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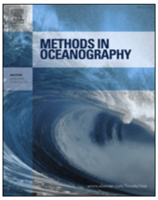

Full length article

Dissipation measurements using temperature microstructure from an underwater glider

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ABSTRACT

Microstructure measurements of temperature and current shear are made using an autonomous underwater glider. The glider is equipped with fast-response thermistors and airfoil shear probes, providing measurements of dissipation rate of temperature variance, χ, and of turbulent kinetic energy, ε, respectively. Furthermore, by fitting the temperature gradient variance spectra to a theoretical model, an independent measurement of ε is obtained. Both Batchelor (ε_B) and Kraichnan (ε_K) theoretical forms are used. Shear probe measurements are reported elsewhere; here, the thermistor-derived ε_B and ε_K are compared to the shear probe results, demonstrating the possibility of dissipation measurements using gliders equipped with thermistors only. A total of 152 dive and climb profiles are used, collected during a one-week mission in the Faroe Bank Channel, sampling the turbulent dense overflow plume and the ambient water above. Measurement of ε with thermistors using a glider requires careful consideration of data quality. Data are screened for glider flight properties, measurement noise, and the quality of fits to the theoretical models. Resulting dissipation rates from the two independent methods compare well for dissipation rates below 2×10^{-7} W kg^{-1}. For more energetic turbulence, thermistors underestimate dissipation rates significantly, caused primarily by increased uncertainty in the time response correction. Batchelor and Kraichnan spectral models give very similar results. Concurrent measurements of ε and χ are used to compute the dissipation flux coefficient Γ (or so-called apparent mixing efficiency). A wide range of values is found, with a mode value of $\Gamma \approx 0.14$, in agreement with previous studies. Gliders prove to be

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suitable platforms for ocean microstructure measurements, complementary to existing methods.

1. Introduction

Direct measurements of turbulent mixing in the ocean require datasets of variables such as small-scale temperature or current shear sampled at high-frequency. Traditionally, such data are acquired using loosely-tethered profilers, deployed repeatedly off a ship's side (Lueck et al., 2002). This method provides data with little disturbance from vibrations, and repeated profiles can be made relatively fast. However, dedicated ship time is expensive, and microstructure surveys are sporadic. As an alternative, equipping underwater gliders with turbulence sensors facilitates continuous sampling on a low-vibration platform (Fer et al., 2014).

A glider is an autonomous vehicle that moves by changing its buoyancy, and can receive navigational instructions remotely via satellite. The wings, and to a lesser extent a tail fin, translate vertical motion into horizontal motion. This causes the glider to move through the water column in a vertical sawtooth pattern, resulting in quasi-vertical profiles. Dedicated ship time is not needed, making gliders a potentially very useful platform for turbulence measurements. Another benefit of gliders as an instrument to sample ocean microstructure is their ability to collect data during extreme atmospheric forcing. During stormy conditions, conducting profiling from ships is hazardous, and such mixing events are thus rarely sampled.

The first attempt to obtain turbulent dissipation rates from a glider was based on an indirect method utilizing standard sensors of the glider: Beaird et al. (2012) analyzed a large dataset from Seaglider (University of Washington) deployments over three years around the Greenland–Iceland–Scotland ridge, and inferred dissipation rates from finescale vertical velocity and density measurements. Their method is based on a scaling of the turbulent kinetic energy (TKE) equation, and relies on a scaling constant that is site specific, and accurate vertical water velocity measurements from a glider flight model. Energy loss at viscous scales is inferred from the larger, energy-containing scales. The results from this method compared very well to a co-located microstructure survey from the Faroe Bank Channel (FBC), with an agreement to within a factor of two, when ε varied over several orders of magnitude. The method allowed Beaird et al. (2012) to remotely map turbulent mixing and identify turbulent hot-spots in the region using gliders.

The first test using a Slocum electric glider equipped with turbulence sensors was done by Wolk et al. (2009) in an approximately 20 m deep freshwater pond. The glider was equipped with a self-contained microstructure instrument package (MicroRider, Rockland Scientific Int., Canada) with shear probes and thermistors. The vertical speed of the glider was typically 10 cm s^{-1}, corresponding to 40 cm s^{-1} along the glider's path, suitable for shear probe measurements. Wolk et al. (2009) found the glider to be a favorable platform for turbulence measurements.

The first detailed measurements in the ocean from a glider equipped with shear probes were reported by Fer et al. (2014). A deep Slocum electric glider equipped with a MicroRider with two shear probes was deployed in the FBC. Dissipation rate measurements from the glider and a ship-based vertical microstructure profiler were analyzed and compared. Vibration levels of the glider were generally small, and did not interfere with measurements of small-scale turbulent quantities. The glider measurements were shown to be of high quality, with the exception of the turning depths of the glider, where Taylor's hypothesis becomes invalid. The shear probes were able to resolve dissipation rates of TKE, ε, down to 5×10^{-11} W kg^{-1}, comparable to the best tethered free-fall profilers. In the turbulent bottom layer of the FBC, average profiles of ε from the glider and the microstructure profiler agreed to within a factor of two, whereas higher in the water column averaged glider-derived values were up to 9 times larger than the ship-based measurements. The discrepancies were attributed to the different sampling scheme (glider's slanted path), spatial and temporal separation between the instruments,