Parameterizing mesoscale eddy buoyancy transport over sloping topography

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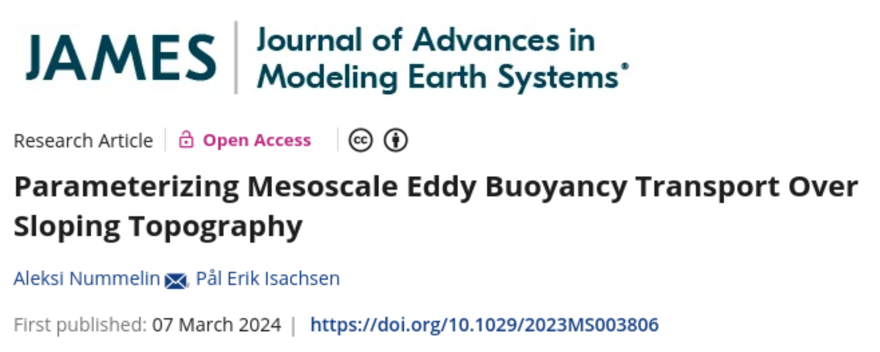
Thanks to Miriam Sterl, Joe LaCasce, Sjoerd Groeskamp, and Michiel Baatsen

EGU 16.04.2024



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Article Type: Research Article

Suppression of mesoscale eddy mixing by topographic PV gradients

Miriam F. Sterl, Joseph H. LaCasce, Sjoerd Groeskamp, Aleksi Nummelin, Pål E. Isachsen, and Michiel L. J. Baatsen

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DOI: https://doi.org/10.1175/JPO-D-23-0142.1

Sharing is encouraged

Status quo

$$\frac{\partial}{\partial t} h_\rho + \nabla \cdot (\mathbf{u} h_\rho) = \nabla \cdot (\kappa \nabla h)_\rho$$

Gent (2011)

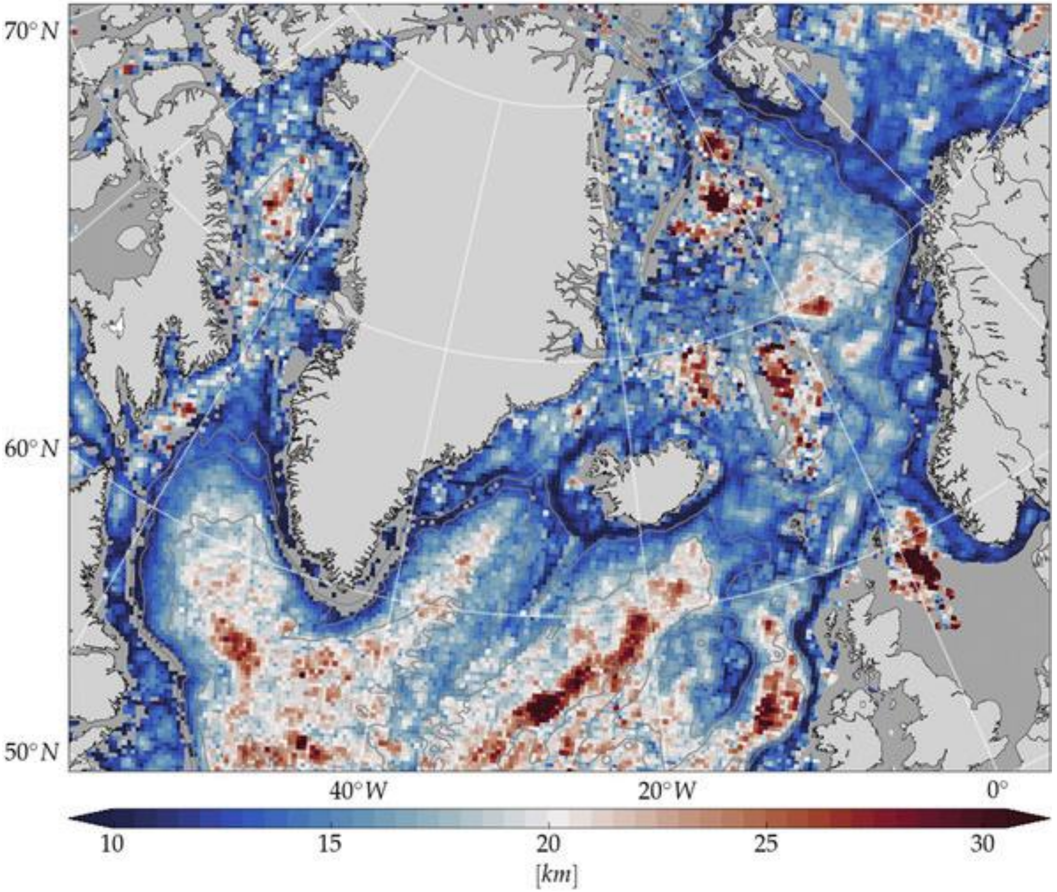
- κ is often based on mixing length argument
  - We estimate *V* with Eady growth rate and length scale
    - Overall L^2 dependence
  - *L* is estimated as a minimum of two length scales
    - Deformation radius
    - Planetary Rhines scales

$$K_{ML} \propto VL$$

$$V_{par} = \sigma_E L$$

$$K_{par} \propto \sigma_E L^2$$

Mean eddy radius in the North Atlantic from a ROMS simulation



Trodahl, M., and P. E. Isachsen, 2018: Topographic Influence on Baroclinic Instability and the Mesoscale Eddy Field in the Northern North Atlantic Ocean and the Nordic Seas. *J. Phys. Oceanogr.*, **48**, 2593–2607, https://doi.org/10.1175/JPO-D-17-0220.1.

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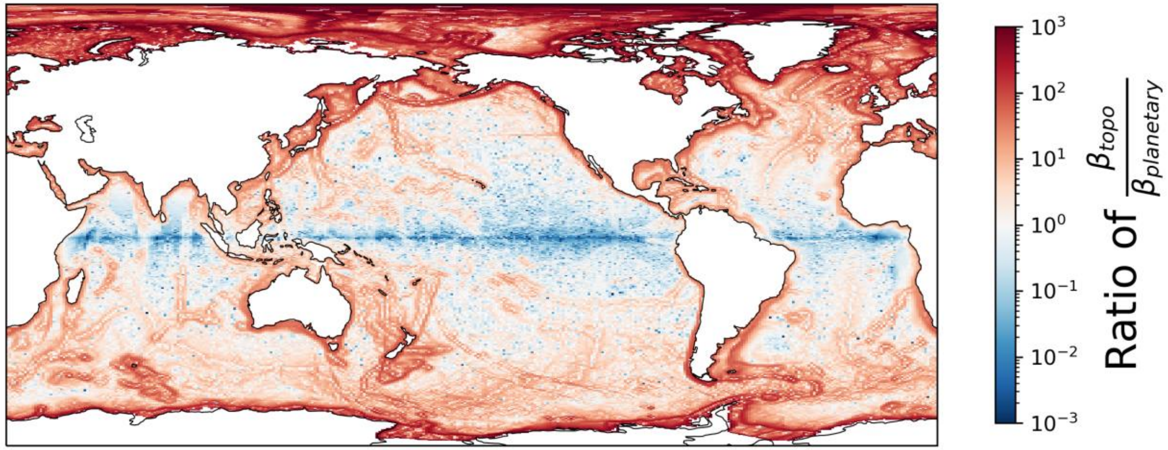
  - We suggest adding topographic Rhines scale to create bottom slope sensitivity

$$L_T = \left(\frac{V_{par}}{\beta_T}\right)^{1/2} = \frac{\sigma_E}{\beta_T}$$

$$\beta_T = (|f|/H)|\nabla H|$$



Nummelin & Isachsen (2024)

$$\boxed{K_{par} \propto \sigma_E L_T^2 = \sigma_E^3/\beta_T^2}$$

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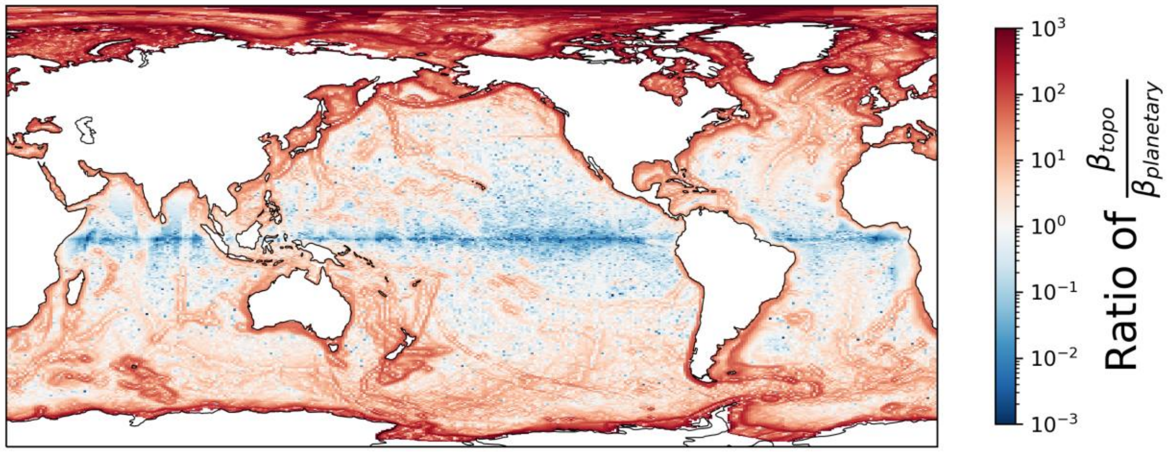


Nummelin & Isachsen (2024)

$$\boxed{K_{par} \propto \sigma_E L_T^2 = \sigma_E^3 / \beta_T^2}$$

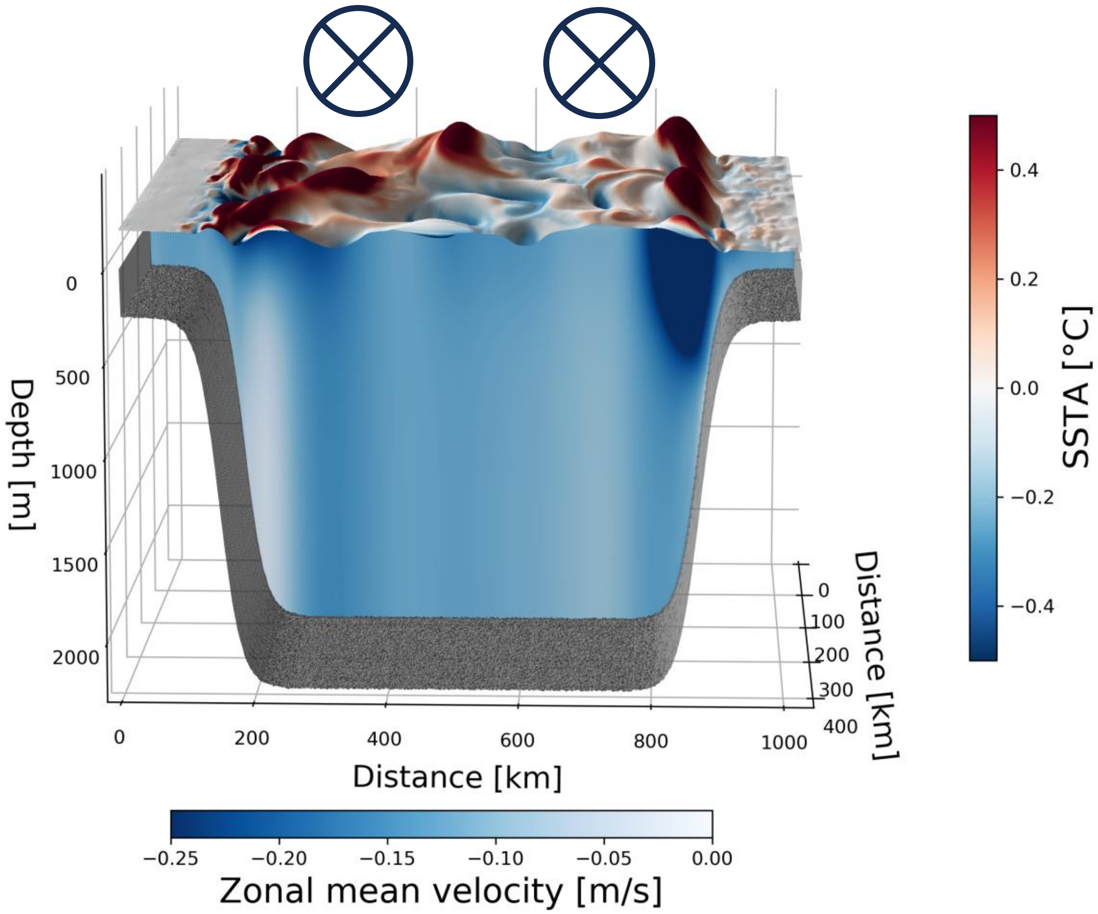
Sterl et al. (2024)

$$\boxed{K = \frac{K_0}{1 + \frac{A}{\gamma^2 \kappa^2} \beta_T^2}}$$

Model setups using the NorESM framework

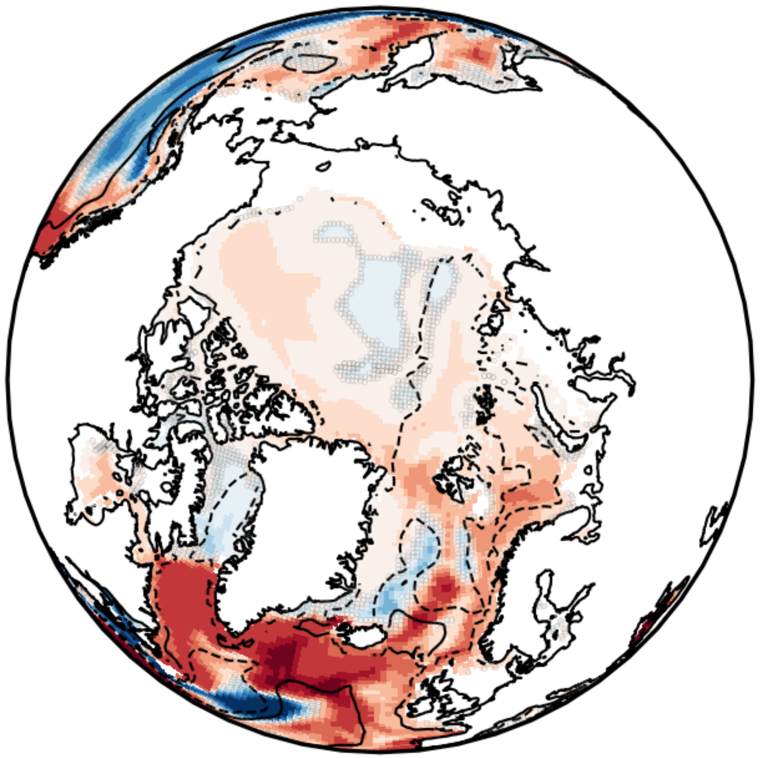
BLOM channel simulations

15 years, constant winds, several slope angles/stratifications, f-plane, eddy resolving and parameterized resolutions.



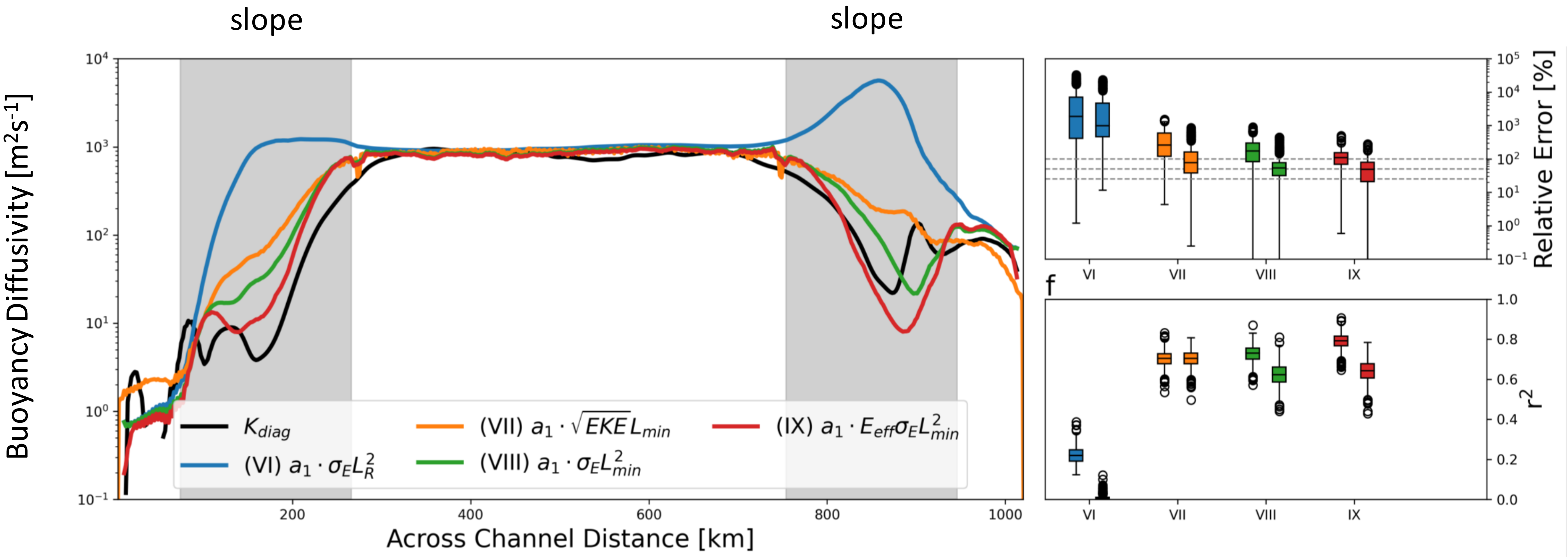
BLOM OMIP-II simulations

2-cycles (110-years), global 1-deg resolution (NorESM2 CMIP6).



Results – channel model

- Including the topographic Rhines scale (VII, VIII, IX) improves the results in comparison to using deformation radius (VI)



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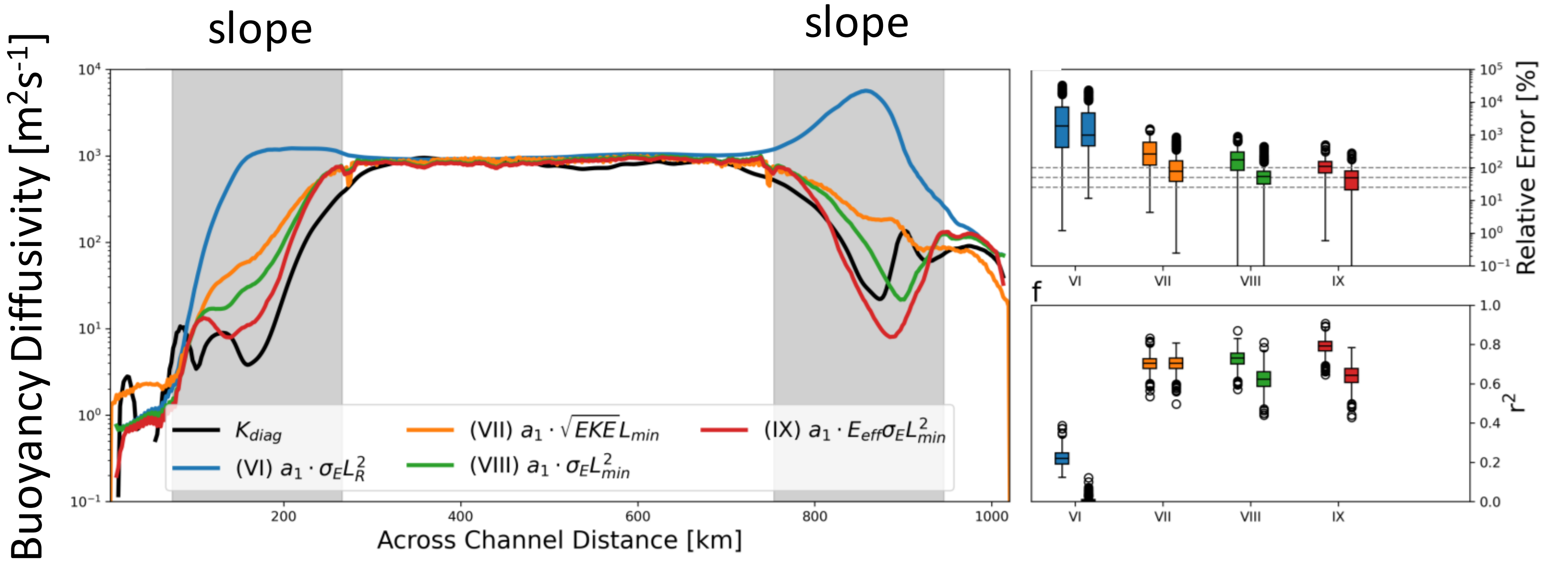
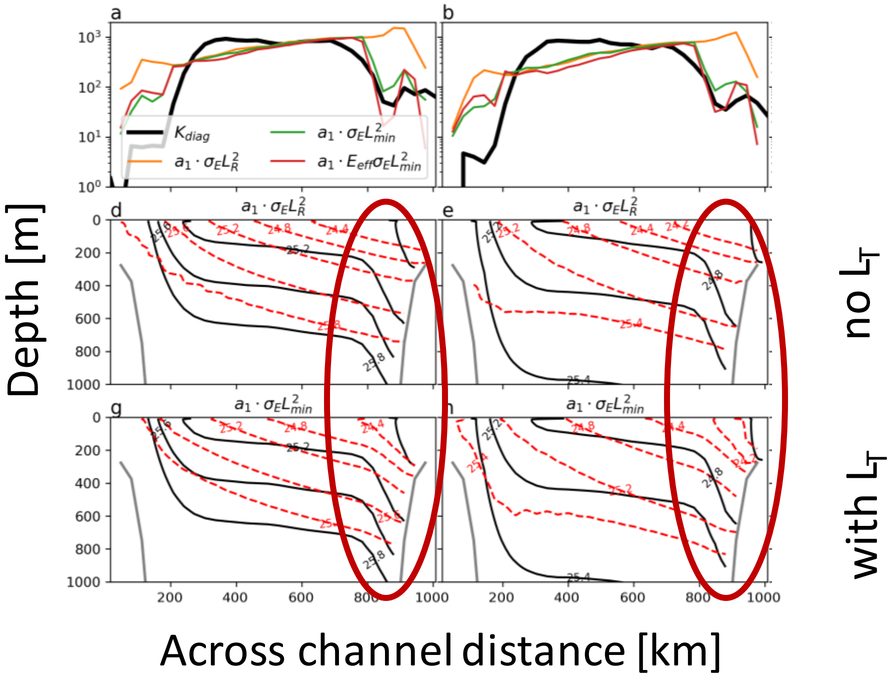


- Results holds at coarse resolution

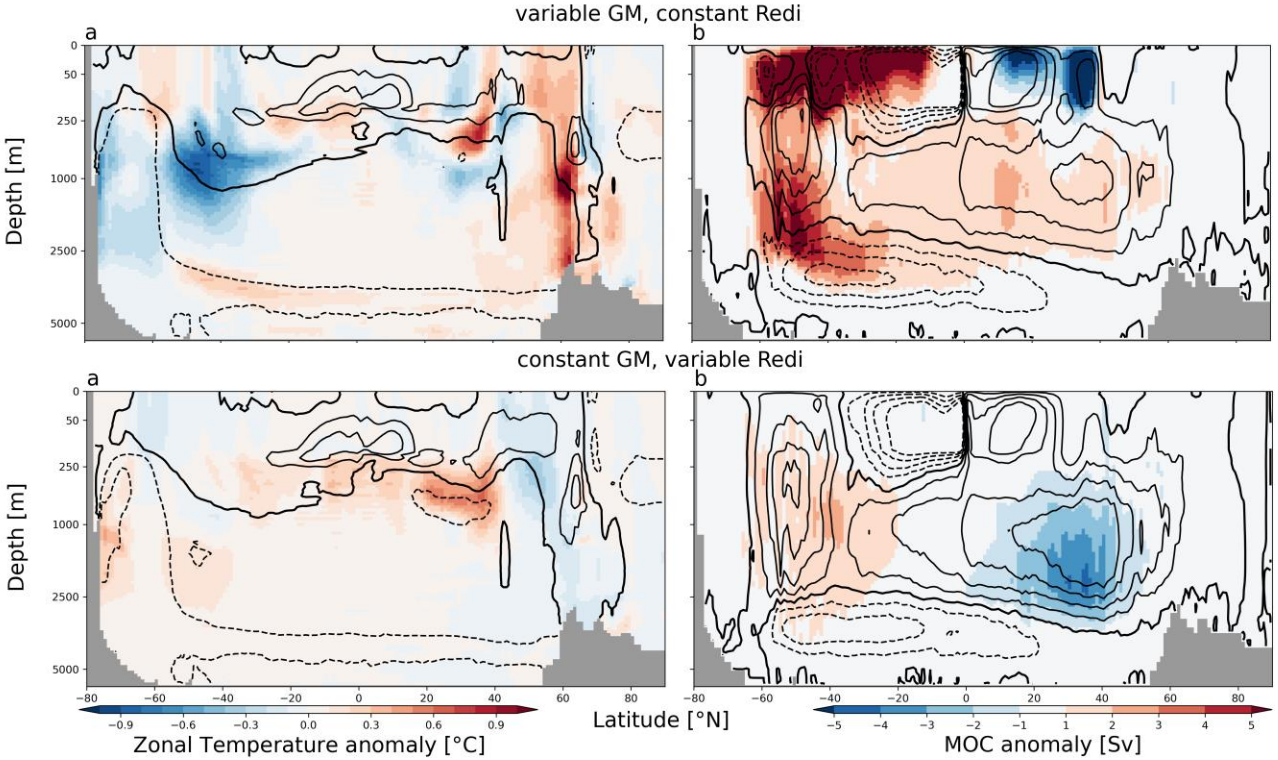


Black contours: density in the high resolution simulations

Red contours: density in the coarse resolution simulations

Results – argument for making consistent changes to GM and Redi parameterizations

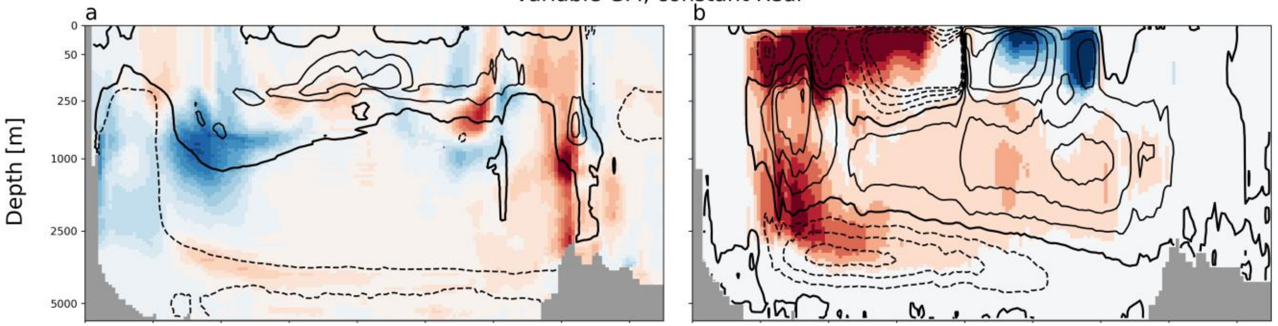
- Changing GM in isolation gives strong MOC response but acts to worsen temperature bias in SO
- Changing Redi in isolation leads to weak MOC response, but acts to improve temperature biases



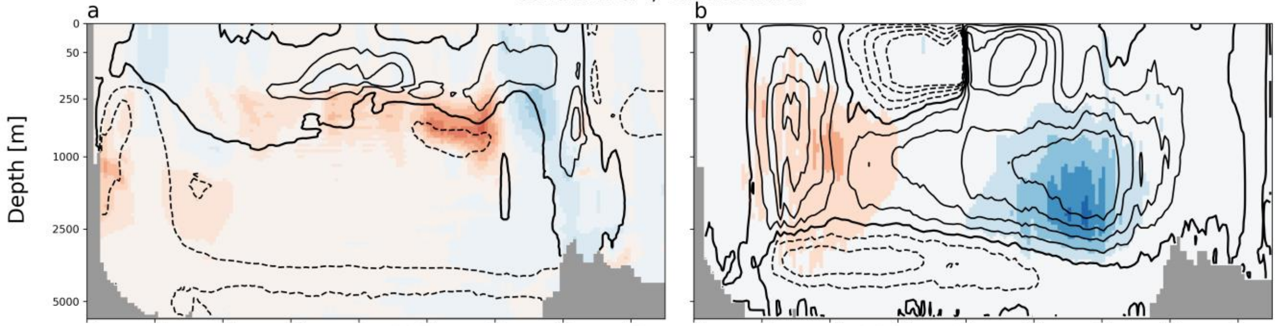
Results – argument for making consistent changes to GM and Redi parameterizations

- Changes in isolation are mostly linearly additive, except in the SO
- We suggest changing GM and Redi together
  - Consistent MOC change
  - Improved bias in SO

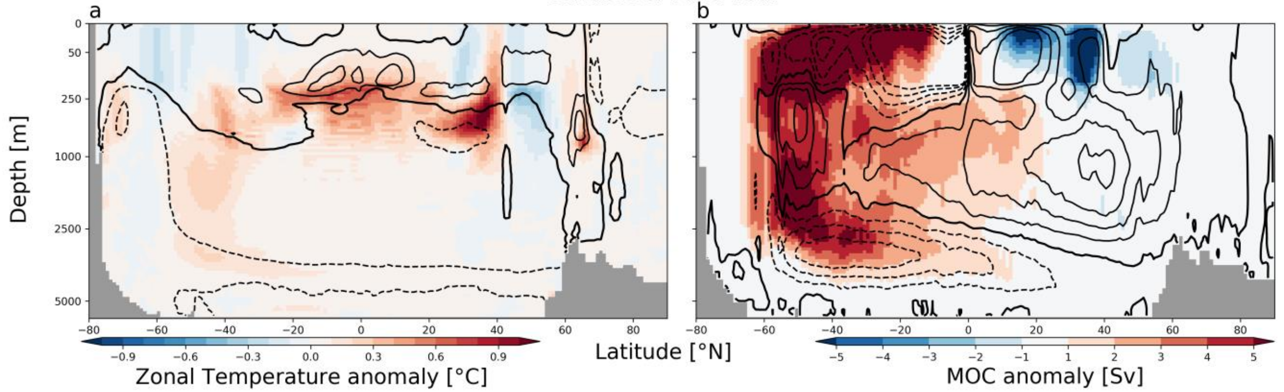
variable GM, constant Redi



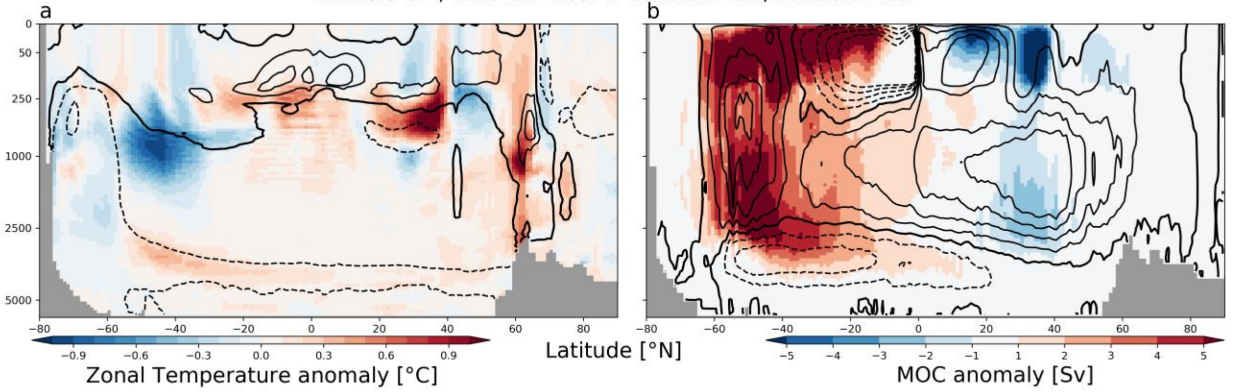
constant GM, variable Redi



variable GM and Redi

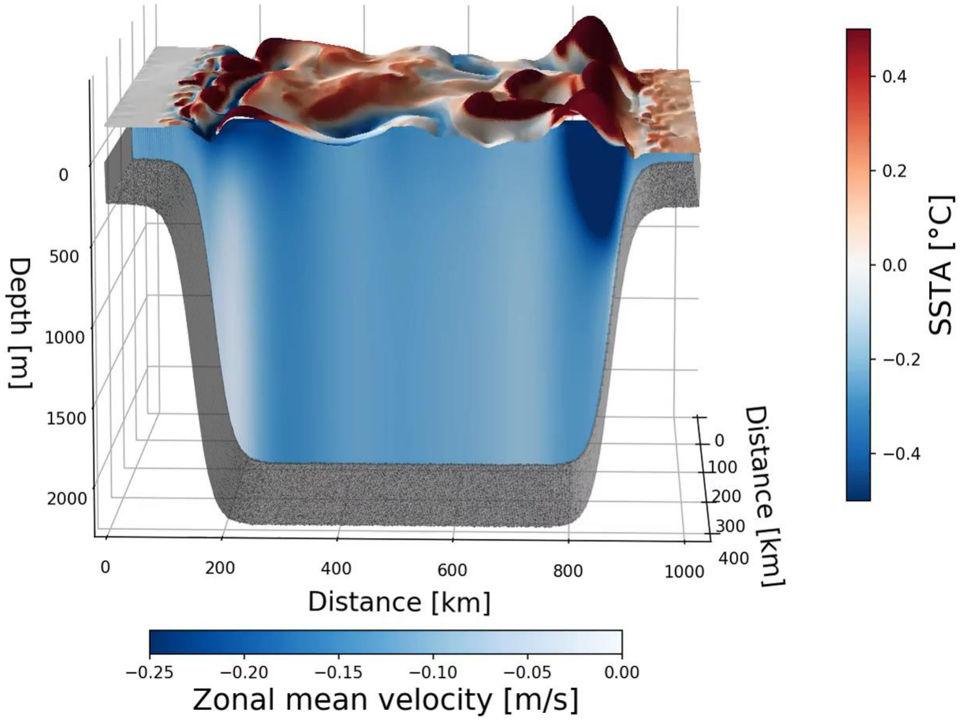


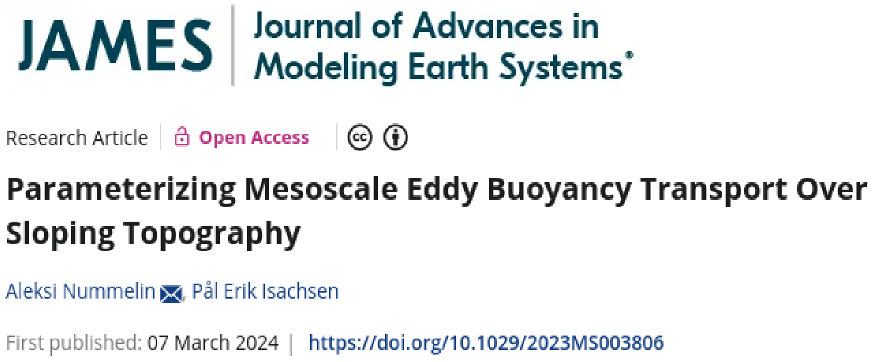
variable GM, constant Redi + constant GM, variable Redi



Results – channel model

- Theory and simulations suggest that over the sloping topography eddy transport **has strong β^{-2} dependency.**
- Mixing length approach with a topography aware length scale leads to reduced diffusivity over the slopes, stronger mean flow, and globally reduced biases.
- More info: *aleksi.nummelin@fmi.fi*





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