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Meteorological Analysis for Black Cloud (Episodes) Formation and its Monitoring by Remote Sensing

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Abstract: The black cloud (air pollution episodes) hovers over the ancient city of the pharaohs, poisoning the air for its 14 million residents. From eroding the celebrated monuments to causing a plethora of illnesses, Cairo has suffered greatly from its air pollution. How much longer will it stay there? The question of how to most effectively reduce this pollution remains unanswered for Cairo and other mega cities in the developing countries. The air pollution episodes arose as another priority for Who???. Regardless of actions by the Government, the Egyptian media carried the issue extensively. This in part led to serious attention by Egypt's Prime Minister and the Parliament. With integrated messages working in various air monitoring and analysis findings to explain air pollution, its causes, what the government and others are doing, and what outcomes had been realized. This study gives basic description and analysis of black cloud formation due to accumulation of pollution from different sources and the effect of the meteorological conditions. There are numerous sources to air pollution in Egypt as in other countries. However, the formation and levels of dust, small particles, and soot are more characteristic in Egypt than presently found in industrialized countries. Some of the sources for these pollutants, such as industries, open-air solid waste burning, and transportation were also 20 years ago well known problems in most countries. The time of black cloud formation over Cairo city is always in parallel to the period of rice straw burning by farmers in the delta Governorates especially Dakahlya, Sharkia, and Kalyobia which are the nearest Governorates to Cairo. The metrological conditions of very low wind speed and cold temperature causes the phenomena of thermal inversion. Remote Sensing is the best means of acquiring basic information particularly on the regional scale and through a repetitive schedule. By using this technology we can detect and monitor the sources of burning the rice straw in the delta region.

Key words: episodes, air pollution episodes, dispersion modeling, rice straw

INTRODUCTION

Establishing the "right" environmental policy is a very difficult task. As we learned in the study of Cairo, each country must be analyzed separately. Cairo's climate and desert dust should be taken into consideration when placing restrictions on emissions (perhaps by instituting stricter guidelines to coincide with specific climate forces). A strengthened economy and an enlightened populace enhance environmental agendas, as in the case of Bangkok and Thailand. Faced with the knowledge that mega cities are on the rise, perhaps the best environmental policy to adopt is one of prevention, the least expensive way to reduce air pollution.

The Main Air Pollution Problem in Egypt: Another important source for particulate matter is the wind blown dust from the arid areas. These particles are to be found in the larger particle fraction. For instance, the data collected at Tabbin in southern Cairo of diameter less than 10 micrometer (PM10) are mainly generated from industrial processes.

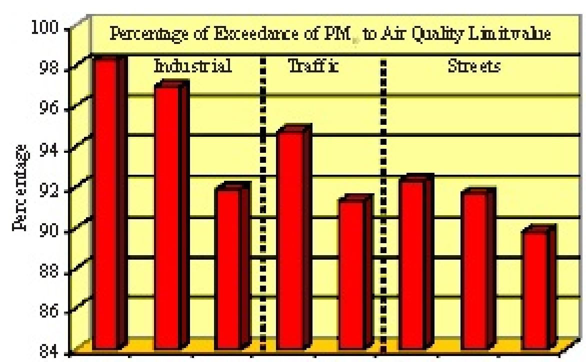

Fig. 1:

To illustrate the magnitude of the suspended particulate matter problem, Figure 1 shows the percentage exceeding the air quality limit value during the year 2006.

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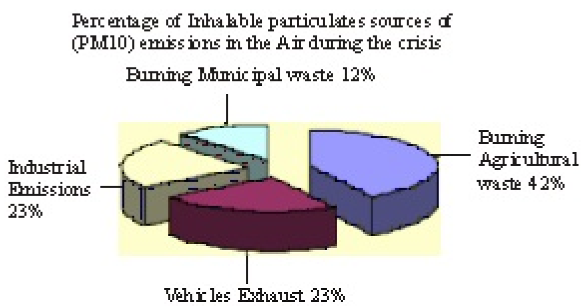
In addition to particles, also SO_2 in urban areas and in industrial areas, as well as NO_2 and CO in the streets may exceed the air quality limit value.

Sources of Air Pollution: Air pollution is generated from a number of different sources. The concentrations of air pollutants that are measured at the sites will always be a sum of the interactions from different sources. It is therefore important to have some basic knowledge about the characteristics of the sources in the different areas, as showing in Table 1 and Figure 2.

Table 1:

Sources	Percentage
Burning of Agricultural	42%
Vehicles Exhaust	23%
Industrial Emissions	23%
Burning of Municipal Waste	12%



1- Burning of Agriculture
2- Vehicles Exhaust
3- Industrial Emissions
4- Burning of Municipal Waste

Fig. 2:

Typical Sources of Air Pollution: Total Suspended Particulate matter (TSP), solid and liquid particles, are emitted from numerous man-made and natural sources such as open air waste burning, industrial processes (large industries and small enterprises), diesel powered vehicles, and wind blown dust from arid areas may create particles in the air. Sulphur dioxide (SO_2) is formed when fossil fuels such as coal, gas and oil are used in large and small industries and for power generation. Nitrogen oxides (NOx) are mostly generated from automobile traffic and from burning of fossil fuels.

Other pollutants include carbon monoxide (CO), emitted mainly from gasoline powered motor vehicles; lead, resulting from the use of alkyl lead as an anti-knock agent in gasoline, and various toxins generated from open-air burning and a numerous type of small smelters and enterprises. Some of the more important industrial sources in Egypt are given below indicating also some of the areas where these sources may be found (the list is not complete, but serves as an example):

Waste burning, Specific Problem (Burning of Agricultural and Burning of Municipal Waste): Open air waste burning has been observed in several areas of Egypt. This type of burning at large waste collection areas may create considerable health impact to the population. Presently no measurements have been performed of PAH (Poly Aromatic Hydrocarbons) and dioxins downwind from these sources. Dioxins are by-products generated from processes when heat is applied to substances containing carbon, oxygen hydrogen, and chlorine.

The main source of dioxins at present is waste incineration and agricultural waste (rice straw) as shown in table 2. Other sources exist, such as emissions from electric steel making furnaces, cigarette smoke, and automobile exhaust.

Industrial Impact (Emission): Various industries may create air pollution problems in many parts of Egypt. The sites at Tabbin and Shoubra El-Kheima are both impacted by industrial sources as shown in Figure 5 and Table 3. At Tabbin a large number of industries such as smelters coke factory, chemical industries, and a power plant is located south of the site. The highest SO_2 concentration at Tabbin (TIMS) has been shown to occur when the wind is blowing from around south; from the industrial complexes at Tabbin south. The cement factories north of the site emit large amounts of relatively coarse particles, while our data show that the thoracic part of the dust (PM10) is emitted from the smelter area. Figure 3 show the individual observations of PM10 (1-h average) as a function of wind directions.

The SO_2 concentrations as a function of wind directions at Shoubra El-Kheima is presented in Figure 4.

Table 2: Rice Cultivated areas in Governorates during 2006.

Govern orate	Cultivated area(Feddan)	Quantity of Straw (ton)	Quantity of Straws (%)
Kalyobia	**36.000**	**72.000**	**2.43**
Kafr El sheikh	271.469	542.938	17
Dakahlya	**458.359**	**916.718**	**30**
Beharia	216.178	432.356	14
Sharkya	**299.466**	**598.932**	**19**
Gharbeya	**181.122**	**362.244**	**12**
Damitta	66.138	132.276	4
Fayoum	24.489	48.978	1.57
Total	1.553.221	3.106.442	100%

Source: Ministry of Agriculture, Governorates that affecting Greater Cario **(in Bold)**

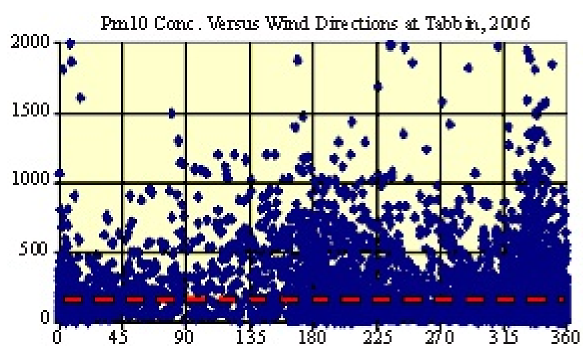


Fig. 3: The 1-h average PM10 concentrations as a function of Wind directions (WD) at Tebbin 200: WD: 0 or 360 = wind from North, WD: 90 = wind from east, WD wind from south = 180

Impact from Traffic (Vehicles Exhaust): The average diurnal variations of the different indicators presented above clearly indicate that the traffic density variation, traffic congestion and traffic flow influenced the concentrations at some of the sites.

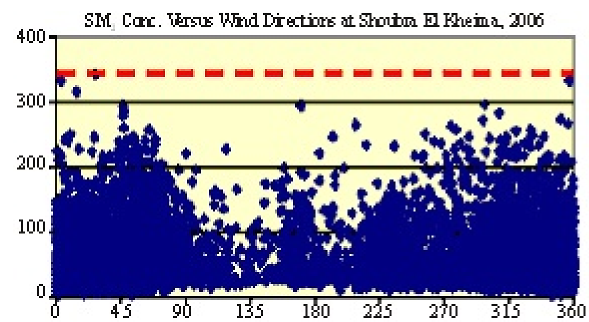


Fig. 4: The 1-h average concentrations of SO_2 as function of high SO_2 concentrations exceeding the air quality limit value seem to occur for many wind directions. Most of the concentrations above 350 g/m^3 were recorded at winds from around north and west.

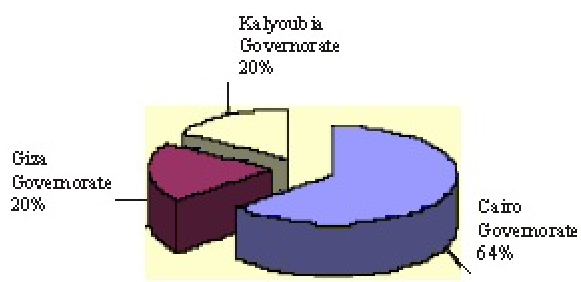


Fig. 5:

Table 3: Number of industrial Establishment and their distribution at Great Cario.

Govermorate	Number of Establishments	Percentage
Cario Governorte	Establishment 10162	64%
Giza Governorate	Establishment 3104	20%
Kalyoubia Governorate	Establishment 2587	16%
Total	15853	100%

A further investigation shows that the different modes of traffic and different types of vehicles give

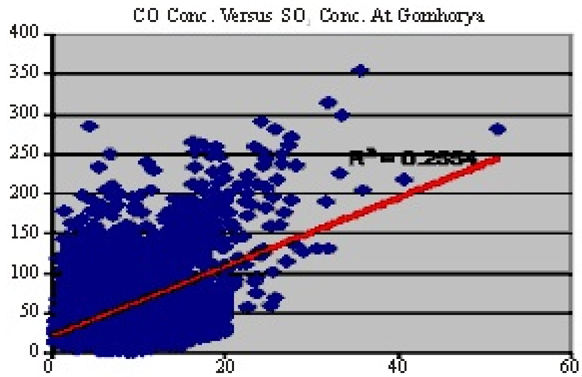


Fig. 6: Simultaneous observations of one-hour average SO_2 and CO concentrations at El-Gomhoriya Street during 2006. With high speed, the CO concentrations are reduced.

rise to different levels of different pollutants. Selected indicators are compared to each other at the sites El-Kolaly, El Gomhoriya Street, and Fum El-Khalig. An example of one of several analyses performed to explain the impact from traffic sources and other sources to pollution in the streets is shown in Figure 6. Simultaneous observations of SO_2 and CO indicate two axes of very high concentrations. High SO_2 concentrations with simultaneous observations of relative low CO concentrations indicate impact from diesel buses generating high SO_2 emissions while moving. This part of the distribution may also represent burning of waste or fossil fuel in other sources.

Air Pollution Episodes: There are three reasons we believe the Minister of Environment and other policymaker's have picked up messages. First, the issue required their attention. Second, many discussions on monitoring and other programs convinced them that the information they received was credible. Third, there was at least some good news they could show: simple yet scientific graphics demonstrating substantial and progressive reductions in airborne lead and the frequency and severity of air pollution episodes.

In 1999, residents of Cairo began noticing serious air pollution episodes — labeled the "black cloud" — during the fall. These peak levels were measured and reported by air monitoring network. The Egyptian Government requested support to this news and politically charged priority. EEAA responded with the following plan:

1- Get the facts about episodes through sound data analysis.
2- Help the Government anticipate episodes by developing an air quality forecasting program.
3- Identify short and long-term mitigation options.

Clear information is a prerequisite for sound decision-making. In the beginning there was tremendous disagreement on the causes of the episodes. The local press was filled with wild speculation about the sources of this serious health event. The EEAA source attribution study connected pollutant levels in the air with their contributing sources. For the first time, EEAA was able to show that the additional contributions from burning garbage and waste from the agricultural harvest could be drivers for these events. In addition, the analysis showed that serious episodes can occur with the normal load of pollution in the city if poor meteorological conditions exist. With this information, the Ministry of Environment has helped raise waste management to the national agenda. Public pressure is contributing to the drive for solutions. Dozens of "black cloud" related articles in the local press have appeared during the fall and winter about when episodes are anticipated. When episodes first occurred, Government Officials were frustrated by their inability to anticipate them.

While episode prediction became a political imperative, solving the problem was even more important. For the immediate term, EEAA provided the Minister's office with an analysis of pollution reduction and exposure mitigation measures that had been applied successfully in other countries.

Government and the public on the need for integrated strategies and long-term commitment to solve the problem. The utility of the data and analysis generated is clear. Already it has demonstrated the tremendous progress in reducing airborne lead levels and air pollution episodes. Ten years ago the need for better information was clear. Now the enhanced data set is guiding updated assessments of the health and economic impacts of air pollution and severity of air pollution episodes trend in the fall episode.

MATERIAL AND METHODS

Analogy Between Black Cloud Formation and Hazardous Gas Cloud after an Accidental Chemical Release: In order to evaluate the relative impact of the Black Cloud and its effects, study the exchange process and its dynamics, and derive effective emission rates depending on application modes, we will discuss and study in this paper one of the most powerful meteorological and monitoring model for dispersion.

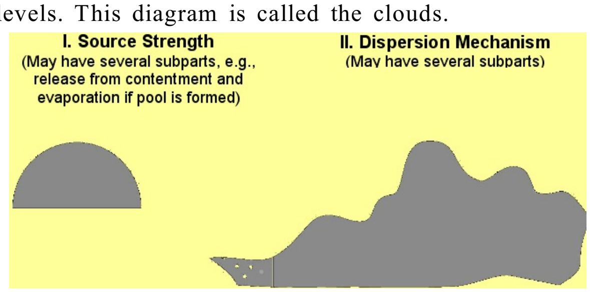
The particular Areal Locations of Hazardous Atmospheres (ALOHA) model used in this study runs with different input data (meteorological data and/or emission data). Advanced visualization techniques are used to interpret the great amount of digital data collected in these runs and to show clearly the different trends and relationships that are normally hidden behind many numbers.

ALOHA (Areal Locations of Hazardous Atmospheres) is a computer program designed especially for use by people responding to chemical accidents as well as for emergency planning and training. ALOHA can predict the rates at which chemical vapors may escape into the atmosphere from broken gas pipes, leaking tanks, and evaporating puddles. It can then predict how a hazardous gas cloud might disperse in the atmosphere after an accidental chemical release.

ALOHA is an air dispersion model, which you can use as a tool for predicting the movement and the dispersion of gases. It predicts pollutant concentrations downwind from the source of spill taking into consideration the physical characteristics of the spilled material. ALOHA also accounts for some of the physical characteristics of the release site, weather conditions, and the circumstances of the release. Like many computer programs, it can solve problems rapidly and provide results in a graphic easy-to-use format. This can be helpful during an emergency response or during planning for such a response.

What is dispersion? Dispersion is a term used by modelers to include advection (moving) and diffusion (spreading). A dispersing vapor cloud will generally move (advect) in a downwind Direction and spread (diffuse) in a crosswind and vertical direction (crosswind is the Direction perpendicular to the wind). A cloud of gas that is denser or heavier than air (called a **heavy gas)** can also spread upwind to a small extent.

ALOHA models the dispersion of the cloud of a pollutant gas in the atmosphere and displays a diagram that shows an overhead view of the area in which it predicts that gas concentrations will reach hazardous levels. This diagram is called the clouds.



Footprint: To obtain a footprint plot, you first must identify a threshold concentration of an airborne pollutant, as shown in Figure 7, usually the concentration above which the gas may pose a hazard to people.

This value is called the **Level of Concern**. The footprint represents the area within which the ground-level concentration of a pollutant gas is predicted to

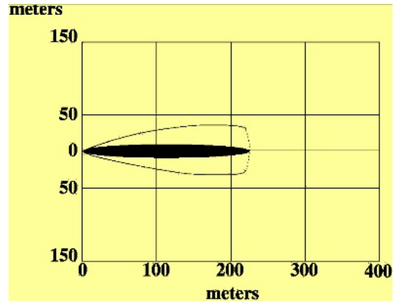


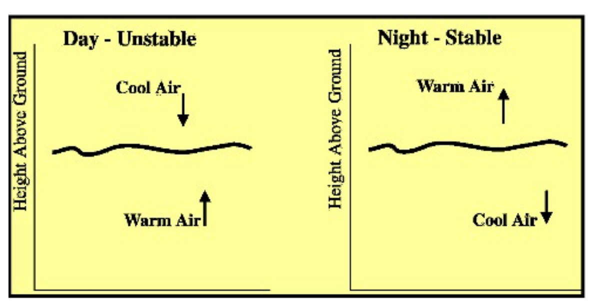
Fig. 7:

exceed your Level of Concern (LOC) at some time after a release begins.

Many different types of air dispersion models exist. They range from simple equations that can be solved by hand to complex models that require massive amounts of input data and powerful computers. The type of model appropriate for a particular use depends on the scale of the problem, the level of detail available for input and required for output, the background of the intended user, and the time available to wait for the model computations to be completed.

ALOHA was designed to be used for predicting the extent of the area downwind of a short-duration chemical accident where people may be at risk of exposure to hazardous concentrations of a toxic gas. Neither ALOHA is intended for use with accidents involving radioactive chemicals, nor is it intended to be used for permitting of stack gas or modeling chronic low-level ("fugitive") emissions. Other models are designed to address larger scale and/or air quality issues[14]

Very Stable Atmospheric Conditions: Under the most stable atmospheric conditions (most common late at night or very early in the morning), there is usually very little wind and almost no mixing of the pollutant cloud with the surrounding air. Gas concentrations within the cloud can remain high far from the source.



The accidental release of methyl isocyanate gas at Bhopal, India, in 1984 is an example of what can happen under very stable atmospheric conditions as

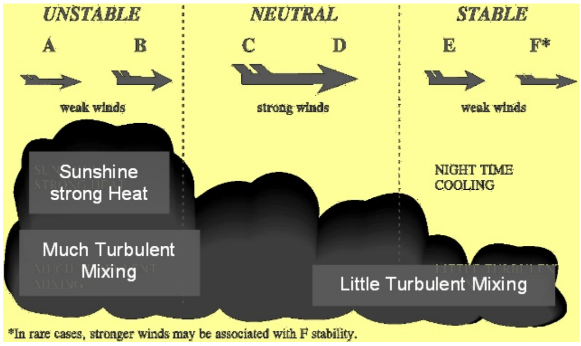


Fig. 8:

show in Figure 8 and table 4. Thousands of people died, including many who were far from the release. In a very stable atmosphere, a chemical cloud will spread out in the same manner as cream poured into a coffee cup.

This is the case which happened due to thermal inversion and caused the black cloud formation.

Using Remote Sensing for Monitoring and Detecting the Burning Sources: Remote sensing is the non-contact recording of information from the ultraviolet, visible, infrared and microwave regions of the electromagnetic spectrum by means of instruments such as cameras, scanners, lasers, linear arrays and/or area arrays located on platforms such as aircraft or spacecraft, and the analysis of acquired information by means of visual and digital image processing".Remote sensing is unconstructive if the sensor is passively recording the electromagnetic energy reflected from or emitted by the phenomenon of interest. i.e. The passive remote sensing system does not disturb the object or area of interest. Remote sensing devices are often programmed to collect data systematically. This systematic data collection can remove the sampling bias introduced by some in-situ investigations. Remote sensing can provide fundamental biophysical data including: - X, Y coordinates, Z elevation or depth, temperature, moisture, content …… etc.

Table 4:

Wind speed			Day			Night	
(meter per second)	(knots)	(miles per hour)	Incoming Solar Raditation Storng Moderate Slights			Cloud Cover >50%	>50%
<2	<3.9	<4.5	A	A-B	B	E	F
2-3	3.9-5.8	4.5-6.7	A-B	B	C	E	F
3-5	5.8-9.7	6.7-11.2	B	B-C	C	D	E
5-6	9.7-11.7	11.2-13.4	C	C-D	D	D	D
>6	>11.7	>13.4	C	D	D	D	D

Stability is D for completely overcast during day or night

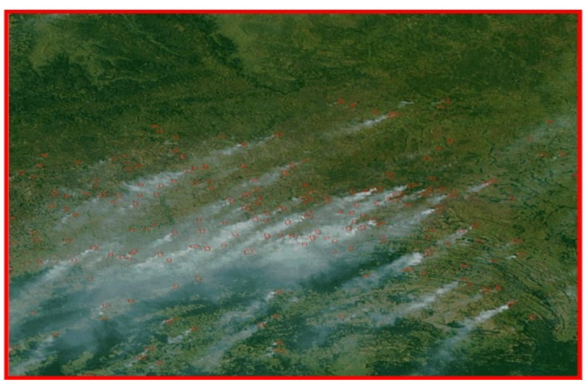


Fig. 9:

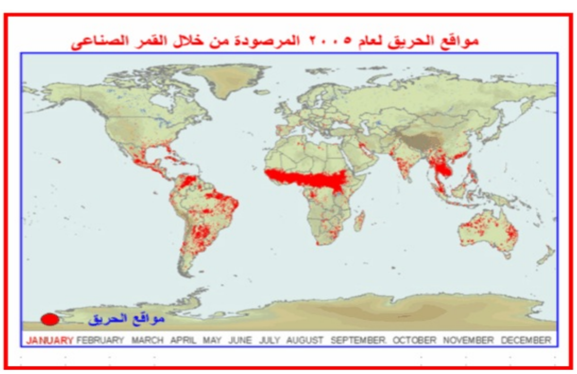


Fig. 10:

Analysis and Monitoring: Each of these fire maps accumulates the locations of the fires detected by MODIS on board the Terra and Aqua satellites over a 10-day period as shown in Figure 9 and Figure 10. Each colored dot indicates a location where MODIS detected at least one fire. during the compositing period. Color ranges from red where the fire count is low to yellow where number of fires is large. The compositing periods are referenced by their start and end dates (Julian day). The duration of each compositing period was set to 10 days. Compositing periods are reset every year to make year-to-year

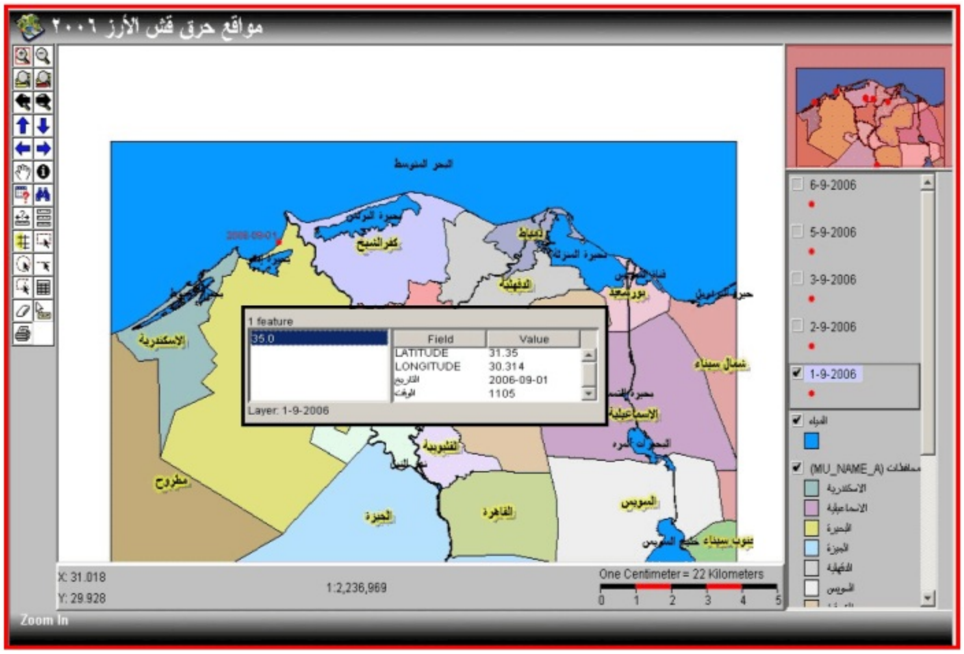


Fig. 11:

Fig. 12:

Fig. 13:

comparisons straightforward. The first compositing period of each year starts on January 1. The last compositing period of each year includes a few days from the next year. The Fire Information for Resource Management System (FIRMS) integrates remote sensing and GIS technologies to deliver active fire locations, as shown in Figure 11, 12& 13, MODIS to natural resource managers and other stakeholders around the World. FIRMS are funded by NASA and builds on Web Fire Mapper, which is a web mapping interface that displays active fires detected by the MODIS Rapid Response System.

RESULTS AND DISCUSSIONS

To explain the formation of this phenomenon due to the increase of pollution and the thermal inversion as follows:

1- The air movement causes dispersing the pollutants emitted from different sources of pollution.
2- No air movement to disperse the pollutants emitted from different sources of pollution.
3- No air movement, Thermal inversion and pollutants accumulation leads to formation of the episodes.
4- The analysis of factors and causes for black cloud formation and its happening during a specific time every year as well as the analogy with the formation of toxic cloud due to accidental release of hazardous chemicals.

5- An environmental policy is needed to reduce the air pollution and a mitigation plan to face this problem which affects the health of the Cairo citizens, by reducing the number of cars in the street, shutting down the factories producing heavy pollution of Co_2 , So_2 ,..., preventing the open burning of municipal waste, and avoiding the burning of rice straw in the area near Cairo.

6- Encouraging the use of natural gas instead of gasoline in private cars and public transportation to reduce the car emission.

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