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Evaluation of Long Range Transport of Ozone in Western Mediterranean Basin

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ABSTRACT

This study investigates the photochemical air pollution formed in a metropolitan area in terms of precursor pollutants. This investigation concerns an episode registered in Mediterranean region (Algerian Coast) occurred from 28th to 29th July, 2013, precursor emissions, meteorological and topography conditions were faced to the combined reliable systems of advanced atmospheric modelling (No-Hydrostatic SKYRON/CAMX). The production and transport of tropospheric ozone over the Mediterranean region is examined by applying a spatiotemporal analysis of the atmospheric circulation in order to investigate the origin sources of polluted air masses (O_3, NO_2 and NO) and their impact on the Algerian O_3. This effort of photochemical modelling, discussed here, show some results, such as the appearance of high ozone levels in the vicinity of urban areas as well as in remote locations. Ozone plumes of South and West of Europe can travel long distances over the Mediterranean Sea affecting remote locations of North Africa, precisely the Algerian coast. Incidentally, the modeled ground-level ozone during this episode is higher (0.162 ppm) than regulation value of the region is around 0.080 ppm.

INTRODUCTION

Air pollution and photochemistry in the atmosphere are complicated processes that alter air quality standards in urban and remote locations. This concerns areas with complicated physiographic characteristics (rough terrain, coastal areas, vegetation variability etc). Mediterranean Region is characterised for its topographic variability (Hills and mountains) and distinct climatic characteristics (increase, decrease of the temperature respectively in summer and winter). These regional and local climatic characteristics are in favour of photochemical processes and smog formation (Jiménez et al. 2004), which is considered as the most important forms of air pollution. It appears often over urban areas as a chemical mixture of gases and particles leading to air quality problems. Photochemical smog is common in regions where certain geographic features as mountains and hills which impede air movement and weather conditions contribute to the trapping of air pollutants. The location of sources both anthropogenic and natural is in favour of multi-scale transport that is responsible for air quality problems in several locations (Benzaama et al. 2016). Most of the anthropogenic sources are located in Europe while natural ones have their origin in North Africa (desert dust) and Mediterranean Seas (sea salt, dimethyl sulphate). Ozone and aerosol formation in the Mediterranean Region is a major problem for many places not only urban. It is well known that large increase in ozone concentration tropospheric background mainly due to transport of long-range and anthropogenic emission of gases leading to ozone formation, the so-called ozone precursors (NOx, CO, CH_4 and volatile organic compounds VOCs) (Gerasopoulos et al. 2006). Great consideration should be given to the problem of air pollution with ground-level ozone; sulfur-dioxide; nitrogen oxides and particulate matter (PM_{10}) are different from other air pollutants particularly with regard to the chemical process of its production.

Millan et al. (2002) have noted that ozone concentrations in remote areas of the Mediterranean region have increased especially in summer. It is likely that this increase in original levels is due to the increase of anthropogenic emissions coming from South Europe affecting the levels of air pollution in West North African Coast (Saidi et al. 2014). In addition, the Mediterranean region is characterised by weather specification dominated by strong north wind component regardless of season. This wind flow transports the polluted air masses from Europe to North Africa across Mediterranean Sea. As it is suggested in previous studies, the synoptic and regional wind circulation during summer promotes of the transport air pollutants over long-distance (Kallos 1997). Air mass flow trajectories were previously calculated based on meteorological data (Max Planck Society for the Advancement of Science 2002), showing the

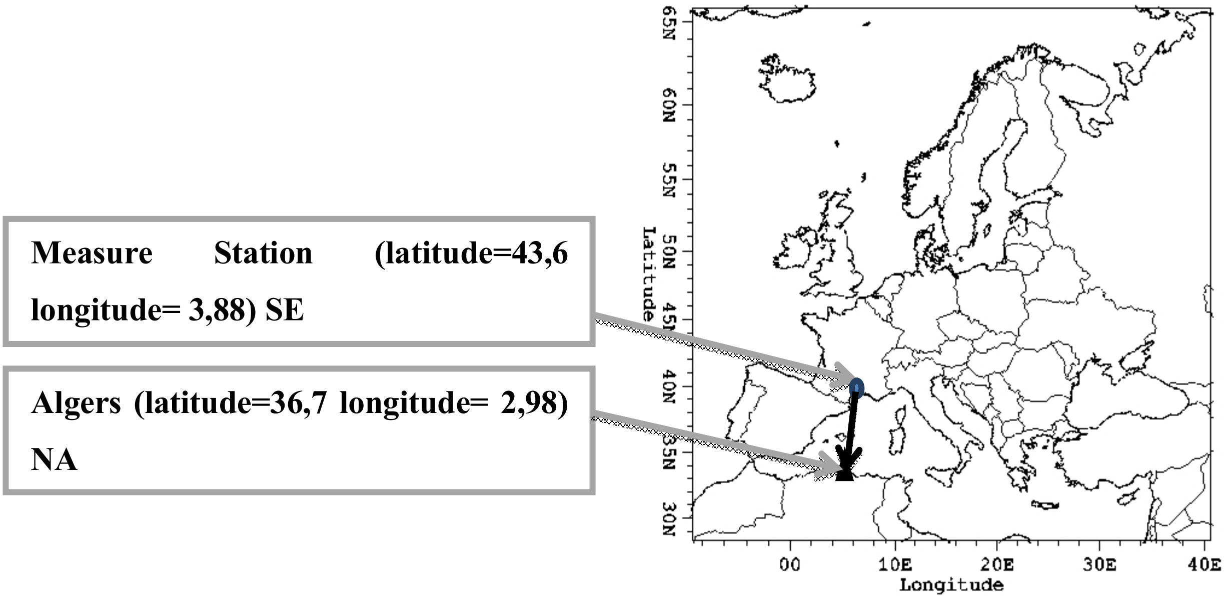

Fig. 1: Computing domain for resolution of 12*12 km (longitude*latitude).

movement of pollution from Europe to the Mediterranean Region in the lowest atmosphere (2-4 km). On the other hand, the local thermal circulation and the major sources nearby the coastal zone aid to the trapping and formation of smog affecting air quality.

AIR POLLUTION TRANSPORT AND TRANSFORMATION OVER THE MEDITERRANEAN REGION

The air pollution transport and transformation was the subject of various studies during the last 20 years. Projects like SECAP and T-TRAPEM grave the first information about the re-circulation mechanisms, the layering, the paths and transformation processes, mainly the photo-oxidants (Gangoiti et al. 2001). In continuity, the International team investigates atmospheric pollution over the Mediterranean/ pollution transport into the region causes large scale decrease in air quality and precipitation (MINOS) (Max Planck Society for the Advancement of Science 2002).

Regions of Mediterranean Basin are characterised: During the cold period of the year, the washout mechanisms are important. Photochemical processes are not at their peak due to limited insolation and cloud formations. During the warm period, the wet removal processes are very limited and insolation helps photochemical processes, moreover, they affect the weather at higher latitudes (Varinou et al. 2001). The meteorology and the air masses coming towards North Africa are highly influenced by strong sea-land breeze (differencing in temperature) and the intensity of the Azores high-pressure system, which is overlooked the Western Mediterranean Basin (Milan et al. 2000).

The Algerian Coast is mainly located under the topography and climate of Mediterranean basin, surrounded by high coastal mountains and characterised by dry hot summers and mild winters. Precipitations are poor and irregular, sometimes drought. Annual average temperature is 18°C, with annual average precipitation around 450mm. Nevertheless, there is a diverse climate, with strong contrasts through the year (Hamoudi et al. 2014). The sun provides the energy to drive the winds by heating the surface of the earth and in turn the air above it (land-sea breeze during the day and sea-land breeze in the night). It is this heating that drives the in Algerian Coast most of the time.

DOMAIN OF STUDY

The domain selected is shown in Fig. 1. The horizontal resolution is 12×12 km^2 and 14 vertical layers were used to cover the lower troposphere with a depth starting from 50,

Table 1. CAMx Specification

Specs	Description
Model	CAMx v5.2
OS/compiler	Linux, Ifort
CPU type	USTO Cluster
Emissions source	EMEP Inventory
Initial conditions	camx.v5.2.inst.5.2
Boundary conditions	camx.v5.2.BC
Meteorological data	Skiron Meteorological Model

100, 200, 300, 450 m, etc., up to the model top at 4 km where the vertical spacing has increased to about 500 m. The time step used for the simulation is 24, as given in Table 1.

CLIMATOLOGY OF THE EPISODE

The general meteorological conditions simulated (Fig. 2) were characterised by maximum surface air temperature (1200 UTC) ranging between 34 and 42°C over the Algerian Coast on the first day of the simulation, while the next days it varied between 34 and 40°C the following days over the same area. The temperature distribution over the western Mediterranean Basin (WMB) was associated with a weak Coast flow moving slowly eastwards, this situation induced weak cyclonic circulation over the western and central Algeria and an anticyclonic circulation over the Algerian troposphere over that region. Under this weak synoptic forcing, strong insolation may promote the development of mesoscale flows associated with the local topography (mountain and valley breezes), while the difference in temperature between the sea and the land enhances the development of sea-land breezes. However, the synoptic conditions are the main forcing associated with the long range transport of pollutants from Europe to North Africa. The temperature reaches 32-38°C over the Algerian coast at that time. Later in the day, the surface air temperature decreases also the Algeria coastal land begins to cool, while the air over the Mediterranean Sea is higher to generate an air flow between sea and land. After the sunrise on July 28th as well as the following day, a weak low pressure system exists over Algeria accompanied by a high pressure system over Tunisia and Libya moving slowly to the east with a depression over the Iberian Peninsula. The air temperature ranges between 38 and 42°C in the course of the day and during the night it ranges between 14 and 24°C. The synoptic situation over Algeria was coupled with the local airflow produced by the particular geography of the North Algeria during the period of the case study. The Algerian coastal plain serves to direct the air flow to and from the Mediterranean Sea. The nearby coastal hills of Algeria which contain the marine layer contribute in the trapping of pollutants like O_3 also this coastal mountains prevent this pollution layer from intruding too far inland. In addition, the local hills heat up in the daytime reaching an average of 34°C, giving rise to

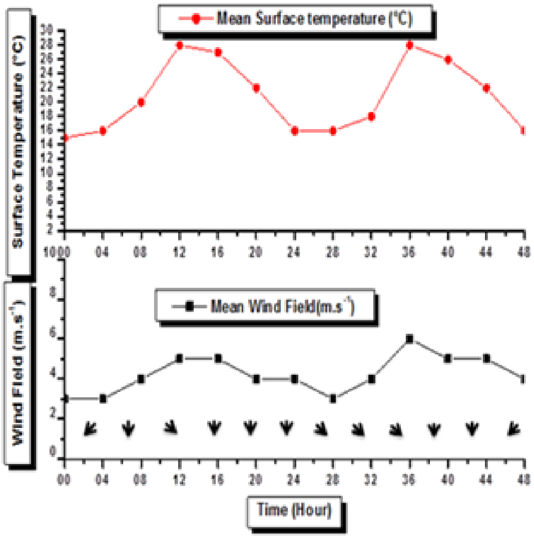

Fig. 2: Mean surface temperatures and mean wind velocity/direction over the Western Mediterranean Sea for 28-29 of July, 2013.

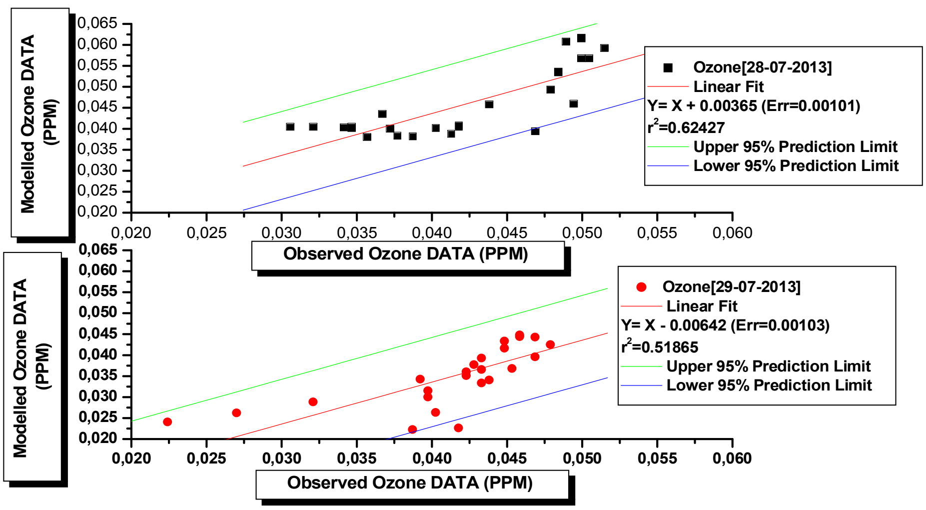

Fig. 3: Scatter plot of CAMx model vs observed Hourly Average Ground-level ozone for Languedoc-Roussillon, Pyrénées at 28th and 29th July, 2013.

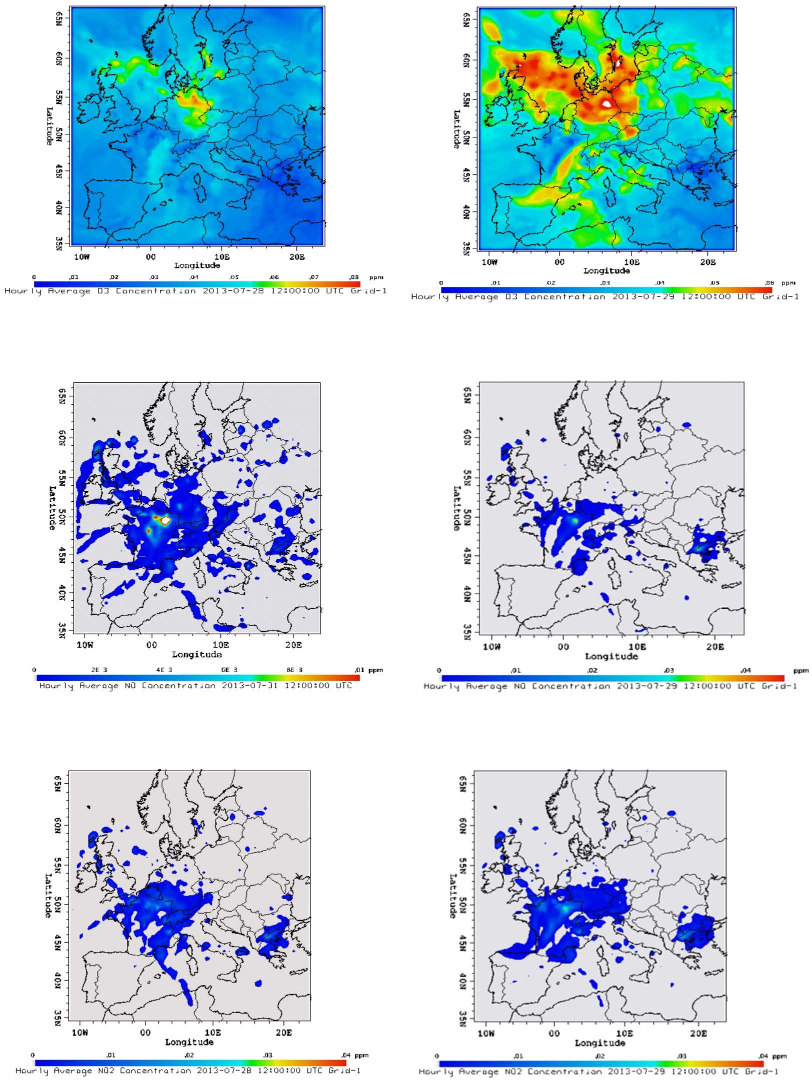

Fig. 4: Hourly average O_3, NO and NO_2 concentrations at 1200 UTC, for 28-29 of July, 2013.

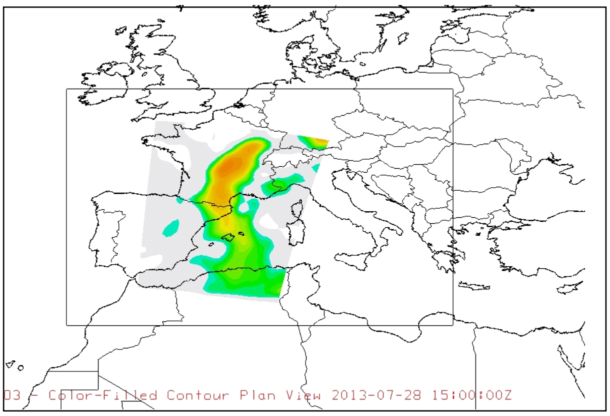

Fig. 5: Spatial distribution of O_3 tracer concentrations.

differences in surface air temperature near the earth and the higher layers, causes an inverse temperature layer.

The particular days were selected for the study, analysis, investigated of photochemical pollution formation and transport favoured by the synoptic meteorological conditions developed. These conditions correspond to a typical summertime period with intense insolation accompanied by a pressure synoptic system that favors high temperature field persistent over the region of interest, i.e. over North Algeria. This situation enhances the photochemical processes, which drive to a high concentration of ground-level O_3, therefore, affecting the air quality of the region. The meteorological patterns during the period 28-29 of July, 2013, fit a typical pattern for O_3 episodes.

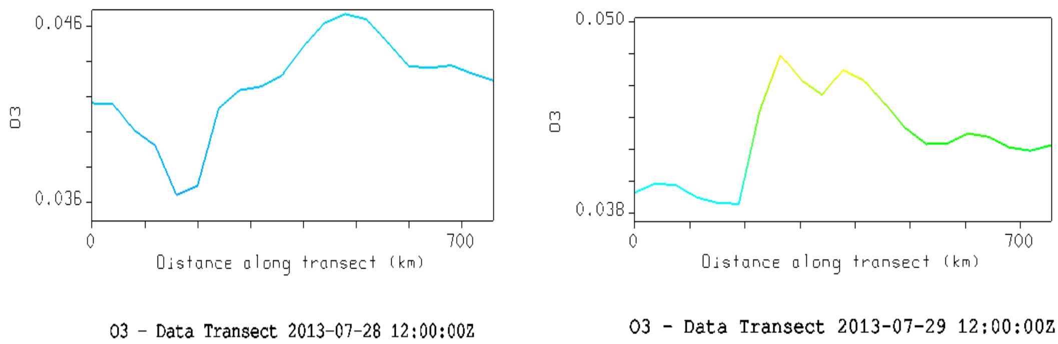

Fig. 6: O_3 Concentration transect between SE and NA, at 1200 UTC for 28-29 of July, 2013.

RESULTS AND DISCUSSION

a. Model validation: Fig. 3 presents typical levels of ozone as the smog process progresses at western North Africa. It presents ozone exactly at South of France: AIR Languedoc-Roussillon, Pyrénées measure Station situated at (latitude=43.6° longitude= 3.88°). The predicted results from a CAMx simulation of the Pyrénées metropolitan area are compared with hourly monitoring data. A good concordance between CAMx model and measure station was noticed (r^2=0.62427, r^2=0.51865) respectively. A slight difference between the model results and observation data have been found due to the grid refinement.

b. Transport and transformation during the episode: The smog day begin as traffic and industrial builds to reach a maximum at around 0800 UTC, there is an attendant rapid increase in the concentration of NO occurs first, as these emitted from sources directly. The increase in NO_2 gaps by a short period because it is formed by atmospheric reactions. Shortly after sunrise and the photochemical reaction sequence, the NO concentration begins a rapid decrease and the oxidant predominantly ozone concentration increase at a similar rate. By 1000 UTC the photochemical process oscillate over the equilibria. Hourly average O_3, NO and NO_2 concentrations at 1200 UTC are shown in Fig. 4. There is the noticeable ozone in the air, increases until about 1100 to 1400 UTC (Fig. 5). At 1800 UTC the intensity of solar radiation has decreased to a low level and the photochemical process has dropped. Oxidant levels turn down rapidly as their production rates go to zero. By 0100 UTC (midnight) the concentration of oxides of nitrogen have again reached normal coastal levels (stagnant air conditions), and are ready to participate in more smog formation reactions the next day. 29th of July, ozone still is available from the reservoir layers (Costal hills) that it has not been depleted fully from the drainage flow, and the concentrations do not drop below 0.4 ppm during the night. While, the O_3 concentration at the Western North Africa more precisely at the Algerian Coast, is low compared to the South Europe area. At the 0800 UTC, the O_3 increases and reaches 0.6 ppm. This increase occurs with a weak wind speed. By 1000 UTC the wind speed at sea surface near the North Africa areas increase to attain 6 ms^{-1}. These two factors (rise of O_3 and wind field) create the transport of O_3 within the marine boundary layer in the reservoir layers above the sea. The O_3 reach its maximum of 0.85 ppm at 1200 UTC, at this time the situation is calm and stagnant. This timing the O_3 keeps increasing and when the maximum wind speed is attained the polluted air masses (O_3, NOx) are dispersed and transported to release a new photochemical production and accumulated above the sea. It reaches a maximum around 1400 UTC with a well-developed sea breeze at the Algerian Coast.

Fig. 6, displays the spatial distributions of the simulated tracer concentrations. CAMxTraceradvects the tracer too far southwest exactly to Gulf of Lyon and Northeast of Spain keeping a circular Gaussian plume distribution and reproduce the northwest to south diagonal orientation (Sea reservoir), afterward to North of Africa Exactly Algerian Coast. The CAMx dispersion models do a better job in reproducing the wind field distribution/direction.

Fig. 7 shows transect of O_3concentrations, as it is shown in Fig. 1, from South Europe (SE: latitude=43.6° longitude= 3.88°) to North Africa (NA: latitude=36.7° longitude= 2.98°) at 1200 UTC of the day.

These charts show the continuity in transporting of studied species O_3 and NOx for long distance. The most significant air pollution masses transported during this episode is $O_3$with regards to the other species. Otherwise it can explain and quantified the air masses transported to the Algerian Coast.

CONCLUSION

The period studied (28-29 of July, 2013) was characterised by a spell of calm and dry weather allowing pollutants to build up near Coastal line. The model results show prominent chemical transport from south Europe towards the western North Africa. The evolution of the concentrations of photochemical pollutants for a daily cycle in the lowest model layer, i.e. near the surface, over the Mediterranean Region show clear diurnal variations, varying from low concentrations at night and reaching maxima in the early afternoon over the entire modeled domain.

The long-range transport towards the Algerian Coast during this study were identified; from East Spain and South France. This transport of polluted air mass can be explained by the polluted air reaches the areas surrounding the Alps as well as the Western Coastal Spain (these region act as temporal reservoir), (1) part of these pollutants mainly O_3 and NOx could be present above the trade winds dominating these two regions (Azores high), (2) The pollutants ruminating in the lower layers could also travel by the marine boundary layer towards and along the Algerian Coast with the trade winds, i.e., the air flow occurs in the lowest layers, near the sea surface. This transport mechanism could be explained some high O_3 levels at the Algerian Coast background occurred in this period.

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REFERENCES

Astitha, M. and Kallos, G. 2009. Gas-phase and aerosol chemistry interactions in South Europe and the Mediterranean Region. Environmental Fluid Mechanics, 9(1), February 2009.

Carvalho, A., Monteiro, A., Ribeiro, I., Tchepel, O. and A.I. 2010. High ozone levels in the northeast of Portugal: Analysis and characterization. Atmospheric Environ., 44: 1020-1031.

European Environmental Agency 2007. Air pollution by ozone in Europe in summer 2006. Technical report, 5: 1725-2237.

Gangoiti, G., Millan, M.M., Salvador, R. and Mantilla, E. 2001. Long-range transport and re-circulation of pollutants in the western Mediterranean during the project Regional Cycles of Air Pollution in the West-Central Mediterranean Area. Atmospheric Environment, 35(36): 6267-6276.

Hamoudi Benameur, Saidi Fethi, Beladjine Boumedienne and Azzi abbes 2014. Meteorology and photochemical air pollution in Western Mediterranean Basin, focused analysis on Algerian Coast. Journal of Environment, 3(4).

Jiménez P. and Baldasano J.M. 2004. Ozone response to precursor control: the use of photochemical indicators to assess O_3-NOx-VOC sensivity in the northeastern Iberian Penisula. Journal of Geophysical Research, 109(D20), D20309.Doi: 10.1029/2004jd004985.

Kallos, G. (Ed.) 1997. Transport and Transformation of Air Pollutants from Europe to the East Mediterranean Region (Final Report Contract: AVI-CT92-0005). European Commission, DG XII, Rue de la Loi, 200, B-1040, Brussels.

Liu, G., Liu, J., Tarasick, D.W., Fioletov, V. E., Jin, J.J., Moeini, O., Liu, X., Sioris, C.E. and Osman, M. 2013. A global tropospheric ozone climatology from trajectory-mapped ozone soundings. Atmos. Chem. Phys., 13: 10659-10675

Max Planck Society for the Advancement of Science, Smog Over the Mediterranean. 2002. International team investigates atmospheric pollution over the Mediterranean/Pollution transport into the region causes large scale decrease in air quality and precipitation. C / T / B / 2002 (28) October 25th, 2002. ISSN 0170-4656

Millan, M., Millan, M., Jose Sanz, Rosa Salvador and Enrique Mantilla 2002. Atmospheric dynamics and ozone cycles related to nitrogen deposition in the western Mediterranean. Elsevier Science Ltd. Environmental Pollution, 118: 167-186.

Millan, M.M., Mantilla, E., Salvador, R., Carratala, A., Sanz, M.J., Alonso, L., Gangoiti, G. and Navazo, M. 2000. Ozone cycle in the western Medeterranean Basin : Interpretation of monitoring data in complex coastal terrain. Journal of Applied Meteorology, 4: 487-507.

Saidi F., Hamoudi B., Azzi A. 2014. Assessment of the long-range transport phenomena of polluted air masses in the Western Mediterranean Region. International Journal of Environmental Sciences, 4(5): 1087-1098.

UNEP Consultant, Mr. Mohamed El Raey; University of Alexandria, 2006. Air Quality and Atmospheric Pollution in the Arab Region. United Nations Environment Program, Regional Office for West Asia, League of Arab states, 2006.

United States Environmental Protection Agency 2012. Documentation of the Evaluation of CALPUFF and Other Long Range Transport Models Using Tracer Field Experiment Data. Office of Air Quality Planning and Standards Air Quality Assessment Division Research Triangle Park, NC Publication No. EPA-454/R-12-003, May, 2012.

Varinou, M., Kallos, G., Tsiligiridis, G. and Sisla, G. 2001. The role of anthropogenic and biogenic emissions on tropospheric ozone formation over Greece. Physics and Chemistry of the Earth, 24(5): 507-513.