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Sampling Turbulence in the Stratified Ocean: Statistical Consequences of Strong Intermittency

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ABSTRACT

Turbulence and turbulent mixing in the ocean are strongly intermittent in amplitude, space and time. The degree of intermittency is measured by the "intermittency factor" σ^2, defined as either $\sigma^2_{\ln\epsilon}$, the variance of the logarithm of the viscous dissipation rate ϵ, or $\sigma^2_{\ln\chi}$, the variance of the logarithm of the temperature dissipation rate χ. Available data suggest that the cumulative distribution functions of ϵ and χ in stratified layers are approximately lognormal with large σ^2 values in the range 3–7. Departures from lognormality are remarkably similar to those for Monte Carlo generated lognormal distributions contaminated with simulated noise and undersampling effects.

Confidence limits for the maximum likelihood estimator of the mean of a lognormal random variable are determined by Monte Carlo techniques and by theoretical modeling. They show that such large σ^2 values cause large uncertainty in estimates of the mean unless the number of data samples is extremely large. To obtain estimates of mean dissipation rates $\bar{\epsilon}$ and $\bar{\chi}$ with ±10% accuracy at the 95% confidence level in the seasonal thermocline, the main thermocline or Pacific equatorial undercurrent (all stratified layers with large internmittency) requires 2600 or 10 000 independent data samples for σ^2 = 3 or 7, respectively.

If intermittency is ignored and the data are treated as if normally distributed, mean dissipation rates will probably be underestimated from a small number of samples. For example, it is generally accepted that canonical estimates of the main thermocline vertical eddy diffusivity of order 1 $cm^2\ s^{-1}$, based on bulk property models, are inconsistent with

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much smaller values inferred, ignoring intermittency effects, from themocline microstructure measurements. However, after accounting for the intermittent lognomality of the data, no statistically significant discrepancy exists.

Intermittency may cause qualitative as well as quantitative undersampling errors: minimum values in the vertical profiles of mean dissipation rates are commonly inferred from individual profiles at the seasonal thermocline depth and the equatorial undercurrent high-velocity core depth where maxima may actually exist. From the new confidence intervals, such minima are shown to be artifacts of the extreme intermittency in these strongly stratified layers.

top

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