Relating the Optical and Acoustical Properties of Oceanic Particles

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LONG-TERM GOALS

- To develop improved predictive capabilities for the distribution of particulate material in the coastal ocean.
- To develop predictive models for optical properties from measurements of acoustical properties and vice versa.

OBJECTIVES

To understand the relationship between acoustical and optical properties of suspended particles as a function of the particle's composition, size distribution and degree of aggregation.

APPROACH

Laboratory experiments of aggregation have been taking place at the University of Maine MISC Lab. The experiments are designed to measure the optical and acoustic response to inorganic aggregates, namely induced clusters of flocculated clays. The experiments are conducted in a large sink to allow for simultaneous measurements by several instrument all focused on the same depth.

Measurements include near forward optical scattering (providing information of cross-sectional area, and thus size, of aggregates, LISST, Sequoia Scientific), optical transmission and backscattering (WET Labs' BB(RT)) and acoustical backscattering at 6MHz (Nortek's VECTOR). Concentrations of clays are siphoned out from the sampling volumes of the sensors and measured using suspended sediment (TSS) analysis protocols.

These data are used to contrast the optical and acoustical responses to temporal changes in particle's concentration and size as a result of settling and aggregation. Collected material for mass and analysis of the time dependent signal allow us to study the change in acoustical and optical backscattering per mass as function of aggregate size.

Field data from the OASIS deployments that include an extensive data set of optical and acoustical properties are investigated to find relationships between these properties as well as to link them to processes identified in the water.

WORK COMPLETED

We have conducted extensive analysis of both lab and field data. A PhD thesis by Clementina Russo was completed and defended successfully and two manuscripts have been submitted to peer review publications.

RESULTS

The most significant result we found from the lab experiments is that aggregation results in a *decrease* of acoustic backscattering per mass despite the fact that the aggregate size increases towards the resosnant frequency (ka~1) where maximal response is expected (Fig. 1). A possible explanation for this behavior (suggested to us by Dr. Ken Foote and supported by the literature) may be that the bonds that link particles together within the aggregate absorb acoustic energy and thereby decrease the scattered intensity. This behavior is also observed in the field.

We conducted a detailed study of the degree of correlation between optical and acoustical properties (Fig. 2, Russo et al., submitted to JGR). Strong correlations were observed between acoustic and optical backscatter and from these data, linear models were extracted to predict the backscattering intensity of one method from the other method. Relationships such as these can be useful to predict the performance of an acoustical or optical system when only set of observations is available. We analyzed the deviations of model predictions from in-situ data and found them to correlate with changes in particle size, changes in composition, and degree of aggregation. These results reinforce that co-deployments of acoustical and optical systems provide additional information on particles and their dynamics, however, further work is necessary to elucidate the frequency-variable acoustic backscattering from aggregate particles.

IMPACT/APPLICATIONS

The acoustical results challenge the common view that particles with ka~1 will have the strongest acoustic backscattering signal per mass. This view is based on the assumption that the scattering particles are solid. In the ocean, however, single grain particles re-suspended from the bottom most often are ka<1 (based on the acoustic frequency range of backscattering systems used to study suspended sediments), while aggregates are often in the range of ka~1. Our results indicate that acoustic backscattering per mass decreases in the presence of aggregate particles, and these findings have implications for interpreting field data from acoustic backscatter systems. The calibration of these systems is often performed with solid bead particles, and thus it follows from our observations that because the backscattering of aggregates is unaccounted for in the calibration, aggregate population mass will be significantly underestimated. The correlations observed and quantified between optical and acoustical properties could be used to infer one from the other, for example when optical properties are measured from AUVs.

RELATED PROJECTS

This project is closely linked to the OASIS project (N000141010508 to E. Boss) which provides field data.

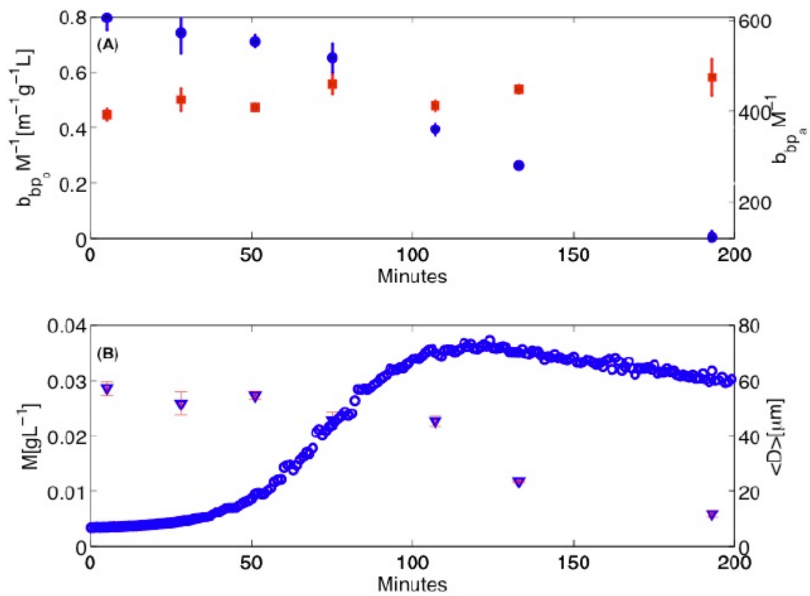

Figure 1. Time series of mass normalized optical (blue squares) and acoustical backscattering during the aggregation experiment (top panel) and suspended mass and averaged particle size as inferred from the LISST (bottom panel). Note that while the mass normalized optical signal changes little, the acoustic signal monotonically decreases as aggregation takes place.

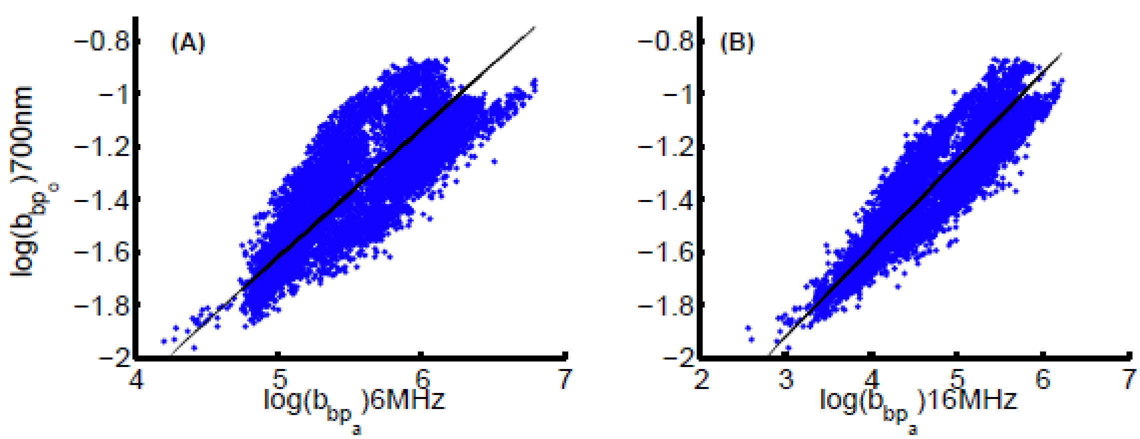

Figure 2. Comparison of acoustical and optical backscattering in the bottom boundary layer for two different acoustical frequencies.