Fine scale calculations of present and future effects of different modes of transport on air quality in Europe

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Introduction

Traditionally the EMEP MSC-W chemical transport model (hereafter the EMEP model) has been run as a regional model with an approximate 50 x 50 km2 resolution on a polar stereographic grid. Over the years modifications of the model has made it possible to run on different grid projection and model resolutions on model domains ranging from local to global. A detailed description of the EMEP model is given in Simpson et al. (2012) and references therein. In EMEP (2012) the effects refinements in model resolution was demonstrated, comparing model results calculated with approximate 56, 28, 14 and 7 km model resolution with measurements from the EMEP database within 200 km from an urban area and from AIRBASE (http://www.eea.europa.eu/data-and-maps/data/airbase-the-european-air-quality-database) where the sites have been characterized as either rural (but within 30km from an urban area), urban or traffic. For the EMEP and AIRBASE urban sites model resolution was shown to have only minor effects on model results. On the other hand refinements in model resolution have been shown to improve model results, in particular for primary pollutants such as NO_2 and PM2.5 with generally higher calculated concentrations at these sites. For ozone calculated levels are lower with finer resolution as a result of increased calculated titration.

In this study the EMEP MSC-W chemical transport model is used to calculate the effects of emissions from the transport sectors on air pollution levels on a European model domain with a 1/8 x 1/16 degree latitude-longitude resolution with the aim of studying the effects of present (2005) and future (2030) emissions on air quality in Europe. Meteorological data for 2009 are used in this study. Thus all changes in calculated pollution levels are ascribed to changes in emissions. The model calculates windblown dust emissions from soil within the computational domain. The inflow of African dust from beyond the (Southern) lateral boundary is accounted for through boundary conditions provided by the global chemical transport model of the University of Oslo (CTM-2) for 2000 as monthly averages (Grini et al., 2005)

Emissions

A new bottom-up emission set for transport modes is integrated in the TNO-MACC European emission data base for 2005 (Kuenen et al., 2010). The emission set has been developed under the framework of the EU 7'th framework project TRANSPHORM (In addition future emissions is projected using the scaling factors developed for the EU FP7 project MEGAPOLI (Theloke et al, 2010) combined with newly calculated future emissions for the transport sectors. As shown in Figure 1, overall PM2.5 emissions do not change dramatically in the near future, but specific source sectors show substantial decreases as illustrated for road transport in Figure 1. There are however substantial changes (mainly reductions) in the emissions for other species. From shipping the assumed increases in NOx emissions are substantial.

2005 versus 2030 emissions

In Figure 2 a) and b) model concentrations of NO_2 and PM2.5 are shown, calculated with 2030 emissions. For NO2 high concentrations are mainly calculated for the major city conglomerations as the Po valley in Italy and the regions around the English Channel in addition to large cities as Paris and Moscow. Major ship tracks can also be identified. The same cities and city conglomerations also have high calculated concentrations of PM2.5, but for PM2.5 concentrations are in particular high over

Northern Africa due to dust formation. Compared to present (2005) levels, calculated concentrations of NO_2 are significantly reduced as a result of reductions in NOx emissions (Figure 2 c). Although primary PM2.5 emissions are not significantly reduced (Figure 1), anthropogenic emissions of most other species are significantly reduced (Figure 2 d), resulting in reductions in secondary PM2.5 formation.

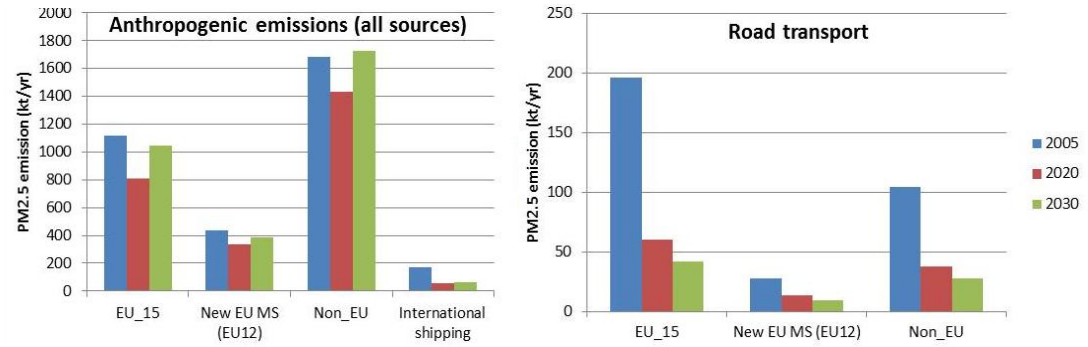


Figure 1. *European emissions of PM2.5 in 2005 (base year) and projections for the years 2020 and 2030. Right, total emissions. Left, road transport only. Notice difference in scale.*

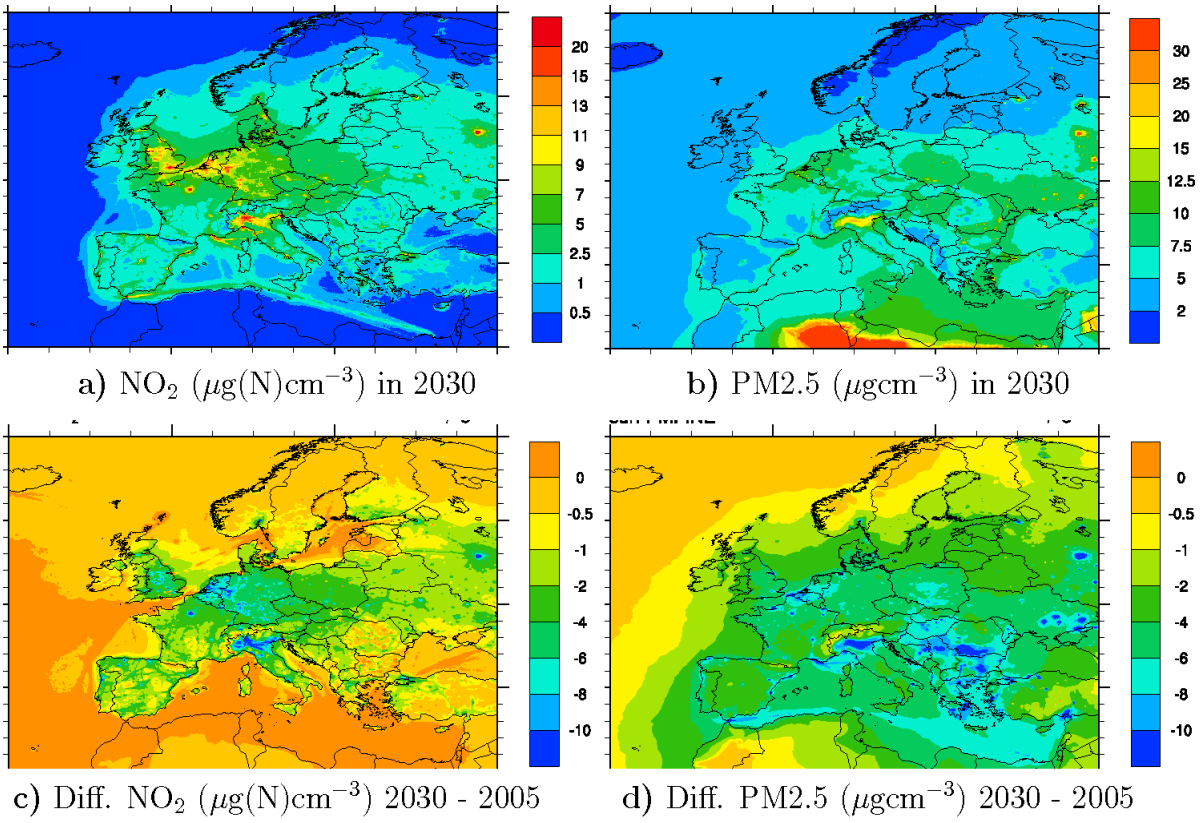
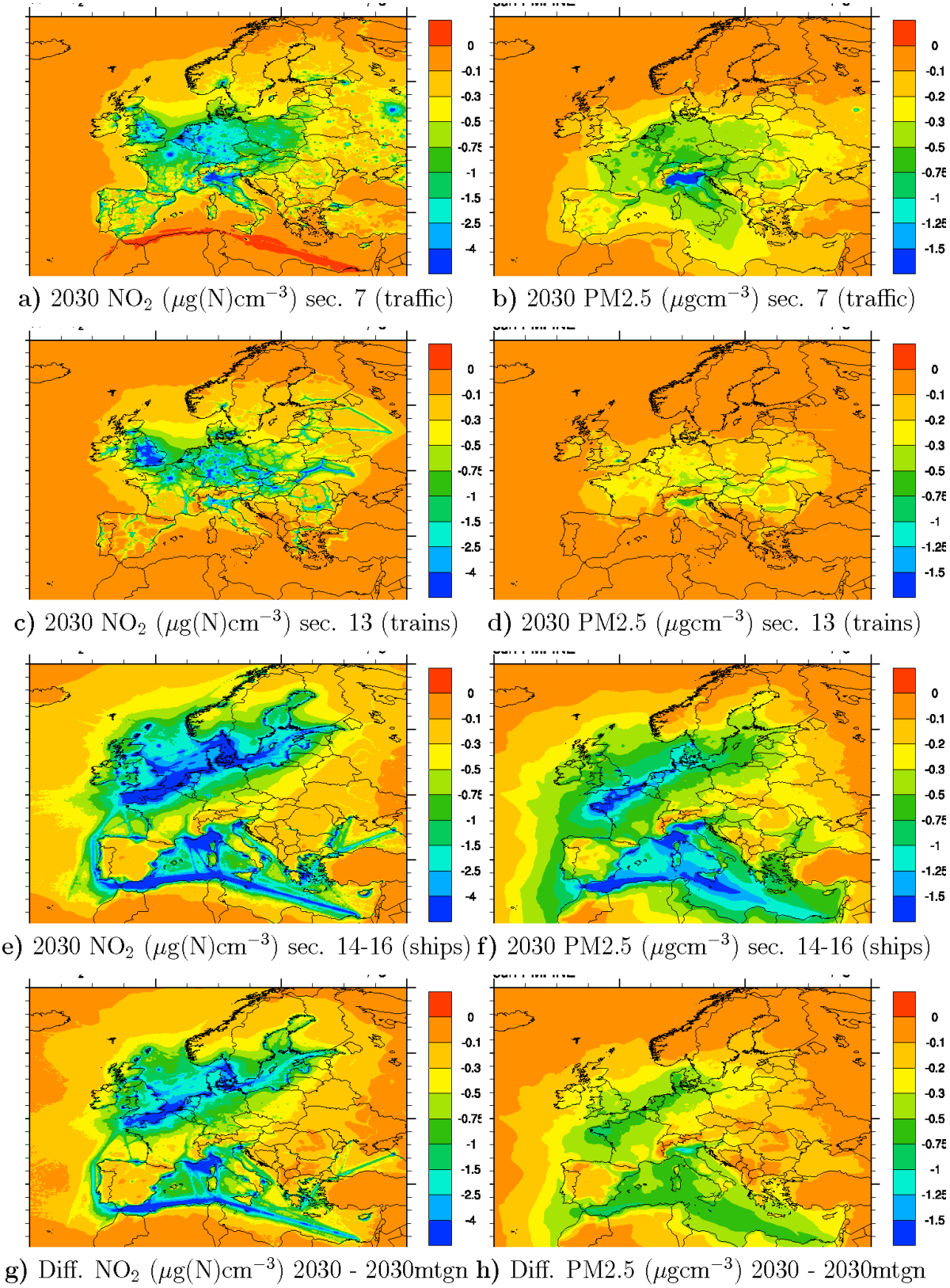


Figure 2. *Model calculated annually averaged NO2* ***a)*** *and PM2.5* ***b)*** *in 2030 for the European region.* ***C)*** *and* ***d)*** *shows the calculated difference in NO2 and PM2.5 with future (2030) – present (2005) emissions.* ***e)*** *and* ***f)*** *shows the calculated difference in NO2 and PM2.5 with 2030 – 2030 mitigation emissions. See text for description of the 2030 mitigation scenario.*

Effects of emissions from different transport modes

For the calculations with future emissions, the effect of emission changes on PM levels has been analysed for different transport modes, including rail, sea transport, road transport and aviation



a) 2030 NO_2 (μg(N)cm^{-3}) sec. 7 (traffic) b) 2030 PM2.5 (μgcm^{-3}) sec. 7 (traffic)

c) 2030 NO_2 (μg(N)cm^{-3}) sec. 13 (trains) d) 2030 PM2.5 (μgcm^{-3}) sec. 13 (trains)

e) 2030 NO_2 (μg(N)cm^{-3}) sec. 14-16 (ships) f) 2030 PM2.5 (μgcm^{-3}) sec. 14-16 (ships)

g) Diff. NO_2 (μg(N)cm^{-3}) 2030 - 2030mtgn h) Diff. PM2.5 (μgcm^{-3}) 2030 - 2030mtgn

Figure 3. Year 2030 *model calculated effects of: road traffic on NO_2* ***a),*** *of road traffic on PM2.5* ***b),*** *of trains on NO_2* ***C),*** *of trains on PM2.5* ***d),*** *of ships on NO_2* ***e),*** *of ships on PM2.5* ***f),),*** *of mitigations on NO_2* ***g)*** *and of mitigations on PM2.5* ***h)***

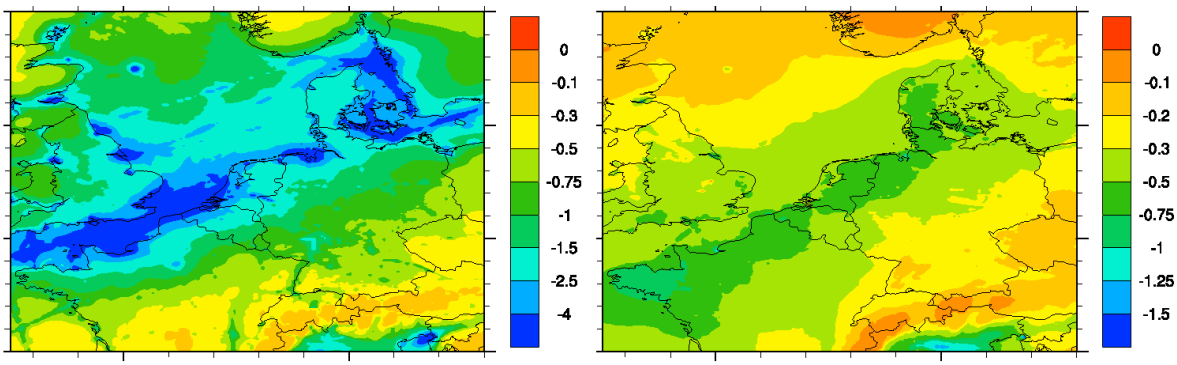
(not shown here). The main focus is on PM2.5 concentrations as particles in this size range are believed to have substantial health effects, but also on NO_2. This species also has some health

effects. NO_2 has a short lifetime in the atmosphere, and thus concentrations largely reflect NOx emissions.

The impact of different transport modes (road traffic, shipping and trains) is evaluated in Figure 3 a) – f) for NO_2 and PM2.5. The effect of aviation has also been calculated, but is not shown here as the calculated effects are very small. Contrary to almost all other sources, NOx emissions from shipping are projected to increase from 2005 to 2030. As a result removal of emissions from shipping has the largest effect on both NO_2 and PM2.5 levels in 2030 as shown in Figure 3 e) and f). For NO_2 the effects of (diesel) trains and road traffic are comparable. For PM2.5 the effects of road transport is in particular large in the Po valley in Northern Italy. This seems to be related to a larger fraction of VOC emissions in Italy originating from road transport than for other countries/regions in 2030. For the effects of traffic and trains on NO_2 levels several major highways and railway lines can be identified.

Effects of the mitigation scenario for 2030

We have also calculated the effects of a mitigation scenario for year 2030 provided by TRANSPHORM. The effects of the mitigation options are shown in Figure 3 g) for NO_2 and Figure 3 h) for PM2.5. Marked reductions are seen for both species. The largest decreases are associated with reductions in the emissions from shipping off more than 50% for NOx. This is also illustrated for the sub-domain focusing on Northwest Europe and the North Sea shown in Figure 4 a) and b). The effects of the mitigation scenario are dominated by changes in NOx emissions. For PM2.5 the largest reductions are calculated slightly inland from the North Sea.



a) Diff. NO_2 (μg(N)cm^{-3}) 2030 - 2030mtgn b) Diff. PM2.5 (μgcm^{-3}) 2030 - 2030mtgn

Figure 4. *Year 2030 model calculated effects of mitigations on NO_2* ***a)*** *and on PM2.5* ***b)*** *. (same as Figure 2 g) and h), but for sub-domain bounded by* 5 degrees West, 16 degrees East and 45 degrees North and 60 degrees North.

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