1. Introduction

Interfacial form stress (IFS) is thought to be the primary mechanism that carries momentum from the sea surface to the seafloor in the zonally-averaged Antarctic Circumpolar Current (ACC). For quasi-geostrophic flow, downward momentum flux is proportional to poleward heat flux; thus understanding the structure and variability of IFS can help to unravel not only the momentum balance in the ACC, but also how meridional heat flux is carried across the fronts.

The cDrake Experiment (Chereskin et al., 2012) provides a detailed 4D view of the vertical and horizontal structure of IFS in a region spanning 100 km cross-stream and 250 km along-stream in the northern Drake Passage. Daily maps with mesoscale resolution are constructed from the observations for the time period spanning November 2007 through November 2011 (Firing et al., 2013). Maps show the vertical, cross- and along-stream structure of velocity streamfunction and buoyancy; here they are used here to estimate the mean structure and variability of IFS in the northern Drake Passage.

4. Mean structure

IFS averaged over the 4-year timeframe and over depth (below left) shows significant horizontal structure, suggesting a pattern of geostrophic adjustment and lee waves downstream of the Shackleton Fracture Zone.

IFS averaged over the 4-year timeframe and over the Local Dynamics Array region shows a vertical structure and magnitude similar to previous IFS averaged over the 4-year timeframe and over the Local Dynamics Array region.

2. Data: the cDrake Experiment

The cDrake field program deployed 37 Current and Pressure Recording Inverted Echo Sounders (CPIES) in the Drake Passage over 2007-2011. Black dots in maps below show CPIES locations; magenta line denotes limit of mapping accuracy (13% error variance contour). CPIES: Current and Pressure Recording Inverted Echo Sounder

3. Interfacial form stress (IFS)

Interfacial form stress (IFS) represents the transfer of momentum vertically from one isopycnal layer to another. At an interface between two density layers $\eta_x$ and $\eta_y$, we can define IFS in terms of the displacement between the two density layers $v_\eta$ and the pressure difference over some zonal interval $dx$ (Vallis, 2006):

$$ IFS = -\eta_x \frac{\partial P}{\partial x}, $$

where the overbar denotes the zonal mean. For geostrophically balanced flows, the zonal pressure gradient can be written in terms of the meridional velocity $v$:

$$ IFS = -\eta_x \frac{\partial P}{\partial x} = -\eta_x \frac{\partial \rho f v}{\partial x}, $$

where $\rho$ is the density of the layer and $f$ is the Coriolis parameter. Assuming continuous stratification, the interfacial displacement term $\eta$ can be written in terms of buoyancy perturbation $-f/\left(\partial B/\partial z\right)$, yielding the following form for IFS:

$$ IFS = \rho f v \frac{\partial \rho v}{\partial z} = -g \frac{v v'}{N^2}, $$

where we have substituted the Brunt-Väisälä frequency $N^2 = (-g/\rho)\partial B/\partial z$ and the velocity used for calculating the divergent portion of eddy buoyancy flux is the deep reference velocity $v_{ref}$.

5. Variability

The time series of IFS averaged over depth and the Local Dynamics Array region (below) shows significant variability, with short-term events whose maxima reach up to 6 N/m². The IFS time series shown below is calculated via 3-day low-pass filtered velocity and buoyancy fields.

Depth-averaged time series at individual locations (A), (B), (C), and (D), marked on the map at the bottom left, show that IFS at point locations can be much larger than the mean, with maxima that may be an order of magnitude larger than the mean time series.

A mostly positive signal with high variability at point (A) suggests that the strong signal in the mean field in the southwest corner of the array may dominate the overall LDA-mean time series, though a few large-scale events visible at points (B), (C), and (D), especially in February 2008, indicate that this region plays a significant role in the mean signal as well.

Time-mean vertical profiles at each point (below, right) indicate that IFS is largely constant with depth not only in the overall LDA mean (section 4, top right) but at local points as well.

6. Conclusions and future work

Conclusions

- The horizontal- and time-mean vertical IFS profile is similar in structure and magnitude to previous calculations from point mooring observations in the Drake Passage region (above right; Johnson and Bryden, 1989) shown in cyan. Mean vertical profiles and time- and depth-mean fields of divergent buoyancy flux $v'\rho'$ and stratification $N^2$ show that both terms contribute to both the mean vertical (below left) and horizontal (below right) structure.

Future work

- Further investigate the effect of scale on the IFS calculation. IFS maxima increase significantly when averaging over smaller spatial and temporal scales. What is the lower bound on the scales over which IFS can be calculated?

- Investigate the interplay between IFS and other terms in the local momentum budget, and attempt to close the local budget with help from model results from the Southern Ocean State Estimate.

- Use the Southern Ocean State Estimate to evaluate the role of the northern Drake Passage region in the overall Antarctic Circumpolar Current momentum balance.

References


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