

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

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

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

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Reference:

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Coupled Model Intercomparison Project (CMIP)

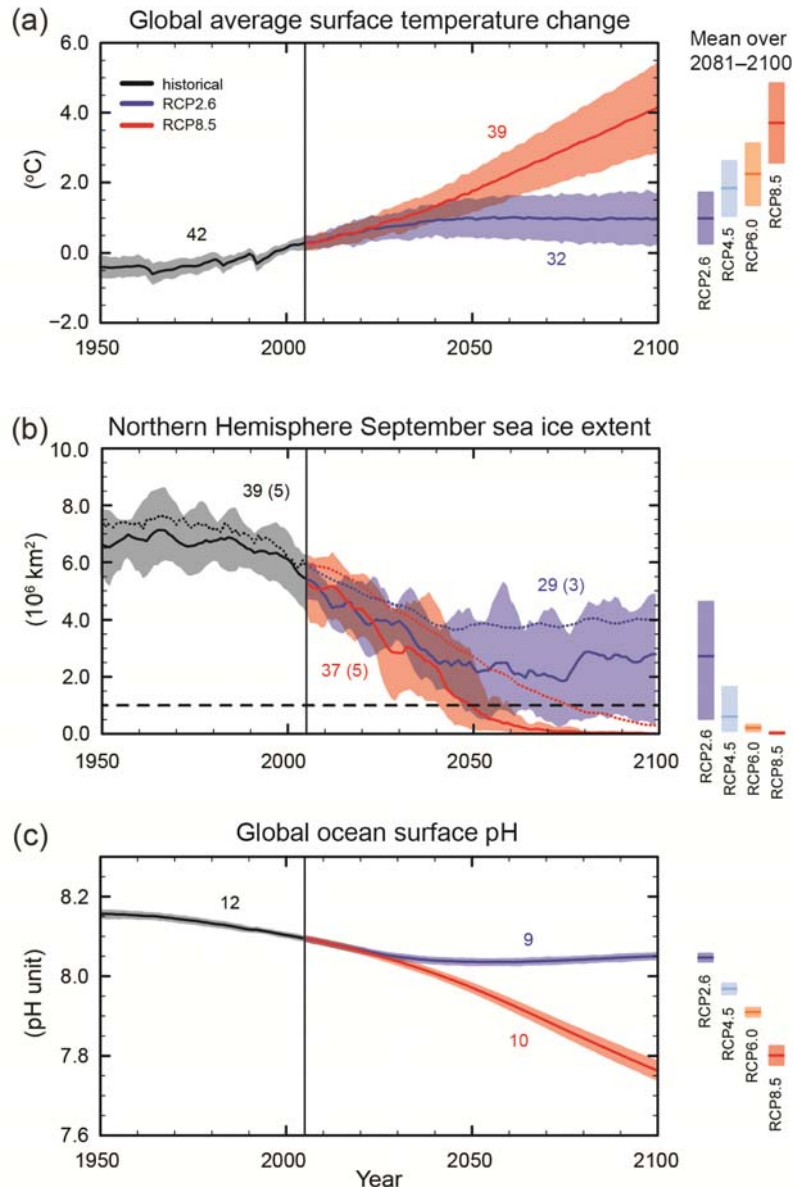
- Understanding past, present and future climate -

- 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 planning of the sixth phase, i.e. CMIP6, well underway.

- 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.

Climate Model Projections WG I AR5

- Largely based on Coupled Model Intercomparison Phase 5 (CMIP5) simulations -
Relative to the 1986-2005 average



WG I

Paleoclimate Archives (Chapter 5)

Process Understanding

Chapter 6: Carbon and other Biogeochemical Cycles

Chapter 7: Clouds and Aerosols

From Forcing to Attribution of Climate Change

Chapter 8: Anthropogenic & Natural Radiative Forcing

Chapter 9: Evaluation of Climate Models

Chapter 10: Detection and Attribution of Climate Change: from Global to Regional

Future Climate Change and Predictability

Chapter 11: Near-term Climate Change

Chapter 12: Long-term Climate Change: Projections, Commitments and Reversibility

Integration

Chapter 13: Sea Level Change

Chapter 14: Climate Phenomena and their Relevance for Future Regional Climate Change

Atlas of Global and Regional Climate Projections

Process understanding and projections including uncertainty estimates also relevant for

WG II and III

Figure SPM.7

CMIP6 Organization

- **CMIP Panel** (V. Eyring (chair), G. Flato, J. Meehl, C. Senior, B. Stevens, R. Stouffer, K. Taylor) 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 & 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.

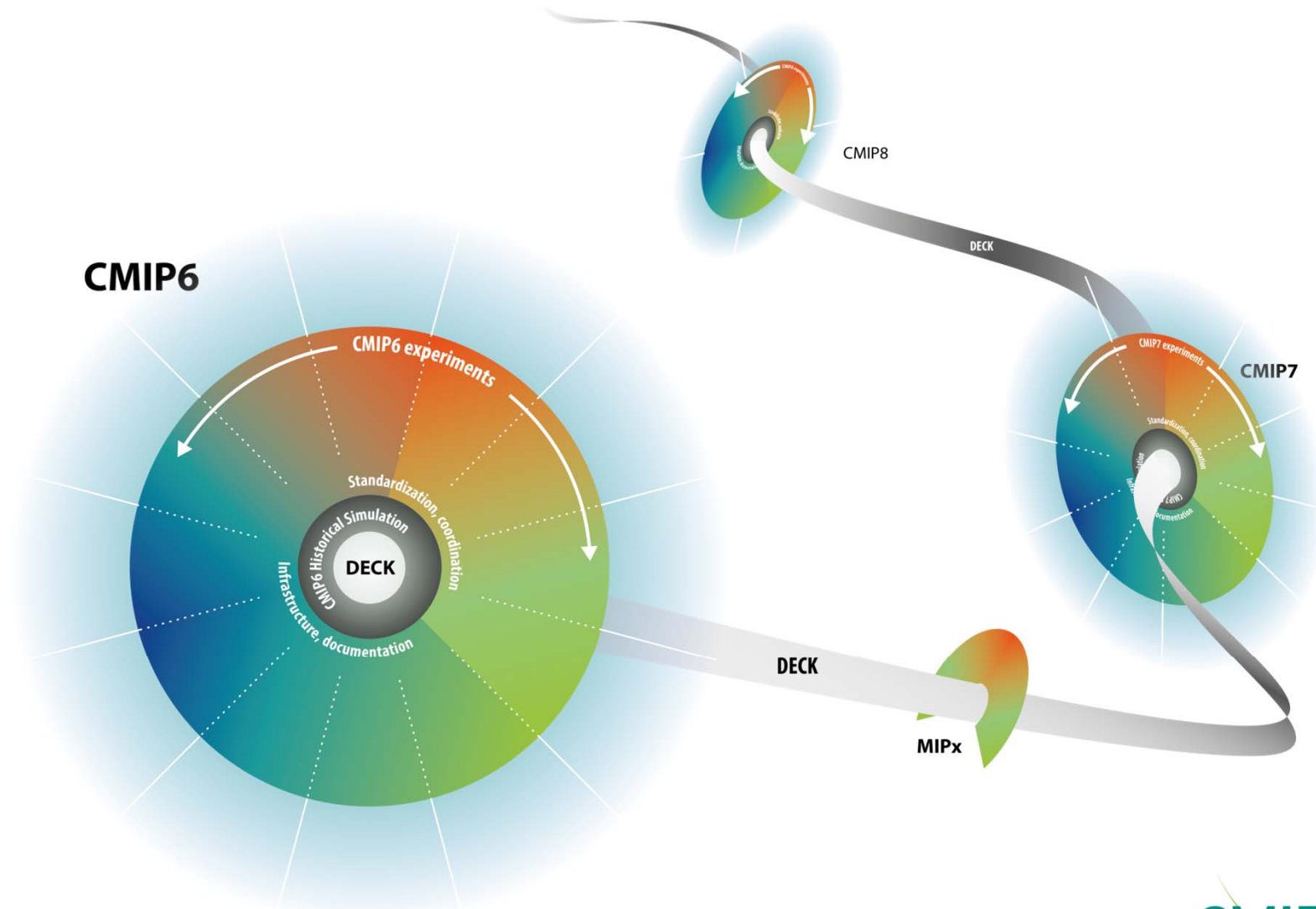


CMIP6 Design: Scientific Focus

- The **scientific backdrop** for CMIP6 is the **WCRP Grand Science Challenges**:
 1. Clouds, Circulation and Climate Sensitivity
 2. Changes in Cryosphere
 3. Climate Extremes
 4. Regional Sea-level Rise
 5. Water Availability
 6. Near-Term Climate Prediction
 7. Biogeochemical Cycles and Climate Change
- 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?

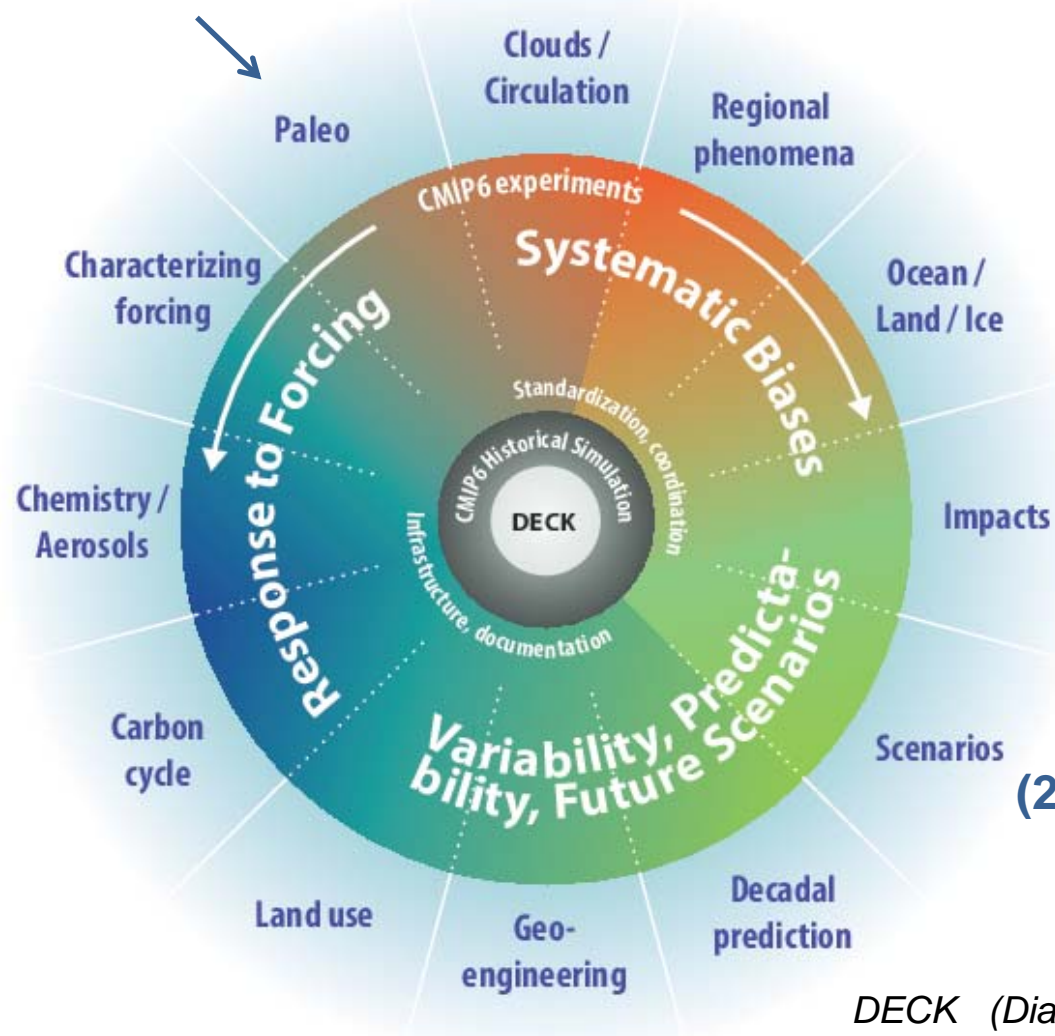
CMIP Continuity

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 CO₂ increase
- iv. Abrupt 4xCO₂ run

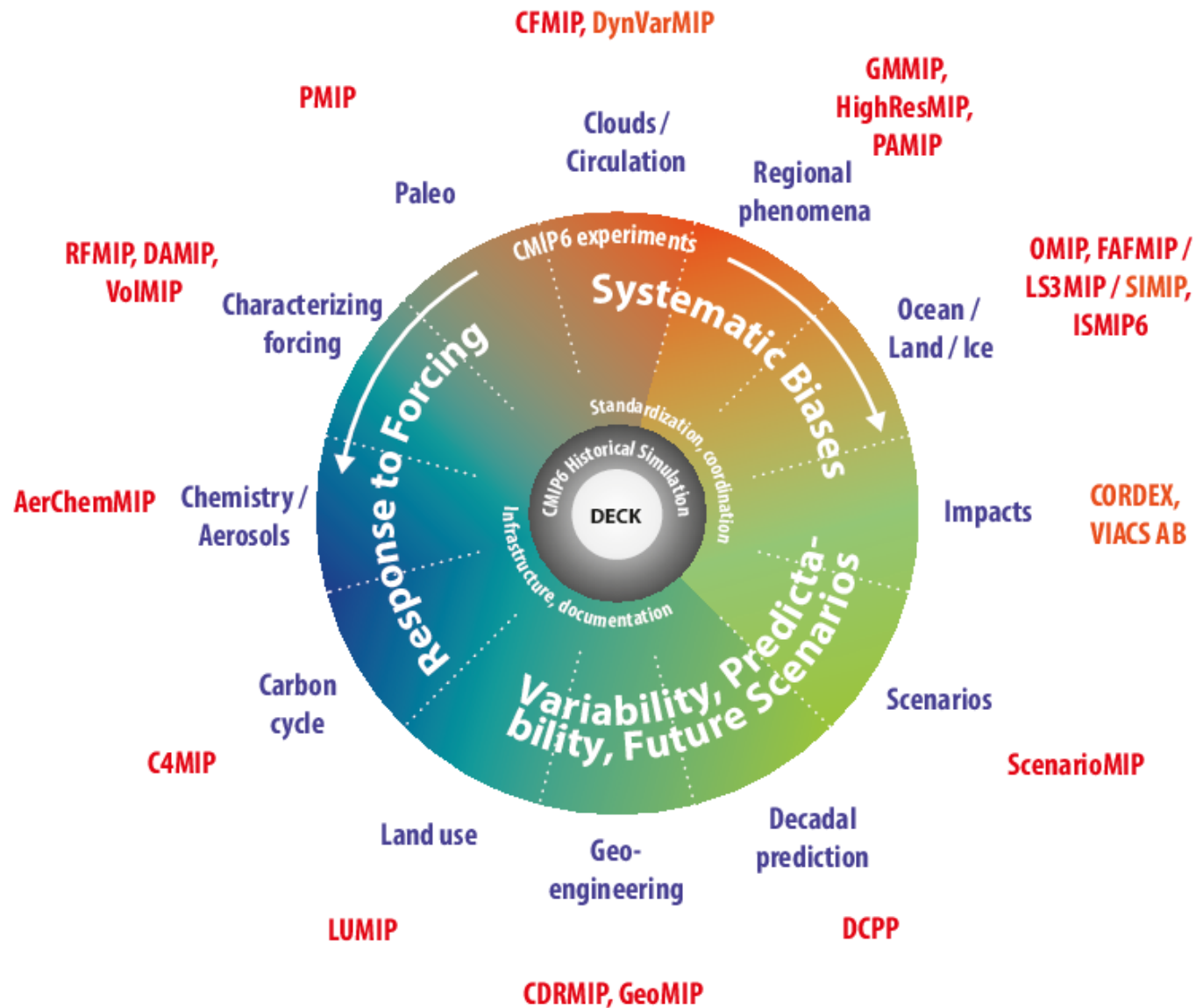
CMIP6 Historical Simulation (entry card for CMIP6)

- 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

23 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.
11. The MIP identifies a person who will become familiar with the CMIP technical requirements and will be responsive in working with the WIP to define the MIP's data request.

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

CMIP6: Participating Model Groups

	Institution	Country		Institution	Country		Institution	Country
1	AWI	Germany	12	DOE	USA	23	MRI	Japan
2	BCC	China	13	EC-Earth-Cons	Europe	24	NASA-GISS	USA
3	BNU	China	14	FGOALS	China	25	NCAR	USA
4	CAMS	China	15	FIO-RONM	China	26	NCC	Norway
5	CasESM	China	16	INM	Russia	27	NERC	UK
6	CCCma	Canada	17	INPE	Brazil	28	NIMS-KMA	Republic of Korea
7	CCCR-IITM	India	18	IPSL	France	29	NOAA-GFDL	USA
8	CMCC	Italy	19	MESSY-Cons	Germany	30	NUIST	China
9	CNRM	France	20	MIROC	Japan	31	TaiESM	Taiwan, China
10	CSIR-CSIRO	South Africa	21	MOHC	UK	32	THU	China
11	CSIRO-BOM	Australia	22	MPI-M	Germany	33	Seoul Nat.Uni	Republic of Korea

New in CMIP:

- 2 new model groups from Germany (AWI, MESSY-Consortium)
- 4 new model groups from China (CAMS, CasESM, NUIST, THU)
- 1 new model group from Brazil (INPE)
- 1 new model group from India (CCCR-IITM)
- 1 new model group from Taiwan, China (TaiESM)
- 1 new model group from USA (DOE)
- 2 new model group from Republic of Korea (NIMS-KMA, SAM0-UNICON)
- 1 new model group from South Africa / Australia (CSIR-CSIRO)

=====

⇒ **13 new model groups so far**

* Other models can join providing DECK and historical simulations are submitted

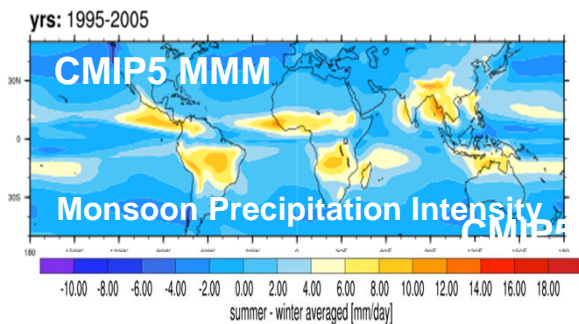
More models (>70)
New models
More complex models
Higher resolution models

How to characterize the wide variety of models in CMIP6?

- Routine Benchmarking and Evaluation Central Part of CMIP6 -

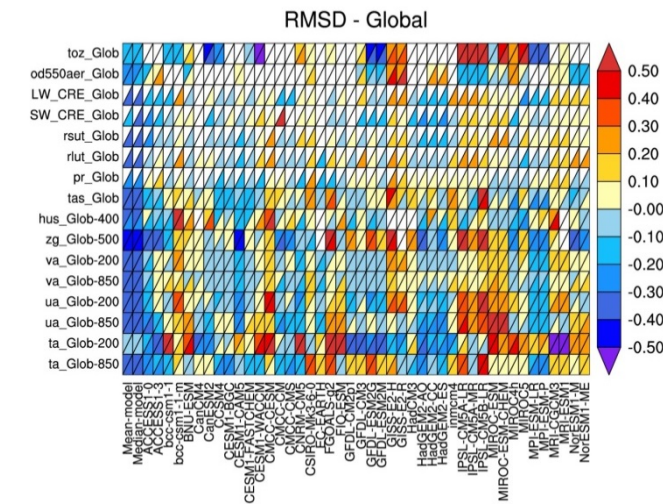
Tools such as the community-developed **Earth System Model Evaluation Tool (ESMValTool, Eyring et al., ESMValTool, GMD (2016b))** that includes other software packages such as the **NCAR CVDP (Phillips et al., 2014)**, and the **PCMDI Metrics Package (PMP, Gleckler et al., EOS (2016))** to produce well-established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

Similar to **Figure 9.7 of AR5**



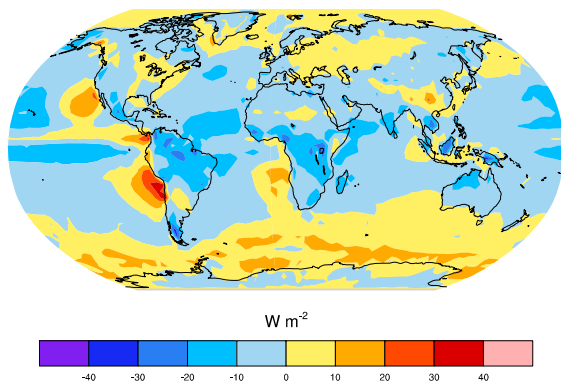
Broad Characterization of Model Behavior
(incl. IPCC AR5 Chap 9 & 12 diagnostics in ESMValTool)

Running alongside the ESGF

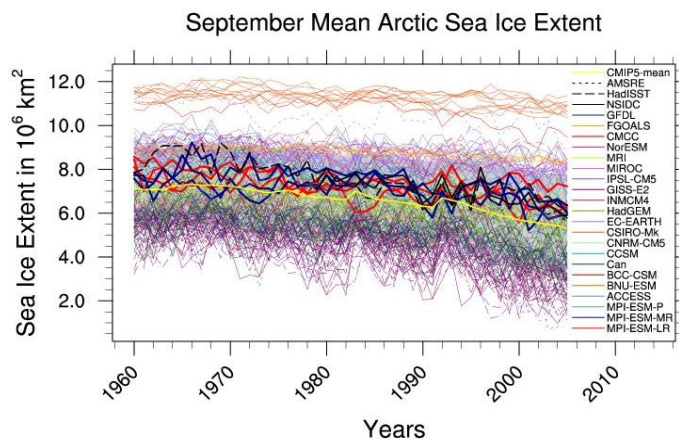


Similar to **Figure 9.5 of AR5**

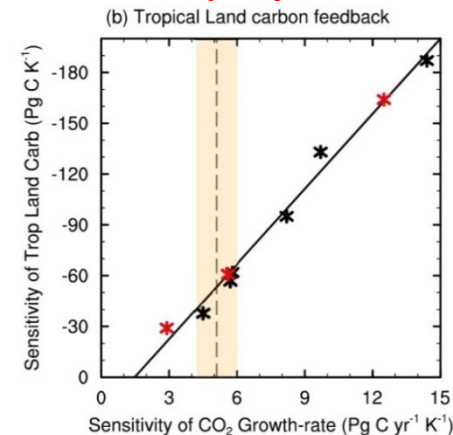
Net Cloud radiative effect against CERES EBAF



Similar to **Figure 9.24 of AR5**



Link to projections



Similar to **Figure 9.24 of AR5**

Envisaged Workflow for Routine Evaluation in CMIP

- Ensuring traceability and provenance of the results -

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

Model Output



Processing Capability



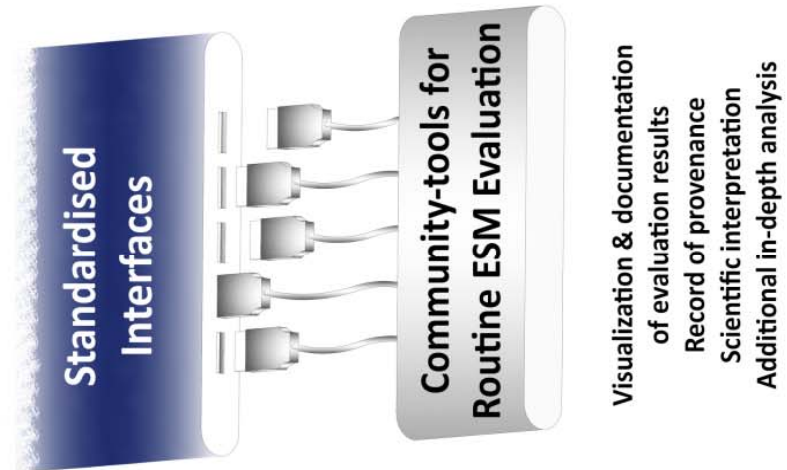
Data Archive

Observations and Reanalyses

obs4MIPs
ana4MIPs



Analysis computing environment integrated with the ESGF



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



Eyring et al., ESD (2016)

Results at <http://cmip-esmvaltool.dkrz.de/>



Key Messages: CMIP6 Design and Organization (1)

1. DECK and CMIP6 Historical Simulations

- Provide opportunity for sophisticated characterization of the CMIP6 ensemble and continuity across CMIP6 phases.
- Newly developed evaluation tools coupled to ESGF (ESMValTool, PMP) will provide a more systematic, open and comprehensive performance assessment on timescales not possible for AR5 (incl. AR5 Chs. 9 & 12 figures).

2. 21 CMIP6-Endorsed MIPs that build on the DECK and historical simulations

- Will address a large range of specific science questions
- Will fill scientific gaps of the previous CMIP phases and support the WCRP GCs
- Will lead to increased process understanding in many areas including clouds, aerosols, internal variability, impact of volcanic eruptions on climate, and geoengineering.
- For the first time in CMIP, an avenue for a formal communication with the vulnerability, impacts and adaptation and climate services community is established (VIACS AB)

3. Enhanced Infrastructure (ESGF) & documentation (ES-DOC) coordinated by the WGCM Infrastructure Panel (WIP)

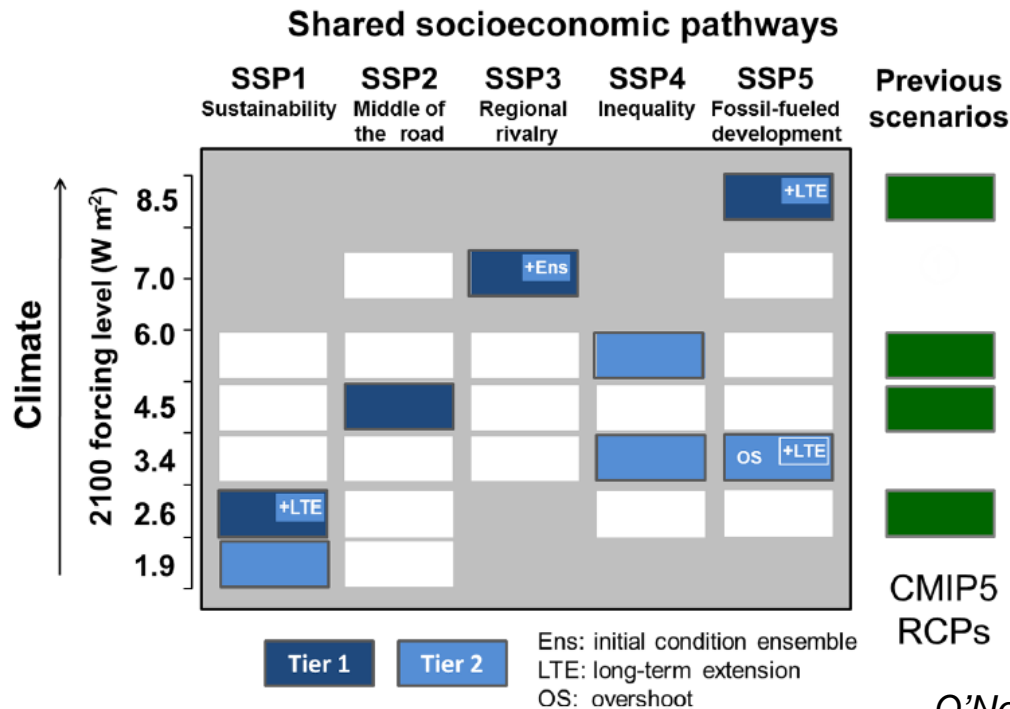
=> More robust statistical testing of model results through a larger ensemble (more models and ensemble members; using CMIP3, CMIP5 & CMIP6 together)

=> Increased information of the role of internal climate variability and observational uncertainty

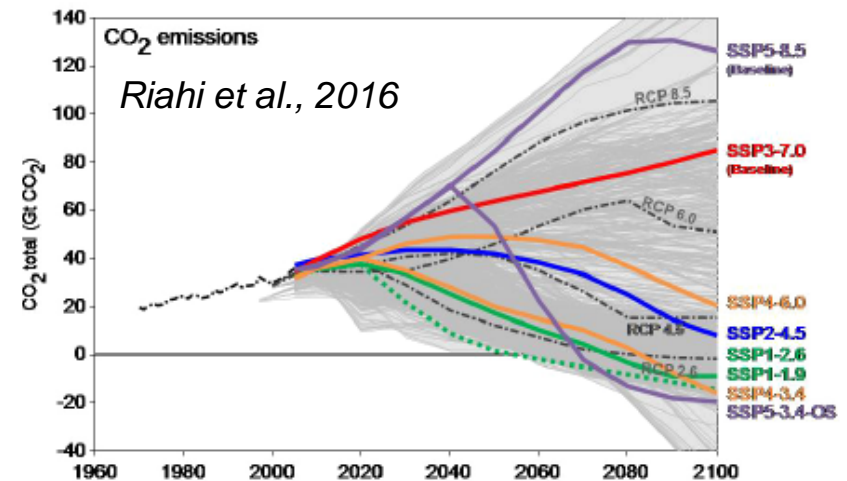
=> Increased evidence for several messages of AR5

Key Messages: Model Projections / Predictions (2)

SSPs: set of baselines, with future developments in absence of new climate policies beyond those in place today



Future in CMIP6: 2015-2100 plus Extensions to 2300



O'Neill et al., ScenarioMIP for CMIP6, GMD, 2016

ScenarioMIP: New scenarios span a similar range as the RCPs, but fill critical gaps, including

- Role of specific forcings such as land use and short-lived species (air quality)
- The effect of a peak and decline in forcing,
- The consequences of scenarios that limit warming to below 2 °C,

DCPP: Improvements in models, reanalysis, methods of initialization and ensemble generation, and data analysis will provide extended comprehensive decadal predictions

Key Messages: New Scientific Methods and Approaches (3)

1. Fitness-for-purpose evaluation

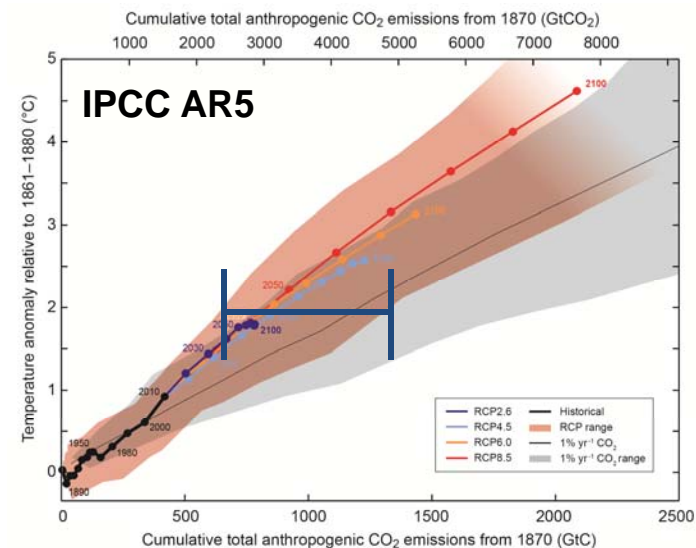
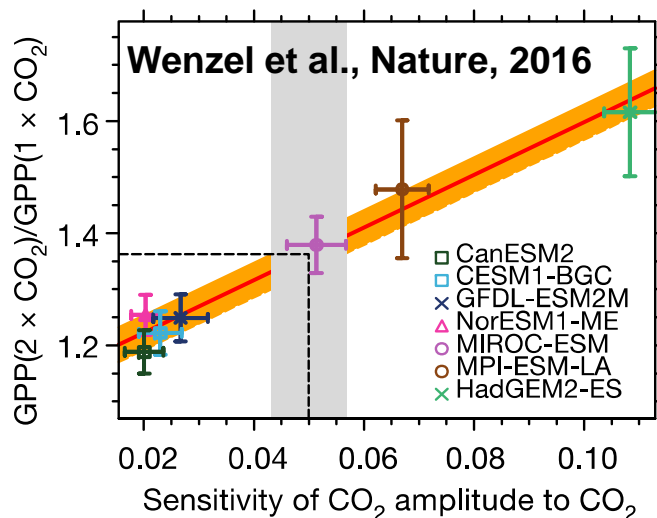
- General model evaluation supported by new CMIP evaluation tools remains important
- Additionally identify “purpose” (e.g. purposes might be projections, regional information, impact studies, mitigation pathways, physical understanding)
- Process-oriented, process-based, regime-based evaluation can be done better given expanded suite of MIPs in CMIP6 => Needs to be fully exploited
- Large number of metrics, process-based, and ensuring that new ones arriving all the time.

2. Emergent constraints and exploration of model weighting: can be used to distill robust information from multi-model output for science and as evidence for policy-making

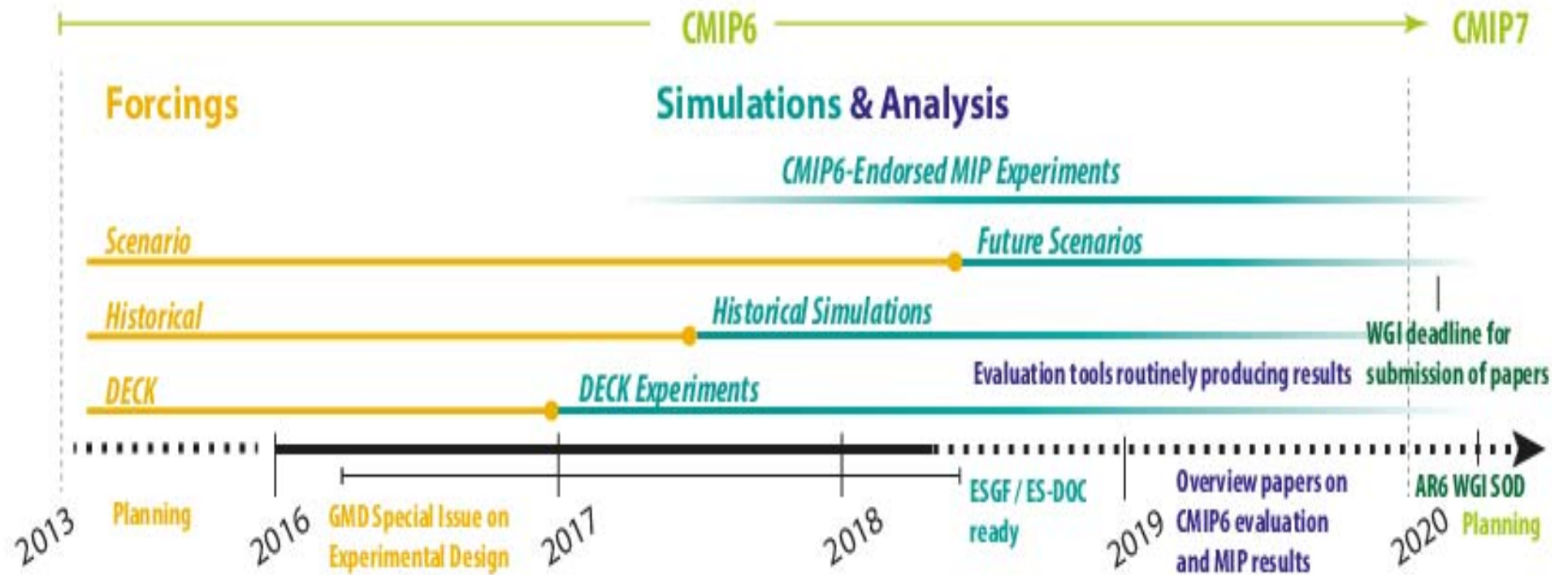
=> Help quantifying & reducing uncertainties in key feedbacks and projections

=> Can be used to draw conclusions for critical questions such as climate sensitivity and cumulative CO₂ emissions for a specific temperature target (TCRE, TCR, ECS).

Relative GPP increase at CO₂ doubling



CMIP6 Timeline



Dissemination of CMIP6 (selection)

- CMIP6 Special Issue in GMD at https://www.geosci-model-dev.net/special_issue590.html
- A Short Introduction to Climate Models - CMIP & CMIP6 Video produced by WCRP
 - Short version on Youtube at <https://www.youtube.com/watch?v=wTBkq9nWNEE>
 - Long version on Youtube at <https://www.youtube.com/watch?v=WdRiYPJLt4o>
- GMD Highlight Article by David Carlson, Veronika Eyring, Narelle van der Wel, and Gaby Langendijk
- Nature Climate Change Interview on CMIP6 at <http://www.nature.com/nclimate/journal/v7/n10/full/nclimate3398.html>
- Model output will be published at the Earth System Grid Federation (ESGF)
- Monitor results of CMIP5/CMIP6 model evaluation with the ESMValTool at <http://cmip-esmvaltool.dkrz.de/>

Status and Outlook



CMIP6 Status

- CMIP6 Experimental Design finalized on time
- Forcing datasets for DECK and CMIP6 historical simulations finalized
- CMIP6 Data Request released but new versions still published
- CMIP6 Simulation Period (2017-2020)
- Infrastructure in preparation by WGCM Infrastructure Panel (WIP)

CMIP6 Participating Model Groups: > 30 using a wide variety of different model versions

23 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.

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

- 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.
- Forcings for future scenarios available by end of 2017, climate model projections expected to be available within the 2018-2020 time frame.

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

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

Geosci. Model Dev. Special Issue on CMIP6 Design

- Overview of the CMIP6 Experiment Design and Organization (Eyring et al., GMD, 2016)
- Experimental design from all 23 CMIP6-Endorsed MIPs
- Description of the CMIP6 forcing datasets
- CMIP6 infrastructure (WIP, Balaji et al.) and data request (Juckes et al., in prep.)

=> We expect CMIP6 to continue CMIP's tradition of major scientific advances