Remote Sensing of Turbidity and Water Clarity along the North Carolina Coast with the use of SeaWiFS Data

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***Abstract*-Turbidity can be defined as the cloudiness of water, caused by suspended materials. The greater the amount of total suspended solids in the water, the higher the measured turbidity. Causes of turbidity include soil erosion, waste discharge, urban runoff, and algal growth.**

Highly turbid ocean waters are those with a large number of scattering particulates in them. In both highly absorbing and highly scattering waters, visibility into the water is reduced. The highly turbid water still reflects light while the highly absorbing water is very dark. The scattering particles that cause the water to be turbid can be composed of many things, including sediments and phytoplankton.

The fishing industry is dependent upon knowledge of small variations in water temperature and visibility. In addition, high levels of turbidity over long periods of time can greatly diminish the health and productivity of the estuarine ecosystem. Turbid waters decrease light penetration into the water, thereby reducing the area available for submerged aquatic plants to grow. As turbidity increases, water loses its ability to support diverse aquatic organisms. Turbidity also warms water by absorbing heat, blocks photosynthesis, irritates and clogs gills of fish, and decreases visibility for predators and prey.

The frequency and extent of turbidity events along the North Carolina coastline will be studied. SeaWiFS Ocean Color data will be utilized to generate secchi disk depth estimates to study water clarity and for analysis of turbidity events. Earth 2.2 and TeraVision will be used for processing and analyzing data. SeaWiFS datasets will be provided by the Center of Excellence in Remote Sensing Research and Education (CERSER), located on the campus of Elizabeth City State University.

I. Introduction

It is possible to define turbidity as the cloudiness of water, which can be caused by suspended sediments in the water. These sediments include but are not limited to dirt, residue, excessive algal growth, phytoplankton, clays and silts. Turbidity can also be caused by land run-off, pollution, dredging operations, shoreline erosion, and the re-suspension of bottom sediments [1]. Water clarity and turbidity have a major effect on our ecosystem. Turbidity may very well be composed of inorganic and/or organic components that may harbor high concentrations of viruses, protozoans, and bacteria [1]. These components greatly increase the possibility for waterborne disease.

The aspect that this research focuses on is the effect of turbidity on the fishing industry. As a result of fishing being a major part of our capital, it is important that its relationship with turbidity be understood as well as researched from new angles. If the turbidity levels are high then the water clarity lessens. Not only is the water clarity affected, but the organisms that thrive in these areas are affected as well [1]. The murkier the water, the less amount of light is able to pass through, therefore decreasing the rate of photosynthesis and the amount of oxygen in the water.

Water clarity and turbidity levels are normally measured during ground-truthing using a secchi disk. A secchi disk is a "circular plate divided into quarters painted alternately black and white." To measure the turbidity, the disk is submerged into the water until it is no longer visible. High secchi readings indicate clearer water in that more rope had to be let out before the rope was no longer visible. Lower readings indicate turbid areas.

Figure 1.1
Secchi Disk

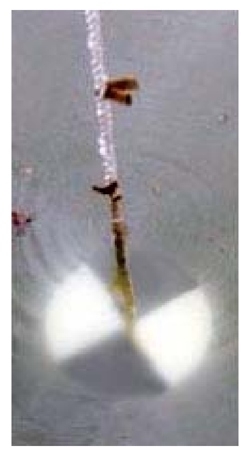

Figure 1.2
Partially submerged secchi disk

This research is also important as well as relevant in that remote sensing capabilities were used in order to pinpoint levels of turbidity and water clarity along the North Carolina coast during 2003 and 2004.

II. Review of Literature

Remote Sensing Techniques for Determining Water Quality: Applications to TMDLs

Jerry C. Ritchie and Charles M. Cooper published an article about techniques for determining water quality and applications to TMDLs. Remote sensing is a technique that is used to determine key factors in defining TMDLs. Whether on aircraft or satellites, thermal and optical sensors provide the necessary information in understanding how water quality changes and how to improve these changes. Some of the water quality parameters discussed in this article were suspended sediments (turbidity), chlorophyll, and temperature. The three parameters just named are the key factors in defining the nature of TMDLs.

A large number of water bodies all over America are polluted, and 40% of these water bodies do not meet the minimum water quality standards [4]. To resolve this problem legislative authority will take action in restoring the polluted waters so that it is clean enough to fish and swim in again. The Clean Water Act, which will assist the government in this problem, is able to provide these significant improvements.

As the article goes on, Ritchie and Cooper state that the purpose of the paper is how remote sensing techniques can be used for identifying the quality of surface waters for Total Maximum Daily Loads (TMDLs) and also how to monitor the effectiveness of clean-up programs [3]. In the background section of the article, TMDLs are explained as the "attempts to define water quality in general terms of the physical, chemical, thermal, and/or, biological properties of water" [4]. It also says "a TMDL is the calculated amount of potential pollutant which will not impair the ecological integrity of a water body" [4].

The major pollutants that are affecting major water bodies are suspended sediments, pathogens, dissolved organic matter, etc. These pollutants require the TMDL correction plans. The article then goes on to fully explain suspended sediments, chlorophyll, and temperature and how extensive research is conducted on each to locate the source of the problem using TMDL correction.

In conclusion the article explained how using these remote sensing techniques have had potential application for monitoring the growth of the clean-up efforts. As new satellites and their sensors are advancing in technology, plans of launching these satellites within the next decade will improve necessary resolutions needed to monitor water quality parameters from space platforms. The information from the space platforms or hyper spectral data will allow future researchers to distinguish between water quality parameters and how to develop a better understanding of substance interactions.

III. METHODS

SeaWiFS (Sea-Viewing Wide Field-of-View Sensor) data was used for this project. This is a sensor on the OrbView2 satellite that consists of eight channels; six channels of visible range and two channels of near infrared and has a 1.1 km field of view. This data was provided by the CERSER (Center of Excellence in Remote Sensing Education and Research) Lab; located on the campus of Elizabeth City State University (ECSU). The data was processed using the TeraScan system which is an integrated system of hardware and software designed to automatically capture data into image and overlay products using SeaWiFS data from the OrbView2 satellite. Processing was achieved by retrieving the data from the tape. Using the retrieved archived data, TeraCapCon was used to look at the satellite schedule to make sure that there were not any passes coming through and also to see if the data was in the coverage area. SeaWiFS data is a broadcast of swcrpt, which is the encrypted version of seawifs. ECSU has an authorized delayed-mode seawifs license that can decrypt the data two weeks or more after data is ingested. The operation used to decrypt data on the TeraScan system is "ogpdecrypt." After the raw images are decrypted, "seawifsin" was used. This creates TeraScan SeaWiFS datasets for SeaWiFS telemetry. "Seawifsin" also calibrates each scan line with its own associated dark restore value. Figure 1 is an example of how the data looks like after being processed.

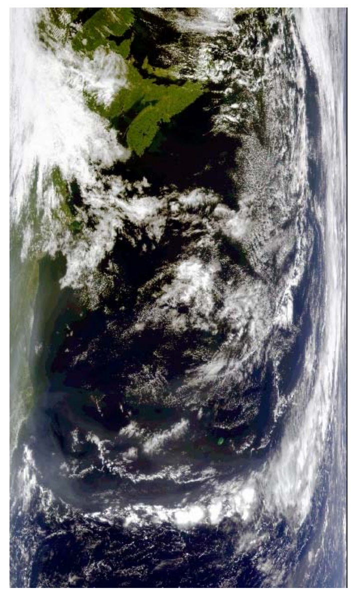

Figure 2.1

In order to find the water clarity we needed to use "swcolor," which implements the official SeaWiFS color algorithms to derive chlorophyll amounts, pigment concentrations, and aerosol optical depth. The most fundamental task of "swcolor" is to derive water-leaving radiance values from radiance values measured at a sensor. Figure 2 shows an example of the chlorophyll data that was processed.

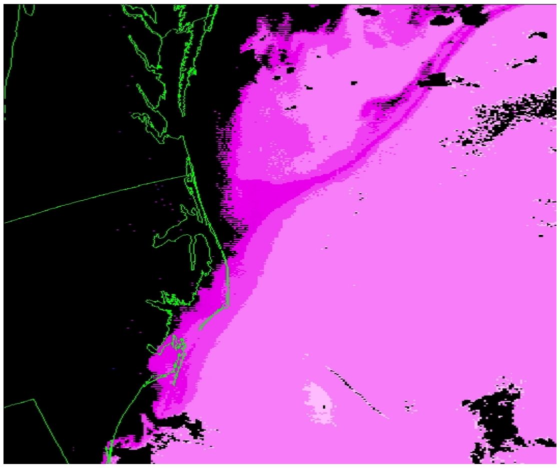

Figure 2.2

Once the color was done we applied the water clarity. The function "water_ clarity" generates secchi disk depth estimates from SeaWiFS ocean color data. Figure 3 is an example of the water clarity data.

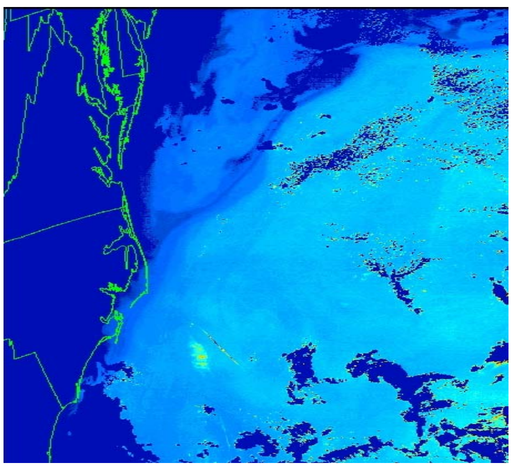

Figure 2.3

TeraVision was then used to analyze the data. TeraVision is a window-based graphic user interface (GUI) for displaying and manipulating TDF (TeraScan Data Format) datasets as data images and overlays. A data table was created to show the water clarity of the images given by TeraVision. One of the challenges faced during this project was finding cloud free days. Many images were processed but only a small number were used. These images are an example of the how cloud cover affected the project. Both images are the same SeaWiFS image with the same date and time, yet one has been processed for water clarity. Where bands of clouds appear in the image water clarity data is missing. Figure 4 is an example of the cloud coverage problem that was faced, and Figure 5 is the same picture after the water clarity data was processed.

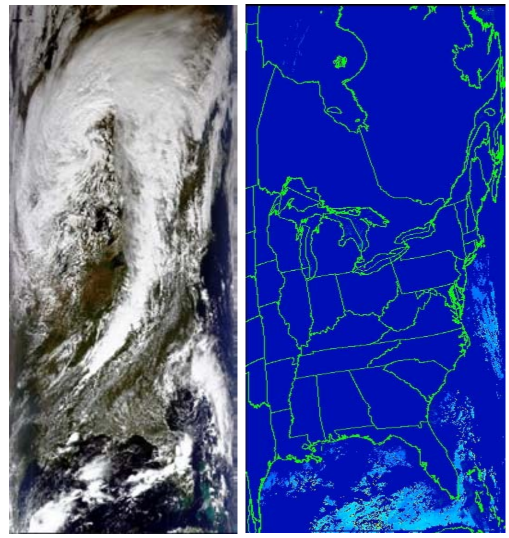

Figure 2.4

IV. Results/Conclusions

After utilizing SeaWiFS Ocean Color data to generate water clarity estimates for the years 2003 and 2004, we chose three different points were chosen along the North Carolina coastline to further compare the two years. Figure 3.1 shows a map of the areas along the coast of North Carolina where we chose our three points. Table 3.1 shows the water clarity results for the fall of 2003 and the winter of 2004. Where the table is blank no data was received.

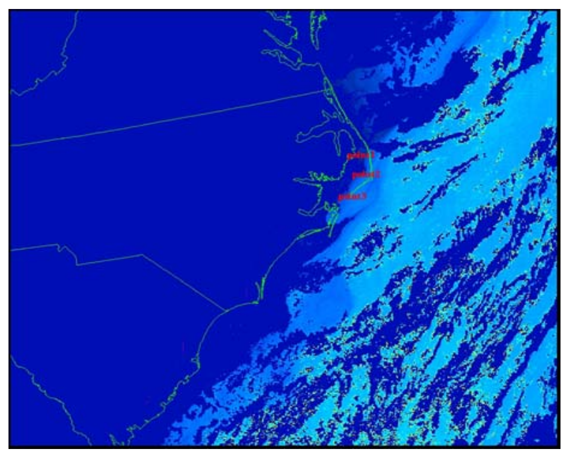

Figure 3.1

ID	File Name	Date	Point 1	Point 2	Point 3	Year
1	1704	8/30/2003	4.273	5.823	5.505	2003
2	1657	8/25/2003	4.511	4.57	4.676	2003
3	1745	8/31/2003	3.14782	4.246	5.048	2003
4	1748	9/29/2003		4.03337	3.50728	2003
5	1823	2/29/2004	4.335	4.335	4.0802	2004
6	1739	3/11/2004	2.085	2.345	2.605	2004
7	1819	3/12/2004	3.507	3.911	3.461	2004

Table 3.1

The graph below shows the water clarity values for 2003 at three different points along the coastline.

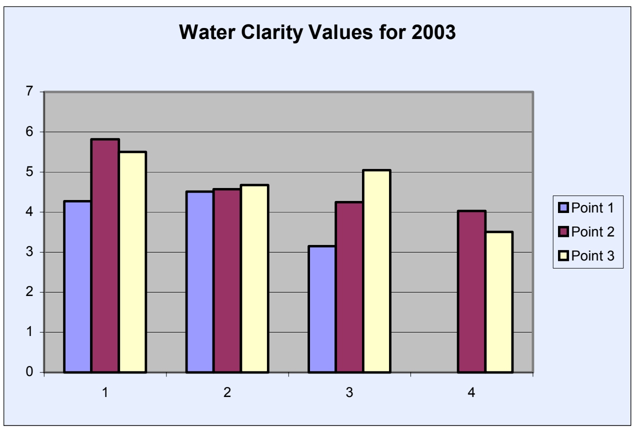

Figure 3.2

The graph below shows the water clarity values for 2004 at three different points along the coastline.

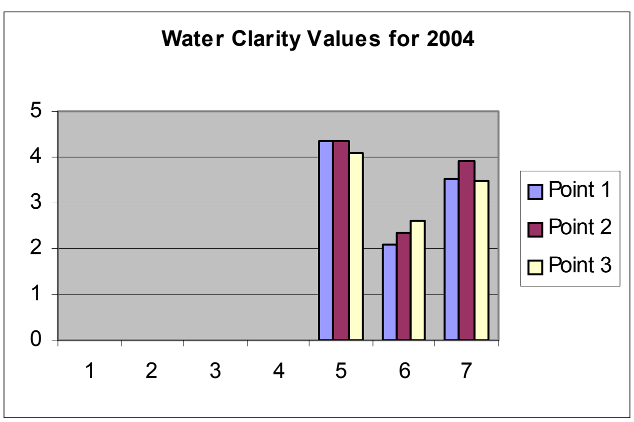

Figure 3.3

To compare the two years, the mean average values for 2003 and 2004 were calculated at the three different points. Microsoft Excel spreadsheets were used to organize the data and to calculate the mean values. The final graph below shows that the year 2003 produced higher water clarity values than the year 2004. The results for 2003 were most likely due to hurricane Isabel bringing in strong winds and heavy rainfall allowing land run-off and shoreline erosion, re-suspension of sediments, and waste discharge [2]. If there are high amounts of turbidity, the water loses its ability to support diverse aquatic organisms, block photosynthesis, and smothers egg masses and nest sites [2]. The values may have also been so high due to clouds, which are also a problem for interpreting satellite derived turbidity.

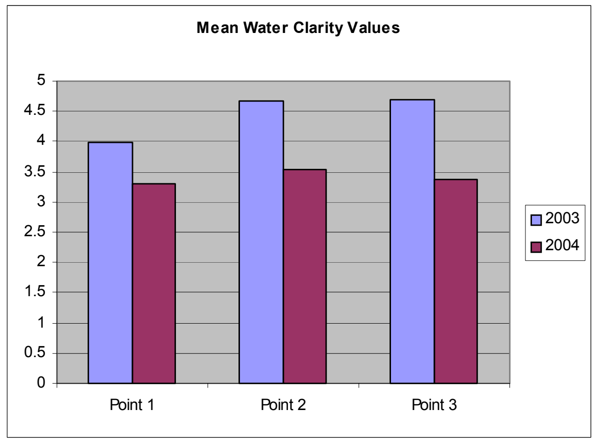

Figure 3.4

ACKNOWLEDGMENTS

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