DOES ELECTRIC VEHICLE INTRODUCTION IN THE CAR FLEET IMPROVE THE AIR QUALITY?

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Introduction

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- Emissions from vehicles contribute to the photochemical pollution involving ozone and nitrogen oxides.
- New technologies allow reducing the NOx emission thanks to the electric engines.
- For this reason, it is very important to evaluate the degree of pollution reduction related to hypothetical scenarios, which account for the introduction of the electric vehicle in the car fleet.

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- Estimating short term non-equilibrium concentrations in a plume with chemical reactions
- The Lagrangian particle model is particularly suitable to simulate the dispersion at the small scale
- One critical point: how to consider the segregation in real atmosphere ?

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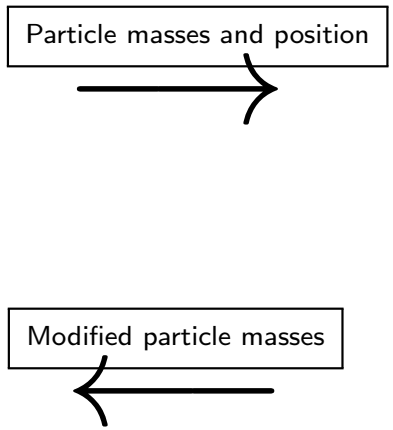
- One-particle model cannot provide second order of the concentration PDF
- Theoretical limit!

An hybrid model

The Eulerian scheme is included inside the Lagrangian model as follows:

Lagrangian Model (Thomson, 1987)

- Particles emission
- Lagrangian particles displacement



Eulerian scheme (Alessandrini & Ferrero, 2009)

- Concentration computation on a 3D grid
- Chemical reactions on the same grid
- New particles mass of each species computation

Chemical reactions (I)

We developed a model able to estimate a secondary pollutant like NO_2 due to the oxidation reaction (the segregation effect is considered):

$$\boxed{NO + O_3 \longrightarrow NO_2 + O_2}$$

The model considers the photolysis of NO_2 due to solar radiation:

$$\boxed{NO_2 + O_2 + h\nu \longrightarrow NO + O_3}$$

Chemical reactions (II)

For each cell we have:

$$< C_{NO} >=< C^*_{NO} > -k\Delta t < C^*_{NO} C^*_{O3} > +j < C^*_{NO_2} >$$

where C^* are the concentrations after the turbulent displacement, k the reaction rate and j the photolysis constant and

$$< C^*_{NO} C^*_{O3} >=< C^*_{NO} >< C^*_{O3} > + \boxed{< c'^*_{NO} c'^*_{O3} >}$$

($c' \Rightarrow$ fluctuations)
being $< c'^*_{NO} c'^*_{O3} >$ unknown we look for a parameterization.

Segregation parameterization

Based on the Brown and Bilger (1986) wind tunnel data, we found:

$$\alpha = \frac{< c'_{NO} c'_{O3} >}{< C_{NO} >< C_{O3} >} = -0.71 e^{-0.106 \frac{x}{N_D x_s}}$$

where x is the downwind distance, N_D the Damkhöler number and x_s the stechiometric distance

- x_s is calculated for a line source
- Alessandrini et al, IJEP, 2012 (H14-188), *Evaluation of the segregation effect in the dispersion from a urban highway*, shown that the segregation effect may be not negligibile

Background concentration

How to solve the problem of the background concentration?

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2. E. Ferrero, L. Mortarini, S. Alessandrini, C. Lacagnina, A fluctuating plume model for pollutants dispersion with chemical reactions (Poster) Proc. of 13th International Conference on Harmonisation within Atmospheric Dispersion Modelling for regulatory Purposes, Paris June 1-4, 2010
3. Alessandrini S. and Ferrero E. (2009). A hybrid Lagrangian-Eulerian particle model for reacting pollutant dispersion in non-homogeneous non-isotropic turbulence. PHYSICA A, ISSN: 0378-4371, 388, 8, 1375-1387
4. S. Alessandrini and E. Ferrero, An application of a Lagrangian particle model with chemical reactions to power plant pollution dispersion in complex terrain, 30th NATO/SPS International Technical Meeting on Air Pollution Modeling and its Application,18 - 22 May, 2009, San Francisco, USA
5. S. Alessandrini and E. Ferrero, A Lagrangian particle model with chemical reactions: application in real atmosphere, Hrvatski Meteoroloski Casopis 43 PART 1 (Croatian Meteorological Journal), 43, 235-239 (Proc. Harmo12 Conference, Cavtat, Croatia, October 6th-9th, 2008)

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- They are respectively located at about $600m$ and $5000m$ from the highway

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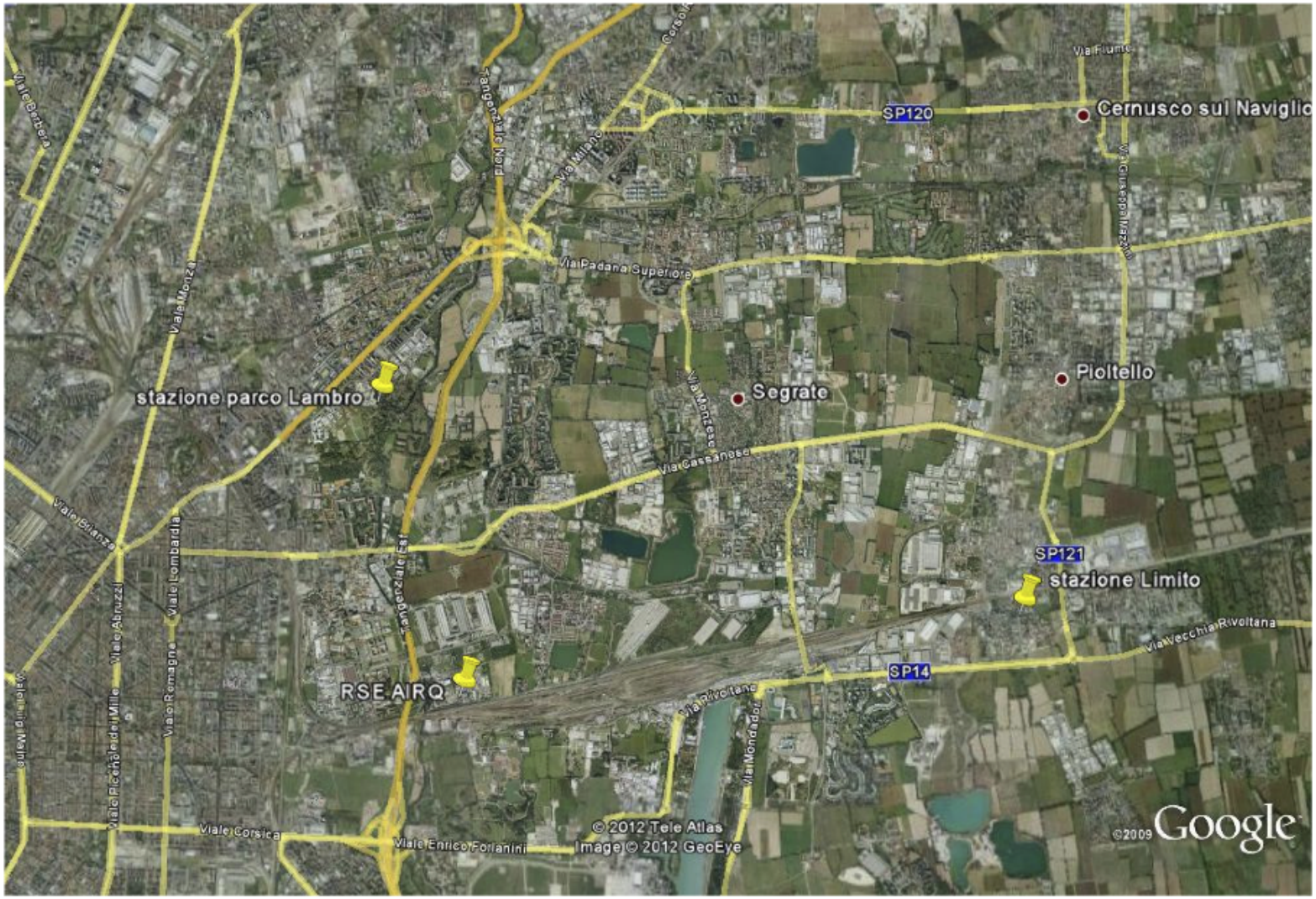

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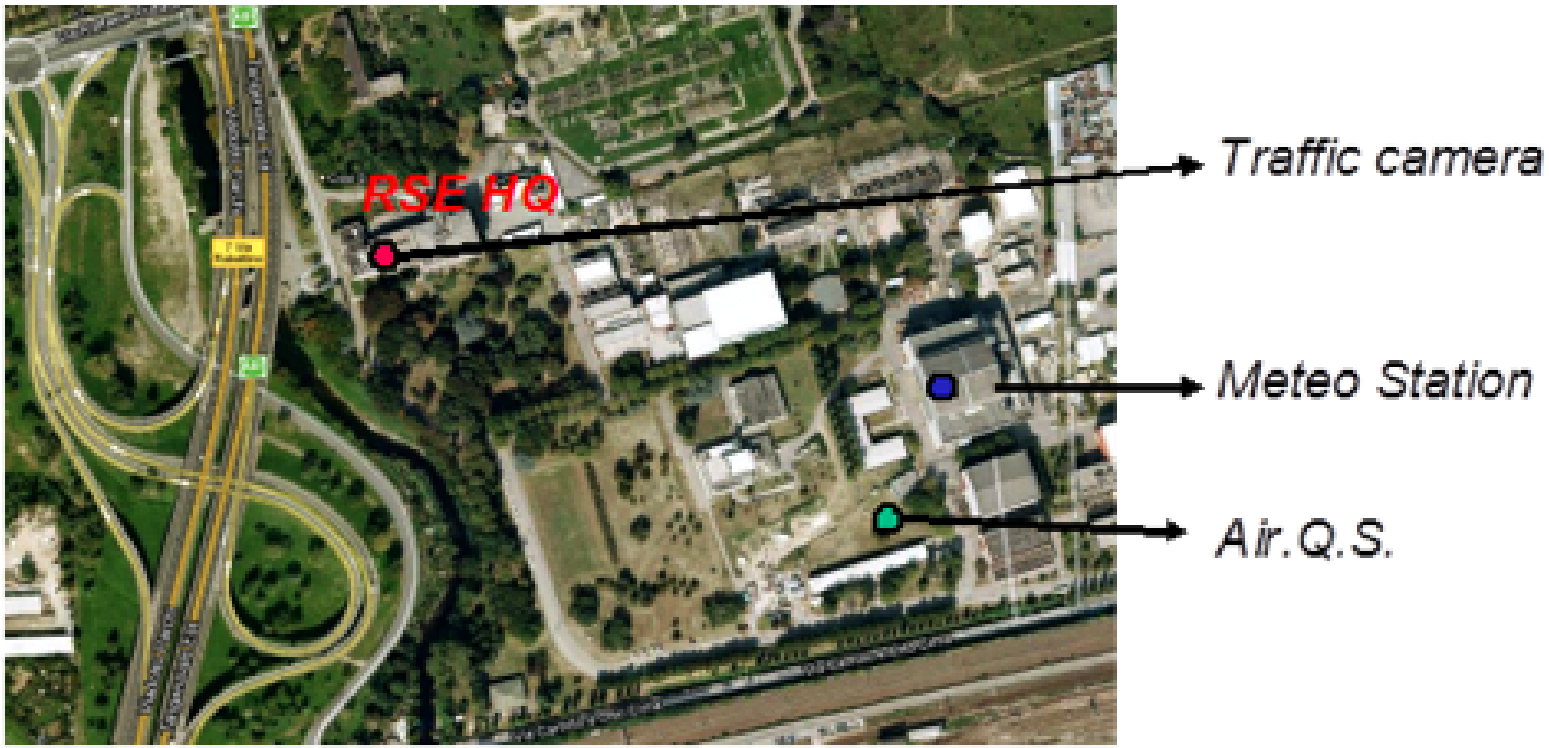

Emission trend from the highway

The traffic flows for the period, required for estimating the emission, were determined from movies recorded by a webcam

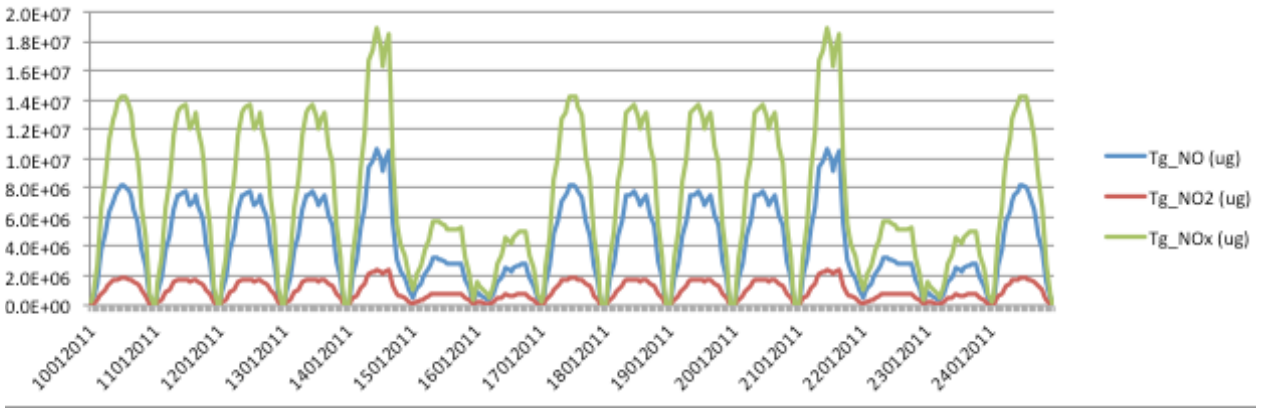

Figure: Emission trend ($\mu g\ h^{-1} m^{-1}$)

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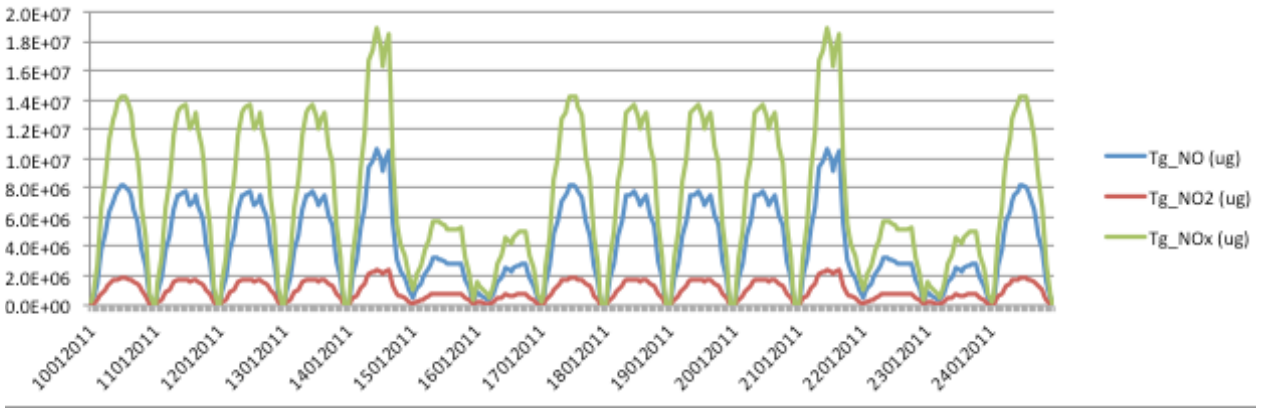

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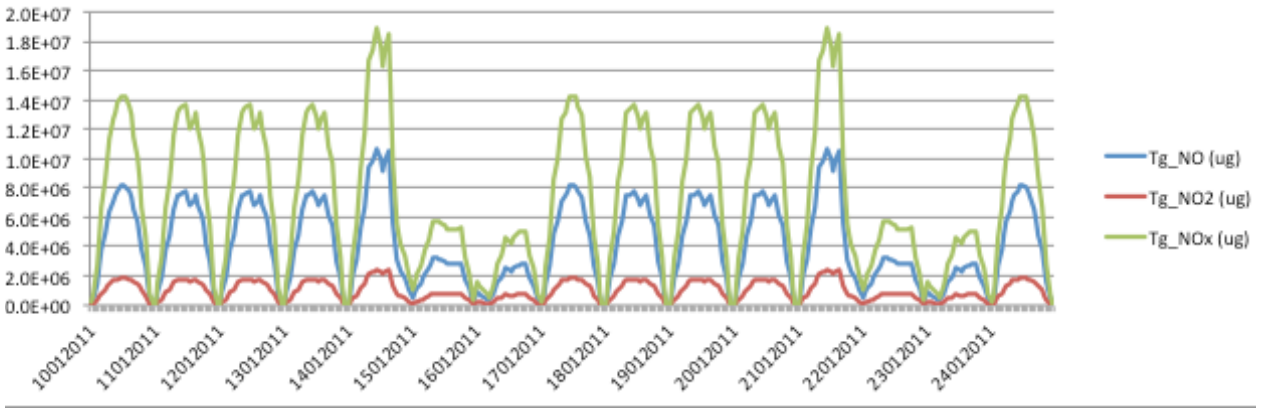

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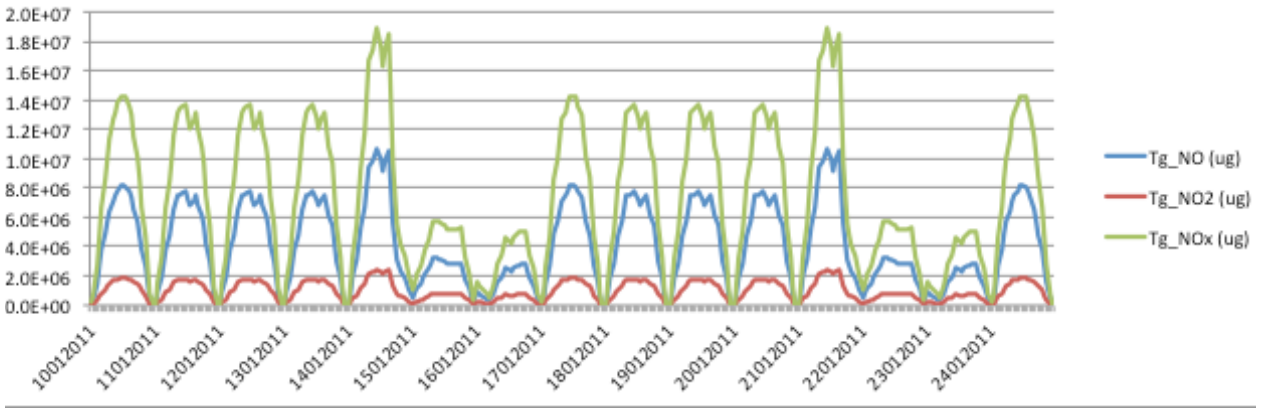

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- Present scenario (NEV), a car fleet without electric vehicle
- Future scenario (EV) in which an introduction of 25% of electric vehicle in the light vehicle fleet
- This brought an emission reduction to about 8%, 10% and 8% for NO, NO_2 e NO_x respectively

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4. Turbulence model, Mellor and Yamada 2.5

NO concentration differences between NEV and EV scenarios at the Lambro (PL) and RSE stations

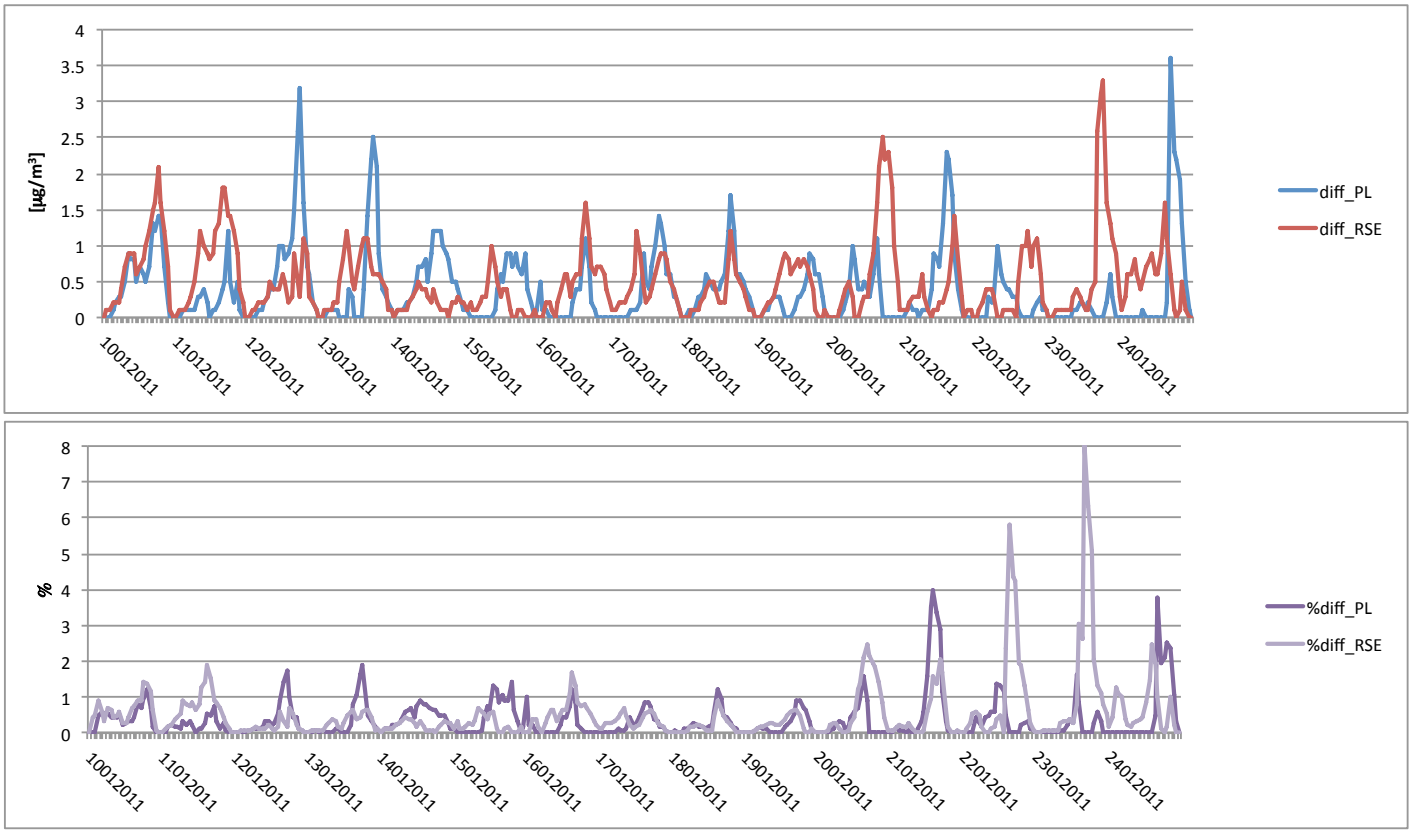
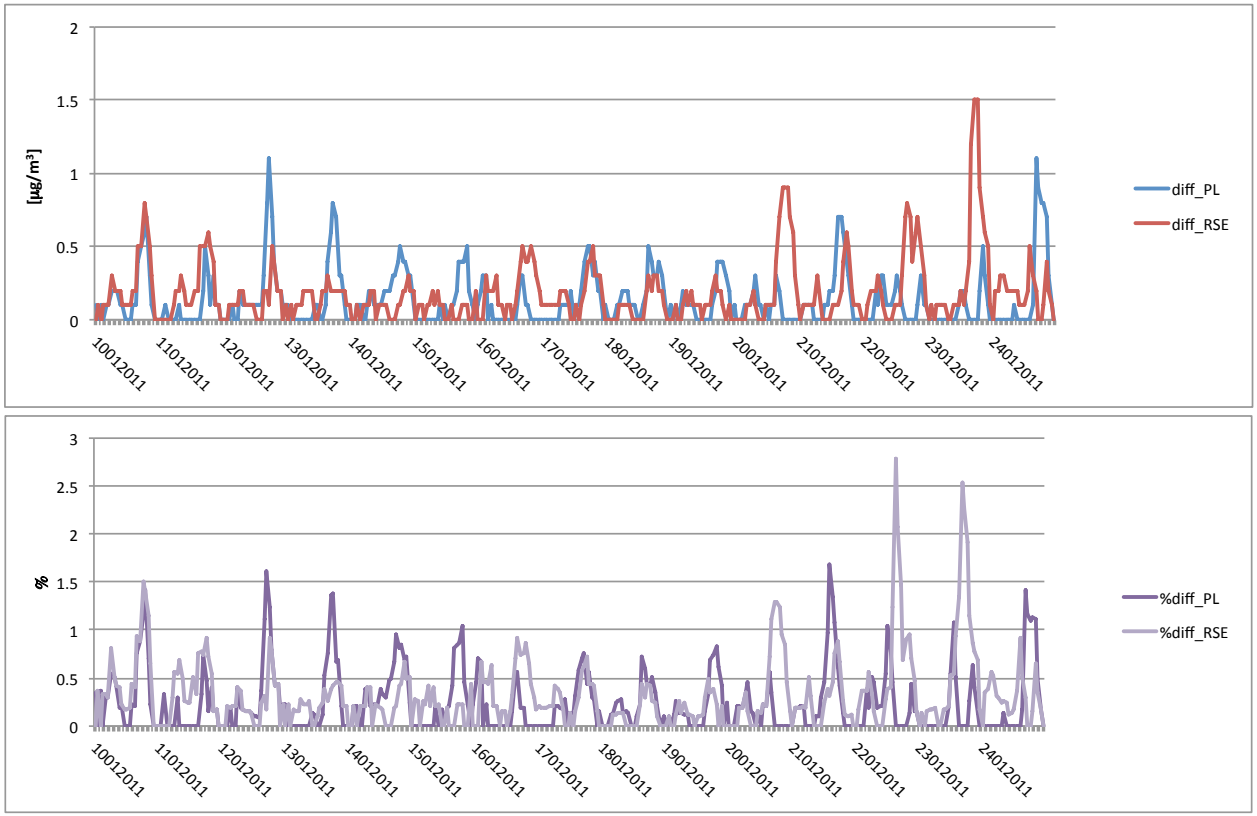


Figure: top: absolute difference, bottom: relative difference

NO_2 concentration differences between NEV and EV scenarios at the Lambro (PL) and RSE stations



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- NO: except for a few episodes the differences do not exceed the value of about $2\mu g/m^3$ and the relative difference is below the 2%
- NO_2: differences are small, generally below $0.5\mu g/m^3$ and the 1% for the relative one
- High background concentrations make the additional contribution of the highway evident only in a few situations, when the meteorological conditions are favourable for the dispersion from the highway to prevail respect to other diffuse sources

Statistical analysis of the difference between the two scenarios

	NOX	NO2	NO
NMSE (RSE)	0.017	0.017	0.018
NMSE (PL)	0.022	0.023	0.022
FB (RSE)	-0.022	-0.022	-0.021
FB (PL)	-0.021	-0.022	-0.021

The difference between the two scenarios are very small, even including the episodes which show peaks in the difference trend, and comparable for the two stations.

Conclusions

1. The Lagrangian Stochastic Chemical/Dispersion Model
   - Background concentrations are simulated as "deficit"
   - Segregation is parameterized
2. The effect of the EV introduction is limited to a mean concentration decrease of less than 1% for NO_2, and of about 2% for NO (400-600 m from the highway)
3. To achieve further improvements on air quality, may be not sufficient to limit the emissions of light transport vehicles, but it is necessary to reduce also emissions from commercial transport