PM SOURCE APPORTIONMENT ANALYSIS

IN THE VENETIAN AREA

S. Pillon[1], F. Dalan[1], F. Liguori[1], and G. Maffeis[2]

[1] ARPAV - Environmental Protection Agency of the Veneto Region, Via Lissa, 30171 Mestre (VE), Italy

fliguori(at)arpa.veneto.it

[2] TerrAria s.r.l., Via Zarotto 6, 20124 Milano, Italy

g.maffeis(at)terraria.com

HARMO 12 Conference

International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes

Cavtat, Croatia, October 6th-9th, 2008

Aim

Investigate Particular Matter (PM10) source apportionment on the wide urban area of Venice and its mainland

Methodology

A multi-scenario approach applied on a CALMET-CAMx System

Nested grid structure to separate local contributions from those of middle and long range transports.

Background

Assessment of Model Uncertainty using measurements of PM10 and chemical speciation of filters

The scene

The Modelling system

… already described in previous Harmo conferences, together with Sensitivity and Uncertainty Analysis applied on 1 year run and on contemporary concentration and deposition measurements

Benassi A. et al., 2007
The Veneto region modelling system for air quality assessment
11th Harmo

Dalan F. et al., 2005
Validation and source apportionment analyses of CAMx model over the Veneto Region and Venice Lagoon
10th Harmo

Initial & Boundary Conditions

CHIMERE

PREVAIR, Laplace Institute,INERIS, LISA, C.N.R.S.

output of 0.5x0.5 degrees

Initial : 3D variable in space

Boundary: function of (z, t) for the four borders;

top: one constant value for each specie

Meteorology

CALMET (version 5.5)

temperature field, horizontal wind (u, v), vertical diffusivity

+

interpolation of radio-soundings data

pressure and water vapour concentration

CTM

CAMx (version 4.0)

CBIV

landuse and albedo: **CORINE LAND-COVER** (250m x 250m);

haze (**AErosol RObotic NETwork - NASA**);

ozone column (**TOMS - NASA**);

photolysis rate.

Gridded emissions

+

Mayor Point Source

Emission Inventory

Top-Down: CORINAIR National Inventory (APAT) for all sources

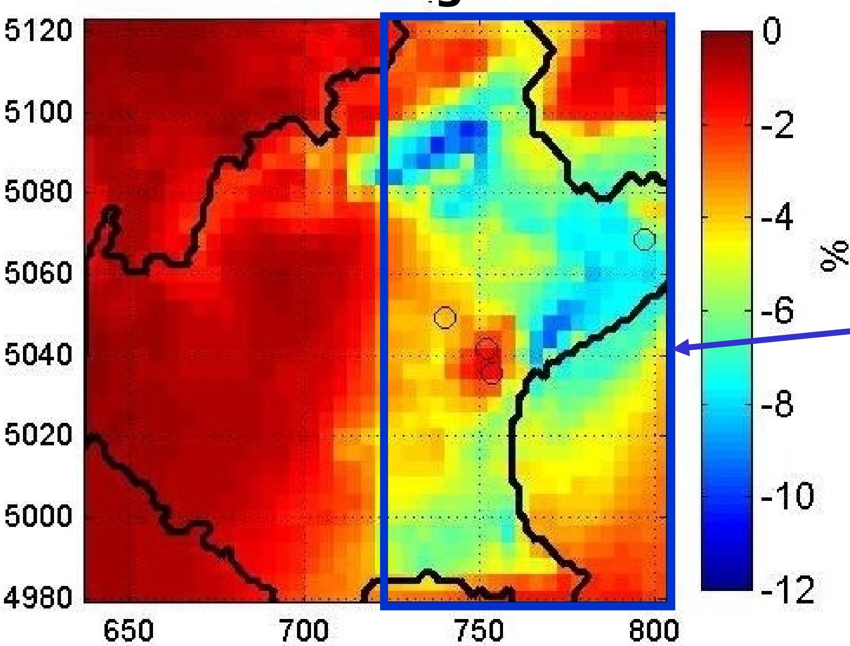
Bottom Up: source sectors 1, 3, 4, 6, 7, 8 (SNAP '97)

The Modelling Approach

Estimation of different emission sectors contribution to PM10 concentrations through:

- scenarios runs with 50% emission reduction for each sector one by one
- calculation of the changes in pollutant concentrations resulting from the perturbations

4x4 km² master grid



50% reduction scenarios in order to minimize non–linear effect due to drastic changes in atmospheric composition and reactivity

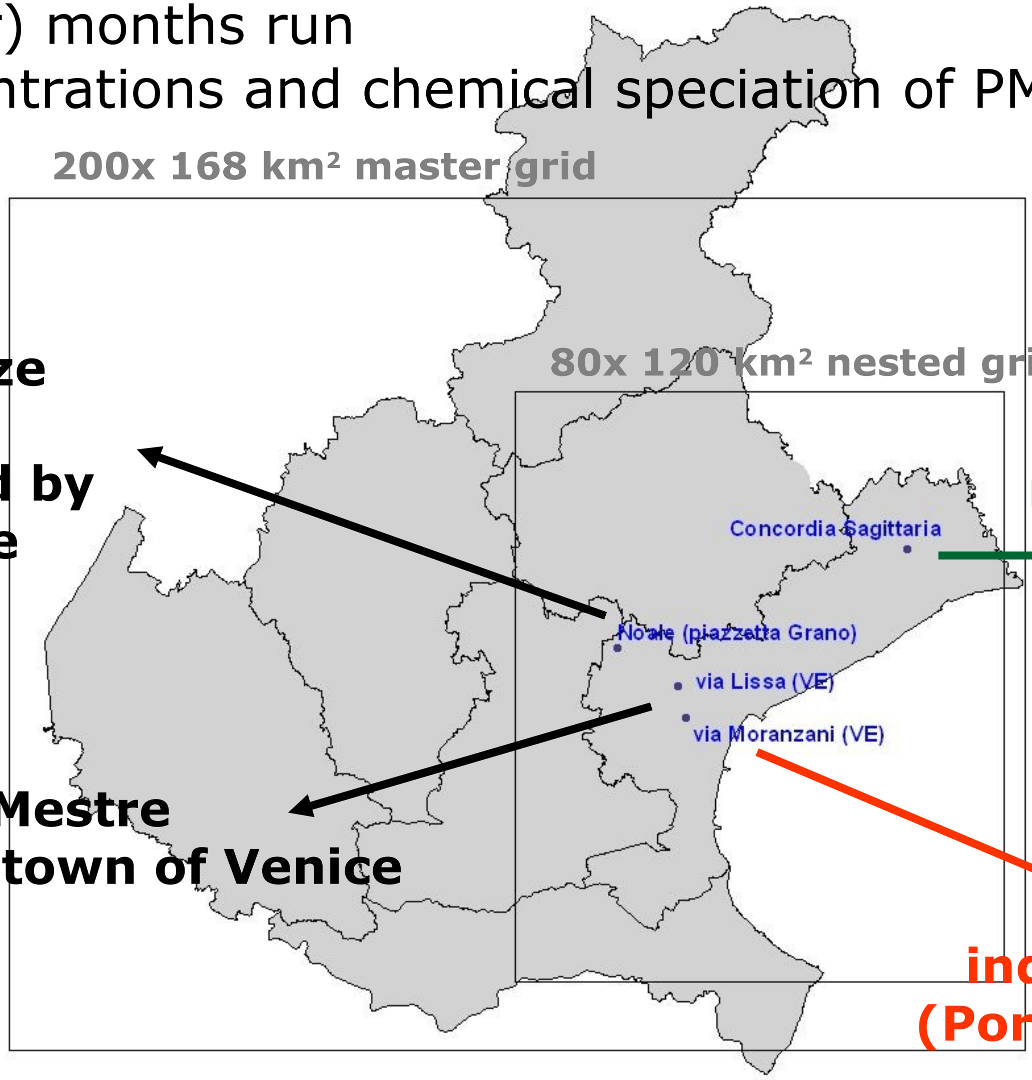
1x1 km² nested grid

Reductions applied only on the ***nested grid*** *in order to separate local contributions (generated in the nested area) from middle and long range pollution transports*

“Brute-force” method, PSAT not avaible for CAMx ver. 4.0

Check of the baseline scenario

a 2 (winter) months run
daily concentrations and chemical speciation of PM10 in 4 sites:



a kerbside in a mid-size town surrounded by countryside

rural background site

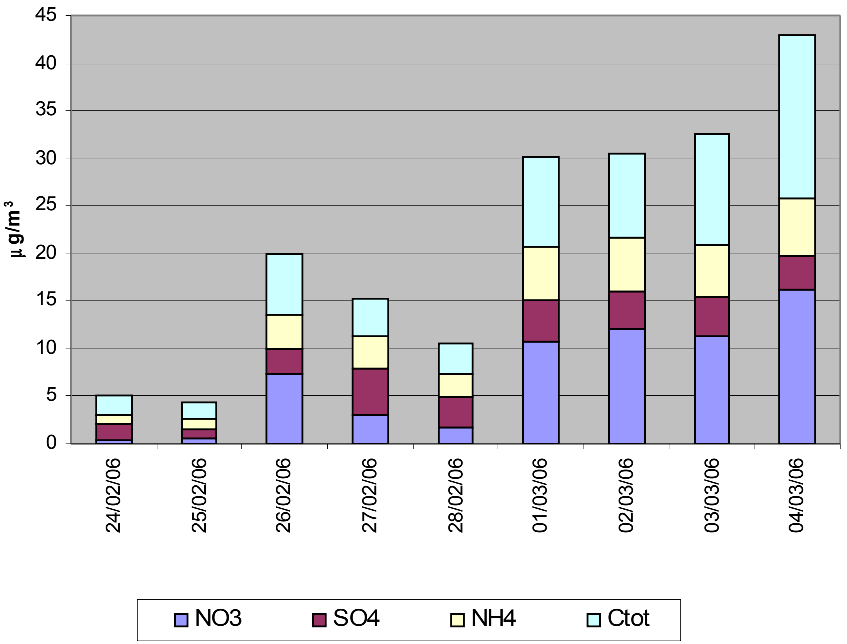
urban site in Mestre the mainland town of Venice

industrial site (Porto Marghera)

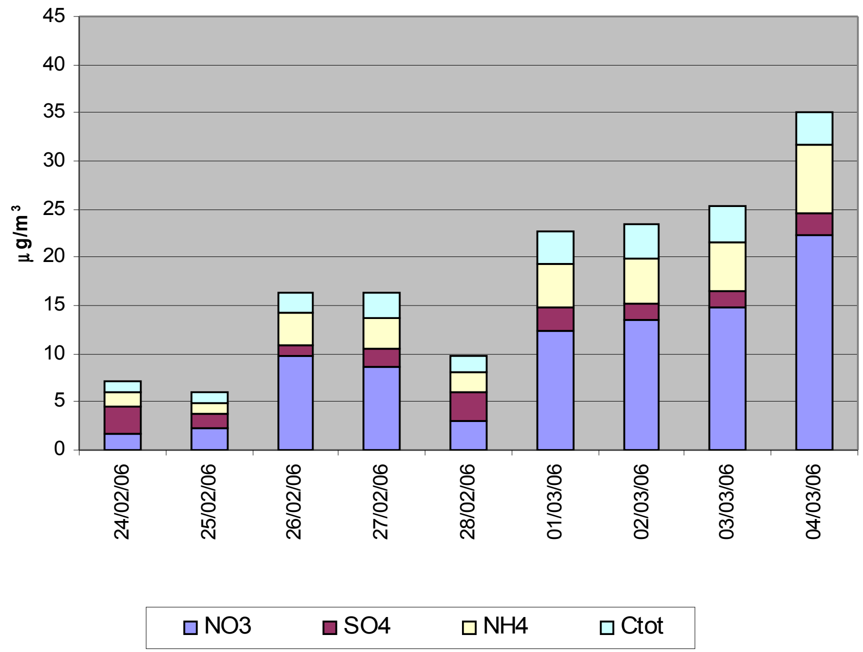
Check of the baseline scenario

Daily measured and modelled PM10 components in the rural site from low PM10 pollution thanks to a thunderstorm to high PM10 build-up concentrations before next thunderstorm arrival.
The model reproduces the inorganic aerosols growth (only SO4 slighty underestimated),
but cannot capture the growth of the total carbon component.

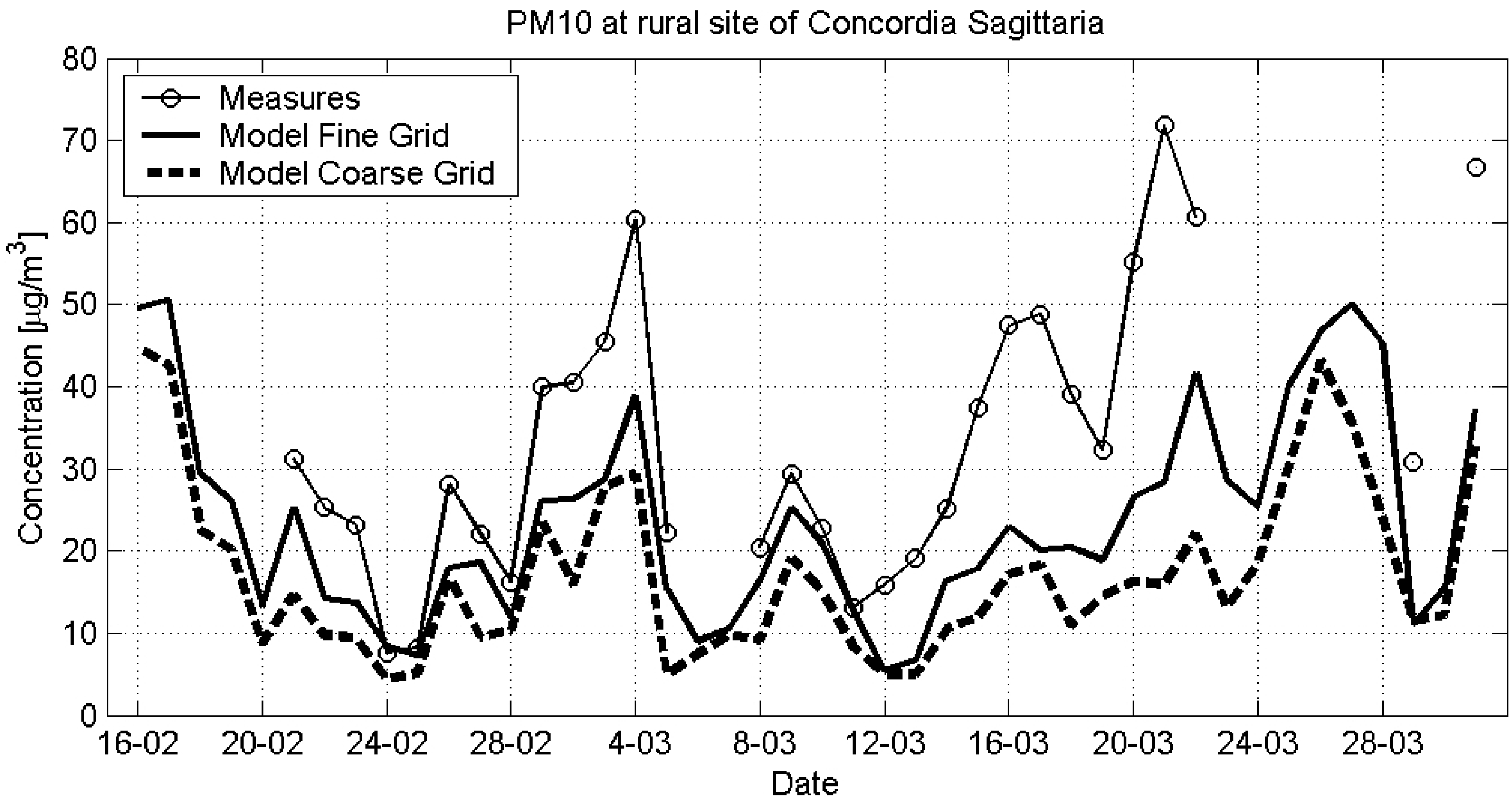
Rural site – inorganics observed



Rural site – inorganics modelled



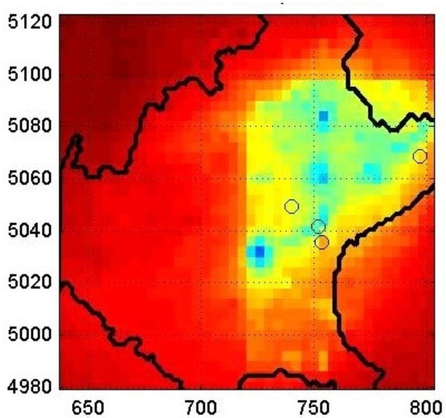
Only PM10 components presents both in measurements and in model outputs are shown.



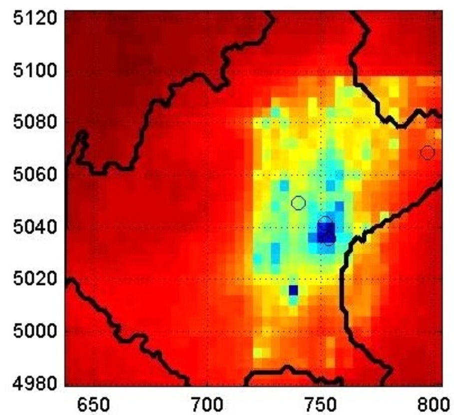
A fine resolution run (nest-grid output - 1x1 km² resolution) improves the model estimate compared to a coarse grid one (master grid output - 4x4 km² resolution).

The Outcome 1/2

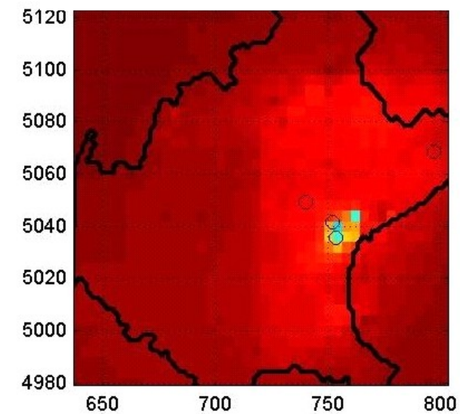
Road Transport



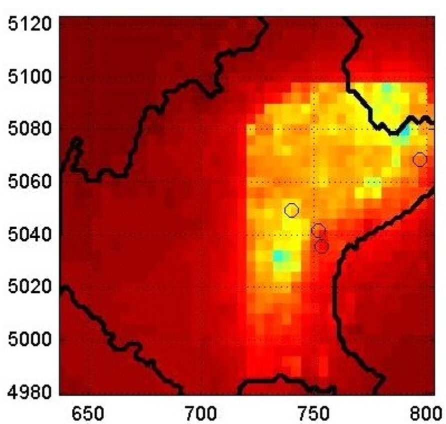
Industrial Plants

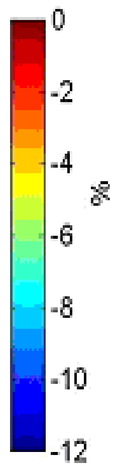


Other transports



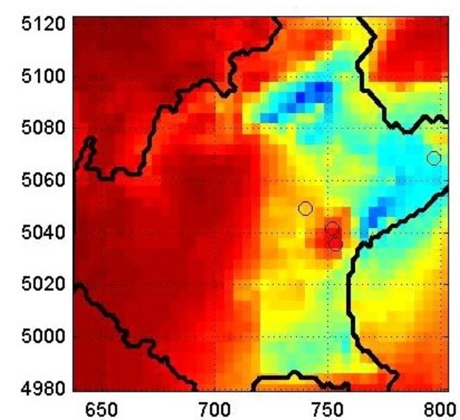
Domestic Heating





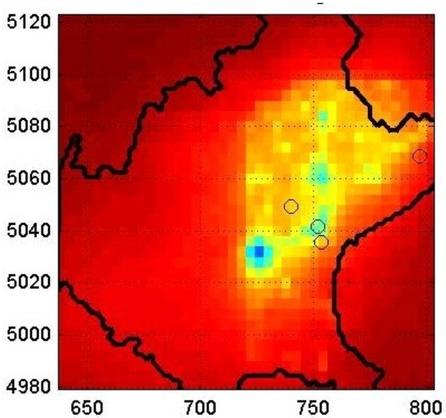
relative (%) reductions of average PM10 of the 2-months period for the 5 reduction scenarios

Agricolture

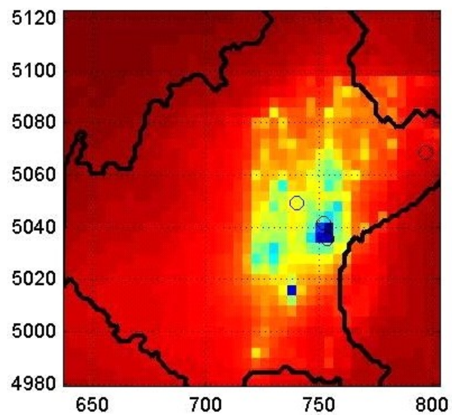


The Outcome 2/2

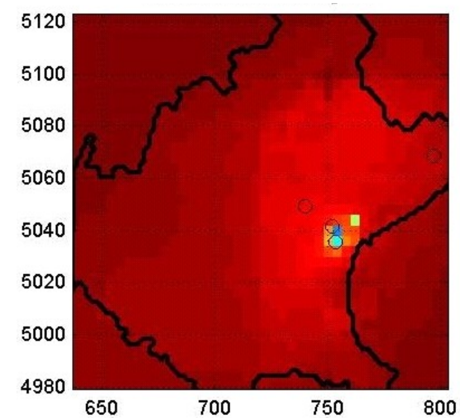
Road Transport



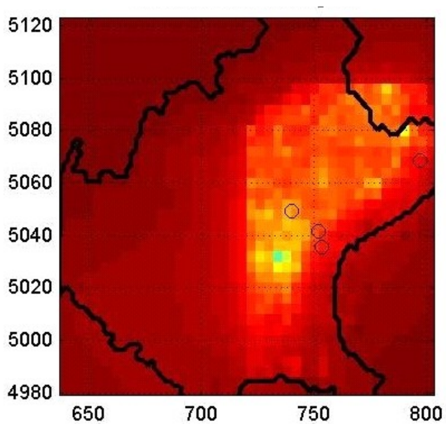
Industrial Plants

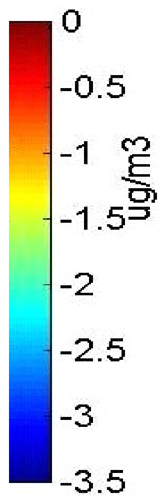


Other transports



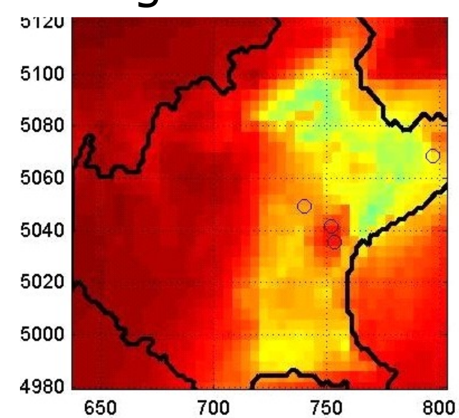
Domestic Heating





The reductions vary from a few tenths to a few units of ug/m^3 of PM10

Agricolture



The average PM10 level estimated by the model is around 17 μg/m3 at the rural site and between 27 and 31 μg/m3 in the other sites arpav

2 different results:

TerrAria s.r.l.

- Estimation of **L**ocal **A**nthropogenic **E**mission **C**ontribution (LAEC) to PM10 concentrations

$$LAEC = 2 * \sum^{5}_{i} \Delta\ sector_i$$

Since:

- scenario reductions applied = 50% of the sector's emission
- 5 scenarios = include all anthropogenic sources

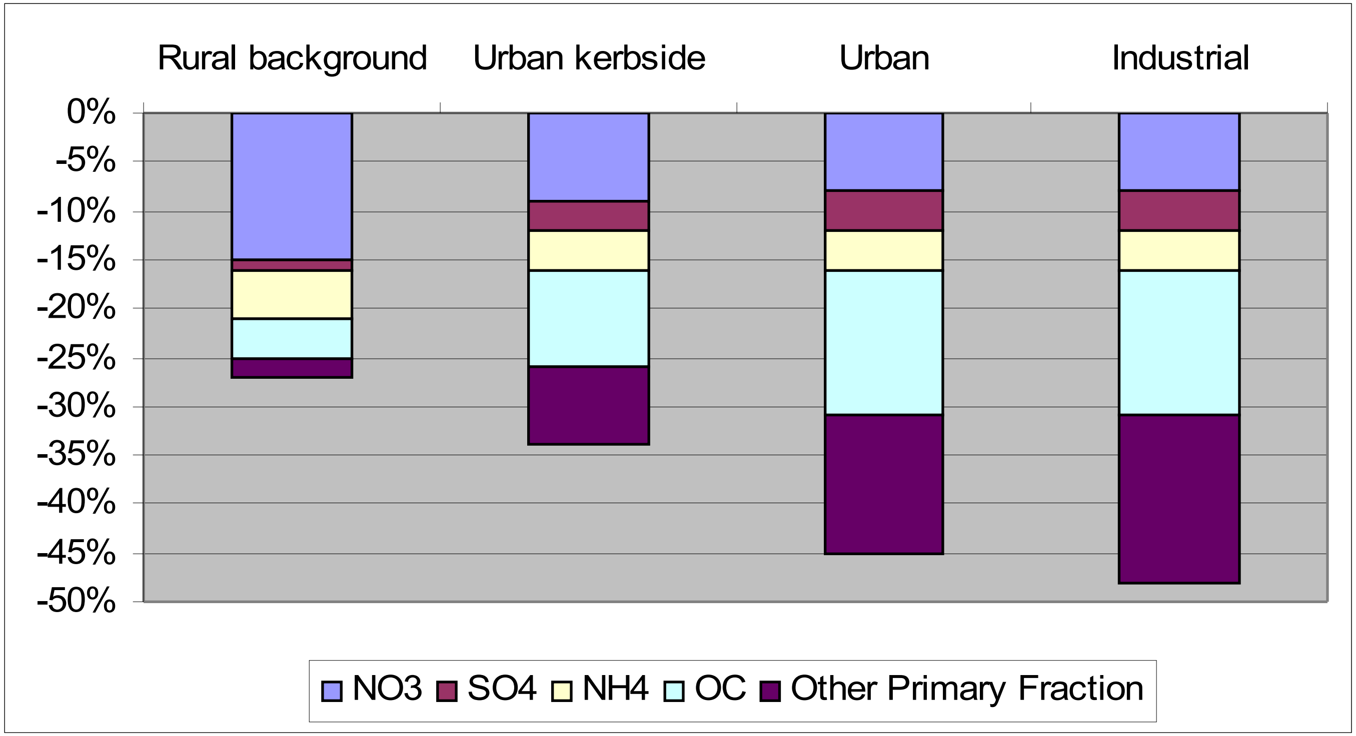
(in the hypothesis that the emission perturbations had not changed significantly the atmospheric composition and reactivity)

2. Source Apportionment (SA) of the different emission sectors to the locally produced PM10

(at least for the primary and the secondary inorganic PM10 components for which the modelling system shows an acceptable level of confidence)

First result

Local emission contributions to PM10 concentrations, divided in the different PM10 components, for the 4 sites

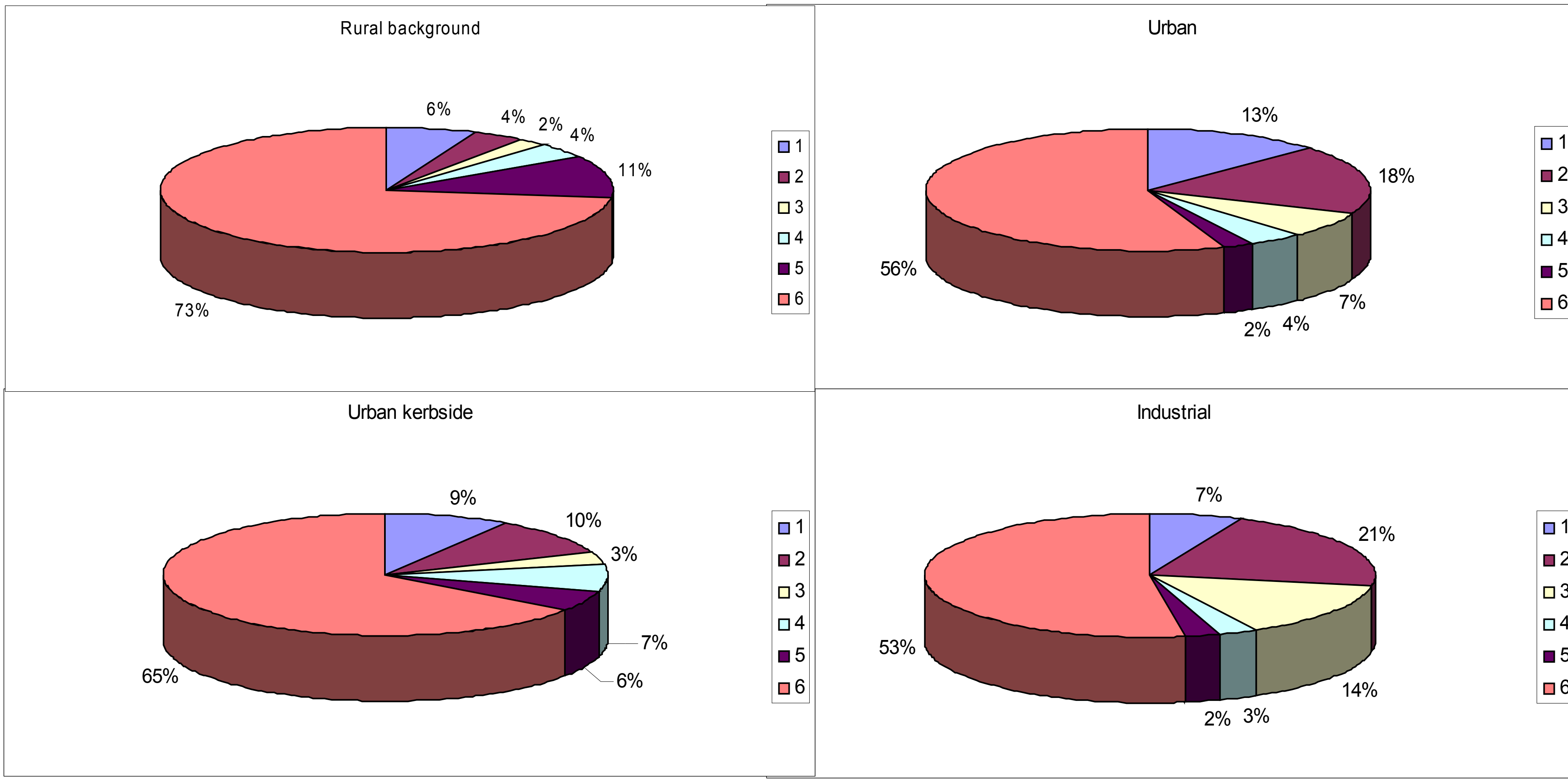


The local contribution is minimum in the rural site (less then 30%) and maximum in the industrial one (more then 45%)

$$2 * \sum_{i}^{5} \Delta \text{ sector}_i / \text{PM10}\_\text{baseline}$$

Second result

SA for total PM10 concentration levels

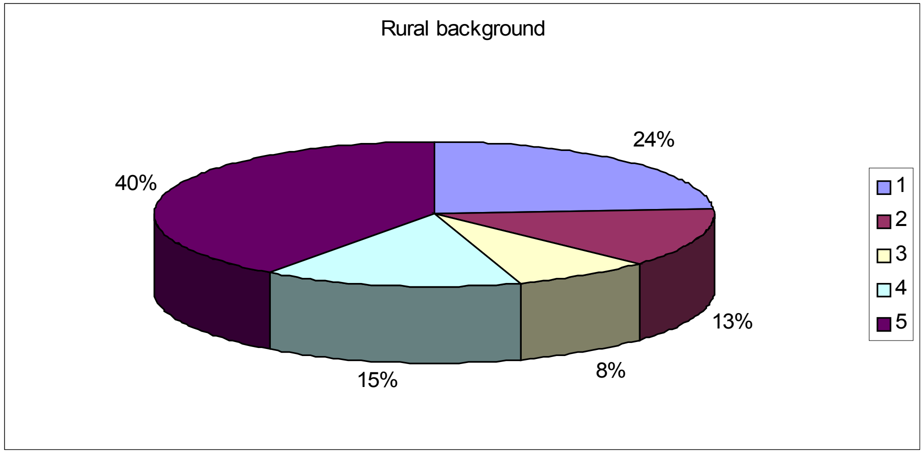


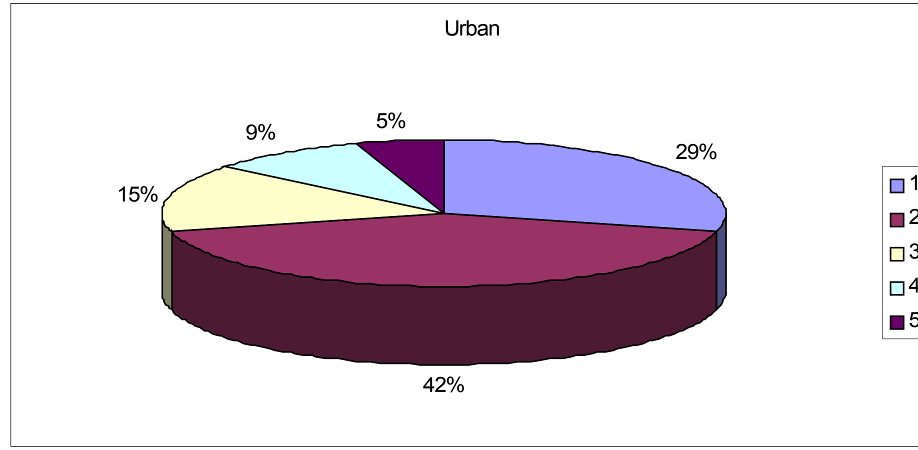
1=Road Transports 2=Industrial Plants 3=Other Transports 4=Domestic Heating 5=Agriculture 6=Extra domain contributions

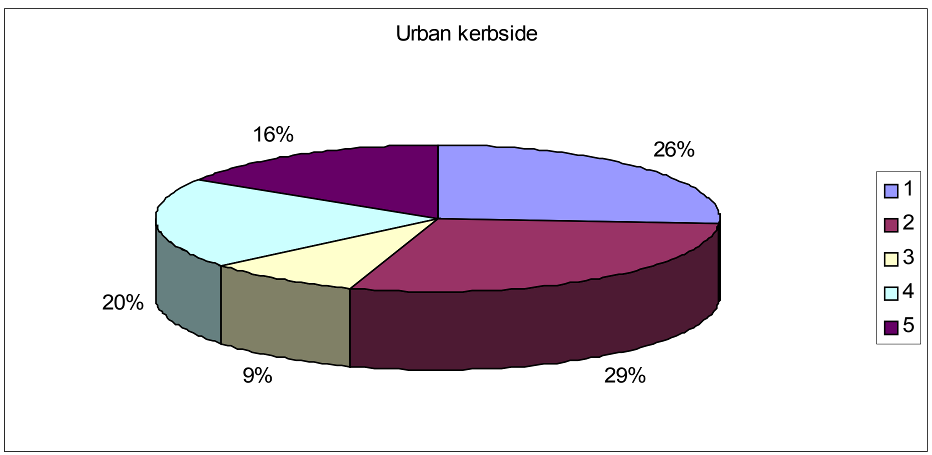
The source apportionment depends on the location of the site

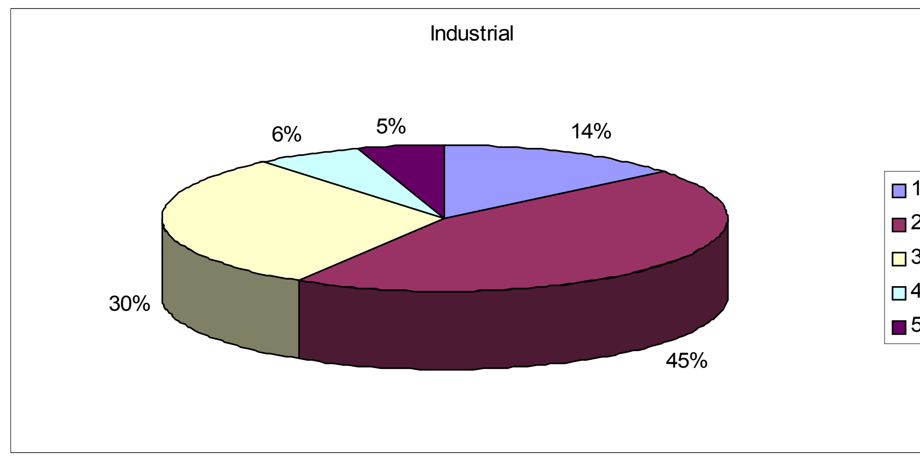
Second result

SA for locally produced PM10 concentrations







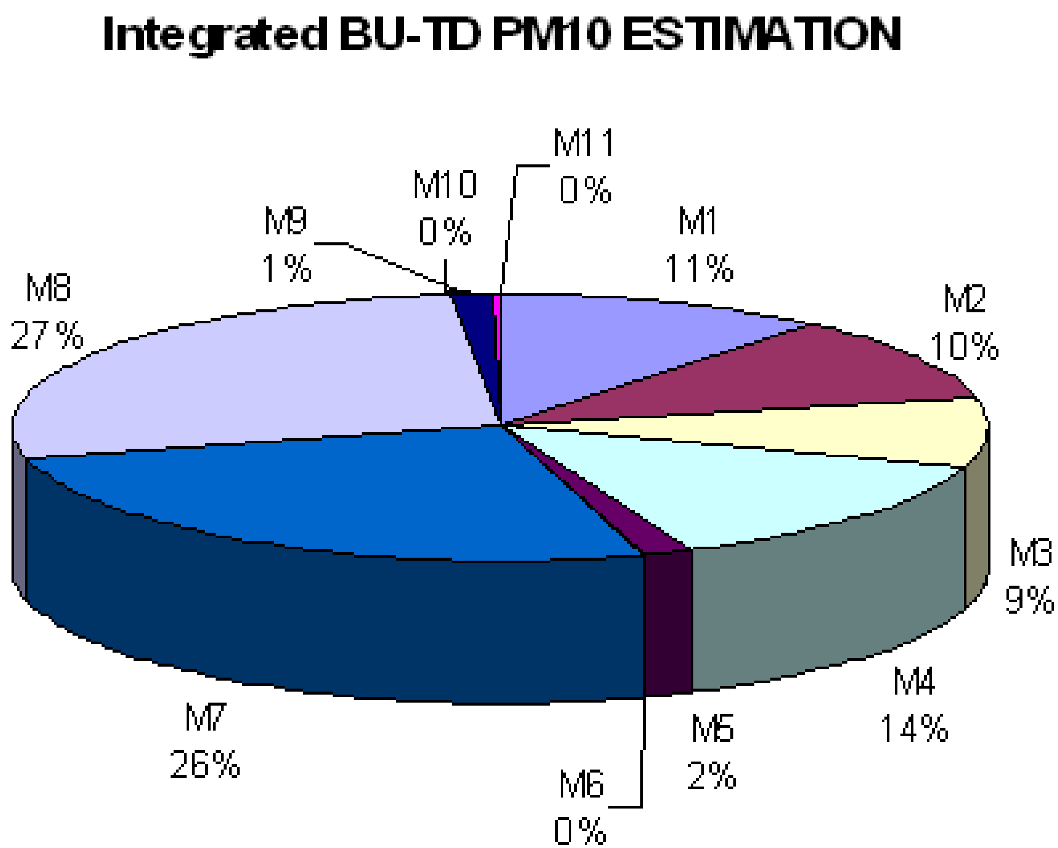


1=Road Transports 2=Industrial Plants 3=Other Transports 4=Domestic Heating 5=Agriculture

The source apportionment depends on the location of the site

From emissions to concentrations

Emissions



M1+M3+M4+M5+M6 = 26%

Concentrations

M1+M3+M4+M5+M6

Urban (Mestre): 41%
Industrial Site: 44%
Rural Background: 13%

M2

Urban (Mestre): 9%
Industrial site: 6%
Rural background: 15%

M7

Urban (Mestre): 29%
Industrial site: 14%
Rural background: 21%

Conclusions

(of general interest)

• daily mean measures of PM10 concentrations are well reproduced by the modelling system for *clean* days, but model underestimates PM10 levels in the days with stagnant air conditions and the underestimation becomes stronger as the stagnant conditions persist;

• secondary inorganic aerosol production proved to be well described by the model; organic aerosol is underestimated;

• the changes in PM10 concentrations resulting from the emission source perturbations are always less severe then the source perturbation itself. Inorganic secondary components of the aerosol are more resilient then primary ones; however the reduction of the local anthropogenic primary aerosol is not sufficient to turn down significantly PM10 concentration levels.

Conclusions

(of local interest)

- the average PM10 level estimated by the model is around 17 µg/m3 at the rural site and between 27 and 31 µg/m3 in the other sites. The average scenarios impact vary between few tenths to few units of micrograms per cubic metre;

- the local emissions contribution to the PM10 varies between 30 and 50% (but the model captures only part of PM in the area under investigation, which, at worst, is about half of the measured value);

- a Source Apportionment analysis has been performed by calculating the differences in concentrations of each scenario and the base case. The traffic emission contributes roughly 26-29% of the locally produced PM10 at kerbside or in a rural background site. Agriculture emission contributes 40% in a rural site and Industrial emissions accounts for 44% of the local portion of PM10 in an industrial site. These estimates do not account for the PM10 concentrations coming from outside the wide Venice area;

Problems

- Understimation of organic aerosol
- Resuspension not modelled
- Not specific (from local data) formulation for sea salt
- Underestimation of water content in the atmosphere
- PM10 and precursor gases speciation profiles from references by work of other part of the world
- non–linear effect in “brute-force” scenarios

(some) Remedies

- BU Wood burning Inventory for M2
- Parametrizzation for resuspension and sea salt
- Prognostic Meteo model instead of diagnostic CALMET (?)
- PM10 speciation profiles from local emission measurements
- New version of CAMx with PSAT Tool

Any other suggestion?

Thank you for your patience

for more information:

Francesca Liguori – fliguori(at)arpa.veneto.it

Silvia Pillon – spillon(at)arpa.veneto.it

Giuseppe Maffeis – g.maffeis(at)terraria.com

THE END

Specie di CAMx

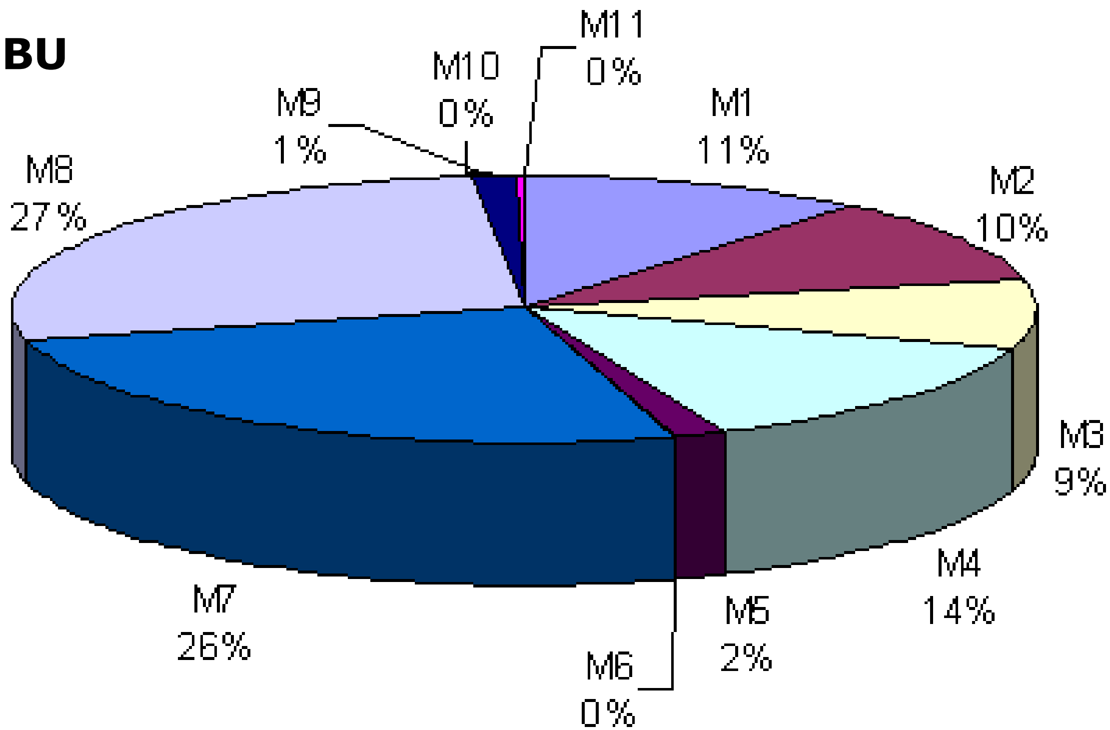
La versione di CAMx (v. 4.0) implementata, permette la trattazione dell'aerosol solo attraverso il meccanismo CBIV. L'estensione consta essenzialmente nell'introduzione delle emissioni di una nuova specie gassosa organica, **OLE 2 che rappresenta i terpeni (emissione biogenica), e di 11 specie aerosoliche:**
-PSO4 (solfato, < 2.5 μm);
-PNO3 (nitrato, < 2.5 μm);
-PNH4 (ammonio, < 2.5 μm);
-NA (sodio, < 2.5 μm);
-PCL (cloro, < 2.5 μm);
-POA (frazione organica antropogenica, < 2.5 μm);
-PEC (carbonio elementare, < 2.5 μm);
-FPRM (altre componenti primarie fini, < 2.5 μm);
-FCRS (componente crostale fine, < 2.5 μm);
-CPRM (altre componenti primarie grossolane, 2.5 - 10 μm);
-CCRS (componente crostale grossolana, 2.5 - 10 μm).
In pratica le frazioni granulometriche considerate sono due: PM *fine* (0 – 2.5 μm) e PM *coarse* (2.5 -10 μm), che sommate danno PM10.
L'emissione primaria di solfati, nitrati e ammonio è in realtà molto scarsa, e tali specie subiscono un notevole accrescimento nel corso della simulazione per formazione in fase omogenea (nitrati, che si formano anche in assenza di acqua) ed eterogenea (nitrati e solfati) [1].
Data la mancanza di informazioni inerenti l'emissione crostale, nell'applicazione presentata le specie FCRS e CCRS sono in realtà presenti nel modello in concentrazioni di fondo (10^{-9} mg/m^3).

[1] La formazione inorganica in fase omogenea è basata sul modulo termodinamico ISORROPIA, mentre quella in presenza d'acqua sul modulo RADM.

Integrated BU-TD PM10 ESTIMATION

Harbour and Airport BU Emission Inventory

(DAPVE, 2007)

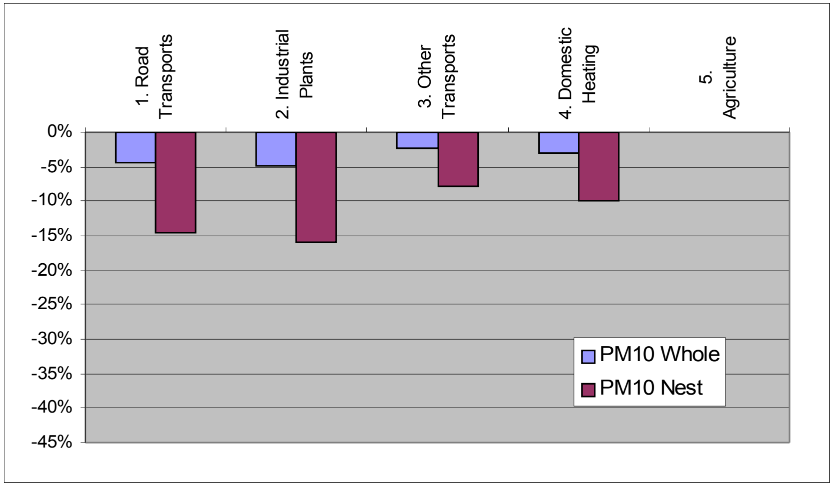


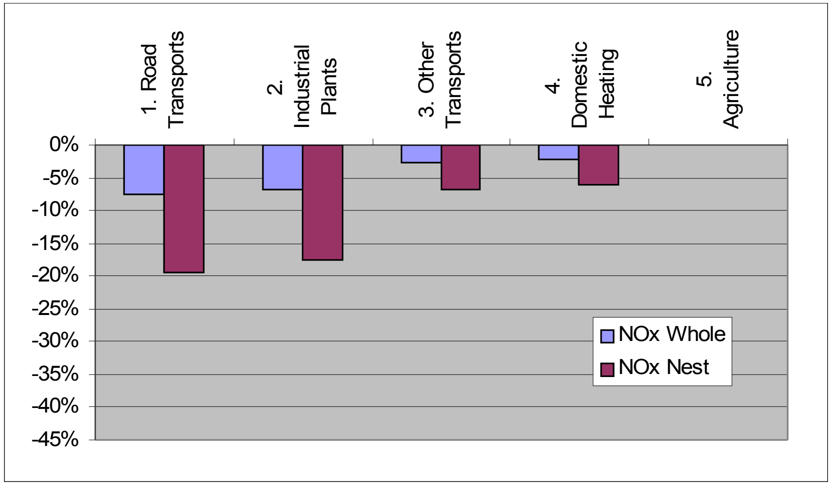
Transport Emissions BU Inentory from vheicular flows

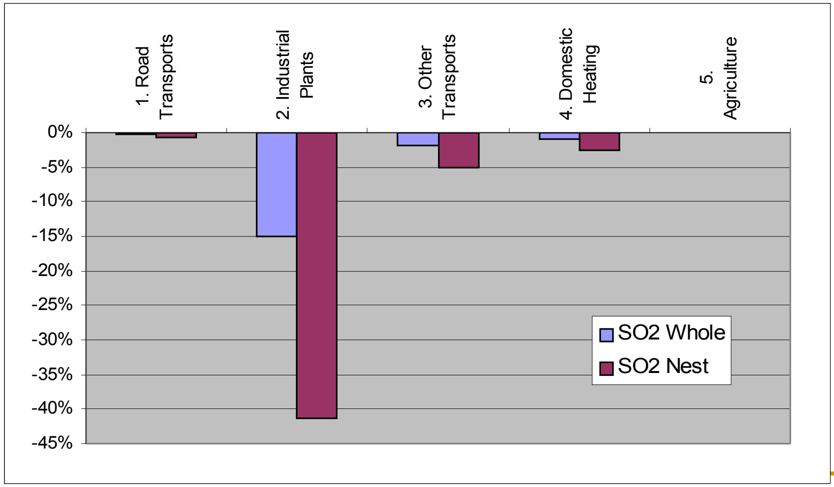
(COPERT III)

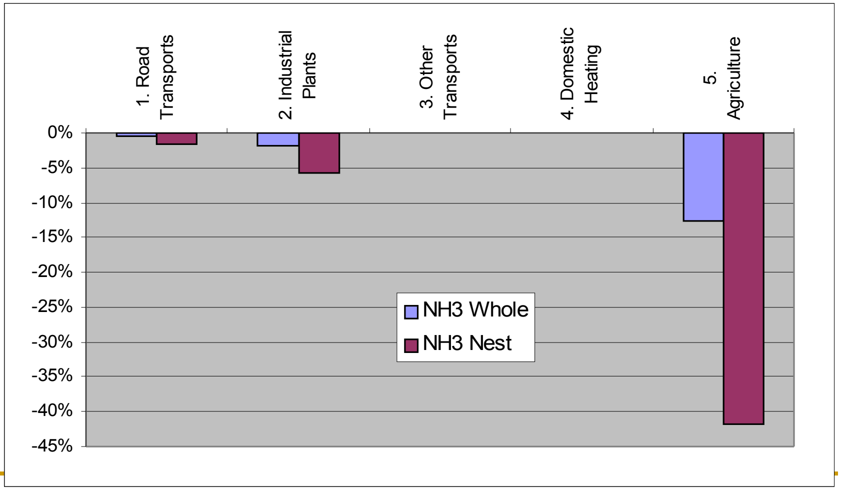
PM10 and gas precursors Scenarios Emissions

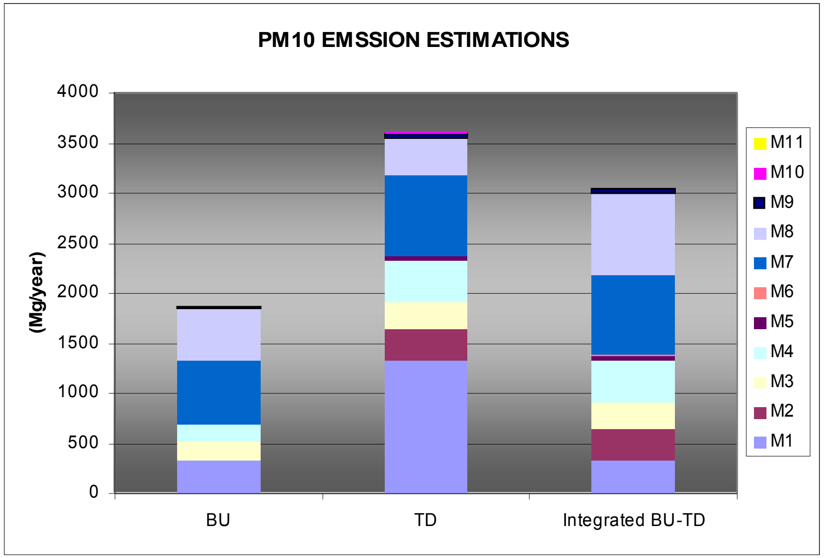
Reductions of each scenario,
relative to the total emissions in the whole domain and in the nested area

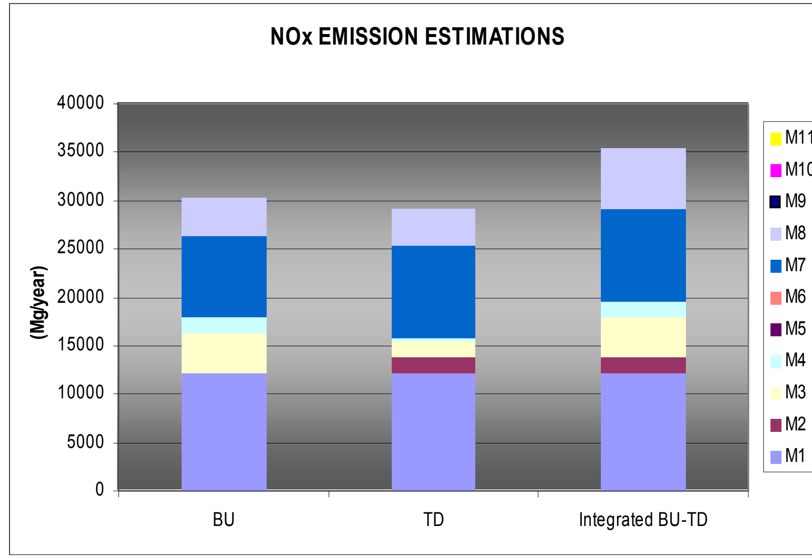


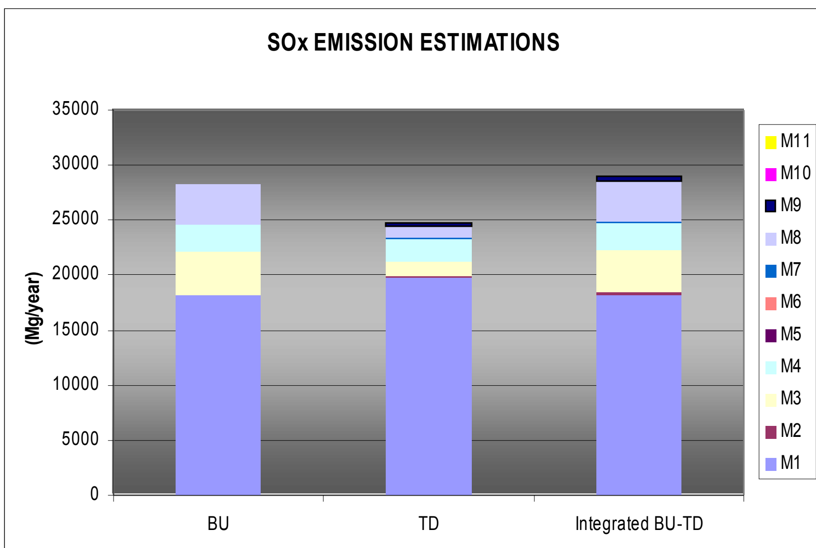


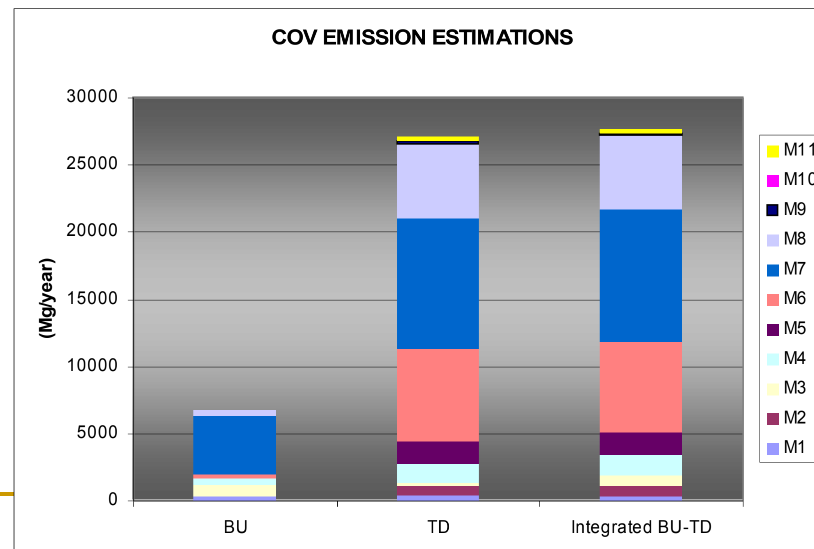





PM10 EMSSION ESTIMATIONS
(Mg/year)
4000
3500
3000
2500
2000
1500
1000
500
0
BU
TD
Integrated BU-TD
M11
M10
M9
M8
M7
M6
M5
M4
M3
M2
M1


NOx EMISSION ESTIMATIONS
(Mg/year)
40000
35000
30000
25000
20000
15000
10000
5000
0
BU
TD
Integrated BU-TD
M11
M10
M9
M8
M7
M6
M5
M4
M3
M2
M1


SOx EMISSION ESTIMATIONS
(Mg/year)
35000
30000
25000
20000
15000
10000
5000
0
BU
TD
Integrated BU-TD
M11
M10
M9
M8
M7
M6
M5
M4
M3
M2
M1


COV EMISSION ESTIMATIONS
(Mg/year)
30000
25000
20000
15000
10000
5000
0
BU
TD
Integrated BU-TD
M11
M10
M9
M8
M7
M6
M5
M4
M3
M2
M1