

Flocculation, Optics and Turbulence in the Community Sediment Transport Model System: Application of OASIS Results

Emmanuel Boss
School of Marine Sciences
5706 Aubert Hall
University Of Maine
Orono, Maine, USA 04469-5706
phone: (207) 581-4378 fax: (207) 581-4388 email: emmanuel.boss@maine.edu
<http://misclab.umeoce.maine.edu/index.php>
Grant Number: N000141010508

In collaboration with:

Paul S. Hill
Department of Oceanography
Dalhousie University
Halifax, Nova Scotia, CANADA B3H 4J1
phone: (902) 494-2266 fax: (902) 494-3877 email: paul.hill@dal.ca

Brent Law and Timothy G. Milligan
Fisheries and Oceans Canada
Bedford Institute of Oceanography
1 Challenger Drive
Dartmouth, Nova Scotia, CANADA B2Y 4A2
phone: (902) 426-3273 fax: (902) 426-6695 email: milligant@mar.dfo-mpo.gc.ca

John H. Trowbridge
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
phone: 508-289-2296 fax: 508-457-2194 e-mail: jtrowbridge@whoi.edu

Chris R. Sherwood
Woods Hole Oceanographic Institution
U. S. Geological Survey, Coastal and Marine Geology
384 Woods Hole Road, Woods Hole, MA 02543-1598
phone: 508-457-2269 fax: 508-457-2310 e-mail: csherwood@usgs.gov

LONG-TERM GOALS

The goal of this research is to develop greater understanding of the how the flocculation of fine-grained sediment responds to turbulent stresses and how this packaging of sediment affects optical and

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 30 SEP 2011		2. REPORT TYPE		3. DATES COVERED 00-00-2011 to 00-00-2011	
4. TITLE AND SUBTITLE Flocculation, Optics and Turbulence in the Community Sediment Transport Model System: Application of OASIS Results				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University Of Maine,School of Marine Sciences,5706 Aubert Hall,Orono,ME,04469-5706				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

acoustical properties in the water column. Achieving these goals will improve the skill of sediment transport models and hence prediction of underwater visibility.

OBJECTIVES

1. Quantify the effects of aggregation dynamics on the size distribution of particles in the bottom boundary layer;
2. Quantify how changes in particle packaging affect the optical and acoustical properties of the water column.
3. Develop models describing the associations between particle aggregation, stress, and the acoustical and optical fields.

APPROACH

The approach is to obtain measurements that permit comparisons of temporal evolution of bottom stress, suspended particle size, and optical and acoustical properties in the bottom boundary layer. We measure optical and acoustical properties of the water column by coupling an ac-9 (9 wavelength absorption and attenuation) and a two backscattering + CDOM fluorometer to the USGS tripod on their profiling arm (hence resolving the first 2m of the bottom boundary layer). Coupling the ac-9 with a switch and a filter, we are able to obtain calibration independent optical properties of particles (Slade et al., 2010) which provide us concentration, size and compositional information regarding the particles. In addition, it allows us to obtain the parameters needed to compute underwater visibility and provide the inputs necessary to Dr. N. Farr's group to model the optical field affecting underwater optical communication.

Collaborating with Dr. Hill, Sherwood and Trowbridge, our data will be used to develop and constrain a sediment concentration module that will be incorporated to the Community Sediment Transport Modeling System (CSTMS).

WORK COMPLETED

Work in 2010-2011 focused on two areas. First, we worked on publication of results from past field experiments. Second, we prepared for another field season in September and October of 2011 at the Martha's Vineyard Coastal Observatory where we integrated our instrument into the USGS tripod which resolves the bottom 2m of the bottom boundary layer. To date we have collected nearly continuous two and a half weeks of optical data.

RESULTS

With our past OASIS support we have gathered three one-month-long time series of observations linking physical forcing, sediment concentration and size distribution, and optical properties. We are collecting a fourth data set in September and October 2011. Over a range of environmental conditions, the conversion from SPM to optical properties is more predictable than the theory that assumes constant-density particles suggests. The broad conclusion that can be drawn from our work is that particle and optical properties are easier to predict when the stress on the seabed is adequate to

resuspend particles. When stresses are too low to resuspend sediment, biology and chemistry determine the concentration, composition, and size of particles in suspension, so biology and chemistry also determine optical properties. When stress grows large enough to resuspend particles, however, particle and optical properties are more closely linked to physical forcing, which is fundamentally more predictable. As well, the composition of particles becomes more uniform with increasing stress.

We have used data from OASIS 2007 to examine the lack of sensitivity of particulate beam attenuation to particle size. Estimated *SPM* and measured c_p from the LISST were linearly correlated throughout the experiment, despite wide variations in particle size. The slope of the line, which is the ratio of c_p to *SPM*, was 0.22. Individual estimates of c_p :*SPM* were between 0.2 and 0.4 for volumetric median particle diameters ranging from 10 to 150 μm (Figure 1). The wide range of values in c_p :*SPM* found in the literature, which has usually been blamed on variable particle size, instead likely results from three factors capable of producing factor-of-two variability in the ratio: particle size, particle composition, and differences among acceptance angles of commercial beam-transmissometers. This work has been published in *JGR Oceans* (Hill et al., 2011).

Our field and laboratory experiments contributed to further our understanding of the effect of aggregation on optical properties; manipulating aggregates in the environments, we observed their effect on attenuation and forward scattering. We developed a new aggregate density parameter, the ratio of the beam-attenuation to total particle volume; this factor is low for suspensions of highly flocculated particles and large for dense particles (Fig. 2). We found that while the particulate beam attenuation spectra changes during aggregation similar changes are not seen in the backscattering spectrum. This is important because spectral backscattering has been proposed as a method to obtain information on particulate size from AUVs. This work has been published in *Optics Express* (Slade et al., 2011).

One of the technical developments we needed to overcome for OASIS was to collect high quality spectral absorption and attenuation of particle over a month long deployment. This is not trivial due to the slow drift and potential fouling of current available technology. Boss's lab developed a system to do it by using an underwater switch that periodically pumped water through a 0.2 μm filter and computing the spectral particulate absorption and attenuation as a difference between the measurements without a filter from those with a filter. This work has been published in *JTECH* (Slade et al., 2010).

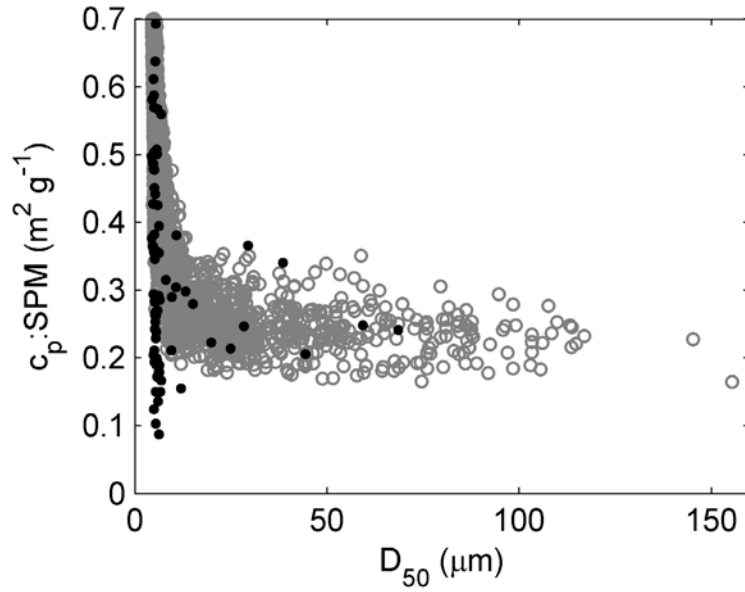


Figure 1. The ratio $c_p\text{:SPM}$ plotted versus median particle size. Closed black circles are associated with values of SPM measured with the in-situ filtration system. Open gray circles are values associated with SPM estimated every 5 minutes from the merged size spectra and the size-settling velocity data. When median particle size is small, $c_p\text{:SPM}$ is variable, but when median particle size grows larger than 10 μm , the value of $c_p\text{:SPM}$ is constrained between 0.2 and 0.4.
From Hill et al., 2011.

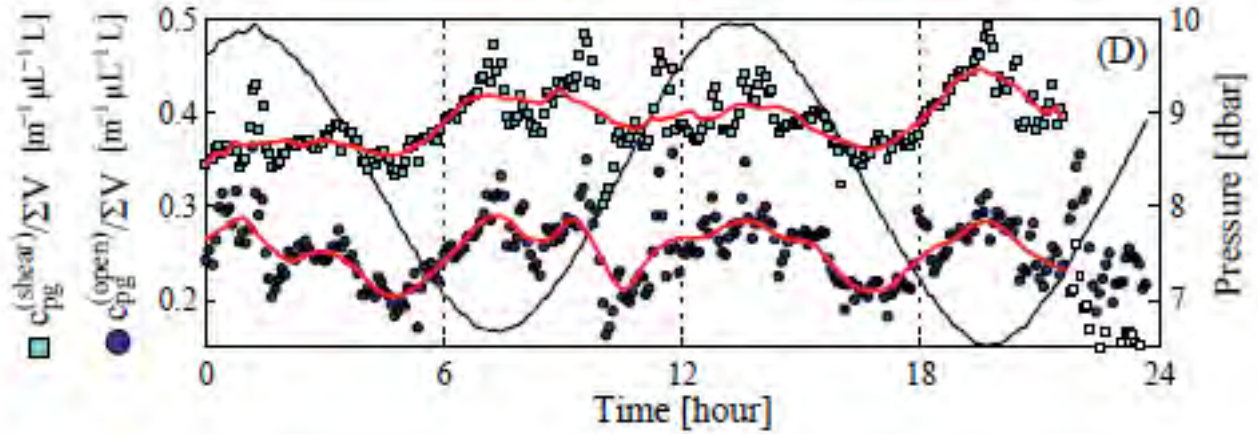


Figure 2. Time series of optical and particle size properties during the in situ disaggregation experiment. The experimental package was deployed in a bottom-mounted configuration thus tidal variability is shown as pressure in each plot. Unfilled symbols indicate the control data where the pump and sample chamber were removed from LISST B and both instruments were open to the environment. The ratio of beam-attenuation to volume concentration as measured by the LISST, indicative of aggregates (From Slade et al., 2011).

IMPACT/APPLICATIONS

The high-resolution time series of particle, optical, and acoustical properties will enhance understanding of the rates and mechanisms by which the water column clears following storm events. This is important for visibility models as well as those for sediment transport.

RELATED PROJECTS

A graduate student (Clementina Russo) is funded to study the link between acoustical and optical properties during OASIS (N000140910577 to E. Boss).

Instruments used in this work have been purchased through a DURIP grant (N000141010776 to E. Boss)

PUBLICATIONS

Hill, P. S., E. Boss, J. P. Newgard, B. A. Law, and T. G. Milligan, 2011. Observations of the sensitivity of beam attenuation to particle size in a coastal bottom boundary layer, *J. Geophys. Res.*, 116, C02023, doi:10.1029/2010JC006539, [published, refereed].

Slade, W. H., E. Boss, G. Dall’Olmo, M. R. Langner, J. Loftin, M. J. Behrenfeld, C. Roesler and T. K. Westberry, 2010. Underway and moored methods for improving accuracy in measurement of spectral particulate absorption and attenuation. *J. Atmos. Ocean. Tech.* 27, 1733-1746. [published, refereed].

Slade, W. H., E. Boss and C. Russo, 2011. Effects of particle aggregation and disaggregation on their inherent optical properties. *Optics Express*, 19, 7945-7959. [published, refereed].