Turbulent Microstructure Studies in Coastal Ocean Boundary Layers

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LONG-TERM GOALS

Our long term goal in this study is to obtain an extensive picture of turbulent mixing processes from near surface to near the bottom boundary layer at dissipation scales in conjunction with measurements of mixing from the injection of a tracer (Ledwell) and in the context of larger scale measurements in the Coastal Mixing and Optics study.

OBJECTIVES

The specific objective of the current year was to prepare instruments for a field experiment and to carry out a two week experiment in which microstructure measurements were obtained at a time of late summer stronger stratification. These were to be carried out in a joint experiment with Ledwell with microstructure profiles interspersed with tracer injection and sampling. This was the second of two field programs related to this study. The primary scientific objective was to compare mixing rates estimated by the dispersion of a tracer and inferred from microstructure measurements.

APPROACH

Microstructure data collection involved using the vertical profiling instrument EPSONDE in repeated profiles from the surface to near the bottom at the Coastal Mixing and Optics experimental site. The strategy was for Ledwell to inject a tracer on a specific density level and to map the area to obtain the initial conditions for the tracer. This was followed by our microstructure survey along the predicted track of the tracer as it advected with the measured currents. Tracer and microstructure surveys were interspersed over several days to follow the evolution of the dye.

WORK COMPLETED

A two week long experiment was successfully carried out from July 30 to August 13, 1997 on the RV Oceanus near the central mooring site of the Coastal Mixing and Optics experiment in water depth of about 70 meters. Two tracer injections were done by Jim Ledwell one about 20 meters from the surface with rhodamine and one at about 5 meters above bottom with fluorescein. At the end of each tracer mapping period we repeatedly profiled with EPSONDE along lines about 3 miles long with the ship underway at about 1 knot at a site that was close to the predicted advection path of the tracer. Microstructure profiling continued for periods as long as 24 hours before the next tracer mapping exercise. During the two week experiment nearly 1200 microstructure profiles were obtained using EPSONDE (shown in Figure 1). There were two previous dye-microstructure studies in the fall of 1996: rhodamine at mid-depth and fluorescein at about 50 meters. The data from each of the studies have been processed.

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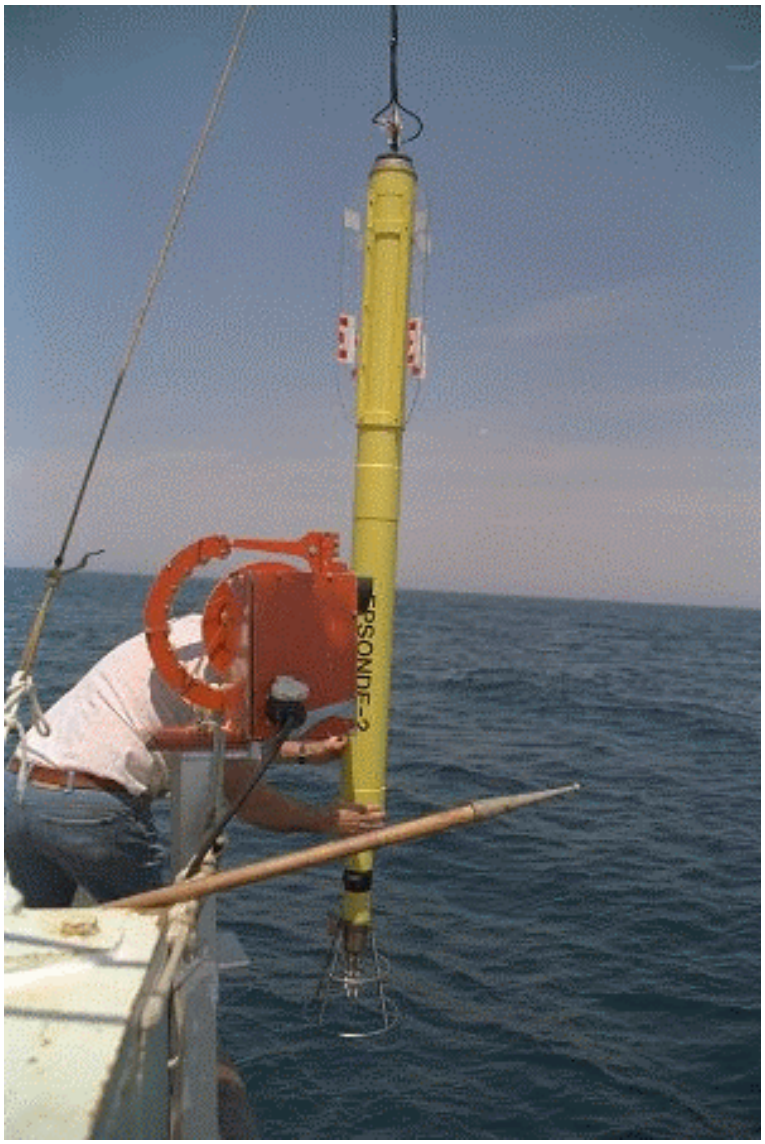

Figure 1: EPSONDE being used at sea during CMO

RESULTS

This experiment is the first time that mixing was measured from a simultaneous tracer and dye study on the same time and space scales. Two dye/microstructure surveys in September, 1996 at a time of rather low stratification and two more similar surveys in August, 1997 at a time of somewhat stronger stratification yielded four comparisons of mixing rates estimated from a tracer (either rhodamine or fluorescein) and microstructure at depths from 20 meters from the surface to about 5 meters from the bottom under various stratifications. Preliminary estimates of mixing estimated from September, 1996 for the deployment at a depth of about 32 meters and N^2 = 5CPH indicate vertical diffusivities from the microstructure of order $K_T = 4x10^{-5}$ m^2/s and for the September, 1966 deployment at about 45 meters and N^2 = 10CPH yielded a value of $K_T = 6x10^{-6}$ m^2/s. Both of these values are consistent with the preliminary estimates of mixing from the tracer. These microstructure estimates were obtained by integrating over a fixed depth interval and we are in the process of developing software to integrate our

data in density space to correspond better to the tracer estimates of mixing and to allow us to calculate error estimates. What is surprising about the results is how low the rates of mixing were.

Data from the August, 1997 experiment have been processed and an example of these data are shown in Figures 2 and 3 near the central mooring site. The ship was steamed at about 2 kts along a line 4 km long a kilometer south of the central mooring and vertical microstructure profiles were obtained along the transit. From the contoured temperature and salinity profiles there is a relatively consistent density structure over this section with some suggestion of moderately large waves; turbulence is strongest at the surface and the bottom boundary layer with fairly active mixing throughout the water column and in particular near the bottom. These measurements were made just prior to the deployment of a patch of fluorescein about 5 meters from the bottom. Average profiles for the section with error bars calculated from a bootstrap technique are shown in Figure 3. In this experiment, even near the bottom, vertical diffusivities can be smaller than 10^{-5} m^2/kg. This section of 15 profiles is only one of more than 20 sections (500 profiles) which will be used to make detailed comparison with the evolution of the tracer.

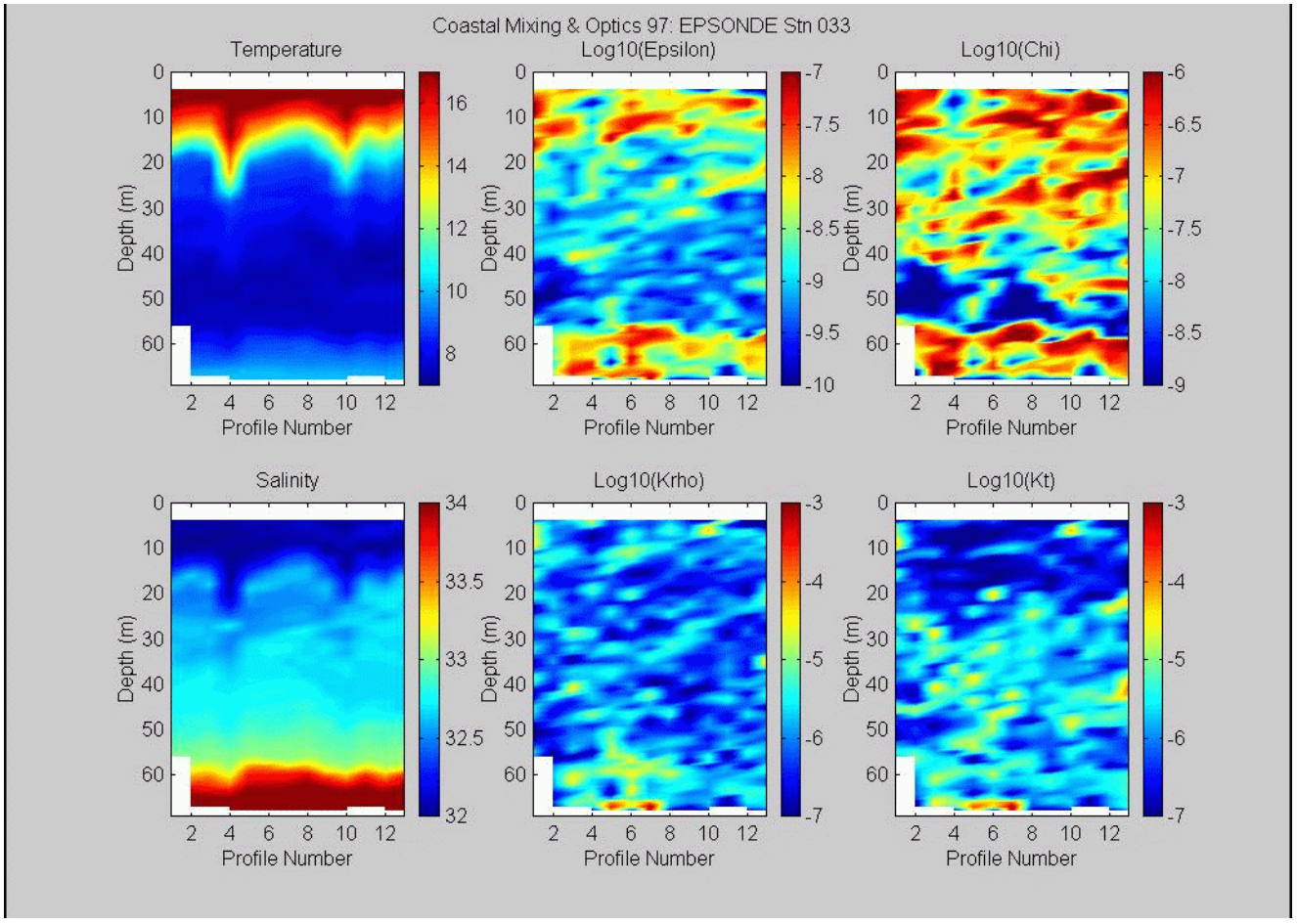

Figure 2: Contoured microstructure profiles along a line near the central mooring.

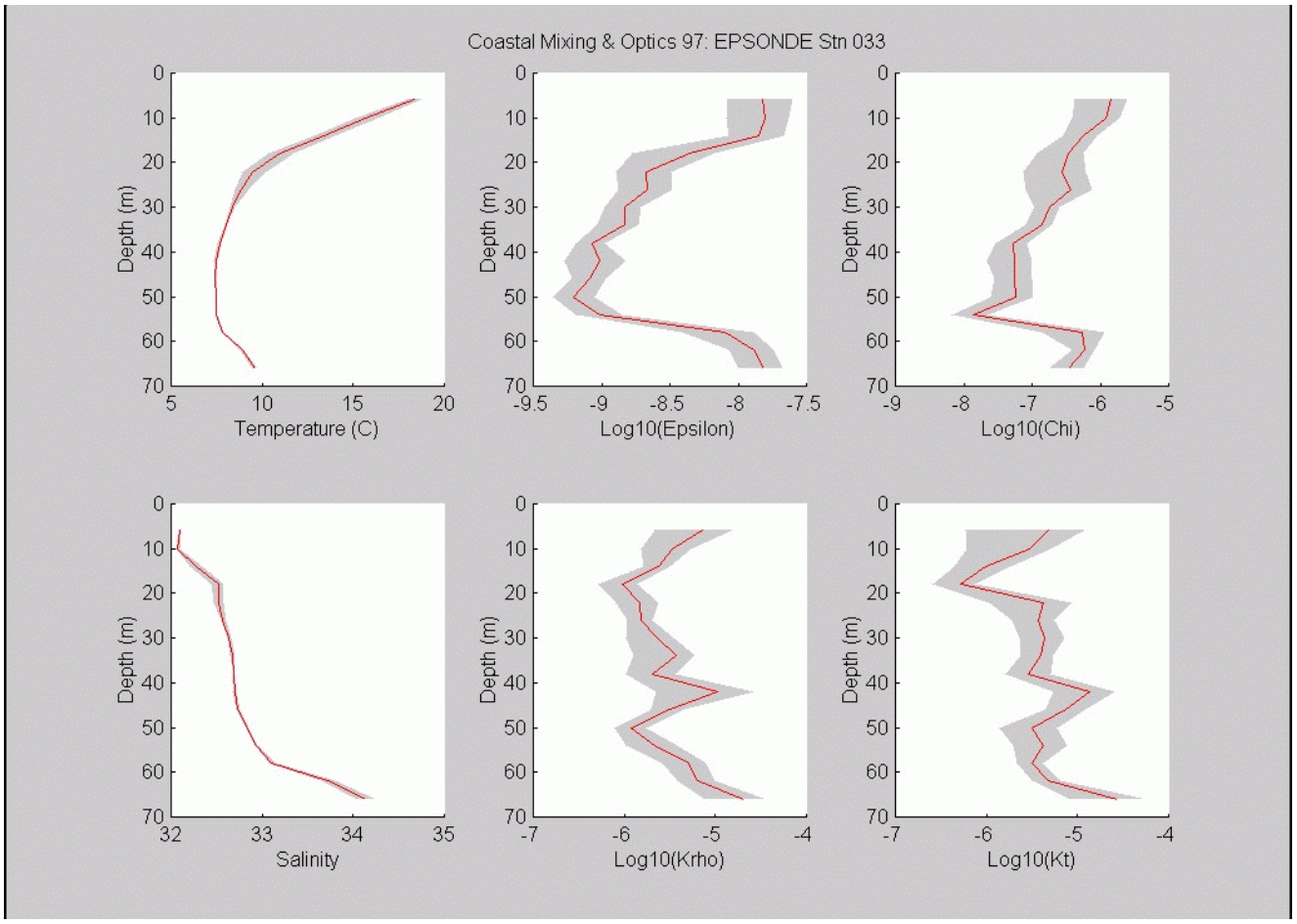

Figure 3: Average profiles from the contours of Figure 2.

IMPACT/APPLICATIONS

This is the first time that tracer and microstructure measurements of mixing in the ocean have been done on the same length and time scales to test commonly used mixing models. Preliminary comparisons of the results of both techniques indicate good agreement.

TRANSITIONS

RELATED PROJECTS

REFERENCES

Further information on this project may be viewed at
http://www.maritimes.dfo.ca/science/ocean/epsonde/welcome.html