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

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Local scale source apportionment

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
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
**Chosen approach: brute force method**

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 (μg m⁻³) calculated applying the relative contribution maps to the original base case-concentration maps.


Case study 1: Acerra

- **SPRAY**
  - Local domain
  - Grid spacing: 250 m
  - Size: 25x25 km

- **FARM**
  - Intermediate domain
  - Grid spacing: 1 km
  - Size: 100x88 km

- **FARM**
  - Regional domain
  - Grid spacing: 4 km
  - Size: 180x176 km

**NAPLES**

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Case study 2: Corteolona

SPRAY
Local domain
Grid spacing: 200 m
Size: 22x22 km²

FARM
Intermediate domain
Grid spacing: 1 km
Size: 40x40 km²

FARM
Regional domain
Grid spacing: 4 km
Size: 256x244 km²

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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)
• 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 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.
**Cortelona 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**
Validation against observed data - II

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

![Graphs showing NO2 and PM10 concentrations](image)

*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.

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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.
Integration of Lagrangian and Eulerian modelling: NO$_2$

NO$_2$ concentrations from SPRAY runs were estimated from NO$_X$ applying the

\[
\frac{\text{NO}_2}{\text{NO} + \text{NO}_2}
\]

ratios derived from the corresponding reactive FARM run.
Source apportionment results - Acerra

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

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

• 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
Further information


- 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](http://cloud.arpa.puglia.it/previsioniqualitadellaria/index.html)

Report

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Poster

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THANK YOU FOR YOUR ATTENTION

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