EFFECT OF ETESIAN WINDS ON OZONE LEVELS IN EASTERN MEDITERRANEAN SEA

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ABSTRACT

The aim of this study is to examine the effect of Etesian winds on ozone pollution levels in Eastern Mediterranean Sea. The Etesian winds are strong winds that blow from northern directions over the Aegean Sea during summer and early autumn. For this reason, estimates of ozone from a model from the atmospheric service MACC (Monitoring Atmospheric Composition and Climate) are evaluated against surface measurements from three air quality stations, located in Malta, Crete and Cyprus. In order to identify Etesian days, wind data are used from the European Centre for Medium-Range Weather Forecasts (ECMWF) for a three-year period (2010-2012). A day is characterized as an 'Etesian day' when two criteria are satisfied, i.e., the wind has a direction of Northwest to Northeast and the wind speed takes values greater than or equal to 5 m/s.

In order to assess model performance, modeled ozone concentrations are compared against measurements using several statistical metrics, separately for Etesian and non-Etesian days. The results show that there is a strong variation of ozone in the Aegean Sea and Eastern Mediterranean during the Etesian days. The station in Crete presents higher concentrations compared to the other two stations. The model underestimates ozone concentrations for Cyprus and Crete stations while it shows a good agreement with ozone observations at Malta station. Moreover, it cannot capture the differences in concentration levels between the Etesian and the non-Etesian days.

Keywords: Etesian winds, ozone, model evaluation, air pollution, Eastern Mediterranean Sea

1. Introduction

The Etesian winds are strong winds blowing from northern directions over the Aegean Sea during summer and early autumn. They are mainly northeasterly in the northern Aegean, northerly in the central and southern Aegean, and become northwesterly near the southwestern Turkish coasts (Kotroni et al., 2001). The Etesian winds are dry and cool winds that decrease surface temperature and play an important role in the dispersion of pollutants including ozone (Melas et al., 1998, Kalabokas et al., 2008; 2012, Mavrakou et al., 2012). The Eastern Mediterranean sea is an area with high ozone levels, especially during summer (Zanis et al., 2014). Photochemistry is a major contributor to the ozone levels in the troposphere and this area is characterized by increased solar radiation. Furthermore, polluted air masses from Europe, Africa and Asia are transported toward the Mediterranean Sea (Lelieveld et al., 2002).
A study has been contacted in order to study the effect of the Etesian winds on ozone levels. In this paper, the first results are presented, focusing on the comparison of the results of a model with ozone measurements from three background stations, along a transverse extending from central to eastern Mediterranean.

2. Data

Air quality data are collected from three surface monitoring stations (Crete, Malta and Cyprus) located in Eastern Mediterranean sea for years 2010 to 2012. Ozone hourly concentrations have been obtained from the Department of Chemistry, University of Crete for Crete – Greece

(Finokalia station), the Malta Environment and Planning Authority (MEPA) for Malta (Gharb station) and the Department of Labour Inspection, Ministry of Labour, Welfare and Social Insurance for Cyprus (Agia Marina station). For the purposes of this study, only rural background stations have been selected.

The ERA-Interim wind data from the European Centre for Medium-Range Weather Forecasts (ECMWF) (Dee et al., 2011) are used to identify the Etesian days in Central Aegean Sea. The meteorological variables used are the 10 metre zonal (u) and meridional (v) wind components at 12:00 UTC, extracted in a 0.25x0.25 degree latitude-longitude. The analysis is done for a grid point with latitude 38° N and longitude 25.5° E, located in Central Aegean Sea.

The MACC (Monitoring Atmospheric Composition and Climate) model, used for the evaluation, is based on the ECMWF Integrated Forecast System (IFS) (Inness et al., 2013). The MACC reanalysis ozone data are available in 6-hourly intervals at 00:00, 06:00, 12:00 and 18:00 UTC, covering the period 2003 to 2012, and are given in standard pressure levels. For this work, the standard pressure level at 1000 hPa for the period 2010 to 2012, is used.

The units of all air quality data have been converted to volume mixing ratio (ppb_v).

3. Methodology

The first step of this study is to identify the Etesian days in Central Aegean during May to September. A day could be identified as an Etesian day when two criteria are satisfied (Poupkou et al., 2011): a) the wind at 1000 hPa has a wind direction in the sector NW - NE, and b) the wind speed takes values greater than or equal to 5 m/s.

Based on the ERA-Interim data, the wind speed and wind direction at 12:00 UTC are calculated from the u and v components for May to September (years 2010 to 2012) for Central Aegean Sea. The aforementioned criteria have been applied in order determine the days when Etesian winds are blowing.

The evaluation analysis is performed by using the 'Myair Toolkit for Model Evaluation' (http://www.myair.eu/). This toolkit has been developed under the local forecast model evaluation support work package of the EU's 7th Framework, PASODOBLE project (Stidworthy et al., 2013).

Several statistical metrics can be selected to assess model performance. To provide a comprehensive evaluation the following metrics from the Toolkit are selected: mean, median and Standard Deviation (SD) for observed and modeled values, Mean bias (MB), Normalised Mean-Square-Error (NMSE), Pearson's Correlation Coefficient (R), Centralised root-mean-square error (CRMSE). Box and whisker plots for each station are also used to better compare the modeled results with the observations.

4. Results

4.1. Etesian and non-Etesian days

Based on the ERA-Interim data the total number of Etesian days in Central Aegean Sea is 71, 95, and 97 for years 2010, 2011 and 2012, respectively. The months with the highest number of Etesian days are July (24 days) for 2010 and August (28 days) for 2011 and 2012. May has the lowest number of the Etesian days for all three years.

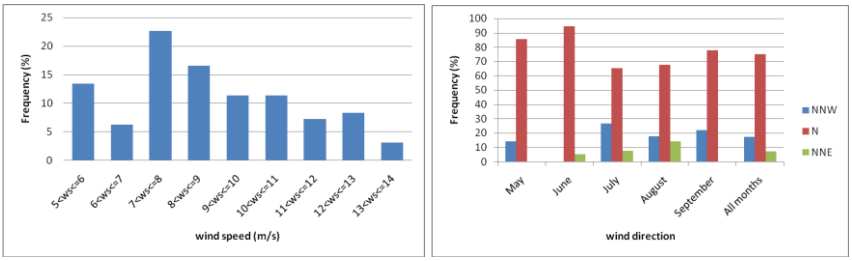

Figure 1: Frequency distribution of wind speed (left) and wind direction (right) in the Central Aegean Sea (Etesian days of 2012).

4.2. Evaluation of the model with surface ozone observations

Higher O_3 levels are observed during Etesian days compared to the non-Etesian days (Fig. 2). Differences in O_3 concentrations range from 5.7, 3.9 and 1.0 ppb for Finokalia, Ag. Marina and Gharb station, respectively. Under the influence of Etesian winds, Finokalia presents higher ozone values than the other two stations (Fig. 2). Ozone levels at Finokalia are 11.4 ppb higher on the average than levels at Ag. Marina and 4.3 ppb higher than levels at Gharb. However, the differences between the stations are lower for non-Etesian days (6.6 ppb between Finokalia and Ag. Marina and 2.5 ppb between Finokalia and Gharb).

On the other hand, the results of the model show higher values at Gharb station, followed by Finokalia and Ag. Marina (Fig. 2). Ozone concentrations at Gharb are 6% higher than concentrations at Finokalia and approx. 19% higher than those at Ag. Marina. Moreover, small differences of predicted concentrations are found between the Etesian and the non-Etesian days for all stations.

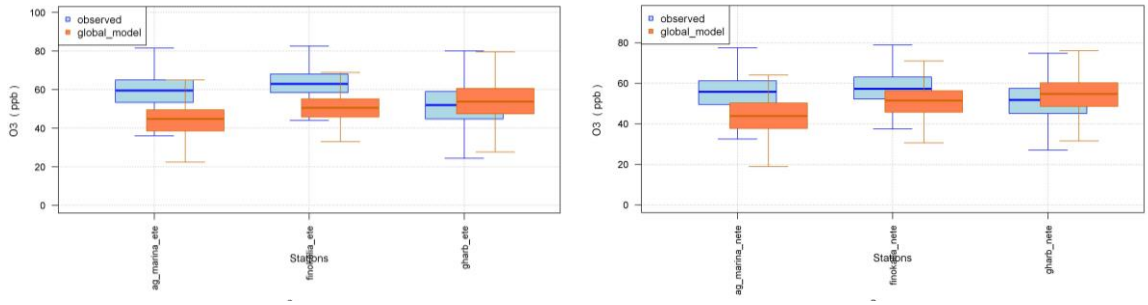

Figure 2: Box and Whisker Plot of observed and modeled hourly mean O_3 concentrations for the Etesian (left) and the non-Etesian days (right) (all stations).

The model underpredicts O_3 concentrations for Ag. Marina and Finokalia but it shows a relatively good agreement with O_3 concentration measurements at Gharb station (Fig. 2) with a low bias and fairly good correlation coefficients, approx. R=0.6 (Tables 1 and 2). Correlation coefficients are higher for the non-Etesian days compared to the Etesian days for Gharb and Ag. Marina stations. The worst agreement between model results and observations is obtained for Ag. Marina station (R=0.14) for the Etesian days. Gharb station has the lowest NMSE value for both the Etesian and non-Etesian days. During non-Etesian days, the NMSE is slightly better for all stations.

Table 1: Statistical evaluation during Etesian days.

Station	Mean (SD) Observed (ppb)	Mean (SD) Modeled (ppb)	MB (ppb)	NMSE (ppb)	R	Median Observed (ppb)	Median Modeled (ppb)	CRMSE (ppb)
Gharb - Malta	51.82 (11.23)	54.07 (9.51)	2.25	0.04	0.55	51.97	53.83	10.02
Finokalia - Greece	63.18 (7.40)	50.58 (6.93)	-12.59	0.07	0.36	62.96	50.55	8.10
Ag. Marina - Cyprus	58.84 (8.86)	43.67 (8.86)	-15.18	0.14	0.14	59.50	44.74	11.59

Table 2: Statistical evaluation during non-Etesian days.

Station	Mean (SD) Observed (ppb)	Mean (SD) Modeled (ppb)	MB (ppb)	NMSE (ppb)	R	Median Observed (ppb)	Median Modeled (ppb)	CRMSE (ppb)
Gharb - Malta	50.82 (9.70)	54.07 (8.54)	3.25	0.03	0.59	51.76	54.75	8.36
Finokalia – Greece	57.45 (8.36)	50.72 (7.54)	-6.73	0.04	0.34	57.29	51.46	9.14
Ag. Marina – Cyprus	54.93 (9.07)	43.41 (9.21)	-11.51	0.10	0.34	55.80	43.79	10.46

The diurnal range, calculated as the difference between the O_3 measurements at 18:00 and 6:00 UTC, is higher for the Etesian days compared to the non-Etesian days for all stations (Table 3). When the Etesian winds blow in Central Aegean, the afternoon values are higher compared to early morning values by 8.6 ppb for Gharb and 7.6 ppb for Finokalia. The simulated O_3 presents almost the same diurnal range for both types of days at Gharb and Ag. Marina.

Table 3: Diurnal range for observed and modeled O_3 (18:00-6:00 UTC).

	Etesian days		Non-Etesian days	
Station	Observed (ppb)	Modeled (ppb)	Observed (ppb)	Modeled (ppb)
Gharb - Malta	8.63	8.54	6.62	8.16
Finokalia – Greece	7.57	11.00	2.68	9.61
Ag. Marina – Cyprus	-6.56	1.16	-4.65	-1.95

5. Conclusions

Ozone levels at Finokalia and Ag. Marina stations are found to be significantly higher during the Etesian days compared to the non-Etesian days. Especially, the highest influence on O_3 concentrations is found at Finokalia station which is directly affected by the Etesian winds. Gharb station shows small differences among the two groups of days. The results of the model do not exhibit the aforementioned differences, the average ozone levels being almost identical during Etesian and non-Etesian days. Moreover, the model results underestimate the observed ozone concentrations at Ag. Marina and Finokalia stations but shows a relatively good agreement with O_3 concentration measurements at Gharb station, with a low bias and a fairly good correlation coefficient. The agreement between model simulations and observations is generally better during non-Etesian days.

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