MM5 fine scale simulations for the support of Athens 2004 Olympic Games: evaluation of the first year of operational activities

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1. Introduction

In spring 2001, the National Observatory of Athens (NOA hereafter) initiated an activity with the aim to provide accurate very fine resolution weather forecasts over the Athens area, Greece. The reason for such an activity at NOA was twofold:

- To assist operational weather forecasting over an area characterised by complex terrain and significant land–sea variability, where about the 35% of the Greek population lives and where the main national financial activities are taking place.
- To be prepared for the meteorological support of Athens 2004 Olympic Games, which are scheduled during August 2004. Although the main responsibility for this support is undertaken by the Greek National Meteorological Service, NOA will also play a role of assistance on this issue, mainly through the execution and evaluation of very fine grid simulations over the area.

For that purpose, NOA selected MM5 modelling system, which offers a great flexibility of choice of physical parameterisation schemes and it is used worldwide for a great variety of applications. This modelling effort follows the worldwide trend to use high-resolution numerical weather prediction models at operational basis, following the significant improvement of computing capabilities at prices that are continuously decreasing. Many previous studies found in literature (see Mass et al, 2002 for a comprehensive review of recent studies dealing with the use of very-high resolution modelling) show that increasing horizontal resolution could be very advantageous, especially in cases of circulations forced by topography and surface contrasts; the Athens area is a very good example of such characteristics. As it was stated by Mass et al (2002) however, the majority of these studies were based on the analysis of case studies and that only a few of them were based on an objective verification of longer periods. The present study describes a preliminary verification effort for the period June 2001-April 2002, but this effort will continue until 2004.

2. The Athens 2004 Olympic Games

All Olympic activities are scheduled to take place within the Athens basin (with the exception of some activities scheduled to take place in 4 provincial cities) in August 2004. The Athens basin includes the cities of Athens and Piraeus and is characterized by a relatively complex terrain (Fig. 1). It is surrounded by mountains on the three sides, while on the fourth side there is a major opening to the sea in the southwest (the Saronic Gulf). The three main mountains are Hymettus to the East, Penteli to the North and Parnitha to the Northwest. These mountains act like physical barriers on the flow with only small gaps between them while a role on the modification of the flow is also played by numerous hills located downtown Athens. The Korinthian Gulf (to the west of Athens basin) is surrounded by high mountains both to the north and to the south, which under specific conditions can result in a channelling of the flow towards the Saronic Gulf.

During August and September, three are the most threatening weather types that can have an impact on the normal execution of the Games:

- High surface temperatures (heat waves)
- Strong surface winds and
- Summer thunderstorms.

The statistical evaluation of MM5 forecasts presented in Section 4 mainly focuses on the ability of the model to provide accurate temperature and wind forecasts. The performance of the model for convective situations is currently under evaluation and the results will be presented in future communications.

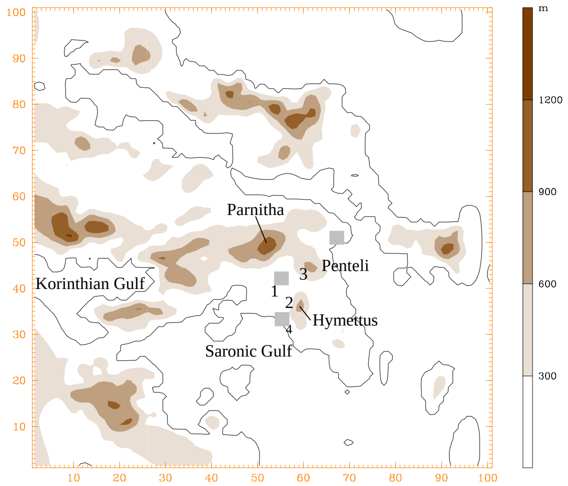

Figure 1: Topography of the Athens area, as resolved by MM5 Grid 3. Grey rectangles denote the location of the main Olympic venues. Numbers correspond to the four surface stations used for the verification (1: Thissio, located downtown Athens; 2: Zografou, located in the foothill of Hymettus; 3: Penteli, located in the foothill of Penteli; 4: Elliniko, located close to the coastline).

3. Model setup

MM5 model (Version 3) is a non-hydrostatic, primitive equation model using terrain-following coordinates (Dudhia, 1993). Several physical parameterization schemes are available in the model for the boundary layer, the radiative transfer, the microphysics and the cumulus convection. In order to select a combination of microphysical and convective parameterisation schemes that better reproduce wet processes, Kotroni and Lagouvardos (2001) performed a comparison of various combinations of schemes for cases with important precipitation amounts over E. Mediterranean. This comparison showed that the combination of Kain-Fritsch (Kain and Fritsch, 1993) parameterisation scheme with the recently implemented highly efficient and simplified microphysical scheme proposed by Schultz (1995) provides the most skilful forecasts of accumulate precipitation. For that reason, the operational chain of MM5 at NOA uses the combination of these two schemes. Concerning the choice of the PBL scheme, the current operational chain at NOA uses the MRF scheme. Experimentation with other available PBL schemes is under way.

Three one-way nested grids are defined and used at an operational basis since June 2001. Grid 1 has 24-km horizontal grid increment, covering the major part of Europe, the Mediterranean and the northern African borders. Grid 2 has 8-km horizontal grid increment, covering the Greek territory and all the Greek islands. Finally, Grid 3 has a 2-km horizontal grid increment, covering the entire Athens area and the adjacent water bodies. The horizontal extension of the 2-km grid is shown in Fig.1. In the vertical twenty-three unevenly spaced full sigma levels are selected (σ = 1., 0.99, 0.98, 0.96, 0.93, 0.89, 0.85, 0.80, 0.75, 0.70, 0.65, 0.60, 0.55, 0.50, 0.45, 0.40, 0.35, 0.30, 0.25, 0.20, 0.15, 0.10, 0.05, 0.00). It is expected that the number of vertical levels will increase in the near future, following the increase of computer capacity at NOA.

Grid 1 simulation lasts 72 hours, Grid 2 starts at t+6 with a total simulation time of 66 h and finally Grid 3 starts at t+18, with a total simulation time of 30 h. The 0000 UTC Medium-Range Forecast (Aviation run-AVN, provided by the National Centers for Environmental Predictions-NCEP, USA) gridded analysis fields and 6-hour interval forecasts, at 1.25 degree lat/lon horizontal grid increment, are used to initialise the model and to nudge the boundaries of Grid 1 during the simulation period. MM5 model is initiated as a “cold start” with no preforecast spin up period or assimilation of additional observations. The topography files are derived from a 30 arcsec resolution terrain data file provided by USGS. The sea-surface temperature analysis provided by the ECMWF (0.5 lat x 0.5 long resolution) is interpolated to the model grid. The main meteorological products are displayed on the Internet site: http://www.noa.gr/forecast together with maps of all available observations (surface reports, lightning impacts, satellite images), in order to have a first subjective verification of model results.

4. Statistical evaluation

In order to evaluate the model skill to provide accurate surface temperature and wind speed forecasts, a verification procedure has been undertaken for the period June 2001-April 2002. The mean absolute error (MAE) and mean error (ME) have been calculated at four main weather stations in Athens area (the location of the stations is given in Fig.1), by interpolating model fields to the observational location. The calculation of ME and MAE is made for Grid 2 (8 km) and Grid 3 (2 km) forecasts, permitting thus to assess the gain of using very fine grid simulations over the area.

Table 1 presents ME and MAE for the four stations of Grid 2 and 3 surface temperature forecasts. As it concerns temperature, MAE of Grid 2 forecasts at 1200 UTC (t+36) range between 2.11 and 3.27 °C in all 4 stations, while there is a substantial improvement of MAE from Grid 3 forecasts. It is obvious that the more detailed description of topography as well as the more accurate description of land-use (the existence of a large urban area which is much better represented in the 2-km grid) lead to improved temperature forecasts and this improvement is more evident on the two urban stations (Thissio and Zografou). The same improvement from Grid 3 forecasts is evident at 0000 UTC (t+48), while MAE values are better at t+48 than at t+36, since they correspond to nighttime forecasts. ME negative values in both grids evidence that there is a net cold bias of the model, bit this bias is lees pronounced in Grid 3 forecasts.

An example of the daily variation of observations versus t+36 forecasts from Grids 2 and 3, for Thissio station is presented in Figs. 2a and 2b. The period shown is split in two: June-October 2001 and November 2001-March 2002. During the warm period of the year (Fig. 2a), both grids underestimate the 1200 UTC temperature, but this underestimation is clearly more pronounced on the Grid 2 forecasts (grey line). It should be noted however, that both grids miss the highest observed values of 37-38 °C in July and this result dictates the need for additional efforts (through data assimilation techniques and/or post processing of forecast values with Kalman filtering) since such high temperatures can provoke serious problems to the major part of population, especially in large urban areas. During the cold period of the year (Fig. 2b) both grids forecasts are close to the observed values. Moreover, the ability of the model to catch the day-to day variability of surface temperature, even in cases of sudden changes, is evident.

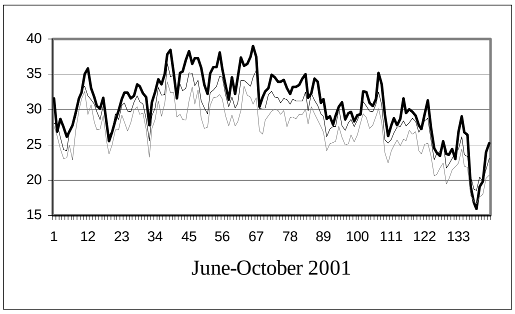

Figure 2a: Temporal evolution of 1200 UTC observed temperature at Thissio (bold line), Grid 2 (grey line) and Grid 3 (solid line) t+36 forecasts, for the period June-October 2001. Values on the vertical axis are in °C.

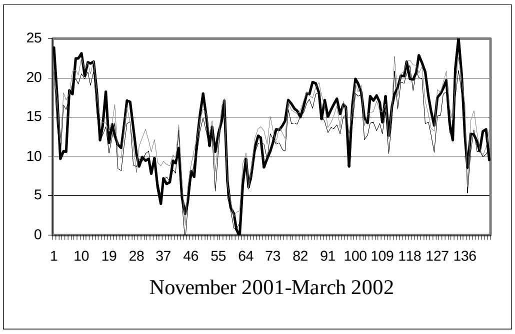

Figure 2b: As in Fig.2a, except for the period November 2001-March 2002.

As it concerns the evaluation of wind speed forecasts, the statistics in Table 2 show an improvement of forecasts when using fine grid forecasts (with the exception of the Penteli station where there is a slight decrease of skill for the Grid 3 forecasts).

Table 1: Mean error and mean absolute error of temperature (°C) forecasts at 1200 UTC (t+36) and 0000 UTC (t+48), for the period June 2001-April 2002. Bold letters indicate the best score of each category.

Temperature	ME at t+36		ME at t+48		MAE at t+36		MAE at t+48	
	Grid2	Grid3	Grid2	Grid3	Grid2	Grid3	Grid2	Grid3
Thissio	-2.35	**-0.42**	-2.68	**-1.39**	2.75	**1.70**	2.82	**1.86**
Zografou	-2.01	**-1.19**	-2.20	**-1.13**	2.42	**2.00**	2.39	**1.78**
Penteli	**0.**	-0.10	-0.38	**0.**	2.11	**2.05**	**1.65**	1.68
Elliniko	**-3.08**	-3.42	-2.34	**-1.92**	**3.27**	3.57	2.71	**2.51**

Table 2: Mean error and mean absolute error of wind speed (in m/s) forecasts at 1200 UTC (t+36) and 0000 UTC (t+48), for the period June 2001-April 2002. Wind data at Elliniko station at 0000 UTC were not available. Bold letters indicate the best score of each category.

Wind speed	ME at t+36		ME at t+48		MAE at t+36		MAE at t+48	
	Grid2	Grid3	Grid2	Grid3	Grid2	Grid3	Grid2	Grid3
Thissio	1.66	**0.12**	1.49	**0.47**	2.23	**1.51**	2.06	**1.50**
Zografou	0.77	**0.43**	2.43	**1.35**	1.91	**1.58**	2.52	**1.70**
Penteli	**0.18**	0.28	**1.25**	1.35	**1.77**	1.87	**2.37**	2.55
Elliniko	-0.01	**0**	-	-	1.96	**1.82**	-	-

5. Discussion-future work

Results from the first 11-month period of operational use of three-nested grid simulations with MM5 at NOA showed that this modelling system can provide useful and accurate weather forecasts that can meet the major part of needs for detailed forecasts required by such a major sport event as the Olympic Games. The statistical evaluation of Grid 2 forecast, compared to Grid 3 forecasts showed that there is a net improvement in forecast skill with increased resolution in most of the stations, especially for temperature at stations that are in highly urbanised areas. Although these first results are promising, there is a clear need to continue the evaluation of model performance during the remaining period of time until 2004. It is obvious that there is a need for a longer verification period (with at least two summer periods) and against more surface stations in order to derive more definite results about the ability of the model to provide accurate forecasts at 2-km grid increment. Post–processing of forecast data (with Kalman-type correction schemes) is also under investigation and the corresponding results will be presented in future communications. Moreover, the verification procedure will be expanded to include the ability of the model to capture the time and location of convective activity, which is not very frequent over the area during summer but when it occurs it can produce significant problems to everyday life but also to the normal execution of the Games.

6. References

Dudhia, J., 1993: A non-hydrostatic version of the Penn State/NCAR nesoscale model: validation tests and simulation of an Atlantic cyclone and cold front. *Mon.Wea. Rev.*, **121**, 1493-1513.

Kain, J.S., and J.M. Fritsch, 1993: Convective parameterization for mesoscale models: The Kain-Fritsch scheme. *The Representation of Cumulus in numerical models, Meteor. Monogr.*, No **46**, Amer. Met., Soc., 165-177.

Kotroni, V. and K. Lagouvardos, 2001: Precipitation forecast skill of different convective parameterization and microphysical schemes: application for the cold season over Greece. *Geoph. Res. Let.*, Vol. **108**, No 10, 1977-1980.

Mass, C. F., D. Ovens, K. Westrick and B. A. Colle, 2002: Does increasing horizontal resolution produce more skillful forecasts? *Bull. Amer. Meteor. Soc.*, **83**, 407-430.

Schultz, P., 1995: An explicit cloud physics parameterization for operational numerical weather prediction. *Mon. Wea. Rev.*, **123**, 3331-3343.