WCRP REPORT
World Climate Research Programme

PROJECT REPORT

Report of the 16th session of the Working Group on Coupled Modelling (WGCM)

24-26 September 2012, Hamburg, Germany

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1. Introduction

The 16th Session of WGCM was held in Hamburg, Germany on 24-26 September 2012, generously hosted by the Max Planck Institute for Meteorology (MPI-M). The WGCM co-Chairs, S. Bony and G. Meehl thanked B. Stevens, M. Giorgetta and E. Manzini for hosting and organizing the logistics of the meeting. They also thanked P. Braconnot, M. Giorgetta, N. Nakicenovic and M. Kimoto, long standing and dedicated WGCM members that are rotating off at the end of 2012. The new members who will officially join WGCM in January 2013 were warmly welcomed: M. Kageyama (LSCE), M. Kawamiya (JAMSTEC), B. Stevens (MPI-M), D. van Vuuren (NEAA) and C. Tebaldi (NCAR).

The objectives of the 16th Session were to review the 5th phase of the Climate Model Intercomparison Project (CMIP5) in terms of the lessons learned from the experiences of the climate modeling centers, and to start thinking about the next round of experiments, CMIP6, building on where CMIP5 has left gaps or raised new scientific questions that could be addressed through coordinated work. The CMIP5 Model Analysis workshop that was held in Hawaii, USA on 5-9 March 2012 proved to be a successful and popular venue to assess the scientific results coming out of CMIP5. WGCM proposes that this poster-based workshop becomes a regular event within the CMIP framework. Computing and software technology has become a major aspect of CMIP5 - the Earth System Grid Federation has seen an unprecedented level of coordination and cooperation and how the modeling community interfaces with this effort is a key topic for WGCM to address.

The meeting also addressed WGCM discussion topics on how observations and metrics for climate model analysis are being developed in an increasingly consistent way with CMIP protocol, the documentation of models and model simulations and model tuning practices. WGCM will lead the WCRP Grand Challenge on clouds, circulation and climate sensitivity and will be key contributor to the Grand Challenge on the provision of regional climate information. The final part of the meeting was held jointly with the Working Group on Seasonal to Interannual Prediction (WGSIP) on the common topic of decadal climate prediction.

2. WCRP Updates

2.1 JSC Report

The long-standing WCRP organization around its core projects, CLIVAR, GEWEX, CliC and SPARC is evolving to best serve the current and future needs of the climate research community. This has been guided by outcomes of the WCRP Open Science Conference, for example through the establishment of the WCRP Grand Challenges (GC) listed below that cut across the WCRP core Projects and serve to identify critical areas where there are opportunities to make progress through enhanced coordination over the next 5-10 years.

1. Regional Climate Information
2. Regional Sea Level Change
3. Cryosphere in a Changing Climate
4. Clouds, Circulation and Climate Sensitivity
5. Changes in Water Availability
6. Prediction and Attribution of Extreme Events

WCRP has a key position in developing the modeling and prediction research pillar of the Global Framework for Climate Service (GFCS). Within WMO there is a push to integrate better across weather and climate to achieve a seamless chain across timescales. Climate information is needed at regional scales, in a form useful for adaptation studies and to inform adaptation and mitigation policy. The WCRP Working Group on Regional Climate (WGRC) has also been formed to coordinate regional downscaling activities and issues related to the provision of regional climate information, oversee CORDEX and act as an interface between climate research and users of regional climate information.

2.2 WCRP Advisory Councils

WCRP has formed two advisory councils to the JSC: the WCRP Modeling Advisory Council (WMAC) and the WCRP Data Advisory Council (WDAC) that respectively integrate modeling (across time and space scales) and data (modeling, reanalyses and observations) activities and needs. The membership of the councils consists of chairs of relevant working groups as ex-officio members, rather than individual members. Their role will be to identify gaps in current observations and modeling activities that would benefit from enhanced collaboration and coordination between groups, for example dynamical aspects (rather than thermodynamic) of climate change, monsoons, data preservation and access, as well as increasing communication and capacity development through increased communication between groups, the organization of summer schools, etc.

RECOMMENDATION:

> Coordination between WMAC and WDAC is imperative to ensure that progress is made in closing the gap between modeling and observations. The WDAC membership should be expanded to improve the representation of the modeling community; linking in particular the data archive software development community (ESGF) and the CMIP panel (WGCM to JSC).

2.3 WCRP Grand Challenge on Clouds, Circulation and Climate Sensitivity

WGCM has the lead on coordinating this GC on how the interactions between clouds, greenhouse gases and aerosols affect temperature and precipitation in a changing climate. The barriers are responsible for many long-standing biases in climate models:

1. Inability to constrain the effects of clouds on climate sensitivity estimates
2. Lack of understanding of regional circulation and precipitation changes, especially over land
3. Unreliable representation of the coupling between cloud processes and large-scale dynamics

There is opportunity for progress, with a wealth of coordinated modeling activities and targeted observations, new modeling tools, a mature understanding of the physical processes involved and an interconnected research community. The following topics have been identified for focused initiatives:

1. Climate and hydrological sensitivity
2. Leveraging the past record
3. Coupling clouds to circulation
4. Changing patterns
5. Towards more reliable models

A steering committee with representation from various relevant elements within WCRP (WGCM, WGNE, GEWEX/GASS) will leverage these activities. Workshops will be organized on each topic to define the initiatives that will be published in high visibility literature to motivate the future directions of the research community.

RECOMMENDATION:

Change the clouds GC title to Clouds, Circulation and Climate Sensitivity (WGCM to JSC)

3. Coupled Model Intercomparison Project (CMIP)

3.1 CMIP5 Update and Initial Assessment

CMIP5 has been a major accomplishment in coordination for WGCM, PCMDI, the CMIP5 partners, the Earth System Grid Federation (ESGF) and the global climate modeling centers. Planning began in earnest in 2006 at the Aspen Global Change Institute Session on Earth System Models: The Next Generation, with the experimental design approved at the 12th Session of WGCM in Fall 2008. The output requirements and list of requested output were finalized in March 2011. The first model output was available in April 2011 and by July 2012, more than 200 publications based on CMIP5 output were in some stage of publication. At the time of the 16th Session of WGCM in October 2012, 1.7 PB in $4x10^6$ files of 59 models from 24 modeling centers were available on the CMIP5 archive, with CMIP5 research just beginning. CMIP5 has been crucial to the assessment activities of the IPCC AR5.

CMIP5 is the largest and most complex international coordinated multi-model experiment ever attempted, and it must be counted a significant achievement for WGCM, which took the lead in planning CMIP5, that the experiments were run, the data archived successfully, hundreds of scientists across the world are accessing and analyzing the model data, and the CMIP5 simulations are forming the basis for assessment in the IPCC AR5. The distributed data management system was the first of its kind and its development brought together people working on many different aspects of the software. The Earth System Grid Federation (ESGF) architecture is designed to be scalable and can be extended to meet future data needs. All other MIPs should be encouraged to embrace and extend this software model, including the use of ESGF nodes, DRS (variable names/units) structure and CIM metadata (METAFOR).

Though CMIP5 has been a huge success, it was not without glitches, some of which were expected due to the unprecedented and pioneering nature of the ESGF, the large number of experiments, and the massive amount of model data. Other issues arose that were unexpected. The CMIP5 experience has led WGCM to identify factors that should be addressed as part of preparations for a possible CMIP6:

- *ESGF Infrastructure funding* specifically targeting CMIP5 was insufficient, resulting in delayed achievement of some of the ambitious goals. ESGF was funded as a "research" project to develop a system that would serve communities broader than CMIP. (CMIP was one of 4 "use" cases, though it was bigger than the other three put together). Efforts to make the system work operationally for CMIP were initially under-funded
- *ESGF governance* needed to be in place earlier. The governance model was informal with poorly understood procedures for decision-making. Uncertainty and disagreements on the timing of upgrading the system meant a delay in integration of the METAFOR model documentation effort with ESGF
- *Delayed capabilities* important to scientists attempting to meet IPCC-dictated deadlines were not deployed in time (access to CIM metadata, data citation mechanism using DOIs, replication of data to improve accessibility, quality assurance checks on model output)
- *Server-side analysis* - users still download data instead of leaving it on the servers for analysis
- *Delay in making data public* by modeling groups wanting to get the latest version of the models included, tension between making data public and writing papers on new results, under- estimate of the amount of work required by the post-processing of the model data; even though CMIP5 started earlier relative to CMIP3 because there were complaints that there was not enough time for the modeling groups to prepare new versions and complete the runs in CMIP3, many of the modeling groups found themselves in a similar situation in CMIP5 due to delaying finalizing new model versions to the last possible moment to be able to include the maximum number of

model improvements in their models to run for CMIP5; it appears this will always be an issue in future phases of CMIP for that reason.

- *METAFOR questionnaire* publishing and quality control was very labor intensive for modeling groups, who have received little feedback so far. The potential usefulness has yet to be demonstrated and exploited

3.2 Earth System Grid Federation (ESGF) and CMIP5 Data Services Update

On the modeling center side, work involved the data provision to users involved saving the CMIP-requested variables, rewriting the data in conformance with CMIP-imposed data standards, placing the data on a server, installing the "Earth System Grid" (ESG) software to make data uniformly accessible from all models and "publishing" the data to the CMIP5 distributed database. PCMDI and the ESGF were responsible for providing the CMOR software and tables to re-write the data to CMIP standards and perform a first order quality control. Software to publish the data, install the protocols allowing external user access and perform data replications was provided to modeling groups and data centers. PCMDI and ESGF also provide the portal software that enables users to search the distributed archive and download the CMIP data.

The operational ESG has evolved from CMIP3, when PCMDI acted as a central data repository to which data had to be shipped by hard drive, to a distributed archive with data distributed over data nodes (e.g. servers at modeling centers with CMIP5 data from that modeling group) and hosted (or accessed) by gateways (user interfaces). Problems encountered with the first version of the distributed archive included a slow search engine and inaccurate reporting of data holding by gateways. The peer-to-peer (p2p) ESG Federation was developed in Spring 2010 as an alternative. The p2p architecture is designed to be scalable to future data needs. It has simplified and modularized software that facilitates modifications, is open-source to attract contributions and resources across the community, is easy to interface and has multiple, fast search options. See here to explore the p2p ESGF: http://pcmdi9.llnl.gov

Additional resources are available for users. These are detailed model and experiment documentation (METAFOR questionnaire results), the CMIP5 website (http://cmip-pcmdi.llnl.gov/cmip5/guide_to_cmip5.html), and a searchable database of CMIP5 journal publications (http://cmip.llnl.gov/cmip5/publications/allpublications). The latter keeps a record of CMIP5 publications that can be searched and quantified in a variety of ways, for example by experiment, model, variable and keywords.

Various activities are underway to enhance the CMIP5 data services, for example the development of an interface to model and experiment documentation, the capability of replicating a subset of data (improved performance, server-side calculations) implementing additional download methods (gridFTP, i.e. ftp of a subset) and a service to inform users of new datasets according to their interests. Other services that are in development include greater sub-setting capabilities and server-side computation, a method of recording provenance of data used in CMIP5 publications (e.g., DOI assignment and other options), a scalable method of reporting/notifying users of errors in data, and improved automated quality control. Software is also being developed that will ensure that data replicated at different sites conforms to the latest version available to avoid users working with outdated data.

3.3 Integrated Assessment Modeling (IAM) Consortium Update

The integrated assessment modeling community has been active in various scenario development activities relevant for the climate modeling community. In general, the collaboration between the climate modeling community and the integrated assessment modeling community is increasing as the two communities continue to iterate on the "parallel process" of scenario development that was initiated for CMIP5 and that is leading to CMIP6. In addition to those reasons, this connection between the two communities is important to nurture because of increasing interest of policy-makers in weighting mitigation/adaptation/laissez faire strategies and the expanding research agenda of both scientific communities.

For the RCPs, it would be useful to follow-up now the original plans to compare IAM and ESM outcomes for these scenarios (e.g. in terms of carbon budgets and temperature outcomes). Some important issues to look into are land use and air pollutant emissions. For land use, some comparisons have already shown that the implementation of the land use scenarios in ESMs might depend on a number of key assumptions. It will be useful to jointly look into the land use scenarios, the implementation of these scenarios in both IAMs and ESMs and the consequences of uncertainty. In that context, it should be noted that the future land-use patterns are much more dependent on other uncertain factors than future climate policy. Different land-use patterns can therefore be combined with each of the RCPs. A simple test to influence the impact of land use would be to combine the land-use patterns of the different RCPs with different forcing pathways.

For air pollutant emissions, it should be noted that while the RCPs cover the range of greenhouse gas scenarios very well, they only represent part of the possible range of air pollutant emission outcomes. In particular, they all represent the lower end of the range of aerosol concentrations, leaving open the possibility that the models that have run the RCPs could all have lower-than-observed aerosol concentrations (with consequent reduced cooling contributions) and thus be biased warm for climate change before mid-century. The reason is that all RCPs have adopted the (likely) assumption that (developing) countries will strengthen and improve their air pollution policies along with development (in order to protect human health). Moreover, 3 of the 4 RCPS include climate policy which also reduces air pollutant emissions. Together, this implies that a "worst-case" scenario for air pollutant emissions in which air pollution policies do not improve (or only marginally improve) and fossil fuel use is high has not been included. While the choices were logical in the context of the main objectives of the RCPs, this has implications for use of the scenarios in the scientific community interested in air pollution problems (as no counterfactual case is included that can be used to show what happens if people do not act) but also for the climate modeling community (in all RCPs, negative forcing from aerosols becomes rapidly less over time). The RCP overview paper published in Climatic Change already addressed this issue. If useful, it might be interesting to explore the impact of alternative futures with respect to air pollutant emissions.

The Integrated Assessment Modeling Consortium (IAMC) is currently also involved in developing a second set of pathways, that this time particularly link-up the "working group 2" and "working group 3" research communities (impacts and mitigation). As the RCPs only address land use, emissions and climate outcomes, in order to assess the impacts of climate change information on the socio-economic parameters is also needed. This is the aim of the Shared Socio-ecosystem Pathways (SSP) that provide information on population, GDP trajectories as well as information on energy use and food productions. The SSP and RCPs are designed to draw up a matrix in which one axis represent different socio-economic trajectories (for instance low population / high economic growth as one possible trajectory) and the RCPs form a second axis that represents both uncertainty in climate outcomes and the stringency of climate policy. Matrix elements link these axes (e.g. a combination of SSP1 and RCP2.6 forms a world that is characterized by low population growth and low greenhouse gas emissions). The SSPs are planned to become available in 2013.

Recommendation:

> Hold a WGCM-IAM workshop to assess, for example, how well the CMIP5 scenarios have performed and ESM sensitivity to land use changes, and to evaluate the scenario development process and design for future CMIP experiments

3.4 Synthesis of CMIP5 Science - Outcomes of CMIP5 Analysis Workshop

WGCM organized the WCRP Workshop on CMIP5 Model Analysis, hosted by the International Pacific Research Center (IPRC) at the University of Hawaii, on 5-9 March 2012. The workshop followed the same short presentation/poster format as the CMIP3 Analysis workshop held in 2005. About 160 people were selected to participate out of about 240 poster abstracts that were submitted. The workshop consisted of a series of half-day sessions; each session began with presenters in that session given three minutes to show no more than one powerpoint slide summarizing the main conclusion; the rest of the half day session consisted of viewing that session's posters.

Despite some delays in model availability and challenges in downloading model data (though still farther along than in a similar stage for CMIP3), analyses included between 15 and 22 AOGCMs, 4 to 8 decadal prediction simulation sets, about 6 high-top models, and 3 to 8 ESMs. The concern that the spread of future projections from the new generation of AOGCMs with more complexity, or from ESMs with coupled carbon cycle, would be wildly greater than from the AOGCMs of CMIP3 was unfounded. The spread of projections in CMIP5 AOGCMs is comparable to CMIP3. Most first generation ESMs are well-behaved and produce comparable first order results to AOGCMs, but with all their additional capabilities.

Early results show that:

- Patterns of future change of temperature and precipitation, equilibrium climate sensitivity, and spread among CMIP5 models are similar to previous generations of models but we have the opportunity to better understand the spread
- Characteristics of model simulations in CMIP5 are either similar to CMIP3 or improved somewhat; nothing appears to have degraded
- Some quantities show considerable improvement (e.g. rate of sea ice loss in the Arctic, reduction in cloud brightness) or decreased model spread (e.g. AMOC, seasonal cycle of precipitation in Caribbean, Greenland ice sheet mass balance from temperature and precipitation, Nino3 standard deviation)
- Some things have not significantly improved (e.g. double ITCZ, Arctic clouds and atmospheric circulation, Antarctic sea ice loss, southern ocean too warm, SPCZ too zonal, humidity in subtropical descent regimes too high)

CMIP5 provides many more capabilities and new types of climate change information:

- Carbon cycle feedback, quantifying sources and sinks of carbon for land vs ocean, allowable emissions for different levels of mitigation in the RCP scenarios, ocean acidification, physiological effects of vegetation changes
- High resolution time slices to study tropical cyclones
- Decadal climate prediction for short term climate change and possible climate shifts
- Paleoclimate simulations that allow analysis of climate response across past, present and future climates, and that provide "out of sample" insights to build model credibility and provide possible constraints on nature and magnitude of future climate change
- Analysis of cloud feedbacks and tropospheric adjustments
- Revisiting forcing and feedback to better support the interpretation of the spread of model projections
- Attempts to relate 20th century model biases to projections

The following are some examples of new topics or types of results (many more were presented at the workshop):

- AMO more predictable than PDO

- Critical thresholds for Arctic sea ice loss
- Regional climate regimes like Indian Ocean Dipole and connections to east African rainfall
- South Pacific Convergence Zone
- Ocean wave heights
- Changes in monsoon onset characteristics
- Role of salinity and patterns of changes connected to hydrological cycle and ocean response
- Effects of aerosols on Atlantic SSTs
- Tracking regional ocean heat content changes and relation to regional patterns of sea level rise
- Better quantification of factors affecting cloud feedback
- Mechanisms for regional precipitation and temperature changes and extremes: Caribbean drying, SE US wetter, drying Amazon, connecting Arctic sea ice loss to European cold extremes, atmospheric rivers and extreme precipitation, importance of circulation changes, blocking, what will not change in a future climate is also useful information

The workshop was successful in encouraging the community to access the CMIP5 archive and to make multi-model analyses, and in providing a forum to discuss new results. The poster format combined with syntheses by the session chairs gave IPCC AR5 authors a preview of what they could expect for their assessment and was popular with those attending for its participatory nature.

WGCM suggests that the communities participating in CMIP5 prepare synthesis review papers to be published as a special journal issue or peer-review book, highlighting new robust results and the future challenges breaking the traditional barriers between MIPs, for example in terms of the WCRP Grand Challenges, and laying out the foundations for the design of CMIP6.

RECOMMENDATION:

CMIP model analysis workshop to become a regular WCRP-WGCM event.

4. Update from WGCM partners

4.1 Chemistry-Climate Modeling Activities within WCRP SPARC and IGBP IGAC

In contrast to CMIP3, where half of the models prescribed a stratospheric ozone climatology instead of a time series, the CMIP5 models all consider past ozone depletion and future ozone recovery, either prescribed or interactive. 18 of 46 CMIP5 models have either interactive or semi-offline ozone chemistry. The remaining 46 have prescribed ozone mostly based on the original or a modified version of the Cionni et al. (2011) dataset. This results in substantial improvements of stratospheric ozone compared to CMIP3, leading to a more realistic representation of the effects of anthropogenic forcings on stratospheric temperatures and subsequent impacts on tropospheric climate. Interactive chemistry models do well at representing observations compared to simple chemistry models where prescribed ozone may be better.

The first phase (within the AR5 deadline) of the Atmospheric Chemistry-Climate Model Intercomparison Project (ACCMIP) documents and analyses the radiative forcing in CMIP5 models (14 models participated), and evaluates chemistry used to provide concentrations and depositions. ACCMIP-1 time-slice runs include detailed chemistry diagnostics to provide information on the forcings of historical and future climate change in the CMIP5 simulations The second phase (post AR5 deadline) consists of emission sensitivity studies based on simulations to determine sensitivity to fully or partially interactive natural emissions that will vary between models.

SPARC held a workshop with the IGBP International Global Atmospheric Chemistry (IGAC) project in May 2012 on Global Chemistry-Climate Modeling and Evaluation with the aim to increase coordination. The motivation was that:

i. The chemistry and dynamics of the stratosphere and troposphere are increasingly being modeled as a single entity in global models (and increasingly a coupled ocean)
ii. Tropospheric and stratospheric global chemistry-climate models are continuously being challenged by new observations and model intercomparisons
iii. There is a need to better coordinate the previously separate activities addressing these two domains and to assess scientific questions in the context of comprehensive stratosphere-troposphere resolving models with chemistry

Also, the SPARC CCMVal Report (2010) recommends that development should continue towards comprehensive troposphere-stratosphere CCMs, which include an interactive ocean, tropospheric chemistry, a naturally occurring QBO, spectrally resolved solar irradiance, and a fully resolved stratosphere.

The goals of the workshop were to:

1. Improve process-oriented evaluation and understanding of CCMs (including extending the CCMVal approach to the troposphere)
2. Identify observations for model evaluation and new methods for improved comparability between models and observations (for example the development of tools, and how to implement in situ measurements and aircraft campaigns in a standard way for model evaluation)
3. Define community-wide simulations in support of upcoming ozone and climate assessments and for process studies

The clear recommendation that emerged from the CCM community was to create a joint IGAC/SPARC Chemistry-Climate Model Initiative (CCMI) to coordinate future (and to some extent existing) IGAC and SPARC chemistry-climate model evaluation and associated modeling activities. CCMI will encompass (or supersede) CCMVal, as well as AC&C Hindcast and ACCMIP. Phase 1 of CCMI will start now and continue to mid-2015. Phase 2 is scheduled to continue after that and coincide with a future CMIP6.

4.2 Update from SPARC DynVar (Modeling the Dynamics and Variability of the Stratosphere-Troposphere System)

The SPARC DynVar (see: research topics and groups) goals are to:

- Promote development of coupled atmosphere, ocean, and sea ice global models with tops above the stratopause
- Promote analysis and evaluation of model outputs on:
    - Stratospheric dynamical variability and processes,
    - Two-way dynamical couplings between the stratosphere and the troposphere, and
    - Their impacts on tropospheric and surface climate predictability

The current DynVar focus is on the intercomparison of high and low top models within CMIP5. Two synthesis papers have been submitted on the CMIP5 multi-model ensemble:

- Mean Climate and Variability of the Stratosphere in the CMIP5 models (Charlton-Perez et al., submitted to JGR, 2012)
- Role of the stratosphere in Northern winter climate change as simulated by the CMIP5 models (Manzini et al., submitted to JGR, 2012)

The recommendation from DynVar for a future CMIP6 is to incorporate diagnostics on stratospheric dynamical processes into the mainstream data request and to design idealized experiments aimed at demonstrating the role of stratospheric dynamics on the surface climate.

4.3 WCRP-WWRP/THORPEX MJO Task Force

The MJO Task Force is involved in the Vertical Structure and Diabatic Processes of the MJO Global Model Evaluation Project together with the Year of Tropical Convection (YOTC) and the GEWEX Atmosphere System Study (GASS). The objective of this project is to characterize, compare and evaluate the heating, moistening and momentum mixing processes associated with the MJO that are produced by global weather and climate models, with a particular focus on their vertical structure. The goal is to improve understanding of the role that convection, cloud, radiative and dynamic processes play in the development and evolution of the MJO in order to achieve better fidelity of the MJO in global prediction models. The experimental framework takes advantage of the known links between biases seen in short-range forecasts and long-term climate simulations. Making use of the ECMWF YOTC analysis and profiling products from contemporary satellites (e.g. TRMM, CloudSat, Calipso, AIRS), along with a set of systematic and complementary model experiments, the vertical processes associated with the MJO produced by global models will be characterized, compared and evaluated.

The project involves three types of simulations:

1. 20-year climatological simulations: model simulations from both ocean-coupled global models as well as those that use prescribed SSTs
2. 2-Day MJO hindcasts: a series of daily initialized hindcasts for two MJO events within the YOTC period, specifically the two successive MJO events during boreal winter 2009-10 (i.e. YOTC events E and F)
3. 20-day MJO hindcasts: to analyze the performance of the models MJO as a function of forecast lead time from 1 to 20 days

The project has benefited from the implementation of the CMIP protocol and data will be served via the ESG. A focus of the project is to develop metrics to evaluate the representation of physical processes in models.

RECOMMENDATION:

> Encourage modeling groups to participate in the MJO Task Force / Years of Tropical Convection "Vertical Structure and Diabatic Processes of the MJO" model evaluation project

4.4 WCRP Coordinated Regional Climate Downscaling Experiment (CORDEX)

CORDEX will generate a coordinated ensemble of high-resolution, historical and future regional climate projections for land-regions of the globe sampling multiple GCM/RCP/RCM/ESDs methods (see here for a full list of objectives: http://wcrp-cordex.ipsl.jussieu.fr/). The first phase is based on CMIP5 historical-projection runs and/or ERA-Interim boundary conditions. The data is compatible with the peer-to-peer ESG system.

The aim is to enhance coordination between different downscaling efforts and to encourage local participation, in generating downscaled simulation, then analyzing and communicating potential regional climate change and associated uncertainties and risks. The initial emphasis has been on Africa, with similar activities now starting for South Asia, East Asia and South/Central America.

The WCRP Task Force on Regional Climate Downscaling has become the CORDEX Science Advisory Team (SAT) and will report to the new WCRP WG on Regional Climate (WGRC). Members have a 3-year mandate. CORDEX continues to organize regional conference/workshops/training events and the 2nd pan-CORDEX conference will be held on 4-7 November 2013 in Brussels, Belgium, jointly organized by the EC, WCRP and IPCC (WG1).

RECOMMENDATION:

Maintain the reporting link between CORDEX and WGCM

4.5 CLIVAR Working Group on Ocean Model Development (WGOMD)

WGOMD is running the Coordinated Ocean-ice Reference Experiments: Phase II (CORE-II), an experimental protocol for ocean–ice coupled simulations forced with inter-annually varying atmospheric data sets for the 1948-2007 period (Large and Yeager 2009). These CORE-II hindcast simulations serve the CMIP5 community in the evaluation of historical coupled climate simulations of the 20th Century as well as in initialization and evaluation of decadal prediction experiments.

The CORE-II hindcast simulations are relevant for CMIP5 and future CMIPs because they provide a framework to

- Evaluate ocean components of ESM (provides more robust understanding, improves the models, especially by identifying outliers)
- Understand mechanisms of ocean phenomena and their variability (observed climate variability and change) from seasonal to decadal timescales
- Identify forced variability changes
- Evaluate the robustness of mechanisms across models
- Bridge observations and modeling, complementing reanalysis products from data assimilation, particularly for pre-ARGO period
- Offer an alternative to data assimilation in providing ocean initial conditions for decadal prediction simulations

With the hypothesis that models forced with the same CORE-II inter-annually varying data will produce similar solutions (mean and variability), the following studies are underway:

- North Atlantic mean and variability with a focus on Atlantic Meridional Overturning Circulation (AMOC) and sub-polar gyre
- South Atlantic mean and variability
- Sea surface height and variability
- Arctic Ocean and AOMIP related analysis
- Southern Ocean circulation and variability, including ventilation and water mass formation

About 20 groups are participating with level, isopycnal, sigma coordinates, forward running models and data assimilation systems. The resolution is mostly 1^{o} and the models are in general the same as those used in the CMIP5 coupled simulations.

4.6 International Detection and Attribution Group (IDAG)

The single forcing CMIP5 detection and attribution experiments are widely used, including analyses by the Working Group 2 community. The following are issues encountered with the CMIP5 design and suggested improvements to the design of CMIP5 or future CMIP experiment:

- The historic simulation should be extended beyond 2005 since extending these to cover the observational record is problematic, especially for aerosols. Single forcing projection experiments would be interesting and, if run by multiple centres, single members would be enough for the multi-model ensemble
- Single forcings should be better addressed, ideally separating solar and volcanic forcing, and more widely performed across groups. There would be benefit in exploring forcing uncertainty for the last 40 years (e.g., since the satellite record). This would not require the full historical run to be repeated, just branching out over the period 1970-2010
- Short-lived forcings (SLFs) experiments could be folded into the exploration of the last 40 years' forcing uncertainty to see whether their signal in the last few years can be detected. This would be informative for the analysis of future projections that include SLF cut down. The extension of SLFs experiments over the next 20/30 years (for example, for running RCP8.5 to 2040, removing the SLFs at some rate) would be complimentary to the historical SLFs experiments. Note, this would not be for models in decadal prediction mode, rather as traditional uninitialized projections
- Decadal hindcasts should run every year, not every five years
- Prognostic ozone experiments look inconsistent across models. There is inconsistency in the results of experimental runs with prognostic ozone. The signal associated with tropospheric ozone is very different across models and regionally variable. The uncertainty in tropospheric ozone may be greater than for black carbon aerosols and comparable to methane. These experiments should be looked at in detail with greater coordination amongst groups

The Attribution of Climate-related Events (ACE) group held a workshop on the Attribution of Climate and Weather Extremes: Assessing, Anticipating and Communicating Climate Risks in September 2012. The community favors physical, climate model-based attribution, not empirical, statistically-based attribution. Framing the question is important, for example, are we addressing frequencies or intensities? This activity is a key component of climate services and the communication of the results is a crucial issue, for example educating the public about the role of natural and forced variability and providing information for adaptation policy. It also provides interesting information for insurance and legal concerns too.

The real-time attribution paper "Explaining Extreme Events of 2011 from a Climate Perspective" (Peterson *et al.*, 2012) was published as part of the BAMS supplement, the State of the Climate in 2011. The positive reception of the paper from outside of the attribution community has increased the general interest in papers about current events explained in a climate context. The issue explaining events in 2012 is being prepared (mid-February first submission - end-of-May final version) and will be a supplement to the July BAMS issue together with the State of the Climate. There is a need for papers like these to be published about extremes in regions other than Europe and North America and for multiple papers on the same event for a more detailed analysis.

The C20C Detection and Attribution of Climate Change project is underway. NERSC has agreed to host a data portal for this project that will be served via the ESG. The project will look at variability and trends in the probabilities of damaging weather events, together with a strong component of coordinated attribution experiments.

5. Model Intercomparison Project Updates

5.1 Cloud Feedbacks Model Intercomparison Project (CFMIP)

A hierarchy of models, in-situ and satellite observations and process studies are used in CFMIP to assess cloud feedback processes though improved physical understanding and representation in climate models. The CFMIP2-CMIP5 experiments and outputs have already proved to be useful in a variety of ways**.** Cloud observations simulators (COSP) have been implemented so far in about 10 CMIP5 climate models (plus other NWP and CRM models) and hopefully more in the future. As a result, the 3-d distribution of clouds in climate models can be evaluated for the first time and multiple observed and modeled cloud quantities can be compared consistently to understand model systematic biases. For example the comparison of the cloud radiative effect with low cloud cover shows that climate models are producing too few and too bright low clouds, and that models exhibit difficulties in simulating clouds in the Arctic. The satellite and in-situ observations used in the CFMIP analysis are available on the ESG. The evaluation of CMIP5 models has shown that the spread of climate sensitivity has not changed since CMIP3. However, the different contributions to the climate sensitivity (feedbacks and adjustments) can be better quantified. Cloud feedbacks still constitute the largest source of spread.

CFMIP collaborations with GEWEX/GASS and WGNE are developing well, for example through the CFMIP-GCSS Intercomparison of Large-Eddy and Single-Column Models (CGILS) project on marine low-level clouds and the Transpose-AMIP project.

CFMIP interests have progressively extended into the climate modeling community, for example on role of clouds in large-scale dynamics and climate variability. The range of idealized experiments and configurations (including Aquaplanet experiments) advocated by CFMIP as part of CMIP5 has already proved its usefulness to better understand the relative roles of CO_2 and temperature in climate change.

Through CFMIP, the cloud research community (GCM, processes, observations) has become increasingly interconnected, as well as with the broader climate community. CFMIP-CMIP5 model output is still welcome and much work remains to be done to exploit it fully. The Clouds ON-OFF Klimate Intercomparison Experiment (COOKIE - http://www.euclipse.eu/wp4/wp4.html), a coordinated set of idealized atmosphere-only experiments, is proposed as an extension of the CFMIP-CMIP5 AMIP and Aquaplanet and is targeted at:

- Identifying robust effects of cloud-radiative interactions in climate (climate change, atmospheric circulation, climate variability)
- Assessing how the atmospheric response to ENSO, the structure of the ITCZ and the MJO depends on cloud-radiation interactions
- Assessing to what extent predictions of climate changes become more robust in the absence of cloud-radiative feedbacks

The CFMIP community will produce synthesis papers related to CMIP5 after the bulk of the analysis has been completed, in 1-2 years from now.

5.2 Paleoclimate Model Intercomparison Project (PMIP)

PMIP, now in its third phase (PMIP3) is endorsed by WCRP/CLIVAR/WGCM and IGBP/PAGES and its objectives are to:

- Understand mechanisms of past climate change
- Evaluate roles of feedbacks from the different climate subsystems (atmosphere, ocean, land-surface, sea-ice)
- Evaluate the ability of climate models to simulate a climate different from that of today

Three simulations out of the PMIP3 suite are included in CMIP5 with the condition that the same model version is used for past, present and future simulations. 21 groups, some with multiple model versions, have run the PMIP3 simulations. Work is on-going to efficiently connect the PMIP3-CMIP5 archive that is served through the ESG with the rest of the simulations run by groups just participating in PMIP3 that are archived by IPSL. The groups that are just involved with PMIP3 encounter difficulty in submitting data to their national ESG nodes.

The key areas of focus for PMIP3 are:

- Benchmarking (addressing the reliability of ensemble and relating model behavior/feedbacks in paleoclimate simulations and future projections)
- Climate sensitivity and polar amplification
- Uncertainties in boundary conditions

- Ocean circulation (THC and fresh water fluxes)
- Climate variability

A special issue of Climate of the Past is being produced on progress in paleoclimate modeling that will address aspects of these focus areas. A suite of papers and newsletters are also being produced on the outcomes of recent PMIP meetings, updates on PMIP boundary conditions and on the synthesis and outlook of PMIP2.

5.3 Coupled Climate Carbon Cycle Model Intercomparison Project (C4MIP)

For the CMIP5, there were experiments on the coupled-carbon-climate model simulations (C4MIP), which have been analyzed by the community. Several papers will come out regarding the performance of the models (e.g. Friedlingstein et al., Jones et al., Arora et al., all submitted to JOC). In addition, there are other papers in preparation (e.g. Hoffman et al.), and 16 currently appear on the PCMDI website in connection with coupled carbon cycle modeling. The models have been critically evaluated for their ability to simulate the carbon cycle, as well as to address the differences among the models. The models are adequate in simulating the carbon cycle, but there is more work to be done. All predict higher CO_2 values for a given emissions scenario than predicted by the IAMs which provided the concentration scenarios, especially for the nitrogen-limited models, which have less carbon fertilization. On the other hand, the modeled range of impact of climate onto the carbon cycle since AR4 has gone down because of the inclusion of nitrogen-limited models (as well as the reduction in the prediction of the climate feedback onto carbon from the model that was highest in the last assessment).

It should be noted that although CMIP5 was successful in including assessments of the carbon portion of the earth system model, CMIP5 archive aerosol simulations are not being evaluated very well. More needs to be done to include that community in evaluation efforts.

5.4 Transpose-AMIP

Climate models are run for Transpose AMIP in NWP-mode for detailed process and model evaluation while the large-scale dynamics is well constrained. 5-day hindcasts are initiated from ECMWF YOTC analysis, as well as additional optional simulations initiated from the NASA MERRA reanalysis or the centre's own analysis. The hindcasts are spread through the annual and diurnal cycles during 2008/9 and were chosen to tie in with YOTC and coincide with some of the IOPs in VOCALS (SE Pacific stratocumulus), AMY (Asian monsoon) and T-PARC (mid-latitude Pacific). Any global modeling centre (NWP or climate) can submit data. Those taking part in CMIP5 should use the same model as is being used for their AMIP simulation.

About 10 groups are currently participating in T-AMIP. Since this project was not included in the CMIP5 suite of experiments, it has been viewed as a lower priority and so uptake has been slower. The community is using the available models for a wide range of diagnostic studies aimed at improved understanding and representation of key processes and modes of variability. The first major paper is targeted at Southern Ocean clouds. The use of short-range forecasts for climate model development is becoming well established in WCRP programs (e.g. MJO studies in GASS). T-AMIP could evolve into a more formal 'framework' that can easily be targeted at future observational programs.

RECOMMENDATION:

WGCM to raise the profile of Transpose-AMIP and encourage wider participation.

5.5 Geoengineering Model Intercomparison Project (GeoMIP)

There are 19 modeling groups (more are expected) participating in the four idealized Geo-MIP experiments, with consistent results increasing confidence in the robustness of model response to geoengineering. Initial results for example show that offsetting solar radiation cannot reverse projected climate change precipitation changes in the Tropics. Limited resources mean that time dedicated to GeoMIP is currently voluntary. Some of the experiments (particularly G3) are difficult to carry out and analyze. A special issue in JGR-Atmosphere is planned (deadline 1st April 2013). Experiments on stratocumulus brightening are planned.

6. Summary of Climate Modeling Center Updates

Modeling groups were solicited to report on the status of their participation in CMIP5, on the successes and difficulties encountered and to provide recommendations for future CMIP plans. Appendix 4 provides a table that summarizes the reports.

7. Discussion Topics

7.1 Climate model metrics

Work is ongoing by the ad-hoc WGCM-WGNE Metrics Panel to identify a limited but diverse set of climate model performance metrics that can be justified and promoted in an attempt to establish routine performance benchmarks. Redundancies are being examined to see where different metrics that are in use in the community yield similar answers. The group is coordinating with other WCRP working groups to identify metrics for more focused evaluation (e.g., variability modes, 'process' level) and to facilitate further research of increasingly targeted metrics. The evaluation is being focused on the analysis of historical runs, rather than the evaluation of forecasts or predictions.

Benchmark metrics are selected that can be compared with observations, preferably multiple observations, that are well established in the literature and are already in widespread use, fairly robust and easily interpretable. The aim is to cover a diverse suite of climate characteristics of large- to global-scale mean climate and some variability of the atmosphere, oceans, land surface, and sea-ice.
The panel's wiki was made public in April 2012: http://www-metrics-panel.llnl.gov/wiki

The priorities for the panel are to strengthen the wiki so that it becomes recognized as a useful resource. All modeling groups will be provided with a database of standard metrics code and results from all CMIP 3/5 models. This will enable groups, if interested, to incorporate the ability to examine how their model compares to others into their development process. A manuscript will be prepared that synthesizes the metrics panel results for CMIP 3 & 5 and the concept of a repository for metrics/analysis codes will be promoted. A workshop dedicated to performance metrics is being planned to follow on from the April 2013 WGNE systematic errors workshop.

7.2 Obs4MIP

Obs4MIPs is a pilot effort to improve the connection between data experts and scientists involved in climate model evaluation. Observational data is being organized in a way that is technically aligned with CMIP5, both in terms of format and metadata, and accessed by the ESGF. CMOR has been generalized to conform observational data, as well as model data, to CMIP5 and ESGF standards.
NASA and U.S. DOE initiated this activity. There are now a variety of NASA products available, each accompanied by a technical note that includes information on the data origin, an instrument overview, references, an estimate of uncertainty and caveats regarding comparisons with models. A current priority is to enable other data communities to contribute data.

It is hoped that the WDAC can provide primary oversight to this activity, together with encouragement and feedback from WGCM. For example, guidance is sought on what additional products would be particularly helpful for advancing model development and evaluation. Further coordination with CFMIP-OBS and other efforts is a priority. ESA and NOAA have expressed interest in joining the initiative. The protocol for data contributions will be strengthened to ensure other data providers can contribute. If successful, Obs4MIPs will improve the connection between modeling groups, analysts and the data experts/providers, who will be thus motivated to keep their product versions and documentation up-to-date on the ESGF.

RECOMMENDATION:

> WGCM supports the Obs4MIP activity and recommends that it should be broadened beyond NASA, also to include ground observations. The activity should report to both WDAC and WMAC.

7.3 Documenting climate models and their simulations

The METAFOR (EU) and CURATOR (US) projects have established a metadata repository to make generally available an unprecedented level of detailed information on the models and simulations for CMIP5 (Guilyardi *et al.,* 2012). The motivation has been to expand the use of climate model data by a broad range of climate specialist and non-specialist users, to increase the credibility and transparency of climate science and model development, to facilitate the comparison of simulations, and to understand the structural uncertainty in climate simulations resulting from the use of different models and model versions.

A metadata conceptual model has been designed by climate and information technology experts based on the information that is necessary to describe models and their simulations: the Common Information Model (CIM). A questionnaire (the 'METAFOR Questionnaire' http://q.cmip5.ceda.ac.uk/cmip5/) was designed and implemented as part of the CMIP protocol. The result is a repository that documents the 42 models and 600 simulations available on the CMIP5 archive. The next steps to be addressed include enabling metadata and model data to be peer-reviewed and referenced with the DOI (Digital Object Identifier) system. Beyond CMIP5, the intention is that the CIM and the associated standards will become increasingly adopted by climate modeling frameworks in much the same way that promotion of the CF conventions led to standardization of climate model output. The activity seeks oversight from WGCM or WDAC.

7.4 Model tuning

Chapter 9 of the IPCC AR5 (CH9) has a 'box' on model development that includes a brief description of model tuning. It is defined as the final parameter adjustment procedure, after all model components are assembled into a final coupled model configuration. However, this is not a universally-accepted definition. This tuning typically involves a relatively small number of parameters, and adjustment is toward a small set of large-scale constraints (like global-mean top-of-atmosphere energy balance) usually, 'time-mean' quantities, though historical transient change may be targeted explicitly or implicitly.

In evaluating model performance, this poses a problem: *one cannot use model-observations error as a measure of model quality if the observations in question were used as a tuning target*. Quantities related in some way to tuning targets provide weaker tests of model fidelity than those that are truly independent. There is also a question of the extent to which tuning impacts model sensitivity and hence future climate response. The correlation between model bias and model sensitivity should be investigated in greater details.

The tuning process and observational targets used by each modeling group are seldom comprehensively documented. By looking at a wide range of performance metrics, making use of metrics connected to processes, and exploring a wide range of climate phenomena on a wide range of time scales, the problem is minimized (since no model could possibly be tuned to satisfy all of the corresponding observational constraints). It would be valuable to have better documentation of the tuning process for each model. Being more 'transparent' about model tuning, what it is, what it is *not*, what effect it has, how it is done, etc. would be helpful in dispelling certain myths and misconceptions.

Discussion points:

- Should WGCM promote more thorough documentation of model tuning, and more exploration into the impact of various kinds of tuning on model behavior?
- Can this documentation become a standard component of model intercomparison projects?

Modeling centers may be unwilling to share information on model tuning because of worries on how the information would be used or, in particular, mis-used or mis-interpreted. However IPCC AR5 Chapter 9 demonstrates that the hundreds of constraints of coupled climate models means that not all could possibly be tuned to obtain a 'preferred' result, as climate skeptics would suggest.

A workshop on model tuning has been suggested, following the example of the WGNE model systematic errors workshops. Tuning is a feature of the modeling community as a whole (WGCM, WGSIP, WGNE, WGOMD, etc) so this may be a WCRP-wide topic that WMAC could promote, for example by organizing a workshop.

RECOMMENDATION:

Recommend to WMAC to organize a WCRP-wide workshop on model tuning

8. Discussion on a future CMIP6

The CMIP framework has established the value of the multi-model ensemble and has subjected models to wider scrutiny. At the same time, modeling groups have been taxed considerably by the heavy resource requirements of participating in CMIP5. This, combined with the rush to keep to IPCC assessment deadlines lays the basis for the possibility of decoupling the CMIP framework from the IPCC cycle by establishing a set of benchmark simulations that modeling groups run as part of their model development process, additional specialized experiments (CFMIP, PMIP, etc) that groups can run depending on their resources and interests, and the RCP scenario runs that would be produced for IPCC assessment. The benchmark experiment design would evolve more slowly, being revisited as new models are developed. The additional, specialized intercomparisons would build on these benchmark simulations, keeping to the same standards and infrastructure.

8.1 ESGF Governance

The ESGF is being increasingly used, for example to serve observations for model evaluation, so the user needs are increasing. A governance proposal for the ESGF is in preparation. It would consist of a high level governing panel and a technical panel under it. The high level panel would have representatives from the technical panel, modeling groups and users to formalize how users and data providers input their needs as ESGF operational and development priorities. The U.S. Department of Energy (DOE) currently funds over 90% of the ESGF so the governing panel Chair is expected to be a DOE-funded representative. The panel must also be inclusive of other contributors, recognizing different levels of support. Current third-level players may raise their role in the future, such as the European IS-ENES project. The technical panel would have leaders representing contributions to the technical development of the ESGF from around the world. WGCM will maintain its link to the ESGF via PCMDI representation, ensuring that changes in the ESGF are vetted and communicated well in advance and to raise the profile of the technical aspects of the system, helping to educate the climate community on software developments.

A formal governance structure will encourage the consolidation of ESGF funding with international inter-agency agreements, orchestrated by WCRP. WCRP and NRC endorsement should be capitalized on by agencies to increase the base funding for a global data infrastructure that is both operational and continuously developing. Sustained support for the ESGF is essential to ensure the provision climate data is operational as it is within numerical weather prediction.

ACTION: WGCM to send a letter to the WCRP JSC to recommend that all other MIPs adopt CMIP and ESGF protocols.

ACTION: Ensure that WGCM maintain its link to the ESGF via PCMDI

ACTION: WGCM to send a letter to DOE and other international funding agencies to emphasize the need for consolidated ESGF funding. Seek cosignatories from Chair JSC, Chair WG 1, IPCC. D. Williams to compose list of recipients.

8.2 Experimental Design

Assuming a next phase of CMIP would be in some ways comparable to CMIP5, it would involve several communities, with a core set of experiments of calibration idealized experiments (e.g. 1% runs, 4XCO2, etc.), historical and future prediction/projection runs, and several layers of other experiments. The ESGF makes it possible to have on-going activities with new experiments being initiated and going to WGCM for endorsement. There have been suggestions to decouple model development or idealized aspects of CMIP from the IPCC assessment cycle while having the scenario-driven component timed for IPCC assessment. A balance is needed between continuing with a core set of CMIP experiments and expanding the experimental design to address emerging science questions, as was the case between CMIP3 and CMIP5.

CMIP6 practical considerations:

- CMOR has reached a level of maturity to be promoted as the standard protocol and modeling groups could consider saving their output directly into CMOR format
- Data management planning needs initiation now because of the increasing model resolution and complexity (expect "near-exabyte" scale of CMIP6 data volume)
- International approach to evaluation with an expanded role for the Metrics Panel could be considered as well as implementing semi-regular model analysis workshops
- Idealized experiments have proved to be highly valuable in CMIP5 to address science questions; they should constitute an important component of CMIP6
- High frequency temporal data is desirable for some experiments. A survey of what fields are being used in CMIP5 is needed to assess whether there are redundancies in usage and if there should be a different list of fields for different experiments with prioritized fields
- Data access needs to be easier and needs secure funding for the ESGF
- METAFOR needs further work in concept and application
- Experiment specification requires sufficient detail far enough in advance for effective configuration and prioritized fields need to be finalized early
- CMIP6 should have continuity with CMIP5.
- Continuity with scenarios is required, though the IAM community and the climate modelling community may need to adjust or add sensitivity experiments (e.g. aerosols, land use change, 2C warming bigger peak and decline in RCP2.6)
- Details of land-use change that are adapted by each group need to be addressed

CMIP6 possible science topics:

- Land use –aerosols—ESM applications—interact with a couple of the SSPs that show quite different outcomes from RCPs
- Reversibility or geo-engineering
- Decadal prediction, including extremes and air quality
- More idealized experiments, e.g. like the 1% CO2 runs but for other forcings, idealized aerosol, ozone, land use
- Model systematic biases
- Very high-resolution time slice experiments for tropical cyclones
- Higher resolution coupled simulations for tropical cyclones and extremes

- Coupled land ice for global and regional sea level rise

The CMIP6 design needs to consider how it will feed into climate services. Users should be consulted on the societal relevance of the CMIP experiments and dialogue with the adaptation science community would help in identifying what climate information is needed for better informed adaptation decisions. Increased input into the design from the IGBP community is also needed.

8.3 CMIP6 schedule

Following the example of CMIP5, the following schedule could be envisaged for CMIP6:

- CMIP6 exploratory workshop 2013
- Model analysis workshop with CMIP5 focus 2014 or 2015
- WGCM approval of experimental design 2015 (duration of CMIP6 2015-2019)
- CMIP6 model analysis workshop 2018
- Deadline for AR6 papers - 2019, AR6 published 2019 (Maybe 2020?)

9. WGCM Business

17th Session of WGCM

Greg Flato offered to host the next WGCM meeting in Victoria, Canada in October 2013. The meeting will be held jointly with AIMES with two days separate and one day joint.

Proposed Meetings

RECOMMENDATION:

WGCM recommends WMAC to organize a workshop on model tuning (relevant for WGMC, WGSIP, WGNE) in 2013/14

ACTION: Produce a review paper to communicate issues related to model tuning that should be addressed by the wider modeling community as a rationale for holding a workshop on model tuning.

ACTION: Organize an Aspen Global Change Institute workshop to explore the design of CMIP6 in Summer 2013, ahead of the 17th Session of WGCM, where the modeling groups will review the draft design.

Membership

Rotating off: P. Braconnot, M. Giorgetta, N. Nakicenovic and M. Kimoto

New members (January 2013): M. Kageyama (LSCE), M. Kawamiya (JAMSTEC), B. Stevens (MPI-M), D. van Vuuren (NEAA) and C. Tebaldi (NCAR).

CMIP panel
Rotating off: M. Latif, J. Mitchell and C. Covey
New members: V. Eyring (new Chair, replacing R. Stouffer in 2014, who will remain as a regular member), N. Mahowald and B. Stevens

Decadal Climate Prediction Panel
Rotating off: R. Stouffer, M. Latif
New members: F. Doblas-Reyes, W. Muller, K. Masahide, pending J. Mignot or C. Cassou

10. Joint WGCM-WGSIP Meeting - Decadal Prediction

Objectives of the joint session (WGCM and WGSIP co-chairs)
Adam Scaife outlined the objectives of the session and pointed out that this is the 1st joint meeting between WGSIP and WGCM. The major common topic of both working groups is the decadal prediction effort focusing on initialized predictions. Gerald Meehl recalled that a similar joined WGNE/WGCM meeting was held last year on atmospheric model development.

Overview of WGCM (G. Meehl)
Gerald Meehl recalled that WGCM's mission is to review and foster the development of coupled climate models (AOGCMs) and Earth System Models (ESMs, usually defined as an AOGCM with at least a coupled carbon cycle, can also have dynamic vegetation, chemistry, aerosols, etc.). The working group coordinates CMIP with many MIPs partners and connects to IGBP (AIMES, PAGES), WGNE (Transpose-AMIP), GEWEX/GASS (CFMIP) and WGSIP (Decadal Climate Prediction Panel, DCPP). WGCM also facilitates model validation and diagnosis (e.g. metrics panel, joined between WGNE and WGCM). DCPP has been setup to oversee the decadal experimental design for CMIP5 and possibly for CMIP6.

The discussion emphasized the need for WDAC to liaise with the modeling community. It was recommended to have a WGSIP representation on the metrics panel. Adam Scaife suggested considering probabilistic scores as part of the metrics. Veronika Eyring stressed the need for sharing metrics code to facilitate model evaluation. CMIP membership was questioned as the panel moves to the next phase of experiments.

Overview of WGSIP (A. Scaife)
Adam Scaife stressed the research focus of WGSIP whilst the WMO CBS Expert Group on Long Range Forecast has an operational purpose. He also recalled that WGSIP and WGCM now report to the JSC. The flagship WGSIP project is CHFP with 8 groups contributing hindcasts so far served from CIMA in Argentina. It is planned to update these over time to assess the evolution of skill with models. WGSIP sub-projects focus on land, stratosphere and sea-ice initialization and have developed

their own experiments to evaluate sources of predictability in the climate system that will inform the development of seasonal prediction systems.

Decadal hindcast databases are part of the CMIP5 approach. In contrast, for seasonal forecasts, 12 WMO Lead Centers provide seasonal forecasts in real-time to KMA as part of the WMO seasonal forecast exchange, so building a global MME. Exchange of decadal predictions in the future would require addressing permissions from producing centers but could happen following the example of the Decadal Forecast Exchange initiated by Doug Smith and Adam Scaife. The seasonal forecast approach of full field initialization with bias adjustments contrasts with the anomaly initialization approach adopted by many climate modeling groups to initiate decadal predictions. Initialized decadal predictions are cooler than uninitialized CMIP5 climate projections suggesting that projections are warming too fast. Adam Scaife suggested that initialized near term climate predictions might therefore be a tighter test of climate sensitivity.

Decadal prediction: lessons from CMIP5 experimental design (F. Doblas-Reyes)
Francisco Doblas-Reyes recalled the progression from the weather and seasonal forecasting initial-value problem to climate projections as a forced boundary condition problem, intersecting at the decadal prediction mixed initial value and boundary condition problem. Predictions are distinguished from projections through the use of model initialization. The CMIP5 near-term core experiments prescribe the atmospheric composition in the historical set of hindcasts and are run forwards into the future with RCP4.5 forcing. It is important to properly consider lead time aspects in skill evaluation. Forecasts produced by different groups of the same period may have different lead times. It is not obvious whether they should be evaluated by forecast time or lead time. The importance of accurate SST and ocean sub-surface initialization was stressed. Full field initialization should be used unless there are concerns about dynamic imbalances in the fields. Ensemble approaches should aim at representing the uncertainties in initial conditions.

Systematic error is model dependent and is very different from one system to another. Hindcast runs are used to provide reliability estimates of predictions and to calibrate them. Model drifts are corrected for by analyzing mean climate and tendencies, which requires yearly initializations instead of every 5 years, as initially required by the CMIP5 protocol. By specifying the solar cycle and volcanoes, CMIP5 decadal predictions may be overestimating skill. Hindcasts run as real-time predictions that do not include this additional information will better quantify skill. Skill differs depending on lead time and depending on the initialization approach (full field and anomaly initialization, no initialization), with yearly start dates delivering a more robust result, instead of 5-year start dates. Where there is negative skill, there is likely to be an improvement over time with model improvement reducing systematic biases and improved initialization techniques reducing initialization shock in the system.

Sandrine Bony stressed the interest of precipitation patterns not only over land but also over the ocean. Colin Jones recalled that some skill of initialized predictions might be related to the density of observations (e.g. high in the North Atlantic).

Decadal prediction: science highlights and IPCC AR5 (B. Kirtman)

Ben Kirtman provided an overview of decadal predictability and predictions contributing to AR5 Chapter 11. Globally averaged correlation skill for initialized and uninitialized actual and potential skill were presented. The first 2 years suggest a strong benefit from initialization. Initialization usually improves correlation and RMSE for Surface Air Temperature (SAT) and Atlantic Multidecadal Variability (AMV) whilst initialization shocks pose difficulties on the Interdecadal Pacific oscillation (IPO). An analysis of T2m suggests a higher skill for initialized predictions. It was noted that 75% of models agree over the North Atlantic. Observations after 2005 suggest that projections overestimate global warming as initialized predictions show lower temperatures.

Gokhan Danabasoglu noted that ocean models have issues in representing the circulation correctly and it would be worth looking at the impact of data assimilation.

GC1:"Provision of skillful future climate information on regional scales (includes decadal and polar predictability)" (G. Meehl, F. Doblas-Reyes)

Gerald Meehl and Francisco Doblas-Reyes outlined the barriers to the Grand Challenge 1:

- Less decadal predictive skill over the Pacific compared to the Atlantic
- Less decadal predictive skill for precipitation than temperature
- It is still unclear what the best initialization strategy yields the best predictions
- Bias adjustment remains a major factor in decadal predictions and all groups do it somewhat differently
- The concept of “near term” climate prediction typically extends to roughly 30 years, but the focus of most decadal climate prediction studies until now has been on the next decade
- Need for model development
- Need for large samples to obtain robust forecast quality estimates
- Relevance of decadal predictions for climate services
- Limited skill over land regions
- Very limited skill for extratropical atmospheric circulation

Joint WGSIP/WGCM implications in WCRP Grand Challenges GC4: "Clouds and climate sensitivity" (S. Bony)

Sandrine Bony presented recent developments on this grand challenge that has been revisited since the last JSC in Beijing with inputs from GASS, GEWEX, CFMIP, PMIP, WGNE and others and will be overseen by WGCM. Current barriers pertain to the inability to constrain the effects of clouds on climate sensitivity estimates, the lack of understanding of regional circulation and precipitation changes (especially over land) and unreliable representation of the coupling between cloud processes and large-scale dynamics. Rapid progress could be achieved by the critical mass of MIPs efforts, emerging new models (e.g. LES, CRMs over large domains and super-parameterization), and a golden age of Earth Observations. It is proposed to develop targeted research efforts around 5 initiatives:

- Climate and Hydrological Sensitivity
- Leveraging the Past Record
- Coupling Clouds to Circulations
- Changing Patterns
- Towards More Reliable Models

<u>Ideas for the future (CMIP6 coordinated set of experiments) (inputs from all)</u>
The joint session ended with a discussion about ideas for a possible future CMIP6 coordinated set of experiment.

Hervé Douville suggested CMIP6 as one integrated experimental design and raised the issue of decadal runs and their position in the core vs tier experiments. Core experiments should make due consideration of available CPU resources and should include more coordinated experiments devoted to model evaluation such as AMIP, but also off-line OGCM and land surface model simulations driven by common atmospheric forcings based on bias-corrected atmospheric reanalyses (as in the CORE-2 and GSWP initiatives). In contrast, large ensemble simulations such as decadal hindcasts should not necessarily appear as core experiments, although this view was not that of WGSIP in general.

CMIP5 offered many more experimental degrees of freedom. Uncertainties differ from CMIP3 and causes need to be investigated.

Adam Scaife stressed the importance of users who show a stronger interest for near term experiments. Historical runs provide confidence for future predictions and projections. He also recalled that hindcast experiments are fundamental to understand discrepancies in warming rates between decadal predictions and projections. As such decadal hindcasts should remain part of the core set of CMIP experiments. He also suggested that it would be interesting to add aerosol forcing in decadal predictions.

Colin Jones agreed that core experiment should contain near term experiments because of their importance for users. Ron Stouffer stressed the value of real-time experiments and wondered what role CMIP could play.

Ben Kirtman stressed that hindcasts are essential to calibrate predictions.

Sonia Seneviratne raised the issue of credibility of predictions. Model physics and development are common to several Grand Challenges, especially number 1 and 4. She also highlighted soil moisture initialization issues for decadal predictions.

Bjorn Stevens stressed the importance of having a compact core set of experiments.

Jerry Meehl recalled that there were historical reasons for the separate decadal and long term CMIP5 protocols.

Tim Stockdale noted that there are 2 sets of decadal communities: ESMs multi-decadal initialized simulations and the 1-9 year decadal predictions issued with yearly start dates. CPU considerations should be taken into account.

Karl Taylor noted the critical aspect of differing approaches to bias correction and how to consistently compare various sets of predictions.

Greg Flato wondered if there was any interest in the decadal community to tackle GHGs like methane and black carbon and air quality. Prescribing short-lived species in near term scenario simulations would be of interest to assess the rapid impact of mitigation policies for these pollutants.

Sandrine Bony highlighted the need for synthesis papers, for example in a special issue of a journal, which would be taken up by the various MIPs efforts and could help planning for the future CMIP6.

The meeting was closed at 12.30 by the co-chairs Gerald Meehl and Adam Scaife.

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Appendix 1: Action Items and Recommendations

Nb	Action
1	Coordination between WMAC and WDAC is imperative to ensure that progress is made in closing the gap between modeling and observations. The WDAC membership should be expanded to improve the representation of the modeling community; linking in particular the data archive software development community (ESGF) and the CMIP panel (WGCM to JSC).
2	Change the clouds GC title to Clouds, Circulation and Climate Sensitivity (WGCM to JSC)
3	Hold a WGCM-IAM workshop to assess, for example, how well the CMIP5 scenarios have performed and ESM sensitivity to land use changes, and to evaluate the scenario development process and design for future CMIP experiments
4	CMIP model analysis workshop to become a regular WCRP-WGCM event.
5	Encourage modeling groups to participate in the MJO Task Force / Years of Tropical Convection "Vertical Structure and Diabatic Processes of the MJO" model evaluation project
6	Maintain the reporting link between CORDEX and WGCM
7	WGCM to raise the profile of Transpose-AMIP and encourage wider participation.
8	WGCM supports the Obs4MIP activity and recommends that it should be broadened beyond NASA, also to include ground observations. The activity should report to both WDAC and WMAC.
9	Recommend to WMAC to organize a WCRP-wide workshop on model tuning.
10	WGCM to send a letter to the WCRP JSC to recommend that all other MIPs adopt CMIP and ESGF protocols.
11	Ensure that WGCM maintain its link to the ESGF via PCMDI
12	WGCM to send a letter to DoE and other international funding agencies to emphasize the need for consolidated ESGF funding. Seek cosignatories from Chair JSC, Chair WG1, IPCC. D. Williams to compose list of recipients.
13	Produce a review paper to communicate issues related to model tuning that should be addressed by the wider modeling community as a rationale for holding a workshop on model tuning.
14	Organize an Aspen Global Change Institute workshop to explore the design of CMIP6 in Summer 2013, ahead of the 17th Session of WGCM, where the modeling groups will review the draft design.

Appendix 2 – Meeting Agenda

Monday, September 24

0900 - 0920 - Opening
Welcome, meeting objectives, new WGCM members, agenda (G. Meehl, S. Bony)
Logistics (M. Giorgetta)

0920 - 1000 - WCRP updates (10 minutes each)
Report from JSC-33 (G. Flato)
WCRP Data Advisory Council (M. Rixen)
WCRP Modeling Advisory Council (J. Mitchell)
WCRP Grand Challenge on Clouds and Climate Sensitivity (S. Bony)

1000 - 1030 - IPCC AR5 (10 minutes each)
Issues raised by Chapter 9 (G. Flato, J. Marotzke)
Issues raised by other chapters (TBD)

Discussion: how to improve communication about model adjustments and tuning?

1030-1100 - Coffee break

1100 - 1200 - CMIP5
CMIP5 Workshop (G. Meehl)
Status of model outputs, documentation, ESGF, publications (K. Taylor)
Discussion: how should the ESGF governance evolve?

1200 - 1230 - Obs4MIPs and Metrics Panel (10 minutes each)
Obs4MIPs (P. Gleckler)
Metrics panel (P. Gleckler)

Discussion: what role for WGCM in Obs4MIPs and in the Metrics Panel?

1230 - 1350 – Lunch

1350 - 1530 - MIPs and working groups associated with CMIP5
What have we learned? Issues? Plans for synthesis papers? (15 min, incl questions)
NB: Decadal prediction addressed in WGCM-WGSIP joint meeting
CFMIP (S. Bony)
Transpose-AMIP (C. Senior)
PMIP (P. Braconnot)
CORDEX (C. Jones)
WGOMD (G. Danabasoglu)

Discussion: interactions among the MIPs: gaps, opportunities?

1530 - 1600 - Coffee break

1600 - 1730 - MIPs and working groups associated with CMIP5 (continued)
- C4MIP (N. Mahowald, P. Friedlingstein)
- SPARC-CCMVal (V. Eyring)
- SPARC-DynVar (E. Manzini)
- GeoMIP (K. Taylor)
- IDAG (C. Tebaldi/G. Meehl)
- SSP process (D. van Vuuren)

1730 - 1800 - Recap of the day

Tuesday, September 25

0900 - 0915 Review previous day and outline agenda for the day (G. Meehl and S. Bony)

0915 - 1030 Reports on status of CMIP5 national activities
Your experience of CMIP5: successes, difficulties, plans, recommendations for the future, science gaps and new questions that have emerged, related to how to formulate a possible CMIP6? (15 minutes, incl. questions)
- Germany, MPI (M. Giorgetta, B. Stevens)
- UK Met Office-Hadley Centre (C. Senior)
- France, IPSL; Météo France (P. Braconnot, S. Bony)
- EC-Earth (C. Jones)
- Italy, CMCC (A. Bellucci)

1030 - 1100 - Coffee break

11:00 - 12:30
- USA, GFDL (R. Stouffer)
- USA, NCAR (G. Meehl)
- Japan, AORI/U. Tokyo/JAMSTEC/NIES; MRI (M. Kawamiya)
- China, LASG; BCC (B. Wang)
- Australia, ACCESS (T. Hirst)
- Canada (G. Flato)

1230 - 1400 – Lunch

1400 - 1530 Discussion: (1) lessons from CMIP5 and related activities
- CMIP5 Early Assessment (R. Stouffer)
- Logistical issues: ESGF, CMIP5 format, documentation, etc

Experimental design of CMIP5: benefit, cost, idealized vs realistic expts, socio-economic scenarios, etc
Science: key lessons from CMIP5? what implications for the future?
What about CMIP6? What should it look like? What about new scenarios?

1530 - 1600 - Coffee break

1600 - 1700 Discussion: (2) how to promote and synthesize CMIP5 science?"
Synthesis papers: why? how? when? where?
Should WGCM (eventually with others) organize a regular model analysis workshop (e.g. like the CMIP5 model analysis workshop)? If so, how often?
How to get/organize feedback from CMIP5 analysts to modeling groups?

1700 - 1730: Clouds and Climate Sensitivity: grand ideas for the Grand Challenge? Comments on the white paper.

1730 - 1800 - WGCM business
Workshop (model tuning?)
Next meeting: joint with IGBP/AIMES?
Membership

19:00 Joint WGCM and WGSIP workshop dinner hosted by MPI-M

Wednesday, September 25 - Joint WGCM-WGSIP Meeting - Decadal Prediction

09:00 WGCM-WGSIP Joint Meeting on Decadal Prediction

- Objectives of the joint session (WGCM and WGSIP co-chairs)
- Overview of WGCM (J. Meehl) (20 minutes + 10 minutes Q&A)
- Overview of WGSIP (A. Scaife) (20 minutes + 10 minutes Q&A)
- Decadal prediction: lessons from CMIP5 experimental design (F. Doblas-Reyes)

10:30-11:00 Coffee Break

- Decadal prediction: science highlights and IPCC AR5 (B. Kirtman)
- Joint WGSIP/WGCM implications in WCRP Grand Challenges
GC1:"Provision of skillful future climate information on regional scales (includes decadal and polar predictability)" (G. Meehl, F. Doblas-Reyes)
GC4 : "Clouds and climate sensitivity" (S. Bony)
Ideas for the future (CMIP6 coordinated set of experiments) (inputs from all)

12:30 Lunch
15:00 Meeting Ends

Appendix 3 – List of Participants

Members

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Appendix 4 – Modeling Center Updates on CMIP5 and Future Recommendations

Modeling Center/Country	Positive Experiences	Difficulties	Recommendations
MPI	Focused on the incorporation of interactive vegetation, a carbon cycle, a high-top and modest changes to physics. Model is being used widely by the community and is generating feedback. CMIP is important for MPI, unifying the institute and model development. Connecting to international assessments allows us to make a case for resources and support that would not otherwise be available (e.g. tech. staff, computing time). Participation in international effort is motivational for technical staff.	Do not believe that there is sufficient physical understanding to merit including aerosol indirect effects, so were assumed to be zero. Some internal difficulties (i.e., overly optimistic about scaling led to an inability to get a high resolution coupled model performing satisfactorily). Some of the boundary data specification came late. CMOR was not easy.	Maintain continuity between CMIP5 and CMIP6 Explore scenario-driven simulations (e.g. impact of deforestation in America) Go further to decouple forcings Design protocol to address model biases
UK Met Office – Hadley Center (MOHC)	CMIP5 provides an essential resource for the climate science community and for IPCC. Many papers have been submitted using CMIP5 data and these will figure prominently in AR5. First multi-model ensemble of ES models that will allow much improved analysis of carbon cycle and chemistry CMIP5 enabled the MOHC to make considerable amount of data available to the climate community. MOHC/UK academic community have managed to download data from wide range of other modelling centres In July 2012, MOHC submitted ~40 papers based on CMIP5 data Climate sensitivity and cloud feedbacks and	Timetable for CMIP5 relative to AR5 too short for enough analysis to feed into AR5 CMIP5-AO models are behaving like CMIP3-AO models, suggesting little progress on physical modelling capability – perhaps not a long enough gap between MIPs? Protocol for near-term experiments too vague Data access has been more difficult than necessary High frequency temporal data still not available for many models Insecure funding of resource needed to develop and maintain the archive/data provision Difficulty in reproducing multi-model figures due to ongoing changes in model versions	Second generation ESMs - 'from global to regional'. Emerging science topics: • Nitrogen cycle • Ice-sheets • Land use • On-line impacts modelling • ESM evaluation • Separate role of individual forcings (solar, volcanic, aerosol, methane, black carbon) • Reversibility e.g. for geo-engineering • Real-time decadal prediction High resolution physical models: +6 years will not be so far from where we are now. Maybe need to get to <10km? How long for this? Experimental design • Limited extensions to CMIP5 protocol: value of idealised expts

	attribution studies of continental temp will feature prominently in AR5		• Fuller implementation of the CMIP5 protocol across models • Protocol to be defined well in advance Data access: simpler system
IPSL-MeteoFrance-CERFACS	A trigger for model improvement Same model version between MIPs: progress across the past and future; climate-carbon, predictions and projections Role of idealised simulations Implementation of COSP simulator Climate Dynamics Special Issue to present IPSL and CNRM ESMs: First time key references for the models are available prior to multi-model analyses, stimulating discussions, exiting results, more questions.	Storage requirement was underestimated and experienced problems to migrate onto a new storage system	CMIP5: Synthesis of results and feedback on the whole project in 2-3 years' time Need to define key questions (e.g. for CMIP5: carbon feedback, decadal prediction and extremes) Should be "reasonable" (smaller gap than between CMIP3 and CMIP5), with CMIP5 as a baseline with additions to cover gaps or new questions Build on CMIP3/5 results with a focus on model systematic biases Regional changes in aerosols and land use Review timing with IPCC (different steps) Dedicate time to discuss and share expertise on model development More anticipation needed to plan computing resources, data distribution, software development for analyses, etc. Harmonization of lists of variables and diagnostics ESGF - need: • Transparency / key decisions • Roadmap (short/medium/long term) available to all • User needs to drive ESGF development • Climate modelling representative • Open source approach
EC-Earth	Historical, projections and decadal prediction ensembles produced by 9 institutes in 7 different countries	CMIP5 came a year early in terms of EC-EARTH readiness, so encountered difficulties with data processing issues for the ESG archival, running with distributed centers, leading to a delay in the data being delivered to the ESG.	CMIP6 should emphasize on the near-term climate, on addressing systematic errors and exploring initialization strategies.

		ESG organization in ‘realms’ at the portal level – would prefer a system based on variables that can be separately uploaded. To download a particular variable, have to go through each model, rather than downloading from all available models at once. Yearly-initialized decadal simulations are not visible, only the 5-yearly start dates. Frequent data updates leads to earlier data being no-longer visible	
CMCC		Downloading data from CMIP5 archive harder than for CMIP3	Produce statistics of downloaded variables from CMIP5 archive may help in assessing the real demand of climate models data from users, and so help plan CMIP6 output Promote CMOR as a standard protocol for climate data format (i.e., GCM output directly saved into CMOR format) to alleviate the (very time-consuming) post-processing stage Use the CMIP5□CMIP6 interval to tackle model systematic error reduction in a more systematic way Move towards higher resolution ocean models: the inclusion of mesoscale turbulence in the oceanic component of global CGCMs may have a dramatic impact on our current vision of climatic processes (THC, energy transfer at the air-sea interface, interaction with marine biogeochemical cycles…)
GFDL	Have produced 30,800 of model years, 164.1 TB of data, which is more than the whole CMIP3 archive Over 130 publications so far evaluating GFDL models, plus those that will evaluate the MME	Underestimated the task of CMOR-ising and quality control to publish data. Curator software was being developed while data publishing was being done Very large volume of runs and data requested Variable list kept changing throughout the process METAFOR questionnaire: • Hard and time consuming to complete	Output variables directly in CMIP units and conventions – CMORizing online. Will only run 1-2 models in the next CMIP and will decouple model development process from IPCC cycle.

		• Questions did not "fit" our models so the models are not fully documented or misleading information submitted • Question if METAFOR is of use	
NCAR	15 times more data volume submitted for CMIP5 than for CMIP3. 5 models participated generating 28,500 model years, 1380 TB of data Interesting results, e.g. two models produced contrasting climate sensitivities, global temperature changes can be mitigated, while sea level rise can not. Use of the same model version between paleo and future projections gave a consistent response in terms of climate sensitivity	The process of producing CMIP5 compliant output was time consuming and labour intensive, with different scripts needed for the different model versions with different fields The new atmospheric model in CESM1/CAM5 took longer to finalize than anticipated, delaying the simulations with the newer model version Delays in preparing the 50km coupled version of CCSM4 High resolution time slice experiments had the lowest priority, those experiments still need to be run and analyzed	Better exploit emission-driven ESM runs, particularly to look at land use change feedbacks on the carbon cycle Plan to further exploit high resolution coupled simulations and high resolution times slice experiments
Japan	Kakushin Program is coming to an end this month with a lot of potential contributions to IPCC (ESM, decadal prediction, high resolution time slice experiments)		Encourage future CMIP to balance what is of interest to users and what is of scientific interest, for example recommend scenario run ensembles. Also, users are not so interested in 1% and 4CO2 runs, while these are important scientifically
China	5 models participating in CMIP5 Improved monsoon simulation New coupler developed with direct flux exchange for better parallel efficiency of high resolution models	Technical difficulties to share output with ESG and post-processing output	
Australia	3 models participated Success in running experiments and hosting an ESG node, making use of the same technical support. Made archival experience better than for CMIP3 COSP has helped in the evaluation of clouds Tiered experimental design that prioritised experiments was helpful.	Would prefer not to have to un-publish data before publishing additional fields CMIP5 questionnaire seen as 'difficult', contributing to delay in completion Software delays resulted in delays/extra work for analysts RCPs do not sample the range of plausible pathways for some key forcings, e.g., no case	Concern about how a putative "near-Exabyte" of output for a CMIP6 may be handled Need a prioritisation of atmospheric fields, to allow modelling groups to prioritise their processing. Suggest survey the usage of fields in CMIP5. More information about the spin-up methodologies used by the modelling groups

		has aerosol emissions remaining high for several more decades. Need to consider further the background stratospheric volcanic aerosol loading for the piControl. Zero loading seems inappropriate, affecting especially SLR. Details of land-use change specification in the RCPs largely left to the individual groups. Appears to have very large impact on the range of terrestrial carbon uptake in ESMs.	would help analysts study residual climate drifts in the piControl simulations. Certain additional fields would be helpful to analysts Support the Metrics Panel international approach to model evaluation Ongoing effort needed to ensure adequate recognition for modelling groups, for example better citation of key model papers
Canada	Had model frozen early, and simulations done early (aided by modest resolution and stable computing) Implementing a 'regimented' model development cycle means that will be ready for any MIP or assessment with what ever model version is frozen CMOR conversion went reasonably smoothly via post processing, once tables were stabilized CMIP helps manage model development Have built upon CMIP5 many additional experiments for internal research Have begun exploiting CMIP5 archive for analysis Participation in CMIP and other MIPs means more people are analysing the models, bringing benefits. Feedback is effective if have an internal collaborator on the analysis efforts	Setting up ESG server and publishing data was difficult and time consuming. METAFOR questionnaire difficult If don't have an internal collaborator in model analysis activities, it is too large an effort to digest analysis results and repatriate benefits into model development progress	Would like to see more discussion of idealized experiments, e.g. developing a set of experiments that start from 1% run, which has a long legacy, adding idealized aerosols, ozone etc. With increasing number of requests from MIPs so recommend that WGCM encourages collaboration within CMIP, so specialized results can be more easily compared with a wider suite of MIPs Adoption of CMIP infrastructure and standards by all MIPs