Atmospheric Pollution Research 7 (2016) 339–347

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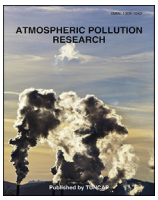
Atmospheric Pollution Research

journal homepage: http://www.journals.elsevier.com/locate/apr



Original article

Investigating ozone high levels and the role of sea breeze on its transport

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ARTICLE INFO

Article history:
Received 31 July 2015
Received in revised form
8 October 2015
Accepted 10 October 2015
Available online 3 November 2015

Keywords:
Ozone episodes
Breeze circulation
WRF model
Backtrajectories
Portugal

ABSTRACT

This works intends to investigate the ozone episodes reported in three different monitoring sites distributed along the Central region of Portugal (from the coast to inland direction). Ozone data time series are first analysed according to the legislation thresholds fulfilment (information threshold and target value) and two episodes are selected according to the magnitude and simultaneously exceedances at the three sites. The episodes are then analysed in terms of meteorological data (surface and vertical profiles) obtained with the WRF model and also using backtrajectories obtained with the HYSPLIT model. The integration of both results, together with the ozone and NO_2 precursor concentration time series, allowed to conclude about the different origin of ozone in the two episodes. A sea breeze circulation is present in the first episode, inducing the transport of this pollutant and its precursors from the coast to inland (about 30 km), which is verified by the wind patterns and vertical profiles and by the daily profile of O_3 measured at the three sites. The second episode studied does not show so clearly this influence.

1. Introduction

During the last few years, great importance has been placed on the study of regional-scale forcing on the formation of specific air quality conditions, especially on the coastal areas, and it has been widely reported that significant degradation of air quality in some areas can be attributed to mesoscale transport phenomena. Serious ozone pollution has been frequently reported inland during sea breeze events in coastal regions (Grossi et al., 2000; Millan et al., 2000; Boucouvala and Bornstein, 2003; Kalthoff et al., 2005; Oh et al., 2006; Ching-Ho et al., 2007; Evtyugina et al., 2007). In particular on the west coast of Portugal, where the human activities are concentrated, there are studies also investigating that (Bonsang et al., 2001; Harder et al., 2001; Carvalho et al., 2002; Barros et al., 2003) since this coastal zone is strongly influenced by the nearby Atlantic Ocean, with frequent sea/land breeze circulation.

Furthermore, most inland ozone pollution is found to be related to landward transport and subsequent mixing of ozone-rich sea breeze air masses. Grossi et al. (2000) and Oh et al. (2006) found that an ozone-rich marine air mass can result from the transport of an inland ozone-rich air mass by land breezes during the night. The influence of land–sea breeze on the nocturnal ozone maxima in two urban sites of Oporto (Portugal) was also evaluated by Alvim-Ferraz et al. (2010) and Sousa et al. (2011). The vertical distribution of ozone in a sea breeze air mass before it is transported inland is also important in determining the contribution of the sea breeze air mass to inland surface ozone concentrations (Ching-Ho et al., 2007). The important vertical dimension of the circulatory patterns of air masses in the region was also studied for Lisbon and Barcelona (Barros et al., 2003). In Lisbon was verified that this sea-breeze mesoscale circulation is, in general, reinforced by the north-northwest synoptic circulation.

Taking into account that high levels of photochemical pollutants, and especially ozone, affect public health and environment (Brauer and Brook, 1997; Hogsett et al., 1997), this is an urgent problem that should be controlled. Due to the harmful health effects of this pollutant (WHO, 2006), standard values, that should not be exceeded, were fixed by the European Union, according to Directive 2008/50/EC: i) information threshold associated with health risks for short-time exposure of groups particularly sensitive (180 μg m^{-3} for 1-h average); ii) alert threshold associated with health risks for

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Peer review under responsibility of Turkish National Committee for Air Pollution Research and Control.

http://dx.doi.org/10.1016/j.apr.2015.10.013

short-time exposure of the population in general (240 μg m^{-3} for 1-h average); and iii) target value for the protection of human health associated with the long-term effects on human health (120 μg m^{-3} for 8-h running average). Ozone is also harmful to ecosystems (Paoletti, 2006; Paoletti and Manning, 2008) and is considered a strong greenhouse gas in the free troposphere (IPCC, 2001). Considering these harmful effects, the knowledge and investigation of the ozone high concentrations is fundamental concerning the implementation of strategies to protect public health and to support efficient air quality management (Pires et al., 2008; Miranda et al., 2015; Borrego et al., in press; Monteiro et al., 2015).

The main purpose of this work is to investigate the role of maritime breeze on the formation and transport of photochemical pollutants. In the present study, the authors went further on this subject by evaluating the influence of horizontal transport on the occurrence of specific ozone episodes in three urban/suburban areas located in the central region of Portugal by analysis of pollutant time series and meteorological data using the WRF meteorological mesoscale model for temperature and wind field analysis and also the HYSPLIT model for air masses trajectory investigation.

2. Ozone data and episodes selection

The ozone data monitored along three different sites located in the center of Portugal were first analysed and high concentration episodes are then selected to further investigation.

In the center region of Portugal are located three different monitoring sites, from the coast to interior, distant from each other 20–50 km as shown in Fig. 1. They are subject to distinct environment and anthropogenic influence: TEI (at north) is characterized by industrial influence and suburban environment while the other two – ILH (center) and IGC (south inland) - have background influence with suburban and urban environments, respectively. All these monitoring sites are located at altitudes below 150 m.

The ozone concentrations registered along these sites were analysed in terms of hourly data and maximum 8 h-daily average following the air quality standards defined by legislation to protect the human health, namely the hourly information threshold (180 μg m^{-3}) and the maximum daily 8 h mean target value (120 μg m^{-3}). Fig. 2 shows the ozone time series corresponding to these 8-h mean and hourly averages for the three sites along 2013. The 2013 year was chosen due to data availability and representability in terms of meteorological conditions.

The maximum daily 8-h mean data series shows similarities between the three monitoring sites, with several days in exceedance of the target value (black line) during July, August and September, which were also registered in the hourly time series.

The ozone episodes to be investigated were selected according similar criteria used by Saavedra et al. (2012). First (i) the days with exceedances to the legal (8-hour mean) target value at the three sites were pre-selected and then (ii) chosen the days with the highest magnitude of the ozone maximum values registered. Fig. 3 shows the maximum daily eight-hour mean concentration for the days of simultaneously exceedances of the target value at the three sites.

Two episodes were selected, both occurred in year 2013, with maximum 8 h average values superior to 140 μg m^{-3} at all sites. These episodes occurred at 6 of July and 3 of September 2013, as highlighted (dotted line) in Fig. 3. Before proceeding with the analysis of the meteorological data and air masses trajectories, the

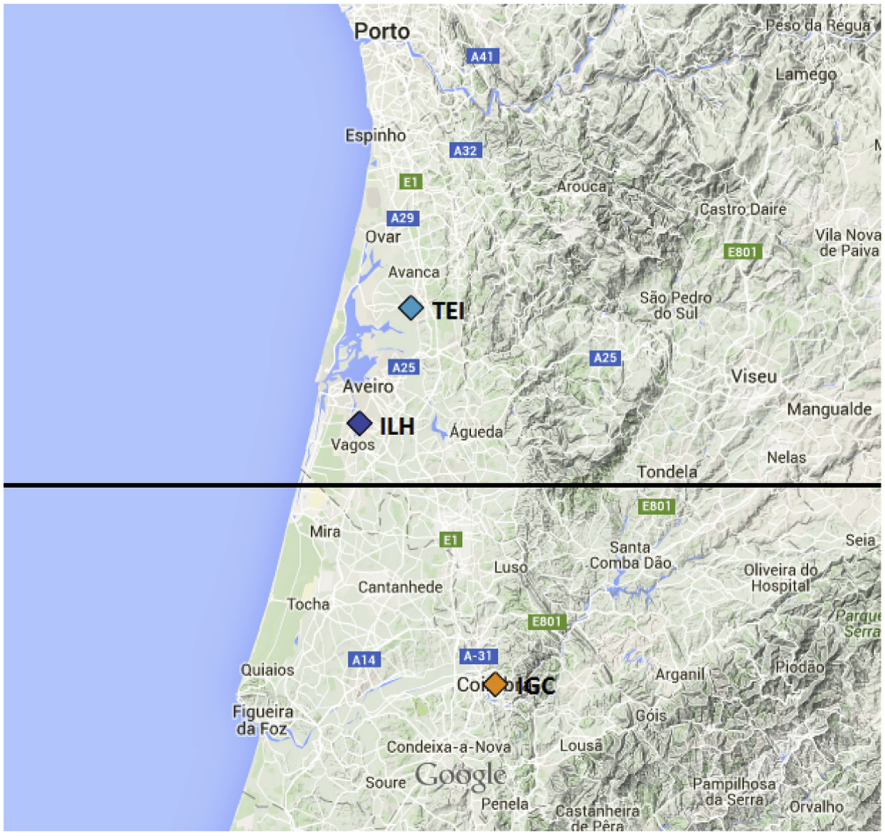

Fig. 1. Location of the monitoring stations used in this study.