PROJECT REPORT

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

Dubrovnik, Croatia
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MEMBERS: Sandrine Bony (WGCM Co-chair), Cath Senior (WGCM Co-chair), Veronika Eyring (CMIP Panel Chair), Pierre Friedlingstein, Masa Kageyama, Michio Kawamiya, Simon Marsland, Gerald (Jerry) Meehl, Bjorn Stevens, Claudia Tebaldi, Bart van den Hurk, Detlef van Vuuren, Bing Wang

EX-OFFICIOS: Gokhan Danabasoglu, Filippo Giorgi, Peter Gleckler, Gerard Krinner, Ron Stouffer, Karl Taylor

INVITED EXPERTS: Julio Bacmeister, V. Balaji, Peter Gleckler, Michaela Hegglin, George Hurtt, Martin Juckes, Beiping Luo, Katja Matthes, Malte Meinhausen, Paolo Nobre, Swapna Panickal, John Thomas Peter, John Scinocca, Dean Williams and MIP co-chairs

WCRP JPS: David Carlson, Michel Rixen

EXCUSED: Greg Flato, Filippo Giorgi, Bill Gutowski, Christian Jakob, Jean-Noël Thépaut, Ayrton Zadra

1. WGCM session

a. Welcome and introduction (WGCM Co-chairs)

WGCM Co-chairs, Sandrine Bony and Cath Senior, thanked all participants for their attendance and Michel Rixen for his help in the preparation of the meeting. They highlighted the importance of this session to review the progress on the CMIP6 implementation. A quick round table allowed everyone to introduce themselves.

b. WCRP update (David Carlson)

David Carlson provided a short update on WCRP, noting 2 new Joint Planning Staff (JPS) staff members (Boram Lee and Mike Sparrow) and 2 junior interns (Gaby Langendijk and Matthias Tuma), the decreasing funding under pressure given changes in the CHF exchange rates and fewer national contributions. He highlighted the need to promote CMIP as a successful WCRP activity, as it is sometimes wrongly considered as an IPCC initiative. The next JSC will be held in April in Geneva for carbon efficiency. He confirmed that the Grand Challenges are part of the priority efforts to be financially supported.

c. WMAC update (Gerald Meehl)

The role of WMAC is to provide the WCRP community with a go-to point for modeling beyond individual Projects, WGs and GCs, to discuss and pursue issues that cut across several or all modeling groups, to identify topical

science connections across the WGs, to leverage communication and scientific synergies, and to advise the JSC, Core projects and GCs on modeling issues.

One of the main activities of WMAC is the Joint WCRP/WWRP Model Development Prize. It was established and first awarded in 2014. There was a strong field of 17 nominees, and the first winner was Peter Lauritzen from NCAR. The award consists of a certificate and funding to go to a meeting of the awardee's choice. The process for the second award started with a call for nominations that came out in July, 2015, with a 1st October deadline. The judging is currently in progress.

Another activity of WMAC is organizing the Model Development Summer School. The first school was held 15-26 June, 2015, in Hamburg, with the topic: Atmospheric Moist Processes. This was a highly competitive process, with 240 applicants for 40 places. The next school is planned for 2016 or 2017. Volunteers will be sought through a letter to all modeling centers soon. Early contact has been made with some groups that have expressed interest in hosting the second summer school.

WMAC made a number of recommendations to JSC regarding modeling in WCRP. WMAC viewed the structure of the modeling groups in WCRP as solid and functioning. While other structures could be envisioned, there is no obvious one that would be more suitable or efficient. However, communication between the groups should be improved through regular joint meetings of the WGs, and by instituting a Modeling "Olympics" which would be a joint meeting of all modeling groups every 4 years (or so; MPI offered to host the first installment in 2017 in conjunction with their Earth System Modeling workshop, and the structure of modeling activities in WCRP could be revisited at this meeting). WMAC recommended a name change for WGSIP to recognize its role in all initialized prediction, and also recommended integration of CORDEX into the WGRC as its core modeling activity, similar to the integration of CMIP into WGCM. WMAC recommended that the individual modeling WGs continue to report to the JSC directly, but with even shorter and more targeted reports to allow time for discussion of WCRP modeling with JSC in plenary.

All modeling groups expressed great support for the current role, structure and meeting strategy of the WMAC with the recommendation of maintaining it as is. It was recognized that the Earth System Grid Federation would host of all WCRP data, from both models and observations. WMAC recommended the formation of a small team to engage with ESGF to see what can and cannot be done, and to begin developing a plan accordingly, with communication with JPS about training needs regarding the ESGF.

Regarding the WMAC Summer Schools (and other training programmes), WMAC recommended that a plan be designed for providing a legacy, e.g., recording and web hosting of lectures. Additionally, WMAC recommended that JSC consider nominating members to oversee and help implement the summer school/training programme.

For the modeling prize, WMAC recommended that the selection criteria be refined and that re-nomination of excellent candidates from last round be encouraged. Regarding CMIP, WMAC supports the role of the DECK experiments as an entry card to CMIP, but urges the introduction some limited flexibility where appropriate, e.g., Decadal MIP. WMAC recognizes the important role played by AIMES in connecting to WGCM with expertise in biogeochemistry in Earth System Models. There are issues around the future of AIMES. WMAC will monitor the situation and report at next JSC

WMAC recommends expanding the scope of the WGNE-WGCM climate metrics panel to (i) include model diagnosis and (ii) cover the WCRP as a whole. This will likely require a multi-step process that would include forming a small team to look into hosting model diagnostic tools for the use by the wider in a WCRP repository. For Earth System Reanalysis, WMAC recommended monitoring existing efforts in modeling centers and potentially inviting a presentation at next JSC/WMAC meeting. WMAC recognizes the need to continue supporting re-analyses of the physical systems as many improvements are still needed, e.g., water cycle, tropical states. For Transpose CMIP, WMAC recommended using the WGSIP "Drift" project as pilot study and potential nucleus, and invited a report on this at next WMAC meeting.

Dave Carlson noted the JSC wish to simplify the structure of modeling groups, and to promote a data prize. He thanked WMAC for the successful implementation of the summer school and prize. He further noted the successful extremes summer school which resulted in a special issue. Sandrine Bony suggested that all DCVP, OMDP could play a role in the WGSIP initial shocks and drifts sub-project. Bjorn Stevens noted there was a survey to find out what applicants were hoping to get out of the school.

d. CMIP6 status and discussion (Veronika Eyring)

Veronika noted that this meeting would focus essentially on near-term issues. The DECK and the CMIP6 Historical Simulation are requested from all models participating in CMIP. The expectation is that this requirement will be met for each model configuration used in the subsequent CMIP6-Endorsed MIPs (an entry card). In the special case where the burden of the entry card simulations are prohibitive but the scientific case for including a particular model is strong (despite only partial completion of the entry card simulations), an exception to this policy can be granted on a model by model basis (as long as it can be demonstrated that the performance and characteristics of the models are sufficiently evaluated and documented) based on a specific recommendation to the CMIP Panel made by the chairs of the affected CMIP6-Endorsed MIP. The importance to have historical runs and controls runs was raised. Some members noted that 500 years might not be necessary for emission driven runs but others argued that there are drifts in models and that 500 years should be enforced. It was suggested to update the text material explaining the considerations on the runs. Julio Bacmeister remarked that the Tier 1 run

for HighResMIP is an AMIP simulation. Claudia Tebaldi noted that ScenarioMIP runs should be consistent with what the modeling groups do on the DECK runs. Karl Taylor volunteered to coordinate a discussion on forcings and volcanoes where DAMIP could provide some recommendations/best practices.

The issue of number of models for each MIP was discussed and it was recommended to focus on the completion of MIPs. It was further suggested that the communication should happen primarily between MIPs and modeling groups. MIPS may spread their efforts over a number of years and many groups will aim for the IPCC timeline anyway but at their discretion.

The importance of the timeline on forcings data availability was stressed. Karl Taylor suggested publishing the forcing data like for CMIP5 on the PCMDI web page and make them available through the ESGF.

e. CMIP6 infrastructure and discussion (V. Balaji/Karl Taylor)

The WGCM Infrastructure Panel was formed in response to the WGCM's (2013) expressed need to provide scientific guidance and requirements for the global data infrastructure underpinning global climate science and modeling. This infrastructure includes ESGF software, and other tools: ESDOC, CoG, CMOR, CF Conventions, etc.

Chaired by V. Balaji (Princeton/GFDL) and K. Taylor (PCMDI), it outlined in 2014 a strategy to develop a series of "position papers" on global data infrastructure and its interaction with the scientific design of experiments; and to present them to the WGCM annual meeting for endorsement by the WGCM, the CMIP Panel, and the modeling groups.

A series of position papers were unveiled at the WGCM-19 meeting (2015) in Dubrovnik. Highlights include:

- Formation of CDNOT: WIP recommended to the WGCM and CMIP panel the formation of a technical consortium charged with operationalizing the CMIP6 ESGF Federation: the CMIP6 Data Node Operations Team (CDNOT). The CDNOT was approved in June 2015, with Sebastien Denvil (IPSL) as Chair.

With the formation of the CDNOT, the governance of infrastructure has been split into requirements (WIP), implementation (ESGF Executive Committee and other bodies undertaking software development) and operations (CDNOT). Overlapping membership on WIP, WSGF-XC and CDNOT ensures close cooperation.

- CMIP6 Data Request: Led by Martin Juckes (STFC), the CMIP6 data request is now available in machine-readable formats, with associated tools for processing and analysis.

- Data reference structure: WIP documents are being finalized covering data syntax, vocabularies, filenames and global attributes. When these are final, the CMOR and DRS specifications are considered “frozen” and modeling groups can begin constructing workflows on this basis.

- Data format: The WIP recommends the use of netCDF4 with lossless compression as the data format for CMIP6.

- Standard grids and calendars: The WIP has initiated discussion with modeling groups regarding standard grids and calendars for output data; those discussions are not yet at consensus.

- Model metadata: ESDOC documents of model metadata are a required element in quality control and DOI generation.

- Persistent identifiers (PIDs): The WIP recommends a method for tracking datasets through creation and eventual use, using PIDs. PIDs will be the basis for replication, versioning, error reporting, and usage tracking of datasets in peer-reviewed literature.

- Data citation: The WIP further recommends a mechanism for generation of DOIs at the granularity of model and simulation, and citation is now required as part of the terms of use.

- Data licensing: The WIP proposes a simplified licensing scheme, wherein licenses are embedded in files. Two license options (open access share-alike, and non-commercial share alike) are proposed.

- Data volume estimates: Once some aspects of the data request are finalized, the WIP will issue preliminary estimates of aggregate data volume for CMIP6, taking into account number of models, years simulated, and increase in resolution.

The 11 position papers currently in draft, and others in progress, will be available on the WIP website, https://www.earthsystemcog.org/projects/wip/resources/

It was suggested to compile these position papers into a summary paper for the GMD special issue. Veronika Eyring recommended that endorsement on these issues comes from WGCM and not from the CMIP panel. She noted the potential absence of some variables if not claimed.

A few variables will dominate the data volume but file size is not a problem anymore. Groups will need to upgrade to the NetCDF4 lossless compression standard, but it is unlikely that they will be offered a NetCDF3 download capability.

In order to recognize efforts of modeling centers, some nice tools could be made available (e.g. bibtex, citex, doi) to facilitate this.

Sandrine recommended a list of information to be included in papers describing models. Regarding grids, it was suggested that model groups do the interpolation, as they know best how for example to conserve properties, but that frequently used fields would be published on a common grid.

Comments were made about the ES-DOC effort, including: the need for the documentation to be traceable to the peer-reviewed scientific literature, the strong desire for modelling groups to not have to duplicate documentation efforts, and the thought that a more graduated approach, which starts by trying to identify a common denominator of routinely provided information and what is desired by ES-DOC. These comments will be transmitted to the ES-DOC team.

f. ESGF and discussion (Dean Williams, remotely)

Dean Williams presented a ESGF update on behalf of the ESGF Executive Committee and Development Teams.

The Earth System Grid Federation (ESGF) is an international collaboration to create open-source software and infrastructure that empowers the study of climate science (http://esgf.llnl.gov/). The mission of ESGF is to create and maintain a robust federated data grid for the international climate-research community with access to relevant data, information, analysis and visualization tools, hardware, and network capabilities to make sense of peta/exa-scale scientific data. ESGF facilitates advancements in climate science by providing:

1. An easy-to-use and secure federated web-based software data infrastructure for large climate data sets;
2. A flexible infrastructure that enables customization by participating data projects to address their specific requirements;
3. High-performance search, analysis, and visualization tools that ensure data accessibility for and usefulness to the climate research community;
4. Access to a broad set of data and tools for comparative and exploratory analysis; and
5. A virtual collaborative environment for diverse research and analysis tasks with large and varied data sets.

ESGF is driven by a collection of independently funded projects that develop, deploy and maintain the necessary open-source software infrastructure to meet the above-mentioned goals. It is a successful international collaboration that manages the first-ever decentralized database for handling climate science data, with multiple petabytes of data at dozens of federated sites worldwide. ESGF's widespread adoption, federation capabilities, broad developer base, and focus on climate science data distinguish it from other collaborative knowledge systems. The ESGF distributed archive holds the premier collection of simulations, together with observations, and reanalysis data to support analysis of simulations. Making it the leading source for today's climate model data holdings—including the most important and largest

data sets in the global climate simulation community. In the future, ESGF intends to widen its scope to include other climate related data sets such as downscaled model data, climate predictions from both operational and experimental systems, and other derived data sets.
The ESGF production environment supports multiple international climate projects, including the WCRP Coupled Model Intercomparison Project (CMIP), whose protocols enable the periodic assessments carried out by the Intergovernmental Panel on Climate Change (IPCC). The data holdings and services in ESGF are distributed across multiple sites (such as BADC, DKRZ, IPSL, LLNL, NASA, NCI, NOAA, the Asian communities, and many more).
ESGF has greatly amplified the value of numerical climate model outputs and climate observations for current and future climate-assessment reports. However, the ESGF team faces substantial technical challenges due to the rapidly increasing scale of climate simulation and observational data, which is expected to grow to tens of petabytes in the next five years. In a world of exponential technological change and rapidly growing sophistication in climate data analysis, ESGF must constantly evolve to remain useful. Fortunately, ESGF's well-defined governance structure helps to ensure that ESGF is advancing in directions that are most relevant to its supported user communities.
For more information on the current state of ESGF, see the Annual Earth System Grid Federation Conference Reports (Lawrence Livermore National Laboratory, Livermore, CA, LLNL-TR-666753; available online: http://esgf.llnl.gov/reports.html).

Members highlighted the importance to ensure the long-term funding for ESGF, which has been made available by DoE and IS-ENES in particular.

The WIP co-chairs welcomed clear timelines and information for ESGF planning such as upload start dates and data volume.

g. WGCM Business (closed session): membership, next session (venue, dates, topics)

There are 3 terms ending in 2016. S. Bony will rotate off at the end of 2016. J. Meehl will rotate off WGCM but will remain in the CMIP panel. Membership specifics were discussed off-line.

It was proposed to hold the 2016 session in October. Considering carbon footprint implications, the following venues were mentioned: PCMDI, Abu Dhabi, Geneva, Boston, Boulder, Princeton.

The WGCM workshop on model tuning held in 2014 was a big success (a paper about its outcome is in preparation), and it was proposed to organize another one in 2016, right before or after the next WGCM session. The following topics were suggested:
- hierarchy of models
- high-resolution modeling

- CMIP
- dynamical cores
- drift and shocks

After discussion, it was decided to focus the next workshop on the “hierarchy of models”. The workshop will discuss the value of using a hierarchy (or spectrum) of models of different complexities, either in their configuration or in their physics, to understand the results of the comprehensive CMIP models. It will be a joint WGCM/Cloud-GC workshop. An organizing committee will be set up soon. Post meeting consultations confirmed Princeton as the venue for the WGCM20 session and the model hierarchy workshop.

The WCRP Model Advisory Council is also promoting the idea of a joint meeting of all Working Groups in 2017.

2. CMIP6 Introduction

a. Welcome (WGCM co-chairs)

WGCM Co-chairs, Sandrine Bony and Cath Senior, thanked all participants for their attendance and welcomed the MIPs co-chairs. They recalled the WGCM mission and highlighted the importance of this special session focused on CMIP forcings and thanked the community for their engagement and contribution to CMIP6. A quick round table allowed everyone to introduce themselves.

b. CMIP6 recap (Veronika Eyring)

Veronika Eyring provided a short summary status on the CMIP6 implementation, which includes all MIPs, and highlighted the unique opportunity to have all key people in the room. The CMIP panel will coordinate DECK and the CMIP6 Historical Simulations, and also the GMD special issue. David Carlson noted there is a degree of moderation in these journals, where editorial decisions can go back to review comments.

3. CMIP6 Forcings

a. Historical SLCF and GHG emissions – Bill Collins

On behalf of Steve Smith, Bill Collins presented the Community Emissions Data System (CEDS), a new data set of Historical Emissions for Aerosol and Chemistry Research. The approach follows a hybrid of bottom-up emissions

and inventory to produce a best, yet not fully independent estimate. Phase I in 2015 focuses on building the emissions data system and updating datasets for CMIP6 focusing on recent decades (fall 2015). Phase II (2016-2017) will:
- Consistently estimate uncertainty over time and region
- Expand sub-regional detail for large countries and extend emissions estimates over entire industrial era
- Improve gridding, add seasonality and other characteristics

There is currently no plan to address uncertainties. There were some concerns about the possible confusion between natural and anthropogenic fires. Water isotopes could be useful for PMIP and CFMIP.

b. Aerosol concentrations – Bjorn Stevens

The MPI-M is developing a simple plume aerosol climatology for implementation in CMIP models. All models participating in RFMIP are expected to use this for some experiments, and those models that do not run their base model with interactive aerosols are asked to use this climatology for the DECK runs. The climatology will consist of FORTRAN code to provide aerosol and cloud active optical properties as a function of height, latitude, longitude, time and wavenumber. The climatology is mostly finished, with the cloud active part being finalized over the remainder of this month. A version is being implemented in the MPI-M for testing through November and December and is expected to be distributed to the modeling centers by years end. The climatology will provide only anthropogenic aerosol contributions to add to the background of the natural aerosol that models use during their spinup. The climatology will also be extended to the future for use with Scenario MIP as the Scenario MIP emissions become available. In addition an easy volcanic aerosol module (EVA) is being developed following a similar protocol, but this is not presently recommended as the basis for the historical forcings.

Veronika Eyring suggested testing the data with an AMIP run at coarse resolution. Detlef van Vuuren noted the importance to connect past and future time series.

c. Ozone and stratospheric water vapor concentrations – Michaela Hegglin (remotely)

Michaela Hegglin (University of Reading, UK) presented plans of the IGAC/SPARC Chemistry-Climate Model Initiative (CCMI) for the production of a new ozone database in support of CMIP6 for use in Earth system models without interactive chemistry. The new CCMI ozone database will replace the IGAC/SPARC ozone database by Cionni et al. (2011) and address known weaknesses therein. CCMI will provide monthly-mean 3-dimensional ozone fields from the ground up to 0.01 hPa (or around 85 km). The time series will span 1850-2014 (using historical emissions from Lamarque et al., 2010), and the future 2015-2100 following different RCP emission scenarios (RCP2.6,

4.5, 6.0, 8.5). The decision not to use new CMIP6 forcings is due to tight CMIP6 deadlines of delivery of the database (with pre-industrial fields ready by end of December 2015, historical fields by April-June 2016, and future fields by October 2016). The solar cycle will be implemented in collaboration with HEPPA-SOLARIS, but no QBO signal will be provided. As emerged from the discussions at the meeting, CMIP6 would also need nitrogen deposition fields and CCMI is currently looking into producing those in addition.

d. Global gridded land-use forcing datasets – George Hurtt

George Hurtt presented the plans regarding the global gridded land-user forcing data sets. Land-use history (reconstruction over 850-2014) and futures (IAM SSPs based for 2015-2100) will be merged, harmonized and gridded (0.25 deg).

The new data set represents approximately a 50x information increase from CMIP5.

The following tight timeline is foreseen:

- 2015 ... <additional prototype release(s)>
- 2016 January: Final Land-use dataset released (v1.0)
- 2016 March: GMD papers due
- 2016-2019: Model experiments, results and synthesis
- 2020: WG1 AR6 Report published

The new data set has extended history, increased spatial resolution, increased data density, new quantities, and covers additional future scenarios. Usage of new features in the dataset is encouraged. Modeling groups are invited to use data prototypes now for I/O and testing, to contribute to ongoing development of data use protocols, and to have potential workshop this spring on data/usage/project integration, and to participate in LUMIP.

e. Solar forcing – Katja Matthes (remotely)

The solar forcing for CMIP6 will be in the following respects different to the CMIP5 solar forcing recommendation:

1. there is a new, lower total solar irradiance (TSI) value 1360.8 +/- 0.5 Wm-2;
2. the variability in the UV part of the solar spectrum will be enhanced with respect to the so far standard NRLSSI1 dataset;
3. besides TSI and solar spectral irradiance (SSI) there will be particle forcing provided for the first time;
4. two future scenarios of solar variability into the future up to 2300 will be provided (reference and more extreme minimum), both provide lower level solar forcing than in CMIP5,
5. solar ozone forcing will be coordinated with CCMI (Michaela Hegglin). One netcdf file with the time series from 1850 to 2300 would be

provided, so that the modeling groups can pick the files needed for their respective radiation and/or photolysis codes.

Bjorn Stevens noted the strong variability in the future, which would warrant an explanation. In addition, some models that do not have the capability of using the high temporal and spectral resolutions of the prepared forcing. Therefore, it was suggested to prepare different versions of the solar forcing: one representing the best estimate of the forcing, and another one which would be somewhat simplified, including for instance annually averaged TSI values and a reduced resolution of the SSI.

f. Stratospheric aerosol data set – Thomas Peter and Beiping Luo (remotely)

Long term (1960 – 2011) data records on stratospheric aerosols were presented, with details on microphysical and radiative properties. There are different aerosol data sets (photometers, SAGE I, SAM II, SAGE II, CALIOP) now homogenized by means of the SAGE_4 method. Lidar/backscatter sonde data have been successfully used for gap filling. Using the AER aerosol model in the pre-satellite period, the resulting latitude/altitude distributions can be derived. SAD and optical properties are internally consistent, based on a single lognormal size distribution (Arfeuille et al., 2013). Extinction coefficients show a good agreement for Pinatubo perturbation and following quiescent period from UV to IR.

g. Future emissions – Detlef van Vuuren

The goal of ScenarioMIP is to simulate future climate outcomes based on alternative *plausible* future scenarios with the view of:
- facilitating integrated research across climate science, IAM and IAV communities
- anchoring targeted experiments (e.g. land-use change/air chemistry) to answer questions about specific forcings

All data (land use, emissions, atmospheric chemistry, extensions) will be made publicly accessible at the SSP database.

h. AMIP sea surface temperature and sea ice datasets – Karl Taylor

Karl Taylor reported that the sea surface temperature and sea ice boundary conditions needed for AMIP simulations continue to be made available on an ongoing basis by the Program for Climate Model Diagnosis and Intercomparison (PCMDI contact: Paul Durack; see http://www-pcmdi.llnl.gov/projects/amip/AMIP2EXPDSN/BCS/amipbc_dwnld.php). The

boundary conditions are based on (but not the same as) the monthly mean merged observations from HadISST2 and NOAA OI-v2. They extend from 1870 to near present and are made available on a 1x1 degree grid. The datasets are updated every few months to include the most recent observations. These boundary conditions should be imposed on CMIP6 AMIP simulations in such a way that the observed and simulated monthly mean surface ocean conditions are identical. Details on how to properly apply the boundary conditions can be found at http://www-pcmdi.llnl.gov/projects/amip/AMIP2EXPDSN/BCS/index.php.

It was recommended to check the consistency of data sets (skin temperature vs bulk SST). Sea-ice thickness is not part of this data set yet.

i. Historical GHG concentrations – Malte Meinshausen (remotely)

CMIP6 Historical GHG concentrations will span 1850 to 2014 with optional backward extension to year 1000 for CO2, CH4 and N2O. Gases will include CO2, CH4, N2O, C2F6, CF4, HFC-125, HFC-134a, HFC-143a, HFC-23, SF6, NF3, and 16 ODS with annual global and hemispheric averages.

John Scinocca offered to talk to Malte about constraints on emissions and concentrations.

j. Discussion on forcings

The availability of forcings data is critical to get simulations completed on-time with prototype products made available for testing. DECK and historical forcings should have the highest priority. Future emissions are expected to be available by March, but without harmonization. It was recommended to base historical forcings on observational records as much as possible. MIPs are free to decide their timeline, aligned with IPCC or not, but some harmonization is recommended.

4. CMIP6 data, tools and requirements

a. Obs4MIPs, metrics panel and evaluation tools for CMIP6 (Peter Gleckler)

Peter Gleckler provided a status report on progress with obs4MIPs, a project dedicated to making observational data more accessible for the evaluation of CMIP class simulations. Data made available via obs4MIPs match fields included in the CMIP5 standard model output, are technically aligned with CMIP data conventions (e.g., they are CF compliant netCDF), and are available through ESGF along with the CMIP data. Technical notes describe these datasets and their relevance for model evaluation. To date, roughly 40 data sets have been published in obs4MIPs. An obs4MIPs-CMIP6 planning

meeting was held at NASA HQ in April 2014 and a full report is now available[1]. A recently published meeting summary in BAMS highlights community interest to expand obs4MIPs with new data sets, higher spatio-temporal resolution, support of off-line simulators, and possibly in-situ data sets. Improved error characterization of the observations is emphasized to be crucial for many aspects of model evaluation. A WDAC task team provides oversight to obs4MIPs and is currently working on a process to streamline contributions and more clearly define the requirements for obs4MIPs. A related initiative, known as ana4MIPs, focuses on atmospheric reanalyses and follows the same principles as obs4MIPs by making results from multiple reanalysis available in the same structure as CMIP data. CREATE-IP has greatly expanded the scope of ana4MIPs by providing reanalysis for many more fields, at higher spatio-temporal frequency, all available levels, and increments and observations. Obs4MIPs project information and data are available via the CoG.

Peter Gleckler also provided an update on the WGNE/WGCM climate metrics panel, which following a recent recommendation from the WMAC has expanded its remit to include oversight of developing diagnostic capabilities. The ToRs of the WGNE/WGNE metrics (and diagnostics) panel have been updated to reflect a priority to promote and coordinate community-based capabilities that are being developed in support of the CMIP DECK. The panel is preparing a catalog of repeat-use capabilities being developed for CMIP and related efforts, and will be making this available through the CoG. The catalog and more importantly the tools themselves are meant to be a resource for modeling groups as well and the diverse research communities involved in CMIP research. The panel is striving to promote best practices for the development of repeat-use capabilities, including the use of open-source tools and the targeting of the CMIP DECK data structure. Ultimately, as DECK+historical simulations are published on ESGF, a limited set of capabilities under development are expected to ensure a set of well-established results are quickly made available to modeling groups and CMIP analysts.

It was suggested to bundle the various metrics packages in some way. David Carlson mentioned the SOCAT as a case study to explore the inclusion of in-situ data sets in obs4MIPs. Balaji noted the importance of process-based metrics to assess models and John Scinocca the uncertainty on observations which can be of great use to tune and verify models. Peter Gleckler recalled that the criteria list is decision-making process for new data sets to enter obs4MIPs.

b. Data requests (Martin Juckes)

CMIP data has experienced a steady exponential increase. CMIP6 volume is expected to reach ~20E16±0.8 Bytes. Data requests encompass variable

[1] www.earthsystemcog.org/projects/obs4mips/planning201405

lists, output requirements and experiment specifications for all endorsed MIPs, noting that:
- “DECK” is not an endorsed MIP …
- The request from each MIP covers the data that they need from the experiments they define, from the DECK + CMIP6 historical, and from experiments defined by other MIPs where it is needed for the analysis they propose
The software architecture includes consolidated documentation, a programming interface, command line for flexible access and web access.

CMIP6 will include:
~800 standard names
~1000 MIP Variable
~2000 CMOR Variables
~3500 Request Variables

Duplicate requests will need to be managed, as well as request for native verses regular grids and orphan variables which have not been claimed but being of high importance.

Some resources include:
-XML request document and documentation;
-Python library and documentation;
-Repository of document versions;
-Persistent identifiers (e.g. w3id.org/cmip6dr/variable/tas);
-Data request handbook (in preparation);
-Additional views of the request (excel, html …);
- forum: dreq01.vanillaforums.com

It was suggested to reconcile requests on different grids and to treat DECK and Historical simulation separately from the MIP requests. Members thanked Martin for his hard work.

5. Group reports

Briefers were invited to focus on updates since the last session and to raise any issue to be addressed by WGCM.

a. Australia (Simon Marsland)

The Australian Community Climate and Earth System Simulator Climate Model (ACCESS-CM2) group is now planning towards CMIP6 and MIPs participation. ACCESS-CM2 comprises the UKMO UM atmosphere, the NOAA/GFDL MOM5 ocean, the LANL CICE sea ice, the Australian CABLE land surface, and biogeochemistry for terrestrial (CASA-CNP) and ocean (WOMBAT) components. We intend primary submission (ensembles for

DECK, historical, ScenarioMIP) at N96 atmosphere and 1 degree ocean/sea ice, and a later aspirational submission with 1/4 degree ocean/sea ice (single member for DECK, historical, ScenarioMIP). ACCESS-CM2 has committed to the following MIPS: future projections (ScenarioMIP), cloud feedbacks (CFMIP), detection and attribution (DAMIP), land use (C4MIP, LS3MIP, LUMIP), ocean (OMIP, FAFMIP) and geoengineering (GeoMIP). The carbon cycling MIPs will use ACCESS-ESM2. Subsequent to discussions at the WGCM/CMIP workshop we will now consider participation in RFMIP and SIMIP. Simulations and submissions are planned for the 2017-18 calendar years. Three issues were raised: the lack of land-ice melt protocols in the historical and ScenarioMIP design; the lower than anticipated priority of extensions to 2200 in ScenarioMIP; and no firm guidance on the inclusion of background volcanic forcing in the piControl design. A call will be made to the wider Australian modelling community for their participation of ACCESS in additional MIPs.

b. China (Bin Wang)

Bin Wang presented an update on recent model developments in China. 18 MIPs are considered by 8 model groups in China running a total of 9 models.

Resolutions are increased generally in the horizontal and partly in the vertical, comparing with the CMIP5 models in China. Some schemes related to key processes of moist physics, surface or boundary layer are improved or updated, and thus biases in precipitation, temperature, shortwave cloud radiative forcing, and so on are reduced.

Terrestrial and marine ecosystem components are developed or improved, and are applied to establishment of ESMs in China. The self-designed coupler, C-Coupler, is further improved with enhanced functions, which are applied to building of CSM/ESMs or their components in China.

It was noted that the improvements have partially solved the double ITCZ problem in coupled runs.

c. EC Earth (Bart van den Hurk)

The EC-Earth consortium is developing its next generation model (V3.2), which has a similar structure as the CMIP5 working horse but contains significant upgrades of many components. Major highlights of the current version include an online coupling of aerosol and atmospheric chemistry, and extensive experience with high resolution modeling. A challenge to the organization remains the governance of the model development and operation, and the maintenance of the various DECK-configurations of the model (ESM/GCM, flavors and resolutions). EC-Earth is committed to participate in AERCHEMMIP, CFMIP, DCPP, GeoMIP, HighResMIP, ISMIP,

LS3MIP, LUMIP, PMIP, ScenarioMIP and VOLMIP, and has shown interest to C4MIP and RFMIP.

The discussion clarified the resolution of these runs, most of them at coarse T255, except for HighResMIP and noted the risk of adding features in a model if observations cannot constrain a new parameterization for example.

d. France (Masa Kageyama/Sandrine Bony)

Masa Kageyama recalled that IPSL and CNRS-CERFACS contributed significantly to CMIP5. Both groups are planning to take part in CMIP6 with several versions of their models (see table in the presentation) and will make large use of their Earth System model versions. Their timing is similar, with first runs planned for mid-2016 and the core of CMIP6 runs in 2017-2018.

The scientific interests of IPSL and CNRM-CERFACS covers:
• consistency between past-present-future
• "realistic" versus idealized experiments and configurations (including aquaplanet)
• stand-alone model vs coupled model

Some other French groups are contributing to regional modeling (stretched and nested).

There are no plans to use the high resolution dynamical core as yet. All model versions plan to run the DECK experiments.

e. GFDL (Ron Stouffer)

GFDL is in the process of developing a new AOGCM and ESM for use in CMIP6. The initial target resolution was 0.5degL48 atmosphere and 0.25degL63 ocean. Unfortunately, it was recently found out that our computer power will be cut from our current amount. This will require a rethinking of the GFDL contributions to CMIP6. Each component has made progress in becoming more realistic. The ocean and sea ice components are completely new re-writes of the code: different grids, new physics and etc. The atmosphere is more of an evolution from the CMIP5 model, AM3. Finally several concerns with regard to the operation of CMIP6 were noted.

f. Japan (Michio Kawamiya)

There are six models from two groups in Japan planning to contribute to CMIP6. One of the two groups is the Team MIROC, which is a joint effort among JAMSTEC, the University of Tokyo, and NIES (plus RIKEN for NICAM development), and the other is Meteorological Research Institute (MRI) of

Japan Meteorological Agency (JMA). Both of the two are joining most of the endorsed MIPs with their different models combined. The third generation of the Earth Simulator, whose theoretical computational speed is 1.3PFlops, will be used for most of the CMIP6 experiments. Activities in Japan for CMIP6 are supported by SOUSEI project, which is coming to an end in March, 2017. A forum has been set up involving both scientists and funding agency to establish a follow-on project. The Japan node for ESG has been also supported by another project-base fund DIAS ending this March, for which a follow-on project is very likely to be established.

The wish to have a Japanese representative on the WIP was expressed. This could be considered as the WIP members rotate every 2 years in principle. NICAM will contribute to HighResMIP, DynVar and CFMIP.

g. MPI (Bjorn Stevens)

The MPI-M will participate in almost all of the individual CMIP6 MIPs. The base version (T63L47 1.5 deg Ocean) of the model is frozen and final tuning on a high-resolution (T127L95-0.4deg Ocean) will be concluded by the end of the year. Many thousands of years of the control and abrupt 4xCO2 have been performed with the low-resolution version and the high-resolution version has run more than three hundred years. The low resolution will form the backbone for most MIPs which will be performed by institute scientists based on their interests. The MPI-M has taken responsibility for qualifying the different model versions it releases through the DECK, and anticipates beginning this process in early 2016 (once the ESGF is ready to accept output). The institute will also lead a broader German community effort to provide high-resolution runs for scenario MIP. The only MIP in which it does not intend to participate is AerChemMIP, although the possibility of doing so as part of a consortium is being discussed. Overall the new design of CMIP aligns strongly and beneficially with the institutes' organizational constraints, and its scientific interests, as for instance through the grand challenges. We have some concern about model evaluation and documentation efforts that are not rooted in the peer review literature.

h. NCAR (Gerald Meehl/Claudia Tebaldi)

The Community Earth System Model (CESM), a jointly funded project from the U.S. National Science Foundation (NSF) and the U.S. Department of Energy (DOE), plans to target a new version, CESM2, for CMIP6 simulations. There will be a number of different configurations run for the various MIPs in CMIP6, all with the ocean model at 1o resolution:

1. AOGCM physical climate (1 deg atmosphere, low-top)
2. + biogeochemistry (1 deg atmosphere, CO2 emission and/or concentration driven, low-top)

3. + atmospheric chemistry + biogeochemistry (1 deg atmosphere, CO2 emission driven, high-top; WACCM)
4. AOGCM physical climate (1/4 deg atmosphere, low-top)

There will also be a few simulations run with the CESM configured as an AOGCM with ¼ deg atmosphere, 1/10 deg ocean.

It is planned that the new CESM2 model will be finalized in mid-2016, with CMIP6 runs starting tentatively in late 2016. It is tentatively planned that nearly all 17 MIPs will be run with CESM2.

For the CMIP6 DECK + Tier 1, the computer time requirements for the 1 deg versions:
– CAM5: ≈12,800 years
– CAM5-BGC: ≈10,500
– WACCM-BGC: ≈ 7,300
– Total cost: ≈150M core-hours
For the ¼ deg version:
– CAM5: ≈ 2,200 years
– Total cost: ≈350M core-hours

There has been considerable work done to improve throughput of CESM model versions. For example, for the high-top WACCM version of CESM, throughput has been improved from about 2 to 6 years per day to nearly 10 years per model day.

Currently there are plans in place to perform the CMIP6 experiments starting in late 2016 and continuing through 2017 and 2018. These simulations will be performed on a combination of NSF and DOE supercomputers.

i. UK/Korea (Cath Senior)

The Met Office and the UK academic community now have a prototype version of the UKESM1 model for use in CMIP6. This consists of the physical model, HadGEM3-GC3 which has many significant developments since the CMIP5 model, HadGEM2-ES. These include new ocean and sea-ice models (NEMO, CICE, Hewitt et al, 2011), enhanced vertical resolution (85 vertical levels), new ENDGame dynamical core (Wood et al 2014) and the PC2 cloud scheme (Wilson at al, 2008) along with many other smaller changes. The Earth System components are UKCA (full stratosphere– troposphere chemistry + GLOMAP-mode aerosols), JULES land surface scheme with TRIFFID (dynamic vegetation) and soil/veg carbon-nitrogen, wetlands, diagnostic wildfires and some permafrost improvements. Ocean biogeochemistry is represented by MEDUSA2 within the NEMO ocean model. Some configurations will include interactive land ice sheets for Greenland and Antarctica through the BISICLES scheme and ice shelf basal and cavity melt within NEMO-ORCA. OASIS3-MCT will be the coupler.

We expect to have up to 4 configurations running our experiments for CMIP6 MIPS. These will be two resolutions of the physical model HadGEM3-GC3 (AO: N96Orca1 and N96Orca0.25) and UKESM1 at N96Orca1. The 4th configuration (under development) is UKESM1 hybrid in which the physical model will run at N216 Orca (0.25) but there will be degraded resolution for the atmospheric chemistry and ocean biogeochemistry.
Using these four configurations we plan to engage in ScenarioMIP, DCPP, CFMIP, C4MIP, HighResMIP, DAMIP, AerchemMIP, LUMIP, RFMIP, GEOMIP, LS3MIP and data provision for ISIMIP/CORDEX/VIAAB (as a priority for the MOHC) and additionally OMIP/OCMIP, ISMIP, FAFMIP, PMIP, GMMIP, VolMIP (led from the UK academic community). Our timelines suggest the majority of the runs would take place during 2017/18.

KMA plan to run two models for CMIP6. Using UKESM1, they will work with the UK to deliver increased ensemble sizes and/or complementary experiments for CMIP6Hist, AerchemMIP, C4MIP and ScenarioMIP. In addition they are developing a new climate model (K-ACE) which will be a physical-only model which they hope to have ready to simulate DECK, CMIP6Hist and maybe some runs for ScenarioMIP.

The discussion noted the difficulty to attribute improvements to the increased ocean resolution, as even if models are traceable, changing the resolution implies changing some parameterization. Hadgem3 is also the current version of the NWP model so it is not just a retuning exercise.

j. Canada (John Scinocca)

In this presentation a proposal was made to add a second, "fast-track" category of MIPs to the current coordinated set of MIPs, which are submitted at the start of each phase of CMIP. Such fast-track MIPs would be subject to the restrictions that they use the coordinated MIP models, data request, and experiments as controls for new science. Such fast-track MIPs would have a rapid turn-around as no coordination would be required. The ultimate result would be the ability to perform multi-model studies of emerging climate questions continually throughout each phase of CMIP. The introduction of this second MIP category, therefore, offers the possibility to relax the need to align phases of CMIP with assessment reports. A short white paper of this proposal has been submitted to the WGCM co-chairs and may be downloaded at:

ftp://ftp.cccma.ec.gc.ca/pub/jscinocca/CMIP6/fast_track_MIP_WP_scinocca.pdf.

Some proposal for fast-track MIPs were made: SnowMIP, a big ensemble experiment. It was noted that there are 2 MIPs in the Grand Challenge on Cloud, Circulation and Climate Sensitivity: TrackMIP (on rain bands) and EasyAerosol (not part of cmip6), Cookie and Spookie. The community was reminded that the scientific exploitation of model results should also remain a priority.

k. Brazil (Paulo Nobre)

The strategy adopted toward the development of the Brazilian ESM (BESM version 2.3.1) was presented by Paulo Nobre. The model uses NOAA/GFDL's FMS coupler with CPTEC's spectral AGCM (at resolution T062L28 and SSIB vegetation model) and NOAA/GFDL MOM4p1 (at ~1 degree lat-lon and 50 z-levels, with marine ice – SIS). BESM2.3.1 was used to generate Brazil's contribution to CMIP5, with 10,000+ years of global simulations available via ESGF. Distinctive features of BESM2.3.1 are presented, namely those related to a better representation of cloud cover parameterization (from NCAR CAM5) and its impacts on Amazon rainfall and global atmospheric circulation patterns. An improved version of BESM is under development for CMIP6, which incorporates several enhancements on the model physics, including but not limited to: a moist PBL; atmospheric aerosols and chemistry - MOZART; dynamical vegetation with surface hydrology and forest fire – INLAND; coupled to MOM5 with biogeochemistry – TOPAZ, and NASA/GISS ocean vertical mixing scheme.

Members acknowledged this contribution (like India over Himalaya) as a good example of regional improvement and recommended Brazil to join GMMIP (monsoon MIP).

l. India (Swapna Panickal, remotely)

P. Swapna with inputs from R. Krishnan, A.G. Prajeesh, D.C. Ayantika, N.S. Sandeep, K. Kulkarni, M.K. Roxy, R. Vellore, S. Manmeet presented an update on IITM activities.

The IITM Earth System Model (IITM-ESM), developed recently at CCCR, IITM, is an outcome of incorporating earth system components in the Climate Forecast System (CFS) coupled model from National Center for Environmental Prediction (NCEP, USA), and thereby transforming the CFS seasonal prediction model to a long-term climate model. The first version of IITM ESM (ESM1.0) showed significant improvements in the simulation of sea surface temperature and captures dominant modes of climate variability and their links with the Indian summer monsoon. In a recent version (IITM-ESM2.0), further improvements are incorporated in order to obtain a radiatively-balanced global climate modeling framework, which is required for predicting long-term climate change. Additionally, radiative effects of natural and anthropogenic aerosols are incorporated by specifying time-varying 3-dimensional fields of aerosol optical properties. The IITM- ESM2.0 also shows improvements in simulating sea ice distribution, ocean biogeochemistry and mean precipitation over Asian monsoon region. The IITM-ESM marks a successful climate modeling development for contributing to the forthcoming CMIP6 with DECK, historic and GMMIP simulations, a first from India. IITM plans to participate in CORDEX and HighResMIP.

m. Other groups (Cath Senior and Sandrine Bony)

Updates and plans from CMCC and Norway were briefly presented. Two other groups were not represented at the meeting, namely NASA-GISS and South-Africa.

6. Summary

The session ended with a summary discussion resulting in the actions reported in ANNEX B.

ANNEX A – CONTACT LIST

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ANNEX B – ACTION LIST

Communication and documentation

ACTION 1: Inform modeling groups about the (revised) CMIP timeline, the availability of prototype forcing datasets and/or code (WGCM co-chairs/CMIP chair)

ACTION 2: Encourage modeling groups to document specific aspects of their model (e.g. the tuning procedure), their simulations (e.g. specification of the volcanic forcing in the pre-industrial simulation) and how they address DECK requirements any divergence (WGCM co-chairs/CMIP chair)

ACTION 3: Invite MIPs to provide a short sentence on their goal for their CMIP6 MIP description (CMIP Chair)

ACTION 4: Send a letter to the developers of ES-DOC to improve traceability of model documentation to the peer-reviewed literature so as to avoid duplication of model documentation efforts within modeling groups (WGCM Co-chairs, done)

ACTION 5: Offer conference call facilities between the MIP organizers and the modeling groups, at their requests, to improve communication between these groups (Michel Rixen, as appropriate)

IPCC

ACTION 6: WCRP to inform IPCC about the CMIP timeline (Michel Rixen, done via consultation on IPCC special report priorities)

Forcing

ACTION 7: Ask the solar group to develop a simplified (e.g. monthly) spectral/temporally resolved dataset for a 'standardized' implementation in models and encourage all groups to consider using this data set (CMIP Chair, done)

ACTION 8: Encourage modeling groups to participate in RFMIP so that forcings may be assessed in CMIP6 (WGCM co-chairs/CMIP panel)

WIP

ACTION 9: Review the CMIP6 data to identify base (including orphan) variables for the DECK and CMIP6 historical runs, request modeling groups to report back on feasibility and ask MIPs about analysis capabilities (publicly available scripts) related to a data request to help modeling groups prioritize their outputs (CMIP Panel mid-January 2016)

ACTION 10: Request modeling groups to confirm their willingness to use netCDF4, (lossless compression) as the data format for CMIP6 (WIP chairs to follow-up with MIP chairs and modeling groups)

ACTION 11: Inform modeling groups about data citation being part of the terms of use of CMIP6 data, request them to generate journal citations to go with the DOIs (e.g in ESSD or Nature Scientific Data), and communicate to this policy to data users (WIP chairs to follow-up with MIP chairs and modeling groups)

ACTION 12: Request modeling groups to endorse the new file-based licensing policy, including the use of one of two WIP-recommended licenses ("open access share alike" and "non-commercial share alike") (WIP chairs to follow-up with MIP chairs and modeling groups)

ACTION 13: Write a letter to ESGF steering committee and DoE to highlight the importance of the ESGF infrastructure for climate research and IPCC (WGCM Co-chairs)

WGCM20

ACTION 14: Poll members for WGCM20 session dates around the last 2 weeks of October 2016 (Michel Rixen, asap)

ACTION 15: Organize a workshop on the use of a hierarchy of models to understand results from comprehensive CMIP ESMs (WGCM jointly with GC Clouds)