Aerosols in the Caribbean - Mid-Atlantic Region as Observed with the EOS Moderate Resolution Imaging Spectroradiometer (MODIS)

Deborah Abrams lavalamp830@yahoo.com
Carla Roig-Silva carlaroig@gmail.com
UPRM-Department of Geology

Abstract

MODIS aerosol products were processed using ENVI 4.3 and the MODIS Conversion Tool-Kit plug-in, in order to observe aerosol behavior across the mid-Atlantic region during spring and autumn months. Four individual mosaics were created for each MODIS sensor platform (Terra and Aqua) for June 7, and November 7, 2006. Results suggest great variability of aerosol concentration during the year, changes in precipitation patterns and greater health risks for the Caribbean region during the spring months.

Keywords: MODIS, MODIS Conversion Toolkit, aerosols, Caribbean region

INTRODUCTION

Aerosols are one of the greatest sources of uncertainty in climate modeling. They include any kind of solid of liquid particle matter less than 2.5 micrometers in diameter that remain suspended in the air and affect air quality and climate throughout the world. Natural sources of aerosols include wind-blown dust, sea salt from ocean spray, and volcanic eruptions. Anthropogenic sources of airborne particle matter include products from the burning of fossil fuels, biomass burning, and industrial emissions. Concentrations and migration of aerosols are closely monitored because they contribute to a variety of health risks and can lead to variations in cloud microphysics, which impact cloud radiative properties. By reflecting sunlight, aerosols cool the planet. By altering the cloud properties (more aerosols lead to more numerous, smaller cloud droplets which are less reflective), aerosols indirectly warm the planet. Finally, smaller cloud droplets can prolong cloud lifetimes, which are not yet well understood (http://www.nrlmry.navy.mil...Aerosol.pdf). For this reason, aerosol optical thickness (AOT) data, which extends from the earth's surface to the upper limit of the atmosphere, is considered to be an integral part of both the health problems millions suffer from and the climate crisis facing the world today. Because on-site data collection is so difficult to obtain simultaneously throughout the globe, remote sensors are the key to observing the impact we make and the changes occurring in our atmosphere.

OBJECTIVES

The main objective of the subject we chose is to observe and compare the AOT in the Caribbean Region between Spring and Autumn of 2006, using ENVI as our image processing tool. By choosing data collected during more temperate times of the year while approaching the hot and cold months, we are able to see the atmosphere in a state of transition, as trade winds shift, instead of at their extremes.

MATERIALS AND METHODS

There are a number of sensors that can detect changes in the world's oceans and atmospheric temperatures, but the Moderate Resolution Imaging Spectroradiometer (MODIS) encompasses a number of data collecting strategies found on land, ocean, and meteorological satellites. MODIS is an Earth Orbiting System (EOS) multispectral sensor whose purpose is to monitor land surfaces, water bodies, and collect data describing cloud cover and atmospheric qualities at a moderate resolution. It is considered 'moderate' because it has a spatial resolution between 250 and 1000-m pixels, which is coarse, related to the Landsat images, but fine compared to the AVHRR (Advanced Very High Resolution Radiometer). What makes MODIS so unique is that it can collect data in 36 spectral bands which describes such local events as forest fires, snow cover, chlorophyll concentrations, surface temperature, and aerosol concentration (Campbell, 2002), the latter of which is the most important in this project. AOT is estimated in bands 1-7 which represent the visible and infrared ranges of the electromagnetic spectrum (Table 1). This sensor is located on two satellites: Terra and Aqua. The Terra platform was launched in December 1999 and is placed in an orbit designed for morning observation, crossing the equator at 10:30 am, which minimizes land areas obscured by cloud cover (Campbell, 2002) of the afternoon heat rising in the atmosphere. Aqua, on the other hand, was launched in February of 2002 and is designed to observe oceanic and atmospheric features later in the day, crossing the equator at 1:30 pm (Table 2).

The daily multi-spectral measurements from MODIS is used to measure global aerosol amounts, providing information about the distribution and characteristics of aerosol plumes and to help scientists estimate the emissions released. Moreover, MODIS measures the properties of clouds, such as droplet size, and helps determine how aerosols may impact clouds' abilities to reflect sunlight back into space (http://terra.nasa.gov/FactSheets/Aerosols/). MODIS contributes to determining the role aerosols play in reflecting and absorbing sunlight, and the indirect effect aerosols have on the properties of clouds. Further, MODIS Aerosol Product monitors the ambient aerosol optical thickness over the oceans globally and over a portion of the continents.

Aerosol Optical Thickness is calculated using the Radiative Transfer Theory to isolate the aerosol content in the satellite imagery. The aim of an algorithm based on Radiative Transfer Theory (RTT) is a physical-bio-optical description of the radiative transfer process in the entire system from the solar source to the remote sensor required for studying the radiative transfer inn absorbing, emitting, and scattering of suspended media. The quantitative description provides a sound basis for the inversion of remotely sensed signals to retrieve the optical water quality parameters (Bagheri, et. al., 2001). In addition to the algorithm itself, information about the geometry between the sun, earth, and satellite, the intensity of solar radiation, amount of reflected sunlight measured by the sensor, and aerosol particle size distribution estimates are necessary over the sensed region.

Aerosol products from MODIS are available through the NASA's Atmosphere Archive and Distribution System (LAADS website). Images from both Terra and Aqua platforms were downloaded from the server to cover the latitude and longitude range between 41° North to 6° South, and 98 West to 8° East. As mentioned above, the Terra platform crosses the equator in the morning, whereas the Aqua platform crosses it during the afternoon. Images downloaded from the website correspond to MODIS aerosol products in HDF format that contains daily Level 2 data, with a spatial resolution of a 10X10 1-km (at nadir) pixel array (MODIS website). The data is downloaded in types, MOD04_L2 for the Terra platform, and MYD04_L2, for the Aqua platform; both files correspond to swath Level 2 files. A total of 80 HDF files were downloaded from the LAADS website.

In order for ENVI 4.3 imaging processing software to understand the files, a conversion tool-kit available from the ITT website was acquired. The MODIS Conversion Tool-Kit (MCTK) was developed to process and convert all the presently available MODIS products into image files ENVI 4.3 can process. This add-in is a very simple way to work with MODIS products on ENVI, as it lets you geo-reference the data file, at the same time it is being converted into an image file.

Once the data files were processed, four individual mosaics of 20 images each were created using ENVI 4.3, in order to compare images from the two different dates, and the two different platforms. Once the mosaic was created, final processing was applied to finish the image. The first step was to build and apply the mask to cover erroneous values such as cloud cover, sun glint, and land. After that, we applied the color mapping, application of world boundaries, and the color ramp legend.

RESULTS AND DISCUSSION

The main obstacle presented throughout our research, which almost lead us to a dead end was a compatibility problem between the data we were able to acquire from the NASA website and the software we were required to use. Luckily, we were able to find a data converter on the ITT Visual Information Solutions website (http://www.ittvis.com/codebank/search.asp?FID=485), the same company that makes the ENVI program. Because images are swath Level 2, they show some vertical dark spots that are due to the limited swath view of the sensor, and the horizontal gaps resulted from a change in orientation of the sensor's lens as it ascends (for Terra) or descends (Aqua) at a certain latitude.

Images from spring (Figure 1, Figure 2), show high concentrations of aerosols (in unit-less values) of 4.8 and 4.7, lowering in concentration as time passed between morning and afternoon. In the autumn images (Figure 3, Figure 4) values of 1.9, and 2.4 where found, having an increase of 0.5 in the aerosol concentrations from morning to afternoon. This suggests greater variability in aerosol behavior during seasonal transition months. Migration of aerosols from the African zone into the Caribbean can be observed during both days.

Furthermore, it was observed that for both Terra and Aqua platforms, higher values of aerosols were found in the month of June, rather than in November. This had been found to be supported by a recent article (Angeles et. al., 2007) where they suggest that the bimodal rainfall behavior in the Caribbean is caused because during spring and summer months there are greater amounts of aerosols that instead of increasing the volume of nuclei for the formation of precipitation, the volume of the particle inhibits the rainfall in the region. This causes there to be greater cloud cover with less precipitation. Thus, the article's finding not only gives another reason to study aerosols but also it validates our results.

CONCLUSIONS

Based on our results, we can conclude that there is variability on aerosols density during spring and autumn, having greater aerosol amounts during spring than during autumn. This implies changes in precipitation patterns for the two seasons, as well as greater health risk to the Caribbean region during the spring than during the fall. Furthermore, ENVI provides the tools necessary for the processing of the various MODIS products available up to date.

REFERENCES

Ángeles M., González, J.E., Ramírez-Roldán N., Comarazamy D.E., Tepley C.A., 2007, Origins Of The Caribbean Rainfall Bimodal Behavior, 19th Conference on Climate Variability and Change, available at http://ams.confex.com/ams/pdfpapers/118594.pdf

Bagheri, S., Stamnes, K., Wei, L., Application of Radiative Transfer Theory to Atmospheric Correction of AVIRIS Data, 2001, NASA/Headquarters-Biology and Geochemistry Program, NSF Grant # 9806982

Campbell, J.B., Introduction to Remote Sensing, 3rd Ed., Guilford Press, 2002, p. 595-599.

ITT Visual Information Solutions MODIS Conversion Tool-Kit http://www.ittvis.com/codebank/search.asp?FID=485

National Aeronautics and Space Administration (NASA): EOS AM-1 http://terra.nasa.gov/FactSheets/Aerosols/

National Aeronautics and Space Administration (NASA): EOS AM-1, MODIS http://terra.nasa.gov/About/MODIS/index.php

NexSat Satellite Product Tutorials: Aerosol Optical Thickness http://www.nrlmry.navy.mil/sat_training/nexsat/aerosol_opt_depth/NexSat_Aerosol.pdf

NASA's Atmosphere Archive and Distribution System http://ladsweb.nascom.nasa.gov/index.html

TABLES

Primary Use	Band	Bandwidth[1]	Spectral Radiance[2]	Required SNR[3]
Land/Cloud/Aerosols Boundaries	1	620 - 670	21.8	128
	2	841 - 876	24.7	201
Land/Cloud/Aerosols Properties	3	459 - 479	35.3	243
	4	545 - 565	29.0	228
	5	1230 - 1250	5.4	74
	6	1628 - 1652	7.3	275
	7	2105 - 2155	1.0	110
Ocean Color/ Phytoplankton/ Biogeochemistry	8	405 - 420	44.9	880
	9	438 - 448	41.9	838
	10	483 - 493	32.1	802
	11	526 - 536	27.9	754
	12	546 - 556	21.0	750
	13	662 - 672	9.5	910
	14	673 - 683	8.7	1087
	15	743 - 753	10.2	586
	16	862 - 877	6.2	516
Atmospheric Water Vapor	17	890 - 920	10.0	167
	18	931 - 941	3.6	57
	19	915 - 965	15.0	250
Primary Use	**Band**	**Bandwidth[1]**	**Spectral Radiance[2]**	**Required NE[delta]T(K)[4]**
Surface/Cloud Temperature	20	3.660 - 3.840	0.45(300K)	0.05
	21	3.929 - 3.989	2.38(335K)	2.00
	22	3.929 - 3.989	0.67(300K)	0.07
	23	4.020 - 4.080	0.79(300K)	0.07
Atmospheric Temperature	24	4.433 - 4.498	0.17(250K)	0.25
	25	4.482 - 4.549	0.59(275K)	0.25
Cirrus Clouds	26	1.360 - 1.390	6.00	150(SNR)
Water Vapor	27	6.535 - 6.895	1.16(240K)	0.25
	28	7.175 - 7.475	2.18(250K)	0.25
Cloud Properties	29	8.400 - 8.700	9.58(300K)	0.05
Ozone	30	9.580 - 9.880	3.69(250K)	0.25
Surface/Cloud Temperature	31	10.780 - 11.280	9.55(300K)	0.05
	32	11.770 - 12.270	8.94(300K)	0.05
Cloud Top Altitude	33	13.185 - 13.485	4.52(260K)	0.25
	34	13.485 - 13.785	3.76(250K)	0.25
	35	13.785 - 14.085	3.11(240K)	0.25
	36	14.085 - 14.385	2.08(220K)	0.35

[1] **Bands 1 to 19 are in nm; Bands 20 to 36 are in µm**
[2] **Spectral Radiance values are (W/m^2 -µm-sr)**
[3] **SNR = Signal-to-noise ratio**
[4] **NE(delta)T = Noise-equivalent temperature difference**

Note: **Performance goal is 30-40% better than required**

Table 1 MODIS band information and usage (taken from http://modis.gsfc.nasa.gov/about/specifications.php).

Orbit:	705 km, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (Aqua), sun-synchronous, near-polar, circular
Scan Rate:	20.3 rpm, cross track
Swath Dimensions:	2330 km (cross track) by 10 km (along track at nadir)
Telescope:	17.78 cm diam. off-axis, afocal (collimated), with intermediate field stop
Size:	1.0 x 1.6 x 1.0 m
Weight:	228.7 kg
Power:	162.5 W (single orbit average)
Data Rate:	10.6 Mbps (peak daytime); 6.1 Mbps (orbital average)
Quantization:	12 bits
Spatial Resolution:	250 m (bands 1-2) 500 m (bands 3-7) 1000 m (bands 8-36)
Design Life:	6 years

Table 2 MODIS technical specifications (taken from http://modis.gsfc.nasa.gov/about/specifications.php).

FIGURES

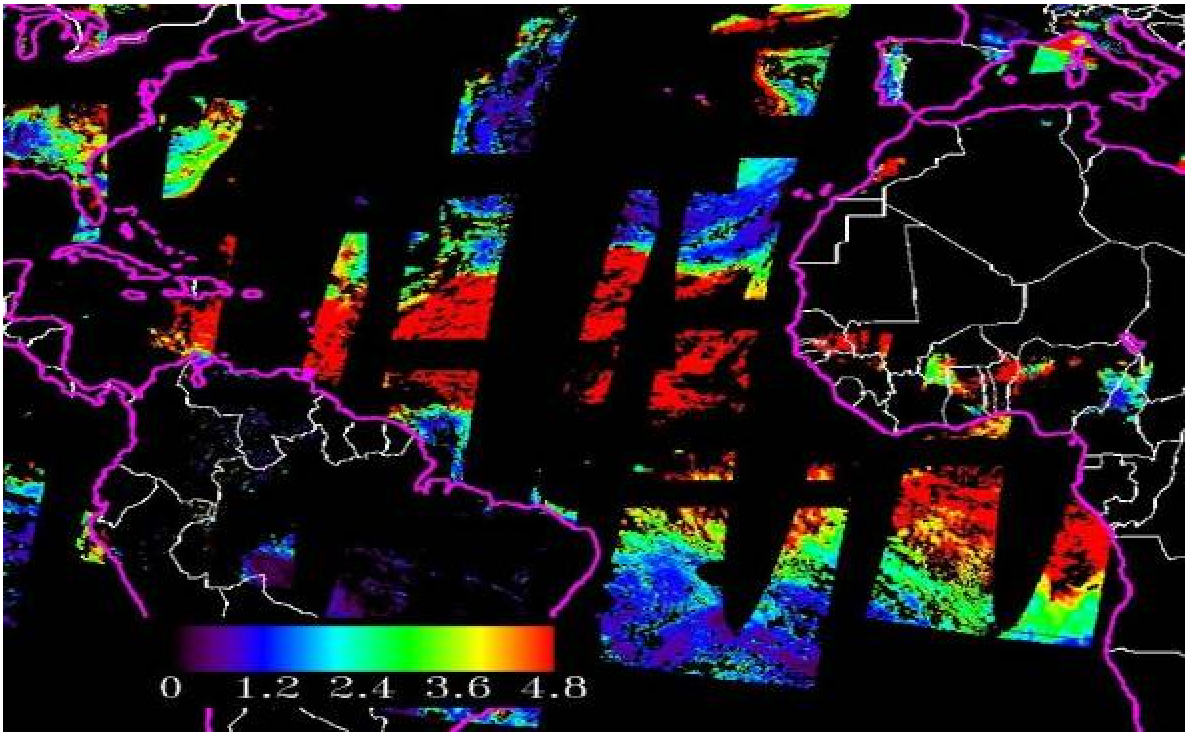

Figure 1 Terra platform image for June 7, 2006

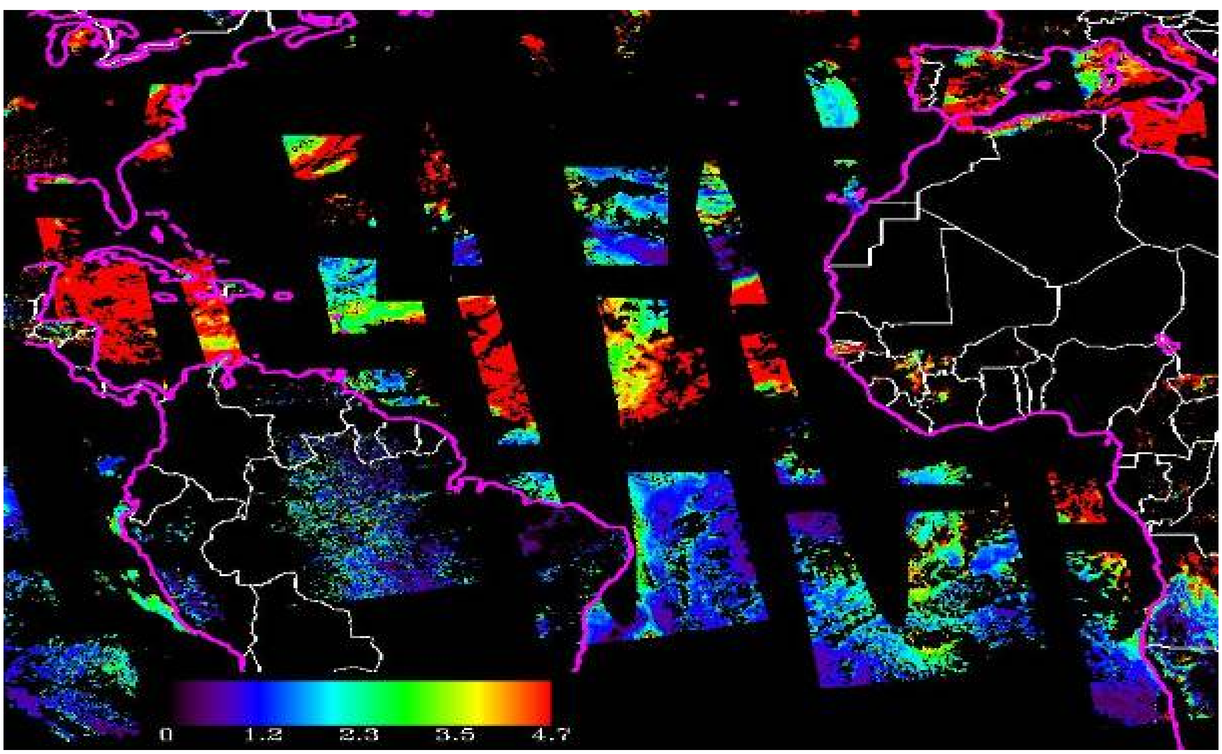

Figure 2 Aqua platform image for June 7, 2006

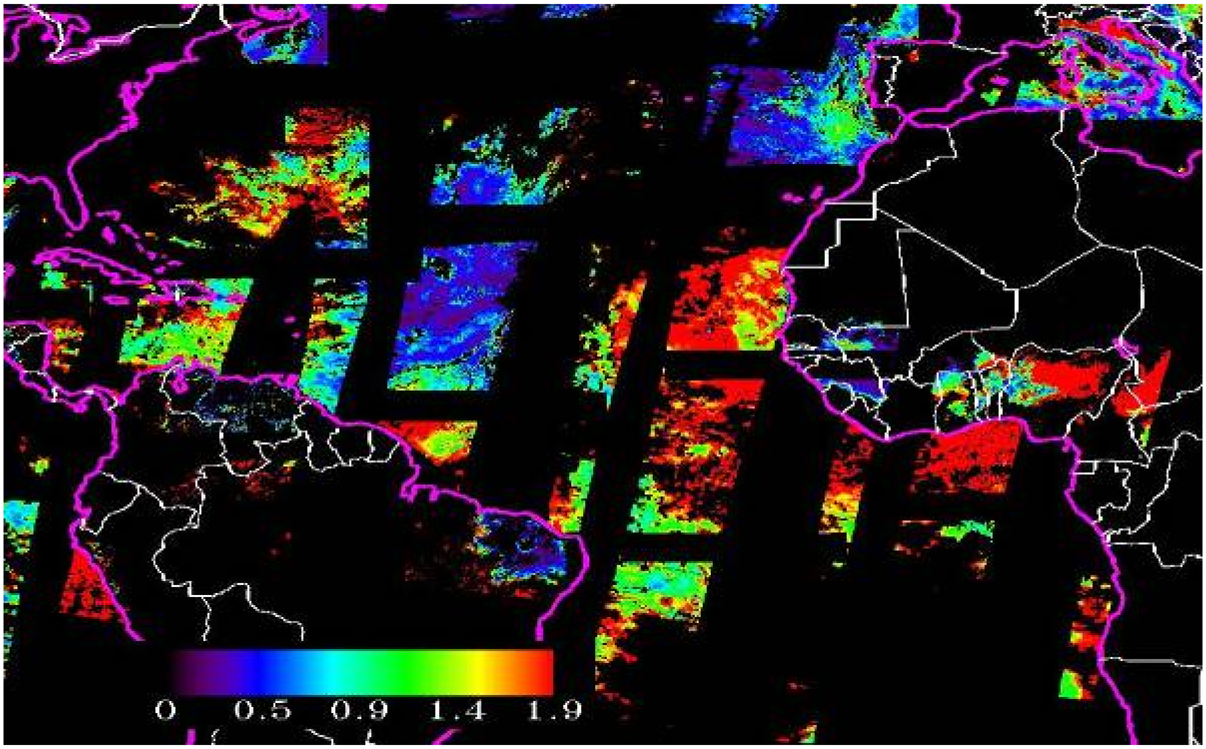

Figure 3 Terra platform image for November 7, 2006

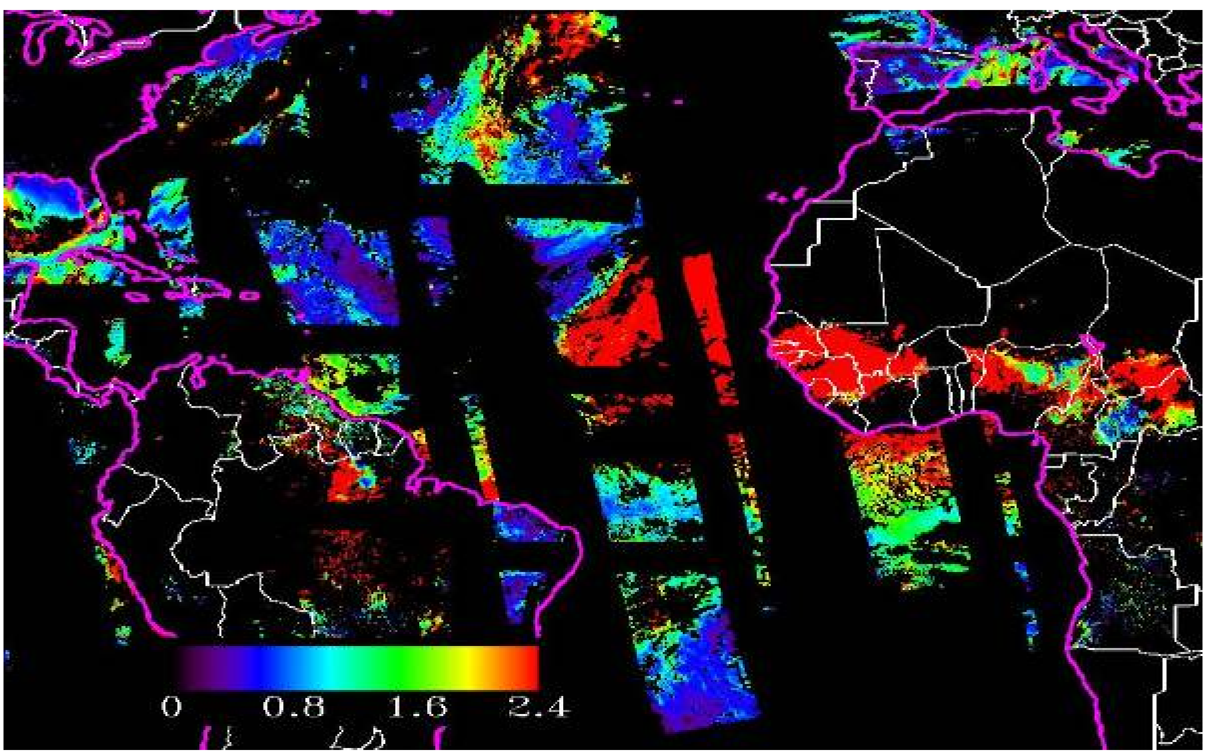

Figure 4 Aqua platform image for November 7, 2006

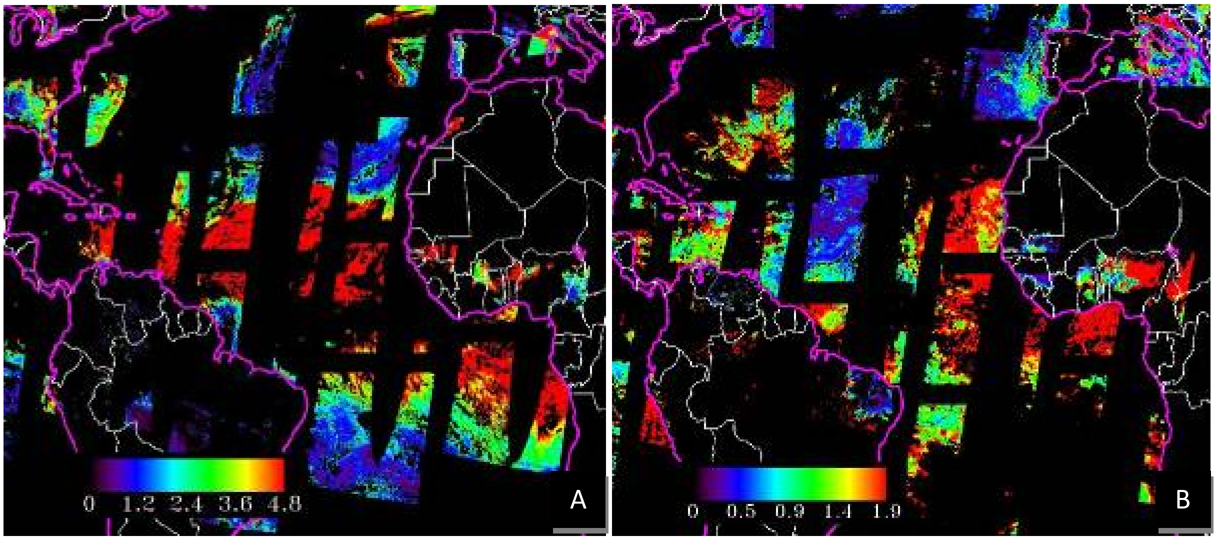

Figure 5 Terra platform images corresponding for June 7 (A), and November 7 (B) 2006.

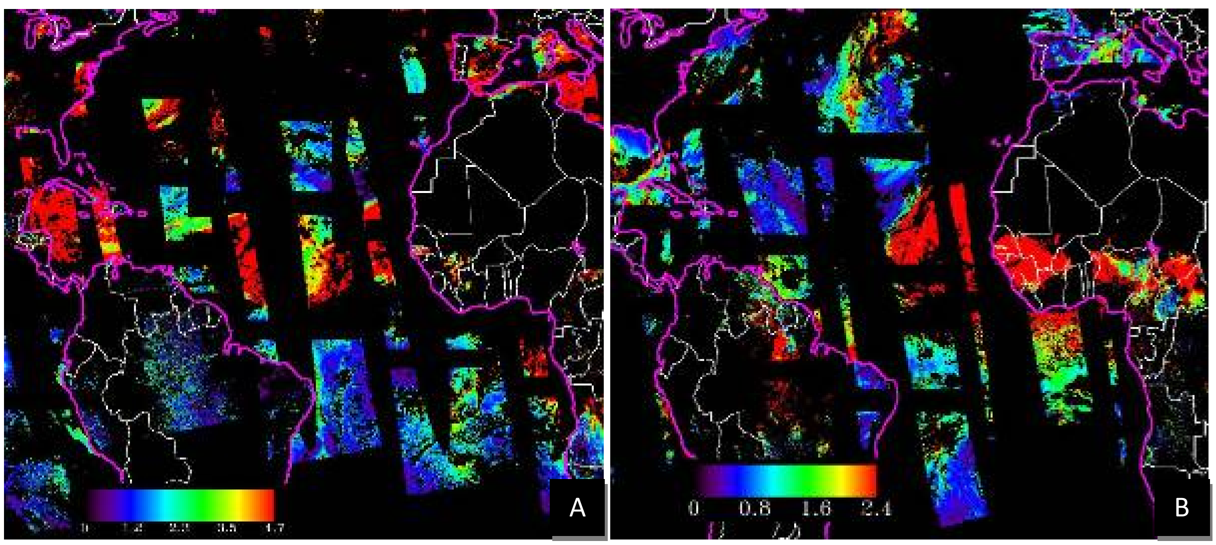

Figure 6 Aqua platform images corresponding for June 7 (A), and November 7 (B), 2006.