Turbulence
Ocean
Microstructure
Acquisition
Profiler

Turbo MAP

A new Instrument that Measures Micro structure Turbulence

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TurboMAP

The interaction of micro-scale turbulence with the planktonic ecosystem is an issue of growing interest to the oceanographic research community, as well as to fisheries management. Unfortunately, the collection and analyzing of microstructure turbulence data has in the past been limited to a handful of specialized research groups. To enable a broad spectrum of researchers to perform turbulence measurements, we developed TurboMAP, a free-falling instrument that measures physical microstructure as well as centimeter-scale bio-optical parameters.

System Overview

TurboMAP is a free-falling profiler designed for easy, straightforward operation in open-ocean, coastal, and limnic water. The instrument is equipped with state-of-the-art sensors for measuring velocity shear (*du/dz*), temperature gradient (*dt/dz*),fluorescence, turbidity, and hydrographic parameters (*C,T,D*). All sensors are mounted on a parabolic nose cone (Figure 1) that points towards the undisturbed flow.

Data are collected only during the downcast at a rate of 256 samples per second; they are recorded internally in non-volatile RAM. The memory capacity (80MB) is large enough to store data from several profiling cycles. After retrieval of the instrument, the data are transferred to a PC through a wet-mating connector in the aft-ward end cap of the pressure case.

The length of TurboMAP's pressure case ensures that the low-wave-number part of the measured turbulence spectrum is not contaminated by the instrument's low-frequency motions. Since the turbulence spectrum begins at a wavenumber of one cpm (one meter wavelength), the length of TurboMAP is two meters.

TurboMAP is deployed with a thin Kevlar rope which is paid out slightly faster than the instrument's sinking velocity. This deployment technique ensures a free descent of the instrument so that the velocity measurements are not contaminated by vibrations. A simple and effective emergency system prevents instrument loss in case the tether line breaks under extreme conditions: two of drop-off weights are released if the profiler sinks below a preselected depth, allowing the instrument to rise to the surface by its own buoyancy.

Figure 1:Sensor nose

Parameter	Range	Accuracy	Resolution
Shear	0-10 s^{-1}	5%	$1 \times 10^{-4} s^{-1}$
Fast temperature	-5 - 45 °C	1×10^{-2} °C	< 1×10^{-4} °C
Slow temperature	-5 - 45 °C	1×10^{-2} °C	1×10^{-3} °C
Conductivity	0-7 S/m	2×10^{-3} S/m	2×10^{-4} S/m
Pressure	0-500 dbar	0.5%FS	1×10^{-2} dbar
Acceleration (x,y,z)	+/- 1g	1%FS	5×10^{-4} g
Fluorescence	0-200 ppb	0.5ppb	5×10^{-3} ppb
Turbidity	0-200 ppm	1ppm	5×10^{-4} ppm

Table 1:Sensor Specifications

Software

With the powerful software package tmTOOLs, it is easy to process and analyze TurboMAP data. The software is available either as a function library for use with Matlab or as a stand-alone GUI application. One can convert the measured data to physical units, or to export raw binary files to ASCII. tmTOOLs has a graphical user interface that enables one to simultaneously display profiles of different parameters simultaneously, or to compute and display power spectra in the frequency or wavenumber domain. With simple click-and-drag operations of the mouse it is possible to zoom in on depth ranges or set intervals for the spectrum computations. Measured dissipation spectra can be easily compared to universal spectra for quality control of the signal.

Turbulence Package

Turbulent velocity fluctuations are measured with a shear probe (Figure 2), which is the standard sensor for turbulence measurements. The probe's sensing element consists of a parabolically shaped, axis-symmetric flexible rubber tip.

For small angles of attack, α , the oncoming flow of velocity W produces a hydrodynamic lift force proportional to the cross-stream velocity component u. A piezo-ceramic beam, located at the center of the rubber tip, translates the lift force into an electrical signal Ep. This signal is differentiated by an analog circuitry inside TurboMAP, which makes the signal proportional to the rate of change of cross-stream velocity *du/dt*. Under Taylor's frozen field assumption, the velocity shear is then $du/dz = W^{-1} du/dt$.

Microstructure temperature fluctuations are measured with a fast response thermistor (FP07, manufactured by Thermometrics Inc.). Before sampling, the fast thermistor signal is combined with its own time derivative, i.e. $T + dT/dt$, to enhance the signal resolution (Mudge and Lueck, 1994). With this treatment, it is possible to resolve centimeter-scale fluctuations of temperature with a resolution of 10^{-4}°C or better. Though highly sensitive and fast, the FP07 lacks long-term stability; therefore, no absolute calibration of this sensor can be performed prior to deployment. Instead, the FP07 signal is calibrated during postprocessing by regressing its signal against the signal of the platinum wire thermometer of the C-T package (cf. Table 1).

Biological Sensors

Biological activity is measured with a combined high-resolution fluorescence/turbidity sensor (shown in the foreground in Figure 1). The chlorophyll concentration is determined by measuring the fluorescent strength in response to the excitation light with a wavelength of 400 - 480 nm. The excitation is provided by six LEDs that are placed on a circumference of 20 mm diameter. Their light is collimated and focused onto a point 15 mm in front of an optical receiver with a 640 - 720 nm pass band, located in the center of the diode ring.

Turbidity is determined from the intensity of backscatter of the excitation light. The backscatter receiver is located on the circumference of the LED array and its receiver beam is focused on the point of convergence of the excitation beams. The backscatter receiver has the same optical pass band as the excitation light, to ensure that fluorescent activity is not mistaken as turbid backscatter. The chlorophyll sensor has been extensively tested in laboratory experiments to establish its sensitivity, linearity, and dynamic range in response to naturally occurring fluorescence sources, as well as the sensors spatial resolution. These tests were carried out at the Tokyo University of Fisheries (Wolk et al., 2000), and the results show that the probe is able to accurately measure the in-situ concentration of chlorophyll and is able to resolve spatial scales down to 20 mm.

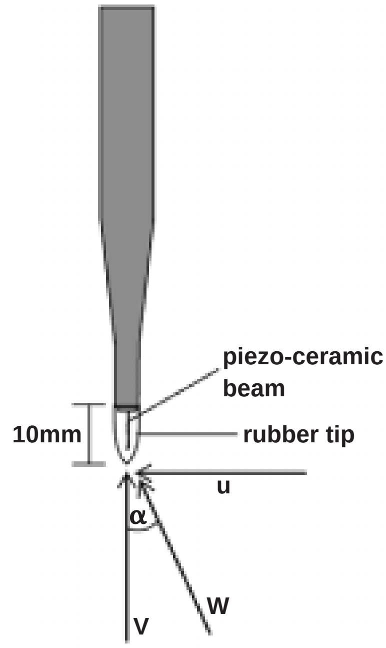

Figure2:Geometry of the shear probe

Ancillary Sensors

In addition to the turbulence probes and bio-optical sensors, TurboMAP carries hydrographic sensors to measure conductivity, temperature, and depth. Furthermore, a set of three orthogonal accelerometers is mounted inside the pressure case. The accelerometers provide a measure of both the instrument’s attitude and its vibrations. Body vibrations, resulting from improper deployment techniques (such as strumming of the recovery wire), are detrimental to turbulence measurements and they must be monitored to verify the integrity of the turbulence data.

Field Test

We tested TurboMAP in several deployments in the coastal and offshore waters around Japan. Figure 4 shows an example of the shear and temperature signals collected in a well mixed tidal channel in Hiroshima Bay. The inset in Figure 3 shows the dissipation spectrum, computed from the shear signal between 1 m and 16 m depth. The measured spectrum agrees in both magnitude and shape with the Nasmyth universal spectrum for a dissipation rate of $\epsilon = 1.7 \times 10^{-7}$ W/kg (Nasmyth 1970).

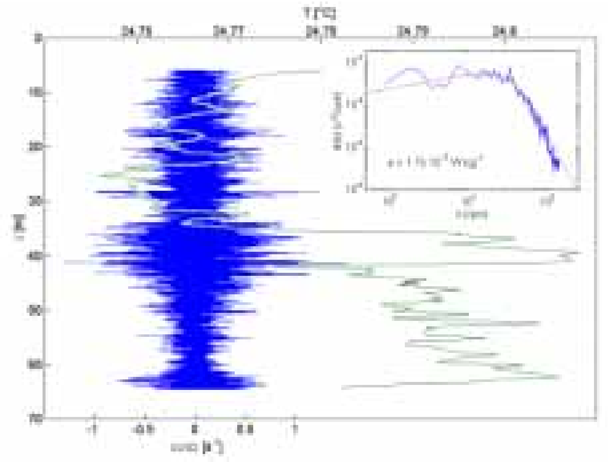

Figure 3:Example of a depth profile of velocity shear and temperature, collected in a well-mixed tidal channel. Shown in the inset in the shear spectrum for the depth range 6-16m, along with scaled universal spectrum.

Figure 4 illustrates the high-resolution temperature signal (T_{fast}) in comparison to the standard thermistor signal (T_{slow}). The inset shows that the fast thermistor is able to resolve fluctuations in temperature much lower than one m°C. Furthermore, the spatial resolution is in the sub-centimeter range. Note how the small temperature intrusion, which is evident in the fast temperature signal at 24.5 m, does not show up in the standard thermistor signal, which illustrates the excellent response characteristics of the fast thermistor. Examples profiles of chlorophyll and turbidity are shown in Figure 5. These data were sampled in a tidal channel in Hiroshima Bay. Both chlorophyll and turbidity show a significant amount of variability throughout the water column. The large excursions of the chlorophyll signal at, e.g. 19 m and 27 m have half-widths of approximately 50 mm, and therefore are within the spatial resolution of the chlorophyll/turbidity sensor. These "spikes" are not an artifact of the sensor, but are caused by encounter of singular phytoplankton organism in the water column.

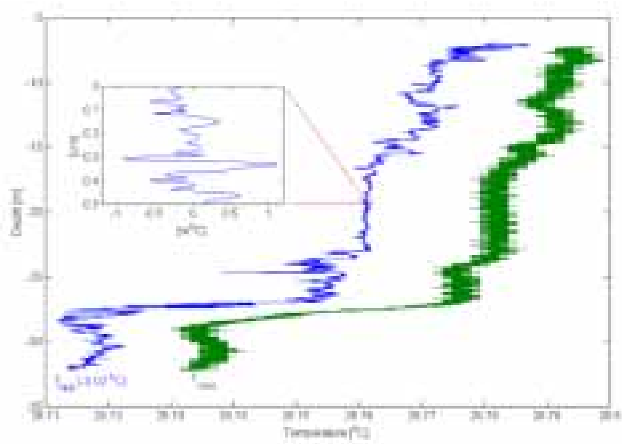

Figure 4:Comparison of the enhanced high-resolution temperature signal and the standard temperature signal.

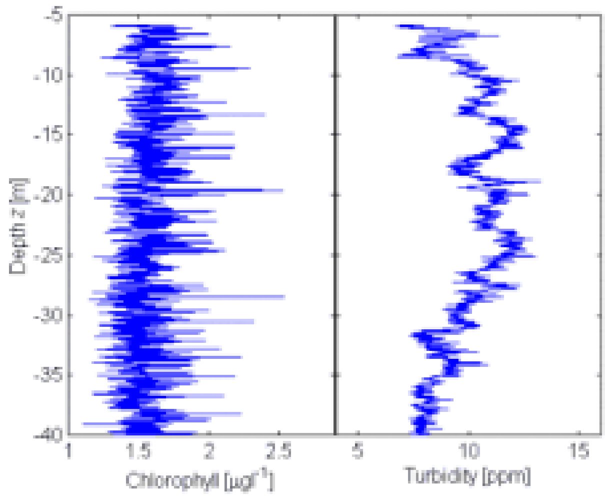

Figure 5:Example profiles of turbidity and chlorophyll.

Dimensions	2000mm(L) x 140mm(OD)
Weight	30kg / 0.5kg (in air / in water)
Nominal fall speed	0.5m/s
Depth rating	500m
Pressure case	HCR treated aluminum

Table 2:Mechanical Specifications

Note that specifications may be changed without prior notice. *2002/4*