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IMPACT OF METEOROLOGICAL MODELLING ON AIR QUALITY: SUMMER AND WINTER EPISODES IN THE PO VALLEY (NORTHERN ITALY)

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Abstract: The Po-valley in Northern Italy has been identified as a hot spot area in Europe where pollutant levels are expected to remain problematic in the years to come despite the application of the legislation devoted to air pollution control. High anthropogenic emissions in combination with frequently occurring stagnant atmospheric conditions cause very high PM concentrations in winter and high ozone episodes in summer. Model capabilities to reproduce observed concentrations in this area were analysed in the frame of the POMI project (Po Valley Model Inter-comparison exercise) where the model MM5 has been used as meteorological driver as input to 6 different chemical transport models.Sensitivity tests for one winter month have shown that the nudging of observational data into MM5 does significantly improve the simulation of frequent low wind regimes in the Po Valley, and as a consequence in certain conditions increases and improves modelled PM_{10} concentrations.

The focus of this work is to extend the study and assess the effect of MM5 nudging options during summer. We analyse here the impact of different observation nudging options (three-dimensional analysis nudging, two- dimensional analysis nudging and direct surface observations nudging, as well as combinations of these methods) on simulated PM_{10} and summer O_3 concentrations using the CHIMERE model.Strengths and weaknesses of nudging approaches in meteorological modelling in one of the most polluted and complex topography areas in Europe are discussed.

Key words: *MM5, nudging, fdda, Chimere, wind, meteorology, PM_{10}, Ozone, Po valley.*

INTRODUCTION

The POMI project (http://aqm.jrc.it/POMI) outcomes confirm the difficulties of the various chemical models to reproduce the pollutants behaviour in the Po valley. Among others, one of the reasons relates to the difficulties of prognostic models to reproduce the local, generally low, ventilation. The fifth Generation Mesoscale Model (MM5) (Grell et al. 1995) gives the possibility to nudge observations into the model, so that the final analysis is more consistent with reality (Stauffer et al. 1991). In previous works (Pernigotti et al. 2010) we verified that this technique produce more accurate low-level wind field (Stauffer and Seaman 1994) and locally strong effects on PM10 concentrations modelled by the MM5-CHIMERE model chain in January 2005. With this work we extend the study to a summer case, June 2005. Both the considered periods are characterized by high pressure and stable weather conditions for most of the time.

EXPERIMENTAL SET-UP

MM5 is used on two nested grids, both based on the central Po valley. The mother domain (D1) has a resolution of 18km and covers an area of 900x900km; the daughter domain (D2) has a resolution of 6km and covers northern Italy including the Alps (an area of 580x420km, Figure 1). The vertical grid has 23 levels, in sigma coordinates from surface to 100hPa. The boundaries, initial and first guess conditions are taken form NCEP (United States National Centers for Environmental Prediction) Global Tropospheric Analysis (1^ox1^o resolution every 6 hours, in the following called NCEP). For the year 2005, in the framework of the POMI Project (http://aqm.jrc.it/POMI), data from 70 surface meteorological stations were collected. Out of these only 56 were used for nudging (marked with + sign in Figure 1) whilst the remaining 14 were rejected due to their limited local spatial representativeness. Radiosounding (black dots in Figure 1) data were collected at the stations of Payerne, Cuneo, Milano Linate, San Pietro Capofiume and Udine.

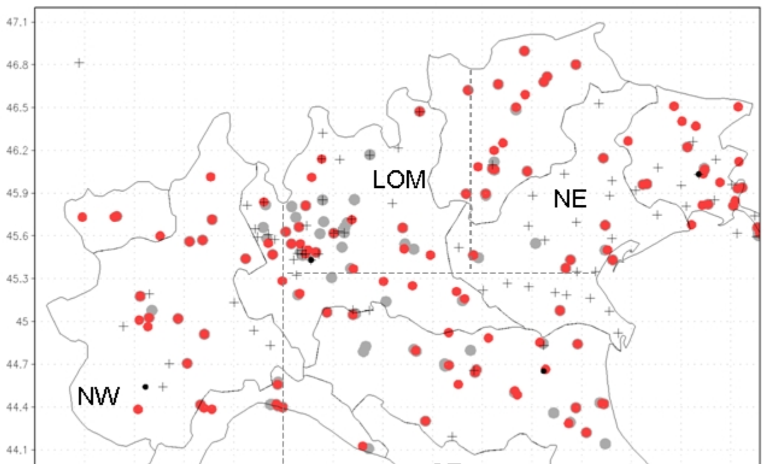

Figure 2. Spatial distribution of monitoring stations: gray cross for surface meteorological, black dots for upper soundings, gray dots for PM10 and red dots for ozone. Subdivision into areas where statistics is calculated is also shown.

CHIMERE is implemented on a similar domain as D2, with 6 km spatial resolution and 8 vertical levels. The emissions come from an ad-hoc inventory (Triacchini et al. 2009) and boundary conditions from the EMEP model. Model outputs are here compared with observations coming from Airbase (http://acm.eionet.europa.eu/databases/airbase). Table 1 reports the number of stations with more than 75% of data availability, used in the statistics reported in this study.

Table 1: number of observations stations per sub-area used for statistics

Number of stations	TOT	NW	LOM	(MI)	NE	SE
meteorology	55	7	15	(4)	16	13
Radio-soundings	4	1	1	(1)	1	1
PM10	97	17	23	(2)	32	25
O_3	88	20	14	(2)	31	23

We performed 7 sensitivity runs of MM5 with a combination of different nudging techniques (and the corresponding 7 runs of CHIMERE). In previous works (Pernigotti et al. 2010) we described the set-up and performance of these various runs for January 2005 for PM_{10}. Since one of the conclusions was that the best performance on wind was reached when all observations are nudged; we therefore focus here on the comparison of the two following extreme runs:

- **nfdda**: nudging of NCEP Global Tropospheric Analysis (gridded by a MM5 pre-processor called Little-R).
- **gdobsfdda**: nudging of upper mixing ratio, upper temperature, upper and surface wind (gridded by Little-R every 3 hours at surface, 6 hours above with NCEP as first guess;), direct nudging of surface wind (every hour). As recommended in (Stauffer and Seaman 1990) temperature in summer is not assimilated in the boundary layer.

METEOROLOGY AND PM10

The analysis has been performed by looking at some performance statistics (mean, bias, RMSE, correlation coefficient) for five different sub-areas within the Po valley (described in Figure 1 and Table 1) for both the meteorological and air quality simulations. The statistics for wind speed is presented in order to evaluate the improvement reached through nudging.

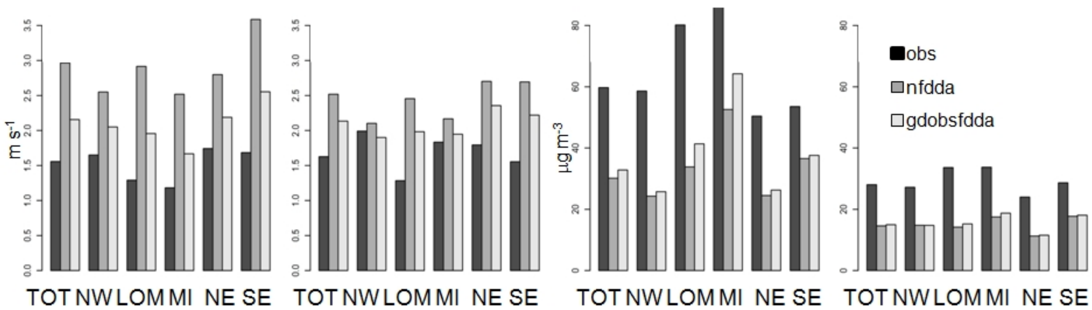

Figure 3: bar-plots for observations, mm5 run with analysis nudging (nfdda) and with nudging of all observations (gdobsfdda). From left to right wind speed for January, June 2005; PM10concentrations for January, June 2005.

The first two bar-plots in Figure 2 show that the modelled wind speed improves significantly with the nudging of observations, especially during winter when the reduction reaches 1 m/s. The effect of this wind speed reduction on PM_{10} concentration (the last two bar-plots of Figure 2) are not so striking, excepted in January in the central part of the Po-Valley (LOM) and in particular in Milan city (see also Figure 3, left panel) where the increase in PM10 goes locally over 20μg m^{-1}.

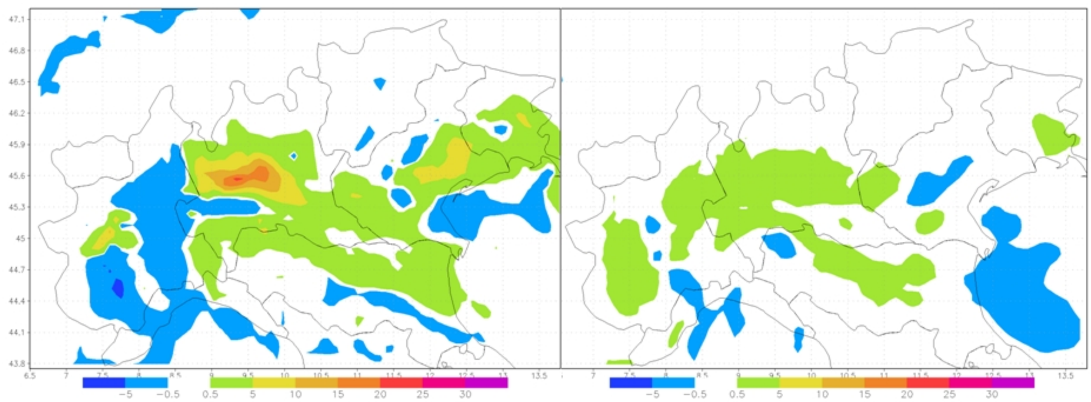

Figure 4: average difference between gdobsfdda and nfdda for PM10 in January 2005 (left) and June 2005 (right)

In winter other meteorological variables such as the planetary layer height (pblh) or the vertical diffusivity are also reduced over the whole domain due to wind reduction (Pernigotti et al. 2010), therefore it is quite surprising that the increase in modelled PM_{10} is observed only in Milan surroundings.

In summer the increase in PM_{10} concentrations is much smaller, especially in the Milan area, but it is still present in the central Po Valley. This relates to the fact that in the cold hours, when thermal convection is not dominant, the reduction of the wind speed is still able to reduce the vertical diffusivity (not shown).

METEOROLOGY AND O_3

The statistics (Figure 4) are performed for June 2005 for O_3, considering the 15LT for meteorology and the daily maximum of the 8h moving average for O_3. Comparing wind speed with the corresponding bar plot in Figure 3 we see that during the warm hours of the day the observed ventilation is normally stronger and the nudging of observations sometimes tend to produce a small underestimation of the wind speed (Figure 4). A small increase in relative humidity (rh), accompanied by a small decrease in temperature, probably due to the assimilation of upper mixing ratio is also seen. The pblh generally increases very lightly everywhere, with the exception of Milan where there is a small decrease.

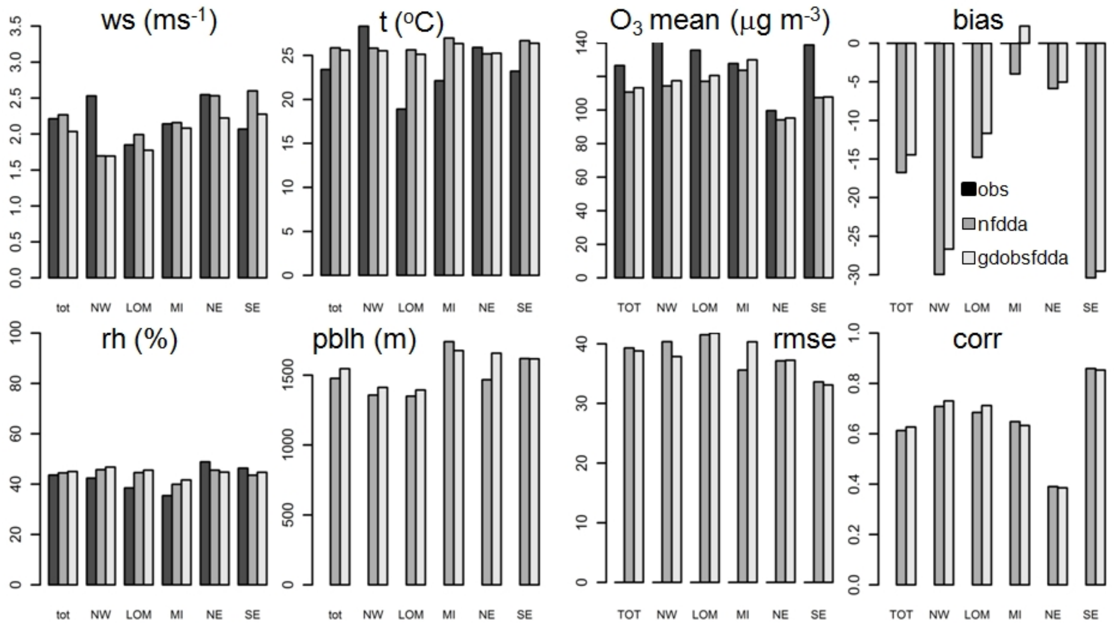

Figure 5: all values are averaged over 27 days in June 2005: on left panels observed and modelled meteorology at 15LT; on right panels O_3 model performance considering the daily maximum of the 8h running average.

As seen from the right panel of Figure 4 and from Figure 5 the impact of the nudged meteorology on O_3 concentration is small. The spatial features of these variations need further investigation and may be related to the assimilation of mixing ratio enhancing the daytime thermal convection in the southern part of the Po valley during some episode.

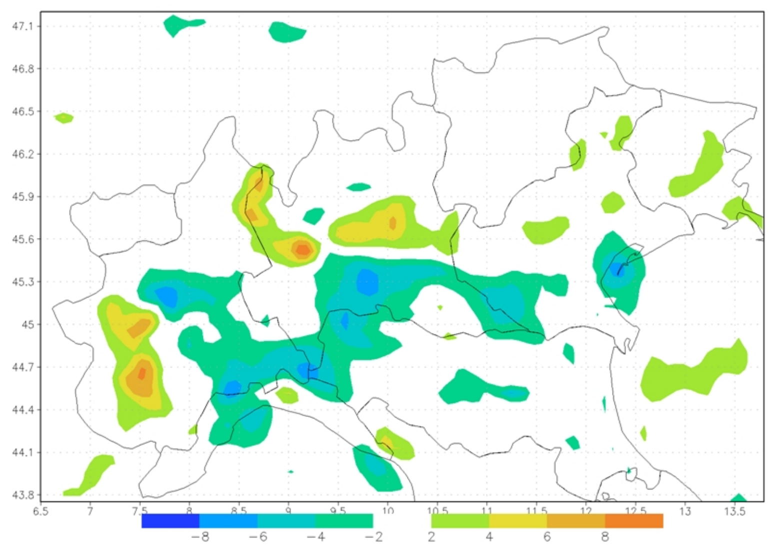

Figure 6. O_3 difference (µg m-3) between gdobsfdda and nfdda at 15LT for period 4-30 June.

CONCLUSION

In a previous work (Pernigotti et al. 2010) a set of simulations has been carried out to investigate the sensitivity of MM5 meteorological fields to different nudging techniques and the sensitivity of the CHIMERE simulated PM_{10} levels to these different set of meteorological fields. In the present work we extend this study which was carried out for a winter-time period to a summer month (June 2005) and look at the effects of nudging of meteorology on O_3 concentrations.

The general conclusion is that the effects are quite significant both for meteorology and PM_{10} concentrations in winter, while in summer the strong thermal convection probably tends to dilute these effects. Both for O_3 and PM_{10} (especially in winter) the concentrations fields show some spatial differences between the nudged and non-nudged version of CHIMERE. These differences which are probably related to the nudging of specific humidity in MM5 need to be further investigated.

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