Sensitive Temperature Probes Detail Different Turbulence Processes in the Deep Mediterranean

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TURBULENCE VALUES FROM MOORED T-SENSOR DATA

Over the vertical range of moored T sensors the Conservative Temperature-density anomaly Θ-σ_2 consistent relationship amounts,

$$\delta\sigma_2/\delta\Theta = -0.85 \pm 0.05 \text{ kg m}^{-3}\,°\text{C}^{-1}. \tag{S1}$$

The relatively tight and consistent relationship in Equation S1 implies the T sensor data may be used as a proxy for density variations. This is useful for inferring turbulence values with the method of reordering unstable data points to monotonously stable vertical profiles (Thorpe, 1977). Turbulent overturns follow after reordering every 2 s the 105 m high potential density (and thus here Conservative Temperature) profile $\sigma_2(z)$, which may contain inversions, into a stable monotonic profile $\sigma_2(z_s)$ without inversions (Figure S1). After comparing observed and reordered profiles, displacements $d = \min(|z - z_s|) \times \mathrm{sgn}(z - z_s)$ are calculated necessary for generating the reordered stable profile. Then the turbulence dissipation rate reads,

$$\varepsilon = 0.64\, d^2 N^3, \tag{S2}$$

where buoyancy frequency N is computed from each of the reordered, essentially statically stable, vertical density profiles. The numerical constant follows from empirically relating the root-mean-square (rms) overturning scale d_{rms} with the Ozmidov-scale (L_O) of largest isotropic turbulence overturns in a stratified fluid as an average over many realizations: $L_O/d_{\mathrm{rms}} = 0.8$ (Dillon, 1982). This ratio reflects turbulence in any high Reynolds number stably stratified environment like the deep sea, in which shear-driven and convection turbulence intermingle at small and large scales and are difficult to separate. In all cases, the mechanical turbulence has to

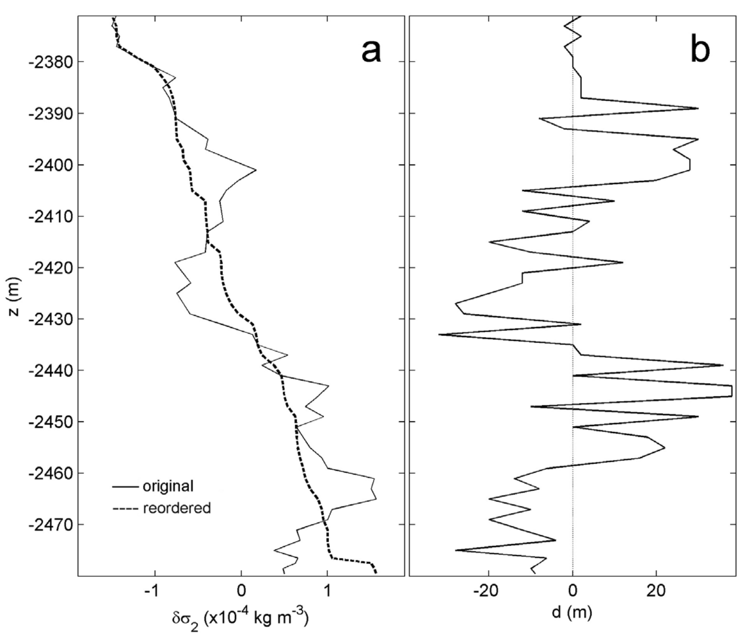

FIGURE S1. Turbulent overturn computation for day 340.14 (Figure 5) of moored T sensor data following the method of Thorpe (1977). (a) Density anomaly profiles, original data including unstable overturns (solid line) and reordered stably stratified data (dashed line). (b) Displacements from original data to arrive at the reordered profile in panel (a).

work against the stratification that follows from the reordering (and which determines L_O). It has thus successfully been applied for mainly convection-turbulence (e.g., Chalamalla and Sarkar, 2015) while first used for mainly shear-turbulence (Thorpe, 1977). Comparison between calculated turbulence values using shear measurements and using Thorpe overturning scales with above constant led to "consistent results" (Nash et al., 2007).

In Equation S2, individual d are used rather than taking their rms-value across a single overturn as originally proposed by Thorpe (1977). The reason is that individual overturns cannot easily be distinguished, first, because they are found at various scales with small ones overprinting larger overturns and, second, because some overturns exceed the range of T sensors. "Sufficient" averaging is required, also to include various turbulence types of different scales and different age with potentially different L_O/d_{rms} ratio (Chalamalla and Sarkar, 2015) during a turbulent overturn lifetime. While shipborne vertical profiling instruments limit to vertical data averaging, the advantage of a densely instrumented mooring line is also averaging data in time.

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