7.13 ESTIMATE OF POTENTIALLY HIGH OZONE CONCENTRATIONS AREAS IN THE CENTER OF THE IBERIAN PENINSULA.

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INTRODUCTION

The Greater Madrid Area is located in the centre of the Iberian Peninsula and it is a huge source of ozone precursors (Palacios *et al.*, 2002a). Under high temperatures and solar radiation can prompt an intense formation of tropospheric ozone. Such conditions are very frequent in summer time but also in late spring and early autumn

As stated by the recent European directives, air pollution modelling is a very important tool not only for researching but also for many aspects of the air quality management, i.e. air quality assessment, design of plans and programs for air pollution abatement or design of networks for air quality monitoring. Furthermore, the development of ozone control strategies requires analysing ozone response to variations in precursors emissions considering a wide range of realistic meteorological conditions.

Previous simulations with the prognostic meteorological TVM model coupled to a transport/chemistry module for two different summer ozone episodes in the Greater Madrid Area, under summer thermal low pressure conditions, have shown that high levels of ozone, above the population information threshold (180 $\mu gr/m^3$, Council Directive 2002/3) and close to the alert threshold (240 $\mu gr/m^3$), can be expected in different areas placed more than 100 km far away from the Madrid city (Palacios *et al.*, 2002b). This was, as expected, in agreement with the simulations of transport pattern of atmospheric pollutants with the mesoscale prognostic model TVM for the same area (Martín *et al.*, 2001b). This is also confirmed by observations (Plaza *et al.*, 1997 and Galán *et al.*, 2001).

In addition, the need of forcing to the reduction of not only traffic road but also total anthropogenic emissions to fulfil standard levels was made clear (Palacios *et al.*, 2002c).

This paper presents a study of which areas could be potentially affected by high ozone levels in the centre of the Iberian Peninsula by using this already evaluated model.

METHODOLOGY

The used methodology can be summarised in the next items:

a) Set up of meteorological scenarios.
b) Simulations of the photochemical air pollution for the meteorological scenarios.
c) Analysis of the simulated spatial patterns of ozone concentration distribution.

Set up of meteorological scenarios

Ozone formation needs two important meteorological factors: high temperatures and intense short wave solar radiation. These factors are more probably met during summer season. However, in the Centre of the Iberian Peninsula, which is affected by a continental Mediterranean climate, days matching both requirements can occur in late spring and early autumn. From this reason, the period used for selecting meteorological scenarios for this study was extended from mid April to mid October. Two years were studied: 1992 and 1995.

The selected variables for setting up the meteorological scenarios were:

a) Surface and 850-HPa-level wind speed representing the intensity of ventilation.
b) Surface air temperature, which is very important for ozone formation.
c) Temperature gradient between 850 HPa level and surface. These provide information about atmospheric stability.

Cluster analysis was applied to these groups of variables, which represents the atmosphere state every day of 1992 and 1995. The k-means technique was used in order to group days with similar meteorological state. All data were previously normalised for avoiding that difference of variability range of each variable could falsify the process.

For this study, we are focused in the summer period and both years were treated separately. The number of significant cluster resulted from every year was three, each of which has remarkable differences. For 1992, cluster 1 corresponds to higher-than-average winds, high temperatures and little atmospheric instability. Such as meteorological conditions do not seem to be frequent (3% of the studied days). Cluster 2 corresponds to very weak winds, very high temperatures and higher atmospheric instability, whereas cluster 3 is related to weak winds but temperatures are higher than former cases. Some similar features can be appreciated in 1995 clusters for the intensity of winds. Cluster 1 also corresponds to stronger-than-average winds, but temperature does not seem to be so high as in cluster 1 of 1992. It does not seem to be frequent (4%) as in 1992. In both years, cluster 2 is dominant with 63 and 77% of the studied cases, respectively, whereas cluster 3 corresponds to 34 and 19% in 1992 and 1995, respectively.

For setting up the meteorological scenarios representing every cluster, wind direction was used. We must bear in mind that wind direction was not used in the cluster analysis process due to circular features of this variable. For every cluster, a frequency analysis (histograms) was done to determine, which wind directions are dominant in each cluster. It results in a subclasification obtaining few sub clusters for every cluster. The representative day (scenario) was determined as that being closest to the mean state of every sub cluster.

In Tables 1 and 2, the meteorological scenarios are summarized for 1992 and 1995, respectively. Hence, 9 representative days for every reference year were used in simulations. These days, which potentially can produce significant ozone formation on the studied area, mostly correspond to summer season, which is the dry season in Madrid, and are roughly a 65% of the period from mid April to mid October.

Simulations of the photochemical air pollution for the meteorological scenarios.

Model formulation.

The meteorological model used in this study is the Topographic Vorticiy Mesoscale (TVM) model (Thunis, 1995). A complete explanation of the model can also be found in Schayes et al. (1996) and Thunis and Clappier (2000).

This meteorological model is coupled to a transport/chemistry module. The first computes the wind, temperature and turbulent fields, and the second one calculates transport and chemical transformations. The transport/chemistry model used here is based on the CIT model developed originally by McRae et al. (1983) and updated by Harley et al. (1993). The photochemical model applies an operator splitting technique by which advection is integrated separately from the diffusion/chemistry. In this work, the highly accurate and computational efficient hybrid scheme Gong and Cho (1993) has been used to solve the chemical system of the RACM mechanism (Stockwell et al., 1997), implemented in the transport/chemistry module. With this technique, diffusion and chemistry are decoupled.

The mesoscale prognostic TVM model has been evaluated previously to simulate the atmospheric flows for anticyclonic conditions and thermal low pressure in the centre of the Iberian Peninsula. Model results agreed in significant aspects with observed wind flows over the GMA (Martín *et al.*, 2001a, 2001b). In addition, the TVM model coupled to the chemistry/transport module above mentioned have been proved to simulated satisfactory ozone pollution episodes taking place in this region (Palacios, 2001; Palacios *et al.*, 2002b).

Model setup.

The meteorological domain corresponds to a geographical area of 360x300 km^2 in the centre of the Iberian Peninsula. The GMA is close to the centre of the domain, between the two ranges. It is a large conurbation extending about 50x50 km and including the city of Madrid and several satellite towns.

A non-regular or stretched grid with variable resolution is used for the meteorological modelling, considering 64x54 grid points. The spatial resolution is maximum at its centre (5x5 km^2), coinciding with the area selected to run the photochemical model. This allows to capture the atmospheric flows and to reproduce the main mesoscale circulations characteristics. At the same time, the boundaries are moved far from the photochemical domain and their influence on the flow is reduced. In the vertical, a terrain following coordinate system with 24 levels is used, the lowest of them at 20 m above the ground. Incrementing spacing is applied thereafter with a maximum of 1000 m. The top of the domain is fix at 15400 m. The simulations cover 37 hours starting at 1200 UTC [in Madrid, the difference between Universal Time Coordinated (UTC) and Local Solar Time (LST) is about 12 minutes]. The model computes the suitable time step for each resolution, but an upper limit is imposed; for these cases, 30 sec was considered.

A different grid than that for the dynamics was used to run the transport/chemical module. The photochemical modelling domain is 270x200 km^2 with a regular resolution of 5x5 km^2. In this case, 54x40 grid points are considered in the horizontal and 8 in the vertical up to 4400 m above the ground.

RESULTS

Analysis of the simulated flow patterns.

In Tables 1 and 2 results of meteorological simulations are summarized, showing the simulated flows over the GMA.

As a general conclusion, we can state that mesoscale wind flows are strongly driving by the synoptic forcing. In many cases, surface winds have the same direction than those of synoptic winds.

Analysis of the simulated spatial patterns of ozone concentration distribution.

Simulation results are summarised in Tables 1 and 2. Results show very high ozone production levels for some days and four typical impact areas have could be identified, located both tens of kilometres away far from the city (in N, NW and E directions) or affecting the whole Community of Madrid. Figure 1 show these four ozone concentration patterns.

As expected, not very high ozone levels are associated to days with strong winds and low isolation and very high ozone levels appear in days with weak winds and high isolation. For each simulation, the areas affected by maximum ozone concentrations are related to the synoptic wind forcing (Figure 1). The more frequent impact areas are: the Sierra de Ayllón (N) and the Sierra del Guadarrama (G), sometimes with very high ozone levels associated. The whole Community of Madrid (A) is affected in a lesser number of cases but simulated ozone levels were remarkable. There is another latter ozone concentration pattern (E) that appears less times and has, normally, not so high concentration levels associated.

Table 1. Scenarios corresponding to every cluster for 1992, percentage of days falling in every scenario. Surface flows over the Greater Madrid Area as resulted from TVM simulations and synoptic wind speed and direction at 700 HPa. Impact locations and daily maximum concentrations within the domain (A=Whole CAM, G=Sierra del Guadarrama, N=Sierra de Ayllón, E=East from Madrid metropolitan area).

Cluster	Julian day	%	Night	Morning	Noon	Afternoon	Evening	Wind speed (m/s)	Wind direction (º)	Ozone max location	Ozone maxima (ppb)
1	133	3					○	5.7	161	G	104
	112	13					○	0.9	212	A	115
	118	19						3.8	227	N	103
2	276	4	○	○				7.8	322	E	91
	177	23	○					3.7	253	N	114
	253	4	○					4.6	232	N	92
	195	9	○					1.8	267	E	112
3	197	9					○	3.7	160	G	110
	213	16						8.0	181	N	88

Table 2. Same as Table 1 but for 1995.

Cluster	Julian day	%	Night	Morning	Noon	Afternoon	Evening	Wind speed (m/s)	Wind direction (º)	Ozone maxima location	Ozone maxima (ppb)
1	256	4	○					11.2	347	E	110
2	192	13						5.6	264	N	117
	186	9	○	○	○		○	1.0	343	A	149
	158	12					○	1.9	152	G	117
	173	13					○	3.0	180	G	126
	215	22						8.4	230	N	81
	153	7						6.4	275	N	103
3	188	12					○	4.2	201	N	121
	209	7	○					7.7	234	N	82

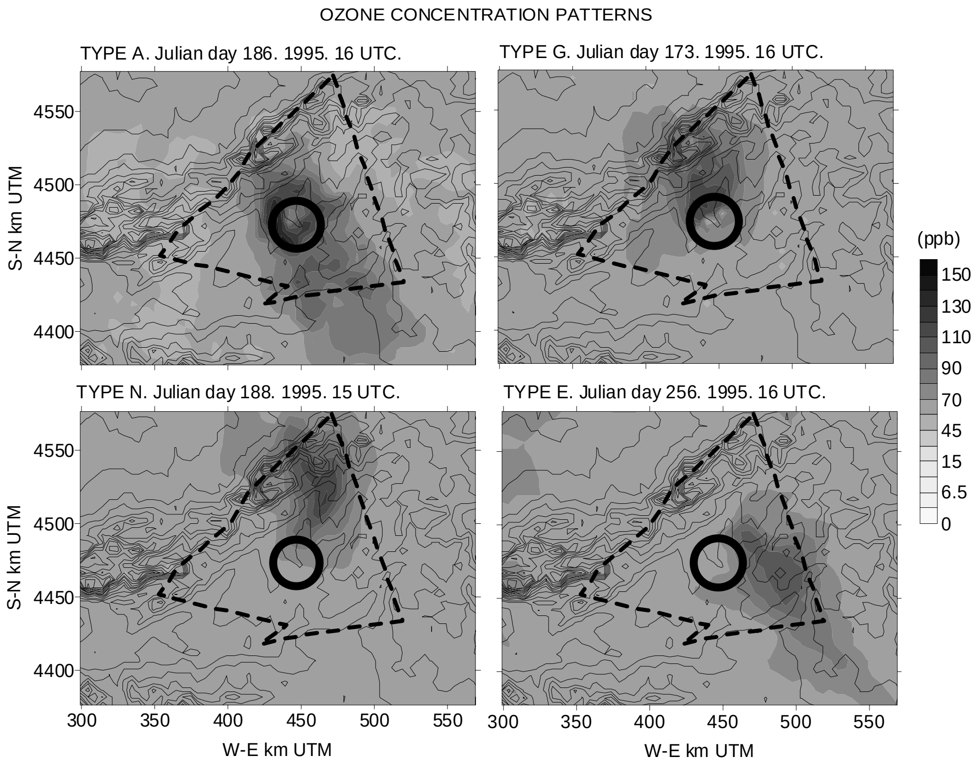

Figure 1. Ozone concentration patterns. Type A : The whole Community of Madrid is affected; Type G: Sierra del Guadarrama ; Type N: Sierra de Ayllón; Type E: East from Madrid metropolitan area. Dashed line delimits the Community of Madrid and the Greater Madrid Area is pointed out with a circle.

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