Comment

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It is always easy to find flaws in a review paper which attempts to cover the whole of one's field. It is a persistent feature of such papers that they will inevitably omit what someone considers the central issue of the field. While the present report does contain some such omissions, it also raises a great many important issues. The application of a number of these issues to the field of satellite remote sensing is well presented in the report and is, in my opinion, important to the development of the field as a whole. In this discussion, I would like to amplify some of the issues raised, by looking at some different examples than those presented in the text. The use of these examples should not be taken as denigrating the importance of satellite-based remote sensing for understanding oceanic dynamics. Rather, I would like to show how some of these issues raised are of broad interest to a range of oceanographers.

In making comparisons between theoretical models of the ocean and real data, a number of problems may arise. In this paper I will focus on four such problems, illustrating each with a separate example.

1. Are the fundamental assumptions of the theory statistically valid? If not, does this explain the difference between theory and data or differences between different measurements?
2. Can we find a theoretical quantity that means something?
3. Can we extract this quantity from the data?
4. What are the errors involved in making the measurement and do they explain any discrepancies between theory and data?

One example where the statistical validity of a theory has been the subject of much discussion in the oceanographic literature is the question of microstructure and eddy diffusivity. Section 1 of the report noted that mixing in the equations of motion is often parameterized using an eddy viscosity (in the case of momentum) or diffusivity (in the case density). One of the standard ways of estimating the deffusivity is by looking at the velocity shear on scales of a few centimeters. The turbulent dissipation ε (representing the conversion of kinetic energy to heat) may be estimated from the small-scale shear

$$\varepsilon = 7.5\nu \left\langle \left(\frac{\partial u}{\partial z}\right)^2 \right\rangle, \tag{1}$$

where ν is the molecular viscosity, u is the horizontal velocity along some axis, z is the vertical direction and $\langle\ \rangle$ denotes averaging of the shear variance over a wavelength range from 100 cm to the order of 1 cm. Within the stratified interior, the turbulent dissipation is forced by instabilities with scales of order 100 cm associated with the field of internal gravity waves. The assumption is made that the turbulence over some portion of the water column is in a statistical steady state and that some fixed fraction of the energy f (of order 0.2) goes to transporting density. Then if the density flux is given by $-K_v\partial\rho/\partial z$, where K_v is the vertical eddy diffusivity and $\partial\rho/\partial z$ the density gradient, then

$$K_vN^2 = -K_v\frac{g}{\rho}\frac{\partial\rho}{\partial z}$$

is the energy flux required to support this density flux and

$$K_v = \frac{f}{1-f}\frac{\varepsilon}{N^2} \tag{2}$$

(N is the buoyancy frequency–of order 0.001 to 0.01 Hz—which is the natural frequency of oscillation of a fluid parcel in a stably stratified water column). These measurements yield eddy diffusivities of order 0.1–0.5 cm^2/s (Gregg, 1987; Polzin, 1992).

If one looks at closed basins where ocean water enters at one temperature, is warmed by diffusion and upwells throughout the basin at the warmer temperature, it is possible to estimate the required eddy diffusion coefficient (Munk, 1966; Hogg et al., 1982; Johnson, 1990). Using these methods, the required eddy diffusivities are of order 1–5 cm^2/s, a difference of an order of magnitude. Explaining this discrepancy is one of the more interesting problems in physical oceanography today.

In a series of papers in the 1980's, Gibson (1986, 1987) proposed that the reason turbulence measurements underestimate the diffusivity is that the actual mixing events are themselves very rare. He

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