OM4: GFDL's ¼° ice-ocean model component for CMIP6

Alistair Adcroft

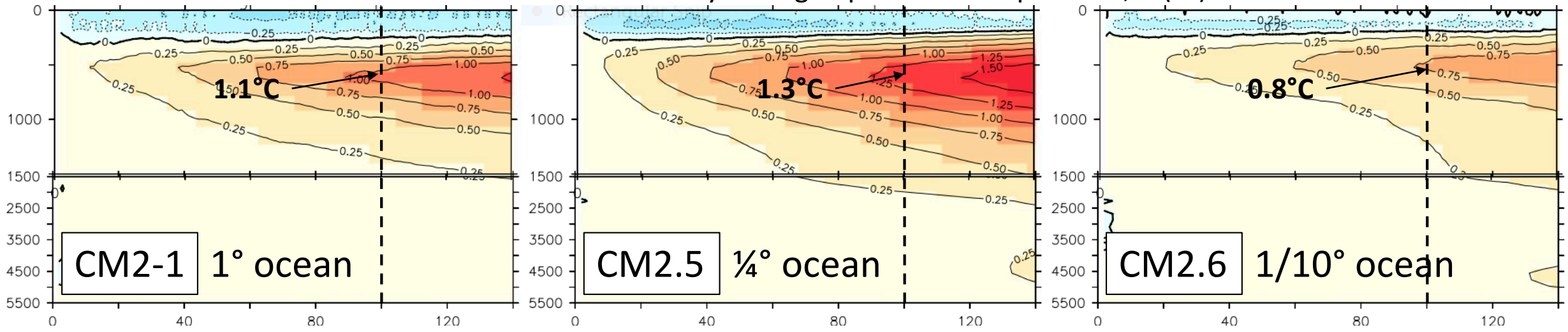
GFDL MOM6 team includes Raphael Dussin, Robert Hallberg, Stephen Griffies, Matthew Harrison, Hae-Cheol Kim, John Krasting , Marshall Ward, Niki Zadeh

Other contributors for presentation: Malte Jansen, Andrew Shao

Horizontal resolution, spurious mixing, and eddies

- Delworth et al., 2012, coupled model series (CM2-1deg, CM2.5, CM2.6):
  - 50 km atmosphere
  - 1°, ¼° and 0.1° ocean
- Ilicak et al., 2012, and others
  - much heat uptake at ¼° was spurious
- Griffies et al., 2015, diagnosed how transient eddies in a 0.1° ocean transport heat upwards
  - Has least heat uptake of CM2.x series
- For CMIP6, **we could afford ¼°** ocean

Evolution of horizontally averaged potential temperature, θ (°C).



OM4

- OM4 is the ice-ocean component of GFDL's latest coupled model CM4 (Held et al., 2019)
- OM4 configuration
  - Identical setup/parameters to CM4
  - Developed almost exclusively in coupled mode
    - Uncoupled OM4
  - Nominally eddy-permitting ¼° horizontal resolution
    - Non-eddying ½° with eddy parameterization (GM+EKE scheme)

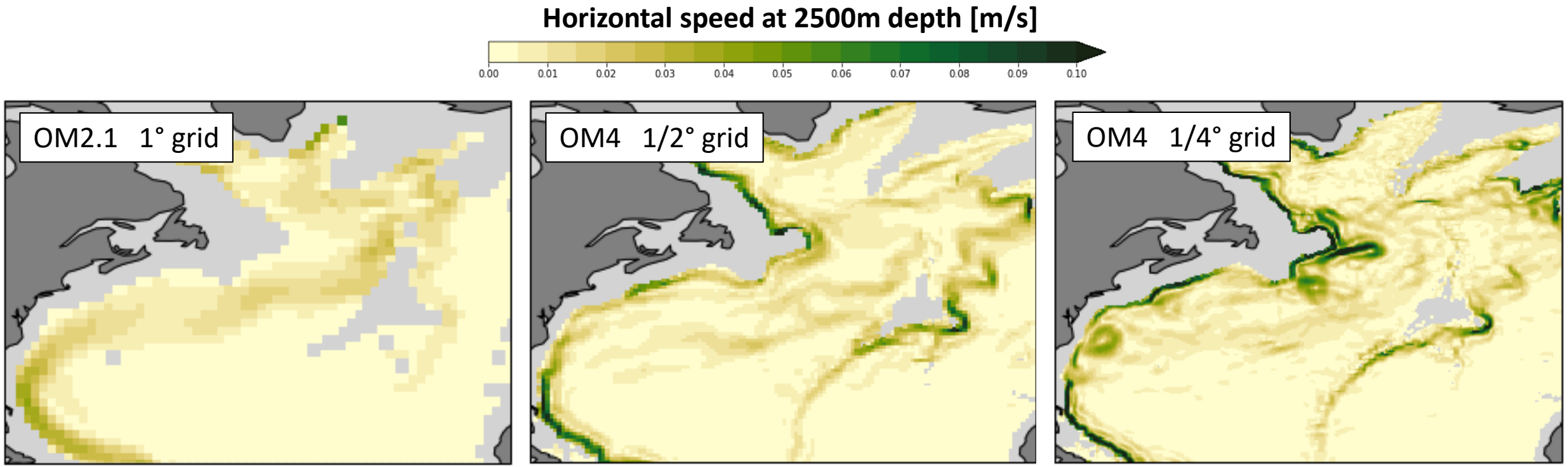
Ingredients:

- MOM6
  - using hybrid z-ρ vertical coordinates
    c.f. HYCOM, Bleck 2002
- ePBL
  - Reichl and Hallberg, 2019
- Scale-aware MLE restratification
  - Fox-Kemper et al., 2011
- Shear-dependent mixing
  - Jackson et al., 2008
- Internal-wave driven mixing
  - Melet et al., 2012
- BBL
  - Legg et al., 2006

Adcroft et al., *JAMES* 2019

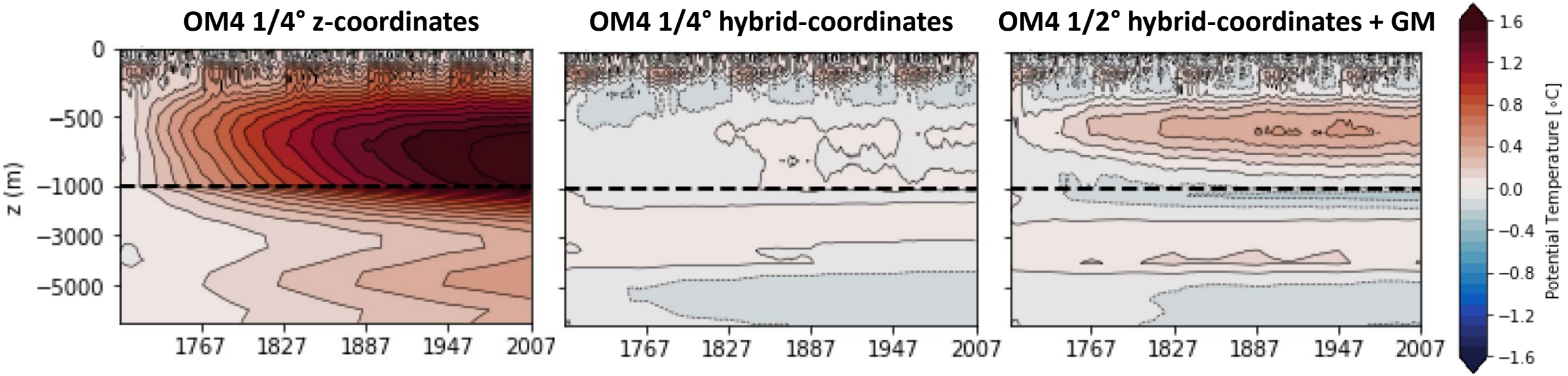
OM4: Why finer resolution than 1° ?

- Justification for ½° and ¼° horizontal resolutions in OM4
  - ½° produces much stronger boundary currents (used for ESM4)
  - ¼° begins to permit large eddies across many basins (used for CM4)



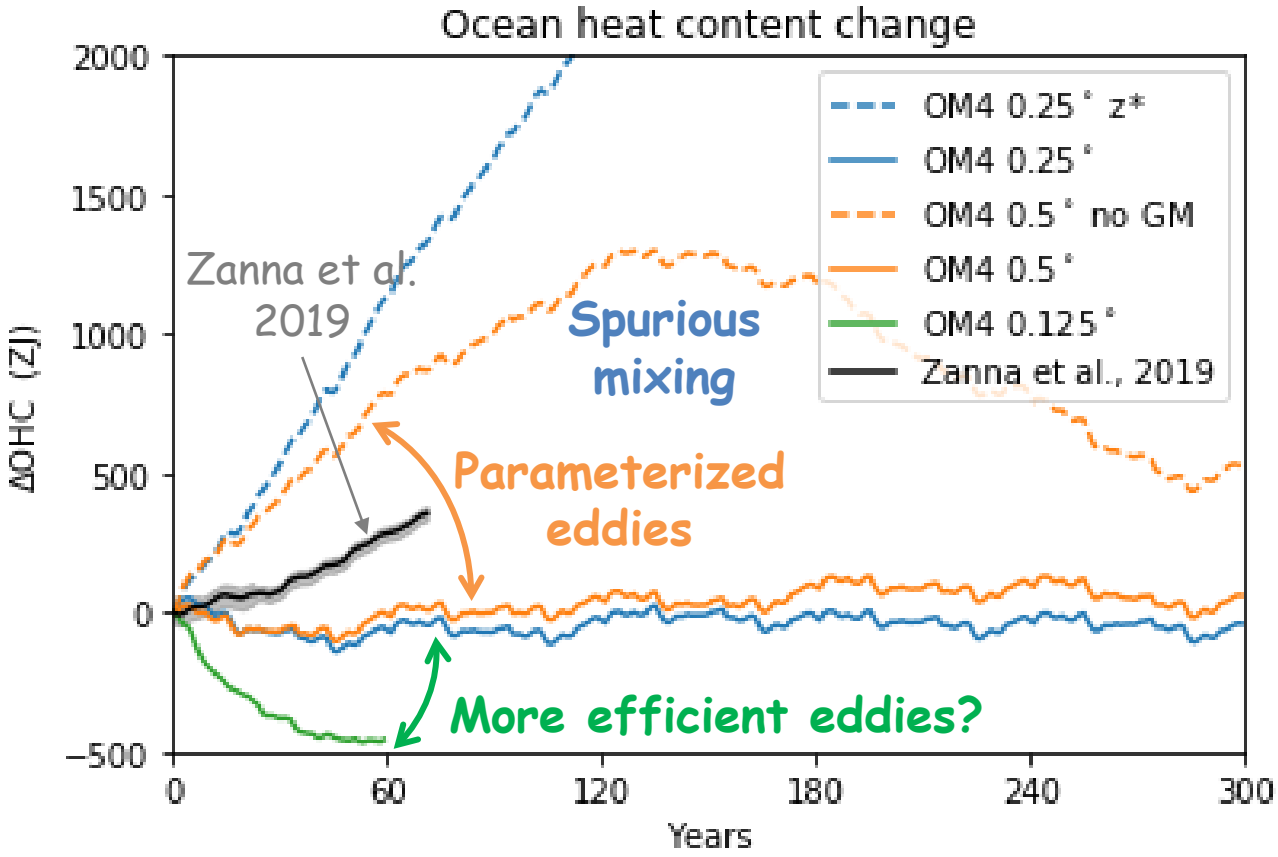
OM4: Minimal spurious mixing?

- Using z-coordinates incurs ~0.5°K / century trend in main thermocline
- Hybrid z-ρ coordinates have much less spurious mixing
  - Suggested in earlier studies, e.g. Chassignet et al., 2003; Megann et al., 2010
- Coarser ½° requires GM parameterization to retain minimal drift



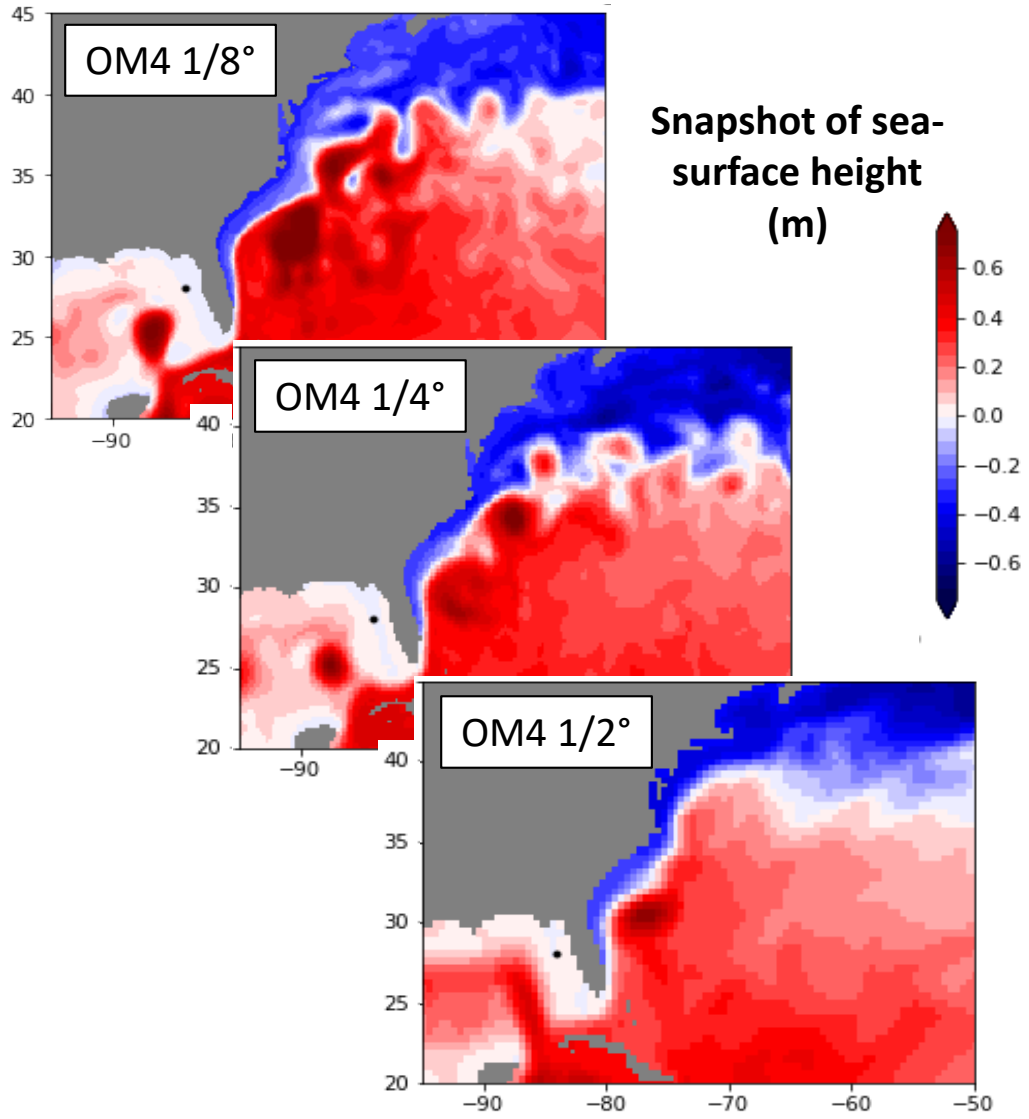
Balancing heat transfer by eddies and mixing

- Comparing z* to hybrid coordinate provides magnitude of spurious numerical mixing
- Reducing resolution from ¼° to ½° (eddying to non-eddying) inhibits resolved re-stratification
  - ½° requires eddy parameterization
- Refining resolution from ¼° to ⅛° reduces heat uptake:
  - more efficient eddies
  - and/or less numerical mixing?



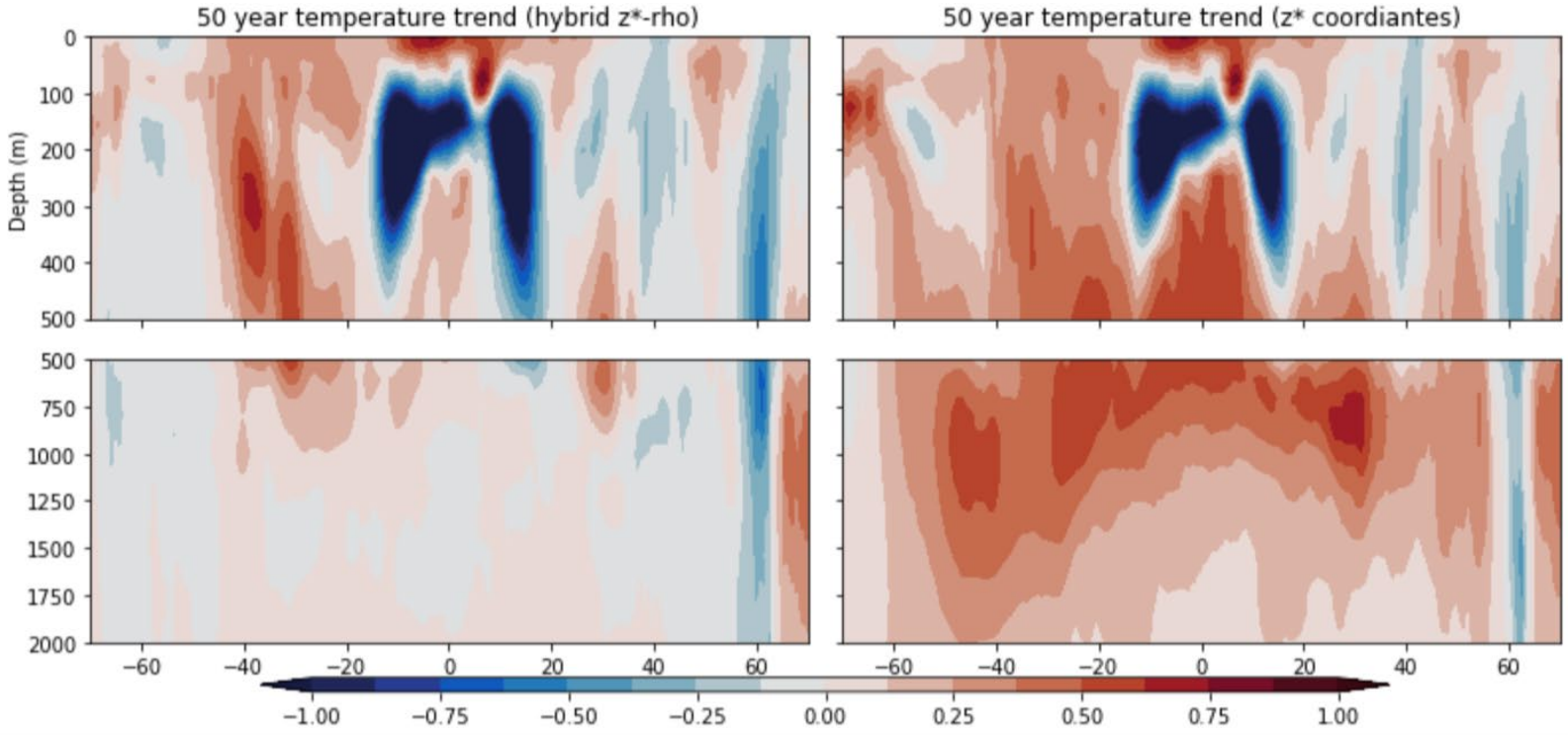
When do we need finer resolution?

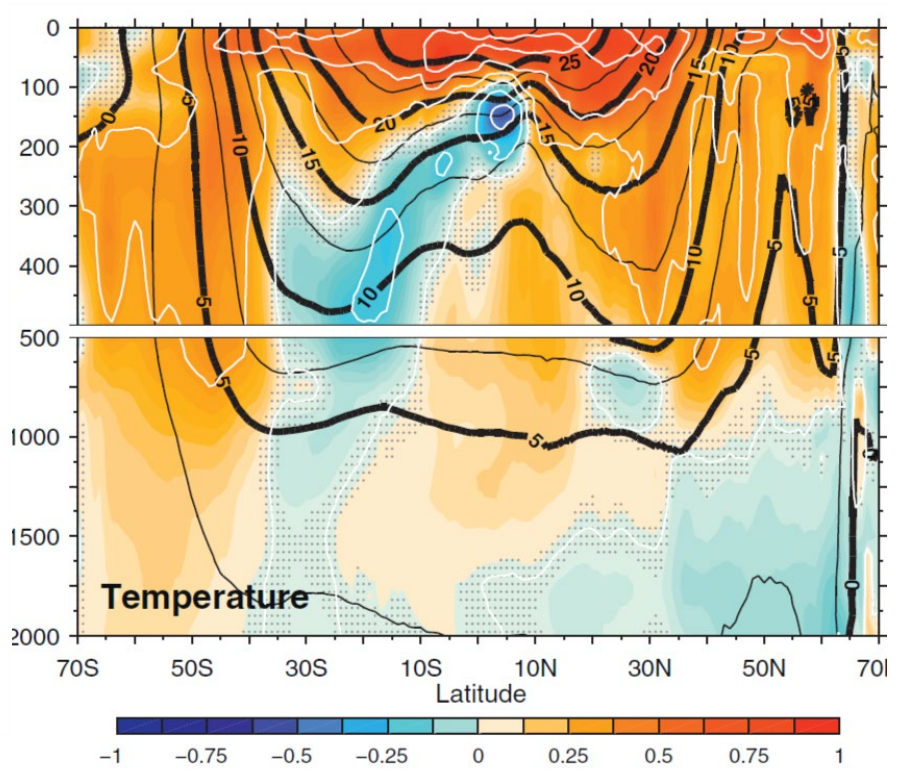
- We just showed sensitivity of OHU to resolution
- Deformation radius is regionally variable
  - Not permitting/resolving eddies everywhere
- Qualitatively refinement not always obvious locally



OM4 CORE IAF hybrid & z* coordinates

50 year change of zonal average temperature [°C]



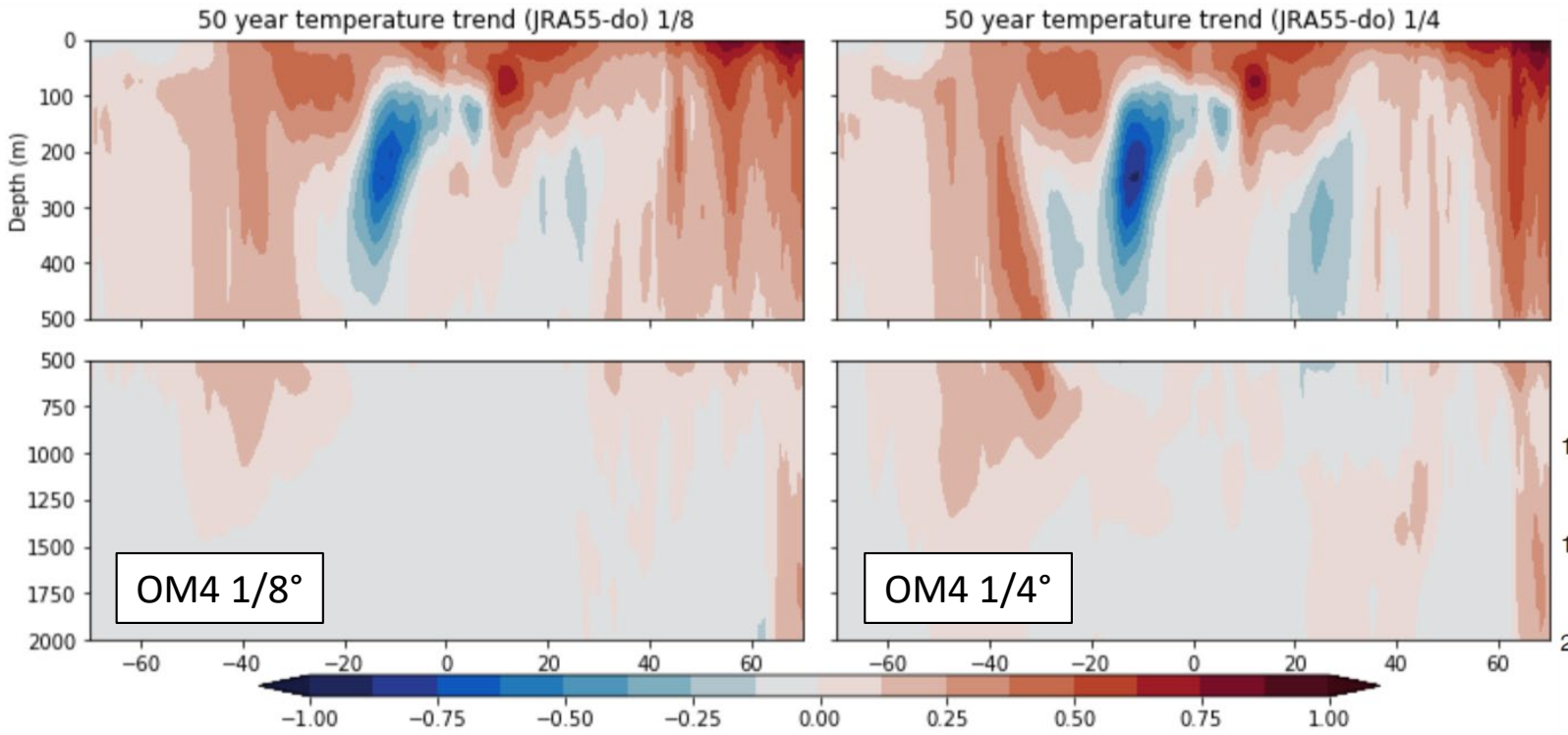


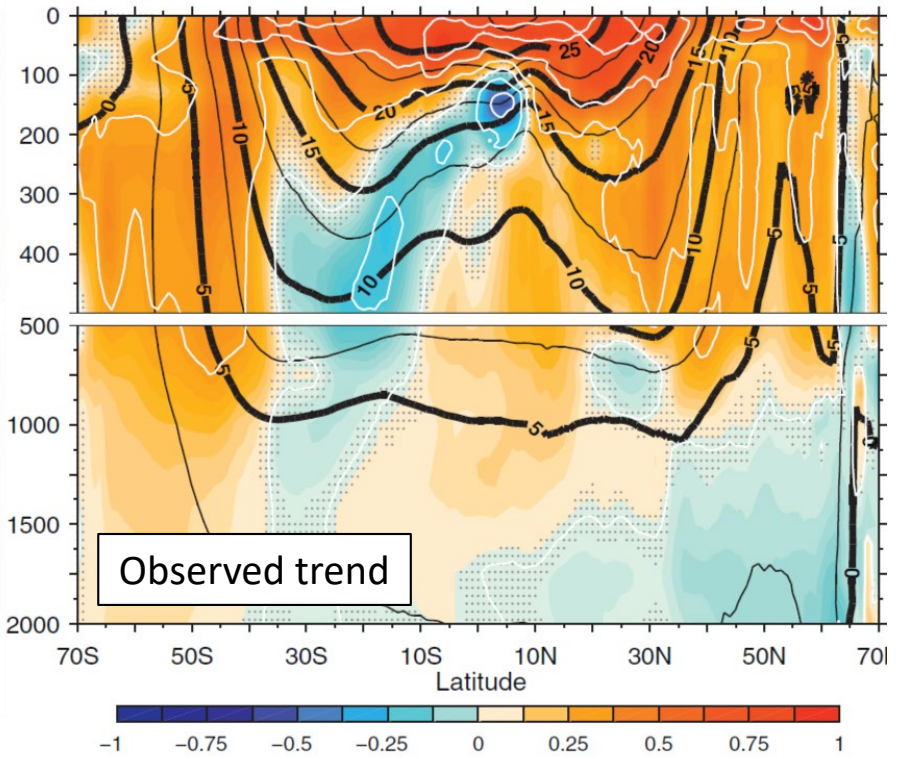
2nd cycle CORE-IAF

From Durack & Wiffels, 2010

OM4 JRA55-do 1/8° & 1/4 °

50 year change of zonal average temperature [°C]

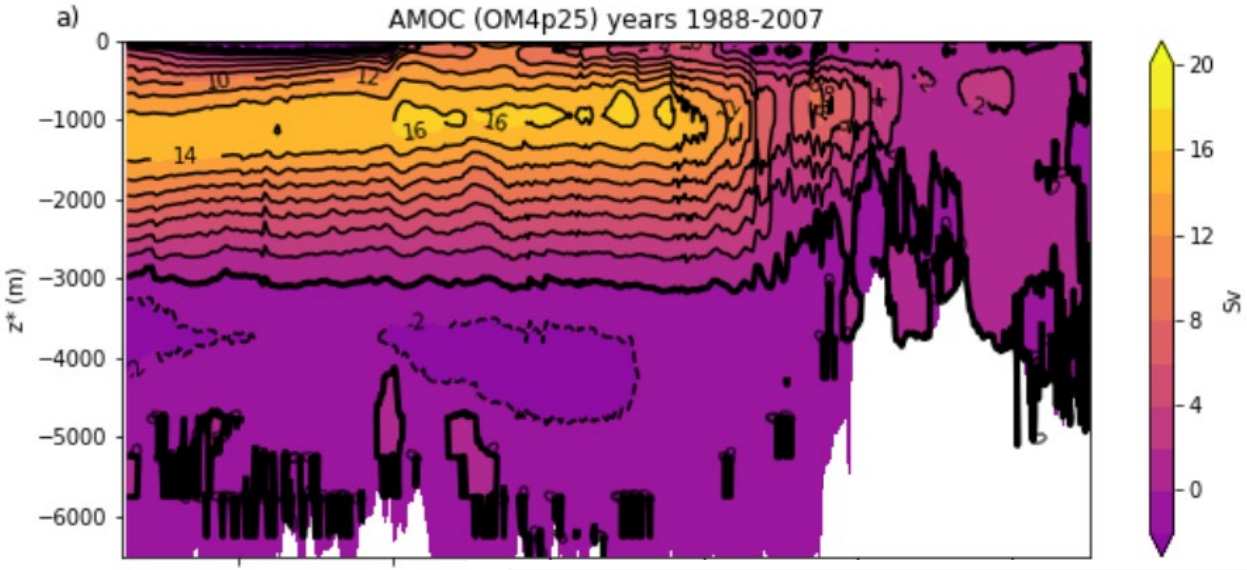


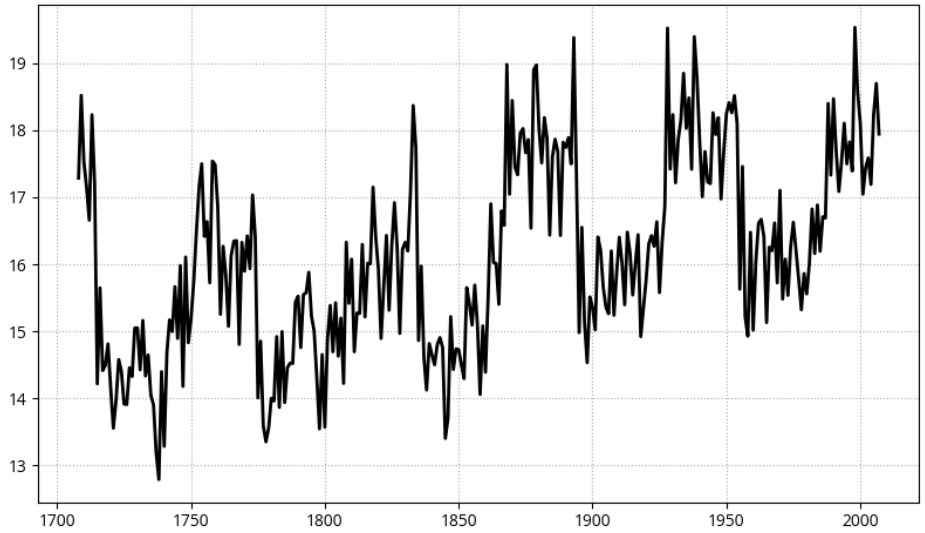


3rd cycle JRA55-do forcing

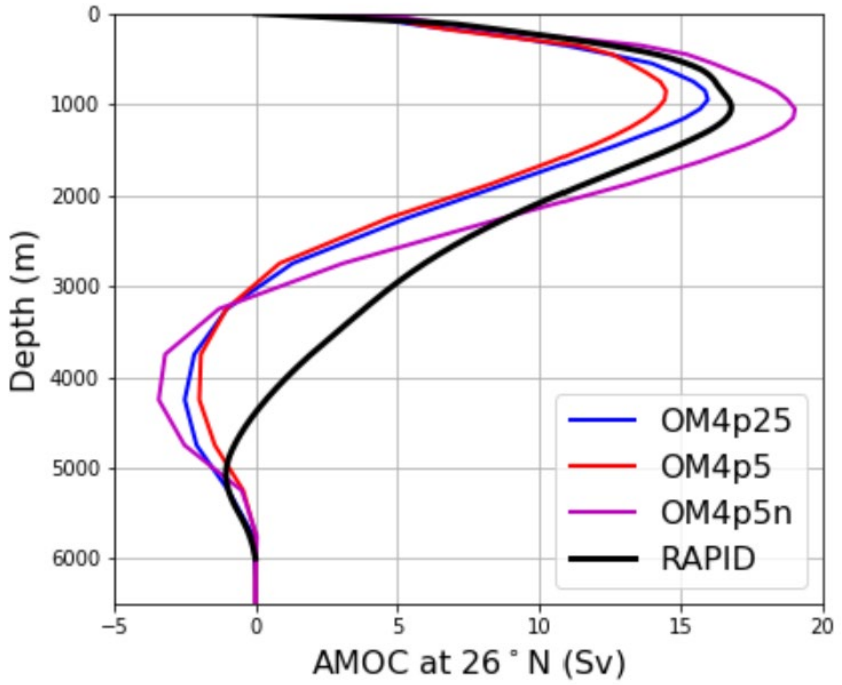
From Durack & Wiffels, 2010

OM4 AMOC



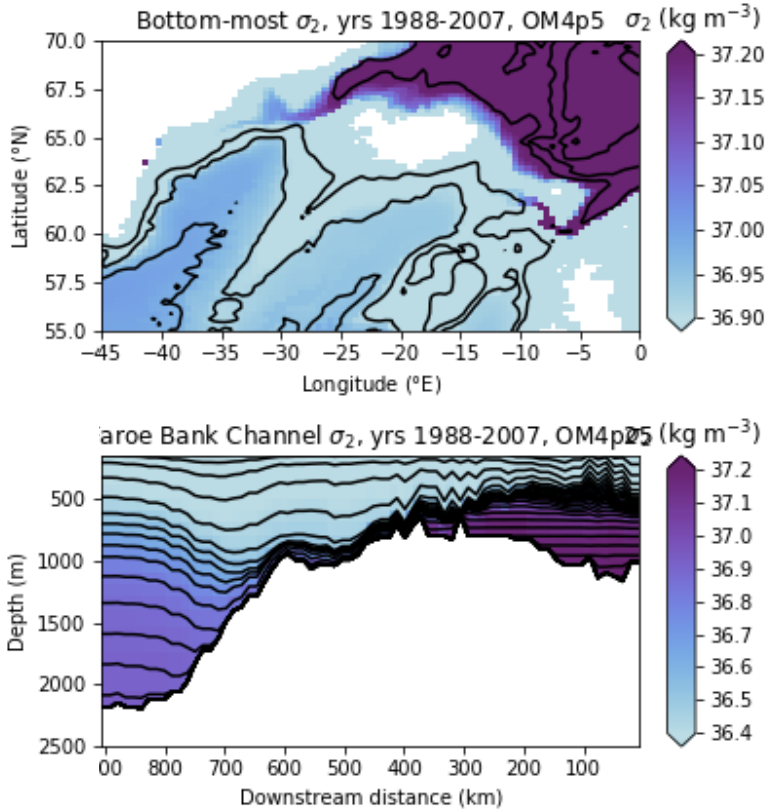


- AABW/NADW interface ~ 3000m

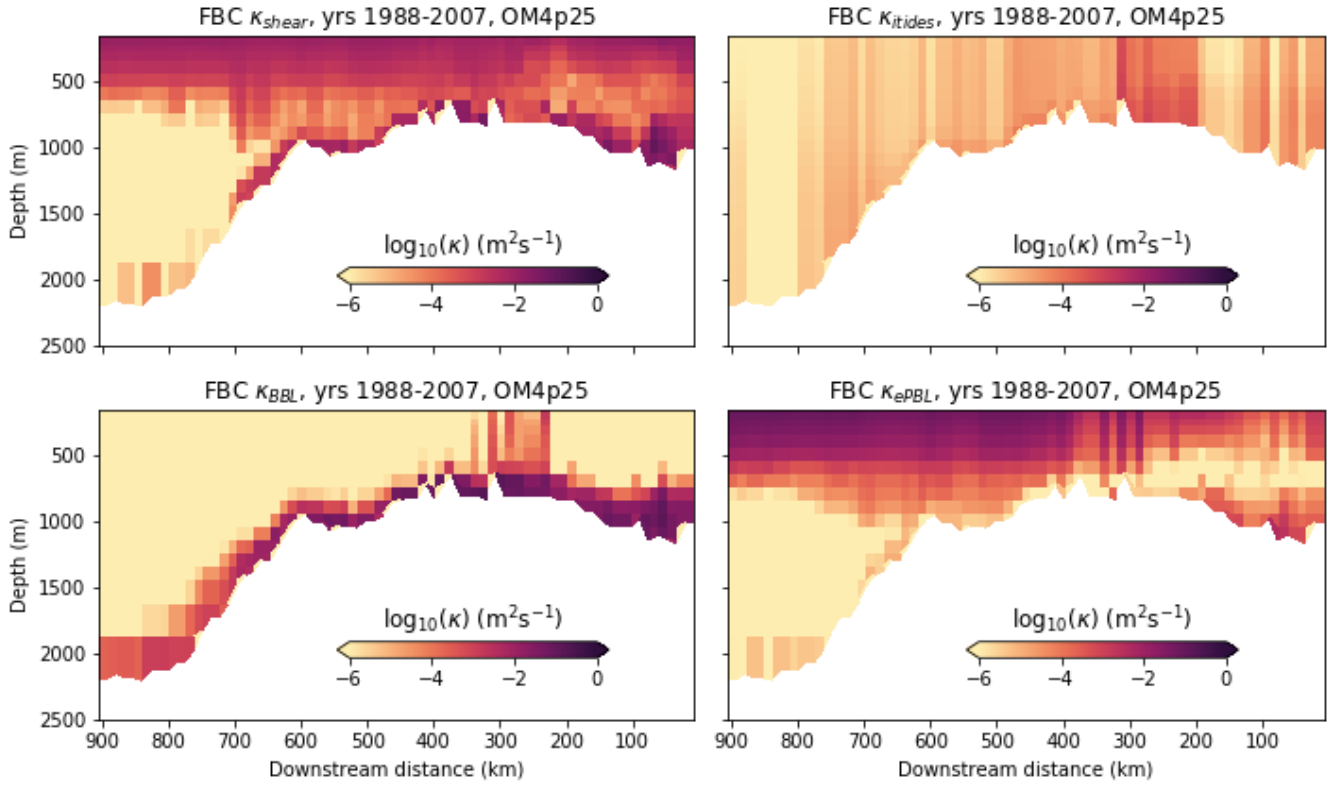


Overflows and mixing rates

- Density, Natl overflows



- Diffusivities along FBC



Summary and conclusions

- OM4 represents a step forward in being able to make statements about ocean heat uptake

  c.f. HYCOM, Bleck 2002

  – Pragmatic configuration to avoid drift even though we do not *fully* understand what is wrong in the balance of heat transfer processes
- We recognize that there are still compensating errors including:
  – Missing parameterizations of unresolved eddies (e.g. backscatter)
  – Incomplete parameterizations of diabatic processes
  – Some unknown numerical mixing
- A hierarchy of finer-resolution models is under development to try to understand how OHU depends on resolution