Optics, Acoustics, and Stress in a Nearshore Bottom Nepheloid Layer

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http://www.whoi.edu/mvco/projects/projects.html
Award number: N000140410449, N000140410221

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LONG-TERM GOALS

- Quantify and understand the effects of aggregation dynamics on the distribution of particles in the bottom boundary layer;
- Understand how the properties of particles (composition, shape, and internal structure) affect their optical and acoustical properties.

SCIENTIFIC OBJECTIVES

We propose an observational study designed to provide a critical evaluation of existing conceptions of the dynamics of suspended particles and their effects on the optical and acoustical characteristics of the water column. The proposed observations will be carried out at the Martha's Vineyard Coastal Observatory, and they will capitalize on routinely gathered fluid dynamical measurements at that site. The routine measurements will be complemented by an array of bottom-mounted and profiling acoustical and optical instrumentation designed to determine the particle concentration and size

distribution and the effect of particles on optics and acoustics. The measurements will be used to evaluate a state-of-the-art model of particle dynamics, and will lead ultimately to model improvements and enhanced capabilities for predictions and interpretations of suspended sediments and the associated acoustical and optical fields.

APPROACH

Site Description:
We propose to make measurements at the Martha's Vineyard Coastal Observatory (MVCO), maintained by the Woods Hole Oceanographic Institution (WHOI). The MVCO, off the southern coast of Martha's Vineyard, Massachusetts, is a cabled observatory consisting of a shore station and a seafloor node at a water depth of 12 m. An air-sea interaction tower (ASIT) has been constructed at a water depth of 15 m as part of the Coupled Boundary Layers and Air-Sea Transfer (CBLAST) program, sponsored by the Office of Naval Research. Atmospheric measurements are obtained routinely at the shore station and, more recently, at the ASIT. At the 12-m node, routine measurements of temperature and salinity are obtained near the surface and bottom, and measurements of fluid velocity throughout the water column are obtained routinely by an acoustic Doppler current profiler (ADCP). With the implementation of the low-wind component of the CBLAST observational program during the summer of 2003, measurements of currents, stratification, and near-bottom turbulent Reynolds stress and dissipation rate will be obtained routinely at the ASIT.

An important recent development at the MVCO that is relevant to the proposed research is the deployment of the Autonomous Vertically Profiling Plankton Observatory (AVPPO) by Scott Gallager (WHOI). The AVPPO occupies a site just offshore of the ASIT at a water depth of 15 m. It obtains power and transmits data in near real-time by means of links to shore. The AVPPO is instrumented with a conductivity-temperature-depth (CTD) sensor, a 9-wavelength optical absorption and attenuation meter (WetLabs ac-9) with separate capabilities for dissolved and particulate measurements, and a video plankton recorder (VPR; Davis et al., 1996), which obtains images of plankton and suspended particles with a resolution of approximately 10 micrometers in a 2 x 2 x 2 cm field of view. The AVPPO obtains a profile from 2.5 meters above the seabed to the sea surface every hour. Scott Gallager has maintained the AVPPO at the MVCO for a period of months, and he currently is seeking funding from ONR and elsewhere to maintain the AVPPO at the MVCO for another two years. The data generated by the AVPPO sensors are very useful to our goal of linking stress, optics, and particle size, and Scott has agreed to make them available to us if his funding proposals are successful. The AVPPO, however, does not measure the particle size distribution and optical and acoustical properties near the seabed, which is the primary source for suspended particles to the water column at the MVCO and elsewhere. Therefore, we propose to complement the data gathered by the AVPPO by collecting nearbed observations, which will be made freely available to the AVPPO group.

Proposed Measurements:
During calendar year 2004, we propose to deploy, near the 15-m ASIT site at the MVCO, a bottom tripod instrumented with a 9-wavelength optical attenuation and absorption meter (WetLabs ac-9, with automated regular dissolved measurement for calibration independent particulate measurements), a LISST-100 laser diffraction particle sizer (Agrawal and Pottsmith, 2000), a digital floc camera (DFC) (Curran et al., 2002b), a Tracor Acoustic Profiling System (TAPS, Holliday, 1987), and an array of three SonTek/YSI acoustic Doppler velocimeters (ADVs) that operate at 5, 10, and 16 MHz

respectively. Near-simultaneous measurements with and without a filter will assure high-quality particulate spectral absorption and attenuation measurements with the ac-9. The LISST-100 and floc camera together will provide particulate size distributions from 2.5 micrometers to 1 centimeter. The TAPS obtains range-gated, vertical profiles of acoustical backscatter intensity at a range of frequencies between 0.3 and 3.0 MHz. The TAPS and ADVs will produce acoustical measurements over a wide range of frequencies that can be used to generate particle size distributions (Holliday, 1987; Hay and Sheng, 1992). The combined optical and acoustical measurements will provide a comprehensive description of the suspended particles near the seabed.

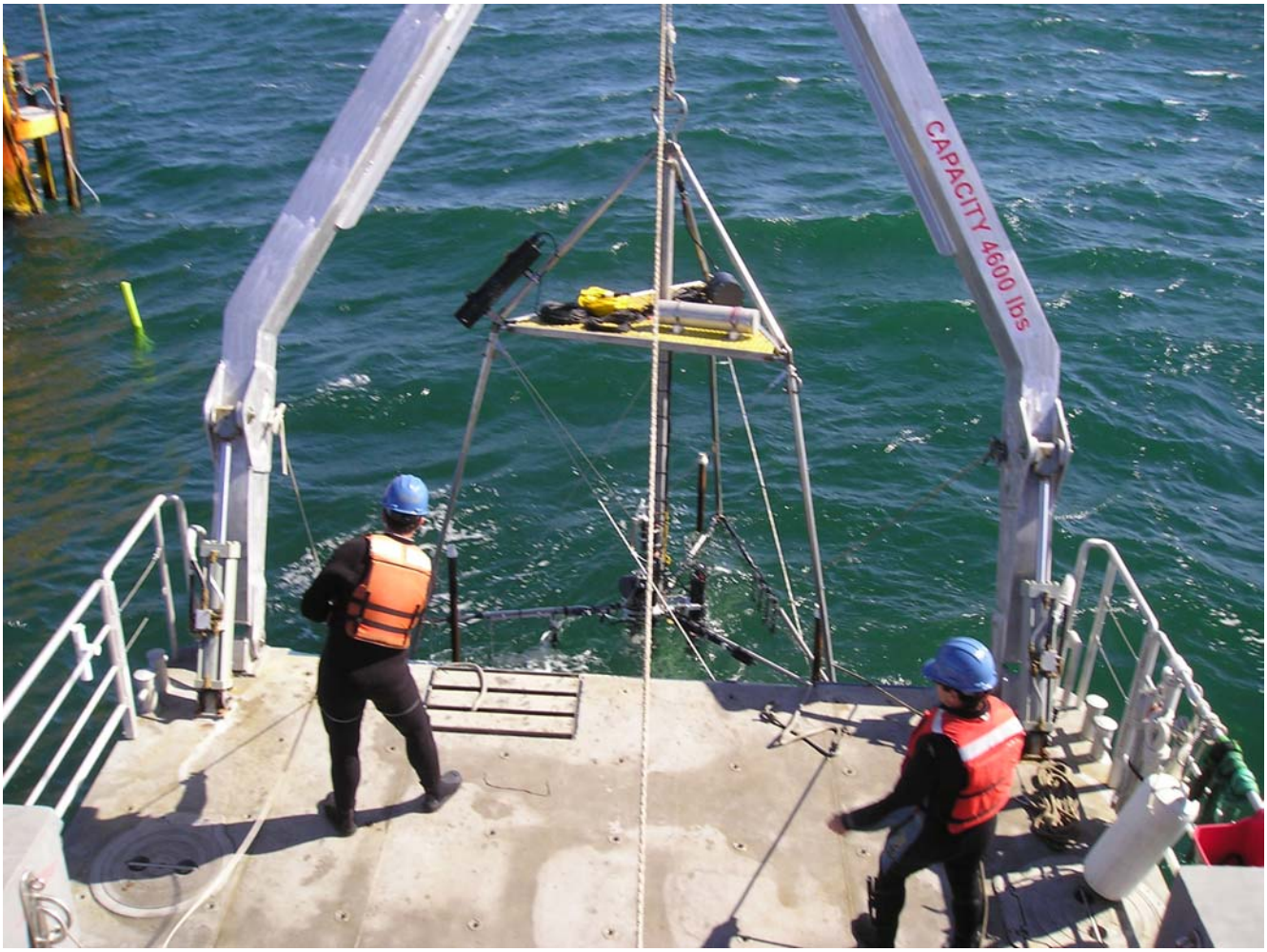
During calendar year 2005, we will either deploy the sensors as in 2004 on the bottom tripod, or we will deploy the ac-9, LISST-100, DFC, and TAPS on the AVPPO. The choice of deployment plan will be based on preliminary analysis of the 2004 data.

During both the 2004 and 2005 measurement periods, deployment and recovery will occur on approximately 1 September 2004 and 1 November 2004, respectively. The optical sensors will be serviced in situ by scuba divers. This schedule will produce observations that span the transition from stably stratified, relatively quiescent conditions, typical of summer, to variably stratified conditions with strong, intermittent wind forcing, typical of fall. This range of forcing conditions will produce a wide range of particle concentrations and sizes, with corresponding variability of acoustical and optical properties of the water column.

Proposed Analysis:
The analysis will capitalize on ongoing oceanic and atmospheric measurements of temperature, density, and velocity at the MVCO, which will determine the wind stress and bottom stress (Trowbridge, 1998; Shaw and Trowbridge, 2001) and the shear and stratification throughout the water column. These measurements will characterize the fluid throughout the water column, which in turn will permit evaluation and improvement of models of coupled particle and fluid dynamics.
The analysis will focus on estimating Reynolds stresses, dissipation rates, and effective vertical diffusivities for mass, heat, and momentum from the fluid mechanical measurements; estimating particle size distribution and concentration from the DFC and LISST-100; and estimating the optical and acoustical properties of the water column from analysis of the ac-9, TAPS, and ADV data. The analysis will evaluate and improve a one-dimensional (vertical), time-dependent model of the particle size and concentration fields and the accompanying optical and acoustical properties. The model will include the effects of sediment resuspension by bottom shear stresses produced by waves and currents, vertical transport of suspended particles by turbulence, gravitational settling of particles, and particle aggregation and disaggregation. Model evaluation and calibration will integrate data both from the bottom tripod and from the AVPPO.

WORK COMPLETED

The project has started in January of 2004.
We designed the tripod and built the tripod for deployment and design and built the floc camera. We ordered received a tested the LISST-Floc and the AQUA-scat purchased with a DURIP proposal to E. Boss. These instruments and others were readied for deployment and deployed on a tripod off the MVCO (see figure). We currently obtain real-time data from most of them which allows us to debug and fine-tune them.



Deoployment at the Optics, Acoustic and Stress in Situ (OASIS) tripod at the Martha's Vinyard Coastal Observatory on September 13, 2004. The TAPS (downward looking black cylindera) and data logger/manager are on the top of the tripod while most other instruments are 1mab.

IMPACT/APPLICATIONS

Optical and acoustical navy system depends on optical and acoustical properties in the water. Understanding the processes that regulate the latter is key to predict the performance of navy systems.

TRANSITIONS

None

RELATED PROJECTS

Acoustical and Optical System for Characterization of particles in the coastal ocean- a Durip grant to E. Boss (N000140410235). Equipment from this grant is providing instrumentation used in the current proposal.

REFERENCES

None

PATENTS

None