Diagnostics and Intercomparisons

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The Ronald J. Stouffer Symposium

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DLR

Diagnostics and Intercomparisons

Times Cited according to Web of Science 30 May 2016

1.	**AN OVERVIEW OF CMIP5 AND THE EXPERIMENT DESIGN** By: Taylor, Karl E.; Stouffer, Ronald J.; Meehl, Gerald A. BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY Volume: 93 Issue: 4 Pages: 485-498 Published: APR 2012	2356
2.	**The WCRP CMIP3 multimodel dataset - A new era in climate change research** By: Meehl, Gerald A.; Covey, Curt; Delworth, Thomas; et al. BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY Volume: 88 Issue: 9 Pages: 1383-+ Published: SEP 2007	1467

Out of his more than 100 papers, many related to model characteristics and systematic model biases; Lead author of IPCC AR4 Climate model evaluation chapter

Coupled Model Intercomparison Project (CMIP)

CMIP & Model Evaluation & Ron’s involvement

- Brief History of CMIP (with input from Jerry Meehl (NCAR))
- Experimental Design and Organization of CMIP6
- Earth System Model Evaluation: Opportunities and Challenges for CMIP6

Origins of CMIP

- Origins of CMIP can be traced to the formation of a WCRP committee in 1990: **Steering Group on Global Coupled Models (SGGCM):** Larry Gates (chair), Ulrich Cubasch, Jerry Meehl, John Mitchell, Ron Stouffer
- Formulate a strategy for developing the **newly emergent global coupled climate models** (atmosphere, ocean, land and sea ice) being used for the first time for century timescale climate change simulations; **Organize coordinated experiments**, and **formulate standards**.
- The first-ever **Global Coupled Climate Model Workshop** (October, Scripps, 1994) organized by SGGCM (changed to CLIVAR NEG2 in 1994; later WGCM),
- The concept for a coupled model intercomparison project first discussed here

CMIP Phase 1 & 2 (1995-2002)

CMIP Panel (1995-2000): Meehl (Chair), Boer, Covey, Latif , Stouffer

- **CMIP1: Global coupled model simulations of present-day climate (1995)**
  - Goals: Document systematic mean climate errors of global coupled GCMs, Quantify effects of flux adjustments, document features of simulated climate variability
  - 21 models from 9 countries; 10 analysis subprojects
- **CMIP2 (1997; limited output) CMIP2+ (2000, all fields): control run, 1%CO_2/yr**
  - Goals: Document mean response and time-evolving climate response to a transient increase of CO_2, quantify effects of flux adjustments on climate sensitivity.
  - 18 /12 models from 8 countries; 22 analysis subprojects
- **1st CMIP Workshop with results from CMIP1/2, Oct 1998 in Melbourne; 2nd CMIP Workshop, Sep 2003 in Hamburg; Examples of emerging themes:**
  - Multimodel means give better agreement to observations than single models on regional scales
  - Several **systematic errors** that have been present in nearly all generations of coupled models are proving difficult to eliminate, such as the double ITCZ
  - Preliminary indications that **sensitivities** of new model versions may be converging near **2– 3°C**

Meehl et al. (incl. Stouffer), EOS, 1997; BAMS, 2000; 2005

The World Climate Research Programme's Coupled Model Intercomparison Project

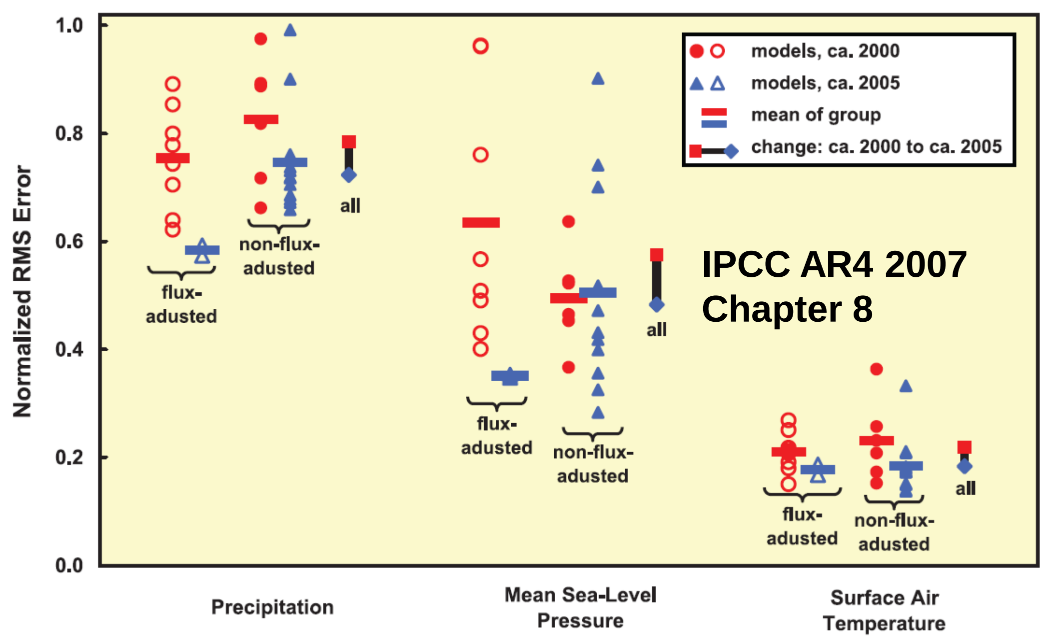
CMIP3 (2003-2007)

CMIP Panel (2000-2007): Meehl (Chair), Boer, Covey, Latif, McAvaney, Stouffer, Taylor

- **CMIP3 experiments** (realistic scenarios for both past and present climate forcing):
  - 20th century simulation to year 2000, then fix all concentrations at year 2000 values and run to 2100 (CO_2 ~ 360ppm) Climate change commitment
  - 21st century simulation with SRES A1B, B1 and A2
  - AMIP, 1%CO_2 increase per year; instantaneous doubling of CO_2
- **PCMDI agrees to archive data** from 20th and 21st century runs (as in CMIP1/2)

Meehl et al. (incl. Stouffer), BAMS, 2007

Modelling groups	17
Models	25
Mean number of simulated years per model	~2800
Data volume (terabytes)	~36



Climate Models and Their Evaluation

Coordinating Lead Authors:
David A. Randall (USA), Richard A. Wood (UK)

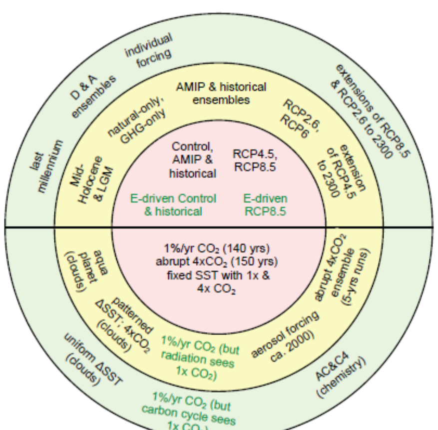
Lead Authors:
Sandrine Bony (France), Robert Colman (Australia), Thierry Fichefet (Belgium), John Fyfe (Canada), Vladimir Kattsov (Russian Federation), Andrew Pitman (Australia), Jagadish Shukla (USA), Jayaraman Srinivasan (India), Ronald J. Stouffer (USA), Akimasa Sumi (Japan), Karl E. Taylor (USA)

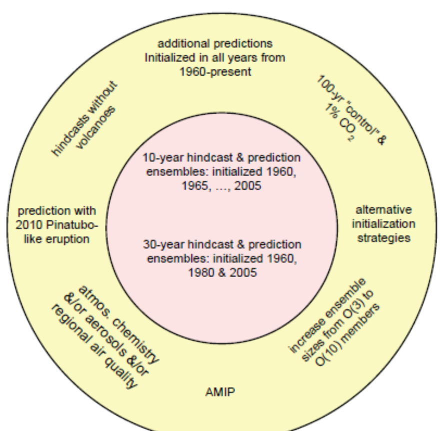
CMIP
The World Climate Research Programme's Coupled Model Intercomparison Project

CMIP5 (2007-2013)

CMIP Panel (2007-2013): Stouffer (chair), Covey, Latif, Meehl, Mitchell, Stockdale, Taylor

- First time to connect the Earth System Modeling Community with the Integrated Assessment Modeling community in planning a CMIP phase
- First time the future experiments divided into near-term and long-term timescales, reflecting a shift of the science with the needs of the stakeholders for near-term climate change information





Modelling groups	29
Models	60
Mean number of simulated years per model	~5500
Data volume (terabytes)	~2,000

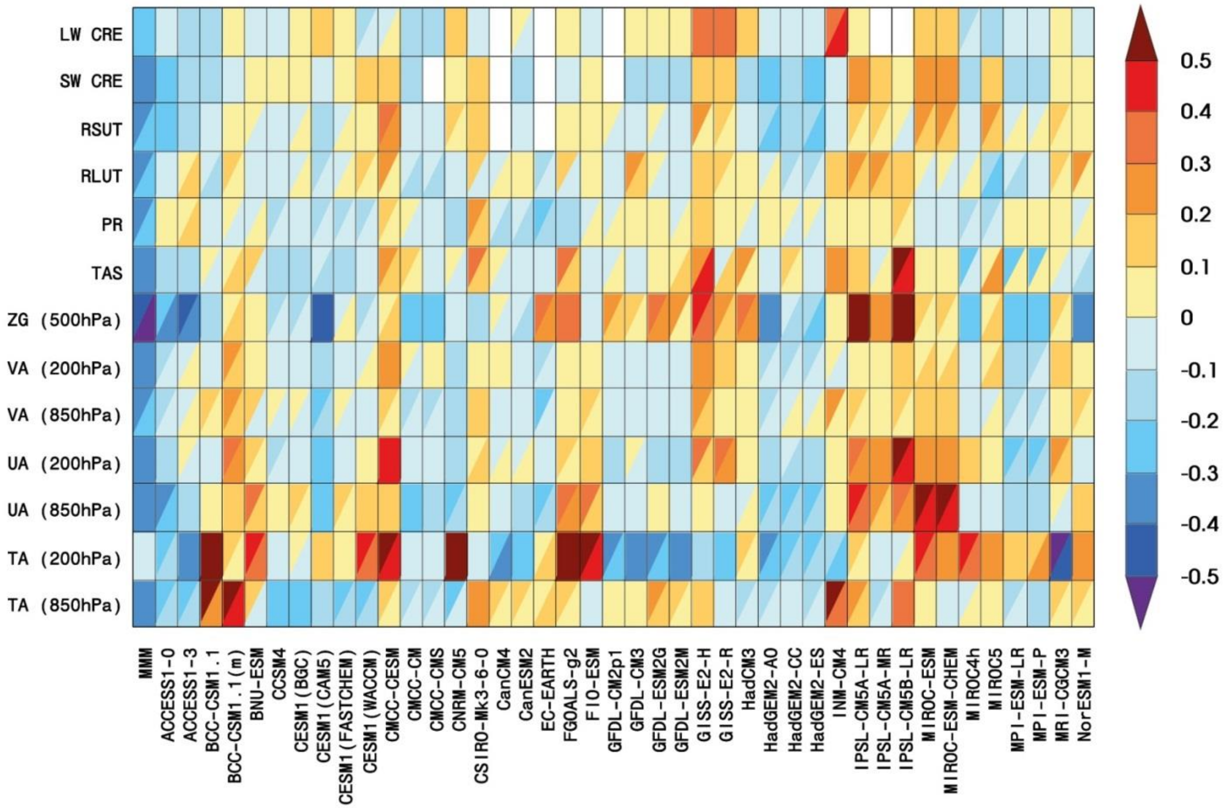
Taylor et al. (incl. Stouffer), BAMS, 2012

CMIP
The World Climate Research Programme's Coupled Model Intercomparison Project

CMIP5 (2008-2013)

CMIP Panel (2007-2013): Stouffer (chair), Covey, Latif, Meehl, Mitchell, Stockdale, Taylor

- First time ESM experiments were included in a CMIP phase, reflecting the rise of carbon cycle components being included in standard AOGCMs
- First time distributed archive (ESGF) to store model output



IPCC AR5, Chapter 9, Fig. 9.7

Relative error measures of CMIP5 model performance (normalized by the median error of all model results), based on the global seasonal-cycle climatology (1980–2005)

- **Climate models have continued to be developed and improved since the AR4.**

CMIP6 Organization

- **CMIP Panel** (V. Eyring (chair), S. Bony, J. Meehl, C. Senior, B. Stevens, R. Stouffer, K. Taylor) which is responsible for direct coordination of CMIP and overseeing the whole CMIP process.

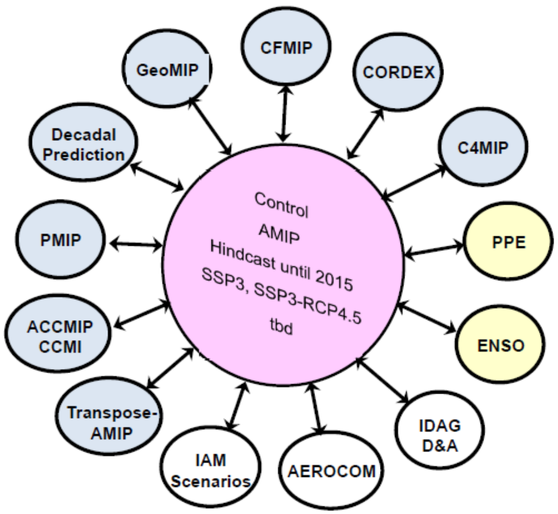
- **WGCM Infrastructure Panel** (WIP, co-chairs V. Balaji & K. Taylor): Establishes standards and policies for sharing climate model output; puts the data request together technically (M. Juckes).

CMIP6 Design

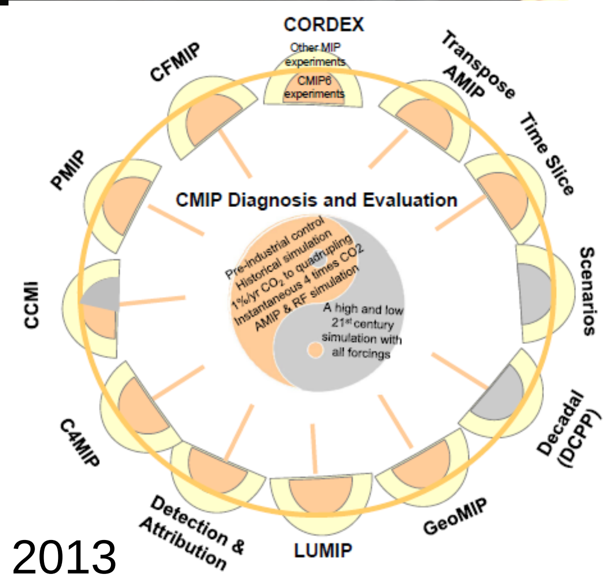
Based on an extensive period (three years) of community consultation

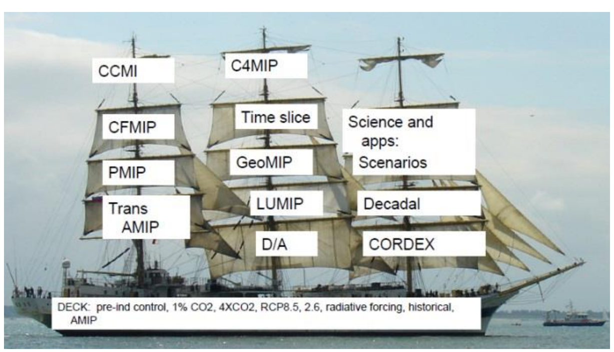
- **Summer 2013 CMIP5 survey** that was presented at the CMIP6 Aspen planning meeting and further at the WGCM/AIMES 2013 meeting.
- Initial proposal for the design of CMIP6 (Meehl et al., EOS, 2014).
- Feedback on this initial CMIP6 proposal has being solicited until September 2014.
- The WGCM and the 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.
- **CMIP5 Scientific Gaps and Recommendations for CMIP6 (Stouffer et al., BAMS, in rev. 2016)**

Planning Workshop: How will CMIP6 look like?

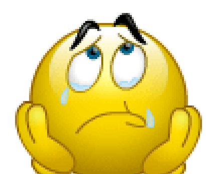


Ron





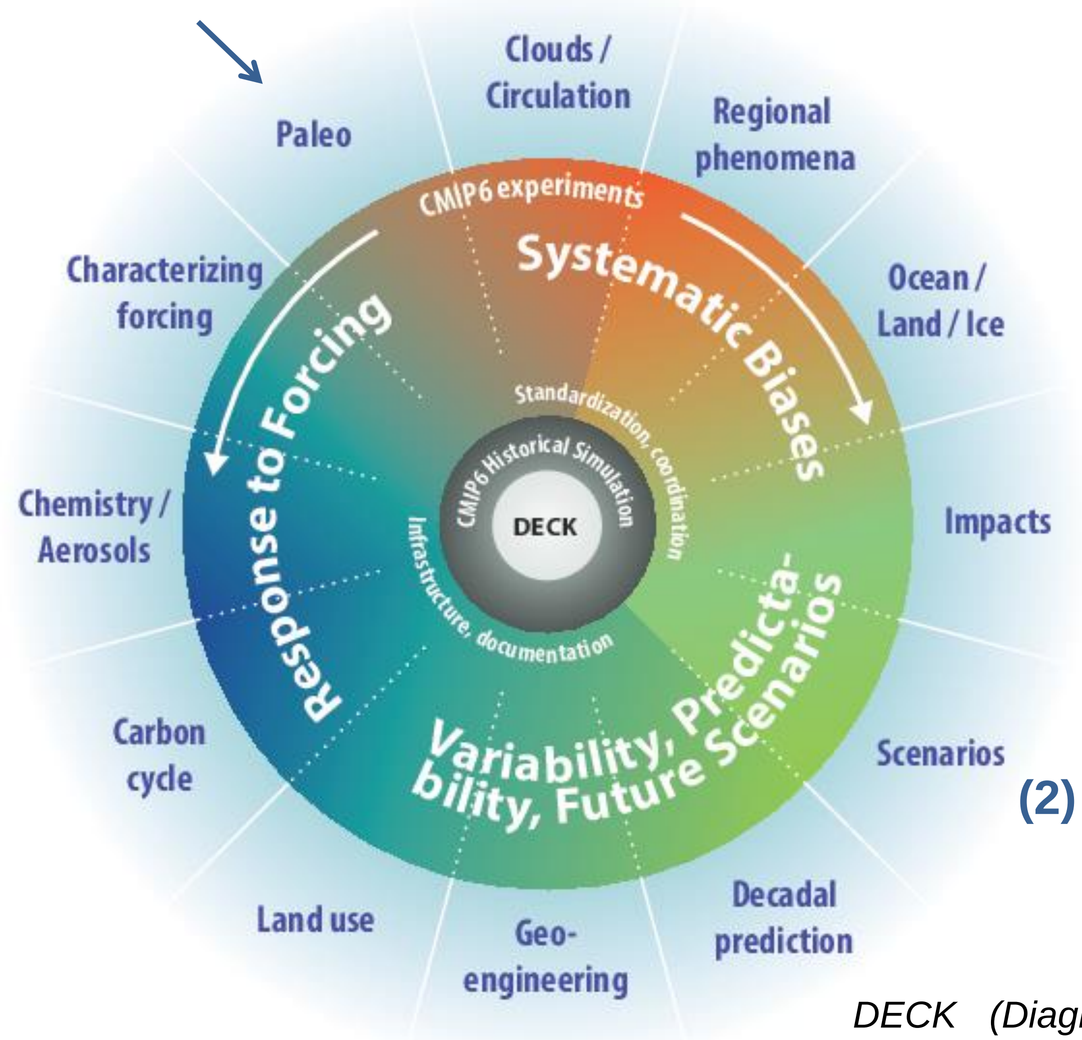
WGCM17 , Victoria, 1-3 Oct 2013



No Ron

CMIP: a More Continuous and Distributed Organization

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



Eyring et al. (incl. Stouffer), GMD, 2016

(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_2 increase
iv. Abrupt 4xCO_2 run

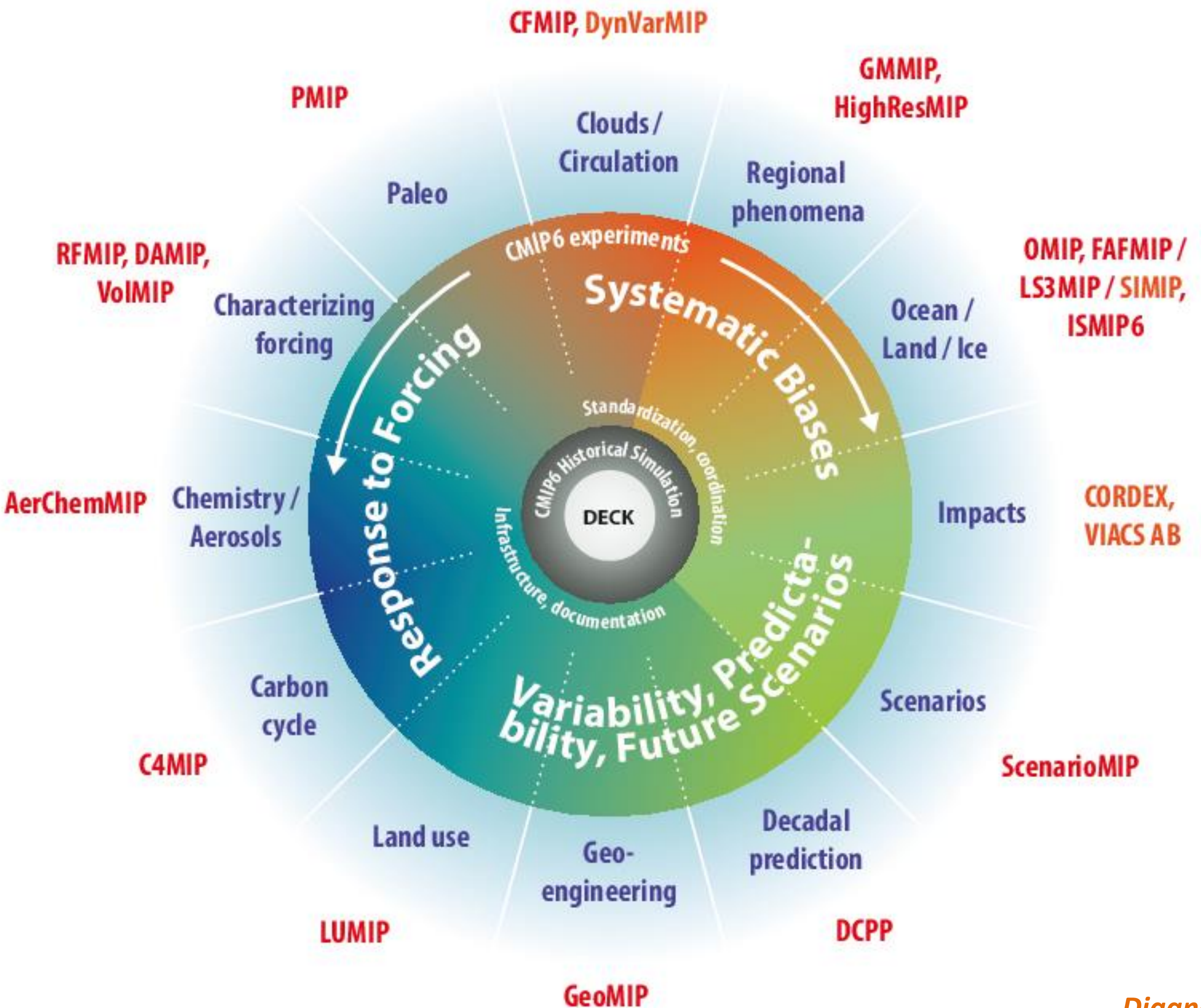
CMIP6 Historical Simulation (entry card for CMIP6)

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



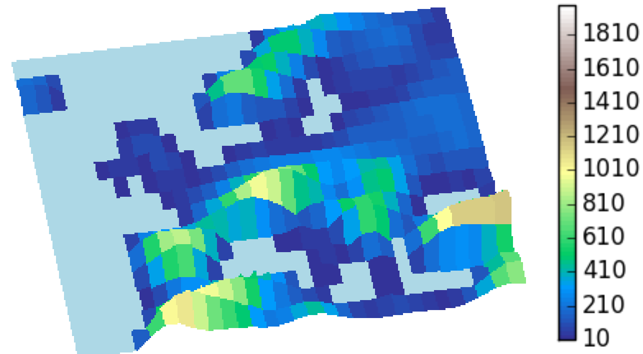
Eyring et al. (incl. Stouffer), GMD, 2016

Diagnostic MIPs

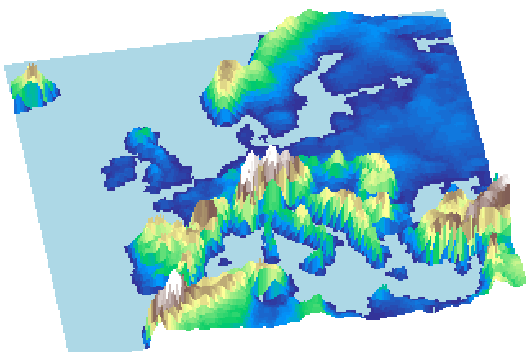
Models are Increasing in Complexity and Resolution

From AOGCMs to Earth System Models with biogeochemical cycles, from lowres to highres

130 km resolution orography

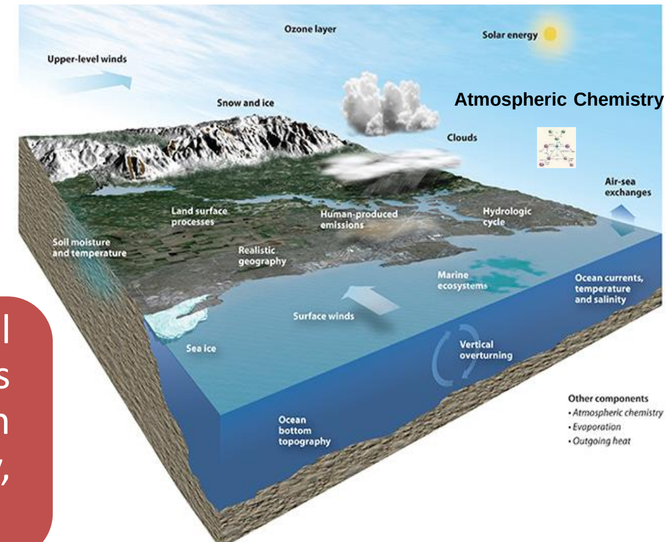


25 km resolution orography

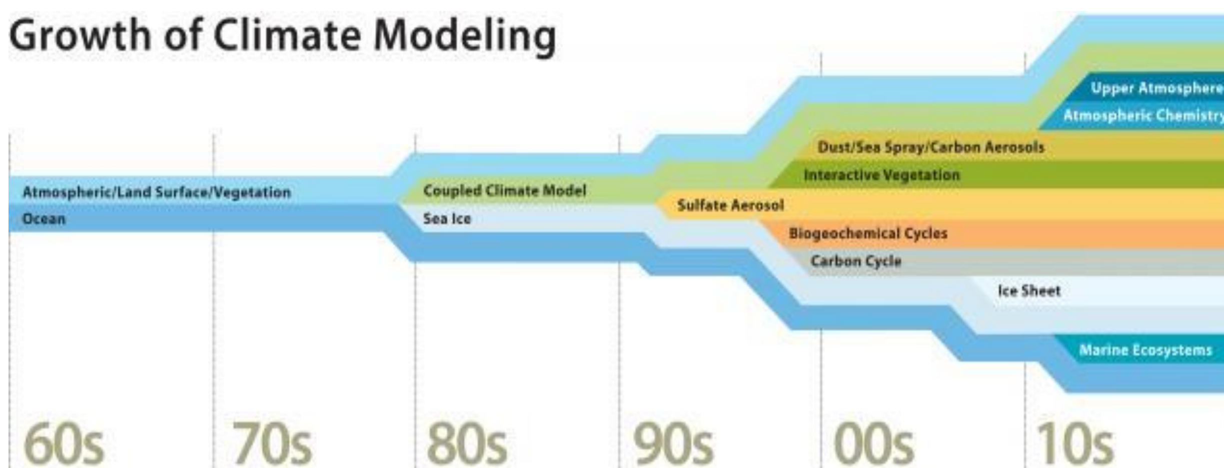


II. Allows to study processes as horizontal resolution is increased to “weather-resolving” global model resolutions (~25km or finer)

I. Improvements in physical processes already included in GCMs



III. Allows to study new physical and biogeochemical processes and feedbacks (e.g., carbon cycle, permafrost, chemistry, aerosols, ice sheets)



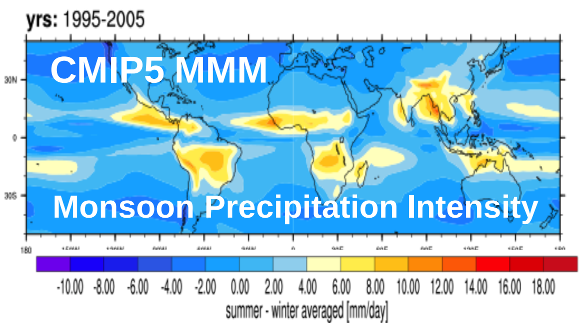
https://www2.ucar.edu/news/understanding-climate-change-multimedia-gallery

How to characterize the wide variety of models in CMIP6?

- Routine Benchmarking and Evaluation Central Part of CMIP6 -

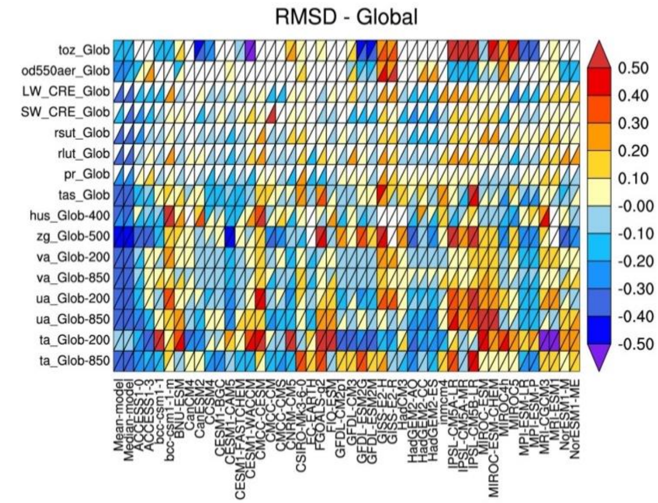
Tools as the community-developed **Earth System Model Evaluation Tool** (**ESMValTool**, *Eyring et al., GMD (2016b) incl* **NCAR CVDP** *(Phillips et al., 2014)*) and **PCMDI Metrics Package** (**PMP**, *Gleckler et al., EOS (2016)*) to produce well-established analyses as soon as CMIP model output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

Similar to ***Figure 9.7*** *of AR5*



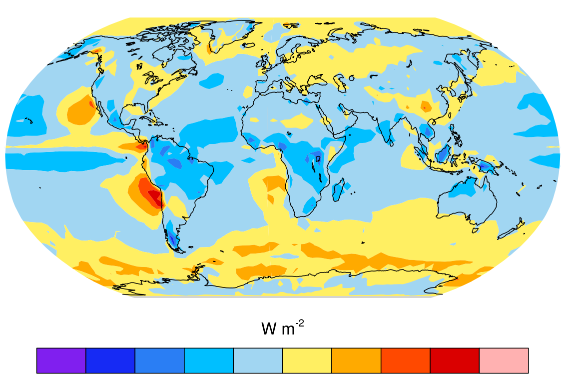
Broad Characterization of Model Behavior
(incl. IPCC AR5 Chap 9 & 12 diagnostics in ESMValTool)

Running alongside the ESGF

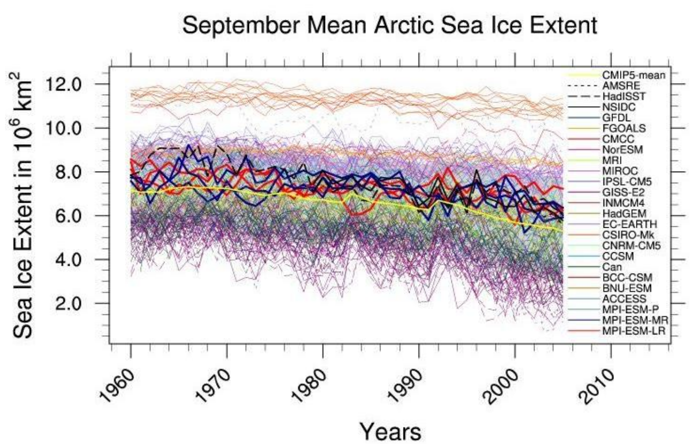


Similar to ***Figure 9.5*** *of AR5*

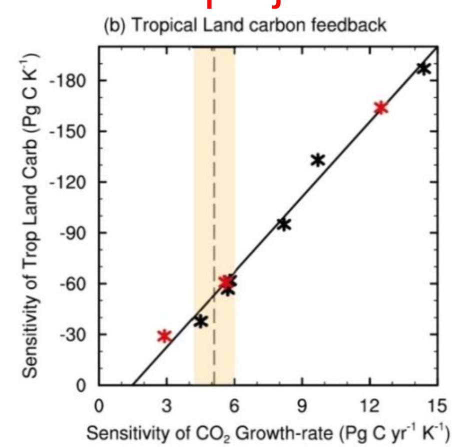
Net Cloud radiative effect against CERES EBAF



Similar to ***Figure 9.24*** *of AR5*



Link to projections



Similar to ***Figure 9.24*** *of AR5*

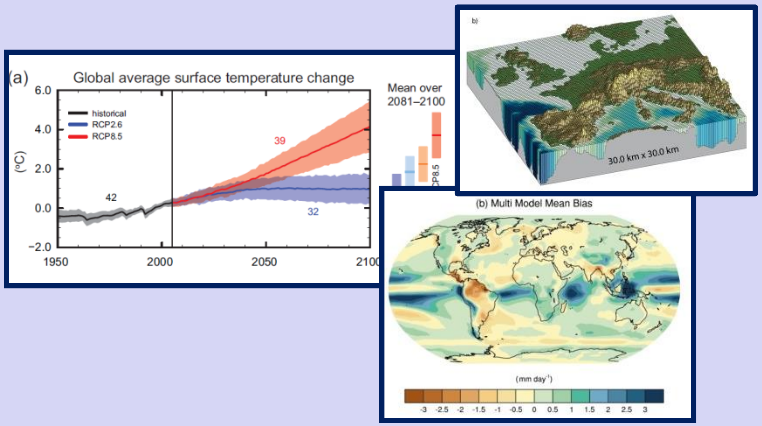
In collaboration with GFDL (J. Krasting & E. Mason, supported by Ron)

Under-Exploited Observations for Model Evaluation

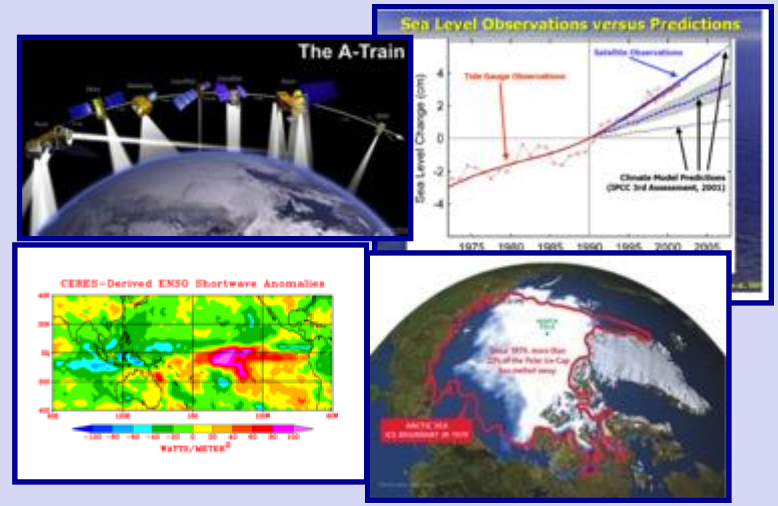
Observations for Model Intercomparison Projects (obs4MIPs)

WCRP Data Advisory Council's (WDAC) Task Team on Observations for Model Evaluation

Co-Chairs: Peter Gleckler and Duane Waliser



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

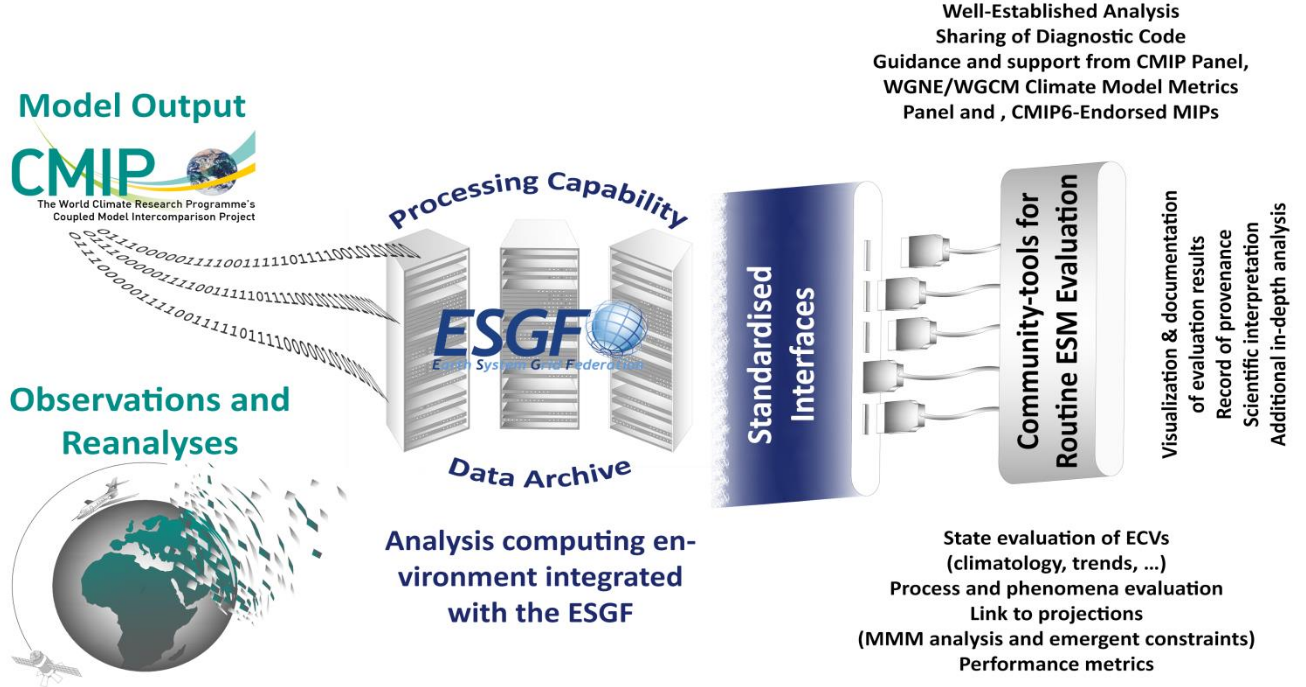


How to best utilize the wealth of satellite observations for the CMIP process?

- 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., BAMS, 2014), including ESA CCI data
- Obs4MIPs has been enthusiastically received by the community; archive is growing
- Sister project ana4MIPs hosting reanalyses data

Routine Benchmarking and Evaluation Central Part of CMIP6

- We argue that the community has reached a critical juncture at which many baseline aspects of ESM evaluation need to be performed much more efficiently
- The resulting, increasingly systematic characterization of models will, compared with early phases of CMIP, more quickly and openly identify strengths & weaknesses of the simulations.
- Emphasize diagnostics & metrics that have demonstrated their importance in ESM
- Evaluation tools designed to facilitate community-development
- This activity also aims to assist modelling groups in improving their models
- Running alongside the ESGF, as soon as the output is published

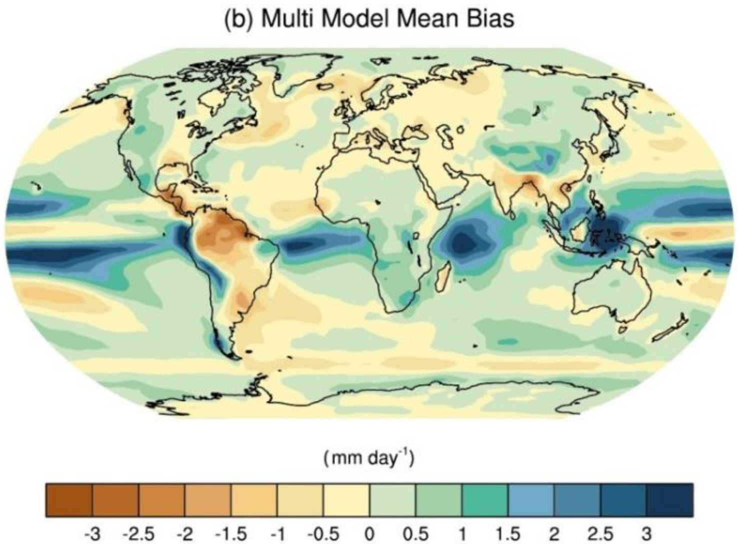


Eyring et al. (incl. Stouffer), ESD, in prep. (2016); Companion paper to Stouffer et al. BAMS, in rev. (2016)

Climate models have continued to be developed and improved since AR4, but further research is required, e.g.

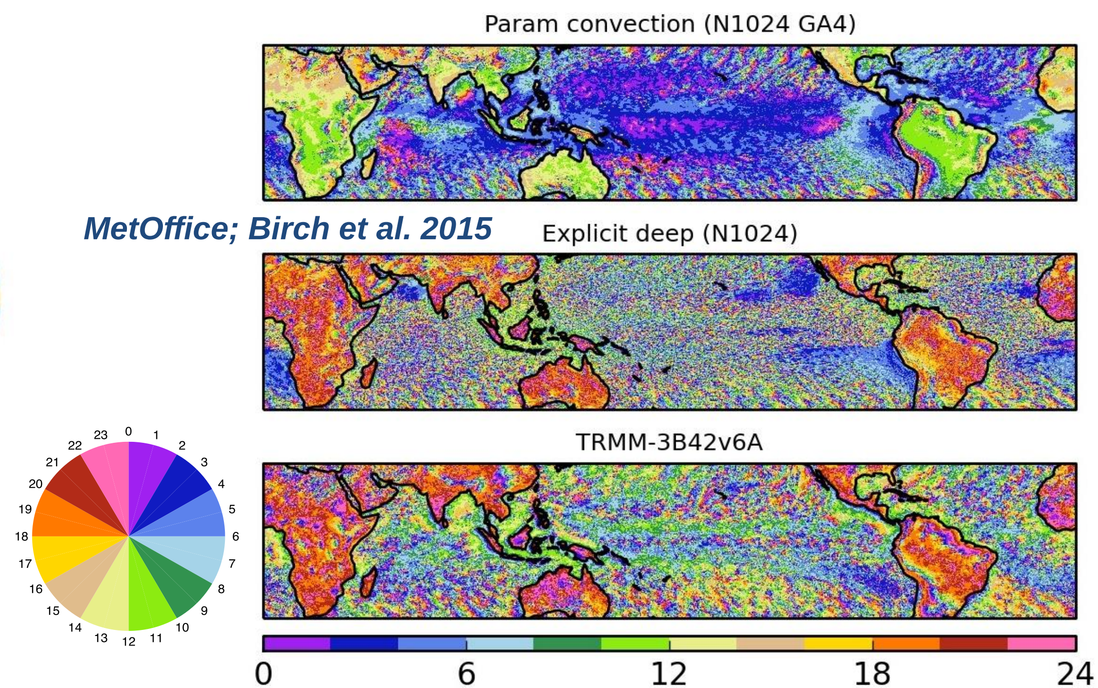
- **Better understanding of internal variability and key processes**
- **Observations for model evaluation…**
  - In many cases the lack or insufficient quality of long-term observations or observations for process evaluation remains an impediment.
  - For many observational datasets formal error estimates are lacking.
- **Systematic Biases:** e.g., Double Intertropical Convergence Zone (ITCZ), i.e. spurious ITCZ in the SH associated with excessive tropical precipitation or the diurnal cycle in precipitation
- **Continuous investment in model improvements**

Precipitation Bias in CMIP5



Produced with ESMValTool v1.0

MetOffice; Birch et al. 2015



Equilibrium Climate Sensitivity Remains Uncertain

Defined as the **change in global mean surface temperature at equilibrium that is caused by a doubling of the atmospheric CO_2 concentration**.

	TAR	AR4	AR5
ECS	Likely range: 1.5 to 4.5°C	*likely* range: 2.0 to 4.5°C *very unlikely* <1.5°C – best estimate about 3°C	***likely* range: 1.5 to 4.5°C** ***extremely unlikely* <1.0°C** ***very unlikely* >6.0°C** –

The model spread in ECS ranges from **2.1°C to 4.7°C** and is very similar to the assessment in AR4 (IPCC AR5, Chapter 9).

Large Uncertainty Remains in Some Projected Variables

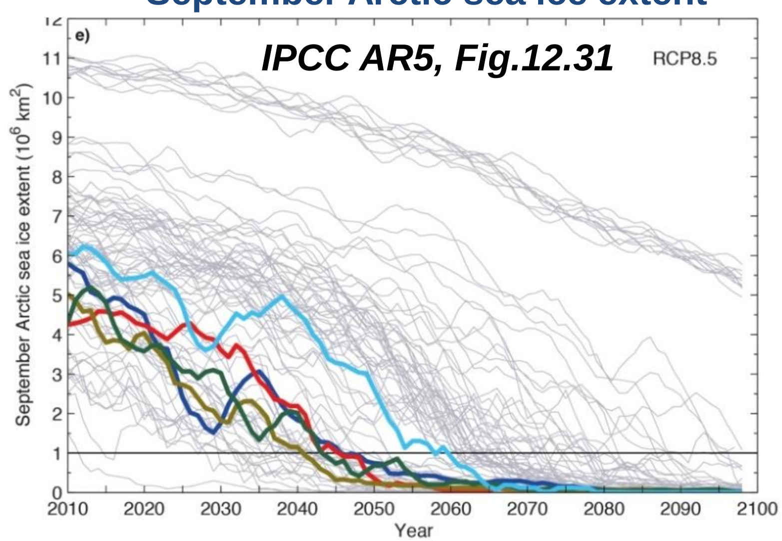
Is the multi-model mean always the best measure?

The spread of an ensemble of models is often used as a first-order estimate of projection uncertainty

– Despite the fact that models differ in terms of resolution, processes and components included, and agreement with observations.

– Despite there is inter-model dependence

September Arctic sea ice extent

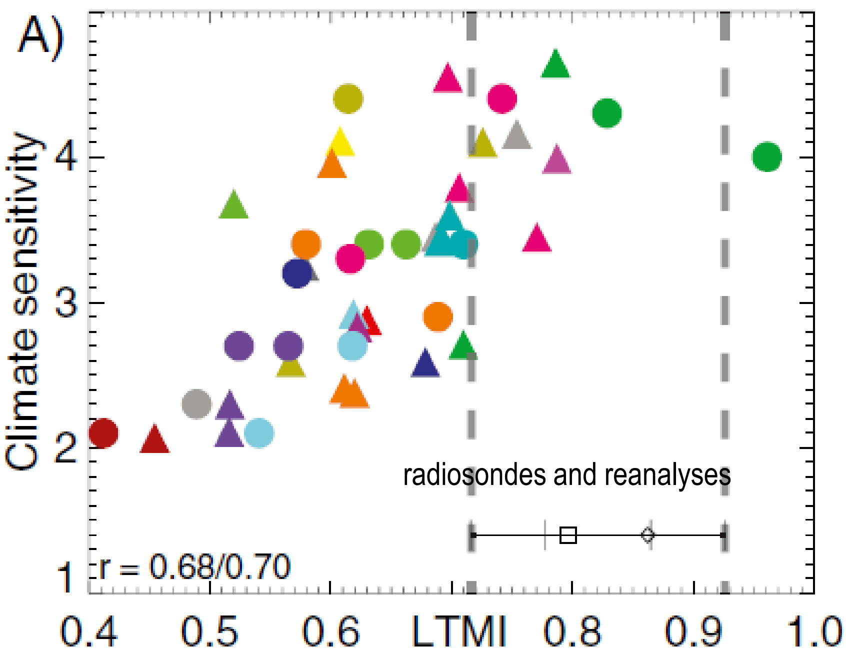


Emergent Constraints on Climate Sensitivity

ECs are a relationship across an ensemble of models, between some aspect of **Earth system sensitivity and** an **observable trend or variation** in the current climate

- Offer the potential to **reduce uncertainty in climate feedbacks and projections**.
- A necessary property of emergent constraints is a physical basis for the relation.
- Can **help guiding model development onto processes crucial to the magnitude and spread of future climate change** and **to guide future observations.**

Sherwood et al., Nature, 2014



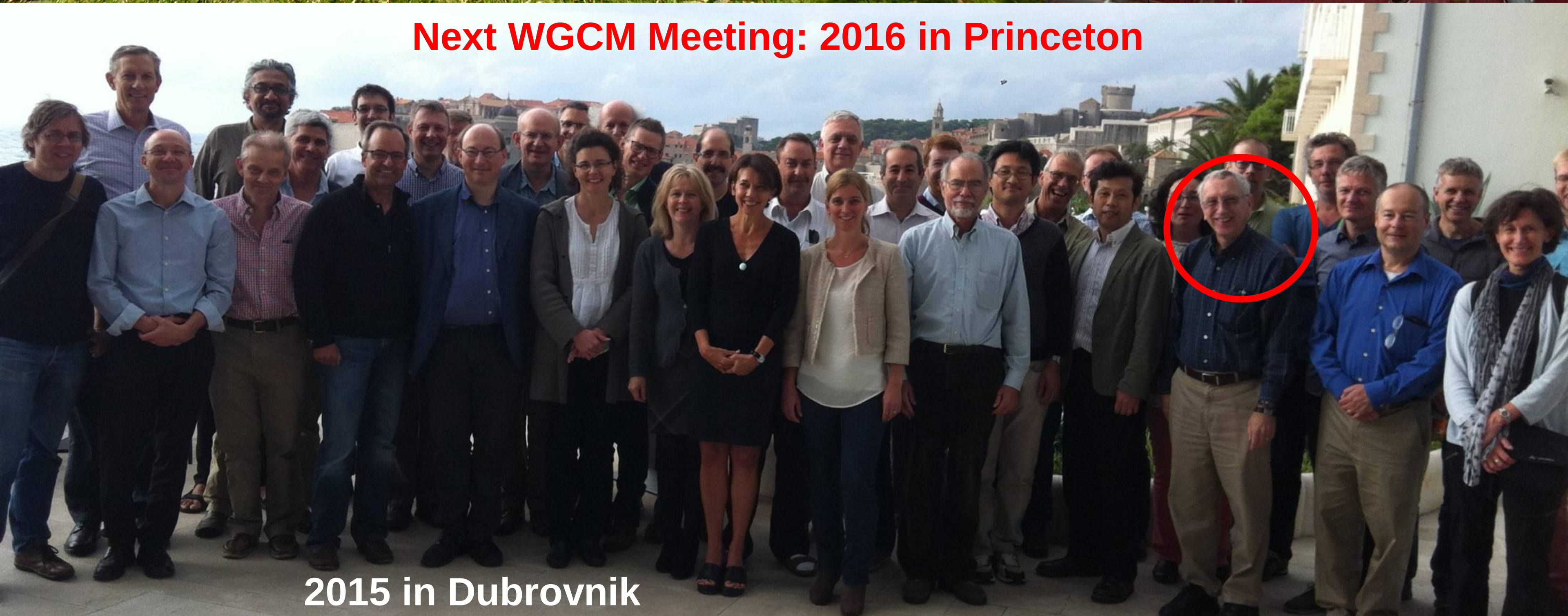
- ECS spread largely from feedbacks in low clouds
- Relates ECS to the strength of mixing over warm tropical oceans via the "Lower Tropospheric Mixing Index (LTMI)"
- Higher-sensitivity models simulate certain cloud-relevant phenomena better, constraining projections towards severe future warming

Better observations are required to constrain key climate feedbacks

WGCM meets Ron


2014 in Grainau


2012 in Hamburg


Next WGCM Meeting: 2016 in Princeton

2015 in Dubrovnik

Summary Model Evaluation

- Many baseline aspects of model evaluation need to be performed much more efficiently to enable a rapid and improved performance assessment of the diverse set of CMIP6 models.
- Systematic evaluation of CMIP simulations with community-based capabilities such as the **ESMValTool** and **PMP** are needed to:
  - Advance scientific understanding more efficiently (less re-inventing)
  - Facilitate model development (via quick feedback) and benchmarking
  - Valuable resource for a variety of demands (assessments, etc.)
  - Leave more time for innovative research, e.g. identifying the processes that are most responsible for systematic biases and the magnitude and uncertainty of future projections
- **The wider community is encouraged to contribute code to the evaluation tools**

Summary Ron and CMIP

Ron plays a crucial role in coordinating CMIP and formulating the multi-model climate change experiments as a service to the international climate science communities since 1990

and in performing state-of-the-art analyses to advance the science.