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Predicting Subsurface Optical Properties

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Abstract

In this paper we compare the 3-D optical field generated by the Predictive Visibility Model (PVM) with the results of *in situ* measurements of inherent optical properties obtained during the Hamlet's Cove I Experiment near the West Florida coast. Preliminary results are encouraging and show that the PVM can qualitatively predict the evolution of inherent optical properties in littoral waters.

1. Introduction

The prediction of inherent optical properties in littoral waters is critically dependent on the spatial and temporal distributions of optically significant constituents such as suspended sediment and biological populations. These distributions, in turn, depend on hydrodynamic transport in the coastal region and photosynthetically available radiation. In this paper we compare the 3-D optical field generated by the PVM, a computer model capable of predicting diurnal and episodic changes in near-coastal water optical properties, with the results of *in situ* measurements of inherent optical properties obtained during the Hamlet's Cove I Experiment in West Florida coastal waters. In the next section we give a brief description of gathering and processing of the experimental data, followed by an overview of the computer model and its predictive capabilities in section 3. Finally, we offer a few preliminary conclusions in section 4.

2. Experimental data

In situ data from the Hamlet's Cove I experiment were collected with two WETLabs Inc. 25 cm pathlength AC-9 beam transmissometers. These instruments collected beam absorption and attenuation data at nine wavelengths ranging from 412 nm to 715 nm. The first AC-9 was anchored as a moored unit at a depth of approximately 6.8 meters and distance of 50 meters from the shoreline. The second transmissometer was configured as a vertical profiling unit, and data was collected at nine stations transecting perpendicularly from the shoreline. The water depth ranged from 2 meters at the shallowest station to approximately 23 meters at the deepest.

The data from both instruments were post-processed according to an algorithm derived at the Naval Research Lab by Dr. A. Weidemann and T. Bowers [1], and approved by WETLabs, Inc. The data were first corrected for instrument drift by applying pertinent field calibrations. A correction was then applied to the near-infrared band to correct for differences in the instrument's initial calibration temperature and the water temperature at the time of the experiment. Next, the absorption measurements were corrected for scattering error with R. Zaneveld's formula [2]. This is necessary due to the instrument's inherent design which causes the data to be overstated. Pure water absorption values for each wavelength are then added to the data according to values calculated by Pope [3]. Pure water scattering values are considered negligible and were not included. The data were then separated into individual time steps and the Kriging approximation was used to create data suitable for surface generation and visualization.

Below are two examples representative of the type of experimental data accumulated at Hamlet's Cove and post-processed. Figure 1a is a plot of the absorption coefficient as a function of depth at station 7 for all nine wavelengths, while figure 1b is a similar plot for the scattering coefficient.

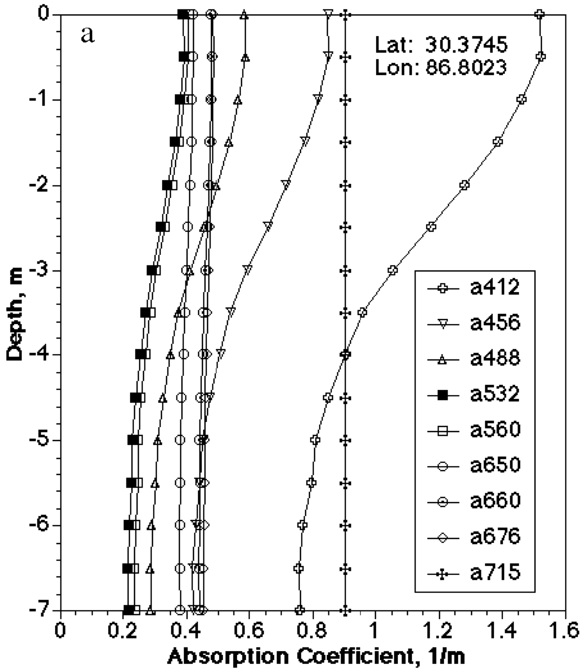

Figure1a:
Experimental values of absorption coefficient.

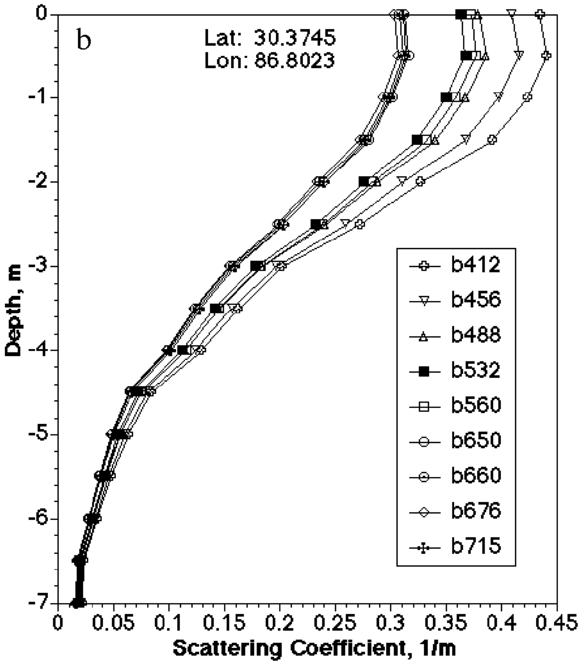

Figure 1b:
Experimental values of scattering coefficient.

Figures 1a and 1b illustrate the depth variation of measured inherent optical properties. Depth dependence is only one of the many predictive capabilities of the PVM. In the next section, the overall goal and purpose of the PVM is explained and we illustrate the temporal and spatial predictive capabilities of the PVM.

3. Predictive Visibility Model

The Predictive Visibility Model was jointly developed by Science Applications International Corp. and the Scripps Oceanographic Institution [4, 5] for the Office of Naval Research and the Naval Research Laboratory.

The PVM was designed to predict the optical properties of coastal waters from first principles using forecasts of waves, currents, river discharge, coastal geomorphology and land use. The model estimates the spatial and temporal distributions of environmental drivers required to predict subsurface scattering, absorption, and diffuse attenuation coefficients within a factor of two and also forecasts episodic changes of environmental significance. Such drivers include river discharge, tidal currents, ocean swell, bottom resuspension, plankton growth and episodic changes in storm related land runoff.

Optically important constituents in the PVM are presently limited to sediments, phytoplankton and colored dissolved organic materials. The spatial and temporal variability in the concentrations of each constituent is driven by mixing and advection in the dynamic coastal environment. Inherent optical properties of the water were calculated with the help of Mie scattering over particle size

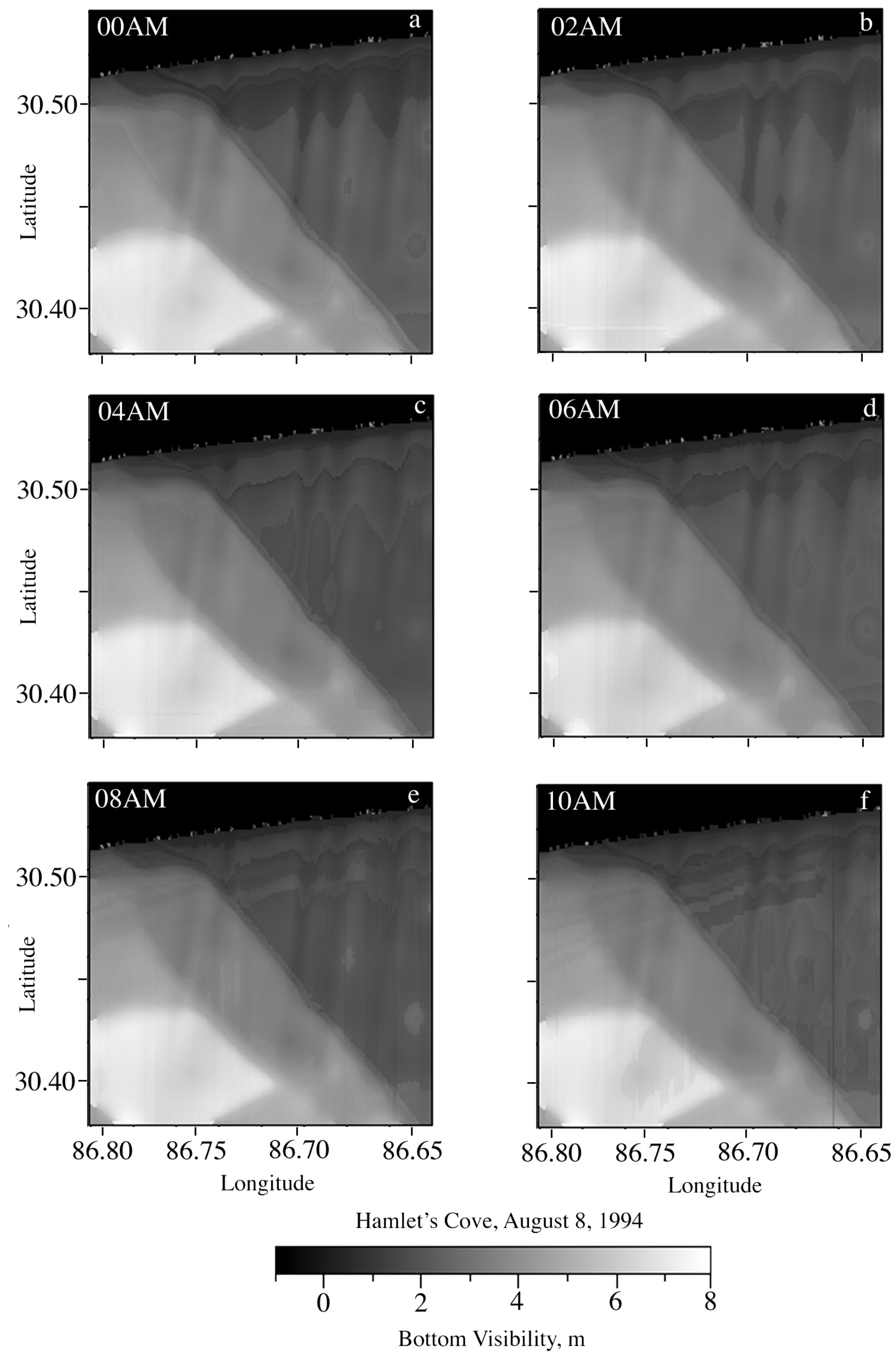

Fig. 2. Catalog of the PVM time-dependent bottom visibility for Hamlet's Cove.

distributions of each constituent. In calculations of scattering on sand and clay particles we used index of refraction data proposed in [6]. Visibility assessment was performed with the help of inherent optical properties. Estimation of the light fields was made according to [7].

A typical PVM run begins with an initialization. This step includes the generation of a 200 x 200, 3 arcsec resolution bathymetry grid, information about water elevation relative to mean sea level, offshore tidal current and direction for each 2-hour time step, and solar irradiance over the 24-hour simulation period. The other time-varying parameters such as cloud cover, air temperature, sea surface temperature, pressure and direction, sea height, swell period, direction and height, and offshore current velocity are linearly interpolated at each 2-hour time step between their nowcast and 24-hour forecast values.

For each time step, one of the outputs of the PVM is the 3D spatial variation of the inherent optical properties. In the PVM, visibility is defined as 3 divided by the total attenuation coefficient. In Figure 2 we present a catalog of the PVM bottom visibility predictions over 5 successive two-hour time steps, from midnight to 10 AM, for the Hamlet's Cove I area.

3. Conclusions

Because the Predictive Visibility Model incorporates the major environmental drivers responsible for the variability of inherent optical properties in littoral waters, it should be capable of predicting the concentrations of optically-important substances from the driving physical, chemical and biological forcing functions. Although it is not expected that the PVM predictions will be as accurate as those achievable for open ocean waters, predictions of inherent optical properties within a factor of two are foreseeable. Comparison with the collected data shows that, in spite of some discrepancies between prediction and ground truth fields, the PVM can be used for qualitative predictions and may serve as a basis for development of more robust predictive visibility models.

4. Acknowledgments

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