



CMIPnext: facilitating international climate science

Paul J. Durack – WIP Co-Chair, CMIP Panel member

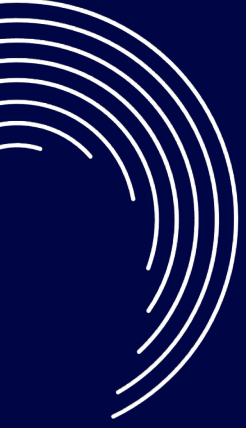
Tuesday 1st August 2023

2023 US CLIVAR Summit (Seattle, WA, USA)



Overview

- Model Intercomparison Projects (MIPs) Overview
- CMIP6 status (current phase)
- CMIPnext planning
 - CMIP surveys; CMIP6Plus
- CMIP7
 - Forcing protocol (idealized/historical-proxy forcings); Data quantities, identities and formats
- CMEC
 - PCMDI Metrics Package (PMP); Collaborative activities in (climate) model evaluation

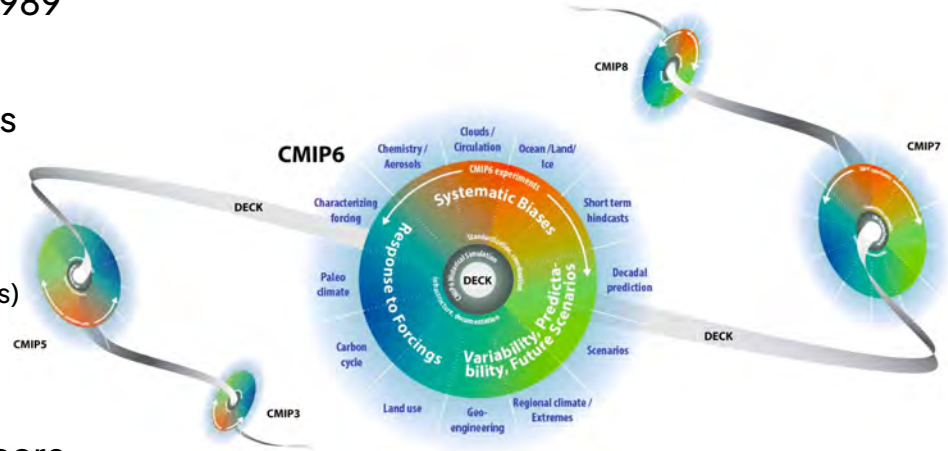


MIPs Overview



What are *MIPs

- Model Intercomparison Projects
- Started with Atmospheric-only MIP (AMIP) in 1989
- Coupled (atmosphere & ocean) MIP (CMIP) initiated 1995, evolved to Earth System Models (ESMs) in CMIP5
- Standardized protocols
 - Experimental (simulation length, model components)
 - Forcing (idealized, or historical-proxy forcings)
 - Data formats, identities and quantities
- Expanded for non-model activities servicing core modelling activities
 - **input4MIPs** – input (forcing) datasets for MIPs
 - **obs4MIPs** – observations for MIPs/model evaluation



Eyring et al. (2016) Overview of CMIP6, doi:10.5194/gmd-9-1937-2016

Timeline of *MIPs

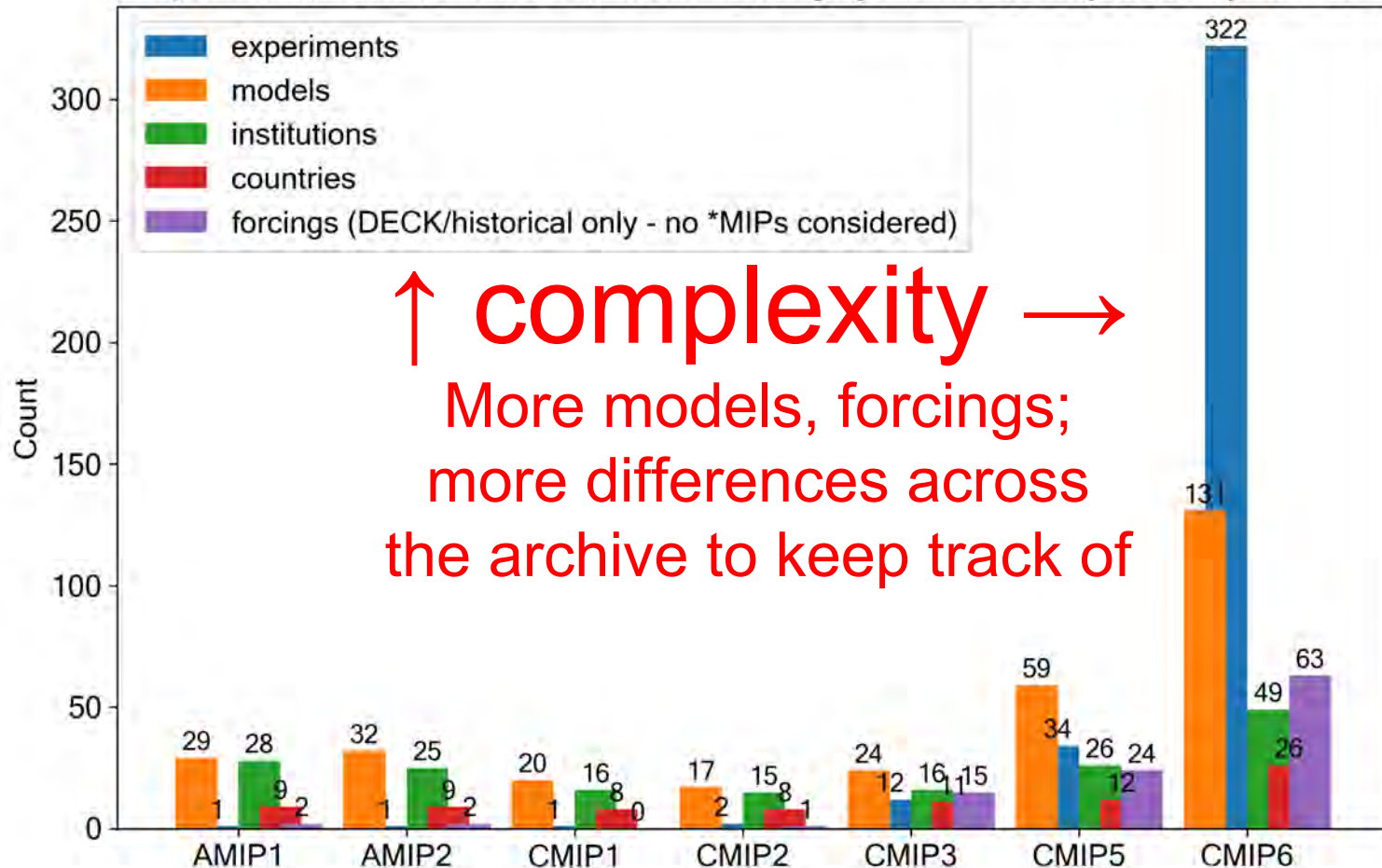
Planning begins	1989	1993	1995	1997	2003	2008	2014
Simulations	AMIP1	AMIP2	CMIP1	CMIP2/ CMIP2+	CMIP3	CMIP5	CMIP6
Data Volumes	~1GB	~500GB	~1GB	~500GB	50TB	2PB	>20PB
Host Infrastructure	LLNL FTP*	LLNL FTP	LLNL FTP	LLNL FTP	LLNL FTP	ESGF 41# nodes	ESGF 30 nodes
Data formats	Fortran formatted binary	Fortran formatted binary, GRIB → DRS▽	GRIB → DRS	GRIB → DRS	CF netCDF-3	CF netCDF-4	CF netCDF-4
Operations begin	1989	1995	1996	1999	2004	2011	2018

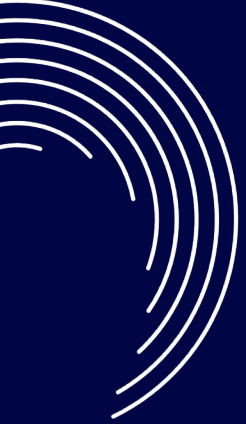
* For some groups in addition to data distribution, LLNL computing facilities were used to run contributing simulations

▽ Data Retrieval and Storage (DRS) software library developed at PCMDI – pre-netCDF file format

The start of data federation - just 17 CMIP5 nodes remain, a ~50% loss from the CMIP5 peak - highlights tier 1 node importance for MIP data preservation

Experiments, Models, Institutions, External Forcing agents and Country counts by *MIP era

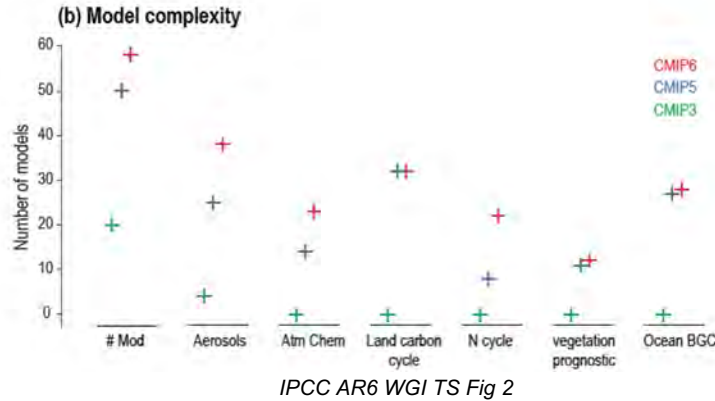
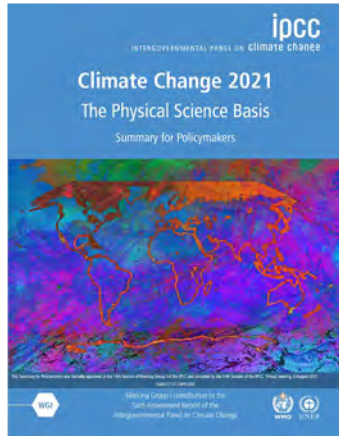




CMIP6 status

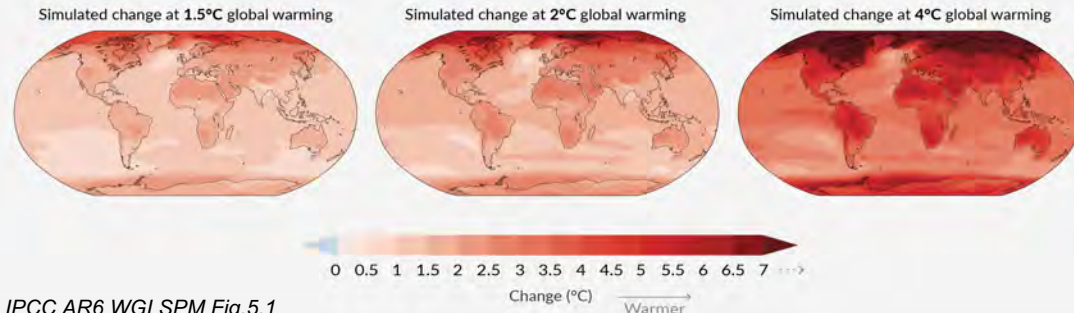


CMIP: driving science, informing policy



(b) Annual mean temperature change (°C) relative to 1850–1900

Across warming levels, land areas warm more than ocean areas, and the Arctic and Antarctica warm more than the tropics.



IPCC AR6 WGI SPM Fig.5.1

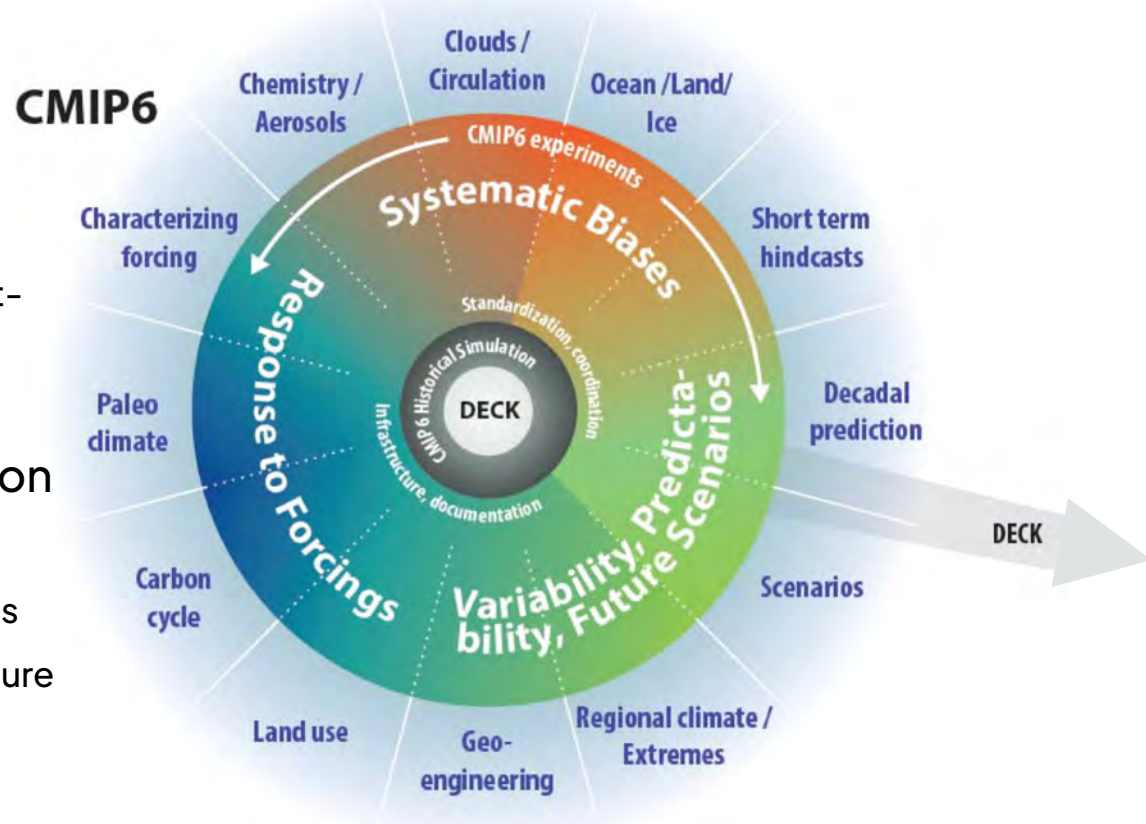
CMIP6: biggest yet!

- 24 endorsed MIPs
- 26 countries
- 48 institutions
- 130 models
- 322 experiments
- 8450 citations of CMIP6 and MIP design papers
- Nearly 26 PB of CMIP6 data
- 30+ ESGF data nodes

CMIP

CMIP6 – current phase

- DECK (core)
 - Dagnostic, Evaluation and Characterization of Klima
 - 4 experiments (1pctCO2, abrupt-4xCO2, piControl, AMIP) + historical + ESM variants
- 24 community MIPs focused on
 - ESM systematic biases
 - Forcing and feedback responses
 - Variability, predictability and future projections
 - Negative emissions pathways



CMIP structure

The DECK

The DECK (Diagnostic, Evaluation and Characterization of Klima) and CMIP historical simulations (1850 – near-present) that maintain continuity and help document basic characteristics of models across different phases of CMIP.

The MIPs

Model Intercomparison Projects (MIPs) address specific science questions across the climate and earth science communities. They are driven bottom up by the community.

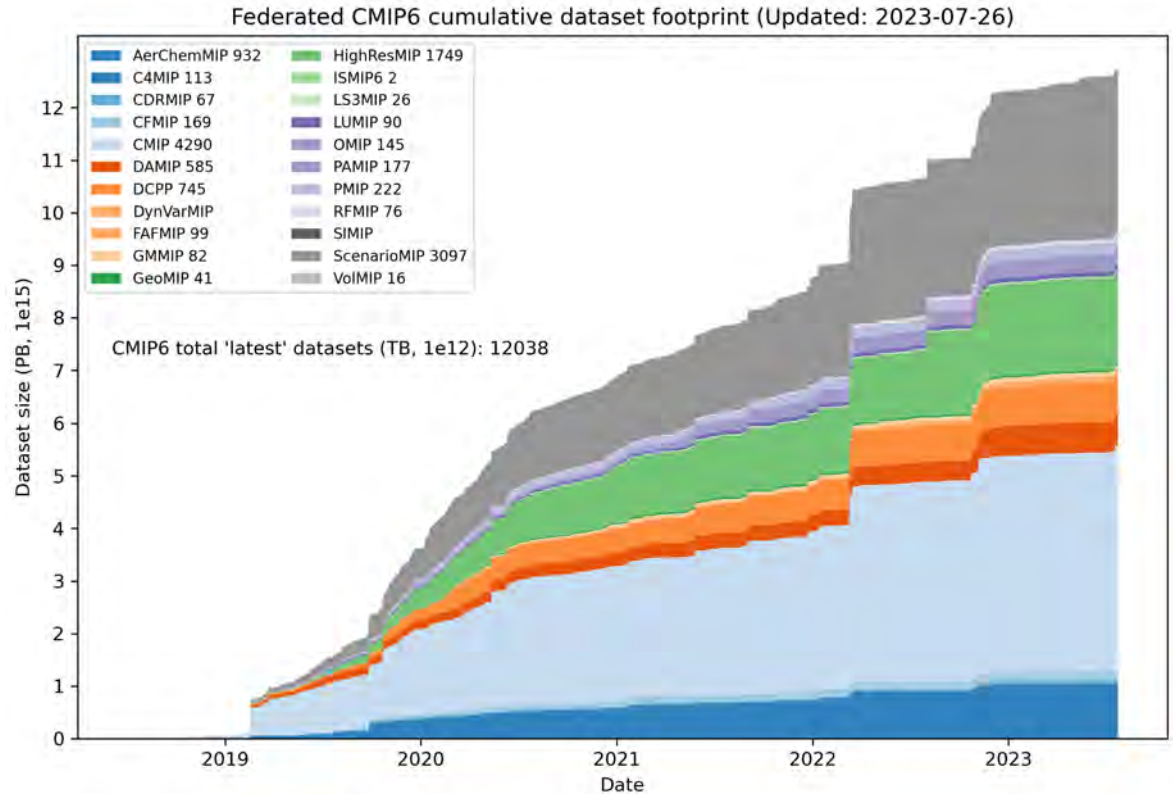
Participation in MIPs by individual modelling groups is at their own discretion and depends on their scientific interests and priorities.

Common standards and open access

Common standards: experimental, forcing, data; Allowing coordination on infrastructure and documentation that facilitates distribution of model outputs and the characterization of the model ensemble.

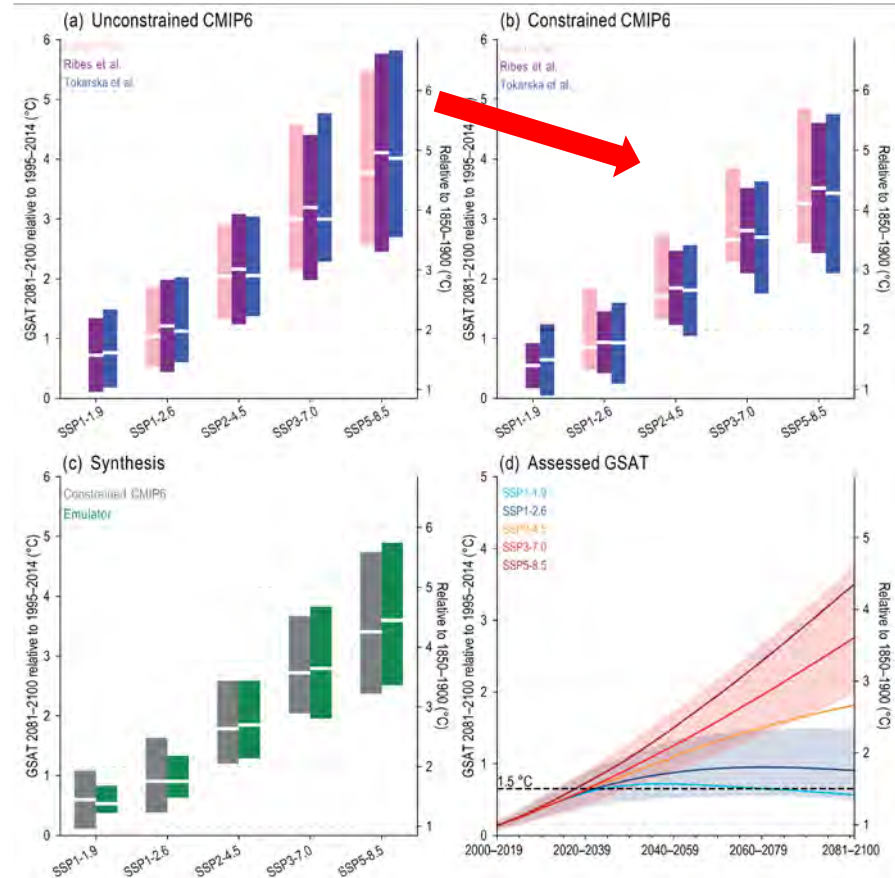
ESGF Published CMIP6 data

- Over 6.4 million CMIP6 ESGF datasets across activities/MIPs
- Seamless delivery – thanks to ESGF data challenges/stability testing
- Datasets – unique variable collections per experiment RIFP (unique simulations)
- Footprint – units of Petabytes



CMIP6 in AR6/IPCC

- CMIP6 “hot models” – climate sensitivity > Sherwood et al. (2020) and > AR6 assessed very likely range
- AR first “constrained projections” – models weighted by observational agreement – downward “correction”
- Getting forcing (and response!) right underpins observed climate change attribution, future projections utility
- Projection user community growing markedly
- Raises model evaluation importance – model projections use requires specialist guidance
- Operational “climate services” need next-level climate science guardrails



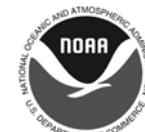
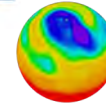


CMIPnext planning



CMIP – a team sport!

- PCMDI
 - U.S. DOE provided 34-years of *MIP support
- ESGF
 - Originated by U.S. DOE ~2007
 - Major recent contributions from numerous others
 - IS-ENES and ENES-RI follow-on
 - European contribution to ESGF & CMIP infrastructure
 - Numerous other projects and institutions, including DKRZ, IPSL, CEDA, ES-DOC, NASA, NOAA, ...
 - CMIP6: 30+ ESGF nodes, 17 countries, 131 models, 48 institutions representing 26 countries, and many, many more...



+

Every modelling group, every forcing dataset provider, ...

CMIP

The CMIP International Project Office

- CMIP expanded to point where coordination of elements requires dedicated administration and facilitation support.
- IPO established March 2022 at host institution, ESA's ECSAT site in Harwell, UK.
- IPO team consists of:
 - Director (*Eleanor O'Rourke*)
 - Programme Manager (*Briony Turner*)
 - Science & Communications Officer (*Beth Dingley*)
 - Technical Officer (*Daniel Ellis*)
 - Part-time administrative support (*Alice Kolesnikov*)



Staff from HE Space Operations under contract to ESA



CMIP6 Survey: Suggestions for CMIP7

- No big structural CMIP6 change but evolution.
- Retain IPCC alignment in some form.
- Reduce huge burden on modelling centres.
- Need for greater focus on climate impacts and adaptation relevant experiments (**including updated scenarios**).
- Need for operationalisation of critical elements (e.g., forcing) – delays in forcing had major CMIP6 delivery impacts.
- Build on substantial CMIP6 data infrastructure progress to facilitate science and support improved, and more user friendly, data access.
- Continue and enhance active community input to the experimental design process.
- Nurture the CMIP future community and promote young and global South scientists.

Addressing community concerns

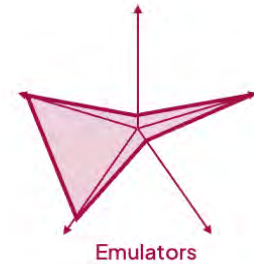
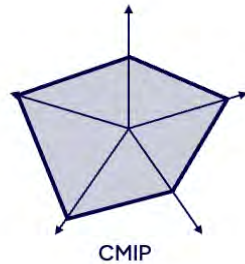
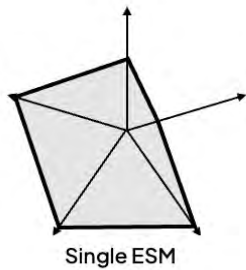
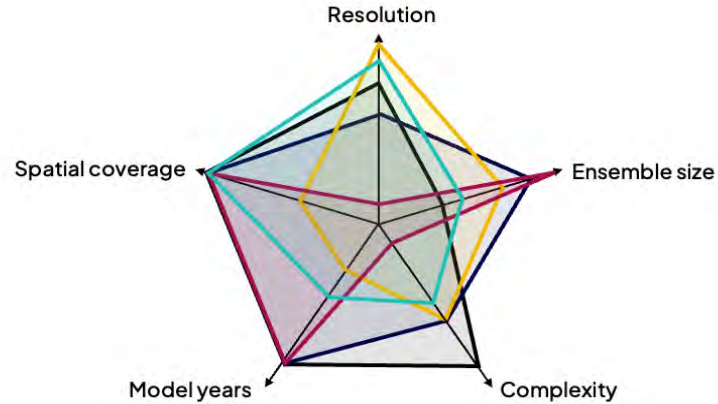
You said....	We are.....
CMIP6 = burden on modelling centres	Reducing numbers of experiments.
IPCC timelines causes pressure	Proposing streamlined experiments on IPCC timeline. Freeing up community driven MIPs
Need for greater focus on climate impacts and adaptation relevant experiments	Seamless delivery across WGI, WGII and WGIII via updated scenarios tailored for mitigation and impacts policy applications with timely delivery to facilitate downscaling
Need for operationalisation of critical elements	Established Task Teams to deliver recommendations for sustainable delivery of near real time forcings.
Need sustainable funding of infrastructure to support improved, and more user friendly, data access.	Established Task Teams to deliver recommendations on requirements for future infrastructure and engaging with funders.
Continue and enhance active community input to the experimental design process.	Expanded CMIP Panel and established Task Teams through open calls plus rolling out extensive community engagement.
Nurture the future CMIP community and promote young and global South scientists.	Launched ECR group (Fresh Eyes on CMIP) and planning for CMIP Panel members from the global South.

The Task Teams

CMIP Task Teams have been established to drive forward definition of CMIP7 in an open and collaborative manner.

- Data access (*Robert Pincus and Atef Ben-Nasser*)
- Data citation (*Martina Stockhause and Sasha Ames*)
- Data request (*Martin Juckes and Chloe Mackallah*)
- Forcings (*Paul Durack and Vaishali Naik*)
- Model benchmarking (*Birgit Hassler and Forrest Hoffman*)
- Model documentation (*David Hassell and Guillaume Levavasseur*)
- Strategic ensemble design (*Ben Sanderson and Isla Simpson*)
- Fresh Eyes on CMIP (*currently under evaluation*)

The role of CMIP within the Modelling Multiverse

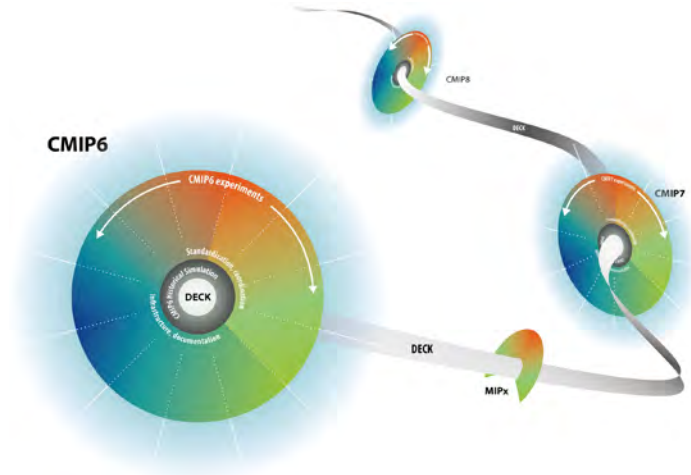


Need for multi-model ensembles beyond CMIP6

- CMIP - provides proven method for testing/validating climate models.
- Enhanced process understanding enabled by improved model fidelity, increased complexity and resolution (e.g., emergent properties).
- Hypothesis testing using climate change projections based on new, updated, and extended scenarios. CMIP infrastructure enables this.
- New observational comparison opportunities emerged that motivate new diagnostics and MIPs (e.g., SWOT, EMIT, BGC Argo – also obs4MIPs).
- CMIP - key international climate service (serves IPCC, policymakers).
- An extended 'gap' in CMIP delivery could result in poorer quality climate information being used by the policy and downstream user community.



CMIP Infrastructure

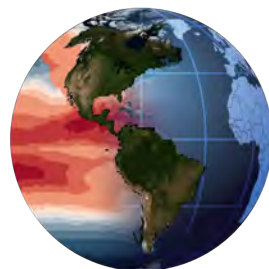


- Leveraging the CMIP6 infrastructure to benefit wider WCRP activities (CMIP6Plus).
- New and ongoing MIP activities can request guidance and limited support.
- Enable responsive activities (e.g., CovidMIP, ZECMIP, LESFMIP, CERESMIP, RAMIP, ...).
- Support CMIP and wider activities' evolution and potential operationalisation of components (e.g., testing next generation forcings)
- Determining a sustainable funding model for CMIP infrastructure.

CMIP6Plus: facilitating and enabling science

Can we leverage existing infrastructure investments, while not waiting?

- Agile, responsive evolution
 - Continuous DECK is a start
 - Facilitate, respond and enable science opportunities
 - CovidMIP, ZECMIP/C4MIP
- Allow CMIP to evolve and “operationalise”
 - Incremental change (e.g., maintain ESGF dependence)
 - Next generation forcings and observations
 - Change little, increment and allow modelling groups to focus on science
- Best prepare CMIP for exascale and the AI/ML onslaught.



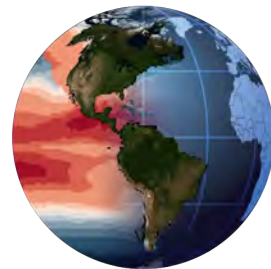
CMIP6+
Coupled Model Intercomparison Project next phase

CMIP

CMIP6Plus: facilitating and enabling science

Can we leverage existing infrastructure investments, while not waiting?

- Continue beyond CMIP6 with few changes as CMIP7 is planned
 - Reduce time pressures – loosen CMIPx to IPCC ARx linkage
 - Continuous CMIP science – move away from monolithic ~7 year phases
- Facilitate and recognise contributors
 - Ensure all contributions are recognised
 - How can we support forcing data providers?
 - Funding? (“CMIP endorsed” data provider)
 - Infrastructure support?



CMIP6+
Coupled Model Intercomparison Project next phase

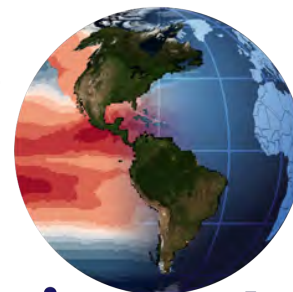
Looking forward: CMIPnext ideas

Can we optimise to meet science goals without bloating the archive?

- Not just data request – rather, MIPs provide diagnostics/code to implement
 - Rather than requesting data, request the targeted diagnostic
 - Plus = less data, minus = locks out spontaneous science opportunities
- MIPs define diagnostics to implement within models
 - Advance the inclusion of key simulators (e.g., COSP)
 - Encourage MIP diagnostic team development – move workload to MIP chairs, not modellers
- How to best leverage community diagnostics
 - ESMValTool, CMEC (Coordinated Model Evaluations Capabilities), NOAA-MDTF
- Amalgamate efforts to reduce overheads (e.g., input4MIPs, obs4MIPs)

Climate forcing

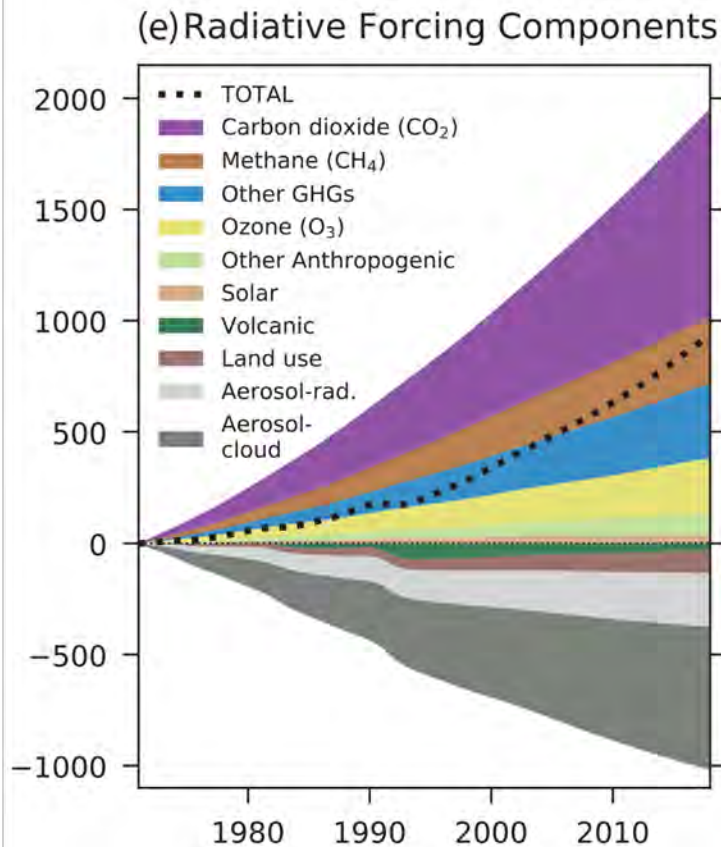
- *MIP history proved external climate forcing matters
- Historical forcings are keys to climate change attribution
- Future forcing will determine future state (accurate projection/predictions)
- input4MIPs began the process
 - CMIP forcing dataset coordination
 - Version control and documentation
- Beyond CMIP6
 - Evaluate, quantify and better understand uncertainties
 - Dataset harmonization across products
 - Quantify, version control and document forcings
 - Feedback on MIP experimental design through forcing evaluation



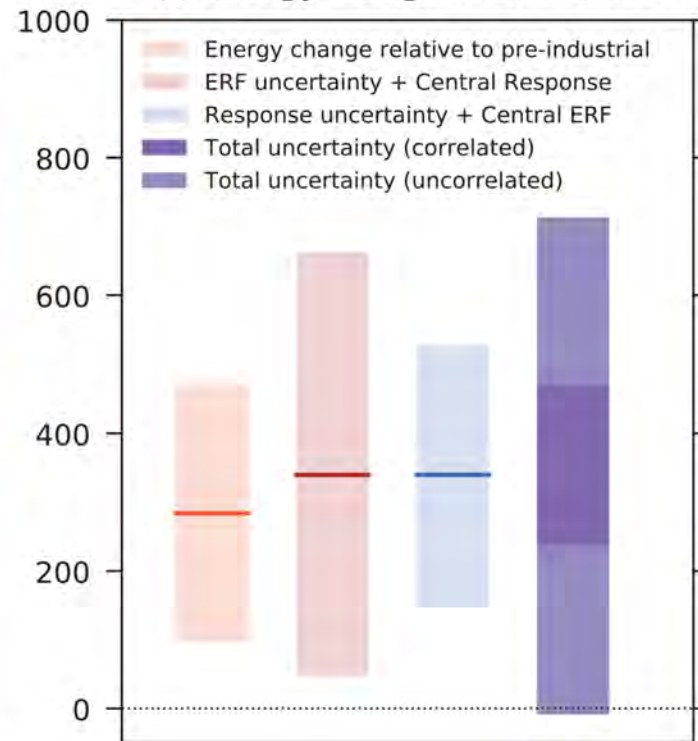
input4MIPs



Climate forcing



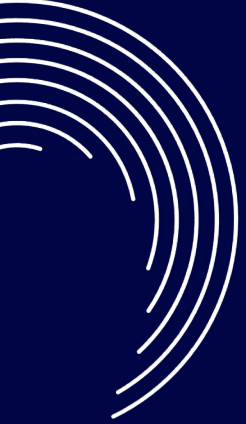
(f) Energy Budget 1971-2018



Forcings provision (including scenarios)

- Delays in forcing dataset provision were highly problematic during CMIP6.
- There is a need to update, and develop new forcing datasets with adequate time for robust evaluation before CMIP7 commences.
- Scenario development is increasingly important to ensuring policy makers have the information they will need to address post 2030 mitigation and adaptation planning.
- Forcings session at AGU23 in December 2023.

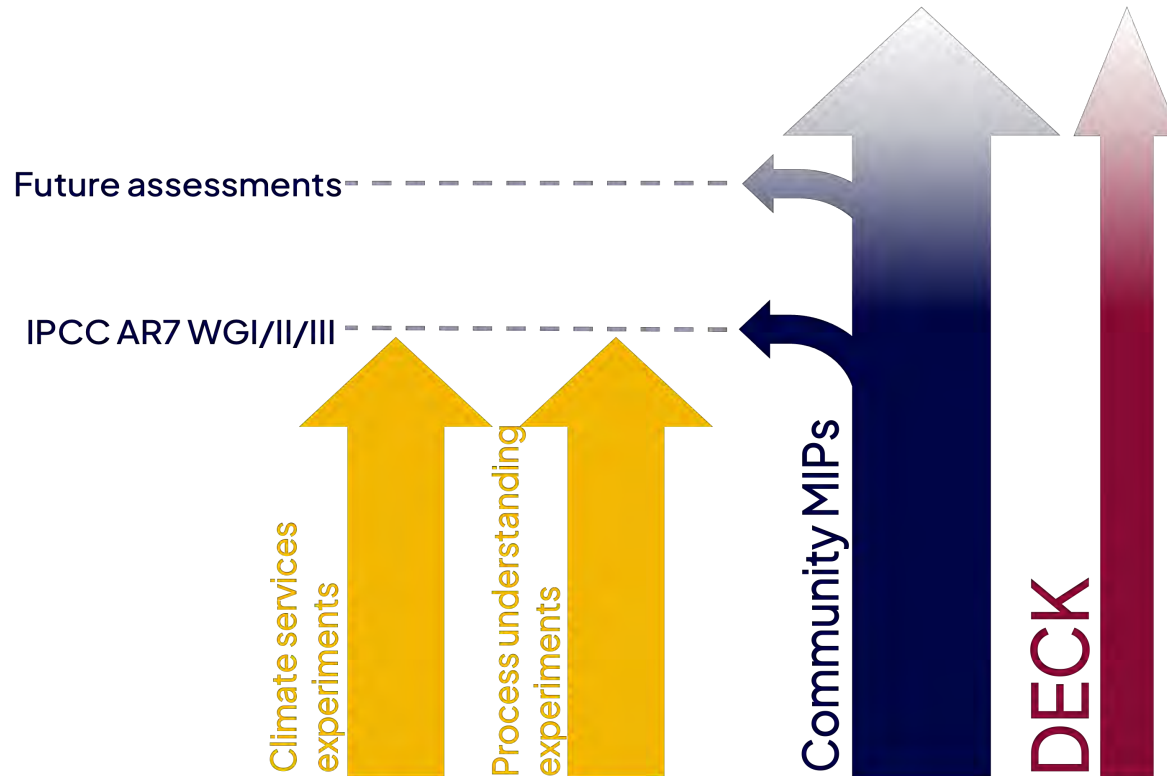




CMIP7



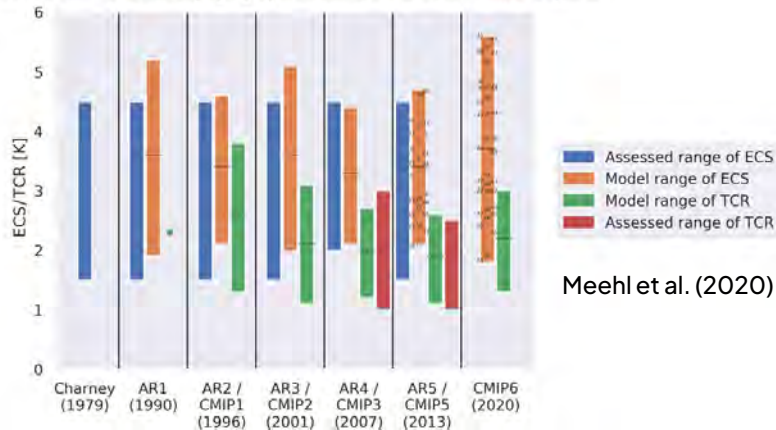
Evolving CMIP7 structure



CMIP7 will address WCRP science objectives

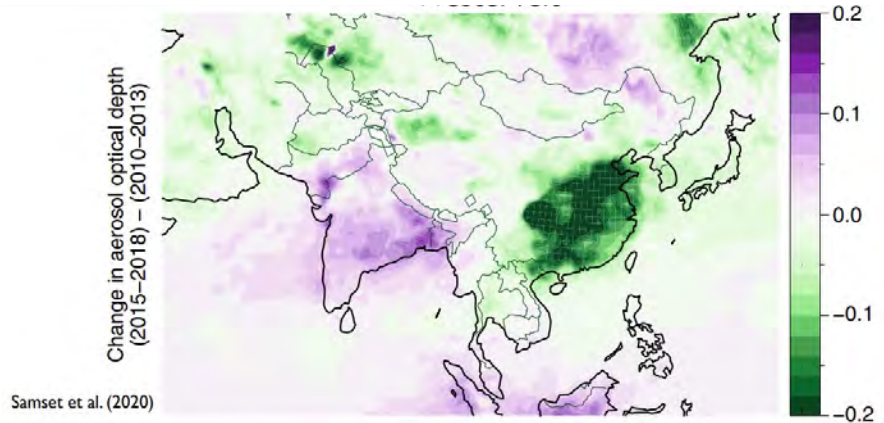
1 Fundamental understanding of the climate system

Equilibrium climate sensitivity (gregory method) and transient climate response



Help reconcile the observational refutation of high ECS models and their continued prevalence in the ensemble.

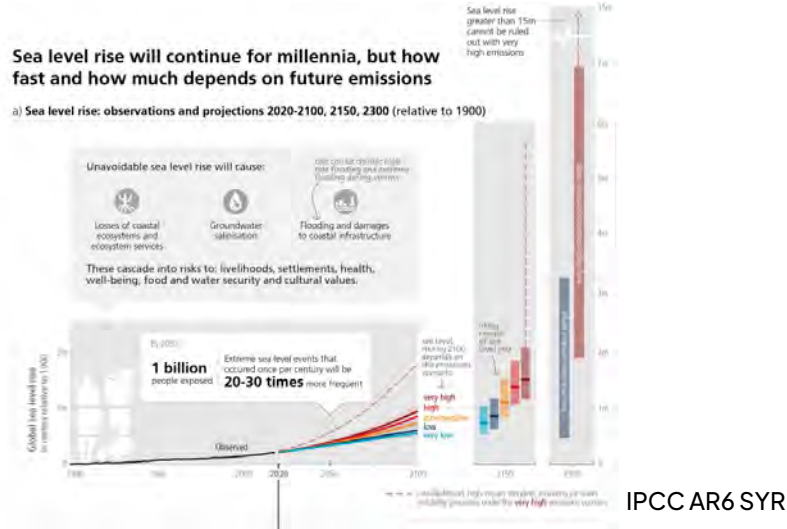
2 Prediction of the near-term evolution of the climate system



Assess forcing uncertainty e.g., the potential to explore sensitivity to high aerosol forcing.

CMIP7 will address WCRP science objectives

3 Long-term response of the climate system



Focus beyond 2100 including overshoots and e.g., how to better constrain sea level rise “deep uncertainty” under $>3^{\circ}\text{C}$ warming.

4 Bridging climate science and society

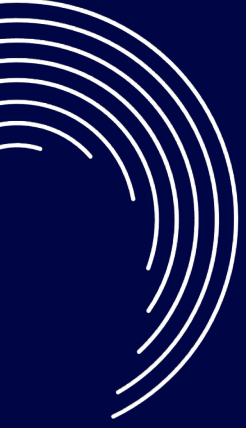




CMIP7 preliminary timeline

For the subset of CMIP7 experiments aimed at IPCC alignment, engagement with the new IPCC leadership is underway. Planning will coalesce in late 2023. Community MIPs do not need to align with that timeline, although they may choose to do so. Current estimates suggest:

- **Historical forcings:** Update expected, with data extending until December 2021 **available by mid-2024 and revised in 2026** ([CMIP Forcings timeline – current status](#)).
- **Scenario forcings:** **late 2026** (link to [ScenarioMIP pages](#))
- **Data request:** Initial production versions expected early to mid-2025, with regular updates thereafter.
- **Modelling centres:** Consulting on expectations for when new models and associated infrastructure will be ready.
- **ESGF nodes:** ESGF needed to collate and serve the data. Ongoing discussions led by the WIP and ESGF community.
- CMIP7 description paper: Intention for **submission in 2024**.



CMEC



Coordinated Model Evaluation Capabilities (CMEC)

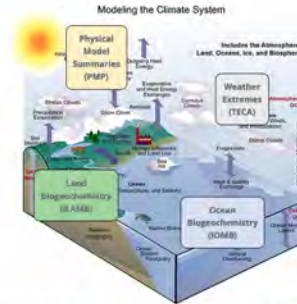


Home Capabilities Results Protocols Contacts

- Effort to bring together a diverse set of analysis packages developed to facilitate Earth System Model systematic evaluation
 - PCMDI Metrics Package (PMP)
 - International Land Model Benchmarking Package (ILAMB)
 - Toolkit for Extremes Climate Analysis (TECA)
- Technical alignment, providing a simple and consistent driver interface across all contributing modules
- Coordinates and organizes output data produced by CMEC packages

Coordinated Model Evaluation Capabilities

Coordinated Model Evaluation Capabilities (CMEC) is an effort to bring together a diverse set of analysis packages that have been developed to facilitate the systematic evaluation of Earth System Models (ESMs). CMEC includes capabilities that are supported by the U.S. Department of Energy, Office of Biological and Environmental Research (BER), and Regional and Global Model Analysis (RGMA), along with capabilities contributed by community-based experts and international agencies.



CMEC is motivated by the need for comprehensive and holistic evaluation of Earth system models and datasets, so as to identify persistent biases and improve data credibility. With widespread and rapid growth in the number of available metrics and diagnostic tools, a lack of standards within the evaluation community have meant that running even a single evaluation tool can require extensive user intervention. Given the significant commonality in how these evaluation tools operate, interoperability is a natural goal achievable through robust and light-weight standards.

The three goals of the CMEC project include: (1) to develop robust and light-weight standards for operation of evaluation packages and their output; (2) to develop accompanying tools for installation of evaluation packages, coordinated execution of evaluation packages, and obtaining data products necessary for operation of these tools; and (3) to build connections across groups, centers, and individual investigators performing model evaluation.

CMEC aims to operate on a variety of Earth system data products including but not limited to: Earth system model data such as contributions to the Coupled Model Intercomparison Project (CMIP), reanalysis data products, and other data products produced by global modeling centers or individual research groups.

To advance this effort, participation is sought from new and existing ESM evaluation packages. Inclusion is not limited to packages for CMIP analysis, and both metrics and diagnostics packages are welcome.

<https://cmec.llnl.gov>



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MIP



The PCMDI Metrics Package (PMP)

The PCMDI Metrics Package (PMP) provides a diverse suite of relatively robust high-level summary statistics that gauge differences between models and observations. The emphasis is on the physical system in Earth System Models (ESMs) and their component sub-models. The PMP provides holistic summaries spanning space and time scales for the simulated atmosphere, ocean, ice and land with the CMEC examples available on this site highlighting atmospheric characteristics.

The goals of the PMP are to:

- Provide objective performance summaries of all CMIP DECK + Historical simulations
- Incorporate results spanning six generations of CMIP/AMIP, and to track performance changes through eras of climate model evolution
- Enable modeling groups to use the PMP in their own analysis/development workflow, so to generate near instant feedback at the time of the model simulation completion, rather than await for feedback through the multi-year process that occurs through peer- publication
- Collaborate with US and international expert teams to further diversify the suite of objective tests and expand these in new and novel ways
- Further leverage and advance the conventions and protocols that were developed by PCMDI for CMIP, and use these to facilitate open source software collaboration across research groups and institutions

The PMP summaries include metrics from PCMDI's research, which rely on several summary diagrams designed by PCMDI (Taylor, 2001; Gleckler et al., 2008) that are now widely adopted by the research community. Well-established metrics generated by various expert teams (e.g., CLIVAR Pacific Region Panel for ENSO) are being implemented into the PMP. The software leverages advanced Python-based model analysis tools that have been developed with over two decades of support from the U.S. Department of Energy, along with the Earth System Grid Federation (ESGF), CMIP6, CMIP5, CMIP3 and earlier data holdings based on-site at LLNL.

As PMP development continues, we welcome collaborations from modeling groups and expert teams to further expand and improve the comprehensiveness of the calculated metrics.

Quick links: [Repository](#), [Installation](#), [CMIP5/6 AMIP and Historical Results](#), [CMIP5/6 Interannual variability](#)

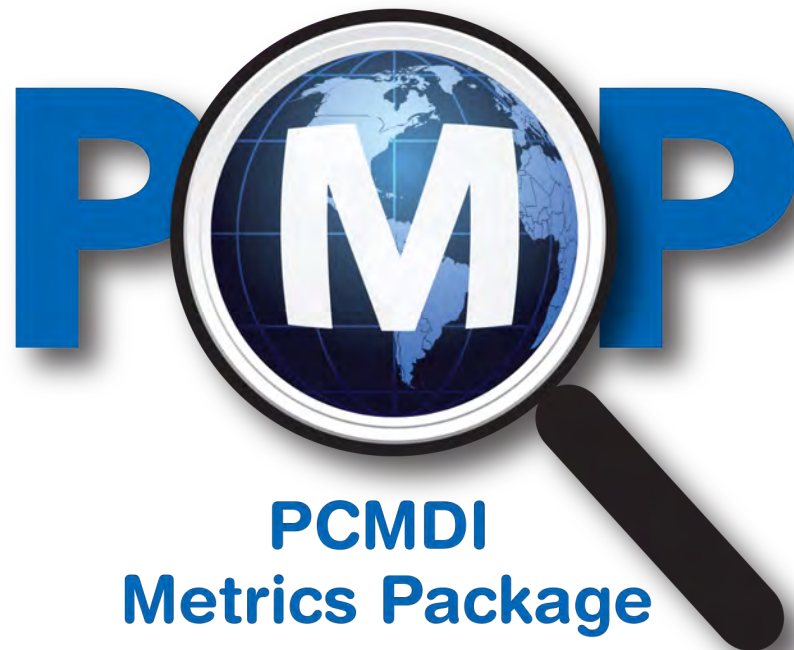
Contact: Peter J. Gleckler (gleckler1@llnl.gov)

ATMOSPHERIC SCIENCES

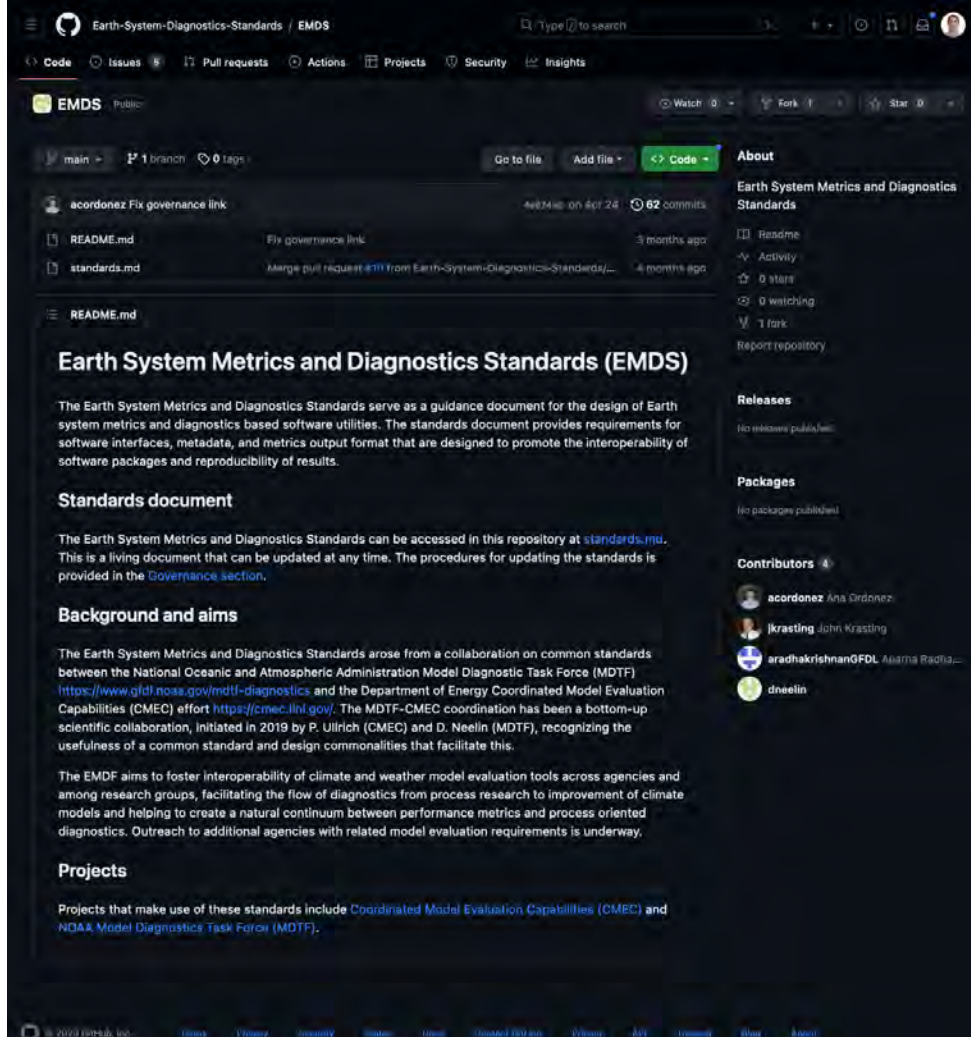
Project Update



A More Powerful Reality Test for Climate Models



<https://pcmdi.llnl.gov/research/metrics/>



CMEC
LLNL, ORNL, LBNL
Dept of Energy



NOAA-MDTF
NOAA-GFDL, UCLA, U/NCAR, PNNL,
Colorado State, Florida State, UCD, UW
Dept of Commerce/NOAA

[https://github.com/
Earth-System-Diagnostics-Standards](https://github.com/Earth-System-Diagnostics-Standards)



Thank You!

Questions, suggestions..?

durack1@llnl.gov

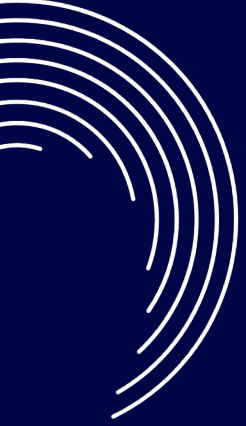
Contact cmip-ipo@esa.int with any questions or feedback.
More information can be found at wcrp-cmip.org

Work completed by the PCMDI project
is funded by the U.S. Department of
Energy, Office of Science, Office of
Biological and Environmental Research,
Regional and Global Model Analysis
Program



Lawrence Livermore
National Laboratory





Extra slides



WCRP-CMIP / CMIP6_CVs

Code Issues Pull requests Discussions Actions Projects Wiki Security Insights Settings

CMIP6_CVs Public

Edit Pins Unwatch 18 Fork 74 Starred 128

master 4 branches 381 tags

Go to file Add file Code About

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- .github Issue #100 durack1 deregister BNU-ESM-1-1 and institution_id BNU ... last year
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- src Revise E3SM-2-0-NARRM source_id license history (#1200) last week
- .githignore Update to collection versioning: 0.2.1.0 8 years ago
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- CMIP6_required_global_attributes... Revise E3SM-2-0-NARRM source_id license history (#1200) last week
- CMIP6_source_id.json Revise E3SM-2-0-NARRM source_id license history (#1200) last week
- CMIP6_source_type.json Revise E3SM-2-0-NARRM source_id license history (#1200) last week
- CMIP6_sub_experiment_id.json Revise E3SM-2-0-NARRM source_id license history (#1200) last week
- CMIP6_table_id.json Revise E3SM-2-0-NARRM source_id license history (#1200) last week
- README.md Revise E3SM-2-0-NARRM source_id license history (#1200) last week
- _config.yml Set theme jekyll-theme-cayman 4 years ago
- mip_era.json Revise E3SM-2-0-NARRM source_id license history (#1200) last week

README.md

CMIP6_CVs Current version: 6.2.56.56

Core Controlled Vocabularies (CVs) for use in CMIP6

Registering Institutions, Models, or requesting changes to CVs:

To register your institution or model or to register a new experiment, please submit an issue/ticket following the instructions on the [CMIP6_CVs issue page](#). Follow the same procedure to request a change in any other CV.

Some support for CMIP participating modeling groups is available: pcmdi-cmip@nl.gov

To view current repository contents in HTML format, point your browser to:

https://github.com/WCRP-CMIP/CMIP6_CVs



CF Metadata Conventions

The CF metadata conventions are designed to promote the processing and sharing of files created with the [NetCDF API](#). The conventions define metadata that provide a definitive description of what the data in each variable represents, and the spatial and temporal properties of the data. This enables users of data from different sources to decide which quantities are comparable, and facilitates building applications with powerful extraction, regridding, and display capabilities. The CF convention includes a standard name table, which defines strings that identify physical quantities.

Conventions: [Latest release \(1.10\) HTML PDF](#) • [Working draft HTML PDF](#)

Vocabularies: [Standard names](#) • [Area types](#) • [Standardized regions](#)

CF is developed through open discussion on GitHub. If you would like to propose a change, make a suggestion, report a problem or ask a question, please [see here](#). Changes are decided according to the CF [governance arrangements](#). The CF community embraces a philosophy of producing excellence by maintaining an open and welcoming culture and an environment that promotes debate and inquiry in a respectful, bold and intellectually rigorous fashion.

Initially CF was developed for gridded data from climate and forecast models (hence "CF") of the atmosphere and ocean, but its use has subsequently extended to other geosciences, and to observations as well as numerical models. The use of CF is recommended where applicable by Unidata.

Quick links

See also the links in the navigation bar at the top of this page.

- Current issues: [general discussion](#) (including standard names), [conventions](#), this [website](#) (including governance)
- [CF GitHub organisation](#)
- [CF FAQ](#)
- [List of software for working with CF](#)
- [Paper](#) describing the CF data model and reference software
- Overview of CF basics as a [presentation](#) and [paper](#)

[Contact the CF community](#) with questions, comments and suggestions about CF metadata or this website

This site is open source. [Improve this page!](#)

<http://cfconventions.org>

PCMDI / mip-cmor-tables

Code Issues Pull requests Discussions Actions Projects Wiki Security Insights Settings

mip-cmor-tables Public Edit file Unwatch Fork Star

main 3 branches 0 tags Go to file Add file Code About

durack1 Merge pull request #17 from PCMDI/issue16_durack1_addAcknowledgements · 2 weeks ago · 12 commits

Tables

- merge up to date changes with almost functional CMIP6tables (#12) 5 months ago
- mip_cmor_tables merge up to date changes with almost functional CMIP6tables (#12) 5 months ago
- erc filled func from juckes notebook #7 10 months ago
- gitignore initial commit last year
- CMOR_input_example.json merge up to date changes with almost functional CMIP6tables (#12) 5 months ago
- LICENSE initial commit last year
- README.md adding acknowledgements 2 weeks ago
- my_input.json merge up to date changes with almost functional CMIP6tables (#12) 5 months ago
- test_python_3D_var_segfaults.py merge up to date changes with almost functional CMIP6tables (#12) 5 months ago
- test_python_3D_var_works.py merge up to date changes with almost functional CMIP6tables (#12) 5 months ago

README.md

mip-cmor-tables

JSON tables for CMOR3 to create Model Intercomparison Project (MIP) datasets

THIS REPOSITORY IS CURRENTLY UNDER ACTIVE DEVELOPMENT


Contributors

Thanks to our contributors!

Acknowledgement

The repository content has been developed by climate and computer scientists representing the Coupled Model Intercomparison Project phase 6 (CMIP6) and earlier phases, including those from climate modeling groups and model intercomparison projects (MIPs) worldwide. A special mention to Dr. Martin Juckes from the UK Centre for Environmental Data Analysis (CEDA) for leading efforts in the [CMIP6 Data Request](#). The structure of repository content and tools required to maintain it was developed by climate and computer scientists from the Program for Climate Model Diagnosis and Intercomparison (PCMDI) at Lawrence Livermore National Laboratory (LLNL) and the UK MetOffice, with assistance from colleagues at the Coupled Model Intercomparison Project International Project Office (CMIP-IPO), the Deutsches Klimarechenzentrum (DKRZ) in Germany and the members of the Infrastructure for the European Network for Earth System Modelling (IS-EMES) consortium.

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<https://github.com/PCMDI/mip-cmor-tables/>

Time-evolving *MIP external forcing

Forcing/MIP era	AMIP1	AMIP2	CMIP1	CMIP2	CMIP3 ^a 20c3m	CMIP5 ^b historical	CMIP6 ^c historical
SST & sea ice	Y	Y			Y (AMIP)	Y (AMIP)	✓ (AMIP)
Greenhouse gases		Y (fixed: CO ₂ , CH ₄ , N ₂ O)	Y (fixed)	Y (fixed and 1% idealized)	Y (~5 species)	Y (~9 species)	✓ (46 species)
Ozone		Y?	Y (fixed)	Y (fixed)	½	Y	✓
Sulphate aerosols (in/direct)					½ / Y	⅔ / Y	✓
Black/Organic carbon					½ / ½	⅔	✓
Land use change					⅓	¾	✓ (4 states)
Solar irradiance		Y(fixed)	Y (fixed)	Y (fixed)	½	9/10	✓
Volcanic aerosols					½	9/10 (3 variants)	✓
Nitrogen deposition							✓ (4 species)
Total varying forcings	2	2	0	1 (idealized)	~15	~24	~63