Proceedings of the Third ***International Airborne Remote Sensing Conference and Exhibition:***
Development, Integration, Applications & Operations, Vol. II, Copenhagen, Denmark
Publication by Environmental Research Institute of Michigan (ERIM), ISSN 1076-7924, 7-10 July 1997.

COMPARISON OF SIMULATED AND MEASURED OPTICAL PROPERTIES OF COASTAL WATERS IN THE HAMLET'S COVE EXPERIMENT*

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ABSTRACT

In this paper we compare the three-dimensional 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.

1.0 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 some of the characteristics of the three-dimensional (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 some 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 the gathering and processing of the experimental data, followed by a general overview of the computer model and its predictive capabilities in section 3. Finally, we offer a few preliminary conclusions in section 4.

2.0 EXPERIMENTAL DATA

In-situ data from the Hamlet's Cove I experiment were collected with two WETLabs Inc. 25 *cm* path length AC-9 absorption-attenuation meters. These instruments collected beam absorption and attenuation data at nine wavelengths ranging from 412 *nm* to 715 *nm*. The first AC-9 was moored at a depth of approximately 6.8 meters and distance of 50 meters from the shoreline. The second meter was configured as a vertical profiling package, 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 15 meters at the deepest. Included in the profiling package was a conductivity, temperature, and depth sensor to collect depth and temperature data used for post-processing. The data from both instruments were post-processed according to an algorithm derived at the Naval Research Laboratory (NRL) by A. Weidemann and T. Bowers (1996) and approved by WETLabs, Inc.

Careful review of the collected data in the laboratory revealed that the first three blue channels

* Presented at the Third International Airborne Remote Sensing Conference and Exhibition, 7-10 July 1997, Copenhagen, Denmark.

(412 *nm*, 456 *nm*, and 488 *nm*) of the absorption data were reading higher than expected. After discussion with the manufacturer, a fixed offset was derived and applied to each channel to correct the measurements. Then the data were corrected for instrument drift by applying pertinent field calibrations. A correction was then applied to the near-infrared band to account 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 errors with R. Zaneveld's (1994) formula. This is necessary due to the instrument's inherent design which causes the data to be overstated. Pure water absorption values for each wavelength, according to the values published by Pope and Fry (1997), are then added to the data. Pure water scattering values are considered negligible and were not included. The data were then binned at 0.5 meter depth intervals, separated into individual time steps, and the Kriging approximation, a method of interpolating scattered data points to an evenly meshed grid, was used to create data suitable for surface generation and visualization.

The *in-situ* data reveals that absorption processes dominate the near-shore stations with a bottom depth of approximately 4 meters or less. This includes the stations that are on top of and inside of the sand bar which lays parallel to the shore. Mixing is intense in this shallow water area, and temporally dense profiles can exhibit wide variability in both structure and magnitude. Outside of these stations, absorption can still drive the surface optics of the water mass, but scattering effects are more pronounced and the single scattering albedo generally increases with depth. Structure and magnitude are still somewhat variable with time, but to a much lesser extent than in the near-shore samples.

Below are two examples representative of the type of experimental data accumulated at Hamlet's Cove and post-processed. Figure 1 is a plot of the absorption and scattering coefficients for 532 *nm* as a function of depth at stations 7 and 10 (filled symbols). The simulated PVM values of the absorption and scattering coefficients over 3 depth layers are shown with the open symbols. It can be seen that there is good qualitative, as well as fair quantitative, agreement between the PVM and experimental data, even though the PVM is presently limited to 3 depth layers. Future allowance of more depth layers should increase the accuracy of the PVM.

Figure 1 illustrates 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. 0 PREDICTIVE VISIBILITY MODEL

The Predictive Visibility Model was developed by Science Applications International Corp. in cooperation with the Scripps Oceanographic Institution (Hammond, Jenkins, Cleveland *et. al.*, 1995, Jenkins, Wasyl, Hammond, 1996) for the Office of Naval Research and the NRL.

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 (Wiscombe, 1979, 1980) over particle size distributions of each constituent. In calculations of scattering on sand and clay particles we used index of refraction data proposed by McBride, Haltrin, Kennedy, and

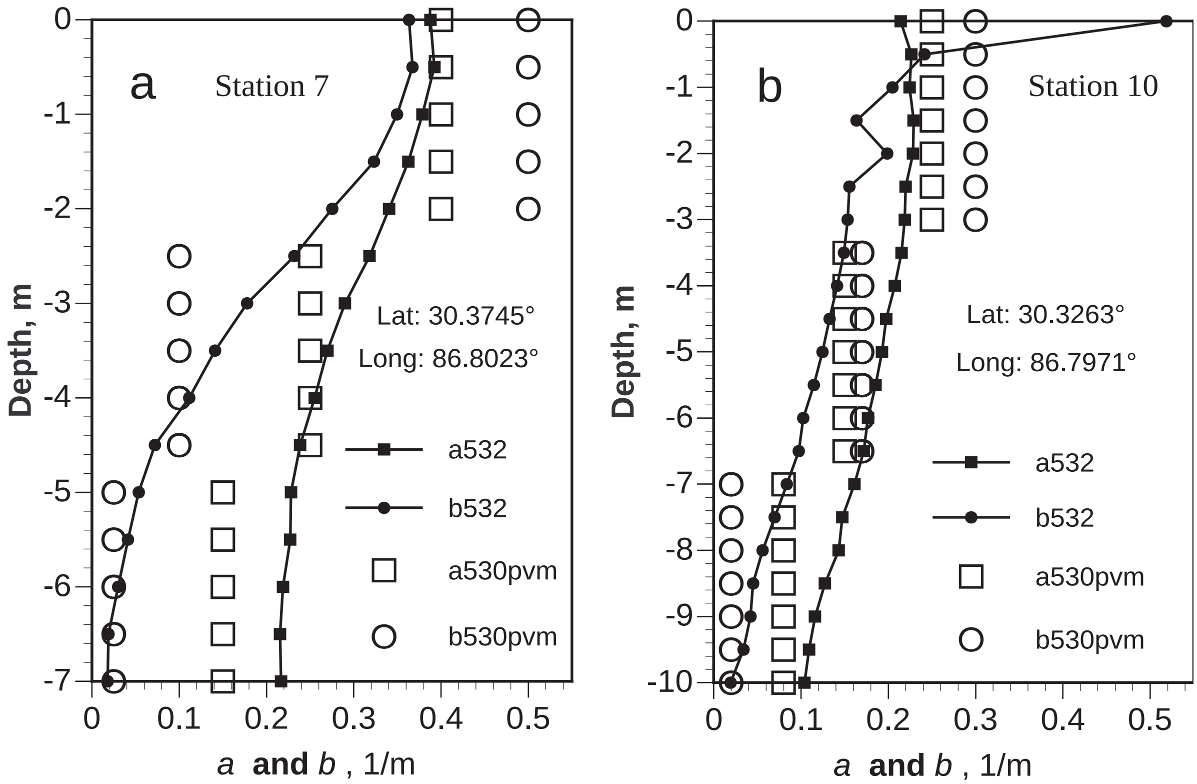

Figure 1. Experimental and simulated values of absorption and scattering coefficients at two stations at Hamlet's Cove polygon.

Weidemann (1997). Visibility assessment was performed with the help of inherent optical properties. Estimation of the light fields was made with the coastal water approaches published in Haltrin and Kattawar (1993), Haltrin and Weidemann (1996), and Haltrin (1997).

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, which typically takes about 15 minutes to run on a SUN ULTRASPARC station, one of the outputs of the PVM is the three-dimensional spatial variation of the inherent optical properties. In the PVM, visibility is defined as $3/c$ where c is the total beam attenuation coefficient.

In Figures 2a and 2b we present a catalog of the PVM bottom visibility predictions over 5 successive two-hour time steps, from midnight (08.00) to 10 AM on August 8, 1994 (08.10), for the Hamlet's Cove I area. Figures 3a and 3b show the final stages of the simulation from 10 PM (08.22) on August 8 to 8AM on August 9, 1994 (09.08). The color palette used in the PVM (Figs. 2a and 3a) does not show much variation between time steps due to its gradual change over the minimum and maximum values. In an attempt to discern the more minute changes between time steps, we transported the PVM files to a Mac, experimented with different palettes, and settled on grey-scale and grey-scale banded palettes. The reader can now clearly see the intricate fine structure inherent in the hydrodynamic mixing with the help of the grey-scale banded palette used in Figs. 2b and 3b. In all figures, the upper black triangular region is the land mass near the shore.

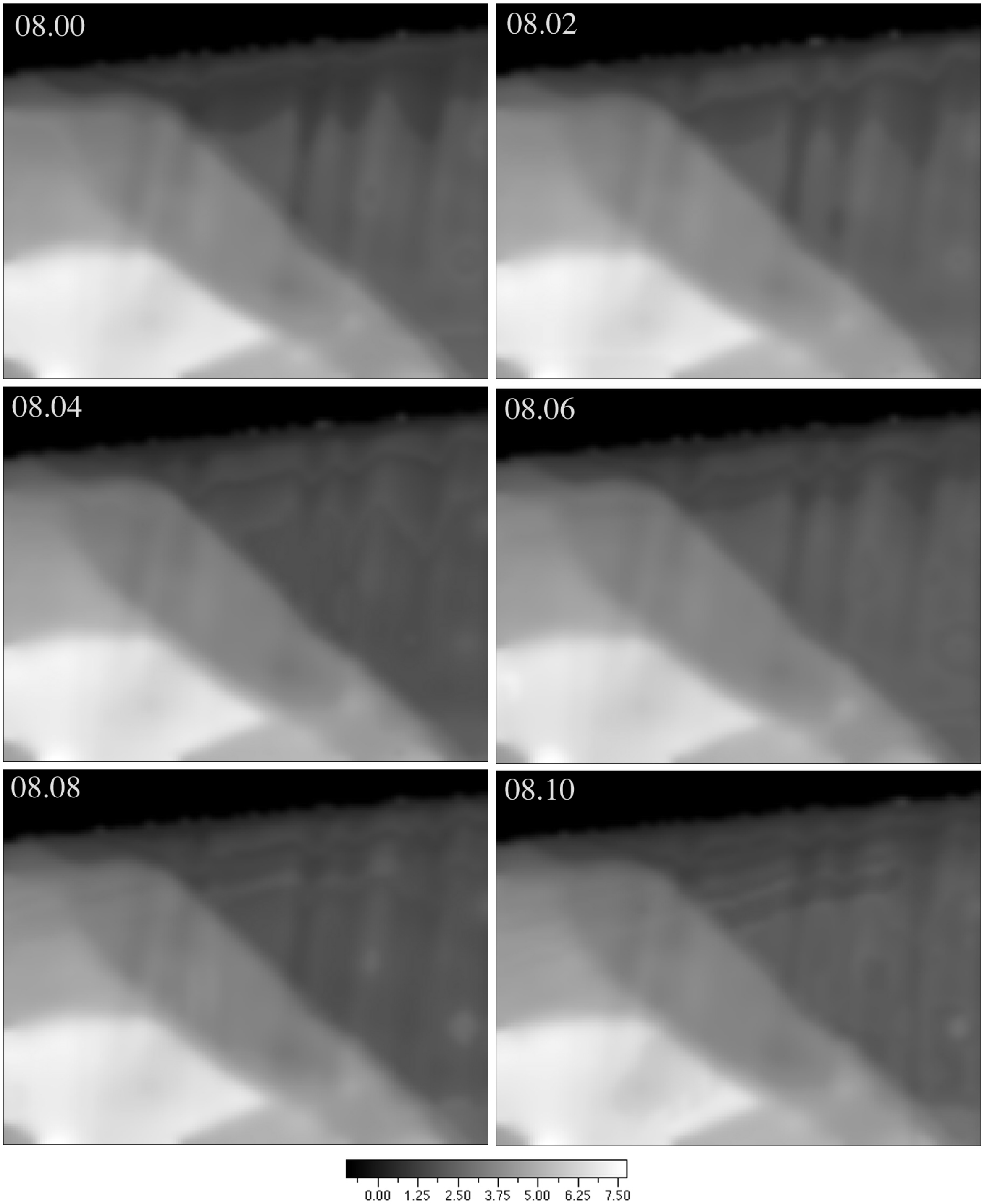

Fig. 2a. Catalog of the PVM time-dependent bottom visibility for Hamlet's Cove area in August 8 1994 in time steps starting from the midnight (08.00) to 10PM (08.10). The displayed areas lie between 30.375 and 30.55 degrees of W Latitude and 86.5 and 86.88 of N Longitude.

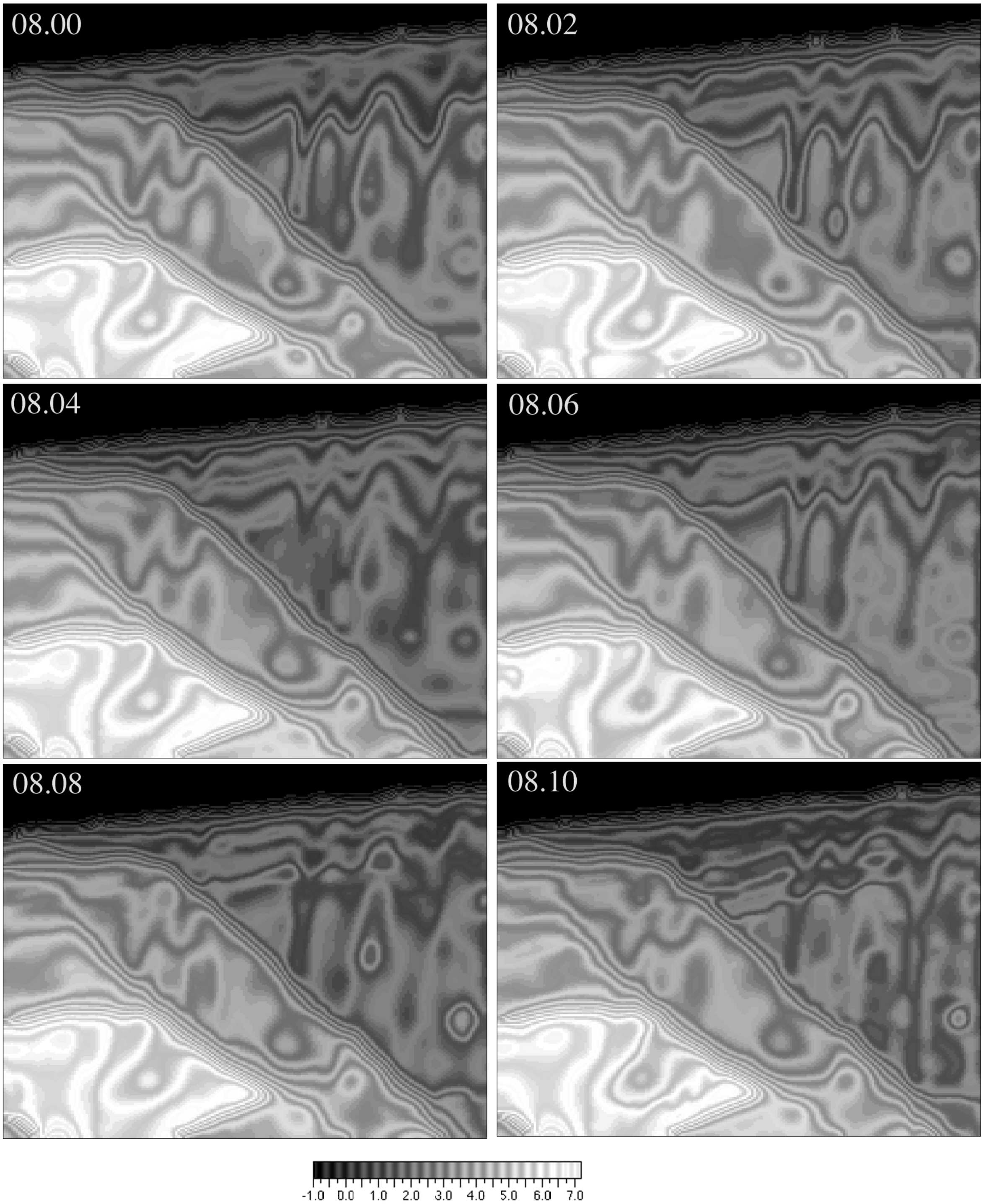

Fig. 2b. The same as Fig. 2a only plotted with the grey-scale banded palette that allows to see the changes in the fine structure of the bottom visibility field.

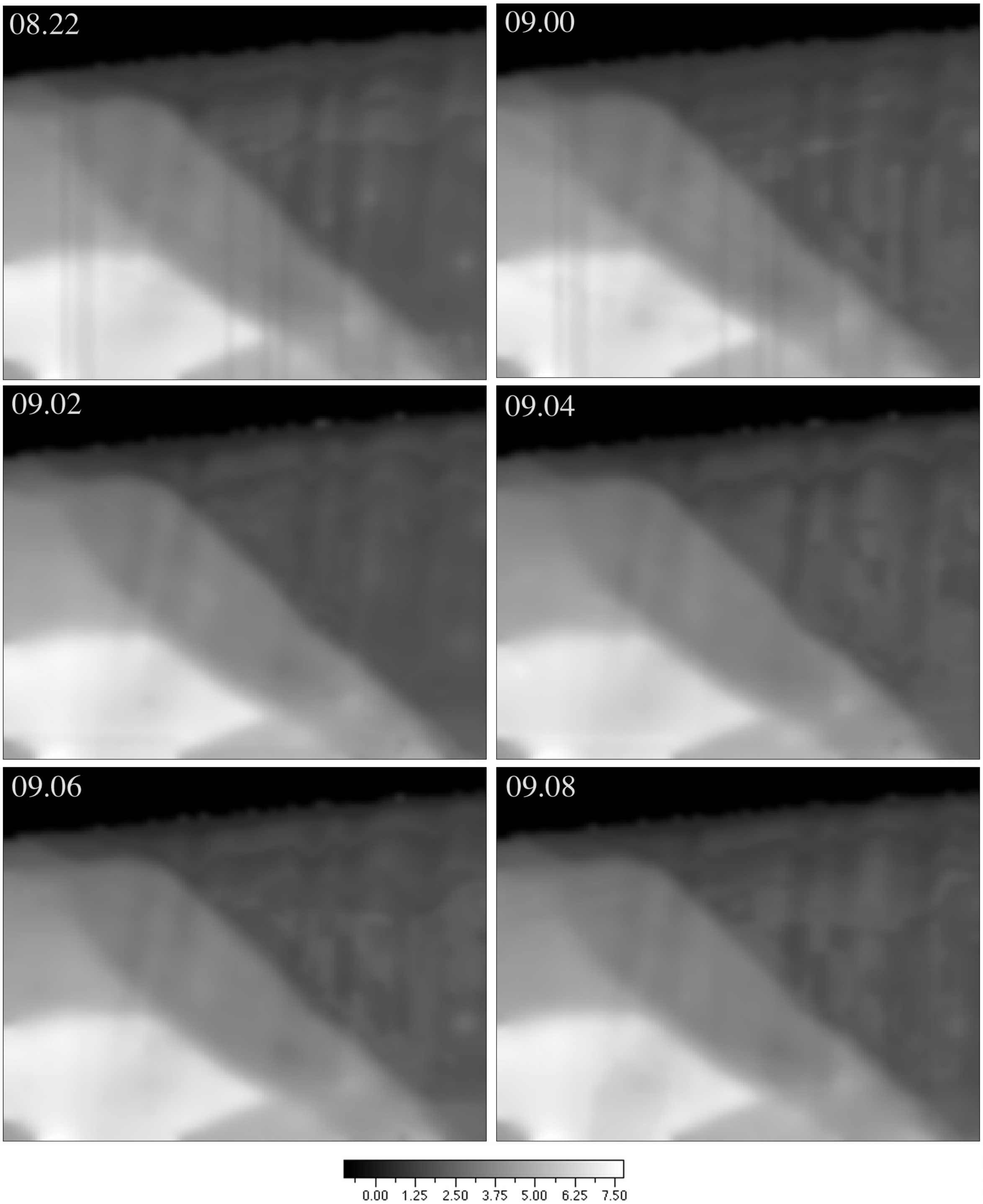

Fig. 3a. Catalog of the PVM time-dependent bottom visibility for Hamlet's Cove area in time steps between 10PM (08.22) August 8 and 08AM August 9 1994 (09.08). The displayed areas lie between 30.375 and 30.55 degrees of W Latitude and 86.5 and 86.88 of N Longitude.

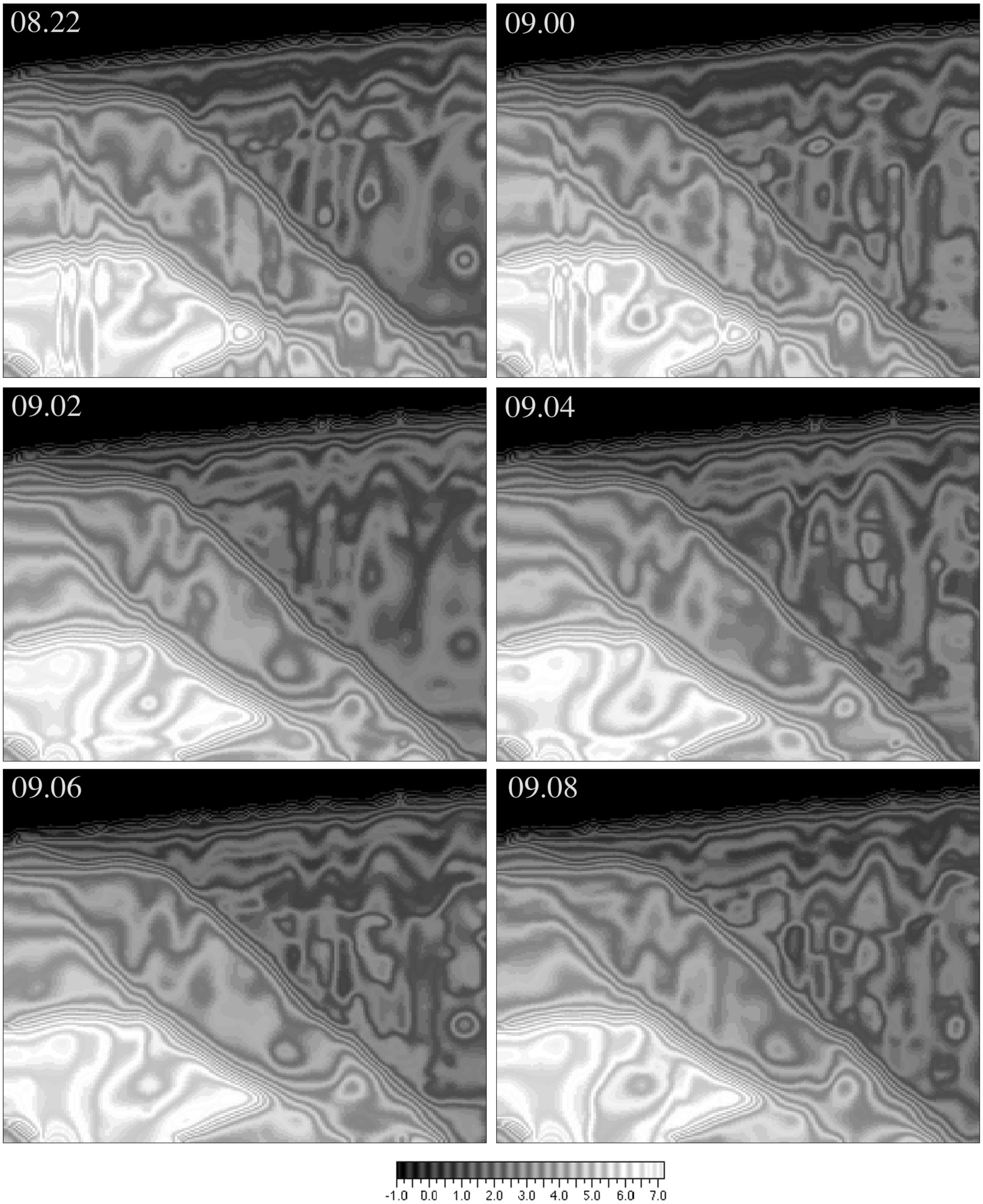

Fig. 3b. The same as Fig. 3a only plotted with the grey-scale banded palette that allows to see the changes in the fine structure of the bottom visibility field.

3.0 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 some of 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.

4.0 ACKNOWLEDGMENTS

The authors thank continuing support at the Naval Research Laboratory through the Littoral Optical Environment (LOE 6640-07) and Optical Oceanography (OO 73-5051-07) programs. This article represents NRL contribution NRL/PP/7331–97–0015.

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