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

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Outline

- Framework: POVA research program
- Presentation of the modelling system
- Validation of the base case: 8-12 July 2003
- Scenario study: impact on air quality of traffic emissions in the tunnel under Mont-Blanc
- Conclusions

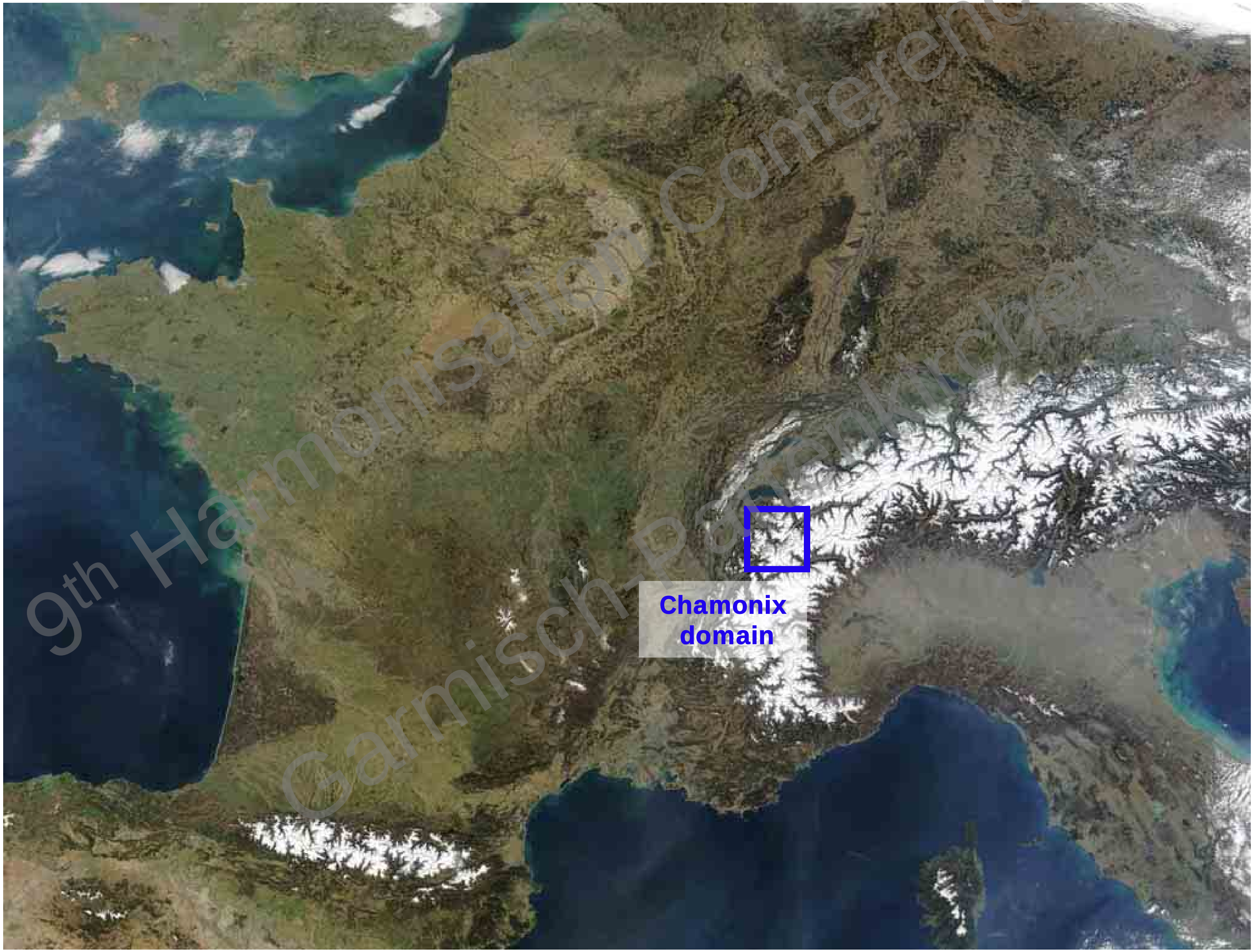
POVA program: objectives

POVA proposed in May 2000
4 main objectives :

- Evaluate the « pollution level » in two Alpine valleys before and after the reopening of the Mont Blanc tunnel (effective in March 2003)
- Evaluate the respective impact of the different types of emission sources
- Develop a 3D model for the atmospheric chemistry in the valleys
- Perform scenario studies (particularly for the evolution of international traffic)

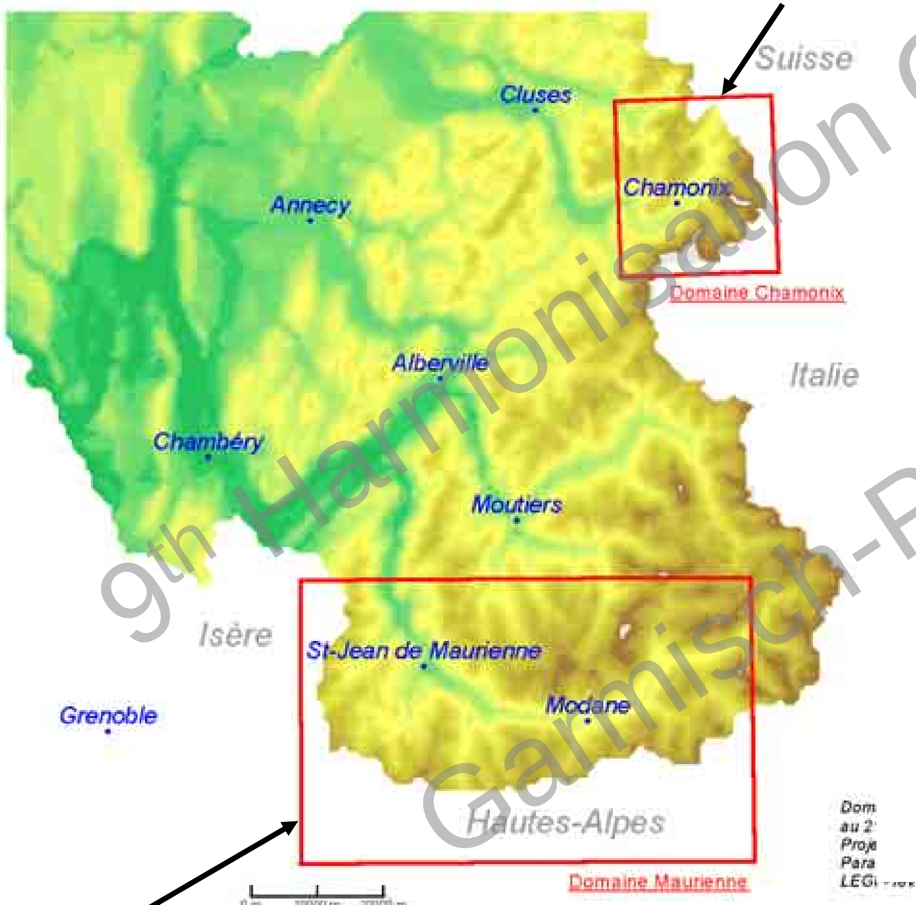
→ General strategy : field studies + 3D modelling

Geographic location

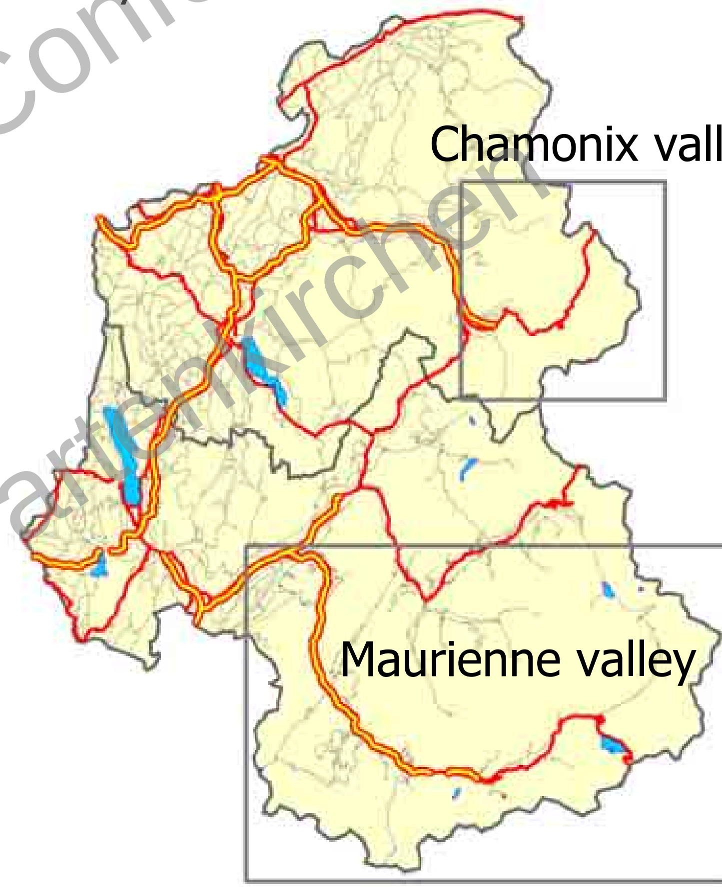


Geography and international traffic

Chamonix valley

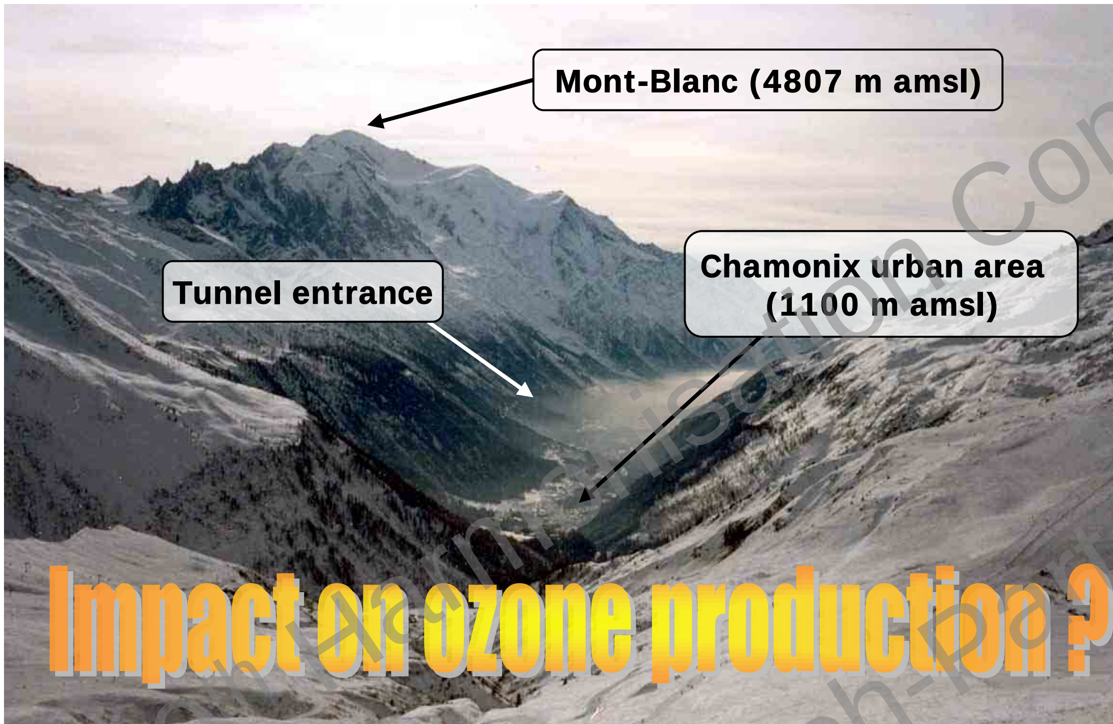


Maurienne valley



Main traffic roads in Rhône Alpes administrative division

Valleys very sensitive to « pollution »



- Very narrow
- Large emissions despite "low" population
- Frequent temperature inversion layers
- Low ventilation
- Preserved areas
- International traffic between France and Italy

View of the Chamonix Valley in winter

Accident in the Mont Blanc Tunnel (March 24th, 1999)

- Before accident :

  2200 HD trucks / day in each valley

- After accident :

  150 trucks / day (local traffic) in Chamonix

Mont-Blanc tunnel after reopening

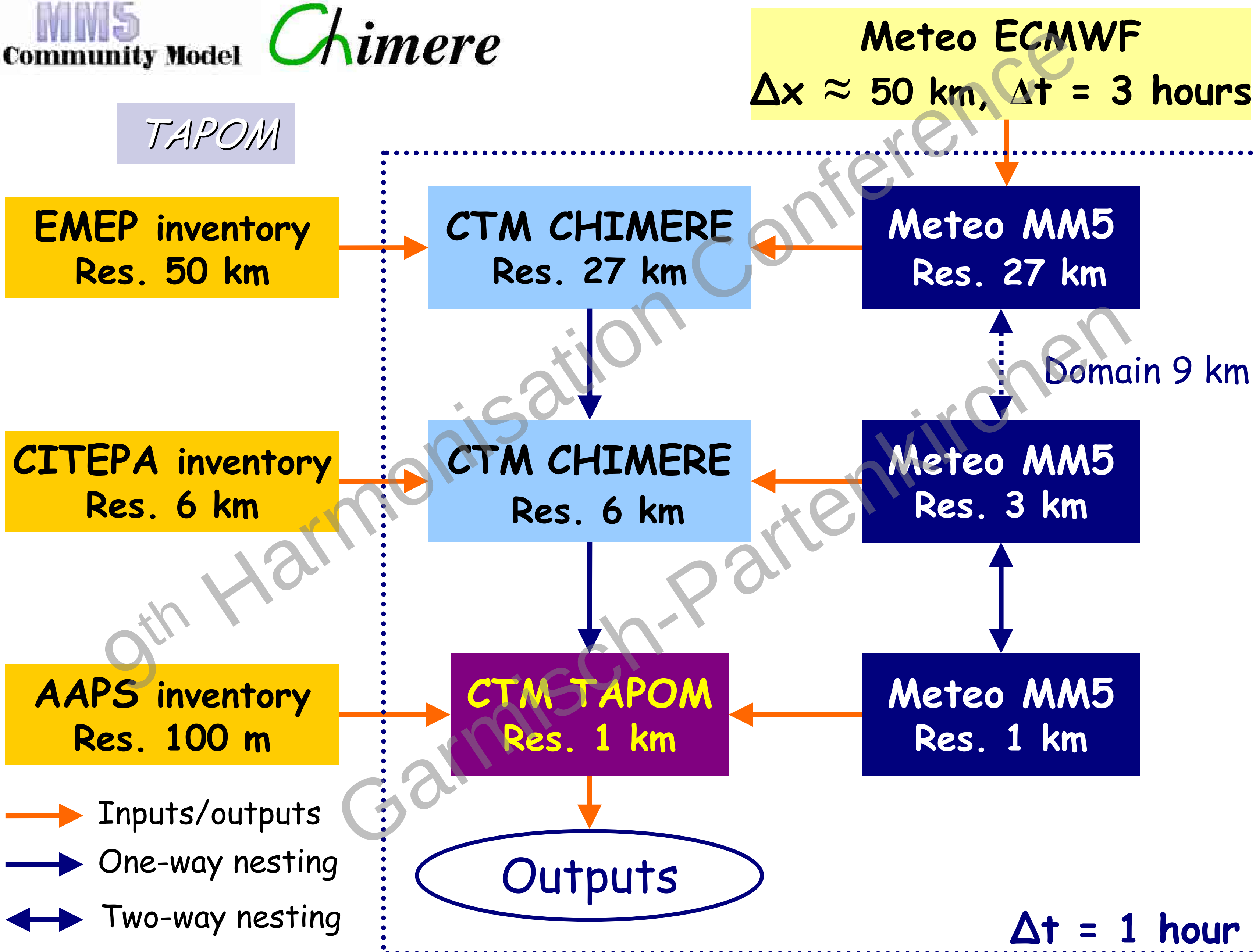
Modelling system

A multiscale approach to meso to local scale

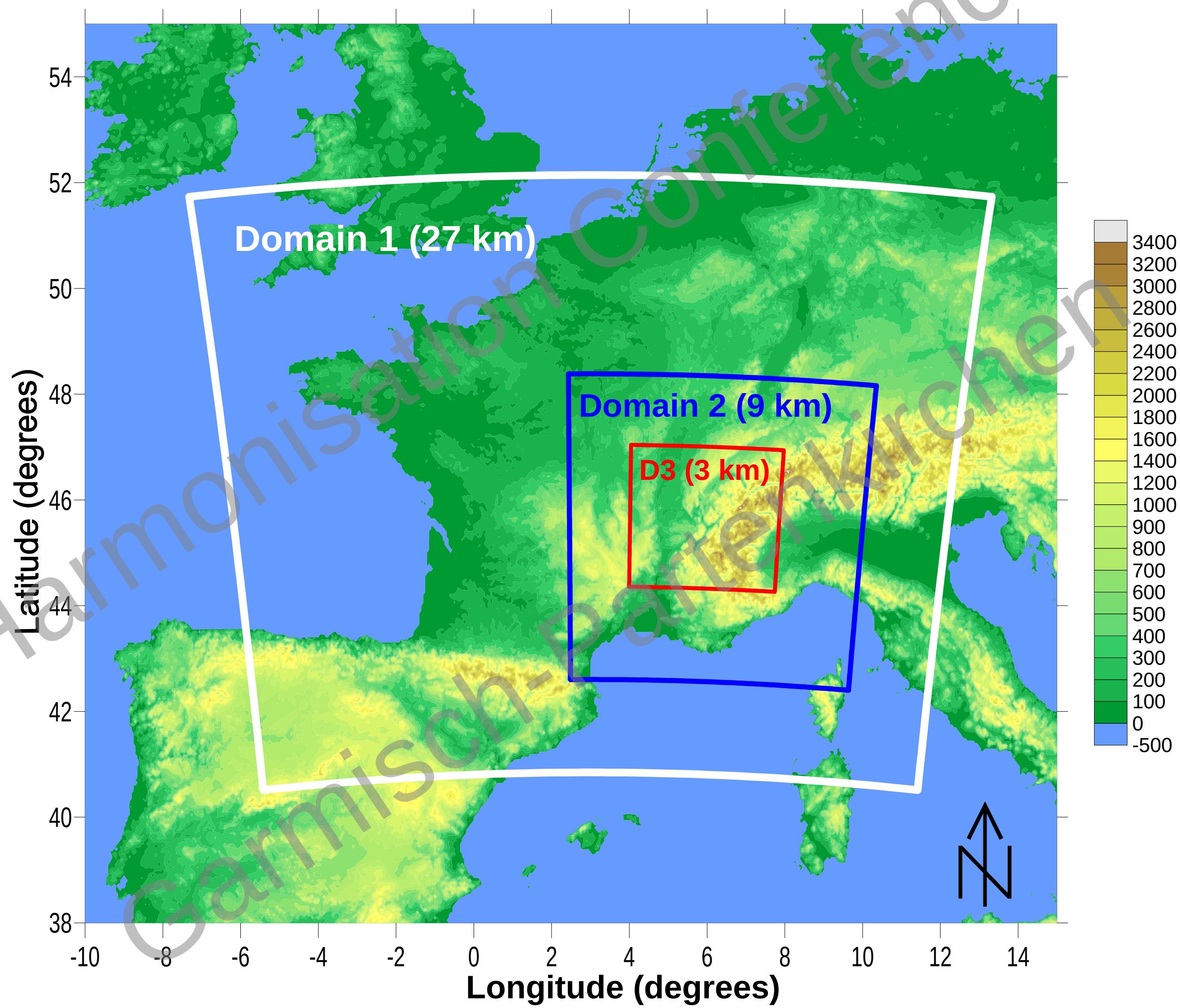
MM5 Community Model

Chimere

TAPOM



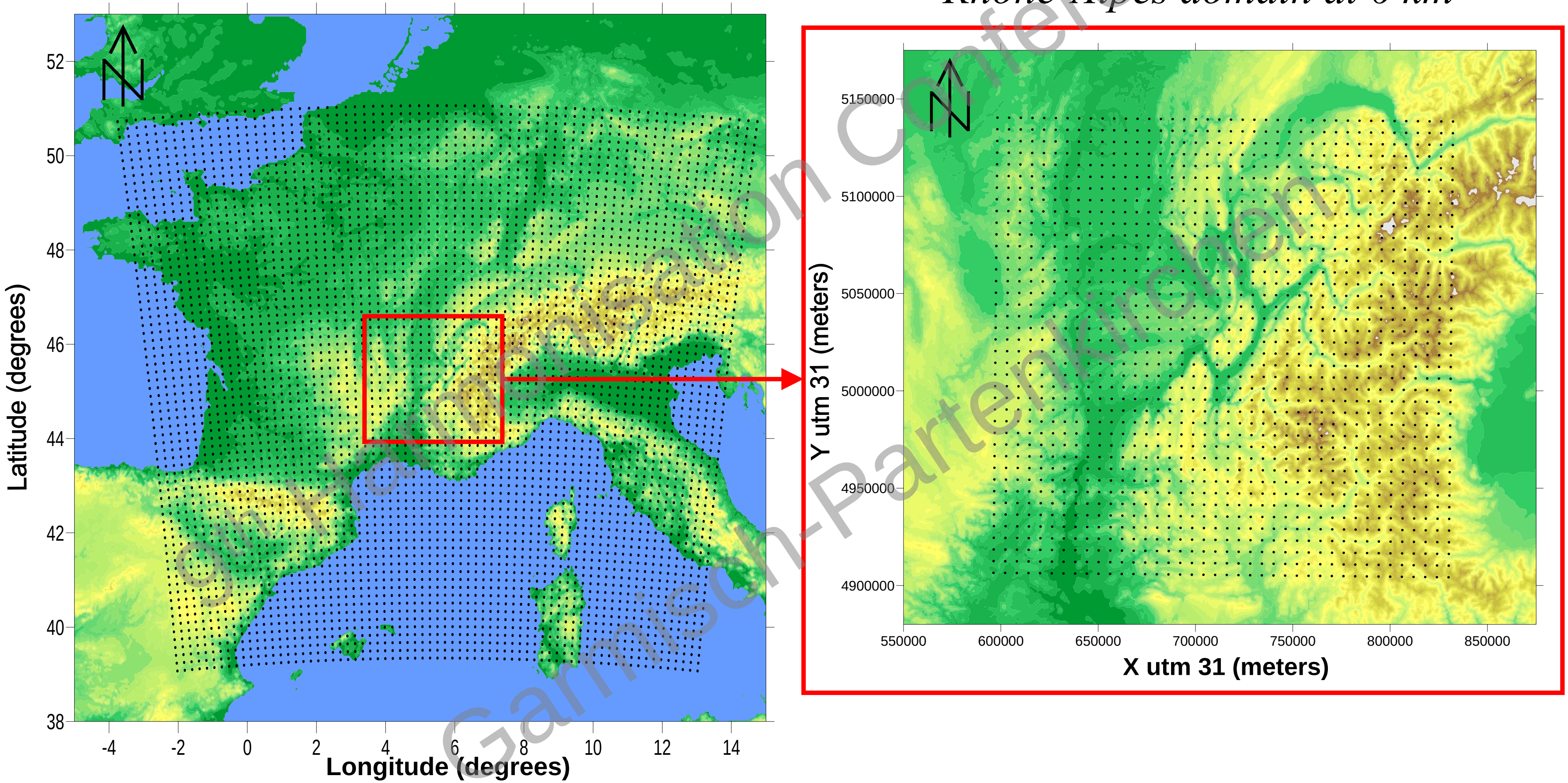
Dynamical calculation domains



Reference: *Grell, G.A, J. Dudhia and J. Stauffer*, 1994: A description of the Fifth-generation Penn State/NCAR Mesoscale Model (MM5). *NCAR Tech Note TN-398, 122 pp*.

Chemical-transport calculation domains *Chimere*

France domain at 18 km | *Rhône-Alpes domain at 6 km*



Reference: *Schmidt H., C. Derognat., R. Vautard and M. Beekmann,* 2001: A comparison of simulated and observed ozone mixing ratios for the summer of 1998 in Western Europe. *Atmospheric Environment,* **35**, 6277-6297.

MM5 configuration

- **General presentation**
  ***Grell, G.A, J. Dudhia and J. Stauffer*, 1994: A description of the Fifth-generation Penn State/NCAR Mesoscale Model (MM5). *NCAR Tech Note TN-398, 122 pp*.**
- **Non-hydrostatic** run
- **27 half-sigma levels** with 15 levels in PBL and top level at 100 hPa
- **Cumulus parameterisation** : **Grell** (for grid mesh larger than 9 km)
- **PBL scheme : Hong and Pan (MRF) PBL**
  ***Hong, S.-Y. and H.-L. Pan,* 1996: Non-local boundary layer vertical diffusion in a medium-range forecast model. *Monthly Weather Review*, 124, 2322-2339.**
- **Soil type**: **Five-Layer Soil model**
- **Radiation scheme: Simple cooling**
- Four-Dimensional Data Assimilation (**FDDA technique**) in the coarsest domain (3D analysis, neither surface nor observations)

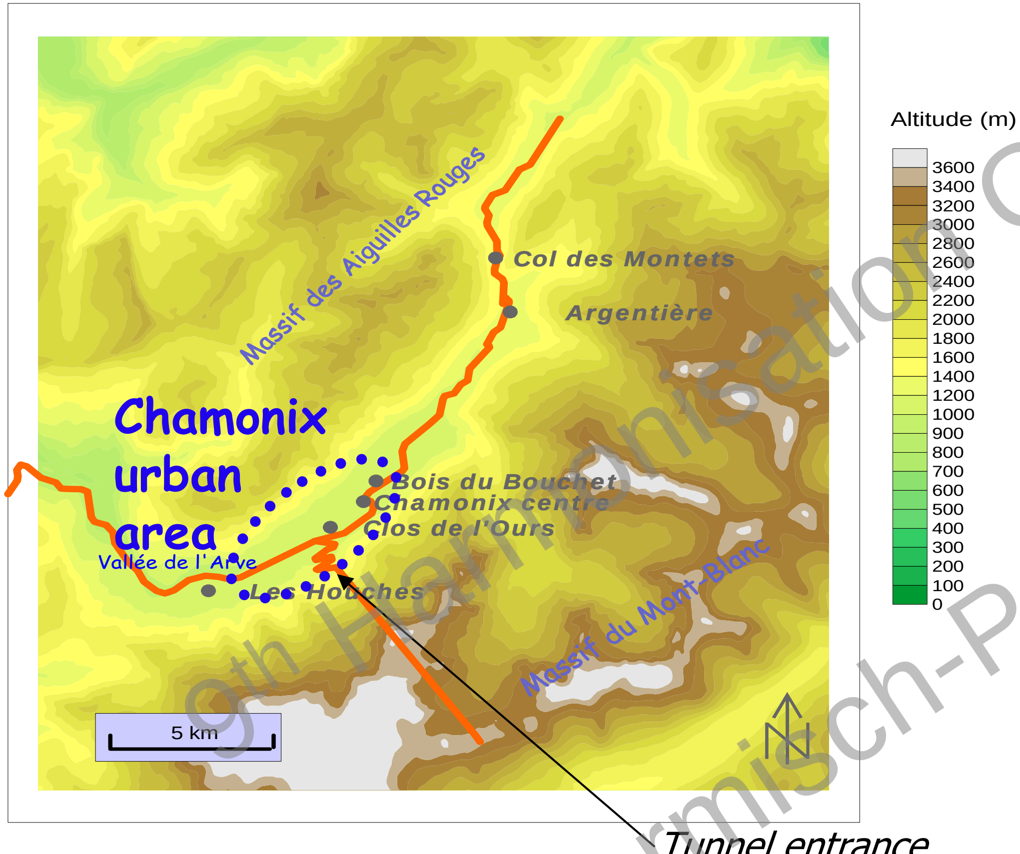
Model validation

Meteorology MM5

Chemistry/Transport CHIMERE

Chemistry/Transport TAPOM

Ground network in Chamonix



Longitude	Latitude	Altitude (m)	Station name	Station type
6.81191	45.89213	1050	Les Houches	Residential
6.85527	45.90933	1080	Auberge de jeunesse	Residential
6.85998	45.91396	1034	Clos de l'Ours	Residential
6.88547	45.9014	2263	Plan de l'Aiguille	Ranged
6.8729	45.92267	1038	Chamonix centre	Urban
6.87767	45.92956	1042	Bois du Bouchet	Residential
6.92943	45.98622	1250	Argentière	Residential
6.92289	46.00392	1464	Col des Montets	Rural

Intensive Observation Period (IOP 4): **4-12 July 2004**

Air measurements: **O_3, NO, NO_2, VOC, PM_{10} and speciation**
Meteorological fields at all sites

Spatial measurements

- Light duty aircraft
  O_3, temp, humidity

- LIDAR
  O_3, NO_2, aerosols

- UHF « windprofiler » radar
  wind measurements (speed, direction)

- Tethered balloon
  O_3, temperature, humidity, wind

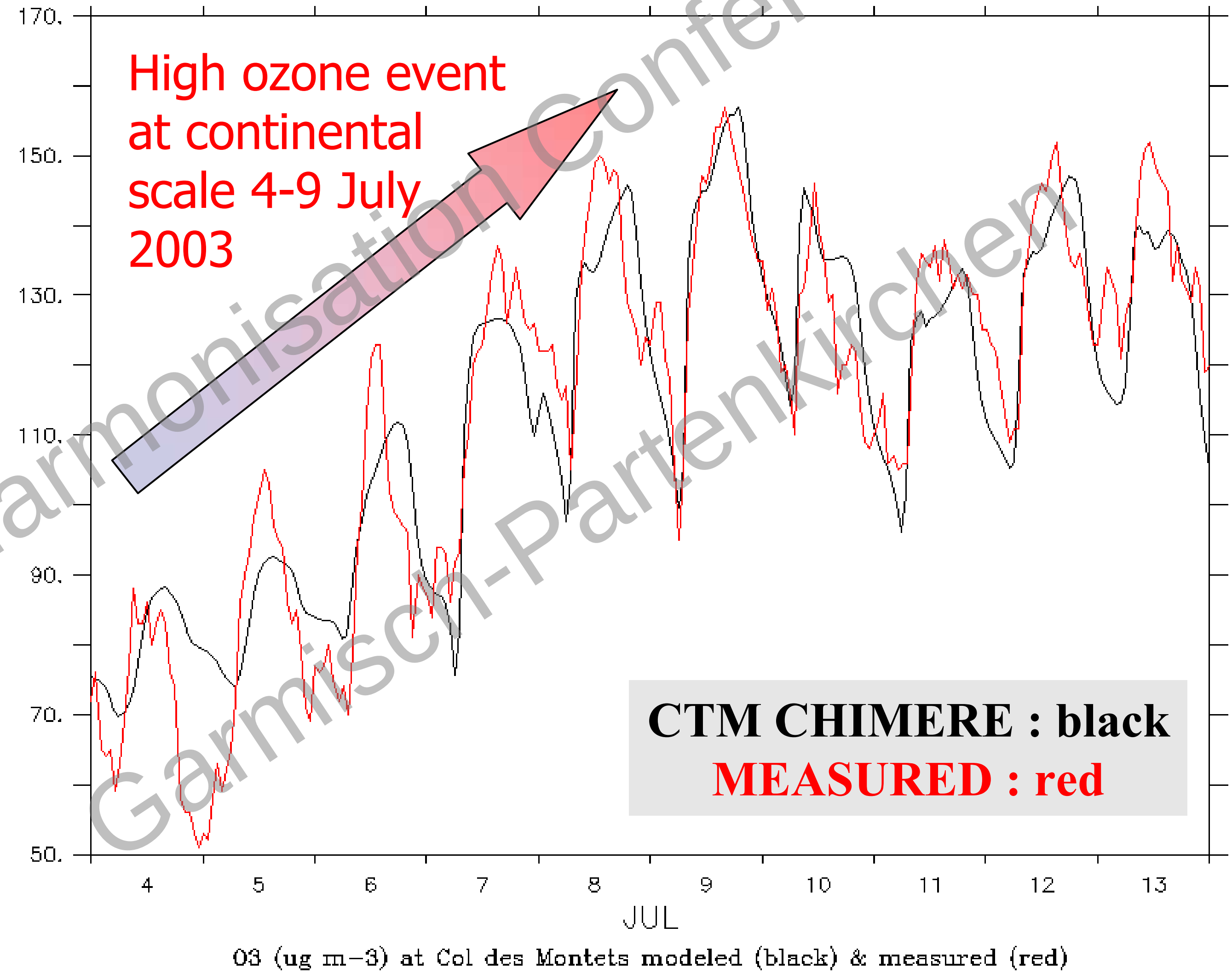
- Instrumented cable car
  O_3, temp, humidity

Chemical composition at boundaries

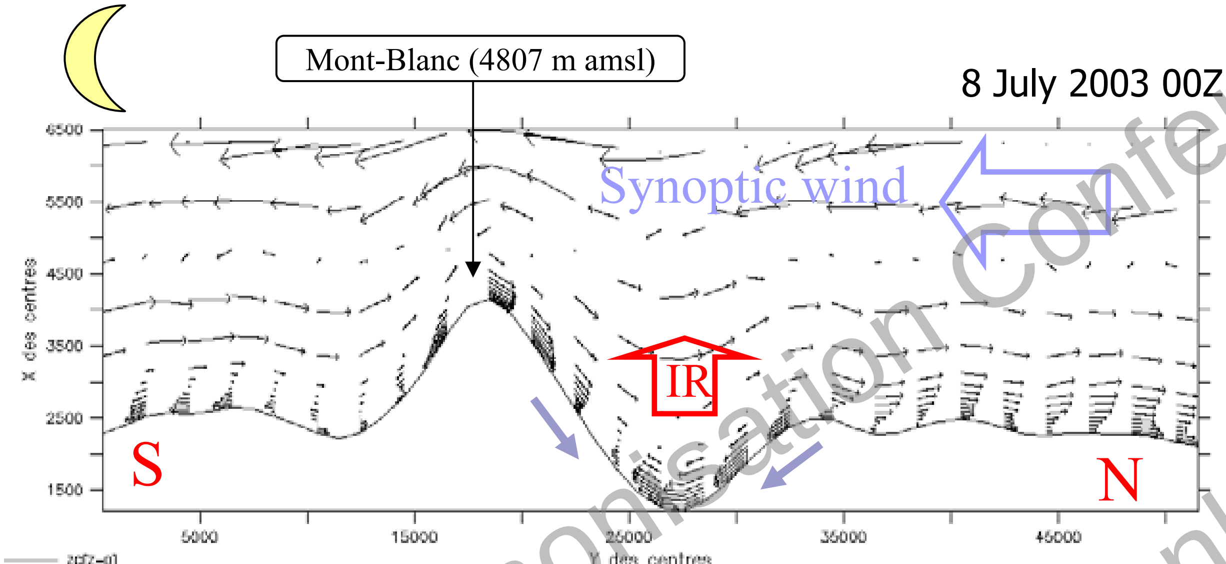
Comparison of simulated ozone from the Rhône-Alpes (6 km) domain with measurements at the rural station Col des Montets (1600 m amsl)

Ground level ozone (µg/m³)

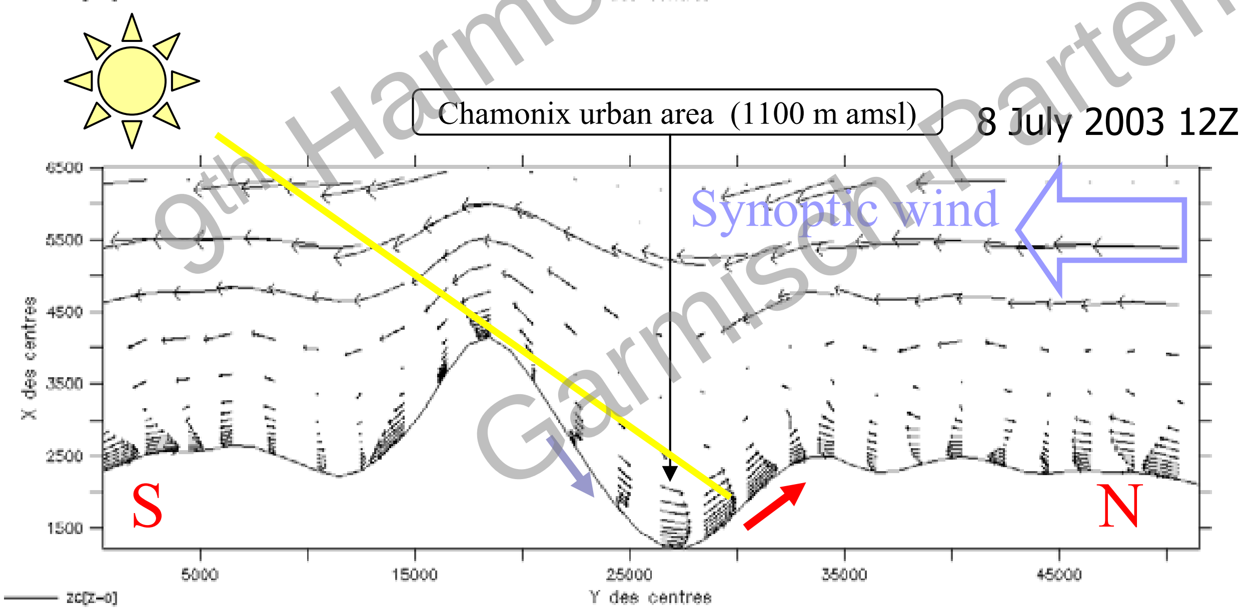
Station col des Montets (rural)

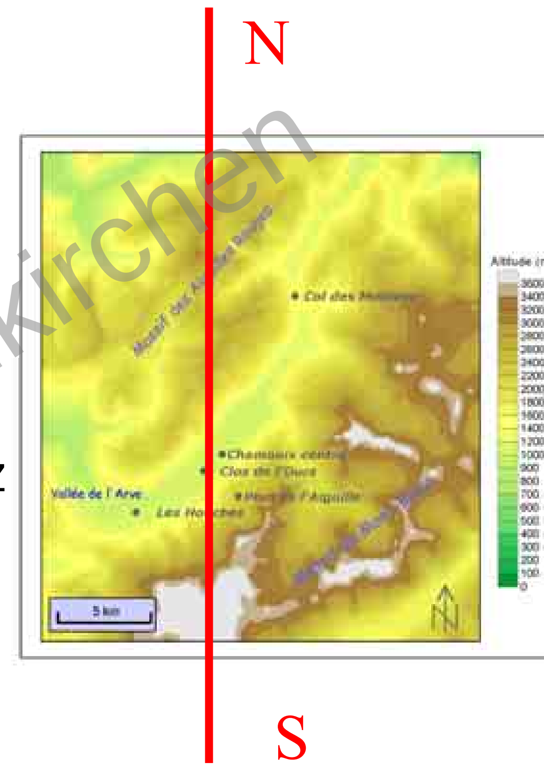


Characterization of the two valley wind regimes with MM5



Cool wind at night



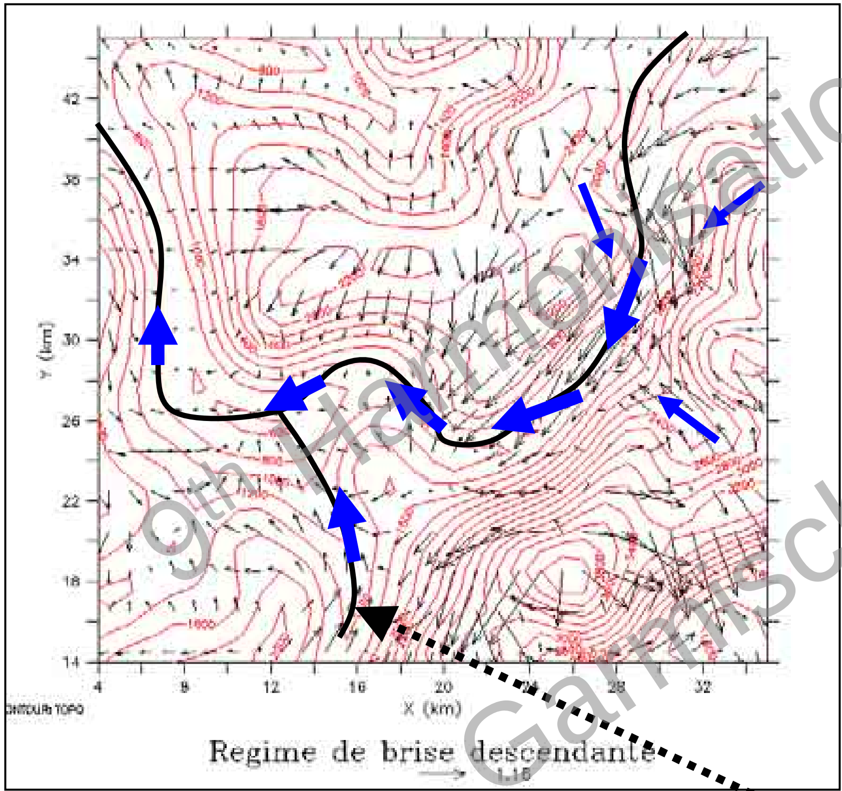


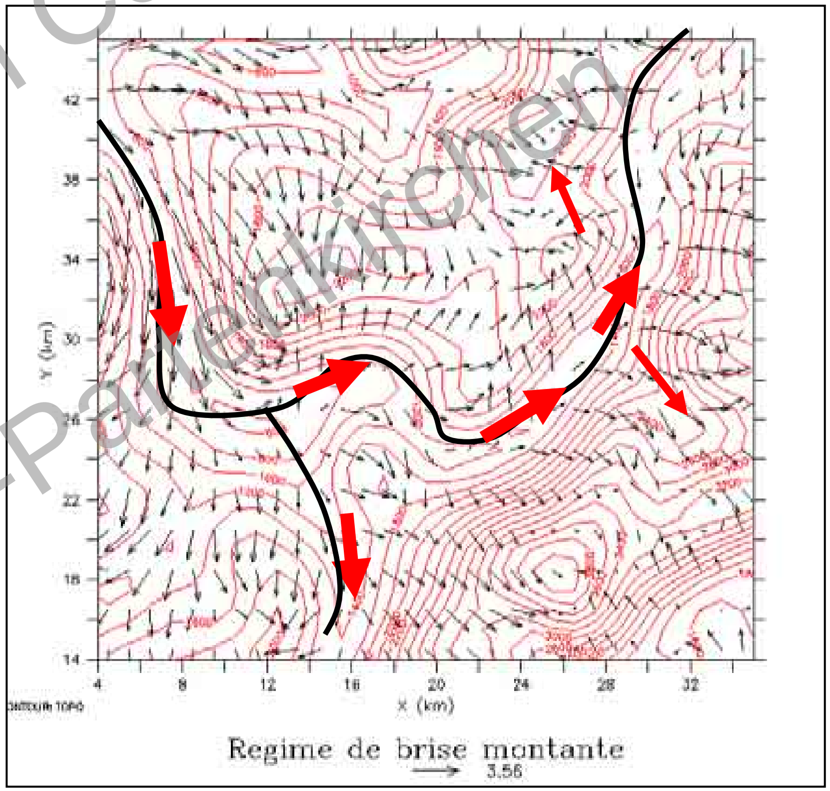
Hot wind during the day

The two valley wind regimes

Cool weak wind at night (≈ 1 m/s)

Hot wind during the day (≈ 5 m/s)

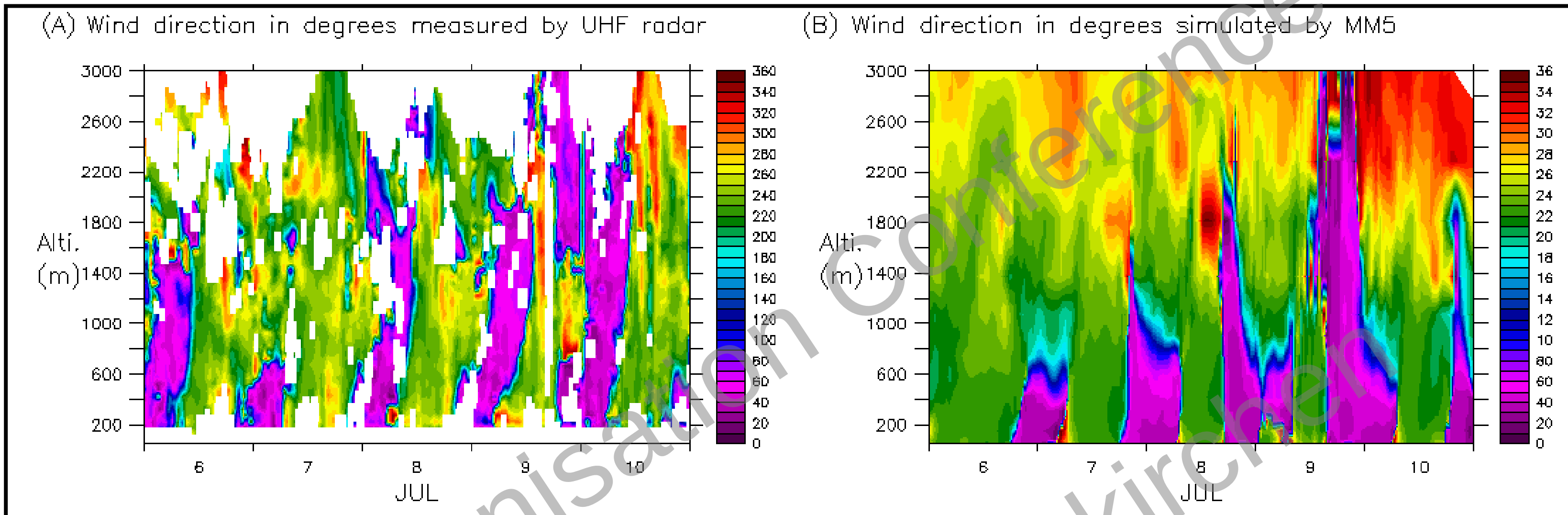




Shapes of the valleys

MM5 at 1-km resolution/windprofiler comparison

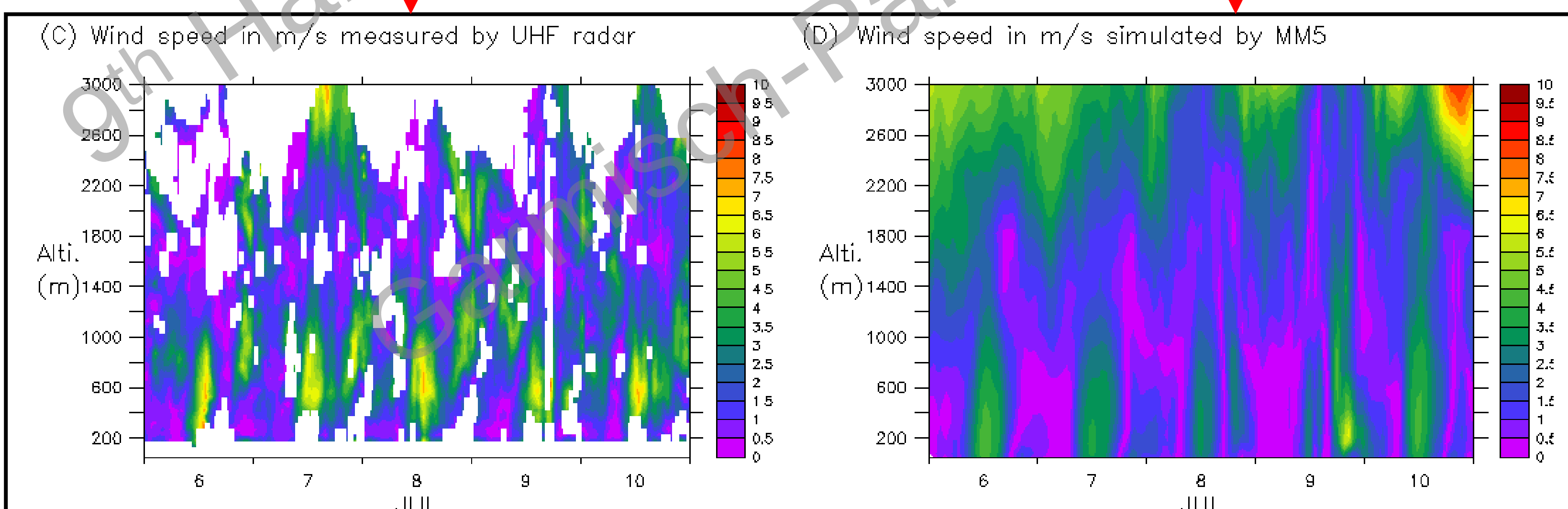
Directions



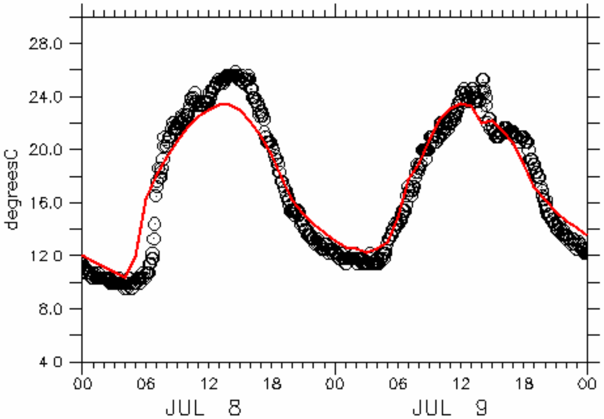
Radar UHF « windprofiler »

MM5 at a 1-km resolution

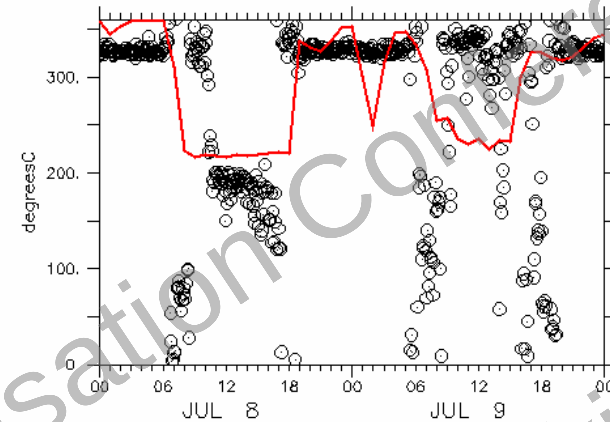
Velocities (m/s)



Plots of simulated (line) and observed (dots) meteorological fields at Argentière station (1450 m amsl.)

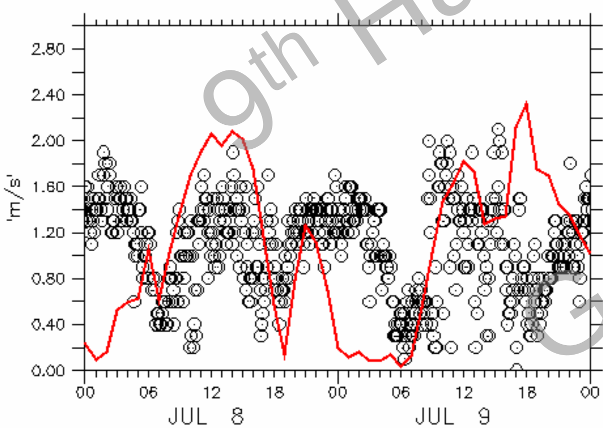


Air temperature (C)

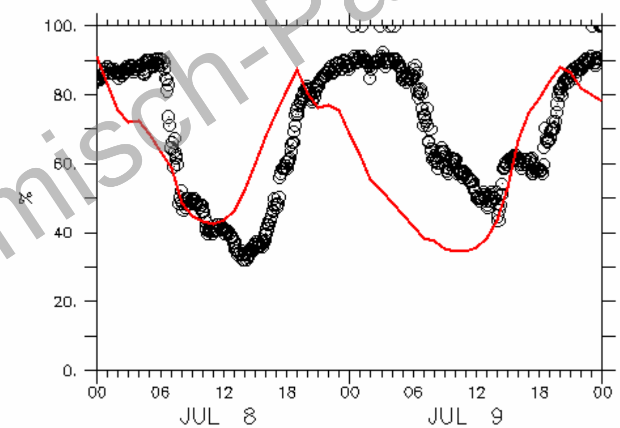


Wind direction (degrees)

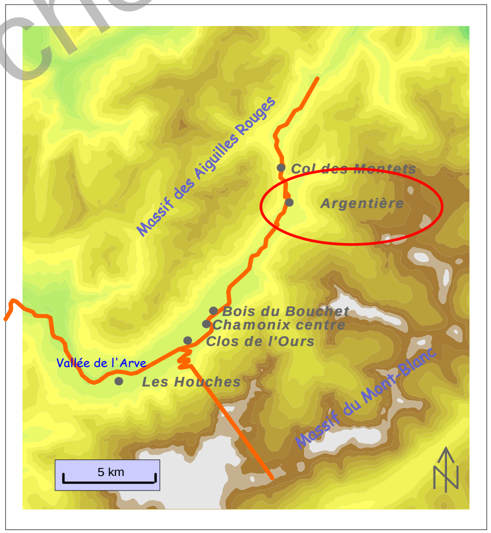
MM5 results



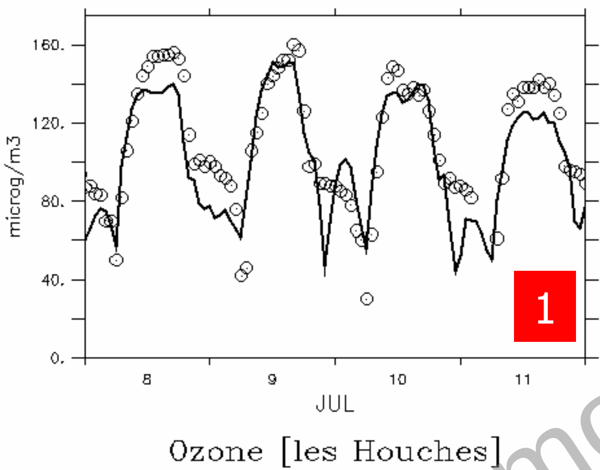
Wind speed (m/s)

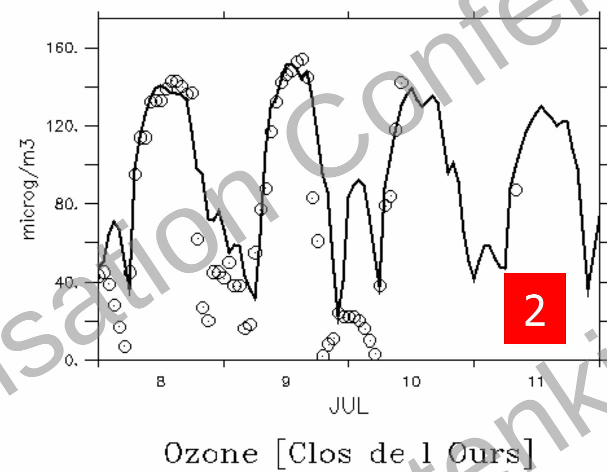


Relative humidity (%)



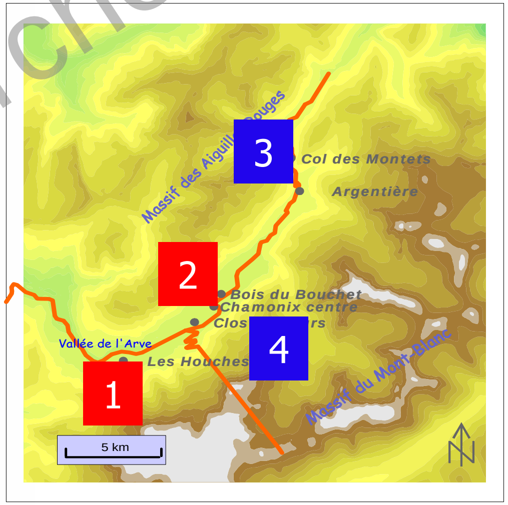
Plots of simulated (line) and observed (dots) ground level ozone concentrations at 4 sites

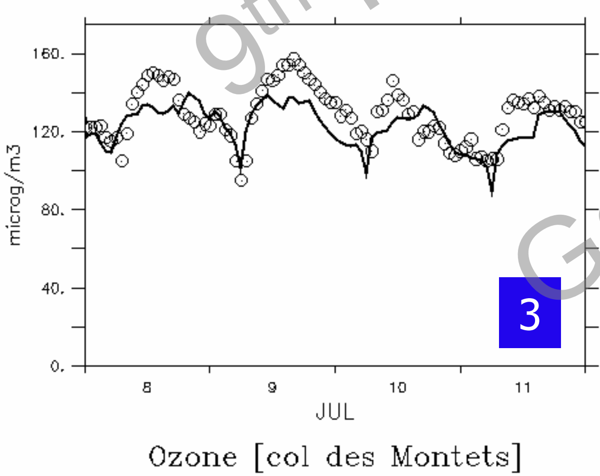


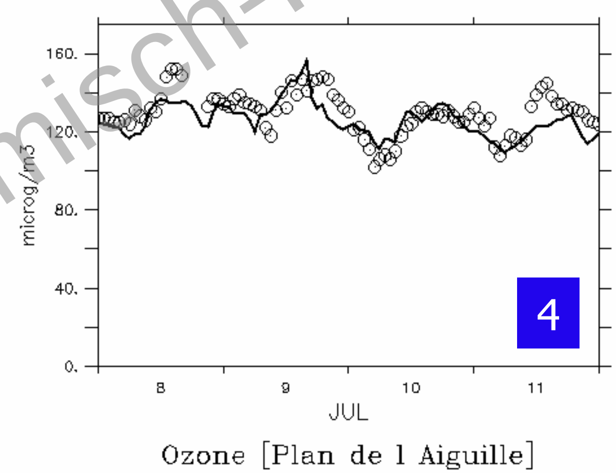


Residential sites

TAPOM CTM results for ozone

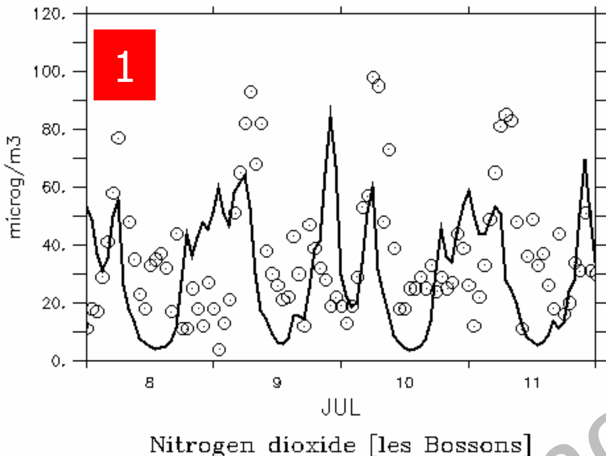


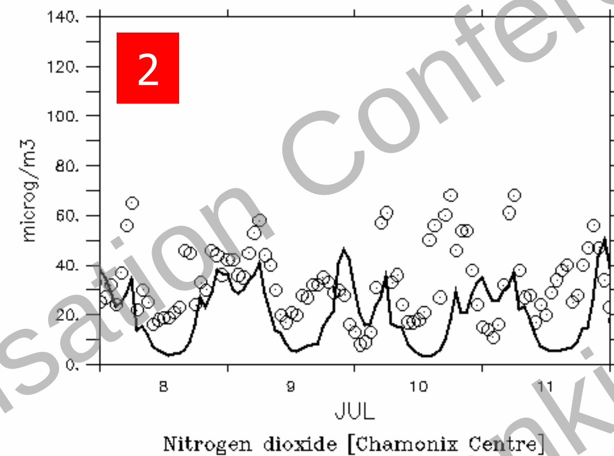




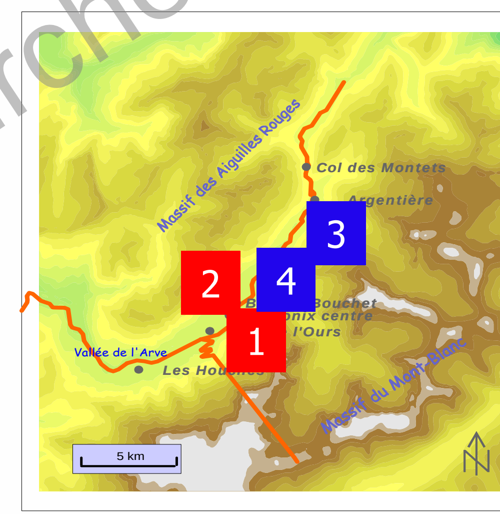
Ranged sites

Plots of simulated (line) and observed (dots) ground level NO_2 concentrations at 4 sites

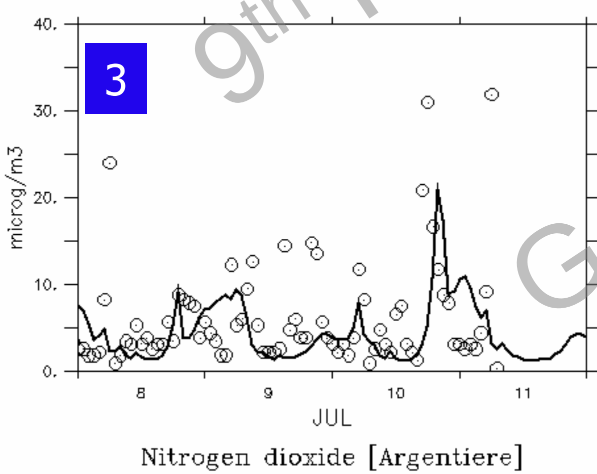


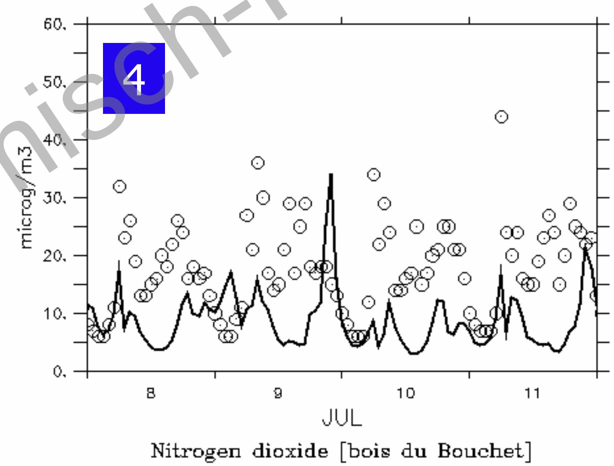


Traffic/urban sites



TAPOM CTM results for NOx



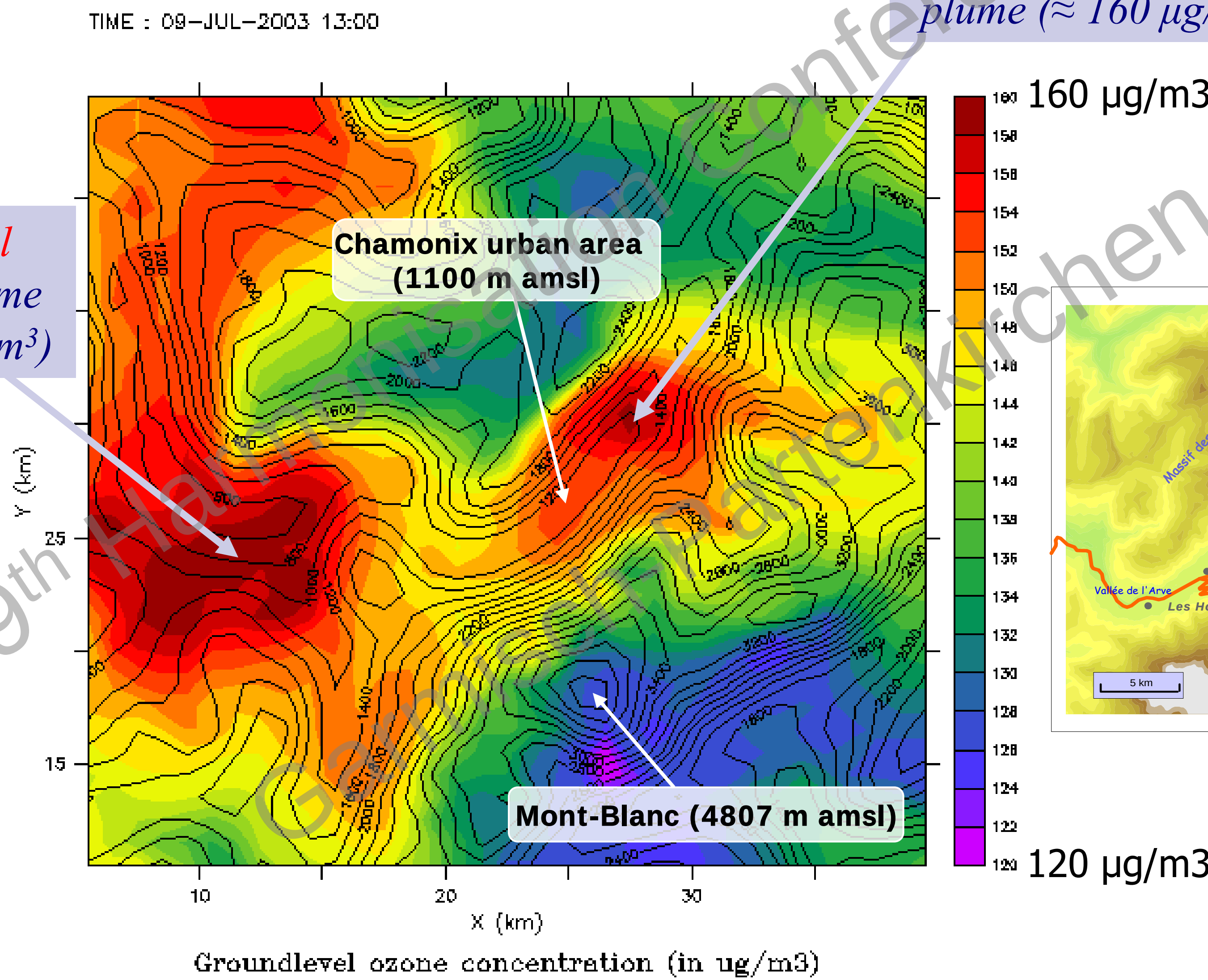


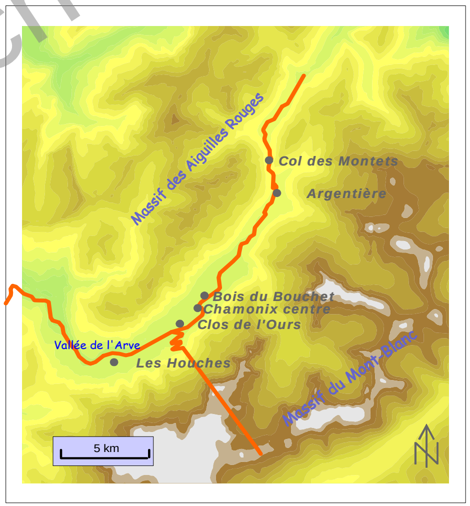
Residential sites

CTM TAPOM results for ground level ozone for 9 July 2003
Horizontal location of ozone plumes

Chamonix ozone plume (≈ 160 µg/m³)

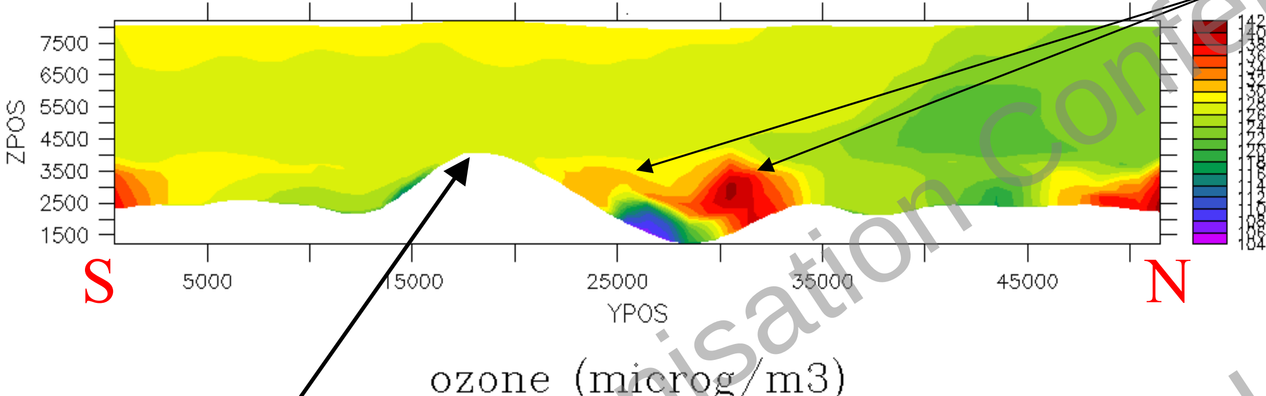
Regional ozone plume (≈ 160 µg/m³)

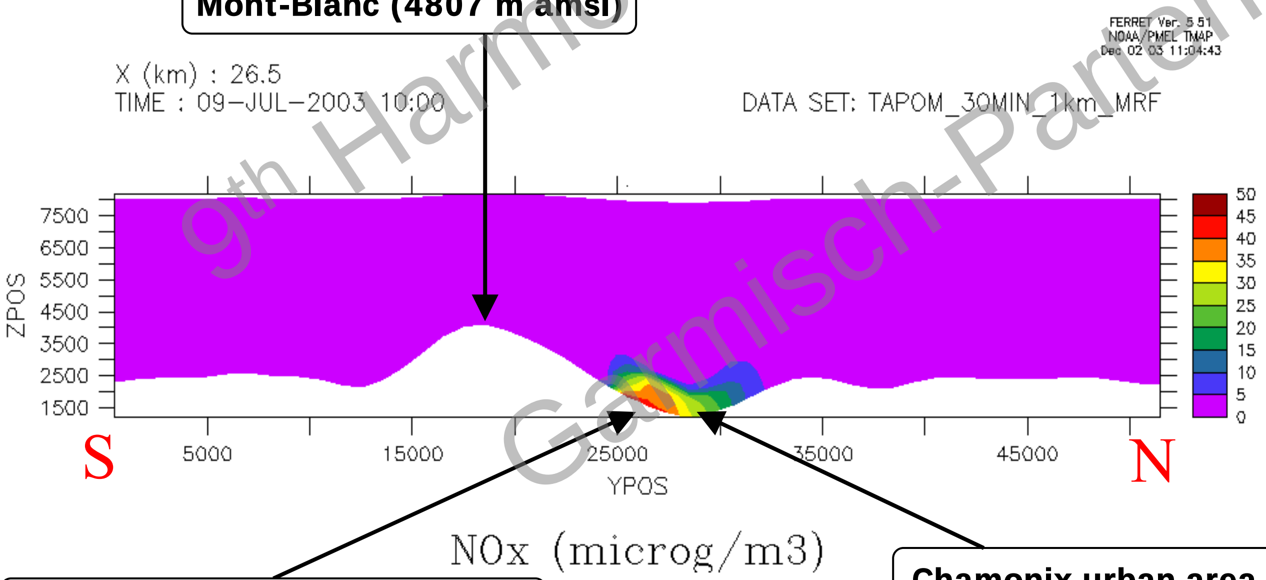


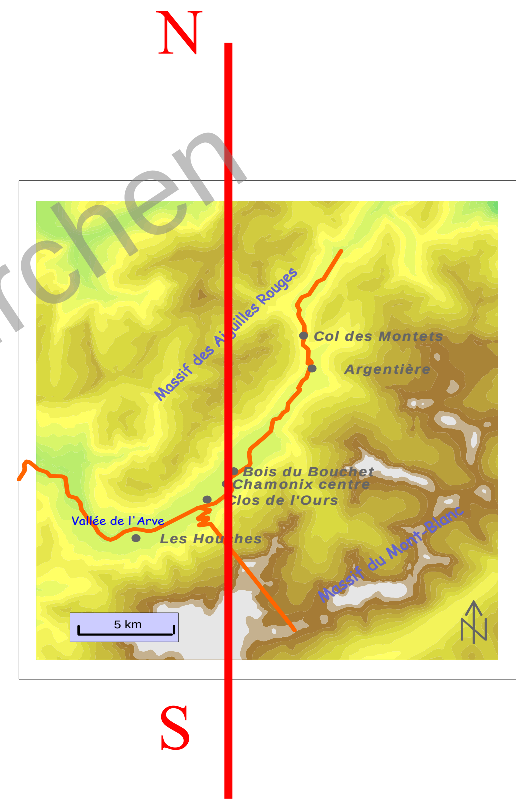


CTM TAPOM results for O_3 and NOx on 9th July 2003
Vertical location of ozone plumes

Chamonix ozone plumes
(production ≈ 20 µg/m^3)







Scenario study

Impact of the tunnel emissions on the ozone production in the valley

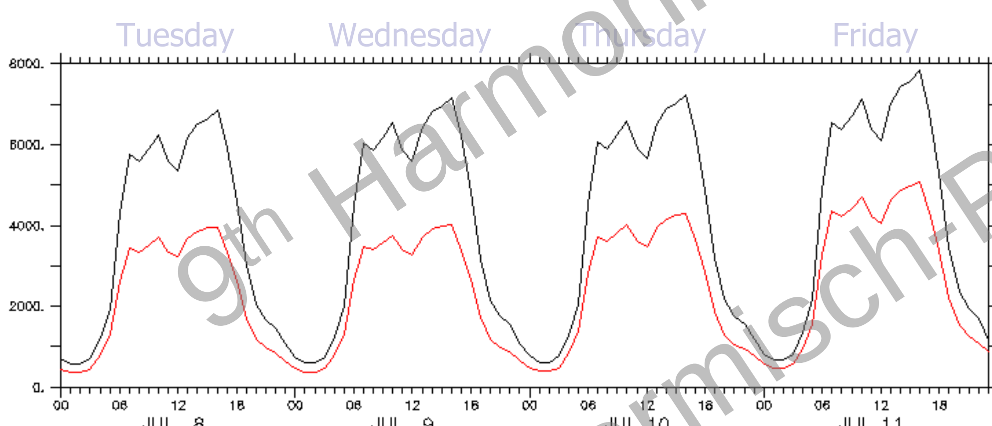
Simulation description: emission reductions

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

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

Two cases:

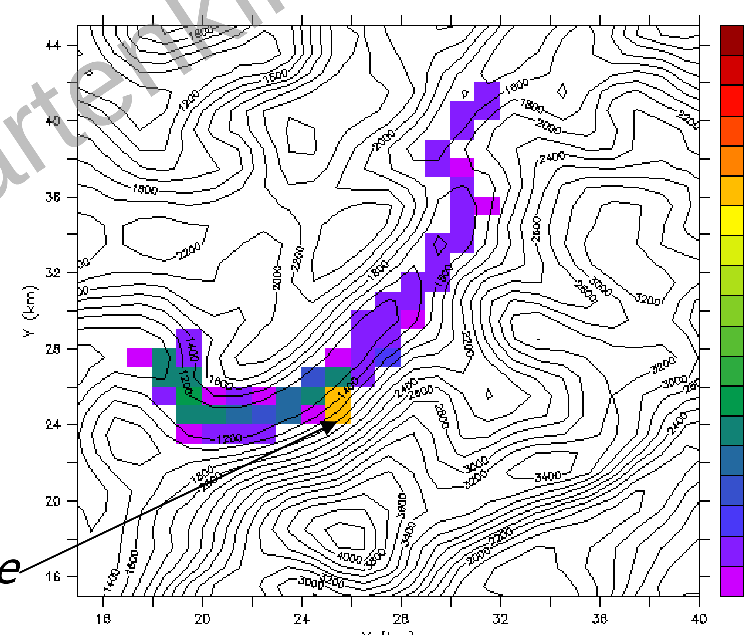
- Base case (1998 emissions)
- Without tunnel traffic (international traffic)



Total NOx emissions in mol/h [BC=black]

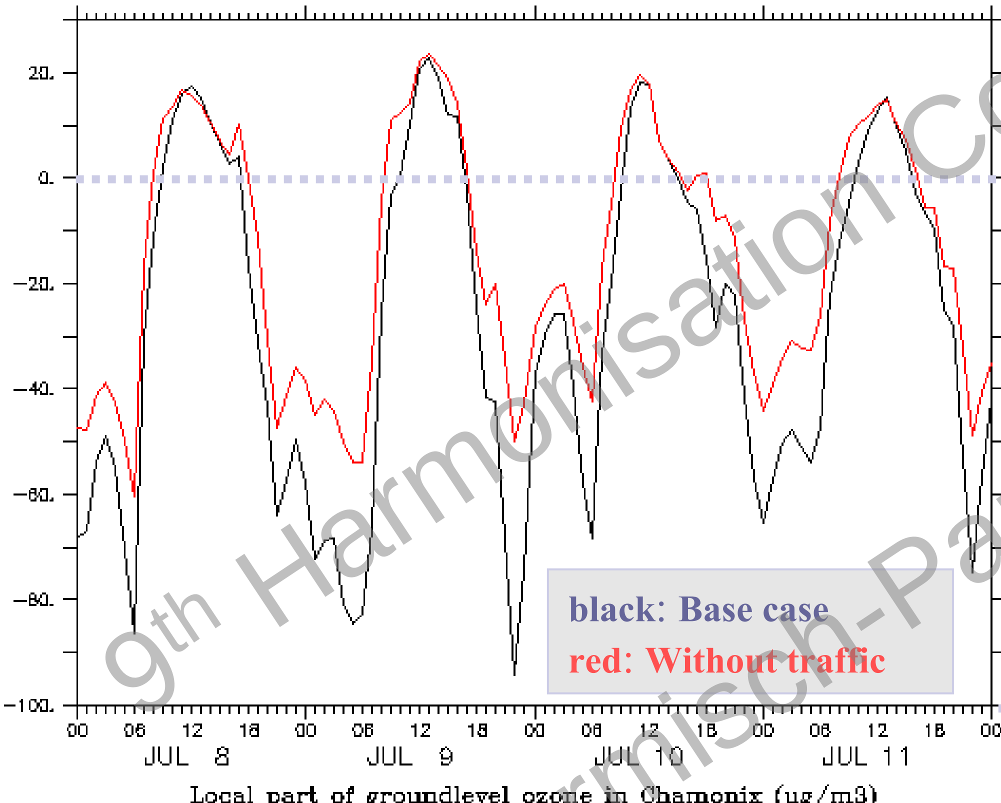
Total emissions of NOx in the entire domain
black: Base case
red: Without international traffic

Tunnel entrance



Emission reduction compared with BC (in percent)

Ozone production downtown Chamonix



Daytime production

$P[O_3] \approx 20\ \mu g/m^3$

Night destruction regime

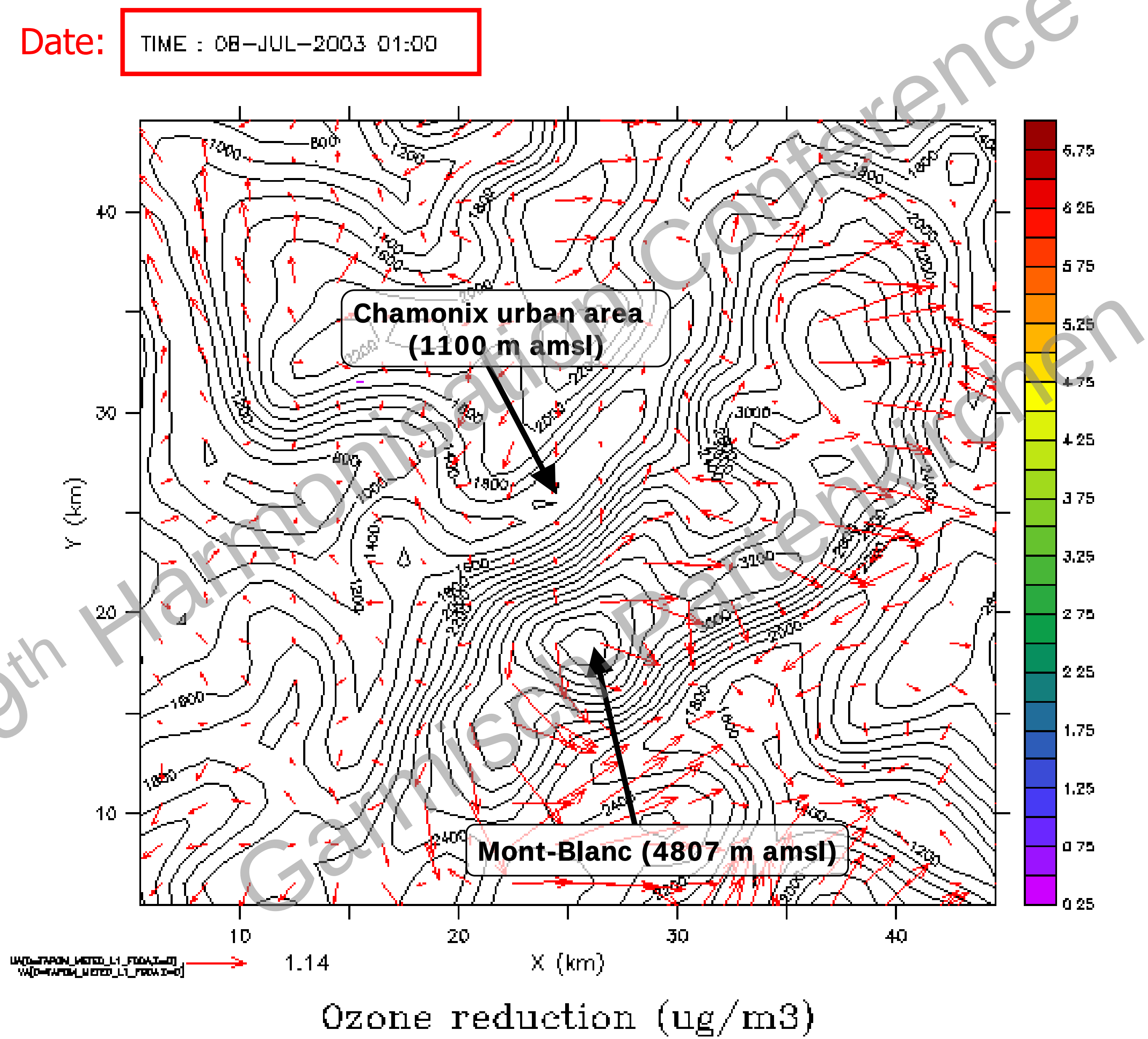
$-100 < P[O_3] < 20\ \mu g/m^3$

depends on NO_x concentration controlled by reaction:

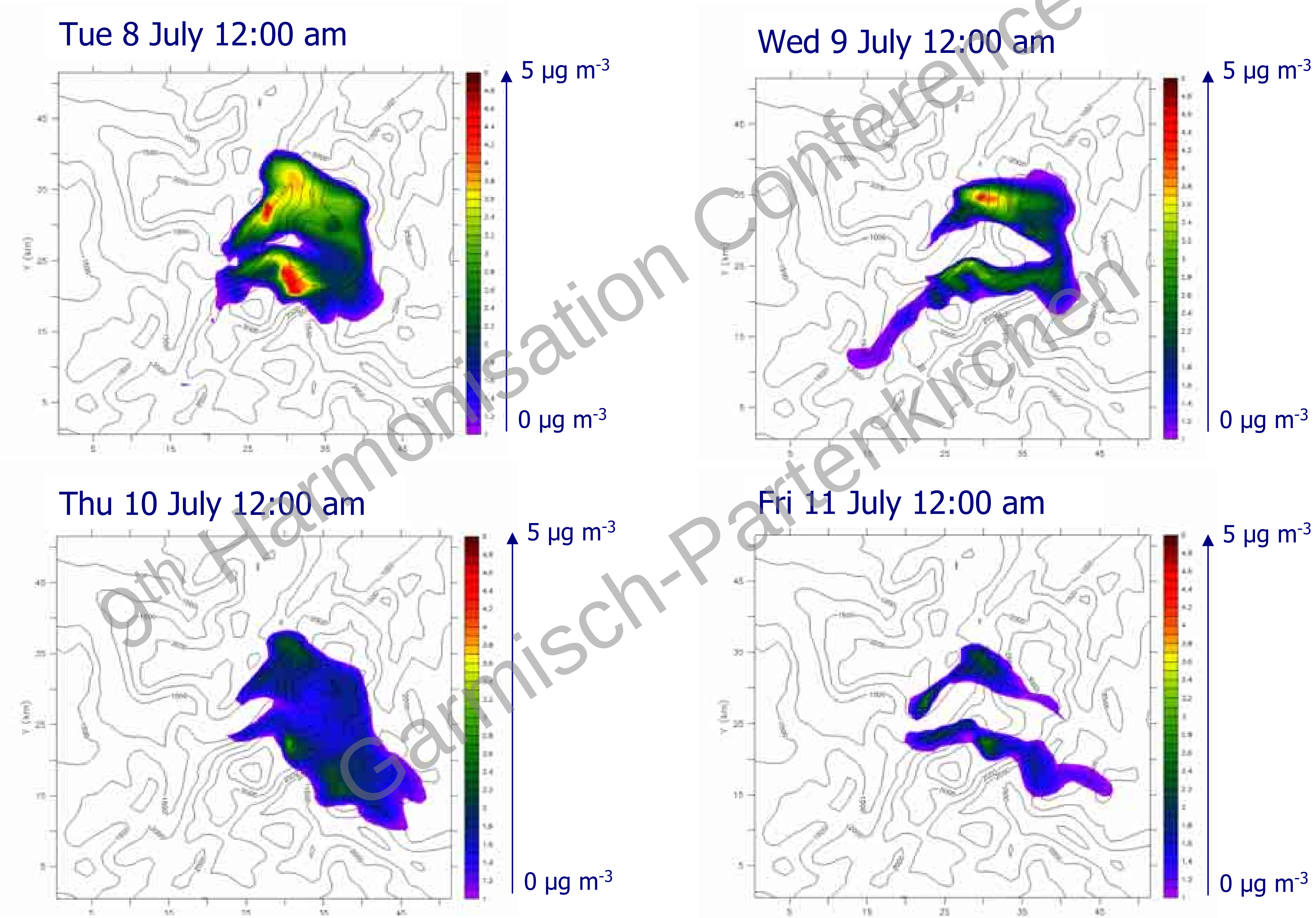
$O_3 + NO \rightarrow O_2 + NO_2$

Methodology for estimation of ozone production:

Ozone production = simulated concentration at Chamonix – background concentration


Date:
TIME : 08-JUL-2003 01:00
Chamonix urban area (1100 m amsl)
Mont-Blanc (4807 m amsl)
Y (km)
X (km)
1.14
Ozone reduction (ug/m3)

Ground level ozone reduction (µg/m³) without tunnel traffic



Main results of our study

- Ozone concentrations in downtown Chamonix are strongly linked to regional background (< 20 % of local production during sunny days)
- **During daytime traffic** due to tunnel does not affect air quality in Chamonix urban area because of strong dilution by valley wind *(valid in Summer only)*
- **During stable conditions** traffic affects air quality in Chamonix urban area by NOx and PM emissions

General conclusion

- Emission reductions in Alpine valleys affect the regional level of ozone at all altitudes
- Simulations at a 1-km resolution give satisfactory results for ozone but not for primary pollutants (NOx, PM)
- MM5 model can not be used at finer resolution than 1 km in complex terrain (due to instability problems)
- Further simulations with a 300-meter grid mesh (with ARPS+TAPOM) give better results for primary pollutants such as NOx or PM

Acknowledgements

French environment agency (ADEME)
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French Ministry of Transportation (METL)
Région Rhône-Alpes

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EMEP website and *Air de l'Ain et des Pays de Savoie*

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