ANALYSIS OF THE IMPACT OF MODEL RESOLUTION ON OZONE PREDICTIONS OVER SOME AREAS IN SPAIN

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Abstract. Due to the complex chemistry involved in troposheric ozone formation, it is difficult to predict the impact of controlling ozone precursor emissions. For this reason, modeling has become an important tool to predict ozone levels under varying emission scenarios. In spite of the efforts focused on reducing pollutant emissions, ground-level ozone concentrations in Spain are still exceeding thresholds established in EU legislation to protect human health and prevent damage to ecosystems. Resolution plays a significant role in modeling, especially when trying to simulate local effects. Higher resolution allows a more accurate definition of air pollutant transport pathways, although higher computing time is required. Besides the better definition of pollutants transport, a better model performance is also expected when simulating higher resolution domains. In this paper model predictions for three different resolutions have been analyzed over some areas in Spain (Madrid, Valencia and País Vasco) for 2004. Simulations of photochemical compounds were carried out using the regional V200603par-rc1 version of the CHIMERE model. A comparison between hourly model predictions and observations was done for O_3 and NO_2 in 2004. An improvement of ozone predictions was found for Madrid and Valencia areas when considering a higher resolution. The improvement of model predictions is more clearly observed for NO_2 in this two areas. In the País Vasco area this improvement is not observed.

Keywords: *ozone, photochemical modeling, air quality, model evaluation, spatial resolution.*

1. INTRODUCTION

Models have become an important tool to evaluate and predict air quality. The CHIMERE model is an air quality model that has been extensively used for the last years over Europe, specially over Mediterranean countries (Schmidt et al., 2001; Bessagnet et al., 2004; Vautard et al., 2003; Derognat et al. 2003; Hodzic et al., 2005, Monteiro et al. 2005). In Spain, an evaluation of the model performance at a 0.2º x 0.2º resolution for O_3 and NO_2 has been shown in Vivanco et al. (2008). This study has indicated that O_3 predictions are in a reasonably agreement to observations registered at rural sites. The capability to reproduce PM_{10} and $PM_{2.5}$ has also been evaluated in Vivanco et al. (2007).

Input data have a critical impact on the quality of model predictions. Nevertheless, emission information is not often provided to the model with the resolution required to simulate urban air quality. In this paper the impact of resolution has been evaluated for three different areas in Spain, using the 50 x 50 km2 EMEP emissions database adapted to a higher resolution according to land use information. The main objective of this paper is to analyse if higher-resolution simulations improve CHIMERE ozone predictions when using the same emissions database.

2. MODEL SIMULATIONS

Simulations of photochemical compounds for 2004 were carried out using the regional V200603par-rc1 version of the CHIMERE model. The impact of resolution was evaluated for three areas in Spain (Madrid, Valencia and País Vasco).

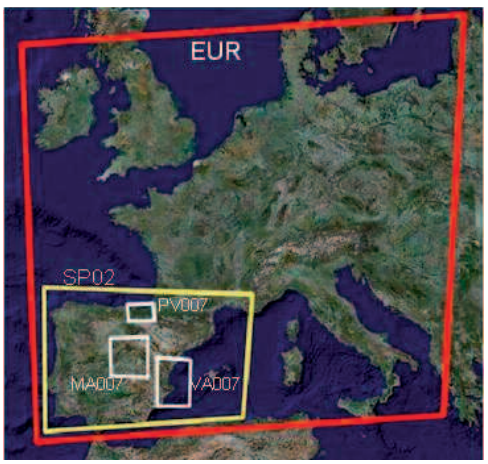

Figure 1. Location of the simulated domains.

For these three geographical areas, three different resolutions were considered: 0.5ºx0.5º (EUR domain in Fig. 1), 0.2ºx 0.2º (SP02 domain in Fig. 1) and 0.07º x 0.07º (MA007, VA007 and PV007 in Figure 1). Meteorological fields were obtained with the MM5 model. Emissions were derived from the annual totals of the EMEP database for 2004 (Vestreng et al., 2005). These EMEP emissions were disaggregated taking into account the land use information, in order to get higher resolution emission data. Boundary conditions for gases concentrations for the coarsest domain were provided from monthly concentrations estimated with the LMDz-INCA model (Hauglustaine et al., 2004).

3. EVALUATION OF MODEL PREDICTIONS

In order to evaluate the performance of the CHIMERE model the statistics presented in Table 1 were calculated. Parameters such as mean bias, mean normalized bias, mean normalized absolute error, root mean square error and root mean normalized square error were estimated for O_3 and NO_2. Regarding ozone, only statistics for moderate-to-high ozone concentration cases (more important for human health protection) were considered by selecting predicted-observed value pairs when hourly observations were equal to or greater than the cut-off of 80 mgm^{-3}. For NO_2 a cut-off value of 5 μgm^{-3} was used.

Table 1. Definition of the metrics used in the evaluation of the CHIMERE model performance

Mean bias	$MB = \frac{1}{N}\sum(M_i - O_i)$
Mean normalized bias	$MNB = \frac{1}{N}\sum(\frac{M_i - O_i}{O_i})$
Mean normalized absolute error	$MNAE = \frac{1}{N}\sum(\frac{\lvert M_i - O \rvert_i}{O_i})$
Root mean square error	$RMSE = \left[\frac{1}{N}\sum(M_i - O_i)^2\right]^{\frac{1}{2}}$
Root mean normalized square error	$RMNSE = \left[\frac{1}{N}\sum\left(\frac{M_i - O_i}{O_i}\right)^2\right]^{\frac{1}{2}}$

Results for ozone statistics are presented in Table 2. For all the domains, mean normalized bias and mean normalized absolute error present values inside the range proposed in Tesche et al. (1990) to consider an acceptable model performance (<15% and <30% respectively). For Madrid and Valencia areas some improvement is found for higher

Table 2. Analysis of model performance for ozone. Based on hourly values higher than 80 μgm^{-3}

	EUR	SP02	MA007
Mean bias (μgm^{-3})	-7.76	-9.61	-8.9
Mean normalized bias (%)	-6.25	-7.79	-6.97
Mean normalized absolute error (%)	16.46	15.81	14.46
Root mean square error (μgm^{-3})	21.19	21.3	20.03
Root mean normalized square error (%)	20.22	19.35	17.75
	EUR	SP02	VA007
Mean bias ($\mu g\ m^{-3}$)	14.21	10.87	7.82
Mean normalized bias (%)	16.57	13.03	9.78
Mean normalized absolute error (%)	22.46	19.29	17.15
Root mean square error ($\mu g\ m^{-3}$)	23.84	20.6	18.43
Root mean normalized square error (%)	26.55	22.67	20.18
	EUR	SP02	PV007
Mean bias ($\mu g\ m^{-3}$)	10.4	6.64	6.85
Mean normalized bias (%)	12.2	8.19	8.43
Mean normalized absolute error (%)	16.75	14.36	14.64
Root mean square error ($\mu g\ m^{-3}$)	18.01	15.7	16.06
Root mean normalized square error (%)	20.3	17.53	17.92

EUR: 0.5ºx 0.5º; SP02: 0.2ºx 0.2º; MA007, VA007, PV007: 0.07ºx 0.07º

resolutions. Nevertheless, results for País Vasco area do not improve. For this domain, statistics for the finest domain (0.07ºx0.07º) are very similar to those at 0.2ºx0.2º. Some studies focused on MM5 predicted meteorological fields are being carried out, and they indicate that the expected improvement for higher resolutions is not observed, specially in País Vasco area.

Statistics for NO_2 were also calculated. Table 3 presents the statistics obtained from hourly NO_2 values higher that an observed cutoff of 5 μgm^{-3}. The improvement in NO_2 predictions is higher than that found for ozone, even for the País Vasco area.

Table 3. Analysis of model performance for NO_2. Based on hourly values higher than 5 μgm^{-3}

	EUR	SP02	MA007
Mean bias (µg m-3)	-40.3	-33.1	-30.1
Mean normalized bias (%)	-61.2	-52.2	-47.7
Mean normalized absolute error (%)	69.8	61.2	57.8
Root mean square error (µg m-3)	50.2	42.2	39.8
Root mean normalized square error (%)	74.5	67.2	64.6
	EUR	SP02	VA007
Mean bias (µg m^{-3})	-26.06	-26.17	-24.4
Mean normalized bias (%)	-42.07	-48.86	-43.66
Mean normalized absolute error (%)	69.16	65.96	64.41
Root mean square error (µg m^{-3})	35.89	34.62	33.32
Root mean normalized square error (%)	80.94	74.46	75.02
	EUR	SP02	PV007
Mean bias (µg m^{-3})	-18.92	-16.06	-15.22
Mean normalized bias (%)	-48.59	-38	-34.52
Mean normalized absolute error (%)	62.19	59.82	60.15
Root mean square error (µg m^{-3})	25.21	23.35	22.99
Root mean normalized square error (%)	69.37	69.93	72.1

The effect of model resolution is not the same for each station. Figure 2 shows the mean normalized absolute error for ozone at each station in the three areas. Most of the stations present better predictions for higher-resolution simulations in Madrid and Valencia areas. Higher improvements are observed in traffic stations.

4. CONCLUSIONS

Comparison between 2004 hourly CHIMERE model predictions and observations indicate that higher resolution simulations drive to a better agreement. This improvement was observed for the statistics described in Table 1 using all the 2004 hourly values. This behaviour is mainly found in Madrid and Valencia areas. País Vasco is a more complex area and this improvement is not observed. Meteorological fields obtained with MM5 model do not present the expected improvement, specially in this area. Thus, a deeper study should be carried out in order to understand the reason of this behaviour. For NO_2 a higher improvement is observed, even for the País Vasco domain.

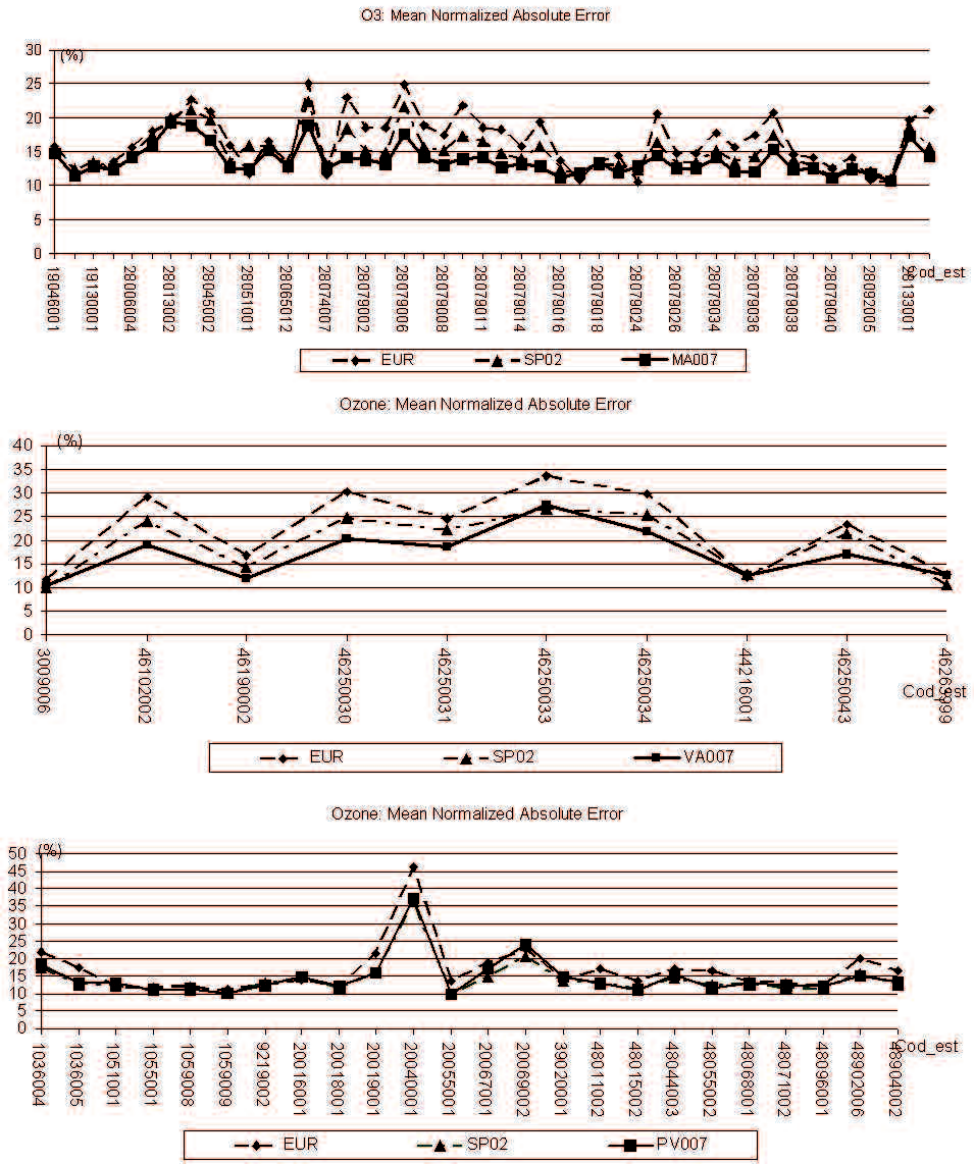

Figure 2. Mean normalized absolute error for ozone for the three resolutions at each station in Madrid, Valencia and País Vasco area

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