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Air quality status in Greater Thessaloniki Area and the emission reductions needed for attaining the EU air quality legislation

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ABSTRACT

This paper aims at imprinting the urban air quality status and assessing the impact of various emission reduction scenarios on the photochemical and particulate matter air pollution levels in the Greater Thessaloniki Area, Greece. In particular, it is investigated under which conditions compliance with the EU air quality legislation can be achieved. For this purpose, the Ozone Fine Structure model is applied for a full calendar period (reference year 2002), as well as for specific scenarios, corresponding to predefined emission reductions for 2010. The model results for photochemical and particulate matter air pollution levels in 2002 agree fairly well with the observations. Predictions for 2010 indicate that significant improvement towards the EU legislation requirements can be achieved for certain emission reduction scenarios. However, an overall strategy will also have to include additional local scale measures.

1. Introduction

Human activities in urban conurbations are inevitably concentrated in a relatively small area. Most economic activities involving the use and conversion of energy are accompanied by emissions of air pollutants, thereby degrading the environment, particularly the urban environment. Urban air pollution is the cause of numerous problems, including most importantly health risks through the inhalation of gases and particles, accelerated corrosion and deterioration of materials, damage to historical monuments and buildings and reduced crop yield within and around the city. A consensus has been emerging among public health experts that air pollution, even at current ambient levels, aggravates morbidity (especially respiratory and cardiovascular diseases) and leads to premature mortality (e.g. Hurley et al., 2005; WHO, 2003; Hoek et al., 2002; Pope et al., 2002; Wilson and Spengler, 1996; Dockery et al., 1993; Krupnick et al., 1990; Brunekreef, 1984). This is based on the past decade's epidemiological studies in Europe and worldwide which have measured increases both in mortality and morbidity associated with air pollution (Krzyzanowski et al., 2002). In order to tackle such problems, efficient, long-term air pollution abatement strategies need to be identified and implemented (Vlachokostas and Moussiopoulos, 2004).

The air quality related European Union (EU) Framework and Daughter Directives (DDs) provide useful information on

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air quality assessment techniques and prescribe limit values that should be attained. Most recently, the EU DDs were merged and streamlined in a European Council's single legal text, the Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe (Official European Union Law web page, 2008). The limit values and model uncertainty indicators remain identical in 2008/50/EC compared to the Framework and DDs for the pollutants considered in this paper.

Currently, within the EU the most severe air pollution threats to human health are ambient concentrations of particulate matter (EEA, 2005; WHO, 2003). In addition, southern Mediterranean countries, especially due to their climate conditions, face compliance problems for ground-level ozone concentrations, while northern EU countries encounter problems related mainly to nitrogen dioxide (Kukkonen et al., 2005; Baldasano et al., 2003). Indeed, a large fraction of the European population is still exposed to air pollution above the limit/target values for these pollutants. In a few cases local concerns still remain regarding carbon monoxide in street canyons and lead, particularly around industrial installations (Moussiopoulos, 2003).

This paper aims at imprinting the urban air quality status and assessing the impact of various emission reduction scenarios on the photochemical and particulate matter air pollution levels in the Greater Thessaloniki Area (GTA) with the application of air quality modelling methods. To our knowledge, this is the first attempt to simultaneously treat particulate matter and photochemical air pollution in the GTA, to this extent of detail and scenario's definition. However, there are important studies for other areas that provide useful background information, where particulate matter and ozone air pollution has been treated simultaneously, especially at a regional scale (e.g. Jiménez-Guerrero et al., 2008; Vautard et al., 2007; O'Neill et al., 2006; Boylan et al., 2006, 2005; Shih et al., 2004; Bonasoni et al., 2004). In addition, the importance of the work presented here also lies in supporting local authorities' planning schemes towards assessing the impact of policy interventions at local level with the adoption of possible emission abatement measures for improving air quality.

The city of Thessaloniki is situated in the northern part of Greece. With more than one million inhabitants (approximately 10% of the Greek population) and approximately 20% of the country's industrial activity, it is the second largest city in the country and one of the largest urban agglomerations in the Balkans. Vehicle and industrial emissions are the two main sources of air pollutants in the GTA. With the vehicle fleet growing at an annual rate of 5–7% (Official General Secretariat of National Statistical Service of Greece web site, 2008) radical improvement of the situation is not expected in the next few years. Compliance in the GTA (Fig. 1) has to be achieved within the deadlines defined by the aforementioned EU air quality legislation.

As shown in Fig. 1, an extended flat area at the west and north-west of the city hosts the largest part of the industrial activity in the region. It stretches over 20 km in a bowl formed by low hills facing a bay that opens into Thermaikos gulf. The cape of Angelohori marks the passing from the Thessaloniki bay to Thermaikos gulf. In addition to this complex coastal formation, mountainous areas, the closest at the east (Mount Hortiatis), form a complex orography pattern which favours local circulation systems of various kinds (sea-land breeze, valley-mount winds), as well as wind channelling phenomena.

More specifically, the prevailing surface level winds in the GTA during the winter period are of NNW origin. This is a result of the synergy between the low pressure areas expanding from the Mediterranean Sea to the Black Sea that usually occur during the cold period of the year (October–March) and the concurrent presence of anticyclones over Central Europe. During the rest of the year, northern winds prevail in the morning and night hours, while at midday and afternoon the predominance of southern winds is apparent, mostly due to sea breeze (Tsilingiridis et al., 1992).

The occurrence of sea breeze is favoured during the warm period of the year (April–September) due to the weak synoptic forcing. The formation of sea breeze starts in the morning when local sea breeze cells develop, initially above the Thessaloniki bay with directions perpendicular to the shore, resulting in an overall inhomogeneous wind pattern. In the afternoon, an extended sea breeze originating from the Thermaikos gulf gradually develops, forming a rather homogeneous southern flow penetrating to the inland up to the northern boundary of the GTA, resulting in the transport of air masses to the northeast.

In the evening, the early morning complex wind pattern starts gradually re-establishing, while even later, weak land breeze develops, which in conjunction with katabatic winds from the surrounding hills, leads to a slight northern stream over the urban area. These nocturnal winds dominate a surface layer of up to 100 m thick and are the main reason for the transport of primary pollutants from the urban and industrial zones of the GTA to Thessaloniki bay during the night-time.

The complexity of the wind circulations in such a complex topography is also highlighted by the wind parameters measured at areas in the vicinity of Angelohori Cape. According to observations, during the night and morning hours Angelohori Cape seems to be affected by the northern flow blowing from the inland, whereas neighbouring coastal areas in Thessaloniki bay are under the influence of the downslope air motion from ESE directions, originating from the Vassilika valley.

As regards the frequency of the occurrence of all wind directions in the GTA, the annual percentage of southern winds is limited to about 6%, while the percentages of calms and northern winds reach 50% and 30%, respectively. The occurrence of the latter ones result in the transport of pollutants from the northern suburbs, as most industries are located at the northwest section of the GTA, to the densely populated city center. Another factor that contributes to the increment of air pollution levels in the GTA, especially in the urban area, is the heat island effect which also leads to weak transport of pollutants from the suburbs to the urban area of the GTA (Moussiopoulos et al., 2006a,b).

2. Air quality status and trends

The measurements conducted by the Air Pollution Monitoring Network of Central Macedonia Region, also available through Airbase (Official Airbase web site, 2008), are used in this analysis to assess air quality status in the GTA. This network (location of monitoring stations is shown in Fig. 1) monitors air quality levels for five air pollutants, namely sulphur dioxide (SO_2), carbon dioxide (CO), ozone (O_3), nitrogen dioxide (NO_2) and mass of particles with diameter less than or equal to