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

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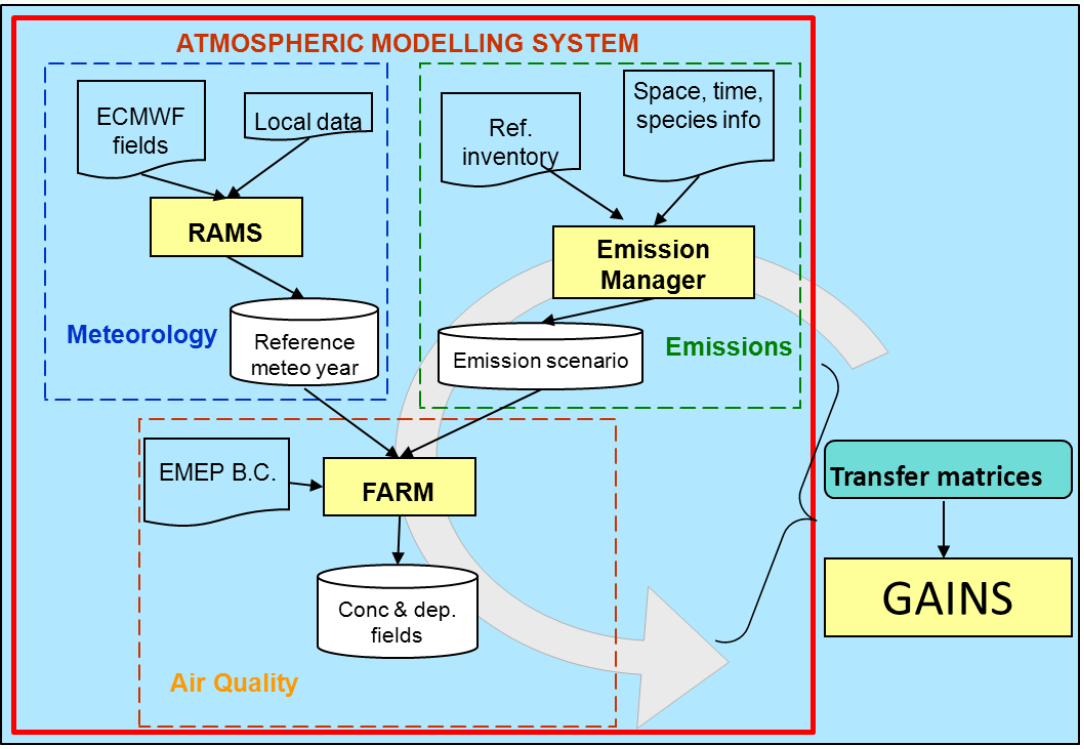
CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

14th Task Force on Measurement and Modelling Meeting: Zagreb (Croatia), 6-8 May 2013

Introduction



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**

Italian Special Purpose Stations Monitoring Network

D.Lgs. 13/08/2010, n.155

Italian Legislative Decree for the compliance with
DIRECTIVE 2008/50/EC
of the European Parliament and of the Council of 21 May 2008
on ambient air quality and cleaner air for Europe

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

Assessment of the **spatial representativeness** of monitoring stations

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 β for the dependency of concentration on land cover
- ✓ Variation of β in the neighbourhood of a selected monitoring site.

The formulation is:

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

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 CLi on pollutant concentration

REFERENCE
Janssen S., Dumont G., Fierens F., Deutsch F., Maiheu B., Celis D., Trimpeneers E. and Mensink C. (2012), "Land use to charachterize spatial representativeness of air quality monitoring stations and its relevance for model validation", Atmospheric Environment, 59, 492-500.

Definition of class and species specific parameters

nCL_i → 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.

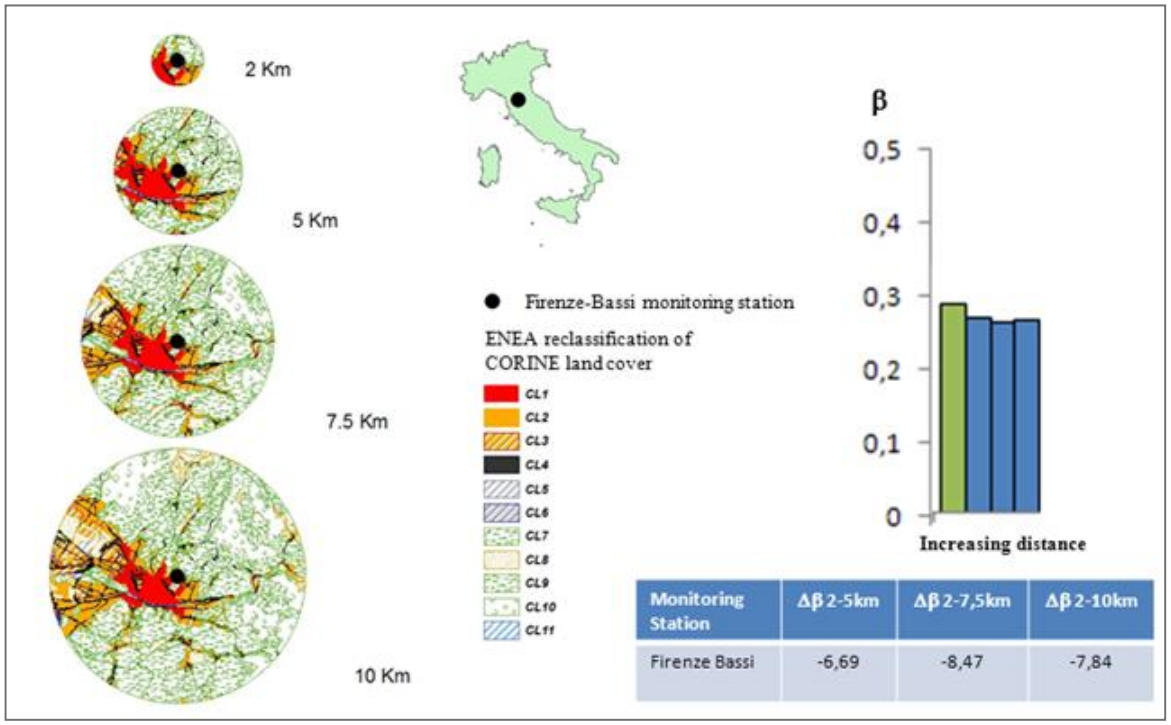
Performed by GIS

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

a_i → statistical optimization of the function $C(\beta)=n\beta 2+m\beta+q$, where C 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 β 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.



Monitoring Station	Δβ 2-5km	Δβ 2-7,5km	Δβ 2-10km
Firenze Bassi	-6,69	-8,47	-7,84

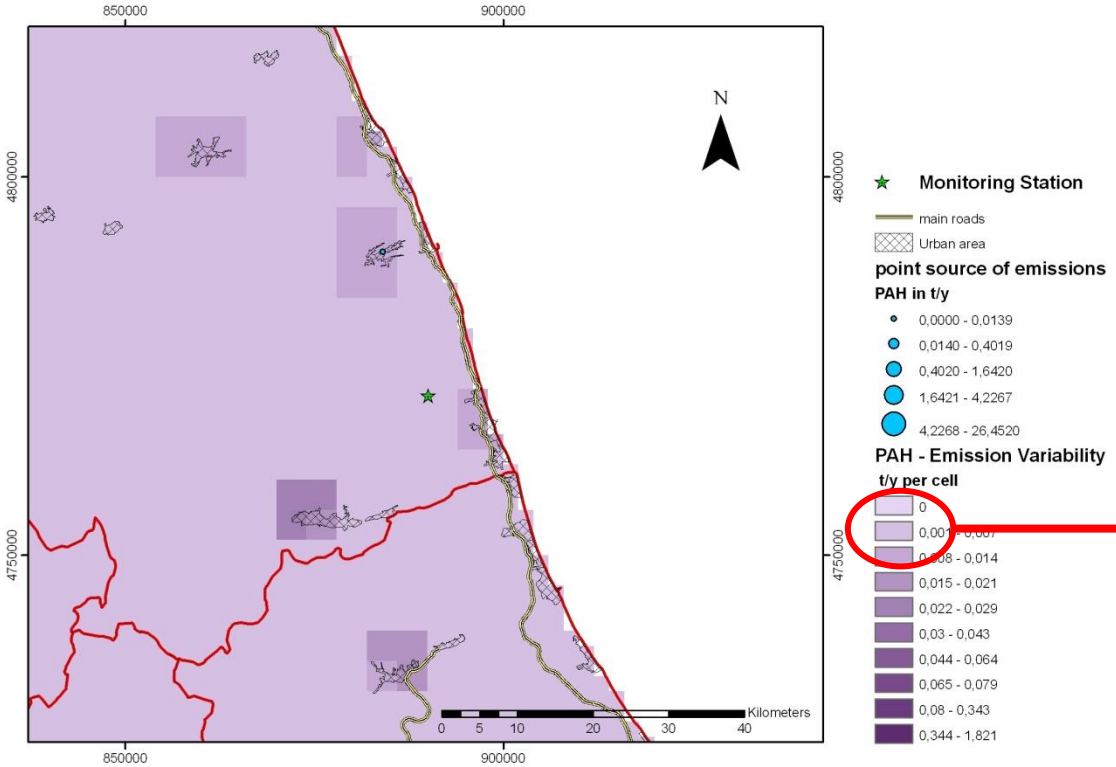
Each value of β is compared with the value in the 2 km radius buffer: a difference of less than 20% indicates that the station measurements is representative of the concentrations inside the buffer.

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 β.

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



Monitoring Station
main roads
Urban area
point source of emissions
PAH in t/y
0,0000 - 0,0139
0,0140 - 0,4019
0,4020 - 1,6420
1,6421 - 4,2267
4,2268 - 26,4520
PAH - Emission Variability
t/y per cell
0
0,001 - 0,007
0,008 - 0,014
0,015 - 0,021
0,022 - 0,029
0,03 - 0,043
0,044 - 0,064
0,065 - 0,079
0,08 - 0,343
0,344 - 1,821

low emission variability

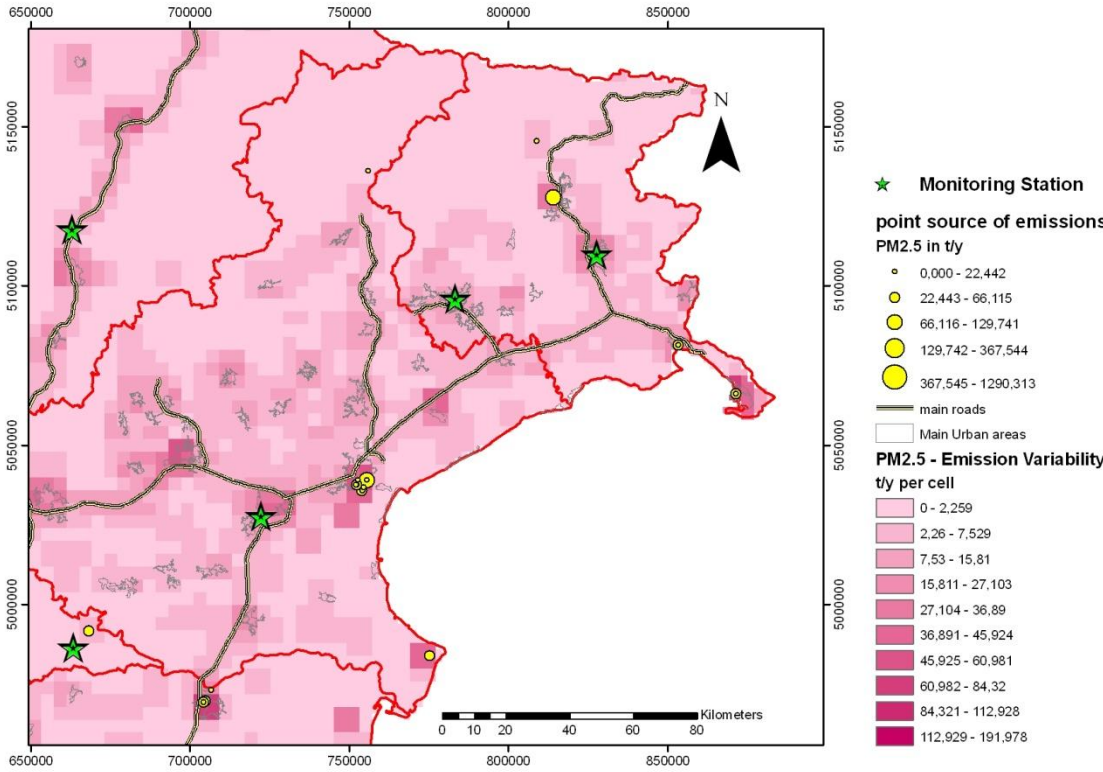
high spatial representativeness

Evaluation of 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.

METHOD 3: CONCENTRATION SIMILARITY

- ✓ 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.

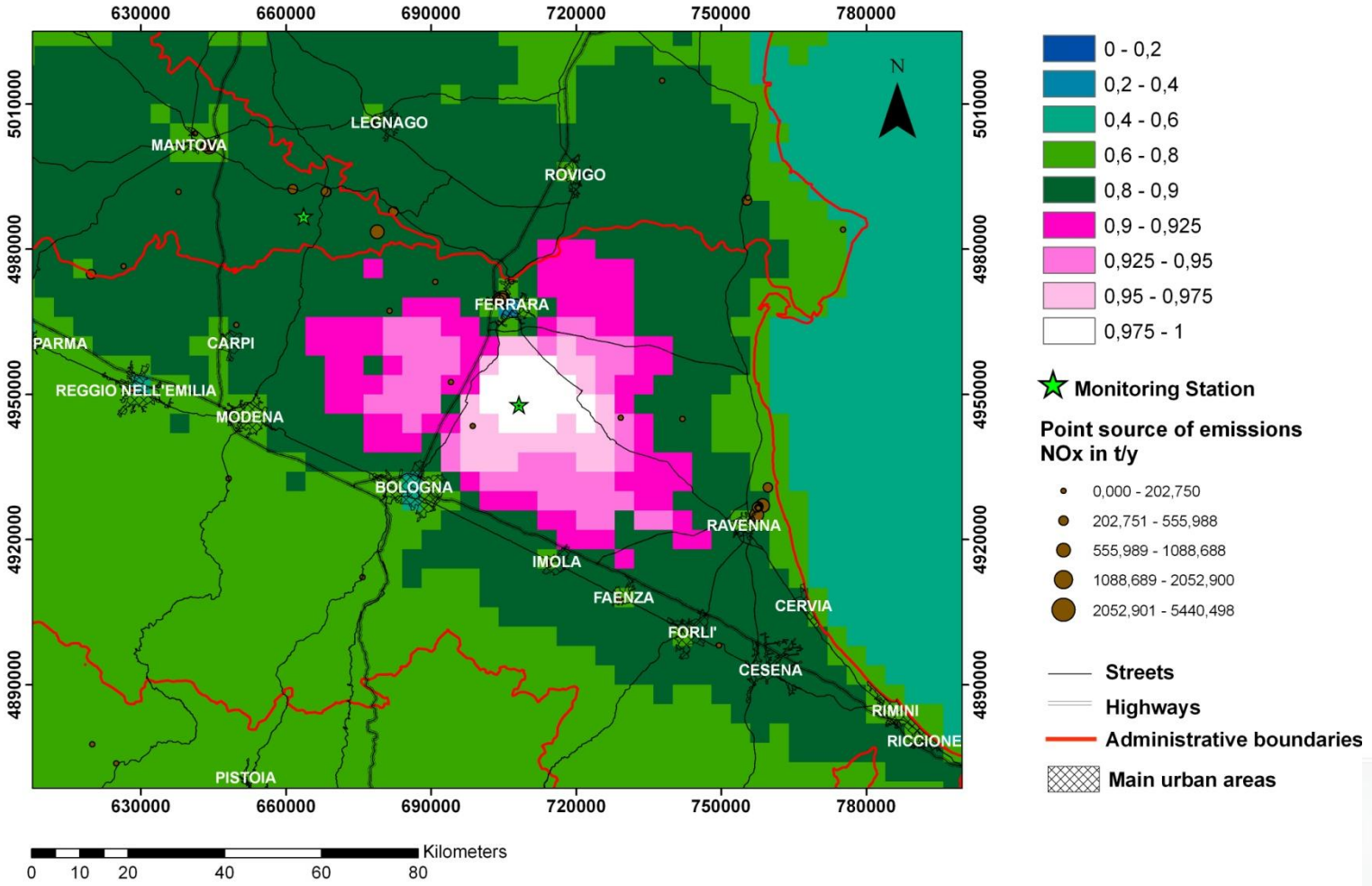
- ✓ At each time step, the difference between the concentrations modelled at the site of interest and at each grid point was calculated. A threshold value of 20% was set.

- ✓ Concentration fields from the MINNI model dataset is used.

- ✓ A 2-dimensional frequency function fsite(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. fsite(x,y) > 0.9 is verified).

Rural background station

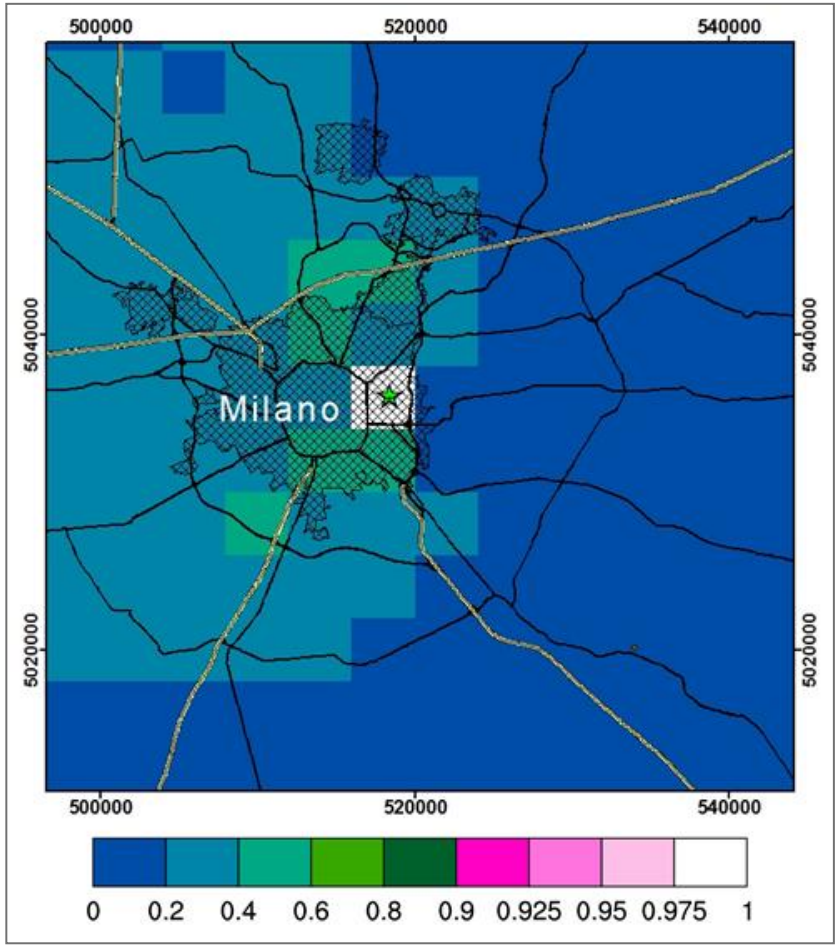
The monitoring station is representative of a wider area if all measurements in this area differ by less than 20% threshold from the station measurements more than 90% of the times (i.e. fsite(x,y) > 0.9 is verified).



Frequency function $f_{site}(x,y)$ for San Pietro Capofiume station.

Representativeness area is in pink and white.

Urban station



Frequency function $f_{site}(x,y)$ 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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