CHARACTERIZATION OF OCEANIC MESOSCALE AND SUB-MESOSCALE ENERGY SPECTRA AND FLUXES

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ABSTRACT

Transition of oceanic scales in space is examined with currents observed from multiple platforms off the U. S. West Coast – satellite altimeter (ALT), high-frequency radar (HFR), shipboard and stationary ADCPs. The wave-number spectra of HFR-derived surface currents agree with that of ALT-derived geostrophic currents at scales larger than 100 km, and decay with k^{-2} at high wave-number (less than 100 km), aligned with submesoscale spectra. Moreover, subsurface currents from shipboard ADCPs support continuous spatial scales in energy spectra. Coastal boundary effects on energy spectra and whether they are anisotropy are investigated with spatial covariance, equivalent to the wave-number spectra. The spatial covariance appears as an anisotropic exponential shape with decorrelation length scales of 20 km nearshore and 100 km offshore parallel to the shoreline. Their overall exponential shapes are consistent with submesoscale wave-number spectra of an approximate k^{-2} decay behavior. The oceanic energy pathways are examined with the advective energy fluxes of observed currents, and the dominant length scales having zero crossings in the kinetic energy fluxes appear at approximately 8 km.

1. INTRODUCTION

The newly-completed USWC high-frequency radar network provides an unprecedented capability to monitor and understand ocean dynamics and phenomenology through hourly surface current measurements at up to 1 km resolution. These novel observations reveal coastal surface ocean variability having multiple temporal and spatial scales and continuity of oceanic energy and their pathways across scales from sub-mesoscale to mesoscale [1] .

2. RESULTS

The wave-number spectra of HFR surface currents show a consistent and continuous variance distribution across three different resolutions (1, 6, and 20 km) (Fig. 1). Resolved scales range from $O(1000)$ km to $O(1)$ km, and the spectra decay with k^{-2} at high wave-number in agreement with sub-mesoscale spectra [e.g., [2, 3]]. Although their spectra can vary with location because of regional variations in driving forces and geostrophic contents, they have

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a robust k^{-2} decay. Moreover, HFR observations resolve variability at scales smaller than $L \approx 100$ km, where the noise in satellite ALT currents becomes dominant over oceanic signals [e.g., [4]]. For example, the wave-number spectra of HFR surface currents in a region (e.g., southern California) with minimum wind-driven components are comparable to the spectra of along-track ALT geostrophic currents (Envisat and Jason-1) in the northeastern Pacific (30°N to 50°N, 114°W to 133°W). The mismatch at low wave-number ($L > 500$ km) is likely due to alongshore coastal signals with large wavelength in the coastal HFR surface currents [1].

The scale-by-scale energy budget equation is a balance of averaged and cumulative following quantities between 0 and k^* in the one-dimensional wavenumber domain: kinetic energy (E; KE), KE flux (Π), enstrophy (Ω), and energy injection (F) [5, 6]:

$$\frac{\partial}{\partial t} E(k^*) + \Pi(k^*) = -2\nu\Omega(k^*) + F(k^*), \tag{1}$$

where ν denotes kinematic viscosity.

The advective fluxes of KE are computed from surface currents observed from HFRs off southern San Diego (1 km resolution) and derived from a sub-mesoscale numerical simulation (0.75 km resolution) [3] (not shown). The primary forcing of the numerical simulation is wind stress, and the sampled HFR surface currents may contain responses of local wind, tides, and low frequency pressure gradients. Although the range of KE fluxes in both estimates is slightly different, the length scales to divide forward cascade (positive KE) and backward cascade (negative KE) are nearly consistent as approximately 15 km.

3. REFERENCES

[1] S. Y. Kim, E. J. Terrill, B. D. Cornuelle, B. Jones, L. Washburn, M. A. Moline, J. D. Paduan, N. Garfield, J. L. Largier, G. Crawford, and P. M. Kosro, "Mapping the U.S. West Coast surface circulation: A multiyear analysis of high-frequency radar observations," *J. Geophys. Res.*, vol. 116, 2011.

[2] J. C. McWilliams, "Submesoscale, coherent vortices in the ocean," *Rev. Geophys.*, vol. 23, no. 2, pp. 162–182, 1985.

[3] X. Capet, J. C. McWilliams, M. J. Molemaker, and A. F. Shchepetkin, "Mesoscale to submesoscale transition in the California Current System. Part I: Flow structure, eddy flux, and observational tests," *J. Phys. Oceanogr.*, vol. 38, no. 1, pp. 29–43, 2008.

[4] D. Stammer, "Global characteristics of ocean variablity estimated from regional TOPEX/POSEIDON altimeter measurements," *J. Phys. Oceanogr.*, vol. 27, no. 8, pp. 1743–1769, 1997.

[5] U. Frisch, *Turbulence: The Legacy of A. N. Kolmogorov*, Cambridge University Press, 1995.

[6] R. B. Scott and F. Wang, "Direct evidence of an oceanic inverse kinetic energy cascade from satellite altimetry," *J. Phys. Oceanogr.*, vol. 35, no. 9, pp. 1650–1666, 2005.

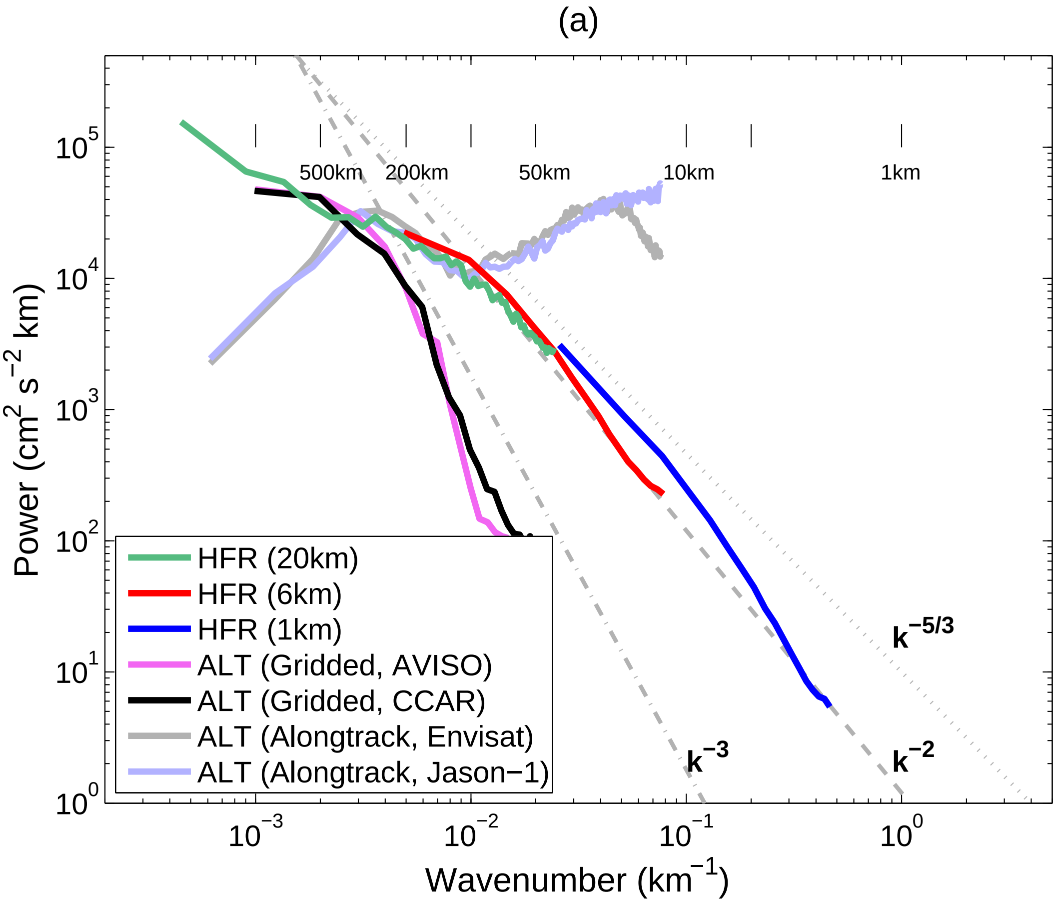

Fig. 1. A study domain for continuity of ocean surface scales off the USWC. Sampling locations of HFR surface currents with three spatial resolutions (1, 6, and 20 km), ALT gridded geostrophic currents (CCAR and AVISO), and ALT along-track SSHAs (Envisat and Jason-1) are indicated. The effective coverage of HFR surface currents is denoted by a dark gray curve. (b) Power spectra of high-frequency radar-derived (HFR; 1, 6, and 20 km resolutions) surface currents and altimeter-derived geostrophic currents [ALT; optimally interpolated current products of CCAR (∼25 km resolution) and AVISO (∼33 km resolution) and along-track Envisat and Jason-1] for two years (2007 and 2008) in the wave-number domain [Length scales (L) of 1, 5, 10, 50, 100, 200, 500, and 1000 km are marked]. The auxiliary lines are denoted as k^{-1}, $k^{-5/3}$, k^{-2}, and k^{-3} in the wave-number domain. The 95% confidence interval (CI) of individual spectra is indicated. This is partially adapted from [1].