Particle Size Distribution and Optical Volume Scattering Function in the Mid and Upper Water Column of Optically Deep Coastal Regions: Transport from the Bottom Boundary Layer

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LONG-TERM GOALS

My long-term goal is to understand the processes that contribute to the establishment of the vertical structure of the size-distribution of suspended sediments and sediment concentration, with the bottom boundary layer acting as the principal source.

OBJECTIVES

In the HYCODE experiment, the focus is on understanding the processes that establish the color of the water. Besides dissolved substances, a principal factor determining the spectral signature of the water-leaving radiance is the particulate content of the water column. The source for particulates in shallow water (though optically deep) is the bottom boundary layer, and subsequent diffusion and advection by processes that include upwelling. My objective in this program is to examine the relative importance of these processes by simultaneously observing the vertical distribution of particles, and the advective-diffusive mixing processes. Simultaneously, the instruments that measure particle size-distribution will also provide measurements of the small-angle **volume scattering function** of water from 0.1 to 20 degrees, at the wavelength of the diode lasers, 0.67 micron.

APPROACH

Measurements of suspended sediments (size distribution and concentration) shall be carried out throughout the water column using a LISST-100 instrument on a profiler. In addition, LISST-100 instruments will measure the same parameters from a bottom-mounted tripod. The settling velocity distribution of the particles – a key parameter that establishes the diffusion-settling balance – shall be measured using a LISST-ST instrument. The 'reference concentration' of sediments – concentration at a small distance above the bed - will be observed with an MSCAT (Miniature Scattering and Transmissometry Instrument). These constitute the set for sediments. The velocity field will be measured with a set of velocimeters mounted on the tripod under leadership of Dr. John Trowbridge, WHOI. All sensors will be synchronized. Data will be stored on-board the instruments and may also be transmitted to shore via the node at the site.

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14. ABSTRACT

My long-term goal is to understand the processes that contribute to the establishment of the vertical structure of the size-distribution of suspended sediments and sediment concentration, with the bottom boundary layer acting as the principal source.

15. SUBJECT TERMS

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WORK COMPLETED

During the first year of this program (FY1999), data were obtained from a single LISST-100 instrument mounted on a vertical profiler at the LEO-15 site.

In the second year, all instruments were completed for deployment and a summer deployment occurred. A tripod carrying a LISST-100, one LISST-ST and an MSCAT instrument was deployed at the LEO-15 site. In addition, the LISST-100 on the vertical profiler was re-deployed.

In the third and final year, all instruments were redeployed, operating in the autonomous mode. Full data were recovered from all instruments.

As a consequence, we now have gathered data on the *size-distribution*, *concentration*, and *settling velocity distribution* of suspended particles, measured both throughout the water column, and more extensively in the bottom 2 meters, from a tripod. As a consequence, (*i*) The volume scattering function (VSF) of the water column has been studied from the data received from the profiling LISST-100. This has been reported in the upcoming Ocean Optics XVI conference Proceedings; (*ii*) Settling velocity spectra have been obtained from the LISST-ST data. Results support hypotheses of fractal nature of the larger particles; and (*iii*) The detailed analysis of size-distribution in the bottom boundary layer is ongoing. These will be combined with the bottom hydrodynamic forcing data of Dr. Trowbridge in the remaining final year of this program.

RESULTS

Volume Scattering Function*:* We have displayed bottom boundary layer data in FY2001 report. This year, we showcase data in the surface-to-bottom profiling instruments, and then we display the settling velocity spectra.

To illustrate the variability of the VSF from top to bottom in the water column, we have selected a spin down period when winds declined from a high magnitude of 10m/s to 2m/s. Optical transmission from this duration shows a dramatic change in water properties, Figure 1.

Settling Velocity: In related work on the settling velocity spectrum of sediments at LEO-15 site, we obtained data that show a departure from constant density prediction of settling velocity. These are shown in Figure 3. If mass density of particles is constant, the settling velocity dependence on size is described by the well-known Gibbs' Law. Figure 3 shows a comparison of measurements with Gibbs' Law prediction. It is seen that the departure from Gibbs' Law increases with growing size. The implication is clear that density of particles reduces as their size increases – most likely due to the aggregated fractal nature of the particles. These data are currently being examined for their implications on the fractal dimensions at this site, and in the context of boundary layer stresses as the latter are known to influence floc formation and survival.

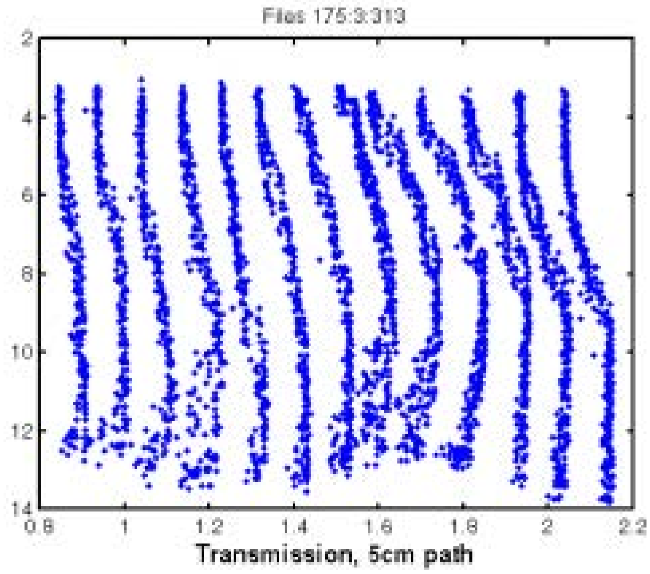

Figure 1 shows the temporal evolution of vertical optical transmission profiles during a wind spin-down period from 10m/s to 2m/s. Note that the surface water at the end of this period is more turbid than bottom water, and the bottom boundary layer appears well mixed. The ordinate is water depth. Each curve is displaced in time by 1.5 hours.

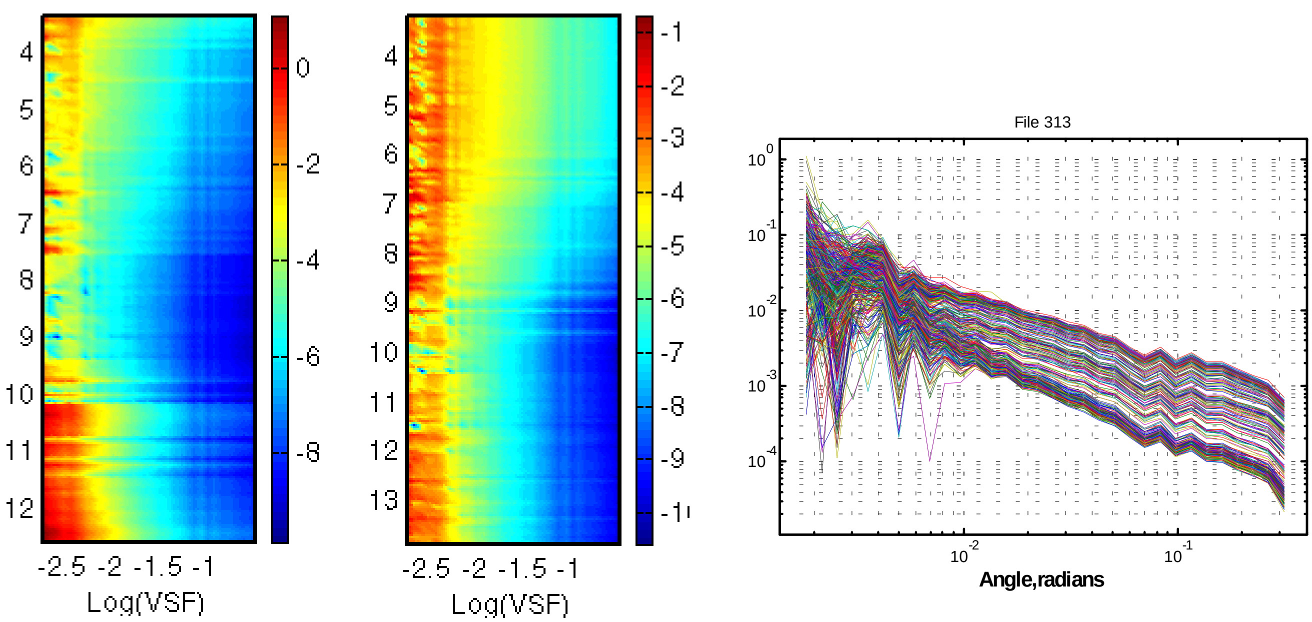

Fig. 2 Depth dependence of VSF, profiles 297,313, (left 2 panels); and the VSF for profile 313 (top). Curves are not displaced. The data show 2 orders of magnitude variation in VSF. The noisy nature at left is an artifact of measurement arising from weak small-angle scattering. This work is to be published shortly.

In a broadly significant research project, we are continuing the study of the small-angle scattering particles of random shape marine particles. This empirical study has direct bearing on the inversion of multi-angle scattering observed by the LISST instruments, and is of fundamental interest in all studies of light scattering. Some results were presented at the Ocean Sciences (2002) conference in Honolulu.

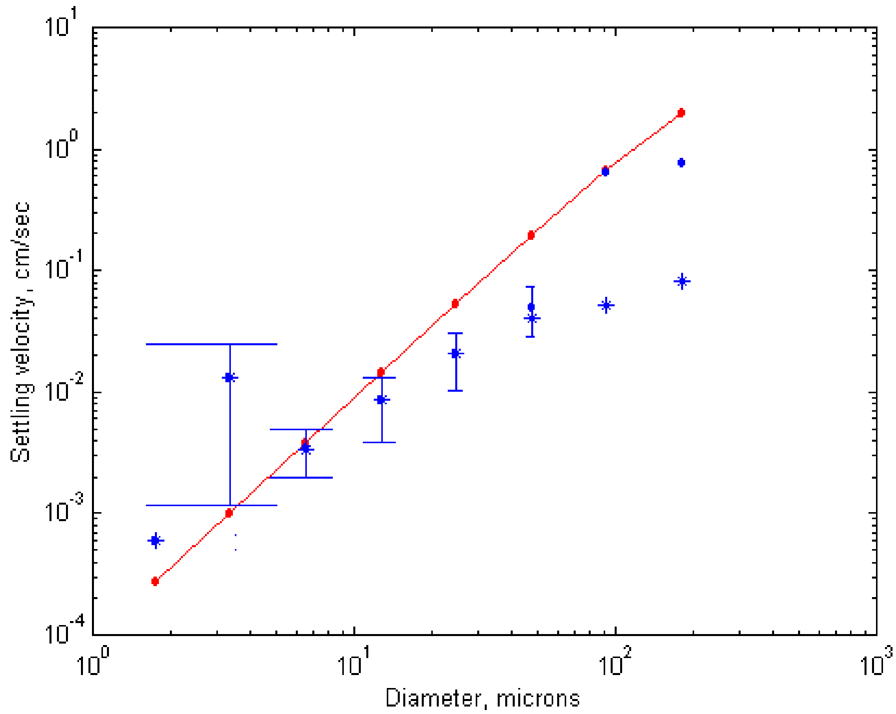

Figure 3: Settling velocity spectra of marine particles measured in-situ at the LEO-15 site. Predictions of Gibbs' Law are shown in red, data are in blue asterisks. The progressively lower settling velocities at larger sizes are strongly suggestive of the aggregated fractal nature of larger particles.

IMPACT/APPLICATION

The work is in early stages of publications. However, research on the fractal nature of particles will be boosted by these studies, in addition to information on the variability of VSF in the water column.

TRANSITIONS

None.

RELATED PROJECTS

1 – **Dissipation Sensor:** In a program funded by NSF, we are examining the rate and kinematics of the dissipation variable in the lowest few centimeters of the bottom boundary layer. This region, the wave boundary layer, is the most critical in determining resuspension or settling of particles. Similar sediment sensors as in use in this program will also be employed, besides a laser dissipation rate sensor.

2 – **Small-Angle Scattering Properties of Natural Particles**:- Spurred by observations of differences in calibrations of sediment sensors for spheres vs. natural particles, we have completed the first phase of empirically characterization of the very small-angle scattering properties of these particles. Using a specially constructed stratified settling column, we have characterized the counterpart to Mie scattering properties for narrow size classes. This work is in preparation for publication.

REFERENCES

Agrawal, Y.C. and H.C. Pottsmith (2000). "Instruments for Particle Size and Settling Velocity Observations in Sediment Transport", Marine Geology, 168,(1-4), pp 89-114.

Risovic, D. M., (1996). " Fractal dimensions of suspended particles in seawater". Journal of Colloid and Interface Science, 182, pp 199-203

PUBLICATIONS

Agrawal, Y.C., and H.C. Pottsmith, 2000: Instruments for Particle Size and Settling Velocity Observations in Sediment Transport, Marine Geology, **v**168/1-4, pp 89-114.

Agrawal, Y.C. and Traykovski, P., 2001: Particles in the bottom boundary layer, dynamics through events, Jour. Geophys. Res., v106, C5, pp 9533-9542.

Agrawal, Y.C., and H.C. Pottsmith, 2001: A new sensor for mean size and size-independent measurement of suspended sediment concentration (*in revision,* Marine Geology).

Agrawal, Y.C., and J. Trowbridge, 2002: The Optical Volume Scattering Function: Temporal and Vertical Structure in the Water Column at **LEO-15,** *in Proceedings of Ocean Optics XVI*, Santa Fe, NM.

Agrawal, Y.C., and O. Mikkelsen: Small-angle scattering properties of natural particles, Applied Optics (to be submitted).

PATENTS

None