Characterization of sea breezes and their effects on Air Pollution in the Tunisian Mediterranean region

[a]K . BOUCHLAGHEM, [b]B. NSOM, [b]N. LATTRACHE, [a]H. H. KACEM
[a]Unité de recherche « Energétique et Environnement » (03/ UR 13-06)
Institut Supérieur des Sciences Appliquées et de Technologie de Sousse
Cité Taffala, 4003 Sousse Ibn Khaldoun,
TUNISIA
[b]Laboratoire d'Ingénierie Mécanique et Electrique (LIME)
Institut Universitaire de Technologie de Brest.
BP 93169, Rue de Kergoat 29231 Brest Cedex 3
FRANCE

Abstract: - A measurement campaign of pollutants concentration has been undertaken during the two months of July-August 2004 in the Mediterranean region of Sousse (35° 48' N, 10° 38' E), Tunisia. The results display that O_3 and SO_2 episodes are connected to the sea breeze circulations. Two types of sea breeze characterize Sousse region. First, once a synoptic wind which blows at night and in the early morning is opposed to the sea breeze direction, the later can only be launched in the afternoon. The sea breeze circulation incites the formation of front breeze and the return flow on the summit of the atmospheric boundary layer. On the surface, we have shown the fast rising of O_3 concentration in the afternoon period (up to 70 ppb). Second, the night and morning winds share the same direction of the sea breeze. During these events, the wind deviates and gets stronger in the sense that the described angle is the weakest, and the sea breeze is launched in the morning. No breeze front and no backward wind flow were recorded. In the light of these conditions, SO_2 morning concentration (toward 0900 LT) is multiplied three times compared to the non breeze cases. At the same time, the ozone concentration rises reaching 50 ppb.

Key-Words: - Mediterranean Sea, Sea breeze, Recirculation, Ozone, Air pollution.

1 Introduction

The transfer from the liquid element (the sea) to the solid one (the land) engenderers 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 This hot continental air rises up, and then is superseded by a colder air coming from the sea; it is the sea breeze.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 [15].

Many experimental and numerical studies have shown the impact of breeze circulations on the evolution of pollutant concentrations [3] [16][2][5][6][8]. 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 [7][11][17] 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 [14] 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 [9] 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.

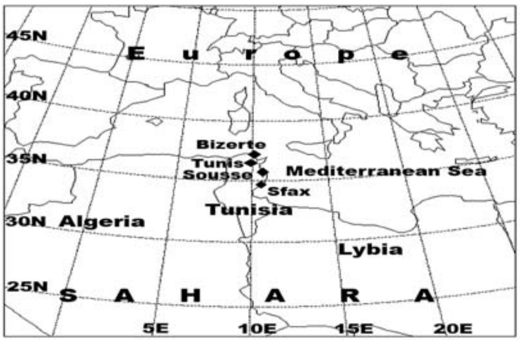


Fig.1: North Africa map displaying Tunisia and Sousse region location (35° 48’ N, 10° 38’ E).

A 3D model of air pollution TAPM (The Air Pollution Model) [10] 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, [4] 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), [18] 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, [12] 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.

The present study focuses the characterization of sea breezes and their effects on the air quality at the Eastern Tunisian Coast.

2 Experimental design and site description

Sousse region (35° 48’ N, 10° 38’ E), is in the East centre of the Tunisian country (Fig.1). The climate of this region has a particularity which is due to the absence of relief, and the opening on the Mediterranean Sea. Under the influence of its location in the Tunisian coasts, our region is distinguished by a hot and dry summer, and cold and humid winter. The main emissions are linked to bricks and cement factories and essentially to the electric power plant in the South East of the region.

We have made a campaign to measure the concentrations of the main atmospheric pollutants (NO, NO_2, O_3 and SO_2) in the period ranging from 1 July to 6 August 2004 using the mobile laboratory of National Agency of the Environmental Protection (NAEP) (Fig.2). The chosen site was the hospital Farhat Hached situated in the town centre of Sousse (500 m from the sea). 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.

$NO_2 + \text{UV radiation} \longrightarrow NO + O$ and

$O + O_2 \longrightarrow O_3$

Then it is consumed by NO

$NO + O_3 \longrightarrow NO_2 + O_2$

Fig.2: Mobile laboratory for air pollutants measurements and Acquisition systems of data.

The high levels of ozone give birth to the formation of the Smog phenomena and the green house effect. The oxidization of NOx and SO_2 in the atmosphere stimulates the formation of aerosols (e.g. H_2SO_4,

HNO_3…) which play a crucial role in the production of acid rain and the damage caused to the environment [1].

3. Experimental results

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°). The increase of wind speed during a time period is too long, followed by a decrease in wind 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.3 illustrates air masses trajectories which reach Sousse region during the campaign. We distinguish three cases. First, an afternoon sea breeze (Fig.3a) in which we notice the recirculation of air masses and the switching of wind direction.
Second, early morning sea breeze (Fig.3b) in which we remark the steady South Eastern wind direction coming from the sea. Third, non-sea breeze (Fig.3c) in which the wind direction is maintained offshore during the day.

3.1 Afternoon sea breeze cases

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

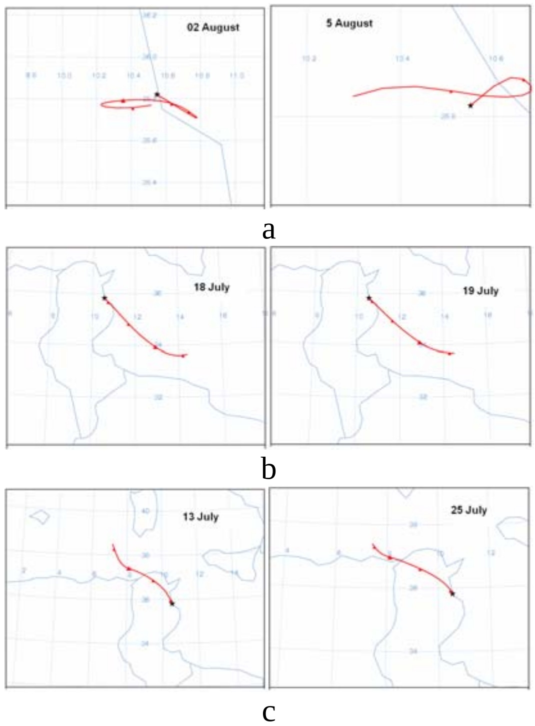


Fig.3: Samples of surface air masses trajectories reaching Sousse region. (a) Afternoon sea breeze cases (b) Early morning sea breeze cases and (c) Non-sea breeze cases (NOAA ARL data).

in the Fig.4. 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.

3.2 Early morning sea breeze cases

In order to visualize the early morning sea breeze variation, we have presented on Fig.5, 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.

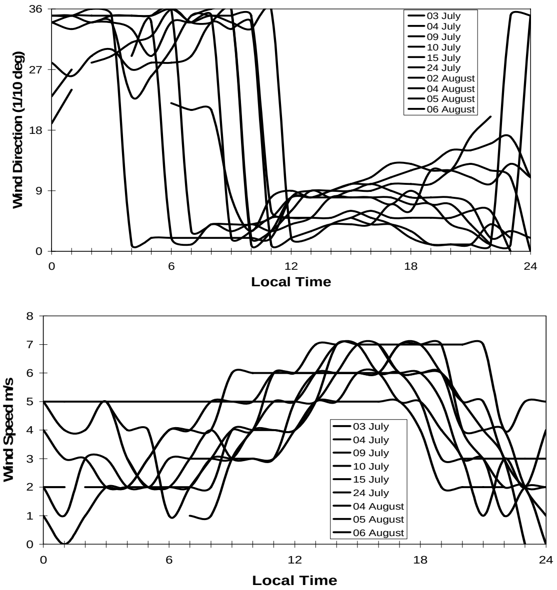


Fig.4: Temporal variation of wind direction, and wind speed during the afternoon sea breeze days.

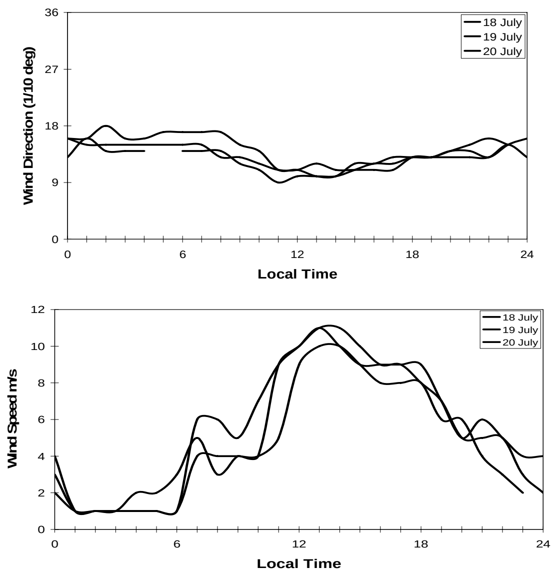


Fig.5: Temporal variation of wind direction and wind speed, during the early morning sea breeze days.

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).

3.3 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.6). 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 [12]. 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: $NO + O_3 \longrightarrow NO_2 + O_2$.

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 [12]. 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 O_3 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 O_3 up to 50 ppb and of SO_2 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.7). 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 SO_2 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.

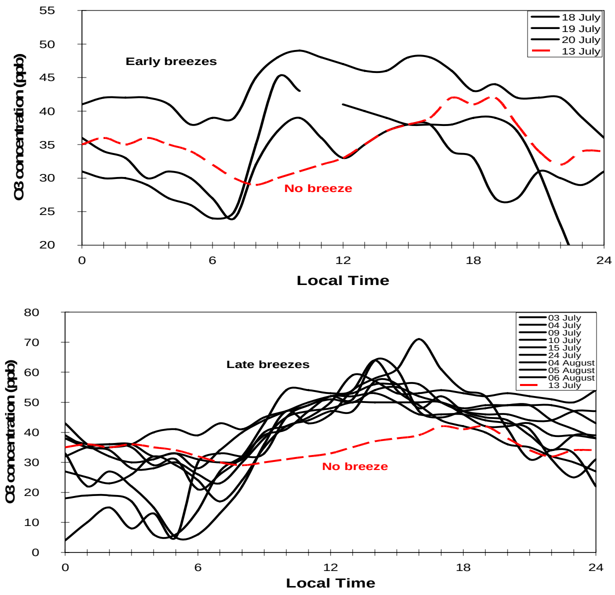


Fig.6: Comparison of the temporal evolution of pollutants concentration related to early morning sea breeze cases and the afternoon sea breeze cases vis-à-vis non-sea breeze cases

During the whole measurement campaign, the evolution of the solar radiation flux is of the same shape (Fig.8). 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 [13]. 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.

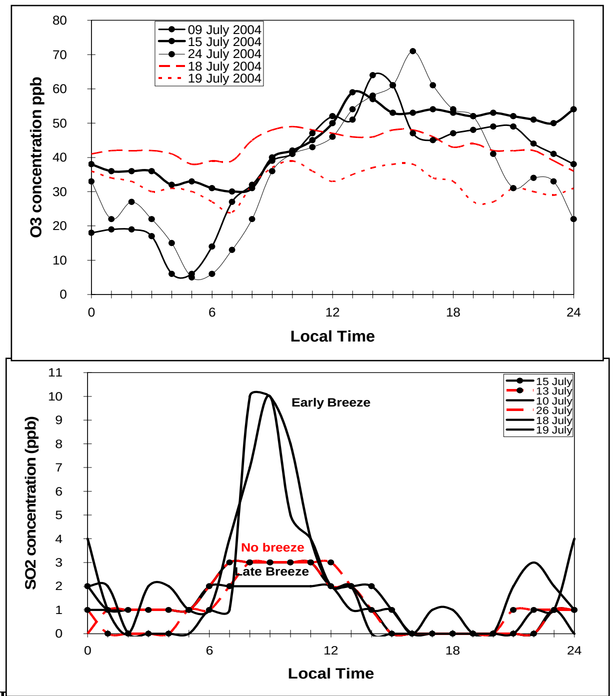


Fig.7: Comparison of pollutants concentrations related to afternoon and early morning sea breezes. (Solid lines are afternoon sea breeze curve).

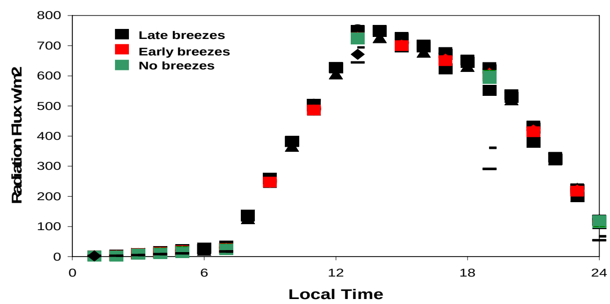


Fig.8: Temporal variation of solar radiation flux at Sousse region (NOAA ARL data).

4 Typical studies of sea breeze cases

With reference to the data of local meteorological stations, to NOAA data and to air masses trajectories, we have treated as an example the days of July 2004 (4, 15, 18 and 19 July) during which the sea breeze flow is clear. The two days 4 and 15 July 2004 represent afternoon sea breeze cases. The 18 and 19 July 2004 are marked by a morning sea breeze. With the assistance of NOAA data, we have studied the late sea breeze vertical evolution. We have represented the vertical speed fields at 1200 UTC (LT= UTC + 1h) but at different heights (100m, 800m, 1500m and 3000m) (Fig. 9). It is important to note the appearance of two types of cells (A and B) close to Sousse coast (A is an upward vertical movement and B is a downward vertical movement). At 100m altitude, the A upward

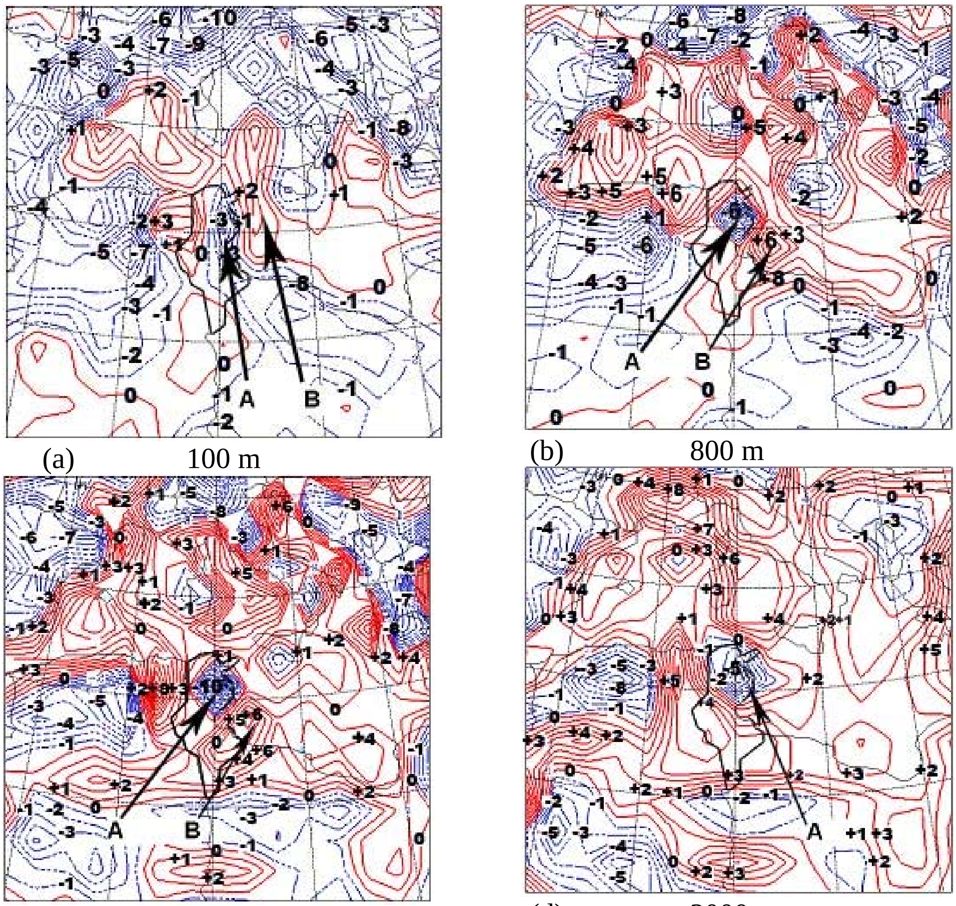


Fig. 9: Spatial evolution of vertical wind component (mb/h) over North Africa and the Mediterranean sea on 4 July 2004 at 1200 UTC. These fields are obtained at (a) 100 m altitude, (b) 800 m altitude, (c) 1500 m altitude and (d) 3000 m altitude. A: upward motion and B: downward motion. (NOAA ARL data).

vertical movement (-3 mb/h) covers the entire Tunisian coast (Fig. 9a). The spread of A cell reaches about 80 km onshore. Over the Mediterranean Sea, the downward movement of B cell is evident. At 800m altitude, the intensity of A cell rises reaching -6 mb/h and is followed by subsidence symmetrical movements over the sea (+6 mb/h, B cell). From 800m to 1500m altitude, the vertical speed intensity accentuates (from -6 mb/h to -10 mb/h) always in the presence of A and B cells. Higher than 1500m altitude which represents the height of the atmospheric boundary layer over Sousse region (NOAA data) the B downward movement disappears and the A cell speed weakens (from -10 mb/h to -5 mb/h). According to this figure, air masses circulation may be described as following: At 1200 UTC, the land is heated up more than the sea. Over the land surface, the heat wave propagates in the surface boundary layer giving birth to upward currents. The rising air is superseded by a colder air blowing from the sea. The return wind direction witnesses a weak deviation according to surface sea breeze. The upward air movements which are the result of the sea breeze launching penetrate inland. The offshore synoptic wind mixes with the rising hot air to form the front of the breeze. This is represented in Fig. 9 by intensified upward winds in the front through the compression of wind current. The formation of such a breeze is often associated with convective clouds parallel to the coast [15]. Fig. 10 indicates the spatial and temporal evolution on the surface of the vertical wind component in North Africa and the Mediterranean Sea for the same day. The surface wind fields are obtained at 00 UTC, 0600 UTC, 1200 UTC and 1800 UTC. At 00 and 0600 UTC the Tunisian territory and the Mediterranean Sea are dominated by downward air movements. Starting from 1200 UTC we witness the appearance of upward movements near the Tunisian coasts. The wind spread reaches about 80 km inland. The subsidence over the Mediterranean Sea is of paramount significance. The reduction of the surface heat flux just before the sun set (1800 UTC) causes the abating of the sea breeze cell.

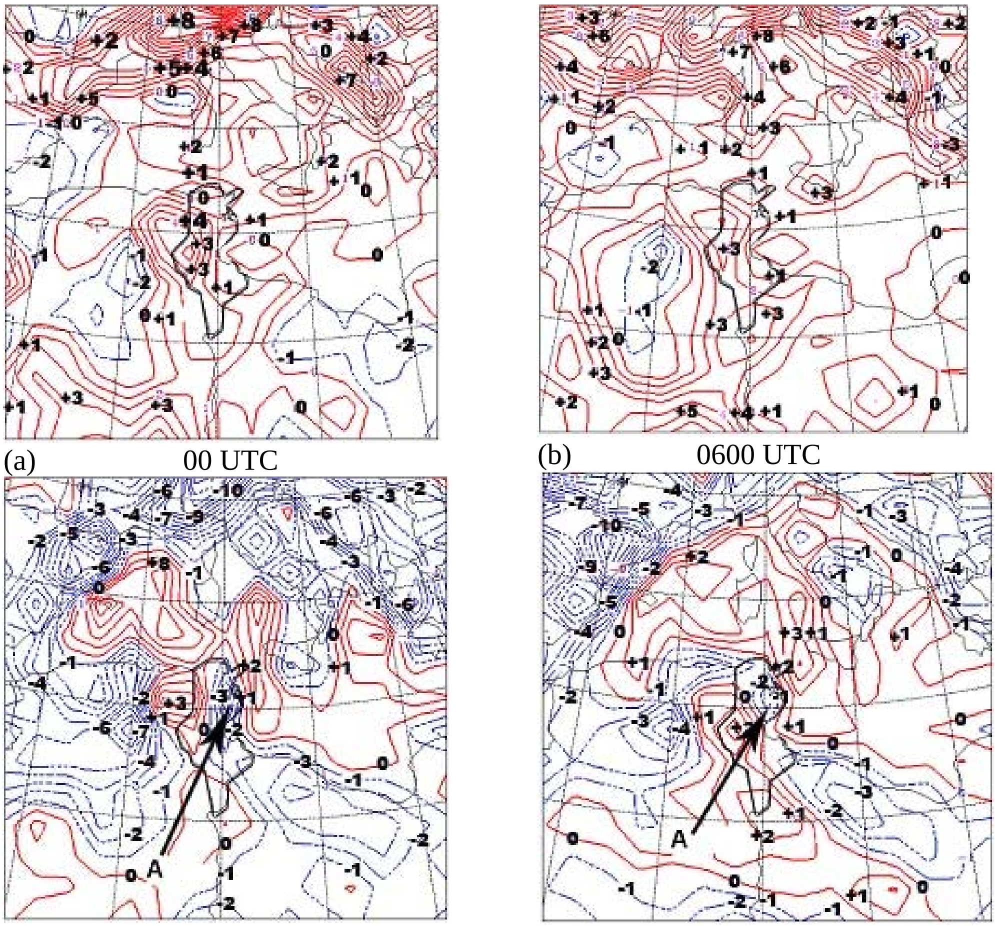
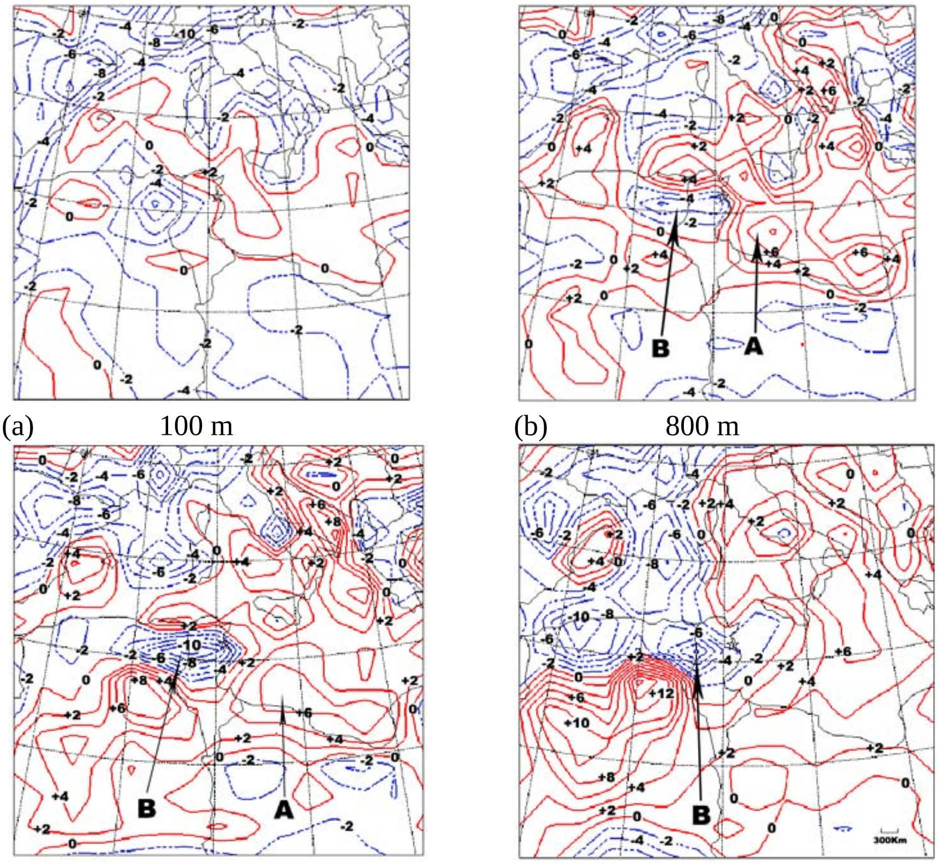


Fig. 10: Spatial and temporal evolution of vertical wind component (mb/h) over North Africa and the Mediterranean sea on 4 July 2004. These surface fields are obtained at (a) 00 UTC, (b) 0600 UTC, (c) 1200 UTC and (d) 1800 UTC. A: upward motion.

Fig. 11 represents the midday vertical wind component evolution of early morning sea breeze at different altitudes (100m, 800m, 1500m and 3000m). At 800m altitude two wind cells (A and B) appear. A cell indicates downward air movements (w = +6 mb/h at 800m) and B cell shows upward movements (w = -4mb/h). We have compared the vertical component of Fig. 11 with the horizontal wind field at each level represented in Fig. 12. We can show that the flow in cell A is transferred to cell B. In reality, this is the cold and humid marine flow which is advected from the Mediterranean to the North of Tunisia and to Algeria where the Atlas Mountains are responsible for the upward movements observed at this level. From 800m to 1500m altitude (Fig. 11b, c) the wind speed in cell B is accentuated (from w= -4 mb/h to w= -10 mb/h). At 3000 m we remark the disappearance of cell A and the persistence of cell B.

Basing ourselves on these data we can put forward the following explanations: On the surface, the onshore synoptic wind accentuated by the sea breeze component propagates from the Mediterranean Sea (cell A) to the Tellian Atlas (cell B) where it is ejected at 3000 m altitude. At this level, upward motion becomes horizontal with clockwise rotation and a slow descent at the synoptic scale [3]. We have compared on Fig. 13 the afternoon sea breeze evolution of 15 July 2004 vis-à-vis that of the morning sea breeze of 18 July 2004. During the afternoon sea breeze, the offshore wind direction dominates Sousse region until 1200 LT (Fig. 13a). The wind flow changes clockwise when the breeze is set. At the peak of the atmospheric boundary layer (1500 m), the flow becomes offshore (Fig. 13a). The continental synoptic wind merges with the upward hot air in the front breeze to trigger the return flow which is



(a) 100 m (b) 800 m

(c) 1500 m (c) 3000 m

Fig. 11: Vertical wind component (mb/h) over the Mediterranean sea and North Africa on 18 July 2004 at 1200 UTC. Four levels are presented (a) 1000 mb (100m height), (b) 925 mb (800m height), (c) 850 mb (1500m height) and (d) 700 mb (3000m height). A: downward motion and B: upward motion.

accompanied by a subsidence on the Mediterranean Sea. Fig. 13c and 13e respectively illustrate the humidity and wind direction profiles relative to the afternoon sea breeze. At this stage, it is of paramount importance to note the wind direction change starting the atmospheric boundary layer summit (1500 m). The relative humidity evolution with the altitude denotes two different phases: In the lower layers (up to 1500 m) the humidity rises from 39% to 54%. The cold and humid air of the sea breeze propagates throughout these layers (Fig. 13c). In the upper layers, the relative humidity profile decreases from 54% to 40%. The hot and dry inland synoptic wind dominates these atmospheric layers. At the top of the atmospheric boundary layer, the two flows interact to produce the divergent return flow and a convergent subsidence on the Mediterranean Sea. Nevertheless, in the morning breeze case, the onshore synoptic wind (Fig. 13b) inhibits the air upward rising. The vertical winds currents are weak due to the setting aside of current flow. The humidity vertical profile is homogenous (Fig. 13d). These conditions are not suitable for sea breeze front formation.

5 Air pollutants concentration

We have pointed out above that the pollution episode in the region of Sousse is principally governed by the intensity of the pollutants emission sources, by the UV radiation photochemical potential and the meteorological conditions promoting the pollutants transport. The solar radiation flux is nearly constant during the whole campaign (Fig. 8). The early morning sea breeze temperature maximum of 18 July 2004 is 31.2°C which is actually higher than that of 15 July afternoon sea breeze (27.5°C) (National meteorological data). These two elements have a significant influence on the photochemical potential of the ozone production. Contrary, the O_3 maximum in the afternoon sea breeze (59 ppb) (Fig. 14c) far out weighs that of the early morning sea breeze (49 ppb) (Fig. 14a). This result confirms the dominance

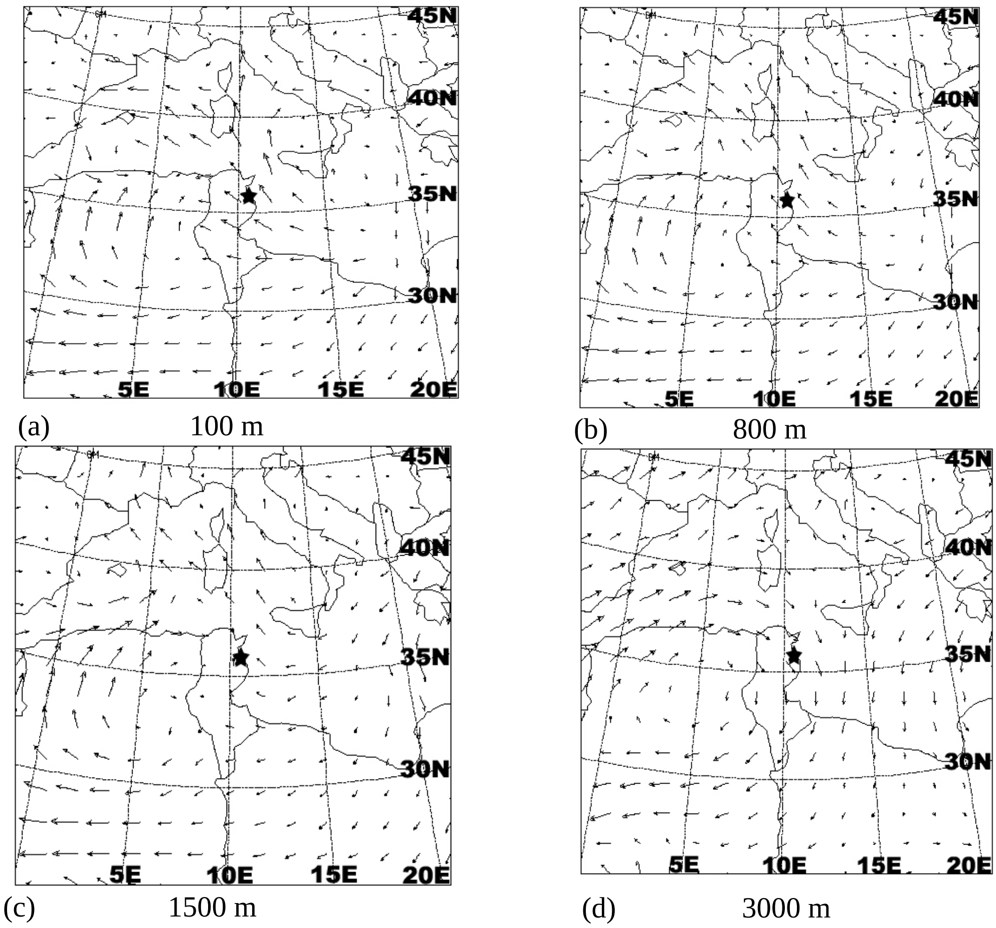
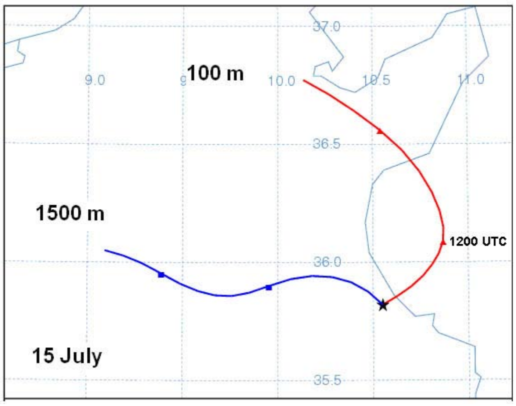


Fig. 12: Horizontal wind flow observed on 18 July 2004 at different levels (a) 1000 mb (100m height), (b) 925 mb (800m height), (c) 850 mb (1500m height) and (d) 700 mb (3000m height). Sousse city is indicated by a star on the figure. (NOAA ARL data).

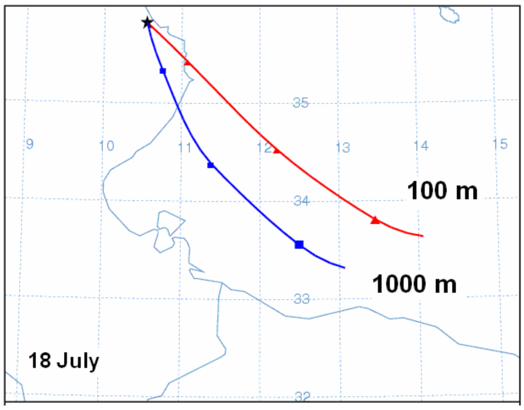
of dynamic effect over the photochemical ones during the campaign. Fig. 14 represents the temporal evolution of the pollutants concentration (O_3 and SO_2) during the two breeze cases. The South East direction of the early morning sea breeze has a significant effect (Fig. 14a, b). This direction allows the pollution transport from the electric power plant to the measurement site. This phenomenon helps the appearance of an ozone maximum (49 ppb) and SO_2 (10 ppb) about 0900 LT. The second ozone peak can be explained by the intense photochemical production in the afternoon.

The temporal development of the ozone concentration on the surface associated with the late sea breeze day has been studied in the same figure. The ozone concentration reduction during the night is displayed by the curve. So the active reaction of destruction governs the ozone depletion. As soon as the sun rises, a combination of hot and cold air next to land surface and of a gradual increase of the atmospheric boundary layer height come into existence due to the heating of the land surface. Thus, the upper reservoir layer of ozone is firmly trapped on the level of the surface which leads to an increase of concentration of early morning ozone [12]. The production of ozone interferes remarkable in the early morning ozone concentration beginning with the newly obtained emissions in the presence of UV radiation.

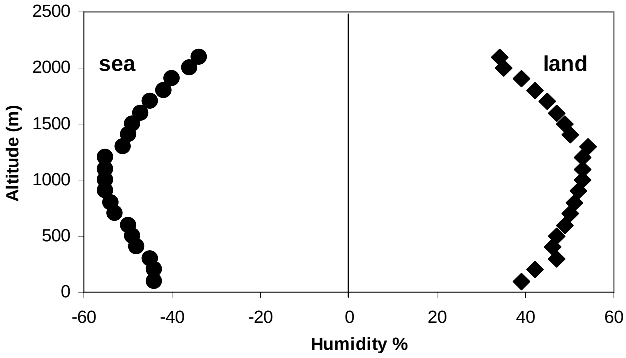
It's crucial to note that in the afternoon, the influence of the sea breeze effects on O_3 concentration is so important since it attains a maximum concentration of 60 ppb and helps maintain the nocturnal level of ozone. Both the photochemical production and the pollution recirculation in the afternoon sea breeze case help bring a concentration of ozone in the region of Sousse. The transport of O_3 and its precursors are promoted by the offshore synoptic wind over the Mediterranean Sea given that the weak wind which precedes the breeze launching contributes to their accumulation in the Mediterranean. The concentration of O_3 is preserved since there are no NO fresh emission.



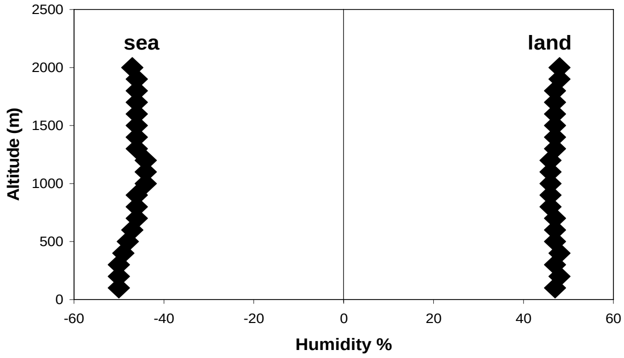
(a)



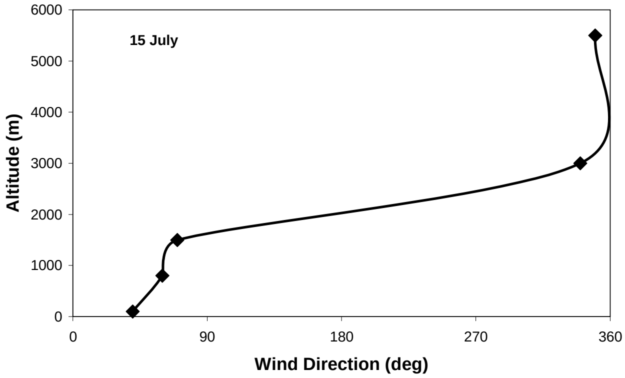
(b)



(c)



(d)



(e)

Fig. 13: (a) Air masses trajectories reaching Sousse at 1500 LT, on 15 July 2004 (100m and 1500m height), (b) air masses trajectories reaching Sousse on 18 July 2004 (100m and 1000m height), (c) relative humidity profile of 15 July 2004 respectively in the land and over the sea, (d) relative humidity profile of 18 July 2004 respectively in the land and over the sea, (e) wind direction profile at Sousse on 15 July 2004 (NOAA ARL data).

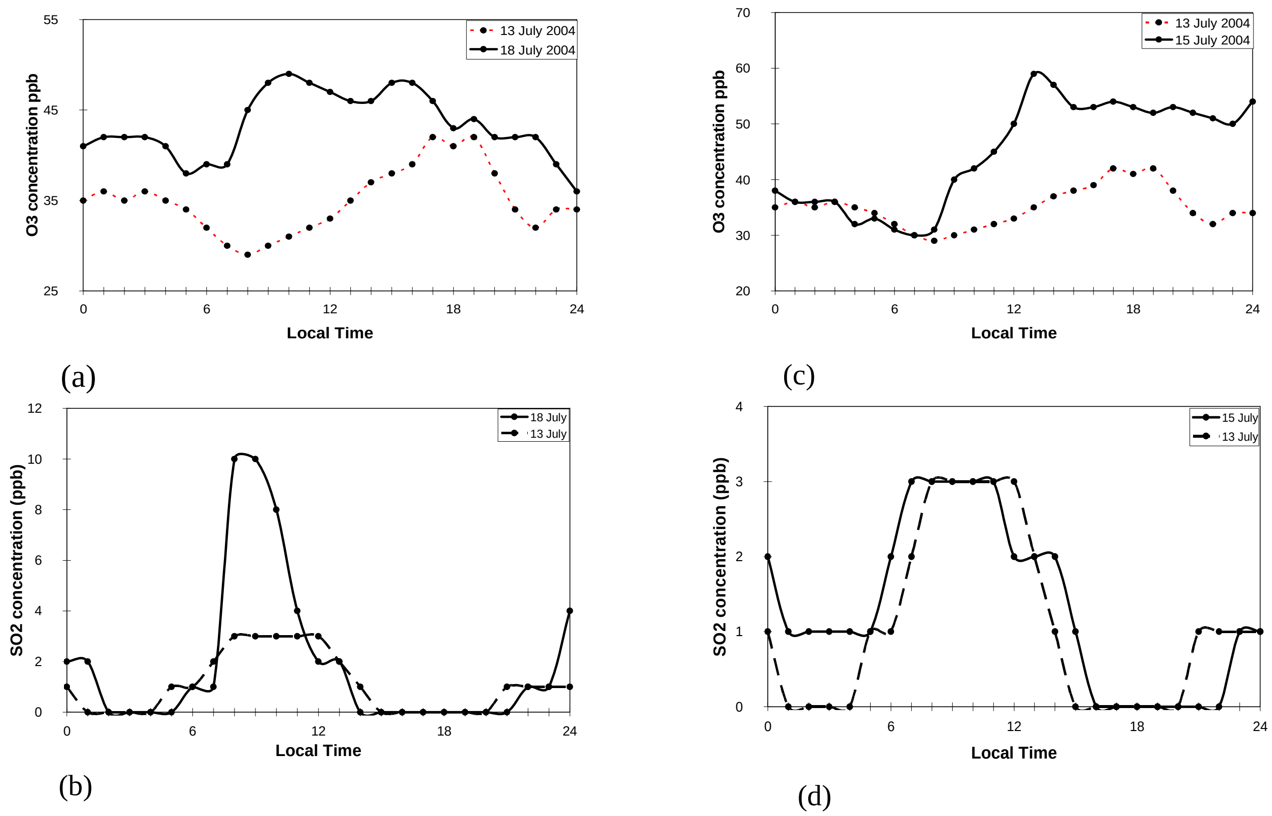


Fig. 14: Comparison of SO_2 and O_3 concentration for early morning sea breeze case (18 July 2004) vis-à-vis non sea breeze case (13 July 2004) (a, b) and afternoon sea breeze case (15 July 2004) vis-à-vis non sea breeze case (13 July 2004) (c, d).

The transport of O_3 and its precursors to the measurement site are promoted by the setting of the afternoon sea breeze. The UV solar radiation and the weak wind are the primary causes of the fast ozone increase at 1200 LT (From 48 ppb to 59 ppb, just in an hour period) as well as the maintaining of the level of concentration in the afternoon (Fig. 14c). Nevertheless, the SO_2 concentration is similar to that in a non sea breeze case (Fig. 14d). Once again, we point out to the fact that the SO_2 increase depends only on the South East wind direction which favorites the pollutants transport from the electric power plant. The comparison of breeze cases to one day of non-breeze shows that the breeze launching is linked to the appearance of photochemical pollution episodes.

6 Conclusions

In the light of this study, we remark that the O_3 and SO_2 accumulation is quite significant in Sousse region. The concentration of their pollutants is tightly related to the breeze circulations. On the one hand, the setting of the early morning sea breeze encourages the formation of an O_3 morning maximum. The South East breeze direction transports the pollutants emissions from the electric power plant of the region to the measurement site. This phenomenon engenders the appearance of an ozone maximum towards 0900LT. At the same time, the launching of the morning breeze favorites the accumulation of an SO_2 maximum. On the other hand, the afternoon sea breeze setting promotes the fast and late rising of ozone concentration. In much the same way, it instigates the transport of ozone and its precursors to the measurement site after its residence on the Mediterranean Sea. The aged ozone is added to the fresh emission of the region.

In this study, we point out that Sousse region is characterized by sea breeze events which are responsible for air quality conditioning.

References:

[1] Avami A., Farahmandpour B. Analysis of environmental emissions and greenhouse gases in Islamic Republic of Iran , WSEAS Transactions on Environment and Development, 4(4), 2008, 303-312.

[2] Baumgardner D., Raga G.B., Grutter M., Lammel G., Evolution of anthropogenic aerosols in the coastal town of Salina Cruz,

Mexico: Part I particle dynamics and land–sea interactions, Science of the Total Environment, 367(1), 2006, 288-301.

[3] Bouchlaghem K., Ben Mansour F., Elouragini S., Impact of a sea breeze event on air pollution at the Eastern Tunisian coast, Atmospheric Research, 86, 2007, 162-172.

[4] Ding A., Wang T., Zhao M., Wang T., Li Z., Simulation of sea land breezes and a discussion of their implications on the transport of air pollution during a multi-day ozone episode in the Pearl River Delta of China, Atmospheric Environment, 38, 2004, 6737-6750.

[5] Evtyugina M.G., Pio T.N.C., Costa C.S., Photochemical pollution under sea breeze conditions, during summer, at the Portuguese West Coast, Atmospheric Environment, 40(33), 2006, 6277-6293.

[6] Flocas H.A., Assimakopoulos V.D., Helmis C.G., An experimental study of aerosol distribution over a Mediterranean urban area, Science of The Total Environment, 367(2-3), 2006, 872-887.

[7] Gualtieri, G., Calastrini, F., Busillo, C. & Pirovano, G., The RAMS-CALGRID modelling system to assess seasonal ozone pollution: a five-month application over Tuscany region, WSEAS Transactions on Environment and Development, 3(11), 2007, 196-205.

[8] Lim J-H., Sabin L.D., Schiff K.C., Stolzenbach K.D., Concentration, size distribution, and dry deposition rate of particle-associated metals in the Los Angeles region, Atmospheric Environment, 40, 2006, 7810-7823.

[9] Liu K.Y., Wang Z., Hsiao L.F., A modeling of a sea breeze and its impact on ozone distribution in northern Taiwan, Environmental Modelling and Software, 17, 2002, 21-27.

[10] Luhar A.K., Hurley P.J., Application of a prognostic model TAPM to sea breeze flows, surface concentrations and fumigating plumes, Environmental Modelling and Software, 19, 2004, 591-601.

[11] Ma Y., Lyons T.J., Recirculation of coastal urban air pollution under a synoptic scale thermal through in Perth, Western Australia, Atmospheric Environment, 37, 2003, 443-454.

[12] Millan M.M., Sanz M.J., Salvador R., Mantilla E., Atmospheric dynamics and ozone cycles related to nitrogen deposition in the Western Mediterranean, Environmental Pollution, 118, 2002, 167-186.

[13] Nair P.R., Chand D., Lal S., Modh K.S, Naja M., Parameswaran K., Ravindran S., Venkataramani S., Temporal variations in surface ozone at Thumba (8.6°N, 77°E) – a tropical coastal site in India, Atmospheric Environment, 36, 2002, 603-610.

[14] Nester K., Influence of sea breeze flows on air pollution over the ATTIKA PENINSULA, Atmospheric Environment, 29(24), 1995, 3655-3670.

[15] Simpson J.E., “Sea breeze and local wind”, Cambridge University, 1994.

[16] Srinivas C.V., Venkatesan R., Bagavath Singh A., Sensitivity of mesoscale simulations of land–sea breeze to boundary layer turbulence parameterization, Atmospheric Environment, 41(12), 2007, 2534-2548.

[17] Vongmahadlek C. & Satayopas B., Applicability of RAMS for a simulation to provide inputs to an air quality model: Modeling evaluation and sensitivity test, WSEAS Transactions on Environment and Development , 3(8), 2007, 129-138.

[18] Ziomas I.C., The MEDiterranean CAmpagn of PHOtochemical Tracers-TRAnsport and Chemical Evolution. MEDCAPHOT-TRACE An Outline, Atmospheric Environment, 32(12), 1998, 2045-2053.