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This program has two components. The first deals with the development of a high - endurance environmentally-powered AUV and the demonstration of moderate term (weeks t o months) operation of multi-vehicle autonomous glider networks in blue water environments. The second component results from a request by the U.S. Naval Oceanographic Office for a technology demonstration of WHOI glider fleet operations in the western tropical Pacific Ocean. The objectives of this component were to demonstrate the potential for integration of glider derived ocean measurements into NAVO operational products, forecast models, and model validation efforts

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Development of Oceanographic Sampling Networks using Autonomous Gliding Vehicles -and- Demonstration of WHOI Glider Fleet Operations in the Tropical Western Pacific for the Naval Oceanographic Office

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LONG-TERM GOALS

Our long-term goal is to develop a relocatable, sustainable, infrastructure-free ocean observing system composed of low-cost, high-endurance vehicles with near-global range and a modular sensor payload. Particular emphasis is placed on the development of adaptive sampling strategies and the automated control of large glider fleets.

OBJECTIVES

This program has two components. The first deals with the development of a high-endurance environmentally-powered AUV and the demonstration of moderate-term (weeks to months) operation of multi-vehicle autonomous glider networks in blue-water environments. The second component results from a request by the U.S. Naval Oceanographic Office for a technology demonstration of WHOI glider fleet operations in the western tropical Pacific Ocean. The objectives of this component were to demonstrate the potential for integration of glider-derived ocean measurements into NAVO operational products, forecast models, and model validation efforts

APPROACH

We collaborated on the development and field-testing of both battery- and environmentally-powered gliders constructed by Webb Research Corporation. Environmentally-powered glider development proceeds slowly as a succession of prototypes are built, tested at sea, critiqued, and improved.

At the request of NAVO, the WHOI Glider Lab performed a demonstration of the open-ocean observational capabilities of a fleet of autonomous gliders in manner consistent with requirements for routine NAVO field operations. Specifically, we demonstrated the operational and scientific utility of a fleet of gliders functioning as a synthetic moored array (SMA). This approach provides an efficient means for a single survey ship to rapidly obtain spatially distributed time-series data at low cost and with minimal need for on-site technical support. The experiment was performed in May 2004 in the western tropical Pacific in a region east of the Luzon Strait and near the subtropical front. The science focus was the observation of mesoscale variability in velocity, hydrographic structure, and sound speed over a 100 km x 100 km domain.

WORK COMPLETED

Initial sea trials of an environmentally-powered glider were be performed in the Bahamas (Tongue of the Ocean) during winter 2003. After analyzing the results of these trials a next-generation prototype has been designed and constructed. This vehicle has been tested at sea and should begin routine operations during late winter 2005. Major improvements include addition of a servo-controlled rudder for improved lateral control, reallocation of internal volume, and a new carbon-composite hull.

We have completed and thoroughly field-proven an integrated glider control and data management system. This system is now in routine use in our laboratory and has been linked with a web-based front-end for near-real-time data distribution via the internet for integration with assimilating numerical models. We have also developed a desktop-based mission simulator which allows efficient prototyping of adaptive sampling algorithms and multiple-vehicle interaction with arbitrary, realistic environmental forcing (winds, tides, currents, etc.). Iridium satellite phone is now the primary means of bidirectional vehicle-to-shore communications. The system is robust and capable of providing truly global operation of autonomous networks.

RESULTS

A synthetic moored array composed of autonomous gliders was used to characterize mid-ocean mesoscale variability in a 100 km x 100 km domain east of Luzon Strait in May 2004 (Figure 1). Each of five gliders (Figure 2) in the array maintained geographic position while profiling between the surface and 200 m. The resulting time series at each array position, including slab velocity estimates every 2 hours and 200 m high-resolution CTD/optical profiles every 40 minutes, may be interpreted in the same manner as a physically-moored chain of instruments. The typical equivalent watch circle of a glider performing a synthetic mooring mission was less than 3 km, comparable to that expected from a bottom-moored surface mooring in similar (6000 m) water depth. The study region was characterized by energetic eddies of O(100 km) horizontal scale (Figure 3). Temperature, salinity, and velocity time series exhibit strong semidiurnal and diurnal fluctuations. Similar temporal variability is also evident in a deep maximum in chlorophyll fluorescence observed near 120-130 m. (see Figure 4). These results will be presented at the Fall 2004 AGU meeting with NAVO colleagues Mike Toner and Mike Carnes.

IMPACT/APPLICATIONS

Continued development of multi-vehicle network operations will enable efficient measurement of transient ocean phenomena such as mesoscale eddies and fronts and streamline distributed environmental observations in remote or hostile locations. A network of gliding vehicles will supply, in an efficient and cost-effective manner, high-quality, near-real-time environmental information for operational ocean/atmosphere forecasting and model validation.

RELATED PROJECTS

An Autonomous Glider Network for the Monterey Bay Predictive Skill Experiment / AOSN-II (D.M. Fratantoni, N00014-02-1-0846)

Optimal Asset Distribution for Environmental Assessment and Forecasting Based on Observations, Adaptive Sampling, and Numerical Prediction (ONR MURI award to Princeton University, subcontract to D.M. Fratantoni/WHOI)

The Physical Context for Layered Organization in the Coastal Ocean (D. M. Fratantoni, N00014-04-1-0250)

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Robinson, A.R., J.G. Bellingham, J.G., Y. Chao, F. Chavez, R.E. Davis, D.M. Fratantoni, S. Haddock, N.E. Leonard, M.A. McManus, J. Paduan, S. Ramp, R. Bachmayer, P. Bhatta, P. Chandler, P. Choi, J.K. Fiorelli, P.J. Haley, P.F. Lermusiaux, W.G. Leslie, Z. Li, J.E. Marsden, 2004. AOSN in Monterey Bay: Modeling and Predicting Multiple Scales for Adaptive Sampling. Presentation at the *American Society of Limnology and Oceanography/The Oceanographic Society 2004, Ocean Research Conference, February 15-20, 2004, Honolulu, HI* (abstract).

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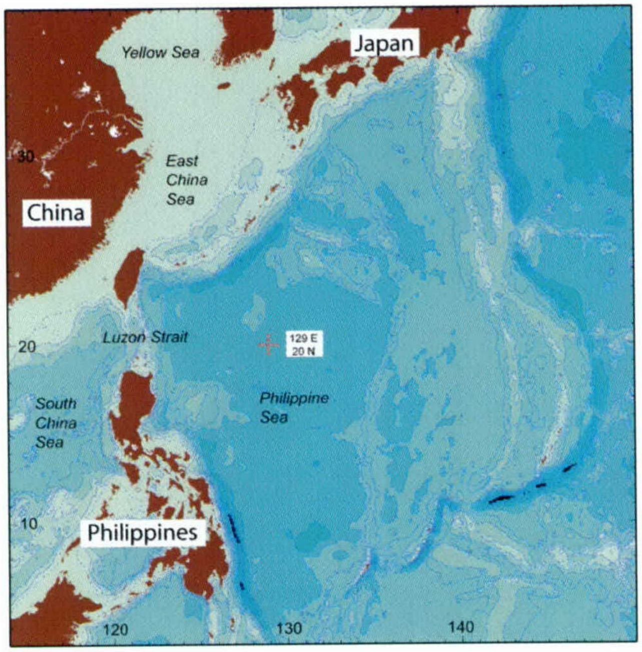

Figure 1: Location of synthetic moored array of autonomous gliders deployed in May 2005. Five gliders were deployed in a cross-shaped array approximately 600 km east of Luzon Strait.

Figure 2: Glider deployment from the stern of the USNS Bruce Heezen in the western tropical Pacific. The vehicle was lowered to the water using a winch and then set free using a quick release on the hoisting line.

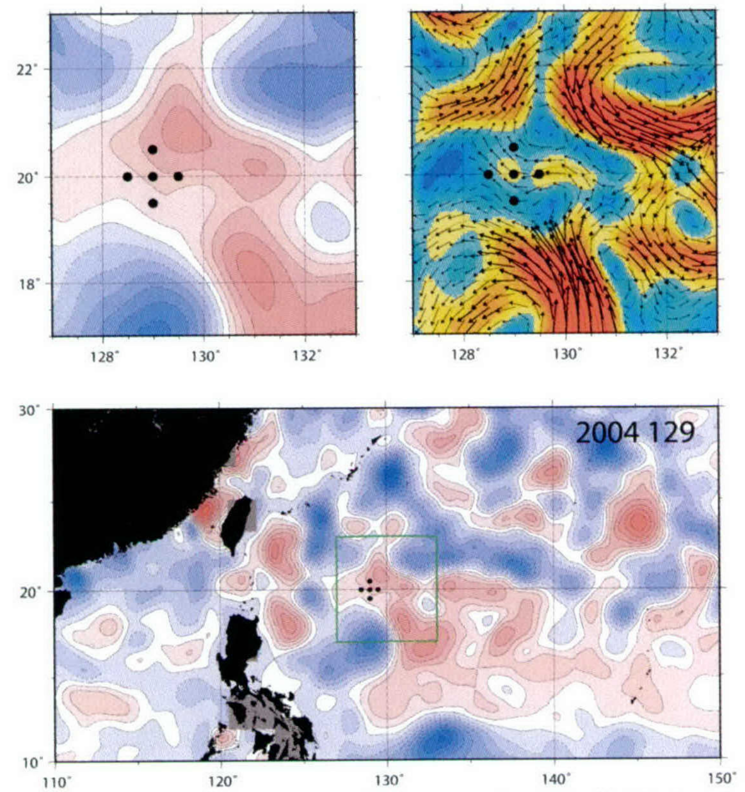

Figure 3: Array location relative to synoptic mesoscale eddy field observed with blended satellite altimetry (TOPEX, Jason, ERS). Upper panels are a zoom on the array location (indicated by green box in lower panel) showing strong eddies of O(100 km) scale. The array was able to maintain its formation even as geostrophic velocities exceeded 50 cm/s.

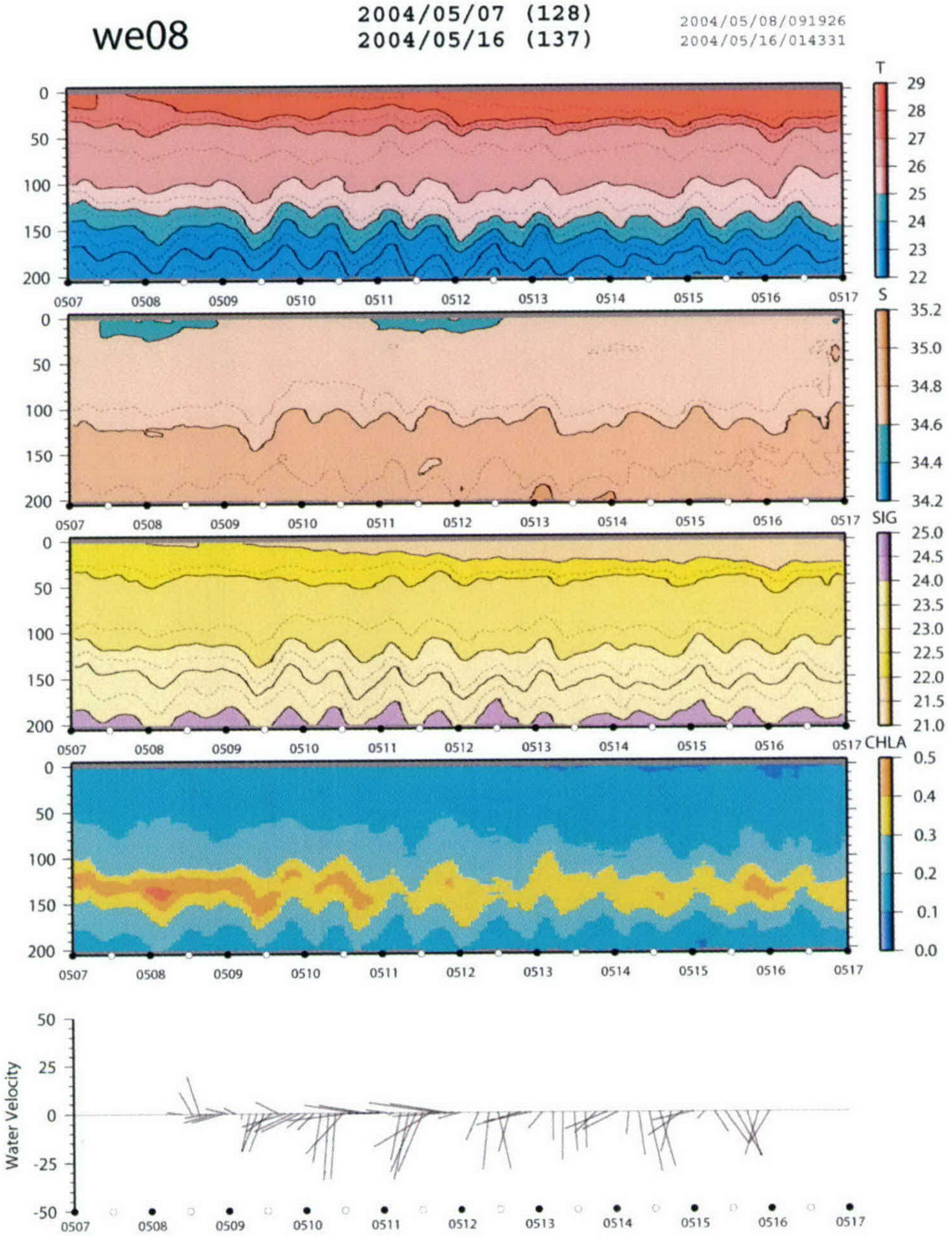

Figure 4: Time series of (top to bottom) temperature, salinity, potential density, chlorophyll fluorescence, and slab (0-200 m) velocity measured by one of the synthetically-moored gliders. Note the large-amplitude semi-diurnal internal waves at depths near 150 m. A deep chlorophyll maximum appears at a similar depth.