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Air quality monitoring in the Mediterranean Tunisian coasts

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1. Introduction

The transfer from the liquid element (the sea) to the solid one (the land) engenders thermal phenomena such breezes. During the day, the land heats up more rapidly than the sea. Over the land surface, the heat spreads in the low layers and gives birth to upward currents. This hot continental air rises up, and then is superseded by a colder air coming from the sea; it is the sea breeze. During the night, the phenomenon is reversed to become a land breeze.

If the synoptic wind is weak, the breezes will take their true size and result in the formation of convergent zones on the land and divergent zones over the sea. Some visual signs can help observe these phenomena. The low clouds of the cumulus type are a proof of the vertical movement. They are often related to the setting of the sea breeze (Simpson, 1994).

Many experimental and numerical studies have shown the impact of breeze circulations on the evolution of pollutant concentrations (Bouchlaghem et al., 2007; Srinivas et al., 2007; Baumgardner et al., 2006; Evtyugina et al., 2006; Flocas et al., 2006; Lim et al., 2006). The photochemical transformation also plays a crucial role in the production and destruction of pollutants. These transformations coupled with the dynamic circulations such as breezes represent the responsible process of the formation, transport and redistribution of reactive chemical species in the low layers of the atmosphere.

The study made by (Ma and Lyons, 2003) via a 3D version of RAMS model (Regional Atmospheric Modelling System) has shown that the recirculation of pollution is a Mediterranean characteristic. They have defined the recirculation as follows: in the presence of a weak synoptic wind, the heating and cooling of the land and the sea determine the local circulation which affects the transport and diffusion of emissions. In fact, during the night, emissions can be transported over the sea via a land breeze or an offshore synoptic wind just to return onshore to the land after the launching of the sea breeze. The study of (Nester, 1995) has shown that the phenomena of photochemical Smog are generally associated with this type of meteorological conditions such as, a weak synoptic wind and a recirculation of

land and sea breezes. He insists that the local recirculation, the topography, the coast shapes and the force of synoptic wind play important roles in the transport of pollution. The numerical study of (Liu et al., 2002) shows the effect of the recirculation of land and sea breezes on the ozone distribution. They demand that the ozone and its precursors be transported over the sea by the land breeze. Later on, the front breeze transports the ozone precursors on the land. A weak sea breeze and the intensification of solar radiations activate the photochemical process and contribute to the ozone increase of concentration.

A 3D model of air pollution TAPM (The Air Pollution Model) (Luhar and Hurley, 2004) second version has been applied to predict meteorological parameters and pollution field on the Mediterranean. The obtained results display that the development of a sea breeze during the day and a nocturnal land breeze due to the temperature contrast between the land and the sea may reduce the diffusion of air masses in the presence of the recirculation. Via a meso-scale model, (Ding et al., 2004) have explained that the late sea breeze development is due to the presence of an offshore synoptic wind. These breezes are generally characterized by the formation of a front breeze and a return current in the upper layers. They display that this dynamic nature contributes to the ozone concentration increase on the coasts. With reference to the experimental data of the MEDiterranean CAMpaign of PHOtochemical Tracers- TRANsport and Chemical Evolution (MEDCAPHOT-TRACE), (Ziomas, 1998) has proved that the pollution problems are strictly interconnected with the launching and the steadiness of the sea breeze. Via the 3D version of RAMS Model (Regional Atmospheric Modelling System) and the experimental data analysis, [Millan et al., 2002] have proved that the sea breeze combines with the mountain breeze to create a recirculation over the Mediterranean basin with a residence time of few days. Under the impact of solar radiation, this recirculation takes the shape of photochemical reactor where the precursors give birth to ozone, acids and aerosols. They remarked that the problem of air quality on the Mediterranean basin is principally governed by diurnal meteorological process such as breezes.

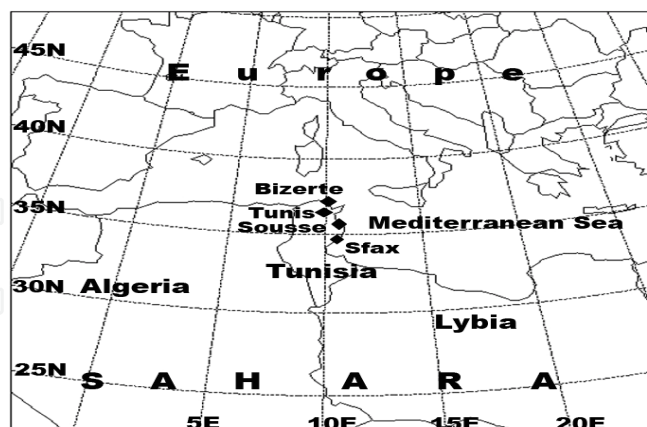


Fig. 1. North Africa map displaying Tunisia and Sousse region location (35° 48' N, 10° 38' E).

Several studies have pointed out, by using both in-situ and remote sensing observation, that dynamics of polluted air masses in the Mediterranean are influenced by local and mesoscale meteorological processes (Bouchlaghem et al., 2007; Helena et al., 2006; Viana et al., 2005; Puygrenier et al., 2005; Pérez et al., 2004; Gangoi et al., 2001, 2002; Kassomenos et al., 1998;

Ziomas, 1998 and Millan et al., 1996). During summer, transport of polluted air masses is influenced by the sea-land breeze circulation (Millan et al., 2002). The later can affect urban areas along the coasts and further inland as it can penetrate up to hundred kilometres inland (Simpson et al., 1977; Simpson, 1994). Simultaneously, the Mediterranean climatic conditions (high temperatures and intensive solar radiation) especially in the summer period, promote the formation of photochemical secondary pollutants.

Synoptic scale meteorology induces frequent outbreaks of African Saharan dust reaching most Mediterranean regions (Lyamani et al., 2005; Alastuey et al., 2005; Querol et al., 2004; Rodriguez et al., 2002, 2004; Viana et al., 2002, 2003, 2007). The occurrence of dust outbreaks affecting the Mediterranean has a marked seasonal behaviour, and is generally driven by intense cyclone generated south of Atlas Mountain by the thermal contrast of cold marine Atlantic air and warm continental air that cross North Africa during summer (Meloni et al., 2007). Rodriguez et al., 2002) pointed out, through an analysis of experimental data recorded on the eastern sites of Spain, that the highest PM event recorded in the Mediterranean were frequently documented during outbreaks of African dust.

Annual pollution studies in the Mediterranean have pointed out that pollutant behaviour is a tracer of seasonal meteorology dynamic and becomes a common feature characterizing these regions (Simon et al., 2006; Marmer and Langmann, 2005).

Martin et al., 1991 suggest that the annual variation in meteorological conditions is a common feature in most of the Mediterranean areas and results in air pollution cycles different from those experienced in other latitudes.

Knowledge of the mechanisms that give rise to pollution episode in the Mediterranean regions is needed for the purpose of providing health advice to the public in events episodes.

To this end, local and seasonal variation of the main pollutants concentration and the meteorological conditions were studied in this chapter.

The studied regions are presented in sections 2. The instrumentation and methods are described in section 3. The seasonal behaviour derived from monthly average concentration and meteorological parameters at the coastal sites is presented in section 4. Summer evolution of Saharan dust and land-sea breeze events and relevant change in pollutants concentrations at a selected site are discussed in section 5 and 6. Pollutants evolution is presented in section 7.

2. Sites description

Tunisia country is located in the North part of Africa (Fig. 1). Its surface is 164.000 km² with 10 millions inhabitants. Coastal cities share about 500 km of beach and are widely influenced by the Mediterranean Sea. The four sites presented in this study are Mediterranean coastal cities with relatively flat terrain.

Bizerte city is located at the North part of Tunisia (37° 16' N, 9° 52' E). Its urban area accounts about 114.000 inhabitants. The measurement station sample is classified as urban which is mainly influenced by residential, traffic and commercial activities. Tunis City (capital of Tunisia) is also located in the North part of Tunisia (36° 49' N, 10° 11' E). The urban area (750.000 inhabitants) is about 212.63 km² surface. The sampling site is classified as urban, located in the vicinity of one of Tunis's major traffic Avenues (Bab Saadoun Ave.).

Sousse city is located at the Eastern central part of Tunisia (35° 49' N, 10° 38'). The urban area (200.000 inhabitants) is about 45 km² surface. The sampling site is urban under the influence of residential, traffic and commercial activities. The main industrial activities are a power plant and bricks work.

Finally, Sfax city is located at the south part of Tunisia (34° 44' N, 10° 46' E) with 270.000 inhabitants. The sampling site is industrial under the influence of intense chemical manufacturing activities.

3. Data and methods

It might be highlighted that there is a lack of knowledge in Tunisia on the pollution concentration, since the national monitoring stations operated by the ANPE (Agence Nationale de Protection de l'Environnement) is localised in the most urban zones. All instantaneous concentrations data can be controlled from the central station.

Surface O₃ levels were continuously monitored using Environment model 41 M analysers. The concentrations of NO_x (NO and NO₂) were measured by using analysers Environment-AC, Models 31 M.

Other stations use standard NO_x (NO & NO₂), O₃ and SO₂ instruments designed by Teledyne Advanced Pollution Instrumentation Company (<http://www.teledyne-api.com>). Data processing techniques and standard methods are described in the analyser instruction manuals. Used Teledyne models are 200A, 400A and 100A for NO_x, O₃ and SO₂ respectively. Additionally, all stations were equipped with automatic weather monitoring. A mobile laboratory is used to control pollutants levels in rural and urban sites. These measured pollutants are harmful both for the human health and the environment: Ozone is a major photo-oxide product of the atmosphere. It is manifested in the presence of UV radiation stemming from ozone precursors.



Then it is consumed by NO



The high levels of ozone give birth to the formation of the Smog phenomena and the green house effect. The oxidization of NO_x and SO₂ in the atmosphere stimulates the formation of aerosols (e.g. H₂SO₄, HNO₃...) which play a crucial role in the production of acid rain and the climatic and environmental change.

The influence of atmospheric transport scenarios on the levels of Particulate Matters was investigated by means of back-trajectories analysis using the Hysplit Model (www.arl.noaa.gov) and information obtained from TOMS-NASA, NRL aerosol and dust maps (TOMS, www.jwocky.gsfc.nasa.gov; NRL www.nrlmry.navy.mil). Satellite images are provided by the NASA SEAWIFS project (www.seawifs.gsfc.nasa.gov).

4. Experimental results

4.1 Seasonal pollutants behavior

Fig. 2, 3, 4 and 5 show time series plots of the main pollutants concentrations (NO, NO₂, NO_x, O₃, SO₂ and PM₁₀) and the local meteorological parameters at selected sites. A seasonal pattern of variation which completes one cycle per year is observed at all sites. NO, NO₂ and NO_x concentrations are lowest in summer (June, July and August) and peaking in

winter (December, January and February). In contrast, O₃ concentration shows reversed tendency of seasonal variation. There is a clear indication of annual trend downward for NO_x (NO and NO₂) and SO₂. This may be due to the reduction of vehicle emission with the renewal of the Tunisian vehicular fleet during the last decade, the use of refined oil products and the application of laws decreasing industrial emissions by substituting heavy fuel for natural gas. Nevertheless there is no indication for annual O₃ and PM₁₀ levels decrease. O₃ and PM₁₀ are approximately stationary in their level and point out to the contribution of additional non local pollution sources during particular weather conditions. NO, NO₂ and NO_x concentrations appear to be a common seasonal pattern across the sites. There is less air mixing in the lower boundary layer during the winter months and this could lead to elevated levels of these pollutants. Additionally, Derwent et al., (1995) suggest that high winter concentration of NO₂ could be enhanced by reduced photochemical activity of the reaction in which NO₂ and (OH) radicals combine to form nitric acid (HNO₃). The winter highs could also be linked to increased industrial and home heating. The summer lows might be due to the enhanced photochemical activity on the presence of powerful solar radiation in which NO₂ promotes ozone production.

Differences of concentration between locations can be described in terms of changes in the average level and the amplitude of the seasonal fluctuation. The main differences seem to be associated with the type of station (industrial, urban, traffic...) and the proximity to the main source emissions. The highest average levels (up to 45 ppb) and the larger seasonal amplitude of NO_x concentration occur in Tunis City where the site is located in dense vehicular activity. The larger average levels (up to 40 ppb) and seasonal amplitude of SO₂ appear in Sfax city where the measurement site is situated in the proximity of the industrial area. During the summer months, the lowest ozone average levels (up to 18 ppb) and the smallest seasonal amplitudes occur in Tunis City because of elevated levels of NO produced by exhausted fumes of vehicles which deplete ozone concentration.

Simultaneously, the seasonal patterns of the weather variables appear to be much smoother than those of the pollution concentrations and show both negative and positive correlation according to pollutants type.

The negative correlation between the seasonal NO_x concentrations and those of wind speed (Fig. 2 and Fig. 5) may suggest the effect of the increased air mixing. The curves show that weak wind conditions encourage pollutants accumulation over the measurement sites. Nevertheless, positive correlation between the seasonal O₃ and PM₁₀ concentrations and the meteorological variables (wind speed, temperature and solar radiation) may account for the meso-scale and long range transport phenomena which promote the increase of these pollutants concentration. The powerful UV radiation encourages photochemical activity and helps ozone production. Thus, O₃ seasonal pattern consists of a roughly symmetric wave with summer peaks and winter troughs.

4.2 Summer pollutants variation

Saharan dust outbreaks over the Mediterranean Tunisian coasts represent the second summer phenomenon which results in a peak PM₁₀ event reaching the highest annual values (by 200 µg /m³) (Fig. 7) and lower O₃ concentration owing to the influence of the relatively clean Saharan air. It is important to note that by this period the daily average O₃ concentration recorded in Sousse city drops to about 30 ppb.

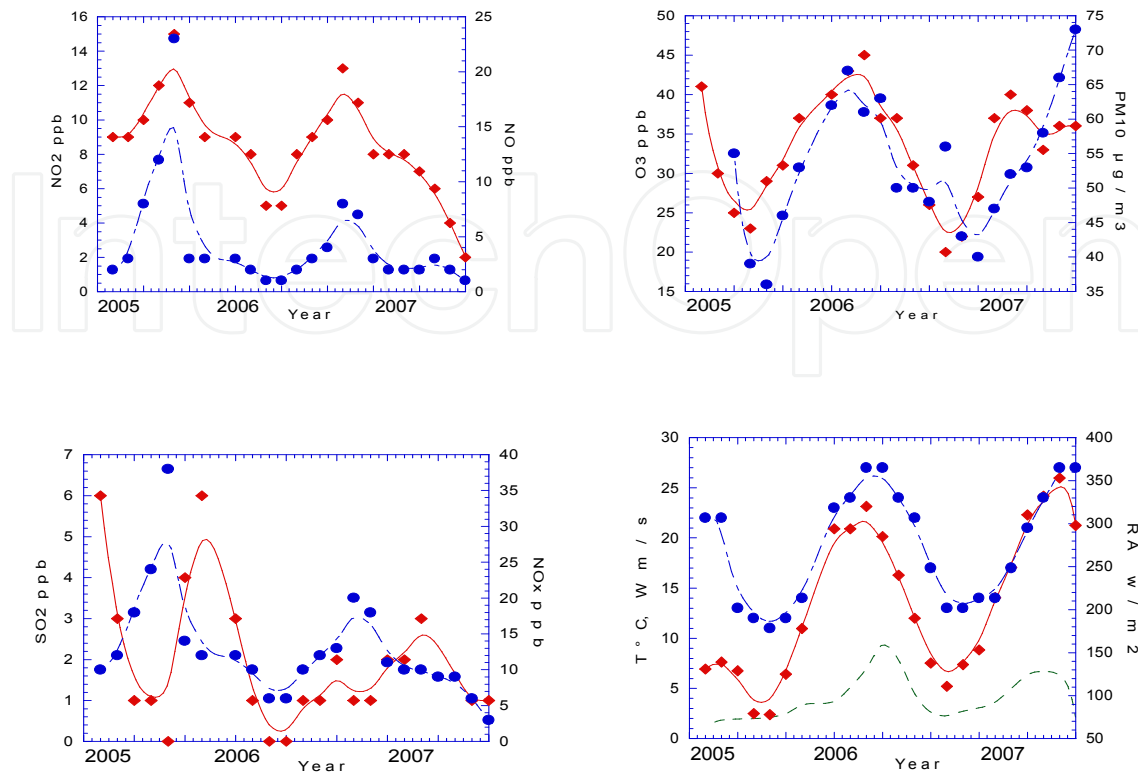


Fig. 2. Time series plots of pollutants concentrations (NO, NO₂, O₃, PM₁₀, SO₂ and NO_x) and meteorological parameters (Temperature, Radiation and wind speed) ranging from September 2005 to August 2007 at Sousse site. Time evolution of the Left y-axis is plotted with Solid line and the right one is plotted with dashed line.

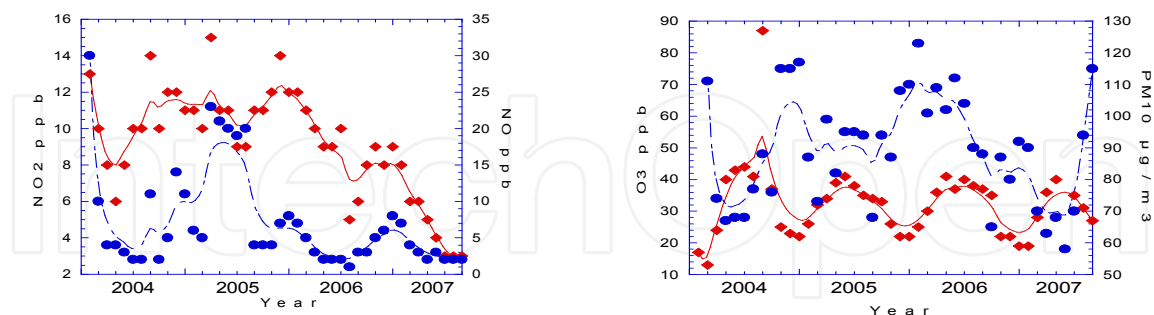


Fig. 3. Time series plots of pollutants concentrations (NO, NO₂, O₃ and PM₁₀) ranging from January 2004 to August 2007 at Bizerte site. Time evolution of the Left y-axis is plotted with Solid line and the right one is plotted with dashed line.

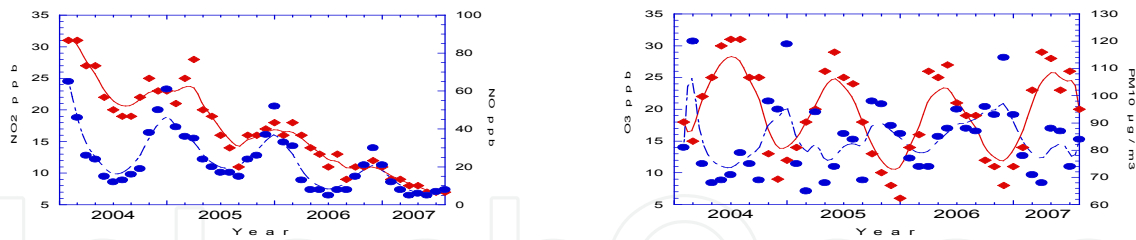


Fig. 4. Time series plots of pollutants concentrations (NO, NO₂, O₃ and PM₁₀) ranging from January 2004 to August 2007 at Tunis site. Time evolution of the Left y-axis is plotted with Solid line and the right one is plotted with dashed line.

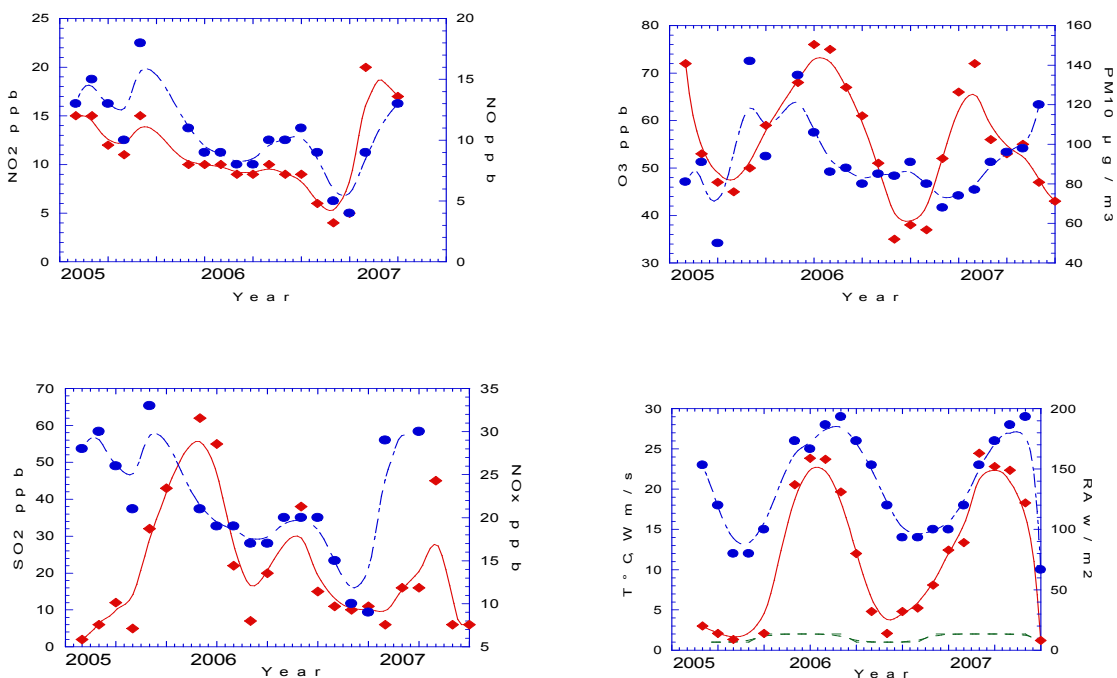


Fig. 5. Time series plots of pollutants concentrations (NO, NO₂, O₃, PM₁₀, SO₂ and NO_x) and meteorological parameters (Temperature, Radiation and wind speed) ranging from September 2005 to August 2007 at Sfax site. Time evolution of the Left y-axis is plotted with Solid line and the right one is plotted with dashed line.

Meloni et al., 2007 suggest that suspended Saharan air masses due to the mixing occurring there can reach 2000m altitude in winter season and 4000m in summer and travelling just above the mixing layer. They pointed out that the air masses loaded with desert dust is expected to become the main aerosol event when the trajectory interacts with the mixed layer.

Here, we presented a sampling PM events reaching Sousse city. During the summer period ranging from 21 June to 24 June 2006, peaks in the PM₁₀ concentrations were reported (Fig. 7). Satellite observation showed a plume of Saharan dust (Fig. 8a) on 23 June 2006 over the Eastern Tunisian coast and the western Mediterranean. The back-trajectory air masse of the same day (Fig. 8b) shows that the air masses reaching the Tunisian costs have a long

range transport origin and the dust outbreaks start from south Algerian Sahara (Fig. 8c). In these conditions, the PM10 concentration at all sites increase rapidly. For instance, in Sousse city, the PM10 concentration increases to reach a level about two to three times the summer one (Fig. 7).

4.3 Winter pollutants variation

A sampling period ranging from 2 January to 5 January 2007 has been selected to study pollutants evolution during winter season. Fig. 9 displays time series of the meteorological parameters and pollutants concentration recorded at Sousse city during this period.

NO and NO₂ peak is much higher in winter than in summer (up to 60 ppb on 04 January). In spite of higher traffic in summer than in winter (national statistics have shown that during the summer season, the vehicle number has doubled in Sousse region due to the increasing number of visitors.), NO and NO₂ higher peak in winter can be explained on the basis of lower ventilation and lower mixing.

With respect to the NO₂, in winter there is less O₃ to oxidize the NO emissions and the NO₂ peak in the morning is hardly detectable. While by the end of the day, there has been sufficient build-up of O₃ to oxidize some of the NO and a peak is detected during that period.

The O₃ concentrations are much higher in summer (up to 65 ppb) than in winter (up to 35 ppb). During summer, meteorological conditions such as high temperature and thermal convection often induce the mixing of the air masses and the photochemical reactions. Observed ozone concentration may be the result of photochemical reaction of primary pollutants (NO_x from traffic). Furthermore, the sea breeze also brings O₃ and the total concentration could result from a combination of local generation and regional transport. Nevertheless, in winter, the O₃ values are limited to lesser photochemical activity and vertical mixing. With NO emissions in a stabilizing air layer, the nocturnal ozone concentration decreases rapidly reaching its minimum value (clear during 4 January) due to the fast reaction between NO and O₃ to produce NO₂ (This phenomenon requires calm wind condition to be clearly detected at the measuring site). Simultaneously, NO, NO₂, SO₂ and PM10 increase to their maximum values showing evidence of low mixing and low ventilation effect during weak wind condition.

With reference to the data of the National Institute of Meteorology, the data of the NOAA ARL model and to the air masses trajectories which come over Sousse region (HYSPLIT Model-Back trajectories) we have identified days during which the sea breeze is evident. In order to distinguish the sea breeze events, we have associated their development in a perpendicular wind direction to the coast (50°- 130°).

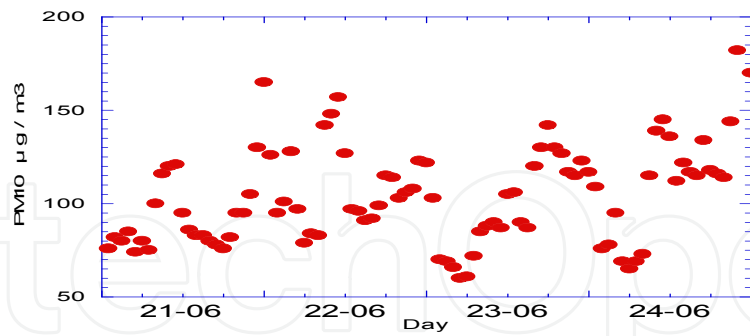
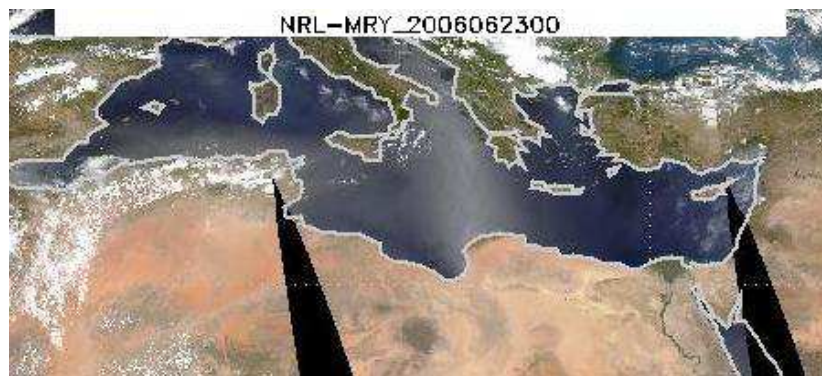
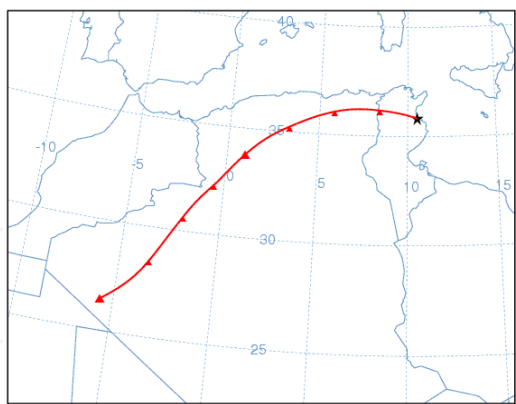


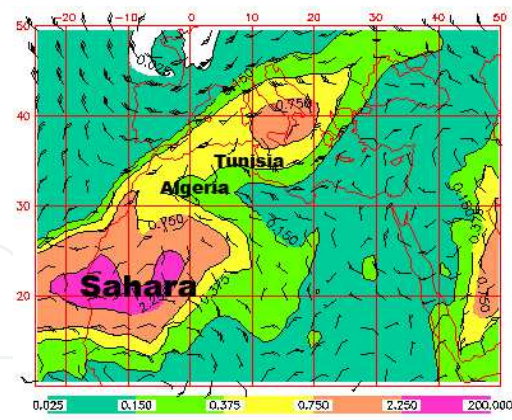
Fig. 7. Hourly averaged series of PM10 concentrations for the period ranging from 21 June 2006 to 24 June 2006.



(a)



(b)



(c)

Fig. 8. (a) Satellite image (b) backward trajectory and (c) Dust map for 23 June 2006.

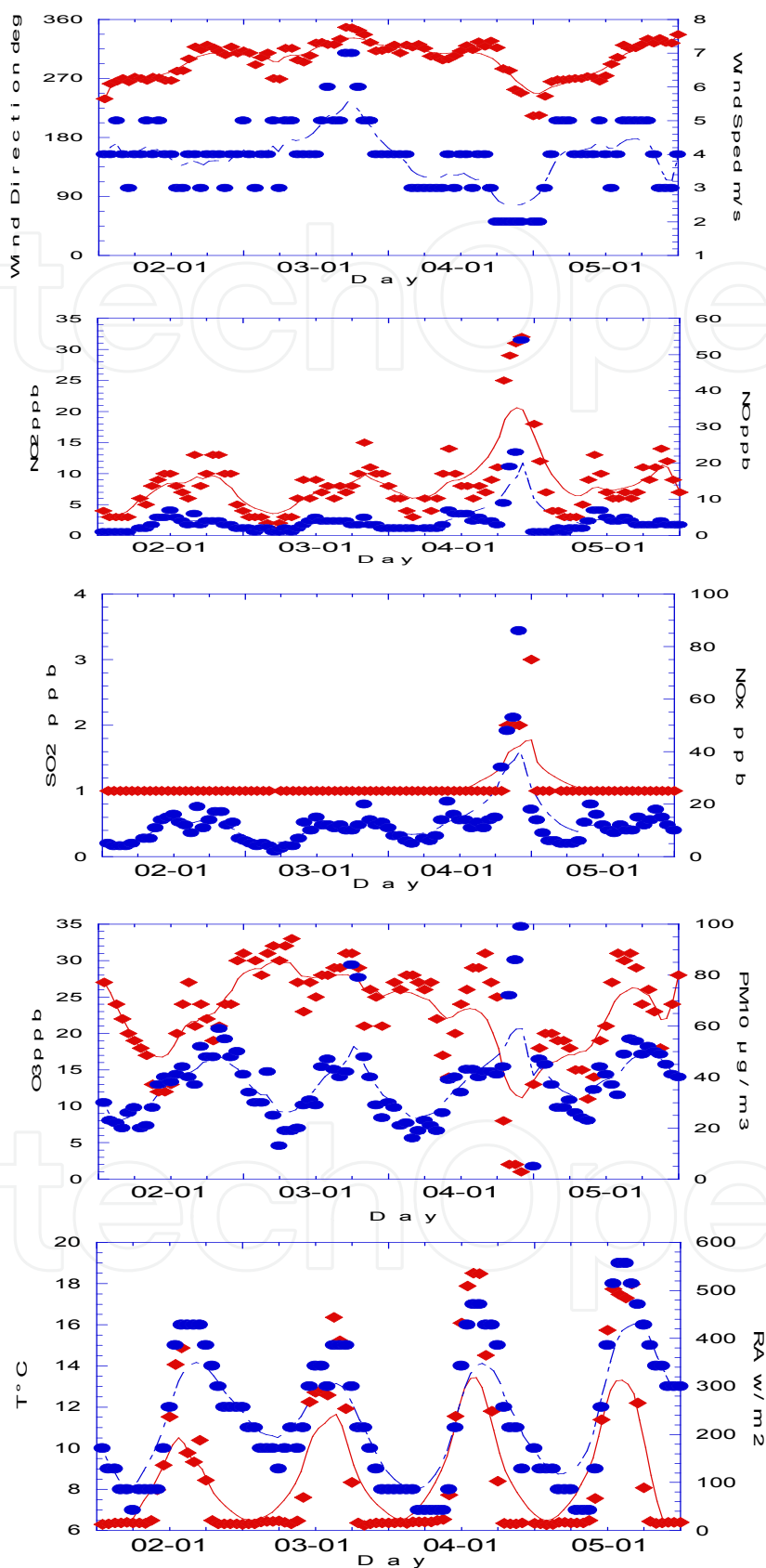


Fig. 9. Hourly averaged series of meteorological parameters and pollutants concentrations for the period ranging from 2 January 2007 to 5 January 2007.

speed at night. On the synoptic scale, we have chosen anticyclonic situation as well as weak conditions of pressure gradient. The activation of the breeze varies between 0800 and 1600 Local Time (LT). We have come across two types of sea breeze: the early morning sea breeze characterized by a setting varying from 0800 LT to 1000 LT. This breeze type represents 35% (5 cases) of breeze days. The afternoon sea breeze characterized by a launching ranging between 1200 LT and 1600 LT representing 65% (10 cases) of breeze days. It is important to note that the sun rise time (ranging from 0500 to 0529 LT during the campaign) and the diurnal evolution of solar radiation intensity (Fig.8) which controls the setting of sea breeze remains nearly constant. This result shows that Sousse sea breeze launching doesn't only depend on the land sea temperature contrast but also on the direction and speed of the synoptic wind. Fig.10 illustrates air masses trajectories which reach Sousse region during the campaign. We distinguish three cases. First, an afternoon sea breeze (Fig.10a) in which we notice the recirculation of air masses and the switching of wind direction.

Second, early morning sea breeze (Fig.10b) in which we remark the steady South Eastern wind direction coming from the sea. Third, non-sea breeze (Fig.10c) in which the wind direction is maintained offshore during the day.

5. Afternoon sea breeze cases

The temporal evolution of the direction and speed of wind relative to afternoon sea breezes are regrouped in Fig.11.

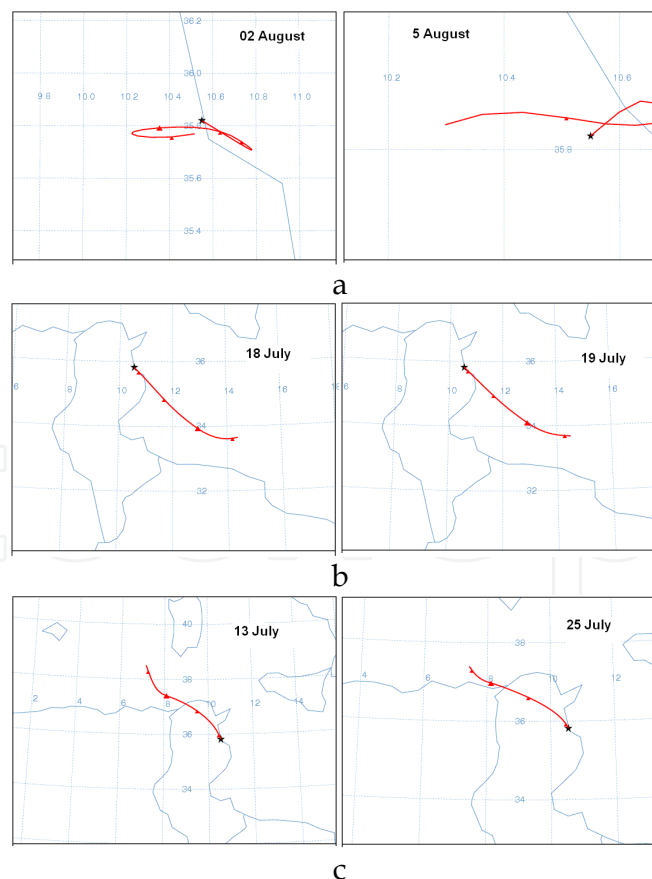


Fig. 10. Samples of surface air masses trajectories reaching Sousse region. (a) Afternoon sea breeze cases (b) Early morning sea breeze cases and (c) Non-sea breeze cases (NOAA ARL data).

The wind direction changes clockwise in a continuous, slow and progressive way starting from the North and the North West direction. The wind speed rises progressively during the period 00-1300 LT. It reaches its apogee between 5 and 7 m/s starting from 1300 LT until the end of the day (about 1900 LT). The maximum of wind speed is synchronized with the late change of the wind direction. The decrease of wind speed after the sun set points out to the disappearance of the sea breeze. This is due to the reduction of sea-land temperature contrast.

6. Early morning sea breeze cases

In order to visualize the early morning sea breeze variation, we have presented on Fig.12, the wind temporal evolution. In the morning (about 0900 LT), the wind direction switches about 30° South East vis-à-vis the synoptic wind direction (SSE). The wind progressively turns anticlockwise until it reaches the sea breeze direction. This rotation associated with a reinforcement of wind is carried out in such a way as the angle described is weak. We notice that the wind returns to its original sector (SSE) when the breeze vanishes. In order to distinguish the different effects which are due to two types of sea breeze, we have to compare the early morning wind direction and speed to the afternoon ones.

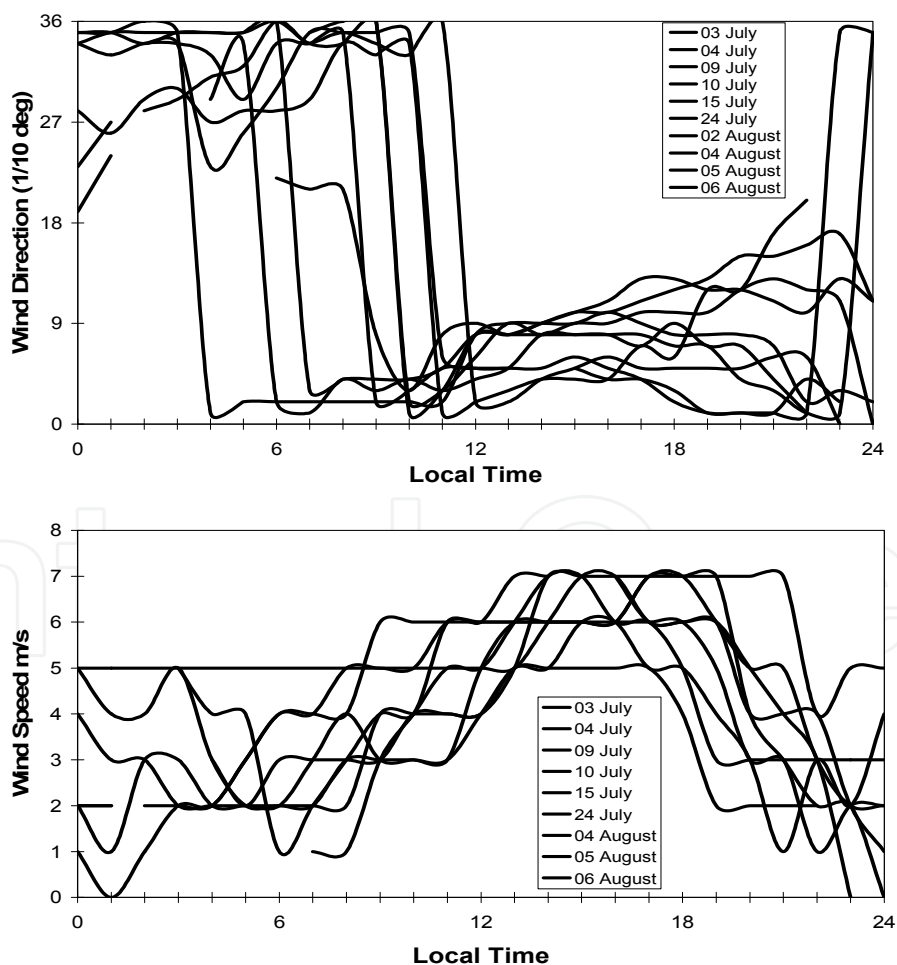


Fig. 11. Temporal variation of wind direction, and wind speed during the afternoon sea breeze days.

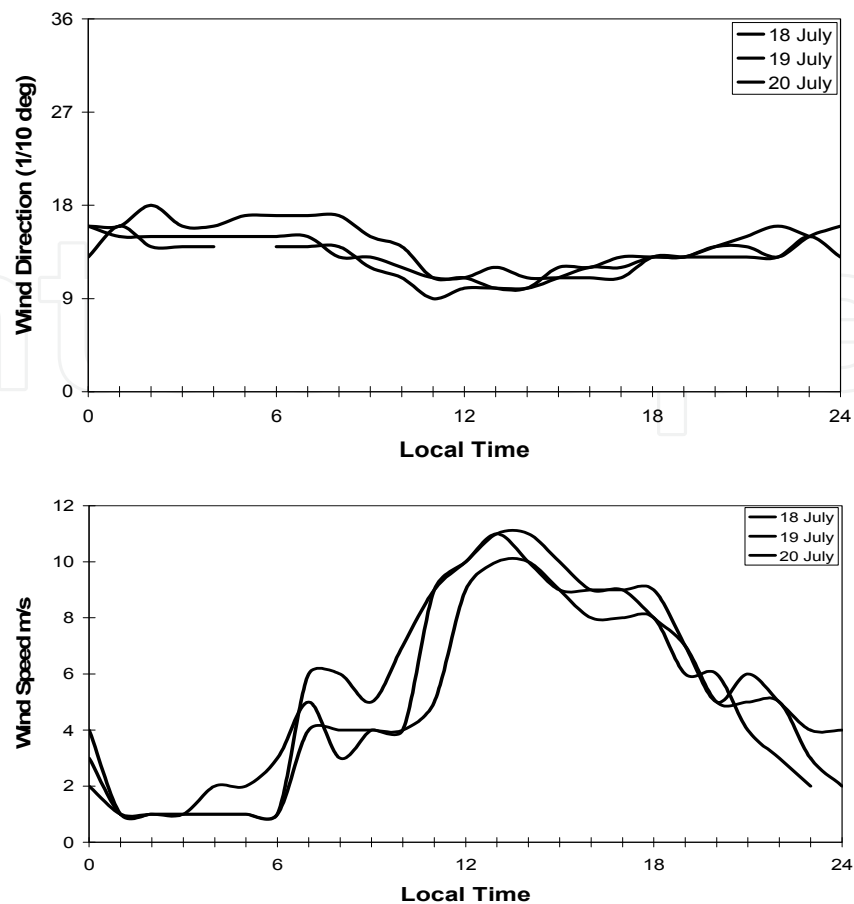


Fig. 12. Temporal variation of wind direction and wind speed, during the early morning sea breeze days.

These later curves are manifested in particular a limited late wind maximum (from 5 to 7 m/s). This wind is inferior to that of the morning sea breeze (11 m/s). This speed difference is attributed to the fact the late sea breeze is opposed by an offshore synoptic wind. Nevertheless, the onshore synoptic wind which characterizes the setting of the early morning sea breeze (about 0900 LT), triggers the wind direction change (anticlockwise) and its strengthening in the morning (11 m/s).

7. Evolution of pollutants concentration

In order to understand the photochemical potential coupled with the sea breeze dynamic circulations, we have carried out comparisons of ozone concentrations for early morning and late sea breeze cases vis-à-vis a non sea breeze case (Fig.13). According to these measurements, the region of Sousse is less polluted without breeze than with breeze. The temporal evolution of the ozone concentration related to late sea breeze days displays the ozone concentration reduction during the night which is due to the stability of air masses and to the decrease of the atmospheric boundary layer height. The polluted air is trapped in the upper layers (Millan et al., 2002). This thermal cover inhibits the upward and downward movements. Moreover, in the absence of UV radiation during the night, the ozone destruction is governed by the following active reaction:



Just after the sunrise, the land surface heating gives birth to the appearance of a mixture of hot and cold air near the land surface and to the progressive increase of the atmospheric boundary layer height. The upper layers ozone is thus trapped on the surface level (Millan et al., 2002). This mechanism contributes to the concentration increase of early morning ozone. Starting from the fresh emissions in the presence of UV radiation, the ozone production notably intervenes in the early morning ozone concentration. As far as the sea breeze effects are concerned, their influence on O₃ concentration evolution is significant in the afternoon. It reaches a maximum concentration of 70 ppb and maintains the nocturnal ozone level. Now let's focus on the evolution of the pollutants concentration on the surface related to morning breeze days. As regards, the temporal evolution of the pollutants concentration, the influence of sea breeze setting is significant. The presence of South-East sea breeze causes the transport of the electric power plant emissions (orientation South-East according to our measurement site). This explains the rapid rise in the concentration of O₃ up to 50 ppb and of SO₂ up to 10 ppb at 0900 LT. Besides, the ozone concentration evolution indicates the presence of a second ozone maximum in the afternoon. The origin of this maximum is attributed to the powerful solar radiation. Now, let's compare ozone and sulfur dioxide during the two different breeze cases (Fig.14). The ozone maximum relative to afternoon sea breeze switches vis-à-vis that of morning breezes. This shift is due to the late wind direction change and to the relatively moderate wind speed. Contrary to the afternoon breeze concentration, the early morning SO₂ concentration is three times higher. This shows the pollutant advection stemming from the electric power plant as soon as the wind direction becomes parallel to direction made by the power plant and measurement site. During the whole measurement campaign, the evolution of the solar radiation flux is of the same shape (Fig.15). Knowing that the powerful radiation is a dominant factor controlling the ozone production, the photochemical potential is not the unique factor responsible for the concentrations difference between the days of breeze. The late wind direction change, the relatively weak wind speed and the air masses recirculation highlight the afternoon ozone maximum. In fact, the ozone and its precursors are advected on the Mediterranean Sea via the nocturnal offshore synoptic wind just to return after the sea breeze setting. The offshore synoptic wind opposes the sea breeze penetration causing the formation of an accumulation over the Mediterranean Sea. The ozone is far from the NO fresh emissions and thus can be saved. The ozone destruction mechanism is 3 to 7 times less rapid on the sea than in the land [Nester, 1995]. Due to the sea breeze setting, the ozone and its precursors return to joint the fresh emissions of Sousse region. This mechanism favours the appearance of an ozone maximum in the afternoon. The relatively weak wind traps the pollutants and promotes the photochemical production of ozone in the presence of intense solar radiation.

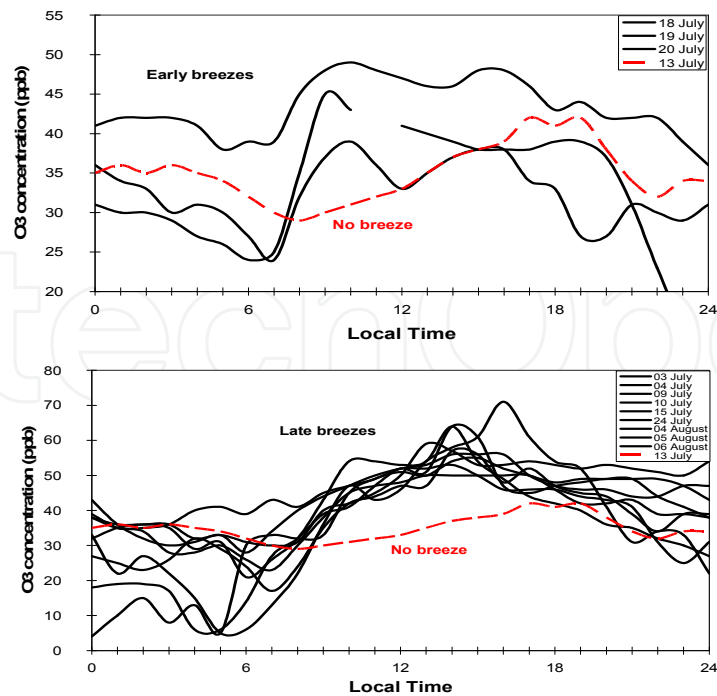


Fig.13. Comparison of the temporal evolution of pollutants concentration related to early morning sea breeze cases and the afternoon sea breeze cases vis-à-vis non-sea breeze cases

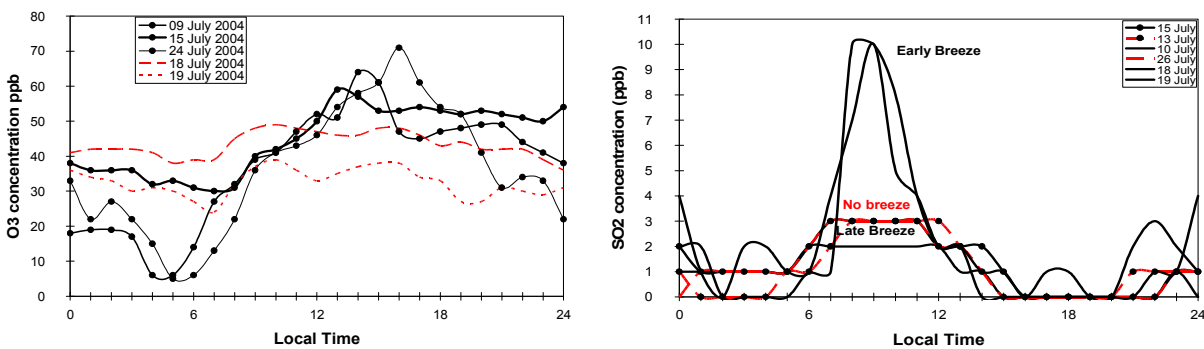


Fig. 14. Comparison of pollutants concentrations related to afternoon and early morning sea breezes. (Solid lines are afternoon sea breeze curve).

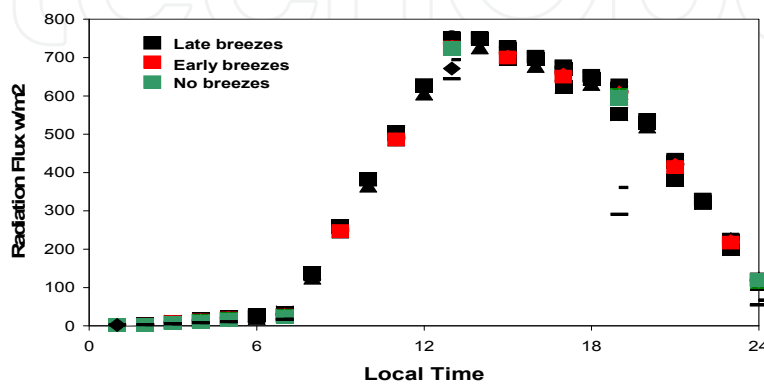


Fig. 15. Temporal variation of solar radiation flux at Sousse region (NOAA ARL data).

8. Conclusion

In this study we have shown that pollutants concentration behaviour depends on the influence of local, meso-scale and long ranges transport phenomenon.

During summer, Ozone concentration reaches its maximum values under the influence of land-sea breeze recirculation and powerful photochemical activity. Saharan dust outbreaks promote PM10 events over the Tunisian coastal sites. This phenomenon was shown to be linked to lower O₃ concentration due to the influence of the relatively clean Saharan air.

In winter season, the O₃ values are limited to lesser photochemical activity and vertical mixing. Primary pollutants peaks were much higher in winter than in summer which can be explained on the basis of lower ventilation in the winter and lower mixing.

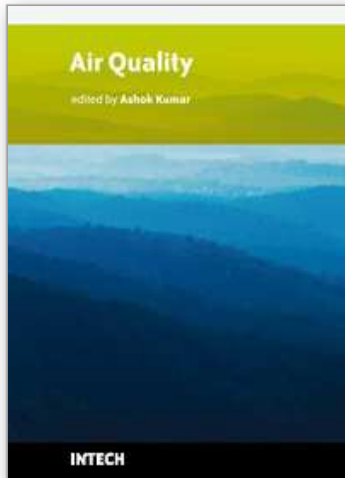
In this paper, we point out that the Saharan dust outbreaks are expected to be an important natural event influencing Tunisian regions and so needs to be more detailed. To improve our understanding about this event and related synoptic phenomena on the Tunisian air quality, we planned to intensify our measurement campaign and to identify pollution episodes which underline the Tunisian pollutants concentrations.

9. References

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Air pollution is about five decades or so old field and continues to be a global concern. Therefore, the governments around the world are involved in managing air quality in their countries for the welfare of their citizens. The management of air pollution involves understanding air pollution sources, monitoring of contaminants, modeling air quality, performing laboratory experiments, the use of satellite images for quantifying air quality levels, indoor air pollution, and elimination of contaminants through control. Research activities are being performed on every aspect of air pollution throughout the world, in order to respond to public concerns. The book is grouped in five different sections. Some topics are more detailed than others. The readers should be aware that multi-authored books have difficulty maintaining consistency. A reader will find, however, that each chapter is intellectually stimulating. Our goal was to provide current information and present a reasonable analysis of air quality data compiled by knowledgeable professionals in the field of air pollution.

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