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Interactive comment on "Air quality forecasts at kilometer scale grid over Spanish complex terrains" *by* M. T. Pay et al.

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We would like to thanks the Referee #1 for his/her constructive remarks and suggestions. All his/her comments have been implemented and commented accordingly in the reviewed version of the manuscript.

Please, find in the next paragraphs answers to Referee #1.

Referee #1: I would need to know if model outputs and stations observations are instantaneous every hour, or if they are integrated in time in some way. If an inconsistency exists in the temporal sampling, one could argue that 4km is a more sensible horizontal scale than 1km, therefore the 1km model outputs should be degraded somehow to reach the spatial and temporal representativity of the station.

Authors: In our comparison both modelled and measured concentrations are hourly averaged. In the case of the CMAQ, the model provides an output file (named ACON*) with hourly averaged concentrations. Concerning observations, which are received in near-real time, the measurements come from automatic monitoring networks, which are hourly averaged by the people that manage those networks.

We have included a comment on that in section 2.4 as follows:

“Representativeness challenges continue to be present whenever gridded simulations are compared to observational data at a point in time and space, as modelled concentrations represent a volumetric average over an entire grid cell, meanwhile the stochastic compound embedded in the observations is not accounted for. Concerning temporal representativeness, in the present comparison both modelled and measured concentrations are hourly averaged. [. . .]”

Referee #1: On a similar topic, the discussion in Section 3 on spatial representativeness is interesting overall, but the reader keeps wondering what support the statements on how realistic are 1km and 4km maps given that we do not have such high resolution data to compare with.

Authors: The realism of the 1 km and 4 km simulations is difficult to evaluate because there are no 2D observations at 1-4 km resolutions. However, the comparison of 1 km and 4 km concentration maps shows that roads are easier identified and better shaped at 1 km than at 4 km. In this sense, we have replaced “better textured”/“significantly better textured” by “more easily identified”/“more textured”.

Furthermore, in order to quantify the spatial representativeness of the concentration maps at both resolutions, we have calculated spatial correlations between modelled (1 km and 4 km) and observed concentrations at available air quality stations. The results indicate an increase of NO2/O3 spatial correlation coefficients from 0.79/0.69 (4 km) to 0.81/0.73 (1 km).

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Referee #1: It is not clear why the evaluation period is so short. If the forecasting system is operational since 2009 for two of the selected areas, one could have expected a more comprehensive validation.

Authors: Although CALIOPE has been forecasting air quality at 1 km resolution over Madrid and Barcelona since 2012, forecasts over Andalucia domain started in 2013. With the aim of evaluating the resolution effect over the most populated areas with complex terrains in Spain (Barcelona, Madrid and Andalucia domains), we selected the most interesting period available by the time we started the present study, which was April 2013 (one month). From the climatological point of view, April is usually effected by transitional synoptic circulations (Valverde et al., 2014), but several exceedances of European limit values for O3 and NO2 in April 2013 justify its interest.

As the Referee #1 points out, a more comprehensive evaluation could cover for instant a full year. In this sense, an annual evaluation (September 1st 2011-September 1st 2012) for the Barcelona domain has been already discussed in Baldasano et al. (2013) and the results are in accordance with the present work. Anyways, in a future analysis we will expand the period of the analysis to a full year over the three domains.

Baldasano, J. M., Arévalo, G., Pay, M.T., and Gassó, S.: Influence of horizontal grid resolution on air quality modelling systems in Barcelona Metropolitan Area (Spain), in: 15th HARMO, Madrid, Spain, 6-9 May 2013, 2013.

Valverde, V. V., Pay, M. T., and Baldasano, J. M.: Climatic synoptic classification over the Iberian Peninsula oriented to air quality dynamic characterization, Int. J. Climatol., submitted, 2014.

Referee #1: P2295 L21: The author may consider relevant to add a couple of sentences on the need to reach high resolution in order to improve covariance between population and pollution for health impact assessment, e.g. as done in Thompson, T. M., Saari, R. K., and Selin, N. E.: Air quality resolution for health impacts assessment: influence of regional characteristics, Atmos. Chem. Phys. Discuss., 13, 14141-14161,

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doi:10.5194/acpd-13-14141-2013, 2013.

Authors: We appreciate the contribution from Referee #1. A comment about the benefits of the resolution increase for the health impact studies will be included in the revised manuscript as follows:

“Now a day, fine horizontal resolution is a persistent challenge for the assessment of health impact and population exposure studies (Thompson et al., 2013).”

Referee #1: P2299 L12&14 : the use of “such as” in this context is surprising.

Authors: We have replaced this sentence from:

“AND includes one of the five biggest cities in Spain such as Seville ($\sim$ 700 000 inhabitants) and important industrial areas devoted to industrial processes, electric generation and maritime traffic such as Strait of Gibraltar.”

by

“AND includes one of the five biggest cities in Spain such as Seville ($\sim$ 700 000 inhabitants), develops industrial and electric generation activities over the Algeciras bay, and is affected by a dense maritime traffic through the Strait of Gibraltar.”

Referee #1: P2303 L 3-6 : in an evaluation paper, it is acceptable and relevant to spend a few lines to introduce the evaluation metrics rather than using references.

Authors: We agree with the Referee #1. We have created an Appendix A with two tables which include the description of the statistics used in this paper, both discrete (Table A1) and categorical statistics (Table A2). The Appendix A has been referred accordingly along the manuscript.

Referee #1: P2304 L16 : “desert”

Authors: Following the reviewer suggestion, the word “dessert” has been replaced by “desert”.

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Referee #1: P2308 L12: PM10 composition data is probably not available over the domains of interest. A reference to other studies having validated the CALIOPE system for individual PM compounds would be interesting. In particular, the abundance of SOA seems small, does it comply with the average load in Spain?

Authors: Measurements of PM10 components for 2013 are not available for the study domains. However, Pay et al. (2012) have already evaluated the PM components at some Spanish urban and rural background stations using the CALIOPE-AQFS based on CMAQv4.5. They showed that the model underestimated the secondary inorganic aerosol by a factor 2-3. The highest underestimation was found for fine carbonaceous aerosols (factor of 4) in part related to the state-of-the-science concerning secondary organic aerosol formation pathways. Based on these results, we can say the SOA in the present work could be underestimated. However, the CMAQv5.0.1 used in the present work includes substantial scientific improvements over the version 4.5, especially devoted to improving SOA formation and dynamic interactions of fine and coarse aerosol.

According to the Referee #1's suggestion, some comments about the CALIOPE-AQFS performance for PM components over Spain have been included in section 4.2 (PM10 components) as follows:

"Pay et al. (2012) have already evaluated the PM components at some Spanish urban and rural background stations using the CALIOPE-AQFS based on CMAQv4.5, and they showed that the model underestimated the secondary inorganic aerosol by a factor 2-3. The highest underestimation was found for fine carbonaceous aerosols (factor of 4) in part related to the state-of-the-science concerning secondary organic aerosol formation pathways. The updated version of CMAQ, v5.0.1, includes scientific improvements concerning SOA formation and aerosol dynamic that could improve the modelled PM10 performance for its components."

Referee #1: P2308 L 17&18: replace "in" for "by".

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Authors: The correction has been amended.

Referee #1: P2308 L26: a word is missing between “wind speed” and “relative humidity”

Authors: The correction has been amended.

Referee #1: P2308 L27 “not shown”

Authors: The correction has been amended.

Referee #1: P2309 L 3: what is the reason for the change in primary PM load with resolution? One can expect increases in horizontal gradients reported later in the same paragraph but the change in total abundance is more surprising.

Authors: The increase of primary PM concentrations when increasing resolution is due to the fact that the 1 km simulations allocate emission in a lower grid cell, which leads to a reduced effect of artificially dilution of emissions, so near high emission sources the concentration gradients could be stronger than at 4 km simulation.

However, as the Reviewer #1 points out the PM10 concentration increase when increasing the resolution is not in the same proportion as for primary pollutants. This is a result of a bias compensation of PM10 components, mainly controlled by the PPM and the EC concentration increase and the SS concentration decrease when increasing resolution. This has been discussed in the manuscript as follows:

“For primary PM components (EC and PPM) increasing resolution depicts the highest increase in concentration (by 10 and $\sim$12%, respectively). As for NO2, the 1 km simulation leads to a reduced effect of artificially dilution of emission in a grid cell, so concentration gradients are stronger than at 4 km simulation.”

“The grid effect is less pronounced for PM10 than for NO2 and O3. The low increment of PM10 mean concentrations when the resolution increases (<0.1 μgm-3) is the result of compensating biases of PM10 components, mainly controlled by the PPM and the

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EC increase and the SS decrease."

Referee #1: P2309 L 15 : "increase on daily cycles"

Authors: The correction has been amended.

Referee #1: P2309 L19: please clarify what is referred to as "lamination" of the PBL.

Authors: This concept of the "lamination of the PBL growth by the Mediterranean sea breeze" makes reference to the entrance of the on-shore flow that leads to a reduced mixing height (Perez et al., 2004; Millan et al. 1997). Millán et al. (1997) have already documented the first rapid rise of the mixing height during the morning followed by the sinking of its capping inversion during the afternoon in the Mediterranean coastal area. Sicard et al. (2006) and Perez et al. (2004) also measured this phenomenon in Barcelona area using LIDAR.

Millán, M., Salvador, R., Mantilla, E., and Kallos, G.: Photooxidant dynamics in the Mediterranean basin in summer: results from European research projects, J. Geophys. Res., 102, 8811– 8823, 1997

Pérez, C., Nickovic, S., Baldasano, J.M., Sicard, M., Rocadenbosch, F., and Cachorro, V.E.: A long Saharan dust event over the western mediterranean: Lidar, sun photometer observations, and regional dust modeling, J. Geophys. Res. 111 (D15214), 1-16, 2006. Sicard M., C. Pérez, F. Rocadenbosch, J. M. Baldasano, D. García-Vizcaino: Mixed-Layer Depth Determination in the Barcelona Coastal Area From Regular Lidar Measurements: Methods, Results and Limitations. Boundary-Layer Meteorology, 119, 1, 2006.

Referee #1: P2310 L8: what is the dynamical process leading to a lower PBL in the high resolution simulation?

Authors: The PBL height diurnal cycle has not been evaluated because there are not available measurements. However, comparison of PBL at both resolutions has been performed in order to find potential reasons of pollutant concentration differences be-

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tween resolutions.

The 1 km resolution displays a lower PBL height than 4 km simulation in the morning after the sunrise and in the evening after the sunset. The reason of this behavior could be a result of features depending on topography like temperature, wind field and mesoscale sea-breeze and mountain-valley circulations. In this sense, some meteorological fields such as wind speed at 10 m (U10), wind direction (WD10) and temperature at 2 m (T2M) have been evaluated when increasing resolution from 4 km to 1 km (Sect. S1, http://www.geosci-model-dev-discuss.net/7/2293/2014/gmdd-7-2293-2014-supplement.pdf). Overall, comparison with METAR reveals that the resolution increase slightly improves T2M (bias in 0.1°C), U10 (bias in 0.1 ms-1 and r in 0.1) and WD10 (error in 52° and r in 0.1). However, it slightly decreases WD10 bias (in 2°).

According to Fay and Neunhäuserer (2006) high resolutions (ranging from 1 to 5 km) are essential to reproduce mesoscale phenomena, e.g. those controlling O3 transport along the mountainous northeastern Mediterranean coast where features depending on topography like temperature, wind speeds, channelling, convergence/divergence lines and mesoscale circulations are better described.

Referee #1: P2310 L 19-24: which additional measurement or modelling experiment could lead to a better understanding of the reason for this diurnal cycle in the model bias?

Authors: Our proposal to go more in detail with the PM10 underestimation during the daily cycle is evaluate the modelled PM10 components with hourly measurements in order to identify if the underestimation come from primary or secondary aerosol. Additionaly, it could be desirable evaluate the PBL height on an hourly basis to check if the model is reproducing the mixing height properly. For instant, high temporal resolution of PBL high from LIDAR measurements can be useful to evaluate modelled PBL.

Interactive comment on Geosci. Model Dev. Discuss., 7, 2293, 2014.