Cloud Feedback Model Inter-comparison Project CFMIP3/CMIP6
http://www.cfmip.net

Objective 1: Inform improved assessments of climate change cloud feedbacks by:
   a) Improving our understanding of cloud-climate feedback mechanisms.
   b) Improving evaluation of clouds and cloud feedbacks in climate models.

   CFMIP3/CMIP6 Hierarchy
   T/q budgets, cfSites

   CMIP6/CFMIP3

   CFMIP Intercomparison of SCM/LES
   Exploitation of Sat Obs via Simulators in CMIP

   CGILS
   COSP

Objective 2: To use the CFMIP experimental hierarchy and process diagnostics to better understand other aspects of the climate response, such as changes in circulation, regional-scale precipitation and non-linear change.

CFMIP is most relevant to the CMIP question ”How does the Earth System respond to forcing?” although it is also strongly relevant to ”What are the origins and consequences of systematic model biases?”

CFMIP is most relevant to the Grand Challenge on Clouds, Circulation and Climate Sensitivity.
The Geoengineering Model Intercomparison Project Phase 6 (GeoMIP6)

**G1ext:** How would geoengineering affect changes in less easily detectable climate features, such as extreme events, modes of natural variability, and regional impacts?

**G6sulfur/G6solar:** What are common model responses if geoengineering is used to partially offset climate change? What are robust differences between solar reduction and stratospheric aerosols?

**G7cirrus:** What are commonalities and differences among model responses to cirrus cloud thinning? How do cirrus thinning responses, particularly on the hydrological cycle, compare to those from solar radiation reduction?

This newest phase of GeoMIP is designed to address the emergent gaps in geoengineering research while providing complementary information about the climate system’s response to forcing.

More information can be obtained from the GeoMIP website [http://climate.envsci.rutgers.edu/GeoMIP](http://climate.envsci.rutgers.edu/GeoMIP) or by emailing Ben Kravitz (ben.kravitz@pnnl.gov).
CMIP6: “How does the Earth system respond to forcing?”.

- How have short-lived species and ODS emissions contributed to global ERF and affected regional climate over the historical period?
- How have WMGHGs forced climate (including through their chemical impacts) over the historical period?
- How will future policies (on climate and air quality) affect short-lived species and their climate impacts.

Diagnostics

Additional output need for CMIP DECK, AerChemMIP and associated MIPs (RFMIP, SCENARIOMUP, LUMIP)

- Column burdens of aerosols and chemical tracers,
- Forcing diagnostics
- Aerosol and reactive gas diagnostics
  - Assess model performance
  - Air quality impacts.
Ocean Model Inter-comparison Project (OMIP)

Co-chairs
Gokhan Danabasoglu (NCAR, USA), Stephen M. Griffies (NOAA/GFDL, USA), and James Orr (IPSL, France)

- OMIP addresses the CMIP6 science question on investigating the origins and consequences of systematic model biases.

- Among the WCRP Grand Challenges (GCs), OMIP directly contributes to the decadal climate variability and prediction topic which is being considered as a new GC.

- OMIP is independent of any CMIPX.

OMIP includes the previously separate Ocean Carbon Model Inter-comparison Project (OCMIP). This merging of ocean physical, chemical, and biogeochemical efforts into a single project allows for efficient communication across these communities participating in CMIP6.
C4MIP 1. what we did

Contributed strongly to AR5 WG1: carbon cycle (Ch.6), projections (Ch.12), evaluation (Ch.9) and TCRE (SPM)

AR5 WG1 said:
• The climate’s changing – we already knew that
• It’s down to humans – we already knew that
• It’s affecting people – some advance
• Now we can quantify what to do about it – new bit! Thanks to C4MIP
TCRE was a defining aspect of AR5, but has substantial uncertainty which hinders usefulness.

The primary aim of C⁴MIP is to understand and quantify future (century-scale) changes in the global carbon cycle and its feedbacks on the climate system, making the link between CO₂ emissions and climate change. This objective is obtained through idealized, historical and future scenario experiments.

Cycle of:
- process development/analysis (1%DECK with BGC/RAD coupled, +new N-cycle options)
- evaluation (E-driven CMIP6 HIST, +PICTL)
- projection (E-driven high scenario, SSP 5-8.5; C-driven BGC-coupled SSP5-8.5 plus extension)

**NOTE** – part of DECK requirement!
PMIP: Paleoclimate Modelling Intercomparison Project

Proposal for CMIP6: 5 key periods.

- Last Millenium
  - 850-1850 AD
  - Observed multidecadal (and more) variability
  - Internal variability vs external forcings

- Mid-Holocene
  - 6000 yrs ago
  - Enhanced hydrological cycle (monsoons)
  - Warmer climate in NH

- Last Glacial Maximum
  - 21000 years ago
  - Extreme cold climate (low CO$_2$, ice-sheets)
  - Constraints on climate sensitivity?

- Last Interglacial
  - ~127000 years ago
  - Warm period
  - Smaller ice-sheets/ high sea-level stand

- Mid-Pliocene Warm Period
  - ~3.2 million years ago
  - Long-term response to 400ppm CO$_2$
  - High sea-level stand

All simulations are basis for additional sensitivity of transient experiments in PMIP

PMIP will address all CMIP6 science questions:
Earth system response to forcings, origins/consequences of systematic model biases, assessment of simulated future climate changes given climate variability
Co-chairs: David Lawrence and George Hurtt
SSG: Almut Arneth, Victor Brovkin, Kate Calvin, Nathalie de Noblet-Ducoudré, Andrew Jones, Chris Jones, Peter Lawrence, Julia Pongratz, Sonia Seneviratne, Elena Shevtsova
https://cmip.ucar.edu/lumip
1 National Center for Atmospheric Research, USA 2 University of Maryland, USA

**Goals**
Develop updated historic and future harmonized land use dataset and execute series of idealized and realistic simulations designed to address the following questions and topics:

**Main Questions**
- What are the effects of land use and land-use change on climate and biogeochemical cycling (past-future)?
- Are there regional land management strategies with promise to help mitigate and/or adapt to climate change?
- (What are the effects of climate on land-use and land-use change?)

**Additional focal topics**
- Assess relative contribution of fossil fuel vs. land use change to climate and BGC
- Isolate biogeochemical vs. biogeophysical impacts of land use
- Explore land cover change vs. land management change impacts
- Assess how land use impact is modulated by land-atmosphere coupling strength
- Determine extent that global CO₂ fertilization is modulated by land use change

**Land Use Harmonization Dataset (LUHv2)**

| Years: 850 to 2100 | Resolution: 0.25° |
|--------------------|-------------------|

**New Land Use History**
- Hyde 4-based Landsat/1/NF
- Updated Forest Biomass
- Shifting Cultivation update

**New Management Layers**
- Agriculture
  - Fraction of cropland irrigated
  - Fraction of cropland flooded
  - Fraction of cropland fertilized
  - Fertilizer application rates
  - Fraction of cropland tilled
  - Fraction of cropland for biofuels

**Wood Harvest**
- Fraction used for industrial products
- Fraction used for commercial biofuels
- Fraction used for fuelwood

**Historic and Future Experiments**
- **Historic exp:** No LULCC experiment to compare to CMIP6 historical to assess LULCC impact on temperatures, water, and carbon cycle
- **Future exp:** Assess how targeted land management could contribute to climate change mitigation and reductions in CO₂ emissions

**Idealized Experiments**
- **Global deforestation:** Remove 20 million km² of forest over 50 years and examine mean and transient response
- **Land Management Experiments**
  - Set of exps with incrementally more comprehensive treatment of land cover and land management change; Evaluate impact on fluxes of water, energy, and carbon

- LULCC (equiv to LUMIP-H)
- No LULCC
- Grassland crop
- Prognostic crop model
- Prognostic crop, no irrigation
- Prognostic crop, no fertilization
- No Wood harvest
- No human ignition/suppression of fire

**Major Activities**
- **Model metrics and diagnostics**
  - Develop metrics to assess/quantify model performance with respect to land use impacts on climate
- **Data standardization**
  - Repeat and mature land use harmonization process with enhanced land-use data set passing minimum amount of common information between relevant communities
  - Provide additional required land management data
  - Data output standardization: new variables, subgrid/tile variables
- **Model experiments**
  - **Phase 1 - Idealized model experiments:**
    - Improve process understanding/assessment of how models represent impact of changes in land state on climate
    - Quantify sensitivity to potential land cover and land management changes
  - **Phase 2 - Realistic model experiments:**
    - Isolate impact of LULCC on climate relative to other forcings

**Subgrid data request**
LUMIP is requesting sub-grid information for four sub-grid categories (i.e., tiles) for selected variables to permit more detailed analysis of land-use induced surface heterogeneity. The four categories are:

1. Primary and secondary land
2. Cropland
3. Pastureland
4. Urban
Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6)
Experimental framework

**Forcing**
Analysis of climate over and surrounding the ice sheets for selected CMIP6 experiments

**Feedbacks**
How do dynamic ice sheets affect climate?

**CMIP6 DECK (AOGCMs)**

**Projections**
Sea level change due to ice sheets, along with associated uncertainty due to ice physics and climate forcing

**Standalone ice sheets models**

**Coupled (Greenland only)**
Our goal is to **disentangle variability in radiative forcing from variability in response** in CMIP models.

**Activity 1:** Characterize effective radiative forcing using **fixed SST** atmos. model integrations  
Tier 1: 180 y to diagnose present-day forcing in detail  
Tier 2: ~750 y to diagnose time-varying forcing, 60 y to diagnose aerosol linearity  
Lightweight specialized diagnostics to help diagnose adjustments (especially clouds)

**Activity 2:** Assess the accuracy of clear-sky forcing against reference calculations  
*Offline radiative transfer calculations* to assess parameterization accuracy in clear, clean skies  
Provide **highly-detailed snapshots** for assessment of aerosol radiative transfer  
RFMIP will provide reference line-by-line calculations

**Activity 3:** Enable D+A of aerosol RF using simulations with **specified aerosol forcing**  
Tier 1: ~500 y coupled all-forcing simulations  
Tier 2: ~1100 y coupled to isolate impacts of aerosol forcing  
~1100 y atmos.-only to assess effective forcing, biases

RFMIP informs CMIP6 historical simulations (secondarily, 4xCO$_2$)

RFmip directly addresses all CMIP questions  
*response to forcing* because accurate forcing is needed to scale response  
*systematic biases* because assessments will uncover such biases  
*future changes* because errors in forcing impact response
HighResMIP
Rein Haarsma KNMI (lead)
Malcolm Roberts Met Office (co-lead)

- Important weather and climate processes emerge at sub-50km resolution
- They contribute significantly to both large-scale circulation and local impacts, hence vital for understanding and constraining regional variability
- How robust are these effects?
- Is there any convergence with resolution across models?

Need coordinated, simplified experimental design to find out

CMIP6 main question: Origins and consequences of model biases

Experimental protocol:
Global models – ForcedAtmos and Coupled
Physical climate system only
Integrations: 1950-2014/2050
Ensemble size: >=1 (ideally 3)
Resolutions: <25km HI and ~60-100km STD
Aerosol concentrations specified
19 models confirmed for Tier 1 (ForcedAtmos)
e.g. Zhao et al, 2009; Haarsma et al, 2013; Demory et al, 2014
The primary goal of DAMIP is D&A of climate changes.

These DAMIP experiments and synergies with other MIPs are important to understand “the Earth system respond to forcing (CMIP6-1)”, “the origins and consequences of systematic model biases (CMIP6-2)” and assess “future climate changes (CMIP6-3)”.
Decadal Climate Prediction Project (DCPP)

Component A: hindcasts
- How skilful are decadal predictions?
- Also needed for bias correction

Component B: forecasts
- Will the AMOC continue to decline?
- What are the climate impacts?

Component C: mechanisms
- What are the mechanisms giving rise to skill?
- Focus on the warming slowdown...
- ...and the impact of volcanoes
Flux-anomaly-forced model intercomparison project

Steering committee: Jonathan Gregory (Univ. of Reading, and Met Office); Stephen Griffies (GFDL); Detlef Stammer (CEN, Univ. of Hamburg)

Participating groups: ACCESS CanESM CNRM/CERFACS GFDL GISS IPSL MIROC6 MPI-ESM MRI-ESM UKESM

- AOGCM intercomparison project aiming to account for spread in simulated ocean response to changes in surface fluxes resulting from CO₂ forcing.
- Targets the CMIP6 science question on the Earth system response to forcing, and of particular relevance to the WCRP Grand Challenge on sea level rise and regional impacts.
- Prescribed set of surface flux perturbations (of momentum, heat and freshwater), applied separately to the ocean water surface, obtained from the ensemble-mean changes simulated at time time of doubled CO₂ by CMIP5 AOGCMs under the 1pctCO₂ scenario.

Change in ocean dynamic topography after 100 years under 1pctCO₂ in CMIP5 Ensemble mean

Change in ocean dynamic topography after 100 years under 1pctCO₂ in CMIP5 2 x ensemble standard deviation
ScenarioMIP coordinates a set of climate model runs based on alternative plausible future scenarios in order to:

- Facilitate integrated research across climate science, adaptation and mitigation research communities.
- Provide a basis for addressing targeted science questions regarding the climate effects of particular aspects of forcing.
- Facilitate research and development of methods quantifying projection uncertainties based on multi-model ensembles.

Three tiers of experiments:

- Providing continuity with CMIP5;
- Filling gaps in Radiative Forcing levels;
- Characterizing internal variability;
- Exploring changes beyond 2100;
- Tracing an overshoot pathway.
Overview and scientific goal

• Multi-model based reanalysis of land surface (from early 20th century)
• Explore land-atmosphere coupling and its impacts (for climate trends, water resources, predictability)
• Link patterns and trends of ECVs to model properties and biases

Experimental design

• **Offline land model simulations** (LMIP): historic and future, for climate analyses and boundary conditions
• Coupled simulations with prescribed land surface states (LFMIP): for diagnosing land surface role and coupling strength
• **Potential predictability** experiments (LFMIP-P): for detecting trends in predictability

Participating models

ACCESS
BCC-CSM2-MR
CanESM
CESM
CMCC
CNRM-CM
EC-Earth
FGOALS
GFDL
GISS
IPSL-CM6
MIROC6-CGCM
MPI-ESM
MRI-ESM1.x
NorESM
UKESM
Simulating volcanically-forced climate variability is a challenging task for climate models.

The model intercomparison project on the climate response to volcanic forcing (VolMIP) defines a *protocol for idealized volcanic-perturbation experiments* to improve comparability of results across different climate models.

**VolMIP – Experimental design**

**VolShort**
- Seasonal-to-interannual atmospheric response to a 1991 Pinatubo-like volcanic eruption
- Disentangling the role of surface cooling and stratospheric warming for the short-term atmospheric dynamical response

**VolLong**
- Decadal climate response to very strong volcanic eruptions (Tambora, Laki)
- Signal propagation pathways of volcanic perturbations within the coupled atmosphere-ocean system

Impact of volcanic forcing on seasonal-to-interannual climate predictability (with DCPP)

Uncertainty in radiative forcing and climate response for the early-19th-century eruptions.
1. What are the relative contributions of internal processes and external forcings that have driven evolution of global monsoons over the CMIP historical period?
2. To what extent and how does ocean-atmosphere interaction affect the interannual variability and predictability of monsoons?
3. How well can high-resolution models with improved dynamics and physics help to reliably simulate monsoon precipitation and its variability and change?

**Tier-1:** AMIP simulation over 1870-2014

**Tier-2:** Pacemaker Exps of fully coupled model, 20th century historical climate simulation with observed SST nudging in the IPO/AMO domains, respectively.

**Tier-3:** AMIP-type sensitivity simulation over 1979-2014 by reducing the altitude and sensible heating of the Tibetan – Iranian Plateau and other highlands.

*At least 3 members are required to estimate uncertainty.*
The philosophy behind SIMIP is very simple.

We want to get prepared now for the sea-ice related questions that we will be asking tomorrow.
CORDEX: Plans for future directions
F. Giorgi (ICTP), W. Gutowski (Iowa State U.) and the CORDEX SAT

Proposed common framework

- Minimum core sets of RCMs and driving GCMs
  - Target resolution: dx ~ 12 km
- Selection of driving GCMs based on objective criteris
- Interactions with Scenario-MIP
- Comparison with HighRes-MIP
- Enhanced input in the next IPCC cycle

Flagship pilot studies

- Added value to scale down to convection permitting scales
- Effects of regional forcings (landuse, aerosols)
- Comparison of different techniques (RCM, ESD)
- Study of phenomena relevant for regional climate through targeted experiments
- High quality, high resolution observations
- Development of regional Earth System models
- Interaction with other WCRP programs (e.g., GEWEX)
- End-to-end, climate-> VIA studies
DynVarMIP proposes a set of diagnostics (variability, atmospheric momentum and heat balances) to enable a mechanistic approach to confront model biases and understand the underlying causes behind circulation changes. DynVarMIP focuses on the DECK experiments.

Motivation: Inter-model spread in the atmospheric circulation of CMIP5 modes is often larger than the response to climate change.
VIACS Advisory Board – Allows for coordinated interaction between CMIP6 and VIACS Communities

CMIP6

VIACS AB
Projects, Regions, Sectors, Communities

Engagement by Project or Region

Engagement by Sector

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

Gerhard KRINNER

Has been amalgamated into Poster 14 (LS3MIP)
obs4MIPS: Observations for CMIP6 Model Evaluation

https://www.earthsystemcog.org/projects/obs4mips/

WCRP Data Advisory Council (WDAC)
Task Team on observations for climate model evaluation

**Overview**

Products available via obs4MIPS are:
- Directly comparable to CMIP6 model output
- Documented, with traceability to version changes
- Served through ESGF in parallel to CMIP data
- To date limited to satellite data but likely to expand

**Guidelines for contributing data to obs4MIPS**

Observationally-based products made available via obs4MIPS:
- Prepared with CMOR and structured like CMIP output
- Include a technical note conforms to obs4MIPS template
- Match a model variable in the CMIP6 protocol
- Have an estimate of the error or uncertainty
- Documented at some level in the peer reviewed literature
- Version controlled; reside in a long term archive
- Span a time period long enough to be useful for model comparison (5 years is advisable).

**Related efforts for reanalyses**

An4MIPS: A CoG “peer project” with obs4MIPS, providing a collection of fields from selected reanalysis well suited for comparison with CMIP simulations (mostly dynamical fields).

CREATE-IP: A resource for reanalysis data in a centralized location on NASA’s NCCS Advanced Data Analytics Platform (ADAPT), standardizing data formats, providing analytic and visualization capabilities, and overall improved access to many fields from reanalysis datasets.

**Additional possibilities**

- WDC encourages a broader involvement
- Other observational communities have expressed interest in contributing to obs4MIPS
- Work needed to generalize infrastructure

**Datasets Currently Hosted at obs4MIPS**

(CF Variable Long Name)

- Air Temperature
- Ambient Aerosol Optical Thickness at 550 nm
- CALIPSO 3D Clear fraction
- CALIPSO 3D Undefined fraction
- CALIPSO Clear Cloud Fraction
- CALIPSO Cloud Fraction
- CALIPSO High Level Cloud Fraction
- CALIPSO Low Level Cloud Fraction
- CALIPSO Mid Level Cloud Fraction
- CALIPSO Scattering Ratio
- CALIPSO Total Cloud Fraction
- Cloud Fraction retrieved by MISR
- CloudSat 94GHz radar Total Cloud Fraction
- CloudSat Radar Reflectivity CAD
- Eastward Near-Surface Wind
- Eastward Wind
- Fraction of Absorbed Photosynthetically Active Radiation
- ISCCP Cloud Area Fraction (Joint histogram of optical thickness and cloud top pressure)
- ISCCP Mean Cloud Albedo (Cloud-fraction weighted & daytime only)
- ISCCP Mean Cloud Top Pressure (Cloud-fraction weighted & daytime only)
- ISCCP Mean Cloud Top Temperature (Cloud-fraction weighted & daytime only)
- ISCCP Total Cloud Fraction (daytime only)
- Leaf Area Index
- Mole Fraction of O3
- Near-Surface Wind Speed
- Northward Near-Surface Wind
- Northward Wind
- PARASOL Reflectance
- Precipitation
- Sea Surface Height Above Geoid
- Surface Temperature
- Specific Humidity
- Surface Downwelling Clear-Sky Longwave Radiation
- Surface Downwelling Clear-Sky Shortwave Radiation
- Surface Downwelling Longwave Radiation
- Surface Downwelling Shortwave Radiation
- Surface Upwelling Clear-Sky Shortwave Radiation
- Surface Upwelling Longwave Radiation
- Surface Upwelling Shortwave Radiation
- TOA Incident Shortwave Radiation
- TOA Outgoing Clear-Sky Shortwave Radiation
- TOA Outgoing Clear-Sky Shortwave Radiation
- TOA Outgoing Longwave Radiation
- TOA Outgoing Shortwave Radiation
- Total Cloud Fraction
- Water Vapor Path

**Facilitating the CF/CMOR/ESGF preparation of obs data**

- CMOR3 is currently developing at PCMDI for use in CMIP6. It is being generalized to be useful for preparing observational data. It will include:
  - A version of CMOR that is accessible via python
  - Templates for defining global attributes
  - Numerous examples (including data) to facilitate ease of use
  - Task team with the help of others is developing a proposal for describing observational data (via the CF convention) in coordination with CMIP
The CMIP6 Data Request

Martin Juckes
October 2015

Variable Lists
- Definition of physical quantities;
- Output specifications.

Output Requirements
- Experiments and time slices
- Objectives supported
- Priority of variable

Experiment Specifications
- Duration of simulation
- Tier
- Number of ensemble members

Recommendations for output and analysis

CMIP6 Data Request

XML
Python
Command line
Forum
Persistent identifiers
......