# Ocean Response Coastal Analysis System (ORCAS)

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## LONG-TERM GOALS

Our long-term goal is to develop instrument systems for coherent, real-time monitoring of multiple biological, physical, chemical, and optical parameters within the ocean, in 3-dimensional space and time. These systems must be readily deployable, yet provide real-time data with sufficient vertical and horizontal resolution for determination of the coastal environmental response to episodic events such as storms, nutrient inputs, hypoxia and algal blooms.

## OBJECTIVES

Our primary objective is to develop, test and demonstrate a system combining ship-deployed and autonomous bottom-up profilers, that will allow coherent, finescale profiling of multiple oceanographic parameters in 3- dimensional space and time. New sensors for inherent optical properties (IOP) and *in situ* nutrient analyzers will also be developed, tested and integrated into the new profiler packages. The system will be designed to be rapidly deployed to quantify the fine-scale biological, physical, chemical, and optical responses of coastal systems to episodic events of interest or opportunity, such as storms, harmful algal blooms, chemical spills, and the onset of hypoxia or anoxia.

## APPROACH

The profiling system will be based on a recently tested technology that used small underwater winches to deploy a CTD/optics package that profiled temperature, salinity, density, oxygen, spectral absorption and transmission at centimeter scales. The existing system is semi-autonomous and connected to shore by a cable that provides for power and data transfer. The new system will be self-contained and able to operate autonomously with real-time control and data transmission by radio telemetry. Data processing will occur on board the profilers so that the transmitted data can be made widely available without extensive post processing. Two types of underwater winch profilers are being developed. The first is a small, low cost, highly integrated profiler that can support a limited number of physical, bio-optical sensors and chemical analyzers. This ‘micro-profiler” package can be deployed singly or as an array of several profilers, to provide broader spatial coverage. This small package will involve a significant reduction in instrument weight and volume without reducing fidelity or resolution, as compared to current state-of-the-art devices. The second is a "mini-profiler" which will allow the bottom-up deployment of a more comprehensive suite of physical, optical, biological and chemical sensors and analyzers. The mini-profiler is designed with considerable flexibility in the types of sensors that can be supported. The mini-profiler can also be moored within an array of micro-profilers. After technical development and evaluation, the new optical sensors, chemical analyzers and profilers will be tested in the field, to insure reliability and utility, and to demonstrate their applicable functionality to the oceanographic community.

**WORK COMPLETED**

The URI group has made significant progress in developing a new generation of underwater winches that have the energy efficiency, reliability, and small size required by ORCAS. The heart of these winches is a compact drive unit consisting of a digitally controlled brushless DC motor, a solenoid brake, a reduction gear and a compact housing that includes bearings, shaft seals and support for the winch spool. These compact drive units have been combined with a microprocessor-based winch controller developed by WET Labs. Three of these units have been constructed and field tested.

A very low power CTD has been developed by SeaBird for the underwater winch profilers. This CTD is optimized for bottom-up profiling with the sensors, pump and electronics all contained in a single housing. This unit collects CTD data at 16 hz and provides the data in real-time to the package controller, winch controller and nutrient analyzer. This system has the same sensitivity, resolution and stability as best ship-deployed CTDs built by SeaBird. These new CTDs have been incorporated into all the underwater winch profilers.

SubChem systems and WET Labs continued to make major progress in developing the submersible, chemical analyzers needed to provide high-resolution vertical and horizontal profiles of nutrients in real-time (1 Hz) at trace level concentrations (nanomolar to micromolar). The ORCAS analyzer has the flexibility to be used for measuring a variety of nutrients and trace metals. During the past year SubChem Systems developed, fabricated and tested a prototype ORCAS nutrient analyzer. Based on the test results, two second-generation ORCAS nutrient analyzers were designed and fabricated. The ORCAS nutrient analyzers are comprised of two compact modules 1) a four channel spectrophotometric reagent delivery and optical detection module that utilizes four miniature absorption detectors made by WET Labs and 2) the reagent reservoir. Instrument control software has also been developed that allows for data acquisition and *in situ* calibration, as required for autonomous operation on the ORCAS mini-profiler. The analytical capability for nitrite, nitrate, phosphate and iron was demonstrated *in situ* during the field tests in Pensacola.

A microprocessor-based package controller has been designed, developed and successfully tested in the coastal ocean. The package controller has been developed by WET Labs in close collaboration with URI and SubChem. The package controller gathers and processes data from all the sensors and the underwater winch controller, sends instructions back to them, and controls power to all components. The package controller uses a 900 Mhz spread-spectrum radio to receive instructions from and to transmit data to ship or shore stations. The package controller has sufficient on board memory to store the data from many casts as is needed when weather or other conditions limit radio communications.

Two micro-profilers have been designed, constructed and field tested. Each of these micro-profilers is a totally self contained system consisting of an underwater winch with winch spool and cable, a package controller with embedded GPS and spread spectrum radio, a mast holding antennas for the GPS and radio link, a 48-volt alkaline battery pack, a suite of sensors (currently including a CTD, dissolved oxygen sensor, chlorophyll a fluorometer and light scattering sensor), a flow sensor, an aluminum frame to hold the components, and a molded syntactic foam shell to provides buoyancy and protection to the various components. The winch cable is attached to a lightweight mooring that consists of a bottom weight to counterbalance lift forces on the package and a small anchor to prevent lateral drift.

One mini-profiler has been designed and constructed. The mini-profiler includes a more extensive instrument suite including a CTD, a multi-angle scattering sensor, a 4-channel irradiance sensor, a light scattering sensor, a chlorophyll fluorometer, a spectral absorption and beam attenuation meter, and a multi-channel nutrient analyzer. The package is powered by a dual-pack, 48-volt, rechargeable, lithium ion battery. The winch, package controller, and radio are the same as used on the micro-profiler. An additional 4-channel, serial multiplexer augments data collection from the various instruments. Flow into the absorption and attenuation meter is measured through a single channel flow sensor. The syntactic foam cowling and frame are similar in the micro–profiler except for their larger size.

A relational database has been created that is capable of storing and retrieving the large data sets that result from ORCAS. This database is run on a portable PC using Oracle software. Data from the micro-profilers was incorporated into this database during the field test and made available to participants.

The first field test of the ORCAS profilers was conducted September 11-26, 2001 in Pensacola Bay and in open waters of the Gulf of Mexico off Pensacola, FL. This test involved close collaboration between the development groups and our NOPP partners at EPA, NRL and NAVOCEANO. The field test was conducted in 3 phases. During the first phase, we used the pier facilities at the Gulf Breeze EPA lab to deploy the underwater profilers in Pensacola Bay and compare their performance to our high resolution profiler that we normally deploy from ships. This phase was conducted in close collaboration with WET Labs engineers, Richard Greene from EPA and Alan Weidemann from NRL. Once we were convinced all components of the micro-profiler were operational, we deployed a micro-profiler from the RV Longhorn in 15 m of water in the Gulf of Mexico 2 km southeast of the mouth of Pensacola Bay. This deployment was made in close collaboration with ongoing tests of diver visibility models being conducted as part of this project by Alan Weidemann (NRL), LCDR Kimberly Lunde and a team of Navy explosive ordinance divers (see separate ORCAS report by Weidemann and Lunde). During this phase, we deployed and operated a micro-profiler just east of the visibility targets of the divers while we used the ship anchored just west of the site to collect high resolution profiles of physical, optical and oxygen structure using our standard slow descent rate profilers. The ORCAS micro-profiler autonomously collected bottom-up profiles every 15 minutes and radioed them to the ship after each profile. The EOD divers made video observations of the *in situ* hydrodynamic performance of the micro-profilers. Following completion of the diver operations, we had the micro-profiler return to the surface and easily recovered it from the RV Longhorn. During the third phase, we deployed 2 micro-profilers at the same open water site and tested their performance during low (less than 5 knot) and high (greater than 25 knot) wind conditions. As in the first deployment, we used the ship to collect high resolution profiles of physical, optical and oxygen structure using our standard slow descent rate profilers (wind conditions permitting). The ORCAS micro-profilers operated and maintained their position throughout the storm, and were recovered after the storm.

## RESULTS

We are very excited and encouraged by the results of our initial field test. These deployments have provided a rich data set to evaluate the scientific and engineering performance of the ORCAS underwater winch profilers. Most importantly, the field tests demonstrated that the core technologies (winch, controllers, CTD telemetry, and system integration) have developed to the point where we can autonomously collect high resolution profiles in the coastal ocean, and then transmit, database and visualize the resulting data in near real-time. As illustrated in Figure 1, these data can be very useful in not only in documenting the effects of storms on water column structure, but also in explaining rapid changes in optical, biological and chemical properties in time and space.

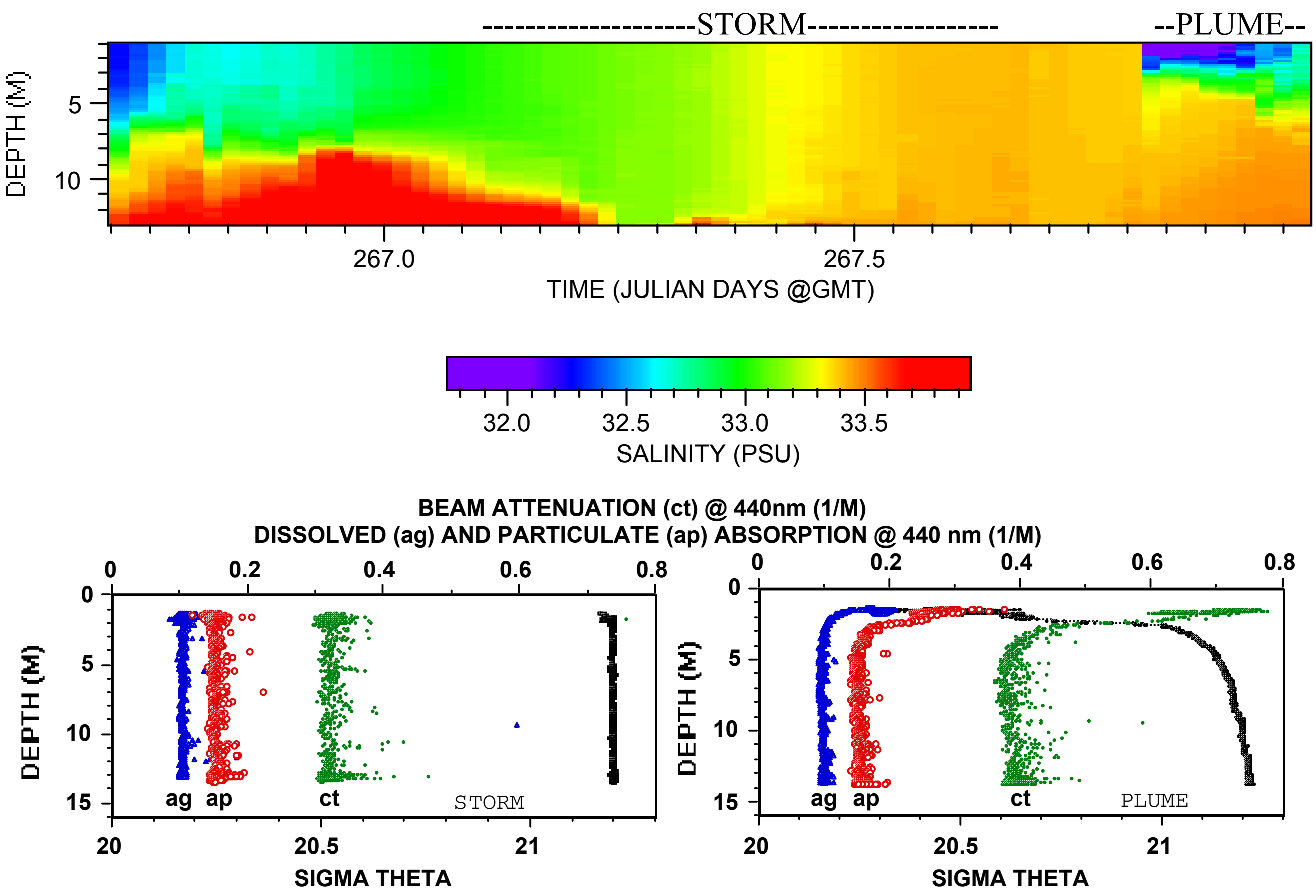


***Figure1. A 31 hour time series of fine scale salinity structure quantified by ORCAS in the Gulf of Mexico 2 km off Pensacola, Fl. During the first 6 hours winds were calm and the system had a strong halocline with at 8-12 m. As winds increased over the next 12 hours to speeds in excess of 25 knots, the halocline deepened until the entire water column was isohaline (well mixed). The water column remained isohaline until 26 hours into the record, at which point surface water salinity dropped 3 PSU re-establishing a halocline that deepened over time. This transition took less than 15 minutes as one might expect when the frontal edge of a buoyant surface plume is advected into the profiler's area. As indicated in the lower panels, optical properties (dissolved absorption, particulate absorption and beam attenuation) more than doubled inside the plume relative to the storm. Optical structure was measured by our ship-deployed high resolution profiler using the dual ac-9 technique Twardowski, et al, 1999)***

## IMPACT/APPLICATIONS

As discussed in the next section, the autonomous moored profilers and compact oceanographic sensors developed in this project have a broad range of scientific, technical, environmental, and defense related applications. Once developed, these systems should have a substantial impact on the way we observe ocean variability, and our understanding of the significant role that episodic events play in the dynamics of coastal environments. The developments this year represent a critical step forward toward our goal of developing sampling systems that could dramatically reduce the temporal-spatial confounding that is inherent in collecting data from single platforms in highly variable coastal systems. The developments this year also represent a major advance in making the data available in real-time so that it can be used to guide sampling, modeling, and making decisions in coastal waters.

## TRANSITIONS

This project has been specifically designed to rapidly transition the results of our research and technology development to users in the Navy, EPA, industry and oceanographic research communities. Our partnership with Alan Weidemann (NRL-Stennis) and LCDR Kimberly Lunde (Commander, Naval Meteorology and Oceanography Command) is specifically intended to insure rapid transition of the results to the Navy. During the field test we cross calibrated instruments, shared data, and had extensive discussions of how we could optimize the profilers to meet Navy needs. As part of this effort, we are providing them with copies of all of the physical and optical data collected by the ORCAS profilers and our ship deployed high resolution profiler. Our partnership with Richard Greene (Environmental Protection Agency Gulf Ecology Laboratory) is designed to insure transitioning to the EPA and other users in the field of environmental assessment. Our use of the Gulf Breeze EPA lab as a base for testing the profilers and nutrient analyzers provided similar opportunities for EPA scientists to become familiar with this emerging technology and discuss how it could be rapidly transition for addressing critical problems such as the hypoxia in the Gulf of Mexico. Our partnership with Casey Moore and Ron Zaneveld (WET Labs) and Alfred Hanson (SubChem Systems) is designed to insure the development of instruments that will be commercially available to other groups. Participation by WET Labs engineers in the test not only accelerated the development of ORCAS, but also gave them a much better appreciation of what was needed to transform the prototype profilers into reliable oceanographic instruments that could meet the needs of the diverse group of users.

## RELATED PROJECTS

1. Percy Donaghay (URI): ONR Biology and Chemical Oceanography Program funding for studies of the biological - biological, physical - biological and chemical - biological interactions that control the initiation, maintenance and dissipation of plankton patches.

2. Margaret Dekshenieks (UCSC), Thomas Osborn (JHU), and Percy Donaghay (URI): ONR Physical Oceanography funding examining large scale physical forcing of thin layer dynamics.

3. Alfred Hanson (SubChem & URI): Internal, state (URI-OTCE), and NOAA funding to develop and commercialize submersible chemical analyzers. Alfred Hanson and James Miller (URI) are collaborating with NUWC (Newport, RI) and WHOI on the integration and application of a chemical analyzer (SubChem Analyzer) and high-frequency forward-looking sonar systems to the REMUS AUV. The integrated multi-sensor systems (ADCP, CTD, OBS, SONAR and SUBCHEM) will be used synergistically to develop, evaluate and implement various AUV search algorithms to map and locate the source of chemical plumes in coastal waters.

4. Richard Greene (EPA-GED): Investigations of environmental factors regulating HAB growth dynamics, life cycles, and toxicity (internal EPA-GED), effects of zooplankton grazing and co-occurring bacteria on HAB dynamics (internal EPA-GED).

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**PATENTS**

None.