Influence of the Mixing Layer on the concentration and size distribution of Particulate Matter over Milan

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Urban activities affect air quality directly; the highest values of PM_{10} and $PM_{2.5}$ in Europe are reached in urban areas (Van Dingenen, 2004). The Po Valley, and in particular the city of Milan, are a good example of this scenario. In addition, the meteorology of this area plays an important role on PM pollution levels (Ferrero, 2007). In 2006, in Milan, $PM_{2.5}$ concentrations reached a mean value of 43 $\mu g/m^3$; in particular from December 2005 to February 2006, during winter times, a mean value of $PM_{2.5}$ of 83 $\mu g/m^3$ (range: 17–250 $\mu g/m^3$) has been measured.

For investigating the influence of atmospheric dispersion conditions on PM pollution levels, vertical profiles of particle number concentrations and particle size distributions (14 classes between 0.3 to 20 μm) were monitored at Torre Sarca site (45°31'19"N, 9°12'46"E) in Milan, starting from December 2005, using an optical particle counter (OPC GRIMM *1.108 "Dustcheck"*) and a portable meteorological station deployed on a 4 m tethered balloon (Ferrero, 2006; 2007). This method provides the direct measure of the PM profile along height, with a direct evaluation of the Mixing Layer (ML) height (Seibert, 2000). Estimation of ML has been performed using both MM5 model and ^{222}Rn measurements. The behaviour of the ML was investigated in 12 days of acute episodes of $PM_{2.5}$ concentration (102±28 $\mu g/m^3$), collecting 94 PM vertical profiles. In Figure 1 a couple among those 12 days are shown; those ML heights lead to high concentrations of particulate matter (100 and 133 $\mu g/m^3$ of $PM_{2.5}$; 117 and 166 $\mu g/m^3$ of PM_{10} respectively for the two days) due to low air volume available for dilution; in addition accumulation processes are possible.

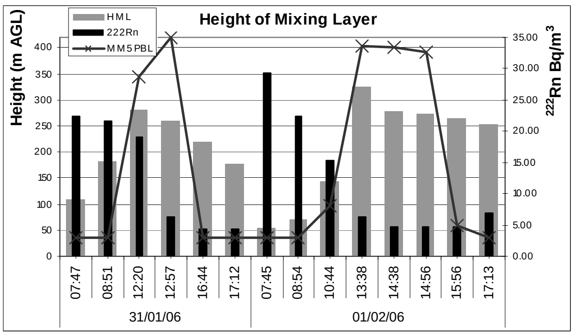

Fig. 1 Heights of ML measured by vertical profiles; MM5 PBL height predictions and ^{222}Rn measurments.

In order to explore also the physical behaviour of particles along height, a cluster analysis of the OPC original size classes was performed on data taken at three different levels: near the ground, in the ML and over the ML; the first cluster corresponds to particles with a diameter of 0.3-0.5 μm at ground level and 0.3-1.6 μm over the ML; the mean particle diameter of the cluster 0.3-1.6 μm was calculated and inspected for each profile. A good correspondance between a rapid increase in the mean particle diameter of this cluster (0.3-1.6 μm) and the height of the ML (fig. 2) in all the winter profiles, has been observed, with an R^2 of 0.883.

This agreement suggests that the ML, under stable conditions, separates two zones in the lower troposphere: the lower one in which an influence of directly emitted PM is evident, and the upper one where aged PM is present.

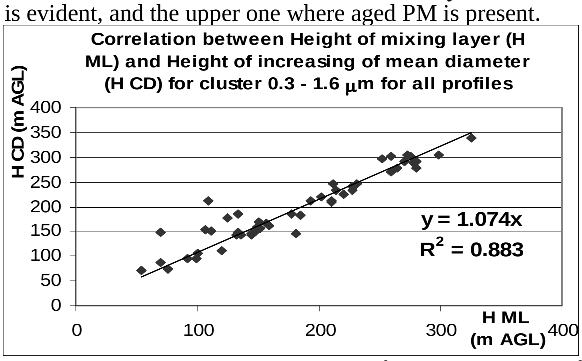

Fig. 2 Correlation between height of ML and height of mean particle diameter increase for cluster 0.3-1.6 μm

In order to check this feature we analyse jointly the proportions of PM classified according to particle size, following the theory of compositional data (Aitchison, 1986) according to two complementary perspectives. First, the relative proportions of particle sizes (compositions) are modelled as linear functions of meteorological variables. Their influence is stronger above ML, likely because only the oldest particles arrive at such heights and dilution occurs. It is lower below ML since particulate emission and persistence of older particulate intertwine and accumulation processes occur. Then, the evolution of the PM compositions are studied along the vertical profile. A hierarchical model which includes random effects related to launch, composition and height, is constructed. By means of this model, data belonging to launches considered as homogeneous are jointly used for evaluating the evolution of compositions with respect to height by means of probabilistic tools (Figure 3). The finest compositions are more relevant below ML, whereas the largest particles become more influent above ML. As a conclusion, the levels of ML are crucial in both approaches, in the three vertical regions: below, within and above ML.

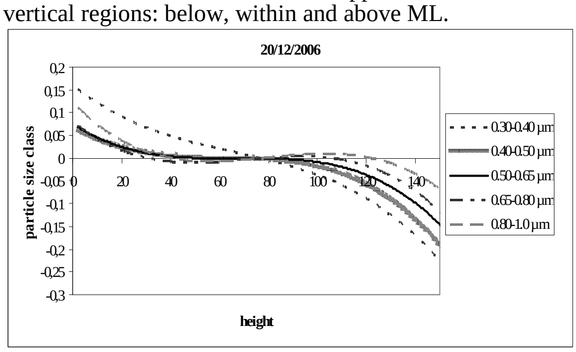

Fig. 3 Outcome of modelling the evolution of PM compositions along height for one launch.

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