Development and application of turbulence estimation using a fast-response thermistor attached to a CTD frame

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A new observational system, microstructure measurements using the CTD-attached FP07 thermistors, was developed in order to widely and frequently perform microstructure observations and then to reveal basin-scale turbulence distributions. Since turbulence estimation with thermistors have not been common due to their insufficient temporal response, assessment of availability was undertaken by comparing energy dissipation rate ε_T from FP07 thermistors with ε_S from shear probes where both the thermistors and shear probes were attached to the same free-fall profiler. ε_T tended to be less than ε_S as ε_S becomes larger in the case without correction for temperature gradient spectra. By correcting the spectra using the single- or double-pole low-pass filter functions with the time constant of 7 millisecond (single-pole) or 3 millisecond (double-pole), respectively, ε_T became consistent with ε_S within a factor of 3 in the range of 10^(-10) < ε_S < 10^(-7) W/kg. From the result, fast-response thermistor measurement is concluded to be practical if temperature gradient spectra are appropriately corrected. Next, influences of "not-free-fall" measurements, that is, variable fall rates of CTD frames were assessed in order to make clear the availability of the CTD-attached measurements. Comparison of turbulence intensities from this method and free-fall profilers at the same depth and location but with temporal difference within about 2 hours show generally good agreement. However, anomalously overestimated data, deviating from a log-normal distribution, appear sporadically in the CTD-attached measurements. They often occurred when the fall rate W [m/s] was small and its standard deviation W_sd [m/s], was large. These overestimated outliers could be efficiently removed by rejecting data with the criterion of W_sd > 0.2 W - 0.06 computed for a 1 second interval. After this data screening, thermal and energy dissipation, χ and ε, from CTD-attached and free-fall profilers were consistent within a factor of 3 in the ranges of 10^(-10) < χ < 10^(-7) °C^2/s and 10^(-10) < ε_T < 10^(-8) W/kg for 50 m depth-averaged data. Based on the above method of correction and data rejection, basin-scale distributions of turbulence intensity in the deep northwestern Pacific were shown for the first time by microstructure measurements, further by rejecting data at which W takes local minimum. Turbulence is intensified over rough topography at around seamounts and ridges in regions with strong internal tide. Observed ε_T from the CTD-attached thermistors depended on internal tide energy and squared buoyancy frequency N^2 through comparing with ε_MODEL used in a previous ocean general circulation model (OGCM) which reproduced deep Pacific water-masses fields (Oka and Niwa, 2013). ε_MODEL was much larger than the observed ε_T by more than 10 times, although spatial variability was correlated between ε_T and ε_MODEL. This difference was relaxed to be within a factor of 3 by changing the vertical structure of ε_MODEL far from internal tide generation sites to be proportional to N^2 and the background constant vertical diffusivity to be the observed minimum of 10^(-7) m^2/s. By conducting widespread observations of CTD-attached thermistors with higher spatial and temporal resolutions, more realistic OGCM with better diapycnal diffusivity distribution will be developed in future.

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