

Coupled Model Intercomparison Project Phase 6

(CMIP6): *CMIP timeline, role of satellite MIPs, what constitutes a CMIP experiment, expectations for MIP proposals*

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EXPERIMENTAL DESIGN FOR CMIP6:

AEROSOL, LAND USE, AND FUTURE SCENARIOS

4-8 August 2014

AGCI, Aspen, CO, USA

Knowledge for Tomorrow



Coupled Model Intercomparison Project (CMIP)

(organized by the WCRP Working Group on Coupled Modelling (WGCM))

Objective: Understanding of past, present and future climate variability and change through a coordinated multi-model experiment design.

Overseen by CMIP Panel: Veronika Eyring (Chair), Jerry Meehl, Bjorn Stevens, Ron Stouffer, Karl Taylor

Coordinated across multiple climate science communities within WCRP and beyond (e.g., AIMES, IAMC)

- Since 1995, **CMIP** has coordinated climate model experiments involving multiple international modeling teams.
- CMIP has led to a better understanding of past, present and future climate change and variability.
- CMIP has developed in phases, with the simulations of the fifth phase, CMIP5, now mostly completed.
- Though analyses of the CMIP5 data will continue for at least several more years, science gaps and outstanding science questions have prompted preparations to get underway for the **sixth phase of the project (CMIP6)** already in 2013.

Preparing for Phase 6 of the Coupled Model Intercomparison Project (CMIP6)



see updates on the CMIP Panel website

<http://www.wcrp-climate.org/index.php/wgcm-cmip/about-cmip>



- Initial proposal for the design of CMIP6 to inform interested research communities and to encourage discussion and feedback for consideration in the evolving experiment design.
- See details at
Meehl, G. A., R. Moss, K. E. Taylor, V. Eyring, R. J. Stouffer, S. Bony and B. Stevens, Climate Model Intercomparisons: Preparing for the Next Phase, Eos Trans. AGU, 95(9), 77, 2014.
- **Feedback on this initial CMIP6 proposal is being solicited over the year from modeling groups and model analysts.** Please send comments to CMIP Panel chair by **September 2014**. The WGCM and the CMIP Panel will then iterate on the proposed experiment design, with the intention to **finalize it at its meeting in October, 2014**.
- Based on CMIP5 survey and Aspen Global Change Institute (AGCI) CMIP6 planning workshop in August 2013 & WGCM/AIMES meeting in Oct 2013.

Initial CMIP6 Proposal: Scientific Focus

- The specific experimental design would be 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 changes given climate variability, predictability and uncertainties in scenarios?
- It is proposed to use as the **scientific backdrop** for CMIP6 the six **WCRP Grand Challenges**, and an additional theme encapsulating questions related to **biospheric forcings and feedbacks**.
 1. Clouds, Circulation and Climate Sensitivity
 2. Changes in Cryosphere
 3. Climate Extremes
 4. Regional Climate Information
 5. Regional Sea-level Rise
 6. Water Availability
 7. AIMES theme for collaboration: biospheric forcings and feedbacks

Initial CMIP6 Proposal: A Distributed Organization under the oversight of the CMIP Panel

CMIP would be comprised of two elements:

1. Ongoing *CMIP Diagnostic, Evaluation and Characterization of Klima* (DECK) experiments:

a small set of standardized experiments that would be performed whenever a new model is developed.

The DECK experiments are chosen to provide **continuity across past and future phases of CMIP**, to evolve only slowly with time, and to take advantage of what is already **common practice in many modeling centers**:

- i. an AMIP simulation (~1979-2010);
- ii. a multi-hundred year pre-industrial control simulation;
- iii. a 1%/yr CO₂ increase simulation to quadrupling to derive the transient climate response;
- iv. an instantaneous 4xCO₂ run to derive the equilibrium climate sensitivity;
- v. a simulation starting in the 19th century and running through the 21st century using an existing scenario (RCP8.5).

2. Standardization, coordination, infrastructure, and documentation

functions that make the simulations and their main characteristics performed under CMIP available to the broader community.

Initial CMIP6 Proposal: A Distributed Organization under the oversight of the CMIP Panel

CMIP Phase 6 (CMIP6):

- **CMIP6-Endorsed MIPs** would propose additional experiments, and modeling groups could choose a subset of these to run according to their interest, computing and/or human resources and funding constraints.
- The MIPs would also likely have additional experiments that would not be part of CMIP6 but would be of interest and relevant to their respective communities.

Participation

- A scientist or group of scientists could send a ‘Request for a **CMIP6-Endorsed MIP**’ at any time to the CMIP Panel Chair (see template on CMIP webpage).

The main criteria for MIPs to be endorsed for CMIP6 are

- The MIP addresses at least one of the key science questions of CMIP6;
- The MIP follows CMIP standards in terms of experimental design, data format and documentation;
- A sufficient number of modeling groups have agreed to participate in the MIP;
- The MIP builds on the shared CMIP DECK experiments;
- A commitment to contribute to the creation of the CMIP6 data request and to analyze the data.
- A commitment to identify or contribute possible observations/reanalysis to obs4MIPs/ana4MIPs for model evaluation and improved process understanding.

ScenarioMIP (Scenario Model Intercomparison Project)

Co-Chairs: Brian O'Neill, Claudia Tebaldi, Detlef van Vuuren

Another new concept proposed for CMIP6 is a “ScenarioMIP”

The main objectives of the ScenarioMIP are:

1. Define and recommend an experimental design for future scenarios to be run by climate models as part of CMIP6.

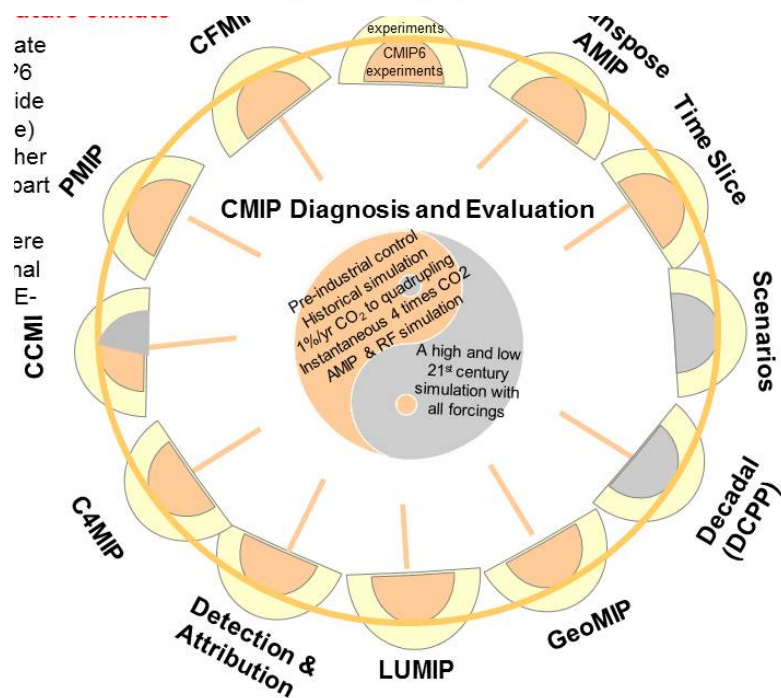
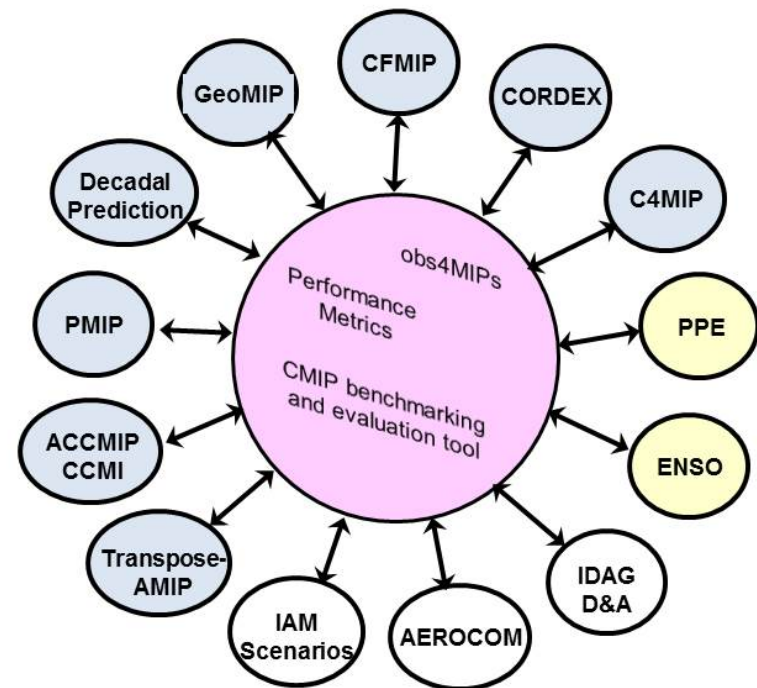
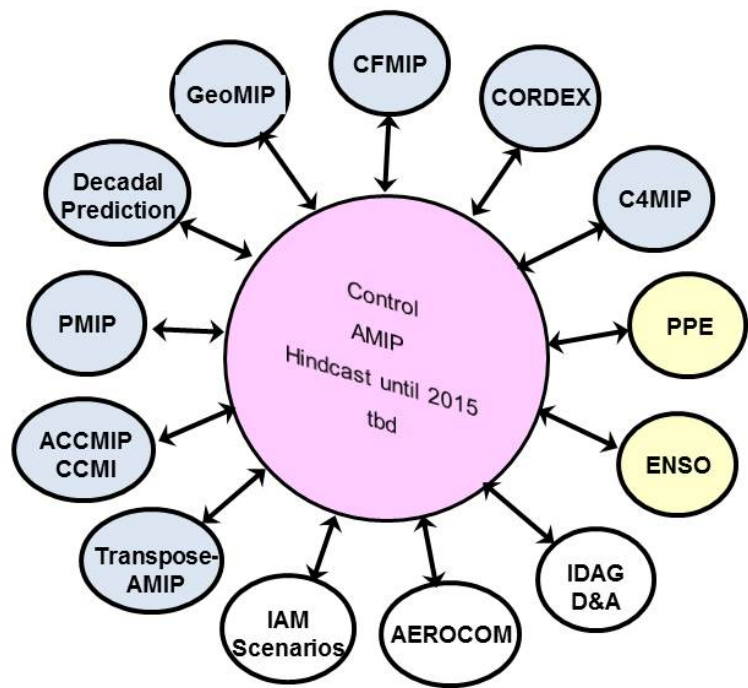
2. Coordinate the provision of IAM scenario information to climate modeling groups, including emissions, concentrations, and land use datasets, coordinating with LUMIP, AerChemMIP, C4MIP, the Integrated Assessment Modeling Consortium (IAMC) and other groups as necessary.

3. Coordinate the production of climate model simulations and facilitate provision of output sufficient to support scenario-based research in the impact/adaptation and integrated assessment communities.

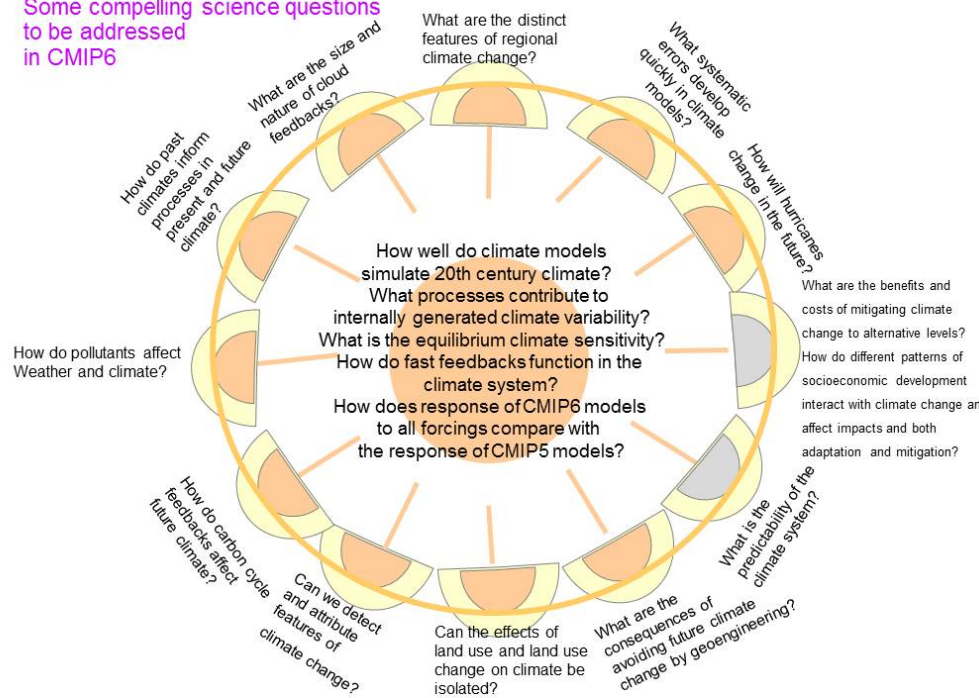
A number of research questions have been identified that require cooperation with integrated assessment and impacts-adaptation-vulnerability researchers. These include

- an overshoot scenario as noted above,
- emissions of short-lived climate forcers and air quality/climate interactions,
- land use and land cover change,
- integrated analysis of impacts and responses;
- climate risk related to variability estimates.

See <https://wiki.ucar.edu/pages/viewpage.action?pageId=282605664>

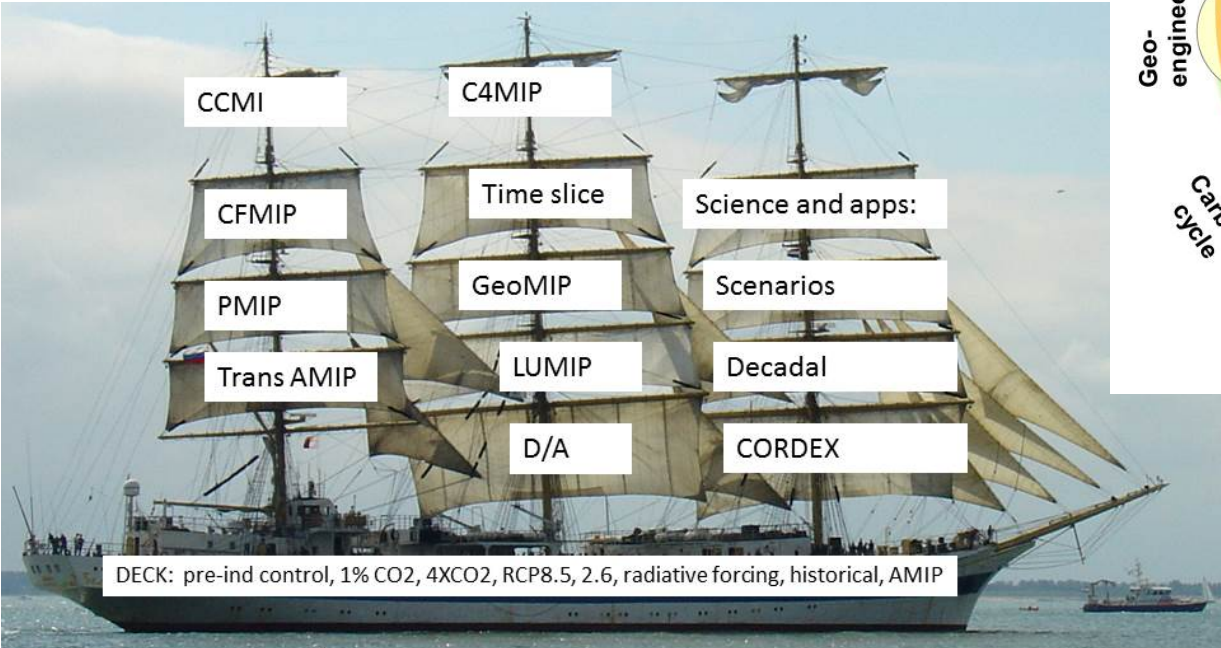
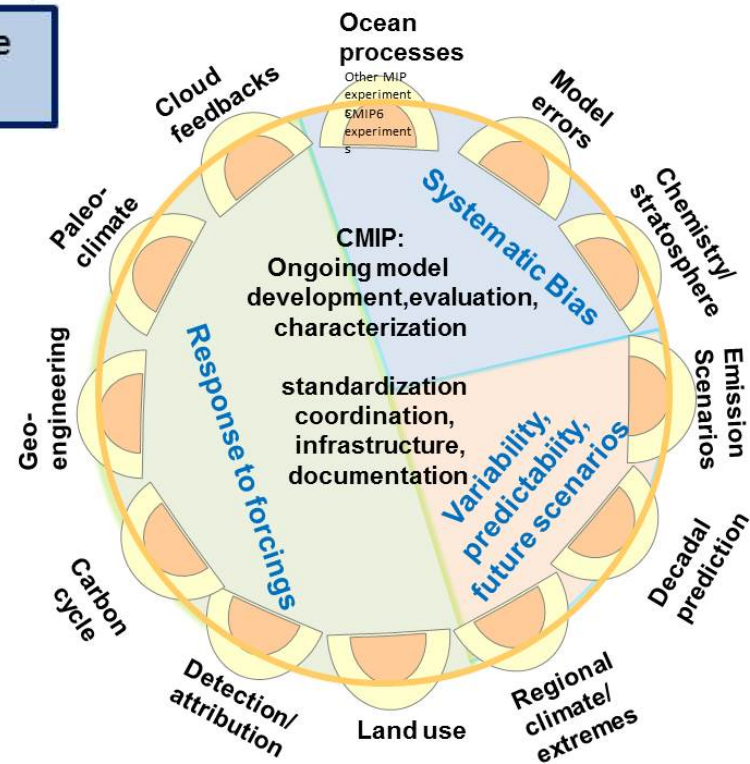


Some compelling science questions to be addressed in CMIP6

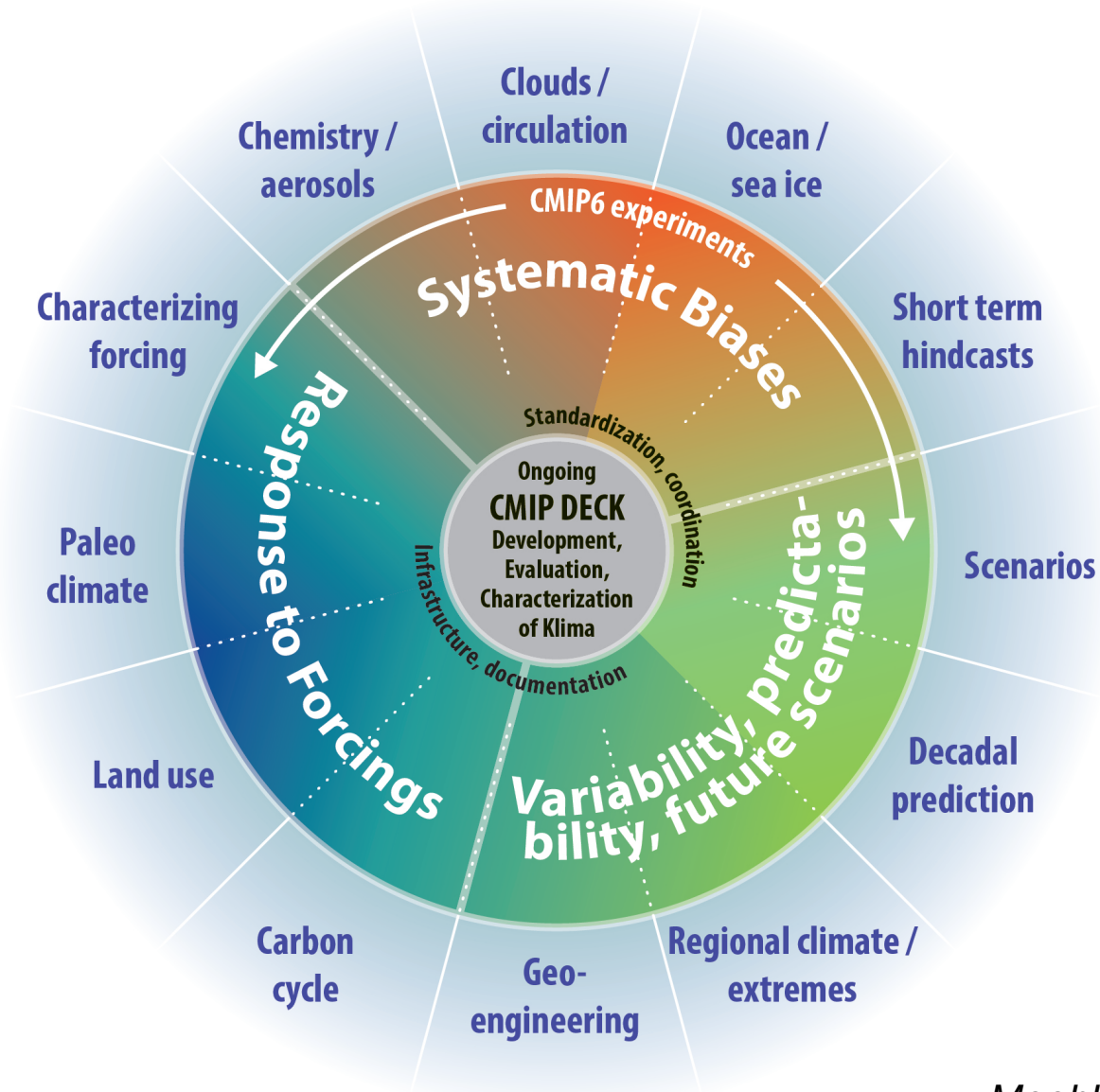


MIPs:	MIPs:	MIPs:	Science and apps:
CCMI	Trans AMIP	C4MIP	Scenarios
CFMIP	Time slice	LUMIP	Decadal
PMIP	GeoMIP	D/A	CORDEX

DECK: pre-ind control, 1% CO₂, 4XCO₂, RCP8.5, RCP2.6, radiative forcing, historical, AMIP



WCRP Grand Challenges: (1) Clouds, circulation and climate sensitivity, (2) Changes in cryosphere, (3) Climate extremes, (4) Regional climate information, (5) Regional sea-level rise, and (6) Water availability, plus an additional theme on “biospheric forcings and feedbacks”



Model Evaluation

- **A CMIP benchmarking and evaluation software package** community-tool would produce well-established analyses as soon as model results become available.
- The objective is to enable routine model evaluation and to aid the model development process by providing feedback concerning systematic model errors in the individual models.

Communication

The new distributed nature of CMIP6 requires WGCM and the CMIP Panel to play a strong role in facilitating communication between MIPs, and between the MIPs and the modeling groups.

Next Steps and Time Line

- The overall data preparation will follow procedures developed in CMIP5.
- The historical emissions would be made available in spring 2015, and the emissions for the future climate scenarios by the end of 2015.
- Analyses of CMIP6 data would be ongoing, with the simulation phase of CMIP6 running for five years, from 2015 to 2020, followed by many more years of model analysis.
- The runs for the ScenarioMIP would probably occur near the end of the CMIP6 cycle, and thus likely begin in 2017 and continue into 2018.
- A possible IPCC AR6 that would likely assess CMIP6 simulations could take place from roughly 2017 to 2020, but when or even whether there will be an AR6 will not be known until 2015 at the earliest. Even without an AR6, CMIP6 will still operate, as previous phases of CMIP have, to provide a set of state-of-the-art global climate model simulations as a resource for the international climate science community.

CMIP6 Timeline

2014

2015

2016

2017

2018

2019

2020

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Diagnostic, Evaluation and Characterization

CMIP
DECK

Model
Version 1

Model
Version 2

Model
Version 3

Model
Version 4

CMIP6
Endorsed
MIPs

MIP1

MIP2

MIP3

MIP1

MIP4

MIP2

Future
projection
runs

Finalize experiment
design (WGCM)

Scenario MIP studies,
MIP matrix, pattern
scaling, scenario pairs

Community input
on CMIP6 design

Formulate scenarios
to be run by AOGCMs
and ESMs

Forcing data:
harmonization,
emissions to
concentrations

Preliminary ESM/AOGCM
runs with new scenarios

Run and analyze scenario simulations from matrix

Possible IPCC AR6

Nominal Simulation Period of CMIP6

CMIP6-Endorsed MIPs: Main Criteria for MIPs & Experiments

The main criteria for MIPs to be endorsed for CMIP6 are

- The MIP addresses at least one of the key science questions of CMIP6;
- The MIP follows CMIP standards in terms of experimental design, data format and documentation;
- A sufficient number of modeling groups have agreed to participate in the MIP;
- The MIP builds on the shared CMIP DECK experiments;
- A commitment to contribute to the creation of the CMIP6 data request and to analyze the data.
- A commitment to identify or contribute possible observations/reanalysis to obs4MIPs/ana4MIPs for model evaluation and improved process understanding.

The additional criterion used to determine whether a particular MIP experiment should qualify for inclusion as part of the CMIP6 suite of simulations is:

- The proposed experiment is of central importance to CMIP6;
- The proposed experiment has been run at least by two modeling groups already;
- The proposed experiment is useful in a multi-model context and to a number of climate researchers.
- A commitment to scientifically analyze, evaluate and exploit the proposed experiment.

Application for CMIP6-Endorsed MIPs

- preferably by mid-September -

** Preliminary information used to determine whether a MIP should be endorsed for CMIP6 or not.*

- Name of MIP*
- Co-chairs of MIP (including email-addresses)*
- Members of the Scientific Steering Committee*
- Link to website (if available)*
- Goal of the MIP and a brief overview*
- References (if available)*
- An overview of the proposed experiments*
- An overview of the proposed evaluation/analysis of the CMIP DECK and CMIP6 experiments*
- Proposed timing*

Template for applications available at CMIP Panel website

<http://www.wcrp-climate.org/index.php/modelling-wgcm-mip-catalogue/modelling-wgcm-cmip6-endorsed-mips>

Application for CMIP6-Endorsed MIPs

- preferably by mid-September -

*** Information that must be provided later (and before the panel can determine which experiments, if any, will be incorporated in the official CMIP6 suite).*

For each proposed experiment to be included in CMIP6**

- the experimental design;
- the science question and/or gap being addressed with this experiment;
- possible synergies with other MIPs;
- potential benefits of the experiment to (A) climate modeling community, (B) Integrated Assessment Modelling (IAM) community, (C) Impacts Adaptation and Vulnerability (IAV) community, and (D) policy makers.
- If possible, a prioritization of the suggested experiments, including any rationale**
- All model output archived by CMIP6-Endorsed MIPs is expected to be made available under the same terms as CMIP output. Most modeling groups currently release their CMIP data for unrestricted use. If you object to open access to the output from your experiments, please explain the rationale.**

Application for CMIP6-Endorsed MIPs

- Contributions to CMIP6 Data Request -

List of output and process diagnostics for the CMIP DECK/CMIP6 data request**

- whether the variable should be collected for all CMIP6 experiments, or only some specified subset and whether the output is needed from the entire length of each experiment or some shorter period or periods;
- whether the output might only be relevant if certain components or diagnostic tools are used interactively (e.g. interactive carbon cycle or atmospheric chemistry, or only if the COSP simulator has been installed);
- whether this variable is of interest to downstream users (such as impacts researchers, WG2 users) or whether its principal purpose is for understanding and analysis of the climate system itself. Be as specific as possible in identifying why the variable is needed.
- whether the variables can be regridded to a common grid, or whether there is essential information that would be compromised by doing this;
- the relative importance of the various variables requested (indicated by a tiered listing) is required if the data request is large.

Application for CMIP6-Endorsed MIPs

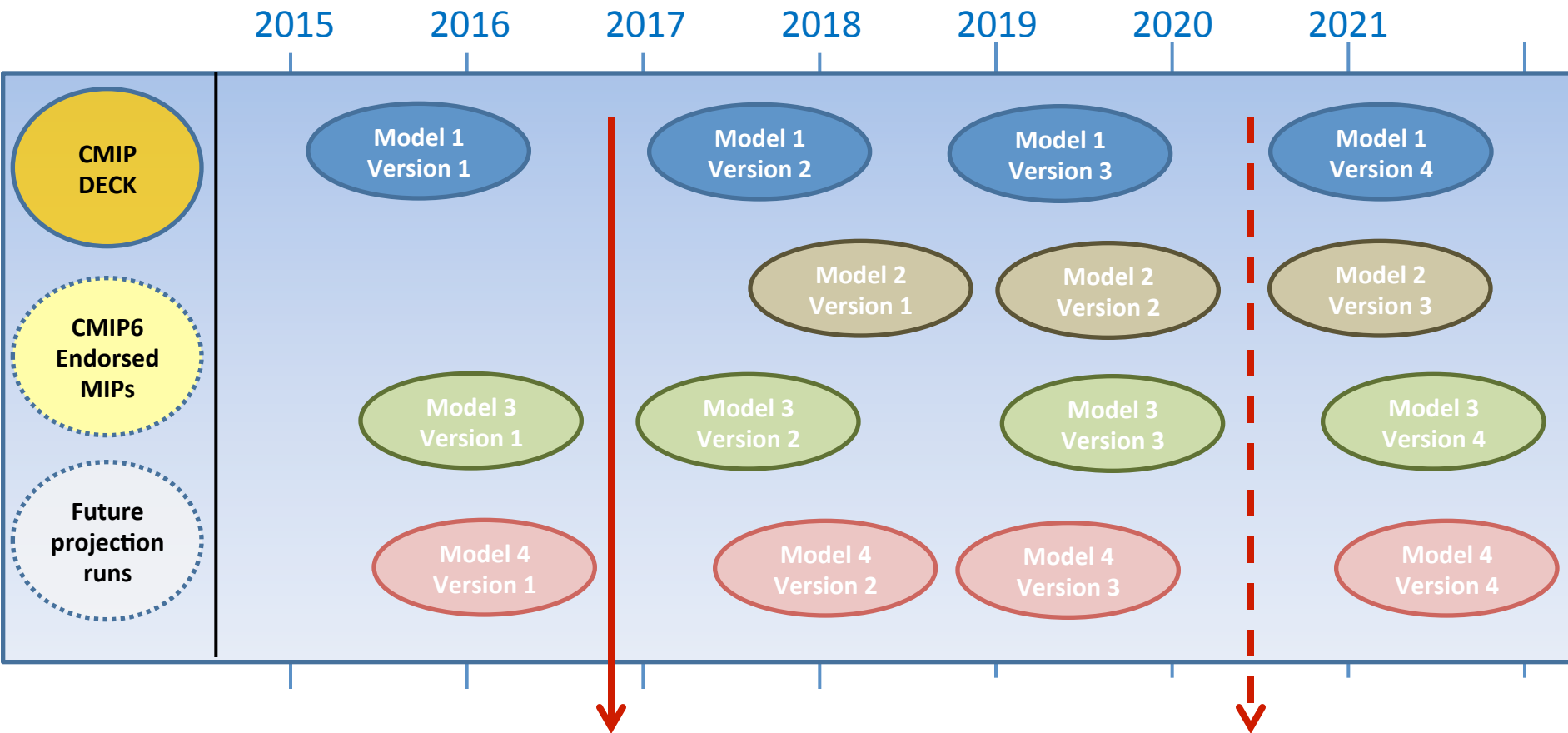
- Contributions to Model Benchmarking and Evaluation -

Any proposed contributions and recommendations for**

- model diagnostics and performance metrics for model evaluation;
- observations/reanalysis data products that could be used to evaluate the proposed experiments. Indicate whether these are available in the obs4MIPs/ana4MIPs database or if there are plans to include them;
- tools, code or scripts for model benchmarking and evaluation in open source languages (e.g., python, NCL, R).

Routine Benchmarking and Evaluation of CMIP DECK Simulations

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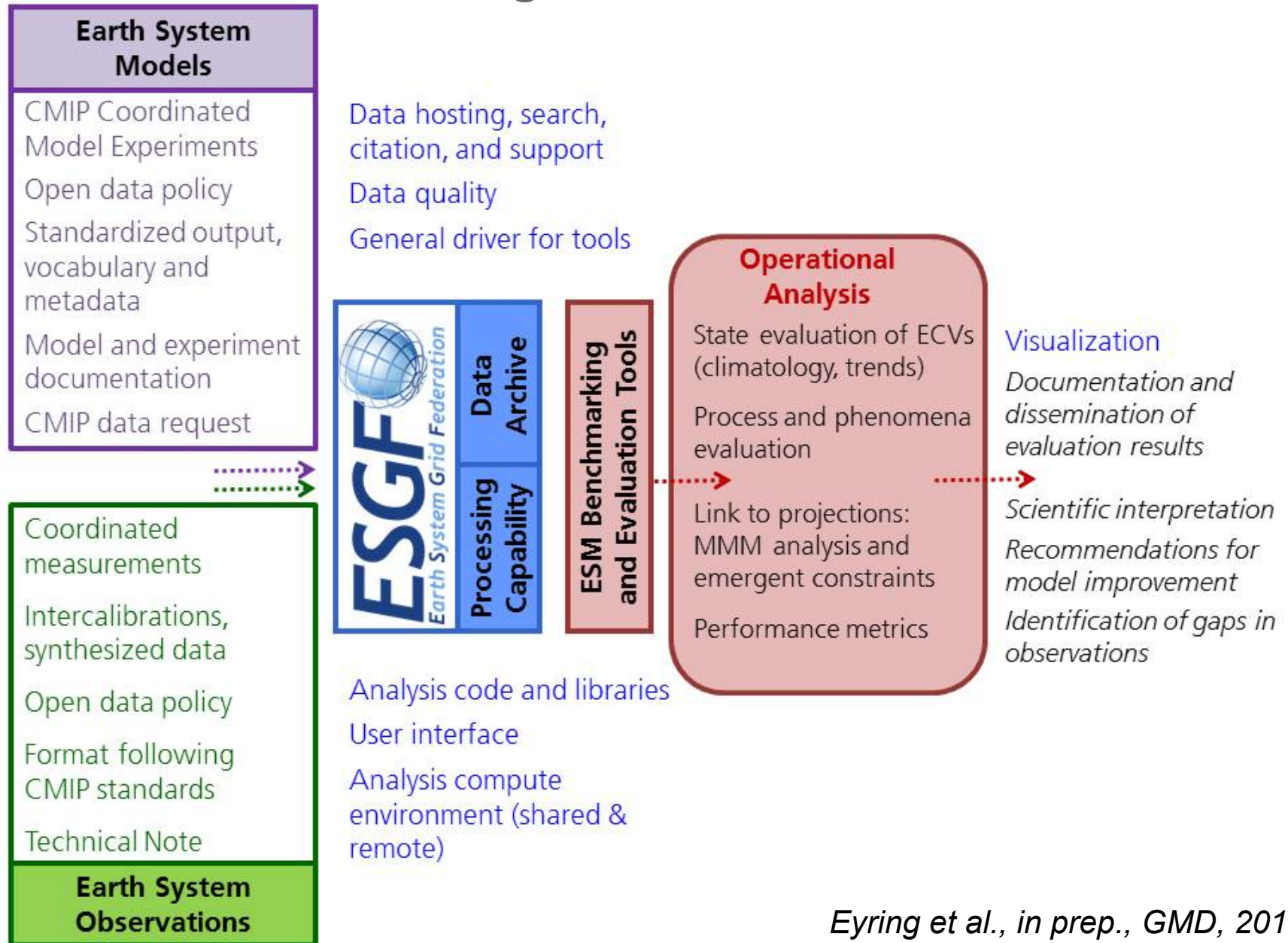
Higher-Order Characteristics of Models: State & Process Evaluation of ESMs at any given time

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Documentation of Progress over Time

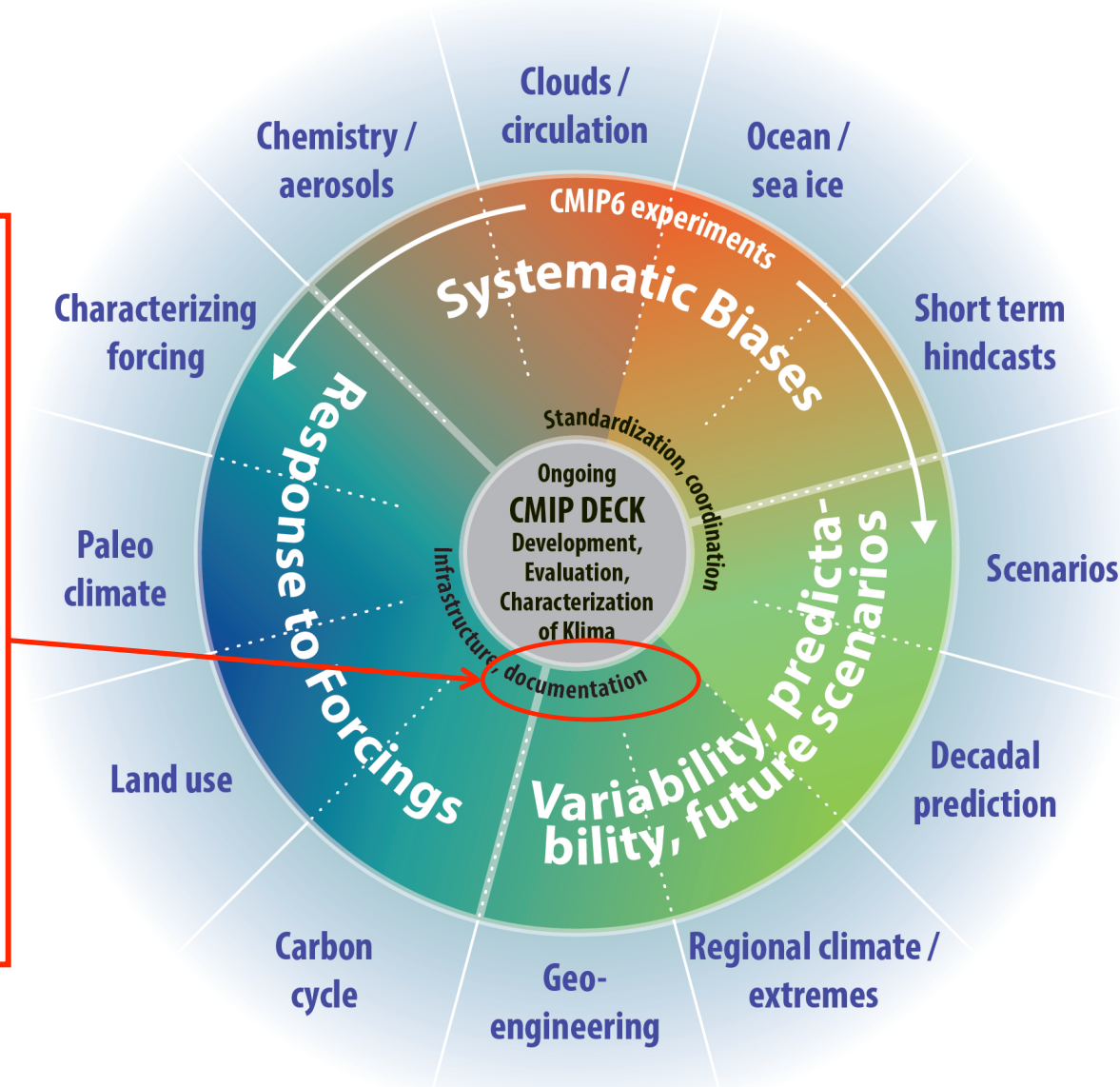
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Infrastructural Needs for Improved Earth System Model Benchmarking and Evaluation in CMIP6



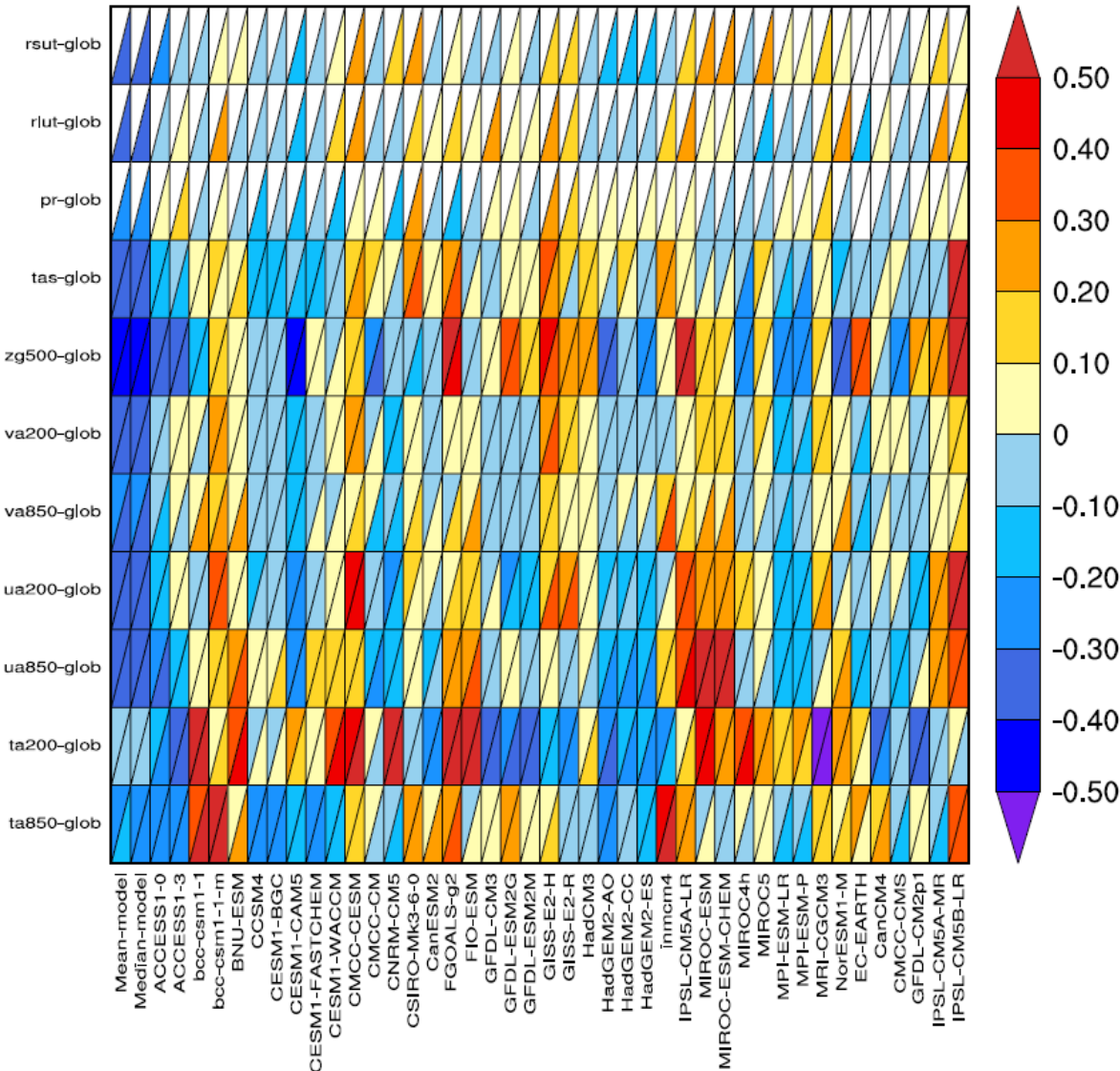
WCRP Grand Challenges: (1) Clouds, circulation and climate sensitivity, (2) Changes in cryosphere, (3) Climate extremes, (4) Regional climate information, (5) Regional sea-level rise, and (6) Water availability, plus an additional theme on “biospheric forcings and feedbacks”

Goal: Community-Developed ESM Benchmarking and Evaluation Tool as one of the CMIP documentation functions to routinely assess the performance of CMIP DECK and CMIP6 simulations running alongside the ESGF



Performance Metrics in ESMValTool

LEVEL 1 Top-Down Evaluation: State Evaluation of ECVs (e.g. Performance Metrics)

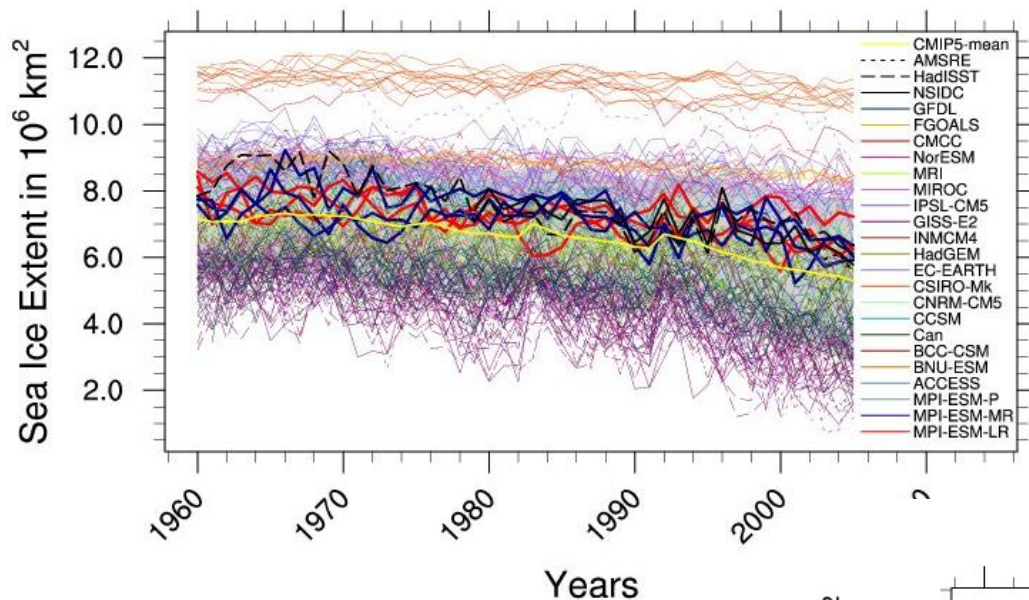


- Metrics facilitate assessing the strengths and weaknesses of different models
- Can be very useful to climate modelers as sanity checks during model development
- Sometimes controversial but acceptance in climate community is growing

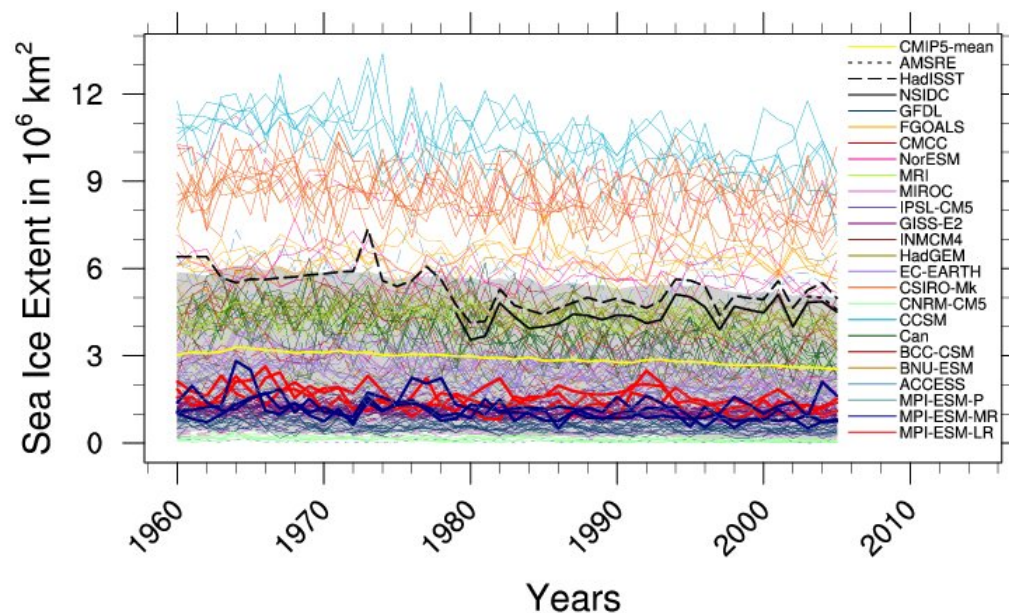
Examples of diagnostics implemented in the ESMValTool

LEVEL 1 Top-Down Evaluation: State Evaluation of ECVs (e.g. Sea-Ice Extent)

September Mean Arctic Sea Ice Extent



March Mean Antarctic Sea Ice Extent

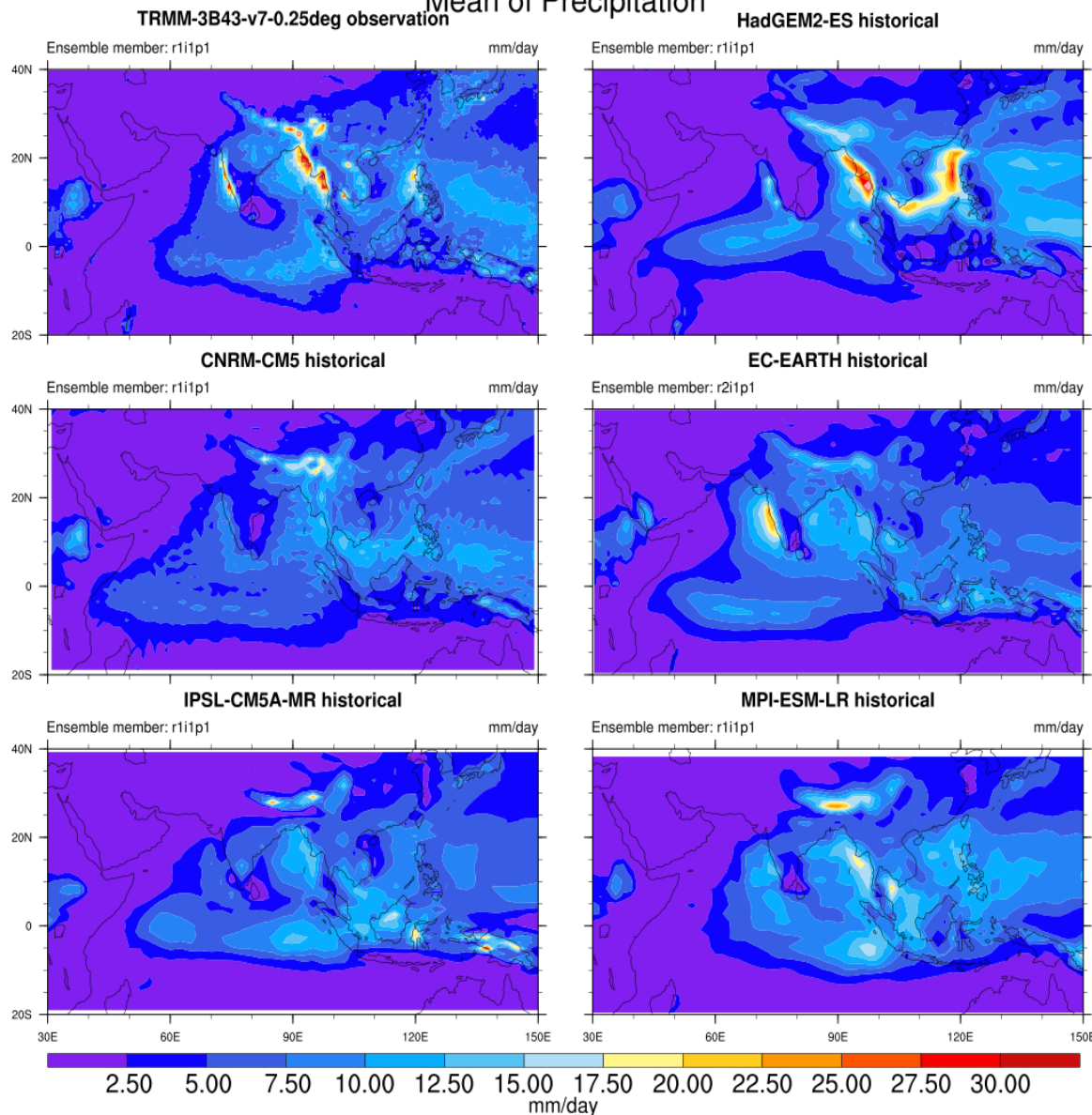


Similar to **Figure 9.24** of AR5

Examples of diagnostics implemented in the ESMValTool

LEVEL 2 Bottom-Up: Process and Phenomena Evaluation (e.g. Tropical variability)

Mean of Precipitation



Implementation of East Asian Monsoon diagnostics

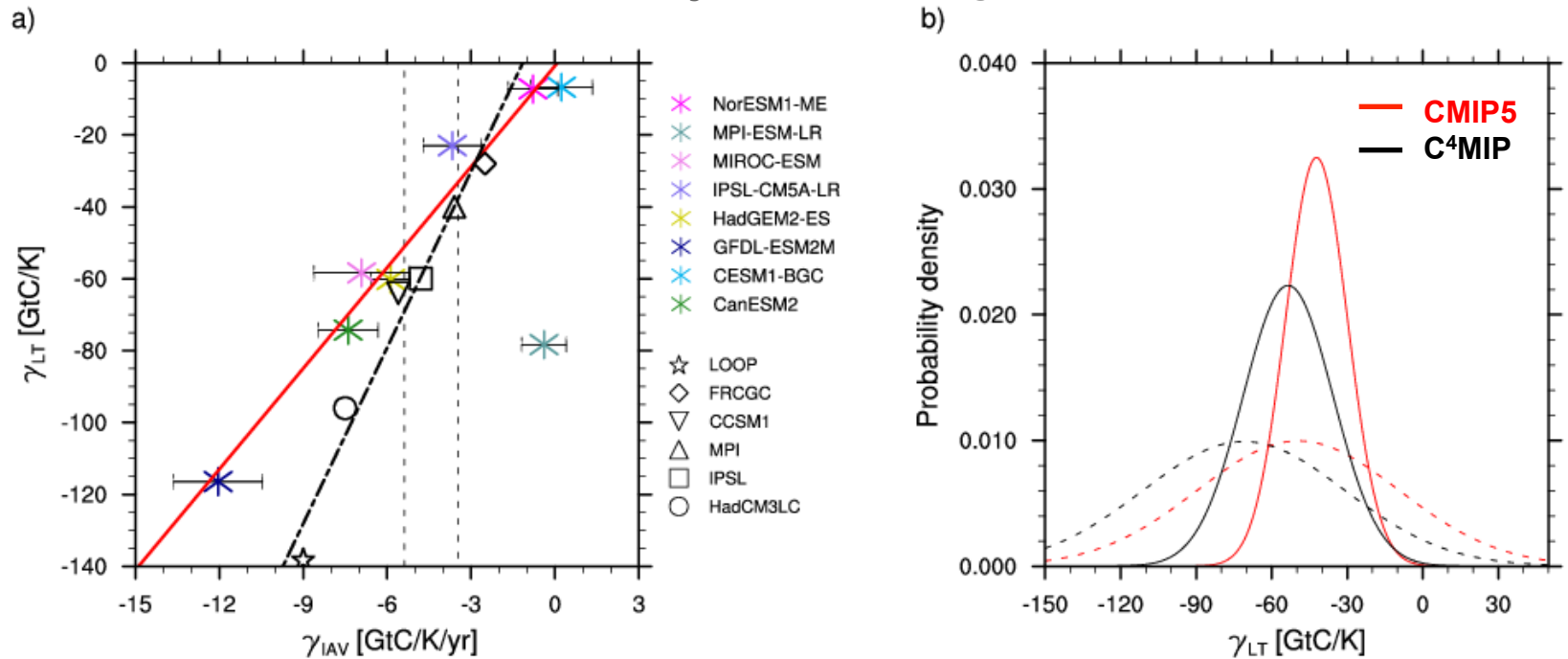
Daily precipitation amount during the monsoon season (June-Sep) for CMIP5 models and satellite observations from TRMM.

- None of the models captures both precipitation maxima along the Indian and the Indochina west coasts.
- The increase in precipitation induced by orographic lifting across the Himalayan mountain range is reproduced by the models.

Set of diagnostics can reproduce Figure 9.32 of AR5: Monsoon precipitation intensity and monsoon precipitation domain.

Examples of diagnostics implemented in the ESMValTool

LEVEL 3 Link to Projections: Emergent Constraints



- A wide spread in tropical land carbon storage is found for the quadrupling of atmospheric CO_2 . Correspondingly, the spread in **long-term sensitivity of tropical land carbon storage to climate warming γ_{LT}** is wide (-49 ± 40 GtC/K) and thus remains one of the key uncertainties in climate projections.
- An emergent linear relationship between γ_{LT} and the **short-term sensitivity of atmospheric CO_2 to interannual temperature variability (γ_{IAV})** has been found.
- Observed γ_{IAV} (-4.9 ± 0.9 GtC/yr/K) sharpens the range of γ_{LT} to -44 ± 14 GtC/K.

Similar to **Figure 9.45b** of AR5

Wenzel et al. (2014), Cox et al. (2013)

Recommendations for this meeting

1. **Identify our contributions to the CMIP6 Science Questions in each MIP**
 - Systematic biases
 - Response to forcings
 - Variability, predictability and future scenarios
2. **Prepare Applications as CMIP6 Endorsed MIPs**
 - **As a minimum the information marked with *:**
 - An overview of the proposed experiments
 - An overview of the proposed evaluation/analysis of the CMIP DECK and CMIP6 experiments
 - Proposed timing
 - **If possible any additional information marked with **, e.g.:**
 - Details on proposed experiments
 - Contributions to the CMIP6 data request
 - Contributions to improved model benchmarking and evaluation of the CMIP6 models
3. **Specifically for AerChemMIP (and LUMIP?): Contribution to CMIP6 theme of collaboration on biospheric forcings and feedbacks, September 2014**
4. **Specifically for ScenarioMIP: A small set of projections to be run by ESMs**