World Climate Research Programme: Scientific Foundation for Decision Making

Introduction

Contact: The World Climate Research Programme (WCRP) supports a number of high priority scientific research activities with the aim of facilitating analysis and prediction of Earth's climate system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society.

WCRP held a successful Open Science Conference (OSC) on 24-28 October 2011, in Denver, Colorado, USA, under the theme "Climate Research in Service to Society. The conference counted more than 1900 participants from 86 nations, including 541 young scholars and 300 scientists from developing nations. Through a community synthesis of research findings, the scientists at the conference assessed the current state of knowledge on climate variability and change, identified the most urgent scientific issues and research challenges, and ascertained how the WCRP can best facilitate research and develop partnerships critical for progress. The conference participants identified several major scientific themes and priorities based on the daily presentations and discussions which include: (1) the need for prediction of the Earth System bridging the physical climate system with biogeochemistry, the socioeconomic and humanity sciences such as the "Future Earth: Research for Global Sustainability"; (2) the opportunity, provided by new satellite observations, to make a quantum leap in understanding of clouds and aerosols and their contributions to climate sensitivity; (3) the necessity of skillful climate information on regional scales, embodying the so-called "seamless prediction" in support of Global Framework for Climate Services; (4) the importance of quantifying "true" uncertainty in climate predictions; (5) the challenges and opportunities of predicting how natural modes of climate variability will modify the "forced" anthropogenic component of climate change over the coming years to decades; (6) the increasing importance of establishing the predictability of polar climate, with possible opening of the Arctic and international policy for commercial shipping and extraction of natural resources; (7) the need to better understand the causes of extreme events and attribution studies in near real-time; (8) the challenges of improved predictions of future sea-level change on regional scales, which will require knowledge of cryospheric, thermosteric, gyre circulations, storm tracks, and tidal amplitudes; and (9) the need to train and empower the next generation of climate scientists.

A major emerging theme was the need for actionable science. Decision makers need climate and other scientific information to guide decisions. The demand for and importance of understandable information about climate is increasing, especially as extreme weather and climate events and their adverse impacts on natural ecosystems and global economic development increase in frequency and severity. More information on the conference is available at http://conference2011.wcrp-climate.org.

On-Going WCRP Research Activities relevant to UNFCCC

Climate Projections

More than 22 modeling groups from around the world are currently running the Coupled Model Intercomparison Project Phase 5 (CMIP5) experiments that represent the most ambitious multi-model inter-comparison and analysis project ever attempted. This and previous phases of CMIP have been organized and coordinated by the WCRP Working Group on Coupled Models (WGCM). The CMIP5 consists of four major categories of experiments and analysis based on model simulations. They are: 1) Atmosphere-Ocean Global Climate Models (AOGCMs , with components of atmosphere, ocean, land and sea ice); 2) Decadal prediction simulation sets (AOGCMs initialized with observations); 3) high-top models (AOGCMs with increased vertical extent to reach

well into the stratosphere); Earth System Models (ESMs, with inclusion of at least a coupled carbon cycle in an AOGCM). Model data are openly available from the Earth System Grid Federation, an international distributed data archival and access system, and more information can be found on the Program for Climate Model Diagnosis and Intercomparison (PCMDI) web page (http://cmip-pcmdi.llnl.gov/cmip5/). Ultimately, these results will be available through the peer-reviewed publications for use in the 5th IPCC Assessment Report (AR5).

Decadal Predictability and Predictions

The enhanced focus on the WCRP CMIP5 near-term climate prediction (to about 2035) is promising exciting developments in the coming years such as the assessment of the benefit of different initialization methods, the formulation of predictions with useful skill over regions and for variables still unexplored or the development of post-processing methods that allow the integration of forecast information from different forecast systems. As already happened in the field of seasonal forecasting, the combination of model improvement, better observational datasets (for both initialization and verification) and a better understanding of the processes at the origin of the interannual to multi-decadal predictability should lead to more skillful multi-year predictions in the future, as well as to an increase benefit from a better informed society.

Seasonal and Interannual Forecasts

Progress in seasonal prediction depends on improvements in the building blocks of seasonal prediction systems: the models, observations and data assimilation systems, as well as improved forecast verification and a more effective transfer of information to forecast users, increasing forecast value. The WCRP Working Group on Seasonal to Interannual Prediction (WGSIP) is coordinating a multi-model, multi-institutional set of hindcast experiments – the Climate system Historical Forecast Project (CHFP, http://www.wcrp-climate.org/wgsip/chfp/index.shtml). The CHFP aims to explore there untapped sources of predictability on seasonal to interannual timescales due to interactions and memory associated with all the elements of the climate system (Atmosphere-Ocean-Land-Ice). These experiments provide a baseline assessment of current seasonal prediction capabilities using the best available models of the climate system and data for initialisation, as well as of IPCC class climate models in seasonal prediction mode. They provide a framework for assessing current and planned observing systems, and a test bed for integrating process studies and field campaigns into model improvements.

The WCRP WGSIP provides an effective interface between the operational community engaged in long-range predictions and the research community engaged in exploring new sources of prediction skill, improvements in long-range prediction methodologies, and other scientific questions of relevance. Improvements in seasonal prediction skill that are derived from the implementation of best practices are expected to be quasi-immediate. Improvements in the building blocks of seasonal prediction systems will continue in the next years and longer and ongoing research into new sources of predictability in the climate system are expected to lead to operational improvements on the longer term.

Regional Climate Information

The provision of climate information at regional to local scales is an important requirement to support informed decision making in response to potential climate change. Such information is needed to assess the impacts of climate change on human and natural systems, enabling the development of suitable adaptation and risk management strategies at the regional to local level.

The WCRP CORDEX project (http://wcrp.ipsl.jussieu.fr/SF_RCD_CORDEX.html) has a twofold purpose to 1) provide a framework to evaluate and benchmark model performance (Model Evaluation Framework); and 2) design a set of experiments to produce coordinated climate projections and estimated uncertainties (Climate Projection Framework). The first step in CORDEX is to evaluate the performance of various Regional Climate Downscaling (RCD) methods for the recent past, both to help define the reliability of future projections and to identify areas requiring improvement. For each region a set of evaluation and diagnostic teams are being formed whose tasks include the design of a set of benchmark regional metrics for model evaluation and the collection of suitable, quality-controlled observations to support this task. However, in a number of regions of the world, access to reliable regional climate change information is extremely limited. One example is Africa. It is in these regions the collaboration developed through CORDEX is expected to bring the largest benefits. With this in mind the international community decided to target Africa for an intensive collaboration with an aim to produce a significant matrix of regional climate change projections, both to support the 5th Assessment report of the

IPCC (IPCC AR5) and to provide useful climate information to decision-makers involved in climate risk management and adaptation planning. Similar teams are in the process of being formed for the other CORDEX domains in Asia and South America.

Detection and Attribution of Climate/Weather Extremes

Research on "Climate Extremes" is one of the WCRP cross-cutting activities and it is focused on the design of an intercomparison framework through which both observations and climate model representations of extremes and projections of climate can be assessed, and by which changes in climate extremes can be better evaluated and communicated to the decision makers. The overall aim of this activity is to accelerate progress on the prediction/projection of climate extremes with a focus on developing capabilities and products, which facilitate practical applications for stakeholders in regions/sectors around the world.

Drought has been identified as an important focus of the WCRP extremes activity and a major international workshop was organized in March 2011 in Barcelona, Spain (http://drought.wcrp-climate.org/workshop/). Among the key recommendations of this workshop is the development of an experimental global drought information system (GDIS). The timeliness of such an effort is evidenced by the wide array of relevant on-going national and international (as well as regional and continental scale) efforts to provide drought information, including the US and North American drought monitors, and various integrating activities such as GEO and the Global Drought Portal. In addition to the evolving drought information systems, there are a number of other emerging capabilities that could become important components of any GDIS. These include regional and global experimental hydrological forecasting capabilities and a number of national and international near real time global multi-model seasonal (short term climate) forecasting capabilities. Also relevant are two additional action items that arose from the WCRP drought workshop to develop a drought catalogue, and to conduct coordinated research on specific high-profile case studies of past droughts. WCRP is will focus on the steps necessary to develop a GDIS that builds upon the extensive world-wide investments that have already been made in developing drought monitoring, drought risk management, and short term climate prediction capabilities. The success of a GDIS will be measured by its ability to provide timely drought-related information and predictions that can inform decision-making.

Emerging issues in climate change research

New Results from CMIP5

New results are emerging from analyses of the multi-model data that are part of the Coupled Model Intercomparison Project Phase 5 (CMIP5). The spread of projections in CMIP5 AOGCMs is roughly the same as the previous generation of models in CMIP3. Most first generation of ESMs produce comparable first order results to AOGCMs, but also include the additional capabilities of ESMs. Patterns of future change of temperature and precipitation, equilibrium climate sensitivity, and spread among CMIP5 models are similar to previous generations of models and present the opportunity to better understand the spread. This increases confidence in these results.

CMIP5 provides many more capabilities and new types of climate change information: (1) carbon cycle feedback, quantifying sources and sinks of carbon for land vs ocean, allowable emissions for different levels of mitigation in the RCP scenarios, ocean acidification, physiological effects of vegetation changes; (2) high resolution time slices to study tropical cyclones; (3) decadal climate prediction for short term climate change and possible climate shifts; (4) paleoclimate simulations that allow analysis of climate response across past, present and future climates, and that provide "out of sample" insights to build model credibility and provide possible constraints on the nature and magnitude of future climate change; (5) analysis of cloud feedbacks; (6) revisiting of forcing and feedback better helps to interpret the spread of model projections; and (7) attempts to relate 20th century model biases to projections.

New types of results include: (1) Atlantic multidecadal variability appears to be more predictable than Pacific multidecadal variability; (2) critical thresholds for Arctic sea ice loss; (3) regional climate regimes such as the Indian Ocean Dipole and its connections to east African rainfall; (4) changes in monsoon onset characteristics; (5) role of salinity and patterns of changes connected to the hydrological cycle and ocean response; (6) tracking regional ocean heat content changes and relation to regional patterns of sea-level rise; (7) mechanisms for regional precipitation and temperature changes and extremes—Caribbean drying, SE US wetter, drying Amazon,

connecting Arctic sea ice loss to European cold extremes, atmospheric rivers and extreme precipitation, importance of circulation changes, blocking, what will not change in a future climate is also useful information.

Indices of weather and climate extremes (coordinated by ETCCDI) are being calculated for the CMIP5 models and for the reanalyses data, and will be made available for users to analyze through a data base, initially from the Canadian Center for Climate Modeling and Analysis (CCCma), and subsequently on the PCMDI web site.

New Results from CORDEX-Africa

10 Regional Climate Modelling (RCM) groups have downscaled ERA-interim data for 1989-2008 on the common Africa CORDEX grid. All these groups have also committed to making at least one climate projection run for the CORDEX-Africa domain, with some groups planning more than one with different CGCM (Coupled General Circulation Model) forcing. A model evaluation/diagnostic team has now been formed for Africa, consisting of 30 scientists from a range of disciplines and representing the majority of sub-Saharan Africa. While there are inter-model differences, the majority of the RCMs capture the ITCZ (InterTropical Convergence Zone) well, with accurate estimates of seasonal rainfall amounts. In fact the ensemble mean bias, when calculated against any one of the four observation data sets, is of similar magnitude, or smaller, to the differences across the 4 observations. The main message we wish to convey at this early stage is that a lot of high quality simulated climate information will be available for the African continent within the next few months.

For practical use in West Africa it is important that models can simulate the onset date of the monsoon, as well as the monsoon duration, intra-seasonal variability within the monsoon season and its north-south propagation. A number of the RCMs simulate the overall monsoon cycle quite accurately, with a few capturing the northward jump in the monsoon seen in early July in the observations, the ensemble mean having a particularly good representation of this phenomenon. A feature common to a number of the RCMs is that during the southward march of the monsoon, in October to November, precipitation rates are overestimated. More work is required to fully characterize the ability of the CORDEX RCMs to simulate climate variability over Africa. This effort is underway now, in preparation for the climate projection phase of CORDEX, which will begin for Africa and other regions in the coming months.

New Re-Analyses of Global Observations

Reanalysis is a scientific method for developing a comprehensive record of how weather and climate are changing over time. In it, observations and a numerical model that simulates one or more aspects of the Earth system are combined objectively to generate a synthesized estimate of the state of the system. A reanalysis typically extends over several decades or longer, and covers the entire globe from the Earth's surface to well above the stratosphere. Reanalysis products are used extensively in climate research and services, including for monitoring and comparing current climate conditions with those of the past, identifying the causes of climate variations and change, and preparing climate predictions. Information derived from reanalyses is also being used increasingly in commercial and business applications in sectors such as energy, agriculture, water resources, and insurance.

The mid-1990s saw the emergence of reanalysis products of more uniform quality covering longer periods, for example by the US National Center for Environmental Prediction (NCEP), ECMWF, the Japan Meteorological Agency and others. For example, ECMWF's two most recent reanalyses, ERA-40 and ERA-Interim, illustrate perfectly the positive benefit of improved observing and forecasting systems on medium-range forecasting and climate monitoring.

ERA-40 covered the period 1958-2001. It used an assimilating model with a -125 km quasi-uniform grid, 60-level vertical resolution and a three-dimensional variational (30-Var} analysis. Otherwise, it used a version of the ECMWF forecasting system that was operational in 2001. ERA-Interim runs from 1979 to the present, and uses -80 km horizontal resolution, 60-level vertical resolution, and otherwise a 2006 version of the ECMWF system, including four-dimensional variational (4D-Var) analysis. The new webpage http://reanalyses.org/ provides researchers with detailed data descriptions, data access methods, analysis and plotting tools of reanalysis datasets created by different climate and weather organizations. In addition, the site is used to discuss these reanalyses, how they compare with each other and with observations. WCRP is convening the 4th International Conference on Reanalysis in Silver Spring, USA, on 7-11 May 2012 with the objective of fostering communications between reanalysis development centers and the research community with a focus on an Earth System approach to reanalysis.

Regional Research, Analysis and Modelling Capacity Development

WCRP partnered with WMO, GCOS and ICPAC to execute a World Bank-sponsored project on climate risk reduction for the Greater Horn of Africa countries (http://www.wcrp-climate.org/CB_projects_GFDRR.shtml). A series of three coordinated workshops brought together climate practitioners and users to assess available climate data and information for water resources and agriculture, and to identify best practices and gaps that need to be filled. The overall objectives of the workshop programme were to help ensure that attention is given by countries in the GHA region to observation and data needs, to demonstrate the use and value of regional models, to provide advice on model limitations, and to improve capabilities across the GHA for using data records and model projections for adaptation planning. WCRP was successful in adopting the materials and process developed for the Horn Africa for the regional capacity development in West Africa with the help from some African scientists and through a partnership with UNDP and WMO Regional Program.

Regional knowledge assessments were and will be conducted in West Africa, East Africa, and South Asia in 2011 and 2012 through a partnership between the WMO/WCRP, IPCC, UNEP, START, the University of Ghana, University of Dar es Salaam and the Bangladesh Centre for Advanced Studies. The effort is being supported through a European Commission, UNEP, USAID and USGCRP-funded project entitled '*Understanding the Findings of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, Climate Change 2007 - Integrating Climate Change Adaptation and Mitigation in Development Planning'*.

The regional knowledge assessments utilizes key findings of the IPCC 4th Assessment Report, Climate Change 2007, as the basis upon which to frame issues of climate change impacts, vulnerability, adaptation and mitigation, and draws upon a wide array of additional sources, including peer reviewed literature published since the 4th Assessment Report pertaining to regional issues, grey literature (i.e. institutional or technical reports, working papers, theses, conference proceedings, statistical bulletins, etc.), and peer-reviewed literature published in non-English languages, which are not normally assessed by the IPCC. The assessments collect and synthesize available knowledge on region and country specific issues of relevance to climate change adaptation and mitigation decision- making, identify knowledge gaps that are critical to decision-making, and prioritize research and assessment needs for adaptation and mitigation decision support.

WCRP, in partnership with START, is developing regional research capacity for Asia and Africa in conjunction with the CORDEX. CORDEX presents an unprecedented opportunity to advance knowledge of regional climate responses to global climate change, and for these insights to feed into on-going climate adaptation and risk assessment research, policy planning, and development in the region. A consortium of organizations consisting of the WCRP, the University of Cape Town's Climate Systems Analysis Group (CSAG), START, the International Centre for Theoretical Physics, the Swedish Meteorological-Hydrological Institute, and the Climate and Development Knowledge Network initiative have developed an analysis and training program to provide an initial assessment of CORDEX output for Africa that is regionally focused and prioritized to the continent's knowledge needs. The training programme focuses on skill development in working with climate model results, analysis of CORDEX datasets, and compilation and writing of analytical results. Participants in the training programme are grouped into teams according to the sub-regions they represent and their respective areas of expertise.

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