WCRP REPORT
World Climate Research Programme

PROJECT REPORT

Report of the 17th session of the Working Group on Coupled Modelling (WGCM)

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Including Joint WGCM-AIMES session

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WGCM - AIMES - joint session additional attendees: Peter Cox, Almut Arneth, Vivek Arora, Victor Brovkin, Gilberto Gallopin, Kathy Hibbard, Taka Hirata, Mark Rounsevell

1. Introduction

The 17th session of WGCM was held in Victoria, Canada on 1-3 October 2013, generously hosted by the Canadian Centre for Climate Modelling and Analysis, Environment Canada (EC/CCCma) and co-sponsored by the Pacific Climate Impacts Consortium and the Pacific Institute for Climate Solutions. The WGCM Co-Chairs, S. Bony and G. Meehl thanked Gregory Flato and Deborah Tubman for hosting and organizing the logistics of the meeting in the best conditions. They also welcomed Cathy Senior (UKMO Hadley Center), present WGCM member taking over G. Meehl as incoming Co-Chair of WGCM effective 1 January 2014.

G. Meehl recalled that CMIP exercises take several years to get started and that the WGCM17 session would focus on the outcomes of the Aspen meeting and on discussions towards a new CMIP structure and a CMIP6 proposal. He also noted that a joint session was planned on 3 October with AIMES to further discuss collaborations regarding the carbon cycle, bio-geochemistry and ecosystem modeling. The last such joint meeting with AIMES was held in 2009. He emphasized that CMIP is important for WGCM in connecting the various MIPs with on the one hand, a dynamic tension to keep the effort focused and on the other hand to expand the experiment to meet stakeholders' needs. The ESGF model-data infrastructure has become central in that context.

2. WCRP update

2.1. JSC and WMAC update (M. Rixen)

Michel Rixen provided an update on the WCRP revised priorities following major events and initiatives such as the OceanObs'09 (which led to the Framework for Ocean Observing), the World Climate Conference (which led to the Global

Framework for Climate Services), the ICSU Visioning process (leading to the Future Earth priorities, including earth system modeling cross-cutting themes) and the WCRP Open Science Conference, The latter led to the 6 Grand Science Challenges, identified as priority research themes for the 5 years to come and now included in the new WCRP structure, the ones on “Regional Climate Information” and “Clouds, circulation and climate sensitivity” being particularly relevant for this session. He recalled the significant contribution of CMIP5 to the IPCC 5th Assessment Report, thanks to common metadata conventions, compliance software and user-friendly data delivery methods via the Earth System Grid Federation (ESGF) and highlighted also the upcoming challenges in preparing for the CMIP6 next round of simulations. He noted the growing expectations from stakeholders for higher resolution products (such as those from CORDEX) and downstream applications. It is hence timely to revisit the experimental frameworks, including the CMIP and CORDEX ones in light of international assessment and research agendas. He outlined the importance of reanalysis for climate assessments, model-data comparisons and boundary conditions for regional downscaling, the central role of data archives such as obs4MIPs and ana4MIPs within the ESGF context and the growing expectation from the global and regional modeling community to facilitate their research. Upcoming meetings include the African Climate Conference, the EUMETSAT Climate Symposium and the International Climate Conference – CORDEX 2013. Relevant actions from the JSC34 and WMAC2 were reviewed, including the increased WMAC focus on model development aiming at organizing dedicated summer schools on the topic and a WCRP prize to recognize significant contributions by Early Career Scientists in the field. He closed the presentation by thanking EC/CCCMA for hosting the meeting and welcomed new WGCM members.

The summer school on model development, which was considered as an important focus of WGCM, is tentatively scheduled at MPI in June 2015. It was advised to pay attention to possible duplication with other summer schools on similar topics such as the UKMO NCAS and NCAR ones. It was confirmed that WGCM would take the lead on organizing the meeting on model tuning. Regarding Future Earth, the importance of disciplinary/fundamental work was highlighted. The growing synergies between WCRP and IGBP/AIMES were noted.

2.2. WCRP Grand Challenge on Clouds and Climate Sensitivity (B. Stevens and S. Bony)

At the 17th session of the WGCM Bjorn Stevens presented an update on the status of the WCRP Grand Challenge for WGCM. WGCM is responsible for this Grand Challenge with Sandrine Bony and Bjorn Stevens as the lead-organizers.

During the past year the grand challenge has made great strides. With considerable input from the community a working white paper was drafted which outlines the Grand Challenge, as well as strategies and an organizational structure for advancing it. The current structure is developed around five initiatives. These initiatives focus on three scientific issues, each led by a coordination team:

- Climate and hydrological sensitivity (Steven Sherwood and Mark Webb);
- Changing patterns (Ted Shepherd and Adam Sobel);
- Coupling of clouds to circulations (Dargan Frierson and Pier Siebesma);

and two cross-cutting initiatives:

- Leveraging the past record (Masa Kageyama and Robert Pincus);
- Towards better models (Christian Jakob and Masahiro Watanabe).

The initiative coordinators are internationally renowned leaders in their fields and capable of articulating the most compelling scientific problems to the broader community.

This coordination team encapsulates the Grand Challenge strategy of leading through the articulation of ideas, with a particular emphasis on identifying gaps where the posing of sharper questions or additional coordination could move the field forward. These ideas and coordination initiatives will be developed through existing organizational structures, namely the core projects and working groups of WCRP, as the Grand Challenge is striving to avoid developing into its own organizational entity.

Beyond organizing the team to coordinate the grand challenge, emphasis has been placed on writing papers. Examples include a perspectives piece for Science ("What are climate models missing?" which appeared in the May 31 issue of *Science Magazine*) and an expository article on "Water in the Atmosphere" which was featured in the June 1 issue of *Physics Today*. More high-profile publications articulating the ideas of the grand challenge, or assessing the state of specific questions, are in preparation. The Grand Challenge team has also leveraged existing projects, in particular the FP7 EUCLIPSE project led by Pier Siebesma to help support coordinated modeling activities, including the CFMIP COOKIE and SPOOKIE projects. The grand challenge was presented, and targeted discussions on specific elements of the challenges were held, at more than a half dozen international meetings over the past year, and seven additional meetings are planned for the coming year; among these is a one week meeting in the Schloß Ringberg in March 2014 which will be dedicated to the Grand Challenge. At the Ringberg meeting the coordination team will be joined by another two dozen individuals to help sharpen the activities that it will lead, to transforming the working white paper into a document for publication, and to propose a few key elements to be incorporated into the ongoing design of CMIP.

The grand challenge is also developing a capacity building component. A summer school on "Clouds and Climate" was held in Les Houches (France) in summer 2013, led by EUCLIPSE in relationship with the GC. Two summer schools are planned: one led by WMAC and supported through the GC will be held in June 2015 and will focus on parameterization development. A second will be led by the GC coordination team and is tentatively scheduled for Les Houches in mid 2016. A *tools for ideas* repository is also being developed.

The discussions suggested paying more attention to the role of surface albedo. Possible synergies with the Grand Challenge on Water Availability were suggested, although more focused on land surface processes. It was also noted that aerosols have played as a major forcing for the last 2 centuries but are now becoming less relevant post 2000 climate change. The interest in monsoon was highlighted. A question arose on the type of metrics to apply to the MIPs and also to this GC.

3. CMIP5 review and looking forward to CMIP6

3.1. CMIP5 Survey (V. Eyring & R. Stouffer)

Veronika Eyring presented a synthesis of the responses received so far on the CMIP5 Survey that was sent to representatives of the climate community (e.g., from CMIP5 model groups, WCRP working group, WGCM-Endorsed Community Coordinated Projects, Model Intercomparison Projects, WCRP core projects, Integrated Assessment Model groups, related IGBP group or activity, ESG Federation and Climate Service Center) in June 2013. The Survey was designed by the CMIP Panel and the WGCM Co-Chairs to learn from those most active in CMIP5 what went well and what didn't to help shape the experimental design of CMIP6 early on in the planning process. The responses to the survey formed the starting point for discussions at a workshop "Next generation climate change experiments needed to advance knowledge and for assessment of CMIP6" that was held in August 2013 in Aspen. At the Aspen workshop a first proposal for the design of CMIP6 was developed which was revisited at the WGCM meeting in October 2013 (see below). A presentation of the synthesis of the CMIP5 Survey is available from the CMIP Panel website (http://www.wcrp-climate.org/wgcm/cmip.shtml). The plan is to write this up in a peer-reviewed publication in the coming months.

The discussions noted the issue of timing of the IPCC process but also the fundamental priority for CMIP to first serve the research community. As a matter of fact, CMIP4 never went off the ground because of these issues. The need to better link with the climate service community was addressed, referring to the WCRP Working Group on Regional Climate (WGRC) questionnaire aiming at better tailoring CORDEX and downscaling products to VIA applications.

ACTION: update MIPs web pages (V. Eyring, M. Rixen)

3.2. Aspen workshop (G. Meehl)

A proposal for CMIP6 based on the Aspen Global Change Institute workshop was presented, proposing a distributed organization focusing on a set of ongoing CMIP Diagnostic, Evaluation and Characterization of Klima (DECK) experiments complemented by specialized intercomparisons ("MIPs") that would make use of the same standards and infrastructure. The WGCM and the CMIP panel would facilitate the communication and coordination between MIPs and the modeling groups. Specifically, the CMIP Panel would coordinate diagnosis and evaluation of simulations with the community, approve experiments and variable lists etc. that are to be part of CMIP6, and coordinate with WCRP Grand Challenges and a collaboration theme with AIMES on biospheric forcings and feedbacks, whilst MIPs would address (at least) WCRP Grand Challenges and other science questions and suggest model simulations to address these science questions. The workshop also raised the issues of more idealized experiments (like 1% CO_2 but for land use, aerosols, etc). Some particular science questions were also addressed, including overshoot scenarios, emissions of short-lived climate forcers, land use and cover change and integrated analysis of impact and responses. Sampling issues of AOGCMs vs. ESMs in paired non-mitigation/mitigation scenario matrices were also debated. A tentative timeline for CMIP6 was presented with runs and analysis starting as early as 2017.

The discussion elaborated on this proposal. ESGF would remain instrumental to implement this and MIPs could have probably their own set of parameters. Twelve MIPs were represented in Aspen, about half of them having ongoing experiments. AIMES (including IGAC and SOLAS) should be consulted on where their research can contribute to CMIP. It was noted that Grand Challenges are living documents that may be updated with inputs and contributions from other groups. Ongoing CMIP DECK experiments would contribute to the core experiments, supported by the specific MIPs. DCPP and CHFP can contribute to both research and operations/climate services. The need for both a CMIP council and a panel was discussed but discussions concluded that introducing an additional management layer would not be helpful.

Concerns were raised regarding the continuity between CMIP3, CMIP5 and CMIP6, including regarding the way ensembles are built. The community expressed the wish to have realistic runs to capture both high and low 21st century simulations as well as simulations with all forcings but the details of how they would be distributed between the MIPS and the DECK was not totally resolved at the workshop nd was taken up at the WGCM meeting. CMIP has been very much focused on CO2 but could also consider additional forcings such as O_3. Decomposition of radiative forcing is required for detection and attribution of climate change.

The Matrix scenario sampling seemed ambitious with uncertain success, both because of challenges in partitioning models across scenario choices in a way that preserve representativeness of model uncertainty ranges, and because of possible pressure on modeling centers to run scenarios that are considered politically relevant, rather than merely scientifically interesting in the context of the design. For the former issue (partitioning of models within the matrix) one possibility to be tested is that characterization runs (from the DECK) would provide useful inputs into a selection, e.g., partitioning based on climate sensitivity. In any case, the process is not necessarily straightforward and missing relevant models assigned to specific cells, or missing altogether cells in the matrix can prove the experiment useless. For example, in order to characterize uncertainty especially for outcomes at continental or smaller regional scales the number of realizations (models) under a specific scenario will be critical. It was subsequently decided to form a Scenario MIP Group to look into a number of issues, first and foremost the pattern-scaling question that will be addressed in a workshop in April in Boulder, CO (convened by Claudia Tebaldi and Brian O'Niell).

Whilst the DECK runs may not address the service side, they generated a lot of enthusiasm for CMIP6, as they directly serve the research community. This is different for policy relevant runs.

There is active discussion in the Integrated Assessment Modeling community regarding new scenarios, particularly in the context of the new Shared Socioeconomic Pathways (SSPs). There was general agreement that forcing for new scenarios should be made available in 2015.

There was an agreement that "core" experiments should be renamed to address "characterization" questions, on which the MIPs would rely on. There was a concern that characterization runs may not be sufficient to justify model funding for some groups, e.g., for those with a climate services/operational orientation, which would need to run realistic scenario simulations. It was stressed however that CMIP6 will include both DECK and MIP experiments, and that the success of CMIP6 will rely on the modeling groups participation in both types of experiments. The discussions *concluded with agreement on the need for a buy-in on the CMIP structure and satellite MIPs from the modeling centers before validating the experimental design.*

3.3. Synthesis of the post-Aspen document (V. Eyring)

A manuscript summarizing the outcomes of the Aspen meeting has been submitted to EOS and will be revised based on the outcomes of the WGCM17 session and the joint session with AIMES.

4. Modeling groups' perspectives on CMIP6

4.1. Canada, CCCma (G. Flato, J. Scinocca)

CCCma has participated in more than 25 MIPs over the past decade and their number and complexity continue to increase with time. CCCma's model development goals for CMIP6 are to unify its chemistry-climate and earth-system modeling capabilities under one model version, to update its ocean GCM and atmospheric model dynamical core, and to improve its existing physical packages. To accomplish this, in the face of increasing MIPs and other model applications, CCCma has instituted a parallel 18-month model development cycle. A key component of this development cycle is the introduction of documenting simulations of new model versions, which are essentially a CCCma in-house version of the proposed DECK experiments. CCCma strongly supports the institution of an ongoing community activity centered around such DEC experiments that includes the documentation of model attributes as well as an associated data request. Such an activity could also serve as the focal point of community efforts to standardize and coordinate the infrastructure of MIPs.

Discussions noted that model development and application are high profile community activities but model documentation has received far less attention. The METAFOR documentation effort on runs, data requests and diagnostic analysis is one experience to build upon. The issue of tuning uncoupled models and the lack of feedback was raised.

4.2. Germany, MPI (B. Stevens)

The MPI was an active participant in CMIP5, as it has been in all of the CMIPs before then. Overall MPI was very excited about the new directions being opened by CMIP5, particularly the emphasis on understanding on the one hand (idealized experiments), and the greater diversity of more operational contributions as reflected in the decadal prediction experiments. On the longer term MPI looks forward to the evolution of CMIP as a platform for more regularly and transparently sharing simulation results, which represent an enormous investment in computational and human effort. Coordinated, and well structured, experiments (particularly as part of MIPs) can be routinely shared through the infrastructure that CMIP has developed even outside of a particular phase of CMIP.

On a more critical side MPI felt that there was room for improvement in the attempts to standardize model documentation. METAFOR while well-meaning, and perhaps appropriate in vision was too large of a step. Smaller steps building on existing practice with a METAFOR like vision for the long run might be more effective. MPI also felt that CMIP3 and CMIP5 have shown that there is little further to be learned from additional emphasis on scenarios, and scenario development, and perhaps this aspect should be de-emphasized, or tasked to a few models with a more operational mission. MPI would happily work with DKRZ to support the more operational aspects of any future CMIP, and see an increasingly important role for select data and computing centers in the development of CMIP.

In the future CMIP should be even more strongly connected to specific scientific questions articulated by the community. It is important for CMIP to serve the needs of WCRP, and combining these two points, an emphasis should be placed on framing CMIP in terms of the grand challenges. One issue that continually arises in this and the broader context is the need to more systematically address long-standing and robust model biases.

The MPI model development is moving toward a standard release cycle, wherein new coupled models are targeted for release on a 24 month cycle. MPI-ESM1.1 is scheduled for release early next year, two years after MPI-ESM1.0 used in CMIP5. This model will have a major update in the treatment of radiation, and has major bug fixes in the representation of clouds and radiation and a number of surface processes. It conserves water and energy in important limits, and includes a multi-layer soil hydrology and a nitrogen cycle. Further development of ECHAM within the MPI-ESM will be discontinued after this release, and MPI-ESM2.0 which will be based on ICON, is scheduled for early 2016. ICON is a new semi-structured grid-point model being jointly developed with the DWD and DKRZ and is the basis for DWD's new operational global model scheduled for use in early 2014.

The discussions addressed the tension in experimental design between pure research and operational centers. In particular, decadal predictions can serve both science and operations/services. The scientific value of projections was highlighted, going beyond 'fortune telling' goals. It was noted that AMIP runs overestimate aerosol forcing by a factor 2 to 10.

4.3. U.K., Hadley Centre; Reading (C. Senior)

UK model development is following twin tracks of physical and Earth-system development. The new physical model, HadGEM3-GC2 has changed considerably since the HadGEM2-AO model in CMIP5 including new ocean and sea-ice models, additional vertical and horizontal resolution in the atmosphere and ocean and substantial changes to the dynamic and physics of the atmospheric model. This model is already running operationally for seasonal prediction and benefits are already being realized notably over Europe on these timescales. UK is about to embark on a limited set of CMIP5 runs (co-incidentally almost exactly equivalent to the proposed CMIP DEC experiments) using HadGEM3-GC2 and information from this will be used to improve the physical model which will form the basis of the next UK Earth System Model (UKESM1). For the first time in the UK, this will be a community model jointly developed by the Met Office and the UK academic community and will include improved land and ocean carbon cycles, the nitrogen cycle, improved aerosol modeling, tropospheric and stratospheric chemistry, land-ice and Fire modeling. Work to develop UKESM1 is well under way. Initial results from HadGEM3-GC2 suggest some significant improvements over HadGEM2-AO, notably in key modes of variability such as the NAO and ENSO.

CMIP6 needs to have a strong science link to the WMO grand challenges. Key topics will include a stronger focus on the near-term and links to the GFCS as well as a clearer analysis of the role of high resolution on the efficacy of projections. Second generation ESMs will be required to move from global to regional projections. We support the restructure of CMIP and the focus on model development and understanding through idealized experiments. Good co-ordination and engagement with the satellite MIPs will be crucial to success, as proliferation of MIPs risks too much diversity and not enough model involvement. UK welcomes the idea of an infrastructure panel and hopes that the users/data providers can be involved.

Concerns were expressed regarding high resolution runs, not always justified as features at low resolution are still poorly understood and deficiencies of models are often due to poor representation of major modes of variability (ITCZ, sub-polar gyre, etc). The question arose whether to increase the focus of decadal 10-30 year predictions, as these inputs are interesting for policy making.

4.4. France, IPSL; Météo France (S. Bony, M. Kageyama)

Sandrine Bony reported about the OAGCMs and ESMs developed by IPSL and Météo-France in the perspective of CMIP6, and then conveyed suggestions and recommendations from these groups regarding the design of CMIP6.

IPSL is currently developing a new AOGCM version that will include improved physics (new radiation scheme, stochastic triggering of atmospheric convection, new soil hydrology, new sea-ice model, coupling with an ice-sheet model, etc) and will have a higher resolution compared to CMIP5. More efforts will be put on the reduction of large-scale biases in the coupled model and on model tuning. An improved version of the ESM will be developed as well, that will include better coupling between atmospheric chemistry and biochemistry over land and ocean, a representation of fires, an improved treatment of high-latitude processes and a proper representation of stratospheric aerosols.

Météo-France is planning to use two model versions for CMIP6, associated with two different resolutions: a lower resolution version using the Arpege-Climat 6 at 1.4 deg resolution and NEMO at 1 deg resolution, and a higher resolution version using Argege-Climat 6 at 0.5 deg resolution and NEMO at 0.25 deg resolution. These models will include new atmospheric physics (including a new convective scheme), a new hydrology scheme and a new snow scheme. The atmosphere-ocean coupling frequency will also be increased. ESM components are also in development, including an interactive stratospheric chemistry on-line, a carbon cycle, an interactive aerosol scheme and tropospheric chemistry. Most ESM simulations will be done with the low-resolution version of the CNRM-CM6 model.

Regarding the future, the French groups (IPSL, CNRM and CERFACS) recommend to focus CMIP6 on three main science questions: the interpretation of long-standing model biases, the understanding of the climate response to various forcings and the interpretation of model uncertainties, and the understanding of mechanisms underlying decadal climate variability and predictability. They also recommend promoting continuity with CMIP5, targeted idealized experiments focused on science questions, to be more specific about forcings, and more consultation of the modeling groups regarding the design of the infrastructure and experiments of CMIP6.

Regarding the experimental design of CMIP6: the French groups recommend the inclusion of forced ocean experiments (aka CORE-II of WGOMD) and forced land-surface experiments, the organization of a « sensitivity to resolution » MIP, experiments focusing on fast biases in coupled models (Transpose-CMIP), on the evaluation of radiation codes, and on the evaluation of clouds and diabatic heating in models. To better understand the climate response to forcings, the groups suggest to include experiments with individual, prescribed forcings (aerosols, solar constant, ozone, volcanoes, land-use). Finally, they recommend that the decadal panel focuses not only on predictability issues but also on the physical mechanisms underlying decadal climate variability and predictability. Finally, it was suggested to promote the organization of « technical workshops » on CMIP infrastructure and data management to facilitate the sharing of experiences around the technical aspects of CMIP.

Discussions emphasized the opportunity to federate the land surface experiments in decadal predictions. Issues of interpolation on other grids were raised. It was suggested that Transpose-AMIP and maybe a future Transpose-CMIP could support some of the currently existing but poorly coordinated research on systematic biases. More in-depth sensitivity analysis to model resolution was also proposed.

4.5. EC-Earth (C. Jones)

Colin Jones provided an update on EC-Earth, a consortium of European National Meteorological Institutes (NMIs) and universities developing the ECMWF seasonal prediction system for use in climate prediction and Earth System Modeling.

EC-Earth contributed to CMIP5 with a large ensemble of historical period simulations and RCP future projections. EC-Earth contributed to the CMIP5 decadal prediction project using both full-field and anomaly initialization methodologies, with annual start dates provided for the 1960-2005 period. EC-Earth was run for CMIP5 using version 2.3 of the coupled model with an atmospheric resolution of T159 (~1.125°) and ocean resolution of 1°.

A new version of EC-Earth (version 3) is under development, using a new cycle (36R4) of the ECMWF atmospheric model, an upgraded version of the NEMO ocean model (presently version 3.3.1) and the LIM3 sea-ice model. The new standard resolution of EC-Earth v3 is T255 (~0.7°) in the atmosphere and 1° in the ocean. Coupled versions are also being used with atmospheric resolutions T799 (~0.22°) and T511 (0.35°) and ocean resolutions of 1° and 0.25°. It is likely that the T255/0.25° model will be standard for CMIP6 with some experiments using higher resolution versions. EC-Earth emphasizes the importance of providing underpinning information for European climate services and the WMO GFCS.

It was highlighted that many participating groups have also an interest in regional climate downscaling and that academic communities are also tuned to climate services.

4.6. Australia, ACCESS (T. Hirst)

The model that CSIRO/Bureau of Meteorology is developing for CMIP6 is ACCESS-CM2/ESM2. This model is planned to have all new component codes relative to the CMIP5 entries of ACCESS1.0 and ACCESS1.3, and will include the Met Office GA6.0

atmosphere, GFDL MOM6 ocean, the LANL CICE5 sea ice, the CERFACS OASIS-MCT coupler and the CABLE2 land surface scheme. The Earth System Modeling (ESM) configuration will also include the CASA-CNP terrestrial biogeochemistry model and the CSIRO ocean biogeochemistry model, and may include the UKCA atmospheric chemistry model depending on readiness.

The initial focus will be on development of a (relatively) low-resolution version, featuring an atmosphere of “N96” (1.25˚ lat by 1.875˚ lon) horizontal resolution and 85 levels in the vertical. The aim is for this version to include the ESM components and it will be known as “ACCESS-ESM2” or similar. The subsequent focus is expected to be on the development of a higher resolution version, featuring an atmosphere of “N216” (0.55˚ lat by 0.83˚ lon) horizontal resolution and again 85 levels in the vertical. This version will be known as “ACCESS-CM2-hr” or similar, and it will not include the additional ESM (biogeochemistry and atmospheric chemistry) components. Its development for CMIP6 will depend on the adequacy of computational resources.

The ACCESS modeling group participated in the CMIP5 Survey, returning a range of comments and suggestions to the CMIP committee. Additional suggestions on CMIP6 and related ‘MIP’ projects from both the ACCESS group and the broader Australian CMIP user community have been forwarded. In addition to the essential characterization experiments and the policy-relevant scenario simulations, of particular interest would be experimentation to explore (1) systematic errors in simulating climate “drivers” in more detail (e.g., monsoon, blocking, hemispheric modes, ENSO, IOD), (2) model forcing effects (e.g., similar to the sstClim and the individual forcing experimentation of CMIP5), and (3) variation of climate and hydrological sensitivity between model versions (e.g., guided parameter perturbation experimentation).

During the discussions, it was suggested to advertise the EOS publication to stimulate feedback. AMIP2 performed studies on covariance, but was not pursued because of a lack of subsequent use of results. The interest in perturbed physics was pointed out. Possible high resolution outputs to study extreme events were suggested, so as to contribute to the corresponding Grand Challenge. The low focus on decadal predictions was emphasized.

4.7. USA, GFDL (R. Stouffer, presented by V. Balaji)

There is a lot of concern inside GFDL on the scope/size of CMIP6 and on the science questions that need to be addressed. The relationship between CMIP and the IPCC is a particular concern. It is felt that the IPCC side needs to be deemphasized while more emphasis needs to be placed on experiments that increase our understanding. There is also a concern about the rush to bring in new results before they are vetted/understood by the community. Examples from AR5/CMIP5 of this problem include the new aerosol-cloud parameterizations, biogeochemistry (particularly land use) and the new efforts in decadal prediction. Doing this ends up hurting the scientific community. In regards to the CMIP6 proposal itself, there is a large amount of skepticism on the time scale to build and initialize AOGCMs and ESMs. It does not seem reasonable to build new models every few years if it takes ~6 wall clock months to “spin up” the model to find stable pre-industrial conditions. There is a lot of support from more runs for understanding…and less realistic scenario runs. It seems possible that the USGCRP of other government groups may want to have a say in what future scenarios runs are made at GFDL (or NCAR or GISS). Finally all agree that the DOI-like tags for the data sets need set up now…and advice not to wait for CMIP6.

The variable lists, model inputs and experiments all need to be defined earlier in the process.

Discussions raised concerns regarding the unclear relationship between aerosol and clouds and questioned the numerical investment in this area. The issue of expensive spin-up of over a thousand years was raised. NOAA provided some guidance regarding DOI and data traceability for application areas.

4.8. USA, NCAR (G. Meehl, presented by Gokhan Danabasoglu)

Inputs to the recent CMIP panel survey from the Community Earth System Model (CESM) perspective were already provided earlier. The brief summary provided some additional concerns and suggestions. Science gaps include understanding available simulations; understanding impacts of model biases; ice sheets and sea level change.

A concern from the timeline and pressure on resources (computer time, disk space, people's time) perspectives is that the demand on these resources was too high. Many simulations were done very close to the deadlines, increasing the pressure on resources. This essentially relates to the CMIP timeline and availability of data sets. Another concern is that there is not enough time to address major and persistent model biases in a meaningful way in between CMIP cycles. Suggestions from CESM include: (i) stress on cyber-infrastructure needs to be balanced with carefully thought out science goals; (ii) core set of experiments should be realistic both in number and length; (iii) estimate storage cost of produced data up front; (iv) forcing data sets for all simulations and their extensions (to year 2300?) should be available much earlier; and (v) selective and better prioritization of experiments should be considered – perhaps staggering of simulations can be an option.

In terms of specific experiments, the general feeling is that there were too many RCP scenarios. A recommendation is to have fewer future scenarios in favor of more ensemble members. Another concern is that CMIP6 will increase rather than reduce the number of experiments, e.g., the question of science gaps to explore could add a large number of runs.

In terms of forcing data sets, it is believed that these datasets through present-day are needed as soon as possible. Availability of their extensions through 2300 needs to be addressed. In CMIP5, there were some missing / non-sensible data in these extensions to 2300, relevant for biogeochemistry. For example, wood harvesting was set to zero after about 2100, with impacts on the carbon budget.

For output archiving, a suggestion is to adopt standard file naming conventions for output fields from different modeling centers with each file containing the same number of time periods. Availability of CMOR information earlier and incorporating sub-setting capability for ESG are among the other suggestions.

An important feature that needs to be added to the ESGF is sending out notification emails to alert the users of the data sets to updates and corrections.

In summary, the main messages from CESM are less is more and earlier is better.

The discussion re-emphasized the need to automatically inform users about new update being made available on ESGF and on some contingency plans to deal with implementation and subsequent publication delays.

4.9. Japan, AORI/U. Tokyo/JAMSTEC/NIES; MRI (M. Kawamiya)

Two groups, MRI/JMA and Team MIROC consisting of AORI/U. Tokyo, NIES and JAMSTEC, submitted simulation data to CMIP5 and plan to do so for CMIP6. MRI is developing an atmosphere only model for time slice experiments with a high horizontal resolution (~20km), and an earth system model (ESM) with a moderate horizontal resolution (~100km) for the atmosphere and ocean. Team MIROC is developing a coupled climate model with a horizontal resolution of ~120km (and possibly ~60km) for the atmosphere and ~100km for the ocean for decadal prediction experiments, and an ESM with a lower resolution equipped with the nitrogen and iron cycle. The model development in Japan is supported mainly through the SOUSEI Project funded by MEXT while MRI provides its own support for the ESM development. In addition, Non-hydrostatic, ICosahedral Atmospheric Model (NICAM) may also join time slice experiments of CMIP6. As preparation for CMIP6 gradually starts, the proposed framework for CMIP6 is being discussed in the community. Suggestions from such discussion include: some of the newly proposed MIPs could work closely together, e.g., LUMIP and ScenarioMIP (and also CCMI, D&A), which would help addressing some crucial scientific questions; importance and time-consuming details such as data format conversion should be well conveyed to the new satellite MIPs joining the next round.

The discussions stressed the opportunities for synergies between several MIPs, which the future CMIP panel could coordinate.

4.10. China, LASG, BCC (B. Wang)

The presentation introduced the plans of six model groups from China for the Coupled Model Intercomparison Project (CMIP) Phase 6 (CMIP6) and some representative works on model developments after CMIP5. Among the six model groups, two are from Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences (CAS) (including one from LASG, i.e., the National Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics), two respectively from Tsinghua University and Beijing Normal University (BNU), one from Beijing Climate Center (BCC) and one from First Institute of Oceanography (FIO). These groups plan to participate in CMIP6 using both climate system models and earth system models. Compared to the CMIP5 models from China, the horizontal resolutions of the new versions for CMIP6 will be greatly increased in both atmospheric and oceanic components. The representative progresses in model developments after CMIP5 presented here include a newly developed coupler that is one of the earliest couplers by Chinese scientists, high-resolution versions of atmospheric and oceanic components and climate system models, ocean wave model, and especially some components for carbon cycle models (e.g., dynamic global vegetation model, land and marine biogeochemical models, and fire model). Finally, some suggestions from Chinese scientists were given on the inclusion of a new experiment on historical responsibility and a new RCP considering the governmental commitments of emission reduction in CMIP6, reduction of CMIP cycle frequency, and more reasonable and scientific approaches to data assimilation of coupled model.

It was noted that the presentation summarizes the work of 6 groups whilst other countries deserve 2 presentation slots. A question arose whether the simulations would include regional emission pledges which would probably be best addressed at the IPCC scoping meeting level, as this is not the role or mandate of WGCM.

5. Discussion: Implications of modeling groups' perspectives for CMIP6

The implications of modeling groups' perspective for CMIP6 concluded on a well accepted 2-level structure (although some concerns were expressed, especially regarding those more involved on the operational/service side), a carefully selected set of few experiments, a consensus about the timeline and documentation on model changes, an increased involvement of modeling groups in the design of experiments and the infrastructure, more emphasis on systematic biases and an interest in having a limited but select set of scenario runs as part of the DECK. It was proposed to form a sub group of volunteers to look at the matrix dictating the sampling of models within alternative choices of scenarios.

Referring to the EOS draft manuscript, further comments were sought from members. Additional guidance would be needed to agree on a variable list. MIPs will need a timeline for their experiments as well. MIPs would not necessarily be repeated over time but outlining some criteria to become a MIP was suggested.

A possible new Grand Challenge covering WGCM-AIMES science was suggested. It was commented that many of these aspects can be addressed within the present GCs whose documents can be further adapted to reflect this more explicitly.

6. Recap of day-1 discussions

Gerald Meehl presented a revised CMIP framework using a slightly modified acronym "DECK" (Diagnosis, Evaluation and Characterization of Klima) to best reflect the various discussions of the day. It was still unclear as to which perspective/diagram would best represent the 'core' CMIP activities and the satellite MIPs experiments. Comments also highlighted the need to distinguish CMIP from CMIP6, envisaging routine model evaluation (see for example talk by J. Scinocca). Sandrine Bony recalled that CMIP and CMIP6 are mainly science driven efforts, and this could provide a way to structure the framework,, e.g. by articulating the CMIP6 experiments around three main science questions: the interpretation of model systematic errors, the assessment of the Earth's system response to forcings, and the assessment of climate variability and decadal predictability and response to climate change scenarios. It was also noted that further iteration and discussions would be needed to converge to a final framework and layout which would be suitable for other efforts focusing also on application and service activities besides pure science.

7. MIPs perspectives on CMIP6

7.1. CFMIP (S. Bony)

On behalf of the CFMIP Co-Chairs (M. Webb and C. Bretherton) and CFMIP coordination committee members (S. Bony, S. Klein, B. Stevens, M. Watanabe), S. Bony presented an overview of CFMIP activities and CFMIP recommendations for CMIP6.

CFMIP activities are organized along three main threads:
- the understanding of cloud-climate feedbacks through a hierarchy of models, model experiments and model configurations
- the consistent evaluation of model clouds against observations, especially those from satellites using the CFMIP Observations Simulator Package (COSP)
- the understanding and evaluation of model clouds and cloud feedback processes at the process level through the analysis and comparison of GCM outputs with field experiments and process model outputs, including the joint CFMIP/GASS CGILS project (CFMIP-GASS Intercomparison of Large Eddy Models and Single Column Models)

The main science questions that were in the focus of CFMIP2 were: (i) how well do climate models simulate clouds? (ii) what is the role of fast adjustments to CO2 ? (iii) what are the physical processes underlying cloud feedbacks and precipitation changes ?

A brief overview of some of the main lessons learned from CFMIP2/CMIP5 regarding these issues was presented, including the evidence that:
- the use of COSP in CMIP models (outputs from more than 10 models are currently available) made it possible to point out biases in the representation of clouds and cloud processes (including in areas such as polar regions where cloud evaluations has long been known to be difficult) which are likely to contribute to some of the systematic biases of coupled models (e.g. warm bias at the eastern side of the ocean biases, SST biases over the southern ocean);
- COSP outputs are not only useful for the evaluation of clouds but also for the diagnostic and physical understanding of cloud feedbacks, as COSP outputs make it possible to break down the global cloud feedback into cloud types and processes;
- the hierarchy of CFMIP2/CMIP5 experiments (in OAGCM, AMIP and aqua-planet configurations) aiming at separating the climate responses to CO2 and temperature has led to new insights into cloud feedback and adjustment mechanisms, and precipitation responses to climate change; these experiments have also formed the basis for additional CFMIP experiments;
- high-frequency process outputs (cfSites) at locations where a wealth of observations is available from field experiments or instrumented sites has a lot of potential regarding the evaluation of the diurnal cycle of models and the interpretation of cloud feedback processes;

To date, several dozens of CFMIP2/CMIP5 studies have already been published or submitted. However, the analysis of CFMIP2/CMIP5 outputs is still ongoing and data are still being received from some modeling groups, so the full value of CFMIP experiments and outputs is yet to be realized.

Considering these lessons, but also recognizing the science gaps of CFMIP2/CMIP5, CFMIP makes a number of suggestions and recommendations for CFMIP3/CMIP6:

- to strengthen, develop and generalize the benefit of CFMIP2/CMIP5, it is recommended to favor the continuity with CFMIP2/CMIP5 to encourage a more extensive participation of modeling groups to CFMIP experiments and outputs;
- to better assess and understand cloud feedbacks and adjustments in coupled models, it is suggested (i) to develop experiments aiming at better diagnosing the time-varying radiative forcing of models in historical and future experiments, (ii) to propose idealized experiments with an abrupt solar forcing (+/- 3%), and to request process outputs (e.g. 3D tendencies of water and temperature) from a subset of coupled experiments;
- to better understand the impact of clouds and cloud changes on regional temperatures, circulation and precipitation, CFMIP recommends idealized experiments in simplified frameworks such as AGCMs or aqua-planets ; CFMIP is also promoting sensitivity experiments such as COOKIE (Clouds On/Off Klima Experiments) to assess the role of cloud-radiative effects on the climate system in present day and in climate change;
- to test physical hypotheses and emerging constraints on the link between cloud feedback processes and model formulation, CFMIP suggests a hierarchy of short-term Transpose-AMIP experiments (control, 4xCO2, +4K), sensitivity tests to parameterizations such as SPOOKIE (Selected Processes On/Off Klima Experiments), and idealized global Radiative-Convective Equilibrium experiments (RCE) ; these latter experiments also constitute an opportunity to fill the gap between GCMs and Cloud-Resolving Models.

More specific recommendations for CMIP6 include: the need to better communicate the rationale for experiments and outputs to tackle science gaps, in connection with the WCRP Grand Challenges, the encouragement to raise the priority of inexpensive idealized experiments, and to attribute a « high priority » to a limited set of key simulator and process diagnostics.

CFMIP is also concerned that key diagnostics (such as COSP or process diagnostics) will need to be in the basic set of CMIP characterization experiments for the hierarchy of CFMIP experiments to be useful. In this perspective, CFMIP will do its best to define the CFMIP design and outputs requirements as early as possible, and to communicate the rationale of CFMIP experiments and diagnostics to modeling groups.

The discussions stressed the importance of Aquaplanet experiments in addressing tropospheric adjustments, cloud circulation feedbacks and in understanding current weaknesses of GCMs. Longer Aquaplanet runs could provide more insights on intraseasonal/interannual variability.

7.2. PMIP (M. Kageyama)

The Paleoclimate Modelling Intercomparison Project (PMIP) has been running in parallel to other MIPs since 1995. PMIP currently involves 21 modelling groups working with 26 climate models and has a long tradition of comparing the results from different models and comparing model results with paleoclimatic reconstructions. The first foci for PMIP have been the mid-Holocene (ca. 6000 years ago) and the Last Glacial Maximum (ca. 21000 years ago). The range of periods of interest have broadened, now encompassing the Mid-Pliocene (ca. 3 million years ago), the last interglacial (ca. 125000 years ago) and climatic transitions (e.g. the last deglaciation) and the last millennium, for which data is available to document the response of the Earth System to different types of forcings.

CMIP5 was the first time paleoclimate experiments have been included in the coordinated experiments of the Coupled Model Intercomparison Project. These experiments were: the last millennium (main forcings: volcanic and solar activities), the Mid-Holocene (main forcing: insolation changes) and the Last Glacial Maximum (main forcings: greenhouse gases and ice-sheets). The project strongly benefited from being part of the CMIP5 experiments, because simulations of these past climates have been obtained with the same model versions as the ones used for future climate prediction. This gives the opportunity, at last, to compare the processes at work in past vs. future climate changes and will allow the evaluation of the very models which are used for climate prediction, while these tasks have been so far hampered by the fact that paleoclimatic simulations were run at lower resolution than the climate prediction runs. The fact that PMIP3 simulations (both the official CMIP5 runs, but also PMIP3-non-CMIP5 runs) are now visible on the ESGF portal is very important and will make the comparisons to simulations of future climate change and to idealized experiments easier. This feature of the infrastructure should be kept for CMIP6, as well as a strong support to run paleoclimate simulations with the same model versions as those used for climate prediction.

The analysis of the results is ongoing, even if some results (from CMIP5 and non-CMIP5 runs) have been available early enough to be published in time for the IPCC deadline. Two examples, on the LGM deep ocean (Fig 9.15, IPCC AR5) and on relationships between changes in temperatures and changes in precipitation (Li et al, GRL 2013), for past and future climates, were shown at the meeting. It is hoped this will draw attention on the PMIP3 results, especially for past vs. future climate change analyses.

Recommendations for CMIP6:

- The need to define the transition between the last millennium forcings and the historical ones more carefully;
- The need to improve the quantification of the forcings and their impact, for each period and to compare then to other periods/future conditions;
- Sensitivity experiments could be useful (e.g. “AMIP_lgmCO2”, “AMIP_MidHoloceneInsolation”, in the same way as the AMIP4xCO2”) in this respect and will have to be designed in coordination with other MIPs;
- The need for a stabilized scenario (e.g. 4xCO2, for several hundred years), for better comparison of past vs future climates, This would also be useful for studying changes in variability.

Further developments:

- Paleoclimate simulations will strongly benefit from progresses in representations of the vegetation (fully dynamical models), aerosols, ice-sheets and of the climatic indicators, this last aspect being crucial for model-data comparisons and better understanding of the paleo-data.
- There is a growing interest in regional model results for past periods too, a high resolution being very important for the “users” communities (e.g. biologists, archeologists). Coordination with CORDEX activities could be useful in this respect.
- Other periods, such as the Mid-Pliocene, could be of great interest for past vs. future comparisons. This would be easy to organize in the proposed CMIP6 organization, in which the different MIPs are given more weight.

The discussions addressed the issue of transient phenomena and the time needed for models to spin-up and adjust. It was noted that the representation of the carbon *cycle in models is also a step forward in simulating some of the land and ocean climate proxies.*

7.3. Transpose-AMIP (C. Senior)

Transpose-AMIP is a WGNE-WCRP endorsed framework for running climate model in weather forecast mode. The design of TAMIP II involved 64 hindcasts of 5 days, across annual and diurnal cycles, initialized from ECMWF analysis. Dates were chosen to coincide with several IOPs. 10 modeling centers have pledged to be involved and 8 have run experiments although getting date on the ESGF has been slow and the number remains at only 4, as last year. There have been 3 main papers using the data but it is hoped that this will grow as more CMIP5 users download and analyze the data. Xie et al (2013) have shown the relationship between long and short-term systematic biases in the ensemble of CMIP5/TAMIP simulations, which can then be exploited to better understand the source of the biases using case studies and direct comparison with detailed observations such as from the ARM sites. TAMIP II has built on the success of TAMIP1 and the CAPT initiatives and there are now more centers involved and able to run these types of experiments. A comprehensive set of data has been saved and became more accessible to users via the ESGF. The methodology is widely supported and has been encouraged as an important route to fixing model biases. In the future TAMIP experiments should be formed around particular science questions (e.g. common systematic biases such as warm continental temperatures or the MJO). It is not yet clear if this is best done by TAMIP remaining as a project within CMIP6 or if the methodology should be used within other MIPs.

The discussion addressed the challenges on how to separate predictive error from forced error. It was recommended to identify 2-3 main science questions for a possible Transpose-CMIP effort.

ACTION: Identify 2-3 main science questions for a possible Transpose-CMIP (WCGM Co-Chairs)

7.4. CORDEX (C. Jones)

Colin Jones reviewed the experimental design and overall aims of the CORDEX program. The new CORDEX website was highlighted along with information from the various regional CORDEX initiatives provided through the bi-annual CORDEX Newsletters.

The regional CORDEX training workshops, recently held in Africa, South Asia and South America were all highlighted as successful means to (i) increase climate science capacity in developing regions of the world, (ii) facilitate delivery of regional climate information to regional policy-makers and stakeholders by local scientists and (iii) to increase understanding of regional climate science, modeling and the generation of climate projections amongst regional stakeholders and the impact-adaptation and vulnerability research communities.

Delivery of CORDEX simulation data onto the Earth System Grid was highlighted, as was the support for CORDEX ESG archiving at a number of European ESG nodes.

It was stressed that CORDEX is now a WCRP project organized under the new WCRP Working Group on Regional Climate (WGRC) Co-Chaired by Bruce Hewitson and Claire Goodess. CORDEX now has a Science Advisory Team (SAT) chaired by Filippo Giorgi and Bill Gutowski.

The 2nd pan-CORDEX conference will take place in Brussels Nov 4-7 2013, with over 650 registered participants.

The question was raised as to whether CMIP6 BC could be used for CORDEX, but the timeline poses serious deadline challenges. The importance of systematic GCM-RCM comparisons was emphasized.

ACTION: ask WGRC for a CORDEX representative on WGCM (M. Rixen)

7.5. WGNE (J-N Thépaut, remotely)

Jean-Noël Thépaut gave an overview of WGNE activities, in particular about the role of this group regarding the coordination, liaison, and activities around workshops, meetings, etc. He listed the coordinated experiments and projects under WGNE umbrella (Transpose-AMIP, Grey Zone, Aerosols for weather and climate, monsoon and momentum budgets intercomparison). Verification and diagnostics remain at the heart of WGNE activities. Two WGNE-co-sponsored important meetings took place this year: the GOV/WGNE Ocean coupling workshop (Washington DC March 2013) and the 4th WGNE workshop on Systematic Errors in Weather and Climate Models (Exeter, April 2013). The former pointed to the need of using short-range coupled systems to understand issues for subseasonal to seasonal timescales, and the latter to the need for enhanced diagnostics to identify timescales on which errors develop, implying strong links across climate, seasonal and NWP communities. Future directions of WGNE encompass addressing short-range (high-res) NWP, Earth System (ensemble, coupling) prediction, with as a backbone a prominent role in model evaluation development. WGNE will continue to coordinate specific projects (grey zone, aerosols, momentum budgets, etc.), and also maintain and increase links with a wide variety of projects (PPP, S2S).

During the discussions, Transpose-CMIP and the coordinating role that WGNE could play in a 'high-res' time slice (mid 21st century AMIP style exp) in CMIP6 was raised. This will be discussed at the forthcoming WGNE meeting. Following a recommendation from the systematic error workshop, clarifications were sought on the need for common model configuration.

ACTION: address Transpose-CMIP on next WGNE conference call and session (M. Rixen, J.-N. Thépaut)

7.6. Decadal panel (G. Boer)

The DCPP is a child of WGSIP and WGCM and the decadal prediction component of CMIP5. The DCPP's interest is in the development and support of the science and practice of decadal prediction and in the provision of an archive of decadal prediction information for research and applications. The DCPP was formed following the WGCM meeting in Exeter in 2009 as a focus for questions and recommendations concerning the new "Near-Term (decadal)" component of CMIP5 which joined the more familiar "Long-Term (century & longer)" component as a core element of the

CMIP5 experimental design (Taylor et al., 2009). Initial DCPP actions included producing a document on bias adjustment and recommending modifications to the experimental protocol to include decadal predictions every year and to reduce the priority of high frequency multi-level data in the archive. Although a new endeavor in CMIP5, the decadal prediction component has had a positive effect on research and offers promise for applications. Many investigations and publications have been, and are continuing to be, made based on these results as reported at the International Workshop on Seasonal to Decadal Prediction http://www.meteo.fr/cic/meetings/2013/s2d/) for instance and as included in Chapter 11 of the IPCC AR5.

The DCPP is in the process of developing a proposal for the decadal prediction component of CMIP6. The core element is a set of hindcasts initialized every year from 1960 to the present. Such a hindcast data set is required for bias correction, for developing methods of combination and calibration of forecasts, for the development of historical skill measures, and for applications. The results may also be used as a benchmark against which to compare improvement in models and prediction quality, to answer broad questions concerning the sources and limits of predictability, and to investigate processes and mechanisms of interest such as the hiatus, climate shifts, AMOC variations etc. Other experiments, of lower priority, may also be proposed in addition to the core hindcasts. The intent is that data from the hindcast data set is coordinated across modeling groups in a timely manner and is readily available for scientific and application analyses in support of the Grand Challenge of Regional Climate Information and in support of the Global Framework for Climate Services.

It was commented that DCPP is currently a panel, but slowly transitioning to a MIP. The focus on 10 year predictions was decided because some regions show skill up to 7-8 years. It was suggested to look at the impact of data assimilation methods in ocean models. Computing resources impose a delicate choice between length of simulation and number of members, both being needed for robust statistical inference.

7.7. GeoMIP (K. Taylor)

On behalf of Ben Kravitz, Karl Taylor presented a GeoMIP status report and proposal for new experiments. The first phase of GeoMIP included four simulations in which CO2-caused warming was counteracted by either an idealized reduction of the solar constant or an injection of tropical SO2. The simplest of the experiments attracted the most interest with 12 climate models providing results. Two papers have been published and additional papers describing GeoMIP first phase findings will appear in a special issue of the Journal of Geophysical Research. There have been exploratory simulations performed to examine the extent to which marine cloud brightening (e.g., induced by artificial enhancement of sea spray) might offset warming. These could become a part of the next GeoMIP phase, which might also include additional idealized insolation reduction experiments. To discuss these and share results, a meeting of GeoMIP participants and interested parties is planned for the spring of 2014. The standards and specifications for CMIP will continue to be followed and the intention will be to rely on CMIP experiments to provide a baseline for the GeoMIP simulations. More information can be found at http://climate.envsci.rutgers.edu/GeoMIP/.

Comments from WGCM members indicated that GeoMIP fits nicely into the proposed framework of “satellite MIPs” being organized around a set of benchmark CMIP *experiments. There was also an opinion expressed that idealized experiments might continue to attract the most interest from modeling groups because they might be easier to set up and can often be easiest to interpret. The discussion also raised the the need for a more formal link to CMIP6.*

7.8. IDAG (C. Tebaldi)

The presentation related essentially to the 20C (historical) experiment and single forcing experiments. The analysis of the CMIP5 ensemble has highlighted a few issues related to this type of experiments (particularly, as Detection and Attribution – D&A - questions are addressed):

- Model variability/uncertainty (aka structural uncertainty) is even more relevant than previously thought in D&A analyses;
- Uncertainty in the size of forcings, particularly aerosols, but also land use, remains perhaps the largest source of uncertainty in D&A analyses;
- The importance of internal variability in the study of the historical period has been put upfront by the consideration of the hiatus and its causes.

The general recommendations therefore are - respectively - that
- CMIP6 should encourage single forcing experiments by as many models as possible (and to achieve this a clear prioritization of the experiments will be useful, not to overwhelm the to-do list of modeling centers);
- Historical forcing scenarios to explore uncertainty in historical aerosol (and other forcings) will be developed (led by N. Mahowald and B. Stevens). This could overlap with proposed forcing MIP, and contribute to the D&A interests;
- A minimum size initial condition ensemble for historical/single forcing runs should be encouraged (3-5?).

Historical simulations should be run as close to the present as possible. This requires better clarity from individual models on exactly which forcings are included in which runs. When possible, simulations should start even earlier than 1850 or, alternatively, last millennium and historical simulation could better mesh. Modeling centers that can afford it could be encouraged to run large IC ensembles limited in length to the present period (say 1970-2030). Single forcing experiments should be run as close to present as possible for their historical part, and over the future period also.

The following priority list for single forcing experiments is suggested:

Higher priority (with IC ensemble):
- ALL (aka historical) including aerosols, ozone, land-use;
- NAT-only as highest priority;
- Aerosols-only (or GHG-only if Aerosol-only experiments are taken up by other MIP).

Medium priority:
- Solar-only (or VOLC-only);
- GHG-only.

Low priority:
- Black Carbon;
- Ozone;

- GHG+Ozone+Land Use;
- CO_2;
- Land Use (coordinate with LUMIP).

*The discussion emphasized the need to understand model uncertainty vs. structural uncertainty linked to aerosols and a better coordination with AEROCOM. It was suggested to prescribe these climatological aerosols, maybe around a few trajectories over the historical period spanning some of the *small* uncertainty range that observations cover, rather than letting models come up with their aerosols concentrations on the basis of emission information. However prescribing Aerosol Optical Depth (AOD) would sweep under the rug many other facets of uncertainty, therefore hiding the fact that there are many possible realizations to the same AOD, but possibly with different effects on climate.*

7.9. WGOMD and CLIVAR (G. Danabasoglu)

The CLIVAR Working Group on Ocean Model Development (WGOMD) continues to focus on the analysis of the phase II of the Coordinated Ocean-ice Reference Experiments (CORE-II). CORE-II represents an experimental protocol for ocean – sea-ice coupled simulations forced with inter-annually varying atmospheric data sets for the 1948-2009 period. These *hindcast* experiments are being used to evaluate ocean and sea-ice model performance and to study mechanisms of time-dependent ocean phenomena and their variability from seasonal to decadal time scales for the recent past, complementing coupled climate models that contribute to CMIPs. The simulations also provide consistent ocean and sea-ice states for initialization of decadal prediction experiments. It is pleasing to have participation of a growing number of groups (currently about 20) in this effort from around the world, representing quite a diverse set of ocean and sea-ice models used in climate simulations. The CORE-II simulations are being analyzed in several separate studies, each focusing on a specific aspect of the solutions, e.g., mean state and variability in the North Atlantic with a focus on the Atlantic meridional overturning circulation; global and regional sea level changes; the Southern Ocean and ventilation properties; eddy compensation in the Southern Ocean; the Arctic Ocean and sea-ice; and mean and variability in the Indian Ocean. The resulting manuscripts will be published in a special issue of *Ocean Modeling*.

As the ocean modeling community interest grows in the CORE-II experiments and as they become a routine means of evaluating the performance of ocean – sea-ice components of the coupled climate models, the WGOMD has been discussing inclusion of the CORE-II experiments in the next CMIP effort, i.e., in CMIP6. It is hoped to make a final decision on this topic at the panel meeting in April 2014, after further discussions.

While recognizing difficulties associated with unstructured-grid ocean modeling frameworks that are currently under development, the WGOMD continues to strongly recommend that the ocean model output fields should be provided on the models' native grids in future CMIPs for physical (science) reasons. To expedite analysis and use of ocean fields, however, an issue to be discussed at the next panel meeting is that a very limited number of "highly-used" variables, e.g., sea surface temperature, can be mapped onto a common, regular longitude-latitude grid. Other recommendations include providing common mapping tools for community use and incorporation of sub-setting capability for non-longitude-latitude grids in ESGF.

Increased use of so-far-minimally-used ocean fields in the CMIP5 archive is expected as the community embarks on more detailed analysis of the simulations after completing initial, low-hanging-fruit analyses. It is also noted that requests for saving additional ocean fields, including biogeochemical variables, will be forthcoming for consideration in CMIP6 planning.

The discussion noted the difficulty to work with unstructured grid and associated interpolation issues. Comments were made about the differences between coupled and uncoupled ocean models.

G. Danabasoglu provided an update on CLIVAR and its proposed new structure. A gap in the WCRP structure with respect to atmospheric dynamics was highlighted at this year's JSC meeting. CLIVAR will lead a discussion over this year, in consultation with GEWEX, SPARC, WGNE, CliC, Regional GC and GC on “Clouds, circulation and climate sensitivity”, to propose a solution with regard of the gap in the WCRP structure in the domain of research on atmospheric dynamics. CLIVAR has formed a small scoping team that has been solicited to produce a short proposal. CLIVAR recommends a close link of the CMIP planning with WCRP programs and Grand Challenges and CLIVAR Research Opportunities seems necessary. Scientific topics of interest require further analysis either from existing model results or new experiments for providing input to CMIP6. It would be helpful to undertake a more thorough consultation of the CLIVAR community, including the U.S. CLIVAR. CMIP6 planning is an opportunity for the projects to feed in recommendations on the experiment design for progress in the priority themes. Suggested paths include surveying the CLIVAR community with more direct communication between the WGCM and CLIVAR project steering committees.

Surface wind waves were identified in the IPCC AR4 as one of the key drivers in the coastal zone, but little information was available on projected changes under future climate scenarios. The IPCC Working Group II recognized that risks to coastal population and ecosystems require inclusion of a broader range of coastal drivers of change. One of the key drivers, which has received insufficient attention to date, is wind-waves. The Coordinated Ocean Wave Climate Project (COWCLIP) team expects to perform similar analyses using CMIP5 and CMIP6 output, so related aspects of design considerations should be maintained. The objective of the U.S. CLIVAR Climate Model Evaluation Project (CMEP) 2011 is to increase community-wide diagnostic research into the quality of model simulations, leading to more robust evaluations of model predictions and a better quantification of uncertainty in projections of future climate. The results of this research will be used for the subsequent evaluations of the quality of U.S. model global and regional climate projections of the 21st century and beyond in the context of an international multi-model dataset.

Some preliminary feedbacks from the CLIVAR community regarding CMIP5 and CMIP6 stress the difficulty of providing feedback due to the number of experiments, the short deadlines and difficulties in accessing the data. The need for long control integrations and more idealized process experiments was noted.

Some preliminary inputs from the Grand Challenge on Sea level were also presented suggesting experiments addressing climate sensitivity and sensitivity to aerosols and their respective impact on ocean heat uptake and sea level, and CMIP runs addressing historical sea level changes for the recent past and last millennium. Simulations could include a possible MIP for ice sheet–ocean interaction, increased ensemble members and long control runs, surface flux perturbation experiments to investigate the effects of the patterns of regional sea level change, and CORE-II simulations.

ACTION: ensure CLIVAR and other WCRP core projects are involved in the preparation of CMIP6 (V. Eyring)

8. Implications for CMIP6

8.1. CMIP5 Synthesis papers and model analysis workshops

The need to promote new synthesis papers was discussed. The question arose whether this would add anything new on top of IPCC AR5 papers. Maintaining a page on CMIP5 papers was also suggested. A special issue in the Journal of Advances in Modeling Earth Systems (JAMES) was proposed as well, which could include contributions on metrics, on the CMIP5 survey, on forcings, and specific inputs from modeling centers. A model analysis workshop is tentatively scheduled for spring 2015 to present results from CMIP5 analyses around the GC questions, so as to encourage people to exploit available simulations.

8.2. Interaction between CMIP and MIPs

Based on earlier discussion, it was decided that there was no need for a CMIP council, as the WGCM and the CMIP panel would cover these coordination aspects.

9. CMIP infrastructure, evaluation and benchmarking

9.1. Proposal for CMIP infrastructure panel (K. Taylor, V. Balaji)

Karl Taylor and V. Balaji provided a summary of the ongoing “global data infrastructure” needed to support CMIP and related activities of interest to the WGCM. Although the WGCM sets the focus of CMIP and endorses a set of experiments, the design details of coordinated experiments like CMIP must be worked out through discussions and negotiations that may require input from broad communities of interested parties. Consensus decisions must be reached concerning all the details of the simulation conditions (from for the “forcing” datasets to the list of requested output).

While the scientific content will thus remain a matter for the scientific communities designing MIPs, the WGCM believes it will be in everyone's interest to have common technical standards to ease the sharing of data. Historically, the WGCM has relied on its CMIP Panel and the Program for Climate Model Diagnosis and Intercomparison (PCMDI) to ensure that these decisions are made to maximize the payoff in terms of scientific utility while respecting the practical limitations set by modeling group resources.

The expansion of CMIP in phase 5, which included experiments from related activities as PMIP, CFMIP, and C4MIP, exposed the inadequacy of the current support of CMIP infrastructure. Although the less-centralized approach for CMIP6 now being discussed will reduce the responsibilities for design details currently shouldered by the CMIP panel and PCMDI, there will be a growing imperative to ensure that all the data standards and protocol specifications in place for CMIP are also followed by the "satellite MIPs". To establish standards that guarantee that users and different data distribution centers can discover, browse, catalog, archive and share climate datasets, a white paper was presented proposing that a WGCM (or WCRP?) Infrastructure Panel (WIP) be formed. As outlined, the standards overseen by this panel would include the:

- CF metadata standards;
- Specifications beyond CF guaranteeing fully self-describing and easy-to-use datasets (e.g., CMIP requirements for output);
- Catalog and software interface standards ensuring remote access to data, independent of local format (e.g., OPeNDAP, THREDDS);
- Node management and data publication protocols;
- Defined dataset description schemes and controlled vocabularies (e.g., the CMIP5 "Data Reference Syntax:");
- Standards governing model and experiment documentation (e.g., CIM).

There was considerable support and no objections expressed by WGCM members, but there was some question as to whether this panel should report to the WGCM or perhaps the WMAC instead. It was also suggested that a workshop on technical infrastructure be added to the list of expert workshops convened by the CMIP Panel. The chairs indicated that assuming the WIP would report to the WGCM, the terms of reference should be drafted by Taylor and Balaji and submitted to the Co-Chairs along with suggested nominations for panel members.

ACTION: WGCM to form a CMIP infrastructure panel with ToR and nominations (V. Balaji and K. Taylor)

9.2. Diagnostic and benchmarking of CMIP models (P. Gleckler and V. Eyring)

Motivated by responses to the CMIP5 survey (see synthesis at http://www.wcrp-climate.org/wgcm/cmip.shtml) and discussions at the Aspen workshop, community-based performance metrics and diagnostics are suggested as being an integral part of CMIP6. An important goal of this aspiration is to develop CMIP benchmarking and evaluation tools that produce well-established analyses as soon as model results become available. The expectation is that the routine and systematic evaluation of model results could be made more efficient, thereby enabling scientists to focus on developing more innovative methods of analysis rather than constantly having to "re-invent the wheel".

Peter Gleckler reported on the progress of the WGNE/WGCM Climate Model Metrics Panel (see http://www-metrics-panel.llnl.gov/wiki/FrontPage). During the past year this group has been working to develop a package for producing routine performance metrics for relevant CMIP experiments (e.g., historical and AMIP). The metrics included thus far results from the following criteria. They are 1) well established in the literature and widely used; 2) easy to compute, reproduce and interpret; 3) yield fairly robust results; 4) well suited for repeated use. The metrics package includes documentation, analysis code, carefully selected observations, and a database of results from all models contributed to CMIP5. The package has been designed with the intent of making it feasible for interested modeling groups to incorporate it into their model development process, effectively enabling them to directly exploit the CMIP database to gain insights on the strengths and weakness on their newer model versions. It is envisaged that the metrics panel package will be incrementally augmented, with modeling groups being given the opportunity to provide feedback to the metrics panel. An alpha version of the package is now under testing and it is expected that it will be available to modeling groups in the months ahead.

Veronika Eyring described a diagnostic package under development as part of the FP7 Project Earth system Model Bias Reduction and assessing Abrupt Climate change (EMBRACE, http://www.embrace-project.eu/). The priority of this effort is to incorporate analysis that target the scientific objectives of the EMBRACE project, focusing on selected Essential Climate Variables (ECVs), tropical variability, Southern ocean, continental dry bias and soil hydrology-climate interactions, and atmospheric CO_2 and NO_2 budgets, but the package is being developed in such a way that it can be further generalized and ultimately be made available for a wider community to either just use the tool or contribute additional analysis. The Earth System Model Validation Tool (ESMValTool) is a community-development under a subversion-controlled repository to allow multiple developers from different institutions to join. The goal is to further develop and share the ESMValTool and routinely run it on CMIP output and utilizing observations available through the Earth System Grid Federation (ESGF) in standard formats (obs4MIPs). The ESMVal tool will be released to the public at the end of the EMBRACE project (Oct 2015), and will also be contributed to the metrics panel code repository (see below).

The metrics panel package and the ESMValTool are examples of how the CMIP modeling groups and analysts might work even more effectively as a community in the area of model evaluation. These efforts will be coordinated as they mature and it is possible that other complimentary capabilities might emerge to build upon. One possibility the metrics panel has been entertaining is the creation of a diagnostic repository that is designed in a way that enables researchers to contribute codes that modeling groups and climate model analysts can select from and readily incorporate into their own analysis framework. To accomplish this, infrastructural efforts would be needed to develop guidelines for coding in a variety of non-proprietary analysis packages that are in common use for climate model analysis.

The discussion raised the importance of metrics with regard to CMIP5 model dependence and size of ensembles and their representativeness. It was further noted that the existing linkages between the metrics panel package and the ESMValTool can be further strengthened. It was confirmed that the ESMValTool will be made available to the scientific community. The need to better understand systematic biases was highlighted and the metrics and diagnostic initiative should support this effort.

10. Expert groups and workshops to be set-up for CMIP6

10.1. Obs4MIPs-CMIP6 workshop (P. Gleckler)

On behalf of Duane Waliser and many others involved in obs4MIPs, Peter Gleckler gave a brief update on the status of the effort and discussed plans for an obs4MIPs workshop in support of CMIP6 (see below). A primary objective of obs4MIPs is to facilitate model evaluation by integrating the organization of observational and CMIP model data. During the past year a variety of new data sets have been made available on ESGF via the obs4MIPs project (e.g., aerosol, sea ice, albedo, snow, additional cloud quantities, additional SST and column water vapor), and more products are in the process of being included. Obs4MIPs is considered by the WCRP Data Advisory Council (WDAC) to be a viable mechanism to improve model-data connectedness, and the establishment of a task team is in progress to help guide the advancement of the project. For now, the project is focused on satellite data and is being advanced by the original team and a NASA obs4MIPs working group.

Preparations for a workshop are underway which will strive to coordinate the CMIP6 standard model output with the evolution of obs4MIPs, with particular emphasis on products that are currently under utilized for model evaluation. The participants would primarily include observation data set providers, model development and analysis leads, CMIP6 experiment architects and obs4MIPs leads/organizers. The workshop goal is to ensure that relevant satellite data sets currently (or potentially) available can be fully utilized for CMIP6 research. The workshop objectives include:

1) Review aspects of model evaluation from CMIP3/CMIP5 that utilize satellite observations and reanalysis for diagnosis and assessment;
2) Assess the utility of the current obs4MIPs holdings, including formatting, documentation, temporal and spatial resolution, and ESGF delivery, in the context of CMIP model evaluation;
3) Identify currently under-utilized and potentially valuable satellite observations and reanalysis for climate model evaluation and process understanding.
4) Examine the mismatch between CMIP model output and satellite-based products, and recommend changes and additions to output and datasets to achieve more effective alignment;
5) Provide recommendations for new observation data sets that target critical voids in model evaluation capabilities, including important phenomena, sub-grid scale features, and holistic Earth System considerations extending to composition, carbon cycle, hydrology, etc;
6) Discuss the utility and expansion of satellite simulators for model evaluation of CMIP6, striving to identify key areas where such developments could yield high impact advancements in model evaluation and improvement.

The workshop is expected to be held at NASA headquarters (Washington D.C.), on April 28-May 1, 2014. Because it is crucial to get the right mix of expertise it will be relatively small and by invitation only. Questions should be addressed to Duane Waliser (duane.e.waliser@jpl.nasa.gov) or Peter Gleckler (gleckler1@llnl.gov).

The discussion highlighted the potential contributions from ESA-CCI and CM-SAF, noting that the latter was more focused on ECVs. This effort would also benefit from *suitable inputs from GEWEX on best practices and from the reanalysis community. The panel membership was confirmed soon after the WGCM session.*

10.2. Model tuning (S. Bony and B. Stevens)

Following earlier discussions within WGCM and WMAC, WGCM will encourage the organization of a workshop on model tuning, with the aim of facilitating communication and exchanges of experience about model tuning practices within the different climate modeling groups. IPSL and MPI volunteered to organize the workshop in 2014.

The idea generated a great deal of interest and discussion. There was some confusion as to what was meant by tuning, what is tuned, and what the outcome of the workshop should be. The point was made that the group should try to involve the ocean community, or an ocean community component. Other points to be considered are the relationship of tuning to performance metrics, and the different types of tuning targets, e.g., major modes of variability such as ENSO, variability or response, also things like aerosol effects. Whilst the tuning against observations is seen as a necessary exercise, tuning against climate change should be avoided.

One outcome would be a brief article explaining the rationale for model tuning, providing an overview of current practices, and outlining best practices. One thing to consider might be to also set a goal for constraining tuning, i.e., by identifying tuning parameters that might be possible to eliminate.

10.3. Radiative forcing (K. Taylor)

A proposal for AOGCM radiative forcing diagnostics in CMIP6 was presented. Following the Aspen Workshop, a panel including Piers Forster, Jonathan Gregory, Tim Andrews, Karl Taylor, Mark Zelinka, Olivier Boucher, Gunnar Myhre, and Drew Shindell was asked to prepare a proposal on how to best diagnose radiative forcing in historical and single forcing CMIP6 runs. The panel communicated via email and several members carried out a preliminary analysis of available simulations, but before a final recommendation can be made, additional study is needed. Karl Taylor provided an interim report in which the two diagnostic approaches were described. Several variants of the “fixed SST” approach (based on Hansen et al., 2005) are being considered (differing in exactly which SSTs are prescribed), as well as a different method first used by Forster and Taylor (2008). The fixed SST approach requires an additional atmosphere-only simulation for each forcing diagnosed, whereas the alternative does not. The fixed SST method provides somewhat less noisy results and makes it possible to examine the dependence of feedbacks on climate state and forcing agents, while the alternative does not. Further work will be done to quantify the relative advantages of the two methods. One proposal that might prove attractive would be to use the fixed SST method for diagnosing forcing in the cases of highest interest (e.g., all forcing and aerosol forcing), and use the alternative for other cases, thereby avoiding the extra expense of additional simulations. A final recommendation from the panel can be expected by the next WGCM meeting. Among WGCM members, there appeared to be strong interest in support of better quantifying differences in forcing in planned CMIP simulations.

A proposal to assess the accuracy of clear-sky fluxes computed using climate model radiation codes is being promoted by Robert Pincus, Eli Mlawer, Bill Collins, James Manners, Lazaros Oreopoulos, and V. Ramaswamy. On behalf of this group, Karl Taylor summarized initial ideas for better quantifying the errors in radiation codes in coordination with CMIP6 simulations. Motivation for this proposal derives in part from a radiation code analysis of CMIP3 models (Collins et al., 2008) which showed that even with the same clear-sky conditions prescribed for a subset of the CMIP3 models, large differences were found in the fluxes of radiation and in the perturbation to those fluxes caused by large changes in CO2. Building on the CMIP3's Radiative Transfer Model Intercomparison Project (RTMIP) and the "Continual Intercomparison of Radiation Codes" effort, the group proposes an RTMIP2 in which a large number of (gas-only) atmospheres is prescribed so that the radiation codes themselves are subjected to identical conditions. In addition, changes in various greenhouse gases (CO_2, H_2O, O_3, CH_4,...) will be imposed to determine how these "forcing agents" (in isolation and in relevant combinations) affect radiation. Evaluations will be made with reference to calculations from one or more line-by-line models. Questions on how to best prescribe the experiment conditions and about the mechanics of doing the runs indicated interest in RTMIP2, but a need to work out the details.

There was encouragement to discuss the alternatives with some modeling group representatives and to proceed with planning for RTMIP2 with a refined proposal with complete design details.

10.4. Pattern Scaling (C. Tebaldi)

Plans for a workshop on Pattern Scaling and its Application to the New Scenario Process were presented. Pattern scaling is a technique for generating spatial projections of future climate using a statistical model designed to reproduce results that would be expected from a projection with a full global climate model. Pattern scaling is expected to play an important role in a new process underway by the climate change research community to produce integrated scenarios of future climate and societal change. These scenarios will underpin research by the integrated assessment and impact modeling communities on options for mitigating or adapting to climate change, as well as on estimating impacts that may occur. The research community would like to explore a large number of scenarios, but projecting climate change in each case with a large, computationally expensive climate model is infeasible. At the same time, the option of using pattern scaling as a practical and credible alternative is open to question. This workshop will have three main goals:

- Assess the current state of pattern scaling science;
- Assess to what extent current approaches to pattern scaling can meet the needs of integrated assessment and impact modelers for climate change information;
- Identify and prioritize research directions so that pattern scaling can better meet the needs of applied research in the future.

The workshop will be held on April 23-25 at the National Center for Atmospheric Research and will bring together statistical, climate, integrated assessment and impact modeling communities. A call for abstracts will be announced in fall 2013.

Goals of the meeting

While impact assessment is often carried out at regional or local scales, and therefore has additional needs (particularly downscaling) beyond pattern scaling, this meeting will focus on pattern scaling, targeting large-scale/global projections for use in impact and assessment modeling at those scales. However, the meeting will seek to locate pattern scaling within the broader set of impact and integrated assessment needs.

Specific issues to address regarding the science of pattern scaling are:

- The extent to which pattern scaling is valid over time, in addition to across forcing levels;
- Assessment of alternative simple modeling techniques in order to achieve maximum traceability to AOGCM results;
- Variables of interest to impact/integrated assessment modeling, and the need for consistency across variables;
- Spatial and temporal resolution of climate information needed for impact/integrated assessment modeling, and limits to the applicability of pattern scaling methods in addressing these needs;
- Application of pattern scaling to variables other than temperature or precipitation, e.g., scaling of regional patterns of sea level rise for use in coastal zone impact analysis;
- Uncertainty characterization and quantification.

To achieve these goals, the workshop will bring together members of the statistical, climate, integrated assessment and impact modeling communities. Sessions will focus on (1) exploration of the method's state of the art, (2) identification of the needs from user communities, (3) evaluation of whether the state of the art can meet those needs, and (4) prioritization of lines of research that should be carried out in the near term to fill the most crucial and time-sensitive gaps identified.

Possible meeting outcomes

- A meeting report that can serve as input to the design of CMIP6, including satellite MIPs related to scenarios, aerosols, and land use;
- A joint paper to be submitted to a peer-reviewed journal assessing the state of pattern scaling science, the degree to which it can currently meet the needs of impact and integrated assessment models, and the priorities for future research;
- Plans for future development of this research area, including new AOGCM runs, future meetings, special sessions at international conferences, etc.

Organizing committee

Claudia Tebaldi & Brian O'Neill (NCAR, US), James Murphy (Met Office, UK), Tim Carter (Finnish Environment Institute, FI)

Sponsors

Institute for the Mathematics Applied to the Geosciences and NCAR directorate and possibly WGCM/WCRP

The discussion noted that model uncertainties are larger than RCP uncertainties and emphasized the opportunity for CMIP to evaluate behavior of models under different forcing. Patterns scaling is known to produce accurate representation of mean surface temperature and – to a lesser extent – average precipitation, but users in the impact and integrated assessment modelling communities need other climate parameters as well (e.g., extremes).

11. Key science questions for CMIP6 – Grand Challenges

As proposed during the session, the MIPs would address the WCRP Grand Challenges and target specific science questions, MIPs would work with the CMIP panel to determine the output list for CMIP6 data requests, and determine which experiments to run and their timeframe.

12. CMIP6 Recap (Discussion)

Gerald Meehl summarized the CMIP discussions to be presented to AIMES during the joint session, noting that CMIP's role would be to provide a framework and to facilitate the MIPs' involvement and contributions around attractive science questions. The CMIP panel could help identify requirements (e.g. via a template) from MIPs and common or almost identical simulations. It was noted that most centers will want to have their own models contributing. Comments also stressed the need to address infrastructure challenges and to carefully develop the detailed output list. There were concerns about the limited size of ensemble runs and the wish to limit the number of experiments. It was recalled that the Aspen meeting recommended the same AMIP period as for CMIP5 and realistic projections in the core set of simulations. Radiative forcing experiments need improvements but their relevance in the set of DECK simulations was questioned. It was suggested to maintain a range of simulations spanning extreme scenarios. ScenarioMIP focus would need to involve the Integrated Assessment Modeling Consortium (IAMC), but actual lead on this effort is still unclear and would require further discussion. It was decided that the ScenarioMIP group would provide the connection between WGCM and IAMC for considering issues related to new scenarios and the feasibility and structure of the scenario MIP.

13. WGCM Business

13.1. Review of actions

Actions from the WGCM session are summarized in Appendix A.

13.2. Membership issues

Effective 1 January 2014, Cathy Senior will take over as WGCM Co-Chair with Sandrine Bony. At their request, Colin Jones and Nathalie Mahowald will step down at the end of 2013.

Veronika Eyring, Tony Hirst and Bin Wang would be proposed for a 2-year extension from 2015. Gerald Meehl's will step down as Co-Chair but remain a WGCM member for an additional year.

ACTION: ask WGRC for rep CORDEX on WGCM (M. Rixen)

13.3. *Next meeting*

The 18th session of WGCM will be held on 8-10 October 2014 with involvement of WGCM members, ex-officios and modeling group representatives at the Eibsee Hotel, Grainau, Germany (http://www.eibsee-hotel.com/). The session will be preceded by a Model Tuning Workshop 6-8 Oct at the same venue.

The formal 17th session was closed by both Co-Chairs who thanked all participants for their active participation in the discussions and were looking forward to the joint session with AIMES.

14. Objectives of the Joint WGCM-AIMES Session

14.1. Objectives (WGCM and AIMES Co-Chairs)

Gerald Meehl introduced the session which was probably the 4^{th} of its kind, and highlighted the fact that the carbon cycle was becoming standard in many global models, stressing the need for connections between the climate and ESM modeling communities, which was the core objective of the session. Peter Cox acknowledged the objectives and stressed the many opportunities for WGCM-AIMES collaboration on CMIP.

14.2. Overview of AIMES (P. Cox, K. Hibbard)

Peter Cox provided an overview of AIMES, its membership, the broad themes focusing on monitoring and prediction of the Earth System, the human-environment coupling and the complex system of the Planet Earth. Activities include carbon cycle model intercomparison and benchmarking projects, land-use change modeling, integrated assessment, the development of socio-economic and climate scenarios, the quantification of biospheric feedbacks, the development of carbon cycle data assimilation and emergent constraints on Earth System feedbacks and studies on tipping points and their potential precursors. He further noted that all core projects are invited to join Future Earth.

Gerald Meehl pointed out that the carbon cycle is central in linking WGCM and AIMES and wondered about the nitrogen or phosphate cycles. Further comments highlighted the gap between data assimilation/initialization and climate projections and the importance of fluxes whose uncertainties remain large. Peter Cox commented on land use change appearing as a major driver of climate change and feedback to be further explored.

14.3. Overview of WGCM (G. Meehl, S. Bony)

Sandrine Bony provided an overview of WGCM which aims to review and foster the development of coupled ocean-atmosphere models, and Earth System Models (i.e. with coupled carbon cycle, chemistry, aerosols, vegetation....), to coordinate model intercomparisons, and to promote and facilitate the models evaluation and diagnosis of shortcomings, and understanding of processes and feedbacks in the climate system. She stressed the need for critical collaborations with WGNE, WGSIP, AIMES and the MIPs to address these challenges. She further presented the objective of CMIP that is aimed at understanding past, present and future climate variability and change through a coordinated international multi-model experiment design and a common infrastructure. CMIP is coordinated across multiple climate science communities within WCRP and beyond (e.g. AIMES) and is now preparing for its

6th phase. CMIP6 will be centered around science questions including some of direct relevance to AIMES.

During the discussion, it was noted that land-use and soil moisture issues within WCRP are mainly addressed within GEWEX/GLASS.

15. WGCM and AIMES meeting summaries

15.1. Recap WGCM discussions about CMIP6 (G. Meehl, S. Bony and WGCM)

Gerald Meehl provided a recap of the WGCM discussions towards CMIP6, highlighting the various recent preparation workshops and meetings to that effect, and stressing the lead time necessary to get the intercomparison projects in motion. An EOS brief report will be further revised based on the outcomes of the WGCM17 session.

The future distributed organization of CMIP6 was presented, composed of a set of ongoing model development, evaluation and characterization of klima experiments to gain basic information about model performance and sensitivity (CMIP), a set of experiments to address science questions within the context of WCRP Grand Challenges and AIMES input specific to CMIP6 (systematic biases; response to forcings and variability; predictability and future scenarios), and specialized intercomparisons ("MIPs") that would make use of the standards and infrastructure addressing the specific WCRP Grand Challenges and science questions. The CMIP Panel would facilitate communication between MIP Co-Chairs and modeling groups, would coordinate diagnosis and evaluation simulations with the community, approve experiments and variable lists etc that are to be part of CMIP6 and would coordinate with WCRP Grand Challenges. IAM and the climate modeling community could decide which scenario non-mitigation/mitigation pairs and AOGCM/ESMs are most useful for mitigation related to land use change, short lived climate forcers and overshoot scenarios, so as to avoid running the full matrix. Within the framework of the WCRP Grand Challenges, the science foci for CMIP6 would include:

1.Interpretation of systematic biases in coupled models:
- WGOMD (forced ocean experiments);
- Process outputs;
- TAMIP/TCMIP;

2. Understanding the impact of forcings on the climate of the 20th and 21st century
- Radiative Forcing (AMIP type);
- Individual Forcings (prescribed concentration of CO_2, aerosol, ozone? specified land use, solar?).

3. Variability, predictability, and future scenarios
- Decadal climate prediction
- Scenario MIP

The discussions covered a broad set of topics relevant to CMIP6. ESGF was considered as a critical tool to support the analysis of results and the archive is still growing with new contributions. There is a need for clarity on what is meant by the CMIP5 archive for reproducibility (which model? which version?) and to think of the archive as being dynamic. The issue of integrity of CMIP experiments and feedback *to MIPs was also raised, WGCM and CMIP being considered as appropriate bodies to look into this.*

It was commented that model development was continuous and not necessarily tied to a particular CMIP iteration or IPCC report, although the relationship was somewhat symbiotic. The IPCC timetable however adds some funding constraints. Two approaches were discussed: either designing experiments fitting available resources or developing science questions and aiming for the resources.

AIMES commented on their possible contribution to all three science questions and Grand Challenges. Emission driven runs were considered as very useful for historical runs but there is a possibility to also do the concentration runs. The question arose as to how to address regional aspects of climate change which is high on the AIMES agenda and currently being addressed within WCRP under its Grand Challenge on Regional Climate Information and under WGRC/CORDEX. It was noted that C4MIP is currently not (systematically) an integral part of the WGCM plans as seen in the experimental diagrams and it was clarified that the diagrams are only notional at this early stage.

Comments on the importance of systematic biases to understand the Earth System response were made. Radiative forcing experiments are useful to answer specific science questions but less relevant for model development purposes. The pattern scaling workshop will focus on how we can exploit this approach to carefully select the relevant simulations so as to reduce the number of runs.

It was recalled that the Aspen meeting concluded with an emphasis on the importance of answering science questions, hence the focus on the analysis vs model development and on investigating user needs regarding vulnerability, impact and adaptation to climate change. An initial suggestion to develop a specific joint WGCM-AIMES Grand Challenge on carbon cycle was made and discussed. It was concluded that an alternate collaborative framework was probably more suitable.

15.2. AIMES perspectives on CMIP6 (P. Cox and AIMES)

Biospheric feedbacks and land-use change are of special interests for AIMES and the preference is to see carbon cycle feedbacks diagnosed in 1% per year runs. There is a need for free CO2 historical simulations (with land use change) to search for observational constraints on carbon cycle feedbacks. AIMES would be interested to contribute expertise on land-use change modeling. Three areas of particular interest were highlighted:

- Monitoring and Predicting Earth System Change, where the challenge is to develop and use model-data fusion techniques to diagnose and forecast changes in the Earth System (e.g. carbon cycle data assimilation, emergent constraints on Earth System feedbacks, consistent observations of biophysical and socioeconomic data);
- Human-environment coupling, where the challenge is to understand and model socio-ecological systems and their contribution to human well-being (e.g. land-use change, trade-offs;
- Planet Earth as a complex system where the challenge is to understand emergent behaviors and forecast critical transitions in the Earth System (e.g. adaptive learning, early warning indicators, tipping points).

16. What have we learned from CMIP5? Questions for CMIP6?

16.1. Design of CMIP6 scenarios (D. van Vuuren - remotely)

Detlef van Vuuren presented latest developments regarding SSP/RCP-based scenarios for CMIP6, noting that RCPs and CMIP5 are now complete whilst integrated analyses for mitigation, adaptation and impacts are underway and socio-economic pathways will be refined after community review. RCPs cover the full range of GHG emissions. Integrated Assessment Models are now exploring Shared Socio-economic Pathways (SSPs). The main architecture of new scenarios will involve a matrix of forcing levels against SSPs. The fundamental research questions being addressed are:
- can we explore together the influence of land use (albedo, CO2)?
- can we explore together the influence of short-lived forcing agents (aerosols)?
- possible exploration of the influence of overshoot?
- possible exploration of costs and benefits of mitigation and adaptation?

The first three questions could possibly be dealt with in specific MIPs. In addition, a scenarioMIP would involve the selection of set of scenarios on the basis of the SSP architecture, bearing in mind the need for a critical mass of pairs along both axes of the matrix with enough baseline/mitigation scenario pairs, an overshoot scenario. The overall number of scenarios was however unclear. The plan is to finish the development of SSPs in IAM models by early next 2014. There is a strong interest in pattern scaling to investigate the level of diversity required in the various scenarios selected.

Discussions highlighted the importance of selecting forcing-socioeconomic reference pathway pairs to answer specific questions. It was noted that some 20th century simulations could be useful to that effect. Single pair approach could suffice for the higher end forcings. Some concerns about the pairing approach were raised because of the tendency of the climate system to spread out and diffuse specific factors such as the land use changes. It was commented that the research question 1 on checking the influence of land use and question 2 on the influence of short-lived forcing agents (aerosols) can probably be taken up by the MIPs, whilst the influence of overshoots should probably fall under a scenarioMIP effort.

16.2. RCPs (R. Moss, K. Takahashi)

Richard Moss presented some general considerations on the RCP process, a.k.a. “parallel process”. He noted that there is a variety of acceptance levels regarding regional forcings. Global change scenarios are used as exogenous inputs to models, for climate projections (hence not for predictions because of underlying assumption), for assessment reports and for decision framing and feasibility testing. The parallel process on one hand provides inputs to Earth System models, which are standardized over time and avoid re-running ESMs for trivial socio-economic changes, and on the other hand, broadens the approach to socio-economic scenarios with more focus on IAV modeling applications and on the exploration of achievable pathways. RCPs provide four levels of radiative forcing (greenhouse gases, chemically active gases, derived GHGs, aerosol emissions) and land use and land

cover, and have been delivered and used in CMIP6 and impact model intercomparisons (ISI-MIP, AgMIP).
RCPs will be further evaluated and improved (e.g. interval ranges of emissions of chemically-active gases, explicit incorporation of land use in radiative forcing). Pattern scaling will be investigated towards an integration of climate, socioeconomic, and first-order impact scenarios.

Kioshi Takahashi provided a few additional comments on CMIP5/CMIP6 based on the RCPs. From the IAM community's perspective, the question for a need to extend or revise the RCPs for CMIP6 experiments was raised (which may equally apply to the SSPs), such as missing variables for the next generation of coupled model experiments, further spatial disaggregation or further temporal extension. The (in)consistency of RCP3PD with the 2 degree target was also raised, namely relating to the different representation of the carbon cycle between IAMs and bio-geochemistry models. The IAV community also suggested applying pattern scaling for climate parameters other than temperature and precipitation (e.g. solar radiation, directly affected by aerosol emissions) and highlighted the need for some guidance material for IAV researchers to utilize CMIP5/CMIP6 data more appropriately.

The discussions highlighted the wide opportunities for collaborations between WGCM, IAM and VIA communities as illustrated by the overlapping areas of interest. Critical science and societal questions could help framing these.

16.3. LUMIP (G. Hurtt - remotely, M. Rounsevell)

George Hurtt presented on the topic of land use and provided a summary of lessons learned from CMIP5, questions for CMIP6, and a proposal for a Land-Use Model Intercomparison Project (LUMIP). For CMIP5, the "land-use harmonization" strategy was noted for combining historical land-use information (1500-2005), and future projections of land-use from IAMS (2005-2011), into a single consistent spatially gridded product required for coupled model input. This strategy was noted for meeting community needs, and enabling the first global projections of both atmospheric CO2 and climate that include both the biogeochemical and biophysical effects of land-use. CMIP5 simulations showed that land-use effects on global climate are generally modest relative to fossil fuel but still important. Land-use transitions are needed for accurately tracking land cover change resulting from land-use change. Land-use effects are complex and challenging to diagnose. Different models implemented standardized land-use data sets differently. Potentially important impacts are management practices, biophysical effects, policy options, uncertainties, and feedbacks not adequately accounted for in current design. It was noted that substantial opportunities exist to build on CMIP5 approach for CMIP6.

For CMIP6 it was suggested that the land-use "harmonization" be repeated and improved with more data, increased resolution, longer period, better communication between groups, and improved standardization of products and usage of products. Also suggested was a better linkage between land-use change and land-cover change, a new emphasis on land use management, an expansion of RCP radiative forcing to include biophysical aspects, and a joint harmonization of land use emissions and land-use changes. The need to prepare now for fully coupled human-physical models was also noted.

To help meet these challenges for CMIP6, a proposal was submitted and summarized to establish the Land-use Model Intercomparison project (LUMIP). The LUMIP concept was conceived in the CMIP6 planning workshop in Aspen Summer 2013. It was proposed that LUMIP will address the effects of land use and land-use change on climate (past-future) and the effects of climate change on land-use and land-use change. It would have 3 main activities (model metrics, data standardization, and model experiments). LUMIP will be coordinated by a small interdisciplinary team and will report to CMIP6 panel. Importantly, LUMIP will provide the link to the CMIP6 panel and other satellite MIPS, and will engage and work with all relevant scientists and other related activities including: AGMIP, C4MIP, Trendy, GLP, iLeaps, LUCID, etc. Workshop(s) are being proposed for spring and summer 2014 to get LUMIP off the ground.

Discussions advised liaison with the metrics panel in developing diagnostic protocols and quantifying model performance. Coordination with the LUCID (Land-Use and Climate, Identification of robust impacts) project established under the auspices of IGBP-iLEAPS and GEWEX-GLASS were suggested. The planned workshop in spring 2014 will look into forcing components and the number of minimal scenarios to bound uncertainties on land use changes. Modelers stressed the need for land cover information in addition to land use.

Mark Rounsevell outlined the challenges of modeling land use change futures impacting on the climate system via biochemical (C fluxes, N emissions, etc) and biophysical (albedo, roughness, evapotranspiration, heat fluxes) processes. Integrated Assessment Models (IAMs) are currently the main way to model global scale Land Use and Land Cover Changes (LULCC) but other models exist as well. IAMS link to Computable General Equilibrium (CGE) models to represent economic sectors. But the land use modelling community rarely engages in global scale applications. LULCC do not yet fully address human behaviour and decision making processes, adaptive learning and agent evolution, societal structures such as networks and interactions, endogenous institutions, global teleconnections other than trade, technological development, etc. The LUC4C EU FP7 project on "*land use change: assessing the net climate forcing, and options for climate change mitigation and adaptation* " was briefly presented and aims to improve LULCC representation in climate modeling by undertaking a comparison of IAMs and global scale LULCC models. Alternatives to IAMs are being explored at the global scale.

The point was made that process studies require land-use changes instead of land cover. The main drivers of land-use models are economic activity and technology improvement (yield increase). Results presented were based on "one" Integrated Assessment Model, which adopts a top-down approach, as opposed to the bottom-up agent-based models currently under consideration.

16.4. Biogeochemistry (N. Mahowald, A. Arneth)

Nathalie Mahowald reviewed the general framework IPCC WGI is operating in and contributing to, by ensuring the link between radiative forcings (e.g. CO2, GHG, aerosols, O3, land surface) and the climate response, whilst IGBP was mainly focused on the role of human activities (e.g. emissions, land use management) on radiative impacts. WGII focuses on impacts and vulnerability to climate response, whilst WGIII deals with societal responses (economics and policies) to influence human activities. She recalled that the goal of WCRP Grand Challenges is to provide actionable information for decision makers.

The dominant biogeochemical feedback considered in the models is the carbon cycle feedback, which was well considered in the CMIP5 and is likely to remain important and active in CMIP6 as described in the C4MIP activity. Other important feedbacks are being discovered and described (e.g. Arneth et al., 2010). At this stage, important feedbacks are being modelled in offline simulations, and then identified as to their importance. For example, earth system models are beginning to incorporate methane fluxes from natural wetlands. However, at this point, it is not clear that these studies are sufficiently mature to need to be incorporated into the CMIP process, although further comparisons and MIPs should be encouraged.

A large gap in the CMIP5, as well as in the WGCM and CMIP panel, are the analyses of anthropogenic aerosols in the coupled system. They were largely unanalyzed in the CMIP5, and what little analysis there was suggests a problem with the simulation (e.g. Schindell et al., 2013). As there is currently no plan to improve either the ability of CCMI or CMIP to evaluate aerosols and their simulations, it is likely this gap will remain a problem with the CMIP6. An important step forward is the proposed RFMIP, which will allow assessment of at least the resulting radiative forcing portion of the aerosol feedbacks.

Because humans modify emissions and land surface, but do not directly modify concentrations or radiative forcing, understanding the relationship between emissions and radiative forcing is an important part of WCRP's goals. However, the grand challenges identified and pursued by the WCRP do not include any evaluation or attempts to improve of the part of the uncertainty that relates human activities (e.g. emissions) to radiative forcing, unfortunately. Thus, the grand challenges of the WCRP are missing important processes, making it impossible for WCRP to achieve its goals as it stands. It is important that WCRP incorporate new grand challenges, in collaboration with former IGBP projects, such as the carbon cycle feedbacks and uncertainties in forcings from aerosols, ozone and land surface change.

A workshop is proposed to develop forcing estimates from 1870 to present, with a particular attention to aerosols, land use (biophysical component) noting that the carbon cycle is already taken care of. The workshop would involve the detection and attribution, aerosol, land biophysical response and radiation communities towards producing multiple time series of radiative forcing and associated uncertainties in a two-year time frame.

Arneth, A., Harrison, S., Zaehle, S., Tsigaridis, K., Menon, S., Bartlein, P., Feichter, J., Korhola, A., Kulmala, M., O'Donnell, D., Schurgers, G., Sorvari, S., Vesala, T., 2010. Terrestrial biogeochemical feedbacks in the climate system. Nature-geoscience 3, 525-532; DOI: 510.1038/NGEO1905.

Schindell, D., Lamarque, J.F., Schultz, M., Flanner, M., Jiao, C., Chin, M., Young, P.J., Lee, Y., Rotstayn, L., Mahowald, N., Milly, G., Faluvegi, G., Balkanski, Y., Collins, W., Conley, A., Dalsoren, S., Easter, R., Ghan, S., Horowitz, L., Liu, X., Myhre, G., Nagashima, T., Naik, V., Rumbold, S., Skele, R., Sudo, K., Szopa, S., Takemura, T., Voulgarakis, A., Yoon, J.-H., Lo, F., 2013. Radiative forcing in the ACCMIP historical and future climate simulations. Atmospheric Chemistry and Physics 13, 2939-2974.

It was suggested that the meeting could be jointly hosted by AIMES and WCRP with involvement of A. Arneth and ETH. This initiative was welcome as it fills a critical gap and combines lots of issues (aerosols, volcanoes, etc), would provide further insights into the hiatus and could also be of interest to the decadal prediction effort. The 1870 date was debated as some groups are also working from 1850.

Some further comments were made about the non-linearities of feedback mechanisms which are not additive and may operate differently under different scenarios. Net effect can be close to zero. It was also noted that uncertainties on CO2 from permafrost remain very large. There is a need to reconcile land use change and dynamic vegetation models with RCPs, raising the wider question on the harmonization between IAM models.

16.5. CCMI (V. Eyring)

Veronika Eyring reported on on-going activities within the IGAC/SPARC Chemistry-Climate Model Initiative (CCMI, http://www.met.reading.ac.uk/ccmi/). This activity presents a new era of cooperation between SPARC (Stratosphere-troposphere Processes And their Role in Climate) and IGAC (International Global Atmospheric Chemistry). It builds on the previous success of the SPARC Chemistry-Climate Model Validation (CCMVal) activity and, in response to SPARC's goal of extending its reach into the troposphere, incorporates core aspects of the former IGAC/SPARC Atmospheric Chemistry and Climate collaboration. Also, new phases of the Atmospheric Chemistry-Climate Model Intercomparison Project (ACCMIP) will merge with the CCMI activities. The goals of CCMI are to (a) contribute to the understanding and improved representation of chemistry-climate processes in global models, (b) to facilitate and improve comparability for model-observation comparisons, and (c) to provide simulations and analysis for process studies and in support of upcoming WMO ozone and IPCC climate assessments. To that end, CCMI Phase 1 (CCMI-1) simulations have been defined to support the 2014 WMO/UNEP Scientific Assessment of Ozone Depletion, and to form an ensemble for a first comprehensive inter-comparison of transient chemistry-climate hindcasts of the late 20th and early 21st century, spanning both the troposphere and stratosphere (*Eyring et al.,* JGR, 2013). In Phase 2, CCMI will be one of the CMIP6 Satellite Model Intercomparison Projects (MIPs) and will support CMIP for example with contributions to updated historical emissions and harmonization with scenarios (*Lamarque et al.*, ACP, 2010), with forcings (e.g. an update of the IGAC/SPARC ozone database by *Cionni et al*. ACP (2011), and with simulations. CCMI will also help evaluating chemistry-climate interactions in the *CMIP diagnostic, evaluation and characterization experiments* in particular in those CMIP6 models with interactive chemistry and will provide related diagnostics and performance metrics for a CMIP benchmarking and evaluation tool.

Discussions addressed the impact of air quality policies on climate change. The question arose whether to use simplified aerosols versus AERONET zonally averaged data for prescribed forcings. The recommendation for historical decadal prediction could be to use prescribed O3. Ideally, aerosols should be computed on-line. Many models might be high-top in the next CMIP iteration. AMAP was highlighted as an opportunity for collaboration on short-lived GHG species in the Arctic.

16.6. C4MIP (P. Friedlingstein - remotely, V. Brovkin)

Pierre Friedlingstein provided an overview of lessons learned from C4MIP, to which 11 modeling groups contributed covering a range of simulations (1%, BGC, RAD, concentration driven and emission driven historical runs and RCPs. The work has generated over 30 publications, a special issue in J. Climate and contributions to AR5 (chap 6, chap 12, TS and SPM). Key messages in the IPCC AR5 SPM that come from C4MIP-related activities are for example: Cumulative emissions of CO2 largely determine global mean surface warming by the late 21st century and beyond - , Climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere (high confidence). - Ocean uptake of anthropogenic CO_2 will continue under all four RCPs through to 2100, with higher uptake for higher concentration pathways (very high confidence). - By 2050, annual CO_2 emissions derived from Earth System Models following RCP2.6 are smaller than 1990 emissions (by 14% to 96%)..

CMIP5 fostered more ESMs with carbon cycle, more in-depth analysis and publications. However, compared to AR4, more processes (land use change, nitrogen cycle) have artificially enhanced the models spread. Also, the carbon cycle was not part of the essential set of metrics during the development/adjustment phase of CMIP5. Something that needs to be considered for CMIP6, in particular for emission driven simulations.

Essential recommendations for CMIP6 include a stronger model evaluation effort with dedicated tuning and evaluation. Metrics such as atmospheric CO2, ocean carbon uptake, land carbon stored in vegetation and soil are available for models evaluation.

CMIP6 simulations should allow to estimate the transient climate response to cumulative emissions (TCRE) of ESMs, for example using simple scenarios (e.g. 1% scenario), and also allow to estimate the carbon cycle feedbacks (e.g. CO_2-carbon (beta) and climate-carbon (gamma) e.g. from two or three 1% scenarios.
Future of carbon cycle and compatible emissions can be diagnosed from new scenarios (SSPs/RCPs matrix) which are more policy relevant. Core simulations should include control runs, 1% CO_2, and historical runs with prescribed CO_2 emissions.

Victor Brovkin complemented the presentation by proposing repeated CMIP5 1%-CO_2 experiments to quantify climate CO_2 feedback in fully coupled mode, in biogeochemically coupled mode and radiatively coupled mode to quantify the effective radiative forcing of several biospheric components (e.g. fire emissions). Emission-driven historical simulations are suggested to benchmark carbon cycle against observations and emergent constraints whilst future runs would be both emissions-driven and concentration driven. He also highlighted the need for interactive CH_4 and N_2O simulations, and EMICs runs with CO_2-pulses to quantify atmospheric CO_2 fraction after 1000 and 10,000 years.

Discussions commented on the pros and cons of emission vs concentration runs. For ESMs and C4MIP, it was recommended to use emission runs pending available resources. For 1% scenario, prescribed concentrations should be used. For CMIP "DECK experiments" in general, concentration runs are recommended, then emission runs for comparison with observations are needed. Differences in 20th century CO_2 *levels are still considered as a model development issues rather than a model tuning issue for which a systematic process is not in place yet.*

17. Towards CMIP6

17.1. Science questions for CMIP6

Examples include:

How can we encourage model evaluation and improvement before scenario runs?
Which new feedbacks will be included for CMIP6, and which WGCM and AIMES activities are required to support these? Are new datasets required?
Can we begin to answer questions on the likelihood of climate “tipping points”?
What questions do we want to address with scenarios?
How do we ensure a balance between scenarios that have scientific relevance and scenarios that have policy relevance?
How different should the scenarios be to provide different climate responses?
How different should the scenarios be to provide different socio-economic responses?
How much can we understand the climate responses to scenarios based on pattern scaling?
How can we make the most of emergent constraints?
Others to be collected from discussions through the day…..

Discussions wondered about the best coordination mechanism for a WGCM-AIMES collaboration. The initial idea of an additional WCRP Grand Challenge focusing on biospheric forcings and feedback evolved into a collaborative WGCM-AIMES framework which could be packaged to also meet e.g. the Future Earth agenda. It was stressed that C4MIP be included in this framework together with other possible foci of interest such as iLAMB (land use, impacts, systematic biases), human geosphere, ocean upwelling (e.g. MAREMIP, covering e.g. the tropical and southern ocean).
It was commented that the WCRP Grand Challenge on cryosphere addresses some carbon issues and that there is a need to ensure coordination between the WGCM-AIMES collaborative framework and WCRP Grand Challenges in general.

17.2. Suggestions of coordinated experiments

Several areas of WGCM-AIMES collaboration where discussed and suggested. It was clear that the scope of C4MIP spans beyond pure carbon cycle issues. Opportunities exist for several MIPs to include a carbon component in their simulations (e.g. PCMIP for a paleo carbon project). iLEAPS could include a focus on systematic biases due to land and atmosphere interactions.

17.3. Connections to analysis

A workshop is tentatively scheduled for Spring 2015 to foster CMIP5 model analysis with a specific focus on Grand Challenges and the aim to encourage people to analyze available simulations.

17.4. Opportunity for a ScenarioMIP?

A small steering committee will be formed to decide the best way to consolidate this by sub-sampling available runs to best represent a large set of simulations, and addressing issues of pairing runs (SSP/RCP). Possible updates on RCsP remained an open question at the Aspen meeting. It was noted that several groups run RCP simulations with different land use and there is a need for coordination within this community. It was suggested to test pattern scaling on various RCPs. Ideas about idealized land use changes (e.g. w/wo Amazon forest) experiments were proposed, which may be part of LUMIP.

17.5. SSP/RCP matrix: questions, sampling strategy, etc.

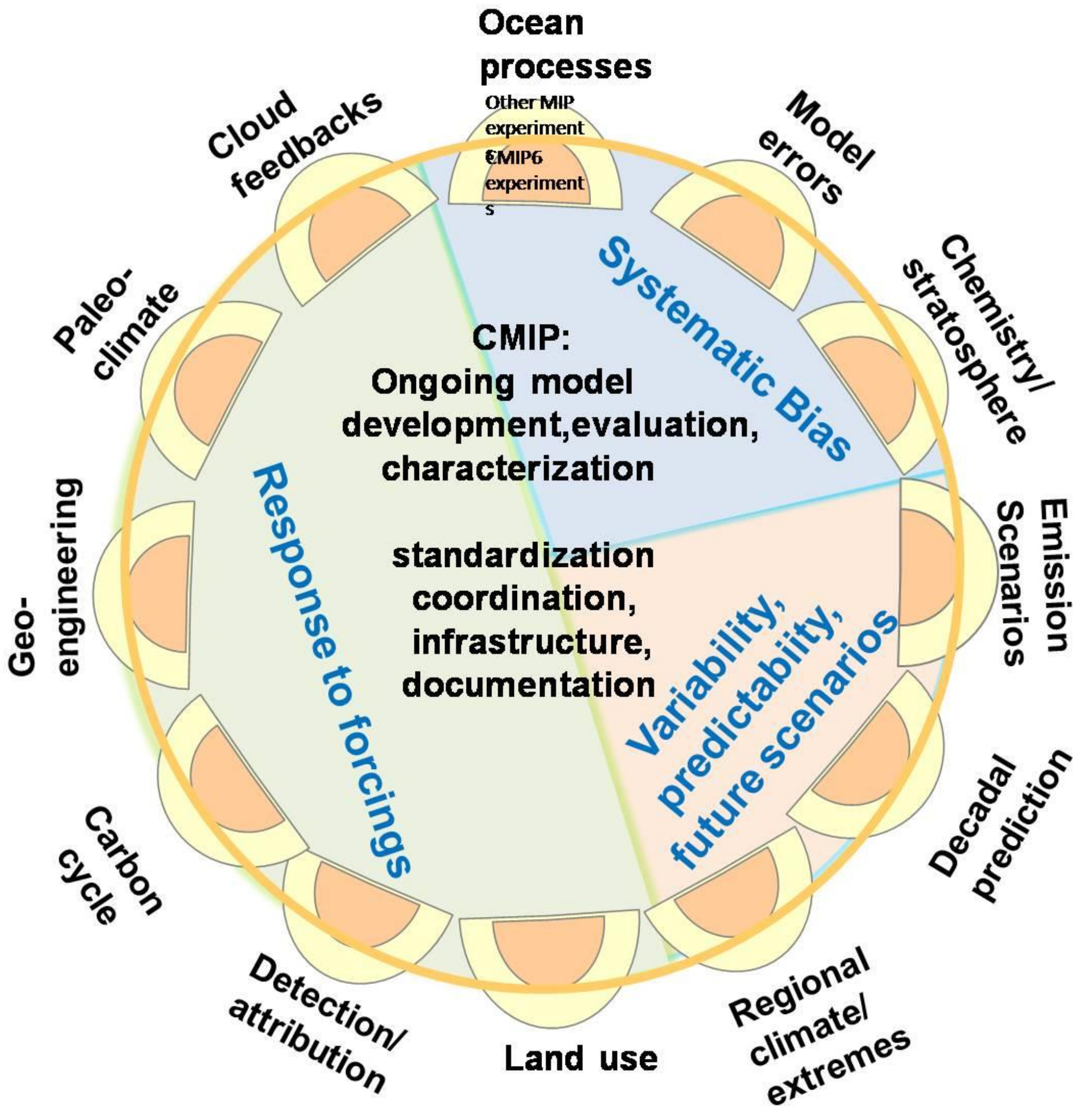
The decision was made to the use of pattern scaling on available simulations to investigate whether the method can provide further insights on the SSP/RCP matrix sampling.

17.6. Scope and outline of the pattern scaling workshop

See summary above.

17.7. Recap of the session and adjourn

The discussions were summarized and concluded on the Action list outlined in Appendix A. The notional figure on a proposal for the CMIP design below represents, in a nutshell, the outcome of the WGCM17 and joint WGCM-AIMES sessions. The joint WGCM-AIMES session was closed by Co-Chairs who thanked all participants for their active participation in the discussions and were looking forward to the active engagement of all towards the agreed actions.


Ocean processes
Other MIP experiments
CMIP6 experiments
Model errors
Chemistry/ stratosphere
Emission Scenarios
Decadal prediction
Regional climate/ extremes
Land use
Detection/ attribution
Carbon cycle
Geo- engineering
Paleo- climate
Cloud feedbacks
Systematic Bias
Variability, predictability, future scenarios
Response to forcings
CMIP:
Ongoing model development,evaluation, characterization
standardization coordination, infrastructure, documentation

Appendix A: Actions

WGCM17 ACTION

ACTION 1: update MIPs web pages (V. Eyring, M. Rixen)

ACTION 2: identify 2-3 main science questions for a possible Transpose-CMIP (WGCM Co-Chairs)

ACTION 3: ask WGRC for a CORDEX representative on WGCM (Co-Chairs, M. Rixen)

ACTION 4: address Transpose-CMIP on next WGNE conference call and session (M. Rixen, J.-N. Thépaut)

ACTION 5: ensure CLIVAR representative receive the CMIP5 survey (V. Eyring)

ACTION 6: WGCM to form a CMIP infrastructure panel with ToR and nominations (V. Balaji and K. Taylor)

JOINT SESSION ACTIONS

WGCM

ACTION 7: form a small steering group to come up with some recommendation regarding ScenarioMIP (Co-Chairs)

ACTION 8: update EOS draft following joint session including carbon cycle and C4MIP (G. Meehl with CMIP panel and R. Moss)

ACTION 9: CMIP to seek MIPs inputs for simulations and rationale for doing it (V. Eyring)

ACTION 10: identify people who can ensure the connection between WGCM-AIMES collaborative framework and WCRP Grand Challenges (WGCM Co-Chairs)

AIMES

ACTION 11: draft a document on biosphere forcing and feedback covering cross WGCM-AIMES collaboration and send it to CMIP panel to include C4MIP (WGCM and AIMES Co-Chairs, CMIP chair)

ACTION 12: apply iLAMB approach to look at systematic error on land use with focus on some important biases: warm bias on US and Europe land, surface albedo, diurnal cycle on tropical convection etc

ACTION 13: investigate possible research on systematic biases due to land and atmosphere interactions (AIMES Co-Chairs)

ACTION 14: organize a workshop on emissions: establish steering committee, investigate funding options, etc

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