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Personal Author
and
Department

Dr. Yogesh C Agrawal
Sequoia Scientific, Inc.
9725 SE 36th St.
Mercer Is., WA 98040

Grantee's Name
and
Address

NorthWest Research Assoc.

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Development, Field Testing of a Laser Instrument for the Measurement of Sediment Reference Concentration in the MARGINS Program

Executive Summary

A small Grant was added to an ongoing Navy program to extend the scope of ongoing work by development of a new laser instrument. The instrument, MSCAT (Miniature Scattering and Transmissometry) uses small angle scattering to obtain the needed multi-parameter information for measurement of particle size distribution and number density. During the short course of the grant, the instrument was built and tested in a field experiment off the coast of North Carolina. Useful data were obtained, and these have been presented at the Fall Meeting of the American Geophysical Union in 1994.

Background

This project was an add-on to the main MARGINS program. The purpose of the program was to estimate the mechanisms and rates of transport of organic carbon on the continental margins of the coastal seas. The experiment was ongoing at a site in the NY Bight off the North Carolina coast.

It is postulated that a significant part of the carbon transport occurs through the net effect of deposition and erosion of seabed material in the bottom boundary layer. For this purpose, a bottom boundary layer (BBL) program was embedded in the larger scientific effort. Measurements of bottom stresses and sediment response to these stresses would be the focus of this effort. At this time, the present investigator proposed the use of more advanced instrumentation to advance the state of the knowledge of BBL dynamics. Specifically, prior measurements in BBL had been carried out with sensors that could not obtain information on particle sizes. It is widely believed that particle size and their settling velocity are key to the quantification of transport rates in the BBL. This was precisely the focus of our work. Furthermore, one of the most intractable problems in sediment transport studies in the BBL is the quantification of the 'reference concentration', i.e. the concentration of sediments, classified into distinct size classes, that results from the action of turbulent erosion and gravitational settling. Not only is this a fundamentally difficult physics problem, the myriad of factors which are believed likely to influence the reference concentration make it impractical to model this quantity. For this reason, a measurement program offered an empirical approach.

The proposed solution was to develop a miniature version of the small-angle scattering instrument LISST-100, developed by us, such that a miniature sensing head would be available to place near the seabed. Such an instrument would then obtain the size-resolved concentration of sediments near the seabed. The instrument would be named

MSCAT. It would have a 'remote sensing head' no larger than about 3 cm dia. x 18 cm long. A fiber-optic cable would connect this head to the electronics and battery housing that would be placed at a meter or so away. The instrument would be internally recording. It would be deployed, mounted on a bottom tripod, from a research vessel.

Accomplishments

In figure 1 we display the MSCAT instrument on an optics bench in the laboratory.

Figure 1: (Right) The sensing head optics display a laser beam collimated by a lens, illuminating particles in water. Scattered light is sensed by a large lens inside the housing. Two prisms fold the laser optical path. A specially constructed ring-detector is employed to make the multi-angle measurement of scattered light. The photograph above displays the sensor head.

The instrument is displayed mounted on a tripod below:

Figure 2: The MSCAT sensing head is shown near the tarmac on a bottom tripod fielded during the MARGINS experiment. The instrument at mid-level shows the LISST-ST settling tube, developed with funding from the Geology and Geophysics program, installed to measure particle settling velocities. At the top of the tripod, releases and recovery aids are visible.

The tripod was deployed from R/V CAPE HATTERAS in the MID-ATLANTIC BIGHT, off Duck, NC. The deployment date was July 21, 1994 and final recovery was affected on September 2, 1994. The instrument had worked successfully and full data was recovered.

Example data are shown in Figure 3 on the next page (Agrawal & Pottsmith, 1994). The Figure 3a shows the multi-angle scattering energy distribution. A peak in the energy distribution at detector ring no. 16 indicates a particle size distribution maximum around 50 microns. Figure 3b shows the volume distribution of particles derived by mathematical inversion of the scattering energy distribution of Figure 3a. The size classes increase logarithmically, from 5 micron to 500 microns. Each size class is 8%

wide. The center size class, numbered 32, is at 50 microns. As can be seen from Figure 3b, a peak in size distribution occurs around the size 50 microns, but there is also a lot of particle volume in the largest sizes.

The size distribution is shown in the middle panel for a 100 second duration, with samples having been taken at a 1 Hz data rate. The ordinate is size class number (as above from 5-500 microns) and the abscissa is time in seconds. The very bottom trace, Figure 3d shows the speed of water current, derived from measurements obtained by Dr. Williams' BASS tripod. The modulation in speed is caused by oscillations induced by surface gravity waves. The observation of speed and concentration (figures c-d) does not suggest an obvious correlation. The absence of correlation suggests that active erosion was not occurring during this period, or that the local erosion did not mix far enough vertically to be sensed by the MSCAT instrument.

These and other conclusions were presented by us at the Fall Meeting of the American Geophysical Union.

Funding for the program ended shortly after this work was reported. The preparation of final scientific papers awaits further funding from the Department of Energy or elsewhere.

Conclusion

By developing and field testing the new MSCAT instrument, we have met the contractual requirements of this program. Furthermore, initial indications from the data are that at least during a part of the experimental duration, surface gravity waves failed to cause local resuspension. The data are of adequate quality to estimate the total concentration and the size-specific 'reference concentration' at the seabed.

Reference

Agrawal, Y.C. and H.C. Pottsmith, 1994: Measuring Particle Ensemble Size Spectra at High Resolution Near the Seabed; Paper O21B-04, presented at the 1994 Fall Meeting of the American Geophysical Union, San Francisco.

fig. 11

fig. 12