Project: **854**

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

Principal investigator: **Axel Lauer**

Report period: **2023-11-01 to 2024-10-31**

1. ESMValTool development

New versions of the Earth System Model Evaluation Tool (ESMValTool) are developed and tested within project 854 before being released. Within the reporting period, ESMValTool v2.10.0 (December 2023) and v2.11.0 (July 2024) have been released. Version v2.12.0 is currently being tested with the release scheduled for early 2025. Examples of new features in v2.10.0 and v2.11.0 include new diagnostics for evaluation of aersol optical depth (AOD) climatologies against ground based observations from AeroNET, analysis of climate patterns from CMIP6 models and a set of diagnostics for monitoring and quick performance assessments of climate simulations; new preprocessing functions such as conversion to local solar time, calculation of histograms and various distance metrics; new reference datasets such as AeroNET, ANU Climate 2.0 Australian data, NOAA-ERSST, NOAA-CIRES-20CR v3 reanalysis, NASA MERRA reanalysis, NOAA marine boundary layer data for CH_4, MOBO-DIC2004-2019; significantly improved performance including better parallelization and memory management through Dask distributed. The latest performance improvements will be documented in:

> *Schlund, M., B. Andela, J. Benke, R. Comer, B. Hassler, E. Hogan, P. Kalverla, A. Lauer, B. Little, S. Loosveldt Tomas, F. Nattino, P. Peglar, V. Predoi, S. Smeets, S. Worsley, M. Yeo, and K. Zimmermann, Improving climate model evaluation with ESMValTool v2.11.0 using parallel, out-of-core, and distributed computing, in prep. for Geosci. Model Dev.*

Figure 1 shows examples of the improvement in run time achieved for selected ESMValTool preprocessors. The shortest run times can be consistently achieved with ESMValTool v2.11.0 on a full compute node with 256 GB of RAM (dark blue bars). Particularly the run time of the memory and CPU intensive vertical interpolation of 3-dim data (extract_levels) could be reduced by up to a 95% (depending on the configuration) compared with the implementation without Dask distributed.

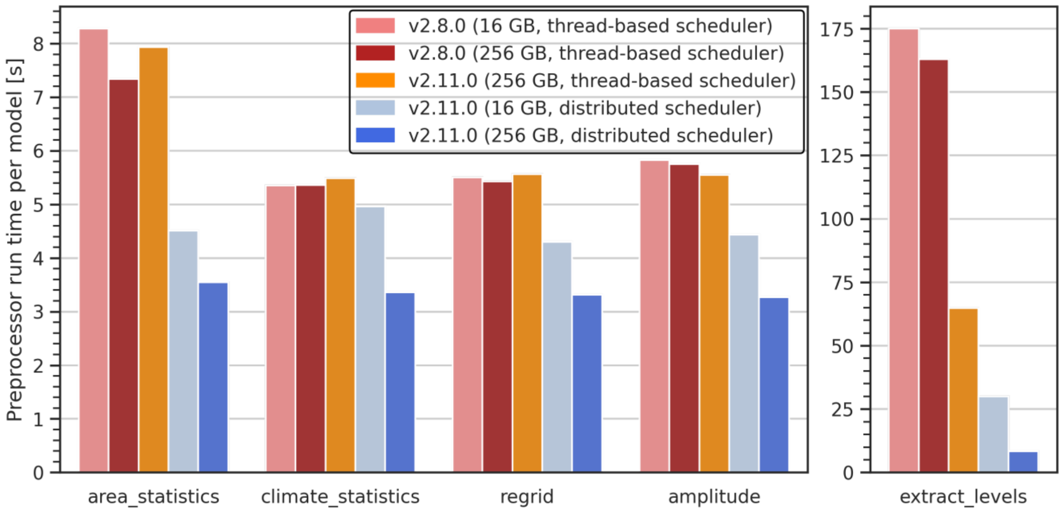

Figure 1 Run times of individual ESMValTool preprocessors when applied to output from a single model data (results averaged over 10 different model data sets) in different setups (see legend). The input data are monthly-mean vertically resolved air temperature (time, pressure level, latitude, longitude) for 20 years of historical simulations (1995–2014) from CMIP6 models. From Schlund et al. (in prep).

2. Analysis and evaluation with ESMValTool

For the analysis and evaluation of CMIP model with ESMValTool, new benchmarking and monitoring capabilities have been implemented and demonstrated in Lauer et al. (in review). The new framework allows to put common performance metrics calculated for a given model simulation into the context of results from an ensemble of state-of-the-art climate models such as the ones participating in CMIP6. Putting the performance of a model simulation into such a context allows to quickly assess whether, for instance, the values obtained for metrics such as bias or pattern correlation for a variable are within the typical range of model errors or might need further, more detailed investigation. This is particularly of help during model development or when monitoring a simulation to identify possible problems already during run-time as this allows a large number of variables to be assessed without the need for detailed expert knowledge on each single quantity. A target application for these new model benchmarking and monitoring capabilities of ESMValTool is the assessment of new model simulations during the preparation phase for CMIP7 such as the ones from ICON.

As an example, Figure 2 shows time series of global average (a) anomalies and (b) RMSE of near-surface temperature simulated by an EMAC example simulation with deliberately erroneous prescribed sea surface temperatures after the first five years of simulation.

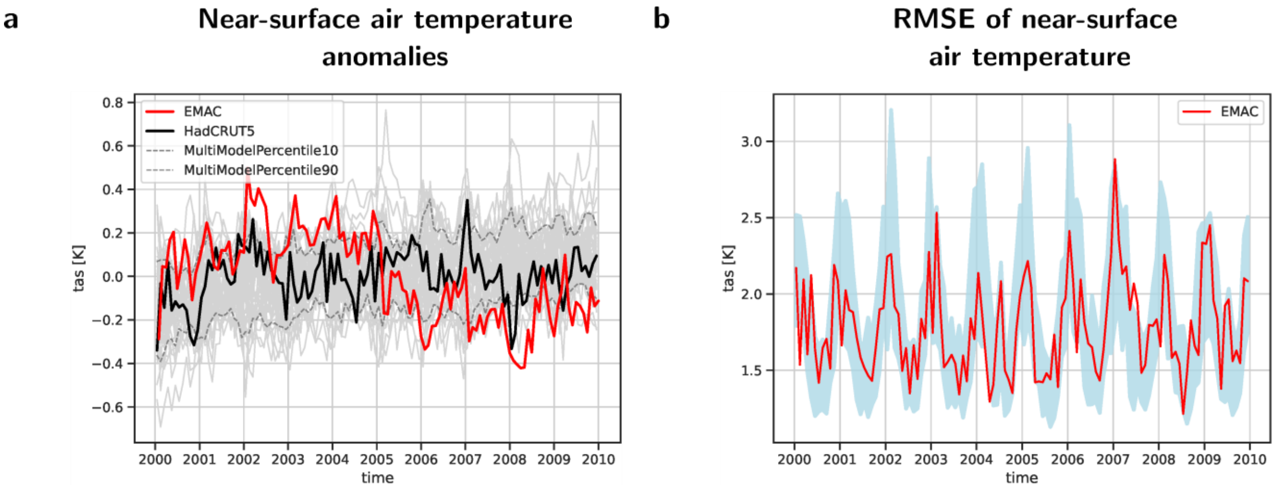

Figure 2 (a) Time series from 2000 through 2009 of global average monthly mean temperature anomalies (reference period 2000-2009) of the near-surface temperature in K from a simulation of EMAC (red) and the reference dataset HadCRUT5 (black). The thin gray lines show 43 individual CMIP6 models used for comparison, the dashed gray lines show the 10 % and 90 % percentiles of these CMIP6 models. (b) Same as (a) but for area-weighted RMSE of the near-surface air temperature. The light blue shading shows the range of the 10 % to 90 % percentiles of RMSE values from the ensemble of 43 CMIP6 models used for comparison. From Lauer et al. (in review).

Publications in 2024 related to project 854

Bock, L., and Lauer, A.: Cloud properties and their projected changes in CMIP models with low to high climate sensitivity, Atmos. Chem. Phys., 24, 1587-1605, doi: 10.5194/acp-24-1587-2024, 2024.

Lauer, A., Bock, L., Hassler, B., Jöckel, P., Ruhe, L., and Schlund, M.: Monitoring and benchmarking Earth system model simulations with ESMValTool v2.12.0, EGUsphere [preprint], doi: 10.5194/egusphere-2024-1518, 2024.