

# Status of the Coupled Model Intercomparison Project Phase 6 (CMIP6) and Goals of the Workshop

**Veronika Eyring, Greg Flato, Jean-Francois Lamarque, Jerry Meehl, Cath Senior, Ron Stouffer, Karl Taylor (CMIP Panel)**

25 March 2019

*CMIP6 Analysis Workshop*

*Barcelona, Spain*



# CMIP6 Organization and Support

- **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.
- **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)
- **input4MIPs**: infrastructure for forcing data (Chair: P. Durack)
- **ESGF** supports a federated data archive hosting the CMIP6 data
- **Other infrastructure support components are the responsibility of multiple, independently-funded projects (e.g., ES-DOC, data citation service, errata services)**
- **Routine evaluation** of the models with newly available tools is now available for the first time

## CMIP6 Design

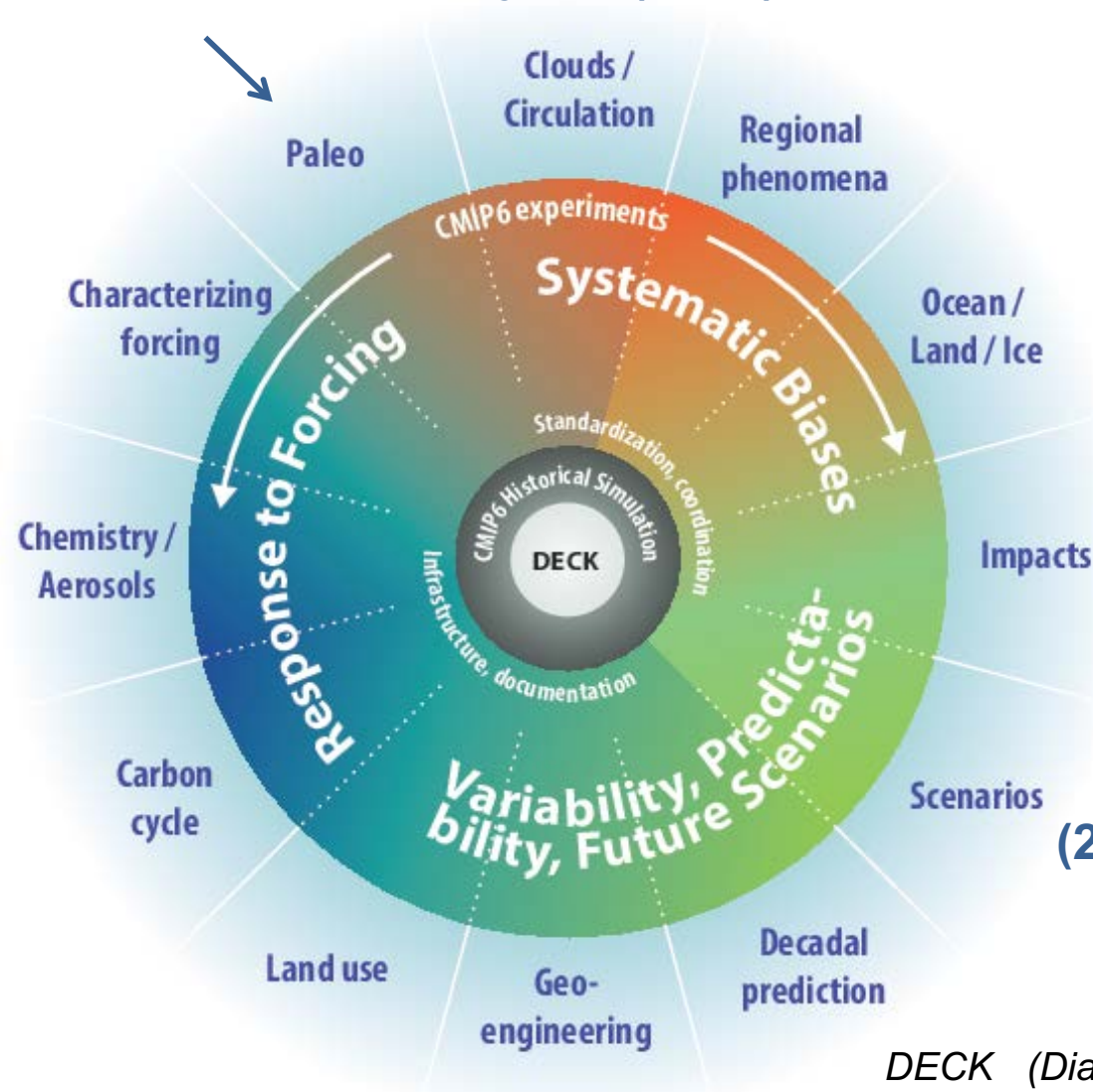
Based on an extensive period (two years) of community consultation

- Based on the 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 over the year from modeling groups and model analysts 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.



# 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)

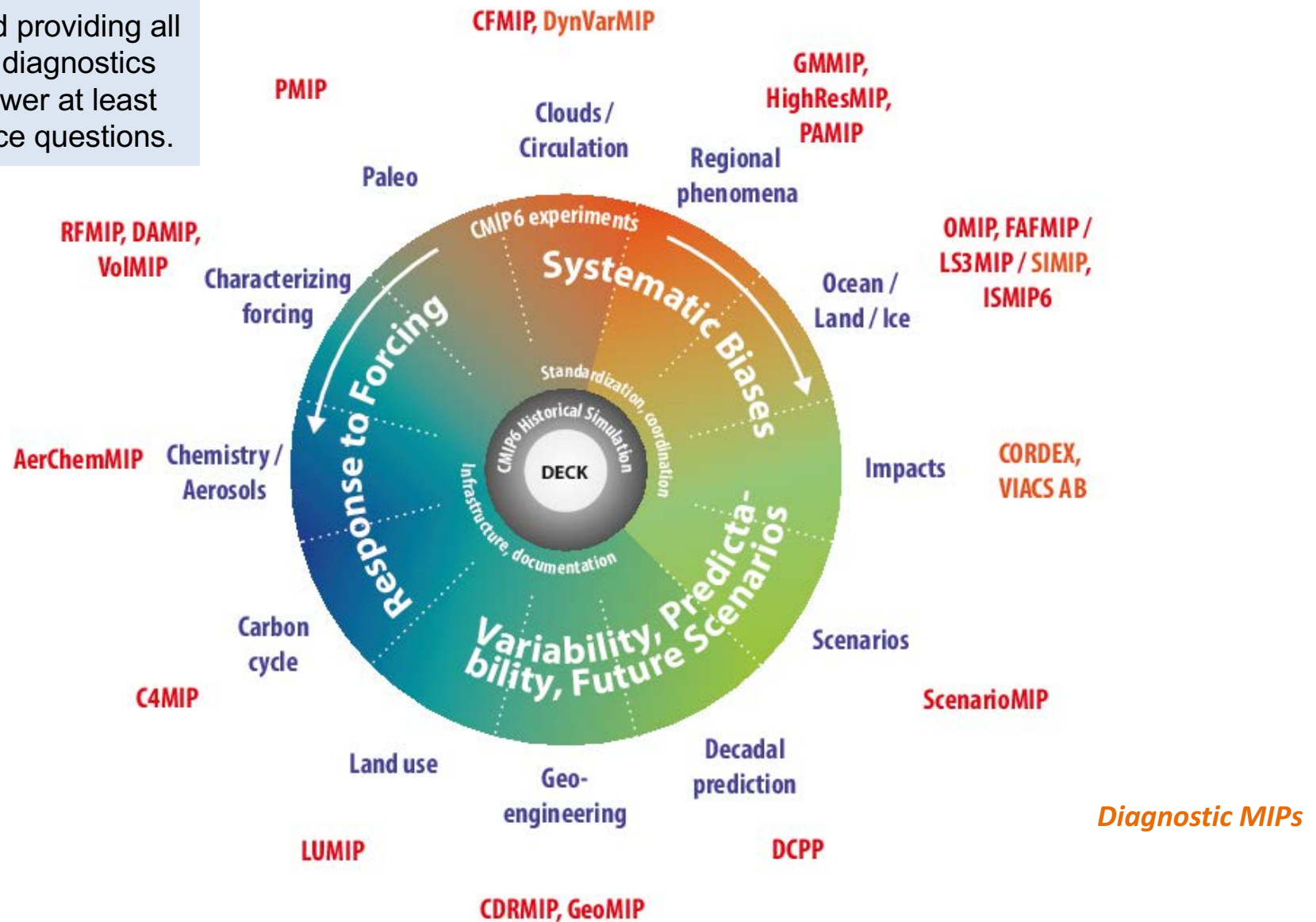
- v. Historical simulation using CMIP6 forcings (1850-2014)

## (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*

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.

# 23 CMIP6-Endorsed MIPs



See *Special Issue on the CMIP6 experimental design and organisation* at [https://www.geosci-model-dev.net/special\\_issue590.html](https://www.geosci-model-dev.net/special_issue590.html) for description of the CMIP6-Endorsed MIPs

# input4MIPs

## (Chair: Paul Durack, PCMDI)

- Forcings provided by individual people and described in the GMD special CMIP6 specials issue
- Project initiated in April 2016 to better curate forcing datasets used in CMIP6
- By December 2016 the first official CMIP Panel release v6.0.0 of the CMIP6 forcing dataset collection for the DECK and historical was in place
- Two more CMIP panel endorsed releases have been announced subsequently
  - 6.1.1            22 May 2017
  - **6.2.1            6 October 2017**
- **One issue that came apparent is freezing of forcings while bugs are still found**
- All datasets and data history is described in <http://goo.gl/r8up31>
- **Very tight timelines** – modeling groups needed datasets to start simulations – project needed to deal with provided data with an inability to request data/format corrections
- Complete project republication 22 Jan 2018 to cleanup evolving metadata, add tracking\_id and metadata inconsistencies (enabling Synda project replication, and DKRZ citation service)
- Project provides data provenance and citation information for accurate reporting by models using various datasets and versions

We got very good feedback from the modelling groups on input4MIPs 😊

# CMIP5/6 evolution: More institutions, more models, more experiments, more data

	Institute	Country		Institute	Country		Institute	Country		Institute	Country
1	AS-RCEC	Taiwan	11	CSIR-CSIRO	South Africa	21	IPSL	France	31	NERC	UK
2	AWI	Germany	12	CSIRO	Australia	22	KIOST	Korea	32	NIMS-KMA	Korea
3	BCC	China	13	CSIRO-ARCCSS-BoM	Australia	23	MESSy-Consortium	Germany	33	NIWA	New Zealand
4	BNU	China	14	E3SM-Project	USA	24	MIROC	Japan	34	NOAA-GFDL	USA
5	CAMS	China	15	EC-Earth-Consortium	Sweden	25	MOHC	UK	35	NUIST	China
6	CAS	China	16	ECMWF	UK	26	MPI-M	Germany	36	SNU	Korea
7	CCCma	Canada	17	FIO-QLNM	China	27	MRI	Japan	37	THU	China
8	CCCR-IITM	India	18	HAMMOZ-Consortium	Switzerland	28	NASA-GISS	USA	38	UA	USA
9	CMCC	Italy	19	INM	Russia	29	NCAR	USA	39	UofT	Canada
10	CNRM-CERFACS	France	20	INPE	Brazil	30	NCC	Norway	40	UTAS	Australia

Check status at PCMDI website below

<https://pcmdi.llnl.gov/CMIP6/>

# CMIP6 status: data availability

- Model output now being served by ESGF from 12 institutions (19 models)
- Much output to be made available over the coming months

source_id	# of activities	AerChemMIP	C4MIP	CFMIP	CMIP	DAMIP	DCPP	FAFMIP	GeoMIP	HighResMIP	LUMIP	OMIP	PMIP	RFMIP	ScenarioMIP
# of models	45	4	1	3	15	4	1	1	1	6	1	1	1	3	3
BCC-CSM2-MR	1				1731										
BCC-ESM1	1				671										
CESM2	2			363	11216										
CESM2-WACCM	1				4856										
CNRM-CM6-1	4	435			7086	2179									1328
CNRM-ESM2-1	4	3375	724		8633									597	
CanESM5	1				515										
E3SM-1-0	1				17										
FGOALS-f3-L	1				1										
GFDL-AM4	1				69										
GFDL-CM4	1				336										
GISS-E2-1-G	4			166	2884	4150					830				
HadGEM3-GC31-HM	1									2					
HadGEM3-GC31-LM	1									2					
HadGEM3-GC31-MM	1									2					
IPSL-CM6A-ATM-HR	1									250					
IPSL-CM6A-LR	11	9494		3397	35696	19586	116015		1156	271		642	1628	4256	12935
MIROC6	2				2347			545							
MRI-ESM2-0	5	162			1242	486								324	648
NICAM16-7S	1									6					

Check status at PCMDI website below

More than 28 days   More than 7 days   Less than 7 days

[https://pcmdi.llnl.gov/CMIP6/ArchiveStatistics/esgf\\_data\\_holdings/](https://pcmdi.llnl.gov/CMIP6/ArchiveStatistics/esgf_data_holdings/)

# CMIP6 status: data availability

- Model output now being served by ESGF from 12 institutions (19 models)
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source_id	# of expts	historical	piControl	1pctCO2	amip	abrupt-4xCO2
# of models	47	11	12	7	10	7
BCC-CSM2-MR	4	574	144	146		146
BCC-ESM1	2	534	137			
CESM2	3	9736	930		550	
CESM2-WACCM	3	2487	962		1407	
CNRM-CM6-1	5	4079	302	387	500	1818
CNRM-ESM2-1	5	2951	440	1506	564	1456
CanESM5	1	515				
E3SM-1-0	1		17			
FGOALS-f3-L	1				1	
GFDL-AM4	1				69	
GFDL-CM4	1		336			
GISS-E2-1-G	5	1711	176	166	665	166
HadGEM3-GC31-HM	0					
HadGEM3-GC31-LM	0					
HadGEM3-GC31-MM	0					
IPSL-CM6A-ATM-HR	0					
IPSL-CM6A-LR	5	22368	885	704	3330	8020
MIROC6	5	1090	109	109	930	109
MRI-ESM2-0	5	270	54	54	162	702

More than 28 days   More than 7 days   Less than 7 days

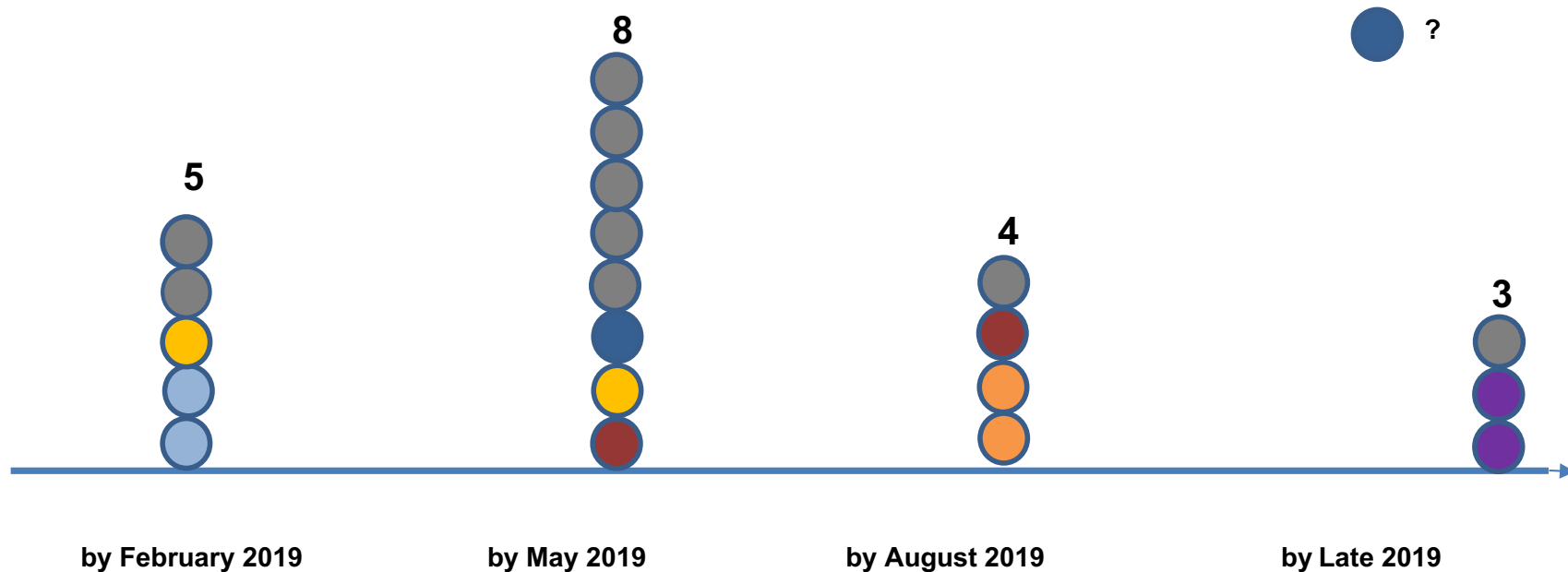
Check status at PCMDI website below

[https://pcmdi.llnl.gov/CMIP6/ArchiveStatistics/esgf\\_data\\_holdings/](https://pcmdi.llnl.gov/CMIP6/ArchiveStatistics/esgf_data_holdings/)



# Current timeline for ScenarioMIP Experiment completion

Tier 1 (**SSP1-2.6; SSP2-4.5; SSP3-7.0; SSP5-8.5; SSP1-1.9**)  
21 Models from 15 Modelling Centres



Same color (other than grey) = same modeling center/different model version

*Courtesy of Claudia Tebaldi and Erich Fisher (January 2019)*

# CMIP6 is more transparent than preceding CMIP phases

- 42 institutions/consortia have registered (CMIP5: 31 inst.)
- 109 models are registered (CMIP5: 59 models)
- 287 experiments defined; 102 tier 1 (CMIP5: 33; 14 tier 1 expts.)
- 10 – 50 PB of model output expected (CMIP5: ~2 PB)

**CMIP6\_CVs** [https://github.com/WCRP-CMIP/CMIP6\\_CVs](https://github.com/WCRP-CMIP/CMIP6_CVs)

Core Controlled Vocabularies (CVs) for use in CMIP6

## Registering Institutions, Models, or requesting changes to CVs:

To register your institution or model or to request changes to a CV, please submit an issue/ticket following the instructions on the [CMIP6\\_CVs issue page](#).

Some support for CMIP participating modeling groups is available: [pcmdi-cmip@llnl.gov](mailto:pcmdi-cmip@llnl.gov)

To view the current `experiment_id` entries point your browser to [CMIP6\\_experiment\\_id.html](#)

To view the current `institution_id` entries point your browser to [CMIP6\\_institution\\_id.html](#)

To view the current `source_id` entries point your browser to [CMIP6\\_source\\_id.html](#)

The CVs build on logic that is described in the [CMIP6 Global Attributes, DRS, Filenames, Directory Structure, and CV's document](#)

Lists of registered:

- experiments
- institutions
- models

Show  entries

Search:

source_id	institution_id	release_year	activity_participation	cohort	label	label_extended	atmos	natNomRes_atmos	ocean	natNomRes_ocean	lan
ACCESS-CM2	CSIRO-ARCCSS-BoM	2018	<b>MIPs</b> CMIP FAFMIP OMIP RFMIP ScenarioMIP	Registered	ACCESS-CM2	Australian Community Climate and Earth System Simulator Climate Model Version 2	MetUM-HadGEM3-GA7.1 (N96; 192 x 144 longitude/latitude; 85 levels; top level 85 km)	250 km	ACCESS-OM2 (GFDL-MOM5, tripolar primarily 1deg; 360 x 300 longitude/latitude; 50 levels; top grid cell 0-10 m)	100 km	none
ACCESS-ESM1-5	CSIRO	2018	C4MIP CDRMIP CMIP OMIP RFMIP ScenarioMIP	Registered	ACCESS-ESM1.5	Australian Community Climate and Earth System Simulator Earth System Model Version 1.5	HadGAM2 (r1.1, N96; 192 x 145 longitude/latitude; 38 levels; top level 39255 m)	250 km	ACCESS-OM2 (MOM5, tripolar primarily 1deg; 360 x 300 longitude/latitude; 50 levels; top grid cell 0-10 m)	100 km	none
ARTS-2-3	UHH	2015	RFMIP	Registered	ARTS 2.3	ARTS 2.3 (Current development version of the Atmospheric Radiative Transfer Simulator)	none	none	none	none	none
AWI-CM-1-1-HR	AWI	2018	CMIP CORDEX HighResMIP OMIP SIMIP VIACSAB	Registered	AWI-CM 1.1 HR	AWI-CM 1.1 HR	ECHAM6.3.04p1 (T127L95 native atmosphere T127 gaussian grid; 384 x 192 longitude/latitude; 95 levels; top level 80 km)	100 km	FESOM 1.4 (unstructured grid in the horizontal with 1306775 wet nodes; 46 levels; top grid cell 0-5 m)	25 km	none
AWI-CM-1-1-LR	AWI	2018	CMIP CORDEX HighResMIP OMIP SIMIP ScenarioMIP VIACSAB	Registered	AWI-CM 1.1 LR	AWI-CM 1.1 LR	ECHAM6.3.04p1 (T63L47 native atmosphere T63 gaussian grid; 192 x 96 longitude/latitude; 47 levels; top level 80 km)	250 km	FESOM 1.4 (unstructured grid in the horizontal with 126859 wet nodes; 46 levels; top grid cell 0-5 m)	50 km	none

source_id	institution_id	release_year	activity_participation	cohort	label	label_extended	atmos	natNomRes_atmos	ocean	natNomRes_ocean	lan
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Showing 1 to 5 of 102 entries

Previous



# 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,  
 WGNE/WGCM Climate Model Metrics  
 Panel and , CMIP6-Endorsed MIPs

Model Output



Processing Capability



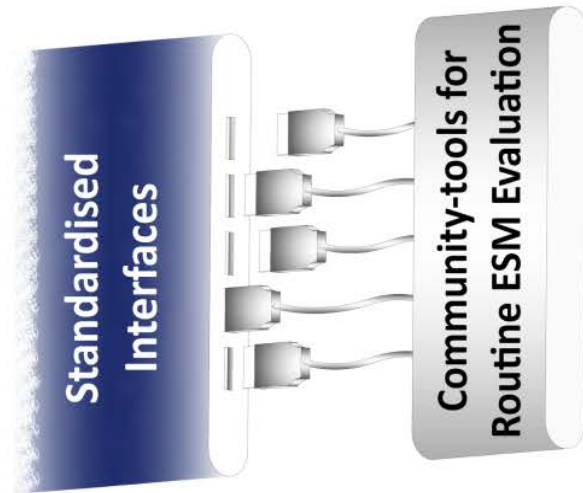
Data Archive

Observations and Reanalyses

obs4MIPs  
ana4MIPs



Analysis computing environment integrated with the ESGF



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

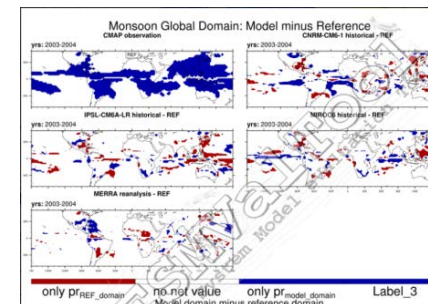
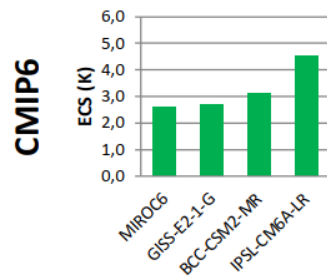
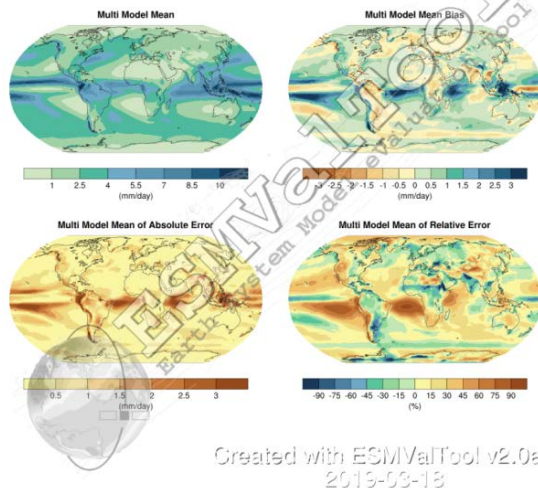
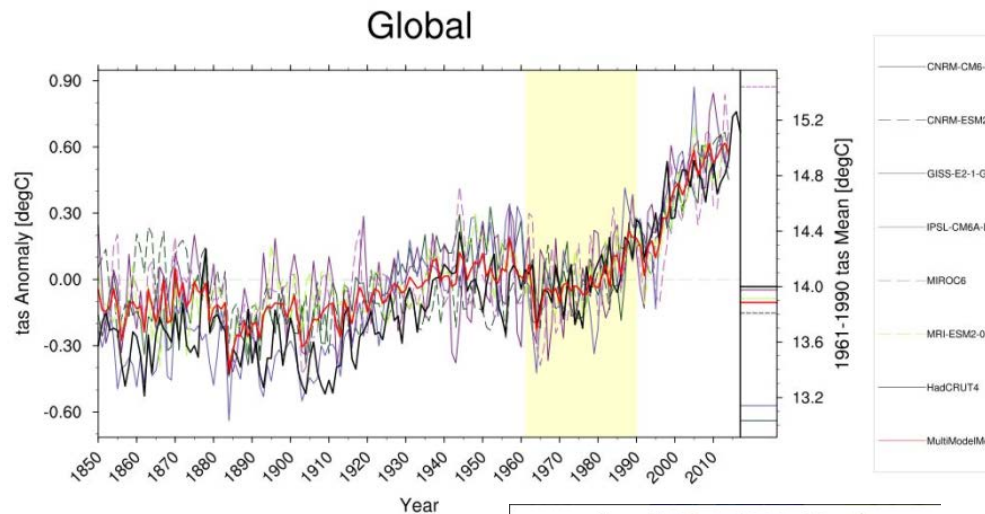
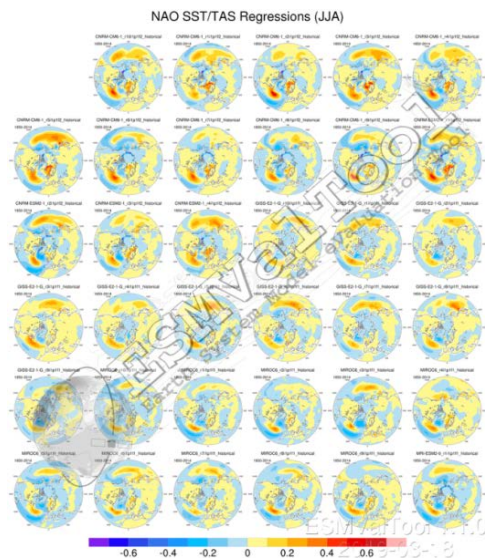
State evaluation of ECVs (climatology, trends, ...)  
 Process and phenomena evaluation  
 Link to projections  
 (MMM analysis and emergent constraints)  
 Performance metrics

Eyring et al., ESD (2016)



# First CMIP6 Results from ESMValTool incl. NCAR CVDP (Password restricted website and watermarked for quality control)

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



## Namelists include for example

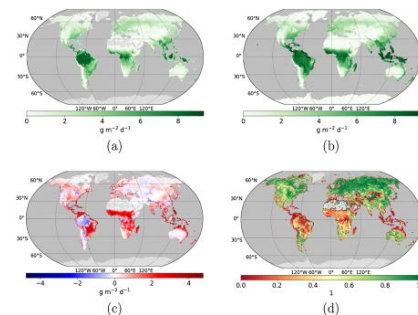
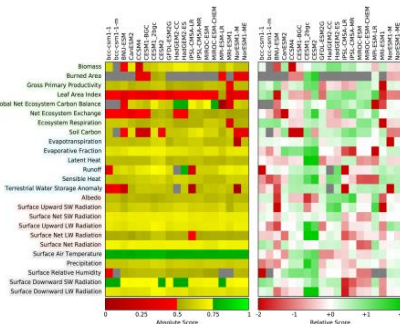
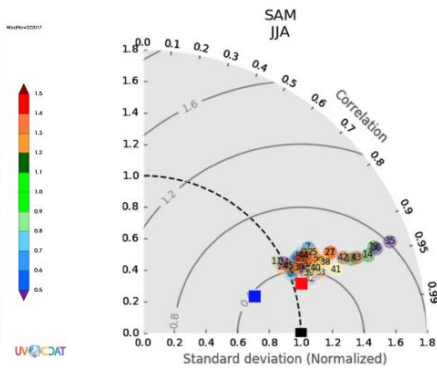
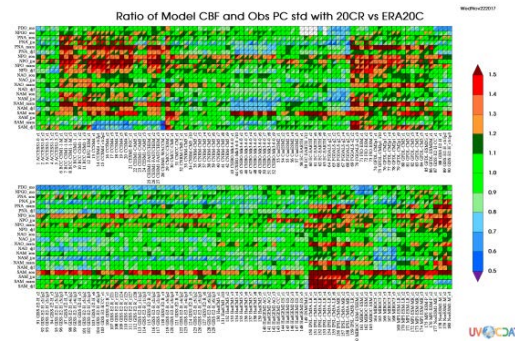
- AR5 Chapter 9 Model Evaluation
- Modes of Variability (NCAR CVDP)
- Monsoon, evapotranspiration, carbon cycle
- ECS, ozone, aerosols

# Another example

## A Coordinated Set of Model Evaluation Capabilities (CMEC)



- Emphasizes development of standards/protocols (akin to CF-conventions for data) for how different tools are operated
- Contributing teams and tools remain independent but optionally can be linked in a common framework
- Currently includes contributions from four projects (PMP, ILAMB, TECA and ARM)
- Interactive quick-look CMIP6 results coming soon at <https://cmec.llnl.gov>



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). Currently, CMEC includes three capabilities that are supported by the U.S. Department of Energy, Office of Biological and Environmental Research (BER), Regional and Global Climate Modeling Program (RGCM). As CMEC advances, additional analysis packages will be included from community-based expert teams as well as efforts directly supported by DOE and other US and international agencies.

Modeling the Climate System

Physical Model Summaries (PMP) includes the Atmosphere, Land, Ocean, Ice, and Biosphere. Weather Extremes (TECA) includes Storms, Heavy Rain, and Precipitation. Land Biogeochemistry (ILAMB) includes Photosynthesis, Plant Growth, and Carbon Cycle. Ocean Biogeochemistry (IOBM) includes Ocean Circulation, Marine Biota, and Carbon Cycle.

A primary motivation for CMEC is to analyze model simulations that are contributed to the Coupled Model Intercomparison Project (CMIP). Virtually every institution worldwide involved in significant development of ESMs contributes simulations to CMIP. The 6th and latest phase (CMIP6; Meehl et al., 2014; Eyring et al., 2016) includes a partial but fundamental shift away from distinct CMIP phases with the advent of an ongoing core of benchmarking experiments known as the CMIP DECK (Diagnosis, Evaluation, Characterization of Klima - Klima being the German word for climate). The DECK includes a short list of experimental configurations that are routinely performed by ESM developers during their model development process. The DECK and "Historical" simulations provide a basis from which ESMs can be compared with available observations.

To date, many ad hoc analysis packages have been developed to target selected aspects of ESM simulations. With the growing scope of CMIP and expectations for efficient "quick look" results, there is a clear need for the community of CMIP analysts to work together. CMEC is establishing a framework for the developers of these capabilities to collaborate and to deliver a unified set of results.

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# 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. 23 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)

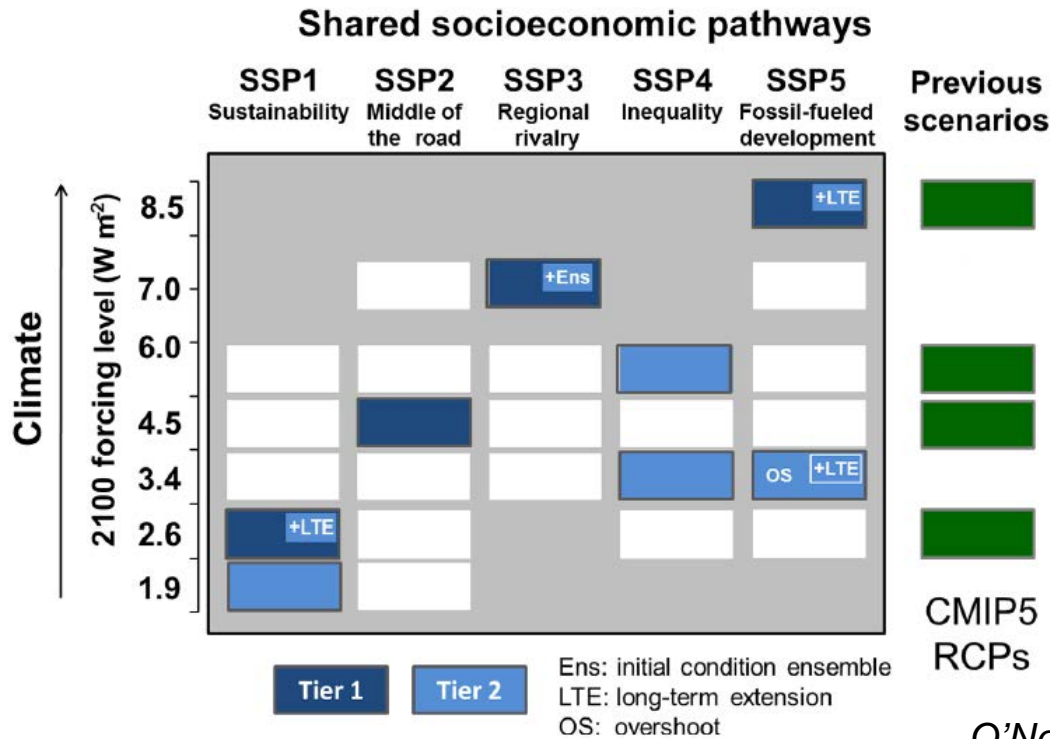
## 3. Enhanced Infrastructure (ESGF) & documentation (ES-DOC) coordinated by the WGCM Infrastructure Panel (WIP)

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

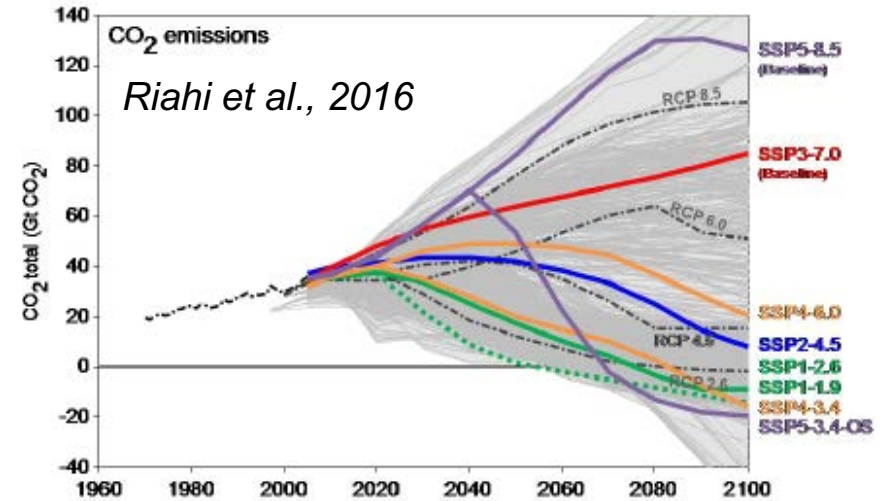
=> Increased information of the role of internal climate variability and observational uncertainty

# 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, reanalyses, initialization and ensemble generation techniques, and data analysis will provide scientific basis for credible decadal predictions



# Key Messages: New Scientific Methods and Approaches (3)

## 1. Fitness-for-purpose evaluation

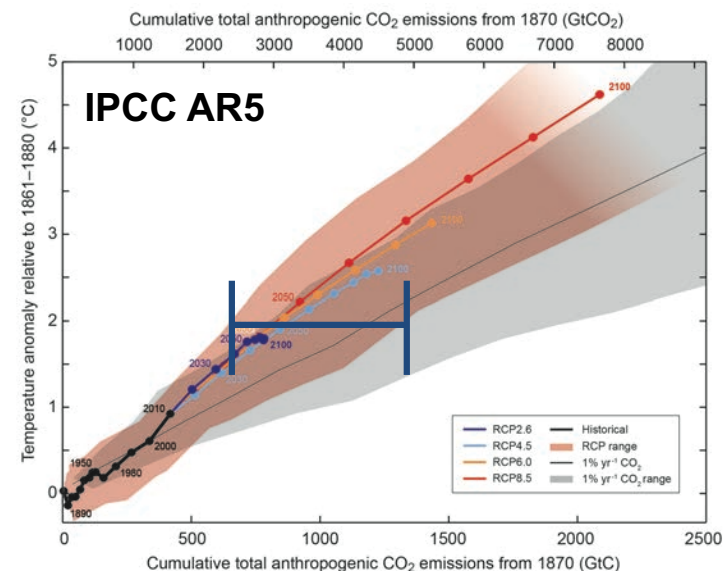
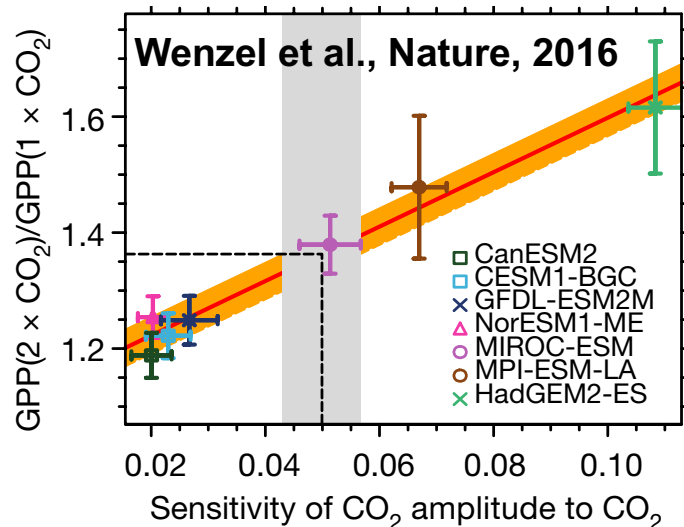
- General model evaluation supported by new CMIP evaluation tools remains important
- Important to identify “purpose” (e.g. purposes might be projections, regional information, impact studies, mitigation pathways, physical understanding)
- Process-oriented, process-based, regime-based evaluation can 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 CO<sub>2</sub> emissions for a specific temperature target (TCRE, TCR, ECS).

Relative GPP increase at CO<sub>2</sub> doubling



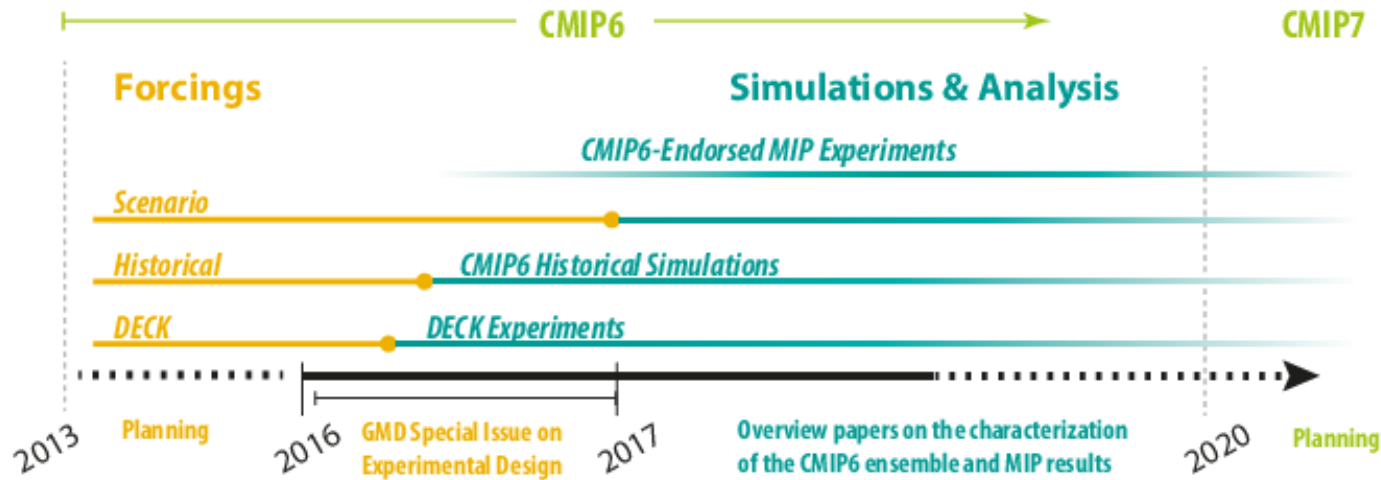
# The value of CMIP6



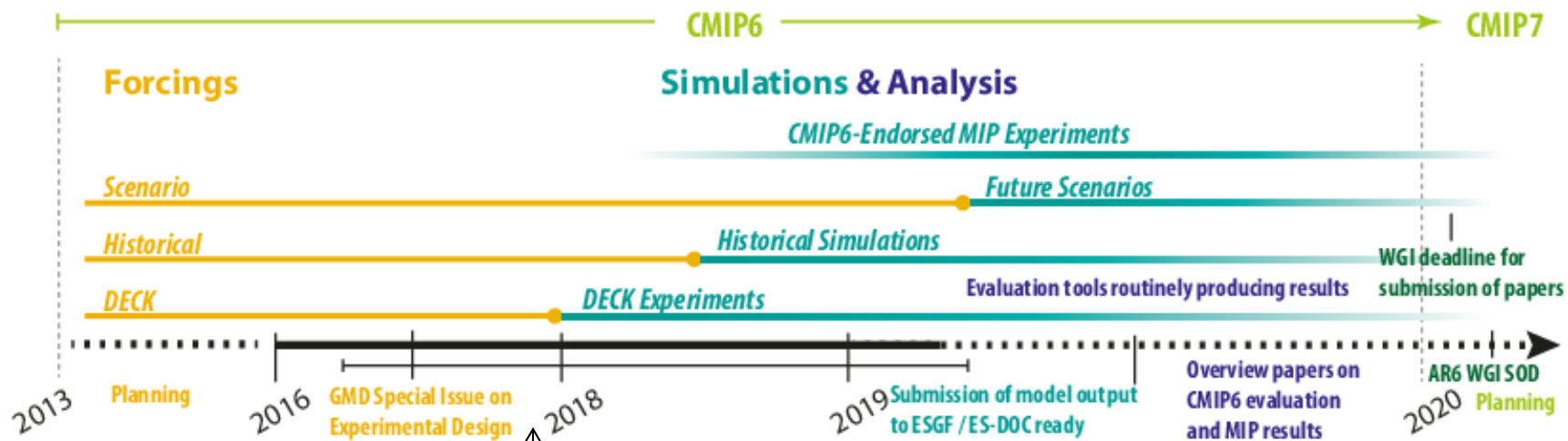
- **The value of CMIP is that it *enables* fundamental research**
  - There is now easy access to multi-model simulation output
  - 100's of research papers based on CMIP3 output
  - 1000's of CMIP5-based research papers
- CMIP also provides a multi-model perspective that can be relied on to help set priorities in model development
  - Can be helpful in gauging progress in model improvement
- The full value of simulations can be realized by subjecting them to the scrutiny and expertise of the climate research community
- We are counting on ***you*** to do innovative science with CMIP6.
- And we must acknowledge that ongoing support
  - for the infrastructure from PCMDI and other institutions ,
  - for research using the CMIP multi-model ensemble,is absolutely essential for CMIP's viability and evolution in order to advance our fundamental understanding of the Earth System
- CMIP is an essential contribution for the IPCC including the global stocktake

# Timeline has slipped, why and how can we do better?

Eyring et al., GMD, 2016  
May 2016

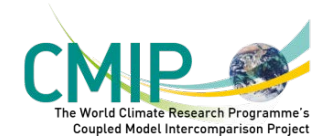


This is where we are now (March 2019)



Forcings for DECK & historical available

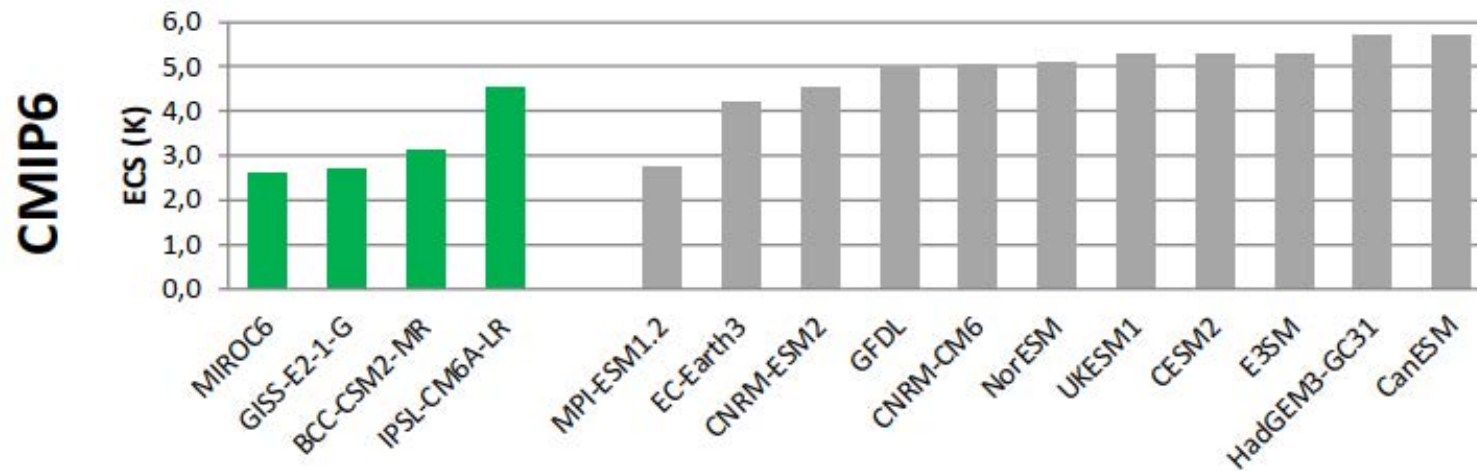
# Summary



- **Forcings for DECK and historical simulations available since Oct 2017**
- **Several infrastructural tools available (see also Karl Taylor's talk tomorrow)**
- **First CMIP6 model simulations available.** More coming in steadily
- **The major CMIP6 infrastructure** elements are in place and working satisfactorily
- **First CMIP6 model evaluation results** available from CIMP evaluation tools; continuous updates as more model output is published to the ESGF
- **CMIP6 analysis has started**
- **Some first emerging topics** from the CMIP6 ensemble have been identified

# Goals of the Workshop

- Discuss first results from CMIP6 analysis (finally!)
- Provide a venue for model groups to discuss issues they have experienced during model development
- Provide a venue for analysts and IPCC authors to exchange first results
- Identify benefits from the different types of models
- Discuss first results from CMIP6-Endorsed MIPs
- Start collecting ideas and suggestions for CMIP7
- Identify emerging topics from the CMIP6 ensemble



# Agenda (Mo/Tue)



## Monday, March 25

### 13:00-14:15 Keynote presentations

CMIP6 modelling status and goals of the workshop (Veronika Eyring)

IPCC AR6 WG1 (Greg Flato)

### 14:15-15:30 Oral Session 1: CMIP6-Endorsed MIPs, model groups, infrastructure

### 15:30-16:00 Coffee break

### 16:00-17:30 Session 1: Poster viewing

## Tuesday, March 26

### 09:00-10 :15 Oral Session 2: Forcings and Feedbacks (2 min each)

### 10:15-10:45 Coffee break

### 10:45-12:15 Poster Session 2: Forcings and Feedbacks

### 12:15-13:30 Lunch Lunchtime session on CMIP6 links to VIACS community

### 13:30-14:15 Keynote presentations

CMIP6 infrastructure status (Karl Taylor)

WMO new strategy and opportunities to strengthen CMIP (Pavel Kabat)

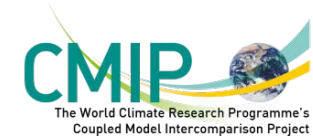
### 14:15-15:30 Oral Session 3: Uncertainty, biases and constraints

### 15:30-16:00 Coffee break

### 16:00-17:30 Poster Session 3: Uncertainty, biases and constraints

### 19:00-21:30 Icebreaker at MACBA (Paça dels Angels 1, Barcelona)

# Agenda (Wed/Thu)



## **Wednesday, March 27 (Joint day with PRIMAVERA)**

**09:00-10 :15 Oral Session 4: High resolution**

**10:15-10:45 Coffee break**

**10:45-12:15 Poster Session 4: High resolution**

**12:15-13:30 Lunch**

**13:30-14:15 Keynote** High Resolution Modelling (M. Roberts / P. L. Vidale)

**14:15-15:30 Oral Session 5: Variability and extremes**

**15:30-16:00 Coffee break**

**16:00-17:30 Poster Session 5: Variability and extremes**

## **Thursday, March 28**

**09:00-10 :15 Oral Session 6: Future Projections**

**10:15-10:45 Coffee break**

**10:45-12:15 Poster Session 6: Future Projections**

**12:15-13:30 Lunch**

**13:30-13:50 Keynote** Integrated Assessment Modelling and emission pathways and the connections to global Earth System models (J. Rogelj)

**13:50-14:30 Session 7: Regional and Impacts**

**14:30-16:00 Poster Session 7: Regional and Impacts**

**16:00-16:30 Coffee break**

**16:30-17:30 Final discussion including emerging properties of CMIP6 ensemble and way forward toward CMIP7**