Bottom Stationed Ocean Profiler

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LONG-TERM GOAL

The long term project goal is development and utilization of a bottom stationed autonomous ocean profiler for enhanced physical chemical and biological measurements in the coastal ocean.. The system is designed to allow bi-directional satellite communcation, user programmability, and data storage and transmission in near real-time. It is envisioned that deployments of large numbers of BSOP systems, each equipped with a highly capable sensor suite, will provide synoptic, very low cost observations of the marine environment.

OBJECTIVES

The project's objective is to develop a Bottom Stationed Ocean Profiler (BSOP) capable of up to 100 profiles over a 3 month time period. BSOP will have a satellite link and near real-time communication capability. The initial BSOP array will consist of four modular units with variable sensor payloads and ten unitary CTD-equipped profilers. Testing of developed units will take place in local near shore waters.

APPROACH

The Bottom Stationed Ocean Profiler (BSOP) is a drifting sensor package designed for use in the littoral environment. It follows from previous drifting system developments (Davis, et al. 1992); the significant difference being an ability to hold general position by stationing on the sea floor. Two specific designs are being pursued: (a) modular design and (b) a scaled down unitary version. Both have the following components: 1) Control System; 2) Transmission System; 3) Buoyancy System; 4) Payload Sensors; 5) Power Supply; and 6) Emergency Abort and Safety Features. Outfitted with a CTD, BSOP is designed to provide relatively inexpensive, synoptically sampled, near real-time profiles for mapping large-scale material property fields and assimilation of these data into models. Other applications with advanced chemical, biological, physical, and optical sensors are in development for broad-based adaptive sampling in support of Navy defense-related and civil applications.

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The long term project goal is development and utilization of a bottom stationed autonomous ocean profiler for enhanced physical chemical and biological measurements in the coastal ocean.. The system is designed to allow bi-directional satellite communcation, user programmability, and data storage and transmission in near real-time. It is envisioned that deployments of large numbers of BSOP systems, each equipped with a highly capable sensor suite, will provide synoptic, very low cost observations of the marine environment.

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BSOP is designed to ascend at approximately 0.5 meters per second or less. CTD and payload data are acquired at 1 m intervals and stored in internal memory. Once on the surface, the unit transmits acquired data and GPS location fixes via a satellite communication link. Each transmission consists of data gathered from the previous descent-ascent cycle. Upon completion of data transmission, each unit floods its internal buoyancy canister and descends at up to 0.5 meters per second, gathering data until impact with the sea floor. The internal microprocessor then shuts down power and enters a "sleep" mode until an internal real time clock initiates wakeup and the cycle repeats.

The remote communications transceiver utilizes the ORBCOMM system. All data are stored within flash memory for retrieval upon recovery of the profiler. The transceiver also acts as a backup microcontroller capable of triggering an abort sequence for recovery of the unit.
Deployments incorporate a program with a user-defined duration up to 100 cycles. Presently work is continuing on both the original modular unit and unitary design.

WORK COMPLETED

Four modular and one unitary BSOP units are currently performing full testing missions. For a full system description please see the BSOP 2001 Progress report or visit our website http://cot.marine.usf.edu/project.asp?projID=7. The majority of the work completed this year has focused on: development of the prototype unitary BSOP; testing deployments of the modular and unitary versions; and system/mission refinement.

The first unitary unit has undergone extensive testing within Bayboro Harbor and is being prepared for its first offshore trip within the next month. Units two through ten are under construction at various stages of completion.

As of this date a total of at least 52 missions have been run using the modular and unitary BSOPs in the Gulf of Mexico, Bayboro Harbor, and at alternative field locations, not including a large number of laboratory simulations. With the information learned from these missions, the system has undergone extensive refinement. The resulting BSOP software and hardware is now ready for long-term missions on the West Florida Shelf.

Both the unitary and modular BSOP units use the same base code with slight adjustments to accommodate the lack of a drop weight module within the unitary version. This minimizes redundant code writing when making changes to the base software of the systems. This base software will be modified in new directions to accommodate creative mission plans such as variable profiling, “hot-air balloon” drifting, and alarm networks. The first of these variations will enable depth stopping and variable ascend/descent rates.

A simple and efficient variable profiling algorithm has been developed and implemented into one of the four modular units. This software modification is contained entirely within the buoyancy controller LON module. This again demonstrates the flexibility and functionality of the distributed control network by allowing the buoyancy controller to focus on achieving the desired profiling status without affecting the main micro controller’s focus on data collection. The buoyancy module monitors the CTD for the unit’s depth and vertical velocity. By comparing these two values to the desired depth and a calculated target velocity, periodic pulsing of the pump and valve to vary buoyancy allows the profiler to sensitively approach the desired depth range. The target velocity is a function of the distance from the desired depth (1):

$$V_t = (d / |d|) * V_m * (1 - C / \sqrt{|d|}) \qquad (1)$$

where V_m is the maximum desired velocity of the unit and C is the range constant. The range constant determines the stability range of the profiler. Within this range the profiler will not attempt to adjust buoyancy. Using this target velocity a throttling coefficient is created using:

$$X = (v_t - v) / |v_m| \qquad (2)$$

This throttling coefficient is then utilized to determine whether the pump or valve needs to be pulsed and what pulse strength should be applied. Using these equations the unit is capable of proportional pulsing, slowing its speed as it approaches the desired depth, based on ascent/descent velocity throttling. Initial testing of depth-stopping and controlled ascent/descent software is described in the results section.

Additional testing of variations to the communication, buoyancy, power supply, and dropweight systems are in development. Work is beginning on the incorporation of an IRIDIUM satellite system transceiver. With increased coverage due to more satellites it is expected that such a system will enable shorter surface durations and a higher transmission success rate. Incorporation of an IRIDIUM system transceiver into one of the modular units for field-testing is expected by the end of the year. An alternative pump is being tested in one of the four modular units to assess potential efficiency gains within the designed BSOP pressure range. One lithium ion battery pack is under construction and will be ready for testing within the next month. This pack will increase our total energy supply by up to 50% while reducing the battery weight by 40%. This will also reduce the flotation needed to achieve neutral buoyancy. The bottom of the drop weight module has been equipped with a spring-loaded drop weight shroud to soften impacts. This will reduce chances of damage to impact sensitive instruments or system components.

Between now and the end of the year an additional sensor will be incorporated into one of the modular units. Primary consideration will be given to the SEAS instrument (http://cot.marine.usf.edu/project.asp?projID=9).

RESULTS

The principal focus of the past year's work has been extensive experimentation, testing, and debugging of both the modular and unitary BSOP units. Significant packaging constraints, proximity effects between components, antenna matching and grounding concerns, deployment and test location issues, surface buoyancy optimization, and bottom composition characteristics have been addressed satisfactorily. As of this date a total of at least 52 missions have been run in the Gulf of Mexico, Bayboro Harbor, and at alternative field locations, not including a large number of laboratory simulations.

Offshore testing on the West Florida Shelf in depths up to 45 m has been a primary interest. Seven offshore deployment missions have been attempted with varying levels of success. Focus on the most recent of those tests provides insight into the present status of the project.

During the last WFS deployment, a modular BSOP unit was untethered and unattended for two days. The unit was deployed one kilometer northwest of the COMPS Navy 2 Buoy site, approximately 33 kilometers west of Sarasota (Figure 1). The unit aborted its mission on the second day. An email was sent to the unit instructing it to turn on the homing beacon and increase the frequency of position-fix emails. The retrieval vessel left shortly after the unit confirmed email processing and proceeded toward the last received position fix. During the two-hour transit, more fixes were received shore side and forwarded to the retrieval vessel using the Quake transmitter. The unit was sighted in calm seas at a distance of over 400 meters and was recovered intact and still functioning. In all, the unit had drifted approximately 1.7 km, consistently to the northwest.

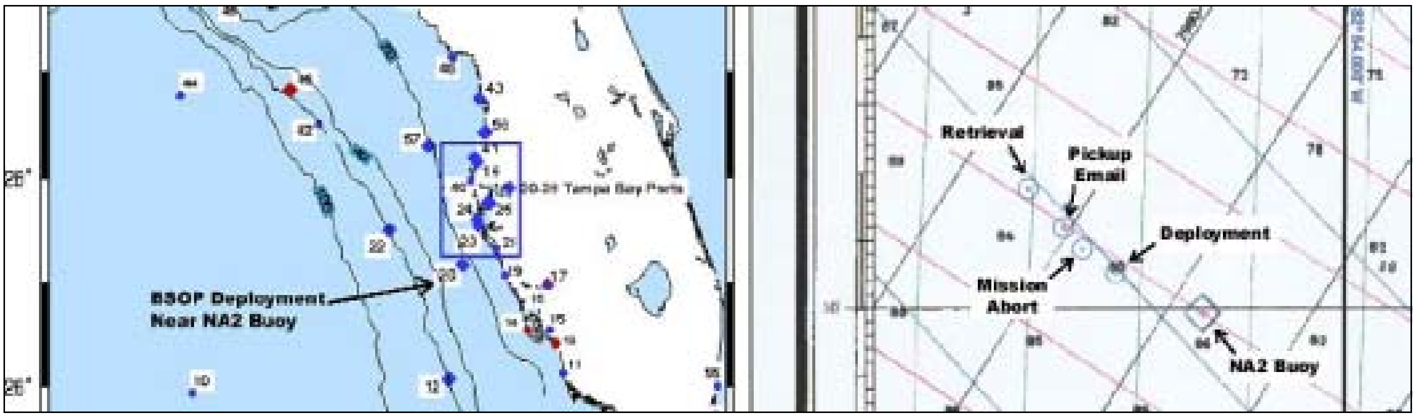

Figure 1: BSOP Deployment Location off of Florida's West Coast

During this deployment, at least one data packet was sent at each surfacing. At the time of abort the unit had sent 100% of data packets collected. Abort emails were sent on each of the 5 abort cycles performed. At the beginning of the 3rd abort cycle an email was sent to the BSOP unit and was received during that cycle, instructing the unit to alter it's transmission pattern. Figure 2 summarizes the cumulative number of emails sent during each data and abort cycle. Note the increased number of position fixes received after the processing of the pickup email reception, allowing the retrieval vessel to easily locate the unit.

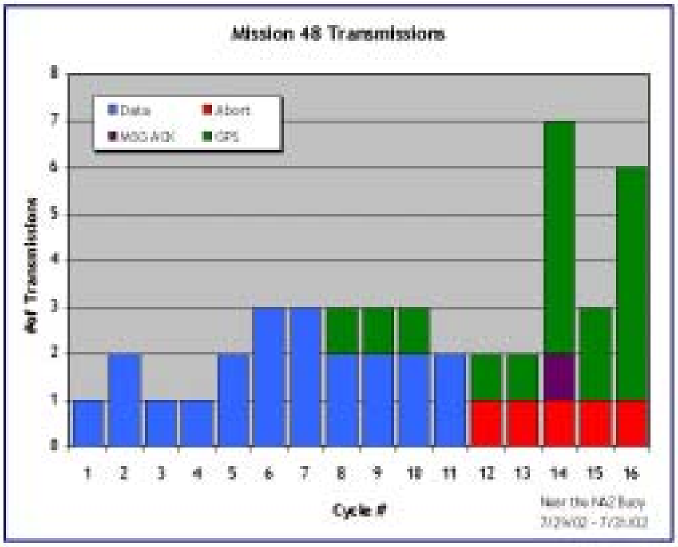

Figure 2: Graph of Transmissions sent during two-day West Florida Shelf deployment

Aborting of its mission was caused by the inadvertent release of the magnetically coupled drop weight during impact with the sea floor. This was due to profiling velocities higher than intended causing impacts stronger than designed for. Descents averaged speeds of up to 0.7 m/s. Slowing the ascent and descent speeds for the unit is easily accomplished by reducing the amount of pumping by the buoyancy module. However, to decrease the potential for damage due to repeated impacts, a compact spring loaded drop weight shroud capable of absorbing the impact energy has been constructed and tested. A sample of the data collected and transmitted during this deployment is shown in Figure 3.

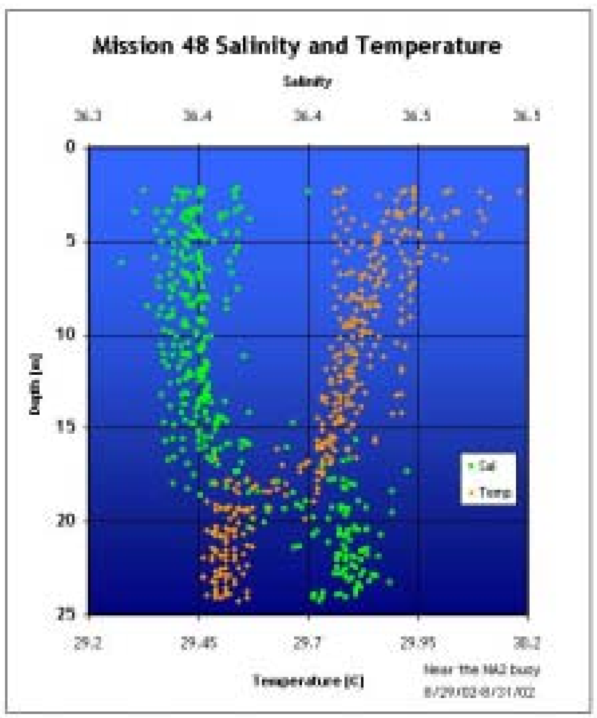

Figure 3: West Florida Shelf temperature and conductivity profiles transmitted by BSOP

Additional testing throughout the year focused on a variety of design issues, all of which have been dealt with to an acceptable level.

Transmission success rates until recently were unreliable due to severe interference between the ORBCOMM transceiver and the control circuits. A number of software and hardware changes had to be incorporated to minimize this interference and maximize data and position transmission. As described above, transmission success rates of 100% are now achievable.

Testing of a simple depth-stopping algorithm has been completed in Bayboro Harbor with encouraging results. Preliminary testing using fixed pulsing values based upon position above or below the desired depth proved unstable with the unit oscillating repeatedly. An algorithm similar to that described above (1), (2), was then developed and modified to its present state. The unit was able to move to and maintain a depth within +/- 1.0 m in less than two minutes with a minimal of oscillation. Testing of both ascent and descent stops were successful. Further testing in deeper water will be conducted in the coming months.

The new pump being tested in one of the modular units runs on 60% of the power consumed by the current pump. Peripheral investigation into alternate pump designs is being pursued.

Work through the rest of the year will include an increased focus on extended offshore deployments of the modular units, incorporation of an iridium transceiver, incorporation of additional sensors, offshore testing of the unitary BSOPs, and completion of construction of the remaining 10 unitary BSOPs.

IMPACT/APPLICATIONS

This project represents a directed effort to build and test inexpensive and efficient systems for characterization of a wide variety of marine environments. Data gathered have direct application to predictive physical, chemical and biological process models. The systems being developed and tested are targeted for deployment in open ocean environments. Experience gained in deploying and developing the BSOP units will have a significant impact on the design of appropriate tools for future automated monitoring of the ocean.

TRANSITIONS

The data output of this project will be of use in physical and chemical process modeling. Investigators involved in measurements of optical properties of seawater and biological - chemical - physical process-models will use the developed system and its stream of real-time data.

RELATED PROJECTS

1) ENHANCED IN-SITU SPECTROSCOPIC ANALYSES OF TRACE SEAWATER SOLUTES

2) CONSTRUCTION OF IN-SITU UNDERWATER MASS SPECTROMETER
(http://cot.marine.usf.edu/project.asp?projID=1&contentID=1)
(http://cot.marine.usf.edu/hems/underwater/)

3) TESTING AND REFINEMENT OF LONG PATHLENGTH LIQUID CORE WAVEGUIDE SENSORS FOR AUTONOMOUS IN-SITU ANALYSIS OF THE UPPER OCEAN (http://cot.marine.usf.edu/project.asp?projID=9)

4) SMART SENSOR PROGRESSION: APPLICATION SPECIFIC CHEMICAL INFROMATION MICROPROCESSOR (ASCI Mp)

5) OBSERVATIONS AND MODELING OF THE WEST FLORIDA CONTINENTAL SHELF CIRCULATION (http://comps.marine.usf.edu/)

PUBLICATIONS

Chad Lembke, Robert Weisberg, Robert Byrne, Larry Langebrake, Ray Carr, Andrew Farmer, Randy Russell, Graham Tilbury, "Bottom Stationed Ocean Profiler", Poster, Ocean Sciences 2002, Honolulu, HI, February 2002.

Lawrence C. Langebrake, Chad E. Lembke, D. Randy Russell, Graham Tilbury, Raymond Carr, Robert H. Byrne, Robert Weisberg, “Design and Initial Results of a Bottom Stationing Ocean Profiler”, MTS Oceans 2002, Biloxi, MS, October 2002.