# Workshop on CMIP5 Model Analysis and Scientific Plans for CMIP6

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## MIP SESSION: Tuesday 20th October

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# The Cloud Feedback Model Intercomparison Project (CFMIP) proposal for CMIP6

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**Abstract**

The primary goal of CFMIP is to inform improved assessments of cloud feedbacks. This involves bringing climate modelling, observational and process modelling communities together and providing better tools and community support for understanding and evaluation of clouds and cloud feedbacks simulated by climate models. CFMIP supports ongoing coordinated model inter-comparison activities by recommending experiments and model output diagnostics for CMIP. The CFMIP approach is also increasingly being used to understand other aspects of climate change, such as circulation, regional-scale precipitation and non-linear changes. CFMIP is proposing a number of experiments and model outputs for CMIP6, building on and extending the CFMIP experiments which were part of CMIP5.

A compact and inexpensive set of Tier 1 experiments are proposed address the question: "What are the physical mechanisms underlying the range of cloud feedbacks and cloud adjustments predicted by climate models, and which models have the most credible cloud feedbacks?" The amip4K, amip4xCO2, amipFuture, aquaControl, aqua4xCO2 and aqua4K experiments the idealized experimental hierarchy of CFMIP-2/CMIP5 while building on the DECK AMIP experiment. These experiments will continue to include outputs from the CFMIP Observational Simulator Package (COSP) to support quantitative evaluation of modelled clouds with observations and to relate cloud feedbacks to observed quantities. CMIP5 process diagnostics including high frequency outputs at selected locations and temperature and humidity budget terms from radiation, convection, dynamics, etc. are also retained. A

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subset of these are also proposed for inclusion in the CMIP6 DECK and CMIP6 Historical experiments.
A number of Tier II experiments are proposed to address additional science questions. Abrupt +/-4% Solar Forced AOGCM experiments are proposed for the question ”How do responses in the climate system due to changes in solar forcing differ from changes due to CO2, and is the response sensitive to the sign of the solar forcing?” Abrupt2xCO2 and abrupt0.5xCO2 experiments are proposed to address the question ”To what extent is regional-scale climate change per CO2 doubling state-dependent (nonlinear), and why?” Other experiments and questions proposed include: amip uniform -4K ”Are cloud feedbacks symmetric when subject to climate cooling rather than warming, and if not, why not?”; AMIP with preindustrial forcing ”Are climate feedbacks during the 20th century different to those acting on long term climate change and climate sensitivity?”; Timeslice experiments forced with SSTs from preindustrial and abrupt4xCO2 simulations ”How do regional climate responses (of e.g. precipitation) in a coupled model arise from the combination of responses to different aspects of CO2 forcing and warming (uniform SST warming, pattern SST warming, direct CO2 effect, plant physiological effect)?” ; Atmosphere-only experiments with clouds made transparent to longwave radiation ”How do cloud-radiative effects impact the structure, the strength and the variability of the general atmospheric circulation in the present-day climate?”

Our plans for CMIP6 will be summarized and positioned in the wider context of the WCRP Grand Challenge on Clouds, Circulation and Climate Sensitivity.

**Keywords:** clouds precipitation circulation feedback forcing

# The Geoengineering Model Intercomparison Project Phase 6 (GeoMIP6): Simulation Design and Preliminary Results

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**Abstract**

We present a suite of new climate model experiment designs for the Geoengineering Model Intercomparison Project (GeoMIP). This set of experiments, named GeoMIP6 (to be consistent with the Coupled Model Intercomparison Project Phase 6), is designed to study several important topics, including key uncertainties in extreme events, use of geoengineering as part of a portfolio of responses to climate change, and the relatively new idea of cirrus cloud thinning to allow more longwave radiation to escape to space. We discuss experiment designs, as well as the rationale for those designs, showing preliminary results from individual models when available. We introduce a new feature, called the GeoMIP Testbed, which provides a platform for simulations that will be performed with a few models and subsequently assessed to determine whether the proposed experiment designs will be adopted as core (Tier 1) GeoMIP experiments. The GeoMIP Testbed is meant to encourage various stakeholders to propose new targeted experiments that address their key open science questions, with the goal of making GeoMIP more relevant to a broader set of communities.

**Keywords:** Geoengineering, GeoMIP, Model Intercomparison Project

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# AerChemMIP: Aerosols, Chemistry and their Climate Effects

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**Abstract**

Aerosols and ozone were identified in IPCC AR5 as the main sources of uncertainty in the radiative forcing since pre-industrial times. Quantifying projections of aerosols and chemically reactive gases in future are key to predicting climate change over the next few decades. Changes in the atmospheric abundance of these species have been and will be spatially and temporally inhomogeneous, leading to regional patterns of temperature and precipitation response significantly larger than the global mean.
Future emissions of aerosols and reactive species will be affected by air quality policies as well as climate policies. The former may act on shorter timescales than climate policy and hence there is an urgent need for quantifying its climate impacts.

AerChemMIP will use simulations from the major Earth System Models driven by emissions (for short-lived species) to address three particular science questions

- How have aerosols near-term climate forcers and ozone-depleting substances affected global and regional climate over the historical period?

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- How will future policies (on climate, air quality and land use) affect aerosols and chemically reactive species and their consequent global and regional climate impacts?
- How have WMGHGs forced climate through their chemical impacts over the historical period?

IPCC AR5 identified the effective radiative forcing (ERF) as being a more appropriate quantity than radiative forcing (RF) to assess the impact of atmospheric constituents. Therefore quantifying the ERFs for constituents will be a major focus of AerChemMIP in addressing the science questions. These will be complemented by a smaller number of coupled-ocean simulations to understand the relationship between forcing and response.

**Keywords:** Aerosols, ozone, effective radiative forcing

# Ocean Model Intercomparison Project (OMIP)

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**Abstract**

OMIP provides a framework for evaluating, understanding, and improving ocean, sea-ice, tracer, and biogeochemical components of climate and earth system models contributing to CMIP6. It represents a merger of the previously separate Ocean Carbon Model Intercomparison Project (OCMIP) with physical oceanography. Among the three CMIP6 science questions, OMIP primarily targets addressing the origins and consequences of systematic model biases. In addition to model evaluation, OMIP presents a framework i) to investigate physical, chemical, and biogeochemical mechanisms that drive seasonal, inter-annual, and decadal variability; ii) to attribute ocean-climate variations to boundary forced versus natural; iii) to evaluate robustness of mechanisms across models and forcing data sets; iv) to bridge observations and modeling by complementing ocean reanalysis from data assimilation; and v) to provide consistent ocean and sea-ice states useful for initialization of climate (e.g., decadal) predictions. The OMIP framework consists of i) a protocol for performing global ocean – sea-ice coupled simulations and ii) an ocean model diagnostics document that contains recommendations and scientific justifications for sampling physical, chemical, and biogeochemical ocean fields for use by all CMIP6 simulations that include an ocean component. The physical portion of OMIP follows the Coordinated Ocean-ice Reference Experiments phase II (CORE-II) protocol, involving use of interannually varying atmospheric data sets. The chemical and biogeochemical portions are based on the OCMIP2 and OCMIP3 protocols, respectively. OMIP contains one tier 1 and one tier 2 simulation. The tier 1 experiment requests a 310-year, global ocean – sea-ice coupled simulation, corresponding to five repeat cycles of the 1948-2009 forcing period. It involves two paths. The groups which do not have the capability to run with biogeochemistry can participate in the physics part, while the groups with the biogeochemistry capability are expected to run with biogeochemistry. The tier 2 experiment is requested from the latter group and involves performing one millennial-scale spin-up simulation to address long time scales associated with biogeochemical variables. OMIP is coordinated by the CLIVAR Ocean Model Development Panel (OMDP).

**Keywords:** OMIP, COREII, OCMIP, biogeochemistry

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# C4MIP: Carbon cycle science highlights from CMIP5

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**Abstract**

The carbon cycle is a key addition to physical climate models that makes them "Earth System Models" (ESMs). CMIP5 was the first CMIP phase to include ESMs as the standard climate change modelling tool and carbon cycle results featured strongly in the IPCC 5th Assessment Report. C4MIP simulations in CMIP5 were targetted to address all 3 of the CMIP science 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 change given climate variability, predictability and uncertainty in scenarios.

Carbon cycle projections from CMIP5 simulations have been used widely. They formed a crucial part of the IPCC WG1 5th Assessment Report where the processes, feedbacks and projections were central to the carbon cycle chapter (ch. 6) and their role in future climate projections were presented in chapter 12. "Offline" process evaluation and "online" or coupled evaluation also contributed in chapters 6 and 9 respectively. These results were

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underpinned by a series of more in depth analyses that formed a special issue of J.Clim. This comprised 14 papers whose focus spanned individual processes (such as permafrost and land use), feedback metrics (and how best to quantify them), future projections (including commitments beyond 2100) and some evaluation studies quantifying the performance of the ESMs.

In this presentation we present a synthesis of these and other key carbon cycle science results and their implications from the CMIP5 simulations.

**Keywords:** carbon cycle, CMIP5, ESM

# C4MIP: Carbon cycle science prospects from CMIP6

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**Abstract**

The carbon cycle is a key addition to physical climate models that makes them "Earth System Models" (ESMs). CMIP5 was the first CMIP phase to include ESMs as the standard climate change modelling tool and carbon cycle results featured strongly in the IPCC 5th Assessment Report (see for example WG1 chapters 6, 9, 12 and WG2 chapter 4). As a prominent new advance since AR4, WG1 SPM highlighted the direct link from anthropogenic emissions to global climate change through the policy relevant Transient Response to Cumulative Emissions (TCRE) metric.

However, large model spread and uncertainty reduces the utility of these results and to date a lack of systematic biogeochemical evaluation of ESMs has meant we have not reduced this spread since the first generation of carbon cycle GCM projections.

For CMIP6, the carbon cycle community propose a range of simulations aimed at:
- Feedback diagnosis and process understanding. How have coupled climate-carbon cycle feedbacks evolved over multiple generations of carbon cycle models, and how have new processes (such as representation of the terrestrial nitrogen cycle) had an effect?

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- Evaluation. How well do these models simulate observed properties of the Earth system from the historical record to process level behaviours and sensitivities and which of these metrics help us constrain future projections?
- Policy-relevant projections. How do climate-carbon cycle interactions under future emissions scenarios affect projections of atmospheric CO2 and hence climate change? What emissions reductions are required to meet given climate targets?

In this presentation we review the experimental design and prospects for progress in the above areas. We will highlight specific science questions and new techniques to answer them and present some key new observational datasets that we hope will enable more systematic and thorough ESM evaluation going forward.

**Keywords:** carbon cycle, CMIP6, ESM

# The Palaeoclimate Modelling Intercomparison Project plans for CMIP6

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**Abstract**

Since the 1990s, PMIP has developed with the following objectives:
- to evaluate the ability of climate models used for climate prediction in simulating well-documented past climates outside the range of present and recent climate variability

- to understand the mechanisms of these climate changes, in particular the role of the different climate feedbacks

To achieve these goals, PMIP has actively fostered paleo-data syntheses, multi-model analyses, including analyses of relationships between model results from past and future simulations, and model-data comparisons. Three PMIP3 simulations were part of the CMIP5 ensemble of simulations: the last millennium, the mid-Holocene (_˜6,000 years ago) and the Last Glacial Maximum (_˜21,000 years ago), hence allowing, for the first time, the rigorous comparison of model results for past and future climates. The rationale for considering these periods was:

- for the Last Glacial Maximum, to evaluate the models on a well-documented climatic extreme, especially in terms of temperatures, and study the role of forcings and feedbacks in establishing this climate;

- for the mid-Holocene, to evaluate and analyse the models on a climate "optimum" for the northern hemisphere, characterized by enhanced monsoons, extra-tropical continental aridity and much warmer summers;

- for the last millennium, to study the mechanisms (natural variability vs impact of solar, volcanic and anthropogenic forcings) of decadal to centennial climate variability and evaluate the models' performance w.r.t numerous detailed records.

For CMIP6, we propose to include two new warm periods in the PMIP/CMIP set of experiments: the Last Interglacial and the Mid-Pliocene, for which simulations have been performed and significantly contributed to AR5.

PMIP simulations specifically address CMIP6 key question on "How does the Earth System respond to forcing" for a variety of forcings and with possible comparisons to data for climates states very different from the current or historical climate. PMIP also addresses

*Speaker

question 2 ("What are the origins and consequences of systematic model biases?") about systematic model biases, with the perspective given by documented climates different from today: PMIP simulations, with comparisons to data, can help assessing whether the biases for present-day are also found for other climate states and whether present-day biases have an impact on the magnitude of simulated climate changes. Finally, PMIP is relevant for question 3 ("How can we assess future climate changes given climate variability, predictability and uncertainties in scenarios?"), by examining these very questions for documented past climate cases and via the use of the last millennium simulations as reference state for natural variability.

PMIP simulations will be analyzed within the Grand Challenge "Clouds, Circulation and Climate Sensitivity". They can also provide valuable input for other grand challenges, such as those on the Cryosphere and on Regional Climate Information, with the challenge of paleoclimate modelling at fine scale. Indeed, PMIP model output is increasingly used in "paleo-impact studies", e.g. on biodiversity.
The five proposed experiments constitute a reference ensemble for further studies within PMIP. This poster will present the experiments and how they are inserted to the general PMIP plans.

**Keywords:** Paleoclimate, PMIP

# Advancing our understanding of the impacts of historic and projected land use in the Earth System: The Land Use Model Intercomparison Project (LUMIP)

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**Abstract**

Earth System Models (ESMs) are including increasingly comprehensive treatments of land use and land management, representing not only land cover change, but also land use in the form of prognostic crop and pasture models, irrigation, fertilization, wood harvest, and urbanization. The Land Use Model Intercomparison Project (LUMIP) is a new (proposed) satellite-MIP within the Coupled Model Intercomparison Project (CMIP) that is designed to address the following main science questions: (1) What are the effects of land use and land-use change on climate (past-future)? (2) Are there regional land management strategies with promise to help mitigate and adapt to climate change? Additional LUMIP scientific priorities include assessments of fossil fuel versus land use forcing, biogeochemical versus biogeophysical impacts of LULCC, land management versus land cover change impacts, modulation of land use impact on climate by land-atmosphere coupling strength, and alterations of global CO2 fertilization strength by LULCC. LUMIP will coordinate across existing land use change projects such as LUCID, AgMIP, GSWP3, Trendy, and LUC4C. LUMIP encompasses three major activities: (1) input and output data harmonization and standardization, (2) development of model metrics to assess ESM performance with respect to the impact of land use on climate and carbon cycling, and (3) design and execution of a concise set of land model and ESM experiments for assessment of the impacts of historic and projected land use on the climate system. Preliminary results from idealized model experiments will be presented.

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**Keywords:** land use change, land cover change, land management

# Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6)

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**Abstract**

The sea level projections made by the glaciological community as part of the Intergovernmental Panel on Climate Change (IPCC) process have often been out of phase with the projections considered by the wider Coupled Model Intercomparison Project (CMIP) community. For instance in AR5, the ice2sea and SeaRISE (Sea-level Response to Ice Sheet Evolution) ice sheet projects predominantly worked with AR4 scenarios, while the CMIP5 community used new future scenarios. As the next phase of CMIP is being designed (CMIP6), an effort for ice sheet models to be better integrated in the CMIP6 initiative has been proposed to the CMIP panel.
We present the framework for the new effort, ISMIP6, the Ice Sheet Model Intercomparison Project for CMIP6. The primary goal of ISMIP6 is to improve projections of sea level rise by focusing on the evolution of the Greenland and Antarctic ice sheets under a changing climate, along with a quantification of associated uncertainties (including uncertainty in both climate forcing and ice-sheet response). This goal requires an evaluation of AOGCM climate over and surrounding the ice sheets; analysis of simulated ice-sheet response from standalone models forced "offline" with CMIP AOGCM outputs and, where possible, with coupled ice sheet-AOGCM models; and experiments with standalone ice sheet models targeted at exploring the uncertainty associated with ice sheets physics, dynamics and numerical implementation. A secondary goal is to investigate the role of feedbacks between ice sheets and climate in order to gain insight into the impact of increased mass loss from the ice sheets on regional and global sea level, and of the implied ocean freshening on the coupled ocean-atmosphere circulation. These goals map into both Cryosphere and Sea-Level Rise Grand Challenges relevant to Climate and Cryosphere (CliC) and the World Climate Research Program (WCRP).

ISMIP6 is primarily focused on the CMIP6 scientific question "How does the Earth System respond to forcing?" and offers the exciting opportunity of widening the current CMIP definition of Earth System to include (for the first time) the ice sheets. The key output

*Speaker

will be an ensemble of past and future estimates of ice sheet contribution to sea level. The proposed experiments both use and augment the CMIP6-DECK, Historical, ScenarioMIP and PMIP experiments. The emphasis on standalone, ensemble modelling with ice sheet models will also shed light on the question "How can we assess future climate changes given climate variability, predictability and uncertainties in scenario" for the mass budget of the ice sheets and its impact of global sea level.

**Keywords:** ice sheets, changes in cryosphere, sea level

# Overview of the Radiative Forcing Model Intercomparison Project RFMIP

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**Abstract**

The Radiative Forcing Model Intercomparison Project (RFMIP) aims to understand the radiative forcing to which models are subject. The project will assess the accuracy of instantaneous radiative forcing calculations for greenhouse gases and aerosols in each model by comparing these to reference calculations across a range of states representative of present-day, past, and future climates. We will increase the accuracy and spatial detail with which effective radiative forcing is known for each model and for each DECK or other experiment by requesting and analyzing matching simulations designed for this purpose, carefully diagnosing the degree to which the diversity in effective radiative forcing is due to variations in rapid adjustments, radiative forcing and climatological base state. We will close the circle by requesting historical-to-near-future simulations in which anthropogenic aerosol optical and cloud-active properties are tightly controlled, allowing us to determine which aspects of the observed historical record consistently emerge and so can be attributed to aerosol forcing.

**Keywords:** Radiative forcing, aerosols, greenhouse gases, effective radiative forcing, rapid adjustments

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# HighResMIP – robust understanding of the impact of model resolution on climate simulation

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**Abstract**

The requirement for a multitude of multi-centennial simulations, including poorly constrained Earth System processes and feedbacks, has contributed to the relatively slow increase in model resolution within CMIP. In CMIP3 the typical resolution was 250km in the atmosphere and 1.5 in the ocean, while more than seven years later in CMIP5 this had only increased to 150km and 1 respectively. However, recent simulations with global high-resolution climate models have demonstrated the added value of enhanced resolution compared to the output from models in the CMIP3 and CMIP5 archive. They showed significant improvement in the simulation of aspects of the large scale circulation such as such as El Niño Southern Oscillation, the global water cycle, and Euro-Atlantic blocking. In addition, the increased resolution enables more realistic simulation of small scale phenomena with potentially severe impacts such as tropical cyclones, tropical-extratropical interactions and polar lows.
The goal of HighResMIP is to assess the robustness of changes such as these in a multi-model context using global, high resolution climate models with minimal Earth System complexity. In doing so, it will also contribute evidence to some of the open questions in IPCC AR5 WG1 particularly relating to circulation, the hydrological cycle, extreme climate events and regional climate change. The experimental protocol has been made as simple as possible, consisting of 1950-2050 integrations at both high (_˜25km) and low (60-100km) resolution (the latter likely the same as the CMIP6 DECK simulations), in both forced-atmosphere and coupled model configurations. Sixteen international groups have so far expressed interest in participating in at least the Tier 1 simulations.

**Keywords:** HighResMIP, CMIP6, high resolution, multi model, robustness

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# Detection and Attribution Model Intercomparison Project (DAMIP)

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**Abstract**

The primary goals of Detection and Attribution Model Intercomparison Project (DAMIP) are to facilitate improved estimation of the contribution of anthropogenic and natural forcing changes to observed global warming; to facilitate improved estimation of the contribution of those forcings to observed global and regional changes in other climate variables; to contribute to the estimation of how historical emissions have altered and are altering contemporary climate risk; and to facilitate and improve observationally-constrained projections of future climate change. Detection and attribution studies typically require unforced control simulations and historical simulations including all major anthropogenic and natural forcings. Such simulations will be carried out as part of the DECK and the CMIP6 historical simulation (hereafter we referred to the CMIP6 historical simulation as histALL). In addition such studies require additional simulations with individual forcings or subsets of forcings. We propose some such separated forcing experiments as DAMIP for CMIP6. Combinations of histALL and separated forcing experiments from models participating in CMIP6 will be useful for model evaluation, better understanding of historical climate changes, and for deriving observational constraints on future climate change projections. Synergies between DAMIP and other MIPs are also important. For example, using combinations of experiments from DAMIP and RFMIP, we can compare transient climate responses per unit radiative forcing across different forcing factors.

**Keywords:** Detection and Attribution: Observational constraints

*Speaker

# The Decadal Climate Prediction Project (DCPP)

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**Abstract**

The term "decadal prediction" encompasses predictions on annual, multi-annual to decadal timescales. The possibility of making skilful forecasts on these timescales and the ability to do so is investigated by means of predictability studies and retrospective predictions (hindcasts) made using the current generation of climate models. Skilful decadal prediction of relevant climate parameters is a Key Deliverable of the WCRP's Grand Challenge of providing Regional Climate Information (http://www.wcrp-climate.org/index.php/gc-regionalclimate). The DCPP consists of three Components. Groups are invited to participate in any and/or all of the Components, each of which are separately "tiered":

- Component A, Hindcasts: the design and organization of a coordinated decadal prediction (hindcast) component of CMIP6 in conjunction with the seasonal prediction and climate modelling communities
- Component B, Forecasts: the ongoing production of experimental quasi-operational decadal climate predictions in support of multi-model annual to decadal forecasting and the application of the forecasts
- Component C, Predictability, mechanisms, and case studies: the organization and coordination of decadal climate predictability studies and of case studies of particular climate shifts and variations including the study of the mechanisms that determine these behaviours

Many scientific and practical questions are involved. The understanding of the physical processes that govern the long timescale predictability of the climate system is vital to improving decadal predictions and these are explored using observations, climate model studies and the results of decadal hindcasts. The analysis of available observations for initializing forecasts, the improvement of the models used in the production of the forecasts, post processing of forecasts including bias adjustment, calibration and multi-model combination, together with the production and application of probabilistic decadal forecasts, are all involved in the research and development efforts contributing to the DCPP.

**Keywords:** decadal climate prediction

*Speaker

# The flux-anomaly-forced model intercomparison experiment (FAFMIP)

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**Abstract**

Projections of regional sea level change by CMIP5 AOGCMs, like earlier AOGCM generations, show a substantial spread due to the different models' differing simulations of regional ocean density and circulation changes, especially in high latitudes and the North Atlantic. Previous analyses have shown that a substantial fraction of the diversity of regional sea level projections arises from the spread in AOGCM projections of changes in surface fluxes of momentum (windstress), heat and freshwater. In the FAFMIP AOGCM experiments, a prescribed set of surface flux perturbations will be applied to the ocean. These perturbations will be obtained from the ensemble-mean changes simulated at time time of doubled CO2 by CMIP5 AOGCMs under the 1pctCO2 scenario, so they are representative of projected anthropogenic climate change. The aims of the experiments are: (1) To quantify the difference in the geographical patterns of sea level change due to ocean density and circulation change simulated by the models, when given common surface flux perturbations. (2) To provide information about the efficiency and interior distribution of ocean heat uptake in response to climate change; the AOGCM spread in these phenomena contributes to their spread in transient climate response and global mean sea level rise due to thermal expansion. (3) To provide information about the sensitivity of the Atlantic meridional overturning circulation (AMOC) to prescribed buoyancy forcing of the character expected for CO2 forcing, rather than idealised freshwater forcing such as has been used in previous AMOC intercomparisons; change in the AMOC is of relevance to both regional and global sea level rise, as well as to regional climate change. The FAFMIP experiments are aimed at increased physical understanding. They are not themselves policy-relevant scenarios, but obviously the uncertainties in projection of global and regional sea level and AMOC change are of great policy relevance.

**Keywords:** sea level, ocean, thermal expansion, ocean circulation, AMOC

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†Speaker

# ScenarioMIP: Key goals and experimental design

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**Abstract**

ScenarioMIP is a proposed component of the Coupled Model Intercomparison Projection Phase 6 (CMIP6). The primary goal of ScenarioMIP is to simulate future climate outcomes based on alternative plausible future scenarios. We present the goals and purposes of ScenarioMIP, describe its experimental design, and outline links to other components of CMIP6. ScenarioMIP's goal of simulating plausible future scenarios serves three purposes. First, it is aimed to facilitate integrated research leading to a better understanding not only of the physical climate change consequences of these scenarios, but also of the climate impact on societies, including considerations of mitigation of and adaptation. Within CMIP6, ScenarioMIP will be the main provider of new climate information for plausible future scenarios that will facilitate integrated research across multiple communities including the (1) climate science, (2) integrated assessment modeling (IAM) and mitigation, and (3) impacts, adaptation and vulnerability (IAV) communities.

Second, together with other MIPS, ScenarioMIP will provide a basis for addressing targeted science questions regarding the climate effects of particular aspects of forcing relevant to scenario-based research. These include the effects of different assumptions in near-term climate forcers and land use on climate change and impacts. Third, ScenarioMIP will also provide a basis for various international efforts that target improved methods to quantify projection uncertainties based on multi model ensembles, taking into account model performance, model dependence and observational uncertainty.

The ScenarioMIP Scientific Steering Committee, in close collaboration with members of the integrated assessment modeling (IAM) community, and with input from the impacts, adaptation, and vulnerability (IAV) community, created an experimental design consisting of six scenarios of future emissions and land use over the 21st century. The design also includes a large ensemble for one of these scenarios, an additional overshoot scenario in which forcing increases beyond a target level before later returning to it, and extensions of a subset of scenarios to 2300. The design was created to serve the multiple purposes of ScenarioMIP, including providing scenarios that will anchor experiments in other MIPs examining scientific questions related to land use, aerosols, geoengineering, the carbon cycle, radiative forcing, ice sheets, and other aspects of the climate system.
Moving forward, ScenarioMIP will continue to work other MIPs and with the IAM, IAV, and climate modeling communities in order to facilitate the provision of emissions and land use information to climate modeling groups running scenarios and of climate model output from these scenarios to the impacts, adaptation and vulnerability communities.

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**Keywords:** scenarios, impacts, cmip6, mitigation, adaptation

# An overview of the Land Surface/Snow/Soil moisture Model Intercomparison Project (LS3MIP)

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**Abstract**

Feedbacks between land surface, snow and soil moisture processes on one hand, and climate on the other have a strong imprint on the predictability, model performance and climate change signals at regional and global scales. The solid and liquid water stored at the land surface has a large influence on the regional climate, its variability and its predictability, including effects on the energy and carbon cycles. Notably, snow and soil moisture affect surface radiation and flux partitioning properties, moisture storage and land surface memory. They both strongly affect air temperature, large-scale circulation patterns and precipitation. Recent research has consistently demonstrated that a good representation of land surface, snow and soil moisure (LS3) in ESMs is crucial but far from trivial, leading to persistent inconsistencies between models and observations. The strong surface/atmosphere feedbacks, and the lack of (soil moisture) observations make it difficult to distinguish and quantify the various potential causes for disagreement in observed versus modelled snow and soil moisture trends.
The LS3MIP tier 1 experiments systematically address the LS3-climate feedbacks using an upgrading a number of successful earlier multi-modelling concepts:

- an offline land surface modelling experiment (LMIP), synchronized with the Global Soil Wetness Project (GSWP) and linked with the Land Use MIP, covering the entire 20th century and a selection of future projections, will provide a benchmark climatology of regionally specific trends and variability of snow, soil moisture, fluxes and vegetation states.
- the Global Land Atmosphere Coupling Experiment (GLACE) protocol is tuned to detecting (trends in) patterns of land-atmosphere coupling strength (LSMIP), and its implications for projected extremes, governing mechanisms and causes of model disagreements. The GLACE prototol essentially compares an ensemble of coupled models

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to an ensemble in which some of the feedback chains are cut by prescribing particular model states, such as soil moisture or snow.

In addition, a set of tier 2 experiments will focus on particular components in the land surface system (such as snow albedo or vegetation water use) and shifts in potential predictability. The combination of experiments will diagnose systematic biases in the land modules of current ESMs, illustrate their response to trends in the forcings, and the land-atmosphere feedbacks.

The experiments also give crucial information on the current and projected state of fresh water availability, of extreme relevance for many densely populated or vulnerable regions. Also temporal and spatial variability of this water availability, governed by climatic fluctuations and trends in water demand, is explicitly monitored and assessed.
The LS3MIP objectives respond to each of the three CMIP6 overarching questions: what are regional feedbacks and responses to climate change, what are the systematic biases in the current climate models, and what are the perspectives concerning the generation of predictions and scenarios?

**Keywords:** land surface, snow, soil moisture, land, atmosphere coupling, fresh water availability, trends and variability

# Towards a coordinated modeling assessment of the climate response to strong volcanic eruptions

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**Abstract**

Large volcanic eruptions eject large amounts of sulfur into the atmosphere that can impact the global climate. Our understanding of the climatic response to volcanic forcing is however limited as large uncertainties affect both the observational records, due to the limited number of observed events, and the non-robust dynamical responses simulated by different climate models.
The lack of agreement between model results is crucially determined by differences in models' characteristics such as resolution, complexity and implementation strategy of the forcing, and uncertainty in the eruption details including magnitude, latitude and season, input data and background climate. The multiple and varied nature of these factors prevents their contribution to uncertainty from being distinguished within existing transient simulations or non-coordinated multi-model experiments. For this reason, current international model intercomparison activities have chosen to design experiments to focus separately on the two major aspects linking volcanic sulfur emissions and the climate response. First, the steps from SO2 injection to effective radiative forcing including the chemical conversion to sulfate aerosols, microphysical transformations and dynamical responses of the stratospheric volcanic cloud; and second, the climate response to the volcanic forcing including feedbacks in the coupled ocean-atmosphere system.

The SPARC Stratospheric Sulfur and its Role in Climate Initiative (SSiRC) has a model intercomparison activity for composition-climate models which simulate stratospheric aerosol interactively, with experiments to understand the quiescent stratospheric aerosol and the radiative forcing from the post-2000 increase in stratospheric aerosol. There is also a focus to intercompare simulated effective radiative forcings from major historical eruptions with an "SO2 emission assessment experiment" for Agung, El Chichón and Pinatubo, potentially

*Speaker

linked to CMIP6 and a comprehensive multi-model uncertainty analysis around Pinatubo.

In contrast, the VolMIP Model Intercomparison Project focuses on the climatic response to major volcanic forcing in the coupled ocean-atmosphere system. VolMIP defines a common protocol to subject Earth system models and coupled general circulation models to the same volcanic forcing - in terms of aerosol optical properties, based on estimates for major historical volcanic eruptions including Tambora and Pinatubo -, and under a similar range of background climate conditions. By doing so, VolMIP aims at assessing to what extent simulated responses are robust across models and at identifying the causes that limit robust behavior, especially as far as different treatment of physical processes is concerned.
This contribution presents ongoing activities and research highlights achieved within VolMIP and SSiRC, illustrating how these coordinated modeling assessments are contributing to constrain uncertainties in the climate response to volcanic forcing, improve the evaluation of climate models, and advance our understanding of past, current and future climates.

**Keywords:** volcanic forcing, climate variability, climate sensitivity, climate response, model intercomparison, aerosol, robustness

# Overview of Global Monsoons Modeling Inter-comparison Project (GMMIP)

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**Abstract**

Monsoons occur in various regions around the world. Prediction of the monsoon rainfall change in the coming decades is of deep societal concern and vital for infrastructural planning, water resource management, and sustainable economic development. Climate models are useful tools in climate variability and climate change studies. However, the performance of the current state-of-the-art climate models is very poor and needs to be greatly improved over the monsoon domains. The Global Monsoons Modelling Inter-comparison Project (hereafter GMMIP) aims to improve our understanding of physical processes in global monsoon systems and to better simulate the mean state, interannual variability and long-term change of global monsoons by performing multi-model inter-comparisons. The contributions of internal variability (IPO-Interdecadal Pacific Oscillation, AMO-Atlantic Multidecadal Oscillation) and external anthropogenic forcing to the historical evolution of global monsoons in the 20th and 21st century will be addressed. This talk will present an overview of GMMIP project and show some preliminary results of GMMIP Tier-1 and Tier-2 Experiments based on one state-of the-art climate system model. For details of GMMIP: http://www.lasg.ac.cn/gmmip/

**Keywords:** GMMIP, monsoon, global, model inter comparison

*Speaker

# Understanding sea ice through CMIP6

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**Abstract**

We outline the central role of CMIP6 for better understanding the role of sea ice in the Earth's changing climate. Such understanding provides relevant insights into the functioning of the Earth's climate system as a whole, since sea ice is both a strong indicator and a strong driver for climatic changes. Despite this importance, much of the sea-ice response and feedbacks related to climatic changes are still not well understood. This is in part because the model output saved from CMIP5 only allowed for a rather limited analysis of the budgets of heat, momentum and freshwater that drive the evolution of sea ice in the polar regions. The CMIP6 Sea-Ice Model Intercomparison Project SIMIP addresses this shortcoming. In this overview, we outline how SIMIP allows for a more in depth understanding of sea-ice processes than was possible before, the key science questions the related diagnostics allow us to answer, and how any CMIP6 MIP can profit from implementing the protocol that is defined within SIMIP.

**Keywords:** sea ice, Arctic, Antarctic, CMIP6, ESM

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# CORDEX: Plans for future directions within the cmip6 context.

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**Abstract**

The COordinated Regional Downsclaing EXperiment (CORDEX) has grown and substantially matured in the last years, thanks in part to the support of the CMIP5 community, which provided global climate model (GCM) fields necessary to run regional climate models (RCMs), and in some cases Empirical Statistical Downscaling techniques (ESD). A number of scientific issues emerged as a result of the first CORDEX activities, which has prompted the CORDEX community to strongly engage in the discussion on future directions, in particular within the context of CMIP6. Among such issues are: a better characterization of the added value of downscaling techniques in different contexts; better process-based assessment of models; move to very high resolution, convection-permitting modeling systems; better integration of different downscaling methods (e.g. RCMs, ESD); increased focus on the role of regional forcings (e.g. land-use change, aerosols); distillation of actionable information from different sources and interaction with stake-holder communities; and characterization of uncertainties in regional projections. Addressing these issues will require the development of targeted CORDEX activities needing a closer interaction with different CMIP6 projects, such as ScenarioMIP, HighresMIP, ISMIP6, LS3MIP and LUMIP. In this paper we will review outstanding issues emerging from the CORDEX discussions and plans for future directions, in particular focusing on how these directions will lead to an enhanced interaction with the global modeling community involved in CMIP6.

**Keywords:** CORDEX, downscaling, distillation

*Speaker

# DynVar – Diagnostic MIP Dynamics and Variability of the Stratosphere-Troposphere System

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**Abstract**

Persistent biases in forecast and climate prediction systems hinder our ability to model circulation changes, both in seasonal forecasting and in climate projections. DynVarMIP proposes a set of diagnostics to enable a mechanistic approach to confront model biases and understand the underlying causes behind circulation changes. DynVarMIP primarily addresses CMIP6 key science questions on the origin and consequences on systematic models biases in the context of atmospheric dynamics; with a focus on: tropical – extratropical connections, storm tracks, polar vortex and sea ice variability.
We are requesting additional output, critical for understanding the role of atmospheric dynamics in both present and past climate, and future climate projections. Without this output, we will not be able to fully assess the dynamics of mass, momentum, and heat transport - essential ingredients in projected circulation changes - nor take advantage of the increasingly accurate representation of the stratosphere in coupled climate models. Our rational is that by simply extending the standard output relative to that in CMIP5, there is potential for significantly expanding our research capabilities in atmospheric dynamics.
Here we detail the DynVarMIP data request, subdivided in three groups: (1) Atmospheric variability across scales, (2) Atmospheric (Transformed Eulerian Mean, TEM) zonal momentum budget, and (3) Atmospheric heat budget; explain how to calculate the TEM quantities; and present motivating examples.

**Keywords:** atmospheric dynamics, variability, climate model biases, climate prediction, climate change

*Speaker

# The Vulnerability, Impacts, Adaptation, and Climate Services (VIACS) Advisory Board for CMIP6

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**Abstract**

The poster describes the motivation for the creation of the Vulnerability, Impacts, Adaptation, and Climate Services (VIACS) Advisory Board to provide a more fruitful bridge between climate change applications experts and climate modelers for CMIP6. The VIACS Advisory Board was created to facilitate a two-way dialogue between leaders of CMIP6 climate modelers and VIACS experts who are looking to apply CMIP6 results for their numerous research and climate services objectives. The Board has already been convened with leading sectoral researchers and representatives who can solicit broader feedback from key applied projects, programs, and regions.
As its first activity, the VIACS Advisory Board solicited feedback from more than a dozen groups across a number of projects, regions, and sectors in order to identify priority variables and MIP experiments for CMIP6. As different VIACS groups have different needs concerning CMIP6 variables, it is not reasonable to create a single priority list that represents the demand of the entire community. Nevertheless, some variables are clearly relevant across all sectors (e.g., temperature, rainfall, solar radiation) and the feedback created provides the clearest yet view of how different variables appeal to a number of sectoral applications. A similar pattern can be found for the MIP experiments: nearly all groups are requesting the historical DECK simulations and the RCPs, while additional requests are a mixture of priorities depending on the sector.
Here, we provide a short overview about the lessons learned in the process of using CMIP5 data for VIACS applications as well as an outlook on plans and opportunities for VIACS research and application in the frame of CMIP6.

**Keywords:** vulnerability, impacts, adaptation, climate services, MIP

*Speaker

# Overview of the Earth System Model Snow Model Intercomparison Project (ESM-SnowMIP)

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**Abstract**

Terrestrial snow cover plays a significant role in the radiative forcing component of the Earth's energy budget by reflecting a high proportion of incident solar radiation back to space. Snow is also a very effective insulator, so variability in the timing of snow cover onset in the autumn and snow melt in spring, as well as the magnitude of seasonal snow accumulation, influences the thermal state of the soil beneath the snowpack (deeper snow = warmer soil). Snow is a significant freshwater resource for a large proportion of the northern hemisphere, and is connected to other hydrological variables such as runoff and soil moisture. Coupled Model Intercomparison Project 5 (CMIP5) climate models show divergent responses and representations of snow-related feedbacks, and systematic biases due to simplifications or missing parameterizations of key processes. An inter-comparison of snow models within Earth System Models was therefore identified by the World Meteorological Program Climate and Cryosphere (WMO CliC) project as a priority contribution to the World Climate Research Program "Cryosphere in a Changing Climate" Grand Challenge. The overall goal of the Earth System Model-Snow Model Intercomparison Project (ESM-SnowMIP) is to investigate the performance of current snow models within land surface modules of ESMs (through both coupled and offline simulations), in order to improve our knowledge and understanding of the temporal dynamics and physical properties of snow as an active component of the coupled climate system. This presentation will provide an overview of constrained land-module only experiments for the assessment of land surface feedbacks and diagnosis of systematic biases in the land modules of current ESMs within the "Land Surface, Snow and Soil moisture MIP" (LS3MIP). LS3MIP was proposed to the Coupled Model Intercomparison Project (CMIP) phase 6 as a collaboration between the snow, soil

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moisture, and land surface communities. Additional coupled and offline (global and point scale) model experiments developed as part of ESM-SnowMIP will also be described. These experiments focus on feedbacks related to snow albedo and the climatic effect of snow linked to its thermal properties. A point of emphasis for ESM-SnowMIP is establishing strong connections between the snow observational and modeling communities. This includes the development of gridded datasets (from remote sensing and reanalysis) with well characterized uncertainty both for the prescription of snow conditions and experiment validation. An international network of sites with comprehensive in situ measurements distributed across the major snow-climate regimes (i.e. alpine, taiga, tundra) will also be utilized for point-scale simulations.

**Keywords:** snow cover, snow water equivalent, snow models, land surface modeling

# An update on obs4MIPs and ana4MIPs

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**Abstract**

Observations are essential for the development and evaluation of climate models. Satellite measurements as well as reanalysis products provide crucial resources for these purposes. In this presentation, we will report on the progress and plans of obs4MIPs and ana4MIPs. This will include plans and recommendations resulting from a meeting devoted to coordinating these projects with CMIP (report available on obs4MIPs website). Key tenets of obs4MIPs and ana4MIPs are that each data set be: 1) of demonstrated value for model evaluation, 2) formatted and structured analogous to the CMIP model output (in terms of variables, temporal and spatial frequency, periods and file format), 3) provided with documentation directly relevant for model evaluation and research, and 4) accessible in parallel to CMIP data via the ESGF web portal. The latest information on both projects is available via:https://www.earthsystemcog.org/projects/obs4mips and https://www.earthsystemcog.org/projects/ana4mips.

**Keywords:** Model evaluation, observations, reanalysis

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# The CMIP6 Data Request: the next generation climate archive

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**Abstract**

The CMIP6 Data Request brings the data requirements of the endorsed MIPs together in a consolidated technical document. These requirements reflect the broad range of scientific interests that will be addressed in CMIP6. There are many challenges associated with the new approach being followed in CMIP6. At the same time it is necessary to address a number of problems which inconvenienced users of the CMIP5 archive. The difficulties of providing robust data access services for a globally distributed archive run through informal cooperation of a large number of independent institutions will be discussed. The request needs to be clear enough to support efficient implementation at all modelling centres, and detailed enough to enable eficient analysis of the archive by the thousands of scientists who will explore this data.

**Keywords:** data standards, archive

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