Energy Spectra and Cascades in the Global Ocean: Planetary Scales to Mesoscales, Surface to the Abyssal Ocean

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Our understanding of the ocean's spatial scales and their coupling has been derived mostly from Fourier analysis in small "representative" regions, typically a few hundred kilometers in size, that cannot capture the vast dynamic range at planetary scales. Using coarse-graining[1], we analyze a 1/12-degree reanalysis dataset on a range of spatial scales spanning more than three orders of magnitude, including both mesoscales and planetary scales. We present a truly global kinetic energy wavenumber spectrum[2], see Fig. 1, as well as the first measurements of the cascade across this entire range of scales. This provides us with the first estimates of the global amount of energy that is transferred by the KE cascade, as well as the scale-dependent depth structure of the oceanic KE spectrum and cascade. We find that within the mesoscales, the seasonal cycles of KE at larger length scales demonstrate a characteristic lag time relative to smaller length scales. The seasonal cycle of the inverse energy cascade exhibits the same lag time but is phase-shifted to earlier times, which suggests causality. This research was supported from the European Research Council (ERC) grant 882340, from US NASA grant 80NSSC18K0772, and from NSF grant OCE-2123496.

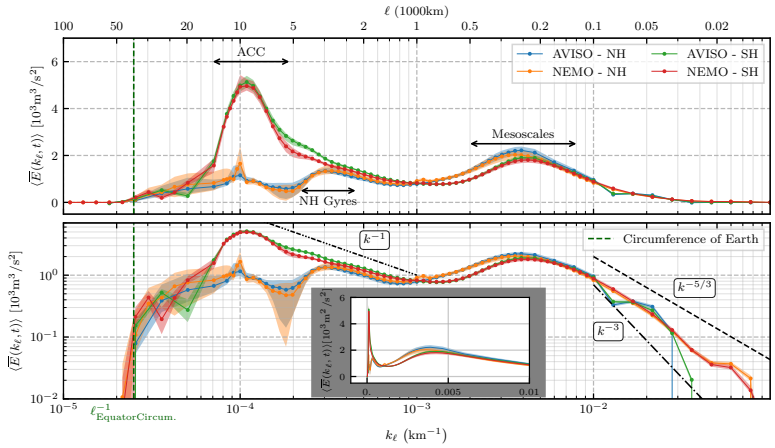

Figure 1: (top) Energy spectra of surface geostrophic Kinetic Energy for the global extra-tropical ocean from AVISO satellite altimetry and NEMO model re-analysis. Northern and southern hemispheres (NH and SH, respectively) extend poleward of 15°. (bottom) The same data are shown using log-log scale in the main panel, while the inset panel uses lin-lin axes.

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[1]Buzzicotti et al., *arXiv preprint (sub. to JAMES)* **2106.04157** (2023).
[2]Storer et al., *Nature communications* **13(1)**, 5314 (2022).