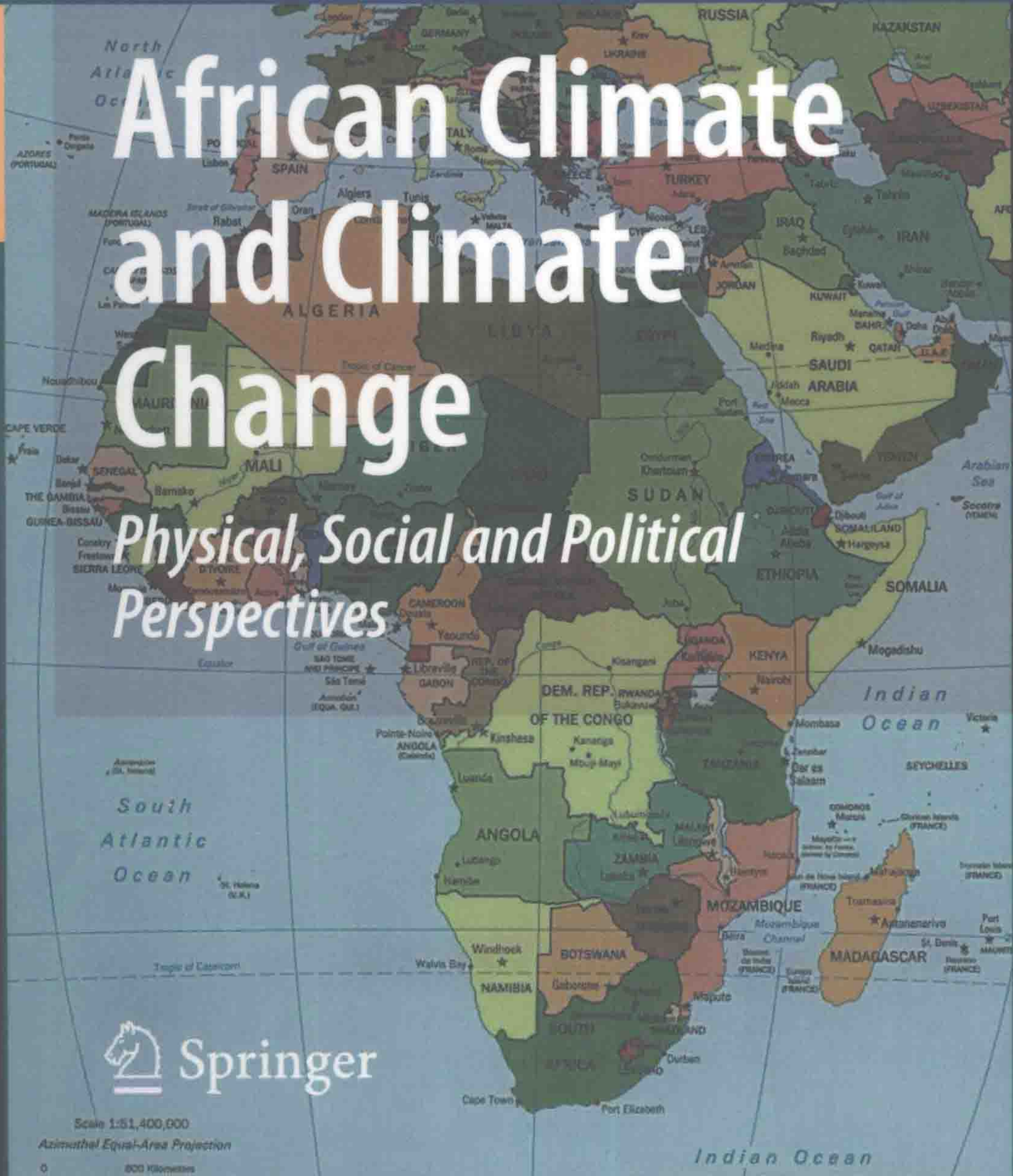
Charles J. R. Williams
Dominic R. Kniveton
Editors

ADVANCES IN GLOBAL CHANGE RESEARCH 43

African Climate and Climate Change

Physical, Social and Political Perspectives



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Physical, Social and Political Perspectives

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Contents

Introduction

Charles J.R. Williams and Dominic R. Kniveton

Keywords Introduction · Background · Climate change · Mitigation · Adaptation · Impacts · Uncertainty · Vulnerability · Options · Resilience

1 General Background

It is widely accepted that the trend in rising global temperatures during the twentieth-century can be attributed to anthropogenic greenhouse gas emissions, stated with 90% certainty by the most recent report of the Intergovernmental Panel on Climate Change (IPCC 2007). Even with immediate and complete mitigation of emissions, an unlikely eventuality under the current political consensus, global impacts of such increasing temperatures are unavoidable; far less certain are the regional impacts. It is generally agreed, however, that economically developing and vulnerable countries will be hardest hit, being less able to adapt to future changes in climate.

Of all developing regions, Africa (and in particular sub-Saharan Africa) is likely to be the worst affected by any present-day climate variability and future climate change. The region is the only in the world to have become poorer in the last generation (Ravallion and Chen 2004), and although it comprises only 12% of the world's population (Population Reference Bureau 2009) it accounted for 28% of the world's poverty in 2005 (World Bank 2005, Washington et al. 2006). It has been estimated that 30% of the population of sub-Saharan Africa suffers from food insecurity and extreme poverty (Balasubramanian et al. 2007). As a whole, Africa's population has recently passed the one billion mark and is expected to double by 2050 (Population Reference Bureau 2009). This population explosion, underdevelopment and poverty can be attributed to many socio-economic, political and environmental factors, one of the most important ones being an inability to adapt to extremes of climate (such as flooding and drought) which are prevalent across the continent (Washington et al.

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2006). Tropical Cyclones Gafilo and Eline in 2004 and 2000, respectively, highlight the sudden impacts of climate variability and extreme events on society, whereas more chronic climate extremes such as the East African and Sahelian droughts demonstrate the longer term impacts. Therefore, even under the current highly variable climate conditions, the majority of sub-Saharan Africa is unable to cope with extremes in climate (e.g. IPCC 2001, Cook et al. 2004, Segele and Lamb 2005, Washington et al. 2006). With projections of future climate change suggesting that the continent will become drier (e.g. Desanker and Magadza 2001, Hulme et al. 2001, Thomas et al. 2005) and extremes more frequent (e.g. IPCC 2007), it is clear that the situation will worsen.

Africa is considered particularly vulnerable to the effects of climate change and climate variability, relative to many other regions of the world. African society possesses a low resilience and limited adaptative capacity to climate-related shocks and stresses, because of widespread poverty, an extensive disease burden and pockets of political instability across the continent. An improved understanding of African climate change and its likely impacts cannot be gained by studying one aspect alone, thus research on the subject of African climate change requires an interdisciplinary approach linking studies of environmental, political and socio-economic spheres. However this interdisciplinary approach has, for the most part, been lacking, with scientists conducting excellent research within their own spheres but often failing to communicate and discuss their findings (and implications) to other disciplines.

This book aims to help rectify this problem. It is the outcome of a 2-day meeting held in April 2007, which was highly successful in bringing together the physical science of African climate with the social, economic and political issues surrounding climate change over Africa. Examples of the physical side of climate research included present-day climate variability and change, past climatic changes and future predictions under various scenarios of climate change, whereas examples of the socio-economic side included adaptation, food security and possible migration outcomes. In this introductory chapter, a general background to the problems facing Africa (within the context of climate variability and change) is provided. Some of the largest uncertainties over climate change, both globally and specific to Africa, are introduced in Section 2. The reasons for Africa's particularly high level of vulnerability to climate shocks and stresses are outlined in Section 3, before a discussion of the main impacts of present-day climate variability and future climate change on Africa in Section 4. An introduction to some possible options for reducing vulnerability is given in Section 5, before concluding with an outline of the rest of the book.

2 Uncertainty over Climate Change

Despite the IPCC's confidence in the causes of twentieth-century climate change, there remains considerable uncertainty as to how this climate change will be manifested and what will be the likely impacts on a regional scale. For African society, it is generally agreed that the availability of water is going to be critical for any future social and economic development, yet at the same time this high level of dependence on water availability (itself dependent on rainfall variability and its efficient management) is coming from a continent subject to highly variable rainfall, both spatially and temporally (Washington et al. 2006).

Furthermore, even at a global scale, of all the possible impacts of increasing global temperatures, changes in mean rainfall, rainfall variability and associated hydrological processes are the most uncertain. Although the models do agree on twentieth-century drying over Africa, there is no robust agreement in their predictions of twenty-first-century rainfall (Giannini et al. 2008). The uncertainty is demonstrated by Fig. 1, adapted from the latest IPCC Assessment Report and showing global changes in precipitation under the expected scenario of future climate change. Both increases and decreases in rainfall are projected across Africa, however the most important point of the figure is the lack of agreement between model predictions. Africa shows the least agreement between models of all the continents and, apart from relatively small regions, for the majority of Africa the models do not agree on even the sign of change, let alone its magnitude (Fig. 1).

At smaller spatial scales, such as the regional, uncertainty over climate change (and its impacts) increases further. For example, Giannini (2010) describes two mechanisms of climate change over the Sahel, both of which show surface warming but with an increase in rainfall in one and a decrease in the other. In the first scenario, increased rainfall occurs because of the increase in net terrestrial surface radiation, amplified by an increase in near-surface humidity and associated water vapour feedback (Giannini 2010). Thus surface warming is resulting in a direct rainfall change. Conversely, in the second scenario it would appear that the reverse is occurring, with rainfall and evaporation decreases occurring due to remote forcings, which therefore contributes to local land surface warming (Giannini 2010). Uncertainty over the Sahel region also varies according to what rainfall metric is used, with the models showing some agreement over changes in the length of the wet season but

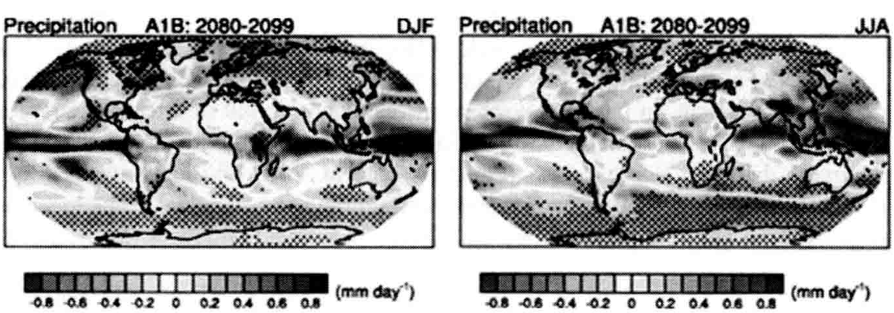

Fig. 1 Multi-model mean changes in precipitation in mm day^{-1}, for DJF (*left*) and JJA (*right*). Changes are given for the SRES A1B scenario, for the period 2080–2099 relative to 1980–1999. Stippling denotes areas where the magnitude of the multi-model ensemble mean exceeds the inter-model standard deviation. Adapted from Fig. 10.9 of the IPCC Fourth Assessment Report (Meehl et al. 2007)

much less agreement in changes to total rainfall (Biasutti and Sobel 2009). There is therefore high uncertainty over future rainfall changes and thus water availability.

3 Reasons for Particularly High Vulnerability of Africa

As explained in Section 1, our understanding of climate variability and change and its impacts over Africa is hampered by numerous problems. These include environmental constraints, such as Africa being a region of relatively low and highly variable rainfall yet at the same time having a high dependence on rainfed agriculture (Williams et al. 2007). Of equal importance are the socio-economic factors, including technological and scientific underdevelopment exacerbated by civil war, political instability, population pressures, extensive poverty, widespread disease and the HIV/AIDS crisis (Desanker and Magadza 2001, Hudson and Jones 2002, Williams et al. 2008).

Yet, despite this high vulnerability, there remain large knowledge gaps on African climate, manifestations of future climate change and variability for the region and the associated negative impacts of climate change. There are several reasons, specific to Africa, for these knowledge gaps, the two most important being a lack of reliable data and a lack of African scientific expertise. For the former, although it is clearly agreed that understanding the climate system requires accurate, reliable, long-term and spatially distributed climate data, Africa has the worst climate-observing system of any continent and this is gradually deteriorating (Washington et al. 2004, 2006). The World Metrological Organisation (WMO) estimates that the network of World Weather Watch (WWW) stations has an average station density that is 8 times lower than their recommended level, at one station per 26,000 km^2 across Africa (Washington et al. 2006). The few stations that do exist are unevenly distributed, and suffer maintenance and transmission problems meaning that much of the continent is constantly unmonitored (Washington et al. 2006). The uneven distribution of observations is particularly poor for rain gauge stations, such as those of the Global Telecommunications System (GTS) network. As Fig. 2 shows, with the exception of certain countries such as South Africa and small regions of West Africa, most of the continent has either very few stations or none at all. One direct result of this is that, of the little work on climate coming out of Africa, the majority of past studies on daily rainfall variability have been mainly restricted to the relatively data-rich South Africa (Fauchereau et al. 2003, Williams et al. 2007). However, even here, institutional support and funding for climate science has been poor over the last few years compared to more developed countries (Reason et al. 2006).

The second main reason for our knowledge gaps is a lack of expertise in African climate science. Although there are several centres of excellence across Africa focusing on a number of crucial climate issues, internationally there is a relative scarcity of climate scientists from Africa and the continent has one of the lowest number of peer-reviewed publications in the world (Washington et al. 2006). This is partly due to the perception of climate science in many parts of Africa, where

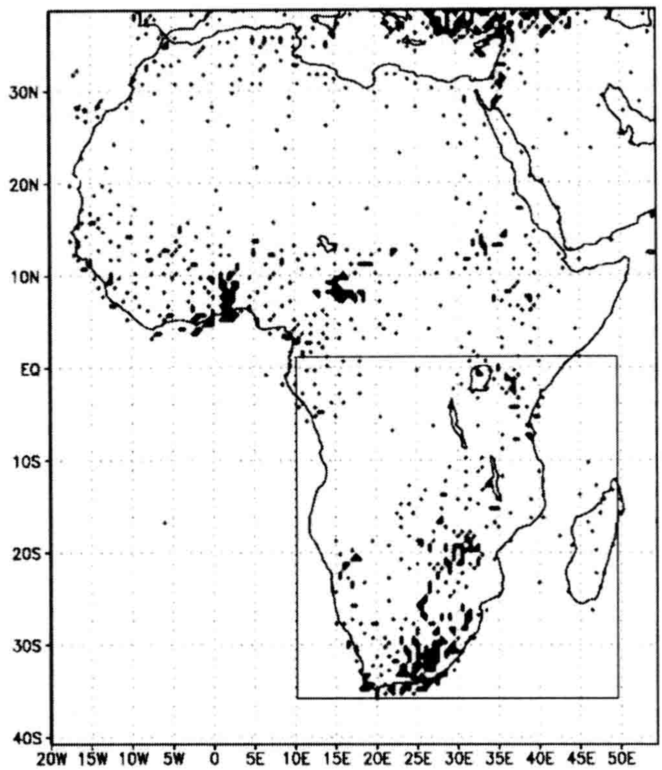

Fig. 2 Spatial coverage of the Global Telecommunications System (GTS) rain gauge dataset from 1990 to 2000, showing cells that contain one or more rain gauges at 0.5° spatial resolution (Layberry et al. 2006)

the imperative to fund climate scientists is at times so low that scientists' salaries are well below administrators (Washington et al. 2006). Many African governments concentrate funding on other issues such as food security, education and health, and although there is clearly a pressing need for this it has often been to the detriment of scientific development. Where there is interest in climate science, it has often been focused on interannual variability and seasonal forecasting only, as data on these timescales (such as wet season start dates or dry spell length) have direct relevance for agricultural production and therefore food security (Washington et al. 2006). Whilst this is of utmost importance, it has nevertheless meant that the longer timescale at which climate change operates is seen as less immediate and therefore less important.

4 Expected Impacts of Climate Change on Africa

Despite the above uncertainties, and in light of Africa's high vulnerability and low adaptive capacity to climate change, there are a number of detrimental impacts on the continent which can be expected as global temperatures rise. In the following, only those impacts directly related to changing rainfall variability are discussed. Whilst other impacts are considered extremely worrying for Africa, including increasing heat stress, sea-level rise (and resultant flooding) and changes in the spatial distribution of diseases (such as malaria, dengue fever and cholera) (Boko et al. 2007), it can be argued that water stress resulting from changing rainfall patterns is of primary concern. Returning to the global scale and Fig. 1, some models suggest that during December–February (DJF) equatorial regions of Africa are expected to become wetter, with drying over the tropics and subtropics. During June–August (JJA), rainfall changes are projected to be smaller, with slightly wetter conditions over equatorial regions. These projections are made, however, within the above caveat of the lack of agreement between models, which only show consensus over eastern (southern) Africa during DJF (JJA). Socio-economic factors such as land-use changes driven by population growth, shifting cultivation and overgrazing will also worsen the large-scale impacts of climate change, with one study suggesting increased temperatures, increased heat stress and drier conditions across Africa as a result of the combined impact of increasing global temperatures and local land-use change (Bronnimann et al. 2008).

At smaller spatial scales, projections of the impacts of climate change have also been made for certain African regions, despite the uncertainty as discussed above. Southern Africa, for example, is expected to experience a decrease in total rainfall and an increase in dry spells during the wet season, both of which will negatively impact crop and livestock production and thus economic development (Twomlow et al. 2008). Projections have also been made at even smaller spatial scales, such as the country or local level. For example, experiments on the effect of increasing temperature on annual mean rainfall over the Highveld region in South Africa suggest a reduction in rainfall over this already dry and thus vulnerable region, with average agricultural yield decreasing by up to 30% as a direct consequence (Walker and Schultz 2008). In Namibia, it has been suggested that the effect of climate change on natural resources alone may cause a reduction in the economy by 5% of GDP over the next 20 years (Reid et al. 2008). Therefore, projections of how climate change may impact Africa do exist, despite the large uncertainty. What is more certain is that whatever spatial scale is used, Africa is likely to be impacted in a number of direct and indirect ways by changing rainfall patterns. For example, climate change will directly impact African society through its impact on crop yields, while indirectly it will influence migration and conflict patterns.

For many countries that already experience semi-arid conditions, changes in rainfall are expected to constrain agricultural production and therefore detrimentally impact food security. An example of this is might be a reduction in the growing season length or bringing increasing uncertainty into wet season start dates. Agricultural yield in some countries is projected to fall by 50% by 2020 and overall crop revenue might decrease by 90% by 2100 (Boko et al. 2007). Because of their low adaptive capacity, small-scale farmers are likely to be the worst affected by these decreases in revenue (Boko et al. 2007). Water stress will also significantly worsen for countries that are already stressed (and will become a risk for the others), with several countries projected to exceed the limits of their usable water resources before 2025 even under current conditions (Boko et al. 2007). Currently, approximately 25% of Africa's population experiences pressure from water availability and accessibility, and this water stress is projected to increase to between 40 and 75% of the population by the 2050s (Boko et al. 2007). This, as has been demonstrated in the past, will undoubtedly worsen both national and international conflict, as countries and societies compete for access to diminishing water supplies. In addition to the large human cost, Africa's ecosystems (such as forest, grassland and marine) will also be detrimentally impacted by this increased water stress, with changes already being detected in certain areas (Boko et al. 2007).

Not all regions are expected to become drier with increasing global temperatures, with expectations that parts of eastern Africa will experience an increase in rainfall (IPCC 2007). However these regions are expected to experience different but equally challenging problems such as flooding, a shift in wet season length and duration, and the destruction of crops because of unpredictable and increasingly erratic rain. Water stress, resulting from either increasing or decreasing rainfall changes, is therefore likely to become a key issue for both human and environmental systems. There are, however, several options for adapting and reducing vulnerability to climate variability, and although it is recognised that these adaptations may not be sufficient to cope with future changes, they are still nevertheless being developed to address current concerns (Boko et al. 2007).

5 Options for Reducing Vulnerability

In order to reduce vulnerability to future climate change, it is evident that adaptation to current climate variability (to reduce vulnerability to present-day climate extremes) is important. Thornton et al. (2006) go further, stating that adaptation is not an option but a necessity for many African countries. It is clear that, in terms of adaptation strategies, there is a distinction between the timescales of climate variability and climate change, with the former receiving the most priority in many African weather and climate centres. There is clearly a need to focus on the climate variability timescale, not least because it is likely that climate change will be partly manifested by a change in the frequency of extreme events currently experienced within present day climate variability (Washington et al. 2006). Lessons can be learnt on how the most vulnerable (usually the rural poor) currently adapt to this variability, and these lessons can then be used to assist in further adaptation to future climate change (Twomlow et al. 2008). Although climate variability and climate change are often seen as separate issues, it is recognised that the two can be bridged, with adaptation to the immediate impacts of climate variability being vital in preparing for the longer term impacts of climate change (Washington et al. 2006). In this way, successful management of shorter term climate variability provides a win–win outcome, by reducing vulnerability both now and in the future. At the same time, however, it is acknowledged that it would be shortsighted to only focus on short-term adaptive capacity, such as immediate responses to climate shocks and uncoordinated or isolated adaptation projects (Sachs 2005).

Adaptation often occurs spontaneously within a society rather than being imposed and managed by governmental policy or another institution (Washington et al. 2006). For example, adaptation to drought often takes the form of evasion, whereby farmers move their livestock on a seasonal basis to exploit the best resources at the appropriate time of year (O'Farrell et al. 2009). However, the extra adaptation needed to cope with future climate change needs to be managed and planned. If properly managed and embedded within civil and political rights, adaptation has been shown to be both successful and sustainable (Brooks et al. 2005). Thus adaptation measures and strategies have already been adopted by many African nations, summarised below. In the following, adapted from Table 9.2 from the IPCC's Fourth Assessment Report (Boko et al. 2007 – see original table for full list of authors), adaptation practices have been divided into those providing social and economic resilience.

1. Social resilience

- *Social networks*
  - Networks of community groups created, depending on the perception of risk, which itself determines the type of adaptation
  - Local saving schemes created, where possible, and subsequently used during times of climate stress
- *Institutions*
  - Institutional support recognised as vital in informing policy to improve resilience, however if not properly managed has danger of constraining adaptive capacity

2. Economic resilience

- *Equity*
  - Needs to be viewed on several scales such as locally (e.g. between communities) and globally/regionally (e.g. Clean Development Mechanisms). Again, if not properly managed, interventions to enhance community resilience can cause reductions in equity
- *Diversification of livelihoods*
  - For example – agricultural diversification and intensification, based on increased livestock, using natural fertilisers, soil conservation techniques, etc
- *Technology*
  - For example – technological improvements to current farming systems, via adaptation measures such as water-harvesting systems, dam building, water

  - conservation, drip irrigation, development and use of other crop types such as drought-resistant varieties, etc
  - Development, production and most importantly successful dissemination and use of improved seasonal forecasting

- *Infrastructure*
  - For example – improvements in physical infrastructure (such as road, rail and communication networks) to allow better exchange of information

In terms of providing climate information, one of the more important examples above is the improvement of early warning systems of extreme weather events, at short timescales such as seasonal, monthly, daily and even hourly. However successful early warning systems require a good understanding of the processes that control climate variability, which requires reliable and well-distributed observational data which, as discussed above, are seriously lacking across Africa. A further constraint for many, if not all, of the above adaptation strategies is the cost, both to initially set up the scheme and then sustainably maintain it (Boko et al. 2007). These costs need to be balanced against the potential costs resulting from climate change impacts with *no* adaptation, despite the challenges in doing so (Yohe and Schlesinger 2002). Therefore, whilst adaptation measures are clearly needed to reduce vulnerability to both current climate variability and future climate change, their implementation is not straightforward and further interdisciplinary work is required.

6 Structure of Book

Despite the relative lack of attention previously given to African climate science, this is starting to be addressed and this book provides a number of examples showing how we can improve our knowledge of current African climate, future African climate change and its potential impacts. In this book we use several case studies of climate variability and change in Africa, to illustrate different approaches to the study of African climate from across the spectrum of physical, social and political sciences. In doing so we attempt to highlight a toolbox of methodologies, along with their limitations and advantages, that may be used to further the understanding of the impacts of climate change in Africa. In turn, this will help form the basis for strategies to reduce the negative impacts of climate change. Despite focusing on Africa, the methodologies illustrated in this book can be extended to other countries and regions, and provide a basis for a framework for understanding climate change globally and its impacts on society in general.

As discussed above, our knowledge of African climate and associated processes relies on a selection of in situ and remotely sensed climate data, reanalysis data and climate models. One of the first steps is to understand the processes occurring over regions of Africa, and ascertain the uncertainty or knowledge base on climate in the region. Using Ethiopia as a case study, Chapters 2 and 3 give an example of this, using observational/reanalysis and climate model-generated data respectively.

The next stage in the process is to try and identify potential controls on climate, as shown by Chapters 4 and 5 which focus on southern and central Africa respectively. An examination of the expected impacts of climate variability and change on hydrology across Africa is then given in Chapter 6, before focusing on the sensitivity of social-ecosystems to changes in climate and possible adaptation strategies in Chapter 7. Finally, the impact of climate change (and also resultant adaptation measures) on African society is addressed, by focusing on the effect of climate change on migration in Chapter 8. In examining the impacts of climate change, two different methodologies are shown: (i) one of scenario modeling, where scenarios of climate change are fed through a series of hydrological and ecological models to assess the potential impacts (Chapter 6); and (ii) one of sensitivity testing, whereby a model of migration decision-making (in the face of climate change) is used to test the sensitivity of migration flows to different climate changes (Chapter 8). The former of these provides useful starting points for discussions over future developments of the affected systems. While less immediately usable by stakeholders, the latter of these approaches attempts to deal with the uncertain and dynamic nature of climate change prediction and promote an adaptation pathway of building resilience. The chapters on impacts also illustrate different methodologies to explore social and physical impacts of climate change, but share the premise of being developed using process-driven theory in order to more accurately represent change which, in the case of climate change, is likely to be outside of that already experienced.

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