# Where monitoring meets modelling: application of a dispersion model in the design of a monitoring campaign

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# the problem

- we have to plan a monitoring campaign
- aim of the campaign is to evaluate the impact on the air quality of a waste incinerator
- there are no data from before the plant was built → a comparison before-after is not possible
- the area is affected by the impact of many other emission sources, with large spatial variability → the impact of the incinerator cannot be considered as superposed over uniform background
- the bulk emission rate of the incinerator is small in comparison to the context
- an incinerator-related tracer could be difficult to recognize

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# the approach

a special effort is required in selecting the sampling sites and periods, in order to collect simultaneous samples so that the differences between them (in chemical and physical characteristics) can mainly be attributable to the incinerator

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*a priori* information on the expected impact of the confounding emissions and - separately - of the plant (i.e. its distribution in space and time) is needed

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## overview of the method

The method has 3 sequential steps:

1. the choice of the sites for monitoring the heaviest impact of the plant;
2. the choice of the monitoring periods;
3. the choice of the control sites.

# step #1: choice of the sites for monitoring the heaviest impact of the plant

- ADMS-Urban gaussian modified dispersion model (Carruthers et al., 1994; CERC, 2006)
- a simulation has been carried out considering the plant as the lonely emission source
  - one year
  - constant emission
  - output over a regular grid
- As result of this first simulation → identification of:
  - "high impact areas" $A_{high,k}$
  - inside every impact area, one high impact monitoring site $S_{high,k}$
  - "negligible impact area" $A_{negl}$ (in this area the simulated concentrations are at least 90% lower than the concentration calculated in the "high impact areas")

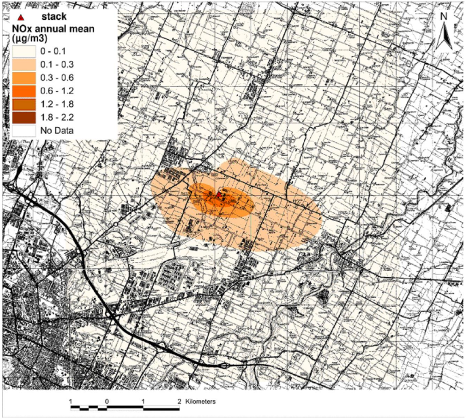


Figure 1: Simulated annual mean of $NO_x$ concentrations, only with plant emissions

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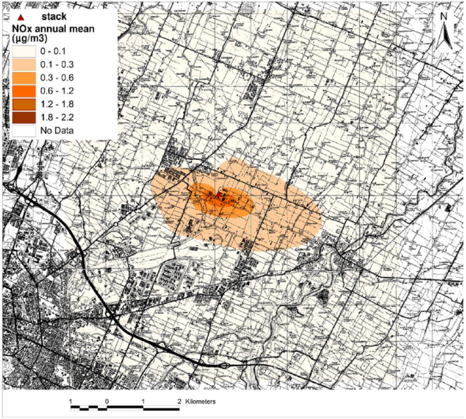


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# step #2: choice of the monitoring periods

- another simulation has been carried out, again considering the plant as the lonely emission source
  - one year
  - constant emission
  - **output over the selected high impact monitoring sites**
- as result of this second simulation:
  - identification of the periods when the impacts are highest
  - the months that show the highest simulated concentrations has been chosen for the campaign
  - identification of meteorological conditions favourable to the highest impact

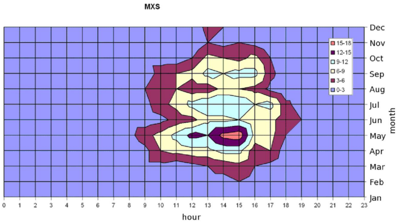


Figure 2: Occurrences of "critical hours" in the monitoring site "MXS"

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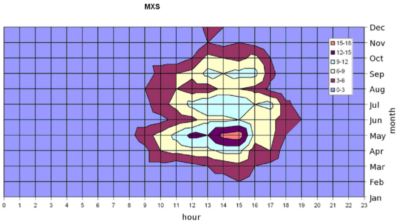


Figure 2: Occurrences of "critical hours" in the monitoring site "MXS"

# step #3: choice of the control sites

In order to have information about the impact of the plant, each **high impact monitoring site** $S_{high,k}$ should be associated to a **control site** $S_{ctrl,k}$. This control sites are chosen in such a way to

- maximize the differences attributable to the plant stack
- minimize the differences between them attributable to the surrounding sources

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How can we fulfill these requirements?

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# step #3: choice of the control sites

→ A simulation has been carried out considering the "confounding" emission sources:

- same meteo input as the other simulations
- output over a regular grid and over additional points close to the emission sources

As result of this simulation:

- the impact $C_k$ of the "confounding" emissions on every high impact monitoring site is evaluated and compared with the impact in the domain
- for every high impact monitoring site $S_{high,k}$, a "similar area" $A_{sim,k}$ has been highlighted, where $C \in [C_k - 25\%, C_k + 25\%]$
- the control site is selected in the intersection $S_{ctrl,k} \in (A_{sim,k} \cap A_{negl})$

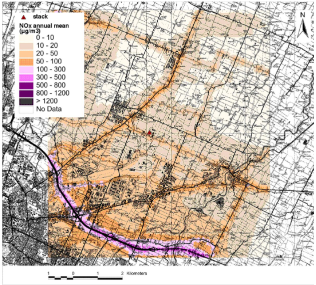


Figure 3: Simulated annual mean of $NO_x$ concentrations, only with "confounding" emissions

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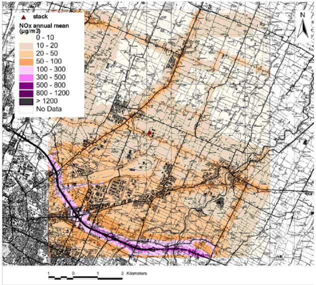


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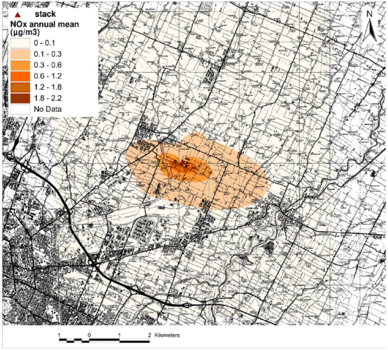


Figure 4: Simulated annual mean of NOx concentrations, only with plant emissions

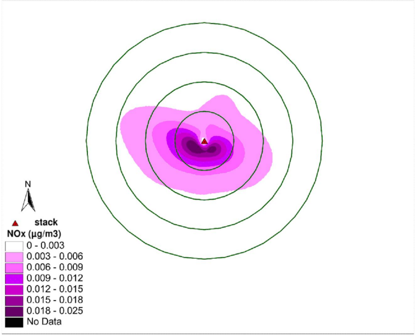


Figure 5: The "high impact" area $A_{high,k}$ (darkest purple shaded) and the "negligible impact" area $A_{negl}$ (white shaded) are identified

- the same analysis was repeated for shorter periods, focusing on summer and on winter months
- in winter the simulated impact of the incinerator is some orders of magnitude smaller
- selected monitoring sites in the "high impact" areas: MXS and MXW

# step #2: choice of the monitoring periods

- the 500 hours with the highest impact of the incinerator are called “critical”
- in the site MXS most of the critical hours occurr between April and July in the timerange between 11 and 16 LST
- in the site MXW, most of the critical hours occurr between July and October in the morning

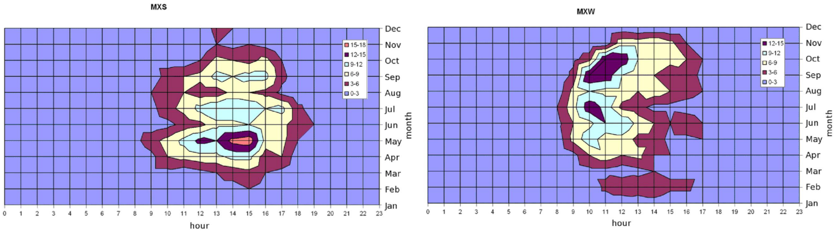


Figure 6: Occurrences of “critical hours” in the high impact monitoring sites.

# step #3: choice of the control sites

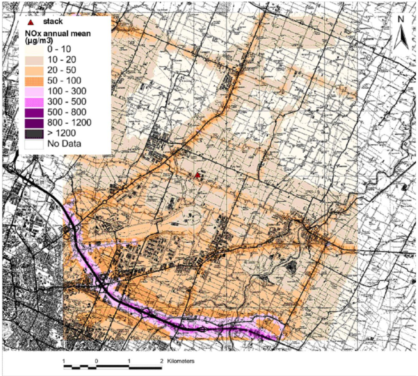


Figure 7: Simulated annual mean of NOx concentrations, only with "confounding" emissions

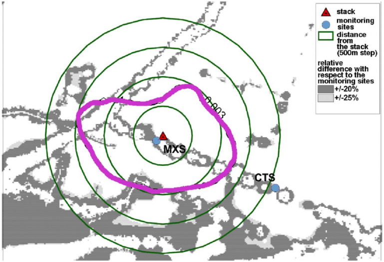


Figure 8: The areas (grey shaded) similar to the maximum impact monitoring site are identified. For every maximum impact monitoring site, a control point is selected in the intersection between "similar areas" and "negligible impact area": $S_{ctrl,k} \in (A_{sim,k} \cap A_{negl})$

# meteorological characterization

The meteorological conditions are statistically analyzed.
Critical hours in site MXS are associated with

- unstable conditions ($-10m < L_* < 0m$, in 100% of the cases),
- high mixing height ($h > 500m$ in 96% of the cases) and
- weak winds ($< 5m \cdot s^{-1}$) from N to E

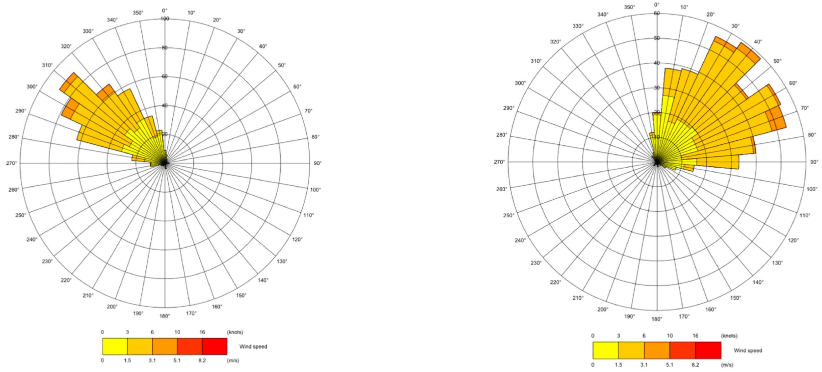


Figure 9: Wind roses of the "critical hours" for sites MXW (left) and MXS (right)

# forecasting "critical hours" probability of occurrence

forecast of the probability of occurrence of a "critical hour" in a monitoring site → near real-time support ⇝ decision to delay the end of the campaign

A classification tree (Breiman et al., 1984) was build and calibrated for each monitoring site:

- predictand is the probability of occurrence of a "critical hour"
- predictors are
  - reciprocal of the Monin-Obukhov length,
  - component of wind along the stack-site direction,
  - mixing height

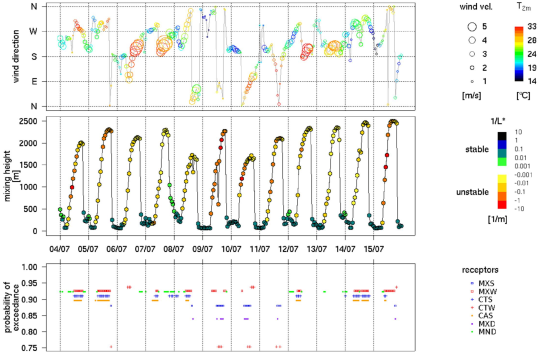


Figure 10: During the campaign, synthetical meteorological information are automatically calculated and plotted

And after the campaign?
See the poster “A new proposal for detecting the impact of a smokestack with the help of a dispersion model” (H14-272)

# References


- Breiman L, JH Friedman, RA Olshen, CJ Stone, 1984: Classification and regression trees. Wadsworth & Brooks
- Carruthers, D., Holroyd, R., Hunt J., Weng, W.-S., Robins, A., Apsley, D., Thomson, D., Smith, F., 1994: UK-ADMS: a new approach to modelling dispersion in the earths atmospheric boundary layer. Journal of Wind Engineering and Industrial Aerodynamics 52, 139-153
- CERC, 2006: ADMS-Urban, User Guide. Available from Cambridge Environmental Research Consultant, Cambridge, UK

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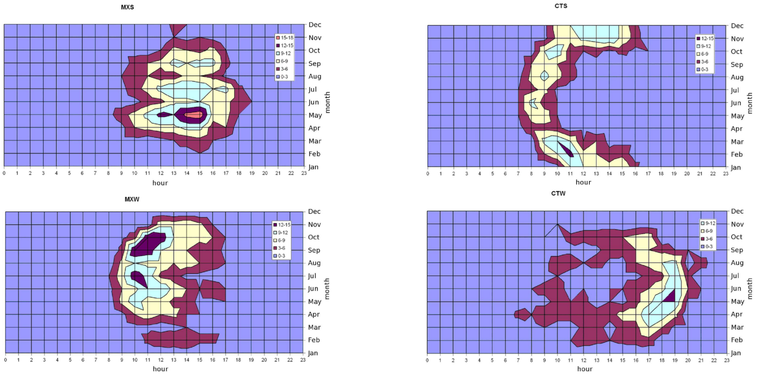


Figure 11: Occurrences of "critical hours" in the monitoring sites.