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WHERE MONITORING MEETS MODELLING: APPLICATION OF A DISPERSION MODEL IN THE DESIGN OF A MONITORING CAMPAIGN

Giovanni Bonafè[1] and Mauro Rossi[2]

[1]Arpa Emilia Romagna, Servizio IdroMeteoClima, Italy
[2]Arpa Emilia Romagna, Sezione di Rimini, Italy

Abstract: In this work a methodology based on a dispersion model is proposed, described and tested, to plan a monitoring air quality campaign nearby a waste incinerator. Aim of the campaign is to evaluate the impact of the incinerator smokestack on the air quality, in an area including many emission sources. The goal of the proposed methodology is to optimize yhe choice of the sampling sites and periods, in order to assess the impact of the incinerator.

Key words: *monitoring, campaign planning, dispersion modelling.*

INTRODUCTION

An intensive monitoring campaign has been planned and carried out in order to evaluate the impact of a waste incinerator on the air quality close to Bologna, Italy. The methodology to define the sampling sites and periods is described here, considering the results of a dispersion model (ADMS-Urban, Cerc UK).

Since there are no data from before the plant was built, a comparison before-after is not possible. Also, the area is affected by the impact of many other emission sources, with large spatial variability, so the impact of the incinerator cannot be considered as superposed over uniform background. Moreover, the bulk emission rate of the incinerator is small in comparison to the context, and an incinerator-related tracer could be difficult to recognise.

Given these constraints, 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. Therefore, *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. In this paper, how the dispersion model simulations have been used to get such information is described.

METHODOLOGY

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.

1. A simulation has been carried out with the ADMS-Urban gaussian modified dispersion model (Carruthers *et al.*, 1994; CERC, 2006), considering the plant as the lonely emission source. The simulation covers one year. The meteorology has been selected in a way without strong anomalies in respect to the climate. Due to its low daily and seasonal variability, emissions are considered constant. Output concentrations are calculated over a regular grid.

As result of this first simulation, the regions of the integration domain where the impact of the plant is higher are identified. Inside each of these “high impact areas” one site for monitoring the maximum impact of the plant is selected on the basis of feasible criteria. Also, a “negligible impact area” is highlighted. In this area the simulated concentrations are at least 90% lower than the concentration calculated in the “high impact areas”.

2. Another simulation, with the same input data as the first one has been caried out. The hourly concentration calculated over the highest impact sites (concentration time series) were the output of this simulation.

The aim fo this two simulations is to identify not only the points where the impact of the plants are the highest (first simulation), but also the periods when those impacts are highest, for every high impact sites considered (second simulation). In particular, the months that show the highest simulated concentrations has been chosen for the campaign. The type 1. simulation has been performed in different time periods to compare seasonal different behaviour of different high impact sites.

Moreover, for each monitoring sites, a classification tree is calibrated to forecast the probability to exceed a given threshold fo the calculated hourly impact of the plant (therefore not directly measurable). For the calibration, the meteorological parameters (input of ADMS-Urban) are used as predictors and the concentration (output of ADMS-Urban) as predictand. These classification trees are a fast tool to provide real-time information during the campaign, e.g. to support the decision to eventually delay the end of the campaign.

3. At last we have to select the control sites. In order to have information about the impact of the plant, each high impact monitoring site should be associated to a control site. This control sites are chosen in such a way to maximize the differences attributable to the plant stack and minimize the differences between them attributable to the surrounding sources. To do that, we need to perform a new simulation. The emission sources taken into account for this simulation were the “confounding”

ones and the meteorology and time period are the same used for the previous simulations. Output concentrations are calculated over a regular grid and over additional points close to the emission sources (CERC, 2006). As a resultthe "similar areas" has been highlighted.In those areas the concentrations due to the surrounding sources are "similar" in respect to the same concentrations calculated in the highest impact monitoring site under study. For our peculiar applied case we had to choose a 25% of tolerance interval. Inside the intersection of the "negligible impact area" with each of these "similar areas", the control site, paired with the highest impact site under study,has been selected, againon the basis of feasible criteria.

RESULTS

The methodology described above was applied to the planning of an intensive monitoring campaign.The aim of the campaign was to evaluate the impact of a waste incinerator on the air quality close to Bologna, Italy. First, a simulation with the dispersion model ADMS-Urban was carried out, using as emission source only the incinerator. The results of this simulation (figure 1, left panel) have been used to define the "high impact area" and the "negligible impact area" (figure 2, left panel). Inside the "high impact area" the site for monitoring the maximum impact has been selected (MXS in figure 2, right panel).

Then, another annual simulation was run, again setting only the incinerator as emission source, but calculating hourly concentrations of $NO_x$for the site selected for monitoring the maximum impact ("MXS"). The 500 hours with the highest simulated values of concentrations (i.e. highest impact of the incinerator) are called "critical"; their distribution in time was analyzed. Most of the critical hours occurr between April and July in the timerange between 11 and 16 LST (figure 3, top left panel).

The same analysis was repeated for shorter periods, focusing on summer and on winter months. This lead to select also one site for monitoring the maximum impact during a winter campaign ("MXW"), even if in winter the simulated impact of the incinerator is some orders of magnitude smaller. In the site MXW, most of the critical hours occurr between July and October in the morning (figure 3, bottom left panel).

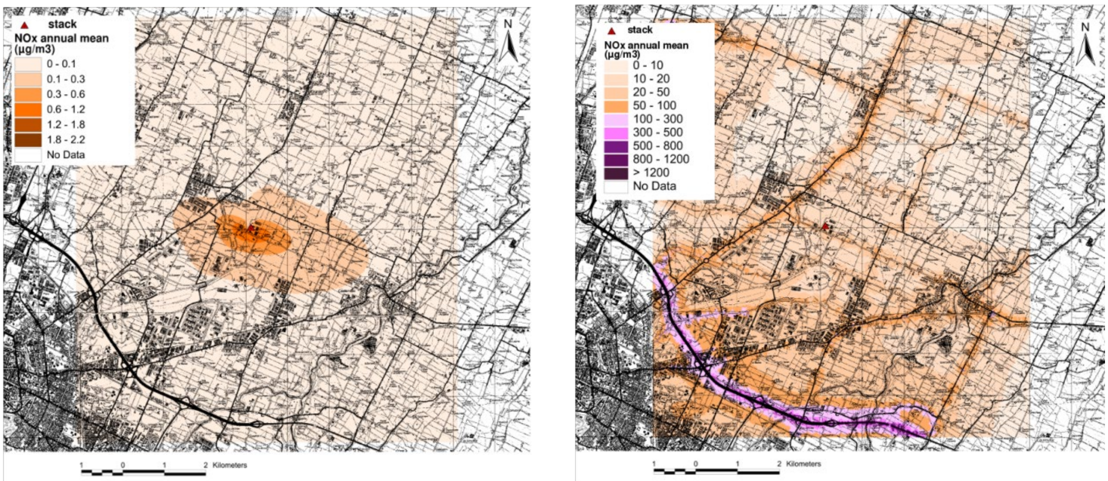

Figure 1. Simulated annual mean of NOx concentrations. Left: only with plant emissions. Right: only "confounding" emissions.

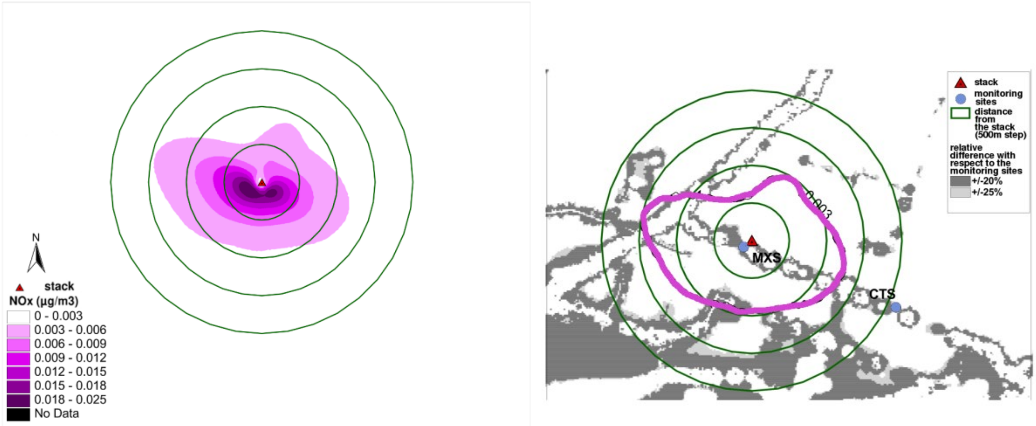

Figure 2. Left panel: by means of a simulation only with plant emissions, the "high impact" area (darkest purple shaded) and the "negligible impact" area (white shaded) are identified. Right panel: by means of a simulation only with confounding emissions, the areas (grey shaded) similar to the maximum impact monitoring site are identified.

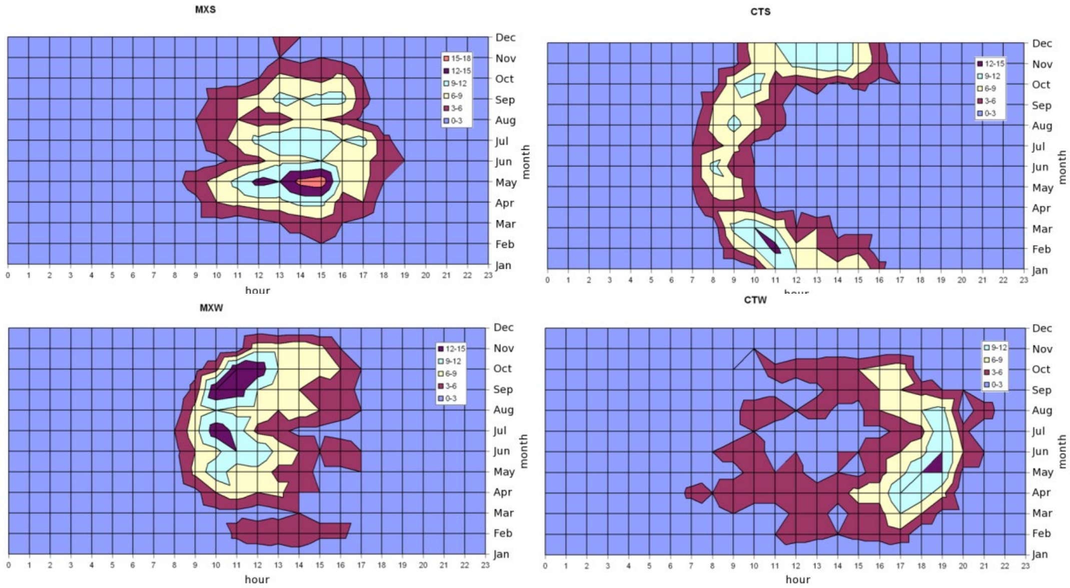

Figure 3. Occurrences of "critical hours" in the monitoring sites.

After the selection of the sites monitoring the maximum impact of the plant, and the selection of the periods of the campaign, we have to choose the control sites. For every selected campaign period, a new simulation was run considering as emission input the surrounding sources, without the incinerator. Then, the "similar areas" are defined, according to the condition that the simulated mean concentrations (i.e. the impact of the "confounding" emissions) are included in the range +/-25% with respect to the same concentrations calculated in the maximum impact monitoring site. In figure 2, right panel, areas "similar" to the site "MXS" are grey shaded.

For every maximum impact monitoring site, a control point is selected in the intersection between "similar areas" and "negligible impact area". In figure 2, right panel, the "negligible impact area" is outside the purple isoline; "CTS" is the control site linked to the "MXS" maximum impact monitoring site. For our campaigns, two maximum impact monitoring sites (MXS and MXW), two control sites (CTS and CTW) and other three monitoring sites close to sensible receptors have been selected.

For each monitoring site the "critical" hours are identified and their distribution in time is analyzed (figure 3). Also, the meteorological conditions are statistically analyzed. Figure 4 shows, represented as "wind roses", the distribution of wind velocity and direction associated with the highest impact of the incinerator in sites MXW and MXS. 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 ($<5ms^{-1}$) from N to E (figure 4, right panel).

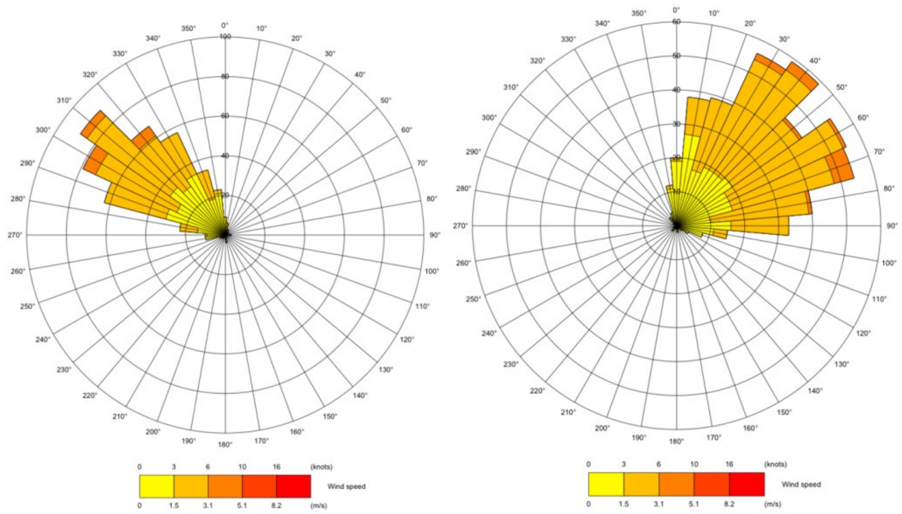

Figure 4. Wind roses of the "critical hours" for sites MXW (left) and MXS (right).

To forecast the probability of occurrence of a "critical hour" in a monitoring site, in order to give near real-time support (eventually supporting the decision to delay the end of the campaign), a classification tree (Breiman *et al.*, 1984) was build and calibrated for each monitoring site. Figure 5 shows the classification tree for site MXW: predictand is the probability of occurrence of a “critical hour”; predictors are the reciprocal of the Monin-Obukhov length (“RECIPLMO” in the diagram, in m^{-1}), the component of wind along the stack-site direction (“wc”, in ms^{-1}) and the mixing height (“H”, in m). During the campaign, synthetical meteorological information are calculated and plotted as shown in figure 6.

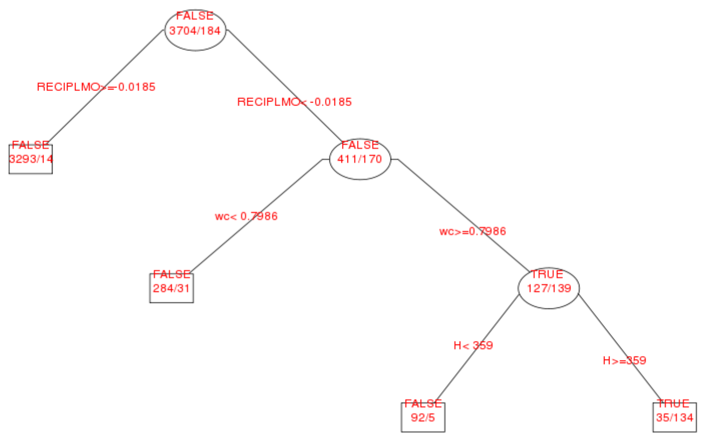

Figure 5. Classification tree to forecast the probability of occurrence of “critical hours” in the monitoring site MXW.

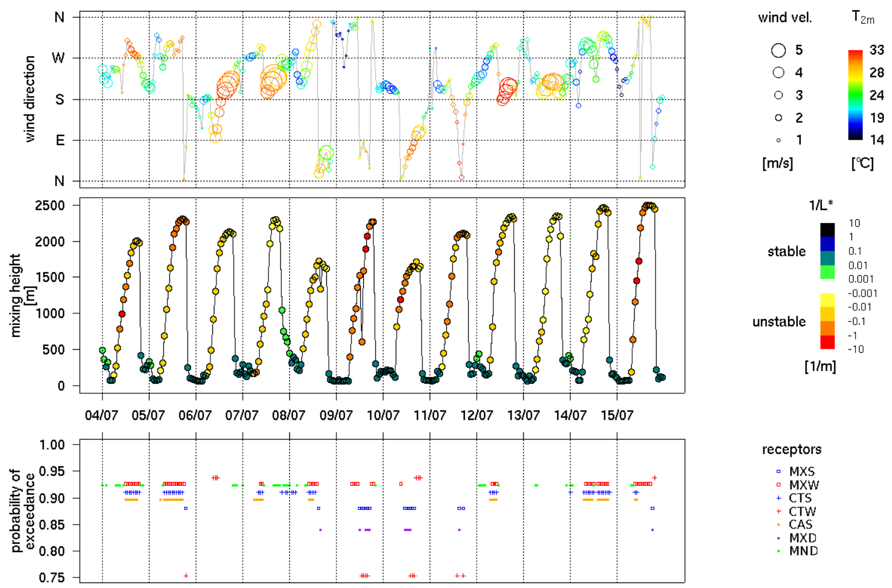

Figure 6. Meteorological characterization of 12 days of the summer monitoring campaign. Top: wind direction, wind velocity (radius of the circles) and 2m temperature (color). Middle: mixing height and inverse of the Monin-Obukhov length (color). Bottom: probability of occurrence of “critical hours” in the monitoring sites, given the meteorological parameters, as forecasted by classification trees.

CONCLUSIONS

A methodology is proposed and described, aiming to select the sampling sites and periods for a monitoring campaign, which goal is to evaluate the impact of a waste incinerator on the air quality. The simulations of a dispersion model have been used to get *a priori*information on the expected impact of the confounding emissions and - separately - of the plant. Moreover, the proposed approach gives information on which are the meteorological conditions favourable to the highest impact of the plant on the monitoring sites.

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