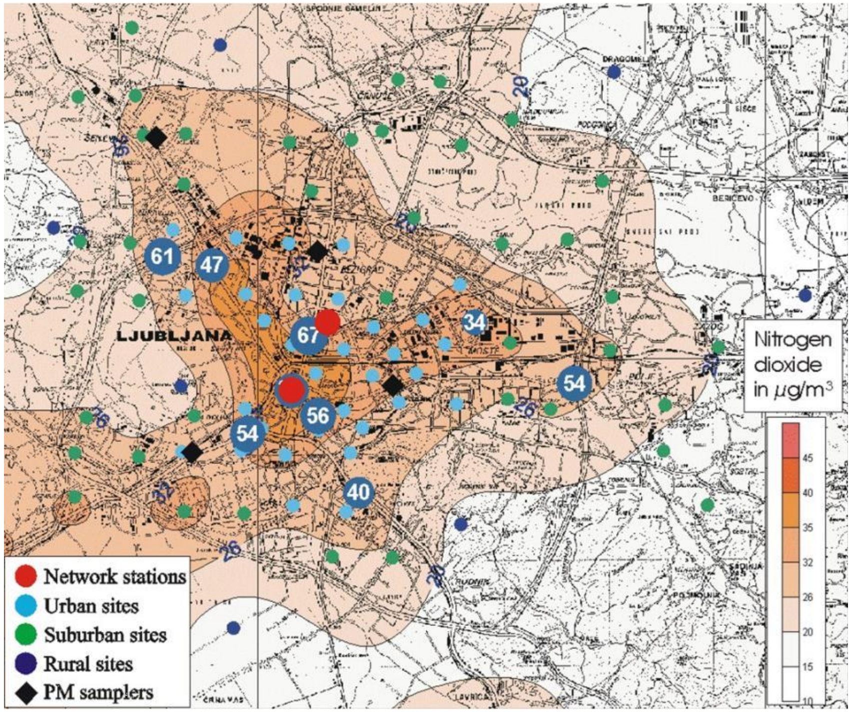
Cross-Cutting Activity on Spatial Representativeness



NO_2 annual average concentration levels in Ljubljana, from *Gerboles et al. (2007)*

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FAIRMODE Technical Meeting

28th and 29th April 2014
Kjeller - Norway

Outline

1) Different topics and variety of objectives covered under the term spatial representativeness
2) WG 1 key questions for participants' contributions to the technical meeting
3) Own research activities in this context (JRC)
    - potential links to spatial representativeness topics in WG 1
    - caveats about porting our approaches to this different field
4) Perspectives for introducing spatial representativeness into benchmarking applications (DELTA tool)

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Spatial Representativeness in the Literature

"Representativeness is the extent to which a set of measurements taken in a space-time domain reflects the actual conditions in the same or different spacetime domain taken on a scale appropriate for a specific application."

(Nappo et al. 1982)

"[the area of representativeness] … is the area in which the concentration does not differ from the concentration measured at the station by more than a specified amount."

(Larssen et al. 1999)

"A monitoring station is representative of a location if the characteristic of the differences between concentrations over a specified time period at the station and at the location is less than a certain threshold value."

(Spangl et al. 2007)

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Possible definitions of Spatial Representativeness

The variety of definitions does also reflect the variety of objectives covered under the term of spatial representativeness:

Different definitions can be required to suit different purposes:

- Model calibration and model validation
- Detection of spatio-temporal outliers
- Design of monitoring networks
- Exposure assessment
- Area of representativeness vs. simplified mathematical definitions
- Statistical evaluations
- Regulatory purposes and legislation
- …

Key Questions to structure participants contribution

CCA Spatial Representativeness:

Q1: What kind of methodology do you use to assess the spatial representativeness of your monitoring stations?

Q2: How do you take into account this information in your model evaluation?

Q3: How do you define outliers in your monitoring network / measurement data set?

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Own research activities:

1) Automatic screening tools for the recognition of anomalies in AQ monitoring data based on attribute values and spatio-temporal relationships *("Automatic Outlier Detection")*

2) Uncertainty of Measurement evaluated by geostatistical tools (using estimated nugget variances)

3) How can this support the consideration of spatial representativeness / spatial uncertainty in MQO and MPC ? (link to the DELTA tool?)

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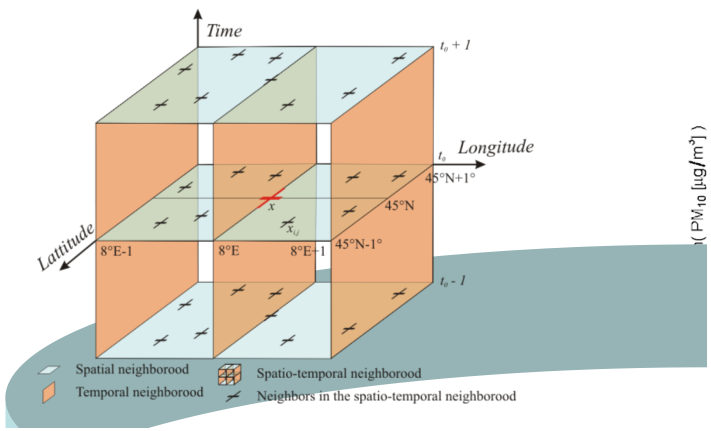
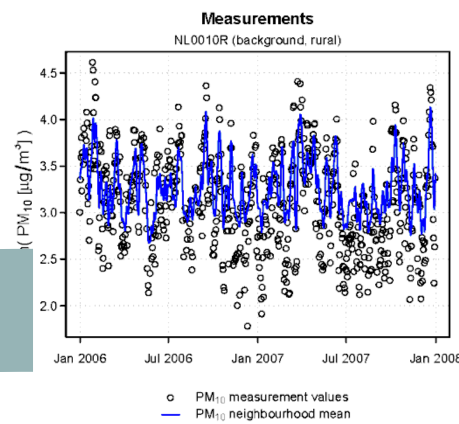
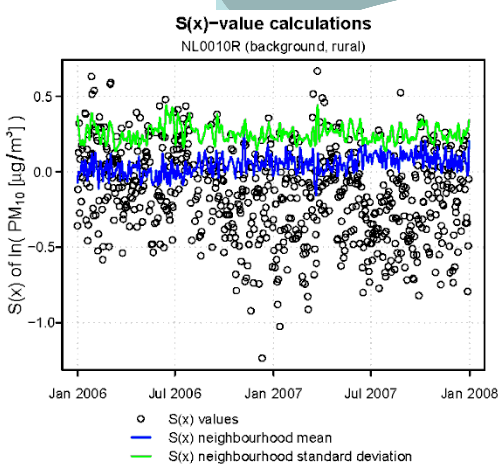
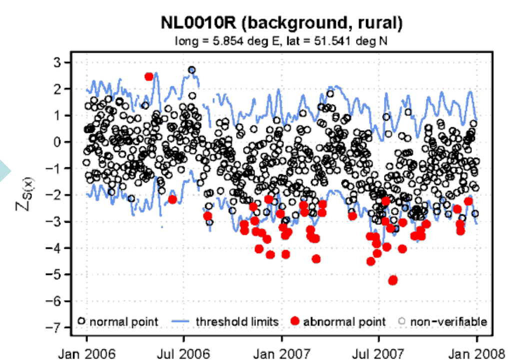
1st method: Automatic screening tools for the recognition of anomalies in AQ monitoring data









number of datapoints investigated for NL0010R: 685
identified outliers: 49 (outlier content = 7.15 %)
outlier counts station ranking = 3 within 24 stations from NL
non verifiable datapoints: 0
spatial neighbourhood: between 5 to 8 stations (between 20 to 40 records)

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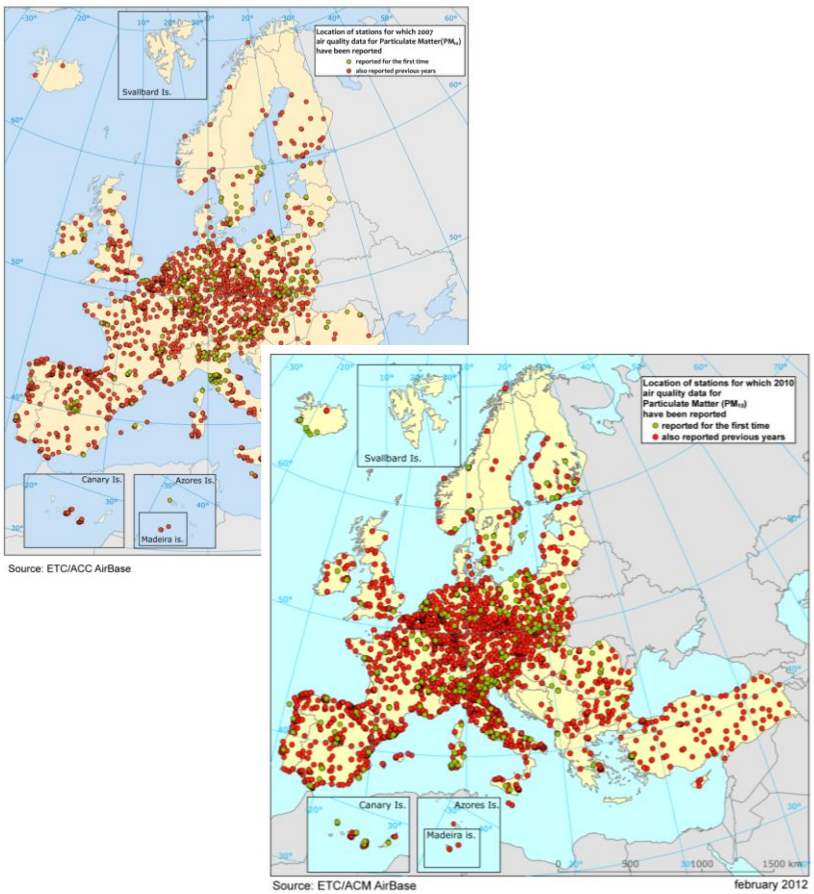
Scope of this application:



- Records with varying time-extend from AirBase versions 4 and 7
- Daily PM_{10} values
- station type "Background"
- all area types (urban, suburban and rural – to be discussed)

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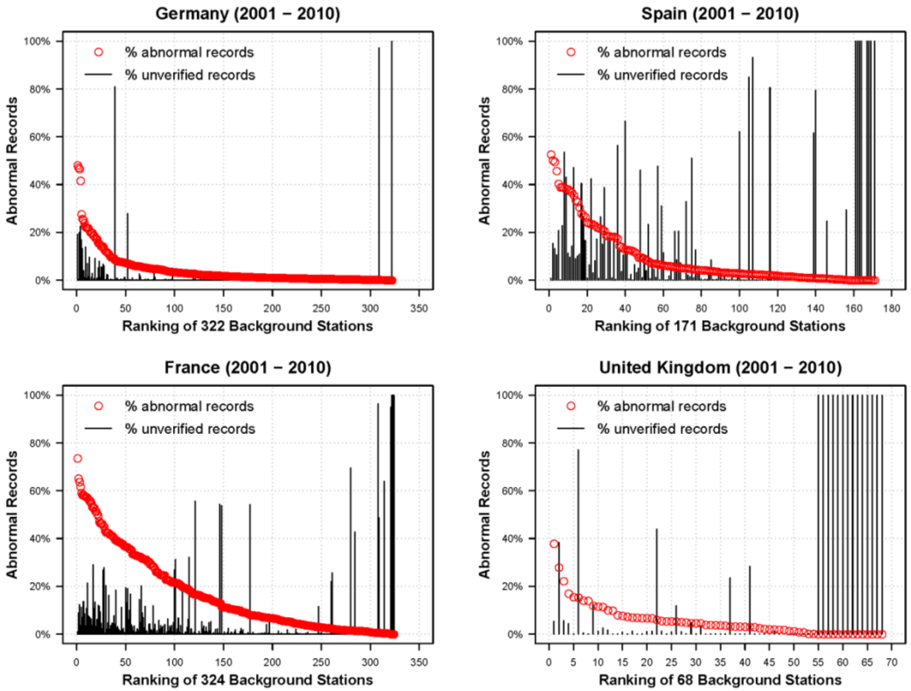
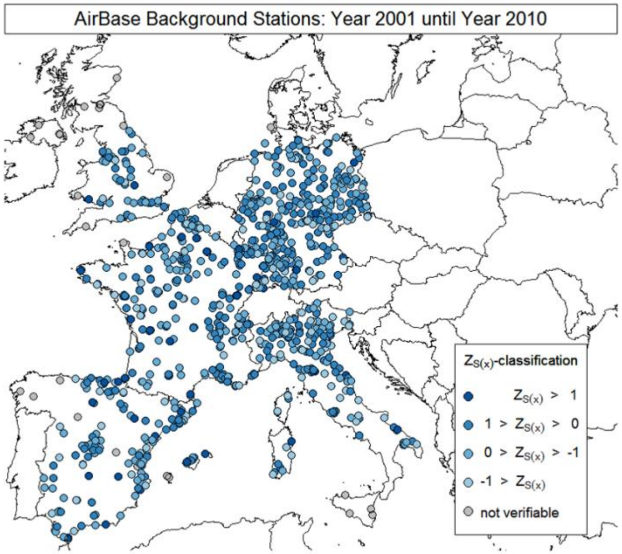
Automatic screening tools for the recognition of anomalies in AQ monitoring data

- Identification of spatio-temporal anomalies
- Indicators for evaluating the consistency of station classifications





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"Smooth Spatial Attribute Method"

- Proposed for traffic sensors by Lu et al. 2003 & Shekhar et al. 2003

  Lu, CH.-T., D. Chen & Y. Kou, 2003: Detecting Spatial Outliers with Multiple Attributes. ICTAI'03, IEEE 2003.

  Shekhar, S., CH.-T. Lu & P. Zhang, 2003: A Unified Approach to Detecting Spatial Outliers. GeoInformatica, 7(2), 139-166.

- 1st quantify how the measurement value of a station deviates from the corresponding values observed within its spatio-temporal neighbourhood (the 'Sx value')

- 2nd compare this Sx-deviation to the corresponding Sx-deviations observed for the station's neighbours

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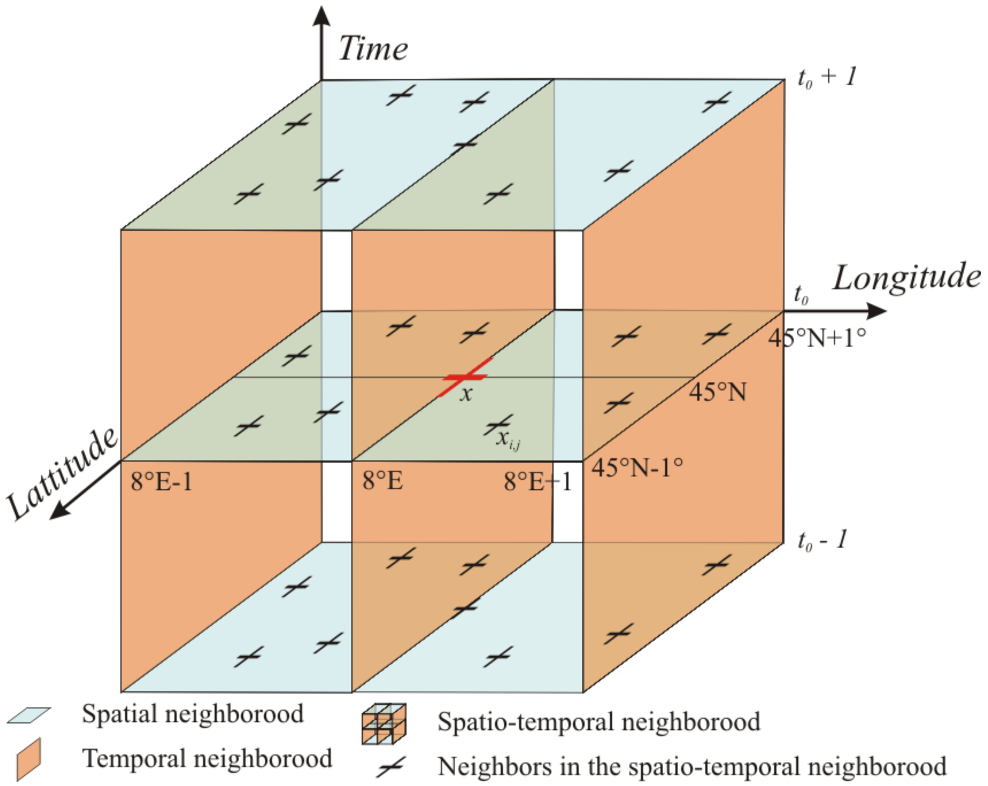
Definition of Neigbourhood in 3 Dimensions:



- spatial domain limited to +/- 1 spherical degrees
- temporal domain limited to +/- 2 days
- temporal domain is automatically expanded if initial neighbourhood is too little

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"Smooth Spatial Attribute Method"

- Proposed for traffic sensors by Lu et al. 2003 & Shekhar et al. 2003)

- Definition of Sx-values (for each individual neighbourhood)

$$Sx = f \quad x - \overline{f \quad x_n}$$

$$\Rightarrow Sx = x - \overline{x_n}$$

- Z-transformation of Sx

$$z = \frac{Sx - \overline{Sx_n}}{s_{Sx_n}}$$

- Test statistics for spatio-temporal outliers

$$\theta - 1.96 < z_i < \theta + 1.96$$

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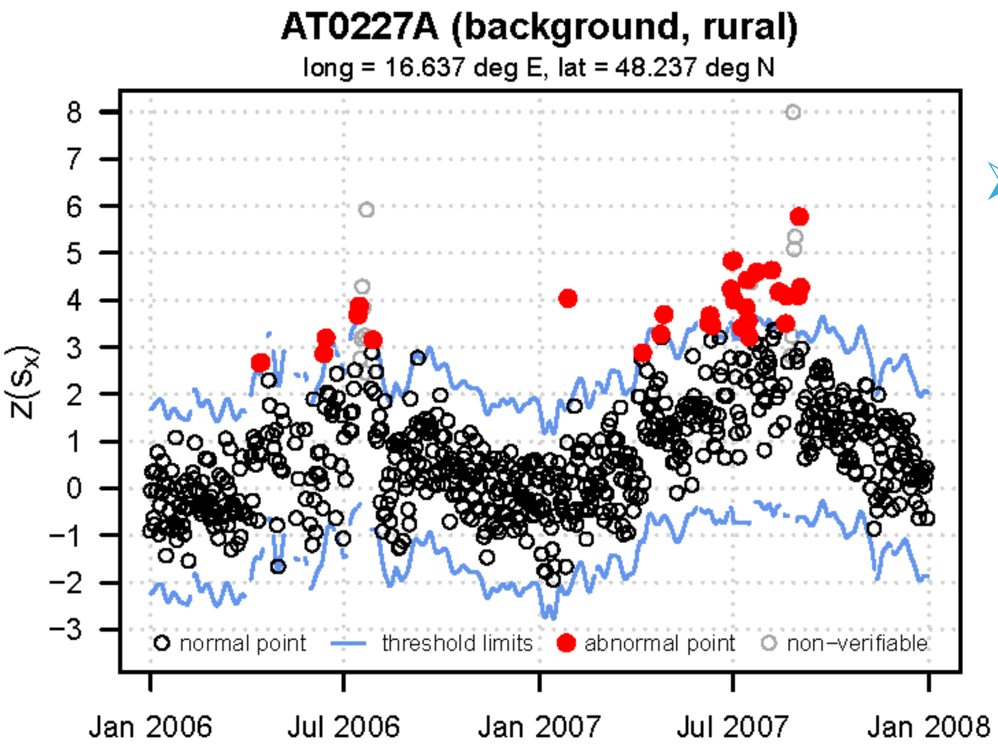
Type of results:



$$\theta - 1.96 < z_i < \theta + 1.96$$

- final step:

  Test statistics for abnormal values searches for z_i values exceeding the upper/lower limits chosen as a reference.

  (e.g., θ +/- a predefined threshold of 1.96)

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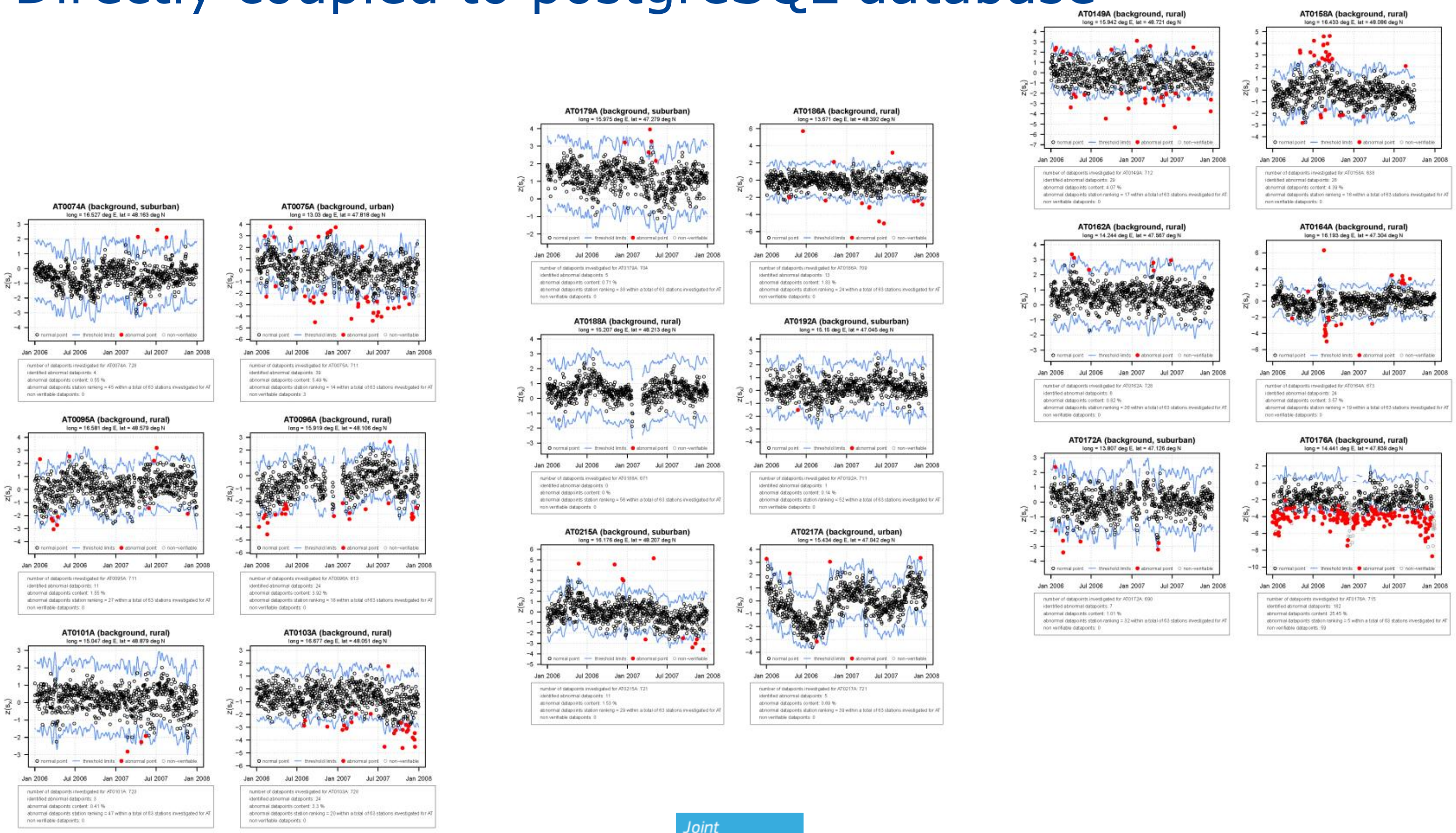
Automated Data Processing

- All codes prototyped in the R environment
- Directly coupled to postgreSQL database



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Input Data Requirements

- Sufficiently dense spatial and temporal data coverage.
- Time Series (e.g., daily values) of a spatially distributed random field.
- Limitations should be anticipated to be imposed from the network design (station density and spatial organisation of the monitoring network).

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Important properties of the method

- Able to detect local outliers which are characterized by a sharp spatial or temporal non-stationarity of a pollutant concentration.
- Values fulfilling the condition of weak-sense stationarity (even less strict, the condition of a smoothly varying spatio-temporal covariance structure) will not be miss-classified as outliers.
- This makes it a useful technique for the analysis of background type monitoring stations.
- The inherent spatial non-stationarity of other types of sites (traffic or industrial) makes it less suitable for such type of applications.

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Important properties of the method

- Results about abnormal data-points content are dependent on the parameter values chosen in the screening method.
- The effective confidence level for real world data depends on the spatiotemporal correlation of the data field.
- An absolute definition for outlying stations is not feasible, but depends on the intended objectives for using the method.
- Limitations can originate from the network design (station density and spatial organisation of the monitoring network).

Possible implementation into the DELTA tool?

1) External pre-processor for the observation datasets.

2) In a first step this might be a collection of R-Scripts and instructions for use made available on the DELTA tool homepage.

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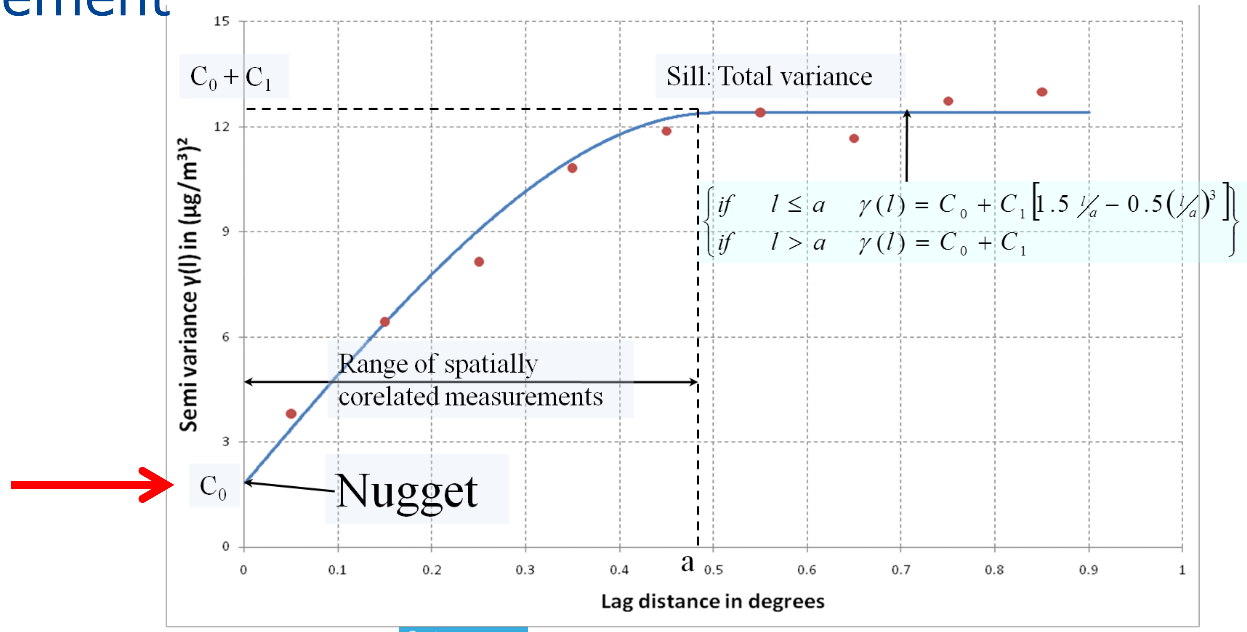
2nd method: Uncertainty of measurement evaluated from estimated nugget variance

- Comparison with the data quality objectives
- Identify trends over time in the nugget variance to investigate improvement (or worsening) of the uncertainty of measurement



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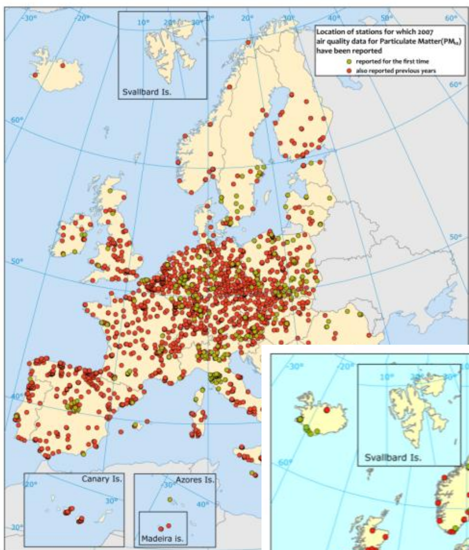
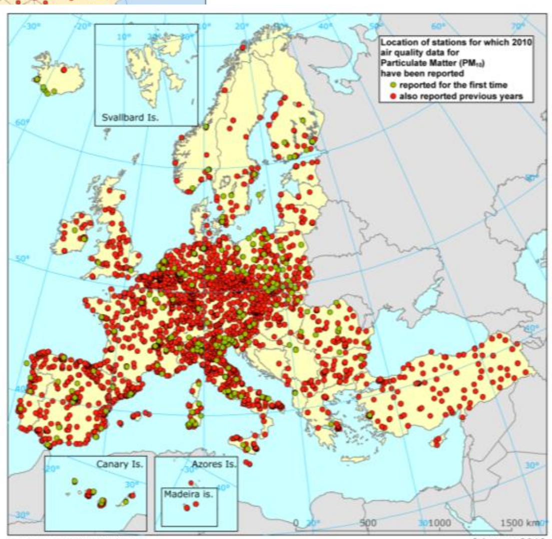
Scope of this application:



Source: ETC/ACC AirBase



Source: ETC/ACM AirBase february 2012

- Country wide records with varying time-extend from AirBase versions 4 and 7
- Daily PM_{10} values
- All station types
- All area types (urban, suburban and rural)

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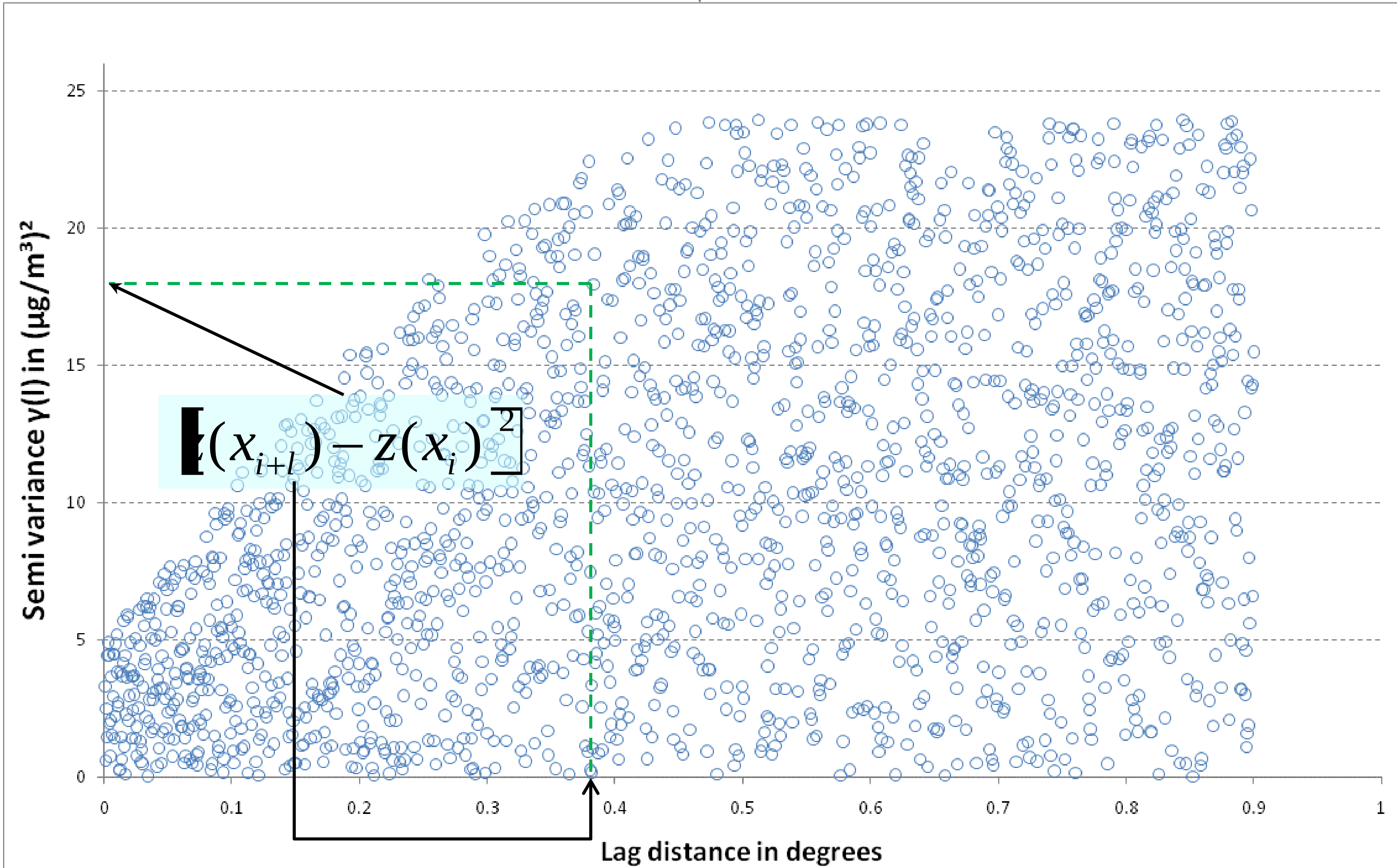
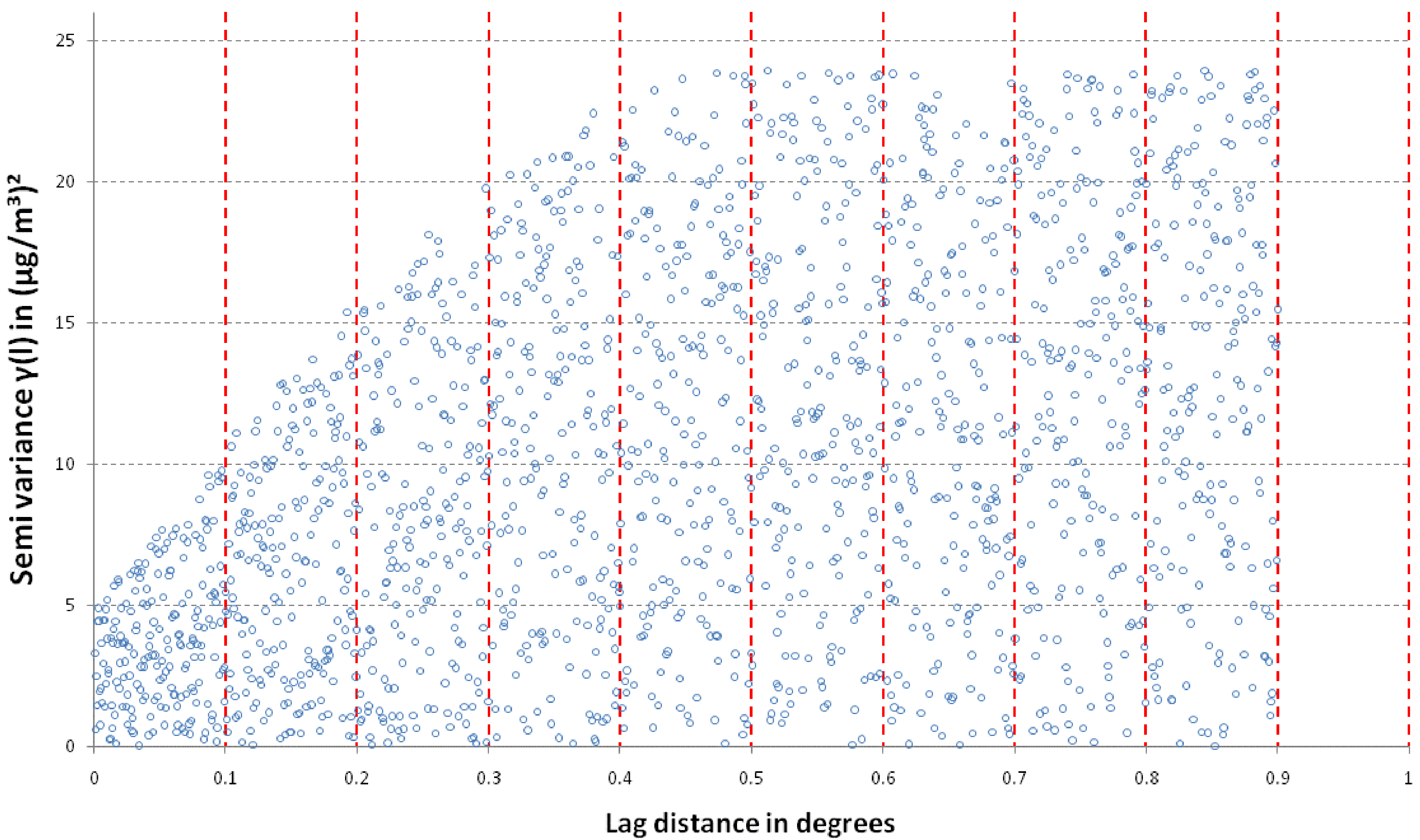


source: explanation of variography techniques, from M. Gerboles (2007): AQUILA Workshop presentation



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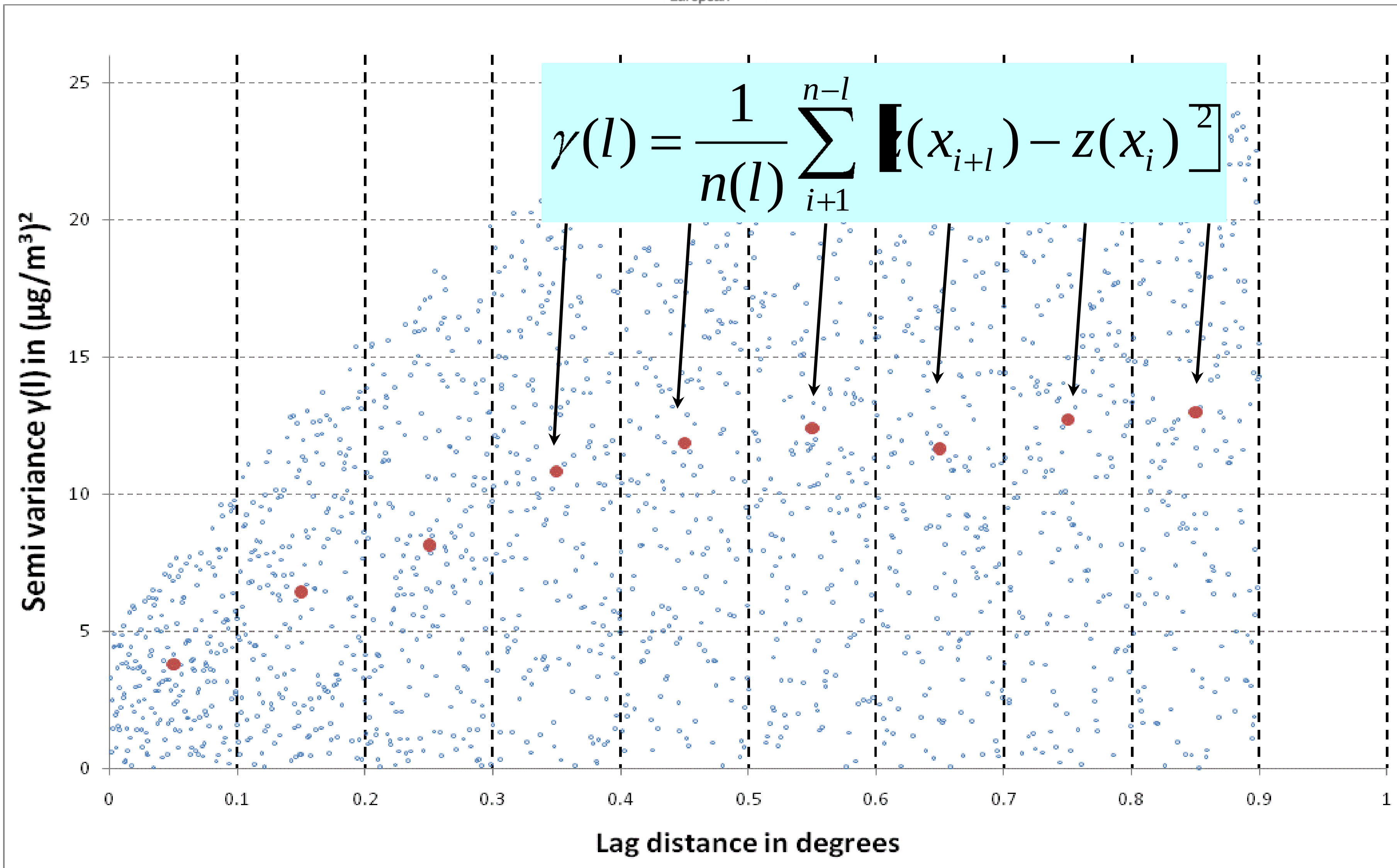

Joint

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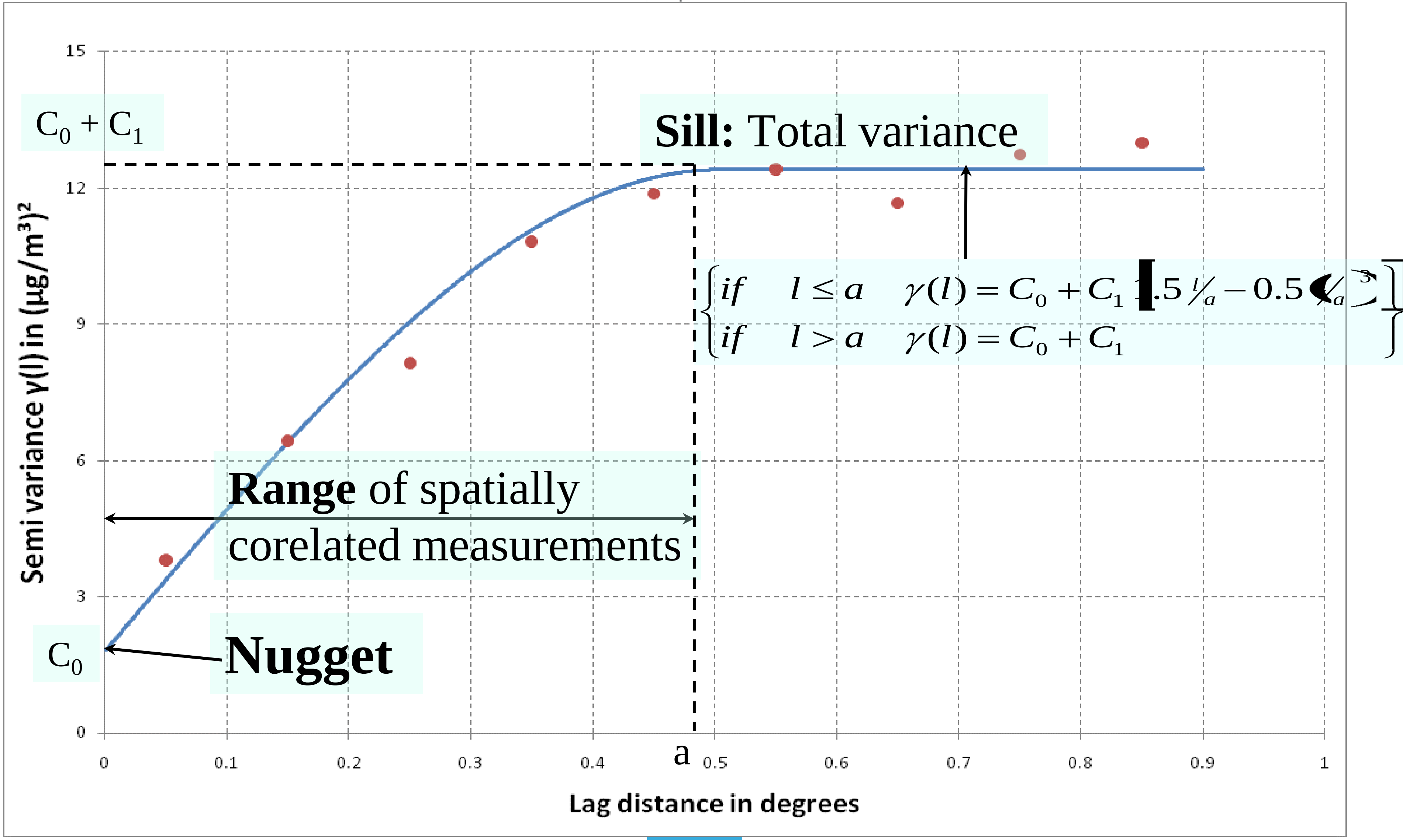

source: explanation of variography techniques, from M. Gerboles (2007): AQUILA Workshop presentation

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Primarily interest in our own research:

The nugget variance is reflecting fluctuations of the measurements at very short distance (towards 0).

$$s^2_{nugget} = s^2_{meas} + s^2_{sc}$$

uncertainty of measurement
variance associated with the sampling and analytical variability

micro-scale variance
variability that occurs at distances lower than the shortest sampling distance (continuity).

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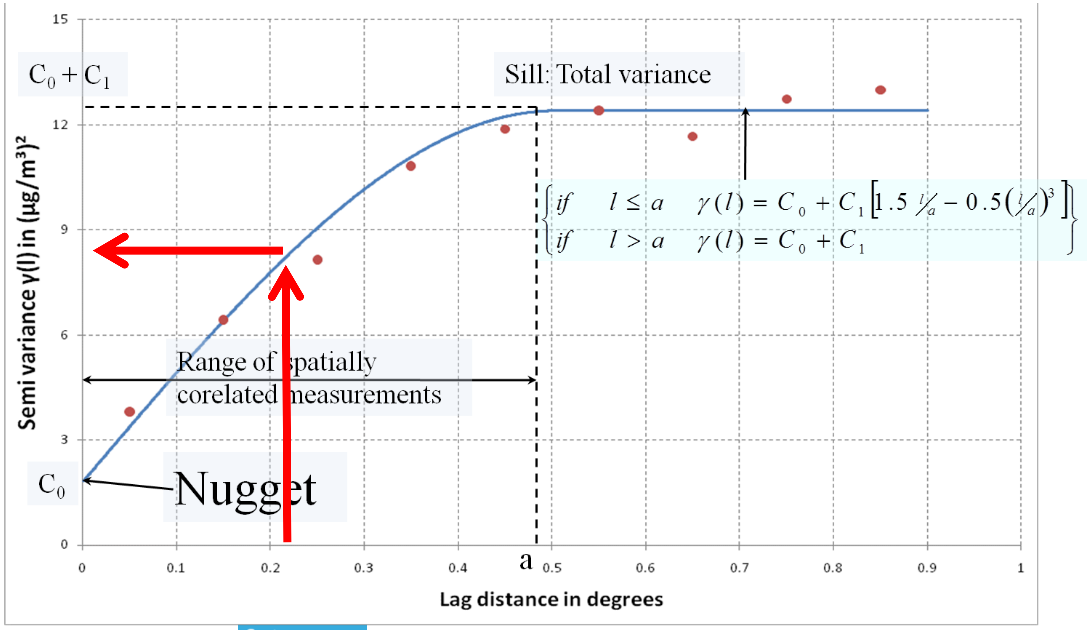
How can this knowledge contribute to introduce spatial representativeness into the model validation step?

- Variogram based specification of spatial uncertainty.
- Spatial Uncertainty as a weighting factor of data points for model validation.



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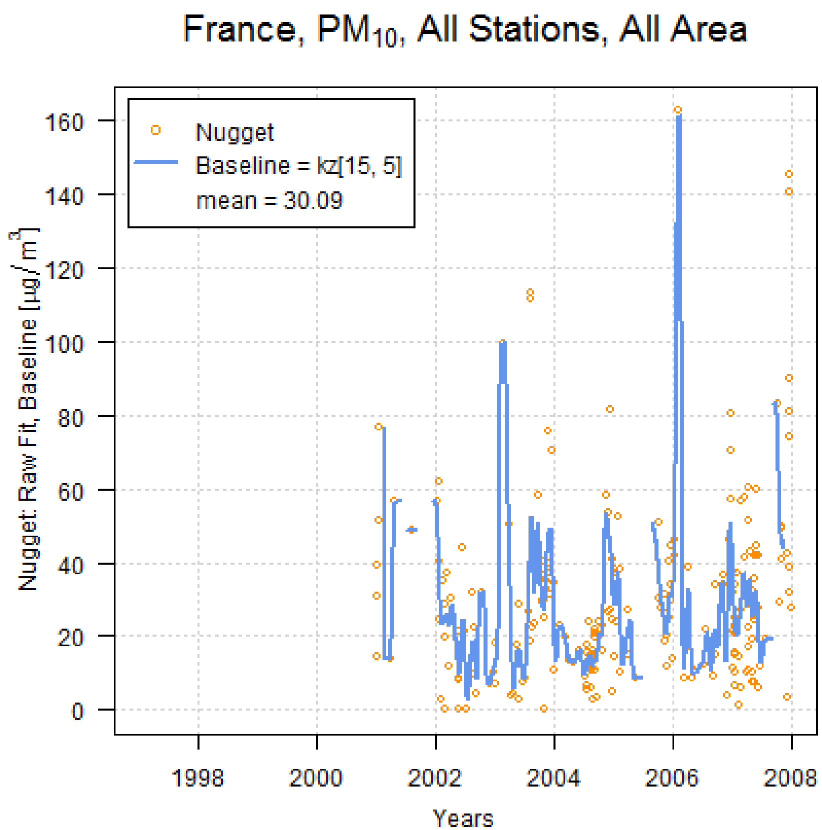
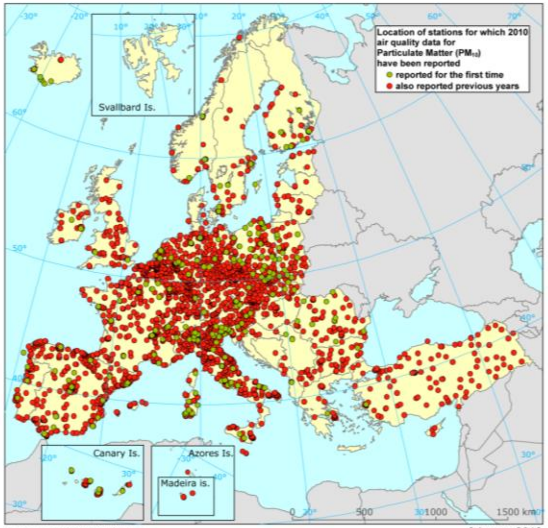
A first trial: Variogram parameters estimated from AirBase daily PM_{10} data



dataset contained 2555 initial cases, 217 accepted cases



Source: ETC/ACM AirBase february 2012

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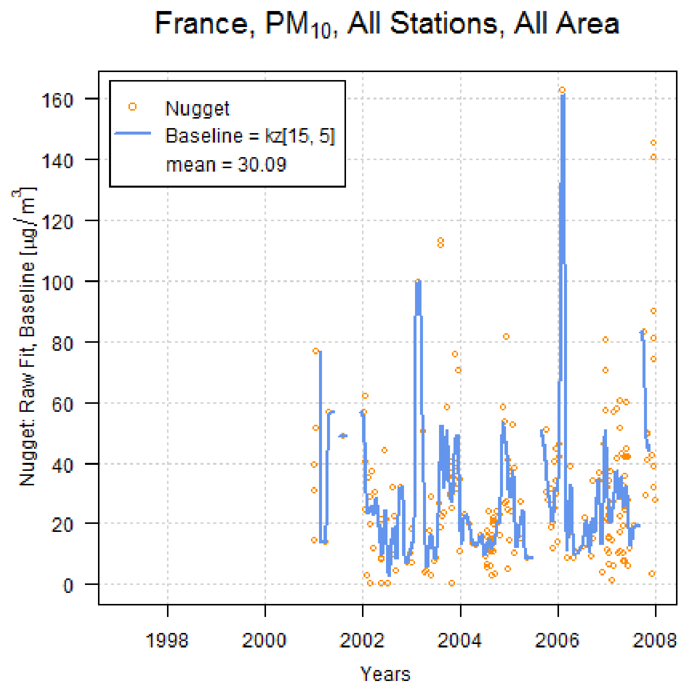
A first trial: Variogram parameters estimated from AirBase daily PM_{10} data



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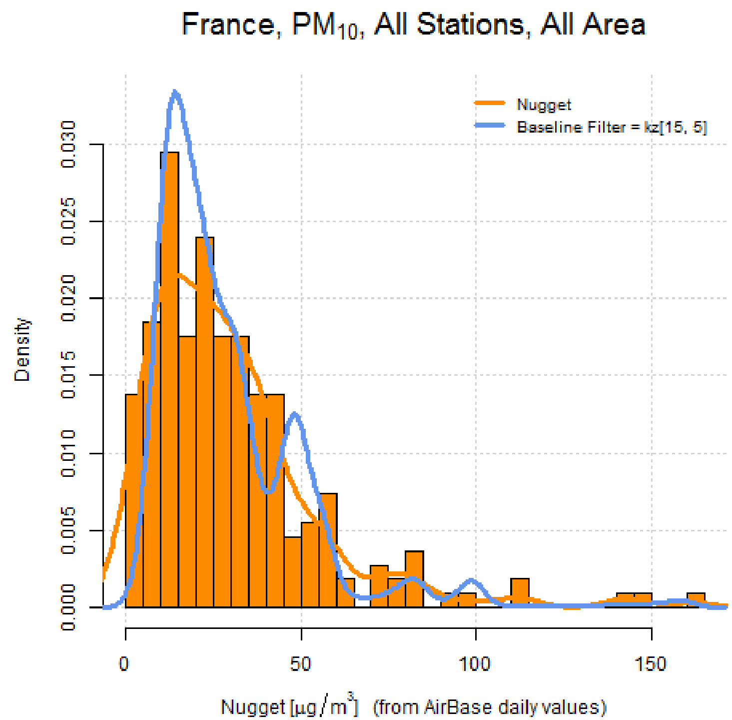

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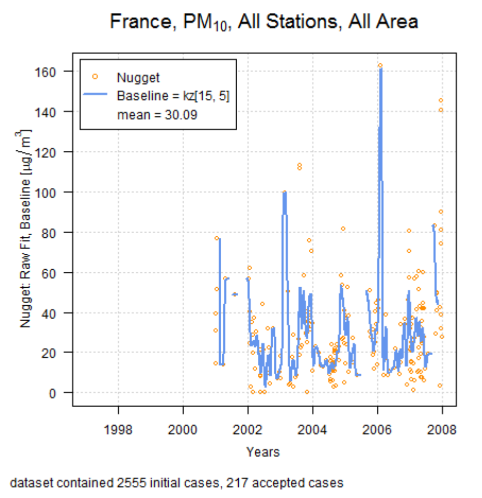
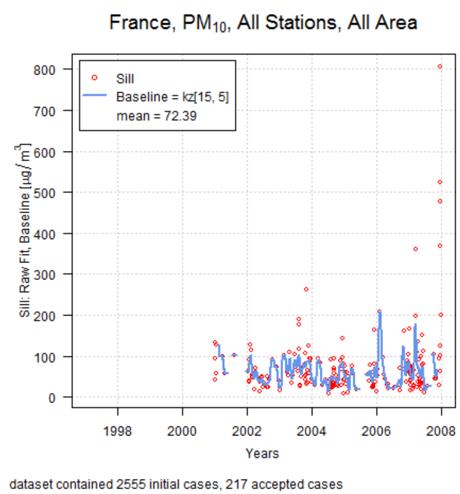
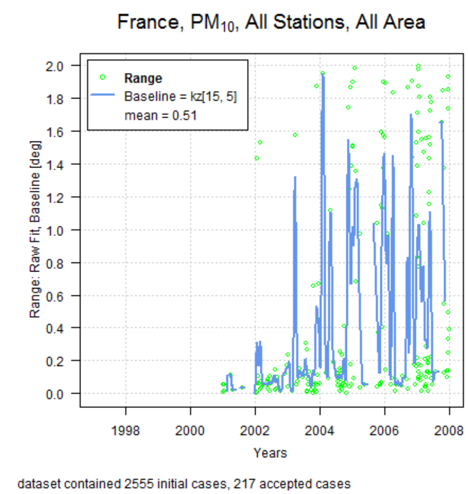
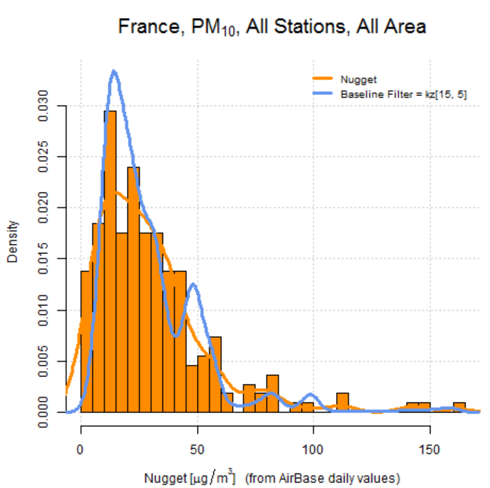
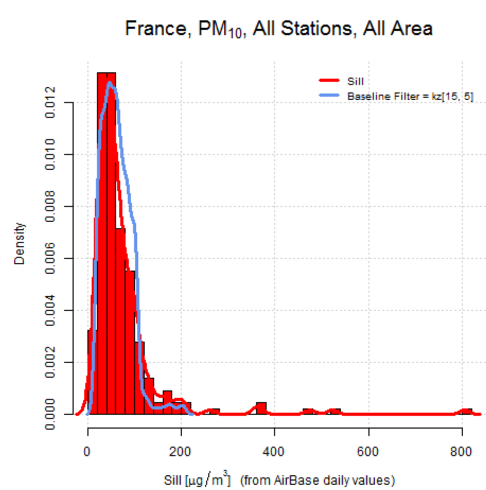
Variogram parameters estimated from daily PM_{10} data

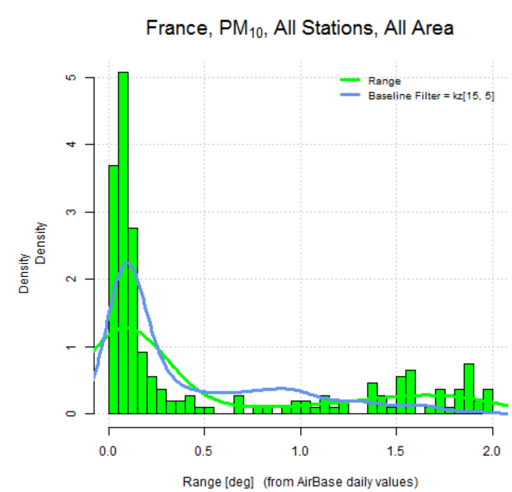












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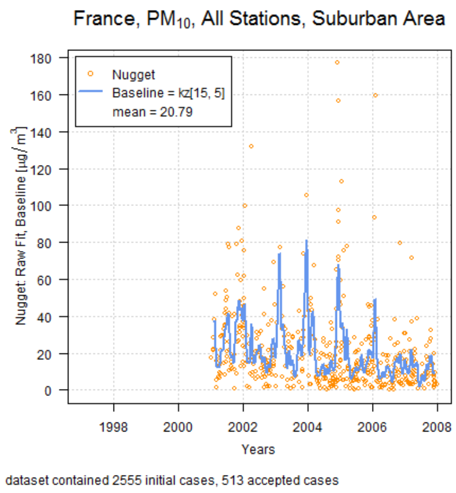
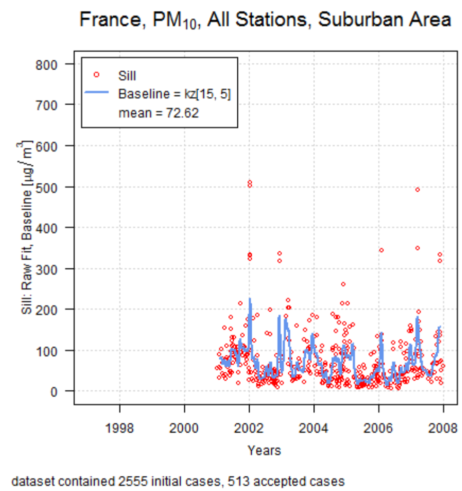
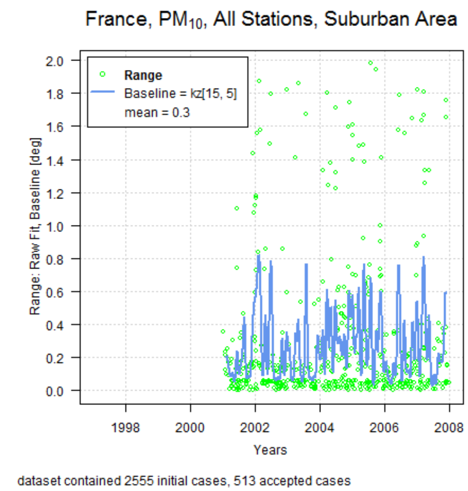
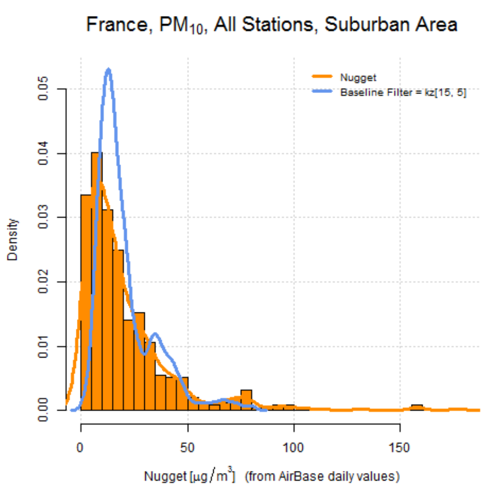
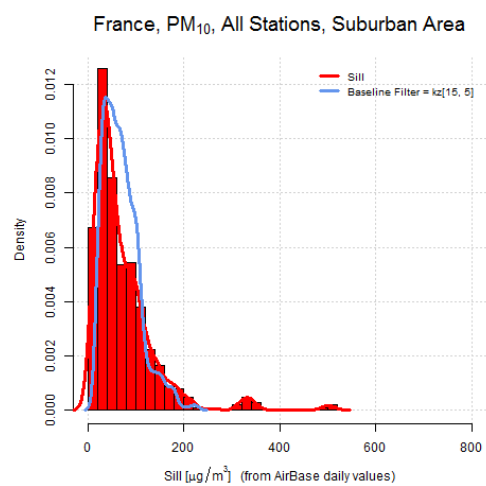
Variogram parameters estimated from daily PM_{10} data

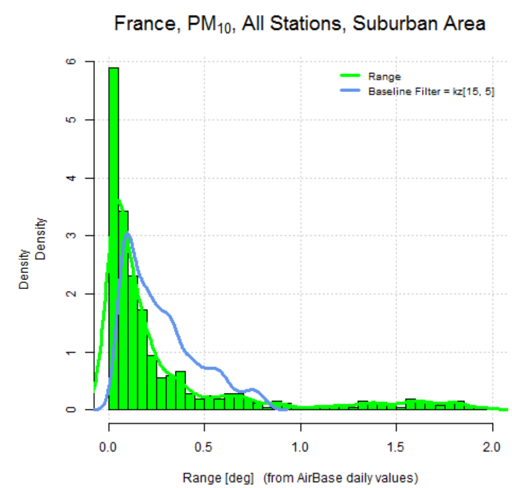












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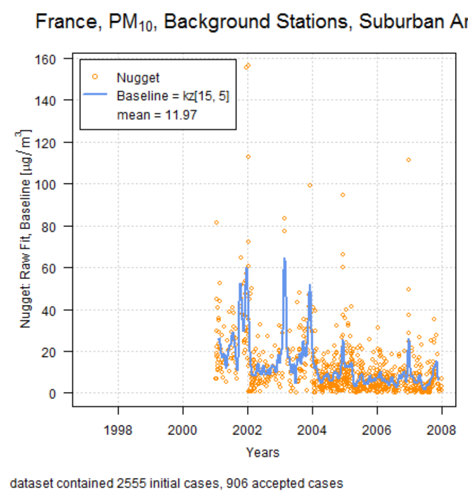
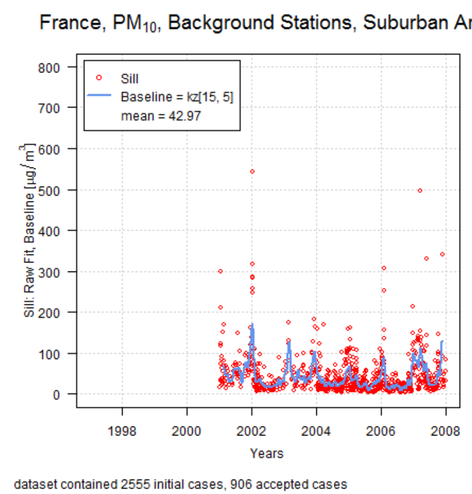
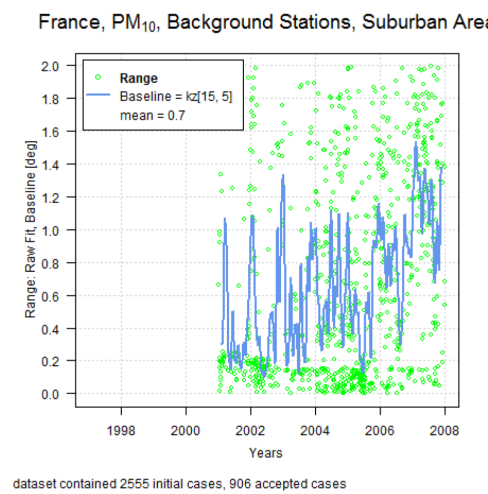
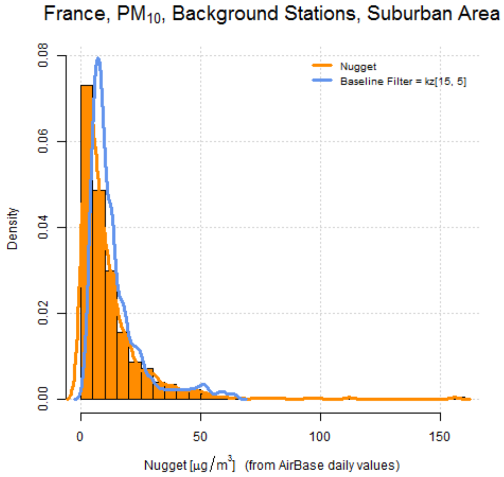
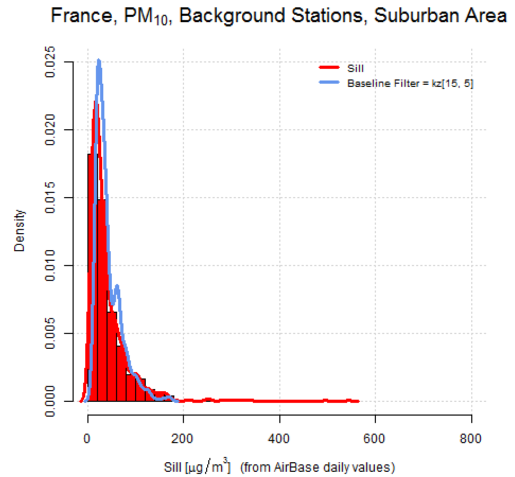
Variogram parameters estimated from daily PM_{10} data

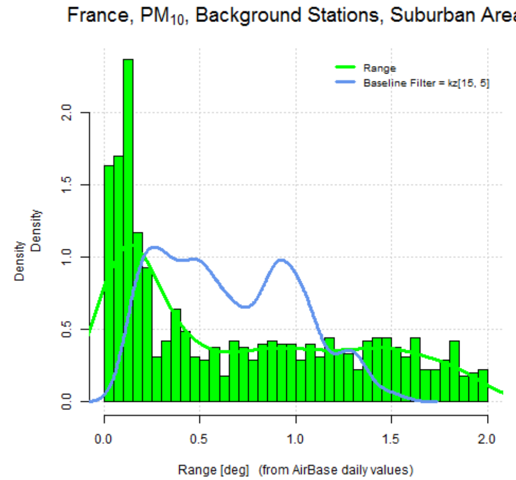












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This is ongoing work …

next steps:

- Improve the automated variogram fits to obtain better stability of the algorithms and quality of fit control.
- Investigate the temporal behaviour of estimated variogram parameters (seasonality, trends over time, etc.).
- In addition to AirBase, the use of information from more densely spaced datasets might be needed.
- However, in the unfavourable case it can be that variogram parameter uncertainties cannot be narrowed down to reasonable intervals for practical applications.

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Possible consideration of spatial uncertainty in the MQO and in the MPC ?

- Variogram based description of spatial uncertainty
- Might be done in similar manner to the implementation of the measurement uncertainty?

$$MQO = \frac{1}{2}\frac{RMSE}{RMS_U} = \frac{1}{2}\frac{\sqrt{\sum_{i=1}^{N}(m_i - x_i)^2}}{\sqrt{\sum_{i=1}^{N}U^2(x_i)}} \leq 1$$

(Thunis et. al, 2013)

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Possible consideration of spatial uncertainty in the MQO and in the MPC ?

- Variogram based description of spatial uncertainty
- Analogy to measurement uncertainty?

$$MQO = \frac{1}{2}\frac{RMSE}{RMS_U} = \frac{1}{2}\frac{\sqrt{\sum_{i=1}^{N}(m_i - x_i)^2}}{\sqrt{\sum_{i=1}^{N}U^2(x_i)}} \leq 1$$

(Thunis et. al, 2013)

- Caveat: a distance based uncertainty measure introduces unfavourable dependencies of MQO from model configuration (grid spacing)
- Caveat 2: uncertainties in variogram parameter estimates can be large (note the different objective of our original approach)

Possible consideration of spatial uncertainty in the MQO and in the MPC ?

- Variogram based description of spatial uncertainty
- Analogy to measurement uncertainty?
- Continuous description of spatial uncertainty vs. definition of area of representativeness (include / exclude approach)?

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Implementations / DELTA tool pre-processor ?

- Variogram based description of spatial uncertainty in the MQO.
- Default sets of variogram parameters might be provided within a DELTA tool extension or DELTA tool pre-processor?
- This could serve a common means for the characterisation of spatial uncertainty influences on model validation.
- It’s clearly a simplified approach. It not aims to replace or conflict with more detailed evaluations on spatial uncertainty performed by modellers in individual applications outside the DELTA tool.

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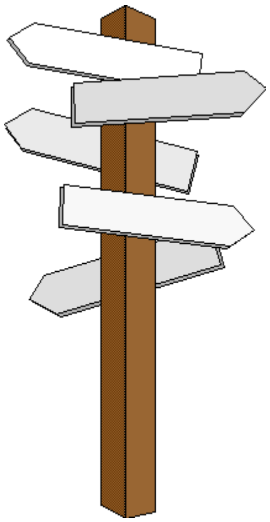
Aims of the Cross-Cutting Activity Session

Objectives for the discussions:



- Identify common needs and objectives on introducing spatial representativeness into model validation.
- Identify the interests in collaborations in this direction.