INNOVATIVE PLATFORMS FOR UPPER OCEAN RESEARCH

Robert A. Weller
Dept of Physical Oceanography, MS#29
Woods Hole Oceanographic Institution
Woods Hole, MA 02543-1541
Phone: 508-289-2508, FAX: 508-457-2163, Email: rweller@whoi.edu

Co-PIs: S. Anderson and R. Trask, Dept. of Physical Oceanography
Woods Hole Oceanographic Institution, Woods Hole, MA 02543
sanderson@whoi.edu, rtrask@whoi.edu
Co-PIs: W. Paul and M. Grosenbaugh, AOP&E, Woods Hole
Oceanographic Institution, Woods Hole, MA 02543
wpaul@whoi.edu, mgrosenbaugh@whoi.edu

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LONG-TERM GOALS

We seek an improved understanding of the dynamics of the upper ocean and the physical processes that determine the vertical and horizontal structure of the mixed layer.

OBJECTIVES

Our ability to fully visualize, measure, and thus understand the physical processes active in the upper ocean in three dimensions on scales from meters to one kilometer is at present very limited. The objective of this project is the development of the technology to make measurements from three-dimensional arrays within the upper ocean. The long term technological objectives for this project are to develop the engineering tools to model, design, build, deploy, and retrieve a reliable horizontal submerged array.

APPROACH

Our approach is an integrated one, combining engineering design, static and dynamic modeling and operational experience. We are designing, modeling and deploying a moored subsurface horizontal array of instruments in the surface boundary layer. This effort would lead to the design and fabrication of a pair of subsurface moorings that would be deployed in 100 meters of water with a horizontal element between the moorings spanning 80 meters and placing a horizontal array of instruments in the mixed layer at 15 to 20 meters below the surface. Two 48 inch steel spheres would be used as buoyancy elements on the subsurface mooring. Instruments, each measuring temperature, pressure, heading and tilt would be placed on the horizontal span 15m apart to monitor the mooring dynamics.

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WORK COMPLETED

In this first year, a numerical model of a subsurface horizontal mooring was developed to aid in the evaluation of horizontal mooring designs. The numerical simulation and study of the performance of the horizontal mooring was performed using a general purpose numerical code, developed at WHOI, for calculating statistics and dynamics of moored and towed oceanographic systems. The simulation is built around a mathematical model of cable dynamics that includes the effects geometric nonlinearities, material nonlinearities, material bending stiffness, and material torsion. This permits accurate three-dimensional modeling of systems in which the cable goes slack. The nonlinear, one-sided boundary condition at the seabed is modeled as an elastic foundation for systems with cable lying on the bottom. The numerical implementation includes an adaptive time stepping algorithm to speed the solution of problems with high nonlinearity.

Instrumentation was purchased for use on horizontal arrays to be designed, built and deployed during this effort, including three Falmouth Scientific Instrument (FSI) 3D acoustic current meters. These instruments were chosen because of their relatively small physical size and their capability to measure three axes of current velocity, temperature, pressure and tilt and record the data internally. Six Richard Brancker Ltd temperature and pressure recorders were also purchased to complement the measurements made by the FSI instruments. Together the velocity, temperature, pressure and tilt measurements will provide information that will be used to assess how the horizontal array performed during its initial deployment and determine the vertical stability of the system.

Several field tests were conducted in 1997. The holding capability of three types of anchors was tested. A standard cast iron cylinder was tested along with a cast iron cylinder that had been modified with steel plates to dig into the bottom as well as a third type of pyramid-shaped cast iron anchor. Three different anchor types were tow tested with the anchoring rope pulling at 45 and at 30 degrees relative to the sandy floor of Vineyard Sound. The anchors respond with a typical slip-stick response to applied anchor line tension. At the higher slip force the anchor breaks out of the sand and is being dragged towards the towing vessel, till the anchor line load is low enough that the anchor buries itself again and is holding. The vessel continues to move forward until the line load is equal to the slip tension, causing anchor breakout and a repetition of the process. The line tensions were monitored with a load cell.

On August 19, 1997, the first horizontal array was deployed off Provincetown, Massachusetts, in 100 meters of water. An instrumented horizontal element, 100 meters long, was tensioned between two sub-surface moorings at 20 meters depth. The three current meters and five temperature/pressure recorders were deployed along the horizontal element recording data every one and two minutes respectively. In addition to these instruments, a motion measuring package was deployed in one of the two sub-surface mooring spheres. Three surface buoy guard moorings were deployed around the array to protect it from any damage due to fishing activities. One of the three surface buoys was deployed with an internally recording wind speed and direction sensor to monitor the surface forcing. A significant storm passed through the area two days after deployment, testing the holding power of the anchors and the integrity of the system under rough weather conditions. The array was successfully recovered on August 27, 1997. All instrumentation deployed along the horizontal element collected data for the entire deployment.

RESULTS

The technique developed to deploy the array proved quite successful. A mooring was deployed for one week with eight instruments, each with temperature and pressure sensors, spaced approximately 10 m apart over a horizontal span of 100m. The instruments were targeted to be 20m below the surface in 100m deep water. The range of instrument vertical displacements over a tidal cycle is confused by the surface displacement of the tide itself. However, the pressure records indicate that the instruments did not deviate from there nominal position by more than 2m over a tidal cycle and daily mean depths changed by less than 0.6m over the 7 day deployment. The next phase of the project is to analyze the complete data set in order to begin to verify the model predictions and evaluate the performance of the array. Design improvements will be identified and incorporated into the next deployment which will be a two dimensional array deployed for a month.

During the design and modeling phase of the moored horizontal array it was discovered that the anchoring system required careful review due to the expected loads, the nature in which the mooring system had to be tensioned to attain the desired performance and the size of the deployment vessel and its capabilities. A comparative anchor evaluation test was therefore conducted prior to the actual system deployment.

The anchor holding power as fraction of its weight was determined for the maximum holding force (= slip force) and the minimum anchor arresting force (stick force), measured in the anchor line. A new anchor type, a pyramid shaped cast-iron Dormoor, showed consistently a stick force of about the submerged anchor weight, and a slip force between 1.58 and 2.2 times its weight. Mace anchors [deadweight steel with bottom skiffs] had a stick force of 66 to 79 percent of its submerged weight, and a slip force of about the anchor weight. A Dome anchor had a stick load of 59 percent and a slip load of 80 percent of its submerged weight. The Dome and Mace anchors would require significantly heavier units to result in the same net holding power as the Dormoor anchors. The holding tensions did not change when the angle between anchor line and sea floor was decreased from 45 to 20 degrees. The proper sizing of anchors is most important in order to not lose the horizontal arrays in severe sea states with strong wave generated oscillating water motion near the sea floor. The local sea floor firmness needs to be tested under the effects of large surface waves although this effect should be somwhat limited at 100 m water depths (Traykovski et al 1997). A literature search has so far not produced reliable methods for the anchor selection.

IMPACT/APPLICATIONS

The successful field deployment and recovery of an instrumented submerged horizontal mooring demonstrated the feasibility of using such moorings for scientific observations. In particular, it will be possible to investigate horizontal variability in the upper ocean on scales of meters to 100s of meters with high temporal resolution. Unlike towed thermistor chains, this new technology will allow for the complete measurement and resolution of the temporal and horizontal variability in the upper ocean.

TRANSITIONS

John Bonardelli, consulting for the project, is reporting on the recent deployment of similar submerged longline moorings for aquaculture in waters off Canada's Quebec province. Sixty-three concrete anchor blocks were deployed in protected waters, 88 in an exposed site, weighing up to 6,000 lbs each. The entire operation took only 2.5 days, utilizing a Canadian Coast Guard buoy tender.

RELATED PROJECTS

Development of nylon rope with compatible electrical core and terminations is performed to add to the available mooring elements. Fatigue testing and sea testing is planned for the Winter 1997/8 The introduction of two-way telemetry with LEO satellites is in progress, with the first at sea demonstration planned for 1998. A mooring for offshore aquaculture is being studied in a WHOI contract with Waldemar Nelson International of New Orleans and in several proposals to demonstrate a mussel growout .

1.) Dan Frye and Walter Paul: "Moored Array Technology", ONR Grant (N00014-94-1-0346) [Tom Swean], 1-94 through 12-97

2.) Walter Paul, Jim Irish, Sean Kery: "Modular Offshore Data Acquisition System"; Subcontract to a NASA Phase II STTR contract awarded to Jackson & Tull, Chartered Engineers, Washington DC, Feb. 1997 to Sept. 98.

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Traykovski, P., J.D. Irish, J.F. Lynch, 1997: "Geometry, Migration, and Evolution of Wave Orbital Ripples at LEO-15." Journal of Geophysical Research, submitted.