National Air Quality Reference Network.
Evaluation of different methodological approaches for station representativeness: the Italian experience

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CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

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Zagreb (Croatia), 6-8 May 2013
Since early 2000s, on behalf of the Ministry of Environment, ENEA has developed the National Integrated Model to support the International Negotiation on Atmospheric Pollution

www.minni.org

ENEA is supporting the design of the Italian Special Purpose Stations Monitoring Network
Selection of best sites, and reference methods, equipment, and laboratories for the Italian Special Purpose Stations Monitoring Network

- Ozone and its Precursors (12)
- PM10, PM2.5 Chemical Speciation (10)
- Heavy Metals: Arsenic, Cadmium, Nickel, Mercury (4)
- 7 carcinogenic PAH (10): benzo(a)pyrene;
  benzo(a)anthracene;
  benzo(b)fluoranthene;
  benzo(j)fluoranthene;
  benzo(k)fluoranthene;
  indeno(1,2,3-cd)pyrene,
  dibenzo(a,h)anthracene
1. Development, evaluation and choice between different methodologies

2. Definition of the best parametrization for each methodology

**WHY DIFFERENT METHODOLOGIES?**

*Because there couldn’t be an unique best method that fits all the situations (location of the station, emission sources, pollutant type, ……)*
Proposed Methodologies

✓ statistical methods based on objective factors (method 1)
Example of objective factors: land use and topographic data, population and build-up area distribution, point sources and road networks position, etc...
APPLICABLE FOR LONG TIME SCALE

✓ methods based on emissions spatial distribution (method 2)
- assessment of both the total surface flux and its variability (sites with small total burden and with small variability of surface fluxes points to larger representativeness area)
- fulfillment the representativeness criteria: a location has to be in the same emission class as the investigated monitoring station.
APPLICABLE TO PRIMARY POLLUTANTS AND FOR LONG TIME SCALE

✓ methods based on model simulations
• analysis of 4D Eulerian concentration fields (method 3)
CONSISTENCY BETWEEN SPATIAL RESOLUTION OF MODELLED CONCENTRATION FIELDS AND SUPPOSED CONCENTRATION VARIABILITY AROUND THE SITE (STATION TYPE)
• analysis of backward trajectories from Lagrangian Particle Dispersion Modelling (method 4)
METHOD 1: OBJECTIVE FACTORS (LAND COVER)

- Development of a synthetic, pollutant dependent, indicator $\beta$ for the dependency of concentration on land cover
- Variation of $\beta$ in the neighbourhood of a selected monitoring site.

The formulation is:

$$\beta = \log[1 + (\sum_i a_i \times n_{CLi} / \sum_i n_{CLi})]$$

- $CL_i$: class of land cover
- $n_{CLi}$: fraction of the area (buffer) corresponding to $CL_i$
- $a_i$: adimensional, pollutant specific, coefficient representing the influence of $CL_i$ on pollutant concentration

REFERENCE
Definition of class and species specific parameters

\[ \text{nCL}_i \rightarrow \text{Corine Land Cover 2006 database + aggregation of the original 44 classes into 11 CLi including the integration of the road network class, with vectorial geometry of national roads.} \]

\[ \text{Performed by GIS} \]

<table>
<thead>
<tr>
<th>ENEA Code</th>
<th>CORINE Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL1</td>
<td>111</td>
<td>Continuous urban fabric</td>
</tr>
<tr>
<td>CL2</td>
<td>112</td>
<td>Discontinuous urban fabric</td>
</tr>
<tr>
<td>CL3</td>
<td>121</td>
<td>Industrial or commercial units</td>
</tr>
<tr>
<td>CL4</td>
<td>122</td>
<td>Road and rail networks and associated land</td>
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<td>CL5</td>
<td>123, 124</td>
<td>Port areas and airports</td>
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<tr>
<td>CL6</td>
<td>131,132,133</td>
<td>Mineral extraction sites, dump sites, construction sites</td>
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<tr>
<td>CL7</td>
<td>141,142</td>
<td>Green urban areas, Sport and leisure facilities</td>
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<tr>
<td>CL8</td>
<td>211,212,213</td>
<td>Non-irrigated arable land, permanently irrigated land, rice fields</td>
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<tr>
<td>CL9</td>
<td>221,222,223, 231, 241,242,243,244</td>
<td>Agricultural land</td>
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<tr>
<td>CL10</td>
<td>311, 312, 313,321,322,323,324, 331,332,333,334,335</td>
<td>Forests, Scrub and/or herbaceous vegetation associations, open spaces</td>
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<tr>
<td>CL11</td>
<td>411,412,421,422,423, 511,512,521,522,523</td>
<td>Wetlands and water bodies</td>
</tr>
</tbody>
</table>

\[ \text{a}_i \rightarrow \text{statistical optimization of the function } C(\beta)=n\beta^2+m\beta+q, \text{ where } C \text{ is the concentration. Multivariable regression on 2007 yearly average measured concentrations from the national database of air quality measurements (pollutant dependent). Performed by statistical code R} \]
Calculation of $\beta$ as «land cover polluting power»

- 10 monitoring stations for PM2.5,
- 12 monitoring stations for $O_3$ or precursors,
- circular buffers with 2, 5, 7.5 and 10 km radius centred at each station.

Each value of $\beta$ is compared with the value in the 2 km radius buffer: a difference of less than 20% indicates that the station measurements is representative of the concentrations inside the buffer.

This approach is applicable when annual time series of measured concentrations are available from a consolidated and spatially uniform monitoring network, allowing a good calibration of $\beta$. 
METHOD 2: EMISSIONS VARIABILITY

- A simplified modelling approach using emission inventory data.
- Spatial emission dataset is produced by MINNI atmospheric modelling system.
- Inversely proportional relationship between emission variability around a monitoring site and its spatial representativeness:

  high spatial emission variability (likely indicating high concentration variability)
  means low spatial representativeness
The evaluation of the representativeness is based on an automatic classification of range of values (natural breaks).

- Different time intervals: whole year, summer, winter
- Primary pollutants (PM10, PM2.5, IPA, As, Cd, Ni, Hg).
- Two different emission inventory sources:
  1. the national emission inventory (ISPRA, 2009) annually (2005) compiled for fulfilment of UNECE CLRTAP international agreements
  2. the national GAINS emission estimates deriving from GAINS Europe scenario analysis methodology (2005).

Urban stations have a low spatial representativeness due to the high variability of emissions in urban areas.
The most intuitive approach: the concentrations recorded at the site of interest are directly compared with concentrations recorded at selected points in the surrounding area, in a fixed time interval.

At each time step, the difference between the concentrations modelled at the site of interest and at each grid point was calculated. A threshold value of 20% was set.

Concentration fields from the MINNI model dataset is used.

A 2-dimensional frequency function \( f_{site}(x,y) \), specific of each site of interest, counting positive occurrences of “concentration similarity” for each grid point of the model domain, was defined and finally an area of spatial representativeness of the site was assessed (i.e. \( f_{site}(x,y) > 0.9 \) is verified).
The monitoring station is representative of a wider area if all measurements in this area differ by less than 20% threshold from the station measurements more than 90% of the times (i.e. $f_{\text{site}}(x,y) > 0.9$ is verified).

Frequency function $f_{\text{site}}(x,y)$ for San Pietro Capofiume station. Representativeness area is in pink and white.
Frequency function $f_{\text{site}}(x,y)$ for PM2.5 at the Milano Pascal station using yearly series of mean daily data. In this case as for other urban stations, the representativeness is not resolved due to the resolution (4X4 Km) of the available simulation.

Therefore this method is not suitable for evaluating the representativeness of urban stations at this scale.
CONCLUSIONS

Method 1
• Based on land cover data as a proxy variable of concentration.
• Strongly depends on the selected dataset of measured concentrations, used in the calibration stage.
• Promising in urban sites due to the free availability of high resolution (e.g. CORINE Land cover in Europe) datasets of land cover.

Method 2
• It uses gridded emission database (MINNI) to analyse emission variability as a proxy variable of concentration.
• It gives a complete picture of spatial variations of the pollution pattern, independent of the monitoring site.
• Useful for a comprehensive evaluation of spatial representativeness, but limited to primary pollutants.

Method 3
• Direct comparison of modelled hourly concentrations at the selected site and surroundings using gridded concentration database (MINNI).
• No proxy variable is used.
• Limited applicability to the urban stations in relation to the spatial resolution of the gridded concentration dataset.

Further implementations are forthcoming:
a fourth method, based on backward trajectories of air masses reaching the selected site, is under development, relying on meteorology only.
Thank you for your attention

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