Regional Climate Information for Risk Management: Capabilities


*International Research Centre on El Niño (CIIFEN), Guayaquil, Ecuador
\[International Centre of Meteorological Application for Development (ACMAD), Niamey, Niger
\[Beijing Climate Center, China Meteorological Administration, Beijing, China
\[International Research Institute for Climate and Society (IRI), Columbia, United States
\[Bureau of Meteorology, Melbourne, Australia
\[Swedish Meteorological and Hydrological Institute, Stockholm, Sweden

Abstract

A comprehensive review of regional capabilities to produce climate information for risk management around the world is done. Data access, quality control and the potential use of regional reanalyses is explained. Progress on seasonal forecast techniques, the increasing skill of statistical and dynamical methods and the challenges on dynamical downscaling and spatial resolution is presented. A comprehensive review of the progress of Regional Climate Outlook Forums around the world is done explaining the mutual learning process among providers and sectoral users, the opportunities created to develop better climate services for the disaster prevention and planning sectors, the lessons learnt and best practices. The potential of Regional Climate Centres (RCCs) to improve climate services is revisited considering the experience of the formal RCCs and other centres working in different regions although not formally recognized as RCCs. Finally a detailed set of recommendations to enhance regional capabilities is listed.

Keywords: Climate information; Regional Climate Outlook Forums (RCOFs); Regional Climate Centres (RCCs); capacity building.

1. Introduction: present status of regional climate information provision

Climate information for decision support at regional, and especially local, scales is needed in order to manage vulnerability to climate variability and adaptation to climate change. Examples of relevant spatial scales range from specific locations and plots, to hydrological catchments, national scales and regions encompassing the same climate regime. Global climate information is typically derived from observations collected at specific locations or over small areas, but this does not mean that the original data are necessarily easily available, nor does all the attainable information always feed back to local or national benefit. This poor information flow also applies to information on possible future climate conditions – climate change projections and scenarios generated using climate model simulations. The degree of spatial and temporal detail provided by climate models is highly limited, and the models are hard-pressed to provide useful information at scales at which most climate information is required. Current global climate change projections are recognized as providing little useful information at scales much finer than sub-continental. Various downscaling techniques [1] are in use as means of providing more detailed information for impact assessment and other decision support, although the degree to which these downscaling techniques can provide added value is still not fully understood, and there is a danger of unjustifiably interpreting improved resolution as improved accuracy.

The present provision of regional climate information is diverse and varies with the source of the information, the provider and the intended use. From the provider side, a distinction can be made between observational data and a range of data that is generated by models on seasonal, decadal and multi-decadal scales. This distinction is not clear cut, however, as observations and modelled data come together in various ways, such as in the various reanalysis products.

1.1 Observational data

Climate data obtained by measurements (monitoring, campaigns) are fundamental for all uses. In addition to the long-term station observations, information is collected with platforms such as aircraft, satellites, weather radars and other means. Considerable parts of the data collection system are dynamic. Ground sites can come and go, even though a fair number of sites have carried out measurements over a long time. Even though data collection by, for example, satellites may be continuous as such, the measurements are made with a series of platforms, each of which has a limited lifetime resulting in possible inhomogeneities. Similarly, changes in instrumentation at observational sites and in their surroundings, measurement practices and other factors can cause inhomogeneities in data. Such inhomogeneities are less of a concern when the use of the data is in operational forecasting, but are a problem if the purpose is climate monitoring. In any case, metadata – information on how the data have been obtained – are crucial.
Data collection is only the first step in securing observational data on climate. Subsequent steps include quality control, archival and retrieval. Free access to available data for analysis and use is generally limited for a variety of reasons, including the fact that station data have commercial value. Consequently, free distribution often means distribution of analysed products, such as spatial or temporal averages, which are sufficient for some uses, but restrict others.

During the past decades, the so-called reanalyses have added new dimensions to observational data, and also made derived products more available (for example, the National Centres for Environmental Prediction [NCEP], ERA, the Japan Meteorological Agency [JMA] – see Kalnay et al. [2]; Uppala et al. [3]; Onogi et al.[4], respectively). A reanalysis can fill in gaps that exist in observational coverage in space, time and even in parameter space. To make use of the successive improvements in data assimilation techniques, forecasting model systems and possibly recovered historical data, successive reanalyses are needed. Until now, reanalyses have been global and, although in some cases the resolution employed has been reasonably high, it nevertheless remains coarser than many of the needs on regional and local scales. Regional reanalyses are being discussed and some are presently being planned or tried out, at least in a showcase mode [5].

Observational data are fundamental, but are not without caveats. Changes in data collection over time have already been mentioned. Each measurement technique is special in the sense that the raw data need to be analysed, sometimes with very complex algorithms. This requires insight into data collection, as well as the realization that observational data come with biases and are imperfect.

1.2 Seasonal forecasting

Seasonal forecasting (for example, Palmer and Anderson [6]) exploits predictability on timescales exceeding normal weather forecasting of up to a few weeks at most. Such capability targets forecasts of probabilities of anomalous regional weather conditions rather than trying to predict the exact outcome. Seasonal predictability is premised on the action of relatively slowly varying boundary conditions such as the ocean state and soil moisture rather than on the immediate evolution of the current weather conditions. Consequently, there is an additional need for observational data beyond that for weather forecasting. As seasonal atmospheric variations are affected both by slowly varying boundary conditions and by atmospheric initial conditions, seasonal forecasts are often expressed as probabilities of different magnitudes of time-averaged (to reduce random noise) anomalous conditions.

Seasonal forecasting is today an operational activity at many forecasting centres. There are forecasting methods used in seasonal forecasting: dynamical methods based on global coupled atmosphere–ocean–land models, and empirical methods based on statistical models that utilize relationships found in observed data. Only since about 2005 have these two classes of methods started to show comparable forecast skill. The skill of dynamical methods has become at par with that of much simpler empirical methods because advances in computer technology have allowed for the production of massive hindcast sets (multi-model, multi-member ensembles), which in turn have allowed for both simple bias correction as well as more elaborate calibration of pattern errors and probability forecast adjustments. Empirical downscaling procedures, or specification methods based on regression, akin to Model Output Statistics (MOS), have been used quite extensively. Such procedures are useful at the seasonal scale, but whether the empirical models are robust under climate change is an open question. Dynamical downscaling of global seasonal forecasting products might open an avenue of providing additional information on regional and local scales, but apart from explorative research projects, this option has yet to be widely explored.

There are two completely separate problems – large uncertainty in the forecast and the mismatch of (spatial and temporal) scales between the forecast and the application. Most users find the tercile-based approach to seasonal forecasts, for example, not very useful partly because the terciles are not always easily understood, but more specifically because they do not map onto impacts very obviously. What many users would ultimately like the forecasters to provide is, in many cases, unpredictable (if not inherently so, at least with the current levels of technology). Some kind of compromise or intermediate solutions should therefore be sought. This approach necessitates a careful dialogue between the forecast producers and the users, and will require research both on the part of the forecasters, who need to seek ways of forecasting variables that are more directly useful, and on the part of the users, who need to explore ways of using the imperfect, but still potentially useful, forecast information that can be provided.

The two most important phenomena contributing to useful seasonal forecasting skill are El Niño–Southern Oscillation (ENSO) and the contemporary climate trends (which in many cases are most probably due at least partly to global climate change). Other factors include soil moisture and the possibility of seasonal-scale predictability based on high latitude upper atmospheric conditions. Whereas ENSO is the most celebrated vehicle for seasonal forecasting for tropical and a few other regions, forecasting the North Atlantic Oscillation (NAO) and Pacific-North America (PNA) pattern are relevant for extra-tropical seasonal prediction. Herein, the successes have been less easily forthcoming.

Modelling systems for seasonal forecasting have lower resolution than models used for numerical weather prediction, and so they are harder pressed to represent smaller-scale organized phenomena that are responsible for crucial weather. An example is the Mesoscale Convective System (MCS), which is of a scale not amenable to representation in typical global models. Mesoscale Convective Systems contribute to a significant part of regional precipitation in parts of Africa, northern America and around Japan. The importance of predicting the Madden-Julian Oscillation (MJO) has received more attention with regard to seasonal forecasting than MCSs, and notable improvements in skill of one-month forecasts are beginning to be realized.

1.3 Decadal climate predictability

Decadal prediction relies on the notion that there are climate system components that retain a memory of past variations and conditions even beyond the seasonal scale [7]. The ocean is the prime example of such a component. It has been shown that knowledge of sea temperature anomalies (and more fundamentally, ocean circulation) may give rise to predictive capability in some regions. The degree to which the climate system has predictability on multi-year scales (and for which regions) is still very much an open question. The evidence of observed variability on decadal timescales (for example, in the Pacific region, in hurricane statistics,
in Sahelian drought) suggests that there might be true decadal predictability to exploit, but its extent remains to be more firmly established [8].

1.4 Climate change projections

Anthropogenic climate change is inherently a global issue. Emissions impact the whole global system that in turn responds with an initial warming, giving rise to feedback and additional changes that reverberate through the climate system. Today’s climate change projections are not predictions in the same sense as weather and seasonal and decadal forecasts. For one thing, climate change projection simulations start from a realistic, but hypothetical, climate state. Thus, they are not initialized in the same sense as weather/seasonal/decadal forecasts. Even if this were the case, the predictability from the oceanic and atmospheric initial conditions that form the basis for seasonal and decadal forecasts would decrease with increasing lead time, leading to the memory of the initial state being overrun by internal variability at the multidecadal lead times of climate change projections. Secondly, climate projections are subject to scenarios on future anthropogenic forcing development, and so the projections should be seen as indications of expected changes under different assumptions about anthropogenic forcing. The climate change projections per se do not provide any comment on the likelihood of any of the different forcing scenarios, and so the projections are not predictions. Nevertheless, a combination of decadal prediction and climate change projections is now being explored, perhaps leading to climate change predictions on short-to-intermediate climate timescales [9][10].

On global and regional scales, climate change manifests itself as changes in both the average conditions and in weather/climate statistics, that is, characteristic variability and the frequency and severity of extreme conditions. Due to the long timescales involved, from a few decades to a century and longer, the gap between the resolution in global climate modelling and the need of regional and local climate information is most evident when it comes to climate change projections. Downscaling is the main method for trying to bridge the gap between the indispensable but inadequate global climate models and the need for climate change information on regional scales. Whereas statistical downscaling, of which there are a multitude of variants, exploits empirical relationships between large-scale and local climatic features, dynamical downscaling builds on limited area (regional) climate models that provide detail and thus potential value for impact and assessment applications, not least to support adaptation. In many regions, downscaling has predominantly been of the statistical kind, for both capability and capacity reasons. It remains, however, problematic to cover all the essential climate aspects by such statistical techniques and there are questions on the validity of the empirical relationships under ongoing climate change.

Regional climate modelling has its own issues relating to the quantification of added value compared to the underlying global modelling, but the community is clear about a more comprehensive accounting of the effect of variable topography on regional climate (such as land–sea contrasts and orography) as well as the effect of higher resolution in simulating synoptic and mesoscale weather systems, extremes of precipitation and so on. Climate models, the global and regional ones alike, exhibit both skill and systematic biases that need to be assessed, recognized and accounted for when utilizing the information for such purposes as input to impact studies. Also the still relatively coarse resolution of even regional climate models, compared to the inherent heterogeneity of the landscape and human systems, needs to be handled in interfacing climate and impact models, and the extent to which available regional climate model outputs reliably estimate the full range of uncertainty in future climates needs to be assessed. Given the computational demands of regional climate downscaling, there are frequently only limited numbers of ensemble members forced with an even more limited number of global models, so that the true uncertainty is almost certainly being underestimated.

Today, downscaling techniques are becoming more widely available and their application more coordinated, thanks largely to recent projects such as Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects (PRUDENCE), ENSEMBLES, the Regional Model Inter-comparison Project (RMIP), the African Monsoon Multidisciplinary Analysis (AMMA), the Assessments of Impacts and Adaptations to Climate Change (AIAAC), the Regional Climate Change Scenarios for South America (CREAS), the Europe-South America Network for Climate Change Assessment and Impact Studies (CLARIS) and the North American Regional Climate Change Assessment Program (NARCCAP). Jointly, the efforts now extend to most regions of the world. Nevertheless, work still remains to be done to increase the availability and usefulness of both the tools and their results, as provision of regional climate change data [11].

1.5 Ongoing development and outlook

There are initiatives aimed at improving access to collected climate data, such as through the Regional Climate Centres of the World Meteorological Organization (WMO). Various providers also invest in making derived products available such as gridded climatologies (the Climate Research Unit [CRU], the European Climate Assessment & Dataset project [ECA&D], the Climate Variability and Predictability programme Variability in the African Climate System [CLIVAR VACS]), and regional and global outlooks. The availability of the underlying raw data is still limited, however, and even in the derived products the quality of the information is restricted by limited access to the raw data.

Modern modelling systems and tools that are the means to translate observed data to forecasts, reanalysis, projections and scenarios are built on the same principles. One strategy to increase the consistency across applications is the concept of seamless prediction systems [12][13], capable of addressing timescales from operational forecasting to seasonal forecasting and further on to decadal and century scales.

Other ongoing development strands include increasing model resolution; utilization of model or simulation ensembles and augmentation of basic physical climate system models into incorporating carbon cycle; interactive vegetation; and more complete simulation of atmospheric chemistry and ocean biology. The promise herein is one of increased versatility of the modelling systems, both in attempting to capture the real system and in providing for a broader range of applications. Climate and environmental applications, for example, can become more interwoven.

The resolution of global models, both for forecasting and for climate projections, is steadily increasing. However, there still is some way to go before the level of detail requested in many regional and local applications can be provided. Downscaling efforts will
thus remain as an essential tool of the trade. Whereas statistical downscaling methods are readily affordable, dynamical downscaling tools, such as regional climate models, are less accessible. Some community tools [14][15] are nevertheless starting to make their mark. Parallel to the resolution increase in global modelling efforts, regional climate models also will become more detailed. Today, state-of-the-art regional climate models operate on approximately 10–50 km spatial resolutions, but are being pushed towards non-hydrostatic regimes of about 1 km. There is a motivation to explore the synergies between global regional climate modelling as well as between the climate modelling community and the climate impact assessment and response community [16].

Perhaps the greatest challenges are:

(a) The provision of consistent climate data and products, ranging from the past to the present and onwards to possible futures, and catering for varying regional, sectoral and local user needs. This requires both continued and collaborative science support and building up production and delivery mechanisms especially for regional provision [17][18][19], as well as strengthened efforts on climate monitoring.

(b) Training user communities and information providers in the proper use of the new products that go beyond both mere observational data and weather forecasts, and in how to communicate this information. Observational systems and modelling capabilities need to be developed in unison and towards more integrated systems.

(c) Development of climate change predictions, learning both from seasonal and decadal forecasting science and from the science on climate model projections and scenarios.

2. Regional climate outlook forums

2.1 Present status of RCOFs

Recognizing that climate information including predictions/outlooks could be of substantial benefit to many climate-sensitive sectors in different parts of the world in adapting to and mitigating the impacts of climate variability and change, WMO has helped establish Regional Climate Outlook Forums (RCOFs) across the world with an overarching responsibility to produce and disseminate a regional assessment (using a predominantly consensus-based approach) of the state of the regional climate for the upcoming season.

The RCOF Review meeting held in Arusha, Tanzania, 3–7 November 2008 provided a comprehensive analysis of the first 10 years of the RCOF process with the participation of experts closely involved in RCOFs operations worldwide. The main conclusions are summarized here.

2.1.1 Establishment of RCOFs

Regional Climate Outlook Forums are an innovative concept developed and supported as part of the WMO Climate Information and Prediction Services (CLIPS) project in partnership with the National Meteorological and Hydrological Services (NMHSs), regional climate institutions and other agencies. The RCOFs have completed about 10 years of successful operation in different sub-regions of Africa, in parts of South America and in the Andean region. Regional Climate Outlook Forums in various forms and sizes are now in operation serving more than 10 sub-regions around the world (see Table 1), and concerted efforts are being made to extend the concept to several other regions. Despite the challenges of resources and human and infrastructural capacities, some of the RCOFs have achieved remarkable progress in regional networking and user liaison, and have contributed substantially to capacity-building and user awareness.

Table 1. Regional Climate Outlook Forums

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHACOF</td>
<td>Greater Horn of Africa COF</td>
</tr>
<tr>
<td>SARCOF</td>
<td>Southern Africa COF</td>
</tr>
<tr>
<td>PRESAO</td>
<td>Prévision Saisonnière en Afrique de l’Ouest</td>
</tr>
<tr>
<td>PRESAC</td>
<td>Prévision Saisonnière en Afrique Centrale</td>
</tr>
<tr>
<td>PRESANORD</td>
<td>Prévision saisonnière en Afrique du Nord</td>
</tr>
<tr>
<td>FOCRAII</td>
<td>Forum on Regional Climate Monitoring, Assessment and Prediction for Regional Association II (Asia)</td>
</tr>
<tr>
<td>SSACOF</td>
<td>Southeast of South America COF</td>
</tr>
<tr>
<td>WCSACOF</td>
<td>Western Coast of South America COF</td>
</tr>
<tr>
<td>FCCA</td>
<td>Foro Regional del Clima de América Central</td>
</tr>
<tr>
<td>PICOF</td>
<td>Pacific Islands COF (Teleconference based)</td>
</tr>
<tr>
<td>PEAC</td>
<td>Pacific ENSO Applications Climate Center (Teleconference based)</td>
</tr>
<tr>
<td>ICU</td>
<td>Island Climate Update forum (Teleconference based)</td>
</tr>
<tr>
<td>SEECCOF</td>
<td>SouthEastern Europe COF</td>
</tr>
</tbody>
</table>
National and regional capacities are varied, but are certainly inadequate to face the task alone. Built into the RCOF process is a regional networking of the climate service providers and stakeholders including user sector representatives. Participating countries recognize the potential of climate prediction and seasonal forecasting as a powerful development tool to help populations and decision-makers face the challenges posed by climatic variability and change. In parallel, NMHSs and some decision-makers have come to realize the potential benefits to be gained and have played larger roles in the processes. Ownership now lies largely with national and regional players, but there is a continuing need for support at all levels to ensure that the momentum gained to date is maintained.

Regional Climate Outlook Forums bring together national, regional and international climate experts, on an operational basis, to produce regional climate outlooks based on input from NMHSs, regional institutions, Regional Climate Centres (RCCs), Global Producing Centres of long-range forecasts (GPCs) and other climate prediction centres. Through interaction with sectoral users, extension agencies and policymakers, RCOFs assess the likely implications of the outlooks on the most pertinent socio-economic sectors in the given region and explore the ways in which these outlooks may be used. Regional Climate Outlook Forums also review impediments to the use of climate information and the experiences and successful lessons regarding applications of past RCOF products in an effort to enhance sector-specific applications. In many cases the RCOFs are followed up by national forums to develop detailed national-scale climate outlooks and risk information including warnings for communication to decision-makers and the public at large.

The RCOF process typically includes the following components:

(a) Meetings of the regional and international climate experts to develop a consensus for the regional climate outlook using national, regional and global information, typically in a probabilistic form;

(b) The Forum proper, which involves climate scientists, representatives from the user sectors as well as the media, for identification of impacts and implications, and the formulation of response strategies;

(c) A training workshop on seasonal climate prediction to strengthen the capacity of the national and regional climate scientists;

(d) Special outreach sessions involving media experts, to develop effective communications strategies.

Regional Climate Outlook Forums provide an opportunity for users to have face-to-face contact with the forecasters. They provide a mutual learning process where users learn about the nature of forecasts, assimilate better their probabilistic nature and, most importantly, realize the limitations of climate predictions. On the other side, forecast producers learn about how the users perceive their products, identifying possible misinterpretations, and learning about needs for new products.

Regional Climate Outlook Forums have been evolving differently in each region. Some of them have maintained many of the features of the original format, with one or two meetings per year to produce a consensus climate outlook through analysis and discussion of global, regional and national forecasts. However, in some regions the RCOFs work differently. For example, virtual forums are held every month for the Pacific region, with countries participating by teleconference.

2.1.2 Consensus forecast

The consensus prediction process that underlines RCOF operations consists of the following elements:

(a) Determine the critical time for development of the climate forecast for the region in question;

(b) Assemble a group of experts:

   (1) Large-scale prediction specialists;

   (2) Regional and local climate applications and forecast/downscaling specialists;

   (3) Stakeholders representative of climate-sensitive sectors;

(c) Review current large-scale (global and regional) climate anomalies and the most recent forecasts for their evolution;

(d) Review current climate conditions and their impacts at local, national and regional levels, and on national-scale forecasts;

(e) Considering all factors, produce a forecast with related output (for example, maps showing probabilities of temperature and precipitation anomalies) that will be applied and fine-tuned (downscaled) by NMHSs in the region to meet national needs;

(f) Discuss, with active involvement of representatives of climate-sensitive sectors, applications of the forecast and related climate information to climate-sensitive sectors in the region;

(g) Consider practical products for development by NMHSs;

(h) Develop strategies to effectively communicate the information to decision-makers in all affected sectors;

(i) Critically evaluate the session and its results:
(1) Document achieved improvements to the process and any challenges encountered;
(2) Establish steps required to further improve the process for subsequent sessions;
(3) Verify the previous year forecast and evaluate its use;
(4) Undertake some training sessions (in new techniques and methods).

2.1.3 Exchange of technical information

Close interaction between the providers and users of climate information and products has enhanced feedback from the users to climate scientists, and has catalysed the development of a number of user-specific products. The RCOF process has facilitated a better understanding of the links between the climate system and socio-economic activities. An increasing demand for climate services has been noted in many parts of the world as a result of these developments. One of the pillars of RCOF activities has been capacity-building, including development of curricula for university education in climate applications.

Awareness has been created that climate information, including short-range climate predictions, is an essential element in mitigating the impacts of climate variations. Regional Climate Outlook Forums have facilitated regional cooperation and networking, and have effectively demonstrated the immense mutual benefits of sharing of climate information and experience.

Regional Climate Outlook Forums have provided lessons and experiences that are critical for climate adaptation. The concept has the potential to be extended to develop our capacity to adapt to climate change. Regional Climate Outlook Forums can be effectively expanded to cater to the needs of developing and disseminating regional climate change information products. This concept is already being tested by some RCOFs (for example, GHACOF). Regional assessments of observed and projected climate change, including the development of downscaled climate change scenario products for impact assessments, can be included in the product portfolio of RCOFs. This potential has already been recognized by the United Nations Framework Convention on Climate Change (UNFCCC) Subsidiary Body for Scientific and Technological Advice (SBSTA), and constitutes a key element of the WMO contribution to the Nairobi Work Programme on impacts, vulnerability and adaptation to climate change.

2.1.4 Communication and information exchange with users

Outlooks derived from most RCOFs are disseminated to the users by the local NMHSs. Many NMHSs have their own distribution lists, which they use for dissemination of the Outlooks. Regional Climate Outlook Forums stimulate the development of climate capacity in the NMHSs and do much to generate decisions and activities that mitigate adverse impacts of climate and help communities adapt to climate variability. Typically, RCOFs attract the participation of practitioners and decision-makers from sectors including:

(a) Agriculture and food security;
(b) Water resources;
(c) Energy production and distribution;
(d) Public health;
(e) Disaster risk reduction and response;
(f) Outreach and communication.

In many regions, the users benefiting from the RCOFs are true stakeholders, contributing to the organization and growth of the sessions, thus ensuring their sustainability and applicability to meeting user needs.

Based on the needs of specific sectors, specialized, sector-oriented outlook forums, such as the Malaria Outlook Forums (MALOFs) are being held in conjunction with RCOFs in Africa. Based on the seasonal temperature and rainfall predictions, and using the present soil moisture conditions, river runoffs for the season are predicted in some of the RCOFs. Regional agriculture and food security outlooks are now regularly produced based on the climate outlooks following the RCOFs in some regions. This information is very important in planning food grain reserves and distribution.

Regional Climate Outlook Forums have provided the opportunity to study the users’ profiles, and with this knowledge, to adjust the way to communicate climate information. Language, native phraseology, ancestral climate knowledge and the intuition of the colour scales are all examples of ways to reduce barriers in communications and to transmit the message more clearly.

Regional Climate Outlook Forums also allow working with users from different development sectors. Learning about what they need leads to improved design formats, graphics or slightly different wording that could ensure a more appropriate communication channel and engagement of users because both the producers and the users feel that they are speaking the same language.

2.1.5 Capacity-building of NMHSs

The capacity-building activities of RCOFs were designed as a major component of climate outlook forums dedicated to regularly upgrade stakeholders’ capabilities to produce, disseminate and use climate information. Global and regional centres, NMHSs, the media and other user organizations are partners in these activities.
The RCOF process typically has a pre-RCOF workshop to build the capacity of experts from specific socio-economic sectors to use climate outlooks in application tools and decision systems. The pre-RCOF workshop provides unique opportunities for interactions between climate experts and sectoral users. Another important aspect of the pre-forum workshop has been capacity-building of national service providers (NMHSs) leading to the production of climate outlooks using the latest seasonal forecasting methods and tools. A training phase followed by a forecast production phase has been a powerful way of adding value to capacity-building activities.

Capacity-building activities usually include:

(a) Assistance to stakeholders for a better understanding of the benefits and limitations of climate predictions;
(b) Basic and advanced courses in climatology, climate predictability, predictions and applications tools usually emphasizing El Niño–Southern Oscillation and its influence in different regions;
(c) Hands-on training of NMHS experts leading to preparation of climate monitoring and outlooks information;
(d) Identification of potential national users and approaches to develop partnerships with the media and specific users;
(e) Approaches to promote two-way interactions and trust-building between climate and user communities;
(f) Development and update of training materials;
(g) Transfer of computing infrastructure, exchanges of methods and tools.

These activities have been instrumental in improving regional and international exchanges leading to more visibility of NMHSs, strengthening of national climate services, enhancing the forecasting capabilities of NMHSs and building trust and confidence of more climate services customers (water, health, disaster management organizations). Some training programmes have provided infrastructure (computers, statistical packages and other software), improving the working environment of many NMHSs particularly in developing countries.

In addition to RCOFs capacity-building hosted by regional centres and NMHSs, WMO/CLIPS have organized training courses for selected experts (national focal points) who usually attend RCOFs, and have developed and distributed training materials to facilitate training for regions and countries. These courses covered climatology, modelling and predictability; information presentation and dissemination; application tools; and project management. International workshops on climate prediction and applications (for example, the Cooperative Institute for Mesoscale Meteorological Studies [CIMMS] at the University of Oklahoma, the United Nations Educational, Scientific and Cultural Organization [UNESCO] the International Centre for Theoretical Physics [ICTP]) followed up CLIPS training sessions.

### 2.1.6 Cooperation with the research community

The current level of interaction between RCOFs and the research community is poor. The improvement of this relationship is necessary to integrate the scientific progress in the improvement of climate operational products provided by NMHSs. There could be several approaches to foster this integration: one of them could be the implementation of a visitors programme to the regions to work on research at regional and local levels. Universities must also be involved in this process and the research priorities must be discussed within the RCOFs and agreed with RCCs or GPCs.

### 2.2 Features of each RCOF reflecting regional conditions

Every RCOF in operation started using a common framework, which has subsequently been adapted to the particularities and specific needs of each region. This evolution has led to different ways of working depending on the different regions even if the print of the initial scheme can be clearly found in each RCOF.

#### 2.2.1 Africa

The GHACOF (Greater Horn of Africa) is held twice a year. The pre-RCOF workshop for issuing national forecasts uses statistical tools (for example, the Climate Predictability Tool), and includes users. The draft of the regional forecast is followed. The forecast is disseminated via Web, e-mail and media.

The SARCOF (Southern Africa) is held once a year. The forecasts are issued based on sea-surface temperature (SST) regressions and other predictors. Outputs of GCM are considered by NMHSs for the first half of the rainy season. Unfortunately, the lead time for forecasts for the second half of the rainy season is beyond the forecast range of most GPCs, and so these forecasts have to be made exclusively using empirical methods. For the first few years of SARCOF, a mid-season meeting was held to provide an update for the forecast for the second half of the rainy season. This mid-season meeting was able to draw upon GPC products. Unfortunately, this update meeting has had to be discontinued because of lack of resources.

The PRESAO (West Africa) and the PRESAC (Central Africa) are each held once a year. The forums consider the state of the global climate system and the evolution of SSTs, and make an inference of rainfall anomalies. A consensus process referring to models and GPC outputs is followed. The forecast is disseminated via Web, e-mail and media.
Based on the needs of specific sectors, specialized, sector-oriented outlook forums, such as the Malaria Outlook Forums (MALOFs) are being held in conjunction with RCOFs in part of Africa.

2.2.2 Central and South America

From 2003, the International Research Centre on El Niño (CIIFEN), with WMO sponsorship, assumed the coordination of the Climate Outlook Forum for Western South America (WCSACOF). The seasonal forecast for the region is produced monthly as a result of a consensus discussion, conducted by e-mail, among all the NMHSs. All the members share a common methodology and several parameters have been agreed upon and are being refined from year to year. This consensus forecast is widely disseminated by e-mail to more than 15,000 users across Central and South America and contacts on other continents. This approach has increased the understanding of the climate information management process, and the organizations have established a regional/national basis for early warning and risk management systems [20].

The CARCOF (Central America) is held at least once a year depending on funding. Climate monitoring information and GCM outputs as predictors are used. Selection of analogous years and national outlooks are used to conduct the consensus process in a regional two-day meeting. A specific forum, which includes key sectors and recommendations at the regional level, is also held. Dissemination of application bulletins, national downscaling, dissemination of national forecasts and follow-up of the evolution are done by e-mail.

The Southeast of South America COF includes Brazil, Paraguay, Uruguay and Argentina. It is normally held twice a year. This COF has more than 25 editions. The analysis is achieved using global models, regional models and the national forecasts of the members. The COF discusses the consensus and agrees to issue the forecast, which is further distributed at national level.

2.2.3. Pacific region

Regional Climate Outlook Forums in the Pacific region (PICOF, ICU and PEAC) are held through teleconference on a monthly basis, and they were established, independently of the WMO/CLIPS project, through the initiative of the Australian Bureau of Meteorology (BOM), the New Zealand National Institute of Water and Atmospheric Research (NIWA), and the University of Hawaii and the National Oceanic and Atmospheric Administration (NOAA).

The Pacific Islands COF (PICOF) is a monthly teleconference, coordinated by the Australian Bureau of Meteorology as part of the Pacific Islands – Climate Prediction Project (PI-CPP, http://www.bom.gov.au/climate/pi-cpp/) and funded by the Australian Agency for International Development (AusAID). The National Meteorological and Hydrological Service representatives from 10 South Pacific Islands participate in this project: Cook Islands, Fiji, Kiribati, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu. Participants use a statistical-based model developed under the project, called SCOPIC for Seasonal Climate Outlook for Pacific Island Countries, to run the seasonal climate outlooks for a number of locations in each country for the upcoming three-month period. The main purpose for the PICOF is to provide a regular forum for the ten participating Pacific Islands countries’ NMHSs to discuss the current ENSO status and their climate (rainfall) outlooks for the upcoming season derived from SCOPIC with the project team. The Pacific Islands COF began in October 2007.

The ICU began in 2000 and is financially supported by the New Zealand International Aid & Development Agency. The backbone of the ICU is the monthly teleconference, which includes participation of several NMHS representatives and New Caledonia and French Polynesia (Meteo France), Australia (BOM), New Zealand (NIWA) and the United States (NOAA and the International Research Institute for Climate and Society [IRI]). The goal of the teleconference discussion is to reach a conclusion about the current state of South Pacific climate and a consensus on the outlook for the coming three-month period. It also has the additional objective of coordinating advice on the state of ENSO among key major climate forecasting countries (Australia, New Zealand and the United States). The Pacific Islands COF and ICU complement each other as ICU focuses on seasonal rainfall outlooks on regional and national levels whereas the PICOF process involves downscaling to various sites/locations in each country.

The Pacific Enso Application Climate Center (PEAC) pilot project began, with NOAA Office of Global Programs (OGP) funding, in 1994. The PEAC project caters to United States Affiliated Pacific Islands. Attendants include the Climate Service Focal Points (CSFPs) from each of the Weather Service Offices in Guam, Palau, Yap, Chuuk, Pohnpei, Majuro and Pago Pago, as well as climate scientists/forecasters from the University of Guam Water and Environmental Research Institute, the Kwajalein Reagan Test Site Weather Station, IRI and the NOAA Climate Prediction Center (CPC). Partners from Pacific Regional Integrated Science Assessment (RISA) and regional partners in the South Pacific are invited to join the monthly discussions. The PEAC is held monthly. Climate diagnoses and forecasts are exchanged via e-mail. A monthly discussion (teleconference) is held and includes verification of previous rainfall reports, previous forecasts, reports from around the region, sea level discussion, ENSO diagnosis and forecast and outlook discussion (produced by PEAC using 7 models). The dissemination is done through Web and e-mail.

2.2.4 Asia

In order to more effectively fulfill all the responsibilities and functions as one of the potential WMO Regional Climate Centres in Regional Association II (Asia), and to provide NMHSs a better platform to share the useful experience and forecasting products for Asia from the climate prediction centres around the world, the Forum on Regional Climate Monitoring, Assessment and Prediction for Asia (FOCRAII, for the summer outlook) has been held annually since 2005, hosted by the Beijing Climate Center/China Meteorological Administration (BCC/CMA). This Forum provides an opportunity to discuss seasonal forecasts (precipitation and temperature) for a consensus summer season prediction statement in Asia as well as to review the limitations and prospects of seasonal to interannual climate forecasting methodologies and systems.

In order to overcome prediction difficulties of the Asian monsoon, CMA, together with the Japan Meteorological Agency (JMA) and the Korea Meteorological Administration (KMA) pushed the plan of holding a joint meeting of long-range forecast experts from the east Asian countries on the Asian monsoon prediction, for improvement of seasonal prediction ability in east Asia. Consequently,
the Joint Meeting on Seasonal Prediction on the East Asian Winter Monsoon (for the winter outlook) has been held annually in turn among CMA, JMA and KMA since 2000.

2.3 Future plans

As identified and recommended at the RCOF Review Meeting, November 2008, in Arusha, Tanzania, the following are key topics for future RCOFs:

(a) Accommodation of decadal variability and climate change in RCOF seasonal prediction;
(b) Predictability of seasonal statistics of tropical cyclones;
(c) Improved and tailored RCOF products;
(d) Customization of dynamical downscaling models;
(e) Virtual RCOF;
(f) Optimization of multi-model ensemble prediction over the RCOFs domains;
(g) Different customizations for different end-user applications;
(h) Development of decision support systems;
(i) High-end visualization through the Implementation of best ways to visualize RCOFs outcomes based on geographic information systems or Google Earth.

3. WMO regional climate centres (RCCs) and other regional climate centres/institutes

3.1 Present status of RCCs

Regional Climate Centres (RCCs) are centres of excellence that assist NMHSs in a given region to deliver better climate services and products including regional long-range forecasts, and to strengthen their capacity to meet national climate information needs. Regional Climate Centre responsibilities are regional in nature and do not duplicate or replace those produced by NMHSs. (It is important to note that NMHSs retain the mandate and authority to provide the liaison with national user groups, and to issue advisories and warnings.) Regional Climate Centres serve the regional level of a three-level climate-related infrastructure: Global Producing Centres for Long-range Forecasts (GPCs, global level), RCCs (regional level) and NMHSs (national level).

The World Meteorological Organization defines RCCs as follows: “Centres designated by WMO for the provision of regional long-range forecasts and other regional climate services, or groups of centres who collectively provide these forecasts and services in a distributed network, are called Regional Climate Centres (RCCs) or RCC-Networks, respectively” [21]. Specifically, an RCC is required to perform the following functions:

(a) Operational activities for long range forecasts;
(b) Operational activities for climate monitoring;
(c) Operational data services, to support operational long-range forecasts and climate monitoring;
(d) Training in the use of operational RCC products and services.

The most important role of NMHSs in climate information services is to produce and provide not only general climate information to the general public but also tailored information for specific purposes. In reality, however, it is difficult for most NMHSs to provide such services operationally. Accordingly, an RCC is expected to play a supportive role in climate information services made by NMHSs in a specific area through the provision of relevant climate information, and to transfer technical knowledge to NMHSs so that they can make tailored information operationally. In other words, its concept is one of the interaction mechanisms to supply climate information and prediction and to facilitate communication among NMHSs at regional levels. The primary clients of an RCC are NMHSs and other RCCs in the region and in neighbouring areas.

The evolution of the RCC concept started after the intensified El Niño event during 1997 and 1998. An Inter-Commission Task Team on Regional Climate Centres elaborated the first framework for WMO RCCs [22]. The influential milestone was the Meeting on Organization and Implementation of RCCs, which provided the first guideline document on the establishment of RCCs [23]. Supported by activities in the Regional Associations, especially RA II [24] and RA VI [25], as well as by discussions and resolutions of WMO-Executive Council, WMO-Congress, WMO-Commission for Climatology and WMO-Commission for Basic Systems, the establishment of RCCs as well as the designation of the Beijing Climate Center of the China Meteorological Administration and the Tokyo Climate Center of the Japan Meteorological Agency as multifunctional RCCs in RA II was authorized at WMO-Executive Council in June 2009. In RA II, the Russian Federation, India and the Islamic Republic of Iran have expressed their intention to be nominated as RCCs.

Other Regional Associations are reiterating their regions’ intentions to implement an RCC network rather than one or several multifunctional centres. For example, the nodes of the RA VI RCC Network will be composed of consortia hosted by respective lead
institutions. This approach has been chosen to ensure incorporation of as much of the competence and know-how of the 50 RA VI Members as possible.

3.2 Activities of the Beijing Climate Center and the Tokyo Climate Center

The Beijing Climate Center (BCC) and the Tokyo Climate Center (TCC) have provided operational climate information services in close collaboration. An example of such cooperation is the homepage of RCC-network RA II which was jointly developed by the two centres (http://www.rccra2.org/detail/index.htm). This homepage enables the access to data and products provided by each centre. Each centre also has its own site making its data and products available (http://bcc.cma.gov.cn/Website/index.php? and http://ds.data.jma.go.jp/tcc/tcc/index.html). Both centres strive to provide not only climate-related data and products through Websites but also capacity-building and support to make tailored information. Examples of main activities by each RCC are as follows:

(a) Probabilistic one-month forecast for 7-day averaged surface temperature and 14-day averaged precipitation at a number of major stations in Southeast Asia (TCC);

(b) Climate monitoring reports on weekly, monthly, seasonal and annual bases consisting of analysis and diagnostic assessment on the current status of the surface climate (BCC, TCC);

(c) Provision of gridded datasets of various meteorological variables from the Japanese 25-year Reanalysis (JRA-25, TCC);

(d) Training courses on climate information systems and forecasting methodologies (BCC);

(e) Group training course in meteorology for experts of NMHSs since 1973 in cooperation with JMA and the Japan International Cooperation Agency (TCC);

(f) Hands-on training courses inviting experts engaged in operational long-range forecasts in response to individual requests from NMHSs mainly in Southeast Asia (TCC);

(g) Supply of interactive tools to analyse and create climate information (TCC);

(h) Coordination of FOCRAII (BCC).

3.3 Future plans

As mentioned in the previous sections, RCCs are expected to play important roles in delivering climate information to NMHSs and in exchanging technical information to improve climate services of NMHSs in the region. In fact, in the Asian region, delivery of climate information and exchange of technical information are being improved evidently. So far, only two RCCs (BCC and TCC) have been designated as a first step. More RCCs should be established all over the world to support NMHSs in individual regions. These RCCs should be designed appropriately in view of natural and social features in the respective regions.

Considering individual countries’ circumstances including language, NMHSs should have primary responsibility for the provision of tailored climate information to national users. To support NMHSs activity, regional cooperation and collaboration are essential and should be further promoted by RCCs in close coordination with RCOFs.

3.4 Other regional climate information centres

3.4.1 Africa

Regional climate information including seasonal outlooks has been provided over Africa since 1997. The African Centre of Meteorological Application for Development (ACMAD) in Niamey, Niger, is responsible for seasonal forecasts provision for west and central Africa. Over eastern Africa, the Intergovernmental Authority for Development (IGAD) Climate Prediction and Applications Centre (ICPAC), based in Nairobi, Kenya, provides seasonal climate information for the region. The Southern African Development Community (SADC) Drought Monitoring Centre (DMC) in Gaborone, Botswana, provides seasonal forecasts for countries of Southern Africa. Over northern Africa, National Meteorological Services (NMHSs) issue seasonal forecasts for respective countries. Initiatives involving ACMAD and NMHSs of North Africa on capacity-building for development of northern Africa regional climate outlooks are being discussed. These three centres – ACMAD, ICPAC and SADC-DMC – collaborate on capacity-building and production of seasonal forecasts across Africa.

For production of climate outlooks, an initial step involves analysis of the recent past and current status of sea-surface temperature patterns in the Pacific (the ENSO region), the Atlantic and Indian Oceans and the Mediterranean Sea based on ocean surface and subsurface temperature and circulation fields. Meteo France, the United Kingdom Met Office Hadley Centre, NOAA/NCEP and the European Centre for Medium-Range Weather Forecasts (ECMWF) provide analysis fields for this purpose a few days to a week after the end of each month. The ENSO region, the tropical Atlantic, the equatorial Indian Ocean and the Mediterranean Sea off the coasts of North African countries are sensitive areas for seasonal forecasting where sea-surface temperature anomalies are examined.

This analysis and the knowledge and theoretical understanding of sea-surface temperature and regional seasonal rainfall relationships provide a first estimate of the quality of expected seasonal rainfall. Outputs of statistical and dynamical seasonal forecasting systems from NMHSs of the region and WMO Global Producing Centres for seasonal forecasting are discussed. The outcomes of the discussion together with the first expected climate condition from analysis of observations form the base for a consensus product for the region of interest.
The current production process provides probabilistic information with little interpretive guidance to facilitate its use. Knowledge and understanding of the seasonal forecasts’ quality must still be provided to improve users’ confidence. More local forecasts would add more value to the regional forecasts for some applications at the national level. Therefore, the current regional scale product should be downscaled for better use at the national level. Expansion of the product with additional information at sub-seasonal and decadal timescales would make the risk management decisions easier based on more comprehensive integrated climate information that is consistent across timescales.

Because there is limited understanding of some decision systems that require climate information, tailoring of the products for specific users has made little progress. Current regional products need more tailoring effort to better support risk management in the region and to provide more relevant inputs to application or impact models for different sensitive sectors. Capacity-building of climate information providers in the regions to better interpret global centres’ outputs is necessary to make better products in areas where the skill of seasonal climate models is high.

In the Southern African Development Community, comprising 15 conterminous and three island states with over 220 million inhabitants, the percentage of climate-related disasters (of all disasters) is higher than 90 per cent as there are no major earthquakes or volcanic eruptions that could command the attention of the catastrophes at other parts of the globe. The mainstay of the economies of the region is agriculture and thus this exposes the subregion to the vagaries of climate systems. Other downstream sectors such as health, power utilities, water resource management and the environment are also equally susceptible to climatic extremes. This has been amply demonstrated since the 1980s. The Drought Monitoring Centre has made great impact in the SADC member states and many users have publicly acclaimed the services and products as being of utmost importance to their operations. Among the principal target beneficiaries of the products are the National Meteorological and/or Hydrological Services, which are members of disaster preparedness and management committees consisting of government ministries and departments. These committees are mandated to formulate policies and at times supervise the exercises and recommend ways of providing emergency food relief to disaster-stricken areas. Other players such as the private sector and non-governmental organizations are co-opted into the committees as the need arises.

### 3.4.2 Central and South America

Six years after its start of operations in January 2003, CIIFEN has consolidated its presence over Central and South America, providing several climate information services mainly focused to address final users and decision-makers’ needs. One of the most relevant achievements of CIIFEN has been the improvement of climate information management. This represents the central basis of real people-centred Early Warning Systems (EWSs), demonstrated through practical and factual experiences [20].

The International Research centre on El Niño and the National Meteorological Services of Western South America have undertaken a complex data recovery and conversion process from meteorological stations, employing digitalization for quality control. At the same time, a regional climate database was designed and filled with 3 879 035 registers of daily data on precipitation and maximum and minimum temperatures from 169 meteorological stations in the region. A Web platform (http://vac.ciifen-int.org) hosts daily data from 1960 to the present. This big step in the exchange and regional integration of climate data is innovative and signifies a new era of cooperation between National Meteorological Services of the region. The regional climate database is administered by CIIFEN. A protocol for its operability was approved and signed by the NMHSs of Bolivia, Colombia, Chile, Ecuador, Peru and Venezuela.

At considerable effort, CIIFEN deployed a system to enhance the national capacities for seasonal forecasting (1–3 months) in the six countries. One of the bases of a climate information system is reliable forecast information that reduces subjectivity and is based on statistical tools and numerical models according the particular conditions of every country. This activity constituted a challenge to the project team at CIIFEN.

Among the most important bases of CIIFEN initiatives are the decision-making support tools. In the case of the agricultural sector, a geographic information system was designed to display the vulnerability of the designated crops in every country. Additional information was added such as layers of exposure to different climate hazard levels. Resiliency levels were estimated on social, economic, political and institutional parameters; land use characterization; and water retention capacity, including topography and texture, among other factors. In the case of crops, phenological cycles including different climate requirements were considered based on historic information.

Once the technological systems achieved the operational stage, intense work within the selected areas in every country was carried out to identify key stakeholders, and to create real alliances with the local and community media and the private sector. An assessment of user perception about the provided climate information was done in the pilot areas in the six countries. Today, the effectiveness of the system is measured through demand. Users with e-mail access subscribe to the system. The number of such users has increased by 80 per cent in two years. Meteorological services have a long list of key users who disseminate the information regularly. The list is also increasing for the users who receive the information by radio, media and cell phones (the latter receiving a massive communication medium in the Andean region).

Community leaders in different countries received training on how to use the climate information. Educational material was prepared to train the trainers in the use of climate information and take advantage of the NMHSs information. This material was designed considering social and cultural features specific to communities in each country.

In order to provide information systems to registered users (more than 15 000 subscribers) in Central and South America, Europe and Asia, CIIFEN maintains several regional operational products. From the record of visits in the products section at the CIIFEN Website, 77 per cent come from Central and South America, 19.4 per cent from Europe, the United States and Canada and 3.6 per cent from Asia, Africa and other regions. The current operational products are:

- **Sea-surface temperature images for the western Pacific (weekly):**
(b) CIIFEN bulletins about ENSO focused on the impacts of Central and South America (monthly);

c) Seasonal forecasts for the western coast of South America (monthly);

d) Eastern Pacific Ocean analysis (monthly).

3.4.3 Europe

The Network of European Meteorological Services (EUMETNET) is a network of 26 European NMHSs (http://www.eumetnet.eu/). It provides a framework for cooperative programmes in the fields of basic meteorological activities (observing systems, data processing, basic forecasting products, research and development, training). These support the development of collective capability for support to environment management and climate monitoring, with the aim of bringing to all regional users the best available meteorological information.

The European Climate Assessment & Data Set (ECA&D) provides monitoring and the analysis of changes in climate extremes, as well as underlying daily datasets (http://eca.knmi.nl/). Ongoing developments include the Generate Climate Monitoring Products (GCMP), the European Climate Information System (EuCLIS), the European Climate Support Network (ECSM) and the EUROGRID. The latter envisions integration of high quality climate data based on statistical methods, dynamic processing of historical data, data from Earth observation and other remote-sensing techniques and ground-based measurements. Creation of products for users from a variety of sectors is included.

The Network of European Meteorological Services is currently drafting its strategy document that will, among other topics, consider coordinated regional climate information services. One key concept is the European Meteorological Infrastructure (EMI) that conjoins capacities on state-of-the-art satellite meteorology and climate monitoring (the European Organisation for the Exploitation of Meteorological Satellites [EUMETSAT]), medium- and extended-range forecasts (ECMWF) and national-to-regional service provision by the NMHSs.

4. Recommendations

4.1 Tailoring climate information for risk management applications

(a) Foster interaction with social and economic information providers to design products which link climate hazards forecast with vulnerability information;

(b) Foster the partnership with disaster management agencies to establish products, communication channels and coordination procedures during prevention, preparedness and response;

(c) Establish regular climate products previously discussed and agreed with national planning agencies and ministries of development;

(d) Encourage the use and application of geographic information systems to generate spatial information about climate risks at national and local scales;

(e) Identify and implement a dissemination list of key stakeholders for climate information to be used for risk management;

(f) Promote more fully collaborative forecast demonstration projects providing high quality climate information for risk management and adaptation with the latest available forecasting systems by preparing and coordinating related demonstration projects to be implemented by sectoral experts and supported by advanced NMHSs or regional centres capitalizing on substantial investments by global centres on infrastructure and human capital for forecast production covering all WMO members.

4.2 Generation of regional climate information

(a) Foster collaboration between global climate modelling and regional downscaling communities, as well as between these communities and the climate impact assessment and response communities;

(b) Strengthen the exploration of seasonal and decadal prediction, as well as climate change prediction, on global, regional and local scales;

(c) Exploit synergies in operational, seasonal, decadal and climate change prediction;

(d) Ensure continuous climate monitoring activities including collection of metadata and effective dissemination of both raw and derived data;

(e) Develop and provide community downscaling tools capable of use in regional and local products;

(f) Develop ensemble prediction methodologies and descriptions of uncertainty in all products;

(g) Enhance production and dissemination of verification products by engaging more global centres in the current verification framework and improving current Standard Verification System of Long Range Forecasts (SVSLRF) documents with
schemes that are relevant to forecast providers who interpret global products and users who should better understand climate information before expanding its use.

4.3 Climate information network

(a) Enhance the RCOF mechanism around the world, and foster the implementation of national COFs;
(b) Foster the establishment of a global/regional climate information network;
(c) Promote the implementation of more RCCs in different regions as a suitable mechanism to improve and sustain NMHSs climate services;
(d) Combine traditional or local indicators/knowledge with scientific knowledge and operational products, where appropriate;
(e) Establish NMHS–user community partnerships to enhance dissemination of climate information and to conduct a dialogue that promotes informed demand for, and supports continued development of, climate information and applications;
(f) Conduct more specialized meetings on climate services aimed at specific sectors and/or regions;
(g) Promote and participate in sectoral planning workshops, such as MALOFs;
(h) Strengthen the weak links in the early warning system for flood forecasting (especially for flash floods);
(i) Promote the use of satellite technology for precipitation estimation data and information exchange.

4.4 Climate Information services

(a) Disseminate warnings based on best available technical and scientific knowledge;
(b) Implement early warning services based on sound analysis of risks;
(c) Promote timely and unrestricted access among countries, particularly regarding cross-border hazards and the exchange of warning information;
(d) Promote improvements in the accuracy and reliability of climate warnings to be in line with international standards, protocols and reporting procedures;
(e) Assign and/or identify key contacts in NMHSs and in user sectors with capabilities to further disseminate, share or transfer information to other relevant contacts;
(f) Demonstrate the benefit of the use of products and related feedback mechanisms;
(g) Develop application tools and better decision systems that can use climate information, including scenarios, and that also provide for improved and tailored products.

4.5 Communication

(a) Improve understanding between providers and users by dialogue, promoting more exchanges on the quality of climate information proposed, identification of best use practices and joint development of user decision systems by the two communities;
(b) Foster the implementation of internationally agreed means of communications to disseminate warnings to specific authorities in the regions;
(c) Develop communication methods based on lessons learned on the past performance of climate outlook products;
(d) Change the language: simplify and translate if possible to meet user requirements;
(e) Combine traditional or local indicators/knowledge to communicate operational products.

4.6 Capacity-building

(a) Promote media training for NMHSs on how to communicate climate information to the media, and prepare press releases and climate outlook bulletins;
(b) Include communication and networking strategies in NMHS future capacity-building materials;
(c) Train users on the understanding of probabilistic climate information and other climate products;
(d) Provide NMHS training on communicating forecasts, probabilistic information and related uncertainties;
(e) Build capacity of NMHSs and users by encouraging GPCs and RCCs to develop and use training materials based on each region’s climate peculiarities and end-user regional context.

5. Conclusions

Free access to available data for analysis and use is still limited. This often means access to analyzed products, which is sufficient for some uses, but restricts others. Regional reanalyses are presently being planned or tried out.

Seasonal forecasting is today an operational activity at many centres. Dynamical and statistical methods are more commonly used. Only since around 2005 have these two classes of methods started to show comparable forecast skill. Empirical downscaling, or specification methods based on regression, akin to Model Output Statistics, have been used quite extensively. Whereas statistical downscaling methods are readily affordable, dynamical downscaling tools, such as regional climate models, are less accessible.

Parallel to the resolution increase in global models, regional climate models also will become more detailed. Today, state-of-the-art regional climate models operate on approximately 10–50 km spatial resolutions, but are being pushed towards non-hydrostatic regimes of around 1 km.

Regional Climate Outlook Forums (RCOFs) are conducted in many regions around the world. They have contributed to the advancement of regional climate information fostering the interaction between users and providers. In some regions (Pacific Islands and western South America), climate outlooks are produced monthly and the consensus is reached by teleconferences or virtually.

Finally, the Regional Climate Centres such as Beijing and Tokyo Climate Centers are expected to play a supportive role in climate information services made by NMHSs in a specific area. The recognition of other centres is highly anticipated and promises to improve climate services at the regional scale.

References


