Momentum balance in the Southern Ocean
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The Southern Ocean acts as an essential nexus of carbon and heat exchange between the atmosphere and the deep ocean, and the Antarctic Circumpolar Current (ACC) momentum balance governs this exchange process. As the winds that drive the ACC have increased in strength over the last few decades (Thompson and Solomon, 2002), understanding where and how momentum exits the ACC is a question with large-scale climate implications. Here we diagnose the Southern Ocean momentum balance in a 6-year run of the 1/6-degree eddy-permitting Southern Ocean State Estimate (SOSE; more information at sose.ucsd.edu), a model that combines millions of Southern Ocean observations with MITgcm physics to produce a best possible guess at otherwise unobservable basin-scale dynamics.

1. KEY FINDINGS
A. SOURCES AND SINKS. The time-mean topographic form stress balances 95% of the time-mean wind stress in the ACC latitudes; the remaining 5% is balanced by bottom friction and momentum flux divergences at the boundaries of the analysis domain. Wind stress is completely balanced by form stress across ridges in the top 3700 meters of the ocean.

B/C. CARRIER MECHANISMS. Barotropic waves carry about 65% of momentum from source to sink on timescales of a day at most; the remaining 35% may be carried via interfacial form stress. Hot spots of interfacial form stress variability appear to occur downstream of topography.


Kerguelen Plateau
(13% of integrated form stress signal)

Southeast Indian Ridge/
Macquarie Ridge/ Campbell Plateau region (20%)

East Pacific Rise
(3%)

South America and
Drake Passage
(42%)

B: CARRIER MECHANISMS: BAROTROPIC WAVES carry at least 65% of momentum from surface source to seafloor sink; variations in the integrated wind stress signal explain 65% of the integrated topographic form stress signal at zero lag for a one-day-averaged 6-year timeseries.

Here we show the total pressure field on August 31, 2010, minus the total pressure field on August 30, 2010. Large-scale surface pressure differences are propagated via full-depth barotropic waves, which allow the fluid to transfer momentum to topography as the waves propagate past undersea ridges.

C: CARRIER MECHANISMS: INTERFACIAL FORM STRESS may carry the remaining 35% of momentum. Hot spots of IFS variability appear in the lee of topography; here we show standard deviation of IFS during the winter months June/July/August, at gamma = 28.2 kg/m³, roughly the upper bound of Antarctic Bottom Water.

4. ACKNOWLEDGEMENTS. This work was supported by National Science Foundation grants PLR-1141512, PLR-0961218, OCE-1234473 and PLR-1425989. J. Masich was also supported by the Department of Defense through the National Defense Science and Engineering Graduate Fellowship Program. SOSE was produced using the Extreme Science and Engineering Discovery Environment (XSEDE), which is supported by National Science Foundation grant number MCA06N007.

3. UP NEXT: GROUND-TRUTHING SOSE VIA DIRECT OBSERVATIONS. The cDrake Experiment (cdrake.org) is a 4-year observational effort in the Drake Passage from which we can map both bottom pressure and interfacial form stress via observations from current and pressure-recording inverted echo sounders (CPIES). We are currently using these maps to ground-truth the mechanisms of vertical momentum transfer that we observe in SOSE.