WCRP Conference for Latin America and the Caribbean: Developing, linking and applying climate knowledge. March, 17-21 Montevideo, Uruguay

Summary of outcomes and recommendations

The WCRP-LAC Conference: *Developing, linking and applying climate knowledge* was organized under the auspices of the World Climate Research Programme (WCRP), with support from the Inter-American Development Bank (IDB), the Inter-American Institute for Global Change Research (IAI), and a number of regional and local organizations.

The subtitle of the conference "Developing, Linking and Applying Climate Knowledge" emphasized that the main goal of this event is to contribute towards defining a research agenda needed to support the provision of effective climate services in the LAC region. The conference was structured around five main themes: health, water & energy, agriculture & ecosystems, urban & coastal environments and climate monitoring & prediction. To facilitate the interaction between these communities, keynote speeches and invited presentations were combined with round tables which included panelists from academia, stakeholders, policy makers and funding agencies. Besides, a game session was developed aiming at illustrating the power of intensely interactive communication strategies as opposed to the usual unidirectional approaches to forecast communication (such as powerpoint presentations and other unidirectional formats). This instance of game-enabled learning and dialogue did successfully convey the value and limitations of science-based forecasts, through a set of simple rules that were easily understood but soon led to emergent complexity, in a way that was both thoughtful and entertaining.

There was no a-priori hierarchy of the most relevant topics for a research agenda to underpin the development of climate services in LAC, yet some issues emerged as critical, leading to an ambitiously defined Conference outcome.

As an overarching idea, **knowledge-networks** organized **to co-explore and co-produce knowledge**, were identified as the most appropriate way to support the provision of effective climate services. This model of co-exploration and co-production is considered a step forward relative to the chains-of-knowledge, widely adopted in the past. A natural reasoning in this approach is that all the actors are expected to work together from the very beginning to articulate the needs, procedures, and decision protocols that will lead to a stated objective. This challenge demands going from the traditional analyses of, for example, changes in land use and soil cover for supporting developing adaptation and mitigation options, to the creation of knowledge-based systems for sustainable development that are credible, relevant, and salient for society, while guaranteeing social inclusion and equity. As a result, another critical issue emerged in the Conference: how can natural and social science problems ("tame vs wicked problems", as used in social planning) be jointly treated? Whenever risk management and human decisions are involved and affected by climate, there is a need to **deal with the social dimension and its complexities**. Recognizing this context necessarily brings the issue of **capacity building** and the promotion of **innovative institutions**, capable of coping with this new approach to the problem. These so-called intermediary or boundary institutions or programs are key to effectively reach all potential users.

All countries in the Americas experience adverse socio-economic and environmental impacts from extreme weather and climate events such as floods, drought, heat waves and tropical storms. The IPCC Reports (Special Report on Extremes 2012; WGI&II Fifth Assessment 2014) have summarized critical features of linking disaster risk reduction to long-term adaptation:

- A changing climate leads to changes in extreme weather and climate events
- For exposed and vulnerable communities, even non-extreme weather and climate events can have extreme impacts
- Effective risk management and adaptation are tailored to local and regional needs and circumstances
- Information on vulnerability, exposure, and changing climate extremes can together inform adaptation and disaster risk management
- Socioeconomic development interacts with natural climate variations and human-caused climate change to influence disaster risk

Throughout the Conference, **climate monitoring and prediction** was naturally recognized as a critical component of the knowledge-network. Although improved predictions are an obvious need, discussions highlighted the importance of combining the forecast-oriented approach with a more general climate information-oriented approach including not only forecast but also monitoring activities to optimize the benefit from what is already available.

As a general conclusion, the **improvement of predictions through better monitoring and representation** of the most relevant climate related processes was given great importance because it can generate meaningful joint work between operational centers and research institutions. In turn, several presentations indicated that with few exceptions, there is a generalized lack of adequate climate observation and monitoring systems in the LAC region. There are not enough systems that can (a) produce the climate information with the right spatial resolution and at real time, and (b) provide access to relevant climate data with sufficient temporal length for characterizing and quantifying climate related risks. Some of the countries in LAC have still very poor information systems, and in general, the quality, number and distribution of meteorological stations, upper air soundings and remote sensing capabilities in many countries is still far from ideal. Accordingly, the Conference has recommended promoting remote monitoring capabilities.

The Table below pinpoints the main challenges for supporting the development of climate services in LAC, and proposes lines of research and/or specific actions that could be handled under the WCRP.

Needs and challenges	Actions
Better understanding of climate drivers in LAC, with emphasis on those that could increase current	Advance research to combine available seasonal to sub-seasonal global forecasts with downscaling and other mathematical techniques to enhance their adequacy for diverse applications in LAC at local and regional scales

levels of predictability from subseasonal to decadal time scales	Refine the understanding of regional processes such as for example, sub-basin hydro-climate diagnostics, modeling and prediction
	Conduct studies on climate variability and change for very specific case-studies. Such approach implies the use of large-scale climate information combined with regional hydro-climate knowledge
	Foster research needed to better understand lack of model agreement, sources of model biases, the role of orography and land surface-atmosphere interactions
	Assess the role of surface state and land-use change on climate variability at diverse time scales
	Expand projection ranges to include Decadal Variability (improved shorter time-horizon projections)
	Foster research to better understand Inter basins (Indian-Pacific-Atlantic) influence on ENSO impacts and the role of the Eastern Pacific in ENSO diversity
	Conduct research to understand tropical Atlantic dynamics and its influence on LACC
	Foster research on ocean-atmosphere interaction in the region of the South Atlantic Convergence Zone and its role as source of regional climate variability on timescales ranging from subseasonal to decades.
	Conduct research to understand the thermocline feedback in the eastern Pacific
	Conduct Research on the effect/role of Short-Lived Climate Forcers (SLCFs), including black carbon, tropospheric ozone and methane, since they are important both as radiative forcers and as pollutant precursors
Improve understanding and assess predictability of climate extreme events	Work into higher-resolution spatial and temporal scales critical to better understand and represent climate extremes and their variability. Sea level rise and hurricanes and their impacts in the Caribbean are two examples of the importance of higher resolution assessments
	Conduct climate studies at local scales, particularly at the mega-cities scales to determine mesoscale forcings that affect (drive) high impact weather
	Foster research on the connection between extreme events and

	different socio-economic relevant areas, like health or energy
	Further assessment of climate extremes in a historical context, including paleoclimate reconstructions (frequency, return times, extent). Emphasis should be given to drought/floods, heat waves and tropical cyclones
Better monitoring climate –including extreme events- and climate drivers and access to climate information	Foster data availability for climate monitoring including data exchange, data rescue, homogenization, archiving and quality control of existing data
	Expand the number of variables monitored to meet research and stakeholders needs. E.g., soil moisture, vegetation status, SLCF (Short-Lived Climate Forcers), emissions, higher resolution, SST, sea level height, erosion
	Conduct research on the value of and document the differences between diverse data sets (e.g. soil moisture) with focus on user needs
	Propose new observational sites (super sites) particularly for air quality applications under a coordinated framework
	Implement the operational monitoring of extreme events
Define Coastal-Climate Services	Identify specific users, stakeholders demands, and main issues in each geographic region of LAC: Pacific, Caribbean and Atlantic coast.
	Expand and strengthen coastal related research such as: 1) Foster research on coastal floods 2) Foster research on climate variability and change on coastal ecosystems
Better synergy between WCRP global initiatives and regional activities	Agree on the necessary arrangements to establish intially a LAC Task Force with the goal of to evaluate the actions and recommendations arising from the WCRP LAC Conference, and advice in a 2-year period on whether a Regional Panel or Working Group for LACC should be established to coordinate WCRP activities in the region.
	Set up, through this TF, coordination with other programs, groups and institutions in the region, with potential to provide very significant contributions to the establishment of effective climate services in the LAC region, such as: CLIVAR/GEWEX Monsoons Panel, WCRP WG on Regional Climate, WCRP CORDEX, Future Earth, UNEP-PROVIA, IAI, ICSU-ROLAC.

Develop knowledge networks adequate for co-exploration and co-production	Foster research on how climate information and knowledge is analyzed, assessed, synthesized and communicated
	Conduct integrated, interdisciplinary climate-related ecosystems and biodiversity vulnerability assessments on a local scale
	Foster research on possible metrics and strategies to assess, quantify and monitor the impact of knowledge networks on sectoral applications
	Foster research to characterize institutions and institutional arrangements needed to build links between the different actors of the knowledge networks
	Promote the development, support, and training of a cadre of scientists, professionals and policy entrepreneurs willing to work under multidisciplinary frameworks

The WCRP-LAC Conference made clear that LAC has a wide diversity of challenges and opportunities: it covers a wide range of latitudes and climate regimes; the region is rich on key physical processes, from deep convection and microphysics in Amazonia and Plata Basin, to the deepening of tropical cyclones in the Caribbean. It is affected by several climate drivers (ENSO, continental surface conditions, anthropogenic forcing), there is potential predictability at intraseasonal scales (in response to MJO, SAM, NAO, among others) and the degree and variety of impacts and vulnerability is huge. The region is an ideal testbed for investigation of predictability of multi-scale processes. On the other hand, a significant climate change might be already visible in the region. Much less is known about climate change in sub-regions.

Several large rivers and reservoirs assure active hydrology-climate interactions. Despite the complexity of LAC's climate, current knowledge research has demonstrated that great progress can be achieved by narrowing down on components, such as the monsoon, synoptic processes, hydrology of large basins, soil processes, etc.

However, current integrative approaches are incomplete, climate monitoring is poor, data sharing is limited. Several attempts to using local climate information for applications have demonstrated potential success, but extension to larger regions is difficult due to big differences in the economic potential of different countries. This background suggests that a coordinating body will accelerate science by bringing together the different participants in a broad international framework. Defining a research agenda to underpin climate services development, suited to cope with this diversity, emphasizes the necessity of an organizational structure to coordinate emerging efforts and initiatives.

Taking into account the general scope of the outcomes resulted from the WCRP-LAC Conference the Scientific Steering Committee considers that it is needed to launch a second work stage focused on the scientific question prioritization and the determination of the corresponding research strategy and it recommends the establishment of a Task Force within the domain of WCRP. The main goal of this Task Force would be to implement a framework to articulate a regional research agenda based on prioritizing the actions raised at the Conference. The framework will define the main challenges underpinning the development of climate services in the region in the near and middle future and the strategy to fulfill it. It is evident that the degree and variety of impacts and vulnerability conditions in LACC is very large. In that sense the role of the Task Force in establishing a framework on the basis of some overarching scientific themes that will be developed differently according to the regional/local needs, will be crucial.

VAMOS, a most successful WCRP/CLIVAR panel, focused on empirical, modeling and predictability studies on the climates of South and Central America. The proposed Task Force will deal with monitoring, prediction, analysis and applications on the Climate of the Americas. As initial idea it is suggested calling it as Climate of the Americas, Monitoring, Prediction, ANalysis and Applications (CAMPANA) Task Force.

CAMPANA will extend VAMOS in two important ways:

- An updated science agenda, with major emphasis on monitoring and prediction, and
- The incorporation of application and social scientists as equal partners with natural scientist in order to provide effective climate services.

The strategy of CAMPANA will be based on:

- Improve predictions through better process monitoring and representation in numerical models
- Encourage production of climate information with high spatial resolution and at real time.
- Facilitate access to climate data with sufficient temporal length for characterization and quantification of climate related risks.

CAMPANAshall be composed by representatives from natural and social sciences, and services providers. The Task Force work will be carried out mainly by email and teleconferences, although a face to face meeting is recommended at some point of its activities. A time limit of around two years shall be established for the CAMPANA work, whose main delivery will be a document describing in detail the future actions and plans. The TF shall maintain close interactions with the WCRP Grand Challenge on Regional Climate Information. It is also recommended that CAMPANA TF explores and/or defines linkages with Future Earth, UNEP-PROVIA and IAI among other programs and agencies, such as CORDEX, that may be interested in this research agenda.

References:

IPCC Fifth Assessment Report (AR5) 2014, On line: http://www.ipcc.ch/report/ar5/

Seneviratne, S. I., Nicholls, N., Easterling, D., Goodess, C. M., Kanae, S., Kossin, J., ... & Zhang, X. (2012, April). Changes in climate extremes and their impacts on the natural physical environment: An overview of the IPCC SREX report. In *EGU General Assembly Conference Abstracts* (Vol. 14, p. 12566).

Appendix 1: Climate Services

Appendix 2: Human Health

Appendix 3: Water Management in a Changing Climate

Appendix 4: Agriculture and Natural Ecosystems

Appendix 5: Coastal Environments

Appendix 6: Climate Monitoring and Prediction

WCRP Conference for Latin America and the Caribbean: Developing, linking and applying climate knowledge. March, 17-21 Montevideo, Uruguay

Appendix 1: Climate Services

***Roger Pulwarty*[1]**

This report describes the following outcomes and positions from the workshop (1) a Summary of the idea of "climate services", (2) Designing climate services in the LAC Region (including Barriers and the role of the GFCS), (3) Implementing climate services: Overcoming constraints on services to inform short-term and long-term risk reduction and management including a potential path forward

1. Climate Services-Summary

Representatives from countries across the Latin America and Caribbean Region (hereafter referred to as "the Region") agree that adaptation to climate (extremes, variability and change) is an issue of national priority. All countries in the Americas experience adverse socio-economic and environmental impacts from extreme weather and climate events such as floods, drought, heat waves and tropical storms

The IPCC Reports (Special Report on Extremes 2012; WGI&II Fifth Assessment 2014) have summarized critical features of linking disaster risk reduction to long-term adaptation:

- A changing climate leads to changes in extreme weather and climate events
- For exposed and vulnerable communities, even non-extreme weather and climate events can have extreme impacts
- Effective risk management and adaptation are tailored to local and regional needs and circumstances
- Information on vulnerability, exposure, and changing climate extremes can together inform adaptation and disaster risk management
- Socioeconomic development interacts with natural climate variations and human-caused climate change to influence disaster risk

Most estimates of disaster losses are based on direct losses, recorded largely as monetized direct damages to infrastructure, productive capital stock and buildings, only, and as a result seriously underestimate loss and excludes indirect losses which primarily constitute livelihoods and informal economies, and intangible losses which include ecosystem services, quality of life and cultural impacts. Many of these impacts are expected to intensify or become

[1] Physical Scientist and Director, National Integrated Drought Information System (NIDIS), Physical Sciences Division and OAR/Climate Program Office, Earth System Research Laboratory, National Oceanic & Atmospheric Administration

more frequent under climate change projections (IPCC AR5). However, as these reports note, at present the complications of present extremes, variability and change are not being fully addressed.

The LAC is home to approximately 70 per cent of the world's species and almost 20 per cent of its eco regions. LAC economies are highly dependent on their rich biodiversity, yet it is increasingly under threat from human activities. There are several encouraging examples of efforts to put the region on a path toward a sustainable future from policies that have reduced deforestation rates in the Amazon to mass-transit systems in Brazil and Colombia that can help reduce fuel demands. Examples of activities being supported by the InterAmerican Development Bank in different countries are given in the Appendix. Throughout the Americas, the demand for climate services to inform decisionmaking from nearly all sectors of society are increasing and are often far beyond the capacity of any one country. Rapid socioeconomic and environmental changes are occurring at the same time as climate changes and co-evolve in non-linear ways increasing the potential for surprises. Even small improvements in *climate services* – which provide climate information for decision making related to day-to-day and longer-term investment and planning. There are a number of partnerships that are demonstrating how countries are benefitting from regional approaches to climate services in the Americas. For example, ongoing Regional Climate Outlook Forums (RCOFs) in South America, Central America and the Caribbean bring together climate information providers with decision makers for a sustained dialogue that reduces climate-related risks and support sustainable development. However, it is unclear at the national and the regional levels whether the actions that must be taken to improve the climate science, adaptation knowledge base and capacity should be focused on according to geography (priority regions) or sectors (water, soil quality, agriculture).

Two key needs identified in Montevideo were to (1) focus research on analyzing and drawing the benefits from already existing datasets, and, (2) identify and characterize important signals focusing on key questions from a portfolio of "user" community. In particular the workshop detailed the need for Early Warning Information Systems as a critical component of a Climate Risk Management System (such as for Health). Thus improving the length of lead-time in providing El Nino–Southern Oscillation (ENSO) forecasts and decadal-scale variability remain central concerns.

Two key barriers to implementing responses to these needs were identified at the Workshop:

- The climate science knowledge generators are mostly decoupled from the users and vice versa. The non-climate stressors (unperceived by the climate scientists) may often swamp the climate stressors. This decoupling of understanding leads to dramatically different prioritization of messages.
- Each community of players within the CS sphere of activities brings little understanding and significant assumptions about other communities. Likewise, each are swamped in terms of time commitment that inhibits fuller engagement across boundaries. The messages are not amenable to one-line distillations, and effective communication requires significant time investment. This is a paradox that undermines responsible uptake of the information.

These are addressed below, in the context of the results of presentations, posters and discussion groups at the Workshop.

2. Designing Climate Services in the LAC Region: Barriers and Opportunities

The workshop presentations reinforced that the dimensions of Climate Services require systematic consideration of (1) Scientific and technological capabilities and current products, (2) User needs and desired climate information applications, and (3) Institutional components of climate services information systems.

As used in the discussion below (and outlined in the Workshop keynotes) a "service" has two components. A "Service" as a set of activities is focused in product development, communication and delivery-to develop and deliver analytical information. A "Service", as an institution, is most critically an administrative network requiring a governance and institutional structure-to coordinate deliberative processes. More specifically the "climate services" concept includes a *network of activities that maintain well-structured paths from observations, modeling, and research to the development of relevant place-based knowledge and usable information.* Within the Global Framework, Climate Services must provide information a continuum of scales in time from hourly to daily to weekly to monthly, seasonal, annual, interannual, decadal, and interdecadal. Many adaptations will be extensions of current practices for coping with extreme events, including:

- Improved understanding of the atmospheric processes that have bearing on climate predictability in the region and socio-economic research for better understand evolving societal vulnerabilities that may result from a changing climate;
- Capability for generation climate products and services through training (statistical climatology, modeling, etc.);
- Improved technical capacities to generate methodologies, tools and products to transform and enhance operational climate services;
- Institutional capacities to observe, monitor, rescue, archive and process meteorological data and generate tailored climate products and services.

Climate services were described at the Workshop as, in effect, attempts to operationalize research that is and will still continue to evolve. Necessarily then, climate service practitioners who are not tightly integrated with the research community (such as consultants and oftentimes National Meteorological and Hydrology Services or "NMHS") will be working with outdated data whose information content may have been superseded by new understanding; as is seen for example in the CMIP3/5 differences. This has real world consequences. Approaches chosen feed into decision and policy frameworks that make a commitment to a trajectory into the future, where a different fundamental choice could have lead to a different trajectory.

Barriers and Opportunities

The Workshop illustrated that the Region's existing public and private institutions have had mixed success, to date, in preparing to deal with existing impacts because of common constraints. At the Workshop several presentations, posters and breakout groups highlighted concerns that are found within the climate enterprises across many regions. These included a number of constraints limiting the use of climate information for decision-making by sectors and communities were discussed including:

- Limited national capabilities for analytical capabilities such as climate data processing, modeling and the generation of information and forecast services including sectoral applications in strategic sectors such as agriculture, health, water resources and others.
- Lack of capacity to communicate information between NMHS and national agencies and authorities.
- Limited capability of governmental institutions and sectoral institutions to identify their climate information requirements.
- Limited coordination between local institutions and agencies.
- Weak or non-existent planning of the investment budget for actions aimed at prevention of and prepared
  Weak or non-existent accountability system for encouraging and mandating use of available scientific information for appropriate risk reduction measures.
- Limited involvement of the private sector to engage with stakeholders in the development of risk management measures.
- Limited knowledge of climate and limited training in application and use of climate information and products by users in many sectors;
- Problems in identifying threats to carry out works on risk reduction because of limited use of the necessary tools for assessment.
- Limited synergy among national institutions to share climate and climate relevant information at national level.
- The absence of an efficient communication system on extreme climate events to disseminate information such as warnings and advisories.
- Overly technical language in some climate information and products, making them difficult to understand by lay people.
- The lack of a culture of prevention of damage and proper maintenance, supported by finances, for the vulnerable physical and social infrastructure.
- Even though climate scientific knowledge and probability modelling have advanced significantly over the last few past decades, especially with respect to the understanding of climate variability and change, the level of uncertainty inherent in probabilistic climate products has tended to make their communication by scientists for integration and understanding by users of the information more challenging.

While the scientific community regards uncertainty as an inherent property of the climate system, which can be assessed through probability analysis, decision makers may consider uncertainty as a barrier to decision making, especially when other socio-economic and political variables also need to be considered. The result is a complex integration situation among actors which requires careful communication to ensure the complex information is understood by all and appropriate decisions are made.

The workshop identified and reinforced well-known needs from the climate research and modeling communities such as improvements in model agreement, narrowing the projection range, higher-resolution spatial and temporal scales, and improved shorter time-horizon projections. These, however, may not have significant progress for a decade or perhaps much longer. Essentially, scientific uncertainty is here to stay, and resource managers must prepare to integrate uncertain climate information into their management and planning. Thus, two immediate needs identified in Montevideo were (1) to focus research on *analyzing and drawing the benefits from already existing* datasets and (2) to identify and characterize important signals focusing on key questions and information entry points from the "user" community and in particular was the need for Early Warning Information Systems as a critical component of a Climate Risk Management System (such as for Health). For the LAC region many of these investments in sustainability strategy, that address the need to manage under these uncertainties, include:

The GFCS: Opportunities for strengthening the role of NMHS in the region

The Role of the Global Framework for Climate Services was NMHSs in the region need to expand their competence and credibility to include the development and delivery of targeted climate services and products that inform decision-making in key climate sensitive sectors. Accomplishing this objective will require political commitment and financial resources. It was suggested that regional entities such as the IAI, the Caribbean Community Climate Change Centre (CCCCC) be consulted on the matter of political buy-in for the process given their successful track record in this area.

A key consideration for advancing implementation of the GFCS in the Region is the limited capacity of most National Meteorological and Hydrological Services. The current status is characterized by limitations in terms of:

- Few, and in some cases, no staff assigned to perform specific climate services functions,
- Observing networks that need to be strengthened by increasing the spatial density and coverage of networks as well as the continuity and reliability of measurements,
- Absence of appropriate legal frameworks that define the roles and responsibilities of NMHSs,
- Limited human and technical capacities to generate, on a continuous basis, the range of climate services required by the user community in the region,
- Limited appreciation of the value of the benefits that can be accrued from the effective application of climate services,

- Limited ability to effectively and efficiently communicate and interact with stakeholders and users of climate data. Gaps in observations-not addressed in presentations

Socio-economic cost-benefit studies to provide concrete examples of benefits derived from effective application of climate services and the implications or cost of not taking action remain critically lacking. To overcome this limitation, it is recommended that the climate scientific and stakeholder communities create an agenda sustained by the evaluation and transfer of requirements, knowledge, tools and instruments allowing the formation of a community of practitioners with analytical skills and sharing basic agreements for action. To improve disaster and climate risk governance, it is proposed that decision-makers should also assume responsibilities concerning the understanding of risks within their sectors and regions, and consider the need to integrate DRR management and CRM using the wide range of currently available instruments and development mechanisms. These studies could contribute for the production of policy briefs to raise the profile of the work done by NMHSs in the eyes of policy and decision makers, in particular ministries of finance. These studies could be conducted with the support of regional and sub-regional development banks and other stakeholders and engaged by the NMHSs.

3. Implementing climate services: Overcoming constraints on services to inform short-term and long-term risk reduction and management

Given a changing climate and variations across months, to seasons to decades, acknowledging the importance of cross-scale nature of climate, of early warning information and adaptation response- and corresponding monitoring and research need is critical. Decadal prediction lies between initialized weather or ENSO forecasts, and future climate change projections. This moves the discussion beyond choices such as between "weather extremes" or "climate trends" but to consider all modes of climate variation.

A synthesis of the papers and posters in the Workshop show that an effective climate service (i) Ensures a strong and healthy transition of research accomplishments into predictive capabilities that serve the region and its nations and communities

(ii) Develops regional enterprises designed to expand the nature and scope of climate services. (iii) Increases support for interdisciplinary climate studies, applications, and education

Regional enterprises in climate services would focus on:

(i) Improving monitoring, modeling and methods of understanding and analyzing risks associated with climate extremes, variability and change

The projection of future precipitation patterns and extreme events remains among the most uncertain aspects of climate variability and change.

The awareness of and the importance of utilizing climate data in risk management to create value, not to merely respond to risk, is increasing in importance. One reason risk management now resides at low levels of many corporations. As observed throughout the literature, insufficient reliable site-specific data—such as local temperature and precipitation projections—complicate national and local decisions to justify the current costs of adaptation efforts for potentially less certain future benefits. A key challenge for linking risk officers and climate extension is the reality, that "people are unaware of what they need to do concerning risk."

(ii) Governance and knowledge management: Improving policy coherence and adaptive management at each scale

Climate Services governance needs to be located in a ministry or department, preferably with planning oversight and some fiscal responsibility to provide political authority and policy coherence across sectors. Emergency management organizations can rarely play that role. However, efficient implementation only occurs when CRM is carried out locally in partnership with at-risk households and communities and organizations that represent them. Benefits are cost-effectiveness, sustainability, citizenship and social cohesion.

More recently it has become necessary to frame the goals and objectives of international and country and local-level program intervention strategy in terms of "securities" of water, food, energy, and nation. Leadership is required, and in many cases exists or arises out of crisis but these "policy entrepreneurs" need to be recognized and supported at several levels, focused on critical regional needs, for example:

- Improving Social Protection at the Local Level
- Sustaining Ecosystem Services
- Early Warning Information Systems
- Financial services and risk pooling

In the context of a changing environment, meeting the most critical emergent needs require that:

- Disasters should be seen as risks to investments in "capitals" including human capital. Faster rates of change of both the climate, including heat stress and evaporative demand, and the development systems may drive surprises and rapid transitions in which early warnings of emergent thresholds will be increasingly critical;
- Impact assessment and scenario development must approach climate model output far more critically than at present. There is no substitute for local monitoring and local communities have to be supported to play a role in data and surveillance gathering;
- Lesson from experience with climate extremes and adaptation (both benefits and

their limits) are adequately drawn on ways to better manage current and future risks related to extreme weather and climate events:

Central to the above factors is the development, support, and training of a cadre of professionals and policy entrepreneurs, such as at the University of the West Indies Program, who view the role of linking science (both physical and social) , policy and practices as a core goal and the systems that support their activities over the long term. On such effort, conducted at the Master of Science level, through the University of the West Indies that is receiving acclaim is the Climate (Science, Vulnerability, Adaptation) Stream within Natural Resources. Indeed the winner of the "Best Poster" prize at the Montevideo Workshop is a graduate of this very program.

A climate service prototype: a potential path forward

As observed by a senior researcher during the Montevideo Workshop "despite advances to date, predicting the future hydro-climate variables will remain a major but important challenge". The researcher went on to note that: "Without some degree of verifiability it is difficult to expect their use will increase or lead to improved decision making" Long-term and sustained observation programs are critical, especially for model verification. There is the ongoing need to address the institutional aspects of "capacity" and coordination" at national and local levels much more directly than is being done. This gap exposes itself vividly when the needed sustained collaborative framework among research, monitoring and decision-making/management to take advantage of windows of opportunity do not exist.

There was increasing recognition that this further emphasizes the need for in country capacity development. As important as it is to describe the components required from research and monitoring systems to risk assessment, communication and management across all timescale. It is also be necessary to provide alternative conceptual frameworks for climate services from a systemic view to engender long-term strategic support for such activities.

The broad categories of institutions involved in developing and delivering services include:

(a) Management and decision making agencies and groups in which decisions about preparation and mitigation are taken (agriculture, water, disasters, state offices….)

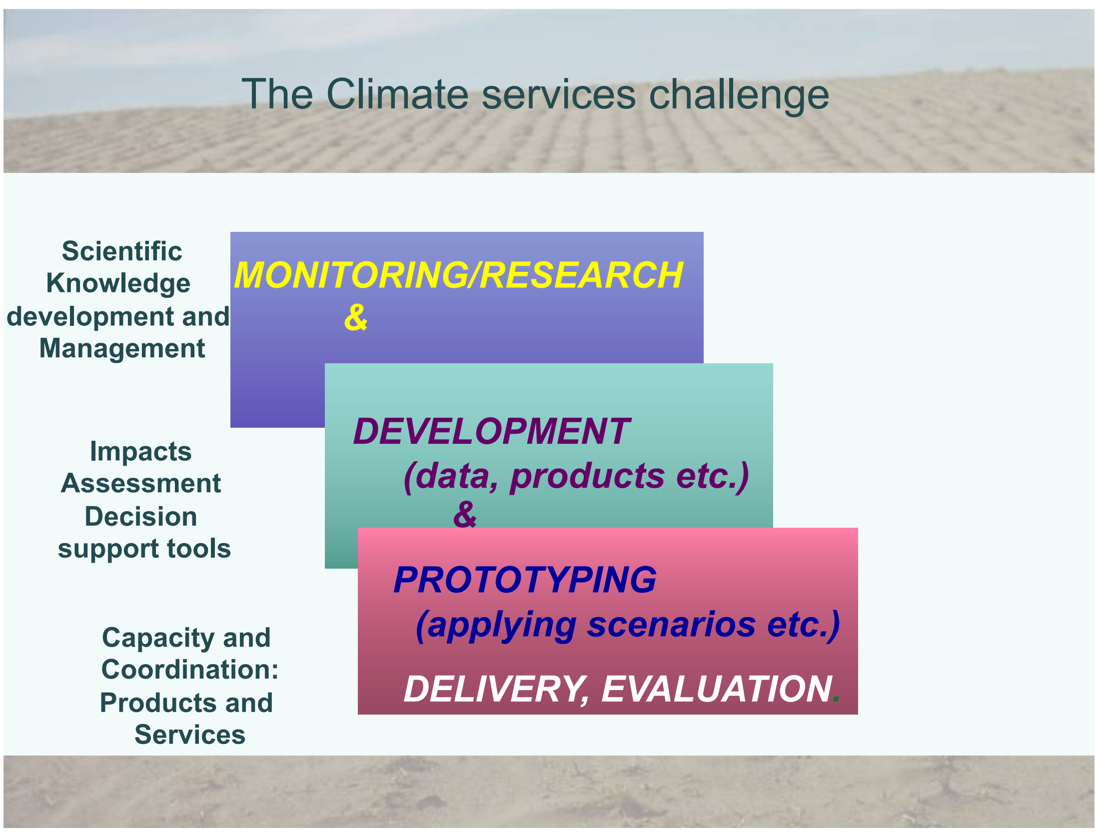
(b) Knowledge systems: What research, information and mechanisms are used to understand and assess salient climate-related risks and benefits (across timescales, property at risk, and environment)

(c) Implementing agencies and offices informing responses : Coordinating roles, authoritity, and relationships

A "climate services" prototype would go beyond a few "use of information" studies to cases to a systemic view that assesses for the three areas categories above:

- Policies and practices that can give rise to failures of the component parts working as a system
- Impediments to the flow of knowledge among existing components
- Be credible and acceptable to private and public partners and be both academically and socially robust

This "prototype" could draw on successful efforts at developing systems of services (beyond individual projects) that integrate all three functions above, such as the National Integrated Drought Information System in the US, PRONACOSE in Mexico and Collaborative Research Networks of the IAI (see for instance Fig. 1)



Some of the enabling capabilities that would be developed and tested include a subset of:

- Development of interagency cultures and professionals to assess climate impacts and evaluate adaptation practices
- Coordination of regional data collection, analyses, and information sharing mechanisms coordinated into early warning information (to inform preparedness) and decision support (to inform adaptation) systems
- Definition of the core set of data characteristics and information technologies needed to maintain the minimum acceptable level of stewardship;
- Placing multiple indicators within a statistically consistent triggering framework - Scenario planning to address problem-definition and characterize multiple uncertainties-technical as well as institutional capacity;
- Inventory and map local resource capabilities (infrastructure, personnel, and government/donor/NGO-supported services) available to complement food, water and other program operations;
- Developing risk and vulnerability profiles of climate risk regions and specific sectors including impact of benefits of early warning for specific insudtries and investments; and
- Understanding and communicating the economic value and societal benefits of early warning information.

A major concern raised in the Workshop was that there were efforts focused on transferring methods or approaches conceptualized by academic researchers or consultants in developed countries which are themselves not tested or applied in those countries. Factoring both anticipation and resiliency in system design and planning is still the safest approach.

Appendix

Climate Change and Water Resources at the IDB: Focus on ADAPTATION

The effect of climate change on streamflow and groundwater varies within the region and between climate scenarios. A consistent projection across most climate change scenarios in LAC is for overall decreases in streamflow throughout the region, with the exception of areas downstream of the Andes (higher runoff due to increased rates of glacial melting). For areas in mid-latitudes (e.g., most of Brazil and Mexico), projections are of decreased streamflow and increasing drought conditions. Areas in the Caribbean and coastal zones throughout the region are vulnerable to sea level rise as water expands with projected increased temperatures. Overall, the LAC region is also likely to be subjected to increased intensity of extreme climatic events, such as El Niño and La Niña.

The principal lessons from emerging adaptation experiences in the LAC region are, first, that infrastructure investments (e.g., dams, levees, canals) remain critical for climate adaptation and reducing vulnerability to climate and weather related events; and, second, that infrastructure investments need to be complemented by previously neglected investments in soft infrastructure (e.g., watershed management, land use planning and information, and stakeholder engagement).

Specific examples of ongoing work targeting challenges in priority adaptation themes are provided as follows.

Incorporation of climate change in the re-definition of proposed development infrastructure in the countries of the region for water availability and use

In this regard, we have engaged in a series of pilot projects in Ecuador (adaptation of water utility reservoirs and conveyance infrastructure to accelerated glaciar melting), Perú (re-designing irrigation canals and groundwater wellfields in response to increasing drought conditions), Uruguay (adaptation of urban drainage and stormwater management infrastructure to increased rainfall intensity), Nicaragua (regulation of Lake Managua's level to prevent flooding), Honduras (embankments for storm surge and re-design of groundwater wells due to aquifer salinization caused by sea level rise), Haiti (water availability in northern watersheds) and Trinidad and Tobago (urban drainage in Port-of-Spain to account for sea level rise). In each of these cases, the IDB is working towards site-specific adaptation measures for current and projected water problems for which climate adaptation is critical (for a total financing of 122M USD).

Generation and mainstreaming of more specific and usable hydrological and climate information in decision-making processes

This requires a greater effort of co-production of this information, in order to direct it to different sectors of users, by those institutions that generate knowledge, those that measure it and report data, and those that apply it through public policies and management activities. The IDB is working with the Skoll Global Threats Foundation to develop a pilot regional drought information system for the La Plata basin, comprising Argentina, Bolivia, Brazil, Paraguay and Uruguay (RG-X1163, 300K USD). Similarly, In Mexico we are working with Arizona State University to develop visualization and communication tools for adaptive water resources management in the Río San Juan watershed (ME-T1188, 400K USD). The Bank has also developed a LAC region-wide hydrological modeling tool (Hydro-BID) to conceptualize and design water resources infrastructure that is adapted to climate change and variability (1.2M USD).

Strengthening of the institutions in charge of public policies through IWRM tools adapted to respond to the effects of climate change in the sector

The IDB is working with the Autoridad Nacional del Agua in Perú to establish, train and implement watershed councils across the country (20M USD).

Conservation and restoration of water sources and associated ecosystems that reduce the vulnerability to climate change

This pilot project is focused on security in the availability of water resources, as well as natural resistance to extreme climate-related events. In this regard, we are working with the World Wildlife Foundation in Mexico to identify "water reserves" nationwide for more efficient water use that balances ecosystem services with ecological conservation (1.0M USD).

Increase and optimize the sources of financing

In order to favor the appropriate planning and implementation of adaptation activities, especially towards the attention of vulnerable groups. The IDB is working with the Nordic Development Fund to identify and conceptualize climate adaptation activities in emerging cities in Bolivia, Honduras and Nicaragua (2.8M USD).

Updating of educational curricula and capacity development programs in the water sector

Through syllabi at all academic levels, wide-range training programs and the introduction of climate change and its associated concepts (mitigation, adaptation, vulnerability, etc) as key elements in the education of new water sector professionals. The IDB is working with Instituto Tecnológico (Tec) de Monterrey in a series of education and capacity building programs throughout the region (3M USD).

WCRP Conference for Latin America and the Caribbean: Developing, linking and applying climate knowledge. March, 17-21 Montevideo, Uruguay

Appendix 2: Human Health

Kristie L. Ebi[2]

The current and projected human health consequences of climate change in Latin America are diverse and wide-ranging, potentially altering the burden of any health outcome sensitive to weather or climate. Climate variability and change can affect morbidity and mortality from extreme weather and climate events, and from changes in air quality arising from changing concentrations of ozone, particulate matter, or aeroallergens. Altering weather patterns and sea level rise also may facilitate changes in the geographic range, seasonality, and incidence of selected infectious diseases in some parts of the region. Changes in water availability and agricultural productivity could affect undernutrition. The pathways between climate change and these health outcomes are often complex with multiple, interacting factors contributing to the burden of any particular outcome. This makes it challenging to understand the role(s) of weather and climate variability in the burden of climate-sensitive health outcomes.

For example, urban areas and megacities, particularly informal settlements, are becoming more vulnerable due to migration from rural areas, conflicts, and environmental degradation and disasters. These vulnerabilities are exacerbated by the frailty and precariousness of health systems, socioeconomic factors, educational levels, inadequate and water and sanitation coverage, and inadequate governance structures. These vulnerabilities can interact with increases in the frequency and intensity of extreme weather and climate events to increase the risks of major impacts and disasters.

The public health activities to address the risks of climate variability and change fall within four broad domains: understanding the problem through monitoring and surveillance; understanding the cause(s) by risk factor identification; understanding which interventions are effective; and evaluating policies and measures to identify lessons learned and best practices. This approach facilitates systems-based understanding of the broad determinants of health, and supports actions to reduce current and future risks.

Climate research outputs needed to inform decision-making, risk management, and adaptation planning:

In the human health sector, climate information is needed to:

- Improve understanding of the pathways by which environmental changes interact with socioeconomic and other factors to increase risk from climate-sensitive health outcomes;
- Support mapping of populations who are particularly vulnerable to weather, climate variability, and climate change;
- Estimate the seasonality of climate-sensitive health outcomes, to improve the timing of interventions;

[2] EPRI, Palo Alto, California, USA

- Monitor and predict year-to-year variations, including designing and deploying early warning systems;
- Monitor and project longer-term trends; and
- Improve assessment of the effectiveness of adaptation policies and measures.

The exact climate research outputs required depend on the specific needs of different end users and stakeholders, and on the health outcome. For example, determinants of outbreaks of waterborne diseases can be associated with temperature and extreme precipitation events, whereas changes in the geographic range of some vectorborne diseases can be mostly temperature dependent. Further, because there are other factors that affect population health vulnerability, information also is needed on the local contextual factors influencing risk, such as age, gender, and socioeconomic status.

Overall, products must combine locally calibrated satellite rainfall and temperature (min and max) estimates and all available quality controlled ground-based meteorological station gauge data for the region of interest. Air quality parameters can be important for understanding and managing the risks of some respiratory diseases. Interpolation algorithms need to take into account the physical-statistical properties of the variables. Long-term average fields of the relevant climatic and chemical variables are required at different timescales from diurnal to intra-seasonal, seasonal, annual, interannual, decadal and beyond. Physically or statistically downscaled information about climate change projections (end of 21st century) is required for improving impacts modeling.

Improving observations and monitoring in the LAC region for enhancing climate services.

Monitoring networks need to be improved and maintained in the LAC region, to support quantifying exposure-response relationships and impact modeling. Meteorological radar is needed to better understand and model rainfall dynamics at a wide range of timescales. Providing open and free access to climate and weather information and products is vital for the health sector.

Improvements are needed in disease surveillance, monitoring risky exposures, and facilitating coordination between health and other sectors to address changes in the incidence and geographic range of climate-sensitive health outcomes.

Priority gaps and challenges in scientific knowledge and institutional capacity that, when overcome, would enhance user-requested research outputs and provide operational climate services in support of decision-making.

Weather, climate variability, and climate change remain relatively new topics for the human health community. Significant efforts are needed to improve the capacity of the health sector to understand and appropriately use climate information to protect, promote, and restore people's health. Achieving this requires more applied research by multidisciplinary teams, and establishing transparent and reliable information systems suitable to the decision-making process. One particularly important component of a climate risk management system for health is developing and deploying early warning and response systems where there is robust enough understanding.

There are still large knowledge gaps with regard to different climatic phenomena operating at different timescales, and about their nonlinear interactions, let alone the interactions between natural and social systems. To bridge this gap, new types of knowledge must be identified from natural and social sciences, as well as from stakeholders and extension communities.

Research on climate science including social and natural dimensions is required, as well as research to improve the way in which climate information and knowledge is analyzed, assessed, synthesized, and communicated, to articulate the needs, procedures, and decision protocols.

Such challenges demand going from the traditional analyses of, say, changes in land use and soil cover to support developing adaptation and mitigation options, to the creation of knowledge-based systems that are credible, relevant, and salient for society, while guaranteeing inclusion and equity. It also involves the transformations of identities, institutions, languages, and discourses that characterize the workings of science and technology within society.

For example, in the health sector, priority gaps include:

- Estimating the populations at risk;
- Determining the seasonality of health outcomes and timing of interventions;
- Monitoring and prediction of year-to-year variations in incidence (including early warning systems), but also monitor and predict longer term trends (climate change impacts and vulnerability assessments); and
- Improving assessments of the impact of interventions (by removing climate as a confounder).

Improving interactions among the science community, intermediary institutions and individuals, and decision-makers to incorporate climate knowledge to facilitate adaptation policies and measures.

The transdisciplinary nature of providing and using climate services demands approaching research in collaborative networks, and the co-production of knowledge between natural and social scientists. Stakeholders and end-users should be involved from the very beginning of the projects and programs, and not at the end of the process. Such an objective demands training and educating a new kind of professional who is able to talk in different languages and utilize or is familiar with a range of method and approaches. The specific roles of the different actors (scientists, stakeholders, end-users) must be clearly defined to guarantee the continuity and efficacy of the process, as well as the ownership of results, but also the maintenance of international research standards.

WCRP Conference for Latin America and the Caribbean: Developing, linking and applying climate knowledge. March, 17-21 Montevideo, Uruguay

Appendix 3: Water Management in a Changing Climate: Challenges in the application of Hydroclimatological forecasting for decision making

Soroosh Sorooshian[3] and Nasrin Nasrollahi[4]

Abstract

This paper will provide a summary of both the progress and the related challenges in the field of water management in a changing climate. Among the issues discussed will be the strength and limitations of remote-sensing observations, downscaled modeling products, assimilated and re-analysis information. Furthermore, the authors encourage further discussion about the recent proposed strategies to advance the development and application of hydroclimatological models for water management in a changing climate.

Introduction

The need for more efficient use and effective management of water resources is a critical global issue facing the 21st century. At least three factors place special stresses and additional uncertainties on water resources planning, development and system operation strategies. First, rapid population growth is occurring in many regions of the developing world. Second, growth in economic prosperity and access to modern amenities over the last few decades has impacted per capita water consumption rates and shifted demands in most regions, especially in countries that have experienced rapid population growth and urbanization. Third, complication arises from the additional regional uncertainty resulting from global climate change and the resulting intensification of the hydrologic cycle and occurrence of more hydrologic extremes (severe floods and droughts). The key issue in managing water resources is to have reliable information. In the next section, after introducing some of the commonly used hydroclimate related data and models, the gaps and shortcomings of observations and forecasts are presented.

Gaps in Observations and Monitoring

[3] Distinguished Professor, Civil & Environmental Engineering and Earth System Science Director, Center for Hydrometeorology and Remote Sensing (CHRS)

[4] Research Associate, CHRS and Dept. of Civil & Environmental Engineering, The Henry Samueli School of Engineering,University of California, Irvine

To be responsive to the need for more effective tools to address hydrologic hazards and manage water resources systems, engineers and scientists have become more reliant on the use of predictive models and stochastic methods. Depending on the problem, the hydrometeorological information needed may range from hourly forecasts (i.e., in the case of flash floods) to seasonal to inter-annual (i.e., in the case of reservoirs and other water resources system operations), and to decadal to century (i.e., in the case of long range water supply planning and structural designs).

Responding to the desired timescale and spatial resolution, varieties of mathematical models have been developed and are continuously being refined. Regional climate models are used with longer time scales, ranging from seasons to decades while information from Numerical Weather Prediction (NWP) models are often employed to help with shorter time scale forecasts (days to weeks). On the daily to seasonal forecast, the International Research Institute (IRI) for Climate and Society provides a real time multi-model probability seasonal forecast dataset available online (http://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/). This model, demonstrates the probability of precipitation above normal or below normal and also validation maps for past events that shows the regional performance of their model.

Considering the long term water resource management, the future projections of global climate models are available to the community. Based on the recommendations of the Intergovernmental Panel on Climate Change (IPCC), the GCM data are available in different concentration trajectories (Representative Concentration Pathways, RCPs) ranging from stabilization to mitigation and baseline emission scenarios (Taylor et al., 2012). Commonly, a set of future projections based on climate model simulations will be considered to account for uncertainty in the models and predictions. The GCMs are usually available in coarse resolution and therefore, the majority of regional hydrometeorological models rely on downscaling of these coarse resolution datasets. The downscaled outputs of such models are then used as input to hydrologic models for a variety of applications, including flood forecasting. While there is a rich body of literature reporting on progress related to both, “weather-scale” and “climate-scale” hydrologic predictions, many challenges face the research community attempting to extend the lead-time and accuracy of both types of predictions. More specifically, despite the progress in each of the three pillars (models, observations and parameterization) of hydrometeorological prediction system over the past several decades, the improvements in the overall forecast quality is yet to reach the users expectations.

One of the issues related to GCMs is that the agreement between different models on future trends of precipitation is not very strong in many regions of the world. Figure (1) presents an example of discrepancies between 4 different model simulations (CNRM-CM5, CSIRO-ML-3.6.0, GISS-E2-R, HadGEM2-ES). The figure shows the rate of decadal precipitation change (mm/day/decade) based on the RCP2.6 scenario by 2100 over South America is not consistent among different models. While French GCM (CN-CM5) projects more rain over the region, the Australian and U.K. models demonstrate a drying pattern over most parts of the area. The GISS-E2-R model displays wetting trend on the eastern side and drying trend on the western region. These discrepancies among different models and having no reference point to assess the skills of future predictions, is a real challenge that the management community face.

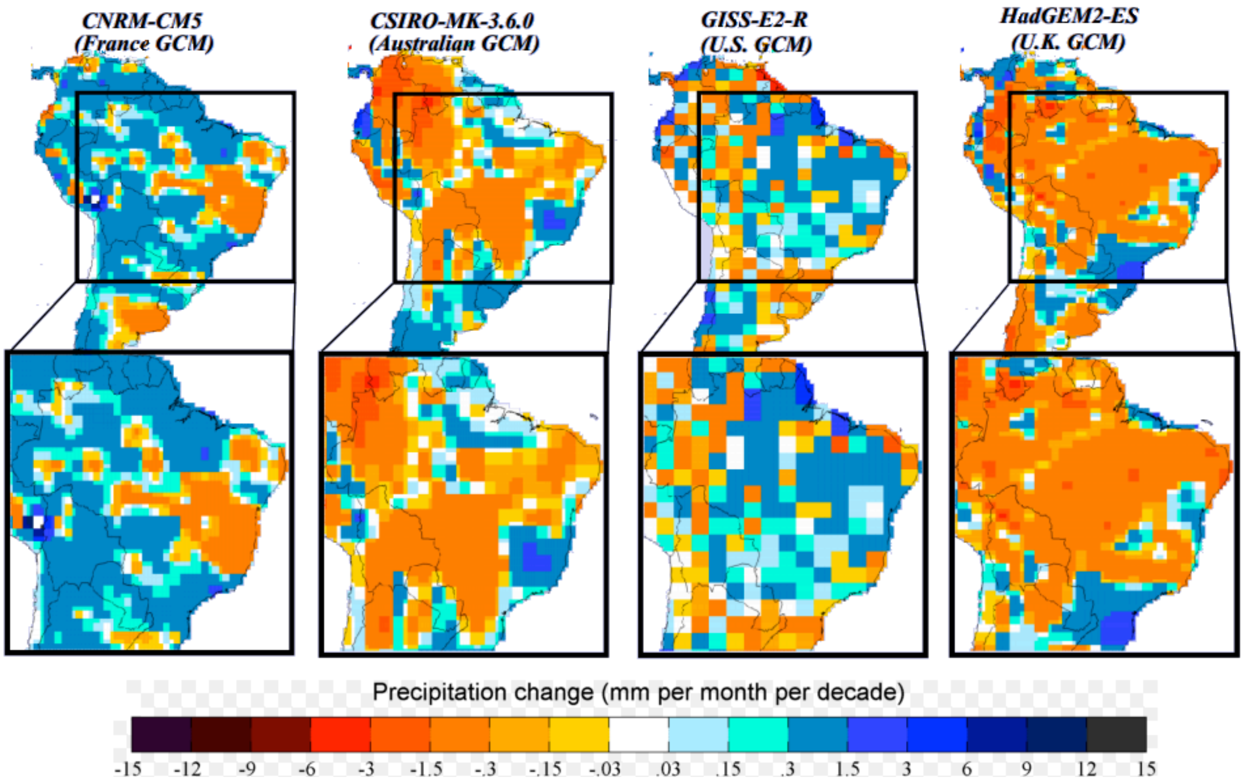


Figure (1). Rate of change of precipitation (mm/day/decade) in 4 different GCM models over the South America based on the RCP2.6 scenario

Solutions to Improve Science Community, Decision Makers, Users and Stakeholders

The best approach to understand the future changes of our system is to find the best models that have better agreements with current and historical observation data available. Measuring precipitation from space has been very promising approach to provide high resolution data over large regions and also over the oceans. The TRMM Multi-satellite Precipitation Analysis (TMPA, Huffman et al. 2007), the NOAA CPC Morphing Technique (CMORPH, Joyce et al. 2004), the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN) algorithm (Hsu et al. 1997; Sorooshian et al. 2000), and PERSIANN cloud classification system (PERSIANN-CCS; Hong et al. 2004) are some of different near real-time precipitation products that are very useful in the hydrometeorological studies.

In addition to near real-time precipitation data, long term historical data are also very valuable in assessing the climatology of the region. The PERSIANN-CDR dataset (available from http://www.ncdc.noaa.gov/cdr/operationalcdrs.html) provides a long term high resolution (0.25 degree) daily scale precipitation data available from 1980. This unique satellite based precipitation data is very valuable especially over remote or data sparse regions. With a more focus on extreme events, PERSIANN-CONNected precipitation object (PERSIANN CONNECT, Sellars et al., 2013) dataset facilitates a search platform to look at the changes of characteristics and also path of all heavy storms globally. The users can search the objects that pass through a geographic region of interest and find all the storms in the region. The data that is currently populating the object-oriented database is the nearly global precipitation estimated by the PERSIANN algorithm for the period 1st March 2000 to 1st January 2011, hourly, 0.25-degree resolution. The database is publically available and can be searched using simple web search queries through:

http://chrs.web.uci.edu/research/voxel/index.html.

The above mentioned datasets are just a subset of global observations that are available to the community. The future satellite missions, as well as recently launched NASA Global Precipitation Measurement (GPM) mission, are all some of the datasets that help us to better understand the current state of the weather and climate systems.

In addition to all these different datasets, the traditional statistical methods with probabilistic approach are a good alternative that can be used to evaluate the system based on historical data. Figure (2) shows an example of a probabilistic model that demonstrates the trend in precipitation or runoff observations (e.g. wetting or drying) to the hydrologic variability (e.g. magnitude, severity, duration). These types of traditional probabilistic models are useful tools while considering the variability and changes in the systems and make decisions based on the uncertainty of the system and the risk level.

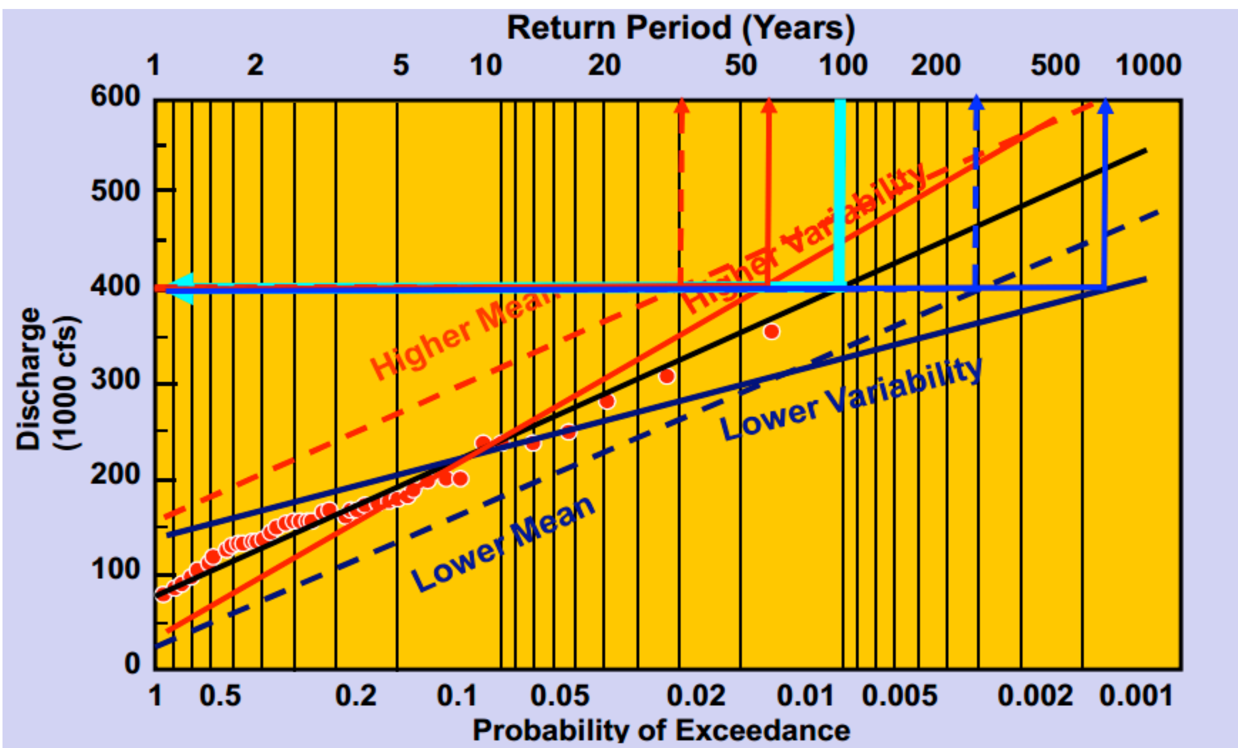


Figure (2). A probabilistic model representing the changes in the discharge and return period based on different hydrologic scenarios

Conclusion

Presently, the accuracy of Hydroclimate model predictions falls short of meeting the requirements of water resources planning. By considering different projections of future changes in climate, or using different global climate models, one can get a future projection of the changes in the hydroclimate variables. However, various models do not necessarily agree with each other in their trend and variability on a regional scale. These differences among models and concentration scenarios make it very challenging for decision makers in the areas related to future water resource management. Therefore, factoring in resiliency in water resources system's design and planning is still the safest approach. Building reservoir to control floods and store water for dry periods, also transferring water from reservoirs to water scarce regions are some of the engineering solutions to mitigate water resource risks and challenges.

References

Hong, Y., K. Hsu, X. Gao, and S. Sorooshian, 2004: Precipitation estimation from remotely sensed imagery using Artificial Neural Network-Cloud Classification System. Journal of Applied Meteorology and Climatology, 43, 18341853.

Hsu, K., X. Gao, S. Sorooshian, and H. Gupta, 1997: Precipitation estimation from remotely sensed information using artificial neural networks. Journal of Applied Meteorology, 36, 1176-1190.

Huffman, G., R. Adler, D. Bolvin, G. Gu, E. Nelkin, K. Bowman, E. Stocker, and D. Wol, 2007: The TRMM Multi-satellite Precipitation Analysis: Quasi-global, multi-year, combined-sensor precipitation estimates at fine scale. J. Hydrometeorology., 8, 3855.

Joyce, R., J. Janowiak, P. Arkin, and P. Xie, 2004: CMORPH: A method that produces global precipitation estimates from passive microwave and infrared data at high spatial and temporal resolution. J. Hydrometeorology., 5, 487- 503.

Sellars, S, P. Nguyen, W. Chu, X. Gao, K. Hsu, S. Sorooshian, 2013: Computational Earth Science: Big Data Transformed Into Insight, Eos, Transactions American Geophysical Union

Sorooshian, S., et al., 2011: Advanced concepts on remote sensing of precipitation at multiple scales. Bulletin of the American Meteorological Society, doi: 10.1175/2011BAMS3158.1.

Taylor, K. E., R. J. Stouffer, and G. A. Meehl, 2012: An Overview of CMIP5 and the Experiment Design, Bull. Amer. Meteor. Soc., 93(4), 485–498.

WCRP Conference for Latin America and the Caribbean: Developing, linking and applying climate knowledge. March, 17-21 Montevideo, Uruguay

Appendix 4: Agriculture and Natural Ecosystems

***Walter E. Baethgen*[5]**

The climate community has been trying to bridge the existing gap between the advances in climate science and the services required to improve adaptation to climate variability and change in different regions and socioeconomic sectors of the world. The third World Climate Conference (WCC-3) organized in 2009 aimed to *"establish an international framework to guide the development of climate services which will link science-based climate predictions and information with climate-risk management and adaptation to climate variability and change throughout the world."* A key outcome of WCC-3 was the creation of WMO's Global Framework for Climate Services. As a parallel and complementary effort the Climate Services Partnership was established as *"a platform for knowledge sharing and collaboration aimed at promoting resilience and advancing climate service capabilities worldwide."* Some of the presentations in the current WCRP LAC conference introduce these efforts and discuss the activities they are developing.

The general concept of "Climate Services" include the generation, translation, dissemination, and actual use of climate knowledge in decision making, policy elaboration and planning. Climate services aim to effectively use the best available climate information, products and tools for improving management of climate related risks and opportunities in agriculture, natural ecosystems, water, health, and other socioeconomic sectors.

Agricultural production is undoubtedly one of the activities with highest dependence on climate. Since the beginning of agriculture farmers have been struggling to cope with unfavorable climate conditions and to take advantage of favorable growing seasons. Consequently, incorporating relevant climate knowledge for improving agricultural production systems should not pose major obstacles: on the one hand there is a clear demand for such knowledge, and on the other hand there is a constant growing capacity of the scientific community to develop it. However, experience shows that effectively embedding climate information, products and tools in the agricultural sector is still a major challenge in both, developing and developed countries.

On the other hand, natural ecosystems are completely dependent on climate conditions and are very sensitive to changes in climate means and variability, and to the occurrence of extreme events. The major threats that natural ecosystems are confronting due to human

[5] IRI, The Earth Institute, Columbia University, New York

activity, for example through changes in land uses, are currently enhanced and will likely be even more enhanced by a changing climate. It is therefore imperative to incorporate relevant climate information and tools into plans for natural ecosystem management and conservation.

The oral presentation and the Round Table in the section “Agriculture and Ecosystems” covered all the aspects of climate services, i.e., the generation, translation, dissemination, and actual use of climate knowledge in decision making, policy elaboration and planning.

The discussion that follows is an attempt to emphasize the key points discussed in the session and is organized following the questions that summarize the main motivations for our Conference.

What are the critical climate research outputs needed from the Climate research community to inform decision-making, risk management and adaptation planning? Which research frontiers need to be addressed first before delivering on end user requests?

Given that the participants in this session were agriculture and ecosystem specialists, the discussions on this subject were not concentrated in the scientific aspects of climate research outputs that are needed in these communities. Instead the emphasis was placed in the need to “translate” and add value to such research outputs.

An important concept that was discussed in the session is that “decision making and planning are concerned with the behaviour of social rather than natural systems”. A direct consequence of this statement is that there is a clear need to establish rigorous and robust research on issues such as: understanding decision processes, characterizing institutions and institutional arrangements, identifying communication formats and strategies that help to translate climate knowledge into actionable information, identifying and characterizing “knowledge networks” through which the climate knowledge flows and reaches different types of users.

Another important issue that came out of the discussions in the session was that increasing the relevance to end users of the climate knowledge generated in the scientific community, typically requires several “links” in between. In other words, the identification of the actual demands of climate information, tools and products needed by end users (farmers, policy makers, agribusinesses, etc.) typically requires the intermediation of institutions and individuals that are interacting directly with those end users (e.g., extension agents, advisors, “boundary” institutions). It is unrealistic to expect that the climate science community can communicate directly with most end users, and it makes much more sense to approach the “knowledge networks” through which end users get their information. Those “intermediaries” are typically individuals or institutions with sufficient scientific/technical background to understand the climate information, and also with ample experience in interacting with end users to define demands.

What are the gaps on the observation and monitoring the climate system in the LAC region? How we can enhance the monitoring system in view of effective climate services?

Several presentations indicated that although there are exceptions in the LAC region, there is a generalized lack of adequate climate observation and monitoring systems. In other words systems that can (a) produce the climate information with the right spatial resolution and at real time, and (b) provide access to relevant climate data with sufficient temporal length for characterizing and quantifying climate related risks. Some of the countries in LAC have still very poor information systems, and in general the quality, the number and the distribution of meteorological stations in many countries is still far from ideal. Several participants in our session reported that there was a decline in the support for maintaining good observation systems in the last 20-40 years in many countries of LAC.

There is thus an obvious need for improving the observation systems with more and good meteorological stations distributed to achieve adequate territorial coverage. In addition, several presentations discussed the need to explore the possibility of complementing this needed effort with the utilization of remotely sensed information and products.

How much do we still not know? What are priority gaps / challenges (both in our scientific knowledge and institutional) that need to be overcome before we can deliver user-requested research outputs and provide operational climate services in support of decision-making?

One key gap/challenge to improve the delivering of climate services is the lack of adequate observation systems mentioned above. Another challenge mentioned throughout the session is the lack of adequate communication between the scientific communities and the end users also mentioned before, and the need to establish good research to work in the "knowledge networks" and intermediary agents. Such research must include members of the climate science community but also researchers from the agricultural, ecosystems and social sciences.

Presentations that described the interaction with end users emphasized the difficulty in applying some of the knowledge generated in climate research. For example, several participants described the difficulty for agricultural stakeholders to use seasonal climate forecasts given the uncertainties and the relative small shift of the forecasts with respect to climatology. However, it was also clear from the discussions in our session that this is also probably affected by the limitations in communication between the different communities. Thus, agricultural stakeholders are constantly making decisions based on uncertain scenarios (for example expected prices of their crops, or expected production costs). It was concluded that improving communication, establishing good research to improve the understanding of the functioning of "knowledge networks" would result in better use of existing information and products as well as in identifying current gaps of knowledge.

Are there concrete solutions to improve the interaction between the science community, intermediary institutions/individuals, and decision

makers? How to overcome the gaps identified in 3) and bridge climate science outputs and adaptation development planning? How to incorporate climate

knowledge into actual decisions and policy?

Some of the concrete solutions that were mentioned in the discussions included:

(a) research for understanding and characterizing the "knowledge networks" and the identification of key links to improve the flow of climate knowledge and the definition of demands and needs

(b) establishing training activities targeted to different levels of the "knowledge networks" to improve all of the components of climate services: generation, translation, dissemination, and actual use of climate knowledge in decision making, policy elaboration and planning.

(c) exploring new approaches for tackling adaptation to climate change. The most common approaches are based exclusively on scenarios that provide information for periods that are very distant in time (e.g., 2080-2100), and that have uncertainty levels that are huge for rainfall at the most frequently needed spatial resolution (local). Complementary approaches should also explore ways to improve adaptation to current climate variability as a means to contribute to improve adaptation to expected increased variability in the future. In turn, this would require establishing integrated research to improve general climate risk management that includes (i) identifying vulnerabilities and opportunities associated with climate variability and change, (ii) identifying technologies that reduce vulnerability and increase resilience, (iii) understanding, characterizing and when possible reducing uncertainties in climate information, and (iv) identifying policies and institutional arrangements that reduce vulnerability and/or transfer risks.

WCRP Conference for Latin America and the Caribbean: Developing, linking and applying climate knowledge. March, 17-21 Montevideo, Uruguay

Appendix 5: Coastal Environments

Claudia G. Simionato[6], Rodney Martinez[7] and Eric Alfaro[8]

The issue:

Latin America and the Caribbean (LAC) have a strong relationship with the coastal environment and there is increasing demand for the subdivision, use and development of coastal space and resources. The complex nature of the coastal environment means that managing the effects of coastal hazards is challenging.

The coastal zone is one of the most dynamic natural systems because there the hydrosphere, the lithosphere and the atmosphere meet and interact, forming interconnected systems. Coastal ecosystems are complex entities consisting of living beings, the physical environment they inhabit, and the interactions within and between these two components. Coastal zones comprise many habitats, all of which have been highly modified over millennia by human activities. As a consequence of the last statements, many of these ecosystems has been considered for marine protected areas trough the Americas, not only for their natural richness, but also because they has been recognize of great economic value.

Coasts are of great ecological and socioeconomic importance. They sustain economies and provide livelihoods through fisheries, ports, tourism, and other industries like their recent consideration for clean ways of power generation. They also provide ecosystem services such as providing food, regulating atmospheric composition and cycling of nutrients and water. These areas have been centers of human settlement since the dawn of civilization, and also have cultural and aesthetic value.

Coastal ecosystems are among the most productive because they are enriched by land-based nutrients and nutrients that well up into the coastal waters from deeper levels of the ocean. As a consequence, they are repositories of biological diversity and provide a wide range of goods and services. Coastlines are among the most populated regions. A number of major cities are located in coastal areas and residential development in coastal areas is rapidly occurring with, in many cases, little future proofing for coastal hazards. Coastal oceans are the most fished, the most modified, and the most subject to natural and industrial disasters.

Loss and degradation of coastal zone ecosystems are affected by direct and indirect drivers and stressors, most of them of anthropogenic origin. The main indirect drivers and stressors are:

[6] Centro de Investigaciones del, Mar y la Atmósfera (CIMA/CONICET-UBA) and Departamento de Ciencias de la Atmósfera y los Océanos FCEN, University of Buenos Aires, Argentina
[7] International Research Center on El Niño (CIIFEN), Guayaquil, Ecuador
[8] Center for Geophysical Research (CIGEFI) and Department of Atmospheric, Oceanic and Planetary Sciences, School of Physics, University of Costa Rica (UCR), 2060 San Jose, Costa Rica

population expansion and increased demands for resources; distribution of wealth and social inequalities; policy failure; market failure and/or distortions; globalization; and poor development model. Direct drivers and stressors are: loss, fragmentation, and degradation of habitats; overexploitation of resources; pollution; introduction of alien invasive species; and climate change and variability, which interacts with the previous factors listed, in many cases reinforcing their impacts.

Both direct and indirect drivers and stressors are agents of global change. They do not operate singly but form an interacting and often synergistic complex. Some of the most dramatic observed and/or predicted consequences of their action are: changes in species distribution, organism metabolism and ecological processes such as productivity and species interactions; changes in ocean chemistry, eutrophication, acidification, hypoxia; rising sea level; chronic erosion and contamination; shifts in weather patterns and greater spreading of exotic species. While the pressures along the coastal zone increase, the challenge of the Integrated Coastal Management remains difficult to accomplish. One of the most important needs to achieve the goal is the availability, communication and proper use of scientific information and here is where the role of ocean/climate services becomes fundamental.

Particular monitoring and research needs in view of effective climate services for Latin America and the Caribbean:

Research is required in a number of specific areas to address the different users' requirements, and issues in each geographic region of LAC.

Observation and monitoring of the climate system in the LAC region is very deficient and in many cases inexistent. Large efforts should be done in this sense, including not only observation and monitoring of meteorological/oceanographic variables but also of the state of coastal ecosystems.

Some proposed research priorities for a regional climate research agenda that emerged during the WCRP-LAC meeting include:

- Inter basins influence on ENSO impacts (Pacific- Atlantic);
- Decadal modulation of ENSO local effects and the role of other sources of variability like Pacific Decadal Oscillation (PDO) and Atlantic Decadal Oscillation (AMO);
- Role of the Eastern Pacific in ENSO diversity;
- Convective processes in the Eastern Pacific and ENSO;
- The thermocline feedback in the eastern Pacific;
- Extreme events prediction and early alarm systems of climate hazards?;
- Impacts of climate variability and change on extreme events.

Finally, the inclusion of socioeconomic issues on the research agenda is a very important aspect and a need for the region.

Strengths and weaknesses:

The principal strengths to progress towards the development of Ocean-Climate services in the LAC region detected during the WCRP-LAC meeting are:

- Capacities in terms of human resources to carry out research on the subject.
- Experience of many institutions of the region in the provision of some services.
- Interest and will of many institutions of the region to expand the range and improve the quality of services provided.
- Commitment of the local scientific community with the issue.
- The existence of regional mechanisms and frameworks to develop research subjects beyond the national level.

Nevertheless a number of weaknesses were also noted:

- The number of trained professionals and students in topics related to oceanography is generally smaller than the needs in most of the region.
- The capabilities developed by research centers and universities are not always exploited by local services due to either lack/failures in communication or joint projects.
- Even though some institutions are providing services, there is a need to progress in the development of standardized methodologies for producing forecasts and climate products.
- The resources of many institutions providing services are limited to the routine tasks and only a small portion of their budget is allocated for research and capacity building.
- Essential interaction between disciplines is rather modest and in some cases inexistent.
- Science information is not being communicated properly to the coastal environment end users and policy developers and managers; science information is frequently not available or not in a form that its usage can be effective.
- Climate predictions are not always translated to the probable climate impacts, making information useless to end users.
- Inability of the scientific community to communicate the inherent uncertainty of climatic products.
- Overlapping of projects and initiatives which split financial resources and the adequate response of end beneficiaries.

Conclusions and proposed actions

The condition of coastal environments in LAC is a perfect example of the urgent need to coordinate efforts and get a serious dialogue and commitment between the research community and the operational agencies.

A great challenge for LAC region is to understand how we can exploit coastal resources within environmental and biological constraints, to ensure enduring access to them through informed regulation, management and utilization. This requires not only the production of scientific information but also its communication to end users, becoming a task that demands the participation of several actors with diverse capabilities. The issue is complicated because the application of science must involve more than just providing information on the state of the coastal environment, identifying indicators for assessing environmental change or developing mechanisms for monitoring and predicting the effect of policy and management options. Information must also inform the analysis of issues, help the user to ask the right questions and then provide signposts to where appropriate data can be found.

The WCRP-LAC meeting showed that there are already established capacities in LAC to think that the development of climate services is possible, although there are some shortcomings and needs. Improvements and progress on scientific research and observation networks and monitoring of the coastal environment, so as changes in the management of operational agencies are required. Increased participation of specialists in social sciences seems to be also a fundamental need to improve the communication of scientific results and their inherent uncertainty, that because the problems identified are of inter, multi and trans-disciplinary nature.

Some important aspects that were mentioned during the meeting were:

- To move towards a definition of Ocean-Climate services by considering specific users (and stakeholders?) demands, and main issues in each geographic region of LAC: Pacific, Caribbean and Atlantic coast.
- To establish specific roles of the components of the Ocean-Climate services for the coastal zones including the mechanisms for their interaction: data monitoring and processing, research, modeling, forecast, information and decision support systems, vulnerability assessments, risk management and policy making (support for help in the protection process support?).
- To ensure coordinated efforts among the global, regional and national programs which really contribute to the sustainability of coastal zones in Latin America.
- (Dudas: mencionar aquí el asegurarse el gestionar fuentes de financiamiento para ayudar con la investigación de aspectos oceanográficos y costeros? Promover los programas académicos de grado y posgrado en temas costeros y oceánicos, es decir marinos, en las líneas de investigación mencionadas? Intercambio de académicos y estudiantil?)

The following actions to foster synergy with ongoing international projects and panels were also proposed:

- To agree the necessary arrangements to establish a Regional CLIVAR Panel, working group or task force for LAC to define the regional research agenda, taking in account the outcomes of the WCRP-LAC Conference.
- To develop a road map for the inclusion of the marine component in the GFCS with focus on LAC.
- To request a regional meeting with GOOS, JCOMM (IOC-WMO) where the agreed research agenda for LAC be presented and coordinated.
- To request to Future Earth and UNEP-PROVIA, information about their plans and activities related to coastal and marine issues for LAC.

WCRP Conference for Latin America and the Caribbean: Developing, linking and applying climate knowledge. March, 17-21 Montevideo, Uruguay

Appendix 6: Climate Monitoring and Prediction

C. Roberto Mechoso[9]

This session focused on aspects that are key for both producers and users of climate information. For operational predictions in a particular region, monitoring is needed to better characterize the current climate state in order to improve forecast skill. There are also important socio-economic sectors that are sensitive to climate variability -- in addition to climate prediction -- that required both real-time and sustained monitoring of climate variables. These include, for example, triggering interventions and performing analyses of historical trends and variability to identify emerging risks.

The first two speakers in the morning session described the current state of climate variability and prediction knowledge in the region and discussed which should be critical topics that the research community should pursue to inform decision-making, risk management and adaptation planning. The last two speakers of the morning session and the five in the afternoon session described more specific results for regional studies. The day concluded with a round table discussion on Climate Services Challenges in LAC.

The research frontiers that need to be addressed first before delivering on end user requests were identified. In this context, the improvement of predictions through better process monitoring and representation was given great importance because it can generate meaningful joint work between operational centers and the research institutions. Another activity of interest for application is to refine the analysis of regional processes such as the sub-basin hydro-climate modeling. The usefulness of conducting studies on climate variability and change in very well defined case-study frameworks was mentioned. Moreover, it was indicated that large-scale climate information combined with regional climate knowledge is added value to climate monitoring. The need for improvement in the translation from monitoring and prediction research into operations was perceived to be of high priority. A suggestion was made that operational centers must be reinforced to the point in which they can host applied research activities leading to model upgrades for higher forecast skill at the regional level.

Several talks and poster presentations illustrated new findings of relevance to the region. A discussion of future seal level change highlighted the vulnerability of countries in the Caribbean. It was shown that a new high-resolution global climate model has significantly improved simulation of South American precipitation, which had proved elusive in the past. Furthermore, observed multi-decadal precipitation changes in response to changing radiative forcing were reproduced. It was argued that well-mixed greenhouse gases play the dominant

[9] University of California Los Angeles, Los Angeles, CA 90095, USA

role - for this model - in the forced precipitation changes. Furthermore, there is a substantial role for decadal/interdecadal variability. As a demonstration of the technical difficulties of predictions with global models it was mentioned that a key goal in the projection of future distribution of is the identification of possible changes in the distribution of extremes, which requires large ensembles of simulations.

It was argued that the recurrence probability of long and severe heat waves, such as those that have affected the large city of Buenos Aires, is small in the present climate but it is likely to increase substantially in the near future even under a moderate warming trend. Several relationships among anomalies in sea surface temperature and soil condition and precipitation in South America of interest for agriculture, hydropower generation, and other sectors were presented. Another presentation compared a different downscaling methodologies to generate daily rainfall sequences from GCM output that can later inform climate risk management, for instance by being used as a forcing for crop or pasture models. Evidence was shown that that the GFDL model under present conditions and in CMIP3 and CMIP5 climate scenarios (A2 and RCP 8.5, respectively) can capture the structure of cold events under present conditions and that such future cold air intrusions may have reduced latitudinal range but may be more persistent. The joint occurrence of daily temperature and precipitation events over Southeastern South America on the basis of observational data and simulations by ERA-40 was examined and found to be difficult to simulate with regional models. The possibility of MJO impact on the South American monsoon breaks was examined.

In general, presentations and posters agreed on the following points:

(1) the improvement of predictions through better process monitoring and representation;

(2) need for refining the analysis of regional processes such as through sub-basin hydro-climate modeling;

(3) importance of conducting studies on climate variability and change for very specific case-studies;

(4) need for improvement in the translation from monitoring and prediction research into operations.

The presentations were followed by a lively round table discussion.

The need for long and high quality time series of climate data in order to develop actionable climate knowledge was re-emphasized. These data are required to assess climate change, calibrate climate proxies, validate climate models, and produce climate information for applications. The data need to be quality controlled, checked for homogeneity and adjusted. One of the gaps in the observation of the climate system is that most of the available time series cover only the second half of the 20th century, pointing to the importance of rescuing data in paper format, digitalizing and making them available. Her presentation showed current WMO activities in data rescue, climate observations and monitoring and climate watch activities in support of the Global Framework for Climate Services (GFCS) with focus on Latin America. It was concluded that in order to support climate monitoring in the region, it is important to build on existing structures and expertise; enhance data rescue activities; collaborate with regional centres and on a national basis; and share knowledge and build capacity.

A report was made on the experience in which USAID and the Climate Services Partnership facilitated the process of Jamaica's Meteorological Service and Agricultural Extension Service jointly producing a drought forecast that provides tailored information to farmers about pest management, seed varieties and other things that can help turn the forecast into tangible action. Regarding gaps on the observation and monitoring the climate system, Jamaica's challenge is not strictly one of a lack of data, since there are over 100 automated weather stations generating data every 3 minutes. The problem was handling all that data. The Met Service had problems extracting and using data for monitoring, historical analyses, forecasts, and to respond to public requests for data and information. Jamaica's weather stations generate data in different formats, and they were using different software applications that required data in different formats. So they were manually cutting and pasting data from about 10% of their active stations for use in the CPT. IRI helped automating their data extraction and reformatting it so they can draw from a larger set of weather stations. Regarding solutions to improve the interaction between the science community, intermediary institutions/individuals, and decision makers, USAID and IRI have been working with Jamaica's Met Service to rebuild relations with its "clients" in other government offices, such as agricultural extension and research, the national water authority, ports and airports authorities. The met service hosted a stakeholder workshop with clients from 6-8 government offices. Participants heard from the met service and IRI about what was possible in terms of climate information support. The met service heard from stakeholders about the decisions they make, and their information needs. The group was asked, if the met service can work with one group to produce one product or service, which stakeholder group is most in need, and which agency would be willing to work with the met service to develop such a service. The agricultural extension service (Rural Agricultural Development Authority, RADA) stepped up, and all agreed that helping farmers anticipate and cope with drought would be of huge value.

Questions and challenges faced by the climate research community in the development of climate services were discussed. It was argued that the LAC community is best placed to give specific answers to the question on the critical research outputs needed from the climate research community to inform decision-making, risk management and adaptation planning, but the engagement with users needs to start now. The WCRP projects and working groups provide a potential framework regarding the priority gaps/challenges that need to be overcome, but the breadth of the issues and the need for major institutional change mean there is also a need to go beyond the scope of the WCRP. Interdisciplinary science is built on good disciplinary science (and data). Since building interdisciplinary research needs lots of time for dialogue and discussion, exchange visits, internships, etc. could complement workshops and conferences. Capacity building (of the climate service providers, intermediaries, users) is essential – particularly for 'small' communities (e.g., E. Caribbean drought managers). Although the GFCS implementation has a key role for NHMSs, RCCs and RCOFs, there are still vital roles for universities, research institutes, etc. In the context of climate services, she emphasized the need to distinguish between seasonal forecasts, decadal predictions and climate change projections (and between weather and climate services).

There were comments from the audience about several issues. About CORDEX and downscaling, it was argued that one of the drawbacks of downscaling is that it does not adequately include remote effects. The importance of enhancing process- oriented investigation over downscaling was also expressed, as well as the need of clearly demonstrate the added value and reliability of downscaling climate change projections. Concerning institutional framework, it was pointed out that it might be helpful to come up with new ways to enhance the regional the WMO framework, which at present is the main source of information in smaller countries (e. g. those in Central America).