ABSTRACT FORM

(Please note: The complete abstract should be limited to three pages, if possible.)

Project Title: 902108 Mixing rates from autonomous profiling floats in the coastal oceans

Expected Project Duration (in years): 1 year

PI	Project Manager	Lead Scientist	Lead Engineer
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(Indicate individuals appropriate for your project. Not all projects need all four positions filled in.)

Other MBARI Team members: Ken Johnson, Yui Takeshita, Andy Hamilton, Yanwu Zhang, and Tom O'Reilly.

Project Description:

Turbulence in the upper ocean influences light and nutrient availability for phytoplankton growth, as well as grazing rates, by altering prey-predator encounter rates. The level of turbulence can also have consequences for the aggregation of organic matter and can impact carbon fluxes to the deep ocean. Ultimately, turbulent eddy diffusivities are key to quantify turbulent fluxes of biogeochemical tracers into and out of the surface mixed layer. In the coastal oceans, where the ocean's surface can be in close proximity to the seafloor, the surface mixed layer often meets the bottom boundary layer by the mechanical action of winds, waves and tides. Thus, mixing rates generated by turbulence can be elevated throughout the water column.

The oceans' turbulent nature requires knowledge of the size, timescales and rates at which turbulent eddies mix properties in the ocean for an accurate quantification of turbulent fluxes of momentum, heat and biogeochemical tracers. Turbulent eddy diffusivity, K, is the key parameter required to quantify turbulent fluxes, along with tracer gradients, but microstructure observations that allow us to infer K are sparse in the global and coastal oceans because they require very highly specialized expertise and costly sensors. Thus, quantification of mixing rates and turbulent fluxes from observations are rare, and often limited to evaluations of heat, salt or momentum fluxes from CTD (i.e, conductivity-temperature-depth) data. Alternative methods to estimate K from coarse resolution CTD data (e.g. Thorpe scales or fine scale parameterizations) are not appropriate for low stratification conditions, such as the surface mixed layer where biological activity from primary producers largely occurs.

Microstructure sensor technology has matured enough that reliable estimates of eddy diffusivities are achievable from autonomous platforms. Microstructure sensor packages have been deployed on autonomous underwater vehicles, gliders, and floats. However, such efforts to integrate microstructure sensors have often been limited to platforms that measure only physical properties. To our knowledge, microstructure sensors have not been fully integrated on floats that carry biogeochemical sensors.

This scoping project aims to investigate the feasibility of integrating microstructure sensors on the Coastal Profiler Float (CPF) that is in development at MBARI by Ken Johnson's Lab. The integration of microstructure shear probes and/or fast-response thermistors on the CPF would generate concomitant observations of biogeochemical tracer concentrations and microstructure observations in the water column, from which vertical diffusivities (a.k.a. mixing rates) can be inferred in the coastal oceans. The CPF stands out among other profiling floats in that it provides higher stability, payload capacity, and full control on profiling speeds, compared to standard BGC floats. These capabilities are required to capture the full range of turbulence scales in the dissipation range.

Fundamental Problem

Walter Munk's seminal paper (Munk, 1966) estimated an averaged eddy diffusivity of order 10^{-4} $m^2 s^{-1}$ needed to close the thermohaline circulation. Since then, turbulence sensor technology has evolved and the ocean mixing community has attempted to observe such order of magnitude of vertical diffusivities. Repeatedly, estimates of diffusivities from tracer dispersion experiments, microstructure sensors, and fine scale parameterizations from coarse resolution data have found orders of magnitude less than Munk's figure. Because turbulence observations mostly come from the open ocean, culprits for the "missing mixing" have been attributed to those regions hard to sample with shear probes: the surface and bottom boundary layers, and the continental margins. From a biogeochemical standpoint, there are also "missing" nutrient fluxes into the surface layer to support biological production (e.g., in the subtropical oceans); and diffusivities are essential to quantify turbulent fluxes of biogeochemical properties, which add to the total fluxes (i.e. by the mean and turbulent flows combined). Thus, adding microstructure observations capabilities to the CPF, currently in development by MBARI scientists and engineers, would allow to infer eddy diffusivity profiles in the coastal oceans, filling the gaps in turbulence measurements while providing reliable estimates of biogeochemical turbulent fluxes in the coastal oceans. The potential for long-term observations that could be achievable from a float would enhance knowledge of spatio-temporal variability of mixing rates that are particularly challenging in the surface mixed layer. Moreover, the unique suite of biogeochemical observations along with turbulence data from the CPF will improve understanding of the competing effects of light and turbulence that create biogeochemical stratification within the surface mixed layer (homogeneous in hydrographic properties), potentially allowing estimation of diffusivities from coarse resolution BGC float data - a method that could be scaled up to the global BGC Argo array.

Technology

Microstructure shear probes and fast response thermistors measure turbulent kinetic energy and thermal variance dissipation rates, from which eddy diffusivities can be inferred. For reliable diffusivity estimates from microstructure measurements, the sensors have to profile fast enough such that Taylor's frozen turbulence hypothesis is valid (i.e. turbulence billows that evolve on timescales that range on orders of 10-100s are "frozen" as one profiles through the water column), but slow enough to capture the full range of turbulence dissipation scales. Typically, high-accuracy microstructure measurements are best collected from free-fall vertical microstructure profilers (VMPs) that sample ~250 m of water column at falling (or rising) speeds of ~0.5-0.8 m s^{-1}. Microstructure measurements of horizontal velocity vertical gradients (i.e. vertical shear, du/dz) and temperature gradients (dT/dz) are sampled in the frequency domain (at 512 Hz), and are scaled by the sensors' profiling speed to convert to the wavenumber domain (i.e., $1/\lambda$ in the vertical).

Microstructure sensor packages from Rockland Scientific International (RSI) Inc. have been developed for integration on autonomous platforms. The integration of microstructure measurements on gliders is more mature. Gliders are advantageous as they have higher payload and stability, but they require a dynamical model to estimate the velocity past the probe needed for appropriate scaling of the wavenumber spectra. In addition they are limited in temporal and spatial coverage to a few 100 km and weeks-to-months deployments. Profiling floats are unique in their long-term observations capabilities. Shear probes and fast-response thermistors have been integrated successfully on profiler floats that have carried sensors for physical parameters, but none of the float efforts have carried biogeochemical sensors. To our knowledge, there are no BGC floats with microstructure sensors currently in the water.

As a first step, we propose to deploy MBARI's CPF with a self-contained MicroRider package from RSI with shear probes, a fast response thermistor and additional vibrational and inclination sensors. These additional sensors will allow us to evaluate the float's behaviour, stability and appropriate removal of mechanical noise from the shear probes signal. The MicroRider records data internally (up to 16 GB), and requires float recovery for data acquisition. Since this sensor package can be self powered and self-logging, minimal engineering effort is required for this integration. Stability of the CPF-MicroRider and flow characteristics will be initially tested in the test tank. The MicroRider package can be leased from RSI at a relatively small fraction of the cost (~20%). A small vessel (e.g. the R/V Paragon or R/V John Martin) will be needed for float deployment and recovery. A second goal of this scoping project is to evaluate and determine the feasibility of fully integrating microstructure probes on the end cap of the CPF. Full integration would require power and software integration for satellite telemetry of processed data, all things that RSI has been developing (to provide in bulk) for float manufacturers.

Data

Vertical profiles of turbulent eddy diffusivities will be generated, along with a full suite of BGC measurements at each profile location. Test deployments of the CPF with a MicroRider will be conducted in Monterey Bay. Profiling frequency will be determined during the scoping project, but will aim to capture the diurnal changes in light conditions (i.e. ~ twice daily).

We estimate ~ 20 MB of raw data per profile to 200 m (e.g., with 2 shear probes + 1 thermistor), which could result in ~1.2 GB of data per month and will be stored on Atlas once recovered from the MicroRider.

Processed vertical profiles of dissipation rates from microstructure shear and temperature data, and derived vertical diffusivities for momentum (K) and temperature variance (χ), will be integrated in FloatViz, for visualization and data dissemination.

Intellectual Property (IP) Considerations

Do you anticipate a need for a cooperative research and development agreement or licensing arrangement with an external entity? Will the work potentially result in a patentable product or service? Will novel IP be created, and how might it be disseminated (e.g., license agreement and/or collaborations)?

For additional guidance please review MBARI's intellectual property internal web page: https://mww.mbari.org/itd/ip/.

Anticipated Impact

Consumers: physical, biological, and chemical oceanography communities will be interested in this effort. The CPF is a one-of-a-kind platform that will allow integration of a turbulence sensor with the full BGC sensor suite, opening doorways to address fundamental scientific questions that have stagnated due to technology deficits. The suite of observations can also be beneficial to the ocean modelling community, to test and improve parameterizations of biogeochemical processes and mixing schemes in the coastal ocean.
Connections: Rockland Scientific, and potential external collaborators from academic institutions such as APL-UW (James Girton), and SIO-UCSD (Peter Franks and Rob Pinkel).

Anticipated Outreach Needs

We will work with ITD to develop graphics and/or animations that would help convey turbulence related biophysical interactions research to a broad audience that may help to clarify the concept of mixed vs mixing layers in the context of turbulence.

Please provide an overall, high-level estimate of resources envisioned for this project in 2020 to help give a sense of the size of the proposed effort. Detailed scoping is not needed at this stage. Simply mark the appropriate box below.

Budget Category	Minimal	Medium	Significant
Labor		X	
Expense	X		
Ship/Assets	X		

If you anticipate a large ramp-up or increase in resource requests in future years of the project, please include that information below.

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