

Coupled Model Intercomparison Project Phase 6 (CMIP6): Experimental Design and Organization

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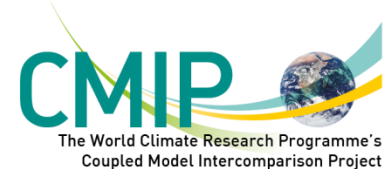
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24 November 2015

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



Knowledge for Tomorrow

CMIP: Understanding past, present and future climate

- CMIP is a project of the World Climate Research Programme (WCRP)'s Working Group of Coupled Modelling (WGCM)
- Since 1995, **CMIP** has coordinated climate model experiments involving multiple international modeling teams worldwide.
- 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 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 early for the **sixth phase of the project (CMIP6)**.
- CMIP's central goal is to advance scientific understanding of the Earth system.
- CMIP model simulations have also been regularly assessed as part of the IPCC Climate Assessments Reports and various national assessments.

CMIP6 Organization

- **CMIP Panel** (V. Eyring (chair), J. Meehl, B. Stevens, R. Stouffer, K. Taylor) which is responsible for direct coordination of CMIP and overseeing the whole CMIP process.
- Sub-committee of **WCRP's Working Group of Coupled Modelling** (WGCM, co-chairs S. Bony and C. Senior).
- **WGCM Infrastructure Panel** (WIP, co-chairs V. Balaji & K. Taylor): Establishes standards and policies for sharing climate model output; puts the data request together technically (M. Jukes).

CMIP6 Design

Based on an extensive period (two years) of community consultation

- Summer 2013 CMIP5 survey and Aspen & WGCM/AIMES 2013 meetings
- Initial proposal for the design of CMIP6 (Meehl et al., EOS, 2014).
- Feedback on this initial CMIP6 proposal has been solicited until September 2014.
- The WGCM and the CMIP Panel have then finalized the CMIP6 design at the WGCM 18th session (October 2014, Grainau) in consultation with the model groups and MIP co-chairs.

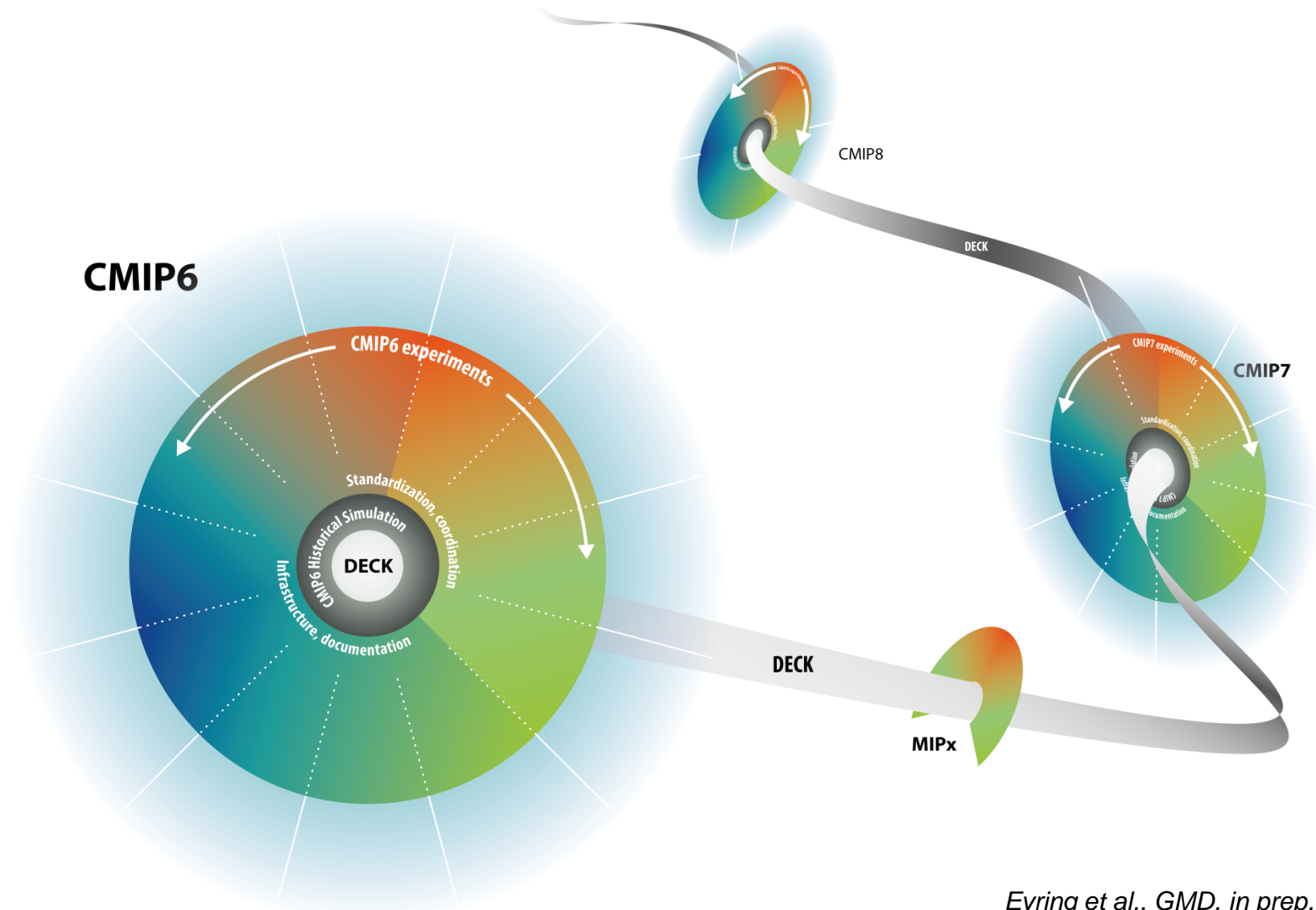


CMIP6 Design: Scientific Focus

- The **scientific backdrop** for CMIP6 is the **WCRP Grand Challenges**:
 1. Clouds, Circulation and Climate Sensitivity
 2. Changes in Cryosphere
 3. Climate Extremes
 4. Regional Sea-level Rise
 5. Water Availability
 6. Decadal Predictability (pending)
 7. Biogeochemical forcings and feedbacks (pending)
- The specific 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 changes given climate variability, predictability and uncertainties in scenarios?

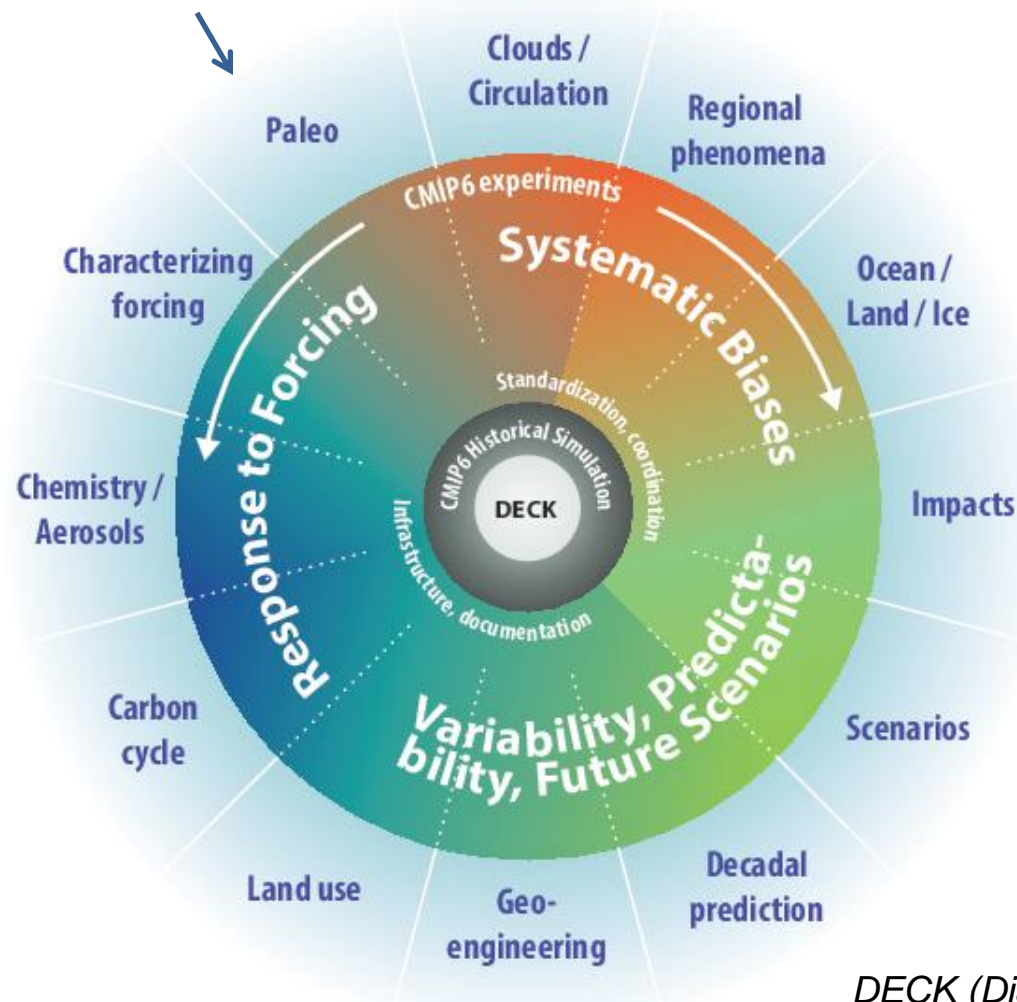
CMIP Continuity

A common suite of experiments for each phase of CMIP provides an opportunity to construct a multi-model ensemble using model output from various phases of CMIP



CMIP: a More Continuous and Distributed Organization

(3) CMIP-Endorsed Model Intercomparison Projects (MIPs)



(1) A handful of common experiments

DECK (entry card for CMIP)

- AMIP simulation (~1979-2014)
- Pre-industrial control simulation
- 1%/yr CO₂ increase
- Abrupt 4xCO₂ run

CMIP6 Historical Simulation (entry card for CMIP6)

- Historical simulation using CMIP6 forcings (1850-2014)

(2) Standardization, coordination, infrastructure, documentation

DECK (Diagnosis, Evaluation, and Characterization of Klima Experiments) & CMIP6 Historical Simulation to be run for each model configuration used in CMIP6-Endorsed MIPs

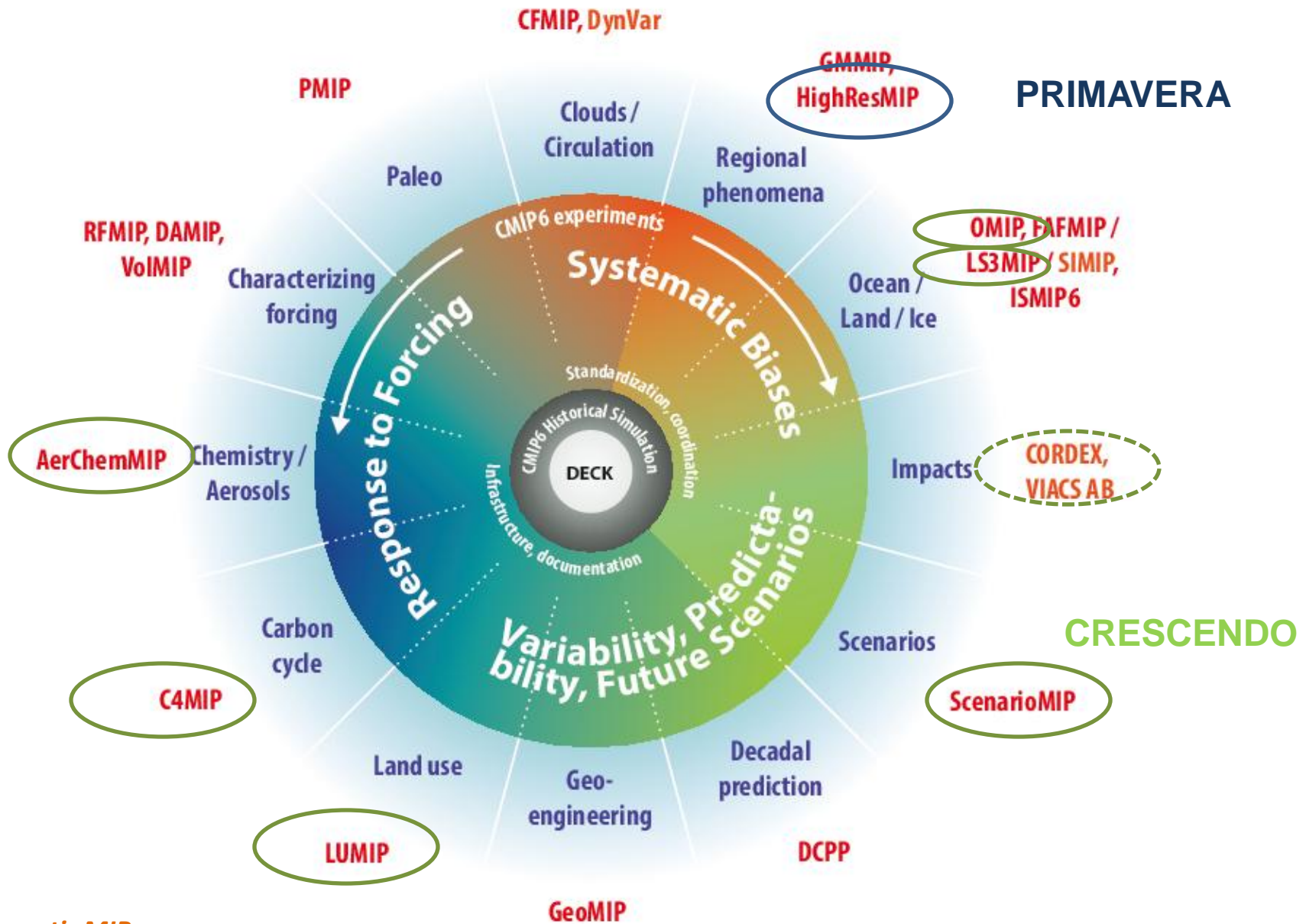
CMIP6-Endorsed MIPs

Main Criteria for Endorsement

1. The MIP and its experiments address at least one of the key science questions of CMIP6.
2. The MIP demonstrates connectivity to the DECK experiments and the CMIP6 Historical Simulation.
3. The MIP adopts the CMIP modeling infrastructure standards and conventions.
4. All experiments are tiered, well-defined, and useful in a multi-model context and don't overlap with other CMIP6 experiments.
5. Unless a Tier 1 experiment differs only slightly from another well-established experiment, it must already have been performed by more than one modeling group.
6. A sufficient number of modelling centers (~8) are committed to performing all of the MIP's Tier 1 experiments and providing all the requested diagnostics needed to answer at least one of its science questions.
7. The MIP presents an analysis plan describing how it will use all proposed experiments, any relevant observations, and specially requested model output to evaluate the models and address its science questions.
8. The MIP has completed the MIP template questionnaire.
9. The MIP contributes a paper on its experimental design to the CMIP6 Special Issue.
10. The MIP considers reporting on the results by co-authoring a paper with the modelling groups.

* For "Diagnostic-MIPs" only non-experimental criteria apply

21 CMIP6-Endorsed MIPs



CMIP6-Endorsed MIPs (mainly addressing forcings)

Some MIPs are developments and/or continuation of long standing science themes within CMIP. These include MIPs specifically addressing science questions related to

1. Cloud feedbacks and the understanding of spatial patterns of circulation and precipitation (**CFMIP**),
2. Carbon cycle feedbacks and the understanding of changes in carbon fluxes and stores (**C4MIP**),
3. Detection and attribution (**DAMIP**) that newly includes 21st-century GHG-only simulations which allowing the projected responses to GHGs and other forcings to be separated and scaled to derive observationally-constrained projections, and
4. Paleoclimate (**PMIP**) that assesses the credibility of the model response to forcing outside the range of recent variability.

These MIPs reflect the importance of **key forcing and feedback processes** in understanding past, present and future climate change and have developed new experiments and science plans focused on emerging new directions that will be at the center of the WCRP Grand Science Challenges.

A few new MIPs have arisen directly from gaps in understanding in CMIP5, for example

5. poor quantification of radiative forcing (**RFMIP**),
6. better understanding of ocean heat uptake and sea-level rise by studying the ocean's response to changes in surface forcing (**FAFMIP**), and
7. understanding of model response to volcanic forcing (**VolMIP**).

CMIP6-Endorsed MIPs (mainly addressing systematic biases)

Since CMIP5, other MIPs have emerged as the modelling community has developed more complex Earth system models with interactive components beyond the carbon cycle:

8. the consistent quantification of forcings and feedbacks from aerosols and atmospheric chemistry (**AerChemMIP**),
9. for the first time in CMIP modelling of sea-level rise from land-ice sheets (**ISMIP6**).

Some MIPs specifically target systematic biases focusing on

10. improved understanding of the sea-ice state and its atmospheric and oceanic forcing (**SIMIP**),
11. the physical and biogeochemical aspects of the ocean (**OMIP**),
12. land, snow and soil moisture processes (**LS3MIP**), and
13. improved understanding of circulation and variability with a focus on stratosphere-troposphere coupling as diagnostic MIP (**DynVar**).

With the increased emphasis in the climate science community on the need to represent and understand changes in regional circulation, systematic biases are also addressed on a more regional scale by

14. the Global Monsoon MIP (**GMMIP**) and
15. a first coordinated activity on high resolution modelling (**HighResMIP**).

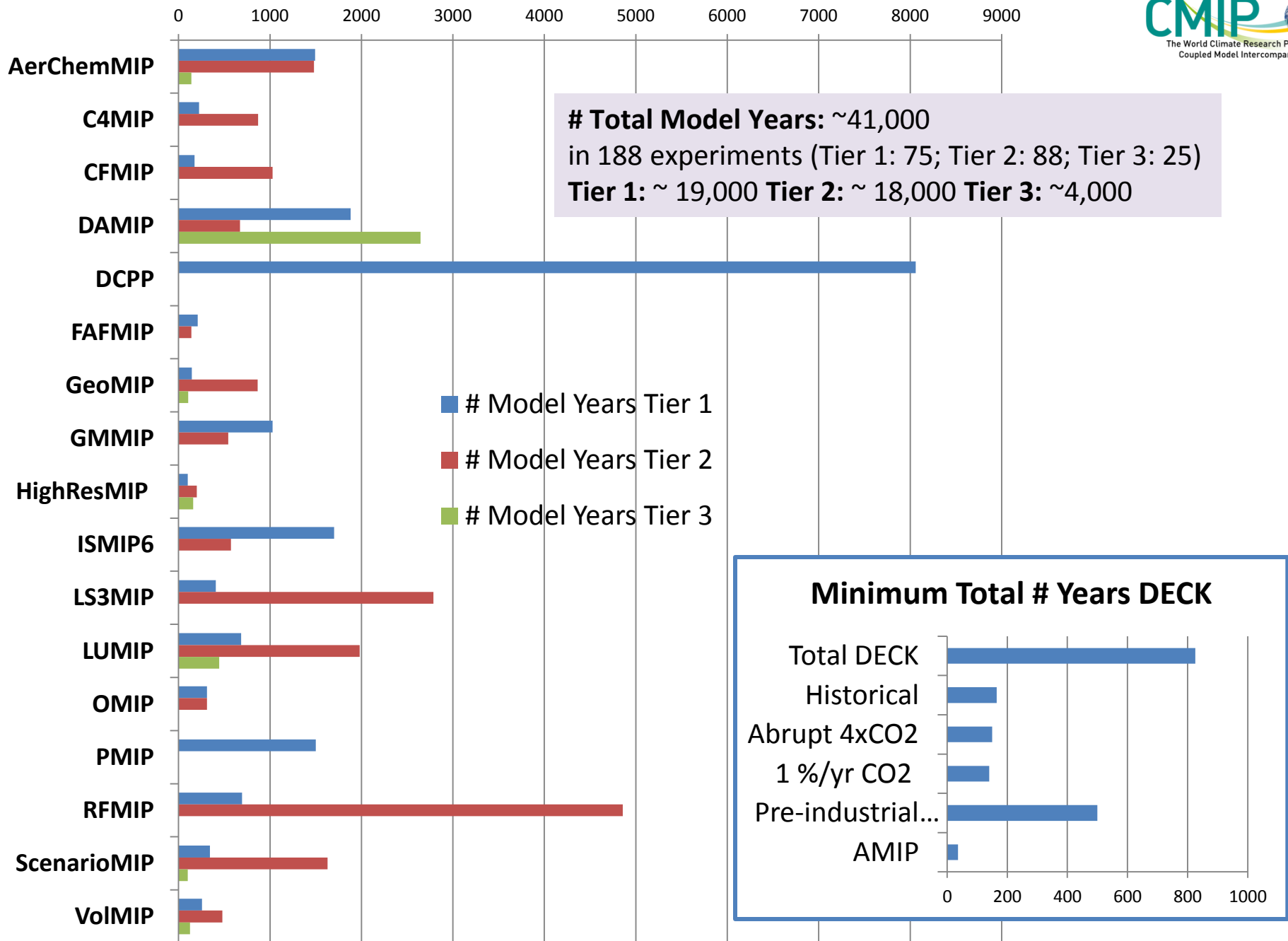
CMIP6-Endorsed MIPs (mainly addressing future projections)

For the first time future scenario experiments, previously coordinated centrally as part of the CMIP5 'core' experiments will be run as MIPs ensuring well-coordinated science questions

16. **ScenarioMIP** will run a new set of future long-term (century time scale) integrations. The new scenarios span the same range as the RCPs, but fill critical gaps for intermediate forcing levels and questions for example on short-lived species and land-use.
17. The near-term experiments (10–30 years) will be coordinated by the decadal climate prediction project (**DCPP**) with improvements expected for example from the initialization of additional components beyond the ocean.

Other MIPs include specific future mitigation options, e.g.

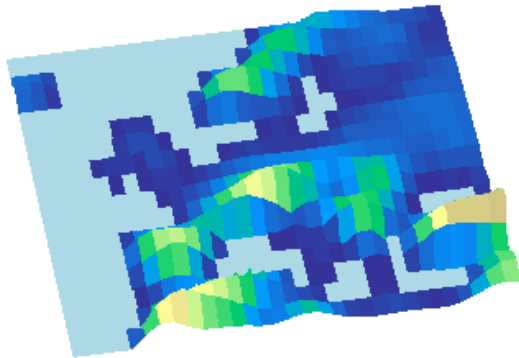
18. the land use MIP (**LUMIP**) looking at regional land management strategies to study how different surface types respond to climate change and direct anthropogenic modifications,
19. the geoengineering MIP (**GeoMIP**) that examines climate impacts of newly proposed radiation modification geoengineering strategies.
20. **CORDEX** will oversee the downscaling of CMIP6 models for regional climate projections.
21. For the first time in CMIP, a more formal communication between the climate modelling and user community is established through the vulnerability, impacts and adaptation and climate services advisory board (**VIACS AB**).



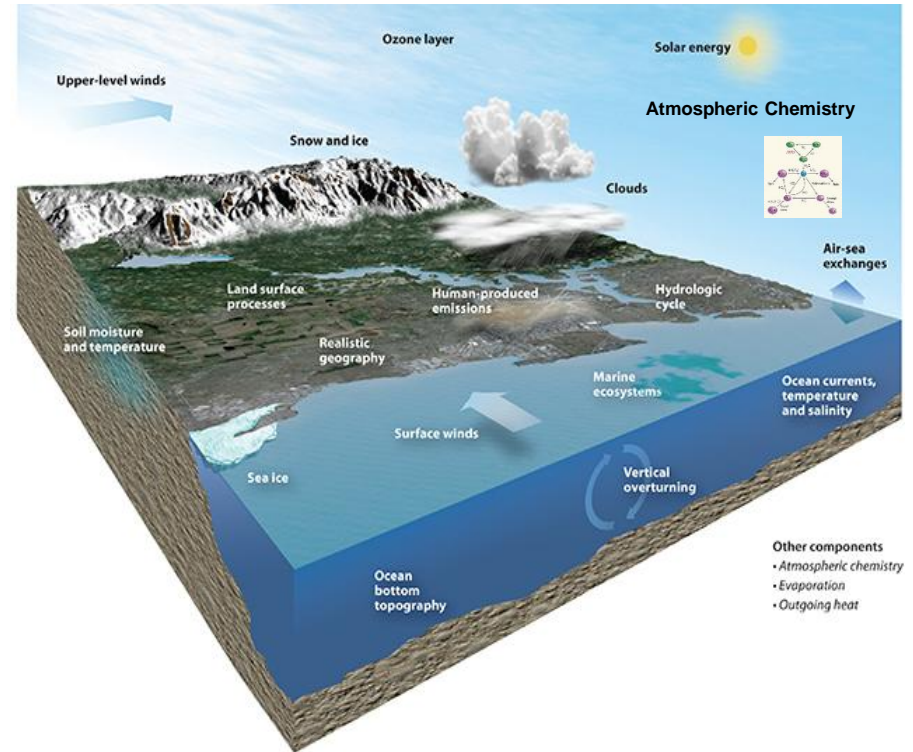
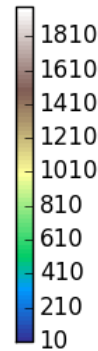
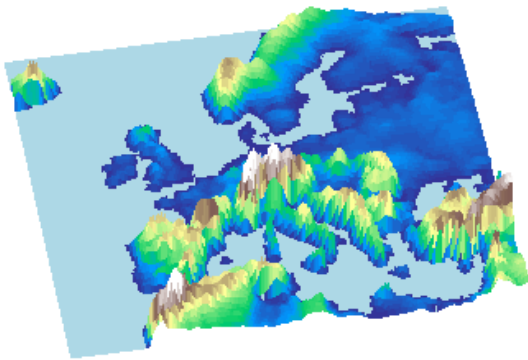
Models are increasing in complexity and resolution

- From AOGCMs to Earth System Models with biogeochemical cycles -

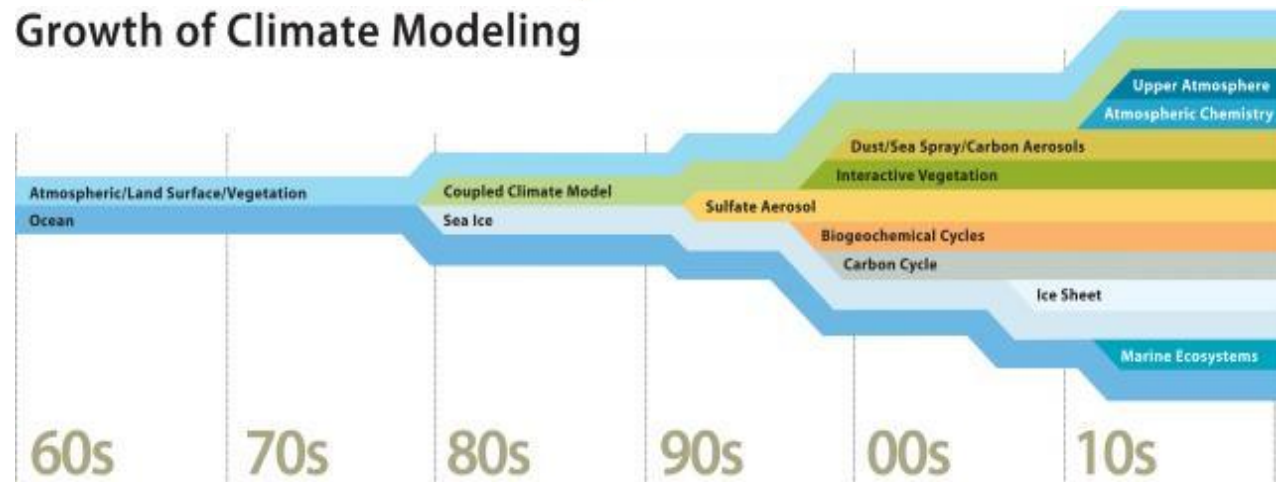
130 km resolution orography



25 km resolution orography



Growth of Climate Modeling



Many groups showed with individual experiments & models:

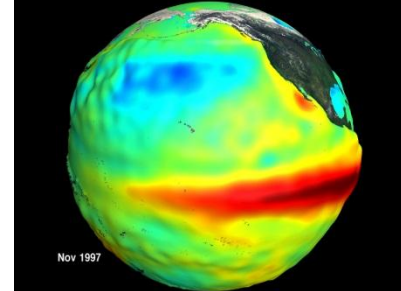
- E.g., significant improvement in the simulation of the large scale circulation (e.g., ENSO, extra-tropical cyclones, storm tracks, blocking) emerge at sub-50 km resolution
- They contribute significantly to both large-scale circulation and local impacts, hence vital for understanding and constraining **regional variability**.

Goal of HighResMIP:

- To investigate the robustness across a multi-model ensemble of changes to the representation of climate processes as model horizontal resolution is increased to “weather-resolving” global model resolutions (**~25km or finer**).
- Emphasis in model error (bias, climate processes and variability) rather than climate sensitivity

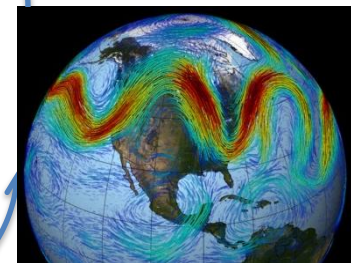
HighResMIP experiments:

- Tier 1: AMIP 1950-2014
- Tier 2: Coupled runs of pairs of both scenario (historic for the past) runs and, for comparison, control runs using fixed 1950s forcings (1950-2050).

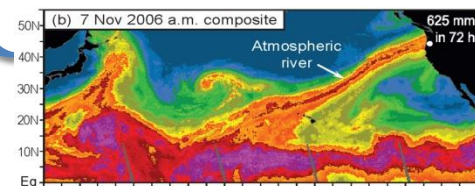


Global drivers

Regional variability



Feedbacks to large scale



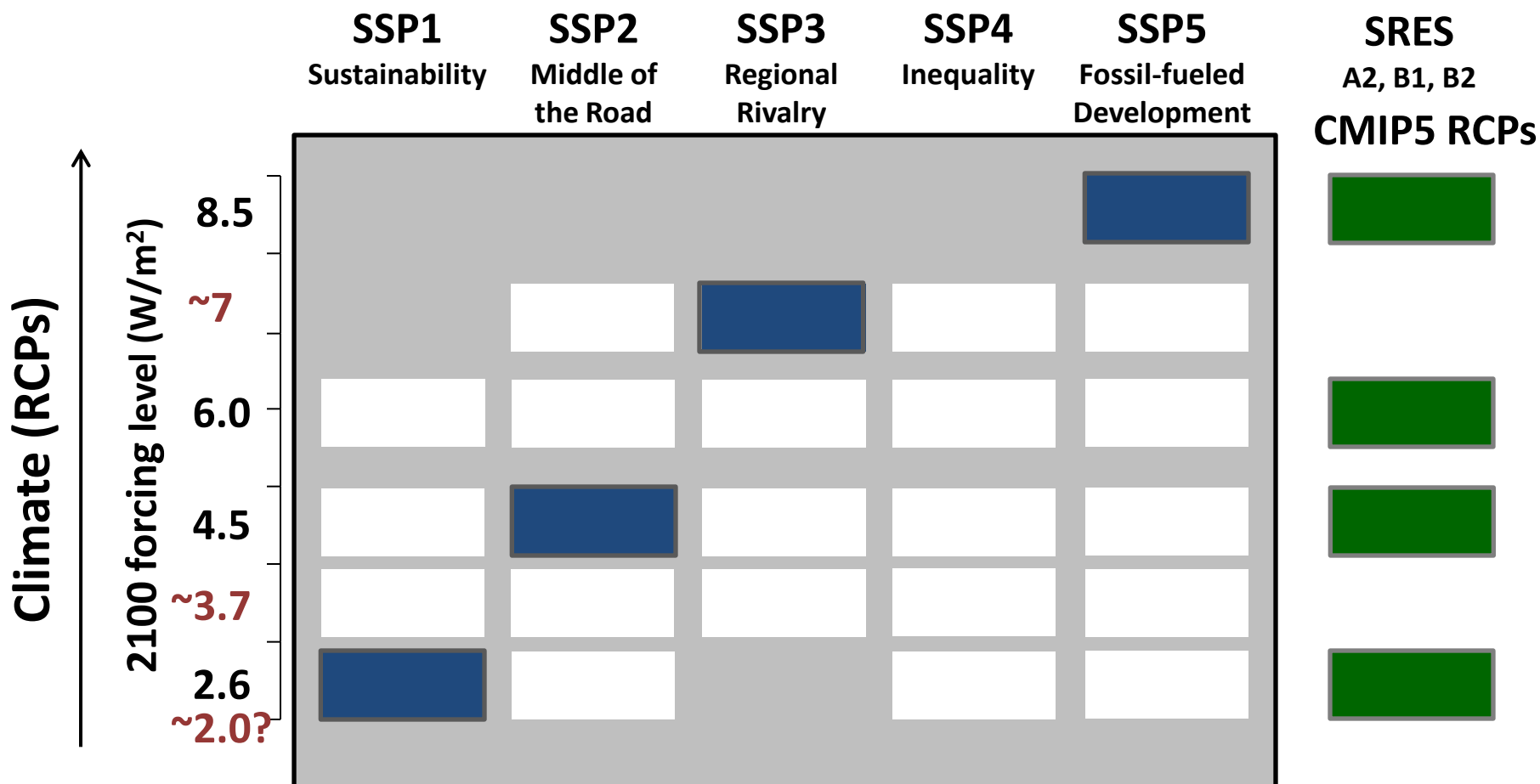
Local processes

Impacts, extremes



ScenarioMIP Design

Shared Socioeconomic Pathways

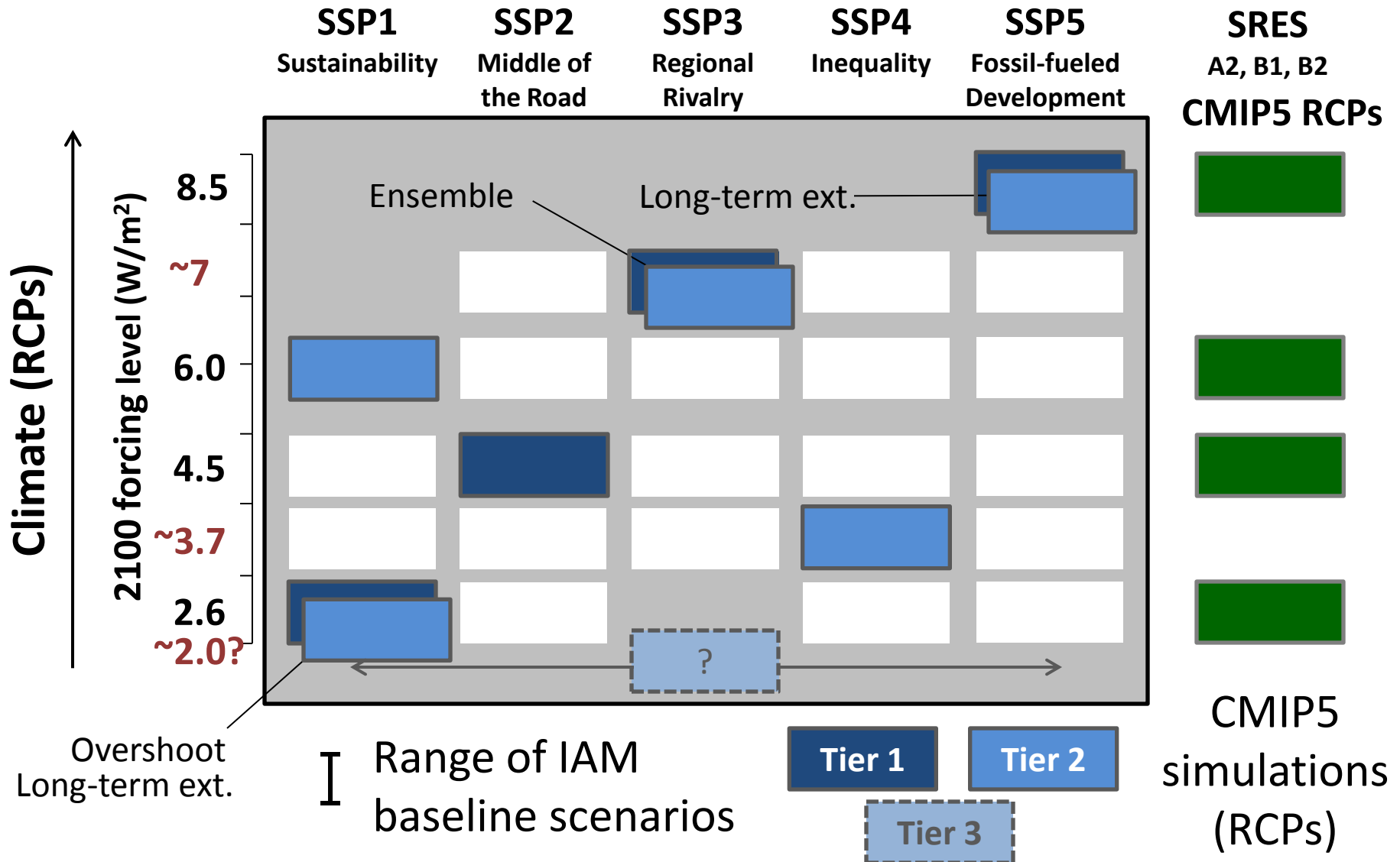


Tier 1: Continuing the CMIP6 Historical Simulation (1850-2014) into the future (2015 – 2100)

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

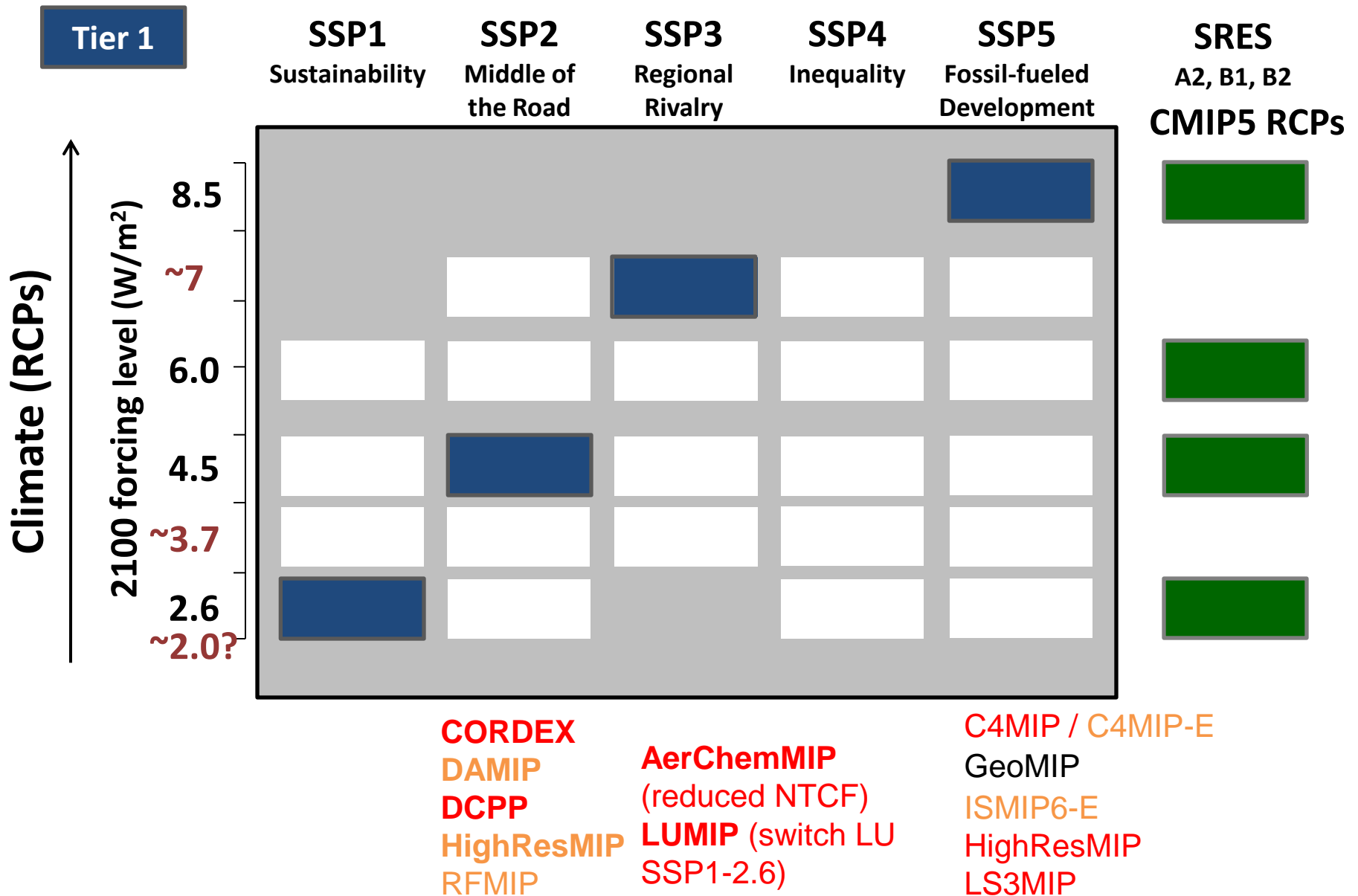
ScenarioMIP Design

Shared Socioeconomic Pathways



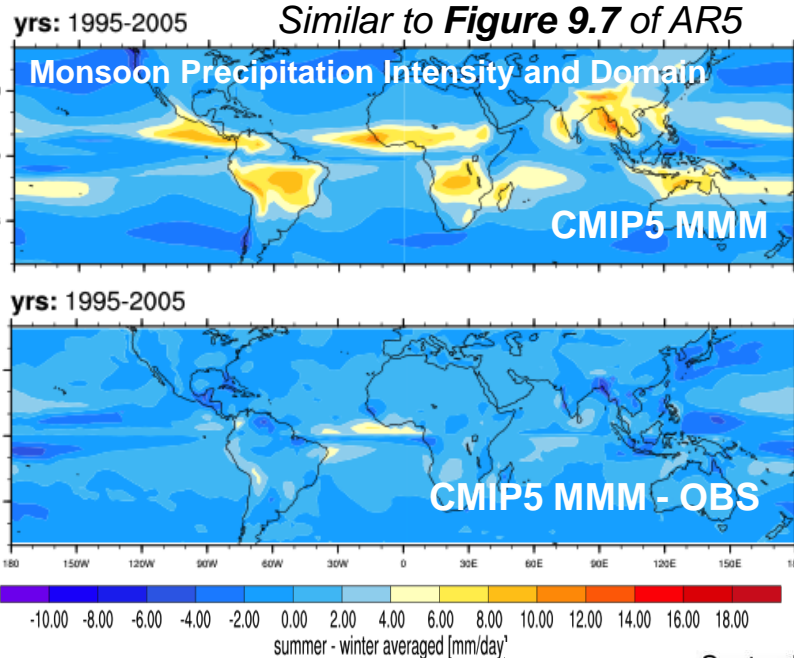
ScenarioMIP Design

Shared Socioeconomic Pathways



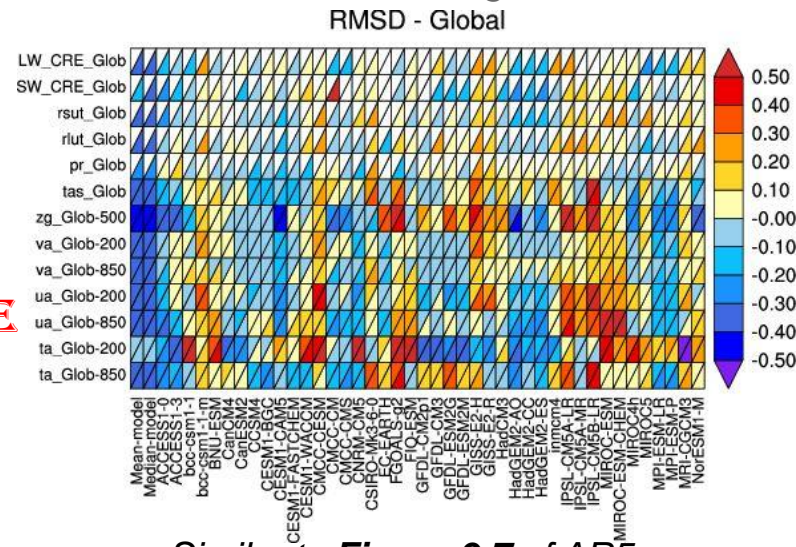
Routine Benchmarking and Evaluation Central Part of CMIP6

CMIP evaluation tool to produce well-established analyses as soon as model output becomes available
e.g., Community-developed ESMValTool (Eyring et al., GMDD, 2015) and PCMDI metrics package (Gleckler et al., EOS, in press) - *Link to WGNE/WGCM Climate Model Metrics and Diagnostic Panel*



**RUNNING
ALONG-SIDE
THE ESGF**

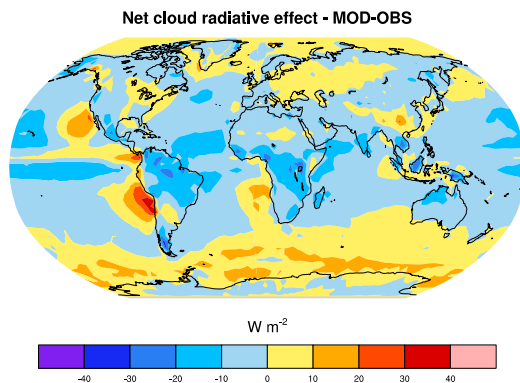
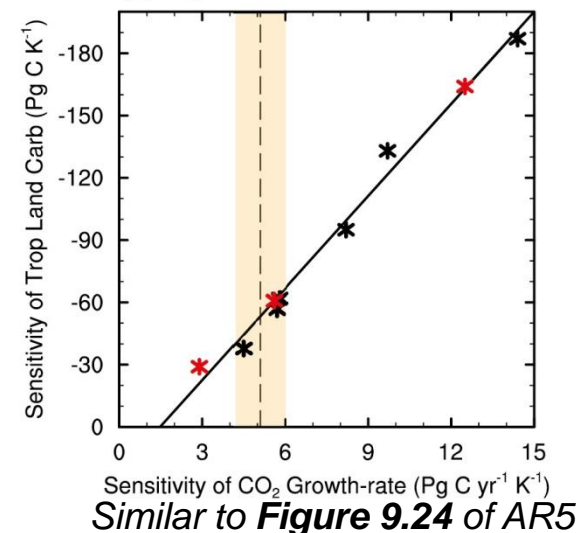
**AR5
CHAPTER 9**



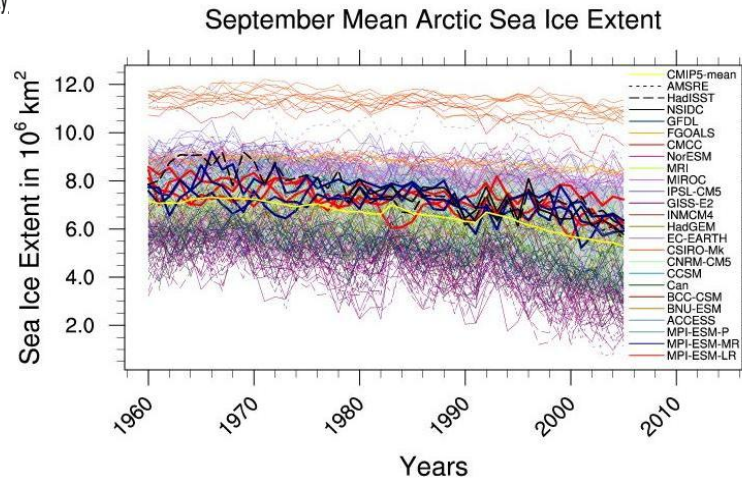
Similar to **Figure 9.7** of AR5

LINK TO PROJECTIONS

(b) Tropical Land carbon feedback



Similar to **Figure 9.5** of AR5



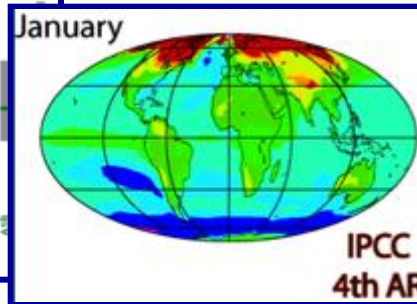
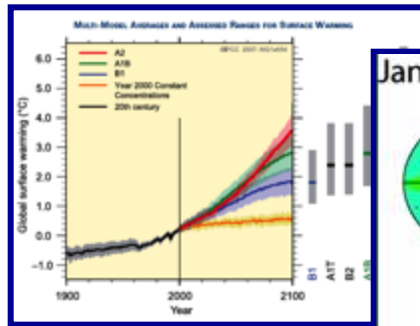
Similar to **Figure 9.24** of AR5

Under-Exploited Observations for Model Evaluation

Observations for Model Intercomparison Projects (obs4MIPs)

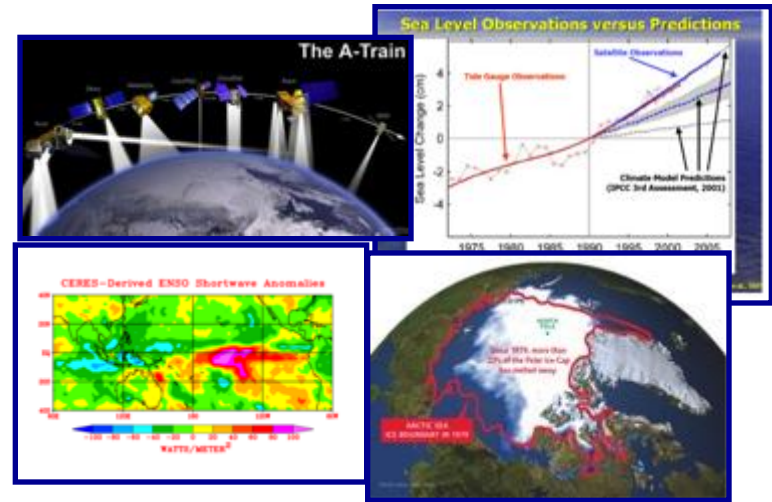
WDAC Task Team on Observations for Model Evaluation

CMIP6



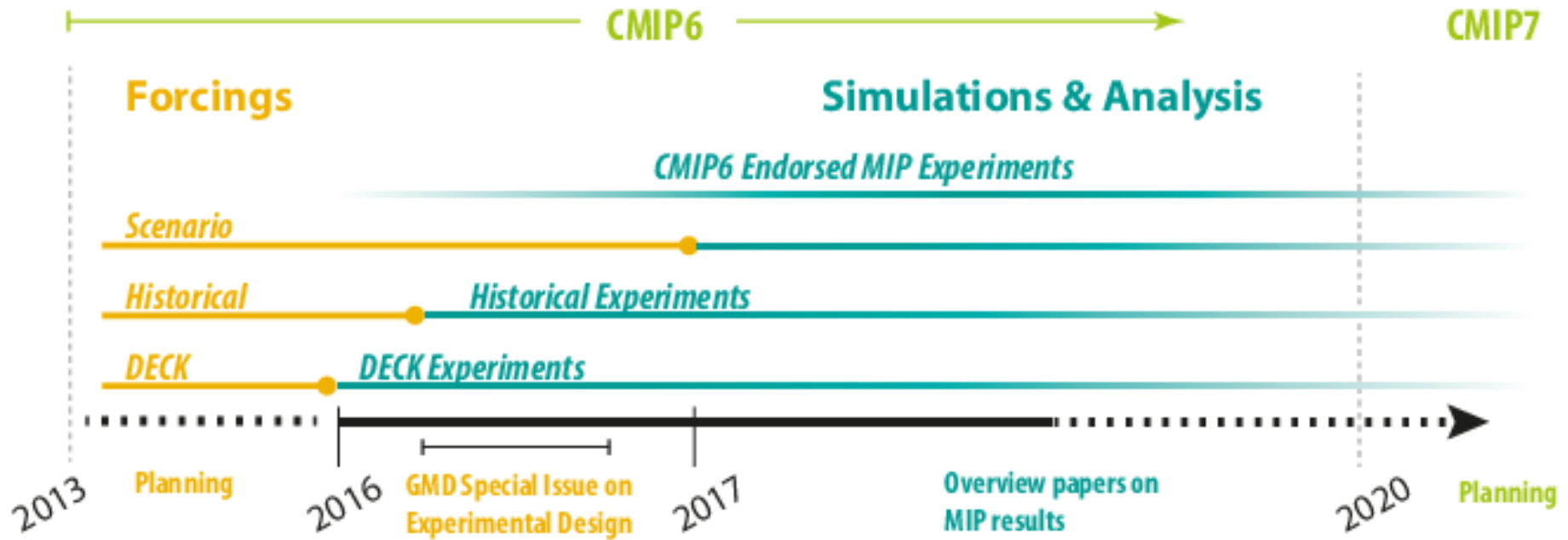
How to bring as much observational scrutiny as possible to the CMIP/IPCC process?

- Obs4MIPs has defined a set of technical specifications and criteria for developing observational data sets that are technically aligned with CMIP model output (with common file format, data and metadata structure).
- Over 50 datasets that conform to these standards are now archived on the ESGF alongside CMIP model output ([Teixeira et al., 2014](#)), including ESA CCI data
- Data users have enthusiastically received Obs4MIPs



How to best utilize the wealth of satellite observations for the CMIP/IPCC process?

CMIP6 Timeline



Status and Outlook

CMIP6 Status

- CMIP6 Organization and Design finalized
- CMIP6 MIP endorsement of April 2015 proposals finalized
- Timelines in place for forcing datasets
- CMIP6 Simulation Period (2016-2020)
- Infrastructure in preparation (including data request) by WGCM Infrastructure Panel (WIP)

CMIP6 Participating Model Groups: > 30 using a hierarchy of models

CMIP6 Scenarios

- New scenarios span the same range as the RCPs, but fill critical gaps for intermediate forcing levels and questions for example on short-lived species and land-use.

A central goal of CMIP6 is routine evaluation of the models with observations

- Coordinated by the WGNE / WGCM climate diagnostics and metrics panel in collaboration with the CMIP Panel

Workshops/meetings

- 18-20 October 2015: WGCM-19 (Dubrovnik, Croatia)
- 20-23 October 2015: WCRP/FP7 EMBRACE Workshop on CMIP5 Model Analysis and Scientific Plans for CMIP6 (Dubrovnik, Croatia)

Geosci. Model Dev. Special Issue on CMIP6 (July 2015 - December 2016)

- Overview of the CMIP6 Design and Organization (Eyring et al., in prep, GMD, 2015)
- Experimental design from all CMIP6-Endorsed MIPs (submission by 31 March 2016)
- Description of the CMIP6 forcing data
- Description of evaluation procedures (including obs4MIPs) and Infrastructure

CMIP6 Special Issue in GMD

1	CMIP6 Experimental Design & Organisation	Overview
2	AerChemMIP	CMIP6-Endorsed MIP
3	C ⁴ MIP	CMIP6-Endorsed MIP
4	CFMIP	CMIP6-Endorsed MIP
5	DAMIP	CMIP6-Endorsed MIP
6	DCPP	CMIP6-Endorsed MIP
7	FAFMIP	CMIP6-Endorsed MIP
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15	PMIP	CMIP6-Endorsed MIP
16	RFMIP	CMIP6-Endorsed MIP
17	ScenarioMIP	CMIP6-Endorsed MIP
18	VoIMIP	CMIP6-Endorsed MIP
19	CORDEX*	CMIP6-Endorsed MIP
20	DynVar*	CMIP6-Endorsed MIP
21	SIMIP*	CMIP6-Endorsed MIP
22	VIACS AB*	CMIP6-Endorsed MIP
23	Historical SLCF and GHG Emissions	Forcings DECK and Historical Simulation
24	Global Gridded Land-use Forcing Datasets	Forcings DECK and Historical Simulation
25	Historical GHG concentrations	Forcings DECK and Historical Simulation
26	Ozone and Stratospheric Water Vapor Concentrations	Forcings DECK and Historical Simulation
27	Aerosol Concentrations	Forcings DECK and Historical Simulation
28	Solar forcing	Forcings DECK and Historical Simulation
29	Stratospheric Aerosol Data Set	Forcings DECK and Historical Simulation
30	Future Emissions	Forcings DECK and Historical Simulation
31	AMIP SSTs and Sea Ice Datasets	Forcings DECK and Historical Simulation
32	WGCM Infrastructure Panel (WIP)	Infrastructure
33	CMIP6 Data Request	Infrastructure
34	WGNE/WGCM climate model diagnostics and metrics panel	Model Evaluation
35	WDAC Task Team on Observations for Model Evaluation	Model Evaluation