Sahara Dust Aerosol Distribution in the Caribbean through Time as Detected by MODIS Terra/Aqua

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Abstract[1]

The Saharan Dust is a natural phenomenon that develops in the Sahara Desert in Africa due to natural causes such as dust storms. It is considered an aerosol, which is defined as a small particle suspended in the atmosphere. This project will visualize how particles rise into the air column and move across the Atlantic Ocean, South America, Central America, North America and the Caribbean. Because it has been proven that this aerosol transport important nutrients in agriculture and ocean productivity, this project decided to focus on processing satellite images in order to understand the distribution of Saharan dust in the Caribbean. This was possible by obtaining from the EarthData database by NASA that was then processed through the ENVI software utilizing the standard aerosol algorithm provided by MODIS above Terra and Aqua Satellites. It was concluded that in order to obtain high-quality images from aerosol particles, specifically Saharan Dust, a more specific algorithm should be used.

Introduction[1,2]

Remote sensing is the science and art of obtaining, monitoring and processing data from sensors. The information is produced first from sun's irradiance, emitting photons that move through space and arrive at Earth. This light transmits, scatters, and reflects depending on the object it encounters. Sensors then survey different wavelengths of objects, and this data can then be processed. In this project, remote sensing techniques will be applied to develop aerosol maps in the area from Puerto Rico to Occidental Sahara, in Africa.

Saharan dust was selected as a topic of interest due to its impacts and how it influences Puerto Rico weather. Investigators were curious to know if the Saharan Dust was something that could be studied with Satellite imagery. After research, it was learned that Saharan dust is, in fact, something that can be remotely sensed, because it consists of aerosol particles.

In the past, researchers such as Madhavan et al. (2017), applied remote sensing techniques (i.e., satellite imagery) to the study of Saharan dust. They developed images in which one could see the Saharan dust density around their study area. In 2017, Madhavan, et al., utilized data obtained from MODIS (Moderate Resolution Imaging Spectrometer) aboard

of Aqua satellite sensor. Due to the spectral properties of the sensor, this instrument can help scientists to detect diverse features within the atmosphere.

Nowadays, there are few sensors and tools that are able to detect aerosol in the atmosphere from "straight-to-the-point" procedures. Using these remote sensing tools such as ENVI software, and satellite imagery from MODIS, it is expected to obtain aerosol distribution measurements. MODIS, aboard of the Terra satellite, is able to detect properties of aerosols in the atmosphere and their spatial resolutions (e.g. 250m from band 1-2, 500m from band 3-4, and 1km from band 6-36). It contains 36 spectral bands, which is ideal for studying reflectance, emissivity, aerosol coverage, among others from one single image.

Scientific Context[2]

The Saharan dust composition can vary depending on its transportation medium or state of transport. In general, most of the minerals that compose the dust are silicates, sulfates, and some types of clayish minerals like kaolinite and illite (Kandler, slide 11). Composition of each of these minerals will be different depending on the state of transport, being through aerosol high-pressure displacement through the atmosphere, or as suspended sediment, when the dust lies deposited on river channels and land surfaces as dust transport ceases.

For the purposes of this research, dust parameters such as land aerosol concentration, compositional and aerosol ratios, temperature, and thickness were chosen to study the effects of Saharan dust across the Atlantic Ocean. This last one has the name of Angstrom Exponent and is measured in micrometers per meter cubed, quantifying dust thickness. These factors are the focus of the research, by using the ENVI software to apply preprocessing steps in order to obtain and display aerosol and temperature distribution.

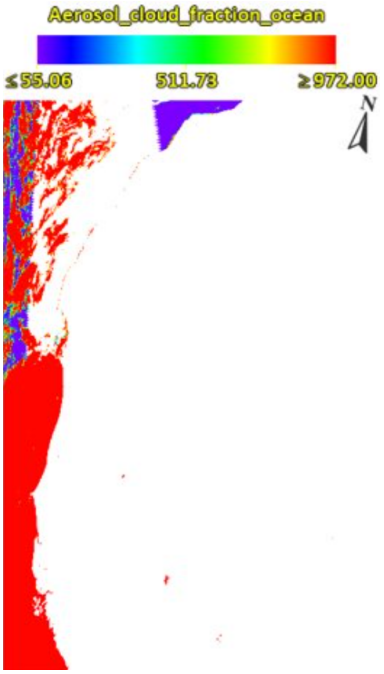

Figure 1: *Aerosol cloud fraction of the ocean in the Occidental Sahara area***,** *MODIS, for March 2021. (Muñiz Llorens, 2022).*

Methodology[2]

The NASA EarthData Database was used to acquire images from MODIS sensor for both Terra and Aqua satellites. It was chosen for the MODIS-Aqua Aerosol L2 Swath datasets, which contained pixel masks with information about some of the aerosol properties of saharan dust. Each of these masks can be assigned to the preferred spectral bands and compare one with another. These files are saved inside a HDF file format for each dataset available in EarthData. The chosen area of interest for this study was from West Africa to Eastern Puerto Rico, in order to determine how much aerosol

particles arrive to the island through a certain time interval. Datasets were selected for March 2021, June 2021, and January 2022, emphasizing 3 locations for dust distribution: West Africa (March 2021), the Atlantic Ocean (June 2021), and Eartern Puerto Rico (January 2022).

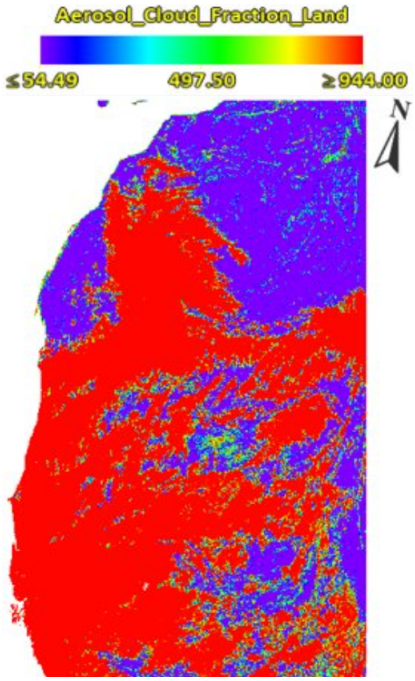

Figure 2*: Aerosol cloud fraction of the land in the Occidental Sahara area, MODIS (Muñiz Llorens, 2022).*

Figure 3: *Mass concentration of land, MODIS, from Occidental Sahara area. (Muñiz Llorens, 2022).*

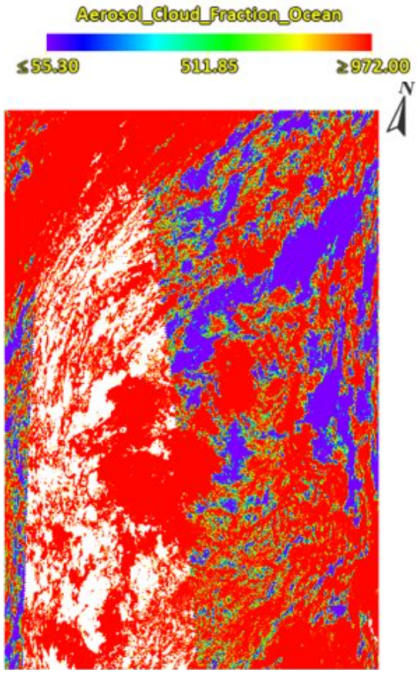

Figure 4: *Aerosol Cloud fraction at East Atlantic Ocean, MODIS (Muñiz Llorens, 2022).*

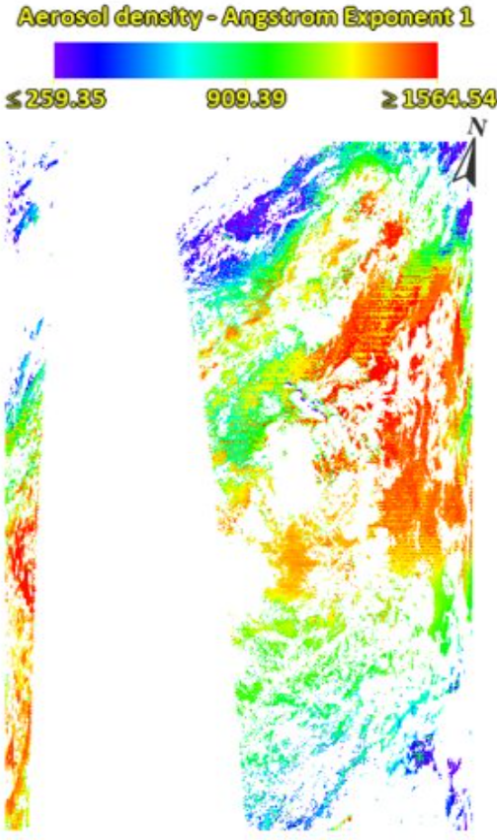

Figure 5: *Angstrom Exponent 2, MODIS. (Muñiz Llorens, 2022).*

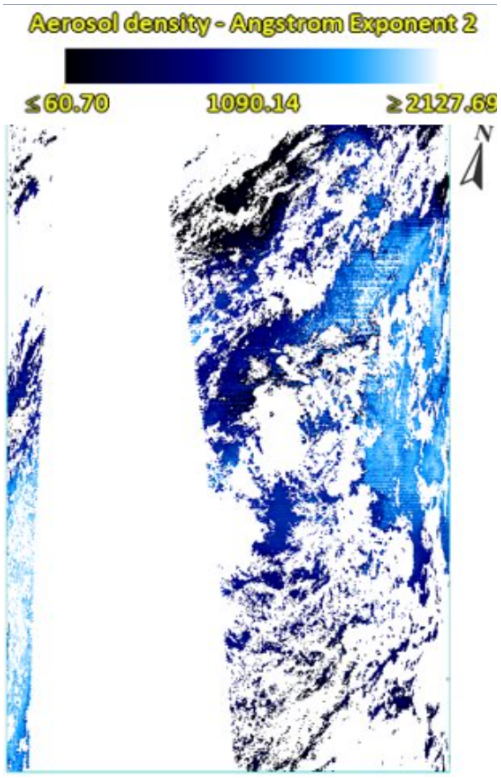

Figure 6: *Aerosol density with Angstrom Exponent 1, MODIS, at Puerto Rico (Muñiz Llorens, 2022).*

Discussion[2, 3]

The HDF file format is a structured file that is a little difficult to work on, since the data types are organized by separate single-band images that are used to be overlayed in each other. Several combinations of these images were selected and opened in ENVI in a RGB order to determine which combination of bands is ideal for the purpose of this study.

Each of the aerosol layers were inspected to verify the credibility of each parameter studied. Masked images from the EarthData database as of January 19, 2022 were studied from a spatial and spectral point of view.

For purposes of visualizing the distribution of dust along our region of study, an image of OLI from Eastern Puerto Rico was chosen to study this. However, the MTL files from the OLI image (around the same date as the mask files) didn't load properly on ENVI software. Therefore, a clear true color image from this area couldn't be processed. Each of the bands can be loaded as GeoTIFF files. However, it was somewhat difficult to distinguish between individual red, green, and blue spectral bands from these files; there was one GeoTIFF file from the NIR band identified by the greater absorption of these wavelengths in water bodies. The MTL file is needed to run all the 8 bands at the same time.

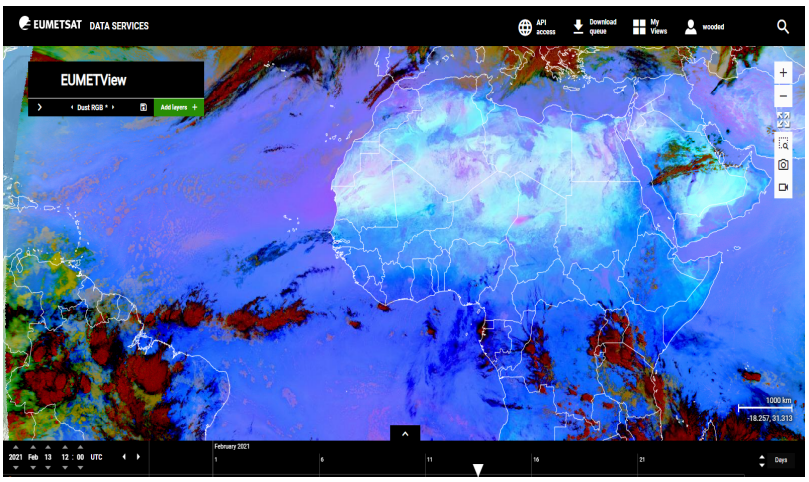

Figure 7: *Image extracted from EUMETSAT, showing the transportation of the Sahara dust from North Africa to the Caribbean (Eumetsat).*

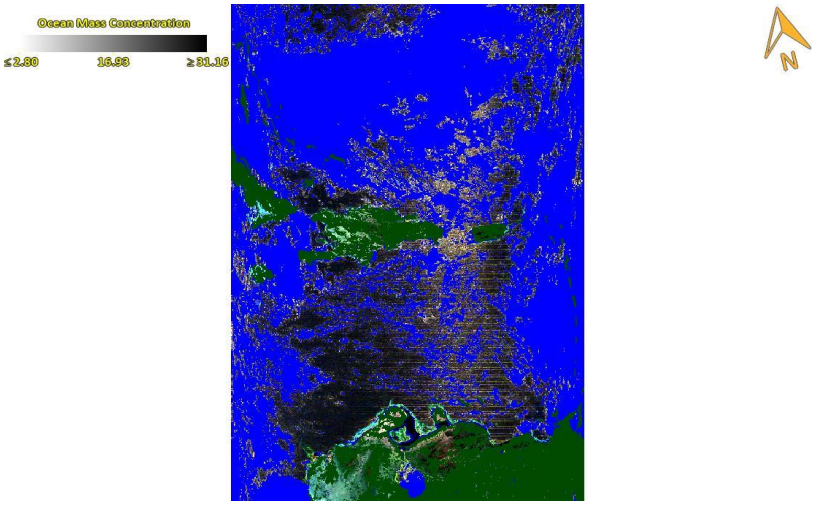

Figure 8: *Processed image from the sensor MODIS that shows the density of aerosols in the Caribbean (Ortiz Jones, 2022).*

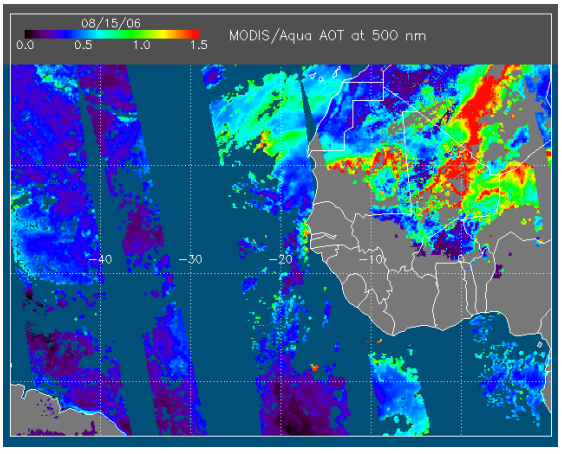

Figure 9: *Image from sensor MODIS Aqua showing the Aerial Optical Thickness (EarthData)*

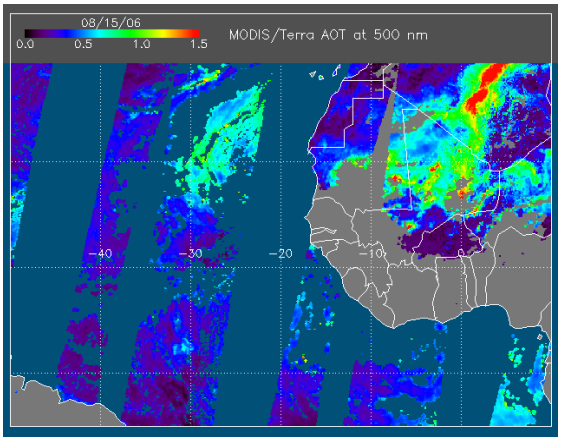

Figure 10: *Image from sensor MODIS Terra showing the Aerial Optical Thickness (EarthData).*

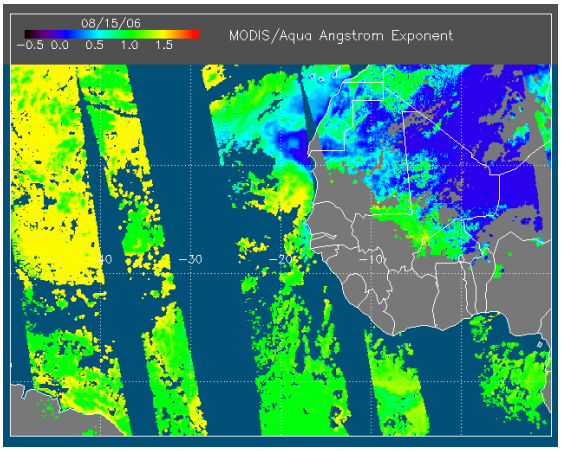

Figure 11: *Image from Modis Aqua that shows the Angstrom Exponent (EarthData)*

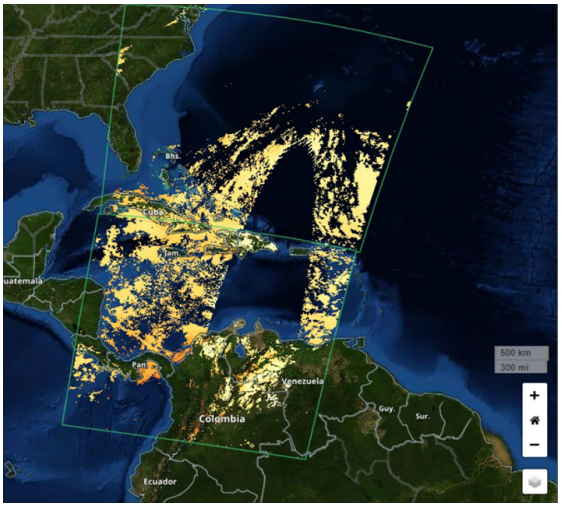

Figure 12: *Image from MODIS Terra at NASA EarthData that shows the region of Puerto Rico where no aerosol data was recorded (EarthData)*

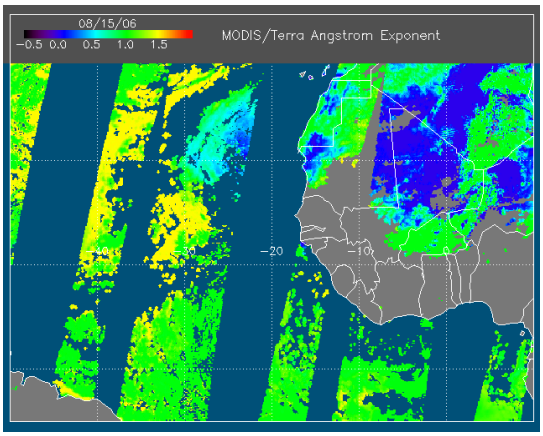

Figure 13: *Image from Modis Terra that shows the Angstrom Exponent (EarthData).*

Other Databases that were searched to assist this investigation were: Creodias, Mundi Web Service, ONDA y Sobloo. The images that were gotten from those databases are from the SENTINEL sensor. These were not used because they were in the HDF format and their spatial resolutions were too big for what it was looking for. The experience and events that happen when trying to download and process images were complicated, because the images, specifically those tested with SENTINEL, were in H5 format, and also very difficult to open them. It was needed to access a table that has multiple levels of data, and each of them are masks that were needed to be put in a certain way one over the other like a puzzle. In the case of the image that shows the concentration of aerosols (Figure #8), the process was tedious because to be able to process the image, approximately 28 rasters were opened with each data mask separately.

Conclusions[1,3]

The expected objectives obtained from the experimentation with the images obtained, it can be said that they were partially satisfactory. The use of satellite imagery to study atmosphere properties could be helpful for scientists in order to monitor the density of aerosols coming out from West Africa. Yet, it is a process that requires time investment, since not all images will have the aerosols of interest. After processing and developing a few images, it was understood why researchers utilized a more specialized algorithm to detect Saharan particles. Utilizing the standard algorithm for aerosol appeared to be a broad classification, since once could not tell between the different types of aerosol particles.

References[1,2,3]

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NASA EarthData Database. www.earthdata.nasa.gov/search

Eumetsat. https://view.eumetsat.int/productviewer?v=default

Images of Modis Aqua and Terra:

- https://search.earthdata.nasa.gov/search?fi=MODIS&fsm0=Aerosols&fst0=Atmosphere