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The contribution of the transport sector emissions to the photochemical formation of tropospheric ozone in the Balkan Region

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Introduction

Ozone is a greenhouse gas and a photochemical pollutant. In the troposphere O_3 is transported from the stratosphere and it is also photochemically formed by reactions of its precursors which are the nitrogen oxides (NOx), the volatile organic compounds (VOCs) and the carbon monoxide (CO). Emissions of O_3 precursors from human activities have modified its budget leading to a net increase in background O_3(Logan, 1994). Elevated levels of O_3 at ground level are of particular concern, since it is known to have adverse effects on human health, vegetation and materials. Regional photochemical air pollution studies in the Balkan region are an important environmental issue since it is an area characterized by high background O_3 concentration values (Zerefos et al., 2002; Kouvarakis et al., 2002) as a result of the high levels of solar radiation in combination with the anthropogenic and biogenic O_3 precursor's emissions.

Pollutant emissions from the transport sector represent a very high share of the overall anthropogenic emissions: about 64% of the total NOx emissions, 40% of the total non-methane VOC emissions and 70% of the total CO emissions in the European Union (EEA, 1997). The photochemical Urban Airshed Model (UAM-V) coupled with the meteorological mesoscale model MM5 has been applied in order to study the contribution of the transport sector emissions to the O_3 levels in the Balkan Region during the summer period when enhanced photochemical O_3 production is favored.

Model Implementation

The UAM-V model is a three-dimensional photochemical grid model designed to calculate the concentrations of both inert and chemically reactive pollutants by simulating the physical and chemical processes in the atmosphere that affect pollutant concentrations. The major processes that the model simulates and which affect O_3 concentration levels are: 1) the spatial and temporal distribution and the composition of emissions of NOx and VOCs, 2) the spatial and temporal variations in the wind fields, the temperature and the solar insolation 3) the dynamics of the boundary layer, 4) the loss of $O_3$and O_3 precursors by dry and wet deposition, 5) the ambient background of VOC, NOx, and other species and 6) the chemical reactions involving VOC, NOx, and other important species. The UAM-V program employs the version IV of the Carbon Bond Mechanism (CB-IV) for solving chemical kinetics (Gery et al., 1989).

The meteorological model MM5 was used to produce the meteorological fields necessary for the implementation of the UAM-V model. The Mesoscale Model MM5 is a limited-area, nonhydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale and regional-scale atmospheric circulation. Using the capability of MM5 for multiple nesting, the model run with the option of two way nesting for two domains. The large domain, covering the South-Eastern Mediterranean, was consisted of 55 x 55 grid points having 30kmx30km spatial resolution. The finer domain, covering the Balkan area of interest (Greece, Bulgaria, Albania, FYROM, Western Turkey, South Serbia and Montenegro), was consisted of 115 x 115 grid points having 10kmx10km spatial resolution. Simulations starting at 18:00 UTC and ending after 78 hours were performed in order to produce meteorological data for the time period of interest extending from 11 June 2000 to 31 July 2000. MM5 simulations were initialised and developed lateral boundary conditions using NCEP Global Analyses. Both of the domains had the same vertical structure consisted of 33 σ levels.

The biogenic and anthropogenic emission data used as input data to the photochemical model were based on an emission inventory compiled for the Balkan Region (Symeonidis et al., 2004; Poupkou et al., 2004). For every month of the year, typical diurnal biogenic emission variations of isoprene and monoterpenes from different land use types of forests, shrub species and agricultural crops, extracted from satellite data, were calculated for the Balkan area with spatial resolution of 10kmx10km. In addition, mean annual emission data of NOx, NMVOC and CO, averaged for the years 1994-2000, were estimated for different anthropogenic emission source sectors such as the transport sector, the industrial sector and the central heating sector with spatial resolution of 10kmx10km. More specifically, for the transport sector, the inventory allowed the determination of the air emissions from both the road transport sector and the other mobile sources and machinery transport sector. For Greece, the transport sector

emission inventory was calculated using the methodologies of the EMEP/CORINAIR emission inventory guidebook (EMEP/CORINAIR Guidebook, 2002) and included emissions from the Greek national and secondary road network, the Greek urban centers, the off-road vehicles, the railway, the air-traffic activities and the maritime transport. For the rest of the Balkan area the estimation of the emission data from the transport sector was performed using the top-down methodology to the EMEP annual gridded transport sector emission data of spatial resolution 50kmx50km. The anthropogenic annual emission data were temporally disaggregated in order to get seasonal and diurnal emission variations.

The UAM-V model was applied for the Balkan area of interest. The model grid had resolution of 10kmx10km including 110x110 grid cells. The model grid was consisted of five vertical layers and their height above ground level was 50,150, 300, 1200, 2500m respectively. The analysis of the model results concerns the first layer of the model. We used background concentrations as boundary conditions for the species of the chemical mechanism while for O_3 we considered 40ppb value as boundary condition. Successive 3-day model simulations were performed in order to calculate O_3concentrations for the time period of interest. The results of each 3-day model simulation were used as initial conditions for running the successive one. The first 3 days of the time period of interest were considered as "start-up" simulation time, so the final period for the analysis of the model results extends from 14 June 2000 to 31 July 2000. The UAM-V model was implemented considering 4 different emission scenarios. According to them O_3 concentrations were calculated with the use of:

1. Base emission scenario: Biogenic and anthropogenic emissions.
2. 2nd emission scenario: Biogenic and anthropogenic emissions excluding all transport sector emissions.
3. 3rd emission scenario: Biogenic and anthropogenic emissions excluding only the road transport sector emissions.
4. 4th emission scenario: Biogenic and anthropogenic emissions excluding only the maritime transport sector emissions.

Our study focuses in the spatial distribution of the percentage differences of the mean and maximum O_3 concentrations of the base emission scenario as a result of the elimination of the emissions from the pre-mentioned transport sectors.

Discussion - Conclusions

The elimination of all transport sector emissions contributes to decreases of the mean O_3 concentrations in regional level. The most important percentage decreases ranging from -20% to -33% are found over continental and maritime areas of Greece. However in places where large urban agglomerations are located, such as Athens, significant percentage increases are found reaching the value of 67%. Similar results are derived for the percentage differences of the mean O_3 concentrations as a result of the elimination of the emissions from the road transport sector. In this case over the greater part of the domain the percentage decreases can reach -10% while calculated percentage increases up to 61% are found mainly in areas where large urban centers are located. As for the maritime transport sector emissions, it can be deduced that, in regional level, their elimination contributes to percentage decreases of the mean O_3 concentrations, that reach -10%. However, over the sea, in some areas the reductions are more pronounced reaching the value of -17%, while in some other maritime areas, influenced by the plumes of the large urban agglomerations like Athens, percentage increases up to 21% are estimated.

The elimination of all transport sector emissions plays a more prominent role in the percentage decreases of the maximum O_3 concentrations occurring over almost the entire modeling domain. The most important percentage decreases ranging from -40% to -67% are found at the central part of the domain, over continental and maritime areas of Greece influenced by high emissions from the transport sector. The elimination of the road transport sector emissions also contributes to decreases of the maximum O_3 concentrations in regional level. The percentage decreases reach the value of -38%. In both cases, there are minor exceptions of areas where percentage increases appear which are not higher that 16% and 19% respectively. A little different is the role of the maritime transport sector emissions. Although their elimination contributes as well to percentage decreases of the maximum O_3 concentrations in regional level, the most significant of which are located over the sea ranging from -20% to -45%, however, there are areas, influenced by the plumes of the large urban centers, where percentage increases up to 25% are calculated.

It can be concluded that in regional scale the transport sector emissions are an important contributor to the formation of tropospheric O_3 in the Balkan region while in local scale, in areas influenced by the emissions of the large urban agglomerations, these emissions can prohibit the formation of O_3.

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