



# COMBINED USE OF EULERIAN AND LAGRANGIAN MODELLING FOR LOCAL SCALE SOURCE APPORTIONMENT

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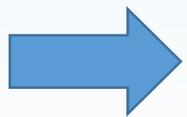
## Important polluting source:

is it the predominant driver of air quality levels in the surrounding area?



## Monitoring networks or campaigns:

- measured pollution includes also contributions from other sources
- sometimes they can lead to inconclusive or even misleading responses, even if receptor modelling is used



Apportionment with **source-oriented models**

## Two case studies on important **waste-to energy plants**

- **Focus:** evaluating the relative impact of stack emissions from the plants with respect to the rest of the surrounding polluting sources
- **Need:** modelling complex dynamics of dispersion and transformation of pollutants from multiple sources over local to regional domains
- **Choice:** combined use of two models, taking advantage of their respective strengths:

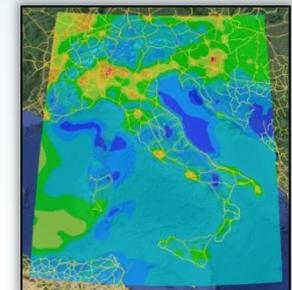
### **SPRAY**, Lagrangian particle dispersion model

- describes detailed dispersion patterns of plumes from individual sources and their footprint on the ground
- is able to model local scale phenomena: wind shear, breezes, orographic effects, calm winds with stagnation
- allows to easily and naturally separate the effects of different sources



### **FARM**, Eulerian chemical transport model

- can more easily consider all the emissions sources over a given area
- accounts for long-range transport from sources outside the computational domain
- models secondary pollution from chemical transformations of gases and particles



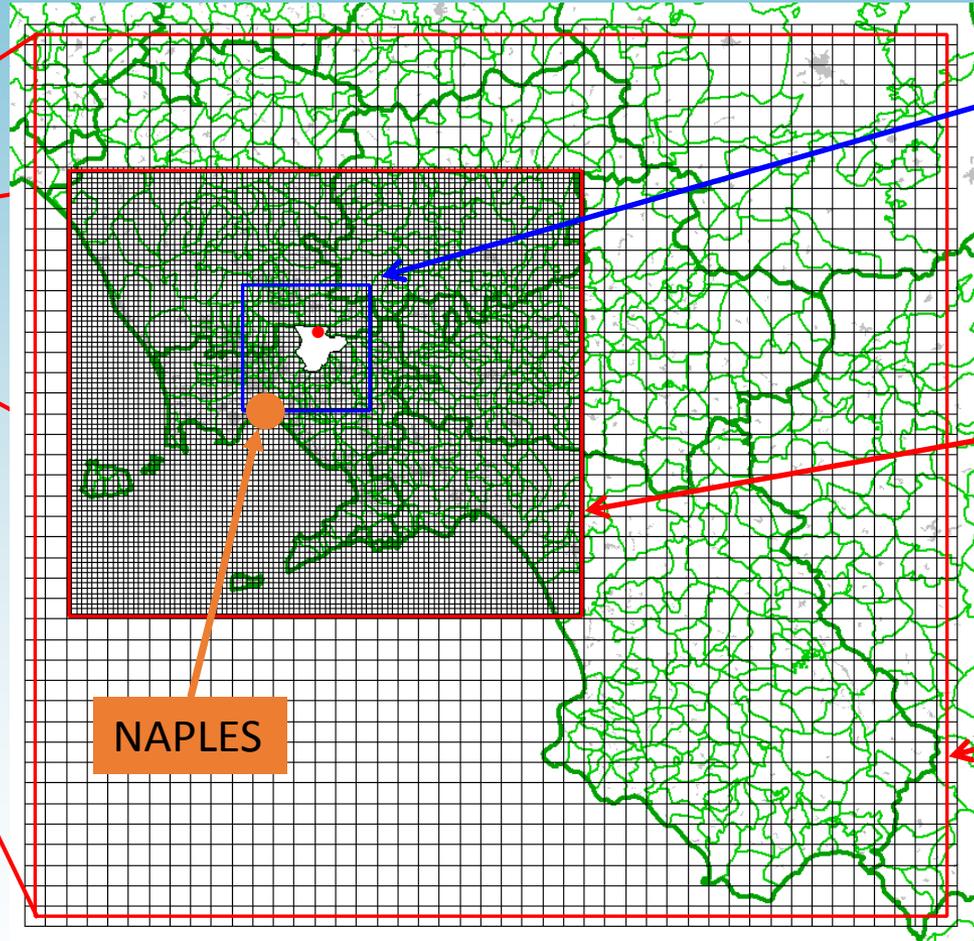
- 1) Yearly base-case simulations considering all the emission sources in the domains.
- 2) Validation against observed data.
- 3) Relative contributions from different sets of sources (e.g. road traffic, heating, ...) calculated with the ***brute force method*** (Koo *et al.*, 2009; Burr and Zhang, 2011):
  - a series of **FARM** simulations, separately varying the emissions from each source set and keeping constant all other model inputs;
  - subtraction of perturbed concentration maps from the base-case map, to obtain a set of variation maps;
  - estimate of the relative contribution due to each set of sources, calculated as the ratio between the variation obtained with the corresponding run and the sum of the variations from all runs.
- 4) Absolute contributions ( $\mu\text{g m}^{-3}$ ) calculated applying the relative contribution maps to the original base case-concentration maps.

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Koo B., Wilson G. M., Morris R. E., Dunker A. M., Yarwood G. (2009) Comparison of source apportionment and sensitivity analysis in a particulate matter air quality model. *Environmental Science and Technology*, **43**, 6669-6675.

Burr M. J., Zhang Y. (2011) Source apportionment of fine particulate matter over the Eastern U.S. Part I: source sensitivity simulations using CMAQ with the Brute Force method. *Atmospheric Pollution Research*, **2**, 300-317.

# Case study 1: Acerra



## SPRAY

Local domain  
Grid spacing: 250 m  
Size: 25x25 km<sup>2</sup>

## FARM

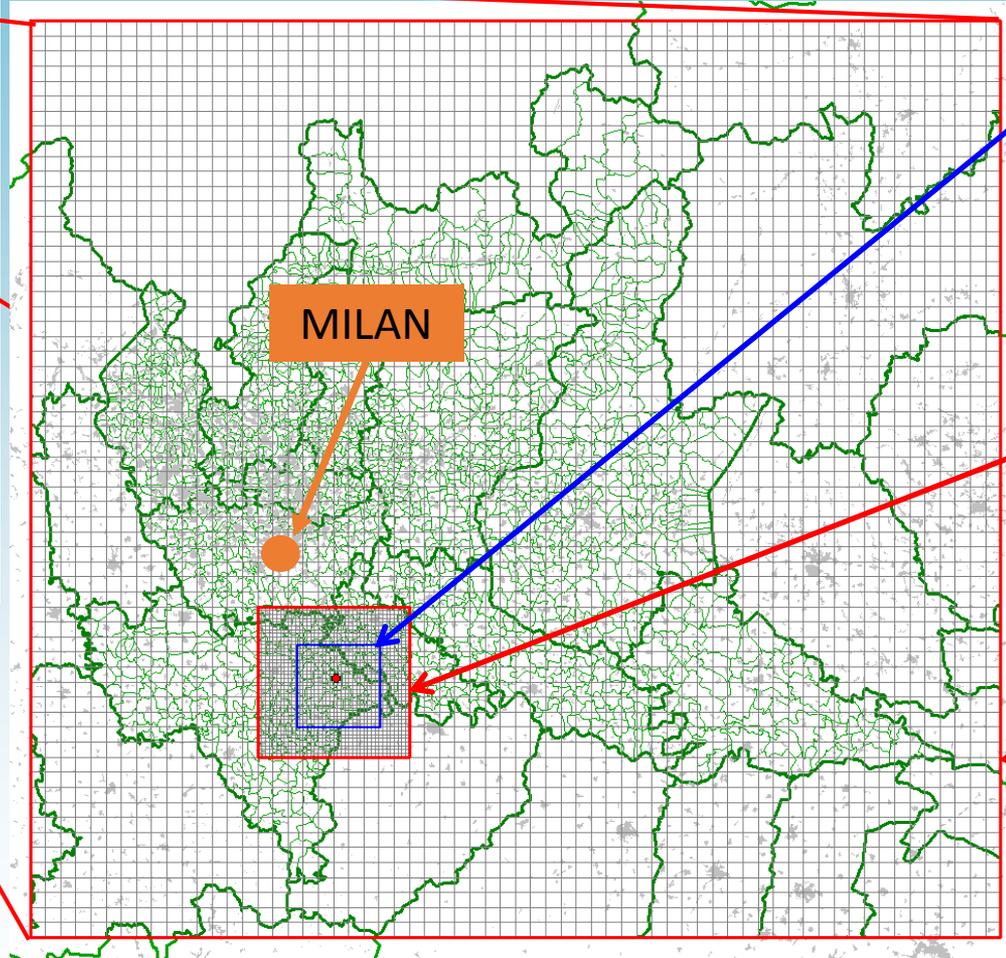
Intermediate domain  
Grid spacing: 1 km  
Size: 100x88 km<sup>2</sup>

## FARM

Regional domain  
Grid spacing: 4 km  
Size: 180x176 km<sup>2</sup>

NAPLES

# Case study 2: Corteolona



## SPRAY

Local domain  
Grid spacing: 200 m  
Size: 22x22 km<sup>2</sup>

## FARM

Intermediate domain  
Grid spacing: 1 km  
Size: 40x40 km<sup>2</sup>

## FARM

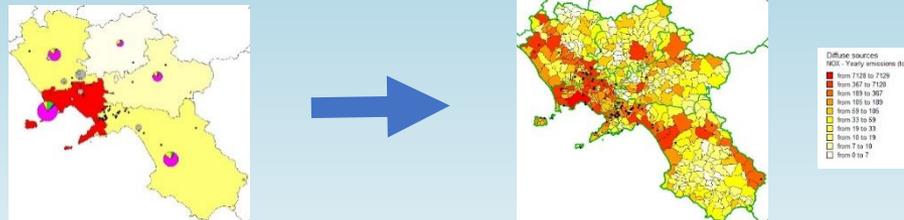
Regional domain  
Grid spacing: 4 km  
Size: 256x244 km<sup>2</sup>

Plant emission data:

- **continuous emission monitoring systems (CEMS)**

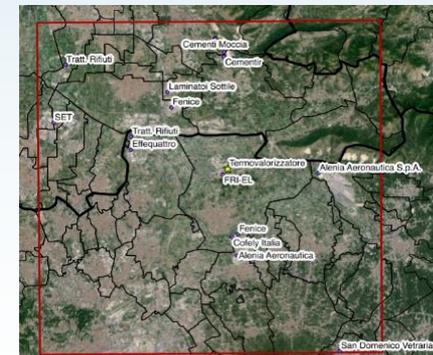
For all other sources, integration of local data to the most detailed inventory available:

- If necessary, downscaling provincial level inventory at municipal level by means of relevant proxy variables



- Updating existing data with information taken from public databases (ETS, E-PRTR, Integrated Environmental Authorisation - AIA)

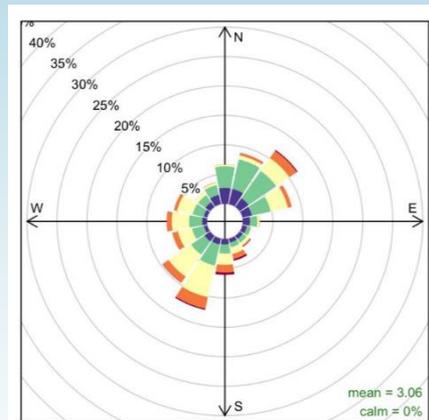
- Identifying and adding data for additional local sources



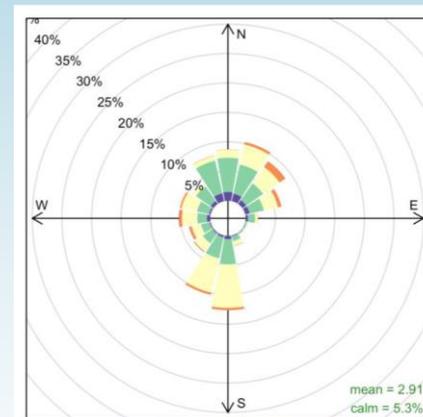
- Background hourly meteorological fields taken from the dataset of QualeAria operational forecast system, covering Italy at 12 km resolution ([www.aria-net.it/qualearia](http://www.aria-net.it/qualearia))
- Downscaling with SWIFT mass-consistent diagnostic model, using topography and land use data at higher resolution.

Comparison with ground observations: good reproduction of the local wind

## Grazzanise airport (Acerra)



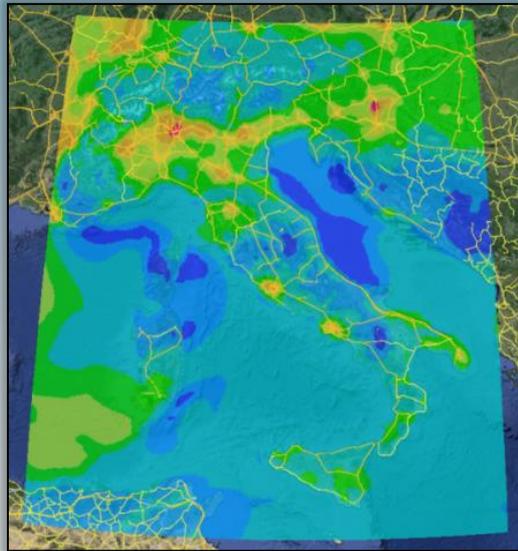
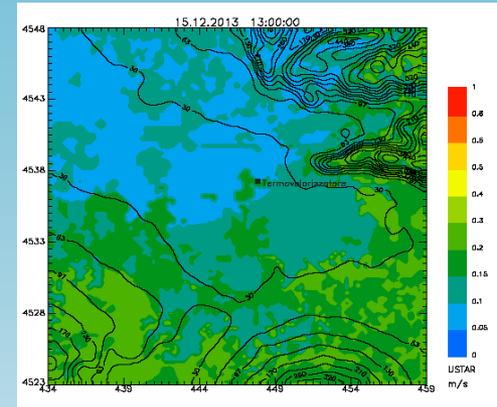
Modelled



Observed

Breeze phenomena in Acerra, synoptic circulation in Corteolona.

- SurfPro pre-processor was used to estimate
  - atmospheric turbulence scale parameters
  - dry deposition rates for **FARM** chemical species describing non-homogeneities induced by land use

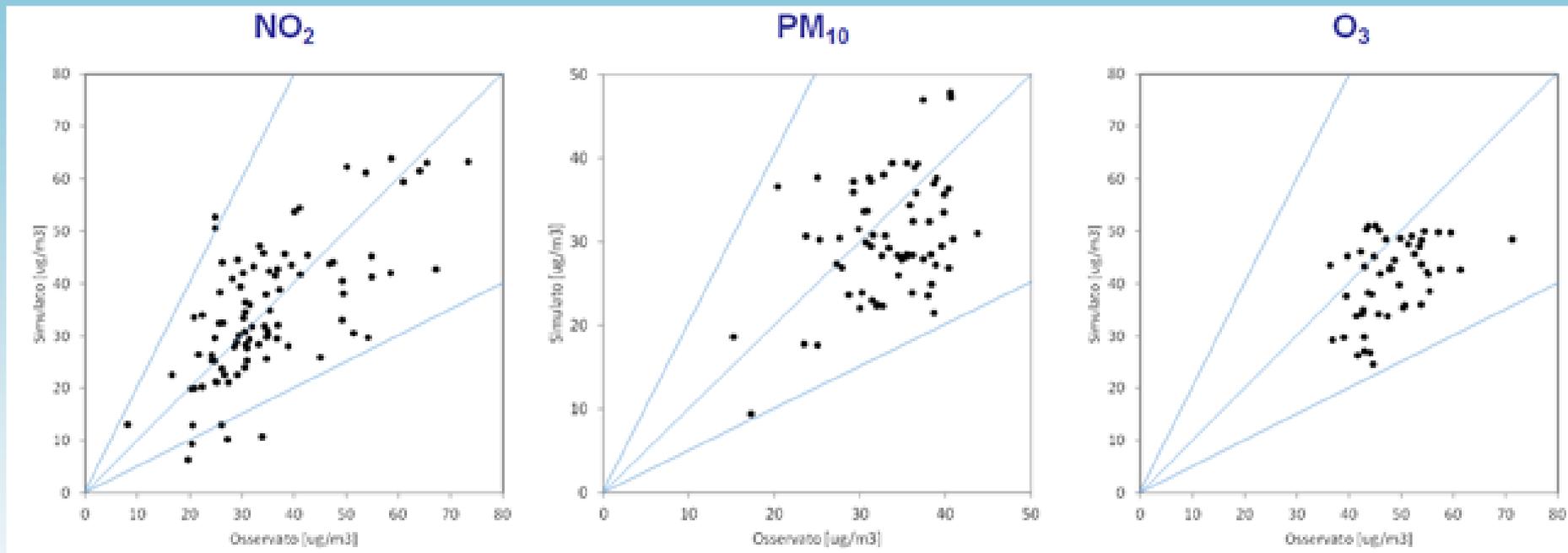


- Hourly boundary conditions for concentration fields were derived from national scale air quality simulations of the QualeAria system (also using **FARM**)

See also talk H18-041 – *D'Allura et al. QUALEARIA: EUROPEAN AND NATIONAL SCALE AIR QUALITY FORECAST SYSTEM PERFORMANCE EVALUATION*

- The **FARM** runs in reactive mode used the SAPRC99 chemical scheme: 121 gas phase reactions, AERO3 module for particulate matter

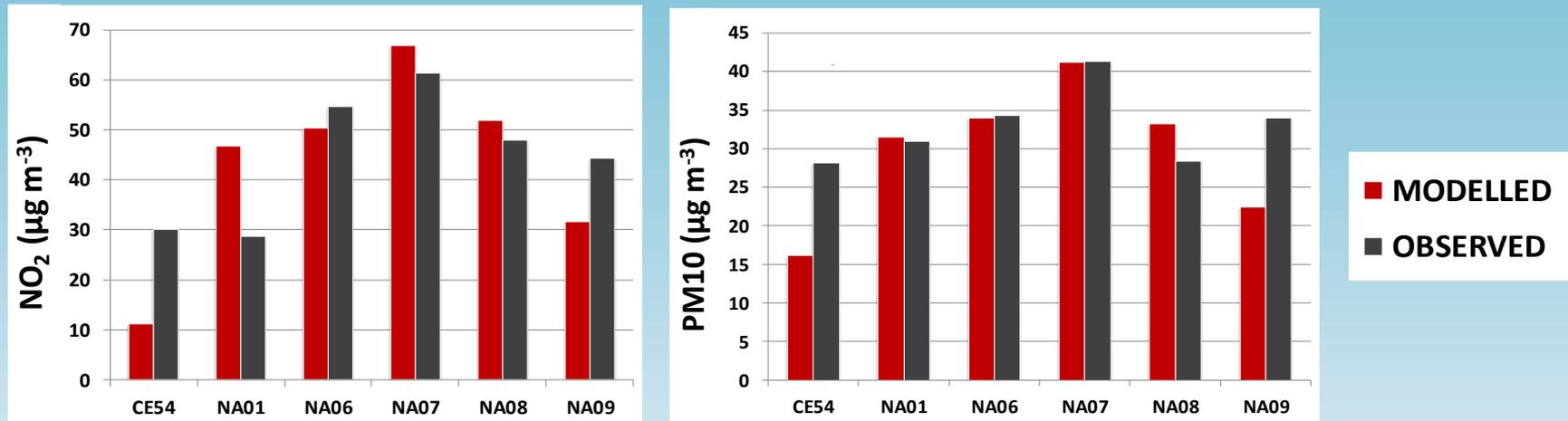
Corteolona base-case: **FARM** yearly run 1/1/2010 – 31/12/2010



*Annual average concentration values from the 4 km grid step simulation, compared to values measured by ARPA Lombardia regional monitoring network*

**Good agreement**

## Acerra base-case: FARM yearly run 1/6/2013 – 31/05/2014



*Annual average concentration values from the 1 km grid step simulation, compared to values measured by ARPA Campania regional monitoring network*

Underestimations probably due to unknown sources, such as uncontrolled fires.

An additional FARM exploratory simulation was performed, adding daily emission data from the "Fire inventory from NCAR" (FINN). From the results, it is reasonable to deduce that contribution of open fires to PM concentrations could be significant.



# Integration of Lagrangian and Eulerian modelling:

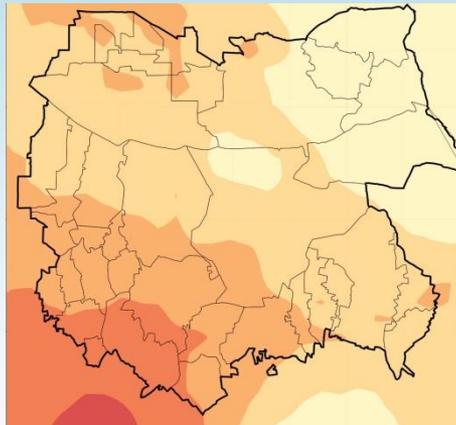
## PM10

Combination of **FARM** and **SPRAY** fields over the "local" domains:

- primary component of PM10 from local sources (the plant and, for Acerra, also from other industries, heating and road traffic) taken from **SPRAY** runs;
- secondary component of PM10 from local sources, and contribution from the remaining sources (primary and secondary component) taken from **FARM** runs.

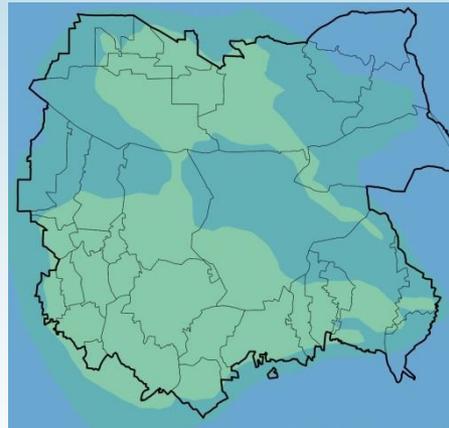
To separate primary and secondary components from local sources, fields calculated by additional **FARM** runs without chemistry were subtracted from the full chemistry fields.

**FARM**, Eulerian – 1 km resolution



PRIMARY + SECONDARY PM10,  
ALL SOURCES

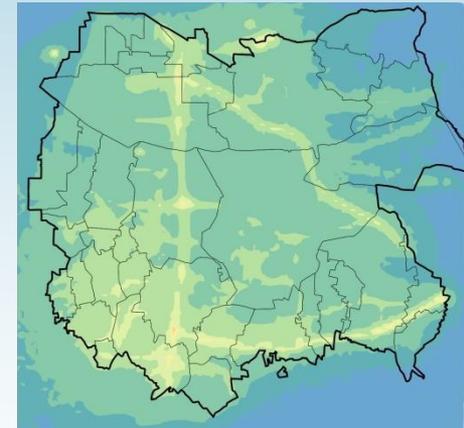
Full chemistry run



PRIMARY PM10,  
LOCAL SOURCES

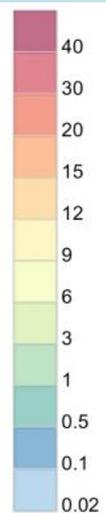
Run without chemistry

**SPRAY**, Lagrangian – 250 m resolution



PRIMARY PM10,  
LOCAL SOURCES

Non reactive



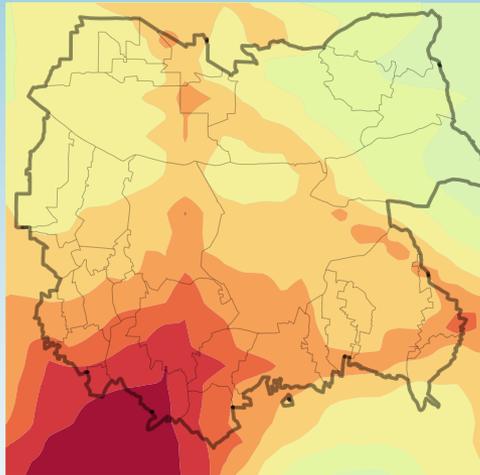
PM10  
 $\mu\text{g m}^{-3}$

## NO<sub>2</sub>

NO<sub>2</sub> concentrations from **SPRAY** runs were estimated from NO<sub>x</sub> applying the

$$\frac{\text{NO}_2}{\text{NO}+\text{NO}_2}$$

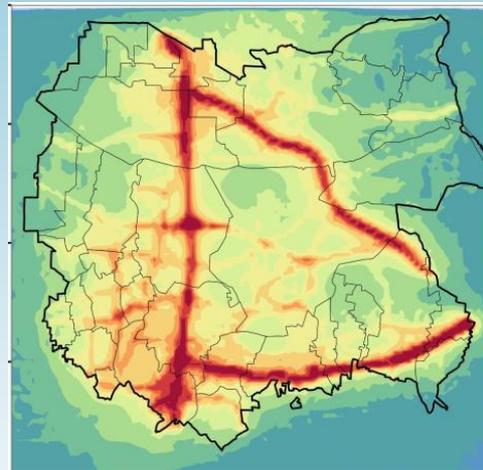
ratios derived from the corresponding reactive **FARM** run



**NO<sub>2</sub>**

**FARM**, Eulerian  
1 km resolution  
Full chemistry

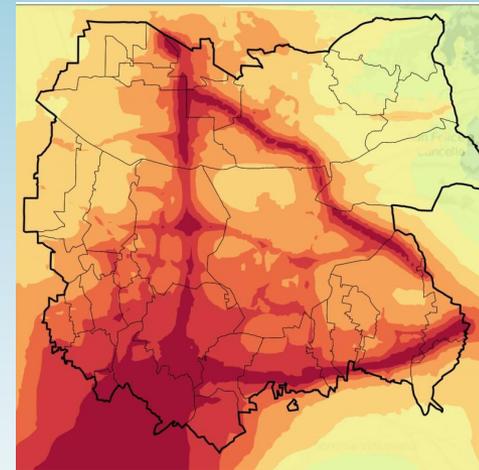
**ALL SOURCES**



**NO<sub>x</sub>**

**SPRAY**, Lagrangian  
250 m resolution  
Non reactive

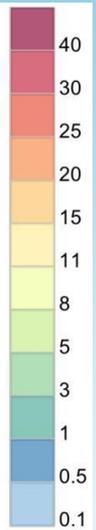
**LOCAL SOURCES**



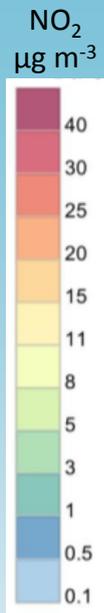
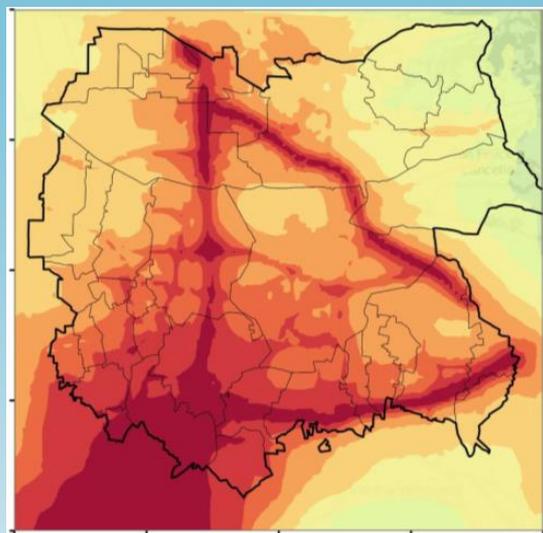
**NO<sub>2</sub>**

**SPRAY + FARM**

after subtraction of local  
sources contribution from  
**FARM** fields and NO<sub>x</sub> to NO<sub>2</sub>  
conversion of **SPRAY** fields



NO<sub>2</sub>  
µg m<sup>-3</sup>



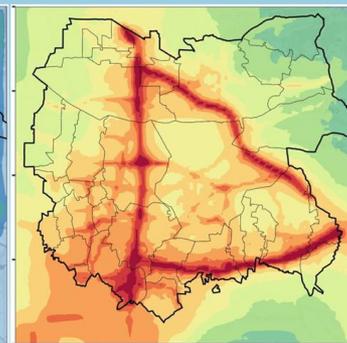
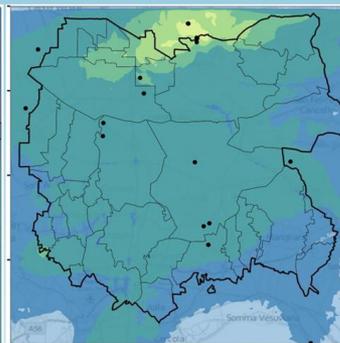
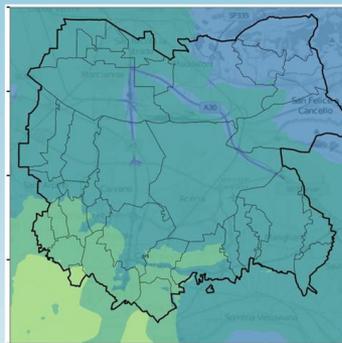
- Road traffic and the port of Naples dominate
- Heating emissions, other industries follow
- The incinerator has very small impact

**Total**

**Heating**

**Industry**

**Traffic**

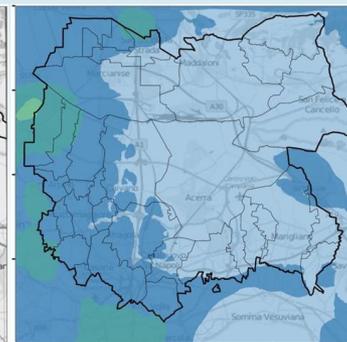
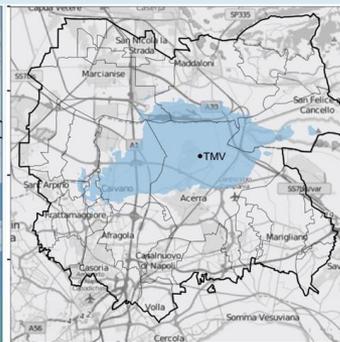
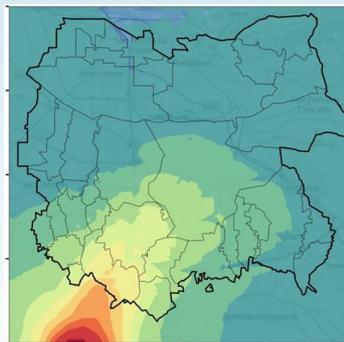


**Ports, airports**

**Agriculture**

**Incinerator**

**Other sources**



Similar results in the Corteolona study, although the predominance of traffic is less pronounced and agriculture also gives a non negligible contribution.

- The combined use of models resulted in a clear picture of:
  - footprint of the most important local sources (**Lagrangian model**)
  - influence of sources outside the high resolution domain (**Eulerian model**)
  - secondary components (**Eulerian model**)
- Such an integrated approach allows to better quantify relative and absolute contributions of sources in different parts of the investigated area
- Further uses of apportionment maps, that can benefit of the shown approach:
  - comparative assessment of future scenarios that can be defined through selection of emission sources
  - assessment of emission sectors on which reduction measures can be most effective
  - epidemiological studies investigating the possible impacts of each source set on the health of the population in the surrounding areas

- Acerra study **report** available: <http://ariasana.isafom.cnr.it/sites/default/files/ACERRA-16-5-2016.pdf>
- Another application with combined use of Lagrangian and Eulerian modelling: **HARMO18 poster 179**  
**A. Tanzarella et al. PERFORMANCE EVALUATION OF A MODELLING SYSTEM FOR AIR QUALITY FORECASTING AND AIR POLLUTION WARNING DURING PARTICULAR WINDY DAYS, IN A HIGHLY INDUSTRIALIZED AREA**  
Daily **FARM+SPRAY** air quality forecasts: <http://cloud.arpa.puglia.it/previsioniqualitadellaria/index.html>

## Report



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## Poster

**PERFORMANCE EVALUATION OF A MODELLING SYSTEM FOR AIR QUALITY FORECASTING AND AIR POLLUTION WARNING DURING PARTICULAR WINDY DAYS, IN A HIGHLY INDUSTRIALIZED AREA**

Annalisa Tanzarella<sup>1</sup>, Angela Morabito<sup>2</sup>, Elena Schipa<sup>3</sup>, Francesca Vitari<sup>4</sup>, Cecilia Menegotto<sup>5</sup>, Andrea Tatoi<sup>6</sup>, Tiziano Pastore<sup>7</sup>, Gianni Tinarelli<sup>8</sup>, Alessio D'Alagni<sup>9</sup>, Marco Paolo Costi<sup>10</sup>, Camillo Silibello<sup>11</sup>, Roberto Cini<sup>12</sup>

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This study evaluates the performance of a forecast modelling system of particular pollution events, named "windy days", due to the aeolian resuspensions of particulate matter from the mineral stockpiles of one of the largest steel plants in Europe located in Taranto (Southern Italy) industrial area. The modelling system is based on the meteorological prognostic model WRF and two dispersion models: the Eulerian photochemical model FARM and the Lagrangian particle model SPRAY. The system performs 72 hour air quality forecasts every day and produces concentration fields of main pollutants. SPRAY supplies the PM10 fields representing the contribution from the mineral stockyards, which are added to the background fields computed by FARM. The fugitive dust emission from the storage piles in the steelworks plant is dynamically modulated over time, depending on the wind speed, simulating the erosion caused by its action (EPA, 2006).

Figure 1: Diagram of the modeling system

Figure 2: Location of monitoring stations (a) and mineral storage areas (dark areas) simulated by SPRAY (b)

To evaluate the modelling system performance for the year 2016, the PM10 predictions are compared with the observations, measured in nine air quality monitoring stations located in the Taranto municipality, managed by ARPA Puglia. The locations of the stations are shown in Figure 2(a). Figure 2(b) also shows the locations of the 8 mineral stockyards areas. The total PM10 emissions considered for 2016 and related to the Taranto industrial area are almost 160 tons/year. 165 tons/year are the contribution from the aeolian algorithm and represent the 28% of the total industrial emission.

Figure 3: Scatter plot of observed vs. modelled PM10 concentrations for FARM (triangles) and FARM plus SPRAY (circles) for annual mean (a) and daily mean of windy days (b).

Figure 4: scatter plots of PM10 at 4 stations

Figure 5: PM10 concentration maps

PM10 - FARM during WD 2016, PM10 - SPRAY during WD 2016, TOT PM10 during WD 2016

PARAMETER	RANGE	FARM	FARM+SPRAY
PM10	10-15	0.50	0.62
PM10 (95%)	20-40	0.16	0.32
PM10 (5%)	10-15	0.88	0.91
PM10 (1-4%)	10-15	0.153	0.003
RMSE		10	40
MAE		2	12
BIAS		200	98
BIAS SCORE		14.0	15.1
RMSE SCORE		14.0	15.1
MAE SCORE		14.0	15.1
BIAS SCORE		14.0	15.1

Figure 5 shows the average concentration maps during the windy days produced by FARM, SPRAY and the sum of both models. Contributions due to the wind action over the stockyards are distributed mainly over the same yards, covering an area of 1 km radius. The assessment of forecast quality is also performed by computing statistical parameters and skill scores (Table 1). The configuration FARM+SPRAY systematically shows better results. The comparison of the skill scores for FARM model and FARM+SPRAY model confirms the better capability of the latter to reproduce the exceedance events during the windy days.



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