Enabling Climate Model Evaluation in Australia

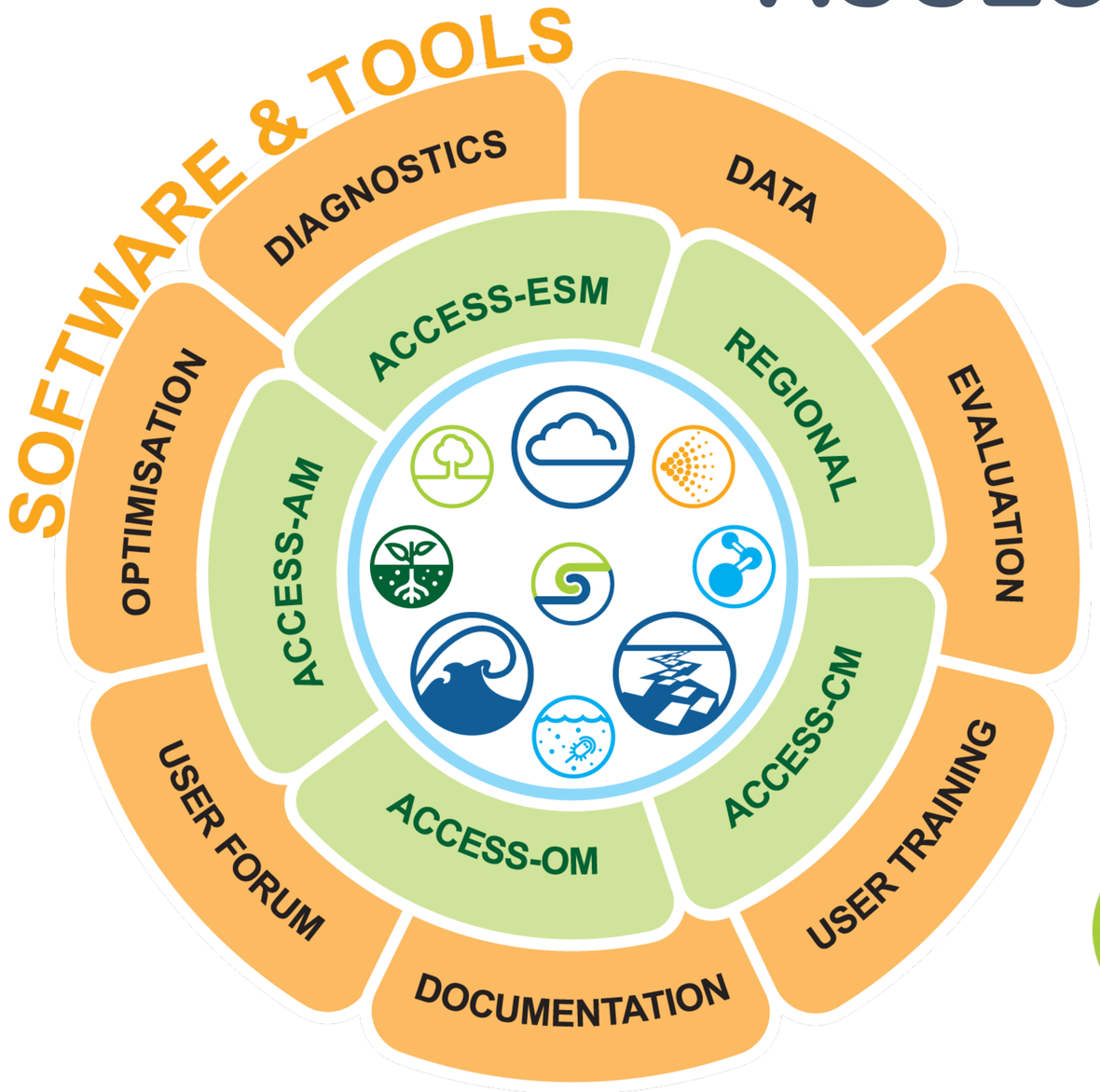
Infrastructure, Standards and CMIP7

Romain Beucher, ACCESS-NRI
CMIP Benchmarking Task Team
October 2025

Australia's climate simulator

ACCESS
National Research Infrastructure

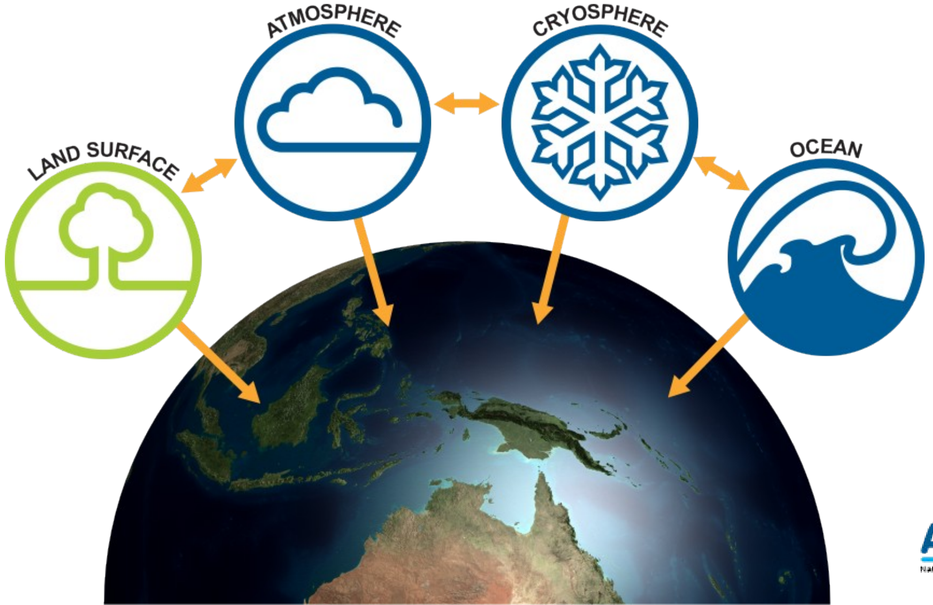
ACCESS-NRI?



ACCESS links separate models of Earth's systems to deliver comprehensive climate simulations over various timescales.

The models use knowledge of how chemical, physical and biological systems work to describe and predict the planet's climate.

ACCESS-NRI is the **national research infrastructure** that develops and maintains the ACCESS model and provides the tools and expertise that supports the research community to use it.



Australia's climate simulator

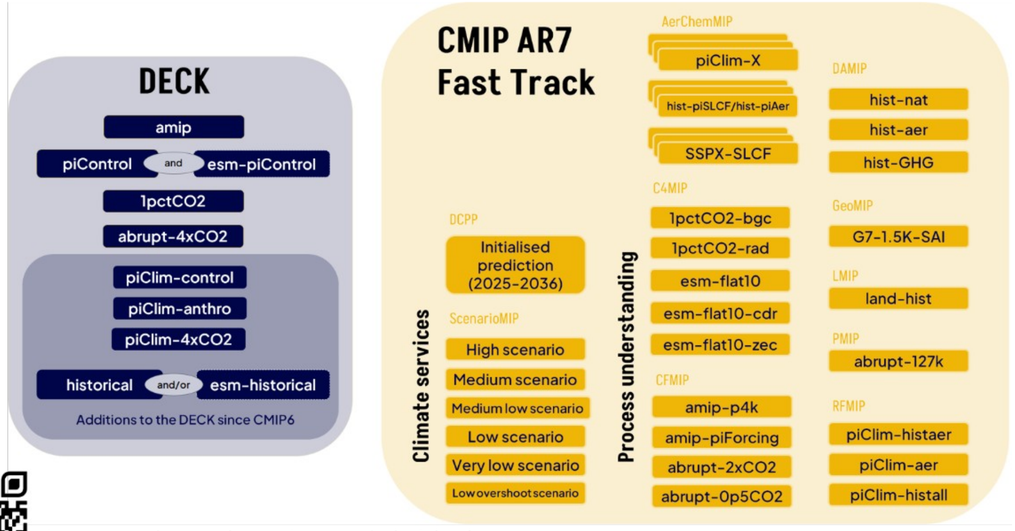
ACCESS National Research Infrastructure

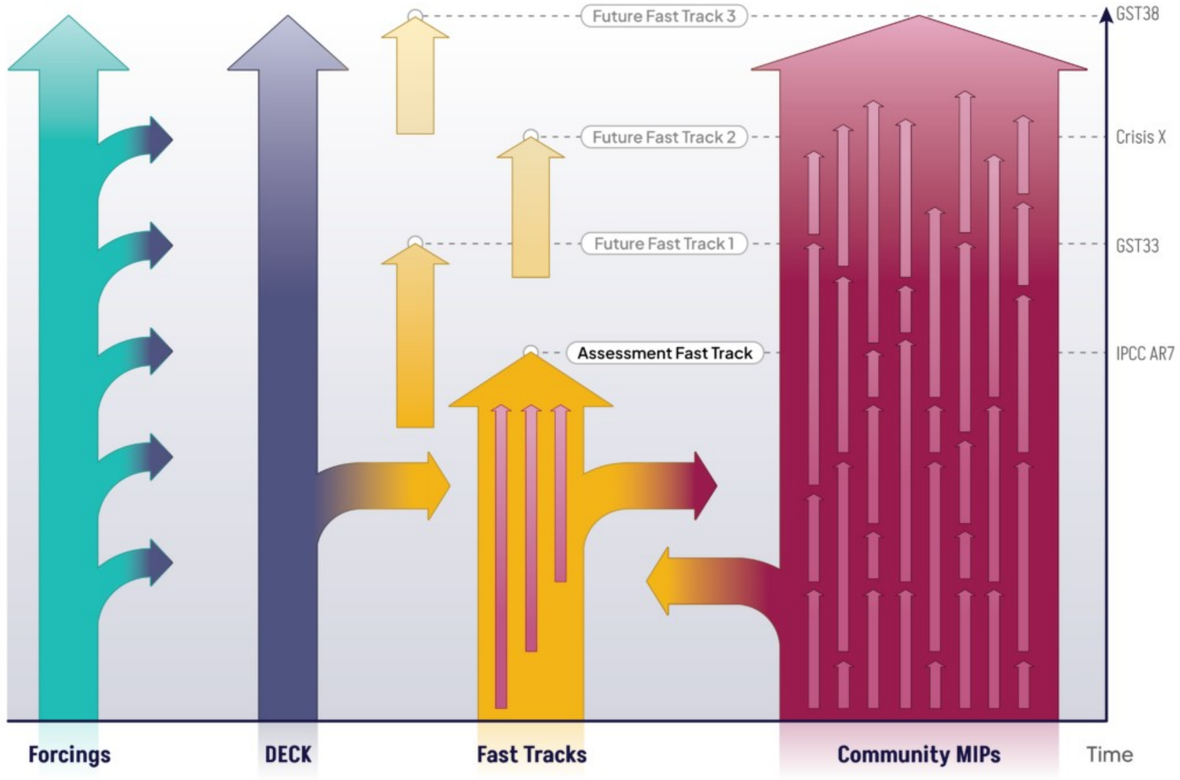
NCRIS National Research Infrastructure for Australia An Australian Government Initiative

Why CMIP7 matters?

Couple Model Intercomparison Project

- Global benchmarking of Earth system models.
- Australia contributes through ACCESS-ESM
- Evaluation critical for credibility and impact.





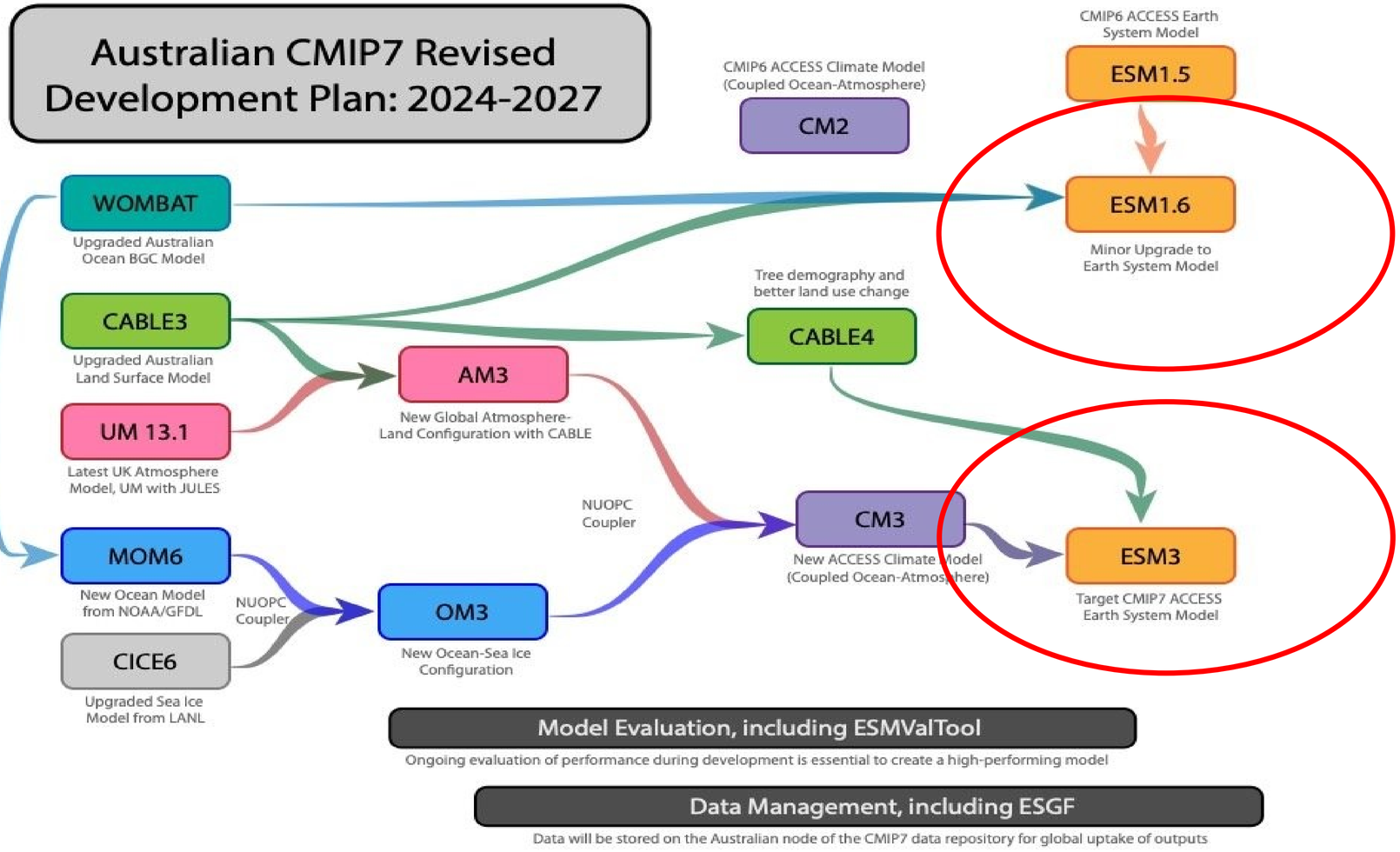
Learn more about each experiment and why it has been included in the Fast Track
bit.ly/FastTrack-experiments

Australia's climate simulator

ACCESS National Research Infrastructure

NCRIS National Research Infrastructure for Australia
An Australian Government Initiative

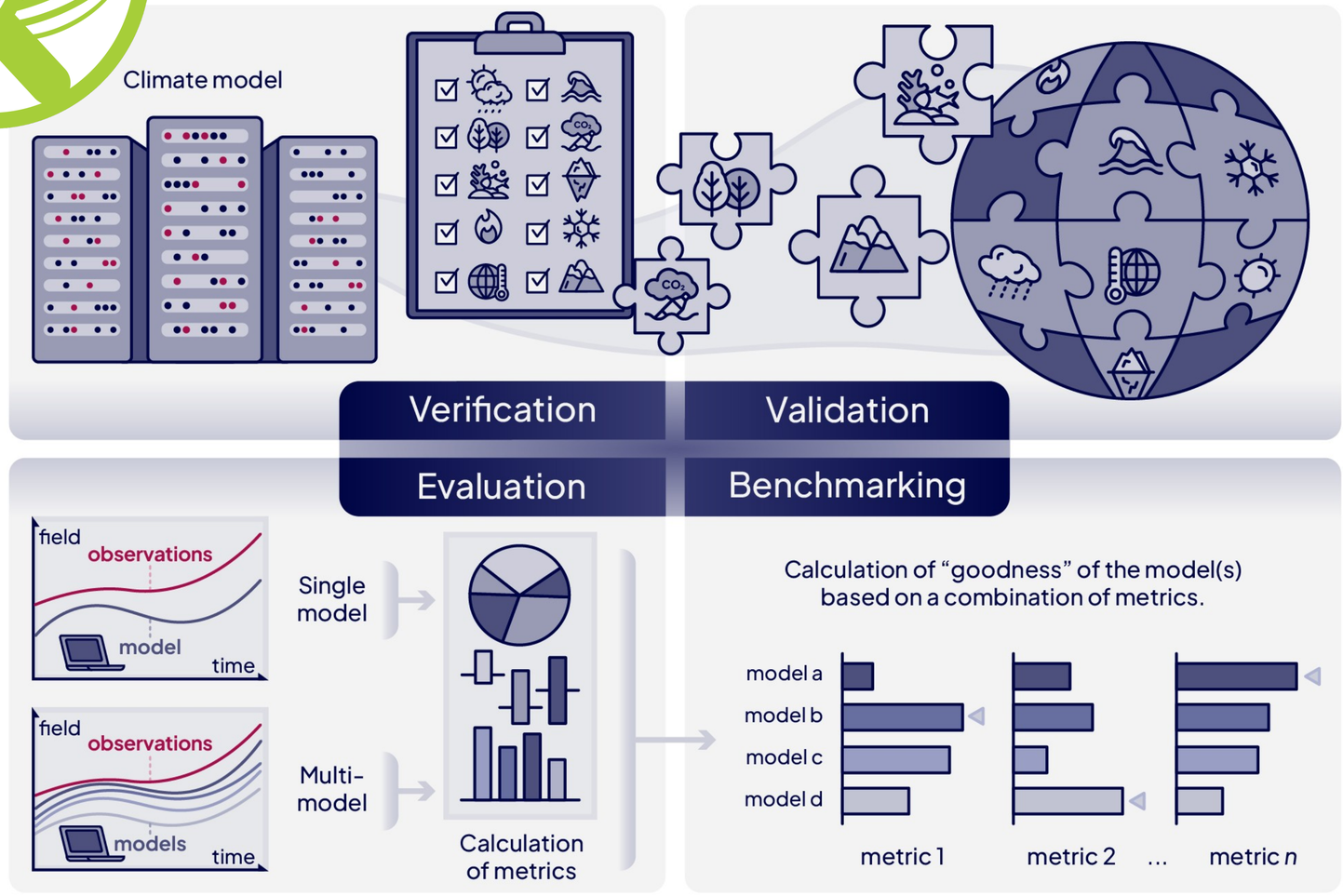
CMIP7 Australian development plan



FAST TRACK

Community MIPs

Importance of evaluation of climate models



As climate models become increasingly complex, there is a need for systematic and comprehensive evaluation and benchmarking through comparison with best-available observational data to assess model fidelity across a wide range of variables.

wcrp-cmip.org/cmip7/rapid-evaluation-framework/

Definition of the terms verification, validation, evaluation and benchmarking for use in the climate model context
DOI 10.5281/zenodo.13985651

Australia's climate simulator

ACCESS National Research Infrastructure

NCRIS National Research Infrastructure for Australia
An Australian Government Initiative

ACCESS-NRI MED TEAM: Core Areas of Work

Model Evaluation and Diagnostics

"Building an Australian community framework for Evaluation of Earth System Models"

Romain Beucher
Team Lead

Felicity Chun
Senior Research Software Engineer

Charles Turner
Senior Research Software Engineer

Rhaegar Zeng
Research Software Engineer

Owen Kaluza
Research Software Engineer, Visualisation

Joshua Torrance
Data Management

Australia's climate simulator

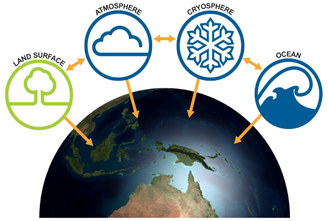
ACCESS National Research Infrastructure

NCRIS National Research Infrastructure for Australia
An Australian Government Initiative

Data Foundations

Data
Standardisation
Metadata
Controlled Vocab.

- Align outputs with CMIP6/7 controlled vocabularies.
- Metadata conforming to CF conventions.
- Use intake catalogs for TB–PB scale discoverability.
- Provide reference datasets ready for direct comparison.



Model Components
Atmosphere • Ocean • Land

NETCDF

Data Schema
CF • CMIP • Controlled Vocab

INTAKE

Intake Catalog
intake-ESM • discoverability

ESMValTool
Earth System Model Evaluation Tool

Evaluation Frameworks
ESMValTool • ILAMB • REF

Australia's climate simulator

ACCESS National Research Infrastructure

NCRIS National Research Infrastructure for Australia
An Australian Government Initiative

ACCESS Model Output Data Specification

Data
Standardisation
Metadata
Controlled Vocab.

CMIP Coupled Model Intercomparison Project

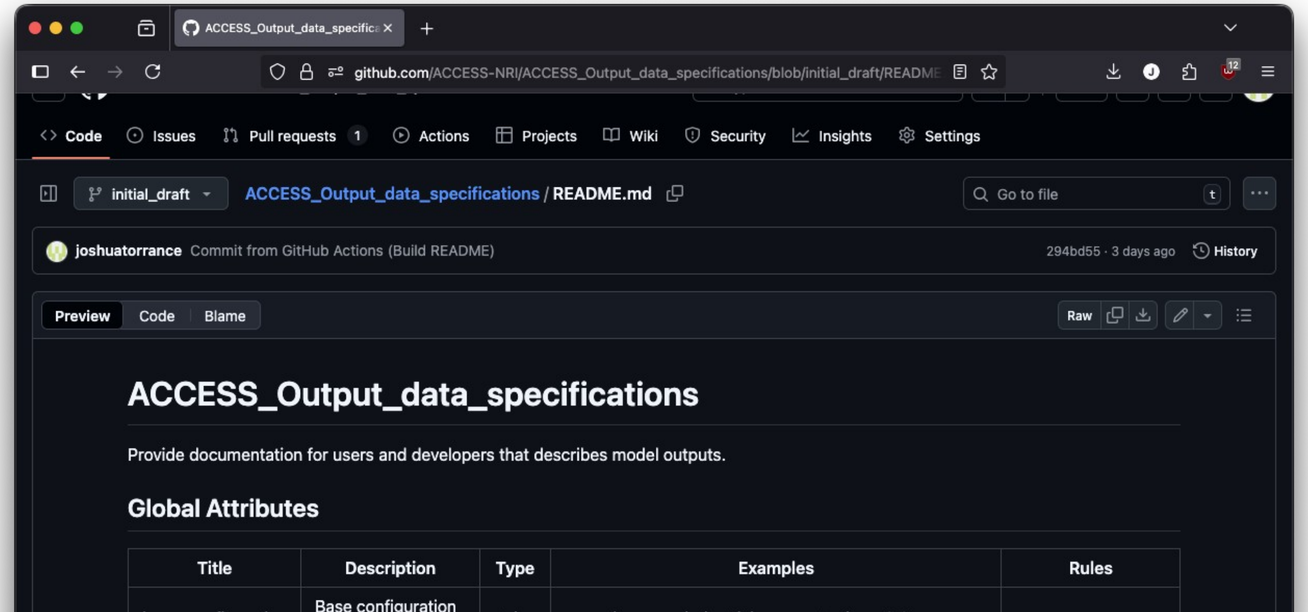
INTAKE

Payu

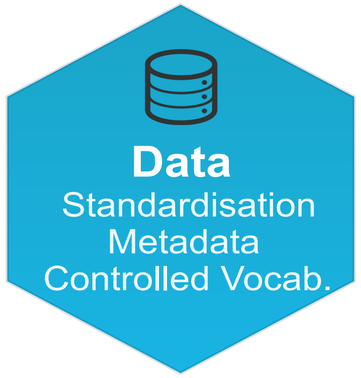
ACDD

JSON Schema

- Progressing towards a unified ACCESS data specification
  - Don't try to solve everything at once
  - Start with lightweight requirements
  - Build off existing specifications
- Keep things FAIR (Findable, Accessible, Interoperable, Reuseable)
- Automate as much as possible
  - Documentation, postprocessing, verification
  - jsonschema as source of truth
  - Github workflows for automations
- Uniform metadata supports integration with Intake catalogs and other tools
- Leverage existing specifications
  - CMIP6/7
  - ACDD
  - CF



Australia's climate simulator



Supporting access to data

ACCESS-NRI Intake Catalog

- Centrally curated and managed store of data
- Easy to search - know what you want, not where you want
- Unifies data discovery and access

```
[1]: import intake
     intake.cat.access_nri
```

access_nri catalog with 119 source(s) across 2969 rows:

name	model	description	realm	frequency	variable
01deg_jra55_ryf_Control	{ACCESS-OM2-01}	{0.1° ACCESS-OM2 repeat year forcing control run for the simulations performed in Huguenin et al. (2024, GRL)}	{sealce, ocean}	{fx, 1mon}	{hi_m, total_ocean_river, yu_ocean, time_bounds, temp_rivermix_on_nrho, v, aicen_m, sfc_hflux_pme, average_T2, temp_submeso, vocn_m, alvdr_ai_m, st_ocean, alvdf_ai_m, total_ocean_hflux_coupler, sw...
01deg_jra55_ryf_ENFull	{ACCESS-OM2}	{0.1° ACCESS-OM2 El Niño run for the simulations performed in Huguenin et al. (2024, GRL)}	{sealce, ocean}	{fx, 1mon}	{hi_m, total_ocean_river, yu_ocean, time_bounds, v, aicen_m, sfc_hflux_pme, average_T2, temp_submeso, vocn_m, alvdr_ai_m, st_ocean, alvdf_ai_m,

```
[6]: catalog["01deg_jra55_ryf_Control"]
```

01deg_jra55_ryf_Control catalog with 7 da

	unique
filename	48
file_id	7
path	126
filename_timestamp	42
frequency	2
start_date	43
end_date	43
variable	181
variable_long_name	182
variable_standard_name	27
variable_cell_methods	3
variable_units	45
realm	2
derived_variable	0

```
[35]: intake.cat.access_nri['01deg_jra55_ryf_Control'].search(
          frequency='1mon',
          variable='temp',
          file_id='ocean_month'
      ).to_dask(
          xarray_open_kwargs = {'decode_timedelta': False}
      )
```

```
[35]: xarray.Dataset
```

▸ Dimensions: (**time**: 42, **st_ocean**: 75, **yt_ocean**: 2700, **xt_ocean**: 3600)

▾ Coordinates:

xt_ocean	(xt_ocean)	float64	-279.9 -279.8 ... 79.85 79.95
yt_ocean	(yt_ocean)	float64	-81.11 -81.07 ... 89.94 89.98
st_ocean	(st_ocean)	float64	0.5413 1.681 ... 5.709e+03
time	(time)	object	2145-01-16 12:00:00 ... 214...

▾ Data variables:

temp	(time, st_ocean, yt_ocean, xt_ocean)	float32	dask.array<chunksize=(1, 19...

▸ Indexes: (4)

▸ Attributes: (16)

ACCESS National Research Infrastructure

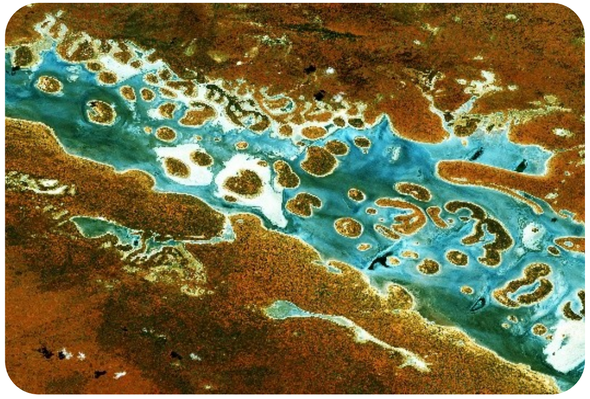
NCRIS National Research Infrastructure for Australia
An Australian Government Initiative

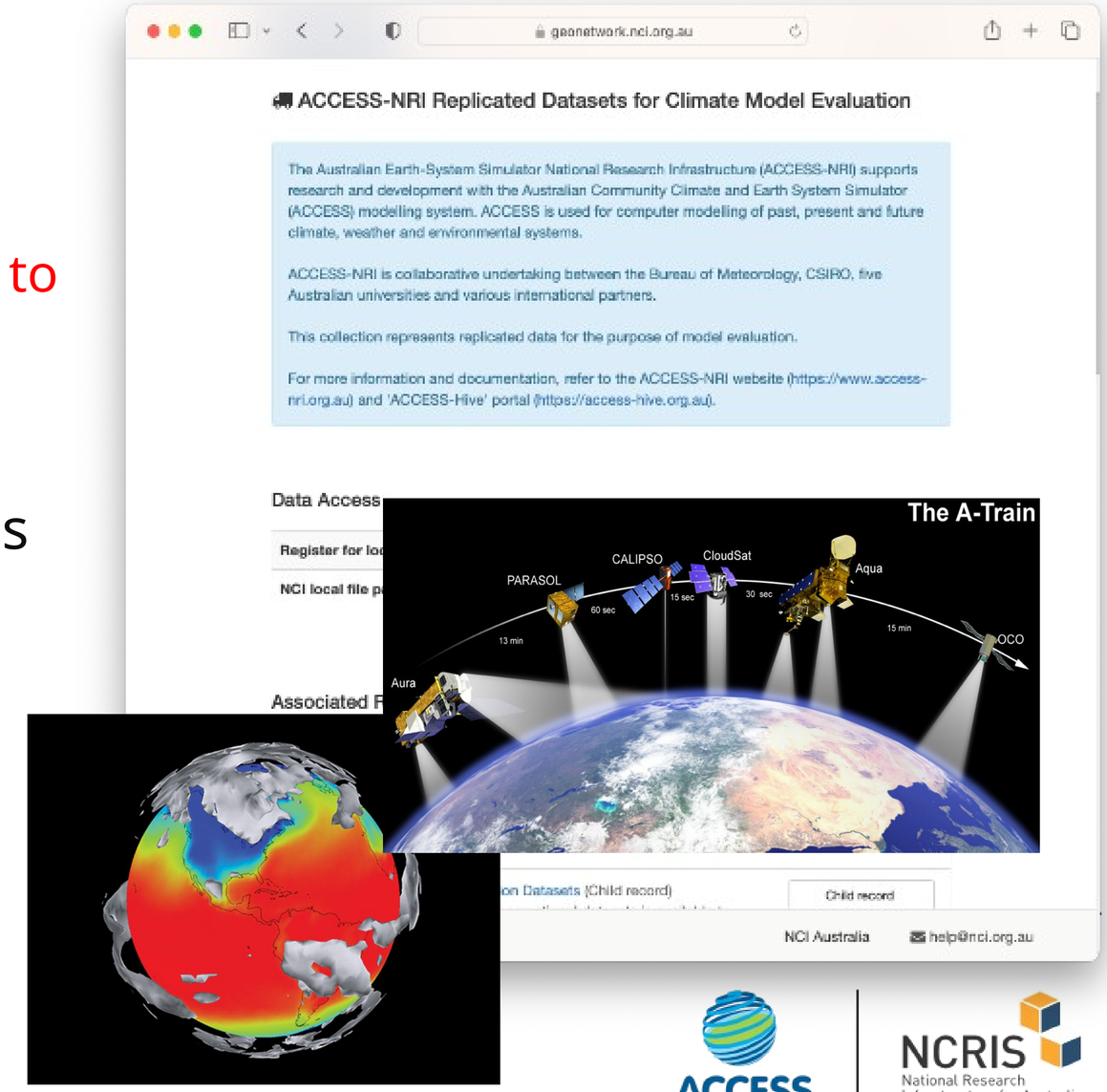
Data
Standardisation
Metadata
Controlled Vocab.

Supporting access to data

- We support a range of **observational products** to benchmark model outputs against real-world data.

- Leverage NCI National Reference Collections
  - Model simulations
  - Satellites data
  - Observation/reanalysis data for Australia





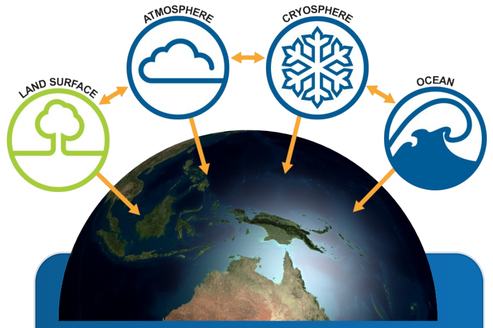
NCI AUSTRALIA

ACCESS National Research Infrastructure

NCRIS National Research Infrastructure for Australia
An Australian Government Initiative

Tools & Evaluation Frameworks

Tools
Frameworks
Diagnostics
CMORisation



Model
Native model output

MOPPeR
Convert • Validate

CMOR Output
CF/CMIP-compliant

ESMValTool
Metrics • Diagnostics

REF Dashboard
Rapid evaluation

ESMValTool
Earth System Model Evaluation Tool

CMIP REF

Australia's climate simulator

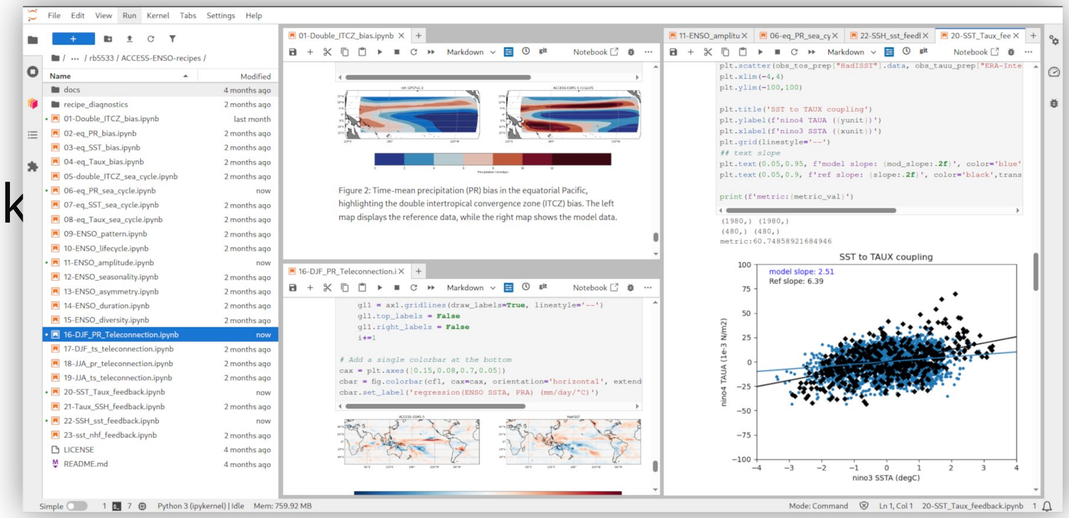
ACCESS National Research Infrastructure

NCRIS National Research Infrastructure for Australia
An Australian Government Initiative

ACCESS ENSO Recipes

Tools
Frameworks
Diagnostics
CMORisation

ESMValTool
Earth System Model Evaluation Tool



- Explore climate model diagnostics in Jupyter notebook
- Enable seamless debugging, visualisation, and user-driven analyses
- 23 Notebooks evaluating different aspects of ENSO(El Niño-Southern Oscillation).
- Scalable, reproducible evaluation workflows with ESMValTool
- Optimised to use Dask clusters
- Supports a range of observational data products

jupyter Iris dask

Australia's climate simulator

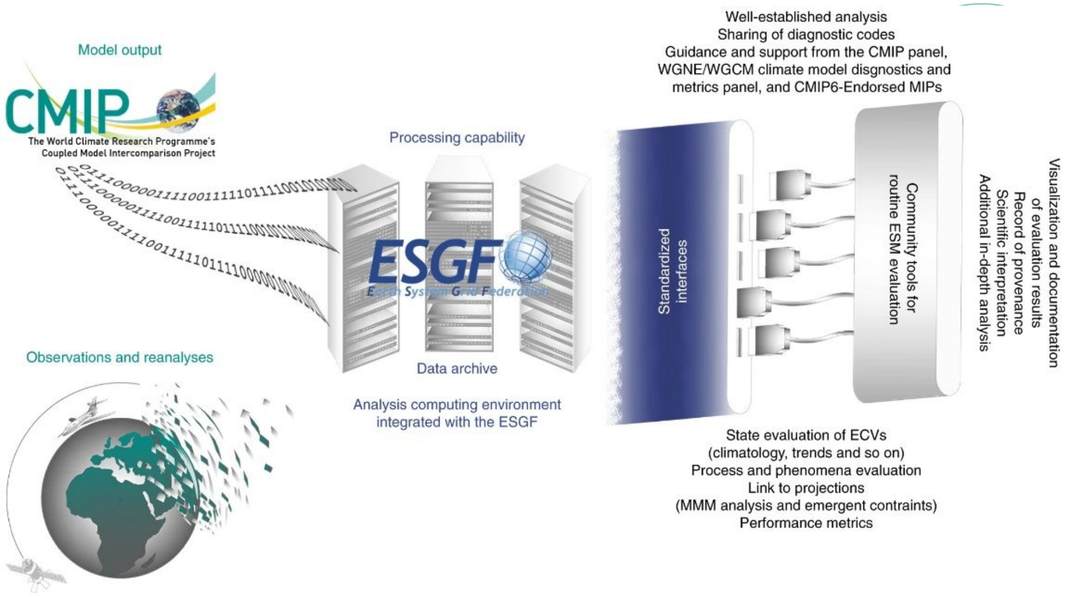
ACCESS
National Research Infrastructure

Tools
Frameworks
Diagnostics
CMORisation

Rapid Evaluation Framework

CMIP Benchmarking Task Team

- **Vision:** A community owned evaluation framework, built upon, and compatible with, existing community evaluation packages that incorporates an application programming interface (API) for executing metrics generation from those community evaluation packages, across the globe.
- **Goal:** The Rapid Evaluation Framework (REF) is a complete end to end system providing a systematic and rapid performance assessment of the expected models participating in the CMIP Assessment Report (AR7) Fast Track, supporting the next IPCC AR7 cycle



Australia's climate simulator

ACCESS National Research Infrastructure | NCRIS National Research Infrastructure for Australia An Australian Government Initiative

-cmip.org/cmip7/rapid-evaluation-framework/

Analysis Environments

are
australian research environment

NCI
AUSTRALIA

CONDA®

NumPy

python™

SciPy

xarray

“Shared environments, reproducible results.”

- 600+ users on NCI Gadi.
- SPEC0 compliance ensures reproducibility.
- HPC-optimised configuration maintained by ACCESS-NRI.

jupyter

Iris

dask

Australia’s climate simulator

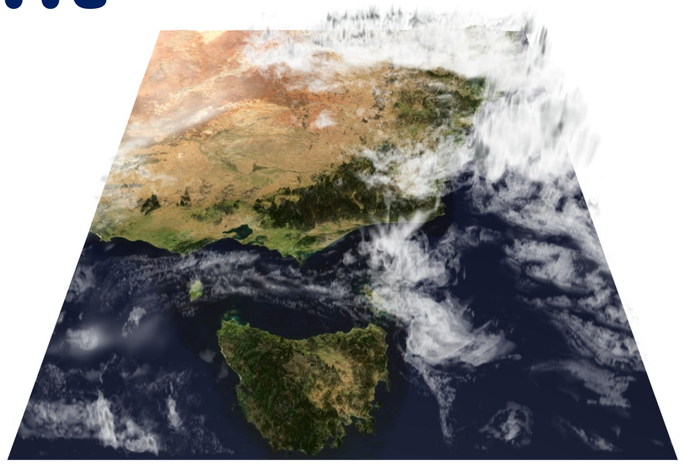
ACCESS
National Research Infrastructure

NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

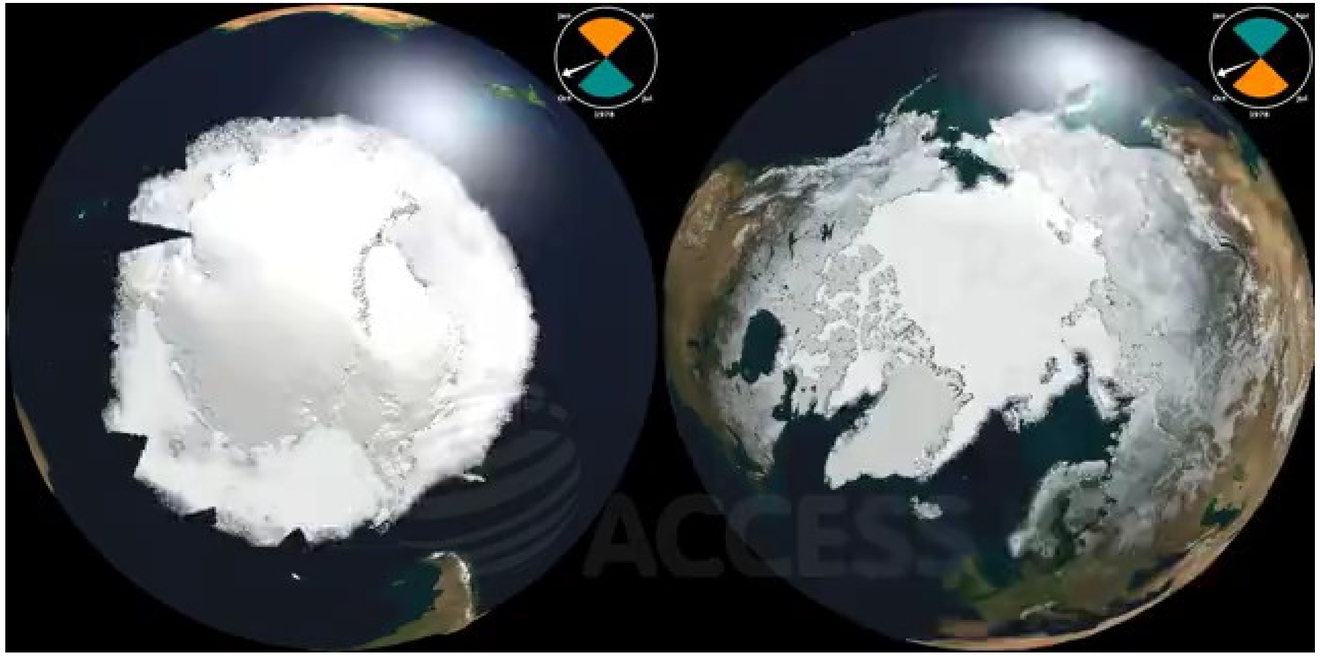
Visualisation & Engagement

Visualisation
3D
Narrative
Communication

“Turning data into stories.”



Some visualisation releases and work in progress:
https://vimeo.com/accessnri



Australia’s climate simulator

ACCESS National Research Infrastructure

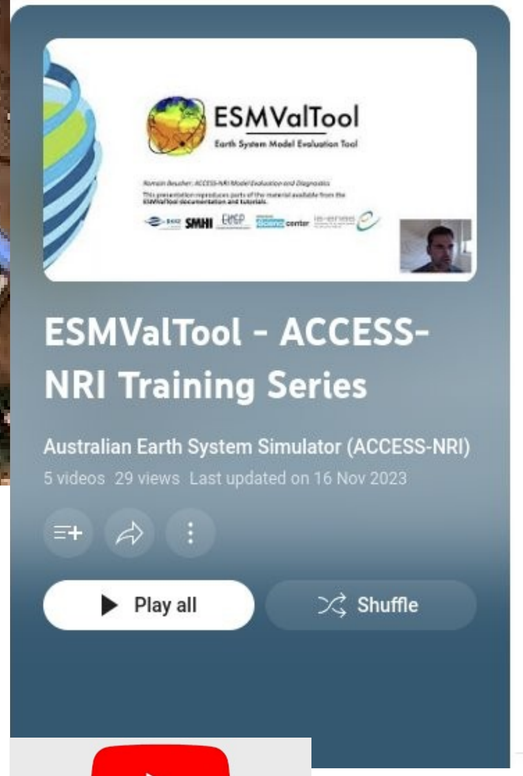
ACCESS National Research Infrastructure

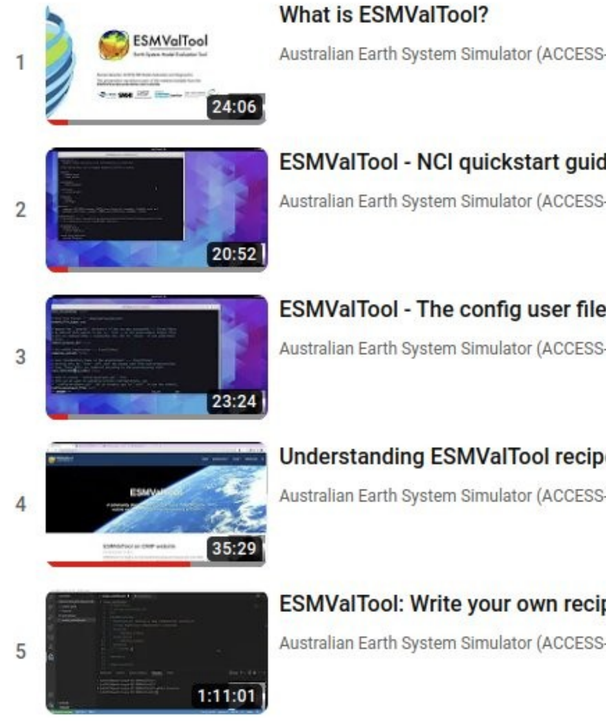
NCRIS National Research Infrastructure for Australia An Australian Government Initiative

Training
Workshops
Tutorials

Training & Community Building

- Interactive notebooks for ESMValTool and ILAMB.
- 3D visualisation workshops.
- Supporting skills transfer and uptake.





CONCLUSIONS

- **Developing and maintaining software for analysing and comparing model outputs.**

- Facilitate access to **observational datasets** and community experiments.

- **Generate diagnostics and evaluate models/configurations** at any stage of model development.

- Help **establish community guidelines and standards**.

- **Support international efforts.**

ACCESS National Research Infrastructure

NCRIS National Research Infrastructure for Australia An Australian Government Initiative

Australia's climate simulator