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Multi-Month Dissipation Estimates Using Microstructure from Autonomous Underwater Gliders

By Luc Rainville, Jason I. Gobat, Craig M. Lee, and Geoffrey B. Shilling

Ocean turbulence is inherently episodic and patchy. It is the primary mechanism that transforms water mass properties and drives the exchanges of heat, freshwater, and momentum across the water column. Given its episodic nature, capturing the net impact of turbulence via direct measurements requires sustained observations over extended temporal and/or broad spatial scales.

Seagliders, autonomous platforms that steer through the water column by controlling pitch, roll, and buoyancy, glide smoothly from the ocean surface typically to 1,000 m depth and back while collecting profiles of temperature, salinity, and other oceanic variables. Mission duration depends largely on ambient stratification and profile depth; some Seaglider missions have profiled continuously for more than nine months while others operate from ships for shorter periods. Based on measurements collected using a fast accelerometer logger during a mission in the Kuroshio, a strong Pacific western boundary current, Seagliders show very little vibration during most of their profile. Platform accelerations are comparable to free-falling microstructure instruments and do not affect microstructure measurements. Similar results have been obtained from Slocum gliders (Wolk et al., 2009). Speeds through the water are about 0.3–0.4 m s^{-1}, predominantly in the horizontal direction, allowing a glider to cover distances of about 20 km per day while occupying regular patterns. Their speed and minimal vibration as they move through the water make gliders desirable platforms for carrying turbulence sensors.

A fully integrated microstructure system has been developed at the University of Washington Applied Physics Laboratory (APL) to directly estimate oceanic turbulent dissipation rates using Seagliders. The system consists of two fast thermistors (FPO7), or one fast thermistor and a thin-film shear sensor, that sample at 400 Hz. These instruments are mounted in a manner that minimizes drag, and thus impact on flight, near the glider temperature and conductivity sensors (Figure 1). The probes and analog signal conditioning boards are provided by Rockland Scientific Inc., and the acquisition and processing electronics and software are developed at APL. Very low power electronics (~150 mW) make it possible to sample one or two microstructure channels in the upper 250 m of the water column during a seven-month mission while using a similar amount of power as other instruments typically integrated on Seagliders.

In addition to recording raw data at 400 Hz (accessed upon recovery of the glider), the system also provides near-real-time estimates of turbulence. Spectra corresponding to temperature or velocity gradients at turbulence scales (wavelengths from 0.01 m to ~1 m) are then computed onboard the glider in real time and combined into ensembles that correspond to roughly 1 m in the vertical. These spectra are then reduced to 12 frequency bands that are chosen to capture the shape of the turbulence spectra. These averaged frequency spectra are transmitted to the base station at APL at the end of every dive, scaled to physical units

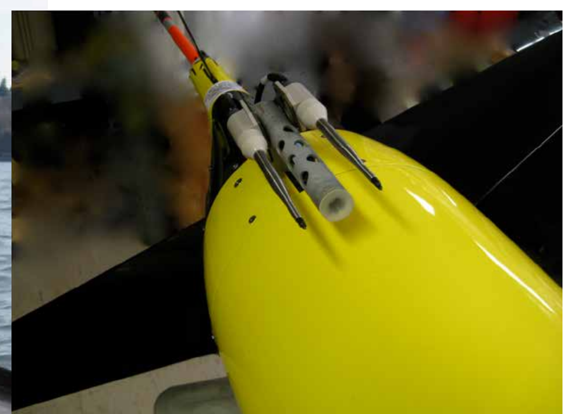

Figure 1. Microstructure probes mounted onto a Seaglider. Low-profile mount points near the temperature and conductivity sensor minimize added drag and can accept either FP07 or shear probes.

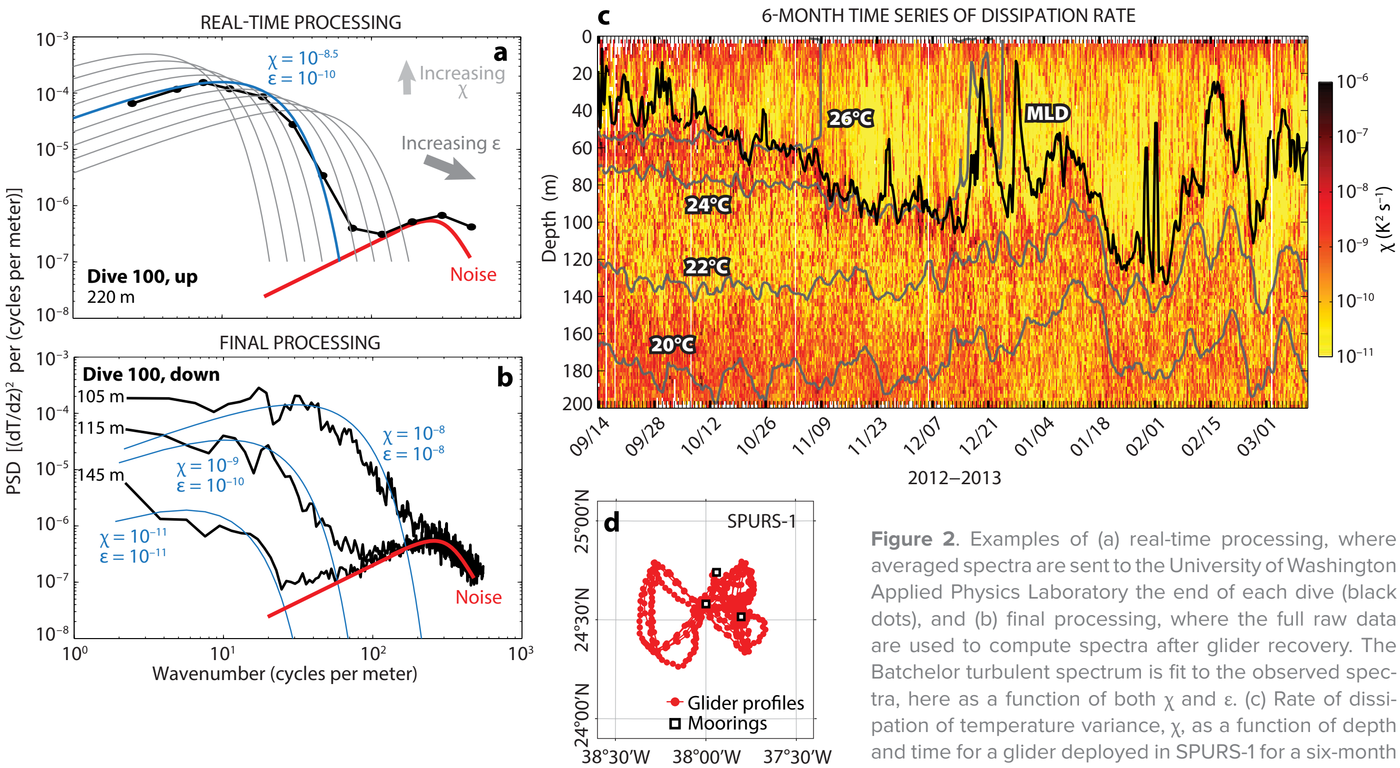

Figure 2. Examples of (a) real-time processing, where averaged spectra are sent to the University of Washington Applied Physics Laboratory the end of each dive (black dots), and (b) final processing, where the full raw data are used to compute spectra after glider recovery. The Batchelor turbulent spectrum is fit to the observed spectra, here as a function of both χ and ε. (c) Rate of dissipation of temperature variance, χ, as a function of depth and time for a glider deployed in SPURS-1 for a six-month period (572 dives). Temperature contours smoothed with a seven-day run, are shown in gray, and mixed layer depth (MLD) is in black. (d) This panel shows the glider track pattern (red) around a central mooring (square).

and converted to wavenumber spectra using the forward speed from the glider flight model, and processed to obtain turbulent dissipation rates in near-real time.

For micro-temperature, dissipation rates are calculated by fitting the theoretical Batchelor turbulence spectrum to each observed spectrum. Dissipation rates of temperature variance (χ) and kinetic energy (ε) can be estimated independently with a two-parameter fit (Ruddick et al., 2000; Figure 2a), or via a one-parameter fit if diffusivities of heat and momentum are assumed to be the same (Zhang and Moum, 2010). Using the raw data stored on the glider, the full spectra can be calculated after vehicle recovery (Figure 1b). This system has been deployed on several missions, including in a series of six-month deployments in the Salinity Processes in the Upper-ocean Regional Study (SPURS)-1 program in the North Atlantic to measure the seasonal cycle of turbulence (Figure 2c). Microstructure shear and temperature sensors are currently deployed as part of SPURS-2 in the Eastern Pacific Ocean, sampling continuously in the top 250 m during the descending portion of every dive (Lindstrom et al., 2017, in this issue).

This system and other recently developed instruments with low-power electronics and high-capacity storage (e.g., moored temperature microstructure instruments; Moum and Nash, 2009) now provide the ability to obtain thousands of turbulence profiles and long time series of dissipation rates in the ocean, thus linking the short temporal and spatial scales over which turbulence occurs with the scales of water mass transformation and global circulation that are ultimately driven by this patchy turbulence.

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