review article

climate and development

# Observing the climate for development

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This article addresses the fundamental importance of observing the climate for development purposes. It first considers the establishment of the Global Climate Observing System (GCOS) in 1992 and its important linkage with the UN Framework Convention on Climate Change (UNFCCC). It also introduces the types of observations that are needed for climate purposes, with a focus on the so-called Essential Climate Variables. It then discusses the requirements for good quality observations for climate risk management, adaptation and sustainable development, noting specific examples of the uses of climate observations in agriculture, health, water resources management, disaster preparedness, tourism, urban development, coastal zone management and energy planning. The article concludes by suggesting measures that both developing and developed countries can take to improve climate observations in developing countries. For developing countries, these include improving national and regional coordination on climate observing issues, rescuing historical data, exchanging data regionally and internationally for mutual benefit, and routinely addressing climate variability and climate change in national development planning. Developed countries need to implement actions agreed by the UNFCCC and to follow up on commitments made in such fora as the G8 Summit Meetings, which include providing developing countries with infrastructure for observation systems and support for capacity building.

Keywords: adaptation; climate; climate change; development; ECV; GCOS; observation; UNFCCC

## 1. Introduction

The link between climate and development has become obvious in recent years, as the editors of the new journal *Climate and Development* have recognized. If the leaders of the world's developing countries are to succeed in their efforts to develop and provide better lives for their citizens, it is essential that they take into account the best available information on present climate and on how climate is expected to change at global, regional and national levels. Only then will it be possible to sustain efforts to improve agriculture and food security, water resources management, human health, energy production, tourism, coastal zone management and other key elements important to national economic vitality. There is more to sustainability than adequately observing the climate and understanding and managing climate risks, but without such observations understanding sustained development will be difficult.

Sustained observation of the climate is necessary to understand how climate at global, regional and national scales is likely to change in the future and, significantly, how a changing climate is likely to affect natural and human systems. Likewise, in order to design effective policies to adapt to climate change, it is essential to have the most accurate and complete information possible on the likely future climate. This also requires that the climate should be rigorously observed. It requires, naturally, that observations be accurate and also that they be undertaken at global, regional and national scales; that they be sustained over long time

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earthscan

doi:10.3763/cdev.2010.0044  ISSN: 1756-5529 (print), 1756-5537 (online) www.earthscan.co.uk/journals/cdev

periods; and that the spatial density and temporal frequency of observations be sufficient to support climate analyses and, ultimately, policy development needs. For many countries, and in particular for many developing countries, the required accuracy, length of record and spatial density of observations are currently far from adequate. A particular challenge faced by the various providers and potential providers of climate observations useful for development has been to demonstrate the added value of additional and higher-quality observations. It is often not easy to demonstrate a direct link between healthy observing systems and achievement of development goals.

This article examines why observing climate is important for development, what types of variables are most important to observe, how observations of the climate are used to support development, and what is being done to ensure that the required observations are available to those who need them. It concludes with several recommendations on how both developed and developing countries can do a better job at ensuring that the observations needed to support development can be obtained and sustained over time.

## 2. Observations in the UN Framework Convention on Climate Change

The UN Framework Convention on Climate Change (UNFCCC) emphasized mitigation concerns when it was completed in 1992. However, the Convention recognizes the relevance of observations for scientific purposes and (at least indirectly) for development needs. A subsection of Article 4 commits Parties, among other things, to promote and cooperate in systematic observation to further understanding and to reduce or eliminate remaining uncertainties regarding the causes, effects, magnitude and timing of climate change, and the economic and social consequences of various response strategies (United Nations, 1992). Article 5 calls for Parties to support international and intergovernmental efforts to strengthen systematic observation, particularly in developing countries (United Nations, 1992). Although these clauses may not have been widely considered central elements of the Convention at the time, those who understood the need for improved global-scale observations of the climate considered them very important.

## 3. The Global Climate Observing System

At the same time as the UNFCCC was being negotiated in the early 1990s, provision was being made for the establishment of a Global Climate Observing System (GCOS). Like the Convention itself, the establishment of GCOS was given significant momentum by recommendations made at the Second World Climate Conference (SWCC) in 1990 (WMO et al., 1991). The Conference Statement noted, among other things, that 'present observational systems for monitoring the climate system are inadequate for operational and research purposes. They are deteriorating in both industrialized and developing nations. Of special concern is the inadequacy of observation systems in large parts of the southern hemisphere'. It also noted that the proposed GCOS should be designed to meet the needs for data relevant to national economic development.

Subsequently, GCOS was established in 1992 by four international organizations that recognized the need expressed in the SWCC Statement: the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP), the Intergovernmental Oceanographic Commission (IOC) of UNESCO and the International Council of Scientific Unions (ICSU – now the International Council for Science). The purpose of GCOS is to ensure that all the observations required for climate monitoring, research, prediction, services, assessment, and climate change mitigation and adaptation are identified, obtained, archived and made broadly accessible to address multiple societal needs. Included in the GCOS mandate is observation of

a multidisciplinary range of physical, chemical and biological properties and atmospheric, oceanic, terrestrial, hydrologic and cryospheric processes (WMO et al., 1992).

GCOS is the climate-focused 'system-of-systems' framework through which all the global observing systems of WMO and its UN and non-UN system partners work together to meet all national and international needs for climate observations. The role of the GCOS Secretariat is to facilitate and coordinate the GCOS system-of-systems. This system-of-systems is built on the largely domain-based (i.e. ocean, atmosphere and land) operational and research observing networks of the GCOS sponsors and other international organizations. Its main components, therefore, are all the climate-relevant observing systems of the IOC-led Global Ocean Observing System, the FAO (Food and Agriculture Organization)-led Global Terrestrial Observing System and the WMO Integrated Global Observing System (GCOS, 2008). In particular, the GCOS Secretariat seeks to promote the availability of sustained, high-quality observations and to facilitate improvements in observing networks worldwide, especially in developing countries where significant needs exist for observations for the support of sustainable development. GCOS also provides the observational foundation for the coordinated UN system response to climate change, and it functions as the climate-observing component of the Global Earth Observation System of Systems (GEOSS).

The interaction of GCOS with the Conference of the Parties (COP) to the UNFCCC and with its Subsidiary Body for Scientific and Technological Advice (SBSTA) has steadily increased since about 2000, as the importance of climate observations for the needs of the Convention has become more clearly recognized. Thus, Parties saw that if they were to better understand the climate system, detect climate change, attribute its causes – whether human or natural or both – and predict future climate change in order to provide a sound scientific basis for climate policy, then they would need to ensure a solid observational foundation. Hence, while many issues pertinent to climate were, and still are, hotly debated because of the broad range of views and national circumstances of Parties, the need for adequate high-quality observations at a global scale and over extended time periods has generally been accepted by all Parties.

Since 2002, there has been an agenda item dealing with research and systematic observation included in most SBSTA sessions, and the GCOS Secretariat regularly reports to the SBSTA on climate observing issues. The COP has adopted the reporting guidelines proposed by GCOS for the preparation of detailed national reports on systematic observation. Such reports, to be provided in conjunction with national communications, are mandatory for Annex I Parties and voluntary for non-Annex I Parties. Furthermore, the SBSTA has requested a number of reports and assessments on systematic observation from GCOS. Significantly, it has requested two assessments of the adequacy of global observing systems for climate in support of the UNFCCC. The first was completed in 1998 and the second five years later in 2003 (GCOS, 1998, 2003).

Based on the observing system requirements identified in the 'Second Adequacy Report', the COP requested that GCOS prepare a 5–10-year implementation plan (GCOS, 2004). This plan – the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (IP-04) – contains 131 separate actions for improving observing systems and suggests international, regional and national 'Agents of Implementation' to undertake these needed actions. In 2009, at the request of the COP and SBSTA, GCOS published an assessment of progress (hereafter cited as the 'Progress Report') in implementing the actions proposed in IP-04 (GCOS, 2009). The Progress Report notes a number of areas in which progress has been made in improving observing systems since 2004. But with respect to the needs of developing countries, the key message is that these countries have made only limited progress in their observing networks, with evidence of decline in some regions. The report found that support for

capacity building in developing countries continues to be small in relation to needs.

In its Decision 5/CP.5 in November 1999, the COP had explicitly invited the GCOS Secretariat to organize regional workshops to 'identify the priority capacity-building needs [of developing countries] related to participation in systematic observation' (UNFCCC, 1999). The GCOS Secretariat responded to this invitation by developing a Regional Workshop Programme (RWP), which it implemented in 10 developing regions of the world between 2000 and 2006 (GCOS, 2009a). The central goal of the RWP was to initiate processes in developing regions that would lead to real and substantial improvements in the global climate observing system. Specific objectives were to assist regions in identifying national and regional deficiencies and needs for climate data (including needs for data to assess climate impacts, conduct vulnerability analyses and undertake adaptation studies) and to initiate the development of Regional Action Plans for improving climate observing systems in each region.

The GCOS RWP achieved its goal of identifying priority needs for climate observations in developing countries. It was likewise successful in raising awareness of the importance of climate observations among National Meteorological and Hydrological Services (NMHSs) and national decision makers. The GCOS Secretariat also facilitated the development of 10 Regional Action Plans, each of which contained a number of project proposals for addressing high-priority observing system needs, which in most regions included needs for improving and sustaining operational observing networks, recovering historical data, improving national and regional coordination, undertaking education, training and capacity building, and implementing national planning and reporting. However, as the 2009 Progress Report has indicated, only modest progress on improving observing systems has been made in developing countries to date, despite the fact that the COP has continued to urge Parties to assist developing countries in implementing their Regional Action Plans.

Many of the projects proposed in the Action Plans have not been implemented, and many are becoming dated and in need of revision. Major constraints on progress have been, and continue to be, the need for external donor assistance in project funding and the need for sustained committed leadership at national and regional levels. However, even if these constraints can be overcome, many developing countries lack an adequate number of trained personnel to prepare competitive project proposals, to implement projects and to maintain efficient operations. Those few with adequate training may be so overburdened that they are unable to do all that is required effectively. Hence, building the numbers and capacity of staff merits high priority. A related issue is that external donors tend to focus on providing funds for one-off infrastructure improvements and/or workshops. Funds for continuing operations are usually expected to be provided at the national level. An all too frequent result of this is that when equipment breaks, it stays broken unless funds are available nationally, and the needed observations are then not made. Perhaps if national-level policymakers in developing countries were more aware of the importance of climate observations for development, the budgets of NMHSs would not be as constrained as they often are.

GCOS has facilitated several actions to help regions obtain the resources required to address priority climate observing needs. The most ambitious initiative launched to date arose as a follow-up activity to seek funding for implementation of the GCOS Regional Action Plans for Eastern and Southern Africa and for Western and Central Africa. To this end, the GCOS Secretariat and the UN Economic Commission for Africa (UNECA) organized a meeting in Addis Ababa, Ethiopia in April 2006 that brought together representatives of development agencies and both providers and users of climate information. The participants discussed needs for climate observations and services to support attainment of the Millennium Development Goals, and they agreed to develop a strategy to address these needs (GCOS et al., 2006). This

strategy eventually evolved into what is now known as the Climate for Development in Africa Programme (ClimDev Africa).

ClimDev Africa is a joint initiative of the African Union Commission (AUC), the UN UNECA and the African Development Bank (AfDB). The Programme responds to the 'urgent challenge that climate change poses to the achievement of Africa's development objectives' and 'seeks to overcome the lack of necessary information, analysis, and options required by policy and decisionmakers at all levels' (AUC et al., 2008). A key and fundamental component of the Programme is to fund needed improvements in climate observations in Africa. Such improvements will, in turn, lead to better information for decision making and better analytical capabilities. It is too early to judge the success of ClimDev Africa in achieving its ambitious goals, as the initial four-year period of the Programme will not get under way until 2010; however, ClimDev Africa has been endorsed by the Heads of State of the African Union and by the Conference of African Ministers of Finance, Planning, and Economic Development, and a number of external donor countries are committed to supporting it.

ClimDev Africa is not yet fully operational. However, at the 15th COP to the UNFCCC in Copenhagen in December 2009 (COP-15), the AfDB signed a Protocol of Agreement with the African Center of Meteorological Applications for Development for a three-year grant of USD30 million to strengthen the African regional climate institutions and to initiate a strategic partnership with the Global Humanitarian Forum. This is considered a first contribution to the new programme. The Bank has established a ClimDev Africa Special Fund and hopes to raise up to USD136 million for the Programme through 2012 from other donors. Thus, the Bank has made a substantial commitment to ClimDev Africa, which it sees as part of its larger long-term strategy to incorporate climate considerations into development planning. Hence, there is every reason to believe that the ClimDev Africa Programme will eventually lead to substantial improvements throughout Africa in climate observations and services in support of climate risk management and, thus, of sustainable development.

## 4. What observations are needed and why?

The 2003 Second Adequacy Report identified for the first time a set of Essential Climate Variables (ECVs). These were defined to be those variables required for understanding and monitoring the global climate system and, in particular, for supporting the work of the UNFCCC and the Intergovernmental Panel on Climate Change (IPCC). Systematic observations of these variables are needed to understand the causes of climate change, analyse its potential impacts, evaluate adaptation options and enable characterization of extreme events such as floods, droughts and heat waves. The set consisted only of those 44 variables that were considered technically and economically feasible to observe at the time (Table 1). Other types of observations, considered useful to have but not currently feasible to observe systematically, for example, those undertaken primarily for research purposes or those that were difficult to measure systematically, were not included. The variables fall into three categories or domains – atmospheric, oceanic and terrestrial – and include both *in situ* observations and observations from space. In the update of IP-04, which will be available in 2010, several additional ECVs have been identified, signifying that it is now feasible to observe these important variables systematically as well (GCOS, 2009b; GCOS, 2010).

In as much as GCOS is intended to support the needs for application to national economic development, conceptually its purview also extends to socio-economic data. Good socio-economic data are essential for vulnerability and adaptation assessments. As the GCOS has developed, however, the initial focus has been on the geophysical variables that allow one to monitor climate and detect climate change. There is increasing international recognition of the need

**TABLE 1** Essential climate variables that are both currently feasible for global implementation and have a high impact on UNFCCC requirements[a]

| Domain | Essential climate variables |
|---|---|
| Atmospheric (over land, sea and ice) | *Surface*: Air temperature, wind speed and direction, water vapour, pressure, precipitation, surface radiation budget<br>*Upper-air*: Temperature, wind speed and direction, water vapour, cloud properties, earth radiation budget (including solar irradiance)<br>*Composition*: Carbon dioxide, methane, other long-lived greenhouse gases, ozone and aerosols (supported by their precursors) |
| Oceanic | *Surface*: Sea-surface temperature, sea-surface salinity, sea level, sea state, sea ice, surface current, ocean colour (for biological activity), carbon dioxide partial pressure, ocean acidity<br>*Sub-surface*: Temperature, salinity, current, nutrients, carbon dioxide partial pressure, tracers, phytoplankton ocean acidity, oxygen, marine biodiversity and habitat properties |
| Terrestrial | River discharge, water use, groundwater, lakes, snow cover, glaciers and ice caps, permafrost, albedo, land cover (including vegetation type), fraction of absorbed photosynthetically active radiation (fapar), leaf area index (lai), above-ground biomass, fire disturbance, ice sheets, soil carbon, soil moisture, terrestrial biodiversity and habitat properties |

[a]The ECVs in italics are those that are included in the draft update to IP-04 (see GCOS, 2010).

to identify an agreed set of socio-economic variables for assessment and adaptation purposes. For example, the GEO Secretariat, IPCC, GCOS and the World Climate Research Programme (WCRP) are jointly organizing a workshop, planned for mid-2010, on the data needs of the climate impacts, adaptation and vulnerabilities research communities. This workshop will address needs for socio-economic data as well as for other types of data.

## 5. Climate risk management, adaptation, sustainable development and systematic observation

Many factors affect, or can potentially affect, the development objectives of developing countries. It has become increasingly recognized in the last few years that climate change is one of those factors. Accordingly, in order to best achieve their objectives countries will need to consider the potential adverse effects of climate variability and change in their development planning and, with these in mind, design appropriate coping strategies. Climate risk management is a means to do this. The International Research Institute for Climate and Society (IRI), based at Columbia University in New York, has been an early champion of climate risk management. The approach seeks to promote sustainable development by reducing the vulnerability of natural and human systems to climate risk. It involves implementation of 'no regrets' strategies aimed at maximizing positive and minimizing negative outcomes for communities and societies in climate-sensitive sectors (Hellmuth et al., 2007). In agriculture, for example, anticipating and monitoring climate conditions allow farmers to adopt improved technology, intensify production, replenish soil nutrients and invest in more profitable enterprises when conditions are favourable. When conditions are not expected to be favourable, knowing this, farmers would be able to more effectively protect their families and farms against such conditions. The case study on agriculture in Mali contained in Hellmuth et al. (2007), for example, convincingly demonstrated that regular provision of agrometeorological information helped farmers in Mali manage the risks associated with increased climate variability. Climate risk management

with a planning horizon of, say, 10 years or more is essentially the same as proactive adaptation to climate change.

Understanding the current climate requires high-quality observations, ideally acquired over an extended period. The data derived from these observations enables planners to comprehend average climate conditions and the frequency of extreme events (and how averages and extremes have changed over time) and thus contributes to decision making related to agriculture, coastal zone management, water resources management, energy, health, tourism, disaster risk management and other activities (UNFCCC, 2007). Moreover, a prerequisite for effective climate risk management and adaptation is the availability of reliable information about how regional climate is likely to vary in the future on seasonal and interannual time scales or change on decadal and longer time scales. Such information is typically generated by regional climate models, and the output of any of the various types of models may or may not be reliable. Clearly, reliable information is key: if management decisions are based on climate predictions or projections that are unreliable, or if the constraints associated with any model output are not thoroughly understood, then the projections may be misleading, and decisions based on them may be ineffective or lead to losses.

Accurate observations of the climate are essential to evaluate climate models and their outputs. Moreover, regional models – and adaptation responses – require denser observing networks than are needed for global models. Adequate spatial density is required because adaptation inevitably occurs at regional and smaller scales. Decision makers from national planners to individual farmers, for example, need information at the scale at which they make decisions. Given the considerable variability of climate within a region, predictions based on only sparse observations are typically overly general and cannot provide the needed specificity. Observations are also required at appropriate temporal scales. Hourly data are important, for example, if one is concerned with managing extreme events such as flooding. However, hourly data are often not exchanged among countries and hence may not be readily available for modelling exercises.

Observations of the past and current state of the atmosphere are essential for the validation of regional models. Where the observational record is lacking, it is not possible to determine the reliability of climate projections. It is important also to understand that different regional models may produce different results, so it is unwise to base decisions on the output of any given model. Results may also vary depending on which global model is used to supply the boundary conditions that drive the regional model. Hence, decision making based on the results of multiple runs using different models is clearly preferable to that based on the output of only one model run.

The GCOS Secretariat, in collaboration with the WCRP, the WMO and the Nairobi-based Inter-Governmental Authority on Development Climate Prediction and Applications Centre (ICPAC), has recently launched a capacity-building programme to address the needs in developing countries for climate observations and regional modelling in support of climate risk management and sustainable development. The programme, which evolved from the paper that GCOS submitted to the Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change, consists of three linked workshops in each region. The first will assess the adequacy of global and regional climate observations for determining regional climate trends for use in adaptation planning. It will also provide an opportunity to encourage countries to improve their observing systems and to undertake data rescue efforts so that adequate data are available for use with regional models and for other needs. Sectoral users of climate information, as well as providers of such information, will participate in the first and subsequent workshops, so that their concerns can be incorporated into the planning process from the beginning. The second workshop will use the available observations to evaluate the adequacy and reliability of regional climate models

for adaptation needs and, using one or more models, will provide qualified projections of likely future changes in climate in each region. And the third workshop, which will be specifically targeted at decision makers, would consider the assessments provided by the first two workshops and offer advice on how model outputs could best be used to develop effective adaptation strategies (UNFCCC, 2007). The workshop programme will initially be implemented for countries of the Greater Horn of Africa. If resources become available, the partners plan to implement the programme in other regions in 2010 and beyond.

As noted above, the GCOS Secretariat has worked to help developing countries understand the importance of systematic observation of the climate and, through its RWP, encourage improvements in climate observing systems. At about the time the RWP came to an end, least developing countries, with the encouragement of the UNFCCC, began preparing National Adaptation Programmes of Action (NAPAs). The NAPAs contain priority adaptation activities and projects needed to address the 'urgent and immediate needs' of countries to reduce vulnerability to climate change (UNFCCC, 2009a). Priority areas typically identified include food security and water resources management. However, few of the NAPAs produced to date have addressed needs for climate observations in more than a cursory manner, indicating perhaps a continuing lack of appreciation of the importance of adequate observing systems as a necessary foundation for development planning. An opportunity exists for those countries that have not yet finalized their NAPAs to include sections in them on observing system requirements, and, for those who have completed initial programmes, to address observing system issues when they are updated.

## 6. Observations and climate services

Although observations fundamentally underpin development planning, they are rarely used directly in such planning. Rather, observations are the foundation on which a great number of climate services useful to society are developed. These services are then used to more directly inform the policymaking process. WMO and its partners gave special attention to the need to strengthen climate services for climate risk management and for adaptation to climate variability and change in World Climate Conference-3 (WCC-3), which was held in Geneva, Switzerland in 2009. The Heads of State and Government, Ministers and Heads of Delegation who attended the High-level segment of WCC-3 decided to establish a Global Framework for Climate Services (GFCS) 'to strengthen production, availability, delivery, and application of science-based climate prediction and services' (WCC-3, 2009b).

The final Conference Statement of the Expert segment of WCC-3 identified five essential elements of a GFCS and called for their major strengthening. These included (1) the GCOS and all its components and associated activities, (2) the WCRP, underpinned by adequate computing resources and increased interaction with other global climate-relevant research initiatives, (3) climate services information systems taking advantage of enhanced existing national and international climate service arrangements in the delivery of products, including sector-oriented information to support adaptation activities, (4) climate user interface mechanisms focused on building linkages and integrating information, at all levels, between providers and users of climate services, and (5) efficient and enduring capacity building through education, training and strengthened outreach and communication (WCC-3, 2009a). The identification of the need to develop stronger climate user interface mechanisms is of special significance, as providers and users of climate information have often not understood one another as well as they might. Moreover, if climate observations and services are to be of use in development planning, it is essential that providers of such information be aware of user needs and that users understand what is or could be available to them.

## 7. The value of national and regional coordination

The future effective functioning of the GCOS will depend greatly on the degree to which efficient coordination mechanisms are put in place at national and regional levels. At the national level, the responsibility for implementation and operation of climate observing systems is typically distributed across many national departments and agencies rather than being focused solely in a single agency, such as an NMHS. NMHSs usually play the central role in providing basic atmospheric observations, but environmental agencies, agricultural agencies, research agencies, space agencies and, where countries are not landlocked, national ocean services (among others) also provide important climate-relevant data. Establishing coordination mechanisms can lead to better awareness of the importance of climate observations and, in some cases, to increased levels of funding for such observations. In Switzerland, for example, the establishment of a national GCOS Office has enhanced dialogue among various national entities and led to a well-received first report on the status of national climate observing systems. This report subsequently helped leverage additional base funding by the national government for sustained climate measurements and operation of international data centres (Swiss GCOS Office, 2008).

The GCOS Secretariat has long advocated the appointment of GCOS national coordinators and the establishment of GCOS national committees. It has been supported in this advocacy by recommendations of the UNFCCC and the WMO Congress. The need for improved coordination mechanisms at the national level has no doubt assumed even greater importance in recent years as the emphasis on climate change adaptation planning has grown and the links between climate and development have become more noticeable. All of the types of agencies cited above contribute to development planning and often need to work together to reach national goals.

Notwithstanding the benefits of greater national coordination on climate observations, some developing countries may still find it challenging to implement coordination mechanisms. Some poor countries with few trained specialists, for example, may see implementation of such mechanisms as an additional burden that they cannot afford, especially given the need to service other competing sectoral needs. Only 14 countries have appointed National Coordinators to date, and most of these have been developed countries. Lack of effective national coordination in most developing countries may be one reason why so few countries have included a discussion of climate observing needs in their NAPAs.

However, a coordinated approach to ensuring that the climate observations needed for planning are available will lead to enhanced benefits and better policies. Establishing a GCOS National Coordinator brings many benefits. Among other things, such a coordinator might act as a national advocate for sustainable climate observation networks and systems and for climate data generally; promote adherence to the GCOS Climate Monitoring Principles and 'best practices' for climate observations; help colleagues in different agencies understand the priorities of potential donor agencies and help to identify sources of funding for national and international GCOS activities; facilitate the identification and provision of GCOS data in a full and open environment to international climate data centres; and provide a national focus for communication with the GCOS Secretariat in Geneva.

Setting up *regional* GCOS coordination mechanisms would also promote the development goals of developing countries. Regional coordination can be difficult, but there are good reasons to improve it. Such coordination would make it easier to advance the implementation of priority projects contained in GCOS Regional Action Plans, would help to maintain an ongoing review of priority observing system needs at the regional level, and would make it easier to assign responsibility for implementing regional actions. A regional coordination mechanism could make it easier to obtain external

funds for regional-scale improvements to observing systems. And it would provide a forum for GCOS national coordinators to meet to discuss issues of mutual concern. Some regional coordination mechanisms have been established, notably in the Pacific Islands region where a Pacific Islands-Global Climate Observing System (PI-GCOS) programme was launched in 2000 in Apia, Samoa (PI-GCOS, 2009). With the assistance of several collaborating developed countries, PI-GCOS has employed a full-time PI-GCOS Coordinator and established a PI-GCOS Steering Group. PI-GCOS is sometimes seen as a model that could be adapted for use in other regions.

## 8. Uses and potential uses of climate observations in development

The uses of climate risk information for adaptation and development planning – and of the observations on which all such information is based – can be categorized in a number of ways. Wilby, for example, notes that observations are needed for designing new infrastructure, such as in building a dam; in resource management, for example, in optimizing crop yields; in retrofitting existing structures, such as older buildings; in operational or behavioural measures, for example, in managing the performance of a reservoir or irrigation system; for institutional needs, as in regulation, monitoring and reporting; in studies of sector-wide adjustments, as undertaken in economic planning; for financial planning needs, such as in designing insurance mechanisms; and for communication of climate risks to various stakeholder groups (Wilby, 2007). The following paragraphs provide some brief examples of some more specific ways in which observations are required in different sectors.

### *8.1. Agriculture and food security*

Forecasts based on good observations allow adjustments in such farm operations as sowing times, weeding, fertilizer application, spraying, integrated pest management, harvesting and drying (WMO, 2001). Farmers and agricultural decision makers, however, require climate observations to be available at a spatial resolution appropriate to their needs. In many developing countries, the density and quality of climate observing networks is not adequate for agricultural purposes. Climate forecasts, using regional models to downscale global predictions to local applications, are increasingly being employed in conjunction with operational crop models to develop scenarios for operational decision making to minimize climate risks and maximize benefits to farming communities (Sivakumar and Hansen, 2007). It is important, however, to use such forecasts appropriately, and in many developing countries too few scientists have the requisite training and experience to interpret and apply climate change data in the agricultural context (Ziervogel et al., 2008).

### *8.2. Health*

Climate is a significant factor in human health, both directly and indirectly. Hence, climate information needs are great in the health sector. The incidence of malaria, for example, is known to be influenced by climate, and rainfall, temperature and humidity observations are used to help predict epidemics. The IRI has reported on the development of a Malaria Early Warning System in southern African countries with epidemic-prone areas. This system provides reliable forecasts of epidemics and thus enables advance planning that helps to reduce the incidence of malaria in these countries (Hellmuth et al., 2007). Also, Africa now holds an annual Malaria Outlook Forum, wherein climate information is used to assess the potential for malaria outbreaks (ICPAC, 2009). The distribution of other vector-borne diseases, such as dengue fever and schistosomiasis, may change as a result of climate change, and thus observations will be key to reducing their impact. More directly, climate change could increase such health risks as heat waves and

waterborne diseases, both of which require substantial observations to help reduce impacts.

### 8.3. Water resources management

Observations are especially important in supporting shorter-term seasonal forecasts that allow water managers to improve the effectiveness of water management decisions for irrigation, water supply, reservoir management, and flood and drought contingency planning. Good climate observations are also needed for the design and siting of long-lasting structures, such as new dams and irrigation systems. Water managers have noted, however, that at present, information on future climate variability and change is only rarely used in decision-making processes, as the state of the art of climate prediction is not yet perceived to be good enough (WMO, 2006).

### 8.4. Disaster preparedness, droughts and floods

There is a need for observations for early warning systems to mitigate the effects of droughts and floods. Drought forecasts supply information on the onset, severity and duration of droughts using information such as monthly and seasonal rainfall, streamflow, groundwater levels and snowpack. Early warning (i.e. up to a year in advance) of El Niño conditions allows for advance planning of agricultural and fisheries production in certain countries and can help these countries cope with predicted flooding.

### 8.5. Tourism

Observations enable monthly and seasonal forecasts that are important for resort operations and that are becoming increasingly important in choosing a resort destination. Climate observations for longer-term projections will be indispensable for such things as the development, management and siting of sustainable tourist facilities (WMO, 2009). The siting of coastal resorts, for example, will benefit from observations of sea level rise, while the development of ski resorts is greatly dependent on the amount of snowfall that can be expected in a given area.

### 8.6. Urban development and coastal zone management

Urban building design, transport planning, urban water supply management, flood control and planning for responses to heatwaves are some urban activities requiring climate observations. In coastal cities, sea-level data are needed for planning physical defences, adjusting building codes, and establishing setback policies related to projected sea-level rise and attendant storm surges.

### 8.7. Energy

Climate information, such as observations of temperature and cloudiness, is needed for energy demand forecasts. Energy production forecasts require observations, for example, of river discharge, snow cover, cloudiness, and wind direction and speed. Climate scenarios are important in the energy sector for long-term infrastructure planning. Climate impacts need to be taken into account in planning, considering that a 1–2°C temperature increase translates into a 10 per cent increase in energy consumption in summer because of the air conditioning needs. Wind energy production forecasts require improved model resolution, which in turn will require considerable regional- to local-scale observations (WMO, 2009).

## 9. REDD, observation needs and development

In recent years, reducing emissions from deforestation and forest degradation in developing countries (REDD) has emerged as the mitigation option with the largest and most immediate carbon stock impact in the short term (UNFCCC, 2009b). Inasmuch as local communities would be rewarded for conserving their

forests, REDD could help to alleviate poverty in developing countries as well as to reduce emissions. Climate observations are important to REDD in that systematic long-term observation of forests and other land cover characteristics and changes is a basic requirement for efforts to reduce deforestation in developing countries. The ability to accurately measure changes in forest cover and associated carbon stocks and GHG emissions will be essential to the success of REDD, but such measurements are not necessarily straightforward. A combination of remotely sensed and ground-based measurements of such relevant terrestrial ECVs as land cover, biomass and fire disturbance will be needed.

## 10. Conclusions and recommendations

Observations of the climate are the necessary foundation – the knowledge base – on which the provision of climate services and climate forecasting is built. Improved services and forecasting enable climate risk management and an enhanced ability to adapt to climate change and thus a more efficient path to national development. Consideration of climate variability and change in national development planning needs to become standard practice. In most developing countries climate observing networks are inadequate and improvements are needed in both the quality and quantity of observations. However, there are a number of things that developing countries can do, some of which do not depend on scarce financial resources, which can lead to improved observations and/or better use of available observations. Likewise, developed countries can assist developing countries to improve their networks, and such assistance may be as much in the interest of the developed world as of the developing world.

### *10.1. Developing countries*

First, greater coordination on climate observing issues at both national and regional scales can lead to improvements in observing systems without large expenditures. The GCOS Secretariat has suggested that countries designate GCOS National Coordinators and establish GCOS National Committees. In addition, countries that have begun coordinating regionally, such as the Pacific Island countries, are better able to pool their expertise and resources and focus on the highest priority needs at the regional level. Second, substantial historical climate data exist in many developing countries, for example in old and deteriorating paper records, which are not in usable form. Such data are valuable for climate purposes and need to be rescued, typically through digitization, while this is still possible. Although data rescue is not cost free, it does have the advantage of being a one-off activity. Older data need only be digitized; they then become a permanent part of a country's usable climate data record and are available for climate analyses. Third, the greater exchange of climate data, at least at the regional level, but ideally internationally as well, would significantly assist in development planning. NMHSs have often been reluctant to exchange data with other countries, in part because they perceive that the data could potentially be sold, and therefore it should not be given away free. However, free data exchange would almost certainly provide benefits that would far outweigh perceived risks. For example, the regional climate models that are becoming increasingly important for adaptation planning require data from the region for their validation, and all countries in a region would benefit from accurate regional model projections. Fourth, developing countries could make explicit reference to observational needs in national adaptation and development planning documents, for example in NAPAs. The more national-level policymakers become aware of the importance of climate observations and use climate information in adaptation and development planning, the easier it is likely to become to obtain national-level funding for improving climate observing networks. The WMO and the AUC, recognizing this fact, hosted the first-ever Conference of Ministers Responsible for

Meteorology in Africa in 2010. Finally, at little cost, developing countries could place greater emphasis on ensuring that those observations that they currently make are of the highest possible quality. Quality improvements might reasonably follow once the importance of climate observations is better recognized at the policy-making level.

### *10.2. Developed countries*

Many developing countries will be able to take the above steps but still find it difficult, if not impossible, to fund needed infrastructure improvements and capacity building related to climate observations. Lack of progress in implementing the GCOS Regional Action Plans is clear evidence of this. On more than one occasion, developed countries have promised to assist developing ones. For example, the Gleneagles Plan of Action produced at the 2005 G8 Summit Meeting in Gleneagles, Scotland, noted the desire of the G8 countries to strengthen international cooperation on global Earth observations. It committed the G8 to support efforts to help developing countries and regions obtain full benefit from GEOSS and GCOS, including 'placement of observational systems to fill data gaps, [development of] in-country and regional capacity for analyzing and interpreting observational data, and development of decision-support systems and tools relevant to local needs' (G8, 2005). The Plan of Action makes special reference to Africa, noting that the G8 will work to strengthen the existing climate institutions in Africa through GCOS. The Hyogo Framework for building the resilience of nations and communities to disasters also notes the importance of climate observations, in particular for enhancing disaster preparedness. It calls on developed countries, among other things, to support actions to improve *in situ* and space-based Earth observations (ISDR, 2005).

Collectively and individually, the G8 and other developed countries need to make their best efforts to follow up on commitments such as those made in the Gleneagles Plan of Action. The provision of funding for the establishment of the ClimDev Africa Programme may be seen as one important action by some developed countries to make good on their commitments; however, similar support is needed in other regions as well. Parties to the UNFCCC continue to affirm, for example in the Ad Hoc Working Group on Long-Term Cooperative Action (AWG-LCA), that developing countries will need substantial additional funding, including for systematic observation for climate data collection, to help them adapt to climate change (UNFCCC, 2009c). The work of the AWG-LCA was not completed at COP-15, but expectations are high that developed countries will eventually provide such funding. Although reaching agreement on many climate change issues will continue to be challenging, most countries do agree on the need to improve climate observations. Hence, there is reason to be optimistic that developed countries will provide support for this purpose. Support is needed for upgrading observing equipment and infrastructure generally, but substantial needs for specialized training, scholarships and other forms of capacity building also exist. The GCOS Cooperation Mechanism (GCM) was established in 2003 as one means by which developed countries can contribute to improvements in observing systems in developing countries, for example, by supporting the implementation of projects contained in GCOS Regional Action Plans. However, the GCM is not yet as effective as it could be. Thus far, only a small number of countries in a position to provide support to developing countries through the GCM have done so. The GCM would also benefit by engaging a broader range of donor organizations, including, for example, foundations interested in climate change and development.

## Note

All GCOS publications may be found on the GCOS website: www.wmo.int/pages/prog/gcos/index.php.

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