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Effects of Natural, Undisturbed Particle Fields on Light Transmission and Dispersion in Coastal Waters

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LONG-TERM GOALS

Our long-term goal is to better understand the links between particle dynamics and the spatial-temporal dynamics of the underwater light field and to leverage/develop technology to explore innovative methods to quantify these relationships.

OBJECTIVES

1) Gather both empirical and quantitative evidence showing that the *in-situ* orientation of sensors affects their resultant measurements.
2) Gather statistical distributions detailing the spatial orientation of both large and small particles collected concurrently with the measurements needed for objective 1.
3) Conduct optical modeling studies using the non-random particle size and orientation statistics gathered for objective 2 and compare to models using the same particle size populations in random orientation and to the instrument measurements gathered for objective 1.

APPROACH

There are two levels of optical measurement bias to potentially characterize: 1) bias created by sensor geometry/orientation for undisturbed, remote scattering measurements because the assumption of random particle orientation is not adequate; and 2) bias created by measuring scattering for particle fields that have been disturbed relative to their natural state, e.g., by discrete sample collection or passage through a flow cell under high shear conditions. Since we are now able to make *in-situ* measurements of light scattering without disturbing the *in-situ* environment of the sample volume, we are more interested in resolving the physical phenomenon of the effects of particle orientation on water column optical properties. We have assembled a research team that has both the expertise and equipment to conduct this project and consists of Drs. James Sullivan and Michael Twardowski at WET Labs, who have developed 1) the only *in-situ* holographic microscope in the world capable of characterizing the size, shape, and orientation of all optically relevant particles from <1 μm to > 1 mm in their undisturbed, natural state, and 2) the only *in-situ*, high sample rate VSF device capable of open path measurements in one azimuthal plane; and Dr. George Kattawar, who has developed the only

small scale radiative transfer code that is capable of executing the necessary calculations to describe scattered radiance from realistic non-spherical particle fields in a practicable timeframe.

WORK COMPLETED

1. The award for our project was only put in place during the last few months. In the last month, a subcontract was delivered to our Academic partner (Kattawar) to hire a post-doc. The post-doc has been hired (Bingqiang Sun) and he has started preliminary modeling.

2. We have started to analyze results from a 2013 deployment of the HOLOCAM that clearly showed particle orientation of large diatom chains (Figure 1). We have collected statistics data on the size/shape characterics of these chains in the water column. These data have been used as inputs to begin prelimiary modeling.

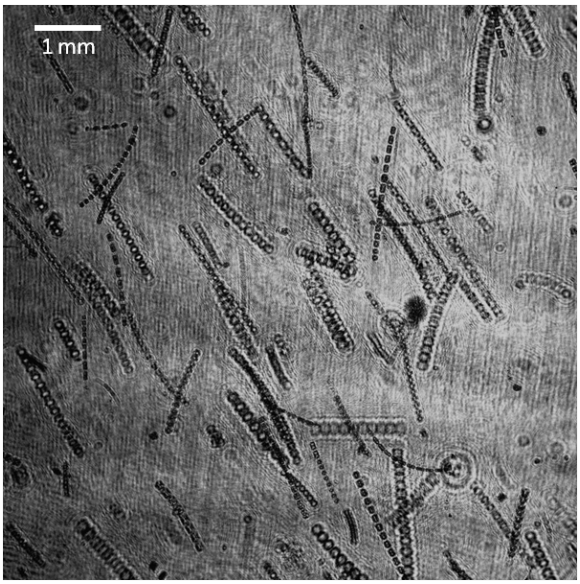

Figure 1. Raw holograms showing the orientation of the chain forming diatom Ditylum within a phytoplankton thin layer in East Sound, WA, 2013. These cells were actually orientated in a horizontal direction. The camera system was tilted during the recording.

3. We have just completed a second field effort with the HOLOCAM in Lake Erie, MI during August of 2014. This deployment was in an extreme algal bloom that commonly occurs during the summer in this location (Figure 2). The particle field was very unusual and dominated by very large colonial phytoplankton (mm in size). Orientation was again observed.

4. We have started initial scheduling of our joint particle orientation and optics cruise with NRL (Stennis Space Center, MS). This cruise will take place during Sept. 2015. A suitable research vessel has been found and reserved.

RESULTS

1. Analysis of field data from 2013 and 2014 is ongoing and providing input to modeling studies. These data are also being compared to simultaneous measurements of IOPs to better understand the effect that natural, undisturbed particle fields have on the measured optics in the water column.

2. Cell size and shape characteristics for the diatom *Ditylum* were determined from analysis of 2013 field data and used to model the effect of orientation of the chains on the VSF/Mueller matrix (Figure 3).

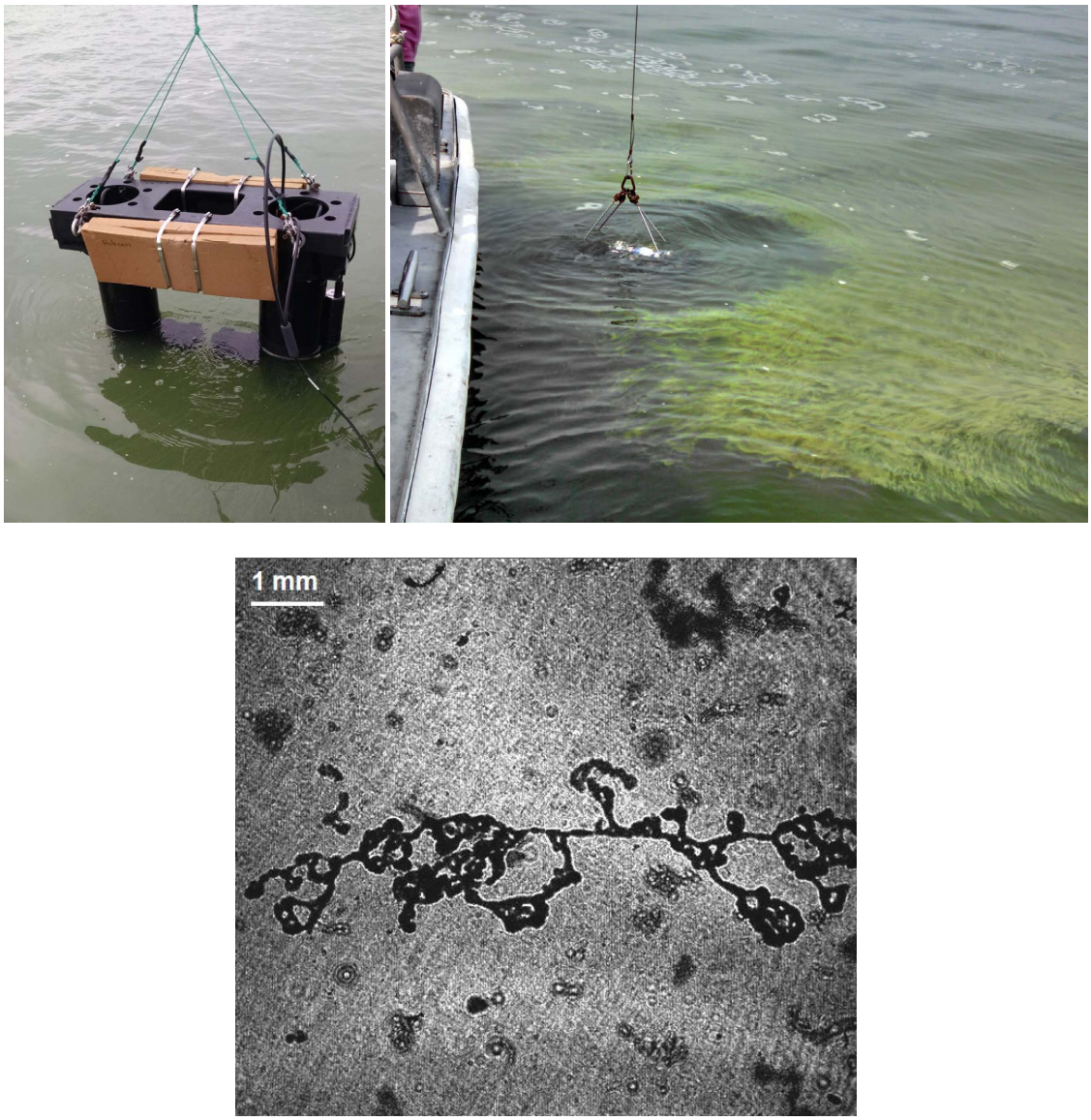

Figure 2. Deployment of the HOLOCAM and an IOP profiler in an extreme algal bloom during August 2014 in Lake Erie, MI (top panels). Super colony of the cyanobacteria phytoplankton Microcystis dominating the large algal bloom (bottom panel). Note this colony is over 7 mm in length.

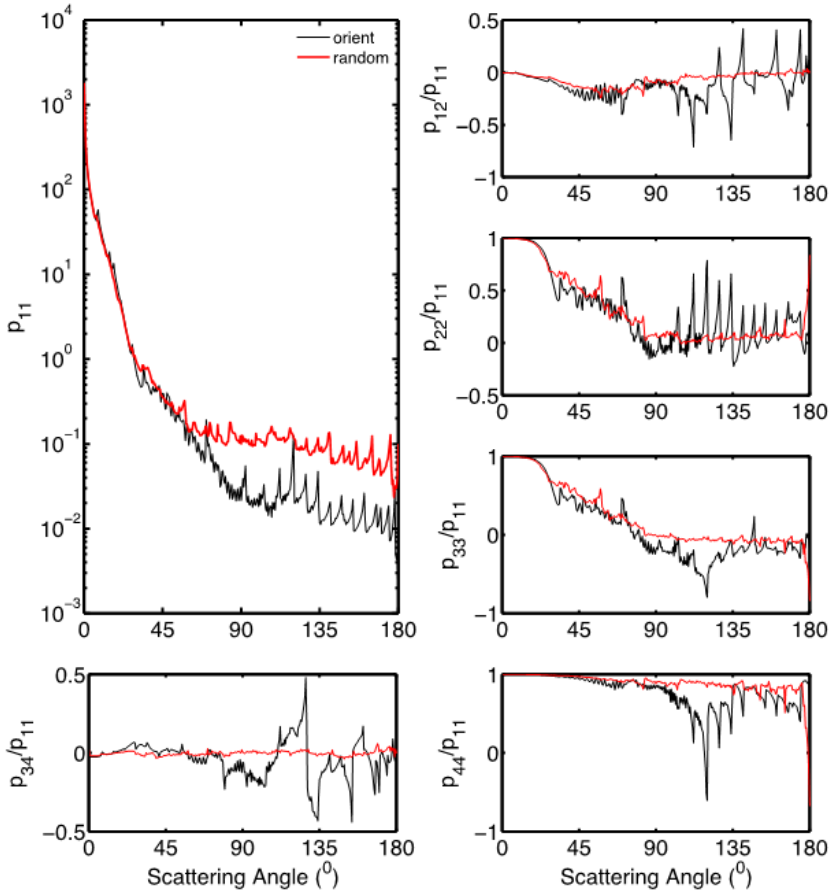

Figure 3. Volume scattering function (Mueller matrix) comparisons between modeled Ditylum diatom chains (15 cells long) in fixed and random orientations.

IMPACT/APPLICATIONS

The results of this study could be used to better understand and optimize the performance of a host of Naval operations that rely on laser imaging systems, laser communications, cameras, and other active and passive remote sensing systems and whose operation is directly affected by the ambient particle field.

TRANSITIONS

The HOLOCAM is being developed as a new commercial product for WET Labs, Inc. The design of the HOLOCAM requires WET Labs to integrate new engineering and manufacturing capabilities in the use of lasers, high-speed fiber optic data transfers, GPU programming and image analysis techniques.