Surface boundary layer turbulence in the Drake Passage region of the Southern ocean

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Recent work has shown that the thickness of the near-surface turbulent boundary layer in the Southern Ocean is biased shallow in climate models [1]. In the Drake Passage region, these errors can exceed 90% [2]. Many dynamical processes are known to be missing from upper-ocean parameterizations of mixing in global models. These include surface-wave driven processes such as Langmuir turbulence [3], submesocale frontal processes [4], and nonlocal representations of mixing.

Because of the remote location and harsh conditions, very few direct measurements of turbulence have been collected in the Southern Ocean. However, this region experiences some of the strongest wind forcing of the global ocean, leading to large inertial energy input along storm tracks [5]. While mixed layers are known to have a strong seasonality and reach 500m depth [6], the depth structure of turbulent dissipation and diffusivity have not been validated using direct measurements.

We present data collected during the Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean (DIMES) field program. The location of microstructure profiles collected on two expeditions are shown in Figure 1a, (Austral summer, 2010: blue, and Austral Spring, 2013: red). Using shipboard-measured meteorological measurements, we estimate the Monin-Obukhov parameter, $|z|/L$, used to assess the relative influence of convectively and shear-driven forcing . In the upper 100m, $|z/L| < 1$ due to relatively weak buoyancy forcing during sampling. Using a hydrographic criterion ($\Delta\sigma$) to compute the mixed layer depth, we define a nondimensional vertical coordinate $z_* = z/MLD$ to study the structure of dissipation.

In a range of wind conditions, the wave affected surface layer (WASL), where surface wave physics are actively forcing turbulence, is contained to the upper 15-20m (Fig 1c). The lag-correlation between wind stress and turbulence (Fig 1b) shows a strong relationship up to 6 hours (~1/2 inertial period), with the winds leading the oceanic turbulent response, in the depth range between 20-50m. We find the following characterize the data: i) Profiles that have a well-defined hydrographic mixed layer show that dissipation decays in the mixed layer inversely with depth, ii) WASLs are typically 15 meters deep and 30% of mixed layer depth, iii) Subject to strong winds, the value of dissipation as a function of depth is significantly lower than predicted by theory.

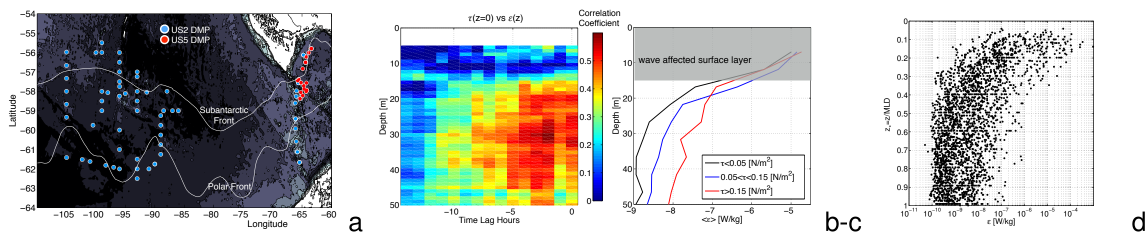

Fig. 1: (a) Map of the Austral summer 2010 (blue) and Austral spring, 2013 (red) microstructure profile locations, (b) Lag-correlation between wind stress (τ) and turbulent kinetic energy dissipation rate (ϵ) as a function of depth. (c) Average profiles of dissipation as function of depth sorted by range of surface wind stress (τ). (d) Distribution of ϵ as a function of depth scaled by the mixed layer depth.

References

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