A National Oceanographic Partnership Program Award

Incorporation of Sensors into Autonomous Gliders for 4-D Measurement of Bio-optical and Chemical

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Long-term goals

Our long-term goal is to develop an autonomous underwater glider that will be useful and affordable for basic oceanographic science and for applied studies, and that will be capable of providing a detailed, four-dimensional view of ocean biology, chemistry and physics for extended periods of time. This technology will ultimately enable networks of distributed observing systems, capable of sustained observations of ocean processes and phenomena, in either a station-keeping or a transect mode.

Objectives

The primary objective of the NOPP project was to expand the capabilities of Seaglider, an underwater glider that moves horizontally and vertically using buoyancy and wings, to enable measurement of dissolved oxygen, phytoplankton biomass, and suspended particle concentration. To enable missions of extended duration, the sensors were designed to be small to conserve space onboard the glider, to be hydrodynamically unobtrusive to minimize drag, and to have low power consumption. A second objective was to improve data transmission via Iridium satellite phone. A third objective of the past year was to demonstrate the capability of using multiple, optically-instrumented Seagliders in the station-keeping mode.

Approach and work plan

In addition to the PIs, the partnership included Mr. Casey Moore and Dr. Ronald Zaneveld of WET Labs, Dr. Jan Newton of Washington State Department of Ecology, and Dr. Emmanuel Boss, formerly of Oregon State University and currently at the University of Maine. Miniaturized optical sensors with low power consumption were developed to measure chlorophyll fluorescence [a proxy for phytoplankton concentration] and two wavelengths of backscattering [a proxy for particle concentration]. A Sea-Bird SBE 43 Clark oxygen sensor was incorporated into Seaglider, in addition to the previously existing CTD. A combined Iridium satellite / GPS antenna was developed to enable two-way communication with Seaglider during offshore deployments; high baud-rate communications are essential to enable transmission of complete data sets for each dive cycle as well as to enable changes in sampling protocol during the mission. Deployments in Possession Sound, Washington, were carried out last year to test new sensors, improvements to glider operations, and the Iridium communication system, as well as to demonstrate the power of a multiple-glider mission.

In the coming year we will continue to validate the optical and oxygen sensors and to test improvements in Seaglider engineering. New improvements to reduce power consumption by the optical sensors are planned. Several new optical sensors, including one that measures broad angle scatter and another that measures diffuse attenuation, will be developed. The true test of Seaglider's observational capabilities must come from science experiments, hence, a continuous series of deployments of Seaglider off the Washington coast will be carried out.

Work Completed

Glider design and operation

Seaglider capabilities and accomplishments have increased dramatically since the beginning ofour current NOPP grant three years ago. Seagliders have logged over two hundred days at sea in the last two years alone. The first glider missions in which chlorophyll fluorescence, oxygen and backscattering were simultaneously measured were executed by Seagliders. Seagliders enabled the first multi-glider missions (four to date). In July 2002, a three-glider, station-keeping mission was conducted in Possession Sound, Washington.

Sensors

The development of small, low power, and hydrodynamically unobtrusive sensors has been amajor goal of our partnership. The new, miniaturized Sea-Bird oxygen sensor was integrated into the glider, and performs well. Miniaturization of the optical sensors was more challenging. WET Labs produced a modular sensor (7.1 cm diameter and 4.6 cm high) with flush face geometry that performs two separate functions: measurement of both chlorophyll *a* fluorescence and backscattering at two wavelengths (blue and near infrared). The sensor does this with two light sources and two detectors. Supplied with external power from the glider, these packages return data to a serial port in the glider. Test tank and field validations of the sensors have been carried out.

Iridium satellite telemetry

Until 2002, Seaglider data telemetry was via cellular telephone, restricting operating areas to inland and coastal areas. Implementation of Iridium communications required development of a submersible antenna, also tuned to operate as a GPS antenna. The small, dual use (Iridium/GPS) submersible antenna we developed has decreased overall vehicle drag by over 20% compared with cellular phone and commercial GPS antennas. The lower drag and smaller size (requiring less energy to lift the antenna across the sea surface) translates to a significant improvement in mission duration.

Results

With multiple gliders deployed in station-keeping mode, we have the opportunity to resolve local changes from advective changes. By measuring physics, biology and chemistry on the same spatial and temporal scale, we have the potential to resolve the forcing functions and interactions. By making measurements below the depth that satellites can "see" we can provide the capability to extrapolate satellite data into the fourth dimension. The results of the Seaglider missions to date show the power of long-term, autonomous presence to observe the ocean. For example, during the three-glider mission in Possession Sound, Washington, in July 2002, we were able to determine along-channel budgets for heat and fresh water. Tidally-modulated mixing resulted in resuspension of bottom sediments more than 50 meters into the water column. Phytoplankton biomass increased in response to a wind reversal. In the coming year we should learn much about the biogeochemistry of waters off the Washington coast.

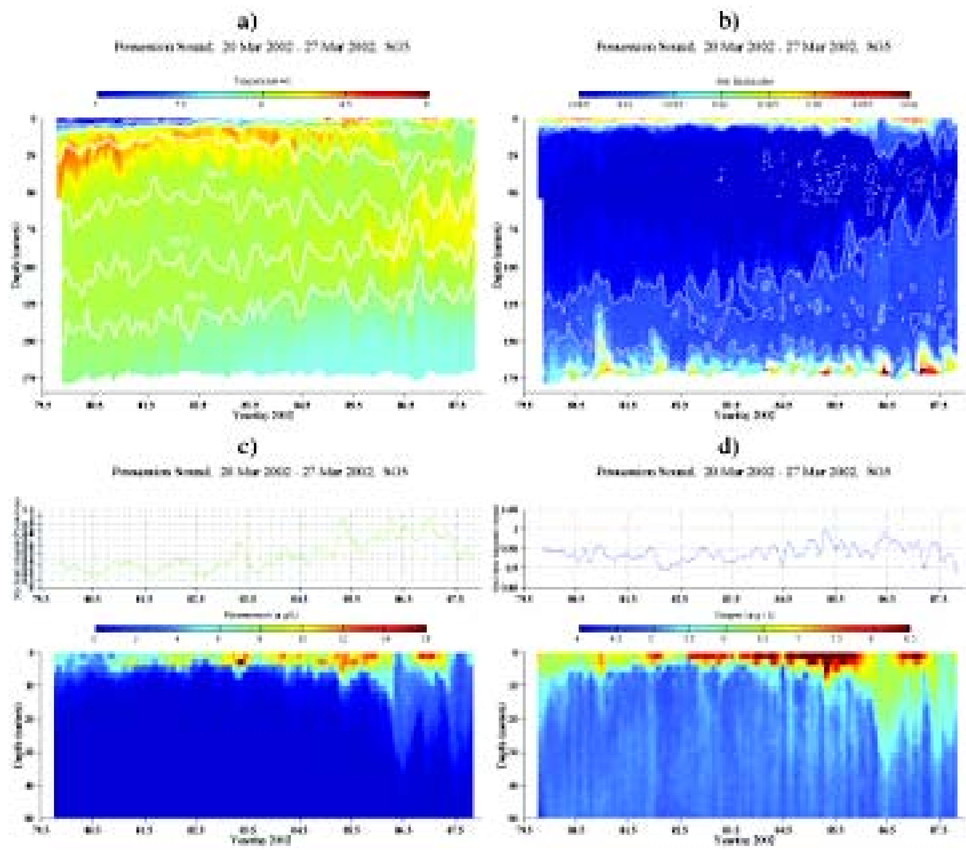

Figure 1. Seaglider data from Possession Sound, March 2002:
a) salinity contours overlain on temperature; b) red backscatter;

c) chlorophyll fluorescence; d) oxygen, uncorrected for changes in glider speed.

<u>Impact and Applications</u>

National Security

Seaglider can provide a discrete observing capability for physical, chemical, and optical properties of remote water masses.

Economic Development

The newly developed small optical sensors will have a market in a diverse array of ocean observing systems and in environmental education.

Quality of Life

Seagliders provide a new capability for monitoring water quality and for understanding the connections between ocean climate and biological response at the base of the food.

Science Education and Communication

The concept of an underwater glider, operating autonomously, captures the imagination. The glider and the data collected on glider missions will be intriguing way to engage students in ocean exploration.

Transitions

Economic Development

The optical sensors developed by WET Labs as part of this partnership will have far-reaching applications in other ocean observing systems, in water quality monitoring, and in education. The sensors are being added to their line of commercial products.

Quality of Life

The capability to observe natural phenomena and events is important to understanding fluctuations in marine resources at the base of the food web. The observing capability developed under NOPP sponsorship (Seaglider and miniaturized sensors) will become an integral part of the U.S. ocean observing capability. In the last two years Seaglider was used to observe currents, phytoplankton and suspend sediment concentrations, and their responses to wind reversals in a region of greater Puget Sound where a major sewer outfall will be placed in the next decade.

Publications

Chiodi, A.M., and C.C. Eriksen. 2002. Geostrophic fjord exchange flow observed with Seaglider autonomous vehicles. J. Phys. Oceanogr. Submitted.

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