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# Ocean Wave Energy for Long Endurance, Broad Bandwidth Ocean Monitoring

By Andrew J. Lucas, Robert Pinkel, and Matthew Alford

Ocean measurement systems—whether large distributed arrays, moving platforms, or discrete sensors—share a common general limit: the information content of the observations, quantified in terms of the number of octaves of wavenumber and frequency resolved, is roughly proportional to the energy available for the measurements. For example, an octave of resolution in the frequency domain can be added either by doubling the sampling rate of a sensor to better resolve high frequencies, or doubling the sampling duration to add an octave at low frequency. Both involve a doubling of energy, assuming a fixed energy per sample. Similar considerations apply in the wavenumber domain.

Energy is a particularly vexing issue at oceanic scales smaller than the mesoscale, where key processes, such as oceanic fronts and internal waves, are broadly but intermittently distributed in space and time. The adequate sampling of such phase-coherent structures requires relatively more energy than monitoring spectrally homogeneous, uniformly distributed flows.

To address the challenge of dynamic, small-scale variability in the ocean, we developed the Wirewalker, a vertically profiling platform powered by surface waves (Rainville and Pinkel, 2001; Pinkel et al., 2011; Figure 1). The Wirewalker has a cam that rectifies the vertical heaving of a wire suspended beneath a surface buoy, propelling it downward. The cam releases the wire at the downward limit of the profile and the positively buoyant vehicle ascends decoupled from the wire, enabling the collection of data uncontaminated by surface wave motion. The Wirewalker profiles at approximately 20 m per minute, and profiling is equally effective in moored (Eulerian) and drifting (Lagrangian) modes. Although non-Lagrangian, drift bias can be diagnosed by onboard velocity measurements combined with the constant positioning afforded by surface buoy GPS. Critically, using surface-wave power allows batteries to be conserved exclusively for onboard instrumentation rather than vehicle propulsion.

Rapid profiling from wave energy enables long-term, high-resolution views of internal wave (e.g., Lucas et al., 2011; Omand et al., 2011), ocean-atmosphere (Lucas et al., 2014), coastal circulation (e.g., Feddersen et al., 2016), and submesoscale (e.g., Lucas et al., 2016) processes. The platform has also proven adept at coastal water quality assessment (e.g., Lucas et al., 2015). Real-time telemetry has now been implemented for a number of sensors, using both cellular and satellite communication (supported by the US Office of Naval Research [ONR] Defense University Research Instrumentation Program). An ongoing test of the system in La Jolla Canyon, Southern California, netted 10 months of nearly continuous profiling, with an average of 120 profiles per day to 100 m depth (Figure 2).

A host of different instruments has been fielded to date, with the bulk of a typical Wirewalker payload consisting of batteries required for sensor power. Under ONR sponsorship, we are developing a prototype wave-powered electrical generator. When mature, this technology will enable longer deployments, depth-targeted adaptive sampling, profiling in extremely calm conditions, and a significant energy quota for biofouling mitigation. We believe that using wave power aggressively can lead to an increase in observing bandwidth at all scales in future ocean measurement systems.

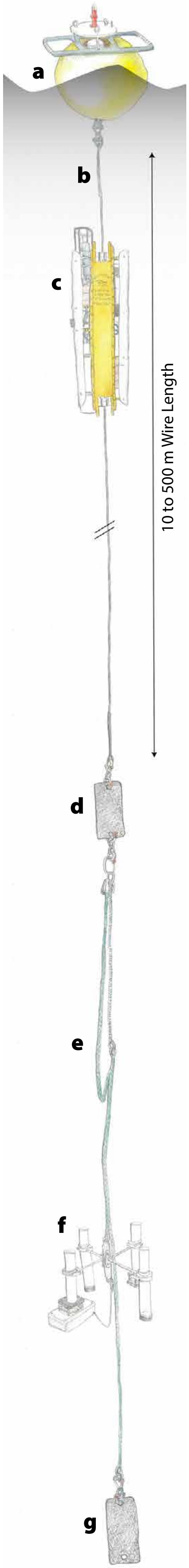


**FIGURE 1.** Components of the bio-optical Wirewalker platform. The assembly consists of (a) a GPS-tracked surface buoy, (b) the wire (of variable length from 10 m to 500 m), (c) the instrumented Wirewalker profiler, and (d) a downweight to maintain the wire in a vertical orientation. Various other instrumentation can be suspended at or below the ballast weight. For example, on a series of recent deployments, Melissa Omand and colleagues used (e, f) a suspended array of particle-intercepting sedimentation traps with a time-lapse marine snow camera and (g) a second ballast weight below. *Watercolor painting by M.M. Omand and K. Carlson; From Omand et al. (2017, in this issue)*

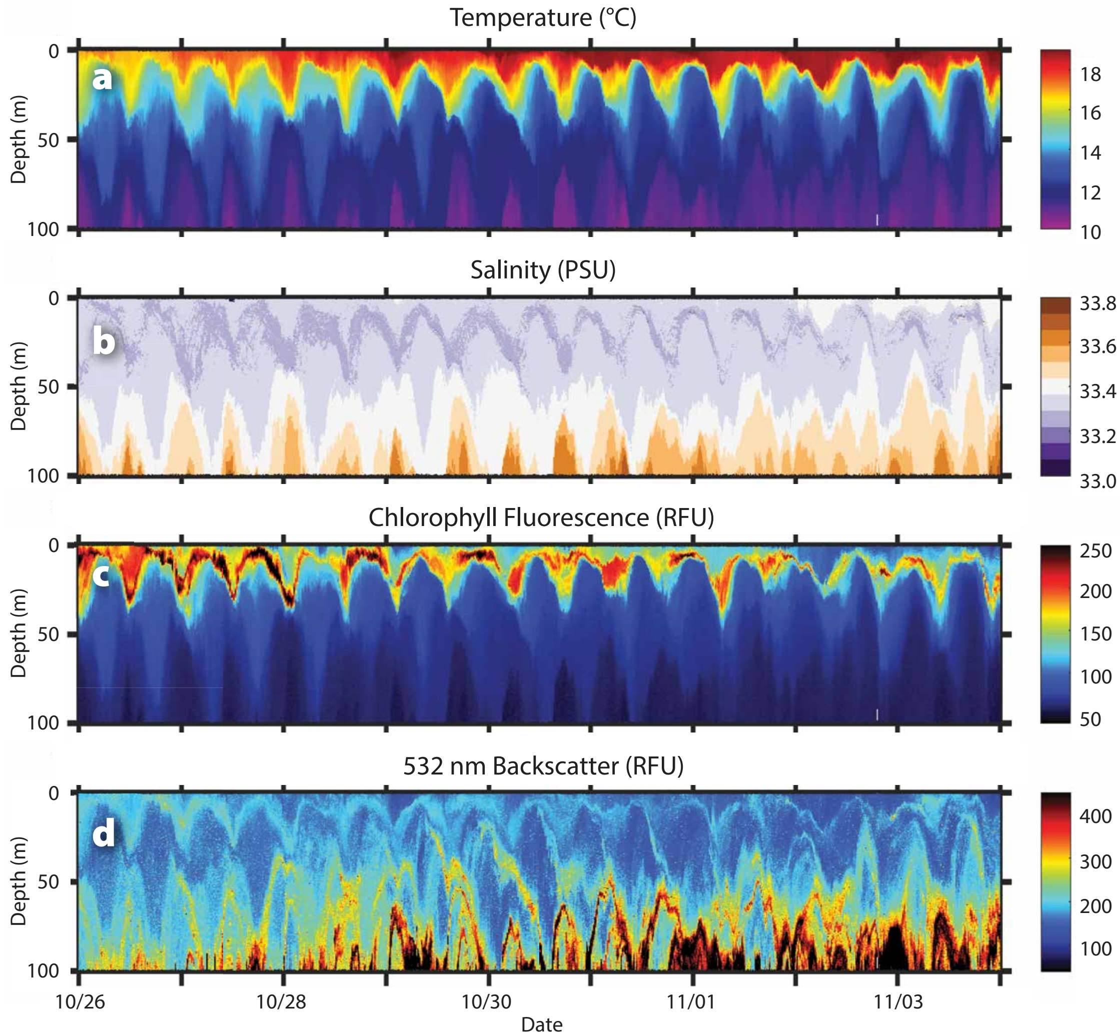


**FIGURE 2.** Monitoring water-column variability in the La Jolla Canyon off Southern California. The figure shows a nine-day segment from a 10-month and ongoing Wirewalker deployment. Profile repeat rate is ~12 minutes (~1,000 profiles are shown here). The canyon is host to an energetic, mode-2 internal tide, with large vertical oscillations of isopycnals and tidally modulated strain (panels a and b). Phytoplankton and sediment concentration (panels c and d) are vertically and temporally modulated by these strong internal tide oscillations, which significantly impact the local ecosystem and littoral sand circulation.

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