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Climate Model Intercomparisons: Preparing for the Next Phase

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Since 1995, the Coupled Model Intercomparison Project (CMIP) has coordinated climate model experiments involving multiple international modeling teams. Through CMIP, climate modelers and scientists from around the world have analyzed and compared state-of-the-art climate model simulations to gain insights into the processes, mechanisms, and consequences of climate variability and climate change. This has led to a better understanding of past, present, and future climate, and CMIP model experiments have routinely been the basis for future climate change assessments made by the Intergovernmental Panel on Climate Change (IPCC) [e.g., IPCC, 2013, and references therein].

CMIP has developed in phases, with the simulations of the fifth phase, CMIP5, now mostly completed. Though analyses of the CMIP5 data will continue for at least several more years, science gaps and outstanding science questions have prompted preparations for the sixth phase of the project (CMIP6). This brief overview of the initial proposed design of CMIP6 is meant to inform interested research communities and to encourage discussion and feedback for consideration in the evolving experiment design (see Figure 1). A more complete description and further information are available at <http://www.wcrp-climate.org/index.php/wgcm-cmip/wgcm-cmip6> and in the additional supporting information in the online version of this article.

Scientific Focus and Structure

The proposed scientific backdrop for CMIP6 consists of the six grand challenges of the World Climate Research Programme (WCRP)—encapsulating questions related to clouds, circulation, and climate sensitivity; changes in cryosphere; climate extremes; regional climate information; regional sea level rise; and water availability—with an additional theme involving biospheric forcings

and feedbacks. The specific experiment design would focus on three broad questions: How does the Earth system respond to forcing? What are the origins and consequences of systematic model biases? How can we assess future climate changes given

climate variability, climate predictability, and uncertainties in scenarios?

Within this scientific framework, a more distributed organization for CMIP6 than in previous phases of CMIP is proposed. This would fall under the oversight of the CMIP Panel (see Figure 1), wherein an ongoing activity, CMIP, is distinguished from a particular phase of CMIP, now CMIP6. This structure involves two basic components.

First, CMIP (inner part of Figure 1) would be composed of two elements: in one, researchers would run a small set of standardized

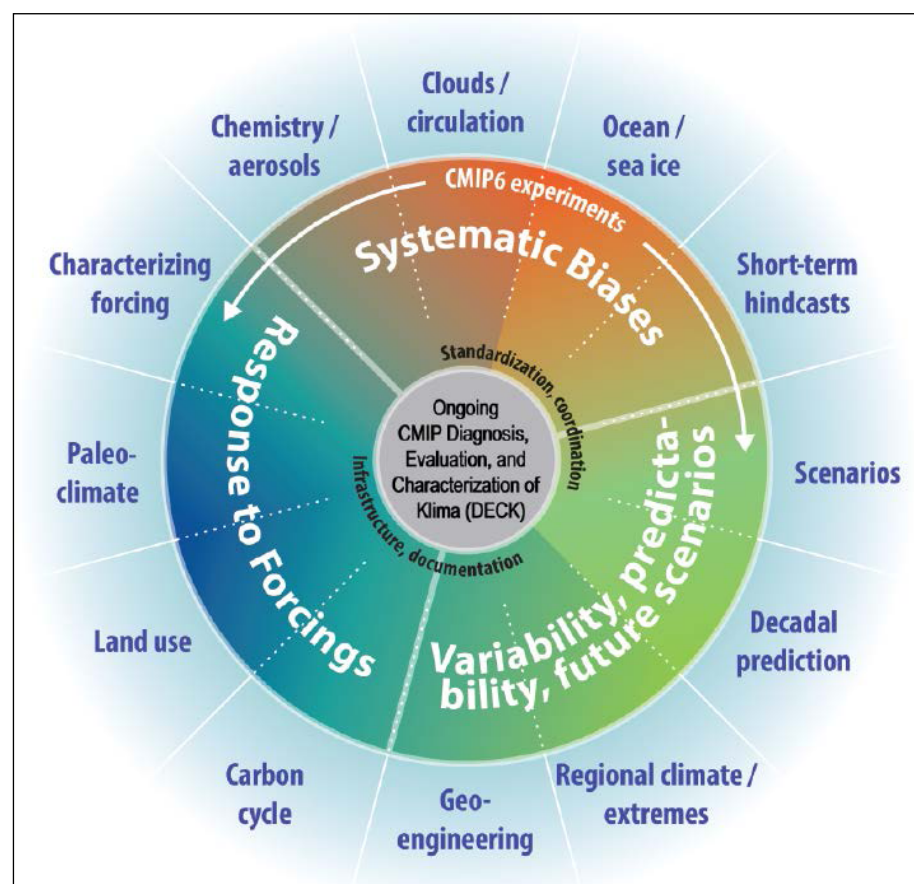


Fig. 1. Schematic of the proposed experiment design for phase 6 of the Coupled Model Intercomparison Project (CMIP6). The inner ring and surrounding black text involve standardized functions of all CMIP, including ongoing Diagnosis, Evaluation, and Characterization of Klima (DECK) experiments (Klima is German for “climate”). The middle ring shows science topics related specifically to CMIP6 to be addressed by the MIPs, with illustrative (and likely not complete) MIP topics shown in the outer ring. This framework is superimposed on the scientific backdrop for CMIP6—the six grand challenges of the World Climate Research Programme (WCRP), which encapsulate questions related to clouds, circulation, and climate sensitivity; changes in cryosphere; climate extremes; regional climate information; regional sea level rise; and water availability. An additional science topic involves biospheric forcings and feedbacks.

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experiments (ongoing Diagnosis, Evaluation, and Characterization of Klima (DECK) experiments; *klima* is German for “climate”), and in the other, the CMIP activity would provide standardization, coordination, and infrastructure, as well as documentation functions that allow the simulations and their main characteristics performed under CMIP to be made available to the broader community.

The DECK experiments are chosen to provide continuity across past and future phases of CMIP and to take advantage of what is already common practice in many modeling centers. They would include five aspects: a simulation with specified observed sea surface temperatures from 1979 to 2010 (typically referred to as an “AMIP experiment” after a previous project called the Atmospheric Model Intercomparison Project); a multi-hundred-year pre-industrial control simulation; a 1% per year carbon dioxide (CO₂) increase simulation run to 4 times current levels to derive the transient climate response; a run with an instantaneous quadrupling of CO₂ to derive the equilibrium climate sensitivity; and a simulation starting in the 19th century and running through the 21st century using an existing representative concentration pathway (RCP) scenario for future climate (RCP8.5) that was run in CMIP5 and assessed in the IPCC’s Fifth Assessment Report. In RCP8.5, concentrations of CO₂ reach about 900 parts per million by 2100—more than twice what they are now.

Second, CMIP6 (the ring outside DECK in Figure 1) would, similar to CMIP5, enable creators of specific model intercomparison projects (MIPs, with related science topics in the outermost ring in Figure 1) to propose experiments to be endorsed by CMIP6. Modeling groups could then choose a subset of these MIP experiments to run according to their interests and within computing and human resource constraints. The MIPs would also likely have additional experiments that would not be part of CMIP6 but would be of interest and relevant to their respective communities.

Scenarios

Another new concept proposed for CMIP6 is a “ScenarioMIP” that specifically targets the science theme: How can we assess future climate changes given climate variability, climate predictability, and uncertainties in scenarios? Within this science focus, a number of research topics have been identified that require cooperation with integrated assessment and impacts-adaptation-vulnerability researchers. These topics include an overshoot scenario as noted above, emissions of shortlived climate forcers and air quality/climate interactions, land use and land cover change, integrated analysis of impacts and responses, and climate risk related to variability estimates.

All participating modeling groups would run some common simulations (e.g., a pair of new scenarios, one nonmitigation and one with mitigation of greenhouse gases and other human climate change drivers) to provide a

basis for research on impacts and damages avoided through mitigation and adaptation. Then, if modeling groups elected to run more scenarios, they could participate in a matrix of scenario experiments. An experiment design strategy is being explored to test the feasibility of assigning a subset of models to scenarios in such a way as to sample a variety of climate model characteristics (e.g., climate sensitivity, model performance, and complexity) for each scenario or pair of scenarios in the matrix.

Phasing of Experiments and Model Evaluation

The Earth System Grid Federation (ESGF; http://cmip-pcmdi.llnl.gov/cmip5/data_portal.html), which was first used in CMIP5, allows modeling groups to post model output to nodes on the ESGF for archiving and access by the community at any time. Therefore, the MIPs would not have to wait until the very end of the CMIP6 cycle to run experiments, thereby avoiding the pressure of running and analyzing a huge number of experiments within a couple of months near the end of the CMIP6 cycle or some assessment deadline.

A CMIP benchmarking and evaluation software package (made available to everyone, for example through the Working Group on Numerical Experimentation/Working Group on Coupled Models (WGNE/WGCM) metrics panel wiki) would then produce well-established analyses as soon as model results became available. The objective is to enable routine model evaluation and to aid the model development process by providing feedback concerning systematic model errors in the individual models.

Participation and Communication

The ongoing nature of the proposed CMIP/CMIP6 structure means that anyone at any time could download model data for analysis. In addition, a scientist or group of scientists could propose a MIP at any time to the CMIP Panel (see template at <http://www.wcrp-climate.org/index.php/wgcm-cmip/wgcm-cmip6>).

The new distributed nature of CMIP6 requires the WCRP WGCM and the CMIP Panel to play a strong role in facilitating communication between the scientists organizing MIP experiments and between the MIPs and the modeling groups running those experiments.

Next Steps and Time Line

Feedback on this initial CMIP6 proposal is being solicited this year from modeling groups and model analysts. Please send comments to CMIP Panel chair Veronika Eyring (veronika.eyring@dlr.de) by the end of September 2014. The WGCM and the CMIP Panel will then revise the proposed experiment design, with the intention of finalizing it in October 2014. The overall data preparation will follow procedures developed in CMIP5. The historical emissions would be made available in spring 2015, and

the emissions for the future climate scenarios would be provided by the end of 2015.

Analyses of CMIP6 data would be ongoing, with the simulation phase of CMIP6 running for 5 years, from 2015 to 2020, followed by many more years of model analysis. The runs for the ScenarioMIP would probably occur near the end of the CMIP6 cycle and thus would likely begin in 2017 and continue into 2018. A possible IPCC AR6 that would likely assess CMIP6 simulations could take place from roughly 2017 to 2020, but when or even if there will be an AR6 will not be known until 2015 at the earliest. Even without an AR6, CMIP6 will still operate, as previous phases of CMIP have, to provide a set of state-of-the-art global climate model simulations as a resource for the international climate science community.

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