Quantifying Sargassum Boundaries on Eastern and Western Walls of the Gulf Stream Protruding Near Cape Hatteras into Sargasso Sea Bermuda/Azores

Derek Morris Jr (ECSU) Tatyana Matthews (ECSU), Hagen Hodgkins (ECSU) Mentor: Andrew Brumfield (ECSU) Principal Investigator: Dr. Linda B. Hayden (ECSU), 1704 Weeksville Rd, Box 672, Elizabeth City, North Carolina 27909

Abstract

The Sargasso Sea has been a ocean life habitat for millions of years, yet accurate assessment of the boundary area and detection of these relatively small sea surface features using Landsat series and Moderate resolution Imaging Spectroradiometer (MODIS) instruments have been found to have difficulty or even impossible due to lack of spatial resolution, coverage, recurring observance,and algorithm limitations to Identify pelagic species of Sargassum. Sargassum rafts tend to be elongated, curved in the upwind direction and warmer than the surrounding ocean surface. Long weed 'trails' extending upwind from the rafts are evidence of plants dropping out and being left behind. Satellite data Utilizing a simple ocean color indexes such as the floating algae Index and Normalized Differential Vegetation Index (NDVI) have been established to detect floating algae in open environments using MODIS instruments. Floating Algae Index (FAI) has shown advantages over the traditional NDVI and Enhanced Vegetation Index (EVI) because FAI is less sensitive to changes in environmental and observing conditions (aerosol type and thickness, solar/viewing geometry, and sun glint) and can see through thin clouds. The baseline subtraction method provides a simple yet effective means for atmospheric correction. The algorithms assisted in identifying the boundary area of the Sargasso sea and the path of this floating algae past cape hatteras into the Atlantic ocean. Due to the fact that similar spectral bands are available on many existing and planned satellite sensors such as Landsat series observations satellites, the NDVI and FIA concept was extendable to establish a long-term record of these ecologically biological dependent ocean plants.

Windrow of Sargassum in the Gulf Stream

Windrow of Sargassum in the Gulf Stream

Methodology

The region selected to search for and evaluate Sargassum is the Gulf of Mexico, as well as, a large area off the east coast of the United States in what is called the Sargasso Sea. This region was selected due to the observed migration of the Sargasso population between the Gulf and Sargasso Sea between July and august. Due to Sargasso paths proximity to the 2010 deep-water horizon oil spill, which caused extensive amount of oil into the Northeastern Gulf of Mexico changes to its ecological surroundings. Within this region quantification on the boundary area of the "Sargasso jet" along the Gulf Stream is crucial to understanding the impact of the oil spill on Sargassum. The areas of interest are primarily between Cape Hatteras and the Bermuda since this is the last segment of its travels into the Atlantic. In order to begin efforts to quantify the Sargassum present the Band wavelengths must be configured for the Landsat band multispectral characteristics. In which the algorithm was established for Landsat FIA.

Landsat FIA = B4 – (B3 + (B6 – B3)*(B4 - B3)/(B6 - B3)

From April to August is when Sargassum is exchanged between the Gulf of Mexico and the Sargasso Sea via the Gulf Stream. The years encompassed by this timeline are centered around the Deep water Horizon oil spill that started on the 20th of April, 2010. The intention behind this was to determine the effect of this oil spill on the Sargassum population by quantifying it before and after the oil spill.

Data selection

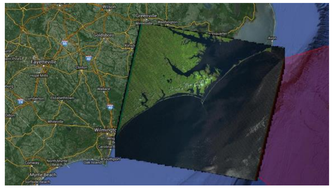
A large quantity of the data collected was provided by the United States Geological Survey (USGS) and consists of imagery from the Landsat series 7 and 4-5 satellites. The Area Of Interest (AOI) within the July to August timeframe. Data was collected from 2015 through to June 2012. Data that was selected from the Landsat satellites needed to meet several requirements in order to be useful to the research. The most important of these is minimum amount of cloud coverage. Images that contain large amounts of cloud coverage or light cloud coverage loosely covering a vast area are incompatible for analysis due to the nature of NDVI image processing. Among other prerequisites for Landsat imagery to be applicable to the research is for the images to have been taken within the July - August timeframe, as well as, within the boundaries of the area of interest around the Sargasso Sea.

Image processing

Processing and examination of the image files that were downloaded and expanded was accomplished using the software called ENVI. Image processing was done by importing Bands 1-5 and 7 from the expanded Landsat files. These bands were then combined into a coherent data stack and reordered from descending to ascending band order. This data stack is then used to create an NDVI stack using bands 3 and 4.
Before creation of the Index's, the individual bands had to be corrected for radiance. To do that ENVI software application has a pre-processing application to change from reflectance to radiance. The bands that needed to be preprocessed were Rred, Rnir, and SWIR (Landsat bands 3, 4, and 6) which are used for NDVI and FIA respectively.
Then the Basic Band math was used to input the Index's algorithms and apply the bands to the applicable variable. With the bands configured and the indexes produced the new products were loaded into three separate display windows, a RGB for color and to distinguish between land cloud and open water and the other two for the Vegetation Index and Floating Algae Index. This NDVI filtered image is compared to a red, green and blue (RGB) render of the same area in order to help identify Sargassum and differentiate it from different environmental factors such as clouds and land.

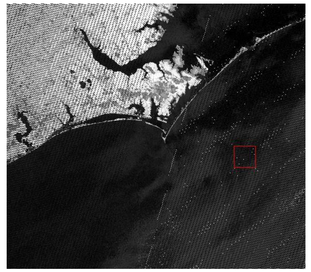
Analysis

Identifying Sargassum is very rigorous feat to find Index values on an anomaly that is believed to be either a large plume of Sargassum by comparing the NDVI filtered image with a RGB version of the same image. The NDVI images was scanned for bright wisps in the otherwise dark water which the AOI would be concluded as Sargassum patch. The area is then looked over in the RGB version to make sure the bright area is not a piece of land, a sandbar or clouds and other atmospheric obstructions.
FAI was tested within the ENVI software; however, it did not provide the anticipated results of providing an Index. When tested using ENVI and the multispectral imagery provided by Landsat models the FAI processing even with Radiance corrected Spectral bands failed to remove cloud coverage from the images as well. It also returned results inconsistent with provided examples of what FAI was intended to return compared to the NDVI index of vegetation located on land. One such inconsistency was with inversion of the Gray Scale. Rather than the anticipated dark black water surfaces denoting the lower end of the Gray scale it returned results in which the water and land were both a light grey, clouds and coastlines contrasting this in a dark grey to black was observed.



USGS AOI image preview of pass

RGB off the Coast of Cape Hatteras July 17th 2015



NDVI off the Coast of Cape Hatteras July 17th 2015

Deep Water Horizon Event in the GOM

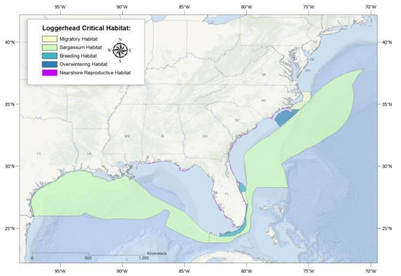
Recorded amounts of Oil leaked into the GOM

Conclusion

The Satellite covers only so much of the earth each day and at different times. To compare of the amount of Sargassum over the years in the same time frame in the same specific location is next to impossible using Landsat data. Further useful observations were reduced by frequent cloud, sun glint, and data gaps in the images. The amount of usable passes from USGS data library are next to the amount of two passes a month in the same area with cloud cover less than 30%. Sargassum that is evenly distributed may not be detected unless it is "aggregated" in concentrated windrows.

Since some of the AOI is directly off the coast some benthic vegetation and coral reefs in shallow water can cause false positive with a very low NDVI index. These can be ruled out because the shape of the anomaly is not elongated windrowed with a curl toward them wind direction.

With the lack of sufficient ground truth or in situ recordings of GPS locations of where larger patches of Sargassum are present floating it is difficult to classify these Sea Surface anomalies through the NDVI index because values for items which were believed not to be clouds or low clouds have negative index values just like the low clouds in the area. A targeted approach is missing which would help pin point times and locations to immediately target reported Sargassum in the area.

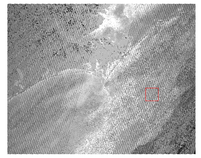


AOI and path of Sargassum from GOM to Sargasso Sea

Future Work

In the future, the research can be continued in several ways. The continuation of image processing is an important task that could be continued in further research. Despite downloading an abundance of data from USGS only a fraction of this data was processed through ENVI. Some of the passes that were previously processed need to be corrected for radiance and the FIA algorithm need to be correctly transformed from MODIS bands to Landsat.

Imagery that is processed was only given a cursory look over before continuing on to process more of the passes to increase the size of the data pool. As a result, a large majority of the data remains unexamined, preventing the team from reaching an answer to our initial research question.
Expanding the search timeline by several years such as from 2005 through 2015 would determine if changes over time were in fact a result of the oil spill or just a consistent multi year cycle in which the oil spill may have only played a minor part in.



FIA off the Coast of Cape Hatteras July 17th 2015

Sargasso pneumatcyst and branched thalluses

Sargasso Sea Currents

References

[1] R. Y. George, "Twin Essays on Sargassum Canopy: God's Meadows in the Sargasso Sea of the North Atlantic Ocean," pp. 1–28.
[2] "Deepwater Horizon Disaster," in Encyclopedia of the Earth, 2010. [Online]. Available: https://www.google.com/search? Accessed: Apr. 7, 2016.
[3] Jim Gower & Stephanie King "Satellite Images Show the Movement of Floating Sargassumin the Gulf of Mexico and Atlantic Ocean" pp. 1-2, 5-6
[4] C. Hu et al., "Did the northeastern Gulf of Mexico become greener after the Deepwater Horizon oil spill?," Geophys., p. 38. [Online]. Available: 10.1029. Accessed: Apr. 7, 2016.
[5] S. Powers, "Study finds Three ways for oil spill to impact gulf seaweed | GoMRI," in News, Gulf of Mexico Research Initiative, 2015. [Online]. Available: http://gulfresearchinitiative.org/study-finds-three-ways-oil- spill-impact-gulf-seaweed/. Accessed: Apr. 7, 2016.
[6] Anas El-Alem, Karem Chokmani, Isabell Laurion, and Sallah E. El-Adlouni "Comparative Analysis of Four Models to Estimate Chlorophyll-a Concentration in Case-2 Waters Using MODerate Resolution Imaging Spectroradiometer (MODIS) Imagery
[7] Chuanmin Hu, "A novel ocean color index to detect floating algae in the global oceans", 27th December 2008
[8] Chuanmin Hu, " Sargassum Injuty Assessment plan : mapping using remote sensing" College of Marine Science, University of South Florida

ACKNOWLEDGEMENT

The team wishes to recognize Andrew Brumfield and Dr. Robert George for their assistance in completing this research. Also, the team would like to recognize Dr. Linda Hayden for the research opportunity that was made possible through the Center of Excellence in Remote Sensing Education and Research (CERSER) program.