Sampling Turbulent Dissipation

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ABSTRACT

Recently it has been argued that in many regions of the ocean the Osborn–Cox model accurately determines the total long-term diapycnal flux of a tracer θ if the mean gradient and dissipation in the model are long-time averages. The mean gradient is easily determined, but averaging the scalar dissipation $\chi = 2\kappa|\nabla\theta'|^2$ is notoriously difficult because of its highly intermittent distribution. The distribution of χ has long been known to be approximately lognormal, and Baker and Gibson suggest estimating $\langle\chi\rangle$ by fitting observations to a lognormal probability distribution. There are four reasons why this does not apply to the observations needed to find long-term averages of χ. First, the theoretical arguments for the lognormal distribution apply to dissipation under a single set of local macroscopic factors (shear, stability, etc.) and low-frequency modulation of macroscopic factors is likely to cause slow changes of the parameters of the local lognormal distribution, leading to a different distribution for the total variability. Second, it is $|\nabla\theta|$ that is most apt to be lognormal, whereas measurements are usually of a single gradient component θ_z; if $|\nabla\theta|$ is lognormal and isotropic, then $|\theta_z|$ is not lognormal. Third, correcting for instrumental response often requires that spatial averages of the squared gradient be processed, and averages of lognormal variables are not lognormal. Finally, even if $|\nabla\theta'|$ were lognormal, very small errors in the estimated mean gradient would upset the distribution. Examination of these departures from lognormality and their effect on estimating $\langle\chi\rangle$ indicates that methods based on knowing the form of the sampling distribution are dangerous. The procedure of fitting χ observations to a lognormal distribution can give quite erroneous results. For this reason direct arithmetic averaging appears to be the best analysis procedure. Similar considerations apply to sampling kinetic energy dissipation $\epsilon = 2\nu\nabla\mathbf{u}:\nabla\mathbf{u}$ although it is more difficult to show that ϵ should have a lognormal distribution or to relate the distribution of total dissipation to that of the shears measured.

1. Introduction

The rates of vertical advection and cross-isopycnal eddy transport are central to understanding the oceanic thermohaline circulation. Indeed Bryan (1987) concludes that the connection between vertical advection and eddy mixing is so intimate and the sensitivity of general circulation models to vertical eddy transport so great that improved parameterizations are necessary before models can reliably describe the ocean's role in global climate. Aside from direct observations of the vertical dispersion of purposefully released tracers that are just now becoming available (Ledwell et al. 1993), the most direct measurements of the diapycnal diffusivity K_V come from measurements of the microstructure of a tracerlike temperature interpreted using the simplified tracer variance budget introduced by Osborn and Cox (1972). This is known as the Osborn–Cox model.

Davis (1994a) argued that a failure of the conventional approach to mixing is that the definitions "mean" and "eddy" components of oceanic fields are not used consistently between analyses of the general circulation and studies of turbulence and microstructure. The general circulation must, of course, be defined before it can be measured, and it was argued that the most appropriate definition is that based on a long-time (multiyear) time average. Within this context, the diapycnal eddy flux is parallel to the time-average gradient of locally referenced potential density and includes both the turbulent flux and any flux supported by larger-scale or lower-frequency components. In contrast, the usual approach to turbulence and microstructure considers all components larger than a few meters, or with timescales greater than a few hours, to be part of the mean field. This view, which was the basis for the Osborn–Cox analysis, assumes that the diapycnal flux is carried only by small-scale high-frequency components. When long-term averages are used, this turbulent flux may not be the whole eddy flux that appears in the general circulation balances.

It is conventional wisdom that diapycnal fluxes must be carried by velocity fluctuations of small enough scale that inertial forces can overcome the buoyancy forces that tend to damp overturning motions in a stably

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