Vorticity balance in Drake Passage from the cDrake experiment

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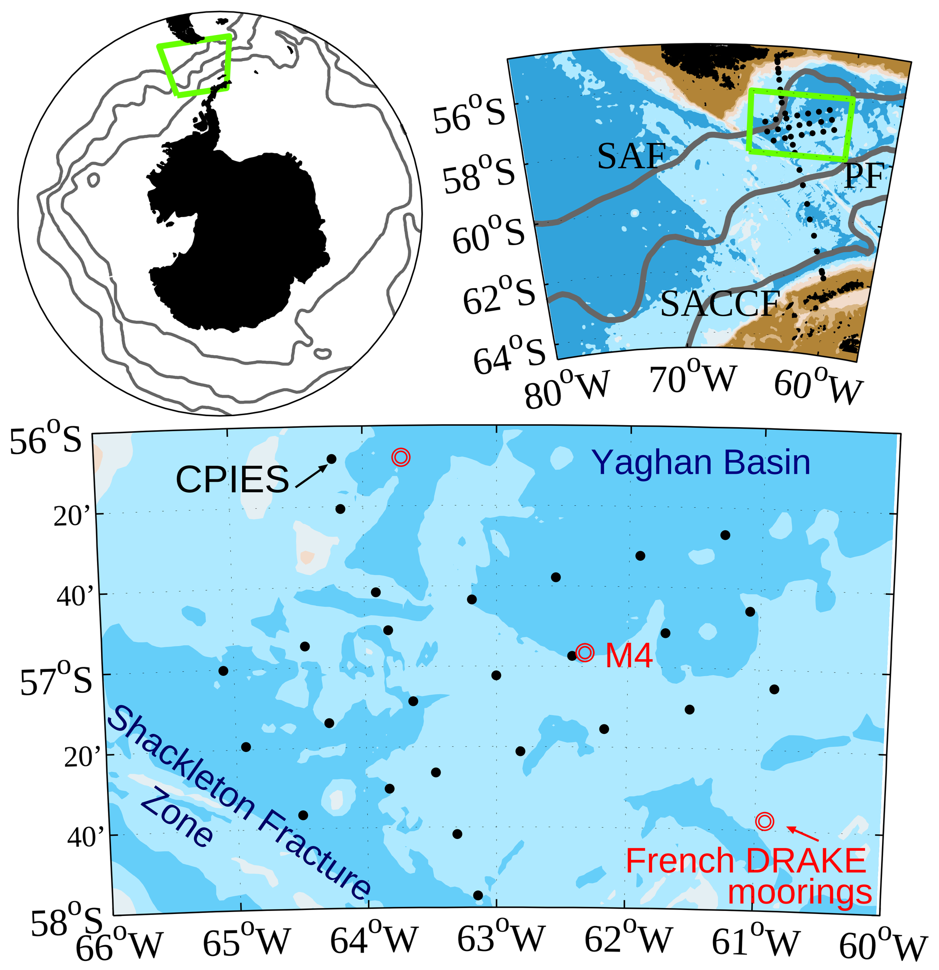
1. cDrake Experiment



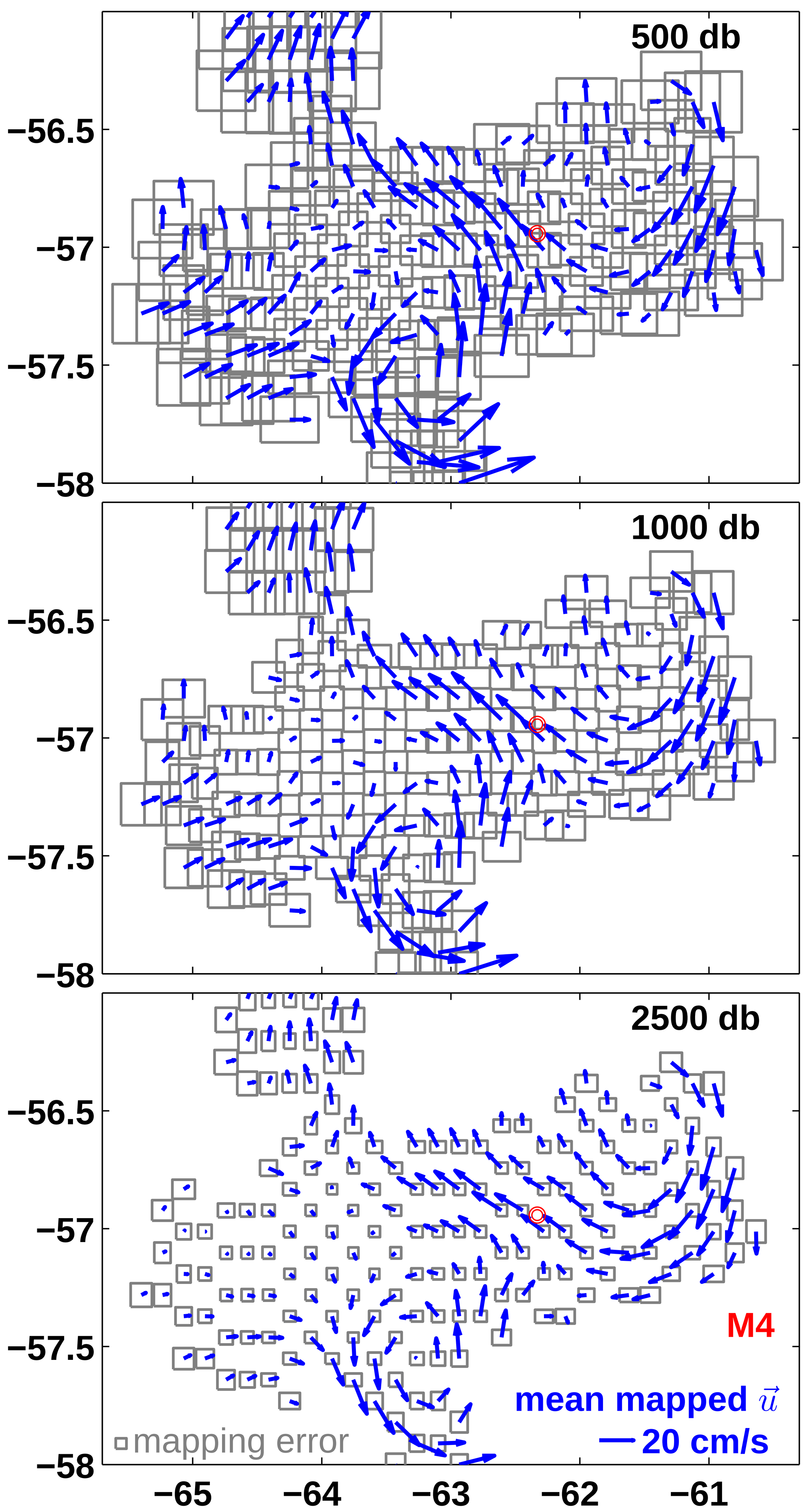
Fronts from *Orsi et al.* (1995).

- 4 year experiment (11/2007 - 12/2011), years 1-3 shown here (*Chereskin et al.*, 2009).
- CPIES (current meter-pressure sensor-inverted echo sounder) measure bottom-surface roundtrip sound travel time τ, bottom pressure p, near-bottom current $\vec{u}$; data filtered to remove tide and daily-averaged.
- 42 CPIES in transport line across the passage plus local dynamics array (LDA).
- 5 cruises, 273 CTD and LADCP profiles, high-resolution multibeam bathymetry. Bathymetry gaps filled with *Smith and Sandwell* (1997).
- Gravest Empirical Mode (GEM) method (*Meinen and Watts*, 2000) uses historical hydrography from Drake Passage region, 1972-2011, to construct lookup table for hydrographic profiles from τ; used to convert τ to geopotential anomaly Φ.
- First 18 months overlap with French DRAKE moorings; current meter timeseries at 500, 1000, and 2500 m from M4 filtered and daily-averaged as for CPIES data, compared to cDrake velocity estimates.

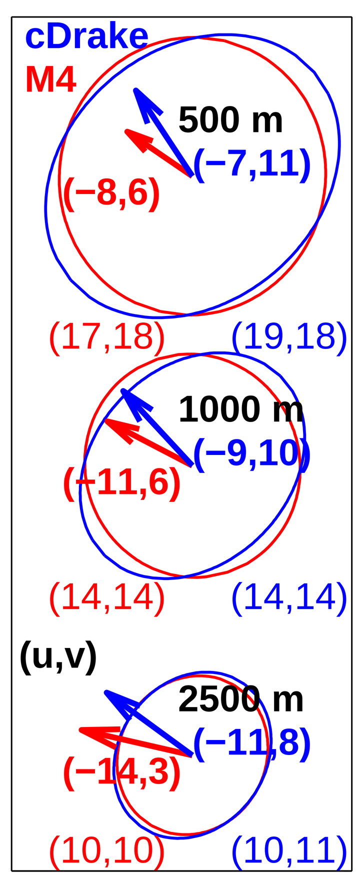
2. Objective Mapping

- Geopotential anomaly Φ and bottom presssure p and velocity $\vec{u}$ objectively mapped to baroclinic and barotropic geostrophic velocity and higher-order derivatives of geostrophic streamfunction on 10 km grid in LDA.
- Optimal mapping length scales and noise:signal variance determined by fitting Gaussian to observed decorrelations; for Φ additional GEM contribution to error variance incorporated.
- Simulations run to verify our ability to estimate desired terms and their errors by objective mapping.
- We can accurately map $\vec{u}$, relative vorticity ζ, ζ gradients; calculate planetary vorticity advection βv, mean relative vorticity advection $\langle\vec{u}\rangle\cdot\nabla\langle\zeta\rangle$, bottom pressure torque $J(p_b,\eta_b)$; estimate wind stress curl $\nabla\times\vec{\tau}_w$ from satellite scatterometer data.

3. Velocity

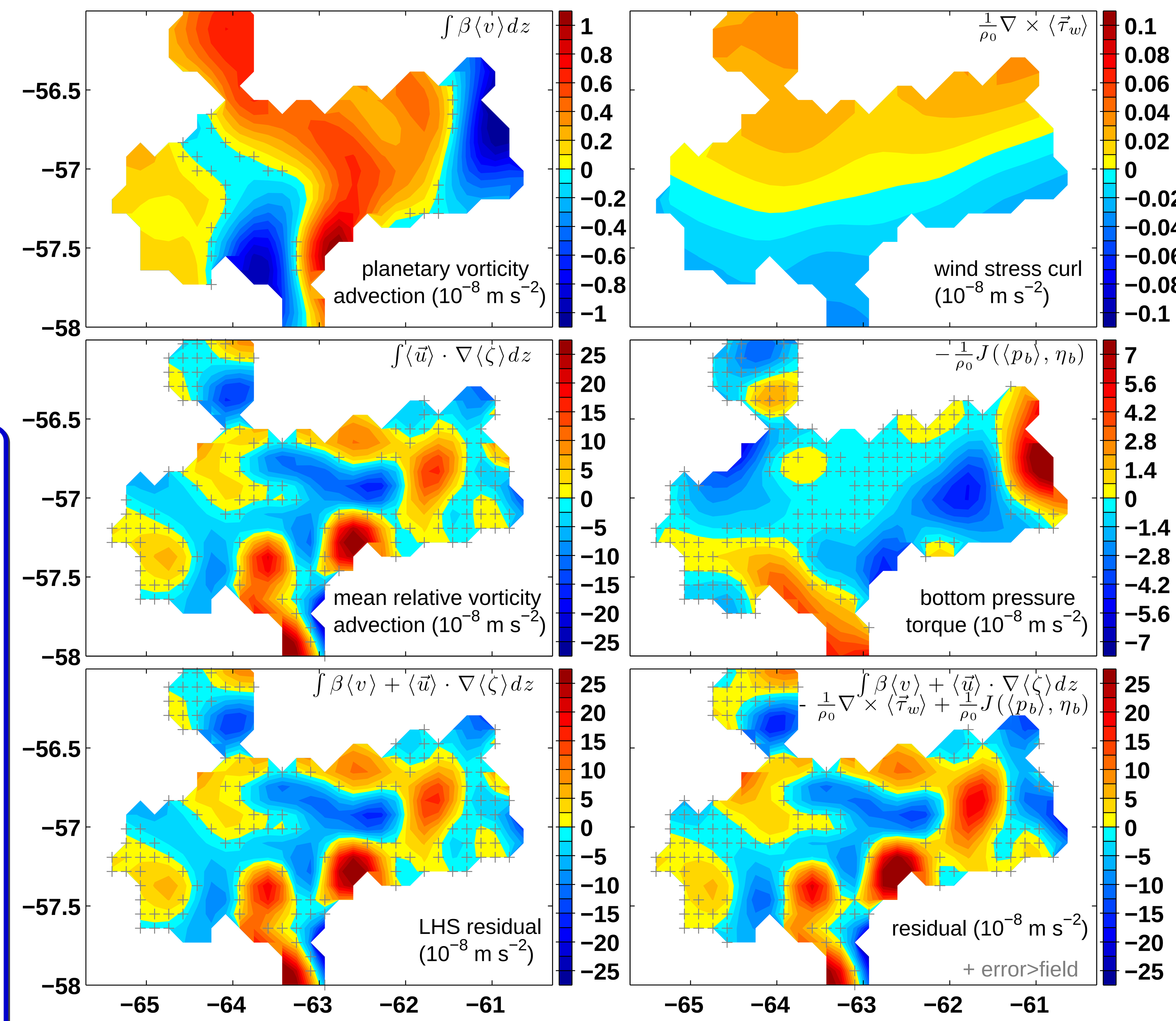


- Velocity field is self-similar with depth, shows the northward deflection of the SAF, as in shipboard ADCP data (*Firing et al.*, 2011); time-mean exhibits clockwise circulation over the Yaghan basin, also seen in French DRAKE (C. Provost, pers. comm. 2011).
- cDrake and M4 current timeseries well-correlated; mean current speeds, variance ellipse sizes and orientations, shear sizes and directions all consistent; cDrake mapped mean biased 22° clockwise of mooring mean; bias reduced to 12° if cDrake baroclinic $\vec{u}$ referenced with $\vec{u}$ measured at nearest CPIES (E02).



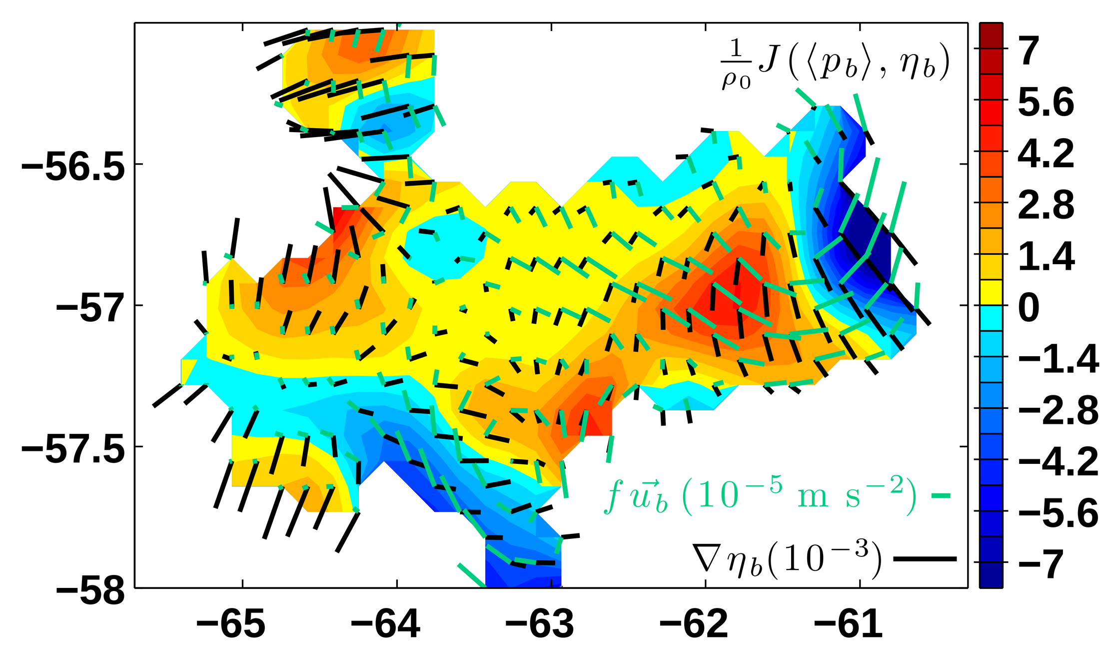
4. Mean Vorticity Balance

$$\int \beta\langle v\rangle dz + \int \langle\vec{u}\rangle\cdot\nabla\langle\zeta\rangle dz + \int \langle\vec{u}'\cdot\nabla\zeta'\rangle dz = \frac{1}{\rho_0}\nabla\times\langle\vec{\tau}_w\rangle - \cancel{\frac{1}{\rho_0}\nabla\times\langle\vec{\tau}_b\rangle} - \frac{1}{\rho_0}J(\langle p_b\rangle,\eta_b), \qquad (1)$$



- Mean relative vorticity advection is the dominant term estimated, about a factor of 3 larger than bottom pressure torque and an order of magnitude larger than planetary vorticity advection.
- The large residual of the estimated mean terms implies a significant eddy relative vorticity advection contribution to the balance.

5. Bottom Pressure Torque



- Bottom pressure torque is negative where the near-bottom flow is towards shallower bathymetry.
- Mean bottom pressure torque (contours, 10^{-8} m s^{-2}) correlated with size of mean bottom current (correlation coefficient 0.80) and mean bottom current orientation relative to topography (0.75).

References

Chereskin TK, KA Donohue, DR Watts, KL Tracey, YL Firing, and AL Cutting, 2009, *Geophys. Res. Lett.*, **36**, L23602.
Firing YL, TK Chereskin, and MR Mazloff, 2011, *J. Geophys. Res.*, **116**, C08015.
Meinen CS and DR Watts, 2000, *J. Geophys. Res.*, **105**, 21869-21891.
Orsi AH, T Whitworth III, and WD Nowlin, Jr., 1995, *Deep Sea Res. I*, **42**, 641-673.
Smith WHF and DT Sandwell, 1997, *Science*, **277**, 1957-1962.

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