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

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Chart 2

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

**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/

• **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)**

Chart 3

**Global annual mean surface temperature anomalies**

**CMIP5**

**Multi-model mean**

**CMIP6 vs. CMIP5**

• Overall warming trend **similar HadCRUT4**

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

**large climate sensitivity**

**high aerosol effective**

*Bock et al., JGR: Atmospheres, in review*

**radiative forcing**

Chart 4

**CMIP6** MMM Bias **CMIP6** MMM **CMIP6** MMM Bias

**CMIP3** MMM Bias **CMIP5** MMM Bias

• Many reasons: errors in simulated **cloud properties**, errors in **oceanic circulation**, etc.

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

**Systematic biases remain in CMIP6**

• Over **ocean upwelling regions**

• In **high elevation** regions

(1995-2014)

(1995-2014) • Near **ice edge** in the North Atlantic

(1985-2004) (1980-1999)

Reference data set: ERA5

*Bock et al., JGR: Atmospheres, in review*

Chart 5

**CMIP6** MMM **CMIP6** MMM Bias

**Low res** MMM Bias **High res** MMM Bias

(1995-2014) (1995-2014)

• Direct comparison to CMIP6 ensemble **not possible** due to different experiment setups **HighResMIP**

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

(1995-2014) (1995-2014)

Reference data set: ERA5

**Related to horizontal resolution?**

*Bock et al., JGR: Atmospheres, in review*

• Most biases **decrease** for HighResMIP model simulations (ocean upwelling regions, high elevations, etc.)

Chart 6

**CMIP6** MMM **CMIP6** MMM Bias

(1995-2014) (1995-2014) **CMIP5** MMM Bias **CMIP3** MMM Bias (1985-2004) (1980-1999) Reference data set: GPCP

• **Southward-shifted ITCZ** in the Atlantic

• **Small improvements**: Indian Ocean ITCZ, South America, North Atlantic

*Bock et al., JGR: Atmospheres, in review*

**Precipitation bias Annual climatological multi-model mean (MMM)**

**Systematic biases remain in CMIP6**

• **Double ITCZ** (Intertropical Convergence Zone) in the tropical Pacific (incorrect simulation of SST gradients)

Chart 7

**CMIP6** MMM **CMIP6** MMM Bias

(1995-2014) (1995-2014) **High res** MMM Bias

**Low res** MMM Bias **P**

**IMseRhgiH**(1995-2014) (1995-2014)

Reference data set: GPCP

**Precipitation bias Annual climatological multi-model mean (MMM)**

**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*

Chart 8

**Geographical Pattern Correlation**

**Near-Surface Air Temperature**

**Precipitation TOA Outgoing**

**TOA Shortwave**

**Sea Level Longwave**

**Cloud Radiative**

**Pressure Radiation**

**Effect**

Better model performance

Poorer model performance

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*

Chart 9

**Effective Climate Sensitivity (ECS)**

= Change in global mean 2m surface air temperature at equilibrium caused by doubling

of atmospheric CO2 concentration Change in net radiative flux (TOA)

Climate feedback parameter

ΔN = F + λ ΔT

ΔN=0

equilibrium ΔT = −Fλ External radiative forcing Surface air temperature

anomaly

**F**

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

**slope** λ

**ECS**

ΔN [W m

-2 ]

ΔT [K]

**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

4.5 K

1.5 K

*Bock et al., JGR, in review*

**Short-wave cloud radiative effect feedback parameter (Wm-2K-1)**

Chart 11

**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

**CMIP5**

*Tebaldi et al. (incl. Debeire, Eyring), in prep.*

**CMIP6**

**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**