Best practices for intercomparing ADCP and altimeter statistics for submesoscale analyses: Lessons learned from the California Current System, the Gulf Stream, and the tropics

Sarah Gille[1*], Saulo M. Soares[1], Teresa Chereskin[1], Julia Hummon[2], Eric Firing[2], Steve Howell[2]

[1]Scripps Institution of Oceanography, University of California San Diego

[2]Department of Oceanography, School of Ocean and Earth Science and Technology, University of Hawaiʻi at Manoa

Funding from NASA's Ocean Surface Topography Science Team (OSTST)

*sgille@ucsd.edu

Shipboard Acoustic Doppler Current Profiler (ADCP)

ADCP data come from transits in the global ocean, available in the JASADCP archive (Fig. 1). We evaluate the capability of this data set to provide a statistical assessment of dynamics to support altimeter-based ocean applications. Data have

- high horizontal resolution, 1-3 km
- high temporal resolution, 2-5 min
- broad range of orientations

We highlight four principal lessons.

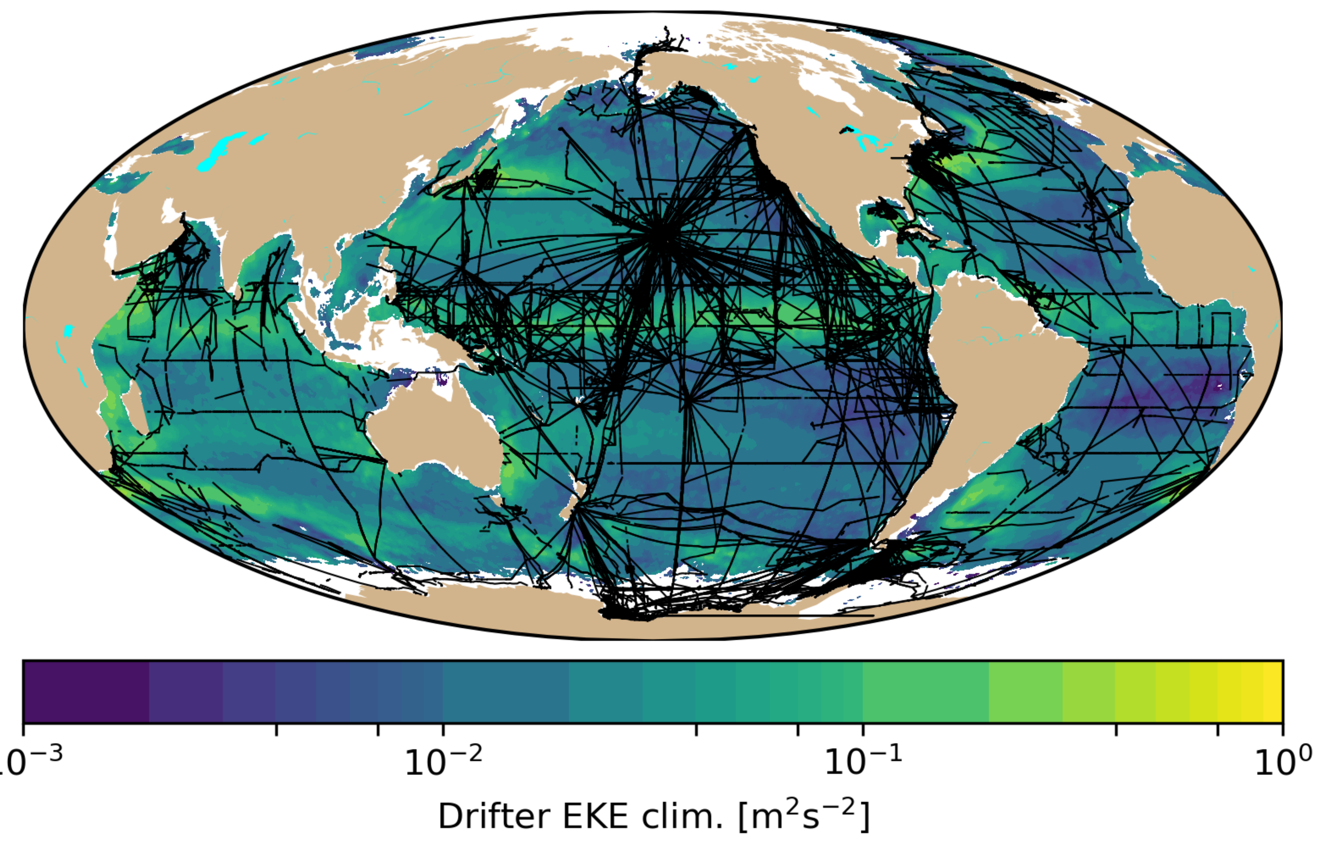

Fig. 1: Map with ship tracks with ADCP data from the JASADCP archive at NOAA NCEI. The color shading is the eddy kinetic energy from a drifter climatology (Laurindo et al, 2017).

Laurindo, L., A. Mariano, and R. Lumpkin, 2017: An improved near-surface velocity climatology for the global ocean from drifter observations *Deep-Sea Res. I*, **124**, pp.73-92, doi:10.1016/j.dsr.2017.04.009 .

1. Robust time series from post-processing practices

For full underway transects (ship speeds > 4 m/s):

- Statistics from data collected in the 1990s with U.S. research vessels, prior to wide usage of differential GPS and the end of select GPS accuracy degradation, are not significantly different from data collected more recently (e.g. Fig. 2).
- Expert post-processing is essential to obtain science-accurate data.

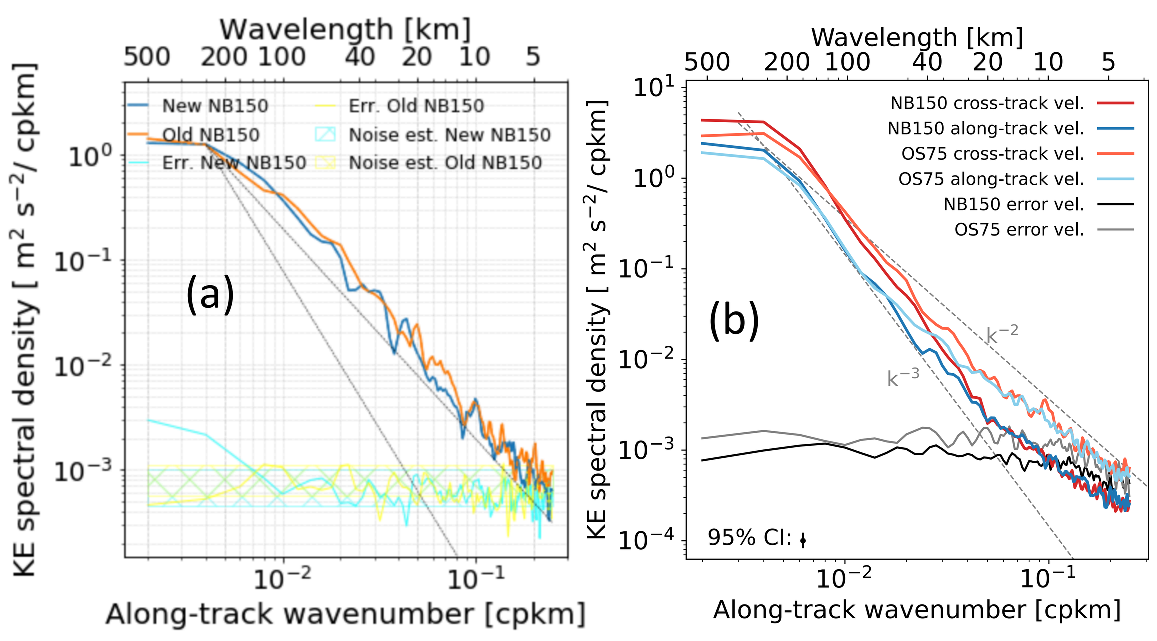

Fig. 2: (a) The kinetic energy spectrum at 30 m for ADCP data collected between 1993-1998 vs. 2002-2010 in the north east tropical Pacific (NETP). (b) Oleander (Gulf Stream area) power spectra for cross-track and along-track velocity components from early data (1993-2004) using a NB150 ADCP vs late data (2005-2018) with an OS75NB at 50 m.

2. Transects are synoptic

For statistical analyses, e.g. power spectrum or structure function calculations , the along-track ship data can be considered synoptic.

- We find that spectral Helmholtz decomposition for transects at ship speeds of 3-6 m/s converge (Fig. 3). The Helmholtz decomposition from ADCP data is also consistent with that from HFR data.
- Sampling experiments with synthetic data show that power ratios are not significantly altered for large ensembles.

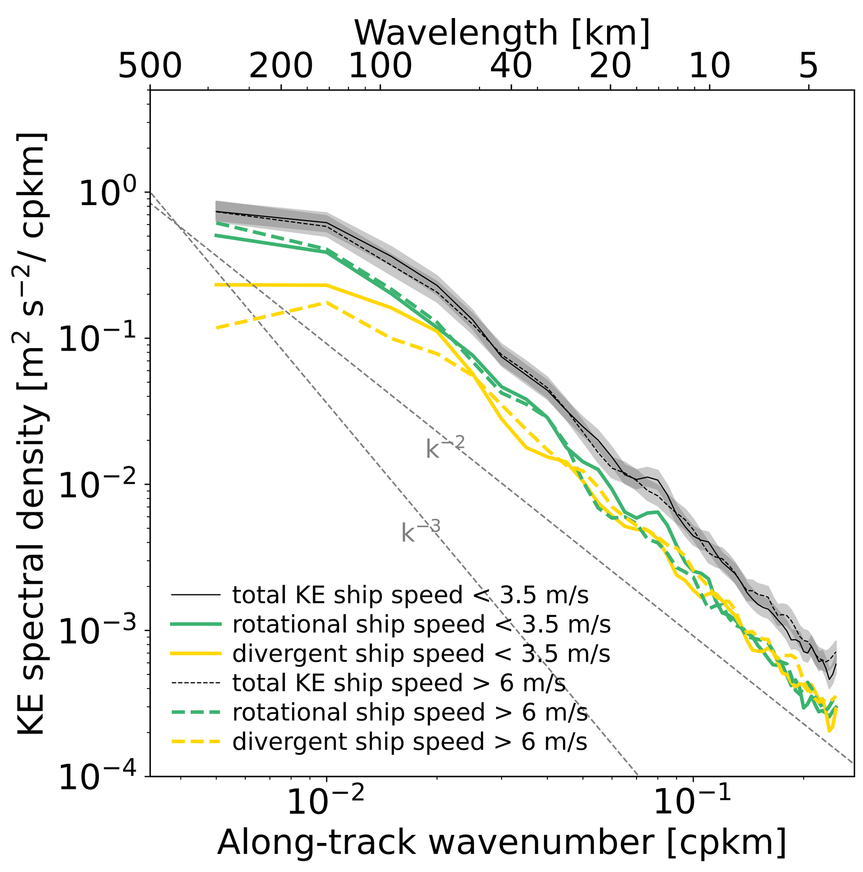

Fig. 3: Example **KE** spectra for ADCP data collected in the California current system (CCS) area. Shows also the Helmholtz KE decomposition into rotational (approximately geostrophic) and divergent (ageostrophic) components. Assumes isotropy. Two ship speeds are compared.

3. Useful multi-directionality

Ships of opportunity sample the ocean with tracks along a broad range of orientations. These are effective at recovering the statistical properties of the underlying dynamics and provide a useful counterpoint to the narrow range of orientations available from nadir altimetry

For most regions within a given dynamical regime, we find that statistics vary little with track direction (e.g. Fig. 4), or when variations are present, there are sufficient samples to average out directional effects. This implies that the bi-directionality of nadir-altimeters is not a significant drawback in sampling flow statistics.

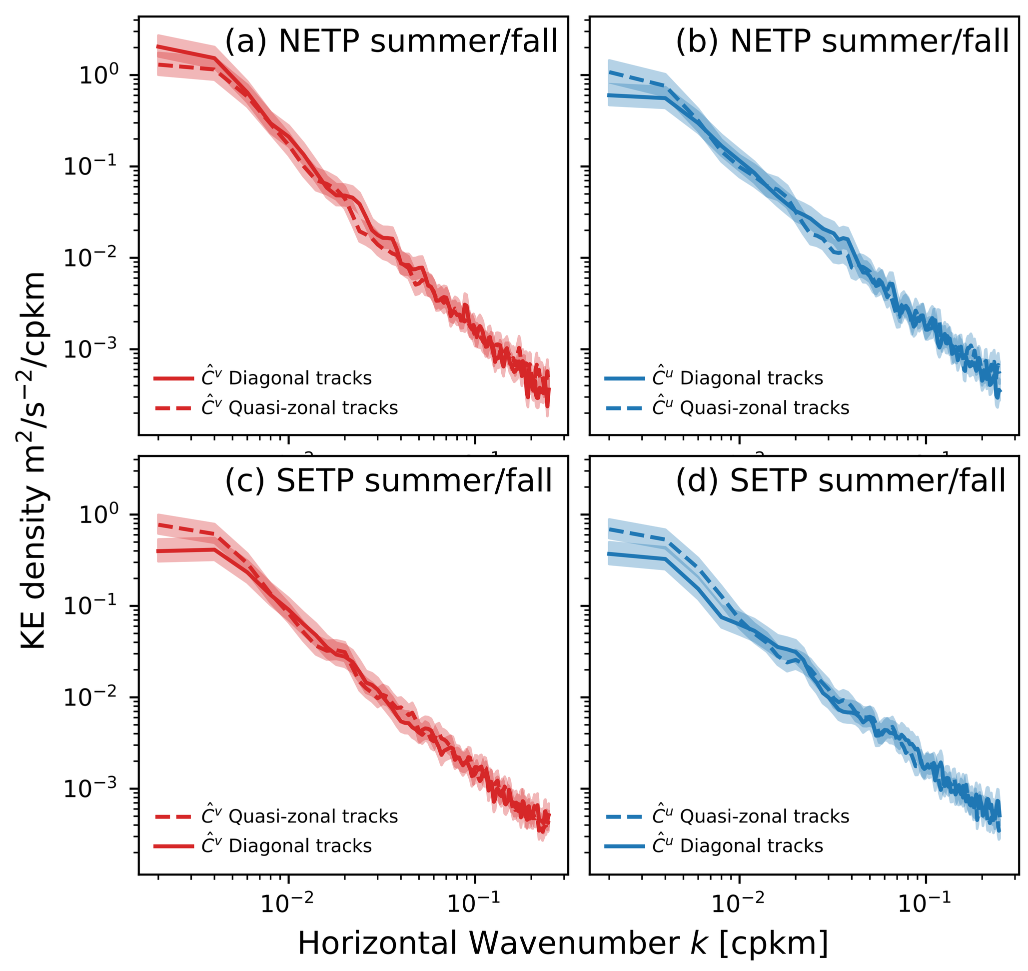

Fig. 4: Spectra for ADCP data collected in two large regions in the eastern tropical Pacific aggregated and averaged by two common directions (quasi-zonal and quasi-diagonal, roughly in the NW-SE direction). (a), (c) cross- and (b), (d) along-track components.

4. Higher frequency sonars have less random noise

Because velocity spectra are red, measurement noise is chiefly a concern at high wavenumbers.

There is no single universal metric for random error in SADCP data. Higher frequency sonars tend to perform better due to higher ping rates and smaller ensonifying volume (e.g. Fig. 5 and Fig. 2b). The error must be evaluated case by case. However, averaging the 3-nearest vertical bins is an effect noise reduction strategy.

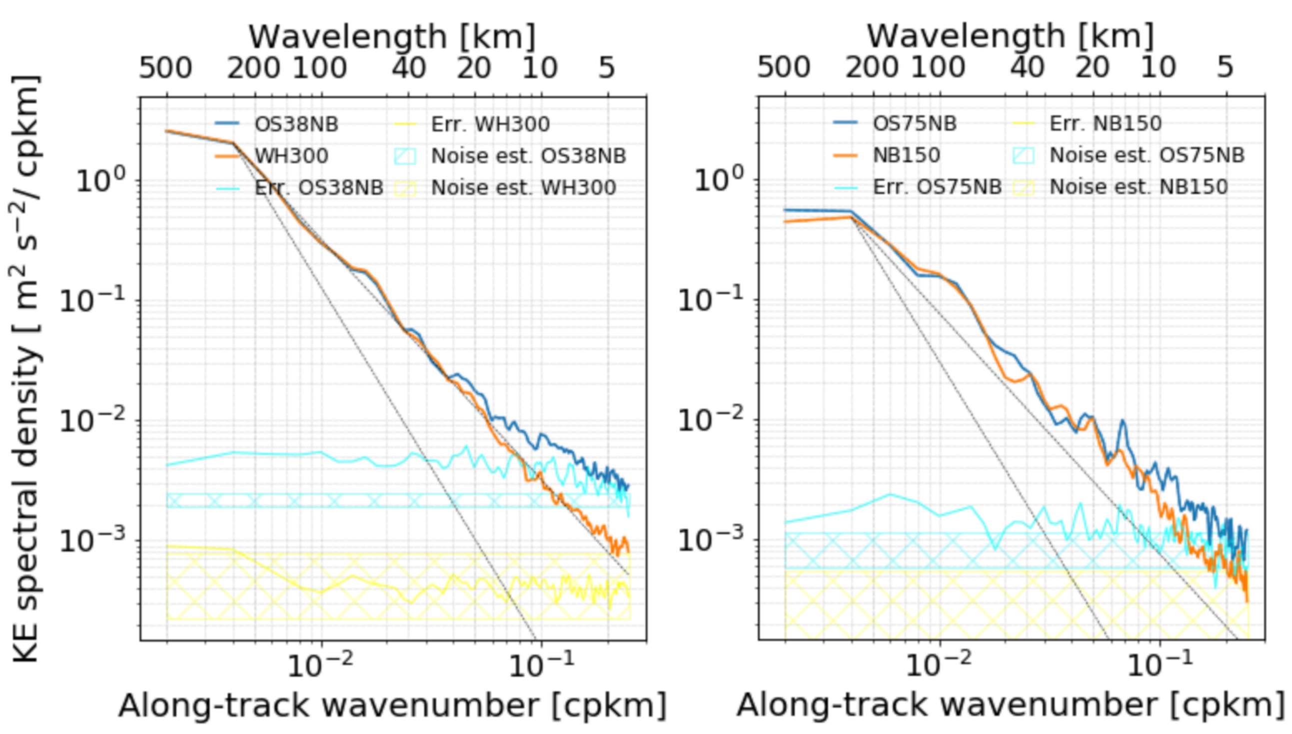

Fig. 5: Comparison between low-frequency and high-frequency sonars from concurrent tracks. Note how high-wavenumber behavior differs between a high-frequency sonar (oranges) and low-frequency sonar (blues). Data from the northeast tropical Pacific.

Key points

- **High-frequency sonars, even older models, are preferred to capture upper ocean variability at small horizontal scales. Beneath 400 m, noise generally limits the ability of SADCPs to capture small-scale variability.**
- **A science-ready underway transect data set is available at https://doi.org/10.6075/J0FJ2GZ3.**
- **See the talk by Soares et al on altimetry applications at Friday's session.**