H13-155

TESTING THE CAPABILITY OF THE MINNI ATMOSPHERIC MODELING SYSTEM TO SIMULATE AIR POLLUTION IN ITALY

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Abstract: MINNI is the Italian Integrated Assessment Modelling System for supporting the International Negotiation Process on Air Pollution and assessing Air Quality Policies at national/local level sponsored by the Italian Ministry of the Environment. MINNI system is made up by two components: an Atmospheric Modelling System (AMS) and a Greenhouse Gas Air Pollution Interactions and Synergies model over Italy (GAINS – Italy). This presentation describes the AMS components: the emission processor (EMMA), the meteorological model (RAMS) and the air quality model (FARM), and shows an extensive validation exercise over Italy.
The simulations were carried out for a whole year, and the AMS ability to predict ozone formation and destruction under different conditions of sun light and temperature, for different seasons was evaluated. The modelled ozone concentrations were compared to surface measurements and statistical indicators such as mean normalized bias error (MNBE), mean absolute normalised gross error (MANGE) and unpaired peak estimation accuracy (UPA) were calculated for the all stations. The results show that the model is able to reproduce temporal evolution and spatial distribution of ozone concentration. The statistical indicators show that AMS performs generally well, simulating the ozone concentrations better during summer rather than winter, and better at rural stations rather than at urban ones.

Key words: *air pollution, ozone, model validation.*

INTRODUCTION

Ozone (O_3) is produced in the troposphere by the photochemical reactions of nitrogen oxides (NOx) and volatile organic compounds (VOC). In the last century, the economic and industrial development had lead to a substantial increase of average surface ozone concentrations with respect to the late 1800s (Volz and Kley, 1988; Anfossi and Sadroni, 1997), reaching levels that are potentially harmful to human health, vegetation and materials. Numerous 3-D air quality models (Zhang *et al.*, 2009; Bessagnet *et al.*, 2009; Mircea *et al.*, 2008; Baker and Scheff, 2007, etc) have been developed to simulate the formation and fate of O_3 on regional scales and significant progress was achieved in reproducing ozone pollution episodes, but the modelling efforts will continue since the complex interplay between meteorological conditions, pollutant emissions and photochemical processes is not fully understood yet.

This study shows results from a full year simulation with the Italian Integrated Assessment Modelling System for supporting the International Negotiation Process on Air Pollution and assessing Air Quality Policies at national/local level (MINNI). Simulated concentrations of O_3 are evaluated against measurements from ground based monitoring network. The domain of simulation covers the Italian peninsula, including the islands: Sicily and Sardinia. The objectives of this study are to evaluate the modelling system capability to reproduce regional air pollution and to understand the model performances in relation to meteorological conditions and monitoring station characteristics/type.

MINNI ATMOSPHERIC MODELLING SYSTEM – DESCRIPTION AND CONFIGURATION

The MINNI system (Zanini *et al.*, 2005) is made up of two main components: an Atmospheric Modelling System (AMS) and a Greenhouse Gas Air Pollution Interactions and Synergies model over Italy (GAINS – Italy). The main AMS components are: the EMMA emission processor, the RAMS meteorological model and the FARM air quality model.

The emission processor EMMA (EMission MAnager) (ARIANET, 2006) generates hourly emissions in every cell of the simulation domain for the photochemical mechanism SAPRC90, splitting the annual data from the emission inventories by applying daily, weekly and seasonal activity profiles (Monforti and Pederzoli, 2005), gridded spatial proxies and activity-related speciation profiles.

The meteorological fields were produced with the prognostic, non-hydrostatic meteorological model RAMS (Cotton *et al.*, 2003), which was run in a 2-way nested grid system: the outer grid covering a large part of Central Europe and the Mediterranean Sea, with a resolution of 60kmx60km and an inner grid including the simulation domain.

The air quality model FARM (Silibello *et al.*, 2008) is a three-dimensional Eulerian model dealing with the transport and the multiphase chemistry of pollutants in the atmosphere. Gas-phase reactions are described by means of SAPRC-90 chemical scheme (Carter, 1990). The dispersion and transport of the pollutants was derived from STEM-II (Carmichael *et al.*, 1998).

The modelling system has been being used for simulating air quality in Italy for several years, and some outcomes of the application to year 1999 are discussed here. The simulations were carried out with the spatial resolution of 20kmx20km, over the whole of Italy including the islands. RAMS model used the European Centre for Medium Range Weather Forecast (ECMWF) analysis at 0.5 degrees and 6 h resolution for initial and boundary conditions.

The anthropogenic emission inventory used in this study over Italy was derived from the emissions for major point sources and for the diffuse sources at provincial level (APAT, 2000). These emissions are classified according to activity level CORINAIR/SNAP (CO-oRdinated INformation on the Environment in the European Community AIR / Simplified Nomenclature for Air Pollution). For the anthropogenic sources of other countries included in the simulation domain the EMEP emission inventory for 1999 was used. The biogenic emissions had also two sources: APAT 2000 over Italy and a global database (Guenther *et al.*, 2005) for the other countries. The emissions fields also include the maritime activities, the ship emissions on the national and international sources and the port areas. The diffuse emissions and the minor point sources are distributed in the lowest model layers of FARM model (below 50 m) with 80% in the first 20 m above ground. The point sources such as industries, power plants, volcanoes, etc., are treated individually in FARM, considering the plume rise effect.

Model evaluation with surface measurements

In this study, the ozone concentrations simulated by the MINNI atmospheric modelling system were compared to data from BRACE, a national database including information from the main monitoring networks distributed over the country.

Here are presented the results for a selection of background stations, located in rural, urban and suburban zones. Table 1 shows the names and geographical coordinates of the stations, while their location on the maps is shown in Figure 3.

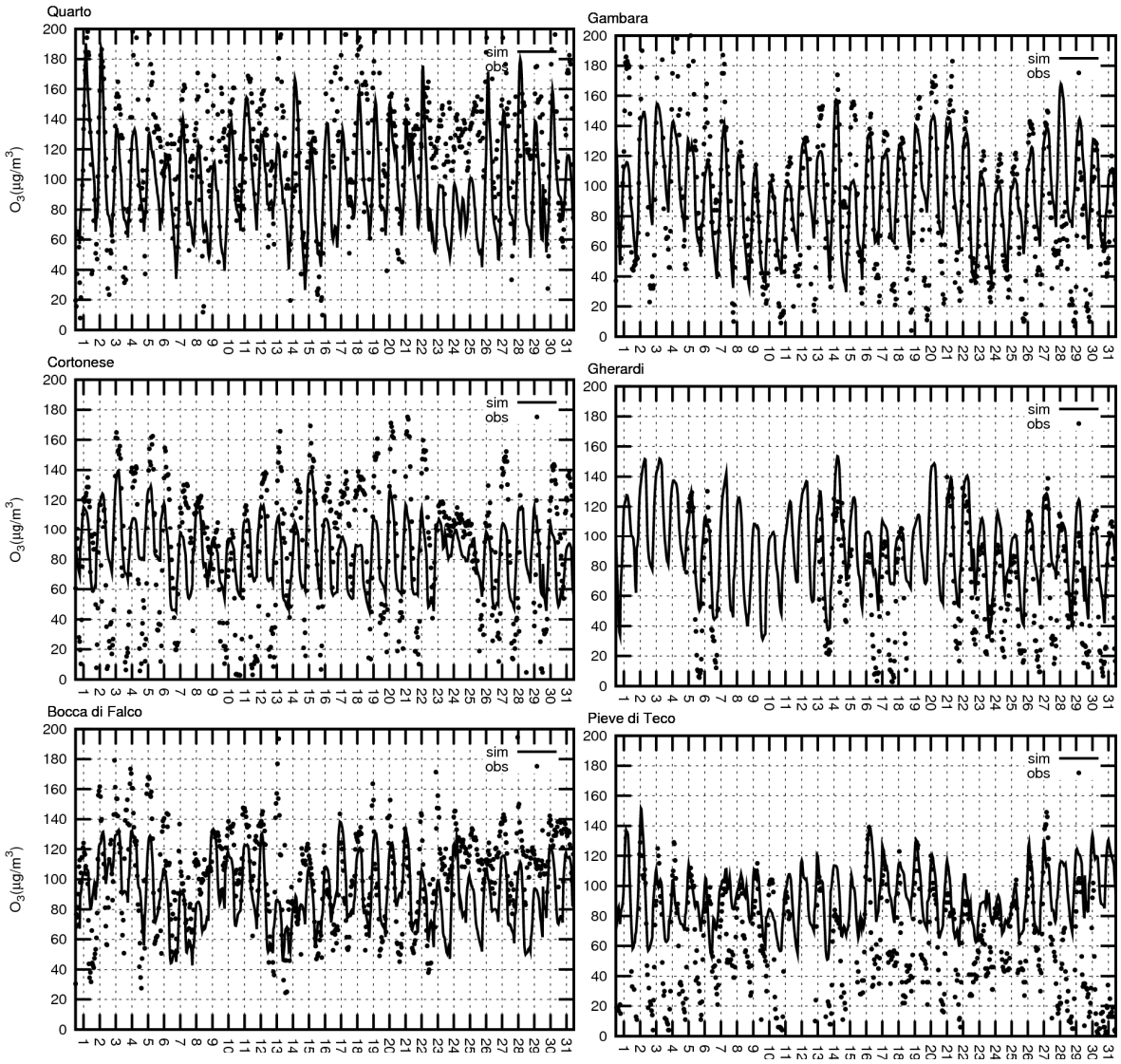


Figure 1. Hourly ozone concentrations measured (dots) and simulated (lines) for July 1999 at monitoring stations.

Figures 1 and 2 show the simulated and measured hourly ozone concentrations as a function of time for two months: July and February, respectively. The modelling system reproduces the maximum hourly ozone concentrations and the daily ozone cycle relatively well for both months, particularly at rural stations. The difference in the model performances at rural stations with respect to urban stations is explained by the low spatial resolution used in the simulation, which artificially creates a dilution of the ozone precursors NOx and VOC in the grid cell determining, thus, low ozone production rates. On the other hand, the measurements made at urban stations show high variability indicating that they are strongly influenced by traffic emissions, which can not be adequately described spatially and temporally in the provincial emission inventory.

Table 1. Geographical coordinates of the ozone monitoring stations.

	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'

In July (Figure 1), the simulated concentrations are lower than the observed ones during the day and and higher during the night. The overestimation of observed ozone concentrations at night-time is a known problem of air quality models, and several factors such as boundary layer height, night chemistry of ozone and NOx (NO titration, in particular) and emission inventory can be responsible for this model behaviour. Moreover the simple station classification is not always coherent with their actual exposure to local and regional sources, e.g. Quarto and Bocca di Falco, that are classified as urban and suburban respectively, show a behaviour expectable for rural background stations, with limited day/night variation of ozone measurements and nightly values well above zero, while Pieve di Teco, classified as rural shows very low nightly values during both summer and winter, as expectable from station directly expose to NOx emissions and affected by titration.

In February, the model reproduces the measurements at Gambara, Gherardi and Bocca di Falco stations fairly well and it highly underestimates the ozone at Quarto station. The high concentrations of ozone observed at Quarto station during the winter and summer suggest that this location is highly influenced by local emissions, which are not included in the emission inventor

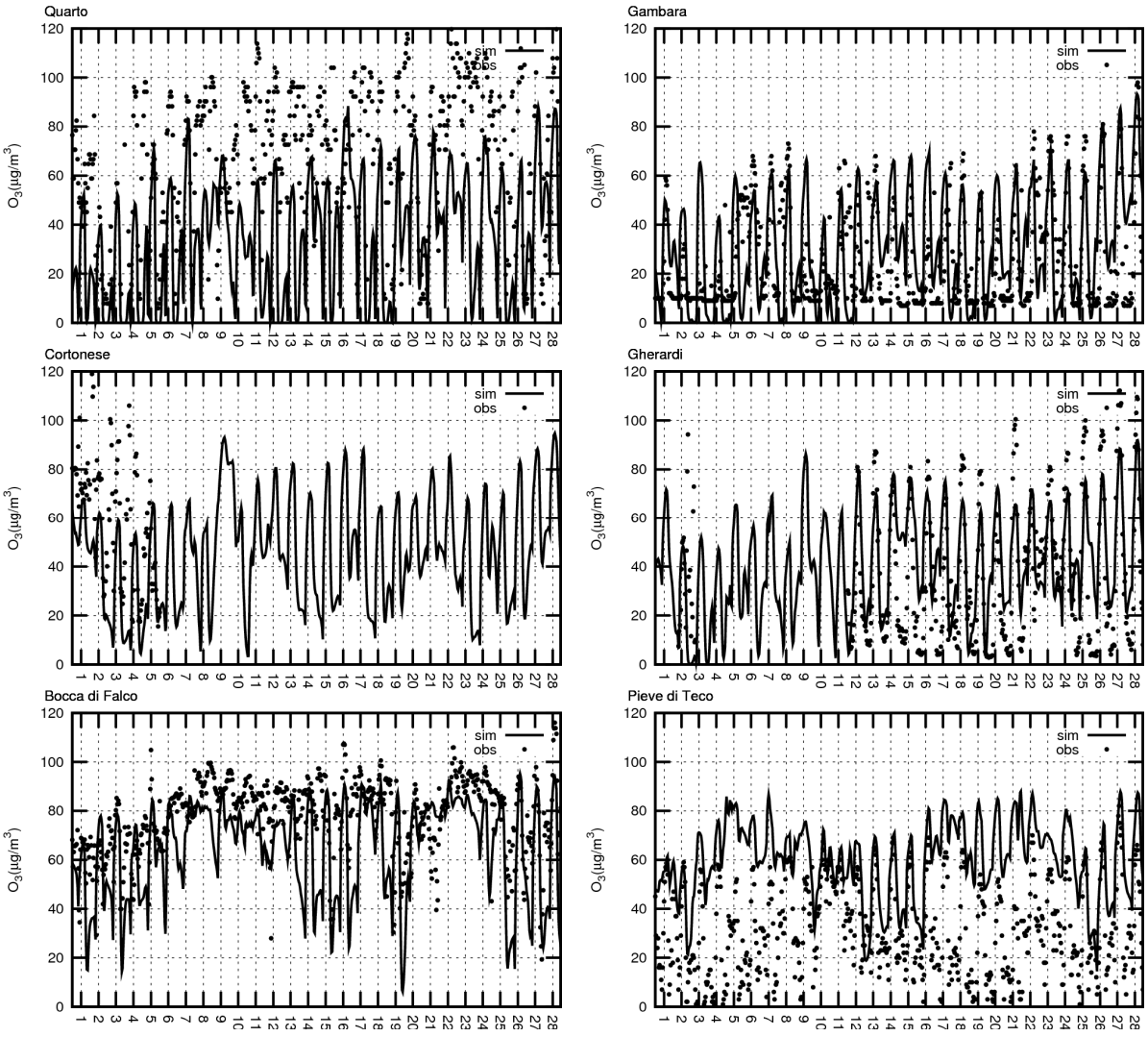
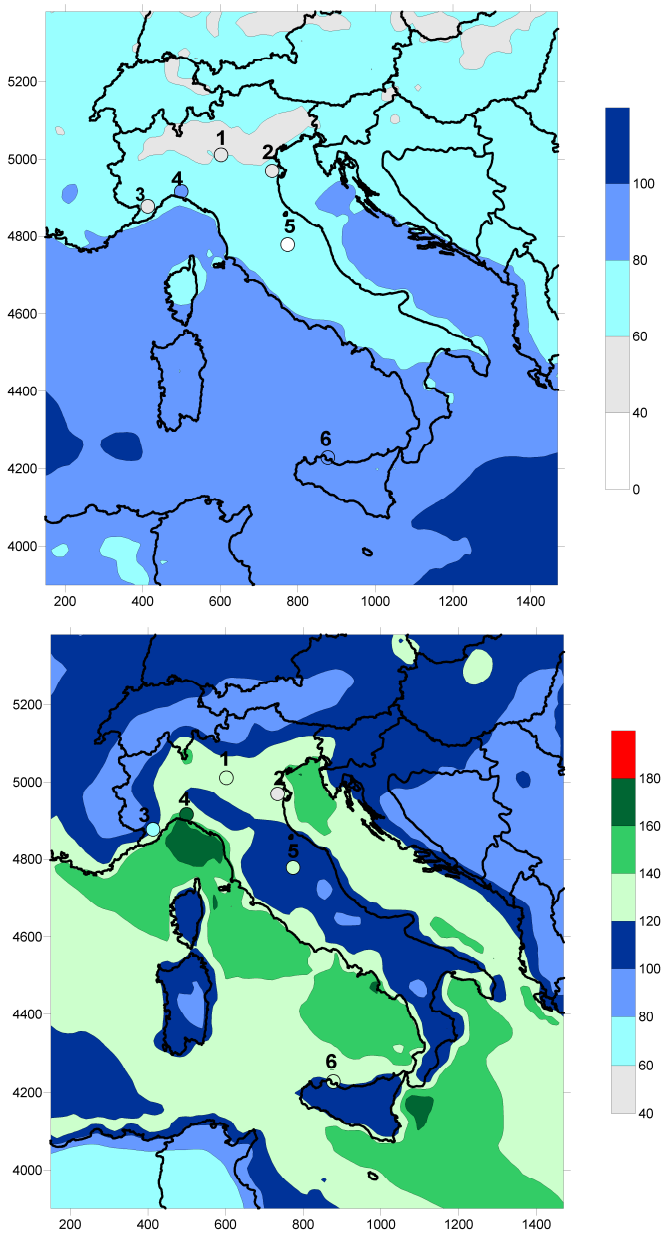


Figure 2. Hourly ozone concentrations measured (dots) and simulated (lines) for February 1999 at monitoring stations.

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 and February at all stations described in Table 1. These statistics confirm that the modelling system behaves better at rural stations than at urban ones for 20kmx20km model resolution, and it behaves better during summer than winter. At rural stations, the model fulfils the US-EPA (US-EPA, 2005) criteria: MNBE is lower than 15% and MANGE is lower than 30-35%.

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

	Station name	Station type	July		February	
			MNBE	MANGE	MNBE	MANGE
1	Gambara	rural	-6.99	18.01	-1.92	5.18
2	Gherardi	rural	10.41	13.88	-22.96	23.06
3	Pieve di Teco	rural	7.66	14.02	1.57	1.57
4	Quarto	urban	-25.18	28.93	-50.81	50.85
5	Cortonese	urban	-19.96	22.45	-53.13	53.13
6	Bocca di Falco	suburban	-18.05	21.81	-17.42	17.99



For 1-4 July 1999, a clear sky period, both the time series of ozone concentrations (Figures 1 and 2) and the statistical scores (not shown) are similar to those shown by Mircea *et al.* (2008).

Figure 3 shows the observed and simulated monthly mean surface maximum 8h-average O_3 concentrations for February and July, 1999. In February, the best agreement between model simulation and measurements is obtained at Bocca di Falco and Gambara. At Quarto, the simulated concentration is lower than the measured one of 20 $\mu g/m^3$ and, for the remaining stations, ozone concentrations are overestimated by 20 $\mu g/m^3$.

For July, model and measurements are in agreement at Bocca di Falco, Gambara and Quarto, and for the other stations, the differences between model and measurements are higher than 20 $\mu g/m^3$.

This confirms the tendency of the modelling system to generally overestimate the maximum ozone concentration.

CONCLUSIONS

The results of this study show that the modelling system is able to simulate the daily ozone cycle and the maximum hourly ozone concentrations.

The statistical indicators show that AMS performs generally well, simulating the ozone concentrations better during summer than winter, and at rural stations rather than at urban ones.

The monthly mean surface maximum 8h-average O_3 concentrations are also reproduced by the modelling system: the differences between observed and simulated monthly mean surface maximum 8h average O_3 concentrations for both February and July are ca. 20 $\mu g/m^3$.

Figure3. The observed and simulated monthly mean surface maximum 8h average O_3 concentrations for February (upper graph) and July (lower graph), 1999.

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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