USE OF 3D ATMOSPHERIC DISPERSION MODELLING FOR AIR QUALITY MANAGEMENT IN A VERY COMPLEX TERRAIN ALPINE REGION (VALLE D'AOSTA)

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INTRODUCTION

The Aosta Valley, an alpine Italian region located close to the northern border between Italy, France and Switzerland, is characterized by an extreme terrain complexity, including the Italian side of the Mont Blanc, as depicted in Figure 1. In such a difficult topographical situation, the application of steady state regulatory dispersion models becomes very critical and a more advanced methodologies are required: models implementing simple algorithms for complex terrain appear to be unable to reproduce relevant features of pollutant dispersion in that conditions (Brusasca et al., 2001).

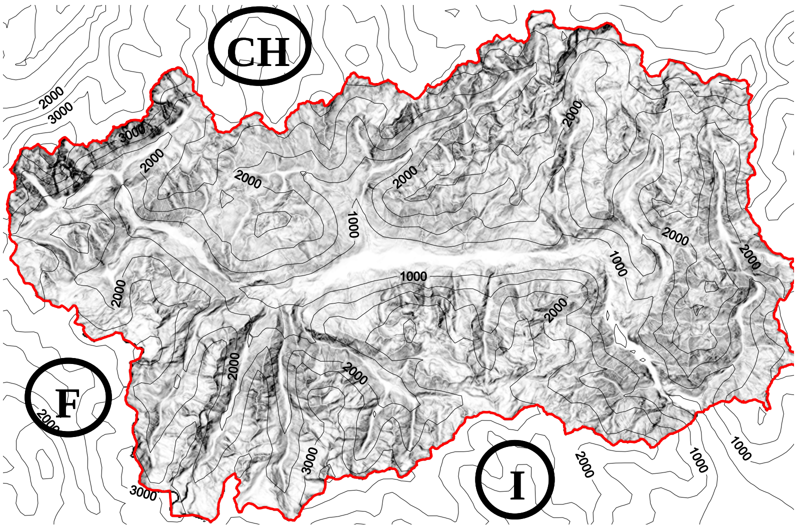

Figure 1. Image of the Valle d'Aosta region. Boundaries (thick line) and isolines of topography levels (thin lines) are represented.

The Regional Environmental Protection Agency (ARPA VdA) has started a program to verify the performances of 3-D modelling systems, potentially able to give a reliable description of the complex dynamic influencing the pollutant dispersion inside the region. During the last 5 years some studies have been carried out, using an advanced 3D modelling suite. The modelling applications have been based on the emission data coming from the Regional Inventory and meteorological data coming from local measurements. This modelling system has been validated versus measurements collected by Regional air quality monitoring network (ARPA VdA, 2004). This has been done in the framework of the 'integrated assessment' realized through the closed linkage of these components (monitoring network, emission inventory and dispersion modelling) to fulfil the recent EU directive on atmospheric pollution control concerning the analysis of the regional territory. The system has been used to reconstruct air pollutants concentration maps at regional scale on a yearly basis. Presently, the modelling system is being used by ARPA VdA to manage all the activities related to the air quality control within the Region. Specific applications concern:

- comparison among different "emission scenarios" (e.g. considering different number of trucks going through the Mont Blanc tunnel, connecting Italy and France);
- air quality impact assessment of new structures (such as special waste landfill) and control of their operational activities;
- simulation of the air quality impact of urban and extra-urban road traffic (e.g. considering the road network of the Aosta city or the entire regional road network);
- analysis of industrial emissions impact (e.g. an iron and steel production factory).

MODELLING SYSTEM AND VALIDATION

The modelling suite is based on a diagnostic model named MINERVE (Aria Tec., 2001, Fischer et al., 1999), to reconstruct the 3D wind and temperature fields using local surface measurements, and synoptic meteorological measurements. The atmospheric turbulence scale parameters (u_*, L, H_0, z_i, w_*) are computed using the meteorological pre-processor SURFPRO (ARIANET, 2004), that can take into account mountain slopes and shadow projection. The Lagrangian particle model SPRAY (Tinarelli et al. 1998, ARIANET, 2001) is finally used to simulate the atmospheric transport and dispersion of pollutants. The first validation of this modelling chain has been made in 2001 in the frame of the "Espace Mont Blanc" INTERREG European project (ARPA VdA, 2003) having as target the study of the air quality in the Mont Blanc area. Annual maps of NOx concentrations have been produced applying a method to sample a significant number of simulation days, in order to reconstruct the statistical properties of the local meteorology and air quality observations (Finardi et al., 2003). Figure 2 shows an example map of NOx annual average ground level concentrations superimposed to the annual values measured by the local network. Using these annual maps, the local authority can subdivide the region into areas characterized by different air pollution levels (zonization), as required by the EU directive on ambient air quality assessment and management.

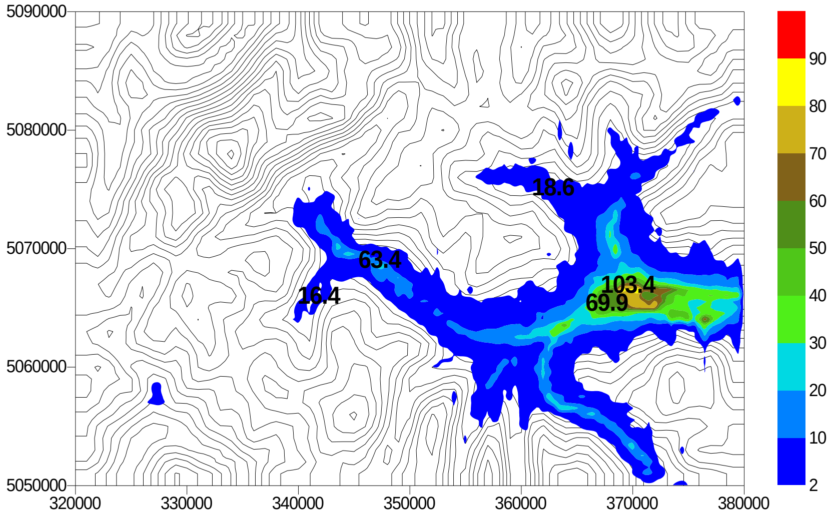

Figure 2. Yearly average ground level concentration map of NOx for year 2001. Values are in □*g/m*^{3}*. Numbers represent annual averages measured by the local network.*

MODELLING ACTIVITIES

Traffic emission scenarios analysis

The modelling system has been applied to assess the air quality impact of the re-opening of Mont Blanc Tunnel, after the tragic accident happened on 24 March 1999. Initially, the effect of the traffic emission all over the valley has been evaluated comparing simulated concentration fields with opened and closed tunnel scenarios, corresponding to traffic conditions occurred before and after the accident (Nanni et al., 2004, Finardi et al, 2003).

On the basis of these evaluation, comparison among different “emission scenarios” (e.g. considering different number of trucks going through the Mont Blanc tunnel) have been performed. This last application has been particularly important as a decision support activity. The results of the study provided to the stakeholders a quantitative estimation of the air quality impact of the maximum number of trucks allowed daily to run the motorway and cross the tunnel. Figure 3 shows that, excluding the urban area of Aosta, all the considered sensible points are below the EU legislation limit for the 99.8 percentile for hourly NO_2 concentration (200 $\mu g/m^3$), with a daily number of trucks below 1000. This evaluation has been based on the analysis of pollutant concentrations at sensible points located in areas directly exposed to major road emissions.

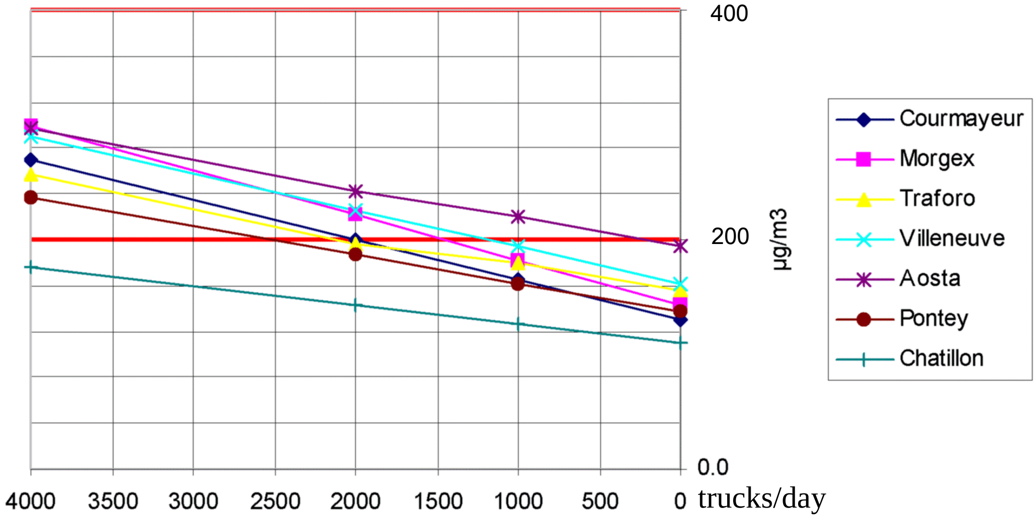

Figure 3. Maximum annual concentration of NO2 calculated at some sensible points close to the main road network as function of the daily number of trucks passing the Mont Blanc tunnel

Evaluation of environmental impact at local scale

The modelling suite can have be used to evaluate local impact due to the different sources located on the regional territory both urban areas or industrial factories. All the type of sources (area, linear and point sources) have been considered and some examples are presented hereafter.

The city of Aosta, being the more important urban centre of the region, required a more detailed study of the air quality impact of urban emission, related both to the traffic and to all the other sources, such as heating systems and industries A local modelling study has been conducted over an area of 5 x 3 km^2 with an horizontal resolution of about 60m. The main aim of the work was to compare the influence of the urban traffic with that of the other sources, as described by the local emission inventory. In particular to define the environmental impact due to the urban traffic, the vehicular fluxes on the Aosta road network was reconstructed using an assignment traffic model (ARIANET, 2003). Figure 4 shows the maps of NO_x annual average ground level concentrations due only to the traffic (left) and generated by all the sources (right). It is evident the impact of the traffic around the main roads, while the other sources contribute to generate a more uniform concentration field. In particular the heating systems contribution is almost uniform on the entire urban area while the south-eastern part of the domain is mainly influenced by the elevated emissions from a big steel factory. Inside the urban area and far from the impact of the industrial source the contribution of urban traffic emissions has been estimated as about 70% of the total air pollution.

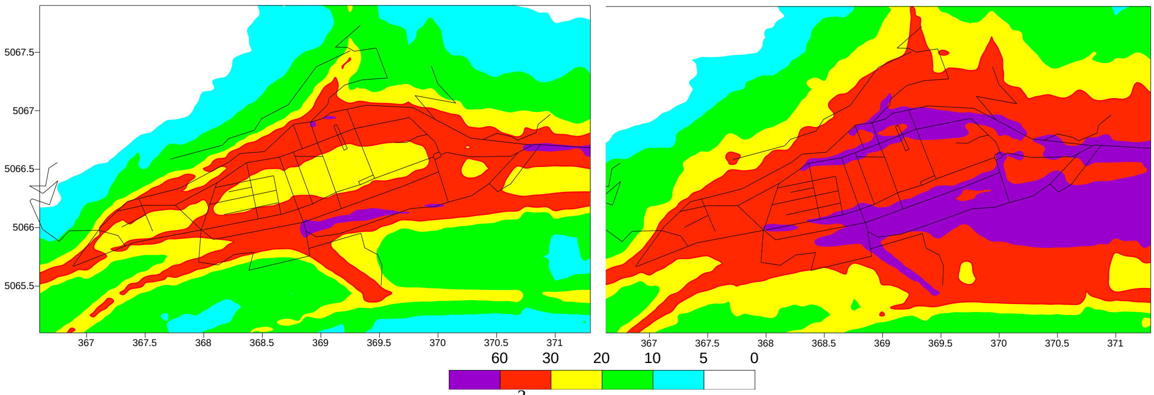

Figure 4. NO_X annual average conc. (□g/m^3) over Aosta town area. On the left side is represented the contribution of urban traffic emissions, while the impact of all sources is depicted on the right side.

During 2003, ARPA VdA studied the possible environmental impact of the future installation of a special waste landfill. The aim of this work was to recognize the main area of impact of the landfill and, at the same time, the present impact of all the other sources located in the same zone (e.g. hydrocarbons emitted by traffic) in order to select the suitable positions for experimental monitoring activity.

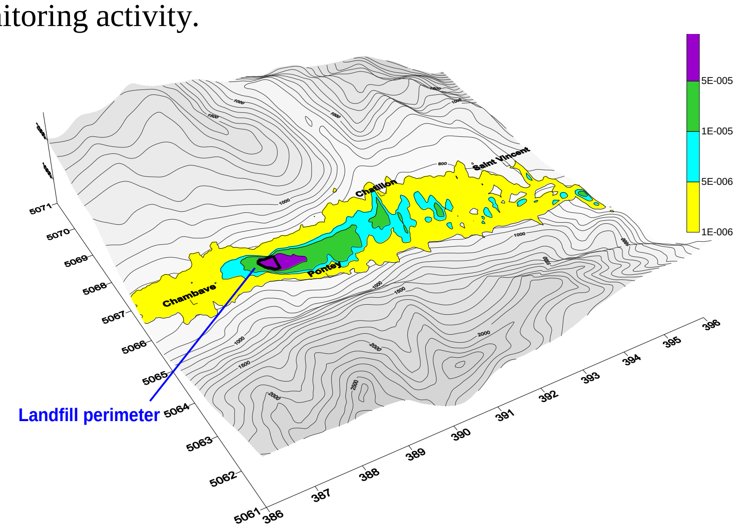

Figure 5. Map of the annual mean dilution factor due to an emission from the area of the landfill.

The geometry of the landfill was known but, being unknown the type and emission rate of pollutants involved, the simulation was aimed to calculate a map of dilution factor. During the future lifecycle of the landfill, the emission quantities from the waste will be available and the calculation of the actual concentrations will then be possible. The availability of waste emissions will also allow a comparison with the impact of the other sources already present in the zone. Figure 5 shows the annual average area of impact in terms of dilution factors.

FUTURE DEVELOPMENTS

On the regional scale, also secondary pollutants have been to evaluate: during the above mentioned INTERREG European project, some measures of vertical profile of ozone and preliminary modelling study with a 3D photochemical model was performed. ARPA VdA is starting activities with the Eulerian model FARM (Silibello et al, 2003) This will enhance the treatment of complex situation involving chemical transformations of many specie and will also allow the realization of an entire year of simulation. The Eulerian model will be driven by meteorological fields derived by simulations performed at national scale, as a result of a national project named MINNI (Zanini et al, 2004) and downscaled using meteorological measurements from the local network and Regional detailed emission Inventory.

CONCLUSIONS

ARPA VdA has validated a 3D modelling system for the reconstruction of pollution impact on its very complex terrain. This modelling tools are presently used, together with a Regional air quality monitoring network and emission inventory, for the air quality management from regional to local scale. On one hand, the complete system can be used as an effective instrument to satisfy the EU directives recommending the use of an "integrated approach" to air quality management. On the other hand the system can be quickly applied to perform emission scenarios evaluations at regional scale and to perform local scale studies and air quality impact assessment of single sources, covering the particular interest and need of the Agency. The realization of emission scenarios analysis resulted to be a useful information for the management of the traffic across the Mont Blanc tunnel. In particular, the Regional Administration used output model results to establish the maximum number of trucks allowed daily to run the motorway and cross the tunnel.

In general, the modelling system has shown to be reliable and easily adaptable to different situations. Simulations, considering any emission typologies and different spatial or temporal scales, have been produced and represent a good example of how a Regional Environmental Protection Agency can employ air quality modelling to help and support the decisions regarding air pollution management on its territory.

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