# Monitoring Sea Surface temperature change at the Caribbean Sea, using AVHRR images.

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**Abstract**

The Caribbean Sea is influenced by rivers, currents and winds which may have a significant impact in the sea surface temperature. The Caribbean Sea is said to be the largest marginal sea of the Atlantic Ocean (Sheng and Tang, 2003). Every year is affected by the runoffs of three major rivers, the Amazonas, Orinoco and Magdalena, which impacts the sea at different year's stations. Caho and Gao (2005) state that the "Satellite retrieval of SST is based on the measurement of emitted infrared or microwave radiation from the ocean surface at "window" regions where attenuation due to atmospheric constituents (e.g., aerosols and water vapor) is small". Images from the Advanced Very High Resolution Radiometer (AVHRR) from 1999, 2004, and 2009 were processed to calculate the SST with an algorithm provided in ENVI software. Results depicted that for winter and spring Caribbean Sea temperature, in general, were high, of 15 - 40° C. Meanwhile, for summer, temperatures are generally cool (15 - 26° C), especially near the islands and small pockets of 40° C, very far away from land.

## Introduction

The Caribbean Sea is said to be the largest marginal sea of the Atlantic Ocean (Sheng and Tang, 2003). Because of highly variable bottom topography and irregular coastlines, the CS physical processes are significantly affected (Sheng and Tang, 2003). The Caribbean Sea waters are highly stratified and are affected by freshwater runoff from three major rivers known as the Magdalena, Orinoco, and Amazon River (Sheng and Tang, 2003). The Amazon and the Orinoco River represent 20% of the total annual

freshwater discharge (Montgomery et al., 2004). The Amazon River influence the Caribbean Sea mainly during the winter and spring while in fall and summer has less influence because the plume flows offshore towards Africa (Sheng and Tang, 2003).

Sea surface temperature (SST) is an indicator of coupled ocean- atmosphere variability as said by Ruiz- Ochoa et al., (2012). Many studies have been developed to measure SST with different instruments such as buoys, however, the AVHRR Earth- Orbiting polar satellite provides better information with better spatial resolution (Ruiz- Ochoa et al., 2012). The Advanced Very High Resolution Radiometer (AVHRR) was introduced approximately 30 years ago and is part of the Pathfinder program developed by the National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA) (Ruiz- Ochoa et al., 2012 and Kumar et al., 2000). AVHRR is commonly used for remotely determining cloud cover and the surface temperature (Kilpatrick et al., 2001). AVHRR spectral regions have been selected to attain meteorological objective, including spectral data to distinguish clouds, snow, ice, and open waters (Campbell, 2007). The recent AVHRR/3 sensor carried in the NOAA-15 scanning radiometer launched in 1998 has 6 detectors to collect different bands of radiation wavelength (NOAA, 2015). Studying the sea surface temperature is important because it drives many of the physical and biological processes that impact the global and local environment (Schott et al., 2012). Seawater vary depending on the density, depth and also, temperature (Pahlevan, 2012). Shallower waters are characterized by greater temperatures than deeper waters.

**Objectives**

Our interest was to develop a project where the change in sea surface temperature of the Caribbean Sea can be obtained by using the AVHRR sensor. To

verify if the temperature change of the water in a specific year is due to any natural occurring event. For this reasons the results will be quantified by the use of graph and data analysis.

## Data and Methodology

The AVHRR images are from 1999, 2004, and 2009. These images were employed to analyze Sea Surface Temperature (SST) in the Caribbean Sea every 5 years. The image processing was possible by the use of ENVI program and the ENVI's specific utility for AVHRR, SST. ENVI computes sea surface temperature in Celsius (C$^{o}$ ) using the AVHRR bands 3, 4, 5 (http://www.exelisvis.com/docs/AVHRRSeaSurfaceTemperature.html). Band 3, 4 and 5 are all within the infrared spectrum which is better to obtain thermal values. The first step was to open the image, which was downloaded from NOAA's, and submit it to an AVHRR specific utility called SST. This utility is within Basic Tools, preprocessing, data-specific utilities, AVHRR and SST. After the SST process, a mask is applied with a minimum of 25° C and a maximum depending on the image statistics. This mask will help to hide all the material that is not within the given range. The color ramp will have a better expression and colors will be more displaced throughout the image.

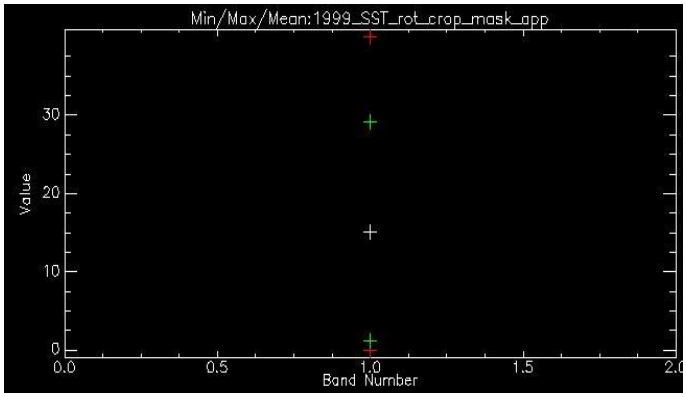
## Results and Discussion

The first processed image is from august 1, 1999, Puerto Rico (PR) is localized to the north, at the center top covered in clouds, to the left is Dominican Republic (DR) and South America (SA) south east of the image. The legend clearly indicates that the sea-water temperatures has a range of ~ 20 - 40° C; purple, blue and green are indicators of normal to intermediate temperatures while red, orange and yellow are indicators of high/hot temperatures. In this year, Caribbean Sea (CS) sea surface temperatures (SST) near the land demonstrate to be hotter that in the open waters, where the basin is located, specifically south of PR and extending a little to the west. South east of the image,

the ocean can be observed with color red, and it is the Amazon River plume, which does not affect the Caribbean during summer, but instead towards the Atlantic Ocean and Africa. Table 1 helps us to observe the values given at the statistics by the program, with a maximum of 39.9° C and an average of 15.15° C which are exactly the values represented in colors at the image. Followed by a plot which identifies the distribution of the values throughout the image.

| Basic Stats | Minimum | Maximum | Mean | Stdev |
|---|---|---|---|---|
| Band 1 | 0.000000 | 39.996155 | 15.155680 | 14.020244 |

***Table 1: Table of statistics of AVHRR SST from 01/08/1999.*** *Presents an average temperature of 15° C and the highest temperature of 40° C.*




In January 1, 2004, PR position is north and DR is northeast of the image with less amounts of clouds throughout the area. Almost all the Caribbean Sea can be observed to be hot (red colored). The temperature range is from an average of 15 - 30° C, therefore the temperature maintains higher than that of 1999. This is related with the fact that in winter, the Amazon River plume, deposits, run towards the Caribbean Sea. The temperature at open sea is 30° C and at the islands coasts, it can be observed with temperatures of 26 - 28° C. This means that for winter coastal waters are hotter than in summer. Statistics histogram demonstrates that most of the temperatures of 25° C and over.

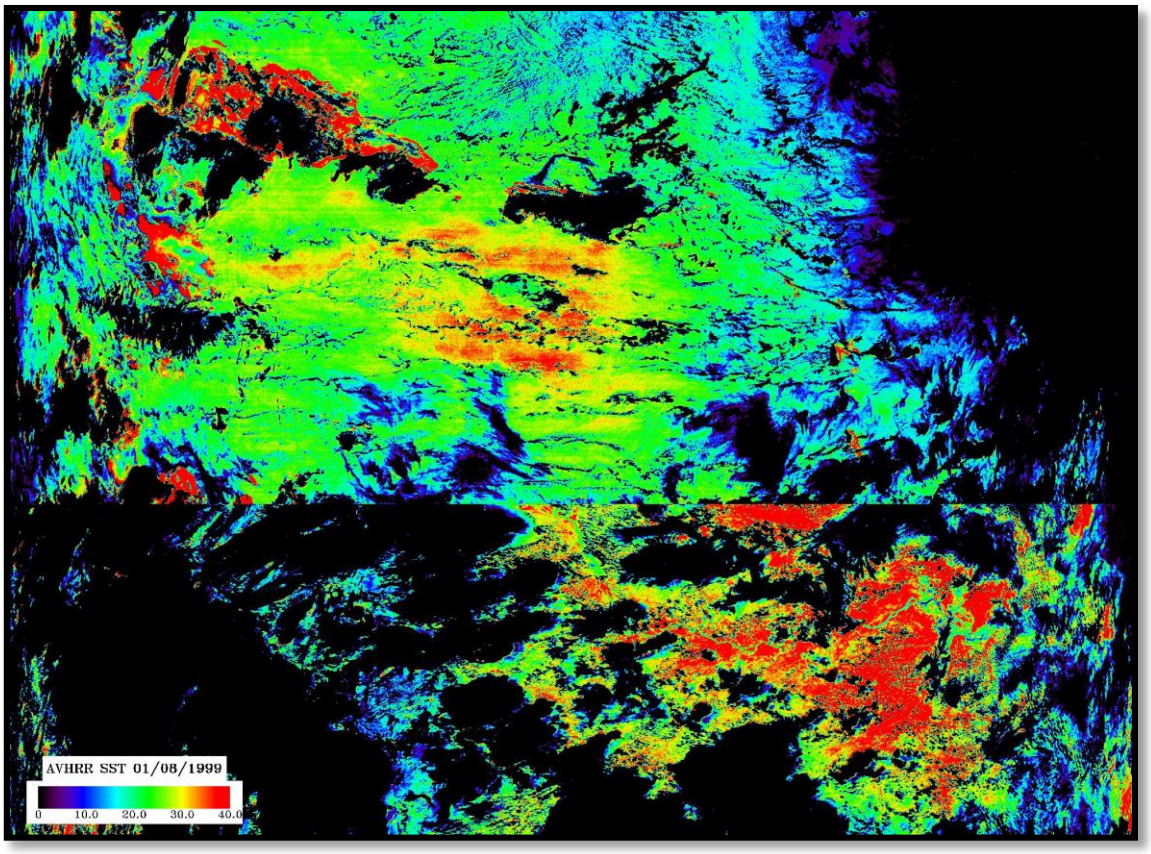



***Figure 1. AVHRR SST, Caribbean Sea in 1999.*** *From purple to light blue are normal temperature; green is for warm waters and from yellow to red are hot/ high temperatures.*

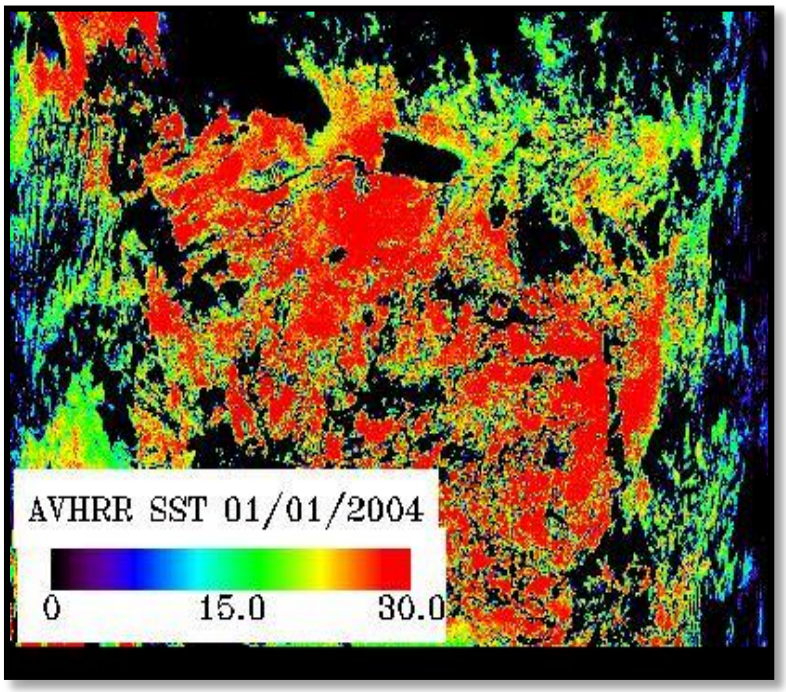
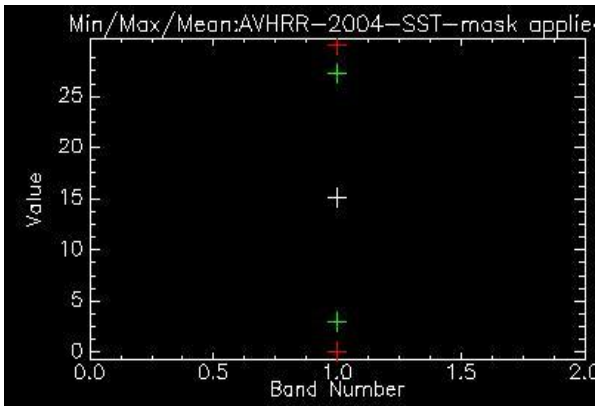



***Figure 2. AVHRR SST, Caribbean Sea in 2004.*** *From purple to light blue are normal temperature; green is for warm waters and from yellow to red are hot/ high temperatures.*

| Basic Stats | Minimum | Maximum | Mean | Stdev |
|---|---|---|---|---|
| Band 1 | 0.00000 | 29.955414 | 15.152631 | 12.161231 |

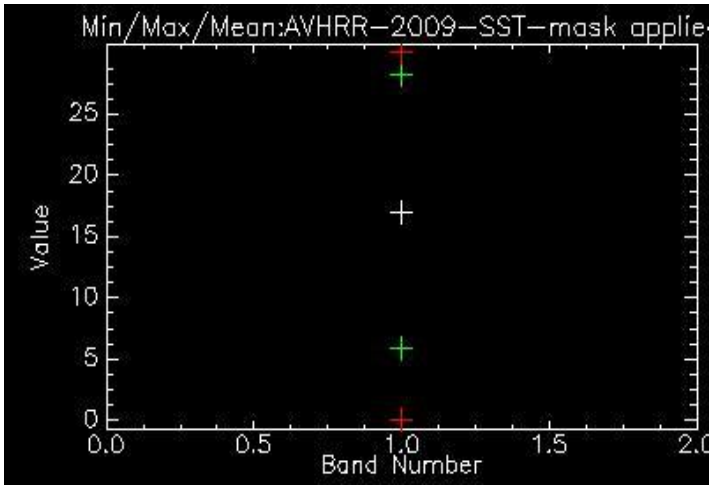
***Table 2: Table of statistics of AVHRR SST from 01/01/2004.*** *Presents an average temperature of 15° C and the highest temperature of 30° C.*




In February 1, 2009, the NOAA's image can be observed to be more centered, a more broad picture of the CS. PR is northeast with coastal water temperatures of 22.5° C and DR, to the west, SST are of 22.5 - 30° C. Throughout the CS, the SST maintains in 22.5 - 30° C very similar to that of January. Statistics helps determine that the average temperature at the CS for february, 2009 are approx. 17° C. Comparing this results with the past two images from 1999 and 2004, which average was of 15.15° C, could be the result of clouds that were not covered with the mask that was built. Another possibility could have been that the selected range for each image needs to be check again and correct it. February falls within winter therefore SST of the CS are being affected by the Amazon river plume. At the statistics histogram it can be observed that temperatures are from 17 - 30° C.

| Basic Stats | Minimum | Maximum | Mean | Stdev |
|---|---|---|---|---|
| Band 1 | 0.00000 | 29.994415 | 17.057420 | 11.128010 |

**Table 3: Table of statistics of AVHRR SST from 01/02/2009.** Presents an average temperature of 17° C and the highest temperature of 30° C.



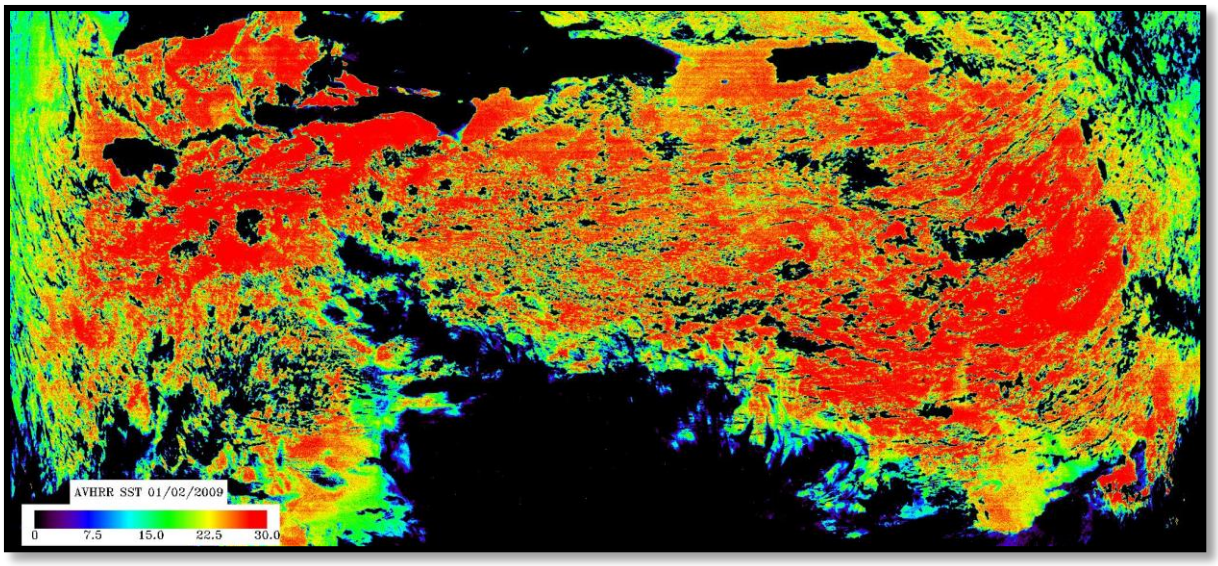



***Figure 3. AVHRR SST, Caribbean Sea in 2009.*** *From purple to light blue are normal temperature; green is for warm waters and from yellow to red are high/hot temperatures.*

## Recommendations

The advantage of The Advanced Very High Resolution Radiometer (AVHRR) is that it has been working since approximately 30 years and by consequence it provides sufficient image results. However, the biggest challenge working with AVHRR is the enormous amount of clouds in the images. In order to develop more accurate results we suggest the usage of other sensors such as the Moderate Resolution Imaging Spectroradiometer (MODIS) which has 36 bands and provides radiometric performance. In addition, MODIS (250, 500, 1000 m) spatial resolution is better in comparison with AVHRR (1.1 km) (http://eoweb.dlr.de:8080/short_guide/D-MODIS.html). Other recommendation would be a mosaic of several images of the same month in order to have a better coverage area without clouds.

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