Future development for ocean and climate modelling in Australia

Andrew Kiss, Andy Hogg, Dougie Squire, Ezhilsabareesh Kannadasan, Anton Steketee, Micael Oliveira, Martin Dix, Kieran Ricardo, Adele Morrison (ANU), Pearse Buchanan, Siobhan O'Farrell (CSIRO)

CESM Ocean Model Working Group meeting, 8 Feb 2024

ACCESS
Australian Earth System Simulator
National Research Infrastructure

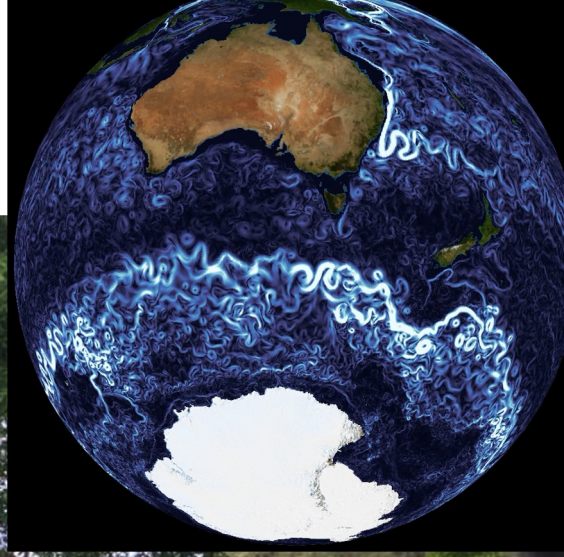
COSIMA

The Consortium for Ocean-Sea Ice Modelling in Australia

cosima.org.au

Australian ocean & sea ice modelling community

2022 COSIMA workshop: >90 attendees



- **>180 researchers** from ANU, UNSW, U Sydney, U Adelaide, U Melbourne, Monash, U Tasmania, UWA, CSIRO, BoM, AAD, etc.
- **ACCESS-OM2** (MOM5-CICE5) underpinned **>70 publications** since 2019, with **>1100 total citations**
  - 1° config used by CSIRO in the **ACCESS-CM2** climate model for CMIP6, and 0.25° for **ACCESS-CM2-025**
  - 0.1° configuration used by BoM & CSIRO for OceanMAPS v4.0 in the latest **Bluelink** global ocean and sea ice forecasting system

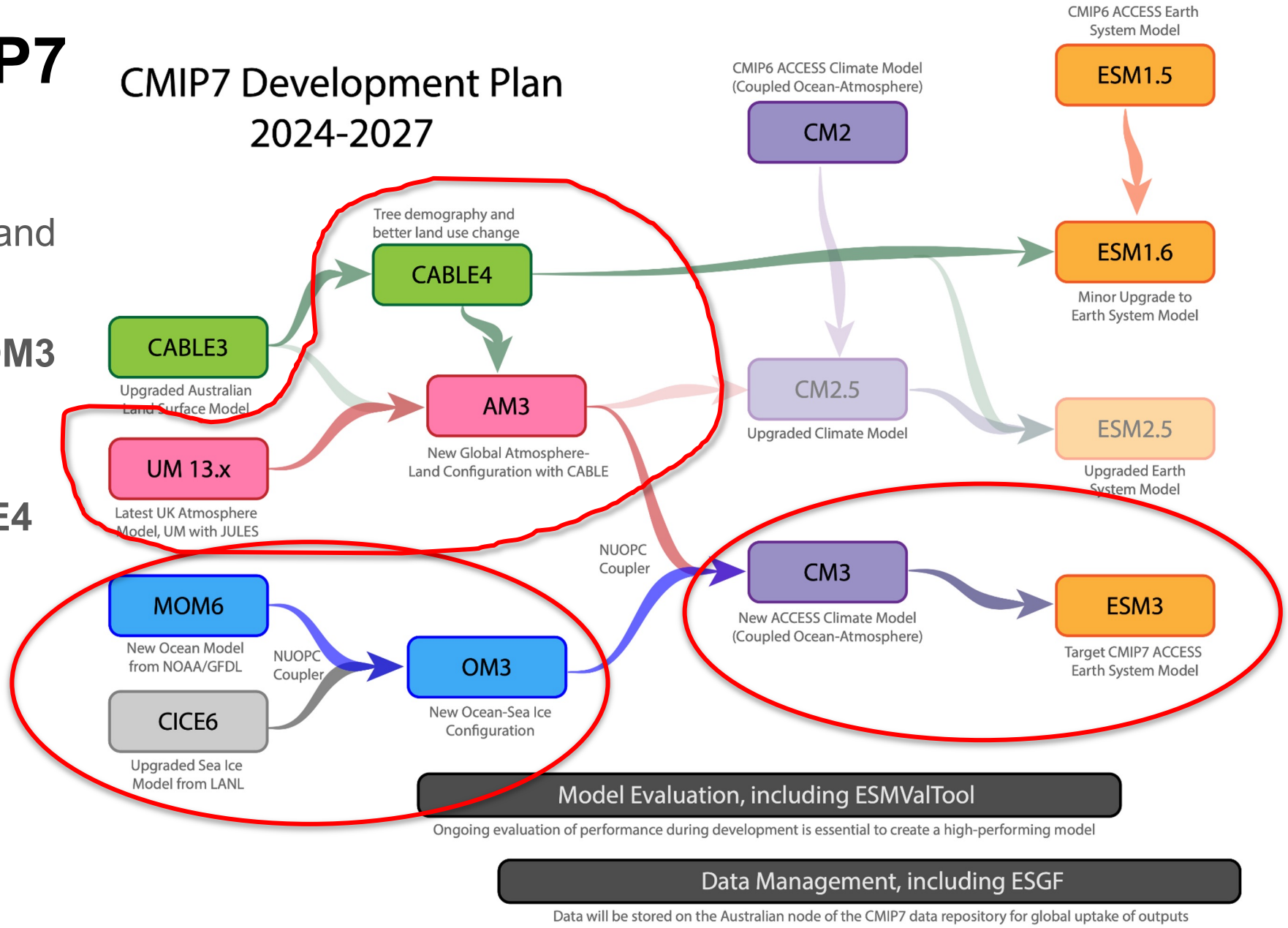
Towards CMIP7

ACCESS-CM3 and **ACCESS-ESM3** climate and Earth system models

To consist of **ACCESS-OM3** (**MOM6-CICE6**)…

… coupled with **UM13.x atmosphere** with **CABLE4** land surface.

Intended for CMIP7



ACCESS
Australian Earth System Simulator
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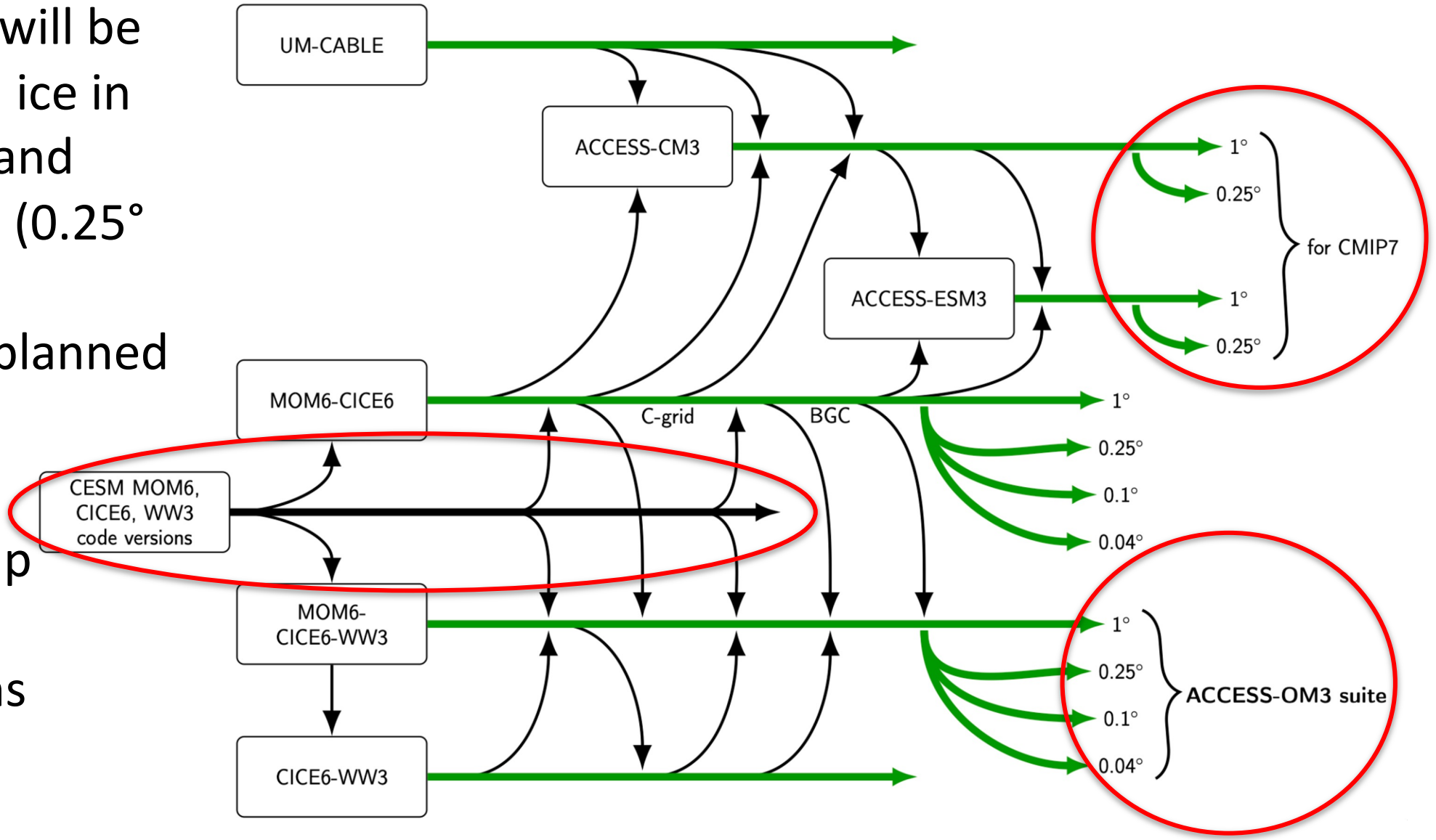
Coordinated development of global models

ACCESS-OM3 will be the ocean-sea ice in ACCESS-CM3 and ACCESS-ESM3 (0.25° ocean, N96 atmosphere) planned for CMIP 7

Will remain up to date with latest versions



Build system

https://github.com/COSIMA/access-om3

- Using Git, CMake and Spack to control all dependencies and compilation flags
- Designed for easy component upgrades
- Currently matching components from recent CESM and will regularly update to leading edge
- Will adopt CICE 6.5 to use C-grid

Increased collaboration

Moving to latest MOM6 & CICE6 facilitates closer collaboration

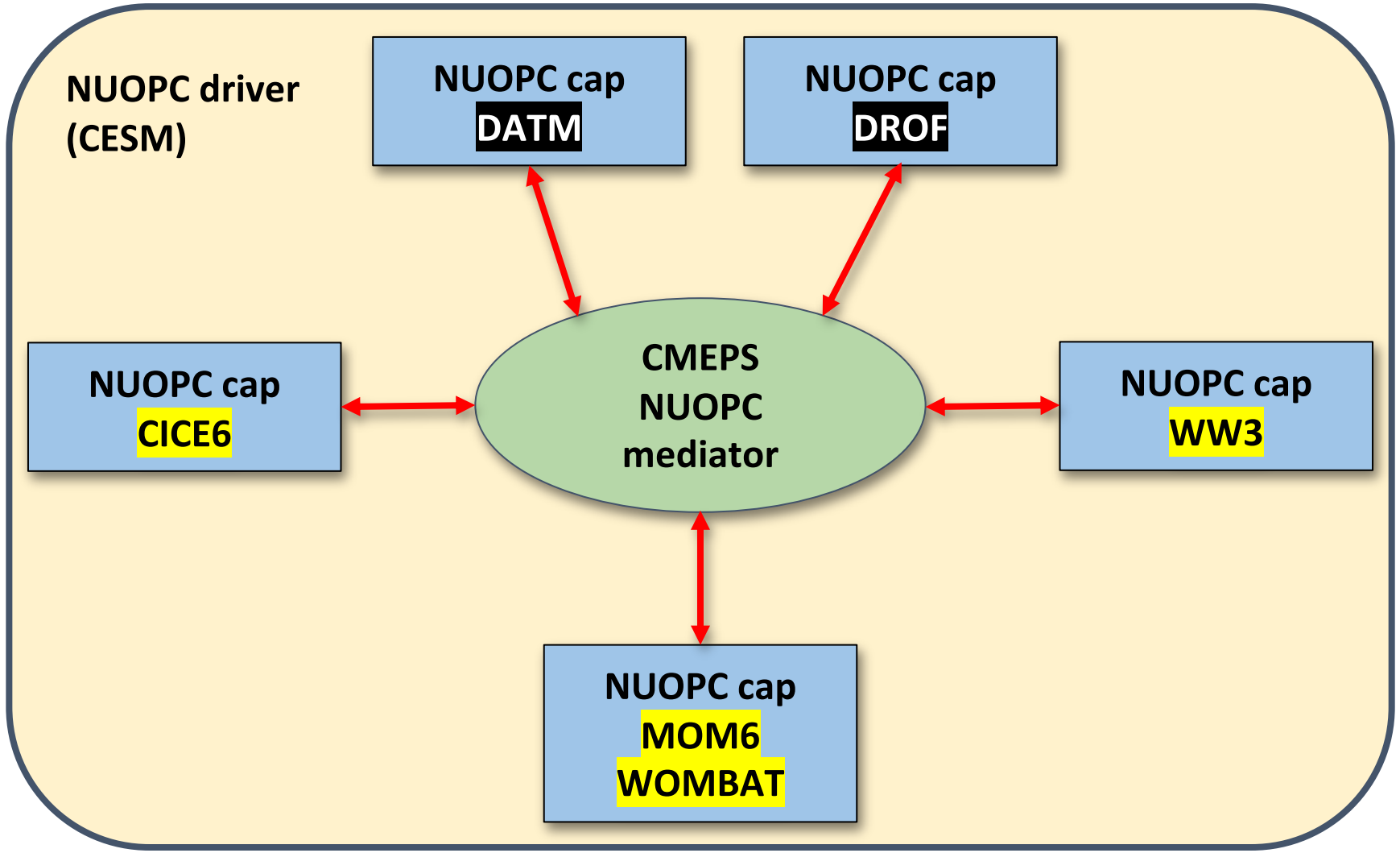
- ACCESS-NRI is now a member of the CICE Consortium
- Aiming to establish an Australian MOM6 node

https://github.com/COSIMA/access-om3
https://github.com/COSIMA/MOM6-CICE6-WW3

ACCESS-OM3: MOM6-CICE6-WW3

- Upgrade to **CICE6**
- Upgrade to **MOM6**
- Add **WW3**
- Use data ocean and runoff (CDEPS **DATM** & **DROF**)
- Couple components via **CMEPS NUOPC mediator**
- Use **CESM NUOPC driver**

- **1° configs running**, being tested and tuned
- **2-way CICE6-WW3 coupling** enabled (Ezhilsabareesh Kannadasan, ACCESS-NRI)
- **WOMBAT BGC** being ported to MOM6 (Dougie Squire, ACCESS-NRI)
- **Working towards 0.25°, 0.1°, 0.04° resolution**

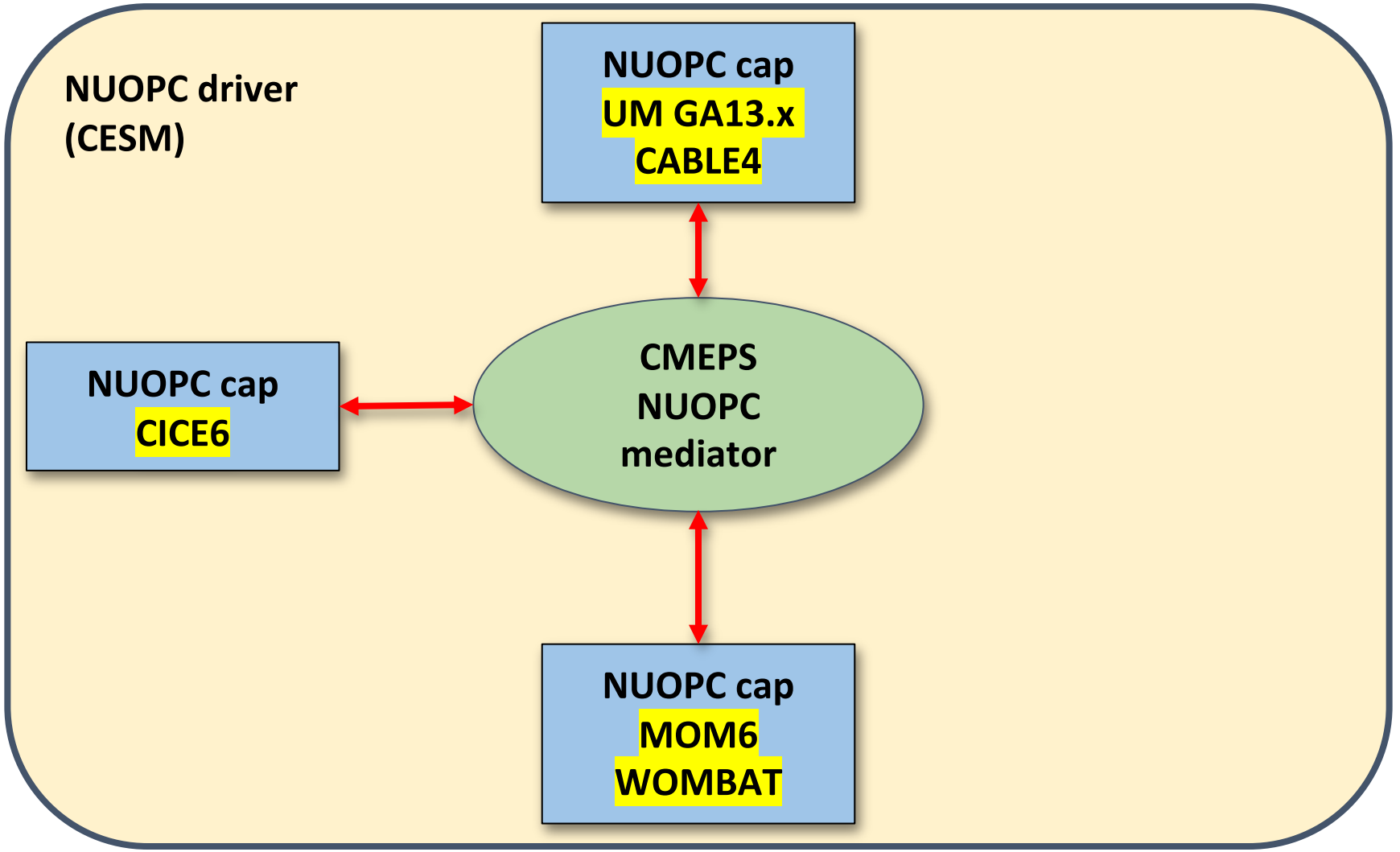


ACCESS-CM3 and ACCESS–ESM3 (target configuration)

- Replace DATM, DROF data atmosphere and runoff with Met Office's **UM GA13.x** with the **CABLE4** land surface model
- No WW3
- **Aiming for 0.25° ocean, N96 atmosphere**

Work in progress (Martin Dix, Kieran Ricardo, ACCESS-NRI)

- **NUOPC cap for UM** is running
- Now working on getting ice surface temperature from UM



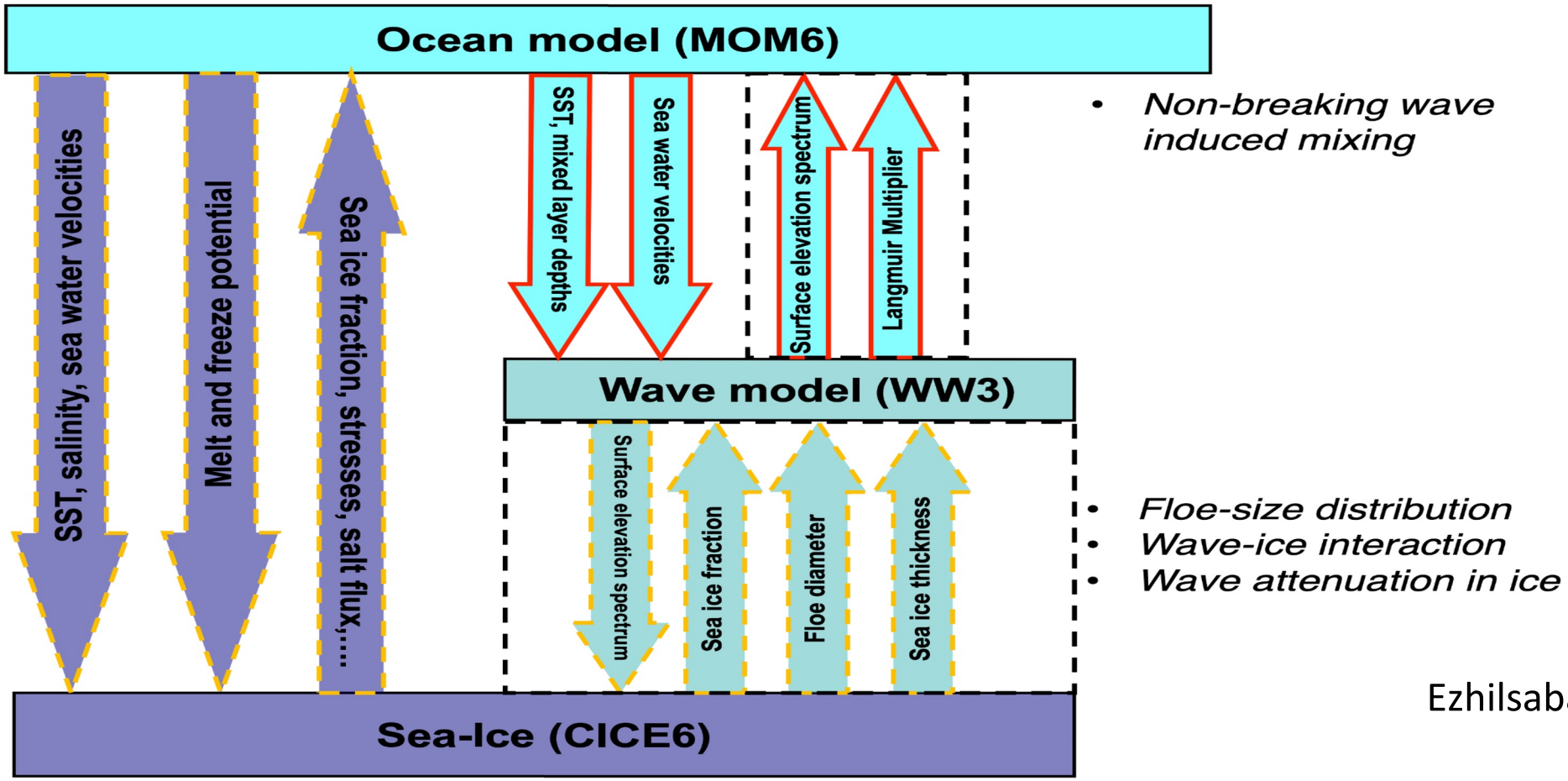
Preliminary results of 1° ACCESS-OM3 MOM6-CICE6-WW3 simulation

Developments:

- Two-way wave-ice interaction implemented
- CICE6 floe size distribution evolves in response to WW3 surface elevation spectrum
- WW3 floe-size dependent scattering using spatio-temporal floe size distribution from CICE6.

In progress:

- Investigating the extent of wave penetration into sea ice to enhance the realism of floe size distribution.
- Enabling the wave fracture scheme in CICE6 to achieve more realistic floe breaking.

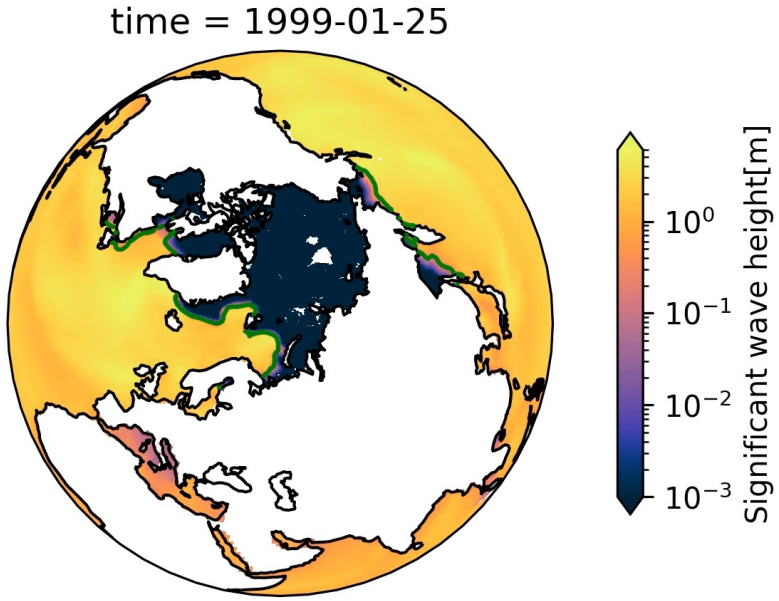


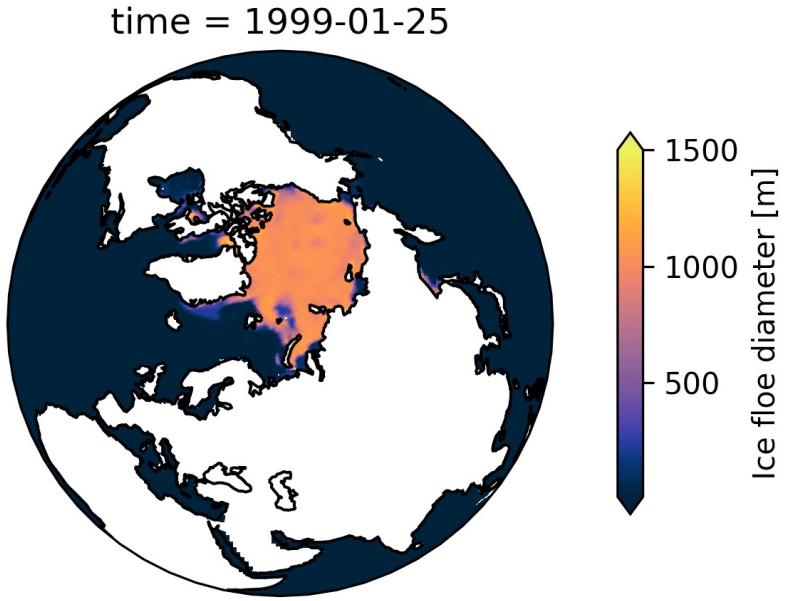
Ezhilsabareesh Kannadasan

Global 1° MOM6-CICE6-WW3 test experiment

Ezhilsabareesh Kannadasan

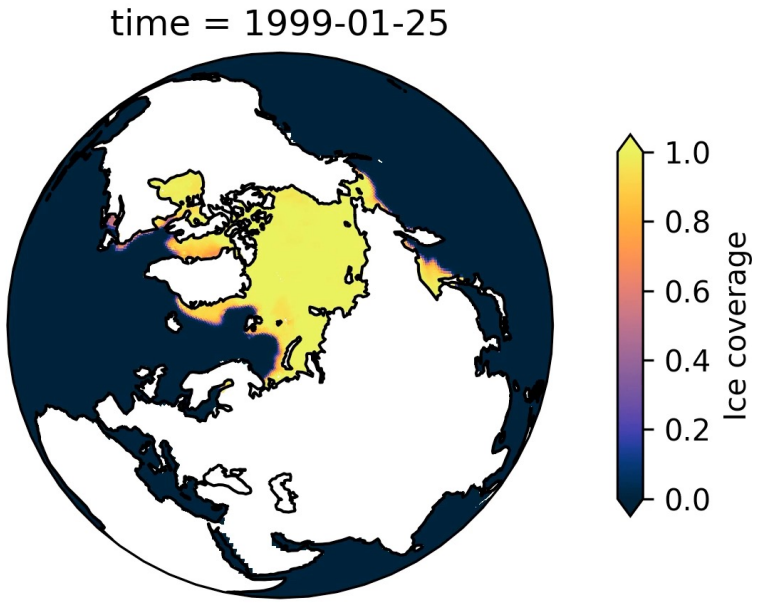
Surface waves damped by sea ice, depending on floe size

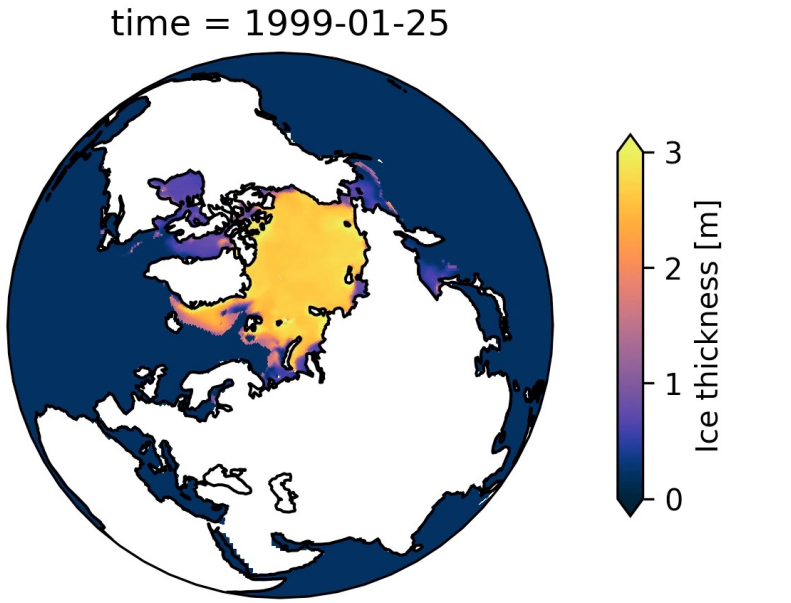




Waves generate floe size distribution

Sea ice concentration





Sea ice thickness

WOMBAT ocean BGC model

World Ocean Model for Biogeochemistry And Trophic dynamics
Oke et al. (2013)

- Ocean BGC used in ACCESS-ESM1 and ACCESS-ESM1.5
- Porting from MOM5 to MOM6 as a generic tracer package (Dougie Squire, ACCESS-NRI)
- Upgrading WOMBAT (Pearse Buchanan, CSIRO)

Photo: Chris Kidd, The Mercury

BGC via GFDL “generic tracer” API in MOM6 with NUOPC

❓ WOMBAT is in MOM5 – how best to port it to MOM6?

💡 Use NOAA-GFDL “generic_tracer” API

- Can be used by both MOM5 and MOM6
- Several tracer modules available from GFDL
  - BGC: BLING, COBALT, ERGOM, TOPAZ, miniBLING
  - Also: CFC, SF6, age…

WOMBAT is not a generic tracer in MOM5, so

1. First implement BLING generic tracer in MOM6 with NUOPC
2. Then convert WOMBAT to a generic tracer and implement in MOM6 the same way

BGC via GFDL “generic tracer” API in MOM6 with NUOPC

🛑 Problem: *Many GFDL generic_tracer modules require coupling with other ESM components via FMS coupler, not NUOPC*

- e.g. air-sea gas fluxes, runoff fluxes, etc.

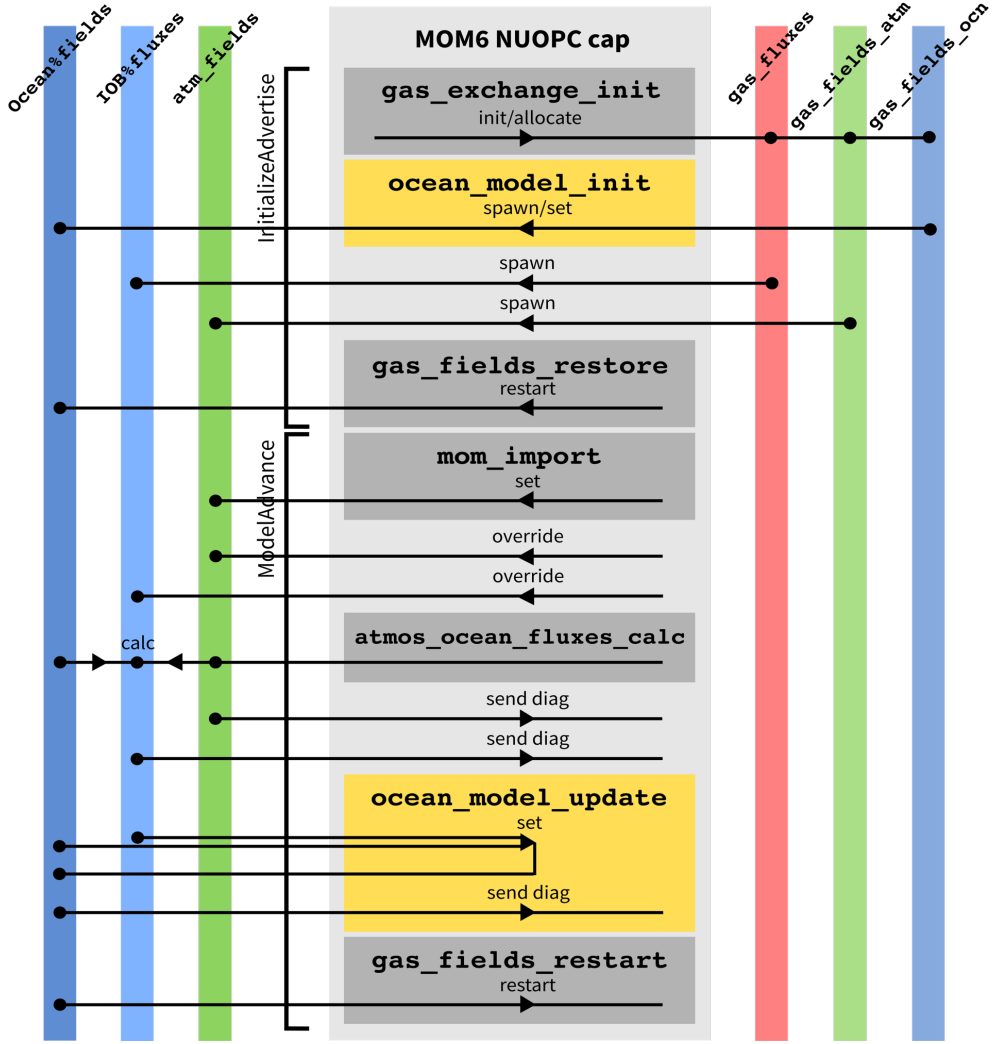
✅ Solution: **modify MOM6 NUOPC cap** to interface with FMS

- no changes to MOM6 itself or GFDL generic_tracer modules

Currently have BLING running as a generic tracer in MOM6 with NUOPC

- Other generic tracers should also be possible

Next step: *use this approach to port WOMBAT to MOM6 as a generic tracer*



Dougie Squire, ACCESS-NRI

WOMBAT upgrade (Pearse Buchanan, CSIRO)

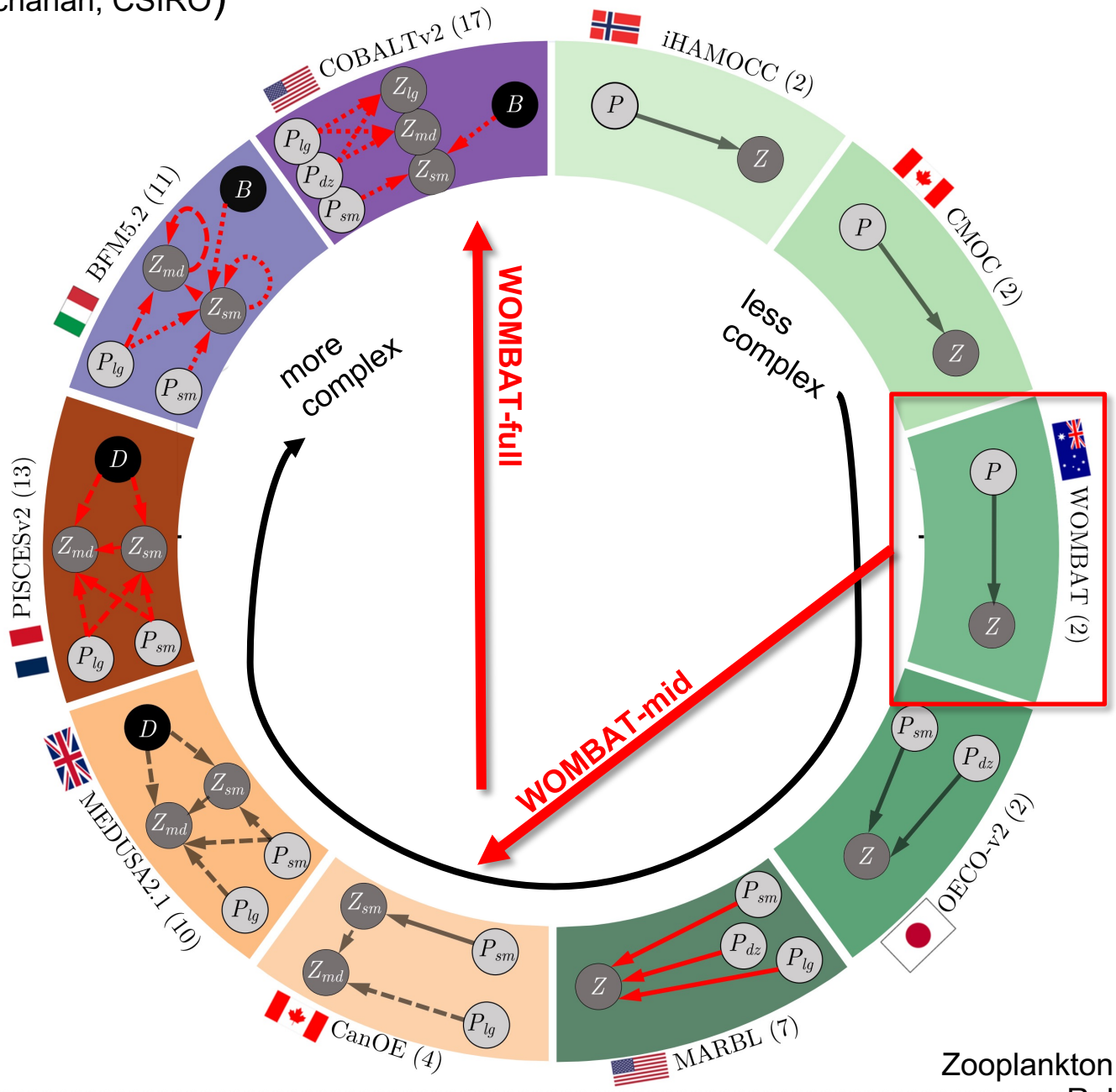
communications
earth & environment

ARTICLE

https://doi.org/10.1038/s43247-023-00871-w OPEN

Zooplankton grazing is the largest source of uncertainty for marine carbon cycling in CMIP6 models

Tyler Rohr[1,2✉], Anthony J. Richardson[3,4], Andrew Lenton[5], Matthew A. Chamberlain[4] & Elizabeth H. Shadwick[1,5]



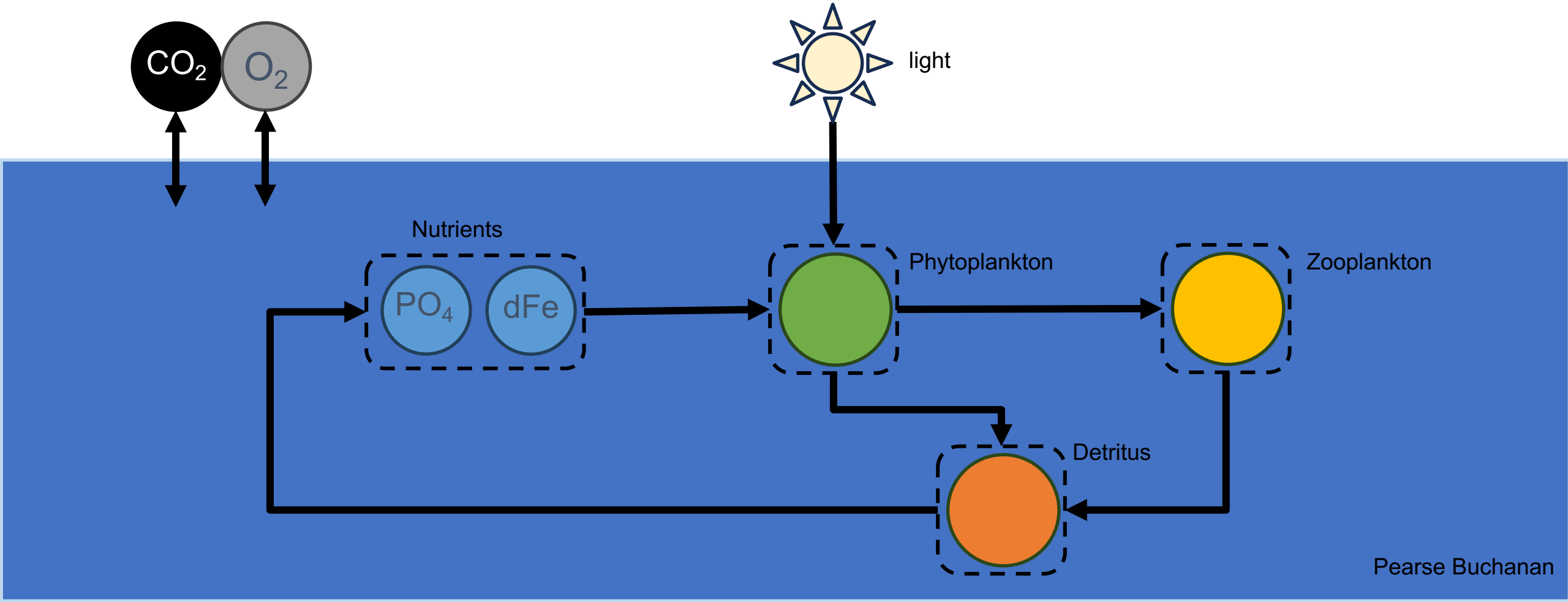
Current **WOMBAT-light** is simple on the world stage

Zooplankton grazing in CMIP6 models
Rohr et al. 2023; Nat Comms

WOMBAT-light (10 tracers)


Photo: Chris Kidd, The Mercury

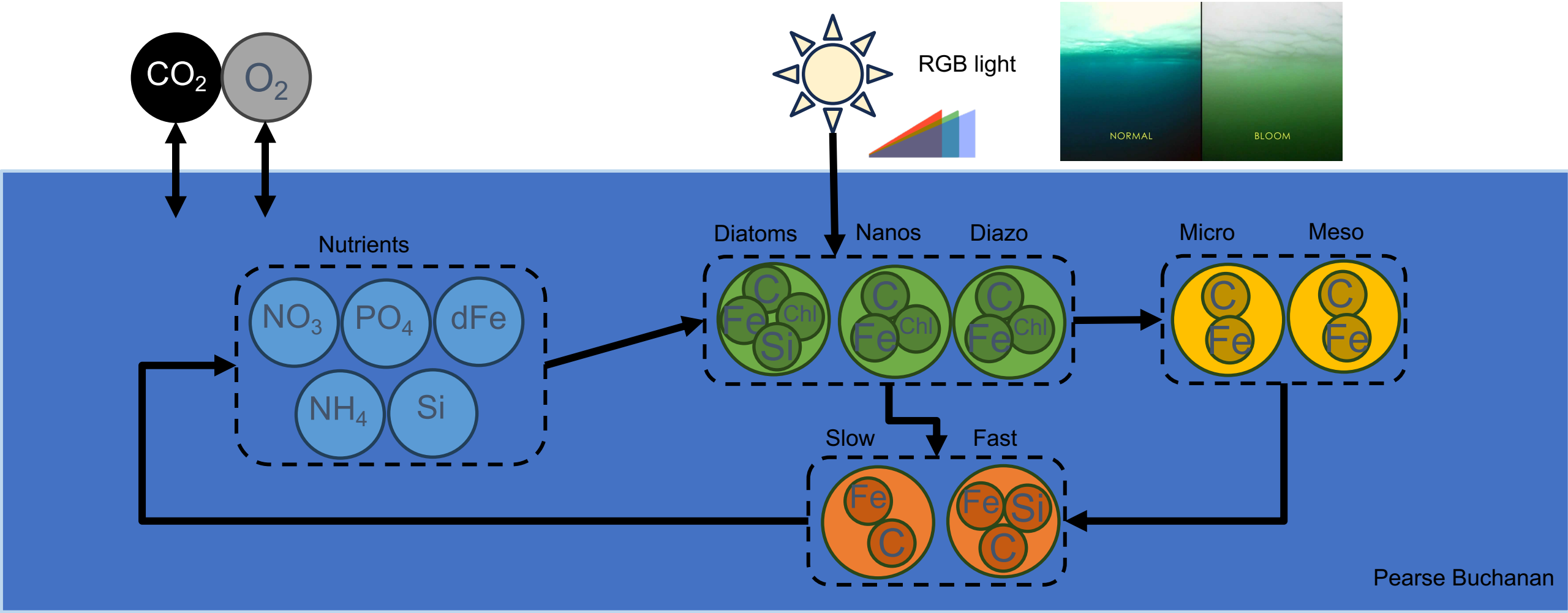
- **Original version** (Oke et al, 2013): 2N-1P-1Z-1D ecosystem
- Used in ACCESS-ESM1 and ACCESS-ESM1.5 (CMIP6)
- Continue to use for large ensembles and high resolution



WOMBAT-mid (30 tracers) – new workhorse, being tested in ACCESS-OM2

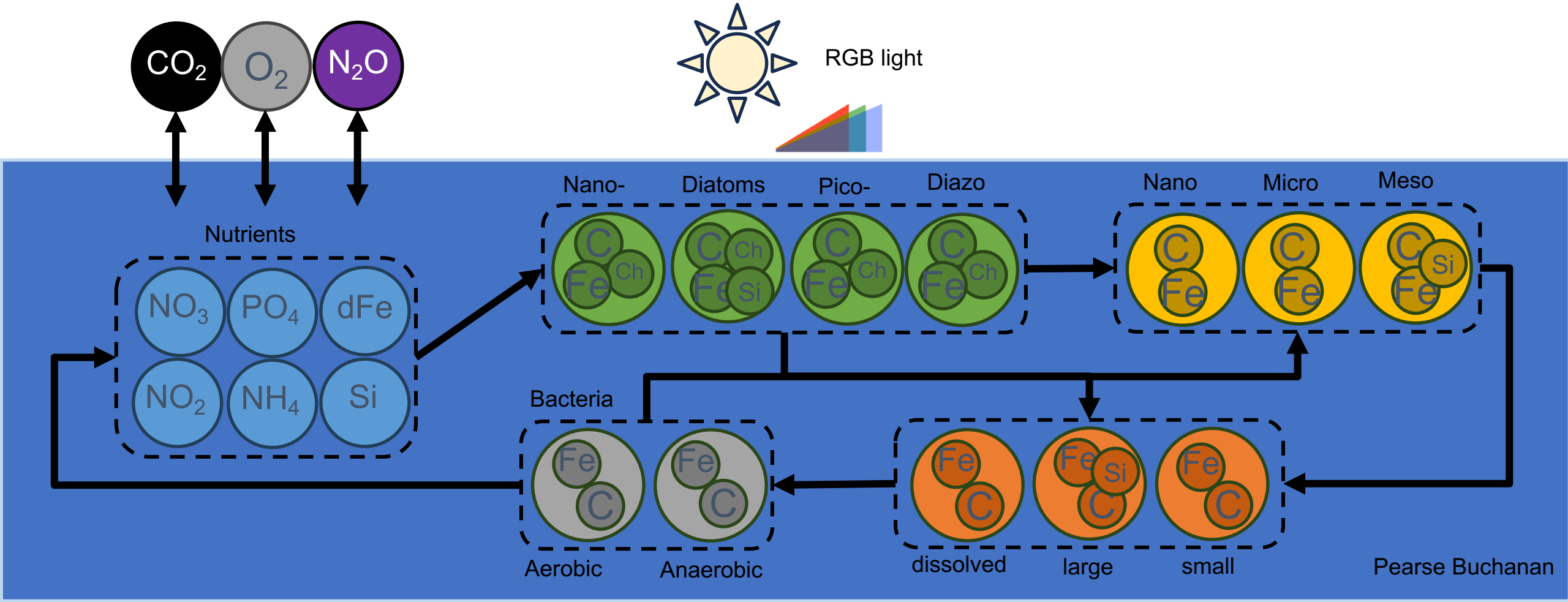
- **New tracers:** 5N-3P-2Z-2D ecosystem; active N and Si cycles
- **New processes:** pigments affect GPP; chlorophyll photoacclimation; permanent detritus burial; grazing Type-III with preferences
- **Improved Fe cycle:** variable Fe:C ratio; Fe limitation via quotas; hydrothermal, river, dust and sediment inputs; upgrade in Fe' and Fe-Ligand dynamics


Photo: Chris Kidd, The Mercury



WOMBAT-full (50 tracers)

- **Future version** (end 2024)
- 6N-4P-3Z-3D-2B ecosystem
- For bacterial-phytoplankton-particle interactions, and N_2O and N cycle studies



Summary

- Large, highly engaged Australian ocean - sea ice modelling community has grown around existing MOM5-CICE5 models (ACCESS-OM2, ACCESS-CM2, ACCESS-ESM2)
- Moving to MOM6-CICE6 based models (ACCESS-OM3, ACCESS-CM3, ACCESS-ESM3) for CMIP7 using CESM components (CMEPS, CDEPS, CESM driver); forced model includes WW3
- NUOPC cap for UKMO Unified Model atmosphere & land
- MOM6 cap improvement: BGC via generic tracers in NUOPC
- Upgraded WOMBAT BGC