CMIP6 Overview

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Image: © NASA/NOAA/GSFC/Suomi NPP/VIIRS/Norman Kuring

Outline

- Coupled Model Intercomparison Project (CMIP)
  - Overview
  - What's new in CMIP6
  - Timelines
  - Model Intercomparison Projects
- Future scenarios for CMIP6
- Where to find CMIP6 data (ESGF)
  - Quick demo
- Summary

What is CMIP?

- **The Coupled Model Intercomparison Project (CMIP) is a project of the World Climate Research Programme (WCRP)'s Working Group on Coupled Modelling (WGCM).**
- **International, multi-model framework designed to better understand past, present, and future climate change.**
- **Defines common experiment protocols, forcings, and output.**
- **Publicly available model output supports national and international assessments, scientific research in diverse arenas, and multi-model intercomparisons.**

https://www.wcrp-climate.org/

CMIP6 Scientific Design

https://www.wcrp-climate.org/grand-challenges/grand-challenges-overview

The WCRP Grand Challenges are the scientific backdrop for CMIP6.

CMIP6 experimental design is focused on three broad scientific questions:

1. **How does the Earth system respond to forcing?**
2. **What are the origins and consequences of systematic model biases?**
3. **How can we assess future climate change given climate variability, predictability, and uncertainty in scenarios?**

CMIP6 scope

Greatly expanded scope and scale of CMIP6 compared to CMIP5

- **296 experiments, 120 registered models (CMIP5: 39 experiments, 59 models)**
- **10-50 PB model output expected (~2 PB in CMIP5)**

- ***More continuous and distributed organization***
  - **Core simulations performed routinely**
    - **DECK = Diagnosis, Evaluation, and Characterization of Klima:**
      AMIP (1979-2014), Preindustrial Control, 1% yr^{-1} CO_2 increase, abrupt 4xCO_2
- **Historical simulation (1850-2014) is also needed to participate in CMIP6.**

- ***23 endorsed Model Intercomparison Projects (MIPs)***

- ***Comprehensive Data Request for model output***
  - ***(~4000 unique variables, multiple frequencies)***

New requirements ensure provenance and traceability

- ***Quality Assurance of data.***
- ***Routine benchmarking and evaluation.***
- ***Earth System Documentation (ES-DOC) of models.***
- ***Digital Object Identifiers (DOIs) for data citation.***
- ***Errata/Retraction.***

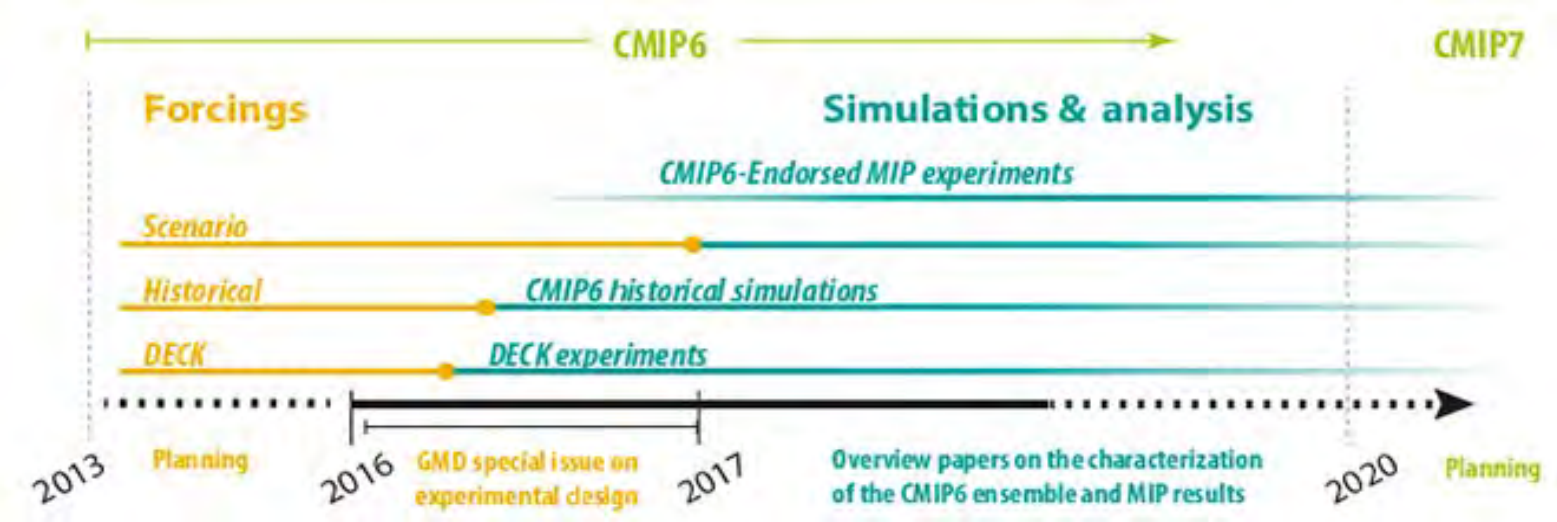
CMIP6 Timelines

Roughly 7 year process from preparation of forcings to analysis of CMIP6 simulations.
Delays can lead to compressed schedules/very tight timelines for modeling centers - *but*

IPCC deadlines are fixed:

- **31 December 2019 – AR6 WG1 literature submission cut off**
- ***31 January 2021* – AR6 WG1 literature acceptance and data cut off**
- ***April 2021* – AR6 WG1 Final Draft**

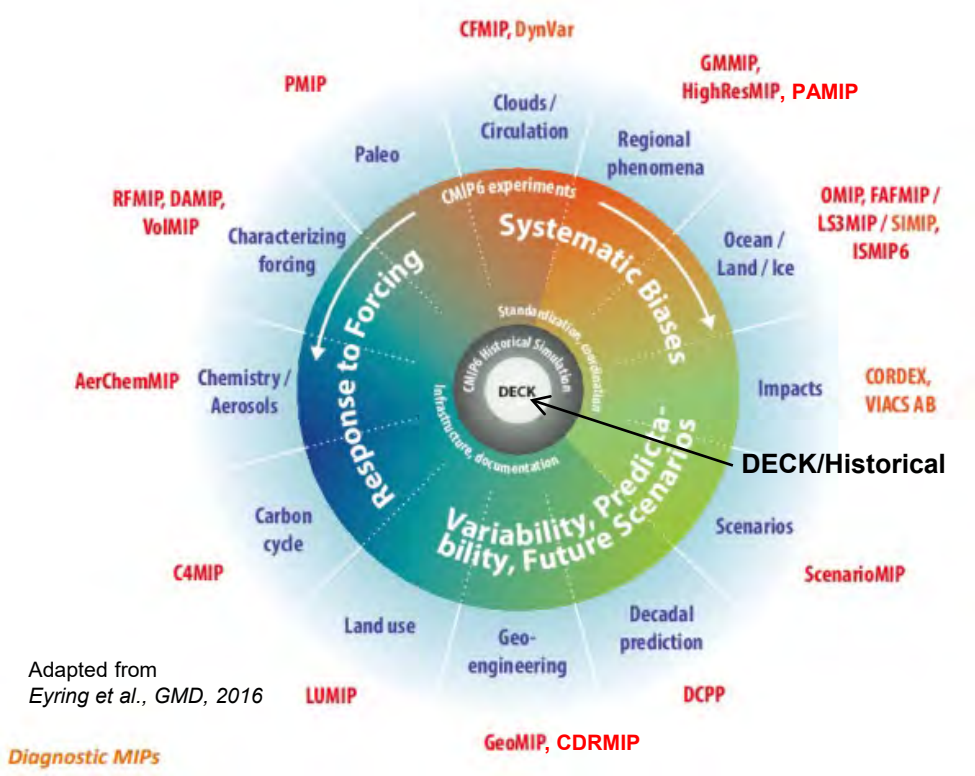
(Revised AR6 WG1 schedule due to COVID-19: ~4 month delay)



Eyring et al., GMD, 2016

CMIP6 Endorsed MIPs

DECK and Historical required for most models participating in CMIP6.
Most MIPs require one or more of these core simulations as prerequisites.



Adapted from
Eyring et al., GMD, 2016

- The Aerosols and Chemistry Model Intercomparison Project (AerChemMIP)
- Coupled Climate Carbon Cycle Model Intercomparison Project (C4MIP)
- The Carbon Dioxide Removal Model Intercomparison Project (CDRMIP)
- Cloud Feedback Model Intercomparison Project (CFMIP)
- Detection and Attribution Model Intercomparison Project (DAMIP)
- Decadal Climate Prediction Project (DCPP)
- Flux-Anomaly-Forced Model Intercomparison Project (FAFMIP)
- Geoengineering Model Intercomparison Project (GeoMIP)
- Global Monsoons Model Intercomparison Project (GMMIP)
- High-Resolution Model Intercomparison Project (HighResMIP)
- Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6)
- Land Surface, Snow and Soil Moisture (LS3MIP)
- Land-Use Model Intercomparison Project (LUMIP)
- Ocean Model Intercomparison Project (OMIP)
- Polar Amplification Model Intercomparison Project (PAMIP)
- Palaeoclimate Modelling Intercomparison Project (PMIP)
- Radiative Forcing Model Intercomparison Project (RFMIP)
- Scenario Model Intercomparison Project (ScenarioMIP)
- Volcanic Forcings Model Intercomparison Project (VolMIP)
- Coordinated Regional Climate Downscaling Experiment (CORDEX)
- Dynamics and Variability Model Intercomparison Project (DynVarMIP)
- Sea Ice Model Intercomparison Project (SIMIP)
- Vulnerability, Impacts, Adaptation and Climate Services Advisory Board (VIACS AB)

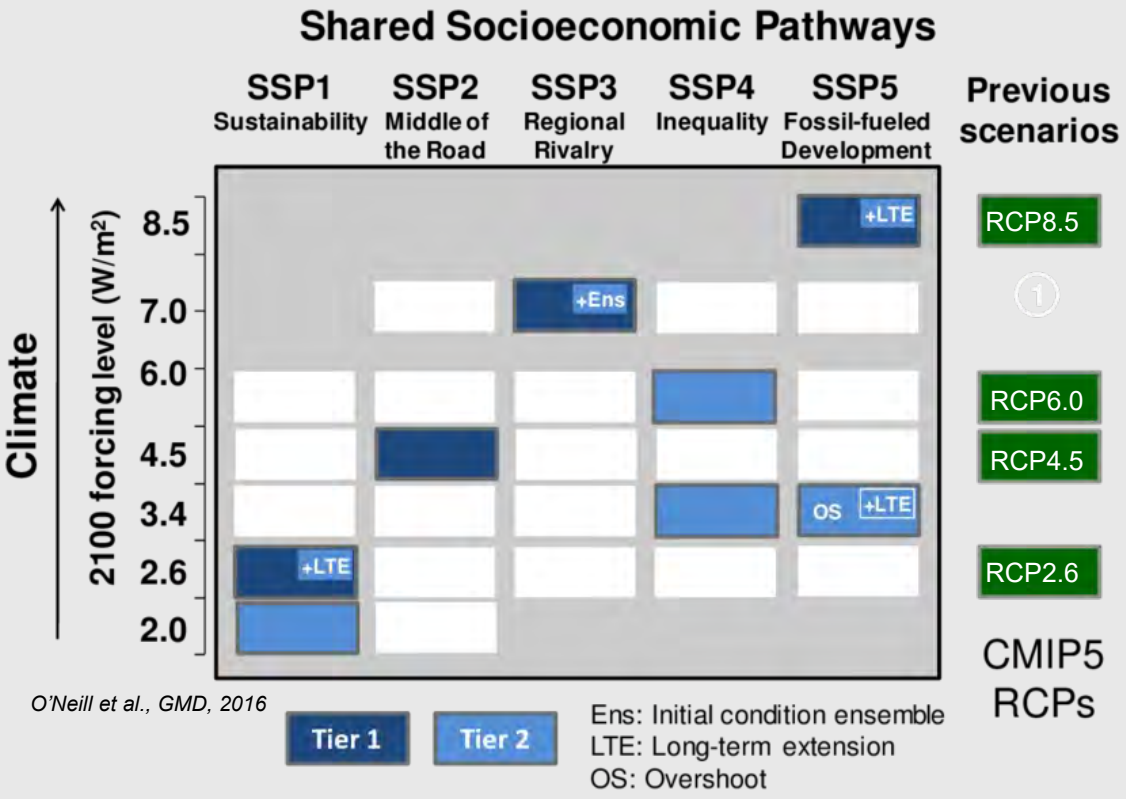
Shared Socioeconomic Pathways for CMIP6

- **Socioeconomic factors (e.g. population, technological and economic growth) can change over time and can lead to different future emissions and warming outcomes, even without climate policy.**
- **Five different ways in which the world might evolve in the absence of new climate policies, beyond those already adopted.**

O'Neill et al., Global Env. Change, 2015

Future Projections (ScenarioMIP)

- 8 pathways of future emissions, concentrations, and land use
- Span a similar range as the RCPs but fill critical gaps (e.g. role of land use and short-lived species, overshoot, limiting warming below 2 °C)
- Two tiers of simulations including ensembles and long-term extensions



Tier 1:
SSP5-8.5 (High)
SSP3-7.0 (High)
SSP2-4.5 (Medium)
SSP1-2.6 (Low)

Tier 2:
SSP4-6.0 (Medium)
SSP4-3.4 (Low)
SSP5-3.4OS (Overshoot)
SSP1.19 (Low)

Earth System Grid Federation (ESGF)

ESGF is an international collaboration that develops, deploys, and maintains software infrastructure for the management, dissemination, and analysis of model output and observational data.

CMIP6 model output available from any node on the Earth System Grid Federation (ESGF).

The US ESGF Portal is the Program for Climate Model Diagnosis & Intercomparison (PCMDI) at Lawrence Livermore National Laboratory.

Websites:
Overview: *https://pcmdi.llnl.gov/CMIP6/*

CMIP6 data: *https://esgf-node.llnl.gov/projects/cmip6*
Search interface: *https://esgf-node.llnl.gov/search/cmip6/*

CMIP6 Data Holdings:
https://pcmdi.llnl.gov/CMIP6/ArchiveStatistics/esgf_data_holdings/

Demo: Searching for surface air temperature

- Don't know the CMIP6 variable name?
  - Use the CMIP6 Data Request to search for variable names
- Near surface air temperature is 'tas'
- Go to the CMIP6 Search interface and enter tas in the text box
  https://esgf-node.llnl.gov/search/cmip6/
- Use the drop-down menus on the left to refine your search by institution, model, MIP, frequency, grid, etc.
- Click on List Files, then on HTTP Download
- Example of naming convention:

  CMIP6.ScenarioMIP.NOAA-GFDL.GFDL-CM4.ssp585.r1i1p1f1.Amon.tas.gr1
  MIPera.MIPname.InstitutionID.SourceID.ExperimentID.VariantLabel.TableID.Variable.GridLabel
  SourceID = Model name, Variant Label = ensemble member

Summary

- **CMIP enables fundamental research**
  - **Data and research papers are used by the IPCC assessment, scientific communities, and a variety of stakeholders.**

- **CMIP6 is much more comprehensive in scale and scope**
  - **CMIP6 MIPs address a broad range of science questions and fill scientific gaps of previous CMIPs**
  - **Many more institutions participating (42 vs 31 in CMIP5)**
  - **More models (109 vs 59 in CMIP5)**
  - **More experiments (287 vs 33 in CMIP5)**
  - **Unprecedented amount of data will be available for analysis**
    - **10-50 PB of model output expected (~2 PB for CMIP5)**

Numbers courtesy V. Eyring/CMIP Panel

- **Enhanced infrastructure and documentation**
  - **Standards and policies implemented to ensure traceability**
  - **Routine evaluation of model results**
  - **Data DOIs to cite CMIP6 data**

Useful Links

- **WCRP Grand Challenges:**
  https://www.wcrp-climate.org/grand-challenges/grand-challenges-overview

- **CMIP6:**
  https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6

- **CMIP6 Data Request (Browsable HTML view):**
  http://clipc-services.ceda.ac.uk/dreq/index.html
  (Sections 1.2, 1.3, 2.4 are useful to search for variables)

- **CMIP6 Guidance for Data Users:**
  https://pcmdi.llnl.gov/CMIP6/Guide/dataUsers.html

- **CMIP6 Citation Service Search (to retrieve data DOIs):**
  https://cera-www.dkrz.de/ords/f?p=127:2

- **ScenarioMIP**
  https://www.cesm.ucar.edu/projects/CMIP6/ScenarioMIP/

Literature

Eyring, V., et al., Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, Geosci. Model Dev., 9, 1937–1958, https://doi.org/10.5194/gmd-9-1937-2016, 2016.

O'Neill, B. C., et al., The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century, Global Environ. Change (2015), http://dx.doi.org/10.1016/j.gloenvcha.2015.01.004.

O'Neill, B. C., et al., The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6, Geosci. Model Dev., 9, 3461-3482, doi:10.5194/gmd-9-3461-2016, 2016.

Riahi, K. et al., The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview, Global Environmental Change, Volume 42, 2017, Pages 153-168, https://doi.org/10.1016/j.gloenvcha.2016.05.009

IPCC, 2018: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press.

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IPCC, 2019: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press

IPCC AR6 WG1 Report – Final draft due April 2021

Tebaldi, C. et al. (accepted): Climate model projections from the Scenario Model Intercomparison Project (ScenarioMIP) of CMIP6. Earth System Dynamics.

GFDL Models participating in CMIP6

CMIP6 generation coupled models:
CM4 (increased resolution), ESM4 (increased comprehensiveness).
Additional CMIP6 models: CM4C192 and OM4p5B
CMIP5 generation model: ESM2M

GFDL	Atmosphere	Atmospheric chemistry	Land	Ocean	Ocean Biogeochemistry	Sea Ice
CM4	AM4.0.1 100km 33 levels	'fast': 100km aerosol only 21 tracers	LM4.0.1 100km	OM4p25 25km 75 layers	BLINGv2 25km 6 tracers (diagnostic only)	SIM4p25 25km
ESM4	AM4.1 100km 49 levels	ATMCHEM4.1 100km aerosol and ozone 103 tracers	LM4.1 100km	OM4p5 50km 75 layers	COBALTv2 50km 33 tracers	SIM4p5 50km
CM4C192	AM4C192 50km 33 levels	'fast': 50km aerosol only 21 tracers	LM4.0.1 50km	OM4p25 25km 75 layers		SIM4p25 25km
OM4p5B				OM4p5 50km 75 layers	BLINGv2 50km 6 tracers (diagnostic only)	SIM4p5 50km
ESM2M	AM2 250km 24 levels	250km (prescribed)	LM3.0 250km	MOM4p1 100km 50 layers	TOPAZ2 100km 30 tracers	SIM2 100km

GFDL Contributions to CMIP6

Five models: CM4, ESM4, CM4C192, OM4p5B, ESM2M

CM4 and ESM4 perform DECK and Historical simulations with new CMIP6 forcings.

18 MIPs: 13 unique, 5 participating using two GFDL CMIP6-generation models.

CFMIP (Cloud Feedback)

DynVarMIP (Dynamics and Variability) (CM4, ESM4)

RFMIP (Radiative Forcing) (CM4, ESM4)

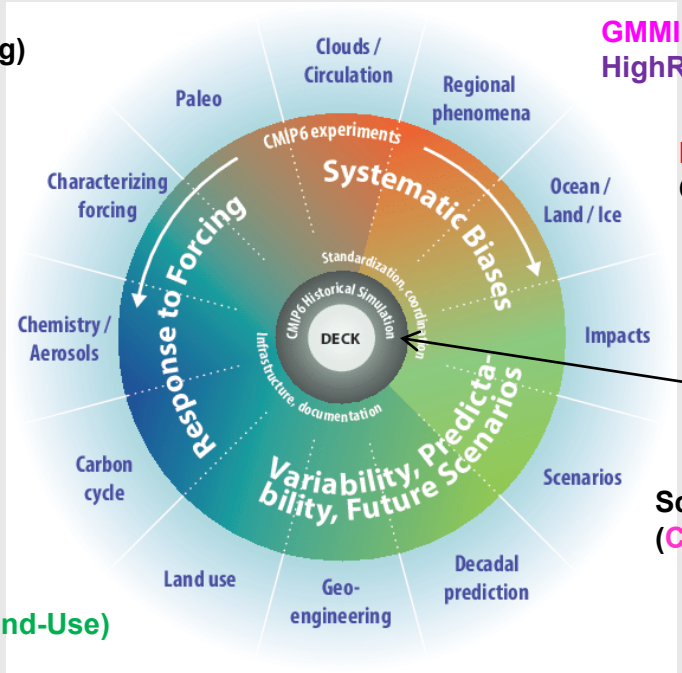
GMMIP (Global Monsoons)

HighResMIP (High-Resolution)

DAMIP (Detection and Attribution) (CM4, ESM4)

FAFMIP (Flux-Anomaly-Forced)

OMIP (Ocean) (CM4, OM4p5B)



AerChemMIP (Aerosols and Chemistry)

DECK and Historical (CM4, ESM4)

C4MIP (Coupled Climate Carbon Cycle)

ScenarioMIP (Future Scenarios) (CM4, ESM4)

LUMIP (Land-Use)

CDRMIP (Carbon Dioxide Removal)

Adapted from
Eyring et al., GMD, 2016

Thank you!

Questions?