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OZONE MODELING OF THE BARCELONA AREA: ANALYSIS OF THE INVOLVED TRANSPORT PROCESSES

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INTRODUCTION

The city of Barcelona (northeastern corner of Spain) and its surrounding area can reach high levels of O_3 in summertime. An ozone episode that took place between the 3rd and 5th of August of 1990 has been simulated with the non-hydrostatic meteorological model MEMO and the photochemical model MARS (Moussiopoulos, 1994). A highly disaggregated emission inventory was also developed taking into account both anthropogenic and biogenic emissions.

The combination of mesoscale circulations (such as sea and land breeze, convection cells and topographic injections) and local emissions strongly influence the production and spatial distribution of ozone in the region. It has been observed how ozone is formed over vegetated areas, where BVOCs (Biogenic VOC) are emitted, due to the inland advection of NO_x from traffic emissions with the sea breeze flow. Orographic injections from the surrounding mountains cause the formation of elevated ozone layers. These elevated layers are dispersed according to the synoptic-scale flow, which is responsible of the orientation of the surface-height decoupled layers

THE SIMULATION DOMAIN

An area centered around the city of Barcelona and including other high-density towns such as Terrassa, Sabadell and Hospitalet was considered for this study (4,124,450 inhabitants). It is an area of complex terrain including a coastal range, whose main peaks are Garraf (594.6 m), Collserola (512 m) and Corredor (657.2 m), and a precoastal range including the mountains of Mediona (744.6 m), Montserrat (1236 m), St. Llorenç del Munt (1104 m) and Montseny (1712 m) (see Fig. 1)). These areas are mainly covered by Mediterranean shrublands and coniferous forests. Extensive vineyards are found in the Penedès depression. In contrast a wide range of land uses are found in the Vallès depression: shrublands, coniferous and sclerophyllous forests and non-irrigated herbaceous crops. Vegetation covers 85% of the land considered in the domain under study.

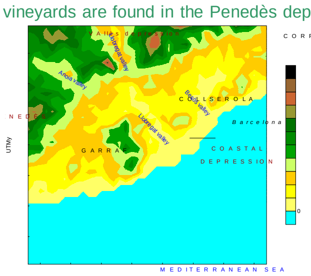


Figure 1: Main Orographic Features in the simulation domain

The Llobregat and Besòs valleys contain highways and roads that link Barcelona and its outskirts towns with the cities in the Vallès depression. Both valleys act as natural passageways for wind flows, such as land and sea breezes that develop in the region due to its sea-side location. There are also major communication links which cross the Vallès depression. These highways and roads bear a considerable volume of traffic, not only because they link the main industrial and commercial centers in the area but also because they link this region with other parts of Spain and with France, specially during summertime.

THE SIMULATED DAY

To study the origin of the photochemical pollution episodes in Barcelona a numerical modeling approach was adopted, and the episode that took place between the 3 and 5 August 1990 was chosen or investigation. During that period, high O_3 concentrations were registered all over central and northern Europe. Analysis of O_3 concentration data from 5 surface measurement stations in the area of Barcelona showed that maximum values were reached within the urban area's core (registering 125 to 170 ppb).

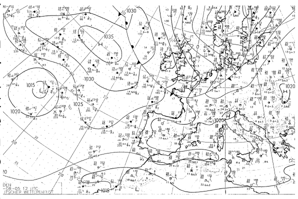


Figure 2: Surface Synoptic chart at 12 UTC on August 5, 1990.

The simulated day chosen was August 5 1990, although the model was initialized the previous day to account for pollution re-circulations. During that day there was a weak pressure gradient all over Europe (Fig. 2), which resulted in a low geostrophic wind speed and stagnant conditions. Under these synoptic conditions mesoscale flows develop, induced by local characteristics of the domain, such as land and sea breezes, mountain winds and topographic injections.

DISAGGREGATED EMISSION INVENTORY

Emissions of VOC, NO_x and CO from road traffic, industries, petrol stations, airport traffic, maritime traffic, port tanks and vegetation were calculated in the studied domain of 80x80 km^2, with a resolution of 2x2 km^2, for 5 August using the EIM-LEM model, a revised version of the one developed by Costa and Baldasano (1996). This model uses emission factors (from CORINAIR's database) to calculate gaseous releases from the different sources considered. Biogenic VOC (BVOC) emissions were estimated using a methodology that takes into account local vegetation data (land-use distribution and biomass factors) and meteorological conditions (surface air temperature and solar radiation) together with emissions factors for native Mediterranean species and cultures (Gomez *et al*, 1999).

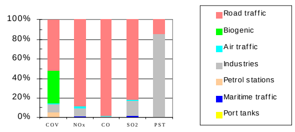


Figure 3: Distribution by source and pollutant of the emissions estimated

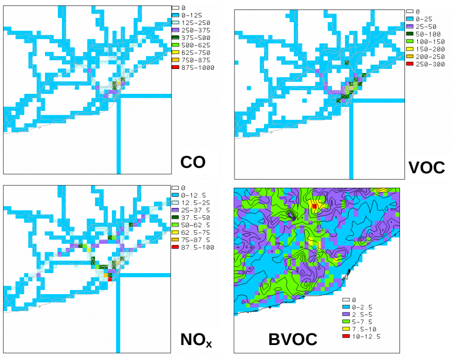


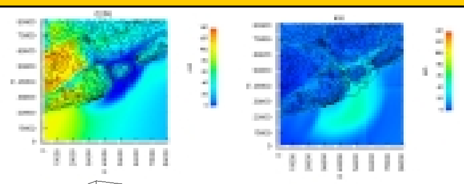
Figure 4. Distribution of emissions between 15-16 LST in kg/km^2

Highest CO and VOC emissions take place in the city of Barcelona and in the junction of some major roads and are due to road traffic. This is explained by the fact that vehicles release higher amounts of CO and VOC at low speeds than at the higher speeds reached on the major routes. NO_x emissions are high in the city of Barcelona, but of the same magnitude as some emissions on major roads. Contrary to CO and VOC, NO_x emissions increase with vehicle speed, explaining the relatively high values on the major roads .The highest BVOC emissions were in the sclerophyllous forests and shrublands of St Llorenç del Munt, Montseny, Montserrat and the Garraf, and also in certain shrubland areas and coniferous forests located at the Vallès depression. Monoterpenes were the most emitted BVOC throughout the day but during the hours of highest intensity of solar radiation and air temperature (between 14 and 16 LST) isoprene emissions exceeded those of monoterpenes.

PHOTOCHEMICAL DISPERSION SIMULATION

The meteorological non-hydrostatic mesoscale model MEMO (version 5.0) was used for the simulation of the meteorological fields, and data from the emission inventory described above were used to carry out a dispersion simulation with the photochemical model MARS, a multilayer Eulerian photochemical dispersion model that solves the coupled advection-diffusion equations for reactive species (Moussiopoulos, 1994).

FIELDS AT 0 LST



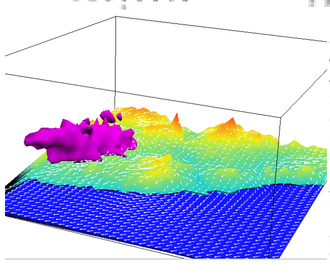
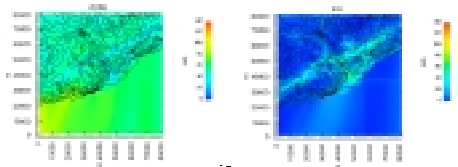


Figure 5: Surface O_3 and NO_2 (top) and iso-surface of 100 ppb of O_3 with surface winds (bottom) at 0 LST. Simulation shows destruction of ozone at nighttime to create NO_2 taking place were NO is emitted. Elevated O_3 are remains of previous day simulation.

FIELDS AT 12 LST



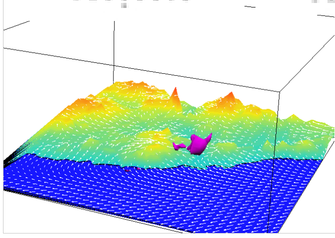
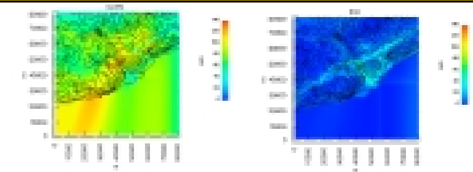


Figure 6: Same as Fig.5 at 12 LST. Increased NO_2 concentration due to increased emissions and reaction of NO with O_3. Ozone concentration due to increasing solar activity and emissions of precursors.

FIELDS AT 14 LST



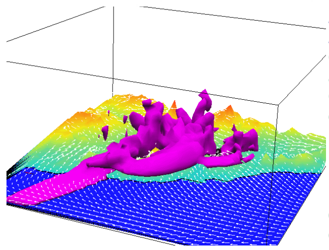
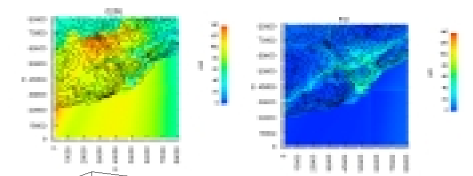


Figure 7: Same as Fig.5 at 14 LST. Ozone precursors above the sea form O_3 due to the increasing solar activity. During the afternoon hours, sea breeze inflow transports NO_x emissions due to traffic in the city and surrounding network towards the interior, where high BVOC emissions are taking place during these hours due to the presence of vegetation and high temperature and solar radiation. Precursors meet and result in formation of O_3 and a concentration maximum. Sea-breeze return and topographic injections bring ozone to higher levels.

FIELDS AT 18 LST



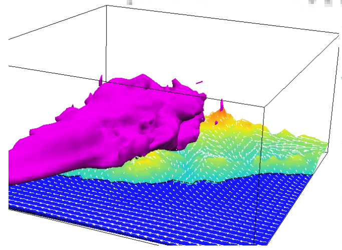


Figure 8: Same as Fig.5 at 18 LST. O_3 is transported towards the interior and concentration is reduced above the sea. Important orographic injections and a bigger return cell of the sea-breeze bring pollutants to higher altitudes, where they are dispersed according to the medium-range flows.

CONCLUSIONS

Further investigation will have to be undertaken to better understand the vertical arrangement of pollutants in the area and the role that this stratification plays in surface air pollution levels. Also, remains of pollutants from previous day emissions and photochemical processes need to be carefully studied, since the synoptic dominant flow seems to determine the reintroduction of those pollutants or its dispersions outside the domain's boundaries (Toll and Baldasano, 1999, 2000).

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