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This report was authored by the WCRP Working Group on Coupled Modeling (WGCM), co-chaired by Cath Senior and Greg Flato.

The WCRP Working Group on Coupled Modeling fosters development and review of coupled climate models. This includes the organisation of model intercomparison projects aimed at understanding natural climate variability and predictability on decadal to centennial time scales, and predicting the response of the climate system to changes in natural and anthropogenic forcing.

The World Climate Research Programme's mission is to facilitate the analysis and prediction of Earth system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society. The two overarching objectives of the WCRP are to determine the predictability of climate and to determine the effect of human activities on climate.

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Executive Summary

The 22nd session of the Working Group on Coupled Modeling (WGCM) was held 25th and 29th March 2019, in conjunction with the CMIP6 Model Analysis Workshop, both kindly hosted by the Barcelona Supercomputing Center (BSC), Barcelona (Spain) together with a number of other meetings, including the EU PRIMAVERA Assembly.

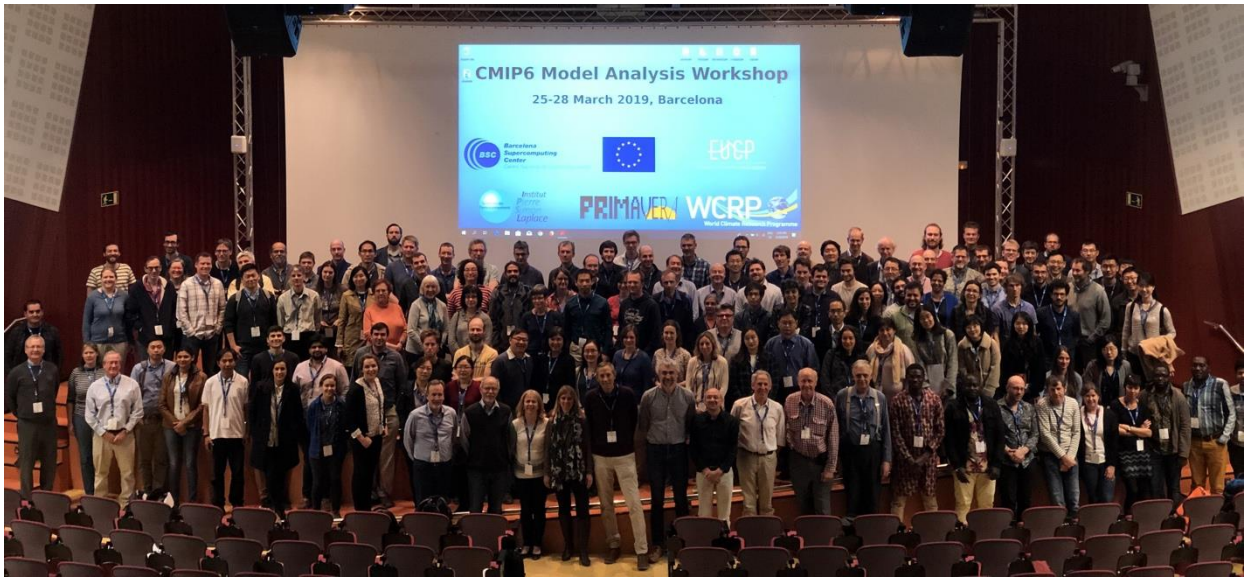
The primary focus of the session was to review progress on CMIP6, including infrastructure, documentation, forcings data requests, model evaluation, linkages to adaptation community, CORDEX, and HighResMIP. Some time was also devoted to analyze and summarize the outcomes of the workshop and develop future strategic directions for WGCM and connections to IPCC and the UNFCCC Global Stocktake.

There are now clear expectations for CMIP to contribute to the global climate agenda on the international scene beyond its typical WCRP research mandate. A major conclusion of the session was that parts of CMIP need to move to a more operational footing. To that effect, support of WMO Members will be sought via a dedicated resolution presented at the 18th session of the World Meteorological Congress in Geneva in June.

Contents

Group picture of the WGCM-22 session, from left to right*: Tianjun Zhou, Ralf Doescher, Eric Guilyardi, Gokhan Danabasoglu, Francisco Doblas-Reyes, Masahiro Watanabe, Peter Gleckler, Veronika Eyring, Greg Flato, Cath Senior, Jean-Francois Lamarque, Masa Kageyama Johann Jungclaus, Venkatramani Balaji, Karl Taylor, Jerry Meehl and Martin Juckes*

Group picture of the WGCM-22 session, from left to right*: Jerry Meehl, Brian O'Neill, Tianjun Zhou, Harilaos Loukos, Gokhan Danabasoglu, Martin Juckes, Eric Guilyardi, Pavel Kabat, Venkatramani Balaji, Pierre Friedlingstein, Greg Flato, Masa Kageyama, Cath Senior, Ralf Doescher, Peter Gleckler, Jean-Francois Lamarque, Veronika Eyring, Karl Taylor, Michel Rixen, Simon Marsland, Johann Jungclaus, Masahiro Watanabe*



Attendees of the CMIP6 Model Analysis Workshop

A testimony of United Nations' and WMO's commitment to CMIP. From left to right: Petteri Taalas (Secretary General of WMO), António Guterres (Secretary-General of the United Nations) and Pavel Kabat (WMO Chief Scientist and Director of Research)

Attendees: Greg Flato (Co-chair), Cath Senior (Co-chair), Venkatramani Balaji, Gokhan Danabasoglu, Francisco Doblas-Reyes, Ralf Doescher, Veronika Eyring, Pierre Friedlingstein, Peter Gleckler, Eric Guilyardi, Bill Gutowski, Martin Juckes, Johann Jungclaus, Masa Kageyama, Jean-Francois Lamarque, Simon Marsland, Jerry Meehl, Karl Taylor, Masahiro Watanabe, Tianjun Zhou

Excused: Swapna Panickal

WCRP JPS: Michel Rixen

1. Introduction

Co-chairs Cath Senior and Greg Flato welcomed all participants and thanked Francisco Doblas-Reyes and the Barcelona Supercomputing Center for hosting the 22nd session of WGCM held in conjunction with the CMIP6 Model Analysis Workshop.

A quick round of introduction allowed everyone to introduce themselves. The new members Johann Jungclaus, Jean-Francois Larmarque, Brian O'Neill, Masahiro Watanabe, and Ralf Doescher (standing in for Bart Van den Hurk) were warmly welcomed.

Co-chairs noted that the last session was held about 18 months ago. The agenda was very busy for a 2 half-day meeting and was designed towards extensive discussions on the future of CMIP.

Pavel Kabat, WMO Chief Scientist and Director Research highlighted the opportunities associated with the WMO Constituent Body Reform, where Research will become more prominent. A new Research Board will cut across two new Technical Commissions resulting from a merger of the current eight Commissions and will also be supported by a Science Advisory Panel. Those WMO bodies shall be supportive of WCRP, including support of Members to CMIP so they are able to fulfill their commitment to the international climate agenda (IPCC, UNFCCC, etc). Following the WCRP Review, a new Strategic Plan is about to be approved by Sponsors and will be followed by the development of an Implementation Plan to take forward a possible new structure of the Programme. The upcoming 18th session of the World Meteorological Congress will address and raise awareness about CMIP and WCRP as a fundamental supporting element of IPCC during a dedicated Research Day.

Post-meeting Note: a side meeting with WGCM and CMIP leadership was convened over lunch time on 25th March to develop the key elements to be included in the information document supporting the WMO Congress Resolution on Science in Support to Policy. The final version of this Information Document submitted to the World Meteorological Congress, as well as the approved version of the Resolution are included resp. in the Appendix B and C of the present report.

2. WCRP update

Michel Rixen updated participants on the WCRP Review, the new Strategic Plan (https://www.wcrp-climate.org/wcrp-sp) to be approved by Sponsors in June and the associated Implementation Plan on which development will start in the context of the 40th session of the Joint Scientific Committee meeting in May 2019. He highlighted the relevance and numerous possible contributions of CMIP in many areas of the Strategic Plan, basically every objective, and also the critical infrastructures of hierarchies of modeling tools, high-end computing and data management. He also noted the upcoming AGU Fall Meeting where WCRP will celebrate its 40th anniversary together with a number of Town Halls, Union Sessions and Early Career events during the so-called WCRP Climate Science Week (see https://www.wcrp-climate.org/wcrp-agu2019/wcrp-csw-overview). In closing, he briefly outlined the concept of Global Climate Indicators developed by GCOS, as these could also possibly become a reference for outreach and communication for climate projections.

3. CMIP6 status

3.1. Overview of CMIP6 progress

Veronika Eyring provided an update on CMIP6 progress, highlighting the growing number of institutions, models, experiments and data, and thanked all modeling groups on behalf of WGCM and the CMIP panel.
Model outputs from 12 institutions (19 models) are now being served by ESGF. The ScenarioMIP timeline on Tier 1 (SSP1-2.6; SSP2-4.5; SSP3-7.0; SSP5-8.5; SSP1-1.9) involves 21 Models from 15 Modelling Centres available by end 2019. She recalled the literature submission cut-off date of 31 December 2019 for the WG I report. The initial CMIP6 timeline has slipped for a number of reasons and will need to be improved for CMIP7. Results from the routine ESMValTool workflow are currently password restricted and watermarked and would be released soon. An emerging topic for the CMIP6 ensemble is the high climate sensitivity of some models which might be due to new CMIP6 forcings or new aerosol/cloud microphysics in those models. There have been numerous outreach and dissemination activities around CMIP6, being a step change compared to CMIP5 in terms of data access, publications and model development.

Considerations for CMIP7 include:

- Increasing number of experiments causes heavy load for model groups
- Ensure enhanced quality control for the forcings
- Ensure that timelines don't slip as they did in CMIP6 and in previous phases
- Most of CMIP coordination occurs through volunteered time of climate scientists
- The growing dependency on CMIP products by a broad research community and by national and international climate assessments means that basic CMIP activities, such as the creation of forcing datasets, the provision and archiving of CMIP products, and model development, require substantial efforts.

Suggestions for possible solutions were outlined:

- Making full use of the continuous structure we have
- Renaming CMIP6 to CMIP7 at some stage (e.g. 1 Jan 2021); we have defined enough experiments and research questions to fuel research over the next phase)
- Reducing reliance on a specific phase (e.g. recommend AR7 is based on further analysis of CMIP6 plus new CMIP7 simulations) such as forcings, data request, etc.

ongoing and more institutionalized and a more automated infrastructure in place, also at the modelling centers (to reduce the burden)
- Closing the loop and assess the benefits also for user needs

She noted the growing CMIP ambition and her concerns with the tight deadlines to meet the IPCC timeline which are firm. To ensure a significant contribution to WG I, some 80% of models would need to be published and archived on the Earth System Grid Federation (ESGF) by August. With regards to paper submission, it was noted that figures can be updated later on as part of the manuscript review cycle.

The main current critical elements of CMIP are the scenarios, forcings, infrastructure and data requests elements. Whilst CMIP is organized to serve the science community, Assessment Reports put modeling groups in an IPCC timeline mindset. Likewise, the Global Stocktake 5-year cycle might equally have some indirect influence on the CMIP timeline or at least strategic thinking. ScenarioMIP is one area of CMIP which could become a critical element of a 'policy/service' component, as opposed to most other MIPs which support mainly the research enterprise of WCRP. Costs of CMIP operational/service elements need to be assessed against benefits.

3.2. Overview of infrastructure

Karl Taylor provided an update on the CMIP infrastructure, which purpose is to facilitate access to model output produced by CMIP, by imposing standards, controlled vocabularies and model documentation and to coordinate with data managers and modeling groups. Dependencies in the infrastructure were reviewed. Experiments, institutions, and models are formally recorded and major infrastructure components are now operational (model output, data request, CMOR, PrePARE). All CMIP6 data can be accessed from each of the 4 CMIP6 portals. The summary of data holdings is available at https://pcmdi.llnl.gov/CMIP6/ArchiveStatistics/esgf_data_holdings/ with more details at https://esgf-node.llnl.gov/search/cmip6/. The next high priority areas are to expand the availability of Globus grid ftp to all sites and to provide server-side computational services. Additional features were reviewed, including the ESGF CoG, the data citation services, ES-DOC (including data errata). Access to CMIP6 forcing data sets (input4MIPs) and observations (obs4MIPs) was highlighted. CMIP6 practical guides for contributors and users are available at https://pcmdi.llnl.gov/CMIP6/. Recording of CMIP publications was encouraged.

Balaji outlined some considerations with regards to cloud storage and computing. Commercial cloud vendors usually have a "Public Datasets" program for "publicly available high-value cloud-optimized datasets" for users seeking to "democratize access to data by making it available for analysis". For public datasets, typically ingress (upload to cloud) and storage are free, egress (download from cloud) is not. Academic users can apply for free cloud research credits. A caveat is that programs can be ended at any time. Many funding agencies are evaluating the relative cost of moving to cloud vs purchasing or leasing on-premises. Major advantage is democratization: large data volumes available for analysis from anywhere in the world without replication.

Despite growing international investment in climate modeling infrastructure, it remains fragile: single points of failure need to be addressed because they can lead to enormous disruptions. Some individuals are irreplaceable. Some software is not well documented. ESGF has become essential to the climate research community: CMIP, input4MIPs, obs4MIPs, etc. Modeling and analysis groups have invested in it. Given resource constraints, we should treat ESGF as part of an operational climate research enterprise; it must be reliable and robust. Underlying data

technologies are in flux: ESGF will adopt promising technical evolutions as they mature, and operationalize them for a broad community. Some concerns were raised about a commercial cloud approach for CMIP. It was also commented that IPCC is now aiming at reinvigorate its data distribution center.

3.3. Update on forcings

Jean-Francois Lamarque updated attendees on progress on input4MIPs and a meeting held prior to AGU2018 to take stock of CMIP6, plan for CMIP7 and to review SLCF emissions, land-use, concentrations (including stratospheric aerosols) and deposition datasets. He noted the long time to generate and coordinate datasets, the original timeline having been overly optimistic. There are single points-of-failure present in several forcing areas. The quality control and early testing is essential, and this was not done enough (e.g. last-minute changes on SO2 emissions or volcanic datasets). CMIP6 funding was (slightly) better than for CMIP5, but most efforts still remain largely underfunded. Some datasets are actually a mix of CMIP5/CMIP6 (ozone and Ndep). Globally/annually the SLCF emissions did not change much from CMIP5 but there are large differences at regional/seasonal scales. Biomass burning changed drastically between Lamarque et al (2010) and van Marle (2017). The formation of a group to coordinate forcings across CMIP was suggested.

3.4. Update on data request

Martin Juckes reviewed progress on the data request which defines CMIP6 diagnostics in terms of scientific and technical specifications and specifies the contexts in which they are required. Version 01.00.30 has been released with web pages and python library, aggregated across all MIPs. Delays in finalising the request caused problems for modeling groups. The Data requirements are tuned to each experiment and each requested variable is linked to the MIP(s) that need it. Additional options related to priorities of variables, tiers of experiments and model configurations. The structure currently includes 927 CF Standard Names, 1272 MIP Variables, 2063 CMOR Variables and 6423 Request Variables. There has been an inflation in priority variables which needs to be re-set for CMIP7 with top priority only assigned with proper justification. The following was suggested for the future:

- Technical: clarify requirements, improve schema, review definitions (priorities, communication platform, feedback from MIP teams and modeling centers, etc)
- Support: improve documentation of process and responsibilities (e.g. named coordinator for each MIP, priority variables by June 2021)
- Governance: clarity about priorities and appropriate deadlines for candidate MIPs.

3.5. Update on modeling groups

Cath Senior provided a status on modeling groups with respect to the DECK, historic simulations, MIPs CMOR and publication on the ESGF. The CMIP6 data availability on the ESGF is updated hourly at https://pcmdi.llnl.gov/CMIP6/ArchiveStatistics/esgf_data_holdings/ with more details at https://esgf-node.llnl.gov/search/cmip6/.

The major issues raised by modeling groups include the forcing data availability, the size of the DECK, lack of staff and HPC to run experiments, the complexity of ES-DOC, inconsistencies

between CMOR3 and PrePARE and limited time to focus on model development. Suggestions were made to communicate progress on runs from other modelling centres, to agree a set of priority variables to upload first to ESGF (e.g. as required by AR6), to hold workshops on topics such as CMOR3, ESGF, model development and to decouple CMIP from IPCC/review dates of IPCC given progress on CMIP6/stagger participation in MIPs so groups focus on DECK/HIST/Scenarios. MIPs commented that the likely very short timescales for analysis covering late spring to summer 2019 when most MIPS anticipate having enough data to start their work. Tier 2 runs will not be until late 2019 at best. They further suggested a peer-review of forcing data requiring institutional support, community engagement in data request, organization of experiments between AR cycles, and technical guidance (WIP to MIP) towards less reliance on CMIP panel. The (small) size of the DECK and distributed structure of CMIP6 were viewed positively.

3.6. Emergent properties of CMIP6 ensemble

Cath Senior presented some very early CMIP6 results hinting to a number of high Equilibrium Climate Sensitivity (ECS) models (above the top of the CMIP5 range), the driver of which being currently unclear. The WCRP sponsored ECS assessment is probably going to lower very unlikely from 6 to ~4.5. Hypotheses currently being explored include microphysics, cloud feedback and aerosols. Model DNA and systematic errors should be considered in this context. The question was posed as to the role of WGCM (e.g. through active encouragement of MIPs?) in supporting AR6 to investigate this. IPCC Chapter 7 will cover ECS considerations.

Suggested ways forward included:
- a possible statement from WGCM on the new generation of models, early indication of a change in ECS, the work underway to understand why
- mobilizing the community to work on this possible increased ECS question together, and reach out to the WCRP Grand Challenge on Clouds, Circulation and Climate Sensitivity

- a few WGCM members to contact modeling groups to make sense of the ECS CMIP6 plot, and then write a perspective (not assessment) paper

It was further noted that WG I will not provide guidance to WG II on what models should be used for adaptation.

3.7. Model evaluation

Peter and Eric outlined possible next steps in community-based model evaluation. Capabilities are becoming a reality, thanks to the design target provided by the CMIP conventions and standards. Such capabilities can contribute to service and policy, as well as advance science and model development more efficiently. There is currently a number of capabilities as well as expert teams active in this area. Interfacing them efficiently in a logical framework could help streamlining workflows. They proposed WCRP and existing panels to help refine the scope and vision for this effort and to take this idea forward.

Attendees cautioned about the risk of too big a challenge, and the need to identify the added value of such an initiative. It was recommended to pursue discussions further off-line.

4. CMIP Workshop Closing Session

Although not formally part of the WGCM22 session, we include here some salient outcomes of the workshop which informed the closing discussion from the Working Groups and ensuing actions, in the spirit of a continued engagement with the CMIP community at large. It was agreed to disseminate the WGCM22 report to the workshop participants.

4.1. General questions

It is expected that June/July will be a peak time when new simulations will be ingested. For specific data requests, e.g. at higher vertical resolution, users should contact modeling centers directly, but there is no guarantee that what they are looking for is actually archived. The CMIP panel recommended not to amend Tiers e.g. in C4MIP or LUMIP. The WIP is putting together a list of variables requested by IPCC authors and will broadcast this information to modeling groups so that they can eventually prioritize those.

People producing the data should have their name associated with it and be recognized for their efforts. The registration service ensures that data will be cited and the system has an explicit acknowledgment section to that effect.

The ESGF includes an errata feature if problems are found in any model. It was recommended to push this information to users automatically. ES-DOC also provides a means to capture live documentation on models.

The WCRP web site https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6 contains a lot of useful links to CMIP6. Attendees were invited to review the page and provide any suggestions for improvements. A dedicated CMIP6 session is planned during the WCRP Climate Science Week at AGU in Dec 2019 to also advertise this. It was noted that the VIACS AB's role is also to disseminate tools for CMIP6.

4.2. Equilibrium Climate Sensitivity

Improvements have been made to models from CMIP5 to CMIP6, including new physical insights in the atmosphere, ocean, sea-ice, and land surface utilizing new observations. In many cases, changes in the detailed representation of prognostic cloud and aerosol processes have been implemented. Consequences of model developments are now being carefully assessed. Initial results show that some of the new CMIP6 models have a higher ECS than their CMIP5 counterparts (from about 6 years ago); the climate science community is actively investigating this important topic and peer-reviewed papers are already in the works. WGCM will work with the community to compile emerging ECS properties in a peer-reviewed perspective paper as input to the assessment of ECS in the IPCC AR6.

4.3. CMIP7

There are currently only a few CMIP6 model simulations published on ESGF. Planning for CMIP6 began in 2013, and the timeline was finalized before IPCC AR6 was initiated; but delays subsequently developed, due to a number of factors. Essential inputs rely on single people and most of this work is unfunded, e.g. forcings, data requests. Though MIPs were entirely voluntary for modeling groups, most aspired to run many of the MIPs, with the consequence of a heavy human and computational load.
Timely delivery and enhanced quality control for the forcings through program-level support needs to be ensured with more continuous, ongoing and more institutionalized support, avoiding single-points of failure. The growing dependency on CMIP products by a broad research community and by national and international climate assessments means that basic CMIP activities, such as the creation of forcing datasets, the provision and archiving of CMIP products, and model development, require substantial efforts that must be better funded.

The new more distributed CMIP organization has been proven successful and can now make full use of the continuous structure established for CMIP6, with separation of the timescales for:

- CORE EXPERIMENTS" REQUIRED FOR USERS (DECK, historical + possibly others, e.g. RFMIP)
    - Can go on faster timescales
    - More automatic infrastructure in place through program level support (e.g. for forcings), also at the modelling centers (to reduce the burden)
- RESEARCH (CMIP6-Endorsed MIPs)
    - Infrastructure also needs to support the CMIP6 Research Activities
    - Could go on longer timescales

There are now enough experiments and research questions in CMIP6 (and CMIP5) to fuel research over the next phase. CMIP7 can fully build on CMIP6-Endorsed MIPs.

CMIP6 planning started before AR6 was even decided, and there is an odd symbiosis between science and delivery for assessments. The Global Stocktake could add some modulation in this context. The IPCC schedule for future cycles is unknown but AR6 will end in 2022. Developing AR7 will eventually start after that. The CMIP7 planning can equally start before and irrespective of the AR7 planning.

The changes in data requests have posed some issues for modeling centers, but fewer updates are expected in future cycles. Attendees appreciated the continuous structure and the separation between core experiments (e.g. operational forcings with annual updates) and the research. Scenarios have a special status in this context, also because they may attract a lot of interest from the policy side.

4.4. IPCC deadlines

Modelling groups are encouraged to submit their model outputs as soon as possible (and ideally no later than Aug 2019), so they can be assessed in time for the Second Order Draft that is due early Jan 2020. The Literature submission cut-off date is 31 Dec 2019. The Cut-off date for accepted literature for inclusion in the Final Draft is 15 Oct 2020.

4.5. Next Analysis Workshop

As in previous CMIP phases (e.g. the CMIP5 analyses at this workshop) analyses of CMIP6 (multi-) model output will continue for several more years. CMIP model analysis workshops will be held regularly to provide insight into what we are learning about the earth system through analysis of the CMIP data. The next CMIP6 Analysis Workshop is tentatively planned for 2021 (location TBD).

5. Linkages

5.1. VIACS

Claas and Alex provided an update on VIACS which aims at building bridges between modeling (CMIP/CORDEX) and application communities (VIA). The VIACS Phase II (2019-2021) will require an updated and geographically balanced Advisory Board. It will focus on an initial evaluation of CMIP6 models using DECK experiments and the application of broader CMIP6 outputs (e.g. HighResMIP, LUMIP, ScenarioMIP). Key challenges for VIACS/ESM connection include:

- Improved VIACS models and analyses to make use of improved outputs
- Practical use of huge variety of models, ensemble members, and MIP experiments
- Incorporation of offline VIA results and VIA-oriented diagnostics for ESM development
- ESM expert guidance and technical facilitation for VIACS translation and application

A survey indicated the wish to use CMIP data to support VIA studies.

Contact with modeling groups needs to be enhanced. PCMDI could help making relevant data more prominent. The ambition of these activities needs to be put in context to similar ones within UNISDR, IPCC WGI/WGII handshake, UNFCCC NAP process, etc.

5.2. CORDEX and HighResMIP

Class briefed participants on CORDEX-HighResMIP collaborations on behalf of Bill Gutowski. Key questions in this context are metrics and methods for comparison as well as overall expected outcome/conclusion. IPSL have already delivered their high-resolution simulations to the ESGF. PRIMAVERA groups have finished their 1950-2014 simulations at (at least) 2 horizontal resolutions. Data upload is beginning now but it is unclear how many have saved boundary conditions.

He then summarized the current CORDEX activities and priorities, including CORDEX CORE (>3 distinct GCMs, CMIP5 historical runs + RCP2.6 + RCP 8.5 to 2100), flagship pilot studies (fine-scale processes with observational basis for verification and VIA user application, 7 on-going projects).

A first intercomparison between CORDEX-CODE RCMs and PRIMAVERA GCMs at 25km is planning to look at mean climate and extremes, targeting Africa, South Asia, East Asia and possibly Europe. CORDEX-FPS will investigate convective scale events on a voluntary basis, noting the possible opportunity to drive RCMs with HighResMIP output. Making the large-scale circulation as accurate as possible provides critical information needed for the regional downscaling to offer increased added value. One attendee noted the need for CORDEX to

support coordinated and consistent synthesis on the added value question across domains, scenarios and models.

6. WGCM Business

6.1. Memberships

Memberships were reviewed in closed session. There are currently 6 terms up for renewal. Masa Kageyama indicated her willingness to rotate off. A call for self-nominations will be issued after the JSC40 session. Co-chairs will examine all applications received in light of terms of current memberships and expertise required. It was suggested to contact modeling centers to submit nominations.

6.2. Review of draft actions list

The draft action list was reviewed and is summarized in Appendix A.

6.3. Next meeting

It was proposed to hold the next meeting around march 2020, possibly collocated with the IS-ENES3 or in Victoria.

APPENDIX A – ACTION LIST

1. Develop ECS ‘perspective’ paper (Cath, Jerry)
2. Develop INF document for WMO Congress, emphasizing forcings and other critical elements (Greg/Cath/Veronika/Mich - done)
3. Promote VIACS data set (CMIP Panel)
4. Submit CMIP sessions at AGU by 17 April (CMIP panel, done)
5. Offline discussion on Metrics Panel (WGCM co-chairs, Veronika, Peter)
6. Recommendation from WGCM to JSC40/IP (WGCM Co-chair w/Paco - done)
7. ESMVAL: open to public from 31 July 2019 onward and inform modeling groups (Greg/Cath)
8. CMIP panel meeting in July 2019 in Boulder (Veronika)
9. Make WGCM22 report available to CMIP workshop attendees/community (Mich)
10. Inform IPCC on WGCM agreement on priority list of data publication (Balaji)
11. Next meeting around March 2020, possibly collocated with IS-ENES3 or in Victoria (Co-chairs)
12. WGCM conference call after JSC40 and in Sep-Nov 2019 (Co-chairs)

APPENDIX B – INFORMATION DOCUMENT SUPPORTING RESOLUTION SUBMITTED TO 18th SESSION OF WORLD METEOROLOGICAL CONGRESS

World Meteorological Organization
WORLD METEOROLOGICAL CONGRESS
Eighteenth Session
Geneva, 3 to 14 June 2019

Cg-18/INF. 7.3(3)
Submitted by:
Secretary-General
31.V.2019

SCIENCE FOR POLICY

WMO SUPPORT TO IPCC AND CLIMATE SCIENCE

Summary

The WCRP and its Coupled Model Intercomparison Project (CMIP) provides valuable multi-model climate simulations and projections that benefit all WMO members, both individually and collectively, providing the foundation for the Intergovernmental Panel on Climate Change (IPCC) assessments, the United Nations Framework Convention on Climate Change (UNFCCC) policy deliberations, and climate services and products disseminated worldwide.

The growing dependency on CMIP products by a broad sector of the research community and by national and international climate assessments means that CMIP activities require substantial efforts in order to provide timely and quality controlled model output and analysis. The current 'volunteer' based system is not sustainable and this vital international activity is at risk if certain aspects are not supported and 'operationalized' in some way.

Background

The World Climate Research Programme (WCRP) is a very broad effort overseen by the WMO, IOC-UNESCO and the International Science Council (ISC). Within the WCRP, the Working Group on Coupled Modelling (WGCM) coordinates international research on the development and improvement of global climate and Earth system models, as well as overseeing a collaborative application of these models in the areas of seasonal to decadal climate prediction and longer-term climate change projection. The Coupled Model Intercomparison Project (CMIP), now in its 6th phase, was initiated in 1995 and involves more than 40 climate modelling centres from around 20 countries. The WGCM and CMIP serve as both organizer and motivator of international climate research through the definition of experimental protocols and provider of supporting infrastructure that allows for coordinated multi-model climate simulations that serve as the foundation for the Intergovernmental Panel on Climate Change (IPCC) assessments, the United Nations Framework Convention on Climate Change (UNFCCC) policy deliberations, and climate services and products disseminated worldwide.

As quoted from the IPCC, "Climate model results provide the basis for important components of IPCC assessments, including the understanding of climate change and the projections of future climate change and related impacts. The IPCC Fifth Assessment Report (AR5) relies heavily on the Coupled Model Intercomparison Project, Phase 5 (CMIP5), a collaborative climate

modelling process coordinated by the World Climate Research Programme" (http://www.ipcc-data.org/sim/gcm_monthly/AR5/index.html)." The IPCC 6th Assessment Report will make extensive use of the CMIP6 multi-model archive that is now being populated. It is important to note that the IPCC does not produce its own climate projections – it assesses the projections initiated and organized by the WGCM's CMIP activity.

CMIP continues to have a profound and positive impact on climate science. Approximately 45% of climate research papers published recently in the Journal of Climate (designated by Thomson Reuters as one of the prestigious journals in the field of climate research) explicitly cite CMIP5. Approximately 15% of climate research papers in Nature Climate Change also explicitly cite CMIP5. CMIP is cited almost 3 500 times in the IPCC Fifth Assessment, and CMIP5 results have been used in more than 1 000 peer-reviewed scientific publications.

CMIP model results also provide the scientific foundation for deliberations and decisions made under the UNFCCC. For example, the confident attribution of observed climate warming to human influence, the concept of a carbon budget, the need to achieve 'net zero' global emissions, the long lifetime of carbon dioxide in the atmosphere, the dependence of future climate on different emission pathways, and the essential irreversibility of temperature increase following cessation of emissions, are all underpinned by CMIP model results.

Regional climate change projections used to inform national and local impact assessments and adaptation plans, all ultimately depend on CMIP climate model projections. The WCRP also coordinates work on regional downscaling to provide more detailed information demanded by climate service providers and end users – but this downscaling requires the CMIP global climate model projections as input.

How do the WGCM and CMIP function?

The WGCM serves as the focal point for interaction and collaboration between climate modelling centres around the world. It organizes meetings, workshops and targeted research activities aimed at improving climate and Earth system modelling capabilities and at objectively evaluating climate model simulations through careful comparison to a wide range of observations. The WGCM has established two sub-groups to facilitate its work. The CMIP Panel is responsible for engaging with the climate modelling community to co-develop the CMIP experimental design and its documentation. The WGCM Infrastructure Panel oversees the complex technical infrastructure that allows model results to be archived and disseminated to users. The underlying system is called the Earth System Grid Federation that is comprised of a distributed system of servers running a software system for ingesting model output in a common format and allowing users from anywhere in the world to download and make use of it. The development of this system is largely supported by the US and Europe, and is augmented by individual nodes in 17 countries around the world. Currently the archive contains about 4PB of model output (expected to grow to about 20PB within a year) and supports 50 to 100 TB/day of downloads to over 10 000 users.

The WGCM and CMIP Panel also organize a rapidly growing suite of model evaluation tools that allow the modelling community to carefully assess model performance and guide ongoing model development. This constant model evaluation and improvement serves to push the envelope of climate science and provides the basis for much of the model-related assessment in IPCC reports.

What are the current issues?

Although CMIP has been extraordinarily successful, and leverages a large investment from individual countries, there are aspects that are fragile or unsustainable due to a lack of

sustained funding. According to a recent review of the WCRP (*ISC, WMO, IOC of UNESCO, Review of the World Climate Research Programme (WCRP). 72 pp. Paris, International Science Council, 2018*), "A conservative estimate of the national investments in CMIP6 places their value in excess of US$ 3 billion, based on scientists' time to develop and run the models and to design the experiments, and the super-computing costs to deliver the simulations."

This impressive leveraging is the consequence of volunteer efforts by the WGCM members, the CMIP Panel, and the individual scientists who contribute to the underlying essential infrastructure. This infrastructure includes the development and careful quality control of the 'forcing data' that goes into the climate model simulations (the specification of historical greenhouse gas and aerosol concentrations, land-use change, volcanic emissions, ozone and nitrogen concentrations, emissions of short-lived species, and solar variability, and the future scenarios of these quantities necessary to make climate projections). The infrastructure also includes the careful development of data formats and standards, documentation, and software that allows modelling centres from around the world to contribute model output to a distributed archive system (the Earth System Grid Federation, 'ESGF') and allows users from around the world to access this massive multi-model data set. Similar, and equally ambitious efforts have been made to assemble and disseminate a vast array of observational data using the same formats and archival system to allow careful evaluation of model results.

The growing dependency on CMIP products by a broad sector of the research community and by national and international climate assessments means that basic CMIP activities, such as the creation of forcing datasets, the provision and archiving of CMIP products, and model development, require substantial efforts in order to provide timely and quality controlled model output and analysis. The current 'volunteer' based system is not sustainable. The coordinated production and delivery of climate model projections in particular serves as the basis for national and international climate assessments (e.g. IPCC) along with a growing network of climate services and climate service providers. This vital international activity is at risk if certain aspects are not 'operationalized' in some way.

Path Forward

The WCRP and its Coupled Model Intercomparison Project (CMIP) provides valuable multi-model climate simulations and projections that benefit all WMO members, both individually and collectively. CMIP is a large project with several hundred climate scientists involved, yet relying heavily on research funding and volunteer work. CMIP has now reached a stage where certain components and activities require sustained institutional support for it to meet the growing expectation to support climate services, policy and decision-making.

Of particular urgency is the systematic development of forcing scenarios that require institutionalized support so that quality controlled datasets and regular updates to present-day can be provided in a timely fashion. In addition, a more operational infrastructure needs to be put in place, so that core simulations that support national and international assessments can be regularly delivered and quality controlled. This includes the oversight and maintenance of the data standards, documentation and software capabilities that make possible this collaborative international enterprise.

The CMIP Panel would also benefit immensely from a dedicated project office to support the panel with organizational, communication, and dissemination aspects.

This would help insure that CMIP can be effectively coordinated to fulfil its growing demands, that the infrastructure remains viable, that the inputs required by modelling centres to conduct climate simulations and projections continue to be provided in time for IPCC assessments, and that the data continues to be effectively and efficiently quality controlled and disseminated in

support of national and international policy development, decision-making and adaptation planning.

APPENDIX C – RESOLUTION APPROVED AT 18th SESSION OF WORLD METEOROLOGICAL CONGRESS (FINAL EDITING PENDING)

[Editor's note: the resolution's final and official version is published in the "World Meteorological Congress: Abridged Final Report of the Eighteenth Session - Part I - Abridged Final Report" as "Resolution 67 (Cg-18) WMO Scientific and Technological Support to the Intergovernmental Panel on Climate Change and Climate Policy", which is accessible from https://library.wmo.int/index.php?lvl=notice_display&id=21440]

World Meteorological Organization
WORLD METEOROLOGICAL CONGRESS
Eighteenth Session
Geneva, 3 to 14 June 2019

Cg-18/Doc. 7.3(2)
Submitted by: Chair
11.VI.2019
APPROVED

AGENDA ITEM 7: **EARTH SYSTEM RESEARCH**

AGENDA ITEM 7.3: **Science for policy**

DRAFT RESOLUTION

Draft Resolution 7.3(2) (Cg-18)

WMO SCIENTIFIC AND TECHNOLOGICAL SUPPORT TO IPCC AND CLIMATE POLICY

THE WORLD METEOROLOGICAL CONGRESS,

Recalling:

(1) Resolution 15 (Cg-17) - *World Climate Programme* and Resolution 56 (Cg-17) – *Intergovernmental Panel on Climate Change*,

(2) Decision 17 (EC-68) – *WMO support to the implementation of activities of the Intergovernmental Panel on Climate Change (IPCC),*

(3) Decision 7 (EC-69) – *WMO support to implementation of the Paris Agreement,*

(4) *Decision 9 (EC-69) – Strengthening the WMO Statement on the State of the Global Climate,*

(5) Decision 50 (EC-69) – *An Integrated Research and Development Approach,*

(6) Resolution 2 (EC-70) - *WMO integrated approach to high-level climate-science-related policy processes,*

(7) Decision 6 (EC-70) - *Implementation of Intergovernmental Panel on Climate Change activities,*

(8) Decision 9 (EC-70) - *Promoting the use and interpretation of climate change projections on regional and national scales*,

(9) Resolution 30 (EC-70) – *The 2018 review of the World Climate Research Programme*,

(10) Resolution 5.2(1)/1 (Cg-18) – *WMO contributions to the provision of climate information and services in support of policy and decision-making*,

(11) Resolution 7.1/1 (Cg-18) – *Future WMO research and supporting activities*,

Recalling further:

(1) The support of WMO, together with the United Nations Environment Programme (UNEP), as parent organizations of the IPCC dedicated to providing governments at all levels with scientific information that they can use to develop climate policies, the hosting of the IPCC Secretariat at WMO and provision of administrative, language and conference services,

(2) The support of WMO, together with IOC-UNESCO and the International Science Council (ISC), as co-sponsors of WCRP, dedicated to facilitating the analysis and prediction of Earth system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society,

Noting:

(1) The report of the Chair of IPCC *[INF. 7.3(2)]*,

(2) The critical role of WMO in supporting IPCC activities and key reports, such as the IPCC Special Report on Global Warming of 1.5ºC invited [Luxembourg] by the UNFCCC Conference of Parties (COP21), and which provided one of the scientific underpinnings [USA, Germany and Luxembourg] for the Talanoa Dialogue at COP24 last year,

(3) The relevance of the IPCC's Sixth Assessment cycle in supporting the climate science-policy interface [USA],

(4) The annual WMO assessments on climate related topics: the Statement on the State of the Global Climate, the annual WMO Greenhouse Gas Bulletin, the WMO Aerosol Bulletin as well as other relevant Bulletins under the Global Atmosphere Watch (GAW) Programme,

(5) The role of WCRP to convene the international climate modelling community, to coordinate the development and improvement of climate and Earth system models, and to deliver climate predictions and longer-term climate change projections, including at regional scale,

(6) That the WCRP Coupled Model Intercomparison Project (CMIP), now in its 6th phase, serves as both an organizer and coordinator of international climate research through the definition of experimental protocols and provider of supporting infrastructure that allow for coordinated multi-model global climate simulations, and that the WCRP Coordinated Regional Climate Downscaling Experiment (CORDEX), now in its 2nd phase, is an initiative to provide global coordination of regional climate downscaling for improved regional climate change adaptation and impact assessment.

Noting further that CMIP contributes to one of the [Luxembourg] foundational [USA] elements for the Intergovernmental Panel on Climate Change (IPCC) assessments, the United Nations Framework Convention on Climate Change (UNFCCC) policy deliberations, and climate services and products disseminated world-wide,

Recognizing:

(1) That CMIP and CORDEX have been extraordinarily successful, and leverage a large investment from individual countries, research centres, agencies and individual scientists who contribute to the underlying essential infrastructure,

(2) The growing dependency on CMIP and CORDEX products by a broad research community, by national and international climate assessments, by climate services and policy making,

(3) That basic CMIP and CORDEX activities, such as the creation and regular update of forcing datasets, the provision, archiving and quality check of CMIP and CORDEX products, model development, and international coordination are currently at significant risk if not institutionalized in some way, as they still rely largely on volunteer work and research funding,

Decides to enhance WMO scientific support to climate policy through:

(1) Coordination of annual WMO assessments on the State of the Global Climate, Greenhouse Gas concentrations and other relevant atmospheric constituents, and climate observations and associated data with IPCC assessments and other complementary reports regularly released by other entities using the mechanism established through Resolution 5.2(1)/1 (Cg-18) [USA];

(2) Coordination through the WCRP international research on predictions, longer-term climate change projections and robust attribution, as well as on associated big data analytics and artificial intelligence techniques [India], including at regional scale, through its new strategic and implementation plans, ensuring key contributions to the Sixth Assessment Report (AR6);

(3) Using the research and innovation framework of the Seamless Data-processing and Forecasting System (GDPFS, Resolution 6.3(1)/1 Cg-18), towards continuous development of CMIP models and tools within a research-to-operation context;

(4) Ensuring institutionalization and operationalization of the CMIP and CORDEX delivery for the preparation of AR6, including timely preparation and quality control of data for producing the appropriate scenarios and projections supporting the IPCC assessments [Germany] and guidance for robust sectoral impacts supporting climate services [India], as well as the application of protocols for standardization developed in [Germany] the CMIP modelling framework;

Urges Members:

(1) To enhance financial support to the IPCC though the IPCC Trust Fund or in-kind contributions [Luxembourg];

(2) To coordinate, via IPCC national focal points, [Russian Federation] among different ministries, agencies and academic networks, including social sciences, to foster, as appropriate, [Russian Federation] the establishment of National Panels or other

institutional arrangements [USA] for the IPCC that can bring together all the relevant expertise;

(3) To contribute institutional, technical and financial resources as necessary to ensure sustainable and robust CMIP and CORDEX climate change projections [Luxembourg] delivery to IPCC;

(4) To adhere to existing standards in order to facilitate data exchange between institutions and to co-develop future adaptations in collaboration with the climate research community; [Germany]

Requests the Secretary General:

(1) To set up a dedicated ad-hoc [Curaçao and Sint Maarten] Task Force with representation of WCRP, UNFCCC and the Infrastructure Commission (in relation to the GDPFS) to prepare recommendations for the Executive Council regarding the implementation of the CMIP and CORDEX delivery to IPCC, and the related organizational and financial aspects. Members of the IPCC (Bureau/Executive Committee) can be invited by the Task Group to present the products of the IPCC;

(2) To consider ways to enhance the coherence and consistency of climate products among WMO climate activities and the [Luxembourg] IPCC;

(3) To continue the support of the IPCC Secretariat [Luxembourg] and to pursue more efficient delivery and closer cooperation on climate assessments.

(4) To strengthen the national human and technical capacities to develop climate models involved in CMIP, in particular in those countries not doing so yet [Uruguay], and to pay particular attention to young scientists from Small Islands and Developing States [Cook Islands].

APPENDIX D – CONTACT LIST

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