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Action Items and Recommendations

I. **WCRP JSC**

1 Need confirmation of continued support from JSC for what WGCM is doing to avoid any confusion in the climate modelling community

2 JSC needs to recognize the importance of model development and better process parameterizations within WCRP

II. **CMIP5**

3 Updated CMIP5 experimental design document for submission to a journal (Taylor, Stouffer and Boer)

4 Coordination needed in choosing focus decade (either 2026-2035 or 2030-2039) setting dates for decadal predictability/prediction experiments and time slice experiments, and for time slice periods (proposed 1996-2005, 2026-2035, 2091-2100) (Meehl to contact Richard Moss and inform Boer and Stouffer)

5 WGCM strongly recommends that modelling groups must provide thorough documentation of their models, the forcing datasets, and the radiative forcing for the different constituents for experiments submitted to CMIP5 archive

6 CMIP panel to communicate desired final date (end of 2010) for submitting CMIP5 data (Stouffer, Taylor)

7 Modelling groups participating in CMIP5 need to quantify expected data volume and output variable list (Taylor, Stouffer)

8 Need to confirm CF standards for stored variables (Stouffer, Taylor, Covey)

9 WGCM endorses the formation of a new Metrics Panel (Taylor)

III. **CFMIP**

10 WGCM strongly recommends that a cloud simulator be used (in-line or off-line) for at least some parts of core runs, and that simulator diagnostics be included in the core set of CMIP5 core diagnostics. Specify time periods desired (proposed 1996-2005, 2026-2035, 2091-2100) and quantify data volume involved (Bony)

11 WGCM encourages modelling groups to participate in the full suite of CFMIP2 experiments and diagnostics.

IV. **Atmospheric Chemistry**

12 Timing for ozone concentration dataset availability including stratospheric and tropospheric ozone; utility for a 'dynamically referenced' ozone database and give feedback on whether prescribed aerosols are needed, also atmospheric oxidants, nitrogen depostion and surface ozone (Meehl to contact Lamarque and inform Eyring)

13 Make forcing datasets from CCMVal community (e.g. solar) available for modelling groups to use for CMIP5 (Eyring)

14 Can solar radiation be extended back to 1850? Ask SPARC whether they can recommend a volcanic aerosols dataset (Eyring)

15 Experimental design for evaluating the aerosol radiative forcing in GCMs: distribute Steve Schwartz and Ulrike Lohmann's proposal derived from FIAS discussions

V. **PMIP3**

16 PMIP3 requests WGCM endorsement, inclusion in AR5 experimental plans and support for database (Meehl to Braconnot)

17 Recommend that models performing paleo experiments also perform full CMIP5 experiments using same model (resolution)

VI. **Regional Climate Modelling**

18 WGCM endorses the formation of a regional modelling task group. Recommend that a WGSIP member participate (Giorgi and Flato to formulate group)

19 Regional downscaling community needs to define which periods want high frequency output from global GCMs (proposed 1996-2005, 2026-2035, 2091-2100); Time periods compatible between CMIP3 and CMIP5 encouraged for comparisons. Alternatively, modelling groups make available all 6 hourly data from 20th and 21st century runs for regional models on local server for a finite time period, and Giorgi can download it and store at his centre (Stouffer, Giorgi, Jones)

20 Provide RCM Task Group names to WGCM, including representatives from climate modelling and other downscaling techniques (Giorgi, Jones)

21 Communicate JSC's long term RCM organizational plans (Asrar to Giorgi, Jones)

VII **Membership**

WGCM:

22 Welcome to S. Bony as new co-Chair of WGCM. G. Meehl, A. Hirst, N. Nakicenvic and P. Braconnot renew their membership. J. Mitchell rotating off but remain ex-officio and member of CMIP Panel, G. Flato to remain as JSC liaison. Welcome to V. Eyring and B. Wang

CMIP panel:

23 B. McAvaney and T. Delworth rotating off. Make K. Taylor and J. Mitchell ex-officio, plus T. Stockdale from WGSIP; CMIP Panel now: R. Stouffer (chair), G. Meehl, M. Latif, C. Covey, K. Taylor, J. Mitchell, T. Stockdale

24 Form a Joint WGCM-WGSIP Contact Group on Decadal Predictability/Prediction – R. Stouffer, M. Latif, G. Meehl, T. Stockdale (this will be a subcommittee of CMIP, making T. Stockdale a member of CMIP); need to consult with WGSIP to see if this is OK and perhaps add G. Boer (Meehl)

25 WOAP representative needed (K. Taylor nominated)

26 TGICA – WGCM recommends D. Karoly for IPCC appointment

VIII **Next meeting**

27 Joint with AIMES, hosted by PCMDI in San Francisco, provisionally on Sept. 28 to Oct 2 2009 (Bader, Hibbard, Meehl)

1. Introduction

The Working Group on Coupled Modelling (WGCM) held a historic meeting in Paris, France on 22-24 September 2008. H. Le Treut, P. Braconnot and C. Michaut of the WCRP Strategic Support Unit generously hosted the meeting at the Ecole Normale Superiéure.

Representatives from 20 of the global coupled climate modelling centres from around the world were invited to hear about the next round of coordinated experiments that were originally proposed by the WGCM/Analysis, Integration and Modelling of the Earth System (AIMES) community in 2006. The modelling groups will commit huge resources over the next two years performing the next climate model intercomparison project (CMIP5). The meeting provided the unique opportunity for the modelling groups to work on reaching a consensus and buy-in to the climate change experiments that WGCM is coordinating, and to discuss ways to maximize the utility of the experiments for the wider scientific community (including CLIVAR, in particular WGSIP, GEWEX, SPARC, CliC, WGNE and AIMES). CMIP5 will provide the framework for climate change modelling research for the next five years and results from these experiments will provide the basis for the next Intergovernmental Panel on Climate Change Assessment (AR5).

Modelling of climate change is not only a scientific challenge of the first order but also a major technological challenge and PCMDI will again play the leading role in supporting the international climate community as it provides access to hundreds of petabytes of simulation data within the next three to seven years. The Earth System Grid is part of an international federated, distributed data archival and retrieval system called the Earth System Grid Centre for Enabling Technology (ESG-CET) and is being developed in partnership with PCMDI to meet the needs of CMIP5.

In addition to serving the coupled modelling community with the coordinated experiments and its data collection and archival needs, the WGCM meeting addressed its other focus topics of improving models, in particular the simulation of cloud and moist processes, and addressing emerging issues including ice sheets and air chemistry. Other major foci for WGCM are regional climate modelling and how this community can best organise itself at an international level, and wider modelling issues within WCRP as its remit evolves to address the science questions emerging with the development of the next generation of models in the next decade and beyond.

What became clear at this meeting was that, as the international climate modelling community takes on ever-increasing climate change modelling challenges, WGCM has been able to build tangible linkages through shared activities and direct communication with other groups representing the research communities involved with CMIP5. AIMES (IGBP) has worked with WGCM to formulate the CMIP5 experimental design. WGSIP and WGCM have formed a joint contact group to oversee the decadal predictability/prediction part of CMIP5. WGNE and GCSS, through shared interests with WGCM in model development, processes, and parameterizations, have a joint stake in the cloud and moist process part of CMIP5. WGCM is now linked to the IPCC Working Group Three integrated assessment modelers (IAMs) through the IAM Consortium where WGCM is working with them to formulate and coordinate the new RCP mitigation scenarios. SPARC and AC&C are providing consultation on the chemistry and aerosol aspects of the long-term experiments with the new earth system models. Thus, as the models have become more complex with higher resolution, and the climate change modelling problem now has short term initialized aspects and long term earth system model components, the various panels and working groups are now functioning not so much as separate independent entities, but more as a network of communities through the coordinating and clearing house role of WGCM.

The meeting agenda is in ***Appendix 1*** and the list of participants is in ***Appendix 2***. The presentations and pre-meeting reports are available at:
http://www.clivar.org/organization/wgcm/wgcm-12/wgcm12.php

Note from G. Meehl, co-Chair WGCM
The 2008 WGCM meeting was the last one with John Mitchell as co-chair. He has stepped down to become an ex-officio member of the CMIP Panel as part of WGCM. John's service to WGCM extends back to the first incarnation of the committee in 1990, the Steering Group on Global Coupled Models (SGGCM) chaired by Larry Gates. Over the years John has been an active contributor to the activities of SGGCM, then its transition to CLIVAR NEG2 from 1994-1997, and then finally to WGCM from 1997 to present. His most recent co-chairmanship has been marked by the successful completion of the CMIP3 coordinated climate model experiments and associated analyses that have changed the face of climate science research. Though we will miss John's thoughtful and insightful guidance as co-chair, we look forward to his continued presence on WGCM as part of the CMIP Panel. Succeeding John as co-chair is Sandrine Bony who, along with continuing co-chair Jerry Meehl, will work with WGCM in shepherding the new CMIP5 activity through the IPCC AR5 process and beyond, coordinating the latest phases of PMIP and CFMIP, and strengthening new connections to WGSIP, WGNE, the Integrated Assessment Modeling Consortium, GCSS and others. From Sandrine and me, we thank John for his service, and we look forward to continued interactions with him on WGCM.

2. Overview of WCRP activities of relevance to WGCM

2.1 First impressions from new Director of WCRP, G. Asrar

I found the 12th Session of the WCRP/CLIVAR Working Group on Coupled Modelling (WGCM), most informative and superbly run by the co-chairs. I had an opportunity to share with the participants a brief overview of the WCRP plans and activities, including the independent review of the Program by its sponsors, ICSU, IOC, and WMO, and the ongoing intermediate-term and long-term planning by the WCRP Projects and the Joint Scientific Committee, respectively.

The substantive discussions on the current state of models and their capabilities, the need for model development and verification, reaching agreement to document models and their input/output for different experiments, establishing a process to develop the list of variables to be produced based on the selected scenarios, the standards and formats for archive and distributions of these variables, and endorsing the development of metrics for model performance were timely and productive. The participants moved on effectively to agree upon modelling scenarios for both centennial and decadal time scales, and to develop and endorse experimental plans for AR5 and the resulting datasets. There was considerable discussion on the close working relationship and interactions with the IPCC Working Groups I and II, but WGCM recognized that the benefits and the scope their research and the use of their scientific understanding and results extend well beyond the IPCC, and they agreed to be sensitive and responsive to this broad mandate. This perspective is indeed in the spirit of the WCRP mission of coordinating and integrating international climate research to the benefits of the global community at large.

The participants moved on to establish a Regional Modelling Task Group to; 1) develop a framework to evaluate Regional Climate Downscaling (RCD), techniques for use in downscaling global climate projections; 2) foster an international coordinated effort to develop improved downscaling techniques and to provide feedback to the global climate modelling community; 3) promote greater interactions between climate modeller and downscaling experts and end-users to better support impact/adaptation activities and to better communicate the scientific uncertainty inherent in climate projections and downscaled products.

It is noteworthy that WGCM could efficiently achieve so much and reach general consensus on the way forward all in a short week. WCRP takes pride in the great accomplishments of this Working Group and its team of scientists and experts from around the world for their effective and significant contributions to the past and future international scientific and technical environmental assessments such as IPCC, Ozone, Millennium, etc. Efforts of this nature demonstrate the true value of the exciting scientific explorations and discoveries of the Earth's complex climate system to the global society.

2.2 JSC-XXVIII Session, Arcachon, France

The following are the main action items from the JSC session that are particularly relevant to WGCM.

Storage of numerical experiment outputs
The Director of WCRP, in cooperation with the Chairs of the modelling groups and WGSIP, is to seek support for storage of numerical experiment outputs, including the continuation of PCMDI archive for CMIP runs, and the identification of a single archive for seasonal forecast experiment runs and decadal ones, if possible. He will also be to writing to PCMDI to express gratitude for their hosting of the AR4 climate model output archive and acknowledging their key role in IPCC AR4, and expressing a recommendation for continuing support.

Decadal Prediction Cross-Cut
The WCRP decadal predictability crosscut is to prosper with a recommendation that the CLIVAR regional panels for the Indian and Pacific Oceans and CLIVAR/CliC Southern Ocean Panel join the CLIVAR Atlantic Panel and GSOP in actively contributing to the development of scientific basis for decadal prediction and in engaging relevant partners in the regions in this process. A WCRP-wide effort is recommended focusing on the development of the science of data assimilation into coupled models and their initialization, including issues related to soil moisture (GEWEX), cryosphere (CliC), and stratosphere (SPARC), and involving young scientists in all areas of this work.

Regional climate modelling and downscaling
A task group on Regional Climate Modelling and Downscaling will be formed to undertake an assessment of all available techniques, for time scales from seasonal forecasts to IPCC time scales. It is to entrain all appropriate expertise, including scientists using RCMs in the regions, and involve WGNE, WGSIP, WGCM, WCP, regional START activities. The Task Group will work on establishing a framework for the evaluation and intercomparison of regional downscaling methods; develop a synthesis document to promote WCRP activities in this field; prepare a longer-term vision for WCRP activities vis-à-vis regional modelling; and work with the WMO to identify mechanisms for making regional downscaling models and techniques and as well techniques specific for certain applications available to scientists and users at regional level.

WMP/Modelling summit
The summit (held subsequent to the 2008 JSC meeting, reaffirmed a need for continuing coordination of WCRP, WWRP and IGBP modelling activities with major emphasis on the seamless prediction. A team is to develop a vision/mission statement for a WCRP

'flagship' activity for input to the Third World Climate Conference (WCC-3). A discussion is also required for defining ways for climate model evaluation, paving the way for the development of suitable climate model metrics.

White Paper on a Revolution in Prediction
The paper, prepared by WWRP/THORPEX, has fuelled the discussion of specific areas where WCRP and WWRP can and should work together. The paper, together with the outcomes of the Modelling Summit will feed into WMO 60th Executive Council (EC-60) and, subsequently, to the WCC-3.

Geoengineering
A working group on geoengineering is being set up to recommend how WCRP might respond to this challenge. All relevant WCRP working groups, panels and SSGs should consider the issue of geoengineering on their agendas, and submit outcomes of the discussion to the WG on geoengineering.

I. WCRP JSC Action Items and Recommendations

1/ Need confirmation of continued support from JSC for what WGCM is doing to avoid any confusion in the climate modelling community

2/ JSC needs to recognize the importance of model development and better process parameterizations within WCRP

2.3 Report on the WCRP Anthropogenic Climate Change (ACC) cross-cutting activity

The ACC cross-cutting activity is led by an ad-hoc subgroup of the JSC: H. Le Treut, J. Church, G. Flato D. Griggs, V. Ramaswamy and is supported by the WCRP Strategic Support Unit in Paris. Its activities concern the following areas:

- Quantitative projections of climate change, 21st century and beyond
  - -Organise/facilitate international multi-model ensemble
  - -WGCM core activity
  - -How to facilitate access to model output
- Quantitative prediction/predictability of near-term decadal climate
  - - predictions based on commitment+forcing+internally generated variability
  - - system initialization, especially the ocean
  - - predictability, ensembles, skill
  - - importance for applications
- Key improvements in climate models
  - -Clouds and aerosols
  - -Carbon cycle feedbacks
  - -Metrics
- Forcing scenarios
  - -must balance 'science' needs with impacts/policy needs
  - -Netherlands meeting (IPCC WG-3)
- Serving the 'Impacts' community
  - -Regional Downscaling
  - -Decadal Prediction (ocean initialization and other research areas
- High Impact or Emerging Issues
  - -Ice Sheets (mass balance; acceleration of ice streams)
  - -Extreme events
  - -Air quality coupled to climate change

The ACC group has identified regional climate modelling and downscaling as an area which is poorly represented within WCRP and has proposed to the JSC that a task group be set up led by WGCM and WGNE to develop a synthesis document on the different methods and their shortcomings, develop a longer term vision for WCRP in this area, and to assess how to best evaluate and compare regional climate models (RCMs).

3. Emissions Scenarios and Coordinated Experiments

3.1 Introduction and overview for CMIP5

As background to the development of the CMIP5 experiments, late in the IPCC AR4 process (2006), several issues of relevance to WGCM emerged that needed further attention:

- Heightened interest in short term (next several decades) climate change information on regional scales, and regional weather and climate extremes;
- A lack of time to address new mitigation scenarios being formulated by WG3;
- Magnitude of carbon cycle feedback was the least quantified uncertainty, particularly in the upper end of projections; Carbon cycle components had matured (e.g. C4MIP) such that some modelling groups would soon be including carbon cycle as part of their "standard" climate change models, some with chemistry (first generation Earth System Models); this strengthened WGCM connection to AIMES.

WGCM and AIMES hosted a session of the Aspen Global Change Institute in August 2006 to formulate a new strategy for climate change modelling and emerging Earth System Models (ESMs) that would connect better to WG3 (through the IAM Consortium) and hopefully to WG2 too (Meehl and Hibbard, 2007, Hibbard *et al.*, 2007). This workshop was designed to take better control of the model assessment process, building on CMIP3 and C4MIP, and the scenario formulation process through the IAM Consortium, and make the process community-based, not IPCC-driven.

The scientific community has formulated the proposed CMIP5 coordinated experiments to address key science questions. Since these experiments will be the major activity of the international climate change modelling community over the next several years, the results will be eligible for assessment by the IPCC AR5. The decision in April 2008 that there will be an IPCC AR5 means that deadlines for completion of the experiments must be related to the IPCC assessment process and schedule (publication of the WG1 AR5 is due in early 2013). New model versions are to be finalized in late 2008-2009, model runs done in 2009-2010, data access/collection in late 2010, and analysis in 2011-2012.

New areas since Aspen 2006:

- Decadal prediction - The decadal signal in a CMIP3 multi-model ensemble (IPCC AR4, Ch.10, Figure 10.8) is a combination of 1) the forced response to increasing GHGs (it doesn't depend much on which scenario is used) and 2) climate change commitment. Are there modes of decadal variability that could be predicted that could increase the regional skill of decadal predictions?
- Long term simulations - Mitigation/adaptation scenarios with allowable/permissible emissions that allow for the system to hit stabilized concentration targets/climate states are to be used (instead of SRES scenarios (Special Report on Emissions Scenarios, Nakicenovic, et al., 2000)). The new scenarios will have implicit policy actions to target future levels of climate change. Since we can only mitigate part of the problem, and we will have to adapt to the remaining climate change, the challenge is to use climate models to

quantify time-evolving regional climate changes to which human societies will have to adapt.

The new strategy proposed at the 2006 Aspen meeting is based on the used of two classes of models to address two time frames and two sets of science questions (Hibbard *et al.*, 2007, Meehl and Hibbard, 2007, also see the meeting report from the 11th Session of WGCM for a summary):

- Longer term projections (to 2100 and beyond) - intermediate resolution (~200 km), carbon cycle, specified/ simple chemistry and aerosols, new mitigation scenarios ("representative concentration pathways" (RCPs)), science question: e.g. the magnitude of feedbacks
- Near term projections (2005-2030) - higher resolution (~50 km), no carbon cycle, some chemistry and aerosols, single scenario, science question: e.g. regional extremes

This strategy has evolved somewhat and, in particular, the Near-Term Projections now have expanded to include a new Decadal Prediction initiative**.** A full summary of the CMIP5 experimental design is given in Taylor *et al.*, 2008. Figure 1 illustrates an overview of the long-term and near-term experimental framework and Figure 2 is a more detailed schematic of the long-term experimental framework (Taylor *et al*., 2008).

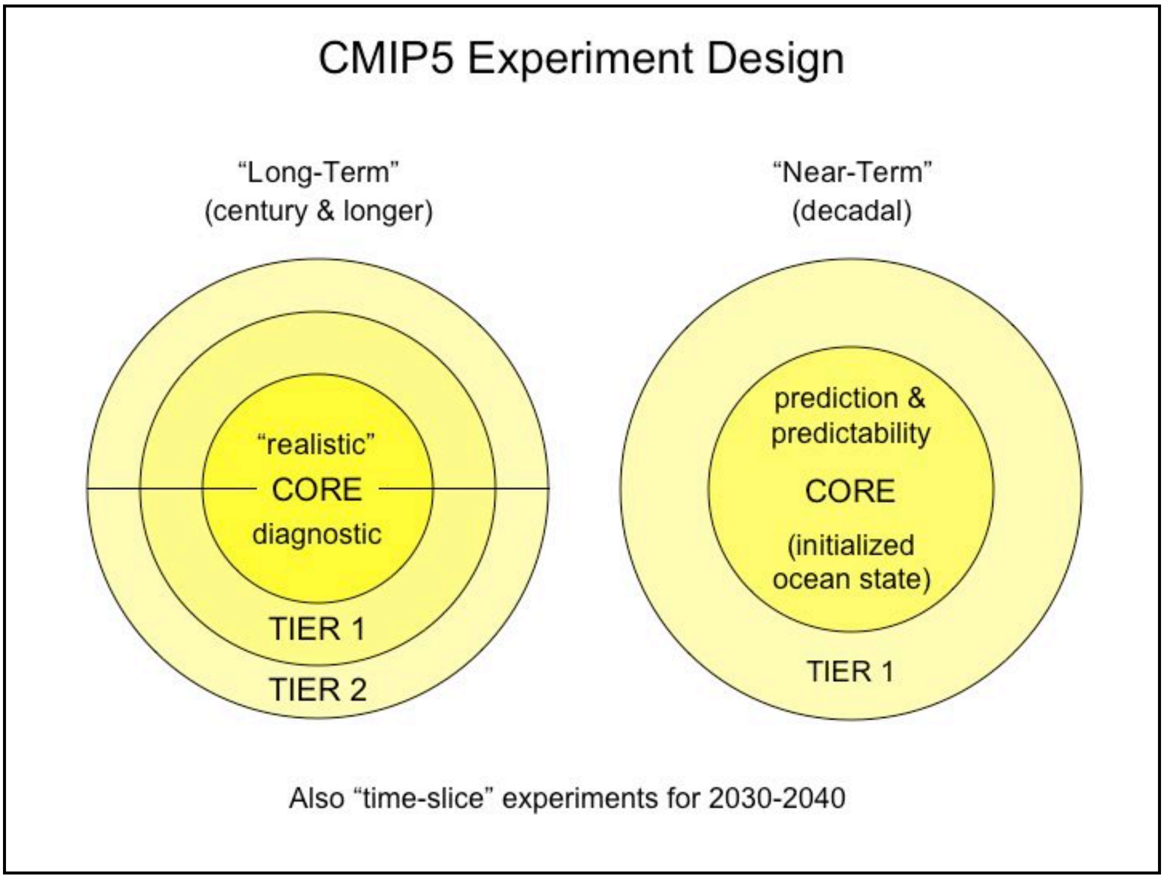

Figure 1: Summary CMIP5 Experiment Design **(***Taylor et al., 2008***)**

Near-Term Experiments
A first major connection was made between WGCM and WGSIP who organised, together

with AIMES, an Aspen Global Change Institute workshop on Climate Prediction to 2030 **(**Meehl, et al., 2008**)**. The near-term projection framework for the next five years and beyond is illustrated in Figure 3. It now includes 10- and 30-year prediction studies and high-resolution time-slice experiments, as summarized in Taylor *et al*., 2008.

There are reasonable prospects for producing decadal forecasts that are of sufficient skill to be used by planners and decision makers, as well as being of considerable scientific interest, and the CMIP5 experimental design provides an opportunity for the international coordination of research and experimentation in this area. There are two aspects to the decadal problem; the externally forced signal (GHG + aerosols, volcanoes, solar, etc.) and the predictable part of the internally generated signal from oceanic mechanisms (e.g. MOC, ACC), coupled processes (e.g. PDO, AMO, ENSO), modulation of climate modes (e.g. PNA, NAO, NAM, SAM) and potentially land and cryospheric processes. To date climate projections have generally treated internal variability as a statistical component of uncertainty. Though there is no marked decadal peak in the spectrum of the climate system, long timescales exist and are potentially predictable. The challenge of prediction/predictability studies is to identify the mechanisms associated with regions/modes of predictability, to better understand the connection between oceanic modes and terrestrial climate variability, and to investigate predictive skill by means of prognostic (including multi-model) decadal predictions.

The results of predictability studies and demonstrations of forecast skill provide the foundations for initiating a coordinated WCRP study of decadal prediction/predictability. There are abundant scientific opportunities to improve and extend models and for the analysis of variability and of modes of variability. There are challenges to develop improved analysis methods, especially in the ocean, and for model initialization, verification and model development, as well as in ensemble generation and the use of multi-model ensembles for prediction on decadal timescales.

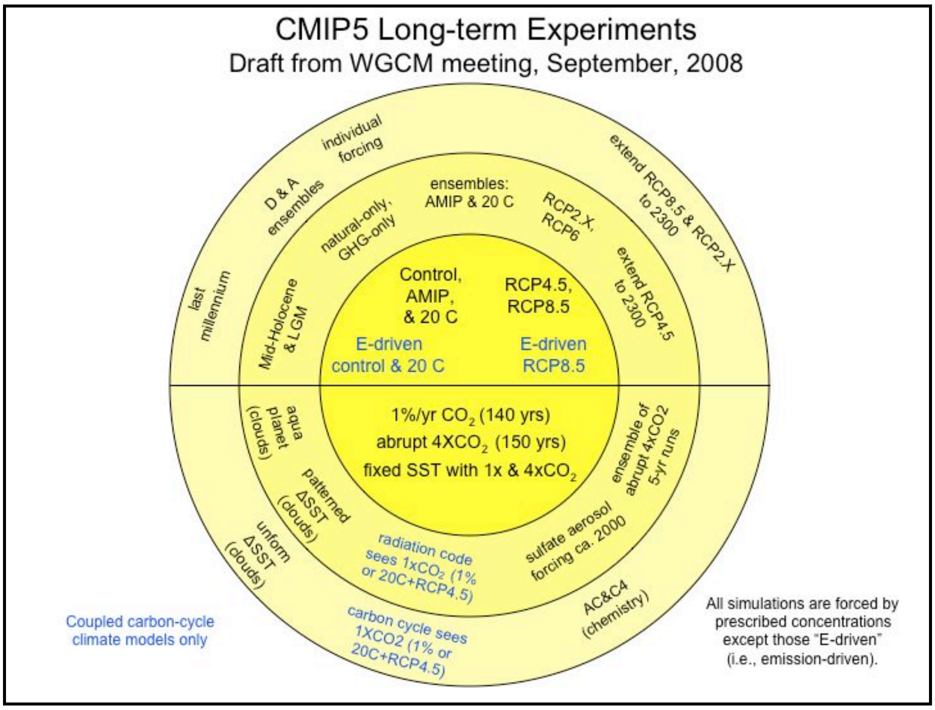

Figure 2: Long-term CMIP5 Experimental Design Summary (Taylor et al., 2008)

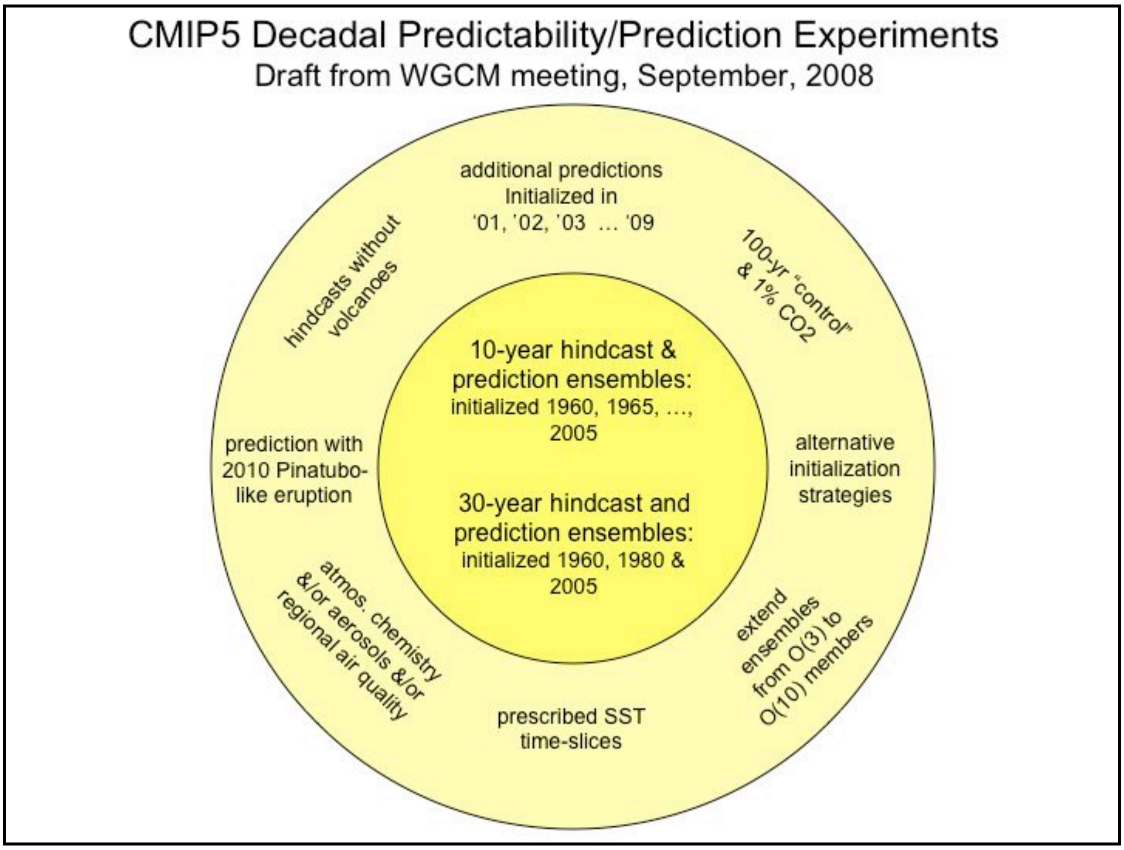

Figure 3: Near-term CMIP5 Experimental Design Summary (Taylor et al., 2008)

3.2 Status of emission scenarios and links to WG II and III communities

Since the 2006 session of the Aspen Global Change Institute, the development of representative concentration pathway (RCP) scenarios, not called 'benchmark' scenarios since each RCP can be achieved through a wide range of scenarios and therefore the RCPs are representative of a family of scenarios.

Historically, a sequential approach was used to develop socio-economic scenarios, with adaptation and mitigation being included later in the process. A new parallel approach proposed at the 2006 Aspen meeting has been approved by the IPCC, whereby four RCPs are developed in coordination with the climate and impacts/downscaling communities.

The IPCC Working Groups I, II and III are the three major scenario user communities:

- Climate modelling community (WG I) - need scenarios to provide coherent, internally consistent time-paths for Earth System Models and as input to near-term Decadal Prediction Models.
- Impacts, adaptation & vulnerability modelling community (WG II) - need scenarios to provide coherent, internally consistent, time-paths to assess the consequences of potential climate changes and to set the context for adaptive strategies.

- Integrated assessment community (WG III) - to provide coherent, internally consistent, time-paths to assess the costs of emissions mitigation, setting policy scenarios.

Figure 4 shows the development of the scenarios in parallel between the Climate Modelling (CM - WG I), the Impacts, Adaptation and Vunerability (IAV – WG II), and the Integrated Assessment Modelling (IAM – WG III) communities (Moss *et al.*, 2008). The preparatory phase will be completed by December 2008 when the climate modelling community will be provided with the four RCPs.

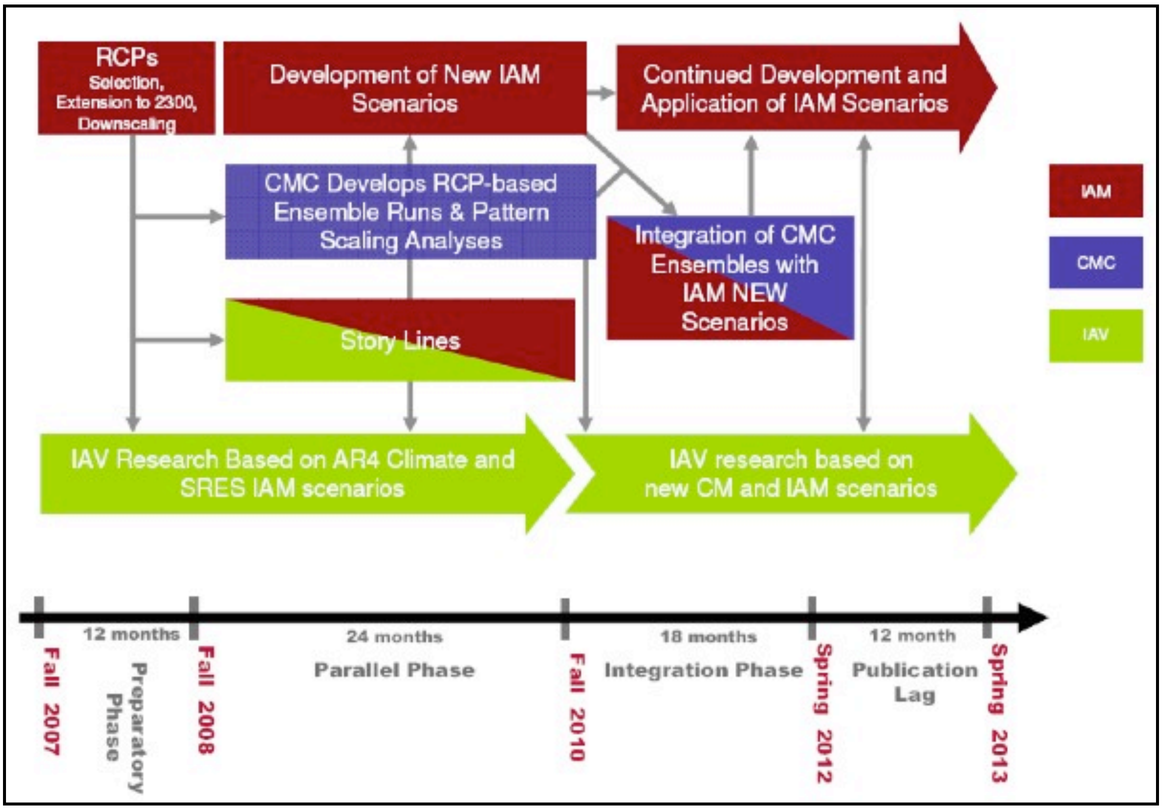

Figure 4: Some of the major scenario-related activities across the IAV, IAM, and CM research communities and relationships among them. The boundaries between these phases are not precisely defined, although near-term deadlines, such as the fall 2008 deadline for availability of RCPs, can be taken as relatively more precise (Moss et al., 2008).

The different research and assessment foci for the near term and long term experiments of each user are:

- Near-term (~2035)
  - -ESM: Extreme events, higher resolution, atmospheric chemistry
  - -IAV: Observed impacts, adaptation
  - -IAM: Baselines, near-term mitigation, climate-air pollution policy interactions
- Long-term (2100 and beyond to 2300)
  - -ESM: Climate dynamics, climate-carbon cycle interactions
  - -IAV: Vulnerability studies, multiple stresses
  - -IAM: Overshoot and other stabilization, etc.

The following are the forcing agents that the IAM community will be providing as part of the RCPs as input for climate models:

- Greenhouse gases: CO2, CH4, N2O, CFCs, HFCs, PFCs, SF6
- Emissions of chemically active gases: CO, NOx, NH4, VOCs
- Derived GHGs: tropospheric O3
- Emissions of aerosols: SO2, BC, OC
- Land use and land cover

The goal for emissions harmonization is to create a consistent dataset for natural and anthropogenic emissions (including biomass burning) for non-CO_2 emissions (including aerosols and precursors, ozone precursors and ozone-depleting substances) for 1850-2300, at 0.5° resolution. Future emissions must be fully consistent with the proposed RCPs. The emissions will be used in climate-chemistry simulations for the IPCC AR-5. The methodology for harmonizing emissions is to initially create a best estimate for anthropogenic emissions in 2000 (biomass burning emissions are taken as average GFED-v2 1997-2006 average), and then past and future emissions are harmonized to 2000 at the regional (17 IMAGE regions) and sectoral level (12 sectors). A combination of existing inventories (HYDE, RETRO, GICC) is used for historical anthropogenic emissions and available inventories (between 2000 and present) are used to constrain future emissions (i.e., ensure recent trends are captured). Anthropogenic emissions are then re-gridded using population maps or sectoral grids if available.

The RCP data will be made available via an interactive and web-based 'working environment' that, amongst other things, gives the option of downloading data into Exel. This will be a central data repository to share information and to provide easy access to the data that will allow for detailed comparisons between RCPs and base year inventory data and quick data visualization to help to understand major data differences (eg. identify definitional issues across RCPs).

3.3 The Earth System Grid

The CMIP5 experiments that will be assessed by the IPCC 5th Assessment Report (AR5) in 2010 are expected to generate between 2.5 to 15 PB of data. A new federated, distributed architecture known as the Earth System Grid (ESG) is being developed in partnership with PCMDI to meet the needs of CMIP5. The ESG's mission is to provide climate researchers worldwide with access to data, information, models, analysis tools, and computational capabilities required to make sense of enormous climate simulation datasets.

The ESG's goals are to make data more useful to climate researchers by developing Grid technology that enhances data usability, meet specific distributed database, data access, and data movement needs of national and international climate projects, provide a universal and secure web-based data access portal for broad multi-model data collections, provide a wide-range of Grid-enabled climate data analysis tools and diagnostic methods to international climate centres and U.S. government agencies and develop key ideas and concepts that are important contributions to other domain areas.

WGCM negotiates data ownership/copyright agreements with the modelling groups and PCMDI enforces WGCM's policies on data usage criteria through centralized registration and use agreements. Technical requirements are developed by modelling/data centres in partnership with PCMDI, working primarily through the GO-ESSP organizational structure. Participating on the network will require meeting standards for data and hardware. PCMDI will be the archive of last resort for groups wanting to participate following the CMIP3 procedure, including data standards.

The federated architecture consists of a layered system based on Gateways and Nodes. Gateways are portals with search capability, distributed metadata, registration and user management. They may be customized to an institution's requirements and there are fewer sites, with a more complex architecture than nodes. Nodes are where data is stored and published. Data may be on disk or as tertiary mass storage. Each node has a trust relationship with a specific gateway for publication. This involves a less complex architecture and a site can be both a gateway and a node.

ESG Timeline

2008: Design and implement core functionality:

- Browse and search
- Registration
- Single sign-on / security
- Publication
- Distributed metadata
- Server-side processing

Early 2009: Testbed

By early 2009 it is expected to include at least seven centres in the US, Europe and Japan:

- Program for Climate Model Diagnosis and Intercomparison - PCMDI (U.S.),
- National Centre for Atmospheric Research - NCAR (U.S.),
- Geophysical Fluid Dynamics Laboratory - GFDL (U.S.),
- Oak Ridge National Laboratory - ORNL (U.S.),
- British Atmosphere Data Centre - BADC (U.K.),
- Max Planck Institute for Meteorology - MPI (Germany),
- The University of Tokyo Centre for Climate System Research (Japan).

2009: Deal with system integration issues and develop production system. By summer 2009, the hardware and software requirements will be provided to centres that want to be Nodes.

2010: Modelling centres publish data

2011-2012: Research and journal articles submissions

2013: IPCC Report

AR5 open issues

- What are the set of runs to be done and, derived from that, the expected data volumes we can expect?
- Expected participants – where will data be hosted? (Who is going to step up and host the data nodes, and provide the level of support expect in terms of manpower and hardware capability.). This includes minimum software and hardware data holding site requirement (e.g. ftp access and ESG authentication and authorization) and a skilled staff help desk.
- The AR5 archive is to be globally distributed with support for WG1, WG2, and WG3. Will there be a need for a central (or core) archive and what will it look like?
- Replication of holdings - disaster protection, a desire to have a replica of the core data archive on every continent, etc.
- Number of users and level of access – scientist, policy makers, economists, health officials, etc.

II. CMIP5 Action Items and Recommendations

3/ Updated CMIP5 experimental design document for submission to a journal (Taylor, Stouffer and Boer)

4/ Coordination needed in choosing focus decade (either 2026-2935 or 2030-2039) setting dates for decadal predictability/prediction experiments and time slice experiments, and for time slice periods (proposed 1996-2005, 2026-2035, 2091-2100) (Meehl to contact Richard Moss and inform Boer and Stouffer)

5/ WGCM strongly recommends that modelling groups must provide thorough documentation of their models, the forcing datasets, and the radiative forcing for the different constituents for experiments submitted to CMIP5 archive

6/ CMIP panel to communicate desired final date (end of 2010) for submitting CMIP5 data (Stouffer, Taylor)

7/ Modelling groups participating in CMIP5 need to quantify expected data volume and output variable list (Taylor, Stouffer)

8/ Need to confirm CF standards for stored variables (Stouffer, Taylor, Covey)

9/ WGCM endorses the formation of a new Metrics Panel (Taylor)

3.4 Proposals from related communities

3.4.1 CFMIP/cloud feedbacks

Cloud and moist processes are important for climate prediction because of their radiative and latent heating effects. Cloud radiative and latent heating effects are major controls of the Earth's radiation balance, atmospheric circulation (both at regional and planetary scales), planetary energy transports, tropical-extratropical interactions and ocean-atmosphere interactions. Cloud and moist processes are highly critical for the representation of current climate (mean patterns, modes of variability), the sensitivity of climate to external forcings (natural and anthropogenic), and impact temperature, precipitation, continental hydrology, extremes, remote responses, etc. Regarding adaptation and mitigation, the consequences of uncertainty in cloud feedbacks and moist processes are thus at least as large as the consequences of uncertainty in carbon-climate feedbacks or decadal predictability.

The difficulty of general circulation models to predict clouds, which was first emphasized thirty years ago by A. Arakawa and J. Charney, has been an unresolved problem for the modelling community. Yet, great resources are now available to observe clouds, such as the A-Train constellation of satellites, long time series of ground-based observations from instrumented sites and many observational campaigns. On the modelling side, cloud-resolving models (CRMs) and large-eddy simulation models (LES) are now run on increasingly large space and time scales, and a new generation of climate models is emerging that uses CRM physics in place of conventional parameterizations, and starts to perform global simulations of the Earth's atmosphere. Finally, the cloud processes community and the climate modelling community are seeking to interact more with each other. The second phase of the Cloud Feedback Model Intercomparison Project (CFMIP2) provides a strategy for collaboration with GCSS (GEWEX Cloud System Study) and WGNE (Working Group on Numerical Experimentation), linking GCMs to new observations from field campaigns and satellites, theoretical and cloud resolving modelling studies and to parameterization developments.

CFMIP recommends to WGCM that COSP (CFMIP ISCCP-CloudSat-Calipso simulator package) be used in a subset of the proposed mandatory/very high priority CMIP5 experiments, to expand the list of CMIP5 model diagnostics to allow for the examination and the comparison of cloud and moist processes in climate models, cloud resolving models and observations. CFMIP recommends and that the set of coordinated experiments be modestly expanded to include some idealized experiments that will help isolate the role of cloud processes and feedbacks in the simulation of the current and future climates and understand the reasons why complex models behave the way they do and why they differ from each other. Modelling centres should be encouraged to participate in the full suite of CFMIP-2 experiments and diagnostics.

COSP Simulator
The purpose of the COSP simulator is to diagnose from model output what different satellites would observe if flying above the model's atmosphere, while taking into account cloud overlap, sensor sensitivity, etc, enabling models and observations to speak the same language (e.g. radar reflectivity, lidar, ATB). It is a freely distributed community software tool (http://www.cfmip.net) developed among several centres (Hadley Centre, LMD/IPSL, LLNL, CSU) that is capable of simulating ISCCP/CloudSat/CALIPSO satellite observations. It can be plugged into different types of models (climate or NWP GCMs, CRMs). Its first release came in February 2008; its second release is in autumn of 2008 and a pilot study will be completed in 2008-2009. If COSP is used in CMIP5 simulations, it will enable a thorough evaluation of clouds simulated by GCMs (climate metrics, process-oriented evaluations, compensating errors revealed, guidance for model development) and consistent comparisons of clouds between models and observations, as well as also between models (analysis of climate change scenarios, GCM-CRM comparisons, etc). In terms of its use in GCMs the ISCCP and CALIPSO simulators can be used on-line or off-line, while it is recommended that the CloudSat simulator be used off-line.

Process Oriented Diagnostics
The purpose of high frequency (3-hourly), detailed (e.g. 3D variables) diagnostics is to enable the assessment of GCM performance along a few transects or over selected locations (e.g. ARM sites) for which a wealth of observations and analyses are available. This will allow for the examination and evaluation of some critical processes such as:

- Stratus to stratocumulus to shallow cumulus transition
- Onset of precipitation in convective boundary layers
- Transition from shallow to deep convection
- Sensitivity of convection schemes to tropospheric humidity
- Frontal structure of clouds in the extratropics, etc.

It will also open the analysis of these GCM diagnostics by the CFMIP, GEWEX-GCSS, and WGNE communities, as well as the GCM/CRM-LES/observations communities (cf GPCI, ARM, EPIC, VOCALS).

As recommended by WGCM last year, CFMIP has prioritized its requests of process-oriented diagnostics (Annex A and Table 1 of CFMIP recommendations in *Appendix 3*).

The expected outcomes of this analysis are the evaluation and the improvement of GCM parameterizations and also the narrowing of the gap between processes and climate. For instance, one would like to be able to answer the questions: what should be improved in models to reduce uncertainties in climate change cloud feedbacks? What observational program or field campaign might help to address these uncertainties?

Recommended Idealized Experiments

- Patterned SST experiments (SST perturbation pattern based on a composite of CMIP3 GCMs in 1%/yr CO_2 experiments): expected to capture most of the spread of the OAGCM cloud feedbacks, isolate the role of atmospheric processes in the spread of cloud and precipitation responses, and determine which aspects of the climate response are robust, which are not. The control simulation for these experiments would be a simulation forced by climatological AMIP SSTs (Table 2 of CFMIP recommendations in Appendix 3).

- Uniform SST perturbation experiments (+/- 2K experiments on top of climatological SSTs): to better separate the relative role of circulation and temperature changes and separate the local/remote effects of surface warming
- Aqua-planet experiments (APE-like) with +/- 2K (no land-surface processes, no sea-ice, no orography, no seasons): to address how clouds and precipitation interact with the atmospheric circulation, whether we can isolate the primary sources of spread of clouds and precipitation responses. These provide a simple framework to understand various aspects of the climate response to global warming (e.g. poleward shift of mid-latitude storms, response of shallow clouds, remote interactions) and for clean comparisons with the next generation of climate models and with conceptual models.

More generally, we recommend that WGCM encourage the development/maintenance of a hierarchy of climate models to better understand the behaviour of complex ESMs and to help prioritize the most critical processes.

In summary, the CFMIP community strongly recommends a large participation of modelling groups in CFMIP-2 evaluations/analyses, together with a wide distribution of CFMIP-2 diagnostics and experiments (PCMDI's support critical here). This is essential for evaluating the realism of GCMs (by means of the COSP + CFMIP outputs requested for key CMIP5 experiments) and for assessing and understanding the robustness/uncertainties of climate projections.

III. CFMIP Action Items and Recommendations

10/ WGCM strongly recommends that a cloud simulator be used (in-line or off-line) for at least some parts of core runs, and that simulator diagnostics be included in the core set of CMIP5 core diagnostics. Specify time periods desired (proposed 1996-2005, 2026-2035, 2091-2100) and quantify data volume involved (Bony)

11/ WGCM encourages modelling groups to participate in the full suite of CFMIP2 experiments and diagnostics.

3.4.2 Atmospheric Chemistry

Effect of including a realistic stratosphere in climate simulations (processes and feedbacks)
The ozone hole has led to changes in Southern Hemisphere high-latitude surface climate. A deceleration of the poleward side of the jet (a decrease in the Southern Annular Mode) is found in multi stratospheric-resolving Chemistry Climate Model (CCM) simulations due to the disappearance of the ozone hole in the first half of the 21st Century (e.g., Perlwitz et al. 2008; Son et al., 2008). This is opposite to the response found in the mean of the IPCC AR4. The Southern Hemisphere high-latitude surface response to the ozone hole is seriously compromised if the stratosphere is not properly represented (Shaw et al., 2008).

Ozone and the recovery of stratospheric ozone will be affected by climate change, not just by Ozone Depleting Substances (ODSs), with an increase in upper stratospheric ozone associated with CO_2-induced cooling, and with a strengthened Brewer-Dobson circulation leading to a decrease in tropical ozone and an increase in extratropical ozone in the lower stratosphere (Eyring et al., 2007; Shepherd, 2008).

Importance of tropospheric composition in climate simulations
Tropospheric composition is an important component of the chemistry-climate feedback system. This includes ozone, which is not only important in terms of its radiative forcing but also for its effects on land biosphere CO_2 uptake and storage, the hydroxyl radical (OH), which reacts with SO_2 and DMS and controls GHG levels (esp. CH_4), tropospheric oxidants, which are needed for sulfur chemistry, and nitrogen deposition on vegetation.

SPARC and AC&C Data sets for CMIP5
The most accurate option in terms of reproducing time varying radiative forcing from ozone is to create a three dimensional (latitude, altitude, time) monthly mean ozone time series based on observations wherever available and based on model output for the period pre-1970 and in the future (consistent with the chosen RCP). Several options are available that can provide input into creation of such a dataset.

An activity under the auspices of SPARC will create a consensus observational stratospheric ozone database. The monthly mean database will be zonal means (5° zones) with global coverage, extending from the tropopause to 70 km at high vertical resolution (~1 km), and spanning the period 1979 to 2006 will no missing values. A fixed monthly mean tropospheric ozone climatology, on the same zonal and vertical grid, and representative of the period 1979 to 2006, will be appended to the transient stratospheric ozone fields to provide a seamless database. While this approach can be expected to provide the most accurate past stratospheric ozone forcing, of course fixed tropospheric concentrations are unrealistic and clearly cannot reproduce time-varying tropospheric ozone radiative forcing. This database will be provided together with regression coefficients for halocarbon effects (EESC) and/or linear trend and various known natural forcings (volcanic aerosol, solar, ENSO, QBO). The regression coefficients will be used to extrapolate that data back in time, and form a stratospheric ozone time series backward to cover the entire time period 1850-2006.

A similar procedure could be used to extrapolate into the future, and would capture changes due to halocarbons that will be an important driver of future ozone behavior. However, coupled chemistry climate model (CCM) simulations (*Eyring et al.*, 2007) indicate that future stratospheric ozone abundance is likely to be significantly affected by climate change, and it is not yet possible to estimate this contribution statistically from observations. Therefore, the SPARC CCMVal activity is proposing to provide a stratospheric dataset for CMIP5 that extends the observational database into the future based on CCM simulations that include the effects of climate change as well as halocarbon changes.

An entirely model-based vertically resolved, monthly mean, full atmosphere ozone and tropospheric aerosol database from 1850 to 2150 from CCM simulations for the entire time period, past and future, will be provided by AC&C activity 4 *(coordinated by Drew Shindell and Jean-Francois Lamarque)*. This has the advantage of being a physically consistent model dataset throughout time and space and including responses to all relevant forcings/composition changes such as methane and nitrous oxide trends since the pre-industrial. However, the models that have thus far expressed willingness to provide output to this activity are models that in general emphasize the troposphere, placing therefore less emphasis and computational resources on stratospheric physics and chemistry.

Those AR5 groups who wish to simulate composition in the troposphere while using prescribed stratospheric ozone can choose from any of the three stratospheric datasets above. Those who would use prescribed composition everywhere could either use the

AC&C activity 4 results or could replace the stratospheric ozone in those results with either of the other two stratospheric datasets as they see fit. Such a decision will depend upon their own subjective evaluation of the relative importance of physical consistency versus fidelity to observations.

To perform the chemistry climate simulations, emissions of all necessary chemical compounds will be provided, e.g. ozone precursors, aerosol precursors, primary aerosols and ozone-depleting substances. An international effort is currently in progress to complete this task. In particular, future emissions (2010-2300) will be generated by the Integrated Assessment Models (IAMs) responsible for the RCPs. In order to ensure continuity of emissions across 2000, the 2000 emissions are being used to harmonize emissions into the future and from the historical perspective as well. Emissions (at 0.5 degrees, available every 10 years over 1850-2300) are expected to be available in the latter part of 2008. The current status on going from past to future emissions in IAMs is to try to be able to get a reasonable representation for 2005 with the highest priority for those gases that determine the climate signal the most, i.e. CO_2, CH_4. The main base year for the inventory remains 2000 and 2005 data will be used to assess and possibly constrain the initial trajectory of the future emissions in the IAMs.

For Solar Irradiance Data (SPARC SOLARIS), see:
http://www.geo.fu-berlin.de/en/met/ag/strat/research/SOLARIS/Input_data/index.html

Heating rates from volcanic aerosol and Surface Sulfate Area Densities can be downloaded from the CCMVal Forcing website:
http://www.pa.op.dlr.de/CCMVal/Forcings/CCMVal_Forcings_WMO2010.html

Summary and Recommendations

- A recommendation for models that do not have interactive chemistry should be made to prescribe ozone according to the new SPARC/AC&C ozone time series, because:
  - -The recovery of stratospheric ozone and ozone in the upper troposphere/lower stratosphere will be significantly affected by climate change, which is important for radiative forcing;
  - -The impact of the ozone hole on high latitude surface climate has been substantial, so the impact of ozone recovery in the future will also be important. This has implications for SH high-latitude climate (e.g., tropopause height, jet location, Hadley Cell extent, carbon uptake, and sea-ice melt).
- A question for WGCM is whether climate models need aerosol distribution as could be generated by the AC&C4 exercise.
- Atmospheric oxidants should be prescribed to capture changes in sulfate formation and methane lifetime.

IV. Atmospheric Chemistry Action Items and Recommendations

12/ Timing for ozone concentration dataset availability including stratospheric and tropospheric ozone; utility for a 'dynamically referenced' ozone database and give feedback on whether prescribed aerosols are needed, also atmospheric oxidants, nitrogen depostion and surface ozone (Meehl to contact Lamarque and inform Eyring)

13/ Make forcing datasets from CCMVal community (e.g. solar) available for modelling groups to use for CMIP5 (Eyring)

14/ Can solar radiation be extended back to 1850? Ask SPARC whether they can recommend a volcanic aerosols dataset (Eyring)

15/ Experimental design for evaluating the aerosol radiative forcing in GCMs: distribute Steve Schwartz and Ulrike Lohmann's proposal derived from FIAS discussions

3.4.3 Ice Sheets

Ice on land holds the potential for having a significant impact on global sea level over the present and subsequent centuries. This ice may melt at its surface in a warming atmosphere, or where it flows from the land out to the ocean and forms ice shelves, it may melt at its base in warming oceans. In either scenario, we presently do not have the modelling capability to make quantitative predictions for the evolution of the state of the land ice. While the thermodynamics of melting of ice is important, it may turn out that the dynamics of ice will be more important in that the rapid transport of ice from land to ocean may produce a surprisingly fast sea level rise. This point was well emphasized in the most recent IPCC report in which it was stated that accurate predictions of sea level rise for the present century were not possible because the IPCC class models did not represent the physical processes associated with rapid dynamical responses of ice-sheets, relevant to ice-streams and outlet glaciers. The concern for possible rapid changes in such ice-streams and glaciers is well founded as there are several in both Antarctica and Greenland that have been observed to undergo large changes over the past decade.

To arrive at a predictive capability for ice sheet behaviour, within the context of fully-coupled global climate models, will require that a number of obstacles are overcome, some relating to the understanding of physical processes, and others to numerical and software issues. In terms of physical processes, despite several decades of research there still remains uncertainty in the physics that controls the rate of flow of ice steams coming from the land and feeding into the ice shelves, floating on the ocean. Some of the major uncertainties are: 1) physics of calving at ice fronts, 2) grounding line migration, 3) buttressing effects associated with ice geometry, 4) basal melting of ice-shelves and the associated sub-ice-shelf ocean circulation. Even regarding the comparatively well-understood processes determining ice-sheet surface mass balance, there are substantial uncertainties. As for numerics, the main challenges are: 1) how to represent on the grids of relatively coarse resolution global climate models the steep marginal areas of ice-sheets, on which any surface melting occurs, and the coastal ocean circulation that may impinge on ice-shelves, and 2) within the ice models themselves how to represent regions of rapid dynamic changes, such as at the grounding line.

The recognition of the importance of ice sheets and the obstacles that prevent their inclusion into coupled models has spawned a number of workshops over the past 18 months. Workshops have been held at national laboratories (e.g., GFDL, and LANL) and within the university community (e.g., NYU), and at international science gatherings (e.g., SCAR). All of these meetings have focused on addressing the key question of getting ice sheets properly represented within climate models. Despite the recognized imperfections in the understanding of the various pieces of model physics and numerics, the community is forging strategies. One approach that is gaining momentum is the development of a community ice sheet model (CISM), much along similar lines to the way in which a community sea ice model (CICE) was previously developed. This activity should lead to the availability of a relatively modular ice sheet model, including a representation of the ice shelves, for inclusion into global climate models. Such a model used within a regional climate model that is fed one-way information from a global climate model will offer an ability to simulate changes in the land ice. However, to have a proper representation, including all potential feedbacks, one must recognize some of the additional complications associated with ice sheet modelling, such as lateral and vertical changes in ocean width and height, and land surface topography and nature. These may require significant modifications to existing climate models within the coupled framework.

3.4.4 Paleoclimate/PMIP

The Paleoclimate Modelling Intercomparison Project (PMIP) is a long-standing initiative endorsed by both WCRP/CLIVAR/WGCM and IGBP/PAGES. It has provided an efficient mechanism for coordinating paleoclimate modelling activities that provide valuable information on the mechanisms of climate change, the identification of key feedbacks operating in the climate system and, through model evaluation, the capability of climate models to reproduce climates different from today. Thanks to the production of data syntheses and to rigorous model-data comparisons, the mid-Holocene climate (ca 6000 yr BP) and the Last Glacial Maximum (ca 21,000 yr BP) are now recognised as benchmark periods for climate models. PMIP, in addition to its focus as an intercomparison project, has promoted the understanding of past climate changes as a necessary basis for having confidence in future predictions. In particular, PMIP has demonstrated the validity of the approach employed by the IPCC, and others, that uses coupled global climate models to simulate climates with large-scale controls that differ substantially from those of the present day.

The Paleoclimate Modelling Intercomparison Project (PMIP3; (http://pmip.lsce.ipsl.fr/)) proposes that a set of simulations of past climates, as detailed below, be adopted by the WGCM as part of the priority CMIP5 simulations. The proposed simulations respond to the priorities of several different communities and incorporate some of the ideas and suggestions from the 70 participants at the PMIP workshop held in Estes Park, Colorado from 14-19 September 2008.

The PMIP3 experiments are listed in *Appendix 4* according to their primary purposes. The model experiments are designed to provide information primarily concerning "long-term" climate change with relevant goals to informing the future listed for each experiment. Tier 1 experiments are first priority and should be considered high priority by all modelling groups involved in WGCM. Tier 2 experiments are also highly relevant to the next assessment and should be endorsed as priority runs to be done by modelling groups participating in PMIP3. Whenever possible, these experiments should be performed with the same model components and at the same resolution as the CMIP5 pre-industrial simulation. When this is not the case, additional experiments will need to be included to provide the corresponding tie points to the CMIP5 simulations (see section 2 experiments).

For most of the simulations proposed, some details concerning experiment design have yet to be fully agreed upon or specified. Experimental designs will be posted to the PMIP3 web page. Included in the experimental designs will be specifications of the forcings, and files containing the boundary conditions and initial conditions. PMIP3 will also provide the proxy data sets relevant for evaluating the paleoclimate model simulations.

V. PMIP3 Action Items and Recommendations

16/ PMIP3 requests WGCM endorsement, inclusion in AR5 experimental plans and support for database (Meehl to Braconnot)

17/ Recommend that models performing paleo experiments also perform full CMIP5 experiments using same model (resolution)

3.4.5 Report from the CLIVAR Working Group for Ocean Model Development (WGOMD)

Recommendations to WGCM for CMIP5

The CLIVAR Working Group for Ocean Model Development (WGOMD), in consultation with the wider ocean modelling community, has presented WGCM with the report 'Sampling Physical Ocean Fields in WCRP CMIP5 Simulations'. This document presents recommendations for sampling physical ocean fields in simulations participating in the WCRP CMIP5 experiments, including guidelines for space and time sampling, and rationalizations for a list of fields to be archived. The perspective taken here is that of physical ocean scientists aiming to enhance the scientific utility of model simulations contributing to CMIP5.

The document serves the following purposes:

- To rationalize a list of physical ocean model fields to be archived for the Coupled Model Intercomparison Project (CMIP5) supporting the IPCC-AR5.
- To offer guidance to ocean climate modelers for enhancing the scientific relevance of sampled model output.
- To articulate certain needs of ocean scientists aiming to analyze CMIP5 model output, and whose research directly supports Working Group 1 (WG1) goals.

There are specific shortcomings in the ocean model data contained in CMIP3, and these shortcomings compromise the dataset's utility for ocean scientists aiming to support WG1 science. Broadly, the following outlines the major shortcomings with the ocean data in CMIP3:

- There is insufficient data for constructing budgets of mass, heat, and salt. In particular, there is incomplete information regarding the boundary fluxes, and those boundary fluxes that are present are generally not archived on the ocean model native grid.
- Vector fields (e.g., velocity, transport, fluxes) are remapped to a spherical grid from the commonly used non-spherical native grids of global ocean models. This remapping occurred despite the absence of a generally agreed upon remapping algorithm. The result is incomplete ocean model datasets, and/or datasets with remapped vector fields that are generally untrustworthy.
- There is a paucity of fields of use for studying the impact of subgrid scale (SGS) parameterizations used by the models. SGS parameterizations are of leading order importance for most IPCC class ocean models. Numerous IPCC class ocean models targeted for CMIP5 will incorporate a broad suite of SGS methods. The CMIP5 archive thus provides the ocean research community with a tremendous opportunity to evaluate the integrity and impact of the various SGS schemes.

By articulating shortcomings with ocean data in CMIP3, and in turn by identifying certain needs of ocean scientists aiming to analyse model output, the document aims to inform those charged with establishing protocols for CMIP5. Entraining more ocean science into the WG1 process will enhance the robustness of climate model projections, which is of fundamental importance for the IPCC process.

Coordinated Ocean-ice Reference Experiments (CORE)

WGOMD is continuing its work in the Coordinated Ocean-ice Reference Experiments (CORE). Details are available on the WGOMD website:

http://www.clivar.org/organization/wgomd/core/core.php.

WGOMD recommends that CORE should form the baseline for ocean-ice simulations and global coupled modelers should include ocean-ice simulations as a central part of their experiment suite.

WGOMD has completed CORE I, a comparison of seven global ocean-ice models run for 500 years using the same atmospheric forcing. The experimental design and simulation results are documented in Griffies et al. (2008, Ocean Modelling, also available on the WGOMD website).

CORE-II focuses on interannually varying forcing based on reanalysis and observational products. The CORE-II effort will provide a common framework for running ocean-ice models for hindcast purposes. WGOMD is in the process of determining the details of the experimental protocol, and then documenting a suite of model simulations with this protocol. Notably, CORE-II efforts will feed into CLIVAR panel activities aiming to use models to identify mechanistic descriptions of observed variability and change. CORE-II initialization issues are common to the CMIP5 decadal experimentation framework.

CORE-III is a freshwater perturbation experiment designed to test model sensitivity to changes to increased freshwater in the Greenland boundary currents that may arise from a strengthened hydrological cycle, melting of Arctic sea ice and from Greenland meltwater. WGOMD recommends that CORE-III be done in a fully coupled framework to avoid problems arising from having to restore salinity in an ocean-ice only simulation.

Repository for Evaluating Ocean Simulations (REOS)
WGOMD is developing a Repository for Evaluating Ocean Simulations (REOS). The motivation for this CLIVAR web site stems from the growing needs of the modelling community to provide benchmarks, thorough evaluations of their simulations, and to make use of newer observational datasets generated over the past decade.

Essentially, this is a website that will facilitate access to observational datasets, develop a discussion on ocean metrics and ocean model evaluation, and provide tools and references for the community. Ideally what will come out of this is a discussion within the ocean modelling community that will lead to a recommendation for a standardized baseline approach for evaluating ocean climate studies. An ocean modeler who wants to compare some results to observations should also be able to use this site to determine what data he/she should get hold of and from where. A prototype web site can be viewed at www.clivar.org/organization/wgomd/reos/reos.php.

3.4.6 Report from the International Detection and Attribution Group (IDAG)

IDAG (International Detection and Attribution Group) is a fairly small group funded by NOAA and DoE in the US to facilitate international research coordination and reviews on the detection and attribution of climate change. This research uses comparisons of climate model simulations with observations to identify forced climate variations in the observational data, as well as using such comparisons of model simulations with different forcings to improve model simulations. IDAG has provided feedback on the design of the CMIP5 experiment. It recommends that simulations of the 20th century extend as close to the present as possible (beyond 2006) for all forcings combined, as well as for anthropogenic forcings only. These simulations should be run as ensembles, instead of just producing a multi-model ensemble, as there are differences in climate sensitivity and differences in forcings between simulations from different modelling centres. Control simulations that are used to spawn the ensemble members should extend longer than the duration of all ensemble members. All modelling centres should be encouraged to use common external forcing datasets, including for volcanic and solar forcing and stratospheric ozone datasets. WCRP SPARC is developing these datasets (see Section 3.4.2).

4. Updates from modelling centres

Appendix 5 lists the response from the different modelling groups represented at the WGCM meeting to the following questions regarding their participation in CMIP5:

- Will groups have an AOGCM, an ESM, or both?
- Will groups perform the short term decadal, long term mitigation, or both?
- Will new models have interactive aerosols or coupled chemistry?
- When is it planned to begin experiments?
- Is the main constraint people, computer resources, or both?

5. WGCM Discussion Topics

5.1 Modelling within WCRP

WCRP is entering a phase of reflection on how it should evolve as an organization to support international modelling activities into the future. The WCRP strategic framework for 2005-2015: Coordinated Observation and Prediction of the Earth System (COPES) continues to provide the theme for WCRP's organization. Currently there is a plethora of modelling activities within the Programme itself and its core Projects. The JSC is currently deliberating how to best organise these activities, such as bringing the topic of parameterization and model development, traditionally done by GEWEX, into the wider WCRP modelling community. Now is the time for WGCM and the rest of the WCRP community to participate in this evolution by communicating with the JSC.

WGCM stresses that it hopes to receive continued support from the JSC to avoid any changes. Anything that the JSC can achieve in terms of improved communication between the Projects on climate change, not just present climate, would be very welcome. WGCM has good links with CLIVAR since it is jointly sponsored by WCRP and CLIVAR and J. Meehl is a member of the CLIVAR SSG. Links between WGCM and WGSIP have not been strong in the past, but have been strengthened by the common CMIP5 near term activity. S. Bony becoming co-Chair of WGCM has linked WGCM and GEWEX. WGCM's interests in atmospheric chemistry and air quality warrant strengthened links with SPARC and progress has been made by inviting V. Eyring to join WGCM. There is very little contact between WGCM and CliC. There is an opportunity for more interaction with the NWP community as they are moving towards forecasting air quality, where climate feeds in, and, in turn, their experience in parameterization development can feed into climate modelling. A link has already been made between GEWEX and WGNE, with C. Jakob coming from GEWEX to become co-Chair of WGNE.

As part of the WCRP consultation process on its future direction in modelling, the WCRP Modelling Summit for Climate Prediction held at ECMWF, UK on 6-9 May 2008 brought together the different modelling activities being coordinated within the WCRP organization. The scientific statement forthcoming from the meeting presents a vision for the future of climate modelling, and recommends the initiation of a Climate Prediction Project. The statement will be presented at the next WMO Executive Committee meeting and feed into the planning for the World Climate Conference Three (WCC-3) to be held in September 2009.

5.2 Regional Climate Modelling within WCRP

The JSC, as outlined in Section 2.2, has requested that a Task Force on Regional Climate

Modelling be set up to assess the RCM and downscaling techniques that are available, for time scales from seasonal forecasts to IPCC time scales. It is to entrain all appropriate expertise, including scientists using RCMs in the regions, and involve WGNE, WGSIP, WGCM, WCP, and regional START activities.

During the last decade, there has been a tremendous evolution in regional climate modelling (RCM) and downscaling techniques. Today, many RCMs are available (some of them are "portable") and are used by a wide community (e.g. RegCM, PRECIS, RSM, WRF). The current "state-of-the-art" grid spacing is 10-30 km (higher for a few models). RCMs are being upgraded to non-hydrostatic, cloud-resolving frameworks in order to go to sub-10 km resolutions. Running decadal to centennial simulations have become the "accepted standard" and virtually all regions of the World have been simulated. A number of review/guidance papers and reports are available and several coupled RCM efforts under way, including atmosphere, ocean, aerosol, and biosphere components. There are encouraging results from first two-way nested experiments and there are new emerging areas of application (seasonal prediction, impacts).

However, this progress was not reflected in the AR4, and most regional climate change information in the AR4 was still derived from AOGCMs (only three figures in Chapter 11 of the AR4 are RCM or statistical downscaling results). RCM information is under-utilized in the current generation of climate change scenarios for impact/adaptation work because RCM studies have not been coherent and comprehensive enough to sufficiently characterize uncertainties in climate change projections. There are exceptions though, such as the European Projects PRUDENCE and ENSEMBLES, and possibly NARCCAP in the US. A 'Hyper Matrix' is needed for running RCMs in different GCMs, with different scenarios. This is already being done at the ICTP and is proposed for the wider international community in Giorgi *et al.* (2008).

The RCM community feels the need for a global coordinated program (analogous to a CMIPn) to produce a next generation set of scenarios for use in the AR5 process. There is a need for a strong/formal commitment from global modelling groups to archive 6-hourly fields for the time slice experiments. This is needed quickly so that the RCM community does not lag behind the CMIP5 schedule and its work can be assessed by the AR5. A fast-tracked procedure for the transfer of GCM fields to RCM users is needed, as well as a databank strategy for the storage of global "driving" fields and RCM output. This is already being done as part of the ENSEMBLES project from which RCM groups can access global 6-hourly fields. To avoid storing this high-resolution data centrally, the data could be hosted by the modelling centres, with a server hosting a toolbox for selecting regions of data for downloading.

There are three main RCM issues that need attention at a WCRP-wide level:

1. Model Evaluation

- Define a standard set of analysis-driven (perfect LBC) benchmark cases to assess the model performance (analogous to AMIP)
- -ERA40, NCEP, ERA-Interim (1989-2006)
- Define a set of benchmark metrics
- -Region dependent?
- -Application dependent?
- Assess the model performance when driven by GCM historical runs (using same metrics?)
- Interface with the Transferability framework

2. Regional Projections

- Multiple regions
- Target resolution: 25 km.
- Top priority runs for which global LBC fields will be needed
  - -Tier 1: RCP4.5 (ideally 1950-2100)
  - -Tier 2: RCP8.5 (ideally 1950-2100)
  - -Tier 2: DHFG (2005-2035)
- Possible (wishful thinking) additional runs
  - -Emission driven coupled carbon runs
  - -Additional DHFG hindcast run
  - -Far future RCP4.5 stabilization time slices (2170-2200, 2270-2300)
- Possible sensitivity experiments to assess the importance of regional forcings (aerosol and land use)

3. International Coordination and Management

- Formal endorsement by WCRP
  - -Set up a formal X-MIP-X
- Formation of a task force (or WG) to design a plan, write a white paper and oversee the process after consultation with the broad community
- Involve a wide RCM (or RCD) community in a coordinated way
- Involve end-users (impact/adaptation)
- Involve (representatives of) the GCM community
- Formal commitment by GCM groups to provide 6-hourly fields for LBCs in a fast track way
- Creation of data-banks for LBC global fields as well as RCM output
  - -Global centre?
  - -Network of regional centres?

The following is a possible timeframe for the RCM community to organise itself:

- September 2008 – December 2008
  - -Formation of the "task force"
  - -Identification of potential participating modelling groups
  - -First draft of "white paper", distribution for comments
- February 2009 – WCRP Workshop in Toulouse (still needs to be announced)
  - -First discussion meeting on technical issues of the program plan
  - -Revision of white paper for further comments-distribution
- May 2009 – Lund workshop
  - -Finalization of plans and white paper
  - -Identification of contributions by different groups
- September/October 2009
  - -Report to WGCM meeting
- June 2009 – December 2009 (or June 2010)
  - -Completion and analysis of first set of validation runs driven by analyses of observations over the different domains
- January (or June?) 2010
  - -Begin scenario runs

VI. Regional Climate Modelling Action Items and Recommendations

18/ WGCM endorses the formation of a regional modelling task group. Recommend that a WGSIP member participate (Giorgi and Flato to formulate group)

19/ Regional downscaling community needs to define which periods want high frequency output from global GCMs (proposed 1996-2005, 2026-2035, 2091-2100); Time periods compatible between CMIP3 and CMIP5 encouraged for comparisons. Alternatively, modelling groups make available all 6 hourly data from 20th and 21st century runs for regional models on local server for a finite time period, and Giorgi can download it and store at his centre (Stouffer, Giorgi, Jones)

20/ Provide RCM Task Group names to WGCM, including representatives from climate modelling and other downscaling techniques (Giorgi, Jones)

21/ Communicate JSC's long term RCM organizational plans (Asrar to Giorgi, Jones)

5.3 Parameterization research in WCRP

Parametrizations are important for all model applications from weather to climate. Their current and future role has been somewhat distorted recently in light of the move towards higher resolution models, leading to slower progress compared to general model development and computer power. Parametrization development needs team effort and modelling centres have reduced their relative effort in this area so that an already small community has shrunk even further. This is further compounded by a lack of visibility of parameterization research in the WMO structure.

The GEWEX Modelling and Prediction Panel (GMPP) proposes to reorganise parametrization research within WCRP. As part of a WMO Commission for Atmospheric Sciences (CAS) reorganization, a request has been made for the WCRP Working Group on Numerical Experimentation (WGNE) to coordinate paratemeterizations research. The result has been a joint proposal made to WCRP-JSC and CAS to have a parametrization sub-group led by a new WGNE co-chair. This has been approved and C. Jakob appointed as co-chair of WGNE. Figure 5 illustrates the proposed framework for more coordination in model development involving the data, model development and model user communities, with a focus on the importance of ensuring that process study results feed into improving the model.

The following are the goals of this subgroup:

- Promote and stimulate parametrization development.
- Facilitate dialogue between developers and model users.
- Facilitate activities like workshops etc.
- Ensure a critical (expert) mass within the community to make real progress in the coming years

Within the WMO, strong and well-coordinated efforts exist for clouds and convection (GCSS), land surface (GLASS), and the planetary boundary layer (GABLS). Some links that are being established between communities are the WGNE-GMPP, CFMIP-GCSS and the THORPEX and YOTC connections. The main gaps and opportunities in current coordination involve poor links to the ocean community and the cryosphere community (both land and sea). Engagement with the model "user" community needs strengthening, for example by better links to WGCM and WGSIP. Coordinated efforts are needed to prioritize developments, building stronger links to the model evaluation and diagnostics community.

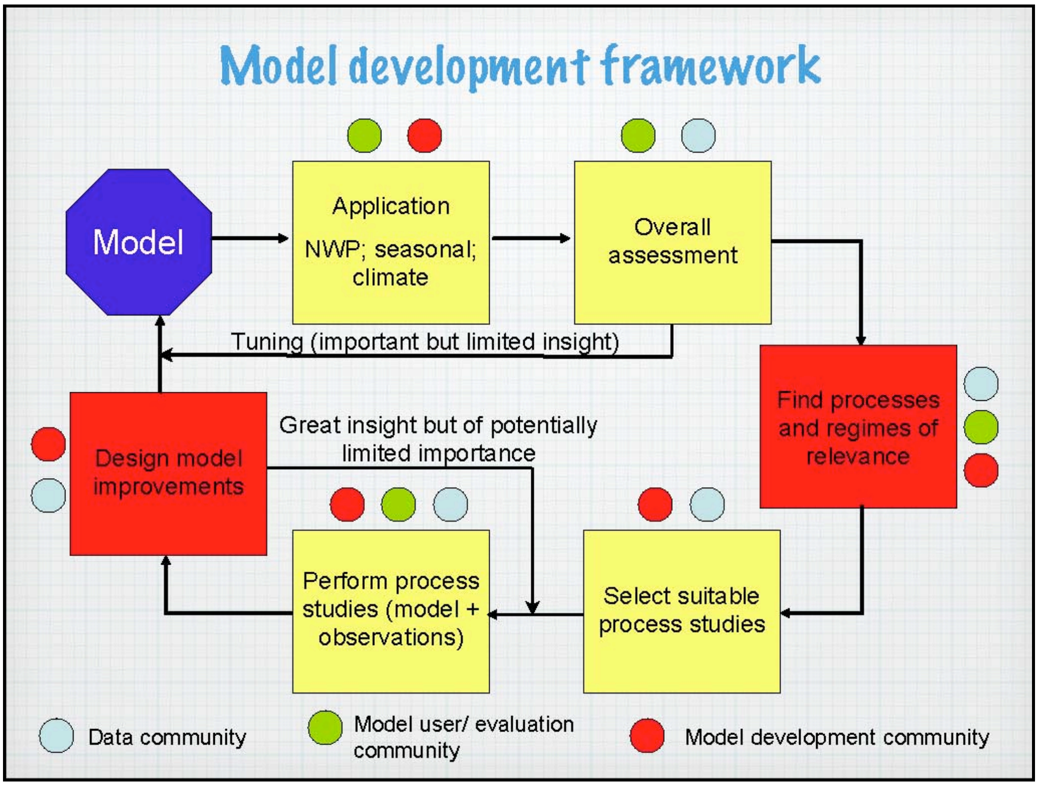

Figure 5: Model Development Framework

6. WGCM Business

6.1 Membership

- WGCM:
  Welcome to S. Bony as new co-Chair of WGCM. G. Meehl, A. Hirst, N. Nakicenvic and P. Braconnot renew their membership. J. Mitchell rotating off but remain ex-officio and member of CMIP Panel, G. Flato to remain as JSC liaison. Welcome to V. Eyring and B. Wang.

- CMIP panel:
  B. McAvaney and T. Delworth rotating off. Make K. Taylor and J. Mitchell ex-officio, plus T. Stockdale from WGSIP; CMIP Panel now: R. Stouffer (chair), G. Meehl, M. Latif, C. Covey, K. Taylor, J. Mitchell, T. Stockdale

- Form a Joint WGCM-WGSIP Contact Group on Decadal Predictability/Prediction – R. Stouffer, M. Latif, G. Meehl, T. Stockdale (this will be a subcommittee of CMIP, making T. Stockdale a member of CMIP); need to consult with WGSIP to see if this is OK and perhaps add G. Boer (Meehl)

- WOAP representative needed (K. Taylor nominated)

- TGICA – WGCM recommend D. Karoly for IPCC appointment

VII. Membership Action Items and Recommendations

WGCM:
22/ Welcome to S. Bony as new co-Chair of WGCM. G. Meehl, A. Hirst, N. Nakicenvic and P. Braconnot renew their membership. J. Mitchell rotating off but remain ex-officio and member of CMIP Panel, G. Flato to remain as JSC liaison. Welcome to V. Eyring and B. Wang

CMIP panel:
23/ B. McAvaney and T. Delworth rotating off. Make K. Taylor and J. Mitchell ex-officio, plus T. Stockdale from WGSIP; CMIP Panel now: R. Stouffer (chair), G. Meehl, M. Latif, C. Covey, K. Taylor, J. Mitchell, T. Stockdale

24/ Form a Joint WGCM-WGSIP Contact Group on Decadal Predictability/Prediction – R. Stouffer, M. Latif, G. Meehl, T. Stockdale (this will be a subcommittee of CMIP, making T. Stockdale a member of CMIP); need to consult with WGSIP to see if this is OK and perhaps add G. Boer (Meehl)

25/ WOAP representative needed (K. Taylor nominated)

26/ TGICA – WGCM recommends D. Karoly for IPCC appointment

6.2 Next Meeting

D. Bader has offered that PCMDI host the 13th Session of WGCM in San Francisco, provisionally on 28-30 September 2009. The meeting will be joint with AIMES, who, provisionally, will meet on 30 September - 2 October 2009.

VIII. Next meeting Action Items and Recommendations

27/ Joint with AIMES, hosted by PCMDI in San Francisco, provisionally on Sept. 28 to Oct 2 2009 (Bader, Hibbard, Meehl)

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Appendix 1

12th Session of WGCM, Paris 22-24 September 2008:
Meeting Agenda

DAY 1 - Monday, September 22

0900 - 0915
Welcome - J. Mitchell, G. Meehl
- Introduction and welcome - H. Le Treut
- Times, local arrangements - P. Braconnot
- Explanation of Agenda - J. Mitchell

Adoption of Agenda

0915 - 0940
Reports and news from governing groups (JSC/CLIVAR) (5 minutes each)
- New Director WCRP: first impressions - G Asrar
- JSC-XXIX session, Arcachon, France - G.Flato
- CLIVAR SSG session and International CLIVAR Project Office - G. Meehl
- ACC - G.Flato
- Modelling Summit - J Mitchell, G Meehl

0940 - 1030
Presentation and discussion of the proposed CMIP5 coordinated climate change experiments to be assessed for IPCC AR5 leading to approval of experimental design by WGCM
- Introduce coordinated experiments addressing short term and longer term climate stabilization experiments (note ENSEMBLES activity) - G. Meehl (30min including questions)
- Status of emission scenarios - links to WGII,III communities – K. Hibbard (20 min including questions)

1030 - 1100 Coffee
- Detail on short term (decadal predictability/prediction) experiments - J. Murphy, G. Boer (60 mins including discussion)
- Detail on long term experiments (and metrics) - K. Taylor, R. Stouffer, C. Le Quéré (60 mins including discussion)

1300 - 1430 Lunch

1430 - 1550
Proposed coordination of experimental design with other activities; presentations of proposals from related communities (20 minutes each including discussion)
- CFMIP/cloud feedbacks - S. Bony
- Chemistry - V. Eyring
- Paleoclimate/PMIP - P. Braconnot
- Regional models - F. Giorgi

1550 - 1620 Break
- WGNE - C. Jakob
- WGOMD – S. Griffies
- Ice sheets - D. Holland, J. Gregory
- Impacts/WGII -J. Mitchell, G. Meehl
- IDAG – D. Karoly

1800 - 1830
Recap of day's session and discussion of topics to be re-visited in the next 2 days

DAY 2 - Tuesday, September 23

0900 - 1100
Present integrated experimental design based on discussions Monday; seek approval from WGCM to proceed; next steps - G. Meehl, J. Mitchell
1100 - 1130 Break

1130 - 1300
Updates from modelling centres
Note some groups have more than one person listed since there are multiple attendees from some groups; we recommend, since the time slots for each group are only 12 minutes long and the time limit will be strictly enforced, that just one person make the presentation on behalf of each group (please focus presentation on where your modelling group is in the model development cycle related to the proposed experimental design, will your group use both classes of models or just one, perhaps illustrated with a science highlight, when do you anticipate starting to run the experiments, computing issues related to the large number of experiments proposed. (12 minutes each, 3 minutes questions)

France IPSL	P. Braconnot/S. Bony/J.L. Dufresne
France Meteo France	S. Planton/D. Salas Melia
Germany MPI	M. Giorgetta
Canada CCCMa	G. Flato
Italy	F. Giorgi/S. Gualdi
Australia ACCESS	A. Hirst/K. Puri

1300 - 1430 Lunch

1430 - 1600

Japan CCSR/FRGC/U. Tokyo/NIES	M. Kimoto
Japan MRI	S Kusunoki
U.K. Hadley Centre	C. Jones
U.K. Reading	L. Shaffrey
U.S. NCAR	G. Meehl/P. Gent
U.S. GFDL	R. Stouffer

1600 - 1630 Break
1630 - 1800

U.S. NGFC	M Suarez
Korea KMA	W.T. Kwon
China LASG	B. Wang/T. Zhou
China BCC	T. Wu/Z. Wang
Denmark Danish Met. Inst.	W. May
Norway NERSC	M. Bentsen, H, Drange
EC-Earth	C. Jones

1815 Review, and plans for Wednesday

1830 Adjourn

DAY 3 - Wednesday, September 24

0900 - 1000
Coupled Model Intercomparison Project (CMIP) - R.Stouffer, C.Covey, K.Taylor, D. Bader

- Current status of CMIP3 multi-model dataset and analysis efforts

- CFMIP next steps (anything not discussed earlier under experimental design or under clouds and aerosols)
- How will model output from the next set of coordinated experiments be archived and accessed?

1000 - 1100
WGCM Discussion topics (30 minutes including discussion each)

- -Regional climate prediction- what are the issues and how should they be addressed by WCRP? - F. Giorgi and J. Mitchell
- -Wider modelling issues – how is modelling best advanced in WCRP? - J. Mitchell and G. Meehl

1100 - 1130 Break

1130 - 1230
Review relation to wider WCRP, and with WGSIP, WGNE, AIMES, WG2, WG3, and others
1230 - 1400 Lunch

1400 - 1530
Recap of session, and re-visit any topics that need further consideration
1530 - 1600 Coffee break

1600 - 1730 Closed Session

- Membership issues
- Next Session: venue, dates

1730 End of WGCM-12 Session

Appendix 2

12th Session of WGCM, Paris 22-24 September 2008: Meeting Participants

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Appendix 3 - The Cloud Feedback Model Intercomparison Project : Summary of Activities and Recommendations for Advancing Assessments of Cloud-Climate Feedbacks

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Summary

The IPCC AR4 reaffirms the spread in equilibrium climate sensitivity and in transient climate response estimates among current models. Inter-model differences in cloud feedbacks remain the primary source of this spread. The identification of low clouds as the primary (direct) contributor to this spread is one of the signature achievements of the research community as summarized by the AR4. Cloud processes also play a critical role in the large-scale atmospheric circulation and the hydrological cycle. If we are to have confidence in simulations of climate change, particularly at regional scales where cloud biases induce especially strong control on the local energy balance and dynamics, and hence response, developing a better understanding of cloud and moist processes remains imperative.

The main objective of CFMIP-2 is to make, by the time of the AR5, an improved assessment of climate change cloud feedbacks by making progress in the (1) evaluation of clouds simulated by climate models and the (2) understanding of cloud-climate feedback processes. Toward this end CFMIP-2 has been engaged in three types of activities :

1. The development of a CFMIP Observation Simulator Package (COSP). Currently this has modules capable of simulating ISCCP/CloudSat/CALIPSO satellite observations. It is to be distributed to the modelling groups to evaluate model clouds (and thus contribute to the model development process) using satellite observations from the new generation of space-borne sensors.
2. Design and analysis of idealized experiments, requiring simulators and other diagnostics, to better understand the physical mechanisms underlying the different cloud-climate feedbacks in climate models.
3. Collaboration with GEWEX-Cloud Systems Studies (GCSS) to assess the credibility of cloud-climate feedbacks, through the coordinated use of CFMIP-GCSS CRM/LES/SCM[1] case studies focused on the sensitivity of specific cloud types (e.g. low clouds) to changes in climate, and process studies based on the analysis of high-frequency outputs at selected locations.

As a result of these activities CFMIP, in coordination (Annex B) with WGNE, the GEWEX Modelling and Prediction Panel (GMPP), and the GEWEX Radiation Panel (GRP) is recommending that WGCM :

- Incorporate COSP in a subset of the proposed mandatory CMIP-5 experiments (Table 1),
- Modestly expand the set of CMIP-5 experiments to include some that will help isolate the role of cloud processes and feedbacks (Table 2),
- Encourage modeling centers to participate in the full suite of CFMIP experiments and diagnostics.

So doing would recognize the importance of clouds and moist processes to climate prediction, and would help build a bridge between the scientific communities involved in climate modeling, fine-scale process modeling and observations. Linking CFMIP activities to CMIP5 (use of simulators, idealized experiments) will ensure a large participation of the modeling groups to studies aiming at evaluating cloud processes and their role in climate, at developing thorough climate metrics, and at unraveling and understanding uncertainties associated with climate projections. The extensive use of satellite simulators (COSP) is essential to evaluating and improving models, and merits special attention.

[1]CRM: Cloud Resolving Model, LES: Large-Eddy Simulation model, SCM: Single-Column Model.

I. Introduction

Improving climate models to make climate change projections more reliable constitutes a key objective of WGCM. Cloud-climate feedbacks remain one of the largest sources of uncertainty for estimating climate sensitivity and for predicting the global climate state at the end of the 21st century (Randall et al. 2007, Dufresne and Bony 2008). Owing to the strong interaction of clouds with the local energy balance, the atmospheric circulation and the hydrological cycle, biases in the models' representation of clouds and moist processes are also critically problematic for the reliability of climate predictions at regional scales.

To improve this situation, the second phase of the Cloud Feedback Model Inter-comparison Project (CFMIP-2) aims at fostering coordinated research in the area of climate change cloud feedbacks. More specifically CFMIP-2 wishes to make progress by the time of the AR5: (1) in the evaluation of clouds simulated by large-scale models (a "CFMIP simulator" has been developed to facilitate the comparison of model simulations with satellite observations), (2) in the understanding of the physical processes that control cloud-climate feedbacks in the various models, and the understanding of their dependence on cloud modeling assumptions, and (3) in the assessment of the relative credibility of the cloud feedbacks produced by the different models.

For this purpose, CFMIP is developing collaborations between the global climate modeling community and the scientific community involved in high-resolution (LES/CRM) cloud modeling and in the observation of clouds by satellites or ground-based measurements. With this in mind, the CFMIP coordination committee has representatives from the climate model development and evaluation community, the GCSS (GEWEX Cloud System Study) community, the ARM (Atmospheric Radiation Measurement) community and the US-CLIVAR Climate Process Team on subtropical cloud feedbacks (CPT). For the second time since April 2007, the CFMIP and GEWEX/GCSS communities organized a meeting together (PAN-GCSS meeting held on June 2008) and devised collaborative actions to be included in CFMIP-2 plans.

The CFMIP-2 project has been presented in a proposal available from http://www.cfmip.net, and has been discussed at the 11th session of WGCM held in Hamburg in August 2007. At this session, WGCM endorsed CFMIP-2 plans, recommended that the CFMIP simulator be used in some CMIP5 simulations, supported the storage of additional 3D model outputs, and endorsed that CFMIP-2 data be hosted together with the CMIP5 archive. WGCM also requested that additional model outputs be prioritized.

The purpose of the present document is twofold:

1. To provide the CMIP panel with recommendations, based on our accumulated experience, for advancing our understanding of clouds and moist processes in coupled models. In accordance to WGCM requests, those are rationalized and prioritized.
2. To report on the advancement of CFMIP-2 activities since the 2007 WGCM meeting, in particular on the development of: (i) COSP and its distribution to the modeling groups; and (ii) coordinated experiments involving a hierarchy of models to better understand and evaluate cloud feedbacks.

II. COSP, the CFMIP Observation Simulator Package.

Given the importance of the cloud problem to emerging initiatives in regional climate, and given the investment in the current observational system, a special effort to advance our understanding, diagnosis and evaluation of cloud processes in climate models participating in the AR5 is strongly required.

There is no unique definition of clouds or cloud types, neither in models nor in observations. Therefore, to compare models with observations, and even to compare models with each other, it is necessary to use a *consistent* definition of clouds. By using model outputs to diagnose quantities that can be directly observed from satellites (e.g. visible/infrared radiances, radar reflectivities or lidar backscattered signals), "simulators" allow models and observations to speak the same language and be compared quantitatively.

The ISCCP simulator, which is now routinely used by many modeling groups, has been very valuable to compare models with each other and with passive observations, to point out systematic biases of climate models and to analyze cloud feedbacks (e.g. Webb et al. 2001, Zhang et al. 2005, Webb et al. 2006, Williams and Tselioudis 2007, Williams and Webb 2008).

To take advantage of the new generation of active sensors, new simulators are required, that will provide much better diagnostics about the three-dimensional structure of clouds or about statistical relationships between clouds and precipitation. In that way, it will be possible to know the degree to which the accurate simulation of top-of-atmosphere radiative fluxes is due to compensating errors between cloud fraction, optical thickness, and vertical distribution biases. For this purpose, CFMIP has developed COSP, a package that currently consists of three simulators (ISCCP, CloudSat and CALIPSO), as discussed below, and that is expected to include additional simulators in the future. COSP outputs will also be useful in computing cloud-climate metrics.

<u>II.a The ISCCP simulator</u>

The ISCCP simulator allows quantitative evaluation of model clouds using ISCCP and MODIS data, and is required for the calculation cloud climate metrics which penalise compensating errors in models' cloud simulations which are not apparent from standard CMIP3 outputs (Williams and Webb 2008). These errors undermine the credibility of climate models, and the use of simulators as part of the model development process can help to target efforts on the physical schemes responsible.

Some updates have been made to the ISCCP simulator, which are now being tested prior to an official release for use in CMIP5 and CFMIP-2, due in Autumn 2008. These include a) an improved pseudo-random number generator, b) improvements to the diagnosis of cloud top pressure and c) addition of 'lightweight' diagnostics (grid-box mean cloud occurrence, top pressure and optical depth) to facilitate use of the simulator for longer periods in a wider range of experiments. The requested ISCCP simulator outputs for CMIP5 are listed in Annex A.

<u>II.b CALIPSO/CloudSat simulators</u>

The CloudSat and CALIPSO space-borne cloud profiling radar and lidar instruments in the A-Train constellation of satellites are providing new information on clouds, precipitation and their vertical structures. Although active sensors see more of the 3D structure of clouds than can be seen by passive sensors, the effects of instrument sensitivity and attenuation by clouds and precipitation mean that simulators are still required for quantitative 'like with like' evaluation with models (e.g. Haynes et al 2007, Bodas et al 2008, Chepfer at al, 2008).

CloudSat and CALIPSO simulator modules for COSP were released in February 2008 (http://www.cfmip.net), and are being tested with the models from the Met Office, IPSL, MPI, GFDL, NCAR, JAMSTEC, CCSR/NIES, CCMA, NASA GISS , U. Michigan, U. Reading and ECMWF. A pilot model intercomparison study using COSP is underway to make recommendations on how to use the package at best. A second release with output diagnostics suitable for use in CMIP5/CFMIP-2 is due in August 2008.

These additional packages provide an important complement to the ISCCP simulator as they help rationalize ambiguities associated with cloud overlap, and are thus key components of COSP.

<u>II.c COSP in CMIP5 experiments (Table 1)</u>

In 2007, WGCM recommended that COSP be used in some CMIP5 simulations. A version of COSP including the *updated* ISCCP simulator together with CloudSat and CALIPSO simulators is due in Autumn 2008.

* Long timeseries : At present, only the ISCCP and CALIPSO simulators are ready for in-line, long-term integrations (the codes are vectorized and a lightweight set of diagnostics has been defined)[2]. ***We recommend with the highest priority that these two simulators (at the very least the upgraded ISCCP simulator) be used in-line in several mandatory CMIP5 experiments***, especially in experiments #1.1 (pre-industrial control), #1.2 (20th century), #1.3 (AMIP), #4.1 (1%/year), #4.3 (Hansen-like), #4.4 (instantaneous 4xCO2 coupled run) and #7.1 (high-resolution AMIP with chemistry).

* Short timeseries : ***We recommend with the highest priority that COSP (with the ISCCP, Cloudsat and CALIPSO simulators activated together with the A-Train orbital sampling) be used off-line for short periods*** (a few years) of CMIP5 #1.2 (20th century), #1.3 (AMIP) and #7.1 (high-resolution AMIP with chemistry) experiments.

<u>II.d The GCM-Oriented CALIPSO Cloud Product (GOCCP) dataset</u>

The interpretation of the lidar backscatter ratio in terms of cloud products or variables (e.g. cloud fraction) requires to use a set of criteria or parameters that depends on the vertical resolution at which the lidar scattering ratio is measured or computed. To make consistent comparisons between models and CALIPSO data, we have developed, in collaboration with Dave Winker (NASA/Langley), a GCM-Oriented CALIPSO Cloud Product (GOCCP) dataset derived from CALIPSO Level-1 data which is consistent with the CALIPSO simulator outputs (Chepfer et al. 2008). *A priori*, the CALIPSO level 2 dataset developed by NASA will not be as consistent with the simulator outputs as GOCCP, but a comparison is under-way to quantify the difference between both datasets (Chepfer et al., in preparation).

The GOCCP products will be made available on-line from the LMD/IPSL and CFMIP websites. They will include diagnostics of the global 3D monthly mean and seasonal cloud fraction (using the same vertical grid – 40 levels - and the same cloud detection criteria as the CALIPSO simulator) derived from CALIPSO observations, as well as diagnostics of the layered (low-level, middle-level, high-level) cloud fractions, joint height-scattering ratio distribution of the lidar backscatter ratio and of the depolarization ratio. All the diagnostics will be in netcdf format, and any post-processed versions of the ISCCP and CloudSat datasets which are produced during the project will also be made available.

III. GCM outputs requests to CMIP5

Since the last WGCM meeting, CFMIP has reconsidered the list of additional cloud related diagnostics requested from CMIP5 simulations to best serve the needs of climate model development and evaluation community and to support CFMIP-GCSS studies on cloud processes and feedbacks.

Our selection of GCM outputs was guided by the wish that:

1. The value of GCM outputs be as high as possible, by the AR5 and beyond, maximizing the opportunities for people in the model evaluation and process modelling communities to contribute to future improvement of climate models

2. The selection of diagnostics be justified by published studies demonstrating the effective usefulness of the requested outputs.

3. Diagnostics reflect the tremendous advancement (and enormous investment) in satellite remote sensing available to the current epoch of climate simulation.

[2]If by Autumn 2008 the CloudSat simulator gets sufficiently optimized to run efficiently on vector machines, and if a lightweight set of CloudSat diagnostics gets defined, we will propose the modeling groups (as an option) to run COSP in-line with the three simulators (ISCCP, CALIPSO and CloudSat) activated. This will very modestly expand the set of diagnostics of Tables A1a, A1c, A2a and A2b.

The list of additional CMIP5 model output requested by CFMIP for model evaluation and for understanding of model systematic biases, cloud processes and feedbacks is summarized in Table 1. Several types of diagnostics are requested.

III.a Type of diagnostics #1 : outputs from simulators

The rationale for these outputs has been extensively discussed in section II.

The set of simulator output variables proposed for long-term integrations includes :
(monthly outputs for all years, daily outputs for a subset of years)

- Ptop-Tau diagnostics from ISCCP (7 vertical levels x 7 optical thickness bins)
- gridbox mean cloud cover, cloud albedo and cloud top pressure from ISCCP simulator
- low-level, mid-level, high-level and total cloud cover from CALIPSO simulator
- vertical profile of cloud fraction from CALIPSO (40 vertical levels)

The set of simulator output variables proposed for short periods (1-3 years) includes:
(monthly outputs for all years, orbital outputs for a subset of years)

- the lightweight set of simulator diagnosics defined above
- joint height-reflectivity distribution of radar outputs, on 40 fixed height levels and in 15 bins of reflectivity, required to repeat and extend the analysis of Zhang et al (2007) or Bodas et al (2008) on CMIP5 outputs.
- joint height-lidar scattering ratio distribution of lidar outputs on 40 fixed height levels and in 15 bins of backscattered scattering ratio, to repeat and extend the analysis of Chepfer et al (2008) on CMIP5 output.
- cloud frequency of occurrence as seen by CALIPSO but not CloudSat, required for studies making combined use of CloudSat/CALIPSO simulator output.

Note that COSP simulator outputs will also be useful in computing cloud-climate metrics. Additionally, science teams funded to support the simulated satellites are being coordinated to best support the analysis of outputs derived from COSP.

III.b Type of diagnostics #2 : 3-hourly global instantaneous outputs for a short period

These diagnostics will be requested for the year 2007 of an AMIP experiment.They will serve two main objectives: first, they will allow the GCSS community to examine the representation of cloud processes by GCMs in the current climate in any climate regime or meteorological situations without imposing *a priori* geographical constraints (this is particularly necessary for climate models because the large-scale dynamical structures simulated are often shifted in space compared to observations); second, these high-frequency outputs will enable us to analyze in detail the diurnal cycle of clouds and convection simulated by climate models, which is known to be a long-standing weakness of NWP and climate models. This unique global dataset is likely to be used by the scientific community for a long time, well beyond the AR5.

III.c Type of diagnostics #3 : 3-hourly outputs at selected locations for several years

These diagnostics will be requested for several years (1985-2007) of an AMIP experiment along a few transects (e.g. WGNE-GPCI, VOCALS) or locations for which a large number of observations will be available (satellite data for GPCI, field campaign for VOCALS, long-time series of ground-based observations for ARM instrumented sites). These data will attract the focus of a large community of researchers (within the GCSS and ARM communities in particular) encouraging evaluation with a wealth of in-situ measurements which have not until now been possible. One example application of such data is the EUROCS/GCSS Pacific Cross Section inter-comparison (Siebesma et al 2004), which compared clouds and circulation in climate and forecast models along a vertical section cutting through the Hadley circulation. Another is a comparison of the space-time organization of tropical deep oceanic cumulus convection in three climate models (Mapes et al. 2008). These data will also inform the design of idealized SCM/CRM/LES case studies.

IV. Special CFMIP-2 experiments

Climate models still exhibit large inter-model differences in the response of clouds to climate change, and many factors or processes potentially contribute to these differences. Experience shows that it is generally extremely difficult to determine the reasons why complex models behave the way they do, and why complex models differ from each other. As discussed by Held (2005), this leads to a widening "gap between simulation and understanding in climate modeling".

Isolating the cloud response simulated by climate models in simplified or idealized context is necessary if we are to narrow this gap and thereby provide credible guidance to policy makers and stakeholders in the coming decades.

Toward this end CFMIP has proposed a hierarchy of experiments, building, where possible on experiments already being proposed in the context of CMIP-5. We propose that some of these experiments become part of the set of CMIP-5 simulations (see Table 2). This suite of experiments will help to isolate and to understand the effects of the warming and resultant circulation changes on clouds and precipitation, and will help to build a bridge between fully coupled simulations (from Earth System Models or ocean-atmosphere coupled GCMs), very fine-scale simulations (from LES models, cloud resolving models, and large-scale models using super-parameterizations), and conceptual representations of the climate system.

<u>IV.a Ocean-atmosphere coupled experiments.</u>

Here CFMIP does not propose additional simulations but proposes to diagnostically augment existing proposals, such as the #1.1 (pre-industrial control), #1.2 (20^{th} century), #1.3 (AMIP), #4.1 (1%/year), #4.3 (Hansen-like), #4.4 (instantaneous 4xCO2 coupled run) and #7.1 (high-resol AMIP with chemistry) experiments of the CMIP-5 proposal. See Table 1.

<u>IV.b Atmosphere-only experiments with 'realistic' control simulations.</u>

- Gregory and Webb (2008) have shown that a significant fraction of inter-model spread in cloud 'feedback' in slab models occurs shortly after CO2 doubling. It is not in fact related to the global mean surface temperature response, but results from the rapid cloud response to changes in atmospheric structure that are induced by the CO2 increase. To allow these two aspects of cloud 'feedback' to be separately quantified, in the original CFMIP-2 proposal we had planned a combination of prescribed SST and CO2 forced experiments. The Hansen-like mandatory experiments (#4.3) of the CMIP5 proposal, completed with CFMIP diagnostics (cf section II.c), will fulfil this role.

- On the other hand, *we are asking that a suite of additional experiments be added to the CMIP proposal. They should be run with COSP in-line (Table 2)*.

1/ A patterned SST forced climate change experiment. This consists of a control experiment using the climatological forcing from the AMIP run (CMIP Experiment #1.3) and would be run for 20 years; and the perturbation with the SST perturbation pattern based on a composite of coupled model SST responses taken from 1% coupled model CMIP3 experiments at time of CO_2 doubling, as developed by the CPT (Wyant et al 2006). Although these experiments are not expected to reproduce exactly the global mean cloud feedbacks as in a coupled experiment or slab experiments, they are expected to explore the same range of cloud feedback processes (Wyant et al 2006, Ringer et al 2006).

2/ A uniform (FANGIO-like) SST forced climate change experiment (+2K). This complements 1/ above, and in combination will allow the effects of local and remote changes in SST on cloud feedbacks to be assessed (e.g. as discussed by Caldwell and Bretherton, 2008).

Slab model experiments may remain as part of the coordinated experiments of CMIP5 to ensure continuity with past coordinated experiments, and to enrich the hierarchy of model configurations through which cloud-climate processes may be studied. However, slab model experiments will probably not be the focus of CFMIP-2 activities, mainly because the increasing complexity of sea-ice schemes in coupled models makes it increasingly difficult to have a consistent representation of sea ice in slab and coupled model versions. Moreover, recent comparisons of the CMIP3 slab and AOGCMs show that quantitative predictions from slab models are only a limited guide to the long term sensitivities of AOGCMS models and that some (possibly most) of the differences in the feedbacks between coupled GCMs for 21st century climate change are due to differences in model feedbacks on decadal timescales which are different in slab and coupled models (Williams et al, 2008). It is proposed that these effects be studied via CMIP5 AOGCM experiments where CO_2 is instantaneously quadrupled (Gregory et al 2004, Williams et al, 2008). These experiments will also allow the separation of rapid cloud adjustments in direct response to CO_2 forcing from of temperature dependent cloud feedbacks in the AOGCMs (Gregory and Webb, 2008).

IV.c Aqua-planet experiments

Aqua-planets are examples of simplified models. By using the idealized boundary conditions proposed by the WGNE Aqua-Planet Experiment Project (APE, Neale and Hoskins 2001) and by adding a uniform +/- 2K perturbation of the sea surface temperature, one may investigate the cloud response to global warming in a simplified, idealized framework where complexities associated with land-surface processes, monsoons, or the Walker atmospheric circulation, do not come into play.

With the aim of interpreting differences between the cloud feedbacks produced by the NCAR and GFDL GCMs, Medeiros et al. (2008) showed that the climate sensitivity of aqua-planets was similar to that of the realistic configurations of those models, and that robust aspects of the cloud response were present both in aqua-planet and realistic configurations. Their analysis suggested that the representation of shallow cumulus convection was playing a key role in climate sensitivity differences between the two models. The extent to which these results may be generalized to a larger ensemble of models remains to be investigated.

We are asking that short aqua-planet experiments (CTRL and +/- 2K) become part of the mandatory set of CMIP5 experiments or at least of the "high priority" set of experiments. COSP will have to be run (in-line or off-line) for these simulations (Table 2). The protocol to be followed will be largely similar to that proposed by APE : a "control climate" simulation of 42 months (6 months of spin-up + 3 years of simulation) will be first performed using a zonal distribution of SST derived from observations and no sea-ice at high latitudes; then a sensitivity experiment of similar length will be performed by adding a uniform +/- 2K perturbation on top of this distribution. All other boundary conditions will remain unchanged (no sea-ice, same CO2, etc).

An important feature to be noted is that since SST are prescribed in these experiments, high-resolution models such as the super-parameterized CAM (SP-CAM, Khairoutdinov et al. 2005; Wyant et al. 2006b) or the global CRM NICAM (e. g. Miura et al. 2005) will be able to participate in this aqua-planet inter-comparison, even though ocean-atmosphere coupled versions of these models have not been developed yet.

Several components of the climate response to global warming noted in climate change experiments carried out by CMIP3/AR4 ocean-atmosphere models may be investigated in more detail using these simulations: One may cite for instance : the response of the different tropical clouds to dynamical and thermodynamical changes in climate (Bony and Dufresne 2005, Williams et al. 2006, Wyant et al. 2006, Medeiros et al. 2008), the poleward shift and the change in the strength and the frequency of mid-latitude storms (Yin et al. 2005, Tselioudis and Rossow 2006), the relationship between cloud phase changes and climate sensitivity (Tsushima et al. 2006), the connection between tropical and extra-tropical cloud changes (Volodin et al., communication at the PAN-GCSS meeting, June 2008), as well as the connection between the atmospheric moistening by convection and the response of low-level clouds (Sherwood et al., in preparation).

IV.d SCM/LES cloud feedback experiments

Aqua-planets already represent a simplification of climate models but are still too complex to investigate the dependence of the cloud response on modeling assumptions at the level of the numerical representation of sub-grid scale processes. Uni-dimensional simulations are better suited for this purpose as they are cheap enough to run to repeat and analyze the same experiment with many different representations of convective, cloud or micro-physical processes. Uni-dimensional simulations are also the framework commonly used by climate modelers to develop and test parameterizations within GEWEX/GCSS.

At the time of the AR4, the response of low-level clouds was the largest contributor to for inter-model differences in global cloud feedbacks (Bony and Dufresne 2005, Webb et al. 2006, Wyant et al. 2006, Randall et al. 2007). In subsidence regions of the tropics, for instance, some models (e.g. NCAR CAM3, INM) predict an increase in marine boundary-layer clouds while other models predict the opposite (e.g. MIROC, GFDL or IPSL). To better understand the reasons for these differences, Zhang and Bretherton (2008) proposed an idealized set-up of climate change experiments that simplifies the large-scale dynamics and mimics the behavior of the subsidence regimes of the subtropical eastern oceans where boundary-layer clouds (stratus, stratocumulus or shallow-cumulus) predominate. In brief, this set-up takes advantage of the moist-adiabatic temperature structure of convective regimes and of the weak horizontal temperature gradient of the tropical free troposphere to diagnose the effect, on the subsidence rate of non-convective regions, of a global warming of the tropical ocean.

When applied to the single-column version of the NCAR model, this idealized framework allowed Zhang and Bretherton (2008) to reproduce the negative feedback of low-level clouds produced by the NCAR coupled ocean-atmosphere model in climate change experiments. Recently, Minghua Zhang et al. applied the same framework to different climate models (NCAM CAM3, GFDL AM2, HadGEM2) and to different large-eddy simulation (LES) models (SAM, UCLA) and found more consistent responses among LES models than among climate models (Zhang et al., communication at the PAN-GCSS meeting, June 2008). Chris Bretherton's group has found that at least for one climate model (SP-CAM), it even appears possible to *quantitatively* reproduce the subtropical boundary layer cloud feedbacks of the global model within a column modeling framework (Bretherton et al., communication at the PAN-GCSS meeting, June 2008). Therefore, ***this idealized set-up is promising to examine the physical processes underlying the low-level cloud feedbacks of GCMs in climate change, to investigate their dependence on model parameterizations, and to assess their credibility by comparison with LES or cloud-resolving models (CRMs). Modeling centers should be strongly encouraged to participate in this CFMIP-2 SCM/LES cloud feedback experiment.***

As part of a collaboration between the GCSS Boundary Layer Cloud Working Group and CFMIP, Minghua Zhang and Chris Bretherton will coordinate such idealized experiments across climate models and LES/CRM models. The goal will be both to understand and to assess the credibility of cloud-climate responses produced by climate models using SCM/LES models. The focus will be put first on trade cumulus and on stratocumulus-to-cumulus transition regimes, which are thought to be the cloud regimes primarily responsible for inter-model differences in climate change cloud feedbacks (Williams and Webb 2008, Medeiros et al. 2008). Two main hypotheses will be tested: (1) that single-column model case studies can capture the different GCM cloud-climate responses (positive/negative) in these regimes, and (2) that inter-model differences among LES models will be smaller than among GCM models and therefore that LES results expose SCM flaws as well as offer guidances on model improvements . The extent to which SCMs with idealized forcings reproduce the physical feedback mechanisms operating in the full GCMs will be assessed by comparing SCM outputs with the high frequency outputs from the CFMIP-2 GCMs at selected locations. The GCM outputs described in Section III will be used to examine and improve the representativeness of (1) the cloud changes at the selected locations to the area averages in the GCMs, and the (2) idealized forcing to the dynamical conditions at these locations in the GCMs.

One other issue relevant to this activity is the extent to which changes in large-scale environment for boundary layer clouds associated with a climate change are consistent between models. Climate responses of temperature, relative humidity and subsidence rate in the CFMIP slab models will be composited by lower tropospheric lapse rate to examine this question. If they are similar across the models then this will indicate that the different low cloud changes in climate models are mainly due to differences in boundary layer moist physics rather than large scale forcings. These results composites will also serve to inform the design of future idealised SCM/LES forcing cases.

IV.e Additional diagnostics in CFMIP-2 experiments

A number of additional diagnostics are proposed for the CFMIP-2 experiments over and above those requested in the CMIP5 experiments. Modeling centers who wish to participate within CFMIP-2 are being asked to augment their CMIP-5 simulations to include these diagnostics. The lightweight nature of the experiments (max 20 years in length) means that data volumes are small compared to CMIP, allowing a more extensive diagnostic list.

Cloud condensate tendency diagnostics (CCTD) will be used to gain insight into the physical mechanisms responsible for cloud feedbacks in the CFMIP-2 experiments. (Ogura et al, 2008a, 2008b). We also plan to save temperature and humidity tendency terms (including 3D radiative fluxes) to assess (for example) the impact of changes in convection and boundary layer mixing on the atmospheric structure, hydrological cycle, and clouds in the warmer climate. (See Zhang and Bretherton 2008 for an example of this analysis in an SCM.)

One year of 3 hourly global instantaneous 'snapshots' of 3D mixing ratios and size parameters (clouds and precipitation) to complement the diagnostics package #2 and support the development of future CFMIP simulator modules (e.g. Combined CloudSat/CALIPSO, TRMM, MLS, RTTOVS...)

We also plan to save high frequency data at selected locations for CFMIP-2 climate change experiments as well as present day, at higher temporal resolution than in CMIP5 (hourly or timestep level instead of 3-hourly in the diagnostics package #3).

IV.f Sensitivity experiments to assess impact of modelling assumptions on cloud feedbacks

The lightweight nature of these experiments (modified SST pattern, uniform +2K or aqua-planet) makes the prospect of running sensitivity tests (where various aspects of model physics are changed) more attractive. Modelling groups participating in CFMIP-2 will be encouraged to use the CFMIP-2 experiments as a base for physical sensitivity tests to clarify the dependence of the cloud feedbacks on any aspects of their model formulation that they consider relevant.

For example, a pilot study with the Hadley Centre model (based on the CFMIP-2 experiments with realistic control simulations) suppressed the two main source terms producing shallow clouds in the subtropics. This showed that the positive shallow cloud feedback in the subtropics in this model is mainly due to reduced detrainment of condensate from shallow convection in stratocumulus/trade cumulus transition region in a warmer climate, although reductions in condensation driven by LW cooling at cloud top also plays a role closer to the coast. (Mark Webb, Adrian Lock and Tomoo Ogura.). Alternatively, modelling groups may choose to assess the impact of increasing boundary layer resolution on the cloud feedbacks in their models.

As the sensitivity experiments will vary from model to model, (and may be made in realistic, aquaplanet or SCM configuration), this is not proposed as a coordinated inter-comparison activity, but more as a 'spinoff' activity to support improved understanding of cloud feedback mechanisms in individual models.

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Table 1. Additional CMIP5 model output requested by CFMIP for model evaluation and for understanding model systematic biases, cloud processes and feedbacks.

<table>
<tr><td>COSP</td><td>CMIP5 Experiment</td><td colspan="2">Priority (H = high, M = medium),
type and length of diagnostics*</td></tr>
<tr><td rowspan="2">in-line

with ISCCP
& CALIPSO
simulators
activated</td><td>1.1 (pre-industrial[+])
1.2 (20th century)
1.3 (AMIP)
4.1 (1%/year CO2)
4.3 a-b-c (Hansen-like)</td><td>H</td><td>Monthly and daily outputs:
A1a, A1c, A2a (all years)
A1d, A2b, A2c (20 years)**</td></tr>
<tr><td>4.2 (ESM 1%/yr CO2)
4.4 (instantaneous 4CO2)
7.1 (high-resol. AMIP)
7.6 (near-term prediction)</td><td>M</td><td>Monthly outputs :
A1a, A1c (all years)
A1d (20 years)</td></tr>
<tr><td rowspan="3">off-line
or
in-line

with ISCCP,
CloudSat &
CALIPSO
simulators
activated</td><td rowspan="2">1.2 (20th century)
1.3 (AMIP)
7.1 (high-resol. AMIP)</td><td>H</td><td>Monthly outputs
CloudSat/CALIPSO: A1e
1-3 years (2006-2008)</td></tr>
<tr><td>H</td><td>Orbital outputs
CloudSat/CALIPSO: A2d
1-3 years (2006-2008)</td></tr>
<tr><td>1.3 (AMIP)</td><td>M</td><td>3-hourly instantaneous outputs
: A3a, A3b
- globally: 1 year (2007)
- at selected locations*** :
23 years (1985-2007)</td></tr>
</table>

* Tables of CFMIP diagnostics (see Annex A):

A1a = monthly 2D (including ISCCP and CALIPSO simulators 2D outputs)
A1c = monthly 3D (including one CALIPSO simulator 3D output)
A1d = monthly 4D ISCCP simulator output (pc-tau histogram)
A2a = daily 2D (including ISCCP and CALIPSO simulators 2D outputs)
A2b = daily 3D (including one CALIPSO simulator 3D output)
A2c = daily 4D ISCCP simulator output (pc-tau histogram)
A3a = same as A2a but instantaneous 3-hourly
A3b = same as A2b but instantaneous 3-hourly
A1e = monthly CloudSat/CALIPSO output (extended)
A2d = same as A1e but in orbital time series format

\+ The pre-industrial run being very long, “all years” outputs will be actually requested for a subset of 140 years.

** Choice of the “20 year” period : in #1.1 and #4.1: centered on CO2 doubling and quadrupling; in #1.2 : last 20 years of the simulation, in #1.3 : 1985-2008.

*** Selected locations (about 100 stations): see http://cfmip.metoffice.com/cfmip2/pointlocations

Table 2. Additional (atmosphere-only) experiments proposed by CFMIP for understanding inter-model differences in cloud feedbacks and interactions between moist processes and the large-scale atmospheric circulation. CFMIP proposes that these experiments be added to the Table 4 of the CMIP-5 proposal. The use of COSP in these simulations is highly recommended (in-line for #4.6a-b-c, in-line or off-line for #4.6d). The diagnostics associated with these experiments will be monthly and daily outputs **(**A1a, A1c, A1d, A2a, A2b, A2c, A3a, A3b plus A1e for #4.6d). Modelling groups are strongly encouraged to also save the additional diagnostics (cf sections IV.e and IV.f) to support participation in the CFMIP-2 project.

#	Proposed Experiment	Notes	# of years
4.6a*	climatological AMIP (control)	Perform a control simulation using climatological SSTs from AMIP (or eventually from expt 4.3a of the CMIP5 proposal)..	20
4.6b*	patterned ΔSST	Perform a sensitivity simulation using a prescribed SST perturbation pattern[$] on top of SSTs used in experiment #4.6a (CO2 and other boundary forcings unchanged)	20
4.6c[%]	uniform ΔSST	Perform a sensitivity simulation using a prescribed uniform SST perturbation (+2K) on top of SSTs used in experiment #4.6a (CO2 and other boundary forcings unchanged)	20
4.6d*	aqua-planet experiments	Perform an aqua-planet experiment following the WGNE APE protocol (Neale and Hoskins 2001) and using the "Qobs" zonal distribution of SST ; then perform +2K and -2K experiments.	3 x 4

* proposed as an additional mandatory (or at least highly recommended) CMIP5 simulation

[%] proposed as an additional CMIP5 simulation recommended but not mandatory

[$] SST perturbation pattern based on a composite of coupled model SST responses taken from 1%/year increase CO2 experiments from CMIP3 at time of CO2 doubling, as developed by Wyant et al. (2006).

Annex A: Additional CMIP model output requested by CFMIP

These are additions to the tables for CMIP3 which are available at
http://www-pcmdi.llnl.gov/ipcc/standard_output.html

Notes that most of the additional diagnostics can be found in the CFMIP tables:
http://cfmip.metoffice.com/CFMIP_standard_output.html

This list is based on initial work by Keith Williams and Karl Taylor.

Priorities are marked H/M/L High, Medium and Low

To be added to the existing table A1a (monthly 2D):

water_evaporation_flux	evspsbl	kg m-2 s-1	H
isccp_total _cloud_area_fraction	tclisccp	dimensionless	H
isccp_mean_cloud_albedo	albisccp	dimensionless	H
isccp_mean_cloud_top_pressure	ctpisccp	Pa	H
air_pressure_at_convective_cloud_base	ccb	Pa	H
air_pressure_at_convective_cloud_top	cct	Pa	H
convection_indicator	ci	dimensionless	M
shallow_convection_indicator	sci	dimensionless	M
deep_convection_indicator	dci	dimensionless	M
calipso_total_cloud_fraction	cltcalipso	dimensionless	H
calipso_low_level_cloud_fraction	cllcalipso	dimensionless	H
calipso_mid_level_cloud_fraction	clmcalipso	dimensionless	H
calipso_high_level_cloud_fraction	clhcalipso	dimensionless	H

To be added to the existing table A1c (monthly 3D):
(all of these additional fields required on model levels)

mass_fraction_of_cloud_liquid_water_in_air	clw	dimensionless	H
mass_fraction_of_cloud_ice_in_air	cli	dimensionless	H
convective_cloud_area_fraction_in_atmosphere_layer	clc	%	M
mass_fraction_of_convective_cloud_liquid_water_in_air	clwc	dimensionless	M
mass_fraction_of_convective_cloud_ice_in_air	clic	dimensionless	M
stratiform_cloud_area_fraction_in_atmosphere_layer	cls	%	M
mass_fraction_of_stratiform_cloud_liquid_water_in_air	clws	dimensionless	M
mass_fraction_of_stratiform_cloud_ice_in_air	clis	dimensionless	M
eddy_viscosity_coefficients_for momentum_variables	evu	m^2s^{-1}	H
eddy-diffusivity_coefficients_for_temperature_variable	edt	m^2s^{-1}	H
eddy-diffusivity_coefficients_for_water_variables	edw	m^2s^{-1}	H
convective_mass_flux	mc	$kgm^{-2}s^{-1}$	H
updraught_convective_mass_flux	mcu	$kgm^{-2}s^{-1}$	M
downdraught_convective_mass_flux	mcd	$kgm^{-2}s^{-1}$	M
shallow_convective_mass_flux	smc	$kgm^{-2}s^{-1}$	M
deep_convective_mass_flux	dmc	$kgm^{-2}s^{-1}$	M
calipso_cloud_fraction (40 levels)	clcalipso	dimensionless	H

Table A1d (monthly 4D ISCCP simulator output)

isccp_cloud_area_fraction (7 levels x 7 tau)	clisccp	dimensionless	H

New Table A1e CFMIP CloudSat/CALIPSO simulator output (monthly)

cloudsat_radar_reflectivity_cfad[3] (40 levelsx15 bins)	cloudsatcfad	dimensionless	H
calipsonocloudsat_cloud_fraction (40 levels)	clcalipso2	dimensionless	H
calipso_scattering_ratio_cfad (40 levelsx15)	calipsosrcfad	dimensionless	H
calipso_polarisation_ratio_cfad (40 levelsx4)	calipsoldrcfad	dimensionless	M

To be added to the existing table A2a (daily 2D):

surface_temperature	ts	K	H
surface_air_pressure	ps	Pa	H
specific_humidity	huss	dimensionless	H
toa_incoming_shortwave_flux	rsdt	Wm-2	H
toa_outgoing_shortwave_flux	rsut	Wm-2	H
net_downward_radiative_flux_at_top_of_atmosphere_model	rtmt	Wm-2	H
surface_downwelling_shortwave_flux_in_ir_assuming_clear_sky	rsdscs	Wm-2	H
surface_upwelling_shortwave_flux_in_air_assuming_clear_sky	rsuscs	Wm-2	H
surface_downwelling_longwave_flux_in_air_assuming_clear_sky	rldscs	Wm-2	H
toa_outgoing_longwave_flux_assuming_clear_sky	rlutcs	Wm-2	H
toa_outgoing_shortwave_flux_assuming_clear_sky	rsutcs	Wm-2	H
cloud_area_fraction	clt	%	H
atmosphere_cloud_condensed_water_content	clwvi	kg m-	H
atmosphere_cloud_ice_content	clivi	kgm-2	H
lagrangian_tendency_of_air_pressure_at_500hPa	wap500	Pa s-	H
air_temperature_at_700hPa	ta700	K	H
isccp_total _cloud_area_fraction	tclisccp	dimensionless	H
isccp_mean_cloud_albedo	albisccp	dimensionless	H
isccp_mean_cloud_top_pressure	ctpisccp	Pa	H
air_pressure_at_convective_cloud_base	ccb	Pa	H
air_pressure_at_convective_cloud_top	cct	Pa	H
convective_precipitation_flux	prc	kg m-2 s-1	H
calipso_total_cloud_fraction	cltcalipso	dimensionless	H
calipso_low_level_cloud_fraction	cllcalipso	dimensionless	H
calipso_mid_level_cloud_fraction	clmcalipso	dimensionless	H
calipso_high_level_cloud_fraction	clhcalipso	dimensionless	H

The existing table A2b (daily 3D) to all be changed to all be on model levels and the following added:

lagrangian_tendency_of_air_pressure	wap	Pa s-1	H
geopotential_height	zg	m	H
relative_humidity	hur	%	H
cloud_area_fraction_in_atmosphere_layer	cl	%	H
mass_fraction_of_cloud_liquid_water_in_air	clw	dimensionless	H
mass_fraction_of_cloud_ice_in_air	cli	dimensionless	H
convective_cloud_area_fraction_in_atmosphere_layer	clc	%	M
mass_fraction_of_convective_cloud_liquid_water_in_air	clwc	dimensionless	M
mass_fraction_of_convective_cloud_ice_in_air	clic	dimensionless	M
stratiform_cloud_area_fraction_in_atmosphere_layer	cls	%	M
mass_fraction_of_stratiform_cloud_liquid_water_in_air	clws	dimensionless	M
mass_fraction_of_stratiform_cloud_ice_in_air	clis	dimensionless	M
eddy_viscosity_coefficients_for momentum_variables	evu	m^2s^{-1}	H
eddy-diffusivity_coefficients_for_temperature_variable	edt	m^2s^{-1}	H
eddy-diffusivity_coefficients_for_water_variables	edw	m^2s^{-1}	H
convective_mass_flux	mc	ms-1	H
air_pressure_at_convective_cloud_base	ccb	Pa	H

[3]CFADs (Cloud Frequency Altitude Diagrams) are joint height - radar reflectivity (or lidar scattering ratio) distributions.

Appendix 4

Paleoclimate Modelling Intercomparison Project 3 - Experiments

P1. PMIP3 experiments of past climate change

#	Experiment	Notes	# of years
P1.1 Tier1	Mid-Holocene (6 kyr ago)	All earth system components respond to the changed orbital configuration. Initialize from pre-industrial control. Prescribed atmospheric concentrations of all well-mixed gases (including CO_2, CH_4, N_2O) from ice-core measurements as well as the absence of man-made gases, such as CFCs. Dynamic vegetation may respond.	500 (after spin-up period)
P1.2 Tier1	Last Glacial Maximum (21 kyr ago)	All earth system components respond to the changed greenhouse gases and ice sheets. Initialize all components except ocean from pre-industrial control. Initial conditions for ocean will be from a cold spun-up state provided in 3D Levitus format by PMIP. Prescribed atmospheric concentrations of all well-mixed gases (including CO_2, CH_4, N_2O) from ice-core measurements as well as the absence of man-made gases, such as CFCs. Ice sheets will be provide from PMIP and will require both changes to land surface type and topography. Dynamic vegetation may respond.	500 (after spin-up period)
P1.3 Tier2	Last Interglacial (130 kyr ago)	All earth system components respond to the changed orbital configuration. Initialize from pre-industrial control. Prescribed atmospheric concentrations of all well-mixed gases (including CO_2, CH_4, N_2O) from ice-core measurements as well as the absence of man-made gases, such as CFCs. Dynamic vegetation may respond.	500 (after spin-up period)
P1.4 Tier2	Mid-Pliocene (3 myr ago)	All earth system components respond to the changed greenhouse gases and reduced polar ice sheets. Initialize all components except ocean from pre-industrial control. Initial conditions for ocean will be from PRISM3 provided in 3D Levitus format by PMIP. Prescribed atmospheric concentrations of all well-mixed gases (including CO_2, CH_4, N_2O) from PRISM as well as the absence of man-made gases, such as CFCs. Ice sheets will be provided from PMIP and will require both changes to land surface type and topography. No change to land-ocean grids will be required. Dynamic vegetation may respond.	500 (after spin-up period)
P1.5 Tier2	Last Millennium (850-1850AD)	All earth system components respond to orbital changes, solar variations, greenhouse gases and volcanic activity. Initialize all components from pre-industrial control. Prescribed atmospheric concentrations of all well-mixed gases (including CO_2, CH_4, N_2O), solar variability, and volcanic eruption time series will be provided from PMIP. Dynamic	1000 (after spin-up period)

		vegetation may respond.	

P1.1 Mid-Holocene experiment

a) Evaluate sensitivity of hydrologic cycle and vegetation feedbacks in monsoon regions and coupling to the global warming of oceans as well as patterns of warming among ocean basins. Particularly relevant for understanding why models disagree in future response of Sahel-Sahara precipitation change.
b) Evaluate sensitivity of high-latitude warming to expansion of boreal forests poleward with warming.

P1.2 Last Glacial Maximum experiment

a) Evaluate sensitivity of tropical oceans and land to lowered CO_2 as compared to proxy indications of temperature changes.
b) Understand feedbacks between sea ice and ocean thermohaline circulation.

P1.3 Last Interglacial experiment

a) Evaluate Arctic warmth and sensitivity of Greenland ice sheet to this warmth.
b) Understand ocean warming and transmission of subsurface warming from North Atlantic to Southern Ocean, with implications for basal melting of West Antarctic Ice Sheet.
c) Relevant for offline ice sheet and coupled climate-ice sheet models to assess the stability of the polar ice sheets.

P1.4 Mid-Pliocene experiment

a) Equilibrium climate for world with CO_2 at 400 ppm and reduced extents of ice sheets of Greenland and Antarctica.
b) Earth system sensitivity.
c) High-latitude warming.

P1.5 Last Millennium experiment

a) Evaluation of decadal to centennial climate variability, natural and that related to solar and volcanic forcings.

<u>P2. Control simulation and idealized climate sensitivity simulation</u>

The PMIP3 protocol will adopt the pre-industrial control experiment specified by CMIP5 as its control simulation. This simulation will need to be repeated if the PMIP3 experiments are not run with the same model components and resolution as the CMIP5 pre-industrial experiment, which may be the case for Tier 2 experiments. In addition, a 1% CO_2 to quadrupling experiment will also need to be run with the model setups used for these PMIP3 experiments.

#	Experiment	Notes	# of years
P2.1	pre-industrial control (1.1 CMIP5 simulation)	Specified non-evolving, pre-industrial conditions, which may include: Prescribed atmospheric concentrations of all well-mixed gases (including CO_2) and some	500 (after spin-up period)

P2.1	pre-industrial control (1.1 CMIP5 simulation)	Specified non-evolving, pre-industrial conditions, which may include: Prescribed atmospheric concentrations of all well-mixed gases (including CO_2) and some short-lived (reactive) species? Prescribed non-evolving emissions or concentrations of natural aerosols or their precursors including, possibly, an average background volcanic aerosol and some short-lived species. Unperturbed land use.	500 (after spin-up period)
P2.2	Idealized 1%/yr run	CO_2 concentration will quadruple after 139	140

P2.1 Pre-industrial control

a) Serves as baseline for analysis of historical and future scenario runs with prescribed concentrations.
b) Estimate unforced variability of the model
c) Diagnose drift in the unforced system
d) Serves to provide initial conditions for some of the other experiments

P2.2 Idealized 1%/yr run

a) Evaluate model response under idealized forcing (without the complications of aerosols, land-use changes, etc.)
b) Evaluate total carbon-cycle response

Table 1: CMIP5 Model Groups' Summary; WGCM Meeting, Paris, 22-24 September 2008
Deadline for output to be submitted to PCMDI: middle of 2010

Model group	PIs	AOGCM, or ESM or both?	Interactive aerosols or coupled chemistry	Resolution	Short term decadal	Long term mitigation	When do you plan to begin your experiment?	Is the main constraint people, computer resources, or both?	CFMIP / satellite simulators	Contribution to related MIPs
France IPSL	P. Braconnot/S. Bony/J.L. Dufresne	**ESM:** ocean, carbon cycle, land-surface, chemistry; **AOGCM:** with different parameterization	YES (aerosols and chemistry)	2.5° x 1.5°	Time-slice with interactive chemistry	**IPSL-ESM:** With interactive aerosol (maybe not in all runs) With carbon cycle **IPSL-OAGCM**	End of 2009	Man power	Observation simulator COPS	PMI, CFMIP, C4MIP, CCMVal, AEROCOM
France Meteo France (ARPEGE)	S. Planton/ D. Salas Melia	**AOGCM:** 1.4° **ESM:** uncertain PMIP: Tier #1, possible #2 CFMIP: offline	Aerosols prescribed; interactive ozone chemistry	2.5°, maybe 1.4°but only in AOGCM	By CERFACS ; 1° horizontal resolution	**AOGCM:** 1.4° By CNRM	Early 2010	Data storage		ENSEMBLES
Germany MPI COSMOS	M. Giorgetta	**Only ESM:** carbon cycle; vegetation model, top at 0.1 hPa	Interactive aerosols (maybe); at lower resolution with	Not yet decided but between T85L47	YES	Low resolution	Spring 2009	both	ISCCP implemented; COSP implementation in	PMIP and ENSEMBLES: using low resolution ESM

			interactive chemistry and aerosols	and T159L95					progress	
Canada CCCMa	G. Flato	**CanESM1:** ecosystem; carbon cycle but not in time for CMIP5; Seasonal forecasting; forecasting	Interactive chemistry (trop&strat) but not included in CMIP runs (for CCMVal)); interactive aerosols in CMIP5 runs	T47/L31 (~3.75) AOGCM: ESM: T63 (~2.8°) Middle-atmosphere ozone at T47	Hope to (same resolution as long-term)	YES	Early 2009 as soon as RCPs are available	both	ISCCP implemented; other simulators will be added	CCMVal
Italy	S. Gualdi	**ESM** carbon cycle; **AOGCM**	NO	T30-L19/2-0.5°	High resolution (T159L31/2-0.5°)	With carbon cycle	First half of 2009	both	In principle depends, but depends on the cost	
Australia ACCESS	A. Hirst/K. Puri	**Only AOGCM**	Interactive aerosols but no interactive chemistry	T63 Grid N96 (1.875° x 1.25° / 25 levels)	NO	YES (RCPs planned)	Test and tune in 2009; run in 2010	people	NO	
Japan CCSR/FRGC/U. Tokyo/	M. Kimoto	**AOGCM; ESM** (carbon cycle, aerosols, chemistry,	Interactive aerosol (yes) Chemistry in ESM (offline	ESM: T42L80 AOGC	YES with AOGCM and interactive	YES with ESM	Spring 2009; Earth	Both but more computer	Cloud simulator included	CFMIP, CMIP

NIES		dynamical vegetation; raise the upper lid and fully included stratosphere)	in AOGCM)	M: T213)	aerosols on high resolution (T213AGCM) Medium resolution T85 or T42		Simulator or upgraded early 2009				
Japan MRI	S Kusunoki	**MRI-ESM:** ice sheet, carbon, ozone chemistry, aerosols (MASINGAR); fully coupled **AGCM** (20km mesh) ocean prescribed	YES in ESM	ESM T42 AGCM : 20km (no ensembles)	YES	YES	2009	Both but in particular people			
U.K. Hadley Centre	C. Jones	**AOGCM and ESM (fully coupled)**	tropospheric chemistry (from UKCA) and aerosols interactive in ESM; dust scheme and deposition		**AOGCM:** HadCM3 N48 L19; 1.,25° ocean (ensemble perturbing the physical parameterization) HGEM N144 L38°; HadGEM T216	**ESM: HadGEM2-ES** (carbon cycle, vegetation, fully coupled)	Early 2009	both	ISCCP ; COSP, Aqua-planet (probably not)		
U.K.	L.	**AOGCM:**	NO	30L	YES	NO		Main	COSP		

Reading	Shaffrey	HiGEM (higher horizontal resolution than HadGEM1)						constraint is time, but also computer	(offline maybe do online), no Aqua-planet	
U.S. NCAR	G. Meehl/P. Gent	**AOGCM and ESM:** CCM3 standard for CMIP3; improved convection scheme in the new CCSM4; carbon cycle included	Coupled chemistry in WACCM, likely in new CCSM4 in some form; prognostic aerosols maybe	0.5° in AOGCM; 2° in ESM	0.5° for decadal prediction	YES	Early 2009	People	ISCCP works; COSP very likely Aqua-planet	
U.S. GFDL	R. Stouffer	**ESM:** closed carbon cycle; based on CM2.1, land vegetation, ocean biogeochemistry; chemistry-climate feedbacks; sea ice, land surface, iceberg scheme **AOGCM CM3:** aerosol-cloud scheme;	Interactive chemistry to link emissions to aerosols composition Raising lid to include: Stratospheric model for chemistry and possible links to troposphere on multi-year time	2° ESM;	2-0.5° for decadal prediction atm 0.25° ocean (initialization problems) **CM2 based**	2 ESMs AOGCM CM3	Early 2009	Success of runs – science questions ESM: people AOGCM: CPU Model development: People/knowledge	COSP not in near-term but in the long-term CM3	Interest in LGM with ESM
U.S. NGFC	M Suarez	**GEOS-5**: atmospheric data assimilation and NWP with O3	Coupled chemistry migrated into GEOS-5	Mostly 1°	YES (1°) With GEOS-CCMv3	NO		Both in particular for long-term runs	ISCCP, likely Aqua-planet	CCMVal

		assimilation; aerosols; no carbon; **GEOS-CCMv3 with AOGCM**: full trop&strat interactive chemistry at 2°	Mostly strat chem.; aerosols coupled		with AOGCM					
Korea KMA	W.T. Kwon	Develop a prototype ESM	Not yet		2-3 more yrs	HadGEM 2 in cooperati on with Hadley center				
China LASG	B. Wang/T. Zhou	**2 AOGCMs** (spectral and grid); ESM may not be ready in time	AGCM-Aerosol model two-way coupled	1°x1° atm	YES (high resolution model)	YES	Early 2009	Both		Regional modeling; CLIVAR
China BCC	T. Wu/Z. Wang	**ESM: BCC_CSM** **AOGCM BCC_VIM:** Soil vegetation; carbon cycle	YES - Atmospheric chemistry (MOZART) will be included (end 2009); aerosols coupled		YES	YES	Early 2009	computer		
Denmar k Danish Met. Inst.	W. May	AOGCM	NO	T159 and 2°	Focus on short-term decadal predictions and high-resolution	Could be EC-Earth	End of 2009			

					runs					
Norway NERSC	M. Bentsen, H. Drange	**Bergen Climate Model (BCM)**; chemistry-aerosol-cloud-package in CAM developed at the University of Oslo and the Norwegian Met Institute; carbon cycle included; **NorESM:** GCM is CAM; own chemistry, sea-ice, land, carbon cycle fully coupled	YES Definitely in time-slice runs	1.9° x 2.5°	NO	Focus on mandatory long-term	Summer 2009	60% People, 30% computer resources, 10% storage		Contribute to PMIP hopefully CFMIP is capability
EC-Earth	C. Jones	**Longer term ESM EC-Earth:** ECWMF coupled seasonal prediction system for climate prediction Coupled version under development and testing (with luck ready for CMIP5)	No for CMIP5; YES on the long-term; atmospheric chemistry (TM5); interactive chemistry aerosols	T159L62-ORCA2	Main focus on decadal simulations (seasonal prediction; get weather variability correct)	Not in CMIP5, but later	Late 2009	People	ISCCP simulator available; no Aqua-Planet	No PMIP

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