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FROM LOCAL - SCALE TO MICRO - SCALE ASSESSMENT OF THE ATMOSPHERIC IMPACT OF THE POLLUTANT PLUME EMITTED FROM A POWER - PLANT STACK

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Abstract: A tri-generation power-plant has been designed in order to supply the energy demand for the city hospital of Modena (Northern Italy). A previous local-scale simulation of NO_x dispersion from the same plant (Ghermandi *et al.*, 2012) showed that maximum average concentration values fall a few hundred meters nearby the plant stacks, in a densely populated urban area. The present study investigates NO_x dispersion pattern close to the plant by means of a micro-scale high-resolution domain, by taking into account turbulence effects due to the urban canopy.

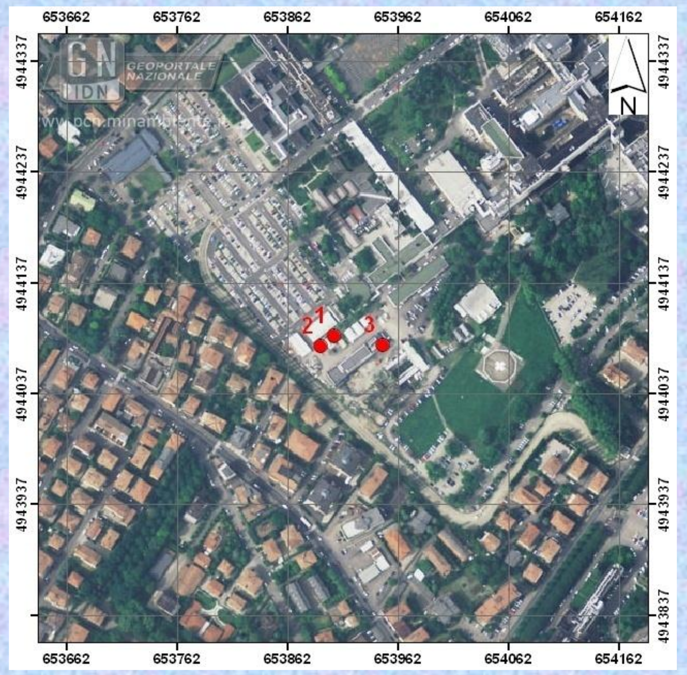


Fig. 1

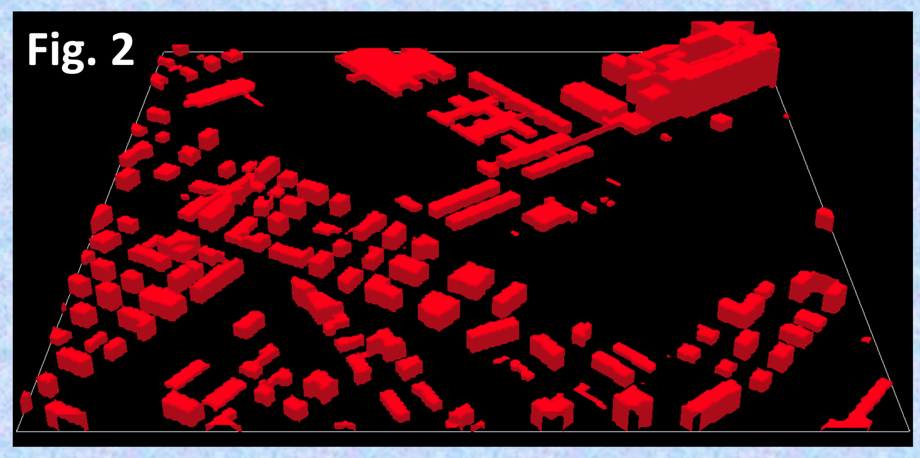


Fig. 2

Fig. 1: source position (red numbered points) within the micro-scale domain: *Boiler (1)*, *Steam Generator (2)* and *Tri-generator (3)*.
Fig. 2: Building geometry, deduced in a GIS from a high-resolution 3D cartography.

Micro - SWIFT - SPRAY

Software package for micro-scale simulations by Arianet s.r.l.:

Micro-SWIFT: Mass-consistent wind-field interpolator from on-site observations within building texture (Aria Tech., 2010).

Micro-SPRAY: 3D Lagrangian Particle Dispersion Model for airborne pollutant dispersion in urban environment (Arianet, 2010).

Emission sources: The plant was sized according to safety criteria and the *tri-generation* unit is supported by two auxiliary devices: one conventional *boiler* and one *steam generator*, which emission patterns vary according to the hourly average fuel consumption in the monthly mean day.
Stack heights are all equal to 10 m, except for the tri-generation unit (15 m).

Domain & data set

Horizontal dimensions: 500 x 500 m^2.

Domain top: 200 m above ground level.

Horizontal grid step: 2 m square cells.

Concentration computing: n. 20 vertical layers; 1st layer is placed 2 m above ground level.

Meteorological data: ARPA (Regional Environmental Agency), CALMET model and Osservatorio Geofisico of Modena & Reggio Emilia University.

Simulation period: two days (24 hours), January 14th and February 6th, according to different meteorological conditions in 2010 winter season.

Meteorological scenario

January 14th 2010

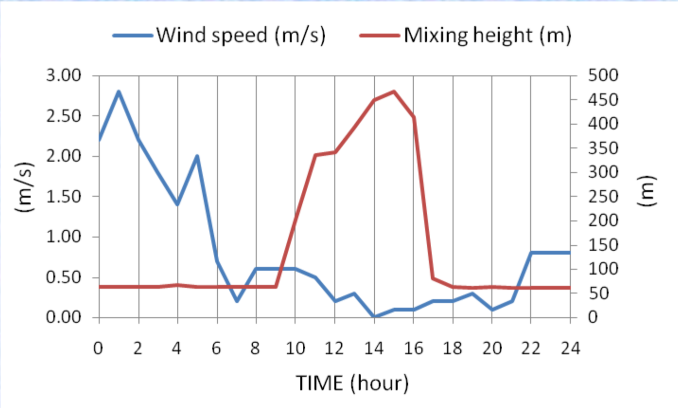


Fig. 3*: daily pattern for Mixing Height and Wind speed.*

Daily average values for:
Wind speed: *0.78 m/s* ; *Mixing Height*: *150 m.*

February 6th 2010

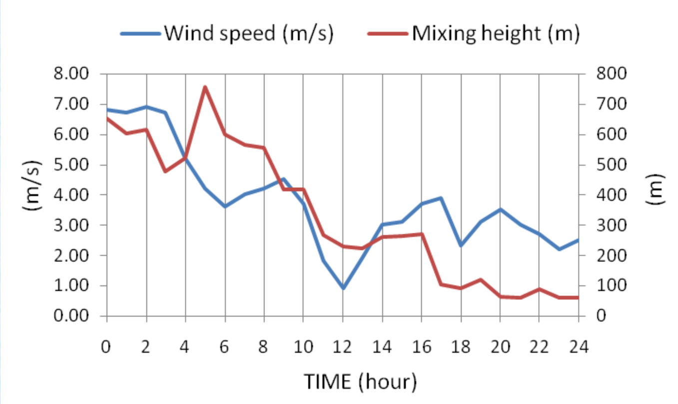


Fig. 7*: daily pattern for Mixing Height and Wind speed.*

Daily average values for:
Wind speed: *3.76 m/s* ; *Mixing Height*: *333 m.*

Daily average concentration maps

(Computed in the 1st layer, 2 m above ground level).

January 14th 2010

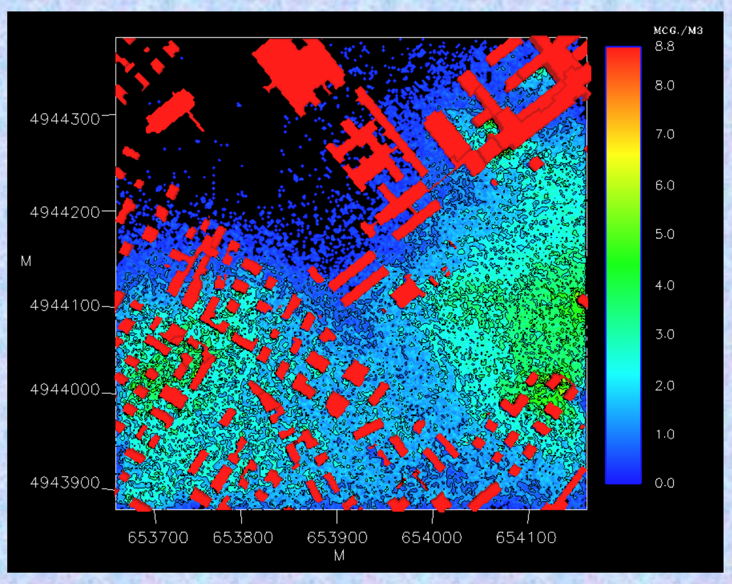


Fig. 4*: all plant sources.*

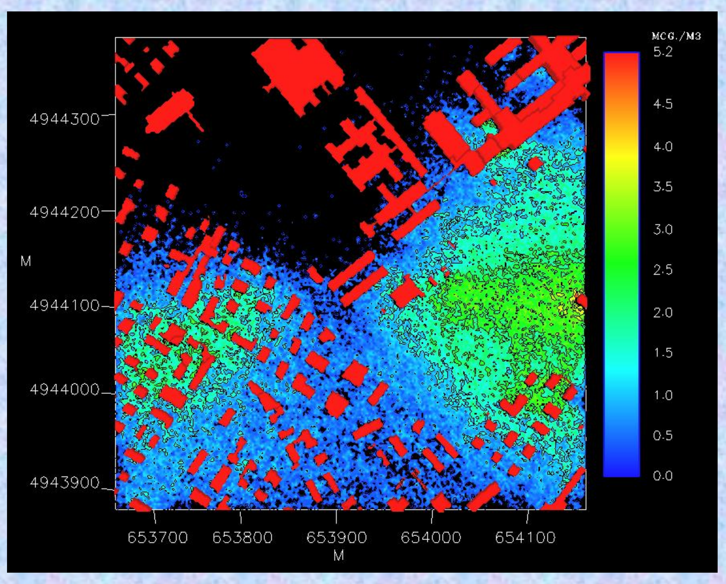


Fig. 5*: auxiliary devices.*

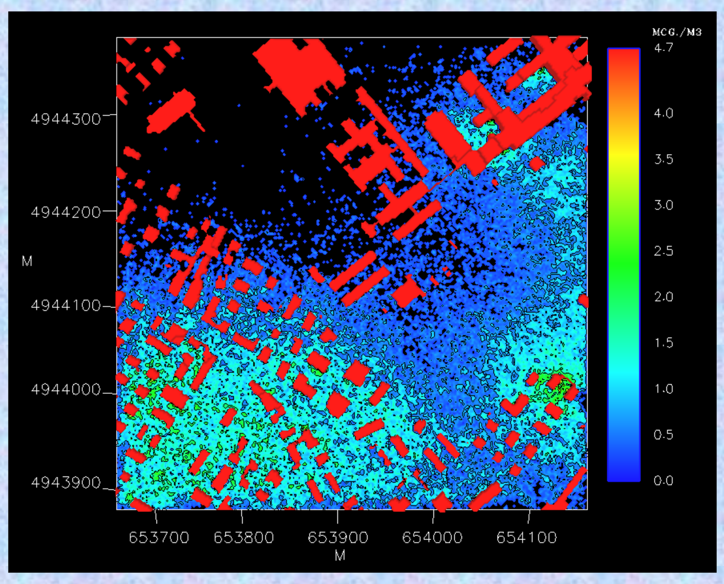


Fig. 6*: tri-generator unit.*

February 6th 2010

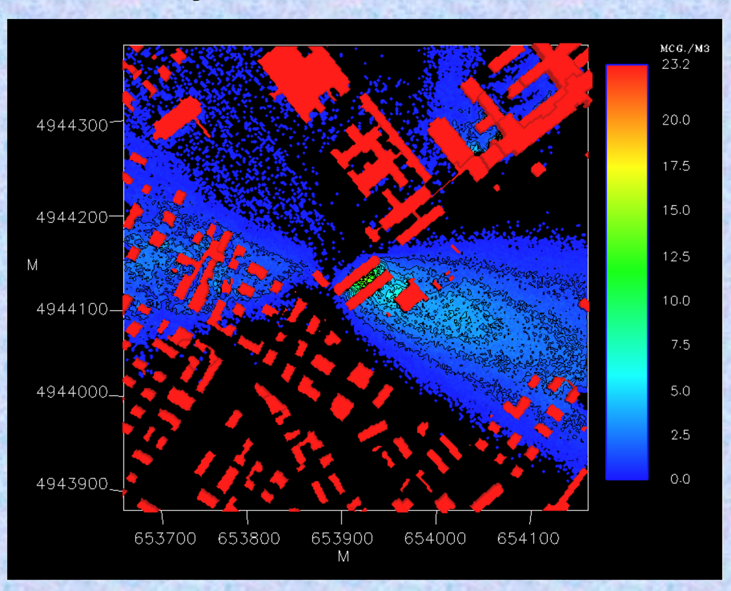


Fig. 8*: all plant sources.*

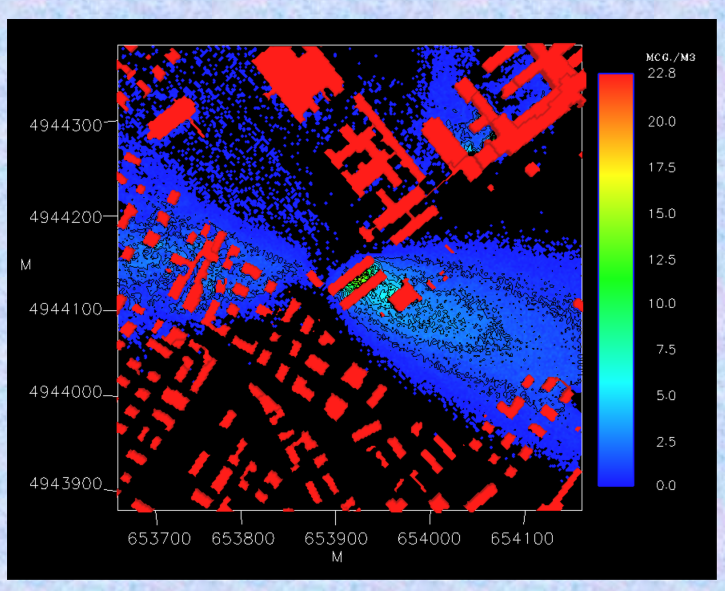


Fig. 9*: auxiliary devices.*

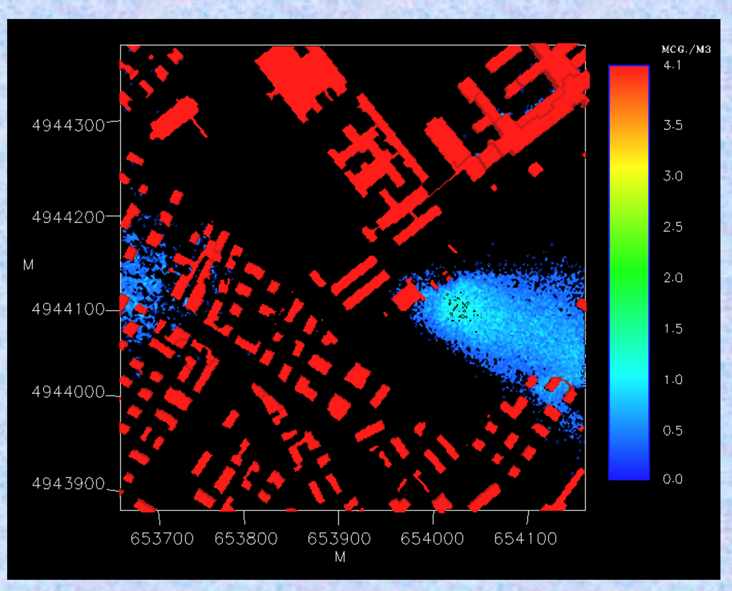


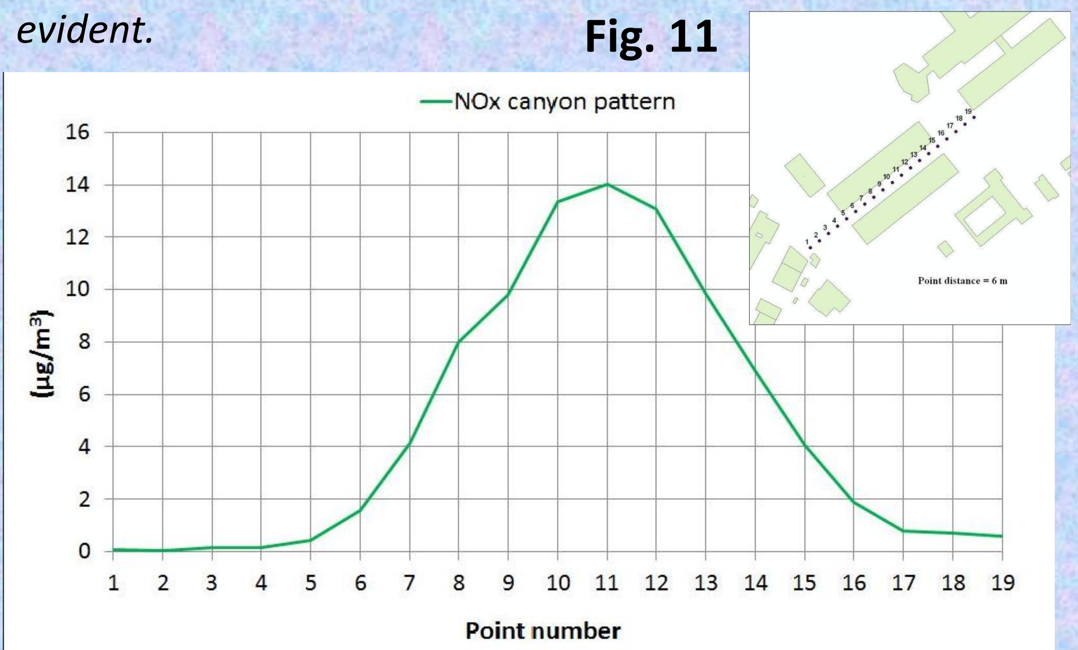
Fig. 10*: tri-generation unit.*

- ***January 14th***, *low wind conditions*: pollutant plumes tend to stagnate in the surroundings of the sources, and there is no preferential direction for plume dispersion. Mixing is confined nearby the sources and ground level impacts of the auxiliary devices and tri-generator are similar.
- ***February 6th***, *moderate wind conditions*: wind force stretches plumes at ground level so that the combined effect of different stack eights and buildings becomes more relevant. Maximum daily average concentration values are one order of magnitude higher than in January 14th.

Canyon effect

Fig. 11*: daily average NO_x concentration trend in the cavity between two buildings, where concentration maximum falls. Concentration values were interpolated from simulation results (February 6th). The concentration gradient between the cavity and the open field is quite evident.*

Fig. 11



Conclusions

As shown in a previous local-scale simulation, performed over the whole 2010 winter season (Ghermandi *et al.*, 2012), the atmospheric impact of auxiliary devices is the most relevant at ground level. This is mainly due to the combined effect of the emitted gas exit speed and the stack height, which are higher for the tri-generator unit than for the auxiliary devices. Nevertheless, at urban micro-scale, the combined effect of urban obstacles with bottom stacks may cause pollutant stagnation in urban canyons even in windy conditions when, on the contrary, more favourable conditions for pollutant dispersion should be expected.

References:

Arianet, 2010: SPRAY5-General Description and User's Guide, ARIANET R2010.08.
Aria Tech., 2010: SWIFT Wind Field Model, General Design Manual.
ARPA E. R., 2008: Le analisi meteorologiche di ARPA - SIM: costruzione del dataset Calmet-SIM, vers. 1.0.
Ghermandi G., Teggi S., Fabbi S., Bigi A., Zaccanti M. M., 2012: Tri-generation power plant and conventional boilers: pollutant flow rate and atmospheric impact of stack emissions. *Atti del convegno SIDISA 2012,* Milano, 26-29 Giugno 2012.
Oke T. R., 1987: Boundary Layer Climates, Routledge, Cambrigde, 435 pp.