ESMValCore and ESMValTool: analyzing CMIP data made easy

B. Hassler[1], A. Lauer[1], V. Eyring[1,2]

& the ESMValCore and ESMValTool development teams

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AGU Fall Meeting 2020

1-17 December 2020

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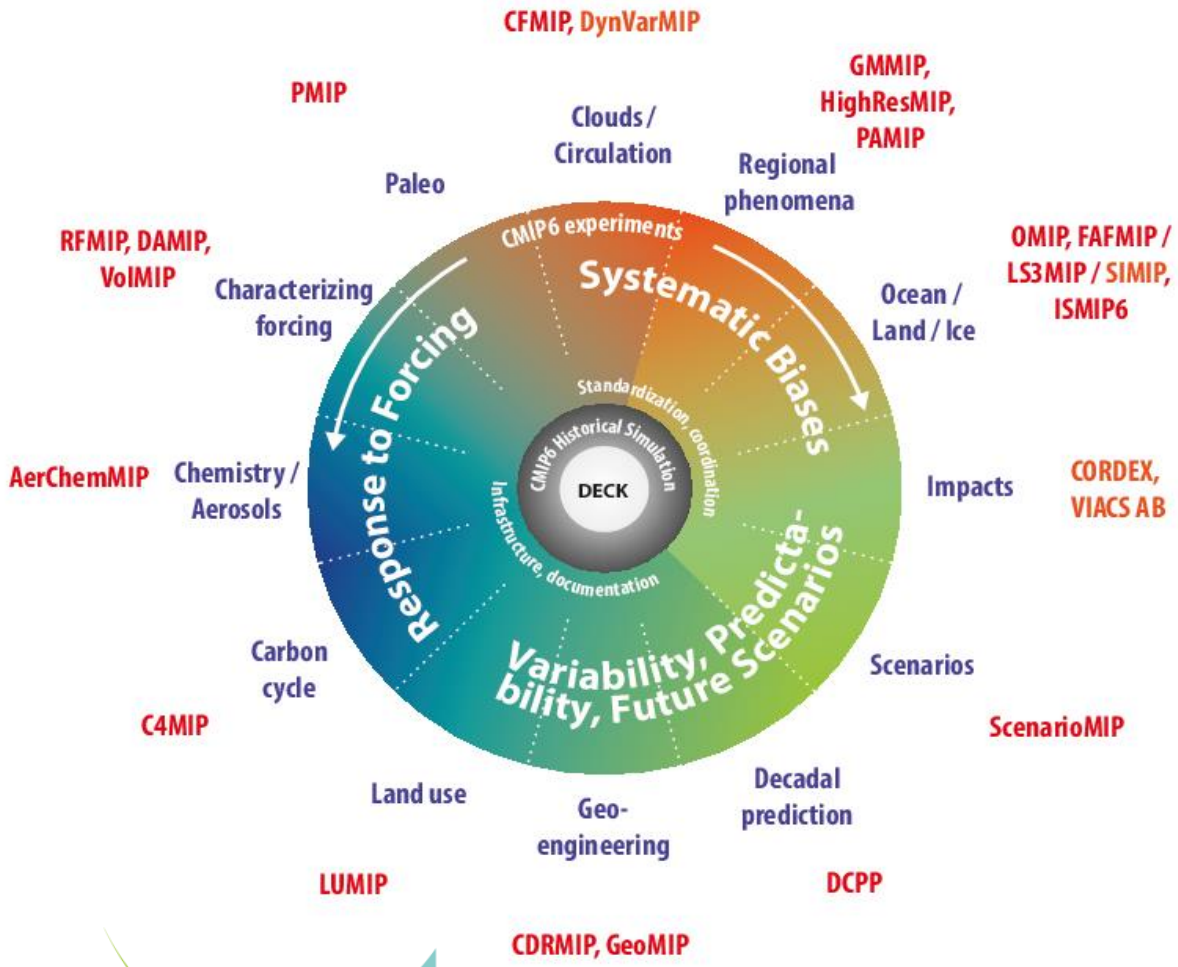
Coupled Model Intercomparison Project Phase 6 (CMIP6)

- 48 institutions/consortia have registered (CMIP5: 31)
- 126 models are registered (CMIP5: 59)
- 299 experiments defined (CMIP5: 33)
- 10 – 50 PB of model output expected (CMIP5: ~2 PB)
- Higher complexity and resolution compared to CMIP5

→ **Challenges for the entire community**



CMIP
The World Climate Research Programme's Coupled Model Intercomparison Project

Eyring et al., Geosci. Model Dev., 2016

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ESMValTool
Earth System Model eValuation Tool

Motivation I

➢ Easier and faster evaluation of complex Earth System Models

- Easy analysis of CMIP models
- Fast overview due to standard diagnostics, figures and variables
- Easy comparison of new model simulations with already existing runs and observations (e.g. obs4MIPs, ESA CCI)

Development and documentation

GitHub repository allows development with many users

Issue tracking system (GitHub)

Online documentation (readthedocs)

Automatized quality control

Automatized code checking (Codacy)

Automatized testing (CircleCI)

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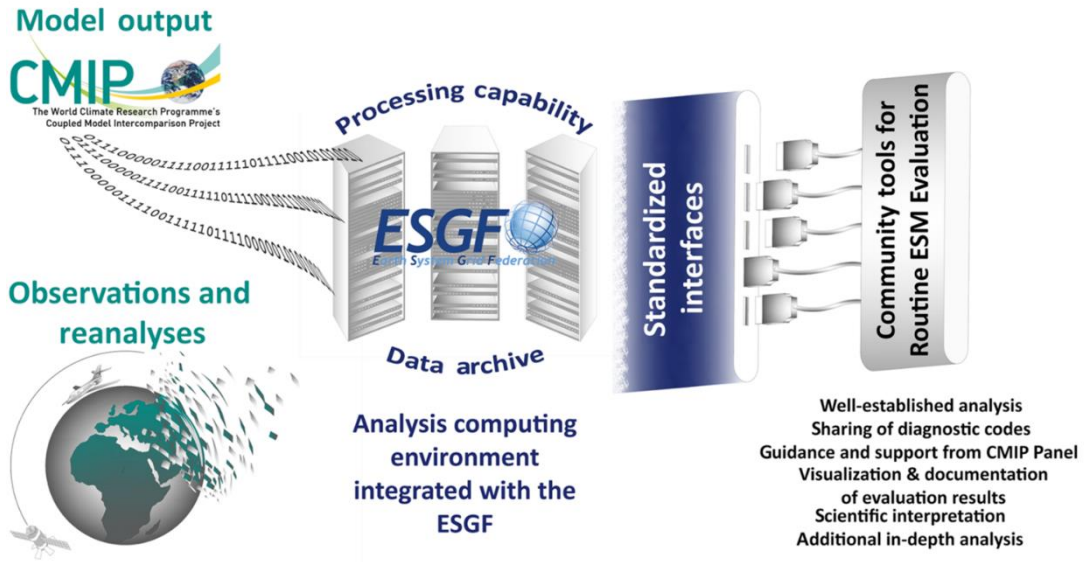
Motivation II

- **Improved quality standard for model evaluation**
  - Growing number of included diagnostics
  - Reproduction of special reports or scientific papers with standard „recipes“
  - Traceability and reproducibility of results
- **Easily expandable**
  - Synergy with other software projects to expand the ESMValTool (e.g. NCAR CVDP)
- **Coupling to Earth System Grid Federation (ESGF)**
  - Complete and timely analysis of CMIP simulations with observations



ESMValTool information

1. Github repositories

https://github.com/ESMValGroup/ESMValTool

2. Documentation

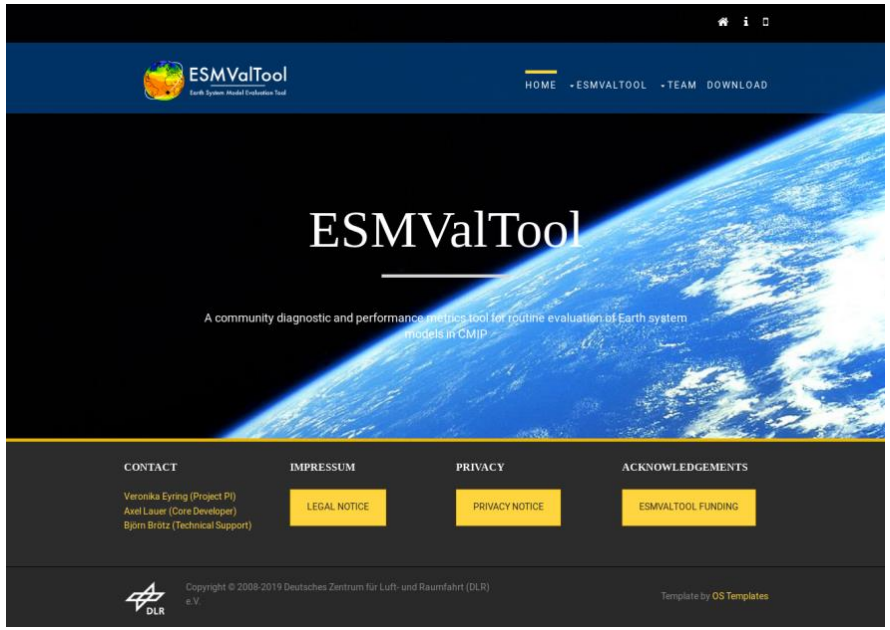
https://docs.esmvaltool.org/

3. Tutorial

https://esmvalgroup.github.io/ESMValTool_Tutorial/

4. Webpage

https://www.esmvaltool.org/



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ESMValTool v2.0

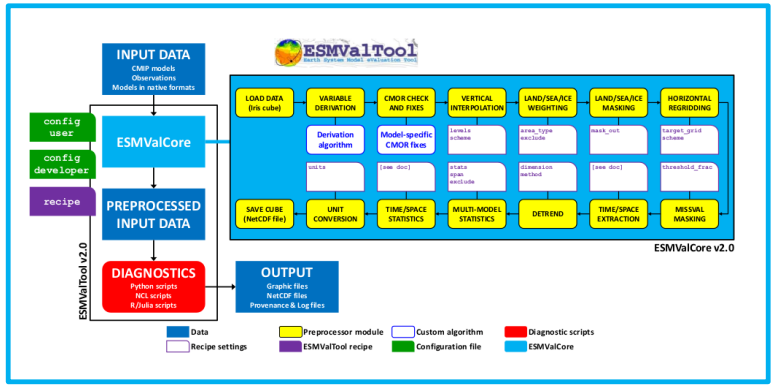
Release v2.0 August 2020

- 3.5 years of work
- 8 coding workshops
- 416 pages documentation
- 776 solved issues
- 1276 merged pull requests
- 1725 files
- 544,971 lines of code

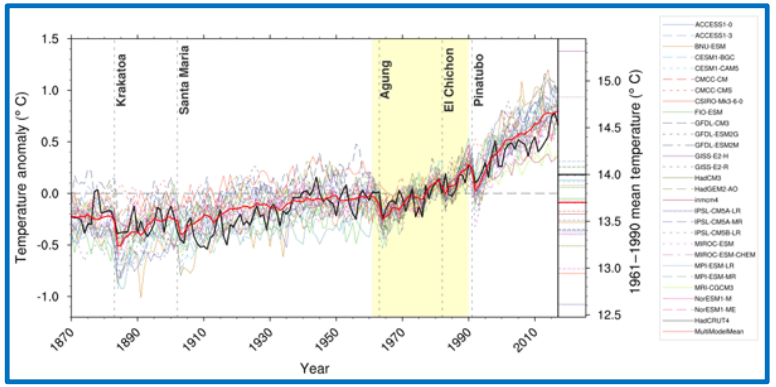
International ESMValTool development team

- 17 funded projects
- 63 institutions
- 203 developers

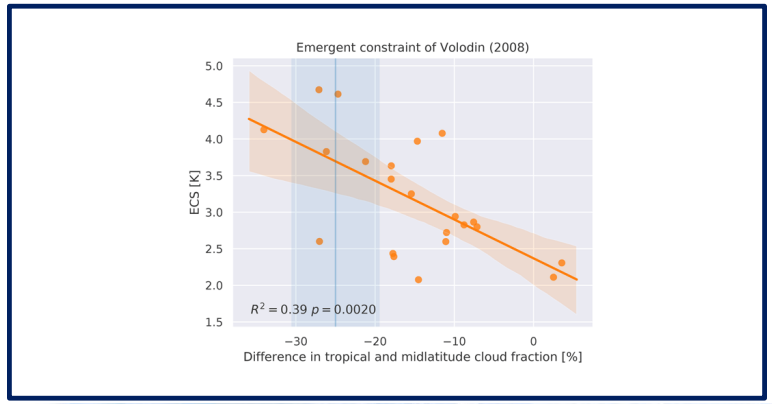
Righi et al., 2020
Technical overview



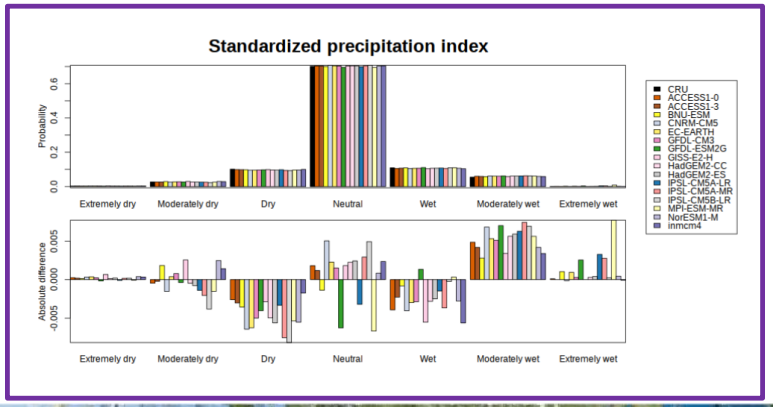
Eyring et al., 2020
Large-scale diagnostics



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



Weigel et al., in review
Diagnostics for extreme events, regional and impact evaluation



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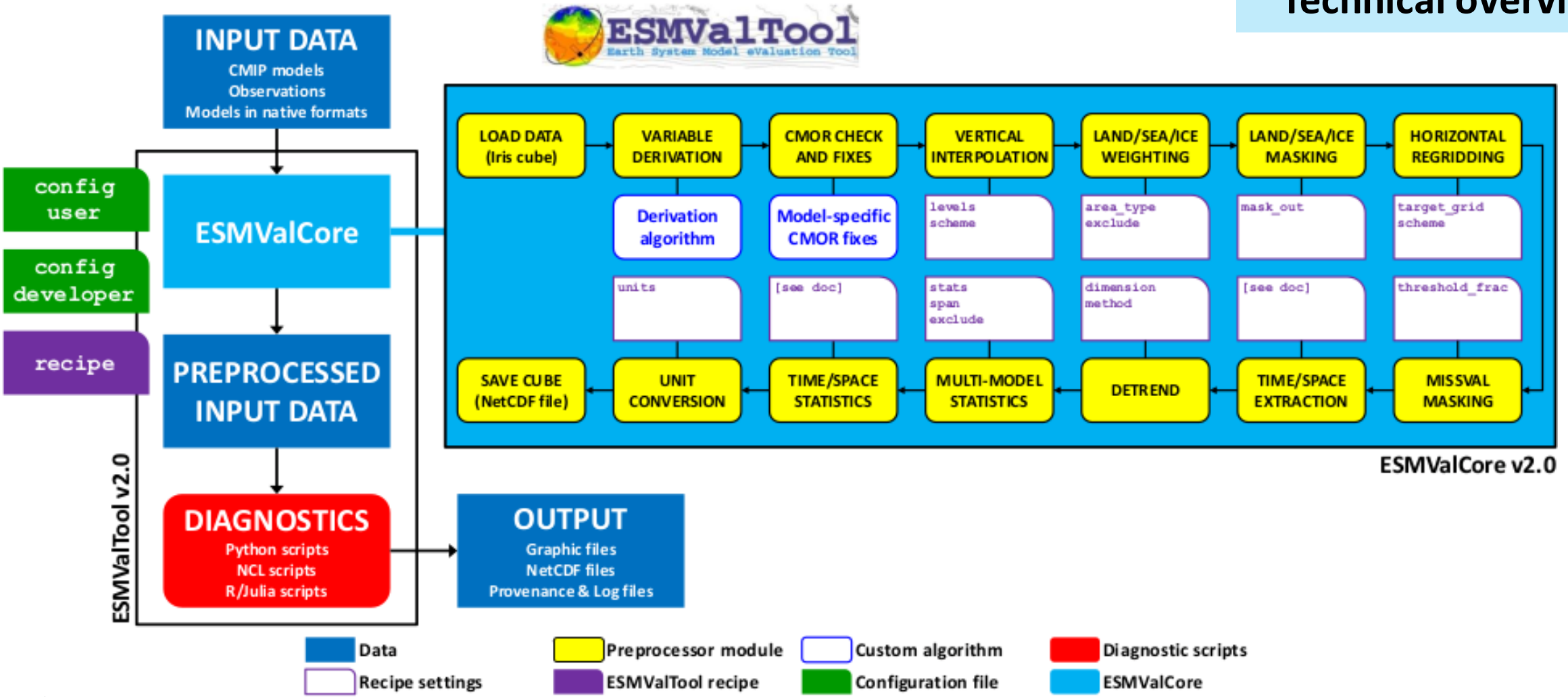
ESMValCore

Righi et al., 2020

Technical overview



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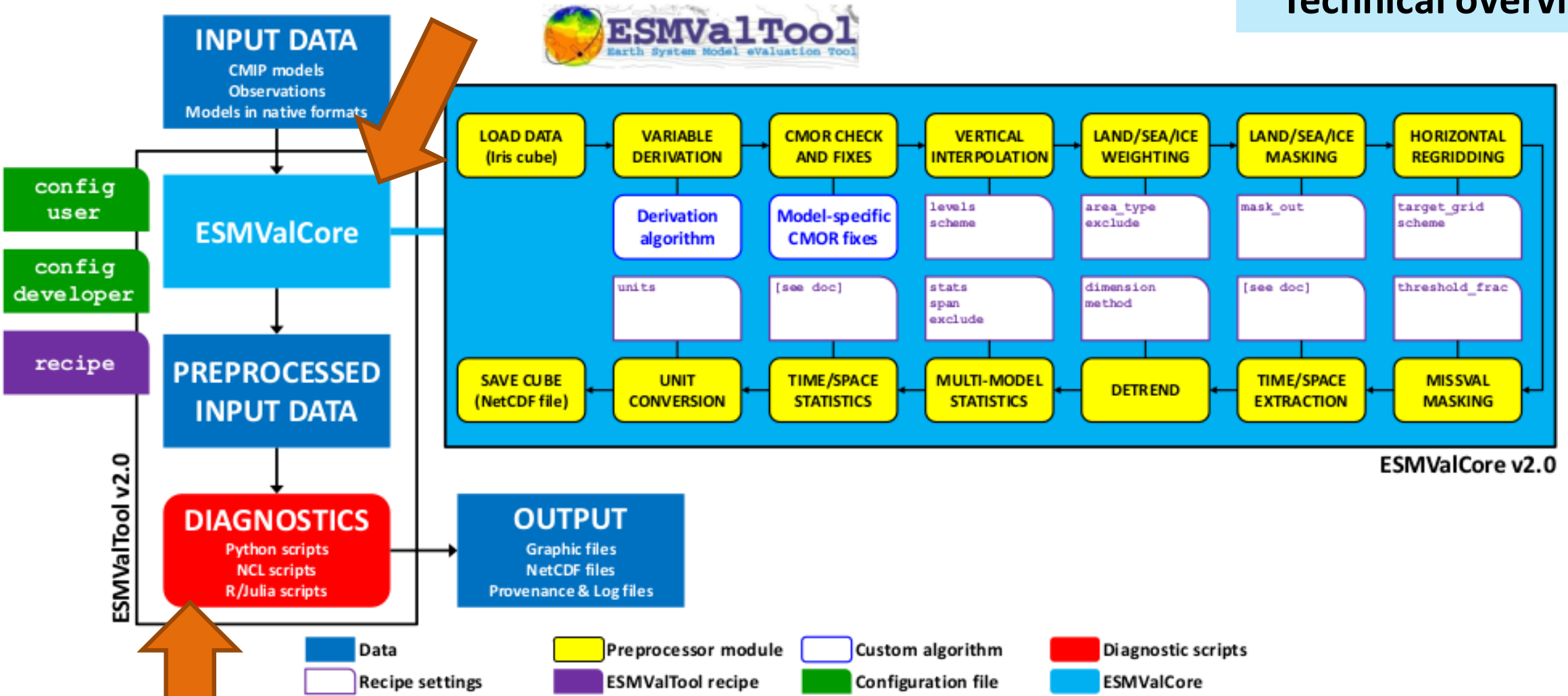
Righi et al., 2020

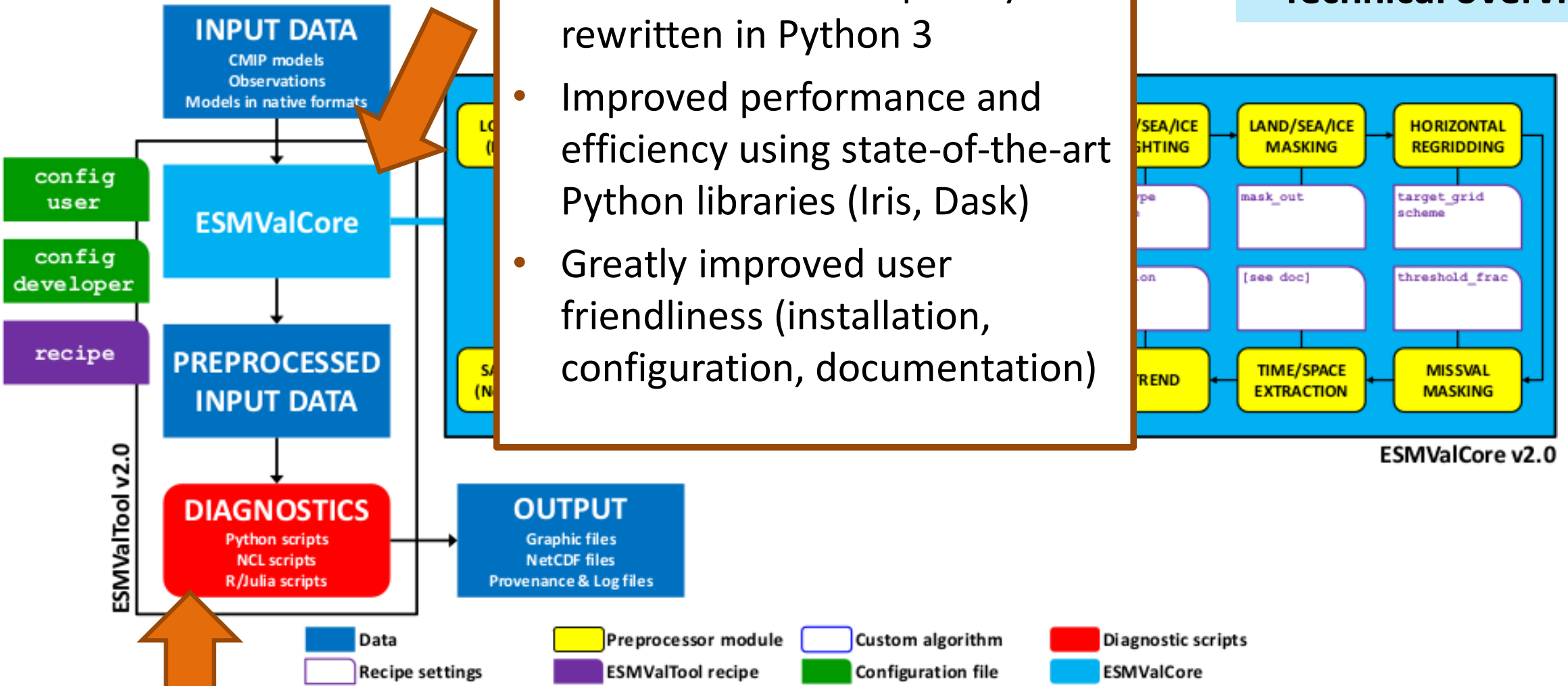
Technical overview



ESMValCore

Righi et al., 2020
Technical overview

- Core functions completely rewritten in Python 3
- Improved performance and efficiency using state-of-the-art Python libraries (Iris, Dask)
- Greatly improved user friendliness (installation, configuration, documentation)



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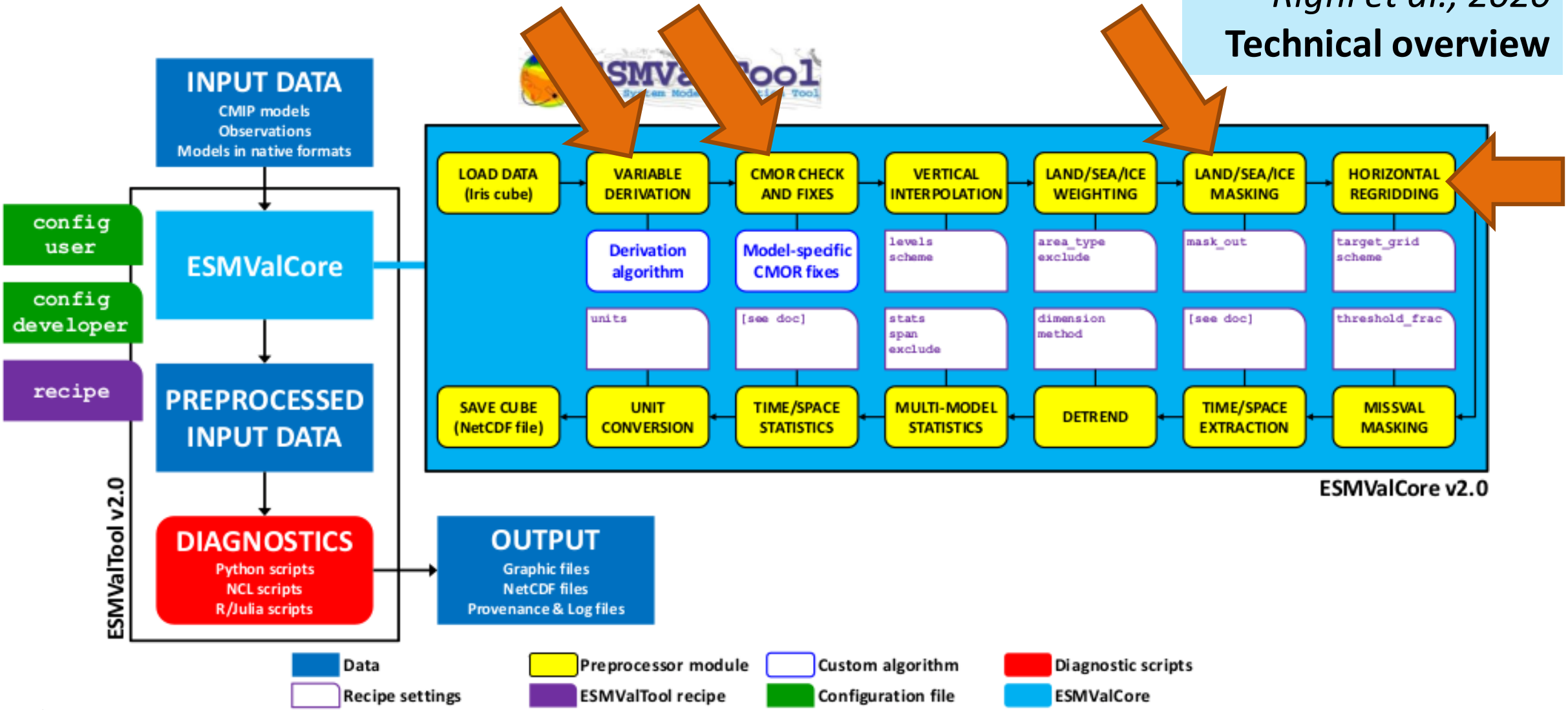
ESMValCore

Righi et al., 2020
Technical overview



ESMValTool – diagnostics expansion

Eyring et al., 2020

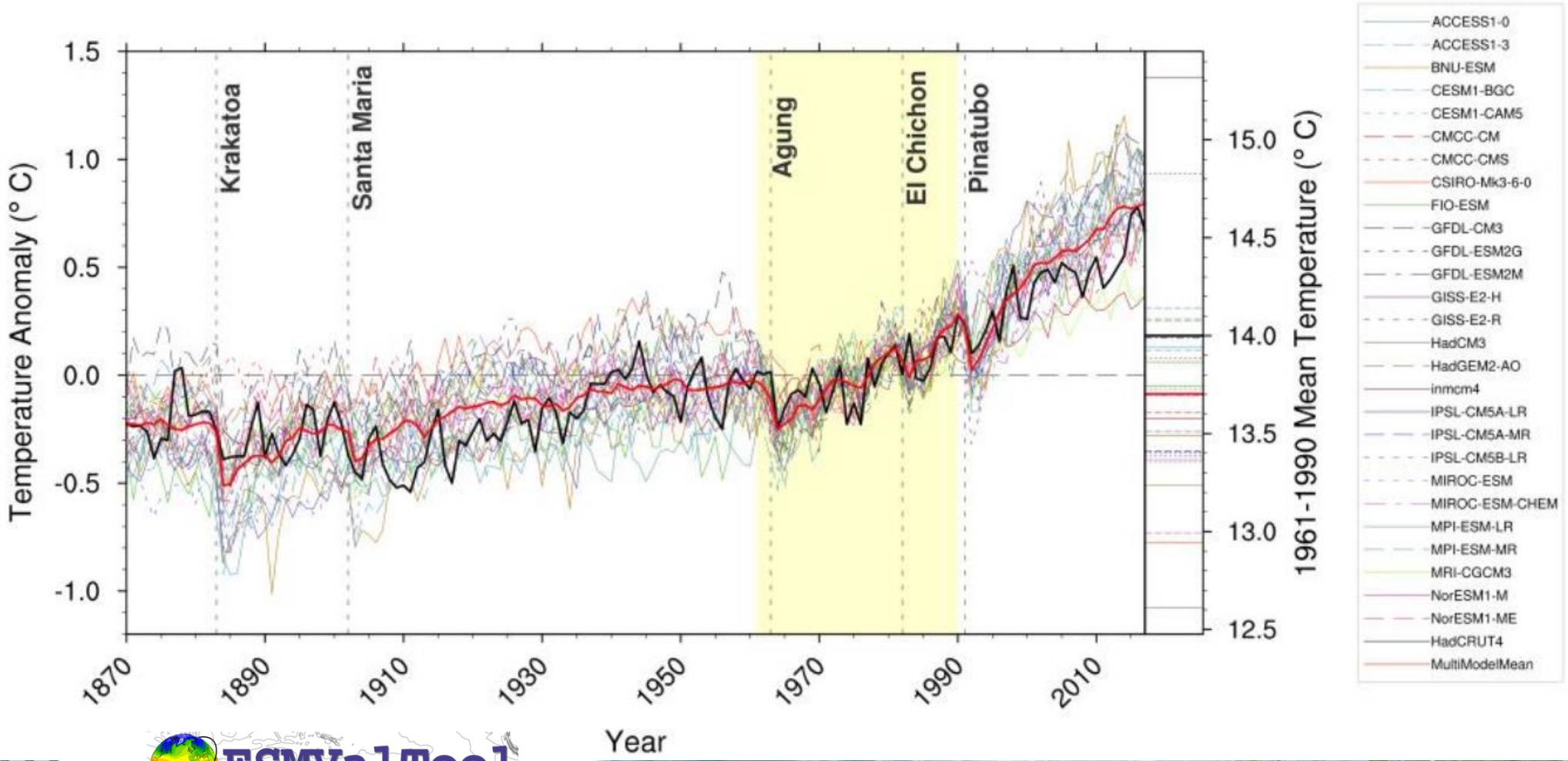
Large-scale diagnostics

- **Integrative measures of model performance**
- **Large scale diagnostics:**
  - Atmosphere
  - Ocean and cryosphere
  - Land processes
  - Biogeochemical processes

ESMValTool – diagnostics expansion

Eyring et al., 2020

Large-scale diagnostics



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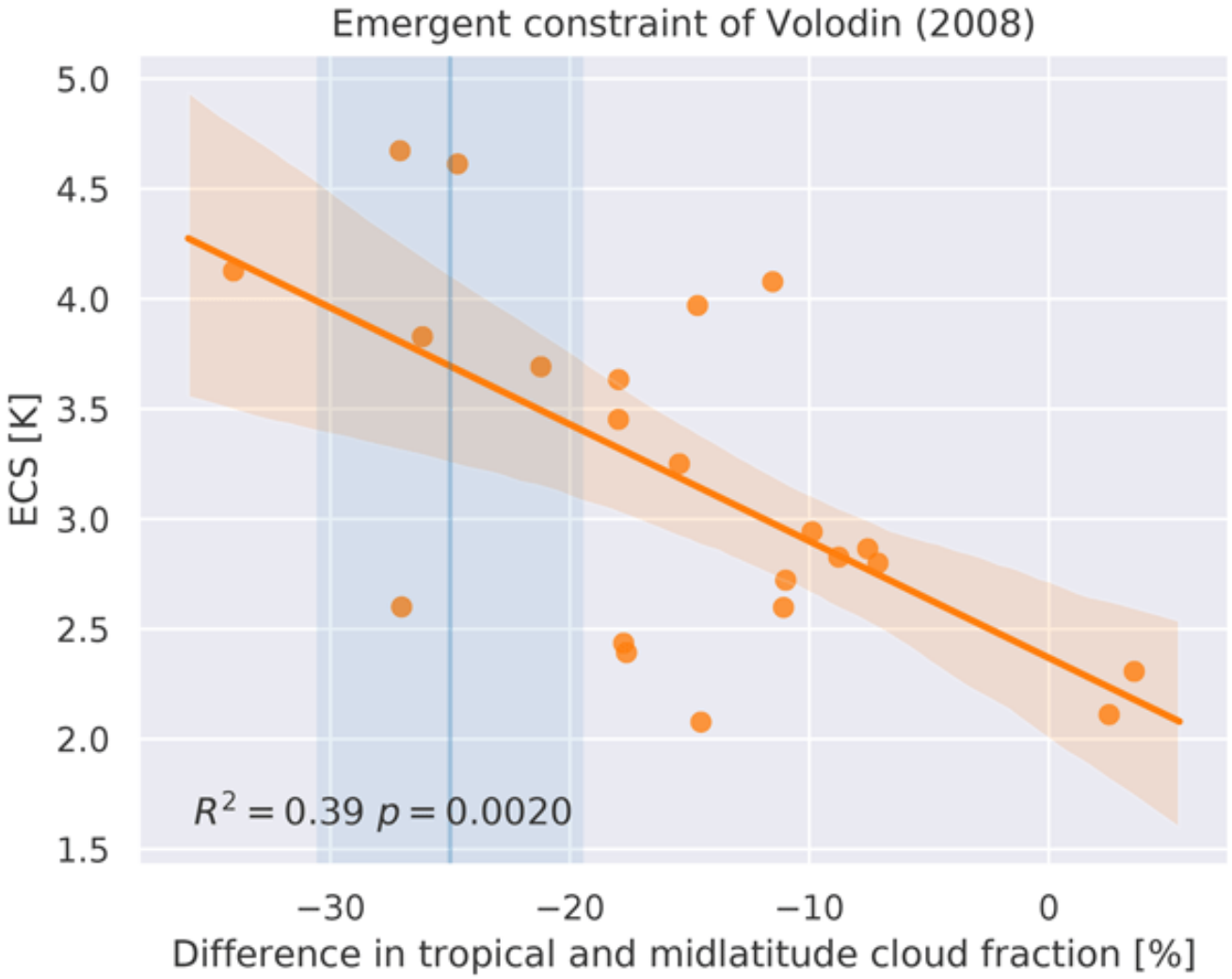
ESMValTool – diagnostics expansion

- **Effective climate sensitivity (ECS) and transient climate response**
- **Emergent constraints,** e.g.
  - Carbon cycle
  - Hydrological cycle
  - ECS
- **Climate model projections**, e.g.
  - Sea ice

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

ESMValTool – diagnostics expansion



Lauer et al., 2020

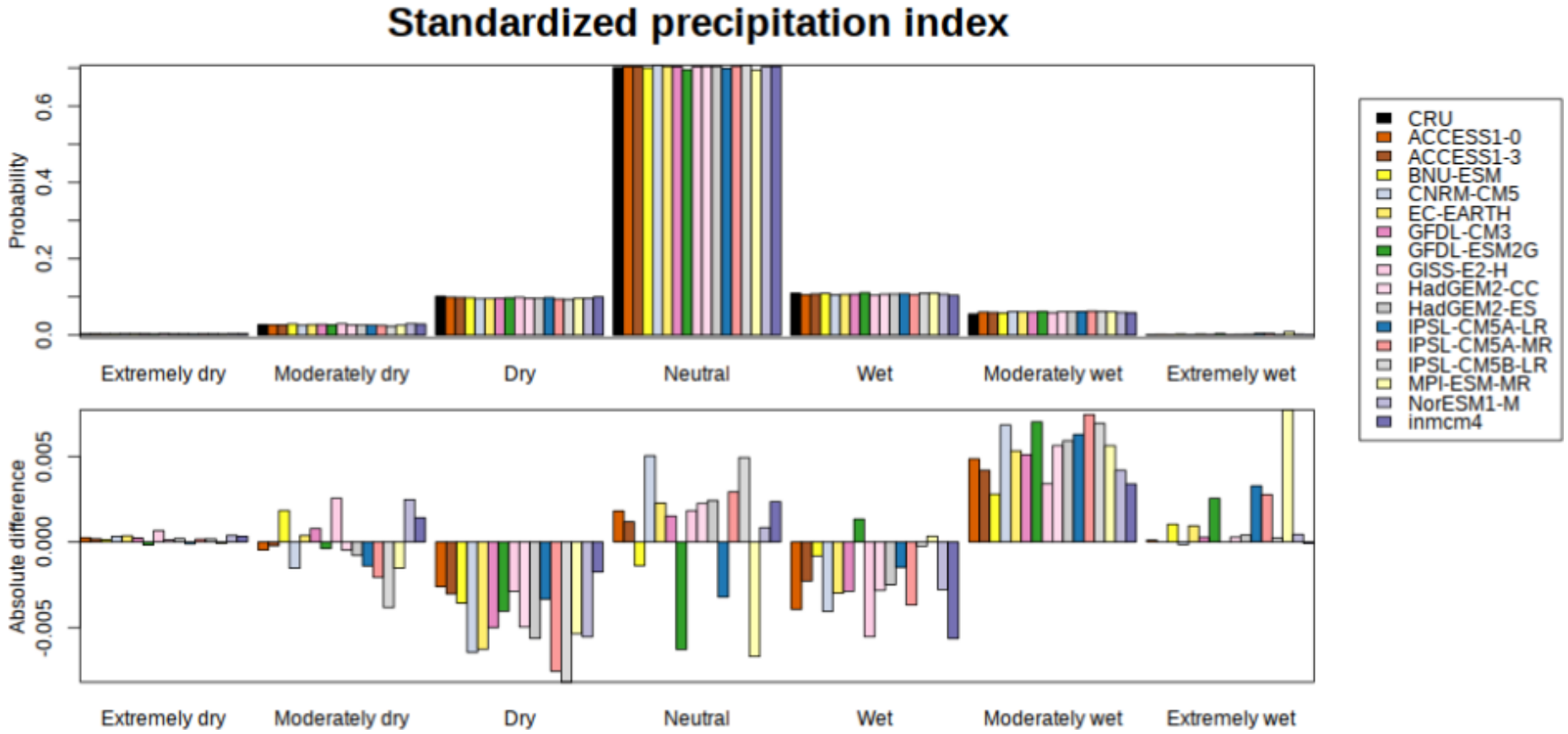
Diagnostics for emergent constraints and future projections

ESMValTool – diagnostics expansion

- **Hydrological cycle**
- **Extreme events**
- **Evaluation for impact assessments,** e.g.
  - Heat and cold wave duration
  - Combined Climate Extreme Index
- **Regional features**

Weigel et al., in review
Diagnostics for extreme events, regional and impact evaluation

ESMValTool – diagnostics expansion



Weigel et al., in review

Diagnostics for extreme events, regional and impact evaluation

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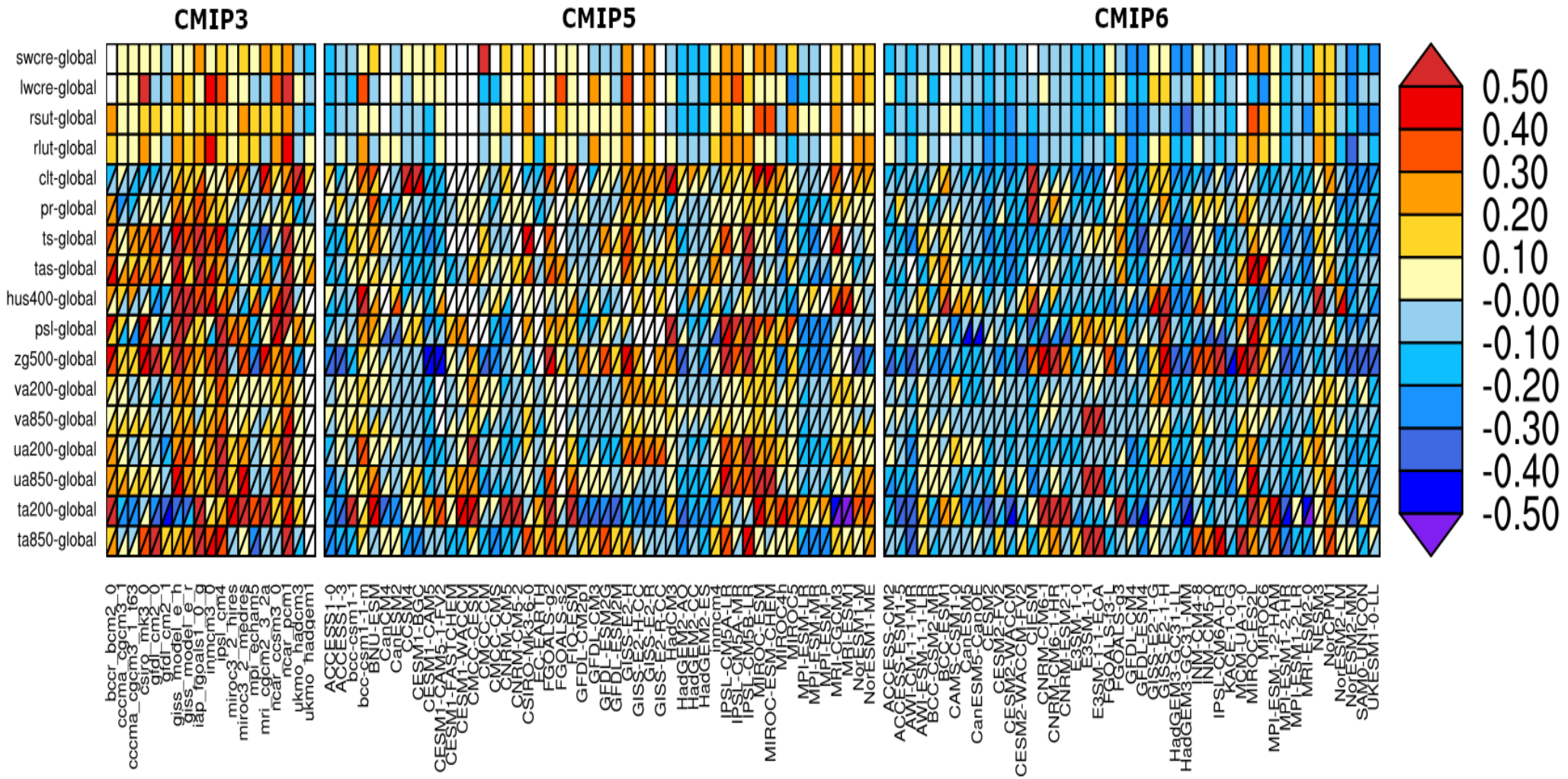
ESMValTool
Earth System Model eValuation Tool

Earth System Models are Improving: Mean Climate



Bock et al., JGR: Atmospheres, 2020

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Summary

- **ESMValTool:** Tool for fast and easy routine evaluation and analysis of Earth system models including provenance records for all results (traceability and reproducibility)
- ESMValTool coupled to ESGF provides a systematic, rapid and comprehensive **performance assessment** that can also enhance quality control
- **Publicly** available and developed in an international **community** effort
- **v2.0 vs v1.0**: clear improvements in core capabilities (pre-processing options), code quality (automatized code checking), and documentation
- **Diagnostics:** more large-scale diagnostics, emergent constraints and future projections diagnostics, extreme events and regional and impact diagnostics available than before
- Supporting production of a subset of figures of the upcoming **IPCC WGI AR6**