Comparison and evaluation of the 1km and 5km resolution FRAME modelled annual concentrations of nitrogen oxides

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1. Introduction

Atmospheric transport models (ATM) are important tools supporting environmental management and provide spatially continuous information on current, past and future air quality. The ATM provided gridded information is used, among others, for the assessment of the critical levels and loads exceedances and population exposure to protect human health and ecosystems. The large number of models and their various configuration often leads to different results of estimated spatial patterns of concentration and deposition of atmospheric pollutants.

The aim of this work is to present and compare the results of NO_x air concentration modelling with the Fine Resolution Atmospheric Multi-pollutant Exchange (FRAME) model applied for Poland with the spatial resolutions of 1km x 1km and 5km x 5km. The changes in model performance for coarse and fine grids are compared both visually and quantitatively by comparison of the model error statistics.

2. The FRAME model

- Lagrangian statistical trajectory model used for the UK and Poland to support environmental management (Singles et al. 1998, Dore et al. 2007, Kryza et al. 2010).
- The 9.2 version of the model is applied in this work.
- The simulations are run for the domains with grid size of 1km x 1km (D1km) and 5km x 5km (D5km) spatial resolutions.
- The D1km mesh is composed of 800 x 800 grids.
- The D5km mesh is of size 160 x 160 grids.
- The model was run for two years: 2005 and 2008.

3. Emission and meteorological data

- National emission inventory for years 2005 and 2008 used.
- 1km emissions regridded into 5km grid for the D5km simulations.
- Higher uncertainty of 2008 emissions - road traffic intensity measurements not available for this year.
- Year specific meteorological data used in all simulations.

4. Evaluation of the model results

Annual average NO_x air concentrations calculated by the FRAME model were compared with the measurements performed on Polish air quality network and provided through the AriBase database. For the model – measurement comparison, only background urban (BU) and background rural (BR) stations were used. For each year, configuration of the measuring network differ significantly, both in terms of total number of sites and fraction of urban and rural stations (Table 1).

The model error was calculated for each site as a difference between model (Mi) calculated and observed (Oi) value. To summarize the model performance, the mean bias, mean absolute gross error, root mean squared error, correlation coefficient, fraction of two and relative error statistics were calculated (Yu et al. 2006).

Table 1 Summary of the NO_x measuring sites for year 2005 and 2008 used for model evaluation

Type of station	Year 2005	Year 2008
Background urban	47	81
Background rural	14	21
Total number of sites	61	102

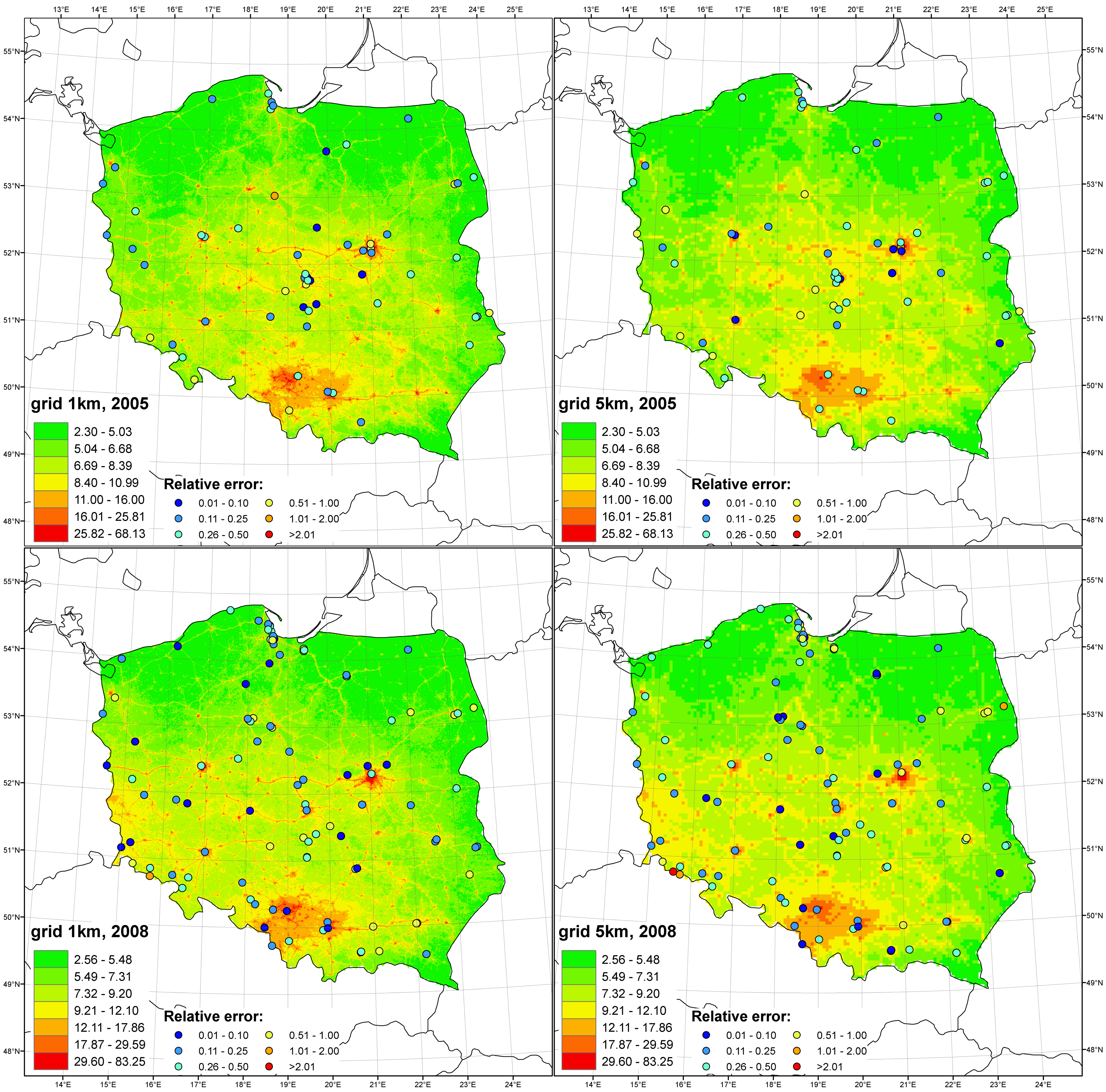

Fig. 1 Modelled 1km and 5km NO_x concentrations for years 2005 and 2008 and the relative error for each of the NO_x measuring sites

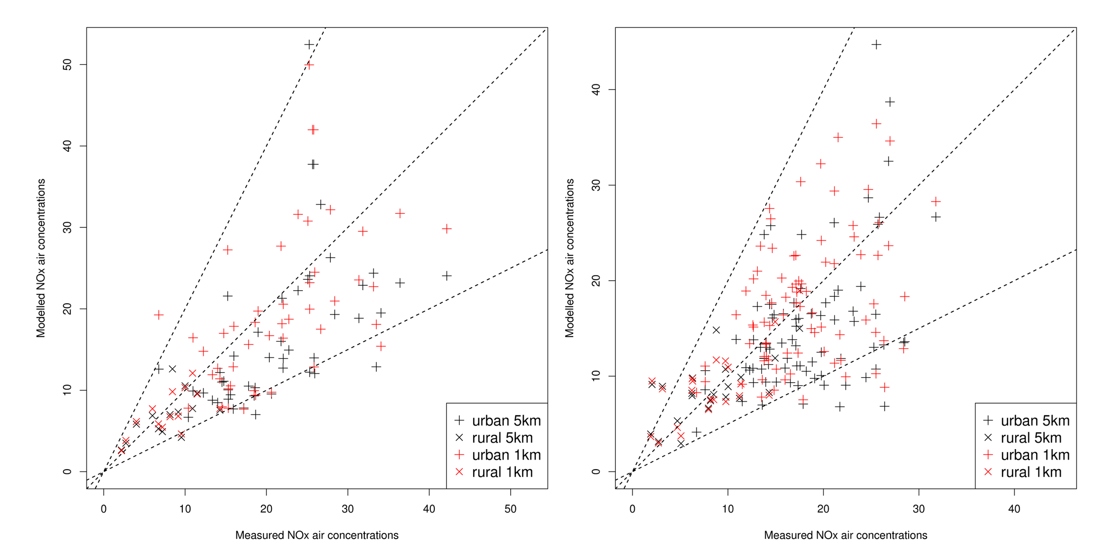

Fig. 2 Modelled vs. measured NO_x air concentrations for urban and rural stations in year 2005 (left) and 2008 (right)

Table 2. Error statistics for urban and rural stations for 1km and 5km model runs

Year	Model grid	Urban stations					Rural stations				
		MB	MAGE	RMSE	R	FAC2	MB	MAGE	RMSE	R	FAC2
2005	1km	-1.84	6.87	8.68	0.53	0.89	-0.82	2.00	2.59	0.67	0.93
	5km	-4.94	7.90	9.58	0.54	0.83	-1.08	2.32	2.95	0.59	0.93
2008	1km	-0.34	5.48	6.93	0.37	0.94	0.63	2.41	3.08	0.71	0.90
	5km	-3.09	5.62	7.33	0.44	0.89	0.28	2.59	3.26	0.63	0.86

References:

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5. Results

Main cities and roads are the areas of the highest air concentrations on both D1km and D5km maps (Fig. 1). For the D1km model setup, there is a strong separation of the emission source areas with high values of NO_x air concentrations from the background regions, especially along the main roads crossing the clear areas.

The grid average NO_x concentrations are similar for both domains, reaching 6.0 $\mu g\ m^{-3}$ in year 2005 for D1km and D5km, and 7.0 $\mu g\ m^{-3}$ in year 2008. For both years, the D1km simulations results in significantly higher maximum and lower minimum values of NO_x (68.1 for D1km and 52.5 $\mu g\ m^{-3}$ for D5km in 2005, for year 2008 the respective values are 83.3 and 64.0 $\mu g\ m^{-3}$).

For the D1km, the number of sites that fall below or above 1:2 and 2:1 lines is lower than for D5km for both years, which results in higher FAC2 values for D1km except for rural sites in year 2005 (Table 2). The D1km model run gives overall higher NO_x air concentrations for urban stations, which results in decreased MB (Table 2), and for some sites this is the reason for the overestimation of the observed values. The D1km model still have a general tendency for underestimation of the annual NO_x air concentrations for both urban and rural stations, reflected in the negative mean bias for both years 2005 and 2008, with the exception of the rural sites for the year 2008. Both MAGE and RMSE show the improvement of the D1km over the D5km. The uncertainty in 2008 emission data is reflected in worse model performance for BU sites if compared to 2005.

6. Summary and conclusions

The main aim of this paper was to compare the FRAME modelled annual air concentrations of NO_x for two domains of high (1km x 1km) and coarse (5km x 5km) spatial resolutions for the area of Poland. The model was run for two years: 2005 and 2008. The main findings are:

- Spatial patterns of modelled NO_x air concentrations are similar for 1km and 5km grids. The highest concentrations are calculated for the emission source areas.
- There is a strong separation of the source and background areas in the 1km simulations.
- Country average NO_x concentrations are similar for fine and coarse gird domains.
- There are large differences in modelled maximum NO_x concentrations. The 5km simulations give lower values if compared with 1km, due to spatial averaging over the coarse grid. This is important in terms of ecosystems and human health protection.
- The model-measurement agreement is better for the 1km domain for both urban and rural sites, especially in terms of mean bias, average error and FAC2 statistics.
- The quality of the emission inventory is especially important for 1km domain and especially for urban sites - the year 2008 is an example (no detailed traffic measurements available for emission model).