Front Resolving Observational Network with Telemetry: Turbulence Characterization from an AUV

Edward R. Levine
Naval Undersea Warfare Center, Division Newport
Code 8211. Bldg 679/2
Newport, RI 02841-1708
phone: (401) 832-4772 fax: (401) 832-2146 email: levineer@npt.nuwc.navy.mil

Award #: N0001400WX20536
http://www.sp.uconn.edu/~wwwmsd/nopp_pgm/noppprop.html

LONG-TERM GOALS

A Front-Resolving Observational Network with Telemetry (FRONT) is being developed for a region of the coastal ocean. The long-term goal is to demonstrate and evaluate a real-time data collection network in concert with a data-assimilative dynamical model, which is designed to resolve or parameterize the needed range of scales.

OBJECTIVES

The lack of observations of vertical mixing imposes a severe limitation on modeling of coastal mixing processes near dynamic features such as fronts. The specific objectives of the AUV-based turbulence characterization component of this network are to evaluate the system on the microstructure scale.

APPROACH

The FRONT system includes data-assimilative models that mitigate the impact of sampling error by producing dynamically consistent maps from the data, enabling physical and biological forecasting in four dimensions (Bogden and O'Donnell, 1998). The multi-disciplinary demonstration site lies in a region of strongly varying bathymetry on the mid-shelf (near the 50 m isobath) offshore of Long Island Sound. Tides and energetic wind and buoyancy forced motions combine to produce a complex flow field. Satellite measurements of surface temperature and color show recurrent front-like features at the FRONT site (Ullman and Cornillon, 1999).

The FRONT network is evaluated in three seven-day rapid, high-resolution, surveys of hydrography, circulation, and microstructure. Information is obtained on scales of turbulent dissipation, frontal scales, and mesoscales. Boundary properties are emphasized, from theoretical work on coastal fronts. The turbulence surveys should improve frontal behavior in the model, based on the MIT general circulation model (MITgcm) (i.e., Marshall et al., 1997), adapted to the coastal ocean for FRONT. The non-hydrostatic capability is important for the strong convergence divergence of fronts, and in large aspect ratio flows near topography. MITgcm includes the Large et al. (1994) nonlocal "K profile parameterization" (KPP) of vertical mixing.

The microstructure instrument (Fig 1) (Levine et al, 1999) is a REMUS AUV with: 1) shear sensors for turbulent kinetic energy dissipation rates, 2) a fast thermistors for thermal dissipation rates, and 3) an Acoustic Doppler Velocimeter for 3D velocity. REMUS has two CTDs, and an up/down looking ADCP. The shear probe data are processed to remove noise associated with vehicle vibrations, using accelerometers, and the techniques of Levine and Lueck (1999). In addition to microstructure, these sensors provide stratification and finescale shear, enabling estimation of Richardson number, eddy diffusivity (Gargett and Moum,1995), eddy viscosity (truncated TKE equation), fluxes (correlation technique) and turbulent kinetic energy. This provides a direct comparison between co-located measurements of microstructure and larger scales, critical to develop bulk representations of microscale processes. The AUV will be deployed with the MicroSoar (URI), which uses a rugged conductivity probe to resolve the thermal dissipation rate. In close proximity, they will allow turbulence data to be collected for correlations of mixing processes. Previously, this was done using ships several miles apart (Moum et al., 1994).

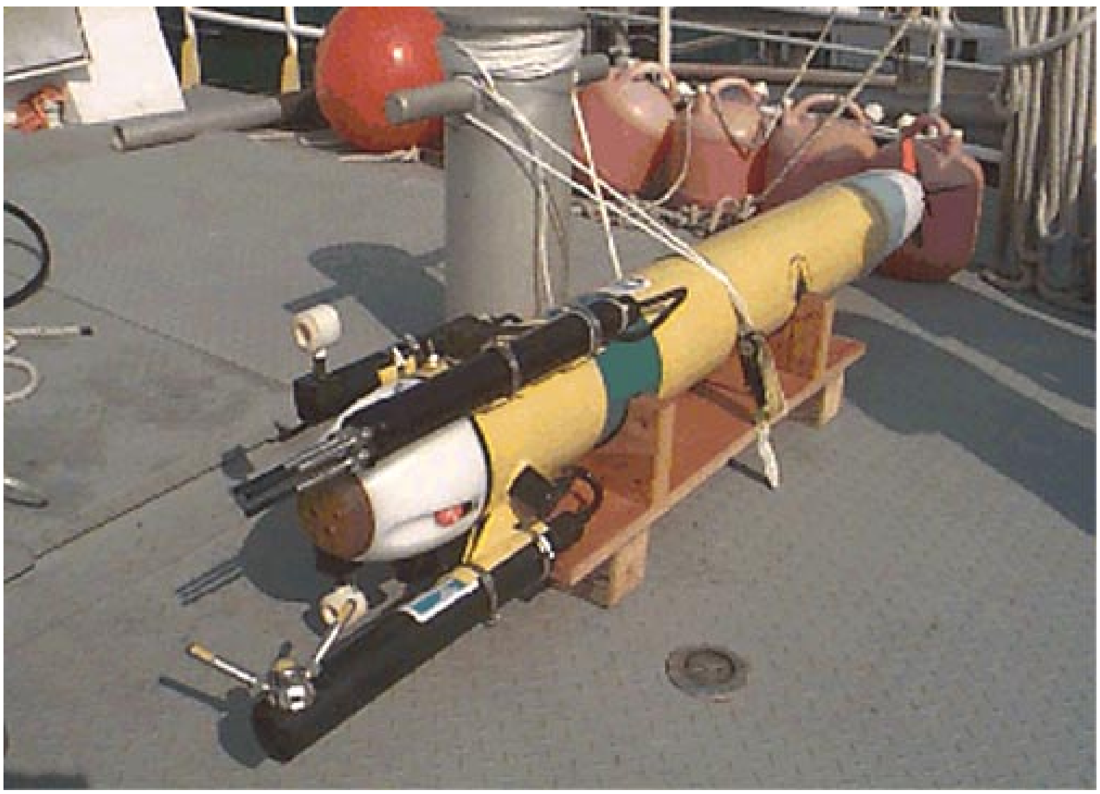

Fig 1. The REMUS AUV instrumented with turbulence sensors

WORK COMPLETED

A REMUS AUV has been integrated with a comprehensive instrument suite for measuring turbulence in the coastal ocean, including the truncated TKE equation. During FY00, the noise floor of the dissipation estimate has been lowered to 10^{-9} W/kg using vibration analysis techniques. This resulted in the fabrication and installation of an aluminum 3-probe stiffener, which shortens the probe cantilever, and raises the shear probe resonance frequency into the kilohertz range. In addition, the AUV, itself, has been modified for deployment and recovery from a large research vessel in the open waters of the mid-shelf, with the addition of a pickup loop near its center of gravity.

During May 2000, using the improved AUV-based turbulence measurement system, a pilot mixing study was conducted in the FRONT region, in the context of supporting frontal scale observations, including shipboard ADCP and CTD, and moored ADCP. Turbulence data were obtained in the upper ocean mid-shelf front, in the region of maximum near surface salinity gradient, as determined from profiling and hull mounted CTD data. In contrast, a brief study of the intense front associated with the Connecticut River plume was also done.

RESULTS

The FRONT pilot study, FRONT 2, was conducted during the spring maximum in runoff from Long Island Sound. A 7.5m transect from SE to NW, approximately 1km in length, was made through the near-surface front. This was done in the region of the most intense near-surface salinity and temperature fronts (Fig. 2), with a transit from the warmer, salty mid-shelf waters into the fresher, colder inshore waters more seasonally influenced by the Long Island Sound outflow. Corresponding frontal scale CTD data show horizontal changes in salinity of 1 psu and temperature gradients of 2C° over 5 km in the frontal zone. Our measurements were obtained during flood tide, with local AUV-measured currents to the northwest.

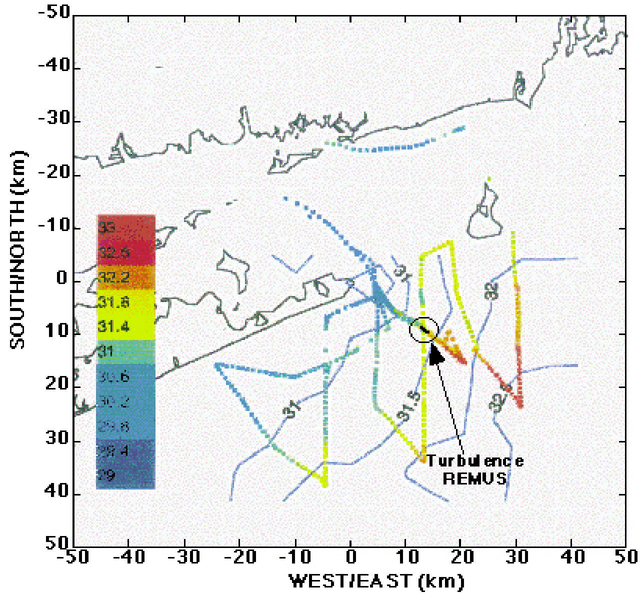

Fig 2. The turbulence data track through the maximum near-surface salinity front in the mid-shelf region off L. I. Sound in May 2000 (FRONT 2)

Turbulence parameter estimates (Fig. 3) include velocity microstructure (vertical and lateral small-scale shear from the shear probes), temperature microstructure (fluctuating component of ultra-fast thermistor data), density gradient (from 2 vertically oriented CTDs) and finescale components of the vertical shear of horizontal velocity (from ADCP bins above and below the AUV). The three microstructure signals often occur in similar busts. The density gradient is stable throughout the track, increasing in value towards the NW. The finescale shear components show lateral changes, corresponding to maximum shear magnitude near the middle of the track.

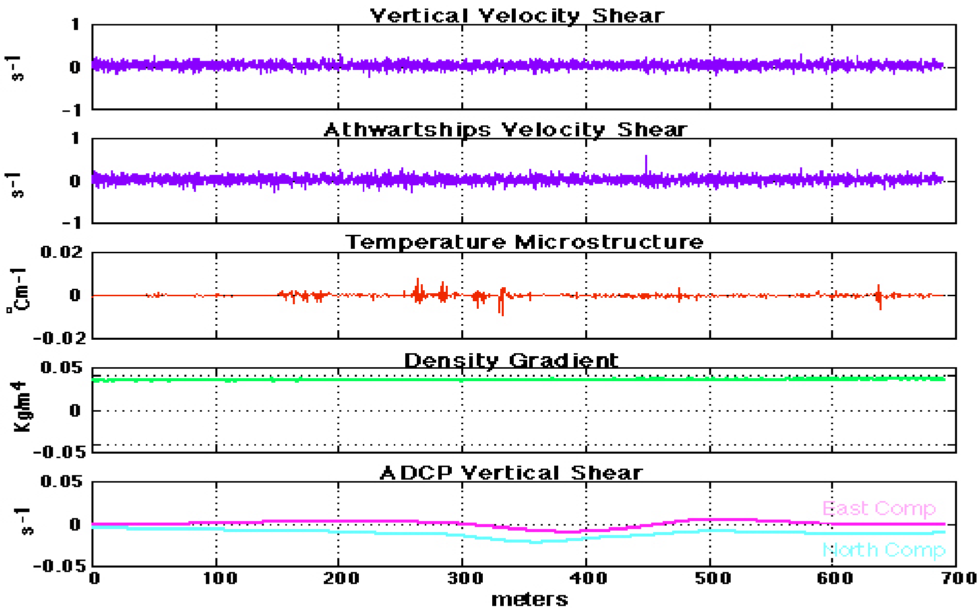

Fig 3. Turbulence parameters obtained for 7.5 m depth level in mid-shelf front for FRONT 2.

These turbulence parameter estimates provide the basis for calculating mixing parameters in the mid-shelf front (Fig. 4.) The shear data correspond to relatively low dissipation rates of order 10^{-8} W/kg. The eddy diffusivity is estimated to be of order 10^{-5} m^2/s, and the eddy viscosity is estimated to be of order 10^{-4} to 10^{-5} m^2/s. Richardson numbers were generally estimated in the range 10^{-1} to 10^{-0}. In contrast, the Connecticut River plume front, in June 2000, at the base of the plume, at 2m depth, showed high dissipation rates of order 10^{-6} W/kg.

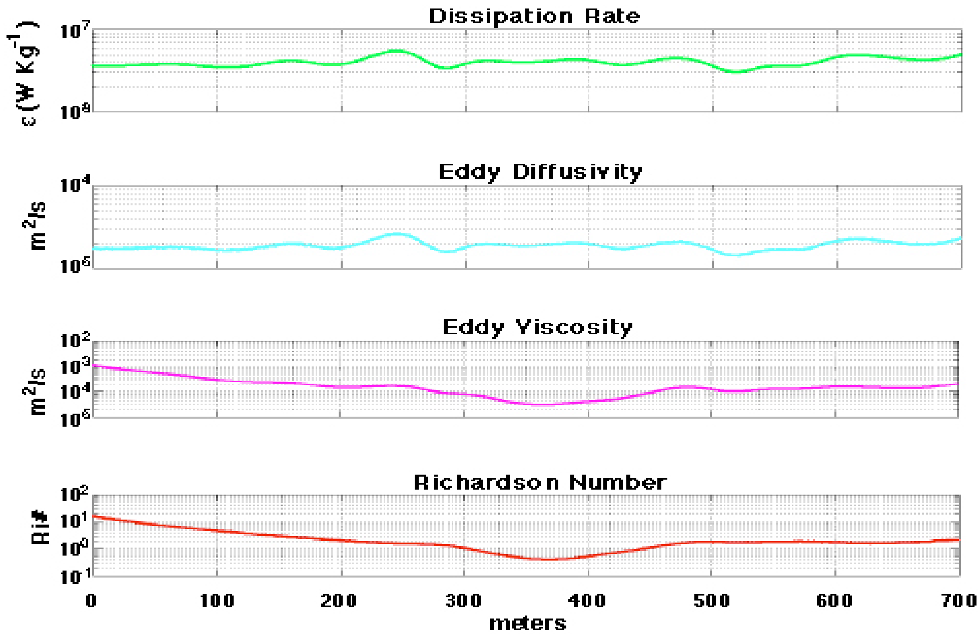

Fig 4. Mixing estimates obtained for 7.5 m depth level mid-shelf front for FRONT 2.

The turbulence parameters and mixing estimates can be utilized to classify the physical processes responsible for mixing by examining distributions on dimensionless parameter diagrams such as Froude number versus Bouyancy Reynolds number. Using this technique, fully three dimensional turbulence can be differentiated from regions where buoyancy forces are still important, and other mixing processes, such as ambient shear from internal waves, may dominate. In fall 2000 and spring 2001, new datasets will be obtained in the mid-shelf front, and mixing processes will be compared for seasonal variability.

IMPACT/APPLICATIONS

The AUV-based turbulence measurements provide a unique horizontal profiling view of the variability of the mixing environment that cannot be obtained by more conventionally sampling measurements, and this approach can be further exploited in yo-yoed horizontal sections. These techniques will be invaluable in frontal process studies utilizing the coastal version of the MITgcm model.

TRANSITIONS

This research demonstrates an Autonomous Ocean Sampling Network (AOSN) in the context of an Integrated Coastal Observing System in a region with tactically significant features. This is a prototype demonstration, which can be extrapolated to an environmental description of the Battlespace for superiority in ASW and MCM.

RELATED PROJECTS

My AUV-based turbulence measurement system has also being utilized in NOPP/ONR studies with the Rutgers University led LEO-15 and Harvard University led LOOPS projects.

REFERENCES

Bogden, P.S. and J. O'Donnell, Generalized inverse analysis of current measurements from a moving ship: estimating the tidal and non-tidal flows in Long Island Sound. J. Marine Res. 56, 1998 , 995-1027.

Gargett, A. E. and J. N. Moum, 1995: Mixing effects in tidal fronts: results from direct and indirect measurements of density flux. J. Phys. Ocean. , 25, 2583-2608.

Gargett, A. E., T. R. Osborn, and P. W. Naysmyth, Local isotropy and the decay of turbulence in a stratified fluid, J. Fluid Mech., 144, 1984, 231-280 .

Large, W. G., J. C. McWilliams, and S. C. Doney, 1994: Oceanic vertical mixing: a review and model with a non-local boundary parameterization. Rev. Geophys., 32, 363-403.

Levine, E. R., R. G. Lueck, 1999: Turbulence measurements with an autonomous underwater vehicle. Journal of Atmospheric and Oceanic Technology, Special Issue on Ocean Turbulence Measurement, 16, 11, part 1, 1533-1544.

Levine, E. R., R. G. Lueck, R. R. Shell, and P. Licis, 1999: Coastal turbulence estimates and physical process studies utilizing a small AUV, Proceedings, Eleventh International Symposium on Unmanned Untethered Vehicle Technology (UUST99), Durham, NH. 94-102.

Marshal, J. , C. Hill, L. Perelman, and A. Adcroft, 1997: Hydrostatic, quasi-hydrostatic, and non-hydrostatic ocean modeling. J. Geophys. Res, 102(C3), 5733-5752.

Moum, J.N., M.C. Gregg, R.C. Lien and M.E. Carr, 1994: Comparison of turbulent kinetic energy dissipation rates from two ocean microstructure profilers. J. Atmos. Ocean Tech., 12, 346-366, 1994.

Ullman, D. S. and P. C. Cornillon, 1999: Surface temperature fronts off the east coast of North America from AVHRR imagery. submitted to J. Geophys. Res.

PUBLICATIONS

Levine, E. R., R. G. Lueck, 2001: Turbulence characterization for Integrated Sampling Networks. Conference on Integrated Sampling Networks, NOPP Special. Session, AMS, Albuquerque, NM, Jan 2001(accepted).

Bogden, P. S., and FRONT Partners, 2000: Front-Resolving Observational Network with Telemetry (FRONT). Abstract invited for AGU/ASLO Ocean Sciences Meeting, Special Session on Coastal Ocean Dynamics and Prediction, San Antonio, January 2000.

Levine, E. R., R. G. Lueck, 2000: Turbulence process studies in coastal predictive networks. ONR Workshop on Vertical Mixing in the Ocean. Seattle, WA, Apr. 2000, report ed. by D. Haidvogel (Invited).

Levine, E. R., R. G. Lueck, 1999: Turbulence measurements with an autonomous underwater vehicle. Journal of Atmospheric and Oceanic Technology, Special Issue on Ocean Turbulence Measurement, 16, 11, part 1, 1533-1544.

Levine, E. R., R. G. Lueck, R. R. Shell, and P. Licis, 1999: Coastal turbulence estimates and physical process studies utilizing a small AUV, Proceedings, Eleventh International Symposium on Unmanned Untethered Vehicle Technology (UUST99), Durham, NH. 94-102.

Glenn, S. M., D. B. Haidvogel, O. M. E. Scofield, C J. von Alt, and E. R. Levine, Coastal Predictive Skill Experiments. Sea Technology, April 1998, 66-72.

Levine, E. R., D. Connors, R. Shell and R. Hanson, 1997: Autonomous Underwater Vehicle-based hydrographic sampling. J Atmos. Oceanic Technol., 14, 6, 1444-1454.