H13-156
IMPACT OF HORIZONTAL GRID RESOLUTION ON AIR QUALITY MODELING: A CASE STUDY OVER ITALY

Mihaela Mircea[1], Andrea Cappelletti[2], Gino Briganti[2], Lina Vitali[1], Giandomenico Pace[1], Pietro Marri[2], Camillo Silibello[3], Sandro Finardi[3], Giuseppe Calori[3], Gabriele Zanini[1]

[1]ENEA, National Agency for New Technologies, Energy and Sustainable Economic Development, via Martiri di Monte Sole 4, 40129, Bologna, Italy
[2]ENEA, National Agency for New Technologies, Energy and Sustainable Economic Development, via Vasco Viviani 23, 56124, Pisa, Italy
[3]ARIANET Srl, Via Gilino, 9, 20128, Milan, Italy

Abstract: The results of air quality models are highly influenced by meteorology and emission inventory. At high spatial resolutions, the meteorological models can capture in a more realistic way the effect of the orography, the interactions between soil/vegetation and atmosphere, the dynamics of the boundary layer, the sea-breezes circulation in the coastal zones, the formation and evolution of clouds and precipitation, etc. Moreover, the emissions produced using local information can capture better both the spatial and temporal distribution of pollution. This study investigates the change in pollutant concentrations in relation to the change of horizontal grid resolution. The analysis is carried out for stations located in zones with different geographic characteristics (mountain, coast, etc) and of different types (rural, urban). The simulations are performed with the Atmospheric Modelling System (AMS), part of the MINNI modelling system (Italian Integrated Assessment Modelling System), for emissions based on municipal and provincial inventories.

Key words: *air pollution, ozone, model validation, horizontal spatial resolution.*

INTRODUCTION
The air pollutant concentrations are determined by extremely complex relations between emissions, multiple chemical reactions and/or physical processes, transport, diffusion and deposition phenomena. While it is intuitively logical that different modelling systems with different chemical, physical, mathematical and numerical representation of these processes produce different pollutant concentrations and, thus, lead to different policy recommendations, it is less obvious the dependence of pollutant concentrations on the scale of application. Modelling air quality at local scales requires very fine resolutions, which increases substantially the computational cost with respect to regional scales. Since nowadays, the advancement of computer technology allows such local studies, the modelling efforts investigating bridging over multiple spatial and temporal scales are intensified.

This study shows the impact of grid resolution on photochemical modelling of tropospheric ozone over Italy. Several yearly simulations were carried out with the atmospheric modelling system (AMS) of MINNI (National Integrated Modelling system for International Negotiation) project (Zanini *et al.*, 2005) for 20kmx20km and 4kmx4km horizontal grid resolutions. More details about AMS components can be found in Briganti *et al.* (2010). The formation and destruction of ozone are described by means of SAPRC-90 photochemical mechanism (Carter, 1990). The simulated concentrations of ozone were compared with the measured ones at stations of different types: rural and urban and located in zones with different geographic characteristics (mountain, coast). The results reported here refer to simulations carried out for July, 1999.

METHOD
Three simulations were conducted with the AMS of MINNI project: one over the whole Italy with horizontal spatial resolution of 20kmx20km (IT), five over sub-domains including respectively north of Italy (NIT), centre of Italy (CIT), south of Italy (SIT), Sardinia and Sicily islands with horizontal spatial resolution 4kmx4km. The meteorological fields for IT simulation were produced with the prognostic meteorological model RAMS (Cotton *et al.*, 2003) using the European Centre for Medium Range Weather Forecast (ECMWF) analysis at 0.5 degrees and 6 h resolution for the initial and boundary conditions. The meteorological fields for the simulations on sub-domains (NIT, CIT, etc) were downscaled from the meteorological fields predicted by RAMS at 20kmx20km spatial resolution by means of the diagnostic meteorological model LAPS (Local Analysis and Prediction System) (McGinJey *et al.*, 1991). The downscaling approach was chosen since it is computationally inexpensive. Moreover, if proper meteorological observations are used, it can furnish a satisfactory representation of the local meteorology.

The anthropogenic emission used for the simulation IT was derived from the diffuse emissions inventory at provincial level (APAT, 2000), while the ones for NIT, CIT and SIT simulations are based on a version of the same inventory scaled down to municipalities using a set of proxies. For the other countries included in the IT simulation domain, the emission inventory EMEP 1999 was used. The EMEP model (Simpson *et al.*, 2003) at 50 km horizontal resolution provided the initial and boundary conditions for IT simulation, while NIT and CIT simulations were nested into IT grid. The same biogenic emissions were used in all simulations (Briganti *et al.*, 2010). The evaluation of hourly ozone concentrations predicted by the AMS was performed at 8 monitoring stations (Figure 1), three rural and three urban (Table 1), one mountain station– Monte Gazza (7) and one coastal station – Chiaravalle (8).

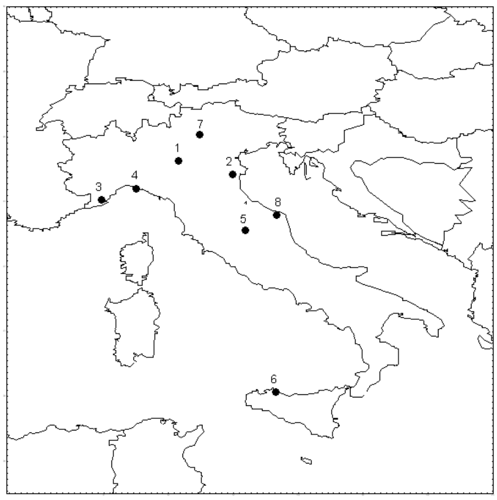

Figure 1. Ozone monitoring stations used in this study.

Table 1. Geographical coordinates of the ozone monitoring stations shown in Figure 1.

	Station name	Station type	lon	lat
1	Gambara	rural	10°17'	45°14'
2	Gherardi	rural	11°57'	44°50'
3	Pieve di Teco	rural	7°54'	44°2'
4	Quarto	urban	8°59'	44°23'
5	Cortonese	urban	12°21'	43°6'
6	Bocca di Falco	suburban	13°18'	38°12'

RESULTS AND DISCUSSION

Figure 2 shows the ozone concentrations measured and simulated at urban and rural monitoring stations (Table 1, Figure 1) for the 14 - 19 July 1999 period. At Quarto station, the simulation with finer resolution (NIT) captures better the maximum ozone concentrations on 15, 16 and 17 July. Similar results are observed at Gambara station, while for the other stations no particular improvement is visible. On the contrary, at Pieve di Teco, the ozone concentrations predicted by the finer resolution simulation (NIT) are much worse than those predicted by IT simulation: the daily ozone cycle is not reproduced by the model from 16 to18 July. The results of finer simulations are also worst at Bocca di Falco, especially in the morning and in the evening.

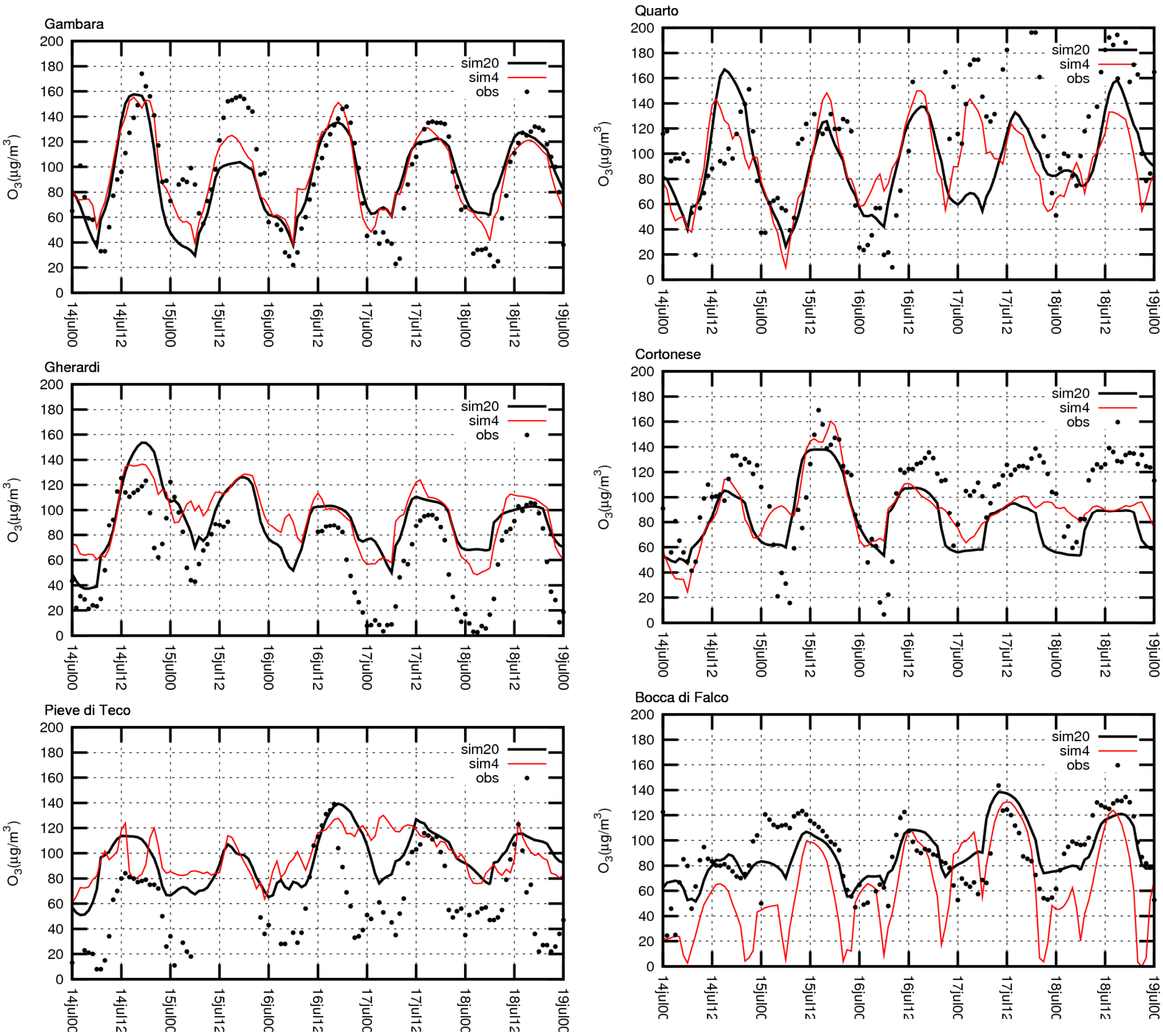

Figure 2. Hourly ozone concentrations measured (dots) and simulated (lines) for 14 – 19 July 1999, for two spatial resolutions: 20kmx20km (sim20) and 4kmx4km (sim4), at monitoring stations shown in Table 1.

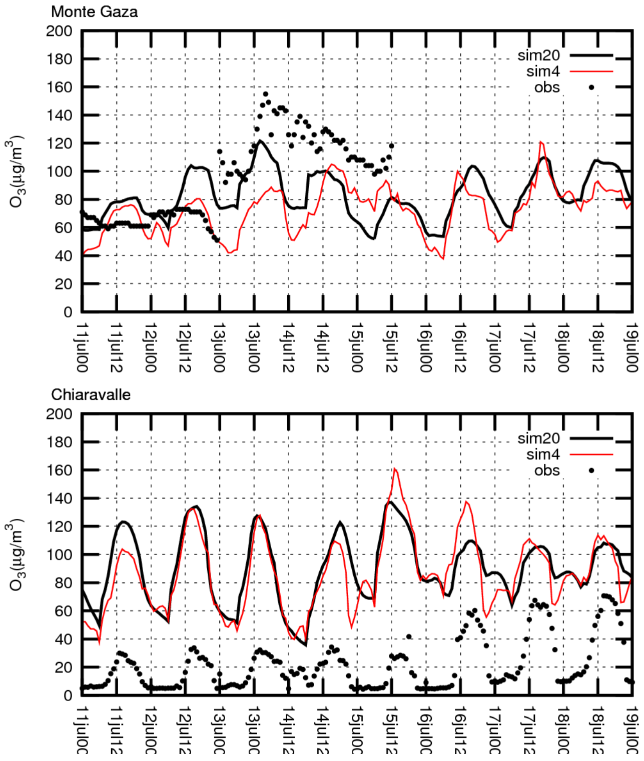

Figure 3 shows the ozone concentrations measured and simulated at Monte Gaza (mountain) and Chiaravalle (coast) stations (Figure 1) for the 14 - 19 July 1999 period. A slight improvement in simulated ozone concentrations can be observed at Monte Gaza on 12 and 14, 15 July, while at Chiaravalle all the simulations highly overestimate the observed concentrations. The relative good model results obtained at Monte Gaza stations can be due to the fact that, even if the station is located at 1601 m height in a complex orography, it is far from anthropogenic emission sources (it is classified as a rural site) and, thus, less affected by errors in emissions inventory. Chiaravalle station is located at 15 m above sea-level, in a flat terrain, not far from Adriatic Sea coast (less than 10 km), in a suburban area. In this case, given the fact that the station is located in the vicinity of an urban area, the systematic overestimation of ozone concentrations by all simulations suggests that some emissions are lacking in anthropogenic inventories of ozone precursors. It has to be noted that Chiaravalle measures ozone levels much lower than all the other considered stations. This behaviour should be justified by different meteorological conditions or, as previously mentioned, station exposure to local emissions.

Figure 3. Hourly ozone concentrations measured (dots) and simulated (lines) for 11 - 19 July 1999 for two spatial resolutions: 20kmx20km (sim20) and 4kmx4km (sim4) at monitoring stations: Monte Gaza (mountain) and Chiaravalle (coast) (numbered 7 and 8, respectively, in Figure 1).

Figure 4 shows ozone concentrations and surface winds for July, 15 at 14:00, for the simulations NIT and CIT (upper and middle graphs) and for the simulation IT (lower graphs). It can be noted that spatial variability of ozone is different in the NIT and CIT simulations with respect to IT simulation: the former simulations show more areas with high ozone concentrations. The increase in concentration for the simulations with finer resolution is from 20 to 40 $\mu g/m^3$ for NIT simulation with respect to IT, and higher in the case of CIT simulation. However, none of the monitoring stations were located in these areas and this explains the little difference between the ozone concentrations simulated with coarse and fine grids shown in Figures 2 and 3. The similarity of the wind pattern and intensity for the coarse and fine grid simulations also suggest that the differences in simulated ozone concentrations at the monitoring stations could be mainly due to the emission inventories than to meteorology. The consistency and the similarity of meteorological fields for the coarse and fine grid simulations, and with observations is extensively presented in Vitali *et al.* (2008, 2010)

Table 2. Quantitative model performance statistics for hourly surface ozone at stations, for July, 1999.

	Station name	Station type	20kmx20km		4kmx4km	
			MNBE	MANGE	MNBE	MANGE
1	Gambara	rural	-6.99	18.01	-9.29	19.03
2	Gherardi	rural	10.41	13.88	10.41	14.02
3	Pieve di Teco	rural	7.66	14.02	-4.46	18.41
4	Quarto	urban	-25.18	28.93	-29.68	32.32
5	Cortonese	urban	-19.96	22.45	-14.92	23.3
6	Bocca di Falco	suburban	-18.05	21.81	-38.05	39.24

Table 2 shows two statistical measures: MNBE (Mean Normalised Bias Error) and MANGE (Mean Absolute Normalised Gross Error), which are usually used to assess air quality model performances, computed for July at all the stations described in Table 1, for the coarse and fine grid simulations. These statistics do not show substantial variation at rural stations, but they have substantially increased at urban stations for fine grid simulations. This indicates that the municipal emission inventories could be more affected by errors than the provincial one. The MNBE and MANGE were not calculated for Monte Gaza e Chiaravalle since the number of observations were too small to be statistically relevant.

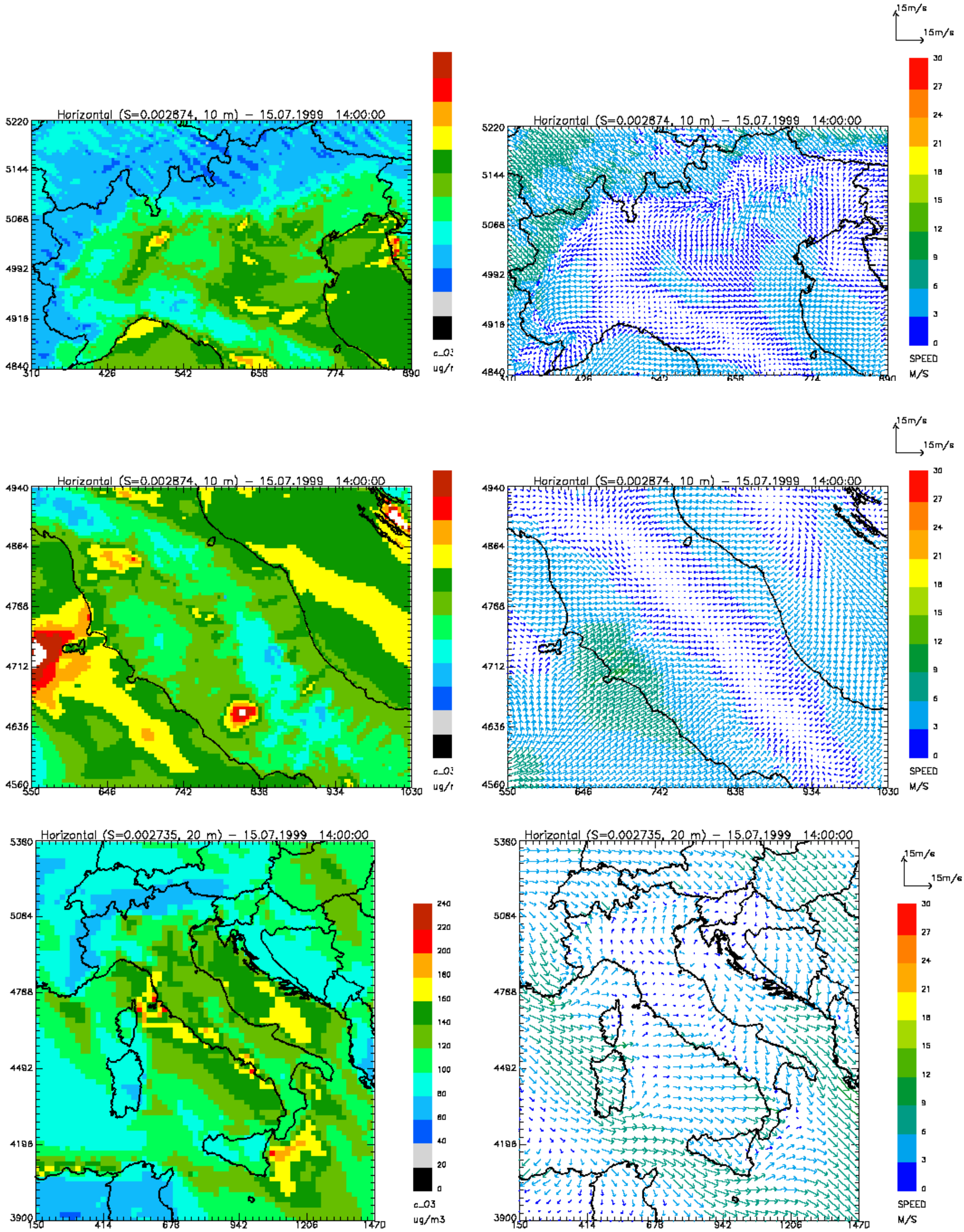

Figure 4. Ozone concentrations and surface winds for July, 15 at 14:00: upper and middle graphs for the simulations with spatial resolution 4kmx4km and lower graphs for the simulation with spatial resolution 20kmx20km.

CONCLUSIONS

This work shows the effect of grid resolution on ozone concentrations over the north and centre of Italy, at rural and urban sites, at a mountain and a coastal site. While it is obvious that finer grid resolutions are able to better resolve inhomogeneities in emission rates, land cover and dispersion (Figure 4), no systematic improvement of calculated statistical scores at monitoring stations used in this study is observed (Table 2). On the contrary, at the urban stations, the MNBE and MANGE are worse for finer grid resolution than for the coarse one. However, the direct comparison of model results with observations shows that finer resolution grids improve model predictions for some particular days, at same sites (see 17 July at Quarto). All these results are in agreement with results from other studies (Cohan *et al.*, 2006; Arunachalam *et al.*, 2006; Kundan Lal *et al.*, 2009), which underline the dependency of the results on particular situations (day, location) and reconfirm the necessity for further attainment studies.

ACKNOWLEDGEMENTS

This work is part of the MINNI (Integrated National Model in support to the International Negotiation on Air Pollution) project, funded by the Italian Ministry for Environment and Territory and Sea and carried out by ENEA.

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