

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 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.					
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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.

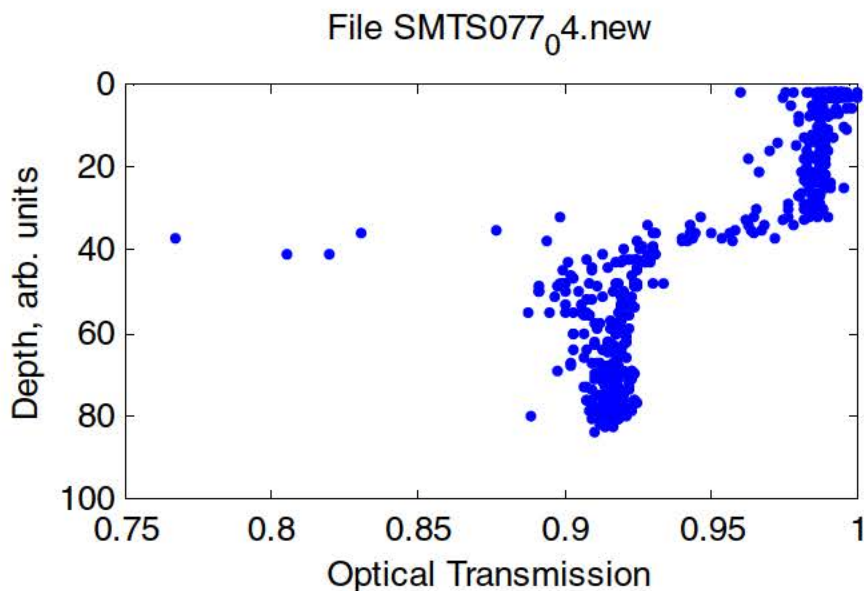
In the second year, all instruments were completed for deployment and a summer deployment occurred. A tripod carrying a LISST-100, one LISST-ST and an MSCAT instrument was deployed at the LEO-15 site. In addition, the LISST-100 on the vertical profiler was re-deployed.

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 .

RESULTS

Figure 1 displays a typical vertical profile of optical transmission measured by the LISST-100 on the profiler. Note the spikiness of the data. Ordinarily, this spikiness would be discarded or edited out. However, we have recognized the spikiness to originate from single flocs crossing the laser beam of the LISST-100 instrument. Due to the ability of this instrument to measure scattering at small angles, 1.7mrad to 340 mrad, these spikes in transmission can be interpreted as the scattering signature of large particles. We are examining this small-angle scattering of marine flocs in light of theory that has recently come to our attention, e.g. (Risovic 1996).



1. A single representative vertical profile of optical transmission measured from a LISST-100 on a profiler. The spikiness is explained below to arise from single flocs whose optical small-angle scattering signatures have been measured during the first deployment in 1999. Water depth is 15 m.

A second, simple but significant result out of this work concerns instrumentation. It has been long our experience that LISST optical transmission records contain much more high-frequency structure than optical transmission measured by Transmissometers. This has now been attributed to the superior spatial filtering of the LISST systems. The essential difference is as follows: as is known to us from our particle sizing work, most of the scattered power from large particles stays in a very small-angle forward cone. The LISST has an extremely small aperture that passes the focused laser beam, and because of the small aperture, distinguishes the laser beam power from the power in the scattered cone. The aperture in other Transmissometers is much larger, so that scattered power is misread as absence of large particles. This work is being written up as a Note for publication. (Agrawal and Chang, *in prep.*).

The second figure, below, is taken from the July-September 2000 summer deployment of our tripod. The multi-angle scattering raw-data from the LISST-100, at 1.5m above the seabed, are displayed.

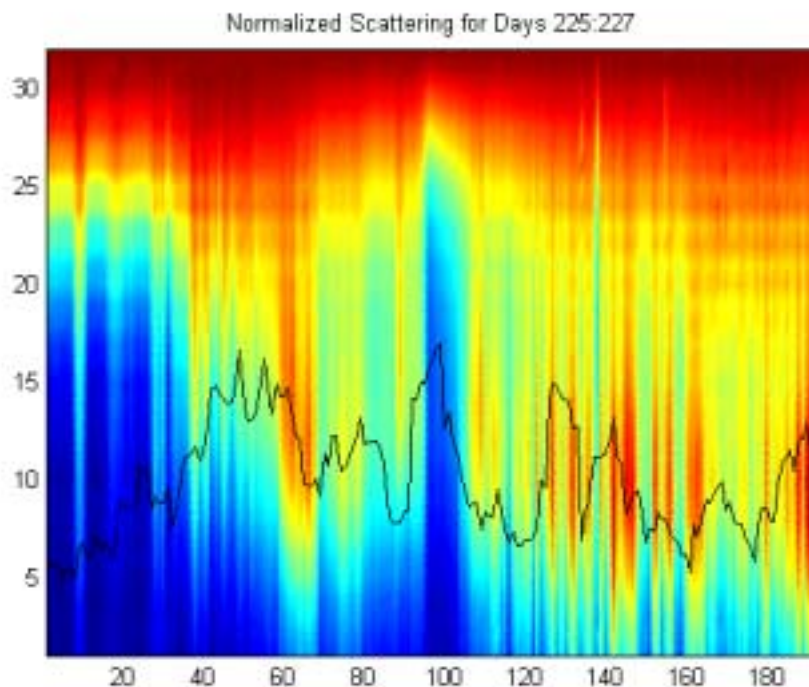


Figure 2: Normalized multi-angle scattering; days 225-227, CY2000. The abscissa is sample no., taken 15 minutes apart; the ordinate is the LISST ring-detector no.(or log of scattering angle). Reds mean high intensity scattering. Note the intrusions of high intensity peaks at smaller angles at samples 60, and between 120-200. These imply the presence of larger size particles.

Similar data for the summer 2001 campaign are also in hand. These data will be interpreted in terms of the size distribution and concentration of sediments and related to local stress. The settling velocity distribution at this site was published by us earlier, (Agrawal and Pottsmith 2000). New measurements of settling velocity distribution were made using the LISST-ST [*strikingly, the LISST-ST instrument which incorporates a laser diffraction sizing measurement in a multiple-opening-closing settling column, operated for 60 full cycles, producing some of the most interesting data towards the last 15 days!*]. After inverting the multi-angle scattering observations (Fig. 3), we have recovered the settling

velocity spectrum. The settling velocity is shown to depend on particle diameter in the form $w_f \sim d^{1.29}$. This dependence is similar to that published earlier by us (Agrawal & Pottsmith, 2000) where the exponent was 1.2. However, there are indications from the data that a single exponential form for settling velocity is not a valid form, and that there are significant day-to-day variability in the settling velocity vs. diameter relationship.

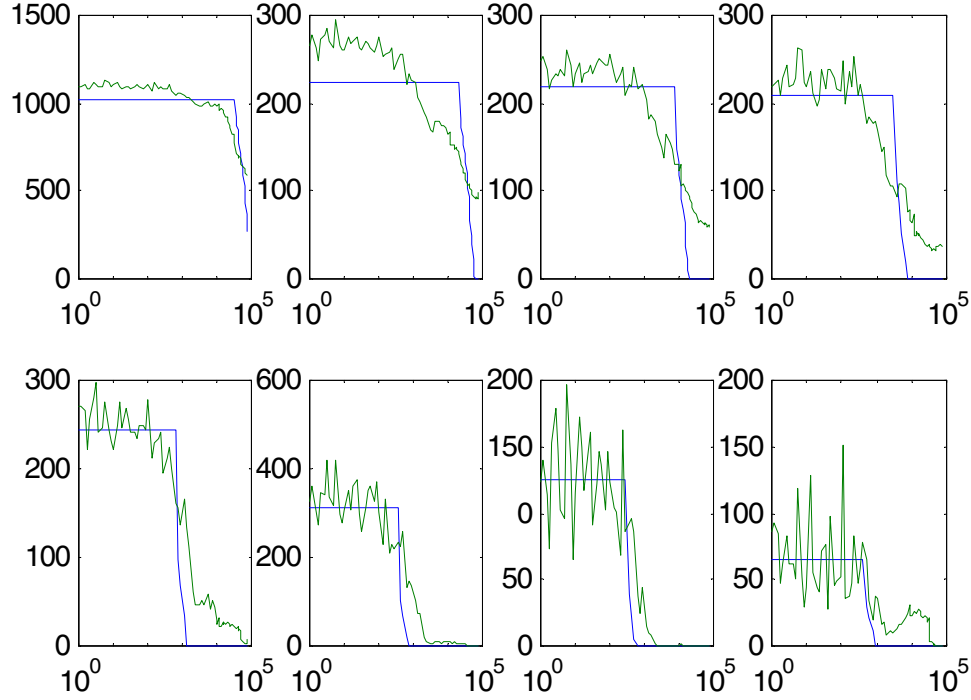


Figure 3: Time histories of, and idealized fits to concentration of 8 size classes in the LISST-ST settling column. For each frame, the abscissa is time in seconds. The size classes are centered at diameters d : (l-r, from top) 6.7, 11.8, 21, 37.5, 66.7, 118.6, 211 and 375 microns. These histories produce a settling law $5.5 \times 10^{-5} d^{1.29}$ [file l_st801.dat, expt. 43].

IMPACT/APPLICATION

The work is still in the early stages to have made an impact.

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 – **LISST-25:** In an unfunded separate program, a new optics principle was discovered that permits the use of two specially shaped detectors placed in the Fourier plane of a receiving lens, for observing the concentration and mean size of suspended particles. This new principle circumvents the difficulty of changing calibrations of prior transmissometers and optical scattering sensors. This program is internally funded from the Company's resources.

3 – **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.

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PATENTS

None.