Using ADCP data and altimetry to evaluate high–wavenumber variability in the California Current and the tropics

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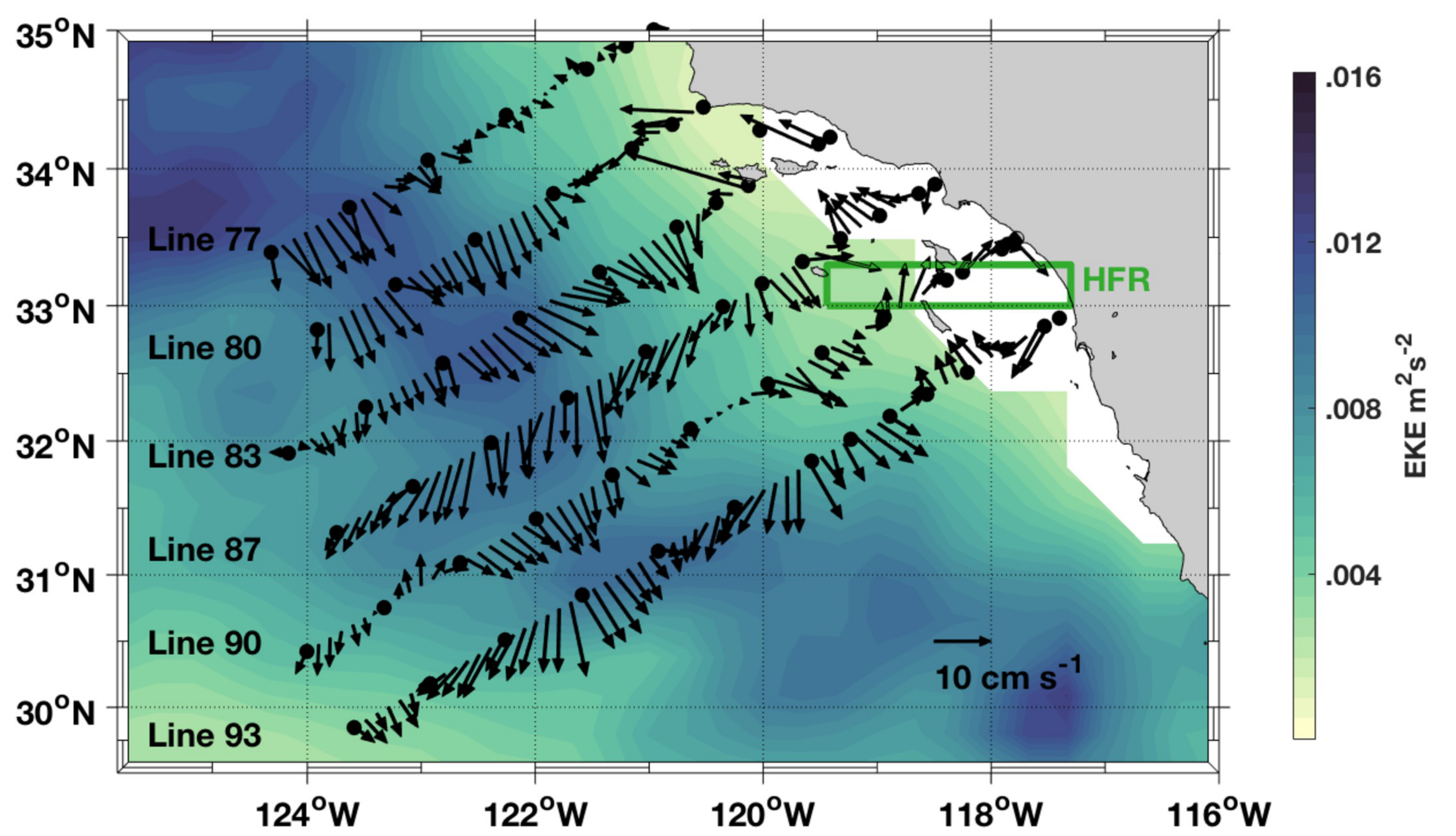
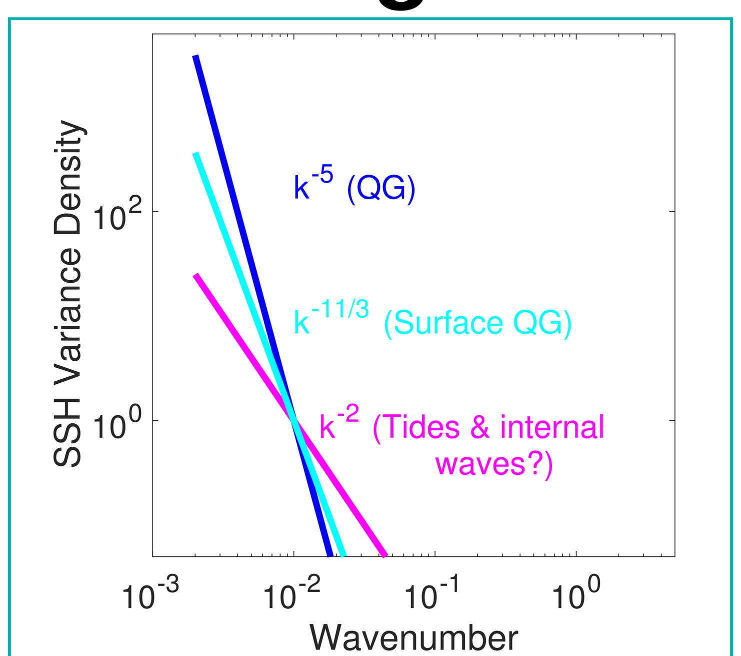
1. Introduction

At scales smaller than 50-100 km, observations from altimetry, Acoustic Doppler Current Profiler (ADCP) data, and numerical model output all suggest that oceanic variability is dominated by processes associated with internal waves and not in geostrophic balance. These unbalanced small-scale motions typically have relatively shallow spectral slopes (k^{-2} for velocities), but they can be hard to evaluate. To compare with altimetry and model output, we focus on two regions: the California Current, where ADCP data have been collected for many years as part of regular CalCOFI surveys of the region, and the tropics, where regular research ship operations have produced long transits that were previously unprocessed and unavailable for research.



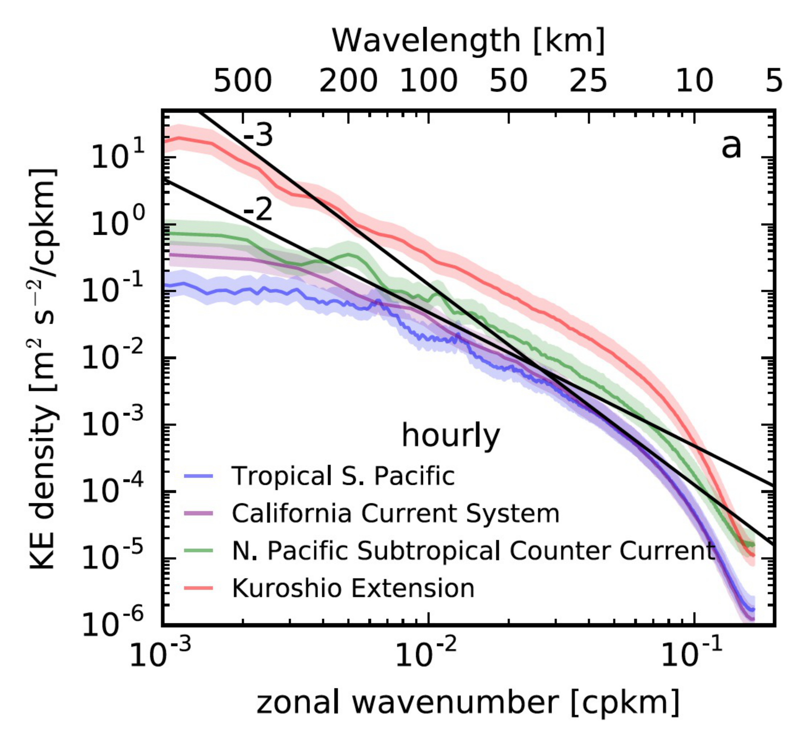
Time-mean currents at 20-m depth from 11 years of ADCP data, superimposed on eddy kinetic energy from the gridded Aviso altimeter product. High-frequency radar (HFR) data are available within the green box.

2. Background



Predictions for sea surface height wavenumber spectra suggest that quasi-geostrophic flows should have spectral slopes of k^{-5}, while internal wave motions would be expected to have flatter spectra.

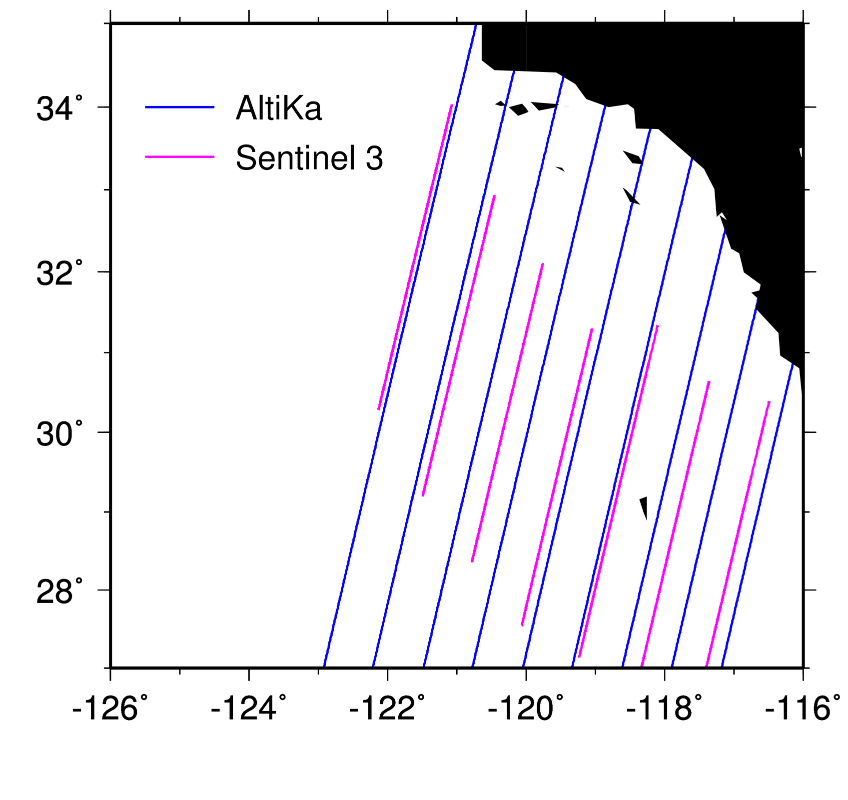
Velocity spectra for balanced flows are predicted to be k^{-3}, 2 units flatter than sea surface height spectra.



Surface KE wavenumber spectra from four regions of the Pacific Ocean from 1/48° model output (llc4320, see box 3), are slightly steeper in the Kuroshio Extension region than in the tropics. Spectral slopes of daily-averaged data (not shown) are steeper than hourly, consistent with the signal from internal waves at 10-50 km scales. Consistent with findings of Qiu et al (2017), outside the tropics, the spectra suggest a change in spectral slope around 50 km.

3. Data (California Current System)

AltiKa and Sentinel 3 ground tracks in the CalCOFI region, provide dense spatial coverage of the region. Descending tracks, which are roughly perpendicular to the coastline, were selected for this study to provide data that are roughly consistent with the CalCOFI sampling lines, albeit more meridional.

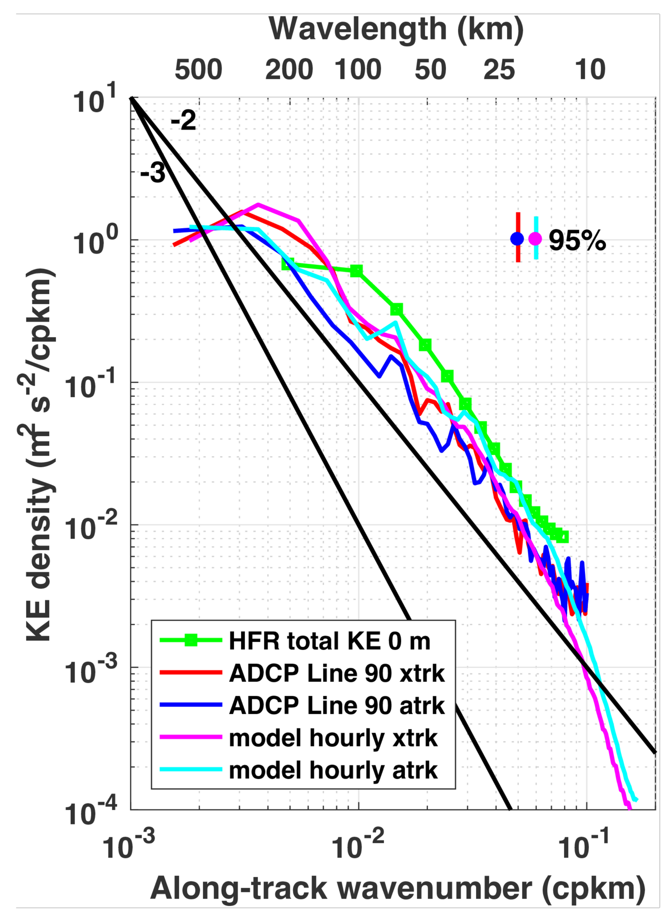


ADCP velocity data serve as an in situ point of reference against which to compare the altimeter observations (see figure in panel 1):

1. 6 lines, with roughly 5-km horizontal resolution
2. Depth range: 20 m to 300 m
3. Time period: 1993-2004, with sampling 4× per year.

Model output from the MITgcm, run at 1/48° (llc4320), resolution are also evaluated following the approach of Rocha et al (2016a, b).

4. Wavenumber spectra (CCS)

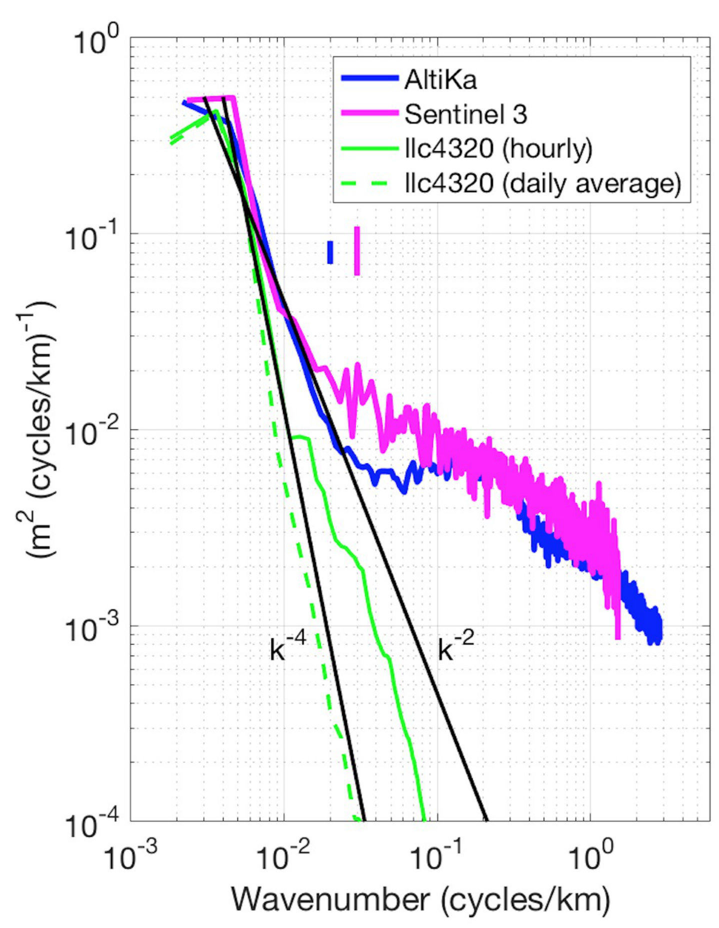


Across-track and along-track KE spectra at 20-m depth for ADCP and model transects along line 90i show spectral slopes that are closer to k^{-2} than k^{-3}. Surface spectrum from HFR is in agreement (Kim et al, 2011).

For ADCP data, the ratio of cross-track to along-track components is about 1.8 for wavelengths longer than ~70 km, consistent with horizontally non-divergent flow with a k^{-2} spectral slope.

For scales shorter than 40 km the ratio is about 1, consistent with flow that is neither strictly non-divergent nor strictly divergent. The change in ratio implies a change in dominant dynamics around ~70 km, in agreement with a Helmholtz decomposition of the flow into its rotational and divergent components.

For scales longer than 30 km, model results are similar. For scales shorter than 30 km, the along-track component is about a factor of 2 larger, consistent with divergent flow.



Sea surface height spectra have slopes near k^{-4} for scales longer than ~100 km.

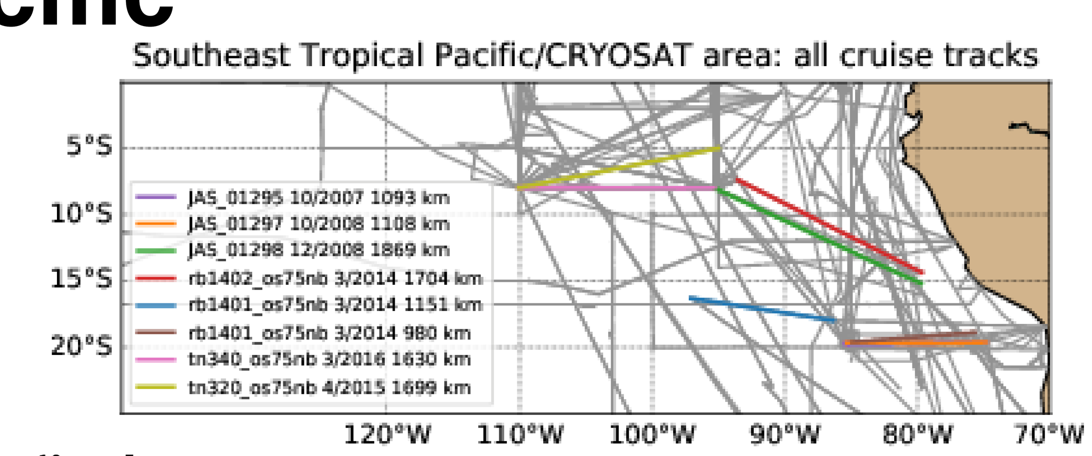
Altimeter-derived spectra from Sentinel 3 and AltiKa are flatter for scales shorter than ~50 km.

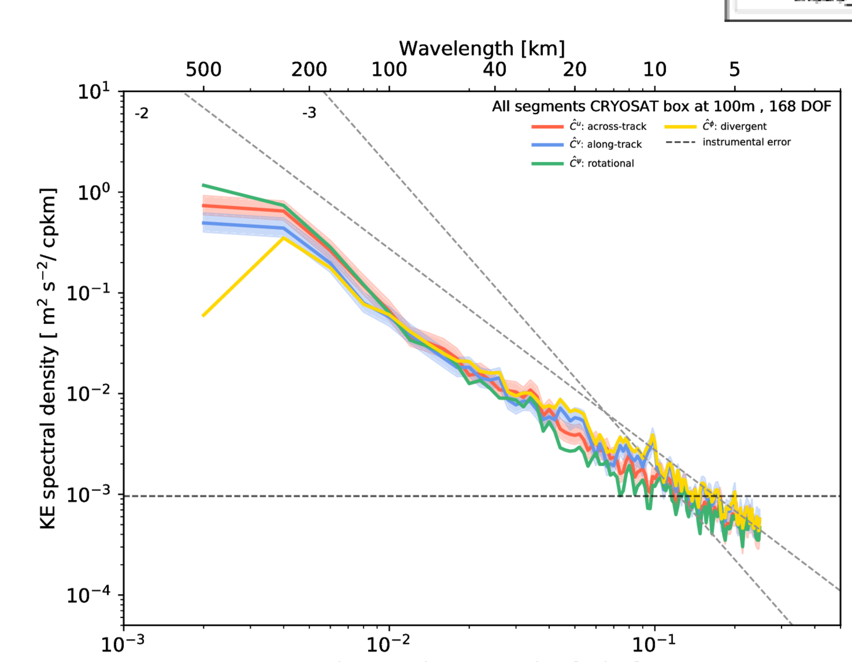
Disagreement between Altika And Sentinel 3 spectra for shorter scales imply the presence of unresolved geoid or noise issues.

Model SSH spectra are steeper, but differences between hourly and daily-averaged data indicate a distinct transition between 50 and 100 km.

5. Tropical Pacific

Shipboard ADCP transects from the tropical Pacific have been processed to expand the range of data available for analysis. We have prioritized uninterrupted transects that had not yet been processed.





Spectra have nearly constant k^{-2} spectral slopes over the full resolved range, when computed at 100-m depth from the color-coded transects in the map. Results indicate no distinction between along-track and cross-track spectra and no distinction between divergent and nondivergent spectra for scales of 200 km or less. This contrasts with results from mid-latitudes.

6. Discussion

California Current:

- For wavelengths > 100 km, ADCP, model and altimetry are consistent, with k^{-2} slopes for KE spectra and k^{-4} slopes for SSH.
- At smaller wavelengths, ADCP and model KE spectra show no change in slope, whereas altimeter spectra start to flatten.
- The change in KE component ratio occurring between 70 and 100 km is consistent with a transition from divergent to non-divergent flows.
- We hypothesize that the California Current transition scale is larger than in more energetic regions such as Drake Passage (Rocha et al, 2016a) or the Kuroshio Extension (Rocha et al, 2016b), because geostrophic energy levels are lower in the California Current, allowing wave-related processes to dominate over a broader range.

Tropics:

- Preliminary KE spectra indicate little variation in slope and a transition in dynamical regimes occurring around 200 km.
- The transition scale is larger than in the sub-tropical western Pacific, and consistent with findings in the western tropical Pacific (Qiu et al. 2017).

References

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Photo panorama of Channel Islands by Jamie Holte.