An annotated environmental bibliography of the Bodélé and related areas

Dust, meteorology, environmental history, recent geology, geomorphology; some archaeology, anthropology and recent history

Abadie, J., Barbeau, J., Coppens, Y. 1959. Une faune de vertèbres villafranchiens au Tchad. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences 248 (23), 3328-3330.
Remains of fossil vertebrates were recently discovered at two localities in the central Chad region, French Equatorial Africa. The presence of Archidiskodon africanavus and Hippopotamus cf. protamphibius shows that the age of the fauna is lower Villafranchian (Pleistocene).

Abell P.I., Hölzmann, P. 2000. Holocene palaeoclimates in northwestern Sudan: stable isotope studies on molluscs. Global and Planetary Change 26 (1-3), 1-12.
Gastropod shells and bulk sedimentary carbonate deposits found in palaeolake sediments in the presently hyperarid regions of NW Sudan provide proxy materials for the evaluation of the vastly different and wetter climatic conditions that prevailed for several thousand years in that region at the beginning of the Holocene. Oxygen and carbon stable isotope ratio measurements on these shells and carbonates suggest that the African Summer Monsoon provided extensive rainfall up to 800 km further north than at present, creating substantial lakes and refilling the deep aquifers of the region with isotopically depleted water up to 21^{o}N. Variations in stable isotope ratios, as one proceeds upwards through the sediments, indicate that the wettest phase occured about 9000 years B.P., and that a considerably drier period began after about 5600 years B.P., after which the record is obliterated by decreasing rainfall and subsequent deflation of the sediments. During the wet phase, large quantities of isotopically depleted (light) moisture - corroborating the convective origin of the rainfall - were brought to the Eastern Sahara by intensified monsoonal rains. Variations in the oxygen isotope ratios during the growth of individual shells demonstrate that considerable seasonality existed in yearly rainfall.

Abell, O., Hölzmann, J., Pachur, H. 1996. Stable isotope ratios of gastropod shells and carbonate sediments of NW Sudan as palaeoclimatic indicators. Palaeoecology of Africa and of the Surrounding Islands 24, 33-52. na geobase/georef

Abouchami, W., Zabel, M. 2003. Climate forcing of the Pb isotope record of terrigenous input into the Equatorial Atlantic. Earth and Planetary Science Letters 213 (3-4), 221-234.
Pb isotopic compositions of bulk sediment cores from the Tropical Atlantic are used here to infer variations in the provenance of terrigenous input to the Tropical Atlantic during Pleistocene climate cycles. The 200-ka high precision (2sigma similar to 100 ppm) Pb isotope records of the Ceard Rise (Western Atlantic) and Sierra Leone Rise (Eastern Atlantic) cores show a clear glacial-interglacial cyclicity, reflected by alternating unradiogenic Pb and radiogenic Ph in both cores. The glacial-interglacial Pb isotopic contrast is also observed in Pb-Pb space and can be explained in terms of binary mixing - variations along the mixing lines reflecting changes in the relative proportions of the glacial (unradiogenic) and interglacial (radiogenic) Pb source(s). The Pleistocene Pb isotopic variability of the terrigenous input to the Ceard Rise can be linked to changes in the weathering styles in the Amazon Basin and, as a result, in the Amazon river discharge. These changes are reflected by a greater contribution from the highlands (Andes) Pb source during glacial times, and strengthening of the lowlands (Shield) Pb source during interglacials. On the other hand, Pb isotopic variations in the Sierra Leone Rise core indicate increased Pb inputs from the Saharan dust plume during glacial times, in agreement with the wind patterns over Africa. Furthermore, this result bears some implications on the cause of the enhanced glacial terrigenous fluxes to the Tropical Atlantic, which we infer to be due to increase in winter wind transport rather than glacial hyperaridity. The cyclicity of the Ceara Rise and Sierra Leone Rise Pb isotopic records together with changes in the proportions of mixing sources throughout the last 200 ka monitor changes in the hydrological cycle over South America and the wind systems over Africa, respectively, both of which are linked to the seasonal latitudinal migration of the Intertropical Convergence Zone. The correlation found between Pb isotope cycles and other paleoclimate proxies suggests that Pb isotopes may be responding to variations in Earth's orbital parameters.

Abrantes, F. 2003. A 340,000 year continental climate record from tropical Africa - news from opal phytoliths from the equatorial Atlantic. Earth and Planetary Science Letters 209 (1-2), 165-179.
Information on the tropical African continental climate and vegetation during the last 340 kyr is derived from a detailed study of opal phytoliths at, the eastern equatorial Atlantic site M16772 (1^{o} 21'S, 11^{o} 58'W). Total phytoliths as well as C-3 and C-4 grass phytoliths are compared to the distribution pattern of other continental climate proxies (freshwater and limnobiontic diatoms). Total phytolith accumulation rate is dominated by C4 grasses and their variability confirms the cold stages and interstadials as times of and conditions in the southern Sahara and Sahel regions, and indicates an increase in aridness from Termination II to Termination I. The good agreement between the total phytoliths and freshwater diatom records observed for most of the 340 kyr is interpreted as indicative of atmospheric dust as the main source of both sediment constituents to this core site. Exceptionally higher land rainfall and river input to the eastern equatorial Atlantic are suggested by the excess of freshwater diatoms over total phytoliths and the limnobiontic diatoms observed during ice growth phases of oxygen isotopic interglacial stages 9, 7 and the 5/4 transition. Major alterations in continental aridity and/or wind strength conditions over north Africa, as reflected by the total and and phytolith frequency spectrum, appear clearly determined by global ice volume and the 100 kyr cycle characteristic for high-latitude climate change. Limnobiontic diatoms, which reflect lake desiccation, respond also to the 41 kyr obliquity cycle. Freshwater diatoms, on the other hand, contain significant variance at 23 kyr periodicities, reflecting the precessional forcing of the African monsoons which determine the precipitation level over the south Saharan and Sahelian source regions. Rapid hydrological fluctuations, as depicted by the changes in the relative contribution Of C-3 and C-4 grasses to the total phytoliths, appear to respond to higher than 19 kyr frequencies, which are observable in all but the aridity index spectra.

Adams, J.M. ,Faure, H. 1997. Atlas of palaeovegetation.
http://www.esd.ornl.gov/projects/qen/adams4.html

Adams, L.J., Tetzlaff, G. 1984. Did Lake Chad exist around 18,000 Yr BP ? Archives for Meteorology Geophysics and Bioclimatology Series B - Theoretical and Applied Climatology 34 (3), 299-308.
A data set is derived describing the climatic conditions in the Chad Basin during the period of the maximum of the N hemispheric glaciation at about 18 000 yr BP. In particular a reduced hydrological input into the lake was assumed as well as higher insolation and wind speed while the air temperature and the atmospheric moisture content were reduced. The resulting surface area of Lake Chad is then diminished by 80% and calculated to be less than 4000 km^2.

Adams, L.J., Tetzlaff, G. 1985. The extension of Lake Chad at about 18,000 yr BP. In: Climate and paleoclimate of lakes, rivers and glaciers, Ed. Kuhn, M., Zeitschrift für Gletscherkunde und Glazialgeologie 21 (1-2), 115-123.
There seem to be some indications that Lake Chad was not completely dry at the Last Glacial Maximum. Using available quantitative data, analytical model simulations, including sensitivity studies, were conducted. These show that the lake was then about 7% of the present day size.

Adebayo, S.I. 1989. Trajectories of advected Saharan dust in Nigeria. Atmospheric Environment 23(7), 1581-1589.
Widespread and intense thick dust spells originating from Niger and Chad Republics affected the whole of Nigeria bewteen 2 and 11 March 1977. The trajectories of the various spells were followed using 0900 GMT visibility isoline analysis as control and 1500 GMT visibility analysis for the monitoring. The trajectories were traced to Southern Nigeria where discrete visibility 'lows' were established with centres at Ilorin, Benin and Calabar from 6 to 8 March. The poleward surge of the Intertropical Discontinuity (ITD) (7-9 March) was associated with moisture in flux which resulted in a mean clearance rate of about 500 m per latitude surge per day. The weight of Harmattan Dust in suspension (the annual removal of top soil in the source region results not only in atmospheric pollution down stream but also aggravates desertification at source) between 770 m and the surface area of Nigeria was calculated to be approximately 1.6 X 10^9 kg on 5 March 1977 when the poorest visibility was most widespread.

Adedokun, J.A., Emofurieta, W.O., Adedeji, O.A. 1989. Physical, mineralogical and chemical-properties of Harmattan dust at Ile-Ife, Nigeria. Theoretical and Applied Climatology 40 (3), 161-169.
no abs on WoK or geobase

Adetunji, J., Mcgregor, J., Ong, C.K. 1979. Harmattan haze. Weather 34 (11), 430-436.
Little is known about the incidence and long term variability of Harmattan dust haze. In this paper, visibility data for Samaru for October 1962-March 1973 are used to examine the phenomenon. The most likely source of dust is the Bodele region, Chad, and January and February are the months of maximum occurrence of haze. In view of the importance of Harmattan haze to Nigeria, a research group has been set up at Ahmadu Bello University to study the problem.

Adetunji, J. and Ong, C.K. 1980. Quantitative analysis of the Harmattan haze by X-ray diffraction, Atmospheric Environment, **14 (7)**, 857-858. na geobase/georef no abs on WoK

Adeyefa, Z.D., Holmgren, B. 1996. Spectral solar irradiance before and during a Harmattan dust spell. Solar Energy 57 (3), 195-203.
Measurements of the ground-level spectral distributions of the direct, diffuse and global solar irradiance between 300 and 1100 nm were made at Akure (7.15°N, 5.5°E), Nigeria, in December 1991 before and during a Harmattan dust spell employing a spectroradiometer (LICOR LI-1800) with 6 nm resolution. The direct spectral solar irradiance, which was initially reduced before the dust storm was further attenuated by about 50% after the spell. Estimated values of the Angstrom turbidity coefficient β indicated an increase of about 146% of this parameter while the Angstrom wavelength-exponent alpha decreased by about 65% within the 2-day study period. The spectral diffuse-to-direct and diffuse-to-global ratios suggest that the main cause of the significant reduction in solar irradiance at the surface was the scattering by the aerosol, which led to an increase in the diffuse component. The global irradiance though reduced, was less sensitive to changing Harmattan conditions. It is recommended that solar energy devices that use radiation from Sun and sky be used under fluctuating Harmattan conditions. There are some deviations from the Angstrom formula under very turbid Harmattan conditions, which could be explained by the relative increase of the particle sizes.

Adeyefa, Z.D., Holmgren, B., Adedokun, J.A. 1995. Spectral solar irradiance under Harmattan conditions. Renewable Energy 6 (8), 989-996.
Results of spectral solar radiation measurements at Ile-Ife (7°30'N, 4°31'E; South Western Nigeria) for two non-consecutive months between December 1991 and February 1992 are presented. The Angstrom atmospheric turbidity coefficients β, β(0.5) (0.5 referring to 0.5 mu m) and a for the wavelength interval 350-1038 nm were derived from a series of spectroradiometric measurements at Ile-Ife. The values of the turbidity parameters, β and β(0.5) are high with averages of 1.06 and 1.38, respectively. The average value of *a* was about 0.5. Classifying the Harmattan season into periods with "moderate" characteristics (background Harmattan) and periods with intensive spells, the mean background conditions had values ranging from 0.99 (at 350 nm) to 0.53 (at 862 nm) while Harmattan spell conditions had higher turbidities varying from 1.95 at 350 nn to 1.51 at 862 mm. There were severe reductions in the direct solar irradiance at Ile-Ife during this period due to the strong attenuating effects of the Harmattan dust. On the other hand, a significant increase in the diffuse irradiance was observed which, in all the cases examined during the period, exceeded the direct irradiance. The parameters β and β(0.5) were found to decrease when the intertropical discontinuity (ITD) moved North of a station during the Harmattan period and to increase when it migrates South of it. The coefficient ct, on the other hand, increased with the Northward movement of the ITD and decreased when it moved southwards.

Afeti, G.M., Resch, F.J. 2000. Physical characteristics of Saharan dust near the Gulf of Guinea. Atmospheric Environment 34 (8), 1273-1279.
The particle size, number and mass concentrations of Saharan dust during three successive Harmattan seasons in 1996, 1997 and 1998 in southern Ghana (6° 40'N, 1° 34'W) are reported. The transport distance for the dust was approximately 3000 km from the edge of the source region in the Sahara Desert and 150 km north of the Gulf of Guinea (5° N). The fluctuations in the physical characteristics of dust, in consonance with the seasonal migration of the Inter-tropical Discontinuity, are quantified. The peak particle number concentration recorded in 1997 (150 cm^{-3}) is approximately two orders of magnitude greater than the minimum background aerosol concentration (1 cm^{-3}) Average mass concentrations are calculated and evidence is provided that even at low latitudes and at great distances from the dust production zones, the Saharan dust influence on the particulate mass content of the atmosphere over West Africa is important. Aerosol mean diameters were 0.96, 1.16 and 1.02 mu m for the 1996, 1997 and 1998 Harmattan seasons, respectively, with average mass concentrations reaching a peak of 134 mu g m^{-3}. In all cases, the mean aerosol diameter is observed to be smaller during the Harmattan period than during the rest of the year, an observation, which is consistent with the transport

of great quantities of small particles during the Harmattan season. It is shown that within the 1-5 mu m diameter range, the Harmattan particle size distribution remains essentially stable regardless of the change in seasonal dust concentrations.

Agwu, C.O.C., Beug, H.-J. 1982. Palynological studies of marine sediments of the West African coast. Meteor-Forschungsergebnisse C 36, 1-30. no abs on georef

Agwu, C.O.C., Beug, H.-J. 1984. Palynological studies of marine sediments off the West African coast). In: Palynologische Untersuchungen an marinen Sedimenten vor der westafrikanischen Kuste. Eds Coetzee, J.A., van Zinderen-Bakker Sr, E.M., Palaeoecology of Africa 16, 37-52.
Seven sediment cores from the cruises of the Meteor and the Valdivia were examined palynologically. The cores were retrieved from the lower continental slope in the area between 33.5 and 8"SUP o"N off the West African coast. The main reason for making this palynological study was to assess the differences between the vegetation of Glacial and Interglacial periods in West Africa. The palynological results from the cores opposite the present day savanna belt indicate considerable differences. Forests and woodland are more important in Interglacial periods. During the Glacial periods, these are progressively replaced from north to south by grassland (savanna type and rainforest type of vegetation development). The southern limit of the Sahara during stage 2 was between 1.5 and 5"SUP o" further south than it is today. The North African desert belt can be said to have expanded during Glacial times both northward and southward

Aina, J.O. 1974. A synoptic study of the Harmattan dust haze In: International Tropical meteorology Meeting, 31 January - 7 February, Nairobi, Kenya, 2, American Meteorological Society, pp. 126-133.

Alawar, M.A., Cordell, D.D. 1986. A concise bibliography of northern Chad and Fezzan in southern Libya. International Journal of Middle East Studies 18 (1), 81-83.

Aleon, J., Cahussidon, M., Marty, B., Schütz, L., Jänicke, R. 2002. Oxygen isotopes in single micrometer-sized quartz grains; tracing the source of Saharan dust over long-distance atmospheric transport. Geochimica et Cosmochimica Acta 66 (19), 3351-3365.
Oxygen isotope compositions were measured by ion microprobe in individual micrometer-sized quartz grains extracted from one aerosol sample collected on the Cape Verde Islands and from four surface samples (three soils and one sediment) representing potential source regions of aerosols in Western and Central Africa (Morocco, Algeria, Niger, and Chad). A large range of $\delta^{18}O$ values, from +6.2 per mil to +39.3 per mil is present within the aerosol quartz grains. The different size fractions of the quartz grains from the surface samples overlap nearly entirely this range but show significant differences in their $\delta^{18}O$ distributions for the different size fractions of the grains (i.e., different modes, different proportions of grains with low or high $\delta^{18}O$, .). These differences in $\delta^{18}O$ distributions can be related to different geological formations (i.e., mantle-derived magmatic rocks, crustal magmatic rocks, or sedimentary rocks) outcropping in each region, thus giving a fingerprint of the source region. Quartz grains with unusually high $\delta^{18}O$ values between +30 per mil and +40 per mil were attributed to lacustrine cherts formed in evaporitic environments (Chad basin). The existence of distinct $\delta^{18}O$ distributions for the surface samples, which reflect regional geology but indicate some transport of the grains, enables the characterization of mixing processes during dust emission in the atmosphere. Particles are mixed at a regional scale in the dust reservoir, but injection of fine particles into the high troposphere occurs as a discrete and localized event with no mixing during the subsequent long-range transport by the easterlies. The comparison of the $\delta^{18}O$ distribution of the quartz from the aerosol sample with the equivalent size fractions in surface samples shows that the Niger area is the more probable source region for the aerosol although the Moroccan source cannot be excluded. This method gives a valuable tool to trace the source region of dust into the atmosphere or into sediment samples, allowing the reconstruction of air mass circulations.

Alexandre, A., Meunier, J.D., Lezine, A.M., Vincens, A., Schwarz, D. 1997. Phytoliths: indicators of grassland dynamics during the late Holocene in intertropical Africa. Palaeogeography Palaeoclimatology Palaeoecology 136 (1-4), 213-229.
The reconstruction of African tropical grassland history during the late Holocene can be carried out using phytolith analysis. Fossil phytolith assemblages from Lake Guiers, in the Sahelian region of Senegal, and from Lake Sinnda, in the Guineo-Congolian region of Congo were investigated. The results are interpreted on the basis of modern phytolith assemblages from the same regions and compared to pollen data previously obtained. Tall or short grass associations are discriminated by their

phytolith index Iph(%)=saddle/(cross + dumbel + saddle), while the density of shrubs and trees is indicated by relative proportions of the dicotyledon phytoliths.
The phytolith data emphasize that, in the Guineo-Congolian region around Lake Sinnda, the driest phase of the late Holocene occurred between 4000 and 1200 yr B.P., commencing with the opening of the dense forest and its replacement by a short grass savanna. From ca. 1000 yr B.P., wetter climatic conditions developed, as represented by the setting up of a tall grass savanna woodland. The modern shrub and tall grass savanna was developed ca. 700 yr B.P. In the Sahelian region around Lake Guiers, the driest phase occurred after about 2000 yr B.P. and has not been followed by moister conditions. A tall grass savanna woodland was gradually replaced by a shrub and short grass savanna which still occurs. A short period of development of swampy vegetation, which can be related to a lake level change, interrupted the semi-arid adaptation of the vegetation, between about 2000 yr B.P. and the present.

Alfaro, S.C., Lafon, S., Rajot, J.L., Formenti, P., Gaudichet, A., Maille, M.2004. Iron oxides and light absorption by pure desert dust: An experimental study. Journal Of Geophysical Research-Atmospheres.109 (D8), art. no. D08208
Theoretical computations based on Mie theory indicate that absorption of light by desert dust aerosols should be highly sensitive to their content in iron oxides (hematite, goethite, etc.). A selective extraction method that has been developed recently now allows quantification of these minerals in aerosol samples less than 500 mug in mass. Thus it is now possible to assess experimentally the part played by iron oxide minerals on dust absorption properties. In this paper we present an adaptation of Bond et al.'s [1999] method for measuring mineral dust mass absorption efficiencies and deriving single scattering albedo values at two wavelengths (325 and 660 nm). It consists in measuring simultaneously the aerosol mass concentration with a TEOM microbalance, its scattering properties in the visible spectrum with a 3 wavelength nephelometer, and attenuation at the 2 aforementioned lambda with a dual-wavelength aethalometer. At first the method is applied to nonabsorbing (iron oxide-free) aerosols in order to check the magnitude of the "apparent absorption" due to scattering artifacts. In good agreement with Bond et al.'s results for visible wavelengths, it is found that 2% of scattering is misinterpreted as absorption. This proportion is also found to be practically insensitive to the aerosol size distribution. After these preliminary measurements the method is applied to aerosols generated by shaking three natural soil samples collected in one of the main Chinese dust source (Gobi desert), in northern Sahara (Tunisia), and in the Sahel (Niger). For these aerosols, mass absorption efficiencies are found to range between 10^{-2} and 2 10-2 m^2 per gram of aerosol at 660 nm and to increase linearly with the iron oxide content at the rate of 0.56 m(2) per gram of iron oxide. Owing to the larger absorbing potential of iron oxides at short wavelengths, mass absorption efficiencies at 325 nm are about 6 times larger than at 660 nm. At this last wavelength the single scattering albedo (SSA) is found to decrease from 0.97 for Chinese and Tunisian aerosols to 0.95 for the Niger one that also happens to have the largest iron oxide content (6.5% in mass). At 325 nm the SSA is much lower for the three aerosols (similar to0.80) than at 660 nm. These values are similar to recent results obtained close to major mineral dust sources by inversion of Sun photometer or satellite data. Finally, simple computations performed for conditions that prevail at regional scale in the vicinity of important dust sources show that, even when mineral dust is mixed with strongly absorbent particles such as black carbon (BC), the effect of iron oxides on light absorption is in the same order of magnitude as the one of BC.

Alfaro, S.C., Rajot, J.L., Nickling, W. 2004. Estimation of PM20 emissions by wind erosion: main sources of uncertainties.Geomorphology 59 (1-4), 63-74.
The physics of the two processes (saltation and sandblasting) leading to fine mineral dust emissions by wind erosion in and or semi-arid areas has been detailed and modeled. The combination of these two models has led to a physically explicit Dust Production Model (DPM). In this work, sensitivity tests are performed with the DPM to determine the nature of the main soil parameters that control dust emissions by sandblasting. It is found that the soil roughness length and the dry size distribution of the soil aggregates constituting the loose wind erodible fraction of the topsoil have the greatest influence on the soil potential for mineral dust production. Contrary to what is often assumed, soil texture is not a relevant parameter.
In the light of these new findings, results of vertical flux measurements performed over a wide variety of sources in Niger and the US south west (14 soils) have been reanalyzed. Results show (1) that for the tested soils the DPM, and hence sandblasting, explain all dust emissions, and (2) that 13 of the 14 soils that had been selected a priori for their high potential for dust emissions contained a fine soil-aggregate component. This is consistent with the sensitivity tests indicating that the presence of such a

component could enhance dust emissions by one order of magnitude. Finally, it can be concluded that most of the apparent scatter in the experimental results was in large part due to an inappropriate choice of soil parameters to interpret them.

Alpert, P., Ganor, E. 2001. Sahara mineral dust measurements from TOMS: Comparison to surface observations over the Middle East for the extreme dust storm, March 14-17, 1998. Journal of Geophysical Research-Atmospheres 106 (D16), 18275-18286.
A comparison of the TOMS aerosol index (AI) with both measurements of dust concentrations and synoptic data over the Middle East for the extremely heavy dust storm of March 14-17, 1998 is performed. Time series over Algeria, Libya, and Israel yield the following findings: The peak values in both surface concentrations and TOMS data suggest that AI values of 2.5 and 1.2 correspond to surface mean daily concentrations of 1900 and 1000 pg/m(3) respectively. Surface concentrations and TOMS maps show that AI values of 3.0 correspond to about 4000 mug/m(3). TOMS AI maximum values were found to increase from Algeria to Israel moving along with the center of the dust plume from 0.9 to 2.1 and 2.5 AI values. This seems to be in contradiction with the fact that the plume moves farther away from the major mineral dust sources over the Sahara and may be caused by either an increased vertical extension of the plume, hence increasing the TOMS AI, or due to convergence of the dust plume over the eastern Mediterranean. The size distribution, morphological, and mineralogical composition of the dust analyzed in this study, as well as other aerosol parameters, are essential for improving the remote sensing methods such as the TOMS Al algorithms. Of course, surface measurements alone do not allow the refinement of the TOMS retrievals; vertical profile dust measurements as well as other physical and optical aerosol parameters are necessary.

Alpert P., Kishcha P., Shtivelman A., Krichak S.O., Joseph, J.H. 2004.Vertical distribution of Saharan dust based on 2.5-year model predictions. Atmospheric Research 70 (2), 109-130.
Within the framework of the NASA-Israeli MEIDEX project, the averaged 3D-distribution of Saharan dust was estimated and analyzed. This averaged distribution was based on the 2.5-year database of 48-h dust forecasts produced by the dust prediction system, which had been developed earlier at the University of Athens and subsequently modified in Tel Aviv University. The performed climatological analysis is the first one based on a large archive of dust distribution over the whole Sahara and vicinity regions; the total amount of vertical profiles in this at-chive is approximately 10(7) per year. Vertical distributions of dust reflect differences between the Atlantic and the Mediterranean dust transport. As a whole, the Mediterranean dust is found to be within a wider range of altitudes, penetrating rattler higher into the troposphere. On average, dust over the Atlantic penetrates up to less than or equal to 5 km while over the Mediterranean up to less than or equal to 8 km. The characteristic feature of dust vertical profiles over the main Saharan dust source near Lake Chad is its maximal concentration near the surface. From April to June averaged profiles over the Chad basin in the Sahara are restricted below the level of similar to 4.5 km. In the winter months and in March, dust concentration over the Chad basin is closer to the surface, under 1.5 km. Dust also maximizes near the surface over another dust source, which is the major one in summer, located in West Africa. These results are consistent with dust-layer altitude ranges from present-day lidar soundings. Besides, the results are in accordance with general synoptic knowledge of the mechanism of dust transport to the Mediterranean. However, only quantitative comparisons of model vertical profiles against lidar measurements, which are under way now, call validate the forecast vertical distribution of Saharan dust.

Andigue, J., Baohoutou, L., Moupeng, B., Passiring, K., Ouaga, H.N., Riser, J. 2001. Les dépôts alluviaux récents des vallées du Chari et du Logoné au Sud du lac Tchad (République du Tchad). Quaternaire (Paris) 12 (3), 149-155.
The wide silty and sandy Chari plain is constituted by Holocene recent sediments deposited by the Chari and this affluent the Logone, in relation with the level fluctuations of the Lake Chad. This publication gives precise details about the recent Holocene and the Chari flood plain extension.

Anonymous 1996. Entre dunes et savane: le Tchad et son environnement. Institut Panos, Paris, 146 pp.

Aranyossy, J.F., Filly, A., Tandia, A.A., Louvat, D., Ousmane, B., Joseph, A. and Fontes, J.C. 1992. Estimation des flux d'evaporation diffuse sous couvert sableux en climat hyper-aride (Erg de Bilma, Niger) (Estimation of diffuse evaporation rates under sandy cover in a hyper-arid climate, Bilma Erg, Niger). In: Proceedings of an International symposium on Isotope techniques in water resources development 1991. Proceedings Series - International Atomic Energy Agency - Collection Comptes Rendus - Agence Internationale de l'Energie Atomique, pp. 309-324.

Arbelo, M., Podesta, G.P., Hernandez-Leal, P.A. and Diaz, J.P. 2003. Use of TOMS data to correct the Saharan dust effects on SST retrievals from satellite. Calibration, characterization of satellite sensors, physical parameters derived from satellite data. Advances in Space Research 32(11), 2175-2180.
High loads of atmospheric aerosols introduce large errors in satellite-derived sea surface temperature (SST) retrievals. Airborne plumes of desert dust from North Africa are the most evident and persistent and cover large areas of the tropical Atlantic Ocean. We propose a methodology to correct for Saharan dust effects on sea surface temperatures derived from the AVHRR sensor. This method links SST errors in AVHRR estimates with concentrations of absorbing atmospheric aerosols as estimated by the Earth Probe Total Ozone Mapping Spectrometer (TOMS) Aerosol Index. Errors in the SST algorithm increase with increasing aerosol index estimates. To avoid these errors a correction term based on the TOMS aerosol index is incorporated to the AVHRR SST algorithm.

Ayliffe, D., Williams, M.A.J., Sheldon, F. 1996. Stable carbon and oxygen isotopic composition of early-Holocene gastropods from Wadi Mansurab, north-central Sudan. Holocene 6 (2), 157-169.
The 8500- to 7000-year-old shell-bearing sediments in shallow claypans near Wadi Mansurab in north-central Sudan appear to reflect a widespread and much wetter period in northeast Africa. Stable carbon and oxygen isotope analysis of the Wadi Mansurab gastropods reveals that the shell carbonate is highly depleted in C^{13} and O^{18}. The highly depleted oxygen isotopic composition is indicative of rainfall derived from a distant oceanic source. The highly negative nature of the oxygen isotopes indicates that the region had significantly less evaporation than today while the extreme variability in isotopic composition (up to 6-7 parts per thousand PDB) is consistent with a seasonal rainfall regime, characterized by a high degree of inter-annual variability. The dominance of semi-aquatic and swamp-dwelling gastropods over truly aquatic species implies that the region was probably a seasonally flooded grassplain similar to the toich-lands of south-central Sudan today. Our data support the inference that towards 8500-7000 BP there was a stronger southwest monsoon and an associated northward shift in the summer rainfall zone, which caused the Wadi Mansurab region in north-central Sudan to be seasonally flooded during a wetter and possibly cooler period with lower rates of evapotranspiration. From 8500 to 7000 BP, lake levels were high elsewhere in northern Africa, suggesting a regionally wetter climate at that time.

Azevedo, M.J. 1996. Roots of violence: a history of war in Chad. Gordon and Breach, Amsterdam. 202 pp. soas WDD967.43 /770502

Balkanski, Y., Schulz, M., Guelle, W., Moulin, C., Lambert, C., Dulac, F., Bergametti, G. and Marticorena, B. 1998. The modeling of Saharan dust aerosol cycle and a comprehensive comparison with observations. In: 1st LAS/WMO International Symposium on Sand and Dust Storms, WMO Programme on Weather Prediction Research Report Series Project No. 10, World Meteorological Organization (WMO), Technical Document No. 864, pp. 137-138.

Ballouche A., Neumann, K. 1995. A new contribution to the Holocene vegetation history of the West-African Sahel - pollen from Oursi, Burkina-Faso and charcoal from three sites in northeast Nigeria. Vegetation History and Archaeobotany 4 (1), 31-39.
A pollen diagram from Oursi in Burkina Faso is compared with anthracological (charcoal analysis) results from three sites in northeast Nigeria (Konduga, Gajiganna, Lantewa). The present-day vegetation at all four sites is Sahelian or Sahelo-Sudanian and under heavy human impact. At Oursi, a closed grassland with only few trees and almost no Sudanian elements can be reconstructed for the middle Holocene. At the Nigerian sites, on the other hand, Sudanian woody plants were present during this period. We assume that the Sahel was not a uniform zone during the middle Holocene but rather a mosaic of different vegetation types according to local site conditions. In the light of these results, a simple model of latitudinally shifting vegetation zones is not applicable. Around 3000 B.P. the closed grassland at Oursi was opened by agro-pastoral activities, and at Gajiganna, plants characteristic of pasture lands can be directly related with the presence of cattle. Human impact seems to have been the dominant factor in the vegetation history of the Sahel from 3000 B.P. until today, masking possible effects of climatic change.

Barakat, H.N. 1995. Middle Holocene vegetation and human impact in Central Sudan - charcoal from the Neolithic site at Kadero. Vegetation History and Archaeobotany 4 (2), 101-108.
Charcoal recovered from middens and graves in the neolithic site of Kadero, north of Khartoum, Sudan was analysed. The site lies within the semi-desert vegetation zone at present. During the occupation

period (5960-5030 uncal B.P.), a scrub and thorn savanna grew around the site. It is further suggested that the vegetation during the neolithic period at Kadero was already under strong human impact through controlled fires, felling and grazing.

Barbeau, J. 1961. Morphologie du quaternaire des abords orientaux du Lac Tchad, Bulletin de l'Institut equatorial de Recherche géologique et minière, 14, 73-82. na georef

Barbeau, J. 1961. Existence d'un dome villafranchien dans la région de Koro-Toro (République Du Tchad). Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences 253 (5), 881-883.
In the Koro-Toro region of Chad, a good part of the Quaternary is exposed in a section extending from the base of the Villafranchian at Koro-Toro to sands of undetermined age at Beurkiat, totalling some 66 meters in thickness. The deposits form a dome whose existence suggests that the Bahr-et-Gazal valley, in its present aspect at least, is post-Villafranchian. The dome probably acted as a barrier separating the lakes of southern Borku and Chad lake; this could have had important consequences on the distribution of the flora and fauna.

Barich, B.E. 1993. Environment and culture; the adaptation paradigm in the study of the Holocene Saharan societies. In: Thorweihe, U. and Schandelmeier, H. (eds.). Geoscientific research in Northeast Africa; proceedings of the international conference A.A. Balkema. Rotterdam, Netherlands, pp. 607-608.

Barich, B. 1993. Culture and environment between the Sahara and the Nile in the Early and Middle Holocene. In: Krzyzaniak, L., Kobusiewicz,M., Alexander,J. (eds.) Environmental change and human culture in the Nile basin and northern Africa until the second millenium BC. Poznan, 171-183. na georef

Barkan, J., Kutiel, H., Alpert, P. 2004. Climatology of dust sources in North Africa and the Arabian peninsula, based on TOMS data. Indoor and Built Environment 13 (6), 407-419.
Aerosol Index (Ab values from the TOMS instrument were used to compute Al climatology in Africa north of the equator and in the Saudi Arabian desert (30^{o}W-60^{o}E, 0^{o}-50^{o}), for the period 1979-1992. Monthly and annual averages are presented for the whole area as well as for 9 other source areas. The highest Al values were found in the summer months of May, June and July. The area around lake Chad has the highest value and, contrary to the other sources, is active throughout the year. The first 4 years of the research period has a significantly lower index value as compared with the later years. There is a sharp discontinuity between the years 1982 and 1983 in the western sources and a more moderate increase in the eastern sources. Two periods with very high Al values are identified, namely 1983-1984 and 1987-1988, while the year 1986 had a low index value. In 1991 and, to a lesser extent, in 1992, very high Al values were obtained in the eastern sources.

Barkan, J., Kutiel, H., Alpert, P., Kishcha, P. 2004. Synoptics of dust intrusion days from the African continent into the Atlantic Ocean. Journal of Geophysical Research-Atmospheres 109 (D8), art. no. D08201.
The phenomenon of dust intrusion from north Africa into the Atlantic Ocean was examined on daily bases for the month of July from 1983 to 1988 (184 cases). Composite patterns of wind flows and geopotential heights for the intrusion versus no-intrusion cases as well as the difference between them (intrusion minus no intrusion), in the area (60^{o}W-25^{o}E, 0^{o}-60^{o}N), were analyzed. For both intrusion and no-intrusion days a closed high pressure, centered at approximately (45^{o}W, 32^{o}N), was found, with a ridge northeastward. East of the ridge was a trough located to the west of the European and the north African coast. Further east was a closed high in the western Sahara with a ridge northeastward. Each of the maps presenting the difference between the two aforementioned variables shows two highs: one over western Europe and the other, quite strong, west of the African coast on the 24^{o}N-25^{o}N latitudes. Between them, centered about (15^{o}W, 37^{o}N), there is a low-pressure area. As a result of the higher pressure at the African anticyclone in the intrusion cases, an easterly-northeasterly flow dominates at the latitudes 18^{o}N-22^{o}N, which presumably causes the dust intrusion from the continent into the Atlantic. Correlation between the Total Ozone Mapping Spectrometer aerosol index on the one hand and the wind magnitude and the u and v components on the other hand was also analyzed for the entire data set. Correlation coefficients of $r = 0.52$, $r = -0.46$, and $r = -0.27$ were found. Analysis of two extreme intrusion and no-intrusion cases in July 1983 demonstrates the synoptic situation that allows the Saharan dust to reach England and NW Europe.

Barreteau, D. and von Graffenried, Ch., Eds. 1993. Datation et chronologie dans le bassin du Lac Tchad, Colloques et Séminaires, Editions d'ORSTOM, L'Institut français de la Recherche scientifique pour le Développement en Cooperation, Paris Bondy, 292 pp.

Baumhauer, R. 1986. Zur jungquartäen Seenentwicklung im Bereich der Stufe von Bilma (NE-Niger). Würzburger geographische Arbeiten 65, 235 pp. no abs in georef

Baumhauer, R. 1987. Holozäne limnische Akkumulationen im Bereich der Stufen von Zoo Baba und Dibella (NE-Niger). Palaeoecology of Africa and the Surrounding Islands 18, 167-177. no abs in georef

Baumhauer, R. 1988. Radiocarbondaten aus NE-Niger. In: Geowissenschaftliche Untersuchungen in Afrika. Eds. Hagedorn, H., Baumhauer, R. Würzburger geographische Arbeiten 69, 53-70. na georef

Baumhauer, R. 1988. Holozäne limnische Akkumulationen im Grossen Erg von Bilma, NE-Niger. In: Geowissenschaftliche Untersuchungen in Afrika. Eds. Hagedorn, H., Baumhauer, R. Würzburger geographische Arbeiten 69, 137-148. no abs in georef

Baumhauer, R. 1988. The Kawar - Holocene lakes in the foreland of a scarp area. Das Kawar - holozane Seen in einen Schichtstufenvorland. In: Becker, H., Hutterot, W.D. Eds. Tagungsbericht und wissenschaftliche Abhandlungen 46. Deutscher Geographentag, Munchen, Steiner; Verhandlungen, 46, 332-341.
This is a former lake area in the south-west of the central Sahara, in the north part of the lake Chad area, running north-south between the Djado plateau in the west and the Great Erg of Bilma in the south. To the west is Tenere, to the east Bilma scarp. The author studies the stratigraphy, chronology and palaeoecology (looking especially at the flora). He compares it with other areas nearby. The lakes are not only signs of wetter times but also of changed hydrological conditions.

Baumhauer, R. 1988. Zur holozänen Klima- und Landschaftsentwicklung in der Zentralen Sahara; Das Beispiel Fachi/ Dogonboulo. In: Thematische Schwerpunkte; Quartärforschung im nördlichen Afrika; Neues zum Quartär der deutschen Mittelgebirge; Umweltbezogene Forschungen aus der Ur- und Frühgeschichte; Kurzfassungen der Vorträge, Ed. Hagedorn, H., Kurz, R., DEUQUA, Deutsch. Quartärvereinigung. Hanover, pp. 26-27. no abs in georef

Baumhauer, R. 1990. Zur holozänen Klima- und Landschaftsentwicklung in der zentralen Sahara; Am Beispiel von Fachi/ Dogonboulo (NE-Niger). In: Forschungen in ariden Gebieten; aus Anla der Gruendung der Station Bardai (Tibesti) vor 25 Jahren. Ed. Gabriel, B., Berliner geographische Arbieten 30, 35-48.

Baumhauer, R. 1991. Palaeolakes of the South Central Sahara - problems of paleoclimatological interpretation. Hydrobiologia 214, 347-357.
The results of palaeoecological studies of Holocene swamp and lake deposits of a number of endorheic depressions of the Kawar, Djado and Great Erg of Bilma region of eastern Niger are presented, comprising analysis of their stratigraphy, sedimentology, diatom flora and macrofossils.
The investigations demonstrate that various palaeolakes have reacted differently in space and time and by type of lake to climatic conditions. Some of the lakes reacted rapidly to changes in the precipitation regime, as evidenced by changing size, level, water balance and water chemistry, while perennial freshwater lakes nearby show changes relatively independent of short-term climatic fluctuations. These facts suggest a more complex influence of local and regional geomorphological, hydrological and hydrogeological factors on the Holocene lake evolution than a mere climatic dependence. Beyond doubt humidity considerably increased during early and mid-Holocene periods, but the stratigraphical and ecological status obtained for individual endorheic depressions seems to be mainly a reflection of differences among groundwater catchments, aquifers of different size, local topographical conditions and changes in geomorphology (e.g. dune activity) - superimposed on the major climatic tendencies - and thus of a considerable diversity of palaeoenvironmental conditions occurring within the region at any given time of the Holocene.

Baumhauer, R. 1992. Radiocarbon-und Grundwasserisotopendaten aus NE-Niger. Würzburger Geographische Arbeiten 84, 235-246.

Baumhauer, R. 1993. Probleme der paläoökologischen Interpretation limnischer Akkumulationen im Ténéré, NE- Niger Trierer Geographische Studien 9, 33-49.

Baumahuer, R. 1995. Environmental records from Holocene lakes of Tenere, Great Erg of Bilma, and Erg of Fachi-Bilma and Erg of Tenere, central Sahara. In: Abstracts of the International conference on Quaternary deserts and climatic change. Eds. Alsharhan, A.S. and Glennie, K.W., 69. UCL GEOGRAPHY F 22 ALS no abs in georef

Baumhauer, R. 2004. Late Pleistocene and Holocene palaeolakes in the central Sahara - New results from Tenere, Erg of Tenere and Erg of Fachi-Bilma, NE Niger. Erde 135(3-4): 289-313
Palaeoecological studies of Late Pleistocene and Holocene deposits in the Central Sahara allow for the first time the reconstruction of the palaeoenvironmental development of the vast Tenere sand plain, Erg of Fachi-Bilma and Erg of Tenere region, NE-Niger. The environmental changes are deduced from geomorphology, sedimentology and biological remains as well as from palaeolimnological and prehistoric evidence. Comparing the lacustrine sediments, three stages of waterbodies with different conditions may be distinguished. Topographical factors, geomorphological evidence and biological remains (e.g. Lates niloticus) suggest that from 11.5 ka BP onwards a wide-spread lakeland country exists with perenial lakes changing in size, water level and water balance. Until 6.5 ka BP in the northern part of the investigation area and 6 ka BP in the southern part, the desiccation of the shallow permanent freshwater lakes sets in and ephemeral ponds with saline/alkaline superficial dilute/stratified waters develop and finally turn into a swamp environment. Neolithic artifacts scattered on the surface of the lake sediments show that the lakes had lost much of their Late Pleistocene/Early Holocene size by the time of the neolithic settlement. Screening all palaeoecological evidence, annual precipitation is estimated at at least 400 mm for the end of the Late Pleistocene and the beginning of the Early Holocene, resulting from an interaction of monsoonal precipitation with atlantic/ mediterranean cyclones of the zone of the westerlies, then considerably further south than today. In the course of the Early Holocene and more so during the Mid-Holocene this interaction was very reduced and the character of precipitation became more heavy, indicating a stronger seasonality of the climate as well as a reduction of annual precipitation, with a stronger gradient from SW to NE.

Baumahuer, R., Busche, D., Sponholz B. 1989. Reliefgeschichte und Palaeoklima des saharischen Ost-Niger. Geographische Rundschau 41 (9), 493-499.

Baumahuer, R., Hagedorn, H. 1990. Problems of groundwater capture in the Kawar (Niger). Applied Geography and Development 36:99-109.

Baumahuer, R., Hagedorn, H. 1989. Probleme der Grundwassererschliessung im Kawar (Niger) (Problems of ground water capture in the Kawar, Niger). Die Erde 120(1):11-20.

Baumahuer, R., Schulz, E. 1984. The Holocene lake of Seguedine, Kaouar, NE Niger. In Coetzee, J.A., van Zinderen Bakker, E.M.Sr. Eds. Palaeoecology of Africa and the surrounding Islands and Antarctica 16, 283-290.
During a research programme on the palaeoenvironmental changes during the last 20 000 years in the central Sahara a sediment core was taken in the sebcha of Seguedine. The first results of the sedimentological and palynological investigations of this core are presented.

Baumhauer, R., Schulz, E. and Pomel, S. 2004. Environmental changes in the central Sahara during the Holocene- the mid-Holocane transition from freshwater lake into sebkha in the Segedim depression, NE Niger. In: Smykatz-Kloss, W. and Felix-Henningsen, P. (eds), Palaeoecology of Quaternary Drylands. Springer, Berlin, pp. 31-45.

Beavington, F. and Cawse, P.A. 1978. Comparative studies of trace elements in air particulates in northern Nigeria. Science of the Total Environment 10 (3), 239-244.

Beavington, F. and Cawse, P.A. 1979. The deposition of trace elements and major nutrients in the dust and rainwater in northern Nigeria. Science of the Total Environment, 13 (3), 263-274.

Becker, R.E., 1979. Die tertiare und quartare Entwicklung im Bereichder Kufrah-Oasen (Zentrale Sahara) unterbesonderen Berucksichtigung aktualistischerVorgange. Geologische Rundschau 68 : 584-621.
During the U.Cretaceous and Tertiary the area developed into a peneplain. The eroded sands and gravels only a few metres thick became lateritic during a warm and moist period and were hardened to ironcrust I during a semiarid climate. On the higher erosional plains a silicacrust was developed. A change to a more humid climate caused erosion and breccias and fanglomerates were deposited. After laterization and hardening the ironcrust II was formed. A short interruption in the erosional activity during Early Quaternary favoured the sedimentation of coarse grained material which was laterized to ironcrust III. At the close of the Pleistocene the aquatic erosional activity ended by a change from humid to arid climate.

Bejjani, M.-C. 1975. Étude des perturbations synoptiques sahariennes associées à un soulèvement de sable: mise en évidence du rôle radiatif de ce sable (Study of the Saharan synoptic disturbances associated with a sand storm: description of the radiative role of the sand). Thèse, Université de Paris IV, France, 131 pp.

Bellair, P. 1952. Le hydrogeology du Sahara oriental et la desséchement du desert libique. Comptes rendus de la 19^{e} session, Congrès géologique international, Alger, 8, 9-13.

Bennett, V. 2003. Shadows across the Sahara - Travel with camels from Lake Chad to Tripoli by Hare, J. TLS-The Times Literary Supplement (5235), 29-29.

Bernet, G., Dhonneur, G., Falque, P. and Schroeder, L. 1967. Les lithométéores au Tchad. Direction de l'Exploitation météorologique, Publication 8, 24 pp.

Bertrand, J. 1977. Action des poussières sub-sahariennes sur le pouvoir glacogène de l'air en Afrique de. Doctoral thesis, Université de Clérment-Ferrand.

Bertrand, J., Baudet, J. and Drochon, A. 1974. Importance des aerosols naturels en Afrique de l'Ouest. Journal de Recherches atmosphériques 8:845-860.

Bertrand, J., Cerf, A. and Domergue, J.L. 1979. Repartition in space and time of dust haze south of the Sahara. World Meteorological Organization (WMO), Technical Document No. 538, pp. 409-415.

Besançon, J. 1967. Les formations plio-quaternaires du Ouadai Yahfoufa. Hanon, Revue libanaise de Géographie 2: 61-82.

Bigelstone, H.J. 1957. Harmattan haze at Kano. British West African Meteorological Service, Technical Note 10, 4 pp.

Birket, C.M. 2000. Synergistic remote sensing of Lake Chad: variability of basin inundation. Remote Sensing of Environment 72(2):218-236.
During recent decades, drought and anthropogenic influences have led to the diminishment of Lake Chad with adverse effects on both food and water resources. The local population has learned to adapt to the reduced seasonal inundation of the lake basin but are vulnerable to both droughts and excessive inflows. Here, synergistic satellite radar altimetry and near-infrared imagery are employed to gain knowledge of the current flooding patterns. Variations in surface level for the inflowing rivers and the permanent and seasonal lake waters are derived for the 1990S using data from the TOPEX/POSEIDON satellite. National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometer images provide additional variations of basin inundation from 1995 to 1998, using a simple pixel histogram technique. With accuracy _10 cm rms, the altimetry reveals seasonal water-level variations of the order 0.5-6 m and there is a notable rise in minimum levels, 15-35 cm year^{-1} within the lake basin. Peak-level phase lags of 4 to 5 months are also observed between the headwaters of the Chari/Logone rivers and the western lake marshes. Image results reveal that the permanent lake area is 1,385 km^{2}, and that with an accuracy of 5% the surrounding regions have been additionally flooding by up to 3,600 km^{2} year^{-1}. Despite current basin complexities, the synergistic area/level measurements corroborate the known hydraulic relationship at low water levels. Both measurement sets reflect the poor inundation years of 1993/1994 and 1997/1998, despite the indication of a general recovery in regional precipitation to the southeast of the lake. The observed relationships between precipitation,

inundation extent, and surface water level offers these remote sensing techniques as an additional tool for flood/draught forecasting and the availability of future fast delivery data, a mechanism for near-real time monitoring.

Bernet, G., Dhonneur, G., Falque, P. and Schroeder, L. 1967. Les lithométéores au Tchad (Mineral dust in Chad). Direction de l'Exploitation météorologique, Publication 8, 24 pp. (in French)

Biroue, W.K., Schneider, J.L. 1993. Towards the drying of the water-table aquifer in the Chad Sahel Comptes Rendus hébdomidaires des Séances de l'Académie des Science, Série II 317 (1), 89-92.
The piezometric data obtained in the Chad Sahel since 1963 reveal the importance of the losses due to evapotranspiration in the fluviolacustrine environment. The palaeoclimatological data show that these losses are in line with the arid climate which has affected the region since 4,600 BP, i. e. the limit between middle and late Holocene. The water-table has already fallen in several areas, passing from the lower Pleistocene sands to the Pliocene clays, producing local desiccation of the water-table aquifer.

Bizard C., Bonnet A., Freulon J.M., Gerard G., Delapparent A.F., Lelubre M., Vincent P., Wacrenier, P. 1955. Sur l'extension de couches continentales tertiaires (Continental Terminal) dans le nord-est du bassin du Tchad. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences 241 (24), 1800-1803.
Tertiary continental beds which are younger than the Nubian sandstone formation are widely developed in the northeastern portion of the Chad basin, French Equatorial Africa.

Bizard, C., Freulon, J., Lapparent, A.F., Vincent, P. 1955. Observations geologiques sur l'Ennedi, le Mourdi et les Erdi (territoire du Tchad, A.E.F.). Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences 241 (20), 1403-1405.

Blanco, A., De Tomasi, F., Filippo, E., Manno, D., Perrone, M.R., Serra, A., Tafuro, A.M., Tepore, A. 2003. Characterization of African dust over southern Italy. Atmospheric Chemistry and Physics 3, 2147-2159.
Dust samples from rainfall residues have been collected in southeast Italy (40^{o}20' N, 18d^{o}6' E) during dust outbreaks occurred from April to June 2002 to characterize morphological and elemental particle composition by different techniques, and investigate the dependence of particle properties on source regions. Four-day analytical back trajectories and satellite images have been used to infer source regions of the investigated dust samples.
It has been found that the TOMS absorbing aerosol index was in the range 0.7-2.2 over Southern Italy when samples have been collected. The particle-size and -shape analysis by a scanning electron microscope (SEM) has revealed either that the particle-diameter distribution was between 0.3 and 30 μm with median-diameter values between 1.7-2.4 μm, and that the particles were characterized by a roundness factor varying from 0.8 to 2.5. The infrared transmission spectra have allowed recognizing that all dust samples contained a significant amount of illite. The X-ray energy dispersive (EDX) measurements have revealed that the Al/Si ratio of the transported dust varies from 0.41 to 0.50, and that the Al/Si, Ca/Al, K/Ca, and Fe/Ca ratios differ according to source regions and therefore can be used as indicators of dust source regions. Indeed, it has been found that dust samples with larger Ca/Al and Si/Al ratios and lower Fe/Ca and K/Ca ratios, have been collected along dust events with a source region in northwestern Sahara. On the contrary, the samples collected along dust events with the origin mainly in Chad, Niger, Algeria and Lybia were characterized by larger Fe/Ca and K/Ca ratios.

Boeglin, J.L., Mortatti, J., Tardy, Y. 1997. Chemical and mechanical erosion in the upper Niger basin (Guinea, Mali). Geochemical weathering budget in tropical environment. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences, Série II Fascicule A – Sciences de la Terre et des Planètes 325 (3), 185-191.
Seventy-two water samples were collected in the Niger river at Bamako (Mali) during the years 1990, 1991 and 1992. Analyses allow the determination of the geochemical weathering budget, estimation of the rates of chemical erosion, physical erosion and profile thickening for a tropical basin under rather dry climatic conditions. For comparison, the same weathering parameters were determinated for the basins of the Amazon (Brazil) and the Chari (Chad).

Boisserie, J.R., Brunet, M., Andossa, L., Vignaud, P. 2003. Hippopotamids from the Djurab Pliocene faunas, Chad, Central Africa. Journal of African Earth Sciences 36 (1-2), 15-27.

In the Djurab Desert (Chad), the fossiliferous sectors of Kossom Bougoudi, Kolle and Koro Toro have yielded a great amount of fossil hippo remains aged between ca. 5 and 3 Ma. Hippos from the first two areas represent a distinct lineage evolving in Chad during the early Pliocene. Indeed, a new species from Kolle is described (*Hexaprotodon mingoz* sp. nov.) and the Kossorn Bougoudi fossils may constitute its ancestral stem. At Koro Toro, a different but very rare form occurs, and its affinities remain unclear. These hippopotamids testify to a more complex family history than previously recognized, and reinforce the idea of using this group for biochronology. The hippos underscore relative endemism of the Chadian fossil faunas and would indicate a greater and earlier aridity of this region in contrast to East Africa.

Bonnet, A., Freulon, J.M., Delapparent, A.F., Vincent, P. 1955. Observations géologiques sur L'Ennedi, le Mourdi et les Erdi (Territoire du Tchad, AEF). Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences 241 (20), 1403-1405.
Briefly discusses the regional occurrence of Precambrian, Paleozoic, and discordantly overlying continental sandstones of the Chad region, French Equatorial Africa.

Böttcher, U., Ergenzinger, P.-J., Jäckel, S. H., Kaiser, K. 1972. Quartäre Seebildungen und ihre Mollusken-Inhalte im Tibesti-Gebirge und seinen Rahmenbereichen der zentralen Ostsahara. Zeitschrift für Geomorphologie NF 16 (2), 182-234.
Quaternary deposits and their mollusk content in the Tibesti Mountains and the surrounding east-central Sahara.

Bouquet, C. and Cabot, J. 1972. Atlas pratique du Tchad, Institut géographique national, Paris, 76 pp.

Boye, M., F. Marmier, C. Nesson and G. Trecolle, 1978. Les dépôts de la Sebkha Mellala. Revue de Géomorphologie dynamique 27 : 49-62.

Braquaval, B. 1957. Etudes d'écoulement en régime désertique: Massif de l'Ennedi et région nord de Mortcha, Office de la Recherche scientifique et technique d'Outre Mer (ORSTOM), Commission Scientifique du Logoné et Tchad, Policopie, 92 pp.

Breunig, P., Neumann, K., Van Neer, W. 1996. New research of the Holocene settlement and environment of the Chad Basin in Nigeria. African Archaeological Review, 13 (2), 111-144.

Breunig, P., Garba, H., Hambolu, M. 1999. Perspectives on the Later Prehistory of the Chad Basin. Abstract. Symp. Kulturentw. und Sprachgeschichte im Naturraum Westafrikanische Savanne, Frankfurt, 16.Breuning, P. 1994. Der Einbaum von Dufuna-das älteste Boot Afrikas. Forschung Frankfurt, Univ. Frankfurt, 4, 22-24.

Breuning, P., Ballouche, A., Neumann, K, Rüsing, F.W., Thiemeyer, H. Wendt, K.P., von Neer, W. 1993. Gajiganna-New data on early settlement and environnement in the Chad basin. Ber.SFB 268, Frankfurt,2, 51-74.

Bromfield, A.R. 1974. The deposition of sulphur in dust in Northern Nigeria, Journal of Agricultural Science, Cambridge, **83** (3), 423-425. na georef

Bromfield, A.R. 1974. The deposition of sulphur in the rainwater in Northern Nigeria, Tellus, **26** (3), 408-411. na georef

Brookes, I.A. 1989. Early Holocene basinal sediments of the Dakhleh Oasis region, South Central Egypt. Quaternary Research, 32 (2), 139-152.
Twenty samples of ostrich eggshell and hearth charcoal, associated with basinal lacustrine, playa, and sand in the Dakhleh Oasis of south-central Egypt, yield radiocarbon ages between ca. 8800 and ca 4700 yr BP. The sediments record sedimentary responses to an early Holocene pluvial interval.

Brooks, N. 1999. Dust climate interactions in the Sahel Sahara zone of northern Africa, with particular reference to late twentieth century Sahelian drought. Doctoral thesis, University of East Anglia, Norwich, England, 355 pp.

Brooks, N., Legrand, M. 2000. Dust variability over northern Africa and rainfall in the Sahel. In: McLaren, S.J. and Kniveton, D.R. (eds), Linking Climate Change to Land Surface Change, Kluwer, Dordrecht, pp. 1-25.

Brostrom A., Coe M., Harrison SP., Gallimore R., Kutzbach JE., Foley J., Prentice IC., Behling, P. 1998. Land surface feedbacks and palaeomonsoons in northern Africa. Geophysical Research Letters 25 (19), 3615-3618.
We ran a sequence of climate model experiments for 6000 years ago, with land-surface conditions based on a realistic map of palaeovegetation, lakes and wetlands, to quantify the effects of land-surface feedbacks in the Saharan region. Vegetation-induced albedo and moisture flux changes produced year-round warming, forced the monsoon to 17°-25°N two months earlier, and shifted the precipitation belt approximate to 300 km northwards compared to the effects of orbital forcing alone. The addition of lakes and wetlands produced localised changes in evaporation and precipitation, but caused no further extension of the monsoon belt. Diagnostic analyses with biome and continental hydrology models showed that the combined land-surface feedbacks, although substantial, could neither maintain grassland as far north as observed (approximate to 26°N) nor maintain Lake "MegaChad" (330,000 km^2).

Brovkin, V. 2002. Climate-vegetation interaction. Journal de Physique IV 12 (PR10), 57-72.
The climate exerts the dominant control on the spatial distribution of the major vegetation types on a global scale. In turn, vegetation cover affects climate via alteration of the physical characteristics of the land surface like albedo, roughness, water. conductivity (biogeophysical mechanisms) and atmospheric gas composition, for example, CO_2 and CH_4 (biogeochemical effects). The chapter covers biogeophysical interactions between the land surface and the atmosphere. Recent progress in vegetation and land surface modelling is briefly discussed. Research on climate-vegetation interaction is mostly concentrated on "hot spots" where the interaction is die most significant: boreal forests, North Africa, and Amazon forest. Boreal forests, even deciduous ones, significantly reduce the albedo of snow-covered surfaces. Simulations with different climate models reveal that positive feedback between forest and surface air temperature in the boreal region is not strong enough to establish multiple steady states. Nonetheless, the simulations show a significant cooling trend due to historical land cover changes, mainly as a result of temperate and boreal deforestation. In general, the climate models agree that tropical deforestation exerts a net regional warming while an effect on extratropical regions is more uncertain. In the Sahel/Sahara region, several models are able to simulate "green Sahara" phenomenon during the mid-Holocene. Some models reveal multiple steady states in the region due to a strong interaction between vegetation and monsoon precipitation. Sensitivity simulations show that some expansion of vegetation cover into the Sahara is possible under CO_2-induced climate changes.

Brovkin V., Claussen M., Petoukhov V., Ganopolski, A. 1998. On the stability of the atmosphere-vegetation system in the Sahara/Sahel region. Journal of Geophysical Research - Atmospheres 103 (D24), 31613-31624.
A conceptual model has been developed for the analysis of atmosphere-vegetation interaction in subtropical deserts. The model can exhibit multiple stable states-in the system: a "desert" equilibrium with low precipitation and absent vegetation and a "green" equilibrium with moderate precipitation and permanent vegetation cover. The conceptual model is applied to interpret the results of two climate-vegetation models: a comprehensive coupled atmosphere-biome model and a simple hox model. In both applications, two stable states exist for the western Sahara/Sahel region for the present-day climate, and the only green equilibrium is found for the mid-Holocene climate. The latter agrees well with paleoreconstructions of Sahara/Sahel climate and vegetation. It is shown that for present-day climate the green equilibrium is less probable than the desert equilibrium, and this explains the existence of the Sahara desert as it is today. The difference in albedo between the desert and vegetation cover appears to be the main parameter that controls an existence of multiple stable states. The Charney's mechanism of self-stabilization of subtropical deserts is generalized by accounting for atmospheric hydrology, the heat and moisture exchange at the side boundaries, and taking into account the dynamic properties of the surface. The generalized mechanism explains the self-stabilization of both desert and vegetation in the western Sahara/Sahel region, The role of surface roughness in climate-vegetation interaction is shown to be of secondary importance in comparison with albedo. Furthermore, for the high albedo, precipitation increases with increasing roughness while, for the low albedo, the opposite is found.

Brooks, I.A. 1993. Late Pleistocene basinal sediments, Dakhla Oasis region, Egypt; a non-interglacial pluvial. In: Geoscientific research in Northeast Africa; proceedings of the international conference. Eds. Thorweihe, H., Schandelmeier, H., Balkema, Rotterdam, 627-633.

Brunet, M., Beauvilain, A., Coppens, Y., Heintz, E., Moutaye, A.H.E., Pilbeam, D. 1995. The first australopithecine 2500 kilometres west of the Rift Valley (Chad). Nature 378(6554), 273-275.
The first sites with Pliocene and Pleistocene mammals west of the Rift Valley in Central Africa in northern Chad were reported in 1959, and documented the presence of mixed savannah and woodland habitats. In 1993 a survey of Pliocene and Pleistocene formations in the Borkou-Ennedi-Tibesti Province of Chad led to the discovery of 17 new sites in the region of Bahr el Ghazal near Koro Toro. On site, KT 12 yielded an australopithecine mandible associated with a fauna biochronologically estimated to be 3.0-3.5 Myr old. This new find is most similar in morphology to Australopithecus afarensis , documents the presence of an early hominid a considerable distance, 2500 km, west of the Rift Valley.

Brunet, M., Beauvilain, A., Geraads, D., Guy, F., Kasser, M., Mackaye, H.T., MacLatchy, L.M., Mouchelin, G., Sudre, J., Vignaud, P. 1998. Chad: discovery of a mammal fauna in the Early Pliocene. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences, Série II, Fascicule A-Sciences de la Terre et des Planètes 326 (2), 153-158.
In Northern Chad, the site of Kolle in the Djourab erg has yielded a vertebrate fauna including 21 species, 14 of which are Mammals. This fauna provides evidence of a mosaic of environments: fresh-water, woodlands, grasslands. In spite of possible taphonomic or collecting bins, and of some endemicity, this fauna allows us to propose an age in the range 5-4 My.

Brunet, M., Guy, F., Boisserie, J.R., Djimdoumalbaye, A., Lehmann, T., Lihoreau, F., Louchart, A., Schuster, M., Tafforeau, P., Likius, A., Mackaye, HT., Blondel, C., Bocherens, H., De Bonis, L., Coppens, Y., Denis, C., Duringer, P., Eisenmann, V., Flisch, A., Geraads, D., Lopez-Martinez, N., Otero, O., Campomanes, PP., Pilbeam, D., de Leon, MP., Vignaud, P., Virio,t L., Zollikofer, C. 2004. 'Toumai', Late Miocene of Chad, the new earliest member of the human branch. Comptes rendus Paléovol 3 (4), 277-285.
The new Chadian hominid Sahelanthropus tchadensis Brunet et al., 2002, nicknamed 'Toumai', recovered by the MPFT (Mission paleoanthropologique franco-tchadienne, scientific collaboration between the University of Poitiers, University of N'Djamena and CNAR, National Center for the support of Science of N'Djamena) from the Late Miocene of Toros-Menalla (Djurab desert) is associated with a vertebrate fauna (more than 45 species) for which the mammalian component (at least 25 species) indicates a biochronological age close to 7 Ma. The fauna comprises vertebrates that are aquatic (fish, turtles, crocodiles) and amphibious (anthracotheriids, hippopotamids) but also species adapted to the gallery and islet forests (monkeys), wooded savanna (proboscideans, giraffids, suids, etc) and grassland (bovids, tridactyl equids). Sedimentological data (aeolian sandstones, perilacustrine sandstones, diatomites) agree with this mosaic of environments and indicate a vegetated perilacustrine belt between lake and desert. The new hominid is probably temporally close to the common ancestor of chimpanzees and humans but displays a unique combination of primitive and derived characters that clearly shows a close relationship with later hominids rather than with chimpanzees or gorilla. The geographic location of Toumai, 2500 km west of the Rift Valley, along with its great antiquity, suggest an early widespread hominid distribution (Sahel and East Africa, at least by 6 Ma), and a somewhat earlier chimpanzee-human divergence (at least by 7 Ma ago) than previously indicated by many molecular studies.

Brunet, M., Guy, F., Pilbeam, D., Lieberman, D.E., Likius, A., Mackaye, H.T., de Leon, M.S.P., Zollikofer, C.P.E., Vignaud, P. 2005. New material of the earliest hominid from the Upper Miocene of Chad. Nature 434 (7034), 752-755.
Discoveries in Chad by the Mission Paleoanthropologique Franco-Tchadienne have substantially changed our understanding of early human evolution in Africa(1-3). In particular, the TM 266 locality in the Toros-Menalla fossiliferous area yielded a nearly complete cranium (TM 266-01-60-1), a mandible, and several isolated teeth assigned to Sahelanthropus tchadensis(3) and biochronologically dated to the late Miocene epoch (about 7 million years ago). Despite the relative completeness of the TM 266 cranium, there has been some controversy about its morphology and its status in the hominid clade (4,5). Here we describe new dental and mandibular specimens from three Toros-Menalla (Chad) fossiliferous localities (TM 247, TM 266 and TM 292) of the same age(6). This new material, including a lower canine consistent with a non-honing C/P-3 complex, post-canine teeth with primitive

root morphology and intermediate radial enamel thickness, is attributed to S. tchadensis. It expands the hypodigm of the species and provides additional anatomical characters that confirm the morphological differences between S. tchadensis and African apes. S. tchadensis presents several key derived features consistent with its position in the hominid clade close to the last common ancestor of chimpanzees and humans.

Brunet, M., Guy, F., Pilbeam D., Mackaye H.T., Likius A., Ahounta, D., Beauvilain, A., Blondel, C., Bocherens, H., Boisserie, JR., De Bonis, L., Coppens, Y., Dejax, J., Denys, C., Duringer, P., Eisenmann, V.R., Fanone, G., Fronty, P., Geraads, D., Lehmann, T., Lihoreau, F., Louchart, A., Mahamat, A., Merceron, G., Mouchelin, G., Otero, O., Campomanes, P.P., De Leon, MP., Rage, JC., Sapanet, M., Schuster, M., Sudre, J., Tassy, P., Valentin, X, Vignaud, P., Viriot, L., Zazzo, A., Zollikofer, C. 2002. A new hominid from the Upper Miocene of Chad, central Africa. Nature 418 (6894), 145-151.
The search for the earliest fossil evidence of the human lineage has been concentrated in East Africa. Here we report the discovery of six hominid specimens from Chad, central Africa, 2,500 km from the East African Rift Valley. The fossils include a nearly complete cranium and fragmentary lower jaws. The associated fauna suggest the fossils are between 6 and 7 million years old. The fossils display a unique mosaic of primitive and derived characters, and constitute a new genus and species of hominid. The distance from the Rift Valley, and the great antiquity of the fossils, suggest that the earliest members of the hominid clade were more widely distributed than has been thought, and that the divergence between the human and chimpanzee lineages was earlier than indicated by most molecular studies.

Brunet M., Guy F., Pilbeam D., Mackaye HT., Likius A., Ahounta D., Beauvilain A., Blondel C., Bocherens H., Boisserie JR., De Bonis L., Coppens Y., Dejax J., Denys C., Duringer P., Eisenmann VR., Fanone G., Fronty P., Geraads D., Lehmann T., Lihoreau F., Louchart A., Mahamat A., Merceron G., Mouchelin G., Otero O., Campomanes PP., De Leon MP., Rage JC., Sapanet M., Schuster M., Sudre J., Tassy P., Valentin X, Vignaud P., Viriot L., Zazze A., Zellikefer C 2002. A new hominid from the Upper Miocene of Chad, Central Africa (vol 419, pg 145, 2002). Nature 418 (6899), 801-801.

Brunet, R. 1998. Ou se trouve le centre du Monde? Mappemonde (2), 17-22
Depending on your point of view, the centre of the world doesn't exist or there exists an infinite number. However, the most central point can be calculated using either above water land surfaces or world population statistics. Several calculation methods are compared in this paper. The obtained points range from Chad to Ganges by way to Qatar.

Bryson R.A. 1992. A macrophysical model of the Holocene Intertropical convergence and jetstream positions and rainfall for the Saharan Region. Meteorology and Atmospheric Physics 47 (2-4), 247-258.
Using a macrophysical model, it has been found possible to model the Late Pleistocene and Holocene history of glacial volume and mean temperature as a function of solar radiation seasonality and modulation of the solar radiation by volcanic aerosols (Bryson, 1988). From this model it has been possible to model the Indian monsoon with fair agreement with the field data (Bryson, 1989). The present paper represents an extension of this effort to the modeling of the position of the Intertropical Convergence in North Africa and the latitude of the atmospheric polar jetstream in the same longitudes. From these two latitudes it is possible to simulate the seasonal rainfall history of the Saharan region. The preliminary results suggest that maximum intrusion of summer rains into North Africa should have occurred between 11,000 and 5000 BP, with a lesser intrusion between 30,000 and 28,000 BP. Winter rains, though not abundant, should have been present in the central Sahara until 12,000 BP then diminishing to negligible by 8000 BP, according to the model.
On the Mediterranean coast of North Africa, the winter rains should have been about 100% greater than the present until about 18,000 BP, diminishing to near the present value by about 8000 BP. Radiocarbon dated occupation sites appear to be most abundant at about the indicated times of greatest rainfall in sub-Saharan Africa, as does the frequency of high lake levels.
A collateral purpose of this paper is to test the utility of the present inter-monthly changes in the parameterization of inter-century changes.

Buijtenhuijs, R. 2001. The Chadian Tubu: Contemporary nomads who conquered a state. Africa 71 (1), 149-161.

In the literature on pastoralist groups and the state, nomads are usually seen as increasingly marginalised today, whereas in the past nomads have often been described as 'state builders'. But one interesting, if atypical, case has been overlooked: how a contemporary group of nomads, though they did not create a state, nonetheless came to conquer and dominate an existing one. The article starts by describing how the Tubu of Chad established dominance over the central government in the late 1970s and early 1980s. An evaluation is then made of the consequences this take-over of the Chadian state had for Tubu society. Admittedly the date for this evaluation are rather cursory and tentative, but it is possible to identify certain tendencies.

Burke, K. 1976. The Chad Basin; an active intra-continental basin. Tectonophysics 36 (1-3), 197-206.

Burr, J.M. 1999. Africa's thirty years war: Libya, Chad, and the Sudan, 1963-1993. Westview, Boulder, 300 pp. soas WDD967.4304 /811703

Busche, D., Erbe, W. 1987. Silicate karst landforms of the southern Sahara (northeastern Niger and southern Libya). Zeitschrift für Geomorph Supplementband 64, 55-72.

Busche, D., J. Grunert, E. Schulz and A. Skowronek, 1979. Erste Radiokarbondaten aus dem Vorland des Messak Mellet und Plateau du Mangueni, Zentral-Sahara.Wurzburger Geographische Arbeiten 49 : 183-198.

Busche, D. and Hagedorn, H. 1980. Landform development in warm deserts - the central Saharan example, *Zeitschrift für Geomorphologie, Supplementband*, **36**, 123-139.

Busche, D., Heistermann, Chr. 1992. Wechselbeziehungen zwischen geomorphologischer und prähistorischer Forschung in der Sahara von Ost-Niger. Würzburguer Geographische Arbeiten 84, 169-200.

Busche, D. and Stengel, I. 1993. Rezente und vorzeitliche äolische Abtragung in der Sahara von Ost-Niger. Petermanns Geographische Mitteilungen 137(4):195-218.

Butzer, K.W. 1971. Quartäre Vorzeitklimate der Sahara. In: Die Sahara und ihre Randgebiete; Darstellung eines Natur-Grossraumes; I. Band, hysiogeographie. Afrika-Stuidien 60, 349-388.

Cabot, J. 1971. Les limites meridionales du paléo-Tchad. In: Etudes sur le Quaternaire dans le Monde, Vol. 1. Bulletin de l'Association française pour l'Etude du Quaternaire 4, 133-136.
Climatologic and geomorphologic evolution of Logone River Basin, cycles, heavy mineral analyses, Quaternary.

Cakmur, R.V., Miller, R.L., Torres, O. 2004. Incorporating the effect of small-scale circulations upon dust emission in an atmospheric general circulation model. Journal of Geophysical Research-Atmospheres 109 (D7), art. no. D07201.
Realistic simulation of dust emission in an atmospheric general circulation model (AGCM) is inhibited by the model's coarse resolution compared to the scale of the circulations observed to mobilize dust. We construct a probability distribution of wind speed within each grid box that depends upon the speed explicitly calculated by the AGCM and the magnitude of fluctuations about this speed. This magnitude is calculated by incorporating information from the AGCM's parameterizations of the planetary boundary layer along with dry and moist convection. Emission depends on the fraction of the wind speed distribution above the threshold value. As a consequence, emission can occur even if the explicitly resolved wind speed is less than the threshold, as long as the subgrid scale variability is large enough. In the AGCM, subgrid wind fluctuations are dominated by dry convection. This favors dust emission over deserts, where there is continuous mixing within the boundary layer due to intense solar heating of the surface. Particles emitted over arid regions are farther from precipitation and mixed higher above the surface by dry convection. This increases their wet and dry deposition lifetimes, respectively, increasing the aerosol load for a given emission. The AGCM's identification of "preferred meteorology" for emission by subgrid circulations complements the preferred sources of erodible particles included in other models. Given the introduction of subgrid variability, the AGCM's dust aerosol burden improves significantly, compared to the Total Ozone Mapping Spectrometer (TOMS) and advanced very high resolution radiometer (AVHRR) aerosol optical thickness (AOT) retrievals, over the Sahara, Sahel, and the Taklimakan as well as downwind of these regions, considered to be

major sources of dust emission. This mechanistic representation of subgrid variability allows us to calculate the atmospheric burden of dust under different climates, where emission can change due to altered boundary layer variability in addition to changes in the mean wind speed.

Cameron, T.P. 1944. A study of harmattan haze at Maiduguri, Nigeria. United States Air Force Technical Document AWS TR 105-49 (ATI-65153), 13 pp.

Capot-Rey, R. 1964. Les missions Berliet-Ténéré-Tchad, Annales de Géographie, **73** (395), 108-110.

Capot-Rey, R. 1957. Le vent et le modelé éolien au Borkou. Travaux de l'Institut de Recherches Sahariennes 15:149-157.

Capot-Rey, R. 1957. Sur une forme d'érosion éolienne dans le Sahara français. Koninklijk Nederlands Aardrijkskundig Genootschap, Geografisch Tijdschrift 2, 74:242-247.

Capot-Rey, R. 1957. Introduction à une géographie humaine du Borkou, Travaux de l'Institut de Recherches sahariennes, 16, 41-72.

Capot-Rey, R. 1959. Le sel et le commerce du sel au Borkou-Ennedi-Tibesti, Travaux de l'Institut de Recherches sahariennes, 18, 187-194.

Capot-Rey, R. 1961. Borkou et Ouanyanga. Institut de Recherches sahariennes, Mémoire 5, 178 pp. SOAS L WDD301.3 /365273

Capot-Rey, R. 1963. Le nomadisme des Toubou, In: Nomades et nomadisme au Sahara, Ed. Bataillion, Arid Zone Research, 19, United Nations Educational, Scientific and Cultural organisation (UNESCO), Paris, 81-92.

Capot-Rey, R. 1963. Contribution à l'étude et la représentation des barkanes, Travaux de l'Institut de Recherches sahariennes, 22, 37-60.

Capot-Rey, R. 1964. Les missions Berliet-Ténéré-Tchad, Annales de Géographie, 73 (395), 108-110.

Capot-Rey, R. 1965. Premier effects des fourages artésiens au Borkou, Travaux de l'Institut de Recherches sahariennes, 24, 1-6.

Caquineau, S. 1997. Les sources des aerosols sahariens transpores au dessus de l'Atlantique tropical nord: localisation et caractéristiques minéralogiques. Doctoral thesis, Université de Paris 12.

Caquineau S., Gaudichet A., Gomes L., Legrand, M. 2002. Mineralogy of Saharan dust transported over northwestern tropical Atlantic Ocean in relation to source regions. Journal of Geophysical Research-Atmospheres 107 (D15), art. no. 4251.
On the basis of daily Saharan dust samples collected at Sal Island (Cape Verde Archipelagos) and Barbados (Caribbean Sea) over 3 years, this study focuses on the mineralogical signature of the African sources providing dust over the tropical North Atlantic Ocean. First, the sources of the collected dust were localized by using relative clays abundance (illite-to-kaolinite ratio) combined with Meteosat infrared imagery, horizontal visibility, and backward trajectories of dusty air masses. Then, each identified source was linked to a single value of the illite-to-kaolinite ratio. Those results highlight that the clay content of the emitted dust depends directly on both the latitude and the longitude of the source. Dust originating from northwestern sources exhibits illite-to-kaolinite ratios higher than those from Sahelian regions. Likewise, illite-to-kolinite ratio decreases from west to east.

Caquineau, S., Gaudichet, A., Gomes, L., Magonthier, M.C. and Chatenet, B. 1998. Saharan dust: clay ratio as a relevant tracer to assess the origin of soil-derived aerosols. Geophysical Research Letters 25(7):983-986.
The aim of this study is to find a tracer allowing retrieval of the regional origin of mineral dust for Saharan aerosols transported over the North Atlantic Ocean. Because of physical and chemical

fractionation processes occurring at the soil-atmosphere interface and during the atmospheric transport of dust, clay mineral species seem to be the best candidate. This study shows that the ratio between relative abundance of illite and kaolinite (I/K ratio) is the parameter that is the most sensitive to the regional origin of Saharan dust collected on Sal Island (Cape Verde). By comparing the I/K ratio measured in dust emitted from the same Saharan source and collected along its transport both oil Sal Island and Barbados (Caribbean Sea), we show that this ratio seems to remain unchanged after long-range transport.

Carlson, T.N. and Benjamin, S.G. 1980. Radiative heating rates for Saharan dust. Journal of the Atmospheric Sciences 37(1):193-213.
A combined longwave and shortwave radiative transfer model was used to determine effects of Saharan dust on the radiative fluxes and heating/cooling rates in the atmosphere. Cases are treated for cloud-free and overcast conditions over the ocean and for cloud-free sky over desert.

Carlson, T.N. and Caverly, R.S. 1977. Radiative characteristics of Saharan dust at solar wavelengths. Journal of Geophysical Research 82(21):3141-3152.

Carmouze, J.-P., Carré, P., Chéverry, C., Dupont, B., Gac, J.-Y., Memoalle, J., Maglione, G., Roche, M.A., Servant, S. and Servant, M. 1972. Alteration, erosion, transport, sedimentation dans un bassin continental endoreique; la Cuvette Tchadienne rapport preliminaire. In: African Geology; Quaternary Rocks and Geomorphology of Angola, Chad, Cote d'Ivoire, Nigeria and Sahara, University of Ibadan, Department of Geology, pp. 363-370.

Caruana, J.C., Robinson, J.A., Wilkinson, M.J., Willis, K., Amsbury, D.L. 1999. Evidence of climate change as seen from low Earth orbit. In: Geological Society of America, 1999 annual meeting. Abstracts with Programs 31 (7), 246.
Photographs taken from low earth orbit by astronauts illustrate geomorphologic changes caused by climatic changes in the variable time scale of decades to 100,000 years. Using various examples such as shoreline changes, underfed rivers, and paleodune fields we will show some of the rich content of the photography. For example, the changing beachridge patterns of the Brazilian coast caused by shifts in the alongshore currents. Changes in the Andean lakes and paleodunes east of the Andes are shifted as climate changed. In Africa, widespread paleodunes formed 8,000 to 12,000 years ago and are now inundated by Lake Chad and The Inland Delta of the Niger River. Recent climate shifts in Sub-Saharan Africa have also been observed since the 1960's in the variable shorelines of the two bodies of water. Lake level fluctuations in Mono Lake and Great Salt Lake in the Basin and Range province of North America also are short-term climate indicators. The photographs can be coordinated with paleoclimatic ground observations and recent short-term data. Each photograph is unique in composition and we will attempt to show the Best use of the different photographic techniques.

Cautenet, G., Guillard, F., Marticorena, B., Bergametti, G., Dulac, F. and Edy, J. 2000. Modelling of a Saharan dust event. Meteorologische Zeitschrift 9(4):221-230.
We have coupled a non hydrostatic mesoscale model with a simple but comprehensive mineral aerosol source scheme. We present a simulation of a Saharan dust transport event (4 days), including mass uptake estimates, spectral 3D transport and dry deposition. The model is initialized with ECMWF data. Meteosat imagery is used to check the dust uptake and trajectory. The main results are: the estimates of dust uptake and fallout are realistic when compared with the few available literature data concerning the same region; some of the governing mechanisms of aerosol cycle (dust uptake and outbreak triggering) are illustrated; the location of the source areas agree with satellite IR imagery; the behavior of the dust plume (towards Mediterranean) agrees roughly with satellite vis data too; the aerosol size spectrum becomes more and more narrow by loss of the largest fraction of particles, which could have an important effect on dust radiative properties.

Cautenet, G., Legrand, M., Cautenet, S., Bonnel, B., Brogniez, G. 1992. Thermal impact of Saharan dust over land .1. Simulation. Journal of Applied Meteorology 31 (2), 166-180.
Simulations are carried out to verify a mesoscale model in order to perform sensitivity tests of satellite response to atmospheric dust content. The model chosen is the mesoscale model of Colorado State University with a modified radiation parameterization in order to take atmospheric dust content into account. Downward and upward longwave irradiances are estimated using a 25-interval model. The shortwave part of the spectrum is processed by a very fast, highly parameterized, single- interval code. Tests using experimental data gathered during the Etude de la Couche Limite Atmospherique Tropicale

Seche (ECLATS) experiment performed during the 1980 dry season near Niamey (Niger, West Africa) prove that dust content is satisfactorily handled. Three 24-h simulations performed under various meterological and turbidity conditions show that ground surface energy exchanges are satisfactorily described, so that surface temperature is predicted with a standard deviation of about 1-degrees-C. Vertical profiles of computed air temperature and shortwave and longwave irradiances are also realistic.

Chamard, Ph.C., 1973. Monographie d'une sebkha continentale du sud-ouest saharien : la sebkha de Chemchane (Adrar deMauritanie). Bulletin de l'Institut francaisd'Afrique noire, Senegal 35A : 207-243.

Chamard, Ph.C., R. Guitat and G. Thilmans, 1970.Le lac holocene et le gisement neolithique del'0um Arouaba (Adrar de Mauritanie). Bulletin del'Institut francais d'Afrique noire, Senegal 32 : 688-723.

Chamard, Ph.C., 1972. Les lacs holocenes de l'Adrar de Mauritanie etpeuplements prehistoriques. Notes africaines,Bulletin de l'Institut francais d'Afrique noire 133 : 1-8.

Chapelle, J. 1982. Nomades noirs du Sahara: les Toubous. L'Harmattan, Paris, 459 p. soas
UZ306 /472556

Chappell, A., Warren, A., Taylor, N., Charlton, M. 1998. Soil flux (loss and gain) in southwestern Niger and its agricultural impact. Land Degradation and Development 9 (4), 295-310.
It is widely believed that wind and water erosion are widespread in the Sahel, but there is little evidence either for the rate of soil loss or for its agricultural impact. In the present study the radionuclide caesium-137 (Cs-137) was used to make net time-integrated (30-year) measurements of soil flux (loss and gain) at a site in southwestern Niger. Accelerating soil gains occurred where the surface is protected by woody vegetation. The source of this material may be secondary entrainment of Harmattan dust following the removal of vegetation elsewhere. The accumulation rate at these sites for the last 30 years was +3.5 +/- 0.2 t ha^{-1} yr^{-1}. This compares well with data from monitoring the dust in the region over the last 8 years (Drees, et al., 1993). However, the net soil flux for the study area was -48.5 t ha^{-1} yr^{-1}, which is four times as large as Lal's (1993) estimate for this region. Point samples in the main agricultural fields have revealed soil losses of between 26 t ha^{-1} yr^{-1} and 46 t ha^{-1} yr^{-1}. Yet when the agricultural system in these fields is examined, it is found to be so complex that it is difficult to assess the impact of these rates of loss.

Chapuis, A., Serie, E. and Tinga, A. 1996. Contribution à l'étude du soulèvement des aérosols en région sahélienne: expérience STARS (Source Transport des Aérosols en Région Sahélienne. In: Buerkert, B., Allison, B.E. and von Oppen, M. (eds), Wind erosion in West Africa: the problem and its control, 5-7 December 1994, Universität Hohenhiem, Margraf Verlag, Weikersheim, 87-93.)

Chiapello, I., Moulin, C. 2002. TOMS and METEOSAT satellite records of the variability of Saharan dust transport over the Atlantic during the last two decades (1979-1997). Geophysical Research Letters 29 (8), art. no. 1176.
We combined aerosol observations of TOMS/Nimbus-7 (1979-1993) and Meteosat/ VIS (1984-1997) to investigate the variability of Saharan dust transport over the Atlantic over nearly 20 years. We first used three years (1986-1988) of coincident daily Meteosat images over the northern tropical Atlantic (15-30^{o} N, 5-30^{o}W) to convert the TOMS semi-quantitative index into dust optical thickness by means of two ("winter" and "summer") linear relationships. We then processed the whole TOMS/Nimbus-7 archive and found that both seasonal and interannual variability of the mean dust optical thickness over the Atlantic retrieved by TOMS and Meteosat are consistent. This consistency offers an unique opportunity to monitor the export of Saharan dust over the Atlantic during the last two decades. This analysis provides the first evidence of the high year-to-year variability of dust transport during winter, and confirms the importance of meteorological factors, through the North Atlantic Oscillation, in affecting its occurrence at this season.

Chomette, O., Legrand, M. and Marticorena, B. 1999. Determination of the wind speed threshold for the emission of desert dust using satellite remote sensing in the thermal infrared. Journal of Geophysical Research -Atmospheres 104 (D24), 31207-31215.
The Infrared Difference Dust Index (IDDI), derived from images obtained from the Meteosat 10.5- to 12.5-mu m channel, describes the dust distribution over the Saharan-Sahelian region. This IDDI,

associated with the 10-m wind speed reanalyses from the European Centre for Medium-Range Weather Forecasts (ECMWF), reveals whether or not the observed dust is associated with emission from an underlying source. This result allows one to determine the wind speed thresholds for dust emission from targets located in the western, central, and eastern Saharan-Sahelian region, by means of satellite remote sensing. Threshold values determined for seven targets are presented. A comparison is carried out between such values and direct determinations obtained through the description of the soil texture and surface roughness of these targets. The agreement between these quite independent determinations is conclusive, with an average difference of 0.3 m s^{-1} and a rms difference of 0.35 m s^{-1}.

Chylek, P., Lesins, G., Lohmann, U. 2001. Enhancement of dust source area during past glacial periods due to changes of the Hadley circulation. Journal of Geophysical Research-Atmospheres 106 (D16), 18477-18485.
Tropical deserts (e.g., Sahara, Arabian desert, Australian desert) are located within the Hadley circulation. Most of the dust uplifted from these deserts is carried by trade winds and deposited in tropical oceans with very little, if any, transported to polar regions. During glacial periods the dust concentrations in polar ice cores were a factor of 10 to 100 higher than during interglacial periods, including the current Holocene. The early general circulation model simulations of the past glacial climate were not able to reproduce these high mineral dust concentrations; the most recent attempts achieve an increased dust transport to polar regions by extending dust source areas to higher latitudes. We present a hypothesis that during glacial periods the Hadley cell is confined closer to the equator. This contraction of the Hadley circulation leads to the geographical change of the boundary between the tropical and the midlatitude circulation regimes. During the glacial periods a considerable fraction of the current tropical deserts was located outside the region of the Hadley circulation. This allowed the dust to be uplifted and transported by midlatitude storm systems to the polar regions. We present a model for the contraction of the Hadley circulation during the past glacial periods based on the Schneider-Lindzen and Held-Hou model of symmetric tropical circulation and on the assumption that the tropical sea surface temperatures were lower during glacial periods than they are today.

Clark, I., Assamoi, P., Bertrand, J., Giorgi, F. 2004. Characterization of potential zones of dust generation at eleven stations in the southern Sahara. Theoretical and Applied Climatology 77 (3-4), 173-184.
Synoptic wind data for multi-decadal periods at eleven stations located in the southern Sahara region (Agadez, Atar, Bilma, Dori, Gao, Kayes, Nema, Niamey, Nouadhibou, Ouagadougou and Tessalit) are used to study the monthly dust deflation power over the region. We found that, regardless of the conditions of the soil, the deflation power (or wind efficiency) is not sufficient to generate significant amounts of aerosols south of 15^{o}N. North of this latitude, the deflation power is much larger, with potential zones of either very strong deflation (Nouadhibou and Bilma) or severe deflation (Gao, Tessalit, Nema, Atar, Agadez). Stations in the Sahel region such as Gao, Agadez and Tessalit are characterized by a gradual reinforcement of the deflation power between 1970 and 1984 in correspondence of increasing desertification over the region. During this same period, Bilma, a well know region of dust source, experienced a major reduction in deflation power due to shifts in large scale wind patterns.

Claussen, M. 1998. On multiple solutions of the atmosphere-vegetation system in present-day climate Global Change Biology 4 (5), 549-559.
An asynchronously coupled global atmosphere-biome model is used to assess the stability of the atmosphere-vegetation system under present-day conditions of solar irradiation and sea-surface temperatures. When initialized with different land-surface conditions (1, the continents, except for regions of inland ice, completely covered with forest; 2, with grassland; 3, with (dark) desert; and 4, with (bright) sand desert), the atmosphere-biome model finds two equilibrium solutions: the first solution yields the present-day distribution of subtropical deserts, the second reveals a moister climate in North Africa and Central East Asia and thereby a northward shift of vegetation particularly in the south-western Sahara. The first solution is obtained with initial condition 4, and the second with 1, 2, 3. When comparing these results with an earlier study of biogeophysical feedback in the African and Asian monsoon area, it can be concluded that North Africa is probably the region on Earth, which is most sensitive considering bifurcations of the atmosphere-vegetation system at the global scale.

Claussen, M., Brovkin, V., Ganopolski, A., Kubatski, C., Petoukhov. 1998. Modelling global terrestrial vegetation-climate interaction. Philosophical Transactions of the Royal Society of London B, 353 (1365), 53-63.

By coupling an atmospheric general circulation model asynchronously with an equilibrium vegetation model, manifold equilibrium solutions of the atmosphere-biosphere system have been explored. It is found that under present-day conditions of the Earth's orbital parameters and sea-surface temperatures, two stable equilibria of vegetation patterns are possible: one corresponding to present-day sparse vegetation in the Sahel, the second solution yielding savannah which extends far into the south-western part of the Sahara. A similar picture is obtained for conditions during the last glacial maximum (21 000 years before present (BP)). For the mid-Holocene (6000 years BP), however, the model finds only one solution: the green Sahara. We suggest that this intransitive behaviour of the atmosphere-biosphere is related to a westward shift of the Hadley-Walker circulation. A conceptual model of atmosphere-vegetation dynamics is used to interpret the bifurcation as well as its change in terms of stability theory.

Claussen, M., Brovkin, V., Ganopolski, A., Kubatzki, C., Petoukhov, V. 2003. Climate change in northern Africa: The past is not the future. Climatic Change 57 (1-2), 99-118.
By using a climate system model of intermediate complexity, we have simulated long-term natural climate changes occurring over the last 9000 years. The paleo-simulations in which the model is driven by orbital forcing only, i.e., by changes in insolation caused by changes in the Earth's orbit, are compared with sensitivity simulations in which various scenarios of increasing atmospheric CO_2 concentration are prescribed. Focussing on climate and vegetation change in northern Africa, we recapture the strong greening of the Sahara in the early and mid-Holocene (some 9000-6000 years ago), and we show that some expansion of grassland into the Sahara is theoretically possible, if the atmospheric CO_2 concentration increases well above pre-industrial values and if vegetation growth is not disturbed. Depending on the rate of CO_2 increase, vegetation migration into the Sahara can be rapid, up to 1/10th of the Saharan area per decade, but could not exceed a coverage of 45%. In our model, vegetation expansion into today's Sahara is triggered by an increase in summer precipitation which is amplified by a positive feedback between vegetation and precipitation. This is valid for simulations with orbital forcing and greenhouse-gas forcing. However, we argue that the mid-Holocene climate optimum some 9000 to 6000 years ago with its marked reduction of deserts in northern Africa is not a direct analogue for future greenhouse-gas induced climate change, as previously hypothesized. Not only does the global pattern of climate change differ between the mid-Holocene model experiments and the greenhouse-gas sensitivity experiments, but the relative role of mechanisms which lead to a reduction of the Sahara also changes. Moreover, the amplitude of simulated vegetation cover changes in northern Africa is less than is estimated for mid-Holocene climate.

Claussen, M., Gayler, V. 1997. The greening of the Sahara during the mid-Holocene: results of an interactive atmosphere-biome model. Global Ecology and Biogeography Letters 6 (5), 369-377.
An asynchronously coupled atmosphere biome model was used to assess the biogeophysical interaction during the mid-Holocene, 6000 years before present. The model determines its own land surface conditions and can, therefore, predict quasiequilibrium changes in global vegetation patterns. For the mid-Holocene, the coupled model simulated a northward shift of savanna up to 20^o N into the Sahara which in turn amplified the response of the atmospheric circulation to changes in the Earth's orbit during the Holocene. Moreover, in the simulation, most of the western part of the Sahara appeared to be vegetated by xerophytic woods/shrub and warm grass, while the eastern part remained a desert. The simulated vegetation distribution agreed better with palaeobotanical reconstructions than results from the same model, but omitting vegetation-atmosphere interaction.

Claussen, M., Kubatzki, C., Brovkin, V., Ganopolski, A., Hölzmann, P., Pachur, H.J. 1999. Simulation of an abrupt change in Saharan vegetation in the mid-Holocene. Geophysical Research Letters 26 (14), 2037-2040.
Climate variability during the present interglacial, the Holocene, has been rather smooth in comparison with the last glacial. Nevertheless, there were some rather abrupt climate changes. One of these changes, the desertification of the Saharan and Arabian region some 4 - 6 thousand years ago, was presumably quite important for human society. It could have been the stimulus leading to the foundation of civilizations along the Nile, Euphrat and Tigris rivers. Here we argue that Saharan and Arabian desertification was triggered by subtle variations in the Earth's orbit which were strongly amplified by atmosphere- vegetation feedbacks in the subtropics. The timing of this transition, however, was mainly governed by a global interplay between atmosphere, ocean, sea ice, and vegetation.

Cline, W.B. 1950. The Teda of Tibesti, Borku, and Kawar in the eastern Sahara. G. Banta, Menasha, WN, 52 pp. UCL STORE 97-10153

Clos-Arceduc, A. 1971. Disposition des structures d'origine eolienne au voisinage d'un groupe de barkhanes a parcours limite. Photo-Interpretation 10, 71-2 (1), 1-7.

Clos-Arceduc, A 1971.Etude d'un groupe isolé de barkhanes au sud du Tibesti. Photo-Interpretation. 10, 71-2 (2), 8-14.

Clos-Arceduc, A. 1971. Evolution des barkhanes sur un parcours limite par deux bandes ou la deflation éolienne interdit la presence de dunes. Photo-Interpretation. 10, 71-2 (3), 15-21.

Close A.E. 1990. Living on the edge - Neolithic herders in the eastern Sahara. Antiquity 64 (242), 79-96.
Southwestern Egypt, the arid heart of the eastern Sahara Desert, was extensively occupied by Neolithic societies when rain fell there during the earlier parts of the Holocene. However, the rains ceased over 5000 years ago. Since that time, the essentially rainless desert has been traversed but has not been occupied. It is now subject only to the processes of aeolian erosion and deposition. These processes are slow, so that the landscape which we now see is the one that was abandoned by the last Neolithic groups, save only for the subsequent stripping of the final remnants of vegetation. This paper reports the results of an archaeological survey and the patterns of use and human interaction which we may deduce for the Holocene occupants of the area.

Close, A.E. 1992. Holocene occupation of the Eastern Sahara. In: Klees, F., Kuper, R. (eds.) New light on the Northeast African past. Acta Praehistorica, 5. Köln, 155-183.

Coe, M.T. 1995. Mid-Holocene simulation of surface water in North Africa. AGU 1995 spring meeting. Eos, 76 (46), Suppl., 191.

Coe M.T. 1997. Simulating continental source waters: An application to Holocene Northern Africa. Journal of Climate 10 (7), 1680-1689.
A model (SWAM) to predict surface waters (lakes and wetlands) on the scale of atmospheric general circulation models is developed. SWAM is based on a linear reservoir hydrologic model and is driven by runoff, precipitation, evaporation, topography, and water transport directions.
SWAM is applied to the modern climate using observed estimates of the hydrologic variables and a 5' x 5' digital terrain model to represent topography. It simulates the surface water area of northern Africa (about 1% of the land area) in reasonable agreement with observed estimates (0.65%). A middle Holocene (6000 yr BP) simulation using the results of the GENESIS atmospheric general circulation model (AGCM) illustrates the sensitivity of the simulated surface waters to climatic changes and the model's utility as a diagnostic tool for AGCMs. SWAM and GENESIS capture the general pattern of climate change 6000 yr BP. There is an increase in the simulated surface water area from about 1% to about 3% of the land area, including an increase in the area of Lake Chad by about five times and extensive surface water throughout northern Mali, consistent with observed patterns of surface water change during the Holocene. Limitations in the modeling of surface waters appear to result from the relatively coarse resolution of global elevation data.

Coe, M.T. 1997. Global simulation of lakes and river transport in climate models, and investigations of lake/ climate feedbacks during the middle Holocene. Doctoral thesis, University of Wisconsin-Madison. 133 pp.
The goal of this study is to investigate the sensitivity of climate to changes in the area and location of surface waters (lakes and wetlands). A model (SWAM) is developed to predict surface water area and river transport globally. SWAM is based on a linear reservoir hydrologic model and requires, as input, climatic estimates of runoff, precipitation, and evaporation from either observations or climate simulations, and estimates of topography from digital terrain models.
SWAM is first applied on a $2\sp\circ$ x $2\sp\circ$ resolution to modern and middle Holocene climates of northern Africa. The middle Holocene simulation (6000 years before present), using climate input from the GENESIS climate model experiment, illustrates the potential sensitivity of surface water area to climatic change. SWAM simulates an increase in surface water area of northern Africa from about 1% coverage (modern) to about 3% (6000 yr BP). The increase is primarily a result of a greatly expanded Lake Chad and increased waters to the north of the Niger bend.

The second part of this study examined whether expanded middle Holocene surface waters may have had an impact on the strength of the summer monsoon of northern Africa. Three experiments with the National Center for Atmospheric Research Community Climate Model version 3 are analyzed: (1) a modern simulation, (2) a middle Holocene simulation with 6000 yr BP orbital forcing, and (3) a middle Holocene simulation with 6000 yr BP orbital forcing and prescribed expanded surface water. The expanded surface waters in northern Africa result in significant changes in the simulated climate especially in northern summer. Net surface radiation and evaporation increase due to expanded surface waters by amounts, which are comparable to changes due to orbital forcing alone. Precipitation increases regionally, but decreases to the south of the lakes. The geographic distribution of precipitation in the experiment with increased surface water area is in better agreement with observations than the simulation without surface water changes. This result demonstrates the need for including interactive lake models within climate models.
In the third part of the study, SWAM is applied on a higher resolution $(5\sp\prime$ x $5\sp\prime$) to simulate present-day lakes and river transport for all continents (except Antarctica and Greenland). The model develops its own river transport directions based on elevation. Subjective and objective techniques are developed to reduce the digital terrain model bias of overestimating surface water. The model simulates the large scale modern surface water features and river transport in fair agreement with observations. The simulated modern lake area (about 3% of the land area) is somewhat larger than the observed area (about 2%). Wetlands are poorly simulated by the model due to the coarse resolution of the digital terrain models. The results obtained from SWAM indicate that present-day terrain models are adequate for including interactive lakes and rivers in climate simulations.

Coe, M.T., Birkett, C.M. 2004. Calculation of river discharge and prediction of lake height from satellite radar altimetry: Example for the Lake Chad basin. Water Resources Research 40 (10), art. no. W10205.
The application of satellite radar altimetry to the determination of lake and river elevations has been used in numerous projects, and is well validated. Here we show that with the aid of ground-based information, this technique can be extended to determine river discharge and predict downstream lake and marsh height. The Lake Chad basin provides an ideal case study due to its well-known hydrology and complex lake and marsh morphology and because prediction of lake and marsh height has been identified as potentially useful to people living in the region. Altimetric stage measurements from the TOPEX/Poseidon satellite, at the Chari/Ouham confluence, estimate river discharge about 500 km downstream at N'Djamena 10 days in advance (r(2) = 0.9562). Via simple linear correlation methods, the stage measurements successfully estimate the height of the permanent waters of the lake (600 km downstream) 39 days in advance (r(2) = 0.9297). Predicting the water height on the western marshes of the lake bed is poorer (r(2) = 0.7958) due to a change in response time of the local stage to the seasonal floods coincident with an observed increase in mean water level in the latter half of the 1990s. Before 1997 a 96-day phase lag results in the best fit (r(2) = 0.6463). After 1997 the best fit is obtained with a 66-day phase lag (r(2) = 0.8139). The excellent river discharge and lake height predictions show that altimetry is a useful tool where ground-based data are difficult to obtain and where rapid water resource assessment is desirable.

Coe, M.T., Foley, J.A. 2001. Human and natural impacts on the water resources of the Lake Chad basin. Journal of Geophysical Research - Atmospheres 106 (D4), 3349-3356.
An integrated biosphere model (IBIS) and st hydrological routing algorithm (HYDRA) are used in conjunction with long time-series climate data to investigate the response of the Lake Chad drainage basin of northern Africa to climate variability and water use practices over the last 43 years. The simulated discharge, lake level, and lake area of the drainage basin for the period 1953-1979 are in good agreement with the observations. For example, the correlation coefficient (r(2)) between the simulated and the observed level of Lake Chad for the 288 months of available observations is 0.93. Although irrigation is only a. modest portion of the hydrology in the period 1953-1979; representing only 5 of the 30% decrease in simulated lake area for the decade 1966-1975, the simulated lake level and area are in better agreement with the observations when irrigation is included. For the period 1983-1994 the observed water use for irrigation increased fourfold compared to 1953-1979. A comparison of the simulated surface water area, with and without irrigation, suggests that climate variability still controls the interannual fluctuations of the water inflow but that human water use accounts for roughly 50% of the observed decrease in lake area since the 1960s and 1970s.

Commelin, D., N. Petit-Maire and J. Casanova, 0. Chronologie isotopique saharienne des derniers10,000 ans. Bulletin du Musée d'Anthropologie préhistorique de Monaco 23 : 37-88.

Commission Scientifique du Logone et du Tchad 1956. Le Bahr el Ghazal, Office de la Recherche Scientifique et Technique de l'Outre-Mer (ORSTOM), Paris, 8 pp.

Connah, G. 1981. Three thousand years in Africa - man and his environment in the Lake Chad Region of Nigeria. Cambridge University Press, Cambridge, 268 pp. soas VW966.9 /437853

Conrad, G. and Conrad, J. 1965.Precisions stratigraphiques sur les depots holocenes du Sahara occidental grace à la géochronologie absolue. Comptes rendus hebdomadaires des Seances de l'Academie desSciences 7 : 234-236.

Coppens, Y. 1960. Le Quaternaire fossilifere de Koro-Toro (Tchad) - resultats dune premiere mission. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences 251 (21), 2385-2386.
During a two-month expedition in the Chad region, equatorial Africa, two known lower Villafranchian (Pleistocene) vertebrate localities in the vicinity of Koro-Toro were excavated. Three others of the same age were discovered in the region, as well as some thirty in two younger horizons. Data on some of the elements of the principal faunas are summarized.

Coppens, Y. 1961. Découverte d'un Australopithecine dans le Villafranchien du Tchad. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences 252 (24), 3851-3852.
The discovery of an australopithecine skull fragment (belonging to the genus Australopithecus or possibly a new genus) in a Villafranchian (Pleistocene) formation in northern Chad extends the range of the australopithecines through the whole African continent.

Coppens, Y. 1965. L'hominien du Tchad. Comptes rendus hébdomidaires des Séances de l'Académie des Sciences 260 (10), 2869-2871.
A human skull fragment found in 1961 in northern Chad exhibits anatomic characters intermediate between Australopithecus and Pithecanthropus. Stratigraphically, its position is between the end of the lower Pleistocene and the beginning of the middle Pleistocene. It is named Tchadanthropus uxoris.

Coppens, Y. 1966. Le Tchadanthropos, L'Anthopologie, **70** (1-2), 5-16.

Coppens, Y. 1967. Essai de biostratigraphie du quaternaire de la region de Koro-Toro (nord-Tchad). In: Problemes actuels de paleontologie (evolution des vertebres). Colloques internationaux, 163, Centre national de la Recherche scientifique (CNRS), pp. 589-595.

Coppens, Y. 1967. Les faunes de vertébrés quaternaires du Tchad, in Background to evolution in Africa, Eds. Bishop, W.W. and Clark, J.D., University of Chicago Press, Chicago, 89-97.

Coppens, Y. 1968.Gisements paleontologiques et archeologiques decouverts en 1961 dans le nord du Tchad au cours d'une seconde mission de trois mois. Bulletin de l'Institut fondemontal de l'Afrique noire, Série A. Sciences naturelles 30 (2), 790-801.
Observations made during a second trip to north Chad, which covered an area of 5000 km, confirmed previous conclusions of the first trip on the variations of the parameters of Chad lake during the Quaternary related to alternating pluvial and arid periods and a succession of transgressions and regressions. It is noted that at one time the lake extended 400 km farther north of the present shoreline. Abundant vertebrate and invertebrate fossils, and Paleolithic pottery and implements collected are listed chronologically and geographically.

Coppens, Y. 1968. Première découverte au Tchad de galet aménégé in situ. Paris, C.N.R.S. éd., Paris 125-128.

Coppens, Y. 1972. La paléontologie de l'homme et la paléontologie de vertébrés du Tertiare et du Quaternaire d'Afrique dans les récents congrèsses, Bulletin de Liaison, L'Association sénégalaise d'Etude du Quaternaire ouest africain (ASEQUA), Dakar, **33-34**, 57-66.

Coppens, Y. 1994. East Side Story: the origin of humankind. Scientific American **270** (5), 88-95.

Coppens, Y., Koeninguer, J.-C. 1976. Signification climatique des paleoflores ligneuses du Tertiaire et du Quaternaire du Tchad. Bulletin de la Société géologique de France 18 (4), 1009-1015.

Coque, R. 1991. Remark about Quaternary lakes in Sahara. Bulletin de la Société géologique de France 162 (6), 1183.

Coudé-Gaussen, G. 1990. Les régions-sources de poussières au Sahara. Sécheresse, 2, 134-141.

Cour, P., Duzer, D. 1976. Persistence of hyper-arid climate in central and southern Sahara during Holocene period. Revue de Géographie physique et de Géologie dynamique 18 (2-3), 175-198.

Courtin, J. 1968. [Le]Ténéréen du Borkou, Nord-Tchad. Paris, Editions C.N.R.S., Paris, 138 pp.

Cremaschi, M. 1998. Geological evidence for Late Pleistocene and Holocene environmental changes in south-western Fezzan (Central Sahara, Libya). In: Di Lernia, S., Manzi, G. (eds.), Before Food Production in Africa**,** A.B.A.C.O., Forlì, pp. 53-69. INST ARCH DC 100 DIL

Cunnington, W.M. and Rowntree, P.R. 1986. Simulation of the Saharan atmosphere: dependence upon moisture and albedo. Quarterly Journal of the Royal Meteorological Society 112(474):971-999.

Daget, J. 1961. Restes de poissons du quaternaire saharien. Bulletin de l'Institut français de l'Afrique noire 23 (1), 182-191.

Damnati B. 2000. Holocene lake records in the Northern Hemisphere of Africa. Journal of African Earth Sciences 31 (2), 253-262.
Regionally coherent, long-term changes in lake status during the Late Quaternary are in equilibrium with the climate. A new compilation of lake status data provides a record of climate change in the Northern Hemisphere of Africa.
The majority of lakes were at high or intermediate levels between 10,000 and 6000 yr B.P. Wetter conditions were first registered in east Africa (between 0^{o} and 14^{o}N) and subsequently rose progressively in the Sahara and Sahel, where the response has been extended from 9500 to 7000 yr B.P. Between 7000 and 6500 yr B.P., there is an abrupt palustral episode. The majority of northern African lakes were at a high level at 6000 yr B.P, although some had already begun to fewer [?]. The lakes show increasingly drier conditions after 6000 yr B.P. with the minimum lake levels being registered just after 4000 yr B.P.

de Backer, S.M. 1945. Les tempêtes de sable au Sahara. Observations météorologiques à la station d'Ouanyanga-Kebir du 23 janvier au 21 mars 1941. Institut Royal Météorologique de Belgique, Mémoires 22, 28 pp.

Delaume, D. and Pias, J. 1971. Caracterisation de paléosols de la cuvette tchadienne. In: Etudes sur le Quaternaire dans le Monde, Vol. 1. Bulletin de lAssociation français pour l'Etude du Quaternaire 4, 405-412.

de Lestang, J. 1968. Das Palaeozoikum am Rande des afro-arabischen Gondwanakontinents; mitteilung ueber des Erdi-Becken (Republik Tschad), Zeitschrift der deutschen geologische Gesellschaft, 117 (2-3), 479-488.

Delibrias, G. and P. Dutil, 1966. Formations calcaires lacustres du Quaternaire superieur dans le massif central saharien (Hoggar) et datations absolues. Comptes rendus hebdomadaires de l'Academie des Sciences, Paris262D : 55-58.

Delire, C., Levis, S., Bonan, G., Foley, J.A., Coe, M., Vavrus, S. 2002. Comparison of the climate simulated by the CCM3 coupled to two different land-surface models. Climate Dynamics 19 (8), 657-669.
We present results from a coupled atmosphere-biosphere model CCM3/IBIS (the Community Climate Model coupled to the Integrated BIosphere Simulator), which is designed to study the dynamic interactions between climate and vegetation and the global carbon cycle. We analyze the climate simulated by CCM3/IBIS with fixed vegetation conditions and we compare it to the climate simulated by the standard CCM3, which includes the LSM (land surface model) land-surface package. Important differences between the two models include simple parametrizations of lakes, wetlands and crops in CCM3/LSM not taken into account in CCM3/IBIS. CCM3/IBIS and CCM3/LSM share common biases

(compared to observations) in the temperature field in boreal winter and in the precipitation field annually, making the atmospheric model the most probable cause of those biases. The models differ in the temperature field and surface energy balance in the Sahara annually and in the mid-to high latitudes from spring through fall. CCM3/IBIS simulates global annual air temperatures that are on average 1.7^{o} C higher than CCM3/LSM and 0.5^{o} C higher than the observed climatology. Differences in albedo and/or snow parametrization explain most of the Sahara and high-latitude temperature disagreement. Our sensitivity study with CCM3/LSM shows that the presence of lakes and wetlands in CCM3/LSM can account for about half of the difference in temperature in summer over the lake and wetland regions of the mid-latitudes. A second sensitivity study shows that higher surface roughness length in CCM3/IBIS can also explain part of the difference in summer surface temperature in the mid-latitudes. Surface roughness length affects the surface temperature through a feedback mechanism linking surface wind speed, planetary boundary layer height, low level cloudiness and radiation.

DeMenocal, P., Ortiz, J., Guilderson, T., Adkins, J., Sarnthein, M., Baker, L., Yarusinsky, M. 2000. Abrupt onset and termination of the African Humid Period: rapid climate responses to gradual insolation forcing. Quaternary Science Reviews 19 (1-5), 347-361.
A detailed (ca. 100 yr resolution) and well-dated (18 AMS C^{14} dates to 23 cal. ka BP) record of latest Pleistocene-Holocene variations in terrigenous (eolian) sediment deposition at ODP Site 658C off Cap Blanc, Mauritania documents very abrupt, large-scale changes in subtropical North African climate. The terrigenous record exhibits a well-defined period of low influx between 14.8 and 5.5 cal. ka BP associated with the African Humid Period, when the Sahara was nearly completely vegetated and supported numerous perennial lakes; an arid interval corresponding to the Younger Dryas Chronozone punctuates this humid period. The African Humid Period has been attributed to a strengthening of the African monsoon due to gradual orbital increases in summer season insolation. However, the onset and termination of this humid period were very abrupt, occurring within decades to centuries. Both transitions occurred when summer season insolation crossed a nearly identical threshold value, which was 4.2% greater than present. These abrupt climate responses to gradual insolation forcing require strongly non-linear feedback processes, and current coupled climate model studies invoke vegetation and ocean temperature feedbacks as candidate mechanisms for the non-linear climate sensitivity. The African monsoon climate system is thus a low-latitude corollary to the bi-stable behavior of high-latitude deep ocean thermohaline circulation, which is similarly capable of rapid and large-amplitude climate transitions.

DeNoblet, N., Braconnot, P., Joussaume, S., Masson, V. 1996. Sensitivity of simulated Asian and African summer monsoons to orbitally induced variations in insolation 126, 115 and 6kBP. Climate Dynamics 12 (9), 589-603.
We have conducted four numerical experiments with an atmospheric general circulation model (AGCM) to investigate the sensitivity of Asian and African monsoons to small changes (-5 to +12%), with respect to present-day, in incoming solar radiation at the top of the atmosphere. We show that, during the mid-Holocene (6 kBP where kBP means thousands of years before present-day) and the last interglacial (126 kBP), the Northern Hemisphere seasonal contrast was increased, with warmer summers and colder winters. At the time of glacial inception (115 kBP) however, summers were cooler and winters milder. As a consequence, Asia and tropical North Africa experienced stronger (weaker) summer monsoons 6 and 126 kBP (115 kBP), in agreement with previous numerical studies. This present study shows that summer warming/cooling of Eurasia and North Africa induced a shift of the main low-level convergence cell along a northwest/southeast transect. When land was warmer (during the summer months 6 and 126 kBP), the monsoon winds converged further inland bringing more moisture into northern India, western China and the southern Sahara. The southern tips of India, Indochina and southeastern China, as well as equatorial North Africa became drier. When land was cooler (during the summer 115 kBP), the main convergence zone was located over the west Pacific and the wet (dry) areas were those that were dry (wet) 6 and 126 kBP. The location and intensity of the simulated precipitation maxima were therefore very sensitive to changes in insolation. However the total amount of monsoon rain in Asia as well as in Africa remained remarkably stable through the time periods studied. These simulated migrations of convective activities were accompanied by changes in the nature of precipitation events: increased monsoon rains in these experiments were always associated with more high precipitation events (>5 mm day^{-1}), and fewer light showers (less than or equal to 1 mm day^{-1}). Rainy days with rates between 1 and 5 mm day^{-1} were almost unchanged.

de Noblet-Ducoudre, N., Claussen, R., Prentice, C. 2000. Mid-Holocene greening of the Sahara: first results of the GAIM 6000 year BP Experiment with two asynchronously coupled atmosphere/biome models. Climate Dynamics 16 (9), 643-659.
The mid-Holocene 'green' Sahara represents the largest anomaly of the atmosphere-biosphere system during the last 12 000 years. Although this anomaly is attributed to precessional forcing leading to a strong enhancement of the African monsoon, no climate model so far has been able to simulate the full extent of vegetation in the Sahara region 6000 years ago. Here two atmospheric general circulation models (LMD 5.3 and ECHAM 3) are asynchronously coupled to an equilibrium biogeography model to give steady-state simulations of climate and vegetation 6000 years ago, including biogeophysical feedback. The two model results are surprisingly different, and neither is fully realistic. ECHAM shows a large northward extension of vegetation in the western part of the Sahara only. LMD shows a much smaller and more zonal vegetation shift. These results are unaffected by the choice of 'green' or modern initial conditions. The inability of LMD to sustain a 'green' Sahara 6000 years ago is linked to the simulated strength of the tropical summer circulation. During the northern summer monsoon season, the meridional gradient of sea-level pressure and subsidence over the western part of northern Africa are both much weaker in ECHAM than in LMD in the present as well as the mid-Holocene. These features allow the surface moist air flux to penetrate further into northern Africa in ECHAM than in LMD. This comparison illustrates the importance of correct simulation of atmospheric circulation features for the sensitivity of climate models to changes in radiative forcing, particularly for regional climates where atmospheric changes are amplified by biosphere-atmosphere feedbacks.

de Smet, K. 1998. Status of the Nile crocodile in the Sahara desert. Hydrobiologia 391 (1-3), 81-86.
Middle Holocene remains and rock paintings show that the Nile crocodile (*Crocodylus niloticus* Laurenti) used to occur across the whole Sahara. It also occurred at the South Mediterranean shores, in swamps and rivers and it may even have been circum-mediterranean. Until the beginning of this century, many permanent waters in the Sahara still housed relict populations. Nowadays, only few specimens survive in pools in few river canyons of the Ennedi plateau (N. Chad), where they are threatened with extinction. Another relict population, in the Tagant hills of Mauretania, was found to be probably extinct in 1996.

Desio, A. 1941. Appunti geomorfologico sul Sahara Libico, Ann. Mus. Libia St,. Nat., Tripoli, 8, 17-32.

Dia, A., Chauvel, C., Bulourde, M. and G¨rard, M. 2006. Eolian contribution to soils on Mount Cameroon: Isotopic and trace element records. Chemical Geology 226(3-4):232-252.
We determined Sr, Nd and Pb isotopic compositions and major- and trace-element compositions of soil samples recovered from three soil profiles developed on relatively young pyroclastic deposits, less than 10,000 years old, of the Mount Cameroon volcano. The time elapsed since then is short compared with the half-lives of Rb, Sm, U and Th, suggesting that radioactive decay can be neglected. We therefore assumed that (i) these polyphase soils developed on isotopically homogenous substrates and (ii) any isotopic variation within such profiles cannot be due to selective dissolution of primary minerals with isotopic compositions different from that of bulk bedrock. Any Sr, Nd or Pb isotopic variation would therefore record an allochtonous input occurring either in a solid or dissolved state.
Sr and Nd isotope compositions change systematically with depth in the soil profile; in particular, Sr-87/Sr-86 ratios are far greater in the humic horizons than in the underlying horizons, except in the CA9H soil profile. Although smaller than for Sr isotope compositions, Nd-143/Nd-144 ratios displayed an inverse relationship with a decrease towards the uppermost organic-rich horizons. These isotope shifts correlate with changes in Sr and Nd contents, suggesting an allochtonous input characterized by significantly different isotope compositions and slightly lower Sr contents but higher Nd contents. Pb isotopic compositions and Pb concentrations in the uppermost horizons were distinct from those of underlying horizons in the soil sequences.
Since an anthropogenic contamination such as from leaded petrol cannot explain the Pb shifts, a natural source has to be invoked for Pb, as well as for Sr and Nd. Considering both the wind paths in West Africa and the isotopic shifts registered in the uppermost horizons, Saharan dust appears to be the best candidate to explain such variations. These inputs probably happened in winter when dry warm Harmattan wind blows from the northeast. A maximum of 8% of Saharan dust accretion was calculated for the Mount Cameroon soils. This corresponds to average dust deposition rates between 1.3 and 0.8 g cm(-2) ka(-1), values that are much higher than those found in Hawaiian soils by Kurtz et al. [Kurtz, A.C., Derry, L.A., Chadwick, O.A., 2001. Accretion of Asian dust to Hawaiian soils: Isotopic,

elemental and mineral mass balances. Geochim. Cosmochim. Acta 65, 1971-1983.], and are probably related to shorter distance between dust source and deposit.
Any elemental mass balance calculated in the upper organic-rich horizons should be then corrected from allochtonous wind-borne Saharan dust before evaluating weathering-linked chemical mobilities

Díaz, J.P., Expósito, F.J., Torres, C.J., Herrera, F., Prospero, J.M. and Romero, M.C. 2001. Radiative properties of aerosols in Saharan dust outbreaks using ground-based and satellite data: Applications to radiative forcing. Journal of Geophysical Research 106(D16):18403-18416.
We report on measurements of atmospheric transmission (AT(T)) and aerosol optical depth (AOD(T)) made at three wavelengths (368, 500, and 778 nm) with a spectroradiometer placed on Tenerife (28.5 degreesN, 16.31 degreesW), Canary Islands. Using the National Oceanic and Atmospheric Administration (NOAA) advanced very high resolution radiometer (AVHRR) channel 1, we also measured the aerosol optical depth (AOD(S)) and albedo over a region of the North Atlantic Ocean extending from 15 degrees -35 degreesN to 12 degrees -25 degreesW. We observe large changes in AT(T) and AOD(T), when dust outbreaks pass over this region. Using all these data, we derive the asymmetry factor (g), the single-scattering albedo (omega), and the local mean AOD(T), and we compute the direct radiative forcing DeltaF attributable to mineral dust. The local radiative forcing obtained is over the ocean DeltaF = -9.7 W/m(2) and for the land DeltaF = -4.5 W/m(2) with an error of +/- 25%. Extending these results to global-scale averages, we obtain values of DeltaF of -1.22 W/m(2) over the ocean and -0.57 W/m(2) over land. The forcings attributable to dust are comparable in magnitude to those reported in the literature for anthropogenic sulphate and for biomass burning aerosols.

Digard, J.P. Baroin, C., Boutrais, J. 2002. Humans and animals of the Chad basin. Homme (161), 261-262.

Dijkstra, S.J. 1971. The megaspores of boring Tchad. Mededelingen – Rijks Geologische Digest, NS 22, 25-35.

Dorize, L. 1974. L'Oscillation pluviometrique récente sur le Bassin du Lac Tchad et la circulation atmospherique generale. Revue de géographie physique et de géologie dynamique, Deuxième série, 16(4):393-420.

Douvillé, H. 1933. La géologie de la région au nord du Tchad. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences 197 (19), 1012-1016.

Drake N. and Bristow, C.S. (2006). in press. Shorelines in the Sahara: geomorphological evidence for an enhanced monsoon from palaeolake Megachad, The Holocene.

Drees, L.R, Manu, A., Wilding, L.P. 1993. Characteristics of aeolian dusts in Niger, West-Africa. Geoderma 59 (1-4), 213-233.
Dust-laden Harmattan winds are a recognized phenomenon of the Sahel region of Africa. Atmospheric dust inputs have been monitored at two sites in Niger, West Africa since July 1985. Dust traps of the open bucket type were placed 2.5 and 5 m above the soil surface. Dust was collected and analyzed quarterly for total infall, particle size, mineralogy, and water-soluble and exchangeable cations. Surface soil samples adjacent to the dust traps were also analyzed for the same properties. Of the similar to 2000 kg ha^{-1} yr^{-1} of dust infall, over half came during April to July, after the Harmattan wind season. Atmospheric dust inputs varied by season as did particle size, being coarser during periods of minimal infall. The dust contributes similar to 4.8, 2.8, 1.1 and 0.6 kg ha^{-1} yr^{-1} of exchangeable plus water-soluble Ca, K, Mg and Na, respectively. The nutrient status of the dust is substantially greater than the native soil and may serve as a nutrient renewal vector.

Dubief, J. 1943. Les vents de sable dans le Sahara français. Travaux de l'Institut de Recherches Sahariennes 2:11-35.

Dubief, J. 1952. Le vent et le déplacement du sable au Sahara. Travaux de l'Institut de Recherches Sahariennes 8:123-164.

Dubief, J. 1956. Sur l'évolution du climat saharien au cours des derniers millénaires, Proceedings of the **4**th INQUA Congress, Rome-Pisa, **2**, 848-851.

Dubief, J. 1959/63. Le climat du Sahara, Mémoire (Hors de Série), 2 volumes, Institut Recherches sahariennes, Université d'Alger, 312; 275 pp.

Dubief, J. 1953. Les vents de sable dans le Sahara français. In: Actions éoliennes, phénomènes d'évaporation et d'hydrologie superficielle dans les régions arides, Centre national de la Recherche scientifique (CNRS), Paris, Colloques internationaux 35, pp. 45-70.

Dumont, H.J. and El Moghraby, A.J. 1993. Holocene evolution of climate and environment, and stone 'city' ruins in Northern Darfur, Sudan: Is there a relationship? In: Krzyzaniak, L., Kobusiewicz, M. and Alexander, J. (eds.), Environmental change and human culture in the Nile basin and Northern Africa until the second Millenium B.C., Poznan, 381-397.

Dupont, B. 1967. Étude des formations sédimentaires du Kanem. Primers résultats. Office de la recherche scientifique et technique outre-mer (ORSTOM), Fort Lamy, 150 pp.

Dupont, B., Delaume, M. 1970. Etude de quelques coupes dans le Quaternaire récent du sud du lac Tchad. Cahiers d'ORSTOM, Série Géologie 2 (1), 49-60.
Lithology, lithofacies, heavy minerals, size analysis, two lacustrine transgressions, arid climatic episodes, C^{14} dating.

Dupont, B. and Delibrias, G. 1967. Datation par le carbonne 14 d'un niveau sédimentaire de l'archipel du lac Tchad, Cahiers géologiques, 2 (1), Office de Recherches scientifiques et téchniques d'Outre Mer (ORSTOM), 43-48.

Dupont, L.M., Agwu, C.O.C. 1992. Latitudinal shifts of forest and savanna in NW Africa during the Brunhes chron: further marine palynological results from site M 16415 (9°N 19°W). Vegetation History and Archaeobotany 1, 163-175.

Dupont, L.M., Hooghiemstra, H. 1989. The Saharan-Sahelian boundary during the Brunhes chron. Acta Botanica Neerlandica 38 (4), 405-415
Atmospheric circulation patterns over NW Africa are recognized in isopoll maps of offshore bottom sediments. Assuming that the atmospheric circulation model of the last glacial-interglacial transition, based on snapshots of three time-slices, holds for the entire Brunhes chron, the 0.7 Myr-long pollen record of ODP Site 658 has been interpreted. Fluctuating percentages and influx rates of pollen of Chenopodiaceae-Amaranthaceae, Poaceae, Cyperaceae, and savanna elements record a repeatedly shifting Saharan-Sahelian boundary between c14^{o} and 23^{o} N during the Brunhes chron. Most of the humid interglacials occurred before 280 ka, and extreme glacial conditions are only found during the last 480 ka.

Durand, A. 1980. Cordon dunaires périlacustres et oscillations de Lac Tchad au Quaternaire récent (abstract), Resumé du 26ème Congrès géologique international, Paris, 650.

Durand, A. 1982. Oscillations of Lake Chad over the past 50,000 years - new data and new hypothesis. Palaeogeography Palaeoclimatology Palaeoecology 39 (1-2), 37-53.
A recent sedimentological study of the Chari deltas area allowed an evaluation of the oscillations of palaeolake Chad over the past 50 000 yr. Three maximum lake levels at c 38 000, 22 000 and between 12 000 and 8000 yr BP have been described. The levels reached by these large lakes were never very high, and there has not been any major variation over the last 8000 yr. A large expansion at 6000 yr BP is rejected. A new interpretation is proposed for the 'perilacustrine dune ridge' which was considered to run along the shoreline of the 320m level.

Durand, A. 1993. Enregistrement sédimentaire de la dynamique climatique au quaternaire superieur dans le Sahel central (Niger et Tchad). Thèse, Université de Bourgogne, Dijon, 458 p.

Durand, A. 1995. Geomorphological records of neotectonics in the Lake Chad basin - the changes in drainage pattern and the pseudo shoreline of Lake Megachad in Kadzell. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences, Série II Fascicule A – Sciences de la Terre et des Planètes 321 (3), 223-229.

In western Kadzell, a shift of the Yobe River is related to the uplift of a horst between ca 7,500 and 6,000 years C^{14} BP. The fault-line scarp, East of the uplifted block, was previously interpreted as the shoreline of a hypothetical Holocene Lake Megachad. During the Quaternary, four main changes in the course of the Yobe are described.

Durand, A., Fontes, J.C., Gasse, F., Icole, M., Lang, J. 1984. The northwestern region of Lake Chad during the Quaternary - alluvial, eolian, palustrine and lacustrine paleoenvironments. Palaeoecology of Africa 16, 215-243.
Lake deposits have not been recorded for the Ghazalian period (40 000 to 20 000 yr BP). In Kadzell as well as south of the lake, no lake deposits were dated from about 6000 yr BP, which is the proposed age for the maximum extension of a huge Paleochad at an elevation of 320 m (instead of 278-284 m today) in the north. The morphological feature interpreted as a 320 m 'paleoshore' seems in fact to coincide with an ancient major structural accident still visible in the present sand cover. On the contrary, the geomorphological analysis showed three major successive deltas of the Komadugu river. They established upstream three terraces, which may be correlated with the deposits on the borders of the basin during the late Pleistocene and Holocene. Diatom assemblages demonstrate variations in water depth, pH and salinity between 12 000 and 1900 yr BP. The stages of maximum lacustrine extension, respectively dated from 12 000 to 10 000 yr BP and 9500 to 7000 yr BP, are characterized by a slightly alkaline clear-water planktonic flora.

Durand, A., Fontes, J.C., Gasse, F., Icole, M., Lang, J. 1987. Nord-ouest du Lac Tchad; Manga et Kadzell; incidence des milieux de dépôts sur le cadre géomorphologique et chronologique. In: Paleolacs et paleoclimats en Amerique latine et en Afrique (20 000 and B.P.-actuel), Ed. Martin, T.Y. Géodynamique 2 (2), 144-145.

Durand, A., Lang, J. 1986. Approche critique des méthodes de réconstitution paléoclimatique; le Sahel nigéro-tchadien depuis 40 000 ans. Bulletin de la Société géologique de France 8^{e} Série 2 (2), 267-278.

Durand, A., Lang, J. 1990. Valeur stratigraphique des differents types d'évenements climatiques arides enrégistrés au Sahel depuis 20 000 ans. In: Etudes récentes sur la géologie de l'Afrique; 15^{e} colloque de Géologie africaine; resumés détailles, Eds. Roci, G. and Deschamps, M., Publication occasionelle – Centre international pour la Formation et les Echanges géologiques 22, 289-292.

Durand, A., Lang, J. 1991. Breaks in the continental environmental equilibrium and intensity changes in aridity over the past 20 000 years in the central Sahel. In: Sedimentary and diagenetic dynamics of continental Phanerozoic sediments in Africa, Ed. Lang, J.L., Journal of African Earth Sciences 12 (1-2), 199-208.
The record of arid climatic events in continental sedimentation is subject to the intensity of the climatic mechanism which generated them and to the nature of the environment which recorded them. In the Sahel, where the environmental equilibrium is particularly precarious, all types of arid climatic events are likely to be recorded. But the consequences of events of small global intensity (exceptional climatic events and local climatic anomalies) merge with the effects of the 'average climate'. On the other hand, climatic events on a global scale (climatic rises and climatostratigraphic events) are clearly pointed out, due to the large breaks in environmental equilibrium that they initiate

Durand, A., Lang, J., Morel, A., Roset, J.P. 1983. Evolution géomorphologique, stratigraphique et paléoclimatique au Pléistocène superieur et à l'Holocène de l'Aïr oriental (Sahara meridional, Niger). Revue de Géologie dynamique et Géographie physique 24 (1), 47-59.

Durand, A., Mathieu, P. 1979-80. Le Quaternaire superieur sur la rive sud du lac Tchad. Cahiers d'ORSTOM, Série Géologie 11(2), 189-203.
Sedimentation shows successive fluvio-deltaic formations ranging from Upper Pleistocene to Holocene south of Lake Chad. The only important lacustrine phase which was clearly identified is of Ghazalian age (40 000 to 20 000 yr BP). Deposits in the Kanemian (20 000-12 000 yr BP) reveal the existence of steady flows during this period which is characterized by a very high aridity in the northern part of the basin. The increase in the flooded areas from 17 000 yr BP shows that the maximum relative drought occurred between 20 000 and 17 000 yr BP. The high lake level close to 320m in the middle Holocene has not been identified.

Durand, A., Mathieu, P. 1980. Evolution paléogeographique et paléoclimatique du bassin tchadien au Pléistocène superieur. Revue de Géologie dynamique et Géographie physique 22 (4-5), 329-341.
A sedimentologic study of the district of the Chari deltas enabled the authors to retrace its paleogeographic and stratigraphic evolution during the Upper Pleistocene (ca. 50 000 to 10 000 BP), 3 periods of high lake levels were proved (before 35 000 BP and ca. 20 000 then 11 000 BP) and the fact that there was an arid period was confirmed ca. 30 000 BP.

Durand, A. , Paris. F. 1986. Peuplement et climats Holocènes de l´Azawagh (Niger nord occidental). Premiers resultats. In: Faure, H., Faure L. Diop. E.S. (eds.) Changements globaux en Afrique durant le Quaternaire. Passé, present, Futur. Symp. Dakar, Paris, 127-130.

Durand, A., Philippe, M. 1979. Essai de réconstitution de l'évolution paléoclimatique du bassin tchadien au Pléistocène supèrieur a partir de l'étude des formations fluvio-deltaiques du fleuve Chari. In: Dynamique sédimentaire, paleoenvironnements et paleoclimats dans les regions sahariennes et saheliennes; les diverses approches pour la reconstitution des successions de climats. Bulletin de Liaison – Association Sénégalaise pour l'Etude du Quaternaire de l'Ouest Africain 56-57, 69-71..

Duringer, P., Ghienne, J-F., Schuster, M., Bano, M., Brunet, M., Vignaud, P. and Mackaye, H.T. 1999. Nature et dynamique des milieux continentaux des sites pliocènes à Australopitheques du Tchad, 7^{e} Congrès français de sédimentologie; resumés, Association des Sedimentologistes français, **33**, 137-138.

Edmunds, W.M., Baba, F.H. 2000. Late Pleistocene groundwater recharge history and modern recharge in the Lake Chad basin. Geological Society of America, 2000 annual meeting. Abstracts 32 (7), 471.

Edmunds, W.M., Fellman, E., Goni, I.B. 1999. Lakes, groundwater and palaeohydrology in the Sahel of NE Nigeria: evidence from hydrogeochemistry. Journal of the Geological Society 156 (2), 345-355.
The geochemistry of natural waters from rain, soil, the unsaturated zone, shallow aquifers, lakes and the stratified aquifer system of the Chad Basin sediments has been investigated to interpret modern hydrological processes and to reconstruct the palaeohydrology of NE Nigeria, a type region of the southern Sahel. Recharge to the confined Middle and Lower aquifers, recorded in NE Nigeria, occurred between 24 and 18.6 h-a BF, prior to the last glacial maximum. The mean annual temperature at this time derived from dissolved noble gas ratios was at least 6^{o} C cooler than at the present day. This groundwater is not coupled to the active: modern recharge cycle and was not reactivated during the Holocene wet phases as elsewhere in the Saharan region, a reflection of changing lake levels and/or of changing climatic regimes. The absence of groundwater recharge at the time of the last glacial maximum supports other evidence for aridity at this time. Present day direct recharge rates in the Manga Grasslands are high (mean 44 mm a^{-1}). However, regional recharge in NE Nigeria at the present day is even higher (60 mm a^{-1}) emphasizing the importance of infiltration from surface runoff as input to groundwater. The present study confirms that the shallow aquifer in the region contains significant renewable groundwater resources. However the confined aquifer of the Chad Basin clearly contains palaeowater and this declining artesian basin will need careful conservation prior to a return to traditional water use methods via improved management of the renewable waters in the shallow phreatic aquifers.

Egan, W.G. 1994. Radiative transfer properties of the Sahara Region. Remote Sensing of Environment 50(2):182-193.
Two radiative transfer models are applied to the characterization of radiative transfer properties of Sahara dust aerosols in the western Sahara. One model, the Dave vector program, allows computation of she photometry and polarization of dust storms as well as the characterization of the solar flux divergence in the spectral range from the ultraviolet to the near infrared. The other model, LOWTRAN 5, computes the radiance and transmission of the atmosphere, including aerosols, from the near infrared to the far infrared. As a result of the modeling at wavelengths of 0.33 mu m, 0.400 mu m, 0.500 mu m and 1.0 mu m and comparison to measurements at 0.33 mu m and 1.0 mu m, the models are valid for the application. The desert dust aerosols have a very small effect on the infrared atmospheric transmission, but water vapor has a significant effect. It also appears that aerosol content, composition, and distribution may be inferred by remote sensing. It is also evident that polarization can be a valuable adjunct to photometry in the remote sensing of Sahara dust aerosol.

Ehrlich, A., Manguin, E. 1970. Examen de quelques diatomites du Tibesti et du Bahr-El-Ghazal (Tchad). Cahiers d'ORSTOM, Série Géologie 2 (1), 153-157.

El-Baz, F. 1998. Aeolian deposits and palaeo-rivers of the eastern Sahara: significance to archaeology and groundwater exploration. Sahara 10:55-66.

El-Baz, F., Mainguet, M. and Robinson, C. 2000. Fluvio-aeolian dynamics in the north-eastern Sahara: the relationship between fluvial/aeolian systems and ground-water concentration. Journal of Arid Environments 44(2):173-183.
This paper highlights the relationship between ground-water concentration and sand accumulations in the eastern Sahara by presenting a synoptic view of the surface geomorphology. It illustrates that the sand of the Sahara mainly originated from fluvial processes, and was deposited in inland lacustrine depressions by palaeo-rivers and streams. This is implied by the spatial organization of palaeo-channels that were revealed by radar images from space, the localization of major sand seas in topographic depressions, and by geoarchaeologial evidence. The fluvially-deposited sand was subsequently reshaped by aeolian activity into dunes and sheets during periods of drier climates. Aeolian processes are discussed, taking into account the wind currents and sand drifts, the sediment balance, and the initiation of aeolian deposits, including sand seas, using the concept of a regional aeolian action system (RAAS).

El Ramly, I.M., 1980. Al Kufrah Pleistocene lake - its evolution androle in present-day land reclamation. In: " TheGeology of Libya volume II", pp.659-670, (M.J.Salem and M.T. Busrewil, Eds.), Academic Press, London.

Eltayeb, M.A.H., Injuk, J., Maenhaut, W., Van Grieken, R.E. 2001. Elemental composition of mineral aerosol generated from Sudan Sahara sand. Journal of Atmospheric Chemistry 40 (3), 247-273.
Eighteen soil samples from central Sudan were fractionated by dry sieving in a size fraction from < 45 μm to > 300 μm while aerosols generated from these soils were fractionated in the particle size range from 0.25 μm to > 16 μm. The elemental concentrations of soil samples were determined by energy-dispersive X-ray fluorescence, while the elemental concentrations of generated aerosols were analysed by particle-induced X-ray emission. The elements Al, K and Rb show a slight positive fractionation with decreasing particle size throughout the particle size range studied. The concentrations of Ca, Mn, Fe, Sr and Y are maximum in the small soil size fraction (< 45 μmμ) and decrease for the coarse soil size fractions, while in the mineral aerosol particle sizes (0.25-> 16 μm) the concentrations remain more or less constant. The size distributions for Cr, Ti and Zr show a maximum in the particle size range 45-100 μm and the concentrations of these elements decrease sharply in the aerosol fraction down to 16 μm to remain constant in the smaller aerosol fractions.
Enrichment factors for the elements were calculated relative to five reference materials: average crustal rock, average soil, the investigated Sahara bulk soil, the finest fraction of this soil and the aerosol generated from this soil, and using four reference elements: Al, Si, Ti and Fe. The enrichment factors were found to vary significantly depending on the choice of the reference material or the reference element. The enrichment factors for the Sudan mineral aerosol were almost identical to those for Khartoum atmospheric aerosol but different from those for Namib mineral aerosol and Israel atmospheric aerosol following dust storms. Multivariate display methods (cluster analysis, principal component analysis and linear discriminant analysis) were applied to the element ratios in the mineral aerosol from the Sahara and Namib and this showed that these mineral aerosol can be differentiated into different groups. An attempt was also made to relate the mineral aerosol to its parent soil through the use of these multivariate techniques and the elemental ratios in both the mineral aerosols and the bulk soils (Namib and Sahara). It was also possible using the elemental ratios and the multivariate display methods to associate the crustal component to the mineral aerosol generated from the Sahara. Can desert dust explain the outgoing longwave radiation anomaly over the Sahara during July 2003?

Engelstaedter, S., Tegen, I. and Washington, R. 2006. North African dust emissions and transport. Earth Science Reviews 79 (1-2):73-100.

Ergenzinger, P. 1978. Das Gebiet des Enneri Misky im Tibesti-Gebirge, République du Tchad: Erläuterungen zu einer geomorphologischen Karte 1:200 000: Arbeit aus der Forschungstation Bardai/Tibesti, Berliner geographische Abhandlungen, 23, 49 pp.

Ergenzinger, P.J., Rosenkranz, E. 1984. The méthodes de réconstitution paléoclimatique region in the Tibesti mountain-range, Chad. Petermanns Geographische Mitteilungen 128 (1), 77-78.

Erhart, H. 1953. Sur la nature minéralogique et la genèse des sédiments de la cuvette tchadienne, Comptes rendus de l'Académie des Sciences, Paris, 237 (5), 401-403.

Erhet, C. 1993. Nilo-Saharans and the Saharo-Sudanese neolithic, in The archaeology of Africa, Eds. Shaw, T., Sinclair, P., Andah, B. and Okpoko, A., Routledge, London, 104-125.

Estoque, M., Fernandez-Partagas, J., Helgren, D.M. and Prospero, J.M. 1986, Genesis of major dust storms in West Africa during the summer of 1974. ARO Technical Report No. 19684.2-GS (contract to University of Miami).

Eugster, H.P., Maglione, G. 1979. Brines and evaporites of the Lake Chad basin, Africa. Geochimica et Cosmochimica Acta 43 (7), 973-982.
The waters of Lake Chad in Central Africa are dilute and of the Ca-Mg-Na-HCO_3 type with low Cl and SO_4. In the Kanem region, NE of Lake Chad, such waters are subjected to evaporative concentration and brines and evaporites form in the many depressions between sand dunes. 3 brine types evolve, each representing a specific subenvironment: 1) small, saline, playas (0.5 x 2km) with shallow groundwater tables, b) small perennial lakes (interdunal lakes) and c) lakes and playas located on islands within Lake Chad. The behaviour of the major solutes can be interpreted by using chloride as a monitor of the extent of evaporative concentration

Evans, R.D., Jefferson, I.F., Kumar, R., O'Hara-Dhand, K., Smalley, I.J. 2004. The nature and early history of airborne dust from North Africa; in particular the Lake Chad basin. Journal of African Earth Sciences 39 (1-2), 81-87.
Africa is the great source of airborne dust, and a very large proportion of it blows out of the Lake Chad basin. There are various types of dust, an initial simple division might be into large dust and small dust, but the small dust category is itself divided into essentially monomineralic dust and clay mineral agglomerate (CMA) dust. The monomineralic dust populations are separated by Tanner gaps. Long weathering times allow small CMA dust particles to be produced (the PI process); the initial transportation processes (T1) have led to the vast accumulation of dust material in the Lake Chad basin. These early processes are important in the study of African dust. Ground material controls the nature of the dust cloud. Small dust is essentially old dust; large dust is young dust, and the two form distinct populations. CMA dust derived directly from old lake basins is basically controlled by the nature of the lake sediment. A simple Monte Carlo model shows how particle packing parameters control the size of small CMA dust, limiting it to the very fine silt fraction

Facchini, F., Fulcheri, E., Veschi, S.A. 1998. Neolithic fragmentary skull from Erg Djourab in Chad. Anthropological and paleopathological observations. Anthropologie 102 (3), 319-327.
A fragmentary skull, found in the Erg Djourab region (Chad) in 1996, and dated 8400 +/- 1100 years BP by a direct gamma-ray spectrometric method, and 3310 to 2895 years(calibrated age, 95 %) BC by C^{14} method, is studied here. The skull, referred to Neolithic period, is elongated, massive, and presents a thickening in some zones of the vault, probably caused by a trauma. On the basis of the analysis of cranial sutures and dental wear, the skull can be referred to an adult male of 30-35 years of age, and can be arranged among the Neolithic populations of Central Sahara.

Faizoun, C.A., Podaire, A., Dedieu, G. 1994. Monitoring of Sahelian aerosol and atmospheric water-vapor content characteristics from sun photometer measurements. Journal of Applied Meteorology 33 (11), 1291-1303.
Atmospheric measurements in two Sahelian sites in West Africa are presented and analyzed. The measurements were performed using a sun photometer with five bands in the visible and near-infrared range of the solar spectrum. This instrument measures spectral values of the solar irradiances that are used to derive the aerosol optical thickness in three bands; the two other bands are used to derive the integrated atmospheric water vapor content using a differential absorption method. The Angstrom exponent, which is an estimate of the aerosol particle size, is derived from the spectral dependence of the optical thickness. Although the sites were located far from Sahara Desert aerosol sources, the observed aerosol optical thicknesses were high, with a mean annual value of 0.5 at 550 nm. The spectral dependence of aerosol optical thickness is generally low, with a mean annual value of Angstrom's exponent of 0.4. The aerosol optical thickness and the atmospheric water vapor content are

both characterized by high temporal variability and exhibit seasonal cycles. From these measurements, climatological values and associated probability distribution laws are proposed.

Faure, H. 1954. Géologie des régions au nord du Tchad (territoire du Niger). Cimptes rendus simmaires de Séances de la Société géologique de France 13, 309-312.

Faure, H. 1959. Une hypothèse sur la structure du Ténéré (Niger). Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences 249 (23), 2591-2593.

Faure, H. 1959. Sur quelques dépôts du quaternaire du Ténéré (Niger). Comptes rendus hébdomadaires des Seances de l'Académie des Sciences, 249 (25), 2807-2809.

Faure, H. 1962. Reconnaissance géologique des formations sédimentaires post-paléozoiques du Niger oriental. Thèse, Paris, Mémoire, 47 (1963), Bureau de Recherche géologique et minière (BRGM), 630 pp.

Faure, H. 1962. Esquisse paléogéographique du Niger oriental depuis le Crétacé, Comptes rendus de l'Académie des Sciences, Paris, D 254 (26), 4485-4486.

Faure, H. 1965. Inventaire des evaporites du Niger, Rapport, Bureau de Recherche géologique et minière (BRGM), Dakar, 430 pp.

Faure, H. 1966. Evolution des grands lacs sahariens à l'Holocène. Quaternaria 8, 167-175.
New observations and carbon-14 dates from lacustrine deposits in the arid regions in the north and the Sahel region in the south of the Niger Sahara indicate that large lakes were present in the Niger desert 22,000 years ago, but toward 7000 B.P. drought and rapid evaporation resulted in salt deposition in the basins with limestones and soluble salts deposited on diatomites. Evaporation of the lake surfaces was much more rapid than that of the underground water resulting in the lowering of the water table beneath the basins.

Faure, H. 1966. Reconnaissance géologique des formations sédimentaires post-paléozoïques du Niger oriental, Mémoire, 47, Bureau de Recherche géologiques et minière (BRGM), 632 pp.

Faure, H. 1966. Une importante période humide du Quaternaire supérieur au Sahara, Bulletin de Liaison, 10-11, L'Association sénégalaise pour l'Etude du Quaternaire de l'Ouest-Africaine, 13.

Faure, H. 1967. Lacs quaternaires du Sahara, Proceedings of the International Symposium on Palaeolimnology, Tihany, Hungary, August, 16 pp.

Faure, H. 1969. Lacs quaternaires du Sahara, International Vereinigung Limnologische Mitteilungen, 17, 131-146.

Faure, H., Ed. 1970. "Lake Chad edition", Cahiers, Série Géologie, 2 (2), Office de la Recherche scientifique et technique de l'Outre Mer (ORSTOM), Paris, 157 pp.

Faure, H., Breed, C.S., Faure-Denard, L., McCauley, J.F., Page, N., Simon, B. 1992. Ténéré of Tafassasset; a preliminary investigation of SIR-C. In: Résumes des communications françaises presentées au 29^{e} congrès géologique international. Géochronique 42, 57.

Faure, H., Breed, C.S., McCauley, J.F. 1992. Paleodrainages of the eastern Sahara - the Nile problem and its relevance to the Chad basin. Journal of African Earth Sciences 14 (1), 153-154.

Faure, H., Fontes, J.Ch., Gischler, C.E., Mook, W.G., Vogel, J.C. 1970. Un exemple d'étude d'hydrogéologie isotopique en pays semi-aride, le bassin du Lac Tchad. Journal of Hydrology 10 (2), 141-150.

Faure, H. and Gac, J.-Y. 1981. Un futur cycle aride au Sahel vers l'an 2005? In: First meeting of the European Union of Geosciences.Terra Cognita. Special issue, 105 pp.

Faure, H. and Koeniguer, J.C. 1967. Etude paléoxylolique du Niger oriental: sur la présence de *Faureoxylon princeps* n.g. sp. et de *Opilioxylon nigerium* n.g. n. sp., **92**ième Congrès de la Société des Savantes, Strasbourg.

Faure, H. and Lang, J.L. 1991. Dynamics of continental and paralic sedimentation in Africa; Quaternary models. In: Sedimentary and diagenetic dynamics of continental Phanerozoic sediments in Africa, Ed. Lang, J.L. Journal of African Earth Sciences. 12 (1-2), 1-7.
The geographical extent and geomorphology of the continent mean that a wide range of zonal climates is represented, from equatorial to mediterranean, that are not affected unduly by relief. They are marked, however, by strong contrasts between dry and wet seasons which can sometimes be represented by discontinuities in the sediments. The record of climatic zones, together with evidence of climate-induced diagenesis, allows a reconstruction of the latitudinal drift of the African plate after the break-up of Pangea at the end of the Jurassic.

Faure, H., Manguin, E., Nydal, R. 1963. Formations lacustres du Quaternaire supérieur du Niger oriental: Diatomites et datations absolues. Bulletin du Bureau de Recherche géologique et minières, (3), 41-43.
All ^{14}C ages. Agadem (16 50N, 13 20 E), diatomite 8580 ± 100 BP; Kafra (N19 E 12 20), “calcaire” 21,350 ± 100 BP; Fachi (….) calcaires 21,350 ±350 BP; NE of Kandel Bouzou N15 54, E 10 59), diatomite 6,900 ± 150 BP; Bouloum Gana 15 01 N, 10 02 E), diatomite ± 9159± 200 BP; Adrar Bous (20 18 N 9.02 E), calcaire 7300± 120 BP

Faure, H., Servant, M. 1970. Evolution récente d'un bassin continental; le Tchad; programme. Cahiers d’ORSTOM, Série Géologie 2 (1), 5-8.

Faure, H., Vincent, P.M., Beauvilain, A., Mbaitoudji, M. 1995. Quaternary lakes of Trou au Natron (Tibesti). In: European Union of Geosciences 8; oral and poster presentations. Terra Abstracts 7, Suppl. 1, 266.

Felix-Henningsen,P. 1992. Früholozäne Feuchtzeitböden auf Altdünen der Ténéré und des Tchigai-Berglandes, Ost- Niger. Würzburger Geographischen Arbeiten, 84, 97-132.

Felix-Henningsen, P. 2000. Paleosols on Pleistocene dunes as indicators of paleo-monsoon events in the Sahara of East Niger. Catena 41 (1-3), 43-60.
In a SW-NE traverse across the Tenere desert and the southern Tchigai mountainous region, only one generation of ancient dunes was found, overlain by recent, active eolian sand sheets and dunes. Paleosols on these dunes display red-brown to yellow-brown Bw horizons up to 100 cm thick and an classified as Chromi-Cambic Arenosols and Cambic Arenosols, respectively. The structure of the soil horizons is stabilized by pedogenic cementation and often shows effects of bioturbation. Near the shores of previously more extensive paleolakes, these paleosols change into Gleyic Arenosols. The former shore lines are frequently marked by seams of goethite rhizoconcretions ("bog iron ores"). Within the paleolake depressions, ancient dune sediments bleached by gleying are covered by silt-rich lacustrine sediments. Neolithic artifacts on the lacustrine sediments indicate that during an arid climatic period, the paleolakes contracted in size and did not reach their fullest original extent during the late Neolithic humid period. This suggests the existence of earlier periods with enhanced humidity. Because of a decrease in humidity from SW to NEI the degree of rubefication and several physical, chemical and mineralogical properties of the paleosols an related to their position along the traverse. A gradient of decreasing weathering intensity from SW to NE is paralleled by local variations in mineralogical properties of the parent materials and in rates of dust deposition. Consequently, the two effects on soil properties are difficult to separate.

Felix-Henningsen, P. 2004. Genesis and paleo-ecological interpretation of swamp ore deposits at Sahara paleo-lakes of east Niger. In: Smykatz-Kloss, W. and Felix-Henningsen, P. (eds), Palaeoecology of Quaternary Drylands. Springer, Berlin, pp. 47-72.

Fernandez-Partagas, J., Helgren, D.M. and Prospero, J.M. 1986. Threshold wind velocities for raising dust in the western Sahara Desert. ARO Technical Report No. 19684.3-GS (contract to University of Miami).

Feyler 1935. Observations de géographie physique dans le Ténéré, région du Tafassasset, entre Ahaggar, Air, Tibesti et Tchad. Bulletin de l'Association de Géographes Francais (89), 91-95.

Foley, J.A., Coe, M.T., Scheffer, M.R., Wang, G.L. 2003. Regime shifts in the Sahara and Sahel: Interactions between ecological and climatic systems in northern Africa. Ecosystems 6 (6), 524-539.
The Sahara and Sahel regions of northern Africa have complex environmental histories punctuated by sudden and dramatic "regime shifts" in climate and ecological conditions. Here we review the current understanding of the causes and consequences of two environmental regime shifts in the Sahara and Sahel. The first regime shift is the sudden transition from vegetated to desert conditions in the Sahara about 5500 years ago. Geologic data show that wet environmental conditions in this region, giving rise to extensive vegetation, lakes, and wetlands, came to an abrupt end about 5500 years ago. Explanations for climatic changes in northern Africa during the Holocene have suggested that millennial-scale changes in the Earth's orbit could have caused the wet conditions that prevailed in the early Holocene and the dry conditions prevalent today. However, the orbital hypothesis, by itself, does not explain the sudden regime shift 5500 years ago. Several modeling studies have proposed that strong, nonlinear feedbacks between vegetation and the atmosphere could amplify the effects of orbital variations and create two alternative stable states (or "regimes") in the climate and ecosystems of the Sahara: a "green Sahara" and a "desert Sahara." A recent coupled atmosphere-ocean-land model confirmed that there was a sudden shift from the "green Sahara" to the "desert Sahara" regime approximately 5500 years ago. The second regime shift is the onset of a major 30-year drought over the Sahel around 1969. Several lines of evidence have suggested that the interactions between atmosphere and vegetation act to reinforce either a "wet Sahel" or a "dry Sahel" climatic regime, which may persist for decades at a time. Recent modeling studies have indicated that the shift from a "wet Sahel" to a "dry Sahel" regime was caused by strong feedbacks between the climate and vegetation cover and may have been triggered by slow changes in either land degradation or sea-surface temperatures. Taken together, we conclude that the existence of alternative stable states (or regimes) in the climate and ecosystems of the Sahara and Sahel may be the result of strong, nonlinear interactions between vegetation and the atmosphere. Although the shifts between these regimes occur rapidly, they are made possible by slow, subtle changes in underlying environmental conditions, including slow changes in incoming solar radiation, sea-surface temperatures, or the degree of land degradation.

Fontes, J.C., Gasse, F., Andrews, J.N. 1993. Climatic conditions of Holocene groundwater recharge in the Sahel zone of Africa. In: Isotope techniques in the study of past and current environmental changes in the hydrosphere and the atmosphere. Proceedings Series – International Atomic Energy Agency. STI/PUB/908, 231-248.

Fontes, J.C., Gasse, F., Callot, Y., Plaziat, J.C., Carbonell, P., Dupeuble, P.A., Kaczmarska, I. 1985. Fresh-water to marine-like environments from Holocene lakes in northern Sahara. Nature 317 (6038), 608-610.

Fontes, J-C., C. Moussie, P. Pouchan and M. Weidmann, 1973. Phases humides au Pleistocene superieur et a l'Holocene dans le sud de l'Afar (T.F.A.I.). Comptes rendus hebdomadaires de l'Academie des Sciences, Paris 277 : 1973-1976.

Foody, G.M. 2001. Monitoring the magnitude of land-cover change around the southern limits of the Sahara. Photogrammetric Engineering and Remote Sensing 67 (7), 841-847.
Studies of land-cover change using satellite remote sensing are often constrained to depict land-cover conversions only, with the equally important modifications undetected or misrepresented, resulting in significant error. Desert fluctuations within the Sahel were examined using an approach that indicated the magnitude of land-cover changes. This showed that the conventional post-classification comparison method of change detection appeared to underestimate the area of land-cover change and, where a change was detected, typically overestimate its magnitude. At the regional scale, the land-cover changes detected were strongly related to rainfall variability This relationship did not, however, explain changes at a finer spatial scale and indicated that dryland degradation, and its causes, may remain far from understood.

Frangi, J.P., Druilhet, A., Durand, P., Ide, H., Pages, J.P., Tinga, A. 1992. Energy budget of the Sahelian surface-layer. Annales Geophysicae – Atmospheres, Hydrospheres and Space Sciences 10 (1-2), 25-33.

This paper presents a synthesis of results obtained during different measuring campaigns that were conducted in the Niamey area (Niger). These campaigns concerned the study of the atmospheric boundary layer and the surface layer. This synthesis focuses on the measurement of the energy budget and related problems. The effect of dust haze on the climatic parameters and on the energy budget components is shown and figures as an original contribution in this work. The radiative contribution to the heat flux in the surface layer is also indicated. Finally, practical conclusions are drawn concerning the generalization of fixed point measurements from regional integration by means of airborne measurements.

Frangi, J.P., Yahaya, S., Piro, J. 1992. Characteristics of solar-radiation in the Sahel - case-study - Niamey, Niger. Solar Energy 49 (3), 159-166.
The principle climatic characteristics of the region of Niamey, Niger, in the Sahelian belt are illustrated on the basis of long meteorological series and with the aim of understanding the influence of dust on radiation. Empirical formulae are presented which make it possible to determine global radiation on the basis of duration of insolation, and diffuse radiation on the basis of global radiation. These formulae contain monthly constants, and it is shown that these are linked. The formulae are of practical interest for users of solar energy in the region.

Franz, H. 1967. On the stratigraphy and evolution of climate in the Chad Basin during the Quaternary. In: Background to evolution in Africa, Eds. Bishop, W.W. and Clark, J.D., Chicago University Press for Wenner-Gren Foundation, Chicago, pp. 213-284.
Throughout most of the Chad basin continental Tertiary and Quaternary sediments overlie a faulted ancient crystalline basement, with Paleozoic rocks intervening only in the north. The Quaternary is represented by fluviatile deposits and, toward the center of the basin, lacustrine sediments. Four types of sediments and four erosion levels are distinguished in the fluviatile deposits; three different types of sediments and evidence of four different lake levels are identified in the lacustrine deposits. Relief forms and sediments in the basin indicate that repeated climatic changes were fully effective south of the Sahara during the Quaternary.

Frédoux, A. and Tastet, J.-P. 1988. Stratigraphie pollinique et paléoclimatologie de la marge septentrionale du Golfe de Guinée depuis 200,000 ans. Inst. Français de Pondichéry, Traveaux, Section Scientifiques et Technique 25, 175-183.

French, T.T., Hermens, R.D.D. 1984. The Paleolithic in the northern Chad Basin (Nigeria-Chad) - Anthropologie 88 (3), 471-471.

Frumkin, A., Stein, M. 2004. The Sahara-East Mediterranean dust and climate connection revealed by strontium and uranium isotopes in a Jerusalem speleothem. Earth and Planetary Science Letters 217 (3-4), 451-464.
This paper explores the potential of Sr and U isotope systems in speleothems as tracers of eolian dust transport and hydrological conditions. The study focuses on a speleothem from Jerusalem spanning the past 220 kyr. This speleothem provides a precisely dated record of dust flux from the Sahara to the East Mediterranean. Enhanced dust flux and Terra Rossa soil development are reflected by elevated Sr-87/(86) Sr ratios in the speleothem (0.7082-0.7086), while lower Sr-87/Sr-86 ratios (similar to0.7078) indicate higher contribution of the local bedrock due to low dust flux and low soil accumulation. The strontium isotope system in the speleothem is a robust monitor of the Sahara monsoon-modulated climate, since dust uptake is related to development or reduction in vegetation cover of Sahara soil. The [U-234/U-238] activity ratios in the speleothem range between 1.12 and 1.0. The high activity values may indicate selective removal of U-234 from the soil while the low values converge to the bedrock. The migration of U-234 to the cave reflects mainly the regional hydrological conditions that are modulated by the North Atlantic-Mediterranean climate system. Thus, the speleothem provides a combined record of the monsoon-North Atlantic climatic systems. Long-term stability in glacial Sr-87/Sr-86 ratios (0.7083 +/- 0.0001 over the past 220 kyr) suggests an overall similarity in eolian dust sources, and uniformity in the synoptic conditions that dominate the dust storm tracks during glacial periods.

Gabriel, B. 1972. Terrassenentwicklung und vorgeschichtliche Umweltbedingungen im Enneri Direnao (Tibesti, östliche Zentralsahara). Zeitschrift für Geomorphologie, Supplementband 15, 113-128.

Gabriel, B. 1977. Zum ökologischen Wandel im Neolithikum der östlichen Zentralsahara, Berliner geographische Abhandlungen, **27**, 111 pp.

Gabriel, B. 1986. Die östliche libische Wüste im Jungquatär, Berliner geographische Studien, 19, 217 pp. [rgs M 70 B

Gabriel, B. and Kröpelin, S. 1983. Jungquatär limnische Akkumulationsphasen im NW Sudan, Zeitschrift für Geomorphologie, Supplementband, 48, 131-143.

Gabriel, B., Kröpelin, S. 1984. Holocene lake deposits in Northwest-Sudan. Palaeoecology of Africa 16, 295-299.

Gabriel, B. and Kröpelin, S. 1986. Habitats dunaires néolithiques au Soudan séptentrional et implications paléoclimatiques, in Changements globaux en Afrique durant le Quaternaire, INQUA-ASEQUA symposium, Dakar, Editions de l'ORSTOM, Trauvaux et Documents, 197, 157-160.

Gabriel, B., Kröpelin, S., Richter, J. and Cziesla, E. 1985. Parabeldünen am Wadi Howar; Besiedlung und Klima in neolithischer Zeit im Nordsudan, Geowissenschaften in Unserer Zeit, 3 (4), 105-112.

Gac, J.-Y. 1980. Géochimie du bassin du lac Tchad; bilan de l'alteration, de l'érosion et de la sédimentation. Travaux et Documents de l'ORSTOM 123, 251 pp.

Gac, J.-Y., Al-Droubi, A., Paquet, H., Fritz, B., Tardy, Y. 1979. Chemical model for origin and distribution of elements in salts and brines during evaporation of waters; application to some saline lakes of Tibesti, Chad. In: Origin and distribution of the elements, Ed. Ahrens, J.L. Physics and Chemistry of the Earth 11, 149-158.

Galy-Lacaux, C. 1998. Precipitation chemistry in the Sahelian savanna of Niger, Africa. Journal of Atmospheric Chemistry, 30 (3), 319-343.
Within the framework of the IDAF (IGAC DEBITS AFRICA) network, we present in this paper data on precipitation and aerosol chemistry in the semiarid savanna of the Sahelian region of Niger. An automatic wet-only precipitation collector was operated at the Banizoumbou station during the entire 1996 rainy season (June to September 1996). Inorganic (Na+, NH4+, K+, Mg2+, Ca2+ Cl-, NO3-, SO42-) and organic contents of the precipitation (HCOOH, CH3COOH, C2H5COOH) were determined by Ion Chromatography (IC) in 29 rainfall events. Once per week, bulk particle samples were collected on the same site, and soluble water material was determined by IC. We examined the influence of atmospheric gas and particle sources on the precipitation and aerosol chemical contents. We established the influence of marine, terrigenous, and biogenic sources in the Sahelian region. The terrigenous signature is dominant and related to Sahelian soil erosion, with a high calcium content in precipitation (31.2 mu eq L^{-1}) and in aerosols (1.8 mu g m^{-3}). Two other signatures of atmospheric sources are highlighted by the relatively high nitrogenous (ammonium and nitrate) and organic contents (formate, acetate) in the precipitation. Ammonium (12.9 mu eq L-1) and nitrate (12.3 mu eq L-1) contents confirm respectively the biogenic source of ammonia released by domestic animal excreta in Niger and the natural emissions from semiarid savannas soils, perturbed by wild or domestic animal grazing. In spite of a high potential acidity given by nitrate, formate and acetate; a weak acidity (H+ (2.1 mu eq L-1) is calculated from the mean pH of 5.67 measured. A statistical analysis of the aerosol chemical composition clearly indicates that nitrates are strongly correlated at the 1% level with terrigenous ions, i.e., Ca2+ and Mg2+ ($0.95 < r < 1$). We observed a similar relationship between all the terrigenous ions and nitrate in the precipitation. In the Sahelian region, alkaline soil dust representative of the terrigenous contribution interact, with gaseous nitrogenous and carbonaceous compounds, leading to the neutralization of acid gases and subsequent weak acidity in precipitation. Finally, taking into account the main chemical characteristics of Banizoumbou precipitations and aerosols, which demonstrate the importance of heterogeneous and multiphase chemical processes, we propose a conceptual model of the atmospheric chemistry in the Sahelian region.

Galy-Lacaux, C., Carmichael, G.R., Song, C.H., Lacaux, J.P., Al Ourabi, H., Modi, A.I. 2001. Heterogeneous processes involving nitrogenous compounds and Saharan dust inferred from measurements and model calculations. Journal of Geophysical Research-Atmospheres 106 (D12), 12559-12578.

Experimental data on aerosol chemical composition and gaseous concentrations in various African ecosystems have been obtained under the IGAC DEBITS AFRICA (IDAF) program. In this paper, data covering a complete wet and dry season (1996 and 1998) in the semiarid savanna of the Sahelian region of Niger are presented. The analysis of the aerosol chemical composition and the gas phase concentrations at the Banizoumbou station indicates two strong signatures: a nitrogenous component composed of nitric acid, ammonia, particulate ammonium, and nitrates; and a terrigenous component originating from semiarid and desert soils (calcium, carbonates, magnesium, potassium, sulfate). To further investigate the interactions between gas and particles and to help interpret the IDAF experimental data, these data are analyzed using a gas aerosol equilibrium model (Simulating Composition of Atmospheric Particles at Equilibrium (SCAPE)). The model is found to accurately represent the mean aerosol composition for the dry and the wet season of the studied region. It is found that heterogeneous processes involving terrigenous compounds are important and play a major role in partitioning semivolatile species, such as nitric acid, between the gas and aerosol phases. The important role of these heterogeneous processes in the atmospheric chemistry in the Sahelian region is discussed. To compare results obtained in the semiarid savanna of Niger and other African ecosystems, SCAPE model is also applied to humid savanna and forest using IDAF and Experiment for Regional Sources and Sinks of Oxidants (EXPRESSO) measurements.

Ganor, E. 1991. The composition of clay-minerals transported to Israel as indicators of Saharan dust emission. Atmospheric Environment, A 25 (12), 2657-2664.
Ambient particles, following dust storms originating in the Saharan region as identified by meteorological analysis of synoptic maps, satellite pictures and back-trajectory calculations, transported over Israel, were collected and analysed. In studies of 28 heavy dust storms originating in the Saharan region, during a 22 year period (1967-1988), clay mineral analysis provided information about the characteristics of dust particles transported over Israel. Relatively high concentrations of montmorillonite and mixed-layer minerals were found in the particles when the storms originated on the western deserts of the Tibesti mountains. Following storms that originated in Saudi Arabia, Jordan and the Dead Sea deserts, the dust particles contained a high percentage of palygorskite. Following storms that originated in the Chad, Lybian plateau deserts and the Great Sand Sea of Ahaggar Massif, predominantly high concentrations of illite was found in the ambient particles in Israel. These data indicate that ambient particles in Israel following dust storms originating in the Saharan region may be characterized by their mineral content.

Ganor, E. and Foner, H. 1996. The mineralogical and chemical properties and the behaviour of aeolian Saharan dust over Israel, in The impact of desert dust across the Mediterranean, Eds. Guerzoni, S. and Chester, R., Kluwer Academic, Dordrecht, 163-172.

Ganor, E. and Mamane, Y. 1982. Transport of Saharan dust across the eastern Mediterranean, Atmospheric Environment, 16 (3), 581-587.

Garba, Z., Durand, A. and Lang, J. 1995. Enregistrement sédimentaire de l'activité éolienne et de l'aridité pendant la transition Tardiglaciaire/ Holocène à la limite Sahara/ Sahel (Térmit, bassin du lac Tchad). In: Echelles des variations chronoclimatiques quaternaires et reponses des environnements. Ed. Rousseau, D.D., Biglione, A.M. International Union for Quaternary Research, Comté national français, Zurich, Quaternaire (Paris) 6 (2), 91-98.

Garba, Z., Durand, A. and Lang, J. 1996. Enregistrement sédimentaire des variations de la dynamique éolienne pendant la transition Tardiglaciaire/Holocène à la limite Sahara/Sahel (Termit, Bassin du lac Tchad), Zeitschrift für Geomorphologie, Supplementband, 103, 159-178.

Garba, Z., Durand, A., Lang, J. 2003. Identification and quantification of Late Quaternary eolian dust deposits at the Sahara/Sahel boundary (Termit Massif, Republic of niger, Lake Chad Basin). Zeitschrift für Geomorphologie 47 (3), 307-328.
Identification and quantification of late Quaternary Eolian dust deposits at the Sahara/Sahel boundary (Termit Massif, Republic of Niger, Lake Chad Basin). - A 15.57 meter core was extracted from the West-Termit endoreic depression at the present-day Sahara/Sahel boundary (NW of Lake Chad Basin, Tenere, Republic of Niger). Three formations were identified representing widely contrasting paleoclimates; they are attributed to the end of the Late-glacial period, the Younger Dryas period of maximum aridity, and the early Holocene period of maximum humidity. A range of methods was used to analyze the sedimentology of these essentially siliciclastic formations, including the quantum model

of FOLK (1971). The proportion of eolian deposits could thus be identified and quantified. Six eolian stocks are distinguished by analogy with present-day regional eolian dynamics. They reflect different dynamics (deflation, accumulation by saltation, and suspension deposits from a nearby or remote area). Their co-occurrence or alternatively their absence serve as markers of varying degrees of aridity (seasonal or permanent, local or regional, slight or intense). Whereas paleoclimatic studies are usually based primarily, if not exclusively, either directly (paleolimnology) or indirectly (paleobiology) on the presence of water, we widen and reverse the scale of reference by using aridity to define a climatic situation. Thus, the uninterrupted input of fine dust during the early Holocene period of maximum humidity calls into question the often suggested idea of a "green Sahara".

Garba, Z., Durand, A., Lang, J., Alzouma, K. 2003. Signification paléoenvironnementale des minèraux argileux dans les dépôts de dépressions fermées du bassin du Lac Tchad au Tardiglaciaire et a l'Holocène; Termit et Bougdouma, Niger oriental. In: Abuja geocongress. African Geosciences Review 10 (1-2), 141-152.
In the Lake Chad basin, clay minerals were studied in two cores from closed lacustrine geosytems: a piedmont lake and an interdunal lake, located in the Tenere and Manga sand-sea. These lakes are very good recorders of paleoenvironments during the Late Glacial and the Holocene, according to their simple geomorphologic, geologic, hydrologic and climatologic features. In both closed depressions, the clay mineral suite was the same: kaolinite, illite and smectite. Palygorskite which is considered as a Saharian Eolian dust indicator and as an aridity index was not found. Clay mineral sedimentary processes and paleoenvironments depend on the features of the closed depressions. As an uplifted block protected the closed depression of Termit-Ouest against Eolian dynamics, run-off processes thus dominated. In the case of Bougdouma, located in a leveled sand-sea, groundwater feeds a permanent lake where Eolian processes are continuous. In both environments, the only neogenetic clay mineral is smectite.

Gasse, F. 1980. Late Quaternary changes in lake-levels and diatom assemblages on the southeastern margin of the Sahara. In: Sahara and surrounding seas; sediments and climatic changes; proceedings of an international symposium. Eds. Sarnthein, M., Seibold, M., Rognon, P. Palaeoecology of Africa and of the Surrounding Islands and Antarctica 12, 333-350.
Reviews recent research and compares the evolution of the Ethiopian lake with some equatorial lakes in East Africa. Special emphasis is given to changes in diatom assemblages which provide evidence of hydrologic and climatic fluctuations.

Gasse, F. 1987. Diatoms for reconstructing palaeoenvironments and paleohydrology in tropical semi-arid zones (example of some lakes from Niger since 12000 BP). Hydrobiologia 154, 127-163.

Gasse, F. 1988. Diatoms, palaeoenvironments and palaeohydrology in the western Sahara and the Sahel. In: Geowissenschaftliche Untersuchungen in Afrika. Eds. Hagedorn, H., Baumhauer, R. Würzburger geographische Arbeiten 69, 233-254.

Gasse, F. 2000. Hydrological changes in the African tropics since the last glacial maximum, Quaternary Science Reviews, 19 (1-5), 189-211.
Paleohydrological data from the African tropics and subtropics, including lake, groundwater and speleothem records, are reviewed to show how environments and climates from both hemispheres are inter-related. Although orbitally induced changes in the monsoon strength account for a large part of long-term climatic changes in tropical Africa, the Late Pleistocene-Holocene hydrological fluctuations rather appear to have been a series of abrupt events that reflect complex interactions between orbital forcing, atmosphere, ocean and land surface conditions. During the Last Glacial Maximum (23-18 ka BP), most records indicate that generally dry conditions have prevailed in both hemispheres, associated with lower tropical land- and sea-surface temperatures. This agrees with simulations using coupled ocean-atmosphere models, which predict cooling and reduced summer precipitation in tropical Africa; the global hydrological cycle was weaker than today when the extent of large polar ice-sheets and sea-ice was a prominent forcing factor of the Earth's climate. Glacial-interglacial climatic changes started early: a first wetting/warming phase at ca. 17-16 ka BP took place during a period of rapid temperature increase in Antarctica. Next, two drastic arid-humid transitions in equatorial and northern Africa occurred around 15-14.5 ka BP and 11.5-11 ka BP. Both are thought to match the major Greenland warming events, in concert with the switching of the oceanic thermohaline circulation to modern mode. However, part of the climatic signal after 15 ka BP also seems related to the Antarctica climate. During the Holocene, Africa has also experienced rapid hydrological fluctuations of dramatic magnitude

compared to the climatic changes at high latitudes. In particular, major dry spells occurred around 8.4-8 ka and 4.2-4 ka BP in the northern monsoon domain. Comparison with other parts of the world indicates that these events have a worldwide distribution but different regional expressions. In the absence of large polar ice sheets, changes in the continental hydrological cycles in the tropics may have a significant impact on the global climate system. Climate information gathered here allows to identify geographical and methodological gaps, and raise some scientific questions that remain to be solved to better understand how the tropics respond to changes in major climate-forcing factors, and how they influence climate globally.

Gasse, F. 2002. Diatom-inferred salinity and carbonate oxygen isotopes in Holocene waterbodies of the western Sahara and Sahel (Africa). In: Interactions between arid and humid records of Quaternary change in drylands (IGCP 413), Eds. Thomas, D.S.G., Singhvi, A.K. Quaternary Science Reviews 21 (7), 737-767.
Thirteen Holocene palaeolakes in the western Sahara and Sahel have provided diatom records, with carbonate oxygen isotope profiles available from eight of them. Most of these palaeolakes were groundwater-fed. Lake water chemistry is reconstructed using diatom transfer functions. Lake water salinity and ^{18}O records are assembled with some isotopic and chemical groundwater data to better understand the response of the hydrological systems to climate changes over the past 15,000 yr. Data are in general agreement with climate simulations using coupled atmosphere-ocean-vegetation models which show a mid-Holocene wetting over the whole of northwest Africa, and a rapid drying by 6-4 ka. The lake record also shows that at many sites the major lake infilling lags the end of the Younger Dryas by 1-2 ka. Regional differences also appear in the timing of the lake hydrological optimum: ca. 10.5-8.5 and 7.5-4.5 ka in the northern Sahara, 10-8.5 ka in the Air-Tenere, 10-5.7 or 4.5 in the Sahel, and 7.5 ka in Lake Chad. The whole of the Holocene is punctuated by short-term drying events. Changes in water isotopic composition through time are partly explained by changes in rainfall amount and air humidity. During the wet Holocene period however, the very low γ values in the southern Sahara also imply changes in the moisture transport pattern or rainfall mechanisms. Data suggest an apparent decrease in ^{18}O content of precipitation along the monsoon flow, in contrast with modern patterns. Changes in water availability and quality have driven population migrations in and out of the Sahara-Sahel, but relationships between climate and cultures are complex. Short-term dry events might have driven inventive adaptations. In the Sahara, drying at 5-4.5 ka coincides with both the collapse of the classical Neolithic civilization and the settlement of new cultures

Gasse, F., Juggins, S., Khelifa, L.B. 1995. Diatom-based transfer-functions for inferring past hydrochemical characteristics of African lakes. Palaeogeography Palaeoclimatology Palaeoecology 117 (1-2), 31-54.
A new dataset of 282 modern diatom samples and associated environmental information has been created by merging existing regional datasets from North and East Africa and Niger. The relationships between diatom species distributions and hydrochemistry are examined using canonical correspondence analysis (CCA) and partial CCA. Variables reflecting water conductivity, pH, and cation and anion composition account for significant and independent components of the total variation in the diatom data. Predictive models (transfer functions) are developed using the method of weighted averaging for conductivity ($r(2) = 0.87$), pH ($r(2) = 0.77$), and ratios between alkali and alkaline earth metals ($r(2) = 0.81$), and carbonate-bicarbonate and sulphate + chloride ions ($r(2) = 0.82$). Prediction errors are estimated using the computer-intensive method of jackknifing. These transfer functions enlarge the potential domain for reconstruction of past hydrochemistry from fossil diatoms preserved in lake sediments.

Gasse, F., Lin Ruifen 1998. Lacustrine isotope archives of past climate and environmental changes in the tropics and subtropics; some examples from Africa. In: Isotope techniques in the study of environmental change; proceedings. Proceedings Series – International Atomic Energy Agency 519-531.
The paper shows how isotopic data from lake sediments may contribute to an understanding of the response of continental systems to changes in major climate forcing factors. It focuses on the African tropics and subtropics. Selected examples highlight the interest of (1) carbon isotopes in plant material and (2) oxygen isotopes in carbonates in groundwater fed lakes. In organic rich lacustrine sediments, carbon isotope composition in plant material can provide insights into past changes in biome distributions and the carbon cycle. The major factors that control $^{13}C/^{12}C$ ratios in organic matter in peats and lake sediments are briefly summarized. In Africa, a major decrease (> or =10 per mil) in $\delta^{13}C$ is observed in peats and lake records from both hemispheres during the last deglaciation.

Comparison with other proxy data (notably pollen) and with past atmospheric CO_2 concentrations suggests that the latter have been the major factor controlling the distribution of tropical biomes rather than available water. Carbonate rich sediments from groundwater fed lakes may provide a means of reconstructing climatic conditions that controlled the lake status. In appropriate systems, climatic parameters, e.g. ambient humidity, can be theoretically determined if a salt balance equation is introduced in addition to those for the water and isotopes and if information on inflow waters is available from groundwater records. This is exemplified with a small Holocene palaeolake from the northern Sahara. Lacustrine isotope archives represent a powerful tool for extending our knowledge of the amplitude and causes of climate changes. In many cases, interpretation of the isotope signal should be supported by a multi-proxy approach. Detailed studies of modern systems as references should be encouraged for establishing calibration functions that may be used to transfer isotope proxies in terms of quantitative environmental and climate variables.

Gasse, F., Tehet, R., Durand, A., Gilbert, E., Fontes, J.-C. 1990. The arid-humid transition in the Sahara and the Sahel during the last deglaciation. Nature 346 (6280), 141-146.
At the time of the Last Glacial Maximum, the Sahara and Sahel regions of North Africa were extremely dry. New records of rainfall show that, during the subsequent deglaciation, the transition from arid to humid conditions in these regions occurred synchronously in two main steps. Comparison with other records of palaeoclimate in Europe and the North Atlantic Ocean shows that certain common factors controlled changes in ocean and atmosphere dynamics during the deglaciation.

Gasse, F., VanCampo, E. 1994. Abrupt postglacial climate events in West Asia And North-Africa monsoon domains. Earth and Planetary Science Letters 126 (4), 435-456.
Regions beyond the present or past penetration of the Indian and African monsoons have experienced several large and abrupt climatic fluctuations over the past 13 C^{14} kyr.
Pollen and lake records from West Asia (Western Tibet and Rajasthan), East Africa (Ethiopia) and West Africa (Western Sahara, Sahel and subequatorial Africa) were selected on the basis of chronological control, sensitivity of both site and environmental indicators to climate change, the continuity of the record, and interdisciplinary control of the palaeoclimatic interpretation.
Conditions wetter than those of today prevailed during the early-mid-Holocene period, but major dry spells are recorded at all sites during the intervals similar to 11.0-9.5 kyr BP, similar to 8-7 kyr BP and 3-4 kyr BP. Several records also suggest dry events of minor amplitude around 6 kyr BP. Potential boundary forcings of insolation and sea surface and tropical land surface conditions are discussed. The solar radiation accounts for the general envelop of the post-glacial monsoon fluctuations, but explains neither the timing nor the amplitude of the short-term changes. In spite of apparent covariation between fluctuations in sea surface conditions in the North Atlantic and the monsoon record, no direct mechanism could be found relating the intensity of the oceanic thermohaline conveyor belt to the monsoon strength. Changes in tropical land surface conditions (soil moisture negative feedback, and changes in CH_4 production from wetlands) provide a more satisfactory hypothesis for explaining abrupt reversal events.

Gavrilovic, D. 1970. Die Ueberschwemmungen im Wadi Bardague im Jahr 1968 (Tibesti, Rep. du Tchad). Zeitschrift für Geomorphologie 14 (2), 202-218.
River erosion, sedimentation, flood effects, criteria for former moist climate

Geraads, D., Brunet, M., Mackaye, H.T., Vignaud, P. 2001. Pliocene Bovidae (Mammalia) from the Koro Toro Australopithecine sites, Chad. Journal of Vertebrate Paleontology 21 (2), 335-346.
The Australopithecus-bearing of Koro Toro in central Chad yielded at least 9 species of bovids (Ruminantia: Bovidae). They all belong to genera found in North and/or East Africa, but three new species are named. Kobus korotorensis, sp. nov. is quite distinct from East African species, and is probably an early offshoot from primitive Reduncines. Kobus tchadensis, sp. nov. is more like some East African forms. Parmularius pachyceras, sp. nov. should rather be compared with a North African species. This relative endemism hinders precise biochronological correlation, but the best fit is in the range 2.7-3.4 Ma. The lack of Tragelaphines, and an abundance of Reduncines, Alcelaphines and Antilopines definitely points towards an open environment, that was drier than most East African sites of this age.

Geyh, M.A. and Jäkel, D. 1974. Spätpleistozäne und holozäne Klimageschichte der Sahara aufgrund zugänglicher 14C-Daten. Zeitschrift für Geomorphologie NF. 18 (1), 82-98

Geyh, M.A. and D. Jakel, 1974.14C-Altersbestimmungen im Rahmen derForschungsarbeiten der Aussenstelle Bardai/Tibesti der Freien Universitat Berlin. PressedienstWissenschaft der Freien Universitat Berlin 5 :107-117.

Geyh, M.A., Jäkel, D. 1974. Late glacial and Holocene climatic history of Sahara Desert derived from a statistical assay of C^{14} dates. Palaeogeography Palaeoclimatology Palaeoecology 15 (3), 205-208.

Geyh, M.A. and Jäkel, D. 1977. The climate of the Sahara during the Late Pleistocene and Holocene on the basis of available radiocarbon dates, Natural Resources and Development, 6, Institute for Scientific Cooperation, Tübingen, 64-79.

Ghienne, J.F., Bano, M., Duringer, P., Ferry, M., Schuster, M. 1999. Nature et origine des surfaces de discontinuités imagées par georadar au sein d'une dune éolienne active. In: 7^{e} congres francais de Sédimentologie; resumes, Centre national des Recherches scientifiques, Département des Sciences de l'Univers, Nancy, CNRS, France, Association française de Science 33, 169-170.

Ghienne, J.F., Schuster, M., Bernard, A., Duringer, P., Brunet, M. 2002. The Holocene giant Lake Chad revealed by digital elevation models. Quaternary International 87, 81-85.
The Chad Basin is a closed basin in the Central part of North Africa. A southern sub-basin, which is supplied by the humid tropics, includes the present-day Lake Chad. The northern sub-basin is presently dry, as it only receives drainage from Sahara rivers. In these areas, the existence of a giant lake known as the Lake Mega-Chad has been debated for a long time. Its level would be controlled by the Mayo Kebbi threshold in the southern part of the lake, which joined the Lake Mega-Chad and the Niger River via the Benoue Trough. Digital elevation models (the TOPO6 and GLOBE data sets) are used to characterise a well-defined shelf-like morphology, locally up to 50 km wide, followed at a constant elevation over hundreds of kilometers. This strictly horizontal geomorphic feature is interpreted as a wave-cut lacustrine shoreline terrace. It is associated with a sandridge that represents a barrier-island system built by wave-generated currents. This study demonstrates that a Holocene Lake Mega-Chad was present from 11^{o}N to 18^{o}N, across the southern and northern sub-basins. The influence of such a water vapour source must be considered in palaeoclimatological reconstructions.

Giles, J. 2005. The dustiest place on earth. *Nature* **434** (7035), 816-819.

Gillies, J.A., Nickling, W.G., McTainsh, G.H. 1996. Dust concentrations and particle-size characteristics of an intense dust haze event: Inland Delta region, Mali, West Africa. Atmospheric Environment 30 (7), 1081-1090.
An Intense dust plume was monitored in the Inland Delta region of Mall during the period 27-30 April 1990. The plume was generated by thunder cell downdraughts 500 km from the study site and subsequently carried by low-velocity winds to arrive approximately 28 h after its generation. Peak atmospheric dust concentrations (13,735 mu g m^{-3}) measured during the event and under very low wind shear conditions exceeded any previously reported in the literature for dust haze events. Particle-size features of the plume dust indicated a distant source. The distribution of dust-particle sizes was uni-modal with a mean of 3 mu m at 10 m. Calculated vertical dust fluxes indicated that, upon arrival of the plume, the vertical flux of particles was not in equilibrium with the local wind shear. This was the result of the very high mass concentrations of dust in the atmosphere. After the peak levels of concentration had passed, the relationship between vertical dust flux and wind shear velocity tended towards a relation which predicts dust moving upwards through the atmosphere, varying with wind shear velocity to the fourth power.

Ginoux, P., Chin, M., Torres, O., Prospero, J., Dubovik, O. and Holben, B. 2000. Relative contributions of the Saharan and Sahelian sources to the atmospheric dust load over the North Atlantic, EOS- Transactions of the American Geophysical Union, 81 (48), Supplement, F56.

Ginoux, P., Prospero, J.M., Torres, O., Chin, M. 2004. Long-term simulation of global dust distribution with the GOCART model: correlation with North Atlantic Oscillation. Environmental Modelling and Software 19 (2), 113-128.
Global distribution of aeolian dust is simulated from 1981 to 1996 with the Global Ozone Chemistry Aerosol Radiation and Transport (GOCART) model. The results are compared with in situ measurements and satellite data. An index is calculated from the model results and the satellite viewing angles to allow quantitative comparison with the Total ozone mapping spectrometer (TOMS) absorbing

aerosol index. The annual budget over the different continents and oceans are analyzed. The simulated annual emission varies from a minimum of 1950 Tg in 1996 to a maximum of 2400 Tg in 1988. Of these emissions, 65% is from North Africa and 25% from Asia. It is found that North America received twice as much dust from other continents than it emits per year. There is no significant trend over the 16-year simulation. The inter-annual variability of dust distribution is analyzed over the North Atlantic and Africa. It is found that in winter a large fraction of the North Atlantic and Africa dust loading is correlated with the North Atlantic Oscillation (NAO) index. It is shown that a controlling factor of such correlation can be attributed to dust emission from the Sahel. The Bodélé depression is the major dust source in winter and its inter-annual variability is highly correlated with the NAO. However, the long record of dust concentration measured at Barbados indicates that there is no correlation with the NAO index and surface concentration in winter. Longer simulation should provide the information needed to understand if the effects of the NAO on dust distribution is rather limited or Barbados is at the edge of the affected region.

Gischler, C.E. 1967. A hydrological synthesis of the Chad Basin. Nature and Resources 3 (3), 9-15.

Goni, I.B., Fellman, E., Edmunds, W.M. 2001. Rainfall geochemistry in the Sahel region of northern Nigeria. Atmospheric Environment 35 (25), 4331-4339.
Chemical data and stable isotope ($\delta^{18}O$, $\delta^{2}H$) results are presented for monsoon rains for several years during the 1990s from northern Nigeria in the Sahel region of Africa. The isotopic data from Garin Alkali (Nigeria) are related by a line $\delta H^{-2} = 6.33\ \delta O^{18} + 9.9$ with a weighted mean value of - 3.6 parts per thousand for δO^{18}. The heaviest rains have the lightest isotopic compositions, the lighter rains' enrichment is as a result of convection. The mean 1992 concentrations of Cl in rain ranged from 1.3 to 2.8 mg l-1 for the two stations in Nigeria. The early rains have higher Cl than the later events although Cl accumulations are in general directly related to rainfall amount. The Br/Cl ratios of all rains are enriched above marine values, which may in part be attributed to a preferential concentration of Br in smaller size particles, although more likely, is related to release from the biomass as the air masses pass over vegetated areas. The high Br/Cl ratios rule out dust from halite sources during the monsoon. The ratios of Na and CI are similar to those in sea water, although all other elements (especially Ca, SO_4, NO_3 and K) are enriched relative to marine aerosols and indicate continental sources. The element ratios (Ca/SO_4); K/Mg; K/Na) are remarkably similar to those in ash leachates from tropical vegetation and this is proposed as the main solute source in the present day monsoon rains, reinforcing the evidence of Br/Cl ratios. The chemical results show the considerable Terrestrial influence and are in line with isotopic evidence, which demonstrates considerable modification by convective circulation and continental influence as the monsoon air masses track northwards over the Sahel.

Gaouna, B.O. 1996. L'érosion éolienne au Tchad; ampleur des degats et amorce de controle et esquisse de solutions dans la région de Bokoro. In: Buerkert, B., Allison, E. and vonOppen, M. (eds.), Wind erosion in West Africa; the problem and its control; proceedings of the international symposium, Margraf. Weikersheim, pp. 173-180.

Gossel, W., Ebraheem, A.M. and Wycisk, P. (2004). A very large scale GIS-based groundwater flow model for the Nubian sandstone aquifer in Eastern Sahara (Egypt, northern Sudan and eastern Libya). *Hydrogeology Journal* 12 (6), 698-713.
A three-dimensional GIS-based groundwater flow model for the Nubian Sandstone Aquifer in the eastern Sahara was developed and calibrated under steady-state and transient conditions. The model was used to simulate the response of the aquifer to climatic changes that occurred during the last 25,000 years. The simulation results indicated that the groundwater in this aquifer was formed by infiltration during the wet periods 20,000 and 5,000 years B.P. The recharge of groundwater due to regional groundwater flow from more humid areas in the south was excluded. It also indicates that the Nubian Aquifer System is a fossil aquifer, which had been in an unsteady state condition for the last 3,000 years.

Goudie, A.S. 1978a. Dust storms and their geomorphological implications, Journal or Arid Environments, 1 (4), 291-310.

Goudie, A.S. 1983a. Dust storms in space and time, Progress in Physical Geography, 7 (4), 502-530.

Goudie, A.S. 2001. The global distribution of dust storms: patterns and controls. Annals of Arid Zone 40 (3), 303-315.

Dust storms have important environmental consequences that include climate change, nutrient additions to ocean and Terrestrial ecosystems, ocean sedimentation, soil formation and loess deposition. The use of meteorological observations and various satellite-borne sensors (including the Total Ozone Mapping Spectrometer) has enabled the global and regional patterns of dust source areas to be determined. Dust source regions are especially important in the Northern Hemisphere, with the Sahara being predominant. Many of the most important sources are very dry areas, which are, or have been, basins of interior sedimentation.

Goudie, A.S. and Middleton, N.J. 1992. The changing frequency of dust storms through time, Climatic Change, 20 (3), 197-225.
Dust storms are major, but under-studied actors in the world's drylands. Not only are they an important manifestation of desertification and land degradation, but they also have a whole suite of important environmental impacts, including possible rainfall suppression (Maley, 1982), fertilization of offshore areas, and disturbance to satellite communications. It is therefore important to ascertain whether their frequency and extent is changing. An increasing dust-strom incidence could be both a manifestation of and a contributor to global change.

By analysing long-term meteorological records for a large number of areas (the Great Plains of the USA, the USSR, Morocco, The Arabian Gulf, Australia, the Sahel-Sudan zone of Africa, China, Mongolia and Mexico) certain conclusions can be drawn. The first of these is that there is no one global pattern of dust-storm frequency trend. Some stations (e.g. in the Sahel) show a clear upward trend of great severity, others show a downward trend (e.g. Mexico City), while others show a more cyclical pattern. In many cases it is evident that essentially natural processes (precipitation totals, snow cover, wind strength) determine the frequency of dust events in any one year. It has also been possible to show the importance of runs of drought years (e.g. in the High Plains in the 1930s, and in the Sahel zone of Africa in the 1970s and 1980s). Elsewhere, however, various human activities have been significant in determining dust-storm frequency variations: the introduction of centre-pivot irrigation in the High Plains, the abstraction of water from the Owens and Mono basins in California, the disruption of surfaces by construction activity and vehicle use (e.g. in Ulan Bator, Mongolia), and the deliberate stabilisation of susceptible surfaces (e.g. the Lake Texcoco scheme in Mexico).

Goudie, A.S., Middleton, N.J. 2001. Saharan dust storms – nature and consequences. Earth Science Reviews 56 (1-4), 179-204.
This paper reviews recent work on the role of Saharan dust in environmental change, the location and strength of source areas, the transport paths of material away from the desert, the rates of Saharan dust deposition, the nature of that material (including PeriSaharan loess) and the changing rates of dust activity in response to long and short-term climatic changes. The Sahara produces more aeolian soil dust than any other world desert, and Saharan dust has an important impact on climatic processes, nutrient cycles, soil formation and sediment cycles. These influences spread far beyond Africa, thanks to the great distances over which Saharan dust is transported. The precise locations of Saharan dust source areas are not well known, but data from the Total Ozone Mapping Spectrometer (TOMS) suggest two major source areas: the Bodélé depression and an area covering eastern Mauritania, western Mali and southern Algeria. Trajectories of long-distance transport are relatively well documented, but the links between source areas and seasonal Saharan dust pathways are not. However, it is possible that Harmattan dust from the Bodélé depression may not be the source of the prominent winter plume over the tropical North Atlantic, as is often suggested in the literature. Few of the data on particle size characteristics of Saharan dust are derived from major source areas or from Africa itself. Saharan dusts sampled from the Harmattan plume and over Europe are dominated by SiO_2 and Al_2O_3, a characteristic they share with North American and Chinese dusts. The concentrations of these two major elements are similar to those found in world rocks. PeriSaharan loess is conspicuous by its relative absence, considering the Sahara's dominance of the global desert dust cycle both in the contemporary era and through the geological past. In recent decades, the frequency of Saharan dust events has varied markedly in response to climatic factors such as drought and anthropogenic disturbance of desert marginal surfaces. Nonetheless, the Sahara's two major dust sources are little affected by human activities and are in fact located in areas that receive very low rainfall totals. Hence, the Sahara does not fit the postulated global picture of a peak in dust storm activity in the 100-200-mm mean annual rainfall zone.

Goward, S.N. and Prince, S.D. 1995. Transient effects of climate on vegetation dynamics: satellite observations. Journal of Biogeography 22(2-3):549-564.

Ecological modellers are preparing to address how the biosphere may respond to decadal- to century-scale changes in the Earth's environmental system. This endeavour has revealed a question for which no immediate answer is readily available: how do ecosystems respond dynamically to climate variations? This question is explored with a 10 + year record of global vegetation dynamics recorded by a satellite remote sensing observatory. It is found that the average geography of observed vegetation patterns is well explained by continental-scale patterns of climatology in both North and South America and Africa. However, there is little relation observed in inter-annual deviations of the two data sets, with the possible exception of marginal cold and/or dry environments. Evidence from the African continent suggests that even in marginal environments the apparent correlation between climate and the satellite vegetation measurements varies from year to year indicating some persistence or lag between vegetation activity and climate dynamics. These observations lead to a conceptual model of vegetation amount and activity in the presence of climate variation. Testing the model is an important objective that could be addressed by the Global Change and Terrestrial Ecosystems, International Geosphere-Biosphere Project over the next decade.

Griffin, D.L. 2002. Aridity and humidity: two aspects of the late Miocene climate of North Africa and the Mediterranean. Palaeogeography Palaeoclimatology Palaeoecology 182 (1-2), 65-91.
The physiography of North Africa is not greatly changed from that of the Messinian. With the drawdown of the Mediterranean in the late Messinian the then existing river systems were incised into the landscape and emptied into Lake Cyrenaica, which occupied the substantially drained Eastern Mediterranean Basin. The record of incision provides a record of the magnitude of the Messinian river systems. An analysis of these river systems demonstrates that Messinian rainfall, a consequence of the Zeit Wet Phase, was greatest in east and south-central North Africa, in keeping with the derivation of the water mainly from the Indian Ocean. In central North Africa the Eosahabi River flowed from Messinian Lake Chad eroding the East Tibesti Valley and cutting a channel which is especially well preserved near the coast of the Gulf of Sirt. The penetrated sediments of Lake Cyrenaica and the marginal basins of the Messinian transgression are known as the Upper Evaporites and are generally fine clastics, gypsarenites and gypsum/anhydrite. They were rapidly deposited. Underlying them is the halite of the Lower Evaporites. This sequence of Upper and Lower Evaporites is much like the lower halite of the Tortonian South Gharib Formation and the overlying clastics and anhydrite of the Messinian Zeit Formation in the Gulf of Suez/Red Sea area. This type of sequence is termed an evaporitic couplet and, as has been demonstrated for the Gulf of Suez/Red Sea, is a consequence of a transition from a dry to a more humid climate in a restricted or semirestricted basin. This transition occurred at about 7.5 Ma in the Gulf of Suez/Red Sea and at about 5.8 Ma in the Mediterranean. The Zeit Wet Phase manifest in the above events developed in association with the initiation and development of the Asian monsoon and the drying of the Mediterranean. It can be understood in terms of the development of an evolving monsoon/desert system. The Asian monsoon was initiated 8-7 Ma in association with the uplift of Tibet; at this time the North African desert zone was displaced northwards to be over the Mediterranean and central and eastern North Africa became seasonally humid. A concept is advanced in which the early stage of the development of the Asian monsoon is seen as having two phases alternating at the precessional ca 21 ka cycle. One phase transferred moisture from the Indian Ocean mainly to southern Asia, the other phase transferred moisture mainly to North Africa. With the drawdown of the Mediterranean at about 5.8 Ma the Zeit Wet Phase intensified. A further northward movement of the humid and desert zones occurred at the time of drawdown. With the Messinian and early Pliocene transgressions the wet phase ameliorated but a substantial river system still crossed central North Africa. At about 4.6 Ma North Africa became drier probably in response to the developing dominance of the features of the monsoon that transferred moisture mainly to southern Asia, features of the monsoon that are well recognised today.

Grini, A., Myhre, G., Zender, C.S., Isaksen, I.S. 2005. Model simulations of dust sources and transport in the global atmosphere: Effects of soil erodibility and wind speed variability. Journal of Geophysical Research-Atmospheres 110 (D2), art. no. D02205.
Global atmospheric dust is simulated using the Dust Entrainment and Deposition (DEAD) model in combination with the global-scale Oslo chemical transport model CTM2 using meteorological data for 1996. Dust sources are calculated using both mean wind speeds with model resolution T63 and subgrid wind speeds. Different data sets are used to describe soil erodibility. We explain how the different assumptions about dust production affect atmospheric dust burden and deposition. Some aspects of the annual dust cycle, such as the east Asian dust emissions, are largely dependent on the data used to determine soil erodibility. Other aspects, such as the timing of the maximum in the African plume at Northern Hemisphere summer, are well modeled with all data sets applied here. We show that the daily

variation in optical depth at Cape Verde on the west coast of Africa is well simulated when we assume that erodibility is correlated with surface reflectivity from Moderate-Resolution Imaging Spetroradiometer (MODIS) satellite data. Using a subgrid probability density function of wind speed to drive the dust sources facilitates dust emissions in areas with low wind speeds. Dust concentrations in remote areas are sensitive to the parameterization of wet deposition. Our results point out the need for a detailed soil erodibility data set for global dust modeling, and they suggest that surface reflectivity is potentially valuable for producing or evaluating such data sets.

Grini, A., Zender, C.S. 2004. Roles of saltation, sandblasting, and wind speed variability on mineral dust aerosol size distribution during the Puerto Rican Dust Experiment (PRIDE). Journal of Geophysical Research-Atmospheres 109 (D7), art. no. D07202.
Recent field observations demonstrate that a significant discrepancy exists between models and measurements of large dust aerosol particles at remote sites. We assess the fraction of this bias explained by assumptions involving four different dust production processes. These include dust source size distribution (constant or dynamically changing according to saltation and sandblasting theory), wind speed distributions (using mean wind or a probability density function (PDF)), parent soil aggregate size distribution, and the discretization (number of bins) in the dust size distribution. The Dust Entrainment and Deposition global model is used to simulate the measurements from the Puerto Rican Dust Experiment (PRIDE) (2000). Using wind speed PDFs from observed National Centers for Environmental Prediction winds results in small changes in downwind size distribution for the production which neglects sandblasting, but it results in significant changes when production includes sandblasting. Saltation-sandblasting generally produces more large dust particles than schemes which neglect sandblasting. Parent soil aggregate size distribution is an important factor when calculating size-distributed dust emissions. Changing from a soil with large grains to a soil with smaller grains increases by 50% the fraction of large aerosols (D>5 μm) modeled at Puerto Rico. Assuming that the coarse medium sand typical of West Africa dominates all source regions produces the best agreement with PRIDE observations.

Grousset, F.E., Parra, M., Bory, A., Martinez, P., Bertrand, P., Shimmield, G., Ellam, R.M. 1998. Saharan wind regimes traced by the Sr-Nd isotopic composition of subtropical Atlantic sediments: Last Glacial maximum vs today. Quaternary Science Reviews 17 (4-5), 395-409.
New Nd-Sr isotopic data on the < 30 mu m lithic particles of surface and Last Glacial Maximum sediments recovered along the African margin between the Equator and the Gibraltar Strait are presented in combination with grain-size measurements. This < 30 mu m size fraction allows us to eliminate any hemipelagic contribution that could occur in the coarser fractions. In the eolian fraction, both Sr and Nd isotopic tracers reveal the same major northwestern origin (Mauritania, Mali, southern Algeria and Morocco). The Archaean formations of the western Saharan shield could be the source of the very unradiogenic ratios observed here. The more southern regions (Senegal, Guinea) act only as secondary sources. A similar pattern is observed for the LGM. Lithic particles are mostly transported by both Trade and Saharan Air Layer (SAL) winds, along an approximate NE-SW axis; this main feature matches the 'southern plume', characterizing the dust transport observed during winter. No significant latitudinal shift of the belt winds is observed between the LGM and today. At the LGM, however, dust fluxes were 2-4 times higher than today, leading to a more 'Archaean-type' imprint in the deposits. We do not observe any clear relationship between the latitudinal variability of the upwelling systems identified in this region at the LGM and the location of the major wind systems. Both enhanced aridity on the continent and increased wind speed probably occurred together over western tropical Africa during the Last Glacial period.

Grove, A.T. 1959. A note on the former extent of Lake Chad. Geographical Journal 125 (3-4), 465-467.
A sand ridge between Maigumeri and Bama (Nigeria) is interpreted as representing a former shore line of Lake Chad. The lake is therefore considered to have occupied a considerably greater area than at present and the climate to have been some 5^{o} C lower.

Grove, A.T. 1960. Geomorphology of the Tibesti region with special reference to the western Tibesti, Geographical Journal, 126 (1), 18-31.

Grove, A.T. 1970. Rise and fall of Lake Chad. Geographical Magazine 42(6, Mar):432-439.

Grove, A.T. 1988. Lake levels in tropical Africa with special reference to Lake Chad and to future research needs. In: Deserts; evolution passee et future; 1ere reunion annuelle du Programme

international de Correlation geologique, Ed. Pitit-Maire, N., Centre international pour la formation et les échanges géologiques, Paris, 70-75.

Grove, A.T. and Pullan, R.A. 1963. Some Aspects of the Pleistocene Paleo-Geography of the Chad Basin. In: Howell, F.C. and Bourliere, F. (eds), African Ecology and Human Evolution. Chicago: Aldine Publishing Co. 230-245.

Grove, A.T., F.A. Street and A.S. Goudie, 1975.Former lake levels and climatic change in the rift valley of Southern Ethiopia. Geographical Journal 141 : 177-202.

Grove, A.T. and Warren, A. 1968. Quaternary landforms and climate on the south side of the Sahara, Geographical Journal, 134 (2), 194-208.

Grunert, G. 1972. Die jungpleistozänen und holozänen Flussterrassen des oberen Enneri Yebbigue im zentralen Tibesti-Gebirge (Rep. du Tchad) und ihre klimatische Deutung. In: Arbeitsberichte aus der Forschungsstation Bardai/ Tibesti; III, Feldarbeiten 1966/ 67. Berliner geographsche Arbeiten. 16; 105-116.

Grunert, G. 1972. Zum Problem der Schluchtbildung in Tibesti-Gebirge (Rep. du Tchad). Zeitschrift für Geomorphologie, Supplementband 15, 144-155.

Grunert, J. 1976. Die Travertinterrasse des oberen Yebbigué im zentralen Tibesti-Gebirge (Rép. du Tchad). Palaeoecology of Africa 9, 14-19

Grunert, J. 1988. Klima- und Landschaftsentwicklung in Ost-Niger während des Jungpleistozäns und Holozäns. In: Geowissenschaftliche Untersuchungen in Afrika. Eds. Hagedorn, H., Baumhauer, R. Würzburger geographische Arbeiten 69, 289-304.

Grunert, J., Baumhauer, R., Volkel, J. 1991. Lacustrine sediments and Holocene climates in the southern Sahara - the example of paleolakes in the Grand Erg of Bilma (Zoo Baba And Dibella, eastern Niger). Journal of African Earth Sciences 12 (1-2), 133-146.
Two endoreic depressions of the central Erg of Bilma/eastern Republic of Niger are described here. Special interest is given to widespread lacustrine sediments (diatomites) in the depressions, indicating paleolakes with an extension of some 10 km^2. The minimum depth of the lakes has been found to be 25 m (Zoo Baba) and 36 m (Dibella). At Dibella there is evidence of two lacustrine phases of Early Holocene (9785-7890 years B.P.) and of Mid-Holocene age (about 6500 years B.P.). At Zoo Baba only one lacustrine phase of Mid-Holocene age (about 6000-5370 years B.P.) can be proven for Zoo Baba. The difference between the Early- and Mid-Holocene diatomites Di I and Di II is based not only on radiocarbon data but also on geomorphological characteristics. Despite the small distance of only 70 km between the two depressions, the reconstruction of pluvial water chemistry particularly by analyzing the diatoms shows great differences. The Mid-Holocene Zoo Baba lake was a freshwater lake; the Early- and Mid-Holocene Dibella lakes obviously contained brackish water with great fluctuations of salinity. An explanation may be given by the varying groundwater influence during the pluvial periods. It is supposed that Zoo Baba has been touched by the large Kaouar/Bilma aquifer while Dibella has been influenced by a smaller local aquifer. Any groundwater supply from Paleo-Chad can be excluded. Both the rising of groundwater table and of lake levels must have been induced by a largely increased annual precipitation rate (today 20-40 mm only), combined with a very effective reduction in evaporation rate. Based on lacrustine sediments, paleosoils and geomorphological features (fossil landslides of Zoo Baba), the Early Holocene annual precipitation rate is estimated at least at 300-400 mm, the Mid-Holocene rate at 200-300 mm. The special character of precipitations cannot be reconstructed.

Grunert, J. and Hagedorn, H. 1976. Beobachtungen an Schichtstufen der Nubischen Serie (Zentralsahara), Zeitschrift für Geomorphologie, Supplementband, 24, 99-110.

Gsell, J. 1953. Obsérvations preliminaires sur la constitution géologique de la bordure orientale de la cuvette tchadienne. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences 236 (4), 399-400.

Gumnior, M., Thiemeyer, H. 2003. Holocene fluvial dynamics in the NE Nigerian Savanna: some preliminary interpretations. Quaternary International 111, 51-58.
The development of the main northeast Nigerian river complex, the Komadugu System, is reconstructed, and the possible relation to Holocene environmental changes is investigated. At this stage of research, some field work, concentrating on the lithostratigraphy of the alluvial deposits, has been carried out along the middle and lower courses of the Komadugu Yobe and the Komadugu Gana and is supported by laboratory analyses of sediments and soils. The data obtained so far confirm earlier suggestions that the alluvium can be distinguished into Late Holocene floodplain deposits and a wider, fossilized terrace complex that may reflect a rather palustrine to lacustrine palaeoenvironment possibly related to the Early and Mid-Holocene Lake Megachad.

Guo, Z.T., Petit-Maire, N., Kröpelin, S. 2000. Holocene non-orbital climatic events in present-day arid areas of northern Africa and China. Global and Planetary Change 26 (1-3), 97-103.
A preliminary comparison between the climatic evolution of the arid regions in northern Africa and northern China showed that the variations in continental aridity, on time scales of 10^4 years, were roughly synchronous over the last 140 ka. Whether this relationship can be established for the Holocene drought events on a century-scale, as reported for tropical and equatorial Africa, is still not known. The comparison of 560 radiocarbon dates on surface fresh water indicators from the Sahara with 158 dates on palaeosols and lake sediments from the arid regions in northern China demonstrates that the Holocene humid phase has been affected in both regions by several drier events, inlaid in the slow trend attributable to orbital forcing. The variations of the southern margins of the deserts, associated with the northern monsoon front, are documented by the latitudinal distribution of these indicators through time. The most startling aspects are a prolonged somewhat drier interval between 7000 and 5600 years BP and the onset of severe aridity at c. 4000 years BP similar to glacial conditions.

Guy, M. and Mainguet, M. 1975. Les courants de transport éolien au Sahara et leurs manifestations au sol. Comptes rendus hebdomadaires des Séances de l'Académie des Sciences, Paris, Série D, 281(2-3):103-106.

Haberland, W. 1975. Untersuchungen an Krusten, Wüstenlacken und Polituren auf Gesteinsoberflächen der nördlichen und mittleren Sahara (Libyen und Tchad), Berliner geographischen Abhandlungen, 21, 274-289.

Haberland, W., Franzle, K. 1975. Untersuchungen zur Bildung von Verwitterungskrusten auf Sandsteinoberflächen in der nördlichen und mittleren Sahara (Libyen und Tschad). Würzburger geographische Arbeiten 43, Dynamische Geomorphologie, 148-163.

Haberland, W. and Pachur, H.-J. 1980. Über Deflationsformen in der zentralen Sahara. In: Hofmeister, B. and Steinecke, A. (ed), Beiträge zur Geomorphologie und Länderkunde, Prof. Hartmut Valentin zum Gedächtnis, Berliner geographische Studien 7:309-322.

Hagedorn, H. 1968. Ueber äolische Abtragung und Formung in der Suedost-Sahara; ein Beitrag zur Gliederung der Oberflächenformen in der Wueste. Erdkunde 22 (4), 259-269.

Hagedorn, H. 1971. Untersuchungen über Relieftypen arider Räume an Beispielen aus dem Tibesti-Gebirge und Seiner Umgebung, Zeitschrift für Geomorphologie, Supplementband, 11, 251 pp.

Hagedorn, H. 1974. Gegenwaertige dealische Abtragunbgsprozesse in der Zentrale Sahara, Akademie der Wissenschaften in Göttingen mathematische-physikalische Klasse Abhandlungen, 3 (29), 230-249.

Hagedorn, H. 1974. Gegenwärtige äolische Abtragungsprozesse in der Zentralsahara. Abhandlungen der Akademie der Wissenschaften in Göttingen, Mathematische-Physikalische Klasse 3 (29), Geomorphol. Prozesse u. Prozesskom. in der Gegenwart, Vandenhöck und Ruprecht. Göttingen, 230-240.

Hagedorn, H. 1974. Gegenwaertige dealische Abtragunbgsprozesse in der Zentrale Sahara, Akademie der Wissenschaften in Göttingen mathematische-physikalische Klasse Abhandlungen, 3 (29), 230-249.

Hagedorn, H. 1986. On the problems of deflation landscapes). Zum Problem äolischer Abtragungslandschaften. Geograficky Casopis. 1985. 37(2-3), 172-186.
Examples from the Borkou Mountains in the northern part of the Republic of Chad are taken to describe the relief forms of an aeolian corrasion landscape with yardangs and wind-lanes, also of an aeolian deflation landscape with wind depressions and a 'mixed' landscape with relief forms created by both processes. The region of aeolian relief formation has expanded and contracted with the climatic oscillations during the Quaternary.

Hagedorn, H. 1988. Äolische Abtragungsformen im Massiv von Termit (NE-Niger). In: Geowissenschaftliche Untersuchungen in Afrika. Eds. Hagedorn, H., Baumhauer, R. Würzburger geographische Arbeiten 69, 277-287.

Hagedorn, H. 1990. Beobachtungen über Paläowindrichtungen bei Faya im Borkou-Bergland (Tschad). In: Forschungen in ariden Gebieten; aus Anla der Gruendung der Station Bardai (Tibesti) vor 25 Jahren. Ed. Gabriel, B., Berliner geographische Studien 30, 235-246.

Hagedorn, H. and D. Jakel, 1969.Bemerkungen zur quartaren Entwicklung des Reliefim Tibesti-Gebirge (Tchad). Bulletin de Liaison de l'Association senegalaise pour l'Etude duQuaternaire africain 23 : 25-42.

Hagedorn, H., Pachur, H.J. 1971. Observations on Climatic Geomorphology and Quaternary Evolution of Landforms in South Central Libya. In: symposium on the Geology of Libya. Ed. Gray, C., Faculty of Science, University of Libya, pp. 387-400.

Hagedorn, H., Sponholz, B. 1990, Silikatkarst in Nord-und Ostniger-Einbindung der Verkarstung in die tertiäre und quartäre Landschafts-geschichte. Mainzer Geographische Studien, 34, 77-90

Harrison, S.P., Kohfeld, K.E., Roelandt, C., Claquin, T. 2001. The role of dust in climate changes today, at the last glacial maximum and in the future. Earth Science Reviews 4 (1-3), 43-80.
Natural mineral aerosol (dust) is an active component of the climate system and plays multiple roles in mediating physical and biogeochemical exchanges between the atmosphere, land surface and ocean. Changes in the amount of dust in the atmosphere are caused both by changes in climate (precipitation, wind strength, regional moisture balance) and changes in the extent of dust sources caused by either anthropogenic or climatically induced changes in vegetation cover. Models of the global dust cycle take into account the physical controls on dust deflation from prescribed source areas (based largely on soil wetness and vegetation cover thresholds), dust transport within the atmospheric column, and dust deposition through sedimentation and scavenging by precipitation. These models successfully reproduce the first-order spatial and temporal patterns in atmospheric dust loading under modem conditions.
Atmospheric dust loading was as much as an order-of-magnitude larger than today during the last glacial maximum (LGM). While the observed increase in emissions from northern Africa can be explained solely in terms of climate changes (colder, drier and windier glacial climates), increased emissions from other regions appear to have been largely a response to climatically induced changes in vegetation cover and hence in the extent of dust source areas. Model experiments suggest that the increased dust loading in tropical regions had an effect on radiative forcing comparable to that of low glacial CO_2 levels.
Changes in land-use are already increasing the dust loading of the atmosphere. However, simulations show that anthropogenically forced climate changes substantially reduce the extent and productivity of natural dust sources. Positive feedbacks initiated by a reduction of dust emissions from natural source areas on both radiative forcing and atmospheric CO_2 could substantially mitigate the impacts of land-use changes, and need to be considered in climate change assessments.

Haynes, C.VJr. 1979. Pluvial lakes in the north-western Sudan, Geographical Journal, 145 (3), 437-445.

Haynes, C.V.Jr. 1980a. Geological evidence for pluvial climates in the Nabta area of the Western Desert, in Prehistory of the eastern Sahara, Eds. Wendorf, F. and Schild, R., Academic Press, New York, 353-371.

Haynes, C.V.Jr. 1980b. Geochronology of Wadi Tushka: lost tributary of the Nile, Science, 210 (4465), 68-71.

Haynes, C.V.Jr. 1981. The Darb-el-Arba'in Desert: a product of Quaternary change, Annals of the Geological Survey of Egypt, 11, 91-119.

Haynes, C.V. 1982. Great Sand Sea and Selima Sand Sheet, eastern Sahara - geochronology of desertification. Science 217 (4560), 629-633.
The relation of playa sediments and associated archeological sites with longitudinal dunes allows estimation of ages for the two uppermost strata of the Great Sand Sea. Active dune formation corresponds with interpluvial periods of hyperaridity; dune stability corresponds with semiarid pluvial periods. Archeological sites associated with truncated paleosols in the Selima Sand Sheet suggest a similar climatic relation and indicate that the isohyets of central Sudan shifted at least 400km northward during the peak of pluvials

Haynes, C.V. 1982. Quaternary geochronology of the Western Desert. In: Proceedings of the International symposium on remote sensing of environment; First thematic conference; Remote sensing of arid and semi-arid lands, Environmental Research Institute, Ann Arbor, MI., 297-311.

Haynes, C.V.Jr. 1983. Quaternary studies, Western Desert, Egypt and Sudan, 1975-1978, National Geographic Society Research Reports, 15, 257-293.

Haynes, C.V.Jr. 1985. Quaternary studies, Western Desert, Egypt and Sudan, 1975-1978, National Geographic Society Research Reports, 19, 269-341.

Haynes, C.V.Jr. 1987. Holocene migration rates of the Sudano-Sahelian wetting front, Arba'in Desert, eastern Sahara, in Prehistory of arid North Africa, Ed. Close, A.E., Southern Methodist University, Dallas Texas, 69-84.

Haynes, C.V. 1989. Oyo; a "lost" oasis of the southern Libyan Desert. Geographical Journal 155 (2), 189-195.

Haynes, C.V. 1989. Bagnold's Barchan - a 57-year record of dune movement in the eastern Sahara and implications for dune origin and paleoclimate since Neolithic times. Quaternary Research 32 (2), 153-167.
Describes an exceptionally long record of barchan movement

Haynes, C.V. 2001. Geochronology and climate change of the Pleistocene-Holocene transition in the Darb el Arba'in Desert, Eastern Sahara. Geoarchaeology-an International Journal 16 (1), 119-141.
More than 25 years of geoarchaeological investigations in the hyperarid regions of southwestern Egypt and northwestern Sudan, the Darb el Arba'in desert, demonstrate that Holocene pluvial conditions began about 9800 yr B.P., essentially at the end of Younger Dryas cooling. The eastern Sahara changed from a hyperarid, lifeless desert dominated by eolian activity and deflation to an and to semiarid savanna that attracted Sudano-Sahelian fauna and Neolithic pastoralists to the region until about 5000 yr B.P., when the current episode of hyperaridity ensued. In the lake and playa basins of the eastern Sahara, Younger Dryas time, about 10,800-9700 yr B.P., is represented by an erosional hiatus, during which deflation of basins occurred. The only deposition that may have occurred during this hyperarid period is sand sheet aggradation and dune formation consistent with the Sahara being hyperarid during the glacial periods. Younger Dryas-age eolian deposits have yet to be identified by optically stimulated luminescence (OSL). The current hyperaridity would imply that glacial conditions exist in the northern hemisphere, yet the opposite is the case. Perhaps global glaciation lags the onset of Saharan hyperaridity by several millennia, and the area is in a transitional phase much like the Bolling and Allerod periods.

Haynes, C.V., Eyles, C.H., Pavlish, L.A., Ritchie, J.C., Rybak, M. 1989. Holocene palaeoecology of the eastern Sahara; Selima Oasis. Quaternary Science Reviews 8 (2), 109-136.
The arid eposides, from prior to 8.4 ka BP, and subsequent to 7 ka BP, are characterized by high $CaCO_3$ deposition, abundant diatom indicators of relatively high salinity and well developed periphytic communities, and pollen spectra dominated by desert-grassland indicators. A humid period centered on 8 ka BP is indicated by low $CaCO_3$ deposition, high organic rich mud and Al and Si oxide deposition,

diatoms indicating a fresh, deep (20 m) lake, and a pollen assemblage with maximum values for Sahelo-Sudanian tree taxa suggesting a thorn tree and shrub savanna vegetational mosaic.

Haynes, C.V., Haas, H. 1980. Radiocarbon evidence for Holocene recharge of ground water, Western Desert, Egypt. In: Proceedings of the Tenth international radiocarbon conference, Ed. Stuiver, M., Kraa, R.S., Radiocarbon 22 (3), 705-716.

Haynes, C.V.Jr., Maxwell, T.A., El Hawary, A., Nicoll, K.A. and Stokes, S. 1997. An Acheulian site near Bir Kiseiba in the Darb el Arba'in Desert, Egypt, Geoarchaeology, 12 (8), 819-832.

Haynes, C.V., Maxwell, T.A., Johnson, D.L. 1993. Stratigraphy, geochronology, and origin of the Selima Sand Sheet, eastern Sahara, Egypt and Sudan. In: Geoscientific research in Northeast Africa; proceedings of the international conference, Eds. Thorweihe, U., Schandelmeier, H., Balkema, Rotterdam, 621-626.

Haynes CV, Maxwell TA, Johnson DL, Kilani A 2001.Research note: Acheulian sites near Bir Kiseiba in the Darb el Arba'in Desert, Egypt: New data Geoarchaeology-An International Journal 16 (1): 143-150.

Haynes, C.V.Jr. and Mead, A.R. 1987. Radiocarbon dating and palaeoclimatic significance of subfossil Limicolaria in northwestern Sudan, Quaternary Research, 28 (1), 86-99.

Haynes, C.V., Mehringer, P.J.Jr., Zaghloul, S.A. 1979. Pluvial lakes of north-western Sudan. Geographical Journal 145 (3), 437-445.
The extreme desert of SW Egypt and NW Sudan has revealed traces of numerous small, shallow, rain-fed lakes, relict from earlier periods of less arid climate. Samples of lacustrine deposits were radiocarbon dated, indicating that the lakes dried up some 6000 years ago, occasioning the withdrawal of the Neolithic inhabitants. Sediment cores taken at Merga for pollen and radiocarbon analysis suggest a later hyperarid phase ending about 600 years ago.

Haywood, J.M., Allan, R.P., Culverwell, I., Slingo, T., Milton, S., Edwards, J., Clerbaux, N. 2005. Can desert dust explain the outgoing longwave radiation anomaly over the Sahara during July 2003? Journal of Geophysical Research-Atmospheres 110 (D5), art. no. D05105.
Measurements of the top-of-the-atmosphere outgoing longwave radiation (OLR) for July 2003 from Meteosat-7 are used to assess the performance of the numerical weather prediction version of the Met Office Unified Model. A significant difference is found over desert regions of northern Africa where the model emits too much OLR by up to 35 Wm^{-2} in the monthly mean. By cloud-screening the data we find an error of up to 50 Wm^{-2} associated with cloud-free areas, which suggests an error in the model surface temperature, surface emissivity, or atmospheric transmission. By building up a physical model of the radiative properties of mineral dust based on in situ, and surface-based and satellite remote sensing observations we show that the most plausible explanation for the discrepancy in OLR is due to the neglect of mineral dust in the model. The calculations suggest that mineral dust can exert a longwave radiative forcing by as much as 50 Wm^{-2} in the monthly mean for 1200 UTC in cloud-free regions, which accounts for the discrepancy between the model and the Meteosat-7 observations. This suggests that inclusion of the radiative effects of mineral dust will lead to a significant improvement in the radiation balance of numerical weather prediction models with subsequent improvements in performance.

Haywood, J.M., Francis, P.N., Geogdzhayev, I., Mischenko, M. and Frey, R. 2001. Comparison of Saharan dust aerosol optical depths retrieved using aircraft mounted pyranometers and 2-channel AVHRR algorithms. Geophysical Research Letters 28(12):2393-2396.
The 0.55 mum optical depth of the Saharan dust aerosol plume is determined from C-130 pyranometer data for two different days and the results compared to those from a 2-channel Advanced Very High Resolution Radiometer (AVHRR) retrieval algorithm. When the time difference between the C-130 and AVHRR overpasses is small, the geographic distribution of the aerosol optical depths are similar and differ by less than +/- 0.1 despite the different refractive indices, size distributions and atmospheric profiles implicit in each method. The pyranometer derived optical depth at 0.55 mum exceeds a value of I on one of the days, which exceeds the cloud threshold used in many satellite retrieval algorithms with implications for the accuracy of satellite derived aerosol optical depths. The difficulties in making

extensive geographical comparisons between satellite and aircraft measurements owing to the differential speed of the observing platforms are also highlighted.

Haywood, J.M., Francis, P.N., Glew, M.D. and Taylor, J.P. 2001. Optical properties and direct radiative effect of Saharan dust: A case study of two Saharan dust outbreaks using aircraft data. Journal of Geophysical Research 106(D16):18417-18430, doi:10.1029/2000JD900319.
The radiative effects of Saharan dust are measured during two flights by the Met Office C-130 aircraft off the west coast of Africa. Data from the broadband radiometers suggests that the perturbation to the top of the atmosphere net solar irradiance is as strong as -60 W m(-2) +/-5 W m(-2) during the dust events. In situ measurements with the nephelometer and particle soot absorption photometer suggest that the single scattering albedo is approximately 0.87 at a wavelength of 0.55 mum. This is in agreement with the optical parameters calculated from independent measurements of the particle size distributions combined with suitable refractive indices and Mie-scattering theory. The wavelength dependence of the extinction coefficient derived from measurements of the scattering coefficient by the nephelometer is also in excellent agreement with the calculations. Independent surface-based measurements from Cape Verde suggest that the wavelength dependence of the aerosol optical depth appears reasonable. Calculations of the downward solar irradiances within the aerosol layer are generally in good agreement with the measurements demonstrating consistency between the measurements and the modeling efforts. The terrestrial radiative effect is not detectable by the current instrumentation, though it cannot be considered negligible. These measurements suggest that satellite retrieval algorithms may misclassify the aerosol outbreak as cloud because the aerosol optical depth at 0.55 mum is as high as 1.15, which is in excess of the thresholds used in some cloud detection algorithms. The measurements demonstrate that this method could be used to provide an accurate benchmark for satellite-based estimates of the radiative effect of aerosols.

Hebrard, L. 1970. Fichier des âges absolus du quaternaire d'Afrique au nord de l'equateur. Geologicky Pruzkum 26, 39-56.

Herman, J.R., Bhartia, P.K., Torres, O., Hsu, C., Seftor, C., Celarier, E. 1997. Global distribution of UV-absorbing aerosols from Nimbus 7/TOMS data, Journal of Geophysical Research-Atmospheres 102 (D14), 16911-16922.
Global distributions of UV-absorbing aerosols are obtained using measured differences between the 340 and the 380 nm radiances from the Nimbus 7 Total Ozone Mapping Spectrometer (TOMS) for the years 1979-1993. Time series are shown for major sources of biomass burning and desert dust giving the frequency of occurrence and areal coverage over land and oceans. Minor sources of UV-absorbing aerosols in the atmosphere are also discussed (volcanic ash and oil fires). Relative values of year-to-year variability of UV-absorbing aerosol amounts are shown for major aerosol source regions: (1) central South America (Brazil) near 10^{o} S latitude; (2) Africa near 0^{o} –20^{o} S and 0^{o} to 10^{o} N latitude; (3) Saharan Desert and sub-Saharan region (Sahel), Arabian Peninsula, and the northern border region of India; (4) agricultural burning in Indonesia, Eastern China, and Indochina, and near the mouth of the Amazon River; and (5) coal burning and dust in northeastern China. The first three of these regions dominate the injection of UV-absorbing aerosols into the atmosphere each year and cover areas far outside of their source regions from advection of UV-absorbing particulates by atmospheric wind systems. During the peak months, smoke and dust from these sources are transported at altitudes above 1 km with an optical depth of at least 0.1 and can cover about 10% of the Earth's surface. Boundary layer absorbing aerosols are not readily seen by TOMS because the small amount of underlying Rayleigh scattering leads to a small signal. Significant portions of the observed dust originate from agricultural regions frequently within arid areas, such as in the Sahel region of Africa, especially from the dry lake-bed near Lake Chad (13.5^{o} N, 14^{o} E), and intermittently dry drainage areas and streams. In addition to drought cycle effects, this suggests there may be an anthropogenic component to the amount of dust injected into the atmosphere each year. Detection of absorbing aerosols and calculation of optical depths are affected by the presence of large-scale and subpixel clouds in the TOMS field of view.

Hermann, L. 1996. Staubdeposition auf Böden West-Afrikas. Eigenschaften und herkunftsgebiete der stäub und ihr einfluß aud boden und standortseigenschaften. Hohenhiemer Bodenkundlich Hefte 36, Stuttgart, 239 pp.

Herrmann, L. 1997. Staubdeposition auf Boeden Westafrikas - eine Zusammenfassung. Mitteilungen der Deutschen Bodenkundlichen Gesellschaft 85 (1),15-22.

Herrmann, L., Bleich, K.E., Stahr, K. 1993. Veränderung eines landwirschaftliche genutzten Standortes in Niger/Westafrika durch Staubeintrag. Mitteilungen der Deutsches Bodenkundlichen Gesellschaft 72, 927-930.

Herrmann, L., Bleich, K.E., Stahr, K. 1994. Influence des dépôts éoliens sur la restauration de la fertilité des sols sous végétation en friche au Niger. Résau Erosion Bulletin, Organisation de Recherches scientifiques et techniques d'Outre mer (ORSTOM), 14, 74-81.

Herrmann, L., Graef, F., Jahn, R., Stahr, K. 1998. Dust transport in eastern West Africa: perspectives of source region characteristics and dust deposition estimations. Abstracts, International Conference on Aeolian Research (ICAR-4), July, Oxford, 37.

Herrmann, L., Jahn, R., Stahr, K. 1996. Identification and quantification of dust additions in peri-Saharan soils. In: The impact of desert dust across the Mediterranean, Eds. Guerzoni, S. and Chester, R., Kluwer, Dordrecht 173-182.

Herrmann, L., Sponholz, B., Stahr, K. 1993. Quellregionen für den Harmattan-Staub in Westafrika: Ein mineralogischer und geochemischer Ansatz. Mitteilungen der Deutsches Bodenkundlichen Gesellschaft 74, 367-370.

Herrmann, L., Stahr, K. and Jahn, R. 1999. The importance of source region identification and their properties for soil derived dust: the case of Harmattan dust sources for eastern West Africa. Contributions to Atmospheric Physics 72 (2), 141-150.

Herrmann, L., Stahr, K. and Sivakumar, M.V.K. 1996. Dust deposition in south-western Niger, in Wind erosion in West Africa: the problem and its control. Proceedings of the International Symposium, 5-7 December, 1994, Universität Hohenhiem, Eds. Buerkert, B., Allison, B.E. and von Oppen, M., Margraf Verlag, Weikersheim, 35-48.

Herrmann, L. and Sterk, G. 1996. Towards a regional mass budget of aeolian transported material in a Sahelian environment, in Wind erosion in West Africa: the problem and its control. Proceedings of the International Symposium, 5-7 December, 1994, Universität Hohenhiem, Eds. Buerkert, B., Allison, B.E. and von Oppen, M., Margraf Verlag, Weikersheim 319-326.

Hill, C.L. 2001. Geologic contexts of the Acheulian (Middle Pleistocene) in the eastern Sahara. Geoarchaeology - an International Journal 16 (1), 65-94.
The Bir Tarfawi and Bir Sahara East region of northeast Africa contains sedimentary remnants associated with Acheulian artifacts. The geology of these localities can be used to help examine paleobiogeographic and taphonomic contexts and paleoclimatic chronologies related to Middle Pleistocene hominids. Recognized by the presence of handaxes, Acheulian occurrences in the Eastern Sahara have been found with paleosols, cemented gravels, and tufas, and are often found as deflationary lags. In the Tarfawi region, handaxes were found embedded in sands overlain by carbonates, embedded in limestones, and in deflated contexts. These Acheulian sites likely date to before 300 ky B.P. The lithostratigraphic sequences indicate that paleoclimatic conditions in the Sahara during the Pleistocene were wetter than in the Holocene. The geologic context (stratigraphy, sedimentology, dating) of the Acheulian in the Eastern Sahara seems to indicate wet paleoclimatic intervals during the Pleistocene when biogeographic conditions were favorable for hominid habitation in the region.

Hillaire-Marcel, C., J. Riser, P. Rognon, N. Petit- Maire, J.C. Rosso and I. Soulie-Marche, 1983.Radiocarbon chronology of Holocene hydrologic changes in Northeastern Mali. Quaternary Research 20 (2): 145-164.
The presence of cemented paleodunes indicates that the end of the Pleistocene was an arid period. This was followed by an early Holocene lacustrine episode (ca. 9500-6500 yr B.P.) during which numerous lakes occupied depressions formed in the Cretaceous limestones and between the sand ridges. These lakes reflect a significant rise in the water table. Between ca. 6500 and 5500 yr B.P. the lakes dried up, although the water table remained close to the ground surface in several areas. Calcareous concretions formed at the water table fringe during this time, thereby "fossilizing" some of the middle Holocene

dunes. A second lacustrine episode is dated between ca. 5500 and 4500 yr B.P.; it corresponds to the establishment of numerous Neolithic settlements in the area. Arid conditions have developed since about 4500 yr B.P. to attain the conditions of the present day. Groundwaters were recharged by precipitation which was occasionally very depleted in heavy oxygen (delta (super 18) O congruent to -13 per mill). Evaporation induced an enrichment in (super 18) O. The (super 13) C content of fossil shells reflect: (1) species ecological requirements, (2) isotopic composition of the total inorganic dissolved carbon (TIDC) in groundwaters, and (3) the lake metabolism

Himida, I.H. 1972. The Nubian Artesian Basin, its regional hydrogeological aspects and palaeohydrological reconstruction. In: Symposium on the results of research on representative and experimental basins, Vol. II; New techniques. International Association of Scientific Hydrology (IASH-AIHS), Publication 97, 370-390.

Hofmeister, B., Voss, F., Eds. 1986. Die östliche Libysche Wüste im Jungquartär. Berliner Geographische Studien 19, Berlin.

Holben, B.N., Eck, T.F., Fraser, R.S. 1991. Temporal and spatial variability of aerosol optical depth in the Sahel region in relation to vegetation remote-sensing. International Journal of Remote Sensing 12 (6),1147-1163.
A network of Sun photometers was established in the Sahel region of Senegal, Mali and Niger in order to monitor the aerosol characteristics needed for atmospheric correction of remotely sensed data. The aerosol optical thickness tau-a computed from the spectral Sun photometer measurements exhibited very high day-to-day variability ranging from approximately 0.1 to greater than 2.0 at 875 nm for both the wet and dry seasons. A gradient of decreasing tau-a from north-to-south latitudes in the Sahel for the wet season, July-September, was observed, which may be caused jointly by increased washout owing to the gradient of increasing precipitation to the south and the location of source regions for dust in the north. The Angstrom wavelength exponent alpha-was found to vary with the magnitude of the aerosol optical thickness, with values as high as 0.75 for very low tau-a, and values of 0.25 to 0.0 for high tau-a conditions. Analysis of tau-a data from this observation network suggests that there is a high spatial variability of tau-a in the western Sahel region. Statistical analysis performed on the wet season data showed that at a 67 per cent confidence level the instantaneous values of tau-a can be extrapolated approximately 270-400 km with an error tolerance of 50 per cent. Spatial variability in the dry season was of a similar magnitude. The ranges of variations in the NDVI in the Sahel region owing to commonly observed fluctuations in the aerosol optical thickness and aerosol size distribution were shown to be approximately 0.02 and 0.01, respectively.

Holmes J.A., Fothergill, P.A., Street-Perrott, F.A., Perrott, R.A. 1998. A high-resolution Holocene ostracod record from the Sahel zone of Northeastern Nigeria. Journal of Paleolimnology 20 (4), 369-380.
The ostracod record from Kajemarum Oasis in the Sahel zone of Northeastern Nigeria covers the last c. 4 000 cal, years of a 5 500 cal. year lake-sediment sequence. The first appearance of ostracods, around 4 000 cal. yr BP, reflects the switch from a very dilute lake during the mid-Holocene, to slightly oligosaline conditions that favoured the occurrence and preservation of ostracods. Between 3 800 and 3 100 cal. yr BP, the lake remained permanent and fresh or slightly oligosaline, with a Ca-Mg-HCO_3 composition. A rise in salinity c. 3 100 cal. yr BP, accompanied by a change to more variable conditions on a seasonal to interannual timescale, led to the influx of more-euryhaline taxa. Oligosaline conditions continued between 3 100 and 1 500 cal. yr BP Around 1 500 cal. yr BP, there was a sharp rise in salinity, probably accompanied by a shift to Na-CO_3-type water, with marked seasonal and interannual variability. Salinity decreased after 900 cal. yr BP, although short-term variations were marked between 900 cal. yr BP and the top of the sequence, 95 cal. yr BP. Changes in the species assemblages and ostracod abundance were a response to climate-driven variations in the seasonal and interannual stability of the lake, together with changes in its salinity and solute composition, but there is no simple relationship between ostracod faunas and salinity. Within Kajemarum, there is no evidence of ostracod assemblages typical of deep, fresh water, nor of hypersaline Na-Cl waters. The sediments associated with the freshest waters at Kajemarum did not favour ostracod preservation, and the driest climatic conditions were associated with oligosaline to mesosaline water of Na-CO_3-type. The species-poor assemblages reflect the short-term instability of the lake, coupled with the limited opportunities for the colonisation of this isolated basin.

Hölzmann, P. 1992. Palaeoecology of Holocene lacustrine sediments within the west Nubian basin, SE-Sahara, Würzberger geographischen Arbeiten, 84, 59-71.

Hölzmann, P. 1992. Spätquartäre lakustrine Sedimente in West-Nubien, Südost-Sahara. In: Afrikagruppe deutscher Geowissenschaftler; Kolloquium 1992. Zentralblatt für Geologie und Paläontologie, Teil I: Allgemeine Angewandte, Regional und Historische Geologie 3-4, 234-237.

Hölzmann, P. 1993. Palaeoecology of Holocene lacustrine sediments in western Nubia, SE-Sahara. In: Thorweihe, U., Schandelmeier, H. (eds.) Geoscientific Research in Northeast Africa, Balkema, Rotterdam, 569-574.

Hölzmann, P. 1993. Holozäne Limnite im NW-Sudan, Dissertation, Free University of Berlin, 190 pp.

Hölzmann, P., Jolly, D., Harrison, S.P., Laarif, F., Bonnefille, R., Pachur, H.J. 1998. Mid-Holocene land-surface conditions in northern Africa and the Arabian Peninsula: A data set for the analysis of biogeophysical feedbacks in the climate system. Global Biogeochemical Cycles 12 (1), 35-51.
Large changes in the extent of northern sub tropical arid regions during the Holocene are attributed to orbitally forced variations in monsoon strength and have been implicated in the regulation of atmospheric trace gas concentrations on millenial timescales. Models that omit biogeophysical feedback, however, are unable to account for the full magnitude of African monsoon amplification and extension during the early to middle Holocene (similar to 9500-5000 years B.P.). A data set describing land-surface conditions 6000 years B.P. on a 1^{o} x 1^{o} grid across northern Africa and the Arabian Peninsula has been prepared from published maps and other sources of palaeoenvironmental data, with the primary aim of providing a realistic lower boundary condition for atmospheric general circulation model experiments similar to those performed in the Palaeoclimate Modelling Intercomparison Project. The data set includes information on the percentage of each grid cell occupied by specific vegetation types (steppe, savanna, xerophytic woods/scrub, tropical deciduous forest, and tropical montane evergreen forest), open water (lakes), and wetlands, plus information on the flow direction of major drainage channels for use in large-scale palaeohydrological modeling. The data set is available in digital form by anonymous ftp.

Hölzmann, P., Keding, B., Berke, H., Kröpelin, S., Kruse, H.J. 2001. Environmental change and archaeology; lake evolution and human occupation in the eastern Sahara during the Holocene. Palaeogeography, Palaeoclimatology, Palaeoecology 169 (3-4), 193-217.
The West Nubian Palaeolake is the most large-scale hydrographic evidence in the Eastern Sahara of the early to mid-Holocene wet phase that affected northern Africa. It is the result of a significant increase in local rainfall due to the northward shift of the tropical rainfall belt. A series of fieldwork-based differential GPS (DGPS) measurements along several profiles across the West Nubian Palaeolake basin provides the first precise topographic data from this up to a 5330 km^2 large palaeolake feature. In combination with sedimentological, geochemical, and archaeological results, an almost complete picture of significant palaeoclimatic changes and human occupation during the early to mid-Holocene for this region is presented. Different stages of palaeolake evolution ranging from non-existence of the lake through stable freshwater conditions to its extinction were identified in the period from 9400 to 3800 ^{14}C yr BP. These lake stages coincide with phases of intensive human inhabitation between ca. 6300 and 3500 ^{14}C yr BP, and include at least four settlement phases distinguishable by style of pottery. These are known from adjacent areas of the palaeolake region, emphasizing strong prehistoric cultural connections in the Eastern Sahara. During the highstands of the palaeolake in the early to mid-Holocene, the Dotted Wavy-Line pottery relates to the Early Khartoum type culture with its supra-regional distribution from the Nile Valley to the Chad, and possibly with slightly different forms even to the Atlantic coast. Later in the Holocene, Western Nubia with its large palaeolakes and migration paths along palaeowadis, such as Wadi Howar, acted as an important natural and cultural link between the Nile Valley and the Chad Basin until the region was deserted during the fourth millennium BP.

Hölzmann, P., Kruse, H.J., Rottinger, F. 2000. Precipitation estimates for the eastern Saharan palaeomonsoon based on a water balance model of the West Nubian Palaeolake Basin. Global and Planetary Change 26 (1-3), 105-120.
During the Holocene, the eastern Sahara underwent a drastic climatic change: in less than 6000 years, the climate changed from hyperaridity to semiaridity and back to its current hyperarid state. The West Nubian Palaeolake Basin in NW Sudan (ca $18.5^{o}N/25.5^{o}E$) contains widespread lake carbonates, which indicate development of a freshwater lake between approximately 9500 and 4000 years BP. The size of

the lake has been estimated as between 1100 and 7000 km(2). Water balance calculations and a dense drainage net surrounding the terminal lake indicate predominance of superficial and minor importance of groundwater inflow. A lake with an area of 1100 km(2) would require an annual precipitation of approximately 500 mm to balance the respective aerial evaporation. Similar precipitation values are currently observed at a latitude of 12°N, some 600 km farther south, while the West Nubian Palaeolake Basin receives an annual rainfall of less than 15 mm/year. A lake size of 7000 km(2) would have required 900 mm of annual rainfall, an amount characteristic of sub-tropical conditions. This value could indicate inhomogenities in the wet phase climate, which could strongly influence the water level of a terminal lake located in a flat terrain.
The highly depleted oxygen isotope values of the lake carbonates indicate that the Holocene wet phase was characterized by intense tropical summer (monsoonal) rainfall with heavy thunderstorms. Thus, an intensified southwest palaeomonsoon apparently transported large quantities of moisture to the eastern Sahara, producing the necessary conditions for the persisting existence of freshwater in the West Nubian Palaeolake Basin. The reconstructed palaeoclimate implies high groundwater levels and corresponds to precipitation rates from other sites in North Africa.

Hooghiemstra, H. 1988. Changes of major wind belts and vegetation zones in NW Africa 20000-5000yr BP. as deduced from marine pollen record near Cap Blanc. Review of Palaeobotany and Palynology 55 (1-3), 101-140.

Hooghiemstra, H. 1988. Palynological records from northwest African marine sediments: a general outline of the interpretation of the pollen signal. Philosophical Transactions of the Royal Society of London B, 318 (1191), 431-449.

Hooghiemstra, H., Agwu, C.O. 1986. Distribution of palynomorphs in marine sediments; a record for seasonal wind patterns over NW Africa and adjacent Atlantic. Geologische Rundschau 75 (1), 81-95.

Hooghiemstra, H., Agwu, C.O.C., Beug, H.J. 1986. Pollen and spore distribution in recent marine sediments: A record of NW-African seasonal wind patterns and vegetation belts. Bericht über die METEOR-Fahrt 6-5 Dakar-Libreville 15.1-16.2.1988: 87-135.

Hsu, N.C., Herman, J.R. and Weaver, C. 2000. Determination of radiative forcing of Saharan dust using combined TOMS and ERBE data. Journal of Geophysical Research 105(D16):20649-20662.
We determine the direct radiative forcing of Saharan dust aerosols by combining aerosol information derived from Nimbus-7 TOMS with radiation measurements observed at the top of atmosphere (TOA) by NOAA-9 ERBE made during February-July 1985. Cloud parameters and precipitable water derived from NOAA-9 HIRS2 were used to aid in screening for clouds and water vapor in the analyses. Our results indicate that under "cloud-free" and "dry" conditions there is a good correlation between the ERBE TOA outgoing longwave fluxes and the TOMS aerosol index measurements over both land and ocean in areas under the influence of airborne Saharan dust. The ERBE TOA outgoing shortwave fluxes were also found to correlate well with the dust loading derived from TOMS over ocean. However, the calculated shortwave forcing of Saharan dust aerosols is very weak and noisy over land for the range of solar zenith angle viewed by the NOAA-9 ERBE in 1985. Sensitivity factors of the TOA outgoing fluxes to changes in aerosol index were estimated using a linear regression fit to the ERBE and TOMS measurements. The ratio of the shortwave-to-longwave response to changes in dust loading over the ocean is found to be roughly 2 to 3 but opposite in sign. The monthly averaged "clear-sky" TOA direct forcing of airborne Saharan dust was also calculated by multiplying these sensitivity factors by the TOMS monthly averaged "clear-sky" aerosol index. Both the observational and theoretical analyses indicate that the underlying surface properties, dust layer height, ambient moisture content, and the presence of cloud all play important roles in determining the TOA direct radiative forcing due to mineral aerosols.

Hsu, N.C., Tsay, S.C., King, M.D., Herman, J.R. 2004. Aerosol properties over bright-reflecting source regions. IEEE Transactions on Geoscience and Remote Sensing 42 (3), 557-569.
Retrieving aerosol properties from satellite remote sensing over a bright surface is a challenging problem in the research of atmospheric and land applications. In this paper we propose a new approach to retrieve aerosol properties over surfaces such as arid, semiarid, and urban areas, where the surface reflectance is usually, very, bright in the red part of visible spectrum and in the near infrared, but is much darker in the blue spectral region (i.e., wavelength <500 nm). In order to infer atmospheric properties from these data, a global surface reflectance database of 0.1° latitude by 0.1° longitude

resolution was constructed over bright surfaces for visible wavelengths using the minimum reflectivity, technique (e.g., finding the clearest scene during each season for a given location). The aerosol optical thickness and aerosol type are then determined simultaneously in the algorithm using lookup tables to match the satellite observed spectral radiances. Examples of aerosol optical thickness derived using this algorithm over the Sahara Desert and Arabian Peninsula reveal various dust sources, which are important contributors to airborne dust transported over long distances. Comparisons of the satellite inferred aerosol optical thickness and the values from ground-based Aerosol Robotic Network (AERONET) sun/sky radiometer measurements indicate good agreement (i.e., within 30%) over the sites in Nigeria and Saudi Arabia. This new algorithm, when applied to Moderate Resolution Imaging Spectroradiometer (MODIS), Sea-viewing Wide Field of view Sensor (SeaWiFS), and Global Imager (GLI) satellite data, will provide high spatial resolution (similar to1 km) global information of aerosol optical thickness over bright surfaces on a daily basis.

Huang, Y.S., Dupont, L., Sarnthein, M., Hayes, J.M., Eglinton, G. 2000. Mapping of C-4 plant input from North West Africa into North East Atlantic sediments. Geochimica et Cosmochimica Acta 64 (20), 3505-3513.
Mapping the abundance of C-13 in leaf-wax components in surface sediments recovered from the seafloor off northwest Africa (0-35 degrees N) reveals a clear pattern of delta(13)C distribution, indicating systematic changes in the proportions of terrestrial C-3 and C-4 plant input. At 20 degrees N latitude, we fmd that isotopically enriched products characteristic of C-4 plants account for more than 50% of the terrigenous inputs. This signal extends westward beneath the path of the dust-laden Sahara Air Layer (SAL). High C-4 contributions, apparently carried by January trade winds, also extend far into the Gulf of Guinea. Similar distributions are obtained if summed pollen counts for the Chenopodiaceae-Amaranthaceae and the Poaceae are used as an independent C-4 proxy. We conclude that the specificity of the latitudinal distribution of vegetation in North West Africa and the pathways of the wind systems (trade winds and SAL) are responsible for the observed isotopic patterns observed in the surface sediments. Molecular-isotopic maps on the marine-sedimentary time horizons (e.g., during the last glacial maximum) are thus a robust tool for assessing the phytogeographic changes on the tropical and sub-tropical continents, which have important implications for the changes in climatic and atmospheric conditions.

Hugot, H.J., Ed. 1962. Missions Berliet Ténéré-Tchad 9-11-1959 / 7-1-1960 , 23-10-1960 / 9-12-1960, Arts et Métiers Graphiques, Paris, 374 pp. SOAS FXA.L.63 /158515

Imagawa, T., Kadomura, H. 1989. The '320 m -beach ridge' and ancient erg in northern Cameroon: a preliminary note. In: Kadomura, H. Ed., Savannization processes in tropical Africa 1., Tokyo Metropolitan University, Department of Geography; also Occasional Paper - Zambia Geographical Association, 17, 159-167.
In an attempt to establish a baseline used for reconstructing Holocene histories of savannization and desertification with climatic changes in the backdrop, we carried out a preliminary survey on the origins and ages of the Palaeo-Chad '320 m -beach ridge' and ancient erg (old dunes) in Northern Cameroon. Granulometric analysis of sediment shows clearly that sands composing the '320 m -Beach Ridge', not only by the Logone but also by rivers originating from the Mandara Mountains. A radiocarbon date of charcoal fragment collected from the upper part of an old dune at Kalfou indicates that the remobilization of dune sands occurred shortly before 4500 yr BP, probably corresponding with the onset of late Holocene climatic aridification

Ireland, A.W. 1962. Incidences of Harmattan air at the surface in the Lagos area. Technical Note **26**, Nigerian Meteorological Service, 4 pp. abstract in Busche et al. 1984 annexe

Irizarry-Ortiz, M.M., Wang, G.L., Eltahir, E.A.B. 2003. Role of the biosphere in the mid-Holocene climate of West Africa. Journal of Geophysical Research-Atmospheres 108 (D2), art. no. 4042.
In previous studies, a zonally symmetric, synchronously coupled biosphere-atmosphere model (ZonalBAM), which includes explicit representation of ecosystem dynamics, has been developed and validated based on current conditions over the region of West Africa. Here, we use ZonalBAM to study the response of the coupled biosphere-atmosphere system to changes in the Earth's orbital forcing during the Middle Holocene (6K yrs BP) and the relative contribution of vegetation feedbacks. Simulations in which vegetation conditions were fixed to the current distribution, show that an orbitally induced increased seasonality in insolation for the Middle Holocene, by itself, results in a 1.1^{o} northward shift in the location of the southern margin of the Sahara as compared to current solar

forcings. When vegetation is allowed to be dynamic, a 2.4° northward shift is simulated. However, when dynamic vegetation is initialized to palaeovegetation, a 5.1° northward shift is simulated, bringing results more consistent with palaeoevidence. Based on previous studies on the role of the gradient of moist static energy on the dynamics of large-scale tropical circulations, a mechanism for the enhancement of the summer monsoon circulation has been developed. Our results suggest that multiple equilibria could have coexisted over the region of West Africa during the Middle Holocene. Furthermore, based on previous studies on the current climate over the region, we hypothesize that transitions between the different equilibria could have taken place during the Middle Holocene causing the southern desert margin to migrate between 18.1°N and 21.4°N and shaping climate variability.

Israelevich, P.L., Ganor, E., Levin, Z., Joseph, J.H. 2003. Annual variations of physical properties of desert dust over Israel. Journal of Geophysical Research – Atmospheres 108 (D13). art. no. 4381.
The annual variation of the desert dust aerosol loading above the eastern Mediterranean is studied. Three periods are identified, March-May, July-August, and September-November, for which the properties of dust particles are distinctly different. The dust layers are at higher altitudes and consist of larger particles in summer and autumn than in spring. The real part of the refractive index of the particles is the same for summer and autumn periods and exceeds the real part of the refractive index measured during the spring. The imaginary part of the refractive index is negligible both in spring and in summer, whereas the imaginary refractive index becomes significant in September-November, indicating the presence of absorbing aerosols. The difference is attributed to different sources and desert dust trajectories in these periods. In spring the desert aerosol from the source in Chad is transported to the eastern Mediterranean predominantly along the North African coast. This is the motion associated with Sharav cyclones. The aerosols come to the eastern Mediterranean via Egypt from the sources near the Red Sea in July-August. In autumn the dust arrives to the eastern Mediterranean from the Libyan coast.

Israelevich, P.L., Levin, Z., Joseph, J.H., Ganor, E. 2002. Desert aerosol transport in the Mediterranean region as inferred from the TOMS aerosol index. Journal of Geophysical Research-Atmospheres 107 (D21), art. no. 4572.
We proposed to identify the sources of desert dust aerosols with local maxima of the TOMS aerosol index distribution averaged for the long period. Being simpler than the approach based on a dusty days occurrence, our method gives the same results. It was first shown that in spring-summer, the flux of dust from the sources located at latitude similar to16°N and longitude similar to16°E and around latitude similar to19°N and longitude similar to 6°W exceed the sinks due to settling and transport. As a result the atmosphere over North Africa is almost permanently loaded with a significant amount of mineral desert dust in spring and in summer. It is also shown that the Chad basin source located around latitude 16°N and longitude 16°E is relatively more stable with a maximum activity around April. The region around latitude similar to19°N and longitude 6°W appears as a more variable source with maximum in July. Low pressure systems, called Sharav cyclones, mobilize the already suspended mineral dust and transport it eastward and northward along the Mediterranean basin. A new method for description of dust plumes propagation was applied to the study of dust events in the Mediterranean Sea and enabled us to follow their dynamics. Identifiable dust plumes appear first in the western sector of the sea and then move eastward with a speed of about 7° to 8° per day. In spring, this motion continues at least up to the eastern coast of the Mediterranean. In summer the dustplume is prevented from penetrating further east of about 15°E.

Iziomon, M.G., Aro, T.O. 1998. The diffuse fraction of global solar irradiance at a tropical location. Theoretical and Applied Climatology 61 (1-2), 77-84.
The annual and monthly mean diurnal variations of the diffuse fraction of global solar irradiance arriving on the ground at a tropical station in Sub-Sahel Africa is here been reported. The monthly mean hourly values of the diffuse fraction (K-d) for Such clear-sky months as February, March and November at this location, which approach a minimum at about local noon, are observed to lie generally below 0.50 during the period from 11:00 to 15:00hrs (LST). Consequently, solar concentrators utilising parabolic mirrors are expected to have high performance during these months in this region. Like the mainly-cloudy and wet months (June to August) in which monthly mean hourly values of Kd higher than 0.62 have been recorded, the corresponding diffuse fraction for dust-haze :months (mostly December and January) with high turbidity coefficients were generally above 0.50. Monthly mean hourly values of K-d for less cloudy months (April, May, September and October) ranged between 0.48 and 0.77 during the period from 11:00 to 15:00hrs (LST). The effects of atmospheric dust-haze, clouds and albedo on the monthly mean diurnal variation of the diffuse fraction

has been discussed. Also reported are the characteristic values of K-d for sets of months with relatively similar atmospheric and sky conditions at this location. The annual variations of the monthly mean daily values of K-d which exhibit strong seasonal dependence showed a peak in August for both years. Except for the months of February and March, the monthly mean daily totals of K-d exhibited similar annual marches during both years. The major discrepancy in the values of the monthly mean daily totals of K-d in both years were recorded in the months of February, November and December, with the corresponding K-d values for these months in both years agreeing only to within 32.9% in February, 15.4% in November and 16.2% in December. Apart from the aforementioned months, the corresponding monthly mean daily totals of K-d for the remaining nine months in both years agreed mostly to within less than 8.4%. The least monthly mean daily ratios of K-d Were obtained in the relatively clear month of November for both years being 0.43 in 1993 and 0.49 in 1994. On an annual average, the diffuse component was found to constitute 59.6% of the global solar irradiance arriving on the ground at this region in 1993 and 60.9% in 1994. The results been reported here have been compared with a few others emanating from other tropical stations.

Jahn, R. 1995. Ausmaß äolischer Einträge in circumsaharischen Böden und ihre Auswirkungen auf Bodenentwicklung und Standortseigenschaften, Hohenhiemer Bodenkundliche Hefte, 23, 213 pp.

Jahn, R., Herrmann, L., Stahr, K. 1996. Die Bedeutung aeolischer Eintraege fuer Bodenbildung und Standortseigenschaften im circumsaharischen Raum. In: Geowissenschaften in Afrika; Grundlagenforschung und Praxis; Afrikagruppe deutscher Geowissenschaftler (AdG), Ed. Weir, H., Zentralblatt für Geologie und Paläontologie, Teil I: Allgemeine, Angewandte, Regionale und Historische Geologie. 1995; 3-4, 421-432.

Jahns, S. 1995. A Holocene pollen diagram from El Atrun, northern Sudan. Vegetation History and Archaeobotany 4 (1), 23-30.
Palynological investigations on a 3.36 m core from El Atrun, Nubia, show vegetation development and climatic change during a period from approximately 9800 to 7000 uncal B.P. From a dry period with a steppe-like vegetation at about 9800-9500 B.P. (zone A), a change to a period with a more favourable climate and a tree covered savanna-like vegetation can be observed in zone B (about 9500-8900 B.P.). In zone C (8900-8400 B.P.), a climatic setback is indicated, with spreading of steppe vegetation and an increase in swamp vegetation as a result of a low lake level. For zone D (about 8400-7000 B.P.), renewed spreading of wooded savanna is inferred.

Jäkel, D. 1977. The work of the field station, Bardai, Tibesti Mountains, Geographical Journal, 143 (1), 61-73.

Jäkel, D. 1978. Eine Klimakurve für die Zentralsahara, in Sahara: 10.000 Jahre zwischen Weide und Wüste, Museen der Stadt, Koln, Handbuch zu einer Ausstellung der Rautenstrauch-Joest-Museums für Völkerkunde in Zusammenarbeit mit der Institut für Ur- und Frühgeschichte der Universität Köln und dem Museum Alexander Koenig, Bonn, Köln, 382-396.

Jakel, D., 1979. Run-off and fluvial formation processes in theTibesti mountains as indicators of climatichistory in the central Sahara during the latePleistocene and Holocene. Palaeoecology of Africa 11 : 13-44.

Jäkel, D. 1980. Die Bildung von Barchanen in Faya-Largeau/ République du Tchad. Zeitschrift für Geomorphologie 24 (2), 141-159.
Between 1964 and 1974 observations and, in 1974, surface temperature measurements with an infra-red thermometer were made on the barchans. A connection was seen to exist between surface temperature and form of the barchans. This study first discusses movement of material at observation and measuring points, then deals with the theoretical question of how barchans are formed, and develops a theory of barchan genesis.

Jäkel, D. 1983. Rainfall patterns and lake level variations at Lake Chad, in Climatic changes on a yearly to millennial basis: geological, historical and instrumental records, Eds. Moerner, N. and Karlen, W., Reidel, Dordrecht, 191-200.

Jäkel, D. and Dronia, H. 1976. Ergebnisse von Boden- und Gesteintemperaturmessungen in der Sahara, Berliner geographische Abhandlungen, 24, 55-64.

Jänicke, R. 1979. Monitoring and critical review of the estimated source strength of mineral dust from the Sahara. In: Morales, C. (ed), Scope 14, Saharan Dust - Mobilization, Transport, Deposition, John Wiley and Sons, Chichester, 233-242.

Jankowiak, I. and Tanré, D. 1992. Satellite climatology of Saharan dust outbreaks. Journal of Climate 5(6):646-656.
An operational algorithm for detecting dust outbreaks over ocean at global scales is presented. It is shown to be efficient for identifying dusty areas over the eastern Atlantic Ocean using the European Meteorological Satellite (Meteosat). The retrieved values of the dust optical thickness, which is related to the importance of the event, are shown to be in good agreement with simultaneous ground measurements. First results concerning the frequencies and the trajectories of the dust outbreaks that occurred over five years (from 1984 to 1988) are also provided.

Joffé, G., Day-Viaud, V., Compilers. 1995. Chad. World bibliographical series 177, Clio, Oxford, 188 pp. SOAS Ref WDD016 /713250

Jolly, D., Harrison, S.P., Damnati, B., Bonnefille, R. 1998. Simulated climate and biomes of Africa during the late Quaternary: Comparison with pollen and lake status data. Quaternary Science Reviews 17 (6-7), 629-657.
New compilations of African pollen and lake data are compared with climate (CCM1, NCAR, Boulder) and vegetation (BIOME 1,2, GSG, Lund) simulations for the last glacial maximum (LGM) and early to mid-Holocene (EMH). The simulated LGM climate was ca 4^{o}C colder and drier than present, with maximum reduction in precipitation in semi-arid regions. Biome simulations show lowering of montane vegetation belts and expansion of southern xerophytic associations, but no change in the distribution of deserts and tropical rain forests. The lakes show LGM conditions similar or drier than present throughout northern and tropical Africa. Pollen data indicate lowering of montane vegetation bells, the stability of the Sahara, and a reduction of rain forest. The paleoenvironmental data are consistent with the simulated changes in temperature and moisture budgets, although they suggest the climate model underestimates equatorial aridity. EMH simulations show temperatures slightly less than present and increased monsoonal precipitation in the eastern Sahara and East Africa. Biome simulations show an upward shift of montane vegetation belts, fragmentation of xerophytic vegetation in southern Africa, and a major northward shift of the southern margin of the eastern Sahara. The lakes indicate conditions wetter than present across northern Africa. Pollen data show an upward shift of the montane forests, the northward shift of the southern margin of the Sahara, and a major extension of tropical rain forest. The lake and pollen data confirm monsoon expansion in eastern Africa, but the climate model fails to simulate the wet conditions in western Africa

Jolly, D., Prentice, I.C., Bonnefille, R., Ballouche, A., Bengo, M., Brenac, P., Buchet, G., Burney, D., Cazet, J.P., Cheddadi, R., Edorh, T., Elenga, H., Elmoutaki, S., Guiot, J., Laarif, F., Lamb, H., Lezine, A.M., Maley, J., Mbenza, M., Peyron, O., Reille, M., Reynaud-Farrera, I., Riollet, G., Ritchie, J.C., Roche, E., Scott, L., Ssemmanda, I., Straka, H., Umer, M., Van Campo, E., Vilimumbalo, S., Vincens, A., Waller, M. 1998. Biome reconstruction from pollen and plant macrofossil data for Africa and the Arabian peninsula at 0 and 6000 years. Journal of Biogeography 25 (6), 1007-1027.
Biome reconstruction from pollen and plant macrofossil data provides an objective method to reconstruct past vegetation. Biomes for Africa and the Arabian peninsula have been mapped for 6000 years sp and provide a new standard for the evaluation of simulated palaeovegetation distributions. A test using modern pollen data shows the robustness of the biomization method, which is able to predict the major vegetation types with a high confidence level. The application of the procedure to the 6000 years data set (pollen and plant macrofossil analyses) shows systematic differences from the present that are consistent with the numerous previous regional and continental interpretations, while providing a more extensive and more objective basis for such interpretations. Madagascar, eastern, southern and central Africa show only minor changes in terms of biomes, compared to present. Major changes in biome distributions occur north of 15^{o}N, with steppe in many low-elevation sites that are now desert, and temperate xerophytic woods/scrub and warm mixed forest in the Saharan mountains. These shifts in biome distributions, imply significant changes in climate, especially precipitation, between 6000 years and present, reflecting a change in monsoon extent combined with a southward expansion of Mediterranean influence.

Jones, C., Mahowald, N., Luo, C. 2003. The role of easterly waves on African desert dust transport. Journal of Climate 16 (22), 3617-3628.
Mineral aerosols from North Africa represent one of the largest sources of aerosols available to the atmosphere, and their generation and transport are thought to be modulated by African easterly waves. In this study, the relationships between easterly wave activity and model simulations of desert dust entrainment and transport are investigated. National Centers for Environmental Prediction-National Center for Atmospheric Research reanalysis datasets are used to both evaluate easterly wave activity and drive a transport model simulation of desert dust. The focus of this study is on boreal summer, when easterly wave activity maximizes. Periods of high easterly wave activity are identified using filtered (2.5-10 days) relative vorticity at 700 hPa over the tropical Atlantic Ocean. Lag composites of relative vorticity and simulated surface dust concentrations are used to investigate the influence of easterly waves on the spatial transport patterns. A comparison between lag composites of available in situ desert dust data at Barbados and model simulation suggests that the model results are consistent with the variability at Barbados. The results show that approximately 20% of the dust entrainment into the atmosphere over a broad region of North Africa is associated with easterly wave activity, suggesting that easterly waves may regulate desert dust entrainment into the atmosphere. About 10%-20% of the seasonal variability of desert dust concentrations across the North Atlantic is related to easterly waves, which suggests that easterly waves modulate the transport of desert dust.

Joseph, A., Arnyossy, J.F. 1992. Palaeohydrology de la nappe cretacée de Bilma (Niger). Würzburger Geographische Arbeiten 84, 73-96.

Jung, S.J.A., Davies, G.R., Ganssen, G.M., Kroon, D. 2004. Stepwise Holocene aridification in NE Africa deduced from dust-borne radiogenic isotope records. Earth and Planetary Science Letters 221 (1-4), 27-37.
Transfer of tropical heat to higher latitudes is the major driving force of the Earth's climate. Consequently, sediments in regions to the north and south of the tropics potentially retain an archive of past major climate reconfigurations. The climate of one such region, around the Arabian Sea, sensitively depends on the coupled Asian and African monsoons that also control the dust transport. Here, we use the Sr-Nd isotope ratios of the dust fraction from Core 905 (Arabian Sea off Somalia), as a novel tool to deduce the Holocene weathering history of the Horn of Africa with emphasis on the climate transition that took place from a wet early to a dry late Holocene. The highly variable Sr isotope ratios are interpreted to reflect mainly changes in the evaporation/precipitation balance over NE Africa whilst the Nd isotope measurements record no significant variations and point to a prevailing NE African dust source. The Sr isotope record shows that the first aridification step occurred at 8.5 kyr BP followed by an unstable transitional period up to 6 kyr BP, characterized by decadal-scale high-amplitude variations in the evaporation/precipitation balance. A second aridification step began at 6 kyr BP and ceased at 3.8 kyr BP when modern-day dry climate was established. The combined Sr and Nd isotope records probably reflect north-south shifts of the Intertropical Convergence Zone controlling the evaporation/precipitation balance over NE Africa.

Kalashnikova, O.V., Kahn, R., Sokolik, I.N., Li, W.H. 2005. Ability of multiangle remote sensing observations to identify and distinguish mineral dust types: Optical models and retrievals of optically thick plumes. Journal of Geophysical Research-Atmospheres 110 (D18), art. no. D18S14.
We present a systematic theoretical study of atmospheric mineral dust radiative properties, focusing on implications for multiangle and multispectral remote sensing. We model optical properties of complex, nonspherical mineral dust mixtures in three visible-near-infrared satellite channels: 0.550, 0.672, and 0.866 mu m, accounting for recent field and laboratory data on mineral dust morphology and mineralogy. To model the optical properties of mineral dust, we employ the discrete dipole approximation technique for particles up to 2 mu m diameter and the T matrix method for particles up to 12 mu m. We investigate the impact of particle irregularity, composition, and size distribution on particle optical properties, and we develop optical models for representative natural mineral dust composition-size-shape types. Sensitivity studies with these models indicate that Multiangle Imaging Spectroradiometer (MISR) data should be able to distinguish plate-like from grain-like dust particles, weakly from strongly absorbing compositional types, and monomodal from bimodal size distributions. Models containing grain-like, weakly absorbing, bimodal distributions of dust particles were favored for optically thick Saharan and Asian dust plume examples, whereas strongly absorbing and plate-like particles were rejected. We will present detailed, systematic MISR sensitivity studies and analysis of more complex field cases using the optical models derived here in a future paper.

Kalu, A.E. 1979. The African dust plume; its characteristics and propagation across West Africa in winter. In: Saharan dust; mobilization, transport, deposition, Ed. Morales, C. John Wiley and Son, Chichester, 95-118. UCL STORE 04-0917

Karyampudi, V.M., Palm, S.P., Reagen, J.A., Fang, H., Grant, W.B., Hoff, R.M., Moulin, C., Pierce, H.F., Torres, O., Browell, E.V., Melfi, S.H. 1999. Validation of the Saharan dust plume conceptual model using lidar, Meteosat, and ECMWF data. Bulletin of the American Meteorological Society 80 (6), 1045-1075.
Lidar observations collected during the Lidar In-space Technology Experiment experiment in conjunction with the Meteosat and European Centre for Medium-Range Weather Forecasts data have been used not only to validate the Saharan dust plume conceptual model constructed from the GARP (Global Atmospheric Research Programme) Atlantic Tropical Experiment data, but also to examine the vicissitudes of the Saharan aerosol including their optical depths across the west Africa and east Atlantic regions. Optical depths were evaluated from both the Meteosat and lidar data. Back trajectory calculations were also made along selected lidar orbits to verify the characteristic anticyclonic rotation of the dust plume over the eastern Atlantic as well as to trace the origin of a dust outbreak over West Africa.
A detailed synoptic analysis including the satellite-derived optical depths, vertical lidar backscattering cross section profiles, and back trajectories of the 16-19 September 1994 Saharan dust outbreak over the eastern Atlantic and its origin over West Africa during the 12-15 September period have been presented. In addition, lidar-derived backscattering profiles and optical depths were objectively analyzed to investigate the general features of the dust plume and its geographical variations in optical thickness. These analyses validated many of the familiar characteristic features of the Saharan dust plume conceptual model such as (i) the lifting of the aerosol over central Sahara and its subsequent transport to the top of the Saharan air layer (SAL), (ii) the westward rise of the dust layer above the gradually deepening marine mixed layer and the sinking of the dust-layer top, (iii) the anticyclonic gyration of the dust pulse between two consecutive trough axes, (iv) the dome-shaped structure of the dust-layer top and bottom, (v) occurrence of a middle-level jet near the southern boundary of the SAL, (vi) transverse-vertical circulations across the SAL front including their possible role in the initiation of a squall line to the southside of the jet that ultimately developed into a tropical storm, and (vii) existence of satellite-based high optical depths to the north of the middle-level jet in the ridge region of the wave.
Furthermore, the combined analyses reveal a complex structure of the dust plume including its origin over North Africa and its subsequent westward migration over the Atlantic Ocean. The dust plume over the west African coastline appears to be composed of two separate but narrow plumes originating over the central Sahara and Lake Chad regions, in contrast to one single large plume shown in the conceptual model. Lidar observations clearly show that the Saharan aerosol over North Africa not only consist of background dust (Harmattan haze) but also wind-blown aerosol from fresh dust outbreaks. They further exhibit maximum dust concentration near the middle-level jet axis with downward extension of heavy dust into the marine boundary layer including a clean dust-free trade wind inversion to the north of the dust layer over the eastern Atlantic region. The lidar-derived optical depths show a rapid decrease of optical depths away from land with maximum optical depths located close to the midlevel jet, in contrast to north of the jet shown by satellite estimates and the conceptual model. To reduce the uncertainties in estimating extinction-to-backscattering ratio for optical depth calculations from lidar data, direct aircraft measurements of optical and physical properties of the Saharan dust layer are needed.

Kaufman, Y.J., Tanré, D., Dubovik, O., Karnieli, A. and Remer, L.A. 2001. Absorption of sunlight by dust as inferred from satellite and ground-based remote sensing, Geophysical Research Letters, 28 (8), 1479-1482.

Kaufman, Y.J., Tanré, D., Leon, J.F., Pelon, J. 2003. Retrievals of profiles of fine and coarse aerosols using lidar and radiometric space measurements. IEEE Transactions on Geoscience and Remote Sensing 41 (8), 1743-1754.
The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) spaceborne lidar, expected to be launched in 2004, will collect profiles of the lidar attenuated backscattering coefficients of aerosol and clouds at 0.53 and 1.06 μm. The measurements are sensitive to the vertical distribution of aerosols. However, the information is insufficient to be mapped into unique aerosol physical properties and vertical distribution. Spectral radiances measured by the Moderate Resolution Imaging

Spectrometer (MODIS) on the Aqua spacecraft, acquired simultaneously with the CALIPSO observations, can constrain the solutions. The combination of the MODIS and CALIPSO data can be used to derive extinction profiles of the fine and coarse modes of the aerosol size distribution for aerosol optical thickness of 0.1 and larger. Here we describe a new inversion method developed to invert simultaneously MODIS and CALIPSO data over glint-free ocean. The method is applied to aircraft lidar and MODIS data collected over a dust storm off the coast of West Africa during the Saharan Dust Experiment (SHADE). The backscattering-to-extinction ratio (BER) (BER = omega(o)P(180)/4pi) can be retrieved from the synergism between measurements avoiding a priori hypotheses required for inverting lidar measurements alone. For dust, the resultant value of BER = 0.016 sr-1 is over 50% smaller than what is expected using Mie theory, but in good agreement with recent results obtained from Raman lidar observations of dust episodes. The inversion is robust in the presence of 10% and 20% noise in the lidar signal at 0.53 and 1.06 pm, respectively. Calibration errors of the lidar of 5% to 10% can cause an error in optical thickness of 20% to 40%, respectively, in the tested cases.

Kiefert, L., McTainsh, G.H. and Nickling, W.G. 1996. Sedimentological characteristics of Saharan and Australian dusts. In: Guerzoni, S. and Chester, R. (eds), The impact of desert dust across the Mediterranean, Kluwer Academic, Dordrecht, pp. 183-190.

Klitzsch, E. 1966. Comments on the geology of the central parts of southern Libya and northern Chad, in South-central Libya and northern Chad, Petroleum Exploration Society of Libya, Handbook, **8**th Annual Field Excursion, Tripoli, 1-17. soas UVL 5566

Klitzsch, E. 1994. Geological exploration history of the eastern Sahara. Geologische Rundschau 83 (3), 475-483.
The major contributions to our knowledge of the geological history of the East Saharan countries are described. Much work has been published on the history and progress of geographical, socioeconomic and archaeological exploration in North Africa. Little attention, however, has been paid to the question of how our knowledge of the geology of this vast area was developed. Thus, even though progress in geology is vital to the development of Saharan countries, little has been recorded of this progress. Without an understanding of regional geology and without a good knowledge of groundwater, mineral and petroleum potentials, these countries would be in very different situations today. The author has, over the last 35 years, been involved in scientific research and exploration of petroleum, mineral and groundwater resources in Libya, Egypt, Sudan and Chad.

Klitzsch, E. and Eberhard, J. 1966. Satelliten Luftbild. Zentral Sahara, Die Erde, 97 (2), 81-83.

Klitzsch, E. and Eberhard, J. 1967. Bemerkungen zu der Interpretation eines Satelliten-Luftbild der Zentralsahara, Die Erde, 98 (4), 298-300.

Klitzsch, E. and Schrank, E., Eds. 1987. Research in Egypt and Sudan. Results of the Special Research Project Arid Zones, Period 1984-1987, Sonderforschungsbericht, 69, Berliner geowissenschaftliche Abhandlungen, Reihe A, D. Reimer, Berlin, 75.2, 627 pp.

Klitzsch, E. and Schrank, E., Eds. 1987. Research in Egypt and Sudan, Berliner geowissenschaftliche Abhandlungen, Reihe A, 75.3, 9867 pp.

Klitzsch, E., Sonntag, C., Weistroffer, K. and El Shazly, E.M. 1976. Grundwasser der Zentralsahara: fossile vorraete, *Geologische Rundschau*, **65** (1), 264-284.

Klitszch, E. and Torweihe, U., Eds. 1999. Nordöst-Afrika: Strukturen und Ressourcen, Wiley-VCH, Weinheim, 446-506.

Klitsch, E., Wycisk, P. 1987. Geology of the sedimentary basins of northern Sudan and bordering areas. Berliner Geowissenschaftliche Abhandlungen. Reihe A. Geologie und Paläontologie 75 (1), 97-136.

Koeninguer, J.C. 1975. Expeditions paléontologiques au Tchad; I, Les bois plio-quaternaires du Nord-Tchad (Kolinga, Koro-Toro, Angamma). Annales de Paléontologie Invertébrés 61 (2), 179-214.

Koeninguer, J.C., Faure, H. 1970. Etude paléoxylologique du Sahara meridional; sur la présence de *Faureoxylon princeps* n.g., n.sp. et de *Opilioxylon nigerinum* n.g., n.sp. Comptes rendus du Congrès national des Sociétés des Savantes, Section des Sciences 3, 143-152.

Kogbe, C., Lang, J., Durand, A. 1995. Sédiments quaternaires et changements climatiques au Sahel central (Niger and Chad). Africa Geosciences Review 2 (3-4), 323-614.

Kolbe, R.W. 1957. Fresh-water diatoms from Atlantic deep-sea sediments. Science 126(3282):1053.

Koren, I., Kaufman, Y.J. 2004. Direct wind measurements of Saharan dust events from Terra and Aqua satellites. Geophysical Research Letters 31 (6), art. no. L06122.
Wind speed and direction, during Saharan dust episodes are calculated by estimating the movement of the dust plume between the morning observations from Terra and the afternoon observations from Aqua by the MODerate resolution Imaging Spectroradiometer (MODIS). The difference in the position of the dust front (easily identified both near the dust sources and over the ocean) between the Terra and Aqua observations is used to derive the actual wind field of the dust layer. The analysis is used to estimate the near-surface wind properties needed for dust mobilization in the Bodélé depression. Comparison with NCEP reanalysis winds shows that NCEP underestimated by factor 2 the actual speed of the dust front progression near the sources and produced an azimuthal spread, three times wider than the measured one. Over the seashore, with more numerous meteorological observations, the NCEP wind field did match very well the dust measurements.

Kploguede, E. 1996. Haze and sandstorm monitoring over West Africa using WEFAX and HR images. In: Meteorological Satellite Data User's Conference, EUMETSAT Publication 19:361-368.

Kröpelin, S. 1987. Palaeoclimatic evidence from Early to Mid-Holocene playas in the Gilf Kebir (southwest Egypt), in Palaeoecology of Africa and the surrounding islands, 18, Ed. Coetzee, J.A., Balkema, Rotterdam, 189-208.

Kröpelin, S. 1989. Untersuchungen zum Sedimentationsmilieu von Playas im Gilf Kebir (SW Ägyptien), Africa Prähistorica, 2, Heinrich-Barth-Institut, Köln, 183-306.

Kröpelin, S. 1990. Untersuchungen zur Rekonstruktion der spätquätaren Umwelt am unteren Wadi Howar (Südöstliche Sahara / NW Sudan), Ph.D. dissertation, Free University of Berlin, 571 pp.

Kröpelin, St. 1993. The Gilf Kebir and Wadi Howar: contrasting Early and Mid Holocene environments in the eastern Sahara. In: Krzyzhaniak, L., Kobusiewicz, M., Alexander, J. (eds). Evironmental change and human culture in the Nile basin and northern Africa until the second millenium BC, Poznan, 249-258.

Kröpelin, S. 1993. Zur Rekonstruktion der spätquatären Umwelt am Unteren Wadi Howar (Südöstliche Sahara/NE Sudan), Berliner geographische Abhandlungen, 54, 293 pp.

Kröpelin, S. 1993. Geomorphology, landscape evolution and palaeoclimates of southwest Egypt, Catena, Supplement, 26, 31-65.
The southern part of the Western Desert of Egypt occupies the centre of the largest hyperarid area of the earth. It has the features of lithology-controlled scarp lands with ridges separated from each other by up to a hundred kilometres. Apart from the Gilf Kebir and the Egyptian Plateau, the region is devoid of strong relief, barren rocky platforms and sandy plains with isolated zeugenbergs being the main geomorphologic feature. Most of the surface is hamada desert and roughly half of the sedimentary cover consists of Quaternary dune, sand sheet, wadi and serir deposits. The present morphology of the Western Desert is a palimpsest of forms inherited from ancient, contrasted morphogenetic systems and responses to climatic changes. The physiographic framework is largely the legacy of pre-Quaternary fluvial erosion. With most relief features removed by erosion, the large rocky plains may be regarded as remnants of ancient planation surfaces. Aridification and southward shifting of the Sahelian

boundary started around 4500 bp (3300 BC), turning the Western Desert into uninhabitable land, and may not have been without influence in the forming of the pharaonic Nile culture at that time.

Kröpelin, S. 1993. Environmental change in the southeastern Sahara and the proposal of a Geo-Biosphere Reserve in the Wadi Howar area (NW Sudan). In: Thorweihe, U. and Schandelmeier, H. (eds), Geoscientific research in Northeast Africa; Proceedings of the international conference. Balkema. Rotterdam, pp. 561-568.

Kröpelin, S. 1999. Terrestische Paläoklimatologie heute arider Gebiete: Resultate ans dem Unteren Wadi Howar (Südöstliche Sahara/NE Sudan), in Nordost-Afrika: Strukturen und Ressourcen, Eds. Klitsch, E. and Thorweihe, U., Wiley-VCH, Weinheim, 446-506.

Kroepelin, S. 2006. Revisiting the age of the Sahara Desert: Discussion re. "The age of the Sahara Desert" by M. Schuster et al. (10 Feb., p. 821). Science NS 312(5777):1138-1139.

Kröpelin, S., Souliemarsche, I. 1991. Charophyte remains from Wadi Howar as evidence for deep Midholocene fresh-water lakes in the eastern Sahara of Northwest Sudan. Quaternary Research 36 (2), 210-223.
Field research in the eastern Sahara (NW Sudan) revealed extensive early- to mid-Holocene lake marl deposits bearing charophytes along the lower course of the Wadi Howar, an extinct tributary to the Nile. The study of Nitellopsis sites provides a new approach to the reconstruction of Quaternary paleoenvironments of deserts

Krzyżaniak, L. and Kobusiewicz, M., Eds. 1989. Late prehistory of the Nile basin and the Sahara, Archaeological Museum, Pozńan, 547 pp. inst of arch dc 100 poz

Krzyżaniak, L., Kobusiewicz, M., Alexander, J., Eds. 1993. Environmental change and human culture in the Nile basin and Northern Africa until the second Millenium B.C. Pozńan Archaeological Museum, 494 pp. soas FXA /687525

Kuper, R. 1993. Sahel in Egypt: environmental change and cultural development in the Abu Ballas area, Libyan Desert. In: Krzyzaniak, L., Kobusiewicz, M. & Alexander, J. (eds.) Environmental change and human culture in the Nile basin and Northern Africa until the second Millenium B.C., Poznan, 217-223. . soas FXA /687525

Kusmierczyk-Michulec, J., De Leeuw, G. 2005. Aerosol optical thickness retrieval over land and water using Global Ozone Monitoring Experiment (GOME) data. Journal of Geophysical Research-Atmospheres 110 (D10), art. no. D10S05.
An algorithm for the retrieval of the aerosol optical thickness over land and over water from Global Ozone Monitoring Experiment (GOME) data is presented. The cloud fraction in the GOME pixels is determined using the Fast Retrieval Scheme for Clouds From the Oxygen A Band (FRESCO) algorithm. Surface contributions to the top of atmosphere reflectance are determined from the GOME surface reflectance database. The aerosol retrieval algorithm uses lookup tables that were created using the radiative transfer model 6S. The algorithm allows retrieving the aerosol types characterized by angstrom ngstrom coefficients in the range from -0.1 to 2.8; i.e., the range of values observed by the AERONET ground-based measurements. Validation of the algorithm done using the AERONET Sun photometer data for 12 sites in Europe and Africa, for the year 1997, shows very good agreement. The correlation coefficient between the satellite retrieval and AERONET data for the wavelength of 440 nm is 97%, and for 670 nm it is 94%. Validation of the algorithm for the year 2000 was done for a few sites with similar results. The algorithm has been successfully tested over an island influenced by Saharan dust (i.e., Cape Verde, 16 degrees N, 22 degrees W) and over a site located near the Saharan desert (i.e., Bondoukoui, 11 degrees N, 3 degrees W). For other sites located near the Saharan desert such as Bidi Bahn (14 degrees N, 2 degrees W) and Banizombou (13 degrees N, 2 degrees E), the agreement was very good at 440 nm. The algorithm has not been tested over other bright surfaces such as ice-covered regions. Examples of the spatial distribution of the aerosol optical thickness over Europe, north Africa, and the North Atlantic for the year 1997 and 2000 are presented.

Kutzbach, J.E. 1980. Estimates of past climate at Paleolake Chad, North-Africa, based on a hydrological and energy-balance model. Quaternary Research 14 (2), 210-223.

Modeling the combined hydrological and energy balances of basin yields an estimate of at least 650 mm/yr for annual precipitation during portions of the early Holocene; the current rainfall is 350 mm/yr. In the second version of the model the relationship between precipitation and lake area is nonlinear because the runoff ratio and Bowen ratio of the basin are made functions of precipitation. As the lake increases in area in response to increased precipitation, this version of the model allows for further increases in runoff (from the basin into the lake) as the vegetation changes from steppe to savanna and swamp. This nonlinear process may provide a partical explanation for the expansive paleolakes of the early Holocene.

Kutzbach, J.E. 1989. Possible effects of orbital variations on past sources and transports of eolian material: estimates from general circulation model experiments, in Palaeoclimatology and palaeometeorology: modern and past patterns of global atmospheric transport, Eds. Leinen, M. and Sarnthein, M., Kluwer Academic, Dordrecht, 513-521.

Kutzbach, J., Bonan, G., Foley, J., Harrison, S.P. 1996.Vegetation and soil feedbacks on the response of the African monsoon to orbital forcing in the early to middle Holocene. Nature 384 (6610), 623-626.
FOSSIL pollen, ancient lake sediments and archaeological evidence from Africa indicate that the Sahel and Sahara regions were considerably wetter than today during the early to middle Holocene period, about 12,000 to 5,000 years ago(1-4). Vegetation associated with the modern Sahara/Sahel boundary was about 5^{o} farther north, and there were more and larger lakes between 15 and 30^{o}N. Simulations with climate models have shown that these wetter conditions were probably caused by changes in Earth's orbital parameters that increased the amplitude of the seasonal cycle of solar radiation in the Northern Hemisphere, enhanced the land-ocean temperature contrast, and thereby strengthened the African summer monsoon (5-7). However, these simulations underestimated the consequent monsoon enhancement as inferred from palaeorecords (4). Here, we use a climate model to show that changes in vegetation and soil may have increased the climate response to orbital forcing, We find that replacing today's orbital forcing with that of the mid-Holocene increases summer precipitation by 12% between 15 and 22^{o}N. Replacing desert with grassland, and desert soil with more loamy soil, further enhances the summer precipitation (by 6 and 10% respectively), giving a total precipitation increase of 28%. When the simulated climate changes are applied to a biome model, vegetation becomes established north of the current Sahara/Sahel boundary, thereby shrinking the area of the Sahara by 11% owing to orbital forcing alone, and by 20% owing to the combined influence of orbital forcing and the prescribed vegetation and soil changes. The inclusion of the vegetation and soil feedbacks thus brings the model simulations and palaeovegetation observations into closer agreement.

Kutzbach, J.E. and Liu, Z. 1997. Response of African monsoon to orbital forcing and ocean feedbacks in middle Holocene, Science, 278 (5337), 440-443.
Simulations with a climate model that asynchronously couples the atmosphere and the ocean showed that the increased amplitude of the seasonal cycle of insolation in the Northern Hemisphere 6000 years ago could have increased tropical Atlantic sea surface temperatures in late summer. The simulated increase in sea surface temperature and associated changes in atmospheric circulation enhanced the summer monsoon precipitation of northern Africa by more than 25 percent, compared with the middle Holocene simulation with prescribed modern sea surface temperatures, and provided better agreement with paleorecords of enhanced monsoons.

Kutzbach, J.E. and Street-Perrot, F.A. 1985. Milankovitch forcing fluctuations in the level of tropical lakes from 18 to 0 k yr B.P., Nature, 317 (6033), 130-135.
An atmospheric general-circulation model has been used to simulate the climates of January and July at 3000-yr intervals. From 15 kyr BP onwards, the model simulates a strengthed monsoon circulation and increased precipitation in the Northern Hemisphere tropics, culminating at 9-6 kyr BP. The computed hydrological budgets were used to estimate the area of closed lakes between 8.9 and 26.6"SUP o" N, giving, with minor exceptions, results in good agreement with geological evidence

Lafon, S., Rajot, J.L., Alfaro, S.C., Gaudichet, A. 2004. Quantification of iron oxides in desert aerosol Atmospheric Environment 38 (8), 1211-1218.
For assessing the impact of desert aerosols on climate, it is necessary to quantify their content in iron oxides minerals. These minerals are well known for their light absorbing properties. Iron contained in them-the so-called "free-iron" by soil scientists-represents only a part of the total-iron content. Indeed, the latter also includes the iron trapped in the crystal lattice of several desert aerosol mineralogical

species. In this paper we propose an adapted technique to quantify the free-iron in desert aerosol based on a selective extraction method classically used in soil science. Adaptations are made necessary because of the low aerosol load collected on filter samples under field conditions (masses typically lower than 0.5 mg). Validation is obtained by comparing results of the adapted and classical methods when applied to the same geostandards.
We analysed natural samples from three main desert source areas : Sahel (Niger during local erosion events), Sahara (Niger during Harmattan events) and Gobi desert (China). For these samples, the free-to-total iron ratio varied between 0.4 and 0.7. This natural variability indicates that the free-iron in aeolian dust is not directly proportional to the total-iron. As a consequence, total iron cannot be used directly to calculate dust light absorbing properties. The percentages of free-iron relative to the total estimated aerosol mass is 2.8%, 3.7%, and 5.0% in Saharan, Chinese, and Sahelian samples respectively.

Lamb, H.F., Gasse, F. Benkaddour, A., El Hamouti, N., van der Kaars, S., Perkins, W.T., Pearce, N.J., Roberts. C.N. 1995. Relation between century scale Holocene arid intervals in tropical and temperate zones. Nature, 373 (6510), 134-137.
Climate records from lake sediments in tropical Africa, Central America and west Asia show several century-scale arid intervals during the Holocene. These may have been caused by temporary weakening of the monsoonal circulation associated with reduced northward heat transport by the oceans or by feedback processes stimulated by changes in tropical land-surface conditions. Here we use a lake-sediment record from the montane Mediterranean zone of Morocco to address the question of whether these events were also felt in temperate continental regions. We find evidence of arid intervals of similar duration, periodicity and possibly timing to those in the tropics. But our pollen data show that the forest vegetation was not substantially affected by these events, indicating that precipitation remained adequate during the summer growing season. Thus, the depletion of the groundwater aquifer that imprinted the dry events in the lake record must have resulted from reduced winter precipitation. We suggest that the occurrence of arid events during the summer in the tropics but during the winter at temperate latitudes can be rationalized if they are both associated with cooler sea surface temperatures in the North Atlantic.

Lambin, E.F., Walkey, J.A., Petit-Maire, N. 1995. Detection of Holocene lakes in the Sahara using satellite remote-sensing. Photogrammetric Engineering and Remote Sensing 61 (6), 731-737.
During the Holocene warm optimum, the Saharo-Sahelian limit was located at 22^{o} to 23^{o}N latitude, sahelian biotopes and surface wafer being recorded across the current southern Sahara. The extension of lakes during the last warm Holocene optimum is related to the range and frequency of monsoonal rains and/or of Atlantic cyclones. Our objective is to produce a record of Holocene surface water extension in an area presently hyperarid. This study demonstrates the feasibility of detecting the localization of paleolakes by analyzing the spectral information of remotely sensed data. The spectral signature of evaporitic deposits related to the drying up of paleolakes is separable in the red and near-infrared wavelengths from the spectral signature of the surrounding land-cover classes. The most appropriate spatial resolution - in the range of resolution cell sizes of current sensors - to discriminate the residual records of paleolakes is 80 metres.

Lange, E. 1956. Zur Geologic der Tschadsee-Senke. Zeitschrift für Angewandte Geologie 2 (11-12), 490-497.

Larrasoana, J.C., Roberts, A.P., Rohling, E.J., Winklhofer, M., Wehausen, R. 2003. Three million years of monsoon variability over the northern Sahara. Climate Dynamics 21 (7-8), 689-698.
We present a 3 million year record of aeolian dust supply into the eastern Mediterranean Sea, based on hematite contents derived from magnetic properties of sediments from Ocean Drilling Program Site 967. Our record has an average temporal resolution of similar to400 years. Geochemical data validate this record of hematite content as a proxy for the supply of aeolian dust from the Sahara. We deduce that the aeolian hematite in eastern Mediterranean sediments derives from the eastern Algerian, Libyan, and western Egyptian lowlands located north of the central Saharan watershed (similar to 21^{o}N). In corroboration of earlier work, we relate dust flux minima to penetration of the African summer monsoon front to the north of the central Saharan watershed. This would have enhanced soil humidity and vegetation cover in the source regions, in agreement with results from "green Sahara" climate models. Our results indicate that this northward monsoon penetration recurred during insolation maxima throughout the last 3 million years. As would be expected, this orbital precession-scale mechanism is modulated on both short (similar to100-kyr) and long (similar to400-kyr) eccentricity

time scales. We also observe a strong expression of the similar to41-kyr (obliquity) cycle, which we discuss in terms of high- and low-latitude mechanisms that involve Southern Hemisphere meridional temperature contrasts and shifts in the latitudes of the tropics, respectively. We also observe a marked increase in sub-Milankovitch variability around the mid-Pleistocene transition (similar to0.95 Ma), which suggests a link between millennial-scale climate variability, including monsoon dynamics, and the size of northern hemisphere ice sheets.

Leblanc, M., Razack, M., Dagorne, D., Mofor, L., Jones, C. 2003. Application of Meteosat thermal data to map soil infiltrability in the central part of the Lake Chad basin, Africa. Geophysical Research Letters 30 (19), art. no. 1998.
In the central part of the Lake Chad Basin, Africa, the superficial Quaternary aquifer (500,000 km(2)) forms the main water resource. Little is known about the aquifer recharge processes. Large piezometric depressions affect the aquifer and are still unexplained. Meteosat thermal composite data were used to infer qualitative information about time-space variations of soil moisture. Over the aquifer, Meteosat data reveal that after heavy rainfall, the piezometric depressions (Kadzell, Chari-Baguirmi) appear cooler than the surrounding areas (Manga and Harr). The interpretation is that above the depressions, rainwater accumulates at the surface and does not infiltrate deep into the ground, leading to the observed cooler ground. Accordingly, the depressions are characterized by low rainwater infiltrability, which presumably results in a small rainfall recharge. As far as we know, this is the first time that an observed surface phenomenon is directly related to the origin of some piezometric depressions.

Leduc, C., Sabljak, S., Taupin, J.D., Marlin, C., Favreau, G. 2000. Recharge of the Quaternary water table in the northwestern Lake Chad basin (southeastern Niger) estimated from isotopes. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences, Série II Fascicule A – Sciences de la Terre et des Planètes 330 (5), 355-361.
The Quaternary water table is present over almost the whole Lake Chad basin. In its Niger part, where annual rainfall varies from 0 to 350 mm, radioactive isotopes (H^3 and C^{14}) are interpreted in terms of renewal rate; medians are 0.10 and 0.05%, respectively, which means a recharge of about 2 or 3 $mm.yr^{-1}$. This very weak infiltration is compatible with the stable isotope contents (H^2 and O^{18}) in groundwater, which show a mixing of old and recent waters, infiltrated during the last humid period and the present drier times.

Legrand, M., Bertrand, J.J., Desbois, M. 1985. Dust clouds over West-Africa - a characterization by satellite data. Annales Geophysicae 3 (6), 777-783.

Legrand, M., Plana-Fattori, A., N'doume, C. 2001. Satellite detection of dust using the IR imagery of Meteosat 1. Infrared difference dust index. Journal of Geophysical Research-Atmospheres 106 (D16), 18251-18274.
The Infrared Difference Dust Index (IDDI) is a satellite dust product designed for climatological applications, designed specifically for dust remote sensing in and regions such as the Sahel and Sahara. It is based on the atmospheric response to dust, extracted from midday Meteosat-IR imagery, and takes advantage of the impact of dust aerosols on the thermal infra-red radiance outgoing to space. Simulations show a quasi-linear relationship between satellite response to dust and shortwave optical depth, with a sensitivity depending on particle size distribution and radiative surface properties. Comparison of measured satellite response with photometric optical depth agrees with the simulations. Water vapor significantly affects the satellite signal for cases of large columnar amounts and oceanic air masses advected inland. Hence apart from possible coastal effects, the water vapor effect can be neglected in the Sahelian-Saharan zone north of the Intertropical Convergence Zone, coinciding with the major regions of African dust emission and transport. The construction of the IDDI involves the processing of reference images, theoretically representing the outgoing radiance obtaining under clear-sky conditions. Errors may arise from (1) dust remaining in the reference images and (2) seasonal shifts of the reference level; however, the latter error will be offset by averaging used in climatological processing. An error budget is presented for the station of Gao. A statistical comparison of IDDI data with visibility measured at synoptic stations results in (1) a validation of the product, and (2) a climatologically relevant visibility-IDDI relation, valid for the and regions of northern Africa. The latter relation is consistent with both simulations and photometric measurements. IDDI maps over Africa compare successfully with optical depth over adjacent ocean regions derived from Meteosat-VIS imagery. The observed continuity of dust plumes across the African coast demonstrates the consistency between both products.

Lehmann, T., Vignaud, P., Likius, A., Brunet, M. 2005. A new species of Orycteropodidae (Mammalia, Tubulidentata) in the Mio-Pliocene of northern Chad. Zoological Journal of the Linnean Society 143 (1), 109-131.
A new species of fossil Tubulidentata has been found by the Mission Paleoanthropologique Franco-Tchadienne in Northern Chad. It is the first fossil Orycteropodidae (aardvark) from the Mio-Pliocene of Central Africa. The new taxon, Orycteropus abundulafus sp. nov., is considered in the framework of the available Orycteropodidae fossil record. The Chadian specimen is characterized by the highest dental robustness index among all Tubulidentata, the presence of crests on the pterygoid, the triangular-shaped olecranon fossa and the reduction of the deltoid crest. All of these characters are linked to a less fossorial animal that had a tougher diet. This new African. species is closer to the Eurasian O. gaudryi than to any other Tubulidentata. Together they form a clade distinct from that which includes O. afer. This is the first evidence of a relationship for aardvarks between Africa and Eurasia. An initial step is made towards revision of the phylogeny of the order

Le Houérou, H.N. 1997. Climate, flora and fauna changes in the Sahara over the past 500 million years. Journal of Arid Environments 37 (4), 619-647.
The present-day Sahara occupies an area of slightly over 8 million km(2) in Africa, between latitudes 16 and 32^{o} N, circumscribed within the isohyet of 100 +/- 50 mm mean annual rainfall. The hyperarid area alternately expanded and shrank on both sides of a seemingly narrow semi-permanent eremitic zone along the Tropic of Cancer during the course of the Quaternary epoch (1.7Ma). The Cenozoic, Mesozoic and Paleozoic Sahara, in turn, has undergone drastic climatic changes as the African continent drifted northward from its Antarctic position to reach its present latitudinal situation. But, seemingly the Sahara was never the large desert it now is, with the exception perhaps of the Upper Triassic Lower Liassic epochs. The Pleistocene and Holocene contrasting climate changes induced large variations in flora and fauna distribution, as well as in geomorphic processes.
The flora shifted from that of typical desert to tropical savanna and Mediterranean forest or steppe, depending on period and location. Fauna, in rum, changed more in abundance than in nature, since the same groups have been in existence since the Upper Pliocene-Lower Pleistocene. Large mammals, for instance, were mainly of Afro-tropical kinship throughout the Pleistocene and Holocene, while small mammals, in contrast, were predominantly of Mediterranean origin over the same periods. And such is still the case. There were varying large degrees in density of occurrence, but relatively minor fluctuations in nature, in response to such environmental changes as lake and dune expansion and retreat, and even glacier expansion and melting at higher elevations. The present-day man-made expansion of desertic conditions to the north and south actually threaten both flora and fauna alike in the short-and medium-term. Most African large mammals, still present in the desert until the second half of the 19th century, have now become ex-tinct, or are on the very verge of extinction in the Sahara (some may be surviving further south, and/or in the East Africa's parks network). The situation, however, is far less dramatic for the flora, which still includes almost 3000 species of vascular plants, although some species - of economic value or not - are in danger from the man-made destruction of their habitat.

Le Lubre, M. 1946. Le Tibesti septentrional. Esquisse morphologique et structurale, *Comptes rendus de l'Académie royale des Sciences coloniales*, 6 (4), 337-357. soas **Per 40L 139454**

Lemoalle, J. 1978. Stage-area curve for Lake Chad using Landsat images. Cahiers ORSTOM, Série Hydrobiologie 12 (1), 83-87.

Lemoalle, J. 1978. Silica-diatoms relationships in Lake Chad. Cahiers ORSTOM, Série Hydrobiologie 12 (2), 137-141.

Lemoalle, J., Dupont, B. 1973. Iron-bearing oolites and the present conditions of iron sedimentation in Lake Chad (Africa). In: Ores in Sediments.International Union of Geological Sciences, Series A 3, 167-178.

Levy, A. 1991. Remark about Quaternary lakes in Sahara – Response. Bulletin de la Société géologique de France 162 (6), 1184-1184.

Lézine, A.-M. 1987. Paléoenvironnements végétaux d'Afrique occidentale nord-tropical depuis 12.000 B.P. Analyse pollinique de séries sédimentaires continentales (Sénégal-Mauritanie). Géodynamique 2 (2), 137-138

Lézine, A.-M. 1989. Late Quaternary vegetation and climate of the Sahel. Quaternary Research 32 (3), 317-334.
Pollen and phytogeographic evidence provides a vegetational history of the Sahel for the period 0-18 000 yr BP. The zonal vegetation fluctuated latitudinally and its most extreme positions occurred at 18 000 and 8500 yr BP. The first involved a southward shift of the Sahelian wooded grassland to 10°N under the arid conditions of the last glacial maximum. The second shows a rapid northward migration of humid vegetation when the Atlantic monsoon flux increased. In the middle Holocene the spread of Sudanian elements into the modern Sahel suggests a dry season. The modern Sahelian semiarid conditions appeared abruptly at 2000 BP.

Lézine, A.-M. 1989. Vegetation history of the Sahel since 20,000 yr BP. Bulletin de la Société géologique de France 5 (1), 35-42.

Lézine, A.M. 1989. Late Quaternary vegetation and climate of the Sahel. Quaternary Research 32 (3), 317-334.
Pollen and phytogeographic evidence provides a vegetational history of the Sahel for the period 0-18 000 yr BP. The zonal vegetation fluctuated latitudinally and its most extreme positions occurred at 18 000 and 8500 yr BP. The first involved a southward shift of the Sahelian wooded grassland to 10 degreesN under the arid conditions of the last glacial maximum. The second shows a rapid northward migration of humid vegetation when the Atlantic monsoon flux increased. In the middle Holocene the spread of Sudanian elements into the modern Sahel suggests a dry season. The modern Sahelian semiarid conditions appeared abruptly at 2000 BP.

Lézine, A.-M. 1991. West African paleoclimates during the last climatic cycle inferred from an Atlantic deep-sea pollen record. Quaternary Research 35 (3), 456-463.
Pollen studies of marine sediments from Atlantic deep-sea core V22-196 are used to reconstruct paleoclimates of north tropical west Africa since 140 000 yr BP. High concentration of pollen from Saharan and arid coastal zones suggests a strengthened tradewind circulation since ca. 60 000 yr BP that became even stronger after 40 000 yr BP and peaked at 17 000 yr BP. Eolian transport of pollen to the ocean occurred about 94 000 and 105 000 yr BP and during Termination II. High values of pollen are interpreted as reflecting both strong fluvial inputs and the expansion of humid vegetation during wet periods.

Lézine, A.-M., Casanova, J. 1989. Pollen and hydrological evidence for the interpretation of past climates in tropical West-Africa during the Holocene. Quaternary Science Reviews 8 (1), 45-55.
Paleohydrological and palynological data from the three major ecoclimatic zones in modern tropical west Africa - the Guineo-Sudanian, Sahelian and Saharan - have been summarized to provide a 12 000 yr history of paleoclimatic variation. On the basis of 54 limnological sites and 16 pollen sequences, past rainfall patterns can be distinguished with a 500 yr resolution. Paleohydrological data indicate several periods with higher rainfall than present. Those at 9.5 ka-7 ka BP and 4 ka-2.5 ka BP occurred in both the Sahelian and Saharan zones. At 9 ka BP, the vegetation suddenly responded to an abundant increase in rainfall. At 2 ka BP, the vegetation changed quickly to its modern distribution in response to generally drier conditions.

Lézine, A.-M., Casanova, J. 1991. Correlated oceanic and continental records demonstrate past climate and hydrology of North Africa (0-140 ka). Geology (Boulder) 19 (4), 307-310.
Analysis of pollen and dinocysts in a core from the eastern Atlantic (core V22-196; lat 13°50'N, long 18°57'W) provides the first continuous record of paleoclimate and paleohydrology for the latest climatic cycle. During interglacial intervals, increases in pollen input from humid vegetation zones are correlative with high dinocyst productivity. Our data show a close coincidence of northward extensions of Sudanian and Guinean vegetation zones in North Africa and increases in fresh-water input into the Atlantic. Direct evidence indicates positive hydroclimatic phases at 135, 125, 103, 80, 47, and 12-10 ka, coincident with widespread continental records of high lake levels, that confirm the validity of the U/Th chronology.

Lézine, A.-M., Leroux, M., Turon, J.L., Buchet, G., Tastet, J.P. 1995. Pollen transport and atmospheric circulation off tropical West Africa during the last deglaciation, Bulletin de la Société géologique de France 166 (3), 247-257.

High resolution pollen analysis on two cores from the eastern tropical Atlantic between 15°N (A180-48) and 4°N (K5-84063) reveals the variations of intensity of atmospheric fluxes during the last deglaciation. In the Gulf of Guinea, two phases of increase of pollen influx are recorded toward 15,000 B.P. and then during the 11,000-10,000 B.P. time interval: corresponding levels are characterized by the occurrence of pollen grains from Saharan environments (*Artemisia, Ephedra*) and by maximum values of pollen concentration and influx. Conversely, early Holocene levels, about 8,500 B.P., are characterized by minimum values for pollen concentration and influx, with pollen grains mainly from the nearest ecosystems. These results demonstrate that the influence of the NE-SW oriented continental trade wind ("harmattan") could be felt durably down to the latitude of the core during climatic phases dominated by a meridional atmospheric circulation that was intensified by powerful mobile polar highs, at the beginning of the deglaciation and between 11,000 and 10,000 B.P. The pollen influx peak recorded during the latter period off Senegal at 15°N confirms that the strongest intensity of continental trade wind circulation at tropical latitudes in western Africa may correspond to the Younger Dryas cold event described at high latitudes in the northern hemisphere. On the other hand, continent/ocean exchanges were markedly reduced during the early Holocene when SW-NE oriented Atlantic monsoon fluxes reached their maximum intensity.

Lézine, A.-M., Tastet, J.P., Leroux, M. 1994. Evidence of atmospheric paleocirculation over the Gulf of Guinea since the Last Glacial maximum. Quaternary Research 41 (3), 390-395.
High-resolution pollen and eolian input studies from core KS 84063 in the Gulf of Guinea record the response of the tropical atmospheric circulation to global paleoclimatic events during the last glacial/interglacial transition. Two depositional phases centered around 15,000 and 10,300 yr B.P. are characterized by maximum values of pollen concentration and of eolian activity index (EAI). Pollen spectra record the significant presence of *Artemisia* and *Ephedra* of Saharan origin and the scattered occurrence of *Podocarpus* from Guinean mountain forests; these demonstrate the intensity of the meridional atmospheric circulation over equatorial West Africa during dry periods. The early Holocene humid phase, ca. 8500 yr B.P., is marked by minima in pollen concentrations and EAI. Saharan taxa are absent and, in contrast, *Podocarpus* reached its highest relative values. This evidence has been interpreted as reflecting a weakening in the continent-ocean eolian transport and the importance of monsoonal fluxes. Downcore variations in *Podocarpus* percentages are used to identify the atmospheric circulation patterns over the low latitudes of West Africa during extreme (dry/humid) climatic conditions.

Lézine, A.-M., Vergnaud-Grazzini, C. 1993. Evidence of forest extension in West-Africa since 22,000 BP. A pollen record from eastern tropical Atlantic. Quaternary Science Reviews 12 (3), 203-210.
Based on a pollen study of Atlantic deep-sea core KS12 (3°52'06" N - 1°56'16" W; 544 cm length; 2,955 m water depth) a continental paleoenvironmental reconstruction is proposed for the Gulf of Guinea for the time interval 22,000 BP-6500 BP. Repeated freshwater inputs by nearby coastal rivers were responsible for pollen transport from tropical humid environments during the whole period. Strong northerly trade circulation during the time interval 22,000-10,500 BP, with a maximum intensity at ca. 17,000 BP was responsible for pollen transport from Saharan and Sahelian environments which were located more to the south at that time. Near the coast, Guinean swamp and lowland forests were always present. They were particularly well developed around 22,000 BP, and later around 8,500 BP. After 17,000 BP, the progressive replacement of (semi)-arid elements (Sahelian and Saharan) by more humid Sudanian, Sudano-Guinean and Guinean associations indicates the onset of the modem vegetation zonation in West Africa.

Li, F., Vogelmann, A.M., Ramanathan, V. 2004. Saharan dust aerosol radiative forcing measured from space. Journal of Climate 17 (13), 2558-2571.
This study uses data collected from the Clouds and the Earth's Radiant Energy System (CERES) and the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments to determine Saharan dust broadband shortwave aerosol radiative forcing over the Atlantic Ocean near the African coast (15°-25°N, 45°-15°W). The clear-sky aerosol forcing is derived directly from these data, without requiring detailed information about the aerosol properties that are not routinely observed such as chemical composition, microphysical properties, and their height variations. To determine the diurnally averaged Saharan dust radiative forcing efficiency (i.e., broadband shortwave forcing per unit optical depth at 550 nm, W m^{-2} $\tau(\alpha)^{-1}$, two extreme seasons are juxtaposed: the high-dust months [June-August (JJA)] and the low-dust months [November-January (NDJ)]. It is found that the top-of-atmosphere (TOA) diurnal mean forcing efficiency is -35 +/- 3 W m^{-2} $\tau(\alpha)^{-1}$ for JJA, and -26 +/- 3 W m^{-2} $\tau(\alpha)^{-1}$ for NDJ. These efficiencies can be fit by reducing the spectrally varying aerosol single-scattering albedo such

that its value at 550 nm is reduced from 0.95 +/- 0.04 for JJA to about 0.86 +/- 0.04 for NDJ. The lower value for the low-dust months might be influenced by biomass-burning aerosols that were transported into the study region from equatorial Africa. Although the high-dust season has a greater (absolute value of the) TOA forcing efficiency, the low-dust season may have a greater surface forcing efficiency. Extrapolations based on model calculations suggest the surface forcing efficiencies to be about -65 W m^{-2} $\tau(\alpha)^{-1}$ for the high-dust season versus -81 W m^{-2} $\tau(\alpha)^{-1}$ for the low-dust season. These observations indicate that the aerosol character within a region can be readily modified, even immediately adjacent to a powerful source region such as the Sahara. This study provides important observational constraints for models of dust radiative forcing.

Linstadter, J., Kröpelin, S. 2004. Wadi Bakht revisited: Holocene climate change and prehistoric occupation in the Gilf Kebir region of the eastern Sahara, SW Egypt. Geoarchaeology - an International Journal 19 (8), 753-778.
Geoarchaeological and chronological evidence from the remote Gilf Kebir Plateau in southwest Egypt suggests a new model for the influence of early and mid-Holocene precipitation regimes on land-use strategies of prehistoric settlers in what is now the center of the largest hyperarid area on earth. We hypothesize that the quantitatively higher,-daytime, monsoon summer rainfall characteristic of the early Holocene (9300-5400 C-14 yr B.P/8400-4300 yr B.C.) resulted in less grass growth on the plateau compared to the winter rains that presumably fell in the cool nights during the terminal phase of the Holocene pluvial (5400-4500 yr B.P/4300-3300 yr B.C.). The unparalleled climatic transition at 5400 yr B.P. (4300 yr B.C.) caused a fundamental environmental change that resulted in different patterns of human behavior, economy; and land use in the canyon-like valleys and on the plains surrounding the plateau. The model emphasizes the crucial impact of seasonal rainfall distribution on cultural landscapes in and regions and the lower significance of annual precipitation rates, with implications for future numeric climate models. It also serves as an example of how past climate changes have affected human societies.

List, F.K., Stock, P. 1969. Photogeologische Untersuchungen über Bruchtektonik und Entwässerungsnetz im Praekambrium des nördlichen Tibesti-Gebirges, Zentral-Sahara, Tschad. Geologische Rundschau 59 (1), 228-256.
Structural trends of basement rock, distribution of lengths and azimuths of fracture pattern, mature drainage system, quantitative analysis of drainage system.

Littmann, T. 1989. Spatial patterns and frequency distribution of Late Quaternary water budget tendencies in Africa, Catena, 16 (2), 163-188.
Regional water budget tendencies reported by 14C-dated field data are correlated with Late Quaternary cooling and warming phases. The aridification gradient rises exponentially from subtropical arid to humid innertropical Africa whereas the humidification gradient shows a reverse structure. Humid tropical Africa is less susceptible to climatic change than semi-arid regions and the arid zone is least affected. In those regions being susceptible to both cooling and warming trends non-climatic factors may play an important role in ecosystem fluctuations. Water budget tendency analysis does not indicate large-scale glacial and interglacial dislocations of continental atmospheric circulation patterns.

Littmann, T. 1991b. Rainfall, temperature and dust storm anomalies in the African Sahel. Geographical Journal 157 (2), 136-160.
The normal seasonal pattern is characterized by a temperature maximum in June/July, a rainfall maximum in August, and a dust storm maximum in April which is linked to a negative soil water budget towards the end of the dry season. However, the dust storm minimum is reached as late as October, i.e. after sufficient soil water infiltration and vegetation cover increase. Thus, seasonal parameter inTerrelation reflects seasonal shifts in regional atmospheric circulation. Interannual variability, however, seems to occur with periodicities around 2-4 years, 6 years, 11-12 years and 25 years, a result that applies when modelling temperature, rainfall and dust storm series.

Littmann, T., Steinbrücke, Gasse, F. 1990. African mineral aerosol deposition in West Germany 1987-1989; characteristics, origin and transport mechanisms. Geoökodynamik 11 (2-3), 163-189.
Mineral aerosol emission from semiarid and arid areas is a global phenomenon as well as long-range transport and large-scale particle deposition. Apart from source area environmental degradation, desert mineral aerosols (10-20% of the global aerosol emission) may play an important role in tropospheric warming, as they are efficient long-wave absorbers. In the period October 1987 to April 1989 an

unusually high number of 9 deposition events occurred in Bochum, West Germany. This paper shows various strings of evidence to trace back source areas and transport routes of the individual dust plumes (by means of scanning electron microscopical analysis of particle size spectra, mineral particle surface texture, microbiological analysis and flow pattern analysis).

Lioubimsteva, E., Faure, H., Faure-Denard, Page, N., Wickens, G.E. 1996. Sudan biomass changes since 18000 : a test area for tropical africa. Palaeoecology of Africa 24, 71-84

Liu, P., Meehl, G.A., Wu, G.X. 2002. Multi-model trends in the Sahara induced by increasing CO_2 Geophysical Research Letters 29 (18), art. no. 1881.
Five of eighteen climate system models participating the Coupled Model Intercomparison Project (CMIP) are chosen here for analysis based on their ability to simulate a reasonable present-day climatology of the Sahara Desert with similar rainfall distributions and meridional boundaries as in the observational data. When CO_2 concentration is increased at one percent per year for 80 years in these models the Sahara moves north, becomes hotter and dries. Compared to the 40-year control run climatology, the mean average northward shift is around 0.55^o latitude and the surface temperature is about 1.8^oC warmer at year 70 when the CO_2 doubles. The local enhanced greenhouse effect from increased CO_2 increases the net surface sensible heat flux, which in turn contributes to the warming trend.

Liu, P., Washington, W.M., Meehl, G.A., Wu, G.X., Potter, G.L. 2001. Historical and future trends of the Sahara Desert. Geophysical Research Letters 28 (14), 2683-2686.
The Parallel Climate Model (PCM) Version 1.1 simulates a reasonable twentieth century climatology in the Sahara Desert. From late 1940s to the end of 1980s, the simulated Sahara Desert, bounded by the 50 mm mean annual rainfall isoline, becomes larger and shifts eastward. The model produces a decreasing rainfall trend while the surface temperature and meridional boundaries are almost stable. In the usual scenario with increasing greenhouse gases from the 1980s to the 2090s the Sahara becomes smaller, moves north and west and continues to dry. Both the size change and latitudinal shift show a century long trend. Compared to 1961-90 climatology, the average northward shift is around 1^o and the surface temperature about 2.8^oC warmer to the end of 21(st) century. The local greenhouse effect may cause such warming trend.

Louis, P. 1964. Contribution géophysique à la paléogeographie du bassin du Logoné (République du Tchad). Comptes rendus hébdomadaires des Seances de l'Académie des Sciences 258 (25), 6199-6201.

Louis, P. 1970. Geophysical contribution to the geology of the Lake Chad basin. Mémoires d'ORSTOM 42, 303 pp.

Lowman, P.D. 1969. Geologic orbital photography; experience from the Gemini program. Photogrammetria 24, 77-106.

Luo, C., Mahowald, N., Jones, C. 2004. Temporal variability of dust mobilization and concentration in source regions. Journal of Geophysical Research-Atmospheres 109 (D20), art. no. D20202.
The time-varying properties of dust mobilization and concentration variability in source areas are studied in model simulations to understand the processes that control entrainment of dust into the atmosphere. Two different meteorological reanalysis data sets (National Centers for Environmental Prediction/National Center for Atmospheric Research and NASA Data Assimilation Office) and two different source parameterizations are used for the analysis, which is done for six different main dust source regions. The results show that similar to 35 - 70% variance of dust mobilization is associated with diurnal variability of dust mobilization in the major dust sources regions, and this is similar using different meteorological analyses and source parameterizations. Synoptic-scale variability is responsible for 6 - 50% of the dust mobilization, with more variation between different meteorology and parameterizations. The variability of dust concentrations in source regions is very sensitive to source meteorology and parameterization, with the synoptic variability responsible for 30 - 50% of the variability in some configurations or 6 - 40% in other configurations. Diurnal variability in concentrations varies from 20 - 50 to 25 - 80% depending on the model configuration. Analyses suggest that dust mobilization and dust concentration are more influenced by synoptic variability in Australia and east Asia than in North Africa and Arabian dust source regions, consistent with observations of cold fronts and cyclone movements systems driving dust mobilization and transport in Australia and east Asia source regions. Differences in variability between different meteorological data

sets and source parameterizations suggest that possible dust feedbacks onto the dust cycle may be sensitive to source parameterization and model.

Magaritz, M. 1993. Synchronized changes in regional water balance since the mid-Holocene. Climatic Change 24 (3), 179-185.
Detailed records of past climatic changes, especially those related to water balance, can be used to study regional scale climatic changes associated with both natural and anthropogenic causes. Such ancient records are available from various locations around the globe. The four records presented here have sufficient time resolution to demonstrate short-lived global oscillations in parameters related to water balance during the last 7,000 y. The data indicate that sub-Milankovitch climatic events are not restricted to times of major climatic transitions but occurred throughout the Holocene. Most of the past changes due to natural variability are at least of the same order of magnitude as those predicted by various models to occur during the next century.

Maglione, G. 1971. Un exemple de comportement de la silice en milieu confine carbonate sodique; les "natronieres" du Tchad. In: Sédimentologie et geochimie de la surface. Bulletin de la Service de la Carte géologique d'Alsace et de Lorraine 24 (4), 255-268.

Maglione, G. 1972. Evaporites et silicates sodiques de neoformation des dépressions interdunaires du Kanem (littoral nord-est du lack Tchad). In: African Geology; Quaternary Rocks and Geomorphology of Angola, Chad, Cote d'Ivoire, Nigeria and Sahara, University of Ibadan, Department of Geology, pp. 413-426.

Maglione, G. 1974. Un modèlé de sédimentation evaporitique continentale actuèlle; le lac Tchad et ses dépendances hydrologiques littorales. In: Evaporites, Numero Special. Revue de Géologie dynamique et Géographie physique 16 (2), 171-176.

Maglione, G. 1974. Géochimie et mécanismes de mise en place actuelle des évaporites dans le bassin tchadien. Bulletin de Liaison – Association Sénégalaise pour l'Etude du Quaternaire de l'Ouest Africain (42-43), 33-44.

Maglione, G. 1974. Présence de northupite dans une dépression interdunaire du Kanem (littoral septentrional du lac Tchad); ses implications géochimiques. Comptes rendus hébdomadaires des Seances de l'Académie des Sciences, Série D, Sciences Naturelles 279 (5), 377-379.

Maglione, G., Servant, M. 1973. Signification des silicates de sodium et des cherts neoformes dans les variations hydrologiques et climatiques holocenes du bassin tchadien. Comptes rendus hébdomadaires des Seances de l'Académie des Sciences, Série D, Sciences Natureles 277 (17), 1721-1724.
Na, OH, SiO, silica, leaching, brines, paleoclimatology, magadiite, Chad, Niger.

Mainguet, M. 1967. La bordure occidentale de l'Ennedi (Republique du Tchad); étude géomorphologique. Traveaux de l'Institut de Recherches sahariennes 26 (1-2), 7-65.
Geomorphic survey, Precambrian crystalline basement, Cambrian-Carboniferous sandstone cover, typical arid-zone geomorphic features, surface and subsurface hydrography, evolution of relief.

Mainguet, M. 1968. Le Borkou, aspects d'un modèlé éolien. Annales de Géographie 77 (421), 296-322.

Mainguet, M. 1969. Séquences morphogenetiques quaternaires au Borkou (Nord-Tchad). Photo-interpretation 8 (69-3), 22-44.
Aerial photographs, overlays showing relief and structural elements, sandstone ridges, dunes, eolian morphogenesis.

Mainguet, M. 1970. Un étonnant paysage; les cannelures gréseuses du Bembéché (N. du Tchad); essai d'éxplication géomorphologique. Annales de Géographie 79 (431), 58-66.

Mainguet, M. 1972. Le modèlé des grés; problèmes généraux, 2 Tomes Institut géographique national, Etudes de Photo-interpretation. 657 pp.

Mainguet, M. 1972. Étude d'un erg (Fachi Bilma, Sahara central). Son alimentation sableuse et son insertion dans le paysage d'après les photographies prises par satellites. Comptes rendus hebdomadaires des Séances de l'Académie des Sciences, Paris, Série D, 274(11):1633-1636.

Mainguet, M. 1977. Analyse quantitative de l'extrémité sahélienne du courant éolien transporteur de sable au Sahara nigérien. Comptes rendus hebdomadaires des Séances de l'Académie des Sciences, Paris, Série D, 285(10):1029-1032.

Mainguet, M. 1978. The influence of trade winds, local air masses and topographic obstacles on the aeolian movement of sand particles and the origin and distribution of ergs in the Sahara and Australia. Geoforum 9(1):17-28.

Mainguet, M. 1991. Les activités du vent au Sahara: un exemple de système éolien ouvert. Sahara, 4, 7-12.

Mainguet, M. and Callot, Y. 1974. Airphoto study of typology and interrelations between the texture and structure of dune patterns in the Fachi-Bilma erg, Sahara. Zeitschrift für Geomorphologie Supplementbände 20:62-68.

Mainguet, M. and Callot, Y. 1978. L'erg de Fachi-Bilma (Tchad-Niger). Contribution à la connaissance de la dynamique des ergs et des dunes des zones arides chaudes. Centre national de la Recherche scientifique (CNRS), Mémoires et Documents NS 18, 184 pp.

Mainguet, M., Callot, Y. and Guy, M. 1974. Tchad. Fochi. Barkhanes. Photo-interpretation. 13 (1), 10-16.

Mainguet, M., Callot, Y. and Guy, M. 1974. Système crêtes-couloirs. Photo-interpretation. 13 (1), 24-30.

Mainguet, M. and Canon, L. 1976. Vents et paléovents du Sahara. Tentative d'approche paléoclimatique. Revue de géographie physique et de géologie dynamique, Deuxième série, 18(2-3):241-250.

Mainguet, M. and Canon-Cossus, L. 1980. Sand circulation in the Sahara: geomorphological relations between the Sahara Desert and its margins. In: Sarnthein, M., Seibold, E. and Rognon, P. (eds), Sahara and surrounding Seas: sediments and climatic changes, Van Zinderen Bakker, E.M.Sr. and Coetzee, J.A. (eds), Balkema, Rotterdam, Palaeoecology of Africa and the Surrounding Islands 12:69-78.

Mainguet, M., Canon, L. and Chemin, M.C. 1980. Le Sahara; géomorphologie et paléomorphologie éoliènnes. In: The Sahara and the Nile; Quaternary environments and prehistoric occupation in northern Africa. Ed. Williams, M.A.J. and Faure, H., Balkema, Rotterdam, 17-35. UCL GEOGRAPHY QF 19 WIL

Mainguet, M. and Chemin, M.-C. 1990. Le massif du Tibesti dans le système éolien du Sahara. Réflexion sur la genèse du Lac Tchad. Berliner geographische Studien 30:261-276.

Maley, J. 1969. Synthèse bibliographique sur le quaternaire de la Libye désertique. Bulletin de Liaison – Association Sénégalaise pour l'Etude du Quaternaire de l'Ouest Africain 22, 71-85. .

Maley, J. 1970. Atlas de pollens du Tchad. Bulletin du Jardin botanaique national belgique 40, 29-48.

Maley, J. 1972. La sédimentation pollinique actuelle dans la zone du lac Tchad. Pollen et Spores, 14, 263-307.

Maly, J. 1972. La sédimentation pollinique actuèlle dans la zone du lac Tchad (Afrique centrale). Bulletin de Liaison – Association Sénégalaise pour l'Etude du Quaternaire de l'Ouest Africain 35-36, 83.

Maly, J. 1972. Etude palynologique des formations plio-quaternaire du Bassin du Tchad (programme de recherches). Palaeoecology of Africa and the surrounding Islands and Antarctica 7, 13.

Maly, J. 1973. Les variations climatiques dans le bassin du Tchad durant le dernier millenaire; nouvelles données palynologiques et paléoclimatiques. In: Le Quaternaire; geodynamique, stratigraphie et environnement. Bulletin de l'Association française pour l'Etude du Quaternaire 36, Supplement, 175-181.

Maly, J. 1973. Les variations climatiques dans le bassin du Tchad durant le dernier millenaire; essai d'intérpretation climatique de l'Holocène africain. Comptes rendus de l'Académie des Sciences, Paris, Série D, 276 (12 mars), 1673-1675.

Maly, J. 1973. Mécanisme des changements climatiques aux basses latitudes. Palaeogeography Palaeoclimatology Palaeoecology 14 (3), 193-227. 1973.
Higher levels of Lake Chad related to cooler periods, pollen and vegetation analyses; late Holocene, central Africa.

Maly, J. 1976. Les variations du lac Tchad depuis un millenaire; conséquences paléoclimatiques. Palaeoecology of Africa and the surrounding Islands and Antarctia 9; covering the years 1972-1974, 44-47.

Maley, J. 1977. Palaeoclimates of central Sahara during the early Holocene. Nature 269 (5629), 573-577.
In the Central Sahara lying approximately between 27° N and 18° N, rains were primarily due to tropical depressions in the early Holocene up to about 6500 BP. Then the monsoon rains of Sahelian type dominated up to about 4400 BP**.**

Maley, J. 1977. Analyses polliniques et paléoclimatologie des douze derniers millénaires du bassin du Tchad (Afrique céntrale). Recherches françaises sur le Quatérnaire, INQUA, Suppl. Bull. AFEQ 50, 1.

Maley, J. 1979. Four abstracts of publications of the Sahara. Palaeoecology of Africa and the surrounding islands. Eds. Van Zinderen Bakker, E.M.Sr., Coetsee, J.A. 2, covering the years 1975-1977. Balkema, Rotterdam, 79-82.
Abstracts 4 articles by the author since 1976. The first discusses the results and implications of pollen analyses in the Chad region. During the Holocene, the Sahelian zone optima are in phase with global warming periods. The general trend of the Sudano-Guinean curve follows the global warming trend, but during colling periods exhibits strong opposite trends. The second paper is an essay on the role of the tropical zone in changing climates, with Africa as an example. Towards the end of the Pleistocene, as solar input increased, a strong thermal gradient was set up between the Poles and the Equator which led to intense meridional movements of tropical air which subsequently resulted in growth of the ice sheets. The third article emphasises the point that 2 kinds of wetter period have been evident in the Sahara during the Quaternary. One of these is characterized by relatively low temperatures and tropical depressions as a source of precipitation, while the other, operating mainly since 6 500 BP, is a system of direct monsoon rains and higher temperatures. The final article is a discussion of Tertiary climates in Africa.

Maley, J. 1980. Les changements climatiques de la fin du Tertiaire en Afrique; leur conséquence sur l'apparition du Sahara et de sa végétation. In: The Sahara and the Nile; Quaternary environments and prehistoric occupation in northern Africa. Eds. Williams, M.A.J. and Faure, H., Balkema, Rotterdam, 63-86. UCL GEOGRAPHY QF 19 WIL
Until the late Eocene, the Saharan climate was equatorial, becoming tropical during Oligo-Miocene times, when Southern Africa and Zaire were dry. Saharan desiccation began in the late Miocene, increasing during the Pliocene. The Pliocene Saharan flora was pre-adapted to aridity, originating in semi-arid Asia and S. Africa early in the Tertiary

Maley, J. 1981. Etudes palynologiques dans le Bassin du Tchad et paléoclimatologie de l'Afrique Nord-tropicale de 30000 ans à l'époque actuelle. In: Palaeoecology of Africa and the surrounding islands. Eds. Coetze, J.A., van Zinderen Bakker, E.M.Sr. Palaeoecology of Africa and the surrounding Islands and Antarctica. 13, 45-52.
A summary account of a thesis presented in 1980 at the University of Montpelier. The core of the thesis is concerned with the interpretation of precipitation and paleoclimatology from the pollen record.

Maley, J. 1981. Etudes palynologiques dans le bassin du Tchad et paléoclimatologie de l'Afrique nord-tropicale de 30000 ans a l'epoque actuelle. Travaux et Documents de l'ORSTOM, 129, 604 pp.

Maley, J. 1982. Dust, clouds, rain types, and climatic variations in tropical North Africa. Quaternary Research 18(1), 1-16.
Dust and processes of raindrop formation in the clouds play a very important role in the climatic evolution of tropical north Africa. Sedimentologic, stratigraphic, pedologic, geomorphologic, and palynologic data converge to show that a major environmental change occurred in tropical Africa about 7000 yr B.P. In the Sudanian and Sudano-Guinean zones (wet tropical zones), from 15 000 to 7000 yr B.P., rivers deposited mostly clay, while from 7000 to 4000 yr B.P. they deposited mostly sand.

Maley, J. 1983. Histoire de la végétation et du climat de l'Afrique nord-tropicale au Quaternaire récent. Bothalia 14, 377-389.

Maley, J. 1989. 20.000 ans d'évolution des climats du Sahara central aux savanes tropicales humides. In: Sud Sahara - Sahel Nord, Ed. George, D., Centre Culturel français, Abidjan, 34-52.

Maley, J. 1989. L'importance de la tradition orale et des données historiques pour la reconstitution paléoclimatique du dernier millénaire sur l'Afrique nord-tropicale. In: Sud Sahara - Sahel Nord, Ed. George, D., Centre Culturel français, Abidjan, 53-57.

Maley, J. 1993. Chronologie calendaire des principales fluctuations du lac Tchad au cours du dernier millénaire. Le rôle des données historiques et de la tradition orale. In: Datation et chronologie dans le bassin du lac Tchad. Séminaire du Réseau Méga-Tchad, Sept.1989, Ed. Barreteau, D., Von Graffenried, C., Colloques et séminaires d'ORSTOM, 161-163.

Maley, J. 1997. Middle to Late Holocene changes in tropical Africa and other continents: Paleomonsoon and sea surface temperature variations. In: Third millenium BC climate change and Old World collapse. Ed. Dalfes, H.N., Kukla, G., Weiss, H., NATO ASI Series, Global Environmental Change, Springer-Verlag, Berlin, 611-640.

Maley, J. 2000. - Les variations des niveaux du lac Tchad au cours du dernier millénaire: rôle des conditions climatiques régionales et des apports fluviatiles. Comparaison avec le lac Naivasha en Afrique orientale. Bulletin Méga-Tchad, Université de Paris, Nanterre, 24-29.

Maley, J. 2000. Last Glacial Maximum lacustrine and fluviatile Formations in the Tibesti and other Saharan mountains, and large-scale climatic teleconnections linked to the activity of the Subtropical Jet Stream. Global and Planetary Change 26 (1-3), 121-136.
In the mountains of the central Sahara (lat ca. 20° to 22°N, long 16° to 19°E) and particularly in the Tibesti mountains, important lacustrine formations developed during the late Pleistocene, primarily during the Last Glacial Maximum (LGM). Two main phases, separated by a brief regression, intervened between ca. 20,000 and 15,500 BP, and between 15,000 and 12,500 BP. Pollen analyses were carried out on four samples of this formation. The high lacustrine levels were associated to both important precipitations and a reduced evaporation linked to lower temperatures. Similar lacustrine deposits were found in the Djebel Marra in the south of the Sahara. In the mountains of the central and eastern Sahara, during the same period and until the middle Holocene, the "Middle Terrace" Formation was deposited in the river valleys of the Tibesti, Hoggar, Air and the Red Sea Hills. Since the southern headwaters of the Nile were dry from ca. 20,000 to 12,500 BP, the fluviatile sediments deposited in the Nile valley in Nubia may have resulted almost entirely from the numerous wadis flowing from the Red Sea Hills.
The rainfalls which fed these lacustrine and fluviatile formations were related to the Tropical Depressions which are formed in the southern part of the westerlies and are linked to the activity of the Subtropical Jet Stream (STJ), whose path remained over the central Sahara from 20,000 BP to the early Holocene. In the Rocky Mountains of the western US, the palaeolakes Lahontan and Bonneville were very large during the LGM and the main fluctuations exhibit similar chronology to that of the Saharan mountains. Broecker [Broecker, W.S., 1994. Massive iceberg discharges as triggers for global climate change. Nature 372, 421-424] estimates that these two large U.S. wet events between ca. 20,000-15,500 BP and ca. 15,000-12,500 BP may have been an indirect result of two large ice surges in the North Atlantic, related to Heinrich layers 1 and 2. We can assume, however, that the similar climatic variation of the Rocky Mountains and the central and eastern Saharan mountains was also a result of

the activity of the STJ all along its path, which marks the boundary between the polar and tropical circulations. STJ activity can apparently produce long-distance climatic teleconnections. During the LGM similar teleconnections also existed in the Southern Hemisphere between South Africa and Australia. The Tropical Depressions result from the interaction of polar troughs and the influx of humid equatorial air forming transversal cloud bands. The large increase in the intensity of atmospheric circulation during the LGM was responsible for a large increase in Tropical Depressions in both hemispheres.

Maley, J. 2004. Le bassin du Tchad au Quaternaire récent: formations sédimentaires, paléoenvironnements et préhistoire. La question des Paléotchads. In: L'évolution de la végétation depuis deux millions d'années. Ed. Renault-Miskovsky, J., Semah, A.M. Artcom - Errance, Paris, 179-217.

Maly, J., Cohen, J., Faure, H., Rognon, P., Vincent, P.M. 1970. Quelques formations lacustres et fluviatiles associées à differentes phases du volcanisme au Tibesti (nord du Tchad). Cahiers d'ORSTOM, Série Géologie 2 (1), 127-152. 1970.

Maley, J., Roset, J.P., Servant, M. 1971. Nouveaux gisements prehistoriques au Niger oriental; localisation stratigraphique. Bulletin de Liaison – Association Sénégalaise pour l'Etude du Quaternaire de l'Ouest Africain 31-32, 9-18.

Mansour, N. 1990. Geochemisch-sedimentologische und tektonische Untersuchungen am Uweinat-Safsaf-Aswan-Schwellensystem (Südägypten/Nordsudan). Freie Universität, Berlin, 115 pp.

Marticorena, B. and Bergametti, G. 1996. Two-year simulations of seasonal and interannual changes of Saharan dust emission. Geophysical Research Letters 23(15):1921-1924.
Using a soil-derived dust emission scheme, the annual and monthly dust emissions in the western "dry" Sahara have been estimated for 1991 and 1992, respectively to 665 Mt and 586 Mt. Based on these simulations, an investigation of the, seasonal and annual changes in dust emissions has been performed, The monthly dust emissions vary from 163 Mt in March 1991 to 8 Mt in December 1992. These seasonal variations are related to changes in the location and area of the source-regions and in the frequency of dust events, On the opposite, the interannual variations of the dust emissions are due to changes in the occurrence of the most intense dust events.

Marticorena, B., Bergametti, G., Aumont, B., Callot, Y., N'Doumé, C.T. and Legrand, M. 1997. Modeling the atmospheric dust cycle, 2. Simulation of Saharan dust sources. Journal of Geophysical Research 102(D4):4387-4404.
A soil-derived dust emission scheme has been designed in order to provide simulation of mineral dust sources for atmospheric transport models [Marticorena and Bergametti, 1995]. This physical scheme considers the influence of surface features to compute the erosion threshold and the intensity of the dust emissions. It has been validated by comparison with relevant experimental data. However, it was necessary to extend its applicability and to test its capability to reproduce dust emissions over large arid areas. Specific methods have been developed to determine the parameters required by the dust production model for large-scale applications. The surface features (dimensions of the roughness elements and soil mineralogy) and the wind velocity allow the computation of the roughness lengths of the surface, the size distribution of the erodible soils, and the wind friction velocity. A map of these surface characteristics has been established for the western part of the Sahara. This map coupled to the Europan Center for Medium-Range Weather Forecast (ECMWF) surface wind fields are used to simulate dust emissions in this desert region. The simulated emissions have been compared to the Infrared Difference Dust Index (IDDI), determined by means of the Meteosat thermal infrared imagery. The simulated dust event frequencies are in good agreement with those observed by satellite. The comparison between the simulated fluxes and the satellite observations for 3 months of the year 1991 has revealed a linear relationship between the logarithm of the simulated flux and the IDDI. The annual and monthly dust emissions for 1991 and 1992 have been estimated and compared to those established by d'Almeida [1986]. Both the frequencies and the intensities of the emissions are well reproduced by the model associated with the surface features map.

Marticorena, B., Chazette, P., Bergametti, G., Dulac, F., Legrand, M. 2004. Mapping the aerodynamic roughness length of desert surfaces from the POLDER/ADEOS bi-directional reflectance product. International Journal of Remote Sensing 25 (3), 603-626.

Surface roughness is a key parameter for computing the emissions and for simulating the atmospheric cycle of mineral dust. However its assessment on the basis of field measurements from source areas scattered round the globe requires much effort. Here we investigate the retrieval of the aerodynamic roughness length of arid areas using surface bi-directional reflectance products derived from passive multi-directional measurements in the solar spectrum of the POlarization and Directionality of the Earth's Reflectances (POLDER) sensor. The so-called protrusion coefficient (PC) of the surface derived from the POLDER bidirectional reflectance distribution function (BRDF) is well suited to estimate surface roughness. From an appropriate selection of POLDER data, a composite PC dataset has been established over the Sahara and the Arabian Peninsula. We have investigated the relationship between aerodynamic roughness length and PC, and have derived a statistically significant empirical relationship between these two parameters. This relationship is applied to the POLDER-derived PC to map the aerodynamic roughness length of arid areas in northern Africa and the Arabian Peninsula at the spatial resolution of POLDER (gammasimilar to$1/16^{o}$). When degrading these data for global models, we show that the information is essentially preserved at coarser resolutions up to $1/4^{o}$. This map of roughness length derived from the POLDER instrument, and a corresponding map derived from a geomorphologic classification, have been tested by comparing the predicted dust event frequencies obtained using them to dust indices (IDDI) derived from Meteosat IR observations over the Sahara desert. The agreement using the POLDER derived roughness length is at least as good as using the map of roughness length derived from the geomorphologic approach. Our results show promising new prospects for regional and global scale simulations of mineral dust emissions from arid regions.

Martin, G.H. 1995. Chad, In: Regional petroleum geology of the world; Part II, Africa, America, Australia and Antarctica. Ed, Kulke, H., Beitrage zur regionalen Geologie 22 (2), 113-116.

Martin, R.V., Jacob, D.J., Logan, J.A., Bey, I., Yantosca, R.M., Staudt, A.C., Li, Q.B., Fiore, A.M., Duncan, B.M., Liu, H.Y., Ginoux, P., Thouret, V. 2002. Interpretation of TOMS observations of tropical tropospheric ozone with a global model and in situ observations. Journal of Geophysical Research-Atmospheres 107 (D18), art. no. 4351.
We interpret the distribution of tropical tropospheric ozone columns (TTOCs) from the Total Ozone Mapping Spectrometer (TOMS) by using a global three-dimensional model of tropospheric chemistry (GEOS-CHEM) and additional information from in situ observations. The GEOS-CHEM TTOCs capture 44% of the variance of monthly mean TOMS TTOCs from the convective cloud differential method (CCD) with no global bias. Major discrepancies are found over northern Africa and south Asia where the TOMS TTOCs do not capture the seasonal enhancements from biomass burning found in the model and in aircraft observations. A characteristic feature of these northern tropical enhancements, in contrast to southern tropical enhancements, is that they are driven by the lower troposphere where the sensitivity of TOMS is poor due to Rayleigh scattering. We develop an efficiency correction to the TOMS retrieval algorithm that accounts for the variability of ozone in the lower troposphere. This efficiency correction increases TTOCs over biomass burning regions by 3-5 Dobson units (DU) and decreases them by 2-5 DU over oceanic regions, improving the agreement between CCD TTOCs and in situ observations. Applying the correction to CCD TTOCs reduces by similar to5 DU the magnitude of the "tropical Atlantic paradox" [Thompson et al., 2000], i.e. the presence of a TTOC enhancement over the southern tropical Atlantic during the northern African biomass burning season in December-February. We reproduce the remainder of the paradox in the model and explain it by the combination of upper tropospheric ozone production from lightning NO_x, persistent subsidence over the southern tropical Atlantic as part of the Walker circulation, and cross-equatorial transport of upper tropospheric ozone from northern midlatitudes in the African "westerly duct. " These processes in the model can also account for the observed 13-17 DU persistent wave-1 pattern in TTOCs with a maximum over the tropical Atlantic and a minimum over the tropical Pacific during all seasons. The photochemical effects of mineral dust have only a minor role on the modeled distribution of TTOCs, including over northern Africa, due to multiple competing effects. The photochemical effects of mineral dust globally decrease annual mean OH concentrations by 9%. A global lightning NOx source of 6 Tg N yr^{-1} in the model produces a simulation that is most consistent with TOMS and in situ observations.

Masmoudi, M., Chaabane, M., Tanré, D., Gouloup, P., Blarel, L., Elleuch, F. 2003. Spatial and temporal variability of aerosol: size distribution and optical properties. Atmospheric Research 66 (1-2), 1-19.
Spectral optical thickness measurements together with sky radiance measurements at Ouagad gou (Burkina-Faso), Banizoumbou (Niger), Thala (Tunisia), IMC Oristano (Sardinia) and Rome Vergata (Italy) during April, May and June 2001 have been used to derive aerosol characteristics spatial and

temporal variations of aerosol optical thickness tau(a), aerosol size distribution and sin! scattering albedo. The analysed tau(a) data at the different sites show a high spatial variability of aerosol optical thickness. The tau(a) values at 870 nm obtained during the study period show that 97% the data vary between 0.1 and 1.5 for central African sites (Ouagadougou and Banizoumbou) between 0.03 and 1 for Mediterranean sites (IMC Oristano, Rome Tor Vergata and Thala).
The Angstrom wavelength exponent a was found to vary with the magnitude of the aerosol optical thickness. The higher and lower values of a correspond to the lower and higher values of respectively. In European sites, alpha varies between 0.2 and greater than 2.0. In Thala, it ranges from to 1.8 and for central Aftican stations, a exhibited variability from (-0.1) to approximately 0.
The size distribution inversion obtained by combining the spectral optical thickness from di sun measurement and aureole data presents three radius modes in both Mediterranean sites central African sites: the first mode with radius near 0. 1 μm and two second modes with radius at 4 gm. The effective and volume weighted radii are computed for the five studied sites and company. The single-scattering albedo omega(o), obtained from solar aureole data at African sites, shows an increase of omega(o), with wavelength for different aerosol optical thickness values.

Mathieu P. 1983. Le Post-Paléozoïque au Tchad. Pergamon, Oxford, 143-146

Mauz, B. and Felix-Henningsen. P. 2005. Palaeosols in Saharan and Sahelian dunes of Chad: Archives of Holocene North African climate changes. Holocene 15(3): 453-458.
Limnic sediments and palaeosols are frequently present in dunes of the Sahara and Sahel deserts of Chad. This study focused on genesis and degree of development of the palaeosols and the timing of soil formation. The soils are Cambic Arenosols formed by precipitation-induced silicate weathering and leaching. The upper parts of the Cambic Arenosols are indurated due to accumulation of salt and amorphous silica during a drier climate following soil formation. The optical age data reveal the occurrence of one or two distinct short-lived humid climate intervals shortly after &SIM; 5 ka and before &SIM; 2.5 ka and the formation of local desert lakes shortly after &SIM; 5 ka. The study further suggests that rapid climate changes occurred mainly in the mid-Holocene whereas the early-Holocene humid period lasted longer.

Maxwell, T.A., Haynes, C.V. 2001. Sand sheet dynamics and Quaternary landscape evolution of the Selima Sand Sheet, southern Egypt. Quaternary Science Reviews 20 (15), 1623-1647.
The Selima Sand Sheet occupies more than 120,000 km^2 of the hyperarid, uninhabited Darb el-Arba'in Desert centered at the border of Egypt and Sudan at latitude 22^{o}N, and is characterized by a featureless surface of lag granules and fine sand broken only by widely separated dune fields and giant ripples of varying height and wavelength. Monitoring of the largest of these Chevron-shaped ripples using repeat orbital images and field surveys indicates migration rates of 500-1000 m/yr, accompanied by 0-2.0 cm erosion or deposition of the youngest sand sheet stratigraphic units. Beneath this active surface, several developmental stages of sand sheet sediments have undulatory upper contacts and varying degrees of pedogenic alteration. The younger stages retain their horizontal lamination and have cracking patterns indicative of past wetter conditions, while older stages have lost their laminar structure through pedogenesis. Historical remains in the desert as well as C^{14} and Uranium-series dating indicate that the younger strata of the sand sheet have a very low accumulation rate, despite the active movement of the surface. The lower strata were extensively modified during mid and late Pleistocene pluvials, resulting in an initial undulatory surface that set the stage for later accumulation of sand sheet. Below these Quaternary sediments lies irregular topography dissected by channels of mid-Tertiary drainage. The Selima Sand Sheet is neither the result of net aggradation nor degradation, but results from inheritance of an initial fluvial landscape increasingly modified during climatic cycles. Wet periods led to local drainage and deposition, while the increasingly severe and periods of the late Pleistocene and Holocene resulted in deposition of the blanketing bimodal sediments of the sand sheet

Mbourou, N.G. 1988. Étude statistique des brumes sèches au-dessus du Sahara à partir des réductions de visibilité au sol. DEA, Université de Abidjan.

Mbourou, N.G., Bertrand, J., Legrand, M., Baudet, J. 1994. Temporal and spatial variations of the atmospheric dust loading throughout West-Africa over the last 30 years. Annales Geophysicae-Atmospheres - Hydrospheres and Space Sciences 12 (2-3), 265-273.
The dust haze conditions, typical of the African atmosphere south of the Sahara, are a result of wind-generated dust from arid lands. The magnitude of the dust haze is evaluated for the 30-year period beginning in 1957 by calculating the number of occurrences where the observed visibility was reduced

below threshold values of 10 km and 5 km. The frequency of low visibility was several times greater for the 1977-1986 period than for the 1957-1966 period. Large decreases in visibility are observed after the severe droughts of 1972-1973 and 1982-1984. Contrasting regional differences of the dustiness evolution are noticed. These differences are closely related to the differences in the regional rainfall evolution. The increase in dustiness is believed to arise from dust produced in new desertic areas which result from rainfall shortages along the southern border of the Sahara.

Mbourou, G.N., Bertrand, J.J., Nicholson, S.E. 1997. The diurnal and seasonal cycles of wind-borne dust over Africa north of the equator. Journal of Applied Meteorology 36 (7), 868-882.
This article presents a study of the diurnal and seasonal cycles of dust over North Africa, using surface visibility as an indicator of dust. The diurnal cycle shows a reduction of visibility during the daytime hours in the areas where dust is generated, a consequence of the elimination of the nocturnal inversion. The annual cycle reveals that, at latitudes from 5^{o} to 16^{o} N, there is a latitudinal increase in the duration of the presence of aerosols over the course of the year. The presence of aerosols dimishes in the latitudes from 20^{o} to 35^{o} N, indicating that the aerosol content of the Saharan air is lower than that over the semiarid sub-Saharan zones, such as the Sahel. A comparison of three periods, 1957-61, 1970-74, and 1983-87, shows a continually increasing presence of dust, particularly in the western Sahel. The interannual variability of the dust and its annual cycles in these three periods throughout North Africa bear a strong relationship to rainfall fluctuations in the Sahel. Overall, the results indicate that over the last few decades the Sahel region has replaced the central Sahara as the source of atmospheric aerosols over most of North Africa.

McCall, D.F. 1997. Rock art in Chad: “Borku, Ennedi, Tibesti” by Negro G., Ravenna, A., Simonis, R. International Journal of African Historical Studies 30 (3), 660-663.

McCauley, J.F., Breed, C.C., Schaber, G.G., McHugh, W.P., Issawi, B., Haynes, C.V., Grolier, M.J., El-Kilani, A. 1986. Paleodrainages of the eastern Sahara; the radar rivers revisited (SIR-A/ B implications for a mid-Tertiary trans-African drainage system). IEEE Transactions on Geoscience and Remote Sensing GE-24 (4), 624-648.

McCauley, J.F., Schaber, G.G., Breed, C.C., Grolier, M.J., Haynes, C.V., Issawi, B., Elachi, C., Blom, R. 1982. Subsurface valleys and geoarcheology of the Eastern Sahara revealed by Shuttle radar. Science 218 (4576), 1004-1020.
The shuttle imaging radar (SIR-A) carried on the space shuttle Columbia in Nov. 1981 penetrated the extremely dry Selima Sand Sheet, dunes, and drift sand of the E Sahara, revealing previously unknown buried valleys, geologic structures, and possible Stone Age occupation sites. Radar responses from bedrock and gravel surfaces beneath windblown sand several centimeters to possibly meters thick delineate sand- and alluvium-filled valleys, some nearly as wide as the Nile Valley and perhaps as old as middle Tertiary

McHone, J.F., Blumberg, D.G., Greeley, R. 1995. Africa climate changes; constraints revealed by impact craters on Shuttle Radar. 1995 fall meeting. Eos, Transactions of the American Geophysical Union 76 (46), Suppl., 337.

McHone, J.F., Greeley, R., Blumberg, D. 1996. TI: SIR-C/ X-SAR radar studies; impact and aeolian features, Borkou region northern Chad. Abstracts of papers submitted to the Lunar and Planetary Science Conference 27 (2), 849-850.

McHugh, W.P., Breed, C.S., Schaber, G.G., McCauley, J.F., Szabo, B.J. 1988. Acheulean sites along the Radar Rivers, southern Egyptian Sahara. Journal of Field Archaeology 15 (4), 361-379.

McHugh, W.P., McCauley, J.F., Haynes, C.V., Breed, C.S. and Schaber, G.G. 1988. Radar, palaeorivers and geoarchaeology in the southern Egyptian Sahara, Geoarchaeology, 3 (1), 1-40.

McHugh, W.P., Schaber, G.G., Breed, C.S. and McCauley, J.F. 1989. Neolithic adaptation and the Holocene functioning of Tertiary palaeodrainages in southern Egypt and northern Sudan, Antiquity, 63 (239), 320-336.

McKenzie, J.A. 1993. Pluvial conditions in the eastern Sahara following the penultimate deglaciation - implications for changes in atmospheric circulation patterns with global warming. Palaeogeography Palaeoclimatology Palaeoecology 103 (1-2), 95-105.
During the transition from the penultimate glacial to the last interglacial period (Isotope Stages 6-5e or Terminal II), large freshwater lakes abruptly infilled sandy depressions in arid regions of the eastern Sahara. Geochemical and mineralogical studies of samples from lacustrine sequences in the Western Desert of southern Egypt indicate: (1) The sediments are chalk composed of authigenic chemical precipitates, predominantly low-Mg calcite, with carbonate contents averaging about 80%. The low dilution of the chemical precipitate by detrital input implies that physical erosion and transport of detrital grains were minimized by extensive vegetation cover in the catchment area. The fauna and flora associated with the lake deposits and Middle Paleolithic occupation sites on the paleo-shorelines attest to a more amenable environment. (2) Vastly different rainfall or atmospheric circulation patterns than at present must have existed based on consistently negative δO^{18}PDB values for the chalk, as low as -9.5 parts per thousand, which would require precipitation from lake waters significantly more depleted in O^{18} than the modern local spring water (δO^{18}SMOW= -1.8 parts per thousand). (3) The lakes were stable perennial water bodies with relatively long residence times sufficient to produce isotopic covariant signals in the chalks. Apparently, the lakes disappeared as abruptly as they appeared without going through a terminal phase of evaporative enrichment. Extremely arid conditions again prevailed. During the transition from the last glacial to the present interglacial (Terminal 1), a similar change from arid to pluvial conditions occurred. Thus, it is proposed that, during transitions from glacial to interglacial climates, rapid global warming can lead to a temporary alteration of atmospheric circulation with an intensification of the southwest monsoons, bringing large quantities of isotopically light moisture to the Eastern Sahara.

McTainsh, G.H. 1980. Harmattan dust deposition in northern Nigeria, Nature, **286** (5773), 587-588.
Here Harmattan dust deposition measurements at Kano, during the 1978-79 season are reported. A relation between dust deposition, visibility, solar radiation and wind speed is defined, which deteriorates during the latter half of the Harmattan season. A probable explanation of this deterioration is the local remobilization of existing dust.

McTainsh, G. 1985. Dust processes in Australia and West-Africa – a comparison. Search 16 (3-4), 104-106.

McTainsh, G.H. 1985. Desertification and dust monitoring in West Africa. Desertification control Bulletin (Nairobi) 12:26-33.

McTainsh, G. 1986. A dust monitoring programme for desertification control in West Africa. Environmental Conservation 13 (1), 17-25.
Reviews research on Harmattan dust in West Africa and over the Atlantic Ocean, to define the present state of our knowledge. A conceptual model of the Harmattan aeolian system is then described, to provide a framework and an information-base for dust monitoring. Finally, a dust monitoring programme is proposed, with due discussion of appropriate dust collection and measurement techniques.

McTainsh, G. 1987. Desert loess in northern Nigeria. Zeitschrift für Geomorphologie 31 (2), 145-165.
The apparent scarcity of desert loess deposits, compared with glacial loess, may be due to the use of inappropriate 'glacial loess' methodologies in the study of arid and semi-arid environments

McTainsh, G.H., Nickling, W.G., Lynch, A.W. 1997. Dust deposition and particle size in Mali, West Africa. Catena 29 (3-4), 307-322.
Dust deposition samples were collected during April and May (1990) at four sites on the inland delta region of Mali in West Africa. High dust deposition rates were measured and characterised by considerable variations between sites. A major dust plume passed over the area, following a dust storm near Gao, 500 km to the east, however the contribution of this plume to overall deposition was surprisingly small.
Dust particle-size characteristics indicate mixing of dusts from three sources. Long-distance dust deposition producing fine deposits (mainly < 5 mu m); dust from regional sources producing deposits mainly in the size range 20-40 mu m; and local dust arising from human activities, particularly vehicle and livestock movements, producing relatively coarse material in the size range 50-70 mu m, plus some

fines. Local dusts appear to have made the greatest contribution to deposition, with a moderate (though less than expected) contribution from the plume and a minor contribution from long-distance dusts. These results have implications for dust deposition studies aimed at quantifying dust contributions to soils. Although these Mali dust deposition rates are high (2.5-28.6 t^{-1} km^{-2} day^{-1}), the significant proportion of locally derived dust means that new dust inputs to the soils of the Inland Delta region of Mali are small.

McTainsh, G., Walker, P.H. 1982. Nature and distribution of Harmattan dust. Zeitschrift-fur-Geomorphologie 26(4), 417-435.
Harmattan dust deposition rates measured at Kano, northern Nigeria, during 1976-1979 range from 137 to 181 t^2y^{-1}. The median particle size of the aeolian dust decreases dramatically downwind from the source area, from 3.47 phi (74.3 micrometre) to 6.82 phi (8.9 micrometre) and a similar trend emerges transverse to the dominant wind direction. The characteristics and geomorphic history of the Chad Basin source deposits are inferred from the broad particle-size range, and the mineralogical and geochemical characteristics of the deposited dust.

Middleton, N.J., Goudie, A.S. 2001. Saharan dust: sources and trajectories. Transactions of the Institute of British Geographers 26 (2), 165-181.
The Sahara is the world's largest source of aeolian desert dust, but precise information on specific sources of this material is poor and sometimes contradictory. This paper uses daily data from the Total Ozone Mapping Spectrometer (TOMS) for 1999 to identify source areas for major dust events and their trajectories of long-range transport. Two major source areas are identified: the Bodélé depression and an area covering eastern Mauritania, western Mali and southern Algeria. Both of these major dust sources are primarily driven by natural factors since they are little affected by anthropogenic activities.

Miller, G.H., Wendorf, F., Ernst, R., Schild, R., Close, A.E., Friedman, I., Schwarcz, H.P. 1991. Dating lacustrine episodes in the eastern Sahara by the epimerization of isoleucine in ostrich eggshells. Palaeogeography Palaeoclimatology Palaeoecology 84 (1-4), 175-189.
The eggshell of the African ostrich, *Struthio camelus*, closely approximates a closed system for the retention of indigenous proteinaceous residues. Epimerization of the protein amino acid isoleucine follows linear first-order kinetics in laboratory simulations nearly to racemic equilibrium, and the variation in D/L ratio within a single fragment, or between fragments of the same age, is significantly less than in other carbonate systems. These observations suggest that the extent of isoleucine epimerization (aIle/Ile ratio) in ostrich eggshell offers the potential for high-resolution geochronology of Quaternary deposits. From the simulation experiments, and dated early Holocene samples for which we have in situ mean annual sediment temperature measurements, Arrhenius parameters have been calculated; the activation energy is 30.33 kcal mol^{-1}, similar to that of other carbonate systems.
We have measured the aIle/Ile ratio in ostrich eggshell associate with lacustrine episodes at Bir Tarfawi and Bir Sahara East, two depressions in what is currently the hyperarid eastern Sahara. The ratios can be used directly to indicate qualitatively the time represented by each series of lake sediment, and to correlate disjunct lacustrine deposits within and between the basins. Uranium-series disequilibrium dating of algal mats contained within some of the lake beds indicate that a major wet interval occurred about 130 ka ago. Using the U-series date for calibration, the amino acids ratios are used to date the most recent lacustrine interval to about 100 ka B.P., and two older intervals, one about 200 +/- 25 ka B.P., and an older interval that occurred prior to 250 ka ago.

Mirti, T.H., Wallender, W.W., Chancellor, W.J., Grismer, M.E. 1999. Performance characteristics of the shaduf: A manual water-lifting device. Applied Engineering in Agriculture 15 (3), 225-231.
The shaduf is a traditional device to assist human beings in lifting water 1 to 6 m (3-20ft), by minimizing mid distributing (over time and among various muscle systems) the forces that need be applied by the operator. This study reports on both static and videotaped dynamic field measurements with twenty-six typical shadufs in Chad. System outputs, with lifts ranging from 1.8 to 6.2 m (5.9-20.3ft), were 0.65 to 2.18 L/s (10.3-34.6 U.S. gallons/min) resulting in water-lifting power levels of 26.7 to 60.1 W (0.036-0.081 hp). Efficiencies found were on the order of 60%. Efficiency differences between, operators were found, and points of operator technique associated with improved efficiencies were identified.

Mizota, C., Faure, K., Yamamoto, M. 1996. Provenance of quartz in sedimentary mantles and laterites overlying bedrock in West Africa; evidence from oxygen isotopes. Geoderma 72 (1-2), 65-74.

Silty-to-sandy mantle and laterite sediments overlying bedrock in West Africa (Cameroon to Mali) were studied to establish their origin. Oxygen isotope values of fine quartz (1 to 10 mu m in diameter) separated from the samples have a relatively narrow range (+15 to +17 per mil, vs. SMOW) and are indistinguishable from quartz separated from two Harmattan wind dust samples collected in Nigeria (+15.4 per mil). However, the oxygen isotope values are distinctly different from those of quartz in samples of basement Precambrian granites (+10.5 to +12.8 per mil), gneiss (+13.3 per mil), and a Cretaceous shale (+23.2 per mil) from the same area. The $\delta^{18}O$ values of quartz from the studied soils and sediments systematically decrease with increasing particle-size. Small oxygen isotopic variations were observed for quartz up to 105 mu m in size, whereas greater stable isotope variations are present in quartz fractions larger than 105 mu m. Oxygen isotope and particle-size frequency evidence indicate that the fine sand silt-size quartz fraction (<105 mu m) in the mantle and laterite sediments had a distal eolian origin and that the coarser grained quartz (>105 mu m) had a local origin. We conclude that the eolian fine quartz was transported by the Harmattan winds which blow from the Chad Basin to the Atlantic Ocean

Møberg, J.P., Esu, I.E., Malgwi, W.B. 1991. Characteristics and constituent composition of Harmattan dust falling in Northern Nigeria. Geoderma 48 (1-2), 73-81.
During the 1984-1985 Harmattan season, dustfall was collected at six locations in the Zaria-Kano area of Northern Nigeria. From the beginning of November 1984 to late March 1985 the average dustfall at six locations was 580 kg/ha. The total dustfall during that season may have been of the order of 700-1000 kg/ha. Clay (less than 2-mu-m) constituted 25% and silt (2-50-mu-m) 57% of the dust; the rest was very fine sand. The dust had higher pH and cation exchange capacity, and contained more extractable phosphorus, organic matter and exchangeable Ca, Mg, K and Na, but had less extractable Al and exchangeable acidity than the samples from eight soil profiles with which it was compared. The dust also had a higher content of 2:1 layer silicate clay minerals and lower amounts of 1:1 layer silicate clay minerals and Fe-oxyhydroxides than the soil samples. This difference in chemical and physical properties and in constituent composition of the Harmattan dust may be expected to have an impact on the characteristics and development of the soils upon which it is falling.

Mohler, R.R.Jr, Wilkinson, M.J., Giardino, J.R. 1995. Lake Chad, the Quaternary remnant continues its decline. In: Association of American Geographers 91st annual meeting Abstracts 215.

Mohler, R.R.Jr, Wilkinson, M.J., Giardino, J.R. 1995. The extreme reduction of Lake Chad surface area; input to paleoclimatic reconstruction In: Association of American Geographers 91st annual meeting Abstracts 27 (6), 265.

Monod, Th. 1967. Orientation bibliographique sur le Sud-Est du Désert libyque (triangle Uweinat Erdis-Merga), Etudes et Documents Tchadiens (Institu national Tchadien de Sciences humaines), **A 3**, 50 pp.

Monod, Th. 1967c. Rapport sur une mission executée dans le nord-est du Tchad en décembre 1966 et janvier 1967. Etudes et Documents Tchadiens **A 10**, 65 pp.

Monod, T. and Diemer, E. 2000. Zerzura: l'oasis légendaire du désert Libyque. Editions Vents de Sable, Paris, 199 pp.

Moreau, J., Stordeur, D. 1970. Bibliographie du Tchad: (sciences humaines). Études et documents tchadiens Sér. A ; 5, 355 pp. [soas Ref WDD016 /299503

Moreau, R.E. 1963. Vicissitudes of the African biomes in the late Pleistocene. Journal of Zoology 141 (2), 395-421.

Morel, A. 1992. Disappearance of hot and humid climates in the Niger Valley, Azawagh Basin and Air Mountains at the Pliocene-Quaternary Boundary. Zeitschrift für Geomorphologie 36 (2), 191-205.
From morphological and sedimentological observations, in the Niger valley, in the Azawagh basin and in the Air mountains, it is possible to distinguish a succession of different paleoclimatic phases, from Tertiary wet tropical to arid Quaternary climates. They correspond with those already known in other parts of West Africa, from Senegal to Chad. According to the K-Ar datations of basaltic lavas from the Air which cover the paleoformes, we have discovered precise landmarks which pinpoint these different phases: the surface in which the valleys are cut is Pliocene (before 3,8 My B.P.). Erosion was very

quick at first, then slower, but always in response to seasonal climates. Wetter and more arid phases have alternated, causing either erosion or pedogenesis. The first arid phase appeared before the end of the Pliocene, but hydrolysing climates still occured at the beginning of lower Pleistocene. The basaltic lavas flows dated at 2 My show slight weathering; those, however, dated at 1 My have remained unchanged. The phenomena of catastrophic erosion, caused by torrential flows, persisted until around 1 MY B.P. Thus, on the whole, the climate has become progressively drier. But this progression is continually marked by irregularities of both wet and dry periods.

Moulin, C., Chiapello, I. 2004. Evidence of the control of summer atmospheric transport of African dust over the Atlantic by Sahel sources from TOMS satellites (1979-2000). Geophysical Research Letters 31 (2), art. no. L02107.
We used 18 years (1979 - 1992 and 1997 - 2000) of aerosol observations from TOMS satellites to monitor the inter-annual variability of summertime atmospheric dust optical thickness over both Atlantic and Africa. A comparison of TOMS dust optical thicknesses with ground-based Sun-photometer measurements shows that our long-term data set is consistent in time and space and is thus suitable for studying the interannual and decadal variability of African dust transport. Our results show that dust emissions in Northwestern Sahel are so variable from one year to the other that they control most of the variability of summer dust transport to the tropical Atlantic. Our satellite data also demonstrate that there is a large scale correlation between Atlantic dust export and Sahel drought during the previous year, which suggests that dust emissions in this semi-arid region are likely controlled by the position of the vegetated southern boundary of the Sahara.

Moulin, C., Gordon, H.R., Banzon, V.F. and Evans, R.H. 2001. Assessment of Saharan dust absorption in the visible from SeaWiFS imagery. Journal of Geophysical Research 106(D16):18239-18250.
We have examined forty SeaWiFS images acquired during 1997 and 1998 off the west coast of Africa to develop theoretical models of Saharan dust radiative properties that could be used for atmospheric correction in this region, i.e., to predict the dust contribution to the measured reflectance in the visible from that measured in the near infrared (NIR). In contrast to nonabsorptive or weakly absorbing aerosols, the dust reflectance significantly decreases from the NIR to the blue because of the absorption of mineral particles in the visible. We chose simple but realistic vertical structures for the dust layer and examined the applicability of a set of aerosol size distributions and refractive indices with radiative properties computed from Mie theory. We found that 18 models (six aerosol size-refractive index distributions times three aerosol vertical distributions) were general enough to estimate the dust reflectance in the visible with an absolute RMS error of the order of 5%. We show that these dust models can be used within a "spectral matching algorithm" [Gordon et al, 1997] to effect atmospheric correction of ocean color imagery in dust-contaminated regions. We also found that our models all produce very similar top-of-atmosphere outgoing visible flux but that this flux may be significantly different from that predicted by other conventional dust models.

Müller, W. 1984. Remarques sur les conditions météorologiques pour la mobilisation et le transport des particules au sol en milieu aride (Sahara). Travaux de l'Institut de Géographie de Reims 59-60:85-104.

Myhre, G., Grini, A., Haywood, J.M., Stordal, F., Chatenet, B., Tanré, D., Sundet, J.K., Isaksen, I.S.A. 2003. Modeling the radiative impact of mineral dust during the Saharan Dust Experiment (SHADE) campaign. Journal of Geophysical Research-Atmospheres 108 (D18), art. no. 8579.
The Oslo chemical transport model (Oslo CTM2) is driven by meteorological data to model mineral dust during the Saharan Dust Experiment (SHADE) campaign in September 2000. Model calculations of the optical properties and radiative transfer codes are used to assess the direct radiative impact in the solar and terrestrial regions of the spectrum. The model calculations are compared to a wide range of measurements (satellite, ground-based, and aircraft) during the campaign. The model reproduces the main features during the SHADE campaign, including a large mineral dust storm. The optical properties and the vertical profiles are in reasonable agreement with the measurements. There is a very good agreement between the modeled radiative impact and observations. The strongest local solar radiative impact we model is around - 115 W m^{-2}. On a global scale the radiative effect of mineral dust from Sahara exerts a significant negative net radiative effect.

Nachtigal, G. 1974. Sahara und Sudan. V. Fezzan and Tibesti, Translated by Fisher, A.G.B. and Fisher, H.J., Hurst, London, 460 pp. (first published 1879-1889)

N'Doumé, C.T. 1993. Traitement de l'imagerie METEOSAT IR pour l'observation des aerosols desertiques au desus de L'Afrique (Analysis of METEOSAT IR imagery for the observation of desert aerosols over Africa). Thèse de Doctorat, Université des Sciences et Technologies de Lille, France, 137 pp.

Neumann, K. 1987. Middle Holocene vegetation of the Gilf Kebir / SW Egypt, Palaeoecology of Africa, 18, 351-363.

Neumann, K. 1991 Vegetationsgeschichte der Ostsahara im Holozän. Holzkohlen aus prähistorischen Fundstellen (Mit einem Exkurs über die Holzkohlen von Fachi Dogonboulo/ Niger) In: Kuper, R. (ed.) Forschungen zur Umweltgeschichte der Ostsahara. Acta Praehistorica, 2, Köln 13-181.

Neumann, K. 1991. Holocene vegetation of the eastern Sahara: charcoal from prehistoric sites. The African Archaeological Review, 7, 97-116.
The investigation of 320 charcoal samples from prehistoric sites in the Eastern Sahara furnishes evidence for a fundamental change of vegetation during the early and middle Holocene. Two ecological regions can be distinguished. In Egypt desert formations prevailed, consisting of the same vegetation elements as today though with a wider distribution, while in the Sudan tropical savannas occurred. Around 7000 BP the Sahelian vegetation zones were 500-600 km north of their present range, and 300-400 km around 5700 BP. The Sudanian flora of Fachi-Dogonboulo in Niger, dated ca 7000 BP, points to a simultaneous shift of the vegetation zones in the Eastern and in the Central Sahara. With increasing desiccation from 5200 BP onwards, the savanna formations retreated to the south until their present position was reached by 3300 BP

Neumann, K. 1992. Une flore sudanienne au Sahara central vers 7ooo BP.: les charbons de bois de Fachi, Niger. Bulltin de la Société botanique de France 139, actual bot. (2/34), 565-569.

Neumann, K. 1992. Wirtschaftweisen im Neolithikum der Ostsahara und ihr Einfluß auf die Vegetation. In: Kuper, R. et al. (eds.) Überlebensstrategien in Afrika. Coll. Afr. I, Univ. Köln

Neumann, K. 1994. Wirtschaftsweisen im Neolithikum der Ostsahara und ihr Einfluß auf die Vegetation. In: Bollig, M. Klees, F.(eds.) Überlebensstrategien in Afrika. Colloquium Africanum, I, Köln, 7-65.

Neumann, K., Schulz, E. 1987. Middle Holocene savannah vegetation in the central Sahara - preliminary report. Palaeoecology of Africa 18, 163-166.

Ngatcha, B.N., Mudry, J., Wakponou, A., Ekodeck, G.E., Njitchoua, R., Sarrot-Reynauld, J. 2002. The Limani-Yagoua mega sand-ridge, northern Cameroun, and its hydrological importance. Journal of African Earth Sciences 32 (4), 889-898.
The Limani-Yagoua mega sand-ridge, covering an area of 330,000 km^2 is well known in the extreme north of Cameroun. Similar structures have also been described in the Chad Republic (Bongor-Koro-Toro), Niger (Tal) and Nigeria (Bama). Two possible origins can be considered: (i) circum-lacustrine around the Lake Chad Basin, interpreted as a Holocene or Pleistocene palaeo-shoreline, or (ii) aeolian accumulation as a mega sand dune in an area of basin subsidence. The sand-ridge in northern Cameroun is an extremely permeable aquifer with discharge rates of 3-6 $m^3 h^{-1}$. High nitrate levels (27-127 mg l^{-1}) have been observed in several boreholes. Tritium at 4.1 ut indicates recent groundwater recharge, suggesting infiltration of rainfall damned by the sand-ridge.

Nguetsop, V.F., Servant-Vildary, S., Servant, M. 2004. Late Holocene climatic changes in west Africa, a high resolution diatom record from equatorial Cameroon. Quaternary Science Reviews 23 (5-6), 591-609.
Holocene climatic changes in West Africa are usually explained by increased/decreased activity of the monsoon from the Guinean Gulf toward the continent. According to a diatom record from Lake Ossa (3^o50'N, 9^o36E), we suggest that, in the near coastal areas of Cameroon, phases of intensification of the monsoon were marked by reduced precipitation and reduced evaporation, conditions nowadays prevailing South of the equator (4 5^oS) during the austral winter. Lake Ossa is a shallow lake located in one of the rainiest areas of the African rain forest belt. During the wet season (March-November) it is fed by acid meteoric waters entailing low pH in the lacustrine waters. During the dry season (December-February) groundwater discharges allow the persistence of acid waters near the borders of the lake, but, in the inner parts, the waters tend to be alkaline, alkaliphilous diatoms are abundant in the

surface sediment samples and are used as indicators of low precipitation. At that time, atmospheric dust containing reworked diatoms from Saharan Quaternary deposits is transported by the northern trade winds and reaches the Ossa area. Wind blown diatoms are considered as a signature of the northern trade winds. A diatom record from the western deep part of Lake Ossa has provided climatic data for the mid-late Holocene at a resolution of 50-60 years. A major climatic change at 2700 cat yr BP was marked by the appearance of wind blown diatoms. A millennial-scale alternation between low and high precipitation episodes is recorded during the last 5500 years. The low precipitation episodes before 2700cal yr BP are interpreted as a consequence of a northward extension of the climatic conditions that nowadays characterize the Southern Congo during the austral winter, when the monsoon extends into West Africa and reaches the northern sub-tropical latitudes. The effects of low precipitation on the water balance and on the rain forest were obliterated by an extremely low evaporation. Between 2700 and 1300 cat yr BP, precipitation was high and the rain forest intensively disturbed in response to convective storms. A low precipitation episode between 1300 and 600 cal yr BP is explained, contrarily to the previous similar episodes, by tropical rainfalls located farther South than today during a larger part of the year. The modern climate settles at about 600 cal yr BP. The climatic oscillations on a millennial time scale were apparently coincident with temperature changes in the Northern and Southern Atlantic suggesting that the monsoon over West Africa was essentially driven by interactions between both hemispheres. This interpretation is in agreement with available data from other equatorial and sub-tropical regions of West Africa

Nicholson, S.E. 1980. Saharan climates in historic times. In: The Sahara and the Nile; Quaternary environments and prehistoric occupation in northern Africa. Ed. Williams, M.A.J. and Faure, H. Balkema, Rotterdam, 173-200. UCL GEOGRAPHY QF 19 WIL
Data from chronicles and early travellers show that the southern borders of the Sahara were wetter during the 16th to 18th centuries (Little Ice Age of NW Europe), as possibley was the northern margin, perhaps as a result of more frequent spring and autumn rain-bearing depressions

Nicholson, S.E., Tucker, C.J., Ba, M.B. 1998. Desertification, drought, and surface vegetation: An example from the West African Sahel. Bulletin of the American Meteorological Society 79 (5), 815-829.
Many assumptions have been made about the nature and character of desertification in West Africa. This paper examines the history of this issue, reviews the current state of our knowledge concerning the meteorological aspects of desertification, and presents the results of a select group of analyses related to this question. The common notion of desertification is of an advancing "desert," a generally irreversible anthropogenic process. This process has been Linked to increased surface albedo, increased dust generation, and reduced productivity of the land. This study demonstrates that there has been no progressive change of either the Saharan boundary or vegetation cover in the Sahel during the last 16 years, nor has there been a systematic reduction of "productivity" as assessed by the water-use efficiency of the vegetation cover. While it also showed little change in surface albedo during the years analyzed, this study suggests that a change in albedo of up to 0.10% since the 1950s is conceivable.

Nickling, W.G. and Gillies, J.A. 1989. Emission of particles from desert soils, in Palaeoclimatology and palaeometeorology: modern and past patterns of global atmospheric transport, Eds. Leinen, M. and Sarnthein, M., Kluwer, Dordrecht, 133-165.

Nickling, W.G., Gillies, J.A. 1993. Dust emission and transport in Mali, West-Africa. Sedimentology 40 (5), 859-868.
Vertical dust fluxes were measured in the Inland Delta region of the Niger River, Mali, West Africa, during April-June, 1989 and 1990. Measurements of dust Aux represent, for the most part, non-dust storm conditions or 'dust haze' periods. The observed concentration versus height relationships are similar to data presented by other investigators. The relationship between wind shear velocity (u*, m s^{-1}) and vertical dust flux (F, mu g m^{-2} s^{-1}) can be described by a relationship in which F is proportional to u*(4). However, there is considerable scatter within the data set which is attributable to textural controls and surface conditions. The vertical dust fluxes measured in Mali are compared to dust fluxes measured in Texas, USA, and Yukon Territories, Canada. The significantly different values for the constant of. proportionality (a) in the F alpha a u*(4) relationship for these geographically diverse areas is a function of surficial controls on the release of sediments to the air stream. Dust concentrations measured in Mali were found to be uniformly high and in general exceed WHO health standards for acceptable total suspended particulate loadings. As a result background dust may be considered a long term stress on health for the people of this region of Mali.

Nicoll, K. 2001. Radiocarbon chronologies for prehistoric human occupation and hydroclimatic change in Egypt and northern Sudan. Geoarchaeology-an International Journal 16 (1), 47-64.
This article compiles 536 published, uncalibrated radiocarbon ages from well-studied localities in the presently hyperarid Western Desert, or Arba'in Desert, in northeast Africa. The synthesis of these records frames the spatial and temporal context of prehistoric cultural activity during wet periods when the region was habitable (9000-6000 yr B.P.). The variability of records by region indicates that the Holocene was not marked by uniform hydroclimatic conditions; lacunae, or gaps in the record formerly attributed to arid intervals, are not regionally consistent. Since rapid hydroclimatic changes (i.e., "wet-dry" cycles) have played a key role in the geomorphic evolution and human history of Egypt and northern Sudan, the precise definition of and periods will be important in the further analysis of hydroclimatic change as a driver of cultural innovation, migration, and settlement.

Nicoll, K. 2004. Recent environmental change and prehistoric human activity in Egypt and Northern Sudan. Quaternary Science Reviews 23 (5-6), 561-580.
This paper reviews the various Late Quaternary records that are available from western Egypt and northern Sudan, which includes more than 500 published radiocarbon dates and various sedimentary archives from local landscape components, including palaeolakes, soils, drainages (wadis), and archaeological sites. This palaeoenvironmental compilation frames the spatial and temporal context of local cultural activities when the region was most hospitable similar to 9000-6000 BP; at this time, monsoonal weather influenced the portion of the African continental interior, creating enough convective rainfall for occasional surface water storage. In this part of the modern Sahara, rapid hydroclimatic changes play a key role in geomorphic evolution and resource availability. As 'watering holes' formed and dried up in the Early to Middle Holocene, Neolithic people developed various subsistence strategies, including opportunistic hunting of small animals (e.g. gazelle and hare), and food-related (e.g. wild sorghum, millet, and legumes) activities: gathering, plant cultivation and livestock-rearing. During its wettest phases during the 'monsoonal maximum,' the area was drought-prone, sustaining a meager steppe shrub desert flora. Further desertification and aeolian deflation during the Middle and Late Holocene fostered technological innovation, migration and settlement, as well as the further development of agrarian communities and complex culture.

Novaceur, Z. 1996. Analyse d'un image de poussière sur l'Afrique de l'Ouest du décembre 1993:au janvier 1994:et conséquences en Mauritanie. Bulletin de la Veille climatique satellitaires, Office de Recherche scientifique et technique de l'Outre Mer (ORSTOM), Paris 56-57:91-104.

Northwestern University Library: 16th-Early 20th Century Maps of Africa: http://ansel.library.northwestern.edu/ImageServer/index.jsp?filename=/dimages/public/images/afrmaps/inu-afrmap-4007596-recto-ah.jp2&title=A%20new%20and%20accurate%20map%20of%20Africa

Noyalet, A. 1978. Utilisation des images météosat: genèse et évolution d'une tempète de sable sur l'ouest Africain. La Météorologie 14:113-115.

Ntchayi, see Mbourou

Oba, G., Post, E., Stenseth, N.C. 2001. Sub-saharan desertification and productivity are linked to hemispheric climate variability. Global Change Biology 7 (3), 241-246.
Vegetation productivity and desertification in sub-Saharan Africa may be influenced by global climate variability attributable to the North Atlantic Oscillation (NAO) and El Nino Southern Oscillation (ENSO). Combined and individual effects of the NAO and ENSO indices revealed that 75% of the interannual variation in the area of Sahara Desert was accounted for by the combined effects, with most variance attributable to the NAO. Effects were shown in the latitudinal variation on the 200 mm isocline, which was influenced mostly by the NAO. The combined indices explained much of the interannual variability in vegetation productivity in the Sahelian zone and southern Africa, implying that both the NAO and ENSO may be useful for monitoring effects of global climate change in sub-Saharan Africa.

Okin, G.S., Mahowald, N., Chadwick, O.A., Artaxo, P. 2004. Impact of desert dust on the biogeochemistry of phosphorus in terrestrial ecosystems. Global Biogeochemical Cycles 18 (2), art. no. GB2005.

Leaching, biomass removal, and partitioning of phosphorus (P) into reservoirs not available to plants can limit the long-term productivity of Terrestrial ecosystems. We evaluate the importance of atmospheric P inputs to the world's soils by estimating the total soil P turnover time with respect to dustborne P additions. Estimated turnover times range from similar to 10^4 to similar to 10^7 years. Our estimates provide a unique perspective on the importance and patterns of aeolian deposition to Terrestrial landscapes. Dust source regions are areas of intense soil P cycling on large scales, but are too water-limited for this rapid cycling to have a major influence on ecosystem dynamics. By contrast, semiarid desert margins receive significant aeolian P from neighboring deserts and are likely influenced by dustborne P additions for the long-term maintenance of productivity. This is particularly true for the semiarid steppes of Africa and Eurasia. The prevalence of large dust sources in Africa and Eurasia indicates that these areas may generally be more influenced by dustborne P additions than soils in the Americas. Significant western hemisphere exceptions to this pattern occur on very old landscapes, such as the forests of the southeastern United States and the Amazon Basin. The Amazon Basin is highly dependent on aeolian deposition for the maintenance of long-term productivity. Dust deposition to Terrestrial environments has not been constant with time. Variability in past P deposition related to geologically recent climate change may provide the strongest controls on present and future soil P in the Amazon and elsewhere.

Olivry, J.C., Chouret, A., Vuillaume, G., Lemoalle, J., Briquet, J.P. 1996. Hydrologie du lac Tchad. Monographies Hydrologiques O.R.S.T.O.M. 12, 266 pp.

Ologunorisa, E.T., Tamuno, T.T. 2002. The diurnal variation of sandstorms in Nigeria. Journal of Meteorology 27(270): 223-229
Data on hourly occurrence of sandstorms covering the period 1969 - 1992 for 27 synoptic stations were collected from the Nigerian Meteorological Services, Oshodi, Lagos. The results show that sandstorms are restricted to the northern parts of Nigeria, with the highest number occurring in Maiduguri and Sokoto with peak hours at 1700 and 1900 hours (GMT). In addition, the highest frequency of sandstorms is from 1300 to 2100 hours (GMT) with a unimodal peak at 1800 hours, while the lowest frequency was at about 2200 hours (GMT) and the period between 0500 and 0600 hours (GMT). Sandstorm occurrence is highly variable in Nigeria, being least in Yelwa and highest in Ilorin. The frequency per hour also varies widely among the stations that have fairly high frequencies of sandstorm occurrence.

Ologunorisa, E.T., Tamuno, T.T. 2003. Annual sandstorm fluctuations and trends in Nigeria. Journal of Meteorology 28(277): 93-102.
This research examines annual sandstorm fluctuation and trends in Nigeria. Data on annual occurrence of sandstorms covering the period 1969 - 1999 for 27 synoptic stations were collected from the Nigerian Meteorological Services, Oshodi, Lagos for analysis. The trend in sandstorms in Nigeria was analysed using the Pearson product moment correlation coefficient and simple linear regression analysis. The results of the analysis illustrate among other things that sandstorm fluctuations in Nigeria show two periods of high peaks, namely, the early 1970s and the late 1980s. These periods coincide with the drought and dry years. In addition, there is a statistically significant positive trend for stations such as Maiduguri and Sokoto, while Ilorin which has a positive trend is not statistically significant at the 95% probability level. The results show that there is a negative sandstorm trend for Yola, Kano, Zaria and the entire country (Nigeria). Although the negative trend is not statistically significant at the 95% probability level, only Yola shows a statistically significant negative trend.

Ologunorisa, E.T., Tamuno, T.T. 2003. Spatial and seasonal variations of sandstorms over Nigeria**.** Theoretical and Applied Climatology 75(1-2): 55-63.
The study deals with spatial and seasonal variations of sandstorms in Nigeria. Data on monthly and annual occurrence of sandstorms covering the period 1969-1992 for 27 synoptic stations were collected from the Nigerian Meteorological Services, Oshodi, Lagos for analysis. Data were analyzed using descriptive statistics, while co-efficient of variation was used to determine the spatial variations in the annual and seasonal occurrence of sandstorms in the study area. The results of the analysis show that stations with high frequencies of sandstorms which are mainly in the north have low co-efficient of variation while the middle belt and the south with low frequencies have very high co-efficient of variations. The study concludes that the main source region of sandstorms in Nigeria is Sahara desert, and that the major factors determining the spatial and seasonal variations of sandstorms over Nigeria, apart from Inter-Tropical Convergence Zone (ITCZ) are the distance inland from the coast, the distance away from the desert margins, relief, disturbance lines and anthropogenic factors.

Ologunorisa, T.E. and Babatolu, J.S. 2004. Rainfall variability and duststorm production in the Sahelian zone of Nigeria. Journal of Meteorology 29(294):366-373.

Orange, D., Gac, J.-Y., Probst, J.L., Tanré, D. 1990. Mésure de dépôt au sol des aérosols désertiques; une méthode simple de prélevement; le capteur pyramidal. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences, Série DII, Mécanique, Physique, Chimie, Sciences de l'Universe, Sciences de la Terre 311 (1), 167-172.

Oslisly, R. 1997. Environment and populations in the Pleistocene of the Lake Chad basin and adjacent regions: Cameroon, Niger, Nigeria, Central African Republic, Chad, vol 47 – French – NgabaWaye, A. Anthropologie 101 (2), 399-400.

Ozer, P. 2001. Les lithométéores en région sahélienne. International Journal of Tropical Ecology and Geography 24, 317 pp.

Pachur, H.-J. 1967. Beobachtungen über die Bearbeitung von feinkornigen Sandakumulationen im Tibesti-Gebirge, Arbeitsberichte aus der Forshungstation Bardai/Tibesti, Berliner geographische Abhandlungen, 5, 23-26.

Pachur, H-J., 1975. Zur spatpleistozane und holozane Formung auf derNordabdachung des Tibestigebirges. Die Erde 106: 21-46.

Pachur, H.J. 1980. Climatic history in the late Quaternary in southern Libya and the western Libyan Desert. Symposium of the Geology of Libya, Eds. Salem, M.J. and Busrewil, M.T., Academic Press, London 2, 781-788. 1980.

Pachur, H.J. 1987. Vergessene Fluesse und Seen der Ostsahara. Geowissenschaften in Unserer Zeit 5 (2), 55-64.

Pachur, H.J. 1991. Ein wenig beachtetes Artefakt als Klimaindikator. In: Klimäntwicklung und Paläoklimazonen in Afrika. Ed. Hedriks, F. Zentralblatt für Geologie und Paläontologie, Teil I: Allgemeine, Angewandte, Regionale und Historische Geologie 11, 2748.

Pachur, H.-J. 1991. Tethering stones as paleoenvironmental indicators. Sahara 4, 13-33.

Pachur, H.-J. 1996. Reconstruction of palaeodrainage systems in Sirt Basin and the area surrounding the Tibisti Mountains; implications for the hydrological history of the region. In: The geology of Sirt Basin; Volume I. Salem, M.J., Mouzughi, A.J., Hammuda, O.S., Elsevier, Amsterdam, 157-166.

Pachur, H.-J. 1997. Der Ptolemäus-See in Westnubien als Paläoklimaindikator. Petermanns Geographische Mittelungen. 141 (4), 227-250.
Of the palaeolakes of Western Nubia, Lake Ptolemy - a shallow freshwater lake with a chemocline in the pelagic zone - covered an area of more than 10 x 10^3 km^2 during early to middle Holocene time. This estimate is based on evidence of lake carbonate, microbialites, goethite crusts (bog iron deposits), bones of freshwater fish, and the topographic reconstruction of the lake level. At the present time, the lake sediments are undergoing deflation and groups of barchans are traversing the former lake basin. Lake Ptolemy is bounded in the east by an area of lakes and marshes, and in the west by an erg containing isolated lakes and numerous marshes with iron oxide precipitates. Because of the lack of precise topographic data, the estimated westward extent of the lake is on the conservative side. A possible link with Lake Mega-Chad via the Mourdi depression is discussed. Effective palaeo-rainfall may have been triggered by the entire water-vapour-emitting area of Western Nubia, which included the hydrologically significant confluence of Wadi Magrur with Wadi Howar, and a third drainage system (including the locality of Laquia Arbain) that disrupted the region's endorheic state. This impact is signalled by the oxygen stable isotopes in the groundwater. As a result, the area north of 23°N experienced episodic rainfall, increased runoff, and the formation of playas instead of freshwater lakes like those found south of 22°N. Further away, drainage systems were activated in the Western Desert and palaeorainfall was generated. Lake Ptolemy constitutes the eastern part of a chain of lakes that begins in the eastern Sahara, south of 20°N, and ends at Taoudenni/Mali, north of 20°N. During the early to middle Holocene, there existed a NE-to-NW-oriented line of water-vapour sources whose

existence depended on a change in global water-vapour transport; however, the self-stabilizing effect of regionalized rainfall - i.e. the presence of a water-vapour source in a continental location - sufficed for lakes to exist.

Pachur, H.-J. 1999. Paläo-Environment und Drainagesysteme der Ostsahara im Spätpleistozän und Holozän. In: Nordost-Afrika; Strukturen und Ressourcen; Ergebnisse aus dem Sonderforschungsbereich "Geowissenschaftliche Probleme in ariden und semiariden Gebieten". Eds. Klitsch, E. and Thorweihe, U., 266-445.

Pachur, H.J., Altmann, N. 1997. The Quaternary (Holocene ca. 8000 BP). In: Schandelmeier, H., Reynolds, H., Semtner, A.K. (eds) Paleoogeograpghich-Paleoterctonic Atlas of North Eastern Africa, Arabia and adjacent areas. Late neoproterozoic to Holocene. Balkema, Rotterdam, 83-94

Pachur, H.J., Braun, G. 1980. The paleoclimate of the central Sahara, Libya, and the Libyan Desert. In: Sahara and surrounding seas; sediments and climatic changes; proceedings of an international symposium, Ed. Sarnthein, M., Seibold, M. and Rognon, P. Palaeoecology of Africa and the surrounding Islands and Antarctica 12, 351-363.

Pachur, H.-J. and Braun, G. 1982. Aspekte paläoklimatischer Befunde in der östlichen Zentralsahara, Geomethodica, 7, 23-54.

Pachur, H.J., Braun, G. 1986. Drainage systems, lakes and ergs in the Eastern Sahara as indicators of Quaternary climatic dynamics. In: Workshop on hydrology; Special Research Project; Arid Areas. Berliner Geowissenschaftliche Abhandlungen. Reihe A. Geologie und Paläontologie 72, 3-16.

Pachur, H.J., Hölzmann, P. 1991. Paleoclimatic implications of late Quaternary lacustrine sediments in western Nubia, Sudan. Quaternary Research (New York) 36 (3), 257-276.
With the hypercontinental location of Western Nubia, wet phases are representative of conditions over all the SE Sahara. The study area is crossed by the 20-mm isohyet; between 9300 and about 4000 yr BP, when there were widespread lake and swamp environments with freshwater molluscs, ostracods, and diatoms, and a good savanna mammal fauna. The centre of the West Nubian Basin was occupied by a semiaquatic landscape in the same latitude as Paleolake Chad. Environments then are now at latitude 13^{o}N. Radiocarbon dates from lake sediment sequences cluster between 30 and 21 kyr BP, indicates a Pleistocene wet phase. A gap between 21 and 11 kyr BP signals a phase of hyperaridity, similar to today.

Pachur, H.J., Hölzmann, P. 1998. Zur Paläogeoökologie der Ostsahara. In: Forschungsergebnisse zur Klimageschichte und Reliefentwicklung Nordafrikas und Asiens; Festschrift für Dieter Jäkel zum 65. Geburtstag, Ed. Bös, M., Hofmann, J., Häkel, D., Berliner geographische Abhandlungen 63, 27-34.

Pachur, H.J., Hölzmann, P. 2000. Late Quaternary palaeoecology and palaeoclimates of the eastern Sahara. Journal of African Earth Sciences 30 (4), 929-939.
Latest field research and palaeoenvironmental reconstructions have revealed that within less than 6000 years the eastern Sahara experienced a dramatic climatic change similar to that in the western Sahara, passing from hyperaridity to semi-aridity (dry savanna) to its present hyperarid state. Groundwater levels started to rise about 9300 years before present (C^{14} years BP), leading to the formation of a mosaic of freshwater rakes and swamps. Within a few decades, the aquifers were loaded and the palaeopiezometric surface was as much as 25 m higher than it is today. The uplands generated up to 800 km long fluvial systems, which put an end to the endorheic drainage of the region and functioned as migration paths for large savanna mammals. These wetter conditions persisted in western Nubia during the Holocene until ca 5000 years BP. The climatic deterioration began around 5700 years BP as shown by evaporitic sediments. Reversal events prior to aridification during the Late Holocene were not recorded systematically in the sediments of the eastern Sahara because of the stability of the ecosystems. Changes in land-surface conditions such as palaeolakes, swamps and vegetation created water vapour sources that generated local rainfall and buffered short dry spells. Radiocarbon-dated charcoal indicates that Neolithic human occupation culminated during this Early Holocene wet phase and ended ca 2000 years after the fading of the wet phase at about 3000 years BP, when the shallow aquifers were exhausted.

Pachur H.J., Kröpelin, S. 1987. Wadi Howar - paleoclimatic evidence from an extinct river system in the southeastern Sahara. Science 237 (4812), 298-300.
Field research into the climatic history and shifting of the East Saharan desert has furnished evidence that during Quaternary time the present extremely arid western part of Upper Nubia (northern Sudan) was temporarily linked to the Nile by way of a hitherto unknown 400 kilometer long tributary. From about 9500 to 4500 years ago, lower Wadi Howar flowed through an environment characterized by numerous ground water outlets and freshwater lakes. Savanna fauna and cattle-herders occupied this region, which today receives at most 25 millimeters of rainfall per year. At that period the southern edge of the eastern Sahara was some 500 kilometers further north than today and ground water resources were recharged for the last time.

Pachur, H.J., Kröpelin, S. 1989. The aridification of the eastern Sahara during the middle and late Holocene. Bulletin de la Société géologique de France 5 (1), 99-107.
Aridification during the middle and late Holocene is indicated on the basis of a north-south transect starting at the Gilf Kebir at 24°N in the center of the presently hyperarid eastern Sahara and ending in the Wadi Howar area at its southern fringe at 17°N. Aridification probably affected the northern parts from approximately 5000 years B.P., and the southern parts from about 3500 years B.P. The northern fringe of the Paleo-Sahel shifted southward approximately 500 km during the process of aridification, undergoing important oscillations. At least in the lower Wadi Howar, neolithic man seems to have intensified the effects of aridification, thus triggering the onset of desertification

Pachur, H.J., Kröpelin, S., Hölzmann, P., Goschin, M., Altmann, N. 1990. Late Quaternary fluvio-lacustrine environments of western Nubia. In: Research in Sudan, Somalia, Egypt and Kenya; results of the special research project "Geoscientific problems in arid and semiarid areas", Sonderforschungbereich 69); period 1987-1990. Ed. Klitsch, E., Schrank, E., Berliner Geowissenschaftliche Abhandelungen, Reihe A, Geologie und Paläontologie 120 (1-2), 203-260.

Pachur, H.J., Röper, H.P. 1984. The Libyan (Western) Desert and northern Sudan during the late Pleistocene and Holocene. In: Research in Egypt and Sudan; Sonderforschungsbereich 69; Results of the Special Research Project Arid Areas, period 1981-1984. Eds. Klitsch, E., Said, R., Schrank, E., Berliner Geowissenschaftliche Abhandelungen, Reihe A, Geologie und Paläontologie 50, 249-284.

Pachur, H.J., Röper, H.P. 1984. Die Bedeutung paläoklimatischer Befunde aus den Flachbereichen der östlichen Sahara und des nördlichen Sudan. Grundvorstellungen und Entwicklungen in der Geomorphologie. Steiblein, G., Zeitschrift für Geomorphologie, Supplementband 50, 59-78.
During the Early Holocene a gradient of decreasing rainfall from west to east developed along the latitude of the Tropic of Cancer. In the Libyan (Western) Desert silty clay stillwater sediments with a very low organic and a negligible carbonate content occur, whereas in the west there are coeval calcitic lake sediments, deposited in a drainage system extending to the Mediterrancean area. Pelitic sediments in the Libyan Desert fit into two categories: the mountain type (Gilf Kebir), characterized by interbedded sand and gravel, and the plains type, the interbedded material consisting solely of drift sand. A semi-arid climate with severe wind erosion is inferred. Sedimentation of pelites began after 11 000 BP. Up to ca.26 000 BP a hyperarid climate with deflation and aeolian accumulation prevailed.

Pachur, H.J., Röper, H.P., Kröpelin, S., Goschin, M. 1987. Late Quaternary hydrography of the Eastern Sahara. Berliner Geowissenschaftliche Abhandelungen, Reihe A, Geologie und Paläontologie 75 (2), 331-384.

Pachur, H.J., Rottinger, F. 1997. Evidence for a large extended paleolake in the eastern Sahara as revealed by spaceborne radar lab images, Remote Sensing of Environment 61 (3), 437-440.
Recently processed radar images from the two flights of the space shuttle Endeavour by the spaceborne imaging radar-C/X-band synthetic aperture radar instrument in 1994 give a clear view of widely distributed sediments of a palaeolake in today's hyperarid eastern Sahara (NW Sudan). Although a few of the sites of lacustrine sediments were previously examined in the field, their extent now visible on the images yields a new perspective on the Early- to Mid-Holocene wet phase that affected northern Africa. Freshwater wetlands across an area exceeding 15,000 km^2 existed between 8800 and 4500 B.P. owing to a significant increase in rainfall. The phenomenon called the West Nubian Lake constitutes the largest-scale hydrographic evidence in the eastern Sahara for a northward shift of the tropical min belt. Given that the region now receives less than 15 mm of precipitation per year on average, the former open water body and its vegetated catchment may have acted as a modifier of the regional

climate. In connection with the detection of a buried major palaeodrainage system near Kufra (SE Libya), the West Nubian Lake confirms the new multifrequency and multipolarization radar imaging as a powerful tool for the reconstruction of arid land palaeohydrology.

Pachur, H.J. and Wuennemann, B. 2002. Late Pleistocene lake deposits of the Great Sand Sea of Egypt. In: Lehmkuhl, F., Busche, D. and Wuennemann, B.(eds.) Research in deserts and mountains of Africa and Central Asia. Zeitschrift fuer Geomorphologie Supplementband. 126: 75-96.

Pachur, H.J., Wünnemann, B. 1996. Reconstruction of the palaeoclimate along 30° E in the eastern Sahara during the Pleistocene/ Holocene transition. Palaeoecology of Africa and the Surrounding Islands 24, 1-32.

Pandithurai, G., Pinker, R.T., Dubovik, O., Holben, B.N., Aro, T.O. 2001. Remote sensing of aerosol optical characteristics in sub-Sahel, West Africa. Journal of Geophysical Research-Atmospheres 106 (D22), 28347-28356.
We have determined the characteristics of sub-Sahelian aerosols from a 2-year record of continuous ground-based measurements, made at the University of Ilorin, Ilorin (08°19'N, 04°20'E), Nigeria, in cooperation with the Aerosol Robotic Network. Observations of spectral aerosol optical depths during the dusty harmattan season indicate more than a twofold increase, when compared to other seasons. Retrieved columnar volume size distributions show the existence of bimodality with a dominant coarse mode. The retrieved size distributions were grouped according to different ranges of aerosol optical depths to characterize the aerosols for this particular region. Monthly means of retrieved single-scattering albedos show a sharp decrease from similar to 0.95 to similar to 0.85 at 500 nm from the preharmattan to the harmattan season when biomass burning is also practiced, increasing the presence of absorbing aerosols. On the basis of these comprehensive observations, we propose to augment existing desert aerosol models, as presented in the literature, to better characterize the dust outbreak season in West Africa, which is quite prolonged and overlaps with the biomass burning season.

Passarge, S. 1904f. Zum Oberflächengestaltung von Kanem, *Petermanns Mitteilungen*, 50, 210-216.

Patterson, E.M., Gillette, D.A. and Stockton, B.H. 1977. Complex index of refraction between 300 and 700 mm for Saharan aerosols. Journal of Geophysical Research 82(21):3153-3160.
transect of the aquifer was modeled from the area of the Uweinat Uplift to the northern Bahariya Oasis. Predicted groundwater velocities in the deep portion of the aquifer are 0.5 - 3.5 m/ yr with groundwater residence times up to 9 x 10^5 years; residence times up to 1.3 x 10^6 years are predicted in the confining shale. Aquifer properties are estimated by using the model to fit the measured ^{36}Cl/ Cl ratios. Under these conditions, hydrodynamic residence times are within about 30% of those calculated from ^{36}Cl when mixing of Cl- is accounted for in the highest- Cl- deep groundwaters. By mutually calibrating multiple methods (hydrodynamic, ^{36}Cl, and ^{4}He), a consistent picture of the Nubian Aquifer has emerged in which lateral flow from a southern recharge area dominates the deep horizons, while shallow horizons contain younger, autochthonous recharge.

Patterson, L.J., Sturchio, N.C., Kennedy, B.M., van Soest, M.C., Sultan, M., Lu, Z.T., Lehmann, B., Purtschert, R., El Alfy, Z., El Kaliouby, B., Dawood, Y. and Abdallah, A. (2005). Cosmogenic, radiogenic, and stable isotopic constraints on groundwater residence time in the Nubian Aquifer, Western Desert of Egypt. *Geochemistry Geophysics Geosystems* 6: Art. No. Q01005.
Measurements of radiochlorine (^{36}Cl), radiogenic noble gases (^{4}He and ^{40}Ar), and stable chlorine isotope ratios were obtained to assess the residence time of groundwater in the Nubian Aquifer of the Western Desert of Egypt. Measured ^{36}Cl/ Cl ratios yield apparent residence times from similar to 0.2 to 1.2 x 10^6 years in the deep (600 - 1200 m) groundwater (assuming constant Cl) and less than or equal to 0.16 x 10^6 years in the shallow (< 600 m) groundwater. Values of δ^{37}Cl in the groundwater strengthen the application of the ^{36}Cl dating method by constraining Cl sources and identifying groundwater mixing. Dissolved gases were measured in some of the deep groundwater samples. Measured ^{4}He concentrations indicate accumulation of radiogenic ^{4}He that is qualitatively consistent with the age progression indicated by the ^{36}Cl/ Cl ratios, but the flux of external ^{4}He from the underlying crust has not been quantified and is not constant throughout the aquifer. Concentrations of ^{40}Ar range from 3.3 to 6.7 x 10^{-4} ccSTP/ g and indicate excess air incorporation at recharge. Measured transect of the aquifer was modeled from the area of the Uweinat Uplift to the northern Bahariya Oasis. Predicted groundwater velocities in the deep portion of the aquifer are 0.5 - 3.5 m/ yr with groundwater

residence times up to 9 x 10^5 years; residence times up to 1.3 x 10^6 years are predicted in the confining shale. Aquifer properties are estimated by using the model to fit the measured ^{36}Cl/ Cl ratios. Under these conditions, hydrodynamic residence times are within about 30% of those calculated from ^{36}Cl when mixing of Cl- is accounted for in the highest- Cl- deep groundwaters. By mutually calibrating multiple methods (hydrodynamic, ^{36}Cl, and ^{4}He), a consistent picture of the Nubian Aquifer has emerged in which lateral flow from a southern recharge area dominates the deep horizons, while shallow horizons contain younger, autochthonous recharge.

Peck, J.A., Green, R.R., Shanahan, T., King, J.W., Overpeck, J.T., Scholz, C.A. 2004. A magnetic mineral record of Late Quaternary tropical climate variability from Lake Bosumtwi, Ghana. Palaeogeography Palaeoclimatology Palaeoecology 215 (1-2), 37-57.
We report magnetic hysteresis results from sediment cores obtained from Lake Bosumtwi, Ghana. As a hydrologically closed basin, the water budget of Lake Bosumtwi is extremely sensitive to changes in the precipitation/evapotranspiration balance. Lake Bosumtwi lies in the path of the seasonal migration of the intertropical convergence zone (ITCZ); hence, the lake is ideally situated to study monsoon variability in West Africa. Five distinctive magnetic mineral zones (A-E) were identified in the 11-m-long sediment cores that span the last 26,000 calendar years. Prior to 12 calendar (cal) ka, low concentrations of multidomain, high-coercivity magnetic minerals are present. Three prominent shifts towards very high concentrations of high-coercivity iron sulfide (greigite) magnetic minerals are centered at 12,470, 17,290, and 22,600 calendar years during the last glacial period (magnetic zones D1-3). Between 12 and 3.2 cal ka, there is an abrupt shift to moderately high concentrations of mixed multidomain and single-domain, low-coercivity minerals and an organic-rich sapropel lithology. Since 3.2 cal ka, the magnetic mineral parameters reveal a shift to increased amounts of high-coercivity magnetic minerals.
These magnetic mineral zones document tropical climate variability on a variety of temporal scales. Glacial age sediments have a high-coercivity magnetic mineralogy due to increased aeolian dust transport from the Sahel to Lake Bosumtwi as well as postdepositional reductive diagenesis. During the last glacial period, the increased strength of Harmattan and North African continental trade winds, the southward depression of the ITCZ, and weakened summer monsoon strength resulted in increased regional aridity and greater dust flux out of Sahel source regions. The greigite-bearing D magnetic zones correspond to brief lowstands in the level of Lake Bosumtwi and likely represent periods of intensified aridity in West Africa. The D magnetic zones closely resemble the timing and duration of Heinrich events and suggest a hemispheric-scale climatic coupling between the tropics and poles. The well-documented African humid period (AHP) is characterized by abrupt shifts in magnetic parameters between 12 and 3.2 cal ka. Dust flux to Lake Bosumtwi is inferred to be very low during this humid interval due to the strengthening of the summer monsoon. Since 3.2 cal ka, the magnetic mineral parameters suggest increased aridity as compared to the AHP. This work demonstrates that the magnetic properties of Lake Bosumtwi sediment are a sensitive recorder of abrupt climate change of global significance.

Perrott, R., Strett-Perrott, A. 1982. New evidence for a Late Pleistocene wet phase in northern intertropical Africa. Palaeoecology of Africa 14, 57-76.

Pesce, A. 1968. Gemini space photographs of Libya and Tibesti; a geological and geographical analysis. Petroleum Exploration Society of Libya, 37 pp.

Peters, J. 1988. The palaeoenvironment of the Gilf Kebir- Jebel Uweinat area during the first half of the Holocene: the latest evidence. Sahara 1, 73-76.

Peters, J. 1992. Late Quaternarty mammalian remains from central and eastern Sudan and their palaeoenvironmental significance. Palaeoecology of Africa, 23, 91-115.

Petitjean, L. 1937. Cartes mensuelles de la répartition des vents de sables et de pluies au Sahara. Office national météorologique de France, Mémoire 27.

Petit-Maire, N., Ed., 1982."Le Shati : Lac pleistocene du Fezzan (Libye)."Editions du Centre National de la RechercheScientifique, Paris, 118pp.

Petit-Maire, N., G. Delibrias and C. Gaven, 1980. Pleistocene lakes in the Shati area, Fezzan (27o30'N). Palaeoecology of Africa 12 : 289-295.

Petit-Maire N., Faure, M., Gayet, M., Guerin, Cl. 1991. Importance des données paléontologiques pour l´etude des changements climatiques globaux: macropaléontologie et paleoclimats saharien. Bulletin de la Société géologique de France 162 (4), 707-711.
The international projects involved in the study of environmental and climatic evolution generally do not consider macropalaeontological evidence although the latter can yield important quantifiable data (temperature, soil humidity, precipitation, biomass and oceanic currents) similar to other sources of data taken into account in those research programmes (lacustrine sediments, ocean floor cores, ice cores, corals, loess, pollen, paleosols, sedimentary rocks, dendrochronology and historical evidence). Four examples are given: 1) study of marine, lacustrine and terrestrial molluscs; 2) study of fish from lacustrine deposits and middens (kjokkenmoddings) of a presently hyperarid area in North Mali; 3) study of large fossil Mammals from the Taoudenni basin; 4) discovery of Holocene cromagnoid human remains at 20 degreesN in Mali.

Petit-Maire, N., Fortugne, M., Rouland, C. 1991. Atmospheric methane ratio and environmental change in the Sahara and Sahel during the last 130 kyr. Palaeogeography, Paleoclimatology, Palaeoecology, 86, 197-204.
The comparison of the Vostok CH "SUB 4" curve, over the last 130 ka, with the dated succession of humid/arid phases in the 6500 000km "SUP 2" area between 13 degreesN and 27 degreesN, in Africa, shows that they roughly co-vary. We propose those past ecological changes in vast tropical areas as one of the factors that contributed to the global increase/decrease of the methane production.

Petit-Maire, N., Kröpelin, S. 1991. Les climats holocènes du Sahara le long du Tropique du Cancer. In: Paleoenvironnements du Sahara; lacs holocenes a Taoudenni (Mali), Ed. Petit-Maire, N., Editions de la Centre national de la Recherche scientifique (CNRS), 205-210.

Petit-Maire, N. and J. Riser, 1981. Holocene lake deposits and palaeoenvironments inCentral Sahara, northeastern Mali.Palaeogeography, Palaeoclimatology, Palaeoecology 35(1): 45-61.

Petters, S.W. 1981. Stratigraphy of Chad and Iullemmeden basins (West Africa). Eclogae Geologicae Helvetiae 74 (1), 139-159.

Pias, J. 1958. Transgressions et regressions du lac Tchad à la fin de l'ére Tertiaire et au Quaternaire. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences 246 (5), 800-803.
Transgressions and regressions of Chad lake in northwest central Africa are traced and attributed to alternation of very rainy and dry periods corresponding to Quaternary glaciations and interglacial periods.

Pias, J. 1960. Sédimentation au Quaternaire dans l'est de la cuvette tchadienne (massifs du Ouaddai et de l'Ennedi; plaines de piedmonts). Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences 250 (8), 1514-1516.

Pias, J. 1967. Chronologie du dépôt des sédiments Tertiaires et Quaternaires dans la cuvette Tchadienne (Republique Du Tchad) Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences, Série D 264 (21), 2432-2435.
Cenozoic sands and clays of the Chad basin have undergone several soil-forming periods, resulting in ferralitic or leached tropical ferruginous soils. In the Quaternary, an alternation of pluvials and dry periods affected the deposition in Lake Chad and is the cause for the accumulation of three dune systems and three deltas on the Chari river.

Pias, J. 1967. Quatre deltas successifs du Chari au Quaternaire (Républiques du Tchad et du Cameroun). Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences, Série D, 264 (20), 2357-2360.
Four successive deltas of the Chari river are correlated with Pleistocene and Recent high levels of Lake Chad, some of which are represented by sandy shorelines. By comparison with other parts of Africa, these deltas are equated with the standard African pluvial stages.

Pias, J. 1968. Contribution àl'étude des formations sédimentaires tértiaires et quaternaires de la cuvette tchadienne et des sols qui en dérivent (République du Tchad). Cahiers d'ORSTOM, Série Pédologie 6 (3-4), 367-377.

Four lacustrine transgressions, Recent pedogenesis

Pias, J. 1968. Paléosols de la cuvette tchadienne, Proceedings of the 19th International Congress of Soil Science, Adelaide, 4, 139-149.

Pias, J. 1970 Caracterisation de paléosols de la cuvette tchadienne. Bulletin de Liaison – Association Sénégalaise pour l'Etude du Quaternaire de l'Ouest Africain 25, 23-37.

Pias, J. 1970b. *Les formations sédimentaires tertiaires et quaternaires de la cuvette tchadienne et les sols qui en dérivant, Mémoire de l'ORSTOM*, 43, Office de la Recherche scientifique et technique de l'Outre Mer, Paris, 407 pp.

Pias, J., Guichard, E. 1957. Origine et consequences de l'existence d'un cordon sableux dans la partie sud-ouest de la cuvette tchadienne. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences, 244 (6), 791-793.

Pinker, R.T., Idemudia, G., Aro, T.O. 1994. Characteristic aerosol optical depths during the Harmattan season on Sub-Sahara Africa. Geophysical Research Letters 21 (8), 685-688.
Aerosol optical depths were derived from sun photometer measurements in three narrow bands centered at 500, 675 and 875 nm, taken at Ilorin, Nigeria, located in sub-Saharan Africa. Selected results will be presented on the diurnal, seasonal, and interannual variability of spectral aerosol optical depth for two Harmattan seasons, during 1987-1989. At 500 nm values between 0.9-1.6 were quite common while the averages were between 1-1.2.

Pinker, R.T., Pandithurai, G., Holben, B.N., Dubovik, O., Aro, T.O. 2001. A dust outbreak episode in sub-Sahel West Africa. Journal of Geophysical Research-Atmospheres 106 (D19), 22923-22930.
Wind blown dust is a major contributor to the tropospheric aerosol mass loading and has a significant effect on the local radiative forcing. Information on aerosol optical properties and their temporal and spatial distribution is very limited. Attempts to derive such information from space, in particular, over land, are in a preliminary stage. Recently, information on aerosol optical properties is becoming available from ground networks within one day from the time the observations are made. In this study, use was made of such "real-time" aerosol observations, to characterize their optical properties, during a heavy dust event in the sub-Sahel in January 2000. Aerosol optical depths at all wavelengths showed a sharp increase when compared to the average for the season, reaching values up to 3.5 at 500 nm. The Angstrom exponent was reduced from 1.2 to 0.3, and a sharp increase in the single-scattering albedo was found. The aerosol optical properties differed significantly from climatologically available information on dust aerosols, and therefore their timely assimilation into transport models or weather prediction models could be of great relevance. Developments in the ways aerosol are presently observed could influence future treatment of aerosols in climate research.

Pokras, E.M. 1989. Pliocene history of South Saharan/Sahelian aridity: record of freshwater diatoms (Genus Melosira) and opal phytoliths, ODP sites 662 and 664. In: Leinen, M. and Sarnthein, M. (eds), Palaeoclimatology and palaeometeorology: modern and past patterns of global atmospheric transport, Dordrecht: Kluwer Academic, pp. 795-804.

Pouclet, A., Durand, A. 1983. Structures cassantes cenozoiques d'apres les phenomenes volcaniques et neotectoniques au nord-ouest du lac Tchad (Niger oriental). In: Tectonique cassante en distension et coulissement. Annales, Société géologique du Nord 103 (2-3), 143-154.

Pouyaud, B., Colombani, J. 1989. Les variations éxtremes du lac Tchad; L'asséchement est-il possible? Annales de Géographie 98 (545), 1-23.
Using data collected during the past sixty years, the authors have tried to evaluate past predictions. The conclusion is that if the climate does not fundamentally change, a permanent drying of Lake Chad will not occur since a single year with heavy rains is enough to bring water up to normal level. However, if man does not practice environmentally sound management of the Lake Chad catchment there is actual danger for the disappearance of Lake Chad.

Prospero, J.M., Ginoux, P., Torres, O., Nicholson, S.E., Gill, T.E. 2002. Environmental characterization of global sources of atmospheric soil dust identified with the Nimbus 7 Total Ozone

Mapping Spectrometer (TOMS) absorbing aerosol product. Reviews of Geophysics 40 (1), art. no. 1002.
We use the Total Ozone Mapping Spectrometer (TOMS) sensor on the Nimbus 7 satellite to map the global distribution of major atmospheric dust sources with the goal of identifying common environmental characteristics. The largest and most persistent sources are located in the Northern Hemisphere, mainly in a broad "dust belt" that extends from the west coast of North Africa, over the Middle East, Central and South Asia, to China. There is remarkably little large-scale dust activity outside this region. In particular, the Southern Hemisphere is devoid of major dust activity. Dust sources, regardless of size or strength, can usually be associated with topographical lows located in arid regions with annual rainfall under 200-250 mm. Although the source regions themselves are arid or hyperarid, the action of water is evident from the presence of ephemeral streams, rivers, lakes, and playas. Most major sources have been intermittently flooded through the Quaternary as evidenced by deep alluvial deposits. Many sources are associated with areas where human impacts are well documented, e.g., the Caspian and Aral Seas, Tigris-Euphrates River Basin, southwestern North America, and the loess lands in China. Nonetheless, the largest and most active sources are located in truly remote areas where there is little or no human activity. Thus, on a global scale, dust mobilization appears to be dominated by natural sources. Dust activity is extremely sensitive to many environmental parameters. The identification of major sources will enable us to focus on critical regions and to characterize emission rates in response to environmental conditions. With such knowledge we will be better able to improve global dust models and to assess the effects of climate change on emissions in the future. It will also facilitate the interpretation of the paleoclimate record based on dust contained in ocean sediments and ice cores.

Prospero, J.M., Lamb, P.J. 2003. African droughts and dust transport to the Caribbean: Climate change implications. Science 302 (5647), 1024-1027.
Great quantities of African dust are carried over large areas of the Atlantic and to the Caribbean during much of the year. Measurements made from 1965 to 1998 in Barbados trade winds show large interannual changes that are highly anticorrelated with rainfall in the Soudano-Sahel, a region that has suffered varying degrees of drought since 1970. Regression estimates based on long-term rainfall data suggest that dust concentrations were sharply lower during much of the 20th century before 1970, when rainfall was more normal. Because of the great sensitivity of dust emissions to climate, future changes in climate could result in large changes in emissions from African and other arid regions that, in turn, could lead to impacts on climate over large areas.

Quézel, P. and Martinez, C. 1958. Etude palynologique de deux diatomites du Borku (Territoire du Tchad, A.E.F.), Bulletin de la Société de l'Histoire naturelle de l'Afrique du Nord, 49, 230-244.

Rajot, J.L. 2001. Wind blown sediment mass budget of Sahelian village land units in Niger. Bulletin de la Société Géologique de France 172 (5), 523-531.
To assess the mass budget of aeolian sediments transported by wind (erosion vs. deposition) at the scale of villa-e land units (25 km x 25 km), measurements were carried out during 3 years (from 1996 to 1998) in a cultivated field and in a fallow area simultaneously. These were located in the Sahelian zone of Niger with an average annual rainfall of 560 mm. The vertical upward fluxes of particles < 20 <mu>m exported from the study area were estimated from the horizontal sediment fluxes measured using BSNE sand catchers. This mass of exported dust was compared with the vertical downward fluxes of particles of the same size range (< 20 tm) measured using passive CAPYR collectors. Values of deposition recorded in the field and in the fallow were similar. In the field, wind erosion reached its maximum in May and June when the vegetation cover was minimal. In the fallow area, wind erosion was always very low in comparison with the field. It occurred during the strongest storms when the grass cover was minimal. Nevertheless, the net balance between deposition and erosion was highly positive in the fallow areas.
These results have been extrapolated at the scale of the village land units based on the current land use. At this scale, the balance was positive for the arable land, indicating a net deposition of aeolian sediments of +0.36 t ha^{-1} yr^{-1}. However, the complete disappearance of fallow land would result in a balanced budget for the arable land.

Ramsperger, B., Herrmann, L., Stahr, K. 1998. Dust characteristics and source-sink relations in eastern west Africa (SW-Niger and Benin) and South America (Argentinean pampas). Zeitschrift für Pflanzenernahrung und Bodenkunde 161 (4), 357-363.

In order to quantify dust input and to describe its characteristics under different environmental conditions, and to get information on source-sink relation, dust was collected monthly with bulk deposition samplers (open bucket type) in 2 and 4 m height over a 2-3 years period at different; sites in West Africa (SW-Niger and Benin) and in the semi-arid Argentinean Pampas.
Dust input. mineralogy (bulk and clay), chemical properties including total element content and particle-size distribution showed a clear seasonal pattern in eastern West Africa. Far-transported Saharan dust in the dry season could be distinguished from local material transported in the rainy season. In Argentina, high sand content of samples pointed to an important participation of local components in the collected material. This was supported by higher contents of seaborne salts at the coastal sites; and the highest amounts of collected dust at the site of highest wind velocities. Due to the lack bf seasonal differences in dust amount and its characteristics, and the aeolian genesis of the Pampas soils. a separation of local material and long-range dust was not possible.

Reichelt, R., Faure, H. and Maley, J. 1992. Die Entwicklung des Klimas im randtropishen Sahara-Sahelbereich wahrend des Jungquartars. Ein Beitrage sur angewandten Klimakunde, Petermanns geographische Mitteilungen, 136 (2-3), 69-79.

Reichelt, R., Faure, H., Maley, J. Petit-Maire, N. 1992. Die Entwicklung des Klimas im Sahara-Sahel-Bereich während des Jungquartärs; ein Beitrag zur angewandten Klimakunde. In: Klimaentwicklung und Palaeoklimazonen in Afrika. Ed. Hendriks, F., Zentralblatt für Geologie und Paläontologie, Teil I: Allgemeine Angewandte, Regional und Historische Geologie 1991; 11, 2743.

Rendell, H.M., Clarke, M.L., Warren, A., Chappell, A. 2003. The timing of climbing dune formation in southwestern Niger: fluvio-aeolian interactions and the role of sand supply. Quaternary Science Reviews 22 (10-13), 1059-1065.
Contemporary gully erosion has exposed sections in a climbing dune which is banked up against ferricrete terraces along the southern bank of the Niger River in southwestern Niger. The main sand transport direction in this area is from northeast to southwest. and the immediate source of the dune sand is the Niger River. Dune stratigraphy contains evidence of episodic, fluvially controlled accretion. separated by two palaeosols. Channel fills and stone stringers suggest occasional alluvial and colluvial reworking. Infra-red stimulated luminescence dating of the aeolian sands shows that dune development occurred episodically during the African Humid Period (15-5 ka), probably in response to an increase in sediment supply from the Niger River. Soil development occurred during the relatively short-lived period of enhanced aridity associated with the Younger Dryas, driven by weakening of the southwesterly monsoon circulation. Climate-driven dune accretion and further soil development occurred during the Holocene period.

Renssen, H., Brovkin, V., Fichefet, T., Goosse, H. 2003. Holocene climate instability during the termination of the African Humid Period. Geophysical Research Letters 30 (4), art. no. 1184.
The termination of the Holocene African Humid Period (similar to9 to similar to6 kyr BP) is simulated with a three-dimensional global coupled climate model that resolves synoptic variability associated with weather patterns. In the simulation, the potential for "green" and "desert" Sahara states becomes equal between 7.5 and 5.5 thousand years ago, causing the climate system to fluctuate between these states at decadal-to-centennial time-scales. This model result is supported by paleoevidence from the Western Sahara region, showing similar paleohydrological fluctuations around that time. For the present-day, only the desert Sahara state is stable in the model.

Rigby, J.K. 1958. Turbidity currents and displaced fresh-water diatoms. Science 127(3313): 1504.

Ritchie, J.C. 1987. A Holocene pollen record from Bir Atrun, Northwest Sudan. Pollen et Spores 29 (4), 391-340.

Ritchie, J.C. 1993. Imagined and real applications of pollen analysis in reconstructing a Holocene Sahara. Sahara, 5, 111-114.

Ritchie, J.C., Eyles, C.H., Haynes, C.V. 1985. Sediment and pollen evidence for an early to mid-Holocene humid period in the eastern Sahara. Nature 314 (6009), 352-355.
Reports on the discovery of buried lake muds in NW Sudan, in the hyperarid core of the Eastern Sahara, which yield sedimentological and palynological data clearly interpretable as recording an early

to mid-Holocene humid episode that supported a relatively-deep stratified lake surrounded by tropical savanna woodland vegetation.

Ritchie, J.C., Haynes, C.V. 1987. Holocene vegetation zonation in the eastern Sahara. Nature (London) 330 (6149), 645-647.
Recent discoveries of fossil-bearing Holocene lake sediments from the eastern Sahara have brought further confirmation and detail to earlier indirect evidence that a major pluvial episode occurred between 9500 and 4500 yr BP. The botanical results, mainly palynological, show that savanna and desert grassland occupied regions that today are plantless hyperarid deserts. We present here the first evidence from the entire Saharan region of a latitudinal zonation of Holocene vegetation, extending across a 500km wide belt in north-west Sudan. We have completed detailed pollen analyses of three of the several sites discovered so far, and the salient features from two, the northernmost and the southernmost, are presented here to demonstrate a steep gradient of past vegetative cover.

Roberts, N. Lamb, H.F. El Hamouti, N., Barker, P. 1994. Abrupt Holocene hydroclimatic events. Paleolimnological evidence from North-West Africa. In: Millington, A.C. Pye, K. (eds.) Environmental change in drylands: biogeographical and geomorphological perspectives. John Wiley & Sons, Chichester, 163-175.

Robinson, C., El-Baz, F., Ozdogan, M., Ledwith, M., Blanco, D., Oakley, S., Inzana, J. 2000. Use of radar data to delineate palaeodrainage flow directions in the Selima Sand Sheet, Eastern Sahara. Photogrammetric Engineering and Remote Sensing 66 (6), 745-753.
Palaeodrainage directions in the Selima Sand Sheet (centered on 22.5^{o}N, 29^{o}E) were determined using high-resolution, multi-wavelength, multi-polarization Spaceborne imaging Radar (SIR-C) data and the Global Land One-km Base Elevation (GLOBE) Project Digital Elevation Model (DEM). The combined use of these two data sets shows that both large;flood features and later superimposed drainage channels of variable morphology all drain NE and ENE from northwest Sudan toward the Kharga depression in southern Egypt. This is supported by drainage directions deduced from the USGS Global Topography (GTOPO) DEM. These directions are opposite to those of the Trans-African Drainage System (TADS) model in which the large flood features are considered to flow southwest across northeastern Africa into the Chad Basin. Instead, the results show that an internal drainage basin operated in the gently undulating terrain of the Selima Sand Sheet (probably during the Cenozoic period), and that the slope of the North African plate remained generally northeastward during those times. Further, the northeastern parts of the Selima Sand Sheet are likely to be the primary area for ground-water accumulation in southern Egypt.

Rodrigues, D., Abell, P.I., Kröpelin, S. 2000. Seasonality in the early Holocene climate of Northwest Sudan: interpretation of *Etheria elliptica* shell isotopic data. Global and Planetary Change 26 (1-3), 181-187.
The oxygen isotope ratios in the incremental growth layers in the shells of *Etheria elliptica* constitute a proxy record of rainfall patterns, and thus a record of seasonality. Analyses of shells of early Holocene age (6800 C^{14} years BP or 5600 BC) collected from the lower reaches of Wadi Howar, near the confluence of that now-extinct river with the Nile, show an annual pattern of two rainy seasons in the present-day hyperarid southeastern Sahara, similar to that which prevails today in much of East Africa.

Rodwell, M.J., Hoskins, B.J. 1996. Monsoons and the dynamics of deserts. Quarterly Journal of the Royal Meteorological Society 122 (534), 1385-1404 Part B.
The existence of subtropical deserts, such as the Sahara, has often been attributed to the annual-mean, zonal-mean Hadley circulation which shows strong descent in the subtropics. However, the zonal-mean Hadley circulation shows considerable evolution over the course of the year with very strong subtropical descent during winter, but practically no zonal-mean subtropical descent during summer when rainfall over the eastern Sahara and the Mediterranean is least. Charney (1975) proposed a biosphere-albedo feedback mechanism whereby local anthropogenic effects related to over-grazing could affect the radiative balance, enhancing summertime diabatic descent and leading to desertification of the subtropics in general. The present study, which uses an idealized model, suggests a monsoon-desert mechanism for desertification whereby remote diabatic heating in the Asian monsoon region can induce a Rossby-wave pattern to the west. Integral with the Rossby-wave solution is a warm thermal structure that interacts with air on the southern flank of the mid-latitude westerlies causing it to descend. This adiabatic descent is localized over the eastern Sahara and Mediterranean, and over the Kyzylkum desert to the south-east of the Aral Sea, by the mountains of north Africa and

south-west Asia. Trajectories indicate that the monsoon-desert mechanism does not represent a simple 'Walker-type' overturning cell. Instead, the descending air is seen to be mainly of mid-latitude origin. It is speculated that the monsoon-forced adiabatic descent may result in clear air and, therefore, a local diabatic enhancement which effectively doubles the strength of descent. With this mechanism, desertification can be forced by remote changes in monsoon strength rather than by local effects. This conclusion is supported by the observed dramatic strengthening of descent over the Mediterranean and east Sahara during the onset of the Asian monsoon and, on the longer timescale, by relating prehistoric lake-levels to Milankovitch-monsoon forcing. The latter may help to explain the perceived discrepancies between the palaeoclimate of the eastern Sahara and the strength of a 'tropic-wide' monsoon. The monsoon-desert mechanism may not be confined to the Asian monsoon alone and the existence of other monsoon-climate regions over the globe may, in a similar way, explain the observed summertime strengthening of the oceanic sub-tropical anticyclones and the existence of western continental deserts and 'Mediterranean-type' climate regions.

Rohlfs, G. 1874. Quer durch Afrika. Reise vom Mittelmeer nach dem Tschad-See und zum Busen von Guinea. Leipzig, 375 pp.

Romero, O.E., Dupont, L., Wyputta, U., Jahns, S., Wefer, G. 2003. Temporal variability of fluxes of eolian-transported freshwater diatoms, phytoliths, and pollen grains off Cape Blanc as reflection of land-atmosphere-ocean interactions in northwest Africa. Journal of Geophysical Research - Oceans 108 (C5), art. no. 3153.
Fluxes of airborne freshwater diatoms (FD), phytoliths (PH), and pollen grains (PO) collected with sediment traps off Cape Blanc, northwest Africa, from 1988 till 1991 are presented. Both continental rainfall variations and wind mean strength and direction play a key role in the temporal fluctuations of the fluxes of eolian traces in the pelagic realm. Drier conditions in Northern Africa in 1987 could have preceded the high lithogenic input and moderate FD flux in 1988. The PH peak in summer 1988 was probably caused by increased wind velocity. Wetter rainy seasons of 1988/89 might have promoted a significant pollen production in summer 1989, and FD in late 1989 and early 1990, as well as contributed to the reduction of the lithogenic flux in 1989/90. Decreased fluxes of FD, PH and PO, and higher contribution of the 6-11 m m lithogenic fraction in 1991 would mainly reflect minor intensity and decreased amount of continental trade winds. Air-mass backward trajectories confirm that the Saharan Air Layer is predominantly involved in the spring/summer transport. Trade winds play a decisive role in the fall/winter months, but also contribute to the transport during late spring/summer. Origin of wind trajectories does not support a direct relationship between transporting wind-layers and material source areas in Northern Africa. High winter fluxes of eolian tracers and high amount of trade winds with continental origin in summer warn against a simplistic interpretation of the seasonal eolian signal preserved in the sediments off Cape Blanc, and the wind layer involved in its transport.

Romero, O.E., Lange, C.B., Swap, R. and Wefer, G. 1999. Correction to: "Eolian-transported freshwater diatoms and phytoliths across the equatorial Atlantic record: temporal changes in Saharan dust transport patterns (vol. 104, no. C2, pp. 3211-3222, 1999)". Journal of Geophysical Research 104(C5):11225-11226.

Rommerskirchen, F., Eglinton, G., Dupont, L., Guntner, U., Wenzel, C., Rullkotter, J. 2003. A north to south transect of Holocene southeast Atlantic continental margin sediments: Relationship between aerosol transport and compound-specific δC-13 land plant biomarker and pollen records. Geochemistry Geophysics Geosystems 4, art. no. 1101.
We examined near-surface, late Holocene deep-sea sediments at nine sites on a north-south transect from the Congo Fan (4°S) to the Cape Basin (30°S) along the Southwest African continental margin. Contents, distribution patterns and molecular stable carbon isotope signatures of long-chain n-alkanes (C-27-C-33) and n-alkanols (C-22-C-32) are indicators of land plant vegetation of different biosynthetic types, which can be correlated with concentrations and distributions of pollen taxa in the same sediments. Calculated clusters of wind trajectories and satellite Aerosol Index imagery afford information on the source areas for the lipids and pollen on land and their transport pathways to the ocean sites. This multidisciplinary approach on an almost continental scale provides clear evidence of latitudinal differences in lipid and pollen composition paralleling the major phytogeographic zonations on the adjacent continent. Dust and smoke aerosols are mainly derived from the western and central South African hinterland dominated by deserts, semi-deserts and savannah regions rich in C-4 and CAM plants. The northern sites (Congo Fan area and northern Angola Basin), which get most of their Terrestrial material from the Congo Basin and the Angolan highlands, may also receive some material

from the Chad region. Very little aerosol from the African continent is transported to the most southerly sites in the Cape Basin. As can be expected from the present position of the phytogeographic zones, the carbon isotopic signatures of the n-alkanes and n-alkanols both become isotopically more enriched in C-13 from north to south. The results of the study suggest that this combination of pollen data and compound-specific isotope geochemical proxies can be effectively applied in the reconstruction of past continental phytogeographic developments.

Rosema, A., Fiselier, J.L. 1990. Meteosat-based evapotranspiration and thermal inertia mapping for monitoring transgression in the Lake Chad Region and Niger Delta. International Journal of Remote Sensing 11 (5), 741-752.
This paper reports the application of deriving evapotranspiration and thermal inertia from thermal and visible infrared Meteosat data to Sahelian wetlands: the Niger Delta in Mali and the Logone/Chari/Chad system in Chad.

Roset, J.P. 1987. Palaeoclimatic and cultural conditions of neolithic development in the Early Holocene of northern Niger (Air and Ténéré). In: Close, A.E. (ed.) Prehistory of arid North Africa. Southern Methodist Univ. Press, Dallas, 211-234.

Rossi, A.P., Marinangeli, L. 2004. The first terrestrial analogue to Martian dust devil tracks found in Tenere Desert, Niger. Geophysical Research Letters 31 (6), art. no. L06702.
The first example of terrestrial dust devil tracks is presented in this paper. Tracks found in Tenere Desert, Niger are formed by transient events not related to regional winds. Compared to the Martian tracks, Tenere tracks are generally longer and show higher average density. We interpreted these differences as due to different intensities of the dust devil vortices combined with different surface properties. We also suggest that grain size distribution and sorting of surface material is crucial to allow track formation. Major surface changes of Tenere tracks have been observed in selected areas over a time span of 2 years, confirming the very low preservation potential of the tracks. However, no clear evidence for seasonal variations has been found on the available dataset. The Tenere Desert represents a unique site to study the formation and evolution of these peculiar features and to compare their behavior on other planets.

Runge, J. 2002. Holocene landscape history and palaeohydrology evidenced by stable carbon isotope (δC-13) analysis of alluvial sediments in the Mbari valley (5^{o}N/23^{o}E), Central African Republic. Catena 48 (1-2), 67-87.
Pleistocene to Holocene as well as recent trends in climate have an influence on the composition of savanna-forest vegetation fringes in Africa, dominated mainly by savanna (C-4) and mainly forest (C-3) groups of plants. The modified vegetation cover plays an important role on the runoff processes and on the discharge of the draining river systems, Because the majority of forest-savanna borders in Central Africa is situated on geologically old planation surfaces, the main sources of palaeoenvironmental information are alluvial sediments of rivers. Therefore, this study focuses on the examination of alluvial soils and the determination of stable carbon isotopes ($\delta^{13}C$) of organic sediments on the Mbomou plateau and in the Mbari valley in the southeast of the Central African Republic (CAR). It has been shown that there is some evidence for an ongoing increase in C-3-dominated forest plants, reducing the recent extension of savannas in the study area. The most important reasons for this trend are sufficient amount of annual rainfall (> 1500 mm), decrease in bushfire frequency, and negative migration processes of the rural population due to the economic crisis in Central Africa. $\delta^{13}C$ values in fossil soil horizons show that a greater extent of forest on the Mbomou plateau occurred around 7-7.5 ka and between 2.5 and 3 ka. Drier, savanna-dominated vegetation patterns were found at 5 ka and from 1 ka to the present. The more humid and and climate periods during the Holocene partly correspond with high and low lake levels of Lake Chad. The findings also seem to be confirmed by other studies neighbouring Central African regions as Cameroon, Gabon and Congo-Brazzaville (Bateke Plateau), which indicate a more general validity of the findings from the Mbomou plateau, especially for the period since 3 ka.

Said, R. 1983. Remarks on the origin of the landscape of the eastern Sahara. Journal of African Earth Sciences 1(2):153-158.

Salahchourian, M.H., Teherani, S.R.H.M. 1982. Eine photogeologische Luftbildauswertung nördlich und südlich des Enneri Dilenao und Tibesti-Gebirge, Zentral-Sahara, Tschad. Berliner geographische Abhandlungen 32, 99-132.

Salzmann, U., Hölzmann, P., Morczinek, I. 2002. Late Quaternary climate and vegetation of the Sudanian zone of northeast Nigeria. Quaternary Research 58 (1), 73-83.
The Lake Tilla crater lake in northeastern Nigeria (10°23'N, 12°08'E) provides a ca. 17,000 C^{14} yr multiproxy record of the environmental history of a Sudanian savanna in West Africa. Evaluation of pollen, diatoms, and sedimentary geochemistry from cores suggests that dry climatic conditions prevailed throughout the late Pleistocene. Before the onset of the Holocene, the slow rise in lake levels was interrupted by a distinct dry event between ca. 10,900 and 10,500 C^{14} yr B.P., which may coincide with the Younger Dryas episode. The onset of the Holocene is marked by an abrupt increase in lake levels and a subsequent spread of Guinean and Sudanian tree taxa into the open grass savanna that predominated throughout the Late Pleistocene. The dominance of the mountain olive *Olea hochstetteri* suggests cool climatic conditions prior to ca. 8600 C^{14} yr B.P. The early to mid-Holocene humid period culminated between ca. 8500 and 7000 C^{14} yr B.P. with the establishment of a dense Guinean savanna during high lake levels. Frequent fires were important in promoting the open character of the vegetation. The palynological and palaeolimnological data demonstrate that the humid period terminated after ca. 7000 C^{14} yr B.P. in a gradual decline of the precipitation/evaporation ratio and was not interrupted by abrupt climatic events. The aridification trend intensified after ca. 3800 C^{14} yr B.P. and continued until the present.

Salzmann, U., Waller, M. 1998. The Holocene vegetational history of the Nigerian Sahel based on multiple pollen profiles. Review of Palaeobotany and Palynology 100 (1-2), 39-72.
Four Holocone pollen diagrams are presented from interdune depressions in the Manga Grasslands (northeastern Nigeria near 13 N). These sequences are interpreted using modern pollen spectra, statistical analyses and groupings based on phytogeographical affinity (Long Distance, Sahelian, Sudanian, Guinean). The roles of climate change and anthropogenic activity in the vegetational history of the central part of Sahel are evaluated. Particular attention is given to the separation of regional (Manga Grasslands) from local (individual depressions) vegetation trends. Humid conditions in the early and mid-Holocene (from 10,000 to ca. 3300 yr B.P.) enabled the establishment of, and sustained, swamp forest vegetation in the interdune depression. The main taxa (Alchornea, Syzgium and Uapaca) have Guinean affinities. The surrounding dunefields consisted of open savanna with Sahelian and Sudanian (e.g., Combretaceae, Detarium) elements present. Drier conditions ca. 3300 yr B.P. produced abrupt changes in pollen stratigraphy and led to the establishment of the modern vegetation of the Manga Grasslands. Although occupied since at least 3700 yr B.P., there is little evidence of human activity in the pollen diagrams. The nomadic pastoralism practiced by the human occupants of the Manga Grasslands may be palynologically undetectable. Although the Holocene vegetational history of the Manga Grasslands appears to have been primarily controlled by climate, caution should be exercised before drawing climatic inferences from these pollen sequences. For the early and mid-Holocene differences of ca. 1000 years exist in the timing of vegetation changes between the individual depressions. While water levels in the depressions are likely to be coupled to climate, the vegetation response appears to be strongly influenced by local conditions (in particular variations in the depth of depressions and so the relative height of water table). In addition, the Guinean swamp forest vegetation of the early and mid-Holocene is unlikely to be representative of vegetation trends at this latitude, but rather developed extrazonally as a result of the particular topographic hydrological conditions prevailing in the Manga Grasslands. The problems of lags between climate and vegetation change and the presence of extrazonal vegetation, experienced in the Manga Grasslands, are likely to be common to other Sahelian pollen sites. The palynological information presently available for this zone is deemed insufficient for detailed subcontinental scale reconstructions of vegetation and climate to be attempted.

Schaber, G.G., McCauley, J.F., Breed, C.S. 1997. The use of multifrequency and polarimetric SIR-C/X-SAR data in geologic studies of Bir Safsaf, Egypt. Remote Sensing of Environment 59 (2), 337-363.
Bir Safsaf, within the hyperarid "core" of the Sahara in the Western Desert of Egypt, was recognized following the SIR-A and SIR-B missions in the 1980s as one of the key localities in northeast Africa, where penetration of dry sand by radar signals delineates previously unknown, sand-buried paleodrainage valleys ("radar-rivers") of middle Tertiary to Quaternary age. The Bir Safsaf area was targeted as a focal point for further research in sand penetration and geologic mapping using the multifrequency and polarimetric SIR-C/X-SAR sensors. Analysis of the SIR-C/X-SAR data from Bir Safsaf provides important new information on the roles of multiple SAR frequency and polarimetry in portraying specific types of geologic units, materials, and structures mostly hidden from view on the

ground and on Landsat TM images by a relatively thin, but extensive blanket of blow sand. Basement rock units (granitoids and gneisses) and the fractures associated with them at Bir Safsaf are shown here for the first time to be clearly delineated using C- and L-band SAR images. The detectability of most geologic features is dependent primarily on radar frequency, as shown for wind erosion patterns in bedrock at X-band (3 cm wavelength), and for geologic units and sand and clay-filled fractures in weathered crystalline basement rocks at C-band (6 m) and L-band (24 cm). By contrast, Quaternary paleodrainage channels are detectable at all three radar frequencies owing, among other things, to an usually thin cover of blow sand. The SIR-C/X-SAR data investigated to date enable us to make specific recommendations about the utility of certain radar sensor configurations for geologic and paleoenvironmental reconnaissance in desert regions.

Schiffers, H. 1957. Le Borkou et ses habitants (Borkou and its inhabitants). Travaux de l'Institut de Recherches Sahariennes 15:65-88. (in French with English abstract)

Schiffers, H. 1973. Die Südgrenze der Sahara und ihr südliches Randgebiet. In: Die Sahara und ihre Randgebiete; Darstellung eines Natur-Grossraumes; Teil B, Die Teilgebiete der Sahara und ihrer Randzonen; III. Band, Regionalgeographie (Die Landschaften). Afrika Studien 62, 654-728.

Schneider, J.L. 1967. Evolution du dernier lacustre et peuplements préhistoriques aux pays bas du Tchad. Bulletin de l'Association sénégalaise pour l'Etude du Quaternaire ouest-africain 14-15: 18-23.

Schneider, J.L. 1969. Evolution du dernier lacustre et peuplements préhistoriques aux pays bas du Tchad. Bulletin de l'Institut fondemontal d'Afrique noire, Série A. Sciences naturelles 31 (1), 259-263.

Schneider, J.L. 1991. Contribution of isotopic data to palaehydroclimatological investigations - the Late Pleistocene formations of Northern Kanem (Chad). Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences, Série II 312 (8), 869-874.
The O-18 profile of the ice core from Camp Century (Northern Greenland) is used to propose a lithological section of the late Pleistocene of Chad. Eight formations alternately lacustrine/arid are shown for the period 73-12 ky B.P. Isotopic data also provide hydrogeological information.

Schneider, J.L. 1991. The main hydroclimatological events occurred in the Sahelo-Saharan Zone since 1,200 AD. Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences, Série II 312 (1), 93-96.
The oxygen-18 profile of the ice core from Camp Century (Northern Greenland) shows an accurate correlation with the geological data for the late Pleistocene in Chad. The correlation is also fairly accurate as regards the climatic variations which have occurred in the Sahelo-Saharan area during the last milennium. Concordance is established between:
- the cold periods in the Northern hemisphere and the desertification-famine periods in Africa, especially during the 13th century and most notably during the 17th century.
- climatic optima and the height of African Empires (Kanem, Ghana: until the end of 11th century: Mali, Mossi, Ethiopia: 14th century).
The history of Lake Chad shows seven transgression-regression "cycles".

Schneider, J.L. 1996. Chad over the last 25,000 years, Oslisly, R., Anthropologie 100 (2-3), 496-497.

Schneider, S.R., Mcginnis, D.F., Stephens, G. 1985. Monitoring Africa's Lake Chad basin with Landsat and NOAA satellite data. International Journal of Remote Sensing 6 (1), 59-73.
Data from the Landsat and NOAA polar orbiting satellites are used to analyse the Lake Chad basin in Africa. AVHRR measurements spanning the November 1981-November 1982 period are used to monitor lake boundaries, vegetation growth and surface temperature patterns. Historical Landsat data from the 1972-81 period are studied to track changes in lake and basin boundaries. Observations of lake conditions, as viewed from satellites, are related to the recent climate record.

Schulz, E. 1972. Pollenanalytische Untersuchungen Pleistozäner und Holozäner Sedimente des Tibesti-Gebirges (S-Sahara). Palaeoecology of Africa and the surrounding Islands and Antarctica Schulz-Erhard 7, 14-16.

Schülz, E. 1984. The recent pollen rain in the eastern central Sahara - A transect between northern Libya and southern Niger. Palaeoecology of Africa and the Surrounding Islands 16:245-253.

Schulz, E. 1987. Die holozäne Vegetation der zentralen Sahara (N-Mali, N-Niger, SW-Libyen). Palaeoecology of Africa 18, 143-161.

Schulz, E. 1988. Der Suedrand der Sahara. In: Geowissenschaftliche Untersuchungen in Afrika. Eds. Hagedorn, H., Baumhauer, R. Würzburger geographische Arbeiten 69, 167-210.

Schulz, E. 1990. Zwischen Syrte und Tschad- Der Pollenniederschlag in der Sahara.In: Gabriel, B.(ed.) Forschungen in ariden gebieten, Berliner Geographisce Studien 30, 193-220.

Schulz, E. 1991. Paléoenvironnents dans le Sahara central pendant l´Holocène. Palaeoecology of Africa, 22, 191-201.

Schulz, E. 1991. Holocene environments in the central Sahara. Hydrobiologia, 214, 359-365.

Schülz, E. 1993. Dust formation and transport in the Sahara and adjacent regions. In: Thorweihe, U. and Schandelmeier, H. (eds), Geoscientific research in Northeast Africa; Proceedings of the international conference. Balkema. Rotterdam, pp. 647-648.

Schulz, E., 1994. Les indicateurs limniques holocènes au Nordest du Niger (les pigments des plantes, signaux de l´existence des communités algaires et bacteriennes planctoniques et benthiques. In: Maire, R., Pomel, S. Salomon, J.N.(eds). Enregistreurs et indicateurs de l´evolution de l´environnement en zone tropicale. Presses universitaires de Bordeaux, 73-83.

Schulz, E. 1998. The southern margin of Sahara in the Chad republic. Vegetation, soil, and present pollen rain. Geo-Eco-Trop 22(-), 101-112.
The North of the Chad republic exposes a double transition from the contracted vegetation of the desert to diffuse vegetation types. The first is situated in the high mountain region of the Tibesti above 3000 m's altitude as a change to the semidesert of *the Artemisia-Ephedra*-type. The second represents the transition within the *Acacia-Panicum*- units from linear to diffuse repartition. This takes place between 15^{o}N and 16^{o}N. The extended zone of transition is characterized by the densified linear *Acacia-Maerua-Capparis*-units, their change to the saharan savannas and finally to the savannas of the Sahel at about 14^{o}N. Within this region there is a large belt of achabs, receiving regular precipitations out of the contact between the monsoonal and haramattan air masses. The present dynamic of soil formation is restricted to the development of pellicular surface structures and their superposition whereas vertisol activities characterize the center of large inondation plains. Mesurements of the present pollen rain was done in march and april 1997 with help of soil and air filters. The results show a clear representation of the several transitions of the plant cover by the elements of the tree vegetation. The zone of the frequent achab floras is characterised by the maxima of the elements of the long distance transport both from the North (*Artemisia, Alnus, Betula, Picea*) as from the South (*Celtis, Diospyros andt Combretaceae*).

Schulz, E., Agwu, Ch., Dupont, L.,Jahns, S., Niedermeier,N. ,Salzmann,U. 1999. The Holocene landscape and vegetation history of northern an western Africa. A palaeoecological atlas. Http://www.uni-wuerzburg.de/geographie/fachi/pal_atlas_afrika/index_atlas_htm

Schulz, E., Joseph, A., Baumhauer, R., Schultze, E. 1990. Upper Pleistocene and Holocene history of the Bilma-region (Kawar, NE-Niger) - Histoire de la region de Bilma du Pleistocene superieur et a l'Holocene (Kawar, NE-Niger). In: Etudes récentes sur la géologie de l'Afrique; 15^{e} colloque de géologie africaine; résumes detailles. Eds. Rocci, G., Deschamps, M., Publication Occasionnelle - Centre International Pour la Formation et les Echanges Géologiques, 22, 112.

Schulz, E., Joseph, A., Baumhauer, R., Schultze, E., Sponholz, B. 1990. Upper Pleistocene and Holocene history of the Bilma region (Kawar, NE Niger). In: Etudes récentes sur la géologie de l'Afrique; 15^{e} colloque de géologie africaine; résumes detailles. Eds. Rocci, G., Deschamps, M., Publication Occasionnelle - Centre International Pour la Formation et les Echanges Géologiques, 22, 281-284.

Schulz, E., Pomel, S., Abichou, H., Salzmann, U. 1995. Climate and man, questions and answers from both sides of the Sahara. 2^{e} Symposium on the Palynology of Africica, Occasional Publication. CIFEG,

Tervuren (3), 35-47.

Schuster, M., Duringer, P., Ghienne, J.F., Bano, M., Brunet, M., Vignaud, P., Andossa, L. 1999. Dynamique transgressive et régressive des lacs de poche sahariens; exemple de lacs holocénes a diatomites du Tchad. In: &^{e} Congres français de Sédimentologie; Université de Nancy I, Vandoevre-les-Nancy, Institut national polytéchnique de Lorraine, Nancy, etc. Association français des Sédimentologists 33, 275-276.

Schuster, M., Duringer, P., Ghienne, J.F., Brunet, M., Vignaud, P., Mackaye, H.T. 2001. Les conglomerats cotiers du lac Mega-Tchad autour des paléo-iles du Hadjer El Khamis. In: *^{e} congres français de sédimentologie; livre des resumes. Centre National des Recherches Scientifiques, Departement des Sciences de l'Univers, Association des Sédimetologists françaises 36, 337-338.

Schuster, M., Duringer, P., Ghienne, J.F., Vignaud, P.R., Beauvilain, A., Mackaye, H.T., Brunet, M. 2003. Coastal conglomerates around the Hadjer el Khamis inselbergs (western Chad, central Africa), New evidence for Lake Mega-Chad episodes. Earth Surface Processes and Landforms 28 (10), 1059-1069.
This paper reports on a study dealing with the rhyolitic inselbergs of Hadjer el Khamis that formed palaeoislands during Lake Mega-Chad events. Field observations have shown that: (1) conglomeratic patches of immature to mature clasts are preserved at the feet of the Hadjer el Khamis inselbergs; (2) in cross-section, their profile reveals a well defined cliff platform junction at a constant elevation (325 m). The monolithological clasts show all degrees of roundness, from angular cobbles to well rounded pebbles. This wide range of maturity suggests a coastal origin for these cobbles. The system was permanently fed with angular clasts, which were progressively worn by waves. Cobbles that were wave-worked for the longest time are the best rounded. The cliff-platform junction is the result of erosion by waves, which attacked and undercut the inselberg cliffs during Lake Mega-Chad events. Asymmetrical erosion profiles moreover suggest a wind regime dominated by SW to NE oriented winds. These interpretations have two implications. The elevation of the cliff-platform function is an indication of the highest water level of Lake Mega-Chad at 320-325 in, which is in agreement with other observations elsewhere in the basin. The SW to NE oriented winds show that monsoon-related winds were prevalent during Lake Mega-Chad events, suggesting the Inter-Tropical Convergence Zone was located higher in latitude than today

Schuster, M., Duringer, P., Ghienne, J.F., Vignaud, P., Mackaye, H.T., Likius, A., Brunet, M. 2006. Science 311(5762), 821.

Schuster, M., Duringer, P., Ghienne, J.-F.O., Vignaud, P., Mackaye, H.T. and Likius, A.B., M. 2006. Revisiting the age of the Sahara Desert: Response to discussion re. "The age of the Sahara Desert" by M. Schuster et al. (10 Feb., p. 821). Science NS 312(5777):1138-1139.

Schuster, M., Roquin, C., Duringer, P., Brunet, M., Caugy, M., Fontugne, M., Macaye, H.T., Vignaud, P., and Ghienne, J-F. 2005: Holocene lake Mega-Chad palaeoshorelines from space. *Quaternary Science Reviews* 24, 1821-1827.

Sebag, D., Verrecchia, E.P., Durand, A. 1999. Biogeochemical cycle of silica in an apolyhaline interdunal Holocene Lake (Chad, N'Guigmi Region, Niger). Naturwissenschaften 86 (10), 475-478.
During the Holocene, the apolyhaline conditions in interdunal ephemeral lakes in the Lake Chad region led to various diagenetic processes, which resulted in: (a) clay authigenesis, (b) organic matter lithification (plants and cyanobacterial mats), (c) precipitation of sodium silicate (magadiite, kenyaite, zeolite), and (d) chert neoformation. Each step in this diagenetic process involves silica, which can be highly mobile under such conditions. Therefore, the paleoenvironmental variations can be investigated using the Si cycle.

Servant, M. 1969. Etat actuel des recherches stratigraphiques sur le quaternaire dans les pays-bas du Tchad. Bulletin de Liaison – Association Sénégalaise pour l'Etude du Quaternaire de l'Ouest Africain 22, 105-111.

Servant, M. 1970. Donnees stratigraphiques sur le quaternaire supérieur et récent au nord-est du lac Tchad. Cahiers d'ORSTOM, Série Géologie 2 (1), 95-114.

Servant, M. 1972. Les séries sédimentaires continentales du Plio-Quaternaire dans le bassin du Tchad. Bulletin de Liaison – Association Sénégalaise pour l'Etude du Quaternaire de l'Ouest Africain 35-36, 84.

Servant, M., 1973. "Sequences continentales et Variations climatiques: Evolution du bassin du Tchad au CenozoiqueSuperieur." These d'Etat, University of Paris, Paris, 348pp.

Servant, M. 1980. Séquences continentales et variations climatiques: évolution du bassin du Tchad au Cénozoique supérieur, Traveaux et Documents d'ORSTOM, 159, 574 pp.

Servant, M. 1983. Séquences continentales et variations climatiques; évolution du bassin du Tchad au Cénozoique Superieur. Travaux et Documents de l'ORSTOM 159, 573 pp.

Servant, M., Ergenzinger, P., Coppens, Y. 1969. Datations absolues sur un delta lacustre quaternaire au sud du Tibesti (Angamma). Comptes rendus sommaires des Séances de la Société géologique de France 8, 313-314.

Servant, M. and Servant, S. 1970. Les formations lacustres et les diatomées du Quaternaire récent du fond de la cuvette tchadienne. Revue de géographie physique et de géologie dynamique, Deuxième série, 12(1):63-76.

Servant, M., Servant-Vildary, S. 1972. Nouvelles données pour une interpretation paléoclimatique de séries continentales du Bassin Tchadien (Pléistocène récent, Holocène). Palaeoecology of Africa and the surrounding Islands and Antarctica 6, 87-92.

Servant, M., Servant, S. 1973. Le Plio-Quaternaire du bassin du Tchad. In: Le Quaternaire; geodynamique, stratigraphie et environnement. Bulletin de l'Association française pour l'Etude du Quaternaire 36, Supplement, 169-175.

Servant, M., Servant-Vildary, S. 1980. L'environnement Quaternaire du bassin du Tchad. In: The Sahara and the Nile; Quaternary environments and prehistoric occupation in northern Africa. Eds. Williams, M.A.J. and Faure, H., Balkema, Rotterdam, 133-162. UCL GEOGRAPHY QF 19 WIL

Servant, M., Servant, S., Delibrias, G. 1969. Chronologie du quaternaire récent des basses regions du Tchad. Comptes rendus hébdomidaires des Séances de l'Académie des Sciences, Série D, Sciences naturelles 269 (17), 1603-1606.
Upper Pleistocene-Recent, sedimentary formations, paleoclimatology, carbon-14 dates.

Servant, S. 1970. Répartition des diatomées dans les séquences lacustres holocènes au nord-est du lac Tchad; premieres observations et pérspectives de recherché. Cahiers d'ORSTOM, Série Géologie 2 (1), 115-126. 1970.

Servant, S. 1972. Le rôle des études sur les diatomées dans l'interprétation des séries continentales Plio-Quaternaires du Tchad. Bulletin de l'Association française pour l'Etude du Quaternaire 35-36, 85.

Servant-Vildary, S. 1973. Le Plio-Quaternaire ancien du Tchad; evolution des associations de diatomées, stratigraphie, paléoecologie. Cahiers d'ORSTOM, Série Géologie 5 (2), 169-215.

Servant-Vildary, S. 1978. Etude des diatomées et paléolimnologie du Bassin Tchadien au Cenozoique Superieur, 2 Tomes. Travaux et Documents de l'ORSTOM 84, 319 pp.

Servant-Vildary, S. 1979. Paléolimnologie des lacs du bassin Tchadien au Quaternaire récent. Palaeoecology of Africa and the surrounding Islands and Antarctica 11; Covering the years 1975-1977, 65-78.

Simons, P. 1973. Der Östen der Sahara. In: Schiffers, H. (ed), Die Sahara und ihre Randgebiete, 3. Regionalgeographie, IFO Institut fuer Wirtschaft München Afrikan Studien, Weltforum Verlag, Munich 62:433-435.

Skowronek, A. 1985. Zur Morpho- und Pedostratigraphie der zentralen Sahara, Zeitschrift für Geomorphologie, Supplementband, 56, 69-87.
Central Saharan landsurfaces of different ages and their soils are morphochronologically classified according to L.C.King. A deeply weathered Upper Cambrian pediplain and broadly exhumed structural surfaces of the Upper Ordovician are described. The African denudational landsurface (Upper Cretaceous - Middle Cenozoic) is the most important datum level for the following relief development. This development can easily be traced up to present by means of soil formations and absolute datings (K/Ar, "SUP 14"C). The fossil and relic paleosoils of the volcanic Atakor indicate that out of mountains semiarid-arid climatic conditions have been dominating since Miocene.

Skowronek, A. 1985. Zur känozoischen Klimaentwicklung der zentralen Sahara nach bodenstratigraphischen Befunden, Colloquiums, 10, Geomethodica, Veroffentlichungen des basler geomethodischen Colloquiums, 123-151.

Skowronek, A. 1987. Zur Bodenstratigraphie im nördlichen Afrika. Palaeoecology of Africa and the Surrounding Islands 18, 209-216.

Sommer, G. 2001. Humans and animals in the basin of Lake Chad by Baroin C., Boutrais J., Anthropos 96 (2), 612-613.

Soulie-Märsche, I. 1993. Contribution of fossil charophytes to research on abrupt climatic changes, Bulletin de la Société géologique de France 164 (1), 123-130.
The present paper describes two selected examples where the occurrence of fossil charophytes is related to sudden changes affecting continental waterbodies. The first example concerns the very fast appearence of surface water in the El Haijad depression, Taoudenni, Mali, which is demonstrated by the first charophyte-layer immediately overlying an originally arid substrate. The second example is indicative of a sudden and definite drying-up of a former freshwater lake where the abundant charophyte-flora of Wadi Shaw (NW Sudan) has been preserved in the form of its extremely fragile vegetative parts. The chronological framework as well as the possible interpretations of these phenomena with regard to Holocene climatic changes in northern Africa are discussed.

Soulie-Märsche, I. 1993. Diversity of Quaternary aquatic environments in NE Africa as shown by fossil charophytes. In: Geoscientific research in Northeast Africa; proceedings of the international conference. Eds. Thorweihe, H., Schandelmeier, H., Balkema, Rotterdam, 575-579.

Steffan, E.-M. 1983. Untersuchungen zur Morphologie und Genese der aeolischen Akkumulationsformen der Ostsahara mit Hilfe der Fernerkundung. Berliner geowissenschaftliche Abhandlungen, Reihe D 188, 137 pp.

Stokes, S., Bailey, R.M., Fedoroff, N., O'Marah, K.E. 2004. Optical dating of aeolian dynamism on the West African Sahelian margin. Geomorphology 59 (1-4), 281-291.
The Sahelian Margin of West Africa is widely recognised as an area of recent environmental catastrophe and human suffering arising from food shortage and land degradation associated with prolonged drought. The propensity of this region to suffer drought has been related, using environmental data collected during the period of instrumental records, to a combination of low mean annual rainfall levels and a high degree of rainfall variability, which relates to sea surface temperature anomalies in the adjacent tropical Atlantic Ocean. Despite the significant environmental and human consequences of such droughts, there is a paucity of long-term environmental data for the West African Sahel. Aeolian dune reactivations in this area are a potentially highly useful environmental archive of past periods of extended drought conditions, which may have resulted in localised or widespread dune reactivation. Here we describe the initial results from an ongoing programme of research, which seeks to develop a detailed record of past dune reactivations in Mali. We find evidence for repeated Holocene dune reactivation events and a significant number of reactivations, which commenced at the time of onset of the last major drought cycle in the early 1970s. We obtain ages as young as 20-30 years for some significant dune units (thickness up to 1 m) and describe the results of experiments which test the performance of our dating exercise. We specifically test for the significance of preheat temperature on single aliquot regeneration (SAR) equivalent dose determinations and recycling ratios; neither are found vary significantly as a function of preheating. Optical dating of sand sized quartz could provide a useful tool for palaeogeographical mapping of ancient and historical dune reactivations in this region and elsewhere.

Stokes, S., Horrocks, J. 1998. Reconnaissance survey of the linear dunes and loess plains of northwestern Nigeria; granulometry and geochronology. Quaternary deserts and climatic change. Eds. Alsharhan, A.A., Glennie, K.W., Whittle, G.L. and Kendall, C.G.S.C., Balkema, Rotterdam Alsharhan, pp. 165-174. UCL GEOGRAPHY F 22 ALS

Stokes, S., Maxwell, T.A., Haynes, C.V.Jr., Horrocks, J. 1998. Latest Pleistocene and Holocene sand-sheet construction in the Selima sand sea, eastern Sahara. In: Quaternary deserts and climatic change. Eds. Alsharhan, A.A., Glennie, K.W., Whittle, G.L. and Kendall, C.G.S.C., Balkema, Rotterdam Alsharhan, pp. 175-183. UCL GEOGRAPHY F 22 ALS

Stoorvogel, J.J., van Breemen, N., Janssen, B.H. 1997. The nutrient input by Harmattan dust to a forest ecosystem in Cote d'Ivoire, Africa. Biogeochemistry (Dordrecht) 37 (2), 145-157.
During December and January, dry northeasterly surface winds (the Harmattan) distribute dust over West Africa. Rate of deposition and some chemical and physical characteristics of Hammattan dust were measured in Tdi National Park in the southwest corner of Cote d'Ivoire during the 1990-1991 dry season. The dust deposition was estimated by the classical water-filled basin method and by using canopy drip to account for deposition on tree canopies. Contamination by local biotic debris in both, water-filled basin and canopy drip collectors, was corrected for by using Ti (which appears to be wholly of atmospheric origin) as a reference element. Harmattan dust in Tai consisted mainly of kaolinitic silt finer than that collected in North Nigeria, closer to the source area in the Chad basin. The estimates of seasonal deposition rates were 33 to 47 kg ha^{-1} for the water-filled basin method and around 80 kg ha^{-1} for the canopy drip method. The higher value in canopy drip was in agreement with expected higher deposition of fine dust on the canopies than on a water surface, and was therefore considered more reliable to estimate nutrient inputs by Harmattan dust deposition. The seasonal nutrient input by dust was thus estimated to be 0.11 kg ha^{-1} for P, 2.5 kg ha^{-1} for K, 3.5 kg ha^{-1} for Ca and 0.4 kg ha^{-1} for Mg.

Street-Perrott, F.A., Holmes, J.A., Waller, M.P., Allen, M.J., Barber, N.G.H., Fothergill, P.A., Harkness, D.D., Ivanovich, M., Kroon, D., Perrott, R.A. 2000. Drought and dust deposition in the West African Sahel: A 5500-year record from Kajemarum Oasis, northeastern Nigeria. Holocene 10 (3), 293-302.
A high-resolution, multiproxy palaeolimnological record from the Manga Grasslands, northeastern Nigeria, spanning the last 5500 calendar years, reveals the episodic deterioration in Sahelian climate as significant biogeophysical thresholds were crossed. Desert-dust deposition began to increase similar to 4700 cal. BP. Rainfall during the summer-monsoon season declined permanently after 4100 cal. BP. A further significant change in atmospheric circulation, giving rise to multidecadal to centennial-scale droughts and enhanced dust deposition, occurred similar to 1500 cal. BP. Hence, the post-1968 Sahel drought is not unique. The prolonged arid episode that occurred around 1200-1000 cal. BP in Ethiopia, the Sahel and tropical Mexico may have been linked to an abrupt cooling event in the North Atlantic and to a cluster of intense El Nino-Southern Oscillation events in the Eastern Equatorial Pacific.

Street-Perrott F.A., Perrott, R.A. 1993. Holocene vegetation, lake levels and climate of Africa. In: Global climates since the last glacial maximum, Ed. Wright, H.E., Kutzbach, J.E., Webb, T., Ruddimer, W.F., Street-Perrott, F.A. and Bartlein, P.J., University College Press, London, pp. 318-326. UCL GEOGRAPHY E 60 WRI

Sturchio, N.C., Lu, Z.T., Purtschert, R., Lehmann, B.E., Sultan, M., Du, X., Mueller, P., Lorenzo, R., El-Alfy, Z., El-Kaliouby, B 2003. Million-year-old Nubian Aquifer groundwater dated by atom counting of krypton-81. In: Geological Society of America, 2003 annual meeting. Abstracts with Programs - Geological Society of America 35 (6), 412.
Beneath a $2X10^6$ km^2 area of the hyperarid Western Desert of Egypt and adjacent portions of eastern Libya, northeastern Chad, and northwestern Sudan lies an immense reservoir of fresh water in the Nubian Aquifer system. This is a fossil groundwater reservoir with recharge that is minor compared to natural discharge and pumping for agricultural and industrial use.a Its water volume (approximately $5X10^4$ km^3) is equivalent to about 500 years of Nile River discharge. Although there have been a large number of radiocarbon analyses of Nubian aquifer water, indicating that some samples have ages (mean residence times) = $5X10^4$ years, and hydrologic models indicate ages up to 10^6 a, there has not yet been a definitive measurement of the age of the Nubian aquifer water and its variation along flowpath. An outstanding question is whether recharge has been restricted mainly to the highlands in

the southwest, or has been distributed regionally, during humid climate periods during the Quaternary; each of these recharge modes results in a different distribution of natural radioactive tracers within the aquifer. We address this question using measurements of ^{81}Kr, a new tool for groundwater dating. ^{81}Kr has been recognized as an ideal tracer for groundwater dating in the 50,000-1,000,000-year range, but its low abundance (approximately 10^3 atoms/L H_2O) has made routine measurement nearly intractable. We have applied a new analytical method, atom-trap trace analysis (ATTA) (Chen et al., 1999, Science), to measure the ^{81}Kr abundance in samples of Nubian aquifer groundwater. Six groundwater samples were taken from wells screened in the deeper portion of the aquifer (600-1200 m) in major oasis areas of the Western Desert (Baris, Kharga, Dakhla, Farafra, Bahariya). Dissolved gas was bulk-stripped from water in the field. The Kr was separated from the bulk gas and analyzed by low-level counting (LLC) for ^{85}Kr at Bern. It was then spiked with ^{85}Kr, analyzed again by LLC, and shipped to Argonne for analysis of ^{81}Kr/^{85}Kr by ATTA. ^{81}Kr ages of the water samples, obtained by comparing their ^{81}Kr/Kr ratios with that of modern air, range from approximately 200 to approximately 1,000 ka. Ages increase with distance along the flowpath and correlate well with ^{36}Cl/Cl ratios.

Swezey, C. 2006. Revisiting the age of the Sahara Desert: Discussion re. "The age of the Sahara Desert" by M. Schuster et al. (10 Feb., p. 821). Science NS 312(5777):1138-1139.

Szabo, B.J., Haynes, C.V.Jr., Maxwell, T.A. 1995. Ages of Quaternary pluvial episodes determined by uranium-series and radiocarbon dating of lacustrine deposits of Eastern Sahara. Palaeogeography, Palaeoclimatology, Palaeoecology 113 (2-4), 227-241.
As documented by radiocarbon dating and geoarchaeological investigations, the now hyperarid northwestern Sudan and southwestern Egypt experienced a period of greater effective moisture during early and middle Holocene time, about 10-5 ka. We have used the uranium-series technique to date lacustrine carbonates from Bir Tarfawi, Bir Sahara East, Wadi Hussein, Oyo Depression, and the Great Selima Sand Sheet localities. Results indicate five paleolake-forming episodes occurred at about 320-250, 240-190, 155-120, 90-65 and 10-5 ka. Four of these five pluvial episodes may be correlated with major interglacial stages 9, 7, 5e, and 1; the 90-65 ka episode may be correlated with substage 5c or 5a. Our results support the contention that past pluvial episodes in North Africa corresponded to the interglacial periods farther north. Ages of lacustrine carbonates from existing oases and from the sand sheet fail to indicate pluvial conditions between about 60 and 30 ka. Age results and field relationships suggest that the oldest lake- and ground-water-deposited carbonates were much more extensive than those of the younger period, and that carbonate of the latest wet periods were geographically localized within depressions and buried channels.

Tadros, M.T.Y., El-Metwally, M., Hamed, A.B. 2002. Determination of Angstrom coefficients from spectral aerosol optical depth at two sites in Egypt. Renewable Energy 27 (4), 621-645.
Angstrom Turbidity Coefficients (ATC) are estimated from Aerosol Optical Depth by using spectral broadband data. These data are carried out from Pyrheliometric measurements in the period 1991-96 for two sites of different climatological and environmental view; the first one is a highly polluted urbanized site (Cairo), while the other is an unpolluted and site (Aswan). SMARTS2 model proposed by Gueymard and SPCTRAL2 model proposed by Bird and Riordan, with two pairs of spectral broadbands, are used to select the suitable spectral broadband for estimating ATC. The turbidity levels increase during the two transition seasons, spring (due to Khamasin depressions coming from Great Sahara) and autumn (due to extend of Sudan monsoon trough), in addition to summer season. The subsidence inversion is stronger and leads to trap the pollution in the boundary layer in summer. The mean average values of ATC, over the all period, are alpha=0.477, 0.817 and beta=0.283, 0.144 for Cairo and Aswan respectively. Turbidity level in Cairo is higher than that in Aswan because the two big industrial areas Helwan and Shoubra El-Kheima surround Cairo, in addition to traffic.

Talbot, M.R. 1980. Environmental responses to climatic change in the West African Sahel over the past 20,000 years. In: The Sahara and the Nile; Quaternary environments and prehistoric occupation in northern Africa, Ed. Williams, M.A.J., Faure, H., Balkema, Rotterdam, 37-62. UCL GEOGRAPHY QF 19 WIL
Reactivation of dunes between 20 000 and 12 000 BP reflects a decrease in rainfall and stronger trade winds rather than any major change in atmospheric circulation pattern. During 12 000 to 8 000 BP the Sahel rivers and lakes received runoff from the Saharan uplands as well as from the summer rains. Desiccation led to seasonal flow, and by 4000 BP most lakes were dry.

Talbot, M.R. 1981. Holocene changes in tropical wind intensities and rainfall: evidence from southeast Ghana, Quaternary Research, 16 (2), 201-220.
Remnants of a fixed aeolian dune ridge occur along the SE coast of Ghana, just behind the present shoreline. Aeolian sands also cover extensive areas of the Accra Plains. The sediments are of mid-Holocene age and were deposited during the interval 4500 B.P.-3800 yr B.P., when the southwesterly winds were stronger than they are at present and much of tropical Africa seems to have been subject to marked aridity.

Talbot, M.R. 1984. Late Pleistocene rainfall and dune building in the Sahel, Palaeoecology of Africa, 16, Balkema, Rotterdam, 203-214.

Talbot, M.R., Livingstone, D.A., Palmer, P.G., Maley, J., Melack, J.M., Delibrias, G., Gulliksen, S. 1984. Preliminary results from sediment cores from Lake Bosumtwi, Ghana. Palaeoecology of Africa 16, 173-192.
Tanaka, Taichu. Y. and Chiba, Masaru 2006. A numerical study of the contributions of dust source regions to the global dust budget. In: Dong Chaohua and Shao Yaping (editor) Monitoring and modelling of Asian dust storms. Global and Planetary Change 52 (1-4):88-104. .
Contributions of the nine potential dust source regions (North and South Africa, the Arabian Peninsula, Central Asia, eastern and western China, North and South America, and Australia) to the global dust budget are investigated with a global dust transport model. A six-year simulation (1990 to 1995) indicates that the greatest contributor to the global dust budget is found to be North Africa (the Sahara Desert), which accounts for 58% of the total global dust emission and 62% of the total global dust load in the atmosphere. Australian dust dominates the southern hemisphere. The dust emission and atmospheric dust load originating from East Asia (eastern and western China) are estimated to be 214 Tg yr (super -1) and 1.1 Tg, respectively, which are 11% and 6% of the total global dust emission and dust load. Dust from East Asia dominates the atmospheric load over China and Mongolia (about 70%), Korea (60%), Japan (50%), and the North Pacific Ocean (40%). The contribution of dust originating from regions other than East Asia to the dust load over these East Asian countries and the North Pacific Ocean cannot be ignored. The simulated total dust deposition flux on Greenland suggests a possible overestimation of the Saharan dust and an underestimation of the East Asian dust in the Arctic region, which may be a common problem with global dust transport models. Possible reasons for the underestimation of the East Asian dust are discussed.

Tanré, D., Deschamps, P.Y., Deveaux, C. and Herman, M. 1988. Estimation of Saharan aerosol optical thickness from blurring effects in Thematic Mapper data, Journal of Geophysical Research, 93 (D12), 15955-15964.

Tanré, D. and Legrand, M. 1991. On the satellite retrieval of Saharan dust optical thickness over land: Two different approaches. Journal of Geophysical Research 96(D3):5221-5227.
Two approaches are presented to retrieve the desert aerosol optical thickness over land from satellite. One approach uses the infrared imagery, and the other uses contrast reduction in visible imagery. The retrieved aerosol optical thicknesses from Meteosat data are shown in good agreement with simultaneous ground-based measurements. Advantages as well as deficiencies of both methods are compared.

Taupin, J.D., Gallaire, R. and Fontes, J.C. 1995. Isotopic study of rainfall in the Sahelian zone (Niger) along two sections, east-west (Lake Chad-Niamey) and north-south (Agadez-Niamey). In: Application of tracers in arid zone hydrology. Proceedings of international symposium, Vienna, 232:285-292.

Tehet, R., Gasse, F., Durand, A., Schroeter, P., Fontes, J.-C. 1990. Fluctuations climatiques du tardiglaciaire à l'actuel au Sahel (Bougdouma, Niger meridional). Comptes Rendus hébdomidaires des Séances de l'Académie des Sciences, Série II, Mécanique, Physique, Chimie, Sciences de l'Univers, Sciences de la Terre 311 (1), 253-258.
Changes in local precipitation from 13 ka BP are recorded from the depression of Bougdouma. During the Late Glacial period, the major hydrological events appear to be in phase with the major steps of the deglaciation as recorded from deep-Atlantic cores, although a pluvial event is observed during the period 11-10 ka BP which was considered as dry.

Tetzlaff, G., Adams, L.J. 1983. Present-day and early-Holocene evaporation of Lake Chad. In: Variations in the global water budget. Eds Street-Perrott, F.A., Beran, M. Ratcliffe, R.T., Reidel, Dordrecht, pp. 347-360.
The calculations show that the fall in the level of Lake Chad resulted mainly from a substantial decrease in runoff rather than from increased evaporation. A data set for the early Holocene (9000 yr BP) indicated a 15% decrease in annual evaporation compared with the present-day value of 2200 mm yr^1

Tetzlaff, G. and Peters, M. 1986. The atmospheric transport potential for water vapour and dust in the Sahel region, GeoJournal, 12 (4), 387-398.
The yield of the rainy season in the Sahel depends on the conditions in the preceding rains of the season and is closely coupled to the surface heat budget both in the monsoonal air in the S and the trades in the N. The heat budget, in particular the evaporation after the passage of a Squall Line, is influenced not only by the total amount of preceding rains but also by the plant cover pumping the water to the surface and smoothing the magnitude of the evaporation in time. This feed-back mechanism may be made responsible for the persistence of the Sahel drought as experienced in recent years. The dust export from the African continent towards the Atlantic can only be so effective, because the Squall Lines and the African Easterly Jet are meshed in a way that produces large amounts of suspended material and lifts it to great heights where the transport velocity is very fast.

Tetzlaff, G., Peters, M., Janssen, W. and Adams, L.J. 1989. Aeolian dust transport in West Africa. In: Leinen, M. and Sarnthein, M. (eds), Palaeoclimatology and palaeometeorology: modern and past patterns of global atmospheric transport, Kluwer Academic, Dordrecht, pp. 185-201.

Texier, D., de Noblet, N., Harrison, S.P., Haxeltine, A., Jolly, D., Joussaume, S., Laarif, F., Prentice, I.C., Tarasov, P. 1997. Quantifying the role of biosphere-atmosphere feedbacks in climate change: coupled model simulations for 6000 years BP and comparison with palaeodata for northern Eurasia and northern Africa. Climate Dynamics 13 (12), 865-882.
The LMD AGCM was iteratively coupled to the global BIOME1 model in order to explore the role of vegetation-climate interactions in response to mid-Holocene (6000 y BP) orbital forcing. The sea-surface temperature and sea-ice distribution used were present-day and CO_2 concentration was pre-industrial. The land surface was initially prescribed with present-day vegetation. Initial climate "anomalies" (differences between AGCM results for 6000 y BP and control) were used to drive BIOME1; the simulated vegetation was provided to a further AGCM run, and so on. Results after five iterations were compared to the initial results in order to identify vegetation feedbacks. These were centred on regions showing strong initial responses. The orbitally induced high-latitude summer warming, and the intensification and extension of Northern Hemisphere tropical monsoons, were both amplified by vegetation feedbacks. Vegetation feedbacks were smaller than the initial orbital effects for most regions and seasons, but in West Africa the summer precipitation increase more than doubled in response to changes in vegetation. In the last iteration, global tundra area was reduced by 25% and the southern limit of the Sahara desert was shifted 2.5^{o}N north (to 18^{o}N) relative to today. These results were compared with 6000 y BP observational data recording forest-tundra boundary changes in northern Eurasia and savana-desert boundary changes in northern Africa. Although the inclusion of vegetation feedbacks improved the qualitative agreement between the model results and the data, the simulated changes were still insufficient, perhaps due to the lack of ocean-surface feedbacks.

Thiam, A.K. 2003. The causes and spatial pattern of land degradation risk in southern Mauritania using multitemporal AVHRR-NDVI imagery and field data. Land Degradation and Development 14 (1), 133-142.
Multitemporal 1 km NOAA/AVHRR Normalized Difference Vegetation Index (NDVI) maximum composite imagery was utilized in combination with rainfall, soil types, and field survey data on dominant rural activities to assess the risk of land degradation in southern Mauritania. Mauritania is one of eight continental West African Sahel countries that stretch from Chad to the northwestern Atlantic coast, and from the southern fringe of the Sahara Desert to the northern limit of the Sudanian climatic zone. The major environmental problem these countries are currently facing is the temporally and spatially erratic character of rainfall, frequently leading to general or local droughts since the late-1960s with subsequent increase of human pressure on the natural resource base and degradation. Image deviation was applied to maximum NDVI composites of the growing season (June to October) for the period 1990-99 to detect temporal and spatial change patterns over the study area. Only pixels whose values were lower than their temporal mean minus 0.5 standard deviation were retained as areas under

threat. These were combined with soil types and the spatial pattern of deforestation (fuelwood and building material collection areas) grazing, and agricultural land to determine the causes of lowering primary biological productivity. The results show that the below-normal NDVI values generally coincide with the patterns of below-normal rainfall: deforestation, and overgrazing areas, agricultural land, and low primary biological productivity soil types. Thus, the observed substantial decrease in biomass production results from the combined impacts of frequent rainfall deficits and uncontrolled resource-base exploitation by the local population. Large chunks of land that show consistent low biomass production are also observed on unproductive soils. Finally, the below-normal rainfall, below-average NDVI values, and human impacts images were cross-classified to produce a three-class (low, moderate, and high) land degradation risk map along with a table containing the area covered by each class. A Boolean mask of the degradation risk map applied to the soils map showed that all soil types in southern Mauritania are at risk of degradation. These products could serve as a strong basis for decision making in regard to planning resource allocation for environmental rehabilitation.

Thiemeyer, H. 1992. On the age of the Bama ridge - a new C^{14} record from Konduga area, Borno State, NE Nigeria. Zeitschrift für Geomorphologie 36 (1), 113-118.
The so-called Bama Ridge is the Nigerian part of a former beach ridge belonging to a Lake Chad level, about 40 m higher as the level from today. The genesis of the beach ridge is still in discussion (e.g. Servant 1983 contrary to Durand et al. 1984). The ridge sediments themselves have never been dated, only indirect data are available. A new find of charcoal together with potsherds near Konduga/NE-Nigeria gave a C^{14}-age of 6,340 +/- 250 yr B.P. It is the first direct datation of beach ridge sediments of this former lake level. So the hypothesis of a huge palaeolake around 6000 yr B.P. has become more plausible. Moreover, the association of charcoal and potsherds gives a neolithic age of the pottery. Until now this potsherds would be the oldest in northern Nigeria, belonging to the neolithic age.

Thiemeyer, H. 1997. Naturräumliche Voraussetzungen für die Besiedlung des südwestlichen Tschadbeckens im Holozän. Zentralblatt für Geologie und Paläontologie T.I, 1/2, 77-89.

Thiemeyer, H. 1998. The influence of Lake Chad transgressions on NE-Nigerian palaeodune fields. Palaeoecology of Africa and the surrounding islands 1998, 89-100.
Investigations which have been carried out in NE-Nigeria focused on the younger landscape development of different land units, which are palaeodune fields, clay plains and former beach ridges of Lake Chad. The main phase of palaeodune formation is attributed to the Kanemien. The linear dune field as the oldest dune field in NE-Nigeria was not subject to lake transgression, whereas the transversal dune field, despite of older dune remnants, was submerged during the Megachad phase around 6500 BP. After regression aeolian reworking took place and formed the actual surface of the transversal dune field. Afterwards, a younger beach ridge has been formed as well as a lagoon, which covered the area south to the lake. A further regression formed the recent lake. Normally, tectonic aspects don't play any role considering the youngest part of the Quaternary landscape development. However, recent subsidence is for the area of investigation of special importance and must be taken into consideration. Without human impact, only immobile dunes with a savanna vegetation would had existed. Soil development had taken place in humid climatic phases, which resulted in Chronic Arenosols on older dunes and Cambic Arenosols on younger dunes.

Thilmans, G., Regnaud, M., Hebrard, L., Guitant, R., Descamps, C. 1974. Fichier des âges absolus du Quaternaire d'Afrique au Nord de l'Equateur; 9^{e} Série. Bulletin de Liaison – Association Sénégalaise pour l'Etude du Quaternaire de l'Ouest Africain 40, 5-131.

Thinon, M., Ballouche, A., Reille, M., 1995. Holocene vegetation of the central Saharan mountains; the end of a myth. The Holocene 6 (4), 457-462.
Recent pollen and macrofossil analysis of organic sediments from the Ahaggar massif show that mid-Holocene flora was actually very similar to that found at the present day. Earlier studies had included analysis of sediment contaminated by pollen transported long distances which had accumulated over a period of 4000 yr. An endemic olive (*Olea laperrini*) and the Atlas pistachio tree (*Pistacia atlantica*), two species which are still well represented nowadays, dominated the vegetation. The new data question the extension of the Mediterranean vegetation towards the south and the amplitude of the associated climatic change.

Tiessen, H., Hauffe, H.K, Mermut A.R. 1991. Deposition of Harmattan dust and its influence on base saturation of soils in northern Ghana. Geoderma 49 (3-4), 285-299.

Ferruginous soils formed from Volta shale deposits in northern Ghana are highly weathered, have high iron and aluminium oxide contents, and a mineralogy dominated by quartz and low activity clays with low effective CEC. Despite their advanced weathering state, base saturation values of top soils are generally above 80%, and deficiencies of basic cations are uncommon.
We postulated that the annual deposition of dust from the Sahara, carried by the Harmattan weather system may be responsible for the high base saturation. Therefore, we collected dust material for two entire dry seasons at Nyankpala (surrounded by highly weathered Volta shale deposits), and during several events of Harmattan and local dust storms at Bolgatanga (surrounded by a variety of parent materials). Long-distance Harmattan dust had a clearly finer particle size distribution than dust collected during local storms, but angularity and evidence of weathering on dust particles did not distinguish dust from different sources. In Bolgatanga, soils contained unweathered minerals derived from local parent materials, and both local storm and Harmattan dust contained large amounts of bases. Significant amounts of micas and feldspars, and K contents up to 3% in the dust collected at Nyankpala showed Harmattan dust to be the source of K and other bases found on Volta shale soils. Short-distance dust in Nyankpala was mostly quartz and vegetation ashes. Dust deposition during one Harmattan season at Nyankpala amounted to about 15 g m^{-2}, and carried a total of 140, 400, 300 and 60 mg m^{-2} of Mg, Ca, K and Na, respectively. These amounts could account for the high base saturation of the low CEC in Volta shale soils.

Tilho, J. 1925. Sur l'aire probable d'extension maximum de la mer paléotchadienne. Comptes rendus hebdomadaires des Séances de l'Académie des Sciences, Paris 181(19):643-646.

Tilho, J. 1926. Du Lac Tchad aux montagnes du Tibesti, exposé géographique sommaire de l'exploration de Jean Tilho dans les régions du Tchad, du Borkou, de l'Ennegi et du Tibetsi (1912-1917), Paris, 92 pp.

Tlho, J. 1939. Au sujet de la capture du Logoné par la Benoué. Révue scientifique, Paris 3, 159-171.

Tilho, J. 1996. Borkou et Tibesti. 1. Reconnaissance du Tibesti, 4 septembre au 12 novembre 1915 / par Jean Tilho. 2. Tournée dans le Tibesti, 20 décembre 1922 au 21 janvier 1923 ; Tournée dans le Tibesti, 11 juin au 20 septembre 1923 : / rapports de [Henri] Couturier. République du Tchad, Ministère de l'éducation nationale, Centre national d'appui à la recherché, N'djamena, 208 p.

Todd, M.C., Martins, V., Washington, R., Dubovik, G., Lizcano, O., Mbainayel, S. and Engelstaedter, S. 2006. Optical properties of mineral dust from the Bodélé Depression , Northern Chad during BoDEx, 2005, Journal of Geophysical Research, in review.

Treinen, C.F. 1978. Nouveaux élements de datation absolue pour l'Age du Fer de la région de Koro-Toro (Nord du Tchad). L'Anthropogie 82 (1), 103-109.

Urvoy, Y. 1933. Le formes dunaires a l'ouest du Tchad. Annales de Géographie 42 (239), 506-515.

Urvoy, Y. 1933. Modelé dunaire entre Zinder et le Tchad. Bulletin de l'Association de géographes français 10:79-82.

Van Zinderen Bakker, E.M. and Maley, J. 1979. Late Quaternary palaeoenvironments of the Sahara region. Palaeoecology of Africa 11:83-104.

Vernet R. 1996. Neolithic of Sahel: Specific problems, synthetic data and example of the South-West Niger. Anthropologie 100 (2-3), 307-355.
The Prehistory of Sahel has been seldom studied for until recently, Sahara was privileged. Morewer, natural conditions - vegetation, rainfalls and people settlement - make the approach of african archeology difficult.
And yet, the Prehistory of Sahel has been very rich since Acheulean. During Neolithic, this area became populated especially when the climatic conditions in Sahara got worse after 4000 BP.
Some areas, - as a matter of fact, better known - seem to be of a very great importance. That's how it is with Azawad (in the north of Timbuktu), Tilemsi (in the north of Gao), Azawagh (between Air and Adrar des Ifoghas), south west of Niger (around Niamey) or, further east, Termit Mounts.
Relationships of the Sahelian Neolithic with Sahara in the north, and with the forest in the south, are one of the major topics in nowadays studies.

These relationships are still essential at the beginning of the historic era with the emergence of the first towns and the first states (Djenne-Jeno, Koumbi Saleh, Gao or Kingdom of Mall), who are in perfect continuity with the pastoral and agricultural societies of the end of the Neolithic in this area.

Vernet, R., Faure, H. 2000. Isotopic chronology of the Sahara and the Sahel during the late Pleistocene and the early and Mid-Holocene (15,000-6000 BP). In: In honorarium, Nat Rutter. Eds. Catto, N.R., Bobrowsky, P.T. and Liverman, D.G.E. Quaternary International 68-71, 385-387.

Vernet, R., Heine, K. 1998. Holocene chronology of the Saharan margin: coastal Atlantic and western Mauritanian areas. Palaeoecology of Africa and the Surrounding Islands, 43-48
The study of 270 paleoenvironmental 14C dates and 175 dates regarding human settlements of the Atlantic coast and the Mauritanian western areas provides the first synthesis of the Holocene evolution in the region. The findings are based on: (1) See level changes since 7500 yr BP (the end of the Wurm transgression), (2) The variability of coastal environments, (3) The alternation of climatic phases since the end of the Ogolian arid period, (4) The succession of human settlements since the sixth millenium BP and (5) Methodological inadequacies which can easily be spotted (Fig. 1 appendix). The stratigraphic informations of all kinds can be correlated. The Holocene environmental reconstruction of the Mauritanian coastal areas adds to the results from neighbouring Mali and Chad.

Vernet, R., Striedter, K. H. 1992. La place du Djado dans le Sahara Central: Hommes et Climats à l'Holocène. Würzburger geographische Arbeiten 84, 201-234.

Verstappen, H.Th. 1972. Orbital photographs and climatic geomorphology in Chad. Palaeoecology of Africa and of the Surrounding Islands and Antarctica 6, 102.

Verstappen, H.Th. and van Zuidam, R.A. 1970. Orbital photography and the geosciences -a geomorphological example from the central Sahara. Geoforum 2(1):33-47.

Vignaud, P., Duringer, P., Mackaye, H.T., Likius, A., Blondel, C., Boisserie, J.R., de Bonis, L., Eisenmann, V., Etienne, M.E., Geraads, D., Guy, F., Lehmann, T., Lihoreau, F., Lopez-Martinez, N., Mourer-Chauvire, C., Otero, O., Rage, J.C., Schuster, M., Viriot, L., Zazzo, A., Brunet, M. 2002.Geology and palaeontology of the Upper Miocene Toros-Menalla hominid locality, Chad. Nature 418 (6894), 152-155.
All six known specimens of the early hominid *Sahelanthropus tchadensis* come from Toros-Menalla site 266 (TM 266), a single locality in the Djurab Desert, northern Chad, central Africa. Here we present a preliminary analysis of the palaeontological and palaeoecological context of these finds. The rich fauna from TM 266 includes a significant aquatic component such as fish, crocodiles and amphibious mammals, alongside animals associated with gallery forest and savannah, such as primates, rodents, elephants, equids and bovids. The fauna suggests a biochronological age between 6 and 7 million years. Taken together with the sedimentological evidence, the fauna suggests that S. tchadensis lived close to a lake, but not far from a sandy desert, perhaps the oldest record of desert conditions in the Neogene of northern central Africa.

Vischer, H. 1909. A journey from Tripoli across the Sahara to Lake Chad. Geographical Journal 33(3):241-266.

Vischer, H. 1910. Across the Sahara from Tripoli to Bornu, Darf, London, 308 pp. [rgs 244b

Völkel, J. 1987. Geomorphologische und pedologische Untersuchungen in Dünengebieten der Südsahara und des Sahel der Republik Niger, Göttinger Geographische Abhandlungen, 84, 109-125.

Völkel, J. 1988. Zum jungquartären Klimawandel im saharischen und sahelischen Ost-Niger aus bodenkundlicher Sicht. In: Geowissenschaftliche Untersuchungen in Afrika. Eds. Hagedorn, H., Baumhauer, R. Würzburger geographische Arbeiten 69, 255-276.

Völkel, J. 1989. Formation of dunes and pedogenesis as palaeoclimatic indicators in the eastern part of the Republic of Niger (Sahara and Sahel), in Palaeoecology of Africa and the surrounding islands, 20, Ed. Heine, K., Balkema, Rotterdam, 37-54.

Völkel, J. 1989. Geomorphologische und pedologische Untersuchungen zum jungqartären Klimawandel in den Düngebieten Ost-Nigers (Südsahara und Sahel), Bonner Geographische Abhandlungen, 79, 258 pp.

Volkel, J. 1989. Paläoboden unter Hangschuttdecken im nordafrikanischen Sahel (Republik Niger), Erdkunde, 43 (3), 242-253.

Völkel, J. 1989. Untersuchungen in der Republik Niger zur Dünengenese und Dünenverwitterung als palaeoklimatologische Indikatoren in der Quartaerforschung, in Referate der Deutschen Bodenkundlichen Gesellschaft, Mitteilungen der Deutschen Bodenkundlichen Gesellschaft, 59 (2), 1003-1004.

Völkel, J. 1989, Geomorphologische und pedologische Untersuchungen zum jungquartären Klimawandel in den Dünengebieten Ost-Nigers (Südsahara und Sahel). Bonner Geographische Abhandlungen 79, 258 p.

Völkel, J., Grunert, J. 1990. To the problem of dune formation and dune weathering during the Late Pleistocene and Holocene in the Southern Sahara and the Sahel. Zeitschrift für Geomorphologie 34 (1), 1-17.
There are dune generations of different age in the southern Sahara (Erg of Bilma) as well as in the Sahel of the eastern part of the Republic of Niger. They differ by their form and grade of weathering. Dune forming and pedogenesis reveal significant changes of geomorphogenetic and climatologic processes in this area at the end of the Pleistocene and Holocene. Fixed ancient dunes reveal, that because of dislocation of wind patterns arid climate then reached further south than the present southern margin of the Sahel. After 16 000 BP precipitation-rates gradually increased. This tendency had its climax during the great humid period of the early Holocene (Tchadien), which since 10 000 BP produced freshwater lakes in the Erg of Bilma (south Sahara/north Sahel). The younger Pleistocene dunes weathered deeply during this humid time. A short arid period about 6500 BP produced a second generation of dunes in the southern Erg of Bilma (south Sahara/north Sahel). The younger Pleistocene dunes weathered deeply during this humid time. In the Erg of Bilma then the youngest, the third generation of totally unweathered, migrating dunes was formed chiefly from the slightly consolidated sands of the Holocenic, second dune generation.

Voute, C. 1962. Geological and geomorphological evolution of the Niger and Benue Valleys. Annales de la Musée royale de ‘Afrique central (Terburen) 40: 189-207.

Washington, R. and Todd, M.C. 2005. Atmospheric controls on mineral dust emission from the Bodélé Depression, Chad. Geophysical Research Letters 32 (17): L17701
Atmospheric aerosols play an important though uncertain role in the Earth's climate system. The Bodele Depression in Chad stands out as the planet's largest source of dust, yet very little is known about the atmospheric circulation that maintain this source. We investigate what key large-scale features of the circulation over the Bodele account for its primacy as a mineral aerosol source. We show, for the first time, the structure and characteristics of the Bodele Low Level Jet (LLJ) which has a maximum speed near 18 degrees N, 19 degrees E at 925 hPa. It is strongest in the northern winter, receding with the advance of summer in phase with dustiness in the Bodele. Variability of dust over the Bodele occurs contemporaneously with the ridging of the Libyan High and pulsing of the pressure gradient which drives the northeasterlies in which the LLJ is embedded.

Washington, R., Todd, M.C., Lizcano, G., Tegen, I., Flamant, C., Koren, I., Ginoux, P., Engelstaedter, S., Bristow, C., Zender, C.S., Goudie, A.S., Warren, A. and Prospero, J.M. 2006. Links between topography, wind, deflation, lakes and dust: the case of the Bodélé Depression, Chad, Journal of Geophysical Research – Atmospheres **33**, L09401, doi 10.1029/2006GLO25827.
The Bodele Depression, Chad is the planet's largest single source of dust. Deflation from the Bodele could be seen as a simple coincidence of two key prerequisites: strong surface winds and a large source of suitable sediment. But here we hypothesise that long term links between topography, winds, deflation and dust ensure the maintenance of the dust source such that these two apparently coincidental key ingredients are connected by land-atmosphere processes with topography acting as the overall controlling agent. We use a variety of observational and numerical techniques, including a regional climate model, to show that: 1) contemporary deflation from the Bodele is delineated by topography and a surface wind stress maximum; 2) the Tibesti and Ennedi mountains play a key role in

the generation of the erosive winds in the form of the Bodele Low Level Jet (LLJ); 3) enhanced deflation from a stronger Bodele LLJ during drier phases, for example, the Last Glacial Maximum, was probably sufficient to create the shallow lake in which diatoms lived during wetter phases, such as the Holocene pluvial. Winds may therefore have helped to create the depression in which erodible diatom material accumulated. Instead of a simple coincidence of nature, dust from the world's largest source may result from the operation of long term processes on paleo timescales which have led to ideal conditions for dust generation in the world's largest dust source. Similar processes plausibly operate in other dust hotspots in topographic depressions.

Washington, R., Todd, M., Middleton, N.J., Goudie, A.S. 2003. Dust-storm source areas determined by the total ozone monitoring spectrometer and surface observations. Annals of the Association of American Geographers 93 (2), 297-313.
Dust storms are recognized as having a very wide range of environmental impacts. Their geomorphological interest lies in the amount of deflation and wind erosion they indicate and their role in loess formation. Atmospheric mineral-dust loading is one of the largest uncertainties in global climate-change modeling and is known to have an important impact on the radiation budget and atmospheric instability. Major gaps remain in our understanding of the geomorphological context of Terrestrial sources and the transport mechanisms responsible for the production and distribution of atmospheric dust, all of which are important in reducing uncertainties in the modeling of past and future climate. Using meteorological data from ground stations, from the space-borne Total Ozone Monitoring Spectrometer (TOMS), and from the National Center for Environmental Prediction-National Center for Atmospheric Research reanalysis project, we illustrate the key source regions of dust and demonstrate the primacy of the Sahara. Objectively defined source regions for the Sahara are determined from eigenvector techniques applied to the TOMS data. Other key regions include the Middle East, Taklamakan, southwest Asia, central Australia, the Etosha and Mkgadikgadi basins of southern Africa, the Salar de Uyuni (Bolivia), and the Great Basin (United States). In most of these regions, large basins of internal drainage, as defined from a digital elevation model, are dust sources where the near-surface atmospheric circulation (determined by calculated means of potential sand flux) is favorable for dust mobilization. Surface observations indicate some regions as being important that do not appear on the TOMS maps. Possible reasons for these discrepancies are explored.

Weaver, C.J., Ginoux, P., Hsu, N.C., Chou, M.D., Joiner, J. 2002. Radiative forcing of Saharan dust: GOCART model simulations compared with ERBE data. Journal of the Atmospheric Sciences 59 (3), 736-747.
This study uses information on Saharan aerosol from a dust transport model to calculate radiative forcing values. The transport model is driven by assimilated meteorological fields from the Goddard Earth Observing System Data Assimilation System. The model produces global three-dimensional dust spatial information for four different mineral aerosol sizes. These dust fields are input to an offline radiative transfer calculation to obtain the direct radiative forcing due to the dust fields. These estimates of the shortwave reduction of radiation at the top of the atmosphere (TOA) compare reasonably well with the TOA reductions derived from Earth Radiation Budget Experiment (ERBE) and Total Ozone Mapping Spectrometer (TOMS) satellite data. The longwave radiation also agrees with the observations; however, potential errors in the assimilated temperatures complicate the comparison. Depending on the assumptions used in the calculation and the dust loading, the summertime forcing ranges from 0 to -18 W m^{-2} over ocean and from 0 to +20 W m^{-2} over land. Increments are terms in the assimilation general circulation model (GCM) equations that force the model toward observations. They are differences between the observed analyses and the GCM forecasts. Off west Africa the analysis temperature increments produced by the assimilation system show patterns that are consistent with the dust spatial distribution. It is not believed that radiative heating of dust is influencing the increments. Instead, it is suspected that dust is affecting the Television Infrared Observational Satellite (TIROS) Operational Vertical Sounder (TOVS) satellite temperature retrievals that provide the basis of the assimilated temperatures used by the model.

Wendorf, F. and R. Schild, 1980."Prehistory of the Eastern Sahara." AcademicPress, New York, 404 pp.

Wendorf F., Schild, R., Said, R., Haynes, C.V., Gautier, A., Schwarcz, H.P., Miller, M., Kowalski, K., Krolik, H., Bluszcz, A., Robins, D., Grun, R. 1990. The last interglacial in the eastern Sahara. Anthropologie 94 (2), 361-391.

Wendorf, F., Schild, R., Said, R., Haynes, C.V., Gautier, A., Kobusiewicz, M. 1976. The prehistory of the Egyptian Sahara. Science 193 (4248), 103-114.

Westphal, D.L., Toon, O.B., Carlson, T.N. 1988. A case-study of mobilization and transport of Saharan dust. Journal Of The Atmospheric Sciences 45 (15): 2145-2175 AUG 1 1988

Whalley, W.B., Smith, B.J. 1981. Mineral-content of Harmattan dust from northern Nigeria examined by scanning electron-microscopy. Journal of Arid Environments 4 (1), 21-29.
The composition, size, aggregation and morphological characteristics of wind-blown dust particles are examined. Most untreated material lies in the fraction 2-63 micrometres with a modal value of approximately 20 micrometres, but is characterized by coarser grains (20-50 micrometres) with surface aggregations of adhering clay size material.

Wickens, G.E. 1982. Paleobotanical speculations and Quaternary environments in the Sudan. In: Williams, M., Adamson, D.A.A. (eds) A land between two Niles. Quaternary geology and biology of the central Sudan, Balkema, Rotterdam, 23-50.

Wilke, B.M., Duke, B.J., Jimoh, W.L.O. 1984. Mineralogy and chemistry of Harmattan dust in northern Nigeria. Catena 11 (1), 91-96.
In Northern Nigeria deposition rates of the Harmattan wind are coming up to 99 g m^2 during a season. In the present study results of mineralogical and chemical analyses are discussed with respect to effects of Harmattan dust on agriculture. Mineralogical analysis indicates the dust to be mainly composed of quartz (80 wt%). In the clay fraction which is of considerable significance (10-30 wt%), illite and kaolinite are the most abundant minerals. Differences in clay mineralogy of various sampling sites are supposed to be due to inhomogeneity of the source and/or spatial variations in dust deposition. Chemical analysis indicates the dust to be relatively rich in phosphorus. Contents of most trace elements, organic carbon, and nitrogen are also higher in Harmattan dust as compared to soils of the Kano area.

Wood B. 2002. Palaeoanthropology: Hominid revelations from Chad, Nature 418 (6894), 133-135.

Worral, G.A. 1974. Observations on some wind-formed features in the Southern Sahara. Zeitschrift für Geomorphologie. 18 (3), 291-302.

Wright,J. 1989. Libya, Chad and the Central Sahara, Hurst, London, 168 pp. soas WDD327.612 /745635.

Yesou, H., Mbairanadji, L., Bolley, A., Tezenas du Montcel, L., De Fraipont, P. 1997. Pastures monitoring and landsurface characteristics analysis in a Sahelian region using multitemporal SAR data; the Chad case study. In: Space at the service of our environment. European Space Agency Special Publication 414, pp. 229-232.
In the Soudan-Sahel zone of Chad, possibilities of ERS-1 and Radarsat times series data for landscape units characteristics and pasture monitoring began to be examined. Preliminary results have been obtained using ERS data acquired by the Libreville station. Mono season data allow only to distinguish few landscape units and more themes are extractable on data acquired during the rain season. On colour composite, combining rain and dry data, identification of the major pedological units, halomorphic soils, duricrusts can be carried more easily. Plus change in land use can be pointed out such as cultivated fields. Using a long time series Radarsat data, acquired with an high frequency, each seven days, during the 1997 rain season, an assessment on pasture monitoring will carried out.

Zender, C.S., Newman, D., Torres, O. 2003. Spatial heterogeneity in aeolian erodibility: Uniform, topographic, geomorphic, and hydrologic hypotheses. Journal of Geophysical Research-Atmospheres 108 (D17), art. no. 4543.
Soil aeolian erodibility is the efficiency with which soil produces dust for a given meteorological forcing. Quantifying soil erodibility is crucial for forecasting dust events and the climatological distribution and forcing of dust. We use long-term station observations and satellite indices of mineral dust to ascertain the role of regional topography, geomorphology, and hydrology in controlling sediment availability and erodibility. Our null hypothesis is that soil erodibility is globally uniform, so that emissions are determined by instantaneous local meteorology, vegetation, and soil moisture. We describe and quantify three competing hypotheses on regional processes which may affect local soil

erodibility: (1) Erodibility is characterized by the relative elevation of source regions in surrounding basins. (2) Erodibility is characterized by the upstream area from which sediments may have accumulated locally through all climate regimes. (3) Erodibility is characterized by the local present-day surface runoff. These hypotheses are tested in 3-year simulations of the global Dust Entrainment and Deposition (DEAD) model. All three spatially varying erodibility hypotheses produce significantly better agreement with station and satellite data than the null (Uniform) hypothesis. The Uniform hypothesis explains none of the spatial structure of emissions in Australia. Heterogeneous erodibility may explain up to 15-20%, 15-20%, and 50% more of the spatial structure of dust emissions than Uniform erodibility in the Sahara + Arabian Peninsula, East Asia, and Australia, respectively. The Geomorphic erodibility hypothesis performs best overall, but results vary by region and by metric. These results support the hypothesis that dust emission "hot spots" exist in regions where alluvial sediments have accumulated and may be disturbed. Our physically based erodibility hypotheses help explain dust observations in some regions, particularly East Asia, and can be used to help discriminate between natural and anthropogenic soil emissions.

Zheng, X.Y., Eltahir, E.A.B. 1997. The response to deforestation and desertification in a model of West African monsoons. Geophysical Research Letters 24 (2), 155-158.
Since Charney proposed his theory on the dynamics of deserts and droughts in the Sahel [Charney, 1975], there has been significant scientific interest in the interaction between vegetation and climate in this region. The essence of this interaction is that the atmospheric circulation, and therefore rainfall, over this region may be sensitive to changes in vegetation cover near the desert border. Here we describe simulations of the West African monsoons with a simple zonally-symmetric model. The results suggest that the potential impact of human induced change of land cover on regional climate depends critically on the location of the change in vegetation cover. That is, desertification along the border with the Sahara (e.g., in Chad, Niger, Mali and Mauritania) leaves a relatively minor impact on monsoon circulation and regional rainfall; deforestation along the southern coast of West Africa (e.g., in Nigeria, Ghana and Ivory Coast) may result in complete collapse of monsoon circulation, and a significant reduction of regional rainfall.

Zhou, L., Dickinson, R.E., Ogawa, K., Tian, Y., Jin, M., Schmugge, T., Tsvetsinskaya, E. 2003. Relations between albedos and emissivities from MODIS and ASTER data over North African desert. Geophysical Research Letters 30 (20), art. no. 2026.
This paper analyzes relations among MODIS surface albedos, ASTER broadband (3 - 14 μm) emissivities, and a soil taxonomy map over the arid areas of Algeria, Libya, and Tunisia in North Africa at 30 second (about 1 km) and 2 minute (about 4 km) spatial resolutions. The MODIS albedo data are from 7 spectral bands and 3 broadbands during dust-free seasons and the emissivity data are derived from a linear combination of the waveband emissivities of the ASTER five thermal infrared channels. Both albedo and emissivity data in the study region show similar considerable spatial variability, larger than assumed by most climate models, and such variability is related to the surface types (sands, rock, and soil orders). Emissivity over bare soils exhibits statistically significant correlations with albedos at both broadbands and most of spectral bands and decreases linearly with albedos. Albedo and emissivity are more strongly correlated with each other than either is to the surface types, apparently because of their higher resolution either spatially or in surface mineralogy. This paper provides guidance for the possible inclusion of such correlation to specify albedo and emissivity in climate models.

Ziegert, H. 1969. Gebel Ben Ghnema und Nord-Tibesti; pleistozäne Klima- und Kulturenfolge in der zentralen Sahara. Franz Steiner Verlag. Wiesbaden, 158 pp.

Ziegert, M. 1972. Human cultural development and climatic conditions in the Sahara during Pleistocene times. In: African Geology; Quaternary Rocks and Geomorphology of Angola, Chad, Cote d'Ivoire, Nigeria and Sahara, University of Ibadan, Department of Geology, pp. 461-467.