Overview of the Week, Goals & Context

Veronika Eyring, Peter Cox, Greg Flato, and Peter Gleckler

AGCI Session

Earth System Model Evaluation to Improve Process Understanding

July 30 – August 4, 2017

Aspen, CO

Goal and Envisaged Outcome of the Workshop

Goal: This workshop brings together a small but varied group of scientists to 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 - observable aspects of the contemporary Earth System that are most closely related to future projections.

Main topics addressed at the workshop:

- Evaluation tools and workflow for routine model evaluation in CMIP6
- Progress in process understanding and understanding of systematic biases
- Uncertainty in observations and model evaluation
- User oriented metrics (impacts, extreme events)
- Climate/Earth System Sensitivity and Emergent Constraints
- Weighting based on model performance and interdependence

Envisaged outcome

- Forward-looking perspective in Nature Climate Change focusing on recommendations for new research and knowledge gaps that could be filled.
- Should provide guidance for IPCC AR6 by facilitating the assessment of the models in IPCC WG I and by supporting WGs II and III through a better quantification of related uncertainties.

=> Each breakout group will be tasked with planning sections of the final paper

Context and Relevance

The evaluation of ESMs with observations is crucial for model improvements and a better process understanding of the climate system. It is also a vital prerequisite for trustworthy climate projections to be used for policy guidance.

Challenges and Opportunities for CMIP6:

1. Make the evaluation of CMIP models with well-established diagnostics and performance metrics **more routine** (by developing/applying ESMValTool / PMP).
2. **Fully exploiting existing observations** while **taking into account observational uncertainty** and internal **climate variability**.
3. More **process-oriented evaluation.**
4. Model evaluation also needs to be expanded to develop more **downstream, user-oriented diagnostics and metrics** that are relevant for impact studies and to better communicate **uncertainties across IPCC Working Groups**.
5. The studies on **Emergent Constraints and Weighting Model Ensembles**

   help quantifying and reducing uncertainties in key climate feedbacks and projections

   can be used to draw conclusions for critical questions such as allowable CO_2 emissions for a specific temperature target.

   help guiding model development onto processes crucial to the magnitude and spread of future climate change and to guide future observations.

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

- **Observations for model evaluation…**

  In many cases the lack or insufficient quality of long-term observations or observations for process evaluation remains an impediment.

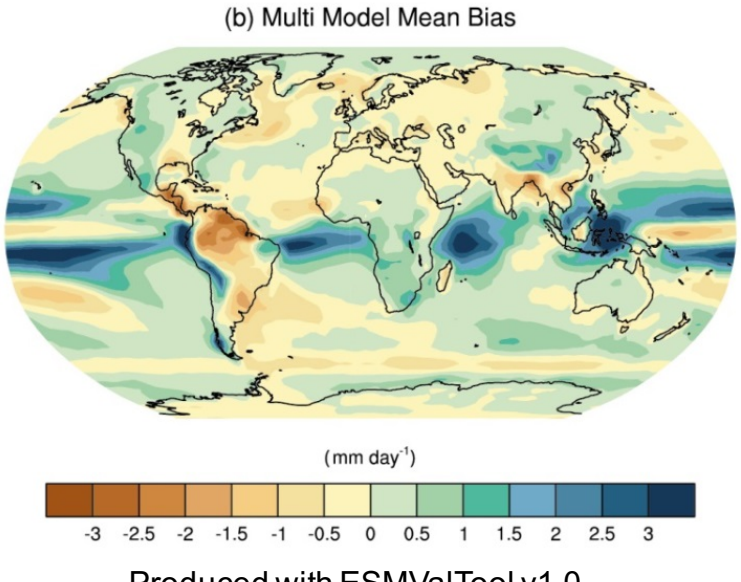
  For many observational datasets formal error estimates are lacking.

- **Better understanding of internal variability and key processes**

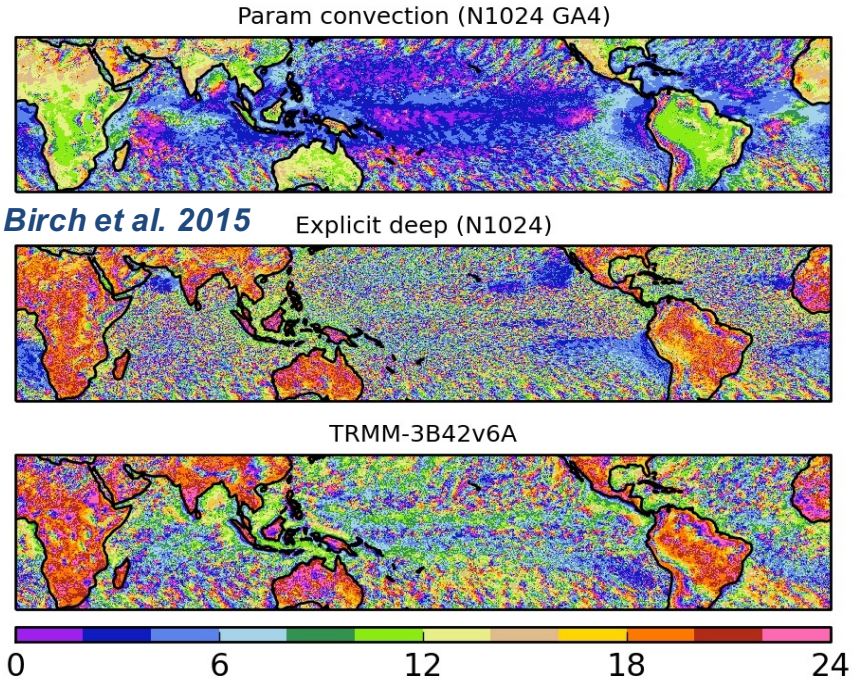
- **Systematic Biases:** e.g., Double Intertropical Convergence Zone (ITCZ), i.e. spurious ITCZ in the SH associated with excessive tropical precipitation or the diurnal cycle in precipitation

=> Continuous investment in model improvements

Precipitation Bias in CMIP5



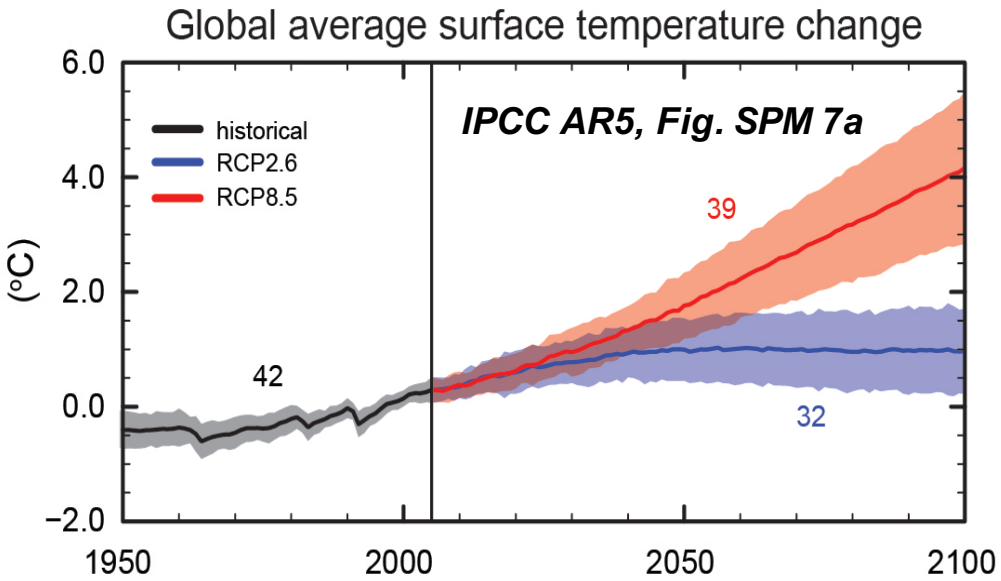
MetOffice; Birch et al. 2015

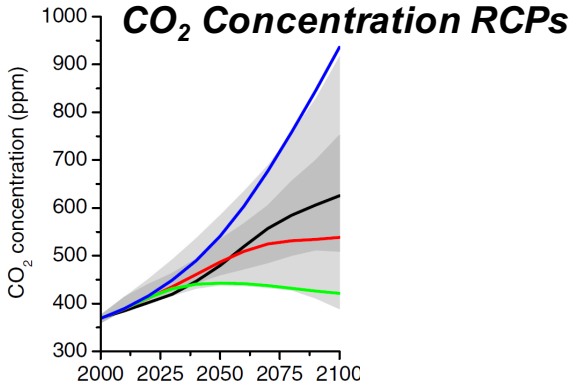


Climate Model Projections

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

- Climate projections in **AR5** based on **climate model output coordinated by CMIP5.**
- **Multi-model mean and spread is commonly used for climate projections**
  1. Spread of model ensemble often used as first-order estimate of projection uncertainty.
  2. Used to determine why similarly forced models produce a range of responses.
- Missing relation between **model performance** and **future projections**





Distillation of robust information from multi-model output is needed for science and as evidence for policy-making

DLR

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

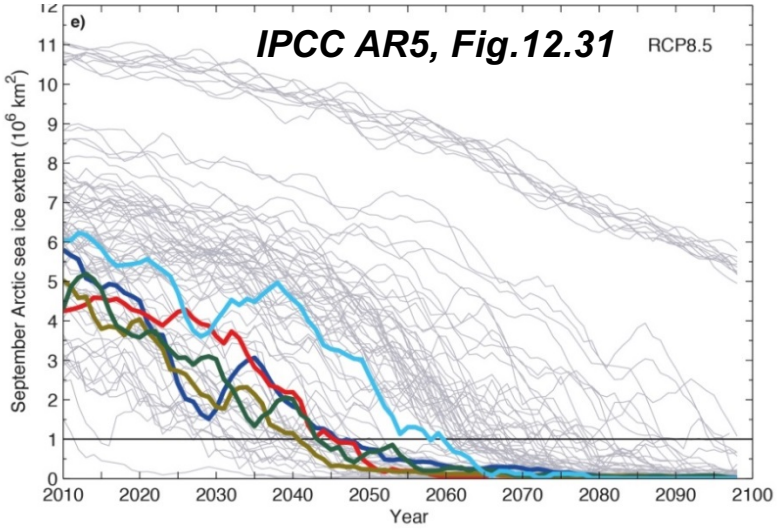
Is the multi-model mean always the best measure?

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.

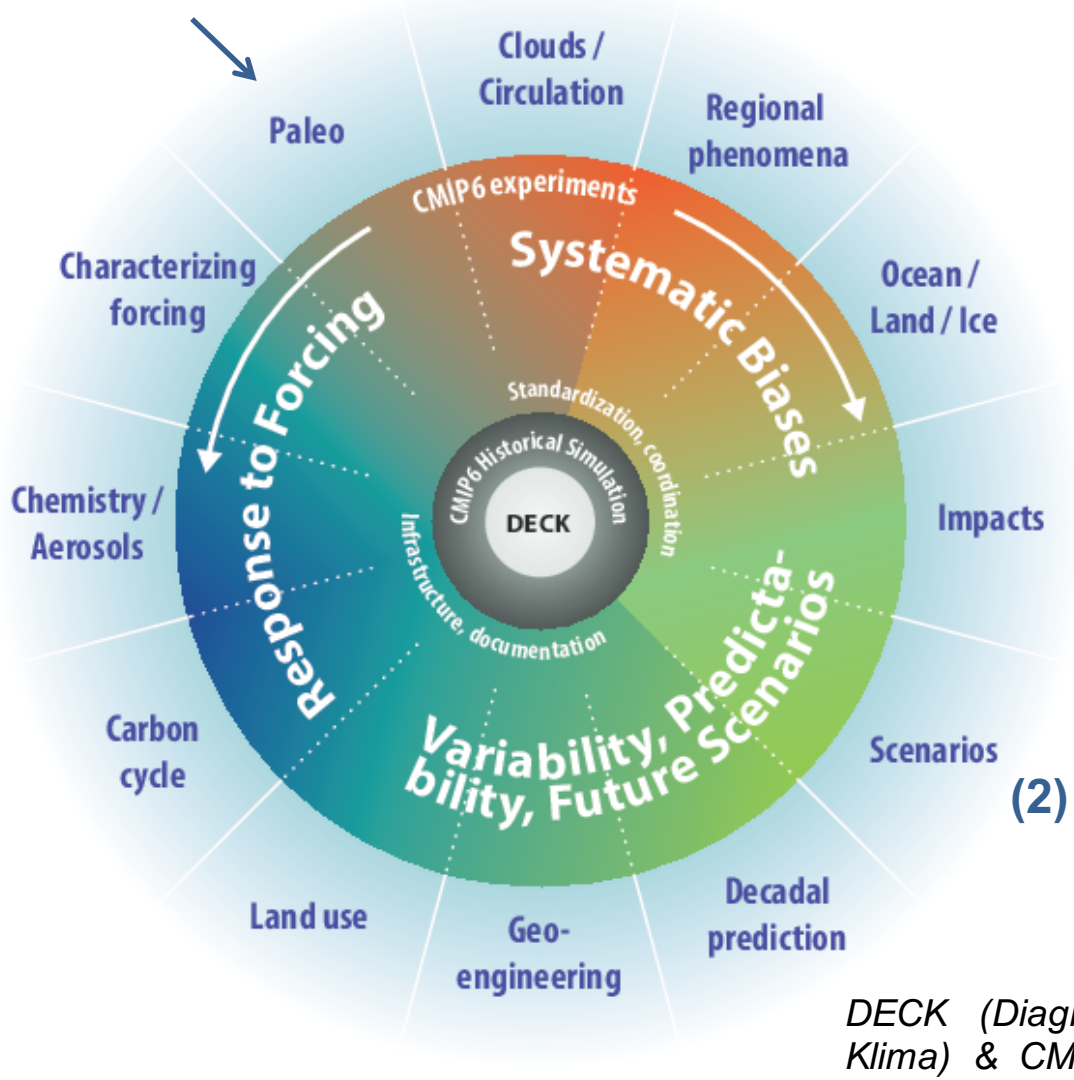
Despite there is inter-model dependence

September Arctic sea ice extent



CMIP: a More Continuous and Distributed Organization

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



Eyring et al., 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)

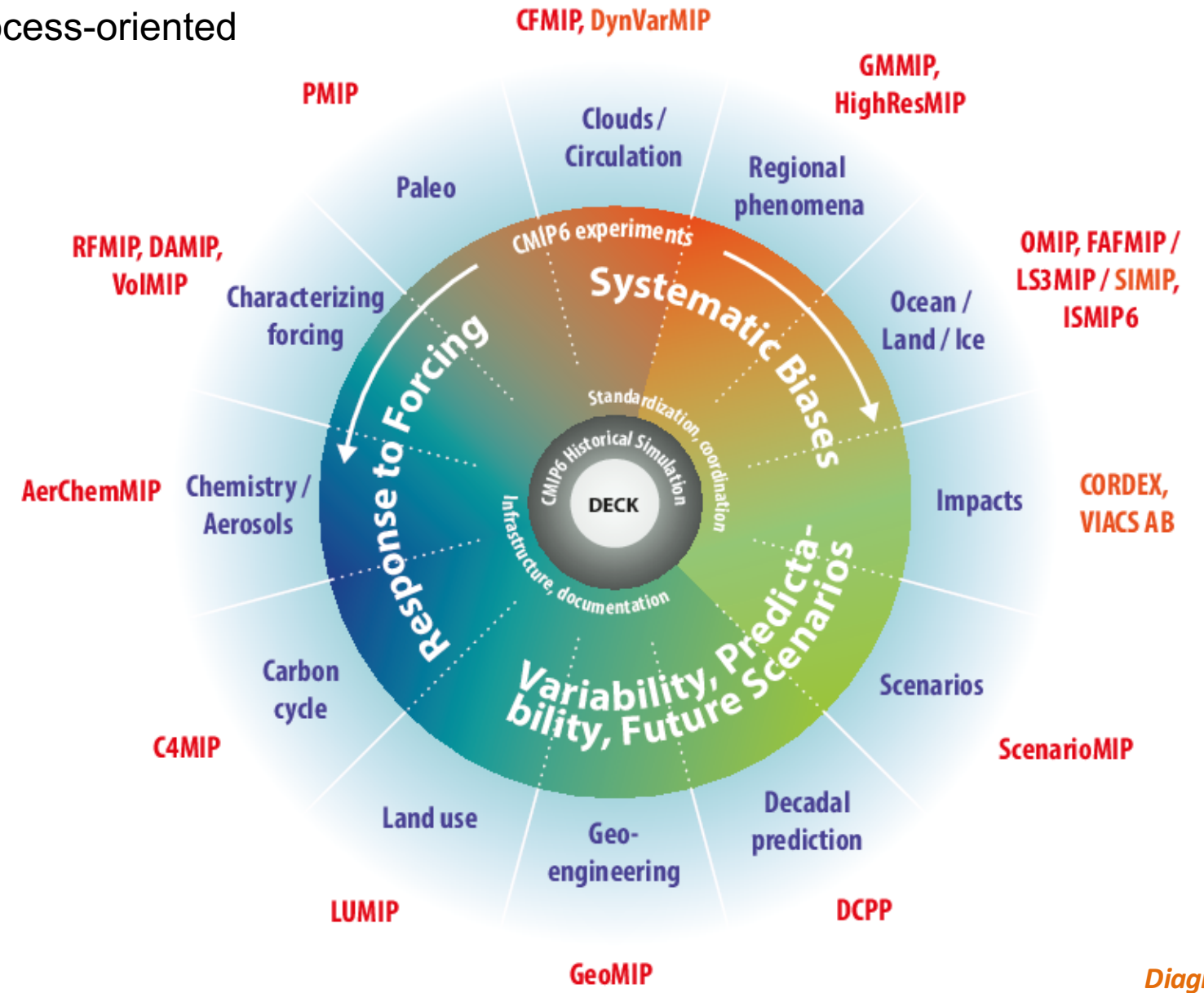
v. Historical simulation using CMIP6 forcings (1850-2014)

(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

=> process-oriented



Diagnostic MIPs

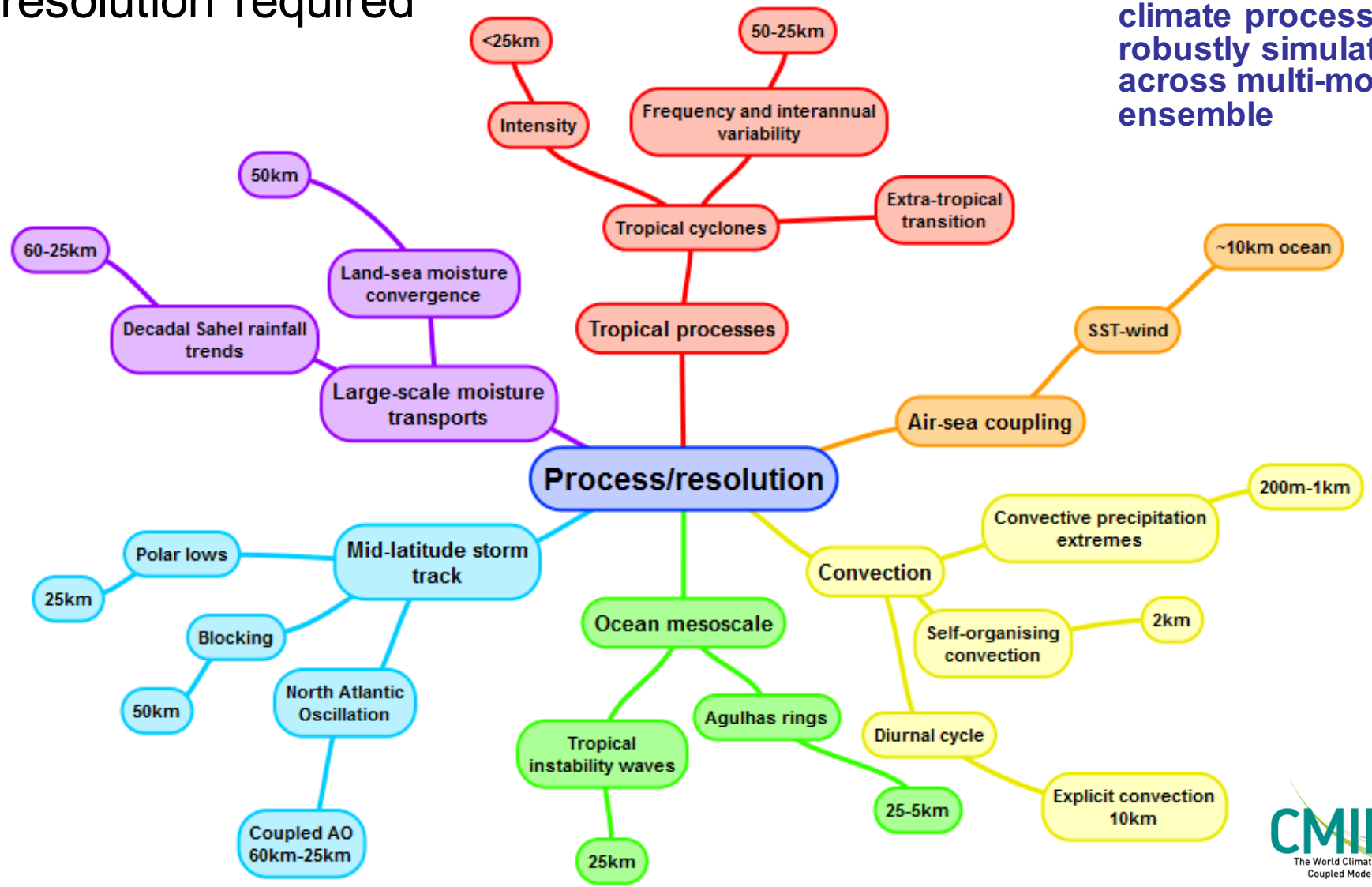
Eyring et al., GMD, 2016

CMIP6-Endorsed Model Intercomparison Project HighResMIP

Co-chairs: Rein Haarsma & Malcolm Roberts

Example map of climate process and model resolution required

Aim: to discover at what resolution climate processes are robustly simulated across multi-model ensemble



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

Examples for New Scientific Methods and Approaches

1. **General model evaluation supported by new CMIP evaluation tools important**
2. **Fitness-for-purpose evaluation**

   Additionally identify "purpose" (e.g. purposes might be projections, regional information, impact studies, mitigation pathways, physical understanding)

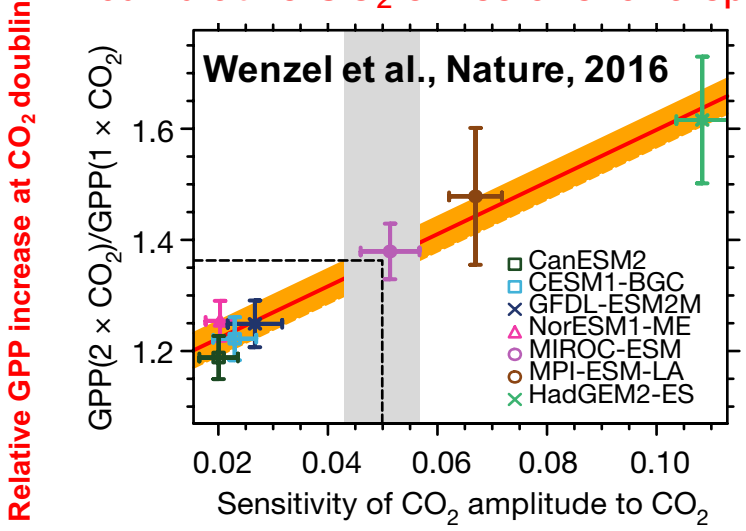
   Process-oriented, process-based, regime-based evaluation can be done better given expanded suite of MIPs in CMIP6 => Needs to be fully exploited

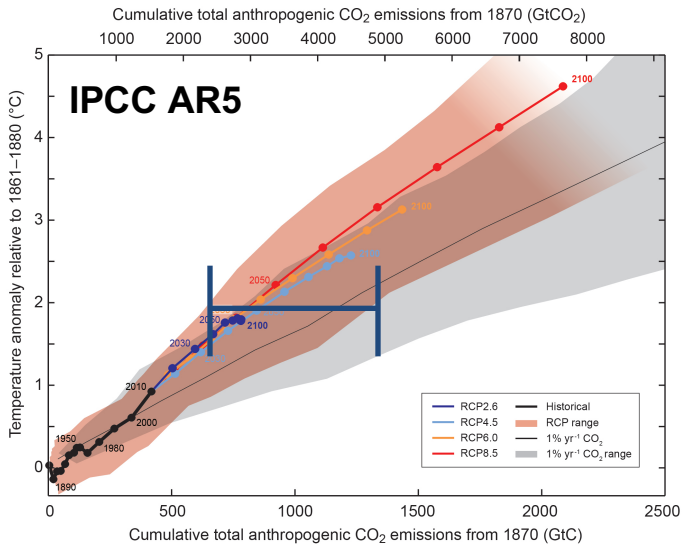
   Large number of metrics, process-based, and ensuring that new ones arriving all the time.

3. **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_2 emissions for a specific temperature target (TCRE, TCR, ECS).





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

- This meeting was organized to bring together a small, but varied, group of scientists to discuss the question of how model evaluation informs us of a model's fitness for a particular application, e.g.
  - detection and attribution of climate change
  - seasonal to decadal climate prediction,
  - long-term climate projection,
  - informing climate impact or mitigation studies,
  - Physical understanding.

  => Performance measures may be different when applied to different purposes

- The fundamental issue is that evaluation of climate models, making use of historical and paleoclimate observations, does not directly inform us about the quality, skill, or trustworthiness of a particular model in the applications listed above. This arose very clearly in the preparation of the WG-I contribution to the AR5 and was reiterated in the WCRP/IPCC 'Lessons Learnt' workshop.

- The objective of the meeting was to discuss ways **in which model evaluation can be better linked to model fitness**, and to provide guidance for research.

- A brief summary paper is in preparation

Agenda (1)

Welcome and Introductions

9:00 am **John Katzenberger** – Welcome

9:05 am **Co-Chairs** – Overview of the Week, Goals & Context

9:20 am Extended introductions for each participant

[Time to offer brief perspectives relevant to session topic and cross-cutting questions to stimulate thought throughout the week]

Block of 8 Sessions with two 30min motivating talks, discussion and breakout group each

Part I: Historical View of Model Performance, and the Role of Models in Understanding the Climate System

Part II: Opportunities from New Observations and Observational Uncertainty in the Context of Model Evaluation

Part III: Application of New CMIP Evaluation Tools to CMIP5/6 Models, Workflow

Part IV: Large-Scale Persistent Systematic Biases

Part V: Progress in Process Understanding (Sectorial)

Part VI: Emergent Constraints on Climate and Earth System Sensitivities

Part VII: Weighting Based on Performance and Interdependence

Part VIII: User and Policy Oriented Metrics and Applications

PLUS 1 additional BOG on Constraining ECS, TCR, and TCRE

Each morning co-chairs will synthesize as we go along

Agenda (2)

MONDAY, JULY 31

Dinner on your own

TUESDAY, AUGUST 1

6:00 pm **Walter Orr Roberts Memorial Public Lecture by Ben Santer** (Guests Welcome)

Title: How a Sentence Changed Science: Lessons Learned from the 1995 Climate Report

Location: Aspen Center for Environmental Studies, 100 Puppy Smith St

Wine and cheese reception to follow

WEDESDAY, AUGUST 2

Afternoon free for group or independent field trips, Hiking trip available (Guests Welcome)

5:30 pm Happy Hour – Aspen Brewing Company (Guests Welcome), 304 E Hopkins Ave

THURSDAY, AUGUST 3

6:30 pm Closing Reception & Dinner (Guests Welcome), **Pyramid Bistro**, 221 E Main St.

FRIDAY, AUGUST 4: Part IX Key Points & Synthesis

9:00 am **Group Discussion** - Key Findings and Synthesis

11:30 am Writing Assignments & Next Steps

12:00 pm ADJOURN

AGCI Science Session

- This is the 64th AGCI Session since the first one in 1990.
- In the category Key AGCI science session “Deep dive” (Meehl & Moss, 2017)

Many thanks to AGCI for hosting us!

Questions to be addressed during the workshop

"How much have models improved in the last 10 years?"

"How do we avoid 'diminishing returns' in model development?"

“Can we move towards a fitness-for-purpose evaluation?”

How can we improve feedback from the modeling community to help inform the design of observational priorities?

How do we know if it is forcings or errors?

“Can the new evaluation tools help to identify & understand model biases quickly?”

“Can we produce mind maps of climate process and model resolution / complexity required?”

“Can we make better use of ‘post-processing’ of model output to reduce the influence of systematic bias?”

How do we conceptualize model evaluation?

"Should model evaluation and tuning remain distinct?"

“How can tuning documentation strengthen the science rather than the contrary?”

"Is it time to go beyond 'model democracy‘ ?“

How can we provide better guidance for model development?

“How to consider ‘model interdependence’? Is the CMIP6 ensemble the range of possibilities”

"Which metrics of model evaluation are most relevant to future projections?“

“Can we better quantify the sources of uncertainty in model projections?”

"Where are the biggest opportunities to improve model performance and reduce uncertainties in future projections, stakeholders and society?”

Deeper dive into uncertainty and how this translates into what decision makers need?

How can we enhance and improve communication of science to the public and policy?

How do we encourage people to make available data and results and how do we encourage

Nature climate change perspective

- Peer-reviewed paper
- Lead author team: co-chairs
- Welcome contributions to the writing
- 3-4000 words

We would ask each breakout group to produce three slides with a bullet list on:

Key scientific advances since the AR5?

Shortcomings, gaps and opportunities?

Long-term perspective?