5.17 ANALYSIS OF EUROPEAN LOCAL-SCALE PM_{10} AIR POLLUTION EPISODES, WITH EXAMPLE CASES IN OSLO, HELSINKI, LONDON AND MILAN

Jaakko Kukkonen[1], Ranjeet S Sokhi[2], Mia Pohjola[1], Lia Fragkou[2], Nutthida Kitwiroon[2], Lakhu Luhana[2], Minna Rantamäki[1], Erik Berge[3], Viel Odegaard[4], Leiv Håvard Slørdal[5], Bruce Denby[5] and Sandro Finardi[6]

[1]Finnish Meteorological Institute, Sahaajankatu 20 E, Helsinki, Finland
[2]University of Hertfordshire, ASRG, Science and Technology Centre, Hatfield, UK
[3]Kjeller Vindteknikk, P.O.Box 122, 2007 Kjeller, Norway
[4]Norwegian Meteorological Institute, Postboks 43, Oslo, Norway
[5]Norwegian Institute for Air Research, Instituttvn. 18, Norway
[6]ARIANET, via Gilino 9, 20128 Milano, Italy

INTRODUCTION

The causes of air pollution episodes depend on various factors including emissions, local and synoptic scale meteorological conditions, topography, and atmospheric chemical processes. The relative importance of such factors is dependent on the geographical region, its surrounding emission source areas and the related climatic characteristics, as well as the season of the year (e.g., Sokhi et al., 2002; Piringer and Kukkonen, 2002).

This paper analyses selected PM10 episodes in two European cities in relation to prevailing meteorological conditions, local emissions, and regionally and long range transported background concentrations. We have analysed primarily the PM_{10}, however, the $PM_{2.5}$ concentrations are included in the analysis wherever those measurements were available. For a more detailed and broader analysis, the reader is referred to Kukkonen et al. (2004).

MATERIAL AND METHODS

The cities considered in this study are located in Northern (Oslo and Helsinki), North-Western (London) and Southern (Milan) European geographic and climatic regions. The areas considered here represent maritime climate (London and Oslo), partly maritime-influenced and partly continental climate (Helsinki), and mainly continental climate (Milan).

Due to space limitations, we mostly focus in the following on selected characteristics of the episodes in Helsinki and Milan.

The topography of the cities and the main emission sources

The city of Helsinki and its surrounding regions are situated in a fairly flat coastal area. The PM_{10} concentrations in street level air are dominated by the combustion, non-combustion and suspension emissions originated from vehicular traffic (e.g., Kukkonen et al., 2001). At almost every spring, PM suspended from the road and street surfaces causes so-called "spring dust" episodes. The influence of small-scale local sources, such as that of domestic wood burning, is negligible.

Milan city and its surrounding urban area are located in the central part of the Po river basin, in a flat area. The atmospheric circulation of the Po valley is characterised by the strong modification of synoptic flow due to the high mountains (Alps and Apennines) that surround the valley on three sides. According to the regional emission inventory, road traffic is mostly responsible for the PM_{10} emissions in the Milan Province.

The air quality and meteorological measuring stations and experimental methods
Comparison of concentrations measured at various site categories makes it possible to evaluate the importance of local emissions. The classifications of the air quality stations were made according to the EU directives.

In Helsinki, at the station of Töölö, the concentration of PM_{10} was measured with TEOM (Tapered Element Oscillating Microbalance). At the stations of Vallila, Kallio 2 and Luukki, the concentration of PM_{10} was measured with Eberline FH 62 I-R. At the stations of Vallila and Kallio 2, the concentration of $PM_{2.5}$ was also measured with Eberline FH 62 I-R. In Milan, at the monitoring stations addressed here, PM_{10} is measured with TEOM.

Modelling methods
The synoptic scale meteorological analyses are based on the results computed by the national versions of the NWP model HIRLAM in case of Finland, and on the ECMWF model in case of Milan.

RESULTS

Concentration time series
The evolution of measured hourly pollutant concentrations at Helsinki and Milan are presented in Figs. 1a-b. In all figures, the ticks on the horizontal axis indicate the beginning (i.e., the time 0.00 a.m.) of the day marked.

In Helsinki, the highest PM_{10} concentrations at most urban stations occurred approximately from 8 to 13 April (from Monday to Saturday); however, there were substantially elevated concentrations also on 3 of April 2002 (Wednesday). In Milan, there was a clearly distinguishable period of elevated PM_{10} concentrations from 14 to 19 December 1998. There were weekends on 12-13, and 18-19 of February.

In Helsinki, the regional background PM_{10} levels measured at a station of Luukki were below 70 µg/m^3 during the whole time period considered here. Although these values are notable, they are substantially lower than the corresponding highest measured urban traffic-site concentrations at the stations of Töölö and Vallila; this indicates that local sources are mainly responsible for the formation of the highest concentrations.

In Milan, the PM_{10} concentrations measured at the urban background site at Juvara are of the same order of magnitude, or even higher, compared with the corresponding values measured at the urban traffic station of Zavattari. The values measured at both of these stations in Milan are slightly higher than those measured at the urban site of Limito that is located in a smaller town in the Milan Province.

Meteorological conditions
As the pollutants were mainly of local origin in the episodes addressed here, we describe only briefly the synoptic scale meteorological conditions. These analyses are based on the results by the Finnish variant of the model HIRLAM and the NWP model of ECMWF.

During the episode in Helsinki, an area of high pressure extended from north-western Russia to Finland. There was some precipitation of snow in the beginning of the episode period (from 3rd to 4th of April 2002), but the sky was overcast during the remaining period (until 13 April). The ground surface was partly covered with snow. The stable atmospheric stratification associated with clear skies lead to the formation of ground-based radiation inversions that lasted from 7 to 12 April. In the middle of April, a colder weather front transported to Southern Finland that caused the break-up of the inversions.

The synoptic weather conditions during the episode in Milan (from 14 to 19 December 1998) were characterised by a high-pressure ridge. This ridge arrived at the Mediterranean basin on 13 December and remained quasi-stationary, centred over the western Mediterranean for the whole of the episode duration (until 19 December).

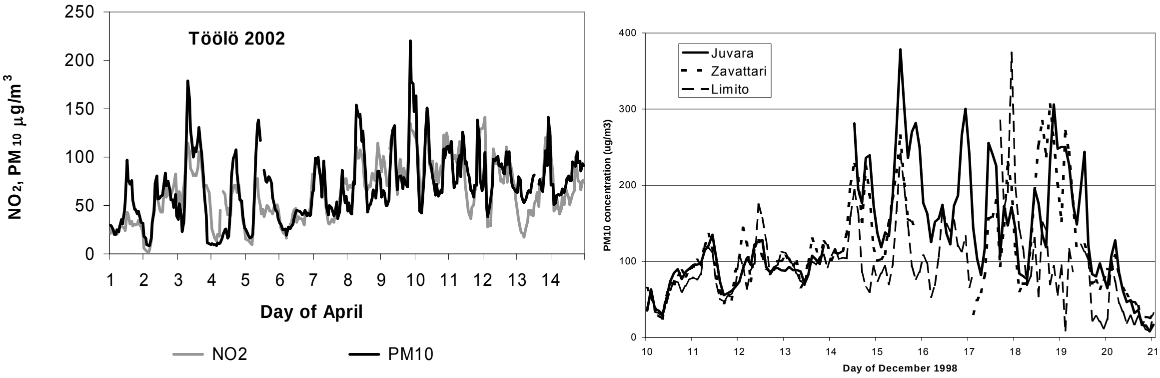

Figure 1. The pollutant concentrations relevant for the analysis of PM_{10} in the course of the selected episodes in a) Helsinki and b) Milan.

Meteorological analysis for Helsinki

The ground surface temperatures at the station of Helsinki-Vantaa varied from – 4 to + 15 °C, and those at the station of Isosaari from –4 to + 6 °C. Commonly in spring, the temperatures in the sea area are substantially lower than those over the mainland, due to the relatively slower seasonal warming of the sea compared with the land areas.

The wind direction was predominantly between northerly and westerly. The occurrence of low and moderate wind speeds shows correlation with the highest PM_{10} concentrations (during 3rd of April and from 8 to 13 April, 2002).

An example of the evolution of the nocturnal vertical temperature profiles at the Kivenlahti mast in the vicinity of Helsinki is presented in Fig. 2a. The measured temperature profiles at midnight show that there was a moderate ground-based temperature inversion on 3 April, and moderate or strong ground-based inversions all days from 7 to 12 April. The maximum ground-based inversion occurred on 11 April, the measured temperature increased 8 °C within the lowest 50 m of the atmosphere. The inversions were radiation inversions, caused by the cooling of the ground surface by outgoing long-wave radiation. The highest PM_{10} concentrations (during 3 of April and from 8 to 13 April, 2002) almost coincided with the occurrence of ground-based inversions.

Meteorological analysis for Milan

The atmospheric pressure remained at an elevated level from 12 to 17 December. The wind speed was low or it was calm during the whole period considered. Prevailing weak winds are one of the main features of the Po valley climatology. These conditions are mainly due to the blocking effect of the high mountains that surround the valley from three sides, and commonly do not allow synoptic flows to enter the lower atmospheric layers in the valley. The city of Milan is at a substantial distance from the mountains (approximately 40 km), and is therefore commonly influenced only by a weak mountain breeze circulation. The wind speed is therefore not an especially good predictor variable in terms of peak pollution episodes within this area.

An intense slightly elevated temperature inversion was formed on 13 December that reached its maximum depth and magnitude (with a temperature growth of about 15 °C in the first 1500 metres height) on 15 December and prevailed until 19 December. This period nearly coincided with the occurrence of the highest concentrations from 14 to 19 December. Near the ground surface, a shallow unstable boundary layer (a few hundred meters) was observed during daytime; however, the temperature decrease with height in this layer was only from 1 to 2 °C over 100 - 200 m. The inversions were caused by the advection of warm air carried by the incoming high-pressure ridge.

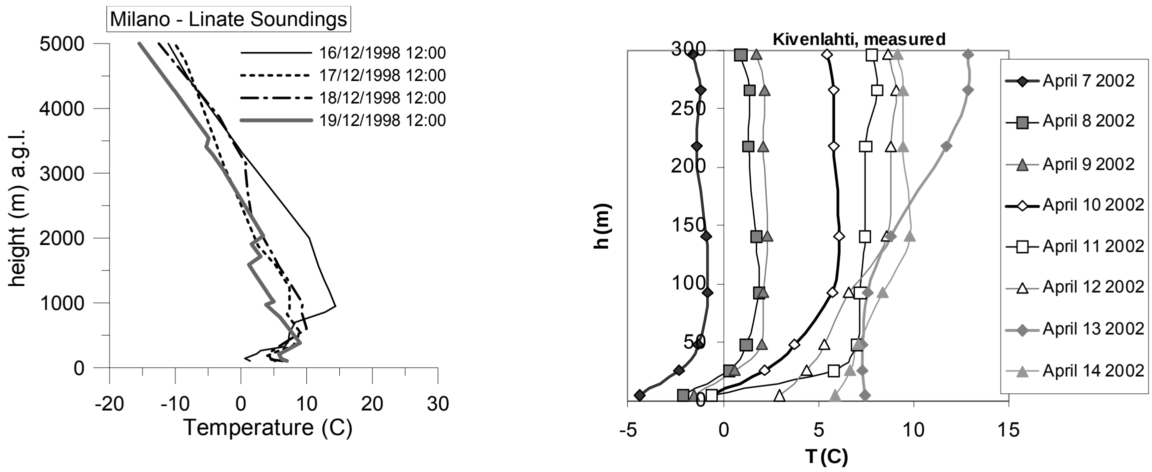

Figure 2 The temporal evolution of the vertical profiles of temperature in a) Milan and b) Helsinki. The times regarding Helsinki refer to midnight (time 00.00 a.m.), and the time regarding Milan noon; both of these in UTC.

CONCLUSIONS

According to the analyses, the selected episodes were caused mainly by local wood combustion in Oslo, mainly by suspended dust and local traffic emissions in Helsinki, by local traffic and long-range transport in London, and mainly by local traffic in Milan. All the episodes addressed were associated with the influence of areas of high pressure (Oslo, Helsinki and London) or a high-pressure ridge (Milan). High atmospheric pressure is commonly related with stable stratification; however, it does not necessarily lead to extremely stable conditions or strong inversions near the ground level. Regarding episodes of PM_{10} and NO_2, an elevated atmospheric pressure is probably a necessary, but not a sufficient condition for the occurrence of an episode. Strong ground-based or slightly elevated temperature inversions prevailed in the course of the episodes in Oslo, Helsinki and Milan, and there was a slight ground-based inversion also in London. The inversions in Oslo and Milan were mainly caused by advection, and that in Helsinki was a radiation inversion.

In the cases studied here, the best meteorological predictors for the elevated concentrations of PM_{10} were the temporal (hourly) evolutions of temperature inversions, atmospheric stability and in some cases, wind speed. The hourly temporal variation of strong ground-based or slightly elevated temperature inversions was closely correlated with that of the highest PM_{10} concentrations. The measured temperature inversions can be recommended as predictor variables for forecasting the likelihood of the formation of air pollution episodes.

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