Subject: WCRP Community-Wide Consultation on Model Evaluation and Improvement

To:
- NWP and Seasonal Forecasting Centers
- World Climate Modeling Centers
- WGCM and associated MIPs (PMIP, CFMIP, C4MIP, etc)
- CLIVAR modeling groups (WGOMD, WGSIP)
- CLIVAR regional and monsoon panels
- US CLIVAR panels and working groups, CPTs
- WCRP Task force on Regional Climate Downscaling
- WCRP Projects (CLiC, SPARC, GEWEX)
- THORPEX, WWRP
- IGBP/AIMES

From:
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Errors in climate (ocean-atmosphere-land-ice) and NWP general circulation models substantially limit the skill of climate and weather predictions on a wide range of space and time scales. Identifying these errors and understanding their root cause constitutes a prerequisite for the planning of model improvement activities. On the other hand, translating the wealth of results from process studies, observational campaigns etc. to model improvements is a non-trivial issue for the modeling community.

For this purpose, we propose to initiate a "bottom-up survey" about the key deficiencies of regional and global NWP and climate models. This survey includes problems identified in operational NWP and seasonal prediction centers as well as deficiencies that climate modelers and analysts of CMIP3 simulations have identified for the current generation of models. The priorities identified by the survey will be the basis of model development/improvements across the entire WCRP Projects and activities, and also through its partnership with WWRP, IGBP and ESSP. WCRP is also currently examining the scope and structure of its modeling activities and the outcome of this survey will also inform these decisions/discussions.

We are asking modelers, analysts and process-orientated panels and international projects six targeted questions – see the template overleaf. The success of the survey in identifying priorities and opportunities depends on the involvement and enthusiasm of the participants in the survey either by sharing results and/or identifying actions to be taken.

The main purpose of the survey is to provide input to the strategic planning for model improvement activities that could be coordinated through the various working groups, projects and panels of WCRP. Suggestions for such coordinated activities are welcome. Results from this survey will be reviewed and discussed at the next WGCM and WGNE meetings. The information collected by this survey, including details, links and references on relevant ongoing and new activities (regional observational studies, observations, process modeling studies, theory, etc) will be made available by means of a community resource website and a white paper will synthesize the outcomes of this survey and make recommendations on where international coordination is needed for the development of the next generation of models.

Please complete the survey by 15 September 2009 and submit your response electronically to Anna Pirani at apirani@princeton.edu

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Please complete the following template by writing your answers into the boxes below the questions, sending any supplementary material such as clearly labeled figures in a separate file. Please submit your response electronically by ***15 September 2009*** to Anna Pirani at apirani@princeton.edu.

Q1: Please state your particular area of interest, e.g. global or regional climate or NWP modeling, seasonal prediction, sea-ice feedbacks, monsoons, troposphere-stratosphere exchanges, etc.
COLA focuses on the predictability and prediction of intra-seasonal to decadal variations in a changing climate, with an emphasis on global coupled system modeling. Areas of interest include the MJO/ISO, south Asian and global monsoons, ENSO, and extending the methods of seasonal predictability to the decadal time scale.

Q2: Given your interest, what would you consider/identify as the KEY uncertainties/deficiencies/problems of current models? What do you think should be evaluated/improved as a priority in models in terms of parameterization and/or interactions among processes? (Give references and/or one key figure where possible)
Grand Challenge: Climate Change Prediction to Advise Regional Adaptation Strategies and Global Mitigation Policies

After decades of careful evaluation of weather and climate measurements, paleoclimate proxy records and the output of global climate models, it is now accepted that the Earth's climate is undergoing change at a more rapid rate than has been experienced in human history and that human activities are partially responsible for the change. To address the threat posed by such change, the global society rightly demands accurate projections of climate change in the future, with ever-decreasing levels of uncertainty, and a complementary demand for greater spatial discrimination in the climate changes that may be anticipated in the next 30 years, especially concerning changes in extreme weather and climate events.

Despite the progress in observing, understanding and modeling climate, there is also a recognition that the climate models of the current generation have reached a plateau in their ability to simulate salient features of Earth's climate. The models used in the most recent assessment conducted by the Intergovernmental Panel on Climate Change are able to unequivocally show that human activities are responsible for the change in the global mean climate and the continental-scale temperature change. Yet the same models cannot discriminate the climate change signal that has been observed in different parts of continents, much less the detailed regional information that is critically needed for developing regional adaptation strategies. Worse, the models in current use have large systematic errors in critical parts of the global climate system and severely underestimate the variability of weather and climate, missing the extremes that have the largest impact on human society and natural ecosystems. This problem is associated with a general climate bias in current coupled ocean-land-atmosphere general circulation model, and several specific errors, including the double Inter-Tropical Convergence Zone, incorrect phase and amplitude of the annual cycle in the tropics, especially the mean monsoon rainfall and its intra-seasonal and interannual variability, the structure of El Nino Southern Oscillation events in the tropical Pacific, the tropical land climatology, and the position of the mid-latitude jet (the latter is an extremely complex problem, because it is the result of interplay among the tropical Hadley cell, the midlatitude baroclinicity and the resolution of the oceanic fronts). These problems can be ascribed to modeling issues including surface boundary layer physics in both the ocean and atmosphere, interactions between the land surface and climate, interactions between the sea-ice and climate, and cloud simulation - including shallow convection, inversion-topped boundary layer clouds and deep convection, most of these problems seem to be related to insufficient resolution.

Q3: Do you see a particular gap (in knowledge, in observations or in practice) that would need to be filled, or a particular connection between different modeling communities or between modeling, process studies and observations that should be made a priority?
(1) Between theoretical understanding and modeling advancements. The sub-grid-scale physical parameterization packages are mostly based on theoretical concepts developed one to two decades ago. While this could be a result of relatively few theoretial breakthroughs in recent times, the transfer of ideas from laboratory experiments, theoretical studies, and field experiments into modeling is also slow. A balanced approach, including advances in physical understanding and computational efficiency is needed. More simply, there is currently no understanding of why different models have different systematic errors.
(2) Between models and observations. There is currently little or no idea of how to relate observations to model parameterizations or how to improve model parameterizations. As modeling communities push the envelope of resolution, there will be an increasing need for observations at comparable resolutions for model validation and initial conditions. There will also be an increasing need for observations of the sub-surface ocean, particularly as decadal scale prediction becomes more important.
(3) Between model developers and model experimenters/analysts. The community that undertakes the tasks of developing models and running experiments is too occupied to carry out in-depth analysis into the phenomena their model simulate. Likewise, the community that carries out theoretical analysis and experimentation does not have sufficient access to the models and simulations.
(3) Between the regional and global modeling groups. There is an urgent need to test the basic hypotheses of regional downscaling by running a global model at the same resolution as the regional model and for the identical physics of the model.For some scientific research purposes, innovative approaches combining the experience of these two groups may be effective.
(4) In the parameterization of fluxes between land and atmosphere (PBL). This gap is well described in Dirmeyer et al. (Dirmeyer, P. A., R. D. Koster, and Z. Guo, 2006: Do global models properly represent the feedback between land and atmosphere? J. Hydrometeor. 7, 1177-1198.).
(5) Between modelers and software engineers. There is too little involvement of professional software developers in the model and model code creation process. This problem will only become more acute over time as computer architecture becomes more complex with the transition to hundreds of thousands or even millions of processors and hybrid computing architectures such as are now dominating the highest-end computing.
(6) Between the supercomputing requirement and the available dedicated supercomputing resources. Sufficient high-end computing resources would provide a great opportunity to improve understanding of the complex interaction across scales in the climate system.

Q4: Do you see any particular resource or opportunity within the modeling/process study/observational/theoretical community (e.g. new results, new observations) that would be particularly useful and should be exploited to tackle this problem?
(1) Global ocean reanalysis and global coupled climate reanalysis.
(2) The SP-CCSM model developed by COLA and Colorado State University.
(3) Cooperation and collaboration efforts involving climate modeling groups and software engineering groups.
(4) Coordinated and co-located observations to close surface energy and water balances for model development, a la ARM CART, in more locations and climate regimes.

Q5 What would best accelerate progress on the topics raised in questions 1-4? Do you have suggestions for new initiatives (new process studies, field campaigns, or new collaborative approaches, eg international Working Groups, Climate Process Teams)?
The international weather and climate modeling community came together in 2008 at the World Modeling Summit (WMS) to reach a consensus that the time is ripe to revolutionize the application of numerical models for prediction of climate through the development of seamless prediction methodologies which unify the weather and climate forecast problems. At the heart of the WMS findings is a hypothesis that resolving important processes in the atmosphere and ocean and at the land surface, as well as the interactions among them, as is already the case in weather prediction models, can dramatically improve the fidelity of the climate models. A report from the WMS calls for a revolution in climate modeling with the establishment of multiple international high-performance computing facilities, e.g. one each in the

Americas, Asia and Europe, all virtually connected and all dedicated to the development and application of high-resolution climate models. Global climate models capable of resolving clouds, the planetary boundary layers in atmospheric and ocean, ocean eddies, the variations of the landscape, and the cracks and seams in sea and land ice, will require spatial resolution of a kilometer or less that can run for simulated centuries or longer within a few days of wallclock time. The computing challenge in high-performance computing is formidable and feeds into challenges in software, data management, analysis and visualization, as well as the necessarily virtual organization across the globe that must work together to develop the models and evaluate their output. Comparable to the computing challenge is the observational challenge: consistent long-term observations at locations over a period of time (many annual cycles) are needed.

This is a grand challenge to improve our understanding of weather and climate, build the next generation models that can resolve the relevant processes and accurately project climate at regional decision-making scale – including the full distribution of weather events that compose the delivery system of climate – and organize ourselves regionally, nationally and globally to address the pressing problem of global climate change. The stakes could not be higher, because the future of human society and the planet's health hang in the balance.

Q6: Any other suggestions/issues to be raised?
There is a need to reduce fragmentation in the modeling community, to make results from one model applicable to another. This will require a major effort to understand why models differ. The current practice is to try to understand why models behave similarly, which is avoiding the major issue.

The outcome of VOCALS, which is currently in progress both in terms of analysis of observations and verification of the main hypothesis through modeling, may help clarify which direction is most important to achieve further progress.