DUST GENERATION AND DISPERSION (PM10 AND PM2.5) IN THE AOSTA VALLEY: ANALYSIS WITH THE FARM MODEL

Giordano Pession[1], *Tiziana Magri*[1], *Manuela Zublena*[1], *Giovanni Agnesod*[1]
Giuseppe Genon[2], *Laurent Blanc*[2]
Camillo Silibello[3], *Sandro Finardi*[3], *Giuseppe Calori*[3], *Alessandro Nanni*[3]

1 ARPA Valle d'Aosta, Saint-Christophe, Italy
2 Politecnico di Torino, Torino, Italy
3 ARIANET s.r.l., Milano, Italy

Abstract: The aim of this work is to analyze the origin and the dispersion of the particulate matter (PM10 and PM2.5) in a mountainous region: the Aosta Valley. To meet this goal, different simulations were performed, using the flexible air quality regional model (FARM), to study two scenarios: winter and summer situations. To evaluate the performance of the FARM model in order to simulate the air quality situation of the selected periods, a comparison of modelled results against observed air quality data was carried out for both primary pollutants and particulate matter next to the measurement stations . Farm performed well in simulating especially ozone (O_3) and nitrogen dioxide (NO_2) concentrations, showing a good reproduction of both daily peaks and their daytime variations. PM model results revealed the tendency to under-predict the observed values, so we tried to use a different emission factor for the road traffic (Lohmeyer factor). The new results were good for the urban and suburban areas, but they give over-predictions close to highways. The PM characterisation provided by the model gives good results: in some different points of the analysis domain (mountain, plain and urban points) we found PM profiles wich reproduce expected values.

Key words*: Air quality modelling, urban and rural air pollution, traffic emission, chemical characterisation of PM10.*

1. INTRODUCTION

The Aosta Valley is one of the deepest and longest valleys of the Alps. It is surrounded by high chains of mountains reaching more than 3000-4000 metres, and, on its western side, it faces the Mont Blanc.

The bottom of the valley has an average height of 600 metres. The valley axis is prevalently oriented west-east: this maximises the shading effects of mountains on the bottom of the valley, enhancing differences in radiation, flow and turbulence over mountain slopes. The high level of naturality is an important resource for the region, but also an element of vulnerability.

In the last years, some stations in the urban area of Aosta failed to comply with the maximum number (35) of exceedances of PM10 daily human health protection limit, (50 $\mu g/m^3$). This fact urged us to investigate the dust origin and dispersion by means of a modelling code.

2. THE MODEL

The simulations were performed using the regional emission inventory for the year 2005. Meteorological analyses were produced starting from the data provided by the ARPA monitoring network, using MINERVE diagnostic model and SURFPRO turbulence processor.

The dispersion and the chemical evolution of the pollutants were simulated by the flexible air quality regional model (FARM) which was derived from STEM-II. Farm is a three-dimensional Eulerian model dealing with the transport and the multiphase chemistry of pollutants in the atmosphere. Gas-phase reactions are described by means of SAPRC-90 (Carter, 1990) whereas the aero3 aerosol module (Binkowski, 1999) is employed for particulate matter. The second module is based on a modal approach, whereby particle size distributions are represented as the superposition of three lognormal sub-distributions or modes: Aitken, accumulation and coarse mode.

3. DOMAINS DEFINITION AND EPISODES SELECTION

To investigate the effect of local and distant sources and describe processes dominated by scales larger than the city scale, a nested approach considering two domains was adopted. The background domain covers all territory of the Aosta Valley (111 x 71 cells at 1 km spacing) and the domain that includes the urban area of Aosta (69 x 29 cells at 250 m spacing).

Two periods were selected: the first episode (09-16 January 2006) was representative of winter condition of atmospheric stability, characterised by high concentrations of pollutants, and the second one (12-14 and 24-28 June 2007) characterised by typical summer conditions.

4. CONCENTRATION MAPS

The outputs obtained by the FARM model were three-dimensional maps of concentrations of major pollutants. The pollutants taken into account were: NOx, NO_2, SO_2, O_3, PM10 and PM2.5 and maps of concentrations were produced for each pollutant on the urban and regional scale (as showed in Fig. 1).

PM2.5 – Winter period

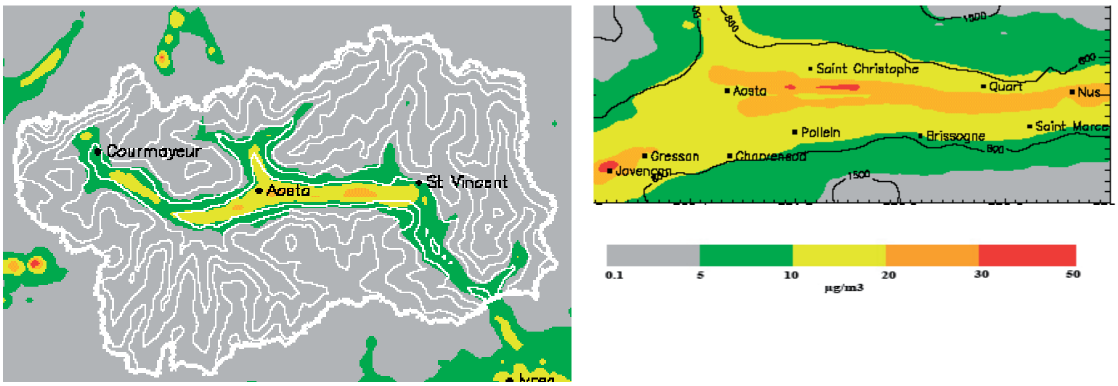

Figure 1. PM2.5 concentration maps during winter episode in the whole region and in the urban area of Aosta.

Pollutants are concentrated along the central valley, where the main sources of pollution are: the urban area, the main road network and plants.

Concentrations are higher in winter, which is primarily due to emissions of domestic heating and to meteorological conditions that reduce the dispersion of pollutants.

5. GASEOUS POLLUTANTS

We analysed in the first place the calculated concentrations of gaseous pollutants, which are decisive also to PM prediction, because they are precursors of secondary particulate matter.

The air quality data obtained through the ARPA monitoring network were used to evaluate the performance of the modelling system.

To quantitatively evaluate the modelling results for the two episodes, the Fractional Bias (FB) as well a standard statistical measure were considered. Values of FB between -0.5 and 0.5 suggest good results. Figure 2 summarizes FB values for each station and gaseous pollutant.

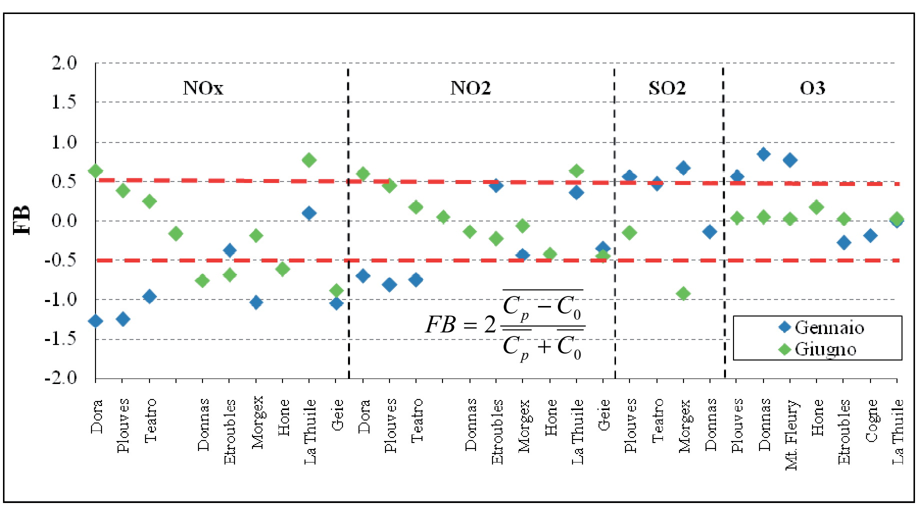

Figure 2. Fractional Bias of gaseous pollutants simulation for each measurement station

We can notice that the model simulated well all the gaseous pollutants during summer period, which was not the case in winter. This different behaviour can be ascribed to difficulties in reproducing flow and turbulence fields, particularly under stable, low wind speed and subsidence conditions during cold seasons. Overall, the model performed well in predicting O_3 and NO_2 concentrations over the complete domain, showing a good reproduction of hourly peak values.

6. PM10 CONCENTRATION

For PM simulations we used two different emission factors (EFs) for vehicles, in order to find out the best one:
IIASA EFs, the most used, emission factors developed by the Austrian Institute IIASA;
Lohmeyer EFs, Lohmeyer and co-workers calculate PM10 as a sum of all emissions for primary sources (exhaust pipe, vehicle parts and road abrasion) and those from material deposited on the road (resuspension).

Table 1. IIASA and Lohmeyer Emission Factors

Road	Highway				National road				Regional road				Urban			
Vehicle	Car	Commercial light	Commercial heavy	Motor Bike	Car	Commercial light	Commercial heavy	Motor Bike	Car	Commercial light	Commercial heavy	Motor Bike	Car	Commercial light	Commercial heavy	Motor Bike
PM IIASA	0.1	0.14	0.61	0.1	0.1	0.15	0.91	0.1	0.1	0.14	0.88	0.1	0.12	0.22	1.18	0.13
PM10 Lohmeyer	0.1	0.34	17.2	0.001	0.1	0.3	11.6	0.001	0.1	0.3	11.6	0.001	0.08	0.27	7.54	0.001

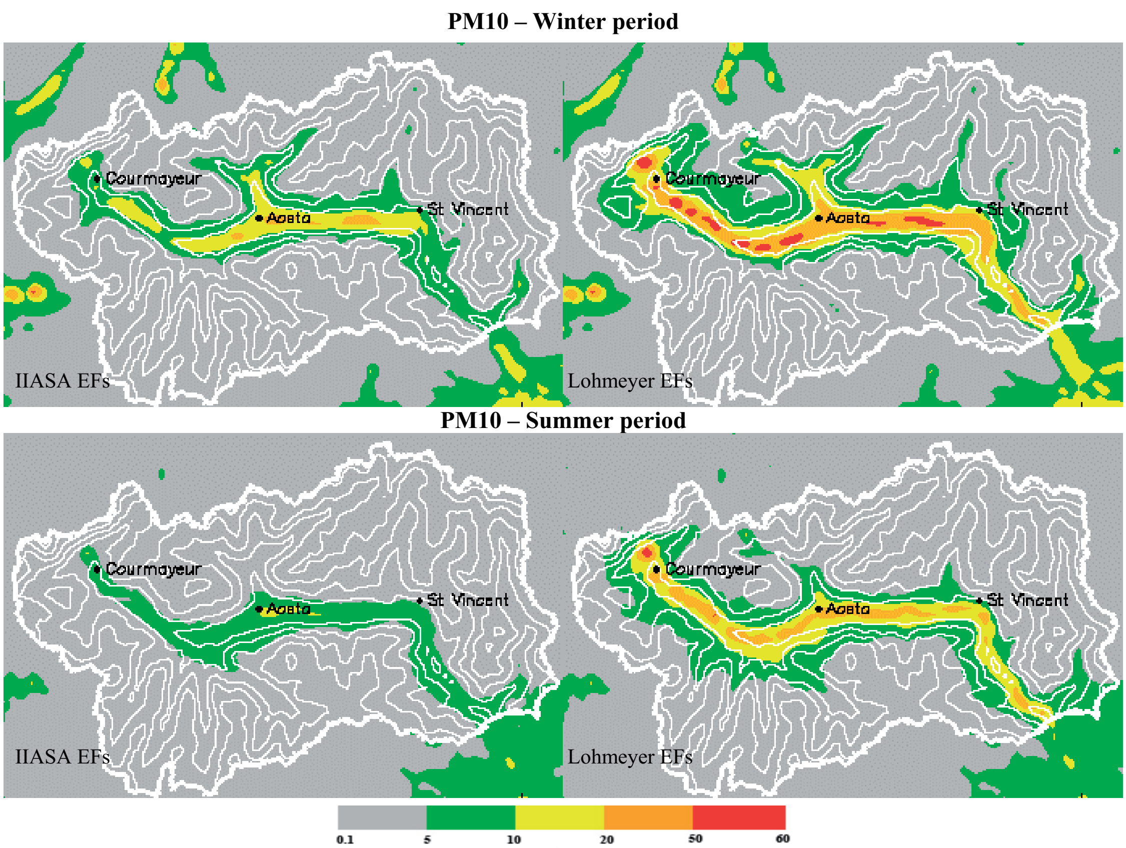

Figure 3. Comparison between concentration maps of PM10 obtained with IIASA EFs and Lohmeyr Efs.

Concentration maps confirmed that the urban area of Aosta and the whole central valley are affected by relatively high concentrations, particularly during the winter season.

As we can see in Figure 3, the values of PM10 concentration are higher for the Lohmeyer EFs. Figure 4 gives the FB values for the urban station of the Quartiere Dora in the summer period, it is evident the better performance of Lohmeyer EFs in urban domain.

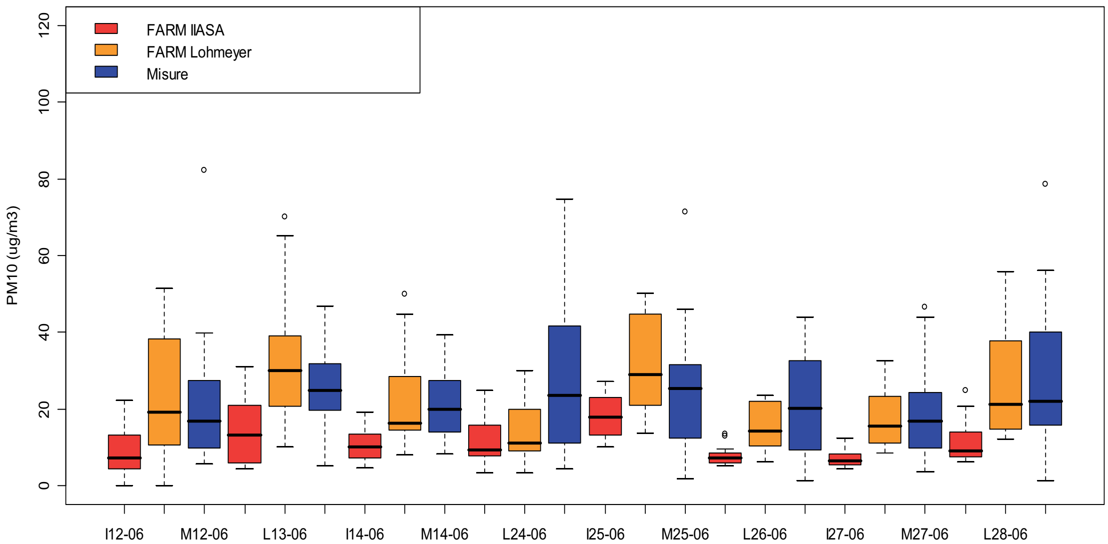

Figure 4. Boxplots of the comparison between concentration calculated with two FEs and measured at the Quartiere Dora station during summer episode.

For quantitative evaluation, also for PM10 we calculated the FB:

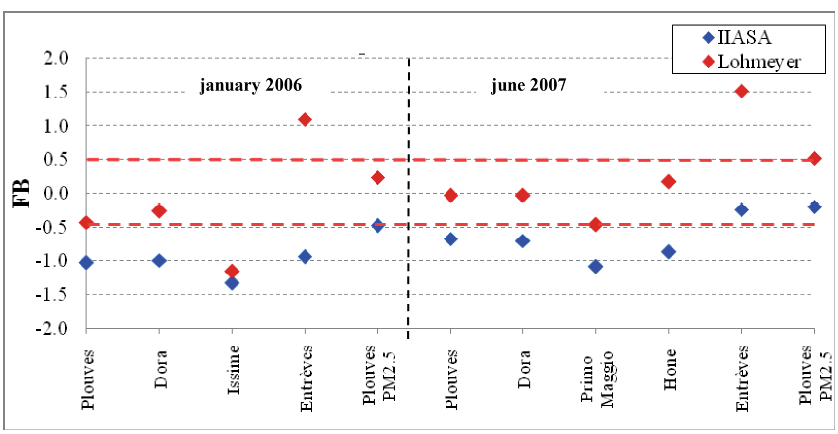

Figure 5. Fractional Bias of PM10 simulation for each measurement station.

The IIASA EFs tend to under-predict the observed values over all domain, especially during the winter period. The concentration values obtained with Lohmeyer EFs are closer to the observed values, but some critical situations remain:

- during winter period concentrations are underestimated in the rural stations, probably because the emissions of domestic heating are also underestimated, especially the PM produced by wood combustion,
- in the highways areas, where there are many heavy goods vehicles, the concentrations are widely overestimated, because the Lohmeyer EFs for these vehicles are too high.

7. CHEMICAL CHARACTERISATION OF PM10

The analysis of the dust chemical characterisation gives that in the urban and traffic areas the main contributors to the PM10 mass concentration are the fractions derived from combustion, like primary, organic and elemental carbon, whereas in the rural station nitrate and crustal fractions are more relevant (Fig. 6).

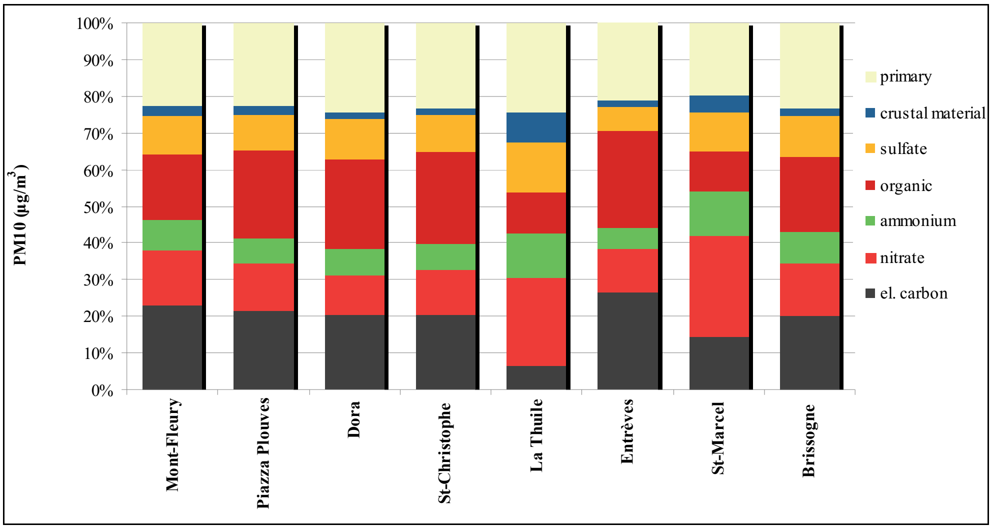

Figure 6. Chemical composition of PM10 for each measurement station in the winter episode

8. CONCLUSIONS

FARM code was used in order to investigate the origin and dispersion of PM10 and PM2.5 in the alpine region of the Aosta Valley. The model well predicts concentrations of gaseous pollutants, especially NO_2 and O_3 during the summer period. PM model results obtained with IIASA EFs revealed the tendency to under-predict the observed values that is why we tried to use a different emission factor for vehicles (Lohmeyer factor). The new results were good for the urban and suburban areas, but some critical situations need more study.

PM10 chemical characterisations give good results which have to be compared with future measurements.

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