WCRP REPORT

World Climate Research Programme

Report

WCRP Modelling Coordination Meeting

15-16 November 2010, Paris, France

February 2011

WCRP Series Report No.133
WMO/TD-N°.1569

Table of contents

Introduction

The WCRP convened a modelling coordination meeting 15-17 November 2010 at the Institute Pirre Simon LaPlace (IPSL), Campus in Paris, France. The purpose of this meeting was to follow-up on the recommendations of the World Modelling Summit and actions resulting from the 31st session of the WCRP Joint Scientific Committee meetings in Antalya, Turkey, on the subject of modelling. The JSC had discussed at length the formation of a WCRP Modelling Council in the context of WCRP visioning and future directions to carry out the following functions:

- Promoting the confrontation of models with observations and results of process studies;
- Promoting collaboration amongst various climate science communities (includes numerical weather prediction (NWP), seasonal to interannual prediction and climate projection communities as well as those dealing with biogeochemistry, air quality, terrestrial ecology, etc.);
- Promoting application of models to problems of societal relevance, quantifying uncertainties and making sure they are well communicated and understood;
- Promoting the model development and improvements.

There was considerable discussion among the participants in the JSC meeting on the similarities and differences between this Council and former WCRP Modelling Panel, both in terms of functions and structure that are captured in the JSC report available on the WCRP website: (http://www.wmo.int/pages/prog/wcrp/PG_Reports_JSC.html).

The WCRP JSC Chair and Director believed it was quite timely to have a modelling coordination meeting among the potential members of the WCRP Modeling Council for several reasons. First, this topic will be further discussed at the next JSC in April 2011, thus those discussions can benefit greatly from the views and insight of the participants in this coordination meeting. Second, we had planned to consult the broader community on the WCRP future scientific coordination role in modelling during the WCRP Open Science Conference to be held on 24-28 October 2011, in Denver, Colorado and we thought that it to be highly beneficial to have some common understanding and agreement on modelling functions/structure among the WCRP leadership prior to the Conference. Third, to discuss the results of the WCRP Modelling Survey focused on the modeling needs and priorities. The survey had been prepared by the co-chairs of Working Groups on Coupled Modeling and Numerical Experiments who were preparing an open publication based on the survey results to be followed by one or two workshops focused on the implementation of the survey findings. Fourth, there were ongoing discussions between WCRP and the International Geosphere-Biosphere Program (IGBP) and the World Weather Research Program leadership on the subjects of Earth system modelling and seamless modelling approach(es) to weather and climate which could benefit from the collective views and perspectives of the participants in this coordination meeting.

In preparation for this meeting, the participants were grouped into five small teams and each team was asked to develop a short concept paper on the four scientific and technical themes identified above. The fifth team was asked to develop a governance concept for coordination of the functions associated with the first four themes, through a grass-root process and across the entire WCRP Projects and Program activities. The initial draft of the five concept papers was shared with all workshop participants for their review and comment prior to the meeting. The agenda for the meeting and the formal presentations and discussions were based on these five papers. The major outcome of the meeting discussions were subsequently integrated into the previous draft of these five concept papers to prepare the final version of their final version that are presented in the next section of this report. The final section of this report describes the overall decisions, actions and the next steps agreed to by the meeting participants. This report will be shared with the WCRP Joint Scientific Committee Members and Chairs of the Science

Steering Groups of the four WCRP Projects for further discussion at the 32nd JSC meeting in April 2011 in Exeter, United Kingdom.

Promoting the confrontation of models with observations and results of process studies

V. Eyring, M. Manton, and D. Stammer

This document draws on the World Modelling Summit workshop report, the White Paper on WCRP Modelling Theme, and the Model Evaluation Survey and summarizes key points considered at the WCRP modelling coordination meeting in November 2010.

Requirements of observations for modeling

Observations are needed for model development, model evaluation, process understanding, data assimilation and reanalysis. There is also an important interaction between model and observations in diagnostic studies aimed at documenting and explaining aspects of the climate system. Further, observations such as climatologies from satellite derived large-scale time series are used to validate spin-up of models in data-poor regions such as the Arctic or Antarctic (i.e. sea ice cover).

The systematic development of model parameterisations is especially sensitive to measured data, as coefficients in the underlying theory are adjusted to best align with observations. Focused field studies, carried out under a range of large-scale conditions, can provide the required data. The WCRP has coordinated a number of these field projects, such as TOGA COARE or a number of polar studies during the recent International Polar Year. The GEWEX CSS has developed second-order approaches to observations, with validated cloud-resolving models being used to provide fine-scale data for use in parameterisations for climate models. Formal parameter estimation techniques can be used to constrain the range of model coefficients.

Requirements for model evaluation

A variety of Model Intercomparison Projects (MIPs) have demonstrated the value of multi-model evaluation, where models are compared to each other, but especially also to observations. Important components of MIPs are coordinated model experiments with a common focus and experimental design (such as CMIP simulations). With AMIP and CMIP, the WCRP developed the protocols and international cooperation needed to conduct consistent inter-comparisons and to provide transparent assessments of climate models that have been incorporated by the IPCC.

Model evaluation requires the availability of consistent, error-characterized global and regional Earth observations (satellite and in situ) as well as accurate globally gridded reanalyses in the atmosphere, the ocean, or, ultimately, the coupled system, that are constrained by assimilated observations. In addition, the following specific issues have been identified as important requirements for improvements in model evaluation:

- Availability of agreed-on diagnostics and observation simulators for process-oriented model evaluation.

- Process studies for development and evaluation of parameterisations.
- Paleo-climate data for simulations of different past climates.
- Sustained data sets for trend comparison and finger-print assessments.
- Integrated data sets covering energy and water cycle – and carbon, nutrients etc.
- Development of data assimilation for coupled models.
- Development of performance metrics (see Good Practice Guidance Paper by Knutti et al., 2010 at IPCC website).

An increasing emphasis is now being put across WCRP on initial value problems, initially associated with seasonal prediction, but now with a focus on inter-annual to decadal prediction. A wide range of data assimilation techniques have been applied to the initial value problem for atmospheric, ocean and land surface models, but greater effort is being devoted now to the assimilation of data directly into the same coupled models required for climate prediction. Observations for data assimilation and evaluation of climate prediction must be obtained from sustained and consistent global monitoring systems, which are promoted by GCOS. Data assimilation provides a further opportunity for model evaluation, with quantification of model and observational errors separately. At the same time it offers a unique opportunity for model improvement through parameter improvement.

Atmospheric reanalysis is a special case of data assimilation, with short-term analysis-prediction cycles repeated over decades with the same system to produce a consist set of global analyses. However, while the model and assimilation system are not changed over the integration period, considerable effort is needed to ensure that inhomogeneities in the observations do not adversely affect the products. In the future more emphasis needs to be put on preserving first principles during the assimilation approach.

Relevant partners within WCRP and external to WCRP

WCRP modelling activities: A number of WCRP working groups have been established that are specifically targeted at coordinating modelling efforts. These are the Working Group on Coupled Modelling (WGCM), the Working Group on Seasonal to Interannual Prediction (WGSIP), and the Working Group on Numerical Experimentation (WGNE). In all three working groups, model evaluation, in particular process-oriented evaluation has been realized as an increasingly important topic and progress in this area is discussed regularly at the annual meetings. Discussions at WCRP working group and project meetings as well as recent advancements in science have also identified the area of performance metrics as important. While the numerical weather prediction community routinely uses skill measures to quantify biases and improvements since several years, this is not yet the case for climate models. In response to this, a WGNE/WGCM metrics panel has recently been established with the goal to promote and facilitate routine calculation of performance metrics for climate models. Similar, coordinated model evaluation efforts and the calculation of performance metrics are part of WCRP Projects (CLIC, SPARC, GEWEX) and their associated MIPs (e.g., C4MIP, CCMVal, CFMIP, CMIP, PMIP).

WCRP observational activities: The WCRP Observation and Assimilation Panel (WOAP), which consists of a panel of representatives from all of the other activities in WCRP (projects and working groups) and GCOS, deals with cross cutting issues related to global observations, their analysis and assimilation, and the resulting products from a research perspective on behalf of WCRP and GCOS. In addition, the WCRP CLIVAR Global Synthesis and Observations Panel (GSOP) is responsible for the definition and fulfillment of CLIVAR's global needs for sustained observations, in collaboration with relevant WMO and IOC bodies. A SPARC Data Initiative on chemical observations has also recently been established. It was motivated by the CCMVal report that has identified the requirement of long-term vertically resolved data sets beyond ozone for a process-oriented evaluation of chemistry-climate models.

External to WCRP: WCRP, via its working groups and projects, is well connected to partners external to WCRP. These connections ensure that WCRP modeling is informed by and complements activities in related fields to further promote the confrontation of models with observations and to encourage process studies. Representatives of the world climate modelling centers are invited regularly to the working group and project meetings and in many cases serve as members on one or the other WCRP committee. A link to the observational community is also being established at the WCRP modelling meetings, and representatives from observational initiatives such as the ESA Climate Initiative or the NASA initiative on observations for CMIP5 are regularly presenting the status. WCRP also seeks the contact with other international organizations and bodies, for example it is part of WGCM's terms of reference to liaise as appropriate with IPCC and the Global Analysis, Interpretation and Modelling (GAIM) element of IGBP, WOAP seeks a strong link to GCOS and the ICSU World Data System (WDS), and WGNE was jointly established by the WCRP Joint Scientific Committee (JSC) and the WMO Commission for Atmospheric Sciences (CAS), which is responsible for WWRP and GAW. The interaction between WCRP and the THORPEX program of WWRP will be especially important in optimizing the global research effort on data assimilation.

Impediments to progress internal to WCRP and external to WCRP

While the individual WCRP working groups and projects have made great progress in promoting the confrontation of models with observations in recent years, it is hoped that the envisaged WCRP Modelling Council will further encourage coordination across the WCRP working groups and projects. The communication between modelling and observational as well as synthesis panels seems to currently be the impediments to progress internal to WCRP in the area of model evaluation. Impediments to progress external to WCRP that have been identified for example in the documents mentioned above are:

- Missing methods to identify the key players in model error at the process level.
- Not enough experts and modelling resources at large.
- Funding opportunities for model evaluation, in particular joint projects between observational and modelling community (mostly the calls are either on observations or on modelling).

Priorities for advancement

The Modelling Evaluation Survey was a "bottom-up survey" that included problems identified in operational NWP and seasonal prediction centers as well as deficiencies that climate modellers and analysts of CMIP3 simulations have identified for the current generation of models. The following key areas of model deficiencies, which should be considered as priorities for advancement, have been mentioned most by the 110 independent:

- Tropical biases and variability (double ITCZ, cold tongue, ENSO, MJO,...),
- Clouds, moist processes and associated feedbacks,
- Carbon cycle and land surface/ocean atmosphere coupling in general,
- Troposphere-stratosphere interaction,
- Physics in high-resolution modelling.

In addition, the following priorities for advancements have been mentioned:

- Understanding whether climate models correctly simulate major climate signals and attributing this to specific causes.
- Establish routine calculation of process-based diagnostics and performance metrics from multi-model simulations such as CMIP5.
- Evaluation of higher model resolution runs as well as runs with more complexity.

- Greater focus on initial value problem beyond seasonal time scales.
- Accurate quantitative description of extreme events.

A high priority for modelling system development and evaluation is the preparation and maintenance of consistent and homogeneous data sets with specified uncertainty characteristics.

Possible ways to accelerate/expedite model-observation interactions within WCRP

The above discussion reviewed requirements, partners, impediments of progress as well as priorities for advancement that have been highlighted in the World Modelling Summit workshop report, the White Paper on WCRP Modelling Theme, and the Model Evaluation Survey. We conclude that large progress has been made in recent years to promote model evaluation and process studies and that the current structure of WCRP modelling working groups, projects and MIPs is working well. To further successfully promote this important activity, we provide below some recommendations, which can be further discussed at the meeting. WCRP should in particular:

- Reduce the gaps between modelling, observations and assimilation communities and promote the use of multiple datasets in model development and evaluation, e.g. by:
    - establishing the WCRP Modelling / Observation Council with at least one observationalist / modeller as a member on this panel;
    - communicating the needs of modelling groups in terms of observations to the WCRP Observations Council and implement them through the various WCRP working groups. The current initiatives of establishing consistent, stable, error-characterized long-term global satellite data products from multisensor data archives for Essential Climate Variables are highly commendable.
    - promoting collaboration between modeling, assimilation, and observational communities in the design, implementation and analysis phases of field projects aimed at providing new datasets based on advanced observing platforms for the development of model parameterizations and the evaluation of models at the process level.
    - organizing targeted sessions on model evaluation at WCRP conferences and other international conferences, where both modellers and observationalists are brought together to discuss advances in this area.
    - encouraging international observational efforts and archives to support the MIPs (C^4MIP, CCMVal, CFMIP, CMIP, etc), similar to international modelling archives.
    - creating better infrastructure to facilitate access to observations for model development and evaluation with agreed protocols and standards, including estimates of uncertainties in datasets.
    - promoting the systematic collection of observations in regions, such as polar areas, the upper tropoposphere / lower stratosphere (UTLS), the deep ocean, where the lack of data is impeding progress.
    - ensuring that the WCRP model requirements for global observations are recorded in the WMO-CEOS database.

- Foster collaboration among the WCRP working groups and projects, e.g. by

- establishing the WCRP Modelling Council and ensure that representatives of the WCRP working groups and projects are members of it.
- bringing together the process and application groups (e.g. latest WGNE development).
- encouraging communication among the various MIPs, e.g. by regular reports at progress meetings or by organizing joint sessions at international conferences
- recognising the cross-cutting nature of diagnostic studies that underpin our understanding of the climate system.

- Reduce the gaps between NWP/seasonal/climate communities, e.g. by
  - holding WGNE, WGSIP and WGCM meetings in parallel, with e.g. 0.5-1 day overlap.
  - establishing joint working groups or panels, such as the WGNE/WGCM metrics panel.
  - organizing joint workshops or sessions at internationals conferences
  - continuing to promote the concept of seamless prediction and the development of coupled data assimilation across WCRP.
  - ensuring close ties between WCRP and WWRP through co-sponsored projects of mutual interest.

- Promote the development of methods to identify the key players in model error at the process level, e.g. by
  - organizing a session on long-standing key biases in climate models.
  - encouraging the development and use of sophisticated diagnostics, performance metrics and other methodologies of model-data comparisons so as to facilitate the characterization, the quantification and the physical understanding of model deficiencies.
  - organizing coordinated investigations into the link between model error and prediction error.
  - facilitating sharing of resources (cf. CMIP).
  - developing improved high temporal resolution (sub-daily) datasets that can be used to assess changes in extremes of all sorts, including especially those with high impacts on humans and the environment, such as drought, heat waves, floods, and storms.

- Engage the potential of high resolution modelling into minimization of risks of extreme climate events and more effective coping with risks. The ‘WCRP-UNESCO Workshop on metrics and methodologies of estimation of extreme climate and weather events’ workshop recommended:
  - Determine the main phenomena responsible for extremes and evaluate models from the standpoint of their ability to reproduce statistics of these, and how they vary and change.
  - Provide a focus for evaluating models with regard to how well they replicate extremes, including developing better methods for comparing model grid point values with observations.
  - Promote sustained observing systems to allow predictions of seasonal to decadal time scales.
  - Develop a CMIP5 focused activity on analysis of extremes.
  - Advance statistical methodologies for extreme event statistics by e.g. (1) building a community of climate scientists and statisticians working together, cross-pollinating the ideas of each other and speaking the same terminology language, develop robust statistical

methods for assessing extremes and their uncertainties and make tools available for wide-spread use, (2) ensure that archives of model projections include sufficient high frequency data to assess the required statistical metrics (higher order statistical moments and probability density functions) required for accurate regional assessment of risks of extreme events and planning adequate risk management actions, and (3) initiate a close co-operation and consolidate a task force of the observational, modeling and statistical communities to improve estimation of probabilities of compound extreme events and their potential prediction, taking into account that particularly compound extremes result in most disastrous economic and human losses and require specific actions to manage their risks.

Promoting collaboration amongst various climate modeling communities:

building and advancing the scientific knowledge on modelling of climate variations and change, with the goal of developing numerical models that are increasingly realistic and accurate for climate predictions (including numerical weather prediction (NWP), seasonal to interannual prediction and climate projection communities, as well as engaging the communities dealing with climate-related challenges in biogeochemistry, air quality, marine and terrestrial ecology, etc.)

B. Kirtman, V. Ramaswamy, J. Slingo, V. Kattsov

The last three decades has seen impressive successes on both weather and climate modelling fronts. For example, in NWP, there has been significant progress in forecasting extreme events and extending the range of predictability. Over the same period, climate modelling on the decadal to centennial timescales has progressed from atmospheric models to coupled atmosphere-ocean models to fully coupled Earth system models, incorporating increasingly realistic physical, chemical and biological processes that seek to capture the range of interactions spanning the atmosphere, oceans, cryosphere and biosphere. At intermediate timescales, such as season-to-decade/s, many modelling centres around the world now are conducting research on and producing numerically-based seasonal predictions using observed initial conditions that extend beyond the period of conventional deterministic predictability. The range of variables in weather prediction has extended from traditional meteorological variables (e.g., temperature, rainfall) to wave and swell forecasts, air quality, visibility and, in the case of seasonal prediction, crop production. In climate modeling, and for timescales longer than seasonal, the focus of the projections and experimental predictions has included model integrations for unforced and forced conditions, investigated the interactions leading to variations and change in climate parameters of interest, and sought to understand the causes and consequences with regards to the past, present and projected future climates.

The science and applications of weather forecasting, seasonal forecasting and climate prediction and projection are thus rapidly becoming intertwined, both in terms of complexity and importance to society. Progress made in one area for a particular timescale is being envisioned to add knowledge or, even better, accelerate improvements for all timescales. There is a growing societal demand for environmental predictions that include a broad range of space and time scales, and that include a complete spectrum of physical processes (e.g., meteorology, oceanography, hydrology, biogeochemistry, ecosystems, air-quality, fisheries, costal zone science…). Meeting this demand necessitates exploring unified approach/es in model parameterizations, resolution, tests, verifications against the real world phenomena, and focused simulations and applications. These will challenge the traditional boundaries of looking at weather, climate, water and environmental science. The need arises for a broader scope accounting for the interactions amongst the components of the conventional physical climate and the emergent Earth System concept, along with a dedicated computational infrastructure and identifying commonalities in the ongoing thrusts of the climate modelling communities (e.g., CMIP5, CFMIP…). This has to be performed on a platform of credible and transparent science that informs in a timely manner the predictions and projections and their impacts and uncertainties to society and decision makers.

On the basis of the above, this white paper offers a few points below for enhancing, enabling and accelerating collaboration among the various climate science communities (numerical weather prediction (NWP), seasonal to interannual prediction and climate projection communities, and those dealing with and requiring information involving biogeochemistry, air quality, terrestrial and marine ecology, etc). The end-goal is one of science-based models that will provide improved predictions and physical understanding across all time scales, with WCRP anchoring and promoting the endeavor. It is important that the scientific underpinnings establish the credibility of the model-based data, information, explanations and predictions/projections.

Recommendations:

1) *Improving models for obtaining practical yet accurate simulations* is a major issue, with the need to be increasingly more realistic and enabling an increased scientific understanding of climate, climate variations and change. It is necessary to proceed on interdependent fronts such as better representations of processes governing climate, obtain a better characterization and quantitative understanding of the uncertainties, and derive improved accuracy of climate information at regional spatial scales that are of societal interest (50 km and finer?). The resolution issue has in recent times received much positive visibility especially as high-performance computing capacity available for climate modeling has increased and afforded perspectives into higher-resolution model simulations. In the context of the global general circulation, capturing the realism of the processes that determine climate, and simultaneously addressing key problems in climate variations and change will require a tight, calibrated balance between increased resolution, incorporating the complexity of process parameterizations, reducing the uncertainties in the physical climate system, and performing integrations for a range of scenarios. This is intellectually and logistically challenging, and is perhaps best addressed in measured steps that ensure traction and progress towards the objective. **How**: Attention on the convection-clouds-weather-climate problem could become a major WCRP focus, since this remains a fundamentally unresolved problem occurring on both weather and climate timescales. Addressing this key problem would be a compelling motivation and could be a testbed for exploring other interactions across the timescales (and even space scales). There is considerable evidence that cloud biases in climate models begin occurring at the weather timescales itself. Testing of climate models for shorter timescales e.g., in the simulation of seasonal-to-decadal phenomena and the process interactions that govern the ability of models to represent this accurately, would be useful. The experience of CMIP5 (about to commence) as well as tests performed by some of the weather forecasting centers recently could also prove useful.

2) *Develop process-level understanding on the weather and climate timescales* including how these affect the ability of the models to simulate phenomena including on regional scales. The knowledge gained herein should aid improvements to model parameterizations. Investigations into the sensitivity to initialization in the coupled atmosphere-ocean framework, are important. Providing feedback from model experiments in the regional to global contexts for particular process interactions with the climate system (e.g. carbon-permafrost, forest fires, dust storms, etc.) would strengthen the applicability of the simulations. **How:** It will be critical to initiate the necessary dialogue and communication not just with the few groups that are working on selected components of global ESM development, but those that are in a position to implement new components based on, and building from previous and ongoing model development activities. WCRP's large-scale outcome-oriented "grand challenges" approach should be extended over IGBP[1] and other major programmes to formulate across-programme "grand challenges". WCRP Modelling Council could take lead in such effort.
3) *Develop a collaborative (TIGGE and CHFP communities) prediction program* focused on examining state-of-the-art NWP model in coupled ocean-atmosphere mode. This would involve sharing models, data, and assimilation systems. The coupling to the ocean could be accomplished via sophisticated ocean mixed-layer models or with full OGCMs. The emphasis should be on the organization of tropical convection on time-scales of hour to seasons. Confronting with available observational estimates would be a key component of the activity. **How:** Envision a YOTC-TIGGE-CHFP working group committed to implementing some demonstration project.

---

[1]The recently initiated joint WCRP/CliC and IGBP/AIMES project CAPER – "Carbon and Permafrost" – addressing feedback between the warming climate and additional emission of GHGs into the atmosphere from thawing permafrost – is an example of an across-programme "grand challenge": (http://www.climate-cryosphere.org/en/themes/IntegrationInitiative/CarbonPermafrost.html).

Numerous cross-disciplinary components possible (e.g., air-quality, costal zone science, hydrology, fisheries) through application modeling. Perhaps even ecosystems could be entrained.

4) *Multi-model analysis* is ideal for fostering collaboration among institutions, and, in part examines how model formulation uncertainty (across time and space scales) contributes to forecast/projection uncertainty. However, it is ad-hoc and does not get at the fundamental question of including a model of the model uncertainty in the evolution of the prediction system. Moreover, increasing number and complexity of the models leave poor chances for decreasing forecast/projection uncertainties in the foreseeable future. Additionally, optimum sizes of multi-model ensembles, discrimination of models to be used in ensemble, etc. remain high on the list of challenges facing the scientific community. A coordinated effort at quantifying uncertainty due to model (e.g., climate models, air-quality models, coastal models, ecosystem models, hydrologic …) formulation that cuts across weather and climate time-scales is required.
   How: Quantifying uncertainty workshop leading up to coordinating modeling efforts. Additionally, CMIP5 provides a near-term opportunity to address some of these issues. Formulating and undertaking is recommended of a number of coordinated multi-aspect studies based on CMIP5 output. WCRP Modelling Council could facilitate this effort by compiling a list of major study areas and approaching research groups with a request to organize and coordinate corresponding targeted diagnostic projects.

Promoting model development

A Discussion Paper for input into the WCRP Modeling Council

C. Jakob, K. Trenberth, T. Shepherd, D. Bromwich

What is model development and how is it approached?

Contemporary numerical models used in weather, seasonal and climate predictions have evolved tremendously over the last decades. All of them now contain complex process representations leading to an increased emphasis in model development through process studies. At the same time, many models are used in a set of applications (e.g., NWP, seasonal and climate prediction, reanalysis) and as a consequence their development must also be driven by shortcomings in those applications. Successful model development requires uniting the application-driven and process- and phenomena-driven approaches to model development, a task that requires the collaboration among different communities and which has proven quite difficult so far (Jakob, 2010). It is important to recognize the complexities of the model development process in our discussion on how to best promote future model development.

Key opportunities for model development

Recent advances in many areas provide new opportunities for model development. New observations both at the global and process level provide new avenues for model evaluation and development. Advanced computing resources also enable new approaches to model development such as high resolution and advanced process modeling. They also provide new opportunities for a better statistical quantification of model behavior through ensembles as well as an increase in model complexity through the inclusion of additional processes. Bringing the new observational and modeling tools together will provide new pathways for model diagnosis and improvement.

Models underpin not only our scientific activities but just like in NWP to date they will provide the foundation for the predictive tools of the newly emerging climate services. Continuous development of modeling tools has been a major contributor, together with advanced observations and improved data assimilation methods, to the notable improvement in numerical weather forecasts. For climate services to be successful it is therefore imperative that model development becomes a central activity and that it receives the support of the entire community.

Challenges and Needs

Modern model development faces a number of challenges, both scientific and “cultural”. First, the application-driven and process-driven strands of model development are too loosely linked. Second, the number of researchers actively engaged in model improvement is far too small compared to that of model users. Given that it will be models that underpin many of the future climate service products and activities, this challenge needs to be met with some urgency. Finally, the challenge of balancing increased model complexity (i.e., new model components), model resolution (both in the horizontal and vertical) and increased process realism (i.e., the more sophisticated representation of a particular process) remains ever present. From the above derive a number of key needs for model improvement. Perhaps the most pressing need is to

- Increase the number of model developers in the classical sense (people who actually implement ideas into GCMs). Many cultural issues need to be overcome to achieve this.

There are a number of additional needs if we are to succeed in accelerating model development:

- *Key need 1:* Enhance research into advanced diagnostics to better connect the various pathways of model development to identify true (rather than perceived) needs for progress
- *Key need 2:* Expand research into high-resolution models as test-beds for their lower-resolution counterparts
- *Key need 3:* Promote the seamless approach to model development and evaluation
- *Key need 4:* Increase the interactions across disciplinary boundaries, to better understand model weaknesses that involve couplings between different climate system components
- *Key need 5:* Increase the interactions between modelers and observationalists, to better make use of existing observations to constrain model behavior
- *Key need 6:* Execute process studies, including field programs, targeted at specific problems identified in models
- *Key need 7:* Develop the observing system to include observations, both as short-term and sustained observations, that target specific model weaknesses
- *Key need 8:* Promote increased interactions among the modelers on different scales, such as those dealing with detailed hydrology in a catchment, to regional models, to global models, and ensure the robustness and transferability of results among regions.
- *Key need 9:* Increase use of assimilation and reanalysis with models to identify shortcomings and ways forward, as a key activity where models are confronted by observations.
- *Key need 10:* Develop a focus on extremes and model performance in this area, with a special focus on the phenomena responsible for extremes, including blocking (drought), tropical storms (flooding, wind storms), and so on.

The issues above are not new and were clearly expressed in the recent modeling survey and at the Modeling Summit in 2008. Strategies and specific activities to address the above needs are discussed in the final section of this document following a brief discussion of the current organization of model development in WCRP and its strength and weaknesses.

Current organization of model development in WCRP

There are many research groups around the world devoted to improving parameterizations and models. While there is some keen competition among groups and countries, there is also strong cooperation. Traditionally model development has been focused in large modeling centers, but more recently a thriving university community that wishes to participate in the model development process has emerged in many countries. WCRP's role in model development is therefore one of coordination and facilitation of the widely distributed efforts as well as the promotion of the importance of model development.

At the level of some applications, model development is very well structured in WCRP through a number of working groups, which directly link to the relevant modeling centers and communities. These are WGNE (mainly NWP), WGCM (mainly climate models), and WGSIP (mainly seasonal prediction). This model of organization has worked well as much of the model development has taken place in the big centers. It is crucial that the strong relationship with those centers be maintained in any future organizational model while at the same time better integrating the academic sector in our activities. Not covered by these is the more detailed small scale modeling such as the hydrological modeling in watersheds and catchments and how to ensure they are robust when applied to different areas.

Process-oriented model development is distributed throughout the WCRP projects. In some instances it is well organized, in others less so. For example, the ocean modeling community has a dedicated Working Group on Ocean Model Development in CLIVAR and regional land modeling is quite well coordinated in GEWEX through GLASS. The new GEWEX Hydroclimatology Panel (GHP) provides a framework for the hydrological modeling. Atmospheric modeling is more disperse with activities spread across GEWEX (atmospheric physics), SPARC (atmospheric chemistry, gravity-wave drag, and stratospheric dynamics), and CLIVAR (tropical dynamics and physics). Ice modeling has so far not received the same level of attention and visibility as the other components.

While extremely successful in an overall sense, the above organization of model development has some potential weaknesses, such as:

- Atmospheric model development appears to be scattered and too loosely coordinated. Recent efforts for coordination, e.g., through WGNE show early signs of improvement.
- Ice model development is not well integrated into WCRP.
- Hydrological modeling is inadequately linked to regional and global modeling.
- Diagnostic activities are frequently not or only loosely tied to development activities.
- Many existing connections occur as an afterthought, rather than being built into the program.
- The scattered approach together with cultural issues (e.g., measures of scientific success) makes it difficult to consistently promote the need for further development of existing model components. This has led to an emphasis on new components that increase complexity (e.g., aerosol indirect effects, dynamic vegetation, etc.) often without addressing existing big or longstanding problems.
- Model development often takes place at low levels in the structure with very little visibility to partners and funders and with very little reward.

Approaches to promoting model development in the future WCRP

From the above discussion we can derive a number of conclusions for the future organization of model development in WCRP (and beyond) and for some specific activities that should be undertaken to promote this very important activity with the clear goal to grow a larger and stronger model development community worldwide that is able to address the challenges inherent in the provision of world-class climate services to the community. Successful model development in WCRP will require:

- Dedicated and clearly identifiable model development programs covering the full scope of WCRP activities that are well coordinated at higher level.
    - Practical steps:
        - Implement a Modeling Council
        - Charge the Council to identify all existing activities potentially relevant to model development with the goal to build stronger connections among them, and identify gaps.

        - Charge all projects and WGs to actively promote model development activities where possible.
- The maintenance and strengthening of the connections to the modeling centers.
    - Practical steps:
        - Maintain the three major working groups, which have well-established connections with the modeling centers, and charge them with specific tasks regarding model development in coordination with the core projects.
        - Consider other ways of raising the visibility and providing focus on model development.
- The promotion of a stronger link between observations, model assessment and model development.
    - Practical steps:
        - Dedicated workshops that aim at high-priority model problems and unite the observations, process, theoretical, model-evaluation and model-development communities. Initially those meetings should aim specifically at long-standing issues (e.g., tropical biases, diurnal cycle, etc.).
        - Design new coordinated diagnostic activities with the specific goal of model improvement (e.g., MJO and CCMVal efforts as well-working examples)
        - Utilize information about evaluations of reanalyses with models to highlight shortcomings and biases (such as imbalances in mass, energy, water, and other physically constrained quantities; and analysis increments).
- The promotion of a stronger link between the computational/mathematical and model-development communities, to take advantage of emerging science in model development.
    - Practical steps:
        - Dedicated workshops that bring together the computational/mathematical and model-development communities, to discuss new approaches (e.g., new grids, stochastic parameterization).
        - Pilot studies that test the benefit of new approaches for specific applications.
- Promotion of the seamless approach through high-level coordination
    - Practical steps:
        - Strengthen the collaboration on model development amongst the WCRP groups and with the relevant CAS groups. This would be a role for the Modeling Council making extensive use of existing links, e.g., through WGNE.
- Promotion of growing the model development community. This will require overcoming a number of cultural issues (e.g., funding models, reward systems) and therefore requires funding agency and modeling center buy-in. Since some of these cultural issues are somewhat different in different countries, a number of parallel approaches will be required.
    - Practical steps:
        - A dedicated cross-project and cross-community outreach program for model development promotion (not unlike an endangered species program) implemented and overseen by the JSC. This program must highlight model development as the foundation of many of our activities and must aim at increasing the relative effort in model development across the community.
        - Sharing of “best practices” between different centers and countries.
        - Strengthening the link between model development and “new science”, to make model development more attractive as a career choice for young scientists.
        - Building the case for model development by orchestrating or facilitating studies that can provide a quantitative link between model weaknesses and uncertainties in projections of key quantities needed for climate services and other applications.
        - Regular Model development workshops organized by the main Working groups (see 2010 JSC White paper).

- Make special efforts to include model developers in the broad WCRP activities (e.g., special sessions at conferences, special presentations to the SSGs and JSC, etc.).
- A clear statement in all programmatic documents of WCRP's commitment to model development with clearly identifiable links to the new structure.

Appendix A – A GEWEX perspective

By K. Trenberth

From the pan-GEWEX meeting in August 2010, it was suggested that there should be a new modeling activity established to deal with atmospheric processes important for climate. This might be a panel or a working group that should be thought of as similar to WGSIP. The presumption here is that WGNE remains more oriented to NWP.

1. From GEWEX, it is further proposed that there should be a panel or WG which should have its base in GEWEX but should be a WG for all WCRP projects. In particular:
2. There should be a modeling group in WCRP devoted to atmospheric processes and model development important for climate: perhaps called the WG on atmospheric processes (WGAP):
    1) It would include GCSS and GABLS, which would be somewhat reformulated with different structure than at present, overseen by a steering committee
    2) It must be oriented to climate modeling and seamless prediction
    3) It should reside in GEWEX but must have strong links to CLIVAR, SPARC and CLIC. It could include activities like the MJO CLIVAR group.
    4) It should have strong links to YOTC, THORPEX, WWRP, and WGNE.
3. There should also be a major land-surface processes and modeling activity in GEWEX that is closely linked to the observations and field programs. This is GLASS Plus, and includes aspects of the former CEOP (now GHP) modeling and monsoon modeling.
4. Some consolidation of current groups is desirable, perhaps with reformulations.
5. Within GEWEX, GMPP is not needed and has been eliminated. Instead the two groups above (GCSS/GABLS and GLASS) should represent GEWEX in the modeling council, WGNE and at the GEWEX SSG.
6. This may still leave the hydrological modeling in GHP without a representative in the modeling council.

Promoting application of models to problems of societal relevance, quantifying uncertainties and ensuring they are well communicated and understood

T. Palmer, C. Jones, J. Hurrell, J. Petch, G. Danabassoglu, M.Latif

The topic of this paper splits into two halves. The first half deals with the difficult question of how to quantify the inevitable uncertainties that exist in climate predictions, and the second half deals with the key problem of making climate predictions useful, given these uncertainties.

1. Quantifying Uncertainty in Climate Predictions

Elements of the Problem

Sources of uncertainty in climate models include initial condition uncertainty (essentially equivalent to uncertainties associated with internal chaotic variability of climate), uncertainties in our computational representations of the underlying equations of climate, and uncertainties in "externalities" such as anthropogenic greenhouse gas emissions, solar radiation and volcanoes. We deal with these externalities by speaking about projections (for a given scenario), rather than predictions per se. In any case, for projections up to a few decades ahead, scenario uncertainty is not considered a dominant source of uncertainty compared with initial condition and model uncertainty. Efforts to predict the evolution of climate over the next several decades that take into account both forced climate change and natural decadal-scale climate variability are in their infancy. Many formidable challenges exist, including the need to initialize models with the best estimates of the current observed state of the atmosphere, oceans, cryosphere, and land surface – a state influenced both by the current phases of modes of natural variability and by the accumulated impacts to date of anthropogenic radiative forcing. However, given imperfect observations and systematic errors in models, the best method of initialization has not yet been established, and it is not known what effect initialization has on climate predictions. Several whitepapers exist on the decadal prediction problem (e.g., OceanObs09), so here we concentrate solely on model uncertainty.

The presence of uncertainties means that our understanding of the Earth System is incomplete. For instance, we do not know whether, even at short time scales up to a few decades, modest radiative forcing will give rise to highly nonlinear behavior in certain subsystems which may reflect itself in rapid climate change. No model, for instance, foresaw the recent very strong Arctic sea ice decline. Another example of an unpredicted fast climate change is the appearance of the Antarctic ozone hole in the early 1980s. At longer time scales, carbon cycle feedbacks are generally assumed to become important. However, we have only a rather rudimentary understanding of the relevant biogeochemical processes, although they may be a major factor determining the level of future global warming by the end of the century. The oceans are subject to many stress factors, not only to global warming, and it is unclear how and on which time scales processes such as acidification affect marine life and thus carbon cycle feedbacks.

The traditional approach to the representation of model uncertainty (e.g. within the IPCC community) has been to through the multi-model ensemble: an ensemble "of opportunity" provided from the pool of climate models around the world. The need to maintain a "gene pool" of different models is often cited as a key reason why we need to promote the development of quasi-independent climate models. Based on numerous seasonal forecast studies (e.g. DEMETER), the probabilistic forecast skill of a multi-model ensemble outperforms the skill of a forecast system based on any one constituent model. In this sense, the multi-model ensemble is a reasonable pragmatic approach to the problem of representing model uncertainty.

However, there are a number of reasons why the multi-model technique is unsatisfactory and why the community should be thinking beyond this pragmatic approach. For one thing, a multi-model ensemble only provides a limited number of ensemble members with different model formulation, and hence the resulting probability distributions (more accurately, frequency distributions) are not well resolved. This can be problematic for predicting probabilities of extreme events. For another, results are dependent on the pool of models that "happen" to be available at any particular time, i.e. the whole notion is ad hoc. However, most importantly the multi-model concept is theoretically flawed; there is absolutely no guarantee that the multi-model ensemble does indeed span the true range of uncertainty. In fact, it has been shown that the effective number of climate models is much smaller than the number of models within the CMIP ensemble, which suggests that current methodologies for the interpretation of multi-model ensembles may lead to overly confident climate predictions. For example, all models in the CMIP ensemble have limited resolution and all have common deficiencies in terms of an ability to simulate basic aspects of the climatology (e.g. Equatorial Pacific cold bias, eastern tropical ocean warm bias) and key modes of variability, such as blocking, MJO, NAO, QBO, and ENSO. At a more fundamental level, all members of a multi-model ensemble are based on a common ansatz whereby the known partial differential equations of climate are projected onto some (Galerkin) basis, with unresolved scales being represented by deterministic bulk formulae. Such bulk formulae assume that, within each grid point, there exists a large ensemble of sub-grid processes (such as convective systems) in quasi-equilibrium with the gridscale flow. Attempts to validate the parameterization process quantitatively using process models such as cloud resolving or large eddy models cast doubt on the validity of this assumption. Furthermore, the response to external forcing may be not well described in the models due to the neglect or too simple representation of important climate subsystems such as atmospheric chemistry; e.g. the climate response to solar forcing may involve changes in ozone chemistry which can feed back, for instance, on the NAO. The "perturbed parameter" approach overcomes the problem of insufficient ensemble sizes; a "perturbed parameter" ensemble can be run with arbitrarily many ensemble members. If parameter uncertainty is merely epistemic, then we can certainly represent this uncertainty by drawing parameter values from some underlying probability distribution. But what, if the source of parameter uncertainty lies in a more systemic error with the concept of bulk-formula parameterization, e.g. that, following the lines of the discussion above, the notion of quasi-equilibrium is invalid. Then parameter uncertainty is ontological and there will exist no set of parameter values which describes the true subgrid tendencies.

This is a real and fundamental problem to which a solution has yet to be found. We need literally to go back to basics and study coarse-grained statistics from observations or process models to find alternative and innovative ways to represent mathematically the processes which climate models cannot resolve. Also, the grid-length, domain sizes and physical complexity required by the process models themselves to advance our knowledge of the interaction of physics with the large scale is not well understood. We do know that models with explicit convection (i.e. no convective parameterizations and grid-lengths of 1-10 km) do capture some aspects of the interactions but it may well be the case that we need to resolve even smaller scales to understand the true statistics. Besides the use of large-scale process models, another useful tool for advancing our understanding in this area is the so called "superparameterization" framework. This work is based on embedding simplified cloud system resolving models within global climate models which can explicitly capture convection but does still impose the same scale break as traditional parameterizations.

A new programme of work has sprung up around the concept of "stochastic parameterization" which in its broadest expression, encompasses this goal of finding new and innovative mathematical methods for attacking the parameterization problem by including an inherent and integral (i.e. not “backstitched”) representation of uncertainty in the subgrid representations. Stochastic parameterization was originally developed to improve the spread of ensemble forecasts in the context of numerical weather prediction and its extension to the climate arena is an example of the “seamless approach” emphazised in WCRP’s strategy. The development of stochastic parameterization has the potential to both reduce model bias and to give more reliable estimates of prediction uncertainty, than are possible using multi-model ensembles.

Impediments to progress, and a role for WCRP to accelerate progress. Relevant partners.

The representation of uncertainty is key for engaging with the user community. The approaches discussed above are something which weather and climate centres have limited time and resources to research, and in any case they are strongly constrained by deadlines, either for operational implementations, or for IPCC commitments. In this respect WCRP could play a critical role in engaging the traditional parameterization and process modeling community (in both weather and climate) on the one hand, with a new community of mathematicians, physicists, dynamical systems theorists, and statisticians on the other. Similar considerations apply also to other climate subsystems. The effect of mesoscale (baroclinic) oceanic eddies on the large-scale ocean currents, for instance, is relatively unclear in certain regions (e.g. the Southern Ocean). In contrast to the atmosphere, we will not be able to explicitly resolve them in standard CMIP-type ocean models during the next years.

Hence we propose a new area for WCRP to support: on the representation of uncertainty in weather and climate prediction, with an inherent link (e.g. through the stochastic parameterization programme) to the issue of finding fundamental new ways of representing computationally the equations of climate. This is an area where different modeling groups within WCRP need to interact (process modeling, NWP, Seasonal and IPCC) with the additional impact of the other more mathematical communities, external to WCRP, already mentioned. Finally, such a group should be complemented by experts in computing hardware. For example, there have been potentially important developments in the concept of “probabilistic chips” in the computing industry, and these may provide new opportunities to climate modelers involved, for instance, in stochastic parameterization.

Finally, we need to address the issue of uncertainty arising from adding more climate subsystems, as climate research is moving toward Earth System research. This by itself may significantly increase model uncertainty, not only because many processes (such as biological) are not based on known principles. Atmospheric chemistry, for instance, is a highly complicated field and requires the inclusion of many reaction equations, which needs large additional computing resources. This sets limits to the resolution used in the classical subcomponent models.

The development of reliable ways to predict uncertainty in climate projections is key to the problem of promoting applications of climate models, a topic which is addressed in the second part of this paper.

2. Promoting applications of models to problems of societal relevance

In the context of climate prediction and future climate change, models have the **potential** to play a central role in the provision of information to support decision-making. This potential is central to the aspiration of developing a climate service sector, whereby the climate science community routinely provides climate data to support societal applications. Part II of this paper discusses some of the steps necessary if this potential is to be realized.

Learn from the past: Look closely at, and learn from, past experience. Here we refer to weather/ocean forecasting and seasonal prediction. Lessons can be learnt both from successes and failures.

Science is not politics: We must not (!) reach a consensus and have not to consider all models worldwide in our assessments. Some models are seriously flawed, and this can be told without much in-depth analysis. We need some type of quality control. WCRP must spell this out.

Engage with the user early and stay engaged. Listen carefully to the envisioned user(s) and engage them as early as possible in defining the problem to be addressed. Experience has shown that scientific quality in a prediction (**usefulness** as defined by the data provider) does not necessarily translate into **usability**, as defined by the intended recipient. To avoid this pitfall requires a sustained engagement with the intended user and a two-way dialogue where the user describes the problem to be addressed and, in their view, the climate data required. The data provider needs to understand the practical problem to be addressed and explain to what degree the climate data requested can be provided, including an understandable explanation of the data limitations, uncertainties and robustness. The data provider should remain engaged with the user throughout the process of applying data, from it's generation right through to the practical decision step. Such a sustained engagement is unlikely to be best achieved by a climate research institute; rather boundary organizations should play this role. Such organizations can be seen as communication intermediaries between climate scientists and data users.

Climate is only one factor in decision-making. Adaptation and decision making is a societal process, involving numerous decisions, where climate is only one of many factors influencing the decision-making process. It is therefore important to engage with users to determine what in the full portfolio of climate information is actually of use in addressing various problems. Again there is a need to distinguish **usefulness** from **usability**. Usability is based on the user perspective of what they require to address a given problem. It is this requirement that must be met by the data providing, climate community.

Communication is critical. Uncertainty is sometimes interpreted by users as misinformation or as a reason to put off a decision until uncertainty is reduced. Inherent uncertainties in climate data need to be fully explained without damaging the credibility of the data. It is important to explain that uncertainty, or the potential for different future climate outcomes, is an inherent part of climate prediction that will never be completely eliminated. Communication and explanation of uncertainties (or spread) in future climate predictions needs to be a continuous process, to help the user understand that an increased spread in predictions does not always mean reduced quality or usefulness. The continuity of communication is also critical so users appreciate how new climate information relates to past data, whether and how it adds value and how updated information should be used in a planning process already underway. It is important the climate community uses a common and accepted language to explain climate prediction uncertainty. To the extent possible, the same type of language should be used in all forms of uncertainty communication, written and oral.

It needs to be explained to politicians that uncertainty, even if large, does not necessarily mean not to act. Dealing with uncertainty is an integral part of our daily life. Consider, for instance, an airplane which will crash with a probability of only ten percent. Nobody would board the aircraft.

Sources of information matter. Users prefer to source their data from local experts. The importance of this should not be underestimated in influencing the practical take-up of climate information. Users have a perception that local scientists have the most knowledge about local climate processes and thereby are best placed to support their needs. The importance of a continuous dialogue between the data provider and data user also points to a local engagement as being the most sustainable option. In presently low-capacity areas of the world this points to a need for capacity building of scientists that can become fully engaged in the generation, evaluation and use of climate data in their region.

Provide data at the scales required. Due to computational limitations, Global Climate Models (GCMs) typically use a grid length of ~100km, providing "reliable" information at best on scales of 500 km or an area of ~ 250000km^2. This may improve in the next 5 years towards ~20km grid-lengths but this still means "reliable" data delivery will be on areas of ~10000km^2. Most impact models and societal decision-making occur on highly localized scales. Hence some form of regional to local downscaling is required. Traditionally this has been through statistical or dynamical downscaling, with little formal standardization of methodologies and guidance on best-practices. With the increasing availability of 'off-the-shelf' downscaling methods, there is a risk the adaptation and decision-making communities use questionable downscaling methods, in a black-box approach, to generate themselves the high-resolution data they require from GCM output. Such an approach may seriously undermine the quality of climate data used in the decision-making process. To address this, the downscaling community requires a mechanism to regulate itself, facilitating the development of best-practice guidance accepted by the community and backed up by some form of accountability.

The downscaling community must also know about the systematic errors in the large-scale models. There is no point to downscale results from a seriously flawed model. The inability of many large-scale models to realistically simulate blocking as noted above is an example. A downscaling using results from such a model with the aim to derive future changes in drought frequency probably yields unreliable results.

Recommendations to WCRP on promoting the application of model data to problems of societal relevance.

1. A partnership system is needed, combining science-driven research with user-driven requirements. This could occur through a WCRP-sponsored activity centred on a limited set of practical applications of climate data and include a full range of required experts in a common chain of activities, from data generation, impact analysis to decision implementation.

2. WCRP should organize regular workshops (bi-annual?) where climate researchers, impact and adaptation scientists and decision-makers meet to better understand the work carried out in each respective sector. Such a workshop should be linked to the practical projects suggested in point 1.

3. WCRP should support capacity building of local climate expertise in, presently, low-capacity regions of the world, making sure data and training in the analysis and use of such data is fully supported.

Role and terms of engagement for the WCRP Modelling Council

Sandrine Bony, David Griggs, Jochem Marotzke, Hervé Le Treut

Why a WCRP Modelling Council?

The World Modeling Summit recognized the important and urgent need to accelerate progress in improving operational climate prediction at all time scales, especially at decadal to multi-decadal lead times, from regional to global scales.

Current WCRP modelling activities are organized through numerous groups, panels and working-groups. The interactions and the integration between these different activities have greatly increased in recent years.

Nevertheless, progress is needed to:

- Advocate for the challenges and needs of the modelling community through a unified voice
- Devise a strategy to tackle ambitious or emerging science projects
- Facilitate the communication, coordination and integration of modeling activities across WCRP
- Foster bridges between WCRP and other partners, especially the weather community and IGBP
- Fill gaps and promote critical activities across panels and projects

The need for progress in these different areas is a clear outcome from the WCRP community-wide consultation on Model Evaluation and Improvement.

Key activities that WCRP aims to promote in the future include:

- Model development and improvements
- The confrontation of models with observations and results of process studies
- The collaboration amongst various climate science communities (including those dealing with numerical weather prediction, seasonal to interannual prediction, climate projection, as well as biogeochemistry, air quality, terrestrial ecology, etc.)
- The application of models to problems of societal relevance, quantifying uncertainties and making sure they are well communicated and understood

To better reach these goals, a recommendation of the Joint Steering Committee 31st session was the formation of a WCRP Modelling Advisory Council.

Main Goals and Terms of Reference of the WCRP Modelling Advisory Council:

The WCRP Modelling Advisory Council would have 3 main goals:

- To act as a focal point for climate modeling in WCRP
- To help identify grand challenges and advance them

- To help coordinate modeling activities by identifying gaps and reducing unnecessary duplication

To reach these goals, the role of the WCRP Modelling Advisory Council should be:

- To assess strategic priority aims for modelling across WCRP
- To assess current capabilities for WCRP, in collaboration with other partners, to meet these aims
- To advise and recommend to JSC activities to be carried out across WCRP projects and programs and collaborations to be developed between WCRP and other partners (including the weather community and IGBP) to meet the priority aims
- To facilitate and enhance the communication and the coordination across the various WCRP modeling groups
- To be a clearing house for exchange of information between modelling groups and the JSC
- To help the WCRP modelling community speak from a common voice to external bodies such as IPCC, climate services or funding agencies.
- To help convey modelling needs to observation panels
- To help the modelling community deal with supercomputing challenges, and advise new supercomputing centers about climate modelling needs

Membership:

The members of the WCRP modelling Advisory Council should at least include:

- Co-chairs of the different WCRP modelling panels and working-groups (e.g. WGNE, WGSIP, WGCM, WGOMD, TFRP, GCSS/GABLS, GLASS, CCMVal, GPC, CFMIP, PMIP)
- Representatives from the Observation and Assimilation Council
- Representatives from other international programmes (e.g. CAS, IGBP)
- Co-chairs from WCRP projects GEWEX, CLIVAR, SPARC, CLIC (unless they can be represented by the co-chairs of their modeling groups)
- Representatives from application modelling
- Representatives of projects of special interest for WCRP modelling such as: YOTC/MJO
- A few JSC members

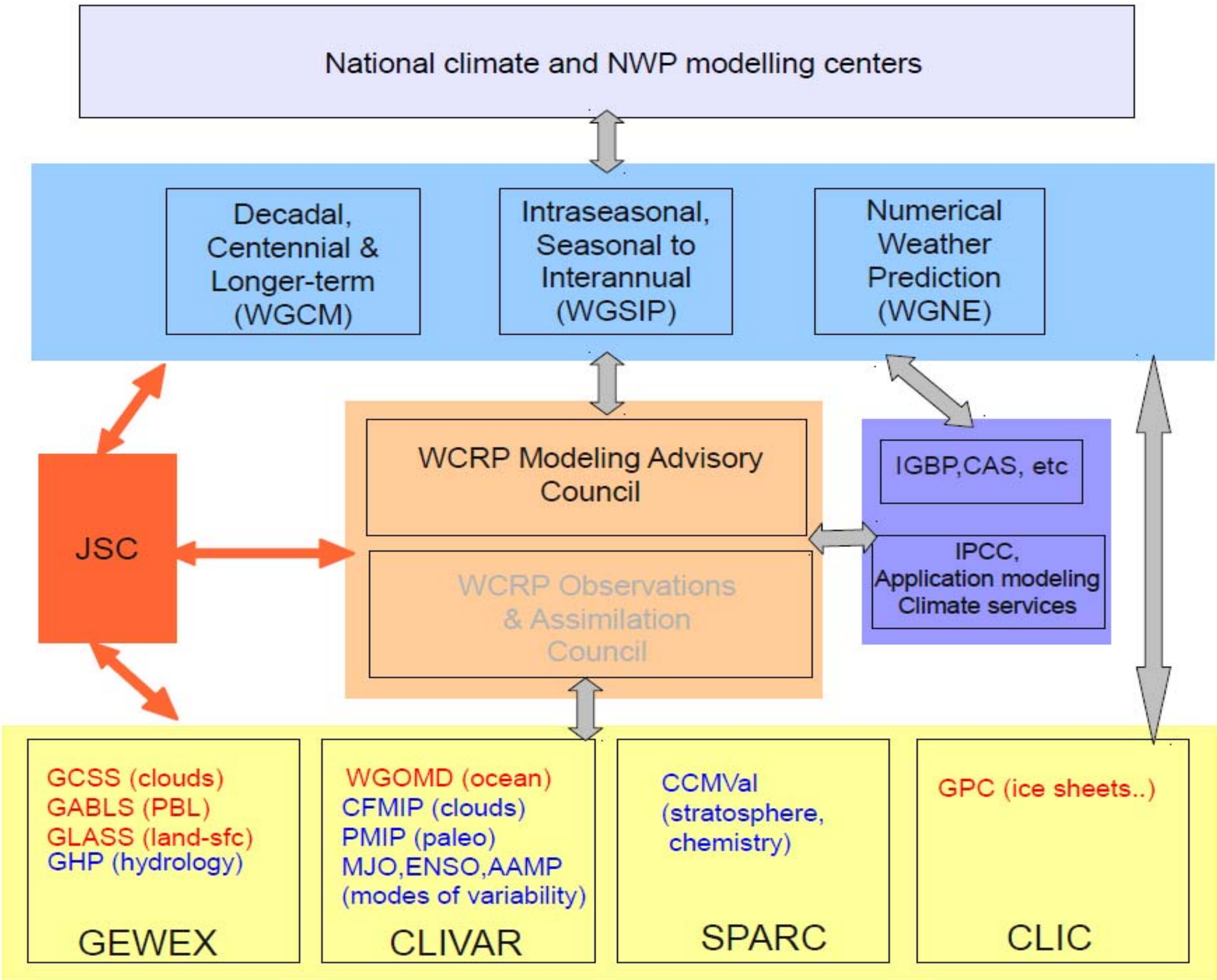
The Chair of the WCRP Modelling Advisory Council:

- should not be a JSC member
- would preferably be a former co-chair of a WCRP modelling group that has rotated off
- would have a rotating position of 2-year term

Mode of functioning:

The WCRP Modeling Advisory Council is expected to:

- Communicate regularly by e-mail
- Meet at least once a year during the annual JSC meeting
- Encourage occasional joint meetings of working groups or panels to promote communication or to launch focused joint initiatives
- Not be a substitute of existing working groups or panels


National climate and NWP modelling centers
Decadal, Centennial & Longer-term (WGCM)
Intraseasonal, Seasonal to Interannual (WGSIP)
Numerical Weather Prediction (WGNE)
JSC
WCRP Modeling Advisory Council
WCRP Observations & Assimilation Council
IGBP,CAS, etc
IPCC, Application modeling Climate services
GCSS (clouds)
GABLS (PBL)
GLASS (land-sfc)
GHP (hydrology)
GEWEX
WGOMD (ocean)
CFMIP (clouds)
PMIP (paleo)
MJO,ENSO,AAMP
(modes of variability)
CLIVAR
CCMVal
(stratosphere, chemistry)
SPARC
GPC (ice sheets..)
CLIC

Summary of Discussions and Conclusions

The presentations and discussions during this meeting resulted in some general agreements and some specific concerns and reservations by some participants. The concerns expressed were based on the past experience associated with the WCRP Modelling Panel (WMP) functions and structure and they are reflected in the overall conclusions and recommendations listed below. The workshop participants agreed that;

- A WCRP modelling coordination council is essential and it should focus on coordination and integration of modelling activities across WCRP Projects and Panels, and with the WCRP partners (e.g. IGBP and WWRP).

- The Modelling Council should promote model development, evaluation and applications in a way that makes the whole Programme activities greater than the sum of individual Working Groups and Panels through "grass roots" efforts and not a "top-down" approach.

- The Modelling Council should build on the strengths of the existing modelling activities rather than duplicate or re-create new ones, unless it is found absolutely essential, e.g. WCRP new initiative in regional models and downscaling.

- Develop an overall modelling strategy for the Programme with associated governing mechanism(s) to implement it, based on the principles stated above for review and discussion by the JSC. Some examples of major topics that the strategy may encompass are:

    - Model development
    - Model evaluation
    - Uncertainty analysis
    - Greater use of observations in model development, evaluation and analysis
    - Common software and standards in modelling
    - Modelling Summit recommendations

The participants were emphatic about the difficult lessons learned by the "top-down and centralized" approach used in the past because such approach was not be consistent with the "grass roots and voluntary" approach that has been the hallmark of WCRP past successful efforts. There were considerable discussions on the membership and functions of the Council that are summarized in Bonny et al. paper. In light of increased complexity in models, i.e. Earth system and seamless approaches, the participants recognized the need for greater collaboration with sister programmes such as the IGBP, WWRP, etc. Thus, there was considerable discussion about whether the representatives from such programmes should interact with the Modelling Council as full or ex-officio members. The general conclusion was to wait until the Council is fully functional and engages in some activities of common interest with these programmes to find out what is the most effective way to forge such partnership arrangements.

There was also some discussion on the GEWEX modelling activities. The participants supported unanimously a proposal by GEWEX to re-organize some of its modelling activities for greater coordination both within GEWEX, and with the pan-WCRP modelling activities. A proposal for establishing the Framework for Atmospheric Model Experiments (FAME) as a pan-WCRP activity did not receive full endorsement by the workshop participants, because of the redundancy of some of its envisioned functions with existing modelling working group(s) and panels. However, this decision does not preclude the option of using FAME as a mechanism for coordination of pan-GEWEX atmospheric modelling activities.

The participants identified an urgent need for access to more advanced and powerful computational capabilities, as was called for by the Modelling Summit participants, in light of increased complexity and greater needs for enhanced spatial and temporal resolution in climate model development and simulations. These capabilities are also needed urgently for assimilation, analysis and re-analyses of very large volumes of Earth observations, especially from space-based systems, that are currently available and most likely to further increase in the future. This challenge present a great opportunity for closer collaboration between the WCRP Modelling and Observations Councils to undertake the task of promoting greater coordination of the use of National computational capabilities in the spirit of making the whole greater than the sum of the individual capabilities. There is currently a proposal for establishing an International Center for Earth Simulations (ICES) through a private-public partnership in Switzerland which could also contribute toward this objective. WCRP made arrangements for presentation of this proposal to major modelling groups, centers and professional scientific societies in France, Germany, United Kingdom, and United States. This proposal will be also presented at the WCRP Open Science Conference.

The outcome and conclusions of this workshop will be presented at the 32nd session of the WCRP Joint Scientific Committees on 4-8 April 2011 in Exeter, UK for further discussion. The resulting decisions and recommendations from the JSC meeting will be shared with the participants in WCRP Open Science Conference on 24-28 October 2011 in Denver, Colorado, USA for further deliberation and discussion. The final outcomes will be captured in the overall WCRP long-term research and implementation strategy for the next decade.

List of Participants

Ghassem R. ASRAR
World Climate Research Programme
World Meteorological Organization
Avenue de la Paix, 7 bis
Case Postale 2300
CH-1211 Geneva 2 - Switzerland
Email: GAsrar@wmo.int

Sandrine BONY-LENA
Laboratoire de Météorologie Dynamique (LMD/IPSL)
CNRS/UPMC, Tour 45-55, 3ème étage
4 place Jussieu, boite 99
75252 Paris Cedex 05 - France
Email: bony@lmd.jussieu.fr

David H. BROMWICH
Polar Meteorology Group, Byrd Polar Research Center
The Ohio State University
1090 Carmack Road
Columbus, Ohio 43210 - USA
Email: bromwich.1@osu.edu / bromwich@polarmet1.mps.ohio-state.edu

Antonio J. BUSALACCHI
Earth System Science Interdisciplinary Center (ESSIC)
Suite 4001, M Square Office Building, #950
5825 University Research Court
University of Maryland
College Park, Maryland 20740 - USA
Email: tonyb@essic.umd.edu

Gokhan DANABASOGLU
Oceanography Section
Climate and Global Dynamics Division
National Center for Atmospheric Research
P.O. Box 3000
Boulder, CO 80307 - USA
Email: gokhan@ucar.edu

Veronika EYRING
Deutsches Zentrum fuer Luft- & Raumfahrt (DLR)
Institut für Physik der Atmosphäre (IPA),
Oberpfaffenhofen
82234 Wessling - Germany
Email : Veronika.Eyring@dlr.de

Jim HURRELL
National Center for Atmospheric Research (NCAR)
Climate Analysis Section
P.O. Box 3000
1850 Table Mesa Drive
Boulder, CO 80307-300 - USA
Email: jhurrell@ucar.edu

Christian JAKOB
School of Mathematical Sciences
Monash University
Monash, Victoria 3800 - Australia
Email: christian.jakob@monash.edu

Colin JONES
Head, Rossby Centre
Swedish Meteorological and Hydrological Institute
S-60176 Norrkoping - Sweden
Email: Colin.Jones@smhi.se

Vladimir KATTSOV
Director of Voeikov Main Geophysical Observatory
7, Karbyshev str.
St. Petersburg, 194021 - Russia
Email: kattsov@mail.ru

Ben KIRTMAN
Rosenstiel School for Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149 - USA
Email: bkirtman@rsmas.miami.edu

Mojib LATIF
Ozeanzirkulation und Klimadynamik
-Maritime Meteorologie-
Leibniz-Institut fuer Meereswissenschaften
Duesternbrooker Weg 20 24105 Kiel - Germany
Email: mlatif@ifm-geomar.de

Hervé LE TREUT
Laboratoire de météorologie dynamique
Institut-Pierre-Simon-Laplace
UPMC/CNRS - Case postale 99
4 place Jussieu
75231 Paris Cedex 05 - France
Email: letreut@lmd.jussieu.fr

Mike MANTON
Monash University
83 Websters Road
Templestowe, Victoria 3106 - Australia
Email: Michael.Manton@monash.edu

Jochem MAROTZKE
Max Planck Institute for Meteorology
Bundesstr. 53
D-20146 Hamburg - Germany
Email: jochem.marotzke@zmaw.de

Catherine MICHAUT
Institut Pierre-Simon Laplace (IPSL/UVSQ)
WCRP Support Unit
Quartier des Garennes
11 boulevard d'Alembert
78280 Guyancourt - France
Email: catherine.michaut@ipsl.jussieu.fr

Tim PALMER
University of Oxford
Atmospheric Physics
Parks Road
Oxford OX1 3PU - UK
Email: Tim.Palmer@ecmwf.int

Jon PETCH
Met Office
FitzRoy Road
Exeter EX13PB - UK
Email: Jon.Petch@MetOffice.gov.uk

V. RAMASWAMY
NOAA Geophysical Fluid Dynamics Laboratory
Princeton University
Forrestal Campus
201 Forrestal Road
Princeton, NJ 08540 - USA
Email: v.ramaswamy@noaa.gov

Ted SHEPHERD
University of Toronto
Department of Physics
60 St. George Street
Toronto, Ontario M5S 1A7 - Canada
Email: tgs@atmosp.physics.utoronto.ca

Julia SLINGO
Met Office
FitzRoy Road
Exeter EX1 3PB – UK
Email: julia.slingo@metoffice.gov.uk

Detlev STAMMER

Oceanography and Remote Sensing of the Earth System
Center for Marine and Climate Research
KlimaCampus Universität Hamburg
Bundesstr. 53
20146 Hamburg - Germany
Email: detlef.stammer@zmaw.de

Kevin TRENBERTH
Climate Analysis Section, NCAR
P. O. Box 3000
Boulder, CO 80307 - USA
Email: trenbert@ucar.edu

Agenda

Monday 15 November

12:30-13:30	Registration and Coffee	
13:30-14:00	Introduction and Expected Outcomes	***T. Busalacchi***
14:00-14:30	Modelling Summit Overview and Recommendations	***T. Palmer / J. Marotzke***
14:30- 17:00	Brief Introduction of Five Themes by the Chairs (20+10 minutes)	***Theme Chairs***
17:00-18:00	General Discussions and Next Step	***All***
19:00-22:00	Working Dinner and Continue Afternoon Discussions Restaurant: "Le vin qui danse" 4 rue des Fossés St Jacques – 75005 Paris	***All***

Tuesday 16 November

8:30-10:30	Detailed Presentation of Five Themes, Recommendations and Discussion (60 minutes per Theme)	***Chairs***
10:30-11:00	*Coffee*	
11:00-13:00	Presentation of Five Themes, Recommendations and Discussion (60 minutes per Theme)	***Chairs***
13:00-14:30	*Lunch*	
14:30-15:30	Presentation of Five Themes, Recommendations and Discussion (60 minutes per Theme)	***Chairs***
15:30-16:30	Summary of Discussions and Recommendations (60 minutes)	***Theme Reports/Reporters***
16:30-17:30	Wrap Up and Next Step	***T. Busalacchi***

Themes

1. Promoting the confrontation of models with observations and results of process studies (***V. Eyring, M. Manton, K. Steffen, D. Stammer***)

2. Promoting collaboration amongst various climate science communities (includes numerical weather prediction (NWP), seasonal to interannual prediction and climate projection communities as well as those dealing with biogeochemistry, air quality, terrestrial ecology, etc.) (***B. Kirtman, V. Ramaswamy, J. Slingo, V. Kattsov***)

3. Promoting application of models to problems of societal relevance, quantifying uncertainties and making sure they are well communicated and understood (***T. Palmer, C. Jones, J. Hurrell, J. Pech, G. Danabasoglu, M. Latif***)

4. Promoting the model development and improvements (***C. Jakob, K. Trenberth, T. Shepherd, D. Bromwich***)

5. Role and terms of engagement for the WCRP Modelling Council. (***S. Bony, D. Griggs, J. Marotzke, H. Le Treut***)