Presentation of a network of MW-radiometers and sodars in the Italian region Veneto

Pernigotti Denise, Ferrario Massimo, Benassi Alessandro, Rossa Andrea, Sansone Maria
ARPAV-Meteorological Centro of Teolo, Teolo (PD) Italy, dpernigotti@arpa.veneto.it

Abstract

The Centro Meteorologico di Teolo (CMT) of the Regional Agency for Environmental Protection and Prevention of the Veneto Region (ARPAV) has recently installed a network of boundary layer profilers on its territory. The network consists of four passive microwave radiometers and four sodars, largely funded in the framework of the DOCUP[1] 2000-2006 Project. This paper presents the network and illustrates potential applications in air-quality forecasting, in particular the use of the thermal profile for in understanding PM_{10} concentration evolution.

1 Introduction

On the European scale the Po Valley certainly is a hot spot when it comes to air pollution issues, especially in the cold season because of the frequent occurrences of very stable meteorological conditions with marked thermal inversions, at times even below 100m above ground. Therefore, monitoring and predicting air quality conditions is an important service to the local authorities and the public at large, for heath prevention and protection.

In order to respond to these requirements, ARPAV CMT has recently installed a boundary layer profiler network (Fig. 1), which consists of one HATPRO radiometer, three MTP5-HE radiometers and four PCS-2000 sodars. Two instruments were funded by Padua Municipality, whilst the others were co-funded by the European Commission, Italian Government and Veneto Region within the DOCUP 2000-2006 Project. As such the network is the first of its kind in Italy and their principal applications are in the field of environmental emergency management and regional air-quality short time forecasting.

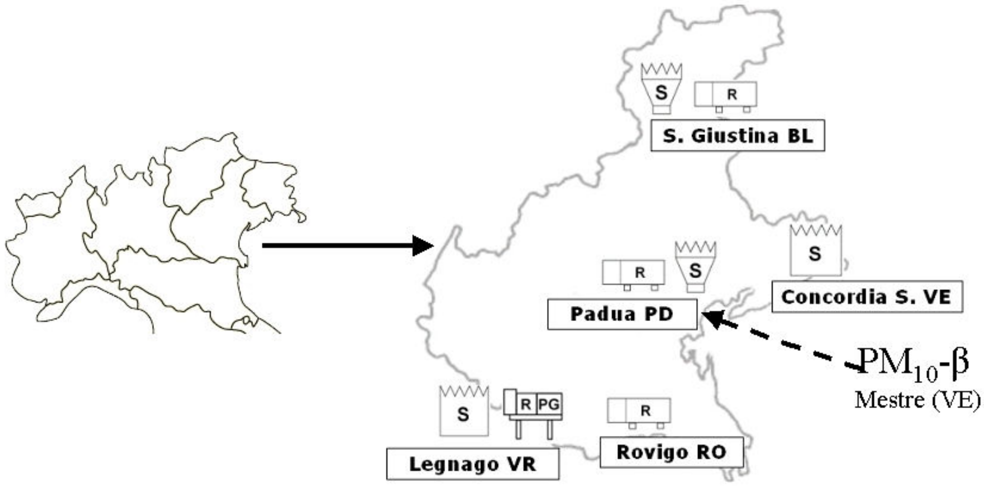

Figure 1. Northern Italy plus location of the PBL network (S=PCS2000 Sodar, R=MTP5-HE Radiometer, RPG=HATPRO RPG Radiometer). The location of the PM_{10} 2-h instrument is highlighted by the broken arrow.

2 Instrumentation and data set

The radiometer MTP5-HE, manufactured by Attex (Russia) and distributed by Kipp & Zonen (NL), is a well proven and robust instrument that measures temperature up to 1000m with a vertical resolution of 50m and a time resolution of 5'. Nominal accuracy is 0.3-0.4K for adiabatic and 0.8-1.2K for inversion conditions, while a good agreement within 1K was found for the CMT radiometers at Padua and Rovigo with the closest soundings in homogeneous conditions (Ferrario et al. 2006). Data

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[1] DOCUP stands for DOCumento Unico di Programmazione, Obiettivo 2, Misura 4.3, co-funded by the national and regional governments of Italy and Veneto, and the European Commission.

availability in the first year of deployment is quite high for the Padua site with 97%, while the lower values for the other two sites, about 75%, are due to prolonged periods of malfunctioning.
The HATPRO, manufactured by Radiometer Physics GmbH (D), is a robust and easy to calibrate instrument that measures temperature and humidity up to 10000m with a vertical resolution of 200m (in PBL mode temperature is scanned every 50m up to 2000m), integrated water vapour, and liquid water content. Nominal accuracy here is 0.6-1K up to 10000m and 1K in PBL mode. Data of this radiometer have been used for 'eyeball' monitoring purposes so far, but are not included in the preliminary analysis presented here. Data availability in the first year of deployment is about 70% (the instrument doesn't measure in case of rain).
The SODAR is an established technology for measuring the vertical wind profile with a high temporal resolution. The instruments installed here are two PCS2000-24 (Padua and S. Giustina) and two PCS2000-64 (Legnago and Concordia S.), manufactured by Metek (D). For these instruments the declared measurement accuracy range from 0.1 to 0.3 m/s for horizontal wind intensity and from 1° to 5° for horizontal wind direction. The data availability of the first year of deployment is around 70% for the first level (40m), decreasing rapidly with height.
The PM_{10} concentrations are available every two hours in real time for four sites in Veneto. For the purposes of this study we only consider the station of Mestre, a site close to Venice and about 25 Km northeast of the Padua profilers. For the present analysis an episode of high PM_{10} concentrations (19-26 December 2005), and a full year of data starting 1 April 2005 were used.

3 Results

The main aim of this analysis is to investigate the ability of the radiometer and sodar sited in Padua to explain the evolution of the PM_{10} concentrations in the area, as represented by the Mestre station. Figure 2 shows PM_{10} concentrations and temperature profiles for a typical situation of high pressure and low winds on the Po Valley. The dependence of the diurnal cycle of PM_{10} on the presence and strength of the thermal inversion, as measured by the MTP5, is quite evident with concentration peaks coinciding with the marked nocturnal inversions. On the other hand, the effect of the inversions on the day-to-day accumulation is less obvious, i.e. there is an increase of the concentrations from 20/21 December to the 23rd, while thereafter the concentrations settle on a relatively high level, before decreasing substantially due to a meteorological disturbance with rain associated.

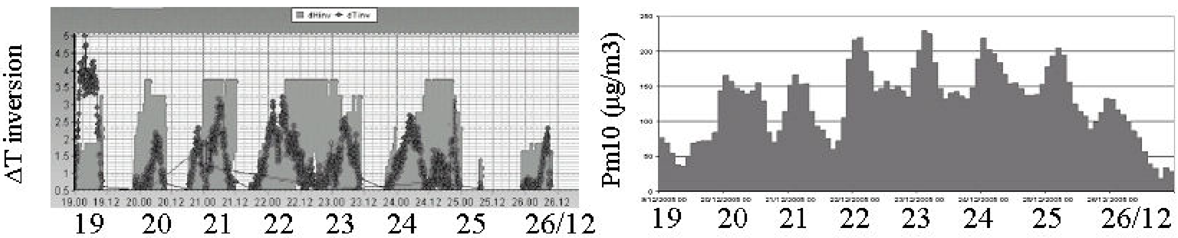

Figure 2: High-concentration episode 19-26 December 2005, inversions strength and height (left panel, dots and bars, respectively) and PM_{10} concentrations (right panel).

In addition, an attempt was made to find such dependence in the entire data set. Table 1 reports the correlation coefficients between PM_{10} concentrations and vertical profile information for temperature and wind. The frequency spectrum of the 2-hly PM_{10} concentration (not shown) exhibits a clear 24h peak, so that we look at the filtered data, i.e. 2-hly PM_{10} minus daily average which retains frequencies below 24 hours only. We calculate correlation coefficients between various profile variables and the following series: 2-hly PM_{10}, daily averaged PM_{10}, 2-hly PM_{10} minus daily average, and daily PM_{10} variance. It emerges that the most closely related meteorological variable is the difference in potential temperature between the 700m above ground level and the surface, then other parameters characterizing the thermal inversion, and then the wind velocity. Also, wind direction shows a correlation with the PM_{10} concentration. In fact, strongest episodes of pollution can be associated with north-westerly wind, blowing from the Po Valley, rather than north-easterly winds which bring clean air from the Adriatic sea.
It is interesting to note that the coefficients change sign when correlated with the normalized variance of PM_{10}. This is plausible as large diurnal variances, normalized by the daily average, are likely to be associated with substantial turbulence which, in turn, is acting to modulate and diminish PM_{10}.

Table 1: 1 year correlations values	ΔT 700m-surface	ΔT 200m-surface	ΔT inversion	Δh inversion	inversion base	wind dir 200m	wind dir 400m	wind vel 100m	wind vel 200m
2h PM_{10} vs 2h	0.50	0.44	0.40	0.33	-0.37	0.39	0.19	-0.25	-0.17
24h PM_{10} average vs 24 average	0.58	0.55	0.46	0.28	-0.51	0.41	0.16	-0.26	-0.16
2h PM_{10} filtered vs 2h filtered	0.33	0.35	0.23	0.24	-0.23	-0.11	-0.10	-0.13	-0.08
24h PM_{10} variance vs 24h average	-0.35	-0.30	-0.21	-0.15	0.30	-0.21	-0.16	0.17	0.17

Figure 3 reports the time series for the high-concentration episode of 19-26 December 2005 (see Fig. 2) of the first three rows of Table 1, i.e. of Δθ with 2-hly PM_{10}, daily averaged PM_{10}, and 2-hly PM_{10} filtered. Indeed, the correlation coefficients are significant with values of 0.65, 0.83, and 0.61, respectively. The highest correlation is found for the daily averages (Fig. 3, middle panel), when the thermal inversion is anti-correlated with the daily averaged wind 100m above ground featuring a coefficient of –0.89. The correlation between the 2-hly values of the latter two variables, on the other hand, is way lower (-0.29). The high-frequency part of the concentration (right panel) follows the thermal inversion signal nicely at times, but not always, pointing to another, independent factor that governs the pollutant. The first peak at about 24 hours, for instance, is coincident with very low winds.

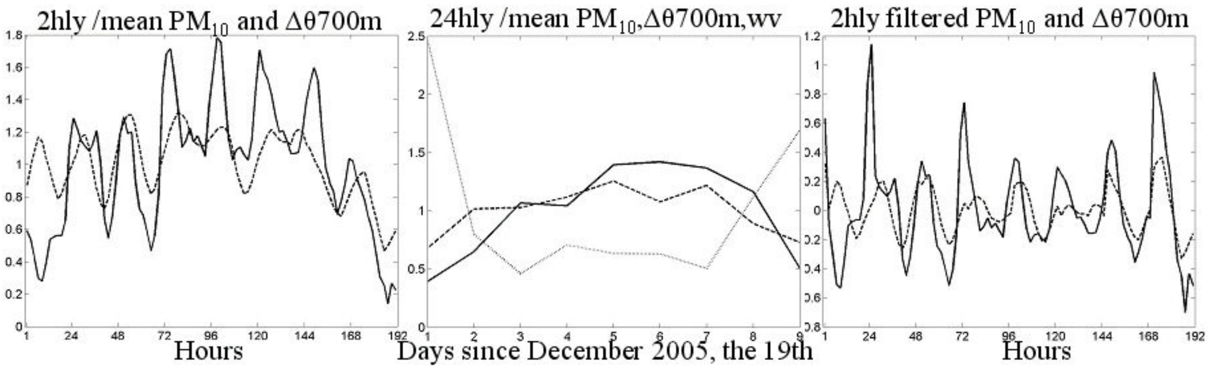

Figure 3. PM_{10} (solid), **Δθ** 700 (dashed) and wind velocity at 100m (dotted, only middle panel): 2-hly data (left panel) and 24hly average (middle panel), both scaled by the period mean, and 2-hly filtered data (right panel).

4 Discussion

As probably expected for a region like the Po Valley, the thermal profile of the atmosphere is the meteorological parameter most closely related to the evolution of PM_{10} concentrations, and this is true both for the high PM_{10} concentration episode and the entire year. This is indeed consistent with the high frequency of occurrence of high pressure situations featuring low winds in the Po Valley, especially during the cold season. The dependence of the day-to-day accumulation of PM_{10} on atmospheric stability (PM_{10} daily average) allowing a prediction of PM_{10} concentrations in the absence of synoptic forcing. The significant anti-correlation of thermal inversion properties with the low-level winds fits well in this line of reasoning. The intra-diurnal variability, as given by the 2-hly values, however, delivers a less coherent picture, probably highlighting that the details of the dynamics that govern both the balance between wind and thermal inversions, and the dispersion of the pollutant is beyond of what a simple linear correlation approach can reach.

References

Ferrario, M.E., A. M. Rossa, D. Pernigotti, M. Sansone. and A. Benassi, 2006. Presentation and first assessment of a radiometer network in the Italian region Veneto. Proc. of the Int. Conf. on Urban Climate, Goteborg, 10-16 June 2006.

Sansone, M., M. Bressan, D. Pernigotti, A. M. Rossa, M. E. Ferrario. and A. Benassi, 2006. A multiple regression approach to forecasting PM_{10} concentraion oin the city of Padua, Italy. Proc. of the Int. Conf. on Urban Climate, Goteborg, 10-16 June 2006.