6.14 MODELLING POLLUTION EPISODES OF PM10

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INTRODUCTION

The new CALMET/CALPUFF modelling system (2003) was tested for a sensitivity study on different input options for the analysis of pollution episodes in the Pisa district. In particular the Cascina and Navacchio towns near Pisa are characterised by frequently high pollution episodes, with exceedance of the PM10 concentration limit of 50 μg/m^3 that occurs in the winter but also in the summer period.

Pollution from particulate matter deals with a complex mixture of inorganic and organic compounds that could be emitted by primary or secondary sources. Their relative contributions to ambient air concentrations varies with seasonal and sites characteristics. This first attempt of parametric analysis by the CALMET/CALPUFF modelling system was made to study the different contributions of the primary emission sources of PM10 present in the Pisa district.

STUDIED AREA

The studied area is a 40km x 35km domain sited in the western part of the Tuscany region is comprised a large part of the Pisa district and the upper part of the Livorno one. The area is characterised by three main geographical zones: a coastal zone (35 km of length) on the west side, the river Arno basin and two chains of hills (height lower than 800 meters) on the north and on the south of the domain. The area is mainly agricultural and only 20% of the domain is urban or industrial. The population density varies from minimum values of 250 inhabitans/km^2 up to 1600 inhabitans/km^2 (urban area of Livorno).

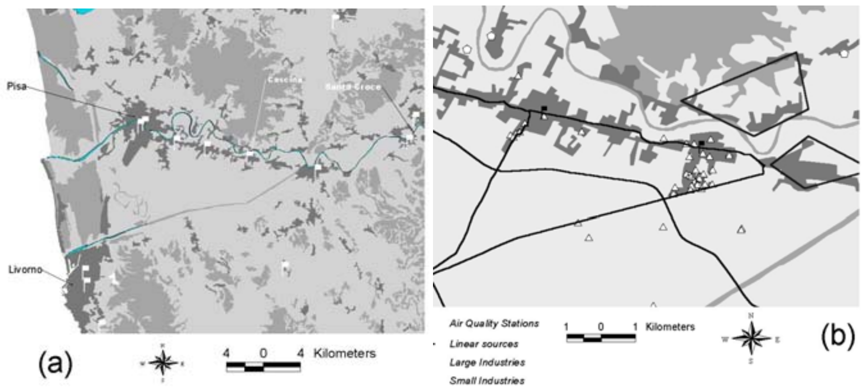

Figure 1. Studied Area (a) Orography and Land Use, (b) Emission sources location (point, linear and area sources).

The area is characterised by the presence of lots of small manufacturing companies (from 5 to 20 employee), with only some relevant industrial sites: the Livorno district of petroleum refinery industries, the glass and mechanical industries in Pisa and Pontedera, the tannery district in Santa Croce. The emission inventory used for the simulations considers all the different possible emissions of primary PM10. The emissions from point sources, divided in large and small plants, were evaluated from the data coming from regional administration, with a detailed view on the Cascina town and considering only large industries in the rest of area. For the linear emission sources, hourly traffic volume on the main roads in the Cascina town was elaborated starting from emission factors of CORINAIR database. All the other emission sources for PM10 inside and outside the Cascina town domain were computed as area sources. Data were taken from the annual mean estimated values of Tuscany Region (IRSE 2000). The related emissions, on the entire domain, from the three source types are, on an annual scale, 1600 ton/year from area sources, 28 ton/year from small industrial point sources in Cascina and 800 ton/year from large point sources in the domain, and 16 ton/year from the linear sources of Cascina domain.

AIR QUALITY DATA AND MODELLING SYSTEM

One year of data from the air quality network of the Tuscany region was elaborated to understand the frequently occurrences of critical days of pollution episodes, in particular for PM10. In fact the monitoring stations situated in the modelling domain, figure 1a, reveal different mean annual values, number of exceedances of the 50 μg/m^3 regulatory limit and seasonal trends. The study was focused on the Navacchio and Cascina towns that show the highest values for the last three years of data related to the stations in Pisa (10km on west side) and Santa Croce (8km on the east side). All these monitoring stations are classified as urban/traffic (1999/30/CE) with the same traffic parameters; however they show different time series for hourly and seasonal time periods. In figure 2a the mean monthly values for the three cited monitoring stations are shown with their standard deviation. The concentration values in Cascina and Navacchio are two times that measured at Borghetto station and the number of exceedances reveals pollution episodes not only in the winter but also in spring and summer period. This different behaviour was taken as a case study for the sensitivity analysis performed by the CALPUFF modelling system.

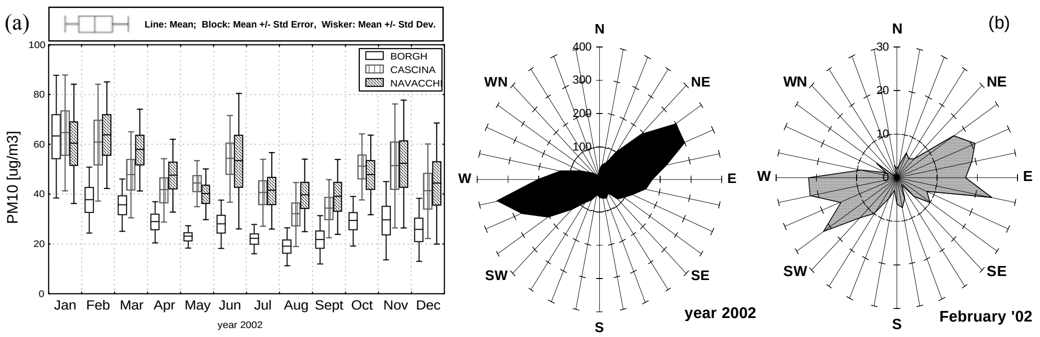

Figure 2. Air quality data from monitoring stations (2000-2003) and meteorological parameters for year 2002 (simulated period)

For the modelling purpose, the meteorological parameters were previously studied taking into account different sources of data. The meteorological data from air quality stations (4m height) and RAMS prognostic model data provided by La.M.M.A (Regional Meteorological Office, Florence, Italy) are used to evaluate the best inputs to be used in the CALMET model. The meteorological data analysis reveals that the data from some monitoring stations, Navacchio and Cascina, are strongly influenced by the micro-scale factors as buildings height, local turbulences or wind calms. For these reasons the RAMS data were finally preferred as input. They also show very good correlation with other meteorological station (Pisa international airport and Livorno 40m height). The RAMS model provides data with a grid resolution of 4km x 4km and 12 vertical levels. The wind rose for the year 2002 (figure 2b) shows the predominant occurrence of west and east winds, with values of the wind speed up to 6-8 m/s. Figure 2b shows the data for February 2002, the chosen period for the modelling applications.

Modelling system

The CALPUFF Modelling System includes two main models:

- CALMET is a diagnostic wind field generator and provides the three-dimensional wind and temperature fields, using a diagnostic and a micrometeorological module;
- CALPUFF is a non-steady Lagrangian Gaussian Puff model, with modules for terrain effects, building downwash, wet and dry removal, simple chemical transformations.

The new version of the CALPUFF modelling system (Scire et al. 2003) has been used. It includes numerous new features and a "no-observations" option in CALMET allowing the model to be run with 3-D prognostic meteorological data (e.g., MM5, RAMS). RAMS data have been used as input to CALMET in this work.

RUNS

As previously mentioned, the simulation period was the month of February 2002. The parametric and sensitivity study was done by the two cited models: CALMET and CALPUFF. For the meteorological diagnostic model different runs were done, changing the land use options: simple (constant values of land use) or complex (sea, urban, agricultural, forest land). The reconstructed wind fields by the prognostic model should be detailed on a fine grid-spacing to obtain data according to a detailed description of the orography. The aim of these runs, see table 1, is to obtain detailed and realistic data for the micrometeorological parameters needed for an advanced application of the CALPUFF code.

Table 4. CALMET parametric sensitivity analysis.

CALMET INPUTS	Options	Details	Grid Resolution	Simulation Period
METEO				
	Prognostic Models	RAMS (38 to 3000 m)	1100m x 1100m	February '02
	Prognostic Models	RAMS (38 to 3000 m)	220m x 220m	February '02
OROGRAPHY				
	Simple	100m height resolution	220m x 220m	Daily / Hourly
	Detailed	15m height resolution	220m x 220m	Daily / Hourly
	Detailed	15m height resolution	1100m x 1100m	Daily/Hourly/Feb. '02
LAND USE				
	Simple	(land)	220m x 220m	Daily / Hourly
	Medium	(land, sea)	220m x 220m	Daily / Hourly
	Complex	(land, sea, urban, forest)	220m x 220m	Daily / Hourly

The obtained data from CALMET were used in the different scenarios described in table 2 for the modelling of the dispersion of primary PM10 emissions. The modelled scenarios are related to the study of the plume dispersion and to the evaluation of the PM10 concentration values from all the previously described sources. For this purpose the chosen fine grid resolution was found to be the best option to obtain a detailed spatial representation of the concentration fields on the entire domain. The results on a monthly scale, minimising computational time, were obtained by the nesting option on an area of 9km x 6km (grid resolution: 1100mx1100m on the entire domain, 220m x 220m nested area).

The detailed available information on the emission of PM10 from the different sources was used to create the scenarios described in table 2. Two different levels of emission sources were taken into account for the two grid domains. For the nested area, the data of the small and large industries and main roads were obtained from local emission inventory. All the information for the emissions on the larger domain was taken from the regional emission inventory and inserted as point or area sources. In this way it was possible to consider all the emissions for primary PM10 (as for example home appliances) that cannot be neglected (*Barna M.G., Gimson, N.R.* 2002) and to evaluate their contribution to the studied area. Comparing annual mean emission rates and detailed hourly variations of these parameters allows to study the different source apportionment in the studied area.

Table 5. CALPUFF simulations with different emission scenarios on the 40km x 35km domain.

	Simulated Period	Emission Sources			Time Resolution of Available Emission Data	Grid Resolution
		Point	Linear	Area		
Scenario 1	Hour/days	√			Mean annual data	220m x 220m
Scenario 2	Hour/days	√			Daily / Hourly	220m x 220m
Scenario 3	Hour/days	√			Daily / Hourly	220m x 220m
Scenario 4	Hour/days		√		Mean annual data	220m x 220m
Scenario 5	Hour/days		√		Daily / Hourly	220m x 220m
Scenario 6	Hour/days			√	Mean annual data	220m x 220m
Scenario 7	Hour/days	√	√	√	Mixed	220m x 220m
Scenario 8	February '02	√	√	√	Mixed	1100m x 1100m + nested 220m x 220m

RESULTS AND DISCUSSION

Wind speed, wind direction and mixing height were chosen for the parametric study by the CALMET code. The differences were estimated by computing the mean square error on the entire grid domain and the local receptor minimum and maximum differences for all these parameters (*Elbir, T.* 2003). The results of the simulations reveal that the mixing height is the more sensitive parameter, showing differences on the entire domain varying from 50 m up to 1670 m, according to the land use description. The wind speed and direction show only local noticeable differences, but still relevant for the pollutant dispersion modelling. In particular, table 3 describes the obtained results.

Table 6. CALMET parametric results of land use inputs parameters.

Tested parameters	LAND USE	
	Simple vs Complex	Medium vs Complex
Max Δwind speed [m/s]	3.5	0.6
% domain (Δspeed>0.5m/s)	5	0.1
Max Δwind direction [°N]	85	28
% domain (Δdir=10°N)	8	1
Max Δmixing height [m]	1670	66
%domain (Δmixh=50m)	99.5	4

In addition to the CALMET-CALPUFF model, parallel simulations were carried-out with ISC3ST for point sources and CALINE4 for linear sources, to compare the predicted concentrations and to optimise the diffusion parameters (es. buoyancy factor). Results of the simulations on the 26 days of February show the contributions on the daily average concentration values in the studied area of all the modelled sources. In figure 3a the predicted and observed concentration trends are compared. The results show a good agreement in the time series reconstruction, even if the differences in the hourly concentration values are systematically underestimated by a factor of 5. This could be related to the necessity of upgrading the emission inventory by estimating for example the resuspension terms of the particulate matter and mainly the contribution of the secondary PM10 sources. This was already found to be one of the most great limits of this type of models (*Levy et al.* 2003).

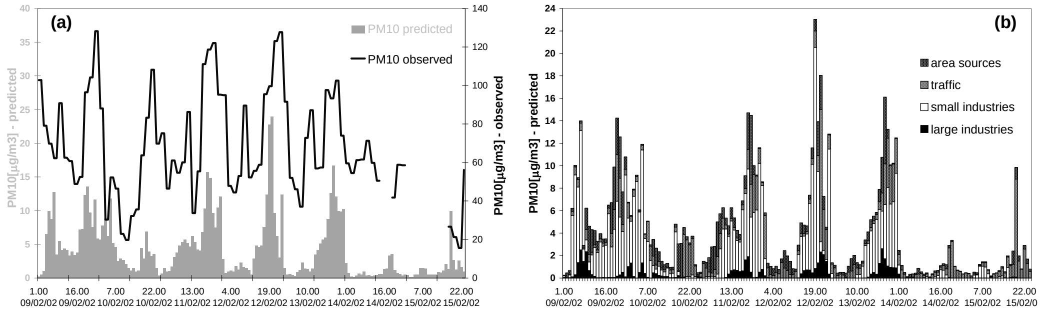

Figure 3. Modelled vs measured data for PM10 (a) and relative sources contribution (b)

In figure 3b the apportionment of the considered emission terms is shown. In particular, the local small industries determine the time series trends on the hourly scale and the area and traffic ones increase the concentration values up to the peak concentrations.

The daily average isoconcentration lines reconstructed on the modelling domain are shown in figure 4a and 4b, for two of the simulated days. It is important to notice how, due to the detailed meteorological conditions in two different situations, the contribution of different sources can be ascertained on a more objective base.

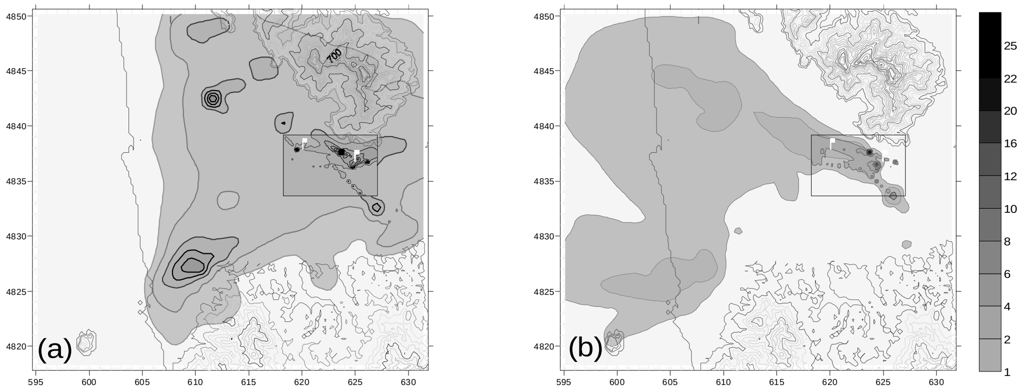

Figure 4. Predicted surface CALPUFF PM10 concentration iso-lines in the nested grid (a) 11th February 2002 (b) 15th February 2002 (unit µg/m³)

In particular when the lower values of the wind speed occur, the detailed description used for the wind fields reconstruction allows to follow with good agreement the complexity of the orography and better models the fate of PM10.

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