6.27 STUDY OF POLLUTANT TRANSPORT IN COMPLEX TERRAIN USING DIFFERENT METEOROLOGICAL AND PHOTOCHEMICAL MODELLING SYSTEMS

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INTRODUCTION

The air quality on a regional and local scale is of great interest for the society, because it affects human health, forest and other ecosystem. During the last decades several efforts has been conducted towards the regulation and reduction of several air pollutants such as ozone and other photooxidants. This pollutants are basically produced by chemical transformation of nitrogen oxides and hydrocarbons (VOC's) from biogenic and anthropogenic emissions, especially traffic and industrial emissions. In this study we focus our attention in the simulation of the dispersion of the plume from an industrial power plant located on a rural area with complex topography. Under these conditions, horizontal inhomogeneities complicate the meteorological fields and therefore the dispersion patterns. On many occasions, meteorological fields are a critical component of the dispersion modelling systems. That is the reason that their evaluation is considered the first step and an important issue of any air quality study to guarantee its success.

To accomplish with this first objective, in this contribution we have evaluated the performance of three meteorological models: MM5, the Fifth-Generation Pennsylvania State University/National Centre for Atmospheric Research (PSU/NCAR) mesoscale model; MASS, Mesoscale Atmospheric Simulation System; and TAPM, the Air Pollution Model, developed at the CSIRO Atmospheric Research group, in Australia.

Due to the fact that, within the rural area under consideration, the power plant emits large quantities of NO_x, these emissions are believed to react with VOC's emissions from the important vegetation and result in the occurrence of ozone episodes, which are often registered several kilometres away from the source.

To investigate this fact, and still in relation with the performance analysis, a photochemical plume dispersion has been simulated coupling two photochemical models to the meteorological models described above. Specifically, the 3-D Urban Airshed Model with variable grid (UAM-V) has been implemented to MM5 and MASS, while for TAPM model its own photochemical model has been run.

The simulations with the three models have been conducted from 21st to 26th June, 2001, during an ozone episode that occurred near the investigated source. The period studied was mainly characterized by a synoptic situation of high pressure, which favours the development of local mesoscale circulations. Simulations have been performed using the nesting capabilities of the three models, with a 1-km horizontal resolution in the inner domain and high vertical resolution in the boundary layer. First results have shown the importance of local wind circulations within the area, showing enough agreement with observations, although some differences between meteorological and photochemical models have been found and evaluated.

THE REGION UNDER STUDY

The area studied is located in the interior of Catalunya, in the north-eastern part of Spain. It is characterized by very complex terrain (it is very close to the Pyrenees) with mountain rising over 2500 m (see Figure 1). The power plant is located in a small village named Cercs (Figure 1), which is located in the Llobregat river valley surrounded by two mountain ranges, Rasos de Peguera (to the West, 2056 m height), and Serrat de Santa Margarida (to the East, 1667 m height). The valley is connected towards the south with the Central Depression and towards the north it becomes wider until the Serra del Cadí mountain range (2531 m height). Data collected every 30 minutes at different meteorological and air quality surface stations (located also in Figure 1) are used in this study in order to compare and to validate the results given by the models.

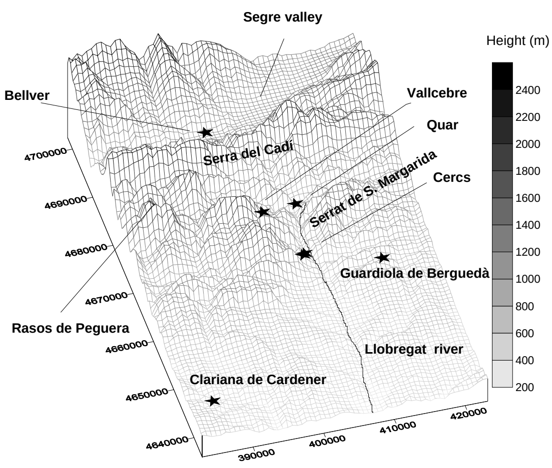

Figure 1.Topography of the studied area

NUMERICAL MODELS

The models used in this study are the MM5 Mesoscale Meteorological Model (Penn State University / National Center of Atmospheric Research, MM5, version 3.34; the Mesoscale Atmospheric Simulation System, MASS, version 5.13; TAPM, the Air Pollution Model, developed at CSIRO Atmospheric Research group; the Urban Airshed Model with variable grid (UAM-V, version 1.15). All models are widely described in Grell et al., (1994); Zack and Kaplan, (1987); Luhar and Hurley, (2003), and Biswas et al., (2000) respectively.

The initial and boundary conditions are updated every six hours with information from a large area model. In the case of MM5, data from the European Centre for Medium Range Weather Forecast (ECMWF) model was used. MASS used data from the NCEP-AVN model, while TAPM assimilated data from the Australian Bureau of Meteorology (BoM) large area model. The meteorological simulations were performed using four nested domains at the following horizontal resolution: 27, 9, 3 and 1 km. The dimensions of each domain are 31x31 for the two outer domains, and 46x40, 67x40 grid cells for the two inner domains, respectively. In the case of TAPM, all domains had the same number of cells (67x40).

The photochemical model simulations were focused on the smallest domain. Two nested domains of 1 and 3 km resolution were performed. Boundary conditions for the outer domain are adjusted as in Hogrefe et al. (2001) with available information.

The power plant emits 528.67 kg/h of CO; 996.21 kg/h of NO_x and 5504.07 kg/h of SO_2 through a stack of 120 m height at an emission temperature of 150 ºC. An emission inventory including traffic and others industrial activities, as well as biogenic emissions, were developed following the method described in Ortega et al. (2004).

PRELIMINARY RESULTS

High surface ozone concentrations occur in the studied area, especially in the Segre valley (upper part of the region represented in Figure 1), during late spring and summer time. These episodes usually take place under large scale situations dominated by high pressure and weak winds, which favours the transport of ozone and its precursors by local circulations. Related to ozone episodes, the most important one is the land-see breeze circulation. The relative proximity of the Mediterranean Sea (not included in the inner domain represented, but included in the outer domains, cause during daytime a general inland flow from the south direction. This front, forced by the complex orography, is believed to overwhelm the mountains and reaches Segre valley during the late afternoon. As an example of this behaviour, Figure 2 shows, for Bellver station, the time evolution of wind speed and direction as well as the ozone concentration for one of the days of the period studied (21-26 June 2001).

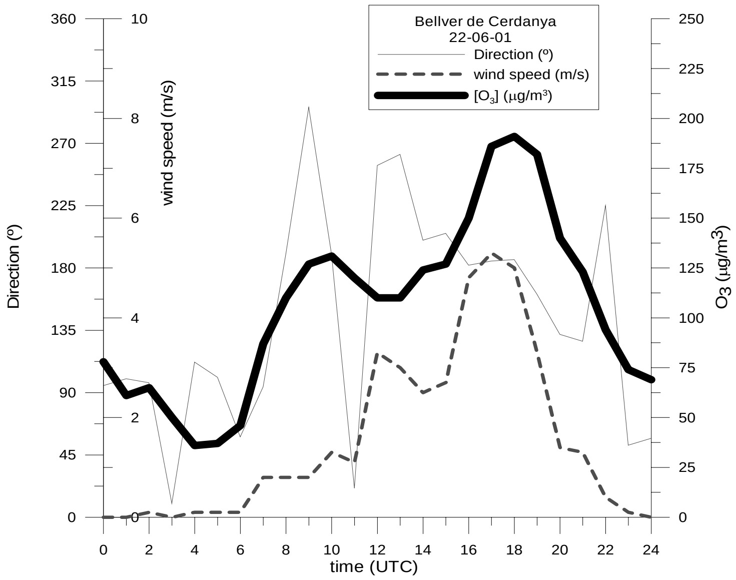

Figure 2. Time evolution of wind speed and direction and ozone concentration at Bellver station, during June 22, 2001.

From these measurements we can see that when the wind speed increases and the direction turns to the South sector, the ozone concentration increases considerably up to values near or sometimes higher than the regulated limit.

Seeing the importance and close relationship between wind speed and direction and ozone concentration, the first steep of this study must be to evaluate the skill of the models to properly forecast the wind field. Figure 3 shows, as an example, the three modelled surface wind (at about 10 m above the ground) cross section, for June 22, 2001 at 1700 UTC (all these plots correspond to predicted winds in the inner of the simulated domains). Results show that, at the bottom of the inner domain, the three models successfully predicted the penetration of the sea-breeze front (characterized as a southerly wind). This front will later overwhelm the mountain range and reach the Segre Valley, where southerly winds are also detected. We are of the believe that this wind is the responsible of the transport of a fraction of the ozone formed as a consequence of the reaction of NO_x emitted by the industrial plant and VOC's from biogenic emissions.

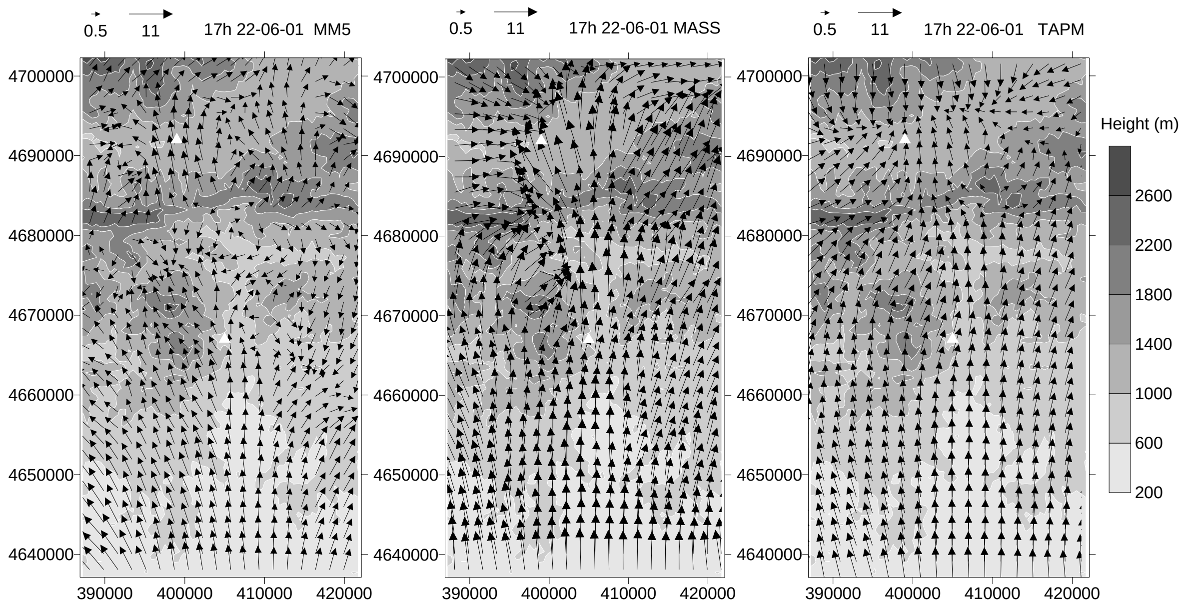

Figure 3. Surface winds (at about 10 m above the ground) for 22 June 2001 at 1700 UTC predicted for the inner domain by the three models (MM5, MASS and TAPM from left to right). Triangles on the figures mark the location of the source (lower triangle) and the surface station of Bellver (upper triangle).

In order to have more detailed information about the accuracy of the models, a comparison is made between the time evolution of winds measured in different stations and those simulated by the three models for the same grid (1x1 km^2). As an example of this type of assessment, a comparison at Bellver station is presented in Figure 4. Results show a quite good agreement between MM5 simulated wind speeds and those measured, while MASS tends to overestimate speeds (by large) during the late afternoon. The simulation results for TAPM indicate that, although the model forecasted increasing wind speeds during daytime, the winds predicted slow down during the late afternoon, in disagreement with measurements.

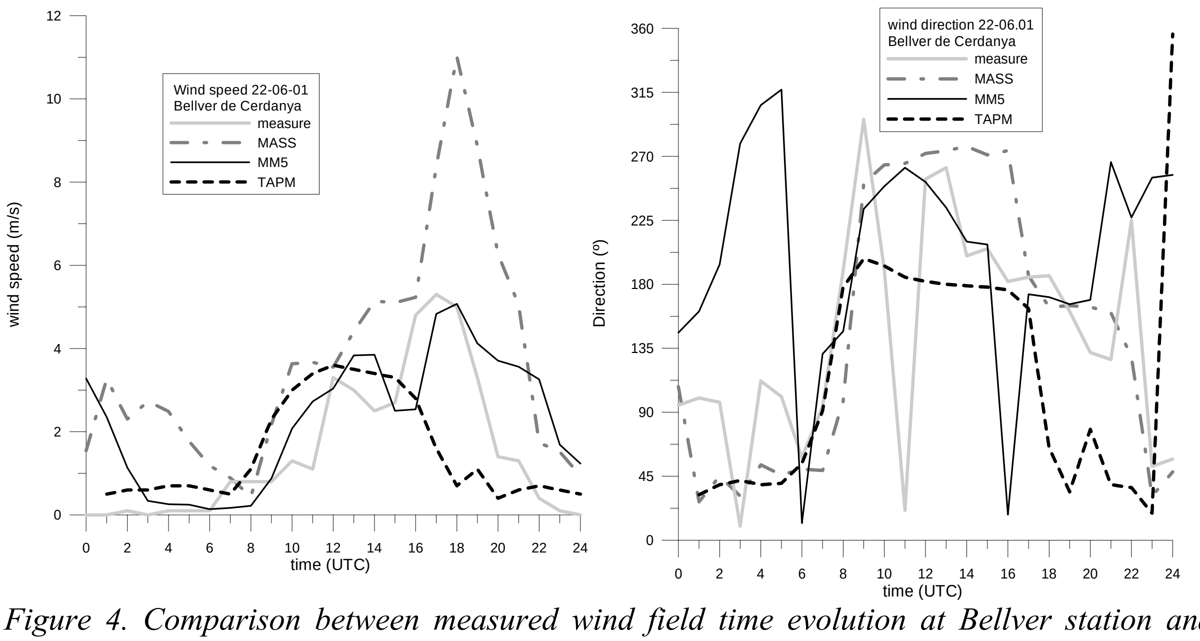

Figure 4. Comparison between measured wind field time evolution at Bellver station and those simulated by the three models for the inner simulation domain.

As for wind directions, comparison should be done carefully during night time due to the little confidence of this measurement during low winds conditions. This is case in the station used until 10 UTC. After this time, the models present several differences between measured and predicted values. In general winds have westerly components bearing towards the South as the late afternoon advances. The bearing is more progressive in MM5, while MASS shifts suddenly around 17 UTC, and TAPM predicts the southerly winds too early in the afternoon.

CONCLUDING REMARKS

The preliminary results of this study indicate that the forecasted south wind entrance through the mountain range to the Segre valley is in quite good agreement with surface observations, although important differences do exist in wind speed and direction.

As the skills of meteorological forecast and emission inventory have an important impact on the performance and success of pollution transport forecast, results obtained so far (very preliminary) with the dispersion simulation show that the direction of the plume is highly dependent on the good prediction of the wind speed and direction. In addition, the emission inventory and boundary conditions have an important effect in ozone production and more accurate revision will be done. Although the simulation takes into account the major physical processes in the atmosphere, the region under study has a very complex orography and the agreement of models and observations are not enough good at this moment. The next step in the investigation is directed towards the improvement of the results given by photochemical models. Better results are expected to be presented at the conference.

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