Estimating Sea Surface Salinity in the Chesapeake Bay From Ocean Color Radiometry Measurements

Christopher W. Brown[1] and Ronald L. Vogel[2]

[1] NOAA/NESDIS Center for Satellite Applications and Research, Satellite Climate Studies Branch, College Park, MD, 20740, U.S.A.

[2] NOAA/NESDIS Center for Satellite Applications and Research, SM Resources Corporation, College Park, MD, 20740, U.S.A.

Abstract

Sea-surface salinity (SSS) is a critical factor in understanding and predicting both physical and biological processes in the coastal ocean. Unfortunately, SSS cannot be currently estimated in estuarine waters at the temporal and spatial resolution required for many applications. To overcome the limitations of deriving SSS from microwave satellite measurements in these coastal waters and assess the likelihood of using satellite-retrievals to improve model forecasts of SSS through data assimilation, we implemented an experimental Artificial Neural Network (ANN) to retrieve SSS from MODIS ocean color radiometry (OCR) measurements and evaluated these retrievals, as well as model predictions of SSS, against in situ observations. A latitudinally dependent bias was observed in OCR-SSS retrievals in the Chesapeake Bay, with highest positive bias in the northern portion of the Bay that generally decreased to a negative bias at the mouth. This bias is likely due to the application of the ANN to waters outside of the salinity range for which it was trained. The root mean square error and bias of the SSS predicted by the Chesapeake Bay Operational Forecast System (CBOFS) model were both lower than OCR-SSS retrievals at all match-up locations. Given this result, assimilation of OCR-SSS retrievals estimated using the present ANN into CBOFS will not improve model forecasts of SSS in the Chesapeake Bay.

Introduction

Sea-surface salinity (SSS) is a critical factor in understanding and predicting physical and biological processes in the coastal ocean. Unfortunately, generating synoptic maps of it with sufficient quality and resolution in a timely manner is difficult. *In situ* measurements, such as from buoys, are often spatially restricted. SSS estimated from aerial surveys are not available in a routine and timely manner, and those derived from satellite microwave measurements are too coarse. SSS predicted from hydrodynamic models, though routine and timely, are often inaccurate and would benefit from routine updates through data assimilation. Recent algorithms using satellite ocean color radiometry (OCR) measurements, based upon the general inverse relationship between salinity and the absorption of light by colored dissolved organic matter, are promising and could provide medium spatial resolution (~ 1 km) estimates of SSS at daily increments (Fig. 1) once validated. ***The objective of this study is to compare the OCR estimates of sea-surface salinity to*** **in situ** ***observations and model predictions.***

Methods & Materials

- Sea-surface salinity derived from satellite ocean color radiometry measurements were compared to contemporaneous observations of surface salinity measured at five buoys of the Chesapeake Bay Interpretive Buoy System (CBIBS) (Fig. 2) and predictions generated by the Chesapeake Bay Operational Forecasting System (CBOFS) from April 2011 to May 2012. CBOFS is NOAA's current operational hydrodynamic model for the Chesapeake Bay.
- OCR-SSS was derived using the artificial neural network (ANN) constructed by Geiger et al., (2012) for the Chesapeake Bay from MODIS-Aqua ocean color radiometry data. The predictor variables include remote sensing reflectances (Rrs) or their ratios at 412nm, 443nm, 412/547, 443/547, 488/547, as well as longitude, latitude, and sea-surface temperature (SST).
- CBIBS surface salinity observations were matched to OCR-SSS estimates from satellite overpasses acquired within 2 hours of buoy measurement

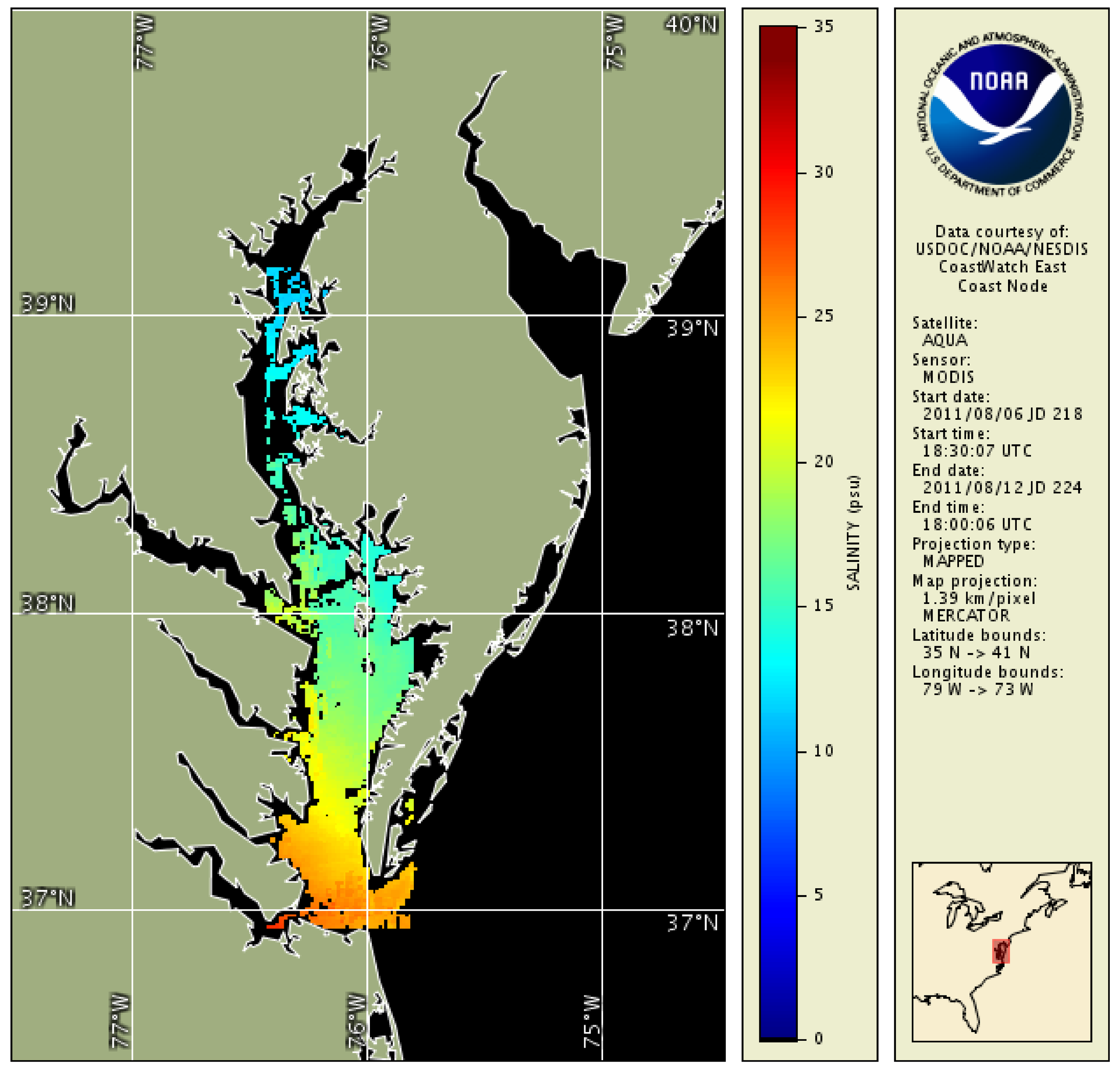

Figure 1. Example of weekly composites of MODIS – Aqua retrieved sea-surface salinity.

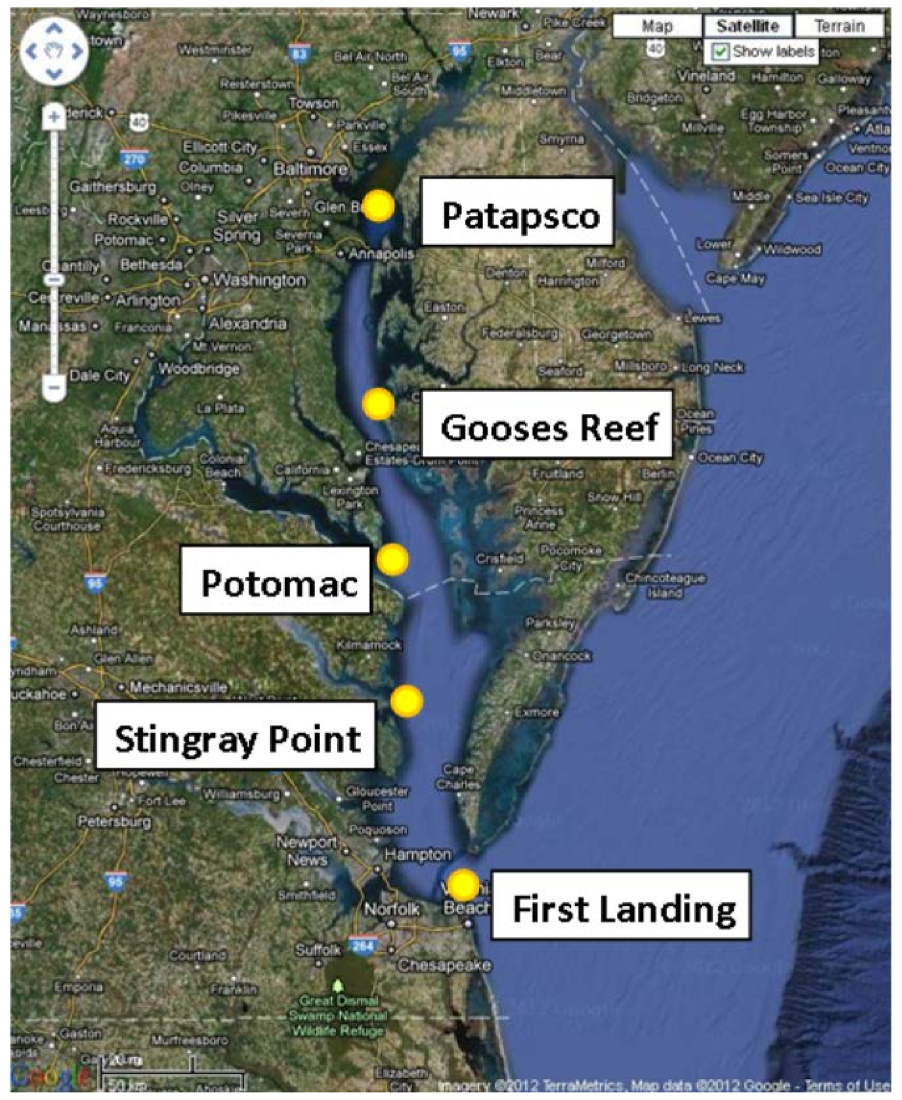

Figure 2. Locations of five Chesapeake Bay Interpretive Buoy System (CBIBS) buoys used in validating MODIS-Aqua retrievals of sea-surface salinity.

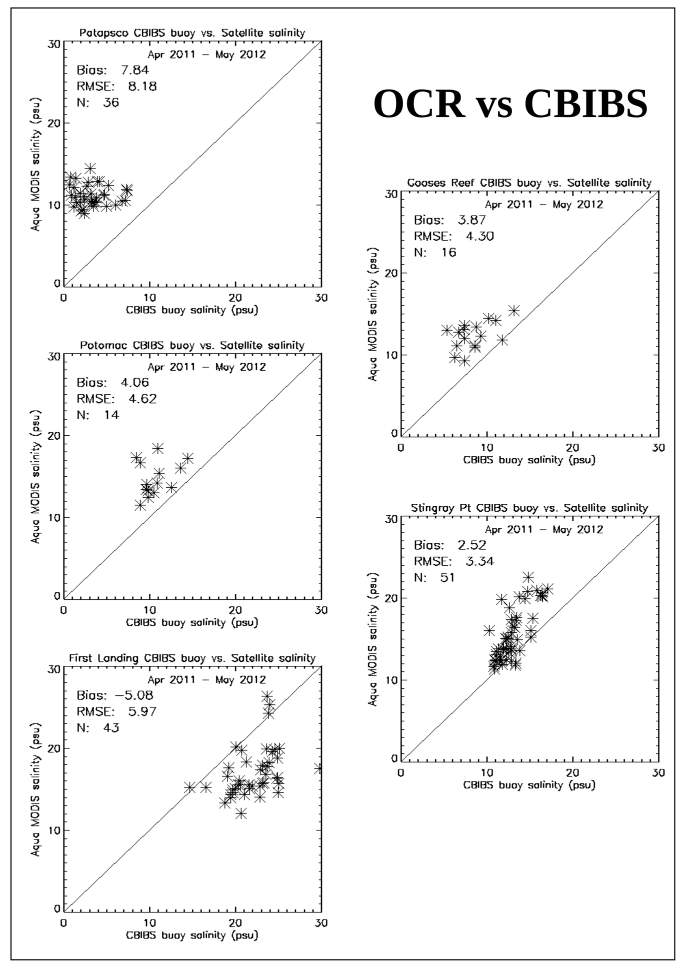

Figure 3. Scatter plots of MODIS-Aqua OCR-derived SSS and SSS observed from April 2011 to May 2012 at each of the five Chesapeake Bay Interpretive Buoy System (CBIBS) buoys used in this study. Plots are arranged corresponding to their north to south geographic position in the Bay.

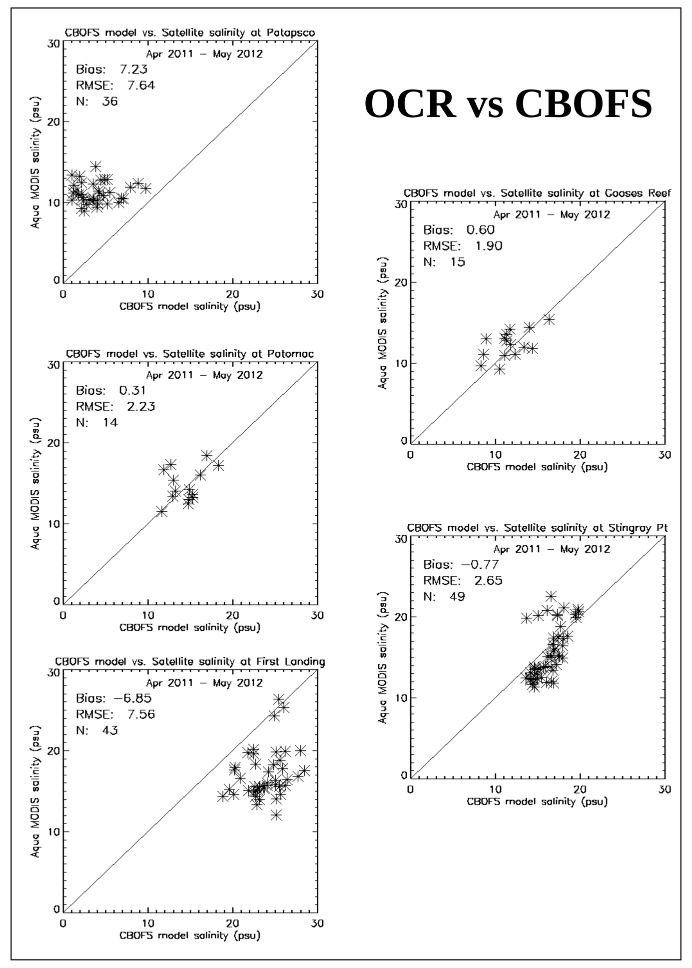

Figure 4. Scatter plots of MODIS-Aqua OCR-derived SSS and Chesapeake Bay Operational Forecasting System (CBOFS) SSS predictions from April 2011 to May 2012 at each of the five CBIBS) buoy locations. Plots are arranged as in Fig. 3.

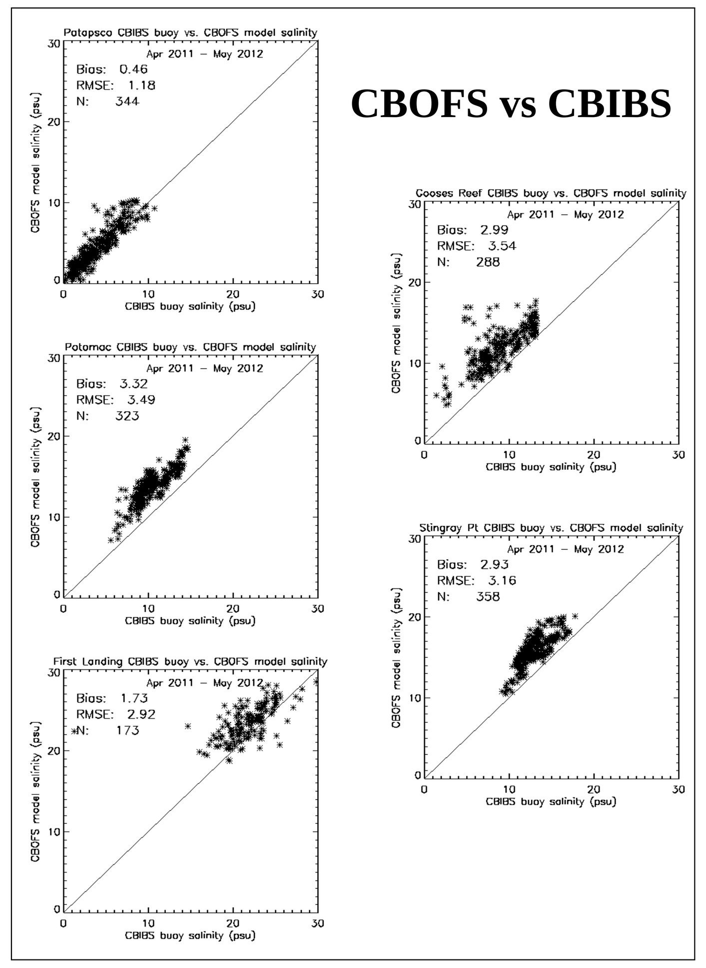

Figure 5. Scatter plots of CBOFS modeled SSS and SSS observed from April 2011 to May 2012 at each of the five CBIBS) buoys. Plots are arranged as in Figure 3.

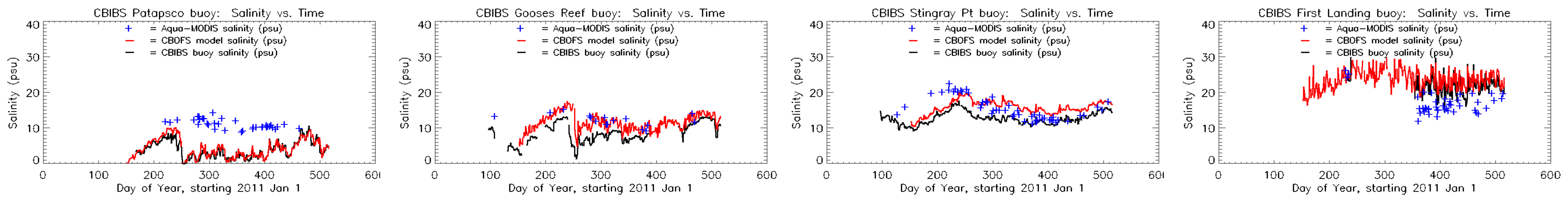

Figure 6. Time-series plots of SSS derived from MODIS-Aqua reflectances (blue cross), the Chesapeake Bay Operational Forecasting System (CBOFS) model (red line), and in-situ observations from April 2011 to May 2012 at four of the five Chesapeake Bay Interpretive Buoy System (CBIBS) buoys used in this study. Plots are arranged on the page left to right corresponding to their north to south geographic position in the Chesapeake Bay.

Results

Error of Satellite OCR-derived Sea-Surface Salinity

RMSE and bias for coincident match-ups of OCR-SSS and SSS measured at the five CBIBS locations ranged from 3.34 to 8.18 psu and -5.08 to 7.84 psu, respectively, with highest errors at the northern (Patapsco) and southernmost buoy (First Landing) buoys. Retrievals from mid-and upper portion of the Bay (Potomac to Patapsco buoys) overestimated SSS and the one near the mouth (First Landing) underestimated it (Fig. 3). This error appears to decrease in some locations, such as Goose Reef and Stingray Point, starting in late 2011 (Fig. 6).

Comparison of Satellite OCR- and CBOFS Sea-Surface Salinity

As observed with the in-situ observations, OCR-derived SSS were higher than the CBOFS predicted SSS at the northernmost CBIBS buoy location and lower at the southernmost buoy location, with similar RMS errors and biases to the OCR - CBIBS SSS matchups at these locations (Fig. 4). The satellite retrievals and model predictions, however, were comparable at the middle three buoy locations. The CBOFS SSS predictions did not appear to change over time as the OCR-SSS retrievals did, with the possible exception with those nowcast for Gooses Reef (Fig. 6).

Error of CBOFS Sea-Surface Salinity Nowcasts

CBOFS model SSS closely matched buoy salinity at the most northern, freshest buoy (Patapsco) but were positively biased at the remaining buoys (Figs. 5, 6). RMSE and bias were lower for CBOFS SSS nowcasts than OCR-SSS at all buoy locations. The large decrease in salinity at the Patapsco, Gooses Reef, and Potomac (not shown) buoys in September 2011 (day 255 on x-axis) was due to the precipitation and river outflow associated with Tropical Storm Lee (Fig. 4).

Discussion

The retrieval of accurate SSS estimates from satellite OCR measurements would provide observations that permit the regular monitoring of this important variable at synoptic scales in the coastal ocean and consequently lead to a better understanding and prediction of abiotic and biotic processes in these waters. Unfortunately, the error associated with the OCR-SSS retrievals is spatially dependent in Chesapeake Bay, with an apparent temporal component in some locations.

The latitudinally dependent bias, in which retrievals overestimated SSS in the fresh, northern portion of the Chesapeake Bay and underestimated it the salty, southern region, is likely due to the extrapolation of the ANN outside its trained variable space. The ANN was trained using SSS ranging from brackish to relatively high salinity waters (9.58 to 32.71 psu). Comparison with coincident SSS retrievals generated using a statistical approach that was constructed with a greater range of salinities, such as the Generalized Additive Model recently developed for the Chesapeake Bay by Urquhart et al. (2012), may help determine if the bias problem, at least in lower salinity waters, is due to extrapolation by the current ANN.

Given that the CBOFS-predicted SSS were more accurate than OCR-SSS retrievals in this study (Figs. 5), data assimilation of the satellite-retrievals generated by the present ANN would not generally improve model forecasts of SSS.

Literature Cited

Geiger, E.R., Grossi, M.D., Trembanis, A.C., Kohut, J.T., and Oliver, M.J., 2012. Satellite-derived coastal ocean and estuarine salinity in the Mid-Atlantic. Continental Shelf Research. doi:10.1016/j.csr.2011.12.001.

Urquhart, E, A., Zaitchik, B. F., Hoffman, J. J., Guikema, S. G., Geiger, E. F. (2012). Remotely sensed estimates of surface salinity in the Chesapeake Bay: A statistical approach. Submitted to Remote Sensing of Environment.

Acknowledgements

This study was funded in part by the NOAA Satellite Ocean Remote Sensing program and by the Center for Satellite Applications & Research. The views, opinions, and findings contained in this report are those of the author(s) and should not be construed as an official National Oceanic and Atmospheric Administration or U.S. Government position, policy, or decision.