REGIONAL AIR QUALITY MANAGEMENT ASSESSMENT BY USING CHIMERE AIR QUALITY MODEL

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Abstract: Air quality models have been developed to better understanding the behaviour of the pollutants in the atmosphere, among other applications. One of them is about the influence of emission inventories and large sources on local and regional air quality. Another is the optimal design and assessment of air quality monitoring networks.
This work aims at three different goals, (1) Optimal design of a regional air quality network: one-year high resolution (3 km^2) meteorological and air quality simulations was applied to establish the past and future most polluted areas over the Galicia (NW of Spain). Simulations was built coupling WRF-ARW meteorological model to CHIMERE v. 2008c air quality model (validated with DELTA Tool), using 2008 year as meteorological basis. For past simulation, a detailed emission inventory was done, based in a combination of the Portuguese (area sources) and Galician (EMIGAL, point and area sources) emission inventories, with EMEP inventory for the year 2008. Future simulation considers a projection of emissions depending on the maxima authorized activities in the region. (2) To evaluate the effects of European air pollutants emissions between 2001 and 2008 over the ozone levels in the NW of the Iberian Peninsula (NWIP). Results show that no effect was obtained in the rural ozone levels of this region, due to the change of European emissions. (3) To evaluate the effect of removing all the emissions of the largest coal-fired power plant (1400 MW) in this region. In this case, a high resolution (3x3 km^2) regional emissions inventory over NWIP was also applied, including more than 300 sources as point sources. Suppressing the power plant emissions derived in an increment of ozone levels around it; and, no effect in the ozone levels was observed over the NWIP region and surrounding areas.

Key words: *WRF, CHIMERE, EMEP emissions, air quality network, power plant emissions, ozone*

INTRODUCTION

Air quality modelling is an integral part of management (Denby et al., 2011). Whilst air quality assessment has traditionally been carried out using monitoring it is not possible to carry out planning activities without the use of some form of air quality model. For assessment purposes the combination of models and monitoring, through data assimilation methods, should provide the most comprehensive information for understanding and assessing the current air quality situation.

In this work, different applications of CHIMERE air quality are presented. First, CHIMERE model coupled to WRF meteorological model was validated over the study region, NW of the Iberian Peninsula. Second, a one-year air quality simulation was done, using a 2012 regional emissions inventory projection, in order to identify the potential high glc areas for different pollutants, to optimize the regional air quality monitoring network. Third, different emissions scenarios were applied in order to evaluate the influence of European and local emissions over the O_3 levels in the study region.

MODELS AND METHODS

Air quality modelling typically requires three different models and datasets: An emissions inventory, a meteorological model and, following the off-line approach, an air quality model. In this work, different emissions inventories were applied covering the whole Iberian Peninsula (IP) and the NW of Iberian Peninsula (NWIP), depending on the modelling application,

(1) In the optimal design of an air quality network over the NWIP, first, a 2008 year regional high resolution emissions inventory (Dios et al., 2012a) was applied to obtain a reference scenario; second, a 2012 year projected inventory, also considering the maximum activity of the industrial sources in this region, was applied to evaluate the future air quality levels in this region; in order to identify any potential high polluted area in the region.
(2) In the evaluation of European emissions change over the air quality levels in the NWIP, both EMEP 2001 and EMEP 2008 inventories were considered.
(3) About the impact of power plant emissions over the NWIP, again 2008 year regional emissions inventory, with and without As Pontes Power Plant emissions, was considered. For an accurate

estimation of the power plant emissions, specific emissions factors were developed (Dios et al., 2013), with large differences to EMEP emissions inventory data over the same location (Dios et al., 2012b).

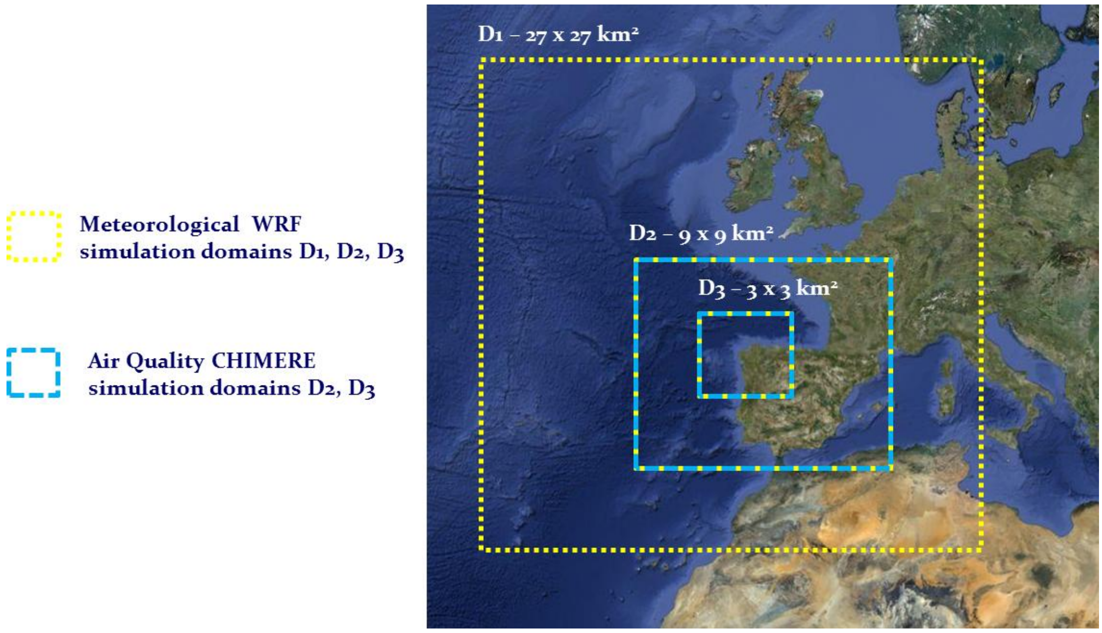


Figure 1. Simulation domains and grids applied in WRF-ARW meteorological model, and CHIMERE air quality model.

As meteorological model, WRF-ARW version 3.2 (Skamarock et al., 2008) was applied, configured with 30 vertical layers, and three nested domains (Figure 1) with horizontal resolutions of 27, 9 and 3 km^2 (Borrego et al., 2012). The other selected model settings include MYU PBL scheme, Kain-Fritsch cumulus scheme (outer and medium domain), WSM 3-class microphysics scheme, a RRTM longwave and Dudhia shortwave radiation scheme, and a 5-layer soil model. A one way nesting option was applied. The NCEP (National Center for Environmental Prediction) GFS analysis data available at a horizontal resolution of 1º x 1º and a 3-hour time resolution were used to input the initial and lateral boundary conditions. Elevation and land cover data were provided by the digital terrain model from the United States Geological Survey (USGS, 2008).

Finally CHIMERE v. 2011a+ air quality model (Menut et al. 2010) was used in all these applications. CHIMERE model was set using Vann Leer advection scheme, in order to solve out 20 of 44 chemical species included in the reduced MELCHIOR2 chemical mechanism; aero flag was set in order to activate the aerosols module using 8 bins size distribution; Secondary Organic Chemistry (SOA) are treated using the medium scheme computing. Biogenic emissions data were integrated using the MEGAN model (Guenther et al., 2006) jointly with a meteorological interface to the WRF model. Finally, as initial and boundary conditions, monthly MOZART model results for gases and GOCART model results for aerosols were input.

Two one-way nested grids (Figure 1), 9 km^2 resolution over the Iberian Peninsula and 3 km^2 over the NWIP, were applied. Previously, air quality modelling results over 2008 year were validated against AirBase dataset, using DELTA Tool software (Thunis et al., 2010).

RESULTS

Air quality modeling results along 2008 year were processed following the legal thresholds established for the following pollutants: SO_2, NO_2, PM10, PM2.5, CO and O_3. However, the CHIMERE model validation (Souto et al., 2013) shows some differences against air quality measurements, which were applied to correct the model results, as follows,

a) SO_2 glc are underestimated over the NW of the region, with higher differences in summertime and along maximum periods. On the other hand, SO_2 glc over the background sites (located at South) is slightly underestimated.
b) Again, NO_2 is underestimated at the NW of the region, but mainly in wintertime. As an exception, NO_2 is overestimated around As Pontes Power Plant, at the North.
c) PM10 are usually underestimated; therefore, model results only are useful to identify the areas with highest relative levels.
d) About O_3, good agreement is achieved in the available sites, especially for the daily maxima.

With these considerations, results for the different management applications were presented.

Optimal air quality network design

In this case, the areas with higher risks of poor air quality over the Galicia region (Figure 2) were identified, considering main primary pollutants (SO_2, NO_x, PM, CO). Results show no exceedances in either upper or lower health thresholds. However, some exceedances in upper vegetation thresholds (Figure 2) are possible at the Northern coast, in Santiago de Compostela, over the southeast of the region, and close to A Coruña (Northwest coast) and West coast. Also, lower vegetation thresholds can be exceeded over other coastal areas (in blue).

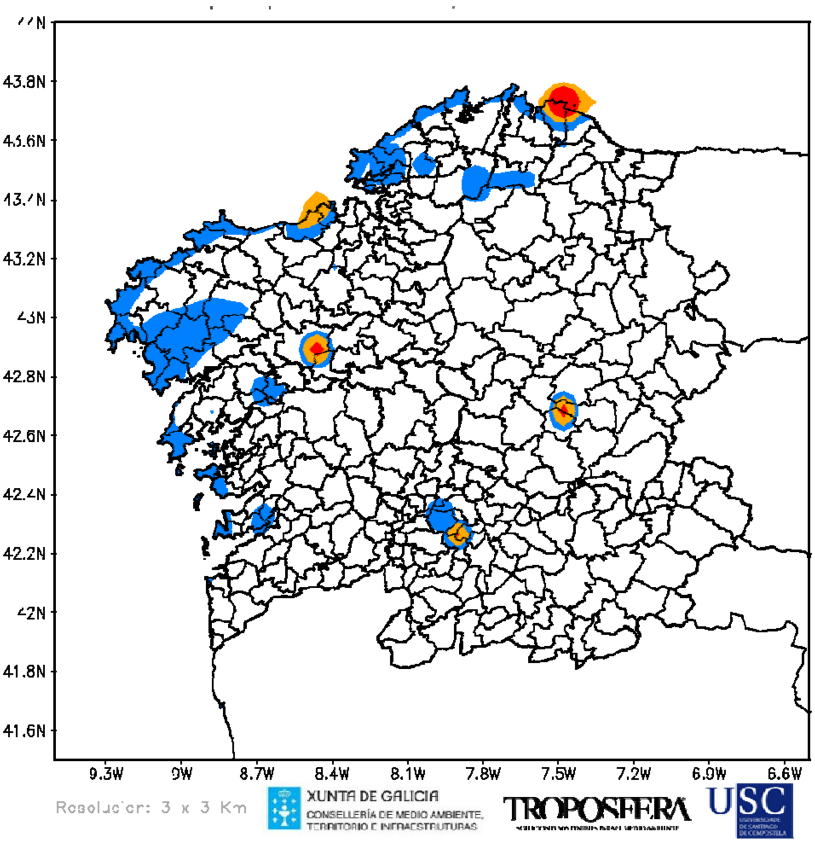
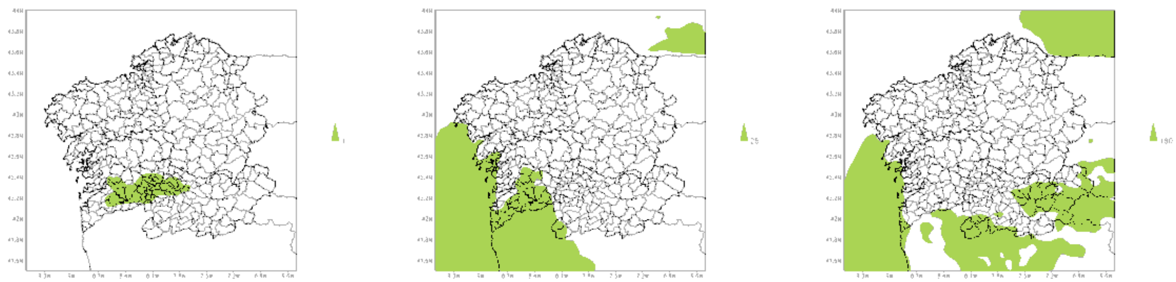


Figure 2. Optimal air quality network design: Areas with exceedances in the upper (orange) and lower (blue) legal air quality thresholds, for any primary pollutant. Red colour shows the threshold value exceedances.

Results are not so good when O_3 is considered. Figure 3 shows the exceedances in different legal O_3 thresholds which could appear, according to the model results. Report to people O_3 threshold exceedances (Figure 3a) are expected over central southern part of the region, with the highest tropospheric ozone concentrations. About health O_3 threshold exceedances (Figure 3b), southwest area and, also, the west coast presented these exceedances. Finally, vegetation O_3 threshold (AOT40) exceedances (Figure 3c) appears in several areas: south Atlantic coast, some areas at the south and the southeast of this region. These results confirm these O_3 exceedances can be related both with local NO_x emissions (especially, from the urban coastal areas) and, also, with O_3 transport from neighbourhood regions: Portugal (at the south) and Iberian Plateau (at the southeast).



(a) (b) (c)

Figure 3. Optimal air quality network design: Areas with exceedances in the O_3 thresholds: (a) report to people; (b) health; (c) vegetation (AOT40).

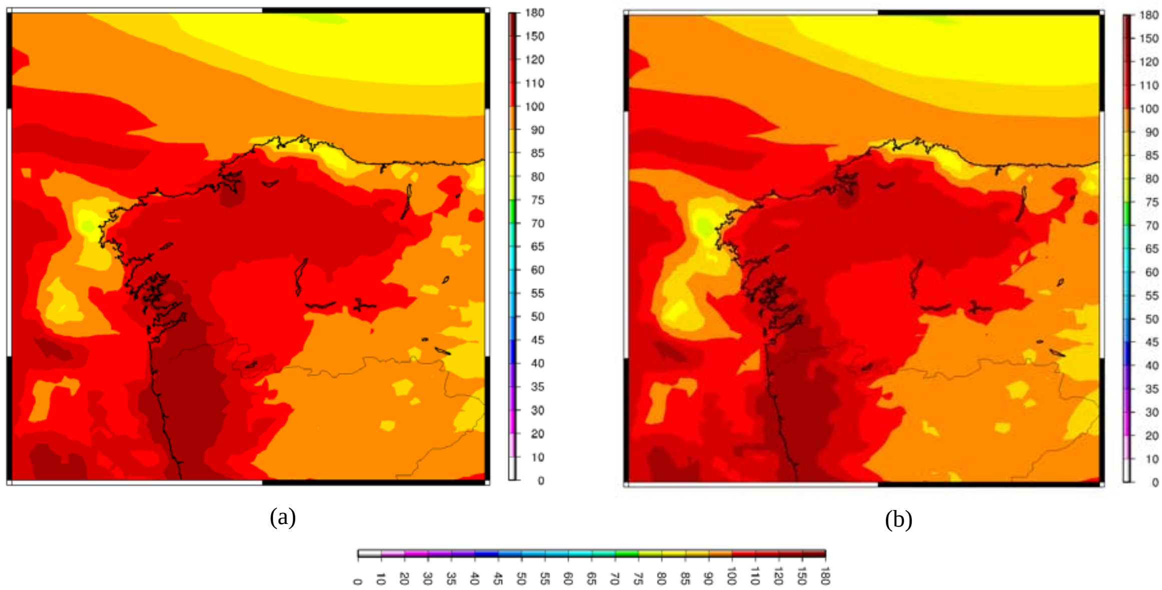


Figure 4. O_3 glc (in µg/m^3) at 12:00 UTC, from the CHIMERE simulations using July, 18th 2002 meteorological conditions, with (a) 2002 EMEP emissions inventory; and (b) 2008 EMEP emissions inventory.

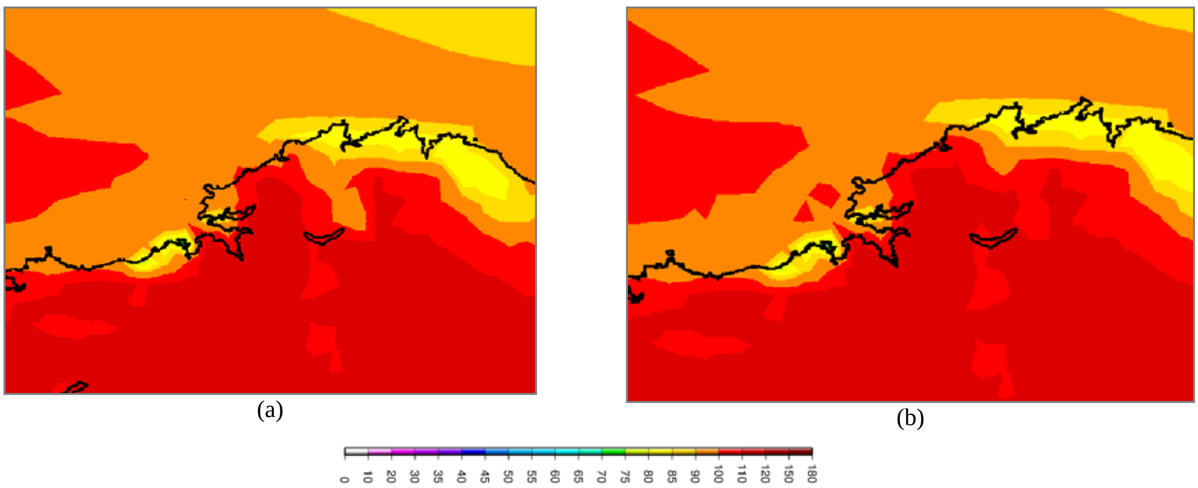


Figure 5. O_3 glc (in µg/m^3) at 12:00 UTC, from the CHIMERE simulations at July, 18th 2002, using 2008 regional emissions inventory, (a) with As Pontes Power Plant emissions, and (b) without As Pontes Power Plant emissions.

Impact of EMEP emissions changes

Evaluation of the impact of EMEP emissions changes between 2002 and 2008, over tropospheric O_3 in this region was done. A typical O_3 episode in this region was selected (Saavedra et al., 2012), covering 14-23 July 2002. Particularly, high O_3 glc was detected on July, 18th. After CHIMERE model validation over this episode, two air quality simulations were run, keeping the same meteorology, but applying either 2002 or 2008 EMEP emissions inventories. Figure 4 shows the 12:00 UTC O_3 glc results on July, 18th, with both inventories. Apparently, 2008 EMEP emissions reduced the O_3 levels, especially over the SW coast of this region. A significant influence in this reduction is the NO_x emissions control over the North of Portugal, as this episode is a typical example of transboundary transport of O_3 and precursors along the Portuguese coast to this region.

Large source impact in O_3 levels

At the North of this study region, a large source with tall stack (356.5 m) from As Pontes Power Plant is located, with significant SO_2, NO_x and PM emissions. Although SO_2 and PM emissions were dramatically reduced since 2008, NO_x emissions rate is high, due to the large total gas flow. Figure 5 shows the O_3 glc estimated by CHIMERE model on July, 18th 2002 conditions, at 12:00 UTC, with (Fig. 5a) and without (Fig. 5b) this power plant emissions. It seems the power plant reduces the O_3 glc close to it (as expected) and, at the same time, has no influence in O_3 levels far from it.

CONCLUSIONS

CHIMERE model was applied to support the air quality management over the Northwest of the Iberian Peninsula. First, air quality simulations with the meteorology provided by WRF model along 2008, but using a 2012 regional emissions inventory projection, allow identifying the main affected areas by main primary pollutants (SO_2, NO_x, CO, PM) and O_3; in order to support the design of a regional air quality network. Second, simulations over a typical O_3 episode show that EMEP European emissions reduction from 2002 to 2008 also reduce the O_3 levels in this region, especially over areas close to neighbourhood regions. Third, the emissions of a large coal-fired power plant located in the North of this region produce a reduction of local O_3 levels, without any effect over the O_3 levels far from it.

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