Turbulent Water Mass Exchanges Across the Antarctic Continental Slope

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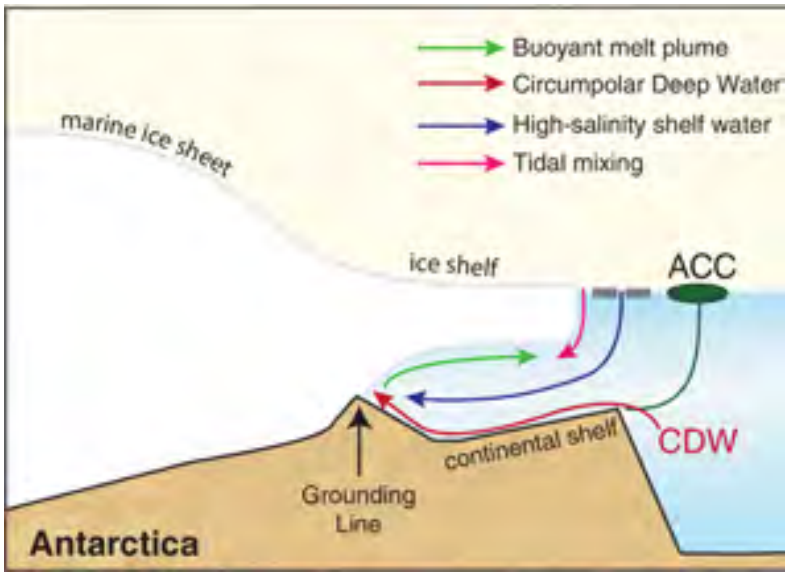
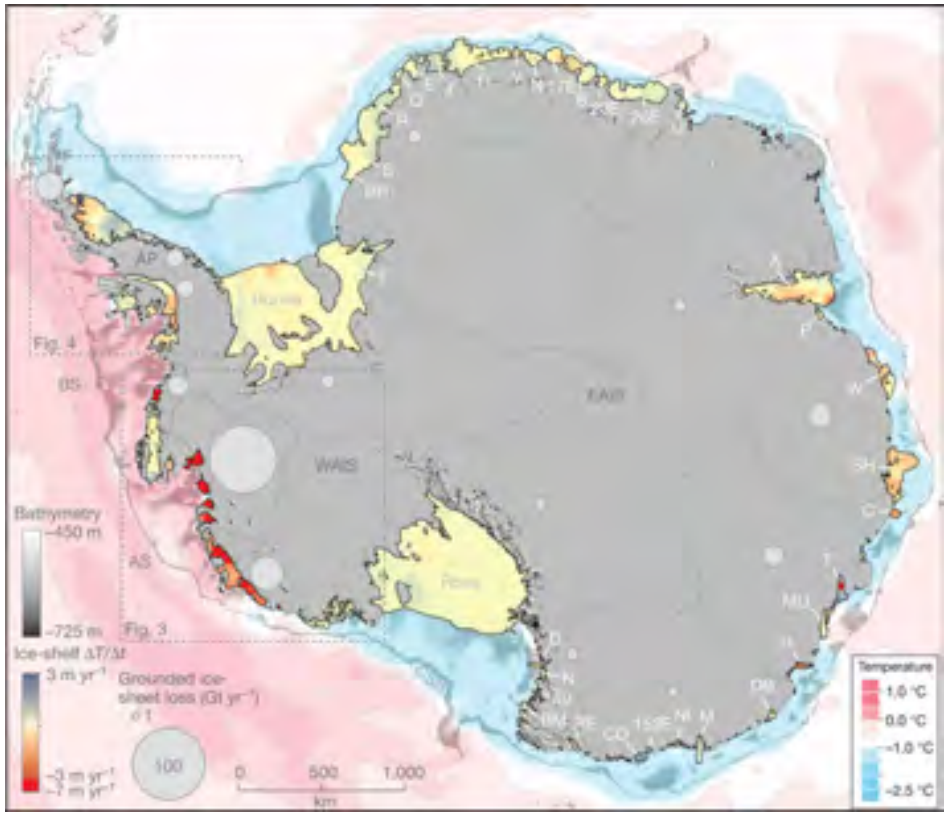
Heat transport beneath Antarctic ice shelves



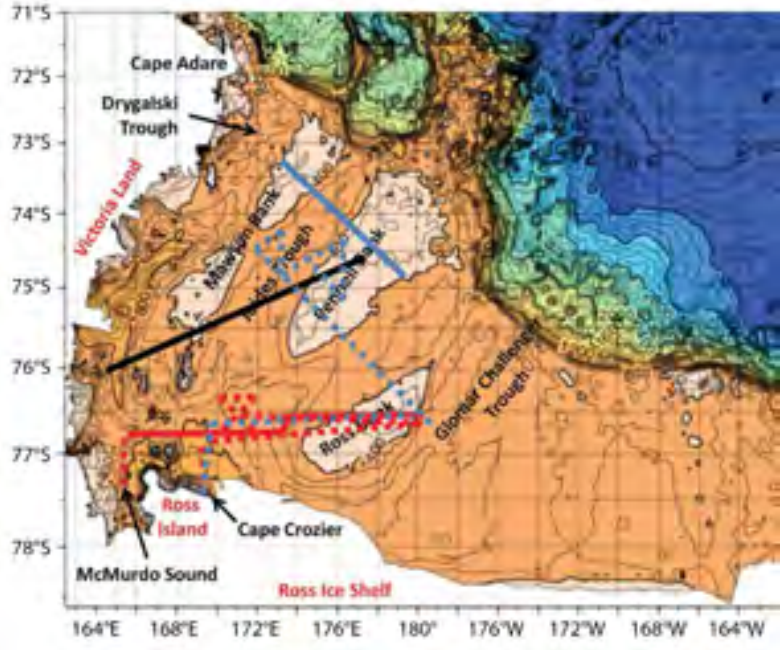
(Joughin et al., Science 2012)



(Pritchard et al., Nature 2012)

- Antarctica is encircled by warm ($\sim 1^{\circ}\mathrm{C}$) Circumpolar Deep Water.
- In the Amundsen and Bellingshausen Seas, CDW floods the continental shelf, leading to basal melt rates $> 10\mathrm{m/yr}$.
- The CDW also supplies nutrients that support coastal ecosystems on the West Antarctic Peninsula (Prezelin et al., J. Mar. Res. 2000).

Phytoplankton blooms in the Ross Sea



(Smith et al., Oceanogr. 2014)

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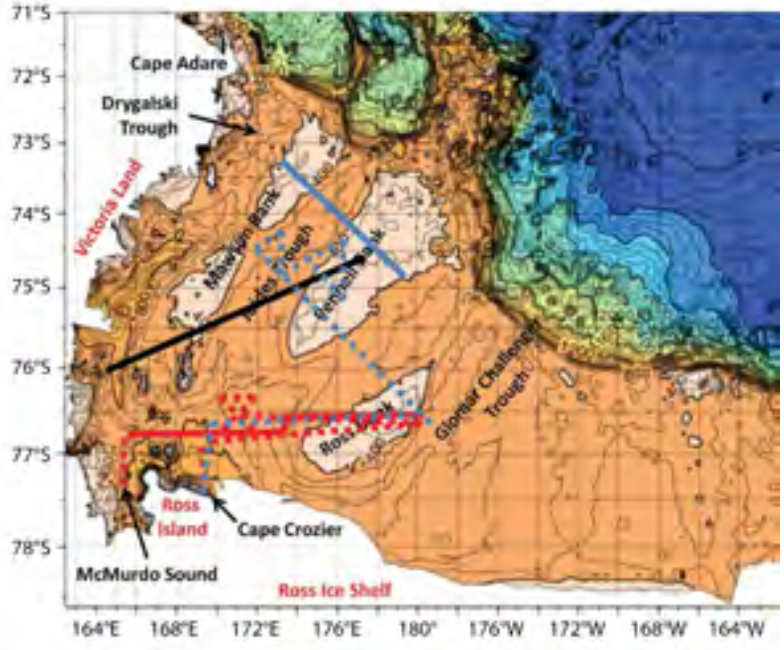

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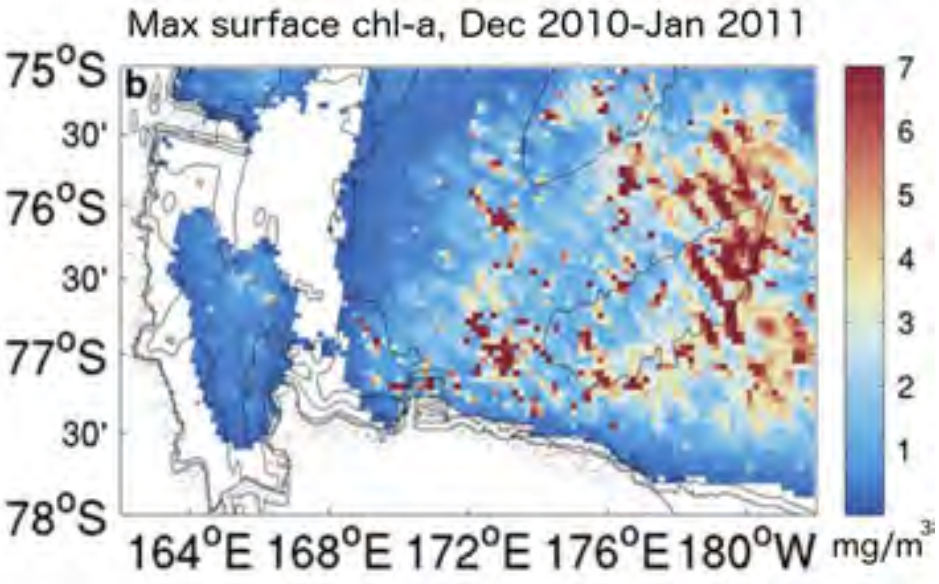

(Queste et al., Ant. Sci. 2015)

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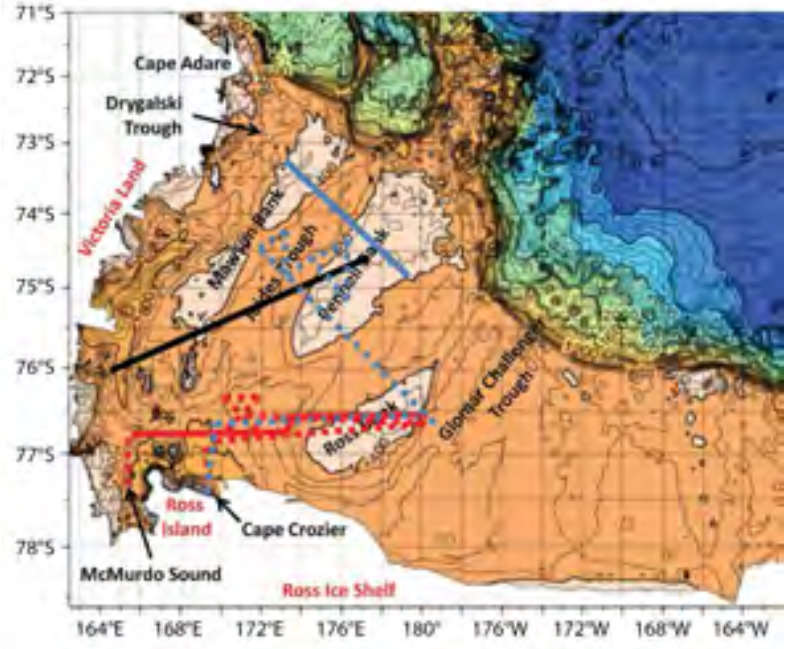
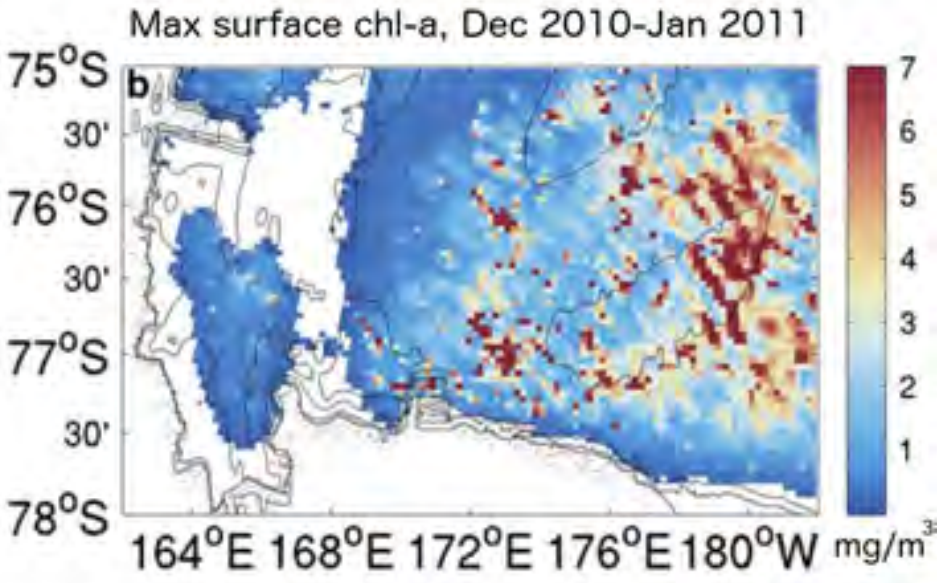
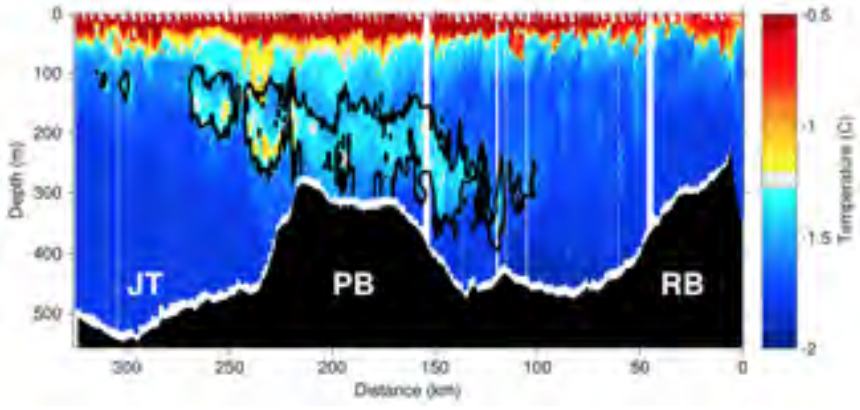


(Smith et al., Oceanogr. 2014)



(Queste et al., Ant. Sci. 2015)



(Kohut et al., J. Geophys Res. 2013)

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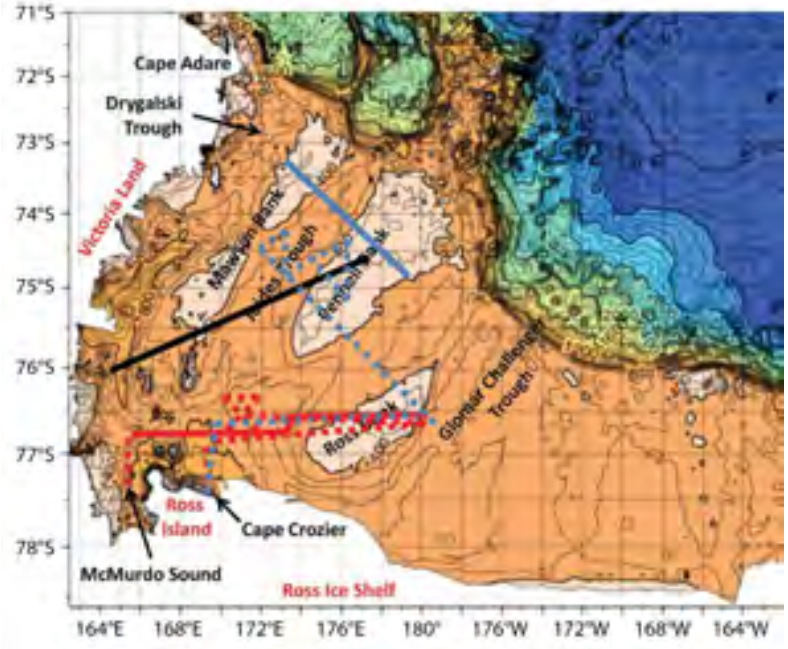

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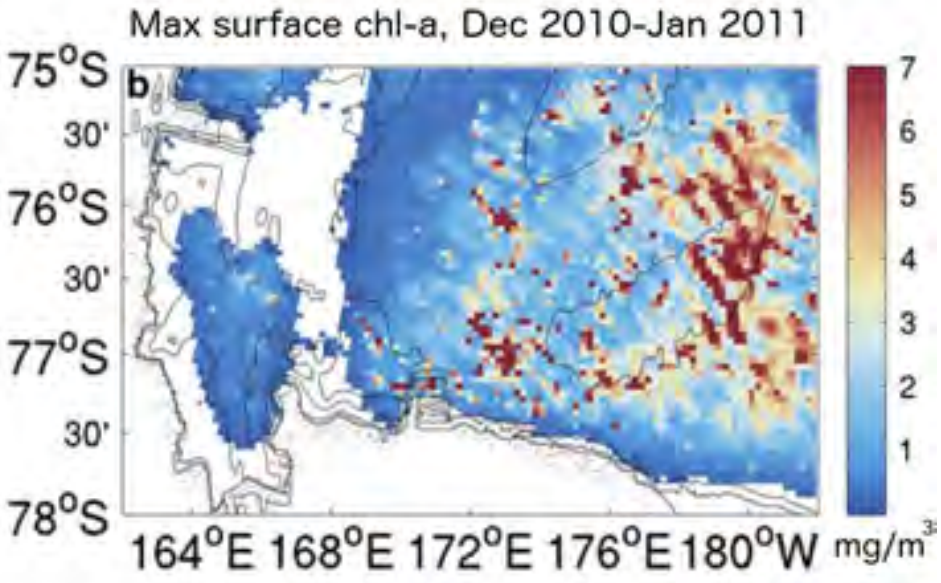
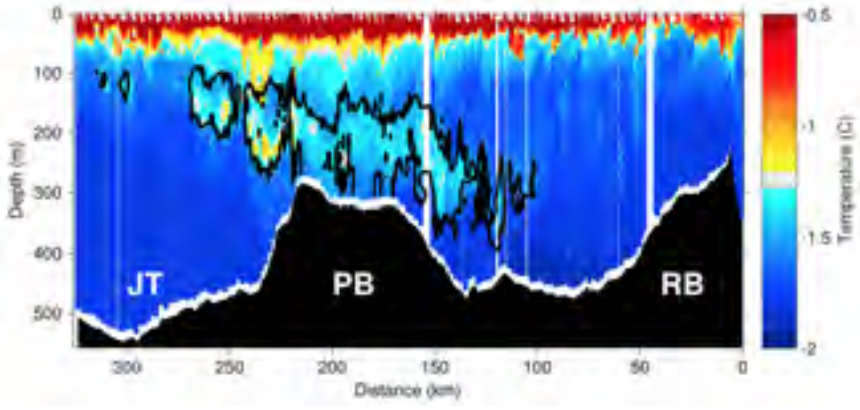


(Queste et al., Ant. Sci. 2015)



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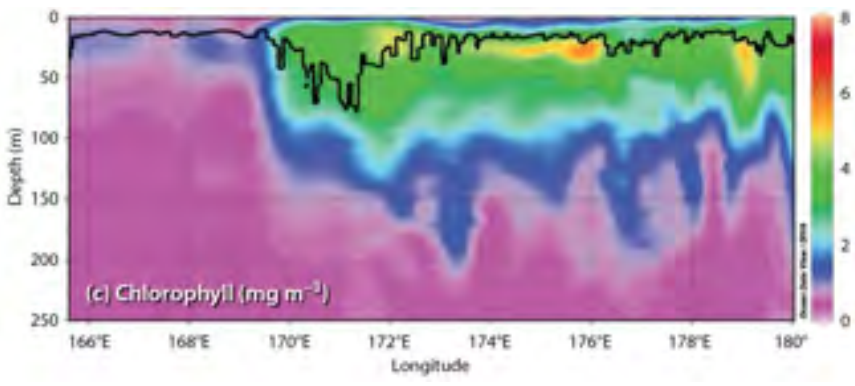
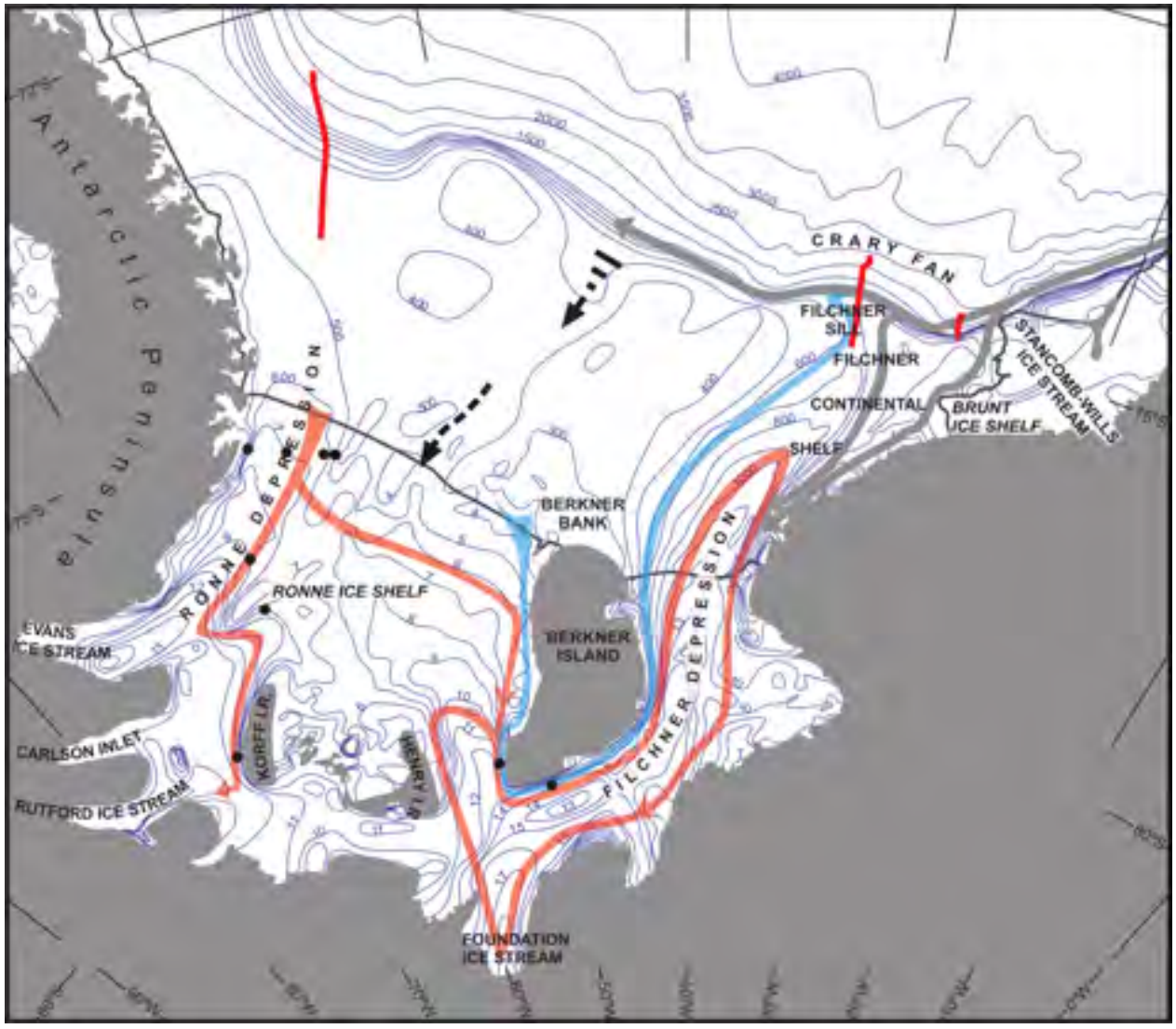
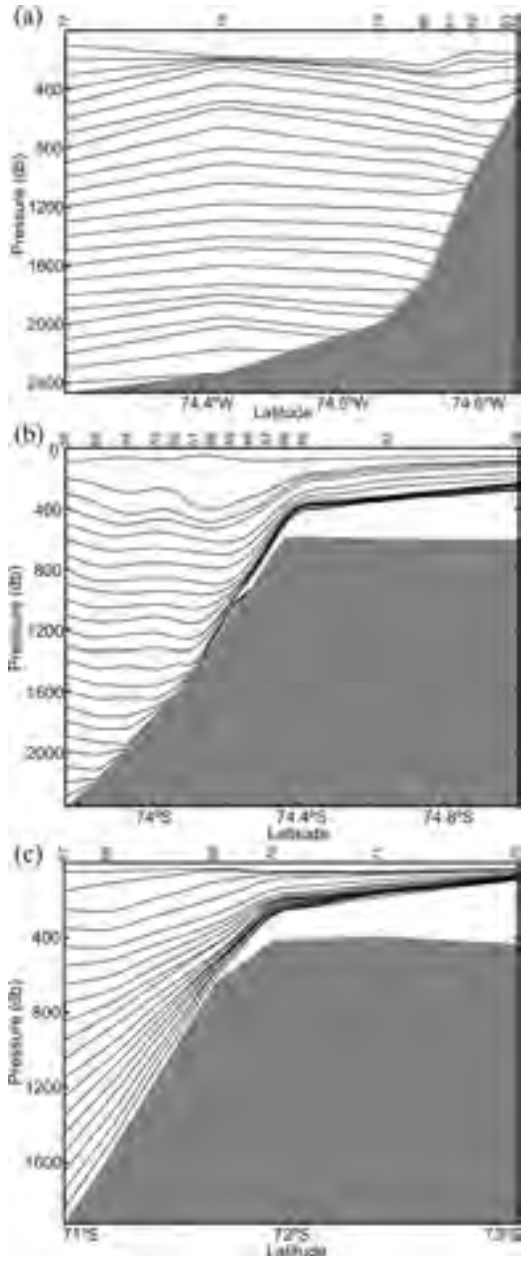


(Smith et al., Oceanogr. 2014)

Antarctic Bottom Water formation





(Nicholls et al., Rev. Geophys. 2009)

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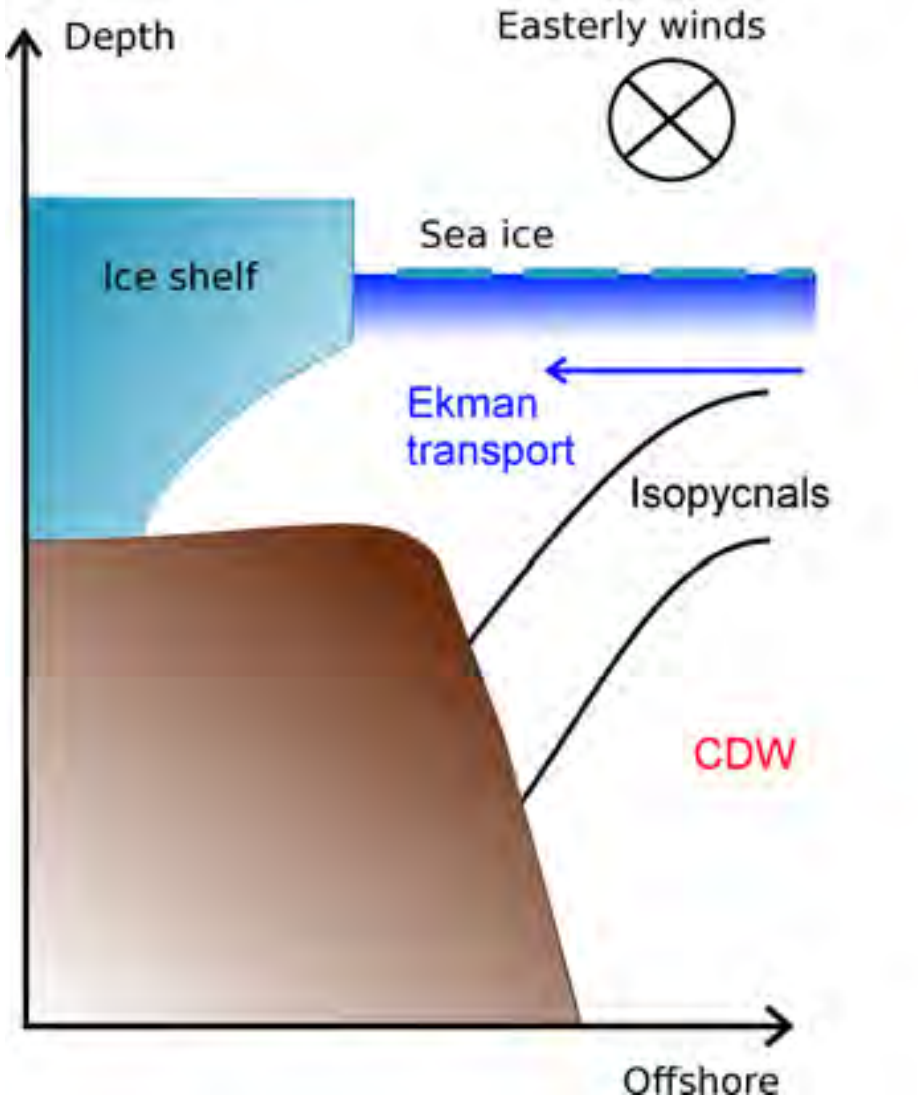

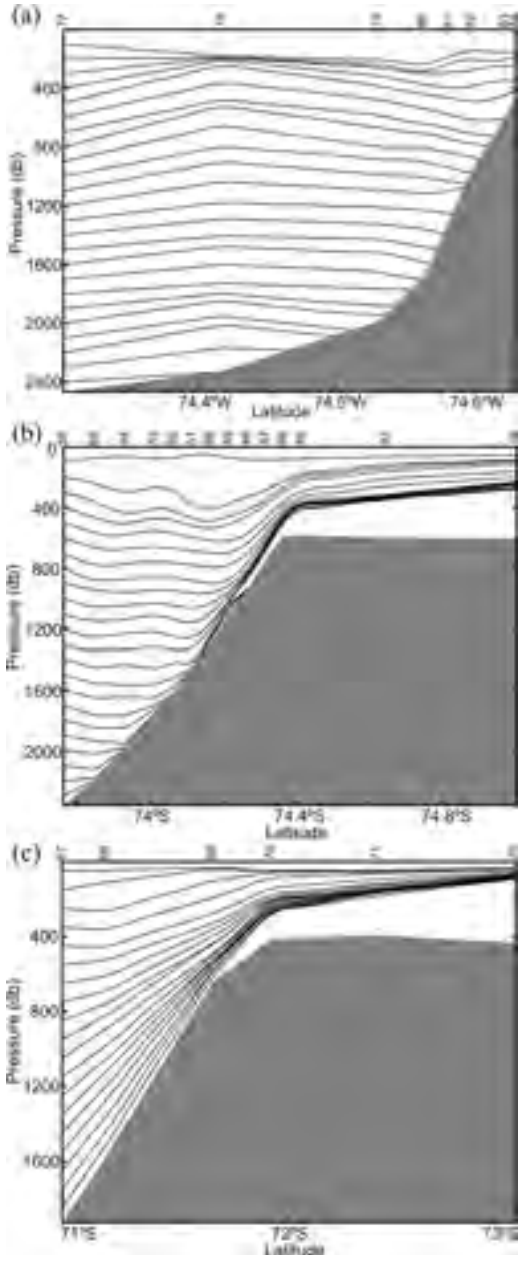

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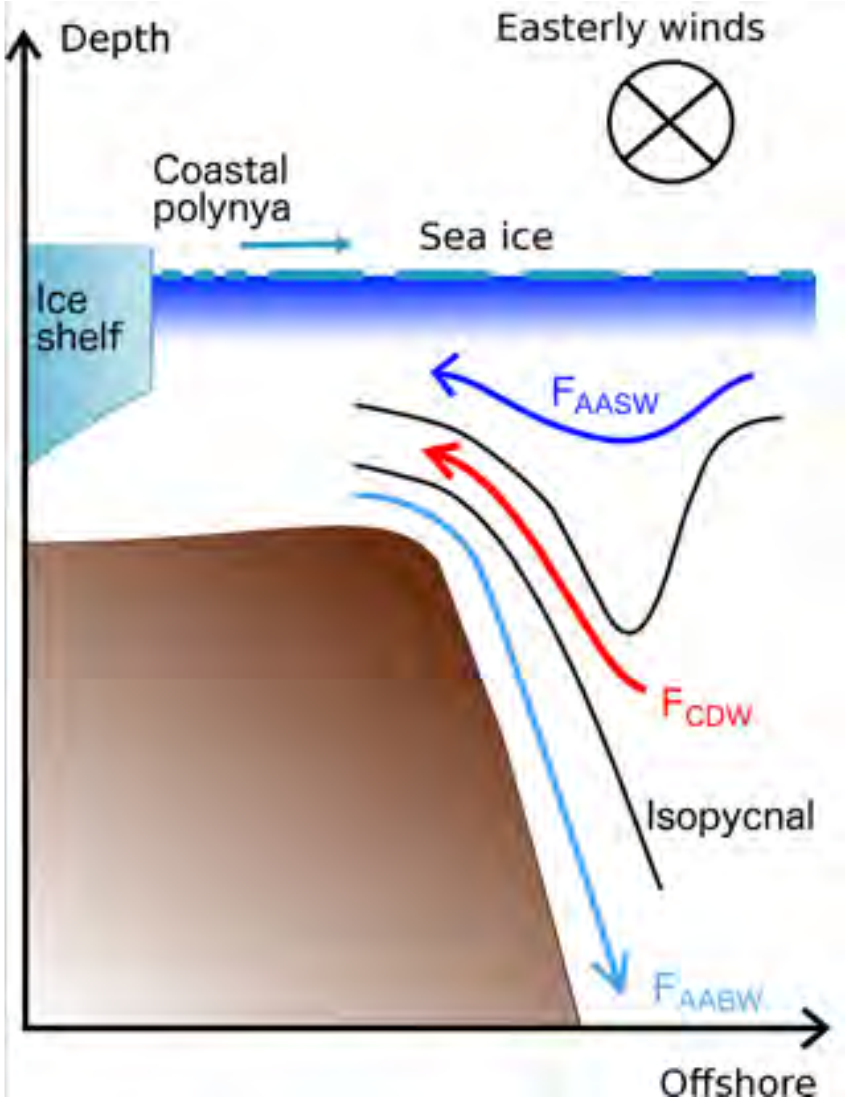
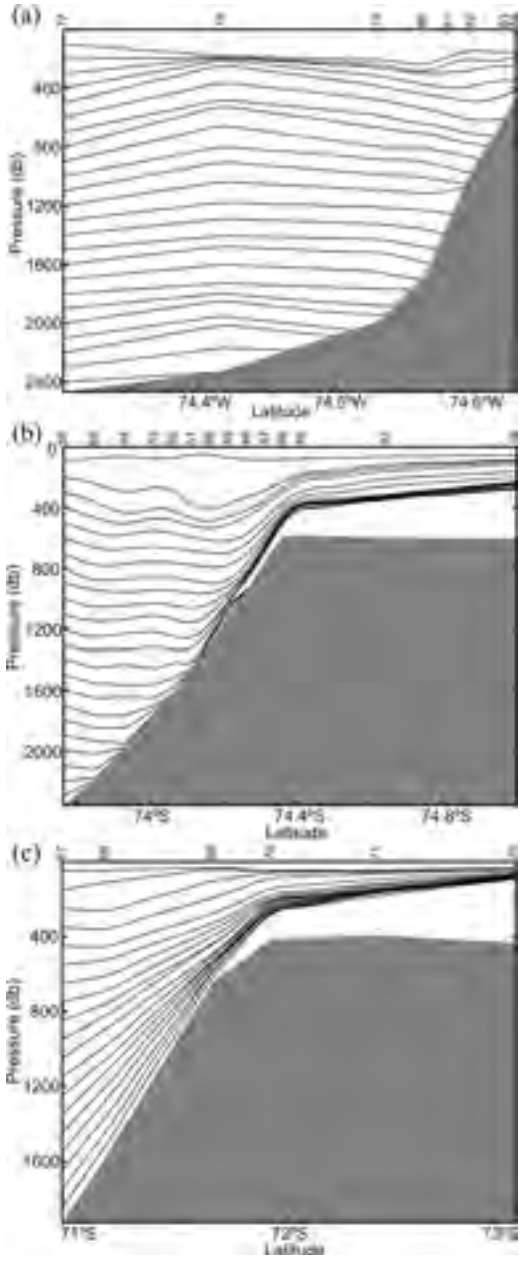
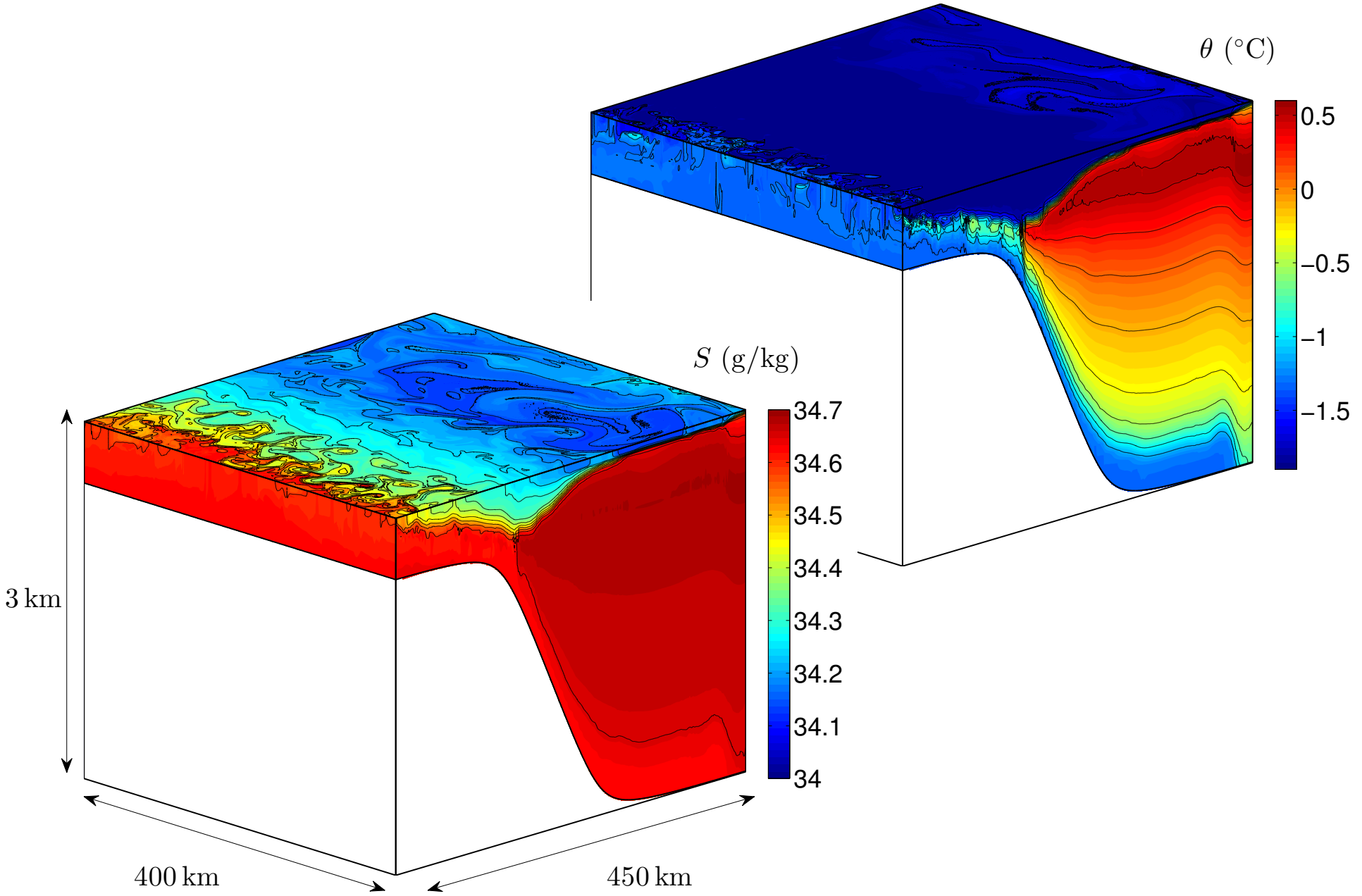


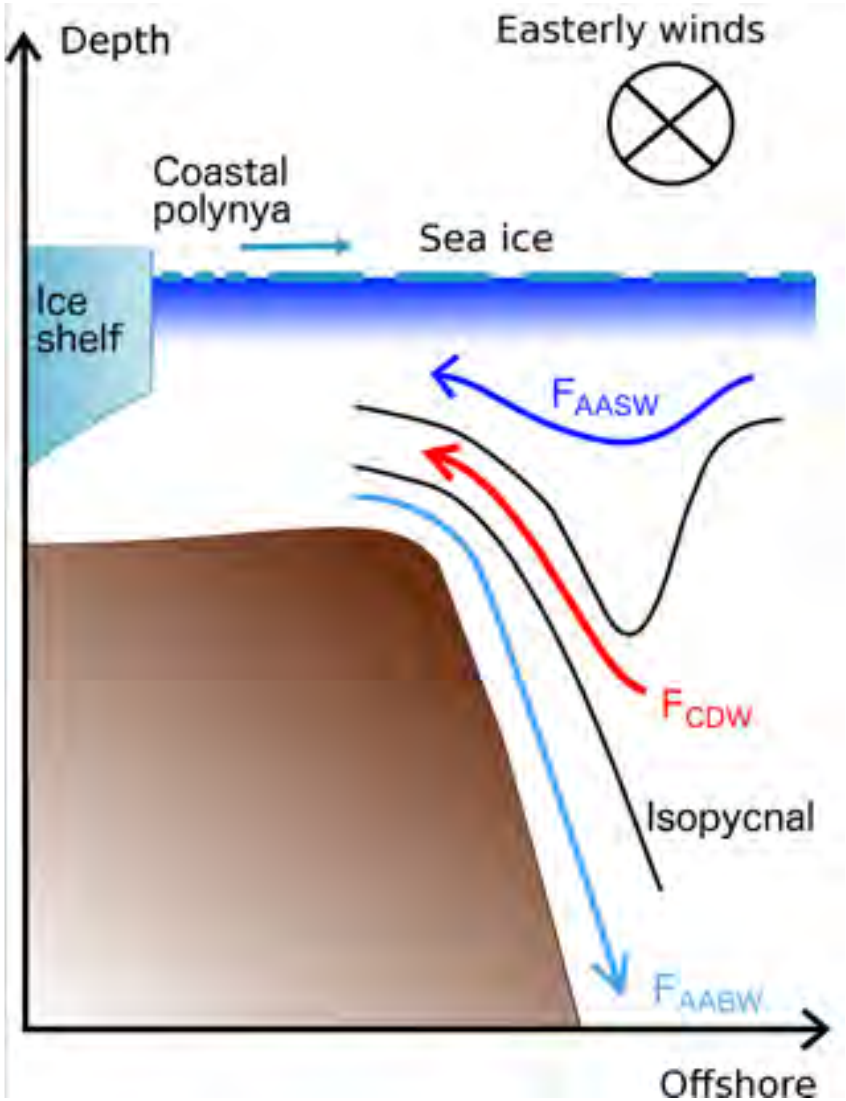


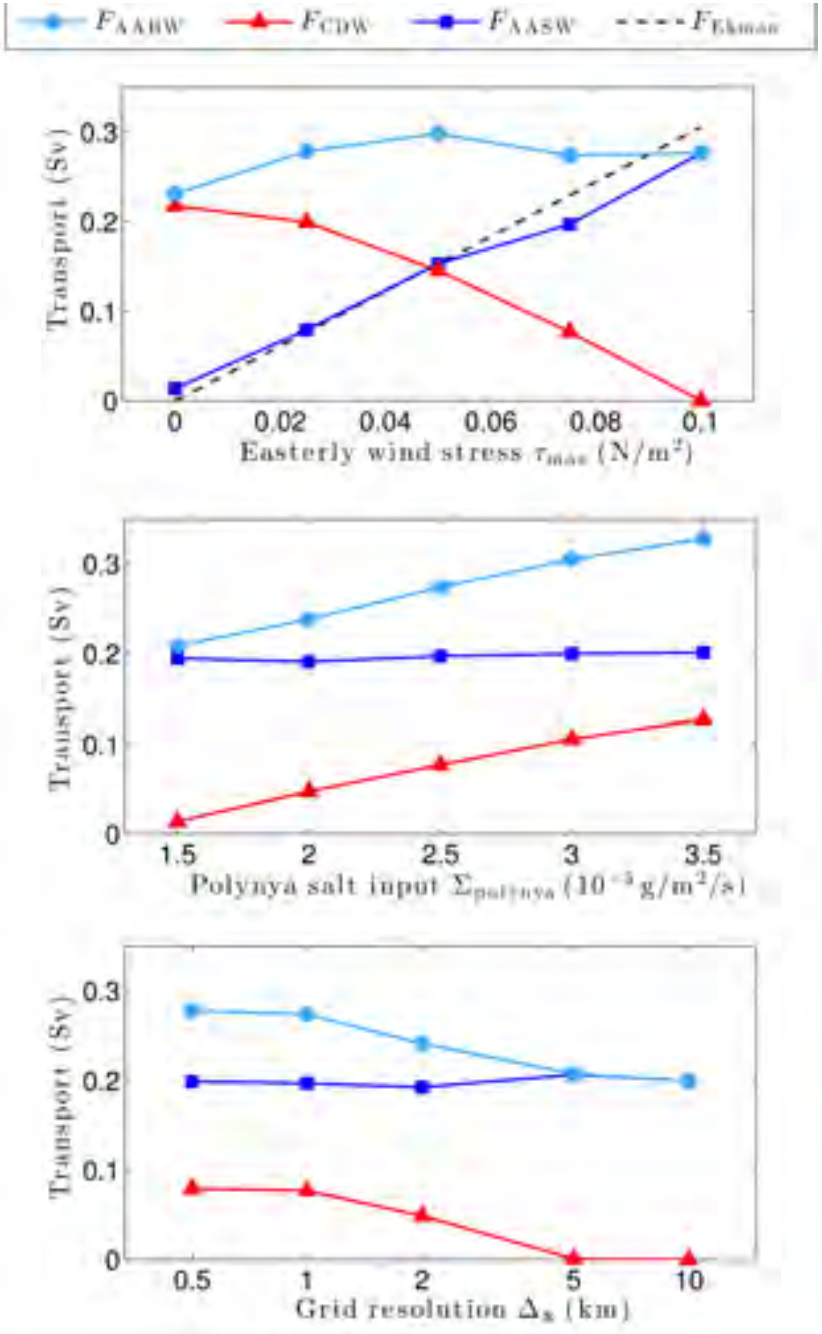
(Stewart and Thompson, GRL 2015)

An eddy-resolving model of the ASF

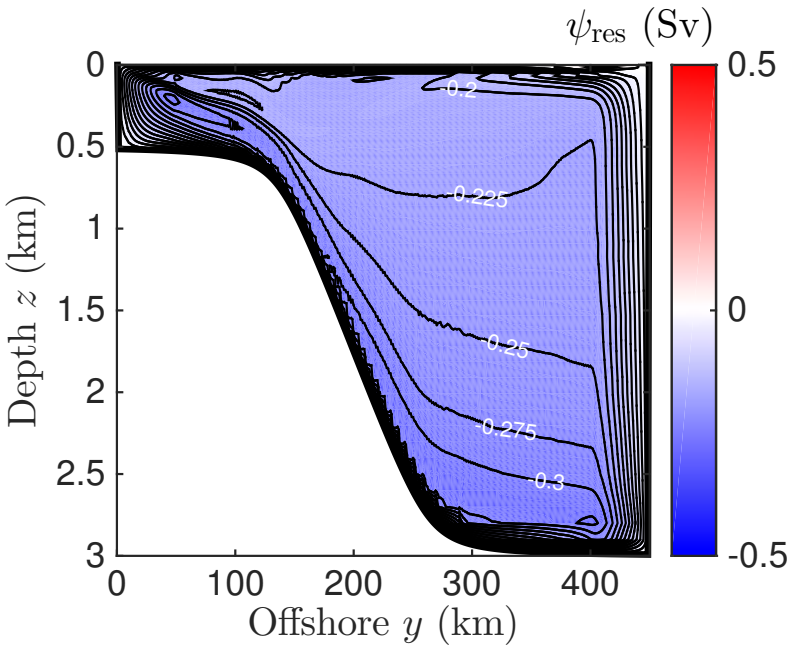


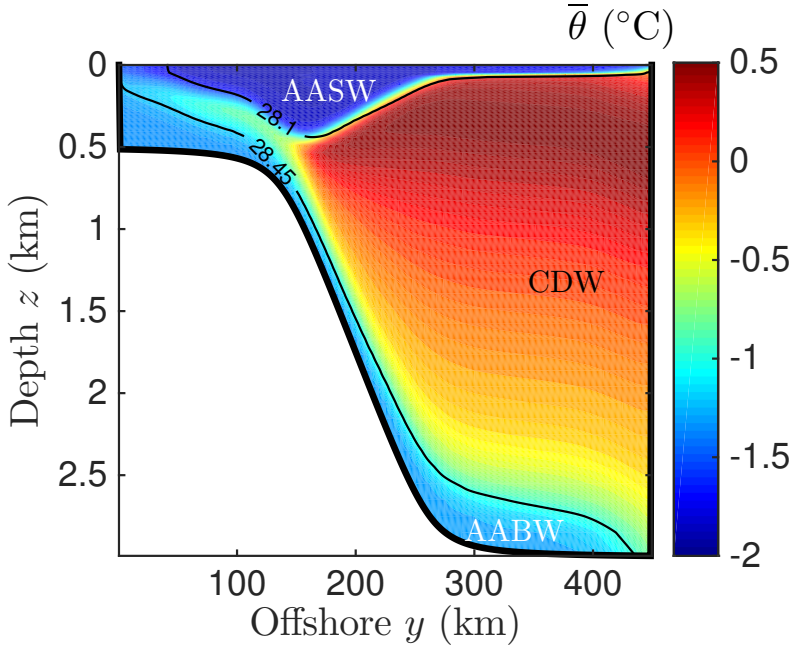
Sensitivity of shoreward CDW transport





Mean/eddy water mass exchange





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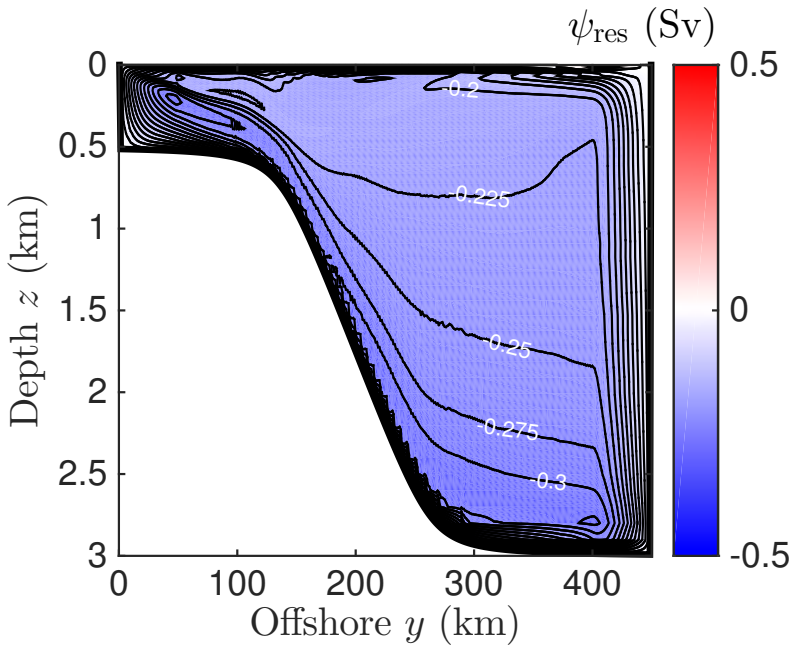
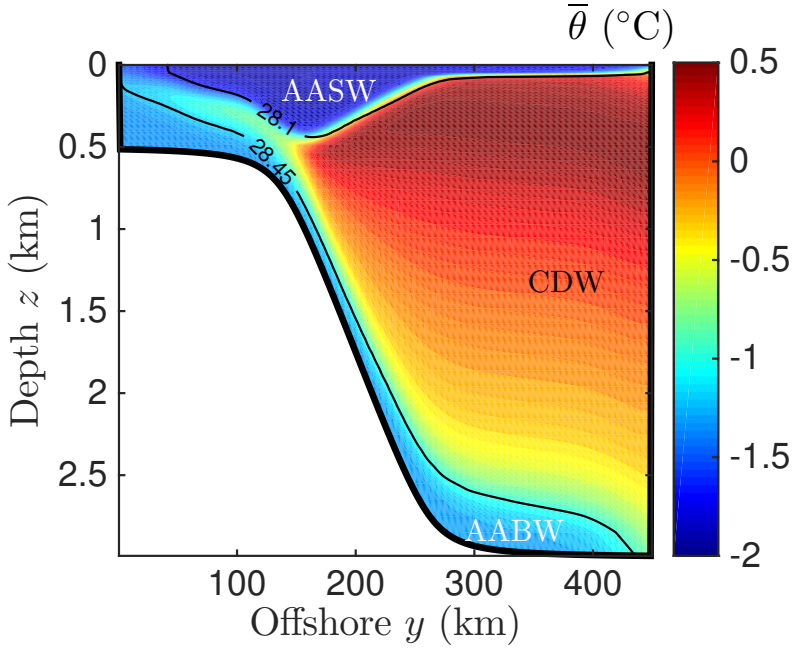
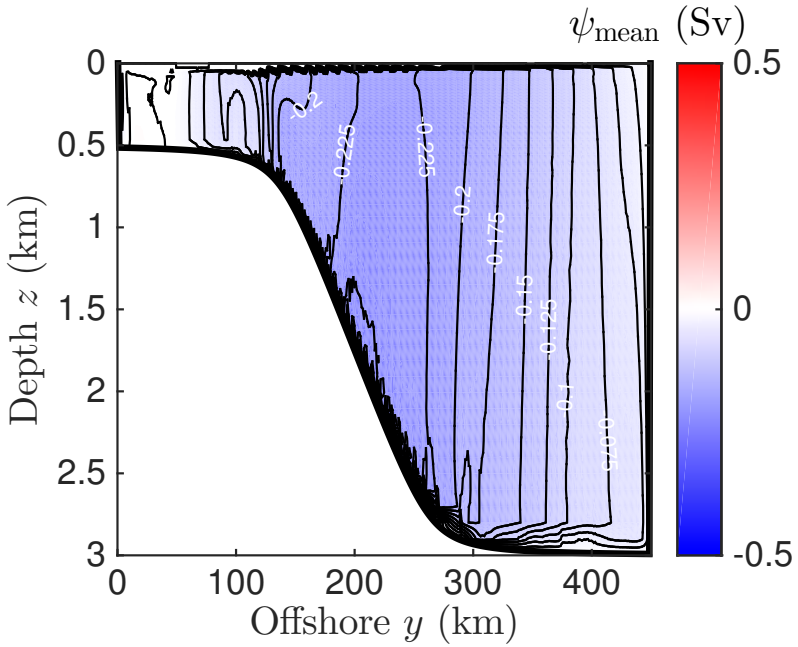
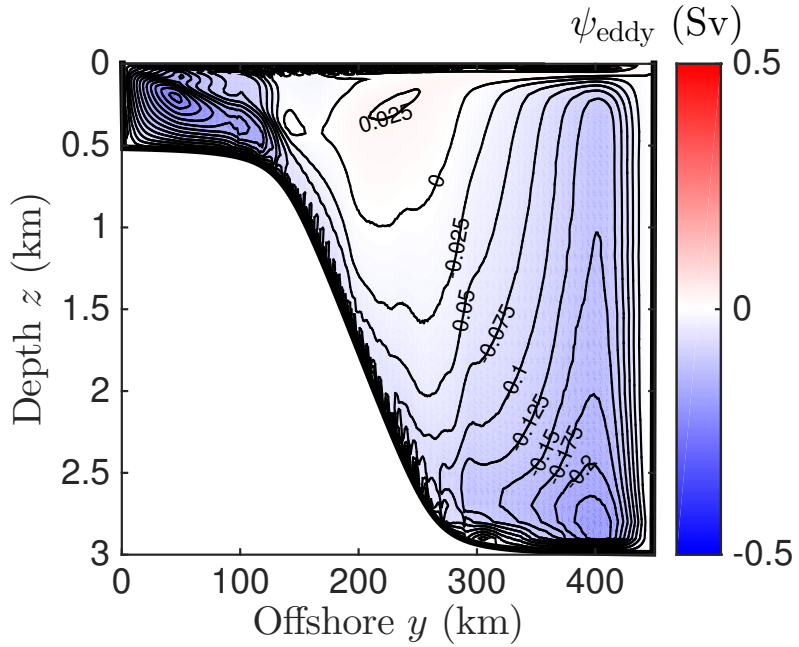
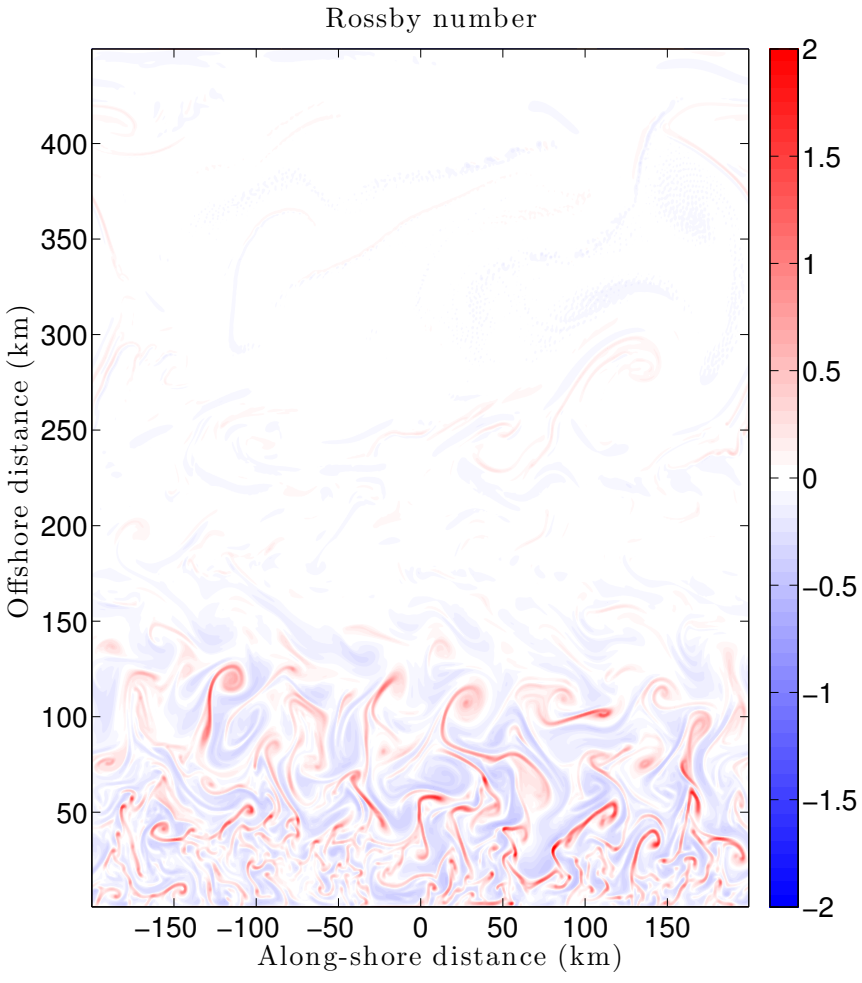








Submesoscale eddy transport of CDW



- Snapshot of the surface Rossby number.

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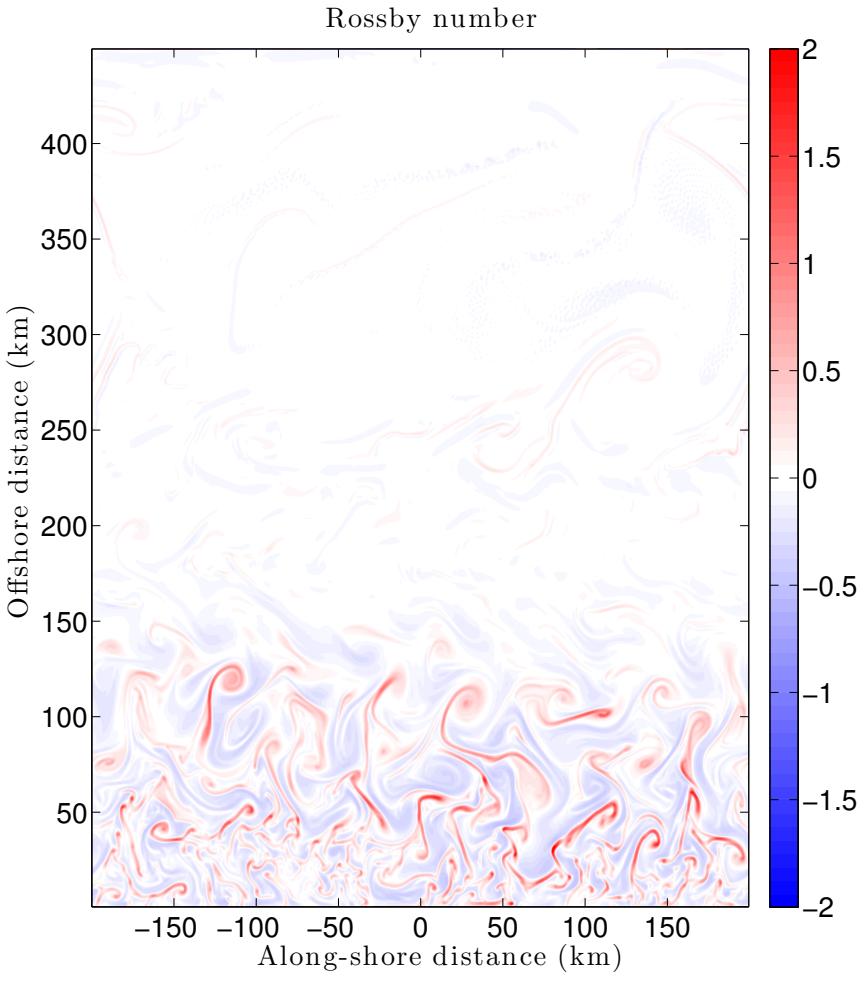

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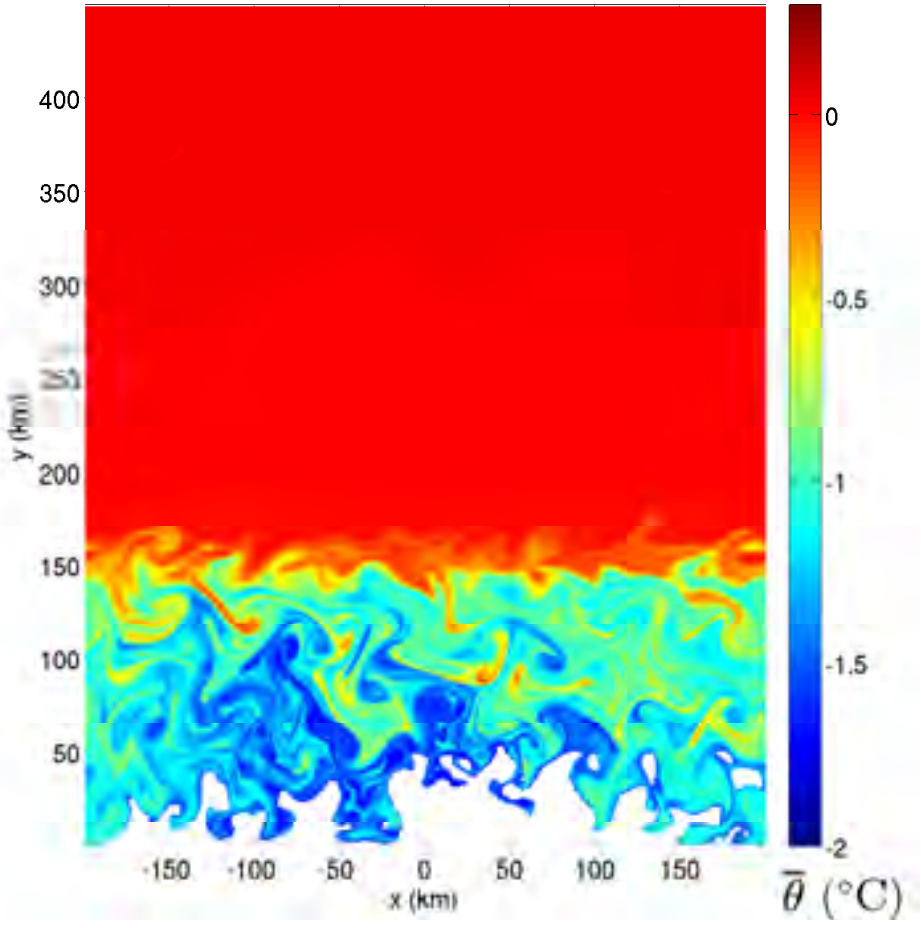
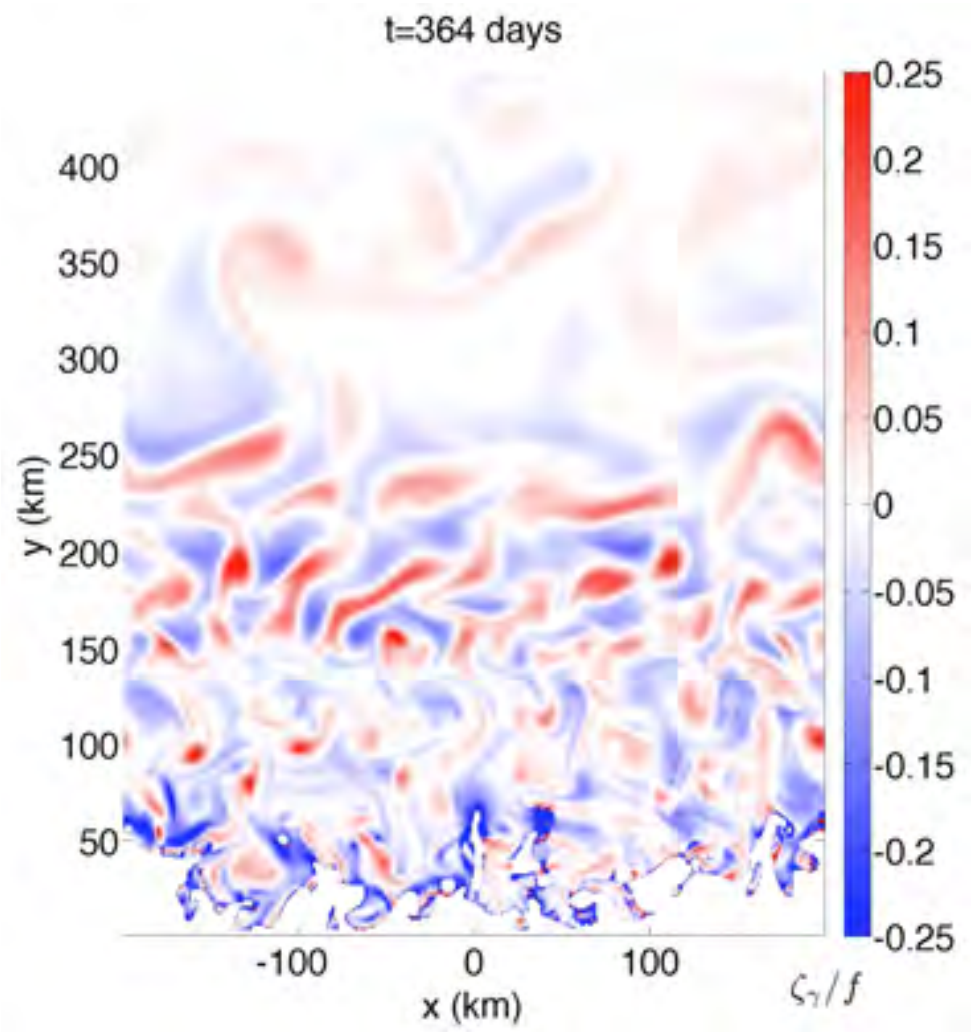
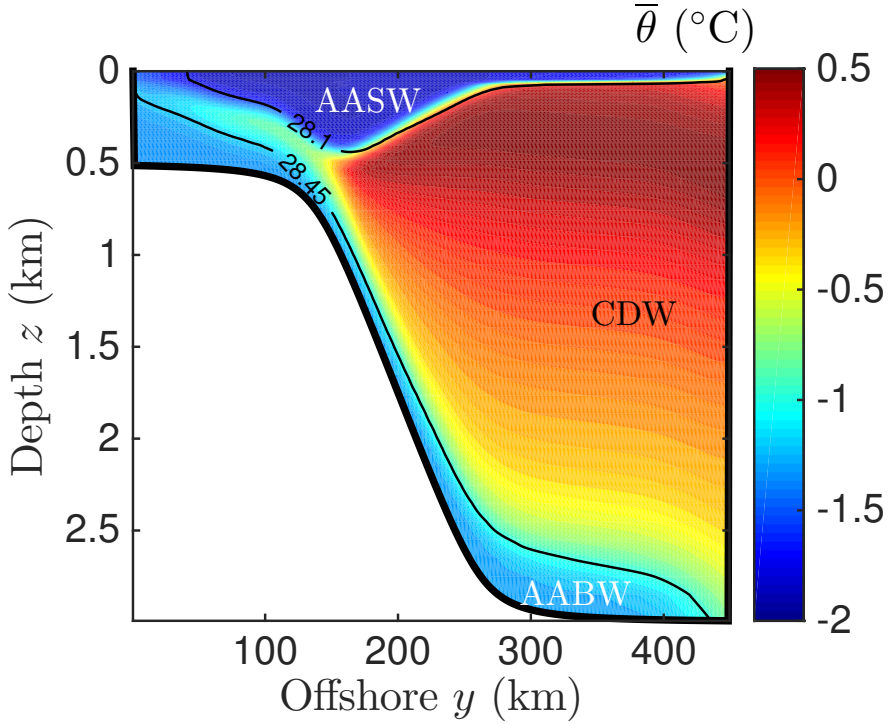


- Mixing of θ on a density surface: $\gamma = 28.25\,\mathrm{kg\,m^3}$

Eddies on the continental slope





- $\zeta_\gamma = \left[\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right]_{\gamma=28.25\,\mathrm{kg\,m^3}}$

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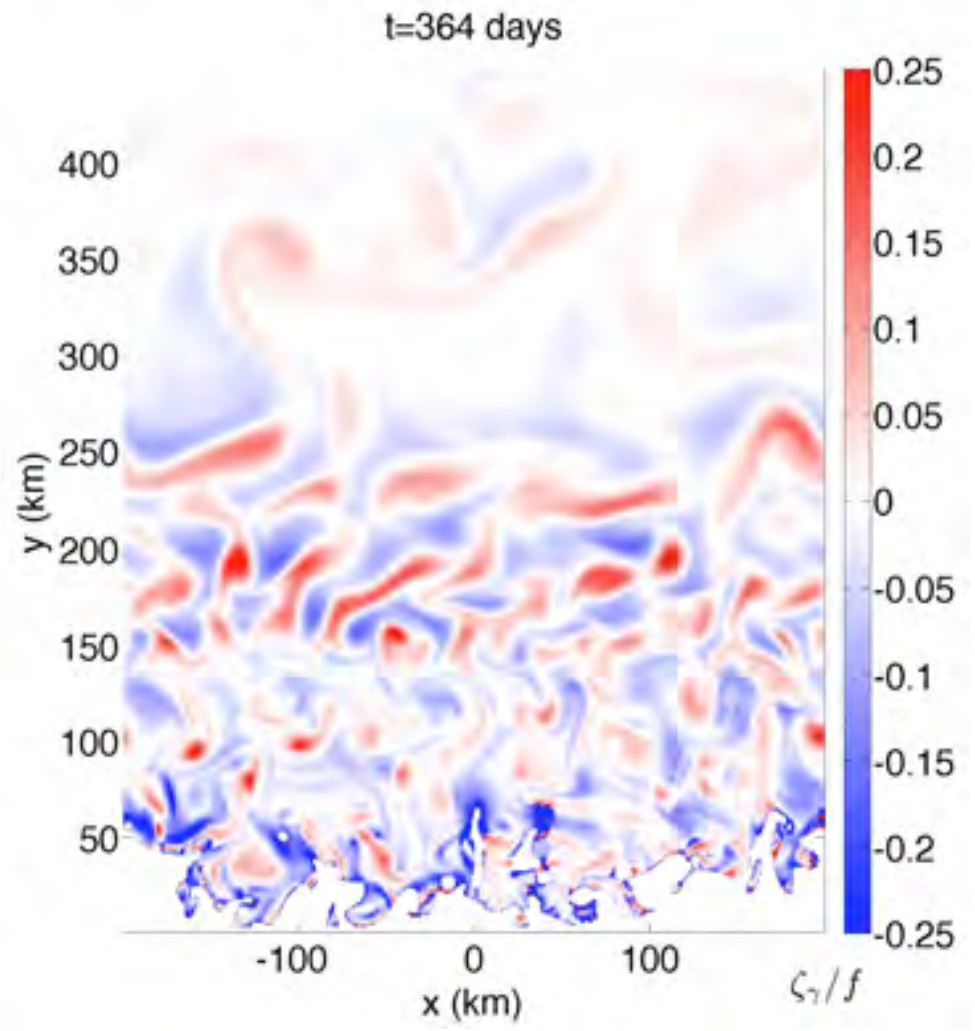

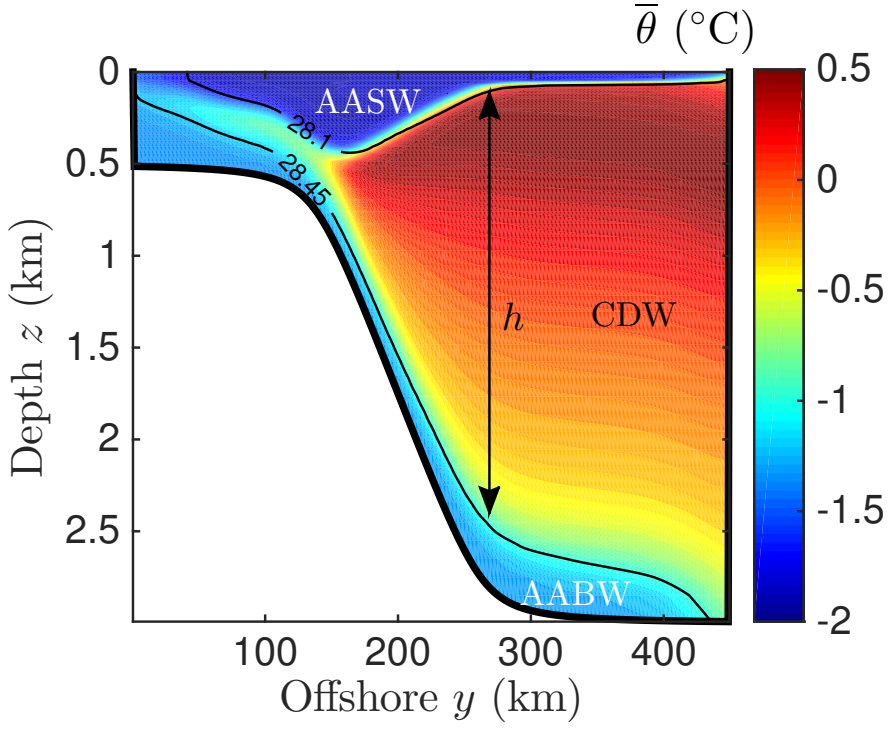

- CDW volume transport:

$$\overline{hv} = \overline{h}\,\overline{v} + \overline{h'v'}.$$

- $\zeta_\gamma = \left[\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right]_{\gamma=28.25\,\mathrm{kg\,m^3}}$

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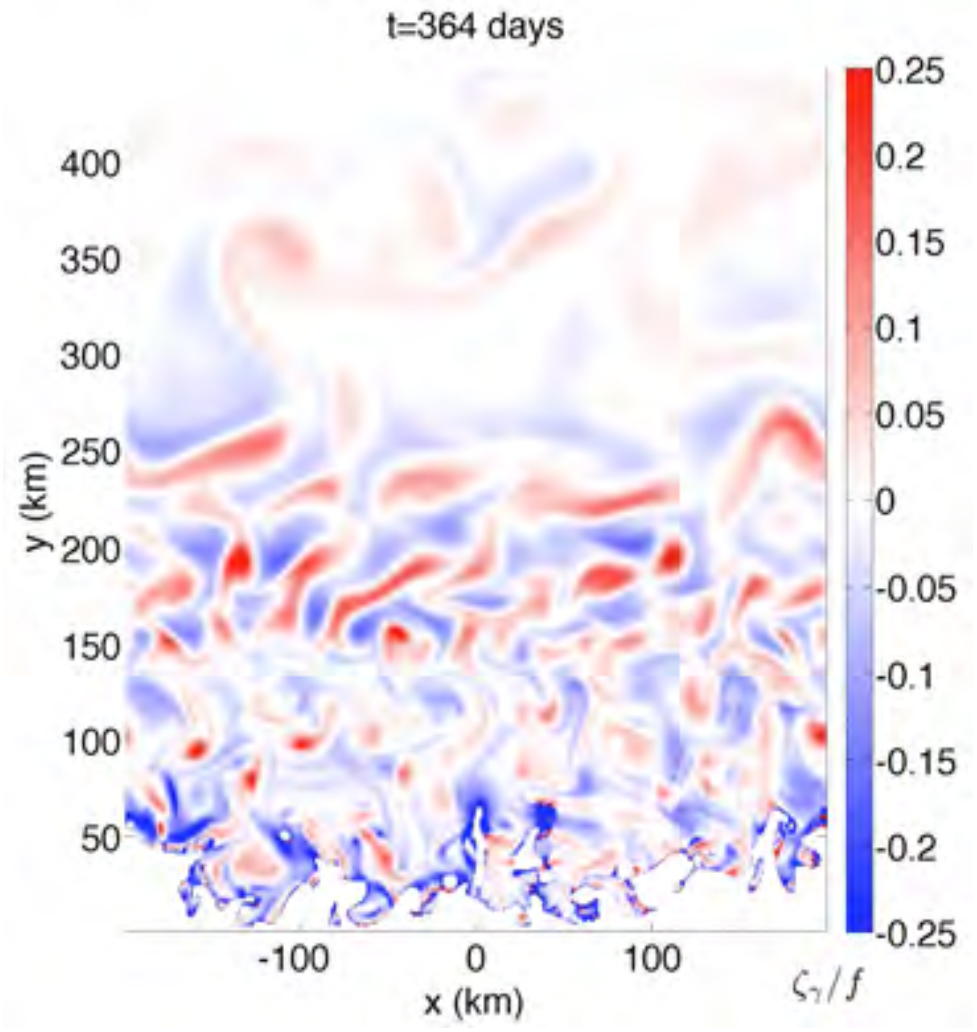

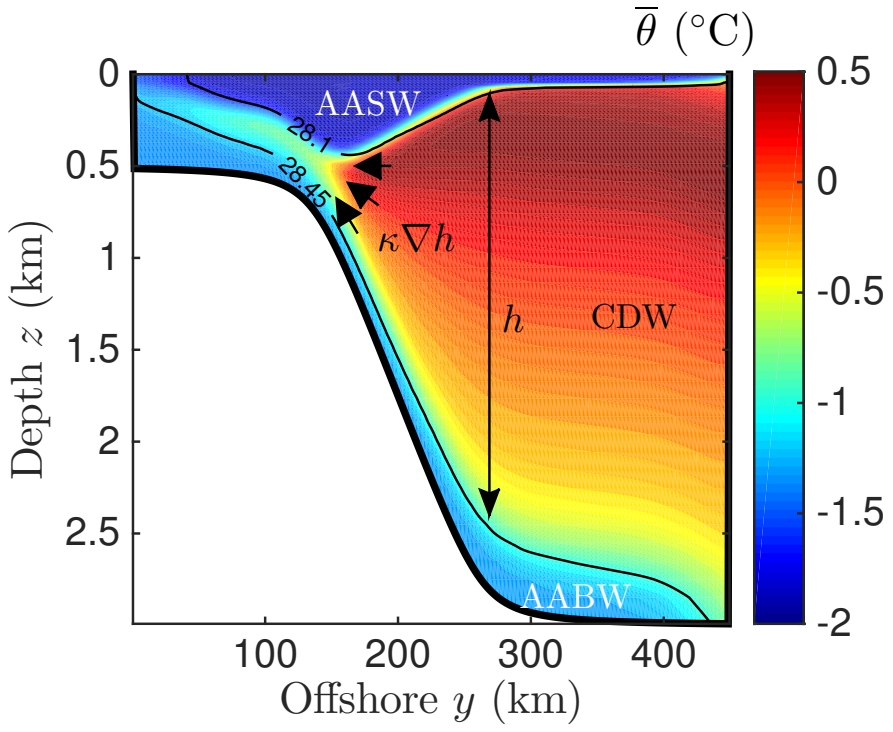

- CDW volume transport:

$$\overline{hv} = \cancelto{0}{\overline{h}\,\overline{v}} + \overline{h'v'} = -\kappa\overline{h}_y.$$

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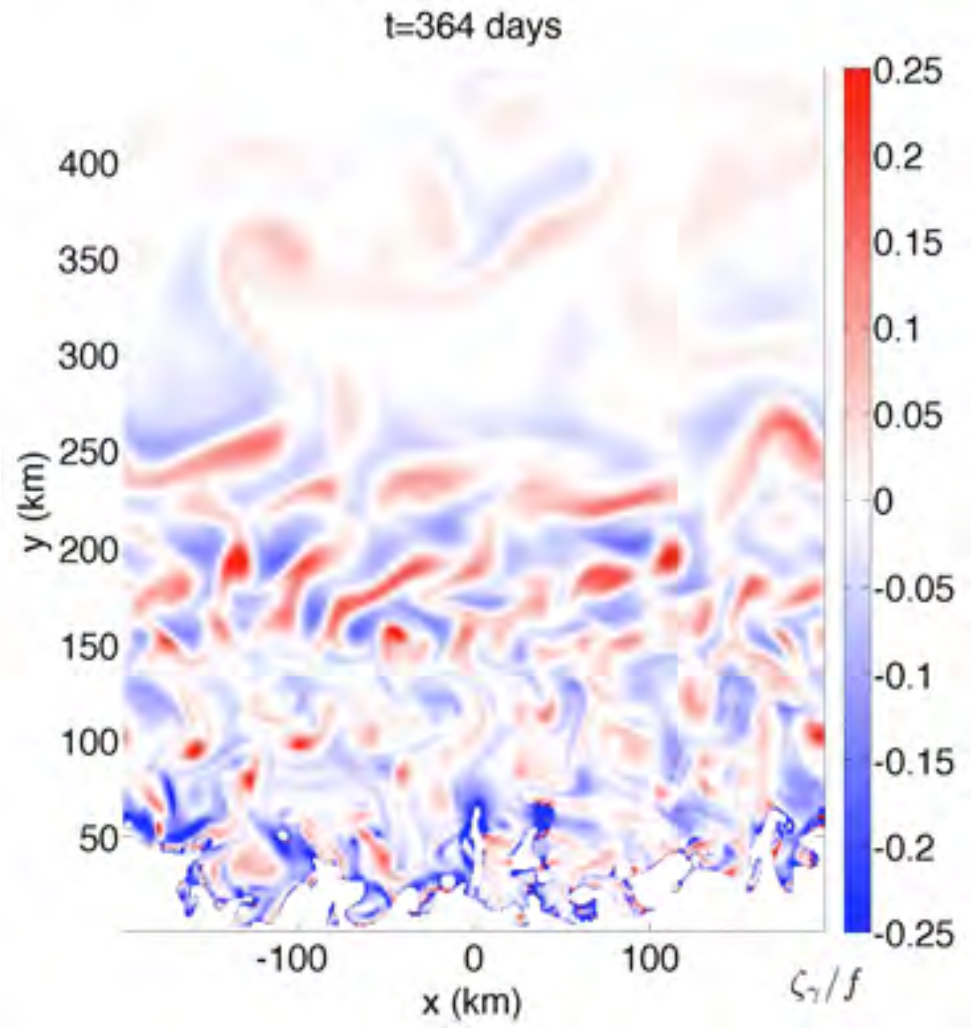

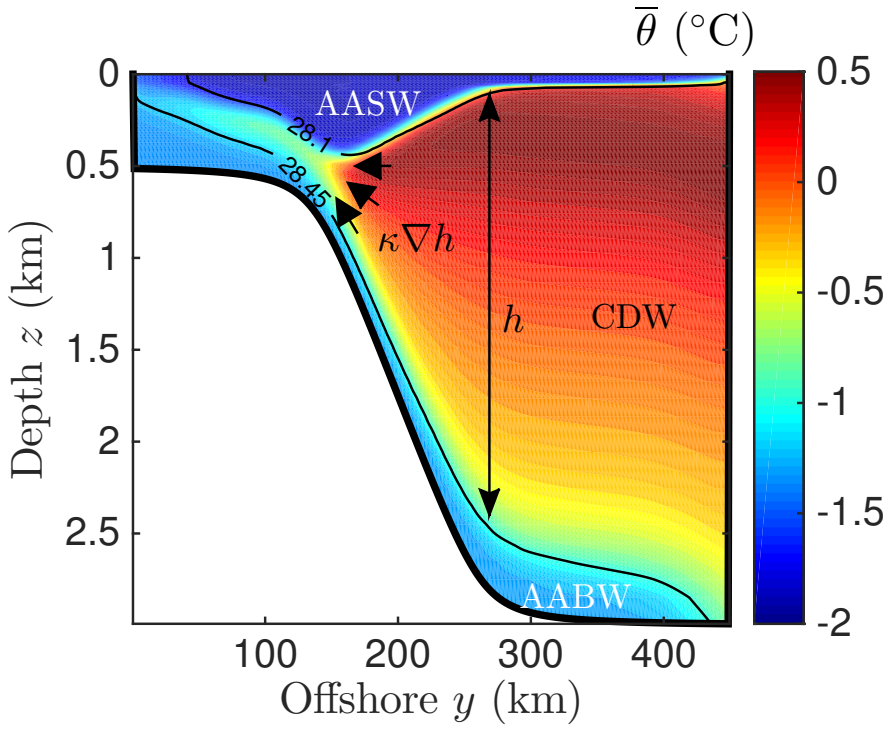

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$$\overline{hv} = \overline{h}\,\overline{v}^{\,0} + \overline{h'v'} = -\kappa \overline{h}_y.$$

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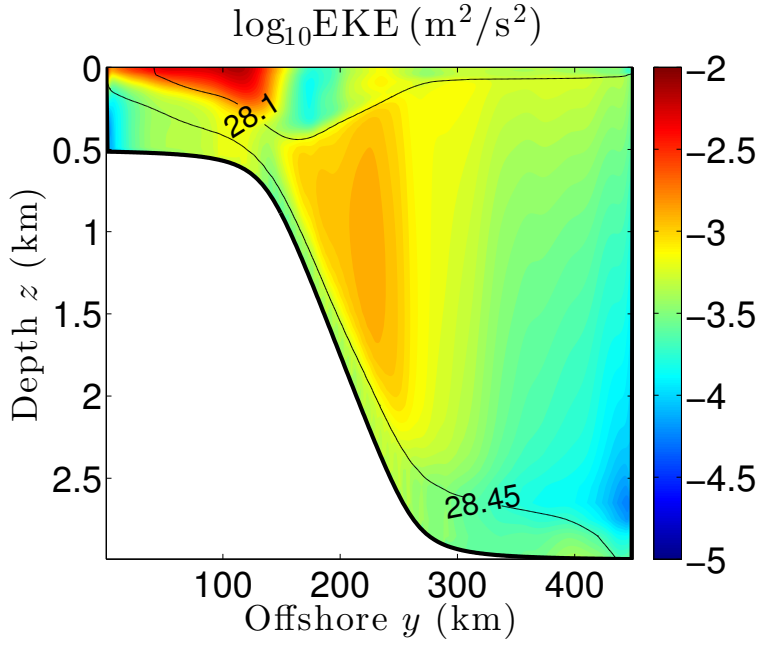
$$\Longrightarrow \quad \kappa \sim 10\,\mathrm{m}^2/\mathrm{s}!$$

Eddy energy on the continental slope



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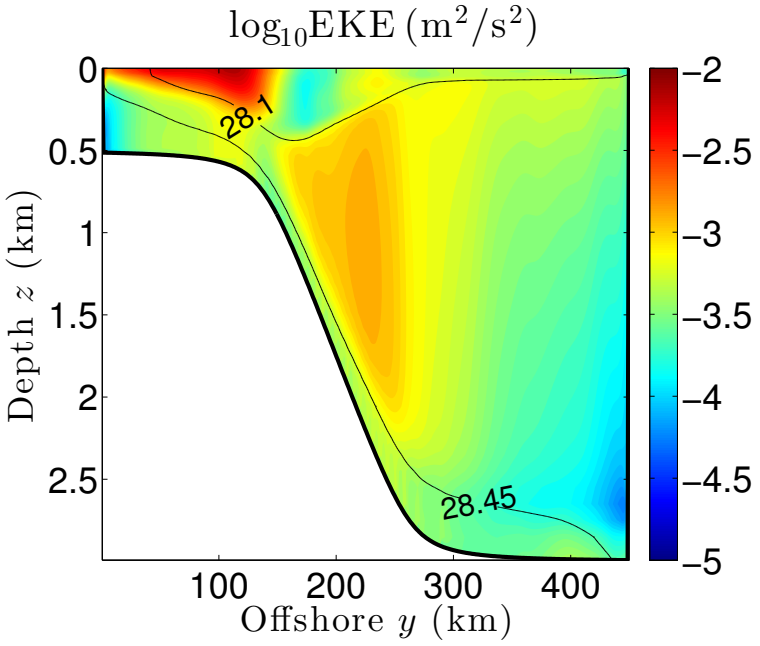

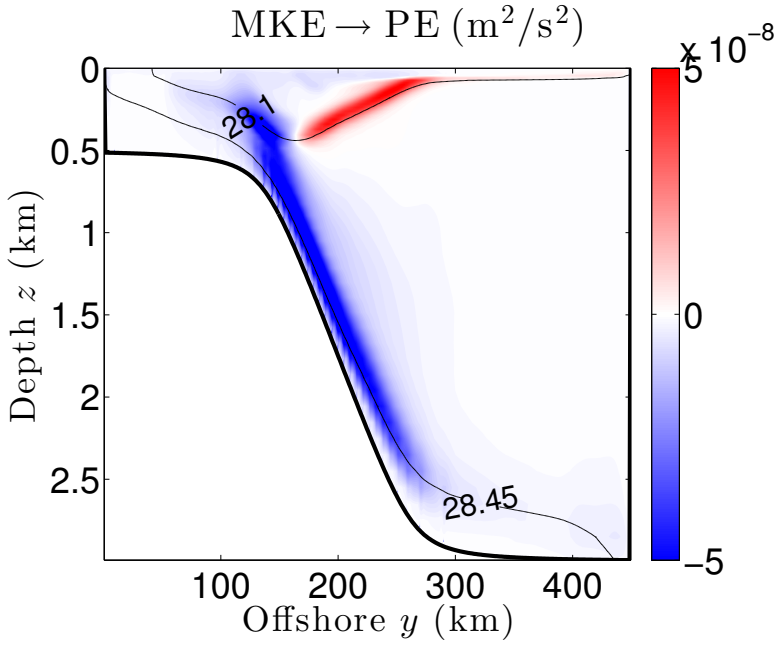

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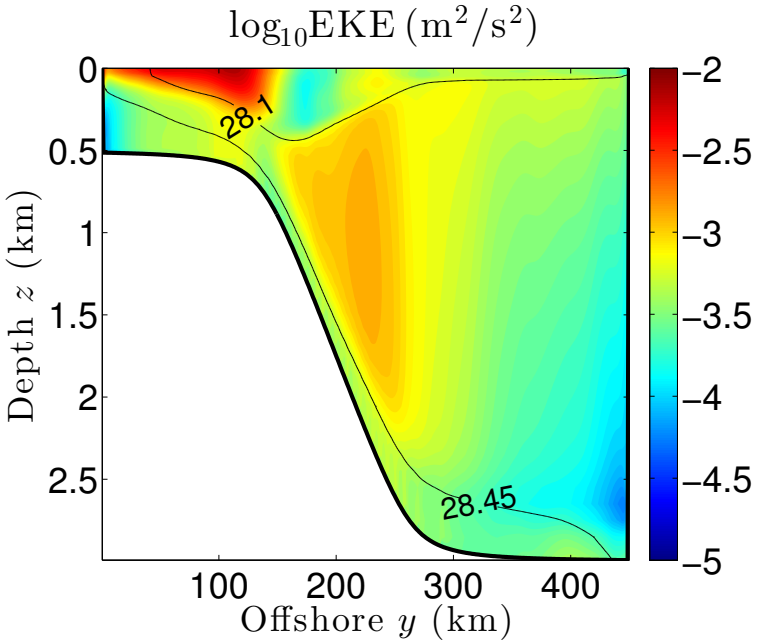

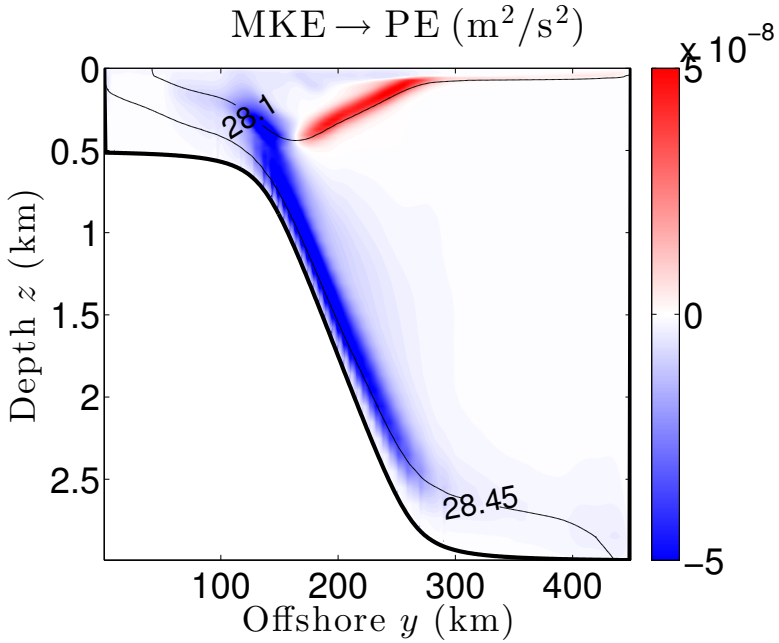

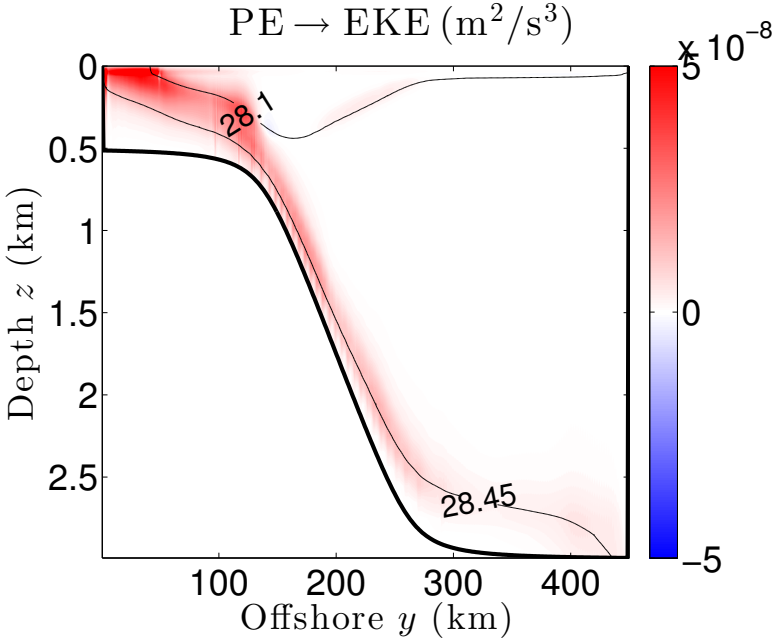

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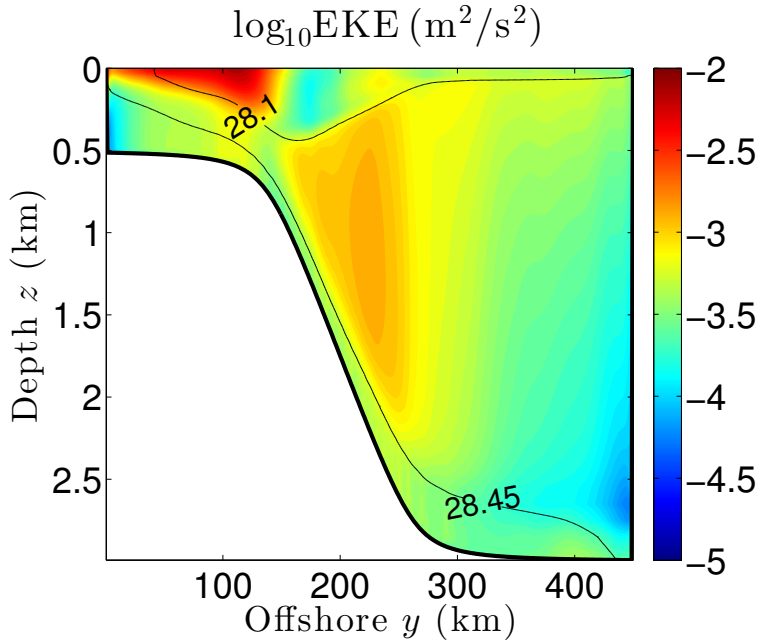
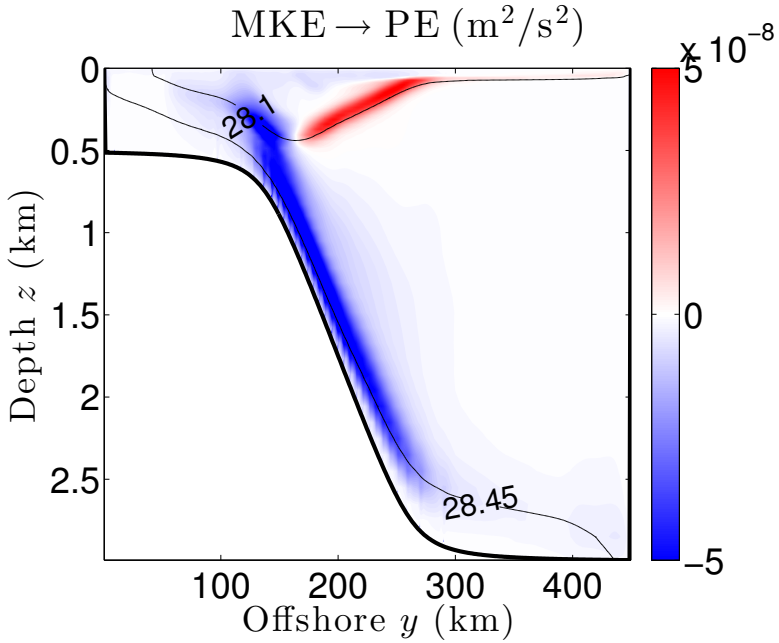
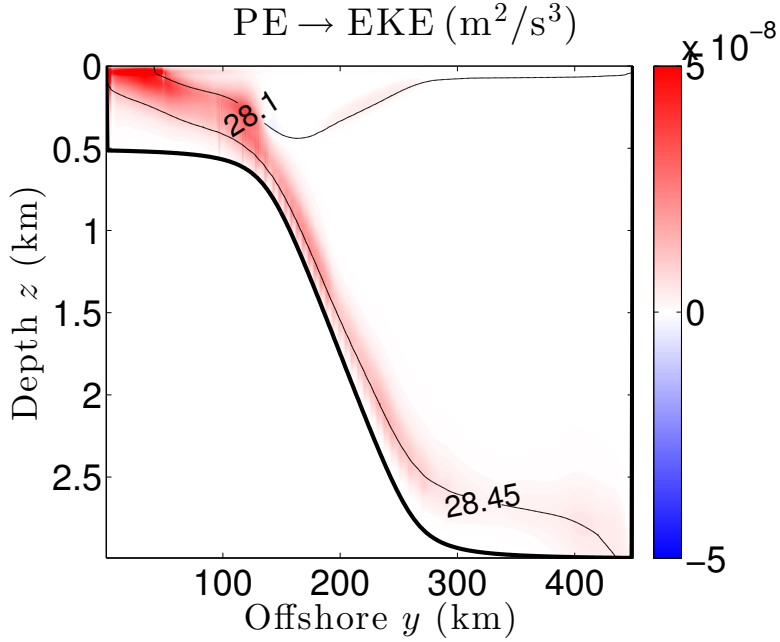
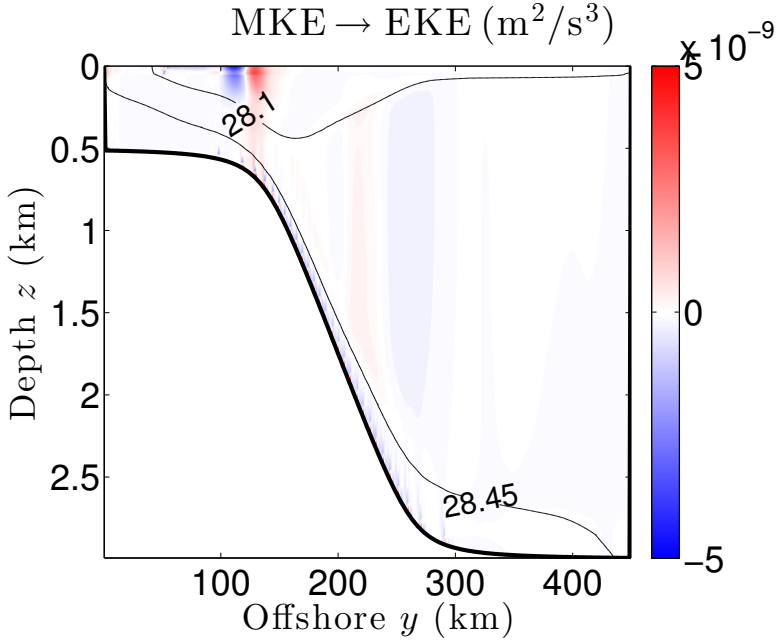
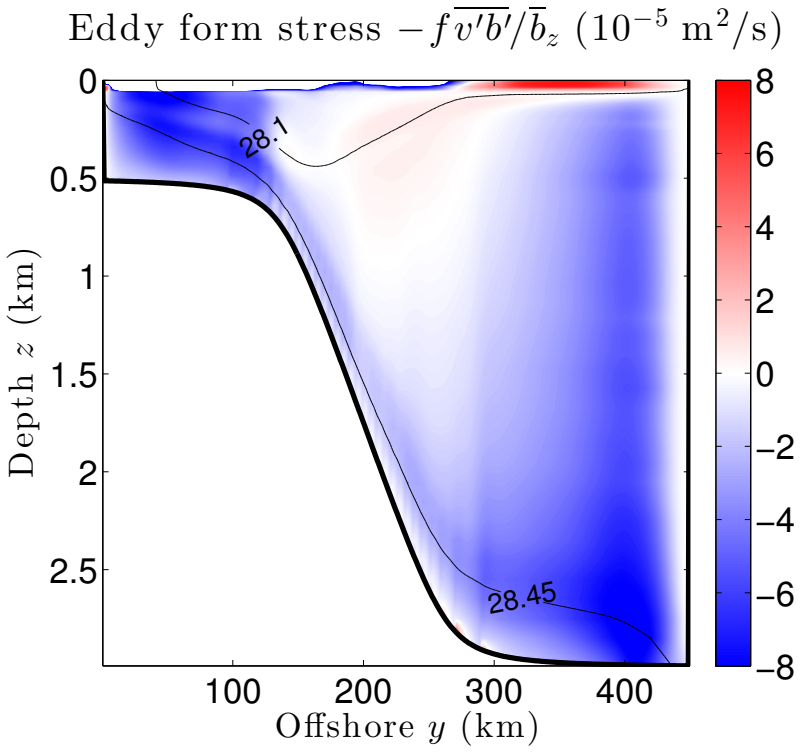


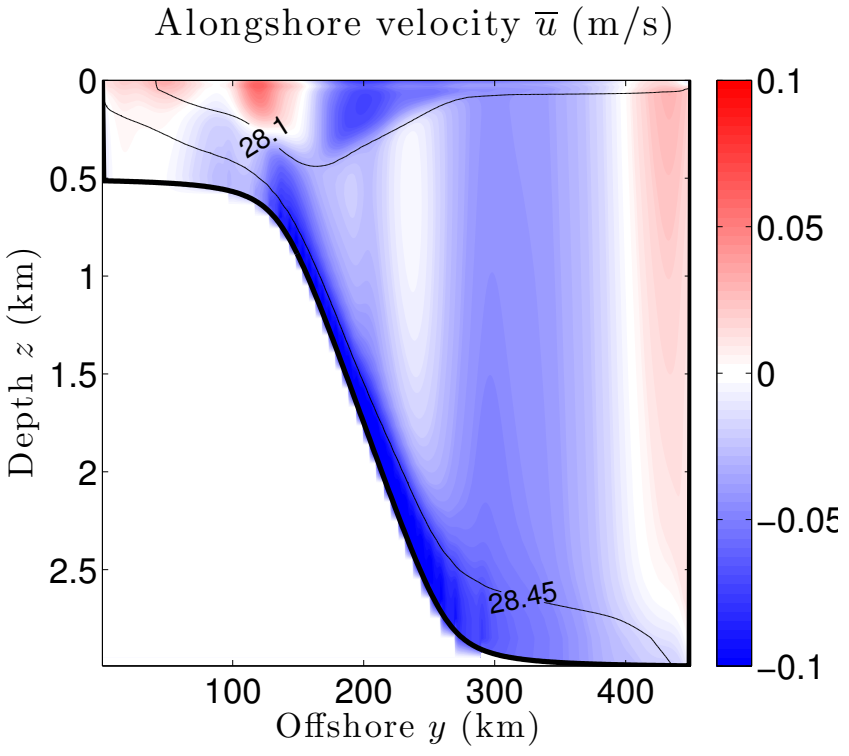






Momentum balance and along-slope circulation





- Alongshore momentum balance: residual offshore transport balanced by convergence/divergence of eddy form stress (EFS),

$$f v_{\mathrm{res}} \approx \frac{\partial}{\partial z}\left(-f\frac{\overline{v'b'}}{\overline{b}_z}\right) = \frac{\partial}{\partial z}F_{\mathsf{EFS}}$$

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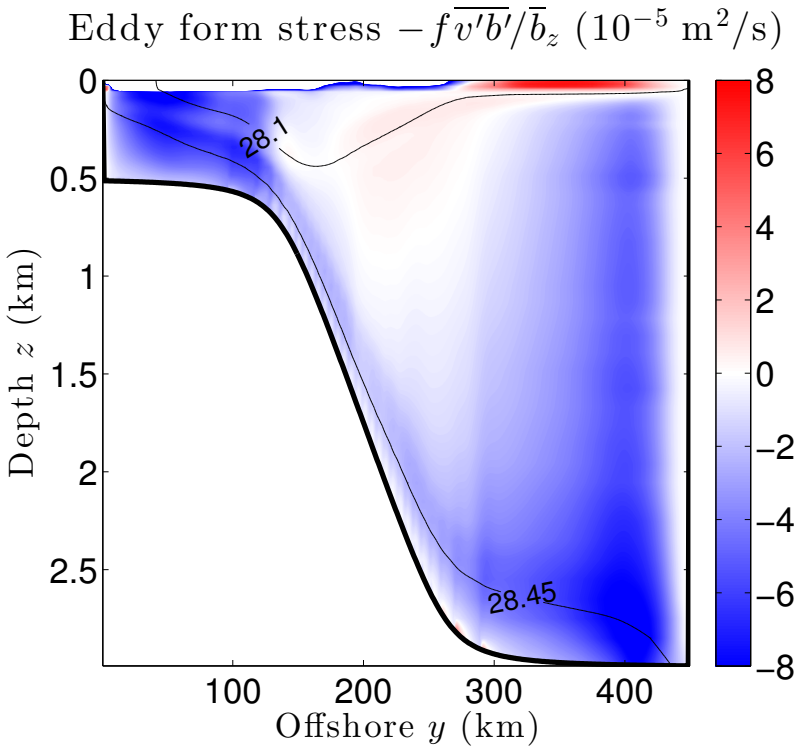

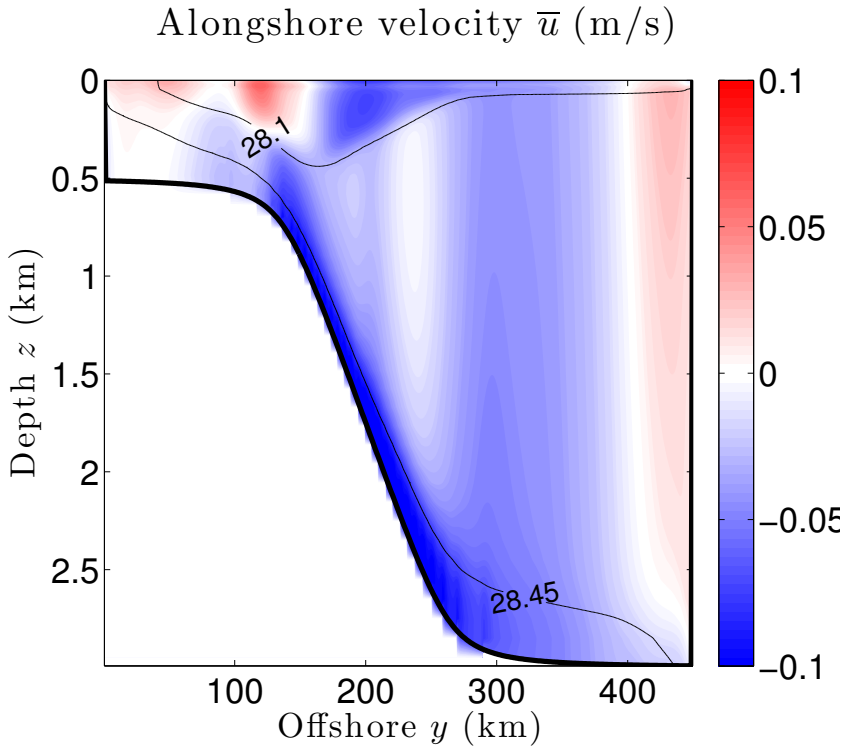

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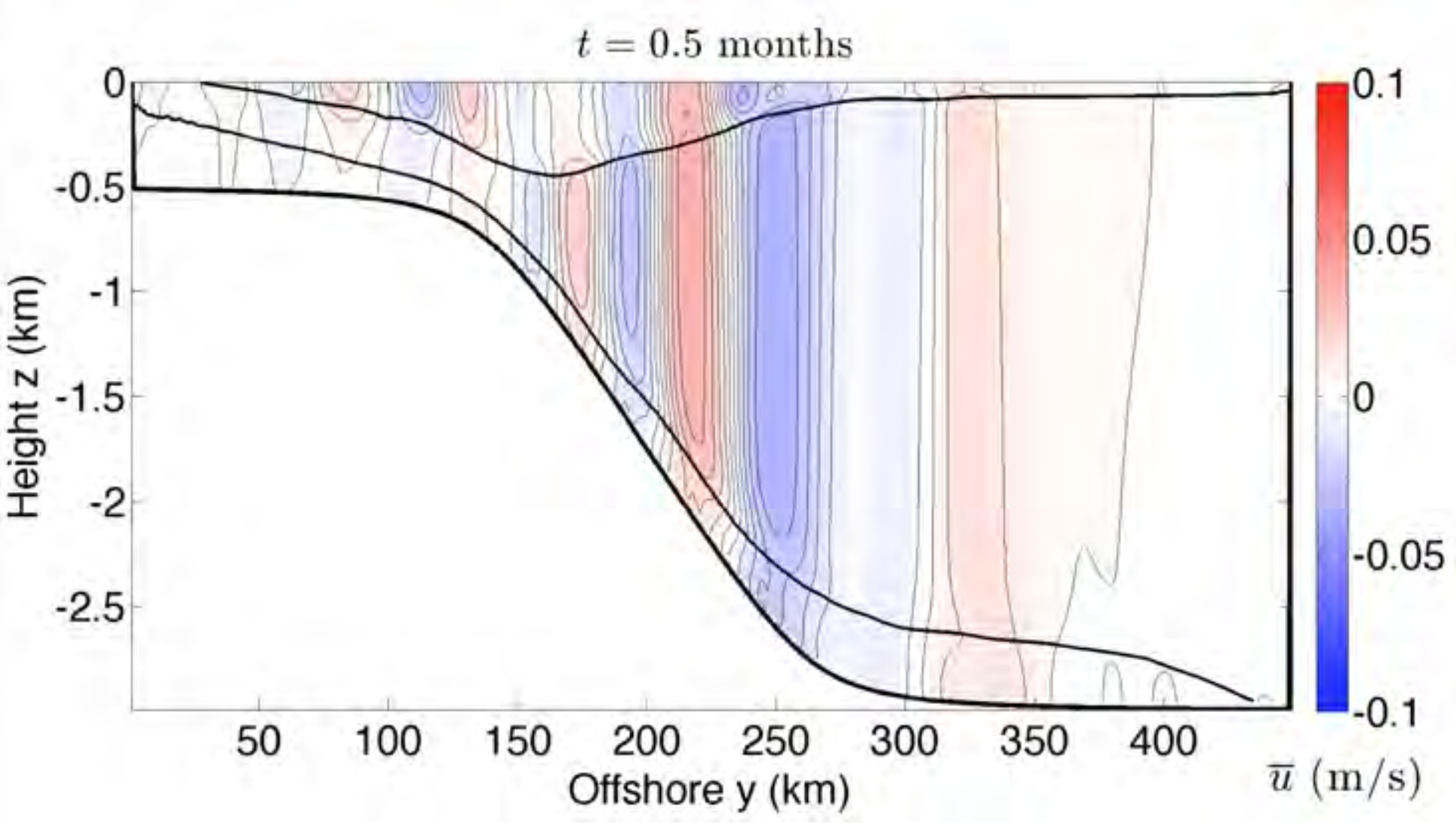
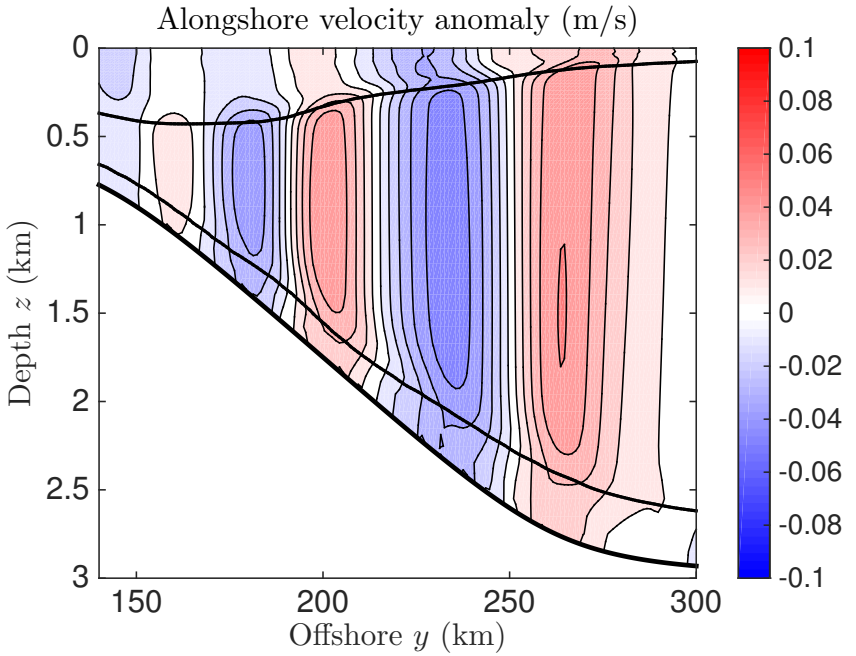
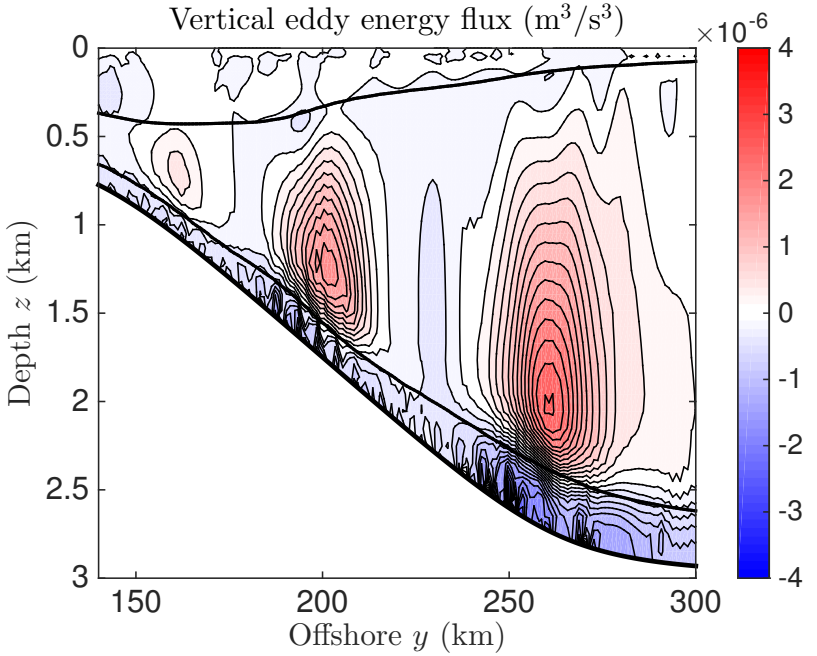
- Shoreward along-isopycnal CDW flux is forced by vertical convergence of westward momentum due to eddy form stress.

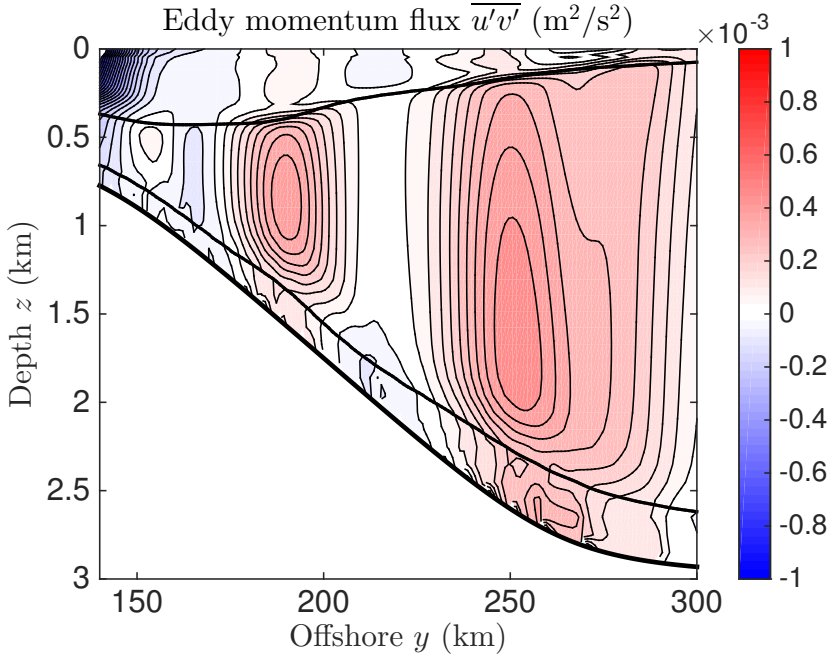
Shifting jets on the continental slope



Eddy fluxes in jets







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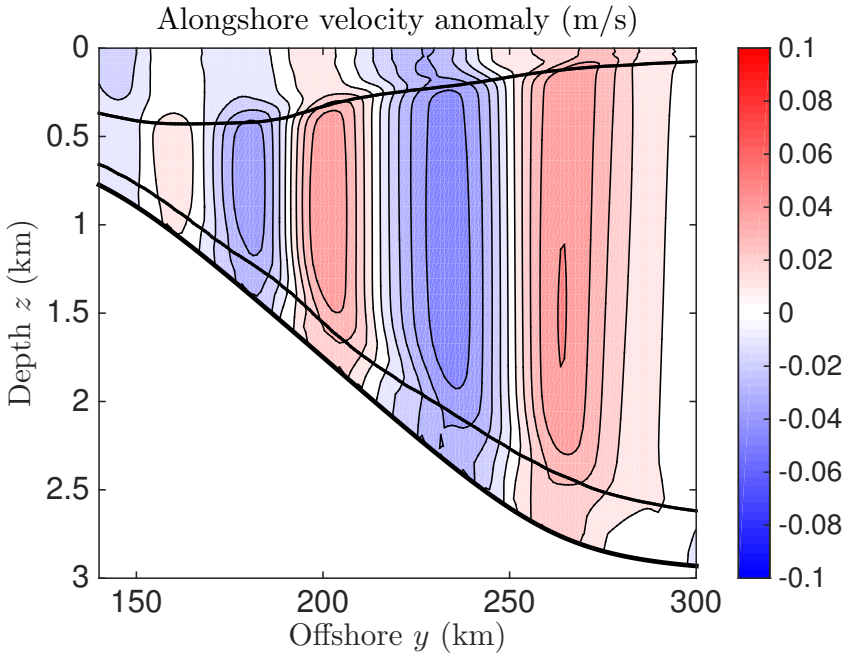
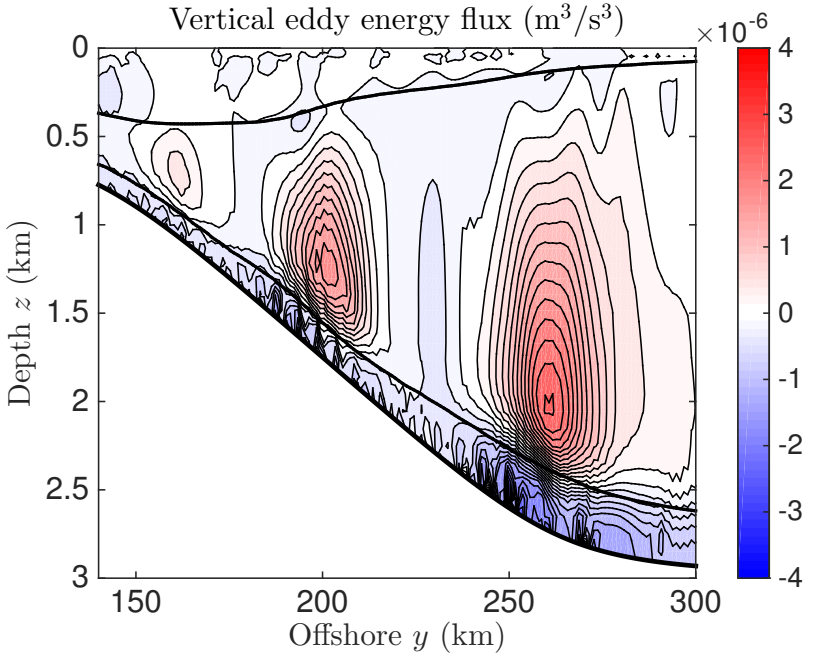
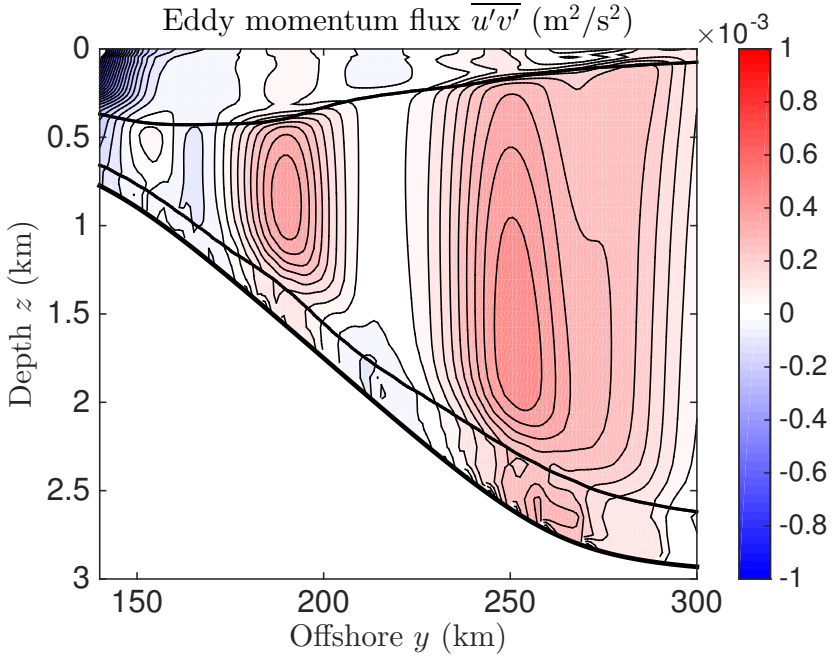
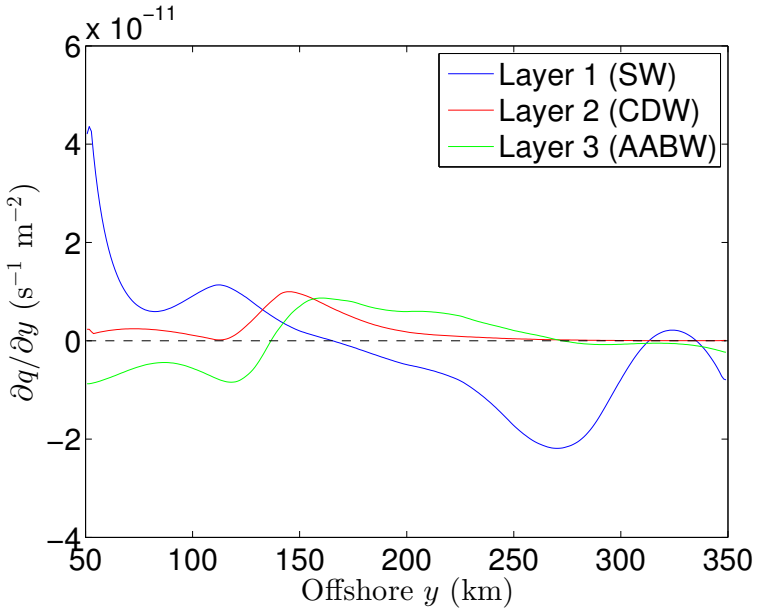
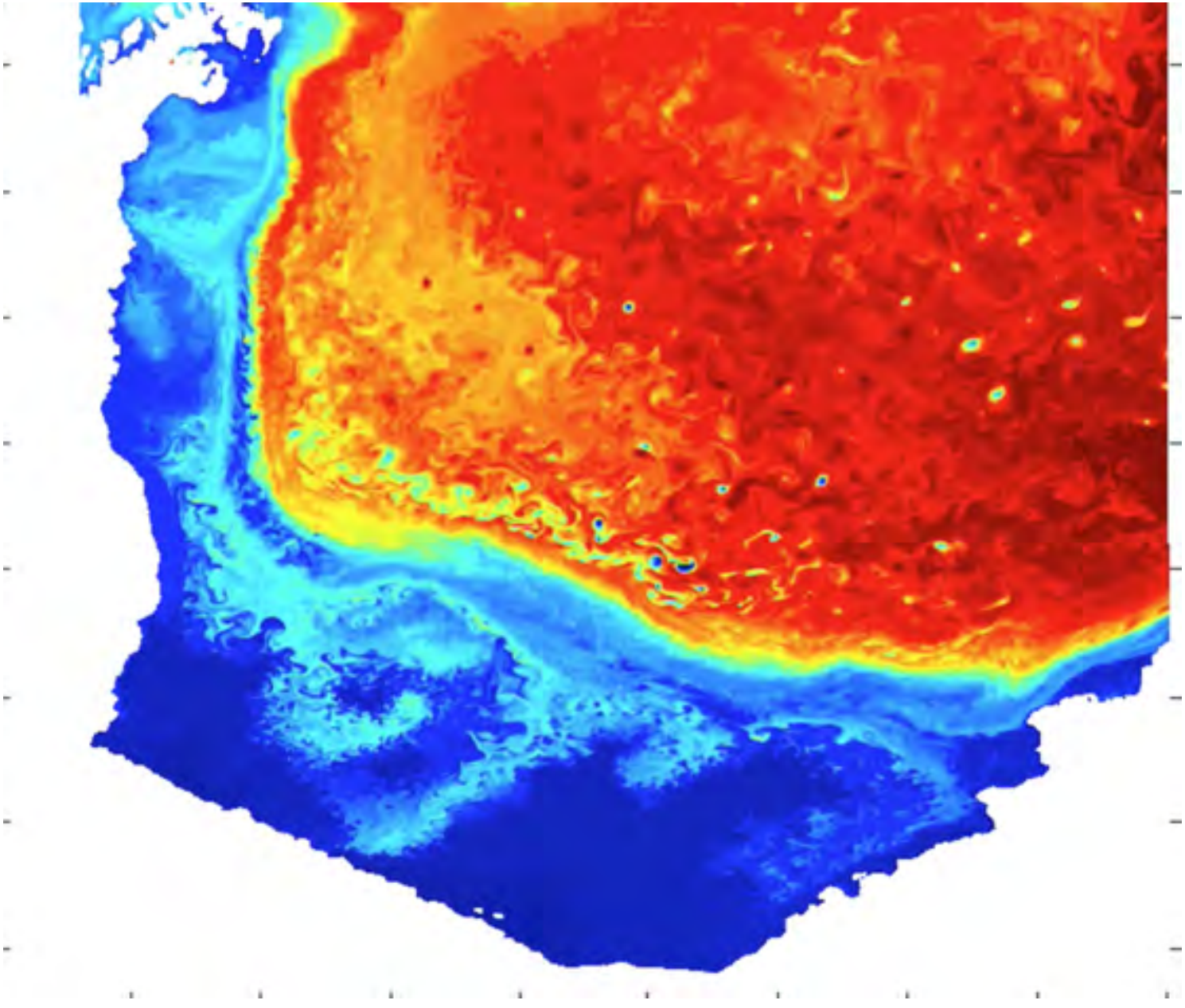




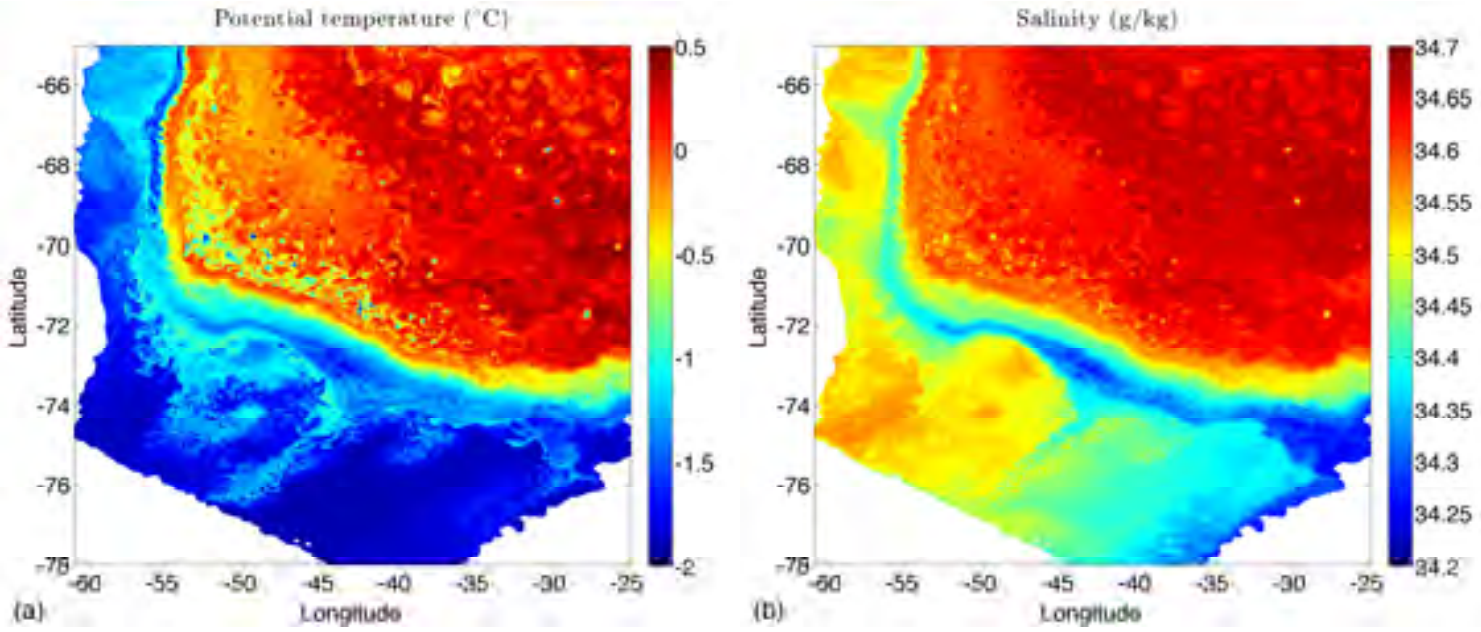




Weddell Sea eddies in a 1/48° global model



Eddy CDW/HSSW transport in the southwestern Weddell



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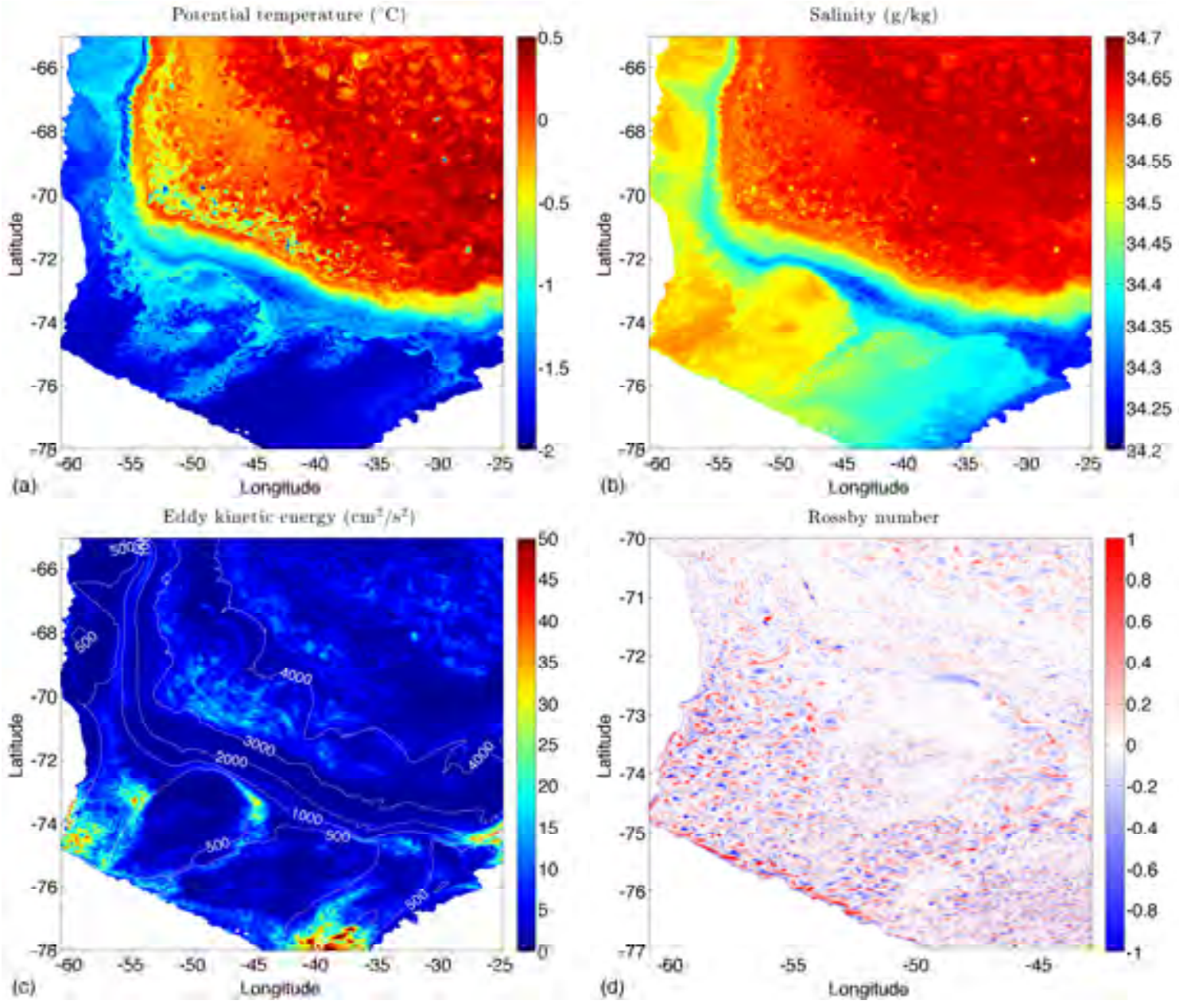
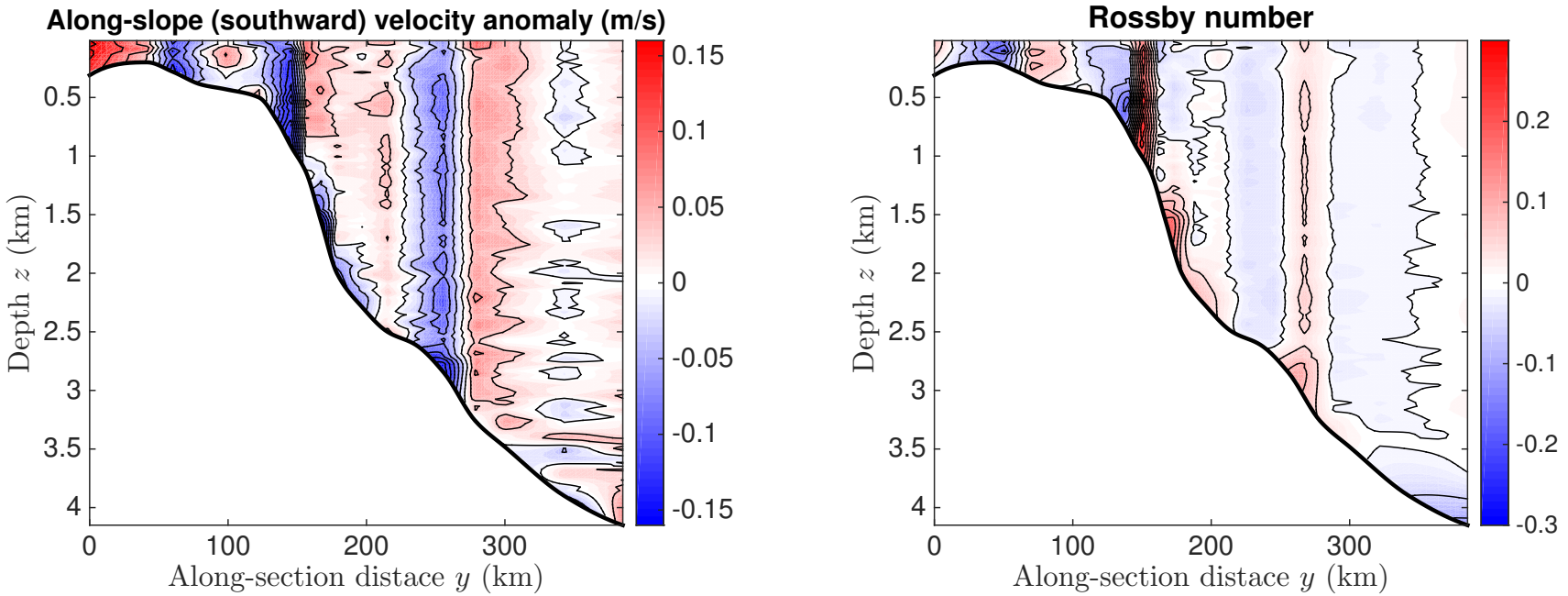


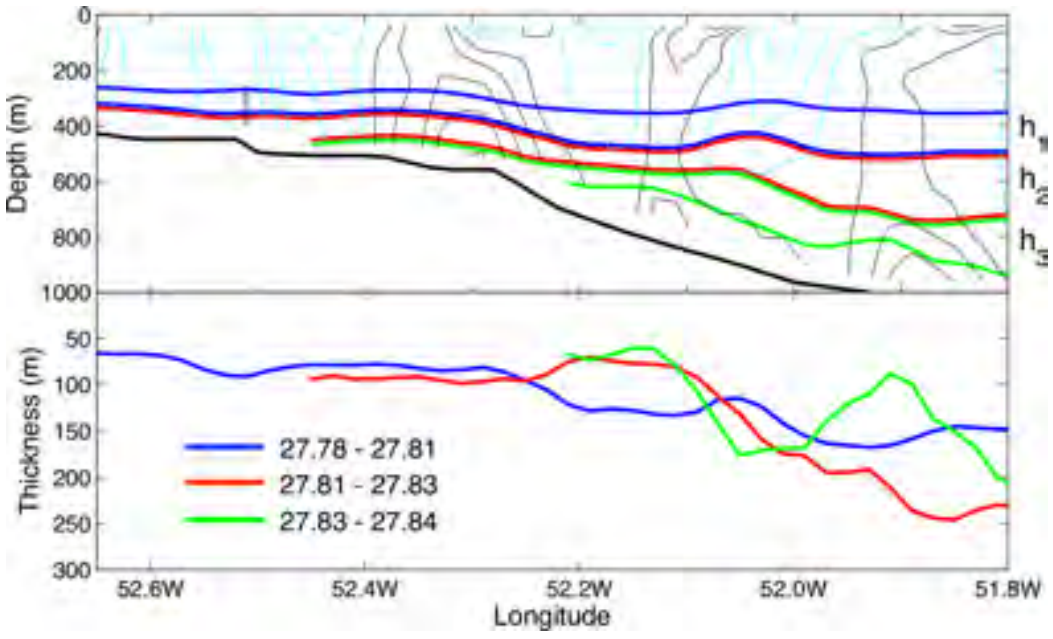
Jets on the north-west Weddell Sea continental slope

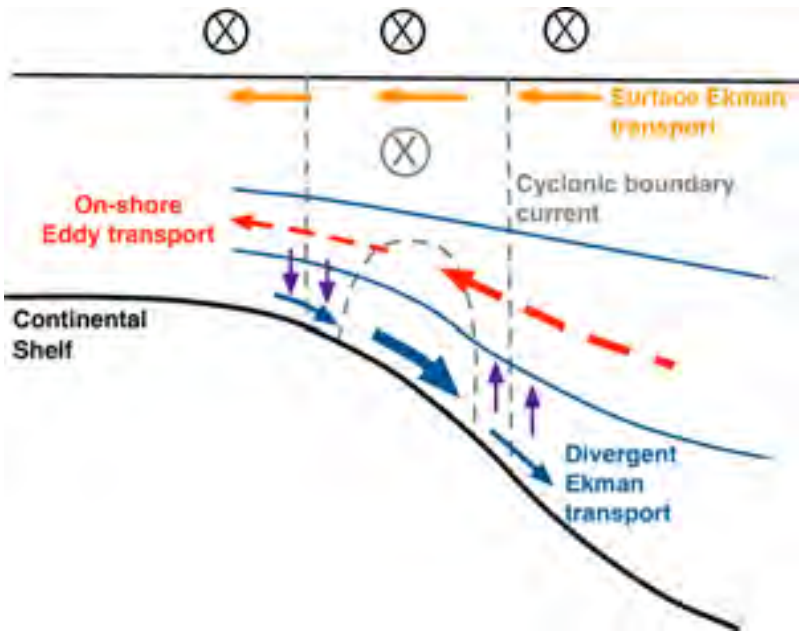


(Data from Thompson et al., Deep-Sea Res. 2008)

- Shipboard CTD casts reveal banded, jet-like structures.
- Relatively high Rossby numbers (up to $\mathrm{Ro} = 0.36$), consistent with our process model.

High-resolution glider observations of the ASF

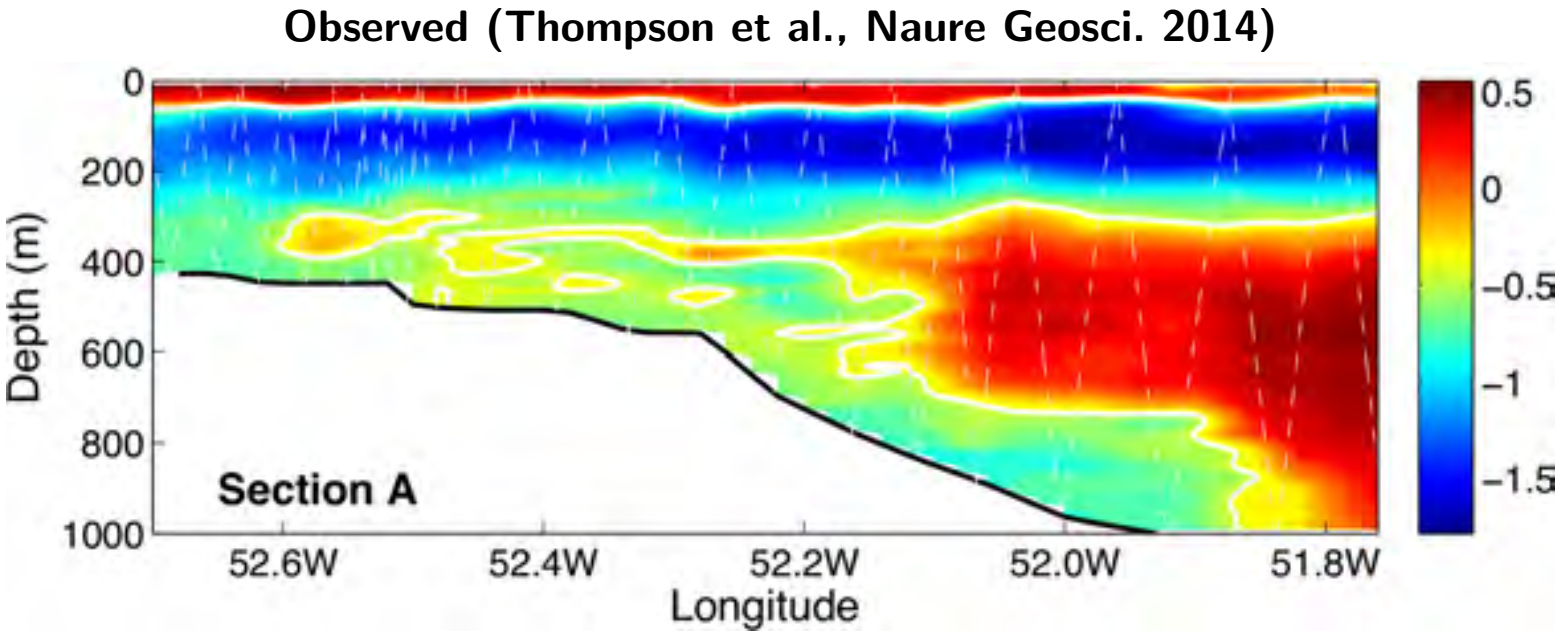


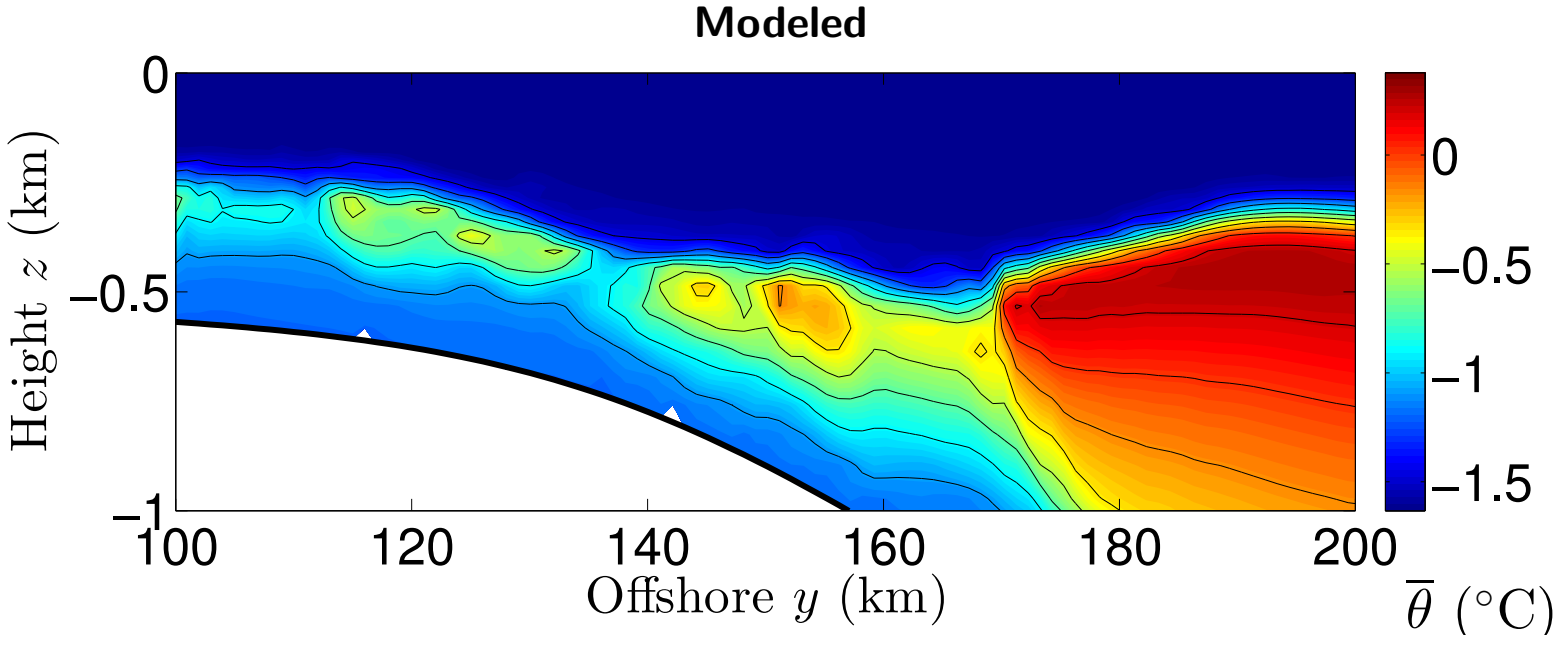


(Thompson et al., Nature Geosci. 2014)

- Strong cross-slope potential vorticity gradients and multiple jets observed in the CDW layer in the northwestern Weddell Sea.

Observed/modeled temperature snapshots





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- The CDW slope eddies self-organize into along-slope jets, which drift across the slope due to variations in the strength of the effective β in the CDW layer.

A shameless plug for our AGU Ocean Sciences session

- Session name: Ice-ocean interactions and circulation around the Antarctic margins.
- Session ID: 9278
- Session convenors: Andrew Stewart (UCLA), Andy Thompson (Caltech), Pierre Dutrieux (UW) and Karen Assman (U. Gothenburg).
- Submissions addressing cross-slope transport and mixing by (sub-)mesoscale eddies are particularly encouraged!
- Observations, modeling, laboratory experiments and theory all welcome.