The role of transient eddies and standing meanders in an idealized Southern Ocean model

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Abstract

We examine the role of transient and standing eddies in an idealized model with a Southern Ocean analog and two basins in the Southern hemisphere. We use the new MOM6 code base in an entirely adiabatic configuration, which allows for full equilibrium integration in only 100 years of simulation time. Fine resolution eddy-resolving simulations at 1/16- and 1/8-degree resolutions are performed in cases with and without continental barriers and/or bottom roughness. A time- and zonal-Reynolds averaging approach is used to decompose eddy fluxes into transient eddies and standing meanders. For a flat bottom channel the wind driven overturning circulation is balanced by transient eddies, consistent with previous studies. However, when continental barriers or bottom roughness are present, we find that standing meanders are dominant in the Southern Ocean.

The role of transient eddies and standing meanders in an idealized Southern Ocean model

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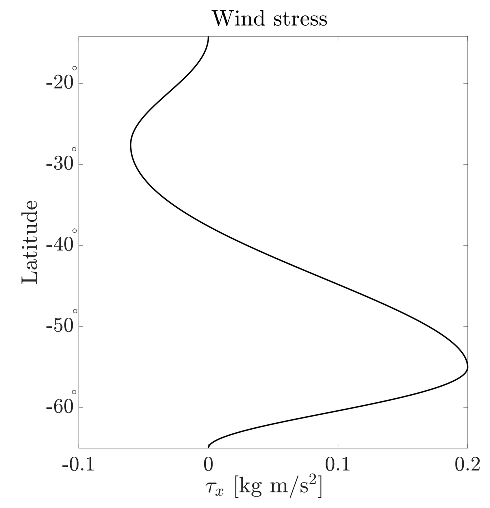
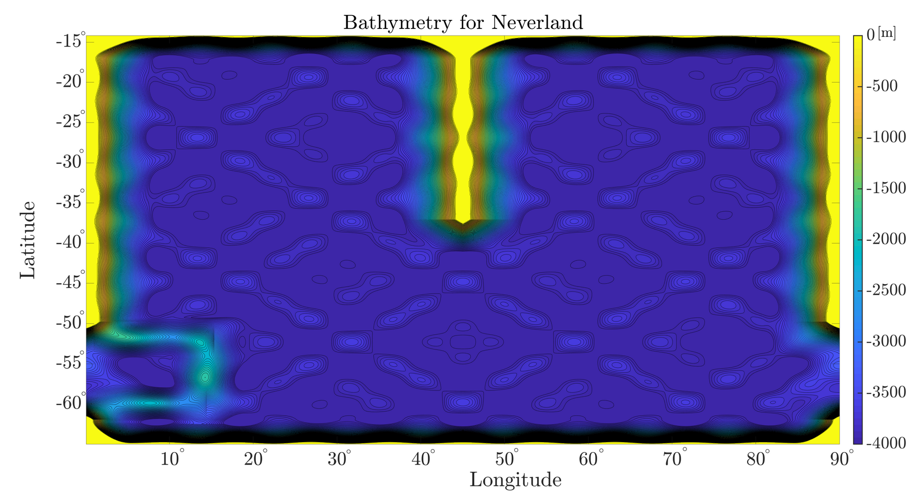
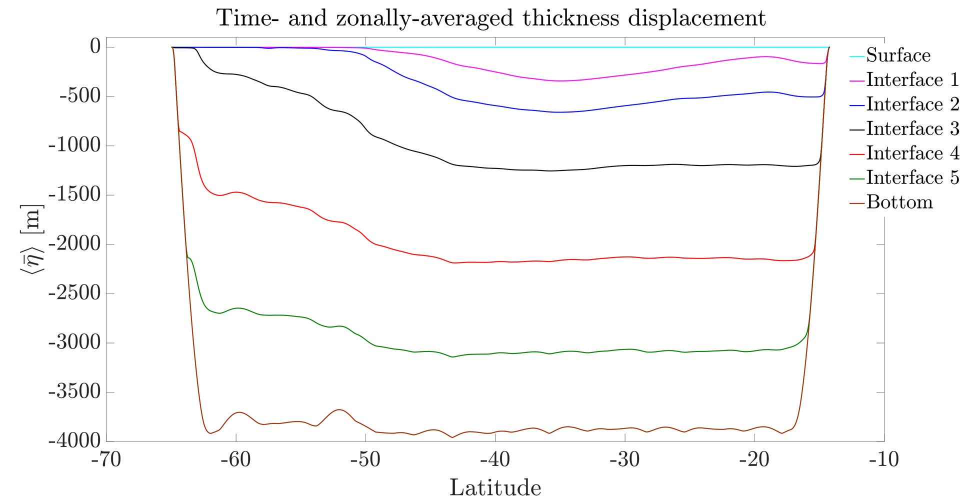
1. Introduction & Methods

Resolving mesoscale eddies is challenging in global scale ocean models because it requires to capture a vast range of scales. As a result, climate models must parameterize the effects of non-resolved mesoscale eddies on the large scale flow. High-resolution simulations of an idealized model with a Southern Ocean analog and two basins in the Southern hemisphere are considered. We use the MOM6 code in an entirely adiabatic configuration, which integrates to full equilibrium in only 100 years of simulation time. The model includes six vertical density layers, where stratification decreases towards the bottom. A turbulent circulation is driven by a latitude-dependent and zonally-symmetric wind stress. For comparison, channel configurations with/without bottom topography are also analyzed.







2. Motivation & Mathematical Formulations

- Time-averaged volume transport:

$$\overline{\boldsymbol{u}h} = \bar{\boldsymbol{u}}\bar{h} + \overline{\boldsymbol{u}'h'}, \tag{1}$$

$\boldsymbol{u} = (u, v)$ is the velocity and h is the layer thickness. For the meridional geostrophic volume transport, $\sum_{bott.}^{top} \langle \overline{v_g' h'} \rangle = 0$, where $\langle \cdot \rangle$ denotes the zonal averaging.

- We can filter high resolution results to obtain coarse resolution variables:

$$\tilde{m}(\boldsymbol{x}, t) = \int_D G\left(\boldsymbol{x} - \boldsymbol{x}^*\right) m\left(\boldsymbol{x}^*\right) d\boldsymbol{x}^*, \tag{2}$$

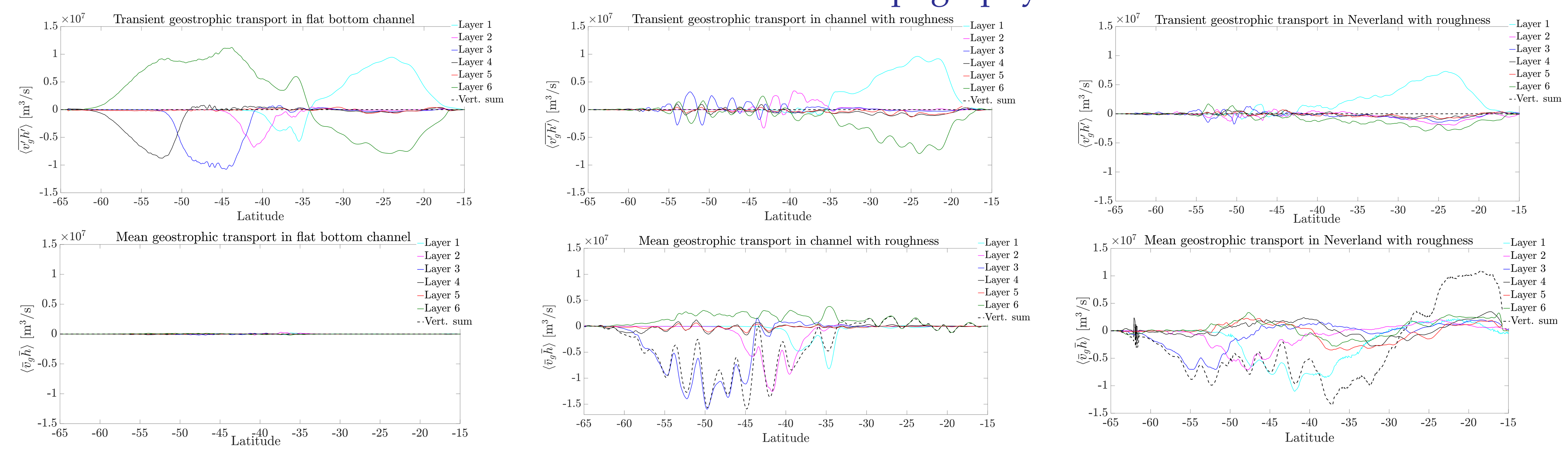
$\tilde{m}$ is the filtered quantity, G is a filtering operator and D is the horizontal domain. The effective subgrid-scale (SGS) eddy fluxes, which are parameterized in non-eddying simulations, can be computed by

$$\boldsymbol{u}h_{sgs} = \widetilde{\boldsymbol{u}h} - \tilde{\boldsymbol{u}}\tilde{h}. \tag{3}$$

- In this work, we show that the geostrophic SGS meridional volume transport $\overline{v_g h}_{sgs}$ substantially differs from the transient eddy transport $\overline{v_g' h'}$. For simulations with continental barriers or bottom topography, there is also a significant net SGS geostrophic transport (i.e. $\sum_{bott.}^{top} \langle \overline{v_g h_{sgs}} \rangle \neq 0$).

3. Time-averaging approach

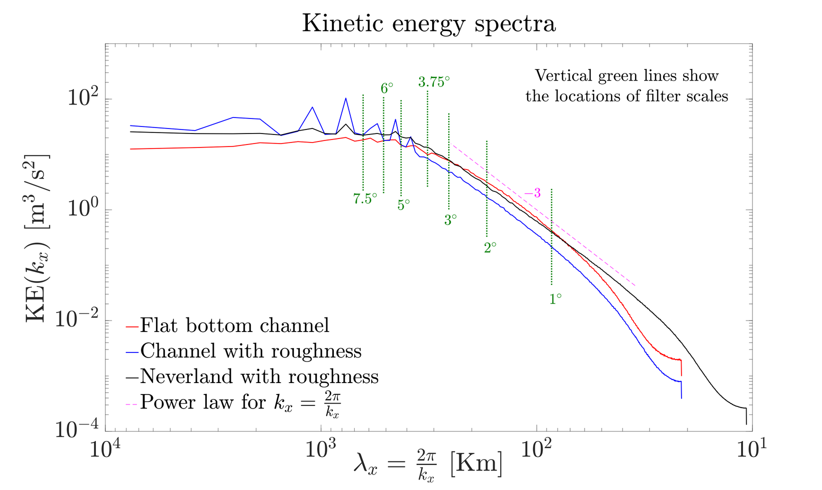
Flat bottom channel | Channel with bottom topography | Neverland



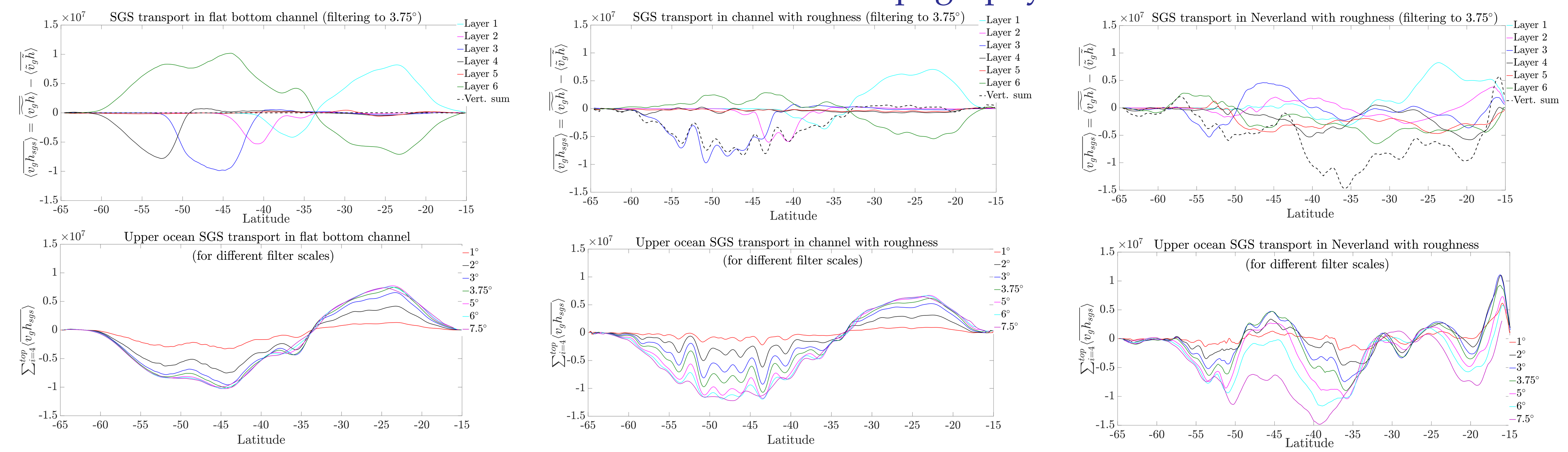
- Wind driven circulation is balanced by transient eddies in the flat bottom channel case.
- Wind driven circulation is balanced by standing meanders in the presence of topography.
- For all configurations, $\sum_{bott.}^{top} \langle \overline{v_g' h'} \rangle = 0$, as expected.

4. Filtering Approach

- In the flat bottom channel case, the SGS transport is very similar to the transient transport and converges when eddy scale is reached.
- In configurations with roughness, $\sum_{bott.}^{top} \langle \overline{v_g h_{sgs}} \rangle \neq 0$.
- The upper ocean SGS transport balances the Ekman transport in the channel part and converges at the eddy scale.



Flat bottom channel | Channel with bottom topography | Neverland



5. Conclusions

- In configurations with bottom topography, geostrophic SGS transports are not controlled by transient eddy fluxes.
- Unlike the transient geostrophic transport, the SGS geostrophic transport does not integrate to zero in the presence of topography, contrary to the assumption in GM-based parameterizations.
- Scale-dependent SGS transport converges at the eddy scale in flat bottom channel, but the convergence is slower and more complicated in the presence of topography.

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