Air quality in Trieste, Italy

A hybrid Eulerian-Lagrangian-statistical approach to evaluate air quality in a mixed residential-industrial environment

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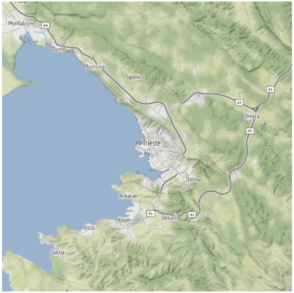
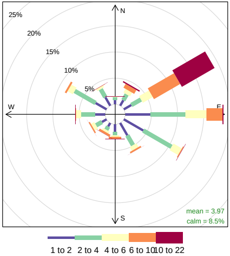
objectives

- to assess the air quality in the south-eastern part of Trieste, specifically the **daily exceedances of PM10**, in a residential district close to a large iron plant
- to evaluate the effectiveness of possible **emissions reductions**

context

- Trieste is a port city with about 200.000 inhabitants
- northern part of the Adriatic Sea, between the Italian peninsula and the Istrian peninsula
- 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**
- wind regimes are characterized by **local scale sea breezes** and by the **Bora**, a north-to-northwest katabatic wind





Frequency of counts by wind direction (%)

sources

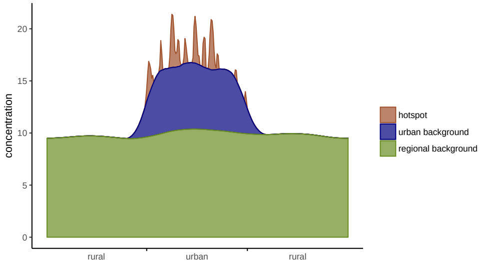
- emissions in the urban area:
  - urban roads,
  - highway,
  - harbour area,
  - industrial area
- primary and secondary pollutants advected from:
  - Venetian-Friulan Plain
  - Po Valley
  - Slovenia ($\sim$ 8 km from the city center)
  - Croatia ($\sim$ 20 km)

plant

- ”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**

method and models

assumptions



1. daily PM10 concentrations considered as the sum of 3 components: regional background, urban background, hotspots additional concentration
2. hotspot contribution considered as passive tracer (chemistry negligible on this scale)
3. traffic, harbour and other urban sources affects only urban background, not hotspots (hotspots affected only by the plant)

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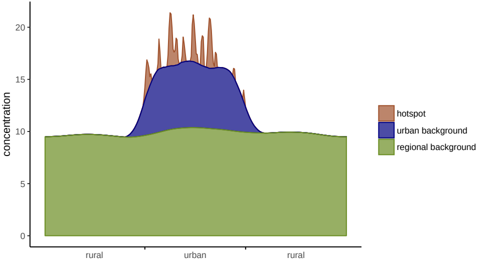

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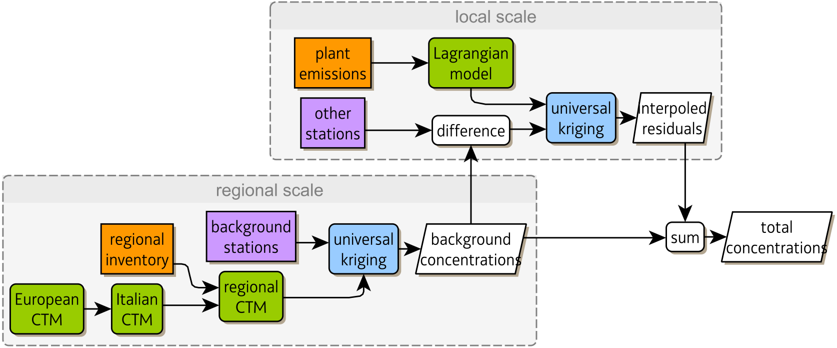
→ assumption 3 is weak, see *final remarks*

modeling hybrid approach

regional scale: $c_{bckg} = f_{Universal\ Kriging}(c_{bckg.stations}, c_{CTM})$

local scale: $\Delta c_{hotspot} = f_{Universal\ Kriging}(\Delta c_{other\ stations}, c_{Lagrangian\ Model})$ where Δ denotes the residual with respect to c_{bckg}

total: $c_{tot} = c_{bckg} + \Delta c_{hotspot}$



Eulerian Chemistry-Transport model (CTM)

- **FARM** model (*Silibello* et al., 2008)
- domain: Friuli Venezia Giulia, Gulf of Trieste, part of Istria, Slovenia and Veneto
- horizontal resolution: 2 km
- boundary conditions: FARM covering Italy[1]
- chemistry: SAPRC99 (gas), CMAQ/AERO3 (aerosol)
- meteorological input: **WRF**[2] (Gladich *et al.*, 2008)
- emission input is based on regional[3], national (De Lauretis *et al.*, 2009) and EMEP inventories

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

post-processing of the CTM

- on a daily basis, data fusion of average PM10 concentrations is performed
- values measured at the **background stations** are interpolated
- horizontal resolution: 500 m
- **Universal Kriging** technique with the output of the CTM as spatial trend (Hiemstra *et al*, 2009; Wackernagel, 2003)

$$c_{bckg} = f_{Universal\ Kriging}\left(c_{bckg.stations}, c_{CTM}\right)$$

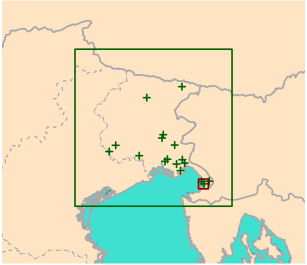
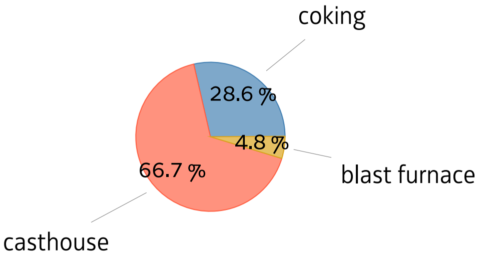


Figure: CTM domain over Friuli Venezia Giulia + background AQ stations

Lagrangian model

- Lagrangian model (LM) **SPRAY** (Tinarelli *et al.*, 2000)
- meteorological input: **WRF** + turbulence postprocessor
- domain: Trieste area
- horizontal resolution: 50 m
- emissions estimates based on production indicators
- emission sources are represented, with some approximations, with three rectangular sources: blast furnace (height 40 m), casthouse (6 m) and coking (20 m)



postprocessing of the LM

- differences between concentrations measured in Trieste and the interpolated background concentrations are again interpolated
- **Universal Kriging** technique with the output of the LM as spatial trend

$$\Delta c_{hotspot} = f_{Universal\ Kriging}(\Delta c_{other\ stations}, c_{Lagrangian\ Model})$$

$$c_{tot} = c_{bckg} + \Delta c_{hotspot}$$

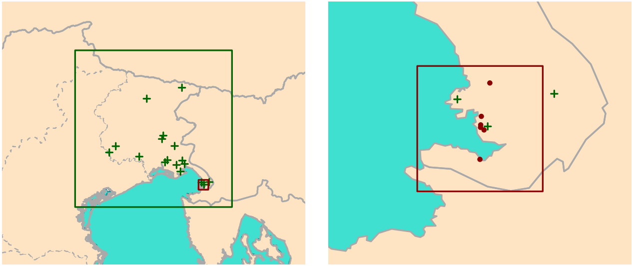


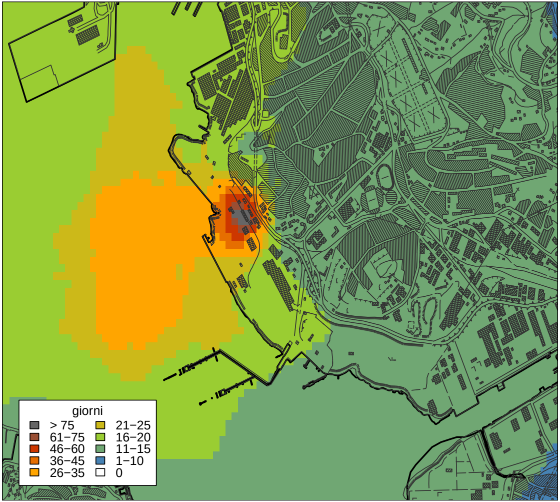
Figure: Green: CTM domain + backgr. AQ stations. Red: LM domain + other stations

assessment

exceedances 2016

PM10

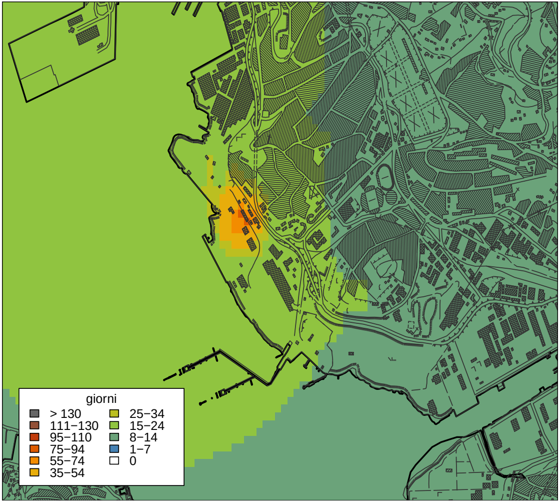
superamenti giornalieri della soglia di 50µg/m²
periodo: 01/01/2016 − 31/12/2016



Jan-Sep 2017

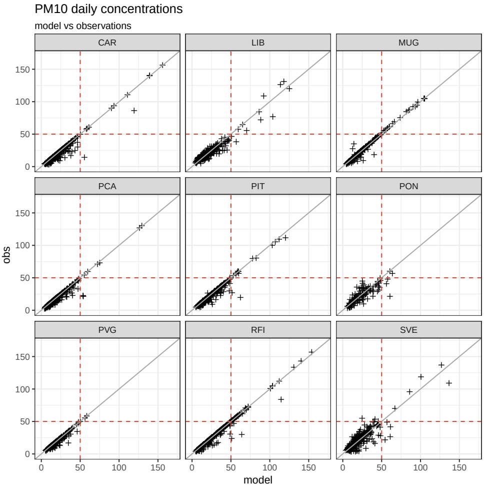
PM10

superamenti giornalieri della soglia di 50µg/m^2
periodo: 01/01/2017 − 30/09/2017



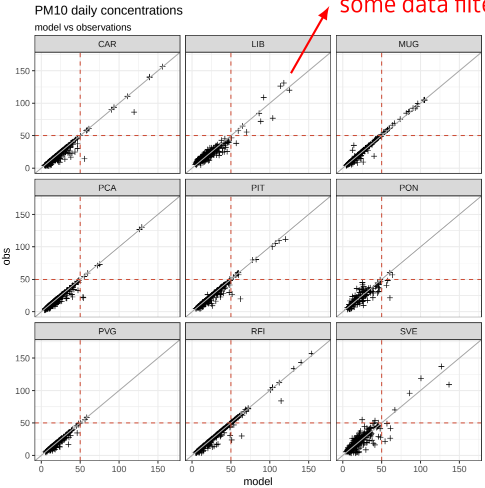
evaluation

daily concentrations



daily concentrations

some data filtered out by QC



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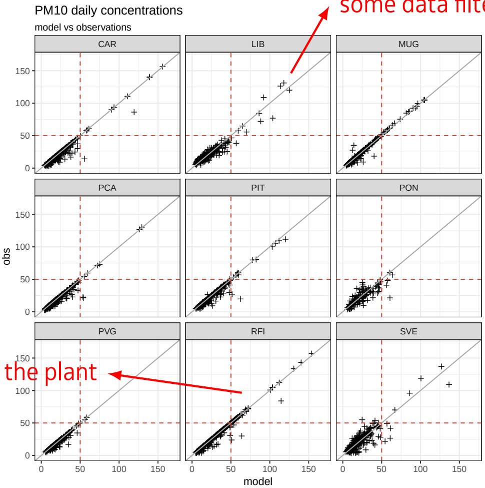
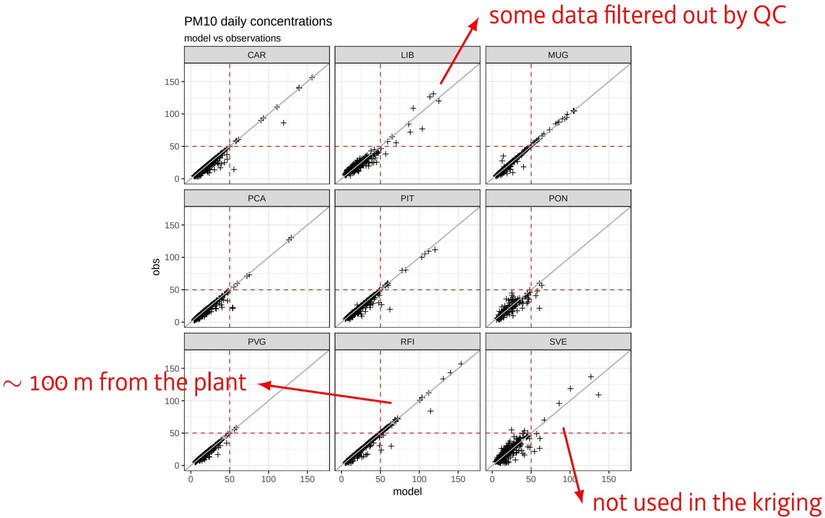


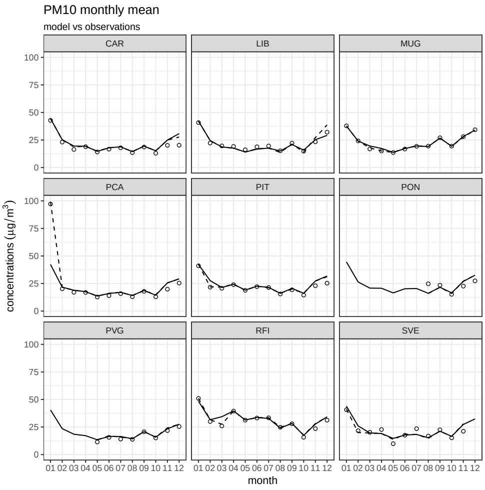
some data filtered out by QC

~ 100 m from the plant

daily concentrations

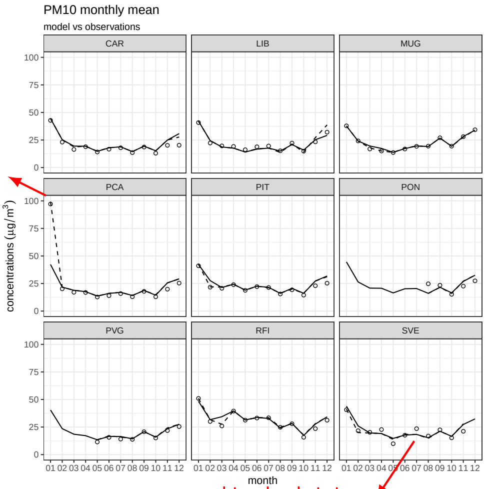


monthly mean



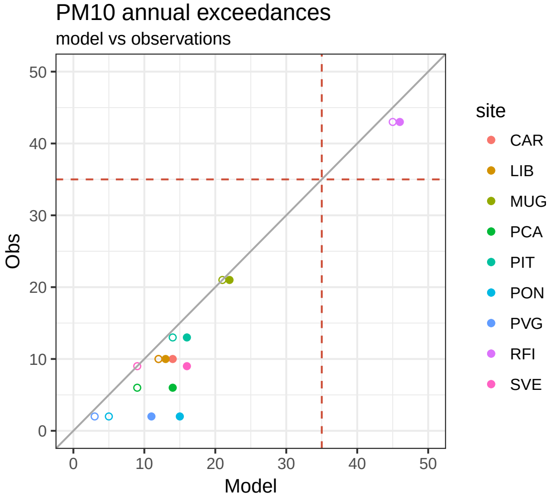
monthly mean

Jan: many missing data



not used in the kriging

total 2016 exceedances



● all days
○ excluded days with missing observation

source attribution

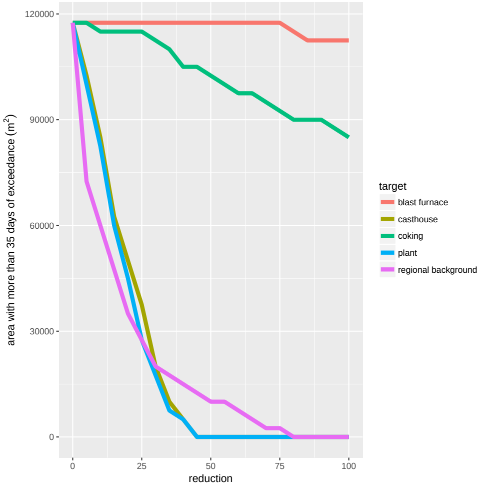
method

- every day, for each cell, residuals are attributed to each of the 3 sources proportionally to the impact calculated by the LM

$$\Delta c_{source} = \Delta c_{tot} \cdot \frac{c_{SPRAY,source}}{c_{SPRAY,tot}}$$

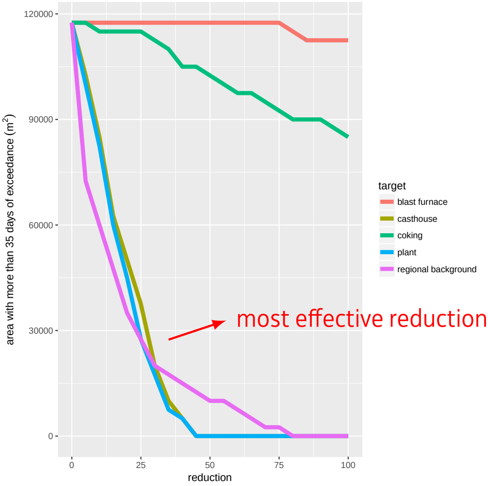
- **scenarios**: for each source, the emission has been progressively decreased
- on annual basis, the indicator "**area with more than 35 daily exceedances**" has been calculated

results



area with more than 35 days of exceedance (m^2)
120000
90000
60000
30000
0
0
25
50
75
100
reduction
target
blast furnace
casthouse
coking
plant
regional background

results



most effective reductions: casthouse and background

final remarks

conclusions

- due to the prevailing wind regimes, the most critical areas for PM10 pollution are in the industrial area itself and over the sea
- the hill of Servola (to the north-east of the plant) acts to some extent as a shield for the residential area
- the buildings closest to the plant are exposed (in 2016) to 5-10 exceedances more than the rest of the neighbourhood

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- different emission reduction strategies have been evaluated; 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 background (regional and urban)

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- different emission reduction strategies have been evaluated; 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 background (regional and urban) $\longrightarrow$ this conclusion may be pretty sensitive to our assumptions regarding the emissions of the plant, see next slide

perspectives

Next steps:

- additional model for the other local relevant sources (vehicles, home heating, harbor and ships), maybe *Land Use Regression* method
- extension to benzene (maybe using benzene/toluene ratio to distinguish between traffic and plant contributions)
- more accurate information about emissions (hopefully)

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.

Thank you for your attention.

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- questions?
- suggestions?

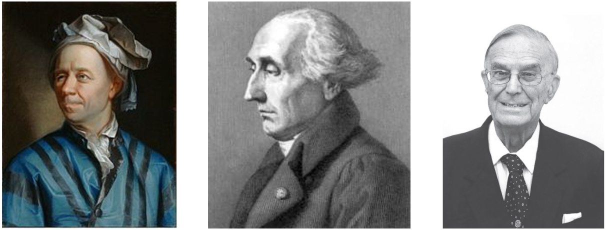

Figure: Left to right: L. **Euler**, J.-L. **Lagrange** and D. G. **Krige**