Erste Ergebnisse der CMIP6 Evaluation mit dem Earth System Model Evaluation Tool (ESMValTool)

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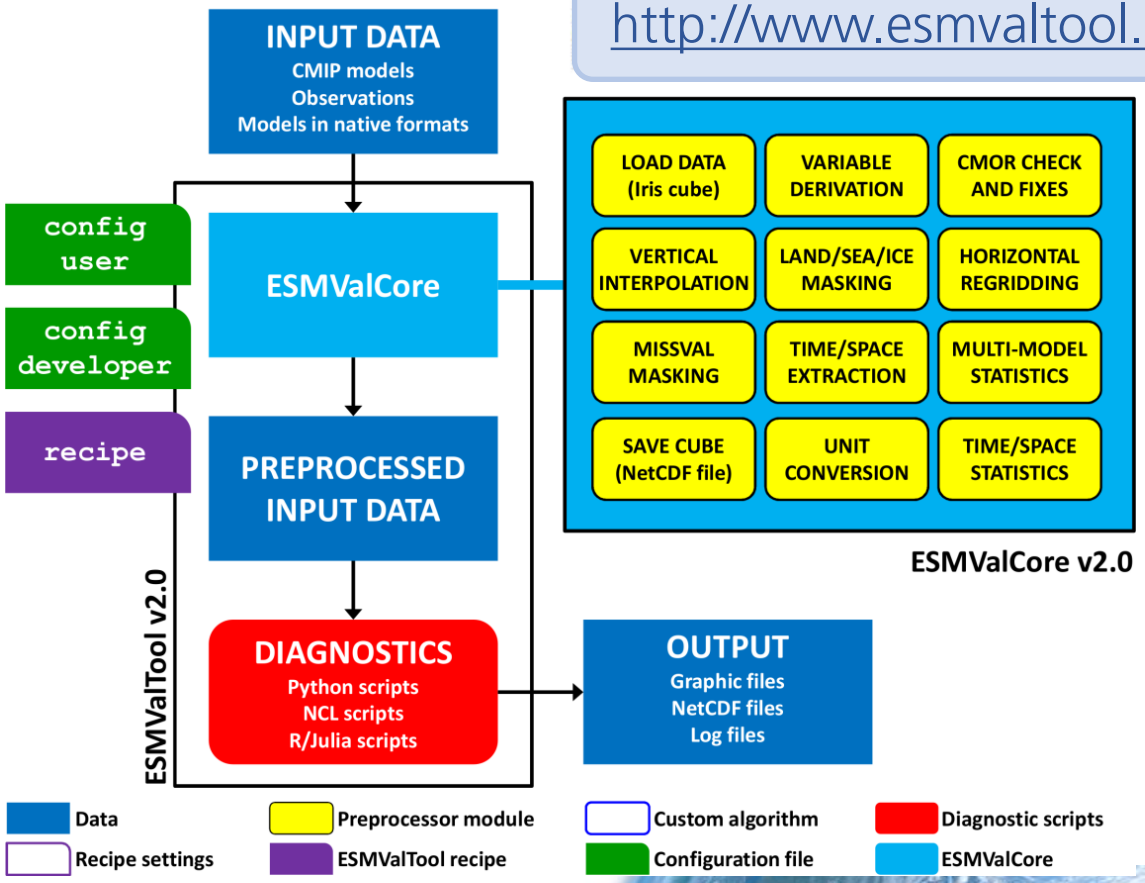
CMIP6-DICAD Abschlusstreffen
22. Juni 2020

Evaluation of CMIP models with the ESMValTool

In order to ensure a rapid and comprehensive evaluation of the models with observations, DLR-IPA is developing the **Earth System Model Evaluation Tool (ESMValTool)** in cooperation with more than 60 international institutes.



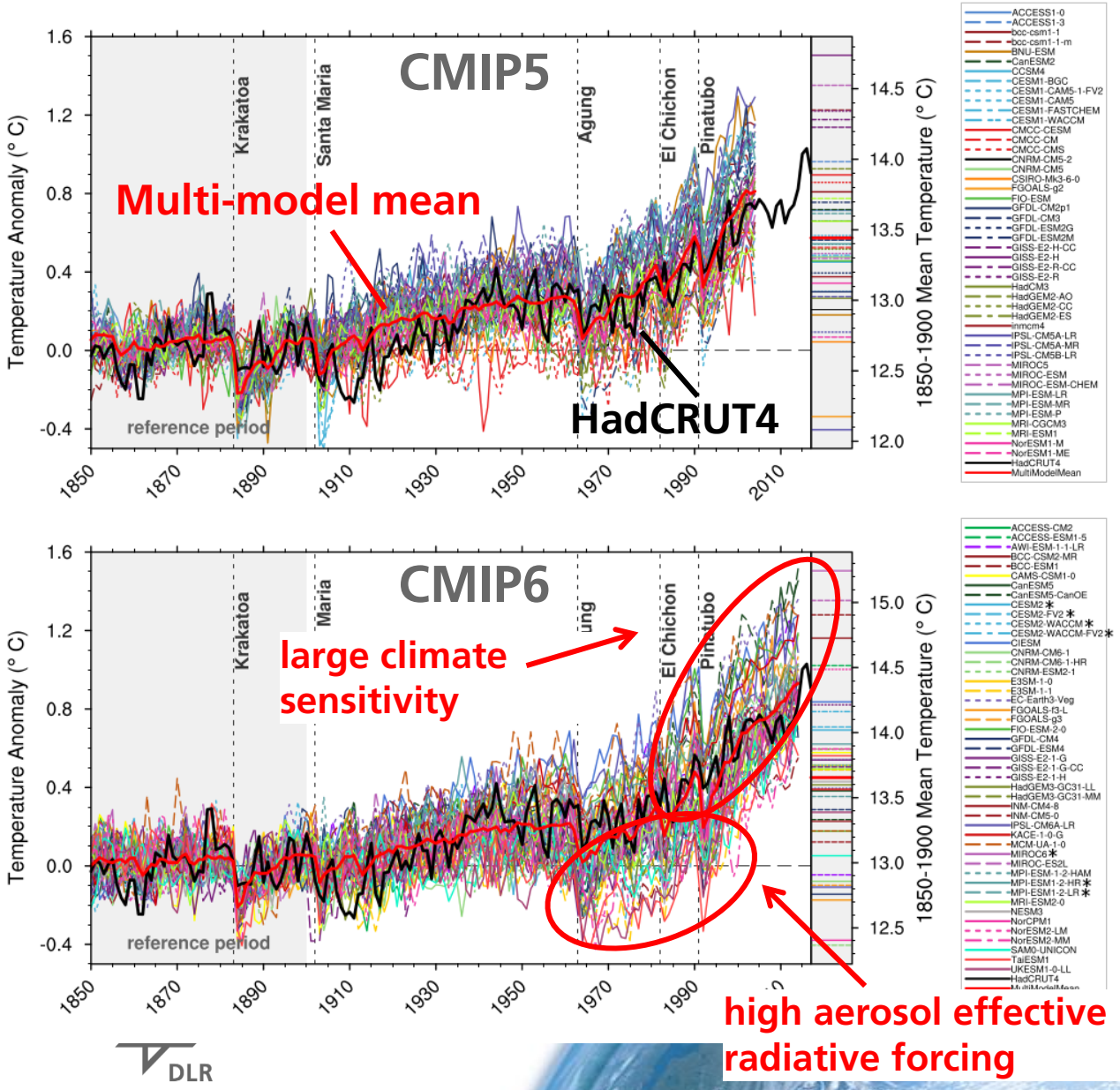
http://www.esmvaltool.org/

ESMValTool
Earth System Model eValuation Tool

- **Open source community development**
- **Diagnostics and performance metrics tool** for the evaluation of Earth System models with observations
- **Ensures provenance and traceability**
- Currently ≈ **150 scientist** from > 60 institutions part of the development team and **many users (including IPCC)**

Righi et al., *Geosci. Model Dev., 2020;* ***Eyring et al.***, *GMD, accepted;* ***Lauer et al.***, *GMD., in review;* ***Weigel et al.***, *GMD, in prep.*

Global annual mean surface temperature anomalies



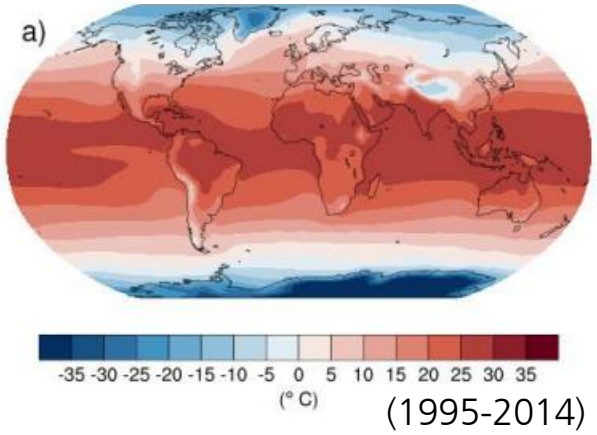
CMIP6 vs. CMIP5

- Overall warming trend **similar**
- Stronger reduction in warming over the period 1950-1990 in CMIP6 (**high aerosol effective radiative forcing**)

Bock et al., JGR: Atmospheres, in review

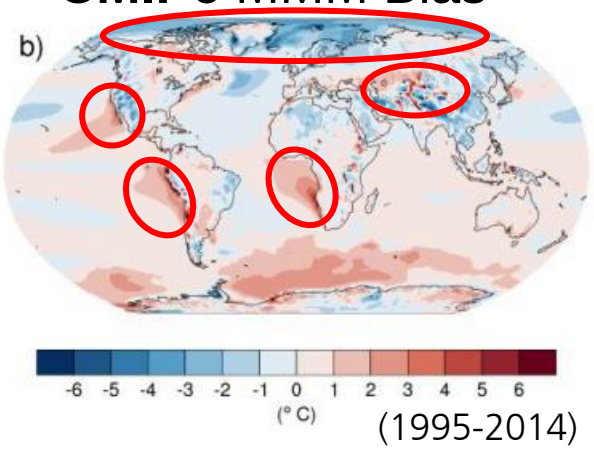
Near-surface temperature bias
Annual climatological multi-model mean (MMM)

CMIP6 MMM



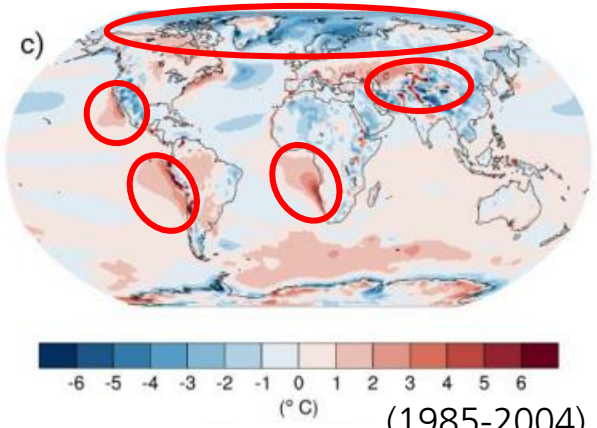
(1995-2014)

CMIP6 MMM Bias



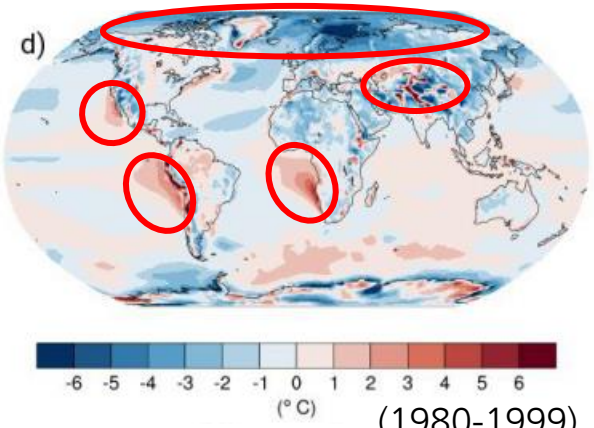
(1995-2014)

CMIP5 MMM Bias



(1985-2004)

CMIP3 MMM Bias



(1980-1999)

Systematic biases remain in CMIP6

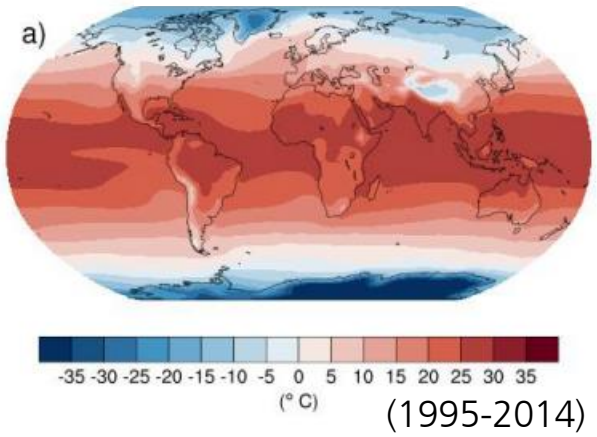
- Over **ocean upwelling regions**
- In **high elevation** regions
- Near **ice edge** in the North Atlantic
- Many reasons: errors in simulated **cloud properties**, errors in **oceanic circulation**, etc.

Bock et al., JGR: Atmospheres, in review

Reference data set: ERA5

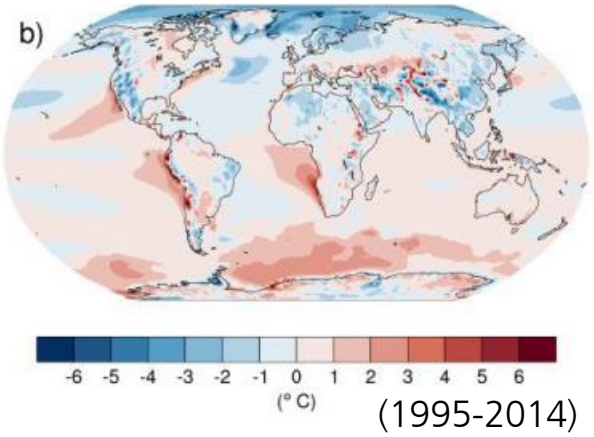
Near-surface temperature bias
Annual climatological multi-model mean (MMM)

CMIP6 MMM



(1995-2014)

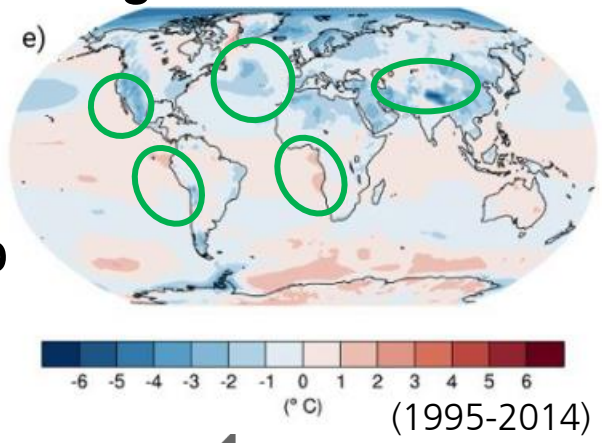
CMIP6 MMM Bias



(1995-2014)

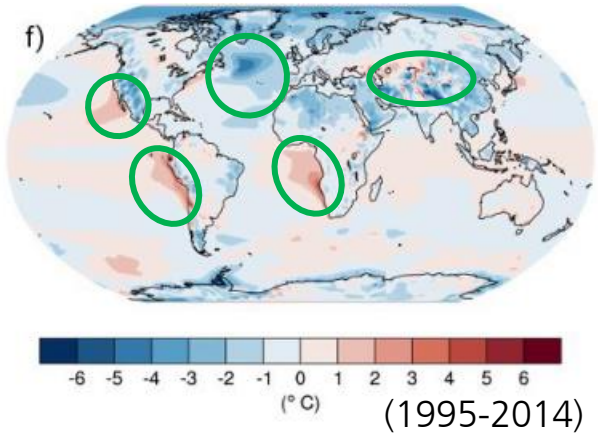
HighResMIP

High res MMM Bias



(1995-2014)

Low res MMM Bias



(1995-2014)

Related to horizontal resolution?

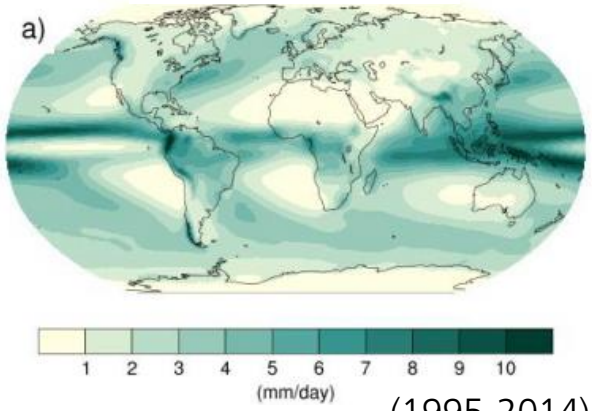
- Most biases **decrease** for HighResMIP model simulations (ocean upwelling regions, high elevations, etc.)
- Direct comparison to CMIP6 ensemble **not possible** due to different experiment setups

Bock et al., JGR: Atmospheres, in review

Reference data set: ERA5

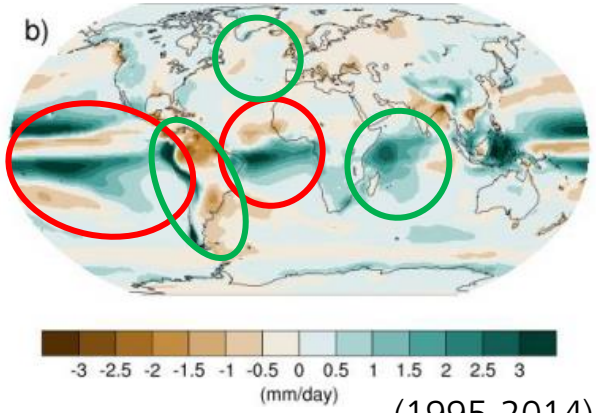
Precipitation bias
Annual climatological multi-model mean (MMM)

CMIP6 MMM



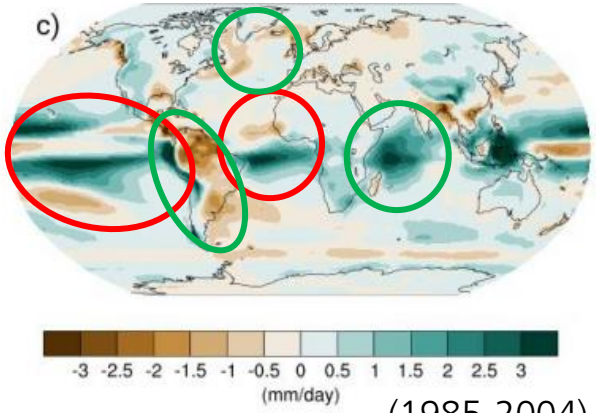
(1995-2014)

CMIP6 MMM Bias



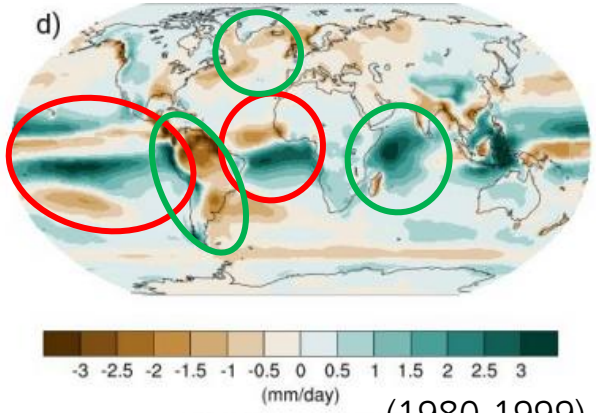
(1995-2014)

CMIP5 MMM Bias



(1985-2004)

CMIP3 MMM Bias



(1980-1999)

Systematic biases remain in CMIP6

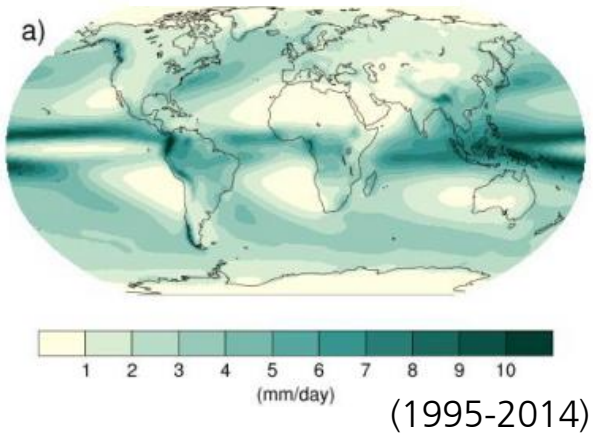
- **Double ITCZ** (Intertropical Convergence Zone) in the tropical Pacific (incorrect simulation of SST gradients)
- **Southward-shifted ITCZ** in the Atlantic
- **Small improvements**: Indian Ocean ITCZ, South America, North Atlantic

Bock et al., JGR: Atmospheres, in review

Reference data set: GPCP

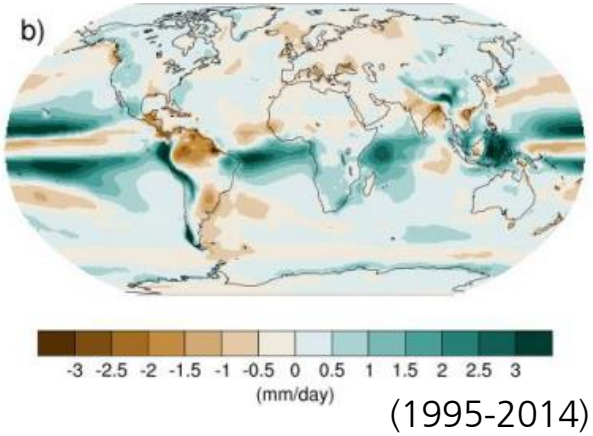
Precipitation bias
Annual climatological multi-model mean (MMM)

CMIP6 MMM



(1995-2014)

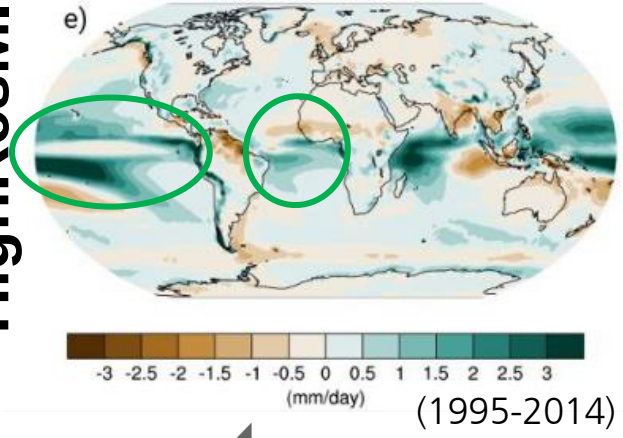
CMIP6 MMM Bias



(1995-2014)

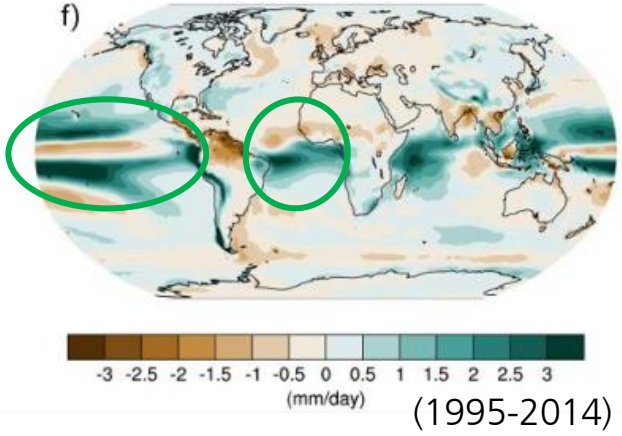
HighResMIP

High res MMM Bias



(1995-2014)

Low res MMM Bias



(1995-2014)

High Resolution vs. low resolution

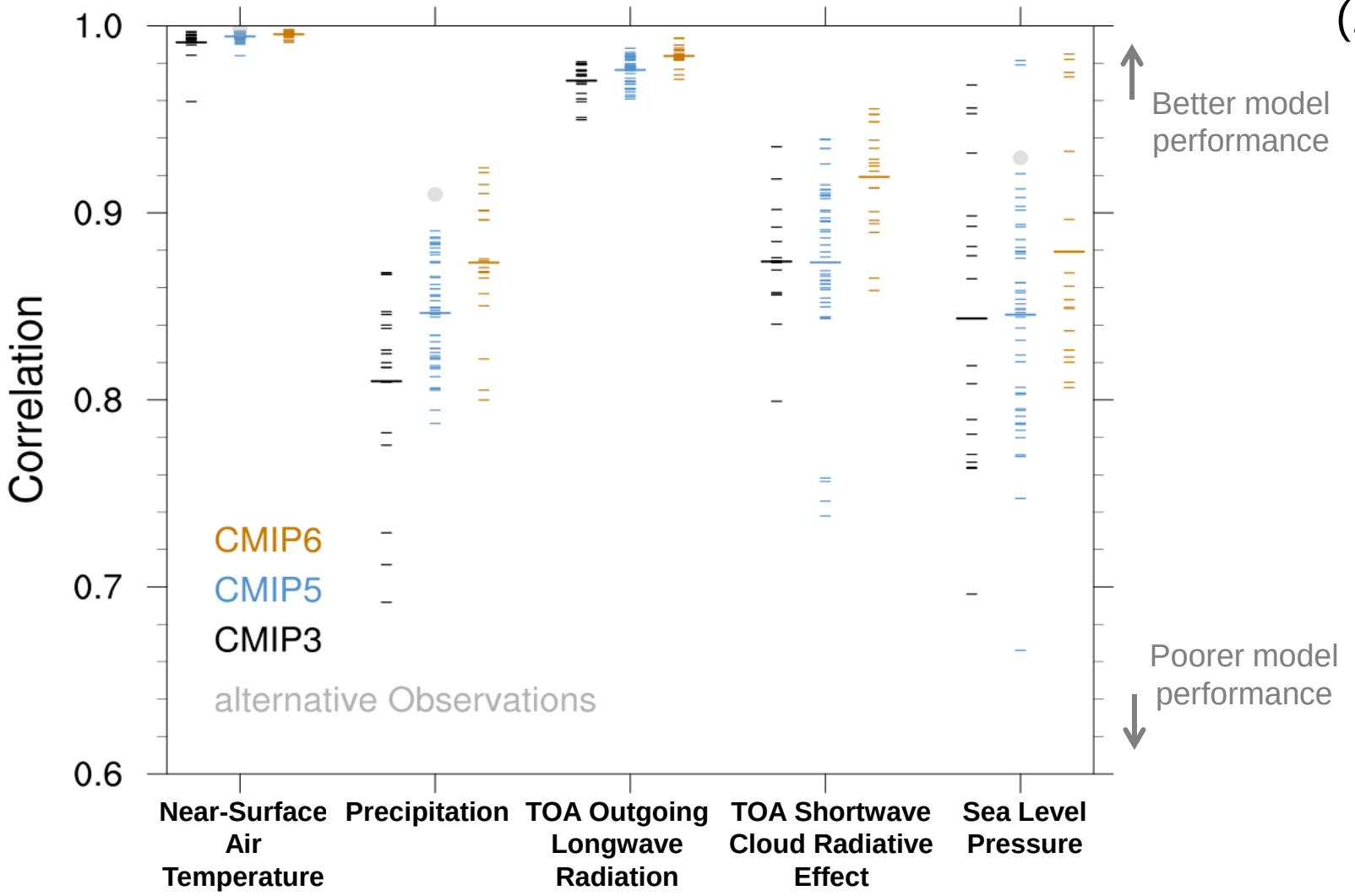
- Improvements in **Tropical Atlantic**
- Disappearance of **dry bias in equatorial Pacific**
- Reasons: **improved SST biases**, improved **seasonal mean circulation** and **ITCZ migration**

Bock et al., JGR: Atmospheres, in review

Reference data set: GPCP

Geographical Pattern Correlation

Annual climatological mean
(1980-1999)



Are climate models improving?

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

Bock et al., JGR: Atmospheres, in review

Effective Climate Sensitivity (ECS)

= Change in global mean 2m surface air temperature at equilibrium caused by doubling of atmospheric CO_2 concentration

Change in net radiative flux (TOA)

Climate feedback parameter

$$\Delta N = F + \lambda \Delta T$$

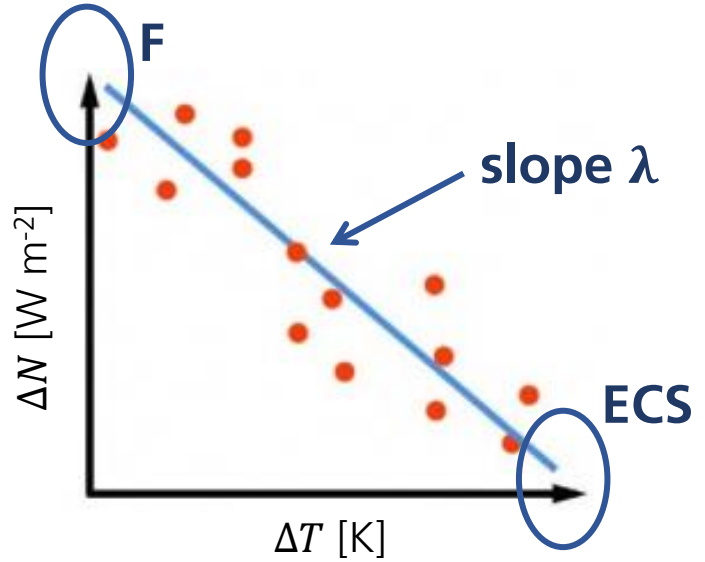
External radiative forcing

Surface air temperature anomaly

$$\Delta N = 0 \iff \text{equilibrium}$$

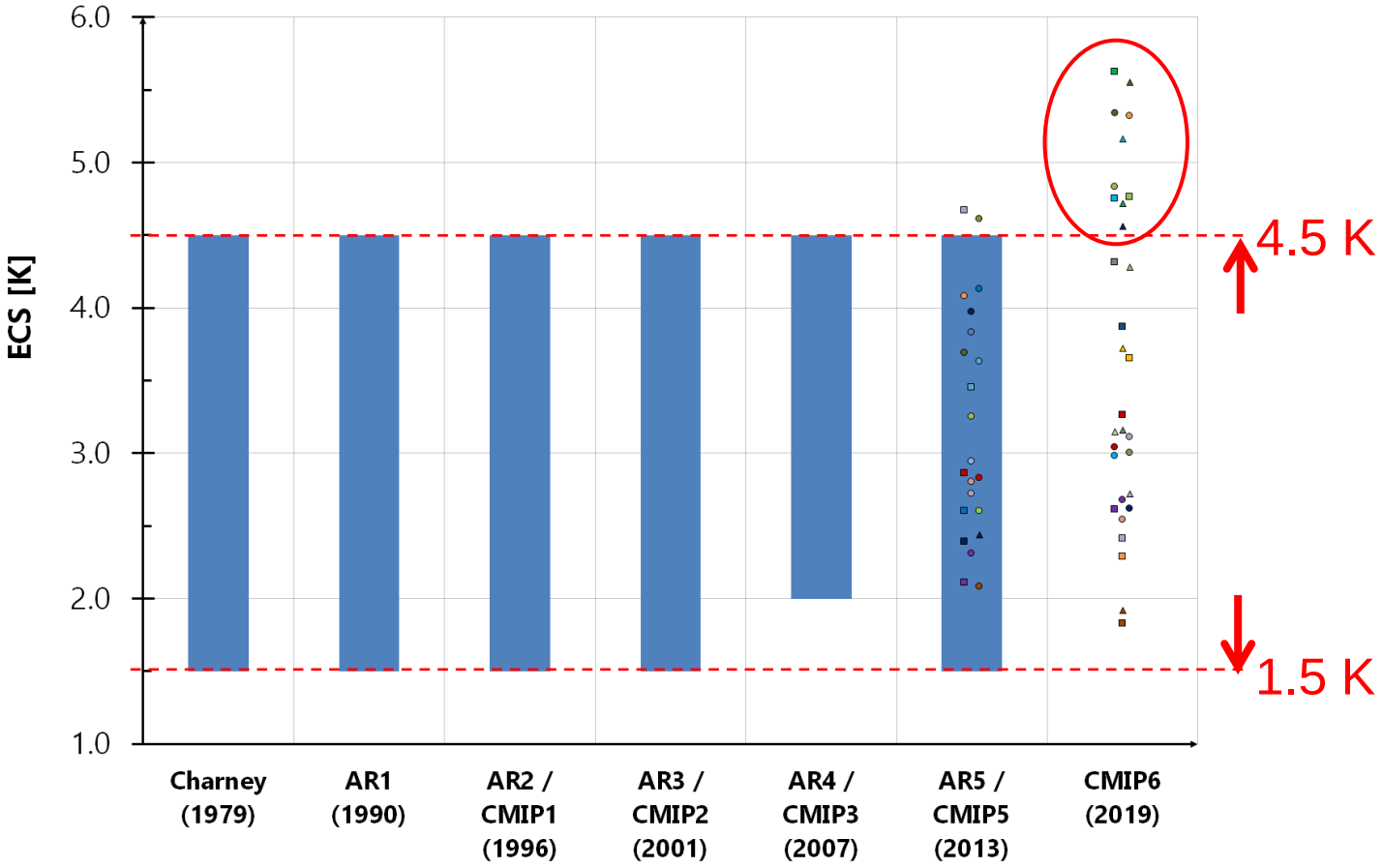
$$\Delta T = -\frac{F}{\lambda}$$

Gregory method (Gregory et al., GRL, 2004)

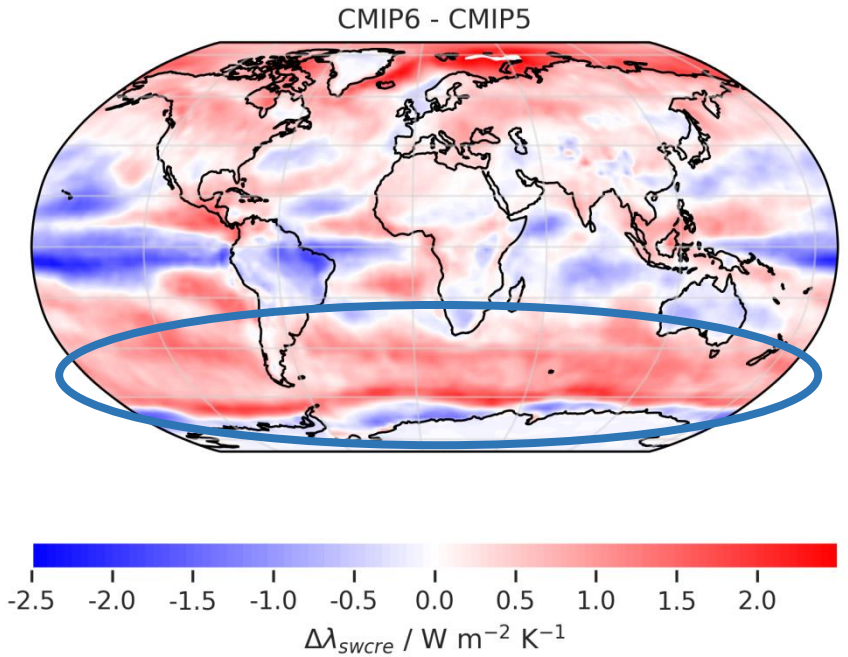


Effective Climate Sensitivity

- Improvements have been made to models from CMIP5 to CMIP6, including new physical insights in the atmosphere, ocean, sea-ice, and land surface utilising new observations.
- In many cases, improvements in the detailed representation of prognostic cloud and aerosol processes have been implemented.
- Several of the new CMIP6 models have a higher ECS than their CMIP5 counterparts

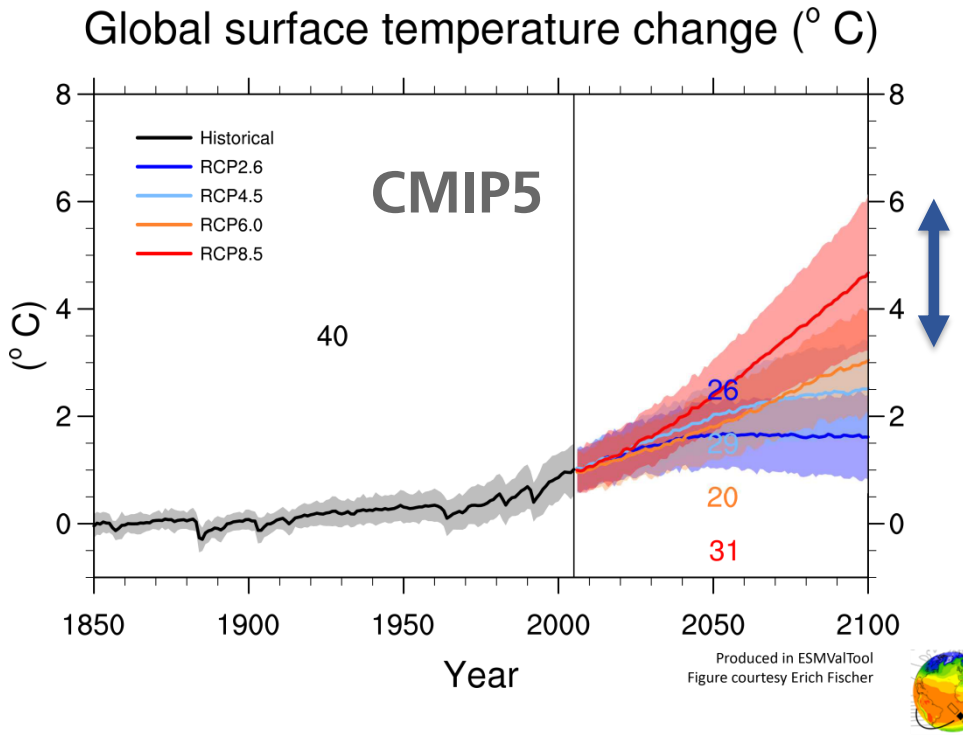


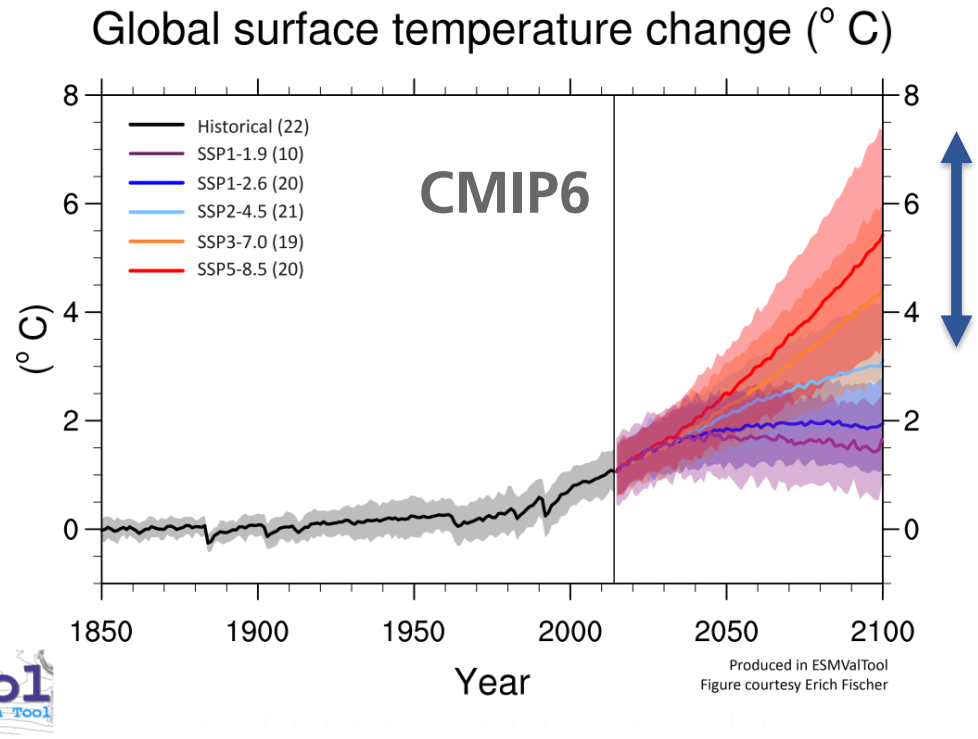
Short-wave cloud radiative effect feedback parameter ($Wm^{-2}K^{-1}$)



Bock et al., JGR, in review

Climate projections





- Some CMIP6 models exhibit **more mid- and late-century warming** compared to their CMIP5 counterparts.
- Suggestion: Models which overestimate current warming trend show too strong warming in future
- **Constraining** future projections?
- CMIP6 model results reinforce the IPCC SR1.5 conclusion that urgent mitigation towards net-zero emissions is needed to limit future climate change risk

…rep.

CMIP6-DICAD TP2 / AP6

WP 6.1 Installation und Betrieb des ESMValTools in der ESGF DKRZ Infrastruktur (DKRZ, DLR)

→ Erfolgreich abgeschlossen

WP 6.2 Nutzung des ESMValTools zur Qualitätskontrolle laufender Simulationen (DLR, DKRZ)

→ Quicklook System für EMAC zur Verfügung gestellt und auf github für Folgearbeiten zur Verfügung gestellt. (Diese Funktionalität wird aber im Rahmen von ISENES3 weiterentwickelt (Lead: SMHI)).

WP 6.3 Nutzung des ESMValTools zur Unterstützung der CMIP6+-Wissenschaftler (DLR, DKRZ)

→ Die Routine-Auswertung wurde erfolgreich implementiert und das ESMValTool technisch signifikant verbessert. Es werden noch weitere Recipes in das ESMValTool v2 eingebaut und die zugehörigen ESMValTool v2 Manuskripte mit CMIP6-DICAD Acknowledgement entsprechend der Reviews überarbeitet bzw. eingereicht:

***Righi et al**., Geosci. Model Dev., 2020:* **ESMValTool v2.0 – Technical overview**

***Eyring et al**., GMD, accepted:* **ESMValTool v2.0 – Extended set of large-scale diagnostics for quasi-operational and comprehensive evaluation of Earth system models in CMIP**

***Lauer et al**., GMD., in review:* **ESMValTool v2.0 – Diagnostics for emergent constraints and future projections from Earth system models in CMIP**

***Weigel et al**., GMD, in prep.:* **ESMValTool (v2.0) – Diagnostics for extreme events, regional model and impact evaluation and analysis of Earth system models in CMIP**

→ Abbildungen des IPCC AR6 Chapter 3 werden komplett mit dem ESMValTool erstellt

ESMValTool Related Milestones in CMIP6-DICAD

- Standardisierte Diagnostiken und Modellevaluation (AP6) -

- **M1: Entwurf mit ausführlicher Spezifikation zum Portal [Monat 6, FUB]**
- **M2: Prototype ESMValTool Version läuft in der ESGF DKRZ Infrastruktur [Monat 9, DKRZ]**
- **M3: ESMValTool steht zur operationellen Laufüberwachung in der DKRZ Infrastruktur zur Verfügung [Monat 12, DLR]**
- **M4: Lauffähiger und getesteter Prototype für das Portal [Monat 15, FUB]**
- **M5: ESMValTool mit erweiterten Diagnostiken auf CMIP5 Modelldaten angewandt [Monat 18, DLR]**
- **M6: ESMValTool mit CMIP6 Modelldaten und Beobachtungsdaten vollständig integriert in der ESGF DKRZ Infrastruktur [neu: Monat 36, DKRZ]**
- **M7: MPI-ESM1/2 und EMAC2 mit erweiterter ESMValTool Version evaluiert und mit anderen CMIP6 Modellen verglichen [neu: Monat 42, DLR]**
- **M8: Produktionssystem des Portals ist installiert [Monat 36, FUB]**

Bock et al., JGR, in review:
Quantifying progress across different CMIP phases with the ESMValTool

DLR