Assessment of the existing fine-scale parameterizations of deep ocean mixing in the Antarctic Circumpolar Current regeon

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The intensity of the observed deep ocean mixing is obviously falling short of the required value to sustain the global overturning circulation. The most likely candidates for this missing mixing are breaking of near-inertial waves induced by strong westerly wind and internal lee waves generated by Antarctic Circumpolar Current (ACC) impinging on rough topography in the Southern Ocean. Quantification of the turbulent mixing in the Southern Ocean is, therefore, an important issue to elucidate the structure of the global overturning circulation.

Because of the difficulty of direct microstructure measurements, it is common to employ finescale parameterizations (especially, Gregg-Henyey-Polzin (GHP) parameterization) to estimate turbulent energy dissipation rates. In these parameterizations, however, turbulent dissipation rates are assumed to be predicted as the rate of energy transfer to small dissipation scales by wave-wave interactions within the background internal wave spectrum and the effects of geostrophic current shear and mesoscale eddies, both of which are ubiquitous in the Southern Ocean, are not taken into account.

In this study, we carried out simultaneous measurements of microscale turbulence and finescale shear/strain in the Southern Ocean, south of Australia to assess the validity of the existing finescale parameterizations in the ACC region where geostrophic flows and mesoscale eddies coexist with the background internal wavefield.

Although the turbulent dissipation rate and derived diapycnal diffusivity were overall small, the internal wave energy was larger than the Garrett-Munk (GM) value. The finescale shear/strain ratio (R_ω) well exceeded the GM value at the stations south of Southern ACC Front, suggesting that the local internal wave spectra were significantly biased to lower frequencies.

Through the comparison of the turbulent dissipation rates inferred from parameterizations with the directly measured values, we find that GHP and Ijichi-Hibiya (IH) parameterizations, both of which take into account the spectral distortion in terms of R_ω, can well predict the observed turbulent dissipation rates in many places, while the shear-based parameterization (the strain-based parameterization) tends to overestimate (underestimate) the observed values, consistent with the large value of R_ω.

However, at the stations where the vertical shear of mean flow, presumably associated with geostrophic flows and/or mesoscale eddies, is enhanced, even GHP and IH parameterizations tend to overestimate turbulent dissipation rates by up to a factor of 3. At one of these stations, in particular, we find dominant downward-propagating near-inertial waves with their vertical wavenumbers possibly doppler-shifted up to the breaking limit at the critical layer. The overestimated turbulent dissipation rates mentioned above might be explained by the fact that the near-inertial wave energy lost at the critical layer is not completely dissipated but partially transferred to the background mean flow.

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