


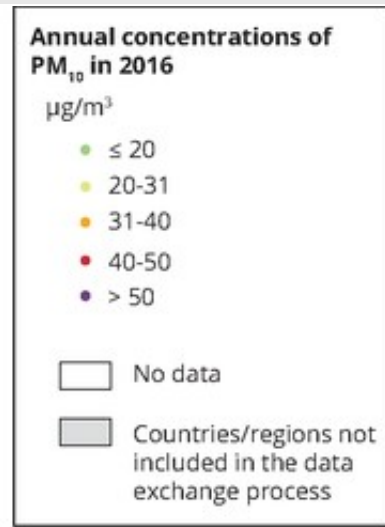
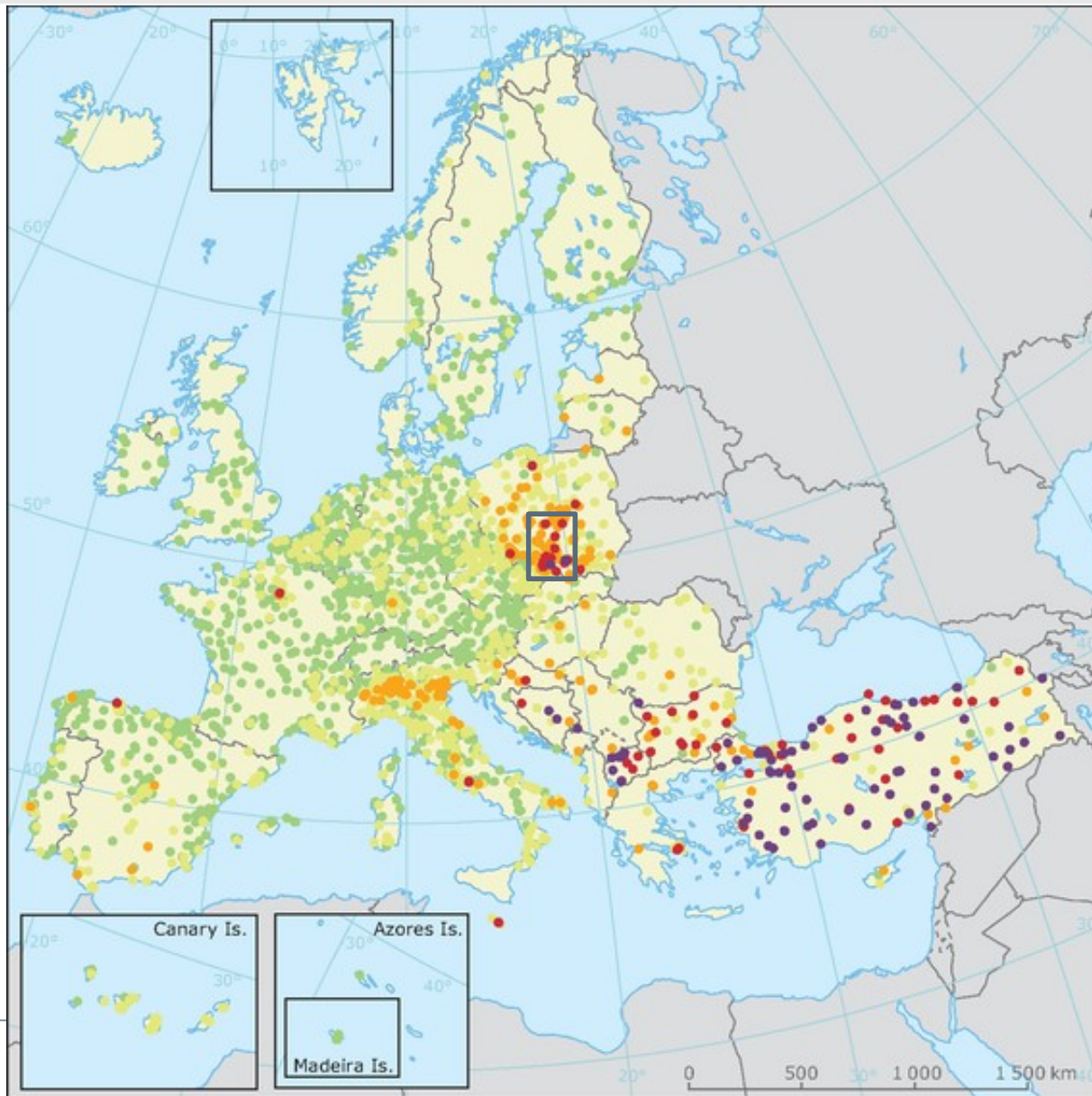


TAKING  
**COOPERATION**  
FORWARD

-  27-th International Seminar on Interaction of Neutrons with Nuclei, JINR, Dubna, RF
-  **Air pollution characterization in industrial urbanized regions using INAA, mathematical modelling and GIS technology**
-  Petr Jancik, Frank Laboratory of Neutron Physics, Sector of Neutron Activation Analysis and Applied Research
- Vladislav Svozilik, Laboratory of Information Technologies

# AIR POLLUTION IN EUROPE (2016)



## The TRITIA Region



# AIR POLLUTION CHARACTERISATION

## By measurement:

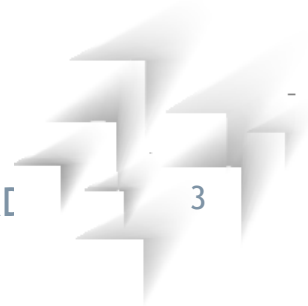
Using results of air quality monitoring stations.

## By modelling:

Using results of mathematical models of air pollutions.

## By special monitoring methods:

Using results of INAA



# AIR POLLUTION CHARACTERISATION

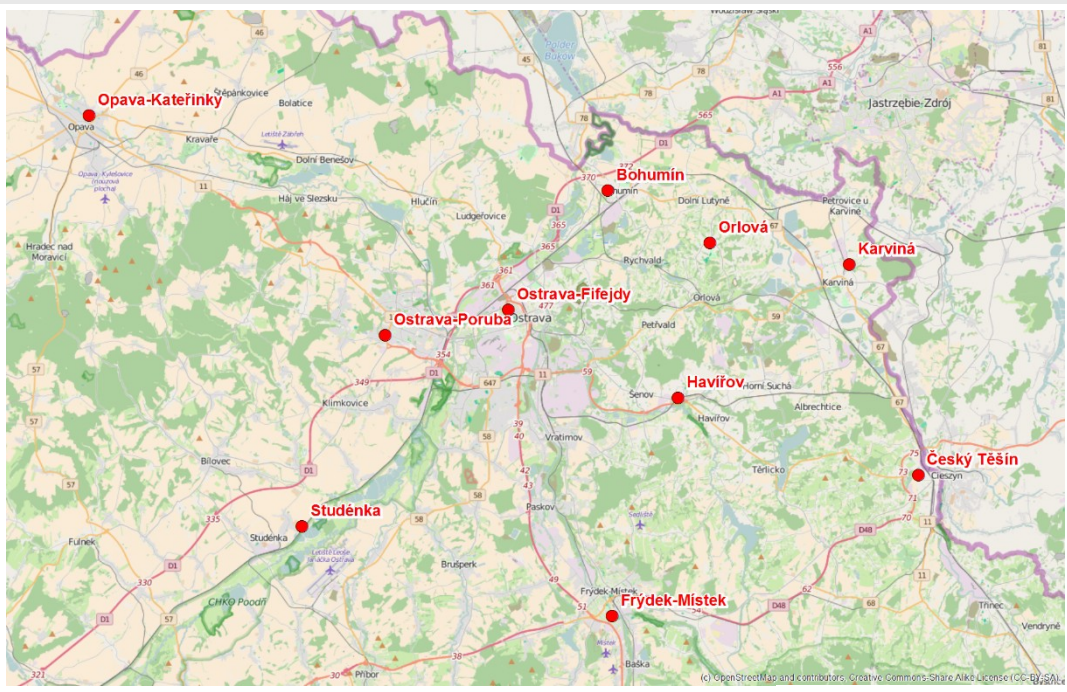
## By Measurement:

Using results of air  
quality monitoring  
stations (MS)

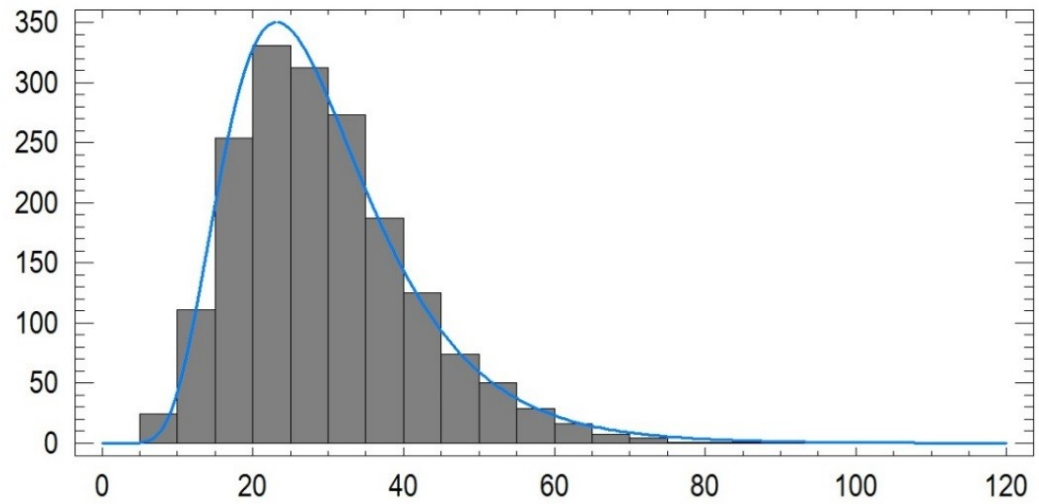
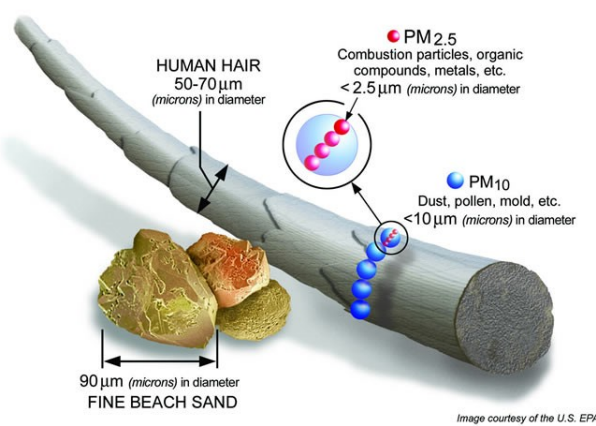




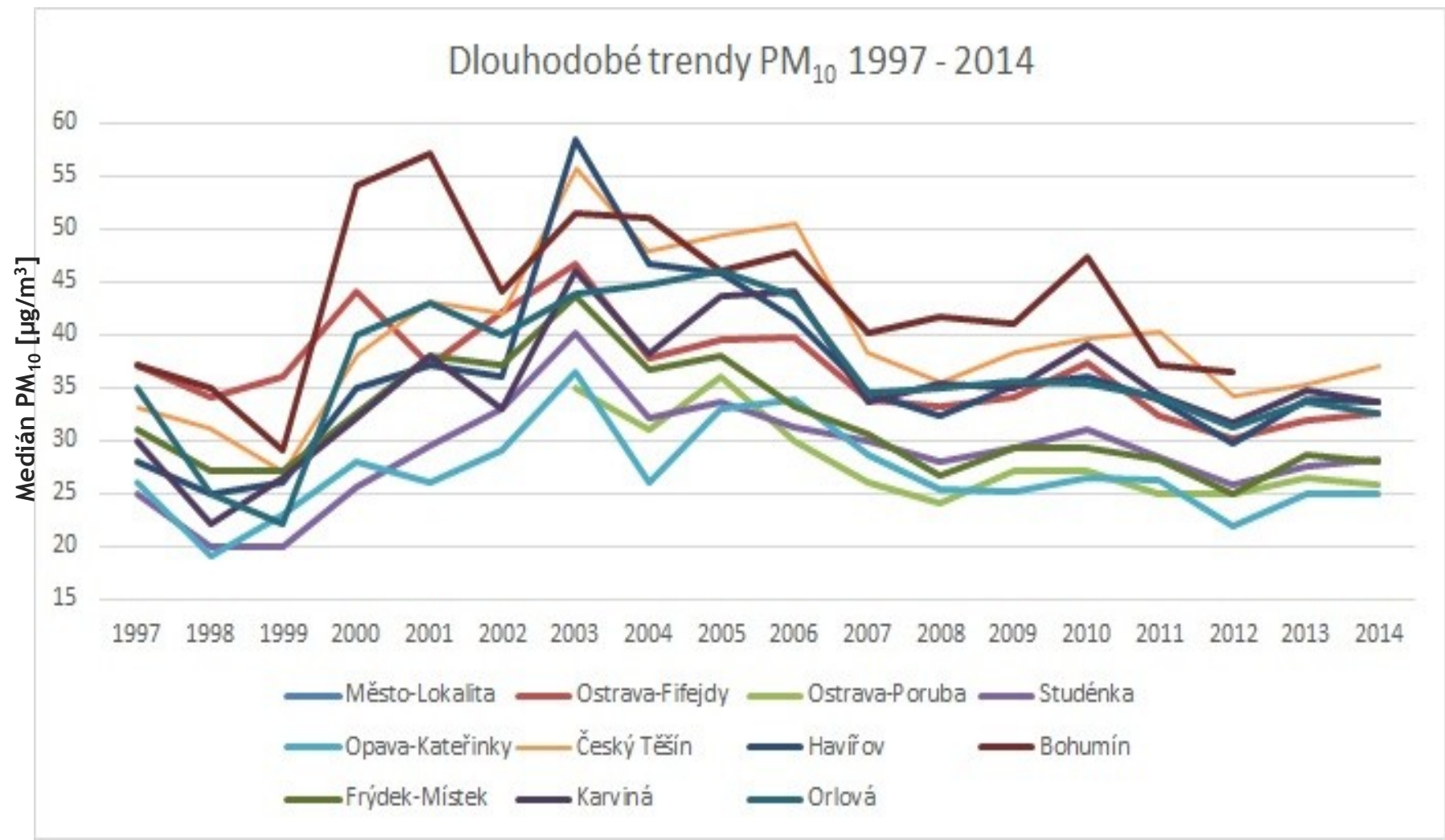
# LONG TERM AIR POLLUTION TRENDS ANALYSIS OF 1 HOUR AVERAGE PM<sub>10</sub> (1998 - 2014)



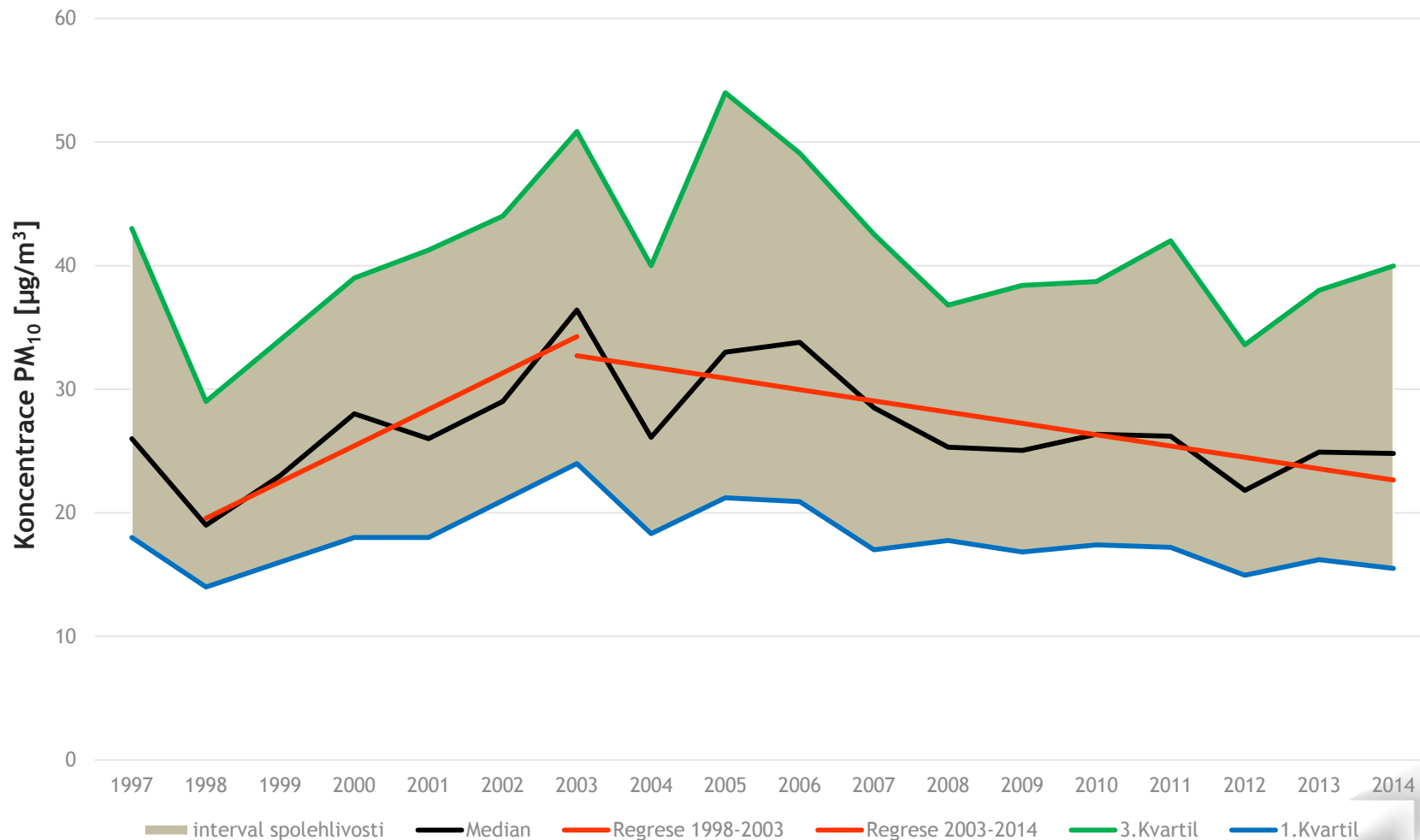
- Regional monitoring stations results behaviour as one system.
- Statistical distribution:



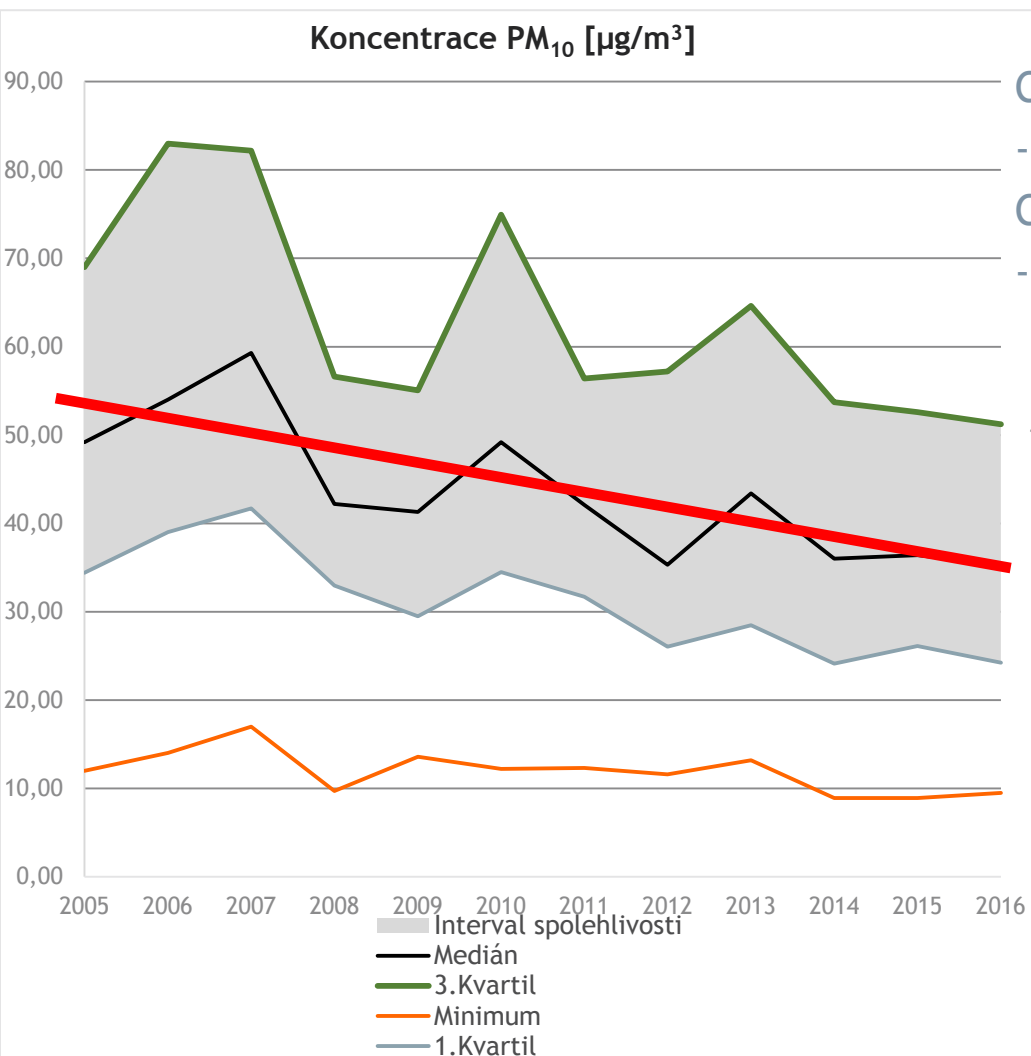
# LONG TERM AIR POLLUTION TRENDS ANALYSIS OF YEAR AVERAGE PM<sub>10</sub> (1998 - 2014)



# LONG TERM AIR POLLUTION TRENDS ANALYSIS OF YEAR AVERAGE, OPAVA, PM<sub>10</sub> (1998 - 2014)



# LONG TERM AIR POLLUTION TRENDS ANALYSIS OF YEAR AVERAGE, OSTRAVA RADVANICE, PM<sub>10</sub> (2005 - 2014)

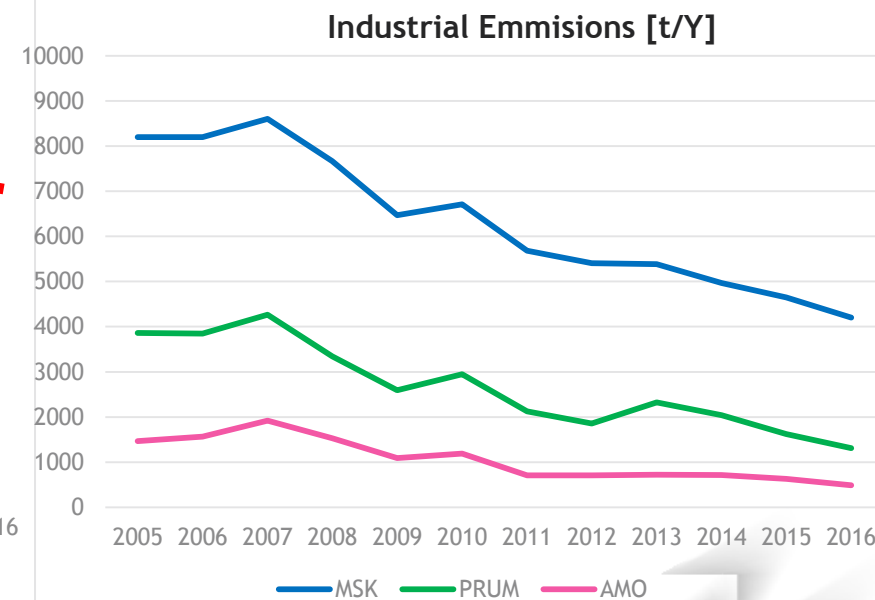


Correlation with AMO emissions = 92%

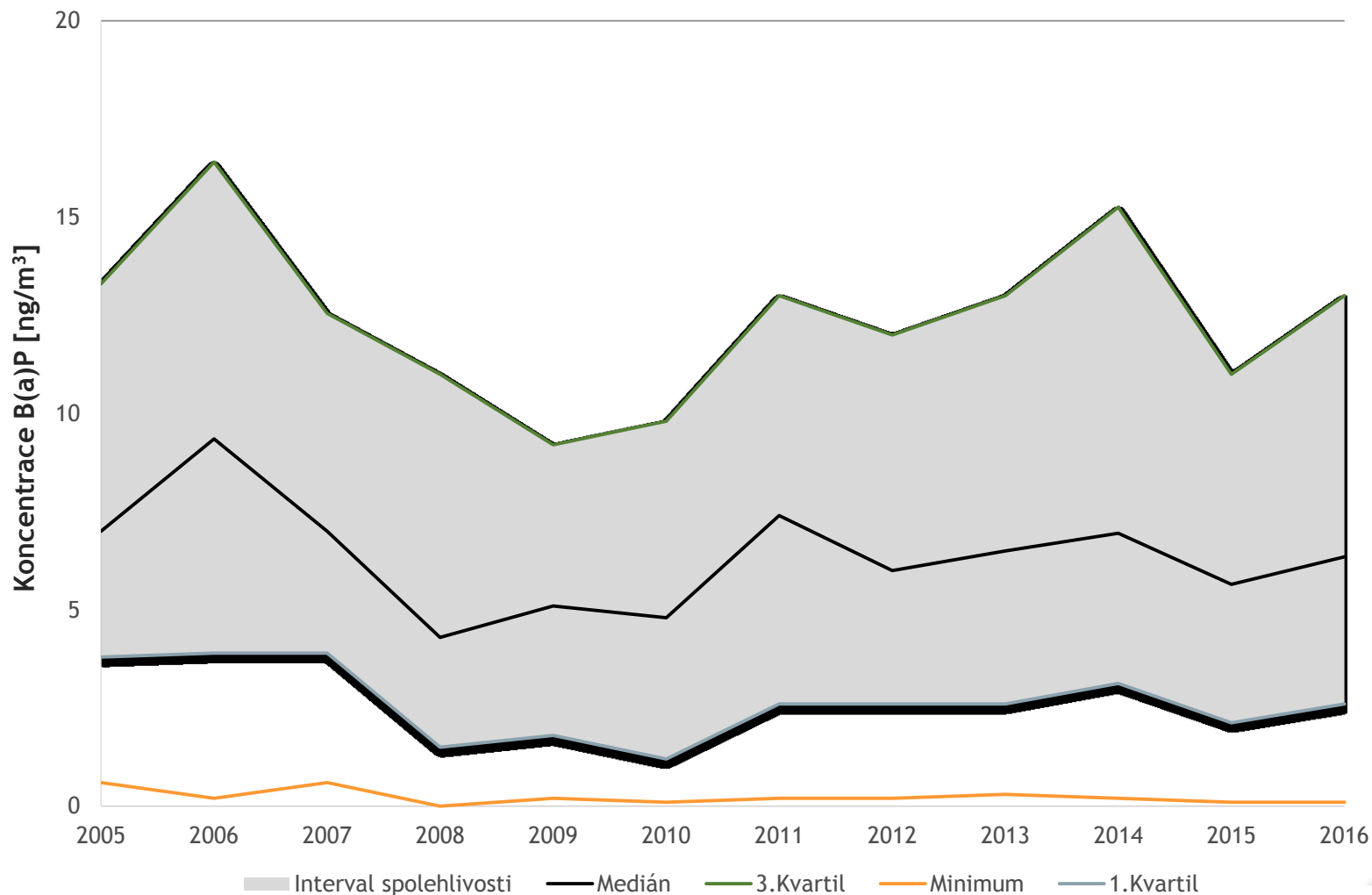
- 100 t/Y AMO cause -1.72 µg/m<sup>3</sup> MS

Correlation with regional heavy industry = 91%

- 1000 run/rok v MSK -> - 6.22 µg/m<sup>3</sup> na IM



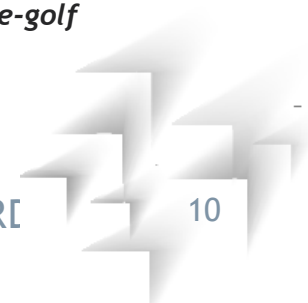
# LONG TERM AIR POLLUTION TRENDS ANALYSIS OF YEAR AVERAGE, OSTRAVA RADVANICE, B(A)P (2005 - 2016)



# LAST DECADE AVERAGE YEAR CONCENTRATIONS OF PM<sub>10</sub>

MS	2006	2016	2017
O.-Radvanice, ZÚ	63.7	41.0	43.9
O.-Poruba, ČHMÚ	37.5	27.3	27.4
Studénka	41.1	27.3	29.3
Opava-Kateřinky	44.4	24.7	26.8
Čeladná	30.8	21.5	20.1*

*Průměrné roční koncentrace PM<sub>10</sub> [μg/m<sup>3</sup>], \* - Ostravice-golf*





## Advantages:

- Exact measurement by standard methods
- Long term data

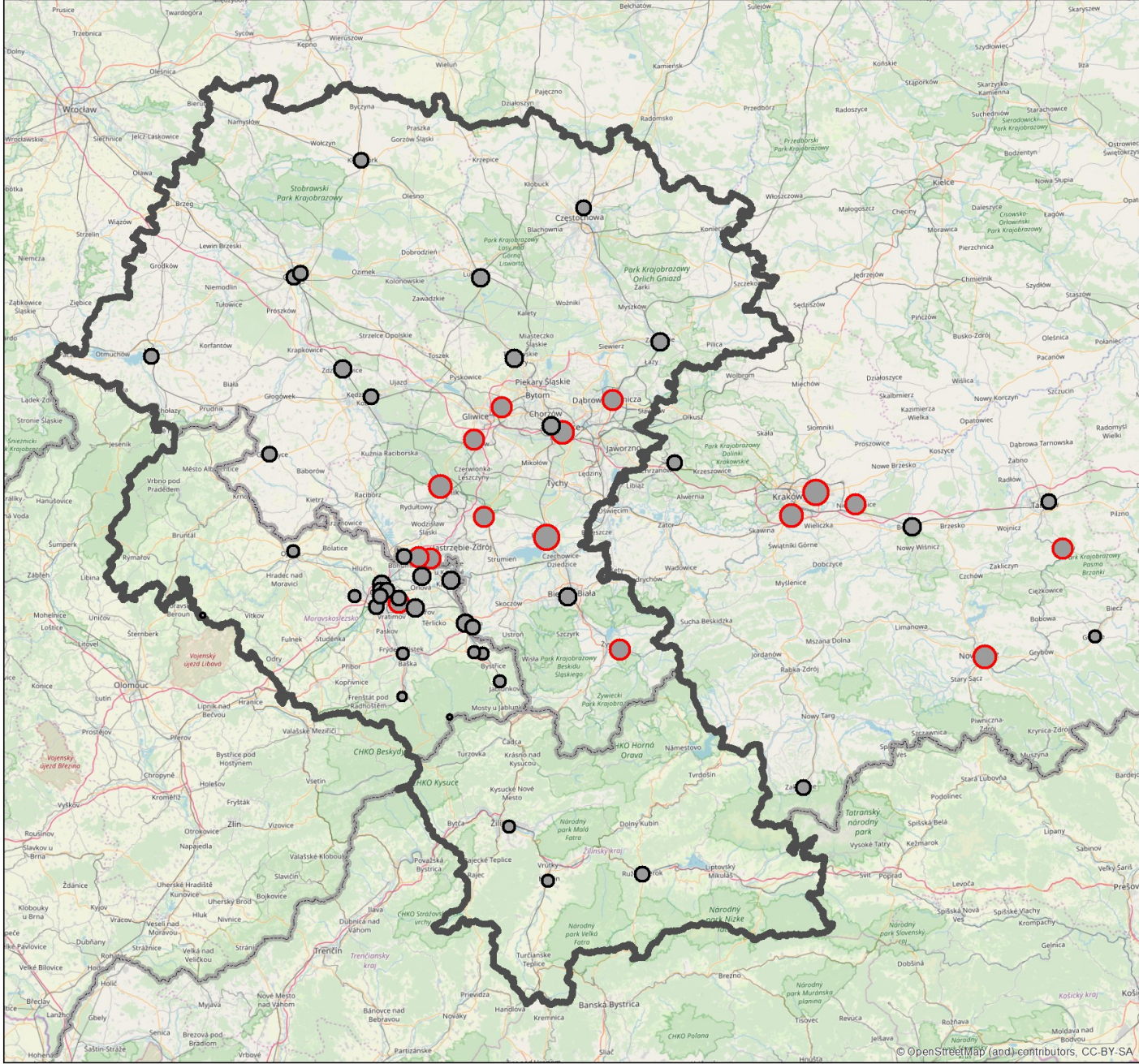
## Disadvantages:

- Local point data
- Uneasy to determine particular air pollution emission sources





# AIR TRITIA - AIR QUALITY MONITORING STATIONS

year 2015



## Measured annual PM<sub>10</sub> concentration [ $\mu\text{g}/\text{m}^3$ ]

- 15,5 - 20,0
- 20,1 - 25,0
- 25,1 - 30,0
- 30,1 - 35,0
- 35,1 - 40,0
- 40,1 - 45,0
- 45,1 - 50,0
- 50,1 - 53,1

 AIR TRITIA - area of interest  
 Borders



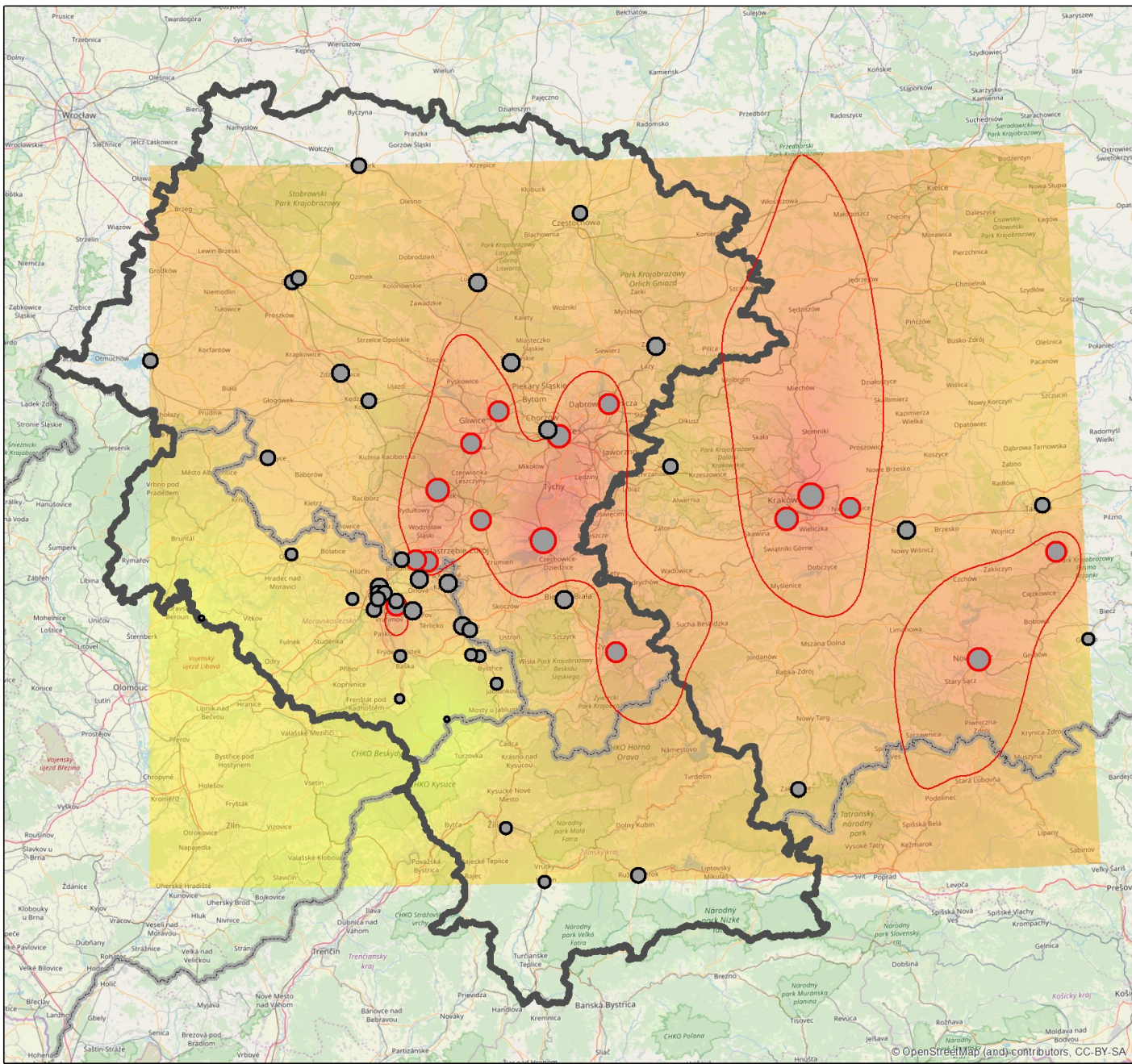
0 20 40 60 80 km

Author: Ing. Vladislav Svozilik  
 Source: Mathematical modelling, OSM, AQM



# AIR TRITIA - AIR QUALITY MONITORING STATIONS INTERPOLATION

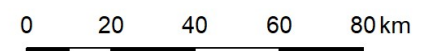
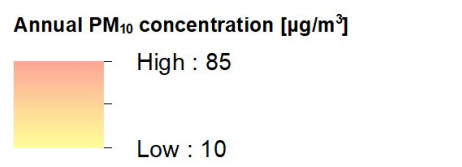
year 2015, Spline\_sa(SPLINE, "TENSION",WEIGHT "10",NUMBER OF POINTS "4")



## Measured annual PM<sub>10</sub> concentration [µg/m<sup>3</sup>]

- 15,5 - 20,0
- 20,1 - 25,0
- 25,1 - 30,0
- 30,1 - 35,0
- 35,1 - 40,0
- 40,1 - 45,0
- 45,1 - 50,0
- 50,1 - 53,1

- Area exceeded PM<sub>10</sub> limit
- ▭ AIR TRITIA - area of interest
- Borders



Author: Ing. Vladislav Svozilik  
Source: Mathematical modelling, OSM, AQM

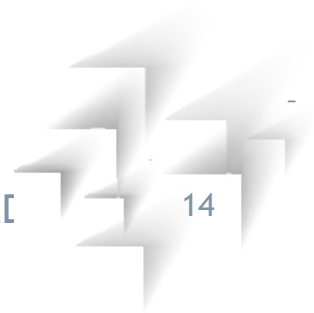
# AIR POLLUTION CHARACTERISATION

## By measurement:

Using results of air quality monitoring stations.

## By modelling:

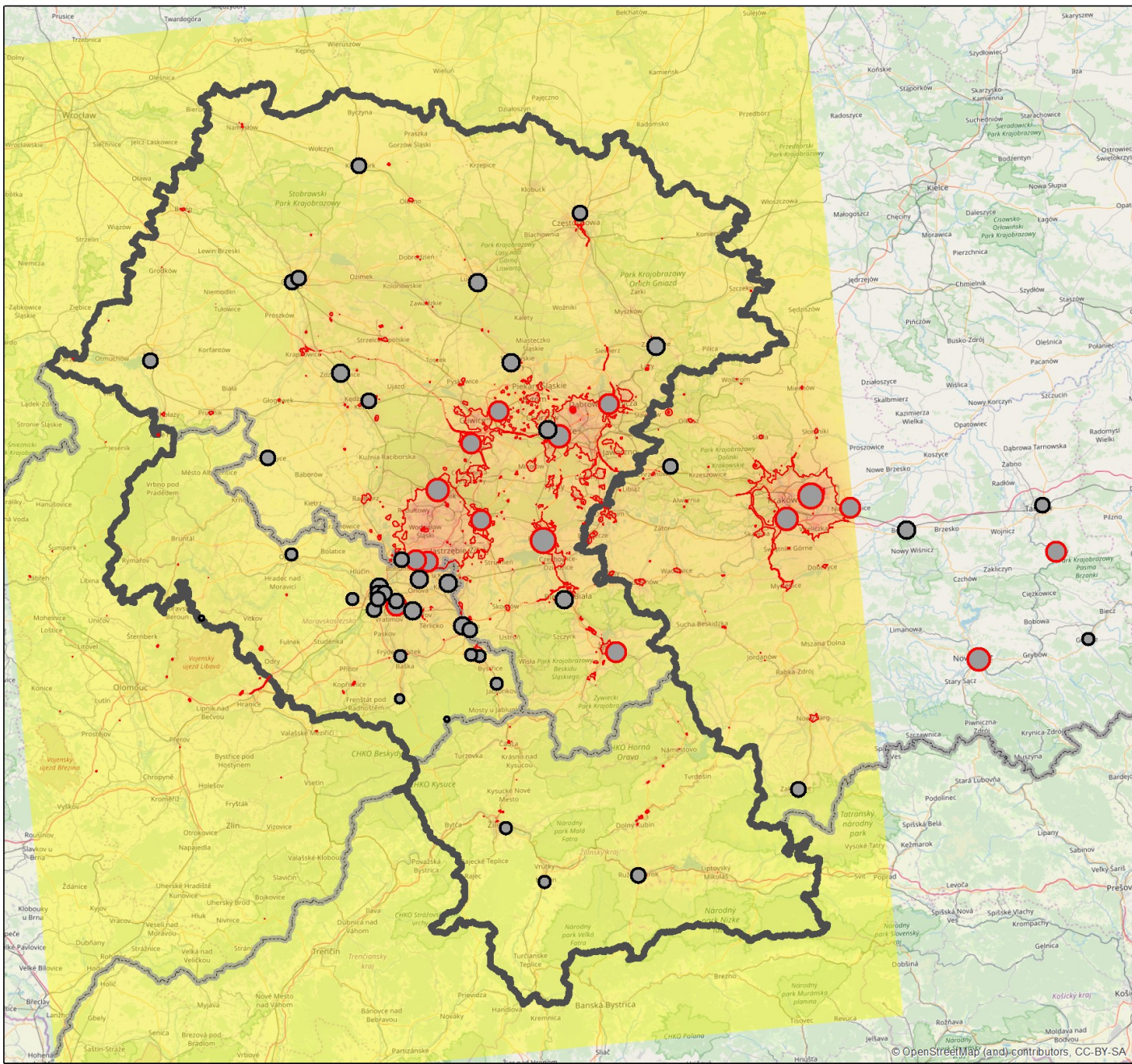
Using results of mathematical models of air pollutions.





# AIR TRITIA - AIR QUALITY MONITORING STATIONS AND MATHEMATICAL MODELLING

year 2015



**Measured annual PM<sub>10</sub> concentration [µg/m<sup>3</sup>]**

- 15,5 - 20,0
- 20,1 - 25,0
- 25,1 - 30,0
- 30,1 - 35,0
- 35,1 - 40,0
- 40,1 - 45,0
- 45,1 - 50,0
- 50,1 - 53,1

— Area exceeded PM<sub>10</sub> limit

▭ AIR TRITIA - area of interest

— Borders

**Modeled annual PM<sub>10</sub> concentration [µg/m<sup>3</sup>]**

85

10

N

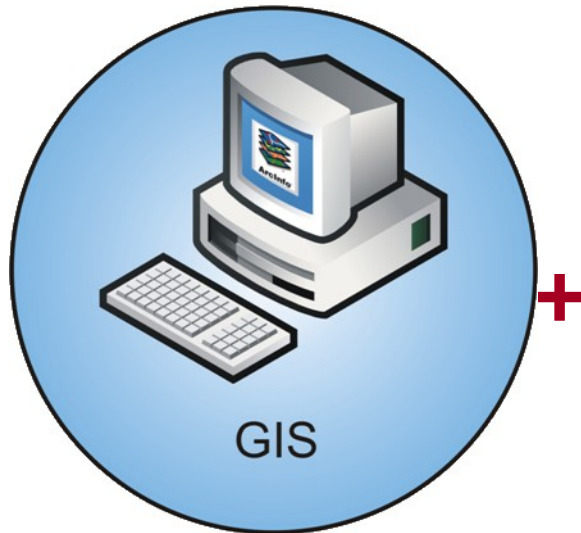
0 20 40 60 80 km

Author: Ing. Vladislav Svozilik  
Source: Mathematical modelling, OSM, AQM

© OpenStreetMap (and contributors), CC-BY-SA

# ADMOSS

=



+

$$C_z = \left[ \frac{4}{(1-n)(2-n)} \left( \frac{N}{u} \right)^n \left( \frac{w^2}{u^2} \right)^{1-n} \right]^{\frac{1}{2}}$$

$$K(x, y, z) = \frac{Q_m}{\pi C_1 C_2 u \alpha^{2+n}} \exp\left(-\frac{y^2}{C_1^2 x^{2+n}}\right) \left[ \exp\left(-\frac{(z-h)^2}{C_2^2 x^{2+n}}\right) + \exp\left(-\frac{(z+h)^2}{C_2^2 x^{2+n}}\right) \right]$$

Mathematical models

+

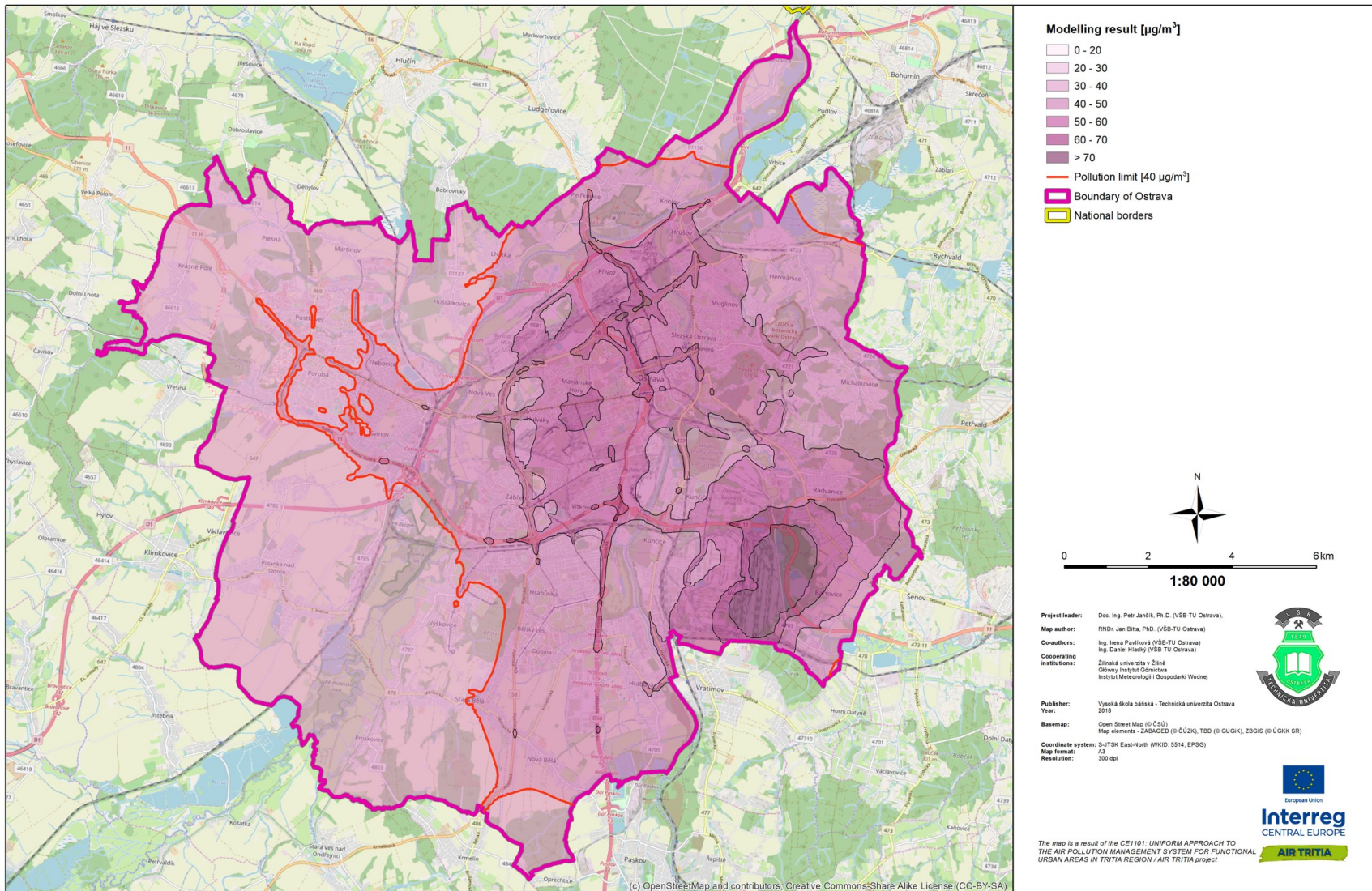




# IS IT POSSIBLE TO VERIFY THE ADMOSS?

## AVERAGE ANNUAL CONCENTRATION OF PM<sub>10</sub> IN OSTRAVA

Total concentration, model SYMOS'97 with correction by pollution monitoring, year 2003

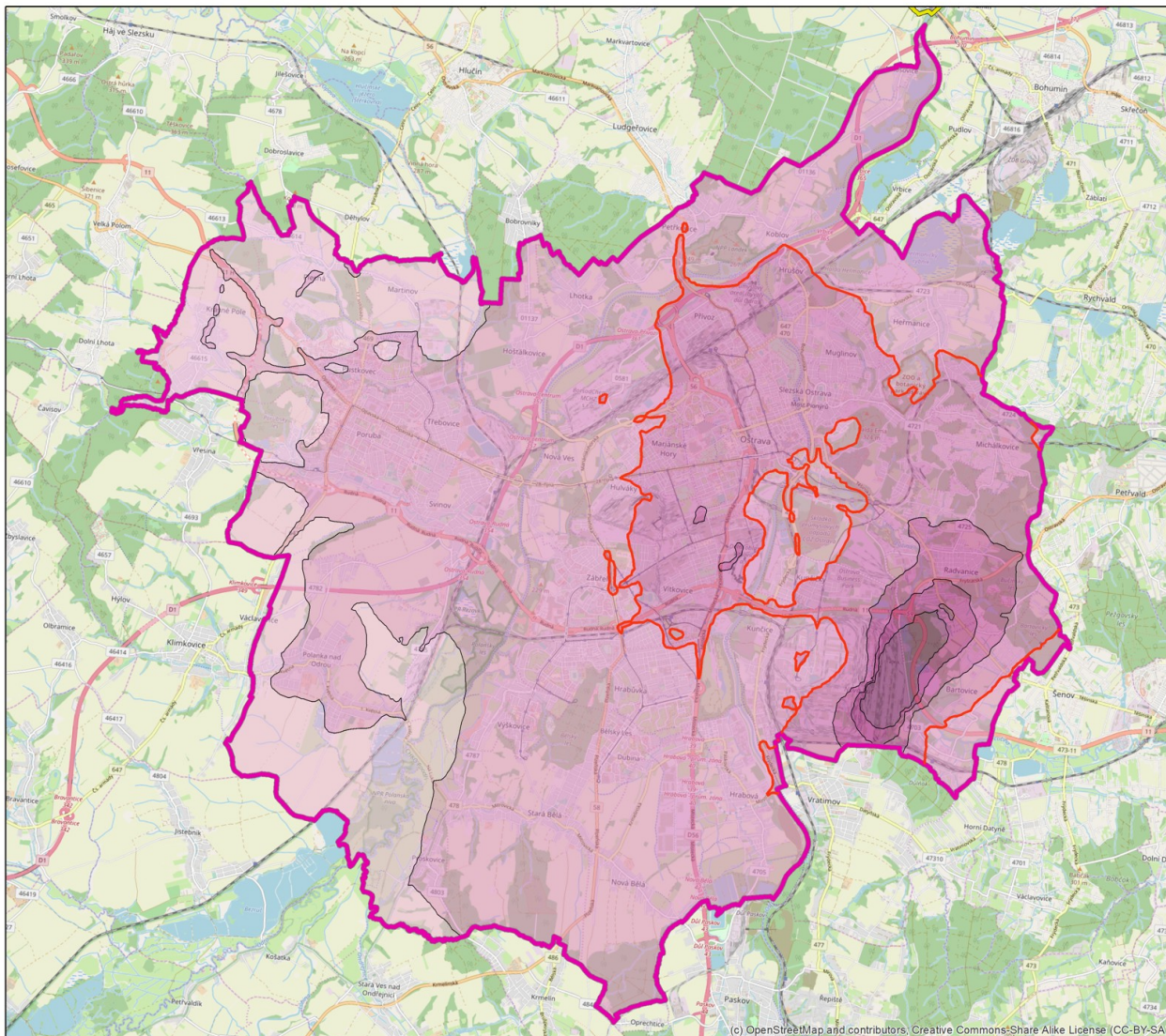




# IS IT POSSIBLE TO VERIFY THE ADMOSS?

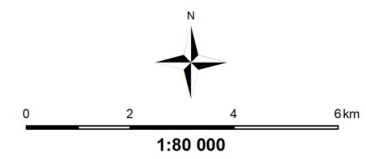
## AVERAGE ANNUAL CONCENTRATION OF PM<sub>10</sub> IN OSTRAVA

Changes in traffic, new roads, model SYMOS'97 with correction by pollution monitoring, year 2007



### Modelling result [ $\mu\text{g}/\text{m}^3$ ]

- 0 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- > 70
- Pollution limit [ $40 \mu\text{g}/\text{m}^3$ ]
- Boundary of Ostrava
- National borders



**Project leader:** Doc. Ing. Petr Jančík, Ph.D. (VSB-TU Ostrava).  
**Map author:** RNDr. Jan Bitta, PhD. (VSB-TU Ostrava)  
**Co-authors:** Ing. Ineta Pavliková (VSB-TU Ostrava)  
 Ing. Daniel Hladký (VSB-TU Ostrava)  
**Cooperating institutions:** Žitná univerzita v Žitě  
 Ostrava Institut Geoinforma  
 Institut Meteorologii i Gospodarki Wodnej  
**Publisher:** Vysoká škola báňská - Technická univerzita Ostrava  
**Year:** 2018  
**Basemap:** Open Street Map (© CSD)  
 Map elements - ZABAGED (© CÚZK), TBD (© GUGK), ZBOIS (© ÚGKK SR)  
**Coordinate system:** S-JTSK East-North (WKID: 5514, EPSG)  
**Map format:** A3  
**Resolution:** 300 dpi



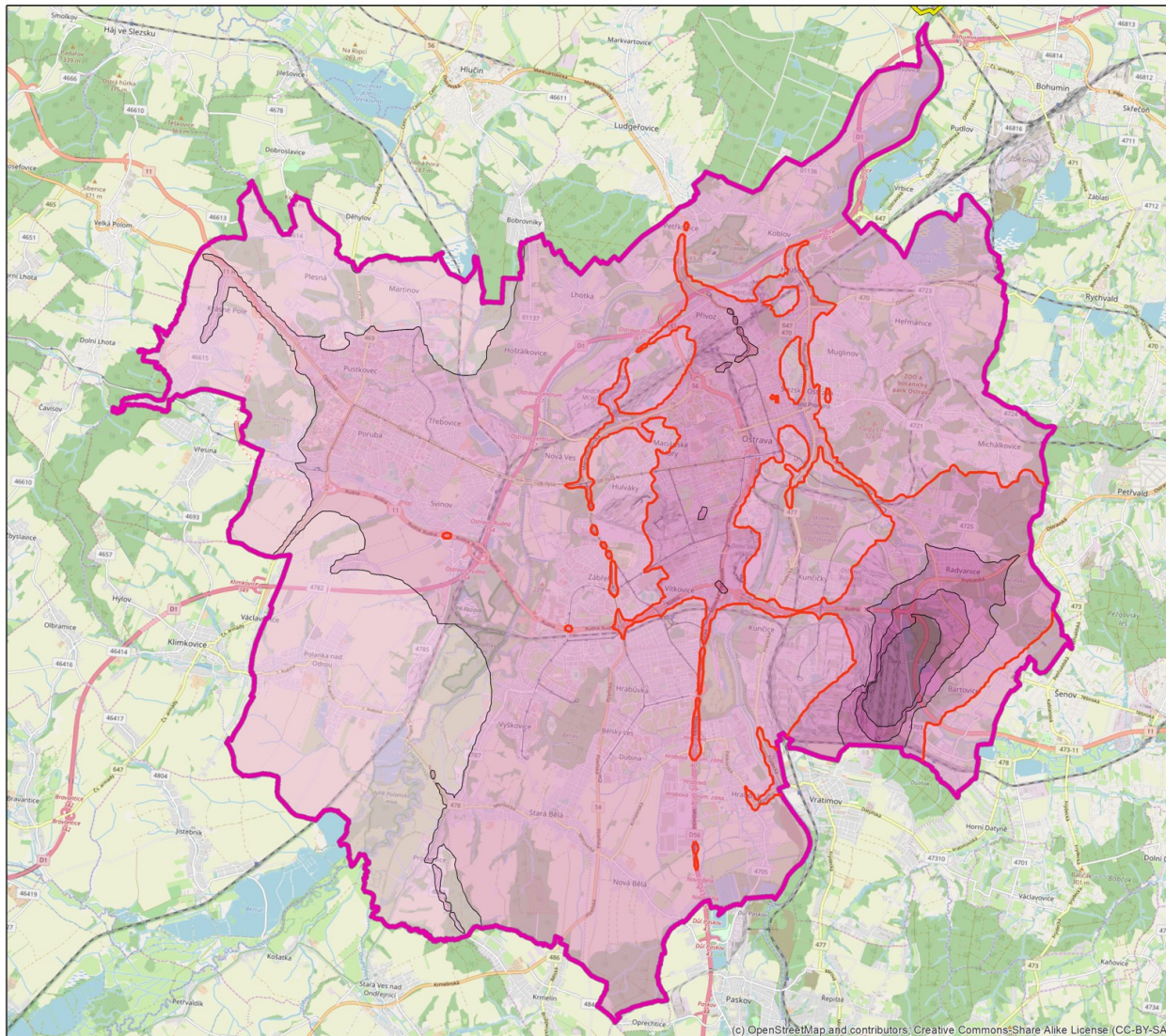
The map is a result of the CE1101: UNIFORM APPROACH TO THE AIR POLLUTION MANAGEMENT SYSTEM FOR FUNCTIONAL URBAN AREAS IN TRITIA REGION / AIR TRITIA project



# IS IT POSSIBLE TO VERIFY THE ADMOSS?

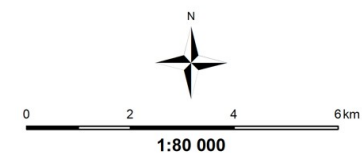
## AVERAGE ANNUAL CONCENTRATION OF PM<sub>10</sub> IN OSTRAVA

Solid fuel replacement in domestic heating, model SYMOS'97 with correction by pollution monitoring, year 2007



### Modelling result [ $\mu\text{g}/\text{m}^3$ ]

- 0 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- > 70
- Pollution limit [ $40 \mu\text{g}/\text{m}^3$ ]
- Boundary of Ostrava
- National borders



**Project leader:** Doc. Ing. Petr Jančík, Ph.D. (VŠB-TU Ostrava),  
**Map author:** RNDr. Jan Bitta, PhD. (VŠB-TU Ostrava)  
**Co-authors:** Ing. Ineta Pavlíková (VŠB-TU Ostrava)  
 Ing. Daniel Hrubý (VŠB-TU Ostrava)  
**Cooperating institutions:** Žitná škola univerzita v Žitě  
 Ústřední ústav meteorologie  
 Ústav meteorologie | Hospodárski Vodnej  
**Publisher:** Vysoká škola báňská - Technická univerzita Ostrava  
 2018  
**Basemap:** Open Street Map (© CSÚ)  
 Map elements - ZABAGED (© ČÚZK), TBD (© GUGK), ZBOIS (© ÚOKX SR)  
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**Map format:** A3  
**Resolution:** 300 dpi



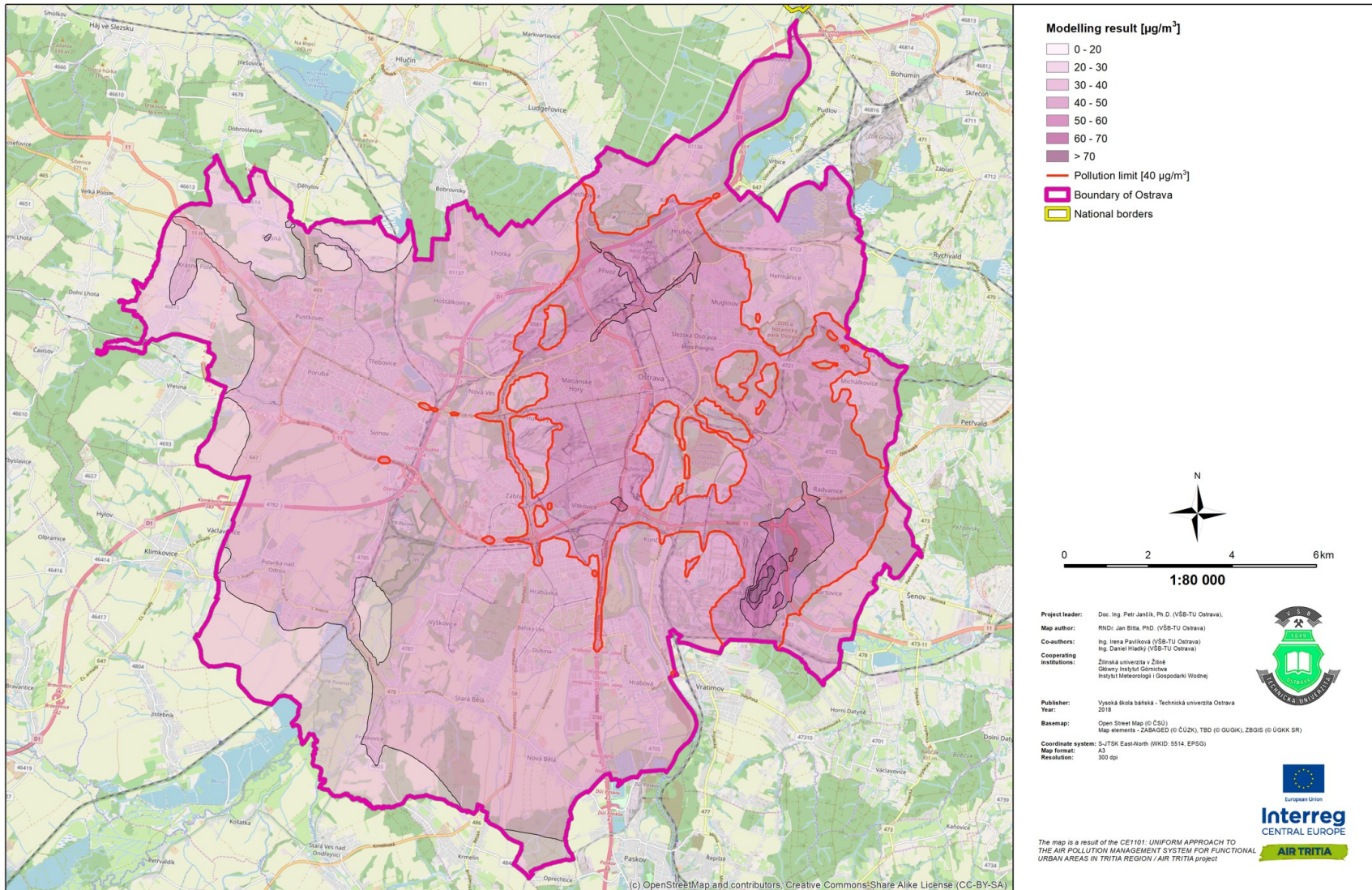
The map is a result of the CE1101: UNIFORM APPROACH TO THE AIR POLLUTION MANAGEMENT SYSTEM FOR FUNCTIONAL URBAN AREAS IN TRITIA REGION / AIR TRITIA project



# IS IT POSSIBLE TO VERIFY THE ADMOSS?

## AVERAGE ANNUAL CONCENTRATION OF PM<sub>10</sub> IN OSTRAVA

Emission ceiling for industrial sources, model SYMOS'97 with correction by pollution monitoring, year 2007

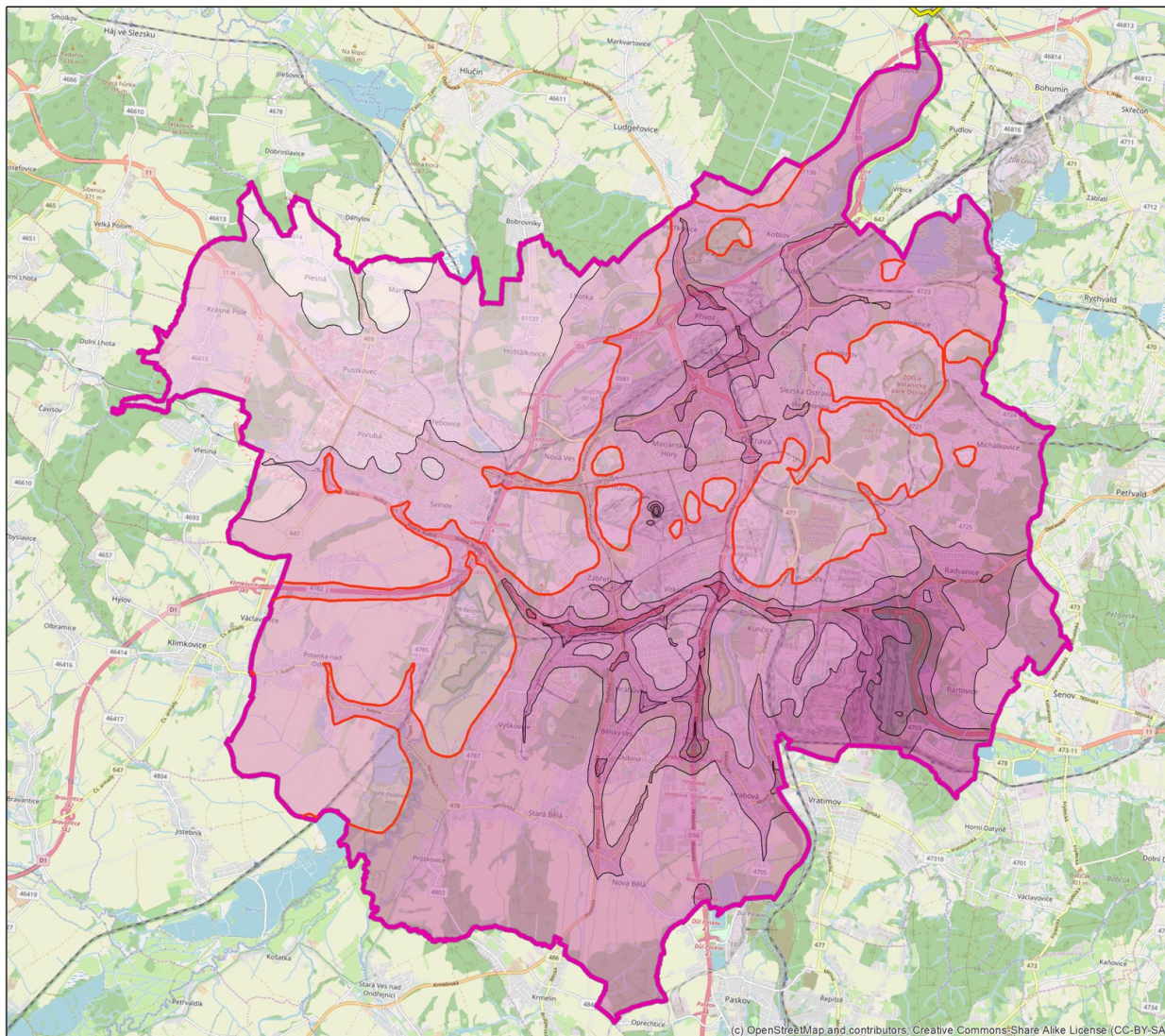




# IS IT POSSIBLE TO VERIFY THE ADMOSS?

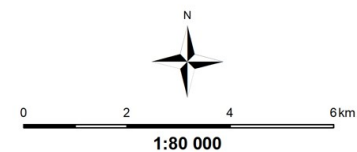
## AVERAGE ANNUAL CONCENTRATION OF PM<sub>10</sub> IN OSTRAVA

Total concentration, model SYMOS'97 with correction by pollution monitoring, year 2010



### Modelling result [ $\mu\text{g}/\text{m}^3$ ]

- 0 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- > 70
- Pollution limit [ $40 \mu\text{g}/\text{m}^3$ ]
- Boundary of Ostrava
- National borders



**Project leader:** Doc. Ing. Petr Jančík, Ph.D. (VSB-TU Ostrava).  
**Map author:** RNDr. Jan Bitta, PhD. (VSB-TU Ostrava)  
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**Publisher:** Vysoká škola báňská - Technická univerzita Ostrava  
 2018  
**Year:**  
**Basemap:** Open Street Map (© ČSU)  
 Map elements - ZABAGED (© ČÚZK), TBO (© GUGK), ZBGIS (© ÚGK SR)  
**Coordinate system:** S-JTSK East-North (WKID: 5514, EPSG)  
**Map format:** A3  
**Resolution:** 300 dpi



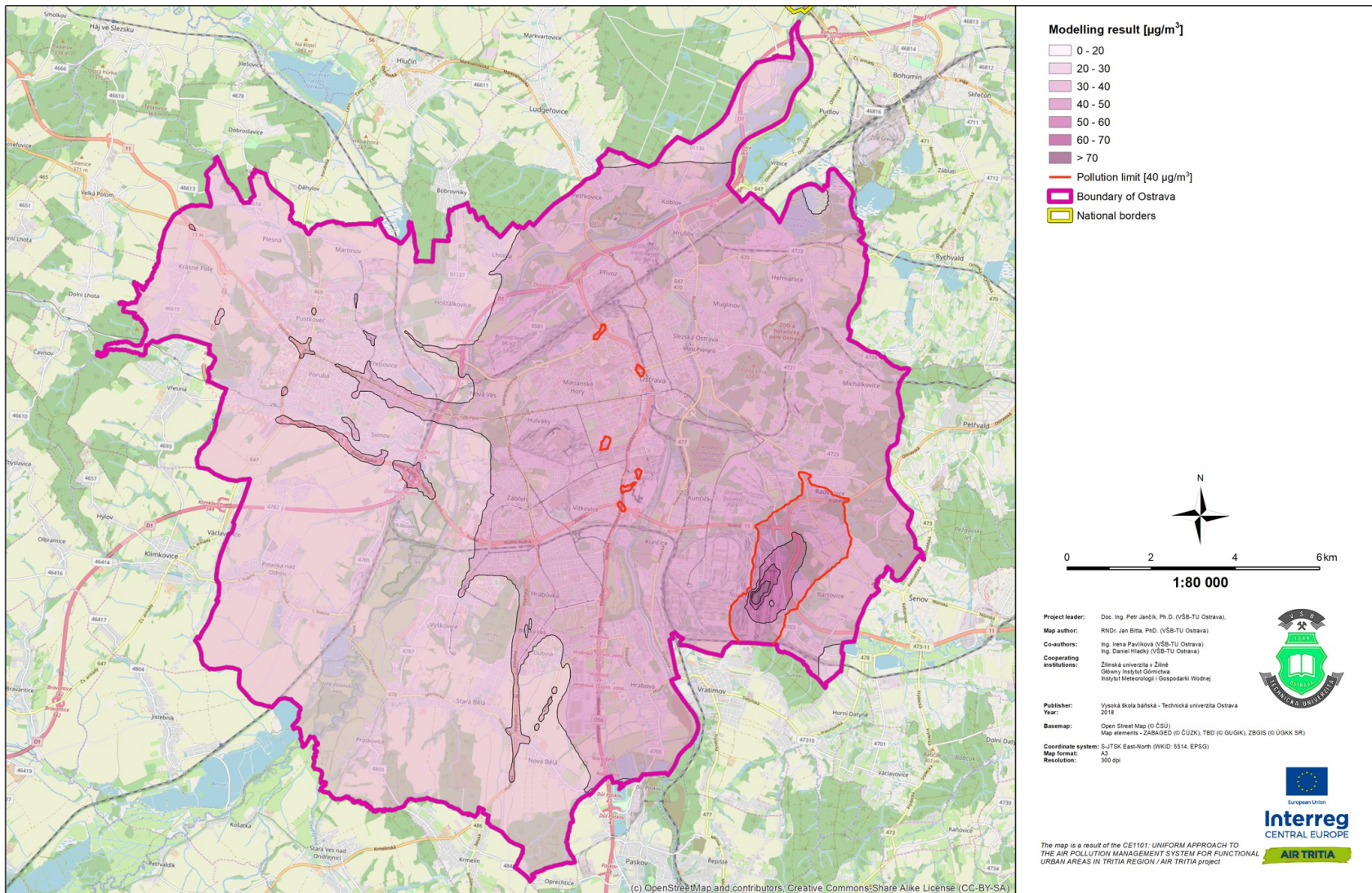
The map is a result of the CE1101: UNIFORM APPROACH TO THE AIR POLLUTION MANAGEMENT SYSTEM FOR FUNCTIONAL URBAN AREAS IN TRITIA REGION / AIR TRITIA project



# IS IT POSSIBLE TO VERIFY THE ADMOSS?

## AVERAGE ANNUAL CONCENTRATION OF PM<sub>10</sub> IN OSTRAVA

All pollution limiting provisions, model SYMOS'97 with correction by pollution monitoring, year 2007

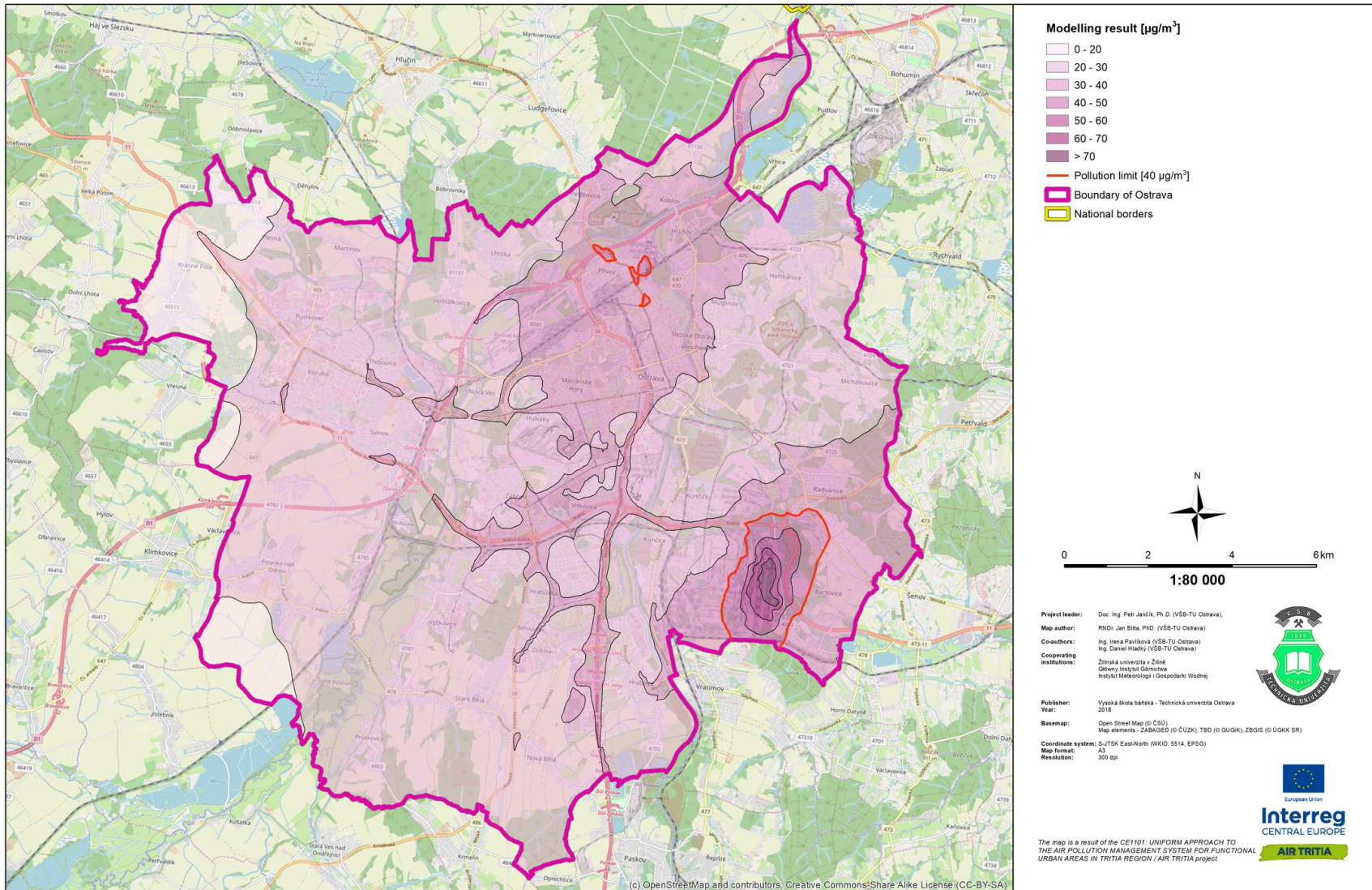




# IS IT POSSIBLE TO VERIFY THE ADMOSS?

## AVERAGE ANNUAL CONCENTRATION OF PM<sub>10</sub> IN OSTRAVA

Total concentration, model SYMOS'97 with correction by pollution monitoring, year 2015



- Collection of common data for the whole region.
- Characterisation of the region related to air pollutions (legislation, social structure, health risk, transport, air pollutions).
- Air Pollution Management System.
- <https://labgis.vsb.cz/test/>
- Ready for scenarios and variants of them.
- Preparing the strategies for selected cities and the whole region after evaluating particular variants. The core is ADMOSS.
- To make the evaluation believable, necessary to proof model results.
- **We decided to use biomonitoring using moss samples with multi element analysis by INAA**



# INDICATION OF 7 MOST POLLUTED INDUSTRIAL AREAS

Czenstochowa  
area

1

Katowice-Gliwice  
area

2

Rybnik -  
Jastrzebie - area

3

Karvina - Ostrava  
area

4

Oświęcim  
area

5

Krakow  
area

6

Trinec  
area

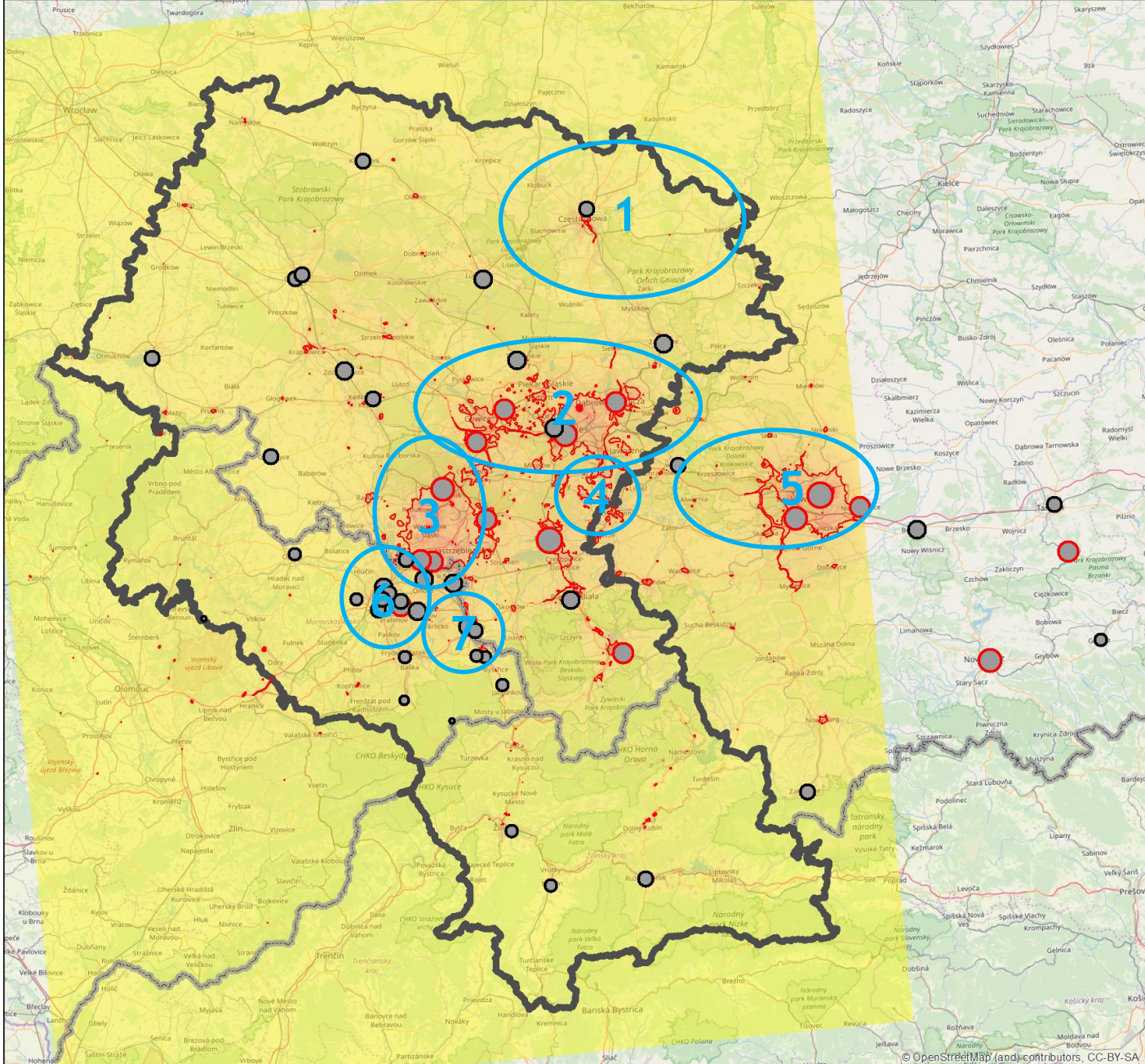
7





# AIR TRITIA - AIR QUALITY MONITORING STATIONS AND MATHEMATICAL MODELLING

year 2015

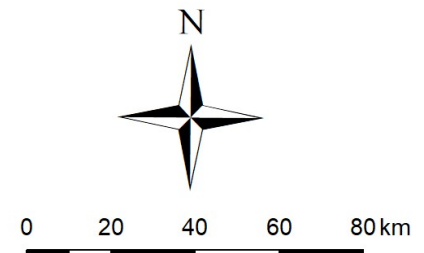
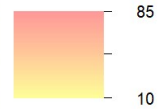


## Measured annual PM<sub>10</sub> concentration [µg/m<sup>3</sup>]

- 15,5 - 20,0
- 20,1 - 25,0
- 25,1 - 30,0
- 30,1 - 35,0
- 35,1 - 40,0
- 40,1 - 45,0
- 45,1 - 50,0
- 50,1 - 53,1

- Area exceeded PM<sub>10</sub> limit
- ▭ AIR TRITIA - area of interest
- Borders

## Modeled annual PM<sub>10</sub> concentration [µg/m<sup>3</sup>]



Author: Ing. Vladislav Svozilik  
 Source: Mathematical modelling, OSM, AQM

# AIR POLLUTION CHARACTERISATION

## By measurement:

Using results of air quality monitoring stations.

## By modelling:

Using results of mathematical models of air pollutions.

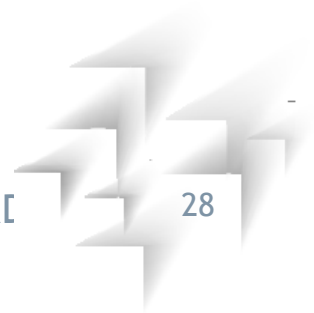
## By special monitoring methods:

Using results of INAA



## Statistical processing of INAA results:

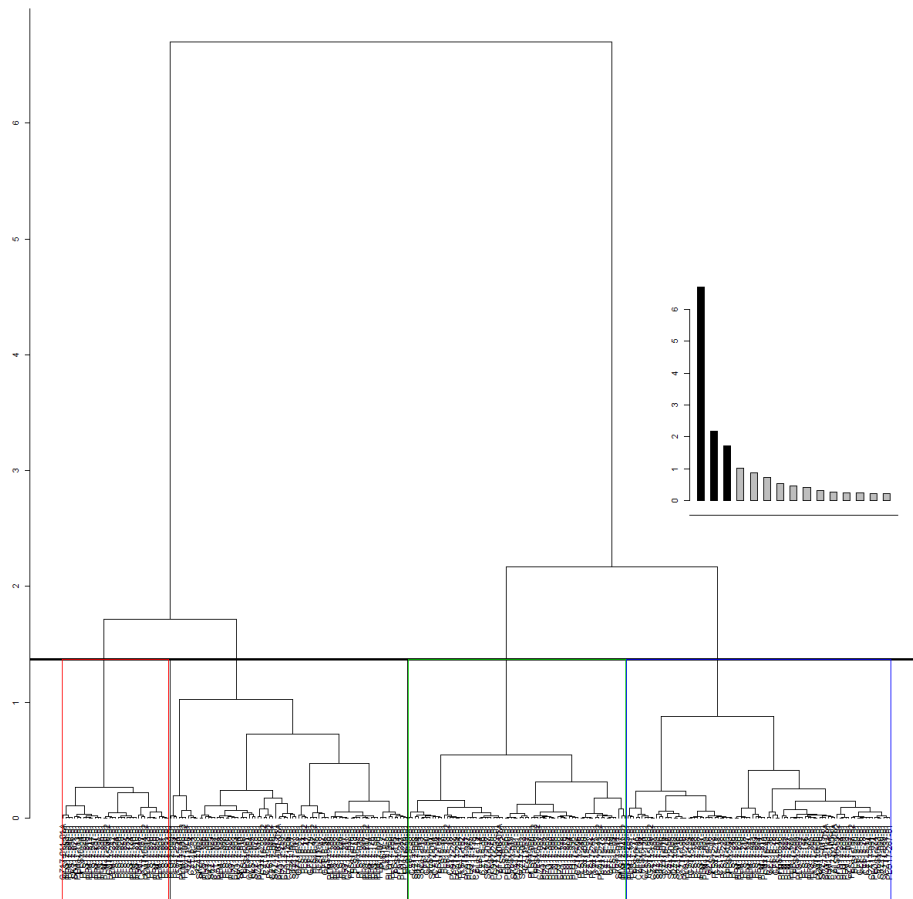
1. Clustering according normalised elements concentrations combination.
2. Factor analysis.
3. Correlation between elements concentrations in samples.
4. Comparing some chosen tracing elements concentrations with mathematical model results .





## HCPCA (The Hierarchical Clustering on Principal Components)

Author: Vladislav Svozilik



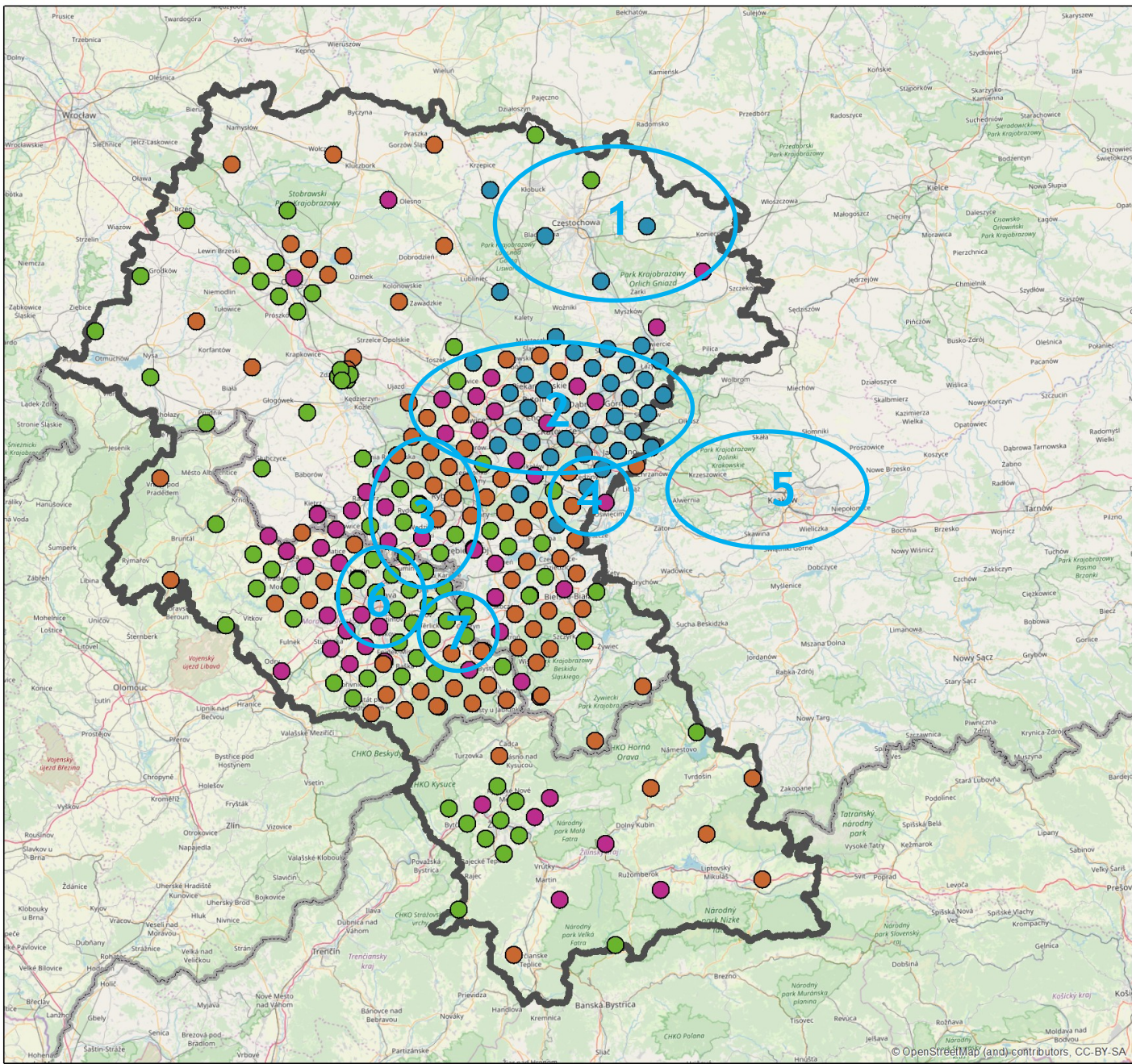
The result = 4 clusters:

**Red**  
**Brown**  
**Green**  
**Blue**



# AIR TRITIA - HCPC / HIERARCHICAL CLUSTERING ON PRINCIPAL COMPONENTS

year 2015



### HCPCA clusters

- 1
- 2
- 3
- 4

AIR TRITIA - area of interest

Borders



0 20 40 60 80 km

Author: Ing. Vladislav Svozilik  
Source: Mathematical modelling, OSM, AQM

# THE FACTOR ANALYSIS

The result = 4 factors, described by groups of elements:

Factor 1: Ni, V, Al, Co, Ce, Na, Sm, U, Nd, Tb, Th, Sc, Ti, La, Hf

Factor 2: Cr, Fe, Sb, Mo

Factor 3: K, Mg

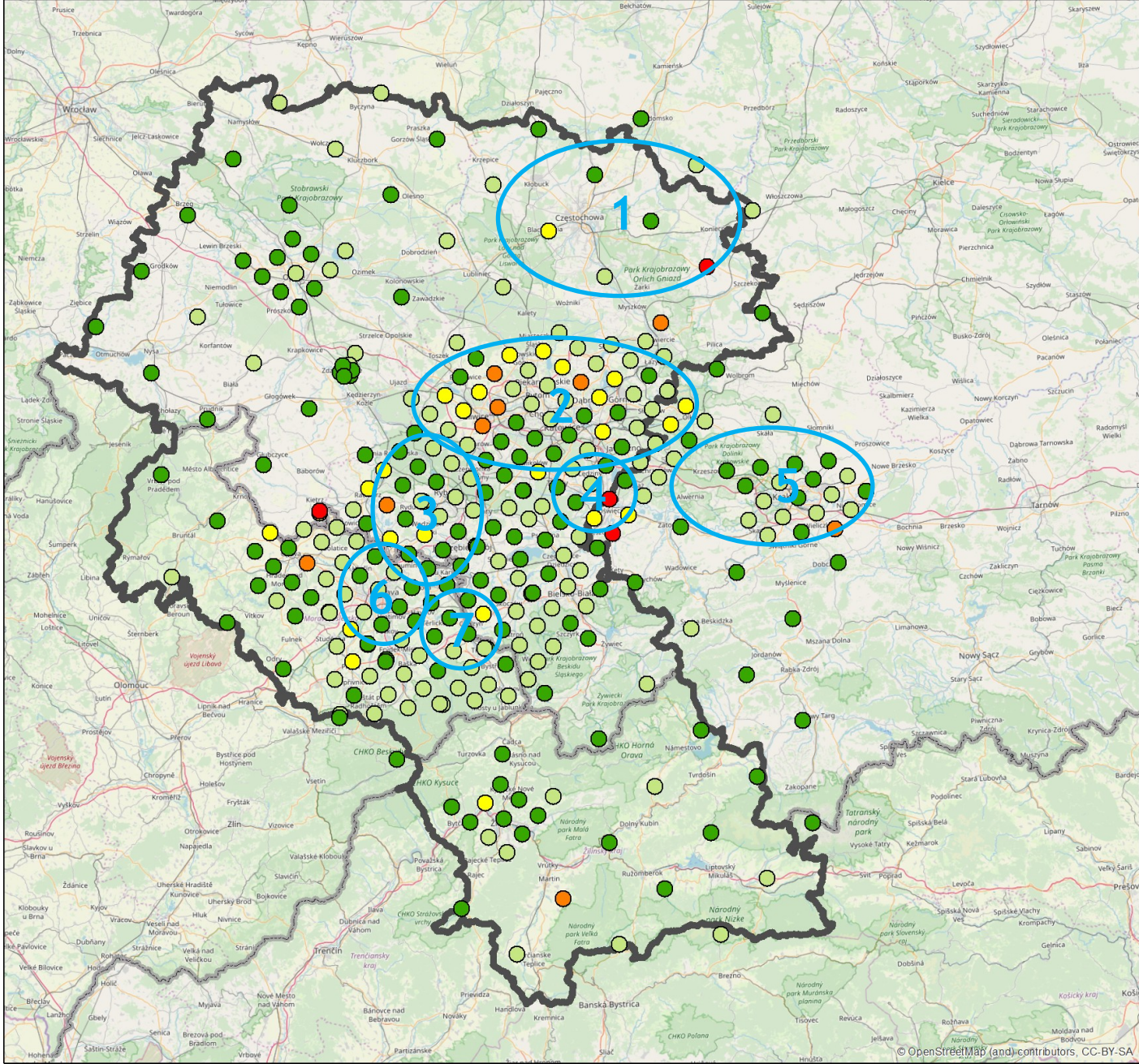
Factor 4: Cd, Rb





# AIR TRITIA - FACTOR ANALYSIS RESULTS

year 2015



## Factor 1

- 0,00 - 0,40
- 0,41 - 0,93
- 0,94 - 1,92
- 1,93 - 4,04
- 4,05 - 6,46

- AIR TRITIA - area of interest
- Borders



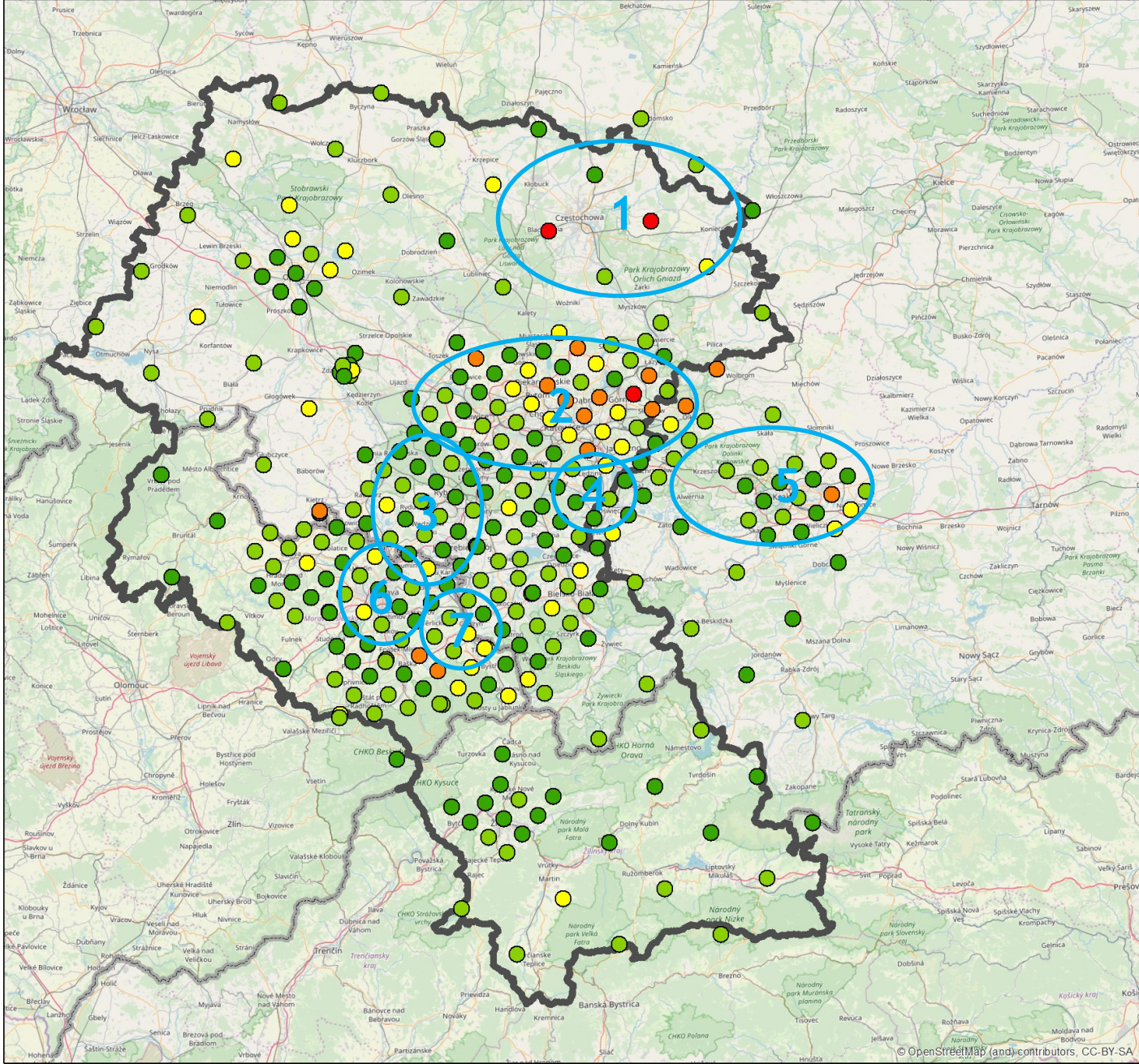
0 20 40 60 80 km

Author: Ing. Vladislav Svozilik  
 Source: Mathematical modelling, OSM, AQM



# AIR TRITIA - FACTOR ANALYSIS RESULTS

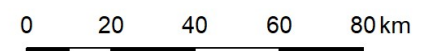
year 2015



## Factor 2

- 0,01 - 0,40
- 0,41 - 0,84
- 0,85 - 1,51
- 1,52 - 3,30
- 3,31 - 9,55

- AIR TRITIA - area of interest
- Borders

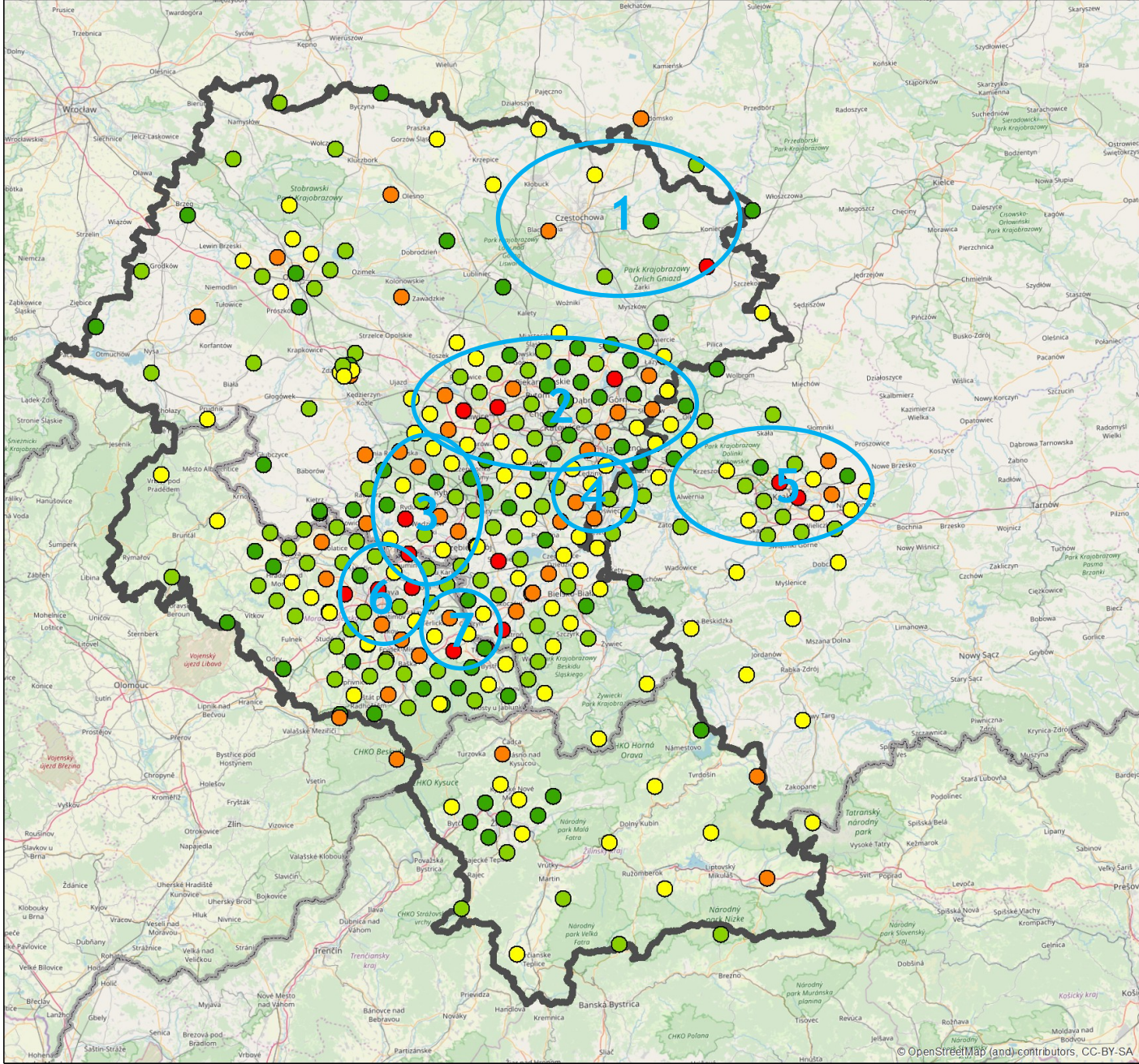


Author: Ing. Vladislav Svozilik  
 Source: Mathematical modelling, OSM, AQM



# AIR TRITIA - FACTOR ANALYSIS RESULTS

year 2015



## Factor 3

- 0,00 - 0,33
- 0,34 - 0,73
- 0,74 - 1,18
- 1,19 - 1,92
- 1,93 - 3,59

 AIR TRITIA - area of interest

 Borders



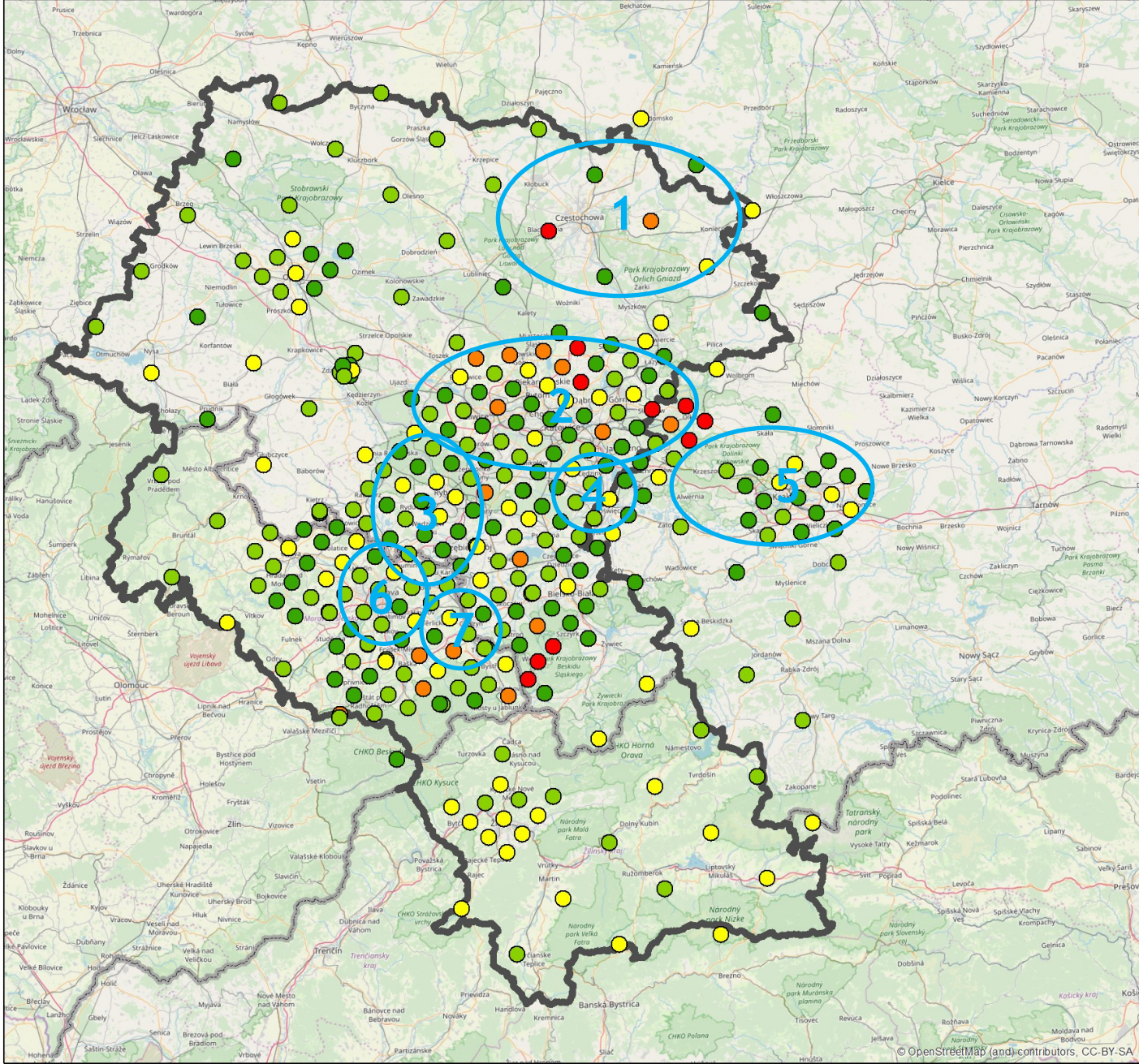
0 20 40 60 80 km

Author: Ing. Vladislav Svozilik  
Source: Mathematical modelling, OSM, AQM



# AIR TRITIA - FACTOR ANALYSIS RESULTS

year 2015



## Factor 4

- 0,00 - 0,39
- 0,40 - 0,83
- 0,84 - 1,53
- 1,54 - 2,52
- 2,53 - 6,38

- AIR TRITIA - area of interest
- Borders



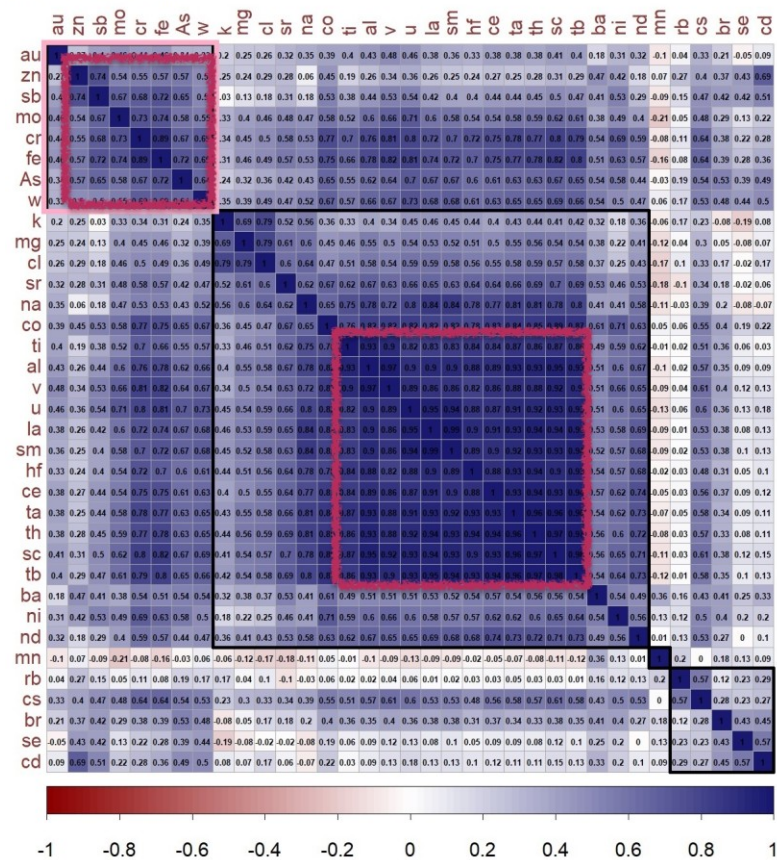
0 20 40 60 80 km

Author: Ing. Vladislav Svozilik  
 Source: Mathematical modelling, OSM, AQM



# THE CORRELATIONS

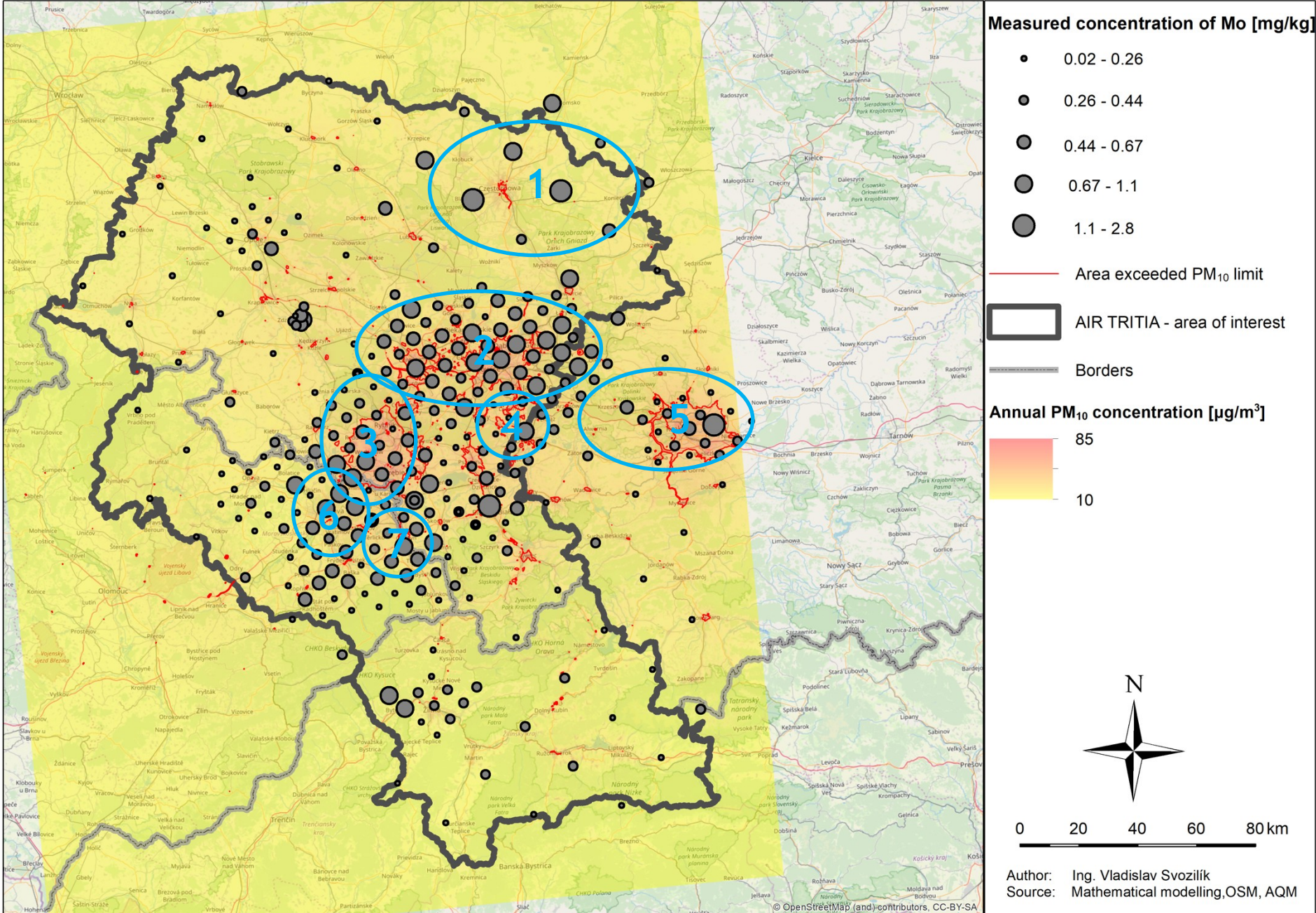
Author: Vladislav Svozilik





# CONCENTRATION DETERMINED IN MOSS BY INAA

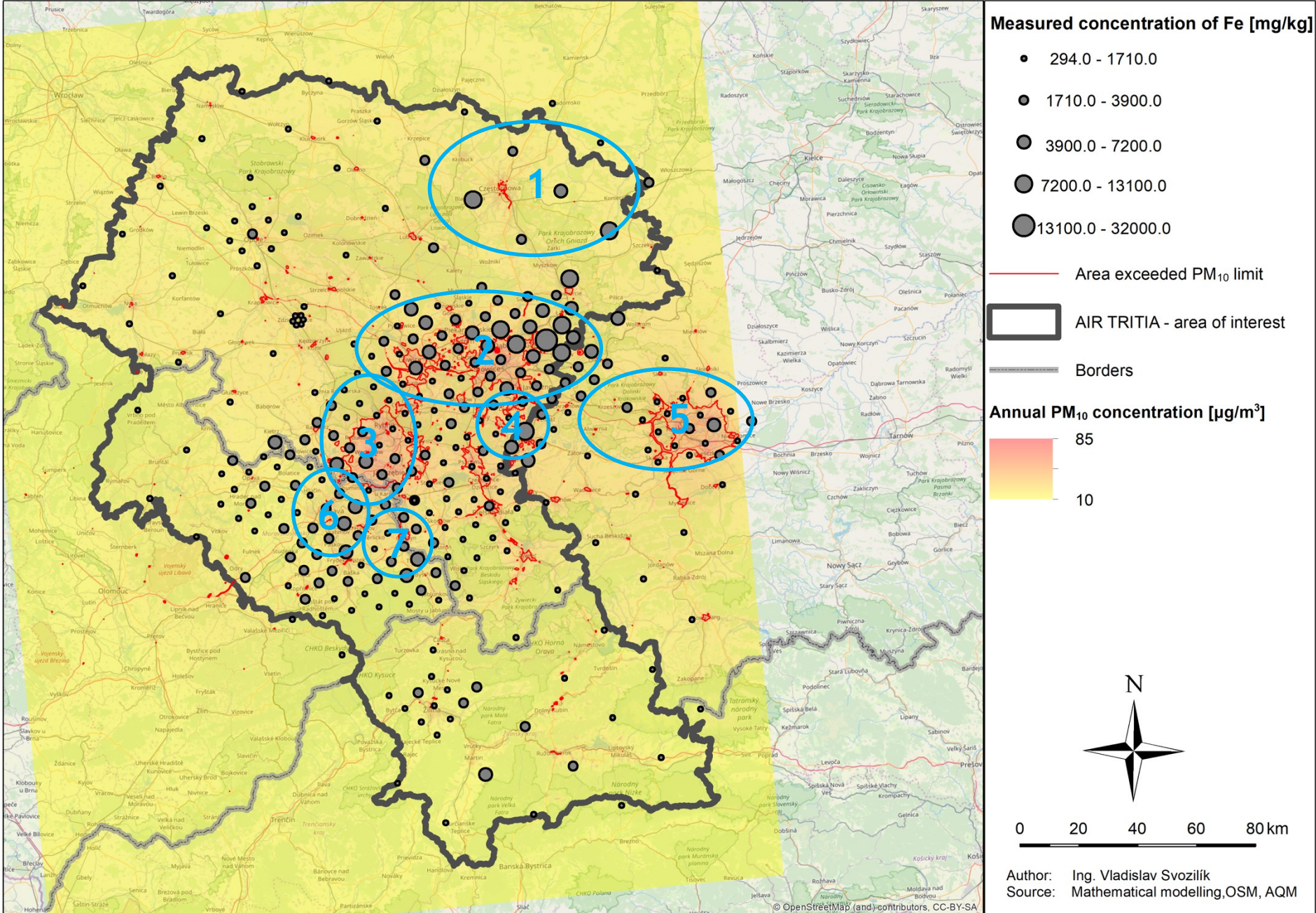
Year 2015, model SYMOS'97, Biomonitoring 2015, 2016, 2017





# CONCENTRATION DETERMINED IN MOSS BY INAA

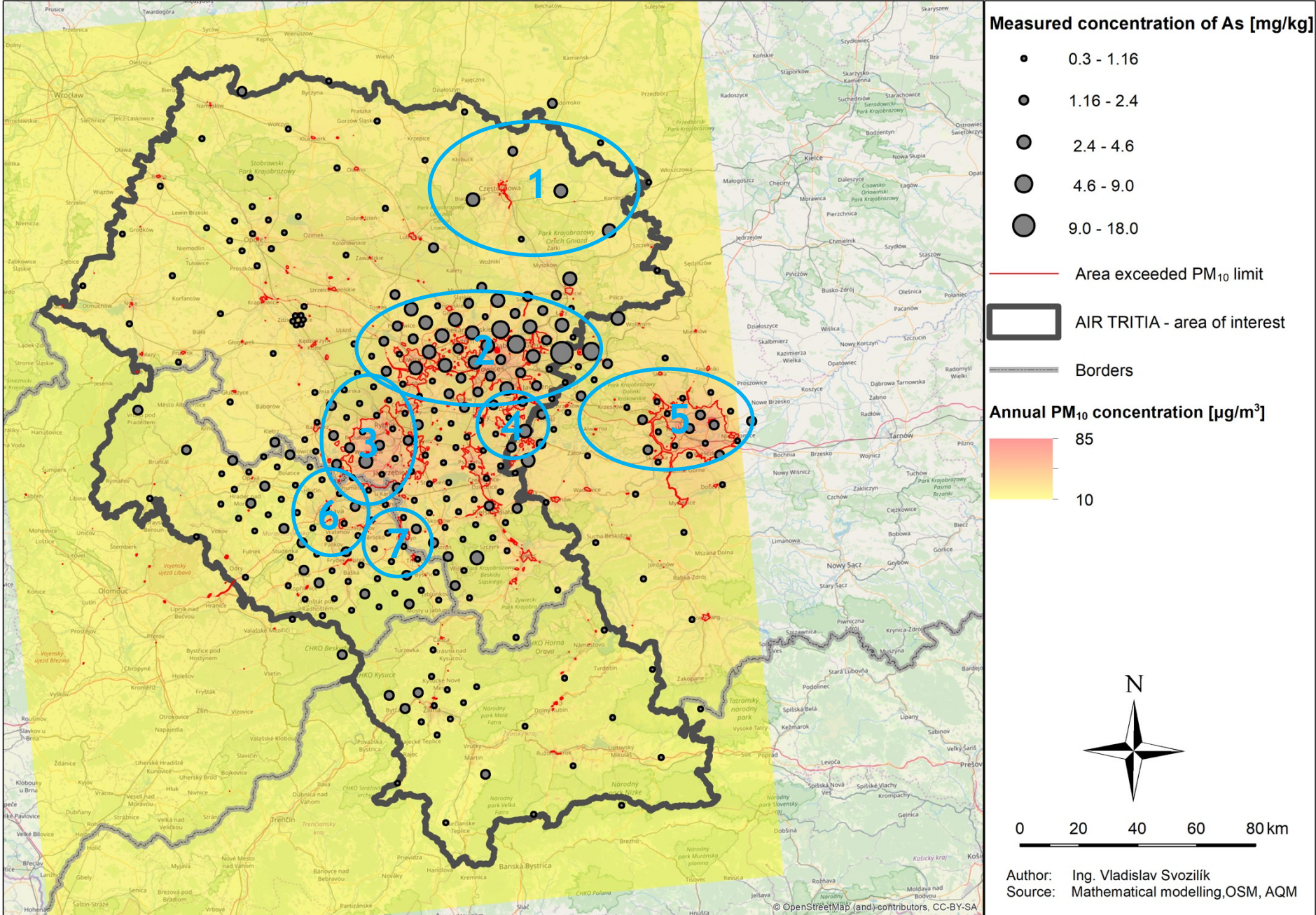
Year 2015, model SYMOS'97, Biomonitoring 2015, 2016, 2017





# CONCENTRATION DETERMINED IN MOSS BY INAA

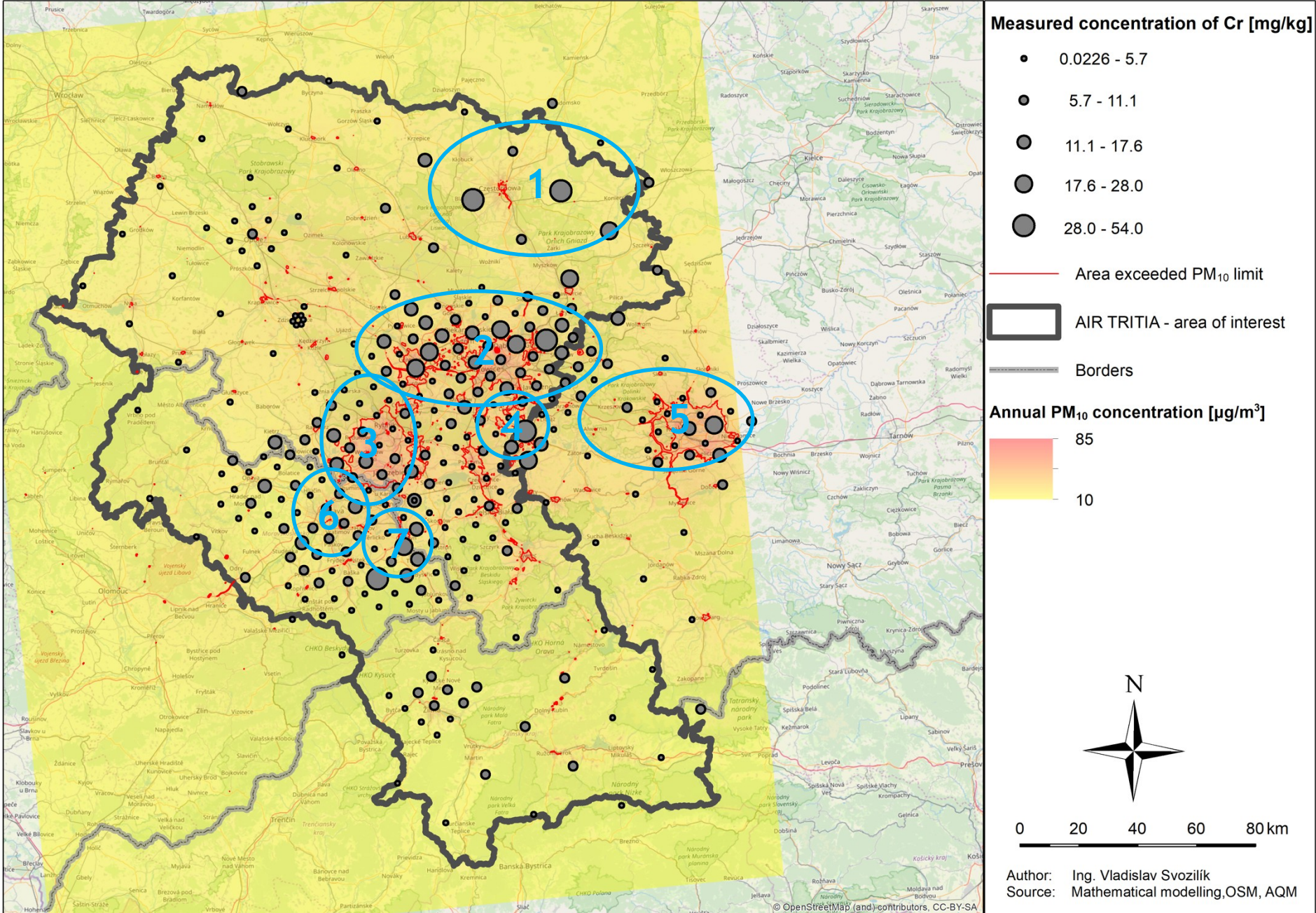
Year 2015, model SYMOS'97, Biomonitoring 2015, 2016, 2017





# CONCENTRATION DETERMINED IN MOSS BY INAA

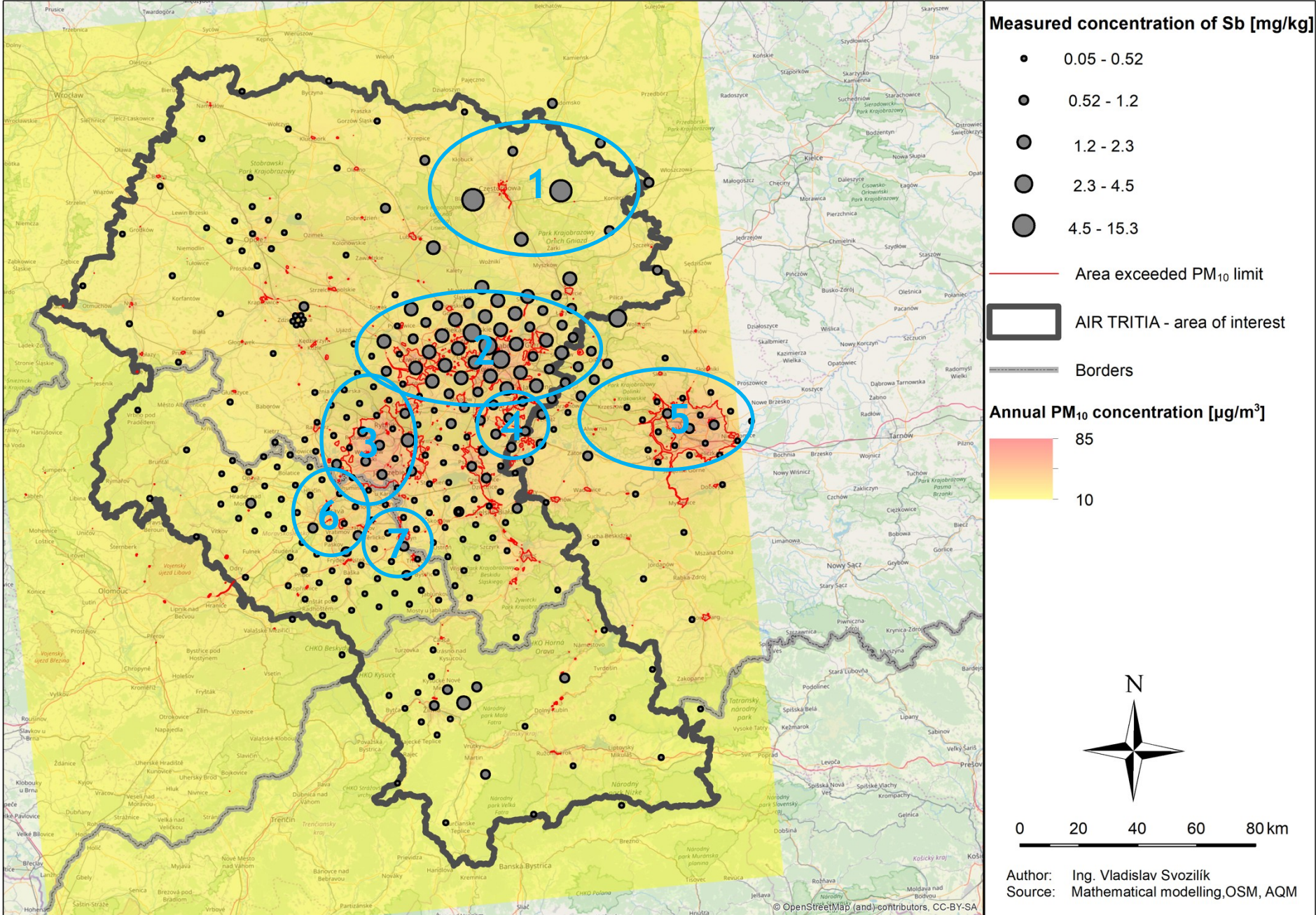
Year 2015, model SYMOS'97, Biomonitoring 2015, 2016, 2017





# CONCENTRATION DETERMINED IN MOSS BY INAA

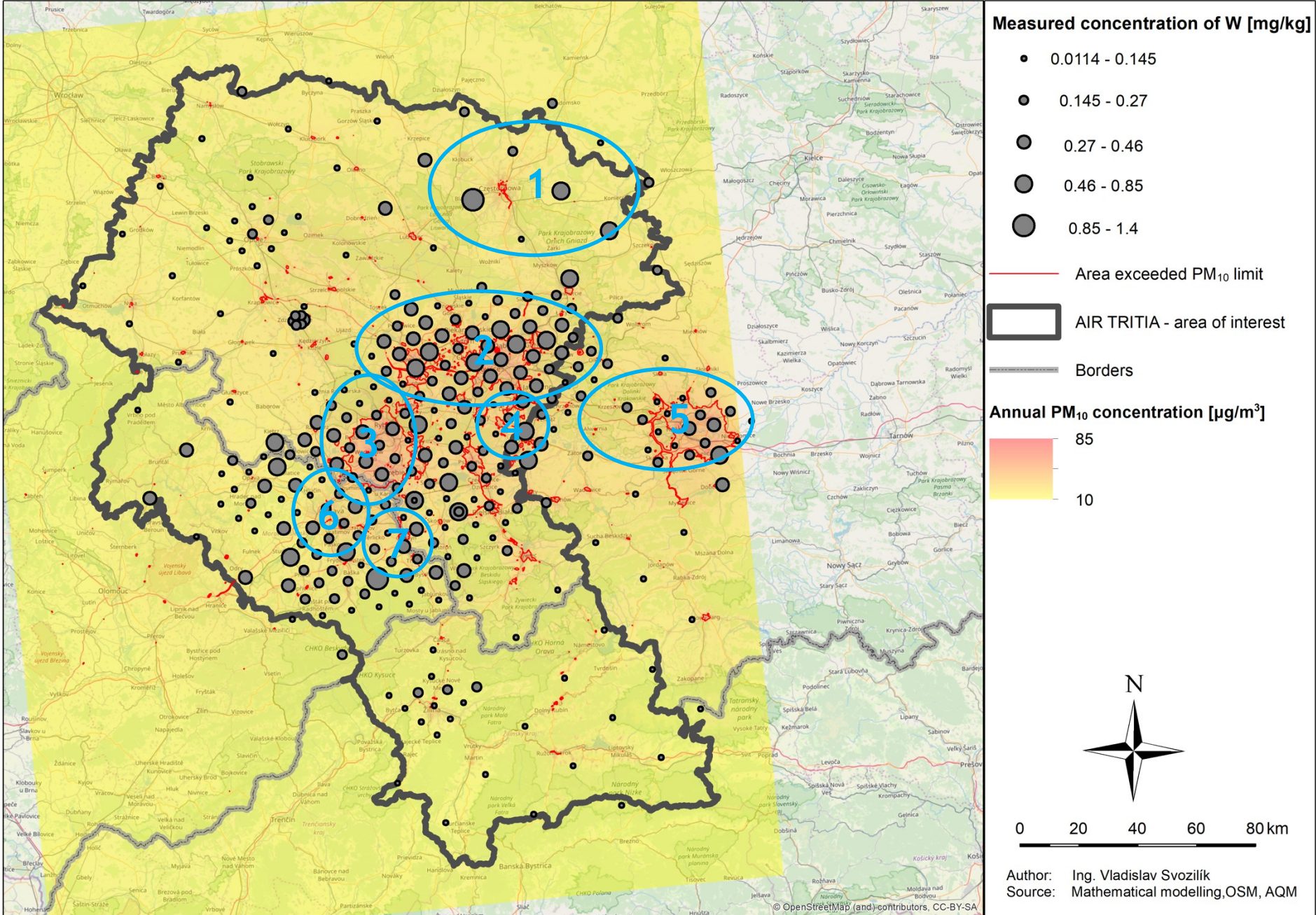
Year 2015, model SYMOS'97, Biomonitoring 2015, 2016, 2017





# CONCENTRATION DETERMINED IN MOSS BY INAA

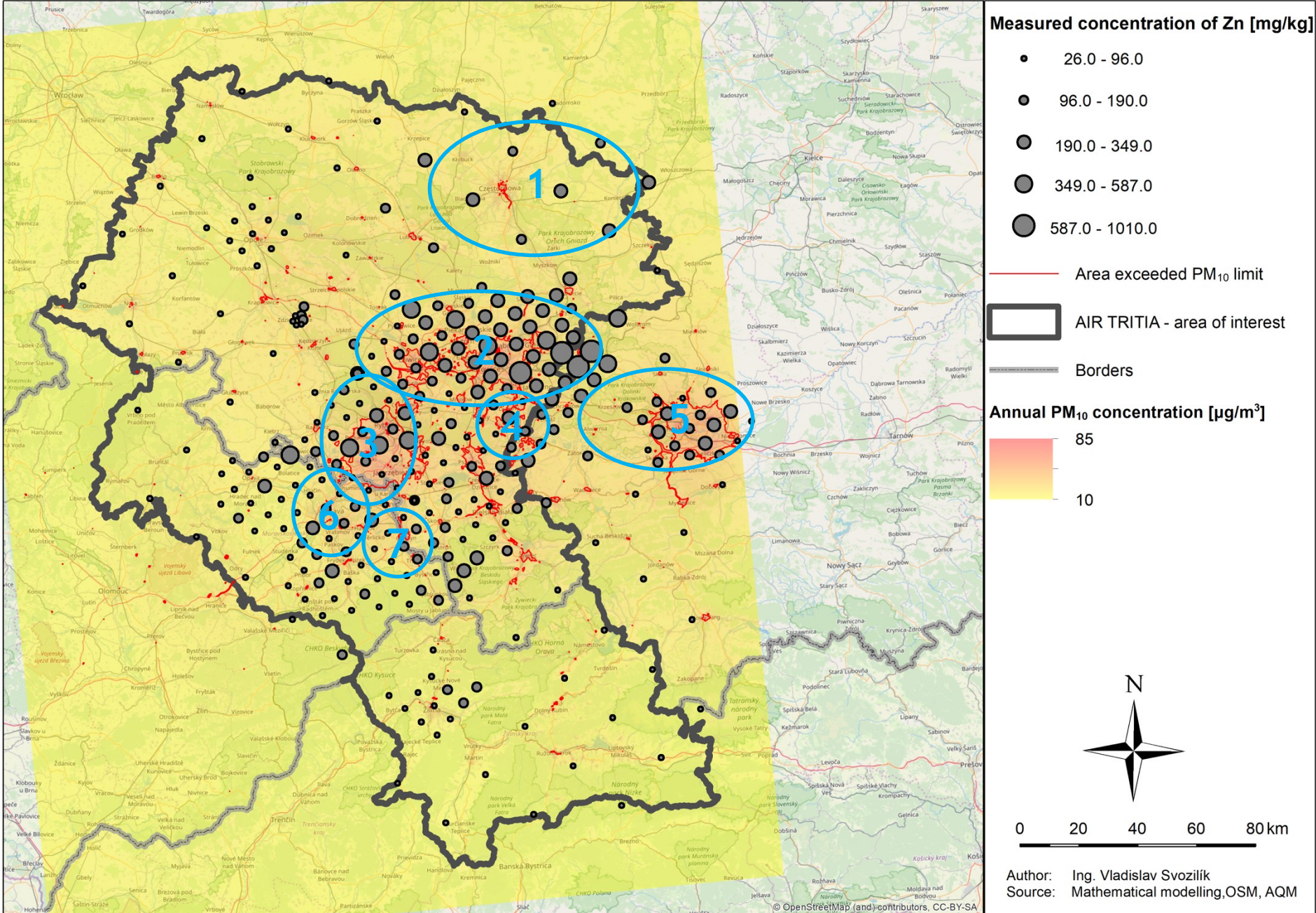
Year 2015, model SYMOS'97, Biomonitoring 2015, 2016, 2017





# CONCENTRATION DETERMINED IN MOSS BY INAA

Year 2015, model SYMOS'97, Biomonitoring 2015, 2016, 2017



# CONCLUSIONS

The model results distribution seems to be OK except area 1 (missing data?)

The air pollutions in Tritia is mixture of two basic sources influents: coal and iron ore

Southern part is also under influence of another group of sources (brown coal?)

Visible differences between sampling years. One campaign is necessary.

The biomonitoring with INAA is usable for regional air pollution characterisation in heavy industrial region.

Next step - whole Czech republic for ICP Vegetation UN project and AIR TRITIA+. Maybe.

The transport influence is almost invisible in both, modelling and monitoring





TAKING  
**COOPERATION**  
FORWARD

 27-th International Seminar on Interaction of Neutrons with Nuclei, JINR, Dubna, RF

 **Thank You for attention.**

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