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A HYBRID EULERIAN-LAGRANGIAN-STATISTICAL APPROACH TO EVALUATE AIR QUALITY IN A MIXED RESIDENTIAL-INDUSTRIAL ENVIRONMENT

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Abstract: Aim of this work is to evaluate the air quality in the mixed urban-industrial environment of the city of Trieste, Italy. In particular, PM10 daily exceedances have to be estimated in a residential district close to a large iron plant. Due to the complex orographic context, to the land-sea discontinuity and to the local scale wind regimes, concentration gradients can be often strong. Therefore it can be misleading to rely only on the monitoring network to assess air quality, since some stations could often have a limited spatial representativeness. On the other hand, under some conditions not only local emissions, but also long-range transport of PM10 or gaseous precursors from the Po Valley cannot be neglected.
To take into account all these elements, we used an Eulerian chemistry-transport model (CTM) to simulate the daily regional background concentrations and a Lagrangian model (LM) to simulate the local impact of the emissions of the iron plant (blast furnace, coking plant and casthouse). Regional scale background concentrations of PM10 have been estimated with a data fusion approach, interpolating the observations of the background stations using concentrations simulated by the CTM as proxy. Then the residuals over the urban stations have been interpolated using concentrations simulated by the LM as proxy. Finally, the sum of background and residuals is compared daily with the 50 $\mu g/m^3$ threshold, in order to assess air quality with a detail suitable for epidemiological purposes.
The effectiveness of different strategies for impact mitigation is also assessed.

Key words: *chemistry-transport model, Lagrangian model, PM10, data fusion.*

INTRODUCTION

Trieste, Italy, is a port city with about 200.000 inhabitants, located in the northern part of the Adriatic Sea, between the Italian peninsula and the Istrian peninsula (Slovenia and Croatia). The urban territory lies on the Gulf of Trieste, at the foot of the Karst Plateau. Reliefs included in the urban area exceed 400 m of height. The orographic complexity and the land-sea discontinuity strongly influence the local climate. Wind regimes are characterized by local scale sea breezes and by the Bora, a north-to-northwest katabatic wind.

Air quality in Trieste is affected by the pollutants emitted in the urban area (urban roads, highway, harbour area, industrial area), by the primary and secondary pollutants advected from the Venetian-Friulan Plain and the Po Valley and by the transboundary pollution coming from Slovenia (the border is about 8 km from the city center) and Croatia (20 km).

The so-called "Ferriera di Servola" is an industrial complex for iron production, established in year 1896 – when Trieste was part of the Austro-Hungarian Empire – in order to provide the steel to the flourishing shipbuilding industry of Trieste. Today, the main activity of the plant is the manufacture of pig iron, cast iron, hard coke, slag and tar. The industrial complex is located in the neighbourhood of Servola, in the south-eastern part of Trieste.

Aim of this work is to assess the air quality in the south-eastern part of Trieste, specifically the daily exceedances of PM10, and to evaluate the effectiveness of possible emissions reductions.

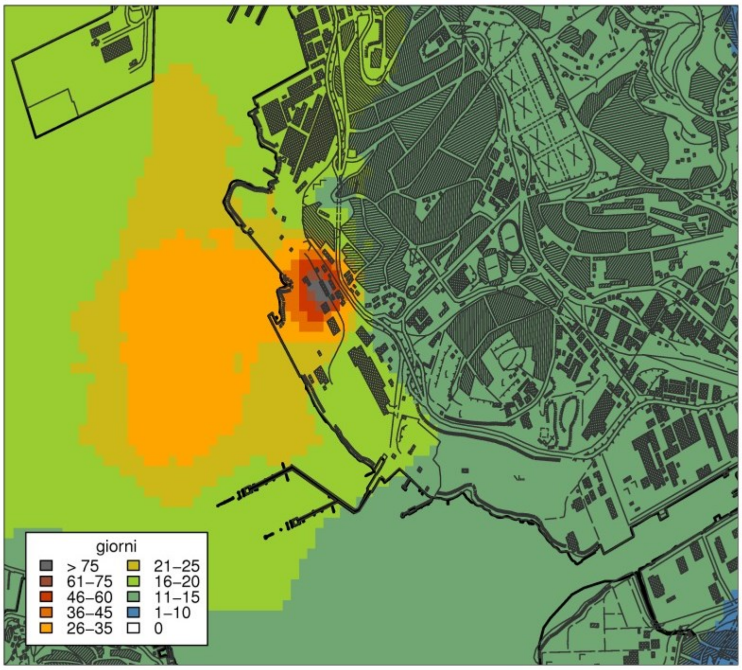

Figure 1. PM10 daily exceedances during year 2016, as estimated with the hybrid approach CTM+LM+kriging.

METHOD

First, the regional and urban hourly background concentrations of PM10 have been simulated with the FARM (Silibello *et al.*, 2008) CTM, run with a resolution of 2 km on a domain covering the Friuli Venezia Giulia region, the Gulf of Trieste, part of Istria and Veneto. Boundary conditions are provided by a run of FARM covering Italy[1]. Meteorological input is provided by WRF[2] (Gladich *et al.*, 2008), while emission input is based on regional[3], national (De Lauretis *et al.*, 2009) and EMEP inventories. On a daily basis, data fusion of average PM10 concentrations is performed: values measured at the background stations are interpolated with the "Universal Kriging" technique assuming the output of the CTM as the spatial trend (Hiemstra *et al*, 2009; Wackernagel, 2003).

Furthermore, the impact of the plant on air quality in the neighbourhoods close to the plant is simulated daily by means of the Lagrangian model (LM) SPRAY (Tinarelli *et al.*, 2000) with WRF meteorological input and high resolution orography. Emissions are represented, with some approximations, with three punctual sources, blast furnace, casthouse and coking, emitting respectively 4.8%, 66.7% and 28.6% of the total particulate matter.

On a daily basis, differences between concentrations measured in the south-eastern part of Trieste and the interpolated background concentrations are again interpolated, on a regular grid with 50 m resolution, with the "Universal Kriging" technique, using the concentrations simulated by the LM as the spatial trend. Finally, the sum of these interpolated residuals and the interpolated background concentrations is considered the best estimate for the PM10 concentration, and exceedances of the 50 $\mu g\ m^{-3}$ threshold are calculated on a monthly basis.

In order to attribute separately, to each of the three sources, part of the total interpolated residual, we assume it proportional to the relative impacts simulated by the Lagrangian model. Given this assumption,

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[1] http://www.aria-net.it/qualearia/en/
[2] https://www.mmm.ucar.edu/weather-research-and-forecasting-model
[3] http://www.arpa.fvg.it/cms/tema/aria/pressioni/Catasto_emissioni/catasto.html

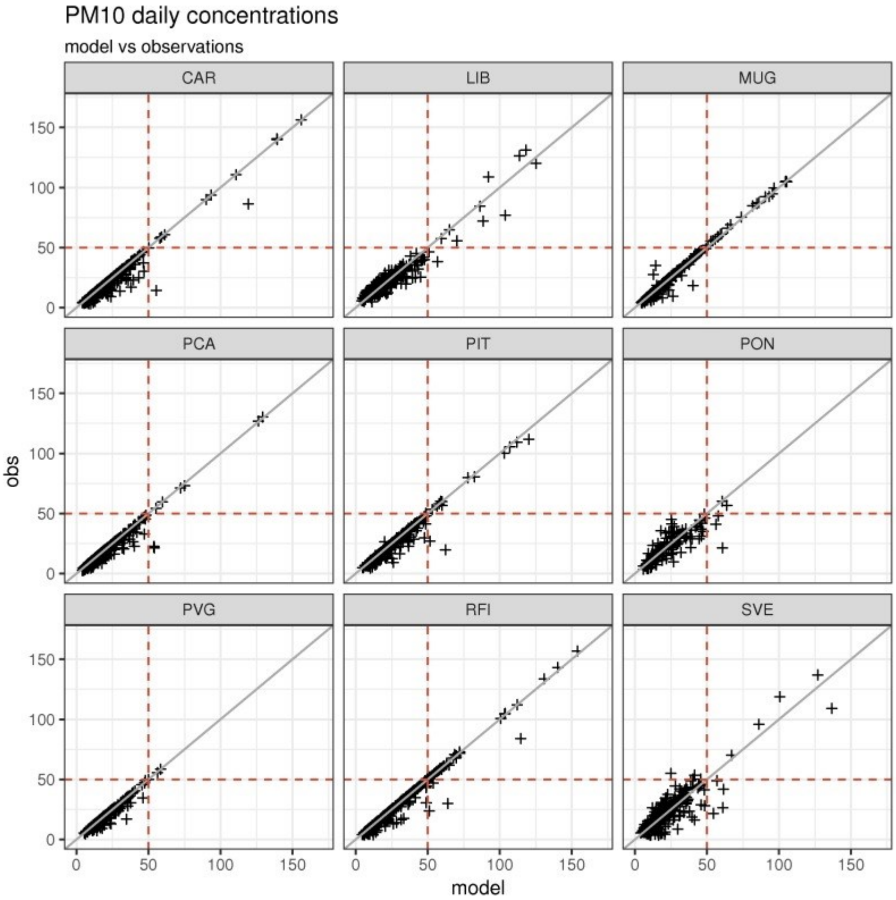

Figure 2. Validation of the hybrid modelling suite against data measured by the stations of the monitoring network. Scatter plots of daily mean concentrations. Most of these observed data are used to feed the universal kriging, in the last step of the modelling procedure, but the station "Via Svevo" (SVE) was kept out; therefore, the SVE panel (bottom right) shows a validation against independent data.

we can evaluate the effect of reducing the emissions of one of the three sources, of the plant as a whole, or of the regional background.

RESULTS

As shown in Fig.1, due to the prevailing wind regimes, the most critical areas for PM10 pollution are in the industrial area itself and over the sea, while the hill of Servola (to the north-east of the plant) acts to some extent as a shield for the residential area. Nevertheless, the buildings closest to the plant are exposed to 5-10 exceedances more than the rest of the neighbourhood.

Estimated daily concentrations of PM10 (Fig.2) are validated against measurements. Results are good not only, as expected, in the monitoring stations used for the interpolation, but also in the "Via Svevo" station (code: SVE), which had been kept out from the calculation.

Finally, different emission reduction strategies have been evaluated (Fig.3): the most effective are the reduction of the emissions of the casthouse, the reduction of all the emissions of the plant and the reduction of the regional background. In each of these three cases, a cut of 25% in the emissions leads to a reduction of 75% of the area with more than 35 daily exceedances in a year. However, these conclusions may be pretty sensitive to our assumptions regarding the emissions of the plant.

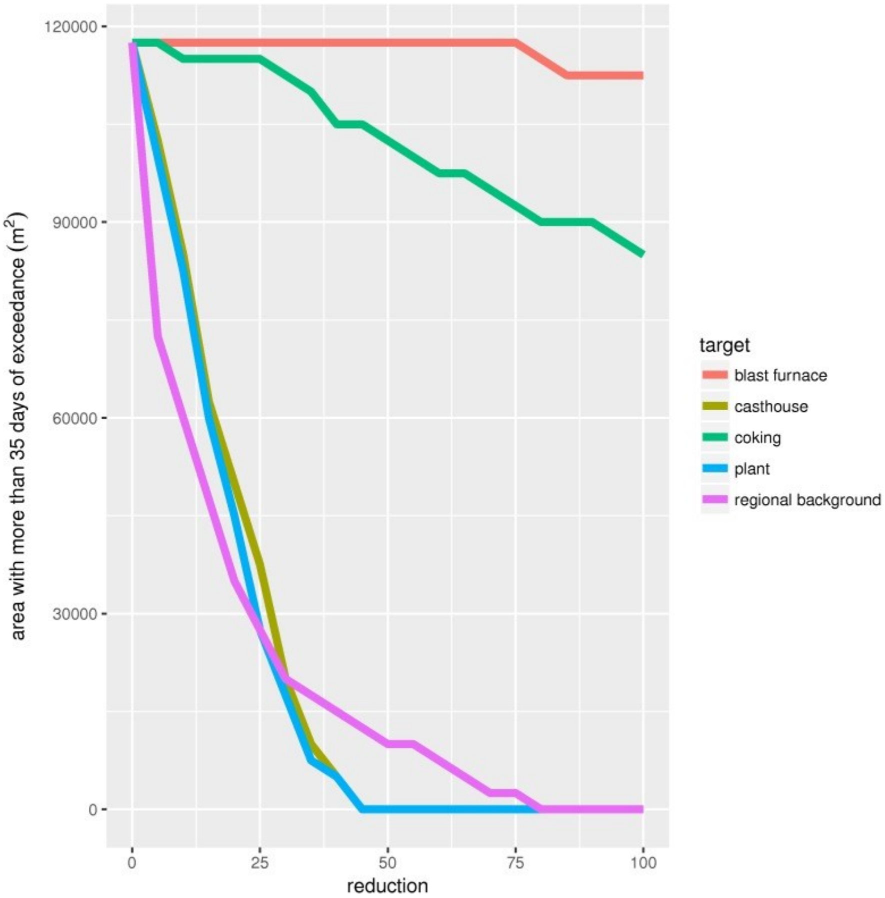

Figure 3. Evaluation of different emission reduction strategies, targeting at specific sources. The area where more than 35 daily exceedances of PM10 occurred in year 2016 was estimated for different emission reduction scenarios and used as indicator of their effectiveness. The extension of this exceeding area is plotted as a function of the reduction of the impact of each source separately, of the plant as a whole, and of the regional background.

REFERENCES

De Lauretis, R. *et al*. (2009). La disaggregazione a livello provinciale dell'inventario nazionale delle emissioni. Institute for Environmental Protection and Research—ISPRA, Technical report, 92, 2009.

Gladich, I., Gallai, I., Giaiotti, D. B., Mordacchini, G., Palazzo, A., & Stel, F. (2008). Mesoscale heat waves induced by orography. *Advances in Science and Research*, **2**(1), 139-143.

Hiemstra, P. H., Pebesma, E. J., Twenhöfel, C. J., & Heuvelink, G. B. (2009). Real-time automatic interpolation of ambient gamma dose rates from the Dutch radioactivity monitoring network. *Computers & Geosciences*, **35**(8), 1711-1721.

Silibello C., Calori G., Brusasca G., Giudici A., Angelino E., Fossati G., Peroni E., Buganza E. (2008). Modelling of PM10 Concentrations Over Milano Urban Area Using Two Aerosol Modules. *Environmental Modelling and Software* **23**, pp. 333-343.

Tinarelli, G., Anfossi, D., Castelli, S. T., Bider, M., & Ferrero, E. (2000). A new high performance version of the Lagrangian particle dispersion model SPRAY, some case studies. In *Air Pollution Modeling and its Application XIII* (pp. 499-507). Springer US.

Wackernagel, H. (2003): Multivariate Geostatistics: An Introduction with Applications, (3rd ed.) Heidelberg: Springer, Berlin.