WMO/ICSU/IOC
WORLD CLIMATE RESEARCH PROGRAMME

JOINT SCIENTIFIC COMMITTEE

THIRTY-FIRST SESSION
ANTALYA, TURKEY
15-19 FEBRUARY 2010

JSC-31/Doc. 2.3
(15.1.2010)

Item number

White Paper on WCRP Modelling Theme

(Submitted by Drs Greg Flato and Gerald Meehl and Professor Christian Jakob)

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15 November 2009

Numerical models are fundamental tools in climate research. They range from very detailed models of a particular process, through complex global and regional climate or earth system models, to more idealized climate system models. They are used in a wide variety of applications including processes studies, data assimilation and analysis, attribution, historical and paleo-climate simulation, seasonal to interannual climate prediction, future climate projections, and regional downscaling. Additionally, climate services and related information used for societal and policy purposes are largely based on the output of such models.

Of course these models all have limitations in their characterization of the climate system since they make various approximations and assumptions, and in particular must represent unresolved processes through parameterizations of some kind. The associated errors and biases contribute to uncertainty in, for example, quantitative climate predictions required for assessing the future impacts of climate change. It is clear that in order for the WCRP to fulfill its aim of facilitating the analysis and prediction of the earth system, a strategy that combines the science learned from the applications with an understanding of these model errors in order to improve the models and thereby reduce the associated uncertainties is required. Such a strategy inevitably connects closely with the other WCRP themes, since observations and detailed process studies are clearly required in order to quantify errors, improve the representation of important processes, and validate models.

The WCRP modelling theme should be based on four complementary activities, each of which build upon past experience and expertise:

1. **Promoting the confrontation of models with observations and the results of detailed process studies**. This builds on very productive exercises like CFMIP, in which coordinated experiments are undertaken to compare model results to a broad suite of observations (satellite and in-situ). It also builds on growing emphasis on attribution and building understanding of why the state of the climate is the way it is. Increasingly these activities will involve the development and implementation of sophisticated diagnostics and observation simulators, which allow more meaningful and revealing quantification of model performance. This will also involve the development of proxy modeling (e.g. isotopologues) to facilitate the assessment of models on very long (from multi-decadal to paleo-climatic) timescales. Clearly this activity requires close coordination between the modelling community and those involved in making observations and undertaking process studies. This activity will essentially build upon existing panels and working groups such as the GMPP, CCMVal, WGOMD, CFMIP, PMIP, WOAP, GRP, CEOP, etc.
2. **Promoting the collaboration among the various climate science communities that are integral parts of WCRP modeling**. This involves initially the numerical weather prediction, seasonal to interannual prediction, decadal prediction, and long term projection communities. With the growing activities in earth system modeling, this also involves the biogeochemistry, atmospheric chemistry and aerosol, dynamical vegetation, and ice sheet modeling communities. Though these communities may use their own models for particular applications, they can provide not only substantive contributions to modeling in other applications but also can contribute alternative insights into model errors or suggest different approaches to modeling. For example, the very high resolution of models used in NWP (compared to that feasible in climate applications), though typically run only for a few days or weeks, can provide extremely valuable insight into the performance of models at high spatial resolution as well as into the behavior of parametrizations, and benefit from being

confronted with observations on a daily basis. They also provide guidance regarding the increasingly important technical issues involved in running comprehensive global models on massively parallel supercomputers. Atmospheric reanalysis is another related activity, and extends also into ocean and coupled reanalysis. These examples are but one of the potentially valuable connections to related environmental modelling communities, which can be leveraged in the WCRP realm. This activity strengthens existing active collaborations involving, for example, the biogeochemistry community represented by IGBP/AIMES with WGCM, and the numerical weather prediction community with WGNE and WGSIP.

3. **Promoting the application of models to problems of societal relevance, and the quantification of model strengths and weaknesses.** This activity clearly feeds into the theme of climate applications and services insofar as it promotes the development and application of models to climate attribution, projection, prediction and downscaling, and the production of model-derived information that will inform decision-making, adaptation planning, and mitigation policy. An important objective here is to insure that climate model results are available and widely disseminated, and that their uncertainties are quantified and communicated. This activity will build upon the existing and very successful WGCM, the WGSIP (and its connections to WGNE for shorter time scales), and the developments underway via the TFRCD. Coordinated international model experiments and climate projections and predictions are a vital role of the WCRP in that they provide an ensemble of comparable model results whose value vastly exceeds that of any individual model run. The maturing activity on seasonal to interannual prediction will continue to be vital to the provision of climate services, as will the developing activity on regional downscaling, since many climate applications require information at a very fine spatial scale.
4. **Promoting the development of model improvements.** An ultimate goal of the WCRP modeling activities must be to improve model performance based on the collective findings of the activities described above. This naturally requires the improvement of the existing model formulations as well as the potential addition of new model components. Basic model development has recently been identified to be in decline and the modeling theme must take up the challenge to reverse that trend. WCRP through its many activities is in a unique position to advance this important issue i) by formulating and implementing a new strategy for model development and ii) by promoting the importance of model development to its stakeholders and funding agencies. It is imperative that any new WCRP structure takes into account this challenge, and that all WCRP activities are encouraged to contribute to solutions.

The WCRP modelling theme clearly cuts across all of the core projects and connects directly with the other central themes. There are already a number of well-established panels and working groups that have community support and a track record of success, and these should be maintained. There is no obvious need for another overarching body to coordinate the activities outlined above, but there should be a WCRP Modeling Council, made up of the co-chairs of the WCRP panels and working groups related to WCRP modeling, and a small subset of JSC members, who will be charged with liaising with the various groups (as is the case now with formal JSC representatives on some of the working groups). The role of the WCRP Modeling Council should be to review and coordinate modeling activities and their connections to all other WCRP activities. In order to achieve this, the Council should

- communicate regularly by e-mail,
- devote one day of the JSC meeting each year to reviewing modeling activities and progress and the connections to other cross-WCRP themes,
- encourage relevant co-chairs to attend the respective working group meetings as needed to foster collaborations

- organize occasional joint meetings of related working groups to promote communication and shared activities (e.g. have two working groups meet in the same location with one day devoted to jointly meet in a mini-workshop format to address problems of shared interest).

The WCRP Modeling Council should oversee the organization of a semi-regular (e.g. every few years) WCRP-wide modeling conference and/or workshop with the particular aim to foster interaction and collaboration across the WCRP modeling activities. The workshop should be organized by the three major modeling working groups (WGNE, WGSIP, WGCM) on a rotating basis, but should be specifically aimed at bringing the various communities together on a modeling issue of common interest (the semi-regular WGNE workshops on systematic model errors serve as a good example).

In addition, after having identified and prioritized major model deficiencies (taking advantage in particular of the on-going community-wide survey on model evaluation and improvement), the WCRP Modeling Council might advise WCRP to set up a few cross-WCRP teams of limited lifetime, that would associate modeling, observations and process studies around a specific, urgent problem. These groups, which might resemble the CLIVAR Climate Process Teams (CPTs), would foster the development of a community of scientists working on a particular issue of direct relevance to model deficiencies. They would ensure that the different WCRP resources and opportunities are exploited, and that the different scientific communities necessary to tackle the problem are well represented. These groups would be overseen by the WCRP Modeling Council and by the JSC.

Modeling is central to almost all WCRP activities. This short discussion paper sets out a path for a better integration of existing activities within the programme. We are looking forward to discussing the ideas presented here with the JSC and the wider WCRP community.

Greg Flato, Gerald Meehl, Christian Jakob