

ESMValTool

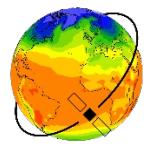
Earth System Model Evaluation Tool

An Introduction to ESMValTool

AI4PEX Kick Off Meeting

May 21st, 2024

Ranjini Swaminathan, Manuel Schlund and Valeriu Predoi and Jarmo
Makela



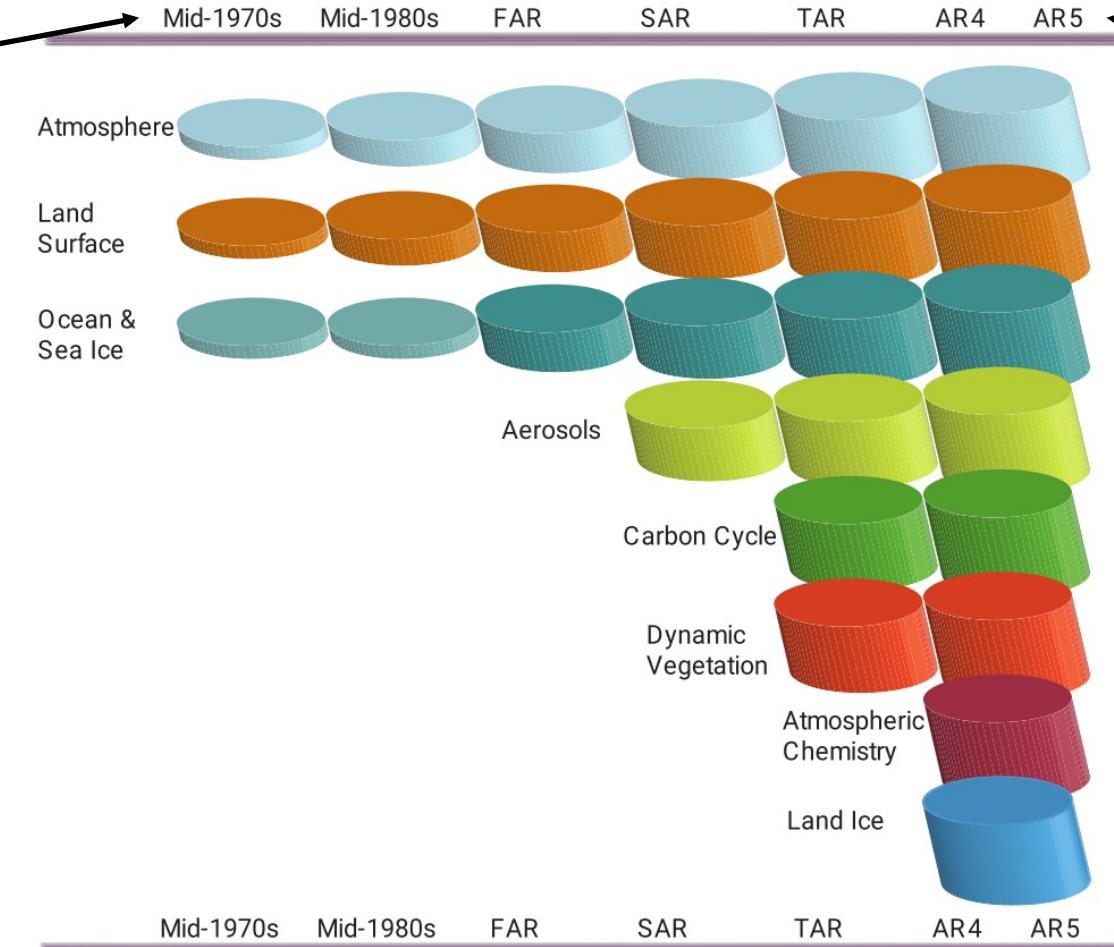
Evolution of Climate Models

AOGCMs

(Atmosphere-Ocean General Circulation Models)

ESMs

(Earth System Models)



IPCC AR5, Ch.

1

Increasing Complexity

ESMs are Complex – and there are Plenty!

Latest Assessment Report of the
IPCC (AR6):

- ~60 ESMs analyzed
- >30 international institutions participated

→ Coordination necessary!

Institution Full Country or Region Name	Models	Main References	Atmosphere 1) Component Name 2) Resolution (km) 3) Top 4) Number of Levels (L)	Aerosol 1) Component Name 2) Emissions- driven or Prescribed 3) Top 4) References	Atmospheric Chemistry 1) Component Name 2) Details 3) References	Ocean 1) Component Name 2) Horizontal Resolution and Number of Levels 3) Vertical Grid	Cryosphere 1) Sea Ice 2) Land Ice	Land 1) Component Name 2) Reference	Land Carbon Active Processes	Ocean Interactive Biogeochemistry 1) Component Name 2) Reference	
CAS Chinese Academy of Sciences China											
CAS											
CCCma Canadian Centre for Climate Modelling and Analysis Canada											
CCCR-IITM Centre for Climate Change Research, Indian Institute of Tropical Meteorology India											
CMCC Centro Euro- Mediterraneo sui Cambiamenti Climatici Italy											
CNRM Centre National de Recherches Météorologiques et CERFACS Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique France											
FIO-QNL First Institute of Oceanography and Pilot National Laboratory for Marine Science and Technology (Qingdao), China	FIO-ESM-2-0	Bao et al. (2020)	1) CAM5 2) 100km, 26 L 3) Top 43 km	2) Prescribed, MACv2-SP (Stevens et al., 2017)		None	POP-W with MASNUM surface wave model 2) 60 km, 60 L 3) z 4) Qiao et al. (2013)	1) CICE4.0 2) Hunke and Lipscomb (2010)	1) CLM4.0 2) Lawrence et al. (2011)	Land carbon N cycle	BEC
E3SM National Laboratories Consortium USA											
HAMMOZ- Consortium Switzerland, Germany, UK, Finland	HAMMOZ- Consortium Switzerland, Germany, UK, Finland	MPI-ESM-1-2-HAM Neubauer et al. (2019a)	1) ECHAM6.3 2) 170 km, 47 L 3) Top 80 km	1) HAM6.3 2) Emissions-driven 3) Teiger et al. (2019)	1) HAM6.3 2) Emissions-driven 3) Teiger et al. (2019)	None	1) MPIOM 1.63 2) 100 km, 40 L 3) z	2) Netz et al. (2013)	1) JSBACH3.20 2) Reich et al. (2021)	Land carbon N cycle Prog. veg. Fires	HAMOCC6
INM Institute for Numerical Mathematics Russian Federation	INM-CM4-8 INM-CM5-0	INM-CM4-8: (Volodin et al., 2018) INM-CM5-0: (Volodin et al., 2017)	CM4: 1) INM-AM4-8 2) 150 km, 21 L 3) Top 31 km CM5: 1) INM-AM5.0 2) 150 km, 73 L 3) Top 61 km	1) INM-AE11 2) Emissions-driven 3) Volodin and Kostykin (2016)	1) INM-AE11 2) Emissions-driven 3) Volodin and Kostykin (2016)	None	INM-OM5 CM4: 70 km, 40 L CMS: 30 km, 40 L 3) Sigma 4) Zalesky et al. (2010)	1) INM-ICE1 2) Yakovlev (2009)	INM-LND1	Land carbon	None
IPSL Institut Pierre- Simon Laplace France	IPSL-CM6A-LR Boucher et al. (2020g)		1) LMDZ NPv6 2) 160 km, 79 L 3) Top 80 km 4) Hourdin et al., 2020)	2) Prescribed 3) Lurton et al. (2020)	2) Specified oxidants for aerosols	1) NEMO 3.6 2) 70 km, 75 L 3) z	1) NEMO-LIM3 2) Rousset et al. (2015)	ORCHIDEE (v2.0, Water/carbon/ energy mode)		PISCES	
IPSL	IPSL-CM5A2-INCA		1) LMDZ APv5 2) 240 km, 79 L 3) Top 80 km 4) Hourdin et al., 2020)	1) INCA 2) Emissions-driven	1) INCA 2) Interactive 3) Hauglustaine et al. (2014)	1) NEMO 3.6 2) 150 km, 30 L 3) z	1) NEMO-LIM3 2) Rousset et al. (2015)	ORCHIDEE (IPSLCM5A2.1, Water/ carbon/energy mode)	Land carbon	PISCES	
KIOST Korea Institute of Ocean Science & Technology Republic of Korea	KIOST-ESM	Pak et al. (2021)	1) GFDL-AM2.0 2) 190 km, 32 L 3) Top 43 km 4) Anderson et al. (2004)	1) GFDL-AM2.0 2) Emissions-driven 3) Anderson et al. (2004)	None	1) GFDL-MOM5.0 2) 90 km, 52 L 3) z	1) GFDL-SIS GFDL-LM3.0 (Milly et al., 2014)	Land carbon N cycle Prog. veg.	TOPAZ2		

IPCC AR6, Annex 2

CMIP – Coupled Model Intercomparison Project

Project

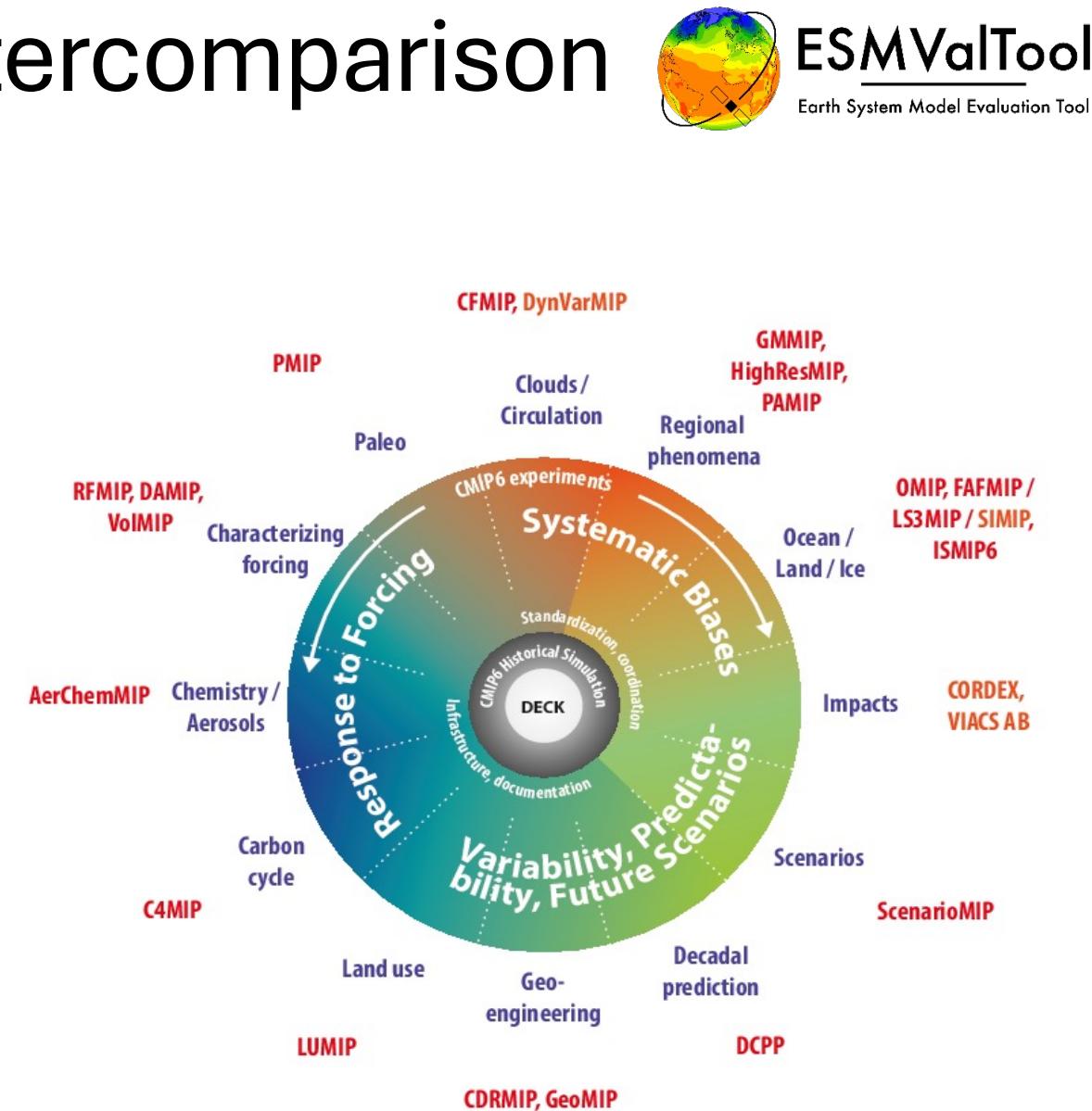
Aim of CMIP: Better understand past, present and future climate changes arising from natural and anthropogenic forcing in a multi-model context.

1) A handful of common experiments

- i. AMIP simulation (~1979-2014)
- ii. Pre-industrial control simulation
- iii. 1%/year CO₂ increase
- iv. Abrupt 4xCO₂ run
- v. Historical simulation using CMIP6 forcings (1850-2014)

2) Standardization, coordination, infrastructure, documentation

3) CMIP-Endorsed Model Intercomparison Projects (MIPs)



Eyring et al., GMD (2016)

ESMValTool

We have:

Many complex CMIP models with standardized output

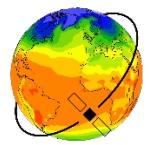
Crucial question:

How well do these models perform relative to reference data sets
(e.g., observations)? → **Standardized model evaluation**

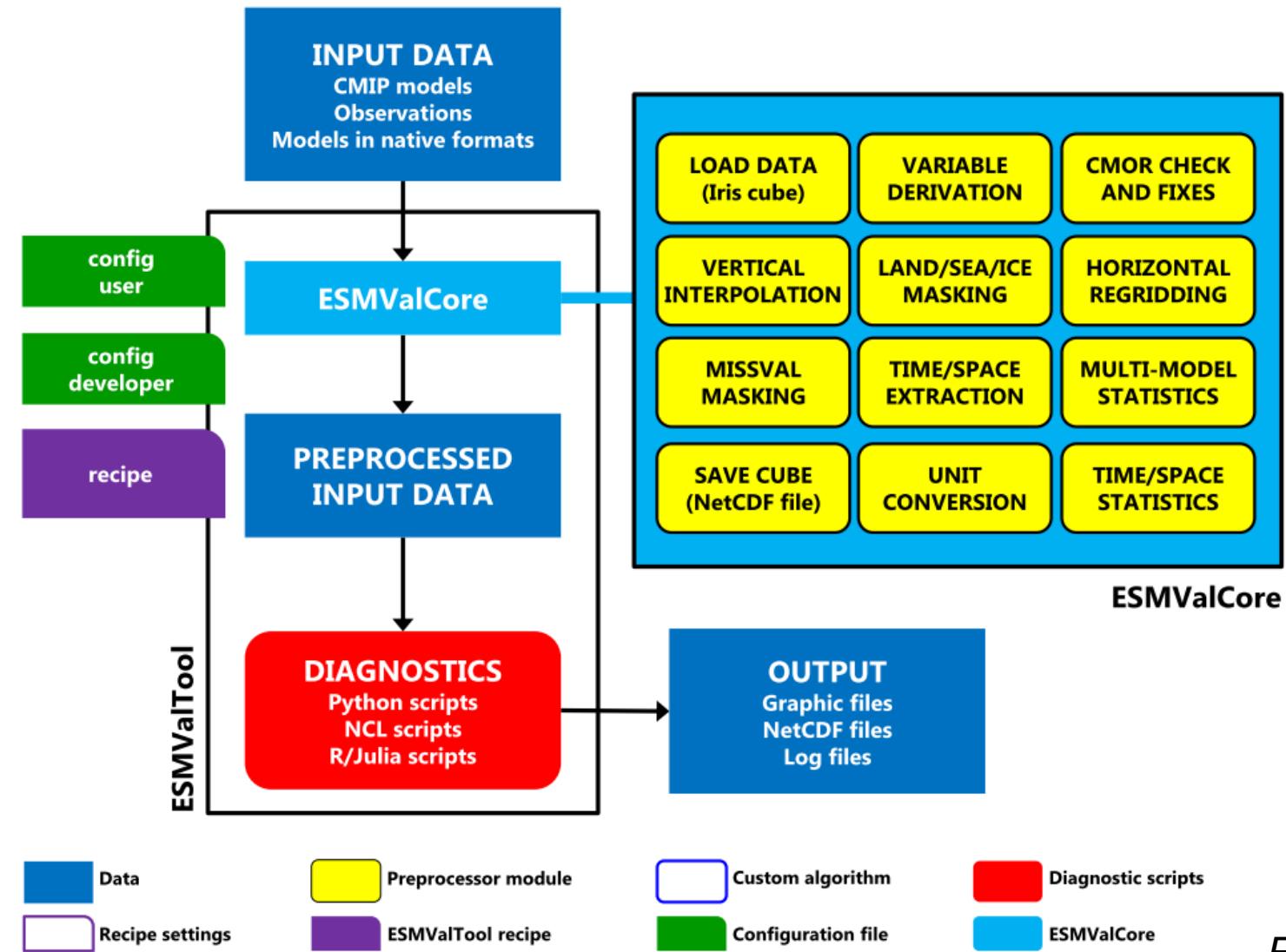


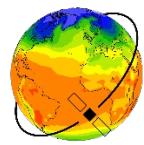
ESMValTool

- **Open source community development** on GitHub (>200 developers; >60 institutes)
- Fast and easy **routine evaluation of ESMs** including provenance records for all results
- Well-established analysis based on **peer-reviewed literature**
- Multitude of commonly used **preprocessor functions** (e.g., calculation of statistics, regridding, masking, etc.)
- **Extensive documentation**

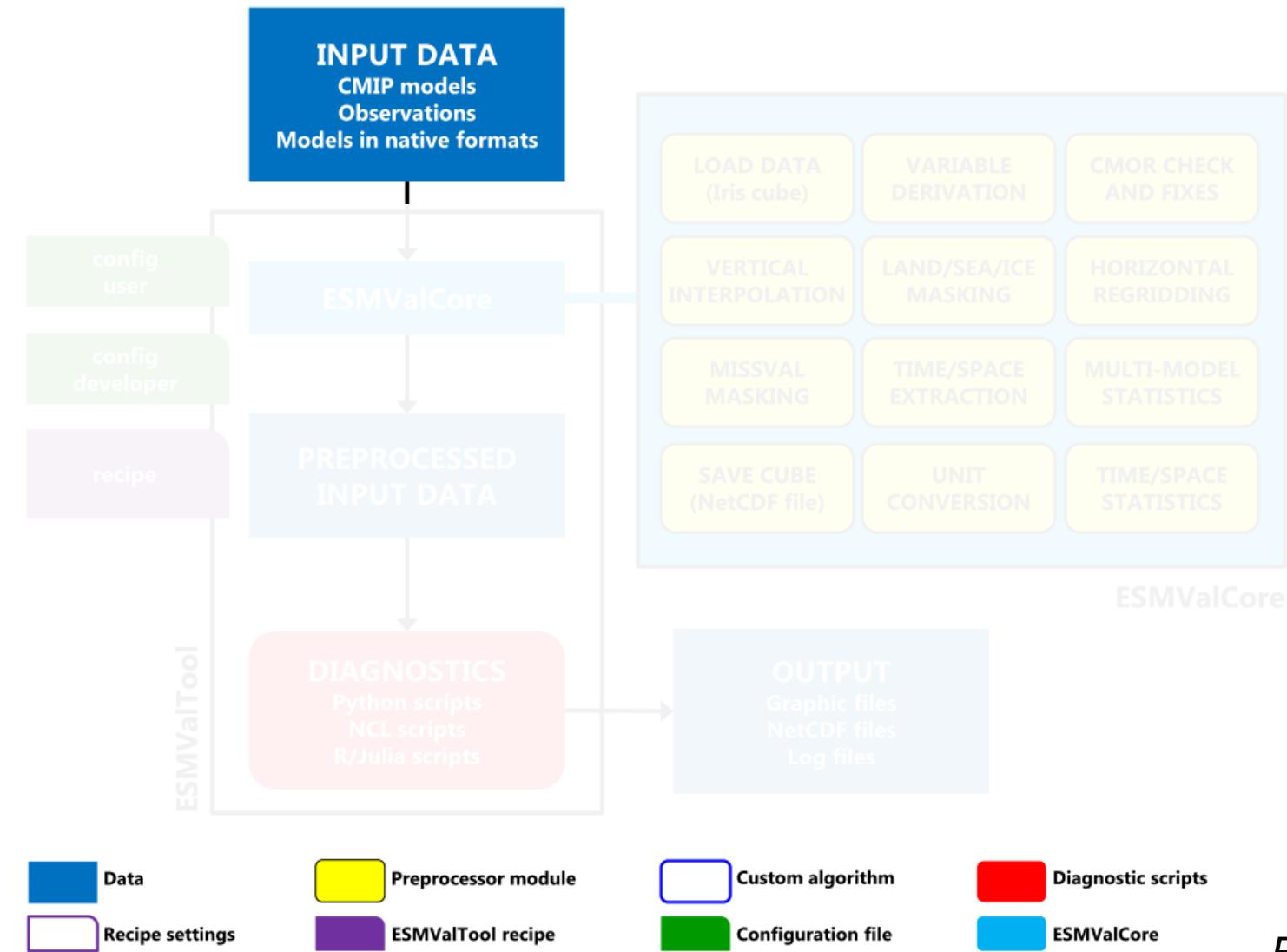


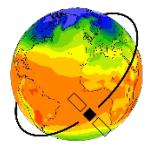
ESMValTool – Details



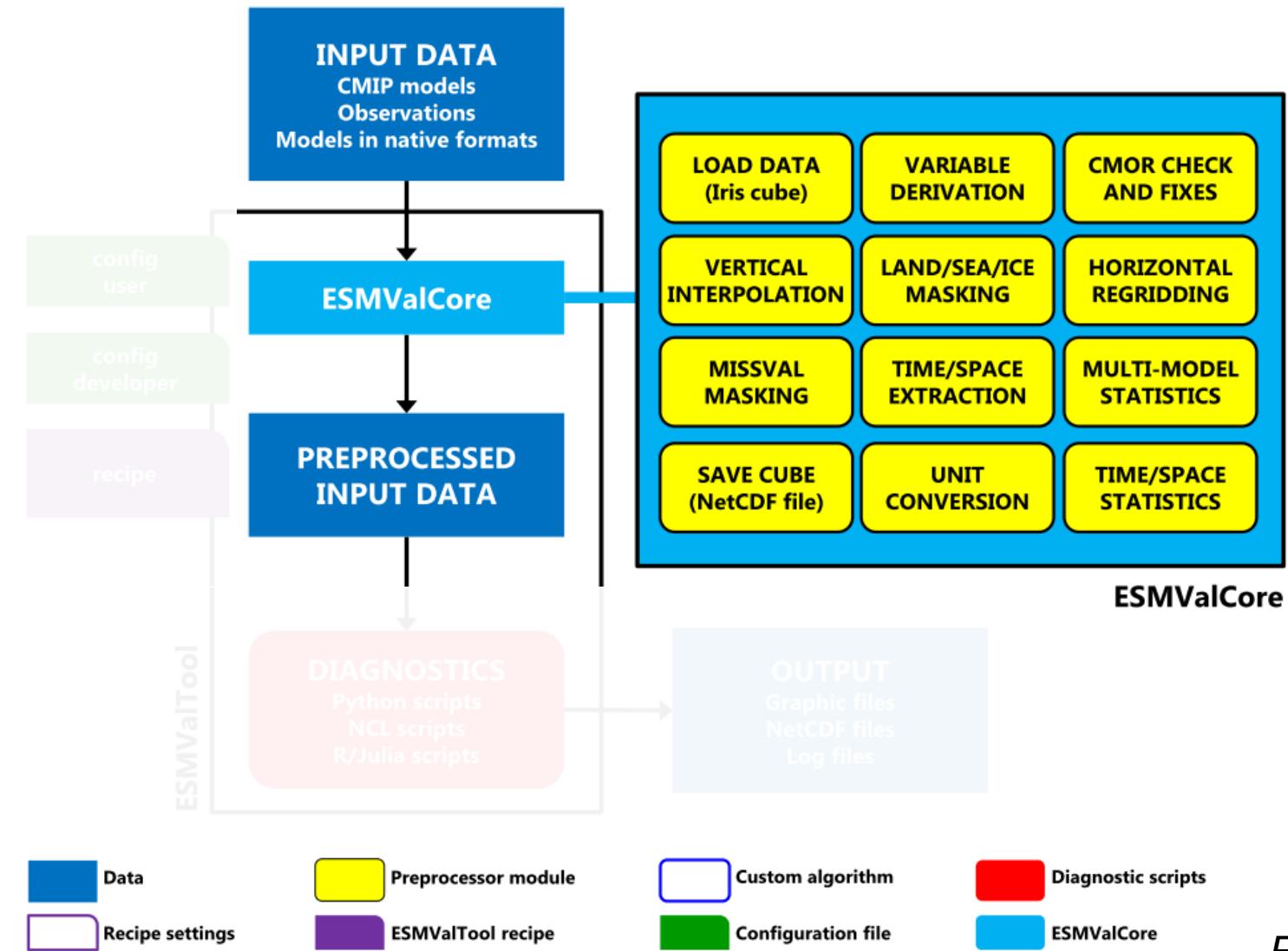


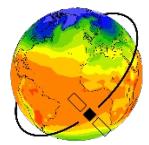
ESMValTool – Details



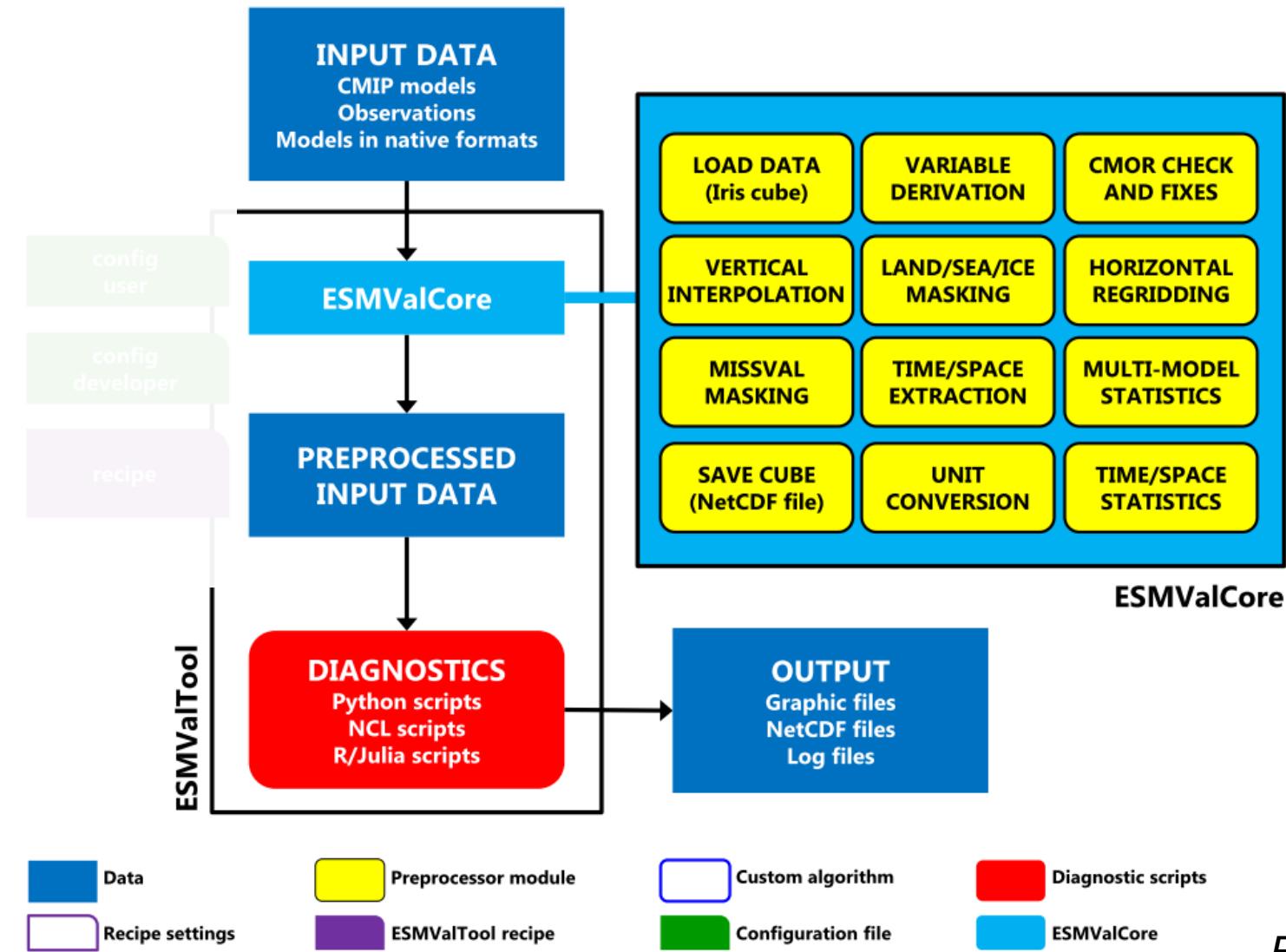


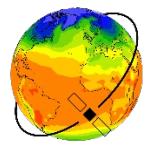
ESMValTool – Details



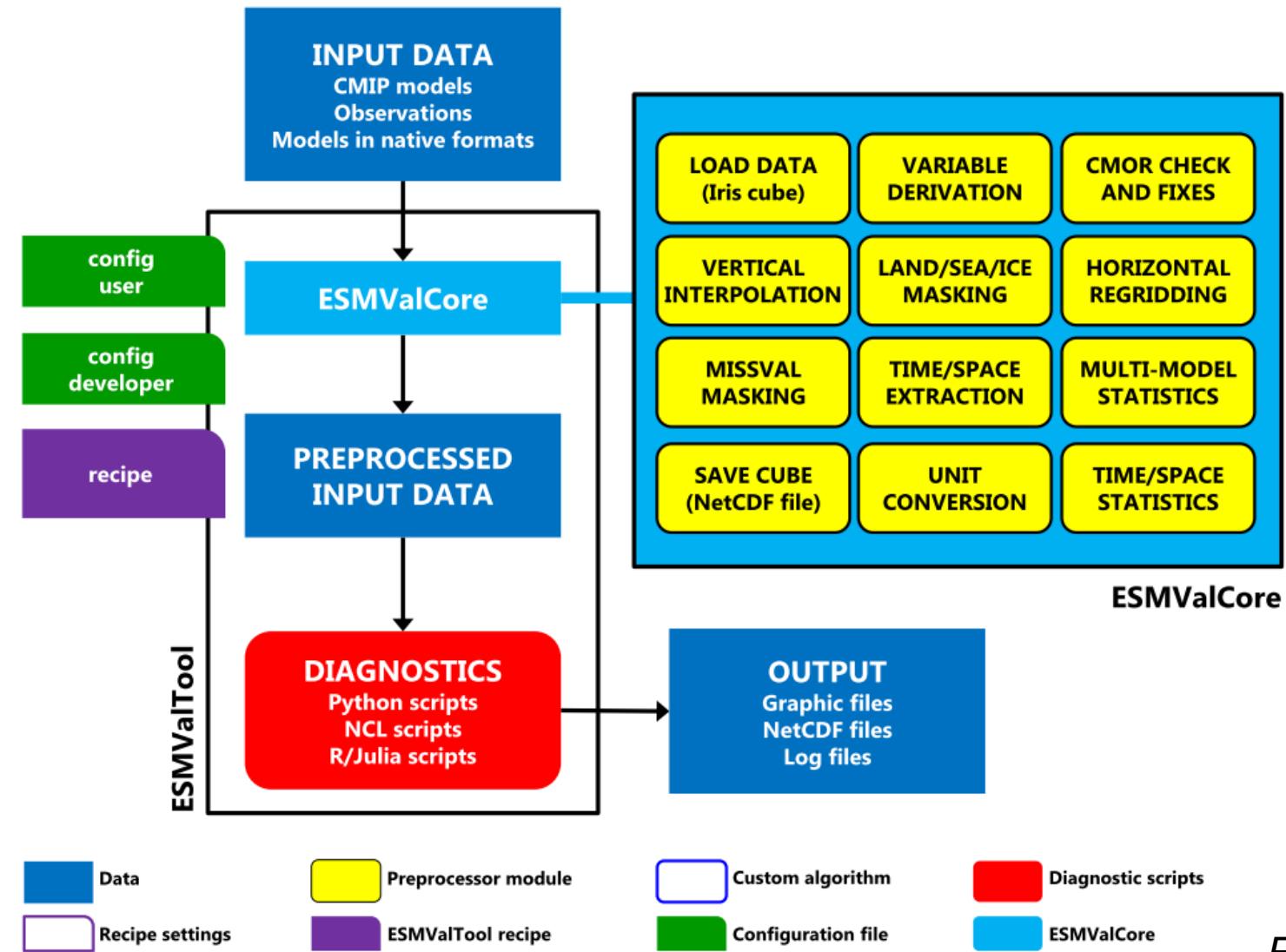


ESMValTool – Details





ESMValTool – Details

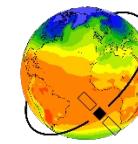


ESMValTool Recipes

ESMValTool is controlled through a **recipe** (text file in YAML format).

Recipes contain

- Datasets to analyze
- Preprocessors to use
- Variables to analyze
- Diagnostic scripts to use (Python, NCL, Julia, or R scripts)



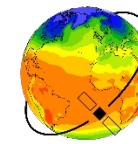
ESMValTool Recipes

```
datasets:
  - {dataset: ERA5,          project: OBS6,    tier: 3,        type: reanaly,   version: 1}
  - {dataset: CanESM5,        project: CMIP6,   exp: historical, grid: gn,      ensemble: r1i1p1f1}

 preprocessors:
  regridding_step:
    regrid:
      target_grid: 1x1
      scheme: linear

 diagnostics:
  example:
    variables:
      tas:
        mip: Amon
        timerange: '1980/2005'
        preprocessor: regridding_step

 scripts:
  example_script:
    script: ~/diag_scripts/example.py
```



ESMValTool Recipes

datasets:

- {dataset: ERA5, project: OBS6, tier: 3, type: reanaly, version: 1}
- {dataset: CanESM5, project: CMIP6, exp: historical, grid: gn, ensemble: r1i1p1f1}

preprocessors:

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regridding_step:  
    regrid:  
        target_grid: 1x1  
        scheme: linear
```

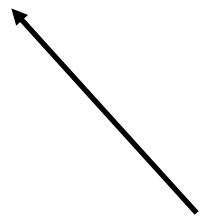
diagnostics:

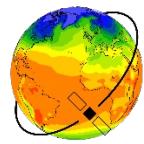
```
example:  
variables:  
    tas:  
        mip: Amon  
        timerange: '1980/2005'  
        preprocessor: regridding_step
```

scripts:

```
example_script:  
    script: ~/diag_scripts/example.py
```

All datasets





ESMValTool Recipes

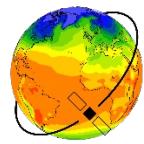
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       preprocessor: regridding_step

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     script: ~/diag_scripts/example.py
```

Preprocessor
settings



ESMValTool Recipes

```
datasets:
  - {dataset: ERA5,          project: OBS6,    tier: 3,        type: reanaly,   version: 1}
  - {dataset: CanESM5,        project: CMIP6,   exp: historical, grid: gn,      ensemble: r1i1p1f1}

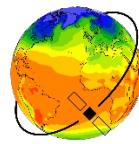
 preprocessors:
  regridding_step:
    regrid:
      target_grid: 1x1
      scheme: linear

 diagnostics:
  example:
    variables:
      tas:
        mip: Amon
        timerange: '1980/2005'
        preprocessor: regridding_step

 scripts:
  example_script:
    script: ~/diag_scripts/example.py
```

Diagnostic scripts





ESMValTool Recipes

```
datasets:
  - {dataset: ERA5,          project: OBS6, tier: 3, type: reanaly, version: 1}
  - {dataset: CanESM5,        project: CMIP6, exp: historical, grid: gn, ensemble: r1i1p1f1}

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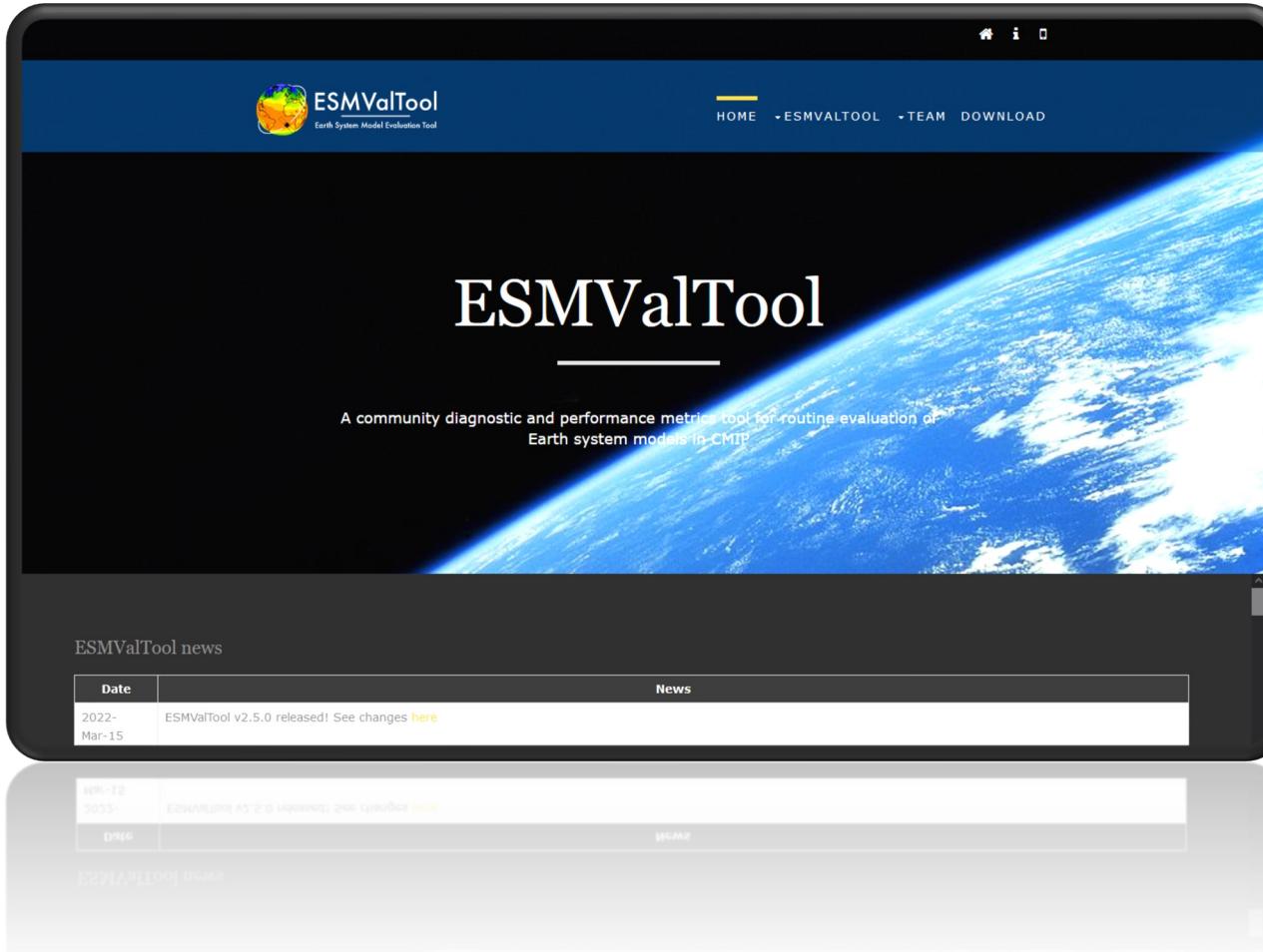
 scripts:
   example_script:
     script: ~/diag_scripts/example.py
```

Variables

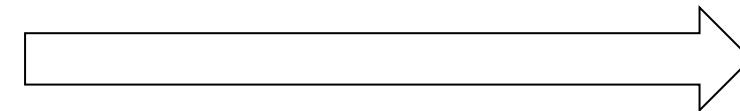


Website

<https://www.esmvaltool.org>

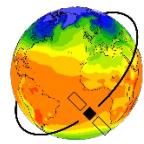


General presentation of ESMValTool:
Important links, gallery, license,
presentations, meeting notes,...



Transfer to GitHub Pages:

- Use website generator Jekyll
- Ported from HTML to Markdown



GitHub Issues

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

Screenshot of the GitHub Issues page for the ESMValTool repository.

The URL in the browser bar is <https://github.com/ESMValGroup/ESMValTool/issues>.

The page title is ESMValGroup / ESMValTool.

The navigation bar includes links for Code, Issues (269), Pull requests (79), Discussions, Actions, Projects (4), Security, and Insights.

A modal dialog is displayed, titled "Label issues and pull requests for new contributors". It informs users that GitHub will help potential first-time contributors discover issues labeled with "good first issue". A "Go to Labels" button is present in the modal.

Filters: is:issue is:open

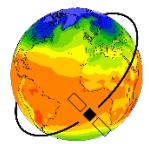
Labels: 39

Milestones: 2

New issue

Issues listed:

- 269 Open ✓ 1,114 Closed
- Skip the Julia test if Julia isn't installed** enhancement #3599 opened 3 days ago by ehogan
- Move from Mambaforge to miniforge** installation #3597 opened 4 days ago by rswamina
- Update cylc version in rtw.lock file in recipe_test_workflow** Recipe Test Workflow (RTW) #3593 opened last week by mo-gill
- Possible improvements to draft_release_notes.py** documentation #3592 opened last week by chrisbillowsMO
- Installation failure in University of Leipzig cluster** installation #3591 opened 3 days ago by rswamina

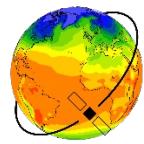


Discussions

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

The screenshot shows the GitHub Discussions page for the ESMValTool repository. The URL in the address bar is <https://github.com/ESMValGroup/ESMValTool/discussions>. The page header includes the ESMValGroup logo and the ESMValTool logo. The navigation bar shows links for Code, Issues (269), Pull requests (79), **Discussions**, Actions, Projects (4), Security, and Insights. A search bar with placeholder text "Type ⌘ to search" is present. Below the search bar are buttons for "Sort by: Latest activity", "Label", "Filter: Open", and a green "New discussion" button. On the left, a sidebar titled "Categories" lists "View all discussions" (selected), General, Ideas, New to ESMValTool, Polls, Q&A, Releases, and Show and tell. The main content area displays several discussions:

- ESMValTool v2.11.0 release** (General) by mo-gill
- Unable to load CMOR table for "tasmax" with mip "days"** (sos) by samlost9-9 (3 weeks ago)
- Highlights for ESMValTool v2.11.0 release** (release) by mo-gill (started last week)
- Matching time coordinates in different variables** (sos) by morobking (Apr 15)
- Data files on JASMIN** (question, observations, Data) by mo-gill (1)



Community Discussions

<https://github.com/ESMValGroup/Community/discussions>

The screenshot shows the GitHub Discussions page for the ESMValGroup repository. The top navigation bar includes links for Code, Issues, Pull requests, Discussions (which is active), Actions, Projects, Security, and Insights. Below the navigation, there are four discussion cards:

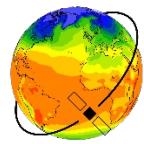
- Next ESMValTool Workshop: dates are fixed!** (Meetings · hb326)
- Monthly ESMValTool community meeting - Apr...** (Meetings · paultgriffiths)
- Agenda workshop May 2024** (Announcements · axel-lauer)
- ESMValTool long-term strategy** (General · hb326)

Below the cards are search and filter controls: a search bar with "is:open", sorting options ("Sort by: Latest activity"), labeling options ("Label"), filtering options ("Filter: Open"), and a green "New discussion" button.

The main content area displays three discussions:

- ESMValTool community meeting June 2024 - Pacific Region Friendly** (community, monthly community meeting) by rbeucher, started last week in Meetings. It has 3 comments.
- Agenda workshop May 2024 workshop** (workshop) by axel-lauer, announced on Apr 11 in Announcements. It has 14 comments.
- Monthly ESMValTool community meeting - April 2024** (monthly community meeting) by paultgriffiths, started on Apr 4 in Meetings. It has 2 comments.

On the left sidebar, there are categories: View all discussions, Announcements, General, Meetings, Polls, Community guidelines, and Community insights.



Documentation

<https://docs.esmvaltool.org/en/latest/>

The screenshot shows the top navigation bar of the ESMValTool documentation. It features the logo "ESMValTool" with a subtitle "Earth System Model Evaluation Tool". Below the logo are several navigation links: "Introduction", "ESMValTool Functionalities", "Getting started", "Gallery", "Available recipes", and a "More" dropdown menu. To the right of these links is a search bar with a magnifying glass icon, a "K" button, and a dark mode switch. The background of the page is white.

Welcome to ESMValTool's documentation!

ESMValTool

[Introduction](#)

[About](#)

[Support](#)

[License](#)

[ESMValTool Functionalities](#)

[Data finding](#)

[Data selection](#)

[Data fixing](#)

[Variable derivation](#)

[Run the preprocessor](#)

[Run the diagnostics](#)

[Getting started](#)

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[On this page](#)

Welcome to ESMValTool's documentation!

[Indices and tables](#)

[Show Source](#)

Twitter account

<https://twitter.com/ESMValTool>

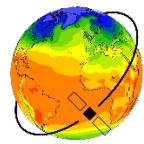


The screenshot shows the Twitter profile page for @ESMValTool. The header features the ESMValTool logo with a globe and the text "ESMValTool Earth System Model Evaluation Tool". Below the header, there are two profile pictures: one showing the Earth from space and another showing a satellite in orbit. A "Folgen" (Follow) button is visible. The bio reads: "Earth System Model Evaluation Tool, a community diagnostic and performance metrics tool for routine evaluation of Earth system models in CMIP." The account was created in March 2020 and has 39 followers. The "Tweets" tab is selected, showing a single tweet from March 2020 with the text: "Here's the crucial #ESMValTool links: Our homepage: esmvaltool.org".

Tweets about:

- Releases
- Publications
- Events (e.g. EGU short course)





Tutorial

https://esmvalgroup.github.io/ESMValTool_Tutorial

Home Setup Episodes ▾ Extras ▾ License Improve this page

Search...

ESMValTool Tutorial

This tutorial helps you to use ESMValTool.

The Earth System Model Evaluation Tool (ESMValTool) is a community developed software toolkit that aims to facilitate the diagnosis and evaluation of the causes and effects of model biases and inter-model spread within the CMIP model ensemble.

This tutorial is structured such that the main body of the tutorial, up to the episode 7, can be done in one sitting. From episode 8, each episode is a mini-tutorial covering an advanced aspect of working with ESMValTool. These mini-tutorials can be appended to the main tutorial or worked through independently.

What will you learn in this course

- What is ESMValTool
- How to install ESMValTool
- How to configure ESMValTool for your local system
- How to run ESMValTool
- How to work with ESMValTool's suite of preprocessors
- How to debug your recipes
- How to access and deploy recipes from the ESMValTools gallery (Advanced)
- How to develop your own diagnostics and recipes (Advanced)
- How to contribute your recipes and diagnostics back into ESMValTool (Advanced)
- How to include new observational datasets (Advanced)

Prerequisites

The prerequisites for the tutorial are listed on the [tutorial setup page](#).

Main things you need to know before starting this course

1. This tutorial can be taken online independently or taught by one of our instructors.
2. Don't be alarmed if you can't work through the entire tutorial in one sitting. It may take some time to get used to working with ESMValTool.
3. If you get stuck, help is always available from the tutors, from ESMValTool developers via the [github issues page](#) or via the ESMValTool email list. Please see [information](#) on how to subscribe to user mailing list.
4. This tutorial includes several advanced lessons after the conclusion. These advanced lessons should be treated like "mini-tutorials", and include aspects like "developing your

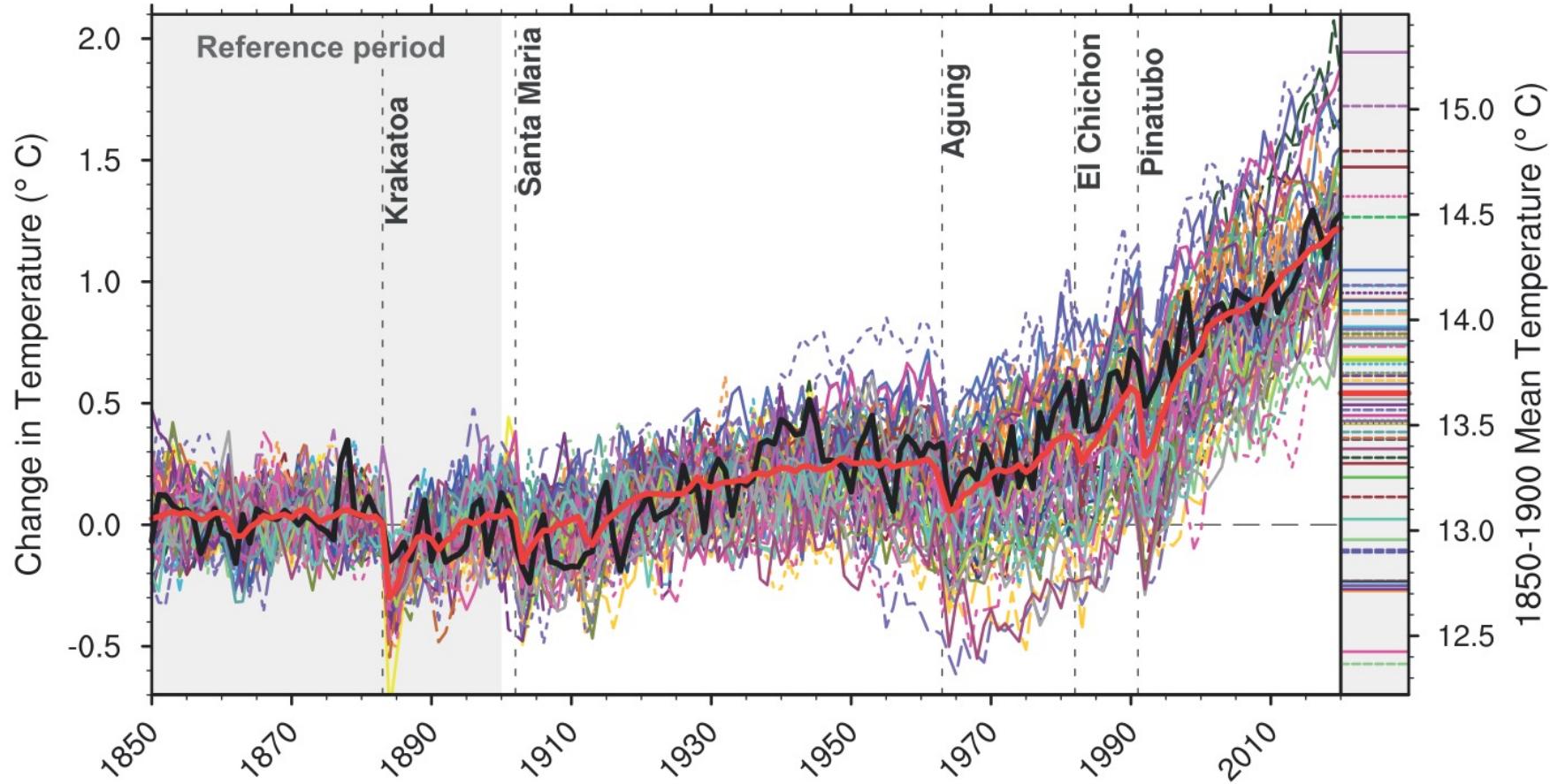
→ basic and an advanced tutorial

User Engagement Team Tasks:

- Maintaining tutorial on GitHub
- Keeping the tutorial updated with the releases
- Handling with user feedback
- Contact for tutorial hosts

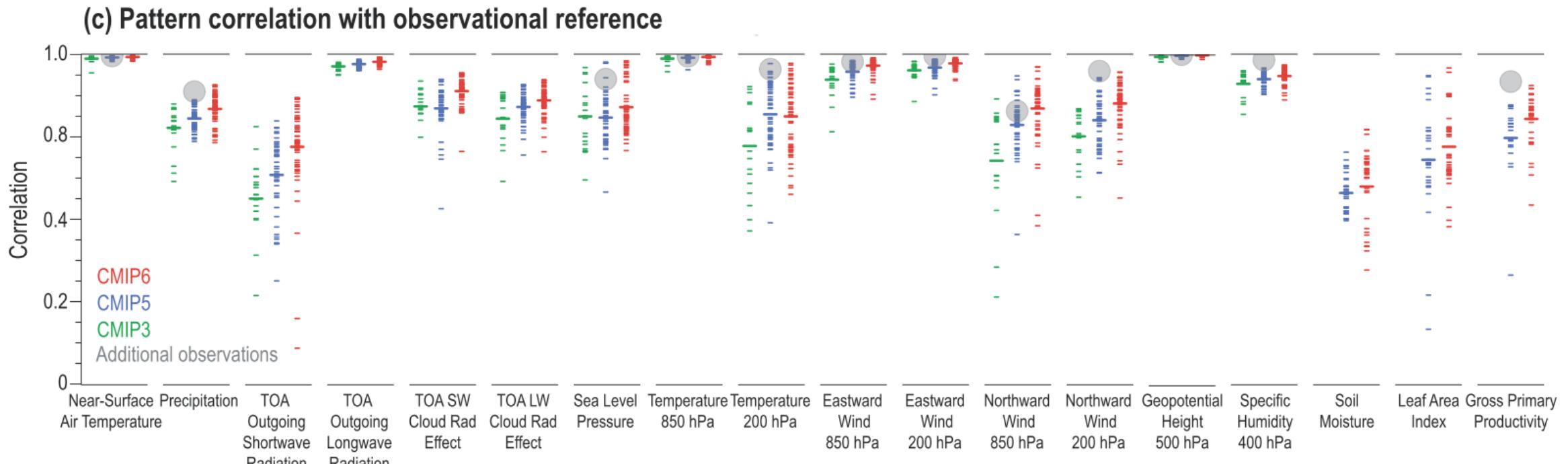
Usage of ESMValTool in IPCC AR6

Global mean surface air temperature



IPCC AR6, Figure 3.4a

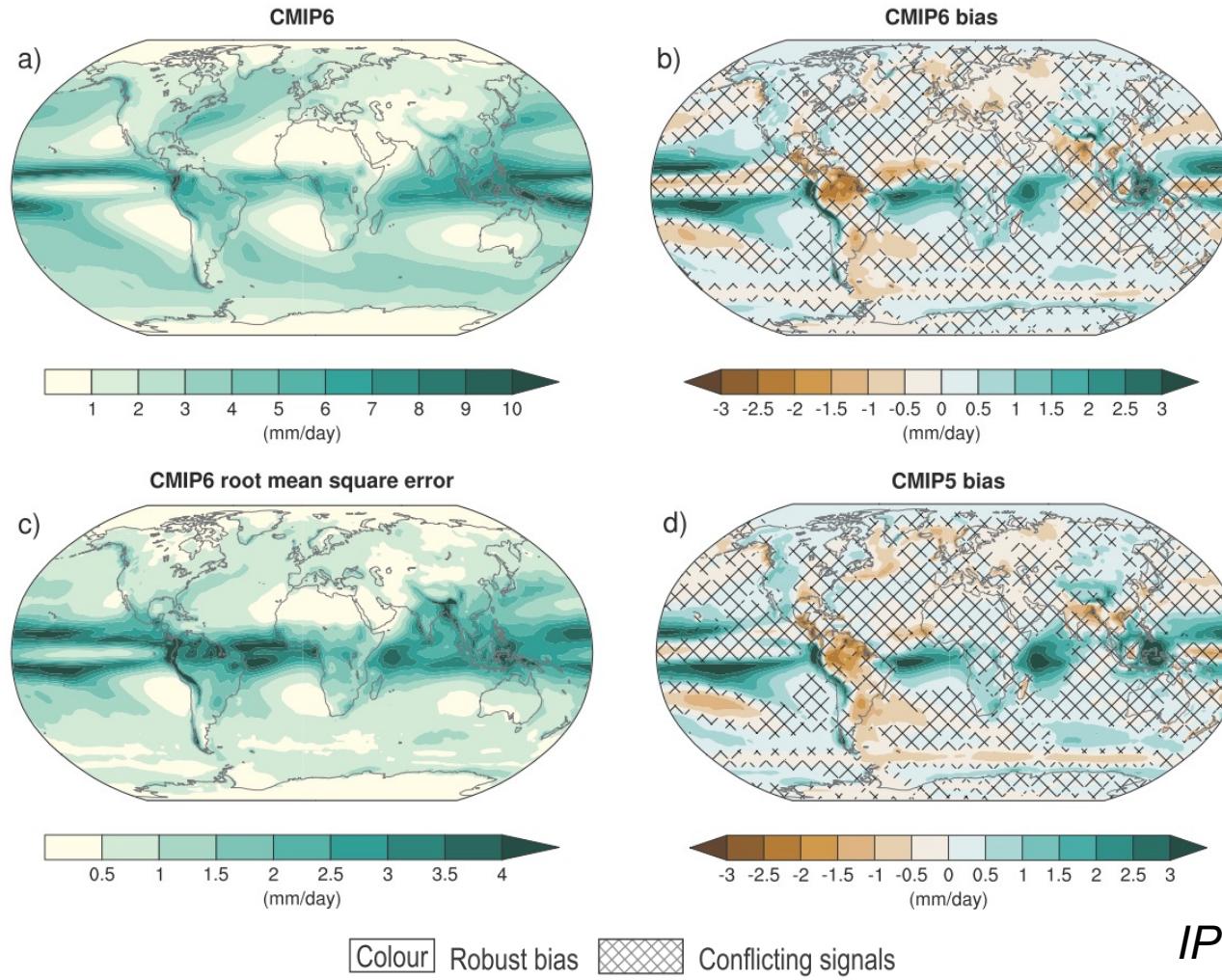
Usage of ESMValTool in IPCC AR6



IPCC AR6, Figure TS.2c

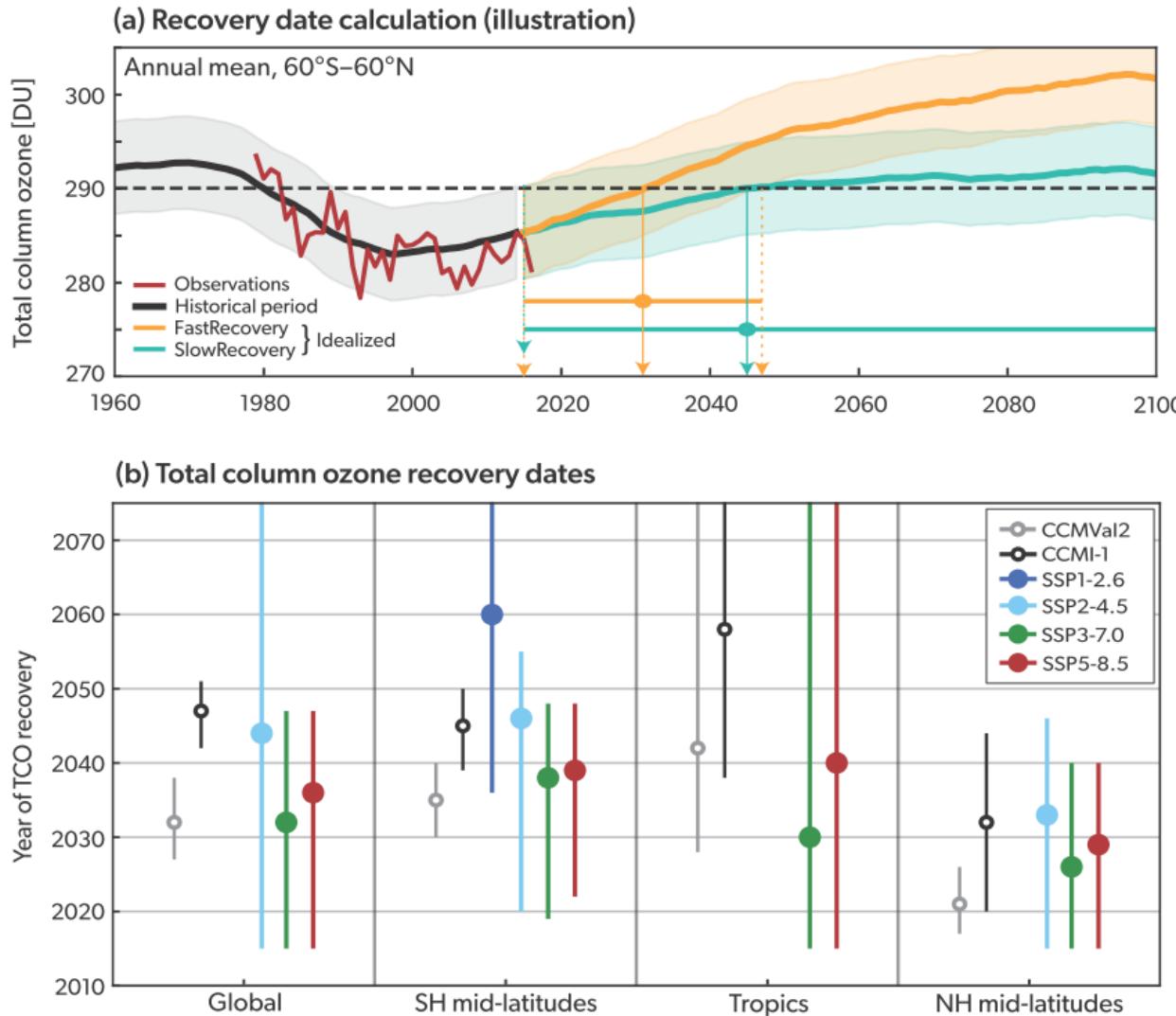
Usage of ESMValTool in IPCC AR6

Precipitation



IPCC AR6, Figure 3.13

Usage of ESMValTool in Scientific Assessment of Ozone Depletion: 2022



WMO Scientific Assessment
of Ozone Depletion: 2022,
Figure 3-24

Questions?

The screenshot shows a web browser displaying the ESMValTool documentation at <https://docs.esmvaltool.org/en/latest/introduction.html#support>. The page title is "Support". The left sidebar has a "Section Navigation" heading and an advertisement for Upstream. The main content area contains sections on Support, User mailing list, and a note about the mailing list archive.

Section Navigation

Support

Support for ESMValTool can be found in [ESMValTool Discussions page](#) where users can open an issue and a member of the [User Engagement Team](#) of ESMValTool will reply as soon as possible. This is open for all general and technical questions on the ESMValTool: installation, application, development, or any other question or comment you may have.

User mailing list

Subscribe to the ESMValTool announcements mailing list esmvaltool@listserv.dfn.de to stay up to date about new releases, monthly online meetings, upcoming workshops, and trainings.

To subscribe, send an email to sympa@listserv.dfn.de with the following subject line:

- `subscribe esmvaltool`

or

- `subscribe esmvaltool YOUR_FIRSTNAME YOUR_LASTNAME`

The mailing list also has a [public archive](#) online.

On this page

- About
- Support**
- User mailing list
- Monthly meetings
- Core development team
- Recipes and diagnostics
- License

[Show Source](#)