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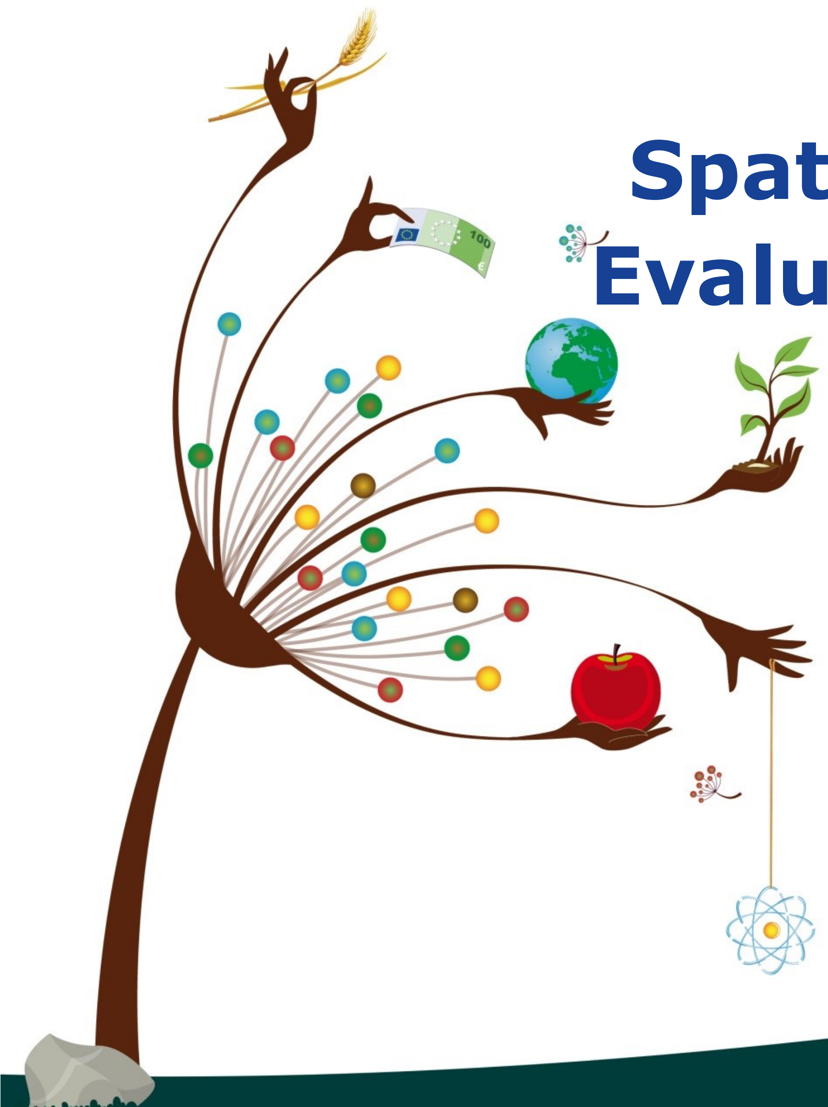

Spatial Representativeness Evaluation by Point-Centred Variography

and links to the FAIRMODE / AQUILA SR Intercomparison Exercise

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18th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes

HARMO

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Spatial Representativeness (SR)

Most basic definition:

- The **representativeness area** is described by the set of all locations where the concentration of a pollutant does not differ from the measurements at the central point (monitoring station) by more than a certain threshold.

A geostatistical approach:

- Classical geostatistical analysis would describe the **spatial correlation structure** of the whole concentration field in terms of the **variogram**.
- The **point-centred variogram** is based on the average of squared concentration **differences** observed in pairs formed between a **particular central point** and the set of **all other points** in the domain.

Context:

- FAIRMODE activities on spatial representativeness (SR).
- FAIRMODE / AQUILA **Intercomparison Exercise (IE)** of Spatial Representativeness Methods (SR-IE).

A geostatistical approach to SR:

Traditional versus Point-Centered Semivariance

Traditional semivariance

$$\gamma(h) = \frac{1}{2}\frac{1}{N_h}\sum_{i=1}^{N_h}\left[Z(s_i) - Z(s_i + h)\right]^2$$

Half the average of the squared deviations between **all paired observations** at distance h.

Point-centered semivariance

$$\gamma_{cp}(h) = \frac{1}{2}\frac{1}{N_{cp,h}}\sum_{i=1}^{N_{cp,h}}\left[Z(s_{cp}) - Z(s_{cp} + h)\right]^2$$

Half the average of the squared deviations within pairs formed by a **single central point (cp)** and all other observations at distance h from this cp.

Point-centered variography places a monitoring station in the **context of the local or regional air quality pattern**.

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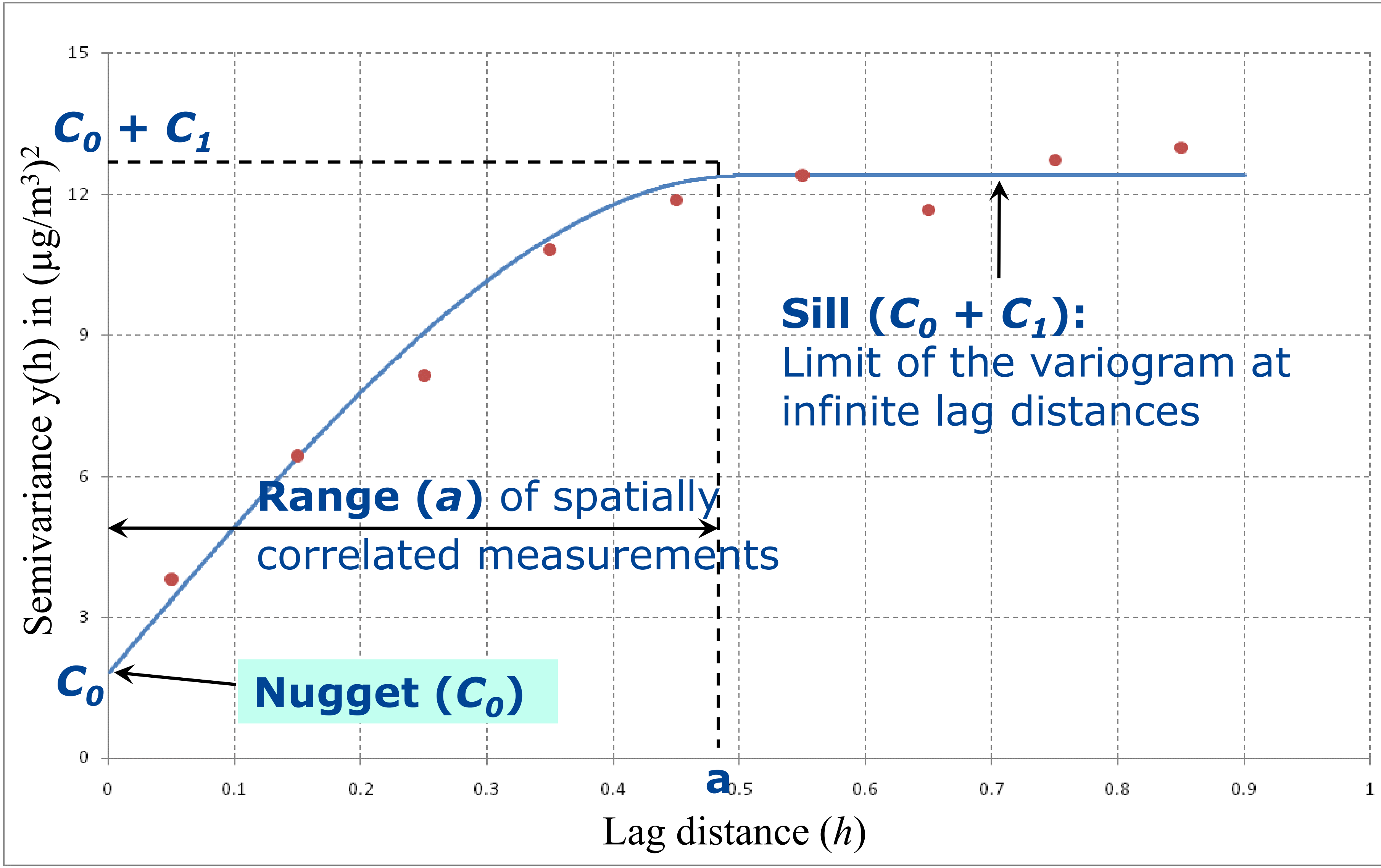
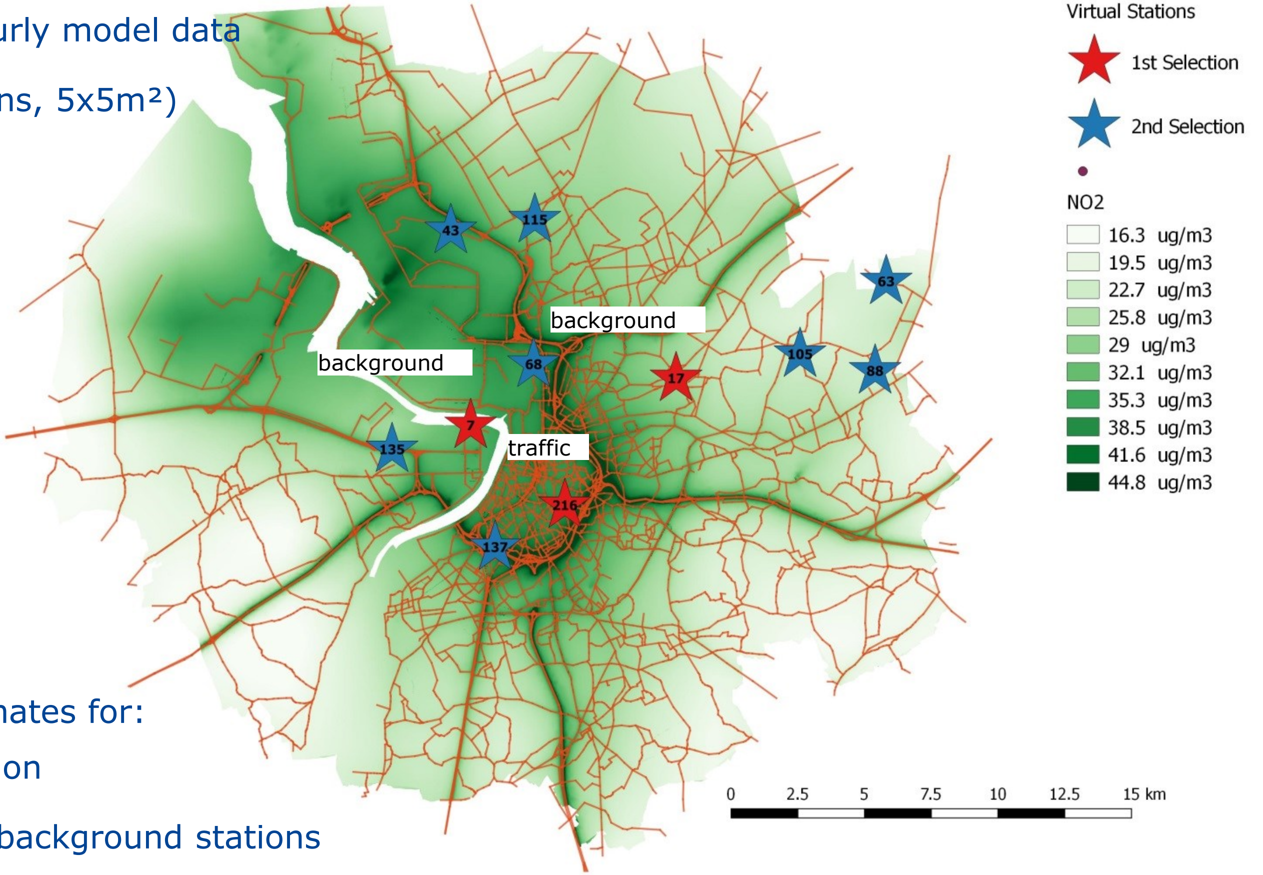
Besides that: same terminology



Context / Case study:

FAIRMODE / AQUILA Intercomparison Exercise of Spatial Representativeness Methods

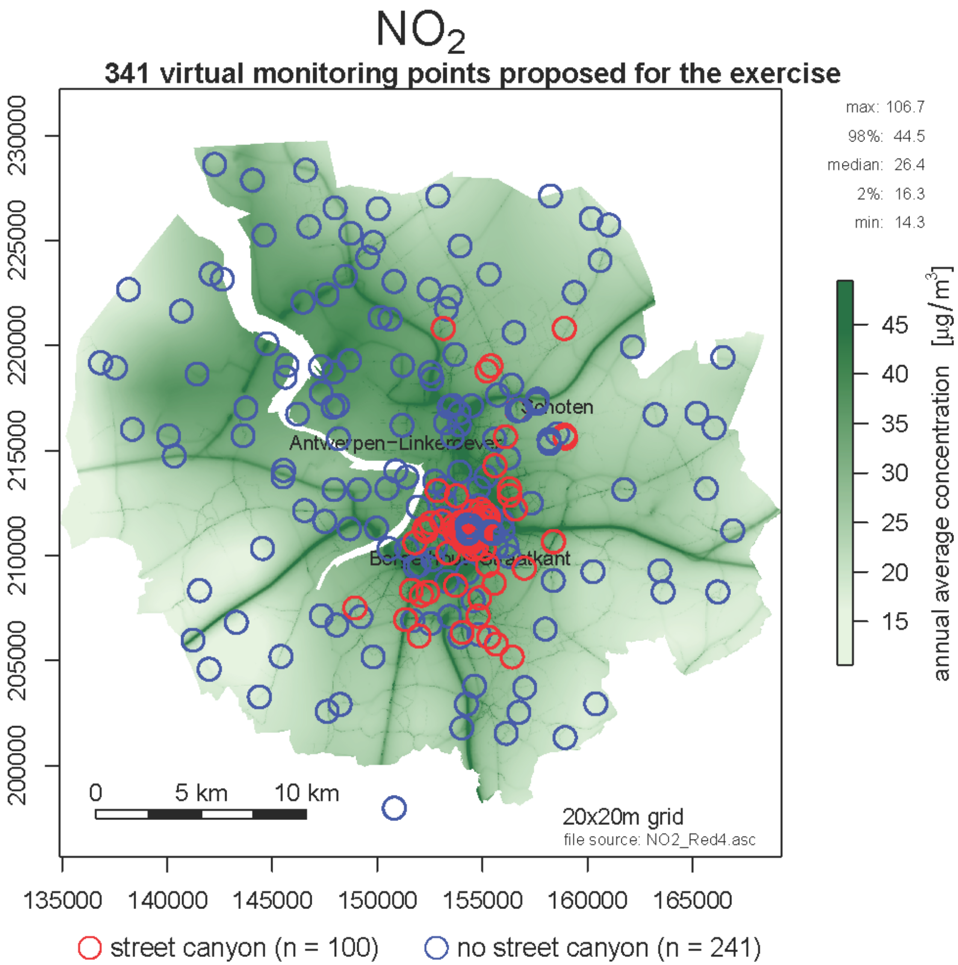
- **Performed by 11 different groups**, but on the same **shared dataset** (prepared by VITO).
- Existing stations for PM_{10} (n=15), NO_2 (n=18) and O_3 (n=3)
- Dataset based on outputs from the **RIO-IFDM-OSPM model chain** for the region of **Antwerp** (year 2012).
- **Virtual stations** (n=341) from hourly model data
- **Gridded model data** (annual means, 5x5m²)
- Emissions
- Population density
- Building heights
- CORINE land cover



- **Spatial representativeness** estimates for:
  - ➢ PM_{10} and NO_2 at one traffic station
  - ➢ PM_{10}, NO_2 and O_3 at two urban background stations

Case study data:

- **n=341 receptor points** ("virtual stations") from hourly model data
- **aggregated to 14-day averages** (i.e. to emulate diffusive samplers)
- classified into **street canyon (SC)** and **non-street canyon (non-SC)** locations

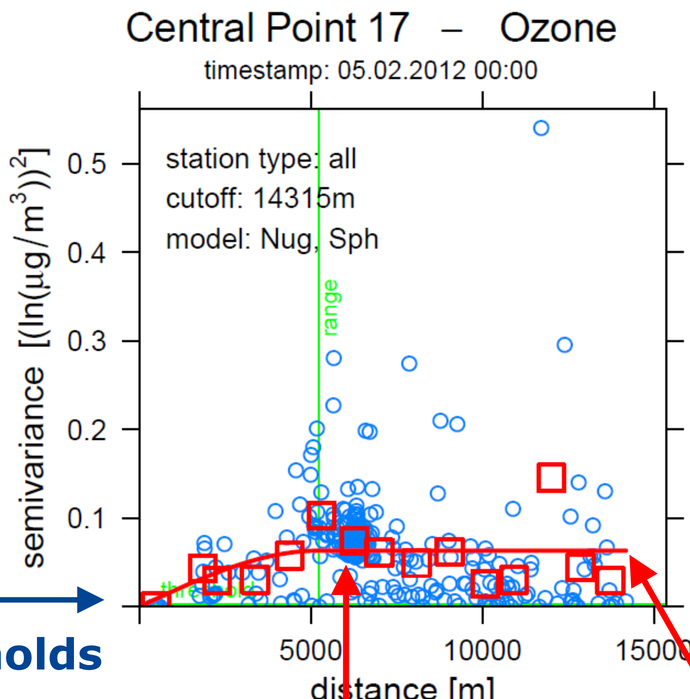


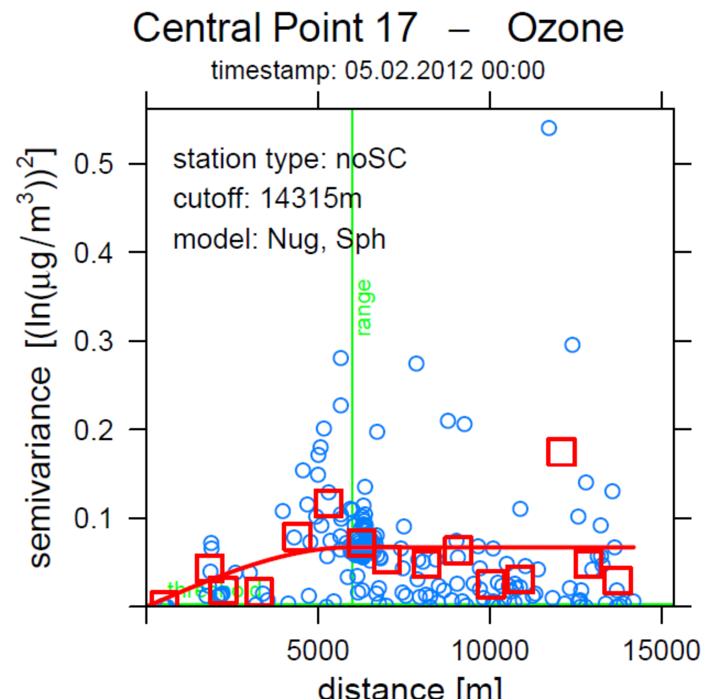
Workflow:

- Aggregate modelled time series of virtual receptors to different integration time scales (shown here: only 14-day averages).
- Log-transformation of concentration values.
- Calculate the point-centered variogram clouds.
  - all data pairs formed between the central point and the other virtual receptors
  - 15 equidistant lag classes
  - cutoff-distance of 14315 m corresponds to one third of the diagonal of the bounding box of the total Antwerp modelling domain.
- Three variations:
  - all receptors ("all")
  - street canyons only ("SC")
  - non-street canyons only ("non-SC")
- Fit point-centered variogram models to the clouds.
  - Using a spherical variogram model
  - Evaluate and filter out (remove) singular model fits (non-convergence)
- Define the semivariance at the limits of spatial representativeness.
  - Threshold values for the maximum relative deviation of concentrations permissible
  - 25% (PM_{10}), 15% (NO_2) , 15% (O_3) at the 2σ-level
  - To obtain these thresholds, used the DQO of European Directive 2008/50/EC as a proxy.
- Invert the variogram models to estimate the distance of spatial representativeness (dist.SR).

Fitting the Variogram Models (examples)

Omnidirectional variogram clouds





SR thresholds

$$\gamma(h_{SR}) = \frac{1}{2}\left(\ln\left(1+\frac{DQO}{2}\right)\right)^2$$

PM_{10}	NO_2	Ozone
25 %	15 %	15 %

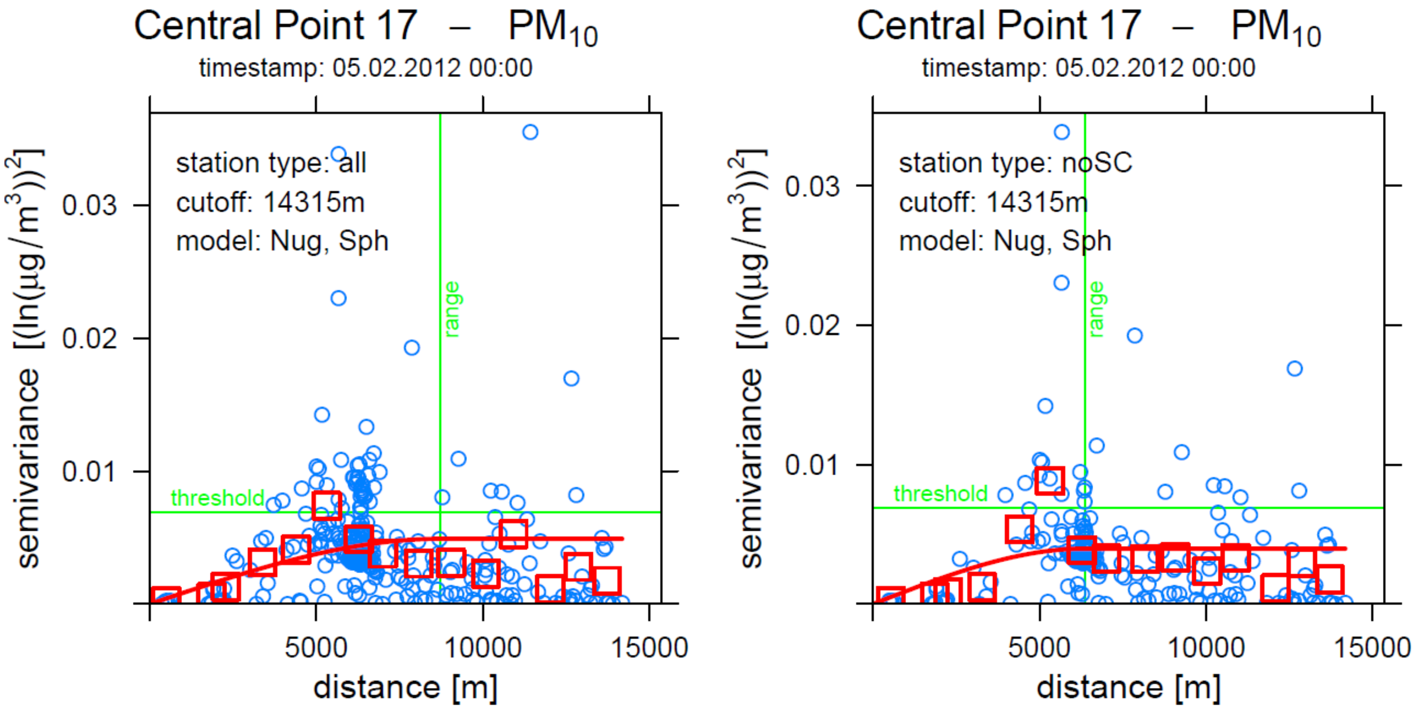
15 lag-classes

Spherical Variogram Model

$$\gamma_{cp}(h) = C_0 + C_1\left[1.5\,{}^{h}\!/_{a} - 0.5\left({}^{h}\!/_{a}\right)^3\right] \quad if \quad 0 \le h \le a$$

$$\gamma_{cp}(h) = C_0 + C_1 \qquad if \qquad h > a$$

Fitting the Variogram Models (examples)



Exception handlings:

- Required semivariance threshold might not be reached within the range of the variogram.
- In such cases we chose the distance of spatial representativeness to equal the value of the range parameter.
- Other interpretations are conceivable ("infinite SR" ?)

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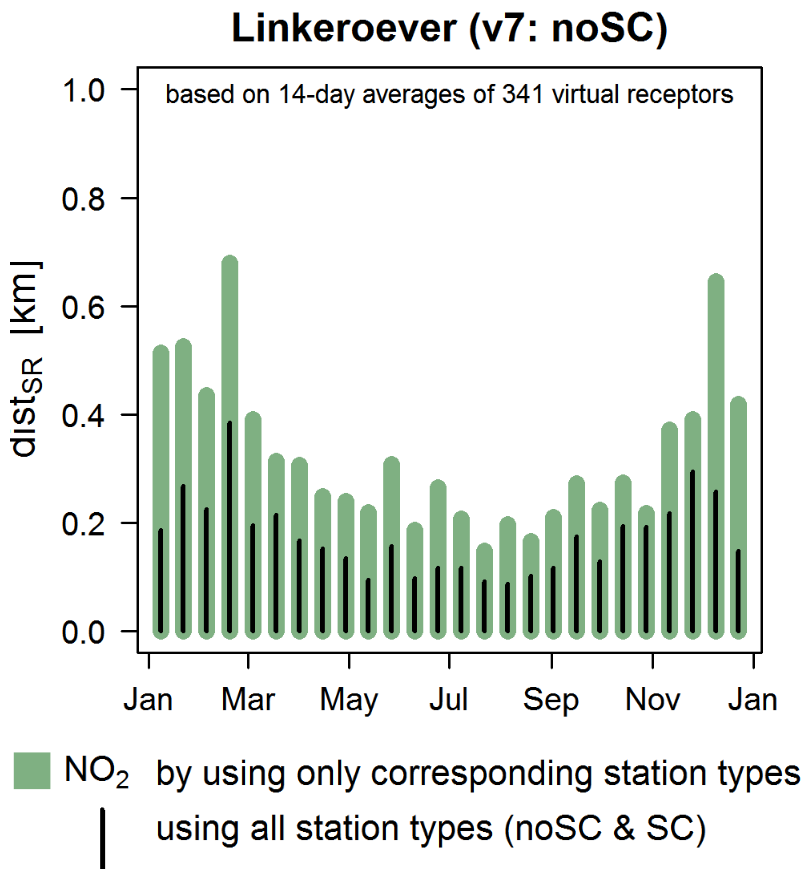
Time Series of SR-distance estimates:

$dist_{SR}$ in [km] for station Linkeroever (urban background site)



(year 2012)

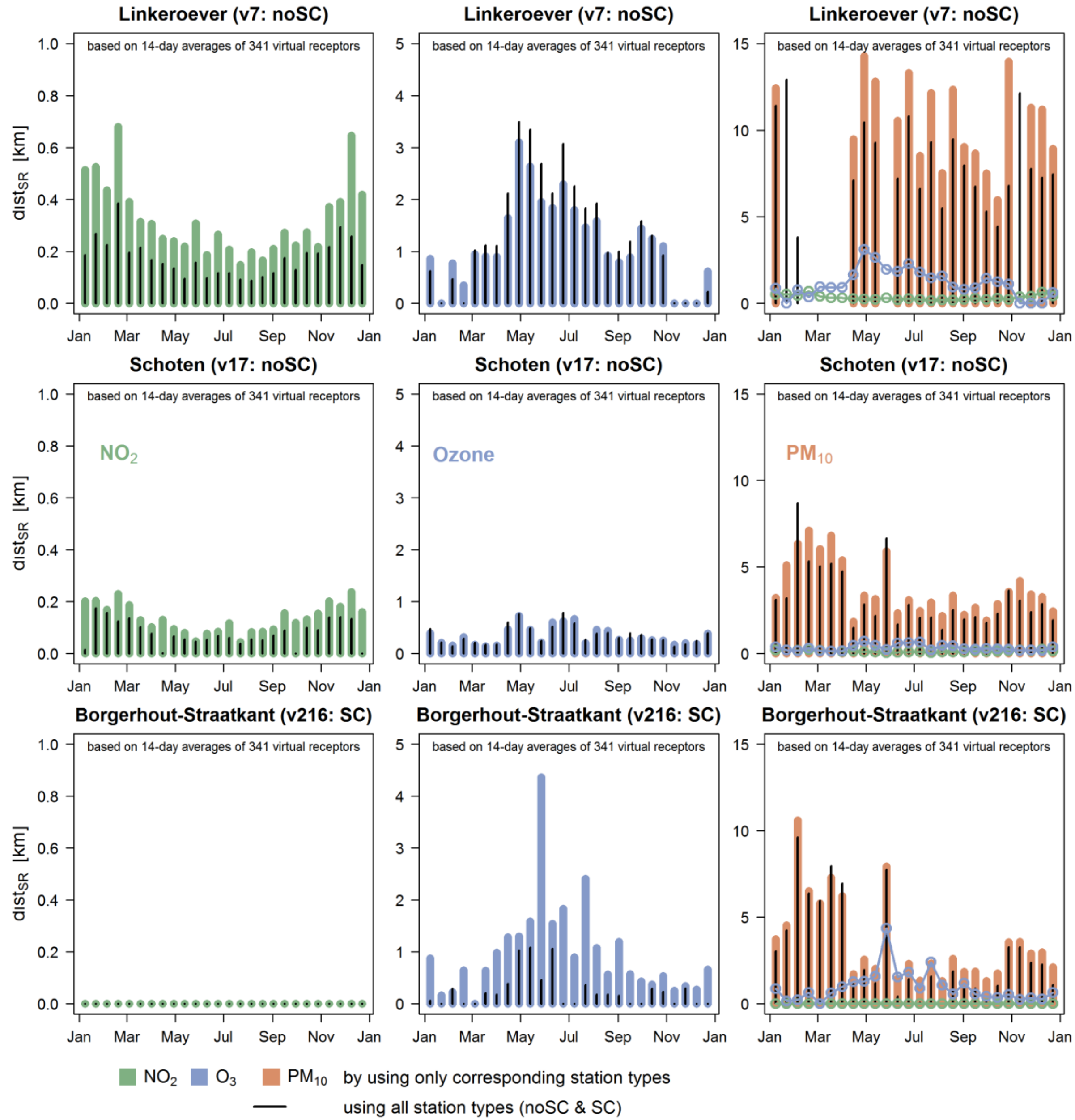
Estimated $dist_{SR}$ tends to be larger when only receptor points of corresponding station types are considered for the analysis (as expected; more homogeneous).

Time Series of SR-distance estimates:

urban background site

urban background site

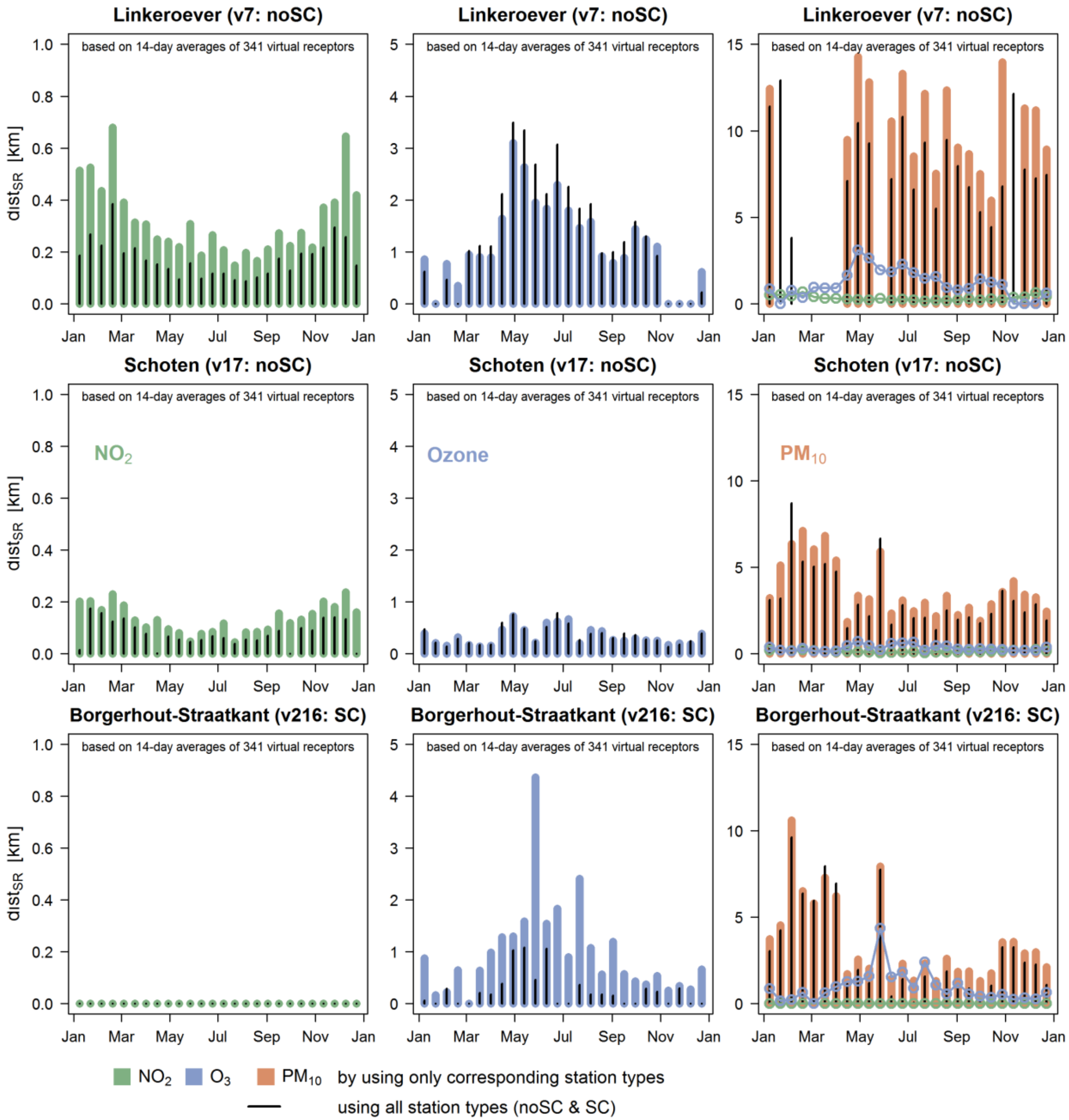
traffic site

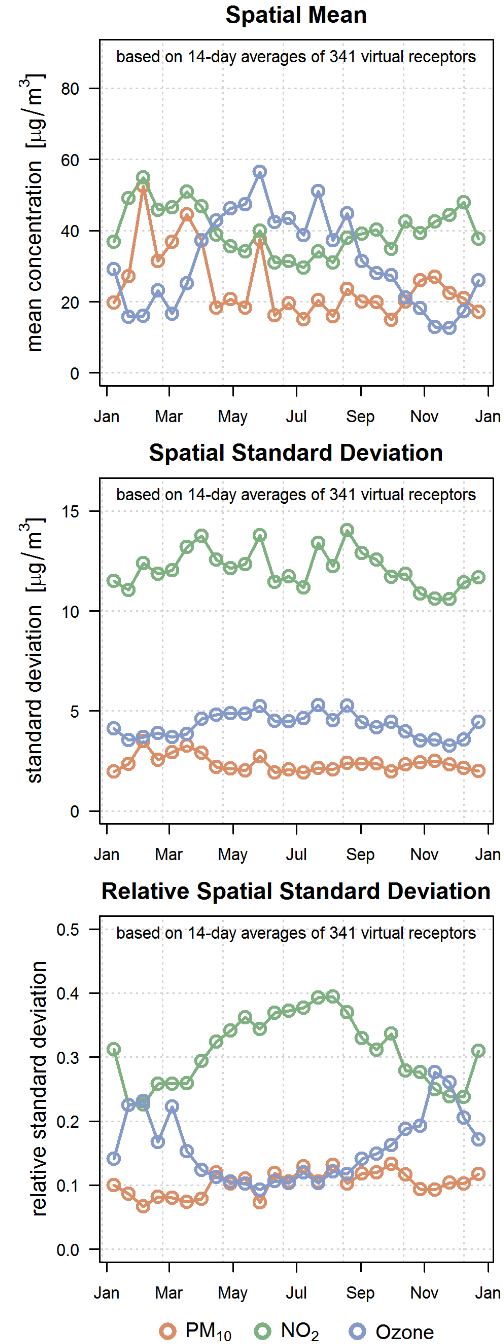


(year 2012)

Note the different scales of the Y-axis: $dist_{SR}(PM_{10})$ > $dist_{SR}(O_3)$ > $dist_{SR}(NO_2)$

Time Series of SR-distance estimates



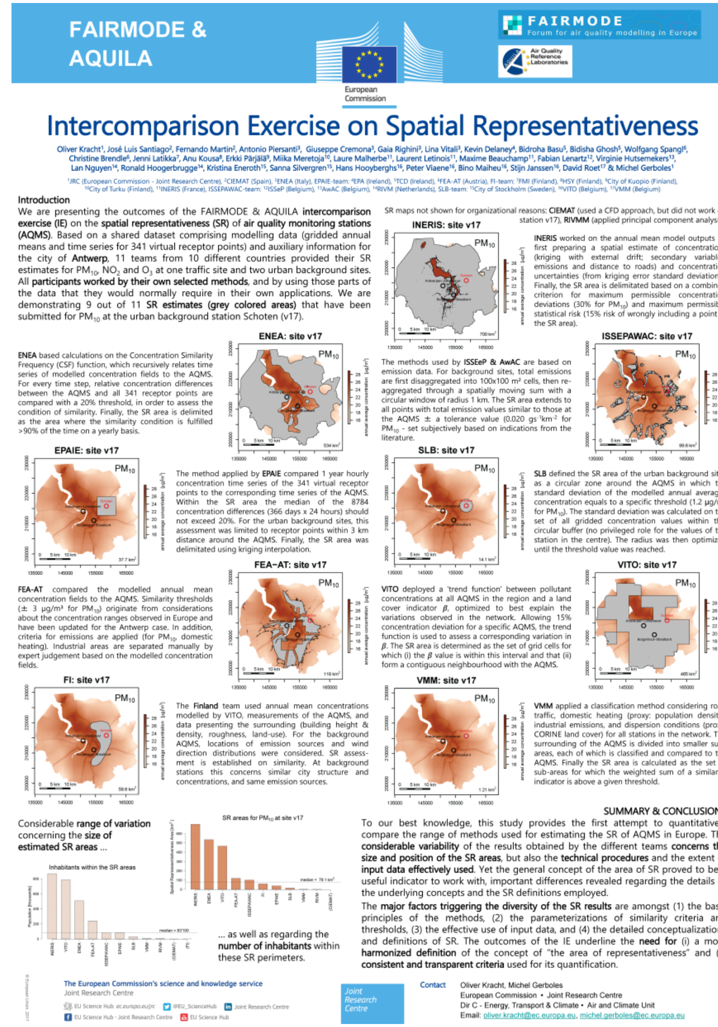


from evaluating the full dataset

Might trigger questions like: Does one need more dense NO_2 observations in summertime?

relation to the
FAIRMODE / AQUILA SR Intercomparison Exercise

How do the estimates from the **Point-Centered Variography** compare to the outcomes of the **SR Intercomparison Exercise**?

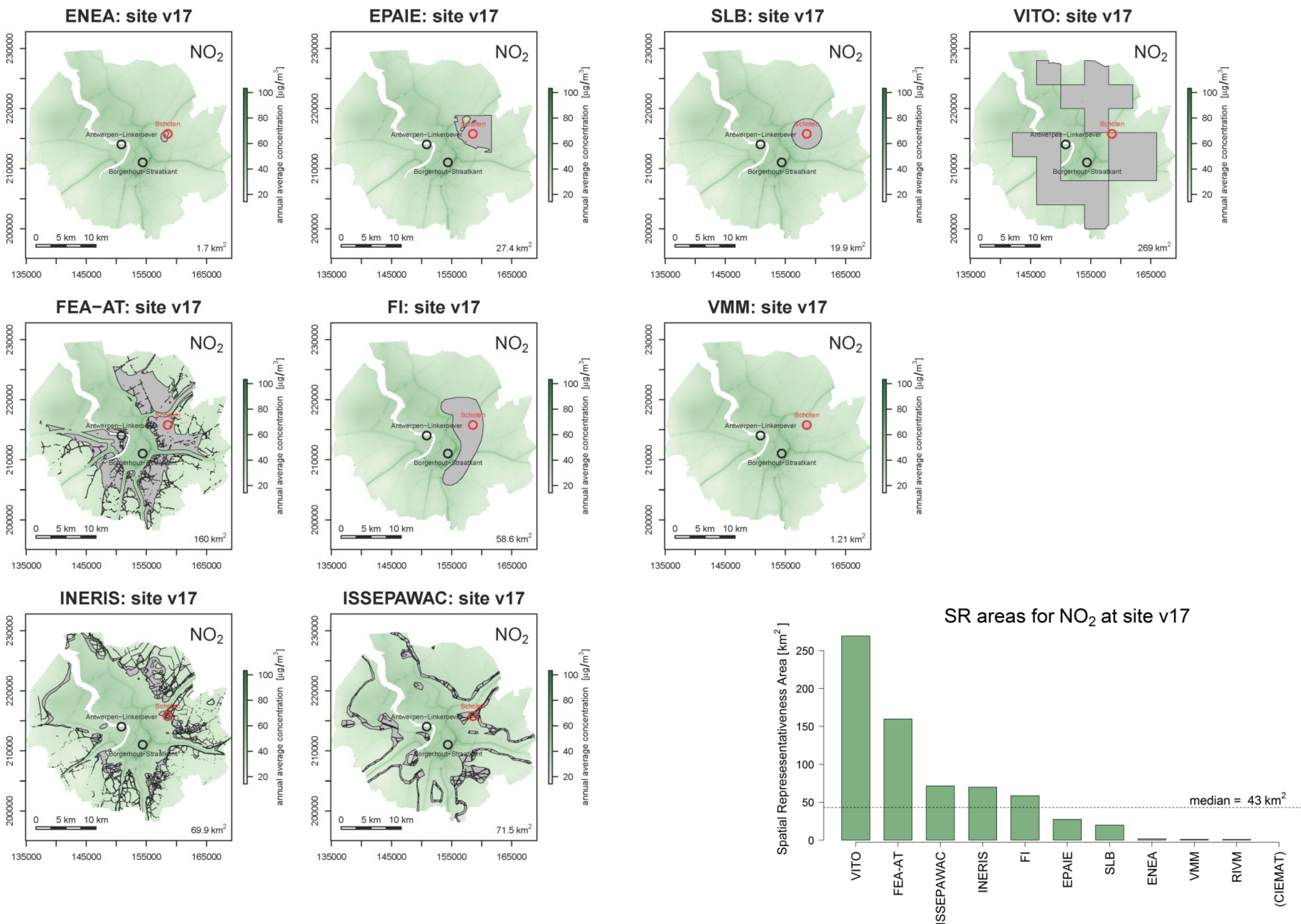


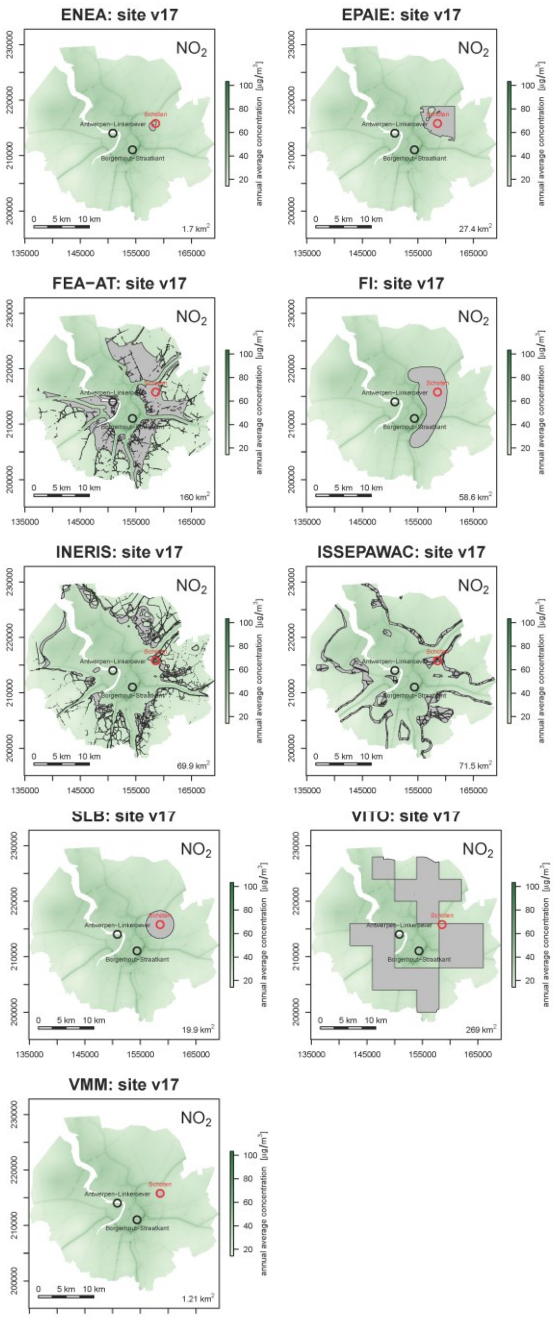
(refer to poster H18-112 for details)

with contributions from:

José Luis Santiago & Fernando Martin (CIEMAT), Antonio Piersanti, Giuseppe Cremona, Gaia Righini & Lina Vitali (ENEA), Kevin Delaney (EPA IE), Bidroha Basu & Bidisha Ghosh (TCD), Wolfgang Spangl & Christine Brendle (FEA-AT), Jenni Latikka (FMI), Anu Kousa (HSY), Erkki Pärjälä (City of Kuopio), Miika Meretoja (City of Turku), Laure Malherbe, Laurent Letinois & Maxime Beauchamp (INERIS), Fabian Lenartz(ISSeP), Virginie Hutsemekers (AwAC), Lan Nguyen & Ronald Hoogerbrugge (RIVM), Kristina Eneroth & Sanna Silvergren (City of Stockholm), Hans Hooyberghs, Peter Viaene, Bino Maiheu & Stijn Janssen (VITO), David Roet (VMM)

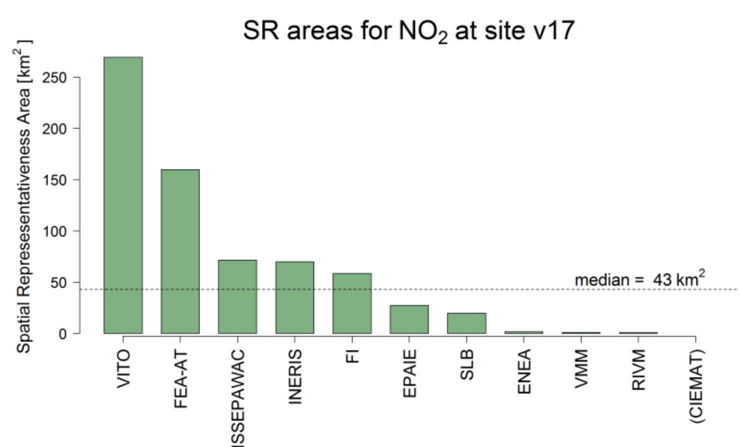
Size and Location of estimated SR areas (NO_2 at site v17)

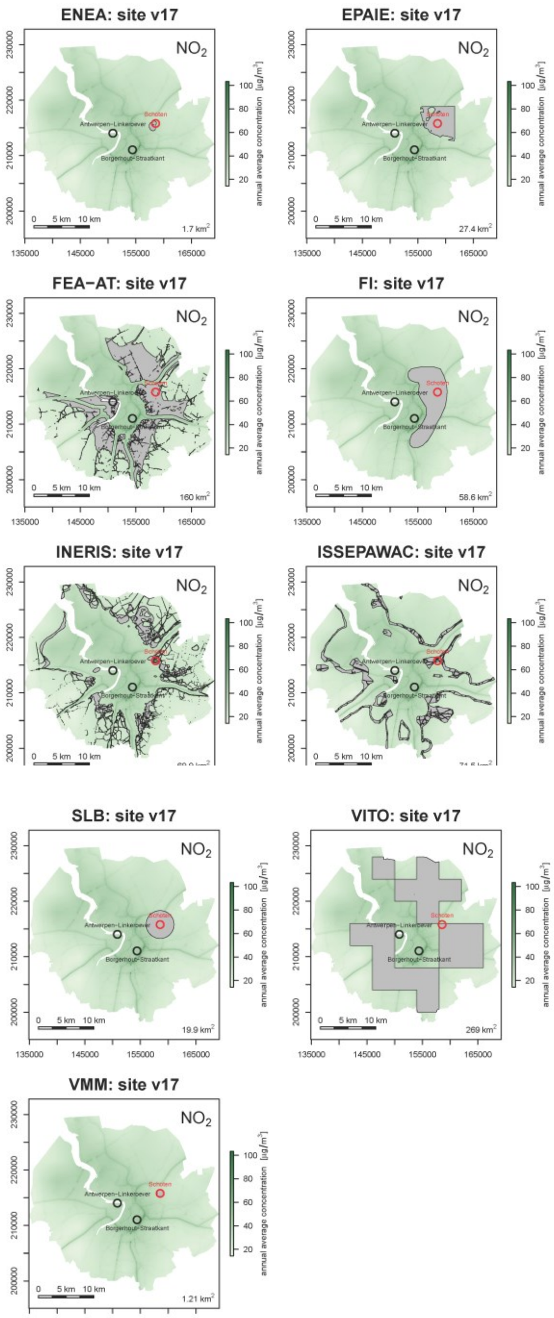


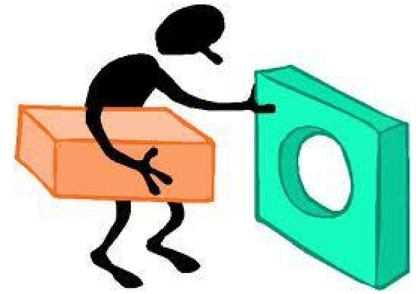


Interim Conclusion from the IE have been:

- The Spatial Representativeness Areas estimated by the different participants are **quite diverse**.
- The results in particular reveal an enormous **scattering of the extent and position** of the estimated polygons.
- This diversity of results deserved a closer look behind the scenes.

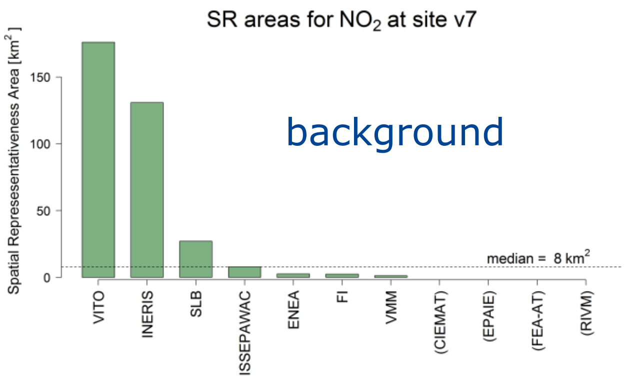


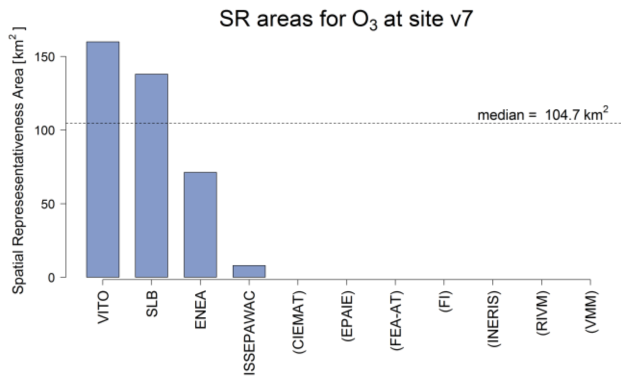


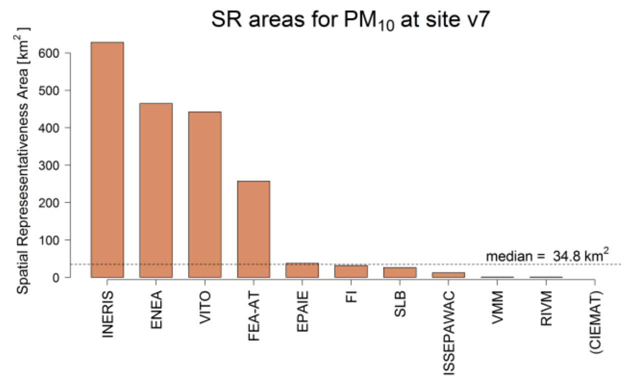


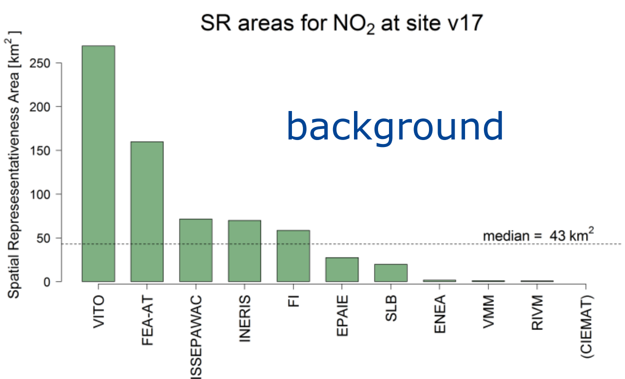
How to compare the PCV results with the IE ?

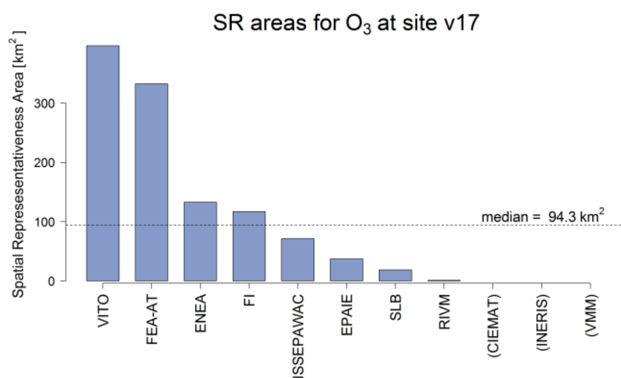
- Subject to site specific conditions and to different SR approaches, SR areas can have **quite complex**, **irregular** and even **discontinuous** shapes.
- In contrast, the point-centered variogram method (as presented here) **delivers on single value** (distance of spatial representativeness: $dist_{SR}$).
- From a conceptual point of view, the latter corresponds to the conception of a **simple circular shaped** area of representativeness.
- We need to accept, that this is likely **oversimplified**.
- In order to compare the results, we **recalculate** the PCV $dist_{SR}$ to the **surface area equivalent of a corresponding circle**.

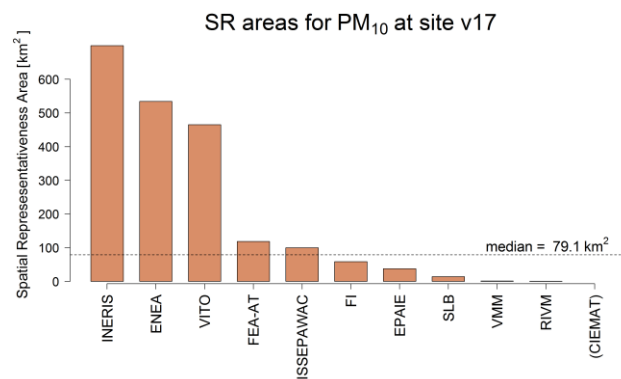


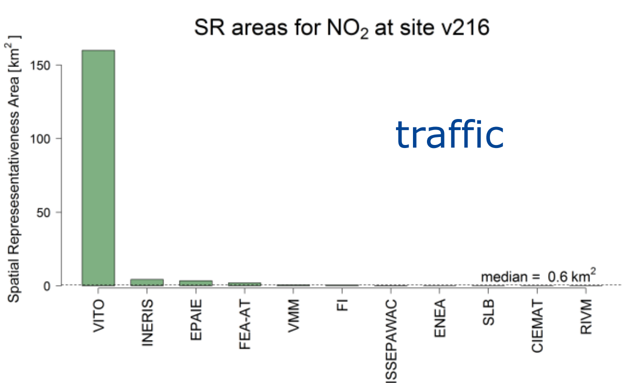








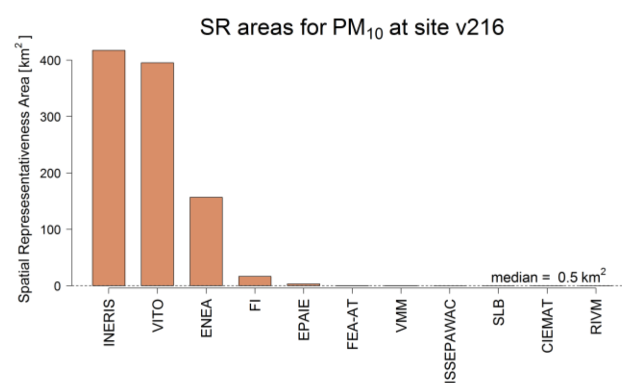


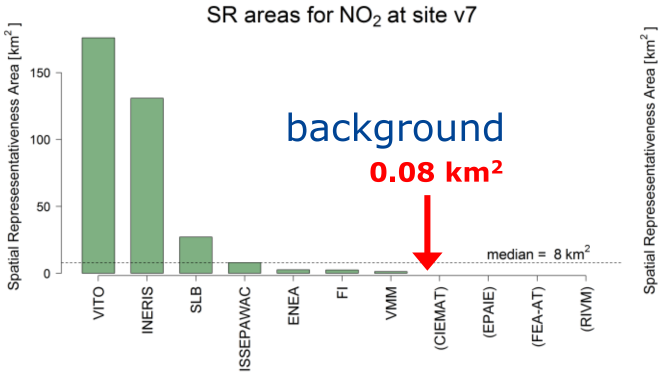


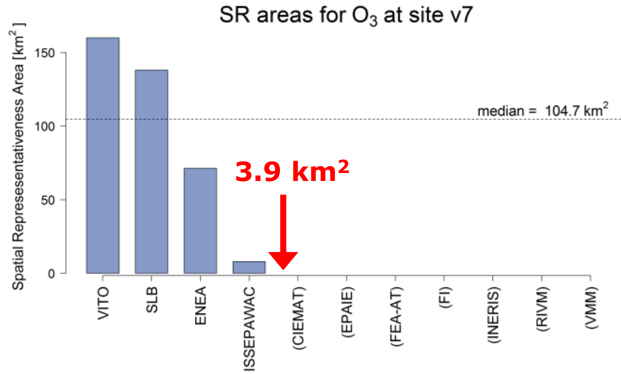
Overview:

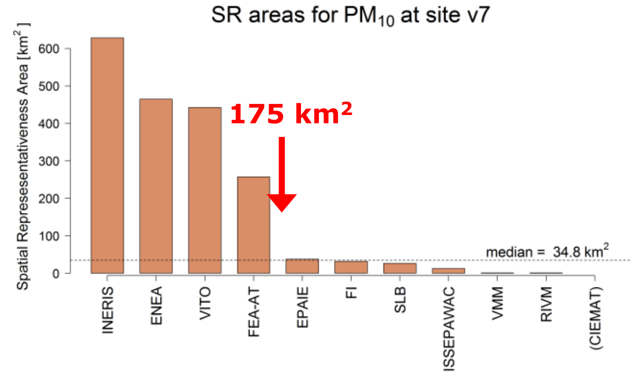
results from the

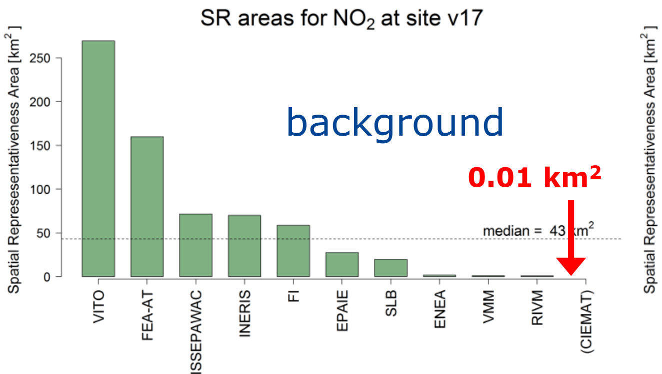
Intercomparison

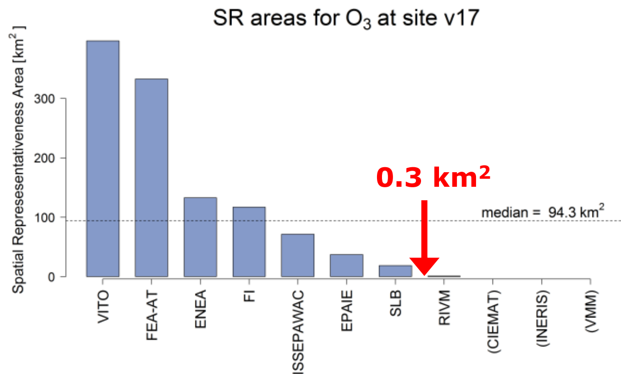


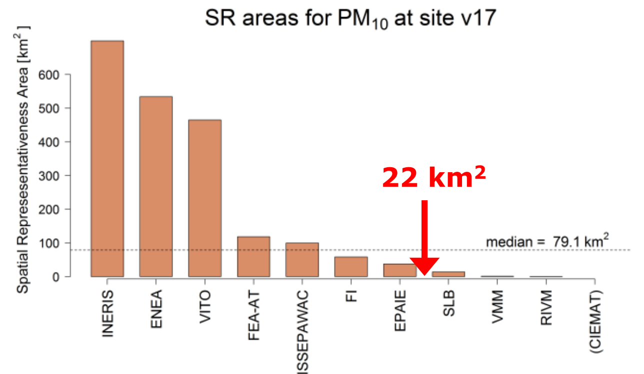


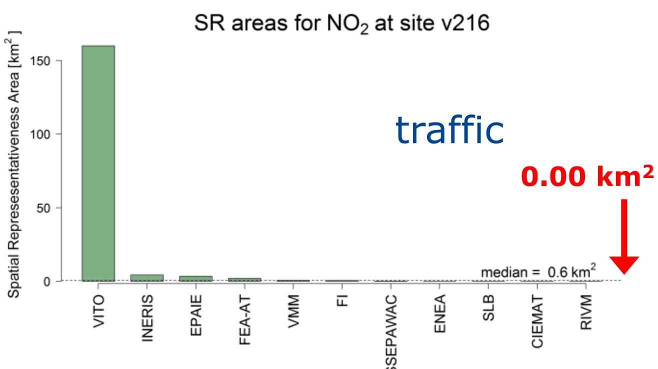






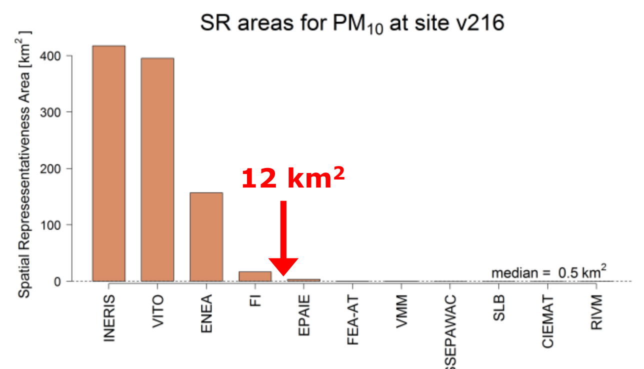






Results from PCV

- PCV results tend to be on the **lower end** of the conceivable SR scale
- PCV delivers **rather strict** SR estimates



Conclusions (1)

Depending on the spatial scale of the investigation, the **Point-centered Variogram** places a monitoring station in the **context of the local or regional air quality pattern**.

The Point-centred Variogram **does not**, however, serve as a **substitute** for **the traditional variogram** in the sense that geostatistical methods like kriging require a model fitted for the traditional variogram.

Point-centred Variography can on he other hand provide **valuable information** with regard to the **spatial representativeness** of air quality monitoring sites.

We may also obtain information about the **temporal variation of SR**.

However, a **comparison with** results obtained by **other spatial representativeness approaches** or based on different conceptualizations is **not necessarily simply one-to-one**.

Conclusions (2)

Way forward:

The concept of a **single spatial representativeness distance** (dist.SR) value implies the assumption of a **radially symmetric area** of spatial representativeness. This corresponds to the use of an **omni-directional variogram**.

The omni-directional approach is **probably overly simplified** and more detailed information (i.e. about the **anisotrophy** of the variogram) could be extracted from the data.

In **future developments** it would be **recommendable** to extend the evaluation by applying **directional variograms**. Disadvantage could be the **limited number of data-pairs** available in the individual directional sectors.

Thank you for your attention!

Conclusions from the SR Workshop in Athens (June 2017)

Participants agreed that the discrepancies observed in this exercise **require further efforts** towards the **quantitative definition** of **the concept of "the area of representativeness"** and in **eliminating unnecessary differences** in the methodologies.

In the second part of the workshop it was therefore more intensively discussed, if for the aim of **harmonization** the concept of spatial representativeness would require a **paradigm shift in** its definition:

1) What are the future needs for **harmonization** and for establishing a **common frame of reference?**
2) Is there a future need for **standardization**, too?
3) Beyond standardization, should the regulators / political bodies make the use of standards **mandatory?**
4) Would it conversely be preferable to have at disposal a **set** of **transparent definitions** and **practical guidelines**, but maintaining the freedom of choosing the most appropriate procedures for the **different** particular **purposes** and **applications**?

It was found consensus amongst participants that currently it **would not (yet) be reasonable to start discussing about (2) or (3)**, but that for the **mid term** future the **efforts** of the experts community should be directed **towards (4)** first.