

Optical Constituents at the Mouth of the Columbia River: Variability and Signature in Remotely Sensed Reflectance

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LONG-TERM GOALS

The goal of our research is to improve our ability to assess and predict the distribution of water column optical properties in the coastal region.

OBJECTIVES

Our research in the mouth of the Columbia River has four primary objectives:

1. Measure the variability of optical properties in-space in the mouth of the Columbia River on ebbing and flooding tides during a high flow period;
2. Relate this variability to the concentration and dynamics of dissolved and particulate materials, including variability in the particle size distribution;
3. Relate the optical properties to the ocean reflectance, so algorithms to invert surface color to in-water constituents can be tested and improved;
4. Investigate sediment parameters that optimize fit between derived suspended sediment distribution in the Columbia River mouth and the distribution produced by Delft-3D.

APPROACH

As part of the ONR-funded DRI entitled “RIVET”, a team from Dalhousie University (Paul Hill), Bedford Institute of Oceanography (BIO, Tim Milligan and Brent Law), and University of Maine

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(Emmanuel Boss) carried out a suite of measurements to characterize the evolution of particle and optical properties in the Columbia River plume, moving from the mouth at Astoria, Oregon to the continental shelf just beyond the river-mouth bar. The measurements were made from the R/V Point Sur on June 1-5, 2013 and from shore on June 7-8.

Two general categories of measurements were pursued from the Point Sur. First, profiles of water-column particle and optical properties were made at the points of release of several types of Lagrangian drifters, and then the drifters were followed, with profiles of water-column particle and optical properties collected amongst the drifters and at locations of drifter recovery. Second, profiles of particle and optical properties were collected on along-river transects in the mouth.

Measurements were made primarily with a profiling instrument package (Figure 1). The package actually comprised two packages that were bolted and hose-clamped to one another. The particle package, constructed at BIO, carried the new Machine Vision Floc Camera (MVFC), a Sequoia Scientific LISST 100x Type B, an RBR CTD, and two pressure-actuated, self-closing Niskin bottles. The Niskin bottles were set to trip at 5-m and 10-m depths. The optical package carried a WetLabs ac-9 absorbance and attenuation sensor with a 10-cm pathlength, a WetLabs Eco bb2fl that measures backscattering at 532 and 650 nm and CDOM fluorescence, a WetLabs WetStar CDOM fluorometer, a Sequoia Scientific flow control switch, and a SeaBird 37 CTD. The flow-control switch allows the ac-9 to collect 0.2- μ m-filtered and raw water samples. The difference between optical properties in raw and filtered water gives calibration-independent particulate absorption and attenuation.

The packages were deployed together in profiling mode. In general, the profiles proceeded as follows:

1. Instrument package lowered into the water to ~ 3 -m depth for ~ 45 s to expel bubbles;
2. Package returned to ~ 1 m;
3. Package lowered at 0.5 m s $^{-1}$ in 2-m increments;
4. Package gathered data for > 11 s at each 2-m depth increment;
5. Niskin bottle closed autonomously at 5 m;
6. Flow control switch actuated at 8 m, directing water for the ac-9 through 0.2- μ m filter;
7. Profiles extended to > 10 m where water depth permitted, allowing second Niskin bottle to close;
8. Package returned to surface at 0.5 m s $^{-1}$, profiling continuously;
9. Flow control switch actuated at 1.5 m, switching ac-9 intake back to raw water;
10. Second profile conducted in same way as the first;
11. Package recovered.

The image-interval for the MVFC was 5 s throughout the cruise. Strobe was set to 7 μ s.

The LISST sampled continuously while in the water. It was started and stopped with the external mechanical switch upon deployment and recovery. It formed 2-s average particle size distributions comprising 50 samples.

The RBR CTD sampled continuously at 6 Hz. No averaging was done.

The ac-9 and bb2fl sampled continuously while switched on. Switching was by a mechanical switch at the surface. Data are recorded as the median over approximately 1.5 s (CTD resolution) which contains 9 ac-9 measurements, ~2 bb2fl measurements, and 6 CDOM measurements.

Water from the Niskin bottles was filtered through 8- μ m Millipore SWCP filters onboard the ship. On the first day, some 0.8- μ m filters were used. Filters were rinsed thoroughly with distilled water from the ship's system. The large filters on the ship's water system were changed midway through the cruise.

Surface samples were collected with a "glug" bottle at the end of the first cast. These samples were filtered through 8- μ m Millipore SCWP filters and through glass-fibre filters. The former will be used to estimate suspended particulate mass (SPM) and disaggregated inorganic grain size (DIGS) distributions. The latter will be used to calculate organic fraction, characterised by loss on ignition. Surface samples were also analyzed for turbidity by Emmanuel Boss with a portable Hach turbidity sensor. At the start of the cruise, one sample was characterized, but by the end samples were run in triplicate. On June 4 and 5, additional turbidity measurements, following gentle shaking, were taken, to characterize fast sinking particles.

Water leaving radiance was characterized two ways by Emmanuel Boss. A WaterInSight WISP-3 was used to measure reflectance from the water surface. The WISP--3 contains three hyperspectral radiometers, measuring respectively the downwelling radiance, the upwelling radiance, and the diffuse downwelling irradiance. From the signal of these three radiometers the reflectance ('the color') of the water can be determined. Boss also used a new iPhone app developed by his student, Thomas Leeuw, at the University of Maine. It also measures reflectance, from which concentrations of in-water constituents are estimated.

A third set of measurements, targeted at estimating bulk settling velocity and extent of flocculation, was conducted after the Point Sur cruise. Water was collected in a graduated cylinder, and timed, 250-ml withdrawals with a pipette were made at 10-cm below the water surface. In order to collect enough suspension for filtration, the measurements for each individual survey were repeated three times, with the withdrawals for each time combined in a single bottle. Withdrawals were immediately after collection, at 2 minutes, 4 minutes and 8 minutes. On June 7, there was also a 1-minute withdrawal. Glug bottle samples were collected at the beginning and end of each set of triple measurements on June 8. Turbidity of the glug samples was measured with a Hach portable turbidity sensor.

RESULTS

PhD student Jing Tao is generating full particle size distributions. She began her PhD program at the beginning of September. We do not yet have complete results to report. Preliminary analysis indicates rapid loss of flocculated sediment from the river plume once the plume loses contact with the seabed. The largest concentrations and particle sizes occur in the toe of the salt wedge. Biological particles dominate in nearshore waters.

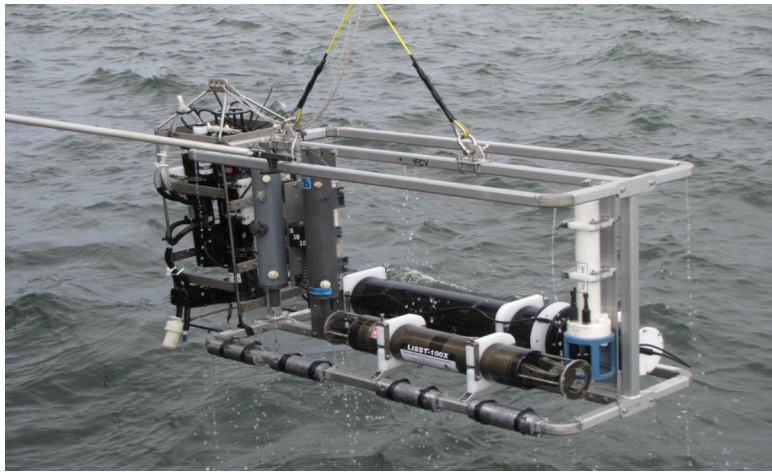


Figure 1. Particle and Optics Profiling package. *On the right is an RBR CTD (vertical white cylinder), a LISST-100x type B near forward scattering and particle sizing instrument (green cylinder) and behind it the Machine Vision Floc Camera (large horizontal black cylinder). Two Niskin bottles designed to collect water by automatically closing at 5 and 10 m are on the left (gray cylinders with white spouts). On the left is the Optical package which comprises a battery, a 10-cm-pathlength ac-9, a CDOM fluorometer, a SBE-37 CTD, and an automatic switch designed to make 0.2-um filtered measurements when the package is raised between 8 and 1.5 m.*

RELATED WORK

The in-situ measurements of particle size, beam attenuation (c_p), and settling velocity from this project are being combined with those from the another ONR funded project designed to explore methods for estimating particle density without collection of water samples. The efforts described here extend our work carried out in RIVET 1 in the New River Inlet. The two LISSTs used in this project were purchased with Canadian funds, one from a project on oil-mineral aggregation (NSERC, Hill) and one on particle transport away from finfish aquaculture sites (DFO, Law).

IMPACT/APPLICATIONS

This proposal seeks to improve our ability to assess and predict the distribution of optical properties in the coastal region. Such information is needed to assess underwater visibility of relevance to both diving operations and underwater communication.

HONORS/AWARDS/PRIZES

Paul Hill, Award for Excellence in Teaching, Faculty of Science, Dalhousie University