AUV-BASED TURBULENCE ESTIMATES NEAR COASTAL FRONTS

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Abstract

Microstructure observations have been made in the FRONT coastal network, near the mouth of Long Island Sound, offshore, and in the plume front of the Connecticut River. The NUWC turbulence AUV acquires both microstructure and finestructure measurements. It is an extended REMUS, with shear sensors to estimate turbulent kinetic energy dissipation rates, and ultra-fast thermistors to estimate thermal variance dissipation rates. Turbulence data were obtained in an shelf front, a headland front, in surface boils over sand waves, and near a MIT gcm predicted tidal mixing front. Inshore of the tidal mixing front, pycnocline estimates of KE dissipation rates of 10^{-6} to 10^{-5} W/kg were obtained, comparable to estimates for the river plume front. Offshore of the tidal mixing front, pycnocline estimates of KE dissipation rates of 10^{-6} to 10^{-9} W/kg were obtained. These estimates are used to verify mixing fidelity in a coastal version of the MITgcm model.

Introduction

The FRONT region (Fig. 1) has been observed to be rich in frontal features, as observed in satellite-derived SST and color. This regime is strongly influenced by tides, estuarine outflow, and alongshore shelf flow. The Connecticut River is the primary fresh water input to the L. I. Sound estuary. The FRONT observational and modeling program provided the framework for multi-scale studies of the fronts and their bio-physical importance.

In addition to the AUV-based observations, frontal scale observations included ship-based hydrography and currents, towed temperature/salinity, and dropped SCAMP microstructure profiles. Larger scale observations utilized bio-physical instrumented moorings, CODAR, and satellites.
The MITgcm (Marshall et al., 1997a and 1997b) was adapted for the coastal ocean for the FRONT study, and can include non-hydrostatic processes. MITgcm includes nonlocal "K profile parameterization" (KPP)

of vertical mixing by unresolved scales for the surface boundary layer.

In previous studies, a large AUV was found to be in sufficiently stable to obtain horizontal measurements of dissipation rate in shallow water (Levine and Lueck, 1999), including in an estuarine front, and a small AUV characterized turbulence in the LEO upwelling region (Levine et al, 2003).

Methodology

The Turbulence AUV (Fig.2) performs synoptic microstructure and finestructure measurements (Levine et al, 2001). It is an extended REMUS vehicle (van Alt et al, 1994) 2.3 m in length, .18 m in diameter, weighing 56 kg in air. With this first generation turbulence measuring AUV, we are currently limited to the mid-water column, for safety, and to an endurance of 4 hours, using rechargeable lead-acid batteries. However, modifications to the internal frame enable rapid redeployment with fresh batteries.

Current scientific sensors include two FSI CTDs, an upward and downward looking 1.2 MHz ADCP, a University of Victoria Turbulence Package (two orthogonal shear probes, three accelerometers and one FP07 fast response thermistor), and a SONTEK ADV-O. Vibration studies have lead to reductions in noise transmitted to the shear probes with the use of a damping material, and a probe stiffener attached to the forward end of the UVIC pressure case. For a more complete description of the techniques used to calculate the dissipation rate, see Levine and Lueck, 1999. The combination of noise limiting vehicle modifications, and the use of the all accelerometers, has resulted in a noise floor that resolves 10^{-9} W/kg.

Results

The turbulence measuring AUV was deployed in a region (Fig. 1) containing coastal frontal features (Bowman, 1988) including a shelf front, a headland front, surface boils over sand waves, a river plume front, and a tidal mixing front predicted by the MIT gcm. In Fig. 1, trajectories of the AUV during the FRONT experiments are shown, and the green boundary is the predicted tidal mixing front.

In each case, observations were made during ebb tide, except for the case of the boils over sand waves, which was sampled on the flood. All observations were made away from the upper and lower boundaries, in the pycnocline. In each case, the frontal feature of interest was originally located in the larger frontal scale and regional scale surveys, but with less resolution.

The December 2001 frontal scale survey for Montauk Pt. showed a frontal feature with warmer, saltier warmer offshore, corresponding to a density increase of approximately 0.3 in sigma-t. For the Montauk Pt. headland front survey, the AUV was yo-yoed between the 3.5m and 7.5m levels. Time series of turbulent parameters measured aboard the AUV, for the Montauk Pt. front, are presented in Fig. 3. The athwartships (u) and vertical (w) velocity shear components are measured using the shear probes, and isotropy is assumed. The temperature and temperature gradient are measured using the ultra-fast thermistor. All three acceleration components are used to remove platform motion from the shear data to resolve ambient turbulence, using a partial coherence technique.

The shear spectra for the entire Montauk point deployment (Fig. 4.), shows good agreement with the Naysmith spectrum, both in shape and magnitude. This universal fit is based only on the dissipation rate, proportional to the integrated area under the shear curve, ?, and the molecular viscosity, ?. Thus, for this example, the AUV-derived velocity turbulence is consistent with classical turbulent measurements.

In Fig. 5, the ranges of turbulent kinetic energy dissipation rate, ? (W/kg), from shear probe data, are shown for the frontal features in Fig. 1. Inshore of the tidal mixing front, pycnocline estimates of KE dissipation rates of 10^{-6} to 10^{-5} W/kg were obtained, comparable to estimates for the river plume front (upper right figure). Offshore of the tidal mixing front, pycnocline estimates of KE dissipation rates of 10^{-6} to 10^{-9} W/kg were obtained. The highest dissipation values are estimated near the headland at Montauk Pt., and in the area with sand waves northeast of Montauk Pt.

The MIT gcm was run for the tidal, wind, and stratification conditions encountered for approximately 20 days prior to our measurements. For ebb tide, dissipation rate estimates obtained from by the MITgcm model prediction, along the AUV transect near the headland front, are presented in the upper panel of Fig. 6. Results from this section, in the depth range of the AUV yo-yo, are of order 10^{-6} W/kg, in good agreement with the AUV-derived dissipation rates shown in the lower panel (Levine et al, 2002).

Conclusions

- For the regime considered (very strong stratification), classical turbulence theory yields promising results for the velocity shear. A similar comparison of the turbulent temperature spectrum will be made with Batchelor scaling.

- For FRONT, comparison of observed and MIT modeled dissipation is reasonable in the vicinity of a coastal front.

Future work

- Explore why classical turbulence theory works for velocity shear in the stratified regime.

- Examine/quantify the role of shallow water internal waves and solibores in the mixing process.

- Repeat the experiment for other regimes including surface and bottom boundary layers, and weaker stratification.

- Examine if an instrumented AUV shows promise for closing turbulent kinetic energy and scalar budgets budget. Preliminary estimates for an estuarine dataset are encouraging.

- Utilize new generation AUV with improved platform speed and endurance, and streamlining. Sensing is improved for both turbulence and CTD instrumentation.

Acknowledgements

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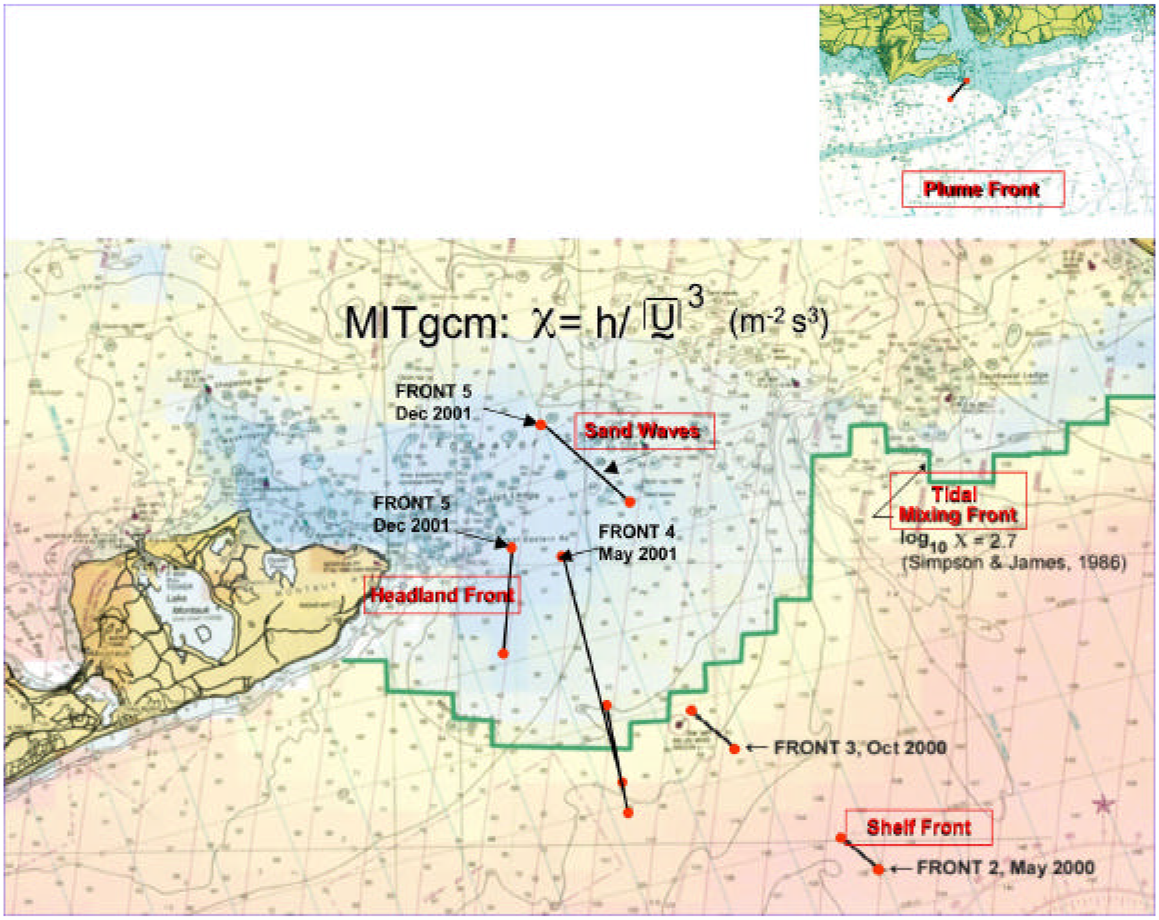

Figure 1. FRONT features

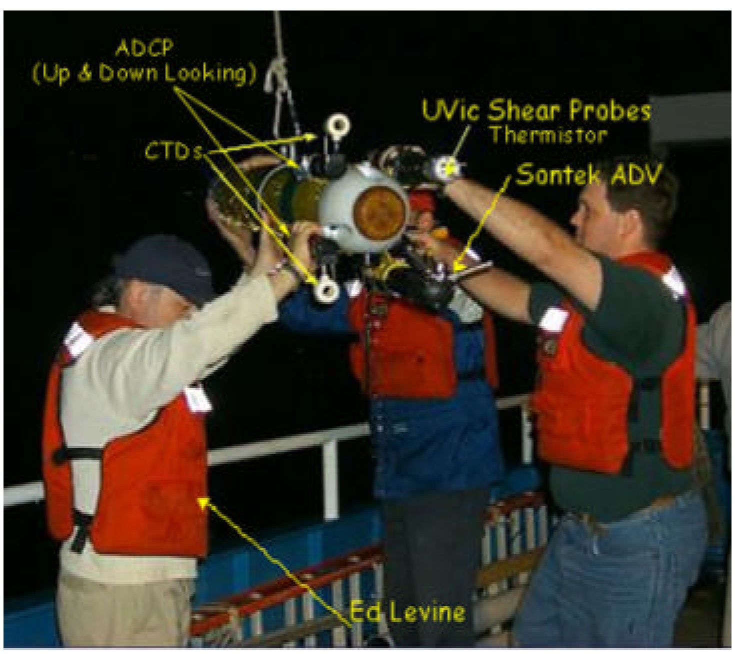

Figure 2. The Turbulence measuring REMUS, nighttime recovery

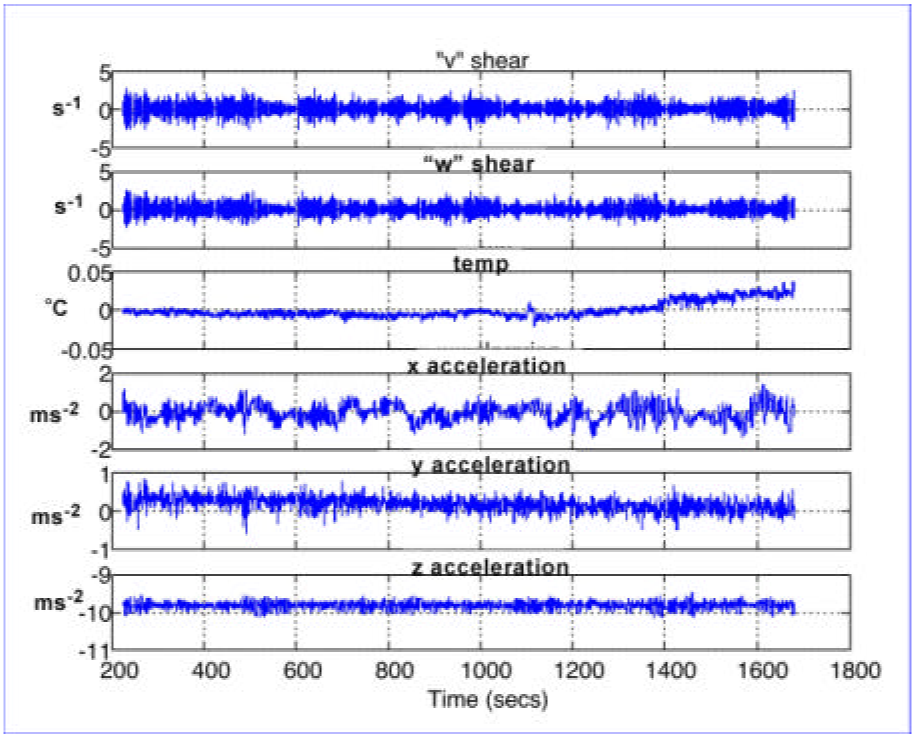

Figure 3. Turbulence data from Montauk Pt. experiment

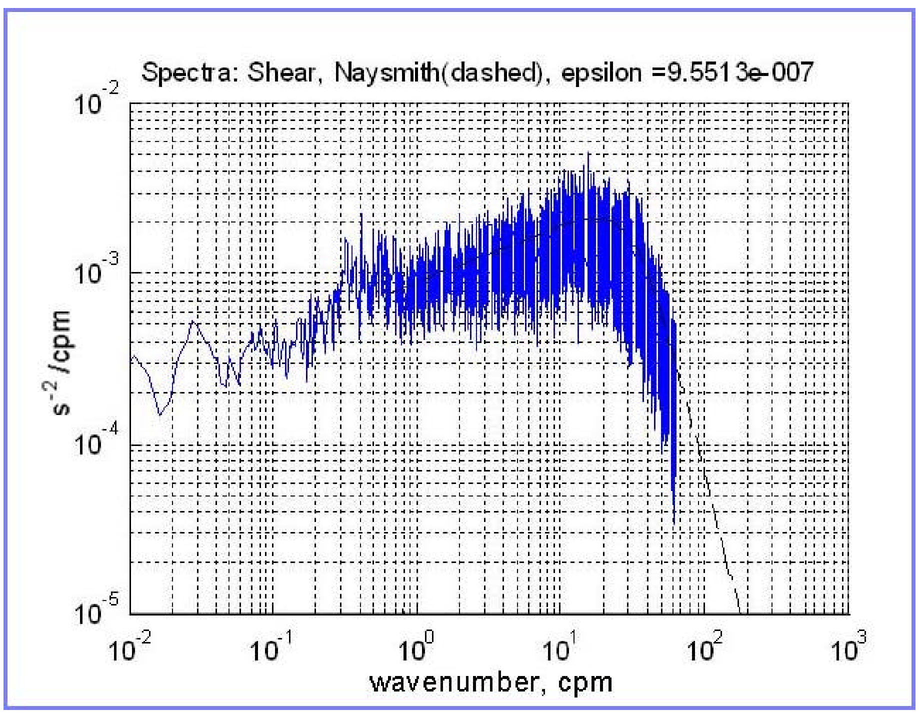

Figure 4. Shear spectra from the Montauk Pt. experiment, universal Naysmith spectra is shown with a dash.

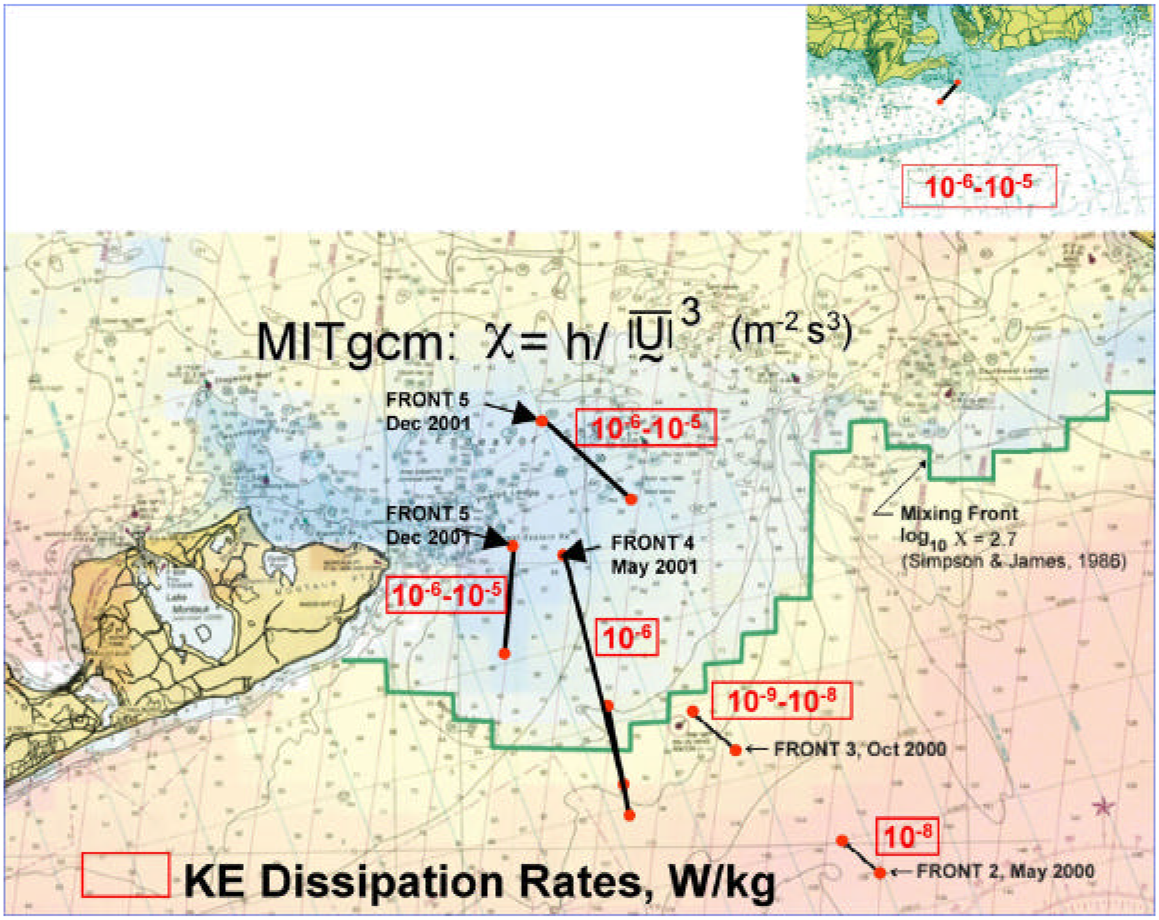

Figure 5. FRONT dissipation rates

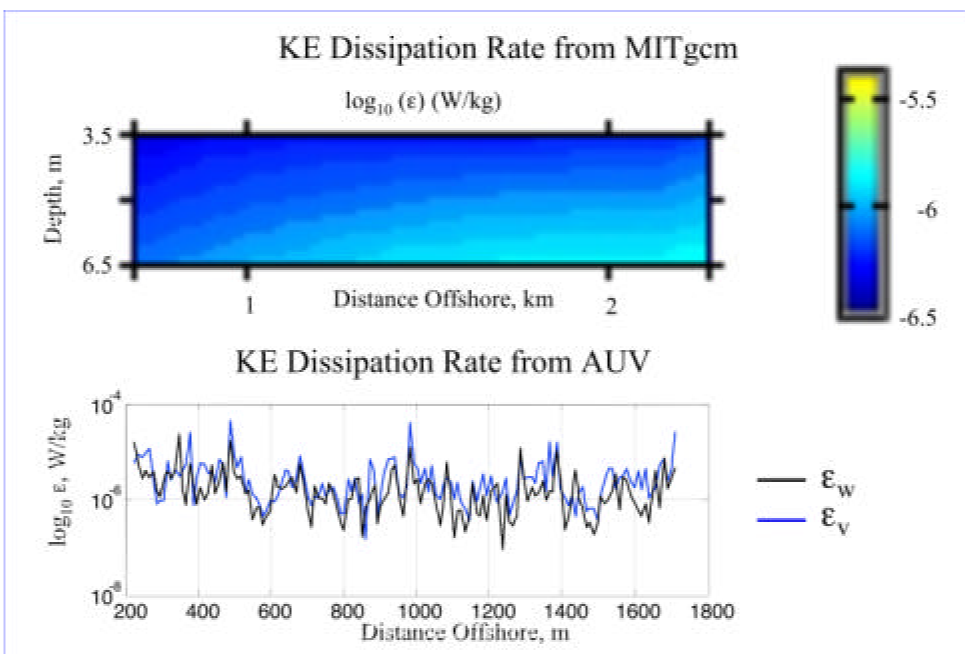

Figure 6. TKE dissipation rate comparison, model and observations