Wirewalker: An Autonomous Wave-Powered Vertical Profiler

LUC RAINVILLE AND ROBERT PINKEL

Marine Physical Laboratory, Scripps Institution of Oceanography, La Jolla, California

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ABSTRACT

An inexpensive vertically profiling float that draws its energy from the ocean surface wavefield is described. Termed the ''Wirewalker,'' it is a generalized platform capable of supporting a variety of self-contained instruments. The motion of the waves drives the positively buoyant profiler downward. It then free floats upward, decoupled from the surface motion field. The design focuses on mechanical simplicity and low cost. In moderate sea states, a prototype Wirewalker has completed profiles to depths of 60 m every 15 min. Profiles from the surface to 50–100 m can be obtained rapidly enough that diel and higher-frequency variability can be resolved.

1. Introduction

An instrument that uses the motion of surface waves to profile in the water column has been developed at the Scripps Institution of Oceanography. The profiling capability of the device, called the ''Wirewalker,'' is not limited by battery capacity, as with the present generation of buoyancy-driven floats (Davis et al. 1992; Schmitt 1996). However, the anticipated lifetime, determined by the mechanical survivability of the system, is shorter. The Wirewalker is intended to complement the existing array of floats, providing an inexpensive means of measuring phenomena that change rapidly in time and depth. An initial application is the study of near-surface temperature, salinity, velocity, and optical fields.

The concept of a wave-powered instrument system is not new. Isaacs and Seymour (1973) and Isaacs et al. (1976) built and tested several devices designed to convert the energy of ocean waves to useful form. More recently, a very advanced prototype wave-powered profiler has been developed (Hamilton et al. 1999). Termed ''SeaHorse,'' this profiler is commercially available. In contrast to SeaHorse, the instrument presented here has no electronic components and is easily deployed from a small boat. Because of its simplicity, expendable as well as captive applications can be envisioned, pending the development of suitable telemetry.

2. Description

The Wirewalker support system (Fig. 1) consists of a length of 3/16-in. (4.8 mm) diameter wire suspended from a 0.5-m spherical surface float and terminated by a 10-kg weight. This moves vertically with the surface wave motion. The Wirewalker itself consists of a positively buoyant element and a drag element, both attached to a ratcheting mechanism that rides on the support wire. The ratcheting mechanism rectifies the vertical motion. At the lower limit of the desired sampling range, the profiler collides with a ''stop,'' which disengages the ratchet. At this point, the platform is completely decoupled from sea surface motion. It smoothly floats back to the surface, collecting high quality data. A negatively buoyant system (sink and pull up) has analogous design considerations.

The ratchet mechanism is shown in Fig. 2. The support cable is fed through a 20-cm tube of inside diameter 1/4-in. (6.4 mm). Along one side of the tube there is a 5-cm slot, in which a roller cam rides. In the rectified operating state, the roller is held very near the cable by an outer jacket with an internal inclined chamber (Fig. 2a). As the cable moves downward, the roller is drawn to the narrow end of the chamber. It pinches the cable, pulling the Wirewalker downward. Upward cable motion frees the roller. The cable can slide upward without hindrance. The oscillatory motion of the surface waves thus forces the Wirewalker downward. The drag element, shown in Fig. 1, keeps the float coupled to the local water as the wire slides upward. The drag must be sufficiently large to overcome friction in the cam mechanism.

At the end of a profiler descent, a stop clamped to the cable contacts the bottom of the cam mechanism, forcing the inner tube upward relative to the outer jacket. Sufficient space is created in the chamber that the roller can no longer engage (Fig. 2b), and free ascent is initiated. A similar stop clamped just beneath the surface float re-engages the ratchet to start the next profiling

Corresponding author address: Dr. R. Pinkel, Marine Physical Laboratory, Scripps Institution of Oceanography, La Jolla, CA 92093-0213.
E-mail: rpinkel@ucsd.edu

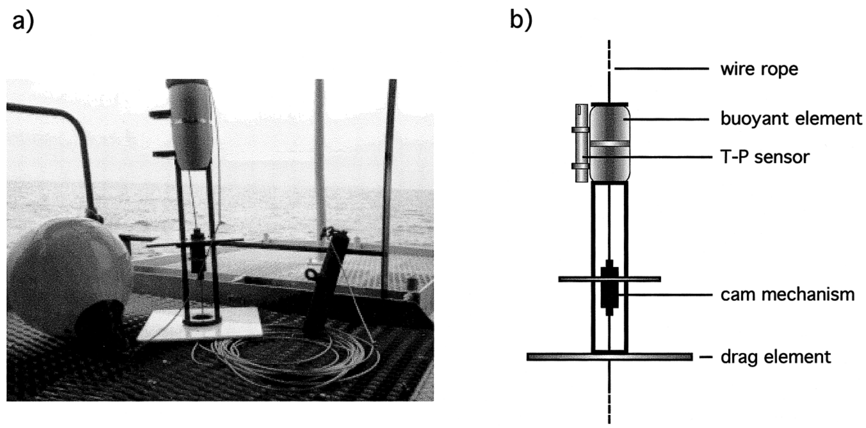

FIG. 1. (a) A photograph showing the Wirewalker (center), together with the surface float, the wire rope, and the weight. As shown in the line drawing of the profiler (b), the temperature and pressure sensor [absent in (a)] goes at the top of the Wirewalker, near the buoyant element. The cam mechanism described in the text is the black box in the center. The white square base of the Wirewalker is the drag element.

cycle. The profiler platform, including the drag and buoyancy elements, is attached to the outer jacket of the ratchet mechanism.

The prototype ratchet was machined out of PVC. Both lexan and steel cam wheels have been used to constrain the stainless steel cable. This design appears capable of an operating life of several weeks. It is felt that an operational life of many months is feasible if more durable materials are used.

While survivability is a major concern, a wave-powered device is not necessarily subject to enormous loads during rough sea conditions. The maximum vertical load the Wirewalker will ever experience is just the weight at the end of the deployment wire plus the weight of the wire itself (more precisely, that fraction of the wire that lies below the profiler at any given instant). The prototype instrument, which profiles the upper 60 m of the water column, is suspended from 10 kg of wire terminated with a 10-kg weight. Relative to alternative near-surface instrument deployments, the loads experienced are not large. However, this entire load passes through the cam mechanism. The cam must be able to transfer this load as the wire descends, release during the ascent periods, and repeat this cycle roughly 10^4 times per day without wearing out or destroying the wire.

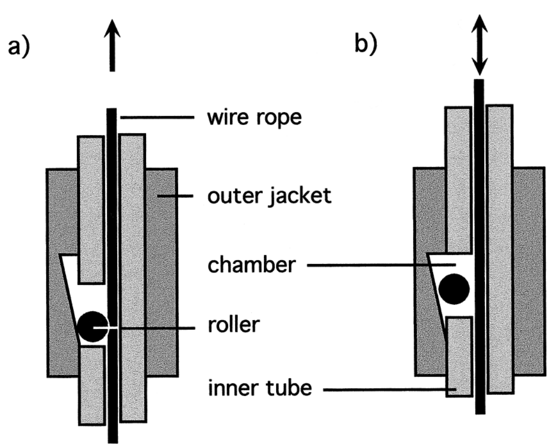

FIG. 2. The cam mechanism. (a) In the climb-down mode, the cable can slide up but not down, so that the Wirewalker is pulled down in the water at each surface-wave trough. (b) Free-float mode: the roller does not engage the cable, and the Wirewalker floats uninterrupted to the surface.

This approach uses the vertical velocity of the surface relative to the local water around the Wirewalker to drive the profiler. Since the vertical velocity associated with gravity waves decays exponentially with depth, operation is most difficult when the profiler is near the surface. One can increase the relative motion through proper selection of the resonant period of the surface float/suspension cable system. High-frequency (above resonance) surface gravity waves drive the float out of phase with the vertical water displacement, maximizing the relative motion between the near-surface profiler and the wire. Since high-frequency gravity waves are present even in light winds and reach a saturated state in moderate winds, a relatively stable power supply is assured. Very large waves (subresonant) move the float, wire, and near-surface profiler in phase, putting little stress on the system. As the profiler descends into calmer water, the power of the large waves becomes available for vertical propulsion.

The size of the drag element must be sufficiently large to overcome cam friction. As larger drag elements are used, a larger weight is needed at the end of the cable to force profiler descent. This increases overall system load. With the drag established and profiler mass set by the instrument payload, buoyancy can be adjusted to provide the desired ascent rate. Unlike buoyancy-driven

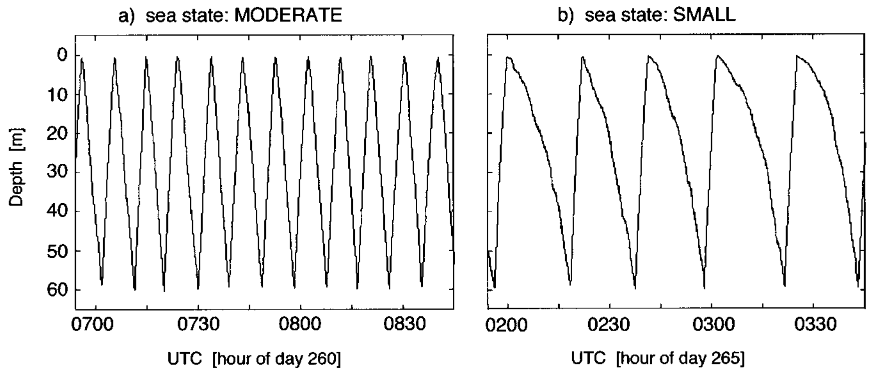

FIG. 3. Depth–time series. (a) On 17 Sep 1999, the sea conditions were moderate, and the Wirewalker was profiling with periods of 9 min. (b) On 22 Sep the sea conditions were small, and the profiling period increased to 20 min.

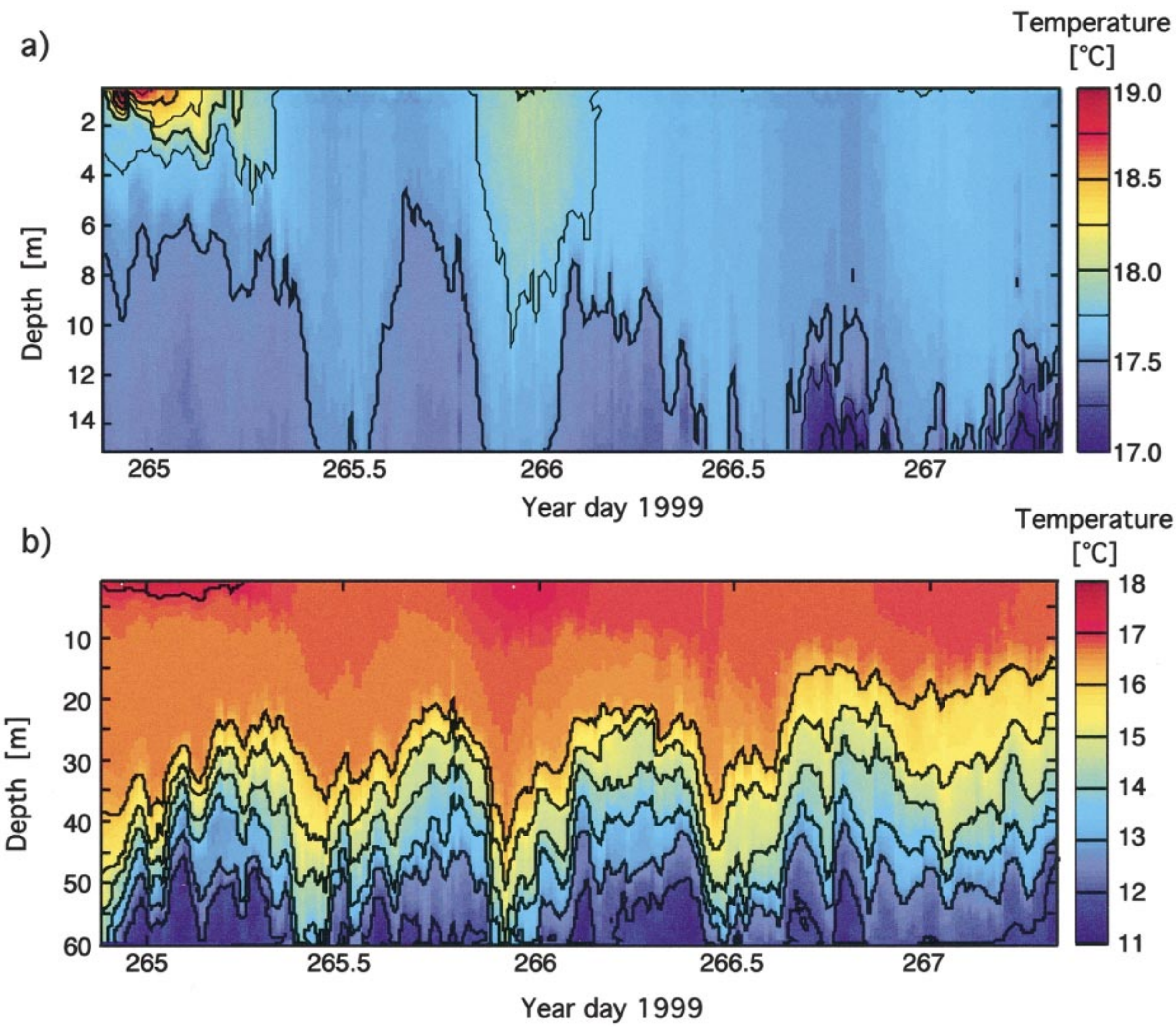

FIG. 4. Contour plot of the temperature as function of time and depth (a) from 0.6 m below the surface to a 15-m depth, and (b) for the upper 60 m of the ocean. Internal waves are clearly visible (tidal and higher frequencies), and the diurnal heating of the upper ocean is also evident.

devices, there is no need for precise tuning or buoyancy compensation of the profiler.

3. Test and observations

A prototype of the Wirewalker was tested in September 1999 on the Research Platform *FLIP*, which was freely drifting off the coast of California (33°N, 123°W). For this test deployment, a line between the end of a horizontal boom and the surface float kept the profiler approximately 25 m from the hull of *FLIP*, out of the wake of the platform.

During this deployment, a temperature and pressure sensor (Sea-Bird SBE39) was mounted on the profiler. A typical depth–time series is shown in Fig. 3. The profiler was buoyancy compensated to ascend at about 0.2 m s^{-1}. Figure 3a shows the depth–time series for moderate sea conditions (wind waves of 1 m). A 60-m profile was obtained every 9 min. In comparison, Fig. 3b shows the depth–time series when seas were calm (minimal wind waves, primarily swell). The profiling period increased to 20 min. For both cases, the low-frequency swell had an amplitude of 1–2 m. Note that in all sea conditions (particularly in Fig. 3b), descent rate is smaller near the surface than at depth. The high-frequency wind waves are most effective in driving the Wirewalker near the surface.

A temperature time series recorded from the Wirewalker is shown in Fig. 4. During this 60-h period, 218 profiles of the upper 60 m of the ocean were recorded, corresponding to an averaged cycle period of 16 min. Typically, the temperature was recorded every 20 cm. The tidal signal is very clear, as are the high-frequency internal waves. The heating of the surface layer in the afternoons of 21 and 22 September (local time 21 September 1700 corresponds to yearday 265 0000 UTC) is also evident.

4. Conclusions

The Wirewalker prototype has demonstrated that the design is functional and that high-quality data can be collected. The profiling rate increases as the seas get bigger. A second-generation instrument, able to profile to greater depths with an extended lifetime is currently being developed.

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REFERENCES

Davis, R. E., D. C. Webb, L. A. Regier, and J. Dufour, 1992: The Autonomous Lagrangian Circulation Explorer (ALACE). *J. Atmos. Oceanic Tehnol.,* **9,** 264–285.

Hamilton, J., G. Fowler, and B. Beanlands, 1999: Long-term monitoring with a moored wave-powered profiler. *Sea Technol.,* **40 (N9),** 68–69.

Isaacs, J. D., and R. J. Seymour, 1973: The ocean as a power resource. *Int. J. Environ. Stud.,* **4,** 201–205.

——, D. Castel, and G. L. Wick, 1976: Utilization of the energy in ocean waves. *Ocean Eng.,* **3,** 175–187.

Schmitt, R., 1996: ALACE, PALACE, SLOCUM: A dynasty of free floating oceanographic instruments. *Oceanus,* **39 (N2),** 6–7.