

# Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) Experimental Design and Organization

Veronika Eyring, Greg Flato, Gerald Meehl, Cath Senior, Bjorn Stevens, Ron Stouffer, Karl Taylor (CMIP Panel)

Thanks to Sandrine Bony!



5 April 2017

Please see the CMIP Panel website for additional information and updates:

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

**Contact for questions:** CMIP Panel Chair Veronika Eyring (email: [Veronika.Eyring@dlr.de](mailto:Veronika.Eyring@dlr.de))

## Reference:

Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., and Taylor, K. E.: [Overview of the Coupled Model Intercomparison Project Phase 6 \(CMIP6\) experimental design and organization](#), Geosci. Model Dev., 9, 1937-1958, doi:10.5194/gmd-9-1937-2016, 2016.

# Coupled Model Intercomparison Project (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 in a **multi-model framework**.
- CMIP defines **common experiment protocols, forcings and output**.
- CMIP has developed in phases, with the simulations of the fifth phase, CMIP5, now completed, and the sixth phase, CMIP6, is underway.
- CMIP's central goal is to advance scientific understanding of the Earth system.
- **CMIP is not done for the IPCC, or run by the IPCC**
- CMIP model simulations, constituting the current state-of-the-art of climate science formulated by the climate science community through WCRP, are assessed as part of the IPCC Climate Assessment Reports and various national assessments.

# CMIP6 Organization

- **CMIP Panel** (Veronika Eyring (chair), Gerald Meehl, Cath Senior, Bjorn Stevens, Ron Stouffer, Karl Taylor, Greg Flato) which is responsible for direct coordination of CMIP and overseeing the whole CMIP process.
- **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. Juckes).

## CMIP6 Experimental Design

**Based on an extensive period (three years) of community consultation**

- Summer 2013 CMIP5 survey and Aspen Global Change Institute & WGCM/AIMES 2013 mtgs
- 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 then finalized the CMIP6 design at the WGCM 18<sup>th</sup> session (October 2014, Grainau) in consultation with the model groups and MIP co-chairs.

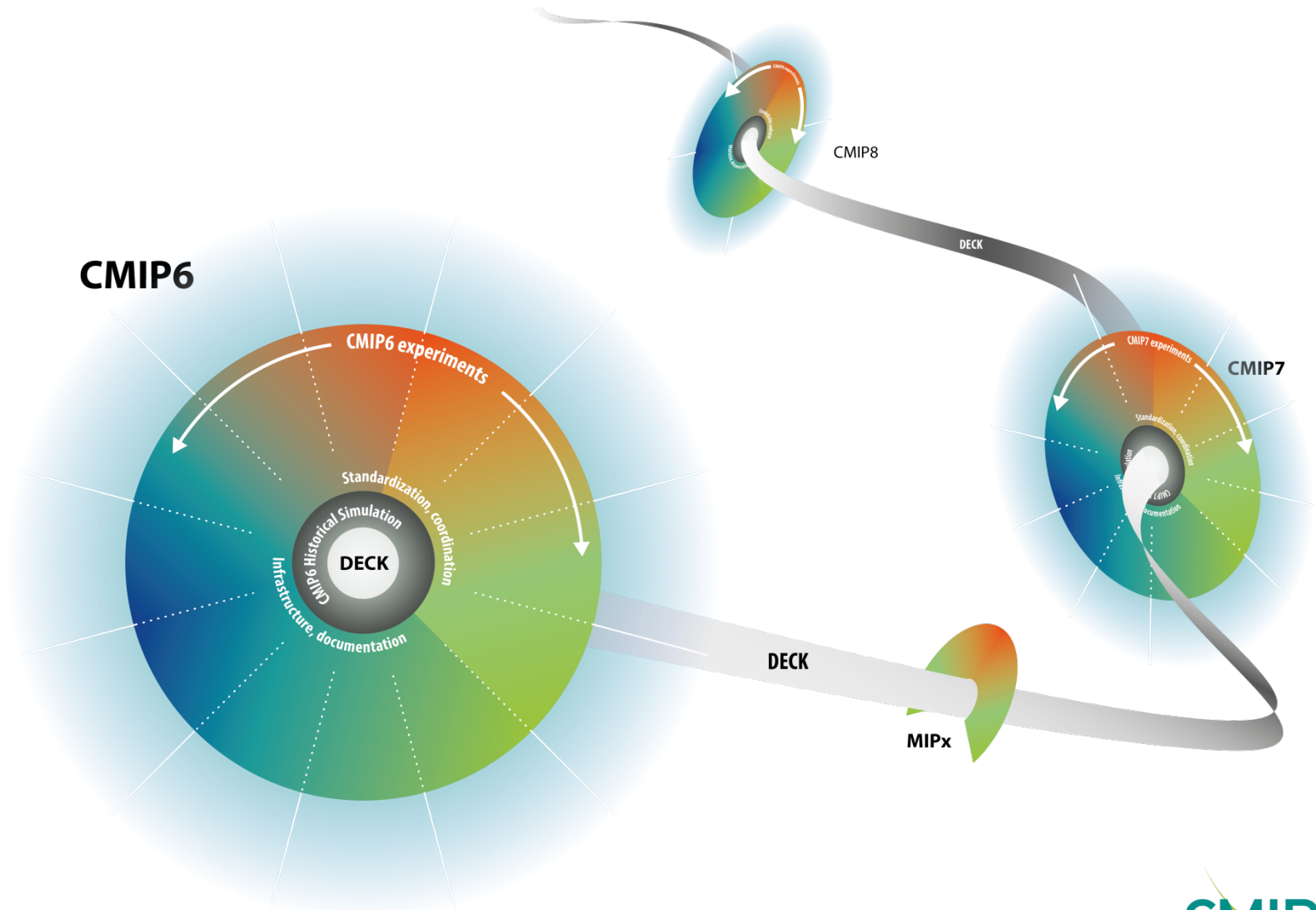


# CMIP6 Design: Scientific Focus

- The **scientific backdrop** for CMIP6 is the **WCRP Grand Science Challenges**:
- [Melting Ice and Global Consequences](#)
- [Clouds, Circulation and Climate Sensitivity](#)
- [Carbon Feedbacks in the Climate System](#)
- [Understanding and Predicting Weather and Climate Extremes](#)
- [Water for the Food Baskets of the World](#)
- [Regional Sea-Level Change and Coastal Impacts](#)
- [Near-term Climate Prediction](#)
- 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?

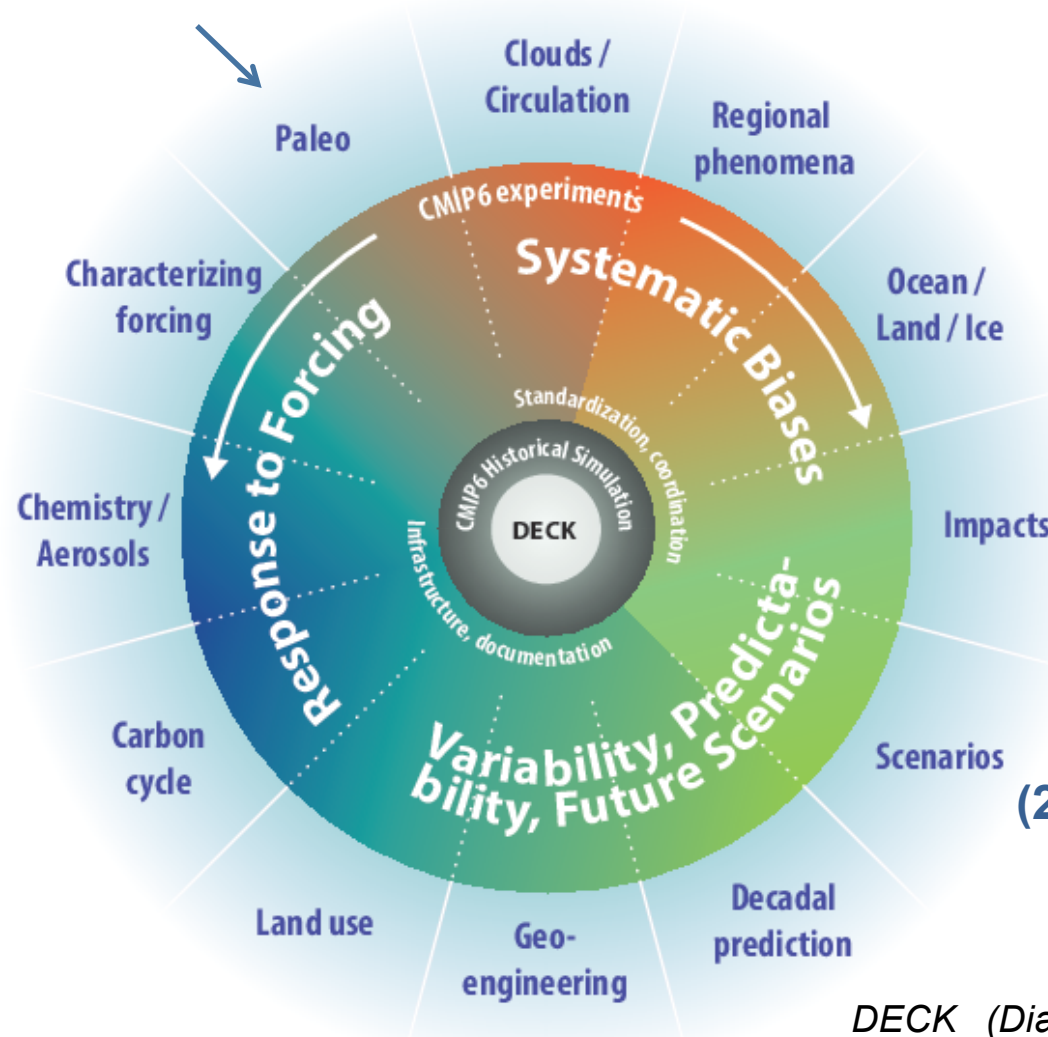
# CMIP Continuity

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)

- i. AMIP simulation (~1979-2014)
- ii. Pre-industrial control simulation
- iii. 1%/yr CO<sub>2</sub> increase
- iv. Abrupt 4xCO<sub>2</sub> run

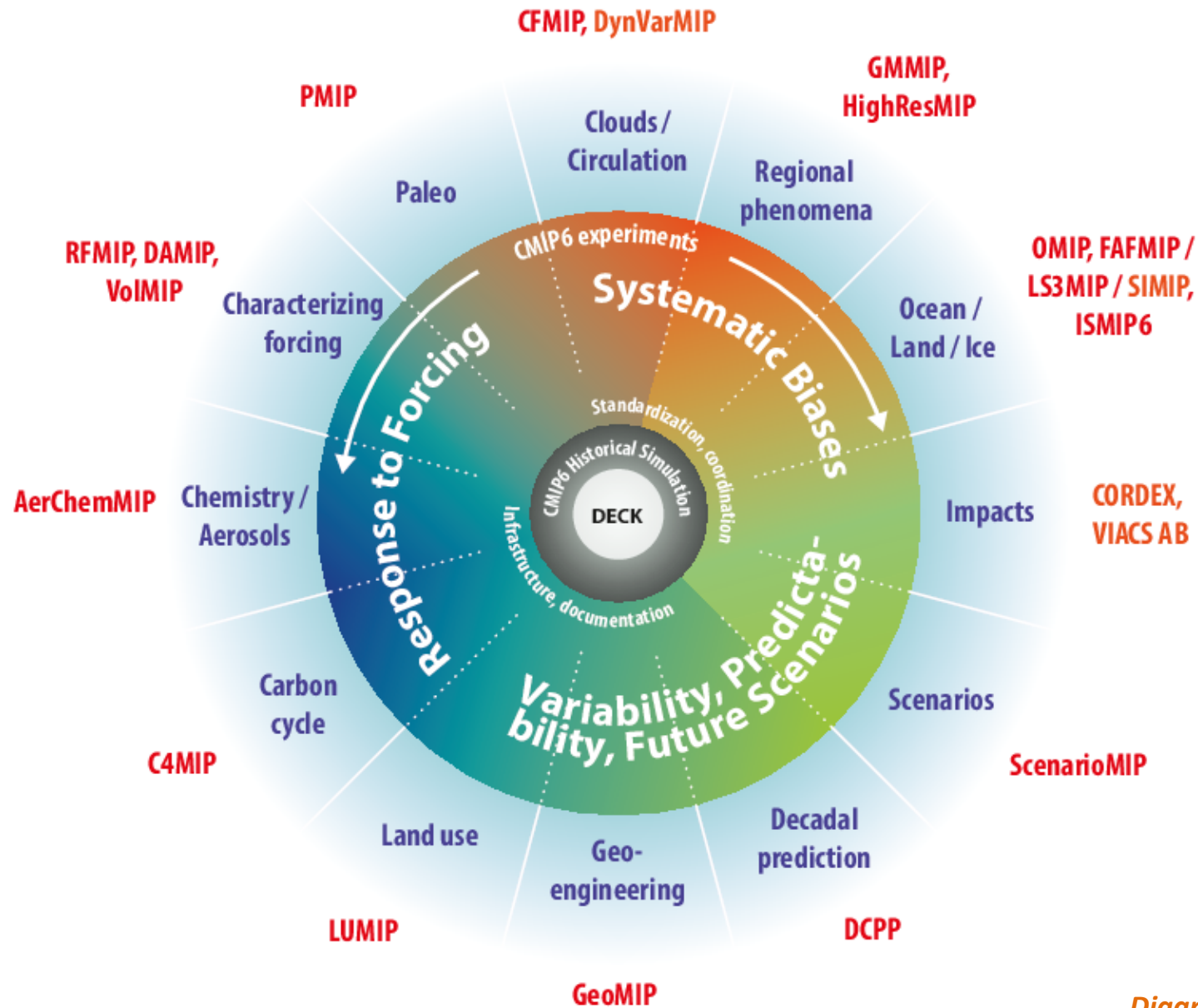
### CMIP6 Historical Simulation (entry card for CMIP6)

- v. Historical simulation using CMIP6 forcings (1850-2014)

## (2) Standardization, coordination, infrastructure, documentation

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

# 21 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

# CMIP6: Participating Model Groups

1	<b>ACCESS-ESM</b>	Australia	12	<b>CNRM</b>	France	23	<b>K-ACE</b>	Republic of Korea
2	<b>AWI-CM</b>	Germany	13	<b>EC-Earth3</b>	Europe	24	<b>MIROC</b>	Japan
3	<b>BCC</b>	China	14	<b>EMAC</b>	Germany	25	<b>MPI-ESM</b>	Germany
4	<b>BESM</b>	Brazil	15	<b>FGOALS</b>	China	26	<b>MRI</b>	Japan
5	<b>BNU</b>	China	16	<b>FIO</b>	China	27	<b>NICAM</b>	Japan
6	<b>CAMS-CMS</b>	China	17	<b>GFDL</b>	USA	28	<b>NorESM</b>	Norway
7	<b>CanESM</b>	Canada	18	<b>GISS</b>	USA	29	<b>NUIST</b>	China
8	<b>CasESM</b>	China	19	<b>IITM-ESM</b>	India	30	<b>TaiESM</b>	Taiwan
9	<b>CESM2</b>	USA	20	<b>HadGEM3</b>	UK	31	<b>UKESM</b>	UK
10	<b>CESS-THU</b>	China	21	<b>INM</b>	Russia	32	<b>VRESM</b>	South Africa / Australia
11	<b>CMCC</b>	Italy	22	<b>IPSL -CM6</b>	France			

## New in CMIP6:

2 new model groups from Germany (AWI-CM, EMAC) [for a total of 3 model groups]

4 new model groups from China (CAMS-CMS, CasESM, CESS-THU, NUIST) [for a total of 8 model groups]

1 new model group from Brazil (BESM)

1 new model group from India (IITM)

1 new model group from Taiwan (TaiESM)

1 new model group from Republic of Korea (K-ACE)

1 new model group from South Africa / Australia (VRESM)

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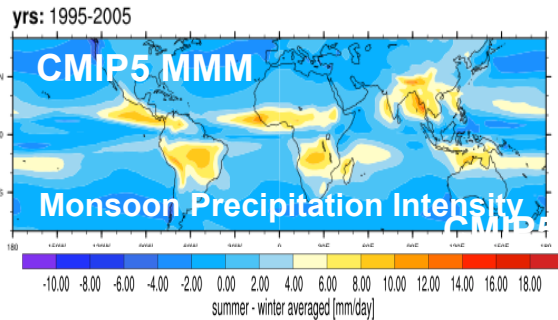
=> 11 new model groups

# How to characterize the wide variety of models in CMIP6?

## - Routine Benchmarking and Evaluation Central Part of CMIP6 -

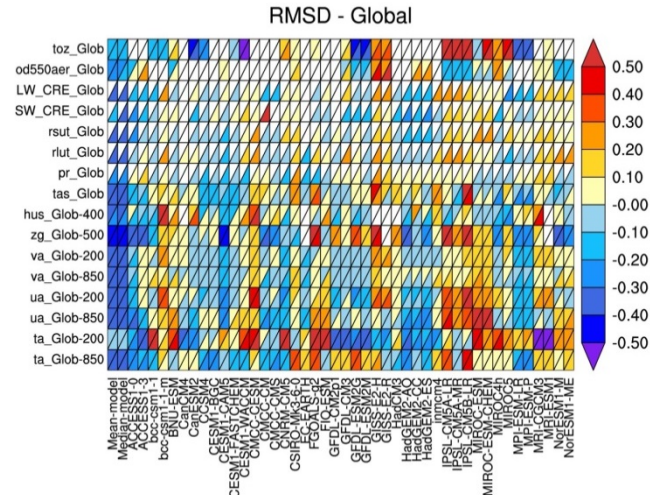
Tools such as the community-developed **Earth System Model Evaluation Tool (ESMValTool, Eyring et al., ESMValTool, GMD (2016b))** that includes other software packages such as the **NCAR CVDP (Phillips et al., 2014)**, and the **PCMDI Metrics Package (PMP, Gleckler et al., EOS (2016))** to produce well-established analyses as soon as CMIP model output is submitted.

Similar to **Figure 9.7 of AR5**



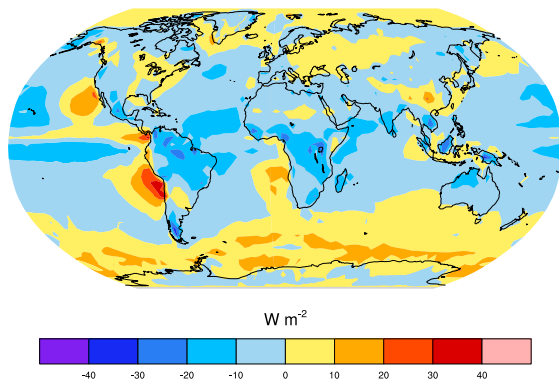
**Broad Characterization  
of Model Behavior**  
(incl. IPCC AR5 Chap 9 & 12  
diagnostics in ESMValTool)

**Running alongside  
the ESGF**

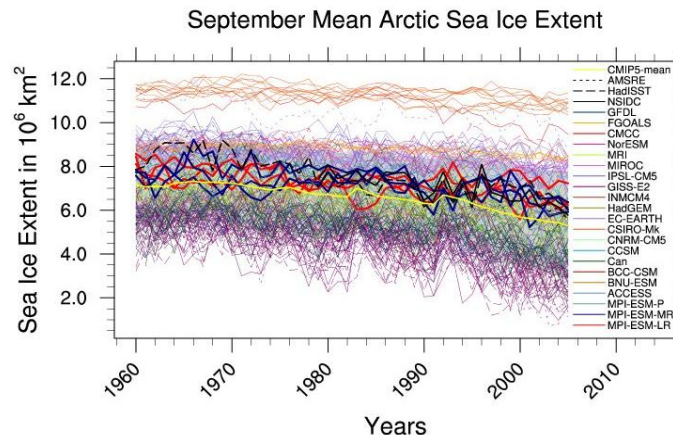


Similar to **Figure 9.5 of AR5**

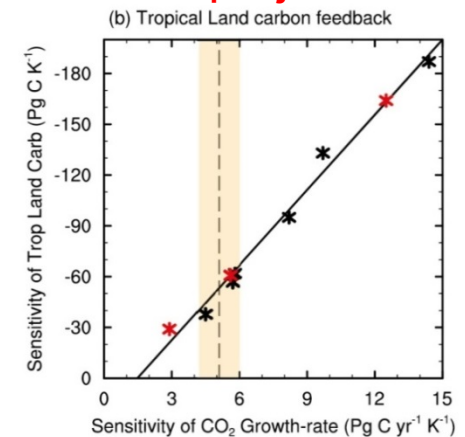
Net Cloud radiative effect against CERES EBAF



Similar to **Figure 9.24 of AR5**



**Link to projections**

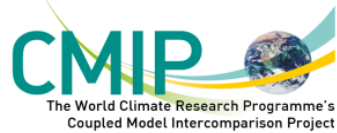


Similar to **Figure 9.24 of AR5**

# Envisaged Workflow for Routine Evaluation in CMIP

Well-Established Analysis  
Sharing of Diagnostic Code  
Guidance and support from CMIP Panel,  
WGNE/WGCM Climate Model Metrics  
Panel and , CMIP6-Endorsed MIPs

Model Output



Observations and  
Reanalyses



Processing Capability



Data Archive

Analysis computing en-  
vironment integrated  
with the ESGF

Standardised  
Interfaces

Community-tools for  
Routine ESM Evaluation

Visualization & documentation  
of evaluation results  
Record of provenance  
Scientific interpretation  
Additional in-depth analysis

State evaluation  
(climatology, trends, ...)  
Process and phenomena evaluation  
Link to projections  
(MMM analysis and emergent constraints)  
Performance metrics



*Eyring et al., ESD (2016)*

**PCMDI Metrics Package (PMP)**



Model evaluation being addressed in two workshops this year

## **1. Workshop on Connecting Climate Model Evaluation to Assessing Fitness-for-Purpose**

Hamburg, Germany, 23-24 February, 2017

Organizing Committee: Greg Flato, Jochem Marotzke, Veronika Eyring, Wilfran Moufouma-Okia

Discuss how model evaluation and model performance metrics are connected to 'fitness-for-purpose', avenues and opportunities for new research, and knowledge gaps that might be filled.

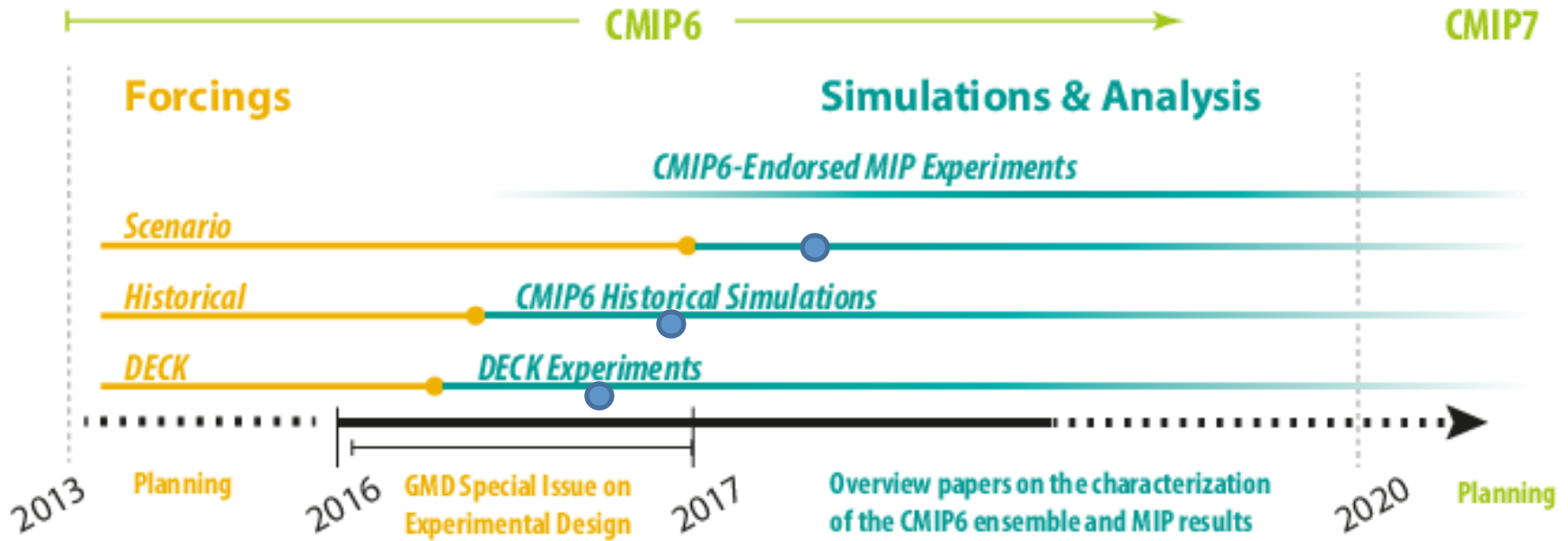
## **2. Aspen Global Change Institute Session on Earth System Model Evaluation to Improve Process Understanding and to Sharpen Climate Projections**

Aspen, Colorado, July 30-August 4, 2017

Co-chairs: Veronika Eyring, Peter Cox, Peter Gleckler

Discuss how the quality of climate projections can be improved by enabling more complete evaluation of model outputs against observations and by identifying emergent constraints

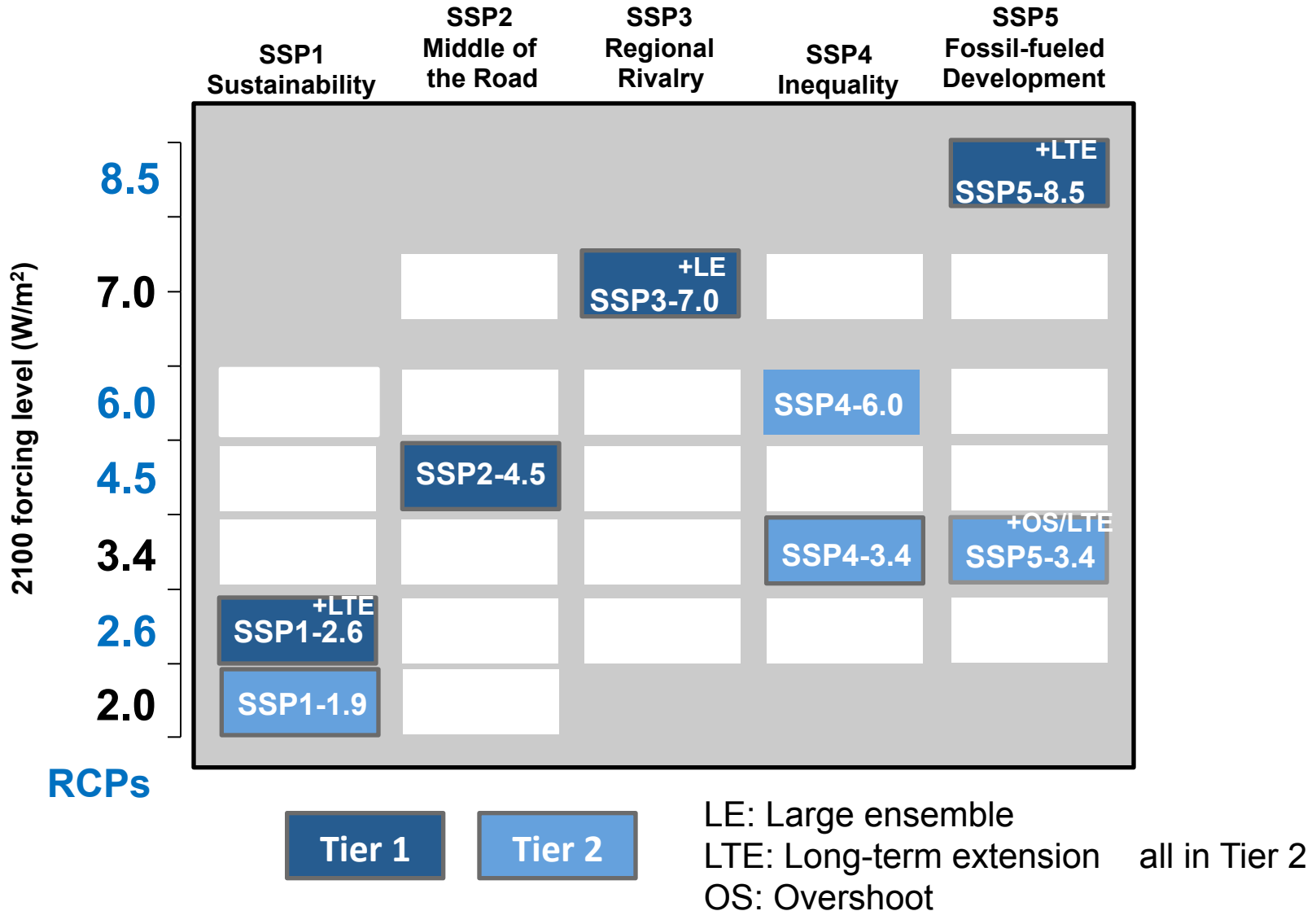
# CMIP6 Timeline



# CMIP6 Climate Projections part of a CMIP6-Endorsed MIP (ScenarioMIP)

Forcings available by August 2017, climate model projections expected to be available within the 2018-2020 time frame.

## ScenarioMIP Design



# Projected simulation lengths and data volumes for CMIP6

Historical data rates:

- **CMIP3**: 17 institutes(groups) and 25 models (40 TB)
  - total years simulated: 70000
  - individual models simulated 500 to 8400 years with a median of 2200 and a mean of 2800
  - individual groups simulated on average  $70000/17 = 4,100$  years
- **CMIP5**: 26 institutes (groups) and 60 models (2 PB)
  - numbers estimated on 10/1/2014 (to within about 20%, I guess)
  - total years simulated: 330000
  - individual models simulated on average  $330000/60 = 5500$  years
  - individual groups simulated on average  $330000/26 = 13,000$  years
- **CMIP6**: 32 institute (groups) and many model versions, more with higher resolution models, 21 MIPs, many experiments (<10 PB)

# Status and Outlook

## CMIP6 Status

- CMIP6 Experimental Design finalized late 2014, MIPs organized, vetted, and approved, and description papers written 2015-2016; preparation of forcing data sets 2015-2016
- Forcing datasets for DECK and CMIP6 historical simulations finalized in late 2016; simulations at some groups are under way
- CMIP6 Data Request finalized in late 2016
- CMIP6 Simulation Period (2017-2020), bulk of experiments performed 2017-2018
- Infrastructure in preparation by WGCM Infrastructure Panel (WIP)
- ES-DOC (Model and experiment documentation), white paper reviewed and approved by the WIP (<https://docs.google.com/document/d/1vsqeEDutNcZN4pHK534MAnkF5sKXcmjPAEfADdJNeF0/>) review of tasks and procedures next week

**CMIP6 Participating Model Groups:** 32 using a wide variety of different model versions

**21 CMIP6-Endorsed MIPs** that build on the DECK and CMIP historical simulations to address a large range of specific questions with WCRP Grand Challenges as scientific backdrop.

## A Central Goal of CMIP6 is Routine Evaluation of the Models with Observations

- Community evaluation tools: development and coupling to ESGF well underway; Concept towards improved and routine evaluation of ESMs in CMIP developed (Eyring et al., ESD, 2016)

## Geosci. Model Dev. Special Issue on CMIP6 Design (

[http://www.geosci-model-dev.net/special\\_issue590.html](http://www.geosci-model-dev.net/special_issue590.html)) **a total of 28 papers (23 published, 5 under review)**

- Overview of the CMIP6 Experiment Design and Organization (Eyring et al., GMD, 2016)
- Experimental design from all 21 CMIP6-Endorsed MIPs
- Description of the CMIP6 forcing datasets
- CMIP6 infrastructure (WIP, Balaji et al., in prep.)



# IPCC Timeline

[http://www.ipcc.ch/activities/pdf/ar6\\_schedule.pdf](http://www.ipcc.ch/activities/pdf/ar6_schedule.pdf)

3 Special Reports plus WG-I, WG-II and WG-III Reports,  
plus Synthesis Report

Special reports:

Global Warming of 1.5C (November, 2018)

literature cutoff March(?) 2018

Oceans, Cryosphere and Climate (Sept., 2019)

literature cutoff February(?) 2019

Land use, Desertification ... (Sept., 2019)

**WG-I – acceptance plenary: April 2021 (literature cutoff, summer, 2020)**

scoping meeting early May 2017;

Call for CLA/LA/RE nominations: Sept-Oct 2017

Selection of authors: Feb 2018

WG-III – July, 2021

WG-II – October, 2021