Real-Time Observational Data Provision and Sampling Strategy Optimization for Adaptive Sampling and Prediction of the Ocean

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LONG-TERM GOALS

The long-term goals of this project are defined in its charter:
"We are designing and building an adaptive coupled observation/modeling system.

- *The system will use oceanographic models to assimilate data from a variety of platforms and sensors into synoptic views of oceanographic fields and fluxes.*
- *The system will adapt deployment of mobile assets to improve performance and optimize detection and measurement of fields and features of particular interest.*
- *The system should be sustainable in its operation, and capable of being readily relocated, in its final form.*

OBJECTIVES

The project seeks to understand and address the opportunities for large-scale ocean observing systems for ocean climate and ecosystem assessment. An extended coastal observatory is a realizable first step. Technical effort is focused on developing key components, specifically: designing tools for optimizing observation system performance, data systems, and mobile autonomous platform technology. For observation system design, we are developing methodologies for configuring and quantifying the performance of observing systems for different objectives such as field reconstruction and flux estimation. Currently we are focusing on methods of designing and evaluating AUV surveys for ocean flux estimation. Our data management objective is to enhance the data system that successfully ran for the AOSN-II and MB2006 experiments, by developing the data management components that make the data easy to find and to access across the collections simultaneously. Our development of a long range autonomous underwater vehicle (LRAUV) has passed a system-level critical design review (CDR). Mechanical, electrical, and software designs and tests are all in advanced stages. Field tests are expected in late 2008.

APPROACH

We have developed an analytical approach for designing and evaluating AUV survey strategies for ocean flux estimation from the vehicles' non-synoptic measurements. We

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14. ABSTRACT
The project seeks to understand and address the opportunities for large-scale ocean observing systems for ocean climate and ecosystem assessment. An extended coastal observatory is a realizable first step. Technical effort is focused on developing key components, specifically: designing tools for optimizing observation system performance, data systems, and mobile autonomous platform technology.

15. SUBJECT TERMS

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are applying it to heat flux estimation in Monterey Bay using ocean model data and field data from the MB2006 experiment. Flux estimation has a different objective function from that for ocean field reconstruction. Computation of flux involves integration in space which is equivalent to low-pass filtering. This implies that the flux estimation error will be lower than the field reconstruction error. New questions arise: do we reap any gain in estimation accuracy by deploying a larger number of relatively slow gliders than a smaller number of relatively fast AUVs, if their total speeds are the same? To verify our theoretical analysis, we are now running AUV simulations using ocean model data. We have also started processing AUV field data from the MB2006 experiment, with the goal of calculating heat flux across the control volume.

WORK COMPLETED

In late 2007, we completed our work on selecting ocean observing locations by supplementing the consideration of mismatch between the base data set (from which we extract the field's spatial modes) and the observations. This consideration is important because in practice, we encounter measurement noise and errors in the base data set. In April 2008, our paper "An Efficient Method of Selecting Ocean Observing Locations for Capturing the Leading Modes and Reconstructing the Full Field" was published in the *Journal of Geophysical Research (Oceans)*. We also continued development of the Metadata Oriented Query Assistant (MOQuA) data exploration tool.

In 2008, we have continued our efforts on AUV data processing and survey design for flux estimation. The science goal of the MB2006 experiment was to close the heat budget in a control volume around an upwelling center at Point Año Neuvo, as shown in Figure 1. The box is about 40 km long and 20 km wide. Two classes of AUVs were deployed to measure temperature, conductivity, and current velocity around and inside the box. Monterey Bay Aquarium Research Institute's propeller-driven Dorado AUV ran at about 1.5 m/s; Scripps Institution of Oceanography's Spray gliders and Woods Hole Oceanographic Institution's Slocum gliders ran at about 0.25 m/s. Current velocity was measured by AUV-borne acoustic Doppler current profilers (ADCPs). In initial processing of Dorado-AUV's current velocity data, we used a series of out-and-back AUV tracks as calibration tracks to make corrections to the raw ADCP data. Then we removed the vehicle's own velocity to extract the earth-referenced current velocity. We also continued to support and maintain the integrity of the MB2006 data set, providing data "snapshots" and data analysis tools to ASAP principal investigators.

RESULTS

For the MB2006 experiment, we processed the Dorado-borne ADCP data in two steps: i. Use the calibration tracks to make corrections to the raw ADCP data. ii. Remove the vehicle's own velocity to extract the earth-referenced current velocity. The result for AUV mission on Day 234 is shown in Figure 1. Current velocities measured by Dorado AUV compare well with those measured by two bottom-mounted ADCPs (installed by the Naval Postgraduate School) near the AUV path, as shown in Figure 2.

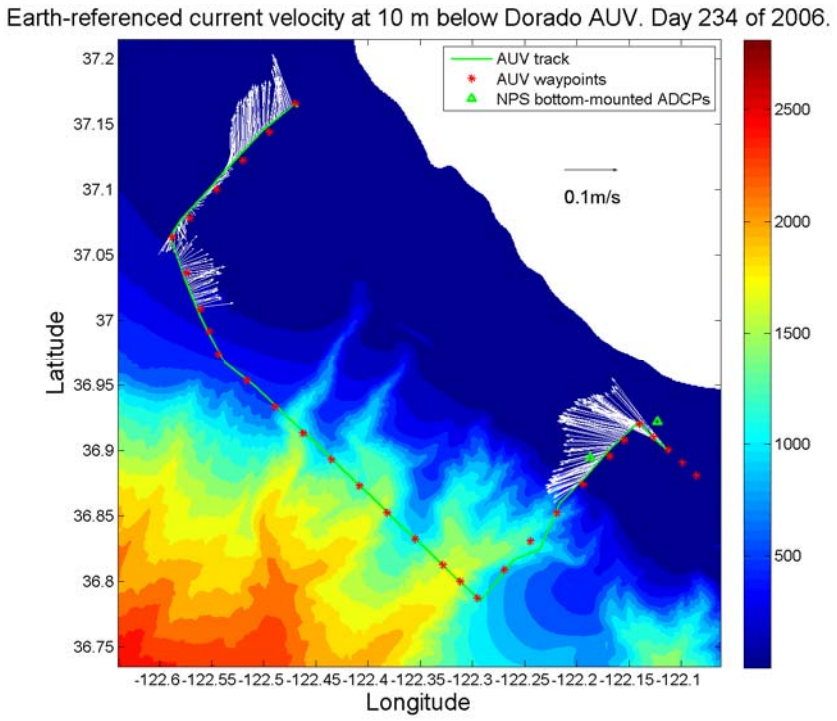

Figure 1. Earth-referenced current velocity measured by MBARI Dorado AUV.

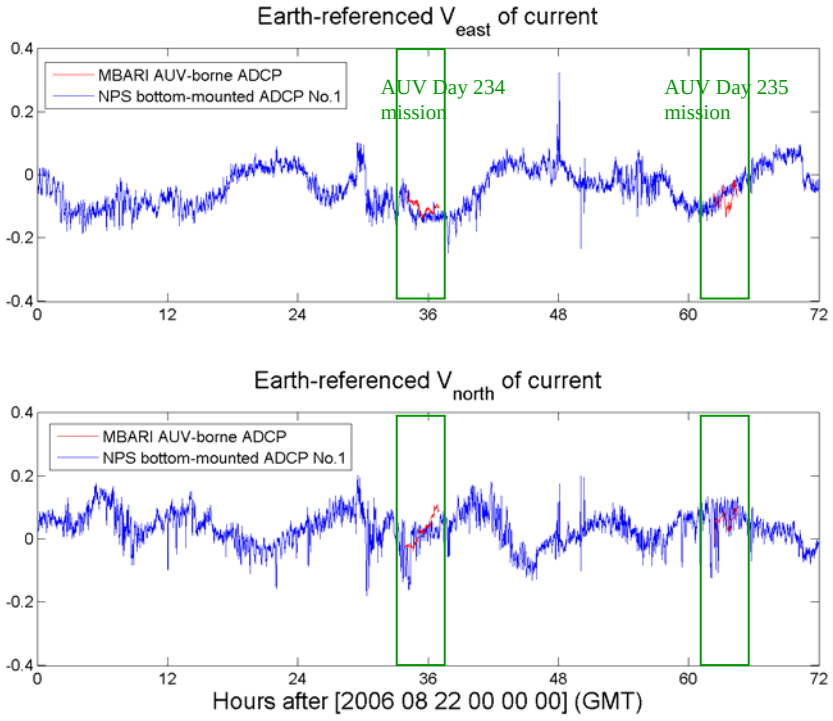

Figure 2. Comparison of Earth-referenced current velocities measured by Dorado AUV and bottom-mounted ADCPs.

In 2006, we developed theoretical error analysis for flux estimation by AUVs. In 2008, we run simulations using the Regional Ocean Modeling System (ROMS) data for Monterey Bay in August 2003. AUVs conduct yo-yo mission (from surface to 100-m depth) on two sides (the southwest and southeast sides) of the MB2006 heat flux box (length = 40 km + 20 km). In Figure 3, we compare the true heat flux with heat flux estimates by one 0.5 m/s AUV, two 0.25 m/s AUVs, and four moorings. It is seen that two 0.25 m/s AUVs provide a more accurate estimate than one 0.5 m/s AUV, while the cumulative speed (vehicle speed × number of vehicles) is the same. Figure 4 shows the relative mean-square estimation errors at different combinations of vehicle number and single-AUV speed. Two predictions by the theoretical analysis are verified: i. Under the same cumulative speed, a larger number of slower vehicles gives a more accurate estimate than a smaller number of faster vehicles. ii. The performance margin shrinks with the increase of the cumulative speed.

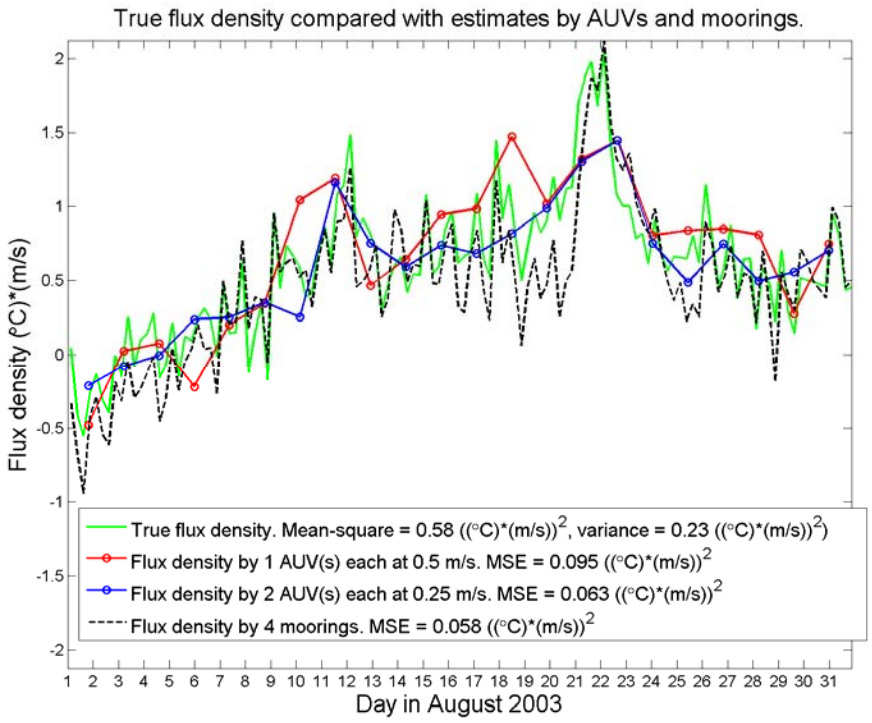

Figure 3. True heat flux density compared with estimates by AUVs and moorings, for two sides (from surface to 100-m depth) of the MB2006 heat flux control volume.

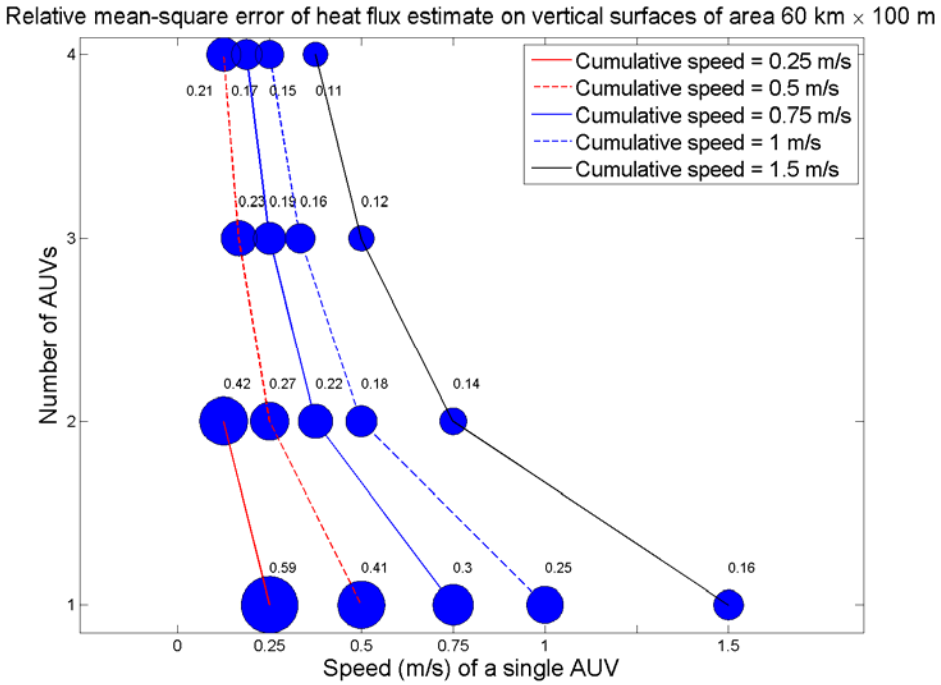

Figure 4. Relative mean-square errors of heat flux estimates by AUVs at different speeds and vehicle numbers.

IMPACT/APPLICATIONS

This project serves as a technology demonstrator to prove concepts and methods for an ocean observing systems. Several large ONR programs are building on progress achieved in the AOSN II program. The data systems and collaborative portals have had particular impact, as they offer the prospect of making long-distance collaboration much more effective. They are under evaluation for adoption by other ONR programs, for example the Impacts of Typhoons effort (ITOP).

RELATED PROJECTS

This program is tightly coupled to the Adaptive Sampling and Prediction (ASAP) program. We have also supported the following ONR programs field efforts (primarily in 2006):

1) Layered Organization of the Coastal Ocean (LOCO)
2) Assessing the Effects of Submesoscale Ocean Parameterizations (AESOP)
3) Persistent Littoral Undersea Surveillance Network (PLUSnet).

As the repository of data associated with several ONR field programs, we also support a variety of requests for data and modeling results from other ONR efforts.

PUBLICATIONS

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In addition, Bellingham is a co-author on two papers submitted to the DSR issue on AOSN II, and two AOSN manuscripts are in advanced stages of preparation.