

Introduction to ESMValTool

ESMValTool workshop, 30-31 May 2023

What is ESMValTool?

The **Earth System Model Evaluation Tool**:

“A community diagnostic and performance metrics tool for routine evaluation of Earth system models in CMIP”

- ESMValTool is ...
 - a tool to analyse climate data
 - a collection of diagnostics for reproducible climate science
 - a community effort (63 participating institutions, 203 developers)
- Model evaluation can be performed against **observations**, against **other models**, or comparing **different versions of the same model**.
- **CF/CMOR compliant**: data from many different projects can be handled (CMIP3/5/6, CORDEX, obs4mips, ana4mips, etc.)
 - Native model output supported for some models, work in progress ...
- **Multi-language support**: Python, NCL, R, Julia

ESMValTool development

The screenshot shows the GitHub profile page for ESMValGroup. At the top, the browser address bar displays 'https://github.com/ESMValGroup'. The navigation bar includes 'Pull requests', 'Issues', 'Codespaces', 'Marketplace', and 'Explore'. The profile header features the ESMValTool logo (a globe with 'ESMValTool' text), the name 'ESMValGroup', the description 'Earth System Model eValuation Tool', and a 'Follow' button. Below the header, there are statistics: 35 followers, the website 'https://www.esmvaltool.org', and the Twitter handle '@ESMValTool'. A secondary navigation bar lists 'Overview', 'Repositories 16', 'Projects 4', 'Packages', 'Teams 14', and 'People 184'. The 'Pinned' section contains four repository cards: 'ESMValTool' (Public), 'ESMValCore' (Public), 'Community' (Public), and 'EGU22-short-course' (Public). The 'Repositories' section is currently empty, with a search bar and filters for 'Type', 'Language', and 'Sort', along with a 'New' button. The 'View as: Public' section indicates that the user is viewing the README and pinned repositories as a public user, with a link to 'create a README file visible to anyone'. The 'People' section shows a grid of profile pictures and a 'View all' link. The 'Top languages' section lists 'Jupyter Notebook', 'Python', and 'HTML' with colored indicators, and 'NCL' and 'R' with black and blue indicators respectively.

GitHub home:

<https://github.com/ESMValGroup>

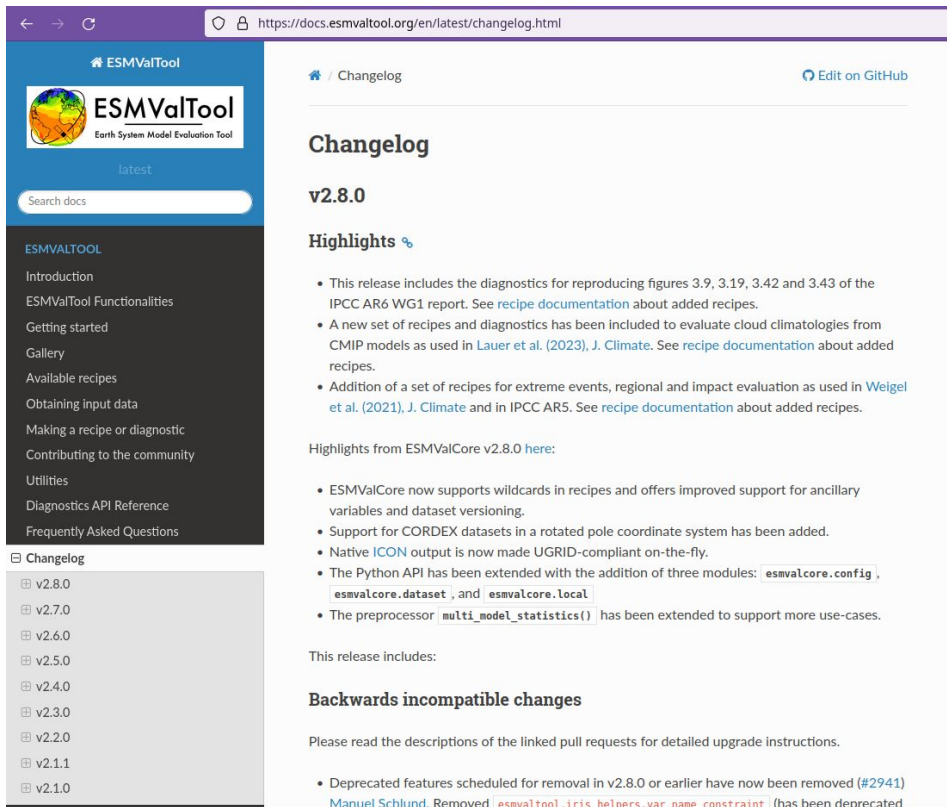
Key repositories:

- ESMValTool
- ESMValCore
- Community

Regular 4 month release schedule

- current version: v2.8.0
- next release due June 19, 2023

ESMValTool development - changelog



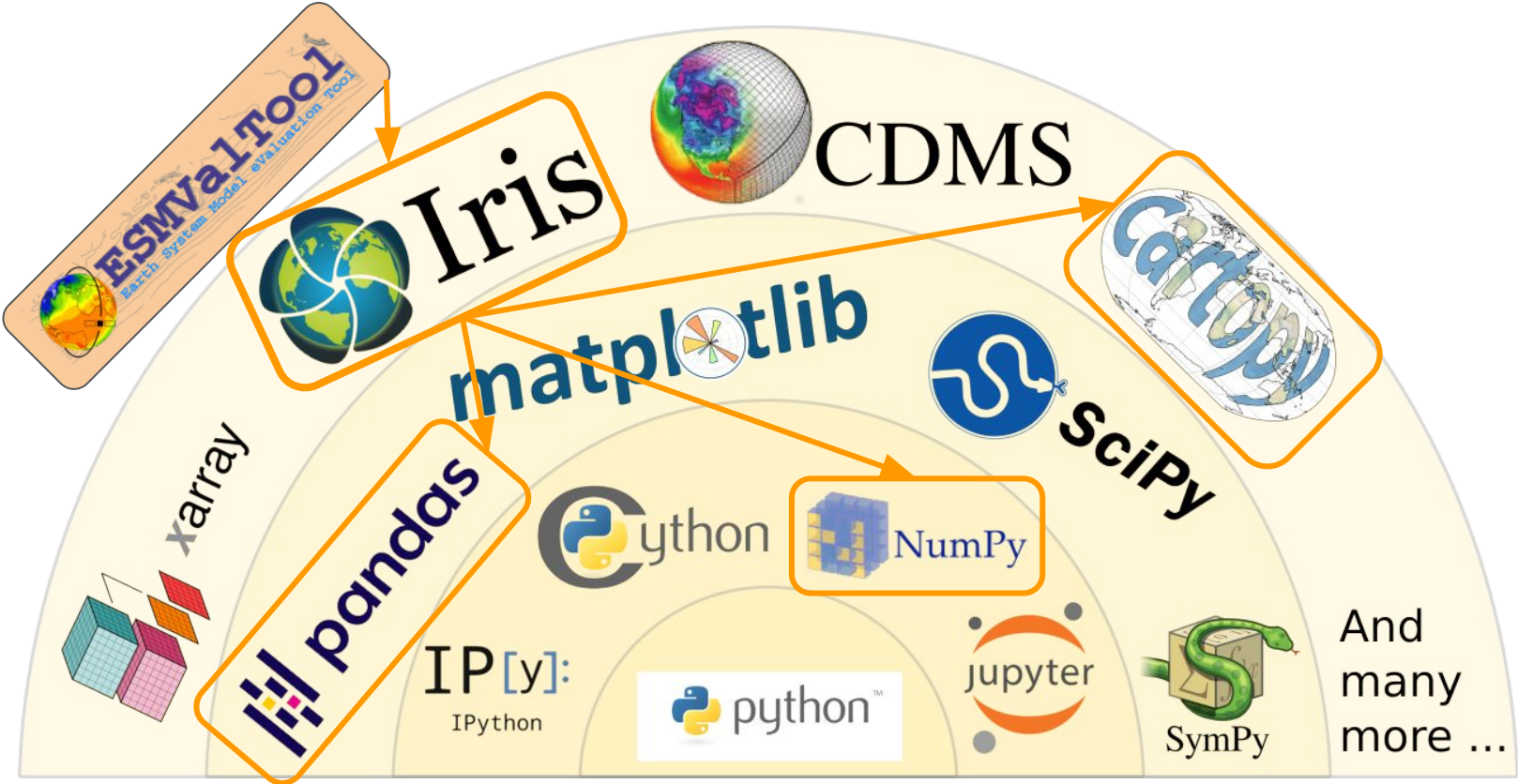
The screenshot shows the ESMValTool documentation page for the changelog. The browser address bar shows the URL <https://docs.esmvaltool.org/en/latest/changelog.html>. The page header includes the ESMValTool logo and the text "Earth System Model Evaluation Tool". A search bar is present with the text "Search docs". The left sidebar contains a navigation menu with items: Introduction, ESMValTool Functionalities, Getting started, Gallery, Available recipes, Obtaining input data, Making a recipe or diagnostic, Contributing to the community, Utilities, Diagnostics API Reference, and Frequently Asked Questions. The main content area is titled "Changelog" and "v2.8.0". Under "Highlights", there are three bullet points: "This release includes the diagnostics for reproducing figures 3.9, 3.19, 3.42 and 3.43 of the IPCC AR6 WG1 report. See [recipe documentation](#) about added recipes.", "A new set of recipes and diagnostics has been included to evaluate cloud climatologies from CMIP models as used in [Lauer et al. \(2023\), J. Climate](#). See [recipe documentation](#) about added recipes.", and "Addition of a set of recipes for extreme events, regional and impact evaluation as used in [Weigel et al. \(2021\), J. Climate](#) and in IPCC AR5. See [recipe documentation](#) about added recipes." Below this, it says "Highlights from ESMValCore v2.8.0 [here](#):" followed by four bullet points: "ESMValCore now supports wildcards in recipes and offers improved support for ancillary variables and dataset versioning.", "Support for CORDEX datasets in a rotated pole coordinate system has been added.", "Native ICON output is now made UGRID-compliant on-the-fly.", "The Python API has been extended with the addition of three modules: `esmvalcore.config`, `esmvalcore.dataset`, and `esmvalcore.local`", and "The preprocessor `multi_model_statistics()` has been extended to support more use-cases." Under "This release includes:", there is a section for "Backwards incompatible changes" with one bullet point: "Deprecated features scheduled for removal in v2.8.0 or earlier have now been removed (#2941) [Manuel Schlund](#). Removed `esmvaltool.iris helpers.var name constraint` (has been deprecated". At the bottom, it says "Please read the descriptions of the linked pull requests for detailed upgrade instructions." and lists "v2.8.0" as the selected version in a sidebar.

Changelog for both ESMValTool and ESMValCore are available in the NorESM documentation:

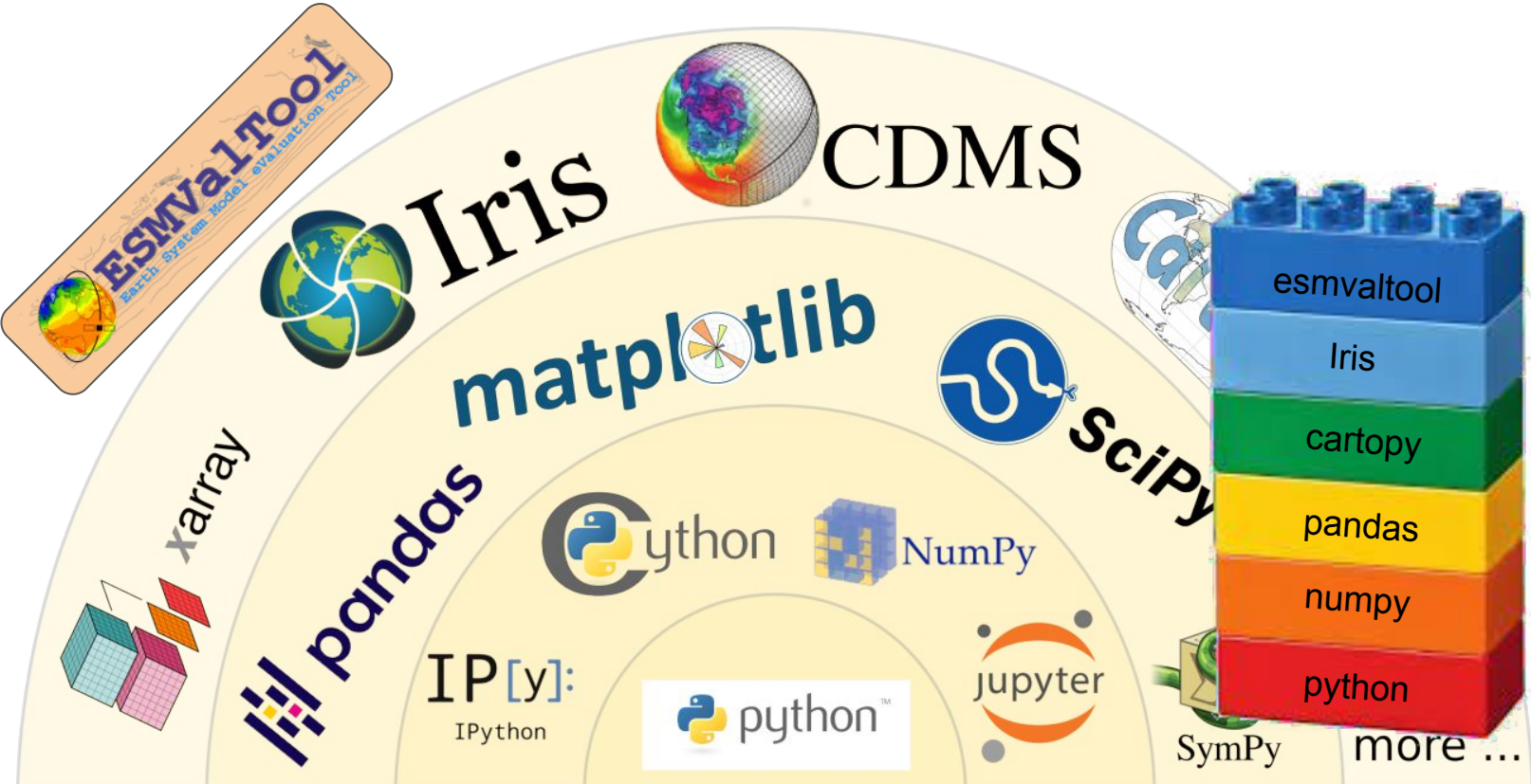
<https://docs.esmvaltool.org/en/latest/changelog.html>

- Highlights for release
- Backwards incompatible changes
- Bug fixes
- Community
- Deprecations
- Documentation
- Diagnostics
- Observational and re-analysis dataset support
- Automatic testing
- Installation
- Improvements

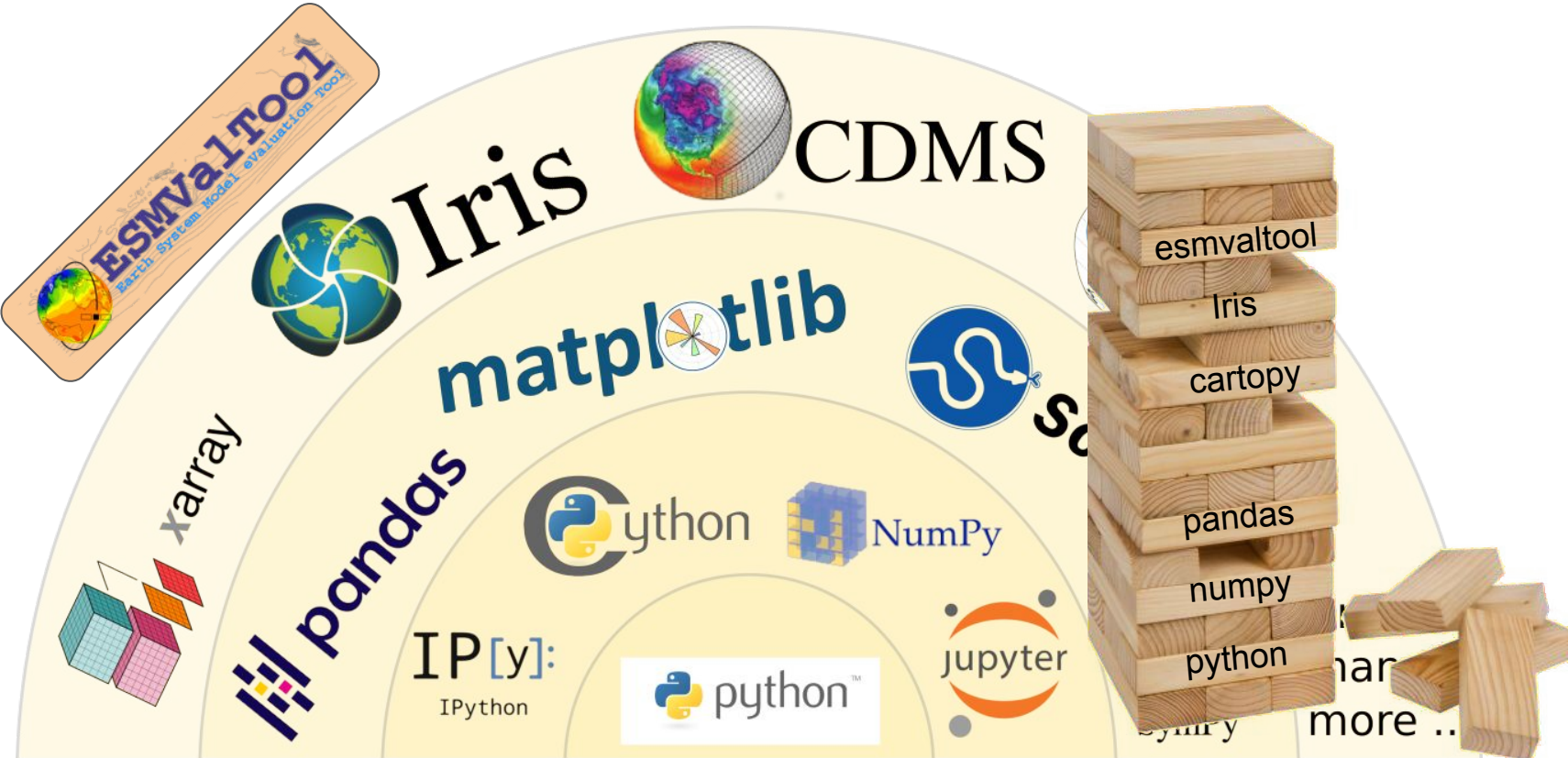
ESMValTool dependencies



ESMValTool dependencies - ideal world



ESMValTool dependencies - reality?



ESMValTool dependencies

ESMValCore installation environment.yml file:
<https://github.com/ESMValGroup/ESMValCore/blob/main/environment.yml>

- Only python dependencies

ESMValTool installation environment.yml file:
<https://github.com/ESMValGroup/ESMValTool/blob/main/environment.yml>

- Includes python, R and NCL dependencies
- Julia is installed separately

ESMValTool / environment.yml 

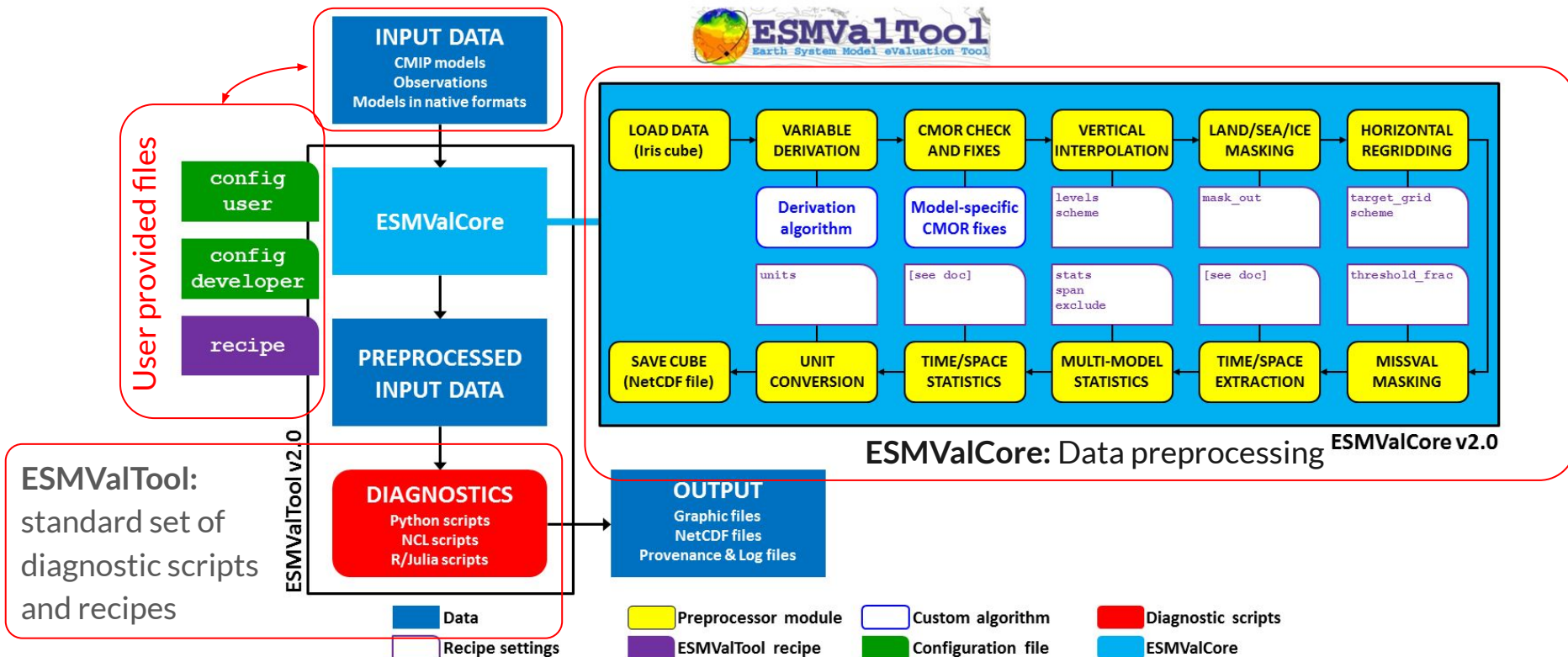
 valeriupredoi Drop python=3.8 support (#3193) ✓

Code Blame 134 lines (130 loc) · 2.32 KB

```
1 ---
2 name: esmvaltool
3 channels:
4   # The release candidate channel should only be activated
5   # during the rc phase right before the next release of the
6   # ESMValCore.
7   # - conda-forge/label/esmvalcore_rc
8   - conda-forge
9   - nodefaults
10
11 dependencies:
12   - pip!=21.3
13   - python>=3.9
14   - aiohttp
15   - cartopy
16   - cdo>=1.9.7
17   - cdsapi
18   - cf-units
19   - cftime
20   - cmocean
21   - cython
22   - dask
23   - ecmwf-api-client
24   - eofs
25   - esmpy
26   - esmvalcore 2.8.*
27   - fiona
28   - fire
29   - gdal
```

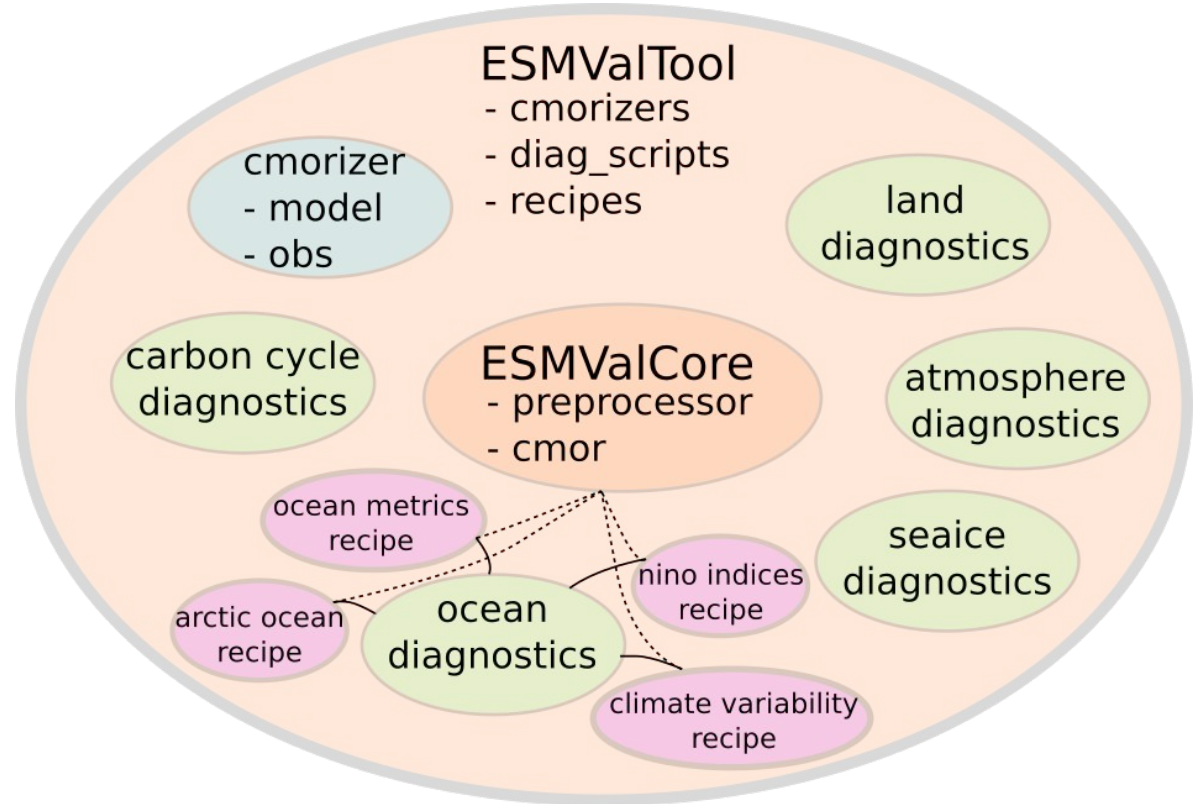
ESMValTool structure

Source: <https://docs.esmvaltool.org/en/latest/introduction.html>



ESMValTool structure

- ESMValCore developed separately from ESMValTool
- ESMValCore can be used separately from ESMValTool, if user provides diagnostic scripts and recipes
- ESMValTool provides a standard set of diagnostic scripts and recipes



ESMValCore - preprocessing

[Preprocessor — ESMValTool documentation](#)

- ESMValCore provides preprocessing procedures that are common for many types of analysis. Not all preprocessing steps are required.
- Preprocessing follows a [default order of procedures](#). The order can be changed by the user by setting the `custom_order` flag in the recipe.

| | | | |
|---|--------------------------------------|-----------------------------------|---|
| ¹ Variable derivation | ⁶ Area masking | ¹¹ Time manipulation | ¹⁶ Detrend |
| ² CMORization and dataset-specific fixes | ⁷ Mask by values | ¹² Area manipulation | ¹⁷ Rolling window statistics |
| ³ Supplementary variables | ⁸ Horizontal regridding | ¹³ Volume manipulation | ¹⁸ Unit conversion |
| ⁴ Vertical interpolation | ⁹ Ensemble statistics | ¹⁴ Cycles | ¹⁹ Bias |
| ⁵ land-sea weighting | ¹⁰ Multi-model statistics | ¹⁵ Trend | ²⁰ Clip data |

ESMValTool - diagnostic scripts

- ESMValtool 2.8.0 includes 59 packets of diagnostic scripts
- Diagnostic scripts can be written in any supported scripting language (currently Python, R, NCL, Julia)

| Examples of diagnostic scripts | |
|--------------------------------|---|
| General purpose | shared, shapeselect, weighting |
| By domain | clouds, ocean, arctic_ocean, hydrology, landcover, seaice |
| By topic/process | austral_jet, draughtindex, extreme_events |

ESMValTool - standard recipes

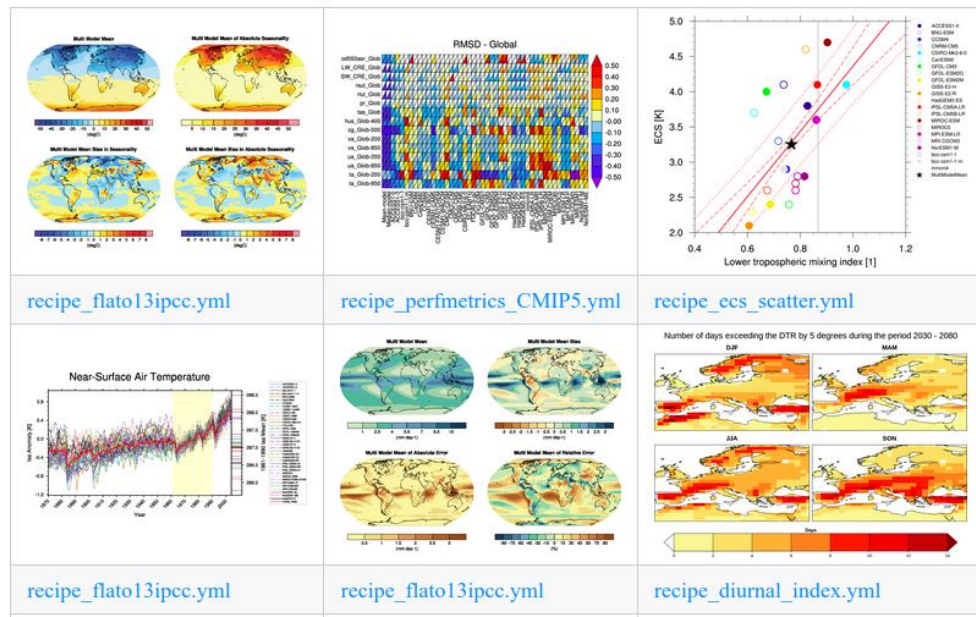
- 150 standard recipes are provided with the source code `esmvaltool recipes list`
- Typical structure of a recipe
 - Documentation
 - Define datasets that should be analyzed
 - Define one or more preprocessor procedures, e.g.
 - Start and end time
 - Regional extent, resolution for regridding
 - Define one or more diagnostics
 - Variables from dataset that should be analyzed (define dataset if not already provided)
 - Preprocessor procedure to be used
 - Observational dataset for comparison
 - Which diagnostic script to run, and parameters for diagnostic

List of standard recipes : <https://docs.esmvaltool.org/en/latest/recipes/index.html>

ESMValTool - standard recipes - gallery

Gallery

ESMValTool examples

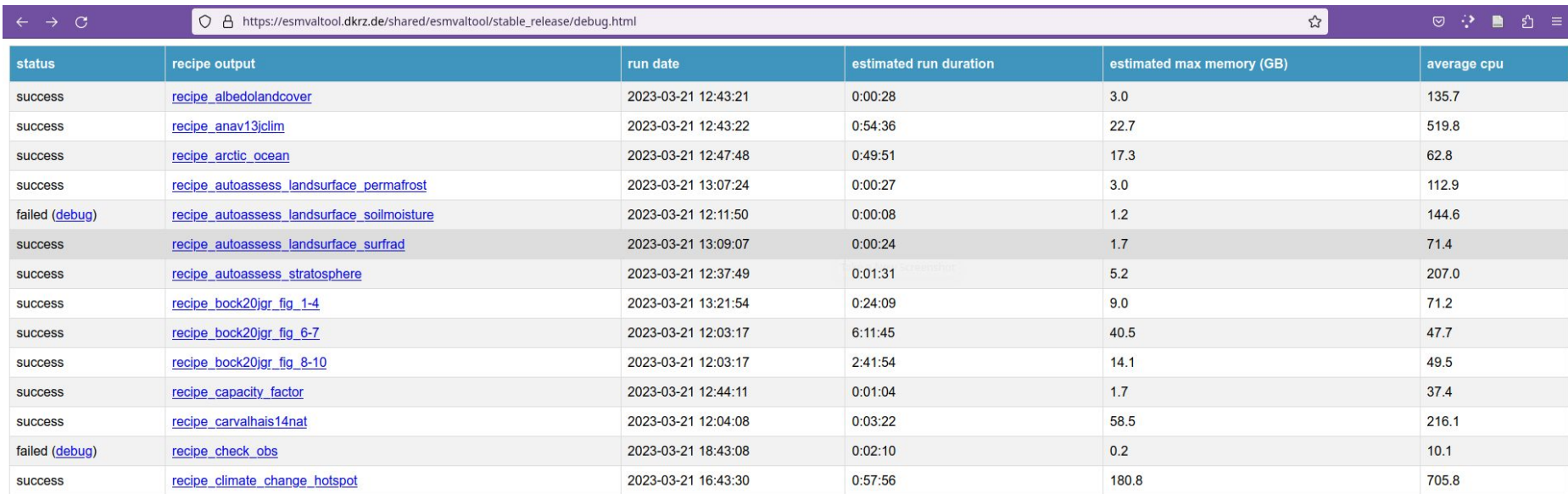


Overview of standard recipes from the ESMValTool gallery:

<https://www.esmvaltool.org/gallery>

Recipe names are often not very descriptive of the content.

ESMValTool - standard recipes - recipe test status

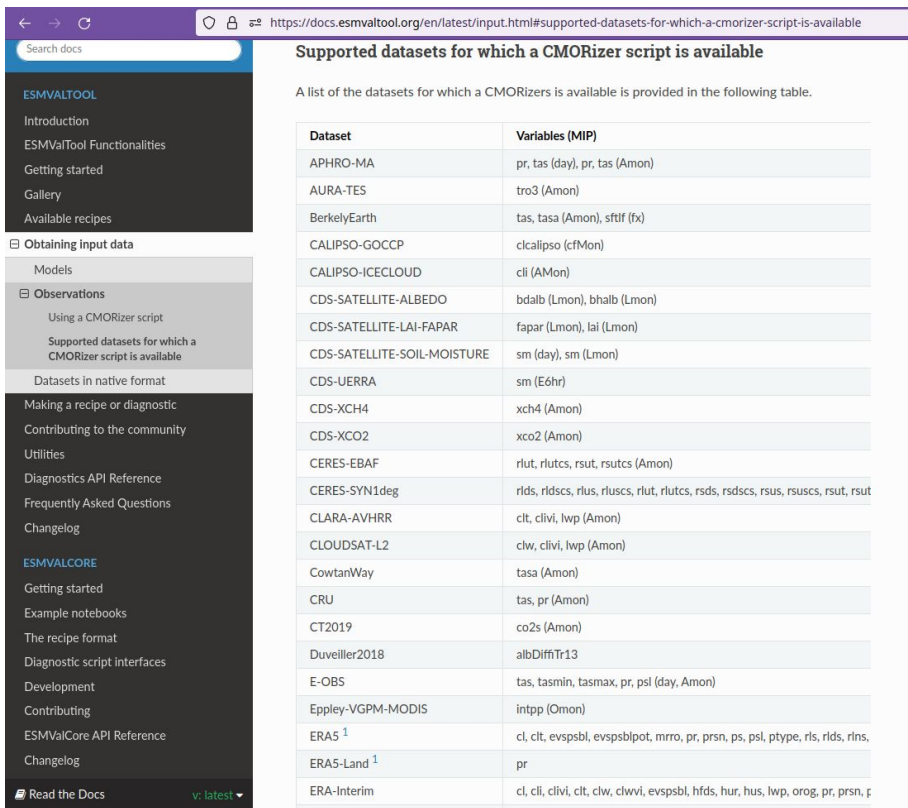


| status | recipe output | run date | estimated run duration | estimated max memory (GB) | average cpu |
|----------------|--|---------------------|------------------------|---------------------------|-------------|
| success | recipe_albedolandcover | 2023-03-21 12:43:21 | 0:00:28 | 3.0 | 135.7 |
| success | recipe_anav13jclim | 2023-03-21 12:43:22 | 0:54:36 | 22.7 | 519.8 |
| success | recipe_arctic_ocean | 2023-03-21 12:47:48 | 0:49:51 | 17.3 | 62.8 |
| success | recipe_autoassess_landsurface_permafrost | 2023-03-21 13:07:24 | 0:00:27 | 3.0 | 112.9 |
| failed (debug) | recipe_autoassess_landsurface_soilmoisture | 2023-03-21 12:11:50 | 0:00:08 | 1.2 | 144.6 |
| success | recipe_autoassess_landsurface_surfrad | 2023-03-21 13:09:07 | 0:00:24 | 1.7 | 71.4 |
| success | recipe_autoassess_stratosphere | 2023-03-21 12:37:49 | 0:01:31 | 5.2 | 207.0 |
| success | recipe_bock20jgr_fig_1-4 | 2023-03-21 13:21:54 | 0:24:09 | 9.0 | 71.2 |
| success | recipe_bock20jgr_fig_6-7 | 2023-03-21 12:03:17 | 6:11:45 | 40.5 | 47.7 |
| success | recipe_bock20jgr_fig_8-10 | 2023-03-21 12:03:17 | 2:41:54 | 14.1 | 49.5 |
| success | recipe_capacity_factor | 2023-03-21 12:44:11 | 0:01:04 | 1.7 | 37.4 |
| success | recipe_carvalhoais14nat | 2023-03-21 12:04:08 | 0:03:22 | 58.5 | 216.1 |
| failed (debug) | recipe_check_obs | 2023-03-21 18:43:08 | 0:02:10 | 0.2 | 10.1 |
| success | recipe_climate_change_hotspot | 2023-03-21 16:43:30 | 0:57:56 | 180.8 | 705.8 |

How to find the recipe test status:

[ESMValTool doc: available recipes](#) > [gallery: stable release](#) > [debug page](#)

Observational & reanalysis data - supported datasets



The screenshot shows the ESMValTool website with the following content:

- Search bar: Search docs
- Navigation menu: ESMVALTOOL, Introduction, ESMValTool Functionalities, Getting started, Gallery, Available recipes
- Current page: Supported datasets for which a CMORizer script is available
- Text: A list of the datasets for which a CMORizer script is available is provided in the following table.
- Table of supported datasets:

| Dataset | Variables (MIP) |
|-----------------------------|---|
| APHRO-MA | pr, tas (day), pr, tas (Amon) |
| AURA-TES | tro3 (Amon) |
| BerkeleyEarth | tas, tasa (Amon), stfif (fx) |
| CALIPSO-GOCCP | clcalipso (cfMon) |
| CALIPSO-ICECLOUD | cli (Amon) |
| CDS-SATELLITE-ALBEDO | bdalb (Lmon), bhalb (Lmon) |
| CDS-SATELLITE-LAI-FAPAR | fapar (Lmon), lai (Lmon) |
| CDS-SATELLITE-SOIL-MOISTURE | sm (day), sm (Lmon) |
| CDS-UERRA | sm (Eghr) |
| CDS-XCH4 | xch4 (Amon) |
| CDS-XCO2 | xco2 (Amon) |
| CERES-EBAF | rlut, rlutcs, rsut, rsutcs (Amon) |
| CERES-SYN1deg | rlds, rldscs, rlus, rluscs, rlut, rlutcs, rsds, rsdscs, rsus, rsuscs, rsut, rsut |
| CLARA-AVHRR | clt, clivi, lwp (Amon) |
| CLOUDSAT-L2 | clw, clivi, lwp (Amon) |
| CowtanWay | tasa (Amon) |
| CRU | tas, pr (Amon) |
| CT2019 | co2s (Amon) |
| Duveiller2018 | albDiffTr13 |
| E-OBS | tas, tasmin, tasmax, pr, psi (day, Amon) |
| Eppley-VGPM-MODIS | intpp (Omon) |
| ERA5 ¹ | cl, clt, evspsbl, evspsblpot, mrrp, pr, prsn, ps, psi, ptype, rls, rlds, rlus, rlds |
| ERA5-Land ¹ | pr |
| ERA-Interim | cl, cli, clivi, clt, clw, clwvi, evspsbl, hfds, hur, hus, lwp, orog, pr, prsn, p |

Observational & reanalysis datasets

Tier1 : obs4MIPs, ana4MIPs (ESGF)

Tier2 : freely-available datasets

Tier3 : restricted access datasets

ESMValTool provides CMORizer scripts for 89 observational dataset.

An overview of supported datasets:

<https://docs.esmvaltool.org/en/latest/input.html#supported-datasets-for-which-a-cmorizer-script-is-available>

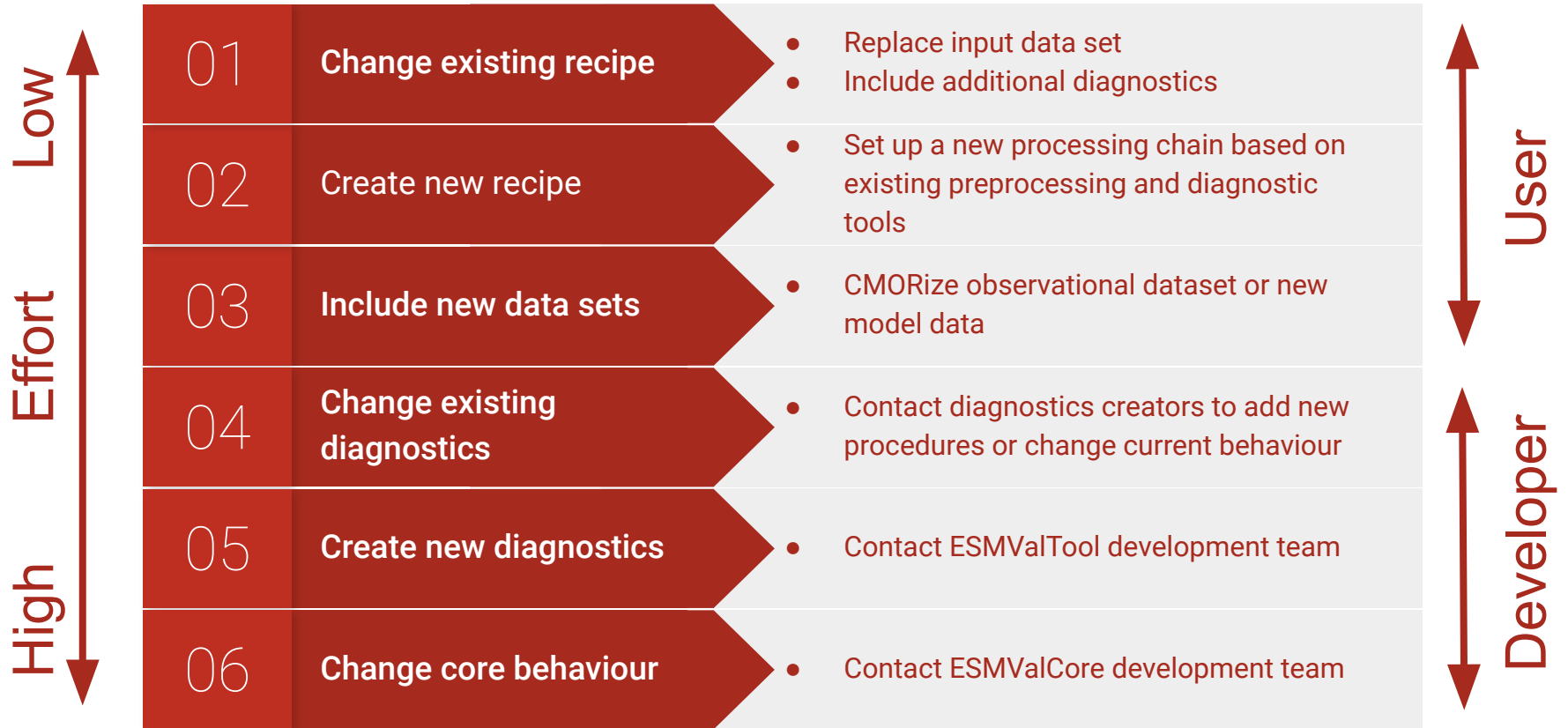
Input data - CMORization

ESMValTool accepts NetCDF input files that follow the CF (Climate and Forecast) convention, i.e. a standardized description of the file content.

CMOR (Climate Model Output Rewriter) is a tool for converting model or observational data into CF-compliant NetCDF files.

Many projects provide CF-compliant data (e.g. CMIP5 and CMIP6), but users may need to CMORize their own model or observational data sets in order to use these as input to ESMValTool.

Should I use ESMValTool?



Should I use ESMValTool? Pros & Cons

- Streamline procedure for routine/repetitive analysis of data
- Open source and active development, responsive community
- Easy to document analysis procedure in publications
 - Provide recipe and ESMValTool version

- Initial setup can be time consuming
- Quality and maintenance of diagnostics may vary
 - Depends on community, no centralized development plan
- Recipes and diagnostics can break between ESMValTool versions, or due to upstream dependencies

Useful links

ESMValTool

- ESMValTool home page : <https://www.esmvaltool.org/>
- Source on gitHub : <https://github.com/ESMValGroup/ESMValTool>
- Documentation : <https://docs.esmvaltool.org/en/latest/>
- Status: https://esmvaltool.dkrz.de/shared/esmvaltool/stable_release/debug.html
- Official tutorial : https://esmvalgroup.github.io/ESMValTool_Tutorial/