AFRICAN CLIMATE CHANGE

Taking the Shorter Route

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Developing the scientific and economic capacity to cope with climate variability in Africa would be a logical first step toward dealing with the greater development and scientific challenges of managing climate change on the continent.

CONTEXT: CLIMATE AND DEVELOPMENT IN AFRICA. Sub-Saharan Africa is the only region of the world that has become poorer in the last generation (Ravallion and Chen 2004). The continent makes up just 13% of the world's population (Population Reference Bureau 2005) but constitutes 28% of the world's poverty (World Bank 2005) and is home to 32 of the 38 heavily indebted poor countries (World Bank and IMF 2005). Its share of world trade more than halved between 1980 and 2002 (UNCTAD 2004). Numerous factors have worked in concert to create this situation of poverty and underdevelopment, and among those is the difficulty of coping with climate variability in a continent subject to frequent droughts, floods, high temperatures, and land degradation. The devastating floods from tropical cyclones in 2000, for example, reduced Mozambique's annual growth rate from 8% to 2.1% (World Bank 2001). East African drought, also in 2000, drastically reduced Kenyan hydroelectric power output, leading to a $72 million (U.S. dollars) emergency loan from the World Bank (World Bank 2000). Droughts in southern Africa during the 1990s resulted in billions of dollars of cereal crop losses (Clay et al. 2003). The human cost of the long-lived Sahelian drought is well documented, even if neither dollar value can be attached, nor the constraint this imposed on development in the region can be estimated.

At the United Nations Millennium Summit in September 2000, world leaders agreed to set time-

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bound and measurable goals and targets for a raft of development issues, including combating poverty, hunger, disease, and environmental degradation (UN 2002). Rainfall, and climate more generally, is implicated directly in the United Nations "Millennium Development Goals" ("MDGs") to eradicate extreme poverty and hunger (Gauci 2005), reduce child mortality, and stem diseases such as malaria by the target date of 2015. But Africa is not currently on target to meet any of these goals (Commission for Africa 2005). No attempt has been made to quantify the actual contribution that climate variability makes to the achievement of the MDGs. We argue that improved management of activities affected by climate variability, both institutionally and by vulnerable rural communities, is an important component of the efforts to meet and sustain the MDGs in Africa.

It is clear that future economic development across the African continent has a high level of dependence upon water availability (Desanker and Magadza 2001). In turn, water availability is directly reliant on rainfall and its extraction and use over a continent subject to marked interannual variations in rainfall (e.g., Nicholson and Entekhabi 1986; Lamb and Peppler 1992; Unganai 1996; Nicholson and Kim 1997; Cook et al. 2004; Dai et al. 2004; Segele and Lamb 2005), which is projected, for much of its surface, to become drier as the atmosphere warms (Desanker and Magadza 2001; Hulme et al. 2001; Thomas et al. 2005). In one study of the effects of climate change, African gross domestic product (GDP) was projected to be lower by 2080 in 10 out of 11 simulations (Fischer et al. 2005). Rapid population growth and socioeconomic changes such as globalization will interact with the impacts and responses to climate change. To a certain extent, development planning within Africa has taken a limited account of climate in an explicit sense (climate has generally been implicit as one of many biophysical considerations), despite the significant vulnerability of the human population to the high levels of climate variability over the continent. The World Bank planning process, for example, at present makes no specific consideration for climate change issues in development projects, although consultation is in progress to develop this as an area for future consideration (Burton and van Aalst 2004).

Perhaps African resilience has reduced as international borders, globalization, adjustments in political structures, and so on, have been introduced. If so, then efforts are needed to rebuild this resilience through improving technical and institutional adaptive capacities and advancing understanding of climate fluctuations, human vulnerability, and their interaction (Vogel 2005).

There have been several recent international campaigns to address development issues in Africa. In the spring of 2004 the U.K. government launched the Commission for Africa, and published "Our Common Interest" in March 2005. This same year saw the Live8 concerts linked with the July G8 meeting at Gleneagles, Scotland, which had two priority items on the agenda: Africa and climate change. Within the context of African climate, this undoubtedly was the most important meeting of the so-called World Government to date. In recognition of this, and with the intention of informing policy making by the G8, the U.K. government funded a wide-ranging report into the status of African climate science. The report (Washington et al. 2004), written by the authors of this paper, benefited from the input of more than 40 experts worldwide, many of whom are African.

Based on the context and findings of Washington et al. (2004), we focus on the status of African climate science in this paper. We pose a number of questions: Is there a common origin to factors that currently constrain climate science? Why is it that in a continent where human activity is so closely linked to interannual rainfall variability (e.g., Jury 2002; Tadross et al. 2005) has climate science received relatively little of the benefit that saw commercialization driving meteorology in the developed world (e.g., Friedman 1993) during the early parts of the twentieth century? And, given the constraints and the plausible reasons for them, what might be suggested as an effective way for the continent to approach future climate variability and change?

We make the case that a parallel route to addressing the challenges of climate change in Africa rests with a close engagement with climate variability. In essence, we are arguing that addressing climate on one time scale may be the best way to approach the informational and institutional gaps that limit progress at another, longer time scale. For this strategy to be viable, the reasons for the constraints that currently curtail progress in African climate science have to somehow be addressed. We start by discussing the constraints and making a case for how the raison d'être for the constraints might be overcome. Leading on, we spell out exactly why we believe the optimal management of activities directly influenced by interannual climate variability has the potential to serve as a forerunner to engagement in the wider issue of climate change. We show this both from the perspective of the climate system and the institutions that engage with climate issues. We end with a thought experiment that tests some practicalities of linking the management of climate variability and climate change in the setting of smallholder farmers in Limpopo Province, South Africa, through the use of seasonal forecasting.

CONSTRAINTS ON AFRICAN CLIMATE SCIENCE.

One plausible reason for the fact that African climate science and the related infrastructure are relatively poorly developed might be that Africa as a whole is underdeveloped. But this would be an inadequate and imprecise explanation. We need to look deeper into the specific fit between climate science and society in Africa. Why, *exactly,* is it that resources are not steered toward climate? We start by examining the climate-observing system.

Constraint 1: Data. Reliable, long-term, and well-distributed climate information is essential to informing any development policy aimed at addressing the consequences of climate variability and change. Yet the African Climate Report (Washington et al. 2004) found that the climate-observing system in Africa is in a rather worse state than that of any other continent, and that it is deteriorating. The network of 1152 World Meteorological Organization (WMO) World Weather Watch (WWW) stations in Africa, which provides real-time weather data as well as forming the basis of international climate archives, has an average station density of just one per 26,000 km^2, which is 8 times lower than the WMO minimum recommended level. This shortage of data-monitoring sites is exacerbated by an uneven distribution of stations and routine failures in scheduled data transmission, with the result that substantial areas of Africa, particularly those in central Africa, are unmonitored. Figure 1 shows that Africa has the lowest reporting rate of any region in the world. Similarly, the density of upper-air observations is somewhat below WMO recommended values (WMO 2003). Satellite-based observations may not provide a complete solution over Africa because algorithms used to interpret them need ground-based data for calibration and validation.

Climate science, regardless of the time scale being studied, is founded on data. But, sampling the atmosphere is expensive and more immediate development demands, including education, health, and defence, are made on many an African country's national budget. If climate science were to fulfill its potential in forming an evidence-based policy, then it seems more likely that investment in basics such as an observing system would be supported. Of the climate-related time scales, climate change is often perceived by African governments to be regarded as among the most distant and least pressing. Interannual climate variability, on the other hand, is rather more immediately geared to the agricultural base that forms such

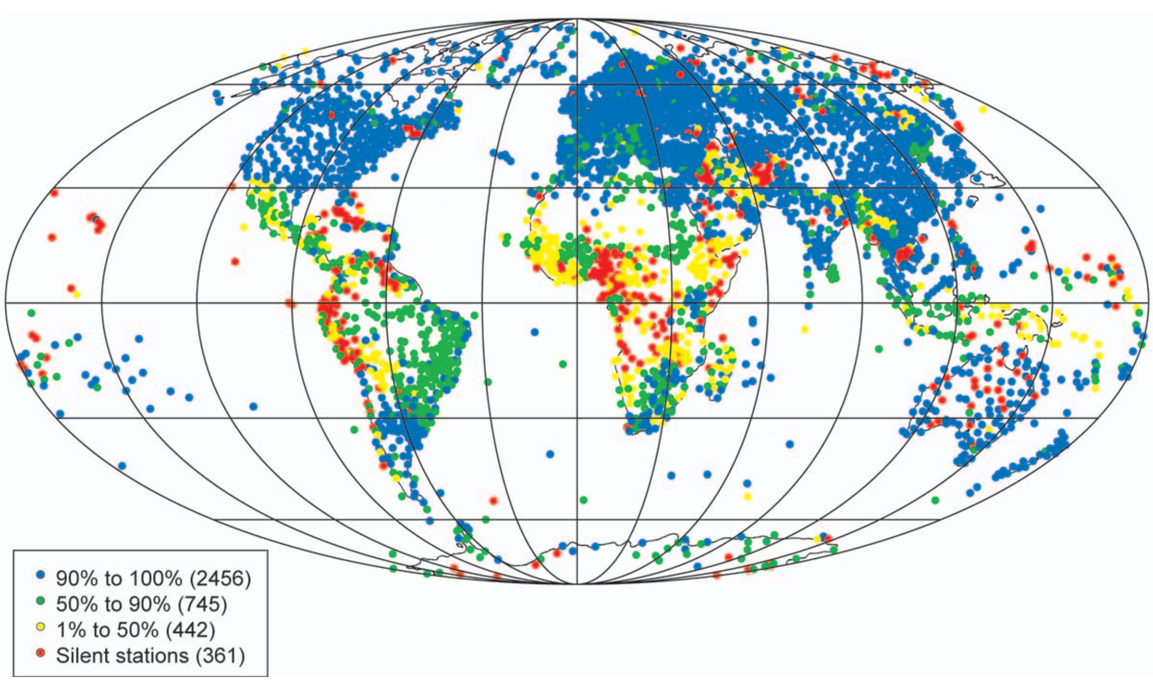

Fig. 1. The global network of World Weather Watch (WWW) stations are color coded to show reporting rates. Data-sparse areas and low reporting rates for Africa are clearly visible (WMO 2003).

a vital component of Africa's economy, and is readily, and simply, served through climate information, such as rain onset dates, dry spell length during the rainy season, and other tried and tested parameters associated with seasonal totals. The improving technology of long-range forecasts promises further significant benefits here. Such gains made on the basis of the use of all forms of climate information, including both analyzed data and forecasts, are readily demonstrable to government ministries responsible for managing environmental, water, and food resources.

In essence, the global climate-observing system, as currently designed, might be seen as a product of the drive to satisfy operational numerical modeling efforts geared at forecasting synoptic systems of the midlatitudes [the case for the economic success of which has already been demonstrated in detail, e.g. Friedman (1993)]. The predictability of convective rainfall in the Tropics, on both synoptic and longer time scales, does not necessarily immediately share the observational requirements of the midlatitudes, and further consideration of the design of observing systems specifically for tropical prediction would be valuable.

Constraint 2: Scientists. The second major constraint on African climate science is the relative scarcity of African climate scientists. The level of peer-reviewed journal publications in Africa is among the lowest anywhere in the world (Table 1). While excellent locally reported science is a feature of several climate centers in Africa (indeed, international leadership in ocean–atmosphere interaction, the downscaling of climate predictions on a range of time scales, and the use of climate information in disaster management, to name a few, are a feature of several centers), the limited extent of international engagement severely isolates African climate science. The capacity that does exist is certainly fragile in terms of numbers.

One upshot of the relative scarcity both of African scientists and of African observations is that we have little to no systematic understanding of the basic state of the circulation over critical parts of the continent, including the central African convective region (which at certain times of the year is the largest on the planet) adjoining Angola and much of the Sahara. Improvements in understanding these circulations across Africa, and their more accurate modeling, are essential for improving the management of activities affected by climate variability and future change, not only over Africa itself, but on a global scale. Without successful new research initiatives, for example, along the lines of the impetus expected from African Monsoon Multidisciplinary Analyses (AMMA) for the Sahel, this state of affairs is unlikely to change.

Why has this situation existed? Arguably, there may be a lack of investment in science across Africa as a whole, presumably in part as a consequence of investment in perceived higher-priority development and educational issues. But, in certain sectors, technological advance shows few limits. Mobile phone use in Africa over the period of 1998–2003, for example, grew 5000%, faster than anywhere else in the world (Coyle 2005). For a wide variety of reasons the technology is well suited to Africa and the take-up thereof is good proof of that. For climate science, on the other hand, the same kind of imperative has never seemed to exist. The salaries of climate scientists at many an institution languishes well below that of administrators, for example. If climate scientists could be shown to be delivering the right kind of information with demonstrated user applications that are related closely to the potential for an economic return, then the need for investment would, at least in part, be demonstrated. We believe that the upsurge of activity in climate on intraseasonal and interannual time scales over Africa, which is discussed next, is an early indicator of a growing political awareness. We recognize, however, that for some regions, climate may not play a central role in development.

CLIMATE VARIABILITY AND CLIMATE CHANGE. Climate change in Africa presents many challenges (Hulme et al. 2001; Desanker and Magadza 2001; Hulme et al. 2005), the solutions to which must accommodate the culture and needs of African societies, as well as provide mechanisms that will deal with the constraints limiting progress in climate science, and more broadly those in development overall. Information on seasonal and interannual time scales, including prediction, has the efficacy to demonstrate the value behind targeted climate information and, in turn, will begin to provide justification of the resources needed to reduce elements of the two key scientific constraints (data and scientific capacity). Climate variability might also be the point through which climate science and the development community engage seriously for the first time.

There is substantial evidence demonstrating that information related to climate variability is being disseminated and used increasingly in Africa. Regional centers that provide climate services, including early warning systems, to all or parts of Africa, have been created through international agreements—African Center for Meteorological Applications and Development (ACMAD) and the Agriculture, Hydrologic and Météorologie (AGRHYMET) research center based in Niamey, Niger; the Southern African Development Community (SADC) Drought Monitoring Centre in Harare, Zimbabwe; and its companion the Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre in Nairobi, Kenya. A further foundation activity has been the initiation of the Regional Climate Outlook Forums (RCOFs), formally agreed upon at the Workshop on Reducing Climate Related Vulnerability in southern Africa (held in Zimbabwe, in October 1996), which have been enacted through a sequence of pilot forums in Zimbabwe, Namibia, and South Africa through the 1997/98 rainfall season. The forums aim at generating consensus forecasts and bringing together climate forecasters and users to discuss the interpretation and use of these forecasts. Regular forums are held in Africa [the Southern Africa RCOF (SARCOF), Greater Horn of Africa Climate Outlook Forum (GHACOF), Prévision saisonnière en Afrique de l'Ouest (PRESAO) in West Africa]; some of which are among the longest running in the world (Washington and Downing 1999; Basher et al. 2001); similar initiatives have more recently taken place in North Africa [Prévision Saisonnière en Afrique du Nord (PRESANOR)]. Within the regions defined by these forums, international leadership is emerging. The South African Weather Service, for example, issues consolidated consensus forecasts to end users [complete with both observed and model data for use by other National Meteorological and Hydrological Services (NMHSs) in the region] while the Global Forecasting Centre for Southern Africa is an example of the type of cooperative development that is necessary to accelerate progress in this field.

Table 1. Affiliation of lead author of papers in two climate journals (2002–04). The number of papers and percentage of total papers published is shown for the *Journal of Climate* (columns 2 and 3, respectively) and the *International Journal of Climatology* (columns 4 and 5, respectively). The rows are world continental regions.

	Journal of Climate		***International Journal of Climatology***	
	Number	**%**	**Number**	**%**
North America (United States)	416	66.7	40	17.4
North America (Canada)	30	4.8	10	4.3
South America	18	2.9	15	6.5
Europe	98	15.7	103	44.8
Africa	**2**	**0.3**	**7**	**3.0**
Middle East	2	0.3	8	3.5
Asia (East)	40	6.4	18	7.8
Asia (South)	5	0.8	11	4.8
Australasia	13	2.1	17	7.4

There is growing evidence of the benefits of successful coupling between climate science and users at seasonal time scales in terms of improving the management of the effects of interannual climate variability on society, especially with regards to agricultural practices, but also in areas such as water management and disease control. Studies now include cattle farming in South Africa (Boone et al. 2004); maize production in semiarid Kenya (Hansen and Indeje 2004) and Zimbabwe (Phillips et al. 2002); pastrolists (Luseno et al. 2003) and smallholder production in Kenya (Amissah-Arthur 2003), southern Africa (Ziervogel and Downing 2004; Ziervogel et al. 2005), and Burkina Faso (Ingram et al. 2002); as well as diseases such as malaria (Thomson et al. 2003; Morse et al. 2005). With targeted climate information and predictions, it is possible for informed management options relating to planting, irrigating, harvesting, and fertilizing and pesticide application to be made (Gadgil et al. 2002), allowing the conclusion to be drawn that forecasts for improved agricultural decision making are advancing well (Hansen 2004).

However, limits remain to the successful incorporation of climate information products into routine procedures in both the public and private sectors. Patt and Gwata (2002) list a set of six constraints that limit the usefulness of forecasts: credibility, scale, legitimacy, cognitive capacity, procedural and institutional barriers, and available choices. Of these, the credibility and scale constraints are the most important because the forecast user community places a premium on certainty. In addition, users are interested in a broader range of characteristics of rainfall than just seasonal totals, notably, patchiness of rainfall, intensity, and season start date. Tarhule and Lamb (2003) found from a large survey of West Africans that access to climate information was limited, with low to nonexistent utilization of results of climate research. In spite of this their respondents exhibited keenness for climate information, although their opportunities to understand and act upon such information remain constrained by institutional and socioeconomic impediments that have prevailed for decades. These issues underscore the need to better integrate climate science communities with user communities.

In what way can the benefits resulting from management of the effects of climate variability be bridged with preparations for the longer time-scale impacts associated with climate change? Here we need to ask the question of what defines the time scales of variability and change. Unless formal distinctions between climate change and climate variability are drawn, climate change itself becomes a difficult concept to define, because all natural "change" is merely a reflection of variability on some appropriate time scale. The United Nations Framework Convention on Climate Change (UNFCCC) addresses this problem by defining climate change only as that component induced by anthropogenic activities. Thus, in the strictest sense, all activities under the UNFCCC banner address only the anthropogenic component, and provide no support for activities related to natural variability on whatever time scale. The terms of reference of the Intergovernmental Panel on Climate Change (IPCC), on the other hand, require consideration of both natural and human-induced variability and change. Nevertheless, the IPCC has tended to focus its activities on clearly discernable anthropogenic influences on climate, be it significant changes attributable to human influence or signals apparent in projections some decades into the future.

The early signs of anthropogenic climate change can be seen already in temperatures, both across the globe and regionally (Stott et al. 2004; Barnett et al. 2005). It has been demonstrated that the early signs of climate change can also be seen in the environment, for example, in the ecology of Lake Tanganyika (Verburg et al. 2003; O'Reilly et al. 2003). Actions to adapt to these existing changes may already have been taken (e.g., responses to increasing insect infestations), but there is little doubt that most adaptation activities badged in terms of climate change and currently under way in Africa relate more to the management of the effects of climate variability in its current form than to adaptation to the changed climate of 2080. In contrast, it is important to note that most decision making under the headings of sustainable development, MDGs, and so on, relates to time scales out to a few years, and generally includes minimal immediate concern for time scales into the latter part of this century. There is good reason for this, because it recognized by some that the ability to handle current climate variability is a vital and prime, if not a sufficient, requirement for managing a future changed climate; handling current climate variability further is directly achievable and provides immediate production and capacity benefits. Adaptation, however, on whatever time scale, is frequently endogenous (spontaneously occurring within a society rather than managed by an external organization or institution), and endogenous adaptation will inevitably form much of the response to both climate variability and to anthropogenically induced change. The excess adaptation required to cope with climate change, beyond that which will be supplied through dealing with the ongoing effects of climate variability, will also need to be handled in a managed manner, but we stress that the immediate imperative is to address climate variability in its present form as part of the continuum of change, as has been argued on many other occasions (e.g., Glantz 1992; Downing et al. 1997). Understanding how to manage the consequences of climate variability in the context of the many other influences on social, economic, and natural systems will clearly provide useful experience when considering strategies for handling future climate change.

Linked with this is the notion that climate change will manifest itself in part, and possibly largely, as a change in the frequency of events that are currently experienced within current climate variability. Consequently, as far as societies are concerned, climate change and climate variability are not conveniently separated processes, but are instead closely coupled in the complicated evolution of the climate system. From a practical perspective, the links may come about simply because some of the largest impacts of climate change could arise through the superposition of more intense forms of existing modes of variability on the underlying change.

For Africa there are very real climate science–related reasons to support this approach of priority management through climate variability. For a start, the amplitude of seasonal-to-interannual climate anomalies on the continent is large, and the exposure of economies to climate anomalies is high, with direct societal consequences. Political will exists to engage with these (shorter) time scales, with the benefit that the potential predictability of climate anomalies on seasonal time scales for parts of Africa is considered to be relatively high (Table 2). This, contrasted with the mixed messages on the African climate change signal, particularly with respect to precipitation (Table 3), does much to justify the shortening of the focus to the management of the effects of climate variability. While the uncertainties associated with projections of both climate change and its impacts can be significant (e.g., Challinor et al. 2005a; Conway 2005), the use of climate information, including seasonal forecasts, can have measurable benefits (e.g., Challinor et al. 2005b).

How sure are we that the increased adaptive capacity resulting from taking advantage of climate information, including predictions, on shorter time scales would enhance adaptive capacity on all time scales, or that the same kind of adaptive capacity would be required across all time scales? Would the improved capacity to adapt to current climate anomalies through operational decision making reduce vulnerability to climate change? A simple answer to these questions may be that seizing the opportunity of the shorter time-scale link between climate information and society would at least establish and nurture structural links at the climate–society interface. If these do not exist at present, then they will have to be constructed some time in the future if climate change is to be managed. But, if they do exist and are nurtured now, then management of climate change has a foundation on which to build. There is comfort also in the fact that adaptation strategies geared to cope with large climate anomalies would embrace a proportion of the envelope of change expected from long-term climate change. This is clearly the case when current climate anomalies, for example, episodes of El Niño, some extended for several years, are as large as, or larger than, long-term climate change anomalies projected by GCMs, especially for the next 20–50 years (see Hulme et al. 1999 for a European example).

Within a global context, information relating to climate variability in Africa has been grasped with considerable enthusiasm. Given the intimate link between climate and sustainable development, the limited technical understanding of climate over Africa, and the restricted resources and expertise in handling climate issues within Africa, it is argued that raising the capacity of Africa to handle climate variability out to a few years is an efficacious means of increasing the resilience and reducing the vulnerability of the continent to climate variability and change on all time scales. This will provide one prime route toward sustaining African society and its environment, as well as offering substantial assistance toward the achievement and maintenance of the MDGs post-2015. Developing the African adaptive capacity for climate variability and for climate change can therefore be achieved through much the same mechanisms.

Our perspective comes from the experience of working with and in climate research in Africa: we recognize that climate information forms one set of opportunities among a range of activities that are required to make real progress toward and beyond the MDGs. In relation to better management of

Table 2. Qualitative assessment of potential predictability (evaluations are relative to other parts of the world rather than absolute) resulting from at least eight expert assessments per region.

Region	Potential predictability
West Africa (July–September)	High
East Africa (October–December)	High
Southern Africa (January–March)	Medium
East Africa (March–May)	Low to medium
North Africa	Low
Congo/Angola/Mozambique	Unknown

Table 3. A summary of interclimate model consistency regarding future rainfall change for Africa caused by greenhouse gas emissions IPCC (2001b). Definitions of consistency: seven out of nine GCMs must show a consistent change for results to be classified in agreement. Large increase (decrease): agreement on an increase with an average change greater than +(–)20%. Small increase (decrease): agreement on an increase with an average change between +(–)5% and +(–)20%. No change: agreement with an average change between –5% and +5%. Results for two scenarios (A2 and B2) are shown for two seasons (December–January and June–August). [Source: Adapted from IPCC (2001b, Box 10.1, Fig. 2).]

	A2	B2	A2	B2
Region	December–January	December–January	June–August	June–August
Sahara	Inconsistent	Inconsistent	Large increase	Large increase
West Africa	Small increase	Small increase	No change	Inconsistent
East Africa	Small increase	Small increase	Inconsistent	Inconsistent
Southern Africa	Inconsistent	Inconsistent	Small decrease	Small decrease

climate variability and extremes, complementary actions include better integrating climate science and user communities (e.g., establishing early warning systems and disaster management), improving dissemination and communication of information, and developing intraseasonal information and downstream applications such as in water resources and health systems. A prerequisite to these activities is the generic need to build the capacity of and opportunity for farmers and other resource users to act on information.

An important qualification to this argument is that we are by no means suggesting that resources should be diverted from other activities such as the climate science associated with long-term climate projections. Such work should continue in parallel. Indeed, the African Climate Report itself was prompted by the climate change imperative and several sectors, for example, reservoir construction and management and hydroelectric generation, urgently require this long-term information. Climate change and climate variability are therefore not best viewed as two camps competing for resources.

TESTING TIMES FOR FARMERS. Although the idea that information related to climate variability offers the best pragmatic approach to strengthening the institutional fabric needed for African climate change is not new (Hulme et al. 2001, 2005), any demonstration of the idea has rested in discourse similar to that offered so far in this paper. A recently completed interdisciplinary study funded by the Tyndall Centre [Climate Outlooks and Agent-Based Simulation of Adaptation in Africa (CLOUD)] set out to formally investigate the hypothesis of whether individuals who adapt gradually to climate variability with the help of seasonal forecasts are better equipped to respond to longer-term climate variability and change in a sustainable manner (Washington et al. 2005; Bharwani et al. 2005).

The study featured the development of a multiagent model to represent the flow of information, decision making, and outcomes for smallholder farmers in Limpopo Province, South Africa. Extensive fieldwork (using surveys, participatory approaches, and computer-based knowledge elicitation tools) in a village in Vhembe District in Limpopo Province was used to formulate rules for climate-dependent agricultural strategies, market interaction, and livelihood needs. The region has been the focus of extensive field-based analyses of seasonal forecasting previously (Archer 2003). The agent-based social simulation incorporated households with varying response options that resulted in differing impacts on crop yields, and thus on food security, dependent on seasonal forecast information. Two broad groups of households are identified—those with slightly higher reserves and a greater number of response options available to them (the better-off farmers), and poorer farmers with low reserves and fewer options at hand. Key variables in the model include the skill of the forecast, the social communication of the forecasts, and the range of available household- and community-based risk-coping strategies. A unique feature of the model is the dynamic and social learning that takes place in response to each forecast and the outcome of each season. Trust in the forecast was defined as the changing perception of the forecast accuracy as experienced among the farmers. In this dynamic system a higher skill results in more widespread benefits (Bharwani et al. 2005).

The computation of trust in the model affects the results. Farmers with a higher proclivity for trust tend to use the forecasts more often. This leads to a buildup in wealth as long as the forecasts are reasonably skillful. However, a poor forecast can trigger a collapse in trust that resets the system essentially to the position that forecasts have to be reaccepted in order to be used again. Trust is unlikely to be regained if there is a run of forecasts will low skill (Bharwani et al. 2005).

The model was evaluated for four distinct circumstances. In a control simulation, with climate information derived from a long control run of the third Hadley Centre Coupled Ocean–Atmosphere General Circulation Model (HadCM3), poorer farmers experienced decreasing and marginal livelihoods with better-off farmers experiencing sustainable livelihoods. The addition of the seasonal forecasting of climate information with moderate skill (equivalent to skill available from consensus forecasts currently available) brings benefit to the better-off farmers who have resources to deploy in response to the information. High seasonal forecast skill, of the order experienced for the short rains in East Africa for some climate models, brings reduced vulnerability to both groups of farmers, but particularly so to the better-off farmers. Crucially, we find that the addition of the climate change signal, taken from a simulation of HadCM3 with greenhouse gas forcing, in the presence of seasonal forecasting information, allows the better-off farmers to maintain the kind of livelihood experienced with present conditions into the future (Table 4).

The simulation described here is a pioneering effort to link fieldwork and formal models as well as

Table 4. Key outcomes from agent-based simulation of two groups of southern African (better-off and poorer) subsistence farmers under current operating conditions (row 1), current operating conditions plus seasonal climate prediction (row 2), climate change plus seasonal climate prediction (row 3), and climate change without seasonal climate prediction (row 4); "+" indicates benefits to farmers, "–" indicates decreased livelihoods, relative to a current baseline (Washington et al. 2005).

Experiment	Better-off farmers	Poorer farmers
Current risk management	+	–
With seasonal climate forecasts	++	–
With improved forecasts (85% skill)	+++	+
With improved forecasts and climate change	+	–

societal responses to climate variability over a range of time scales. This model provides substance to the argument for the management of climate change through the management of climate variability.

A FINAL WORD. An immediate challenge in Africa is to build the capacity needed to handle climate variability. Coping strategies for climate variability that existed perhaps 150 years ago, including migration, diversification, and conflict, are no longer relevant in an era of international boundaries, globalization, urbanization, and growing populations. Developing capacity within the context of variability will contribute significantly toward sustainable development.

Africa has the most limited capacity of any region on the globe in terms of climate expertise and resources. We argue that this restricted capacity, to some degree, inhibits progress toward sustainable development on the continent. We have noted that the detailed scientific knowledge of the mechanisms of African climate lags behind that of other regions, knowledge that would ultimately contribute to building capacity in all its contexts.

In part, the current position in Africa from the international perspective has developed from the perceived lesser importance of circulations across Africa within the context of providing predictions on the global scale. Nevertheless, in some respects, for example, in the genesis of Atlantic hurricanes and Saharan mineral aerosols, African meteorology is seen as playing an important international role. Environmental research programs [e.g., World Climate Research Programme (WCRP), International Geosphere–Biosphere Programme (IGBP), International Human Dimensions Programme (IHDP), International Programme of Biodiversity Science (DIVERSITAS), and AMMA], either within or focused on Africa, are being developed. These projects will build not only knowledge of the climate and environment of Africa, but will also develop capacity and legacy. All, however, are being created from a relatively low-capacity background, and further activities are undoubtedly needed.

Lack of capacity is not the only barrier to progress within the continent. Climate is often seen at the national level as a lesser priority compared to other spending needs, and the case for higher investment has not been accepted in all countries. Traditionally, many African NMHSs have developed around either transport or military demands, with climate being a minor player. More recently, with the development of seasonal forecasting (Dilley 2000; Tarhule and Lamb 2003; Goddard and Dilley 2005), NMHSs have become far more aware of climate issues and of their need to encompass these, but this has also emphasized their resource limitations within this regard.

Change and progress often stem from both the experience of individual extreme events and the material knowledge available to rationally respond to these circumstances. Friedman (1993) provides the example of the October 1921 storm in Scandinavia in his account of the birth of modern meteorology. In retrospect, we may see well the events surrounding the 1997/98 El Niño (Dilley 2000) as those that galvanized the role of climate in African development.

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