9th International Conference on Urban Climate
jointly with 12th Symposium on the Urban Environment

Monitoring of Air pollution and black cloud influence on Aerosol optical properties over Nile Delta based on Moderate Resolution Imaging Spectroradiometer (MODIS) and climatic data from 2002-2012

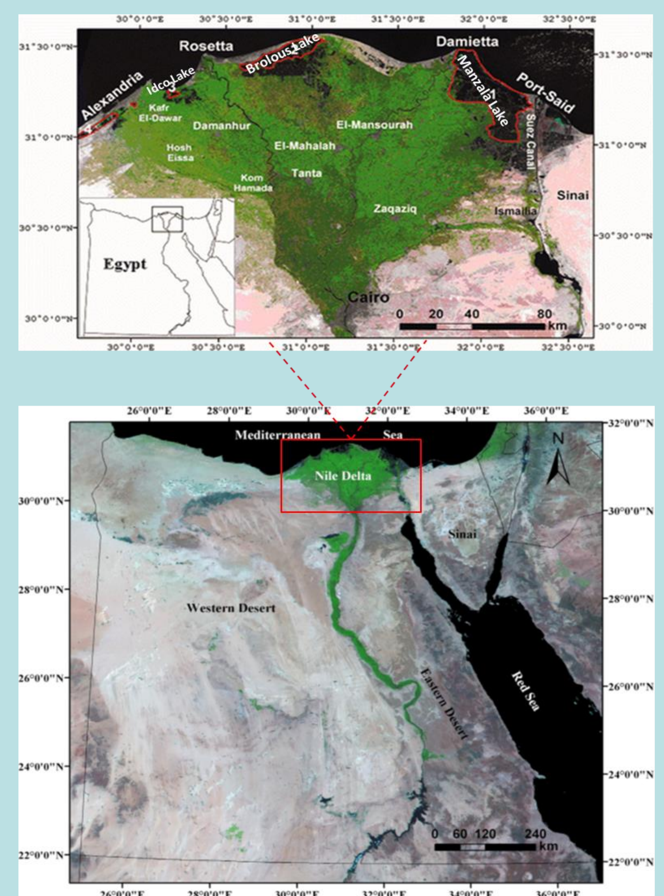
Hossam Ismael
Geography and GIS department., Faculty of Arts., Assiut University (New Valley Branch)., Egypt
hosam.ismael@artnv.au.edu.eg , hossam_geography@yahoo.com

Abstract: Undoubtedly, Climate change is the one of greatest challenges that faces the human being nowadays as the Earth's climate is getting warmer. The National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) have indicated that the temperature average of the Earth's surface has increased about 1.2 to 1.4 C since 1900. Other climatic aspects are exposed to change as well such as patterns of precipitation and storms. The most common reason that leads to climate change is very likely human activities (e.g. fuel combustion and pollution). The Study area is the most affected region in the world by climate change impacts according to the fourth report of the Intergovernmental Panel on Climate Change 4th Report of IPCC, 2007. This report presents a scenario of destruction of the settlement centers in Nile Delta, Port Said in the east and Alexandria in the west (10 million people are at risk), besides, losing more than 86 square kilometers of the northern lakes, about 200,000 acres of the most valuable agricultural land as a result of high temperature and the consequent rise in average sea level. In Egypt, air pollutants (e.g. SO_2 and CO_2) gave rise to high concentrations of air pollutants especially in Nile delta, due to bio mass fire which is called 'Black Cloud' phenomenon. The main aim of this study is to present the effectiveness of using both the MODIS atmosphere data produced by the Terra mission and to describe differences with comparable products to be produced by Aqua. To achieve this aim the study will use the HYDRA visualization software with the characteristics of the MODIS climatic data. Results obtained from MODIS data are validated by using the previously mentioned data sets to reveal the nature and the characteristics of the climate change. Fire, dust Detection with MODIS, AIRS, and AOD analysis clearly indicates large amounts of aerosols that form the black cloud events over various locations within the Nile delta region. Also the results agree with the observed values in the study area, and highly required for many applications related to integrated remote sensing techniques with actual field measurements and data Meteorological Authority in different periods to reduce the risk of climate..

The study area: The Nile delta covers only 2% of Egypt's area but hosts 47% of the country's population and comprises 65% of its agricultural land. According to (Hereher, 2009), the Nile Delta was formed during flood seasons by Nile sediments. After passing Cairo, the Nile bifurcates into two branches: Rosetta in the west and Damietta in the east. Between and beyond these two promontories a wide coastal plain exists that was built up during the last 8–6 ka (Stanley and Warne, 1994), forming one of the most famous deltas in the world in earlier times there were seven branches each one has its own lobe into the Mediterranean Sea. Five of them have silted up, leaving only the Rosetta and Damietta tributaries (Sneh and Weissbrod, 1973).

The Nile Delta occupies an area of 20,000 km^2, and generally flat; its apex at Cairo (160 km upstream) lies at an elevation of +18 m .The climate in the Nile Delta is Mediterranean: hot in the summer and mild in the winter. Temperature averages are 18°C in the winter and 31°C in the summer. Precipitation ranges from 200 mm/year along the Mediterranean coast to only 22 mm/year at Cairo.

.



(Figure 1) an image of the Nile delta on 12th march 2013 compiled from 4 MODIS tiles

MODIS and its products:

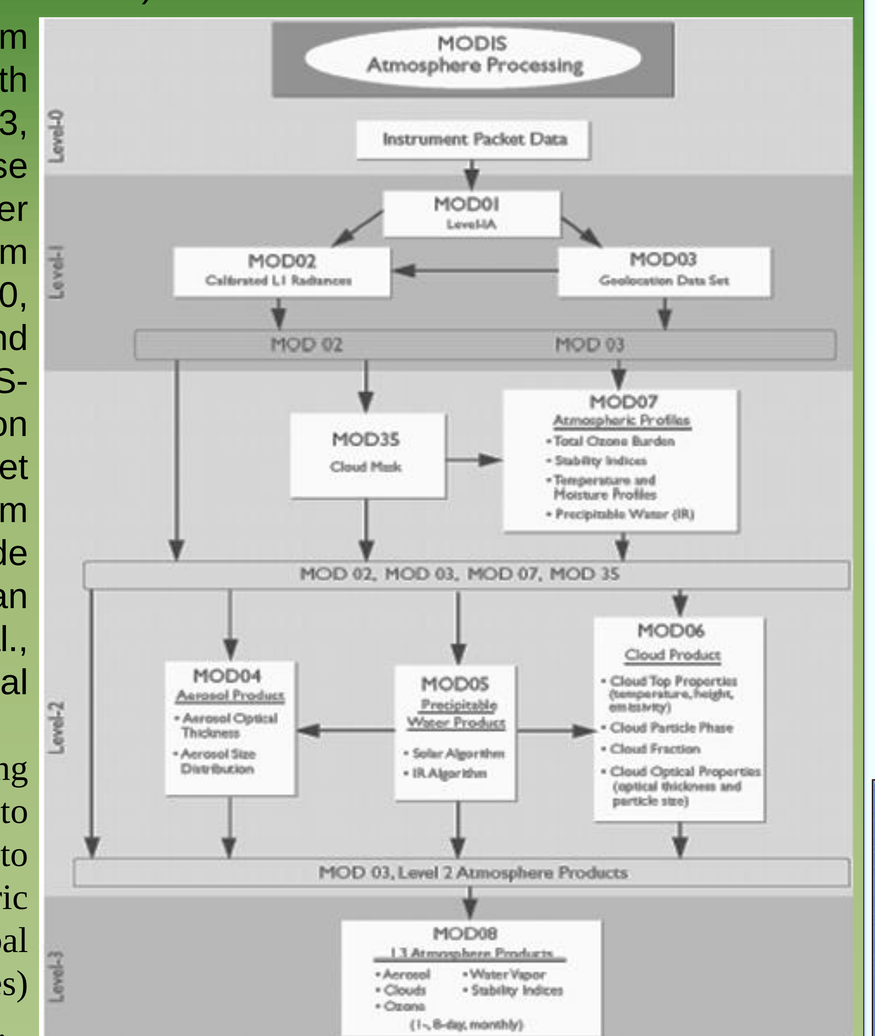
The MODerate-resolution Imaging Spectroradiometer (MODIS) is one of five scientific instruments onboard the satellite platform, Terra, part of NASA's Earth Observation System (EOS), It provides data for retrieving land surface temperature (LST) at 1-km resolution with almost daily coverage of the Earth, which is invaluable for both local and global change research. The Moderate Resolution Imaging Spectroradiometer (MODIS) is an Earth Observing System (EOS) and a facilitating instrument that is currently flying aboard the Terra and Aqua spacecraft. It suits the global monitoring of atmospheric properties from space, and is based on heritage sensors such as the Advanced Very High Resolution Radiometer (AVHRR), Landsat Thematic Mapper (TM), High-resolution Infrared Radiation Sounder (HIRS), and the Nimbus-7 Coastal Zone Color Scanner (CZCS). The wide spectral range (0.41–14.24 m), frequent global coverage (one to two days revisit), and two high spatial resolution bands (250 m), permit state of the art global monitoring of atmospheric profiles, column water vapor amount, aerosol particles, and the subsequently formed clouds (King et al, 1999). MODIS scans a swath width of 2330 km that is sufficiently wide to provide nearly complete global coverage every two days from a polar-orbiting, sun-synchronous, platform at an altitude of 705 km. MODIS provides images in 36 spectral bands between 0.415 and 14.235 m with spatial resolutions of 250 m (two bands), 500 m (five bands), and 1000 m (29 bands) (King et al 2003).

(Table 1) MODIS Channel Number, Wavelength (m), and Primary Application
From (Manzel, 2009)

MODIS Thermal Emissive Bands			MODIS Reflected Solar Bands		
Primary application	Wavelength (micron)	Band	Primary application	Wavelength (micron)	Band
Surface / cloud temperature	3.75(2), 3.95, 4.05	20-23	Land, Clouds	0.645, 0.866	1,2
Atmospheric temperature	4.46, 4.51	24,25	Land, Clouds	0.470, 0.555	3,4
Water vapor	6.71, 7.32	27,28	Land, Clouds	1.24, 1.64, 2.13	5-7
Surface / cloud temperature	8.55	29	Ocean color	0.415, 0.443, 0.490	8-10
Ozone	9.73	30	Ocean color	0.531, 0.565, 0.653	11-13
Surface / cloud temperature	11.03, 12.02	31,32	Ocean color	0.681, 0.750, 0.865	14-16
Cloud top properties	13.33, 13.63	33,34	Water vapor	0.905, 0.936, 0.940	17-19
Cloud top properties	13.93, 14.23	35,36	Cirrus clouds	1.375	26

The MODIS spectral bands have been chosen to be sensitive to various reflection, absorption, and scattering spectral signatures. (Figure.4) shows the processing schema used for deriving atmospheric products from level 0 (raw instrument data) to level 1 (calibrated earth located radiances) to level 2 (5x5 field of view derived atmospheric products) to level 3 (time composited global product fields in even interval lat-lon grid boxes).

The MODIS spatial resolution is 250-m bands are centered at 0.65 and 0.86 µm with the 500-m bands at 0.47, 0.56, 1.24, 1.63, and 2.13 µm. Each band's spectral response is determined by an interference filter overlying a detector array imaging a 10-km along-track scene for each scan (i.e., 40, 20, and 10 element arrays for the 250, 500, and 1000-m bands, respectively. The MODIS-derived aerosol properties (t) and the fraction of fine mode particle over land [Kaufman et al., 1997a; Chu et al., 1998, 2002] in tandem with those (t), the fraction of fine mode particle, and effective radius) over ocean [Tanre´ et al., 1997, 1999; Remer et al., 2002,2005] enable to study the global aerosols comprehensively.



(Figure.4) MODIS Atmospheric Processing schema from level 0 (raw instrument data) to level 1 (calibrated earth located radiances) to level 2 (5x5 field of view derived atmospheric products) to level 3 (time composited global product fields in even interval lat-lon grid boxes) adapted from the EOS Data Products Handbook.

Materials and methods

The study is based on MODIS fire algorithm and uses a series of tests to determine if a pixel contains a fire in order to measure the impacts of the black cloud over Nile delta (table.2). It has also used the visible thresholds tests and spectral cloud mask (MOD35) which serves as a primary ancillary input to the other cloud algorithms. The study is based on HYDRA. HYper-spectral data viewer for Development of Research Applications. HYDRA enables interrogation of multispectral (including hyperspectral) fields of data so that (a) pixel location and spectral measurement values (radiance or brightness temperature) can be easily displayed; (b) spectral channels can be combined in linear functions and the resulting images are displayed; (c) false color images can be constructed from multiple channel combinations; (d) scatter plots of spectral channel combinations can be viewed; (e) pixels in images can be found in scatter plots and vice versa; (f) transects of measurements are displayed, and (g) temperature and moisture as well as spectra from selected pixels are compared. HYDRA software has become a part of the World Meteorological Organization Virtual Laboratory for Satellite Meteorology.

(Table.2) Summary of some MODIS Cloud Test

Scene	Solar/Reflectance	Thermal	Comments
Low cloud over water	$R_{0.86}$, $R_{0.67}/R_{0.86}$, BT_{11}-$BT_{3.7}$	Difficult, Compare BT_{11} to daytime mean clear-sky values of BT_{11}; BT_{11} in combination with BT difference tests; Over oceans, expect a relationship between [BT_{11}-$BT_{8.6}$], [BT_{11}-BT_{12}] due to water vapor correlation to SST	Spatial and temporal uniformity tests sometimes used over water scenes; Beware of Sun-glint regions
High Thick cloud over water	$R_{1.38}$, $R_{0.86}$, $R_{0.67}/R_{0.86}$,	BT_{11} ; $BT_{13.6}$; $BT_{6.7}$ [BT_{11}-$BT_{8.6}$], [BT_{11}-BT_{12}]	Easy, good contrast in vis and IR
High Thin cloud over water	$R_{1.38}$, $\Delta R_{0.86}$, [$R_{0.65}$–$R_{1.6}$]/[$R_{0.65}$+$R_{1.6}$];	$BT_{6.7}$; $BT_{13.9}$ [BT_{11}-BT_{12}], [$BT_{3.7}$-BT_{12}], [$BT_{8.6}$-BT_{11}]	For $R_{1.38}$, be careful of surface reflectance for atmospheres with low total water vapor amounts. For BT difference tests, beware of variations in surface emissivity.
Low cloud over vegetation	$R_{0.86}$, $R_{0.67}/R_{0.87}$, BT_{11}-$BT_{3.7}$; [$R_{0.86}$–$R_{0.65}$] /[$R_{0.86}$+$R_{0.65}$]	Difficult, BT_{11} in combination with BT difference tests.	NDVI (Normalized Difference Vegetation Index). Other ratio tests also are good. Can make tests a function of ecosystem.
High Thick cloud over vegetation	$R_{1.38}$, $R_{0.86}$, $R_{0.67}/R_{0.86}$, [$R_{0.86}$–$R_{0.65}$] /[$R_{0.86}$+$R_{0.65}$]	BT_{11} ; $BT_{13.9}$; $BT_{6.7}$ [BT_{11}-$BT_{8.6}$], [BT_{11}-BT_{12}]	Can make tests a function of ecosystem to account for variations in surface emittance and reflectance.
High Thin cloud over vegetation	$R_{1.38}$, $R_{0.86}$, $R_{0.67}/R_{0.86}$, [$R_{0.86}$–$R_{0.65}$] /[$R_{0.86}$+$R_{0.65}$]	$BT_{13.9}$; $BT_{6.7}$ [BT_{11}-$BT_{8.6}$], [BT_{11}-BT_{12}]	Beware of variations in surface emittance and reflectance.
Low cloud over bare soil	$R_{0.86}$, $R_{0.67}/R_{0.86}$, [BT_{11}-$BT_{3.7}$]	BT_{11} in combination with brightness temperature difference tests. [$BT_{3.7}$-$BT_{3.9}$]	Difficult due to brightness and spectral variation in surface emissivity. Surface reflectance at 3.7 and 3.9 µm is similar.

The results:

MODIS fire algorithm is used to differentiate fire pixels from nearby non-fire (background) pixels. It is used as an indicator for the black cloud impacts. This involves comparing the potential fire pixel to the surrounding pixels. This contextual approach uses the average brightness temperature of the non-fire pixels in Band 21(3.99 m) that surround the potential fire pixel and also the Mean Absolute Deviation (MAD). **MAD = where i is the number of points you are summing.**
For pixels that did not pass the first BT4 test, they must pass the next 3 dynamic thresholds to be labeled a fire pixel (Figure.3)

By loading Band 22 (3.99 µm) into the Multi-Channel Viewer and overlay the MODIS fire Level 2 product. The fire product has displayed over the image and a new MODIS Fire Mask Product window will be displayed, with a button at the bottom that allows you to toggle the mask. After that, we compute and select a potential fire of black cloud over Nile delta region and determine a BT4 average and BT4 MAD and a BTDIF4-11 average and BTDIF4-11 MAD (figure.4).

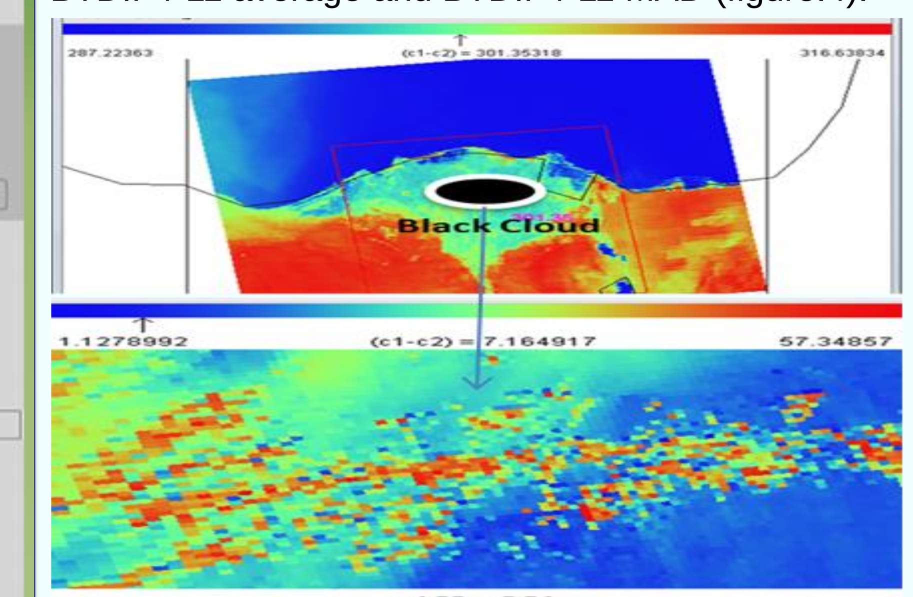


Fig. 4

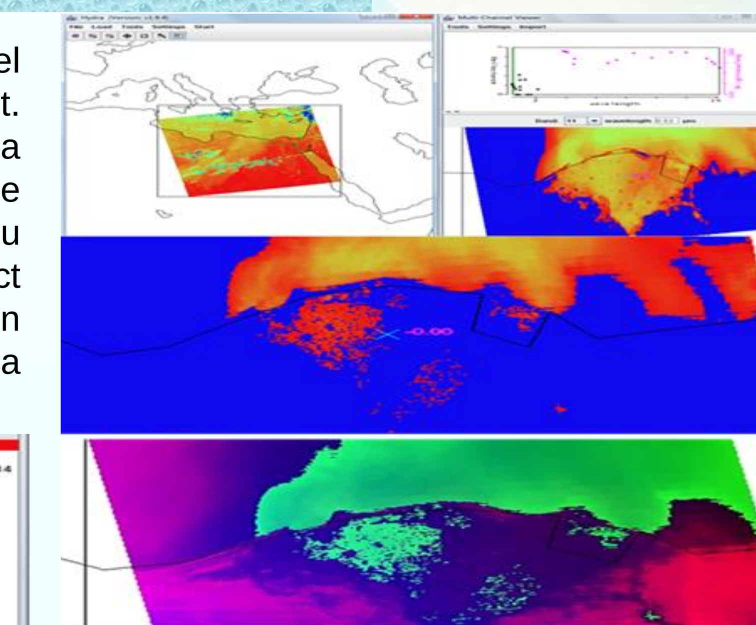


Fig. 3

The MODIS aerosol product is used to study aerosol climatology, sources and sinks of specific aerosol types (e.g., biomass burning aerosol or black cloud over Nile delta), interaction of aerosols with clouds, the hydrological cycle and atmospheric dynamics, and atmospheric corrections of remotely sensed surface reflectance over the land (Figure.4).

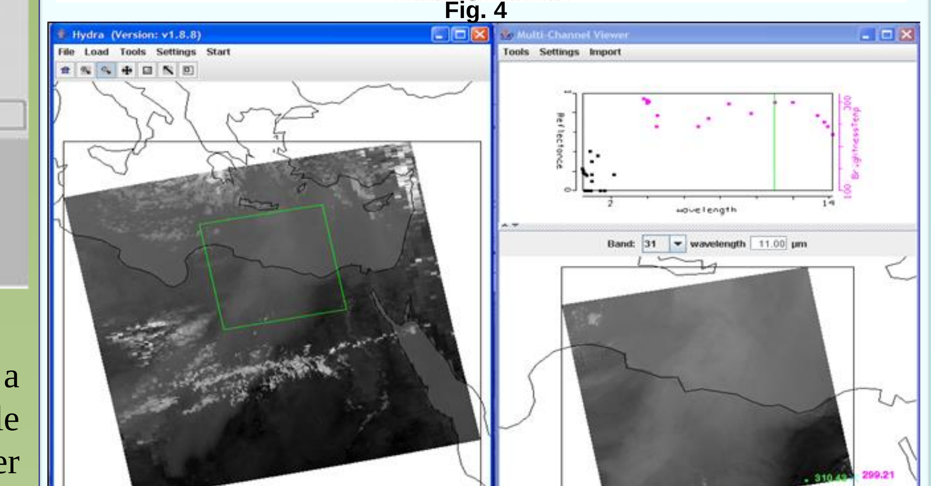


Fig.5

According to dust detection affecting Nile delta with MODIS and AIRS, it was illustrated that by using the main menu load MOD021KM.A2008055.1130.005.2006056124414.hdf. This granule shows a dust storm over Egypt. The temperature brightness differences show a larger range over Nile delta by representing the Band 31 (11 m) on the x-axis and [Band 29 (8.6 m) minus Band 31 (11 m)] on the y-axis. In addition to the capability of distinguishing dust storm from clouds using these channels (Figure.5)

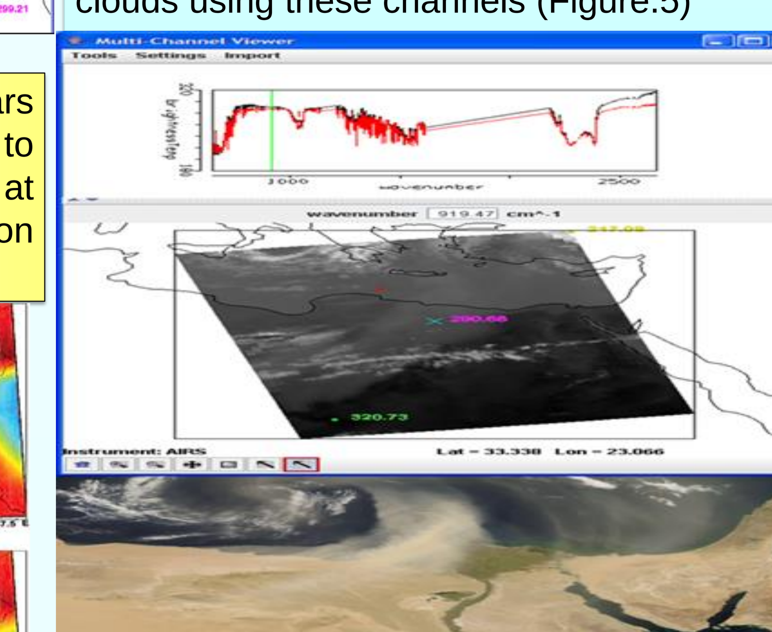


Fig. 6

However, the CTT during SON of the three years shows a decreasing trend from September to November, reflecting the higher levels of aerosols at the beginning and decreasing in concentration towards November, as shown in (Figure.7b).

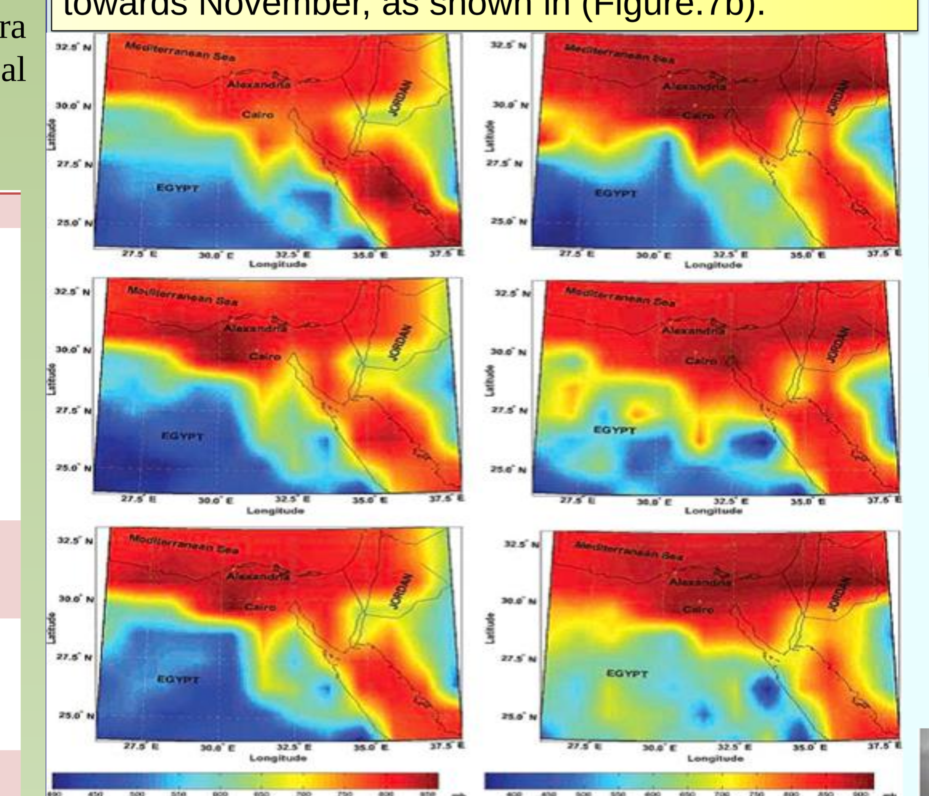


Fig. 7

AOD analysis clearly indicates large amounts of aerosols forming the black cloud events over various locations within the Delta region. The main reasons of the black cloud phenomena over Nile delta are the natural factors, such as desert dust and the anthropic factors, such as Biomass Burning especially for rice crop (Figure..8).

Fig. 8

Conclusion: MODIS is ideal for monitoring large-scale changes in the biosphere that will yield new insights into the workings of the polluted area by the black cloud. While no current satellite sensor can directly measure that anthropic phenomenon concentrations in the atmosphere. MODIS from both the Terra and Aqua platforms can be successfully used as a climate model to integrate with climate data from stations for linear regression estimates and measure the change impacts of some elements such as daily maximum and minimum air temperatures changes, clouds cover, aerosols and carbon dioxide concentrations changes at a local scale on Nile Delta. MODIS products retrievals provide a useful perspective to the capability for monitoring regional and local air pollution and to identify the aerosol source as the burning of agricultural waste after harvest season in the Nile Delta region.

References: B. H. Tang, Z.-L. Li, and Y. Y. Bi, "Estimation of land surface directional emissivity in midinfrared channel around 4.0 µm from MODIS data," Opt. Express 17(5), 3173–3182 (2009), http://dx.doi.org/10.1364/OE.17.003173.
Becker. F, and Z.-L. Li, "Towards a local split window method over land surfaces," Int. J.Remote Sens. 11(3), 369–393 (1990), http://dx.doi.org/10.1080/01431169008955028.
El-Askary H. & Kafatos, M. (2008). Dust Storm and Black Cloud Influence on Aerosol Optical Properties over Cairo and the Greater Delta Region, Egypt. *International Journal of Remote Sensing*, Vol.29, No.24, (December 2008), pp. 7199 – 7211, ISSN 0143-1161.