



Application Note 123
Thetis Profiler Overview

Thetis Profiler for Coastal Environmental Monitoring

Sea-Bird Scientific's Thetis Profiler is a submersible vertically profiling platform for use in coastal marine and fresh water environments.

Thetis Profiler Advantage:

- Vertical profiles of physical, biological, chemical and optical properties at a fixed geographical location.
- Sub-meter scale vertical resolution from 1-2 m above the water floor to the surface in water depths up to 100 m.
- Precise control of the profiler's vertical position in the water column, especially in dynamic surface wave environments.
- Able to "hide" in heavy seas.
- Removes the need for a permanent surface buoy and mooring cable.

Thetis Profiler Features:

- Modular, self-contained, winch-driven platform.
- Integrated control, power, and telemetry systems.
- A basic set of sensors that encompass the core oceanographic measurements of physical and biogeochemical parameters.
- Expansion ports for up to a total of 8 instruments.
- Independent instrument control.
- Break-away detection.



Cost Benefits:

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Costs associated with operations, particularly unplanned outages, can quickly overwhelm research and monitoring budgets. By creating the Thetis profiler as a completely self-contained platform, deployment and recovery are greatly simplified and maintenance costs are significantly reduced. Operational efficiency and stability are the primary criteria of the Thetis Profiler, resulting in a system that can operated successfully over the long haul.

ROBUST PROFILING DURING STORM EVENTS

Mission Flexibility Avoids High Stress

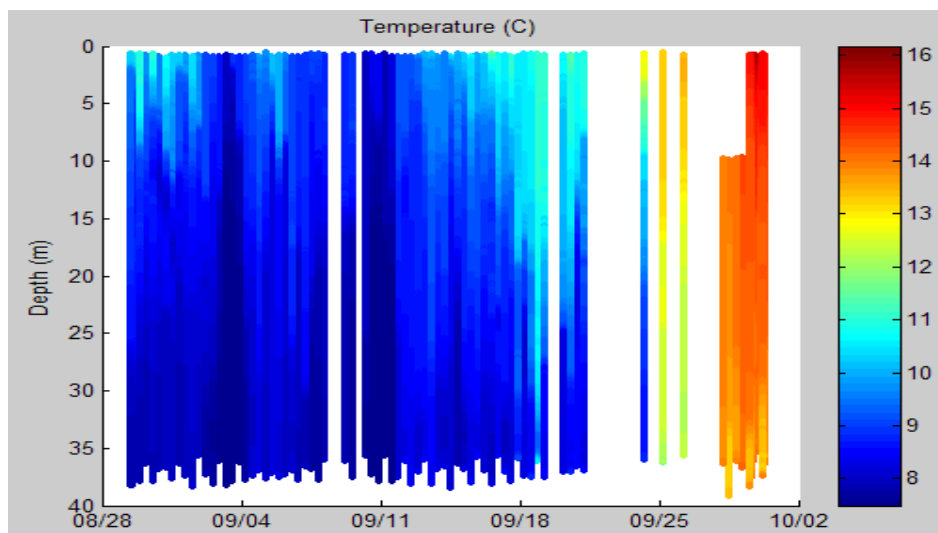
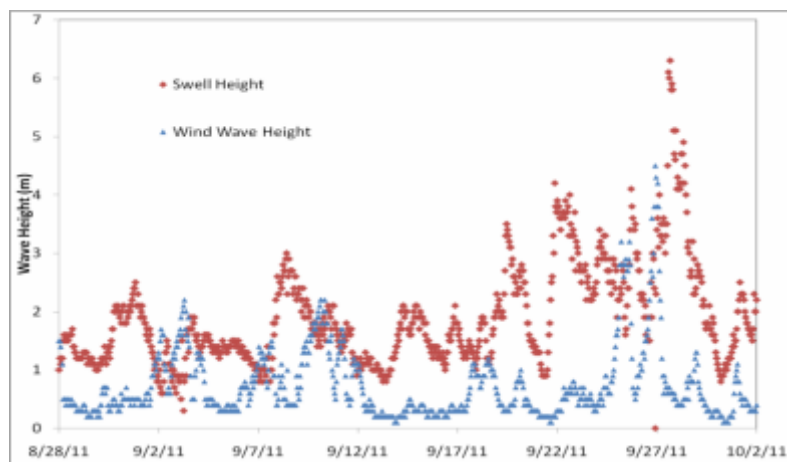


Figure 1 –Upper Panel: Wind wave and swell height at NOAA Buoy 46050 on the Oregon Shelf during a profiler deployment. Lower Panel: Color plot of vertical structure of temperature ($^{\circ}$ C) as measured from the profiler at NOAA Buoy 46050. Missing data (white) is when the profiler was parked to avoid high sea-



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states. Note that on 9/28 the profiler was configured to avoid the upper water column (top 10m) during the high sea state conditions. As the operators gained more experience with the profiler they changed the mission parameters from parking during high waves to sub-surface profiling. The surface ten meters are well mixed during high wave events so the sub surface data can reasonably be extrapolated to the surface for modeling purposes.

Basic Instrument Suite:

The basic instrumentation suite included on the Thetis Profiler is:

- **SBE-49** CTD - for salinity, temperature, pressure/depth and descent/ascent rate.
- Sea-Bird Scientific **TRIPLET-w** - for Chlorophyll, CDOM, and 700 nm backscattering (particle mass concentration).
- Sea-Bird Scientific **PARs** - for the light field in the photosynthetic available radiation band.

These instruments cover the core parameters for physical and biogeochemical research and water quality monitoring.

Additional Supported Instruments:

The Thetis Profiler has expansion ports that can support up to a total of 8 instruments expanding the range of data from the Sea-Bird Scientific instrument suite. This can include pH, absorption and attenuation, optical nitrate, additional backscattering channels and additional fluorescence parameters such as fDOM, crude oil, dyes and phycobilin algal pigments.

Optional instruments:

- Sea-Bird Scientific **FLNTUS** - for Chlorophyll, and turbidity.
- Sea-Bird Scientific **FLS** - for fDOM fluorescence detection, crude oil, dyes and phycobilin algal pigments.
- Sea-Bird Scientific **FL3w** and **BB3w** – for additional backscattering and fluorescence channels.
- Sea-Bird Scientific **C-Star** – for total attenuation.
- Sea-Bird Scientific **ACS** – for spectral absorption and attenuation.
- **SBE-43** or **63** DO - for dissolved oxygen
- Satlantic **OCR** family - for irradiance and radiance
- Satlantic **HOCR** – for hyperspectral ocean color irradiance and radiance
- Satlantic **SUNA V2** (w/ integrated wiper) – for optical nitrate.
- NortekUSA **Aquadopp** – free stream water velocity.



Standard Telemetry:

The standard telemetry system for the Thetis Profiler is:

- FreeWave - a spread spectrum RF communication.

The FreeWave is a line of site, high-band width radio with a range of about 2-3 miles. The Thetis Profiler uses a 900MHz transmitter that does not have to be licensed with the FCC.

Telemetry Options:

The Thetis Profiler has the ability to use other communication technologies. Optional telemetries available are:

- Cellular – G3 and G4 phone communication.
- Iridium – satellite communication.

Standard Power:

The standard power system for the Thetis Profiler is:

- A single Bluefin Robotics 1.5 kWh battery pack.

As examples, the battery is sufficient to acquire:

1. 8 profiles a day over 45 days in 25 m.
2. 6 profiles a day over 35 days in 40 m.

The key advantages of the Bluefin battery packs are its compact size, low weight, high energy density (1.5kWhr @ 30V nominal), built-in power management, full-ocean depth submersible, and the ability to re-charge.

Power Options:

The Thetis Profiler has a second battery platform and a connection to the control electronics allowing for a second Bluefin Robotics 1.5 kWh battery pack to be added. This will double the deployment time before recharging must take place.

Power Options:

- Second Bluefin Robotics 1.5 kWh battery
- Dual-Channel Battery Charger

An optional battery charger can be provided with the Thetis Profiler system. Recharging of the battery can be accomplished with the battery still installed on the profiler, simplifying the turn-around of the system at sea. The charger assesses conditions, and fully recharges the battery(s). Typical recharge time is less than eight hours allowing the rest of the profiler to be cleaned and prepared for redeployment.

Recommended Anchor Systems:

The typical deployment uses a primary anchor (75 – 100 kg net weight in water) at the attachment point for the Thetis Profiler’s mooring line. The primary anchor is attached by a ground line to a secondary anchor. The secondary anchor is attached to a guard buoy at the surface which acts as the retrieval line for the recovery operation. A number of primary anchors have been field tested with the Thetis Profiler system. We recommended two types, depending upon deployment conditions and data goals.

TYPE 1: Chain anchor

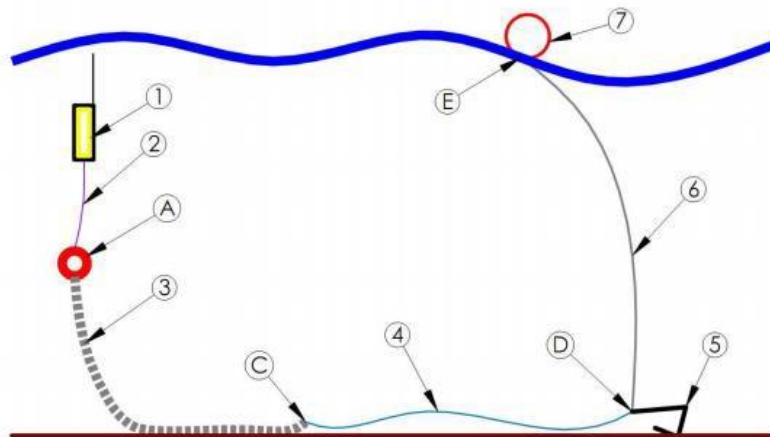
This is the preferred primary anchor for all other locations and conditions. It consists of a section of chain of weighing approximately 150 lbs. and about 40 feet in length.

TYPE 2: Deadweight, “single point” anchor.

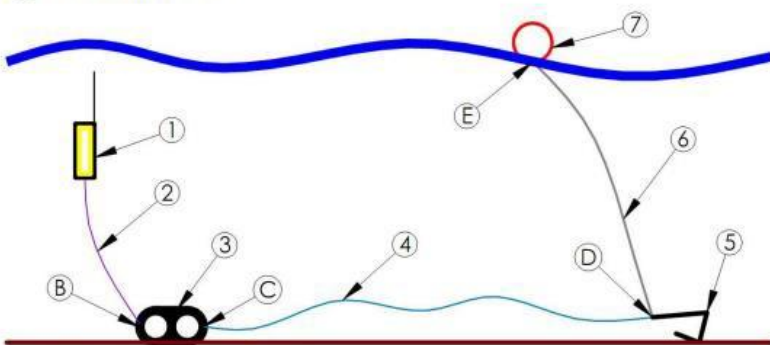
This anchor system is for surface waves <0.5 m or short deployment periods (<15 days).

- The advantage in using this type of primary anchor is that it allows the profiler to profile close to the seafloor.
- The drawback to this anchor is that the profiling line experiences increased stresses due to wave action.

Rigging for Deployment



rigged with chain anchor



rigged with deadweight anchor

Components

1. AMP
2. Winch rope
3. Primary anchor
4. Ground line
5. Secondary anchor
6. Retrieval line
7. Surface float

Rigging Connections

- A. Winch rope to chain isolator (chain anchor only)
- B. Winch rope to primary anchor (deadweight anchor only)
- C. Primary anchor to ground line
- D. Ground line to secondary anchor and retrieval line
- E. Retrieval line to surface float

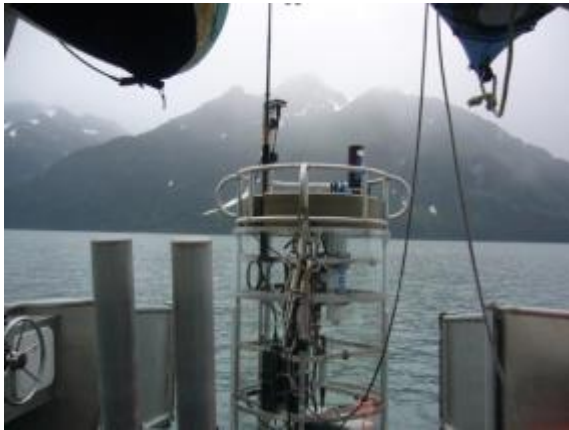
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Deployment:

The Thetis Profiler is designed to be easily deployable from a small vessel, allowing for rapid



servicing of the system.



Steps:

1. The profiler is hoisted from the deck of the ship using an overhead lifting device, usually an 'A' frame by a line with a quick release hook.
 2. At the same time, the primary anchor is gently lowered off the deck via the ground line.
 3. With the primary anchor held at or near the surface, the profiler is lowered into the water, detached from the lifting device and allowed to float free behind the boat.
 4. The primary anchor is then lowered to the bottom in a controlled descent, pulling the profiler along with it.
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5. Once the primary anchor reaches bottom, the remaining ground line, secondary anchor, retrieval line, and the surface float(s) are all deployed.

Typically, this system is deployed within 15-20 minutes.

Recovery of the system is accomplished by first recovering the surface floats, then the secondary anchor, ground line, primary anchor, and then the Thetis Profiler. Recovery time is typically 15-30 minutes.

Operation:

Once deployed, the Thetis Profiler controller operates the profiler autonomously, based on the mission parameters configured by the user and communicated wirelessly to the profiler. Depth data is provided from an integrated pressure sensor within the control electronics. The depth over which the profiler will collect science data is set using two configuration parameters:

- “Start” depth defines the deepest (bottom) depth.
- “Stop” depth defines the shallowest depth.

Two other settings are used:

- “Home” depth defines the depth at which the profiler will be located in between profiles.
- “Radio” depth is the depth near the surface at which the profiler will station to telemeter data wirelessly.

Settings may be changed during the deployment through a wireless telemetry session including profiling ascent and descent rates. Speeds ranging from 2 to 35 cm s⁻¹ are possible. Data from each profile (from the on-board instrumentation suite), as well as status information, gets stored on the controller’s flash drive. Critical engineering data is stored separately, which includes tilt, roll, pitch, motor speed, motor current, battery voltage, motor encoder position, and pressure.

Once communications through the telemetry system has been established, the host program will:

- Synchronize the profiler time and date to the host system time and date.
- Offload profiler status information.
- Offload the most recent instrument and winch files.
- “Release” the profiler to continue profiling with the current profile settings.
 - Alternately, new profile settings may be applied using the Profile tab in the host software.

By default, the profiler will only remain at the surface for 3 minutes from the time the telemetry is activated. This time may be automatically or manually overridden by the host program. Likewise, the profiler may be manually released from the surface holding state by the release button on the profile tab of the host program. Once the surface hold time has expired or the profiler has been released, it will enter the descent mode.

As it enters the descent mode, the package controller will:

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- Turn off the telemetry system.
- Turn on the winch.
- The package controller directs the winch controller to drive to the commanded “home depth” at the commanded “descent rate”.

Upon reaching the home depth, the package controller will:

- Turn off the winch controller.
- Enters a low power sleep state until the next profile start time.
 - Should the profiler not reach the home depth until after the next profile start time has passed, it will begin the new profile as soon as possible.

Thetis Profiler Frequently Asked Questions

1. What is the profiling depth range limitation, and where has the Thetis been tested?

Our current depth operating specification for the Thetis Profiler is in water columns ranging from 5 to 100m in depth. The Thetis Profiler has been most rigorously testing in 50 m offshore of Newport, OR, though other systems have been deployed in several other locations.

2. What power system is used for the Thetis?

The Thetis system uses on board batteries (BlueFin Robotics, 1.5kW) for power (as described above).

3. What is the endurance of the Thetis?

Our endurance is limited by the battery power and instrument configuration. We have demonstrated a 30 day endurance in testing offshore Newport, OR.

4. What is the profiling speed of the Thetis and is this configurable?

The Thetis profiling speeds are user configurable through the Sea-Bird Scientific Profiler Host software, and can be altered during any telemetry session during a deployment. The user can select profiling speeds ranging from 2 to 35 cm/sec.

5. What types of telemetry systems are supported for the AMP?

The most common telemetry system utilized is a FreeWave radio system. Transmission times for the science data are typically 20-30 seconds through the FreeWave modem when the receiver is within 3 km of the profiler.

Other telemetry systems include a broadband cellular and Iridium modems.

6. What location information does the Thetis provide, and are there emergency position locator features for the Thetis?

All Thetis models include an integrated GPS system. GPS acquisition times are typically less than 2 minutes. The GPS is only activated if a break-away condition has been detected.

There is an option to integrate an autonomous (self-contained and powered) Iridium beacon

with the Thetis Profiler.

7. Are all data collected by the instruments on the Thetis time stamped using a common clock source?

All data on-board the Thetis Profiler is time stamped using the on-board processor clock. This clock provides 10 ms resolution. The on-board clock is synced to the shore side host controller computer during each surface telemetry session, though the user can chose to when to update the on-board clock.

8. What is the common or base environmental sensor suite, and what options are there for other sensors?

The base sensing suite includes a FastCat CTD, a combined fluorescence and turbidity sensor, and a PAR sensor. The current supported list of instruments for Thetis include:

- CTD: SeaBird FastCat CTD (SBE49)
- Dissolved oxygen: SeaBird SBE43 or SBE63
- Chlorophyll: Sea-Bird Scientific ECO or WETStar series
- CDOM: Sea-Bird Scientific ECO or WETStar series
- Turbidity: Sea-Bird Scientific ECO series
- Optical absorption and attenuation: Sea-Bird Scientific ACS
- PAR: ECO PARS (Sea-Bird Scientific)
- Nitrate: Satlantic SUNA V2
- Irradiance and Radiance: Satlantic OCR and HO CR
- 3-axis velocity: NortekUSA Aquadopp

Additional sensors can be accommodated but may require NRE. Sensors requiring flow though (pumped) measurements can be accommodated with our system.

The mounting system used for the instruments facilitates replacing sensors by the user. Adding new instruments may require new brackets.

9. What vertical resolution in the environmental sensor data can the Thetis provide?

To first order, the vertical resolution is set by the vertical profiling speed. The profiling speed is user configurable (which can be changed during the deployment). At typical profiling speeds of 20 cm/sec, the Thetis Profiler provides the required 0.25 m vertical resolution (even with the slowest 1 Hz sensors).

10. How much on board memory does the Thetis have?

On-board memory is:

- 2 GB for the science and Thetis controller data
 - 2 GB for the winch system engineering data.
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