Joseph A. Yaro · Jan Hesselberg *Editors*

Adaptation to Climate Change and Variability in Rural West Africa

Springer

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Chapter 1
Introduction to Book

Joseph Awetori Yaro and Jan Hesselberg

1.1 Introduction

This book provides conceptual and empirical discussions of adaptation to climate change/variability in rural West Africa. It brings on-board country experiences in adaptation by different socio-economic groups and efforts at building adaptive capacity. It presents a holistic understanding of adaptation and shows contextual and generic sources of adaptive capacity. Focusing on adaptation to climate change/variability is critical because the development challenges of rural West Africa have been historically intertwined with its climate. Moreover, emerging patterns of climate change are inextricably linked to developmental issues today for West Africa's agrarian communities with high numbers of the population earning a living directly and indirectly from the natural environment. Natural resource dependence and agrarian livelihoods make such communities most vulnerable to climate-driven ecological change. Therefore, it is imperative that rural people adapt to climate change, but their ability to successfully do so may be limited by competing risks and vulnerabilities. Their adaptive capacity may be impeded by sources of vulnerabilities such as agricultural policies, trade arrangements or governance issues that are rooted in the wider political economy. Providing an elucidation of these vulnerabilities and the capacities needed to enable successful adaptation and avoid maladaptation is critical for future policy formulation. Though the empirical discussions in this book are about West Africa, their applicability in terms of the processes, structures, needs, strategies, and recommendations for policy transcends

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West Africa and they provide useful lessons for understanding adaptation broadly in rural settings of the developing world.

West Africa is predominantly a semiarid region with a rapidly growing population and a low gross domestic product (Ayuk and Kabore 2013; Brown et al. 2009; Elbehri 2013; Jerven 2015). The rural population in the West African Savannah and Sahel constitutes one of the most vulnerable on earth, and this vulnerability is partly caused by the variability of the West African monsoon (Barbier et al. 2009). West Africa's climate is among the most variable in the world on intra-seasonal to decadal timescales (see Chaps. 2 and 3). There has been a pattern of continued aridity since the late 1960s and some recovery since the 1990s (Christiansen et al. 2007; Codjoe and Owusu 2011; Nicholson et al. 1999). The projected climate change indicates continuous and stronger warming (1.5–6.5 °C) and a wider range of precipitation uncertainty (roughly between −30 and 30 %) which is even broader in the Sahel and increasing in the farther future (Sylla et al. this volume). The mean precipitation change over West Africa shows a less evident trend and mostly oscillates between −10 and 10 %. Sylla et al. (this volume) assert that in the rest of West Africa the projected rainy season and the growing season will become shorter while the torrid, arid and semi-arid climate conditions will substantially extend. Riede et al. (this volume) assert that climate projections for West Africa show a slight increase of total precipitation and a longer rainy season with a drier phase within. These differences in projections result from the unpredictable West African monsoon system.

The changing climate and increasing variability increases the vulnerability of the region's population to climate stressors such as droughts, floods, heat waves, and changing rainfall patterns, and will increase the cost of food, health, basic infrastructural provision and humanitarian assistance. The impacts of climate change on the region are expected to be widespread, complex, and geographically and temporally variable (Marc et al. 2015; Wakhungu 2011; Yaro et al. 2010). The different climate stressors will reduce agricultural production in West Africa significantly and therefore affect the livelihoods of over half of its population living in rural areas (Hallegatte et al. 2016). The changing climate does not only affect agriculture; it impacts all facets of the lives of rural dwellers.

Rural West Africans deploy a range of ingenious strategies in dealing with climatic changes and variability, including irrigation, change in crop varieties, non-farm activities, and diversification of crops and livestock. These strategies reduce farmers' dependency on rainfall but are insufficient to reduce poverty and vulnerability for the majority (Barbier et al. 2009; Rademacher-Schulz et al. 2014; Resurreccion 2013). These adaptive strategies are dependent on adaptive capacities, which are enabled by social, economic, physical, and cultural circumstances (Derbile and Laube 2014). The IPCC (2001) defines adaptive capacity as the potential, capability, or ability of a system to adapt to climate change stimuli and their effects or impacts. A deeper understanding of adaptation is critical in answering the questions: How effective are these strategies? What determines them? Which interventions are more helpful and to whom? What policies are enabling or disabling? How can we enhance the capacity of rural Africa to adapt appropriately?

The multiplex livelihoods in dry areas mirror complex realities of life. We need to unearth the intricate processes, intentions and aspirations of rural dwellers to understand their adaptation potentials and reasons for failure and success. To be effective, these measures require different structures and institutions to galvanise necessary action and resources. Some of these measures include the following as suggested by Agrawal et al. (2008): information gathering and dissemination, resource mobilization and allocation, skills development and capacity building, providing leadership, and networking with other decision makers and institutions.

Although the main manifestations of climate change are of a physical nature, their consequences transcend ecological, social, cultural, political and economic impacts (Afifi et al. 2014; Hallegatte et al. 2016; Inderberg et al. 2015; Mendelsohn et al. 2006; O'Brien and Selboe 2015; Rademacher-Schulz and Salifu 2014) and shape prospects for food, water and health security. Adaptation can be positive or negative: positive if it is by choice, reversible, and increases security; negative if it is of necessity, irreversible, and fails to increase security. The challenge is to show how the political economy and its embedded social relations impede and facilitate effective adaptation to climate change. Building adaptive capacity requires substantial attention to crucial factors such as land rights and access to resources, legal provisions and policies, trade regimes, as well as governance issues such as elite capture of resources which generate or maintain poverty and shape access patterns defining livelihood resilience. The effects of climate change/variability should not lead to catastrophic and irreversible damage to humans since societies' adaptive capacity can be strengthened and streamlined (Heltberg et al. 2009; IPCC 2007; Leary and 2007).

1.2 Outline of the Book

Chapter 1 introduces the subject matter of the book and provides a summary of its contents. It makes a case for dealing with adaptation to climate change/variability in rural West Africa.

In Chap. 2, an analysis of the IPPCs 5th report is presented to set the background against which the discussions on adaptation can be related. The latest IPCC (2014) report concludes that Africa as a whole is one of the most vulnerable continents due to its high exposure and low adaptive capacity. Temperature projections over West Africa from global climate simulation for the end of the 21st century range between 3 and 6 °C above the late 20th century baseline depending on the emission scenario. The authors of this chapter observe that in the past a shift of the rainy season was discussed, but currently a shift cannot be observed for West Africa. Yet the length of the Sahelian rainy season reveals an increasing trend of 2–3 days per decade, with a drier phase within. However, climate projections show a slight increase of total precipitation and a longer rainy season.

Similarly, Chap. 3 continues the analysis of the physical dimension of climate change in the region. The chapter presents an assessment of recent trends and future changes of the climate in the region. It shows that the Sahel has recovered from the previous drought episodes of the 1970s and 1980s. However, the precipitation amount is not at the level of the pre-drought period. The authors argue that most countries in West Africa will have to cope with shorter rainy seasons; generalized torrid, arid and semi-arid conditions; longer dry spells; and more intense extreme precipitations.

Chapter 4 meticulously argues that the strategies for climate change adaptation designed for deliberate change have to be considered in the context of closely coupled social-ecological systems. It presents examples of prominent adaptation strategies that have been introduced in an attempt to adjust to the already evolving climatic conditions and shows that a lack of whole systems thinking is at the heart of the limited sustainability of promising strategies.

Chapter 5 examines the determinants of adaptive capacity in rural northern Ghana. It reveals that while adaptive capacity in the northern savannah zone is generally low due to high levels of poverty and poor state presence, it varies spatially due to locational, individual and community factors. The importance of both community and individual level factors and characteristics defining the capacities to adopt specific adaptation strategies to climate change threats are cogently discussed.

Chapter 6 evaluates the potential role and limitations of local knowledge in climate change adaptation from an endogenous development perspective in Ghana. It cautions that even though local knowledge enables environmental sustainability and climate change adaptation in smallholder agriculture, it is not without limits and risks.

Chapter 7 examines the concept of community-based adaptation (CBA) as a key strategy in adaptation and rural development landscapes. It shows how CBAs can be very successful at raising the profile of bottom-up expressions in the international climate change architecture with strong top-down, "scientistic" tendencies. Using social capital as an analytical capsule, this chapter investigates competing claims arising in the context of a sudden increase in the value of natural resources.

Chapter 8 focuses on trajectories of rural transformation in northern Ghana by examining changes in rural aspirations and future-oriented strategies among the rural people. It discusses the extent to which these changes contribute to better individual social mobility, rural transformation and enhanced adaptation and concludes that rural adaptation policies, often focussing on agriculture, need to take changing aspirations and larger rural social transformations into account.

Chapter 9 addresses the issue of migration as a societal response to climate change using Mali and Senegal as cases. It shows how the changing and unsteady environmental conditions lead to changing patterns of migration. It examines the interacting influence of environmental and socio-economic conditions on the decision to migrate, but stresses that unfavourable environmental conditions play a decisive role when people migrate seasonally for economic reasons.

Chapter 10 discusses the distinct overemphasis on rural agricultural spaces that undergirds much of the literature on local riskscapes in West Africa. It does this by elucidating how households that live on the fringes of rapidly transforming peri-urban spaces are caught in a double bind of institutional and spatial marginality. The chapter argues that peri-urban households are confronted with socio-environmental risks that are similar to those experienced by their rural counterparts, while at the same time being subjected to interrelated institutional and material transformations which define such spaces as dynamic risk frontiers.

Chapter 11 discusses the turn toward ecosystem-based adaptation, which adopts a multi-sectoral approach to sustaining healthy ecosystems as a means of reducing vulnerability and enhancing the resilience of social and ecological systems to climate change impacts. It shows that although the concept of ecosystem-based adaptation appears promising, the transition from conventional climate change adaptation policies toward ecosystem-based adaptation in West Africa has been slow. The chapter also discusses the potential roles of non-governmental organizations (NGOs) in enhancing awareness, generating interest, creating opportunities, and building capacities for enhancing the transition toward ecosystem-based adaptation.

Chapter 12 employs mapping as a vital tool in using social capital for effective adaptation. It quantifies critical variables, which are displayed in interactive maps to show spatial vulnerabilities and capacities.

The concluding chapter provides general recommendations for improving the lives of the rural population via the creation of macro and micro level conditions and policies that enhance appropriate adaptation for all.

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Chapter 2
What's on the 5th IPCC Report for West Africa?

Jens O. Riede, Rafael Posada, Andreas H. Fink and Frank Kaspar

Abstract The status of knowledge on observed and projected climate change is regularly summarized in the assessment reports of the Intergovernmental Panel on Climate Change. The latest IPCC report (2013) concludes that Africa as a whole is one of the most vulnerable continents due to its high exposure and low adaptive capacity. Here, the major conclusions of the report for Western Africa are summarized. Although there are still large gaps in the available data, evidence of warming over land regions across Africa, consistent with anthropogenic climate change, has increased. Temperature projections over West Africa for the end of the 21st century from global climate simulation range between 3 and 6 °C above the late 20th century baseline depending on the emission scenario. A similar range is produced with regional climate models that are used to downscale global climate simulations. For some regions, unprecedented climates are projected to occur at around 2040. Important progress has been made in the understanding of West African weather systems during the African Monsoon Multidisciplinary Analysis (AMMA; phase 1: 2002–2010, phase 2: 2010–2020) project. For many processes in ecology, agriculture or hydrology, precipitation is one of the most important parameters. In addition to the total precipitation, the onset of the rainy season is of special interest for agriculture. In the past a shift of the rainy season was discussed, but currently a shift cannot be observed for West Africa. However, the length of the Sahelian rainy season reveals an increasing trend of 2–3 days per decade, with a drier phase within. Since the 1950s annual precipitation has tended to decrease in western and eastern parts of the Sahel region, with a very dry period in the 70s and 80s and a slight increase of precipitation afterwards, until today. However, climate projections show a slight increase of total precipitation and a longer rainy season with a drier phase within.

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2.1 Introduction

Climate variability and climate change have impacts on many sectors, such as agriculture, water availability and health. Depending on the adaptive capacity of a society, these impacts might result in strong vulnerability. One of the main features responsible for climatic conditions over West Africa is the West African monsoon system (WAM). The underlying atmospheric processes and interactions with the land surface and ocean are complex and not yet fully understood. Several recent research activities have addressed the knowledge gap the and did advance our understanding of the WAM system. Among these are the African Multidisciplinary Monsoon Analysis (AMMA, phase 1: 2002–2010, phase 2: 2010–2020) or the GLOWA-Impetus and GLOWA-Volta project. Results of these activities have been published in several special issues (Lafore et al. 2010; Plocher et al. 2011; Speth et al. 2010).

The status of knowledge on global and regional climate change and related impacts has been summarized in the 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). Widespread impacts of climate change have been identified on all continents and detailed regional summaries are available.

The following sections provide a summary of these findings. Section 2.2 gives a short introduction to the climate of West Africa. Sections 2.3 and 2.4 provide a summary of the major IPCC conclusions about observed and projected climate change in West Africa. Readers not familiar with the work of IPCC can find some background information in Box 1.

Box 1. The Intergovernmental Panel on Climate Change

The IPCC is a scientific body under the auspices of the United Nations (UN) which reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. This international body publishes Assessment Reports (AR) periodically to provide a clear and up to date view of the current state of scientific knowledge about climate change. The IPCC is currently organized in 3 Working Groups and a Task Force. Working Group I deals with “The Physical Science Basis of Climate Change”, Working Group II with “Climate Change Impacts, Adaptation and Vulnerability” and Working Group III with “Mitigation of Climate Change”. The Task Force on National Greenhouse Gas Inventories is to develop and refine a methodology for the calculation and reporting of national greenhouse gas emissions and removals. The preparation of the last report (Fifth Assessment Report, AR5) involved more than 830 authors and review editors from over 80 countries. They in turn drew on the work of over 1000 contributing authors and about 2000 expert reviewers who provided over 140,000 review comments.

The assessments have become much more complete over time, evolving from making very simple, general statements about sectorial impacts, through greater concern with regions regarding observed and projected impacts and associated vulnerabilities, to an enhanced emphasis on sustainability and equity, with a deeper examination of adaptation options (Hewitson et al. 2014). The AR5 provides an assessment of regional aspects of climate change in different parts of the world. The evidence linking observed impacts on biological, physical, and (increasingly) human systems to recent and ongoing regional climate changes has become more compelling since the AR4. One reason for this is the improved reporting of published studies from hitherto under-represented regions of the world, especially in the tropics (Rosenzweig and Neofotis 2013).

That said, there is still a large disparity between the copious evidence being presented from Europe and North America, as well as good quality data emerging from Australasia, polar regions, many ocean areas, and some parts of Asia and South America, on the one hand, and the much sparser coverage of studies from Africa, large parts of Asia, Central and South America, and many small islands, on the other. However, as the time series of well-calibrated satellite observations become longer in duration, and hence statistically more robust, these are increasingly providing a near global coverage of changes in surface characteristics such as vegetation, hydrology, and snow and ice conditions that can usefully complement or substitute for surface observations (Stocker et al. 2013).

The IPCC AR5 includes an extensive chapter dedicated to Africa in which the observed climate trends and projections are described (Niang et al. 2014). In this section we summarize observed and projected climate trends described in the IPCC Report, with a special focus on the Western part of the continent.

2.2 Climate Zones in West Africa

The climate in Africa has huge variation between the most northern parts in Tunisia and the most southern parts in South Africa. Therefore a variety of climate zones exist in Africa: from tropical rainforest climates in East, Central and West Africa to alpine climate on the East African Mountains. The term "West Africa" is commonly used to refer to the western part of Africa, although the geographical boundaries of this area are not clear and differ from one source to another. For instance, Lélé and Lamb (2010) considers "West Africa" as being bounded by the Atlantic Ocean to the west and south, by the north of the Sahel-zone at around 20° N latitude to the north, and by 10° E to the east. Another definition of Western Africa is the economic area "Economic Community of West African States" (ECOWAS) including 15 countries in Western Africa (Benin, Burkina Faso, Cape Verde, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo). This is the definition that has also been used in the latest IPCC report. On average the region is around 300 m above sea level, with only a few mountainous regions.

Wet and dry tropical climate zones occur in the region. Figure 2.1 shows the distribution of annual precipitation in the region. Precipitation has a strong south-north-gradient: the annual amount decreases significantly from the Atlantic coast in the south towards the Sahara in the north. The aridity increases accordingly with the distance from the ocean. Based on these great differences in precipitation, three climatic zones exist in Western Africa (e.g., according to Njeri et al. 2006, Fink et al. 2016): (a) The Sahelian zone, with irregular annual rainfall that does not exceed 500 mm, and a maximum rainfall occurring in August. This zone is located roughly at 12.5° N latitude and its climate is semi-arid. (b) The Sudanian zone with a precipitation amount between less than 200 mm in the north of Nigeria and 1000 mm in the north of Mali. The climate is sub-humid and located approximately between 9° N and 12.5° N. (c) The tropical humid Guinea Cost zone located along the Gulf of Guinea, characterized by annual mean rainfall higher than 1500 mm.

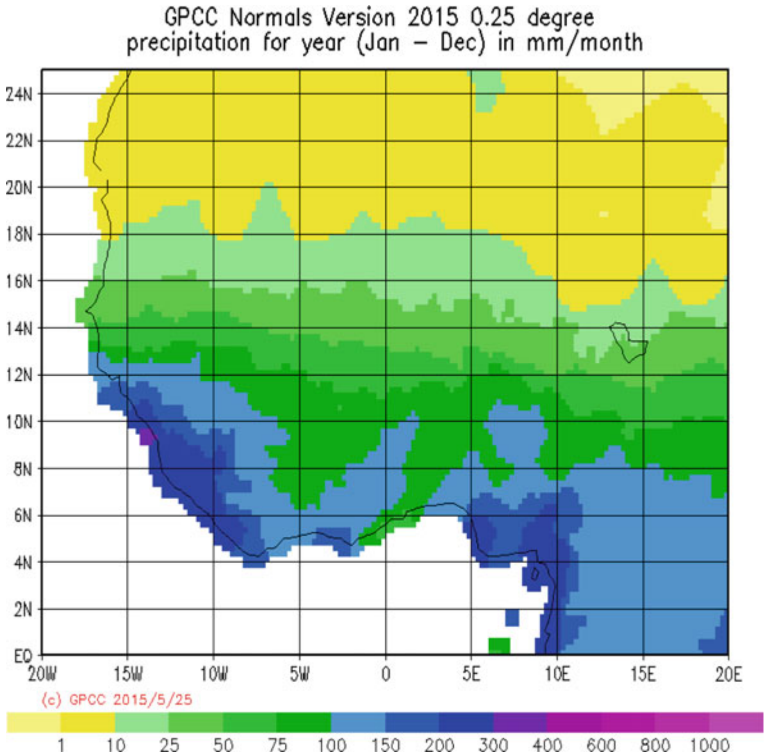

Fig. 2.1 Annual precipitation based on the gridded dataset of the global precipitation climatology center—version 2015 (Becker et al. 2013; Meyer-Christoffer et al. 2015)

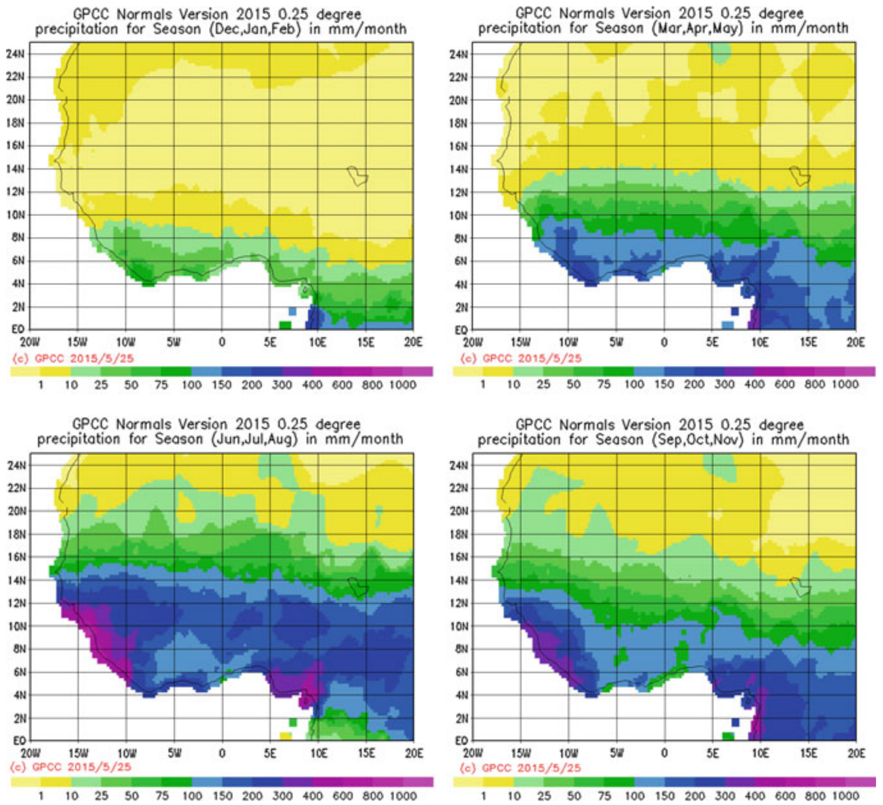

Fig. 2.2 Average annual precipitation over West Africa based on the gridded dataset of the global precipitation climatology center (version 2015; Meyer-Christoffer et al. 2015). There is a strong pattern in seasonality (*upper left*) dry season, DJF, end of dry season, beginning of rainy season from the south to the north MAM (*upper right panel*), rainy season JJA (*lower left panel*), end of rainy season SON (*lower right panel*)

Rainfall in this zone varies according to the orientation of the coastline and inland mountains with coastlines perpendicular to the SW monsoon. These coast show very high precipitation amounts, contrary to, for example the Ghana-Togo dry zone (Fink et al. 2016). The Guinea Cost and the Sudanian zone both have a bi-modal rainfall distribution (Fig. 2.2) (UNEP 2006).

Rainfall in the tropics is mostly convective and therefore rather unevenly distributed over time and space. Convective events can occur at any time in the year, but are more likely in the rainy season. A characteristic feature in Western Africa is that the isolated convective showers organize into large thunderstorm complexes. For details on West African rainfall types see Fink et al. (2010b). The seasonal patterns of rainfall and temperature in Western Africa are influenced by two air masses: the dry and usually hot Harmattan north-easterly winds originating from the Sahara, and the low-level monsoonal south westerly winds originating from the

Atlantic Ocean. The movement of the air masses is associated with northwards and southwards pulsations of a narrow confluence zone of discontinuity ("Intertropical Discontinuity" (Fink et al. 2016)) between the dry Harmattan and the tropical maritime monsoon to the south.

Annual temperatures in these zones are in the range of 26–30 °C, but distinct differences exist in the overnight temperatures and near-surface humidity in winter: night-time temperatures regularly fall below 10 °C in the Sahel. On the Guinea coast, minimum temperatures typically do not fall below 18 °C. Relative humidity stays below 50 % throughout the day in the Sahel, whereas values are high throughout the year on the Guinea coast (Fink et al. 2016).

Box 2. Climate Scenarios (Representative Concentration Pathway Scenarios (RCP))

Climate projections for the period until 2100 are performed with global climate models. Applying the models for that time frame requires assumptions about the atmospheric composition, i.e., the concentration of atmospheric greenhouse gases. The development of future atmospheric composition depends on the emissions of these gases from anthropogenic and natural sources. Anthropogenic emissions are driven by economic and technological development as well as political decisions, especially related to usage of fossil fuels and land use. In order to make climate model runs of different groups comparable, they have to be based on the same assumptions on future emissions or concentration. Assumptions about future development are typically aggregated in 'scenarios'. The assumptions can vary greatly, but should be internally consistent within one scenario. For the climate model runs in the 5th Assessment Report, the scenarios are called 'Representative Concentration Pathways' (RCPs). These scenarios prescribe the temporal development of emissions and concentrations of the full suite of greenhouse gases, aerosols and chemically active gases, as well as land use/land cover. Four main scenarios have been defined with different targets of radiative forcing in the year 2100: RCP 8.5, RCP 6.0, RCP 4.5, RCP 2.6. The numbers refer to the radiative forcing in W/m^2 in 2100. Differences in the radiative forcing between these scenarios are relatively small up to 2030, but become very large by the end of the 21st century and dominated by CO_2 forcing. RCP 8.5 is a high pathway which reaches >8.5 W/m^2 by 2100 and continues to rise for some time after 2100; RCP 6.0 and RCP 4.5 are so-called "stabilization pathways" in which the forcing is stabilized at approximately 6 and 4.5 W/m^2 shortly after 2100. In RCP 2.6 the radiative forcing peaks at approximately 3 W/m^2 before 2100 and then declines to approx. 2.6 W/m^2 in 2100. In order to reach such a forcing, greenhouse gas emissions have to be reduced substantially over time.

The scenarios are used to run global climate models for the 21st century. Such models are developed and operated by several modeling centers. Taken together, the ensemble of results for each RCP scenario allows for assessing

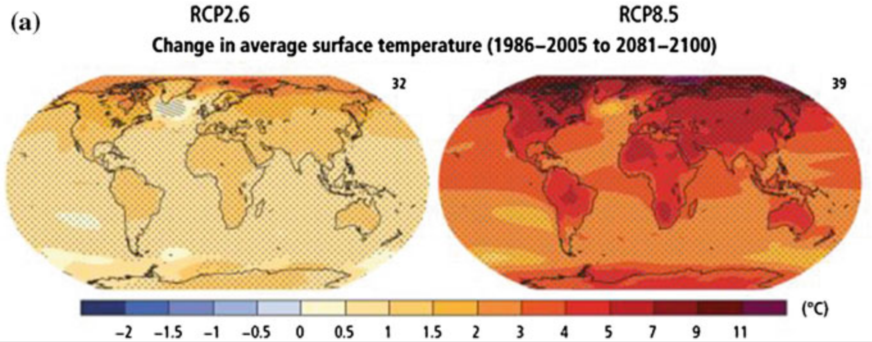

Fig. 2.3 Change in average surface temperature based on a multi-model mean projections for 2081–2100 relative to 1986–2005 under the RCP2.6 (*left*) and RCP8.5 (*right*) scenarios. *Thin lines* denote one ensemble member per model, *thick lines* the CMIP5 multi-model mean. On the *right-hand side* the 5th, 25th, 50th (median), 75th and 95th percentiles of the distribution of 20-year mean changes are given for 2081–2100 in the four RCP scenarios

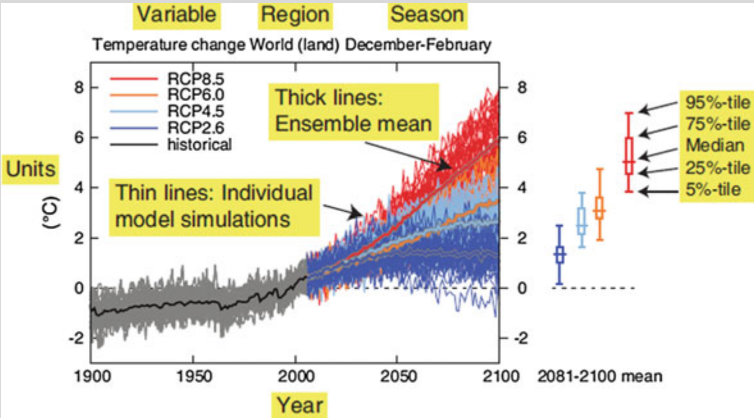

Fig. 2.4 Explanation of the features of a typical time series figure presented in the IPCC AR5. (IPCC AR5 Figure AL.1)

the uncertainty that arises from the use of different models. To provide a framework for systematic comparison the centers agree on so-called "Model Intercomparison Projects (MIPs)". Many results of the AR5 are based on the 5th Coupled Model Intercomparison Project (CMIP5[1]). The typical resolution of the atmospheric component of global climate models in the AR5 is in the order of 1°–2°. Regional Climate Models (RCMs) are used to simulate regional climate at higher spatial resolution. Lateral boundary conditions are taken from global climate simulations. Again, several centers contribute with

[1]The **Coupled Model Intercomparison Project (CMIP)** provides infrastructure in support of climate model diagnostics validation, intercomparison documentation and data access.