Exchanges
- Scientific Contributions -

Water flux correction of an Atmospheric General Circulation Model and its affects on the seasonal predictability of African precipitation*

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Introduction

Climate models are the only viable tool for the prediction of future climates. Similarly, prospects for the development of seasonal forecasts are thought to reside in the development of such models. Substantial biases exist in the climatologies and seasonal cycles of almost all models. Figure 1, for example, shows areas where the yearly precipitation in the Met Office, Hadley Centre, HadAM3 model is 50% larger or smaller than the observed precipitation (New, 2000) average of the Hulme data set from 1979 to 1998. Simulated rainfall in Africa is excessive over large parts of the Sahel, East and southern Africa. The bias in total rainfall is matched by problems in the annual cycle where rainfall in HadAM3 begins several months in advance of the observed rainfall season (March rather than June in the Sahel).

Precipitation biases feedback on boundary layer physics, particularly the partitioning of latent and sensible heat fluxes, which in turn influence surface heating, instability, convection, moisture transport and wind. Cook (1999), for example, has argued that the climate dynamics in West Africa has an enhanced sensitivity to surface conditions. The African Easterly Jet and rainfall regimes have, not surprisingly, been shown to be sensitive to prescribed surface conditions (Cook, 1999). So when models display a large bias in precipitation, it is likely that these sensitivities will perturb the model basic state further away from the observed climate and reduce the utility of the models in representing future climates, whether on seasonal or multi-decadal timescales.

Ultimately, the removal of the model bias is likely to come from more realistic convective parameterisations. In the meantime flux adjustments to models present one possible way forward. In this article we describe an iterative correction factor to model rainfall and show how this improves the skill on seasonal forecasting time scales.

Model Flux Correction

Having noted the bias in model rainfall, we set about constraining the model to observed values by mul-

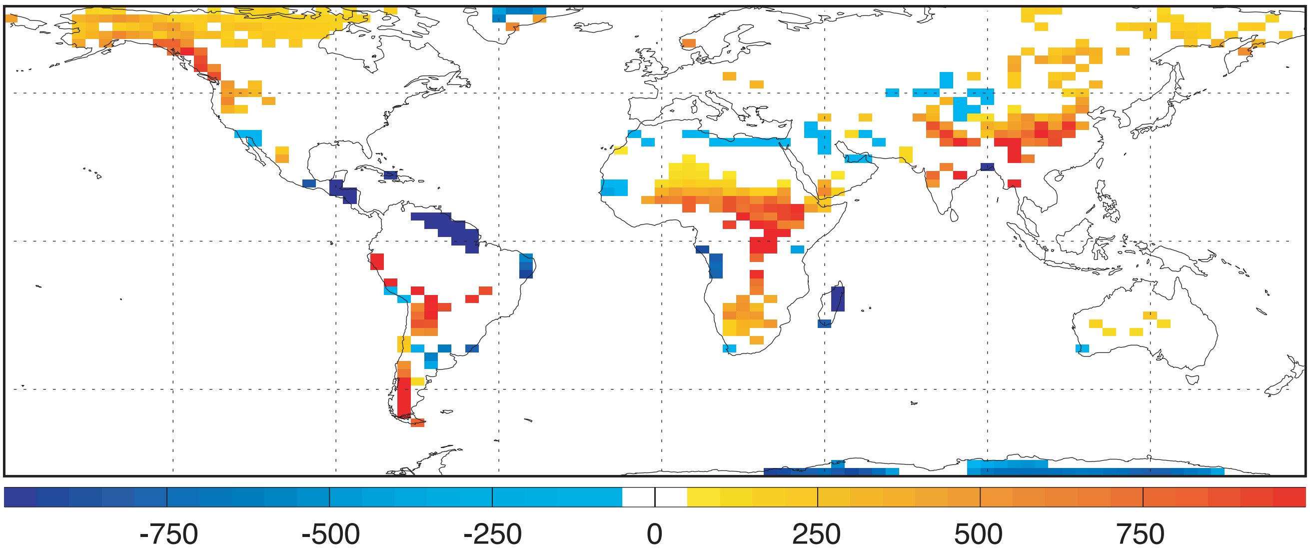

Fig. 1: Annual HadAM3 precipitation minus observed precipitation (Hulme data set) in mm for grid boxes where the annual HadAM3 precipitation is 50% larger or smaller than the observed precipitation (average 1979 to 1998)

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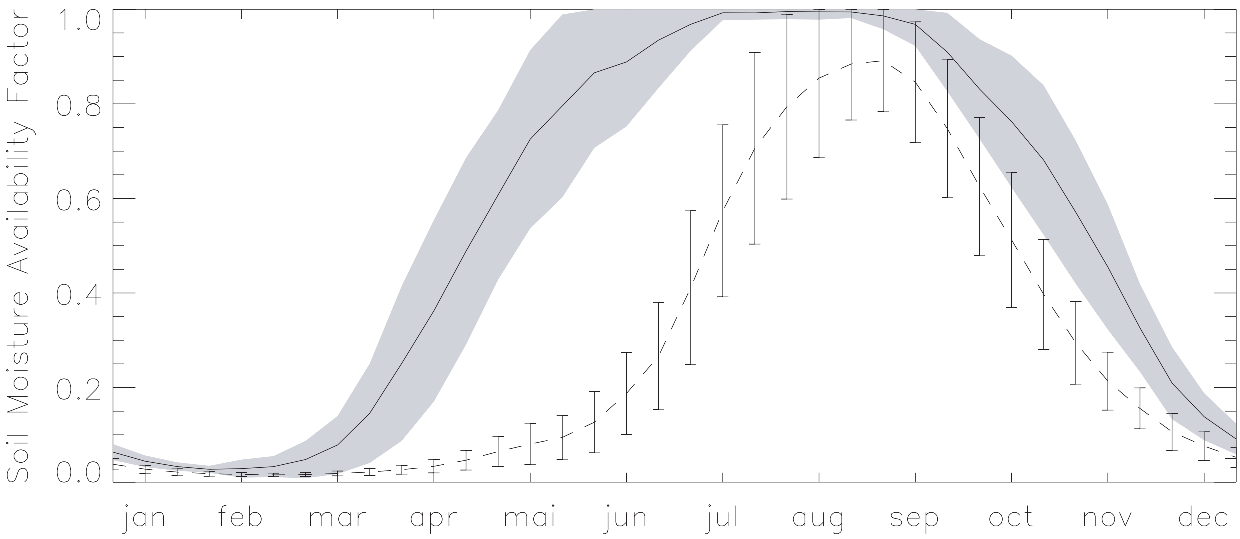

Fig. 2: Soil moisture availability factor and its standard deviation for the standard HadAM3 (solid) and the flux corrected HadAM3 (dashed) at 12.5°N 0°E.

tiplying the rainfall with a monthly correction factor, so that the monthly mean rainfall of HadAM3 equals the monthly mean rainfall of the Hulme data set. These correction factors are derived iteratively to account for feedbacks resulting from the initial correction. Normally two iterations suffice. In the case of seasonal predictions or multi-annual model integrations, the model is set to use the same correction factors for every year.

Multi-annual simulations show that the atmospheric mean state and circulation changes once the precipitation bias is removed. The same correction factors have differing effects for each of the simulated years. This is to be expected since a different circulation changes the relative importance of SST patterns while unobserved (model artefact) soil moisture variability during the dry season is removed (see Figure 2, March – May in the case of the Sahel) and the effects of soil moisture are confined more realistically to the active part of the seasonal cycle (July and August).

Influence on Seasonal Prediction

The impact of the flux correction on predictability is demonstrated with an experiment forced with historical SSTs from 1979 to 1998. The experiment consists of two 8 member ensembles, one using the standard UM and one using the flux corrected UM with correction factors constructed from the precipitation of the control ensemble and Hulme data set.

The relative operating criteria (ROC scores; Mason and Graham, 2002) are calculated for the control experiment and the flux corrected experiment, using the uncorrected seasonal precipitation totals of seven regions (forecast regions of the UK Met. Office and southern Africa). The ELVIS re-sampling technique (Mason and Graham, 2002) is used to enhance the ROC scores. The variance for the ROC score of each area was estimated using a Monte Carlo simulation in order to determine the significance of ROC score changes.

The 6 regions had together 14 seasons with precipitation above 15% of the annual total. 7 of these experienced a significant increase of the ROC score on a 90% significance level, while only one region (East Africa in OND) had a ROC score that was significantly lower.

The improvements were expected to be largest in the Sahel and Soudan, since the monsoon and the African easterly jet depend strongly on the temperature gradient and therefore soil moisture gradient. These expectations were not met, since the Sahelian ROC scores improved significantly only in AMJ and OND, but were unchanged in the main wet season (JAS). For the Soudan, the ROC scores improved in average, but only the quite dry JFM season (3% of the annual observed precipitation) reached significance on a 90% level.

The regions with significantly improved ROC scores are generally further south, with southern Africa experiencing the largest improvements. It is not quite clear why this is the case. A possible explanation is that the northern hemisphere experiences much stronger changes of the atmospheric mean state than the southern hemisphere. This can have a negative influence on the model performance, since the model parameters were tuned to give the best model performance with the biased precipitation and were not re-tuned after the precipitation bias was removed. Hence, some of the improvements due to the improved evaporation cycle are offset by degrading the model climatology.

Summary

Precipitation correction factors were used to linearly increase or decrease the model precipitation, so that its monthly mean matches the observed monthly mean. This removes the bias in the evaporation and changes temperature, humidity and wind fields leading to precipitation changes. The same correction factors lead to different precipitation changes in different years, influencing the model's ability to reproduce observed precipitation anomalies. The ROC scores for seasonal rainfall predictions increase significantly for many regions in Africa and decrease significantly only for East Africa in OND. The skill increases less for the northern hemisphere than for the southern. This might be related to the large change in the atmospheric state of the northern hemisphere, which can have a negative effect on the tuning of the model.

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