Characterization and Dynamics of Total Suspended Sediments (TSS) along Puerto Rico West Coast

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ABSTRACT.- This project intended to investigate and describe sediment distribution and the dynamics of Total Suspended Sediments (TSS) along Puerto Rico west coast using remote sensed images. Sediments have important effects in ecosystems of the bays, reefs and water quality and remotely sensed images provide us valuable information for quantifying sedimentation rates and the different factors that cause it, like it could be erosion, river discharge or contaminants. For this specific project, river discharge data from Rio Culebrinas and Rio Añasco (2005 to 2010) were used to seek dates of high runoff and find Landsat 7 ETM+ images of 30m resolution corresponding to those dates. Images were processed in ENVI 4.7 to better visualize the river plume and calculate runoff extension using the measurement tool and then applying a previously developed algorithm by Rodriguez and Gilbes, 2009. Discharge peaks corresponding to images dates showed a direct relation between amount of discharge and plume length. Better correlation was found for May 17, 2010 with 94 cms of discharge and 4.6km of runoff extension for the Añasco River. Algorithm application to Nov 22, 2009 image gave us higher values of TSS concentration for the river mouth, with up to ~7900mg/L concentration and lower values as we move away from the coast. False color images and unsupervised classification helped us to better visualize and determine plume extension and to make a better cualitative distinction between TSS concentrations while the algorithm implementation helped us made quantitative observations of how TSS was changing along the coast.

KEYWORDS: ENVI, Landsat 7 ETM+, River Discharge, TSS algorithm

INTRODUCTION

Sediments have important effects in ecosystems of the bays, reefs and water quality. Remotely sensed images provide us valuable information for quantifying sedimentation rates and the different factors that cause it, like it could be erosion, river discharge or contaminants. Suspended sediments dynamics along the west coast of Puerto Rico is a topic that although it has been previously studied it is a topic of ongoing study since, as common from coastal environments, Puerto Rico west coast is affected by inland processes including the discharge of two main rivers that heavily influx the sediments, nutrient fluxes and anthropogenic derived discharges to the ocean. These rivers are the Rio Grande de Añasco and Rio Culebrinas, and as the main rivers for West Puerto Rico, they comprise the principal cause of sediment discharge for the area.

Remote sensing is used to monitor the suspended mineral concentration in water bodies but it usually requires in situ measurements to correlate with remote sensor data to derive quantitative relationships and it is important to collect both the sensor data and the in situ collection in days of little or no wind since wind cause specular reflection giving misleading data when acquiring sediment concentrations (Jensen, 2007). For the

nature of this project, we do not count with in situ data collection so we proceed to use a previously developed algorithm by Rodriguez and Gilbes, 2009 for the Mayaguez Bay. In this work they describe the development and validation of an algorithm to estimate total suspended sediment (TSS) based on remote sensing reflectance and MODIS/Terra band 1 data. Since the west coast of Puerto Rico normally receives the least energy of all the coastline of Puerto Rico, winds from the west are rare, and generally light so there is little direct generation of wind waves (Morelock, 2003) so in choosing this area, it ensures similar characteristics for applying the algorithm.

PURPOSE

This study intended to investigate and describe the distribution and dynamics of TSS along Puerto Rico west coast using remote sensing images.

MATERIALS AND METHODS

We selected a 6 year period (from 2005-2010) in order to find river discharge data and correlate it to Landsat 7 Enhanced Thematic Mapper plus (ETM+) images.

A. River discharge Data and images

To be able to study sediment distribution, the first step was to find peaks on river discharge data from 2005 to 2010 corresponding to high runoff (obtained from USGS, 2011) for both, the Añasco and the Culebrinas rivers and find Landsat images corresponding to those dates. Landsat 7 (ETM+) images with a Resolution of 30m were used for West Puerto Rico as obtained from Earth Explorer page (Earth Explorer, 2011). Obtained images correspond to these dates; May 30, 2009; November 22, 2009 and May 17, 2010.

B. Images were processed in ENVI

To better visualize river plumes, false color images were generated by performing interactive stretching. Kmeans unsupervised classification with 20 iterations was made in order to classify different classes and see were sediments were located so that we could calculate the plume runoff extension by using the measurement tool in ENVI.

C. Algorithm implementation

Algorithm used was adapted from Rodriguez and Gilbes, 2009:

TSS=602.63*(0.5157*(TM band 1)-0.0089) +3.1481

We used band 1 in the algorithm because previous work developed algorithm consisted in the combination of two equations, one defining the relationship between field Rrs and TSS, and other establishing the relationship between field Rrs at 645 nm and MODIS band 1. Since Landsat 7 band 1 corresponds to a similar wavelength that that on MODIS (Table 1), relationship could be established.

Spectral Bands		Use
1	Blue-green	Bathymetric mapping; distinguishes soil from vegetation; deciduous from coniferous vegetation
2	Green	Emphasizes peak vegetation, which is useful for assessing plant vigor
3	Red	Emphasizes vegetation slopes
4	Reflected IR	Emphasizes biomass content and shorelines
5	Reflected IR	Discriminates moisture content of soil and vegetation; penetrates thin clouds
6	Thermal IR	Useful for thermal mapping and estimated soil moisture
7	Reflected IR	Useful for mapping hydrothermally altered rocks associated with mineral deposits
8	Panchromatic	Landsat 7 carries a panchromatic band (visible through near infrared) with 15-meter resolution for "sharpening" of multispectral images

Table 1. Landsat TM and ETM+ sensor spectral bands (USGS, 2011)

In order to apply this algorithm radiometric correction has to be made. We used the method of Dark Subtract in ENVI but since our images are affected by the scan lines problem if minimum value was used we would have error so instead user value was selected and we put the lower value for each band individually. Satellite derived reflectance needed for input when evaluating total suspended sediment (TSS) was obtained by using the Calibration Utilities for Landsat TM in ENVI, all bands have were calibrated individually to then create the RGB image to be processed. After that we build and apply a mask to the land by using the masking tool in ENVI and finally we applied the algorithm using the ENVI math band tool.

RESULTS AND DISCUSSION

River discharge data for Rio Grande de Añasco and Rio Culebrinas can be seen in figures 1 and 2; both show data in cubic meter per second. For May 30, 2009 discharge was 106 cms and 6.5417 Km of runoff extension; for November, 22, 2009 discharge was 70 cms and 3.8565 Km of runoff extension; and for May 17, 2010 discharge was 94 cms and 4.6km of runoff extension.

False color image manipulation for emphasis on the river plume along with Kmeans unsupervised classification for all three images is shown on figure 2. K means classification with 20 iterations differentiates all the spectral classes present on the image but since we are only interest in the sediment distribution, we are only interest on the plume length and direction.

Algorithm application to Nov 22, 2009 image (Fig. 3) gave us higher values of TSS concentration for the river mouth, with up to ~7900mg/L concentration and lower values as we move away from the coast.

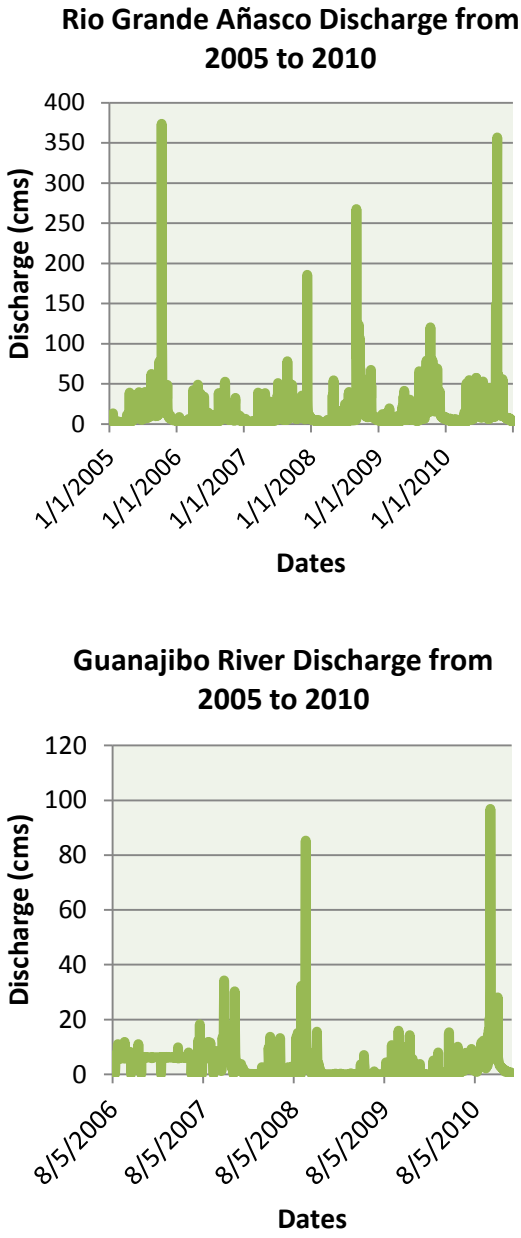

Figure 1. Graphs showing discharge peaks for both, the Rio Grande de Añasco and the Culebrinas River

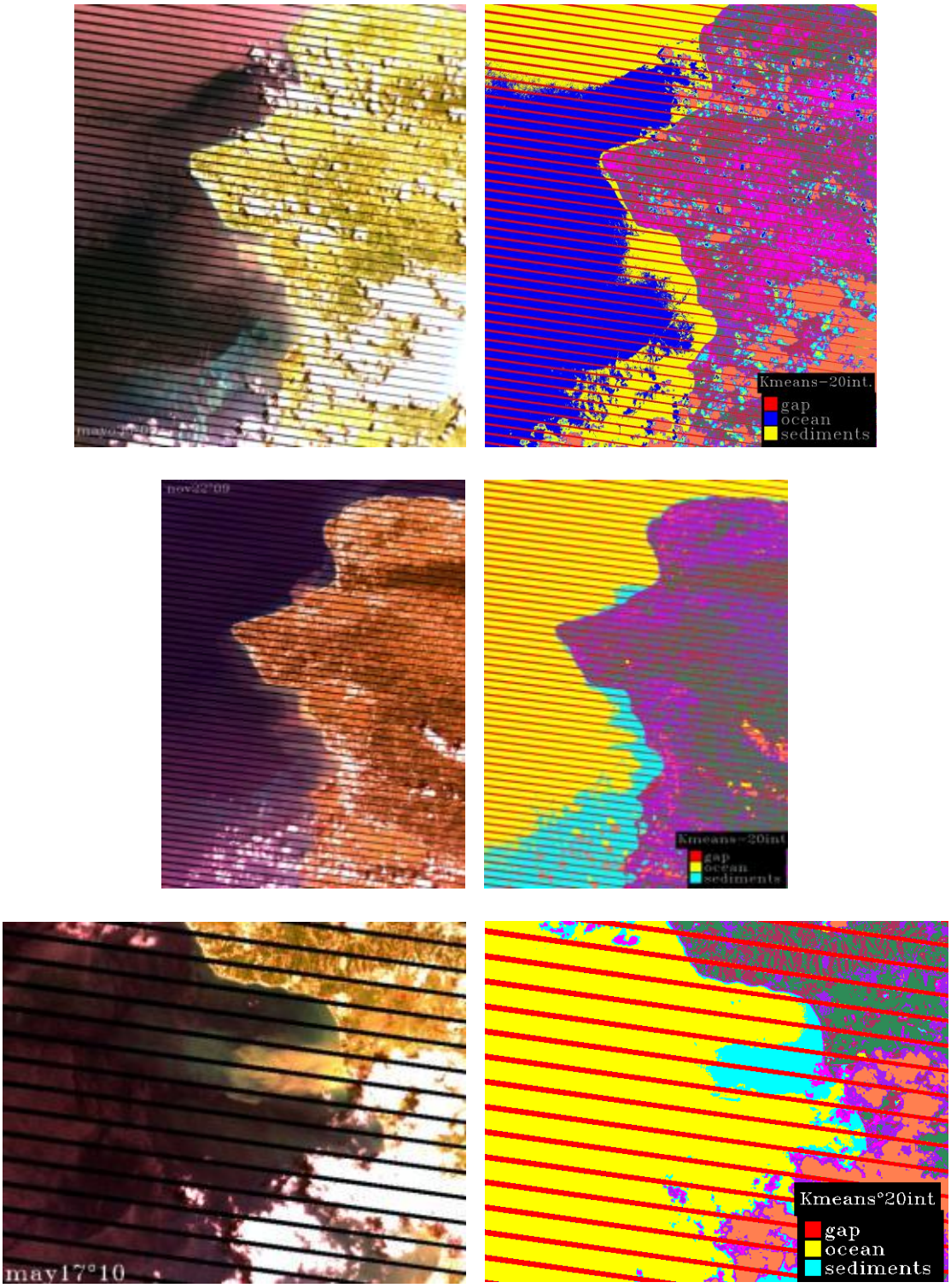

Figure 2. False color and Kmeans classification applied to the three images obtained for west Puerto Rico showing river discharge.

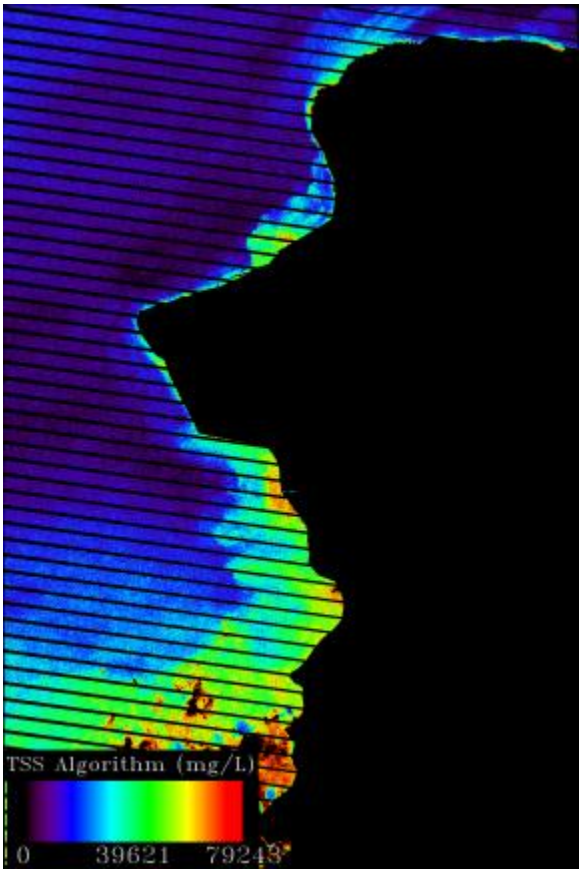

Figure 3. TSS algorithm applied to Nov 22, 2009 image

CONCLUSIONS

Discharge peaks corresponding to images dates show a direct relation between amount of discharge and plume length. Better correlation was found for May 17, 2010 with 94 cms of discharge and 4.6km of runoff extension for the Añasco River. For Culebrinas River we were not able do to any correlation since none of the images were viable to do so. False color images and unsupervised classification helped us to better visualize and determine plume extension and to make a better cualitative distinction between TSS concentrations while the algorithm implementation helped us made quantitative observations of how TSS was changing along the coast. The dymamics of TSS along Puerto Rico West Coast were better defined by the Algorithm application to Nov 22, 2009 image, which gave us higher values of TSS concentration for the river mouth, with up to ~7900mg/L concentration and lower values as we move away from the coast.

RECCOMENDATIONS

Make sure geometric and radiometric corrections utilized during image pre-processing routine are correctly applied since they are crucial for TSS algorithm implementation (Rodriguez and Gilbes, 2009) since this could have been a potential source of error. Also, if working with Landsat, select period of study before 2003 or correct for the scan line problem by filling the gaps of the obtained images. Pancroma, for example, can fix the problem by using different dates images to fill in the gaps. If this affects the algorithm implementation, then another sensor should be used

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