Backscattering by Non-spherical Natural Particles: Instrument Development, IOP's, and Implications for Radiative Transfer

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LONG-TERM GOALS

(i) Quantify and understand the inherent optical properties (IOP's) of natural particles from a standpoint of measuring size-distribution;
(ii) Understand how the properties of particles (composition, shape, and internal structure) affect their IOP.
(iii) Incorporate these properties into radiative transfer models for prediction of downwelling and upwelling radiances.

SCIENTIFIC OBJECTIVES

We have developed the LISST series instruments that provide unprecedented quality of data on the forward scattering of light. In this project, we plan to (*a*) develop a version of this instrument that will deliver the same high-quality data in backscatter, (*b*) guide analytical light-scattering model development with such observations, and (*c*) then apply the results to predicting light propagation in the sea by providing as input, the new estimates of IOP's.

This proposal is relevant to ONR's Sensor and Systems and Modeling thrust areas. It will contribute to understanding of how the shape of oceanic particles affect backscattering and provide an instrument that specifically addresses backscattering near 180 degree - a crucial parameter to understand, predict, and invert LIDAR signal. The LIDAR signal is proportional to the VSF near 180 degrees.

APPROACH

We describe the distinct tasks in the proposed program, identified with person responsible:

a. *Development of a backscatter version of the LISST instrument* (Agrawal). Shown below is a schematic diagram of the proposed instrument.

   Key innovations are the use of a ring-detector to achieve rapid, low-cost measurement over a high dynamic range with strong signal strength, a novel beam-dump incorporating an ink-filled cell, and a direct measure of beam-*c* as with the LISST, which eliminates complications seen in prior backscatter systems such as the Beta-pi (see below).

   Specifications: The proposed back-scattering angle range is from 160-179.9 degrees in 32 steps, as determined by the ring-detector shown above (it yields logarithmically increasing resolution near 180^o). This range is far wider than the 179-180 degree range of the Beta-Pi instrument developed by Maffione and Honey.(1992); plus the instrument that we propose is compact, far simpler, and unlike the Beta-pi does not require an operator in attendance [the Beta-Pi measured roughly 0.5m diameter x 1 m long and did not incorporate batteries or computer; contrasted with LISST at 0.12 m dia x 0.7 m long, roughly 20 times smaller, yet complete with battery and data logger]. This instrument is not meant to replace the Hydroscat which is designed for estimation of the *backscatter coefficient* from a weighted average over 120-150^o , not the high-resolution volume scattering function.

   Using the proposed LISST and the commercial forward-scatter versions now available, we shall attempt to constrain the overall VSF. In any case, with the detail from the new LISST, we can certainly better understand the non-spherical effects on backscatter.

b. *Characterization of scattering from terrigenous and biological size-sorted non-spherical particles* (Agrawal, Boss). The principal task is to make laboratory observations of particles sorted by settling size, as well as quantify the variability of scattering in the back-direction of different phytoplankton (with different morphologies, internal structure, and community structure (e.g. chains)).

c. *Field observations*(Agrawal)*:* We are planning a brief field deployment from the WHOI offshore observatory in the year 2005. For this, we anticipate using the profiler that was employed in HYCODE. It may be necessary to seek a special allocation for servicing this unit at that time; as of now, its condition is not known post-deployment at LEO-15. The idea is to leave the backscatter LISST on the profiler through a large mixing event such as a storm passage, and observe the vertical variation in backscatter VSF that accompanies resuspension throughout the water column.

d. *Modeling of light scattering* (Boss)*:* Theoretical modeling of light scattering by randomly oriented non-spherical particles, based on these observations using a T-matrix code similar to that used in S. Herrings thesis (Boss). Using methods similar to Jonasz (1987a) to derive a non-sphericity index of the natural particle population under investigation.

e. *Modeling of Radiative Transfer* (Mobley): Incorporation of results into radiative transfer calculations. The particle VSF's and cross sections obtained from the laboratory experiments and numerical modeling of non-spherical particles will be used to generate IOPs for use as input to Hydrolight. Hydrolight will then be used to quantify the differences in predicted remote-sensing reflectance spectra for spherical and non-spherical particles.

WORK COMPLETED

The project has just started in August of 2004.

We have begun designing the engineering aspects of the new LISST. Detailed signal strength estimates from backscattering, scattering from optical surfaces, and noise considerations are under study. Based on this study, a final choice of the detector to be employed is to be made. We are also considering incorporating polarization capabilities in backscatter, as part of the instrument's capabilities.

We are in the process of recruiting a trainee (W. Clavano of Dr. W. Philpot's lab at Cornell) to perform the calculations of scattering by non-spherical particles. With Boss she will write a review on the subject of scattering by non-spherical oceanic particles.

RESULTS

None

IMPACT/APPLICATIONS

Ability to understand the impact of shape on marine optical properties will improve our ability to interpret optical measurements.

TRANSITIONS

None

RELATED PROJECTS

Optics, acoustics, and stress in a nearshore bottom nepheloid layer- an ONR funded proposal to E. Boss, J. Trowbridge, P. Hill and T. Milligan. We are planning to coordinate the field work to take advantage of many ancillary optical measurements that will be done.

REFERENCES

Agrawal, Y.C., 2004, The Optical Volume Scattering Function: Temporal and Vertical Structure in the Water Column at **LEO-15,** Limnology and Oceanography, (*in revision*).

Agrawal, Y.C. and H.C. Pottsmith, 2000: Instruments for Particle Size and Settling Velocity Observations in Sediment Transport, Marine Geology v168/1-4, pp 89-114

Maffione, R. M. and R. Honey, 1992: Instrument for measuring the volume scattering function in the backward direction, SPIE vol 1750, pp 15-26.

PATENTS

None