6.13 SYSTEMATIC ANALYSIS OF METEOROLOGICAL CONDITIONS CAUSING SEVERE URBAN AIR POLLUTION EPISODES IN THE CENTRAL PO VALLEY

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INTRODUCTION

The definition of meteorological conditions causing severe urban air pollution episodes is relevant to identify effective mitigation measures that can limit population exposure to peak pollutant concentrations and to define air quality management policies in urban areas. A recent Italian law (*D.M. 261/2002*), stating technical directives for regional air quality evaluation, explicitly requires the analysis of climatic and meteorological data to individuate and characterise typical or frequent conditions adverse to pollutant dispersion and favouring secondary pollutants formation.
The identification of the best meteorological predicting variables for the elevated concentration periods is important for building or improving urban air quality forecasting systems. The meteorological variables better correlated to the air pollution episodes need to be correctly forecasted by numerical weather prediction (NWP) models to feed deterministic air quality models (Baklanov et al, 2002) but can also be directly used to improve the performances of statistical or neural network models (Kukkonen et al., 2003).

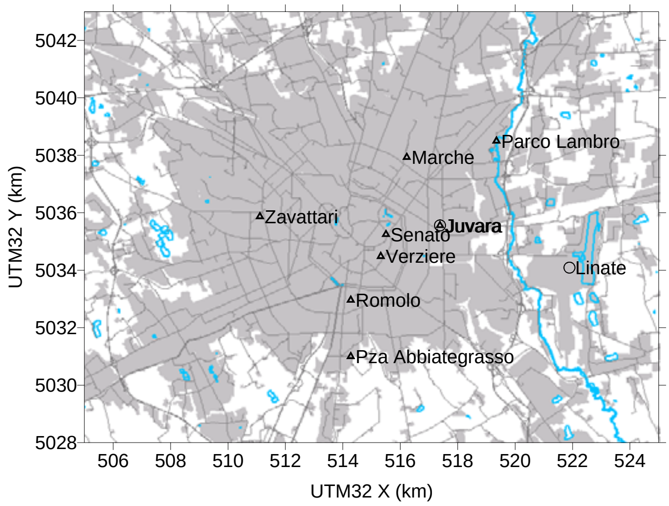

Figure 1. Milan city urban area, grey colour indicates built-up areas. Location of meteorological and air quality stations.

This work is focused on the analysis of severe winter episodes, characterised by exceedances of the EU and Italian air quality standards for PM_{10} and NO_2. The study is based on the air quality and meteorological data recorded in Milan during the period 1998-2003. The city of Milan has been chosen because it offers the longer time series of PM_{10} measurements in Italy and it allows to supplement surface observations with radio soundings launched from the suburban Linate airport (Figure 1). The results of the analysis can be considered representative for central and western Po valley areas.

AIR POLLUTION EPISODES SELECTION AND ANALISYS METHOD

The air quality data recorded by monitoring stations located inside Milan city core area (Figure 1) have been thoroughly analysed to individuate severe pollution episodes occurred during the last six years. The statistical analysis of PM_{10} concentrations sets in evidence the particular condition that affects the Po valley area during wintertime, with very high values recorded from October to February. The large number of exceedances (over 100) of daily average concentration limit (50 μg/m^3) recorded by the urban measuring stations made it impossible to use this indicator to identify and select the episodes.

Table 1. Number of exceedances of NO_2 hourly average concentration limit (200 μg/m^3). Grey cells indicate non attainment of EU air quality standards (EC/99/30).

Station name	1998	1999	2000	2001	2002	2003
Marche	65	33	24	22	46	26
Juvara	137	50	26	10	51	28
Zavattari	77	86	20	10	35	48
Verziere	93	40	24	7	12	11
Romolo	29	31	1	0	10	22
ParcoLambro	43	32	15	6	50	2
Senato	93	36	26	13	24	3
Pza Abbiategrasso	8	24	0	4	29	4
Messina	89	50	27	30	57	20

Table 1 resumes the exceedances of NO_2 hourly average concentration recorded by the urban stations of Milan city. The time variation of the number of exceedances mainly reflects the inter-annual variability of meteorological conditions, even if a certain decreasing trend would be expectable due to the renewal of the circulating car fleet. The number of days during which the NO_2 limit is exceeded (Table 2) varies from few days to about 14 days for all the years but 1998, when over 20 exceeding days are recorded in many stations.

Table 2. Number of days recording exceedances of NO_2 hourly average concentration limit (200 μg/m^3).

Station name	1998	1999	2000	2001	2002	2003
Marche	21	13	8	9	10	8
Juvara	28	11	9	4	10	9
Zavattari	23	23	9	5	9	11
Verziere	21	12	7	4	4	3
Romolo	12	9	1	0	4	8
ParcoLambro	14	13	8	3	11	2
Senato	18	9	9	7	7	2
Pza Abbiategrasso	4	8	0	2	8	1
Messina	13	16	10	12	12	8

To identify severe air pollution episodes, the pollutants concentration time series have been searched for periods characterised by simultaneous exceedances of NO_2 air quality standard and of the threshold of 100 μg/m^3 for PM_{10} daily average concentration. This last threshold has been arbitrarily fixed to identify periods characterised by very high concentrations. Among the episodes identified for each considered year, we selected the one showing the highest pollutant concentration levels and the longest duration (Table 3).

Table 3. Selected episodes and number of exceedances of NO_2 hourly average concentration limit (200 $\mu g/m^3$) measured in Milan Juvara monitoring station.

Year	Episode	Exceedances during the episode	Total yearly exceedances
1998	11-20/12/1998	65	137
1999	24/11-5/12/1999	30	50
2000	27/11-02/12/2000	19	26
2001	18-22/12/2001	6	10
2002	5-21/01/2002	50	51
2003	20/02-01/03/2003	17	28

METEOROLOGICAL CONDITIONS DRIVING AIR POLLUTION EPISODES

The meteorological conditions occurred during air pollution episodes have been analysed on the basis of synoptic information (weather maps and satellite images) local upper air data (radio soundings from Linate airport) and local urban meteorological data (Juvara station).

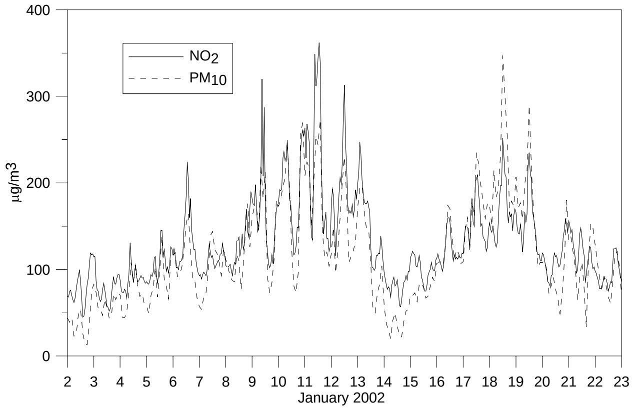

Figure 2. Hourly average concentrations of NO_2 and PM_{10} measured by Juvara station during January 2002.

The analysis of the long lasting episode occurred during January 2002 (Figure 2) is briefly reported to describe the employed methodology. The episode occurred on December 1998 has been described and compared with other European cities episodes in Sokhi et al. (2002).

January 2002 Milan episode

Two large peaks cover the period indicated in Table 3, the highest concentration values are recorded on January 11th and 18th, while a decrease of concentration is observed on January 14th and 15th. The largest fraction of NO_2 exceedances are observed during the first peak period (January 9th-13th), while PM_{10} highest values, for both hourly and daily average concentrations, are recorded during the second peak (January 16th-19th). It has to be remembered that traffic ban was imposed on Sundays January 13th and 20th from 8 to 20 l.s.t.. Synoptic meteorological conditions (not shown) are characterised by prevailing anticyclonic structures of African and Atlantic origin for the whole period. Fair weather is observed during the whole episode, surface pressure (Figure 3) decreases on January 9th-16th and then remains nearly constant. This dynamic is due to the evolution of a small scale low pressure system inside the high pressure body. This small cyclonic structure is located over Italy during the second part of the episode. Weak winds (not shown) characterise the whole period, without showing evident correlation with the time evolution of concentrations.

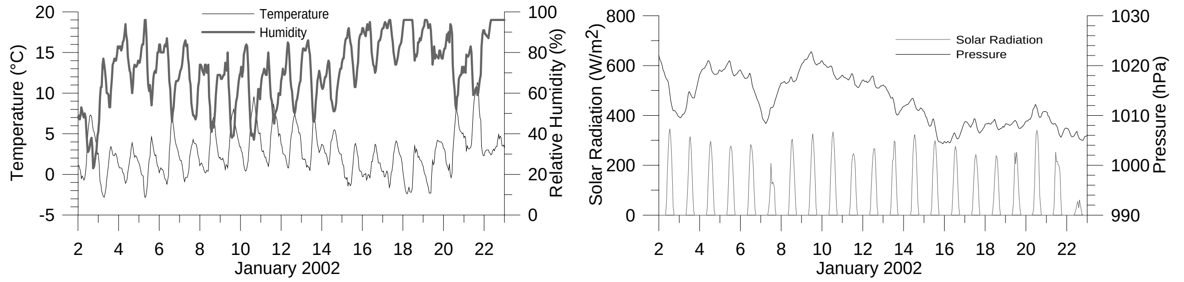

Figure 3. Temperature, relative humidity (left), pressure and radiation (right) measured by the urban station of Milan Juvara.

The first part of the episode is characterised by a slightly growing temperature trend and relative humidity with maximum values around 80%. From the days 14th a reduction of temperature values and excursion is observed together with an increase of relative humidity, that grows during the following days reaching saturation values during night time and indicating the possible formation of fog.

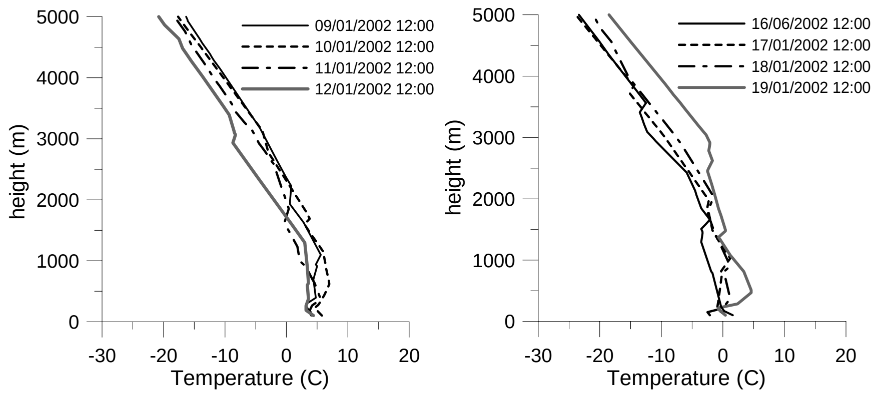

Figure 4. Time evolution of the vertical temperature profiles measured at Milan Linate airport during the highest concentration periods. Soundings refer to 12 noon UTC.

The vertical structure of the atmosphere (Figure 4) showed persistent stable (nearly-isothermal) vertical temperature profiles in the lower 2000 metres. The temperature in the lower 1000 metres of the atmosphere proved to be around 5 degrees colder during the second part of the episode, when small scale cyclonic conditions were observed.

Generalisation of the meteorological analysis

The analysis presented for the January 2002 episode has been applied to all the periods listed in Table 3. Moreover, every calendar day belonging to the studied episodes has been classified employing a meteorological classifications based on the subjective analysis of synoptic scale weather maps (Borghi and Giugliacci, 1980). The weather types classification has been used to identify prevailing circulation features during the different episodes and to state similarities among weather conditions affecting the different studied episodes. All the episodes were found to refer to the circulation types outlined by the geopotential maps showed in Figure 5, that cause anticyclonic conditions over the Po valley.

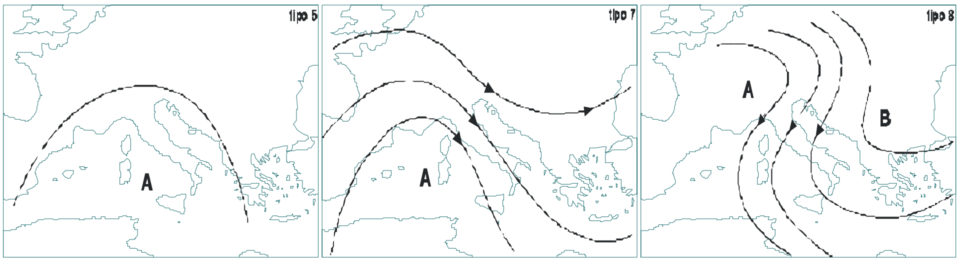

Figure 5. Sketch of geopotential patterns at 850 Hpa representing weather types favouring winter air pollution episodes in Milan urban area.

CONCLUSIONS

The more relevant winter air pollution episodes occurred during the last 6 years inside Milan urban area have been studied to characterise their meteorological features and to identify the key meteorological variables that need to be correctly forecasted to allow episodes prevention. All the episodes show the presence of anticyclonic structures and advection of warm air in the mid-troposphere (850-700 hPa) over the region of interest. The advected warm air, superposed to cold air layers located near the surface, originates a stable thermal structure in the lower atmosphere. Inversions or very stable (isothermal) vertical temperature profiles are observed in these layers (0-2000 metres) during the episodes. Nearly constant surface high pressure is the more frequent condition, even if episodes have been observed with slowly varying pressure. Surface temperature is not directly correlated to the occurrence of episodes, even if cold episodes are those causing the highest concentration levels. Local temperature and humidity conditions seem to be relevant in determining different pollutant behaviour and possibly accumulation features. Wind speed is not a key parameter to identify episodes in Milan due to the high frequency of weak winds and calms that affects the Po valley. A weather types analysis confirmed a clear prevalence of anticyclonic footprint during all the episodes evolution and allowed to identify typical circulation features over the area.
The observed phenomena showed many common features and seem to be rather repetitive and predictable.

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