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A PLATFORM TO MANAGE AIR QUALITY IN KRAKOW, POLAND, WITH THE USE OF HIGH-RESOLUTION MODELLING TOOLS - APPLICATION AND VALIDATION OF ATMO-PLAN

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Abstract:
The ATMO-Plan air quality decision support tool has been configured, applied and validated for the city of Krakow. The tool yields the opportunity to assess the impact of emission reduction scenarios on NO_2, PM_{10} and $PM_{2.5}$ concentrations at high resolution in urban areas. Detailed traffic information is used as input to model traffic emissions and the dispersion of these emissions is combined in high resolution with background contributions. During 2017, two passive sampler campaigns have measured NO_2 concentrations at a variety of locations in Krakow. The model output has been validated against these results obtaining fairly good validation statistics (R^2 equal to 0.67) despite several limitations in input data.

***Key words:** Key words should be written in **9 pt** Times New Roman Italic.*

INTRODUCTION

ATMO-Plan is a user friendly web based decision support tool, designed to facilitate the assessment of the impact of emission reduction scenarios on air quality on an urban scale at a high spatial resolution. As part of the LIFE IP project Małopolska in a healthy atmosphere, the tool has been configured, applied and validated for the city of Krakow in Poland. Krakow is located in the Malopolska province, which forms together with the bordering province Silesia and the cross-border regions in Czech Republic and Slovakia an area with serious air quality challenges. The local air quality in this hotspot region is influenced by different factors amongst which the regional background, meteorology, local emissions and the urban infrastructure. To assess the local air quality, all contributing factors have been integrated into an integrated model setup, schematically shown in figure 1.

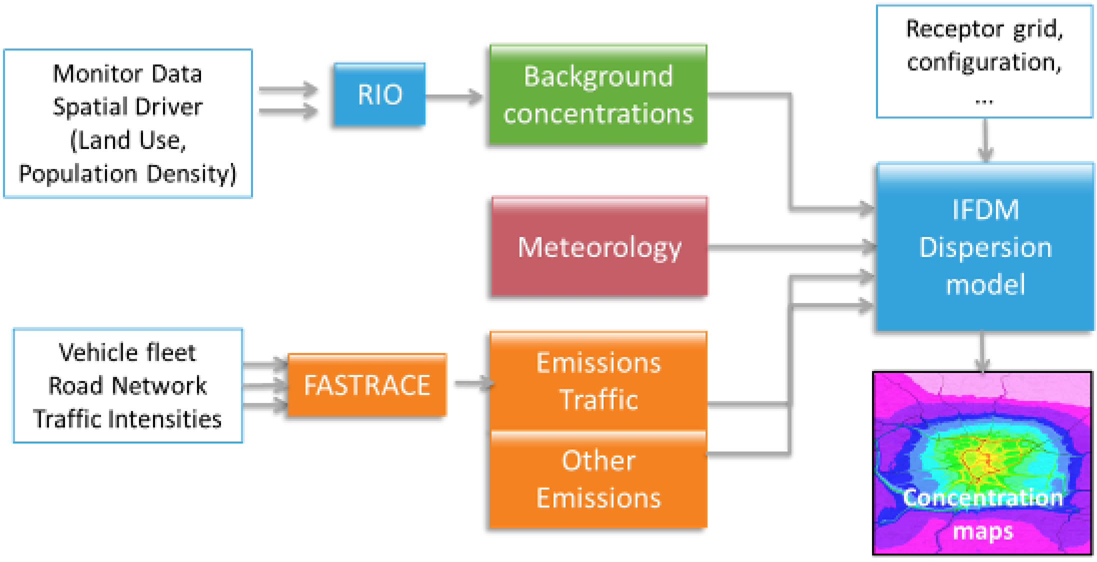

Figure 1: Schematic overview of the ATMO-Plan modelling chain applied to model the air quality of Krakow.

BACKGROUND CONCENTRATIONS

The web-tool applies an operational modelling chain starting from regional background concentrations, meteorology, fleet data and the road network with traffic intensities. Regional background concentrations for the whole interregional hotspot area have been modelled using RIO (Lefebvre et al. 2013). This model is based on a residual kriging interpolation scheme starting from hourly pollutant concentrations as measured by the official monitoring stations and using land use (CORINE) and population density as spatial information for detrending. In a first step the local character of the air pollution sampling values is removed in a detrending procedure. Subsequently, the site-independent data is interpolated by an Ordinary Kriging scheme. Finally, in a re-trending step a local bias is added to the Kriging interpolation results. Land use information, population datasets or emission data can be applied as spatially resolved driving forces in the detrending process. The indicator is optimized independently for different pollutants. As a result, the RIO model is able to account for the local character of the air pollution phenomenon at locations where no monitoring stations are available. The model has been presented, validated and applied in several peer-reviewed papers.

A leaving-one-out validation of hourly background concentrations shows the strength of this modelling approach. Each station is individually left out from the configuration for interpolation and the monitor data are compared to the model values for the location of the station. The spatial validation is summarized as a scatter plot of the annual average station concentration, shown below for NO_2. For NO_2, the validation can be significantly improved by leaving out traffic stations as their observations are heavily influenced by local effects, much harder to capture with an interpolation model. The local trends can be well captured by adding the local emissions in high resolution. The background concentrations are modelled on hourly basis at a spatial resolution of 4.7 km by 4.7 km.

METEOROLOGICAL DATA

To correctly assess the dispersion conditions of the atmosphere, IFDM relies on hourly meteorological data. Because of the underlying set-up using stability classes based on the Bultynck-Malet parametrization, only ambient air temperatures and (vectorial) near-surface wind speeds are required. For each parameter, a single time series for the entire domain suffices, since we assume that the synoptic meteorological conditions do not vary considerably over a city-sized domain. Within this study, the two meter temperature and the 10m (vectorial) wind speed of the ERA-Interim dataset of the ECMWF (European Centre for Medium-Range Weather Forecasts) have been used. This dataset provides three hourly reanalysis data for a range of meteorological parameters for the entire globe at a 0.75 degree resolution.

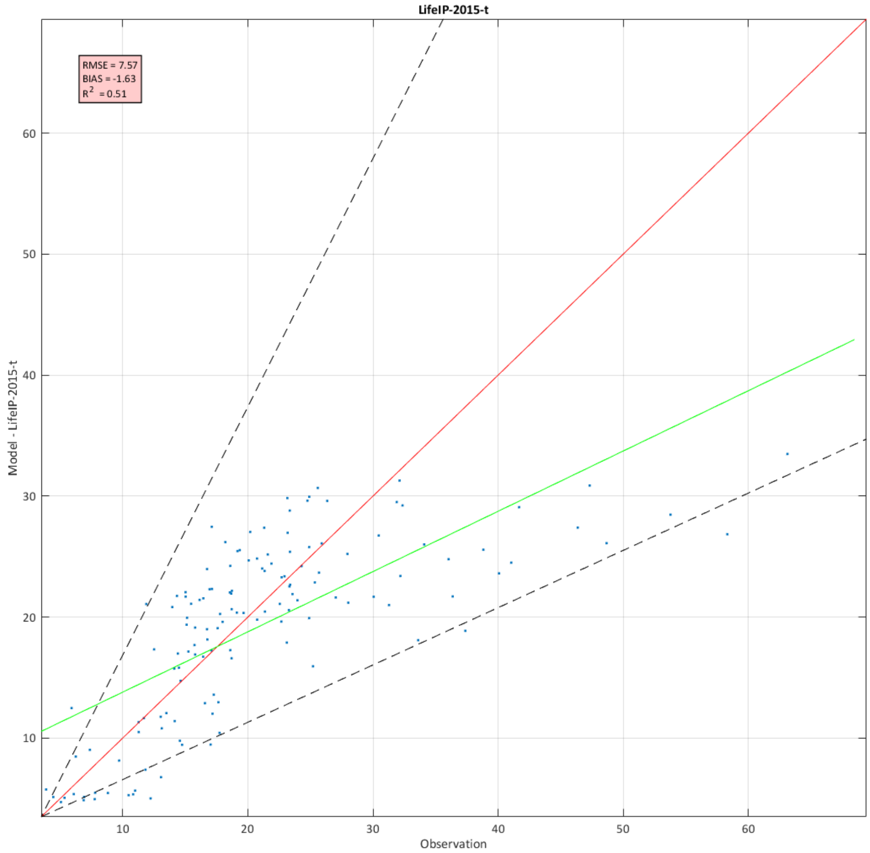

Figure 2: Spatial RIO leaving-one-out validation NO_2 2015 for the whole hot spot region (RMSE : 7.57 µg/m³, BIAS = -1.63 µg/m³, R^2 = 0.51).

TRAFFIC EMISSIONS

As road traffic emission model, FASTRACE is applied, relying on the COPERT methodology and starting from local traffic data from the VISUM traffic model operated by the city of Krakow's transport department and the Polish fleet information (Emisia 2015) enriched with local traffic counts. The emission functions are speed dependent and vary according to the vehicle type, fuel technology, euro standard and capacity or weight class. FASTRACE applies the COPERT methodology and adds the spatial allocation of emissions at street level applying the computational kernel:

Emissions (E) = vehicle kilometers (vkm) * emission factor (EF)

The result of the FASTRACE calculations is an emission per pollutant per road segment, taking into account all available input on the road network, traffic intensities and traffic fleet.

POLLUTANT DISPERSION MODEL IFDM

The Gaussian dispersion model IFDM is applied to model the impact of traffic emissions in high resolution (Lefebvre et al. 2013). The model requires three main types of input: emissions, meteorological data and background concentrations, as described in detail above. The IFDM model calculates the dispersion of pollutants in the atmosphere depending on wind speed/direction & atmospheric stability. IFDM is a bi-Gaussian dispersion model using the Bultycnk-Malet dispersion parameters (Bultynck and Malet, 1972). The model output can be presented as annual average concentration maps for NO_2, PM_{10} and $PM_{2.5}$.

ATMO-PLAN

The full model chain mentioned above has been integrated into the ATMO-Plan application. This application is now available for use as an air quality management dashboard for Krakow (https://krakow.atmo-plan.vito.be). Integrating all relevant spatial scales in high resolution concentration modelling is important for assessing the local air quality. The platform offers the opportunity to perform assessments, to calculate the impact of future (traffic) scenarios and to identify which measures sufficiently improve the air quality to improve the local environmental quality and to meet EU air quality limits.

Figure 3: NO_2 annual average concentration map for the reference scenario in 2015 for Krakow and surroundings.

MEASUREMENT CAMPAIGNS

Two air quality campaigns have been undertaken in Krakow during 2017 to measure pollutant concentration at a wide variety of locations in the city using NO_2 passive samplers. A first campaign has taken place during the summer lasting from 28/05/2017 to 25/06/2017. A second campaign has been performed during winter lasting from 19/11/2017 to 17/12/2018. In total, measurements have been made at 114 locations, with one location having two sensor, making a total of 115 sensors. During the first campaign in summer, 114 out of 115 sensors have been analyzed and reported. During the second campaign in winter, 110 out of 115 sensors have been analyzed and reported. Four locations of passive samplers have been chosen next to official monitoring stations. Based on the results of the passive samplers at these locations, a linear correction to the passive sampler data has been applied.

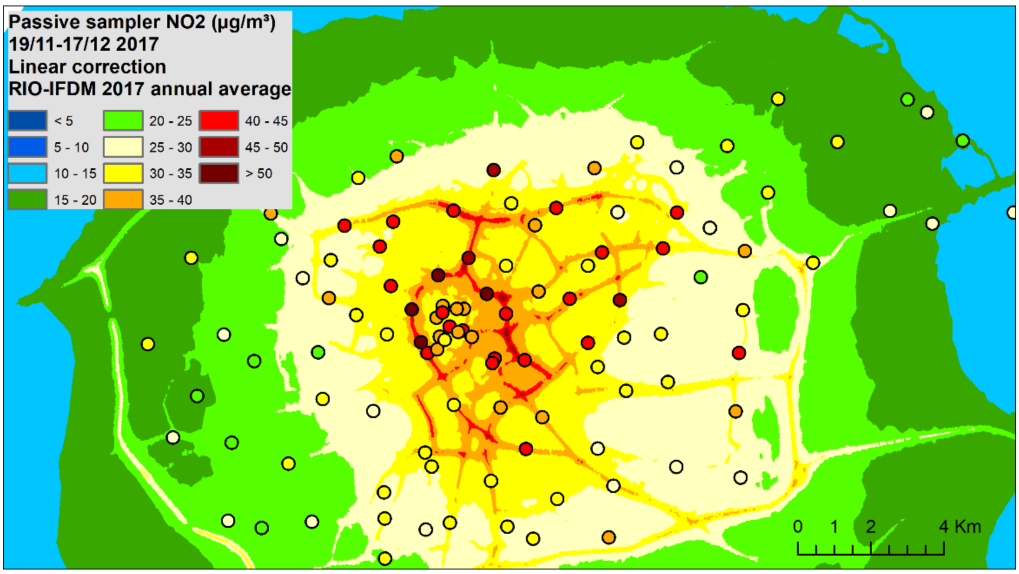

Figure 4: Overlay of the NO_2 passive sampler results for the winter campaign on annual average ATMO-Plan map.

MODEL VALIDATION

The ATMO-Plan application has been applied to model the NO_2 concentration levels at the set of locations during both campaigns. The model output is compared with passive sampler data which have been linearly corrected based on the comparison with the official monitoring stations. The validation proofs to be fairly good, as depicted below, despite several limitations in input data. Currently, no street canyon contributions have been modelled and many measurement location in the city center are located in street canyons. Secondly, the most recent available Polish fleet data during this study were data for 2014. The RIO backgrounds for 2017 have thus been combined with traffic emissions for the network of 2017 but the fleet of 2014. A more detailed modelling exercise is on the way, which will add street canyon contributions and use fleet data for 2017.

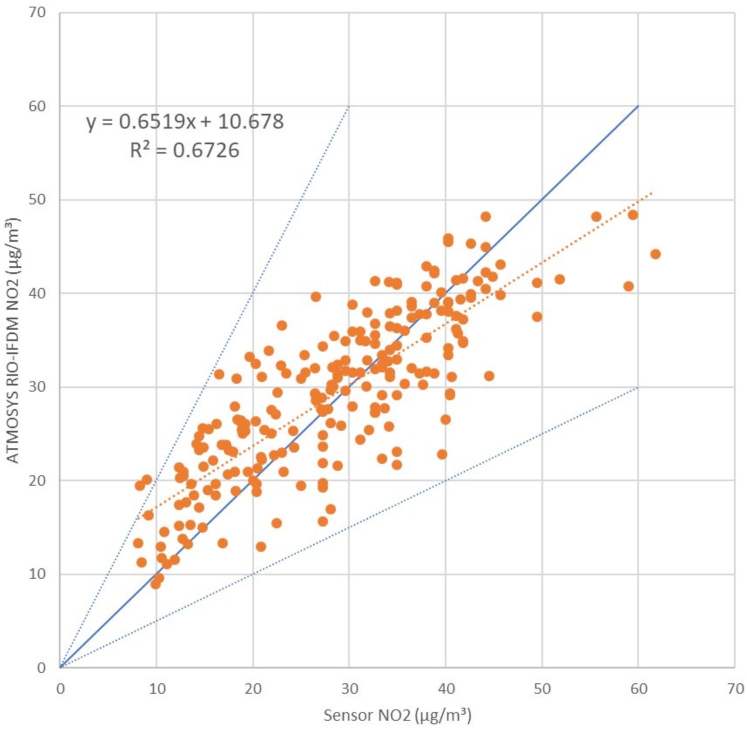

Figure 5: Scatter plot of RIO-IFDM model concentrations against the monthly average NO_2 passive sampler data (linear correction) of both summer and winter campaigns.

ACKNOWLEDGEMENTS

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