



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

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Abstract

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. SO₂ and CO₂) 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 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. 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.

1-Introduction:

The Nile delta is suffering from high ambient concentrations of atmospheric pollutants including particulates (PM), carbon monoxide, nitrogen oxides, ozone and sulfur dioxide (Abu- Allaban et al., 2007, Abu-Allaban et al., 2002, El-Metwally et al., 2008). Pollution in this area is represented in what is called "Black cloud" over Nile delta. The existence of this black cloud could be attributed to many reasons among which are biomass burning, local emission and long rang of transport during the fall season. Several studies have been conducted to investigate this phenomenon using ground-based and satellite air quality data as compared to other megacities (Abu- Allaban et al., 2002, 2007, 2009; Alfaro and Wahab, 2006; El-Askary and Kafatos, 2008; El-Askary, 2006, 2008, 2010); El- Metwally et al., 2008; Favez et al., 2008; Kanakidou et al., 2011; Mahmoud et al., 2008; and Marey et al., 2010; Prasad et al., 2010 and Zakey et al., 2004). Marey et al. (2010) have used a multi- sensor approach using the Moderate Resolution Imaging Spectrometer (MODIS) and the Multi-angle Imaging Spectro Radiometer (MISR) with meteorological data and trajectory analysis to examine the reasons for the black cloud formation over Cairo.

MODIS fire detection has identified the aerosol source which is burning the agricultural waste after harvest season in the Nile Delta region. Prasad et al. (2010) suggest that the long range of dust transport at high altitude (2.5-6 km) from the Western desert and its deposition over the Nile Delta region is one of the major contributors to air pollution episodes during this season. Nile delta and Great Cairo have witnessed different seasonal climate systems that are highly influenced by sand and dust storms coming from the western desert as well as local, increasing anthropogenic activities (El-Askary et al, 2010). As a result, it is characterized by a complicated meteorology that varies in the different times of the year. This study suggests that the pollution during the black cloud episode is the worst on human beings in addition to its effect on the local climate. During winter the climate is generally cold, humid and rainy; while during the summer season the weather is hot and dry (Zakey et al, 2008).

Several studies have been conducted to examine the main reasons for the increasing pollution levels in Cairo and Nile delta using ground-based and satellite air quality data (Zakey et al., 2004; Abu-Allaban et al., 2002, 2007; Alfaro and Wahab, 2006; El-Askary and Kafatos, 2008; Favez et al., 2008; Mahmoud et al., 2008; and El-Metwally et al., 2008; Marey et al., 2010 and Prasad et al., 2010). However, the genesis of the fall episodes (the black cloud season) is still under discussion and needs more investigations. In order to acquire further synoptic information and visualization of the aerosol and clouds characteristics, it is useful to analyze satellite data as well, since these data provide horizontal and vertical covering with fairly high (e.g. daily and monthly) temporal resolution. (Marey et al, 2010, 2011) utilized data from several satellite instruments to examine the most likely reasons for the black cloud formation over Nile delta.

The impacts of pollution on aerosol optical properties and the long range of dust transport have been widely studied over Asia and other regions. Recent studies, using different sensors over optical and microwave spectra, have analyzed aerosol optical properties during dust and pollution events over Northern India and East Asia (Uno et al. 2001, Carmichael et al. 2002, Di Girolamo et al. 2004, Singh et al. 2004, El-Askary et al. 2006).

Dust storms have also been widely investigated over Egypt through a multisensory approach utilizing the differing dust behaviour over ultraviolet, visible and microwave regions of the spectrum (El-Askary et al. 2003), as well as Saharan dust transportation (Kallos et al. 2006). However, a lot still needs to be done for Africa and especially for North Africa, where one of the highest populated cities of the world is present. El-Askary (2006) has recently presented a detailed seasonal analysis of the aerosol parameters over Cairo and the Greater Delta region from 2000 to 2005. High AOD values were found over Cairo and the Greater Delta region during the spring and autumn times of the year using MODIS data. These times represent the periods of dust storms occurrence (April and May) and, more recently, the occurrence of black cloud (September and October).

Also, El-Askary et al (2008) have found that, since 1999, a black cloud appeared, above the Nile Delta and Cairo, during October and was reported by the media. During that time of the year, farmers have burned rice straw, a by-product from the rice harvest, to clear fields for the next crop. The main aim of this study is to present the effectiveness of using each of the MODIS atmosphere data products, that are being produced by the Terra mission and to describe differences with comparable products produced by Aqua. To achieve these objectives, the study has applied some threshold tests, such as MODIS fire detection, investigating Aerosols with MODIS, and dust detection with MODIS and AIRS.

2- 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 (Figure. 1). 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).

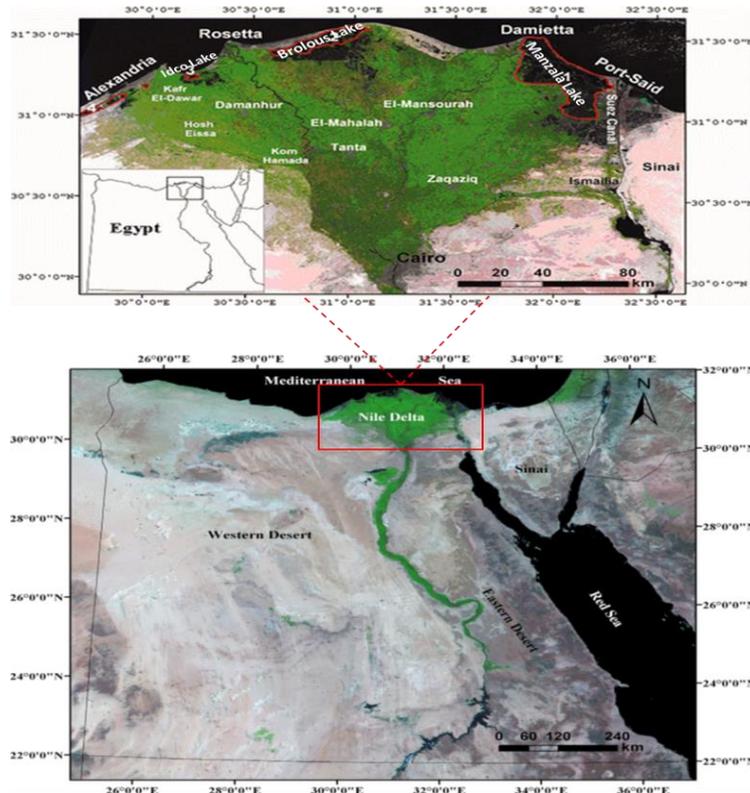
The Nile Delta occupies an area of 20,000 km², and generally flat; its apex at Cairo (160 km upstream) lies at an elevation of +18 m (Sestini 1992). The climate in the Nile Delta is Mediterranean: hot in the summer and mild in the winter. Temperature averages are 18°C in the winter and 31°C in the summer. Precipitation ranges from 200 mm/year along the Mediterranean coast to only 22 mm/year at Cairo. Excluding Great Cairo, the Nile Delta contains another 10 administrative governorates: Alexandria, Kafr El-Sheikh, El-Dakahlia, Damietta, Port Said, El-Behira, El-Gharbia, El-Minofia, El-Sharkia, and Ismailia. Government statistics (the Central Agency for Public Mobilization and Statistics (<http://www.capmas.gov.eg/>)).

3- 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. 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 focus of the product is to prove whether the pixel is unobstructed between the surface and satellite or not. In addition to the potentiality for obstruction in the line of sight due to clouds, heavy aerosols (e.g., fire and dust detection) and will act also to decrease the likelihood of finding clear-sky conditions. The data of this study are collected during two years of monthly average observations of AOD over the Delta region derived from MODIS level-2 AOT atmospheric daily products data at a 10 km resolution.

Finally, 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.



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

4-The results:

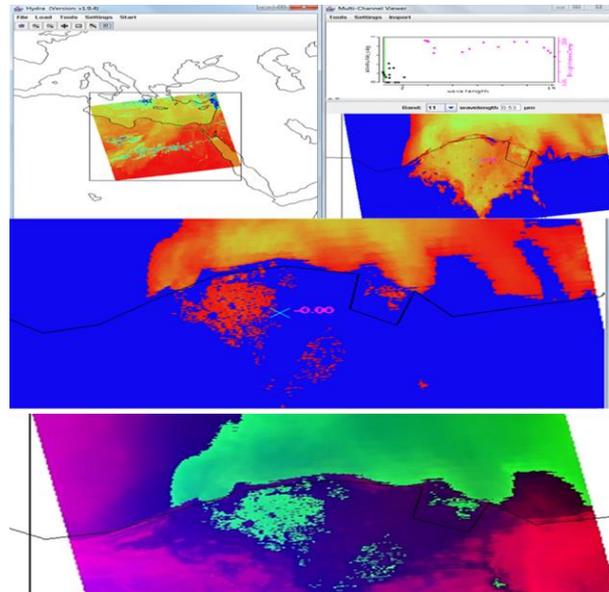
MODIS fire algorithm is used to differentiate fire pixels from nearby non-fire (background) pixels. It is used as an indicator for the black cloud impacts. This involves comparing the potential fire pixel to the surrounding pixels. This contextual approach uses the average brightness temperature of the non-fire pixels in Band 21(3.99 μm) that surround the potential fire pixel and also the Mean Absolute Deviation (MAD). MAD is the mean of the absolute value of the differences between the average and the deviation from the average. MODIS fire algorithm has used to differentiate fire pixels from nearby non-fire (background) pixels. It was 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 μm) that surround the potential fire pixel and also the Mean Absolute Deviation (MAD). MAD is the mean of the absolute value of the differences between the average and the deviation from the average:

$$MAD = \frac{1}{N} \sum_i |X_i - \bar{X}|$$

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.2).

Threshold tests	Thresholds for data selected in (Figure. 5)
BTDIF4-11 > Average BTDIF4-11 + 3.5 (MAD BTDIF4-11)	BTDIF4-11 > 3.2 K + 3.5 * (.63) K BTDIF4-11 > 5.40
BTDIF4-11 > Average BTDIF4-11 + 6 K	BTDIF4-11 > 6K + 3.2 K BTDIF4-11 > 9.2 K
BT4 (Band 21 3.99 μm BT) > Average BT4 + 3(MAD BT4)	BT4 > 298.52 K + 3 * 16.57 K BT4 > 348.23 K

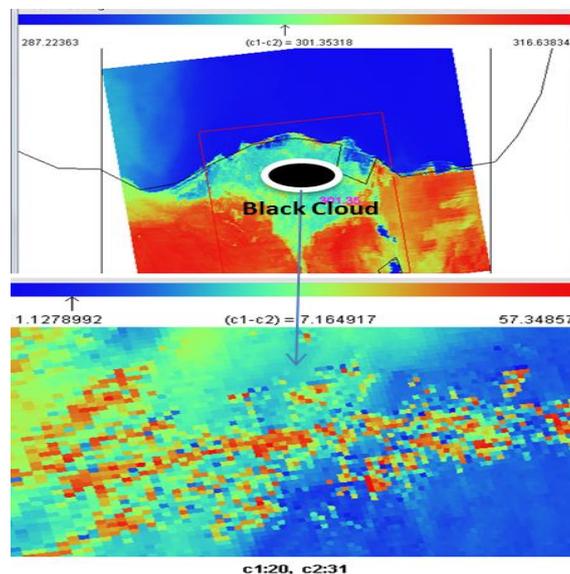


(Figur.2) Black cloud display with 11 μm brightness temperature image at 10 km from Aqua MODIS on 22 March 2010 at 1110 UTC (top), 1 km resolution Band 3 (0.47 μm), Band 13io(0.67μm) reflectance image in the Multi-Channel Viewer (middle and down) respectively.

Manzel et al (2009) have concluded that the high reflectance measurements result from thick clouds at all levels, and the infrared window brightness temperature provides a good indication of the cloud level. Intermediate reflectance data are subject to ambiguous interpretations since they result from a mixture of cloud and surface contributions. Visible data used in the determination of the cloud mask must be uncontaminated by sun glint. Algorithms which include solar reflectance data are constrained to solar zenith angles less than 85°. Sun glint occurs when the reflected sun angle, θ_r , lies between 0° and approximately 36°.

$$\cos\theta_r = \sin\theta \sin\theta_0 \cos\varphi + \cos\theta \cos\theta_0$$

Where θ_0 is the solar zenith angle, θ is the viewing zenith angle, and φ is the azimuthal angle. Sun glint is also a function of surface wind and sea state. The entire single pixel tests mentioned so far relies on thresholds. Thresholds are never global. There are always exceptions and the thresholds must be interpreted carefully. 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.6). By loading Band 22 (3.99 m) into the Multi-Channel Viewer and overlay the MODIS fire Level 2 product. The fire product is displayed over the image and a new MODIS Fire Mask Product window will be displayed, with a button at the bottom that allows toggling 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.3).



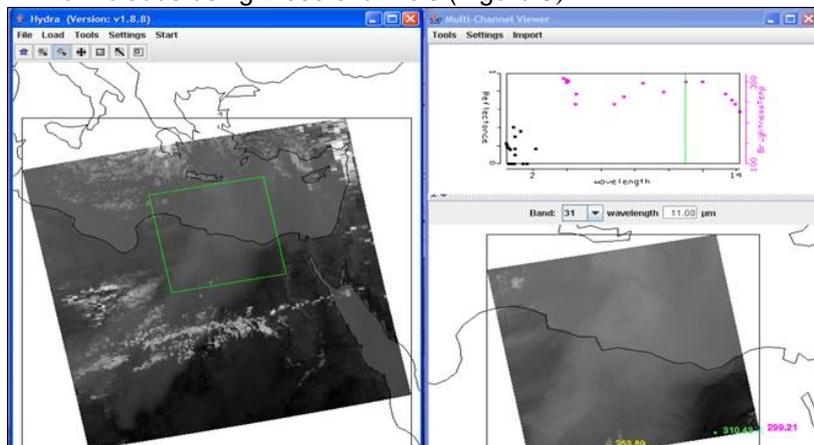
(Figure. 3) The potential fire of black cloud over Nile delta region a BT4 average and BT4 MAD and a BTDIF4-11 average and BTDIF4-11 MAD, showing biomass fir occurrence at lower altitudes .900 mb.

The black cloud over Nile delta was detected with threshold tests that rely on brightness temperatures in three infrared spectral bands; they are BT11, BT13.9, and BT6.7. Infrared window thresholds, BT11, are practical in certain conditions, however, they will vary in moisture content of the atmosphere. Over land, BT11 is further

complicated by the fact that the surface emissivity varies appreciably according to soil and vegetation type. Thus, BT11 is used primarily to detect high, thick clouds and thresholds are set accordingly.

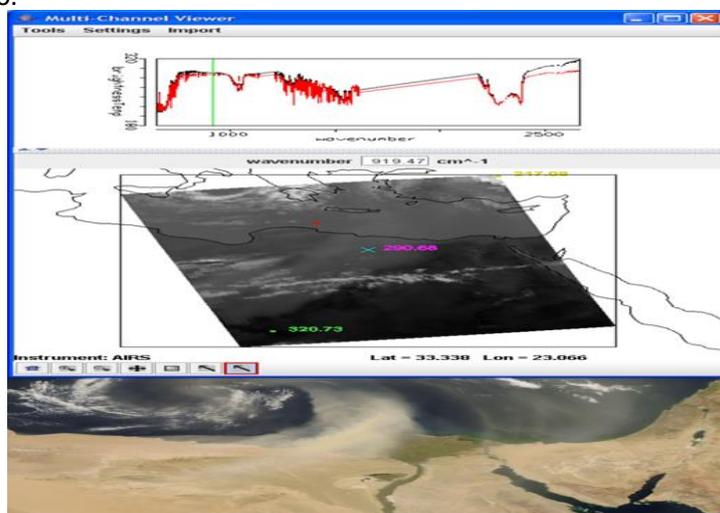
In addition, black clouds are likely present when BT11 is less than 300 K over Nile delta. BT13.9 provides good sensitivity to the relatively semi-arid regions of the atmosphere because of CO₂ absorption. The same is true for BT6.7 because of H₂O absorption. These spectral bands receive most of their radiation near 300 hPa and only clouds above 500 hPa make strong radiance contributions; negligible contributions come from the earth surface. Thus a threshold for BT13.9 and BT6.7 can isolate clouds above 500 hPa (Figure.4).

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)



(Figure.4) Dust storm scene over Egypt affecting Nile delta viewed by MODIS.

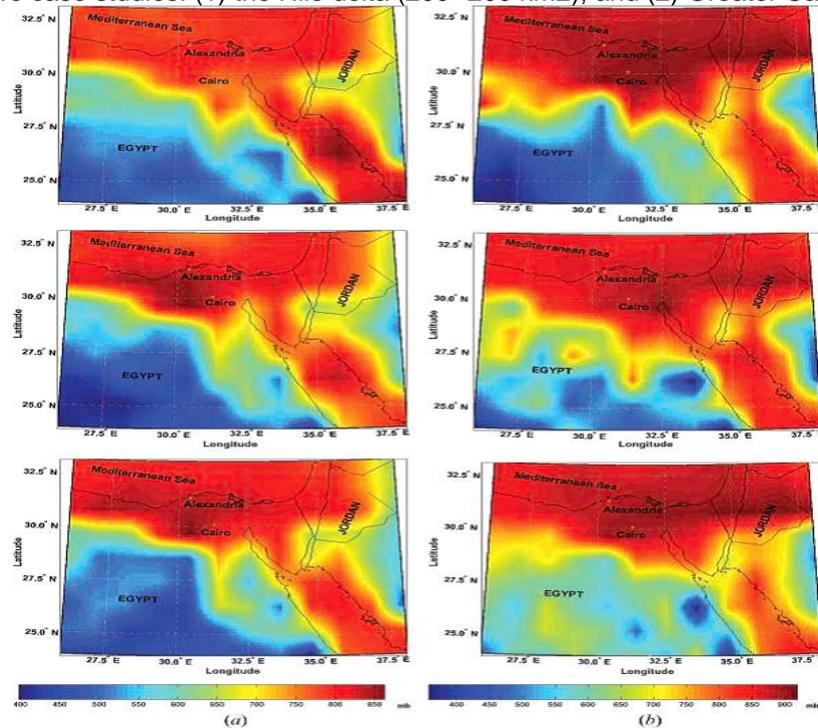
The MODIS aerosol product is used to study aerosol climatology, sources and sinks of specific aerosol types (e.g., biomass burning aerosol or black cloud over Nile delta), interaction of aerosols with clouds, the hydrological cycle and atmospheric dynamics, and atmospheric corrections of remotely sensed surface reflectance over the land (Figure. 5). MODIS measures aerosols, which include dust, sea salt, smoke from agriculture fires, and some kinds of pollution, directly affect the amount of sunlight that reaches the earth by scattering and absorbing the incoming radiation. The MODIS fire and thermal anomalies products contain information unique to understanding the timing and distribution of fires and characteristics such as the energy emitted from the fire and is available for both day and night periods. Temporal composites include an eight-day and monthly day and night fire occurrence aggregation and a summary of the number of fires in classes related to the strength of the fire. El-Askary et al (2008) have used aerosol product seasonally over Nile delta and Cairo, and they had found that the dust aerosols during MAM are found at higher altitudes, yet are low compared to the anthropogenic aerosols revealed from the CTP values shown in (figure.6a). The reason that they are found at higher altitudes as compared to SON aerosols is due to the normal temperature gradient during this particular time of the year over Cairo.



(Figure.5) AIRS measurements over the same dust storm

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.6b). It is evident that, during the pollution episodes, lower CTTs were achieved due to the decreasing trend, as compared to the dust episodes that show an increasing trend in the CTT values (Devasthale et al. 2005). This implies that anthropogenic aerosols have an indirect impact in the thermal infrared, compared to the dust aerosols. Anthropogenic pollutants during SON are found at a very low altitude, less than 1 km closer to

the earth's surface, as revealed from the CTP values (.920 mb). One important issue that needs to be addressed is whether MODIS aerosol retrievals (at 10 * 10 km2 grid size) are applicable to regional or local air pollution. Presented here are two case studies: (1) the Nile delta (200 *200 km2), and (2) Greater Cairo (40 *50 km2).



(Figure.6). The cloud top pressure CTP over Cairo and the Greater Delta region during (a) spring (MAM) of 2004, 2005 and 2006, showing dust occurrence at higher altitudes ,750–800mb and (b) autumn (SON) of 2004, 2005 and 2006, showing anthropogenic aerosols occurrence at lower altitudes .900 mb. (El-Askary et al, 2009).

5-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. 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.7).



(Figure. 7) the anthropic factors affecting black cloud over Nile delta