Evaluating Wavenumber Spectra in Drake Passage with ADCP and Altimeter Measurements

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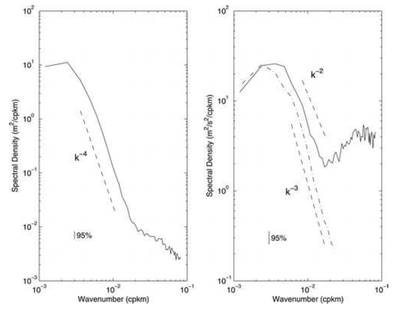
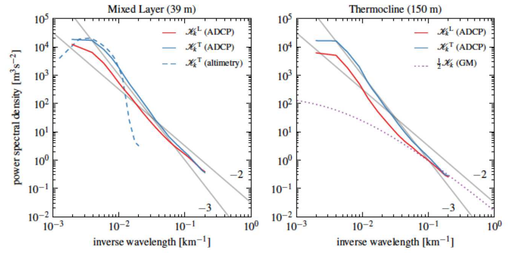
1. Introduction

Small-scale, high-wavenumber processes are difficult to sample with ships and not well-resolved by altimeters that have ∼10-km footprints. These scales are especially challenging in regions such as the Southern Ocean, where the Rossby radius can be as small as 10 km. Our objective is to characterize high-wavenumber processes in this region using altimetry and shipboard acoustic Doppler current profiler (ADCP) velocity data.

Sea surface height (left) and geostrophic velocity (right) spectra from altimeter measurements in the Gulf Stream. Dash-dot line shows velocity spectra from *Oleander* ADCP observations (Wang et al, 2010).



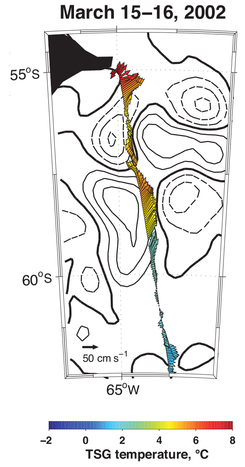


Gulf Stream longitudinal and transverse spectra in the mixed layer (left) and the thermocline (right) from altimetry and ADCP (Callies and Ferrari, 2013).

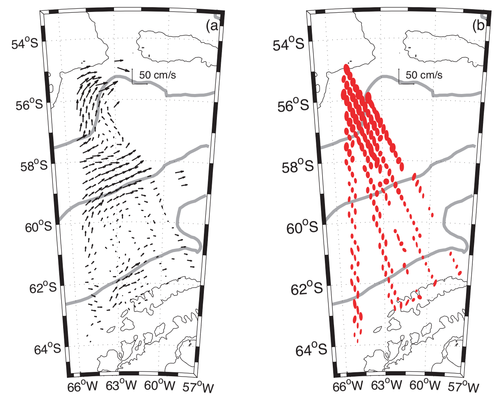
3. In Situ Data: ARSV L. M. Gould

Drake Passage crossings 2–4 times per month in all seasons.

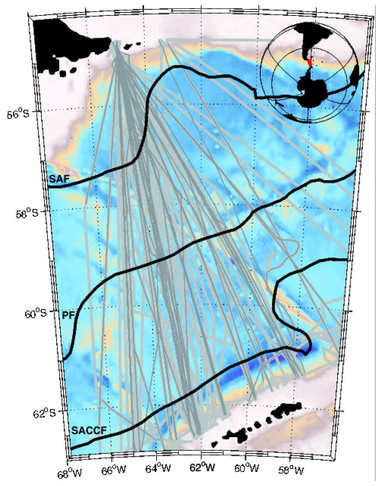
- ADCPs (1999-2013):
  - — 20-22 transects annually
  - — 2-day crossing
  - — Data recorded as 5-min averages (∼1.5 km resolution at 5 m s^{-1} ship speed (10 kts)
  - — 5 km horizontal resolution
  - — Grid to 10 km, implying 20 km Nyquist wavenumber
  - — 300 m vertical range (NB150)
  - — 1000 m vertical range (OS38)
- Thermo-Salinograph and Meterological Data (since 2000):
  - — 1-min samples (∼0.3 km resolution)



March 2002 ARSV L. M. Gould transect ADCP-velocities at 100-m depth color-coded by TSG temperature, overlying altimetric sea surface height anomaly (SSHA) contours (at 5 cm increments).



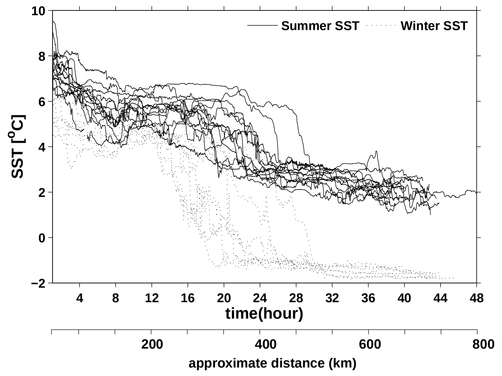
(a) Time-averaged currents, gridded (25 km × 25 km) and depth-averaged (26-298 m), from 262 Drake Passage transects between 9/1999 and 4/2011 and **(b) standard deviation ellipses**. Updated from Lenn et al. (2008).

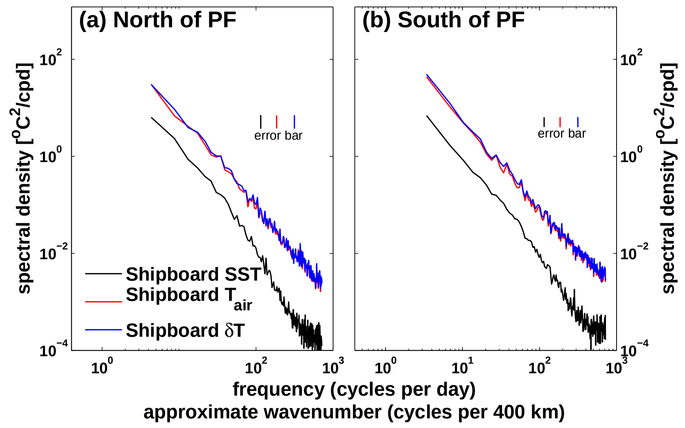


Drake Passage transects (gray lines) with climatological postions of the Subantarctic Front, Polar Front, and Southern ACC Front (Orsi et al, 1995). Tan hues represent depths < 2600 m and transition to blue hues in the deeper parts of the passage.

4. Small−Scales in Drake Passage

Temperature transects show small-scale variability and a sharp front in Drake Passage. Here solid lines are from March and dotted lines from September. (From Jiang et al, 2012)





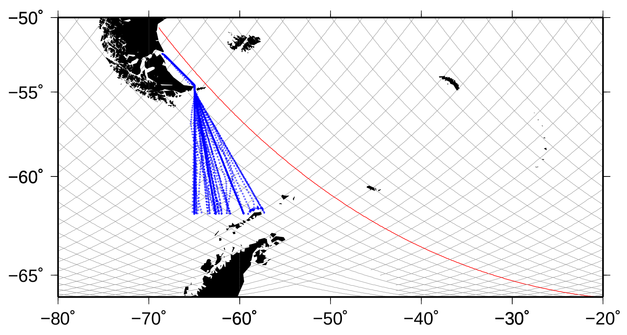
Temperature spectra computed north and south of the Polar Front show slopes around k^{-2}, consistently flatter than spectra computed from Gulf Stream observations. The regional separation is important: otherwise the sharp gradient of the Polar Front would bias the spectral slopes. SST spectra suggest the possibility of steeper spectral slopes for wavenumbers exceeding about 1 cycle/4 km. (From Jiang et al, 2012)

2. Altimeter Data

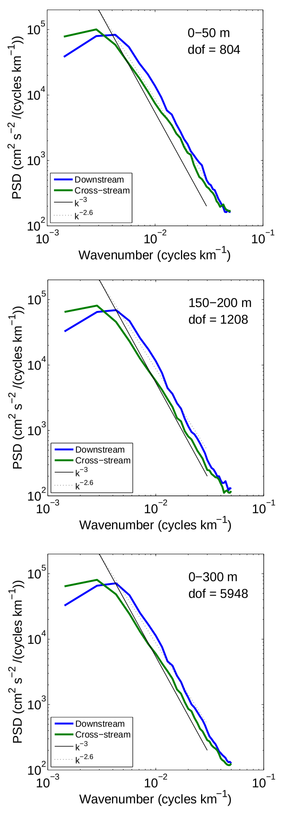
Along-track altimeter measurements:

- Typically reported at 1 Hz, corresponding to 10 km resolution
- 20-years of TOPEX/Poseidon/Jason quality data available
- Higher spatial resolution possible with:
  - — Newer processing approaches designed for coastal altimetry (e.g. X-Track)
  - — Newer satellites (e.g. AltiKa, not considered yet)

We use along-track data from select tracks in the Drake Passage region. Altimeter data (black lines) are not co-located with in situ observations (blue lines), and mapping from one sampling grid to the other would smooth out high-wavenumber variability.



4. Does Altimetry Capture High−Wavenumber Variability?



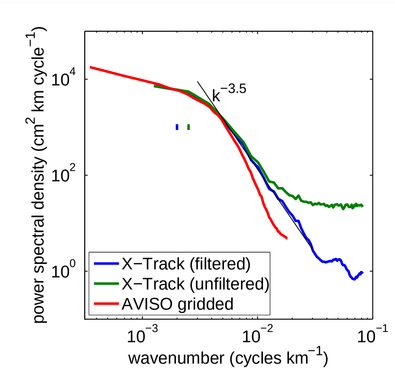
ADCP velocity anomaly spectra have $\sim k^{-3}$ slopes for both the downstream (u) and cross-stream (v) components (though there is more energy in the along-stream u component. In contrast with temperature, velocities do not indicate a sharp transition at the Polar Front (not shown).

There is little variation with depth through the top 300 m.

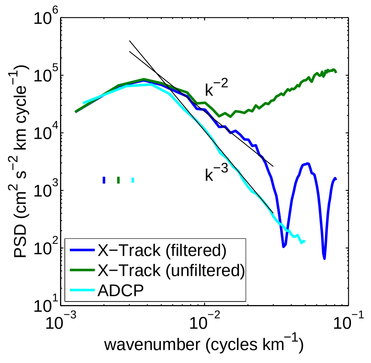
Spectral slope is uniform for nearly all frequencies. In Drake Passage we see no obvious flattening at high wavenumbers.

Here spectra are computed for 248 transects and are averaged over available depth bins.

Altimetric geostrophic velocity spectra have $\sim k^{-2}$ spectral slopes, so can be flatter than spectra from ADCP data (here from the 0-50 m range).



Sea surface height spectra are sensitive to the processing applied to altimeter data. AVISO gridded data smooth high-wavenumber variability, implying steeper spectra than are obtained from high-resolution along-track data from X-Track.



What we understand so far:

- In Drake Passage, sea surface height spectra are comparable in structure to SST spectra, but their steepness depends on the choice of altimeter product
- In situ velocity spectra are steeper than altimeter-derived velocity spectra, both in the top ∼50 meters, where ageostrophic velocities might be expected, and also at depths below 150 m, where the flow might be expected to be largely geostrophic.

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