climate change initiative

CLIMATE MODELLING USER GROUP

Earth System Model Evaluation Tool (ESMValTool)

A. Lauer and the ESMValTool development team

cmug cci

What is ESMValTool?

The **Earth System Model Evaluation Tool** (ESMValTool) is a community diagnostics and performance metrics tool for the evaluation and analysis of Earth System Models (ESMs).

- **Community effort** open to both users and developers
- **Wide scope:** includes many diagnostics and performance metrics covering different aspects of the Earth system
- **High flexibility:** new diagnostics and more observational data can be easily added
- **Multi-language support:** Python, NCL, R, Julia (other open-source languages are possible)
- **Reproducibility** of the results (provenance)
- **Well-documented** source code and diagnostics
- **Online tutorial** for easy introduction for new users
- **Governance** structure in place

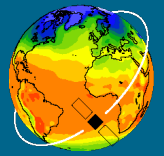
ESMValTool
Earth System Model Evaluation Tool

github.com/ESMValGroup

docs.esmvaltool.org
tutorial.esmvaltool.org

www.esmvaltool.org

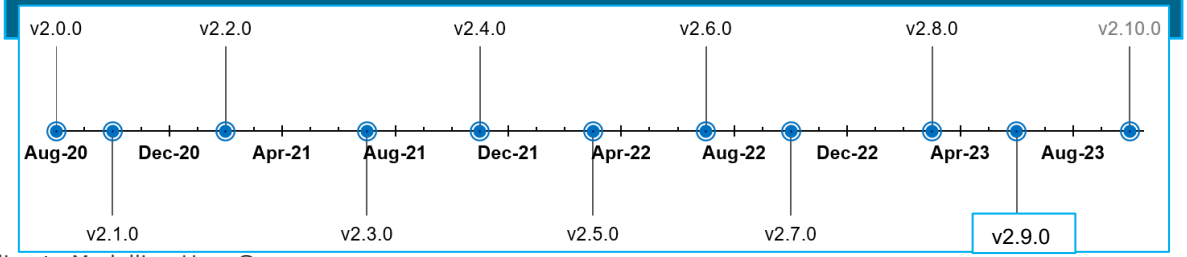
ESMValTool v2



ESMValTool

Earth System Model Evaluation Tool

- Community diagnostic and performance metrics tool for **evaluation and analysis of Earth system models**
- **Open source community development on GitHub** (> 200 developers, > 60 international institutes)
- Used in several chapters of the **Assessment Report 6** of the IPCC's WG1
- Release of v2.0.0 in August 2020, currently at v2.9.0



Scientific Documentation

Righi et al., GMD, 2020
Technical overview

Eyring et al., GMD, 2020
Large-scale diagnostics

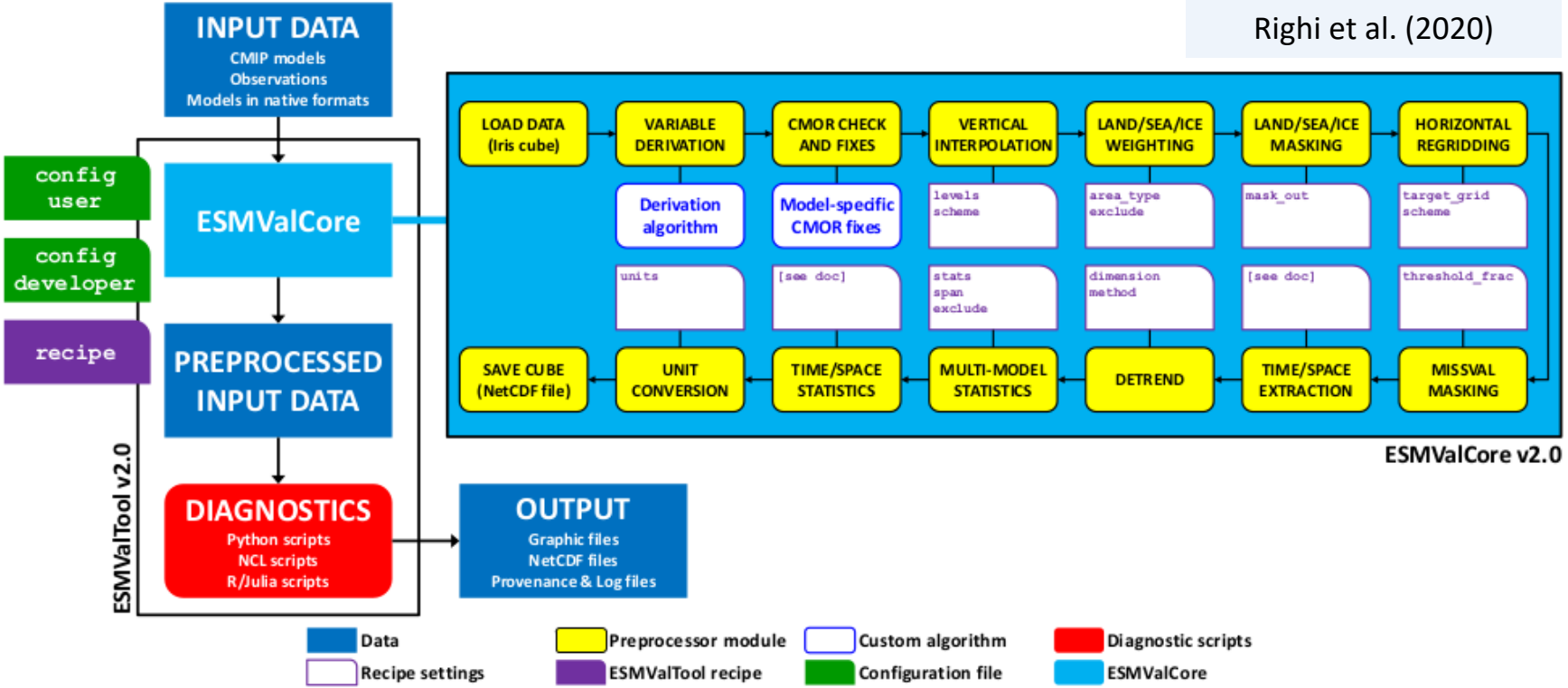
Lauer et al., GMD, 2020
Diagnostics for emergent constraints and future projections

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

Schlund et al., GMD, 2023
Evaluation of native ESM output

Schematic overview

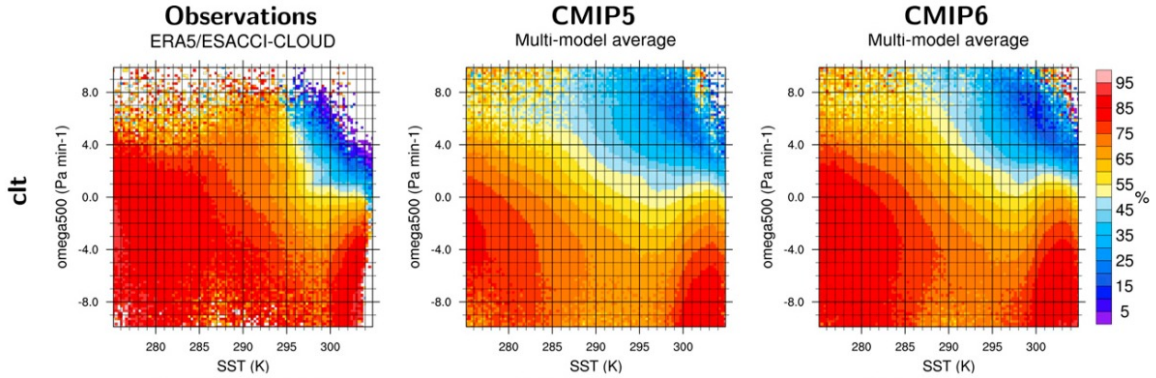
Righi et al. (2020)



ESA CCI datasets implemented into ESMValTool

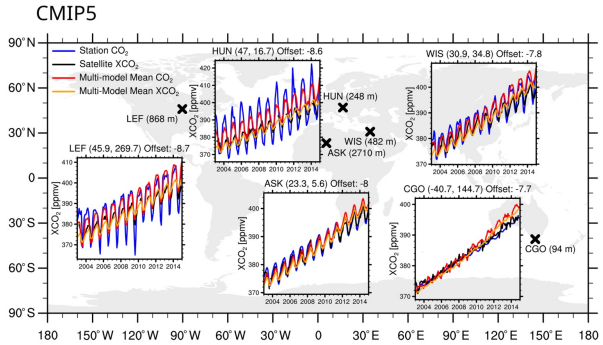
Dataset	Variable(s)	Resolution	Years
Aerosol	od550aer, od870aer, od550lt1aer, abs550aer	1°x1°	1997-2011
Cloud	clivi, clt, clwvi, rlut, rlutcs, rsut, rsutcs	0.5°x0.5°	1982-2016
Fire	burntArea	0.25°x0.25°	2005-2011
Greenhouse Gases	xco2, xch4	5°x5°	2003-2016
Ozone	tro3, tropoz, toz	1°x1°	1997-2010
Land Cover	lccs_class: grassNcropFrac, shrubNtreeFrac	300 m	2000, 2005, 2010
Land Surface Temperature	ts	0.1°x0.1°	2003-2018
Ocean Colour	chl	4 km	1998-2020
Sea Ice	sic	25 km	1992-2008
Sea Surface Temperature	tos	0.5°x0.5° (0.05°x0.05°)	1982-2019
Sea Surface Salinity	sos	25 km (50 km)	2010-2018
Soil Moisture	sm	0.25°x0.25°	1988-2005
Water Vapour	prw	0.5°x0.5°	2003-2017

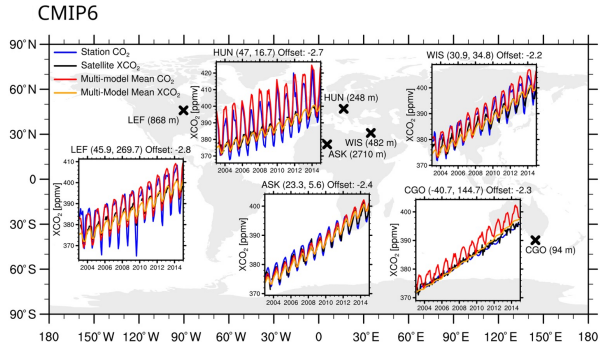
Examples using ESA CCI data



Evaluation of clouds

Lauer et al. (2023)



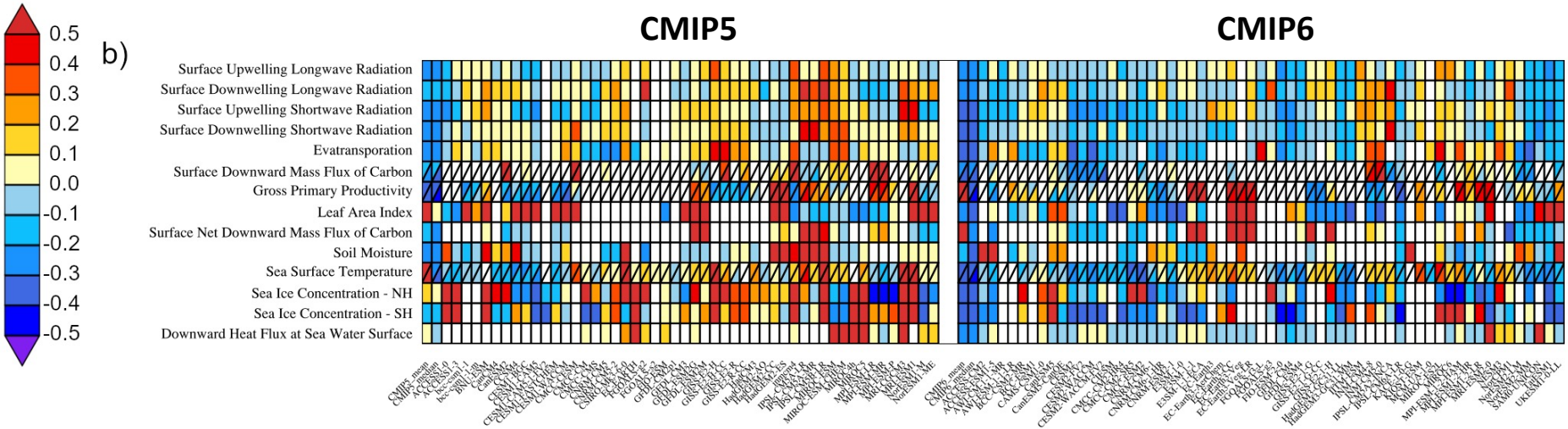


Evaluation of XCO_2

Gier et al. (2020)

Examples using ESA CCI data

Relative model performance (RMSD)



From: IPCC AR6, Chapter 3, Fig. 42

ESMValTool development in CMUG

- Exploit ESA CCI and CCI+ data in the context of **Earth system model (ESM) evaluation** with ESMValTool
- **Enhance the ESMValTool** with additional diagnostics and metrics enabling analysis of models with ESA CCI and CCI+ data
- Implementation of **new CCI datasets and corresponding diagnostics** into the ESMValTool and **updating existing datasets** where needed
- Explore possibilities to **take advantage of the uncertainty information** provided with the CCI datasets for model evaluation

Implementation/update of CCI datasets

aerosol cci	**update** to Swansea ATSR (v4.33) and SLSTR / 3A (v1.12) OR ensemble (ATSR v3.0 and SLSTR / 3A v2.2) v6.1
biomass cci	**implement** L4-AGB-MERGED-100m-2018-fv3.0
cloud cci	v3.0 AVHRR AM+PM **add** L3U data (daily)
land cover cci	**update** to v2.0.7/v2.1.1
land surface temperature cci	v3.00, MODIS EOS Aqua **add** daily values
permafrost cci	**implement** MODISLST_CRYOGRID-AREA4_PP-fv03.0
snow cci	**implement** multi-sensor.multi-platform.MERGED.2-0.r1
soil moisture cci	**update** to version v7.1
sst cci	**add** daily values **update** v3.0 once available
water vapour cci	v3.1 TCWV-global (COMBI) **add** daily values

Implementation of uncertainty estimates

- Available **uncertainty information** will be implemented into the ESMValTool alongside already existing ECVs from ESA CCI datasets
- In order to make **scientific use** of this uncertainty information, possibilities to propagate uncertainty information to the spatial and temporal scales used by the models will be investigated.
- As a **starting point**, work done on implementing uncertainty information for the CCI LAND SURFACE TEMPERATURE (Mittaz et al., 2019) will be used.

Starting point (Mittaz et al., 2019)

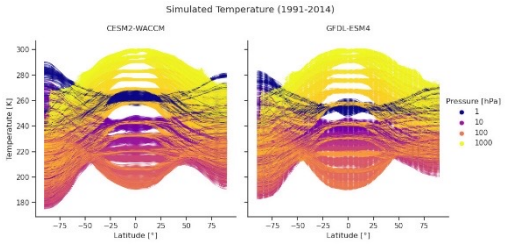
- Uncertainty propagation equations using matrices
- Generic platform for the propagation dependent on the error covariance matrix
- This approach is expected to work for LST and SST.
- It will then be investigated in a case-by-case study if an extension to selected other ECVs is possible.

Latest developments

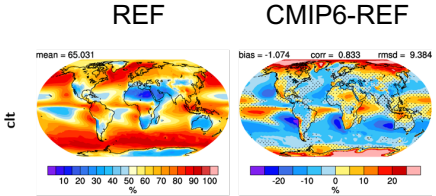
Diagnostics and datasets

- High-level interface to Python data visualization library *seaborn*
- CMIP6 evaluation (e.g. Lauer et al., 2023) and climate projections (e.g. Tebaldi et al., 2021)
- IPCC AR6 diagnostics
- New observational and reanalysis datasets

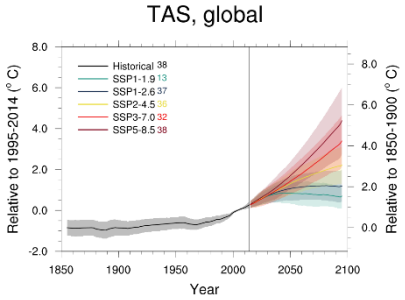
General visualization



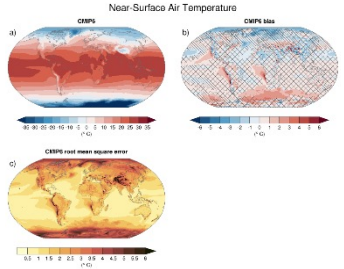
CMIP6 evaluation



Climate projections



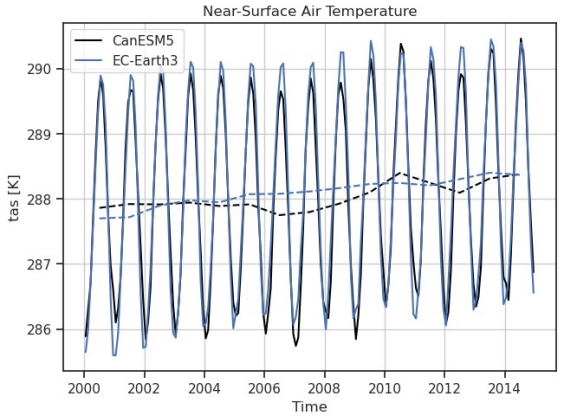
IPCC AR6

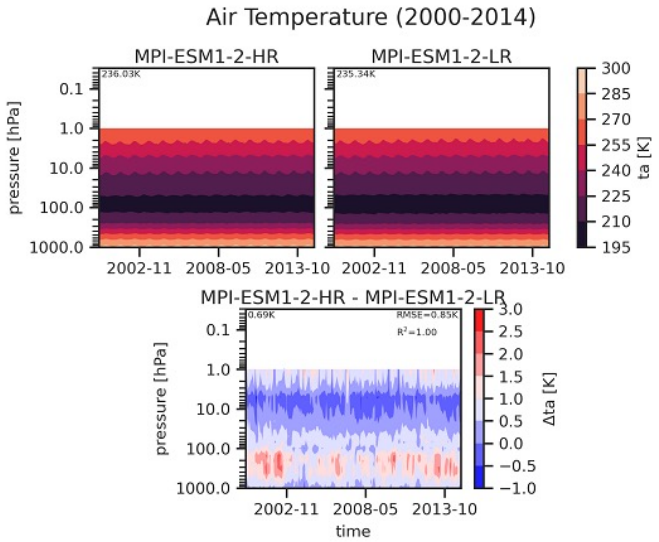


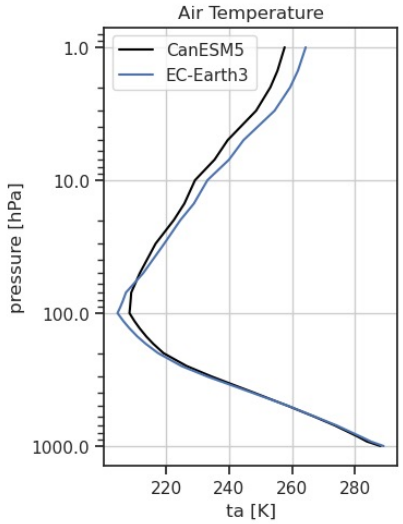
Latest developments

Model development

- Support for processing native model output (e.g. ICON)
- Monitoring diagnostics



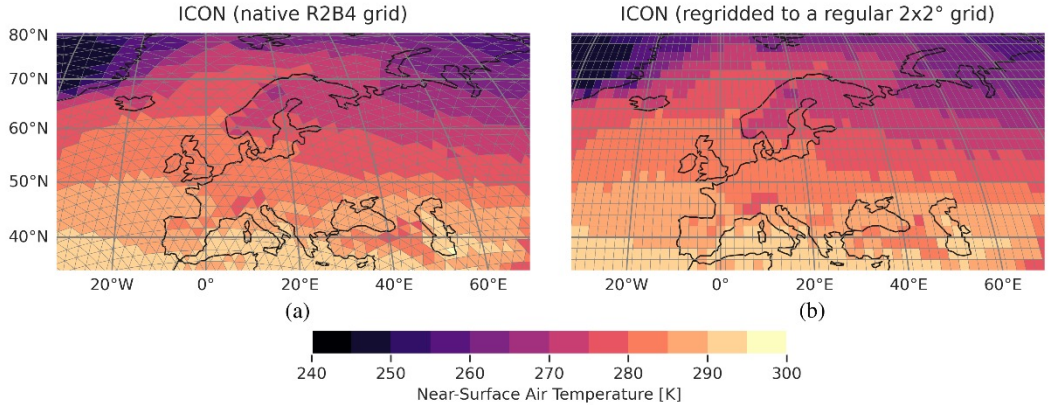




Latest developments

Getting ready for CMIP7

- Improved support for unstructured grids
- Reducing memory footprint: increasing number of lazy functions
- Improved parallel tasking: support for Dask distributed scheduler



Schlund et al. (2023)

RAM

dask

ESMValTool information

ESMValTool
Earth System Model Evaluation Tool

1. Github repositories

https://github.com/ESMValGroup/ESMValTool

2. Documentation

https://docs.esmvaltool.org/

3. Tutorial

https://tutorial.esmvaltool.org/

4. Webpage

https://www.esmvaltool.org/