Abstract

While there are many theories predicting the spectral slopes associated with the statistics of ocean macro-turbulence, there have been no observations at depth to guide these discussions. Here, a method developed for estimating the structure function of atmospheric macro-turbulence using rawinsondes is adapted to estimate the structure function and corresponding spectral slope of oceanic macro-turbulence using data collected by ARGO profiling floats. Structure functions were calculated over a range of depths and latitude bands, as well as at eddy-rich and eddy-poor regions. It is shown that the horizontal structure function evaluated at pressure levels differs from that evaluated along potential density surfaces, consistent with the internal wave spectrum. In pressure coordinates below 45m at larger scales, the results follow the Batchelor (1959) theory, with spectral slope of 1, and smaller scales follow the Kolmogorov (1941) theory of spectral slope of 5/3. The potential density coordinate results are consistent with the Batchelor spectrum at large scales over all depths. Eddy-rich regions show the Kolmogorov spectrum at small scales, and Batchelor at larger scales, while eddy-poor regions have a slope shallower than all theories predicted at all scales. The latitude dependence appears as a difference in structure function strength, rather than slope variation, with higher latitudes exhibiting higher energy levels.

Structure Function and Spectral Slope

The structure function estimates the difference in temperature, velocity, or salinity between two locations a distance, s, apart, using the isotropic kinetic energy:

\[ \overline{\nabla T(s)} = \overline{\nabla T(s)} \]

For velocity, the autocorrelation function, R(t), and structure function, D(t), are calculated by

\[ D(t) = \frac{1}{2t} \int R(x,t) - R(0,t) \]

The primary goal of this project will be to estimate \( T(s) \) from ARGO data over large scales where an inertial range is apparent, and compare to theories that predict \( T(s) \).

Theoretical Predictions

Different theories predict the spectral slope for energy, enstrophy, and temperature cascades at inertial scales, in 3-dimensional, 2-dimensional, quasi-geostrophic and surface quasi-geostrophic cases. Kolmogorov’s (1941) 3D energy cascade and Blumen’s (1978) SQG temperature cascade both predict a spectral slope of 1/3, and at the surface and in the mixed layer, Cappet et al. (2008) and Klein et al. (2008) both find \( 1/2 < \gamma \approx 2 \). We expect to see the spectral slopes equal to either 2/3 or 2 at the macro scale (s ~ 100). For passive tracers, Batchelor (1959) predicts a spectral slope of -2, corresponding to a structure function slope of 3.

Questions to consider

In future work, the assumptions that are made in turbulent theory must be addressed, most importantly the assumptions of homogeneity and isotropy. Especially when looking at latitude bands that extend across both eddy-rich and eddy-poor regions like in Figures 2 and 3, neither of the assumptions are accurate. The eddy-rich and -poor regions were chosen to maximize homogeneity, but in future work, sections will be chosen to match the direction of the flow so that isotropy can safely be assumed. With confidence intervals on the structure functions, error bounds for slope are also possible, and will be calculated soon.

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References


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