

# Evaluation of CMIP models with the ESMValTool

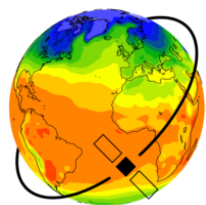
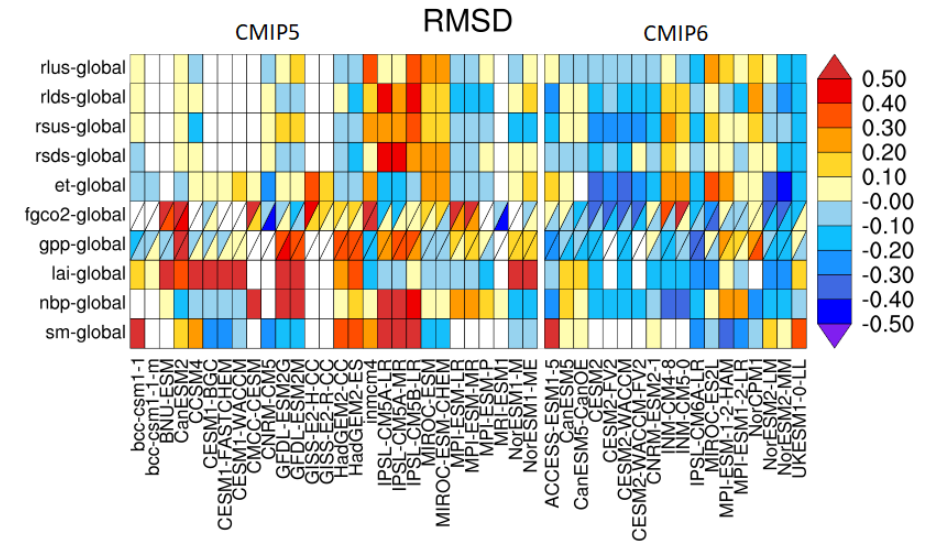
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<sup>1</sup>Deutsches Zentrum für Luft- und Raumfahrt (DLR)

<sup>2</sup>University of Bremen

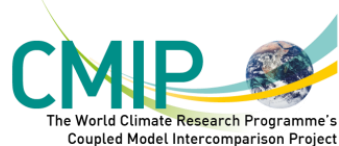
WGCM23

16 Dezember 2020



**ESMValTool**

Earth System Model Evaluation Tool



Knowledge for Tomorrow

# Motivation

## ➤ **Easier and faster evaluation of complex Earth System Models**

- Easy analysis of CMIP models
- Fast overview due to standard diagnostics, figures and variables
- Easy comparison of new model simulations with already existing runs and observations (e.g. obs4MIPs, ESA CCI)
- Easy application of common data operations (e.g. regridding, calculation of statistics, masking, etc.)

<https://www.esmvaltool.org>



# Major Goal CMIP6: Enhanced Routine Model Evaluation

## ➤ Improved quality standard for model evaluation

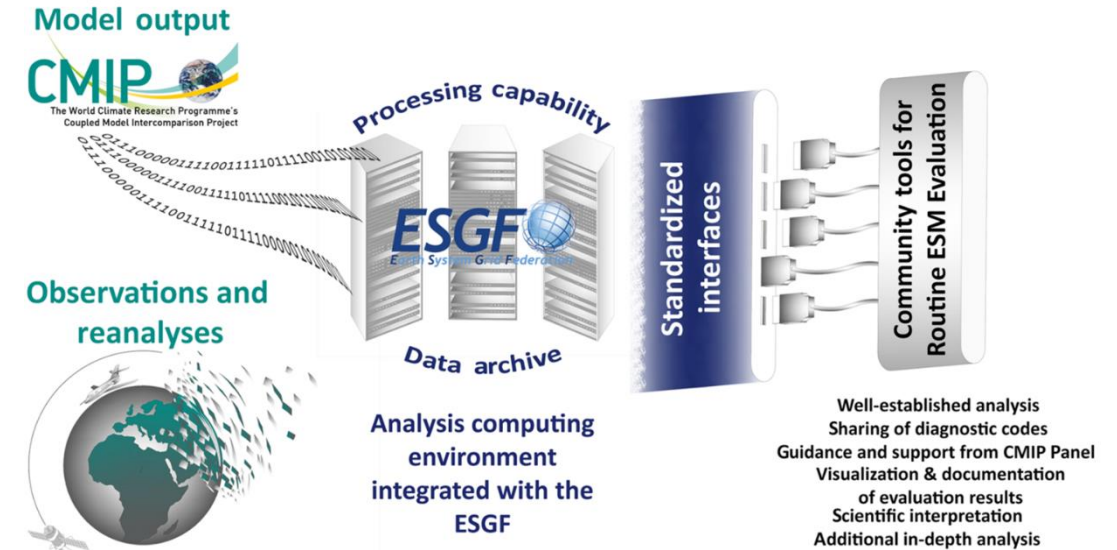
- Growing number of included diagnostics
- Reproduction of special reports or scientific papers with standard „recipes“
- Traceability and reproducibility of results

## ➤ Easily expandable

- Synergy with other software projects to expand the ESMValTool (e.g. NCAR CVDP)

## ➤ Coupling to Earth System Grid Federation (ESGF)

- Complete and rapid analysis of CMIP simulations



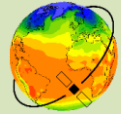
*Eyring et al., ESD (2016)*

<https://www.esmvaltool.org>





# Earth System Model Evaluation Tool (ESMValTool) Version 2.0



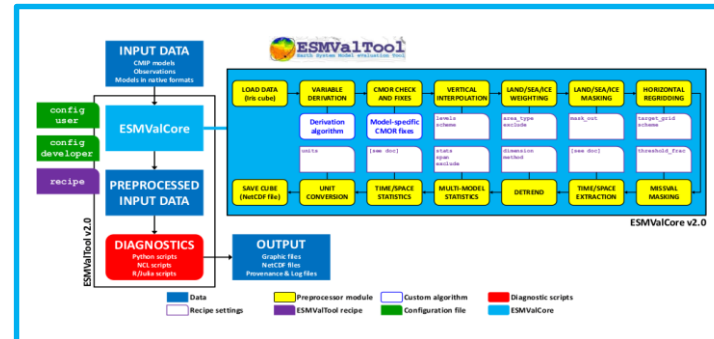
**ESMValTool**  
Earth System Model Evaluation Tool

**Release v2.0 August 2020**

- **Open source community development on GitHub** (> 200 developers, > 70 international institutes)
- **Rapid development** since the first release in 2016 with the support of FP7 / H2020 projects
- **Online documentation**
- **Now a well-tested tool** providing end-to-end provenance to ensure reproducibility
- Used in several **IPCC WGI AR6** chapters

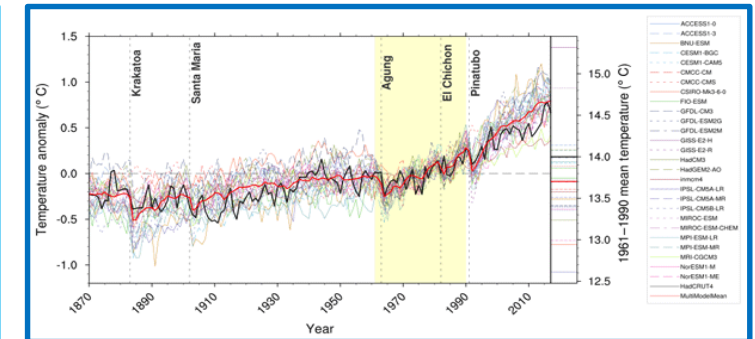
*Righi et al., GMD, 2020*

## Technical overview



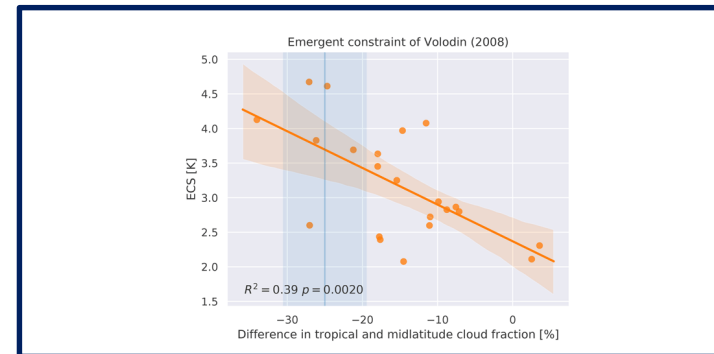
*Eyring et al., GMD, 2020*

## Large-scale diagnostics



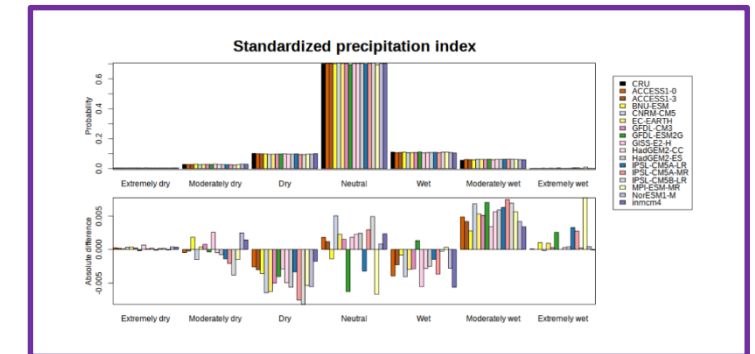
*Lauer et al., GMD, 2020*

## Diagnostics for emergent constraints and future projections



*Weigel et al., GMD, in review*

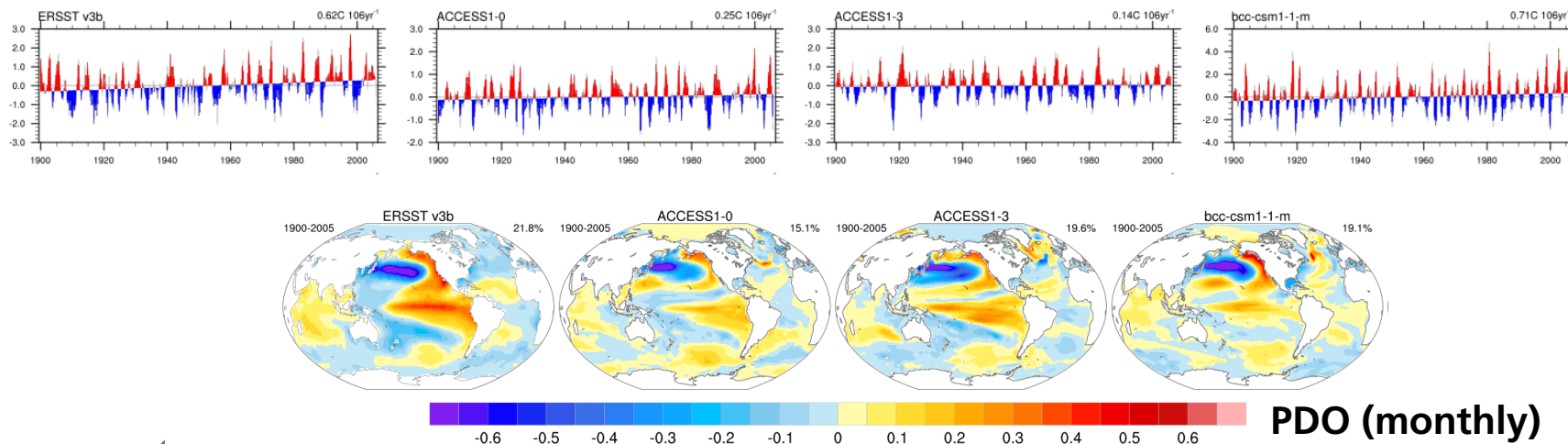
## Diagnostics for extreme events, regional and impact evaluation



# NCAR's Climate Variability Diagnostics Package (CVDP)

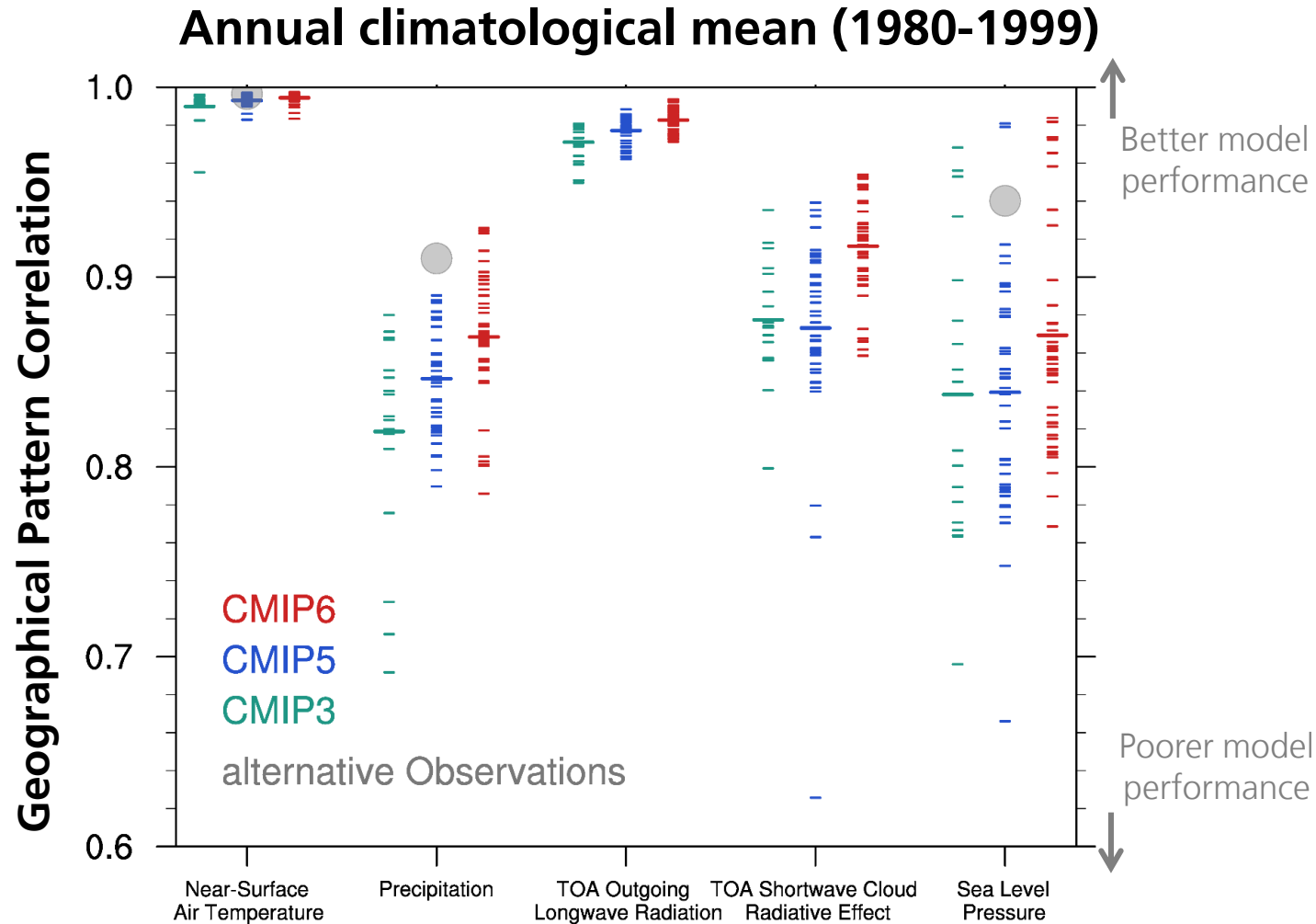
- **NCAR's CVDP has been implemented into the ESMValTool** in order to be able to run it within this framework and alongside the ESGF on CMIP output.
- CVDP can be used to evaluate the major modes of climate variability (e.g. ENSO, PDO, AMO, NAO, etc.).
- CVDP is developed as a **standalone tool outside the ESMValTool**. Once a new version of CVDP is released, the ESMValTool will be updated accordingly.

## Nino3.4 (monthly, -5:5N, 190:240E)



*Phillips et al., EOS (2014)*

# Earth System Models are Improving: Mean Climate



## Are climate models improving?

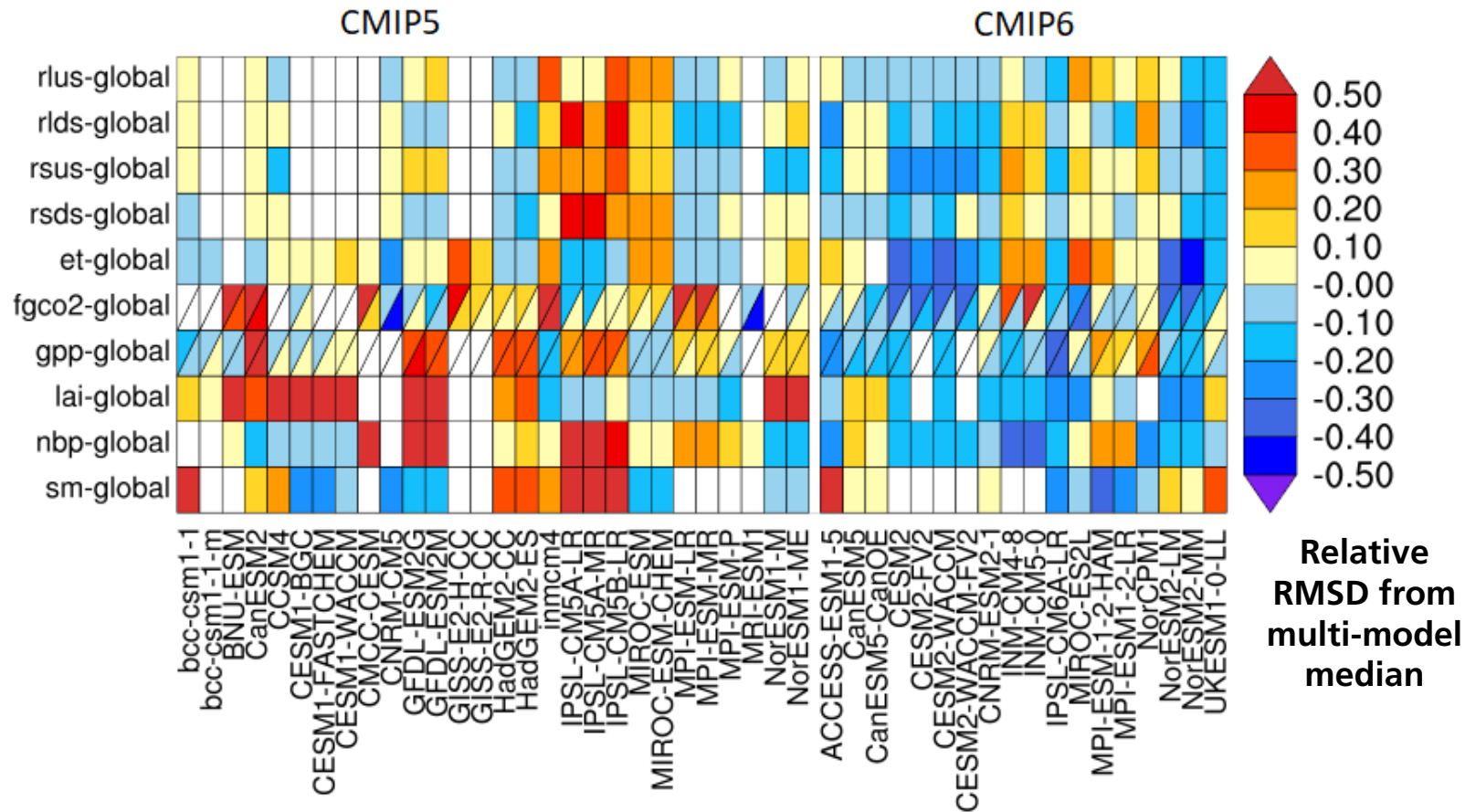
- Significant improvements in mean climate from CMIP3 to CMIP6 in **model performance**
- CMIP6 ensemble shows **mostly better model agreement**

*Bock et al., JGR: Atmospheres (2020)*



# Earth System Models are Improving: Carbon Cycle

## Performance Metrics



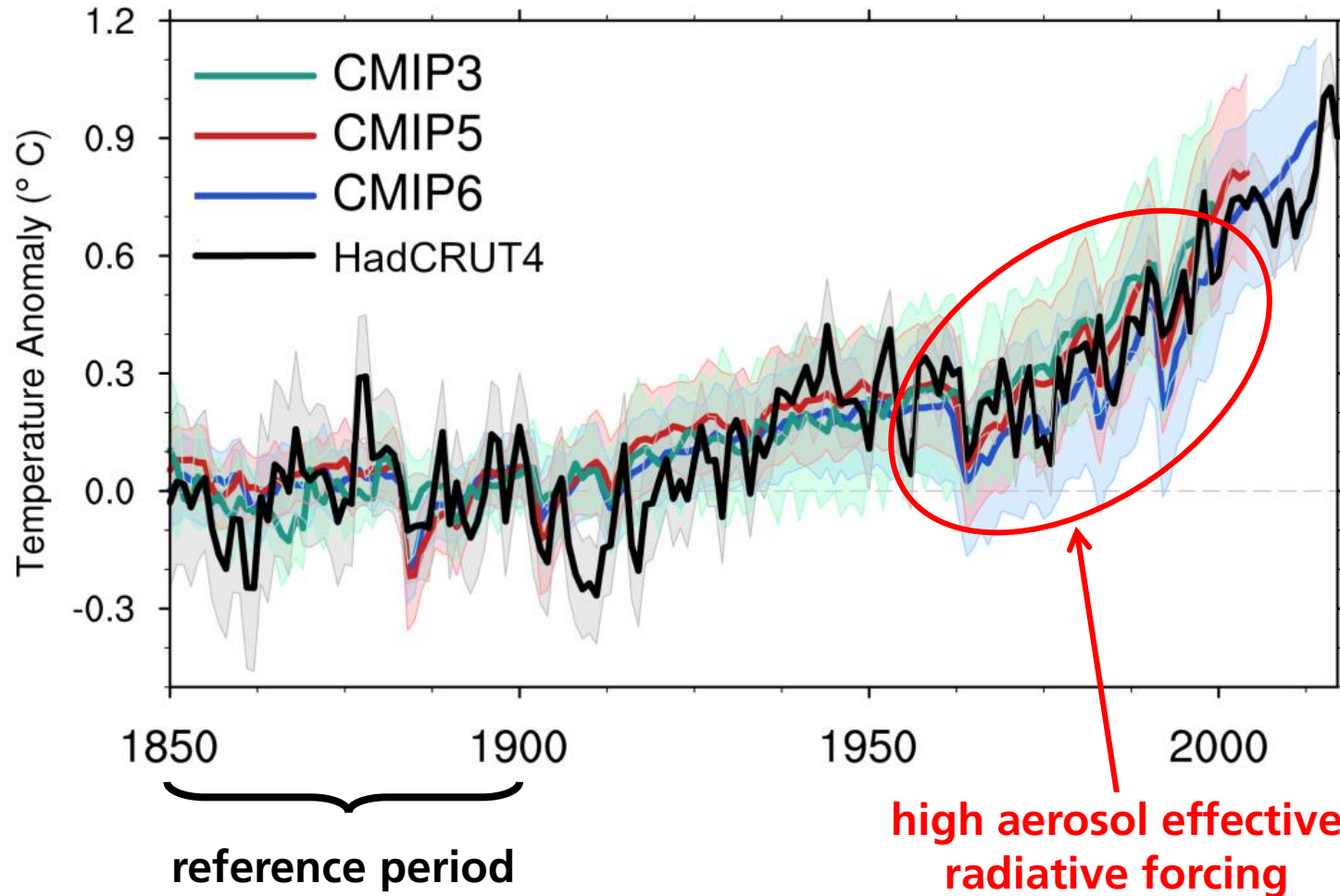
### CMIP6 vs. CMIP5

- **Improvements** in all carbon cycle variables

Gier et al., Biogeosciences (2020); Gier et al., in prep., (2020)



# Global Annual Mean Surface Temperature Trends



## CMIP6 vs. CMIP5

- Overall warming trend **similar**
- Stronger reduction in warming over the period 1950-1990 in CMIP6

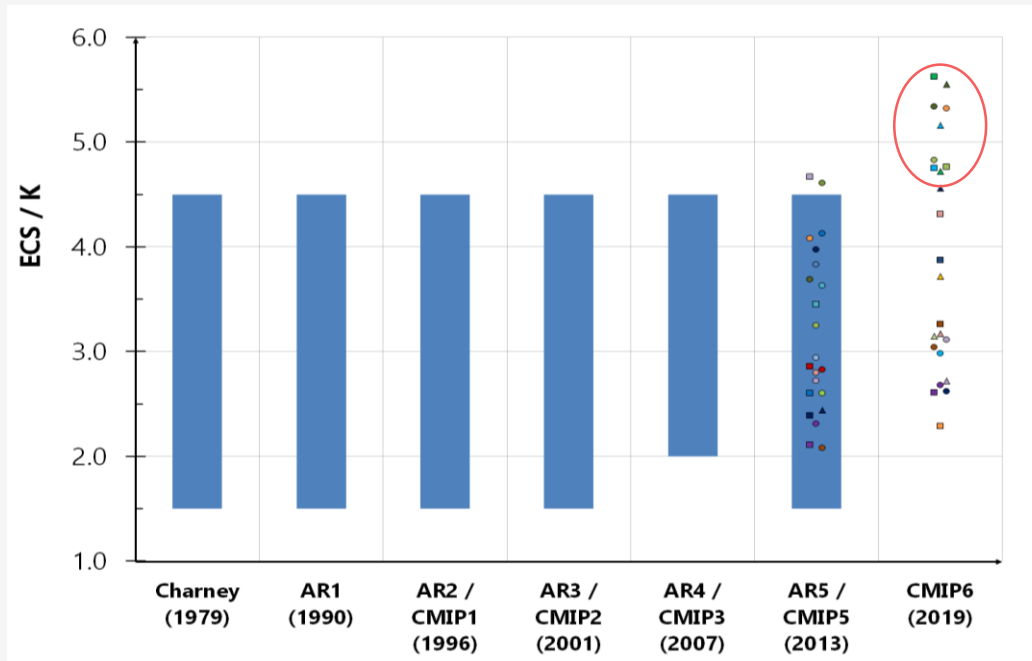
Bock et al., JGR: Atmospheres (2020)





# Large Uncertainties in Climate Projections Remain

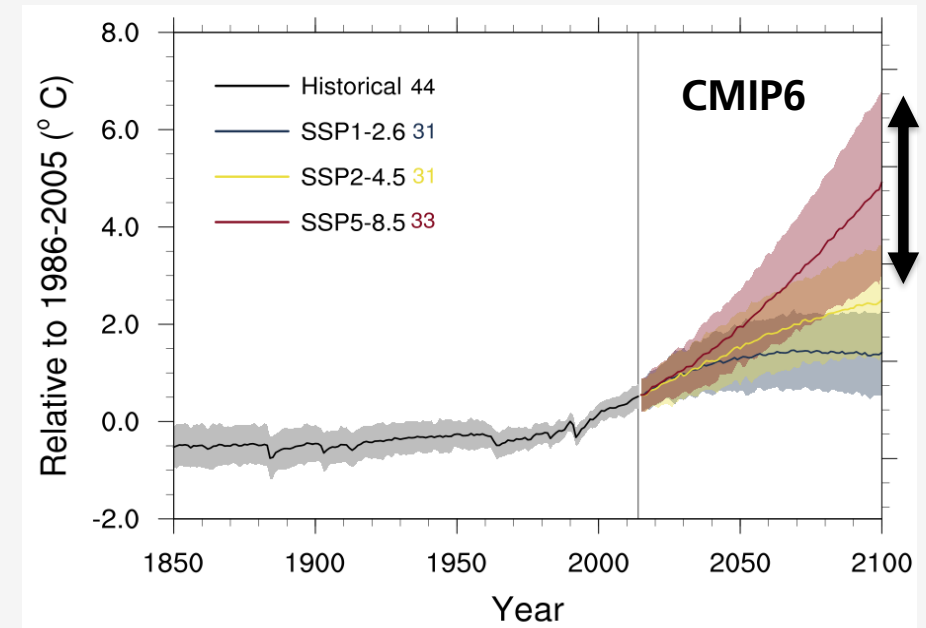
## Climate Sensitivity



Uncertainty range (1.5 - 4.5°C) has **not decreased since 1979**

Meehl et al. (incl. Eyring, Schlund), Science Adv. (2020)

## Global warming projections

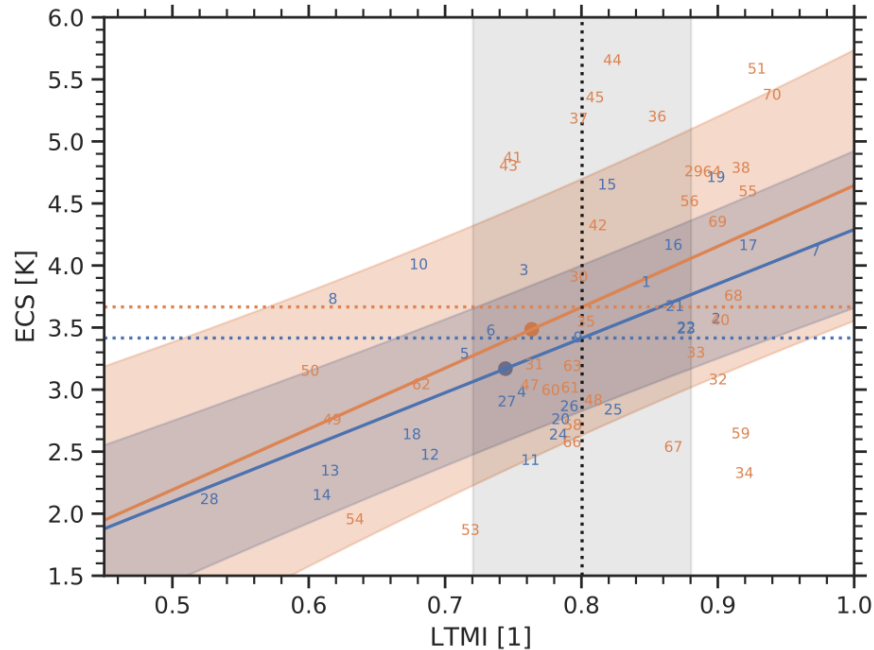


**Large uncertainties** in future projections remain

Tebaldi et al. (incl. Debeire, Eyring), ESDD (2020)

# Emergent Constraints on ECS: Drop of Skill for CMIP6

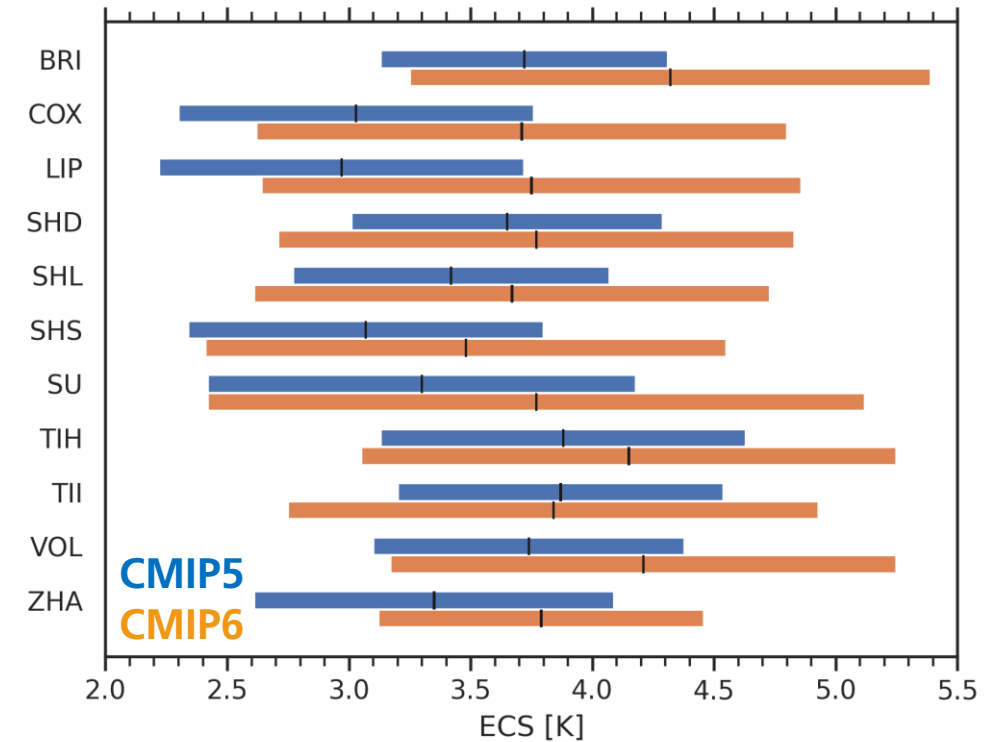
## Example from Sherwood et al. (2014)



**Drop of skill  
in CMIP6**

*Schlund et al., ESD, 2020*

## Analysis of 11 emergent constraints on ECS



- For all but one constraint, the best estimate ECS is **higher** in CMIP6
- For all but one constraint, the constrained ECS range is **wider** in CMIP6

# Summary



- The **Earth System Model Evaluation Tool (ESMValTool)** coupled to ESGF
  - provides a systematic, rapid and comprehensive performance assessment
  - has more diagnostics: large-scale, emergent constraints and future projections, extreme events and regional and impact diagnostics
  - facilitates the routine evaluation of ESMs
  - supports production of a subset of figures of the upcoming IPCC WGI AR6
  - is easily expandable with other software projects (e.g. NCAR CVDP)
  - has a large development team, additional institutions welcome to join!
- ESMs have been further developed and **significant improvements in mean climate and carbon cycle** are found allowing CMIP6 models to be used for policy-relevant calculations such as the assessment of the human influence on the climate system as well as climate projections.

