

6.10 SIMULATION OF AIR QUALITY IN CHAMONIX VALLEY (FRANCE): IMPACT OF THE ROAD TRAFFIC OF THE TUNNEL ON OZONE PRODUCTION

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INTRODUCTION

During the summer 2003 a POVA intensive observation period (IOP) aimed at determining the sources of airborne pollutants and monitoring their concentrations in two French Alpine valleys: the Chamonix and the Maurienne valleys (see figure 1 for geographic location). The Pollution of Alpine Valleys (POVA) program was launched in 2000 after the traffic interruption under the Mont-Blanc that followed the tragic accident in the tunnel. The Mont-Blanc tunnel were reopened at the end of 2002 what caused the high duty vehicle traffic to be back in the Chamonix and the Courmayeur (Italy) valleys. The summer 2003 IOP was the last of a series of four IOPs (two in wintertime and two in summertime) and took place from 5 to 12 July in the Chamonix valley.

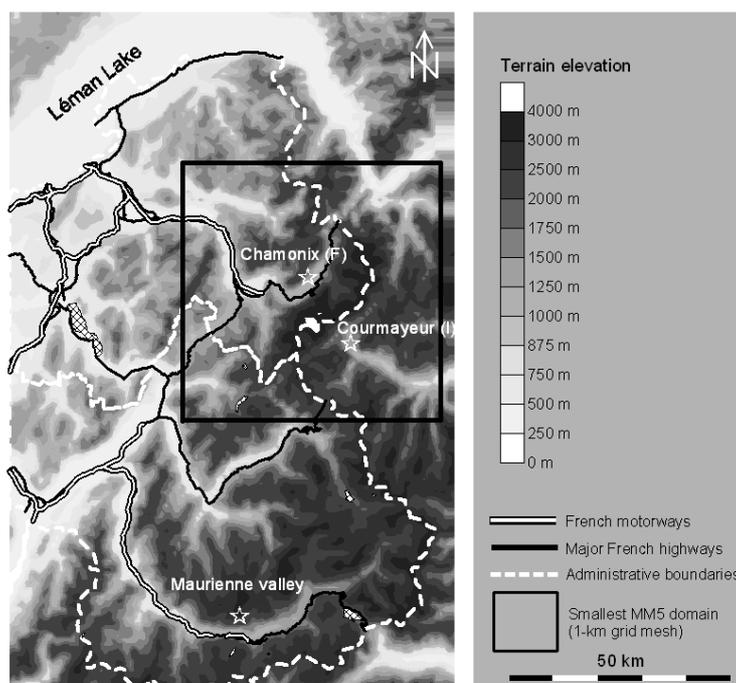


Figure 1. Geographical locations of major roads in the study area

To better understand the very particular atmospheric circulation and to study the chemical reactions of airborne pollutants within the valleys mesoscale modelling is applied. For the calculation of meteorological fields, the fifth generation PSU/NCAR Mesoscale Model (MM5) is used at scales ranging from 27 to 1 km. MM5 is coupled offline with the Chemistry Transport Model (CTM) TAPOM developed at the Ecole Fédérale Polytechnique de Lausanne, Switzerland (Clappier, A., 1998). Simulations were performed for the period 8-12 July 2003 with different emission sets aiming at studying the impact of the road traffic due to the tunnel. This traffic includes the traffic on the main highway leading to the valley, on the ramp to access the tunnel and through the tunnel. This period was particularly interesting because a high ozone event which caused the ozone background concentration to increase occurred from 5 to 12 July.

METHODOLOGY

Before describing atmospheric processes within the valleys such as slope winds and thermal inversions, a good description of the synoptic situation must be performed with a regional model. MM5 was chosen to be used at the different scales and gave good results both at the synoptic and at the local scale compare with available measurements of wind, temperature and humidity. CTMs are then powered with MM5 meteorological fields with additional variables such as turbulent vertical dispersion coefficients (K_z), convective velocity (w^*) or Monin-Obukhov length (L) that are recalculated. The temporal variation of concentrations at the regional scale for principal airborne pollutants are resolved with the CHIMERE model (Schmidt, H. et al, 2001) in its recent multi-scale nested version. The interaction between the different models and domains is presented on figure 2.

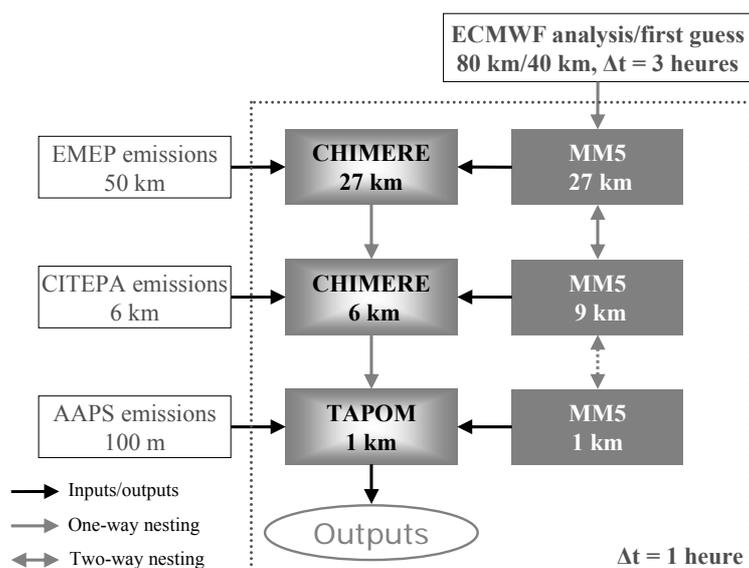


Figure 2. Schematic of the simulation system and its main inputs

Meteorological calculation

The fifth-generation PSU/NCAR mesoscale model (MM5) is a nonhydrostatic code which allows meteorological calculations at various scales with a two-way nesting technique (Grell, A. and al., 1994). For our simulations four different domains are used as shown in figure 2. The smallest domain has a 1-km grid mesh and is shown on figure 1. The coarsest domain is powered with the ECMWF gridded analysis and first guess at a 0.5° resolution. The Four Dimensional Data Analysis (FDDA) technique available in MM5 is used in the coarse domain to provide a better synoptic forcing of the smallest ones. Vertically MM5 uses 27 layers with thickness ranging from 65 m at the ground to 2000 m at 15000 m. The top of the model is at the pressure 100 Pa. The planetary boundary layer (PBL) is thus described with about 15 layers from 0 to 2000 m a.g.l. Even if the PBL height, and so the mixing, tend to be overestimated by MM5 during the simulation period, the PBL height variations are well described by the MRF scheme (Hong, S.-Y. and H.-L. Pan, 1996). This height was experimentally determined using UHF radar located in the middle of the valley. For 8 July 2003 the UHF radar wind profiles indicate a PBL height of 1400 m at noon whereas MM5 predicts a PBL height of 1600 m.

Chemistry transport calculation

As shown in figure 2, CHIMERE is used with a 27-km and 6-km grid mesh. TAPOM which uses the RACM mechanism (Stockwell, R. and al, 1997) to resolve chemistry reactions, is used at a 1-km scale. Chemical concentrations calculated on a large scale domain are used at

the boundaries of a smaller one. A good description of the temporal variation of the background concentrations of ozone and of other secondary species is necessary because of the important photochemical episode that occurred at continental scale during the period 5-12 July 2003.

Emission inventories

Each emission inventory used for simulations has a precision consistent with the associated CTM model. As shown in figure 2, the EMEP emission inventory of 2001 for NO_x, SO_x, CO, NMVOC and NH₃ on a 50-km grid mesh is used in the 27-km grid mesh CHIMERE model by recalculating emissions following the land use. To perform chemistry-transport calculations at 6 km for the Rhône-Alpes area an emission inventory from the CITEPA on a 6-km grid mesh is used for NO_x, CO, NMVOC and SO_x (Couach, O., 2002). At the finest scale an accurate emission inventory developed in the framework of the POVA program by *Air de l'Ain et des Pays de Savoie* with a 100-m resolution is distributed on the 1-km grid mesh used for the chemistry-transport calculation.

Definition of the scenarios

In order to study the impact of the traffic through the tunnel on the ozone production we have to accurately determine which part of the total traffic in the valley is due to tunnel in summer 2003. We consider two cases: one with all the emissions and one without any emission from the vehicles passing through the tunnel. Road counting realized by local agencies and by the company ATMB showed that traffic could be modelled as shown in table 2.

Table 2. Definition of the coefficients assigned to emissions of different sources for the two cases

| Sources | With the tunnel | Without the tunnel |
|---|-----------------|--------------------|
| Personal light duty vehicles on roads | 1 | 0.9 |
| Personal light duty vehicles in city | 1 | 1 |
| Commercial light duty vehicles on roads | 1 | 0.5 |
| Commercial light duty vehicles in city | 1 | 0.9 |
| Heavy duty vehicles | 1 | 0.04 |

DESCRIPTION OF THE BASE CASE

The validation of chemical-transport calculation for the base case showed very good agreement of the modelled concentrations of ozone with measurements. Two comparisons are shown on figure 3 respectively for the suburban site *Clos de l'Ours* (1100 m amsl) and for the high-altitude site *Plan de l'aiguille* (2100 m amsl). For other pollutants such as nitrogen dioxide, temporal variations are slightly less satisfactory described at certain sites but still in agreement with the measurements at background sites located in the Chamonix urban area.

The processes that lead to the observed concentrations are very different during the night and during the day. During the day the strong valley wind system composed of slope winds generated by convection and the main valley wind blowing in the central part of the valley is performing a very effective transport of ozone precursors from the sources to higher altitude areas. The combination of the main valley wind and of slope winds causes the formation of two ozone plumes downwind of the Chamonix urban area. The production of ozone in these plumes is enhanced by the availability on the slopes of the valley of large amount of biogenic VOC such as terpenes. The simulated production rate of ozone in the central part of the valley is 2 µg/m³/h whereas it reaches 5 µg/m³/h on the south face of *Aiguilles Rouges* mountains. This transport starts when the valley wind sets up and is really effective from 8 am to noon.

The calculated ozone concentration in the plumes reaches $150 \mu\text{g}/\text{m}^3$ on 8 July whereas the background concentration is $130 \mu\text{g}/\text{m}^3$ what represents a net production by the valley of $20 \mu\text{g}/\text{m}^3$. The base case simulation highlights that the maximums of ozone are very linked with the background ozone level due to intensive mixing that brings air from free troposphere.

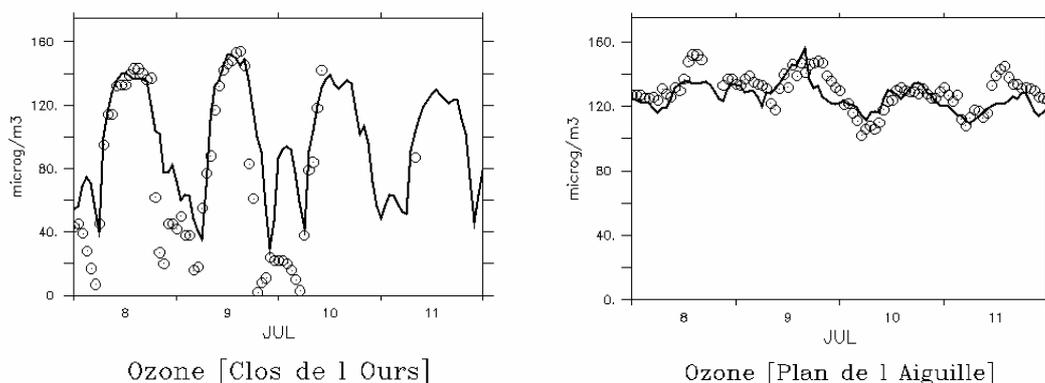


Figure 3. Measured (dots) and modelled (line) ozone at two stations from 8 to 12 July 2003

With sunset the convection stops and the valley wind weakens progressively to become null at 6 pm. The atmosphere becomes stable and primary pollutants such as NO_x are accumulated in the surface layer. Titration of ozone by NO and dry deposition cause the ozone concentrations to rapidly decrease at urban and suburban sites. On figure 3 the *Clos de l'Ours* site sees its ozone concentration reaching $0 \mu\text{g}/\text{m}^3$ during the night from 9 to 10 July. All the sites located at the bottom of the valley have the same behaviour. At ranged sites such as *Plan de l'Aiguille*, ozone concentrations are mainly under the control of dry deposition.

IMPACT OF THE TUNNEL

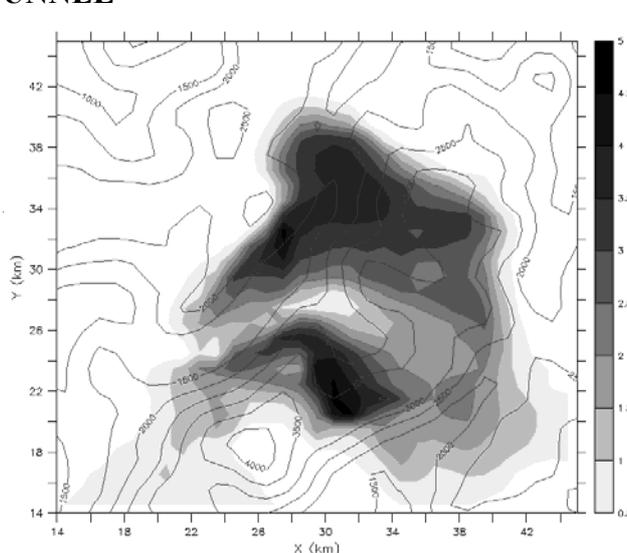


Figure 4. Contour plot of topography with mapped ozone concentration reductions (in $\mu\text{g}/\text{m}^3$) without the tunnel emissions on 8 July 2003 at noon

The simulation performed without the emissions of the tunnel gives very similar results as the base case during the day because of the high correlation of ozone concentrations in the valley with the regional background. However simulations show that the two ozone plumes generated have lower concentrations. Depending on the day the difference between the base case and the case without tunnel emissions is in the range $2\text{--}10 \mu\text{g}/\text{m}^3$. The figure 4 shows that $5 \mu\text{g}/\text{m}^3$ of ozone are produced by precursors released by the tunnel traffic on July 8th. This

production is still negligible in regard with the amount of ozone that is produced regionally and that is advected above the valley and mixed in.

CONCLUSION

This numerical study highlighted the processes of production and destruction of tropospheric ozone in the very narrow valley of Chamonix (France). A pure academic case of emission reduction from road traffic in the valley shows that ozone concentrations are regionally controlled during the day whereas during the night under stable conditions the valley is totally decoupled from synoptic conditions. The precursors emitted by the Chamonix urban area and by the traffic are rapidly dispersed during the day and two plumes are observed downwind of Chamonix at higher altitudes. The net ozone production in the valley during the day accounts for 15 % of the maximum concentrations of ozone which are in the range 140-170 $\mu\text{g}/\text{m}^3$ depending on the day. The impact of the tunnel accounts for 5 % of these concentrations. The aim of this study was also to evaluate the ability of MM5, which is a regional model dedicated to prediction, to provide meteorological fields for a CTM with a 1-km grid mesh. Even if MM5 gives good results for ozone at this scale it remains too coarse to resolve fine scale processes that control concentrations of primary pollutants such as nitrogen oxides and particulate matter ($\text{PM}_{2.5}$ and PM_{10}). It is then interesting to use a finest scale model to better study these species. Additional simulations with MM5 at a 500-m scale showed that the model was unable to work at such scales because processes such as slope winds were resolved twice, explicitly and by the PBL scheme, what causes unrealistic instability to occur near the ground. The use of the MM5 model in our modelling applications will be limited at a 1-km scale until further improvements. The ARPS model (Xue, M., V. Droegemeir and V. Wong, 2000) coupled with the TAPOM model leads to better results at a 300-m scale.

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