

Evaluation of CMIP6 and quantifying progress of climate models across different CMIP phases with the ESMValTool



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AGU 2021

CMIP6 Climate Model Evaluation

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AGU FALL
MEETING



Earth System Model Evaluation Tool (ESMValTool) version 2

scientific documentation

International ESMValTool development team

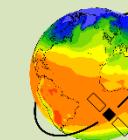
- 17 funded projects
- 63 institutions
- 203 developers

Righi et al., 2020
Technical overview

Eyring et al., 2020
Large-scale diagnostics

Lauer et al., 2020
Diagnostics for emergent constraints and future projections

Weigel et al., 2021
Diagnostics for extreme events, regional and impact evaluation



ESMValTool
Earth System Model Evaluation Tool

- Tool for fast and easy routine **evaluation and analysis** of Earth system models including provenance records for all results (**traceability and reproducibility**)
- Well-established analysis based on **peer-reviewed literature**
- Many diagnostics and performance metrics covering **different aspects of the Earth system** (dynamics, radiation, clouds, carbon cycle, chemistry, aerosol, sea-ice, etc.) and their interactions
- Extensive **documentation** (user guide, peer-reviewed papers)
- Was used in support of production of a subset of figures of the **IPCC WGI AR6**

Website: <https://www.esmvaltool.org/>

Code: <https://github.com/ESMValGroup/ESMValTool>

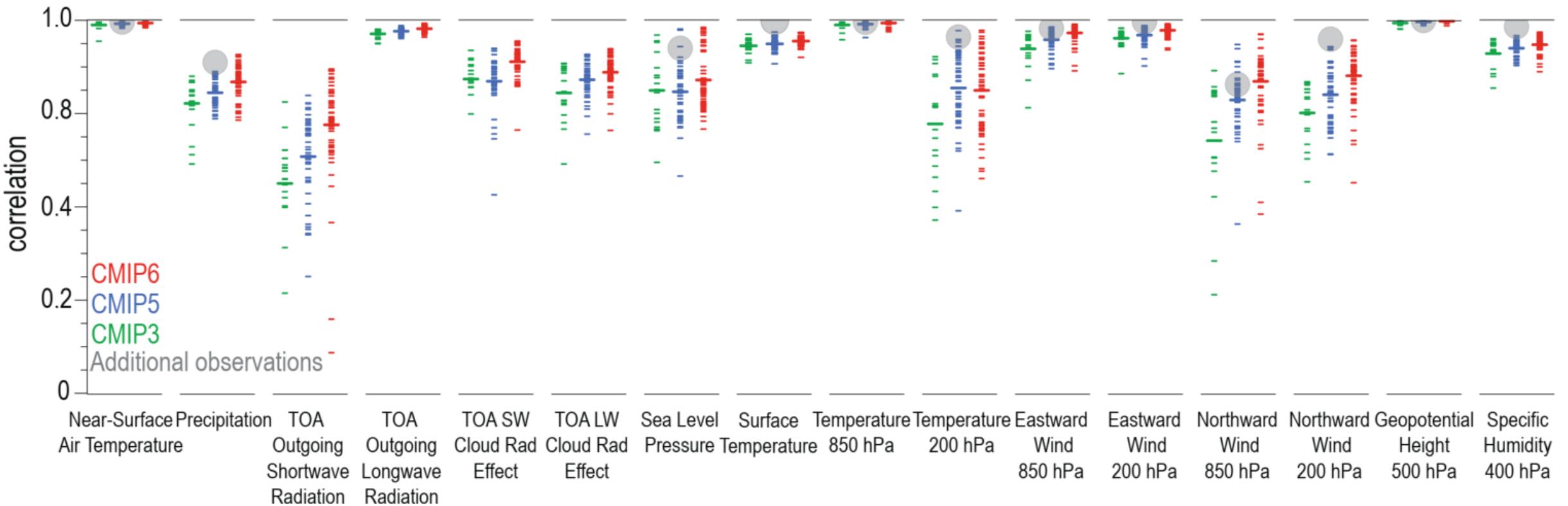
Documentation: <https://docs.esmvaltool.org/>

Tutorial: https://esmvalgroup.github.io/ESMValTool_Tutorial



Climate models are improving

Pattern correlation with observational reference for the annual mean climatology over the period 1980-1999

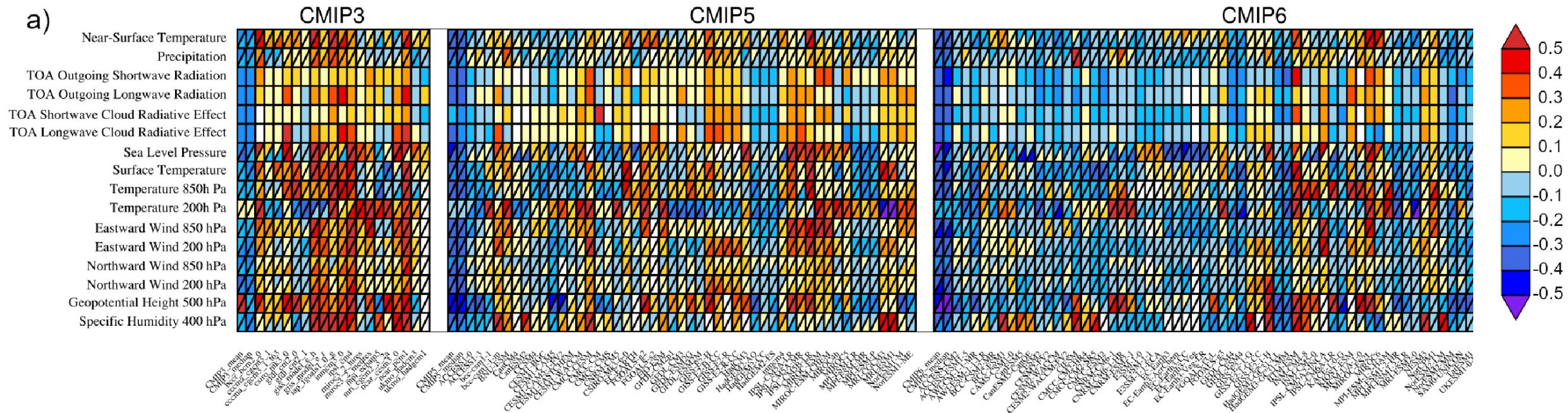


IPCC AR6 WG1 Fig. 3.43 & Bock et al., 2020

Climate models are improving

Relative space–time root-mean-square deviation (RMSD) calculated from the climatological seasonal cycle of the CMIP simulations (1980–1999) compared to observational datasets.

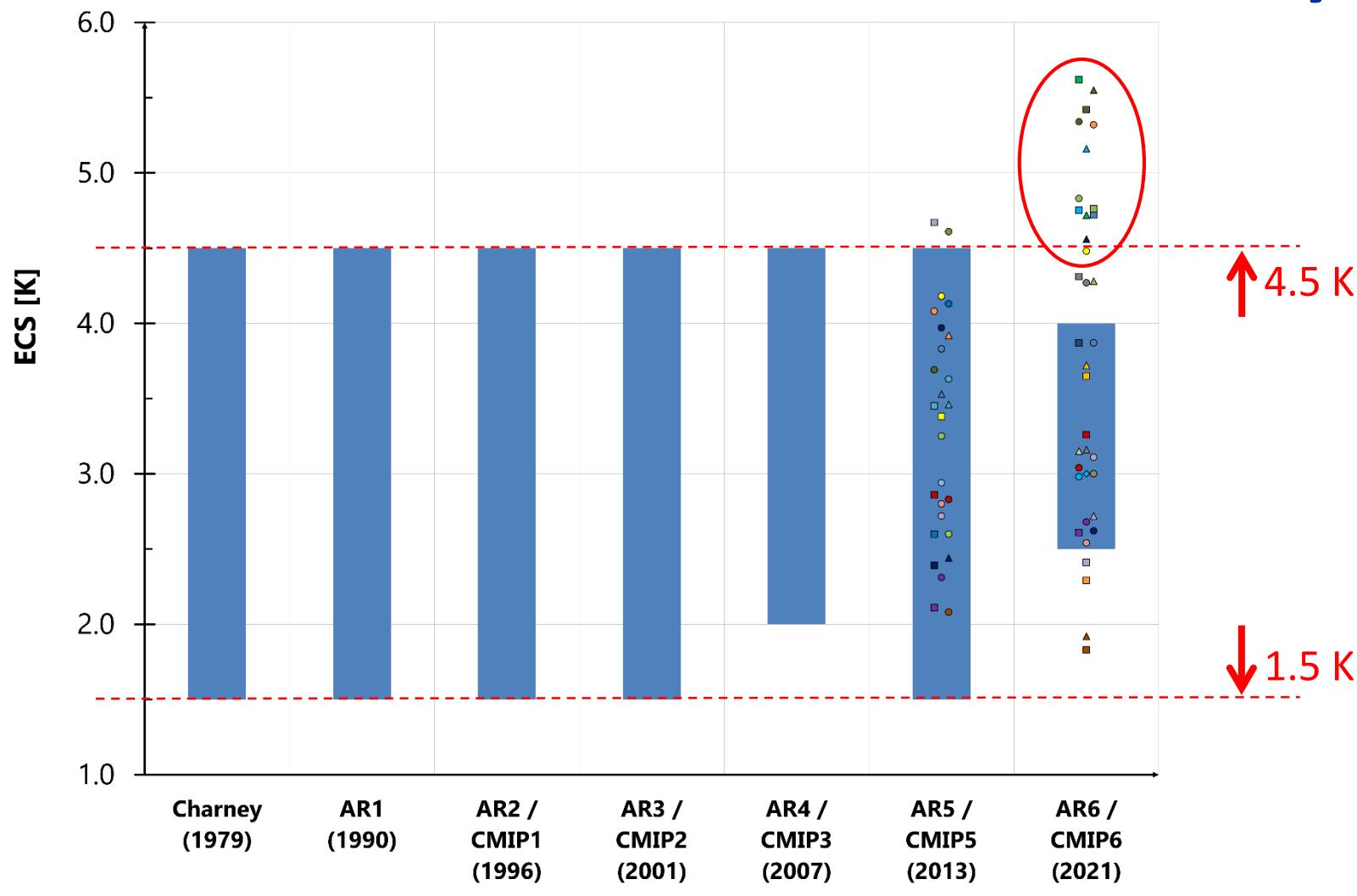
a)



IPCC AR6 WG1 Fig. 3.42 & Bock et al., 2020



Effective Climate Sensitivity (ECS)



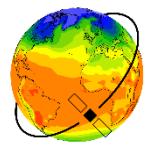
ECS in CMIP6

- Some CMIP6 models show higher ECS values than CMIP5 models
 - Increased ECS range in more complex ESMs
- Important contribution to ECS is the cloud climate feedback

Updated from Meehl et al., Science Advances, 2020

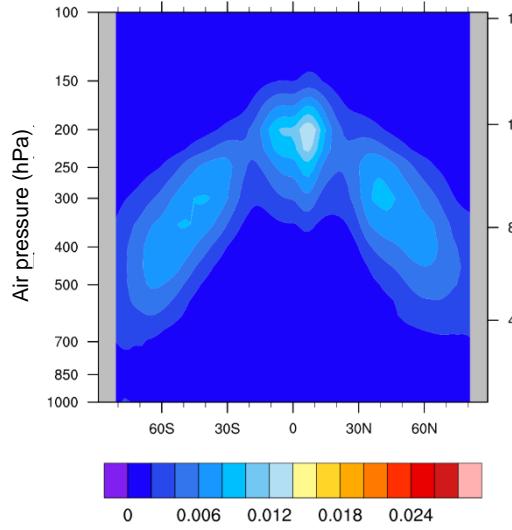


Climatological zonal means

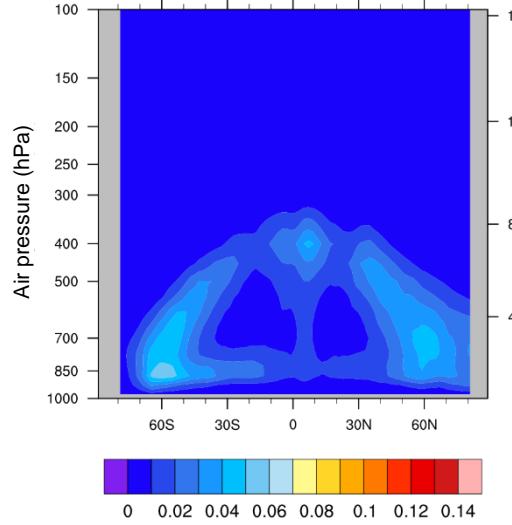


Observations

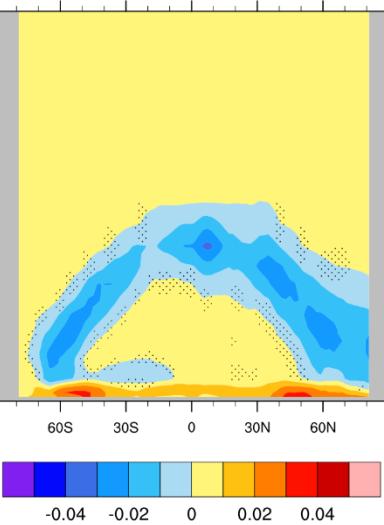
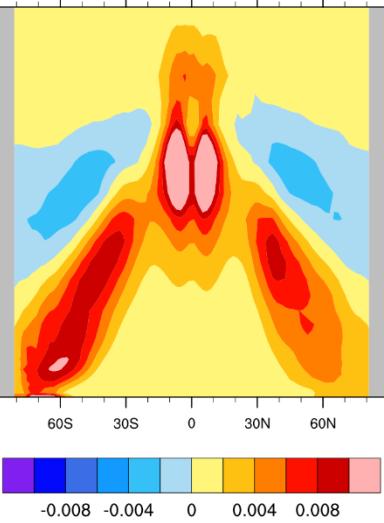
Cloud ice water
(g kg^{-1})



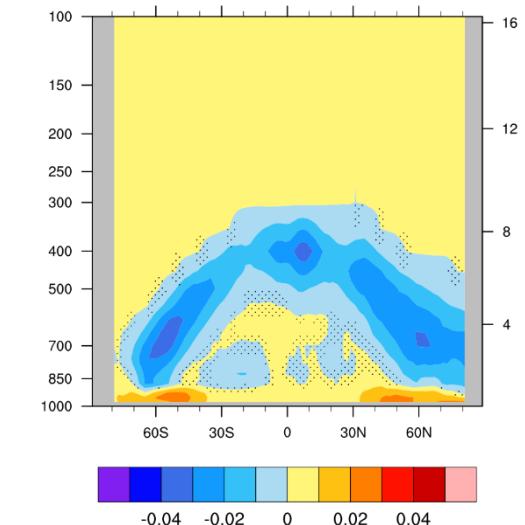
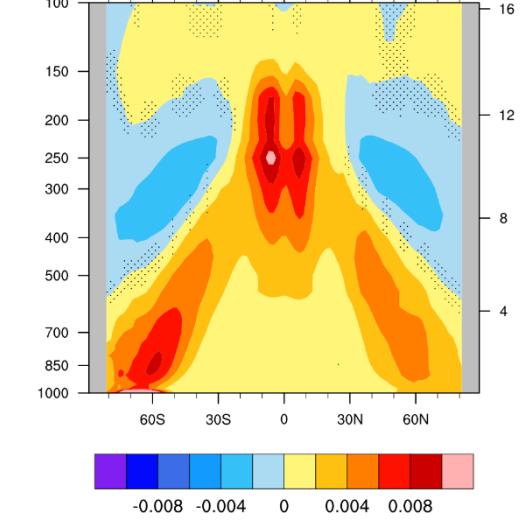
Cloud liquid water
(g kg^{-1})



Δ CMIP5 MMM



Δ CMIP6 MMM



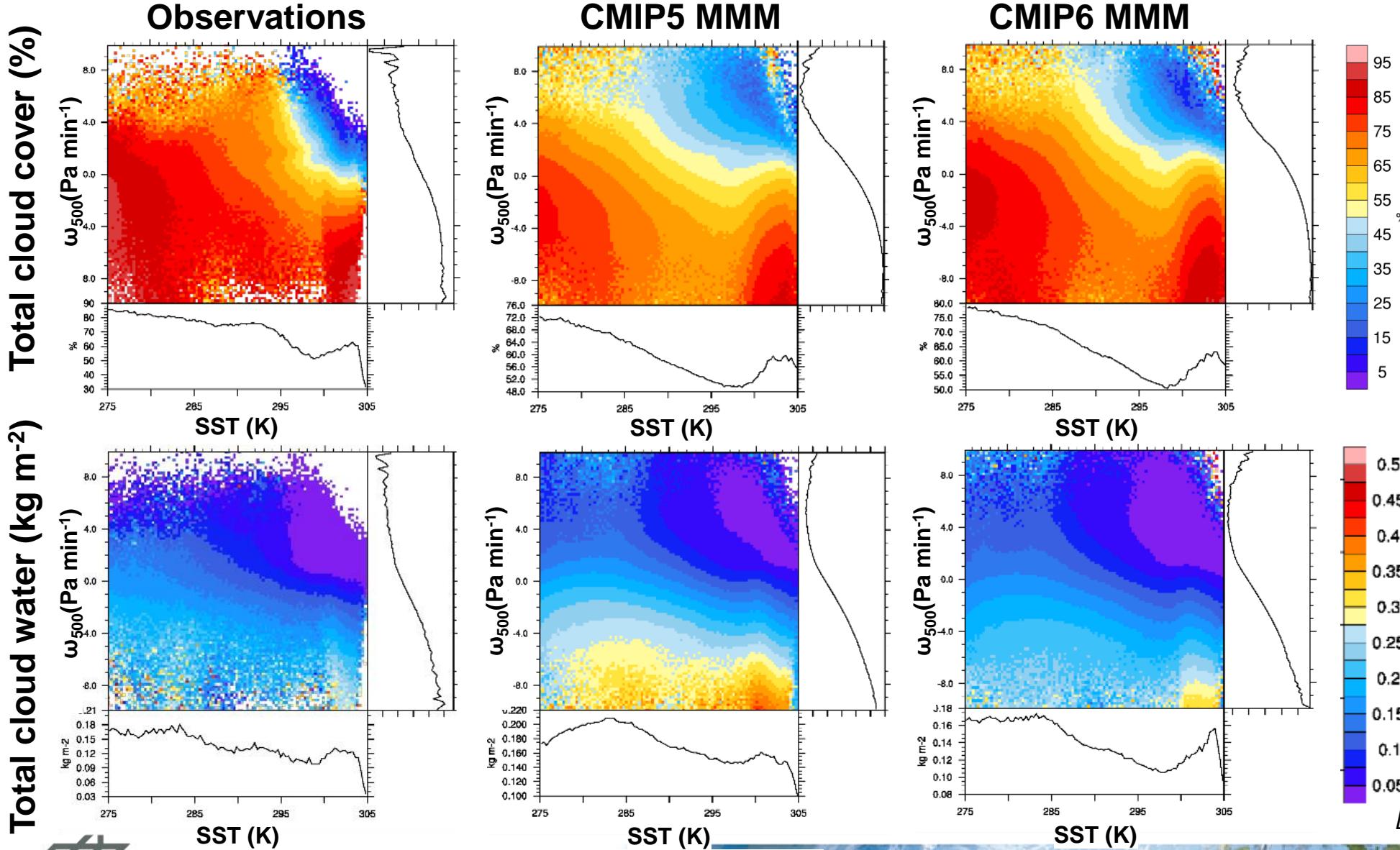
3D distribution of cloud liquid and ice water content

- Reduced cloud ice in CMIP6 models throughout the troposphere
- Improved agreement of CMIP6 MMM with CALIPSO-ICECLOUD (less overestimation of ice)
- Slightly decreased cloud liquid water in CMIP6 compared with CMIP5
- Underestimation of cloud liquid in MMM throughout most of the troposphere except in lowermost boundary layer

Observations: CALIPSO-ICECLOUD, CloudSat



Cloud properties by dynamical regime



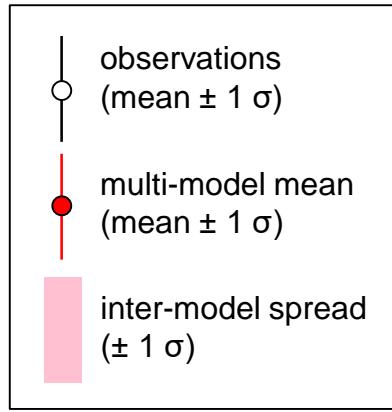
CMIP6 MMM in better agreement with observations

- Increased cloud cover in CMIP6 in moderately descending and ascending regions ($\omega_{500} < 4 \text{ Pa min}^{-1}$)
- Improved agreement of CMIP6 MMM with ESACCI-CLOUD (higher cloud fraction, reduced total cloud water in ascending regions ($\omega_{500} < -4 \text{ Pa min}^{-1}$))

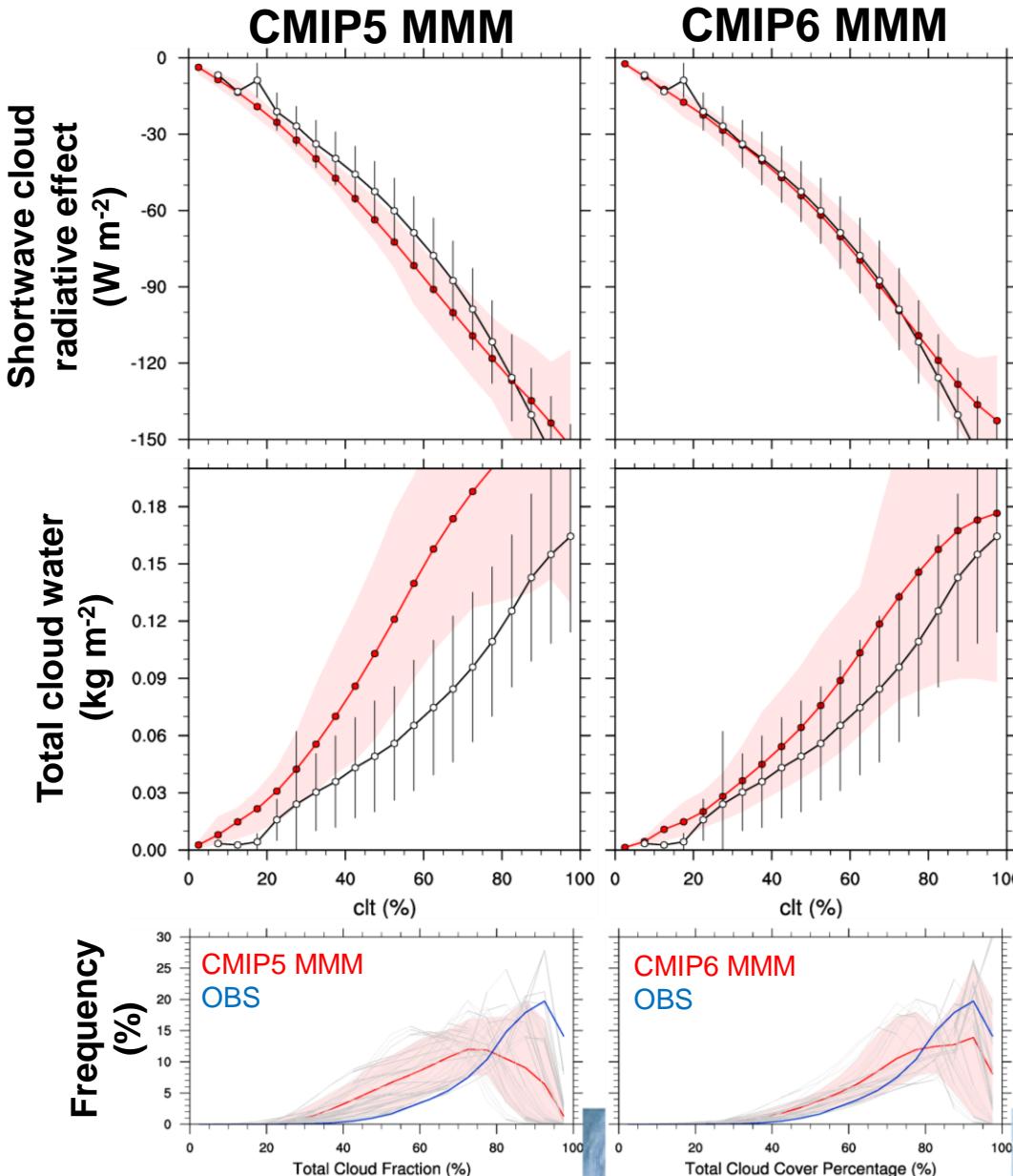
Lauer et al., in prep.



Southern Ocean (Dec-Jan-Feb)



Observations:
ESACCI-CLOUD



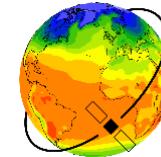
Improved agreement of CMIP6
MMM with observations compared
to CMIP5

- Reduced shortwave cloud radiative effect for given total cloud fraction
 - Reduction in total cloud water path in the CMIP6 models
 - Increased frequency of high total cloud amounts in CMIP6 compared to CMIP5
- Improvement of “too few, too bright problem” in CMIP6

Lauer et al., in prep.



Summary



ESMValTool
Earth System Model Evaluation Tool

- **ESMValTool:** tool for fast and easy routine evaluation and analysis of Earth system models including provenance records for all results (traceability and reproducibility)
- **Climate models are improving:** pattern correlation and performance metrics are showing significant improvement from CMIP3 over CMIP5 to CMIP6
- CMIP6 ensemble shows a **higher effective climate sensitivity (ECS)** and an increased range of values from individual models
- **CMIP6 MMM in better agreement with observations** of cloud properties in some dynamical regimes
- **Improvement of “too few, too bright problem” over Southern Ocean in CMIP6:** improved agreement of shortwave cloud radiative effect and total cloud water path per cloud fraction and of frequency of high total cloud fractions