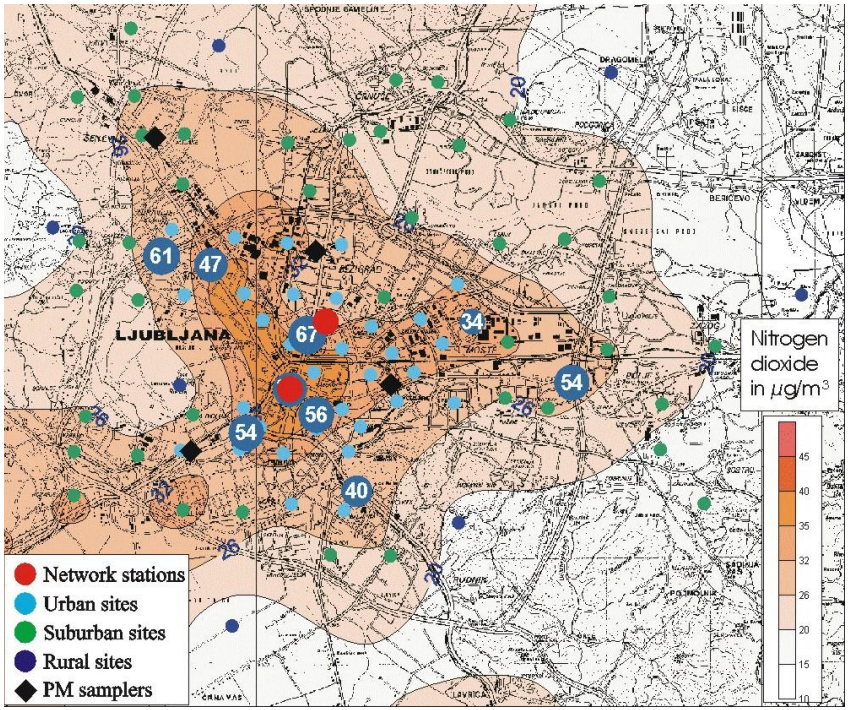
Cross-Cutting Activity on Spatial Representativeness



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

Oliver Kracht

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www.jrc.ec.europa.eu

Fairmode Plenary Meeting

11th and 12th February 2014
Baveno - Italy

Joint Research Centre

Outline

1) Spatial Representativeness in the Literature

   Definitions

   EU Legislation

   "SCREAM" position paper (2013)

2) Some lessons learned from previous FAIRMODE activities

3) Our own research activities in this context (JRC)

   Contributed slides by S. Galmarini and E. Solazzo (JRC)

   Contributed slides by Laure Malherbe (INERIS)

4) Aims of the Cross-Cutting Activity

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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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Spatial Representativeness in the Literature

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European Commission

Spatial Representativeness in the Literature

"A point measurement is representative of the average in a larger area (or volume) if the probability that the squared difference between point and area (volume) measurement is smaller than a certain threshold more than 90% of the time."

(Nappo et al. 1982)

European Commission

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European Commission

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(Nappo et al. 1982)

A unified definition?

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Possible definitions of Spatial Representativeness

A set of spatial points X is considered the representative area of a monitoring station s_0 located at x_0 if:

$$\left| f\ \ x_i\ - f\ \ x_0\ \right| \leq \delta \quad \forall \quad x_i \in X$$

δ: threshold value (e.g., in $\mu g/m^3$)
$f(x_i)$: concentration estimated at x_i
$f(x_0)$: concentration estimated at x_0

Depending on the application, important extensions of such definition can be required to account for:

- The uncertainty of measurement for $f(x_0)$
- The uncertainty for the estimation of $f(x_i)$
- The probability of exceeding the threshold value δ within in a time series

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Depending on the application, important extensions can be required to account for:

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- The uncertainty for the estimation of $f(x_i)$
- The probability of exceeding the threshold value δ within in a time series

Contingent upon the definitions used in detail, this might introduce additional dependencies of the representative area from:

- The actual value of $f(x_0)$
- Time
- Integration time scales
- Meteorological variables
-

European Commission

Possible definitions of Spatial Representativeness

Certainly, the extent of the area of representativeness depends on its definition.

Different definitions might suit different users.

Different definitions might be required to suit different purposes (?):

- Model calibration and model validation
- Design of monitoring networks
- Exposure assessment
- Statistical evaluations
- Regulatory purposes and legislation
- …

Possible definitions of Spatial Representativeness

"Representativeness is assumed to be stable over time periods of at least one year (i.e. not related to shorter time periods). Representative areas may change slightly from year to year and to a larger extent over periods of several years due to changing emissions."

Proposal for the definition and criteria of representativeness in UBA Austria (2007)

cited in the JRC- AQUILA Position Paper "Assessment on siting criteria, classification and representativeness of air quality monitoring stations" (SCREAM)

According to this proposal, the representative area of a monitoring site is defined by:

1. concentrations within a given range
2. similar reasons for this concentration (similarity approach)

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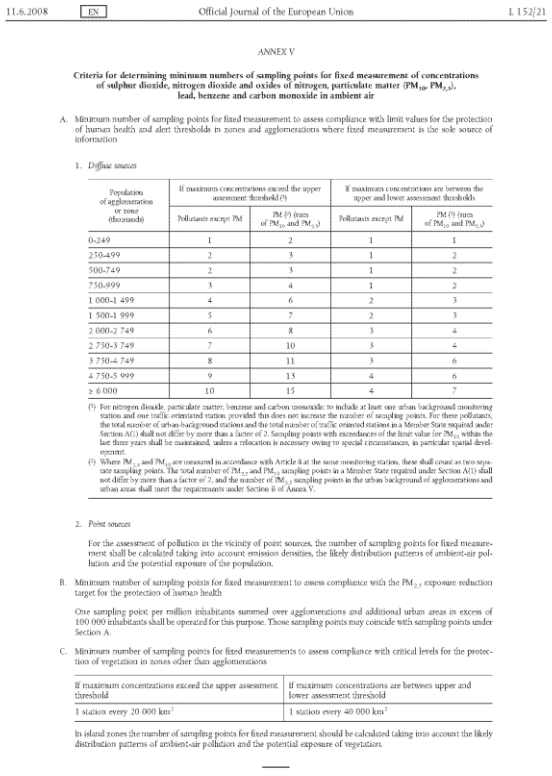
Spatial Representativeness in the EU Legislation
Monitoring criteria laid out in the Air Quality Directive

Annex V of Directive 2008/50/EC:

Sulphur dioxide, nitrogen dioxide, oxides of nitrogen, particulate matter, lead, benzene and carbon monoxide:

Minimum number of sampling points for fixed measurements mainly depends on:

- The current Air Quality status (max. concentration related to the lower and upper assessment thresholds)
- The population of an agglomeration or zone



11.6.2008 EN Official Journal of the European Union L 152/21

ANNEX V

Criteria for determining minimum numbers of sampling points for fixed measurement of concentrations of sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter (PM_{10}, $PM_{2,5}$), lead, benzene and carbon monoxide in ambient air

A. Minimum number of sampling points for fixed measurement to assess compliance with limit values for the protection of human health and alert thresholds in zones and agglomerations where fixed measurement is the sole source of information

1. *Diffuse sources*

Population of agglomeration or zone (thousands)	If maximum concentrations exceed the upper assessment threshold (1)		If maximum concentrations are between the upper and lower assessment thresholds	
	Pollutants except PM	PM (2) (sum of PM_{10} and $PM_{2,5}$)	Pollutants except PM	PM (2) (sum of PM_{10} and $PM_{2,5}$)
0-249	1	2	1	1
250-499	2	3	1	2
500-749	2	3	1	2
750-999	3	4	1	2
1 000-1 499	4	6	2	3
1 500-1 999	5	7	2	3
2 000-2 749	6	8	3	4
2 750-3 749	7	10	3	4
3 750-4 749	8	11	3	6
4 750-5 999	9	13	4	6
≥ 6 000	10	15	4	7

(1) For nitrogen dioxide, particulate matter, benzene and carbon monoxide: to include at least one urban background monitoring station and one traffic-orientated station, provided this does not increase the number of sampling points. For these pollutants, the total number of urban-background stations and the total number of traffic oriented stations in a Member State required under Section A(1) shall not differ by more than a factor of 2. Sampling points with exceedances of the limit value for PM_{10} within the last three years shall be maintained, unless a relocation is necessary owing to special circumstances, in particular spatial development.

(2) Where $PM_{2,5}$ and PM_{10} are measured in accordance with Article 8 at the same monitoring station, these shall count as two separate sampling points. The total number of $PM_{2,5}$ and PM_{10} sampling points in a Member State required under Section A(1) shall not differ by more than a factor of 2, and the number of $PM_{2,5}$ sampling points in the urban background of agglomerations and urban areas shall meet the requirements under Section B of Annex V.

2. *Point sources*

For the assessment of pollution in the vicinity of point sources, the number of sampling points for fixed measurement shall be calculated taking into account emission densities, the likely distribution patterns of ambient-air pollution and the potential exposure of the population.

B. Minimum number of sampling points for fixed measurement to assess compliance with the $PM_{2,5}$ exposure reduction target for the protection of human health

One sampling point per million inhabitants summed over agglomerations and additional urban areas in excess of 100 000 inhabitants shall be operated for this purpose. These sampling points may coincide with sampling points under Section A.

C. Minimum number of sampling points for fixed measurements to assess compliance with critical levels for the protection of vegetation in zones other than agglomerations

If maximum concentrations exceed the upper assessment threshold	If maximum concentrations are between upper and lower assessment threshold
1 station every 20 000 km^2	1 station every 40 000 km^2

In island zones the number of sampling points for fixed measurement should be calculated taking into account the likely distribution patterns of ambient-air pollution and the potential exposure of vegetation.

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Spatial Representativeness in the EU Legislation
Monitoring criteria laid out in the Air Quality Directive

Annex V of Directive 2008/50/EC:

Sulphur dioxide, nitrogen dioxide, oxides of nitrogen, particulate matter, lead, benzene and carbon monoxide:

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Research Centre

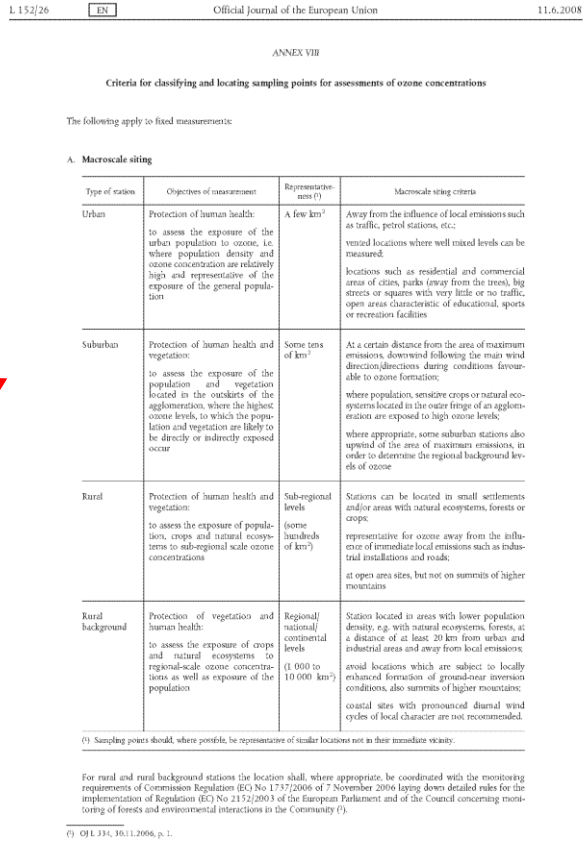
European Commission

Spatial Representativeness in the EU Legislation
Monitoring criteria laid out in the Air Quality Directive

Annex VIII of Directive 2008/50/EC:

Macroscale siting for ozone:

Type of station	Representativeness
Urban	A few km^2
Suburban	Some tens of km^2
Rural	Sub-regional levels Some hundreds of km^2
Rural background	Regional / national / continental levels 1 000 to 10 000 km^2



L 152/26 EN Official Journal of the European Union 11.6.2008

ANNEX VIII

Criteria for classifying and locating sampling points for assessments of ozone concentrations

The following apply to fixed measurements:

A. **Macroscale siting**

Type of station	Objectives of measurement	Representativeness (1)	Macroscale siting criteria
Urban	Protection of human health: to assess the exposure of the urban population to ozone, i.e. where population density and ozone concentration are relatively high and representative of the exposure of the general population	A few km^2	Away from the influence of local emissions such as traffic, petrol stations, etc.; vented locations where well mixed levels can be measured; locations such as residential and commercial areas of cities, parks (away from the trees), big streets or squares with very little or no traffic, open areas characteristic of educational, sports or recreation facilities
Suburban	Protection of human health and vegetation: to assess the exposure of the population and vegetation located in the outskirts of the agglomeration, where the highest ozone levels, to which the population and vegetation are likely to be directly or indirectly exposed occur	Some tens of km^2	At a certain distance from the area of maximum emissions, downwind following the main wind direction/directions during conditions favourable to ozone formation; where population, sensitive crops or natural ecosystems located in the outer fringe of an agglomeration are exposed to high ozone levels; where appropriate, some suburban stations also upwind of the area of maximum emissions, in order to determine the regional background levels of ozone
Rural	Protection of human health and vegetation: to assess the exposure of populations, crops and natural ecosystems to sub-regional scale ozone concentrations	Sub-regional levels (some hundreds of km^2)	Stations can be located in small settlements and/or areas with natural ecosystems, forests or crops; representative for ozone away from the influence of immediate local emissions such as industrial installations and roads; at open area sites, but not on summits of higher mountains
Rural background	Protection of vegetation and human health: to assess the exposure of crops and natural ecosystems to regional-scale ozone concentrations as well as exposure of the population	Regional/national/continental levels (1 000 to 10 000 km^2)	Station located in areas with lower population density, e.g. with natural ecosystems, forests, at a distance of at least 20 km from urban and industrial areas and away from local emissions; avoid locations which are subject to locally enhanced formation of ground-near inversion conditions, also summits of higher mountains; coastal sites with pronounced diurnal wind cycles of local character are not recommended.

(1) Sampling points should, where possible, be representative of similar locations not in their immediate vicinity.

For rural and rural background stations the location shall, where appropriate, be coordinated with the monitoring requirements of Commission Regulation (EC) No 1737/2006 of 7 November 2006 laying down detailed rules for the implementation of Regulation (EC) No 2152/2003 of the European Parliament and of the Council concerning monitoring of forests and environmental interactions in the Community (1).

(1) OJ L 334, 30.11.2006, p. 1.

Joint Research Centre

Spatial Representativeness in the EU Legislation
Monitoring criteria laid out in the Air Quality Directive

ANNEX II of Implementing Decision 2011/850/EU:

(D) Information on the assessment methods:

…

(16) Spatial Extent of representative area (data type 'Spatial Extent') (where available)

(17) Evaluation of representativeness (where available)

(18) Documentation of representativeness (web link) (where available)

Spatial Representativeness in the EU Legislation

Guidance on the Commission Implementing Decision laying down rules for Directives 2004/107/EC and 2008/50/EC:

(IPR - Implementing Provisions on Reporting)

furthermore states that:

- "There is as yet no definition of the spatial representativeness of monitoring stations in the AQ legislation and there is a need to develop tools for its quantitative assessment."
- "In 2007, a study was conducted for the Commission by the UBA Austria to investigate ways of facilitating a more harmonized approach to the classification of monitoring stations (Spangl et al. 2007)."
- "A recent paper of Joly and Peuch (2011) described another method based only on the past time series of the measured pollutant." *(remark: linked to classification)*
- "The evaluation of representativeness will be further evaluated in the framework of the collaboration between AQUILA / FAIRMODE. Once this analysis is concluded, a final recommendation will be included in this guidance."

European Commission

"SCREAM" Position Paper (2013)

Summary about discussions and considerations related to

- siting criteria for AQ monitoring sites
- classification of AQ monitoring sites
- representativeness of AQ monitoring sites

points out that:

- "Since air quality assessment is mainly based on monitoring at distinct locations, it is necessary to extend this point information to spatial information".
- "So far, a definition of the spatial representativeness of monitoring stations is still missing in the AQ legislation and there is a need to develop tools for its quantitative assessment."

(JRC- AQUILA Position Paper: "Assessment on siting criteria, classification and representativeness of air quality monitoring stations")

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Brief look at some lessons learned from previous FAIRMODE activities:

FAIRMODE 2011 survey to elicit expert opinion on the spatial representativeness

"For what horizontal area surrounding a monitoring station (represented by a circular diameter) do you consider the given station classification to be representative, for the given averaging period?"

"A survey to elicit expert opinion on the spatial representativeness of ground based monitoring data"

Compiled by Núria Castell Balaguer and Bruce Rolstad Denby

European Commission

FAIRMODE 2011 survey to elicit expert opinion on the spatial representativeness

Compound: PM_{10}		Averaging period		
		One hour	One day	One year
Station classification	Rural background			
	Suburban background			
	Urban background			
	Traffic			
	Industrial			

"A survey to elicit expert opinion on the spatial representativeness of ground based monitoring data"

Compiled by N. Balaguer & B. Denby

Joint Research Centre

European Commission

FAIRMODE 2011 survey to elicit expert opinion on the spatial representativeness

- A total of 16 people replied to the survey.
- 7 people completed the tables suggested.
- Most of the participants contributed with a comment or a scientific paper for further discussion.

"A survey to elicit expert opinion on the spatial representativeness of ground based monitoring data"

Compiled by N. Balaguer & B. Denby

European Commission

Average Compound: PM_{10}		Averaging period		
		One hour	One day	One year
Station classification	Rural background	10500	19500	29286
	Suburban background	5000	6500	11333
	Urban background	2940	3383	6629
	Traffic	26	91	492
	Industrial	260	1025	2400

Maximum Compound: PM_{10}		Averaging period		
		One hour	One day	One year
Station classification	Rural background	30000	30000	50000
	Suburban background	10000	10000	20000
	Urban background	8000	9000	20000
	Traffic	50	250	2500
	Industrial	1000	5000	10000

Minimum Compound: PM_{10}		Averaging period		
		One hour	One day	One year
Station classification	Rural background	2500	5000	10000
	Suburban background	1000	2500	3000
	Urban background	200	300	400
	Traffic	15	20	20
	Industrial	50	50	50

"A survey to elicit expert opinion on the spatial representativeness of ground based monitoring data"

Compiled by N. Balaguer & B. Denby

Joint Research Centre

FAIRMODE 2011 survey to elicit expert opinion on the spatial representativeness

Three points frequently repeated in the comments:

1. Scientific objective methodology is required to determine the spatial representativeness of a monitoring station.

2. There are more parameters that should be considered when assessing the area of representativeness and that are not included in the table.

3. The concept of circular area of representativeness is not applicable.

"A survey to elicit expert opinion on the spatial representativeness of ground based monitoring data"

Compiled by N. Balaguer & B. Denby

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Our own research activities in this context:

Automatic screening tools for the recognition of anomalies in AQ monitoring data based on attribute values and spatio-temporal relationships

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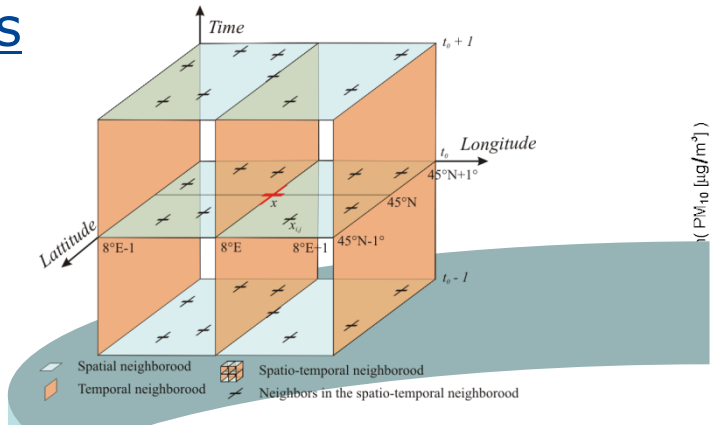
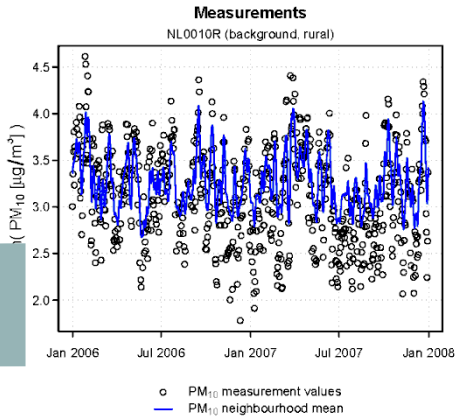
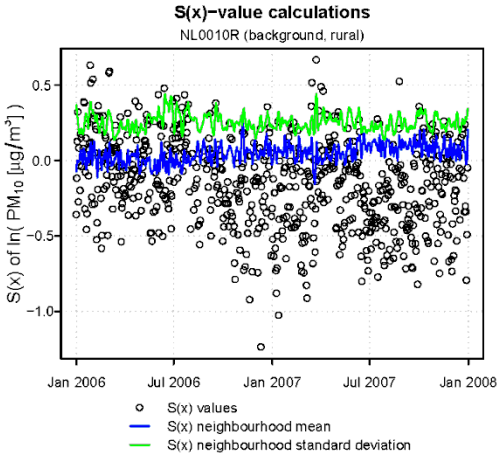
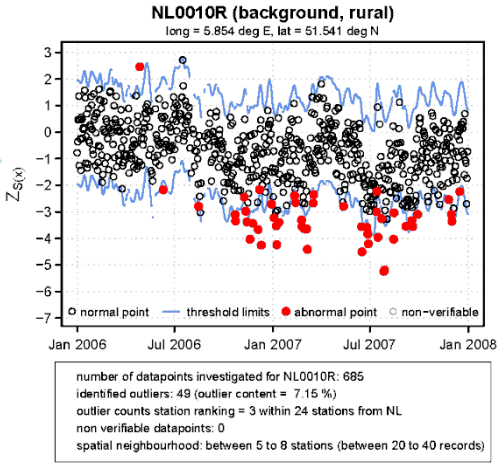
Automatic screening tools for the recognition of anomalies in AQ monitoring data based on attribute values and spatio-temporal relationships









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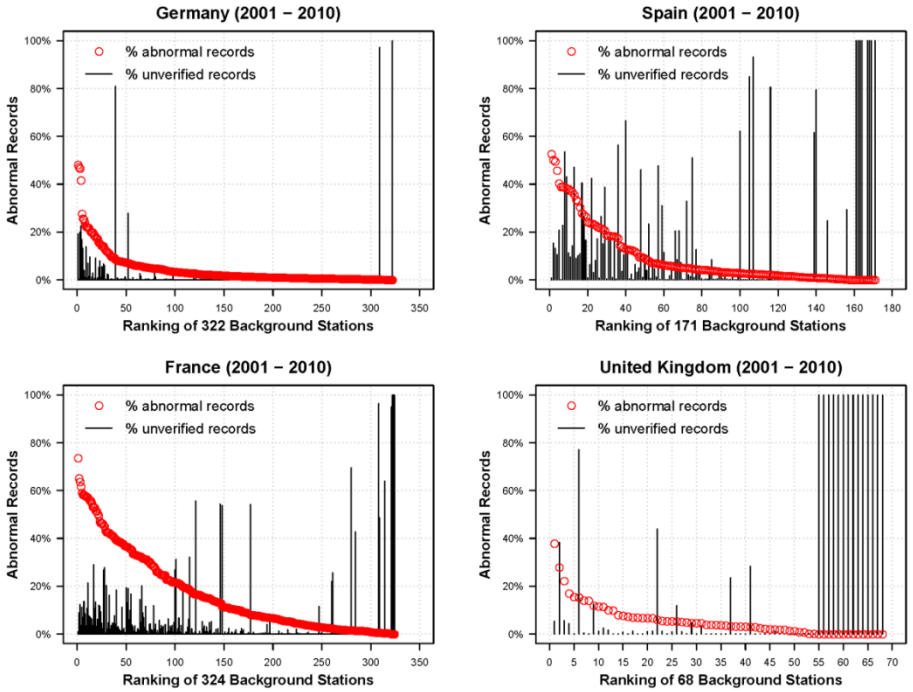
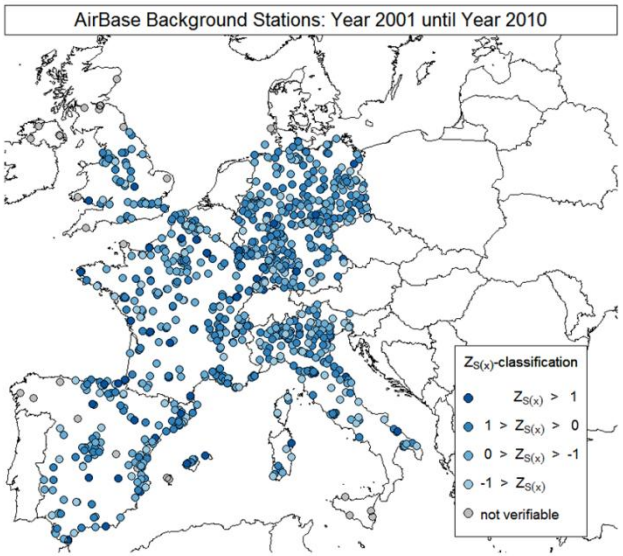
Automatic screening tools for the recognition of anomalies in AQ monitoring datasets based on attribute values and spatio-temporal relationships

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





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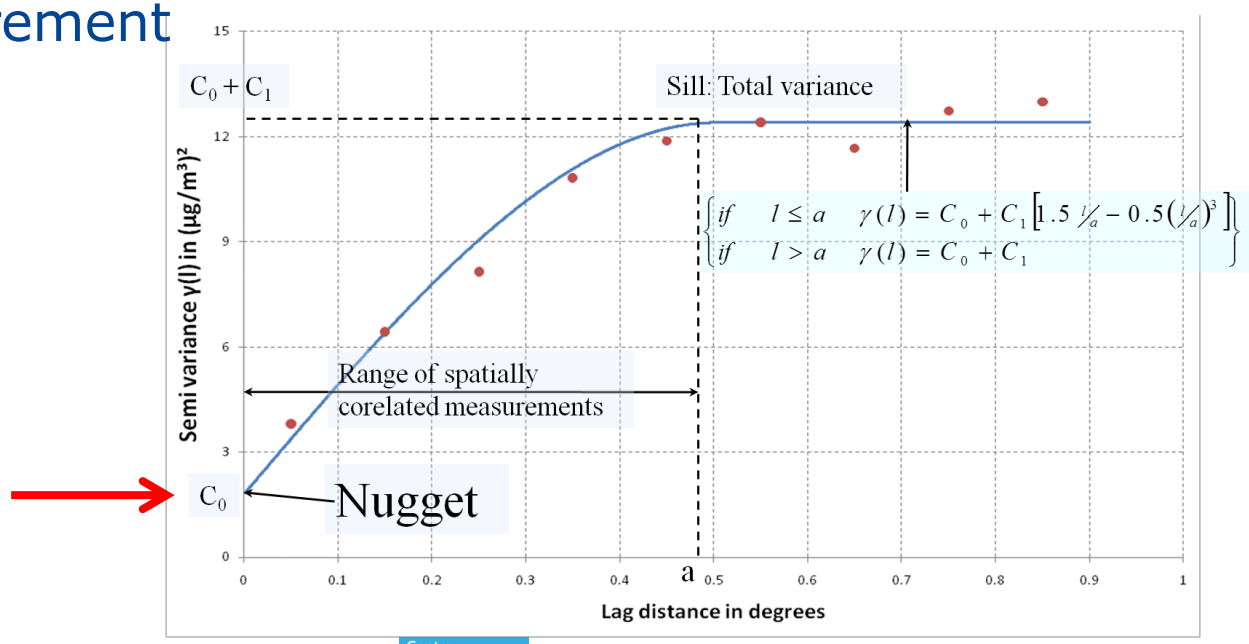
Our own research activities in this context:

Uncertainty of measurement evaluated by using the estimated nugget variance

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



Our own research activities in this context:

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

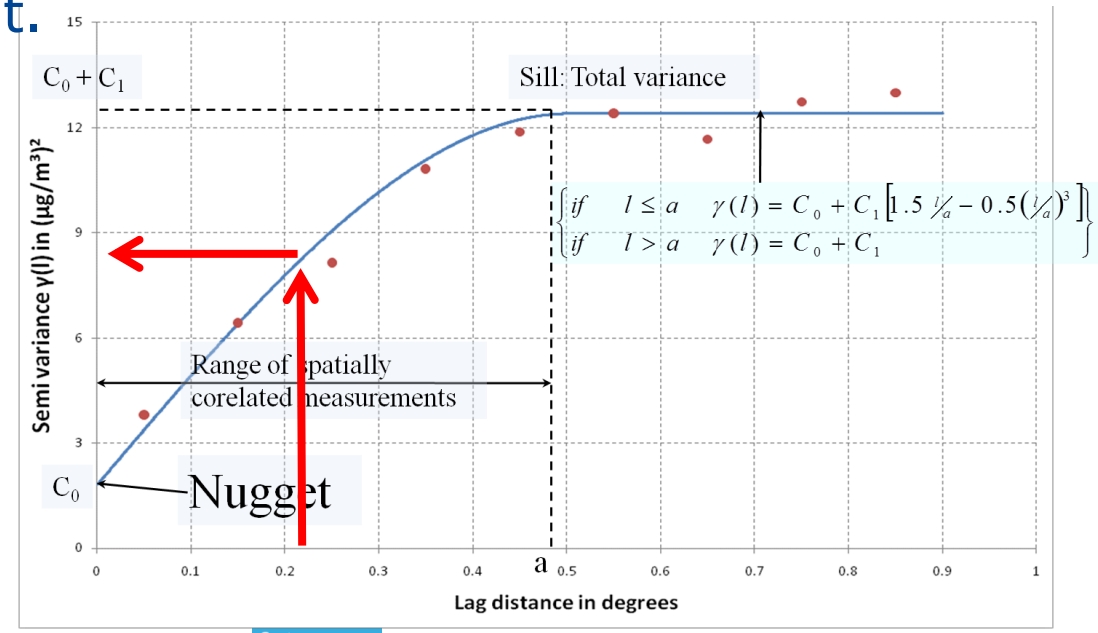
micro-scale variance
variability that occurs at distances lower than the shortest sampling distance (continuity).

European Commission

Our own research activities in this context:

Uncertainty of measurement evaluated by using the estimated nugget variance

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



Contributed slides by S. Galmarini and E. Solazzo (JRC)

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Contributed slides by S. Galmarini and E. Solazzo (JRC)

At the 2013 Fairmode Plenary in Antwerpen, S. Galmarini proposed the transition of SG1 from **Observation/Model** to **Spatial Representativity** as a more fundamental problem to be tackled first (as also emerged from the SG1 activity lead by Bruce Denby up until that moment) and took the leadership of the SG

We present the work performed by E. Solazzo, O. Kracht, M. Gerboles and S. Galmarini (from May 2013 to Dec 2013) on the topic using data kindly provided by CERC (D. Carruther and J. Stocker)

A technical note is published and is available upon request in e-format (email stefano.galmarini@jrc.ec.europa.eu)

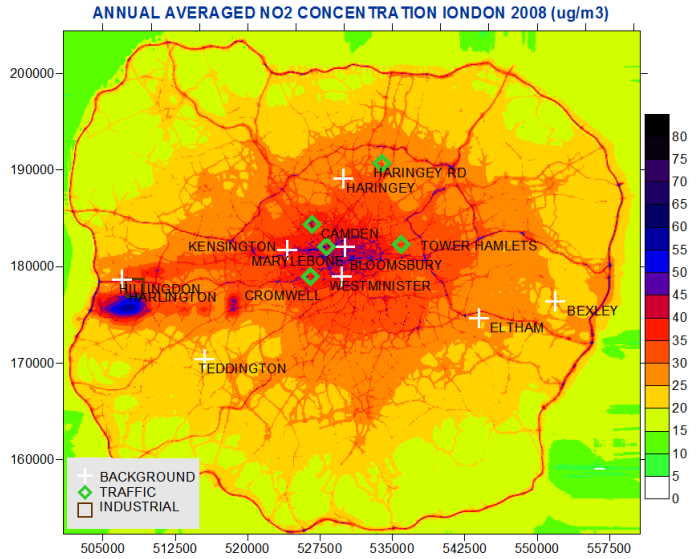
European Commission

Contributed slides by S. Galmarini and E. Solazzo (JRC)

Geo-statistics methodology for assessing how the concentration at the receptor is spatially associated with the concentration in its surroundings

To overcome the sparseness of observational data we used the concentrations predicted by the ADMS model for the city of London as a proxy

ADMS provides high temporal and spatial resolution of surface concentration of PM10, NO2 and O3



Joint Research Centre

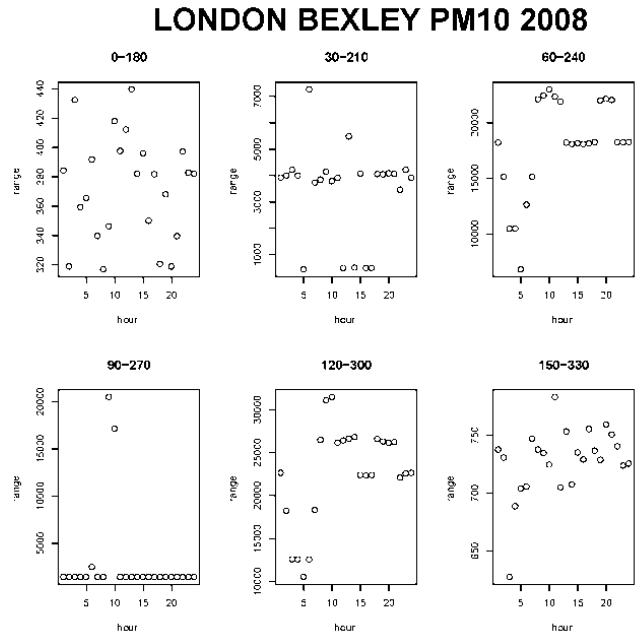
Contributed slides by S. Galmarini and E. Solazzo (JRC)

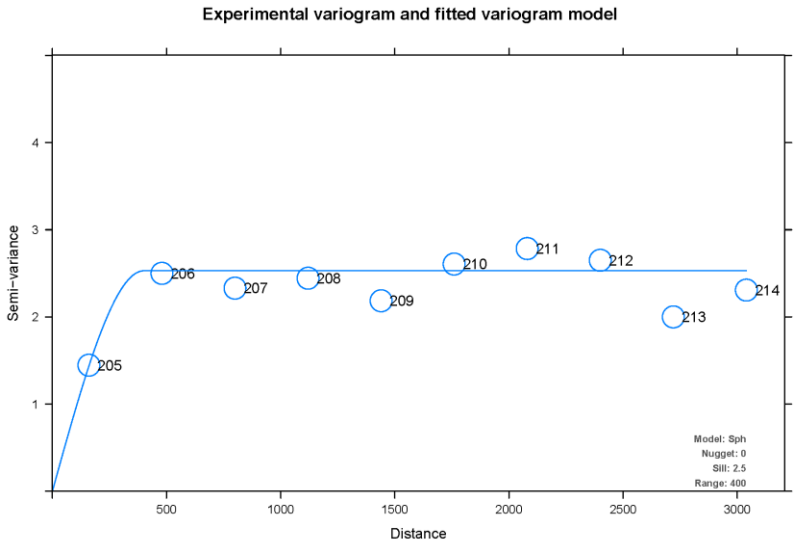
The "point-centred variogram" tool: estimates the range at which the evolution of variance becomes flat.

Parameters can be derived from the fit of the data depending on the hour of the day (averaged over the whole year) and direction.

Results so far show great directionality dependence of the range (aligned vs. normal to the street axes).

Current work is devoted to further test the robustness of the methodology and to put together a journal paper.





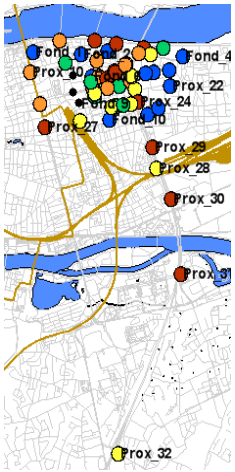
European Commission

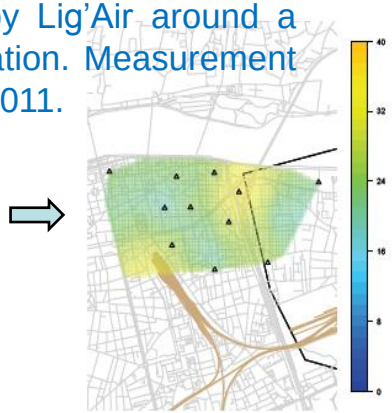
Contributed slides by Laure Malherbe (INERIS)

Assessment of spatial representativeness

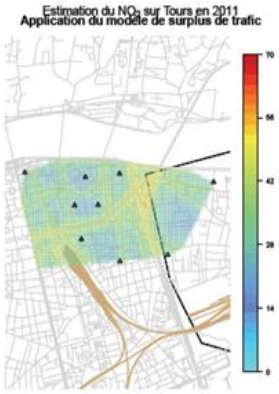
- **Objective:** delimitation of representativeness areas
- **Method:** Kriging with external drift (passive sampling survey with covariates) (Bobbia et al., 2008; LCSQA, 2007, 2010-2012)

City of Tours. NO_2. Passive sampling survey conducted by Lig'Air around a traffic monitoring station. Measurement period: all the year 2011.

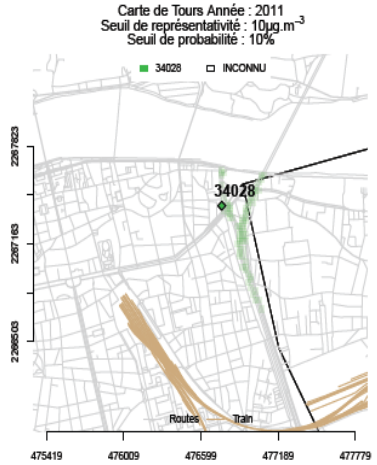




Background map: kriging with NO_x emissions and population density as external drift.



Statistical adjustment for traffic points



Estimated representativeness area for NO_2 annual average concentration.

- **Requirements:** dense sampling campaigns.
- **Spatial scale:** local and urban.
- **Applications:** mostly adapted to NO_2 or benzene annual, seasonal or monthly average concentrations. Requires information on the uncertainty of the concentration map.

Study of station classification

- **Objective:** further qualifying monitoring sites as a function of their environment (land use, population density, emissions…) and/or the measured data

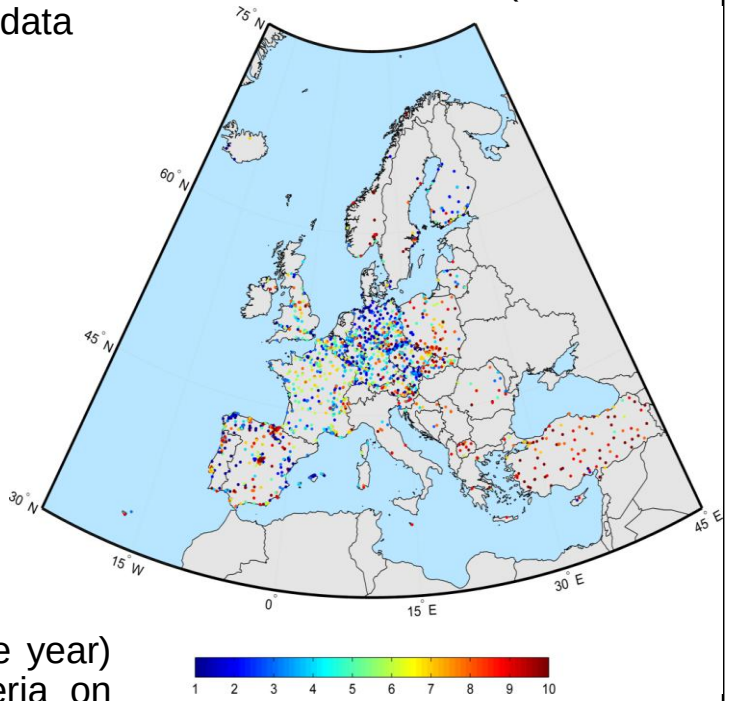
ETC/ACM study (2012-2013):

LDA classification based on the temporal variability of concentrations.

Application of the methodology developed by Joly and Peuch (2012) to AirBase v6 and update with AirBase v7.

Result: pollutant specific classification, from 1 (rural behaviour) to 10 (behaviour mostly influenced by urban traffic)

Requirements: historical time series (at least one year) of hourly values which fulfill certain quality criteria on missing data.



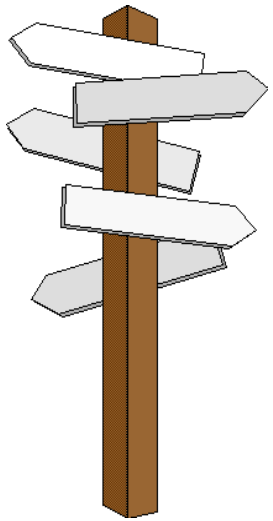
Classification of PM_{10} monitoring stations according to Joly & Peuch (2012) methodology

- **Possible users:**
  - ✓ data providers: to identify specific situations which might need investigation
  - ✓ modelers: to make appropriate selections of stations *e.g.* for model validation, data assimilation, mapping…

European Commission

First aims of the Cross-Cutting Activity

Objectives for the discussions today and in the course of the technical meeting in April 2014:



- Identify current needs within the FAIRMODE community directed to the fields of spatial representativeness, station classification, and related topical areas.
- Identify the interests in collaborations.
- Evaluate the interest to work towards methodological comparisons (example given, on shared datasets).

From the FAIRMODE proposed 2014 – 2016 roadmap:

Cross-Cutting Activity on spatial representativeness:

- Existing methodologies and current needs within the FAIRMODE community?
- Support the development of the MQO: a methodology to assess the spatial representativeness of measurement
- Improvements of the model evaluation methodology: a methodology to automatically screen for anomalies within records of AQ monitoring datasets will bring a clear benefit for choosing monitoring sites for model evaluation purposes.

From the FAIRMODE proposed 2014 – 2016 roadmap:

Cross-cutting activity on spatial representativeness:

- Evaluate the feasibility of methodological comparisons (example given, on shared datasets). However, the methodological diversity of the different approaches might impose significant limitations in this regard.
- Assessing the representativeness of source contribution estimates derived from field data is essential for their proper interpretation. Interest has been expressed to explore the opportunities to review the progress in this subject within the FAIRMODE community.

European Commission

First aims of the Cross-Cutting Activity

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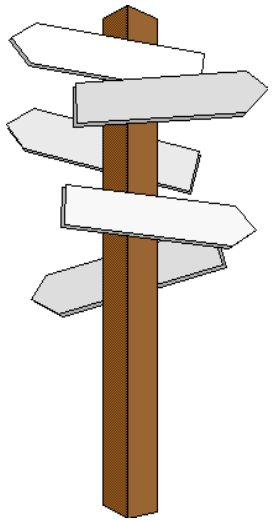

- Identify current needs within the FAIRMODE community directed to the fields of spatial representativeness, station classification, and related topical areas.
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Area of representativeness vs zone of exceedance

(area of the exceedance, e.g. in Annex XV (public information) of Directive 2008/50/EC)

The “area of exceedance” needs to be distinguished from the “area of representativeness”.

The exceedance zone is indeed linked to:

- The area of representativeness around a monitoring station
- The magnitude (measured concentrations) of the exceedance event

Depending on the chosen definitions, the exceedance area may be larger than, smaller than or intersect the representativeness area.