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Operationalizing Surface Piercing Profilers

Abstract: High vertical resolution profiles of multiple parameters extending to the air-sea interface are valuable for understanding coupled physical-biogeochemical ocean processes. However platforms capable of profiling to the surface have been limited by their ruggedness in rough seas, science payload, and deployment duration. Over the last three years, the Ocean Observatories Initiative has partnered with WET Labs to improve a set of WET Labs Thetis profilers so that OOI can operate six of them year-round in waters up to 100 m in depth. These profiles sample 1-16 Hz while rising at a selected rate of 25 cm/s. They include 8 instruments with more than a dozen sensors, and they have room for more. Using a smart winch on-board and a patented control algorithm, these profilers compensate for wave-driven heave, which enables them to surface and telemeter data via Iridium in up to 3 m waves, 10 m/s winds, and 40 cm/s mean water currents. Multiple firmware and electronics upgrades have further enabled these profilers to automatically recover from problems, or at least put themselves in a state that minimizes the chance of loss/damage and allows for remote query & control via acoustic modem from a neighboring surface mooring. These and other improvements enable the system to capture periods of the year, such as the beginning of the annual coastal upwelling-dominated period, without fear from damage by spring storms. This contribution will show the new features, the overall capabilities, the limitations of these profilers, and what data are available from them through OOI.

Introduction: Surface gravity waves make it hard to profile up to the air-sea interface. WET Labs, now Sea-Bird Scientific, has developed a surface piercing profiler over the last 15 years. Development was aided by an NSF OTIC grant in 2006-2010 (PI's A. Barnard, J. Barth, & M. Levine). A commercialized version of this profiler was customized for the Ocean Observatories Initiative, which a focus on improving ruggedness (2012-2014). This profiler was deployed as a long-term part of OOI starting in spring 2015.
This poster describes recent improvements that have made this profiler capable of reliable long-term deployment in rough seas.

Methods

Thetis Profiler Features

- Profiles vertically 1-30 cm/s (adjustable)
- Operates in water depths of 5-100 m
- Can profile in currents of up to 65 cm/s
- Carries up to 8 serial science instruments
- Telemeters via Iridium, Cellular, or FreeWave
- Can report engineering data and accept commands
- Can profile to the surface in up to 3 m waves
  - To surface through waves, the profiler maintains constant rope tension instead of constant velocity to prevent snap loads and winch overwrap via a patented algorithm
  - Surface control algorithm uses the winch to keep the platform vertical when at the surface to facilitate communications

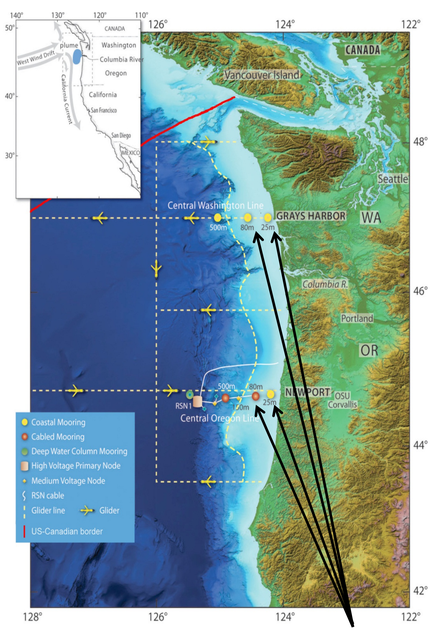
Thetis profiler telemetering while at the surface of Prince William Sound

OOI-Specific Requirements

- Operate year-round at 6 locations in water depths of 25 to 100 m
- Can profile to the surface in waves of up to 3 m height
- Can profile to the surface in currents of up to 40 cm/s
- Surface 2-4 times a day for 3 months at a time
- 25 cm or better vertical resolution for all sensors
- Serviceable at sea
- Sensor suite: SeaBird 49 CTD, Nortek Aquadopp (velocity), WET Labs ECO Triplet-w fluorometer (chlorophyll-a, backscatter, CDOM), Satlantic SUNA (nitrate), Aanderaa Optode (oxygen), WET Labs ECO PARS, WET Labs ac-s (spectral attenuation & absorption), and Satlantic OCR 507 (spectral irradiance)
- Sensor expandability. Elsewhere, Thetis profiles have incorporated plankton counters, bioluminescence sensors, transmissometers, other in-situ nutrient analyzers.

OOI Operationalizations

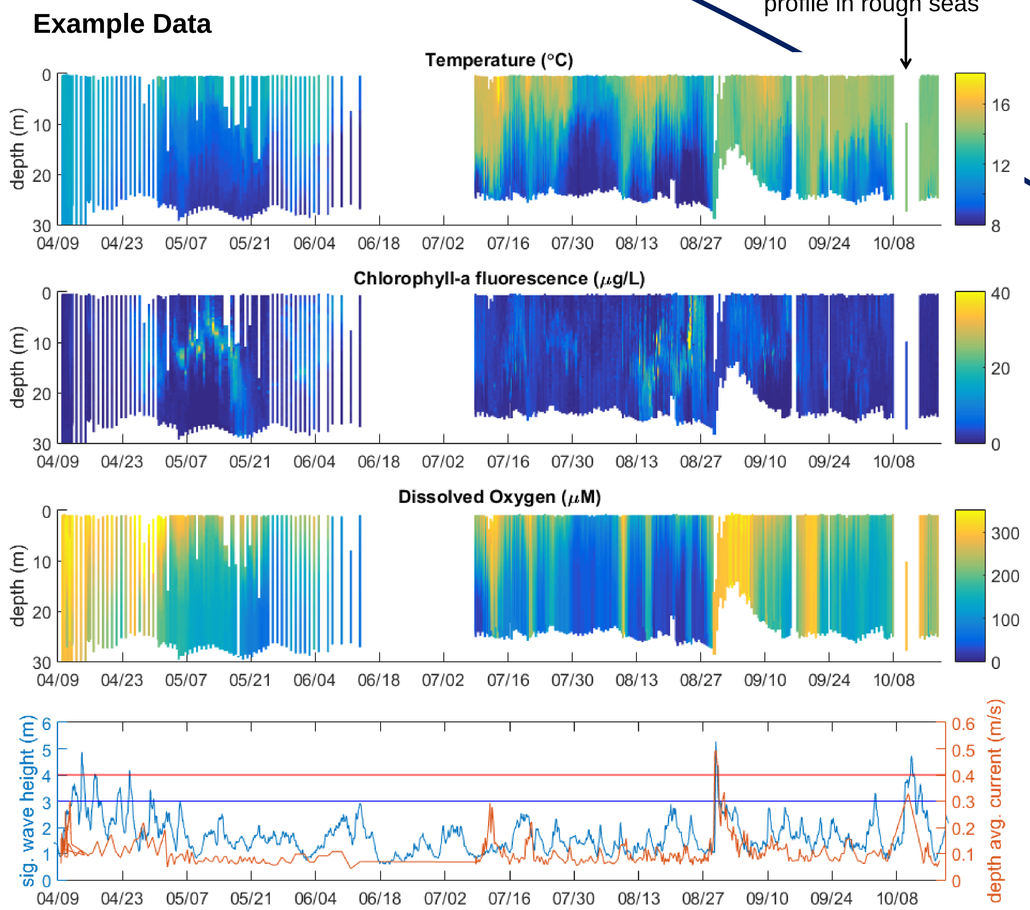
- Winch ruggedized and optimized to minimize chance of overwrap
- Acoustic modem added. Communicates with nearby surface mooring.
- Decimation of telemetered data added
- Field service demonstrated (recover, recharge batteries, replace zincs & other worn parts, download data, wipe optics, clean, recalibrate ac-s, and redeploy in one day)
- Parks at depth to hide from waves. Scooch feature added that varies parking depth to prevent rope wear
- Can now measure wave height while on seafloor, so it can autonomously choose to not surface in unsafe conditions
- New anchor design dampens wave motions with chain.
- New anchor recovery system designed to operate even when fouled by sand
- Flexible antenna lengthened to improve communications
- Addressed software and electronics issues that could stop deployments
- Added safeguards so if a profiler cannot continue normally that it stops at a safe depth, goes to a low power state, and awaits acoustic commands
- Frame ruggedized
- Foam & ballast redesigned to keep profiler vertical



OOI Endurance Array Surface Piercing Profiler locations

Results

Example Data



Time series of profiles of temperature, chlorophyll-a fluorescence, dissolved oxygen, and water velocity collected by OOI at 29 m depth off Grays Harbor, Washington. Other concurrent data streams not plotted. Wind speed and significant wave height from OOI mooring 26 km southwest of the profiler..

Overall Reliability: So far, OOI surface piercing profilers deployed by OSU have completed **81%** of their planned profiles (1200 of 1479), and they have profiled on **65%** of days (308 of 477) they were supposed to profile. Causes for all missed profiles have been addressed.

Deployment Duration Achieved: Biofouling is now a consideration because deployments are longer. This profiler lost its 25 lbs. of buoyancy in 3 months due to barnacles. In the future, more anti-fouling paint and tape will be added

Conclusions

- This surface piercing profiler is more able to operate reliably in rough seas
- See oceanobservatories.org for real-time and archived data
- See wetlabs.com/Thetis-profiler for more information about this profiler

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