CityZen

megaCITY - Zoom for the Environment

Collaborative Project

7th Framework Programme for Research and Technological Development
Cooperation, Theme 6:
Environment (including Climate Change)

Grant Agreement No.: 212095

Deliverable D1.5.2, type R

Evaluation of current state of modelled NO_2, PM_{10} and ozone

Due date of deliverable: project month 22
Actual submission date: project month 29

Start date of project: 1 September 2008 Duration: 36 months
Name of lead beneficiary for this deliverable: FRIUUK
Scientist(s) responsible for this deliverable: H.J. Jakobs, M. Memmesheimer

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
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)	

Overview

During the first phase of the project a standard model configuration has been applied to perform and analyse decadal variations in the Central Europe/BeNeLux-Ruhr area for the period 2000 - 2009. A first preliminary evaluation of the results for NO_2, PM_{10} and ozone is presented within deliverable 1.5.2 for daily averages. The data as calculated by the model have been used also to perform budget calculations for deliverable 1.5.3 as well as model input for a model intercomparison study within CITYZEN with the aim to evaluate the current state of modelled ozone, PM and deposition fields together with other modelling groups (Colette et al., 2011). The results presented here will give a first impression on the performance of the decadal variations for the North-Rhine-Westphalia region on the basis of simulations for the N1-domain with a horizontal grid size of 25 km.

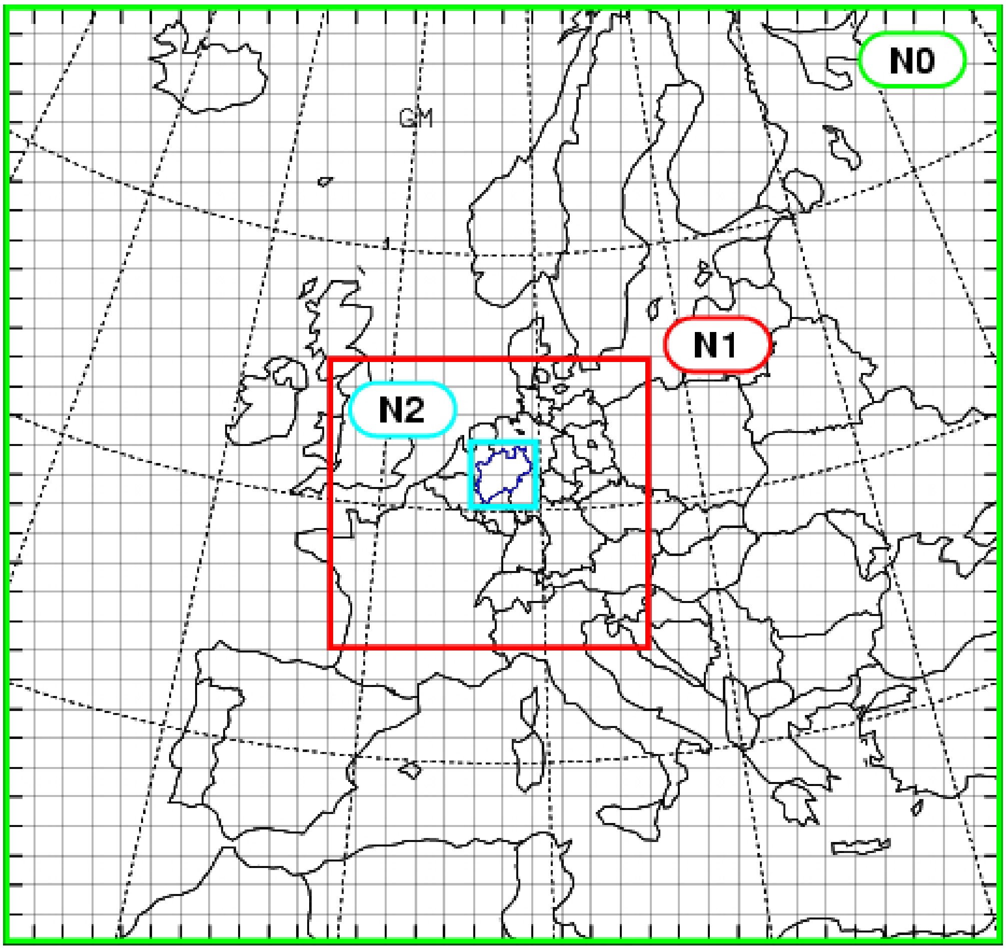

Figure 1: Model configuration from the European scale to the local scale, grid sizes 125, 25, 5, and 1 km. The N1-domain with a grid size for 25 km has been selected for the comparison of results from the numerical simulation covering the decade from 2000 – 2009 with observations based on the local network within North-Rhine-Westphalia.

Model Design

The model design is shown in figure 1. Grid resolutions are 125 km, 25 km and 5 km for North-Rhine-Westphalia, and 1 km for the Ruhr area. Development and testing of methods to perform the decadal numerical simulations and their analysis has been done first with this model configuration, which has been used successfully for daily forecasts before (www.riu.uni-koeln.de). The modelling region will be extended to a larger domain with the aim to improve the applicability and performance of the whole system leading to a more sophisticated model design, which will be investigated in the second phase of CityZen (see Figure 5). Grid sizes in that case are selected to 45, 15, 5 and 1 km. Calculations already have been started and are currently underway. Vertical resolution in both cases is done by 23 layers from the surface up to about 16 km. 16 layers are within the convective boundary layer (3 km), the thickness of the lowest layer is about 40 m. All data have a temporal resolution of 1 h and are stored permanently. On this basis a more sophisticated analysis will be done with the extended model domain.

First results

Figure 2 gives an overview on the results of the model calculation showing the annual average for each of the years 2000 – 2009. In particular in Belgium, the Netherlands, Paris, Northern Italy and parts of England an annual value of 40 µg/m^3 has been exceeded. The figures, however, also show a slight decrease of the annual average of NO_2 approaching the year 2009. An exception are the areas with ship traffic emissions, which are assumed to have increasing emissions and therefore also show a tendency for increasing NO_2 concentrations. A similar effect can be seen for the annual average of PM_{10}, which also show a decrease going from 2000 to 2009. For ozone no clear tendency can be seen.

An example for the comparison between model results and observations is shown in Figures 3a – 3c for NO_2, PM_{10} and ozone for each year during the decade 2000 – 2009. The daily average is selected to display scatter diagrams of measured and simulated values for each year from 2000 – 2009 separately. Measured data are from the network of the North Rhine Westphalia State Agency for Nature, Environment and Consumer Production (LANUV-NRW, www.lanuv.nrw.de).

The annual averages of NO_2 for the decade are between 29.0 µg/m^3 (lowest value, year 2000) and 36.2 µg/m^3 (highest value, year 2003). Even if the highest value occurs in 2003, all the other high annual averages above 35 µg/m^3 are found in the years 2007 – 2009 at the end of the decade. 2003 has been an extraordinary year with respect to air pollution and shows always the highest annual average for all compounds (NO_2, PM_{10}, Ozone, O_x:=NO_2+O_3) presented here (see also Figure 4a – 4d). The simulated annual averages are between 24.4 µg/m^3 (year 2007) and 32.0 µg/m^3 (year 2003). The highest modelled results for NO_2, in contrast to the observation, occur in the beginning of the decade, all values below 30 µg/m^3 show up from 2005 on, i.e. in the second half of the decade. Therefore the bias between observations and modelled results increases during the decade up to more than 10 µg/m^3 in 2007 and 2009 (underestimation of observations). A possible reason might be the increasing contribution of primary NO_2 emissions to the total NO_x emissions. Therefore, even decreasing total NO_x emissions might not lead to decreasing NO_2

emissions and consequently might be one reason for the possible trend of increasing or nearly constant NO_2 concentrations during the decade with some variability which might be attributed to changing meteorological patterns. The increase of the NO_2/NO_x ratio in the NO_x-emissions was not yet implemented in the emissions used in the model calculations, this might be one reason for the increasing bias between model and observation at the end of the decade. Correlation is from 0.52 (2000, 2001) down to 0.37 (year 2007), the 50% hit rate is in the range of 81.5% (year 2000) down to 56.5% (year 2006).

Observed annual PM_{10} values reach from 24.5 µg/m^3 (year 2007) up to 29.4 µg/m^3 (year 2003), modelled values are from 22.4 µg/m^3 (year 2007) up to 29.2 µg/m^3 (year 2003). Except for the year 2000, simulated PM_{10} is always lower than observed PM_{10}, the highest bias is -2.3 µg/m^3 and considerably less than for NO_2 (-11.2 µg/m^3). Correlation is from 0.52 (2000, 2002) till 0.60 (2009) again higher than for NO_2. So, in general, with respect to calculated annual averages the model obtains better results for PM_{10}.

For ozone the observed annual average in the range from 36.7 µg/m^3 (year 2000) till 47.1 µg/m^3 (year 2003), the values as calculated by the model are between 41.3 µg/m^3 (year 2001) and 47.9 µg/m^3 (year 2003). Bias is always positive (observations overestimated by measurements) in the range of 0.8 µg/m^3 and 6.4 µg/m^3, correlation is between 0.60 and 0.78, the 50% hit rate between 78.8% and 89.6%.

Summary and preliminary conclusions

A complex three-dimensional chemical transport model has been used to simulate the chemical state of the atmosphere over Europe and Central Europe for the decade from 2000 – 2009. Results with a horizontal grid resolution of 25 km have been compared for measurement sites in North-Rhine-Westphalia for NO_2, PM_{10} and ozone. Examples have been displayed as scatter diagrams for each year for daily averages and as time series for annual averages. Results for PM_{10} show a good performance even if the modelled values are always lower than the measured data. The general trend over the decade is well represented for PM_{10} showing a decrease during the decade for observations as well as for measurements. The observed trend for NO_2 is not simulated by the model probably due to an underestimation of the NO_2/NO_x ratio (Grice et al., 2009) in the total NO_x-emissions as used in the model. For ozone no clear trend can be seen in the modelled or measured data. Annual average of ozone is always overestimated from the model results, the temporal variability of annual averages during the decade however is very similar for observations and model simulation. Future investigation aim on an extension of the modelling area as displayed in figure 5, contribution to the CityZen modelling intercomparison study (Colette et al., 2011), investigation of the impact of grid resolution and the impact of emissions versus meteorological effects (constant emission run).

Acknowledgements

This work has been supported by the RRZK/ZAIK, University of Cologne and the Research Centre Jülich (FZJ). The availability of EMEP emission data and measurement data from the LANUV NRW is gratefully acknowledged.

References

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ANNUAL AVERAGE 2000 – 2009: NO_2

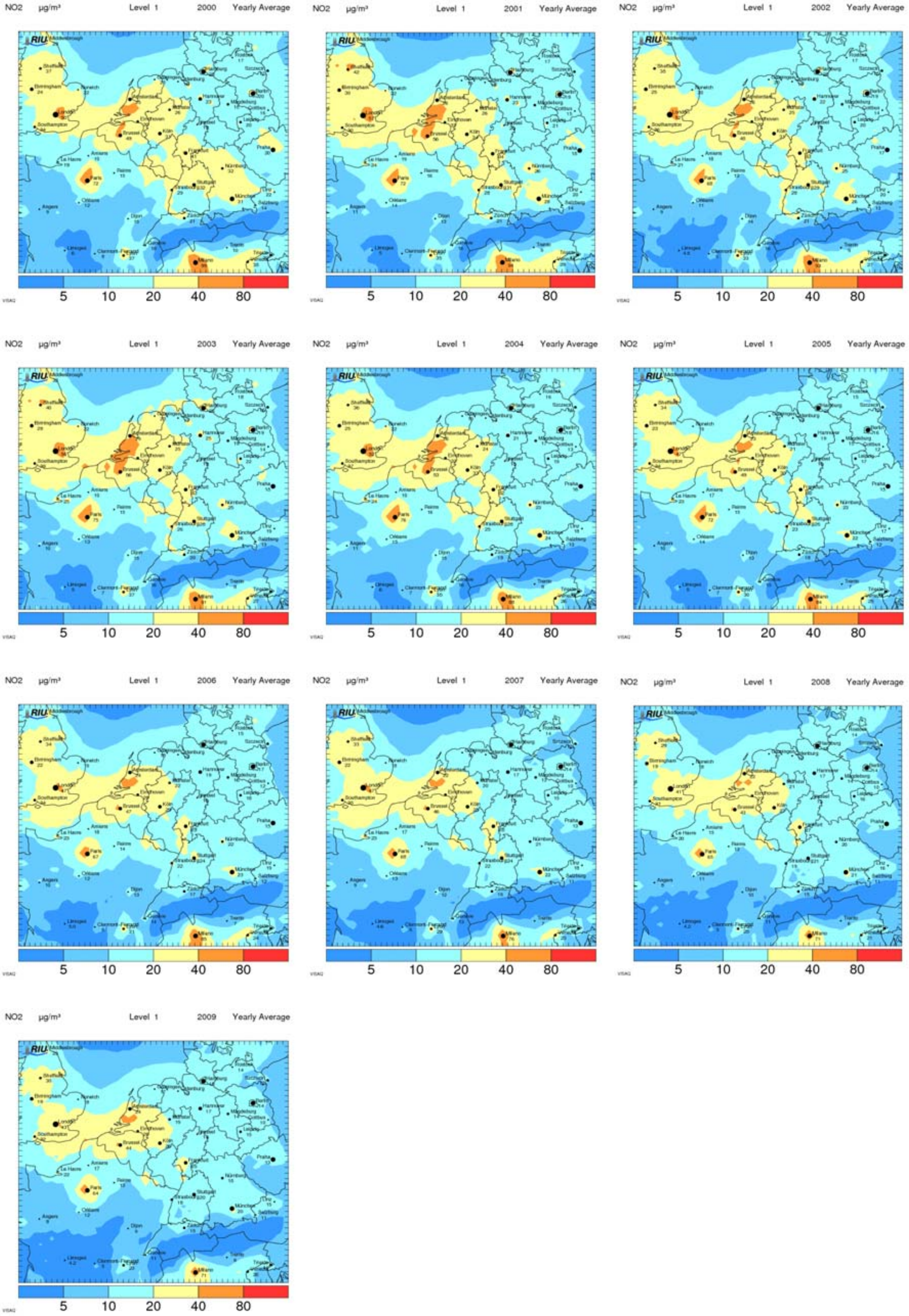

Figure 2a: Annual average of NO_2 for the N1-domain (25 km grid size, see Figure 1) for the year 2000 till 2009.

ANNUAL AVERAGE 2000 – 2009: PM_{10}

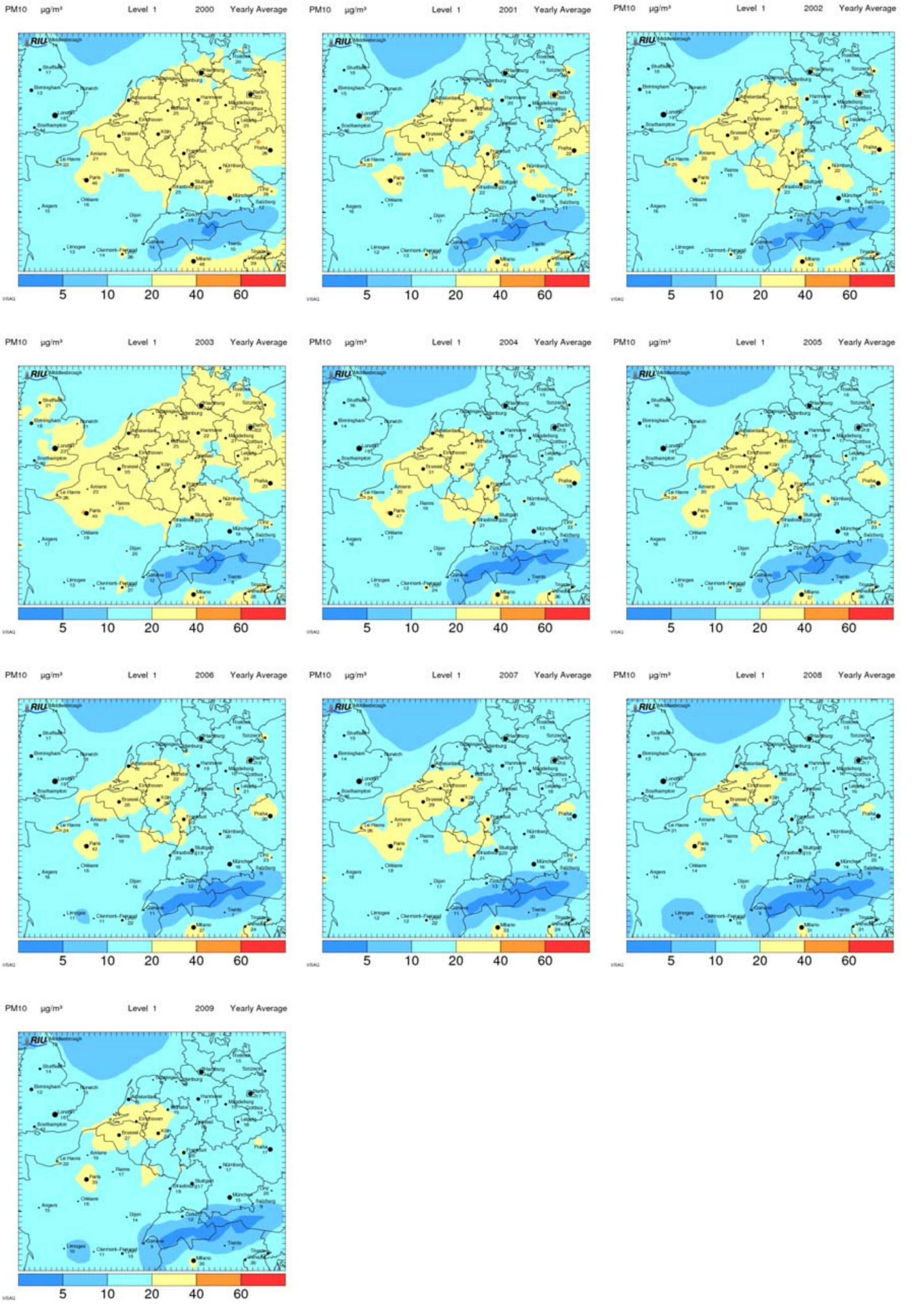

Figure 2b: Annual average of PM_{10} for the N1-domain (25 km grid size, see Figure 1) for the year 2000 till 2009. Data are calculated on the basis of hourly values.

ANNUAL AVERAGE 2000 – 2009: O_3

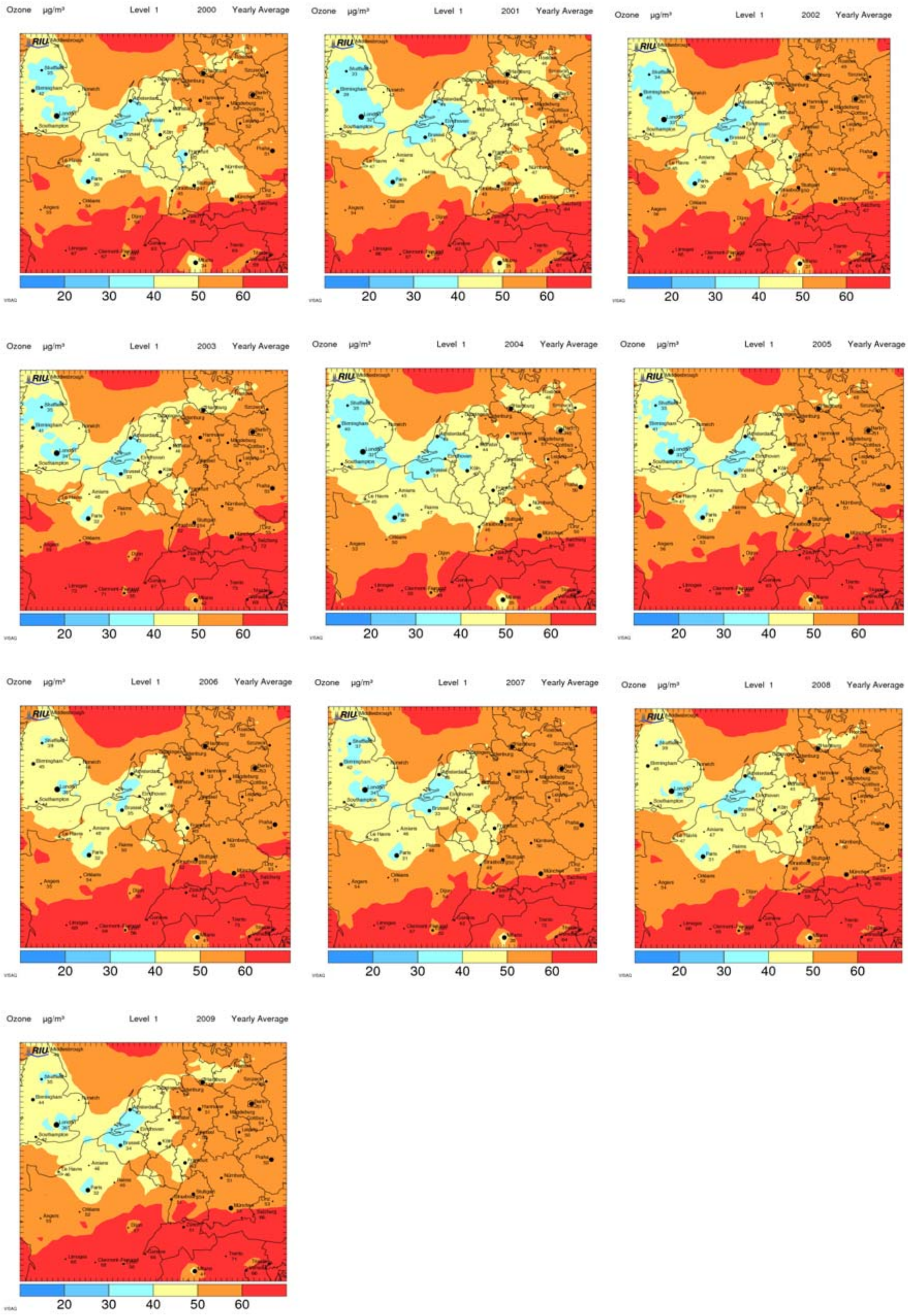

Figure 2c: Annual average of O_3 for the N1-domain (25 km grid size, see Figure 1) for the year 2000 till 2009. Data are calculated on the basis of hourly values.

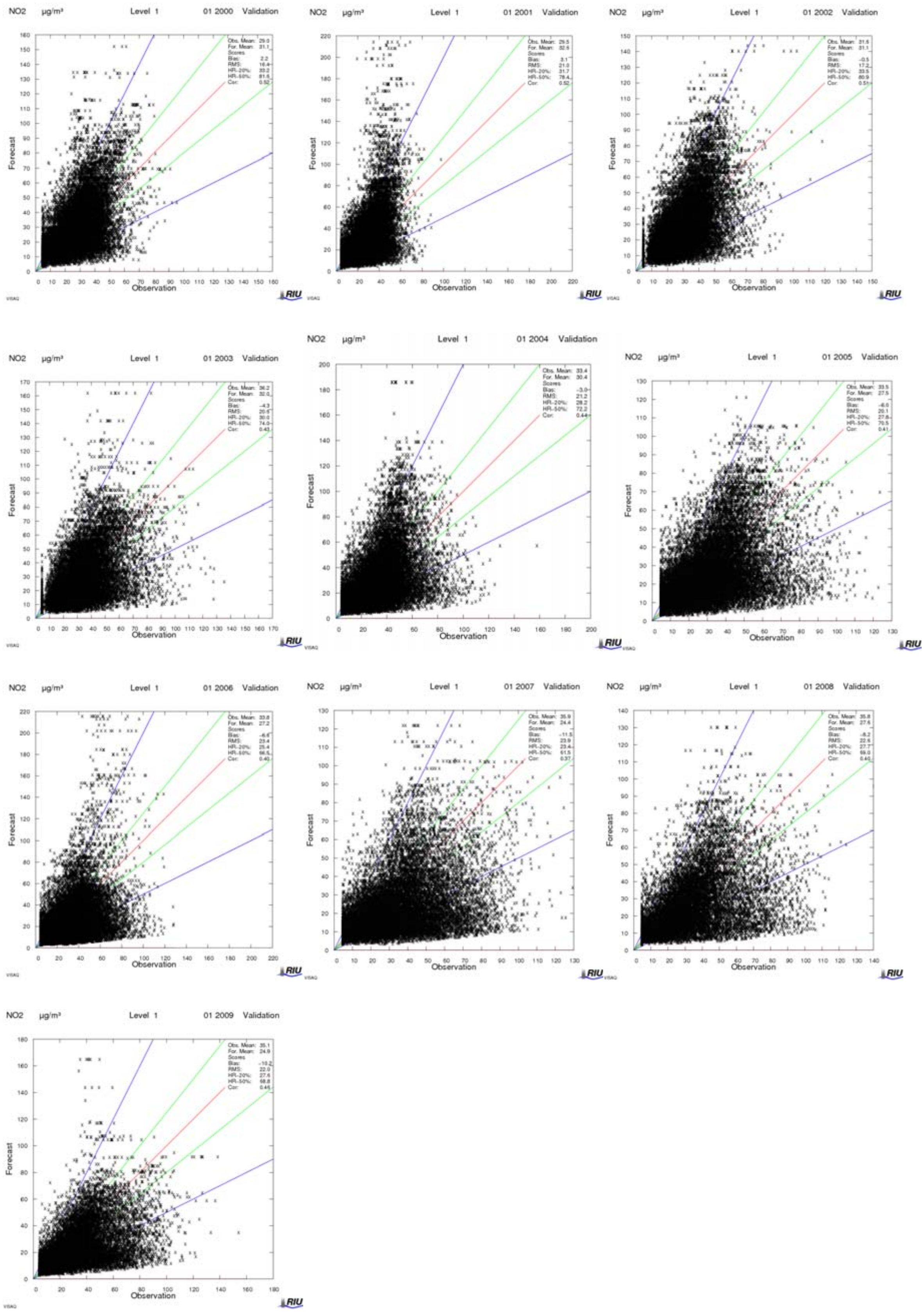

Figure 3a: Comparison of calculated and observed data for the years 2000 - 2009. Daily averages of NO_2. Modeling area is Central Europe, measured data are from North-Rhine-Westphalia.

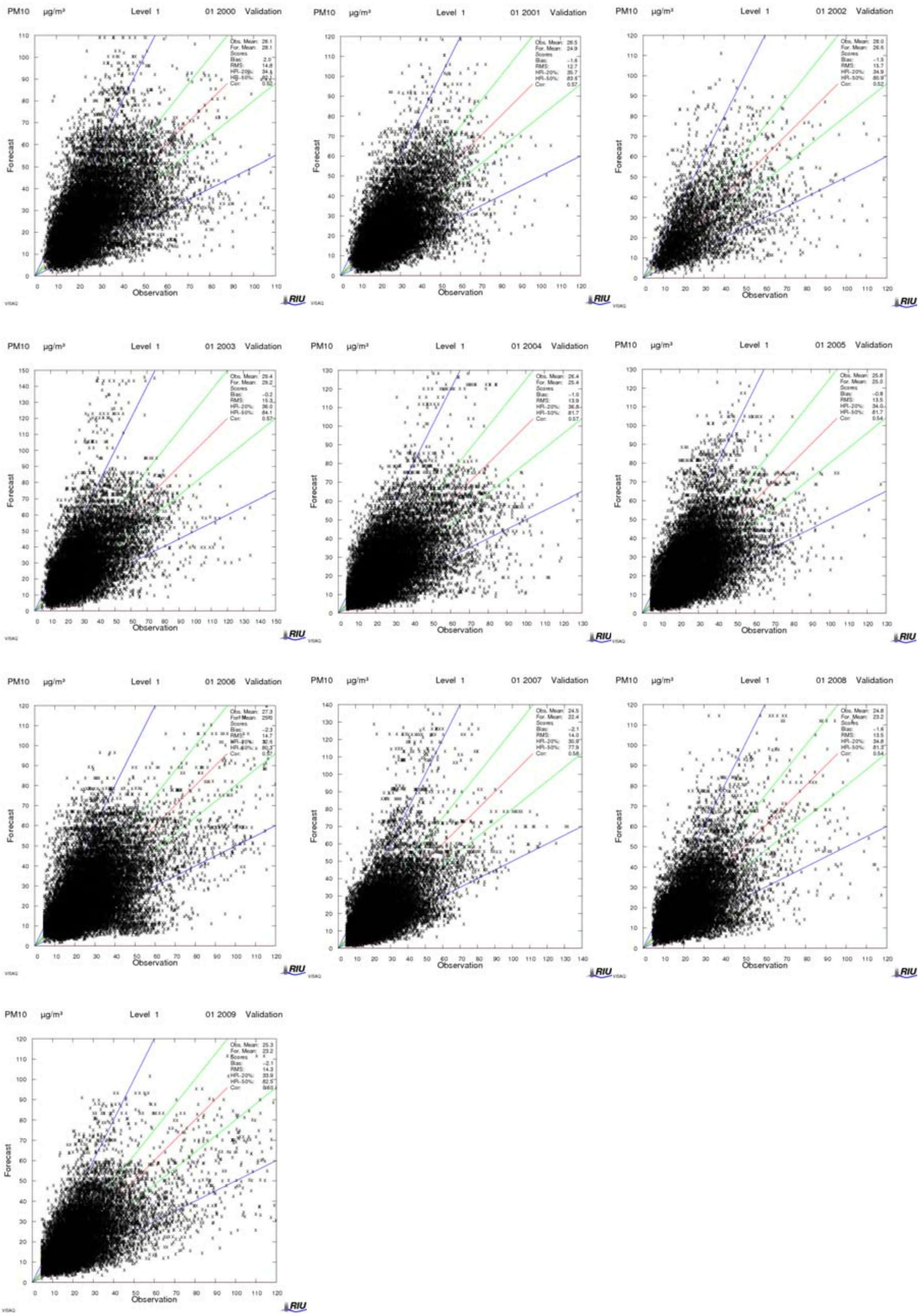

Figure 3b: Comparison of calculated and observed data for the years 2000 - 2009. Daily averages of PM_{10}. Modelling area is Central Europe, measured data are from North-Rhine-Westphalia.

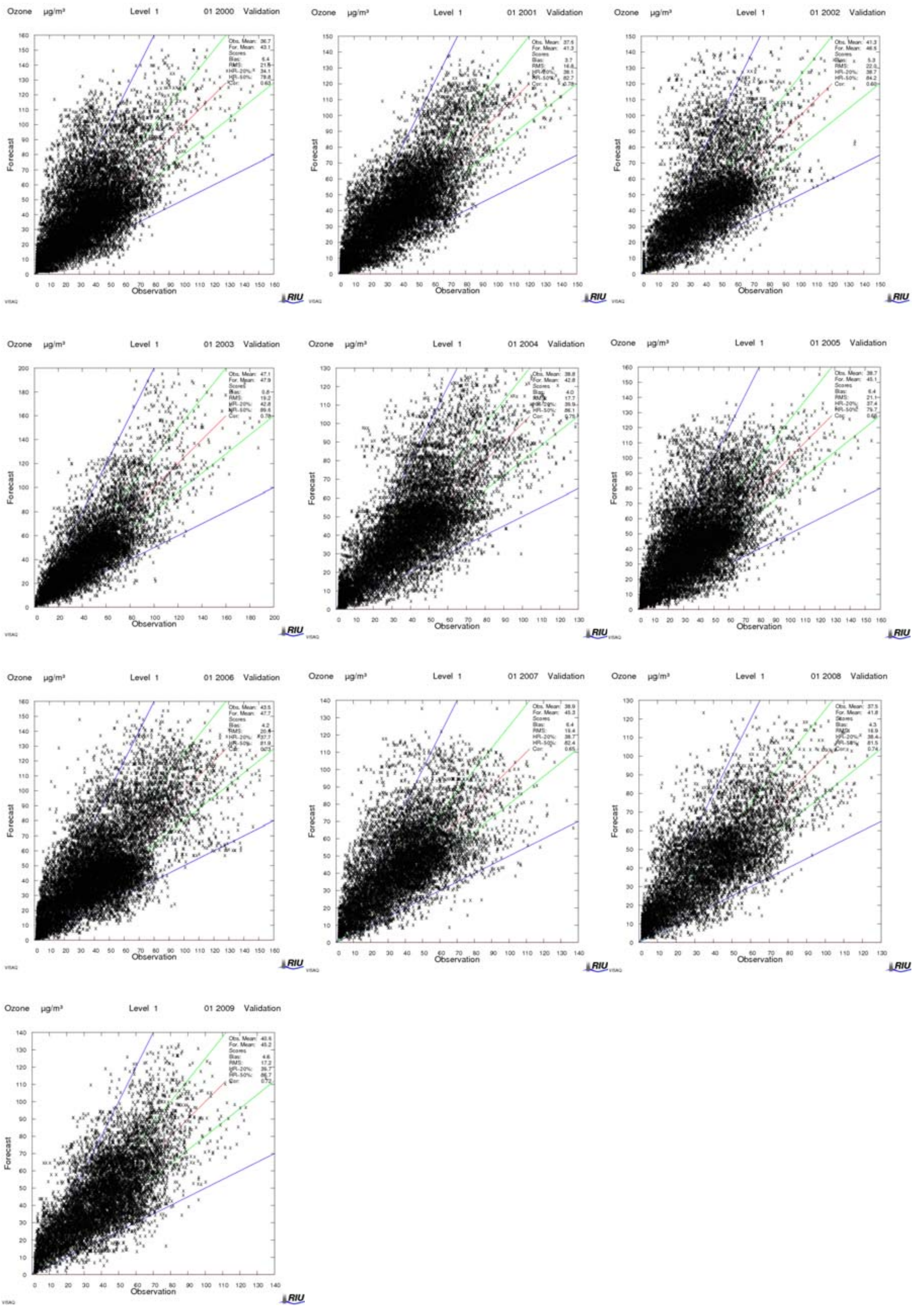

Figure 3c: Comparison of calculated and observed data for the years 2000 - 2009. Daily averages of ozone. Modelling area is Central Europe, measured data are from North-Rhine-Westphalia.

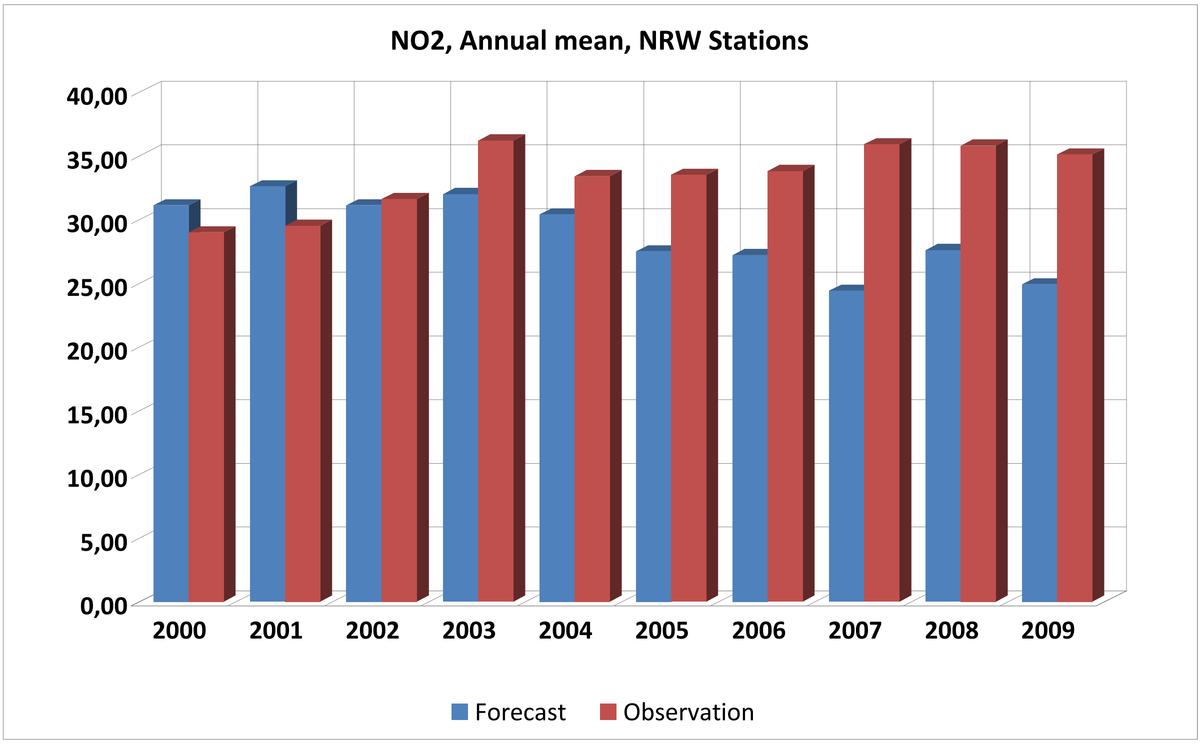

Figure 4a: Annual mean of NO_2 (µg/m^3). Comparison of observed values (red) and modelled data (blue). In the beginning of the decade the modelled values overestimate the observed data. An increase in the observed concentrations can be seen for the years 2000 - 2003 for NO_2. This is also the case for PM_{10} and ozone (Figure 4b, c). However, the trend in observations from 2000 - 2003 is not present in the numerical simulation for NO_2 but can be seen for PM_{10} and ozone. A tendency for underestimating the observed values can be seen in the second half of the decade. Whereas the simulated values show a decrease during the decade, the observed values show no clear tendency from 2003 on. One possible reason might be the increase of the NO_2/NO_x ratio for the emissions from road traffic during the decade. Therefore even a decrease of NO_x-emissions might not necessarily lead to a decrease of NO_2-emissions due to road traffic, and, consequently the NO_2-concentrations remains more or less on the same level with some small interannual variations which might be due to changing meteorological conditions. The variation of NO_2/NO_x ratio in the emissions might not be well represented in the emissions used in the models and it is difficult to do so. Currently a constant value throughout the decade has been assumed. An increase in concentration can also be seen for the years 2000 -2003 for PM_{10} and ozone.

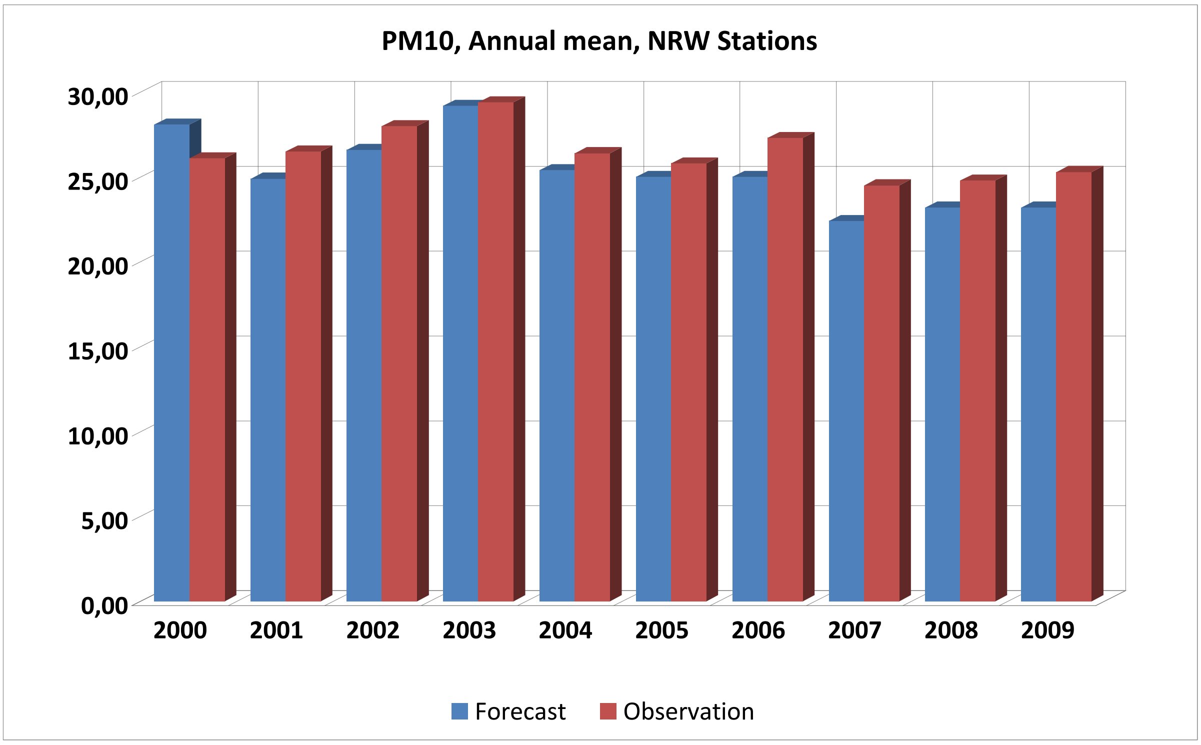

Figure 4b: Annual mean of PM_{10} (µg/m^3). Comparison of observed values (red) and modelled data (blue). Agreement between observed and modelled values for PM_{10} is better than for NO_2. A clear trend during the decade can not be seen, even if the last three years show the lowest values of the decade – in contrast to NO_2. Observed values are higher than the modelled results, except for the first year 2000. Temporal variations from year to year are very similar in observations and modelling. Highest values in observations as well as simulated data occur in 2003 which was an extraordinary year with respect to air pollution episodes. Periods with high pressure systems dominate during winter and summer leading to high concentrations of primary emitted species as well as for photo oxidants with the leading substance ozone. Also NO_2 show the highest values in 2003 as far as the observed values are concerned. However in the case of NO_2 this maximum is not represented in the simulated data. As discussed before this might be due to the changes in NO_2/NO_x ratio in the emissions. Another reason might be the grid resolution of 25 km which might be more important for NO_2 concentration which is strongly influenced by primary emissions.

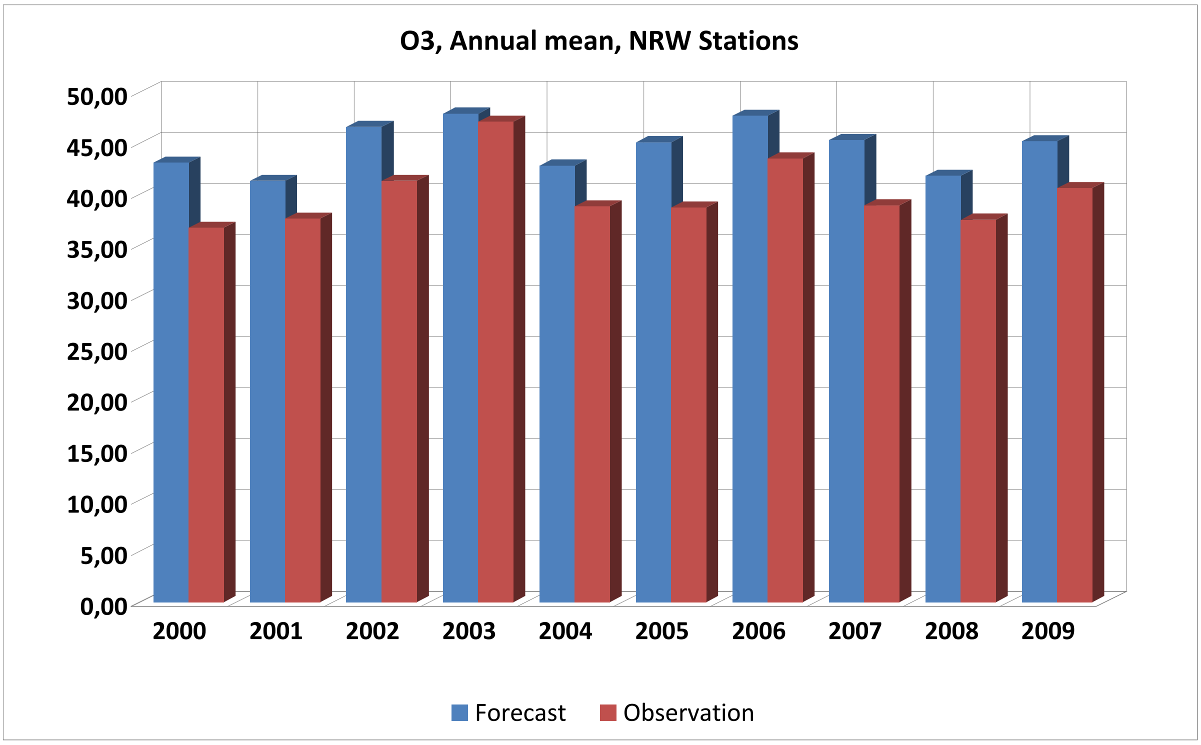

Figure 4c: Annual mean of Ozone (µg/m^3). Comparison of observed values (red) and modelled data (blue). Observed values in contrast to NO_2 and PM_{10} always are lower than the modelled concentrations. A clear trend can not be seen neither in observations nor in simulated values. Forecast and simulation show the highest averaged values in the years 2003 and 2006. Both years are characterized by high pressure episodes in summer leading to photochemical episodes in central Europe.

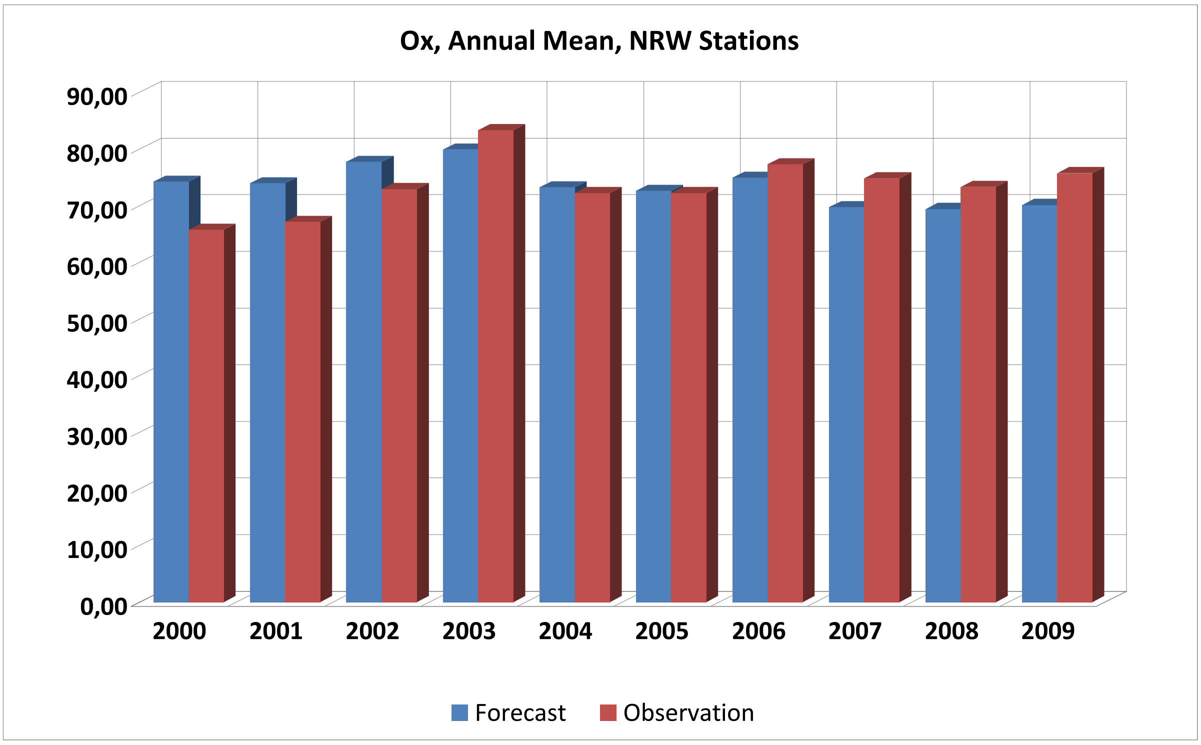

Figure 4d: Annual mean of O_x: = O_3 + NO_2 (µg/m^3). Comparison of observed values (red) and modelled data (blue). From 2004 on, no clear trend can be seen. The temporal variations from year to year for observational and measured data is very similar. Comparison of observations and model results show an overestimation of measured values in the first half of the decade from 2000 – 2003 and an underestimation of observed values in the second half of the decade (2006 – 2009).

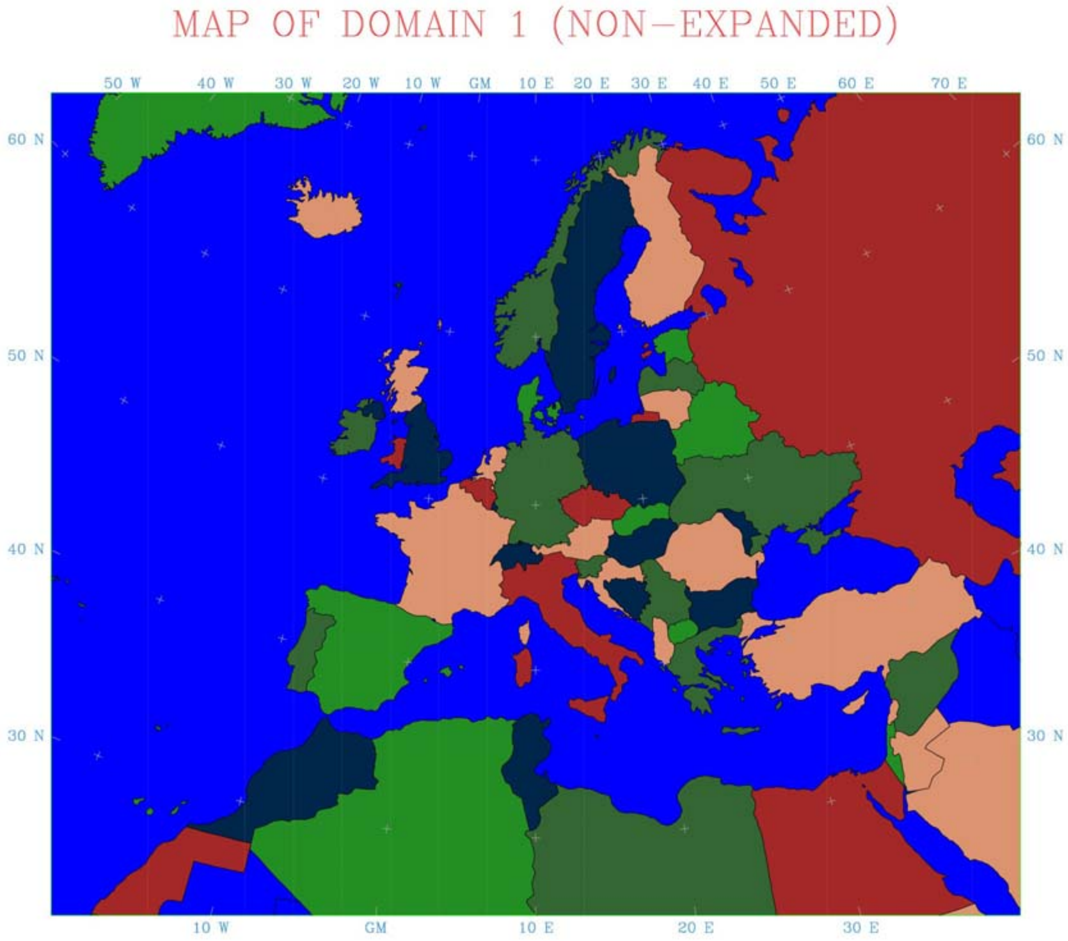

Figure 5: Extended modelling domain for future calculations, grid sizes 45, 15, 5 and 1 km. Calculation on these domains, which has been selected the meet the specific requests of CITYZEN, are currently underway and will be finished during the next months.