Modelling based method for assessing the representativeness of air quality monitoring stations

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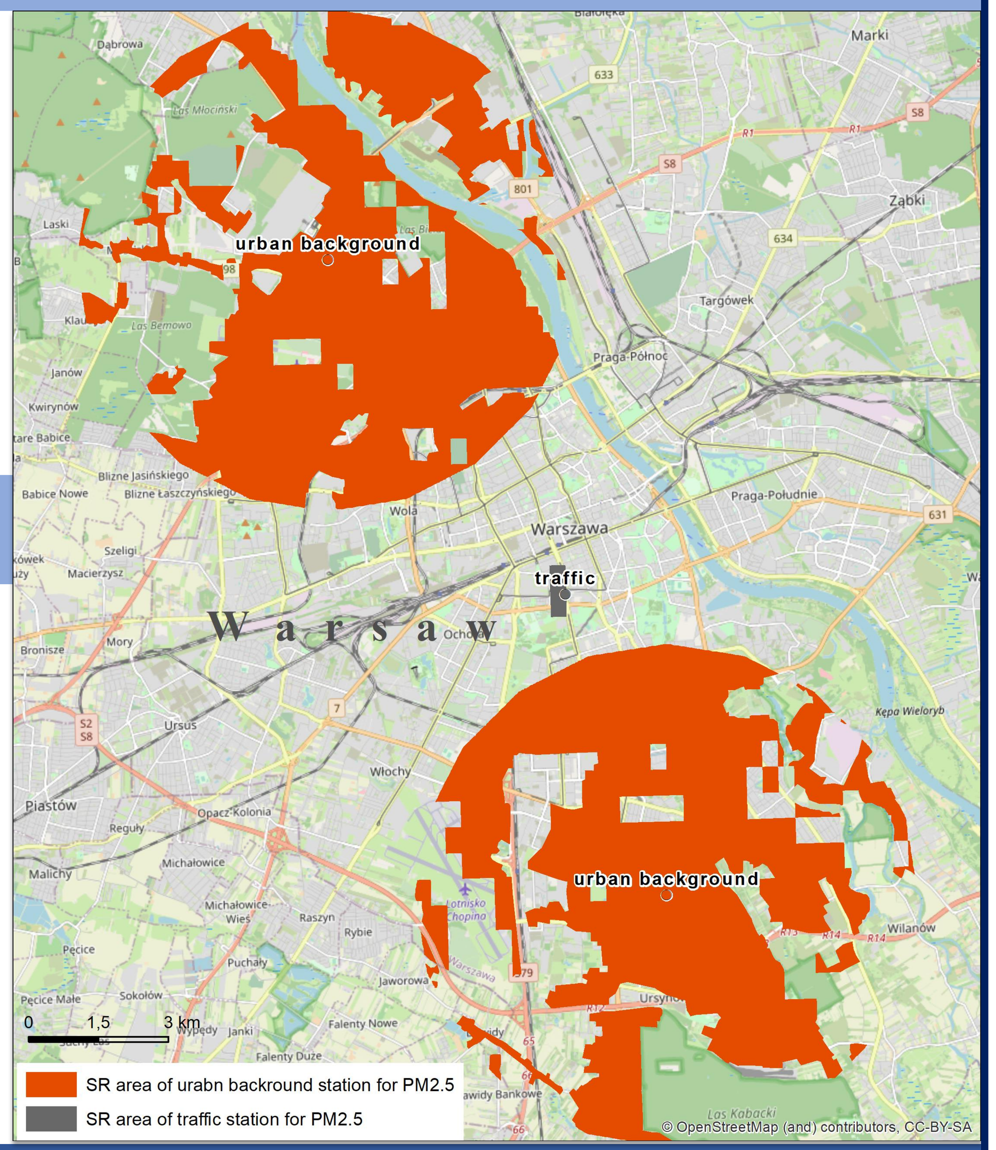
INTRODUCTION

Spatial representativeness (SR) of monitoring stations is the basis of configuring monitoring networks. The evaluation of the SR of monitoring stations is essential where monitoring networks are used to estimate the health and environmental exposure to the air pollution. The requirement of establishing SR areas is due to the Ambient Air Quality Directive 2008/50/EC (AAQD). There is no specific methodology for SR areas in AAQD, thus each member state uses their approach.

In Poland, the Institute of Environmental Protection National Research Institute has been responsible for a methodology of SR areas and its implementation since 2018. The method is based on air quality modelling extended with additional spatial criteria. Air quality modelling results are used to obtain a correlation between concentrations in site spots with other concentrations. The correlation field is calculated for each monitoring station and each pollution separately based on 1 hour modelling results. Additional spatial criteria limiting the SR area take into account: radius range depending on the station and air pollutant type, a ventilation index, the total pollutant emissions and the land use category assigned to the station



DATA SOURCES AND TOOLS

The air quality model GEM-AQ (Kaminski et al., 2008) was used to calculate the concentrations of pollutants at the. Calculations with the GEM-AQ model were performed with approximately 2.5 km resolution over Poland. Local emission inventory used over Poland (CBE-Central Base of Emissions) was developed by the National Balancing and Emissions Management Centre of IEP-NRI. With regard to anthropogenic emissions, data reported by member countries under the LRTAP Convention, at a resolution of 0.1° x 0.1° were used for the European area outside Poland.

All spatial analyses were performed using GIS tools. The following data sources were used for the criteria:

- Corine Land Cover
- BDOT10k (https://www.geoportal.gov.pl/dane/baza-danych-obiektow-topograficznych-bdot)
- Location of monitoring stations (https://powietrze.gios.gov.pl/pjp/maps/measuringstation)
- DEM for Poland (https://www.geoportal.gov.pl/dane/numeryczny-model-terenu)
- Local emission inventory for Poland (IEP-NRI)

METHODOLOGY

SR area of monitoring stations can be interpreted as the actual variability of pollutants sufficient to estimate the level of air pollution in a given zone. Thus our methodology is based on five spatial criteria. Figure 1. shows an example of all criteria for a monitoring station in a town in western Poland – Swiebodzin. Each of the criteria is described below

The area of analysis was limited to a radius range depending on the type of station and air pollutant

This criterion assumes that for each station the area the analysis is limited to the radius resulting from the surface area for which the station should be representative according to Annex 3 of the Regulation of the Minister of Climate and Environment of 11 December 2020 on the assessment of the levels of substances in the air (Table 1). The area size for which the conditions of representativeness are expected to be met was estimated, and the radius was calculated, assuming a circular shape of the area. The minimum radius of representativeness thus estimated was increased by a factor of 2 to 3, assuming that part of the area within the minimum representativeness circle may not be representative due to land use and emission distribution.

Table 1. Maximum range of representativeness assessed under the Regulation of the Minister of Climate and Environment of 11 December 2020 on the assessment of levels of substances in the air and expert assessment

Pollution	Station type	Area	Range - radius [m]	factor	Radius [m]
C6H6, NO2, SO2, Pb, As, Cd, Ni, B(a)P, PM10, PM2.5, CO	Health protection – urban background	few km²	1 800	3	5 400
C6H6, NO2, SO2, Pb, As, Cd, Ni, B(a)P, PM10, PM2.5, CO	Health protection – rural	less than 5 km from agglomerations or industrial installations	5 000	2	10 000
NOx, SO2	Plant protection	at least 1 000 km²	17 800	2	35 600
C6H6, NO2, SO2, Pb, As, Cd, Ni, B(a)P, PM10, PM2.5, CO	Traffic	at least 200 m²	1000 (maximum impact area based on expert judgment)	1	1 000
C6H6, NO2, SO2, Pb, As, Cd, Ni, B(a)P, PM10, PM2.5, CO	Industrial urban	250 m × 250 m	1 800 (same as background stations)	3	5 400
C6H6, NO2, SO2, Pb, As, Cd, Ni, B(a)P, PM10, PM2.5, CO	Industrial suburban	250 m × 250 m	5 000 (same as background stations)	2	10 000
O_3	Health protection – urban	Ara of few km²	1 800	3	5 400
O_3	Health protection Plant protection - suburban	an area of dozens of km²	5 600	2	11 200
O_3	Health protection Plant protection - rural	an area of several hundred km²	17 800	2	35 600
O_3	Health protection Plant protection – regional background	Area from 1 000 to 10 000 km²	56 400	2	112 800

The cross-correlation field of modelled concentrations at each computational grid with modelled concentrations at measurement sites was calculated based on 1-hour data

The modelling results for the station representativeness were used to determine the correlation field. The correlation field of modelled concentrations with modelled concentrations at gauging stations was calculated separately for each station and each pollutant based on modelled 1-hour values according to the formula:

$$AF(i,j) = \frac{\sum_{t=1}^{H}\left[C_{st}(t)\cdot C_{i,j}(t) - \overline{C_{st}}\cdot\overline{C_{i,j}}\right]}{\sqrt{\sum_{t=1}^{H}\left(C_{st}(t)-\overline{C_{st,}}\right)^2\cdot\sum_{t=1}^{H}\left(C_{i,j}(t)-\overline{C_{i,j}}\right)^2}} \tag{1}$$

Where:

$C_{st}(t) =$ the concentration value in the grid cell at corresponding *st* station location in *i* time step

$\overline{C_{st}} =$ annual average concentration in the grid cell corresponding to the st station location

$C_{i,j}(t) =$ the concentration value in the grid cell of coordinates *i,j* at time *t*

$\overline{C_{i,j}} =$ annual average concentration in the grid cell of coordinates i,j

$H =$ number of time steps (1h time step, for the whole year)

Land use criterium

The area of spatial representativeness is limited due to the land use category assigned to the station type. Land use categories are established based on CORINE Land Cover and the Database of Topographic Objects (BDOT10k). Based on Corine LandCover 2018 (CLC2018), classes were created:

- urban development (Corine Land Cover codes: 1.1, 1.4, 1.2.3, 1.2.4);
- agricultural land (Corine Land Cover codes: 2);
- natural areas (including forests and water bodies) (Corine Land Cover codes: 3,4,5).
- industrial sites (Corine Land Cover codes: 1.2.1, 1.3);

A spatial layer of roads was used from the Database of Topographic Objects (BDOT10k), based on which areas with a width of 500 m were created, limiting the range of representativeness in the case of traffic stations.

It was necessary to extend the area for stations located in spa/resort areas because if only urban development were selected (which implies a health exposure), the stations would be located outside the representativeness area.

A ventilation index limits the area of representativeness based on the relative height difference not exceeding 50 m

Due to the great importance of topography for the processing conditions, a criterion was introduced for the relative height difference in the area of influence according to the formula.

Z < Z station location + 50 m, where:

Z – relative height of the terrain

$Z_{station}$ – absolute height of a station

Emissions criterium

Due to the important influence of emissions on the actual variability of air pollutant concentrations, a criterion based on emission data of the pollutant under consideration or its precursors in the case of ozone and benzene has also been introduced. This criterion limits the area of representativeness using emission limit values calculated based on the pollutant's emission values at the site. The criterion results in an area where the total emission of the pollutant is between 10^{-1} and 10^{1} of the total emission flux values in the grid square corresponding to the site location. Where the total emission flux was zero at the site location, an area was used where the total emission value did not exceed a percentile value of 25 from the emissions within the assumed radius for the site.

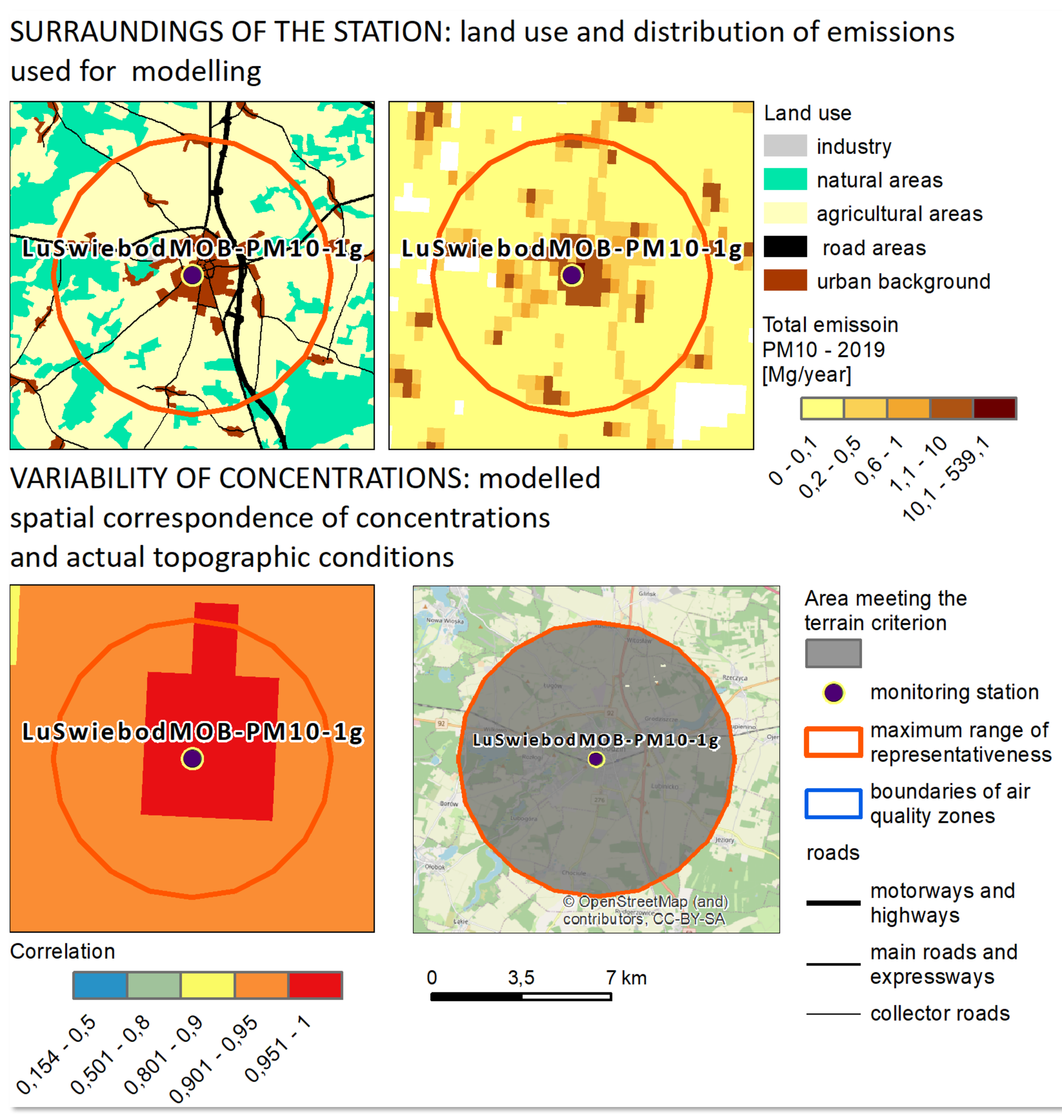


Figure 1. Characteristics of the surroundings monitoring site: surface use, distribution of PM10 emissions, the spatial distribution of correlations of modelled concentrations with concentrations modelled at the PM10 measurement site, actual topographic

RESULTS

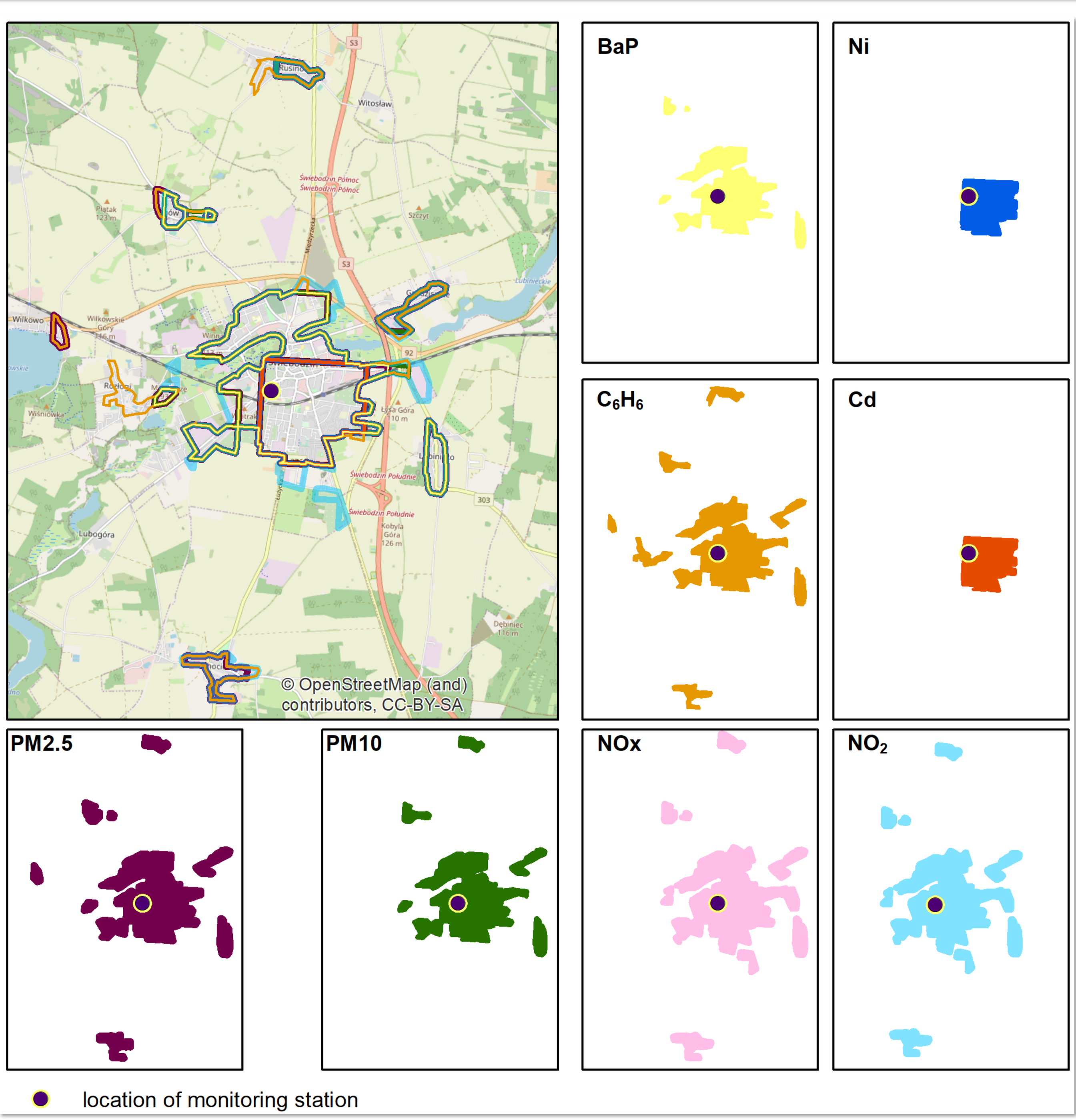


Figure 2. Variability of the SR area for a monitoring station depending on the pollutant

There are almost 300 measurement stations in Poland. Each year the area of representativeness is determined for a different set of monitoring stations. The SR area is the common part of the areas resulting from the criteria presented above.

As regards the modelling results, the methodology assumed the use of a correlation function between the modelled values of one-hour concentrations in the grid square corresponding to the station location and the grid squares in the surrounding area. The area of representativeness is presented for two thresholds of such spatial correspondence measure - 0.95 and 0.90.

The area satisfying the condition of correlation of modelled concentrations with concentrations modelled at the measurement stations was limited by taking into account the surface use conditions corresponding to the station type and topographic conditions potentially affecting ventilation. In addition, emission data were taken into account, assuming that total emission of a given pollutant is in the range 10^{-1} - 10^{1} of the total emission flux in the grid square corresponding to the location. In the case where the total emission flux was zero at the site location, an area was used in which the total emission value did not exceed the percentile value of 25 of the emissions within the assumed radius for the site.

The methodology allows to map the specifics of individual pollutants and station types. Figure 2 shows the differentiation of the representativeness areas for one station (in Swiebodzin in western Poland) but with different pollutants.

REFERENCES

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