INTEGRATED AIR QUALITY ASSESSMENT OF AN ALPINE REGION: EVALUATION OF THE MONT BLANC TUNNEL RE-OPENING EFFECTS

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INTRODUCTION

The Italian law 1999/351, implementing the EU Directive 96/62/CE, assigns to the Regions the task of Air Quality Assessment, aimed to the subdivision of the Regional land in different areas, according to their air pollution conditions. The law suggests the integrated application of different tools: monitoring, emission inventory and dispersion modelling. To fulfil this request, an integrated air quality assessment has been executed for the Valle d'Aosta Region.

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. With its mountain passes and road tunnels (Mont Blanc and Gran San Bernardo), Valle d'Aosta is an important gate to France and Switzerland, carrying a relevant fraction of car and truck traffic flowing through the Alps.

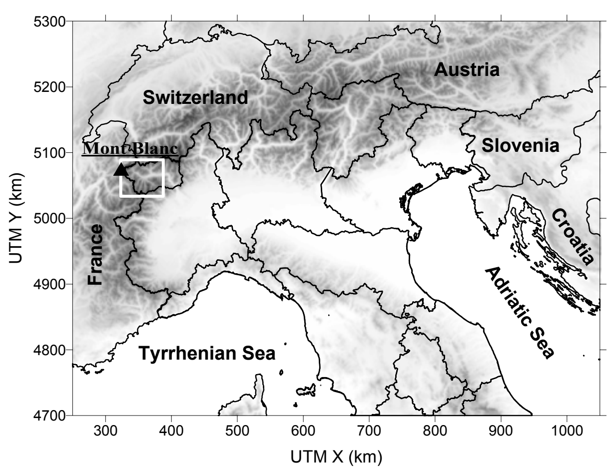

Figure 1. Studied area location. The white rectangle indicates the computational domain, while the Mont Blanc position is pointed out by a black triangle.

The need for an air quality assessment was furtherly fostered by the upcoming re-opening of the Mont Blanc Tunnel, after the tragic accident happened on 24 March 1999, requiring a careful evaluation of the associate environmental effects. The population living in the Mont Blanc area on the Italian, French and Swiss sides showed a considerable attention and concern for the impact on the environment due to the traffic through the Tunnel. This is not only a merely local problem: the management of a sustainable traffic load into the Alpine tunnels is in fact an important component of the European transportation strategy.

INTEGRATED AIR QUALITY ASSESSMENT OF THE VALLE D'AOSTA REGION

The Valle d'Aosta air quality assessment has involved different activities: the upgrade of the monitoring network, the development of a comprehensive emission inventory, including anthropic (road traffic, urban heating, industries) as well biogenic emissions, and the application of advanced 3-D pollution models of on different space and time scales. A reference emission inventory has been built for the Region, following a bottom-up integrated with a top-down approach, and organised to feed air quality simulation models. As for pollutants dispersion, the extreme terrain complexity of the region does not allow the applications of steady state regulatory dispersion models, so a 3D modelling system has been therefore applied to obtain a reliable description of pollutant dispersion inside the valley. The system is built on the mass-consistent wind field model MINERVE (Desiato et al., 1998) and the Lagrangian particle model SPRAY (Tinarelli et al., 1994). Model results have been validated against monitoring network observations, allowing to remove possible model inconsistencies and to improve global system performance.

EMISSION INVENTORY AND MANAGEMENT

The main emission database, based on CollectER structure (EU-EEA), includes all significant anthropic and natural sources, and the main CORINAIR pollutants: SO_2, NO_X, CO, NMVOC and PM. The emission contribution due to road traffic was determined by means of TREFIC (TRaffic Emission Factor Improved Calculation) software, based upon the COPERT III methodology, improved with more detailed emission factors, proposed by IIASA (2001), for particulate species (PM, PM10 and PM2.5). The calculation was extended to all kinds of driving conditions (highway, rural, urban), and applied to the main and the secondary road networks. Emission factors were also characterised by mean speed and slope. The contribution to urban traffic due to the regional mobility demand was estimated by CARUSO (CAR Usage System Optimisation) traffic flow model. The last year not influenced by the Tunnel closure (1998) was chosen as the reference year for the emission inventory. As far as CO, NO_X and PM are concerned (Figure 2), the estimated contribution of road traffic to total emissions is predominant. For NMVOC the largest emissions are due to the forest areas. House heating is by far the major source of SO_2 due to the limited use of natural gas. To evaluate the emissions during the Tunnel closure period a traffic scenario was set up by subtracting, on each road network segment, the traffic contribution related to the Tunnel, as estimated by CARUSO model.

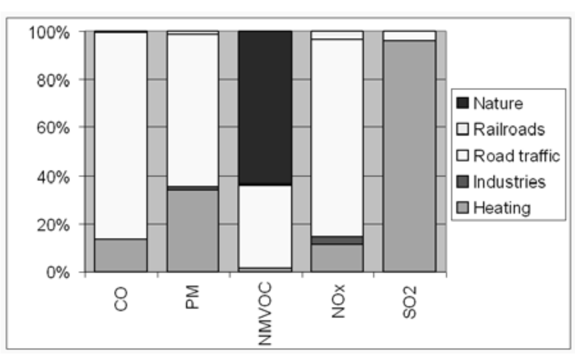

Figure 2. Contribution of the different sources pollutants emission in Valle d'Aosta Region

The aggregated emissions were then disaggregated in space, to locate area sources emissions according to the land cover features (e.g. urban and forest areas distribution), and in time, to reproduce their hourly behaviour, as needed by dispersion models. Weekly and annual traffic modulations have been obtained from car passages at the motorway gates, while daily modulation profiles have been reconstructed from roadside air quality measurements, due to the lack of better information.

Model simulations

Six different episodes (Table 1), representative of the most frequent meteorological conditions affecting the valley, have been then analysed.

Table 1. Simulated episodes dates and associated weather conditions

Date	Weather conditions
10-13/06/2000	Summer perturbation
10-12/08/2000	Summer high pressure
15-18/01/2001	Winter high pressure
23-25/01/2001	Winter perturbation
20-22/02/2001	Föhn
08-11/04/2001	Spring windy day

The wind and pollutant concentration fields have been simulated over a computational domain covering 60x40 km^2, with a horizontal resolution of 1 km (Figure 1). The 3D wind and temperature fields have been reconstructed by means of the diagnostic model MINERVE using local surface measurements, airplane data and synoptic meteorological measurements. The atmospheric turbulence scale parameters (u_*, L, H_0, z_i, w_*) have been computed using the meteorological pre-processor SURFPRO, that can take into account mountain slopes and shadow projection. The Lagrangian particle model SPRAY was used to describe the atmospheric transport and dispersion of pollutants emitted by 12 point sources, 208 line sources and 295 area sources. Hourly ground level concentrations have been estimated from the particle field with a horizontal resolution of 500m. Model simulation results have been compared with continuous air quality measurements from the regional monitoring network. Figure 3 shows examples of the results obtained for the measuring station of Mont Fleury, that, for his suburban position (at the outskirts of Aosta , the largest populated centre), can be considered the more suitable for model results verification.

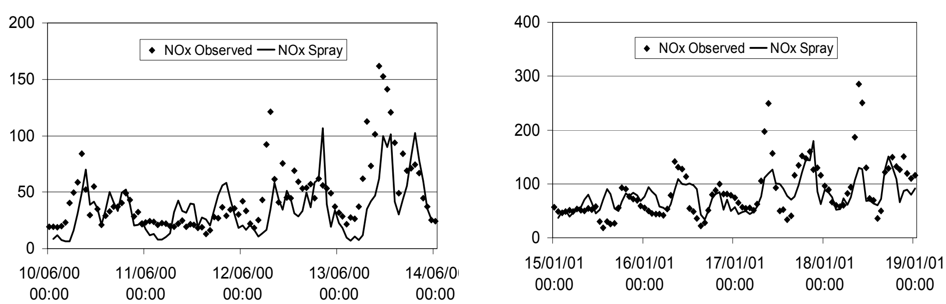

Figure 3. Comparison of computed (solid line) and measured (dots) NO_X (µg/m^3) concentrations for the suburban station of Mont Fleury for two of the simulated periods:10-13/06/2000 (left) and 15-18/01/2001 (right).

COMPUTATION OF EARLY AVERAGE CONCENTRATIONS

Yearly average concentration fields have been estimated from the hourly values, on the basis of the frequency of occurrence of the weather condition associated to each simulated episode.
The use meteorological classifications based on the analysis of synoptic scale weather maps (Finardi et al., 1999) can be questionable in regions like Aosta valley, where the peculiar topographic features strongly influence local circulation. In a large number of situations the winds observed inside the valley exibit in fact a weak correlation with the synoptic circulation structure. An original weather type classification has been then built from the analysis of local measurements of wind, temperature, humidity and precipitation. Comparative tests demonstrated that the local weather classification give a better description of local meteorology than synoptic weather classification.

The local weather type classification has been therefore employed to compute yearly average maps of pollutants concentration over the Valle d'Aosta Region. Table 3 shows the comparison of computed and observed NO_X yearly average concentrations for all the available stations.

Table 2. Comparison of observed and computed yearly average NO_X concentrations

Station	Observed conc. (μg/m^3)	Computed conc. (μg/m^3)
Plouves (urban)	103	72
M.Fleury (sub-urban)	70	52
Morgex (road side)	63	12
Etroubles (remote, elevated)	19	3
LaThuile (remote, elevated)	16	2

Two remote stations (Etroubles and La Thuile), located in side valleys over elevated topography, can be considered unaffected by emissions located in the main valley. Their yearly average concentration values, in the range 15-20 μg/m^3, can therefore be considered representative of the background long-range contribution that has not been taken into account by the simulations. Adding this concentrations to the computed values in Table 3 we get concentrations very near to the measured values in all the stations but Morgex. This last station is located at less than 10 metres from the major road running in the valley bottom. It is hence very hard to reproduce concentrations measured by this station with a dispersion model simulation having a spatial resolution of 500 metres.

MONT BLANC TUNNEL RE-OPENING SCENARIO

To assess the air quality impact induced by the Tunnel re-opening, the emission scenarios with and without the Mont Blanc Tunnel traffic have been compared. The total CO and NO_X emissions over the whole valley showed a reduction of 13% and 18% respectively, due to the Tunnel closure, while traffic emissions of individual segments of the main road running the upper part of Aosta valley (Figure 4) showed a decrease ranging from 50 to 100%.

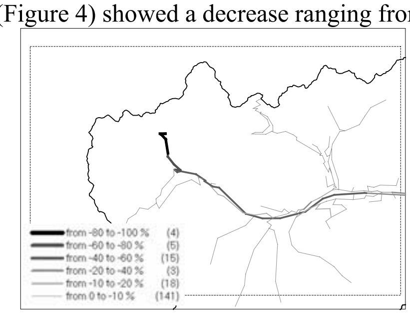

Figure 4. Reduction of traffic emissions over road network due to Mont Blanc Tunnel closure.

The dispersion model simulation results obtained with the two considered emission scenario has been used to compute concentration variation over the upper Aosta valley. According to model results, the NO_X ground level concentration will be doubled in the valley bottom near the main highway, and will be incremented up to 300% near the Tunnel entrance; a lower influence will be exercised over the urban area of Aosta and over topographically elevated regions, where variations will be generally lower than 10%. These variation values have been confirmed by the comparison of road side concentration measurements before and after the Tunnel closure (respectively, during year 1998 and 2000).

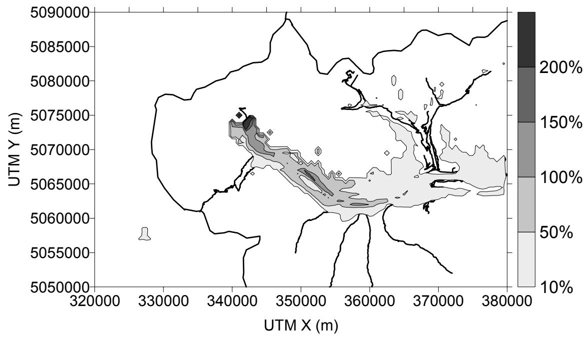

Figure 5. Percent increment of NO_X yearly average concentration due to the Mont Blanc Tunnel re-opening.

CONCLUSIONS

The modelling system set up for air quality assessment and management in Valle d'Aosta Region has been verified through the reconstruction of air pollution episodes and yearly average concentration of air pollutants. The system has been then used to evaluate the impact of the traffic due to the re-opening of the Mont Blanc Tunnel. The increase in concentrations has been computed as difference of ground level concentrations obtained by emission scenarios with opened and closed Tunnel. The increase of road traffic affects mainly the major motorway axis that crosses the valley and carries to the Tunnel. The increase in ground level concentrations is limited to the bottom of the main valley (and it is more relevant in the areas near the Mont Blanc where the international road traffic represents an important pollutant source with respect with the local ones); it can be neglected in the side valleys and over the Aosta urban area. The increase of concentrations ranges from 50 to 150% in the bottom of the upper valley, reaching larger values nearby the Tunnel entrance.

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