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Impact of a sea breeze event on geochemical behavior of aerosols at a Mediterranean coast (Northern Tunisia)

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Abstract – The aim of this study is to identify the impact of a sea-land breeze circulation on the ventilation of air masses over the Mediterranean Tunisian coast (Boukornine area) during the summer period. Our results show the Mediterranean Sea has an important effect on the chemical characteristics of atmospheric aerosols by the advection of particles from the sea to the coastal site. Indeed, the daytime sea breeze as well the nighttime land breeze limits the ventilation of air masses by the redistribution of aerosols. Besides, it was found that higher concentrations of sodium, chlorine and sulfur over the examined area are associated with the sea-land breeze recirculation while the crustal constituents stay practically constant with some fluctuations due to local effect. The contribution of sea-breeze in Boukornine area was more important than those recorded in other sites in Tunisia. This study proves the high influence of topography which increases the effect of sea-breeze.

Keywords: Sea breeze, aerosols, coast, Tunis

1. Introduction

In the coastal regions, the differential heating of land and sea surface is significant. The sea breeze blows from the sea towards the land. The sea surface temperature changes very little but the land becomes hotter and convection currents distribute heat in the surface boundary layer. The resulting pressure difference is responsible for the onset of the sea breeze. The leading edge of the sea breeze front is represented by a convergence line which is limited by the onshore cold marine layer and the offshore hot inland flow.

Different aspects of sea/land breeze circulation have been the subject of investigation for several years, and it has been extensively studied at different coastal regions of the world through field experiments and numerical simulations (Melas et al, 1995; Liu et al, 2002). One of the most important practical applications of the study of sea/land breeze circulation is its effect on the transport of photochemical pollution (Wang et al, 2001; Luhar et al 2004; Puygrenier et al, 2005). The sea breeze has a significant moderating influence at the temperatures in coastal areas. It has been well established that associated with sea breeze circulation a Thermal Internal Boundary Layer (TIBL) develops over land. The formation of TIBL is mainly through turbulence process (Ramana et al, 2004). The development of TIBL is associated with onshore flow has great significance in the dispersion of air particles. During daytime, air particles are transported in land along with the penetration of sea breeze (Uno et al, 1984; Kurita et al, 1986). Pollutants emitted near the shore can be confined for a long period in the closed sea breeze circulation under stagnation conditions (Lyons et al, 1995; Ozoe et al, 1983).

Against this backdrop, the aim of this study is to determine the effect of the Mediterranean Sea and to associate mesoscale dynamics on the transport and distribution of particles in the northern Tunisian coast. To achieve this goal, the temporal distribution of aerosols concentrations is crucial.

2. Material and methods

2.1. Site description

The study region (Boukornine) is situated on the North African coast along the Mediterranean (latitude 36°44'; longitude 10°19') and surrounded in the west by Boukornine Mountains (Fig.1). The climate of

Boukornine is strongly influenced by the sea breeze with mean monthly relative humidity in the range 58%-83% and temperatures comprised between 11°C and 28°C.

2.2. Air sampling and analysis

Samples of atmospheric particle matter were collected in June 2007 by bulk filtration (volume 3l/mn) with sampling time 24h at Boukornine area. The collected aerosols were analyzed by wavelength dispersive X-ray fluorescence at LISA (Laboratoire Interuniversitaire des Systèmes Atmosphériques, France). The analysis included eleven elements: Calcium (Ca), iron (Fe), Aluminium (Al), Silicon (Si), Titanium (Ti), Magnesium (Mg), Manganese (Mn), potassium (K), sodium (Na), Chlorine (Cl) and Sulphur (S) (Quisefit et al, 1998). The weather maps were downloaded from the NOAA ARL model observations, exhibiting sequences of the development and spread of air masses during the study period (National Oceanic and Atmospheric Administration www.arl.noaa.gov).

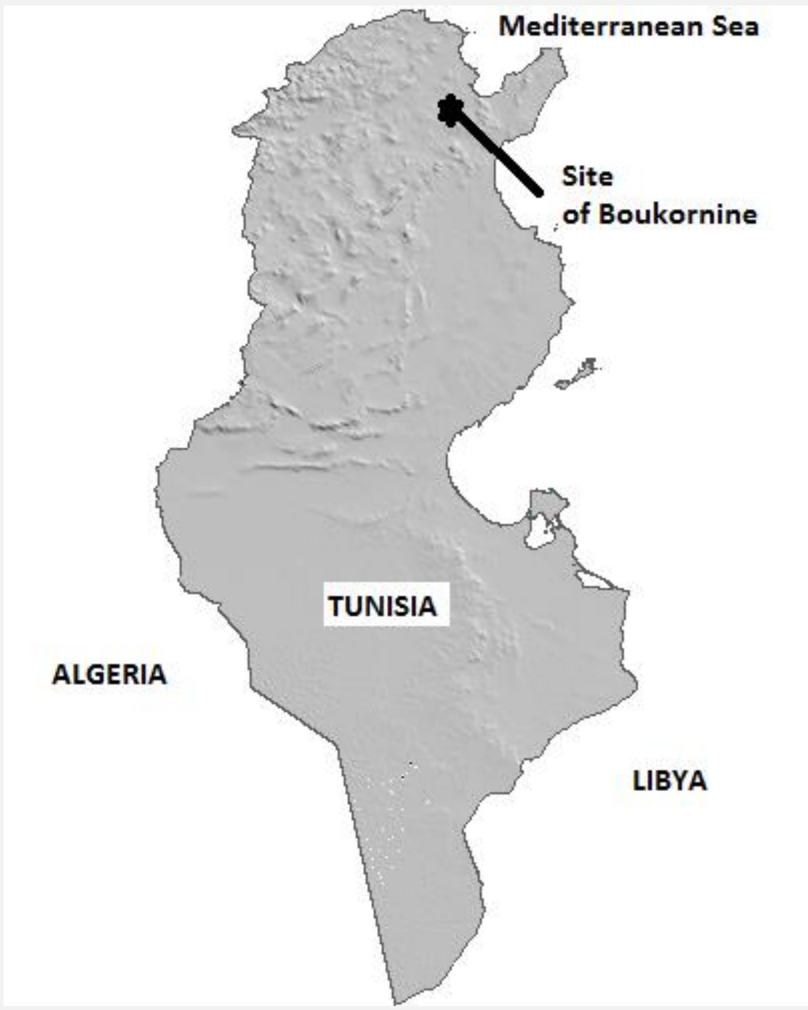

Figure 1. Location of the sampling site

3. Results and discussion

3.1. Temporal evolution of the aerosol constituents

Chemical analysis of the aerosol matter sampled at the study area during June 2007 showed that the concentrations of Si, Ca, Al, Fe, Mg, Mn, Ti, K, Na, S and Cl are characterized by a marked variability in time. Average concentrations of various elements which are measured in this study are given in Fig.2. The mean concentrations of the analyzed chemical elements were shown to vary between 0.4 and 30.8µg/m^3. Ambient air concentrations are varying depending on meteorological conditions, thus resulting in high standard deviations which were determined. Boukornine air contained both crustal and maritime elements, the maximum was obtained for Si (30.8µg/m^3) followed by Ca (29.3 µg/m^3), Al (11.2 µg/m^3), Na (5.9

μg/m^3) and Cl (5.6 μg/m^3). Higher crustal concentrations were explained by the contribution of the Sahara in terms of loading aerosols with particulate matter in period of sirocco (Ellouz et al, 2013). Higher values of S, Cl and Na appeared particularly on 19 June 2007 during the summer campaign due to the effect of sea-breeze recirculation particles. Thus, we focused in this work on identifying the impact of a sea-land breeze circulation on the ventilation of air masses over the Mediterranean Tunisian coast (Boukornine area)
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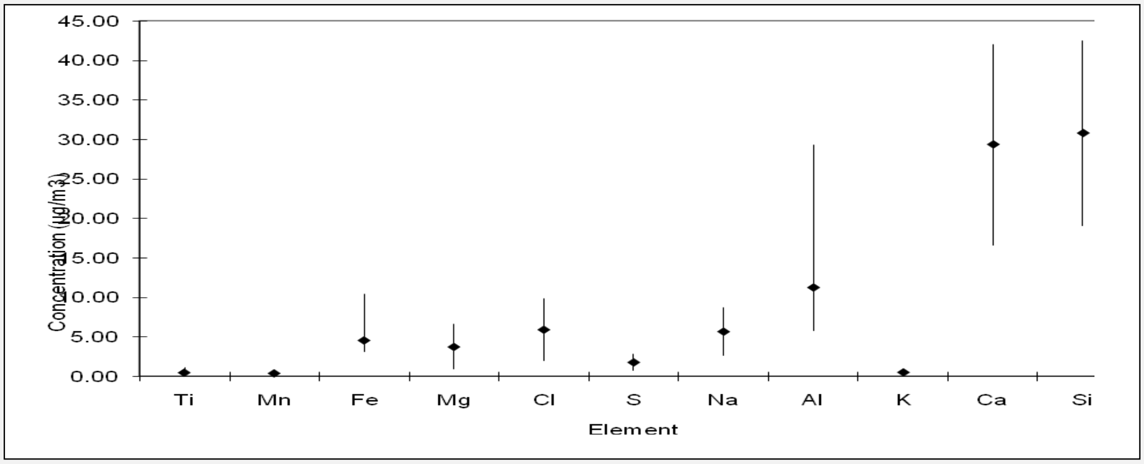


Figure 2. Average concentrations of Si, Ca, Al, Fe, Mg, Ti, Mn, K, Na, Cl and S in air samples collected in Boukornine area in June 2007

3.2. Sea breeze identification

The case of 19 June was selected because it was a sunny day with solar radiation reaching up than 700 w/m^2 , the land temperature ranged from 24 to 32°C, which led to maximum sea land temperature differences of about 6°C (Fig.3).

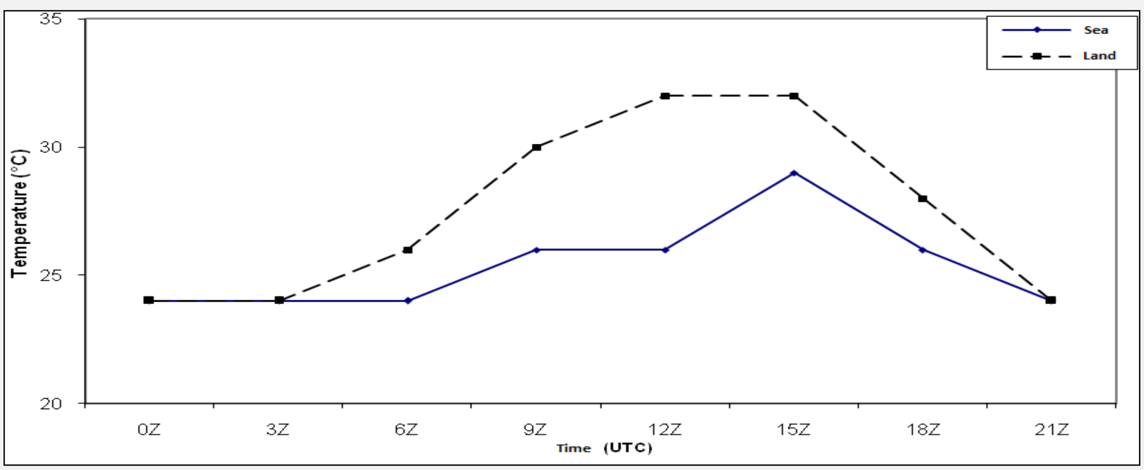
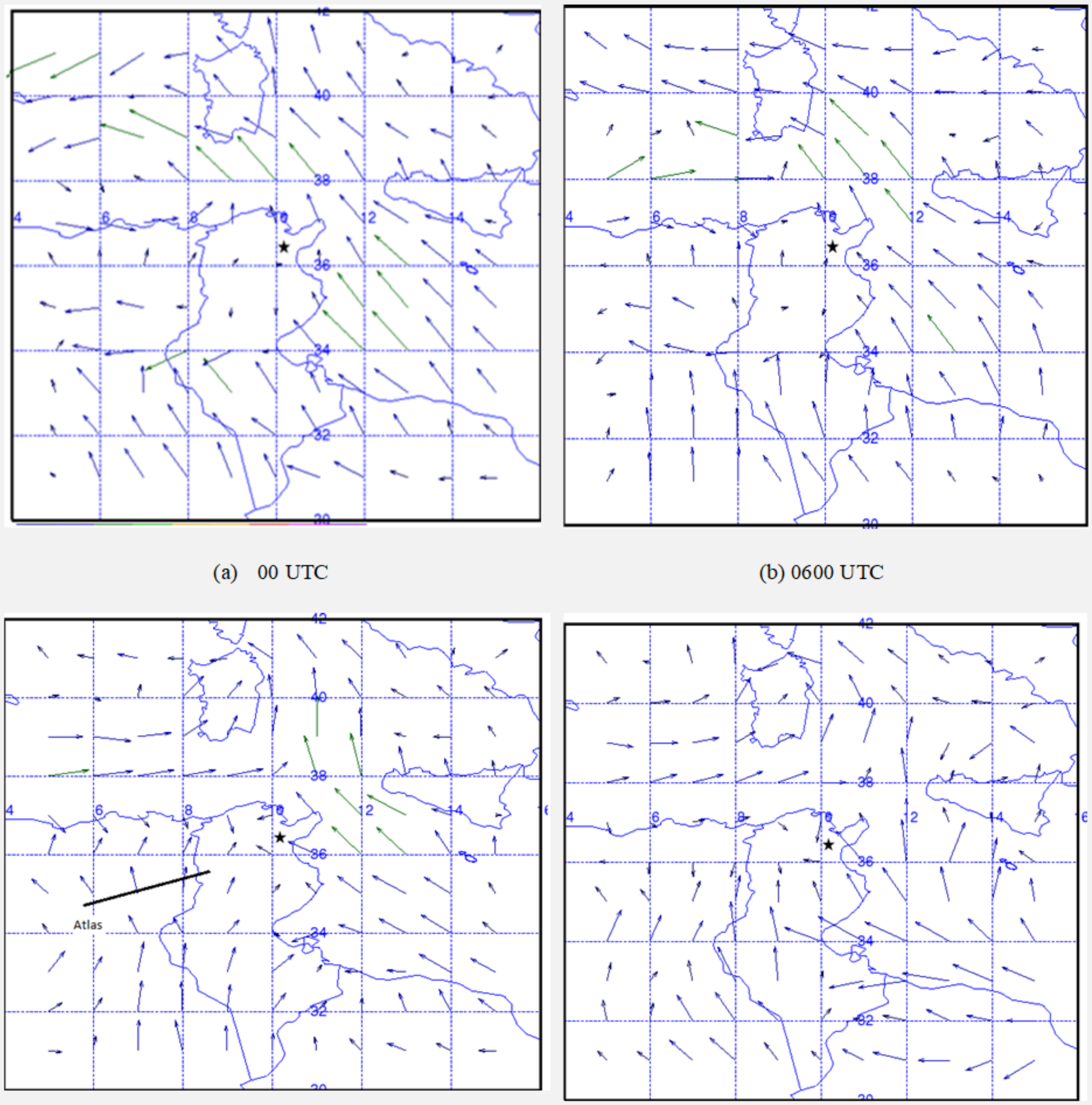


Figure 3. Diurnal variation of temperature over land and sea in 19 June 2007 in Boukornine area

In addition, the surface maps of wind vectors during this day were also typical of a sea-breeze episode (perpendicular at the coast) (Fig.4). Indeed, synoptic wind vectors kept generally the same direction from the Mediterranean Sea at the east to Algerian land at the west. During this day, the wind vectors at height 1500 m showed a backward wind flow (Fig.5): flow return of breeze.

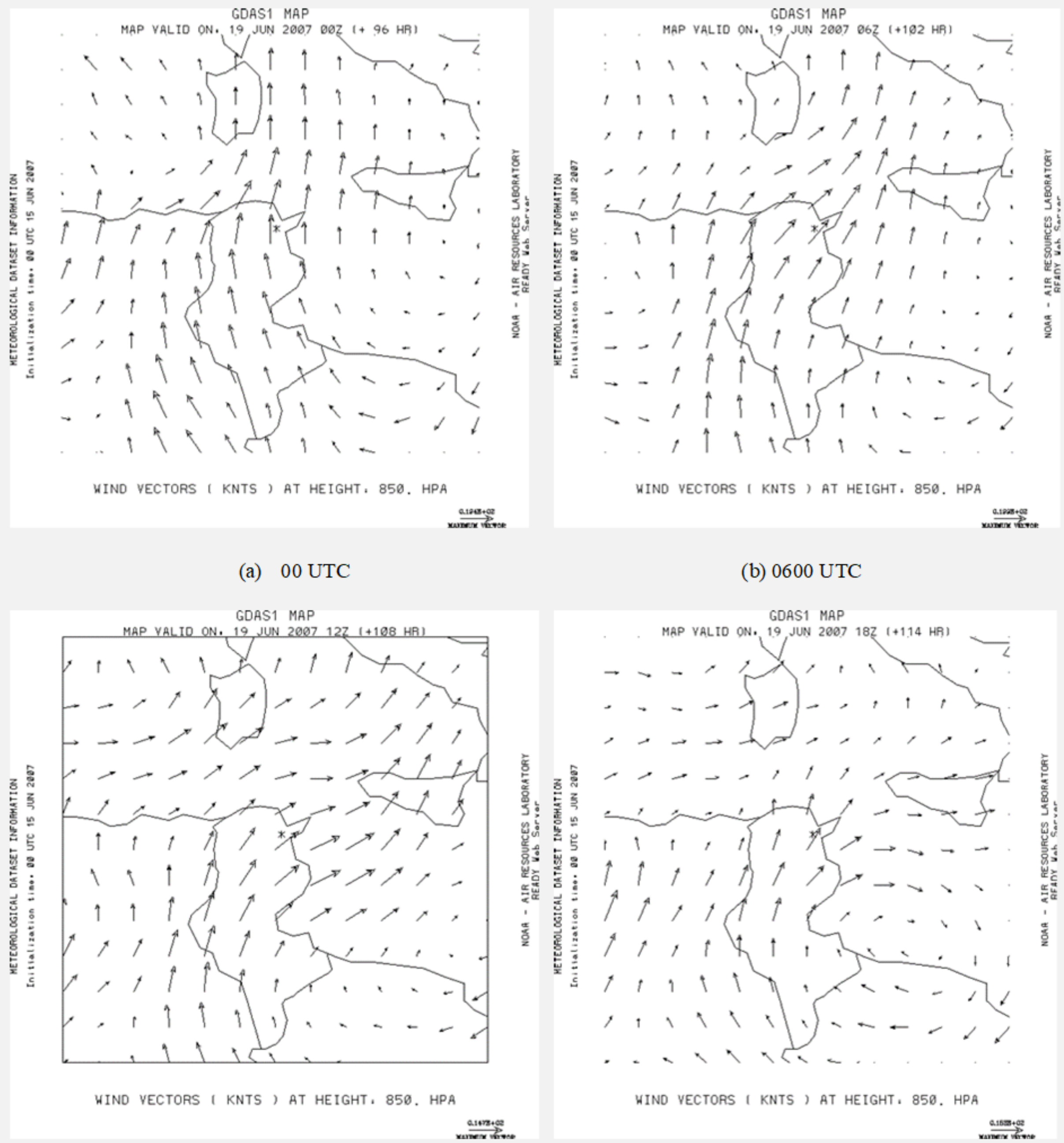


(a) 00 UTC (b) 0600 UTC

(c) 1200 UTC (d) 1800 UTC

Figure 4. Spatial and temporal evolution of the synoptic winds fields over Tunisia and the Mediterranean basin on 19 June 2007.

These surface fields were obtained at (a) 00 UTC, (b) 0600 UTC, (c) 1200 UTC and (d) 1800 UTC. Boukornine area is indicated by a star on the figure.



(a) 00 UTC (b) 0600 UTC

(C) 1200 UTC (d) 1800 UTC

Figure 5. Spatial and temporal evolution of the winds fields over Tunisia and the Mediterranean basin on 19 June 2007 at height 850 hpa.

These fields were obtained at (a) 00 UTC, (b) 0600 UTC, (c) 1200 UTC and (d) 1800 UTC: flow return of breeze.

The analyzed vertical wind component (Fig. 6) at 1200 ULT for four levels (100m, 800m, 1500m and 3000 m height) clearly showed two remarkable cells (A and B) particularly at the height of 1500m. Cell A indicates downward wind vectors (w=+9 mb/h) while cell B indicates upward wind vectors (w=-12 mb/h). This downward air flow at cell A was transferred to cell B. As a result, relatively cold and humid air flow was advected at low altitudes from the Mediterranean Sea to Tunisia and Algeria where the Atlas Mountains seem to be responsible for the recorded upward air flow. Bouchlaghem et al (2007) demonstrated that over the Atlas Mountains, wind vectors moved in clockwise direction from east to west and became perpendicular to those mountains.

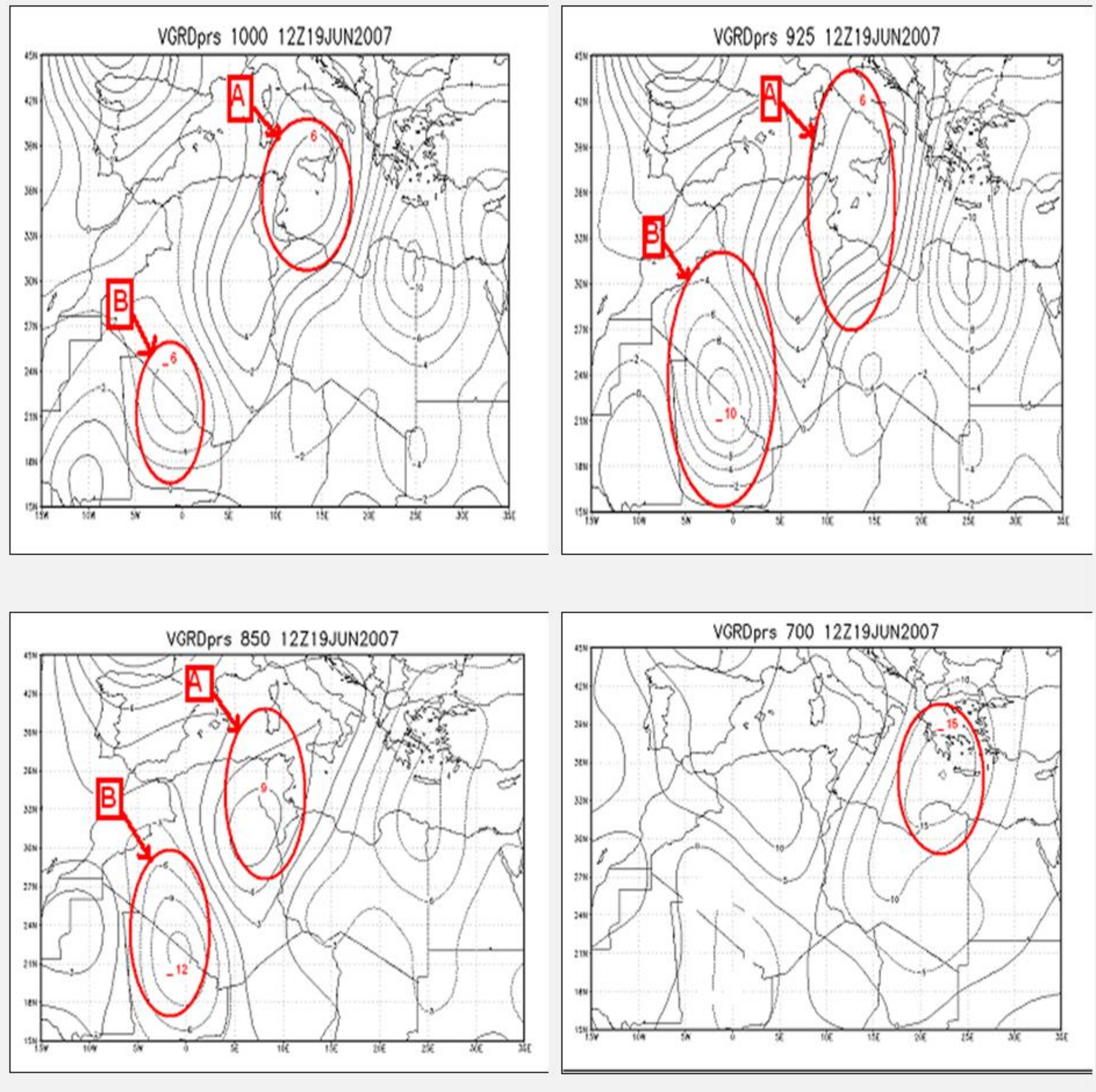


Figure 6. Vertical wind component (m/s) over North Africa and the Mediterranean Sea on 19 June 2007 at 1200 UTC for four levels (100, 800, 1500 and 3000m height).
A: Downward motion and B: Upward motion.

According to Bouchlaghem et al, (2007), horizontal wind vector intensification may be the sum of synoptic and breeze components just during day time. Synoptic wind speed may be estimated from night-time values just before and after the sea breeze episode. Figure 7 shows that the synoptic winds speed was approximately 2m/s and the breeze contribution was about 3 to 5 m/s. This value was compared to the other areas in Tunisia, in the south (Sfax, Azri et al, 2007) and the centre of the country; (Sousse, Bouchlaghem et al, 2007)), where the sea breeze contribution ranged between 2 and 3 m/s. We note that the contribution of sea-breeze in Boukornine area was more important. This proves the high influence of topography which increases the effect of sea-breeze.

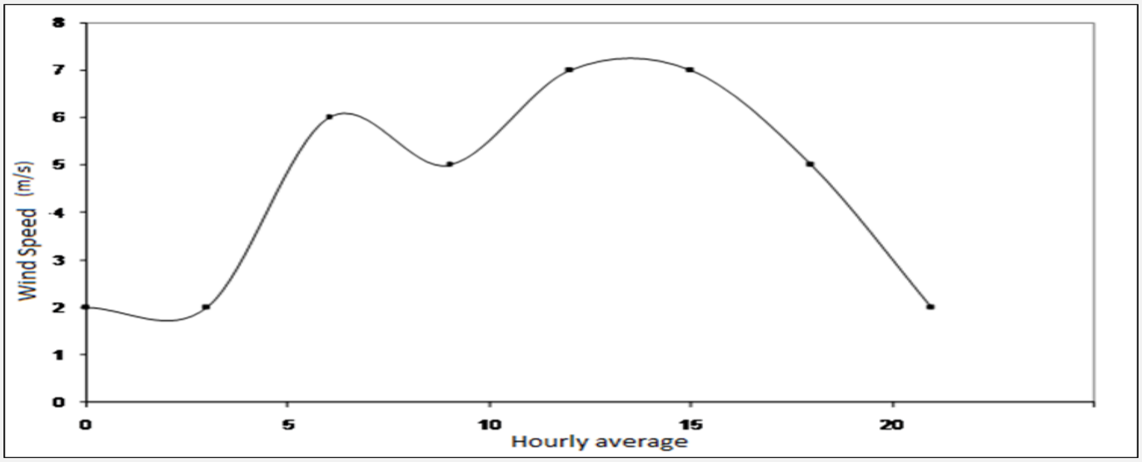


Figure 7. Diurnal variation of wind speed for 19 June 2007

This excess of wind speed could reinforce the natural ventilation of the Tunisian coastal region which trends to attenuate the daily variation of aerosols concentrations as seen before in figure 8 and 9.
The concentrations of Na, Cl and S were multiplied by 2 while the crustal components stay virtually invariable with some fluctuations due to local effect.

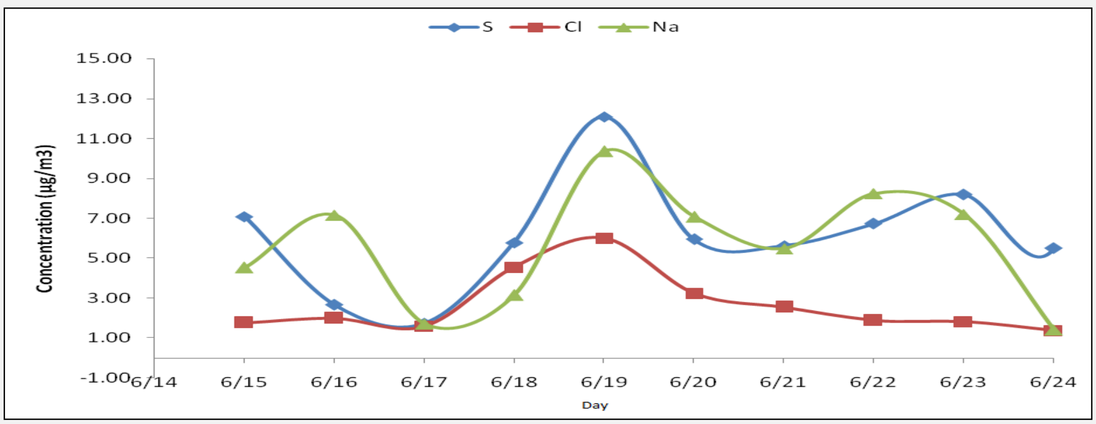


Figure 8. Diurnal concentrations of Cl, Na and S in June 2007

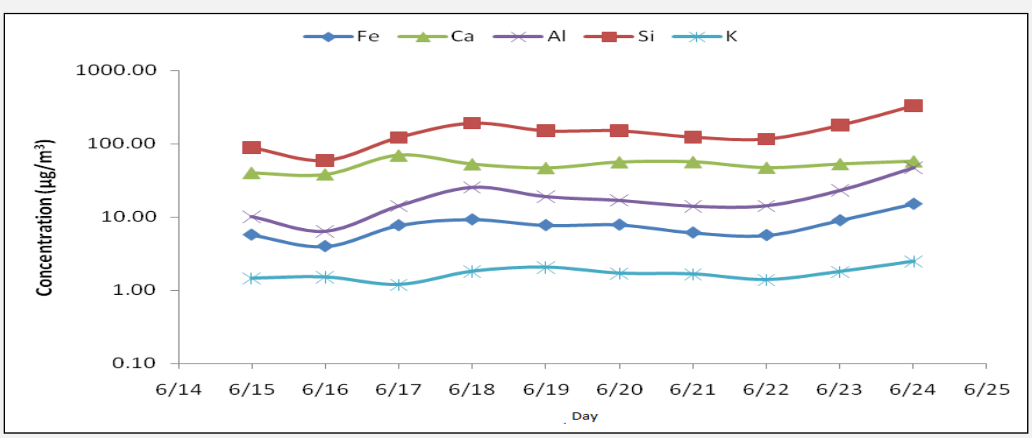


Figure 9. Diurnal concentrations of Ca, Fe, K, Al and Si in June 2007

4. Conclusion

We have presented in this study the results of a field experiment conducted in the Mediterranean region of Boukornine, (Nothern coast of Tunisia). Our results showed a relationship between aerosols constituents and sea-breeze circulations. Higher concentrations of Na, Cl and S over the study area are associated with the sea-land breeze circulation. This may be explained by the quiet important natural ventilation of the mountains region. The comparison between sea-breeze contribution at coastal area of Boukornine and those measured at the centre and the south of the country indicated that more important contribution was recorded in our study area due to topography effect.

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