Development of an Algorithm to Predict Salinity in the Mobile Bay and Mississippi Sound Region

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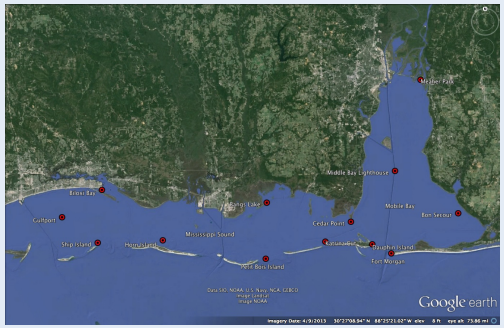
Introduction

Mobile Bay is a dynamic estuary on the Gulf coast of Alabama that is home to several endemic species. Salinity is a variable that determines species habitat and affects dissolved oxygen content.[1] Colored dissolved organic matter (CDOM) has shown to have an inverse relationship with salinity in estuarine environments.[1] Before NASA's launch of the Aquarius satellite, there was no way to directly measure ocean salinity levels remotely. Aquarius now provides salinity levels across global ocean but its spatial resolution limits its use in coastal areas and estuaries. By using moderate resolution imaging radiospectrometer (MODIS) surface reflectance band ratios from NASA's Aqua satellite, models were developed and validated to predict salinity using in situ salinity and MODIS data gathered in the Summers of 2011, 2012, and 2013.

Study Area



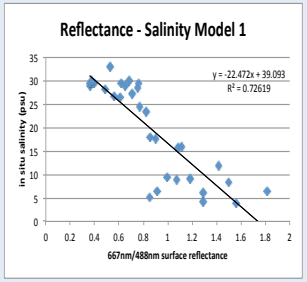
This Google Earth image shows the extent of the study area. It ranges from Mobile Bay, Alabama to near Gulfport, Mississippi and the Mississippi Sound. The red points are locations where in situ salinity and Aqua MODIS surface reflectance measurements were evaluated.

Data and Methods

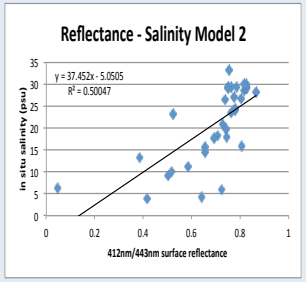
- In situ salinity data were obtained for the estuarine study area from the Mobile Bay National Estuary Program, Grand Bay National Estuarine Research Reserve, USGS, and Dauphin Island Sea Lab for the summer months of 2011, 2012, and 2013.
- Aqua MODIS level 2 ocean color data were obtained for the summer months of 2011, 2012, and 2013 from the Goddard Space Flight Center's ocean color website and was processed using the SeaWiFS Data Analysis System (SeaDAS 7).
- The in situ salinity data were paired with the MODIS ocean color satellite data in a geographic information system and was exported into a spreadsheet for model development.
- Numerous MODIS reflectance band ratio models were developed using remotely sensed and in situ data for 2011 and 2012 and the best model was validated using 2013 salinity data.

Model Development Results

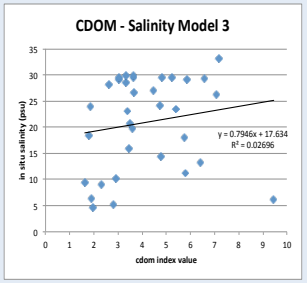
Model 1 demonstrated the best ability to predict salinity using MODIS surface reflectance with $R^2 = 0.73$. This proves a strong correlation exists between some MODIS surface reflectance bands and salinity in the study area. Model 2 was the second best performer with $R^2 = 0.50$. Models 3 and 4 use a CDOM index value from MODIS surface reflectance band ratios to estimate salinity.[1,2] Model 3 showed no correlation ($R^2 = 0.02$) and Model 4 displayed very weak correlation ($R^2 = 0.32$). The determination is that no significant relationship exists between in situ salinity and the CDOM index in the Mobile Bay and Mississippi Sound geographic region.



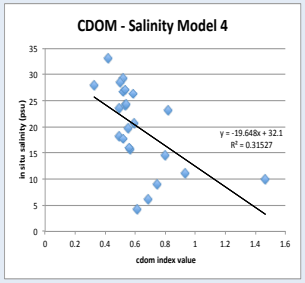
The model with the best predictive ability using MODIS surface reflectance in the Mobile Bay case waters. $df = 42$, $F_{42} = 93.78$, p-value = 0.000



The next best model using MODIS surface reflectance to predict salinity. $df = 42$, $F_{42} = 33.06$, p-value = 0.28



This algorithm (412nm/443nm minus 490nm/555nm) was used to evaluate MODIS derived CDOM with in situ salinity. No significant relationship was found between the two variables.



This algorithm ln(488nm/555nm) was also used to evaluate MODIS derived CDOM with in situ salinity. Weak correlation was discovered between the two variables.

Model Validation

Model 1 was chosen for validation using 2013 in situ salinity data. The low error values, high r and R^2_{NS} values suggest model 1 is well suited for predicting salinity in this area.

- Mean Error = -0.0005
- Root Mean Square Error = 0.0697
- Mean Absolute Error = 0.0112
- Pearson's Coefficient (r) = 0.8341
- Nash-Sutcliffe Efficiency Statistic (R^2_{NS}) = 0.9308

Conclusions

Model 1 successfully demonstrated the ability to predict salinity using selected MODIS surface reflectance bands in the northern Gulf of Mexico. Utilizing model 1 in this geographic area, scientists and researchers can estimate salinity using remotely sensed surface reflectance data where in situ salinity data is unavailable. This is important in researching a variety of environmental issues such as: salinity specific diseases, estuarine stratification, habitat suitability, and climate change.[3] While model 2 is not statistically significant, it could still be useful if there is a gap in MODIS data in either wavelength in model 1. High stratification of the estuary could be the cause of the poor performance of models 3 and 4. Future work using a larger sample size across a longer time frame could strengthen the R^2 values in the salinity models.

The northern shore of Fort Morgan, AL

Water quality sampling at Fort Morgan, AL

Recording water quality variables at Fort Morgan, AL

At left is the Boston Whaler research vessel provided by the Dauphin Island Sea Lab

Acknowledgements

Special consideration goes to NASA and Dale Quattrochi for the opportunity to participate in this summer internship program, the National Space Grant Foundation for funding the internship, Maury Estes for the help retrieving the salinity and MODIS data and the field trip to Mobile Bay, Mohammad Al-Hamdan for your statistical, ESRI ArcMap 10, and Microsoft Excel expertise, and Dr. Sally Horn for your encouragement and sponsorship.

[1]Morel, A., & Gentili, B. (2009). A simple band ratio technique to quantify the colored dissolved and detrital organic material from ocean color remotely sensed data. *Remote Sensing of Environment, 113*(6), 998-1011. doi: 10.1016/j.rse2009.01.008.
[2]Tehrani, N., D'Sa, E., Osburn, C., Bianchi, T., & Schaeffer, B. (2013). Chromophoric dissolved organic matter and dissolved organic carbon from sea-viewing wide field-of-view sensor (seawifs), moderate resolution imaging spectroradiometer (modis) and meris sensors: Case study for the northern gulf of México. *Remote Sensing, 5*(3), 1439-1464. doi: 10.3390.
[3]Ohrel, Jr., R., & Register, K. U.S. Environmental Protection Agency. (2006). *Volunteer estuary monitoring: A methods manual*