



A new tow-yo instrument to observe high-resolution coastal phenomena

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ABSTRACT

Field observations in coastal and estuarine regions are important for studying physical and biological features. Recent studies have presented fine-scale physical features from numerical models and acoustic surveys. However, high spatial resolution data of physical structures are difficult to obtain, since the conventional CTD survey requires a stop-and-measure ship operation. To solve this issue, we have developed a new, portable tow-yo instrument, Yoing Ocean Data Acquisition Profiler (YODA Profiler), that continuously observes many vertical profiles of the fine-scale features in coastal regions. Using the YODA Profiler, we were able to rapidly obtain high-resolution data in a shallow estuary. The results showed fine-scale complicated internal wave features, upslope propagating fronts and a patchy distribution of phytoplankton. These observations are consistent with recent numerical models and acoustic surveys, as well as with the critical angle theory for internal wave reflections along a bottom slope. We have also developed a statistical technique to estimate the rate of turbulent kinetic energy dissipation, ϵ , from the variance of dC/dz data. Using this technique we were able to estimate the turbulent kinetic energy dissipation rate associated with river outflow and internal waves in the river mouth.

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1. Introduction

Understanding the small-scale physical and biological processes in coastal and estuarine areas is a pressing issue in oceanography. Recent observations have captured small-scale physical processes in these areas (e.g., Moum et al., 2003; Van Haren, 2009). Numerical studies have also shown small and complex density structures caused by internal waves in near shore areas (e.g., Venayagamoorthy and Fringer, 2006; Vlasenko and Hutter, 2002). However, no previous study has shown the complex physical structure data from in situ field CTD observations since a conventional CTD survey requires positioning a research vessel from one place to another.

A useful method for observing oceanic processes is a towed observation. With this method, high spatial resolution data can be obtained rapidly and continuously. Examples of towed profiling systems are SeaSoar (Pollard, 1986), AQUAshuttle (Chelsea Instruments, Ltd.), the Moving Vessel Profiler (MVP; Herman et al., 1998) and the Underway CTD (UCTD; Rudnick and Klinke, 2007). SeaSoar and AQUAshuttle are towed and winged instruments. While being deployed the instruments move up and down in the ocean changing their wing angle, allowing for rapid towed observation. This type of observation provides a saw-tow mode data, but the instrument does not produce vertical profiles. MVP and UCTD are tow-yo instruments that succeed

in providing many vertical profiles during a transect. Since both instruments descend at a high speed in order to obtain free-fall profiles from a fast moving ship, they are difficult to operate in shallow waters without hitting the bottom. Furthermore, their deployments require a dedicated winch, and most of them are difficult to use with a small vessel, like a fishing boat. In order to address these issues, we have designed a portable free-fall tow-yo instrument Yoing Ocean Data Acquisition Profiler (YODA Profiler, Fig. 1), to capture high spatial resolution data of physical features in a shallow coastal area. The YODA Profiler is deployed using a procedure similar to that of the MVP and UCTD. Inspired from free-fall microstructure profilers, such as TurboMAP (Wolk et al., 2002), a brush is mounted at the top of the profiler. The brush promotes a stable, uniform sinking velocity in a free-fall mode. We were able to observe detailed fine-scale physical features in shallow coastal areas quickly and efficiently using this new small profiler and a small, inexpensive winch.

We have also developed a statistical technique to estimate the turbulent kinetic energy dissipation rate, ϵ , from the vertical gradient of conductivity (dC/dz) that is the surrogate of the temperature gradient. This method permits us to infer detailed turbulent phenomena in shallow coastal areas.

In this paper, we describe the design of the YODA Profiler and some results from observations made near a river mouth. Functional descriptions are presented in Section 2. The instrumentation and locations of observations are described in Section 3. Results from observations near a river mouth are discussed in Section 4. A statistical technique to estimate the turbulent kinetic energy dissipation rate is described in Section 5. Section 6 concludes this study with a summary.

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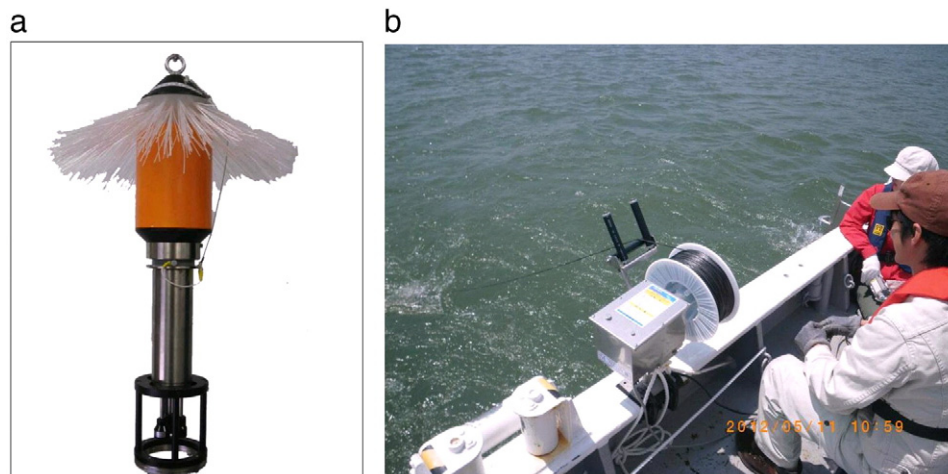


Fig. 1. The YODA Profiler (a) and the winch mounted on the R/V Hiyodori (b).

2. YODA Profiler design

The most important consideration for the design of the YODA Profiler is portability. Observations in shallow coastal areas require small research vessels or small fishing boats, which have limited space, so a small and simple profiling system is desired. Therefore, we selected a small memory-type CTD sensor, a small fishing winch and a strong, thin cable for the YODA Profiler system. Another aspect that must be considered when developing and using high speed profiling systems is the drag of the sensor and the cable. However, the drag of these parts is very small for the YODA Profiler and can almost be neglected, as mentioned in the following subsections.

2.1. Sensors

A small memory-type CTD, RINKO-Profiler (JFE Advantech Co., Ltd.), was selected as the main sensor for the YODA Profiler. The RINKO-Profiler carries temperature, conductivity, pressure, fluorescence, turbidity and oxygen sensors mounted at the bottom of the profiler. The response time of the RINKO oxygen sensor is 0.4 s and 0.2 s for the other sensors.

2.2. Brush and weight

The brush mounted on the top of the profiler acts the same way as those on free-fall microstructure profilers, providing a stable free-fall mode. The difference from general microstructure profilers is that the sloping brush is mounted on the YODA Profiler at approximately 45° (Fig. 2a). The flexible brush expands while sinking to promote a stable

free-fall mode (Fig. 2b). During the recovery phase, it contracts to reduce drag, which allows for a smooth recovery with reduced drag (Fig. 2c).

An accurate sinking velocity is necessary to set the profiling time duration for the target depth. The sinking velocity of the profiler varies sensitively depending on the density of water in the observation area and the condition of the brush. The sinking velocity can be adjusted by altering the ring weight at the bottom of the profiler. The sinking velocity is adjusted to 0.2 m s^{-1} in this study (Fig. 3).

2.3. Winch and line

The recovery winch is a small portable 'Light Weight Fisher 4th (Inoue-kikai)' powered by a 24V DC power supply (Fig. 1b). The weight of the winch is 11 kg. In this study, we used a lead storage battery, which allowed us to set up the winch system on a small vessel without onboard power. We chose a 3 mm diameter 'Dyneema Rope' (Falcon, Ltd.) made from high molecular weight polyethylene, because this material is 1.4 times stronger than aramid fiber. The breaking strength of the Dyneema line is 900 kg, and the relative specific gravity is 0.97 in the water. The slow sinking velocity and the thin recovery line permit us to operate the YODA Profiler without drag, which would prevent a stable free-fall mode.

3. Instrumentation and observations

Observations were repeated numerous times between 2010 and 2012 from the 16.5-m, 19-t R/V Hiyodori (Tokyo University of Marine Science and Technology) near the Arakawa River mouth located in the northern area of Tokyo Bay, Japan (Fig. 4). The minimum and maximum depths of this area are approximately 3 and 15 m respectively. In recent studies, such as Okada et al. (2008), river plumes and a thin phytoplankton layer were reported in the area.

The YODA Profiler observation transects of approximately 6–10 km were set up north to south from the river mouth. The sinking speed of the profiler was adjusted to approximately 0.2 m s^{-1} , which corresponds to a vertical resolution of 0.04 m. The sampling interval for data was set to 10 Hz, and the data were recorded internally. The speed of the ship was kept at approximately 2 kts in order to obtain high spatial resolution data. Several times, microstructure data were collected by TurboMAP (Wolk et al., 2002) to compare with the data from the YODA Profiler. YODA Profiler and TurboMAP deployments were also carried out in the middle of Sagami Bay, Japan ($35^{\circ}02.5'N$, $139^{\circ}20.9'E$), to compare turbulent intensity data from each instrument.

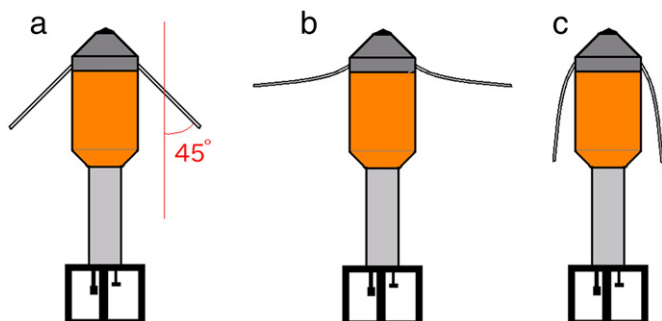


Fig. 2. Schematic images of the YODA Profiler brush: before deployment (a), during descent (b) and at recovery (c).

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