CityZen

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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Assessment of the impact of pollutant height release on its vertical distribution and its transport downwind of urban areas

Abstract

We study the sensitivity of chemistry transport model performance to pollutant height release by investigating model results for a reference simulation and alternate vertical distributions of anthropogenic emissions. Average NO2, O3 and PM10 concentrations show the impact on modelled pollution levels at the surface and vertical cross sections at the latitude of the main European pollution hotspot and allow investigating their transport downwind of urban areas. A comparison against surface measurements indicates that lower injection height improves model performance, whereas an opposite effect was expected in megacities. These results suggest that changing vertical emissions profiles does not constitute a relevant methodology to account for the stronger vertical mixing brought about by the urban heat island. On the contrary, model performance is improved when injecting domestic emissions at a lower altitude than prescribed by the references profiles.

1. Introduction

The performances of Chemistry Transport Models are extremely sensitive to the quality of the input anthropogenic emission inventories. Even inventories based on identical aggregated information (i.e. official country-level reported emissions) can offer substantial differences depending on the downscaling strategy. Amongst the drivers of variability, we can mention: the proxies used for the horizontal distribution (landuse, population, road, etc...), vertical distribution, the seasonal/weekly/hourly temporal variations, etc...

Here we focus on the vertical downscaling: i.e. the vertical venting of emissions at a given grid point. The total emissions are usually prescribed as a total upward flux from the surface to the atmospheric compartment. In some cases, the emission height of a point source might be provided (major industrial facilities, volcanoes), or modelled (wildfires). But the remaining emitted mass shall be distributed over the vertical. This distribution follows prescribed profiles that are often uniform in space and constant in time, having as such a tremendous influence on the model results, which justifies the need for a sensitivity study of their impact on the model results. In addition, an exacerbated impact of pollutant emission height is expected in megacities, where the urban heat island effect is thought to enhance the vertical mixing of pollutants.

2. Description of the Experiment

We use the EMEP official inventory for the year 2007 and we apply three vertical distributions for the emissions. The reference (REF) is obtained from the original vertical profiles used in EMEP models (see e.g. Bieser et al. 2011) and the experiments consist in applying a different vertical distribution to the activity (SNAP) sectors 2 (residential) and 7 (traffic). These sectors are selected because of a) the larger uncertainties in the vertical distribution of these activity sectors compared to, say, agricultural emissions, and b) their relevance to megacity emissions. For “EXP-HIGH” the injection height is increased compared to the reference, while for “EXP-LOW” all emissions are applied exclusively to the first model level. Note again that this applies only to SNAP sectors 2 and 7, while large point sources that are not relevant for megacities are not concerned by this sensitivity study.

Figure 1 provides a comparison of the vertical profiles of the experiments. In both cases, the vertical distribution is arbitrarily modified up to the third vertical level of the EMEP grid (about 200m above the ground).

3. Modelling Setup

We use the Chimere CTM for this sensitivity analysis (Bessagnet et al., 2008). The geographical domain covers the whole of Europe at a 50km resolution with 8 vertical levels up to 500hPa. Both gaseous and particulate pollutants are accounted for. Meteorological fields are obtained with

the WRF mesoscale model forced by ECMWF ERA-interim reanalyses, and boundary conditions are provided by the LMDzINCA global chemistry model climatology (courtesy of S. Szopa and D. Hauglustaine, LSCE/IPSL/CNRS).

For the reference and the numerical experiment, the whole year of 2007 is modelled in order to capture well the variety of vertical mixing regimes that occur for each season.

4. Results

Comparison of modelling experiments

Figure 2 displays the surface mean concentration of NO2, O3, and PM10 for REF and EXP-HIGH as well as the difference. The interpretation of these results is straightforward: primary species (NO2, PM10) are injected at a higher altitude in the experiment, hence their concentrations are lower at the surface. This difference is strongest in the urban emission hotspots of European megacities. For ozone, an increase is observed in urban areas in the experiment due to the lower titration brought about by the NO2 decrease at the surface.

In order to discuss the impact of emission height on the transport downwind of megacities, Figure 3 shows the modelled annual mean West-East vertical cross section at 50N (approximately the latitude of the main European air pollution hotspot) for ozone. It appears that in winter (left) ozone decreases in the lee of megacities (in the eastern part of the domain, exposed to the hotspot plume under dominating westerly winds). While in summer the main European emission hotspot located around longitudes 5W to 10E at this latitude exports photochemical pollution downwind.

Differences EXP-HIGH minus REF are displayed on the last row. They confirm that ozone increases at the surface as a result of reduced NO2 titration. However, at about 500m of altitude, ozone decreases in the experiment in winter. In the numerical experiment, NO2 injection at that altitude is stronger, leading to more titration and a decrease of O3. The interesting pattern here is the difference of DJF compared to JJA because of (1) different photochemical regimes and (2) different mean planetary boundary layer height.

Model performances

Whereas the above discussion of model differences provides a better understanding of the processes involved it is necessary to compare models to measurements in order to find out which setup performs best. An interpolation of model results at the location of Airbase stations (European Environmental Agency) is performed. The distributions of model scores for daily mean ozone and PM10 across all suburban background stations in Europe are displayed on Figure 4 and Figure 5, respectively (other types of stations are omitted for concision purposes but exhibit qualitatively similar behaviour).

It appears that for both PM10 and O3, the experiment with enhanced vertical venting (EXP-HIGH) of emissions performs less well than the reference. While the correlation is not really affected (because the modified setup is constant in time), the average bias increases leading to an increased root mean square error. On the contrary the ozone bias is slightly reduced for the EXP-LOW experiment, leading to a noticeable improvement of the root mean square error.

We can thus conclude that increasing the injection height of emissions compared to the reference profile would be detrimental to the model performance, although recent work on urban heat islands would have suggested that the vertical convective mixing might be enhanced in megacities. On the contrary it turns out that an improvement could be achieved by reducing the injection height of domestic activities.

References

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Bieser, J., et al., Vertical emission profiles for Europe based on plume rise calculations, Environmental Pollution (2011), doi:10.1016/j.envpol.2011.04.030

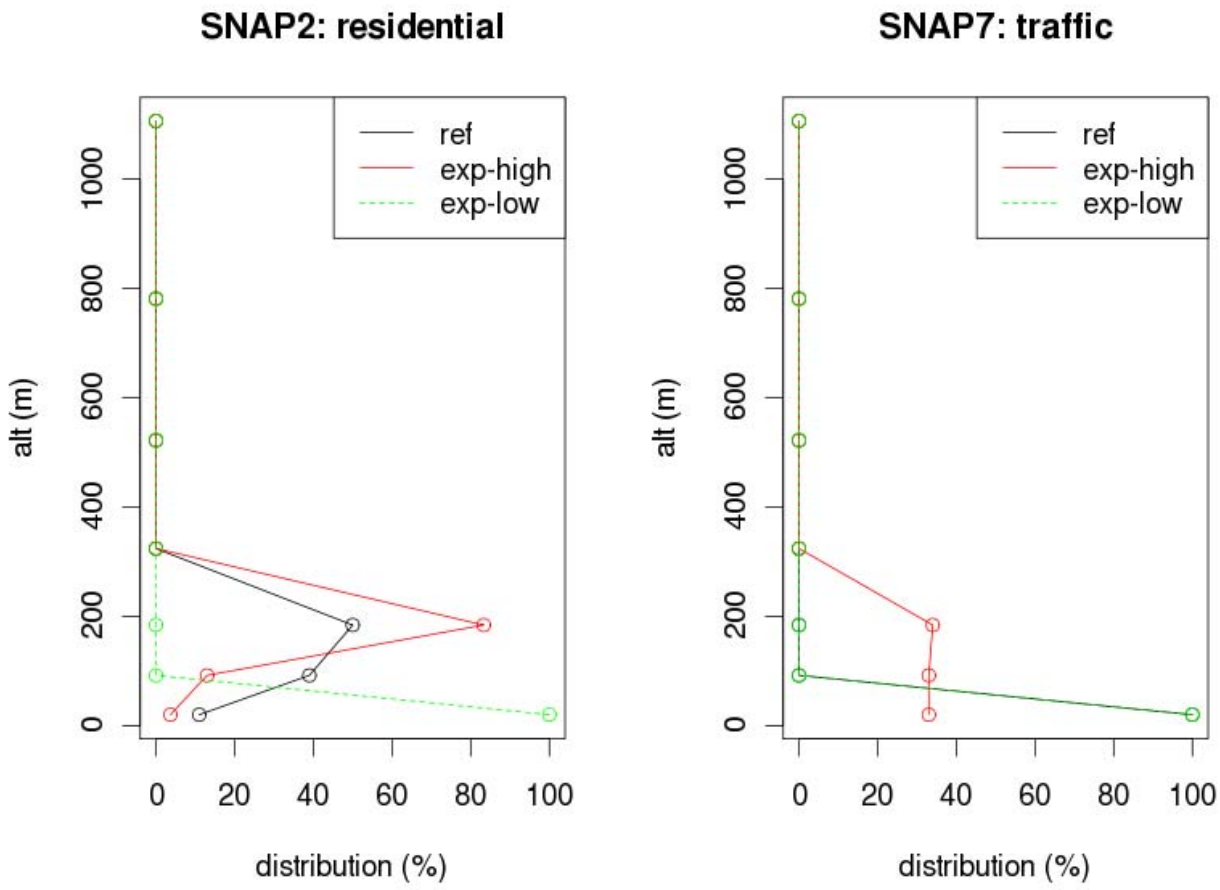

Figure 1: Vertical distribution of anthropogenic emissions for activity SNAP sector 2 and 7. Area emissions are provided as total flux from the surface in the EMEP inventory, and distributed according to the above profiles. Black: original profiles, red: sensitivity experiment with higher emission height, green: sensitivity experiment with lower emission height.

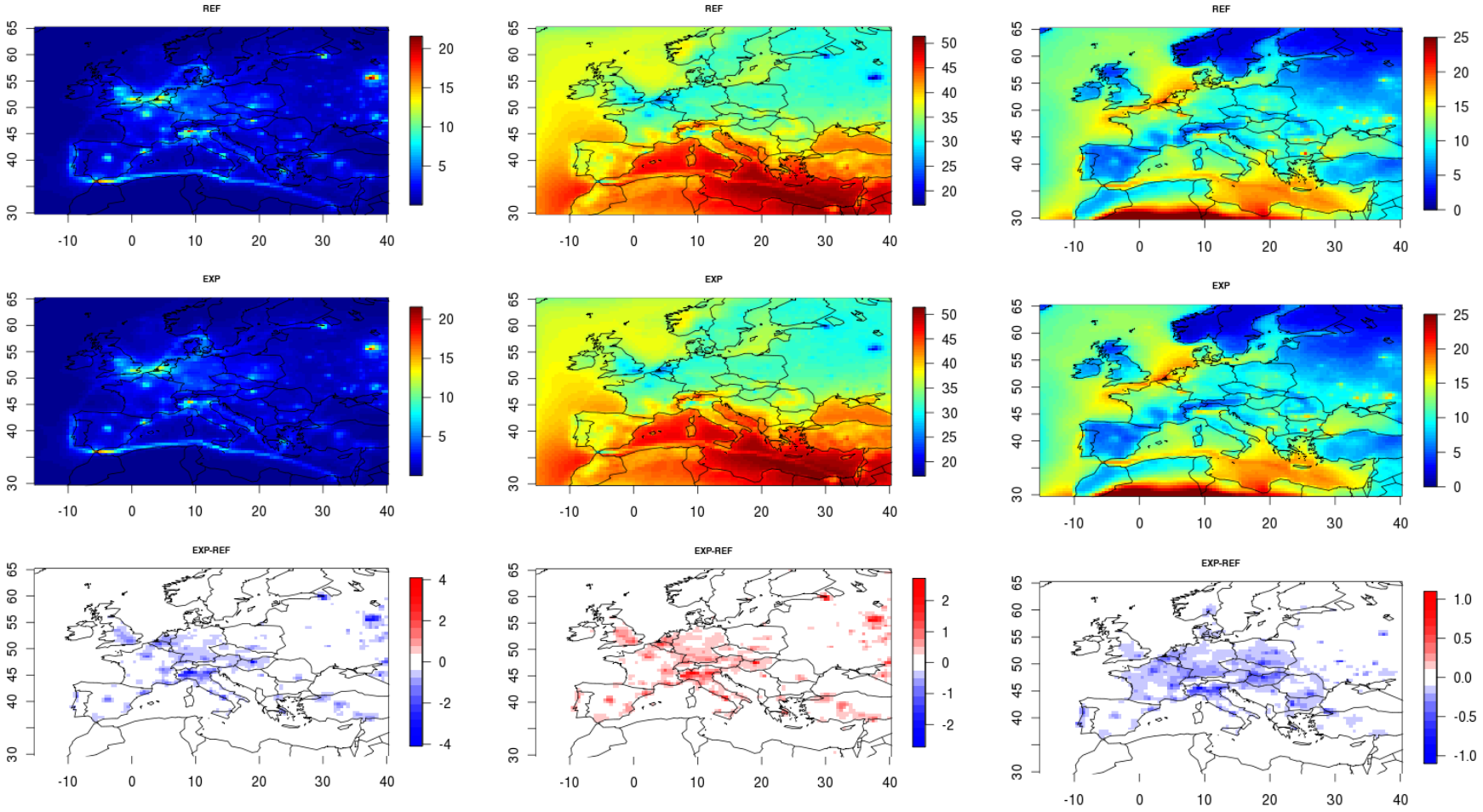

Figure 2: Annual mean map of surface concentrations of – from left to right - NO2 (ppb), O3 (ppb), and PM10 (µg/m3). From top to bottom: reference, experiment and difference (EXP-HIGH minus REF).

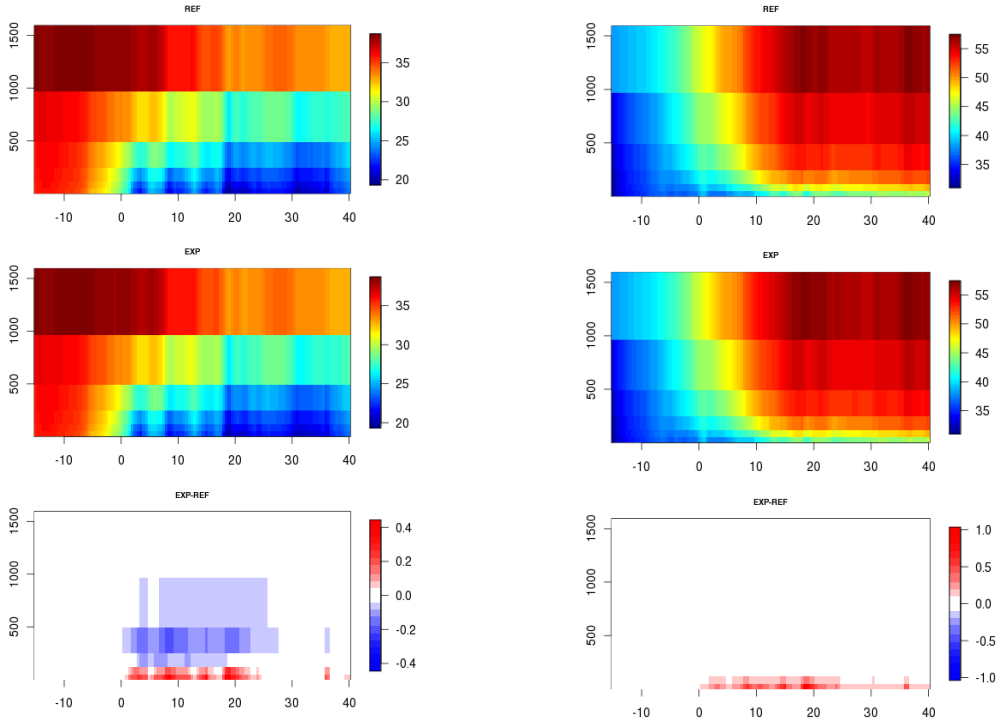

Figure 3: Annual mean West-East vertical cross section up to 1500m at 50N for O3 (ppb). Left: winter (DJF), right: summer (JJA). From top to bottom: reference, experiment and difference (EXP-HIGH minus REF).

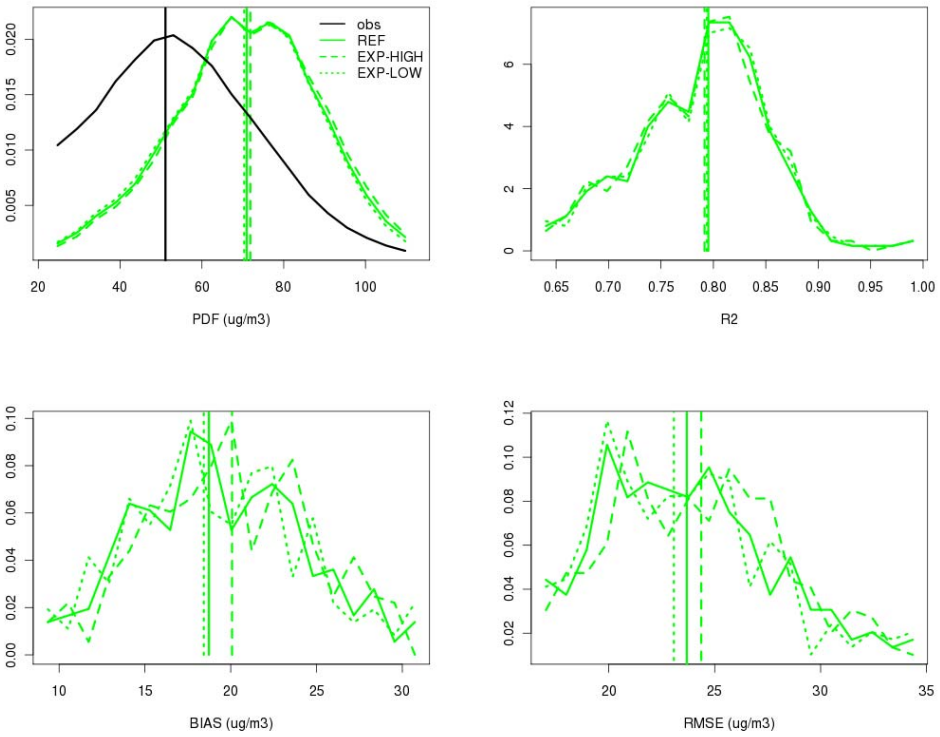

Figure 4: Model performance at suburban background air quality monitoring stations for the reference simulation (solid line) and the numerical experiments (dashed: EXP-HIGH, dotted: EXP-LOW). Top left: Ozone distribution, top right: correlation, bottom left: bias, bottom right: root mean square error. The vertical lines display the median of the distributions.

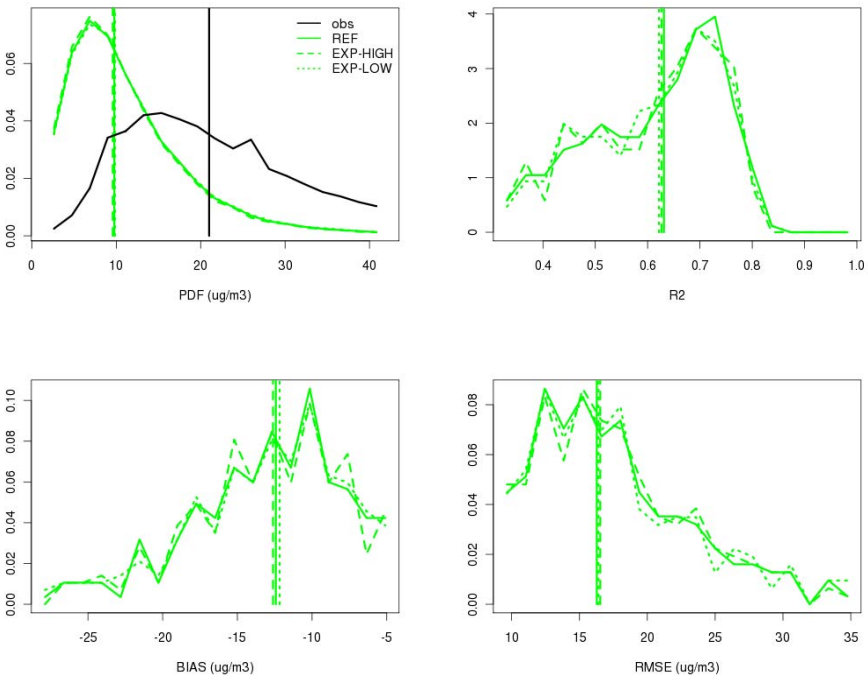

Figure 5: Same as Figure 4 for PM10.