MODELING DIFFERENT METEOROLOGICAL SITUATIONS IN CATALUNYA, SPAIN, WITH MM5 AND TAPM MESOSCALE MODELS

Cecilia Soriano[1], Rosa M. Soler[2], David Pino[3], Marta Alarcón[1], Bill Physick[4] and Peter Hurley[4]
[1]Universitat Politècnica de Catalunya (UPC). Barcelona, SPAIN
[2]Universitat de Barcelona (UB). Barcelona, SPAIN
[3]Institut d'Estudis Espacials de Catalunya (IEEC). Barcelona, SPAIN
[4]CSIRO Atmospheric Research. Aspendale, AUSTRALIA

INTRODUCTION

This contribution analyzes simulations of meteorological fields obtained with two different mesoscale models. One is MM5, the *Fifth-Generation Pennsylvania State University/ National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model, (Dudhia,* 1993), and the other is TAPM, *The Air Pollution Model*, developed at the CSIRO Atmospheric Research group, in Australia, (*Hurley et al.,* 2001).

One of the main differences between the two models used in this exercise is in the different computational resources that they need. In that sense, while MM5 is mostly run in the framework of workstations or supercomputers, TAPM runs on a personal computer. However, the approaches of the developers of the two models are quite different: MM5 is a mesoscale model that was originally intended for research purposes; TAPM has a more practical philosophy and is aimed at a wider group of non-specialized users, mainly from the environmental consulting community.

The study of different alternatives is interesting for environmental managers, because meteorological conditions prevailing during high pollution episodes are the most difficult to model with the computer tools presently available, and therefore practical approaches are required by administrators.

THE REGION UNDER STUDY

We examine here simulations performed in a zone located in the interior of Catalunya. The zone is characterized by its situation in an elevated plateau at about 600 m elevation, surrounded by elevated mountains (the Pyrenees to the north, with height above 2500m and the Montseny mountain range with elevation of about 1700 m in its SE boundary) and located about 60 km from the coastline. The communication with the coastal plain is almost limited to a narrow pass called "El Congost", only a few kilometers wide.

The region can attain high pollution episodes, mainly by ozone, during weak synoptic-scale meteorological conditions in summertime. Under such conditions, mesoscale circulations are prevailing and the establishment of a sea-breeze flow and its penetrations during the daytime is believed to advect air loaded with pollutants emitted in the Barcelona influence area (Soler *et al.*, 2002). Under wintertime situations, temperature inversions are frequent in the region due to the important nighttime cooling, preventing ventilation and circulation of air. Also, due to the prominent mountains surrounding the plateau, katabic winds develop and have been observed by a sodar device available in the region.

SIMULATION OF A SEA-BREEZE SITUATION (SUMMERTIME)

In order to check the capabilities of the two models of generating the mesoscale circulation developed by the local topography, a simulation has been carried out for June 21, 2001, a day with very weak synoptic forcing and development of terrain-related flows such as sea-breezes and mountain winds. In fact, for that day high levels of ozone were attained in several stations in the area, although they did not reach the warning level of 180 μg/m^3. Configuration details of the simulations are given in Table 1. Simulation with MM5 was carried out on an HP Exemplar V2500 and simulation with TAPM was performed on a Pentium III at 1Ghz. TAPM grids were more than three times larger than MM5's grids, but it still completed the simulations in almost one tenth of the time. A spin-up of one day was used with both models.

Table 1. Configuration of the simulations with the two models and simulation times

MODEL	#NEST	RESOLUTION (km)	NXxNY	NZ	TIMING RATIO
MM5	#4	27	31x31	26	1.5 sim/real
	#3	9	31x31		
	#2	3	31x40		
	#1	1	37x61		
TAPM	#4	12	55x80	30	0.17 sim/real
	#3	9	55x80		
	#2	3	55x80		
	#1	1	55x80		

Figure 1 shows horizontal cross-sections of winds simulated by the two models on the innermost grid for the first vertical level (approx. 10 m above the terrain) at 10 UTC. Both models generated the onset of a sea-breeze inland flow at that time of the day, (evident as a southerly wind in the lower part of the domains), but the penetration front of the breeze has not yet reached the plateau of the region under study, where very weak winds (typical of the nighttime regime) are present.

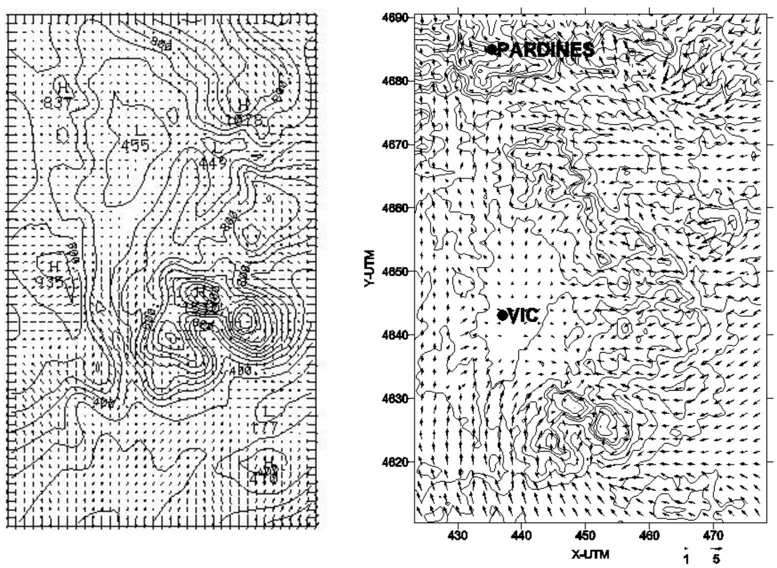

Figure 1. Simulated horizontals winds at approx 10-m above the terrain at 10 UTC on June 21, 2001, with MM5 (left) and TAPM (right). Horizontal resolution is 1km^2. Right panel also includes position of the two stations used for evaluation in Figure 3.

During the afternoon the sea-breeze front penetrates further inland, reaching the whole plateau, as seen in Figure 2. Winds are rather strong and direction rather steady during the whole afternoon and early evening. The advection of air by the incoming sea-breeze from the heavily-populated influence area of Barcelona has probably caused the high levels of ozone reached in the region during that day and shown in Figure 3.

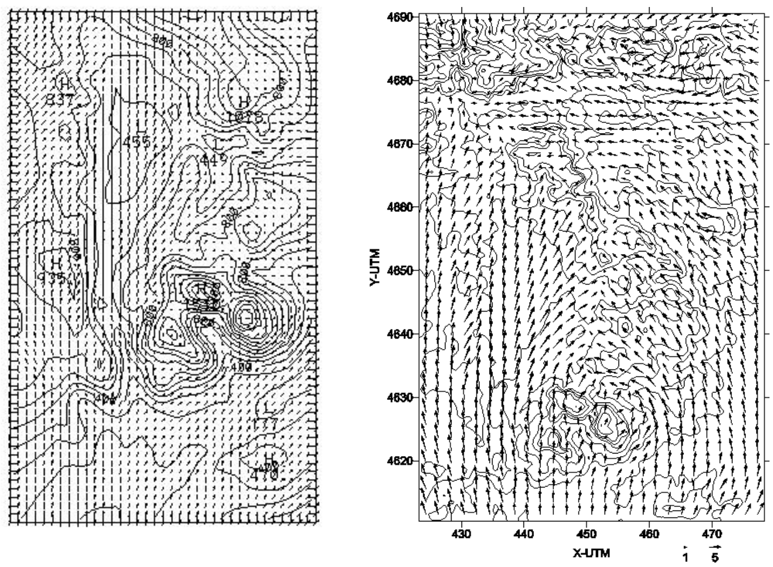

Figure 2. Same as Figure 1 but at 16 UTC on June 21, 2001.

A comparison of model surface winds with meteorological stations in the region has been performed for stations Vic and Pardines, and are shown in Figure 3. Positioning of the two stations in the inner domain of the TAPM simulation is shown on the right panel of Figure 1. Data for Pardines station in MM5 were extracted from the corresponding simulation cell of the domain with resolution 3x3 km^2, since it was located outside limits of the inner domain for that simulation.

The comparisons show that both models generate the daily evolution of the winds at the Vic station, with excellent timing as far as the arrival of the on-shore front. However, both slightly over predict wind speeds (by about 1-1.5 m/s) during the time of its maximum strength. Sea-breeze direction is well reproduced by both models, and directions during nighttime are very scattered due to the extremely low winds. TAPM also over-predicts night-time winds, specially at Pardines, which might have to do with the fine resolution of the grid (1 km versus 3 km for MM5) and the fact that the terrain is very steep in that location, which probably lead to enhancement of katabatic winds by the model . Terrain smoothing may decrease this effect.

Finally, back trajectories calculated from wind fields simulated with TAPM and shown in Figure 4 seem to confirm the advected origin (from the densely-populated area of Barcelona) of the ozone peaks observed in the region during the afternoon and early evening.

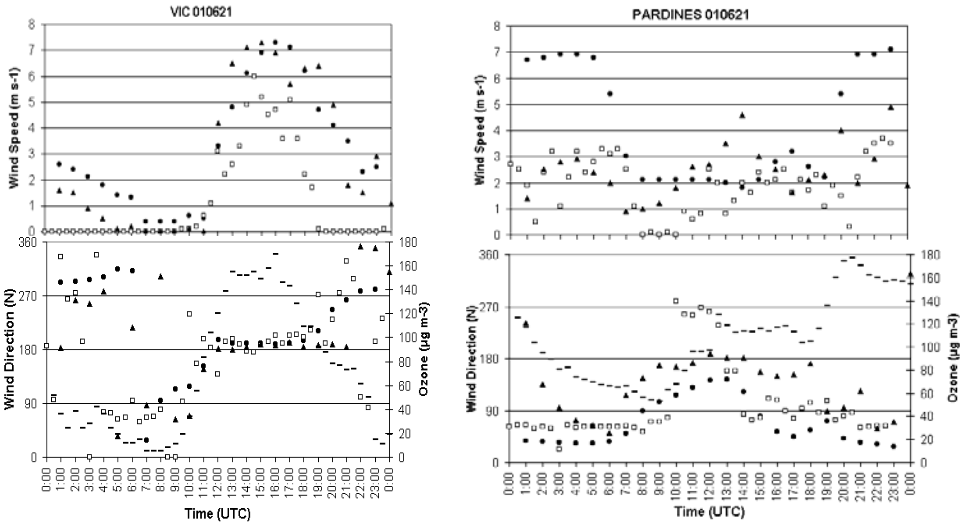

Figure 3. Evaluation of wind speed and direction with measurements at surface station at Vic(left) and Pardines (right) with MM5 (triangles) TAPM (circles) and measurements (empty squares). The wind direction panel includes ozone concentration measurements (horizontal bars), showing its important relationship with the wind regime.

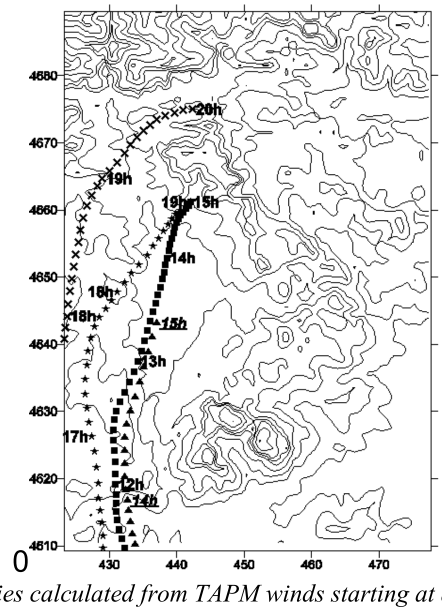

Figure 4. Back trajectories calculated from TAPM winds starting at different times and sites.

SIMULATION OF A DRAINAGE SITUATION (WINTERTIME)

The other day chosen for simulation with the two models corresponds to the night of the 10th to the 11th of February, 2001. The weak synoptic forcing and the intense cooling at night produce important katabatic winds in the slopes of the mountains surrounding the plateau, and an important drainage channeling at the exit of the narrow pass of El Congost. Figure 5 shows horizontal cross-sections of winds simulated by the two models for the first vertical level at 7 UTC. The data from the MM5 simulation were extracted from the 3x3km^2 domain, so that it could include the channeling at the exit of the narrow pass of El Congost. Both models also generated important downslope winds in all the mountains surrounding the plateau under study.

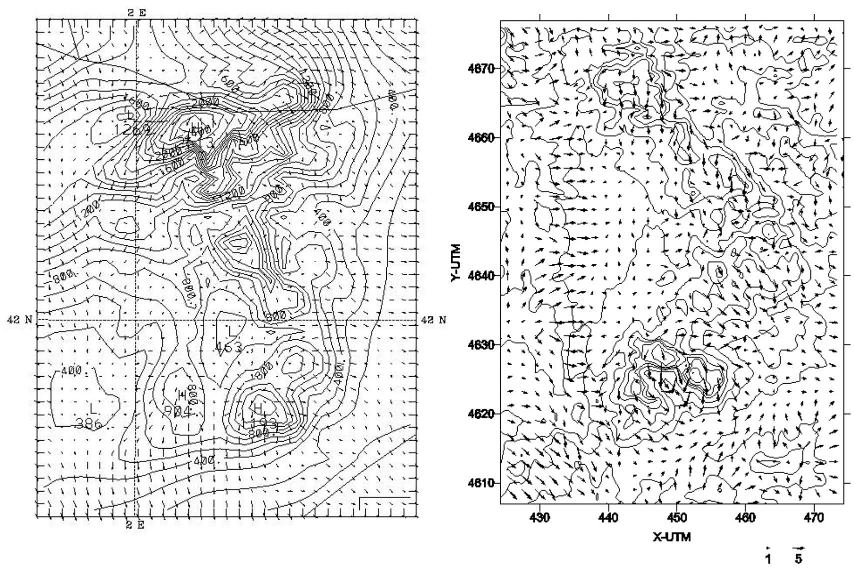

Figure 5. Simulated horizontal winds at approx 10-m above the terrain at 7 UTC on February 11, 2001, with MM5 (left) and TAPM (right). Horizontal resolution is 3 km^2 for the simulation with MM5 and 1 km^2 in the simulation with TAPM.

Vertical profiles of the winds generated by the two models have been compared with those acquired with a Sodar located very close to station VIC shown in Figure 1. Profiles represented in Figure 6 show the *u* and *v* components of the winds at 5 UTC. The representation of both components separately is useful in this case since it isolates the negative *v*-component of the wind and therefore helps to identify northerly winds characteristic of the drainage/katabatic regime.

Both models (maybe with better accuracy by MM5) have generated very low winds in the first meters above the terrain, followed by a layer of higher winds with negative *v* component, indicating a clear northerly flow, which is correlated with the direction corresponding to downslope winds in the region and that was detected by the Sodar. This layered behavior is confirmed by backtrajectories calculated from MM5 wind fields simulated in the 1x1 km^2 domain (not shown).

CONCLUSIONS

This work has shown simulations performed by two mesoscale models under two very different synoptic scenarios. Although the TAPM model is much more modest as far as computations resources needed for a simulation, results have shown that it is able to reproduce the circulatory patterns in the region and that results are not much different from those given by MM5, demonstrating thus its usefulness and accuracy for regional/mesoscale modeling and air pollution management.

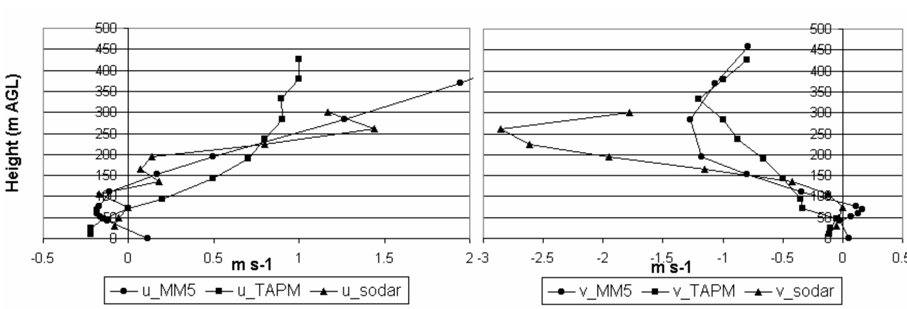

Figure 6. Simulated profiles of u and v wind components with MM5 (circles) TAPM (squares) at 5 UTC on February 11, 2001, compared to Sodar measurements (triangles).

One of the main conclusions of the study has been the confirmation in the region that air masses loaded with pollution generated in an area with strong anthropogenic emissions can travel inland and cause high pollution levels (specially photochemical pollution) many kilometers away from where they were generated.

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