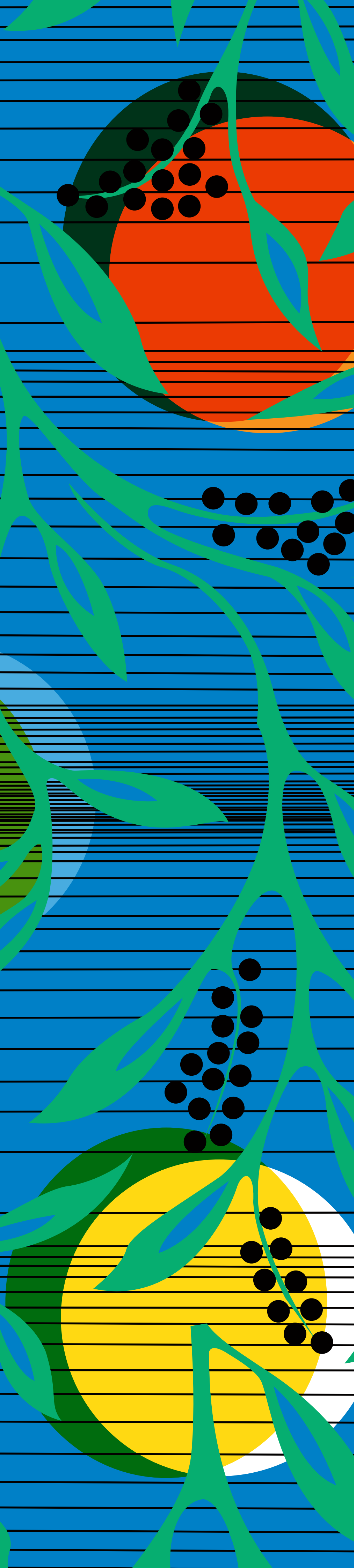

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THE ROLE OF CLIMATE SCIENCE IN POLICY MAKING

WEST AFRICAN PAPERS

August 2016 **No. 02**

SAHEL AND WEST AFRICA Club Secretariat

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CLIMATE IMPACTS IN THE SAHEL AND WEST AFRICA:

THE ROLE OF CLIMATE SCIENCE IN POLICY MAKING

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OECD BETTER POLICIES FOR BETTER LIVES

WEST AFRICAN PAPERS

The West African Papers series is designed to share studies with a wide audience of specialists, practitioners, decision-makers and the informed public. The series explores the nature, dynamics and characteristics of African social, economic and political transformations from a regional and multidisciplinary perspective. It seeks to stimulate discussion and gather information to better anticipate the changes that will shape future policies. Papers are available in English and/or French, and summaries are available in both languages. Initiated by the Sahel and West Africa Club (SWAC) to highlight and promote West African issues, the work presented is prepared by its Secretariat, Members and partners; other OECD departments; related international organisations; and associated experts.

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Authorised for publication by Laurent Bossard, Director, Sahel and West Africa Club Secretariat (SWAC/OECD).

ABSTRACT

Given that the population of the Sahel depends largely on rain-fed agriculture and transhumant livestock rearing, there is a growing concern about the future climate of the region as global warming may alter the availability of water resources. The lack of consensus on climate projections for West Africa results partly from the inability of climate models to capture some basic features of present-day climate variability in the region. As a result, climate model projections are difficult to analyse in terms of impacts and provide little guidance to inform decision making on adaption and resilience-building.

However, by engaging with users of climate information to better understand their activities and their sensitivities to weather and climate, and by looking beyond the user to understand the wider systems context in which climate change occurs, progress can be made in interpreting climate impacts. This paper reviews the latest climate projections for West Africa and considers alternative ways in which the knowledge generated from climate science can be understood in the context of preparing for an uncertain future that provides practical help for decision makers.

Keywords: climate change, climate variability, climate projections, climate science, West Africa
JEL classification: Q540, Q580

RÉSUMÉ

La population du Sahel étant dépendante de l’agriculture pluviale et de l’élevage transhumant, les futures conditions climatiques de la région constituent un sujet de préoccupation majeure, le réchauffement climatique pouvant affecter la disponibilité des ressources en eau. L’absence de consensus sur les projections climatiques en Afrique de l’Ouest résulte en partie de l’incapacité des modèles à saisir certaines des caractéristiques de la variabilité actuelle du climat. Les impacts des projections des modèles climatiques sont ainsi difficiles à analyser et peu d’informations utiles à la décision en termes d’adaptation et de renforcement de la résilience sont disponibles.

Néanmoins, en travaillant de pair avec les utilisateurs d’informations climatiques pour mieux comprendre leurs activités et leur sensitivité aux conditions météorologiques et au climat tout en saisissant le contexte général des systèmes dans lequel le changement climatique se produit, l’interprétation des conséquences climatiques s’améliore. Dans un contexte marqué par l’incertitude sur l’avenir, cette note passe en revue les projections climatiques les plus récentes sur l’Afrique de l’Ouest et aborde des approches alternatives d’interprétation des sciences du climat, susceptibles d’apporter une aide concrète aux décideurs.

Mots clés : changement climatique ; variabilité du climat ; projections climatiques ; sciences du climat ; Afrique de l’Ouest
Classification JEL: Q540 ; Q580

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As senior climate scientist at the Met Office Hadley Centre, Dr. Carlo Buontempo led the climate service development team. Carlo is also the scientific co-ordinator of EUPORIAS, a project funded by the European Commission under its 7th framework programme to promote climate service science in Europe. Carlo, who holds a PhD in Physics, joined the Hadley Centre back in 2007 just after completing his post-doctoral research at the University of York in Canada. Since then he has led numerous projects involving climate change adaptation in Europe, Africa, Asia and North America. Carlo has been the principal scientist in various climate-related projects in Africa, including an assessment of the impacts of climate change on the Nile basin and a study on the possible links between climate change and geopolitical instability in the Sahel. Carlo co-ordinated the Met Office's contribution toward BRACED, a project funded by the UK Department for International Development to build climate change resilience within rural communities for a set of developing countries in Africa and Asia. Since June 2016 Carlo manages the Sectoral Information System of Copernicus Climate Change Service at ECMWF.

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EXECUTIVE SUMMARY

Since the dawn of time humans have had to find ways to cope with the capricious nature of Earth's climate. The lack of mechanised tools to farm with and limited access to irrigation meant that people's livelihoods were often left at the mercy of climate variability. It has even been said that the adoption of agriculture was itself linked to specific variations of the Earth's climate which made farming more convenient than gathering fruit (Diamond, 2005). Although subsistence farming may appear to be very remote to the industrialised estates now common in both Europe and North America, this type of farming is still common in sub-Saharan Africa where it has an important role in the food systems of rural communities.

In addition to the development of mechanised agriculture, humans also discovered a way to predict near-term future weather, and more recently how to make projections of longer-term climate conditions. With these tools, which could potentially provide an unprecedented ability to anticipate, also comes a new sense of responsibility to respond to this information and to protect the most vulnerable from changes in the global climate system by becoming more resilient.

The hypothesis that increased concentration of greenhouse gases in the atmosphere due to the burning of fossil fuels could lead to an alteration of the global mean temperature is not at all new. At the end of the 19th century, the Swedish chemist Arrhenius first calculated the impacts that a doubling of CO_2 concentrations in the atmosphere would have on the temperature of the planet (Arrhenius, 1896). Interestingly, his 'back-of-the-envelope' calculation looks remarkably similar to the results obtained from modern estimates based on complex models of the climate system. Not only was Arrhenius' hypothesis sound, but at present it provides the best explanation available of a number of changes that have been detected in the global climate. Using the numerical models developed over the last four decades, researchers are now in the position to make estimates of what future conditions will look like. The interested reader can refer to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) for a more complete answer but in short, one can assume that:

1) The climate is warming all over the planet.

2) Human activity is largely responsible for these changes.

3) Significant intervention will be needed to contain future warming (mitigation).

4) Even if humans do all they can to reduce emissions, it will still be necessary to adapt to a set of changes that are now inevitable (adaptation).

Climate change is arguably one of the biggest challenges humanity has ever faced, and therefore potentially of great interest to the public, industry, governments and decision makers, and planners at all levels. It is not just the challenge of changing weather in isolation, but how this interacts with the way people live and the wider, often complex interconnected networks that ensure human security and well-being. The context in which climate change occurs, and the vulnerabilities of, for example, food, water and health systems are key to the impacts that humans will experience. The acknowledgement of the critical importance of climate to human and planetary well-being, pushes the demands on climate science to an extreme and the task for climate scientists to meet demands for the provision of high-quality, traceable information to support this discourse, is huge.

CLIMATE AND CLIMATE PROJECTIONS FOR THE SAHEL AND WEST AFRICA

From a climatic point of view the West African region is defined by the mutual interaction of two important drivers: the Atlantic Ocean and the Sahara. At a first order, both temperature and precipitation and their annual cycle depend on the way in which the air masses associated with the dry and hot desert interior and the humid ocean to the south and the west, interact. The West African monsoon, a seasonal low-level circulation pattern, represents the main driver of climate variability in the region. More specifically, the intensity of precipitation associated with the monsoon, its penetration inland and its exact timing are of crucial importance for a number of human activities.

One of the most prominent features of the planet, when looking at it from space, is a ring of deep clouds that circle the equator. This ring, which is known to meteorologists as the Intertropical Convergence Zone (ITCZ), is in some sense the equivalent of a meteorological equator. Air masses from the trade-wind latitudes of each hemisphere converge toward this narrow band of very deep convection where intense precipitation is frequent. The band is not always located in the same place but usually follows the relative seasonal migration of the sun north and south of the equator. The seasonal migration of these rain bands is the main driver of one of the most typical features of the tropical climate: the alternation of dry and wet seasons. Over West Africa, the dynamic of the ITCZ progression is made more complex by its interaction with another driver: the thermal heat low generated by the surface heating over the Sahara Desert.

'Intertropical front' is the term usually adopted to define the separation between the dry and hot north-easterly desert air from the warm and moist monsoon flow that comes from the ocean (Lélé and Lamb, 2010). The separation between different air masses precedes the arrival of the monsoon front and the precipitation maxima by several hundred kilometres. As a consequence of a number of interacting processes, the intra-seasonal movement of the monsoon front is not smooth (Sultan and Janicot, 2000; Le Barbé, Lebel and Tapsoba, 2002). Generally, the first phase starts in May when the intertropical front reaches 15 degrees north and provides a sufficient supply of moist and fresh air from the sea to trigger isolated convection and rain in the Sahel. The second phase is the beginning of the rainy season and typically takes place around June. Its onset is a significant and abrupt movement of the ITCZ front from 5 degrees north to about 10 degrees north, where it stays almost stationary until the end of August. The last phase is the retreat of the monsoon front which typically happens more rapidly than the northward progression that characterises the beginning of the rainy season.

Given that the monsoon varies significantly in both its northward displacement and in its intensity (Buontempo, Booth and Moufouma-Okia, 2012), researchers have looked with great attention at the processes that could alter the characteristics of the monsoon. This is especially relevant considering that most of the Sahelian region receives precipitation in only one or two seasons a year and thus one deficient season could well have devastating effects on local livelihoods and economies.

Evidence available on paleo-climatic timescales shows that the Sahara Desert has gone through different phases over the centuries, with periods where Saharan vegetation cover was significantly more extensive than it is now (deMenocal and Tierney, 2012). However, over the last century the most remarkable feature associated with the climate of the region is undoubtedly the reduction in precipitation that was recorded in the 1970s and 1980s. This followed a relatively wetter period (1950s – 1960s) and caused widespread impact on food security (Dai et al., 2004). A number of explanations have been proposed to explain this drastic reduction of precipitation. Early theories suggested that land-atmospheric feedback played a key role (Charney, Stone and Quirk, 1975) and thus pointed toward desertification and land-management as possible factors. More recently however, a growing consensus has emerged on the role that differential aerosol loading between the two hemispheres due to industrial pollution, has played in changing the surface temperature gradient across the Atlantic Ocean and ultimately in changing the seasonal migration of the ITCZ (Rotstayn and Lohmann, 2002; Kawase et al., 2010; Hwang, Frierson and Kang, 2013). Recent observations in the region (Dong and Sutton, 2015) point toward a moderate recovery of precipitation, which is still below the levels that characterised the relatively humid period of the 1960s.

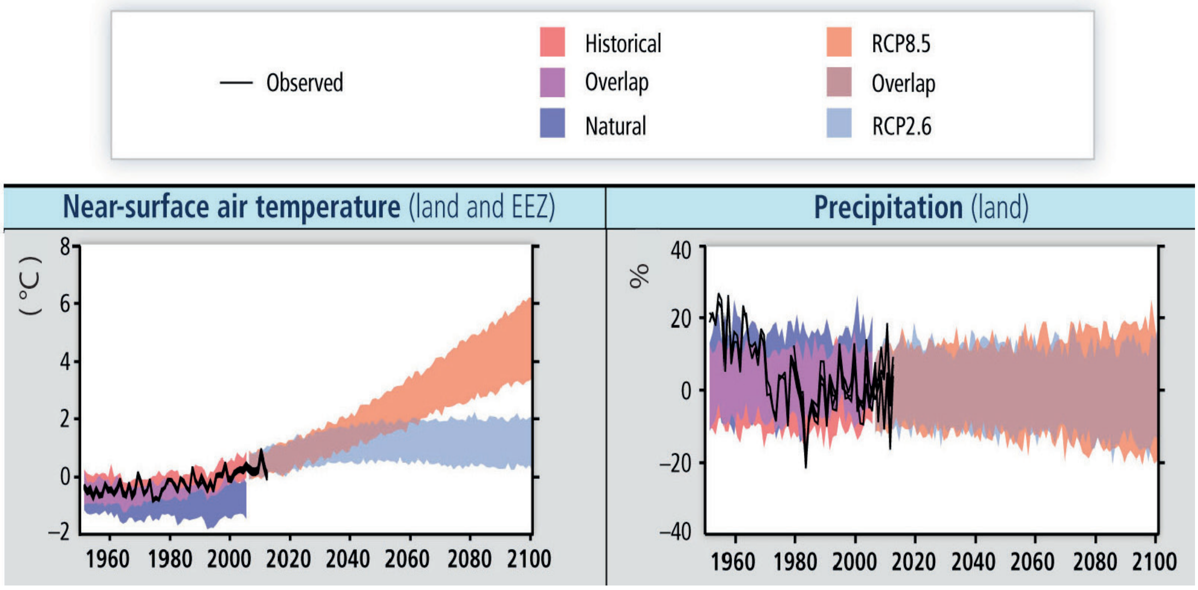
Such centennial trends and variations are important to question. On the one hand it is legitimate to evaluate how well experts understand the mechanisms that control the inter-annual variation of the climate in the region. On the other hand it is also important to understand what can realistically be said about the future climate of the region. The ability to describe the basic structure of the circulation of the West African monsoon gives climate scientists some confidence in their ability to understand how different climate drivers act to alter it. For example it is known that El Niño, the occasional increase of the surface temperature of the central and eastern tropical Pacific, is more frequently than not associated with below average precipitation in the West African region. Similarly, the sea surface temperature in the Gulf of Guinea is negatively (Giannini, Saravanan and Chang, 2003) correlated with precipitation in the Sahel but positively correlated with precipitation along the West African coast (Le Barbé, Lebel and Tapsoba, 2002). We also know that the horizontal temperature gradient across the north Atlantic (Folland, Palmer and Parker, 1986) and the temperature of the Mediterranean Sea impact the intensity and the extent of the West African monsoon (Rowell, 2003).

Critical to this knowledge is that some key features of the monsoon's circulation are not yet adequately reproduced in the current generation of the general circulation model, such as the monsoon jump – the swift movement of the monsoon front that follows its onset - or the longitudinal modulations of the monsoon progression through the region. These model deficiencies are critical to the analysis of future climate scenarios.

Given the challenge climate change represents for human kind, and in particular the precarious balance between human needs and natural resources that characterises West Africa, it is all too natural that scientists have looked at this region with particular interest. The role of scientists is to provide the best available climate information to society so that actions and decisions can be made. Yet, the fact remains that climate model projections are unable to provide a consensus view for the region. The net impact on water resources is likely to be controlled by a fine balance between an increase in precipitation intensity and a plausible increase in evaporation triggered by higher surface temperatures. These changes associated with changes in the general circulation of air masses in the tropics could lead to very different results. While all climate models that contributed to the IPCC Fourth Assessment Report predicted an increase in near surface air temperature for the region (Christensen et al., 2007; Joshi et al., 2011; Sanderson et al., 2011; James and Washington, 2013; Mora et al., 2013) the trend for precipitation was much less consistent. A large number of models predicted relatively small variations around present day values and a couple of models predicted a large increase (MIROC) and a large decrease (GFDL) respectively.

Climate models represent one of the best tools to understand what the future climate holds. They also provide a fundamental machinery to understand the processes that underpin the variability and the long-term change in key meteorological parametres such as precipitation and temperature. However, at the same time any adaptation practice in West Africa based only on model projections would face significant challenges as raw model uncertainties, especially for variables such as rainfall, would certainly appear to be too large to practically inform adaptation decisions directly.

Figure 1
Observed and simulated variations in past and projected future annual average temperature over the Economic Community of West African State (ECOWAS)



Note: Black lines show various estimates from observational measurements. Shading denotes the 5th to 95th percentile range of climate model simulations driven with 'historical' changes in anthropogenic and natural drivers (63 simulations), historical changes in 'natural' drivers only (34), the RCP2.6 emissions scenario (63), and RCP8.5 (63). Data are anomalies from the 1986-2005 average of the individual observational data (for the observational time series) or of the corresponding historical all-forcing simulations.

Source: Niang et al., 2014

CLIMATE SERVICES: WORKING WITH USERS

The previous section underlined that the data generated by climate models cannot provide all the information needed to address the climate challenge per se. Climate scientists had a crucial role in sounding the alarm when it first became clear what the consequences of a warming planet could be for humankind and the natural world. However, climate scientists might not necessarily be in the best position to have the insight required to provide information on climate change which could form the basis for action to prepare for these consequences. It can be argued that climate data is not information unless it is contextualised, targeted for specific users, provided in a timely manner, and distributed through channels that are felt to be trustworthy and legitimate (McNie, 2007). Critical to this is that climate information needs to be relevant. Whilst the rise in global mean temperature may be an important parameter for international negotiations, it is almost certainly true that this kind of information has little or no impact on the decisions of African farmers, who are primarily interested in whether it will rain or not in the future. It is in response to this distinction between climate data and useable, actionable information on climate change, that the international push for climate services emerged.

The United Nations World Meteorological Organization's (UN WMO) Global Framework for Climate Services outlines the requirement "to enable better management of the risks of climate variability and change and adaptation to climate change, through the development and incorporation of science-based climate information and prediction into planning, policy and practice on the global, regional and national scale." (Hewitt, Mason and Walland, 2012).

Despite strong consensus on the need for climate services, the challenge of how to meet this need has not been fully addressed, and there is, as yet, no clear plan on how to develop these services in a way that is both manageable and meaningful. Initial attempts to meet this need, have focused on the development of user-driven services. Although this is clearly a step in the right direction, further development of climate services may struggle with this approach in the longer term. In principle, calling for a user-led service is a good way of addressing the requirement for relevant and useable climate information, but in reality identifying the needs of users and developing the relevant services is a complex and challenging process. From a social science perspective this may seem an obvious point, but to a natural scientist, as climate scientists are, simply asking 'what do you need?' is not sufficient. The response of users to this question is, in many cases, a list of perceived needs mixed with expectations of what they believe science should be able to provide. In that sense it is not surprising to discover that most users ask for a single, high-resolution (both temporal and spatial) time-series of temperature and precipitation. These are the parameters they are used to, and which they regularly receive from local meteorological agencies in the form of weather forecasts. However, the nature of climate information is often quite different from that available in weather forecasts. Uncertainty in projections, as well as lower temporal and spatial resolution of climate models in comparison to weather data, means that climate information is not equivalent to a forecast for the long-term. Climate models explore the behaviours and statistics of the climate system over average regions and time periods. While these are useful for understanding the direction and scale of change, and for evaluating changing risk, they are not what most users familiar with meteorological data might expect and therefore demand.

In order to address the discrepancy between the nature of climate information and the expectation of users, the climate services community developed a new approach to identify users' needs. This is exemplified by a change in the question. Rather than asking people 'what do you need?', climate services ask 'what do you do?'. Understanding the users' universe, including their needs, issues, and priorities can give developers of climate services new information to identify the most relevant aspects of climate information for the user. Climate models are complex machines generating terabytes and terabytes of data on the climate system, and from this vast quantity of data climate scientists are primarily interested in extracting temperature and precipitation information. In that sense climate services are a process of 'creative midwifery' that allow climate scientists and users to work together to jointly identify how to best use the available knowledge.

In a region like the Sahel and West Africa, where projections are not robust (or at least not robust for all parameters) the identification and communication of what is actually known, and not just focusing on uncertainty, is extremely important. There is a balance between the focus on in-depth analysis of the processes that are responsible for climate variability and change (something that is essential to understanding what is known and to make meaningful predictions), and the generation of a climate-related message that is usable and relevant for decision makers and users. It is within this balance of investigative climate science and interpretation and communication, where climate services should be developed to maximise value.

Climate model projections for the Sahel and West Africa do not provide a consistent message on whether precipitation will increase or decrease. This implies that projections of a number of rainfall related impacts with any level of confidence are also unavailable. However, there are a number of aspects of climate change in the region for which there is robust evidence which is not yet incorporated into decision-making processes. For example as Sultan et al. (2013) have demonstrated, crop yield is very likely to be hampered by increasing temperatures, even without any change in precipitation. This means that there is potentially a space here to develop services for the agricultural community in the form of information on possible crop failures resulting from high temperatures. In this example, a user may identify a requirement for high resolution rainfall data, but closer investigation of that user's activities suggest that what they actually want to know is how their crops will fare in a changing climate. If temperature is also an appropriate or at least adequate means of evaluating this, then the climate scientist has more flexibility to interpret the climate model projections in a way that is useful to the user. In this case the conflict between demands for increased data resolution and the consequential increase in uncertainty in projections can be avoided.

Although the development of climate services faces a number of challenges, working closely with users is an effective way to bridge the gap between the potential and the limitations of climate model projections for building resilience in communities.

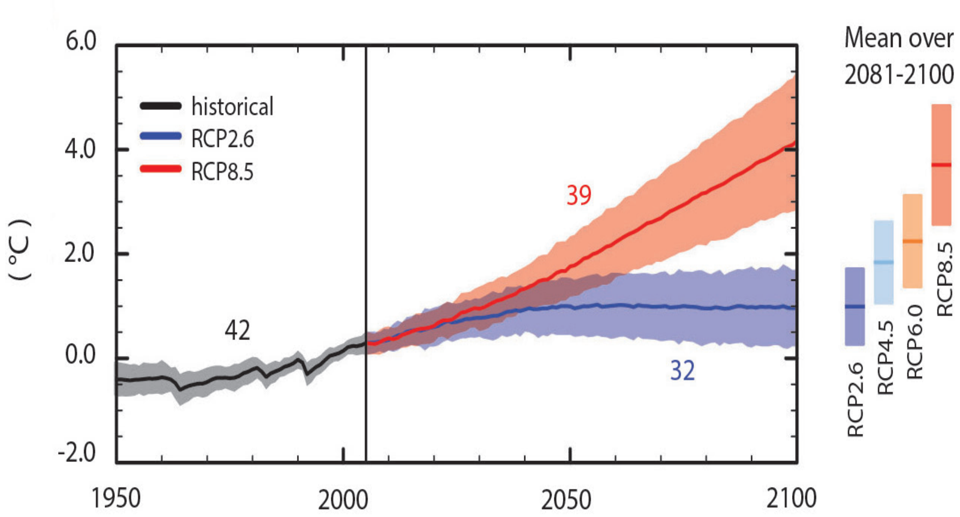
BEYOND THE USER: ADOPTING A SYSTEMS-BASED APPROACH TO CLIMATE CHANGE

Engaging with users directly to better understand their needs and activities is an important step towards more relevant interpretation of climate projections. However, there is one limitation that this approach faces. Many user groups, such as farmers, who recognise the importance of climate information and thus are most likely to engage with climate services, do so because of the operational experience they have of the impacts of weather on their activities. For this group of stakeholders, who are direct users of weather and climate information, the focus is often on the near- to medium-term. For example, farmers planning to invest in their activities benefit from knowing more about the risks associated with drought or flooding, often over the next year or two, than from knowing what the larger-scale changes to the climate will be over the next few decades. That is not to say that there are no users who have longer-term timescales to consider, but most decision makers who recognise the potential impact of climate change do so because they experience the effects of weather and climate from day-to-day. The exception to this may be users planning large-scale infrastructure projects, such as roads, rail or city planning activities, where weather impacts are well understood, and the lifetime of such projects could be decades. Long-term climate change will have profound impacts across society, but aside from specific questions on engineering resilience, users of long-term climate information can be difficult to identify. This makes a user-led approach to evaluating climate model projections a less effective tool for understanding and communicating the impacts of long-term climate change. The impacts of climate change on human activity and well-being can also be much harder to evaluate over longer climate change timescales, simply because it cannot be expected for the planet to remain stationary while only the climate changes. Scientists might be able to demonstrate what a future climate would mean for present day agricultural production, energy generation, supply and demand, or water requirements, for example, but predicting the impacts on these same systems in the future is a much more difficult task, and one that is arguably a research question beyond which operational users of weather and short-term climate information can reasonably answer.

In addition to identifying and engaging with users of climate information, there is also a need to look beyond the operational focus and consider what long-term climate change might mean. Figure 2 shows the global average temperature projections from 1950 (observations) to 2100. It is clear from this figure that, despite the range of possible temperature change associated with different greenhouse gas concentration scenarios, the levels of change expected in the coming decades indicate a climate radically different from that experienced since the start of the industrial revolution. Similarly, although climate model projections of future temperature and rainfall across the Sahel and West Africa region (Figure 1) show little agreement in the specifics of the change (and in the case of rainfall, little agreement on even the sign of the change), all show the potential for that change to be large.

Figure 2
Observed and simulated variations in past and projected annual global average temperature under RCP2.6 and RCP8.5, relative to pre-industrial climate

Global average surface temperature change



Source: IPCC, 2013.

Providing information about the impacts of climate change in a way that engages with long-term planners requires some understanding about the ways in which weather and climate have the potential to affect outcomes. Planners do not necessarily have any particular exposure to the impacts of weather and climate, and broad summaries of climate change, particularly when they focus on variables traditionally used such as global average temperature, can be confusing and appear irrelevant. However, climate change is about much more than just global averages and the impacts of climate change are about much more than changes in the weather. Climate change is also about the changes in variability and extremes, and the potential to threaten human security by impacting food, water, energy, transport, trade, livelihoods and assets. Understanding that this threat exists is one aspect of the engagement challenge; addressing exactly how these impacts will interact with human security outcomes and how to prepare for them and manage risk is the ultimate ambition of a comprehensive climate service for all users. This requires more than just a dialogue with users experienced in handling meteorological information. It requires looking beyond the user to the whole human-environment system and its dynamical responses to long-term changes.

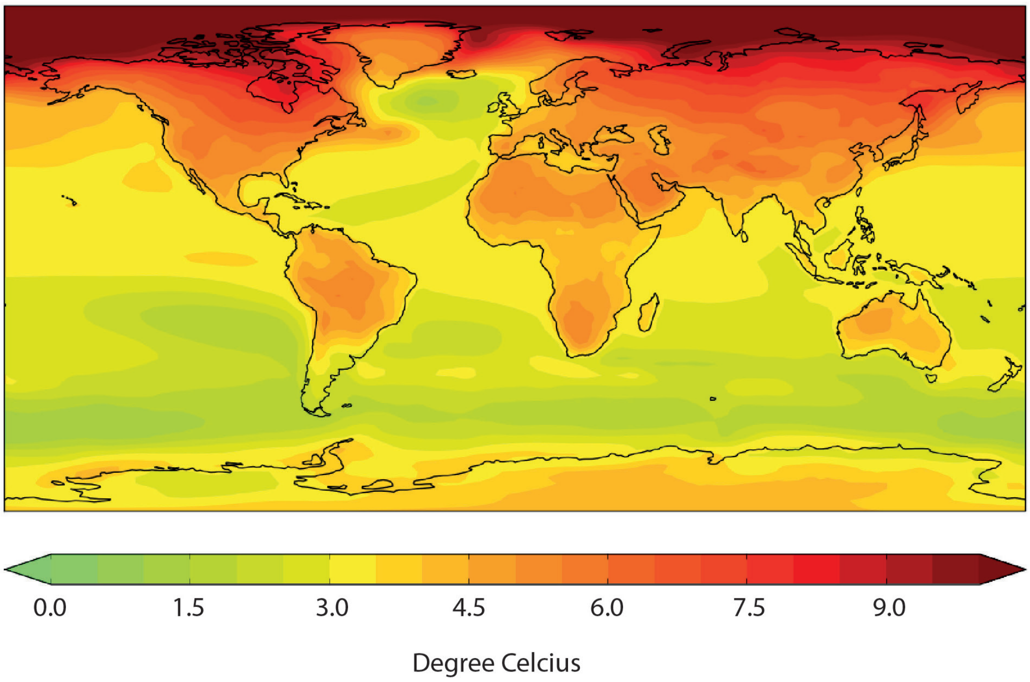
Taking a systems approach to the long-term view of human security involves evaluating the way in which systems work and, from a climate-science perspective, the way these human systems interact with weather and climate. If the knowledge of climate change impacts must first begin with the analysis of climate projections before the potential interaction with human activity can be considered, then this means that climate scientists take the lead in deciding which data is relevant. However, climate scientists are not necessarily equipped to identify the critical aspects of climate and climate change for human outcomes. The results of such climate science-led analyses are often a series of projections, most often of averages over wide areas irrespective of political, economic, industrial or agricultural boundaries, and with emphasis made on the uncertainty of those projections. Figure 1 tells quite a bit about the projected changes in rainfall and temperature across the Sahel and West Africa, but almost nothing about what this means. Some of the uncertainty about climate change is not just about climate science, but around the way climate change, variability and extremes will interact with human systems. This requires looking beyond climate science to the whole human-environment system.

Embracing the complexity of the system, especially over longer timescales, provides an alternative perspective of climate change adaptation. Looking at both changes and uncertainty in a wider systems context can highlight key nodes of variability and tipping points within the system, as well as inform adaptation strategies for building long-term resilience. This approach requires a multi-disciplinary evaluation of the system, mapping what is relevant from a variety of expertise, and then exploring the sensitivities of that system to weather and climate. For a simple example of how alternative presentations of the same climate change information, informed by a systems perspective, can completely change the salience and value of that information, consider global temperature change. Figure 3a shows a typical map of temperature increase by the 2080s under a high greenhouse gas concentration scenario. It shows the land heating up faster than the oceans, and high latitudes warming far more than tropical regions. In fact, areas of the Arctic could warm by as much as 14ºC in this projection. On its own this suggests that the greatest concern over climate change should be in the Arctic, and that the impacts of climate change, and in particular the rise in temperature, will not be substantial at lower latitudes such as in the Sahel and West Africa. However, this is potentially misleading if one considers a wider systems perspective. Local agricultural systems, including the types of crops grown, are well suited to local climates. With little inter-annual or even diurnal temperature variation, crops enjoy a narrow temperature range throughout the year, and rainfall is dependent on the passage of the Intertropical Convergence Zone. With this understanding, a climate scientist might consider re-evaluating the temperature change, by choosing not to plot the absolute change, but rather describe how large that change would be relative to the variability of the present-day climate. The resulting interpretation is quite different (Figure 3b). The absolute rise in temperature in high latitudes may be larger, but relative to the current climatological range it is the change in the tropics which is most significant. This simple example illustrates how dramatically an alternative, systems-based perspective can alter the analysis and communication of climate change projections.

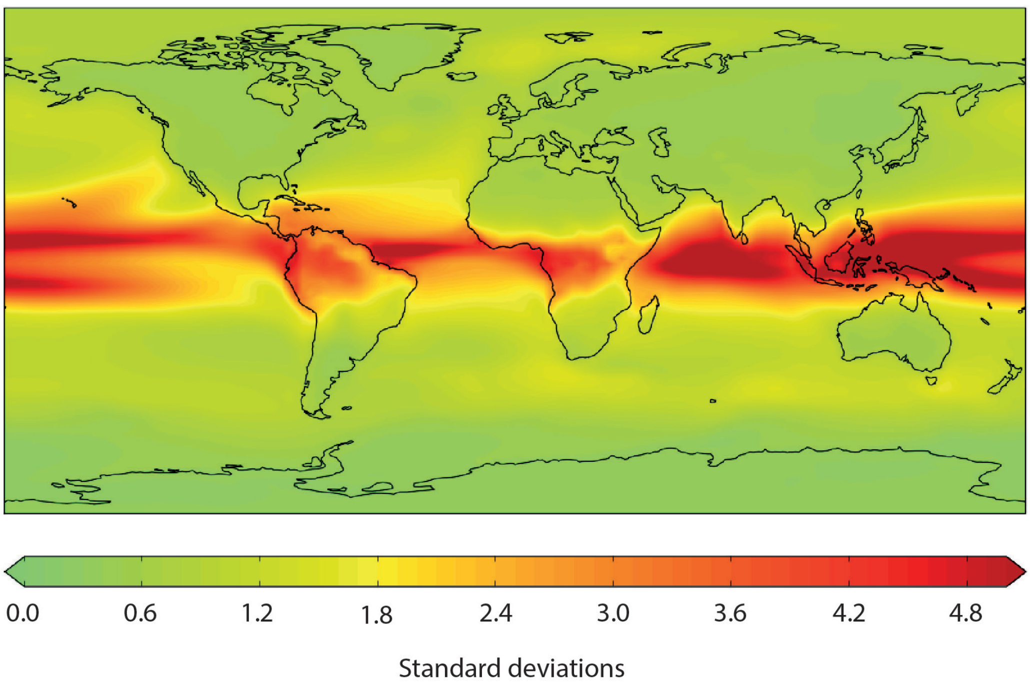
Figure 3
Ensemble mean temperature change from pre-industrial climate (1851-1880) to the 2080s (2071-2100)

(High greenhouse gas concentration scenario [RCP 8.5], for the selection of models used in the Intergovernmental Panel on Climate Change Fifth Assessment Report)

a. Absolute change



b. Change relative to annual variability



Source: Figure produced for this report by the Met Office UK, Hadley Centre.

Understanding and responding to climate change is not just about knowing more and in greater detail what the future weather and climate will be. It is also about the interaction between changes in climate with all other changes in, for example, population, urbanisation, technology, infrastructure and so on, that will take place over the decades to come. The climate services perspective asked the question 'what do you need?', and translated this into 'what do you do?'. In a systems approach this can be extended to also ask 'how do things work?'. This wider systems approach is not constrained by the level of understanding that stakeholders have of the impact of weather and climate on their activities, and in fact is not focused on weather and climate at all. The future prospects for long-term food, water and energy security; as well as long-term health and economic stability; conflict and migration, are critical for long-term human well-being. Climate is a component of these, but is not necessarily central. However, within the context of climate change, the interaction of weather and climate with these 'insecurities' is critical for the future, and information on climate change is required to address these questions. The future of food security cannot be inferred from a projected change in rainfall, but it is important to know what the change in rainfall could be to evaluate food security. In this sense, climate change is considered to be a 'threat' multiplier for long-term security (CNA, 2007) and this is as true, if not more true in the Sahel and West Africa, where vulnerability to climate change is high.

COMBINING USER-LED CLIMATE SERVICE AND SYSTEMS APPROACHES

Taking into consideration both the current climate services approach to user-led climate analysis, and the broader systems approach, provides slightly different insight into how to integrate climate model projections with decision making. Starting with the system and the decision maker may be a way out of the paralysis of uncertainty that can come from the huge amounts of data generated by climate models, or from relying on climate scientists alone to determine what is important to communicate and how. It is also a way of dealing with the inherent uncertainty around predictions or projections of the future. These two approaches however, are not necessarily mutually exclusive. Combining user- and systems-led approaches could be a way of increasing users' understanding of the system, and potentially help users to identify the questions that need answering. The most obvious way to do this is to include users in the analysis of the wider system, going beyond their own decision-making experiences in response to weather events, so that they can also consider the context in which their activities sit. In this way users gain greater understanding of systems processes and sensitivities, which are likely to be helpful in making 'no regrets' decisions. Users may also be a useful bridge between the experts themselves, providing insight into the practicalities of building resilience and managing adaptation.

In the Sahel and West Africa, farmers are important users of weather and climate information. They may already receive weather forecasts from their local meteorological services, and be open to engage in stakeholder workshops to develop climate services for seasonal climate outlooks. In addition, governments, NGOs and other civic organisations may be involved in wider agriculture and food security activities. For this second group, their interest and exposure to the impacts of weather and climate change is more likely to lie in long-term planning activities such as investment in irrigation and water management, road and transport building for market access, economic development, and investment in new agricultural technologies. The combined insight of both climate service users and experts in wider systems interactions with weather and climate, could provide a powerful new perspective on the impacts of climate change. For example, farmers have detailed knowledge of the relationship between climate variability and crop failure, and economists bring expertise on the relationship between crop supply disruption, crop prices and food security and stability. Together these insights can capture the multiple ways in which weather and climate interact with wider socio-economic as well as agricultural systems to help identify the real drivers of resilience and to ensure that climate science analysis is both salient and useful for decision making. A systems approach could help to reverse uncertainties in climate projections and identify possible adaptation options. For example, increasing temperatures could lead to investment in crops that are resilient to heat, or to a diversification away from agriculture that is sensitive to temperature; investment to improve the efficiency of markets and transport networks to promote more food trade between regions; and investment in alternative livelihoods that reduce communities' dependence on agriculture and increase resilience to food insecurity.

The climate change projections for the Sahel and West Africa are complex and there is a high degree of uncertainty, but there is enough information within climate projections to inform robust, no regrets responses to the challenges that a changing climate brings. The key is to look beyond climate science numbers and to engage with individual users not only at the local and near-term levels, but also across the wider system, both globally and in the long-term.

CONCLUSIONS

Although climate projections for the Sahel and West Africa show a strong warming signal, there is little consensus over changes in precipitation which is a critical variable in the region. How to deal with this uncertainty and to communicate the impacts of climate change in a way that is relevant and salient to decision makers is a substantial challenge. Starting with climate projections is not always helpful and can be misleading. It is also not a particularly effective way of engaging with decision makers, who ultimately want the climate science to provide them with information they can act on, not a summary of what climate scientists do and do not know. One means of doing this is to engage directly with users of climate information in order to understand not only what they want, but also to better understand what they do, and how weather and climate interacts with their activities. This is a good way of moving from climate data to useful services. However, users often have a short-term focus which results from their operational experience of coping with day-to-day weather. They primarily ask for higher resolution and more 'accurate' climate data, and can struggle with how to make use of longer-term, lower resolution data of a probabilistic nature. As a group, users of climate information are also not representative of all the areas where climate and climate change will impact. Incorporating a user-led approach with a wider systems analysis is, therefore, a way to address some of these limitations and to provide relevant and actionable information on climate change. This approach depends on incorporating a wider range of stakeholders with both user experience and expertise beyond climate, to capture the full potential of available climate information. In the case of the Sahel and West Africa, it is clear that climate change will interact with local and system vulnerabilities, and despite uncertainty in the direction of change, the potential for large climate shifts as demonstrated by climate model projections, together with user- and systems-led approaches, form a good basis on which to inform adaptation and build resilience. This is true not only for short-term climate variability, but also within the context of the long-term trend of large shifts in climate to come.

NOTES

1. Vegetation cover controls the amount of moisture available in the boundary layer which, in turn, is important in controlling convection and rainfall.
2. The volume of particulate matter generated by industrial processes (e.g. soot, black carbon, etc.).

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