Building the software, data and training foundations to support Australia's climate simulator (ACCESS-NRI)

Kelsey Druken, Romain Beucher, Aidan Heerdegen, Paige Martin, Micael Oliveira and Clare Richards

Acknowledgement of Country

We at ACCESS-NRI acknowledge the Traditional Owners of the land on which our research infrastructure and community operate across Australia and pay our respects to Elders past and present. We recognise the thousands of years of accumulated knowledge and deep connection they have with all the Earth systems we simulate.

Who are we?

ACCESS – the model

ACCESS is a model framework that connects separate models of Earth's systems such as the land, atmosphere, sea and ice to deliver comprehensive simulations of Earth's climate and weather systems.

ACCESS-NRI – the national research infrastructure entity

ACCESS-NRI is the national research infrastructure – the ACCESS model software and the specialist team that develops and maintains it and 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

Our infrastructure journey

Software infrastructure, launched in 2022 (team of 6 all based in Canberra at the time)

Now a team of ~40 staff across Australia (ACT, VIC, TAS, NSW, QLD, WA)

Had to build foundations for:

- (Basic existence as a new org!)
- Community
- Science & model development
- **Software, data & training**

ACCESS
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Teamwork makes the dream work…

Photo credit: Harshula Jayasuriya

Key activities

We work with Australian researchers to maintain the ACCESS model – a framework of open-source climate and weather models using high-performance computers. These models underpin Australia’s climate science capability – and our ability to inform Australia’s climate adaptation strategies.

We develop the computing software expertise required to keep the ACCESS model running optimally, adapt it to current and future computing technologies and make it accessible to all researchers.

We connect Australia’s climate research communities to collaborate and use the models effectively to generate robust climate simulations for research, policy and decision-making purposes.

We develop high-quality climate prediction systems essential to Government agencies working to support Australians coping with the increasing effects of climate change and high-impact weather events.

We deliver a unique Australian and Southern Hemisphere perspective that informs international science and improves the global picture of climate change and its future impacts.

The ACCESS Model framework

- The **ACCESS model** links separate Earth system elements to form configurations that represent the dynamic climate and weather system.
- **>3.5 million lines** of code
- Specifically designed for Australia and the Southern Hemisphere.
- Each component has at least one major software code base.

Australia's climate simulator

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NCRIS National Research Infrastructure for Australia

An Australian Government Initiative

Scene setting

Climate “models” or simulators

Physics-based

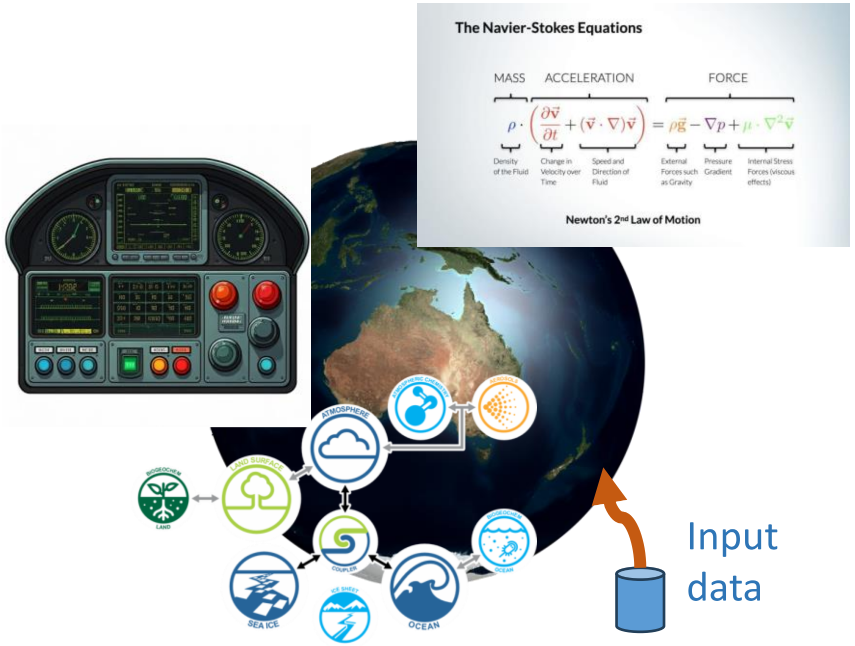

Image credits: Owen Kaluza; Jousef Murad; Xarray; Corey Robinson & Christian Jakob (Monash)

Resource requirements

ACCESS-OM2-01 (1/10th degree resolution)

100 model years

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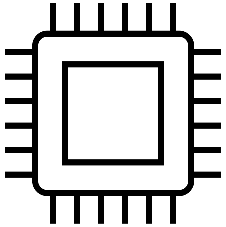
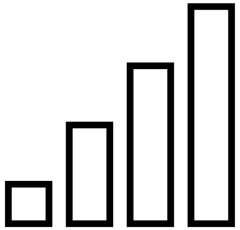
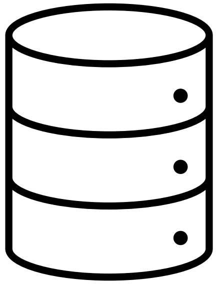


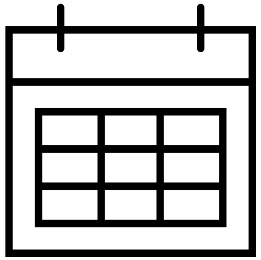
10K+ cores



7 MSU



100TB

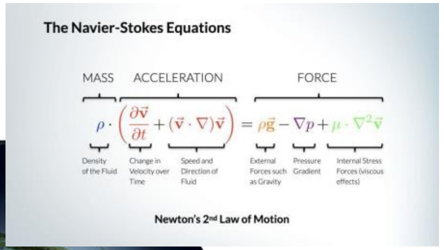


3 Months

Scene setting

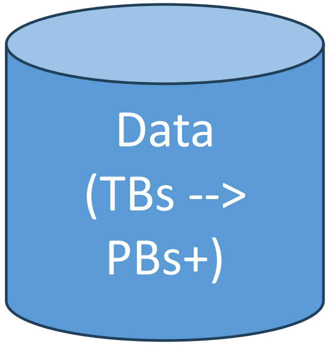
Climate “models” or simulators

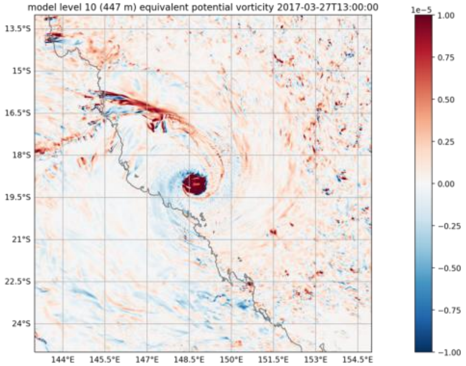
Physics-based



Input data

Data evaluation & analysis (model outputs, observations, etc.)





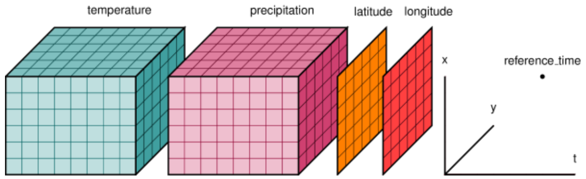


Image credits: Owen Kaluza; Jousef Murad; Xarray; Corey Robinson & Christian Jakob (Monash)

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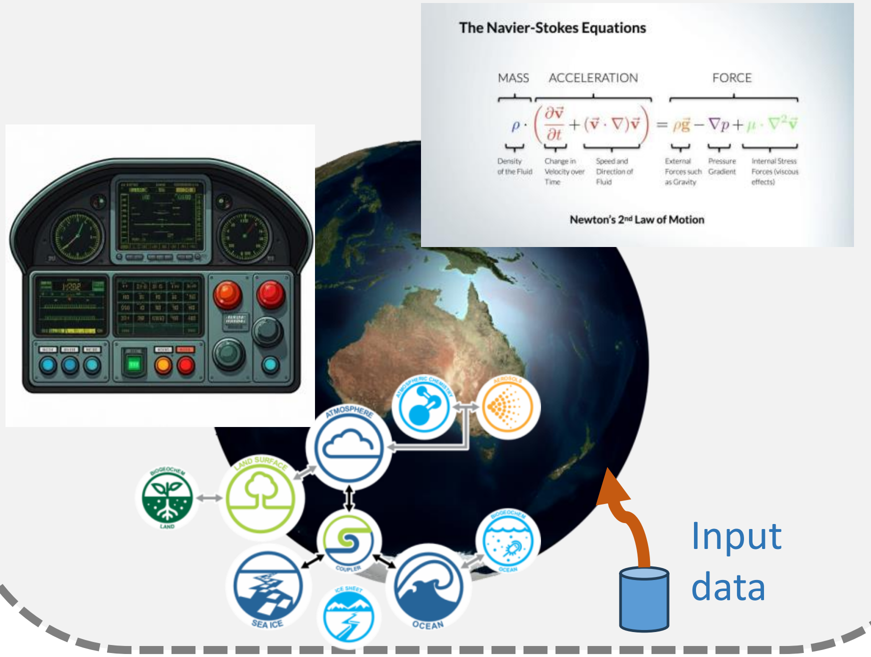
Software

Climate "models" or simulators

Physics-based



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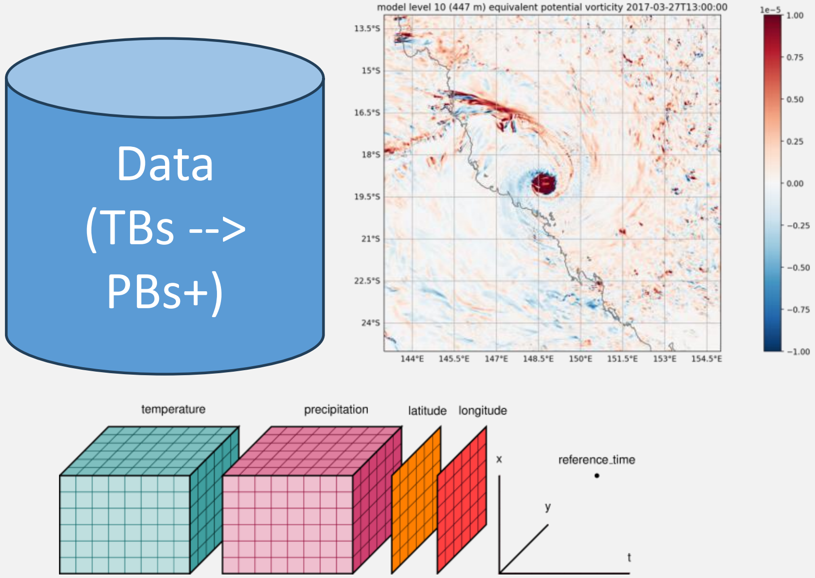

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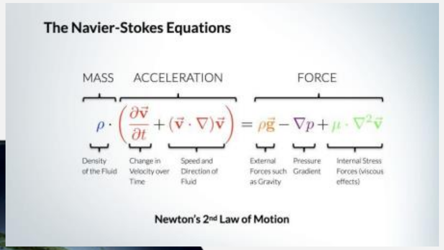
Software

Climate "models" or simulators

Physics-based



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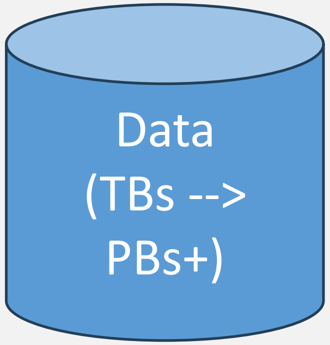

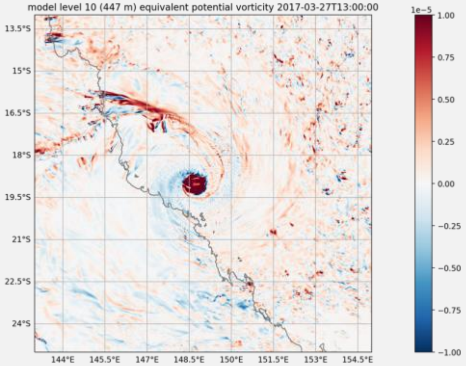

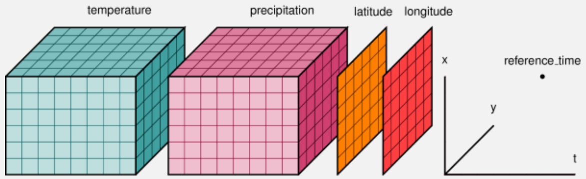

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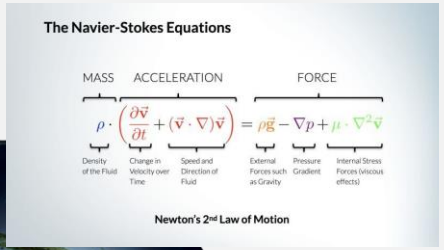
Training

Software

Climate “models” or simulators

Physics-based



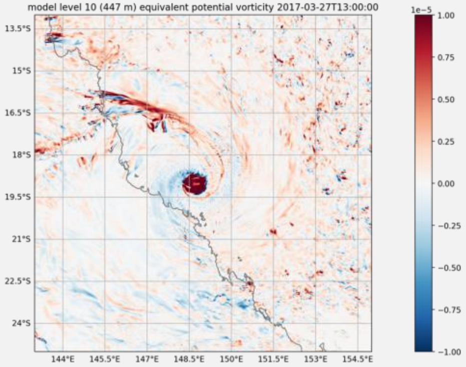
$$\rho \cdot \left(\frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \nabla)\vec{v}\right) = \rho\vec{g} - \nabla p + \mu \cdot \nabla^2 \vec{v}$$

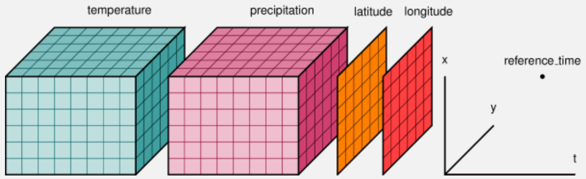
Input data

Data

Data evaluation & analysis
(model outputs, observations, etc.)

Data
(TBs -->
PBs+)





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Software

Climate "models" or simulators

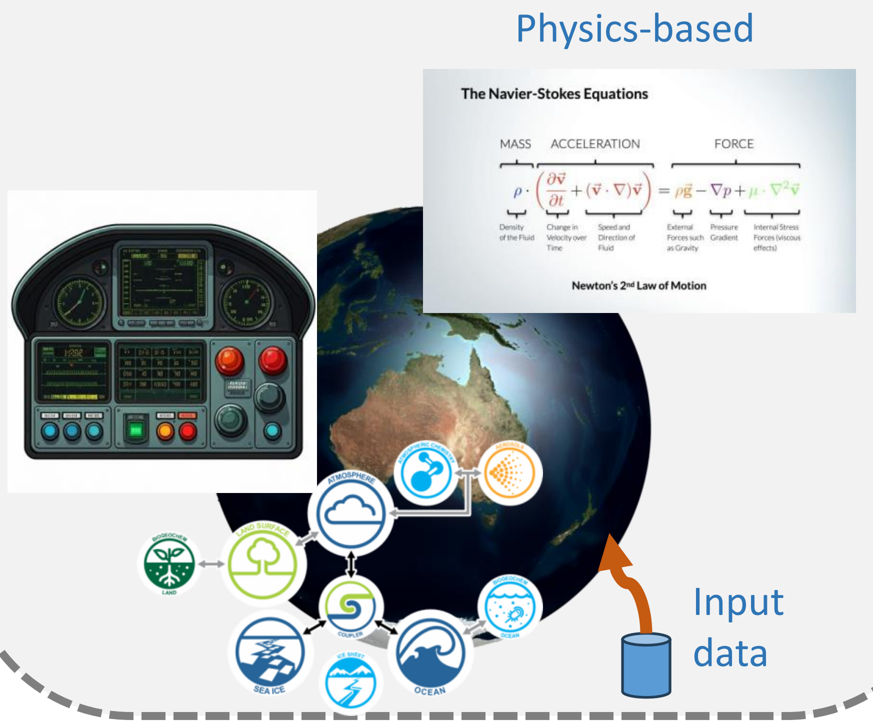

Image credits: Owen Kaluza; Jousef Murad; Xarray; Corey Robinson & Christian Jakob (Monash)

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Modernising climate modelling software

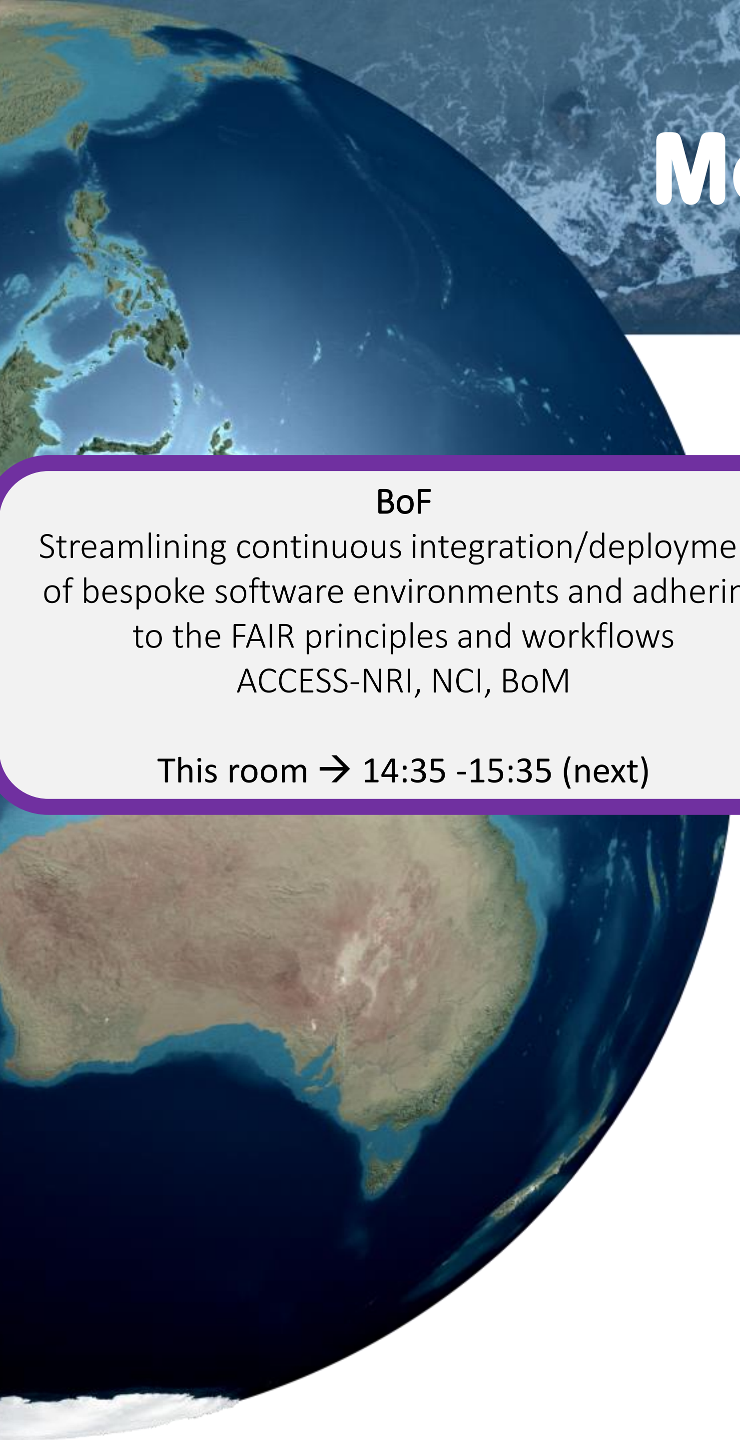
"Scientists can **trust** that any variation in a climate model is due to factors under their control, rather than changes in software dependencies, or the tools used to build the model."

Aidan Heerdegen
Model Release
Team Lead

Modernising climate modelling software

- **Spack,** a build-from-source package manager allowing us to build reproducible and reliable climate models across many platforms
- **Software engineering best practices**, such as continuous integration testing and continuous deployment
- **Pipeline is configured and run from GitHub**, adhering to the FAIR data and software principles

Modernising climate modelling software



BoF
Streamlining continuous integration/deployment of bespoke software environments and adhering to the FAIR principles and workflows
ACCESS-NRI, NCI, BoM

This room → 14:35 -15:35 (next)

- **Spack,** a build-from-source package manager allowing us to build reproducible and reliable climate models across many platforms
- **Software engineering best practices**, such as continuous integration testing and continuous deployment
- **Pipeline is configured and run from GitHub**, adhering to the FAIR data and software principles

Software engineering best practices

- Version control
- Tagged releases
- No code changes without review
- Automated testing:
  - Continuous Integration (CI) - when software is changed
  - Scheduled - to detect changes or errors
- Automated deployment:
  - Isolated deployment from user environment
  - Prevents accidental changes

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Software engineering best practices

- Quality assurance testing:
  - Ensures high quality configurations
  - Removes burden from development teams to do tedious checks that are error prone because tedious and repetitive
- Schemas:
  - Ensures changes do not break existing systems, and updates can be planned and designed for between disparate systems
- Shared code frameworks:
  - Ensures best-practice and improvements are automatically propagated to all systems that share framework

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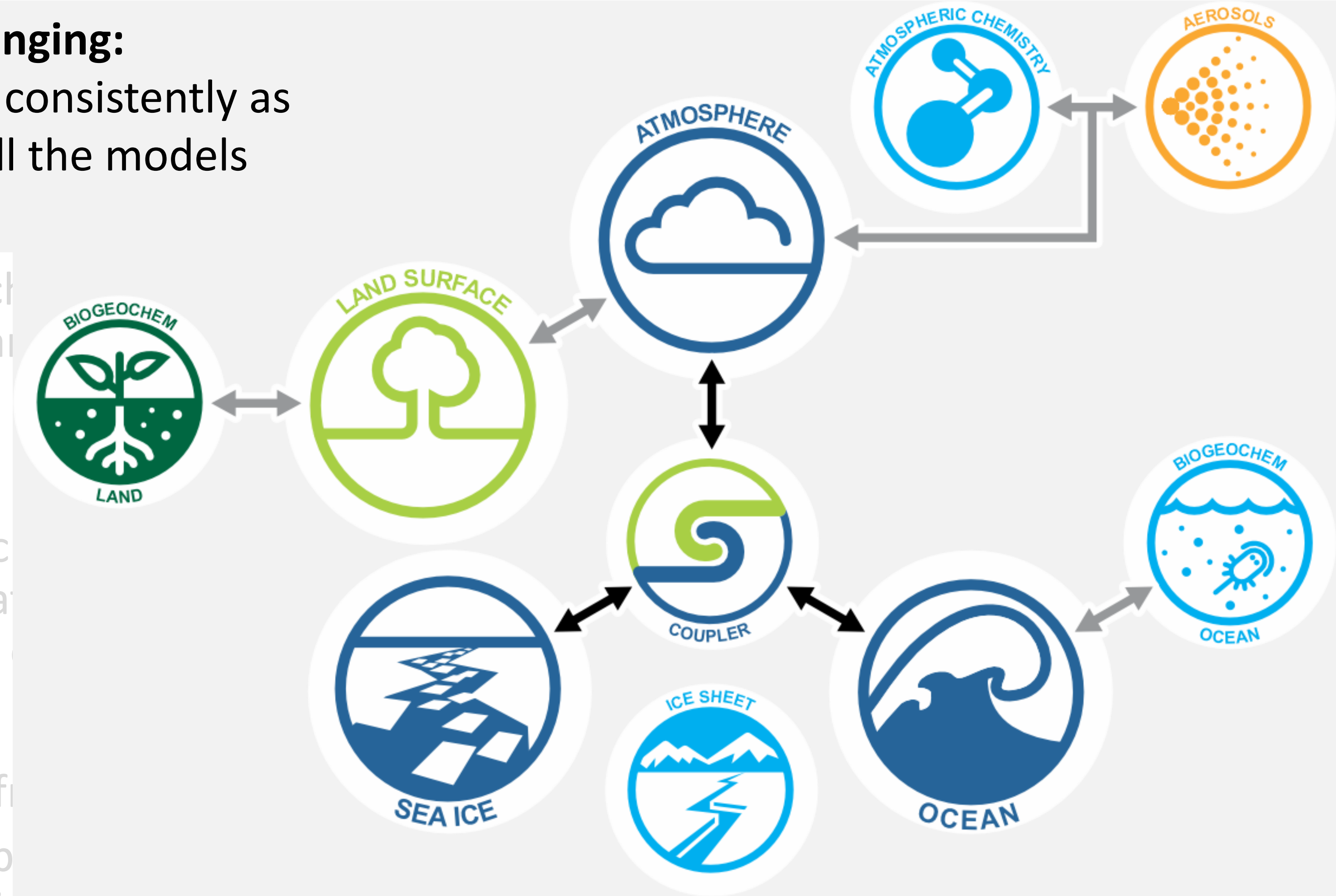
Software engineering best practices

Complex and challenging:

- Need to apply as consistently as possible across all the models



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tedious ar

- Schemas:
  - Ensures c
    and upda
    between

- Shared code f
  - Ensures b
    automatically propagated to all systems that share framework

ACCESS National Research Infrastructure

ACCESS model releases

Year 1 (2022-23):

- Release major refresh of documentation to support legacy code
- While designing and establishing new release pipeline, processes, etc.

Year 2 (2023-24):

- November: Initial release of our first model configuration (Ocean/Sea-ice model, ACCESS-OM2)
- May: Full release (ACCESS-OM2) ***[14 months in total]***

Year 3 (2024-25):

- August: Full release for second model configuration (Earth system coupled model, ACCESS-ESM1.5) ***[8 months in total]***

- *Planned: 3 more model configurations*

Software

Data evaluation & analysis (model outputs, observations, etc.)

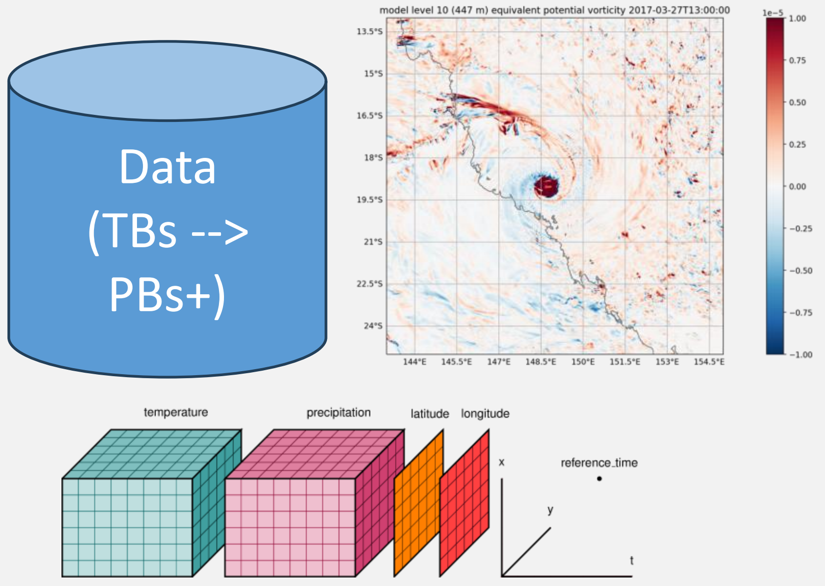

Image credits: Owen Kaluza; Jousef Murad; Xarray; Corey Robinson & Christian Jakob (Monash)

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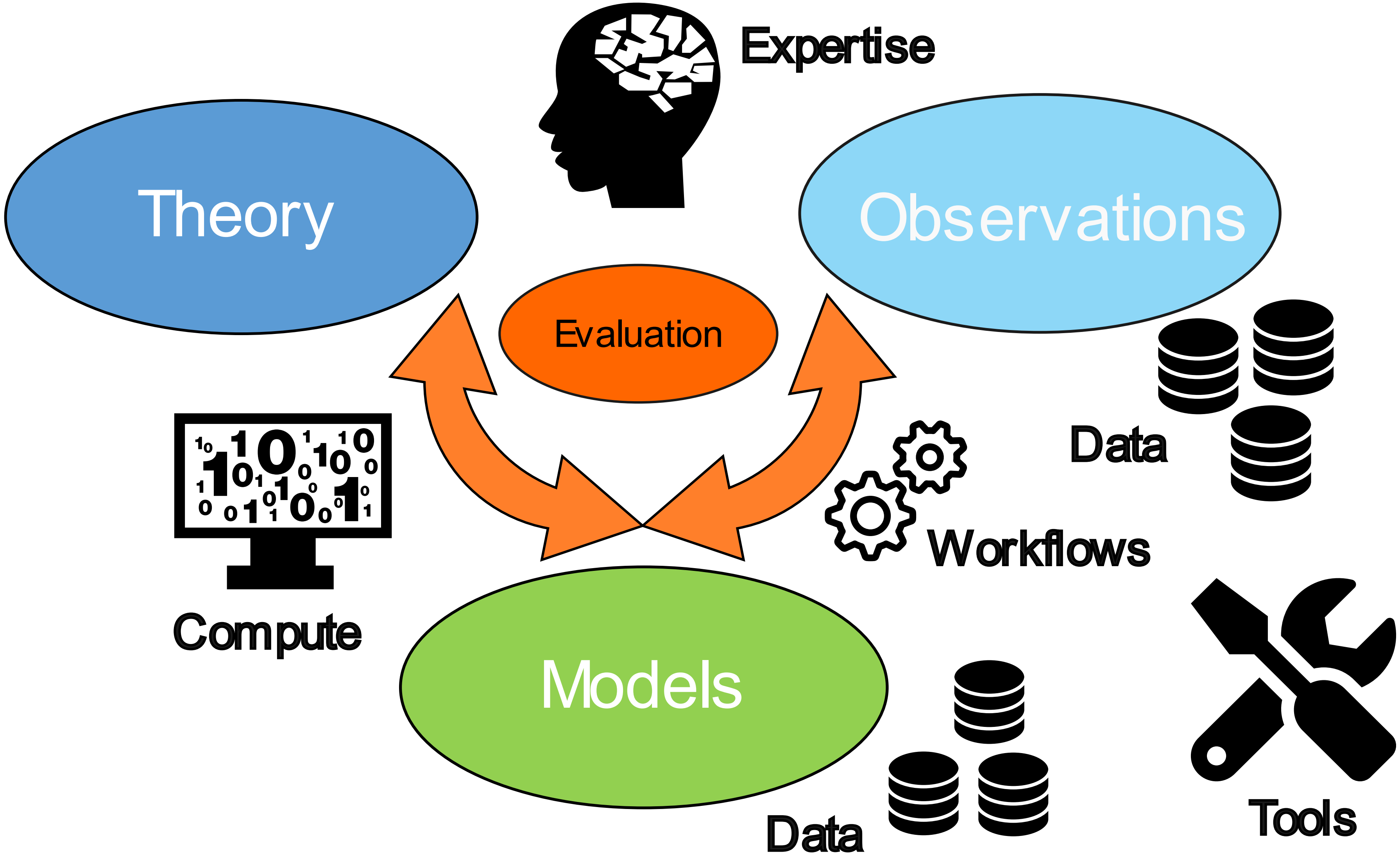
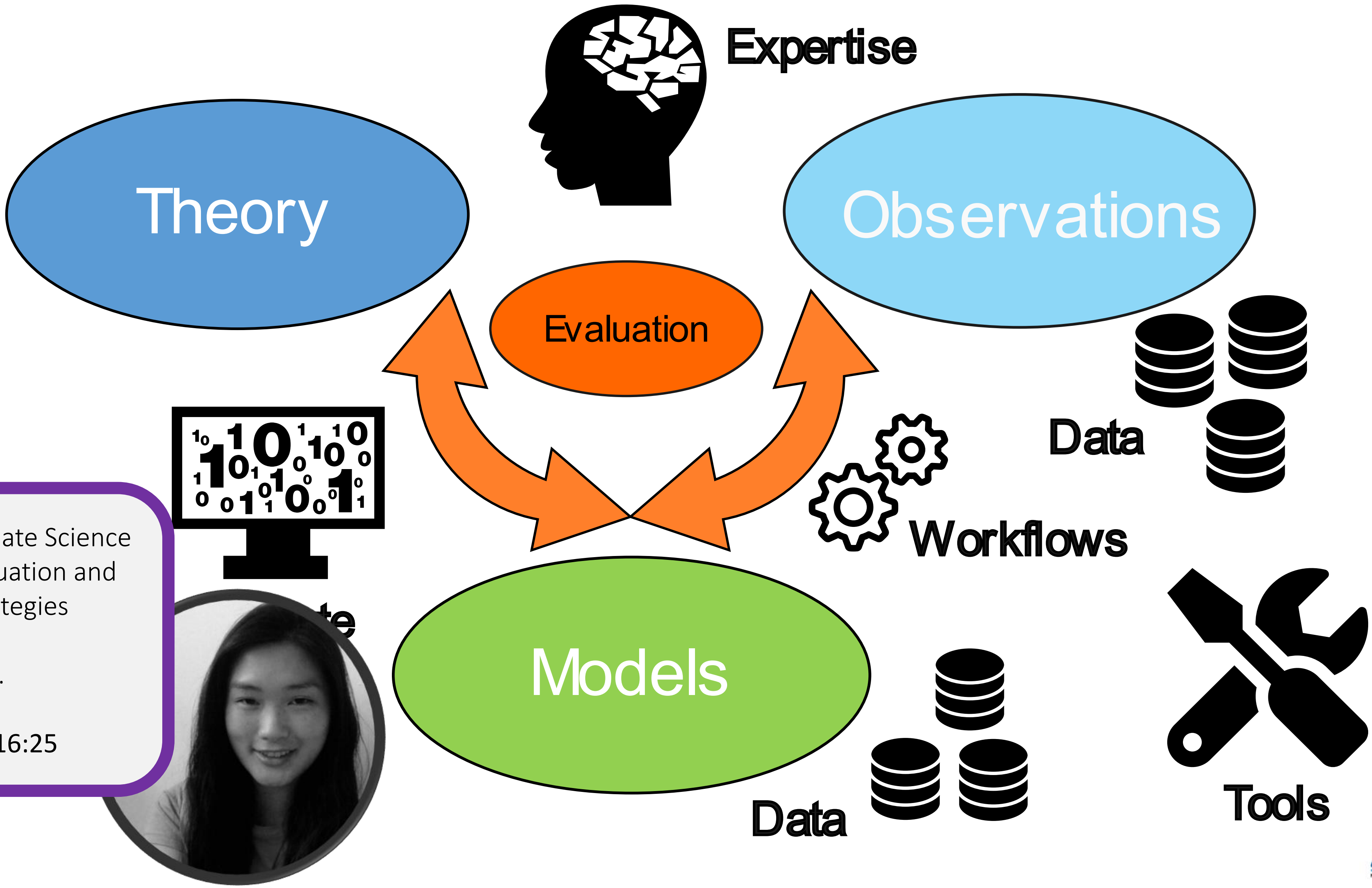
Model Evaluation



Model Evaluation

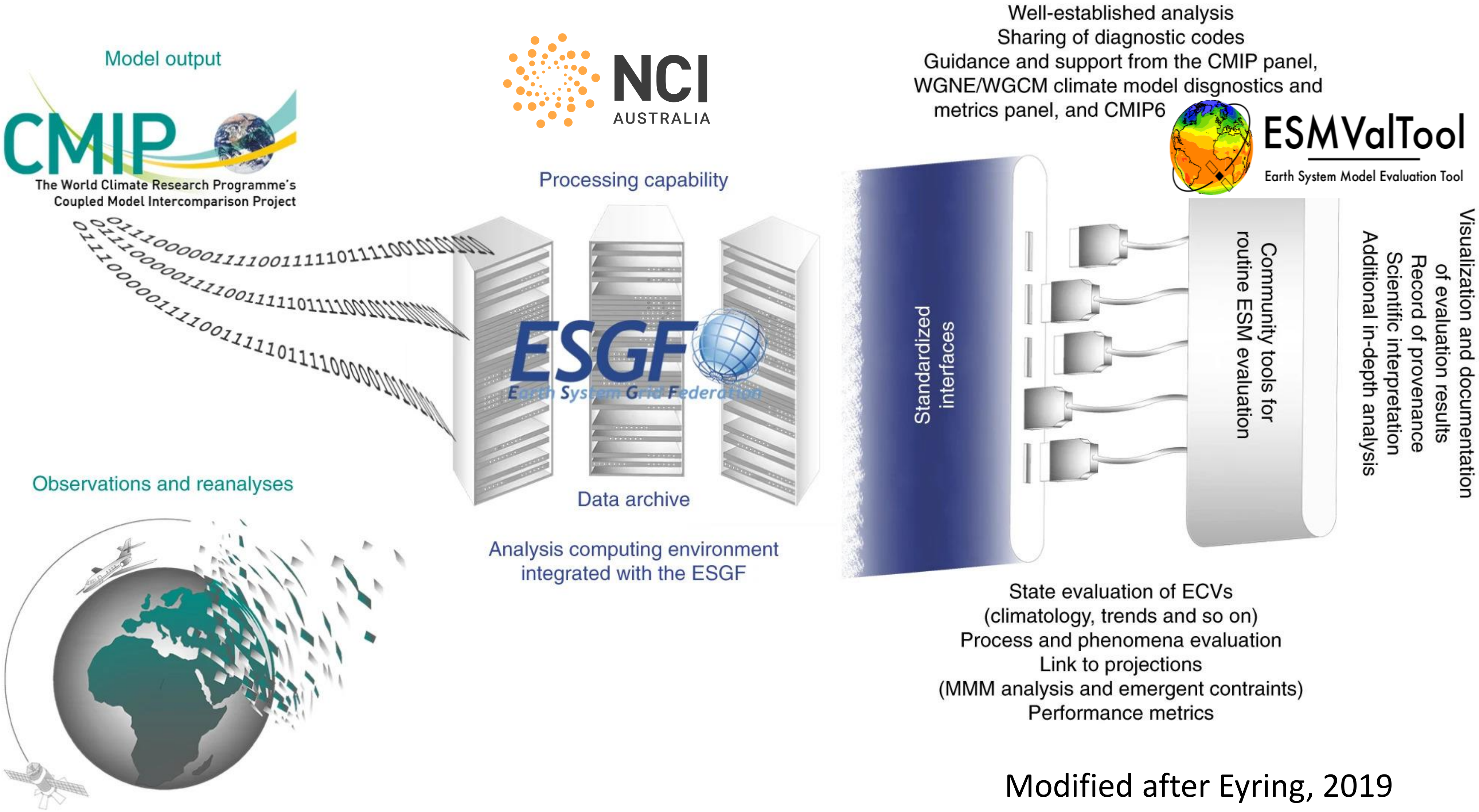


ACCESS-NRI: Supporting Climate Science through Robust Model Evaluation and Community-Driven Strategies

Felicity Chun et al.

This room → 16:05 – 16:25

Evaluation workflow



Modified after Eyring, 2019

ACCESS-NRI Intake catalog

Easily find and load datastores for a wide range of climate model data on NCI.

Also provide tools so you can easily build your own datastores

A simple process for getting these added to the ACCESS-NRI Intake catalog

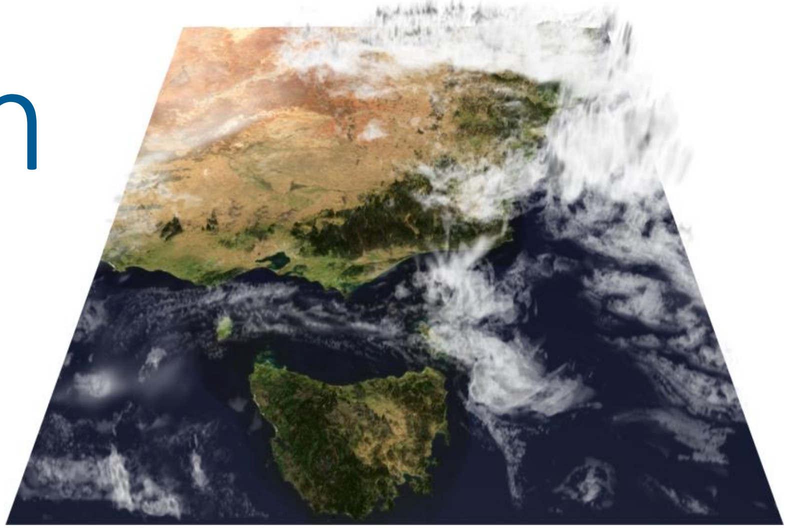
```
import intake

catalog = intake.cat.access_nri
catalog
```

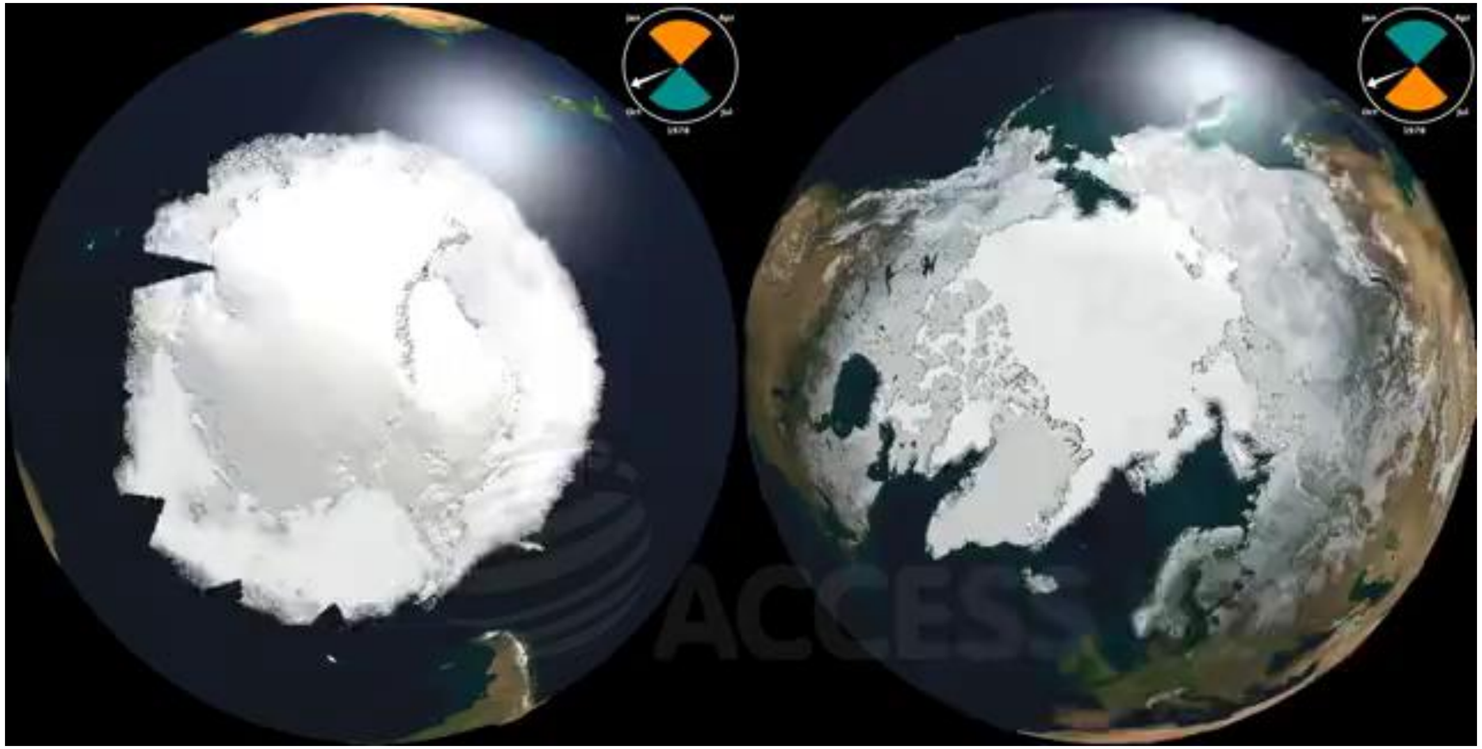
name	model	description	realm	frequency	variable
01deg_jra55v13_ryf9091	{ACCESS-OM2}	{0.1 degree ACCESS-OM2 global model configuration with JRA55-do v1.3 RYF9091 repeat year forcing (May 1990 to Apr 1991)}	{ocean, sealce}	{3hr, 1day, 3mon, fx, 1mon}	{bih_fric_v, sig2_m, ULAT, total_ocean_sens_heat, HTE, frz_onset_m, lprec, area_u, vert_pv, tx_trans_submeso, total_ocean_runoff_heat, total_ocean_evap, sst_m, alvdf_ai_m, wt, total_ocean_calving_...
01deg_jra55v140_iaf	{ACCESS-OM2}	{Cycle 1/4 of 0.1 degree ACCESS-OM2 global model configuration with JRA55-do v1.4.0 OMIP2 interannual forcing}	{ocean, sealce}	{1day, 1mon, fx}	{bih_fric_v, ULAT, mld_max, total_ocean_sens_heat, HTE, vvel, lprec, area_u, vert_pv, bottom_temp, total_ocean_evap, total_ocean_runoff_heat, alvdf_ai_m, wt, total_ocean_calving_heat, vatm_m, tota...
01deg_jra55v140_iaf_cycle2	{ACCESS-OM2}	{Cycle 2/4 of 0.1 degree ACCESS-OM2 global model configuration with JRA55-do v1.4.0 OMIP2 interannual forcing}	{ocean, sealce}	{1day, 1mon, fx}	{bih_fric_v, ULAT, mld_max, total_ocean_sens_heat, HTE, vvel, lprec, area_u, vert_pv, meltb, dvirdgdt_m, bottom_temp, total_ocean_evap, total_ocean_runoff_heat, alvdf_ai_m, wt, vatm_m, total_ocean...

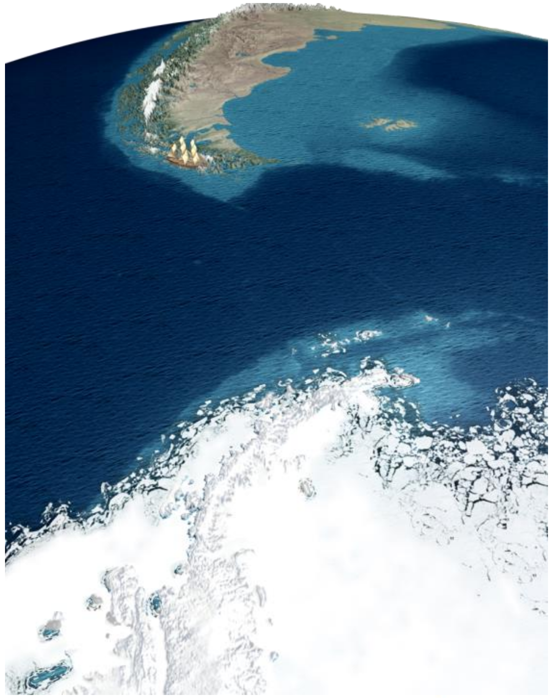
Advanced Visualisation

Release visualisations highlighting ACCESS-NRI data and tools

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



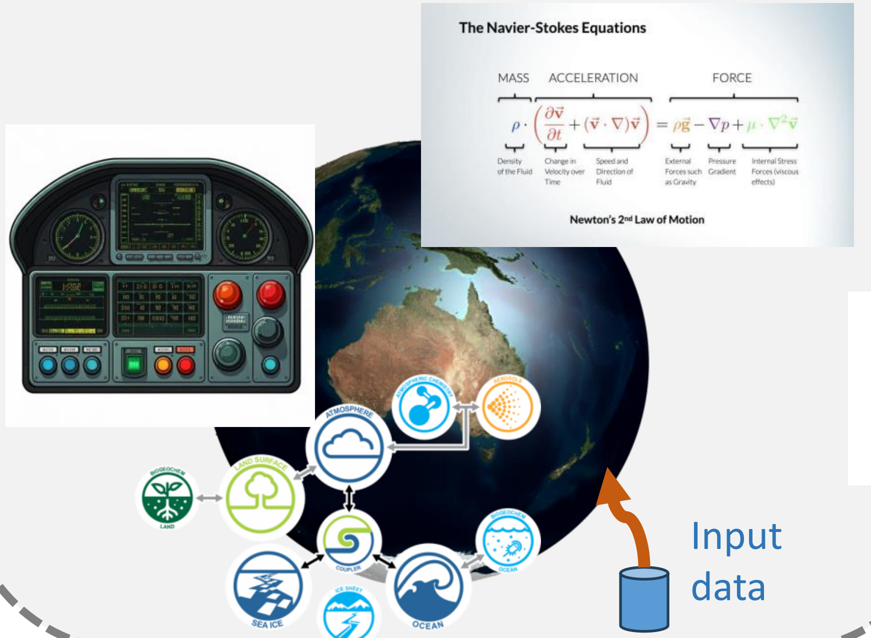




Owen
Kaluza

Climate “models” or simulators

Physics-based

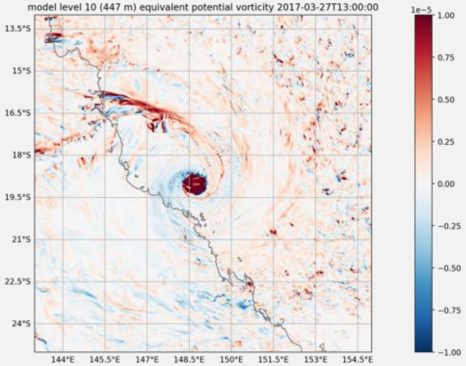


Input data

Data

Data evaluation & analysis (model outputs, observations, etc.)

Data (TBs --> PBs+)



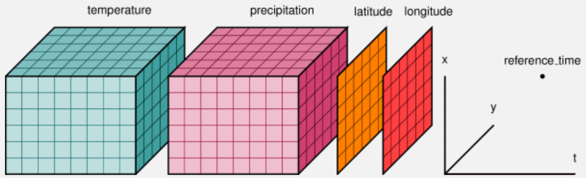
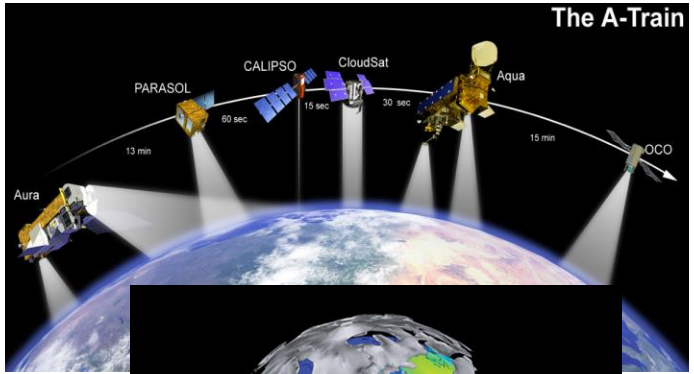


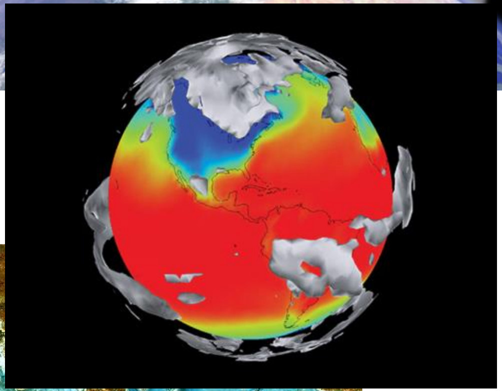
Image credits: Owen Kaluza; Jousef Murad; Xarray; Corey Robinson & Christian Jakob (Monash)

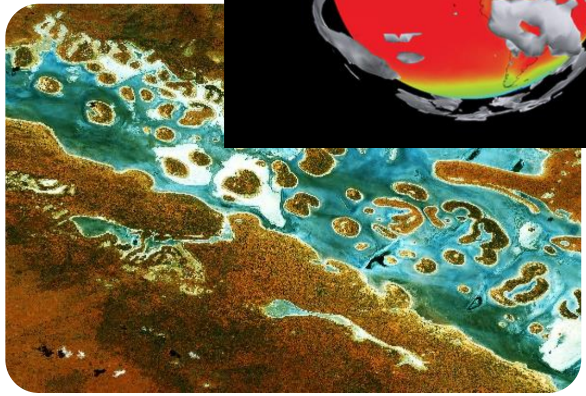
Supporting access to data

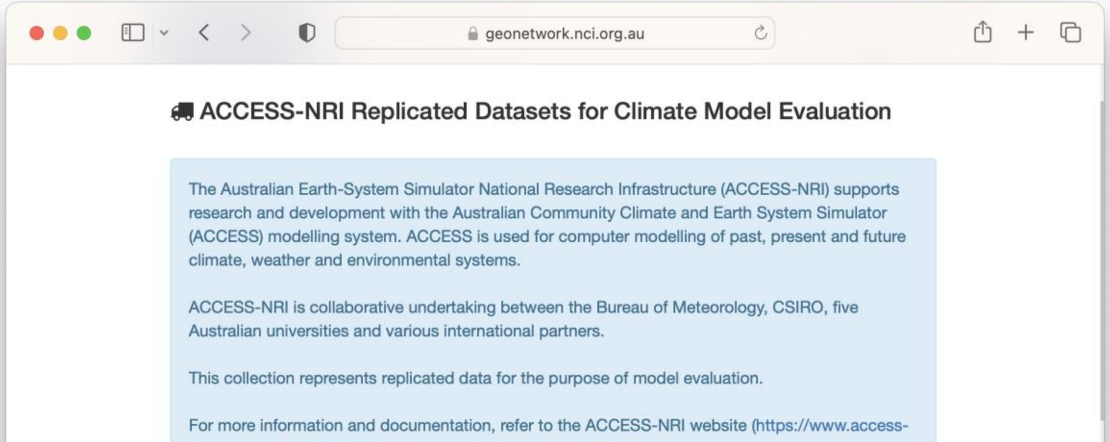
- Leverage NCI National Reference Collections
  - Model simulations
  - Satellites data
  - Observation/reanalysis data for Australia

- For new data produced or additional reference data needs, we offer merit-based data (and storage) support in collaboration with NCI.
  - Will scale up to >2 PBs by mid-2027









ACCESS-NRI Replicated Datasets for Climate Model Evaluation

The Australian Earth-System Simulator National Research Infrastructure (ACCESS-NRI) supports research and development with the Australian Community Climate and Earth System Simulator (ACCESS) modelling system. ACCESS is used for computer modelling of past, present and future climate, weather and environmental systems.

ACCESS-NRI is collaborative undertaking between the Bureau of Meteorology, CSIRO, five Australian universities and various international partners.

This collection represents replicated data for the purpose of model evaluation.

For more information and documentation, refer to the ACCESS-NRI website (https://www.access-

NCI AUSTRALIA

Supporting the sharing of data

Discovery
(Re)use ?
Citation

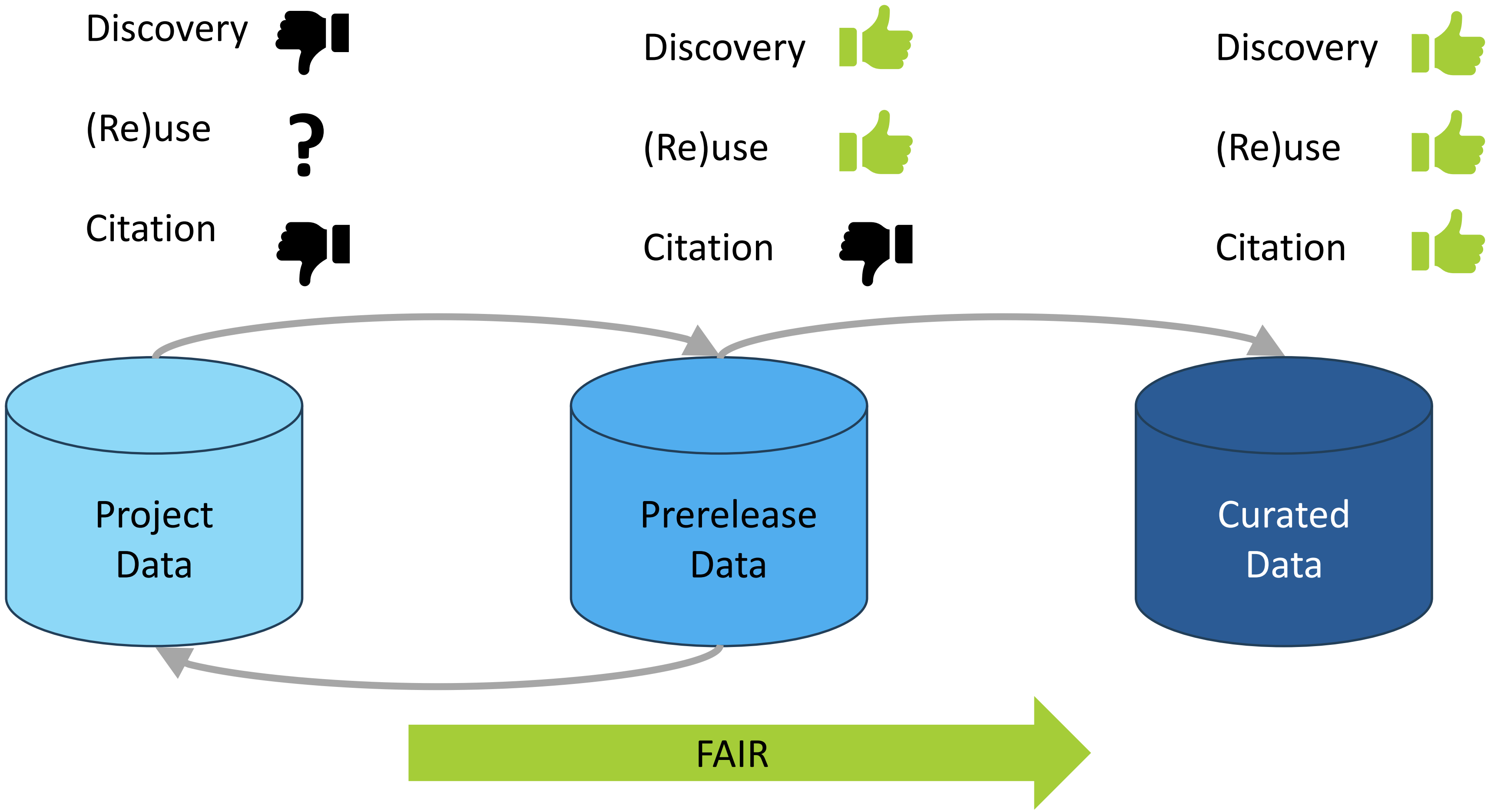
Project Data

FAIR

Discovery
(Re)use
Citation

Curated Data

Supporting the sharing of data



Data standards across ACCESS outputs

- Climate modelling community has exemplars internationally (i.e., large intercomparison project like CMIP) but this doesn't suit all use-cases.
- Data standards used across the ACCESS models vary.
- For ACCESS-NRI data discovery and evaluation tools, the lack of consistency is increasingly adding overheads on the software side to ensure ACCESS data is compatible.
- Window of opportunity with the development of the next generation ACCESS models, to implement some improvements.

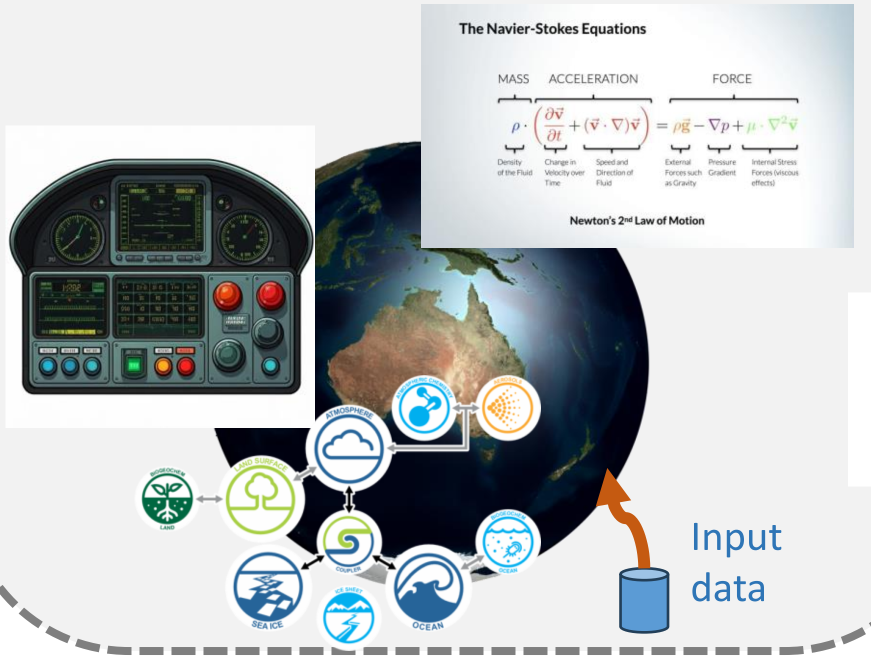
Our goal → clear ACCESS-NRI specification for each supported model we support and release, with the standardisation occurring through the software.

Training

Software

Climate “models” or simulators

Physics-based



Input data

Data

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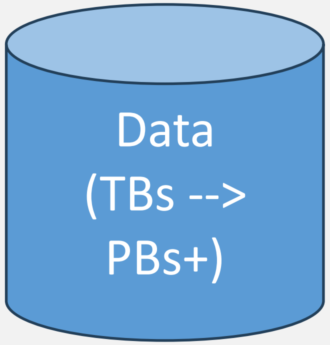

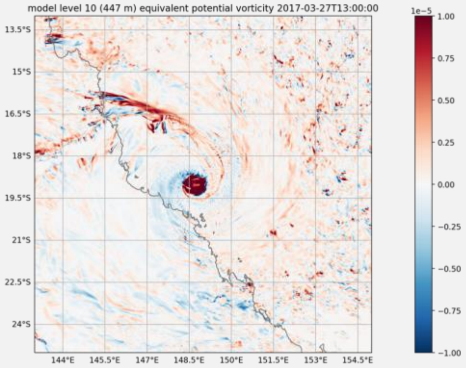

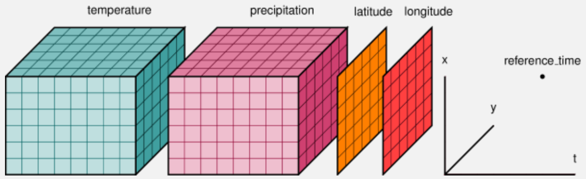

Image credits: Owen Kaluza; Jousef Murad; Xarray; Corey Robinson & Christian Jakob (Monash)

ACCESS National Research Infrastructure

Training and support

- In person, online events (training days, hackathons, webinars)
- Curated online material (documentation, user guides, notebooks)
- Video tutorials
- User support → Knowledge sharing approach with user forum (i.e., stack overflow)
- PhD Internship program (first 2 interns recently started)

POSTER

Streamlining continuous integration/deployment of bespoke software environments and adhering to the FAIR principles and workflows

ACCESS
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The impact we enable

Building and future-proofing Australia's sovereign climate research capability essential to support national resilience and wellbeing

Delivering climate simulations specific to Australian and Southern Hemisphere conditions

Understanding how changes to Antarctic Ice Southern Ocean currents dynamics affect global systems

Understanding El Niño and La Niña and how these climate systems affect Australia and regional neighbours

Forecasting high-impact weather – wind, bushfire, floods, heatwaves – to inform emergency management

Safeguarding Australia's future – long-term forecasting to inform critical decision making across the government, agriculture, insurance and security sectors

Strengthening global efforts to simulate climate of the past millennium and the future

Reconstructing past climate – understanding how climate changed in the past to inform predictions of future change

Australia's climate simulator

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NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

The impact we enable

Building and future-proofing Australia's sovereign climate research capability essential to support national resilience and wellbeing

Safe…
maki…

How do we track and measure our impact?

Strengthening global efforts to simulate climate of the past millennium and the future

Reconstructing past climate – understanding how climate changed in the past to inform predictions of future change

Australia's climate simulator

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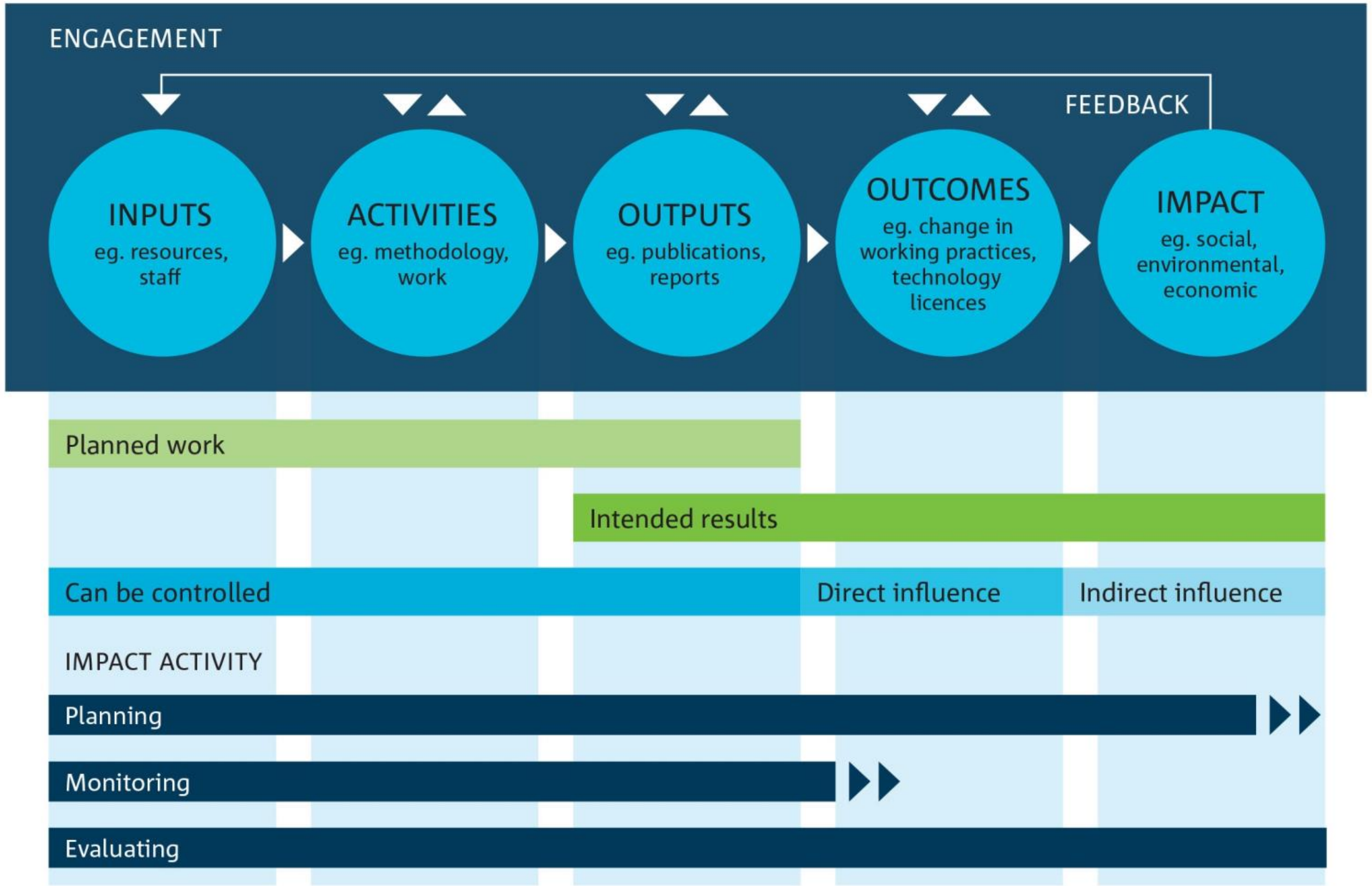
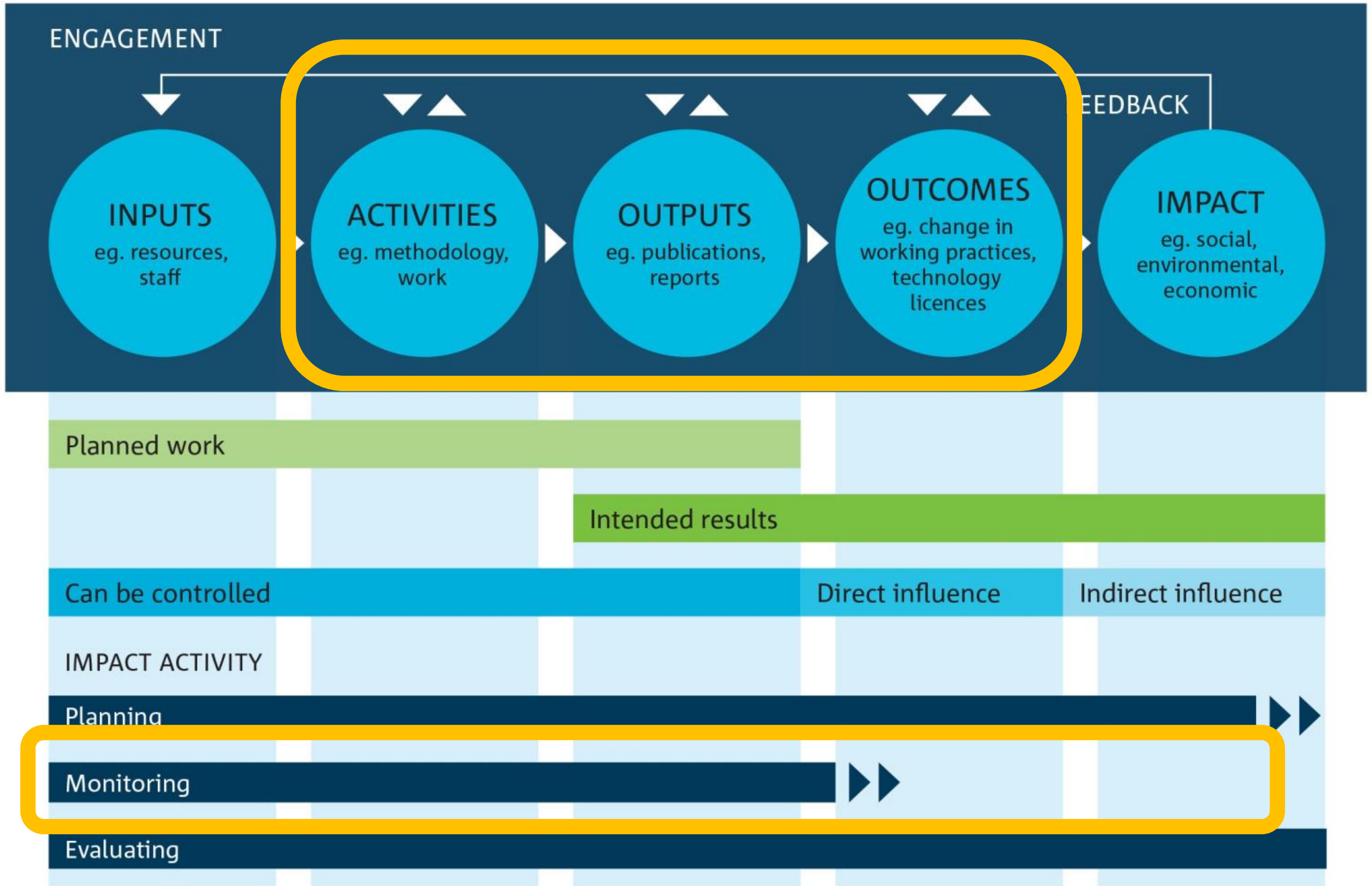
Monitoring and measuring



Impact Framework derived from the work of the *W.K. Kellogg Foundation*

https://www.csiro.au/en/about/corporate-governance/ensuring-our-impact/a-csiro-wide-approach-to-impact

Monitoring and measuring

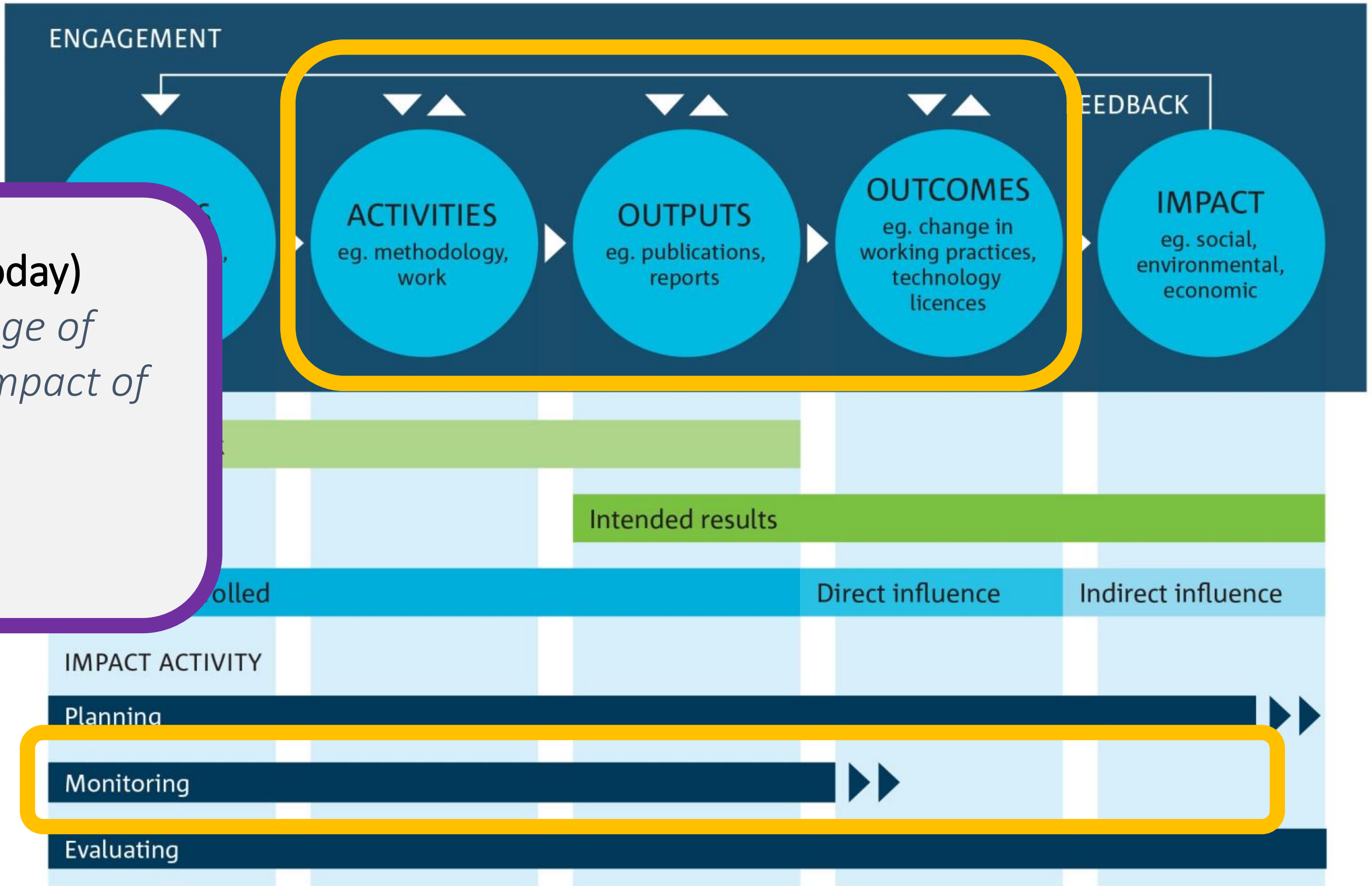


Impact Framework derived from the work of the *W.K. Kellogg Foundation*

Current focus:
Establishing framework with focus on tracking update of software and data

https://www.csiro.au/en/about/corporate-governance/ensuring-our-impact/a-csiro-wide-approach-to-impact

Monitoring and measuring



Impact Framework derived from the work of the *W.K. Kellogg Foundation*

https://www.csiro.au/en/about/corporate-governance/ensuring-our-impact/a-csiro-wide-approach-to-impact

Upcoming BoF (This room, later today)

Revealing the invisible: the challenge of measuring and communicating the impact of research infrastructures

Several NCRIS Facilities

CSIRO

Stop by our booth!

ACCESS
National Research Infrastructure

NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

Australian National University

Australian Government
Bureau of Meteorology

CSIRO

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