Project: **854**

Project title: **Erdsystemmodellevaluierung (DLR-Institut für Physik der Atmosphäre)**

Principal investigator: **Axel Lauer**

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1. ESMValTool v2.0

Within this project, the new version of the Earth System Model Evaluation Tool (ESMValTool version 2.0) has been developed, tested and released. The new version is described in four articles of which three have been published in Geoscientific Model Development during the reporting period (Righi et al., 2020; Eyring et al., 2020; Lauer et al., 2020). The fourth article describing the new version of the ESMValTool is currently in review (Weigel et al.).

2. Analysis and evaluation of CMIP6 results

ESMValTool v2.0 has then been used to evaluate results from the of the Coupled Model Intercomparison Project Phase 6 (CMIP6). The work focused on (a) comparison of CMIP6 results with CMIP3 and CMIP5 (Bock et al., accepted) and (b) assessment of the robustness of emergent constraints for equilibrium climate sensitivity when applied to CMIP6 data (Schlund et al., in review).

2.1 Perfomance of CMIP6 compared to CMIP3 and CMIP5

The ESMValTool has been used to assess the performance of the CMIP6 ensemble compared to the previous generations CMIP3 and CMIP5. While CMIP5 models did not capture the observed pause in the increase in global mean surface temperature between 1998 and 2013, the historical CMIP6 simulations agree well with the observed recent temperature increase, but some models have difficulties in reproducing the observed global mean surface temperature record of the second half of the 20th century. While systematic biases in annual mean surface temperature and precipitation remain in the CMIP6 multi-model mean, individual models and high-resolution versions of the models show significant reductions in many long-standing biases. Some improvements are also found in the vertical temperature, water vapor and zonal wind speed distributions, and root mean square errors for selected fields are generally smaller with reduced inter-model spread and higher average skill in the correlation patterns relative to observations. An emerging property of the CMIP6 ensemble is a higher effective climate sensitivity with an increased range between 2.3 and 5.6 K. A possible reason for this increase in some models is improvements in cloud representation resulting in stronger shortwave cloud feedbacks than in their predecessor versions. This work is summarized in Bock et al. (accepted). As an example from this work, Figure 1 shows a comparison of the simulated multi-model means of global average temperature anomalies from CMIP3, CMIP5 and CMIP6 in comparison with observations.

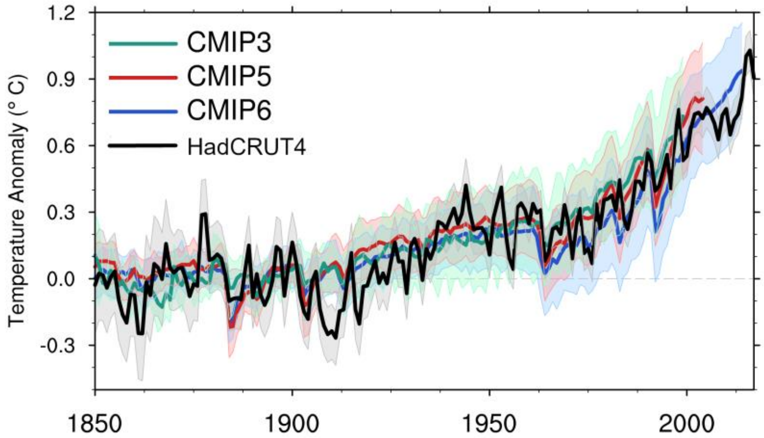

Figure 1 Observed and simulated time series of the anomalies in annual and global mean surface temperature

calculated as differences from the 1850-1900 time-mean. Displayed are the multi-model means of the CMIP 3,5,6 ensembles with shaded range of the respective standard deviation. In black the reference data set (HadCRUT4). Gray shading shows the 5% to 95% confidence interval of the combined effects of all the uncertainties described in the HadCRUT4 error model (measurement and sampling, bias and coverage uncertainties). From Bock et al. (accepted).

2.2 Comparison of constraints on equilibrium climate sensitivity applied to CMIP5 and CMIP6

Eleven published emergent constraints on equilibrium climate sensitivity (ECS) that have mostly been derived from models participating in CMIP5 are analysed and applied to CMIP6 data. The focus of the study is on testing if these emergent constraints hold for Earth system models participating in CMIP6. Since none of the emergent constraints considered here has been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases. Consequently, the size of the constrained ECS ranges (66% confidence intervals) increased by 51% on average (using the arithmetic mean of all emergent constraints) in CMIP6 compared to CMIP5. This is likely because of changes in the representation of cloud processes from CMIP5 to CMIP6, but may in some cases also be due to spurious statistical relationships or a too small number of models in the ensemble the emergent constraint was originally derived from. The emergently-constrained best estimates of ECS also increased from CMIP5 to CMIP6 by 12% on average. This can at least partly be explained by the increased number of high-ECS (above 4.5K) models in CMIP6 without a corresponding change in the constraint predictors, suggesting the emergence of new feedback processes rather than changes in strength of those previously dominant. Our results support previous studies concluding that emergent constraints should be based on an independently verifiable physical mechanism, and that emergent constraints focusing on specific processes contributing to ECS may be more robust than those attempting to constrain the total. This work is summarized in Schlund et al. (in review).

Publications

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