Saharan Dust Aerosols Detection Over the Region of Puerto Rico

ARLENYS RAMÍREZ

University of Puerto Rico at Mayagüez, P.R., 00683. Email:arlenys.ramirez@upr.edu

ABSTRACT.— **Every year during the months of late May through August, aerosol from the Saharan desert travel across the Atlantic Ocean to the Caribbean, reaching the region of Puerto Rico. In this research we used satellite images from the Moderate Resolution Imaging Spectro Radiometer (MODIS) and applied the Brightness Temperature Difference (BTD)algorithm to detect the presence of saharan dust aerosol over the region of Puerto Rico (Lat. 17.0-20.0; Lon.-64.0, -69.0). We used Aqua MODIS Atmosphere Level 2, products images of 1km of spatial resolution for the months of June, July and August of the years of 2011,2012, 2013. Images were also processed using the SEADAS software as an alternative technique to identify aerosols from satellite images. Then we validated these observations with ground-based data using the AOD at 440nm from the Aerosol Robotic Network(AERONET) station of La Parguera (18.0,-67.0). Results for this research were different to the ones expected, since for our study region, non of the two techniques applied in this research were found to be effective for the identification of the dust aerosols due to the presence of clouds in the images. In general BTD is very simple to calculate however there is confusion for images where clouds are present. From the AERONET data we observed that there is a variation in the amount of aerosols presence in the air. Since monthly average values were always higher for the month of June, than for the months of July and August, for the three years studied. Finally there is not a significant difference in the amount of aerosols that reached the region of Puerto Rico (at least in the last three years); since the maximum value (0.27) of AOT between the three years appears in 2012 with a difference 0.03 (3%) from 2013 which was the second year with the higher. AOT value (0.24).**

KEYWORDS.— **MODIS, AERONET, AOD**

INTRODUCTION

The Saharan Desert is the largest source of dust aerosols in the world and accounts approximately half of the dust supplied to the oceans (Christopher and Jones 2010). During the months of April though October, trade winds with enough speeds raises sediments from the ground up to ~5 km above the surface, making it easy for long-range transport of the dust particles over the Atlantic Ocean, and other regions as far as the Amazon. Transportation of the dust particles can take approximately from 5 to 7 days in arrive to the Caribbean, and it varies from season to season (Christopher and Jones 2010). The dust particles sizes varies with distance, with larger particles deposited near the source region, while smaller particles deposited along the Atlantic Ocean and the Caribbean (Christopher and Jones, 2010). Particles of the Saharan dust are mainly composed of silica with varying concentrations of other components, ranging from 0.1m to 10 m in radius size (Tegen and Lacis, 1996).

Dust aerosols from the Saharan Desert have extensive local and regional impacts. Such as serving as a nutrient source for the oceans, modifying rainfall, affecting storms activities, affecting regional climate, algal blooms, and human health by changes in the air quality (Anunforom et al., 2007; Sassen et al., 2003; Longueville et al., 2010; Christopher and Jones, 2010; Goudie and Middleton, 2001). For that reason, during the last decade, the use of satellite techniques to the study of Saharan dust has become very popular. Since it is possible to track the dust aerosols path over a wide range. Based on this approach we wanted to answer the question if there was a significant difference in the amount of aerosols that have arrived to the island in the past three years? To answer this question we used a simple methodology that will be discussed later.

Data and Methods

During the last two decades remote sensing satellite data has been used to the observation and detection of dust aerosols. There are a few methods like the ones shown by Sundar and Jones (2010) and Baddock et al., (2009) which are techniques applied for providing information on dust detection over a region using different algorithms and the Moderate Resolution Imaging Spectroradiometer (MODIS). However, in this study we used a simple methodology consisting of the brightness temperature difference (BTD) using the bands 8 and 11 of MODIS combined with ground-based observations in order to validate the satellite images observations. We used satellite images from MODIS and ground-based measurements from the Aerosol Robotic Network (AERONET), to observe, detect, and compare the presence of saharan dust over the region of Puerto Rico. The objectives of this research were to observe and detect dust aerosols from the Sahara Desert in satellite images. Process and analyze images from different dates (June-August 2011,2012,2013) from the region of Puerto Rico. Finally estimate the concentration of dust aerosols from these dates and compare them.

Satellite images were obtained from the MODIS AQUA sensor, from the period of June-August, 2011 2012, 2013. MODIS Level 2 (1km), Brightness Temperature images from the MODIS 5.1 collection, were downloaded from the National Aeronautics and Space Administration center (NASA) website http://ladsweb.nascom.nasa.gov/data/search.html. MODIS is an instrument that provides high radiometric sensitivity in 36 spectral bands in wavelength from 0.4m to 11.4 m. It was launched onboard of the (EOS AM-1) platform, Terra on December 1999 and MODIS-Aqua on 2002. MODIS-Terra orbits the earth in the morning from north to south across the equator, whereas MODIS-Aqua orbits the earth from south to north over the equator in the afternoon.

For the dates used in this research, images with high amount of cloud or sun-glint were discarded. Then georeferencing, and spatial & spectral subsets were applied to each one of the images selected the images using the ENVI software, in order to select our study region (The region of Puerto Rico 17.0-20.0N,63.0,69.0w). Then in order to obtain the processed images, we manually applied into the ENVI software the Brightness Temperature Difference (BTD) $BTD = BT_8 - BT_{11}$, where BT_8 is the brightness temperature at the band 8 and BT_{11} is the brightness temperature at the band 11. Finally ground-based data was used to validated the results from images. We used the AERONET data from the station of La Parguera (18N,67W) with the parameter of Aerosol Optical Depth (AOD) @ 440nm in order to detect the presence of dust aerosols in the study region. Images were also processed using the SEADAS software as an alternative technique to identify aerosols from satellite images.

Aeronet

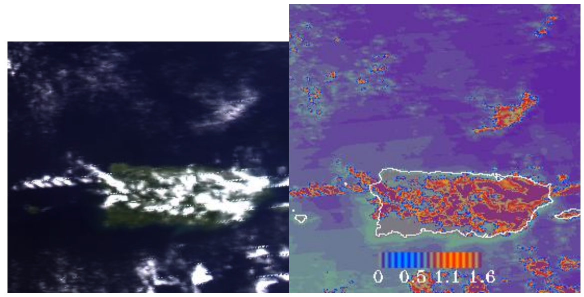
As mentioned before we use data from the AERONET at La Parguera (18N,67W) along with Level 2 Aqua-MODIS Brightness Temperature images from June, July, and August 2011, 2012 and 2013. The AERONET is a federation of ground-based remote sensing aerosol networks that was established by NASA and expanded by other collaborators. AERONET provides globally distributed observations of spectral aerosol optical depth (AOD). AOD or Aerosol Optical Tickness (AOT) is a degree to which aerosols prevents the transmission of light. Being a value <0.1 a crystal clear sky, and a value of 4 indicating high concentration of aerosols therefore is difficult to see the sun. Data for the aerosol optical depth are computed for three data quality levels: 1.0, 1.5 and 2.0. Level 2.0 data. products contains pre and post field calibration applied with cloud-screened data as well as AOD processing of fine and coarse mode AOD fine mode fraction . The Data is submitted every 24 hrs via satellite to the central centre and is available through the AERONET homepage at http://aeronet.gsfc.nasa.gov/new_web/aerosols.html. An important online analysis tool available that is available through AERONET is the Data Synergy Tool, which provides access to MODIS images and data.

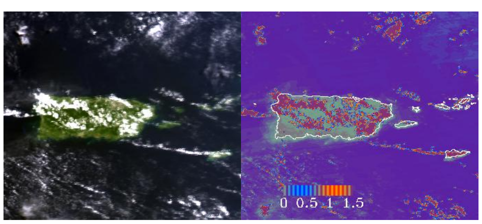
Brightness Temperature Difference

The Brightness temperature difference (BTD) is a straightforward method that according to Baddock et al., 2009, is commonly used for the detection of both dust plume and source detection. Even thought this method is commonly applied to these type of research, these procedure does not appear to be very sensitive to observed the mineralogical variabilities between plumes and dust. Another disadvantage is that since there is no definition of dust/non dust, the data become subjective and can suffer from cloud cover elimination. Baddock et al., 2009 recommend that when applying this algorithm there should be a good understanding about the mineralogy of the aerosols and also an understanding of how and why ground surface characteristics may vary.

Results

Due to limitations with the MODIS images, not all the images that were intended to be used were used since there were a lot of images containing sunglint and clouds. Here we present the results form the images that were selected.





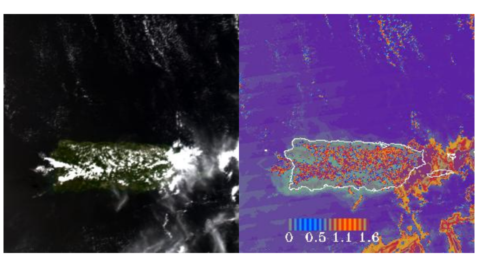
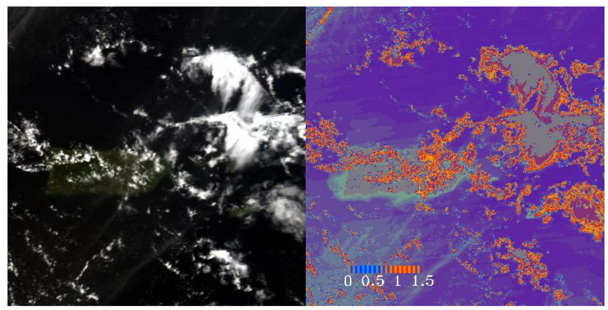
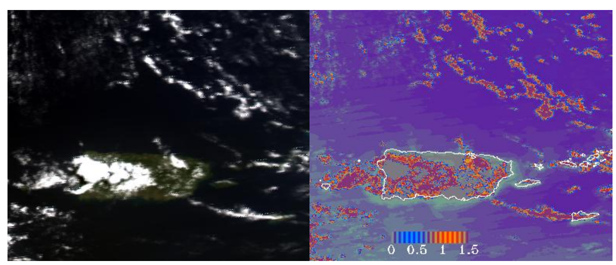


FIG. 1. Images from 2011. The first set of images are from June 21, 2011. The second set of images are from July 18, 2011 and the thrid set of images are from August 1, 2011. All of the sets shows true color images (Left), and processed Image (Right). Red Colors indicate higher values.





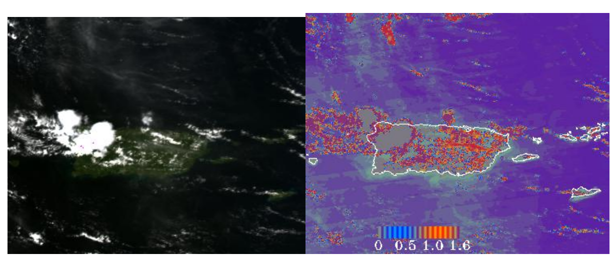


FIG. 2. Images from 2012. The first set of images are from June 26, 2012. The second set of images are from July 1, 2012 and the thrid set of images are from August 1, 2012. All of the sets shows true color images (Left), and processed Image (Right).Red Colors indicate higher values.

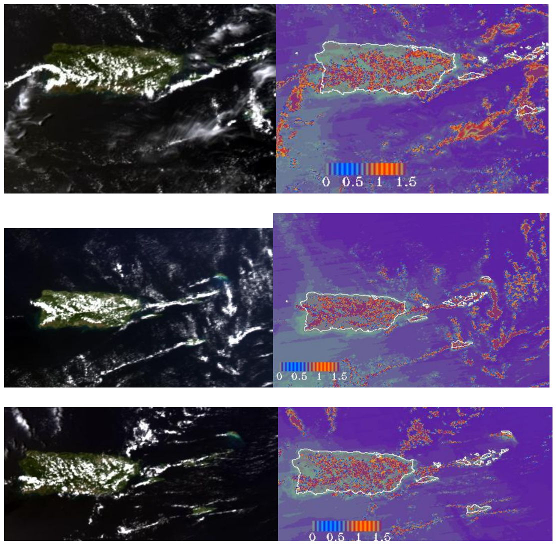
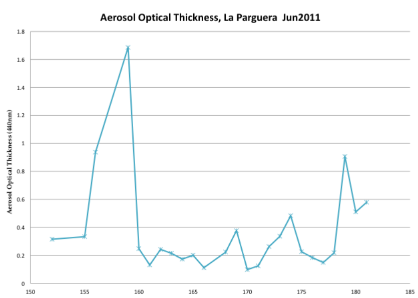
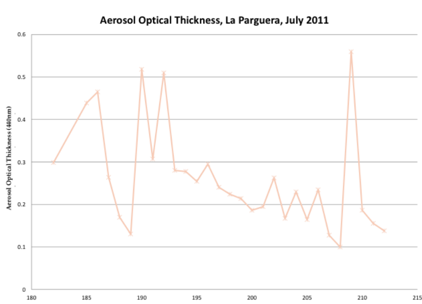


FIG. 3. Images from 2013. The first set of images are from June 21, 2013. The second set of images are from July 5, 2013 and the thrid set of images are from August 1, 2013. All of the sets shows true color images (Left), and processed Image (Right). Red Colors indicate higher values.

Here we present the data that we obtained from the AERONET station of La Parguera, Puerto Rico for the diferent dates under study.





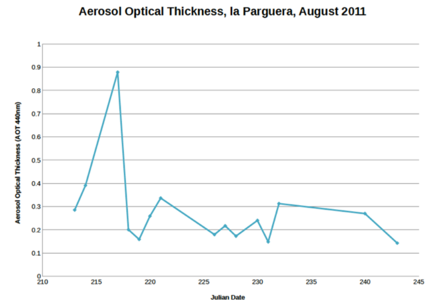


FIG. 4. Shows the AERONET data for AOT at 440nm from La Parguera for June, July and August 2011. Values in this scale goes from 0 to 4, where the values <0.1 indicate clear sky, whereas values of 4 indicates high concentrations of aerosols. Note that the highest pick ocurred during the month of June 2011.

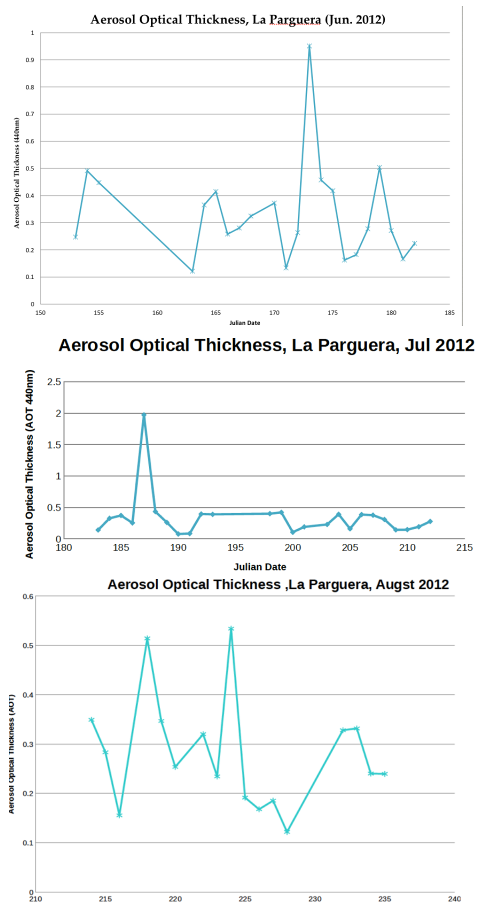


FIG. 5. Shows the AERONET data for AOT at 440nm from La Parguera for June, July and August 2012. Values in this scale goes from 0 to 4, where the values <0.1 indicate clear sky, whereas values of 4 indicates high concentrations of aerosols. Note that the highest pick ocurred during the month of July 2012.

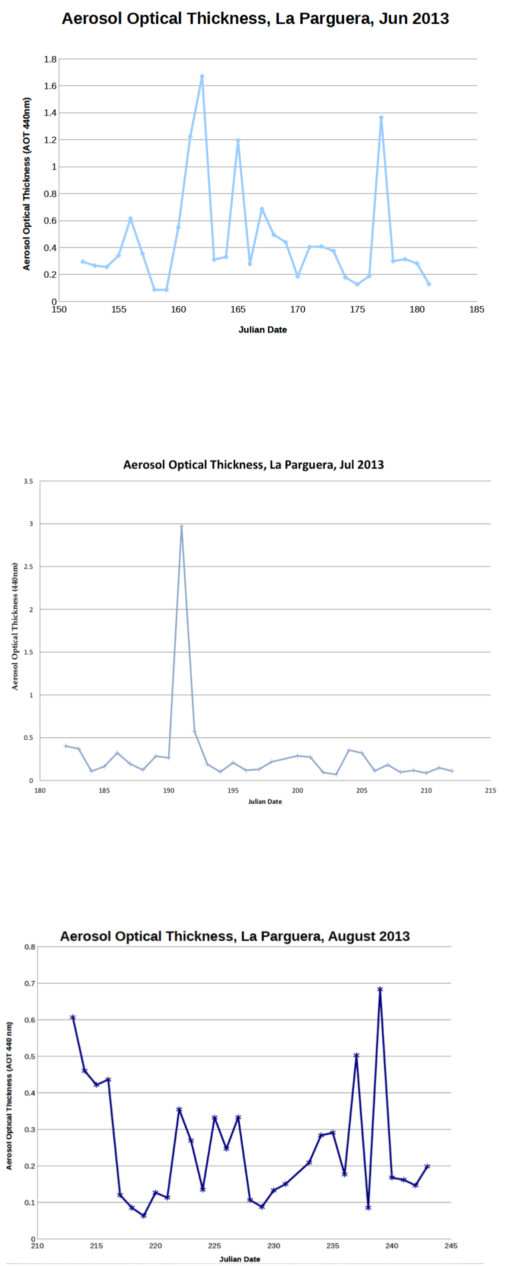


FIG. 6. Shows the AERONET data for AOT at 440nm from La Parguera for June, July and August 2013. Values in this scale goes from 0 to 4, where the values <0.1 indicate clear sky, whereas values of 4 indicates high concentrations of aerosols. Note that the highest pick ocurred during the month of July 2013.

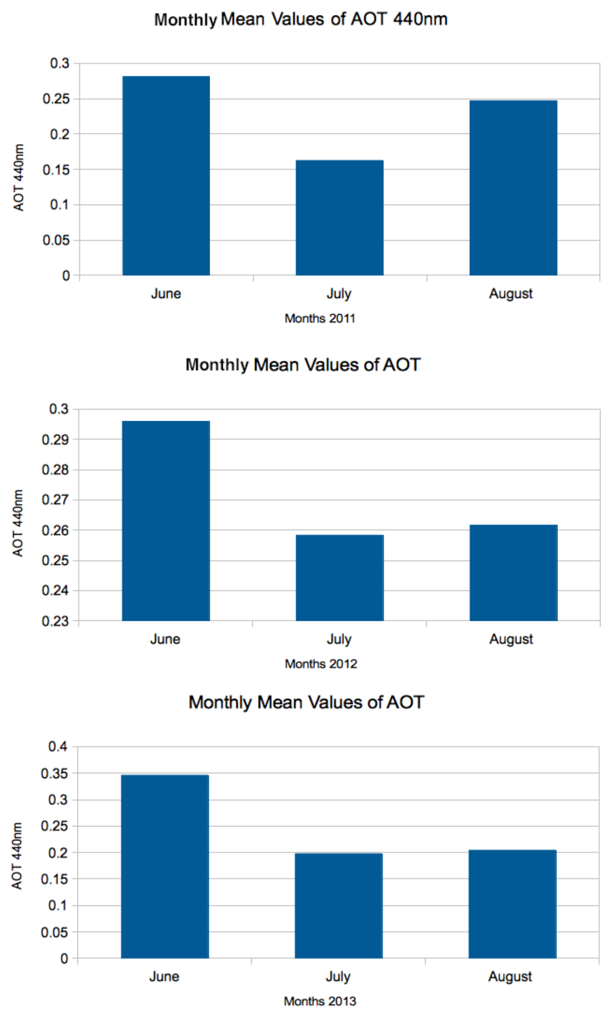


FIG. 7. Monthly mean values of Aerosol Optical Thickness.

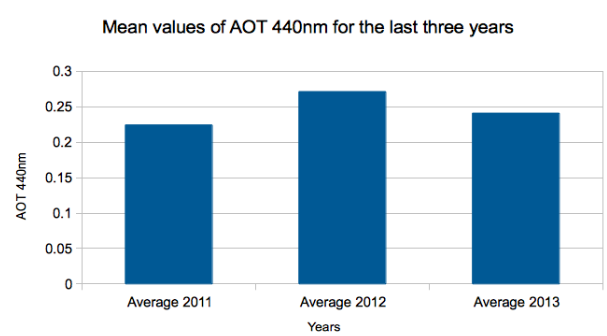


FIG. 8. Mean values of Aerosol Optical Thickness for June, July and Agoust the las three years. Note the higher values where in the year 2012.

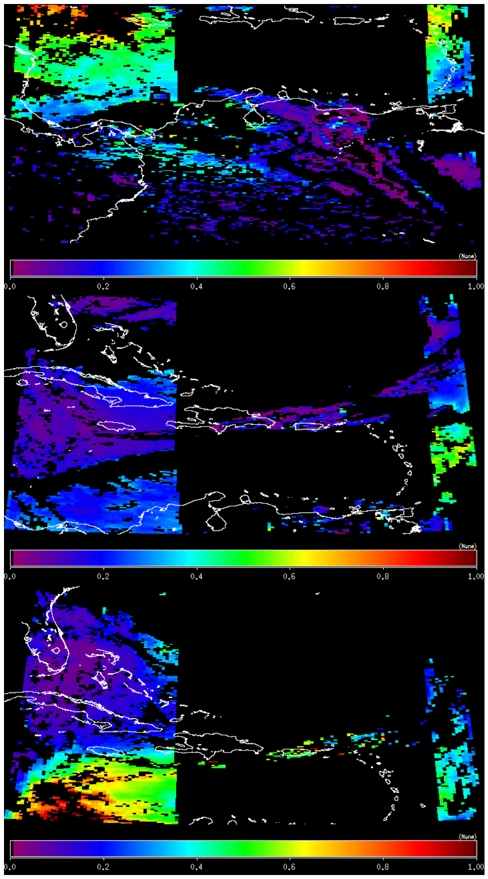


FIG. 9. Images processed in SEADAS, showing the Aerosol Optical Depth for the region of Puerto Rico. Black color indicates no data values, purple colors low values and no aerosol, whereas red colors are high values and higher concentrations of aerosols.

DISCUSSION

The main objective of this research was to evaluate MODIS (Aqua) images to detect dust aerosols over the region of Puerto Rico. Results were different from the ones expected, since for our study region, non of the two techniques applied in this research were found to be effective for the identification of the dust aerosols, due to the presence of clouds in the images. BTD is very simple to calculate however there is confusion for images where clouds are present, as confusion arises when trying to identify clouds from dust. This confusion can be avoided by applying an additional algorithm to the one used in this research and a cloud mask to the images. From the data obtained from AERONET, it can be observed that there is a variation in the amount of aerosols in the air. Also monthly average values were always high for June, than for the months of July and August for the three years studied. Finally there is not a significant difference in the amount of aerosols that reached the region of Puerto Rico (at least in the last three years), since the maximum value (0.27) of AOT between the three years appears in 2012 with a difference of 0.03 (3%) from 2013, which was the second year with the higher AOT value (0.24).

Acknowledgment.— This work is was possible thanks for the help of Dr. Fernando Guilbes, who taught us the key concepts of Remote Sensing and Image processing in ENVI.

REFERENCES

Anuforom A.C., Akeh L.E., Okeke P.N., Opara F.E., 2007, Inter-annual variability and long-termtrend of UV-absorbing aerosols during Harmattan season in sub- Saharan West Africa: Atmospheric Environment, v. 41, p.1550-1559.

Baddock, M.C., Bullard, J.E., and Bryant, R. G., 2009, Dust source identification using MODIS: A comparison of techniques applied to the Lake Eyre Basin, Australia, v. 113, p. 1511-1528.

Goudie, A. S., and Middleton, M. J., 2001, Saharan dust storms, nature and consequences: Earth-Science Reviews, v. 56, p.179204.

Longueville, F. D., Hountondiji, Y. C., Henry, S., and Ozer, P., 2010, What do we know about effects of desert dust on air quality and human health in West Africa compared to other regions?: Science of the Total Environment, v. 409, p. 1-8.

Prospero, J. M., Ginoux, P., Torres, O., Nicholson, S., and Gill, T., 2002, Environmental characterization of global sources of atmospheric soil dust derived from the Nimbus 7 Total Ozone Mapping Spectrometer (TOMS) absorbing aerosol product: Reviews of Geophysics, 40-1, 1002. doi:10.1029/2000RG000095.

Sassen, K.P., DeMott, P.J., Prospero, J.M., Poellot M.R.. 2003, Saharan dust storms and indirect aerosol effects on clouds: CRYSTAL-FACE results. Geophys Ress Lett, v. 30-1,1633. doi:10.1029/2003GL017371

Sundar, C. A., and Jones, T.A., 2010, Satellite and Surface-based remote sensing of Saharan dust aerosols: Remote Sensing of Environment, v. 114, p. 1002-1007.

Tegen, I., & Lacis, A.1996, Modeling of particle size distribution and its influence on the radiative properties of mineral dust aerosol: Journal of Geophysical Research,101, p.1923719244.