University of Puerto Rico

Mayaguez Campus

Department of Geology

Undergraduate Research Report

Report Submitted to Department of Geology

Spectral Slope Analysis of Suspended Sediments from Mayagüez Bay

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Abstract

This project is focus on study the spectral slopes from suspended sediments of Mayaguez Bay. Water samples from last semester of Anasco, Yaguez and Guanajibo River was analyzed to develop the methodology of Cruz (2008). Nine replicates have been done from three different stations: Inside, Mouth and Beach. Radiometric measures was made to this samples of Total Suspended Sediments (TSS) and Inorganic Matter (IM), that I assumed that are minerals. Data from last semester and this semester were compared to see how the spectral slope changes. In general, the spectral slopes are steeper between 500-600 nm. As increasing the concentration IM, increase the Rrs, and their spectral slope. The procedure of Cruz (2008) is good for future study of Mayaguez Bay.

Keywords: Spectral Slope, Suspended Sediments, Remote Sensing Reflectance, Mayaguez Bay, Concentration, Inorganic Matter

I. Introduction

Water observations in Lake Erie suggest that some selective sorption of dissolved organic matter may varies the absorption coefficients (Binding et al., 2007), and can affect the spectral signal. Cruz (2008) showed that the organic matter has a lower value of Remote Sensing Reflectance (Rrs) than the inorganic matter. The complexity of natural seawater as an optical medium obscures the optical signal (Stramski et al., 2004). Minerals that can be found on selected rivers are quartz, augite, magnetite, and from the coral reefs, carbonate and calcareous sediments (Morelock, 1983). On French Guiana it was observed that a high concentration of minerals induces a high Rrs (Froidefond et al., 2001). The spectral response depends on color, type, size and mineral composition of the sediments (Choubey et al., 1990). Because of that, minerals can be determined using color, grain size of sediments, their concentration and their spectral response. Suspended sediments has an important role in the ocean because constrain biological production by limiting sunlight that penetrates the water column (van der Lee et al, 2009). It is now well acknowledged that the water remote sensing reflectance (Rrs) in the visible part of the spectrum provides qualitative and quantitative information on optically significant materials present in natural waters (Lubac and Loisel, 2007)

Mayagüez Bay has been studied for several years. Studies of the Bay have included the dynamics of suspended sediments, optical properties, conditions of coral reefs, and others (Hernández, 2008; Quiñones, 2005; Rosado, 2000). A recent study has found that minerals in suspended sediments of Mayagüez Bay can affect the spectral signal detected by remote sensors (Rosado, 2008).

Cruz (2008) made an experiment to study the spectral effect of minerals in suspended sediments of Mayaguez Bay. Rio Añasco, Yagüez and Guanajibo are the three major rivers that affect the sedimentation of this Bay. In general, high Rrs was found for high TSS concentration. Also, the higher value of Rrs was related with high concentration of minerals (i.e. inorganic material (IM)). Cruz (2008) results will help to develop other studies in Mayaguez Bay and will provide recommendations for other remote sensing studies.

In a related study made by Chiques (2005) in sandy beaches it was found that high magnitude values of reflectance are associated with more that 50 % of carbonate composition, and low magnitude values of reflectance are associated with more than 50 % of dark minerals composition. However, she established that grain size does not affect as much as composition the spectral response of the sediments. Although finer grain size increase the value of reflectance in beaches where the composition are the same. The conclusions provided by Chiques (2005) were compared with this study.

II. Objective

The main objective of this research was to evaluate the slopes of the Remote Sensing Reflectance (Rrs) produced by suspended sediments in the visible and near infrared region of the spectrum. The second objective of this research was to validate the procedure developed by Cruz (2008) and minimizes its errors. The results from Cruz (2008) were compared with new results in order to confirm or reject previous conclusions.

III. Methods

The first part of this study used the same method of last semester in order to confirm the results found by Cruz (2008). This helped to validate some unexpected data. Therefore, the same water samples collected in September 21 and September 26, 2008 were used. It was assumed that collected suspended sediments, and their mineral compositions, do not change with time. This aspect was also evaluated along the study. At that time the field activities included three stations (Inside, Mouth, and Beach) at each river in which suspended sediments were collected. As part of that project, a laboratory procedure was also developed to measure Remote Sensing Reflectance (Rrs) of suspended sediments collected in filters. Rrs was obtained with the GER-500 spectroradiometer.

New Laboratory Work: Large volume of water samples was filtered using pre-weighted Milipore HA 0.45 µm cellulose acetate membrane filters. Nine replicates from each study site were obtained for comparison. All filters were heated at 70-80 ^{o}C during at least 4 hours to reduce water content before weighting. The concentration of total suspended sediments (TSS) was determined by the difference of filter weight between pre and post filtration. Rrs of TSS was determined by measuring the sediments retained on the filters using the GER-1500 spectroradiometer.

The non-mineral particles were removed using standard commercial bleach. All filters was heated again at 70-80 ^{o}C during at least 4 hours to remove the bleach and get them ready for weighting again. A second set of Rrs measurements was taken. At this point it is expected to have only minerals on the filter. Along the processes blank filters (this is filters without sediments) were exposed to the same procedures in order to determine if the filter is damage by the methodology and evaluate its reflectance response. After generating the reflectance curves, the spectral slopes were calculated and analyzed at different wavelengths ranges. Since this is the first time that this analysis is made, several spectral ranges were considered, including from 400 to 500 nm, 500 to 600 nm, 600 to 700 nm and 700 to 800 nm. Spectral slopes from these four ranges were compared with other results. Regression analysis was used to calculate the slope the regression equation is in the next form:

$$y=mx+b \quad (1)$$

where *m=slope* and *b=intercept in y.*

However, the number of the slope in the regression equation does not show it, and the traditional method was used to calculate the slope, using the following equation:

$$m = \frac{y2-y1}{x2-x1} \qquad (2)$$

Reflectance of TSS was determined by measuring the sediments retained on the filters using the GER-1500 spectroradiometer. The measurements collected by the GER-1500 spectroradiometer were used to calculate the Remote Sensing Reflectance (Rrs) using the following equation:

$$Rrs = \frac{Lw}{Ed} \quad (3)$$

Where,

Lw=upwelling radiance (as measured from the filters with sediments),

Ed=downwelling irradiance (as measured using a grey standard card), and the units are steradians^-1.

IV. Results

In the next figures we can see how the concentration of TSS and IM change from last semester to this semester. In general, the concentration of TSS and IM increase, with the exceptions of Yaguez Inside, Guanajibo Inside and Mouth from Figure 1 and Yaguez Inside and Guanajibo Mouth in Figure 2. The concentrations of TSS and IM in the samples controlled how will be the spectral response and affect the spectral slope.

The figures that follow the figures of concentration (Figures 3, 4, and 5) are to compare the Rrs for last and this semester. The bold lines are the graphs for this semester for better appreciation.

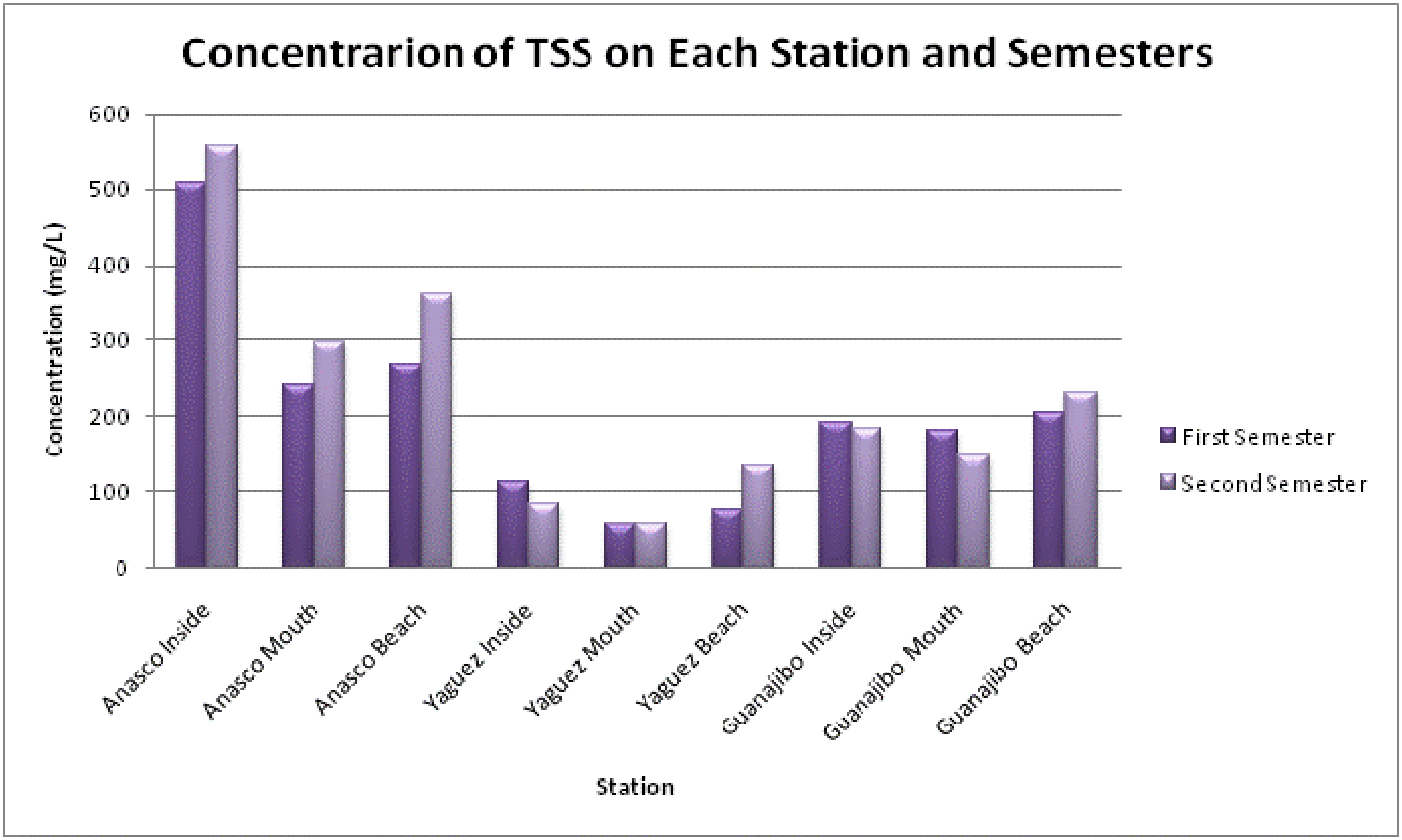


Figure 1 Comparison of concentration of TSS from last to this semester

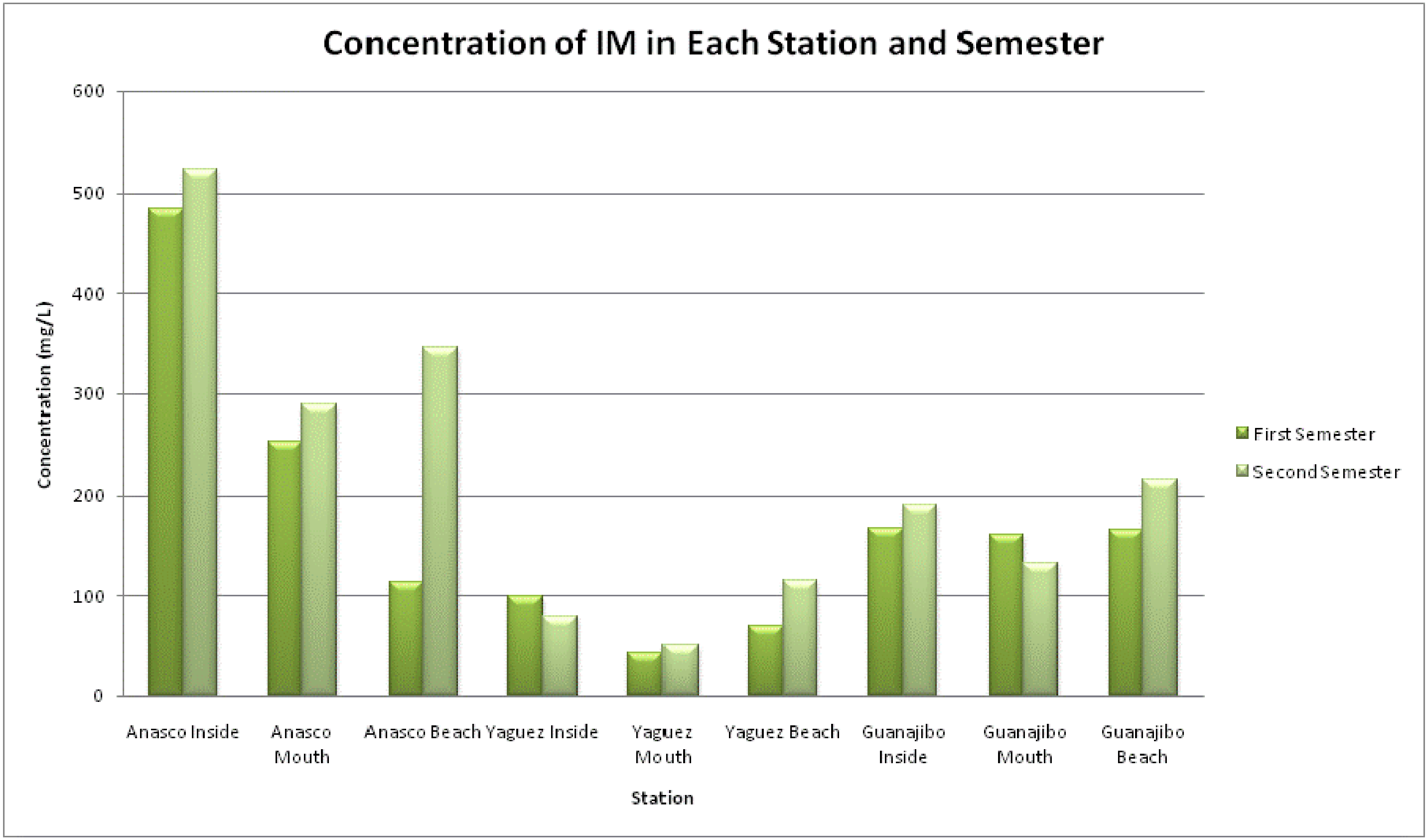
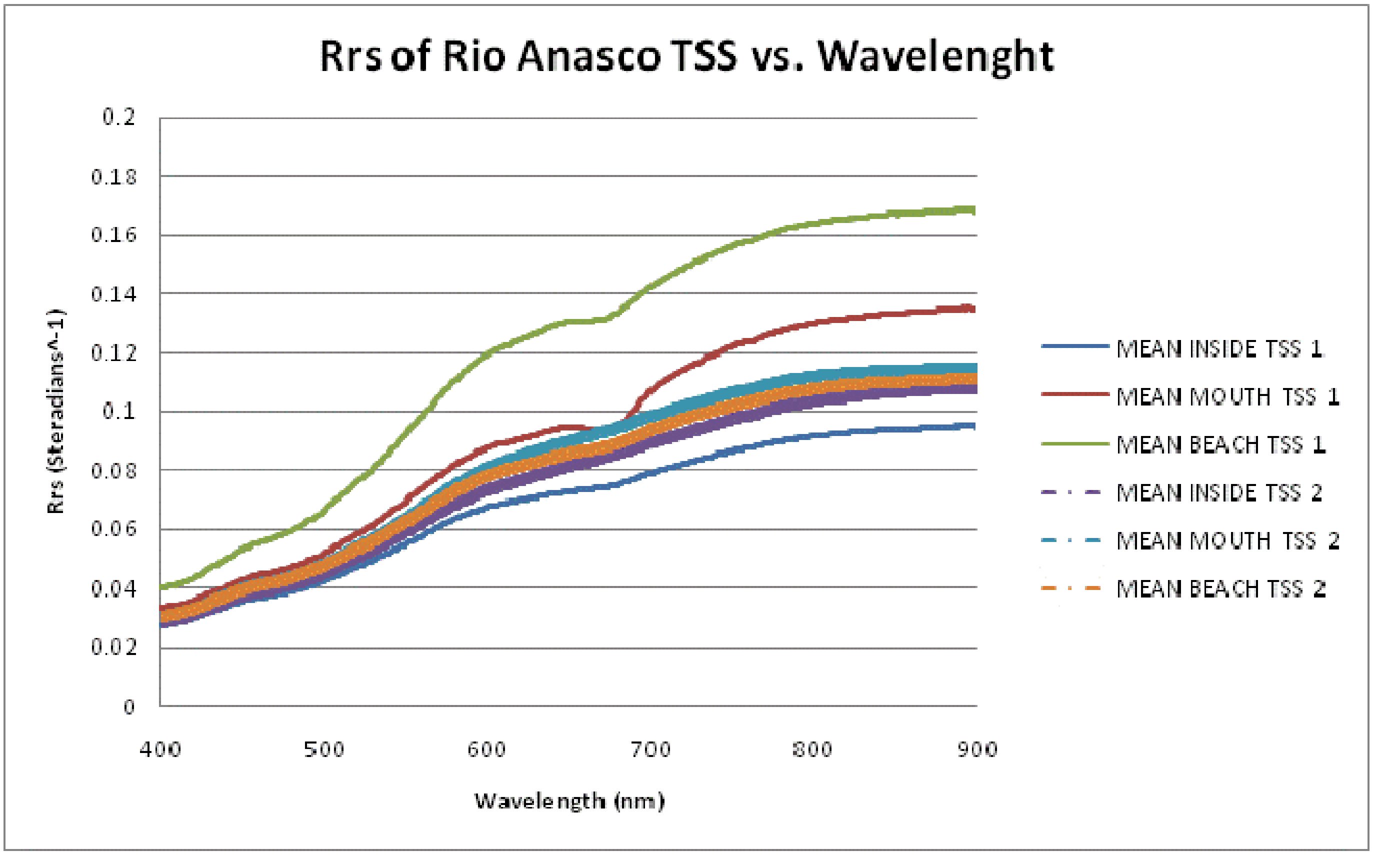


Figure 2 Comparison of concentration of IM from last to this semester



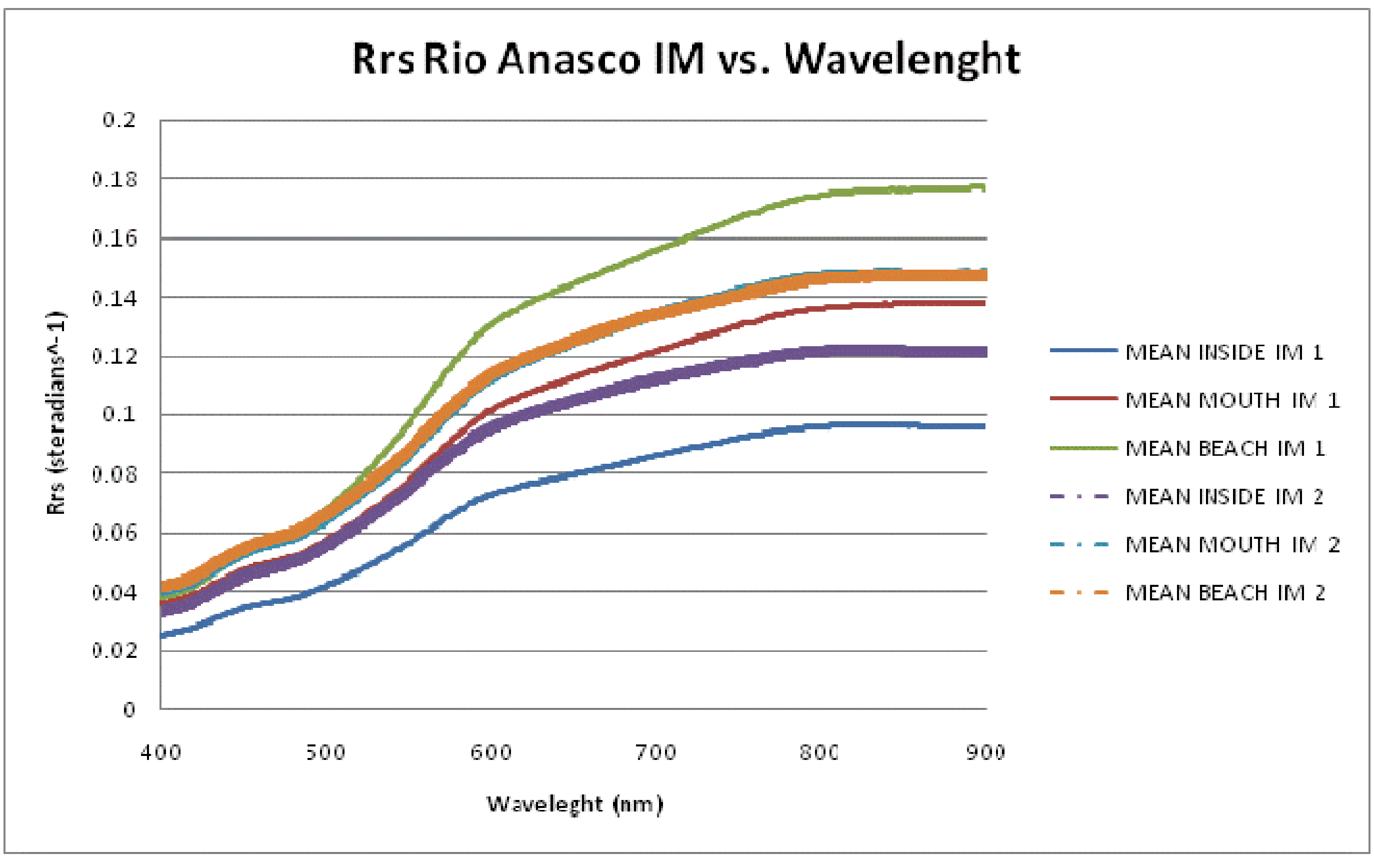
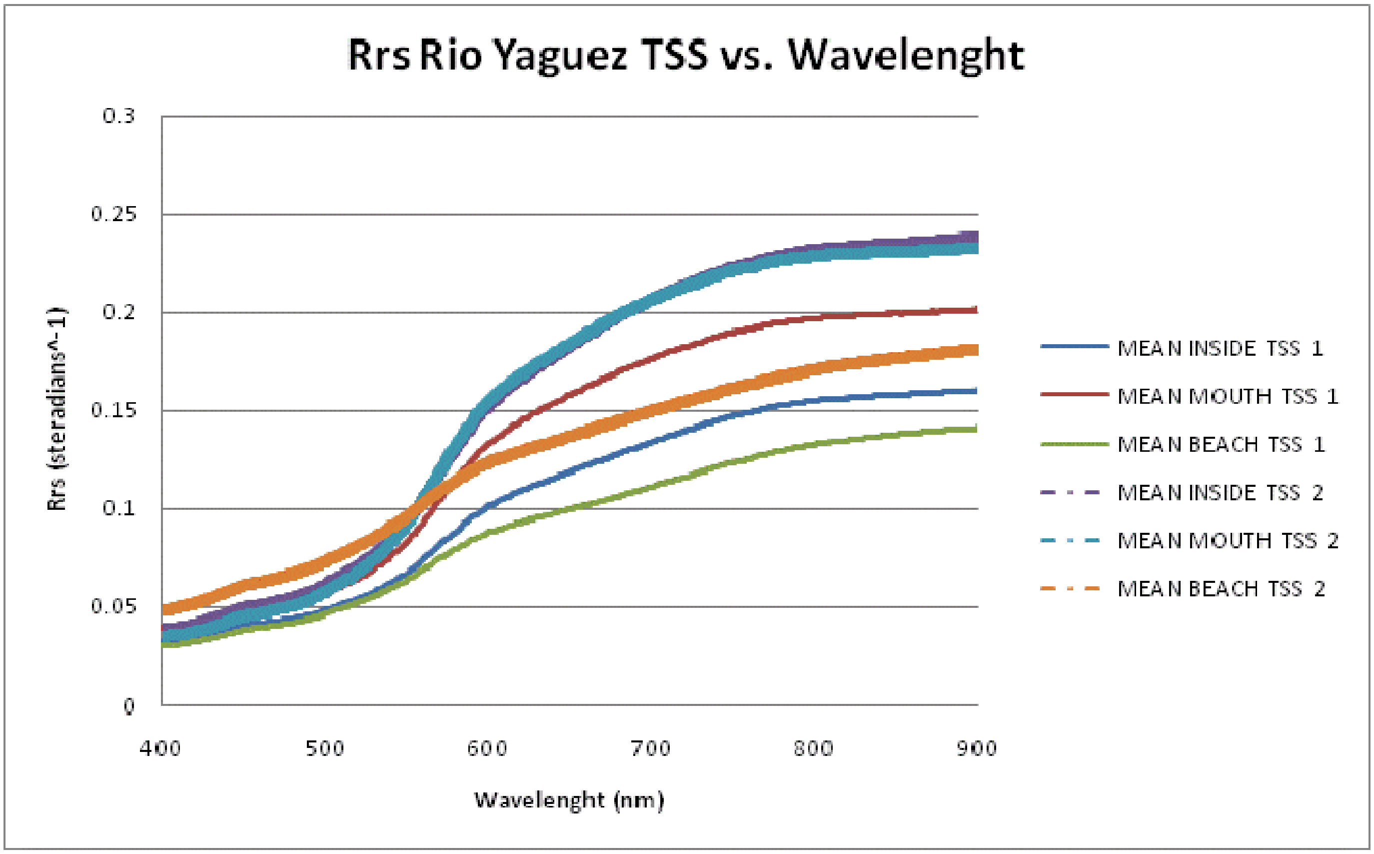


Figure 3. Rrs Rio Anasco Vs. Wavelength for last and this semester.



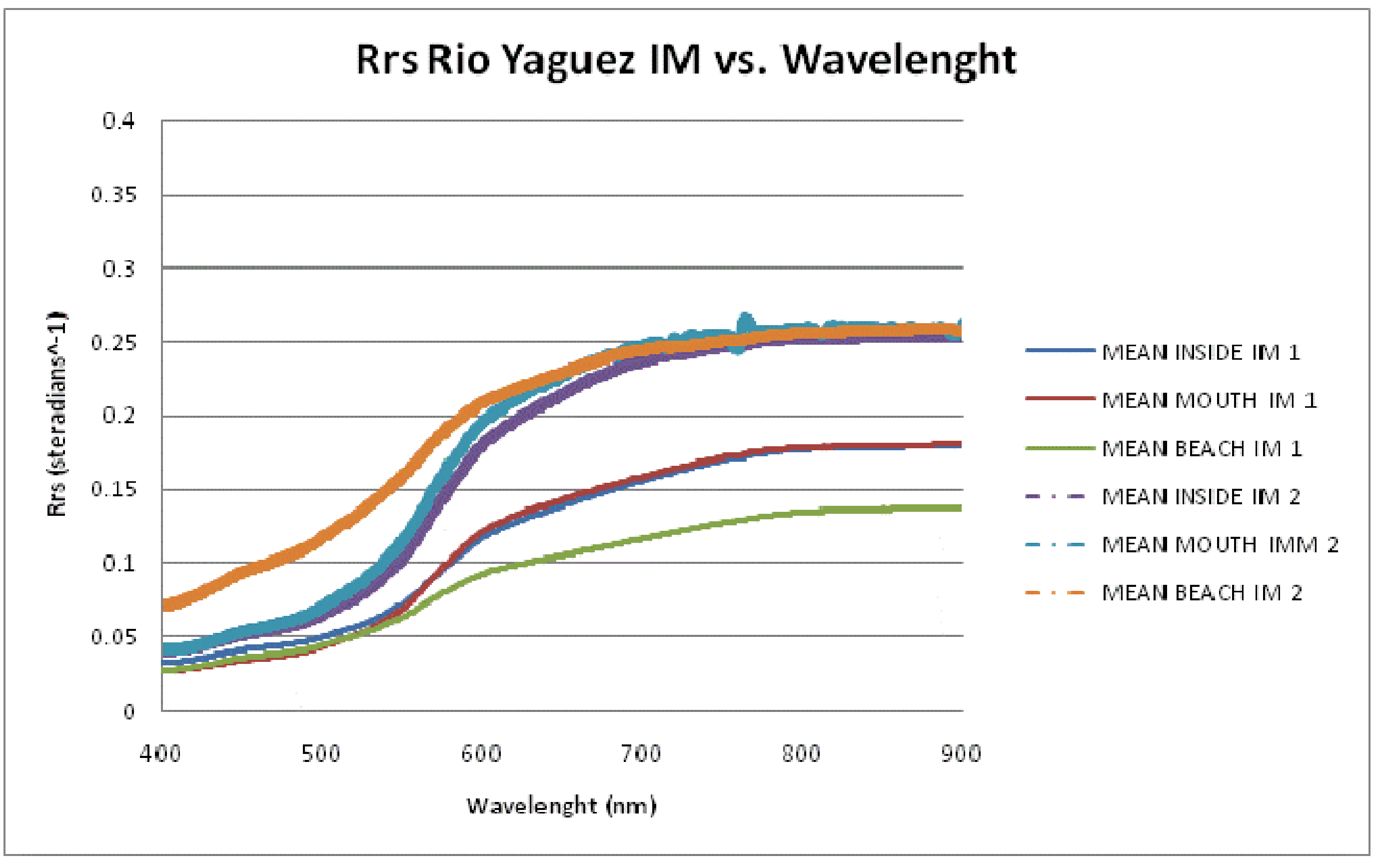
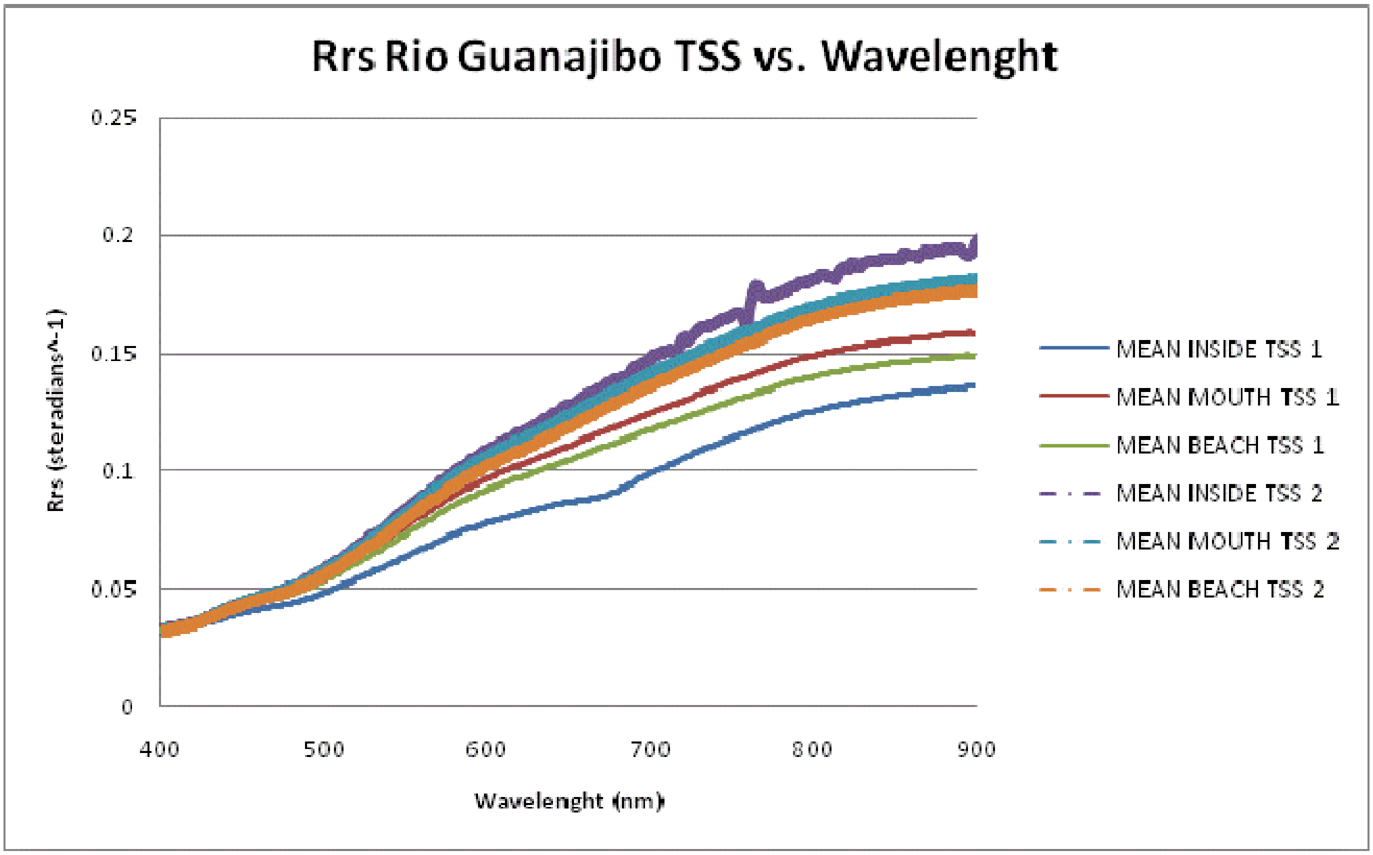


Figure 4. Rrs Rio Yaguez Vs. Wavelength for last and this semester.



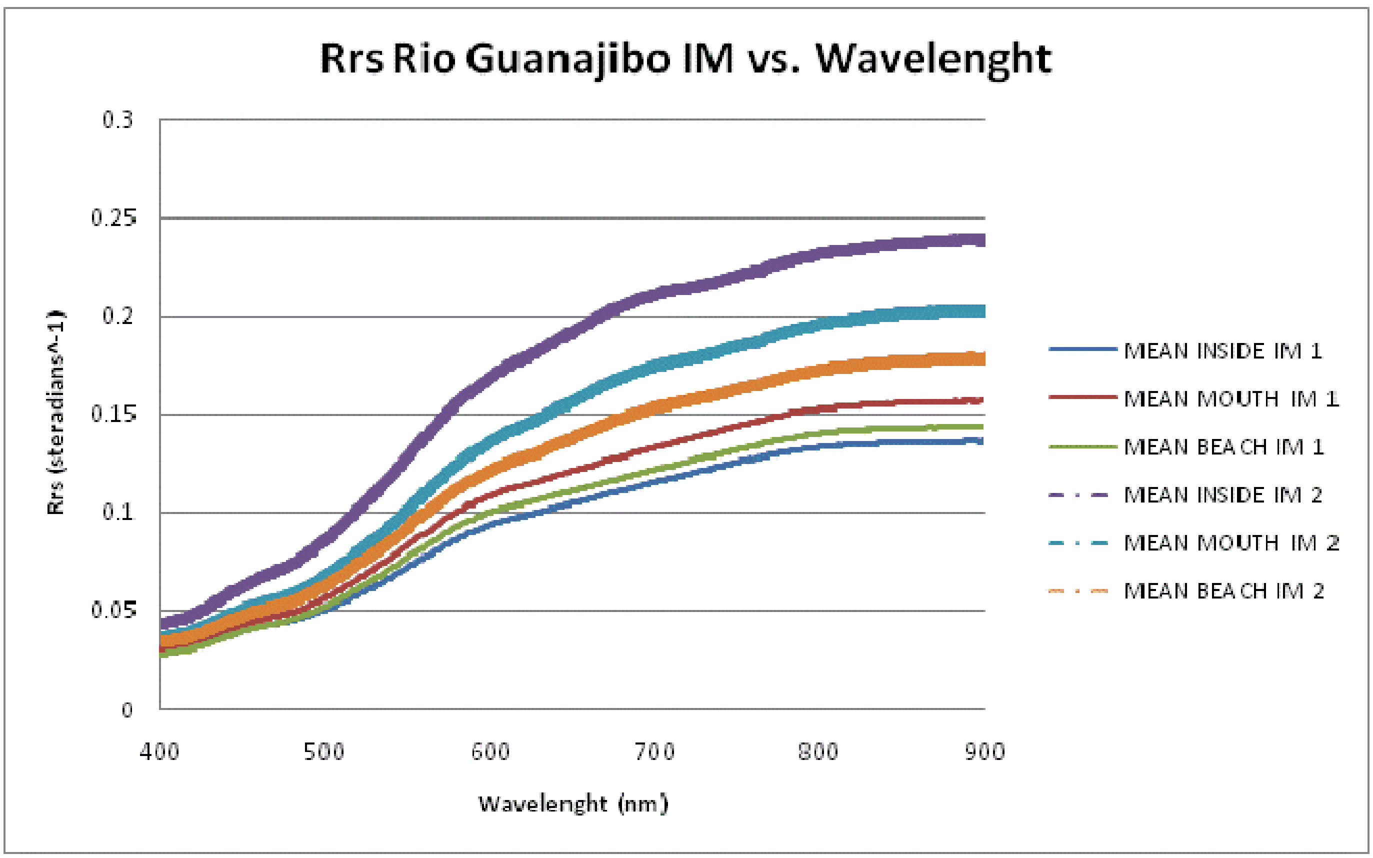


Figure 5. Rrs Rio Guanajibo Vs. Wavelength for last and this semester.

The following tables show the slope of the spectral slope for each river. Table 1, 2 and 3 compares the results from last semester (with number 1) and this semester (with number 2) of each station. Table 1 (Anasco), Table 2 (Yaguez), Table 3(Guanajibo) are showing the spectral slope for samples with TSS. The analysis was made in four different sections: 400-500 nm, 500-600 nm, 600-700 nm, and 700-800 nm. The spectral slopes of these samples are represented in graph on the appendix.

Anasco TSS	**Slope 1**	**Slope 2**
400-500 nm	0.000202	0.000174
500-600 nm	0.000378	0.000304
600-700 nm	0.000177	0.000162
700-800 nm	0.000190	0.000140

Table 1 Spectral slopes for Anasco TSS.

Yaguez TSS	**Slope 1**	**Slope 2**
400-500 nm	0.000164	0.000233
500-600 nm	0.000568	0.000792
600-700 nm	0.000332	0.000441
700-800 nm	0.000211	0.000229

Table 2 Spectral Slopes for Yaguez TSS.

Guanajibo TSS	**Slope 1**	**Slope 2**
400-500 nm	0.000198	0.000248
500-600 nm	0.000366	0.000487
600-700 nm	0.000246	0.000358
700-800 nm	0.000246	0.000303

Table 3 Spectral Slopes for Guanajibo TSS

Table 4 (Anasco), Table 5 (Yaguez), Table 6(Guanajibo) are showing the spectral slope for samples with Inorganic Matter.

Anasco IM	**Slope 1**	**Slope 2**
400-500 nm	0.000226	0.000239
500-600 nm	0.000461	0.000452
600-700 nm	0.000193	0.000193
700-800 nm	0.000144	0.000113

Table 4 Spectral Slope for Anasco IM

Yaguez IM	**Slope 1**	**Slope 2**
400-500 nm	0.000169	0.000331
500-600 nm	0.000645	0.001105
600-700 nm	0.000333	0.000483
700-800 nm	0.000197	0.000127

Table 5 Spectral Slope for Yaguez IM

Guanajibo IM	Slope 1	Slope 2
400-500 nm	0.000242	0.000341
500-600 nm	0.000477	0.000702
600-700 nm	0.000226	0.000374
700-800 nm	0.000187	0.000205

Table 6 Spectral Slope for Guanajibo IM

The differences between the slopes are because the concentration of TSS and Inorganic Matter. The plastic containers where the water samples were collected may have chemical reactions that can reduce the organic and inorganic matter of the sample. This can affect the concentration and the spectral response will change, changing the spectral slope.

V. Analysis

In general, the spectral slope analysis shows that from 500-600 nm, the slope is steeper that the other regions of analysis. Binding et al. (2005) showed an increase in reflectance, at all wavelengths with increasing sediment load, especially at 550 nm, where the graphs show the steeper slopes. Chiques (2005) show in the spectral slope analysis that the steeper slopes it is because the high concentration of light minerals in the sample and a gentle slope, there is more concentration of dark minerals, however, the spectral signal is affected by the grain size. Binding et al. (2005) said that the particle properties and size can affect the reflectance on mineral suspended minerals.

In Table 1 show that the spectral slope for this semester is less than the last semester. According to Binding et al. (2007), suggest that selective sorption of fraction of dissolved organic matter onto suspended particles may be responsible in the absorption coefficients of particulate and dissolved matter, and is an important contributor to the total spectral absorption in Lake Erie. When we see plastic container, organic matter growth in the wall, and may be the concentration of organic matter increase, as well as dissolved organic matter. The concentration of TSS and IM for Rio Anasco of this semester is higher than last semester. As well the concentration of TSS increase, suggest that the organic matter increase, and for that reason in the spectral slope of IM decrease too, because may be not all organic matter was dissolved.

Yaguez and Guanajibo show that the Rrs are higher for this semester than last semester for TSS and IM. An interpretation for why TSS has a higher Rrs than last semester is that chemical reactions occur in the plastic containers that reduce the organic matter. Cruz (2008) shows that as concentration of IM increase, the Rrs increase. Bowers and Binding (2006) show that reflectance of suspended particle increase as wavelength increase. In IM graphs show that this semester has a higher value of Rrs. This is because the in the process of remove organic matter, great part of them was removed, and show a high value of Rrs. Many researches have been done and show that as IM increase, Rrs and reflectance increase (Froidefond et al., 2001, Binding et al., 2005, Doxaran et al., 2002).

About the spectral slope of the graphs, the regression is about 0.90 to 0.99 (90% to 99%). This is that the Rrs and wavelength are strongly related and positive. As the wavelength increase, the Rrs increase too. This is true for the visible and near infrared regions of these graphs.

VI. Conclusion

In conclusion, the laboratory procedure developed by Cruz (2008) was correct and can do other research with the same procedure. In general, as higher concentration of IM, Higher will be the value of Rrs. The spectral slopes are useful to know the concentration of suspended sediments and minerals in Mayaguez Bay. More research has to be making to develop the study of suspended sediments in Mayaguez Bay. This kind of research can be develop to know the biological production of the bay.

VII. References

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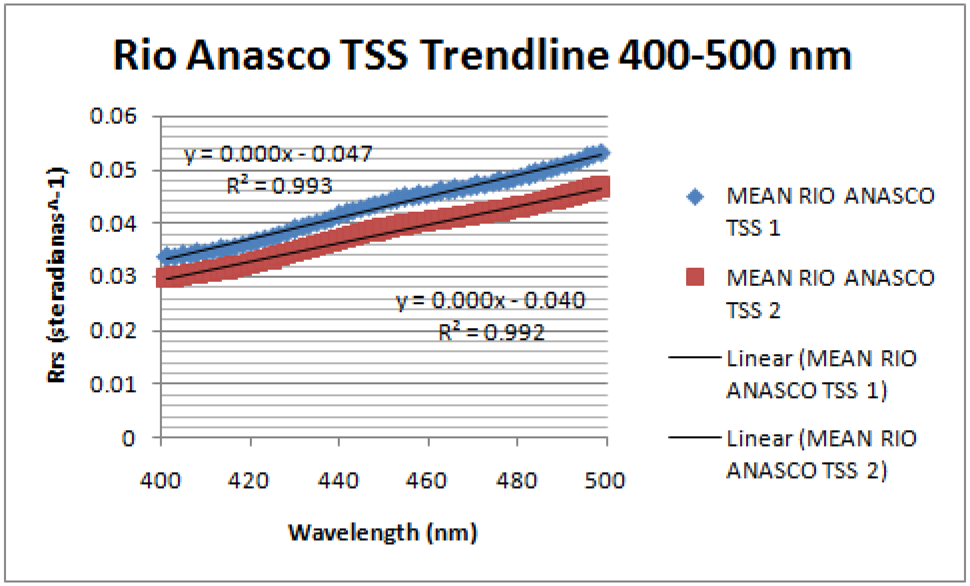
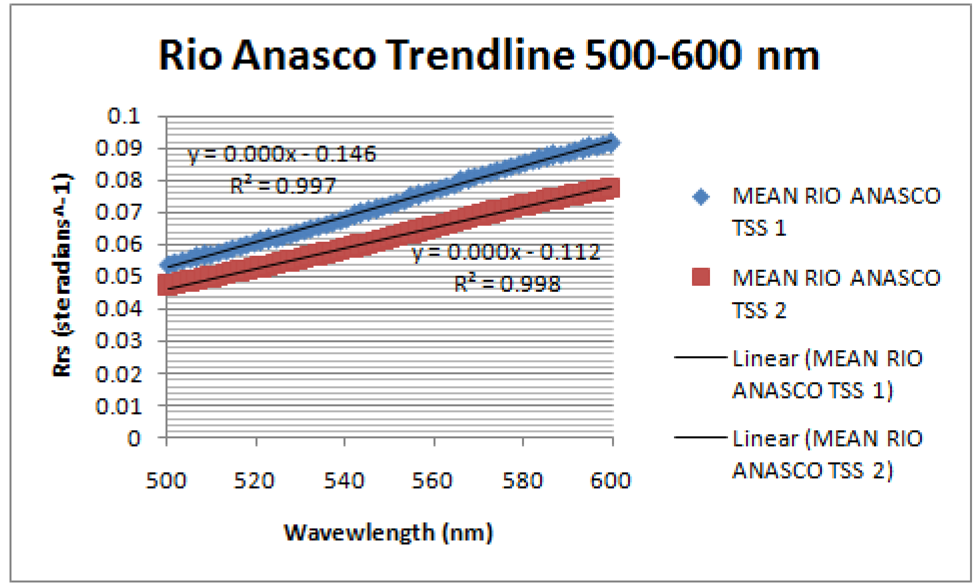
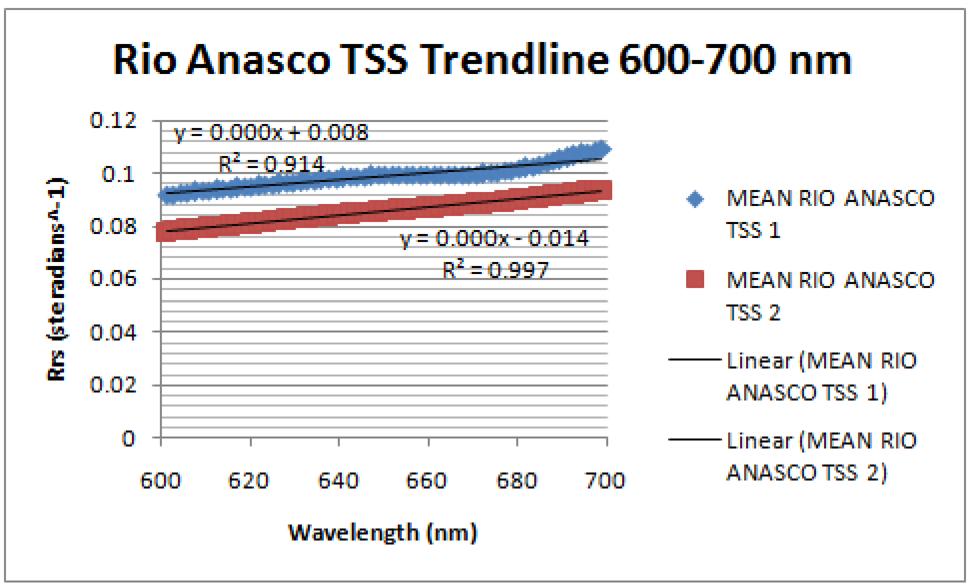
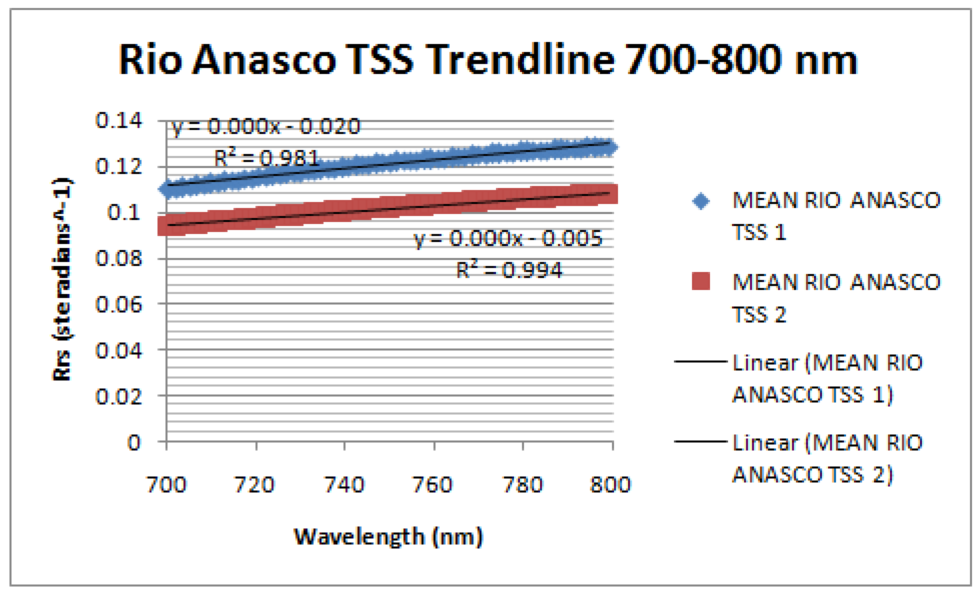
IX. Appendix

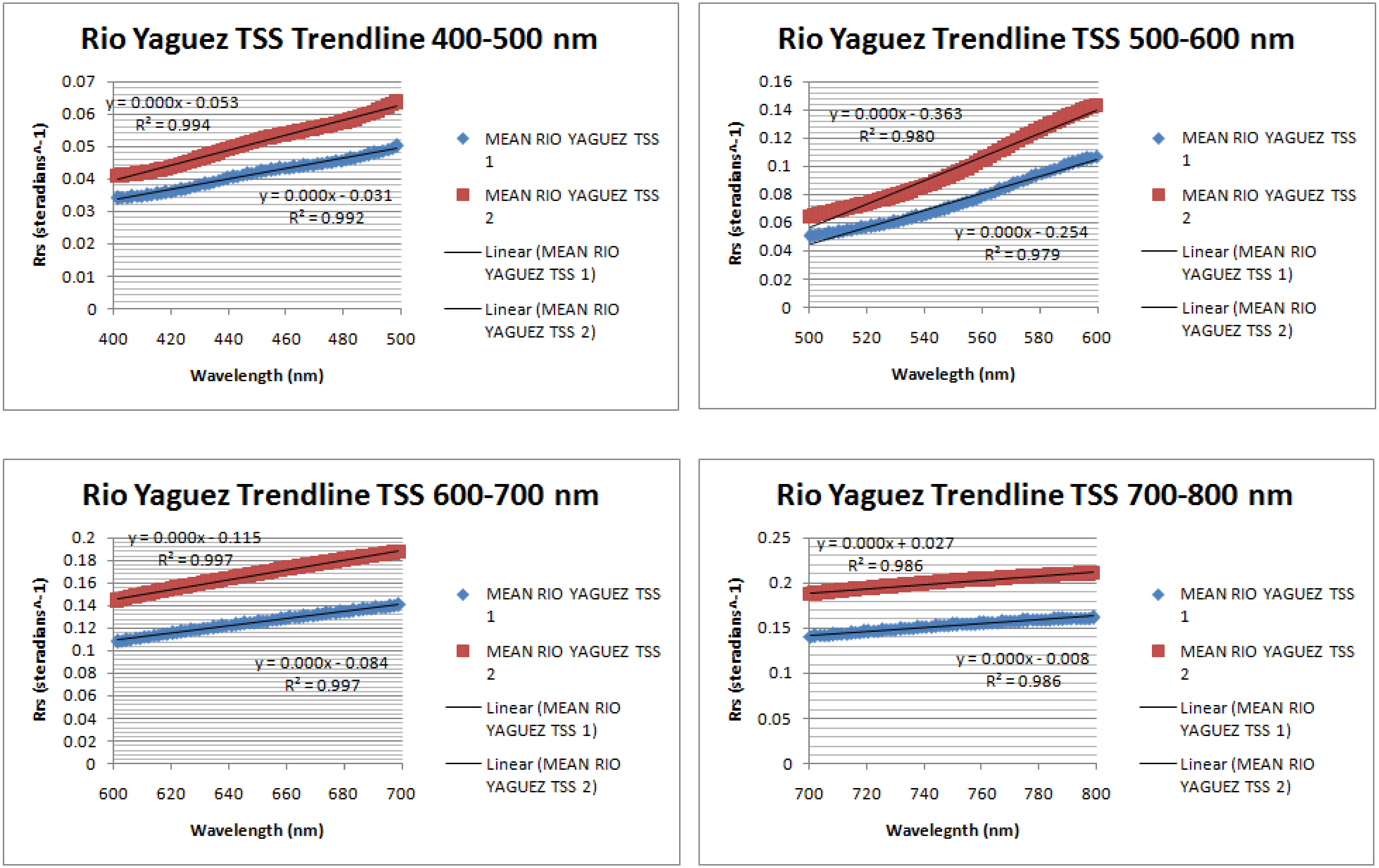




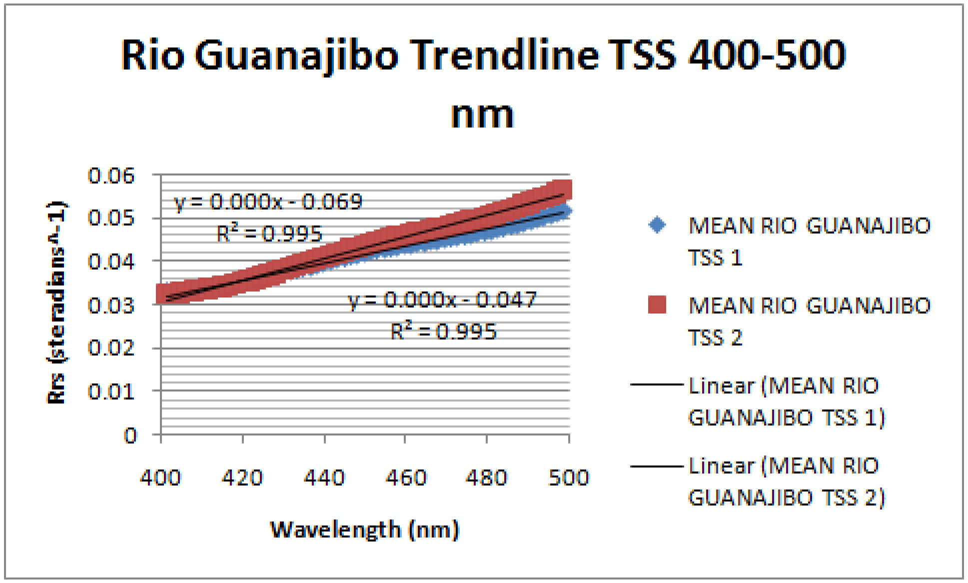


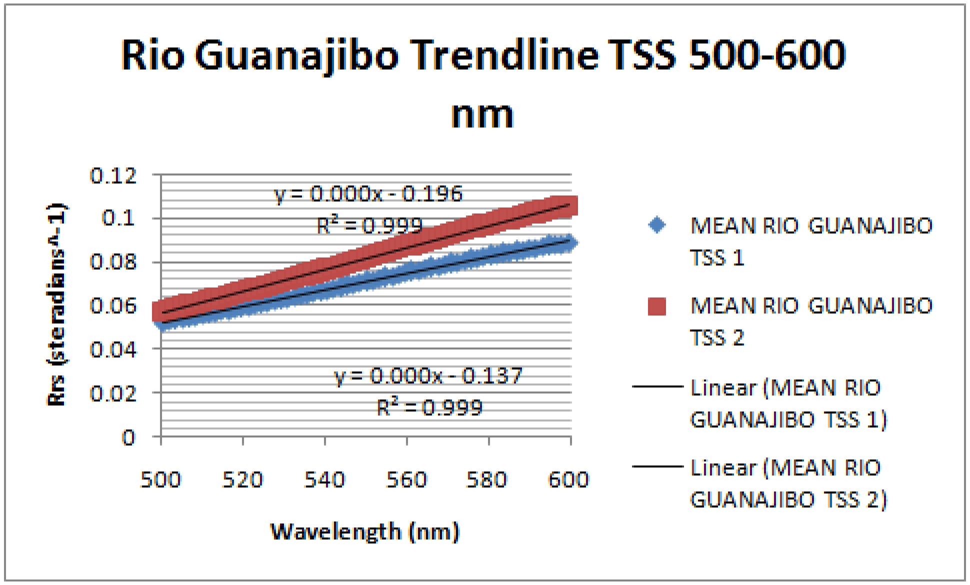


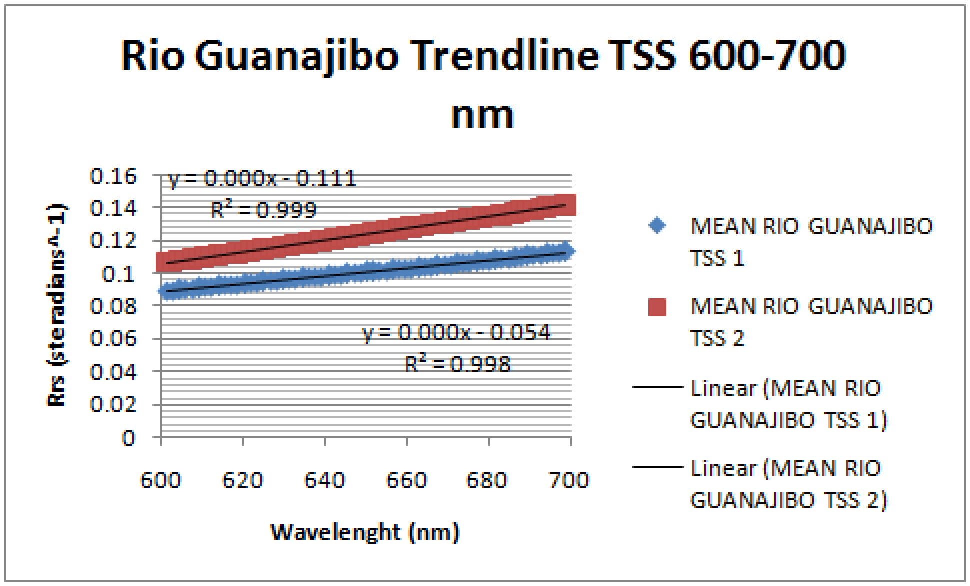
Appendix 1. Spectral Slope for Rio Anasco TSS.

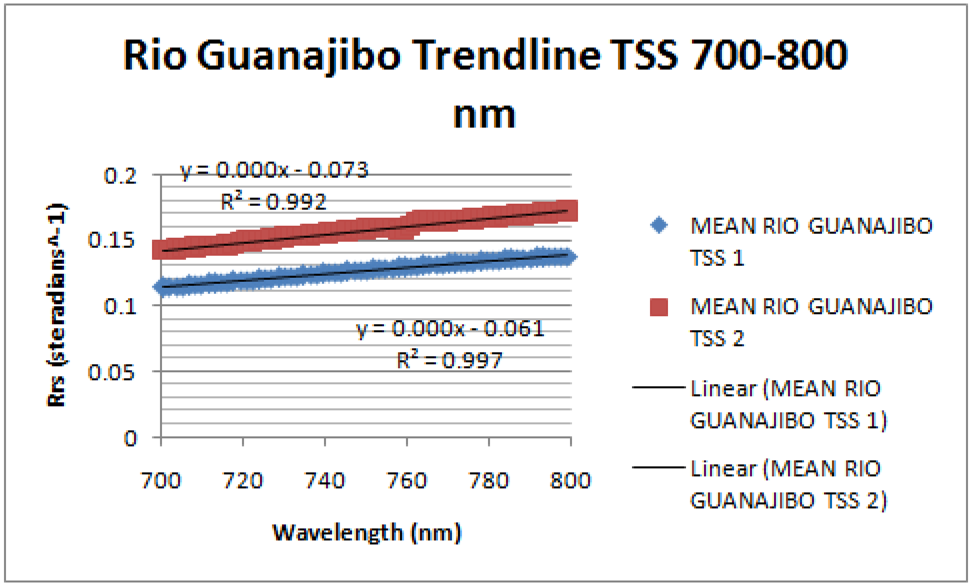


Appendix 2. Spectral Slope for Rio Yaguez TSS.

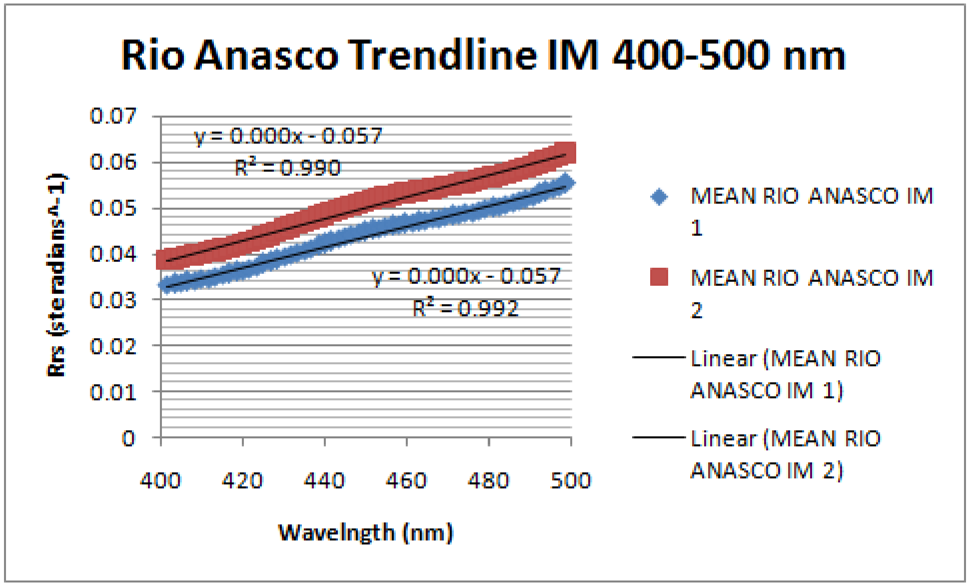


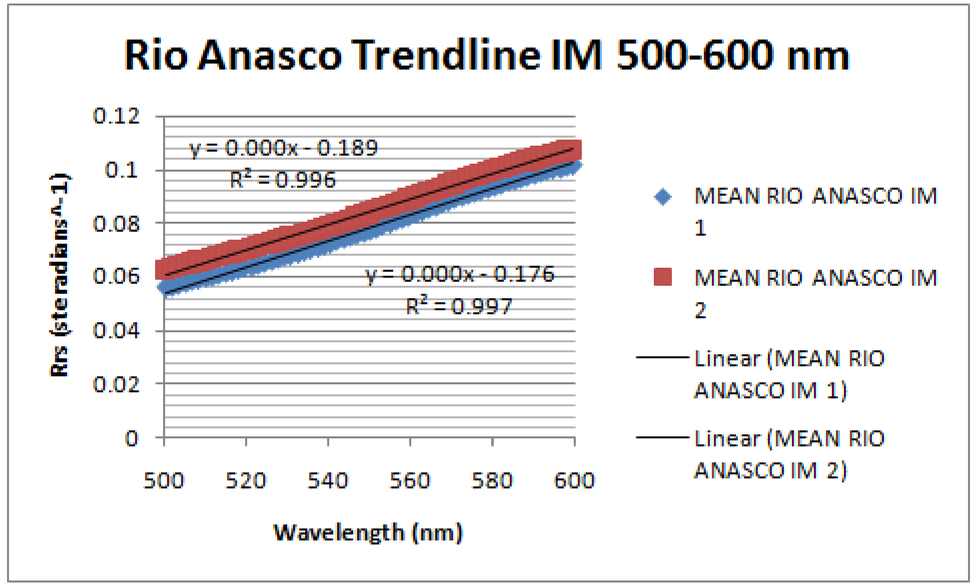


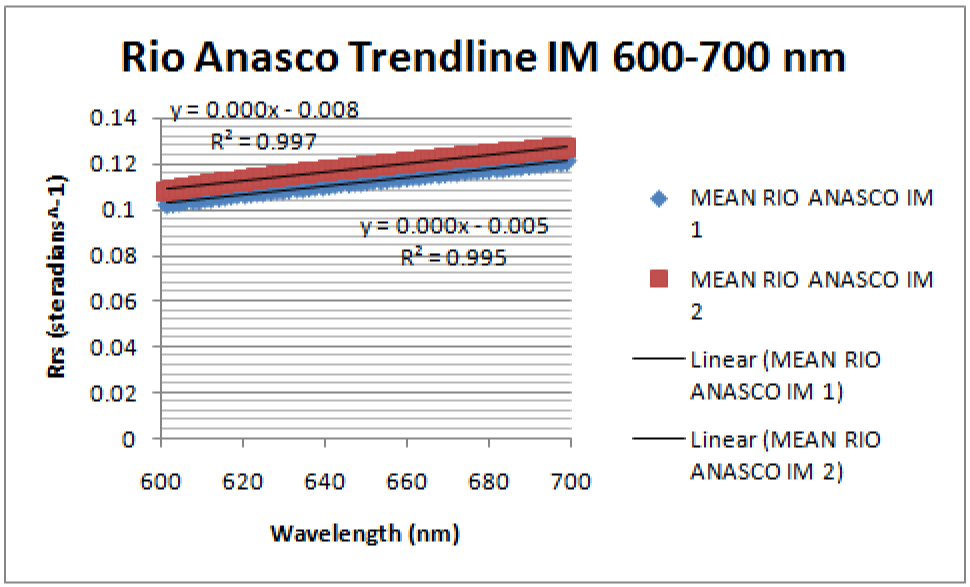


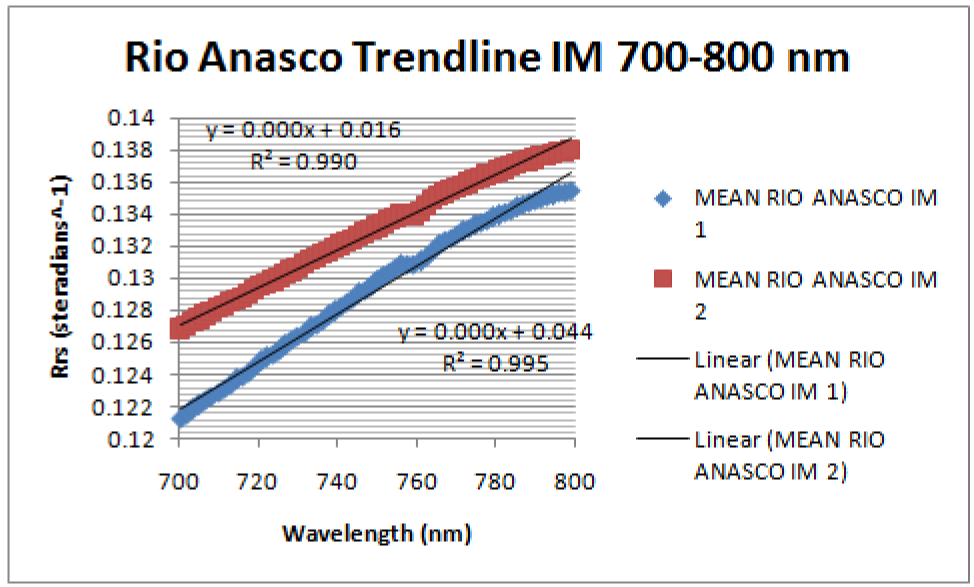


Appendix 3. Spectral Slope for Rio Guanajibo TSS.

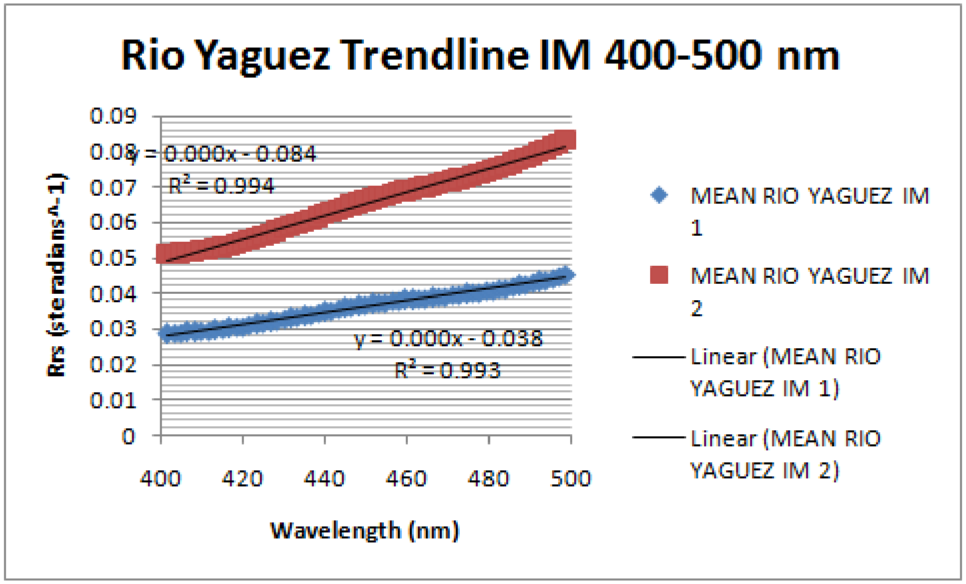


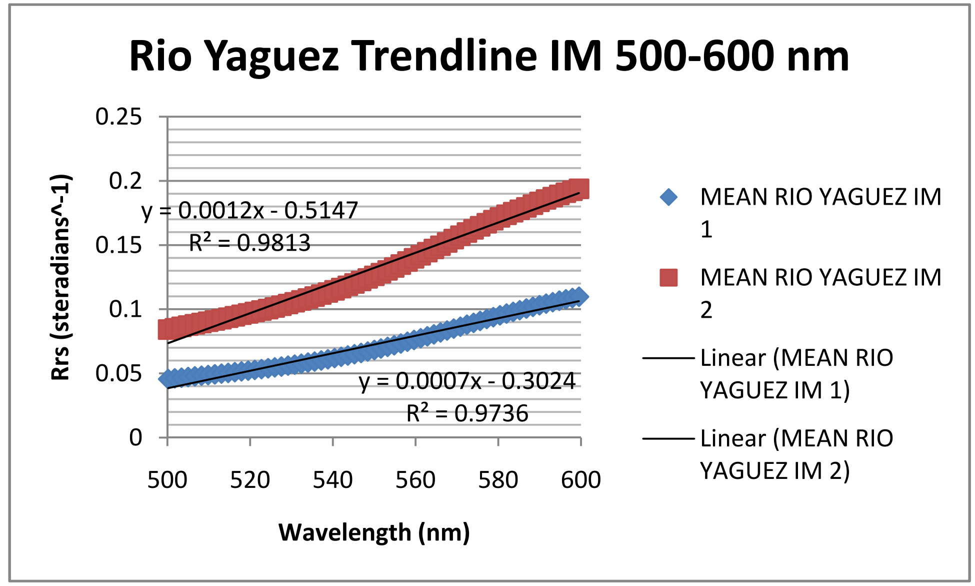


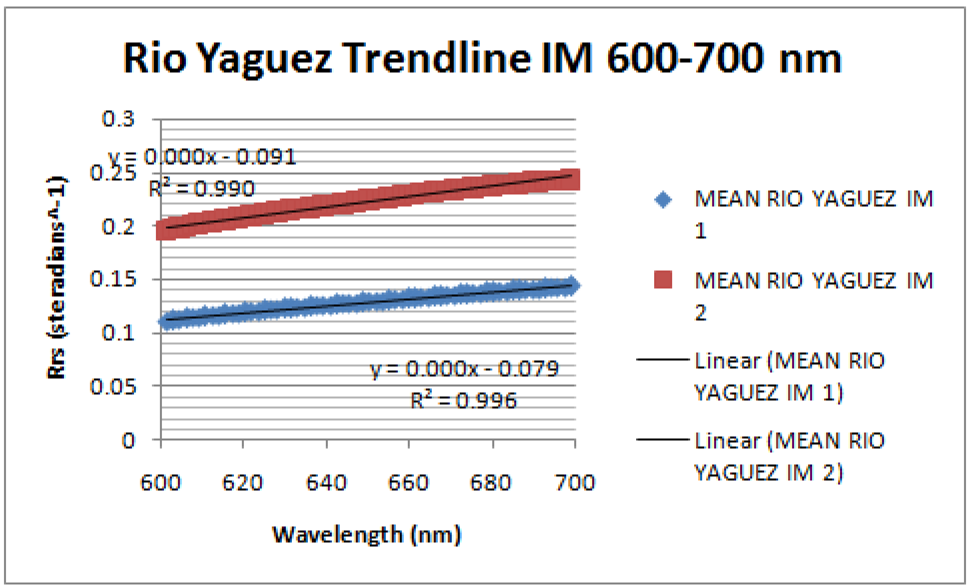


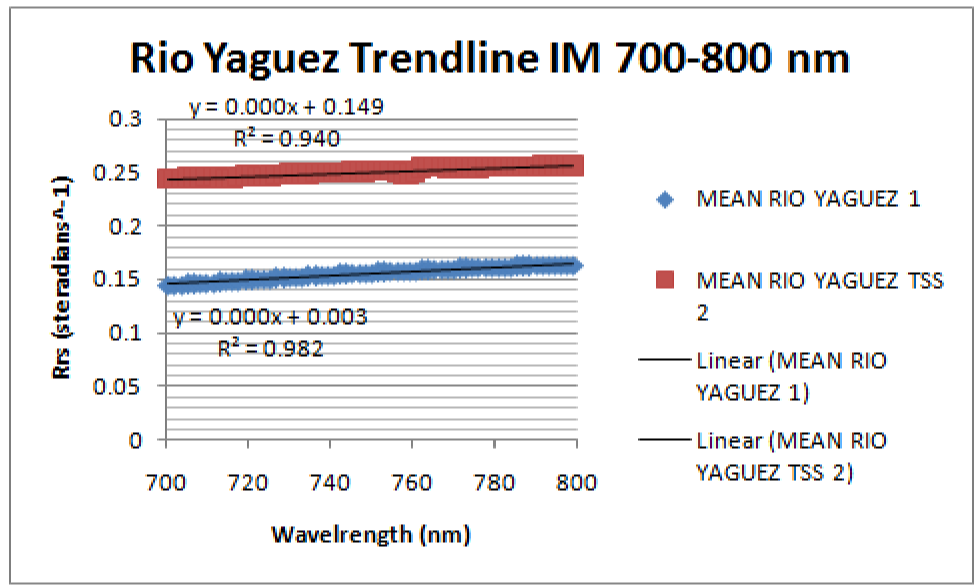


Appendix 4. Spectral Slope for Rio Anasco IM.









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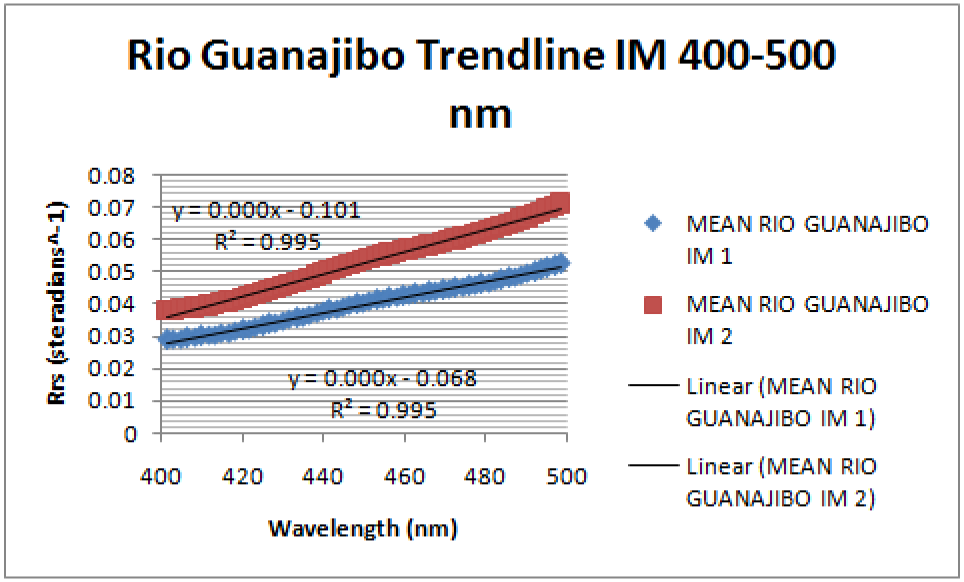

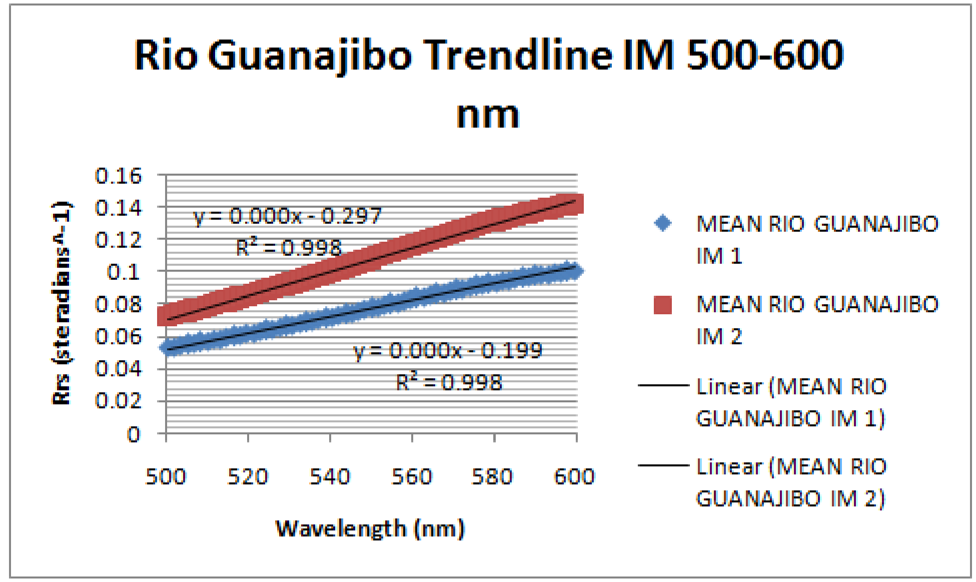

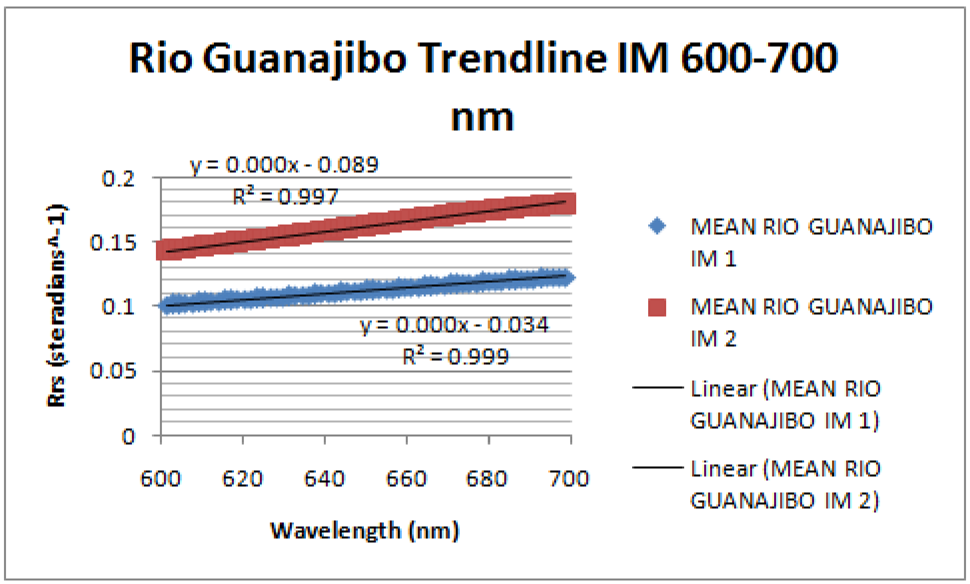

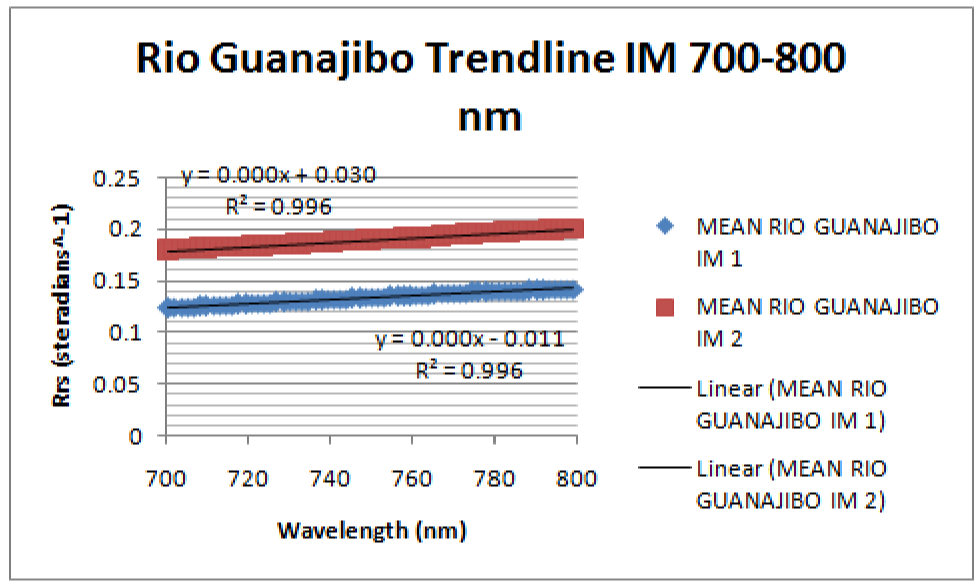

Appendix 6. Spectral Slope for Rio Guanajibo IM.