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Interactive comment on "Modelling NO$_2$ concentrations at the street level in the GAINS integrated assessment model: projections under current legislation" *by* G. Kiesewetter et al.

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We thank the Referee for his/her constructive comments and suggestions on how to improve the manuscript. Below we provide detailed point by point replies to the questions. Referee comments are quoted in ***bold italicised*** font.

Page 22694, equation 3: How big are the residuals as a percentage of NOx?

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Figure 1 shows the distribution of this residual (δ_{NOx} in Eq. 3) over Europe. In most of the European countries, particularly in the EU, the residual (positive or negative) is less than 10% of total NOx concentrations. Only in limited areas, particularly in the Po valley, base case NOx levels are overestimated by the linearised scheme (i.e. $\delta_{NOx} < 0$) by more than 10%, presumably due to nonlinear chemistry in nitrate aerosol formation or deposition. Towards the southern and eastern boundaries of the continent, the influence of external countries becomes visible as a tendency to underexplain the base case with just the emissions of the 53 source regions for which reduction runs were performed. A small contribution to the under-explained areas should also come from soil NO emissions. Note that the relative picture over-emphasizes the δ in regions with low absolute NOx concentrations such as Spain: In absolute terms, positive concentration residuals are less than $0.5\,\mu\text{g/m}^3$ everywhere, while negative residuals are up to $3\,\mu\text{g/m}^3$ in the Po valley and less than $1.5\,\mu\text{g/m}^3$ everywhere else.

Page 22695: How was the factor of 0.5 arrived at? How is it justified?

We have added a sentence in the text to clarify this. In a study based on computational fluid dynamics modelling as well as wind tunnel measurements, Solazzo et al. (2009) showed that the wind speed in the urban canopy layer just above the roof tops is roughly half of that in the undisturbed troposphere.

The text immediately before equation 4 talks of a regression coefficient but it is not clear what has been regressed against what. This process could be made clearer.

The regression relates subgrid increments in surface NOx concentrations in the CHIMERE CTM to subgrid increments in the NOx emissions that were used in the CHIMERE run. Through this regression coefficient, we can calculate the urban increment for different scenario years (i.e. different NOx emissions) although only one full year CHIMERE simulation with 7 km resolution was performed.

Page 22697: How do the calculated NO2/NOx ratios compare with those observed? 'The share of NO2 in NOx emissions' is obtained from emissions modelling — this is a potentially important quantity for roadside/kerbside NO2 concentrations. Not only should the authors say more on how they obtained these numbers but they should also comment on how realistic they might be given recent evidence from real-world measurements in the studies quoted by the authors (Carslaw and Rhys-Tyler, 2013, and Carslaw et al 2011a).

This point was also raised by Referee 1, and we have tried to make this clearer in the text. We are combining a bottom-up calculation with the calibration to observations as follows: We use standard emissions factors derived from COPERT IV for each vehicle technology (= Euro norm). Most uncertain are assumptions for diesel cars and light trucks. The share of primary NO2 in the exhaust is taken from the Handbook Emission Factors for road transport (HBEFA) 3.1 (http://www.hbefa.net), which is based on representative chassis dynamometer tests. Different values have been reported in different studies (see Table 1). The HBEFA shares fall in the middle of other literature values mentioned by the reviewer, and we therefore consider them a good choice.

These emission factors are then multiplied with the (urban) activity of the fleet. Due to lack of specific data at individual stations we assume a national average urban fleet mix, knowing that at each station the fleet is actually specific. We assume that the temporal changes due to turn-over of the fleet, changes in activity and technological progress at each station are as on national average.

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Table 1. Primary NO2 emission shares in the literature. a: Sjödin and Jerksjö (2008); b: Grice et al. (2009); c: HBEFA 3.1 (2010); d: Carslaw and Rhys-Tyler (2013); e: Weiss et al (2011). (c) is used in GAINS.

control	(a)	(b)	(c)	(d)	(e)
no	14%	11%	8%	15%	
Euro 1	14%	11%	8%	14%	
Euro 2	14%	11%	11%	9%	
Euro 3	47%	30%	28%	16%	
Euro 4	55%	55%	47%	28%	40%
Euro 5	55%	55%	36%	25%	46%

Page 22698: The subscripts n, O, V used in equation 9 are not defined.

These quantities are defined in the lines just below Eq. 9. We did not go into the details of describing what they exactly represent since they (like the quantity B) are only used for notational convenience within Eq. 9 and can be directly calculated from the input quantities listed end of p. 22698 – beginning of p. 22699. The full description of the steady state model goes beyond the scope of this article and can be found in Duering et al. (2011).

Page 22704: How do the GAINS emission estimates compare with totals calculated by the countries themselves, using, presumably, data which are more specific to that country?

The work presented has been used by the European Commission in their discussions with Member States. To ensure as much consistency as possible we have calibrated 2005 and 2010 emission inventories to emissions reported to EMEP within 5–10%, by each SNAP sector. We have had extensive consultations with Member States' representatives to understand differences and to agree on common numbers. Hence for historic years emissions should be as comparable as possible.

Page 22705: Figure 8 could usefully show the standard deviation around each measured and modelled point on the graph.

We have followed the referee's suggestion.

Page 22712: What is the justification for using +/- 5 ug/m3? The discrepancies between modelled and measured in Figure 9 are often very much greater. If this form of 'backcasting' is a measure of the uncertainty of the model predictions, then arguably +/-5 ug/m3 is too small?

The $5\,\mu\mathrm{g/m}^3$ margins were seen as a reasonable compromise which do account for the model uncertainties to some extent but are still small enough to make the result usable for policy analysis.

The main idea of the introduction of "compliance classes" is that within the class, positive and negative deviations compensate as there will be stations which have, due to their local situation, a higher than average emission (and/or NO2 emission share) trend, and others for which the decline in emissions will be weaker than average. The European mean bias between observations and model is less than $4.2\,\mu\mathrm{g/m}^3$ for all traffic stations in all years (less than $2.7\,\mu\mathrm{g/m}^3$ for all station types). Note that this value also

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includes inter-annual variability through variations in meteorological conditions, which are not accounted for in the model.

From Figure 9 it is obvious that the model works well in reproducing the observed trends in most countries but has difficulties in a few. Rather than defining a margin individually for each country (which does not make sense for a European wide policy analysis), we defined margins from the European average, and tried to identify the issues that lead to a trend mismatch in individual countries. Examples for trend mismatches (model declining too fast) are Italy, Belgium, and the UK. In all of these countries, the more stagnant observed trends can to our understanding be at least partly explained by the strong increases in NO2/NOx emission shares (p), which do affect urban background NO2 trends in reality but not in our model. Since the increases in p are expected to be much smaller than those seen in the 2000s, we are confident that this systematic trend deviation will not be propagated into the future in a comparable magnitude.

Page 22714: Does the process of adding the large point source emissions to the emissions from lower height sources give erroneous results for the contribution of the large (and higher stack) point sources to ground level concentrations?

The generation of a 7×7 km emission inventory for the whole CHIMERE domain required compromises. To clarify what was done: For each SNAP sector, all contributions in MACC were first summed up and then assigned emission heights according to standard profiles. This procedure was adopted because there simply is no detailed information on stack heights available at a European scale. The MACC inventory quantifies large point source emissions but does not give information about stack heights either. The stack height assignment used here is state of the art for CTM emission modelling; it has been described by Bieser et al. (2011).

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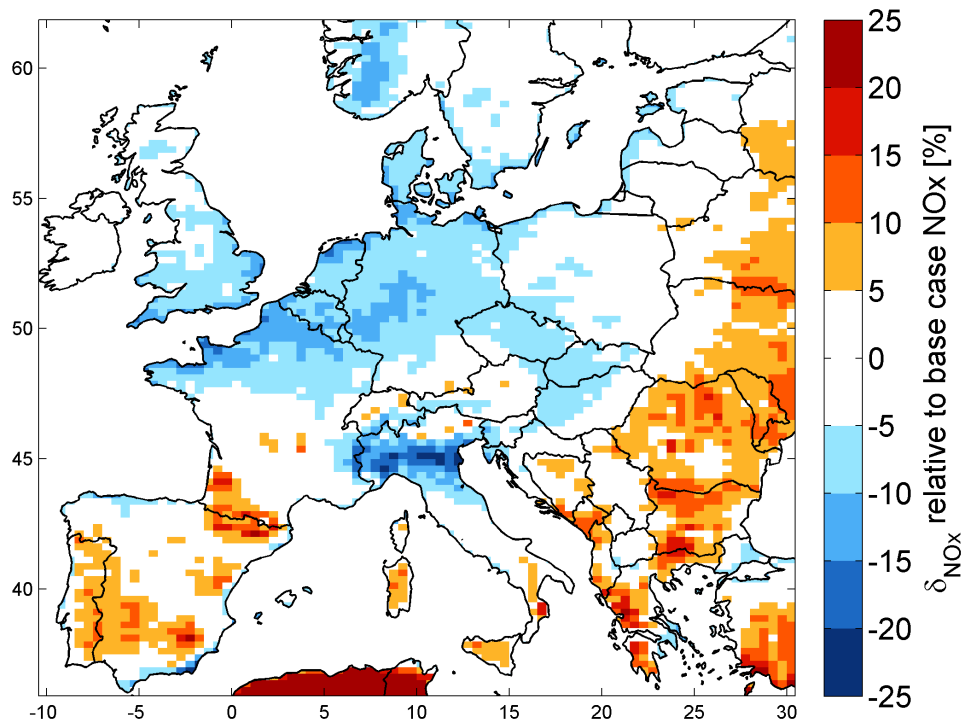
Fig. 1. Residual NOx (difference from linear contributions to base case) as % of base case. Positive values indicate that the linearised model under-predicts the full model and vice versa.

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