Climate Change Research Centre

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Jet-topography interactions affect energy pathways to the deep Southern Ocean

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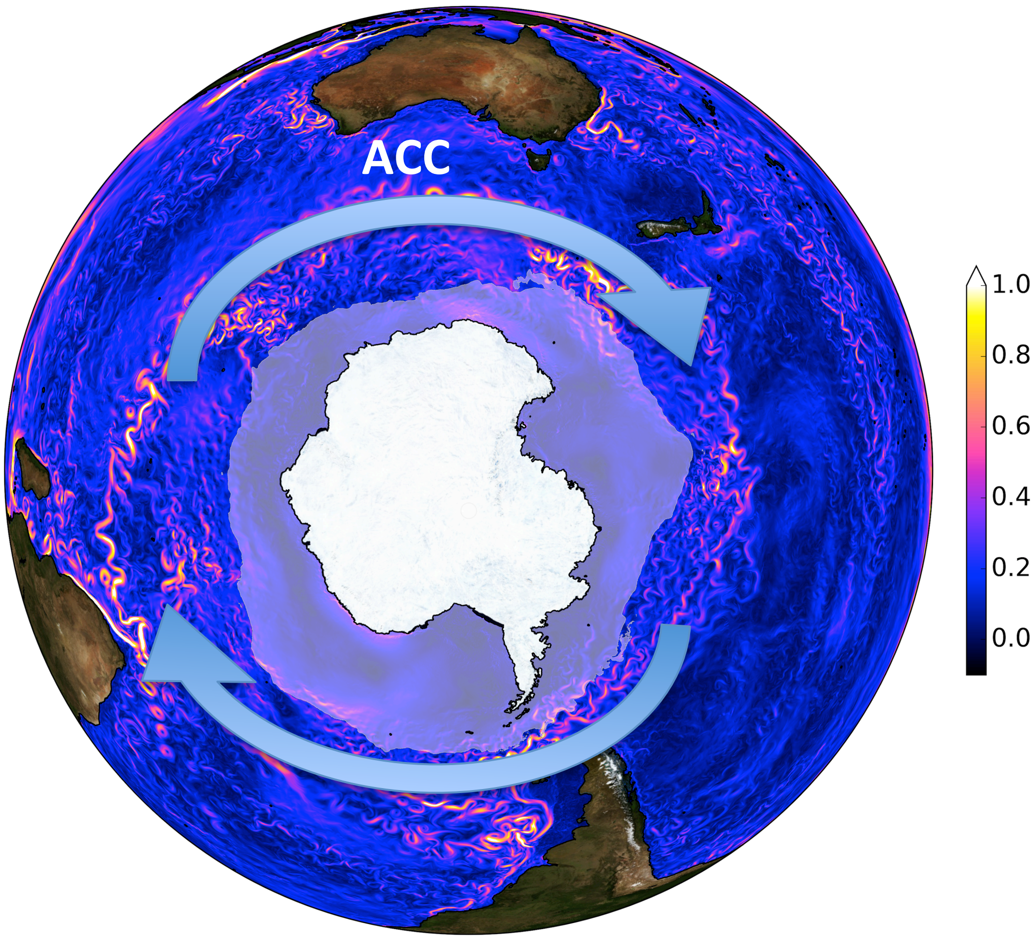
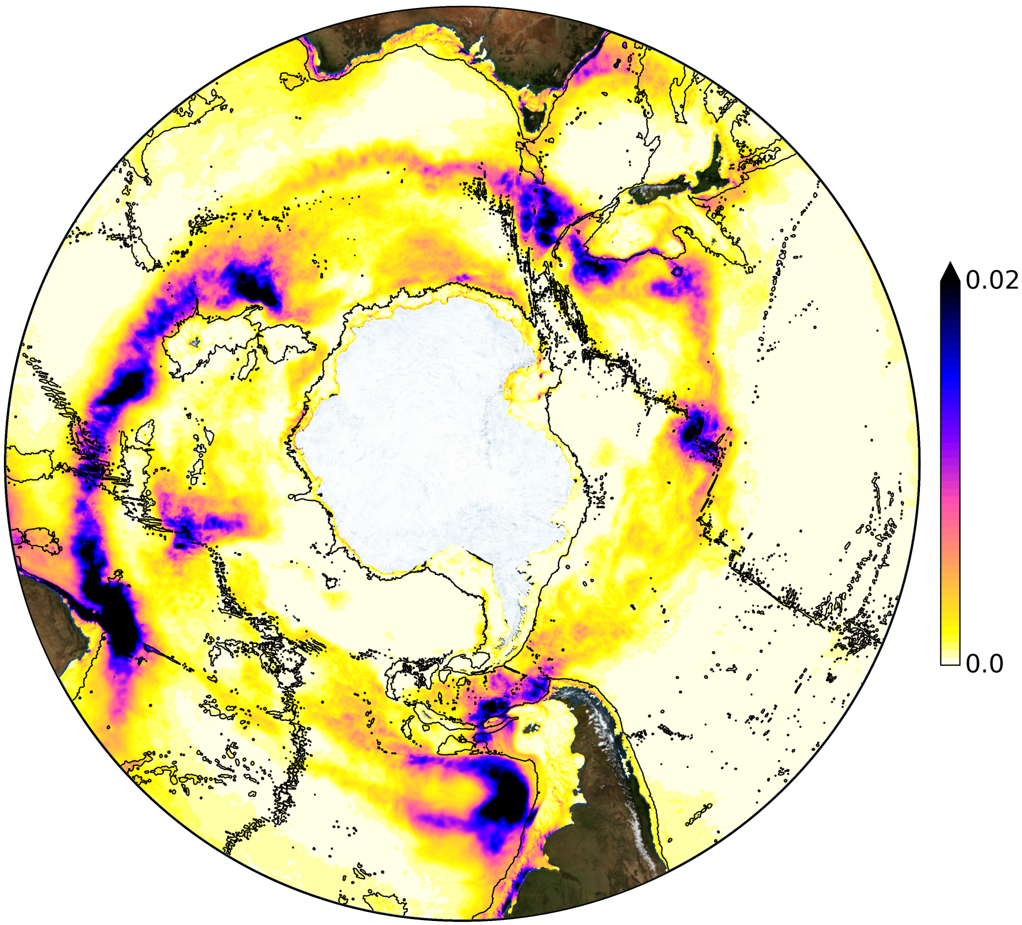
Southern Ocean



Snapshot of **surface current speed** (m s^{-1}) from the MOM 1/10° ocean model. Courtesy of Kial Stewart.

- Circumpolar ocean
- Eastward-flowing jets
- Topography
  - steering

Southern Ocean



Depth-integrated EKE ($m^2\ s^{-2}$) in the MOM 1/10° with the 2500m depth contour superimposed. Courtesy of Kial Stewart.

- Circumpolar ocean
- Eastward-flowing jets
- Topography
  - steering
  - EKE distribution

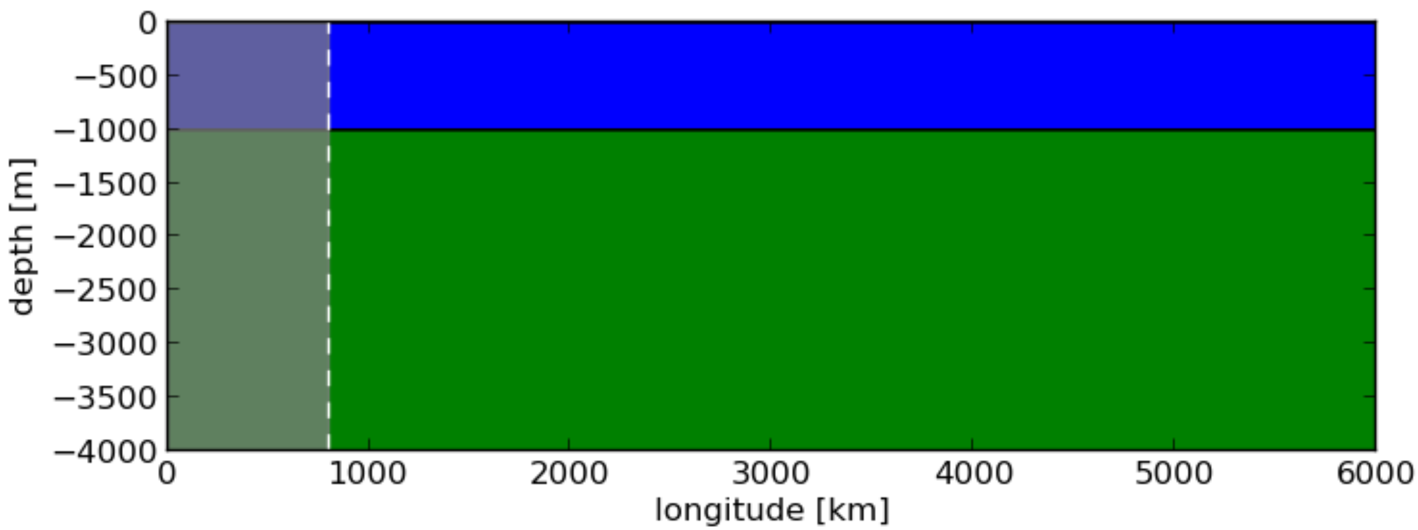
Motivation

- Topography in the Southern Ocean affects the distribution of eddy energy
- Impact on mixing
  - Lee waves generated from geostrophic eddies interacting with topography (Nikurashin et al., 2012)
  - Observed mixing rates are dependent on local eddy energy (Sheen et al., 2014)

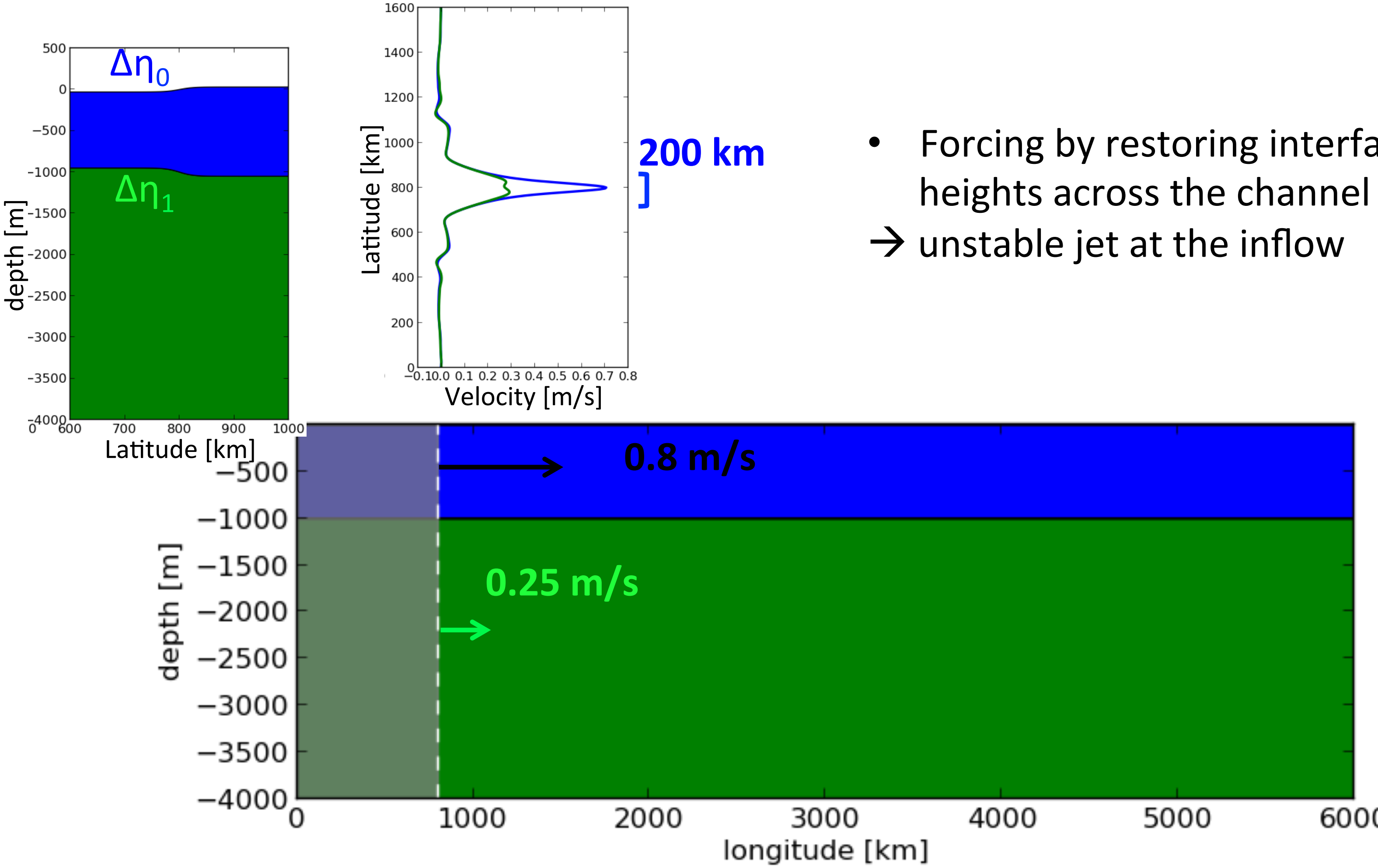
What processes control deep eddy kinetic energy?

2-layer isopycnal model

- 2-layer MOM6 (GFDL)
- Adiabatic
- β-plane channel configuration
- 4km horizontal resolution
- Interface heights are restored along the North and South boundaries.



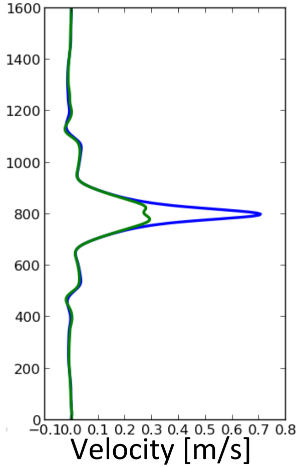
2-layer isopycnal model



- Forcing by restoring interface heights across the channel

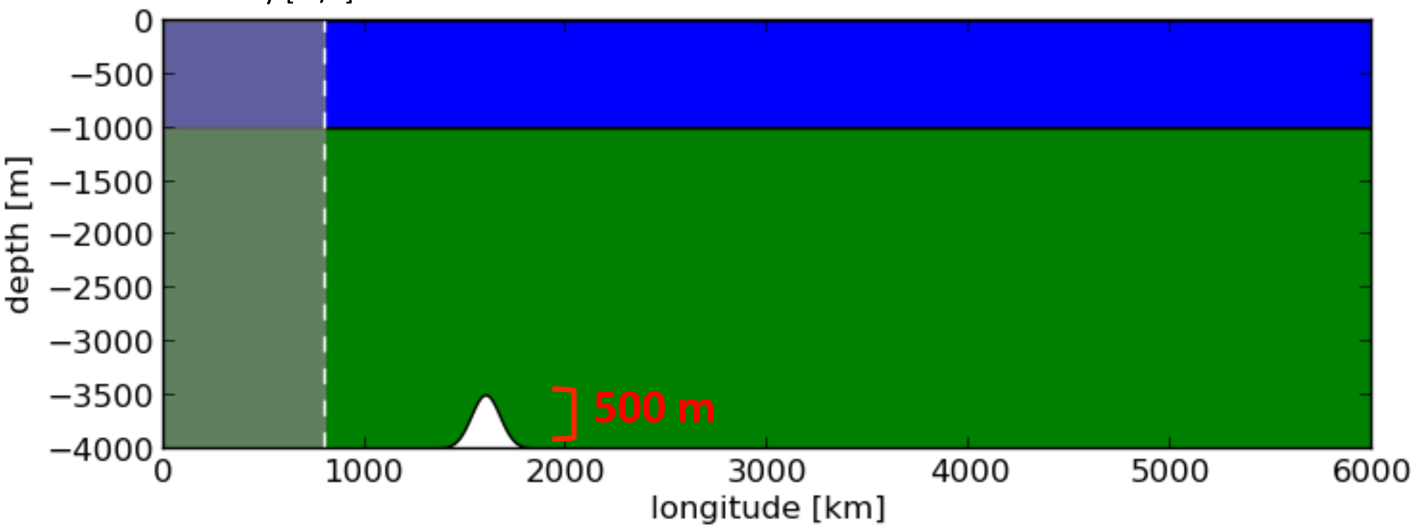
→ unstable jet at the inflow

2-layer isopycnal model



200 km

- Gaussian topography in the lower layer:
  - circular seamount
  - meridional ridge

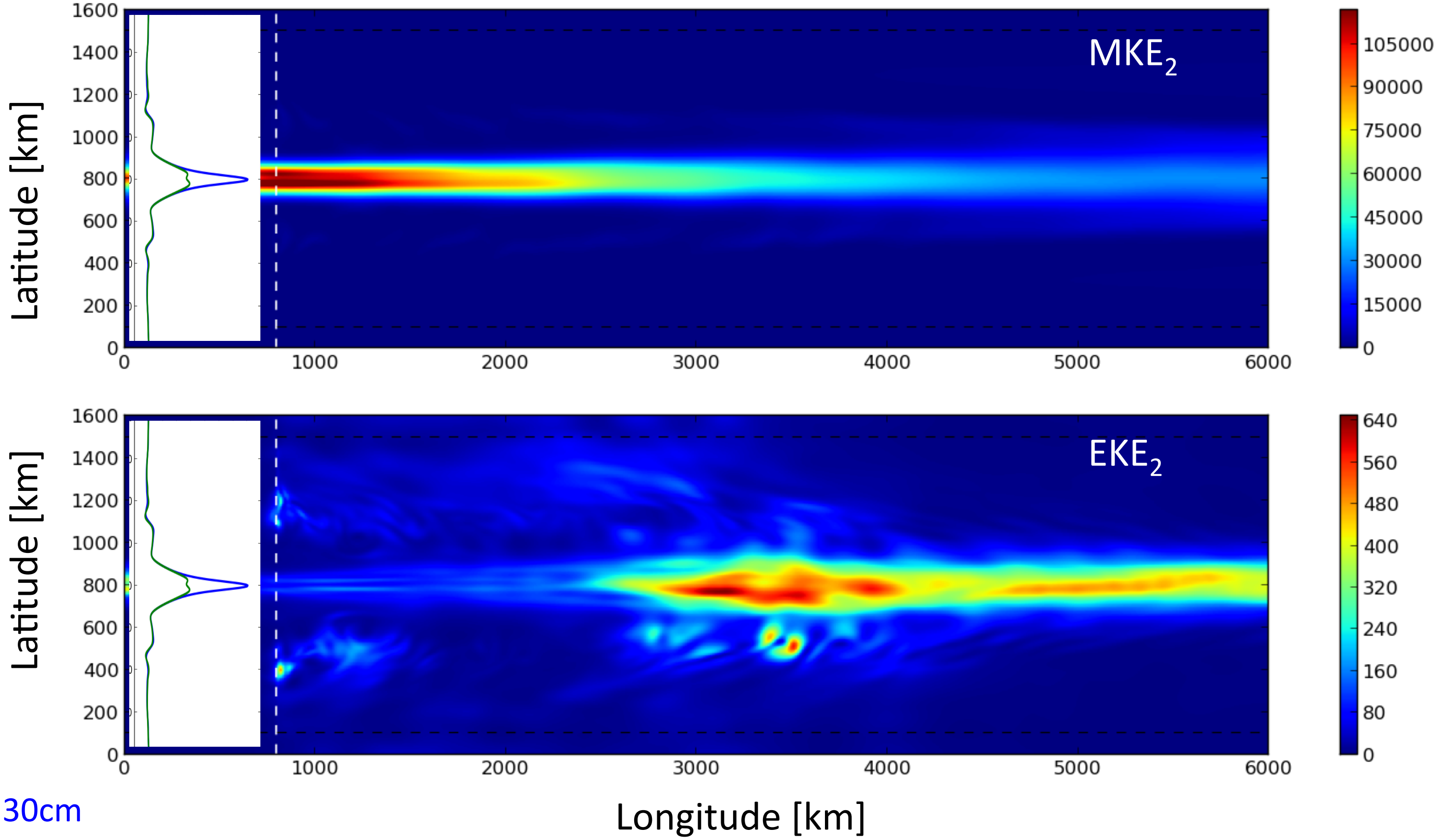


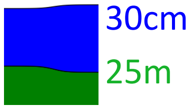
Questions

1. Does topography increase deep eddy kinetic energy (EKE_2)?
2. What are the energy pathways to EKE_2?
3. Is it dependent on the properties of the topography?
4. How sensitive is EKE_2 to the baroclinicity of the ACC jet?

1. Deep eddy kinetic energy

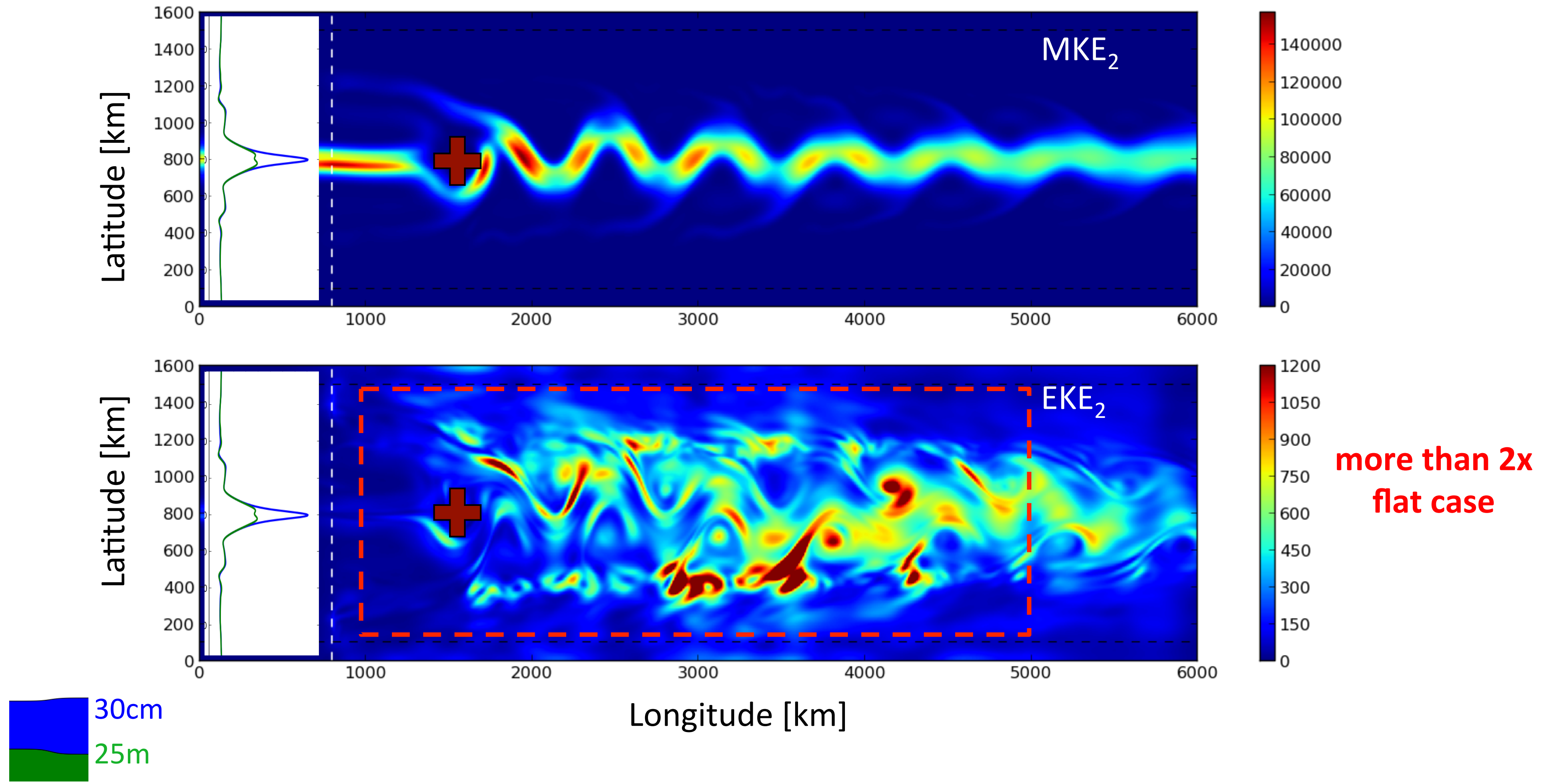
- Flat bottom:



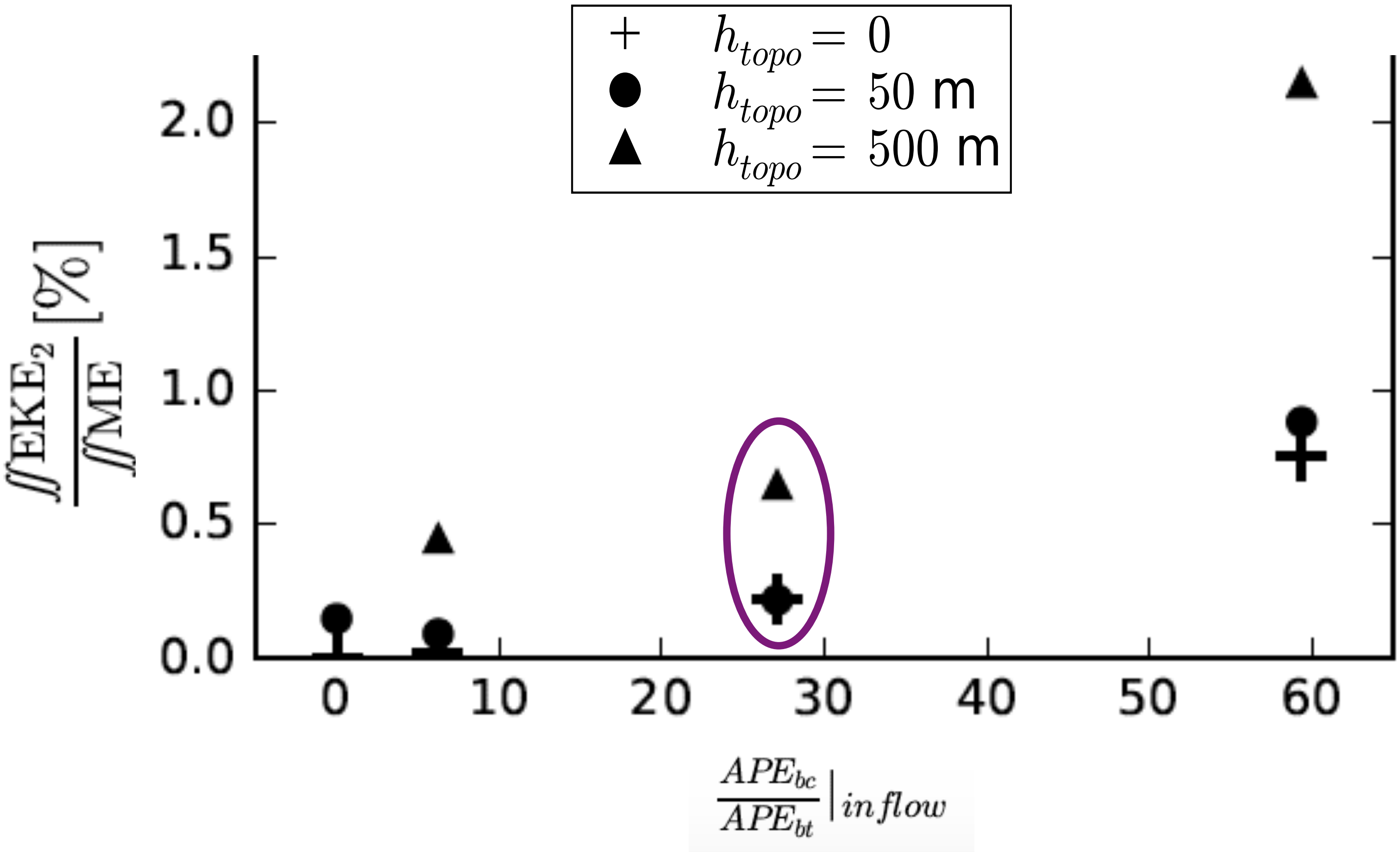


1. Deep eddy kinetic energy

- Interacting with a 500m-tall seamount:



1. A seamount increases deep EKE



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2) Pathways to EKE_2

Energetics in isopycnal framework

- Variable decomposition:

$$h = \overline{h} + h'$$ time-mean + 'eddies'

$$u = \hat{u} + u''$$ thickness-weighted mean + 'eddies'

- Energy terms:

$$\overline{KE_i} = \underbrace{\frac{\rho_0}{2}\overline{h_i}\left\|\hat{u}_i\right\|^2}_{MKE_i} + \underbrace{\frac{\rho_0}{2}\overline{h_i\left\|u_i''\right\|^2}}_{EKE_i}$$

Kinetic energy in layer *i*

2) Pathways to EKE_2

- Evolution of EKE_2:

advective

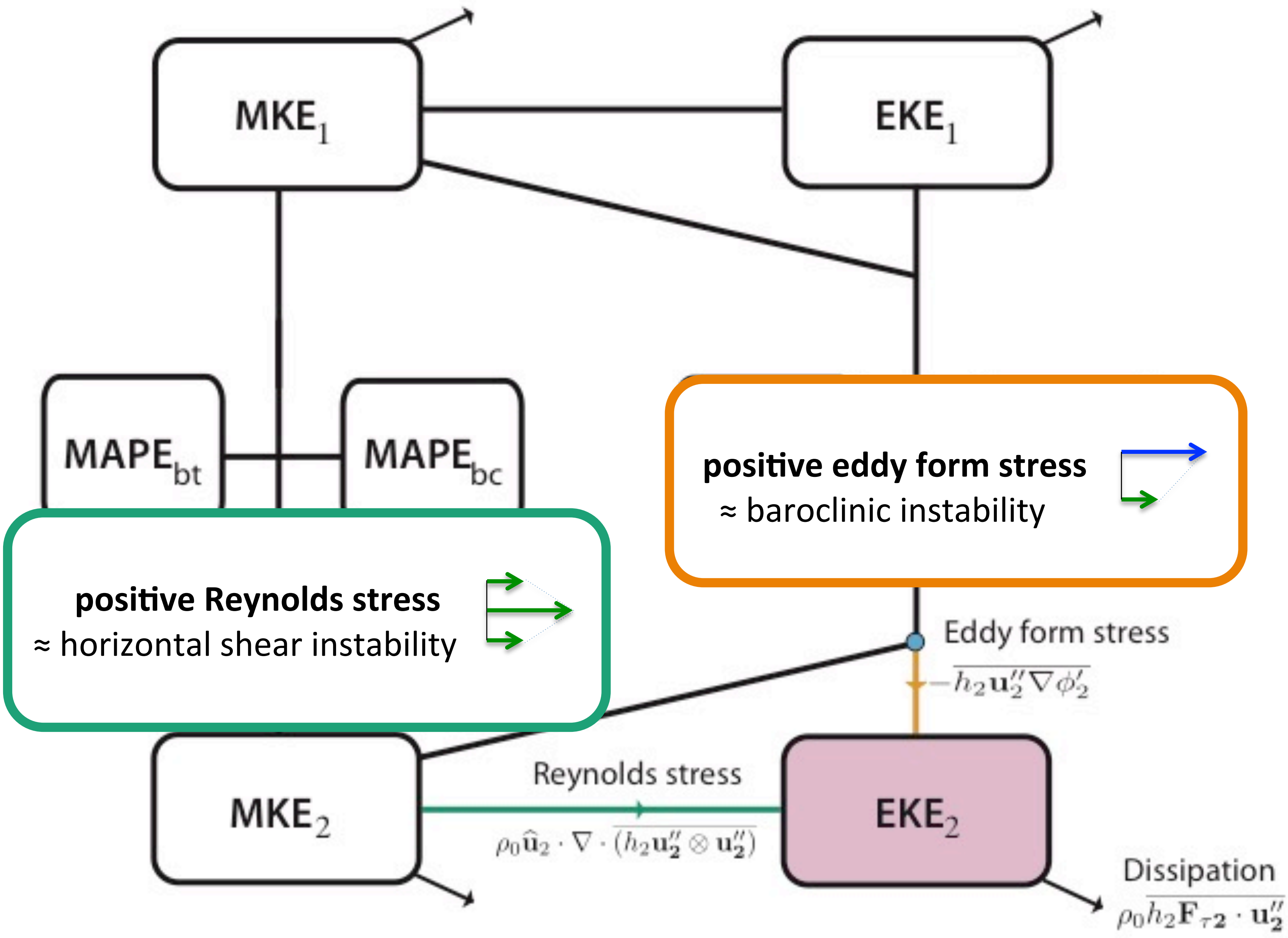
$$\partial_t EKE_2 = \boxed{-\nabla \cdot (\widehat{\mathbf{u}}_2 \, EKE_2) - \nabla \cdot (\overline{\mathbf{u}_2'' EKE_2})}$$

local conversion terms

$$-\overline{\mathbf{u}_2'' \cdot h_2 \nabla \phi_2'}$$ eddy form stress

$$+\rho_0 \widehat{\mathbf{u}}_2 \cdot \nabla \cdot \overline{(h_2 \mathbf{u}_2'' \otimes \mathbf{u}_2'')}$$ Reynolds stress

$$+\rho_0 \overline{h_2 F_{\tau 2} \cdot \mathbf{u}_2''}$$ dissipation

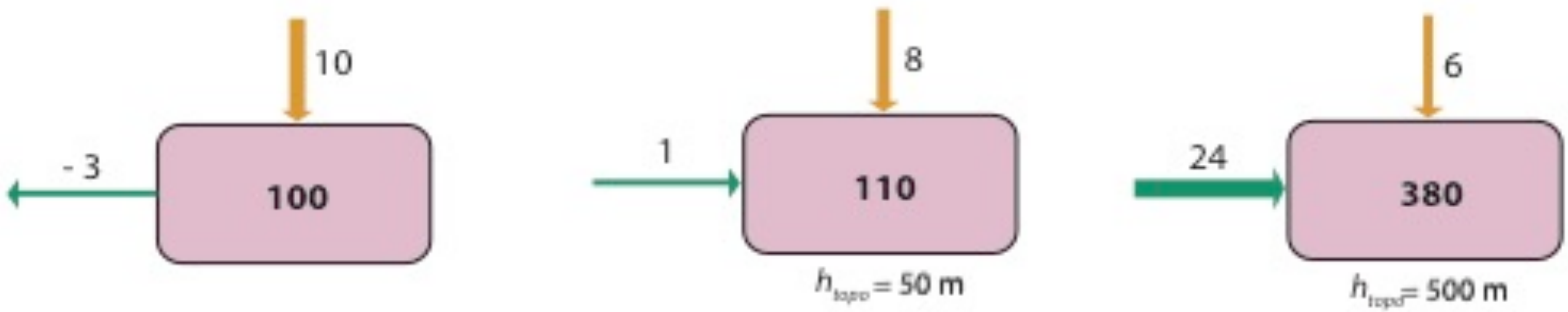


MKE$_1$
EKE$_1$
MAPE$_{bt}$
MAPE$_{bc}$
positive eddy form stress
≈ baroclinic instability
positive Reynolds stress
≈ horizontal shear instability
Eddy form stress
$-\overline{h_2 \mathbf{u}_2'' \nabla \phi_2'}$
Reynolds stress
$\rho_0 \widehat{\mathbf{u}}_2 \cdot \nabla \cdot \overline{(h_2 \mathbf{u}_2'' \otimes \mathbf{u}_2'')}$
MKE$_2$
EKE$_2$
Dissipation
$\rho_0 \overline{h_2 \mathbf{F}_{\tau 2} \cdot \mathbf{u}_2''}$

2) A seamount affect pathways to EKE_2

flat bottom

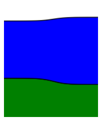
seamount of increasing height - - - - →



EKE (J m^{-2})

fluxes (10^{-6} W m^{-2})

For a given jet upstream, the presence of a seamount increases deep EKE… through horizontal shear.



Questions

1. Does topography increase deep eddy kinetic energy (EKE_2)?
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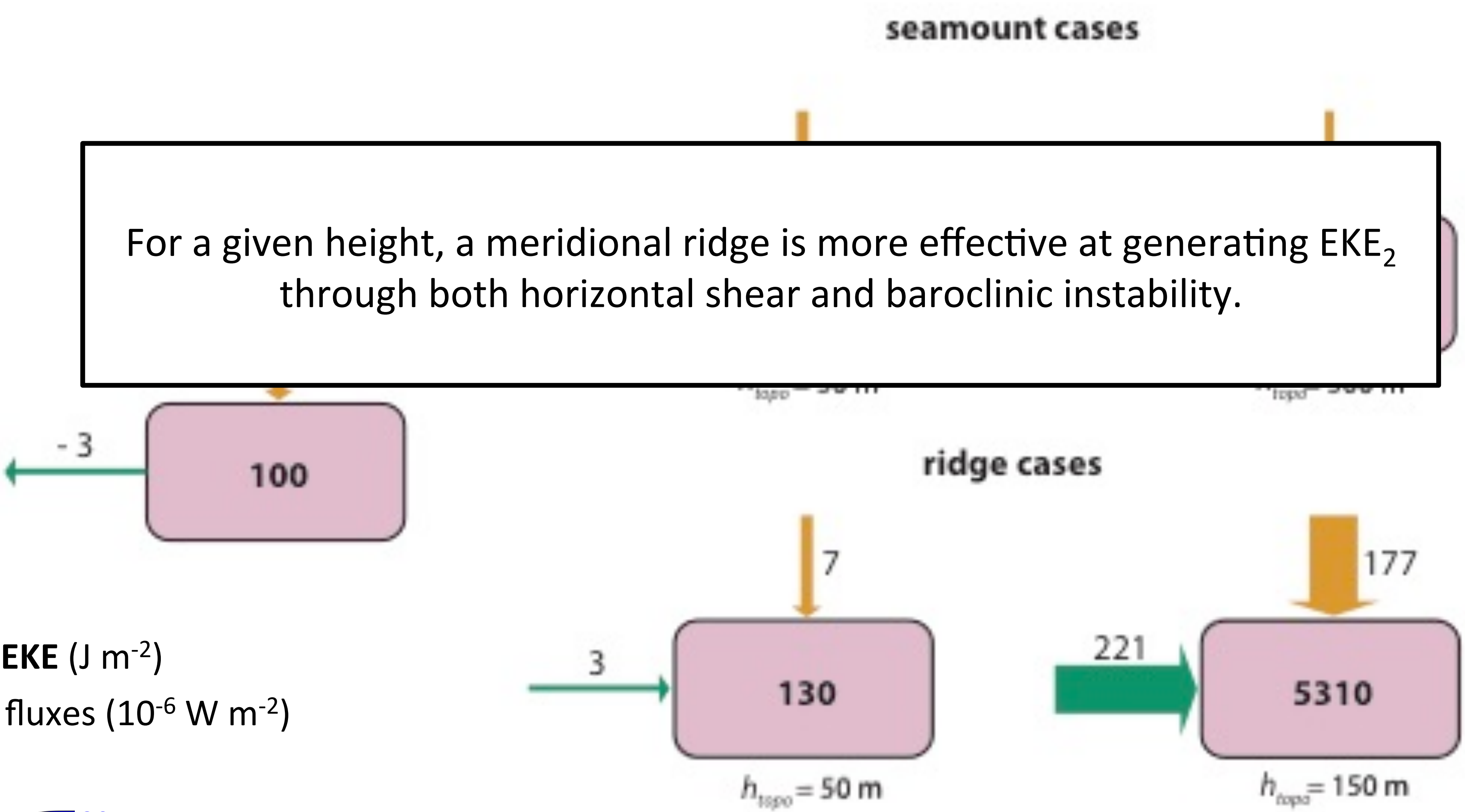
3) Impact of topography

For a given height, a meridional ridge is more effective at generating EKE_2 through both horizontal shear and baroclinic instability.



EKE (J m^{-2})

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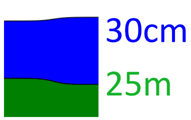

topography of increasing height - - - - →

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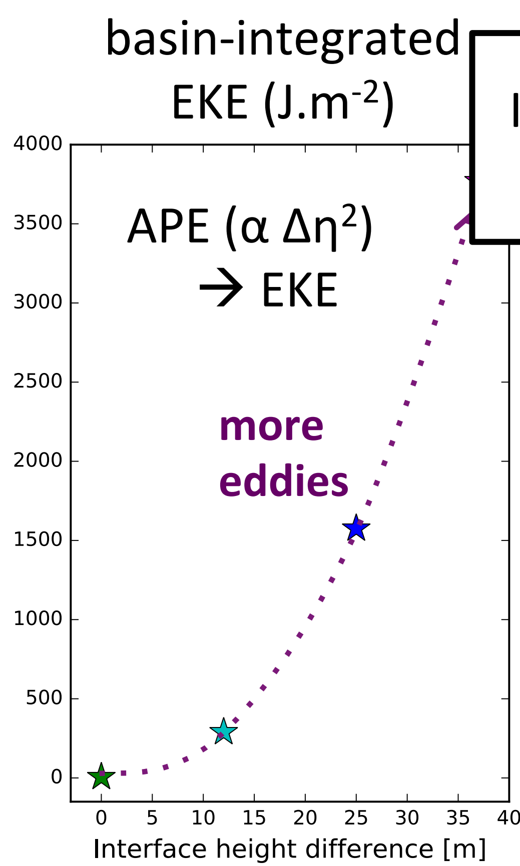
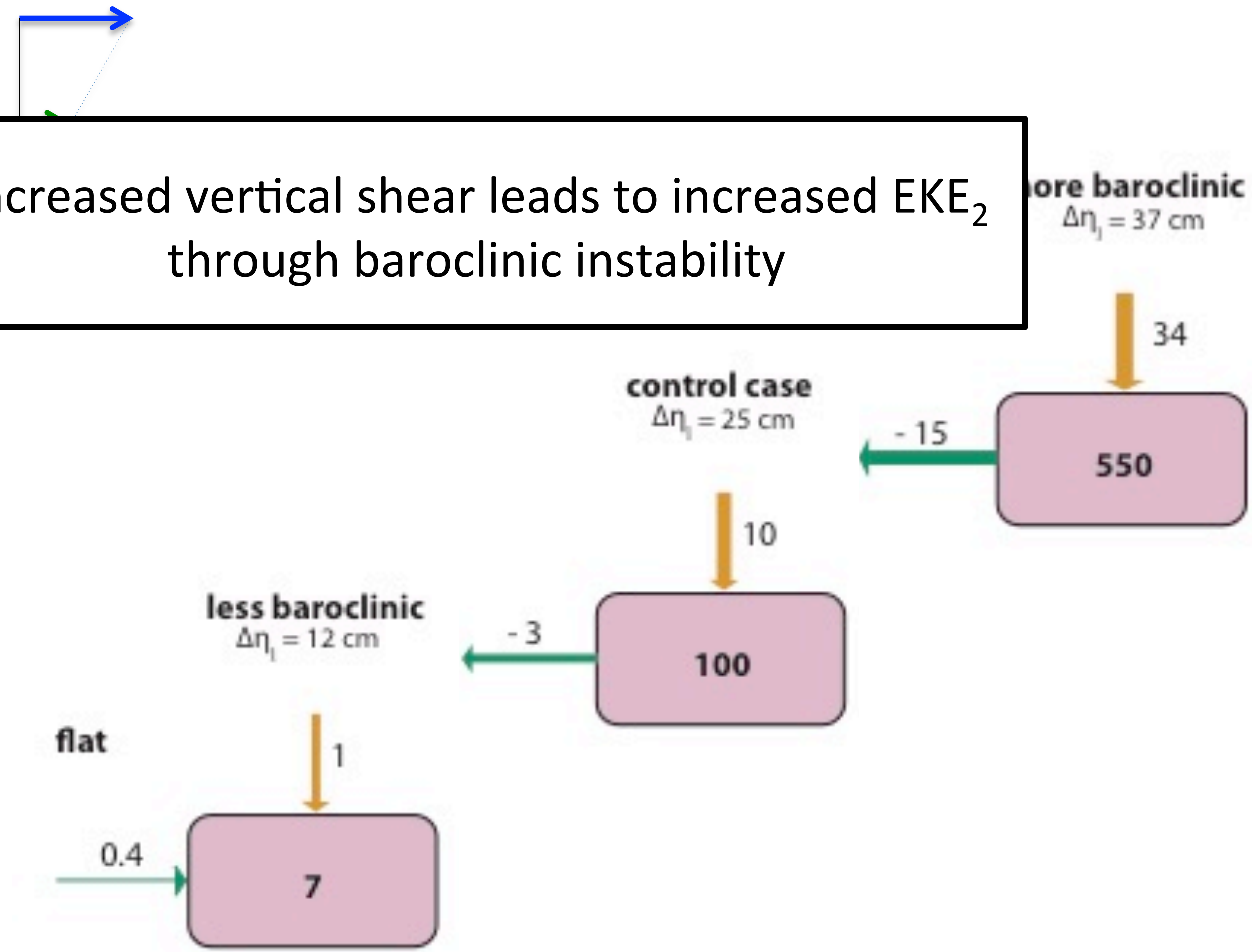
   Wind changes → baroclinic structure of ACC jets (*Langlais et al, 2015)*

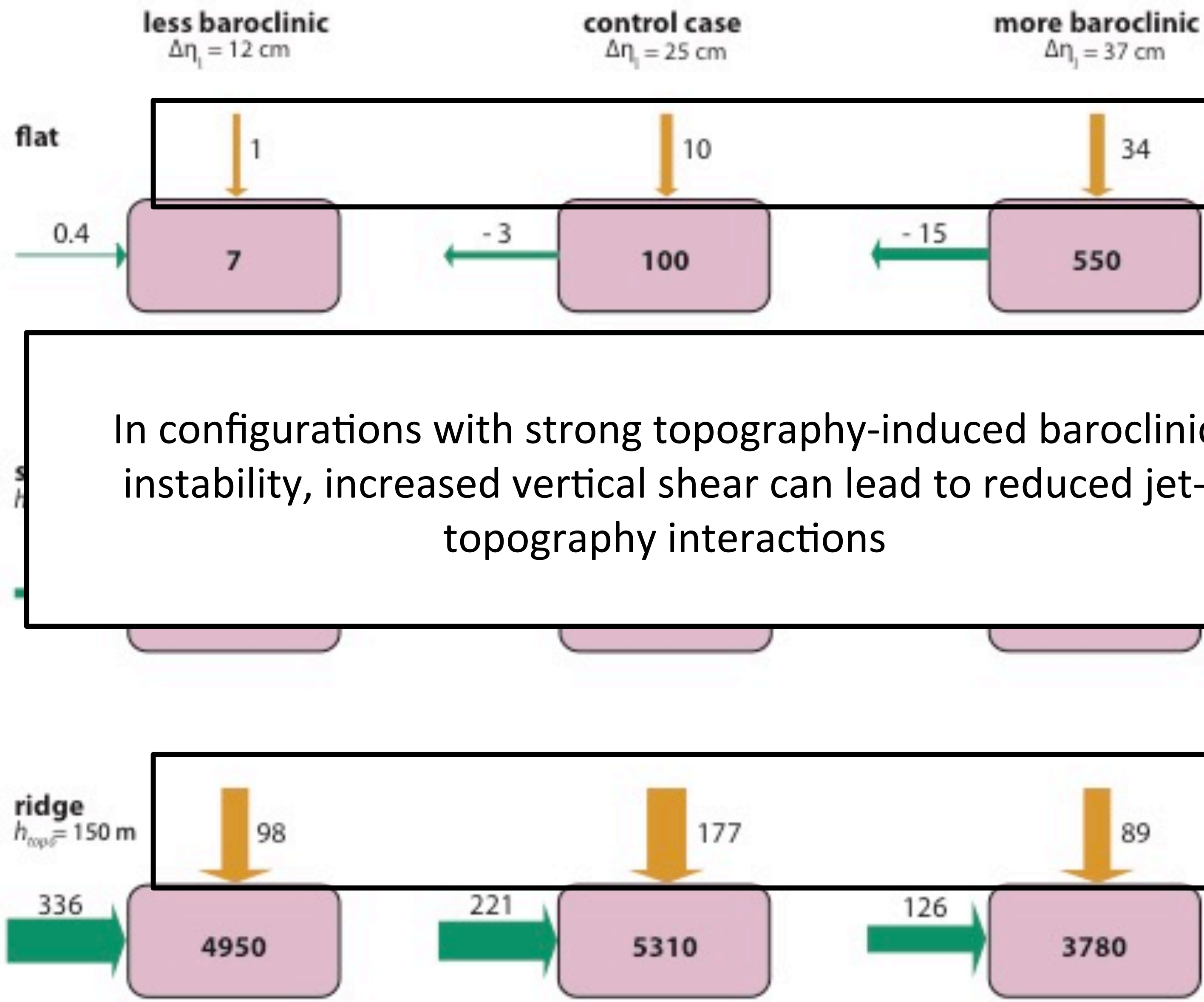
4) Sensitivity to jet baroclinicity



Increased vertical shear leads to increased EKE_2 through baroclinic instability



4) Sensitivity to jet baroclinicity



In configurations with strong topography-induced baroclinic instability, increased vertical shear can lead to reduced jet-topography interactions

Key messages

- High topography contributes to **higher eddy kinetic energy** in the lower layer.
- When high topography can be avoided (seamount), **barotropic-like processes** dominate as a source of EKE.
- **Topography shape matters**: a ridge leads to more EKE, from both barotropic and baroclinic processes.
- **Topography impacts the EKE response** to changes in the ACC jet. Interactions with topography have to be considered for future changes in Southern Ocean dynamics.

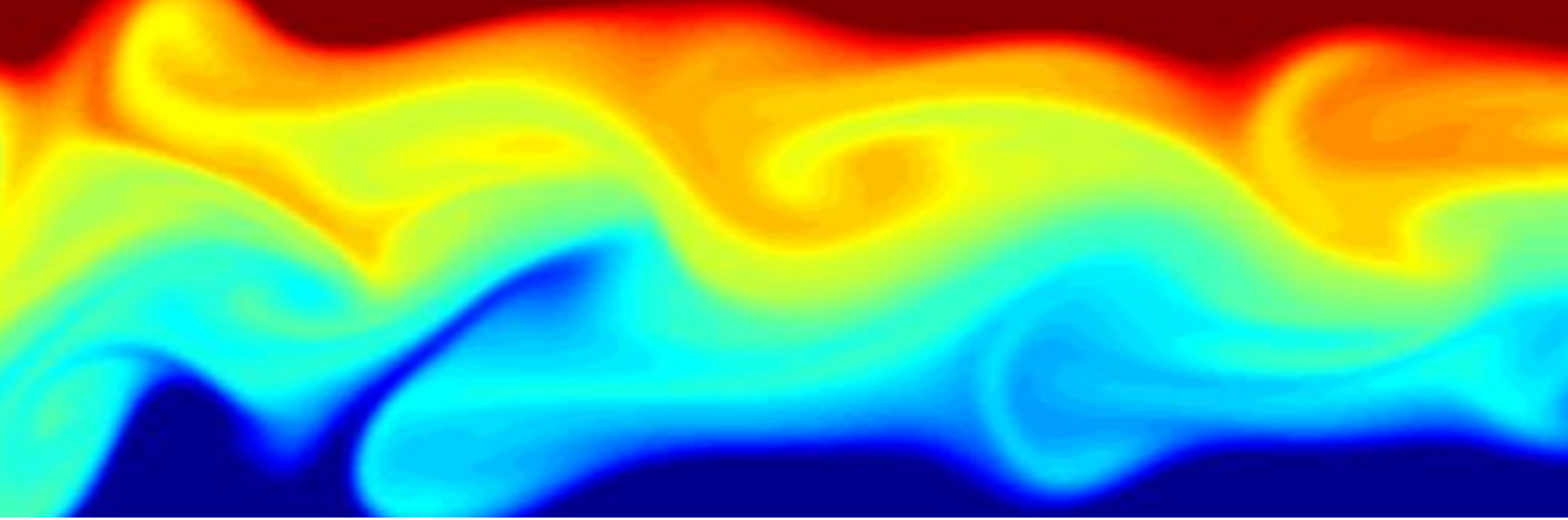
To know more…

- Contact: a.barthel@unsw.edu.au

- A. Barthel, A. M. Hogg, S. Waterman, S. Keating, *Jet-topography interactions affect energy pathways to the deep Southern Ocean*, Journal of Physical Oceanography, in press.

- Topographic control of eddy-driven upwelling

- What next?



Thank you for your attention.
Questions?