

The Earth System Model Evaluation Tool (ESMValTool)

Axel Lauer¹, Veronika Eyring¹, Mattia Righi¹, Alexander Löw², Martin Evaldsson³

¹ Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Oberpfaffenhofen, Germany

² Department of Geography, University of Munich (LMU), Germany

³ Swedish Meteorological and Hydrological Institute (SMHI), Norrköping, Sweden

25 November 2015



Knowledge for Tomorrow

Motivation for the development of the Earth System Model Evaluation Tool (ESMValTool)

- Facilitate the evaluation of complex Earth System Models, e.g.,
 - quick look at standard diagnostic plots & output diagnostic variables,
 - easy comparison of new simulations (e.g. sensitivity runs or runs with new model versions) with existing runs and with observations

Raise the standard for model evaluation

- include additional diagnostics of ongoing evaluation activities so that we do not have to start from scratch each time
- implement more observations, account for observational uncertainties
- Quick assessment of where we stand with a new set of model simulations via standard namelists that reproduce specific papers, reports, etc.
- Traceability and reproducibility
- Facilitates participation in and analysis of Model Intercomparison Projects
 - easily comparison of models participating in CMIP and CMIP6-Endorsed MIPs
- Easy expandability
 - synergies with ongoing projects to expand the tool (e.g. NCAR CVDP)
 - useful for model groups & those analyzing models
 - useful for model development



CRESCENDO

Overarching goal

Improve the process realism and future climate projection reliability of (European) climate models.

Objective

Develop and apply an evaluation tool for routine model benchmarking and more advanced analysis of feedbacks and future projections.

Strategy

- Develop a community benchmarking system (ESMValTool)
 - Comparing with observations and earlier model versions
 - Benchmarking key aspects of simulated variability and trends
 - Including additional biogeochemical and aerosol/trace gas metrics
 - Adding process-level diagnostics
- Implement *emergent contraints* developed in CRESCENDO into ESMValTool
- Make ESMValTool available to the wider research community



Overview ESMValTool

- Routine benchmarking and evaluation of single or multiple ESMs, either against predecessor versions, a wider set of climate models, or observations
- Current implementations include sea ice assessments and other Essential Climate Variables (ECVs), tropical variability, atmospheric CO₂ and NO₂ budget, ...

→ can easily be **extended with additional analysis**

Community development under a *subversion* controlled repository

 \rightarrow allows for multiple developers from different institutions to contribute and join

- Goals:
 - Enhance and improve routine benchmarking and evaluation of ESMs
 - Routinely run the tool on model output of CMIP6 alongside the Earth System Grid Federation (ESGF)
 - Support and facilitate the analysis of the ongoing CMIP Development, Evaluation, Characterization of Klima (DECK) and CMIP6 simulations with a fully internationally developed evaluation tool from multiple institutions

Climate community is encouraged to contribute to this effort over the coming years.



Current Status: Contributing Institutions (currently ~60 developers from 22 institutions)

- 1. Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Germany
- 2. Swedish Meteorological and Hydrological Institute (SMHI), Norrköping, Sweden
- 3. Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA), Italy
- 4. British Atmospheric Data Centre (BADC), UK
- 5. Centre for Australian Weather and Climate Research (CAWCR), Bureau of Meteorology, Australia
- 6. Deutsches Klimarechenzentrum (DKRZ), Germany
- 7. ETH Zurich, Switzerland
- 8. Finnish Meteorological Institute, Finland
- 9. Geophysical Fluid Dynamics Laboratory (GFDL) NOAA, USA
- 10. Institut Pierre Simon Laplace, France
- 11. Ludwig Maximilian University of Munich, Germany
- 12. Max-Planck-Institute for Meteorology, Germany
- 13. Met Office Hadley Centre, UK
- 14. Météo France, Toulouse, France
- 15. Nansen Environmental and Remote Sensing Center, Norway
- 16. National Center for Atmospheric Research (NCAR), USA
- 17. New Mexico Tech, USA
- 18. Royal Netherlands Meteorological Institute (KNMI), The Netherlands
- 19. University of East Anglia (UEA), UK
- 20. University of Exeter, Exeter, UK
- 21. University of Reading, UK
- 22. University of Wagingen, The Netherlands

Development of an Earth System Model Evaluation Tool

Within EMBRACE: DLR, SMHI & EMBRACE partners in collaboration with NCAR, PCMDI, GFDL

- Open Source: Python script that calls NCL (NCAR Command Language) and other languages (R, Python)
- Input: CF compliant netCDF model output (CMIP standards)
- Observations: can be easily added
- Extensible: easy to (a) read models (b) process output [diagnostic] with observations and (c) use a standard plot type (e.g. lat-lon map)



Current developments include

- Essential Climate Variables, e.g.,
 - Sea-Ice
 - Temperatures & Water Vapor
 - Radiation
 - $-CO_2$
 - Ozone
- Tropical variability (incl. Monsoon, ENSO, MJO)
- Southern Ocean
- Continental dry biases and soil-hydrology-climate interactions (e.g., Standardized Precipitation Index)
- Atmospheric CO₂ and NO₂ budget
- More Observations (e.g., obs4MIPs, ESA CCI)
- Statistical measures of agreement

Goal: Standard namelists to reproduce certain reports or papers (e.g., IPCC AR5 Chapter 9, Massonnet et al., 2012; Anav et al., 2012; Cox et al., 2013; Eyring et al., 2013)



Schematic Overview of the ESMValTool Structure



Installation

Software requirements

• Python 2.*

www.python.org

🥐 pytho)∩ ™	» Download
ABOUT	>>	Download Python
NEWS	>>	The current production versions are Python 2.7.5 and Python 3.3.2.

• NCL 6.2 or higher

www.ncl.ucar.edu



• CMIP5 style datasets



e.g.: esgf-data.dkrz.de/esgf-web-fe

• ESMValTool (not yet officially released \rightarrow contact PIs): tarball or from svn repository

Examples of Diagnostics Implemented



Examples of Diagnostics Implemented

Cloud Regime Error Metric (CREM, Williams and Webb, 2009)

2.5

CanAM4 0.0 0.5 1.0 1.5 2.0 Cloud Regime Error Metric

Atlantic Meridional Overturning Streamfunction (AMOC)

AMOC Means (Annual)



^{4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28}

Interannual variability in surface pCO₂ (Rodenbeck et al., 2014)



Tropospheric ozone (Righi et al., 2015)

uatm





CNRM-CM5

http://www.pa.op.dlr.de/ESMValTool/index.html Eyring et al., Geosci. Model Dev. Discuss, 8, 7541-7661, 2015



Summary

- The ESM Evaluation Tool will facilitate the complex evaluation of ESMs and their simulations (e.g., submitted to international Model Intercomparison Projects such as CMIP, C4MIP, CCMI)
- > The tool is developed under a subversion controlled repository
 - Allows multiple developers from different institutions to join the development team
 - Broad community-wide and international participation in the development is envisaged
 - Collaboration with the WGNE/WGCM metrics panel

Current extensions

- Atmospheric dynamics, biogeochemical processes, cryosphere and ocean
- Need for a wide range of observational data to be used with the tool
- Observations should ideally be provided with uncertainty and a technical documentation (e.g. similar to those from obs4MIPs) and in CF compliant netCDF
- Improving statistical comparison and visualization

Regular releases to the wider international community

- Further develop and share the diagnostic tool and routinely run it on CMIP DECK output and according observations (obs4MIPs) alongside the Earth System Grid Federation (ESGF)
- Release of ESMVal tool to the public \rightarrow will contribute to metrics panel code repository
- Work towards a full community-tool developed by multiple institutions / countries

CRESCENDO WP3.1 – Objectives

- Further develop an ESM benchmarking and evaluation tool (ESMValTool): new Essential Climate Variables (ECVs) and standard diagnostics
- Make use of observations from projects such as ESA-CCI and obs4MIPs: new climate diagnostics, e.g., surface radiation, turbulent energy, water fluxes, precipitation variability
- Include new key diagnostics: biogeochemical and aerosol processes
- Extend ESMValTool with **new diagnostics for operational analysis** of multi-model ESM projections: e.g. IPCC AR5 Ch. 9 diagnostics
- Provide user guidelines for other partners to include new diagnostics and performance metrics for process-based model evaluation (RT2) and emergent constraints (WP3.2) into the ESMValTool
- Develop interfaces to existing diagnostic packages such as the UK Met Office Auto-Assess package



Thank you!

Knowledge for Tomorrow

