Modelling the meteorology and traffic pollutant dispersion in highly complex terrain: the ALPNAP Alpine Space Project

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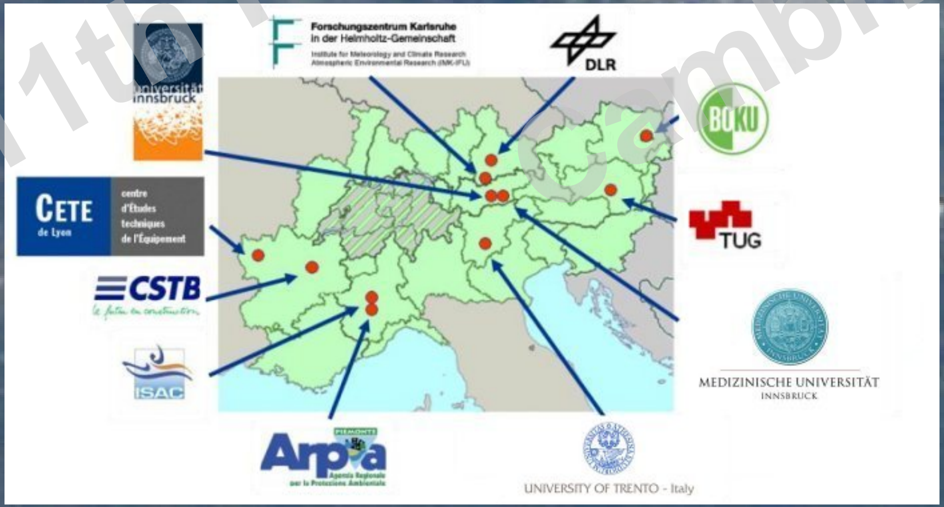
The ALPNAP Project

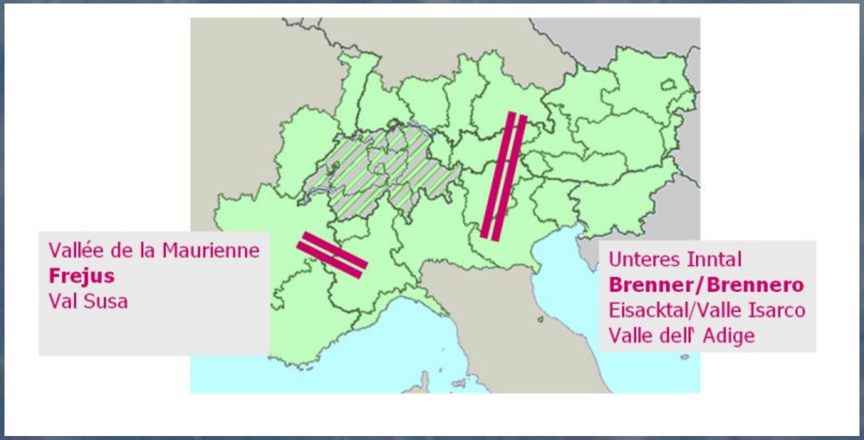
Monitoring and minimisation of traffic-induced noise and air pollution along major Alpine transport routes

Interreg IIIB – Alpine Space

Final goals:

- to describe the peculiarities of the dispersion of air pollutant and the propagation of noise in Alpine Valleys
- to provide science-based method and tools for monitoring and prediction of environmental impact due to trans-Alpine traffic.





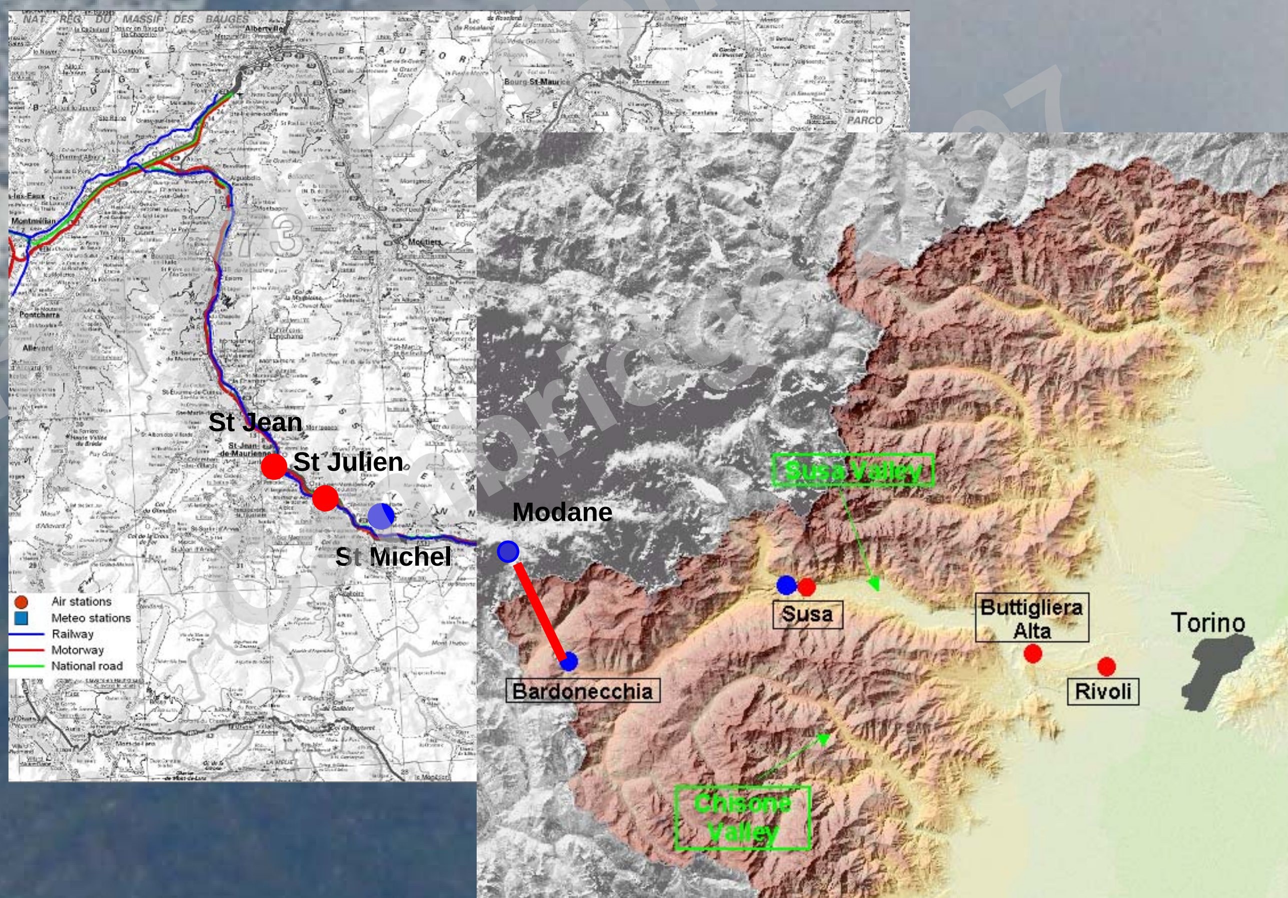
Areas of interest and monitoring stations (meteo and air quality data)

- CETE de Lyon: French side
- ARPA Piemonte: Italian side

● Air quality stations
● Meteo stations

French Side:
South-North: Maurienne Valley

Italian Side:
East-West: Susa Valley



SELECTION OF PERIODS FOR NUMERICAL MODELLING

1. evaluation of main pollutants' trend for the year 2004:

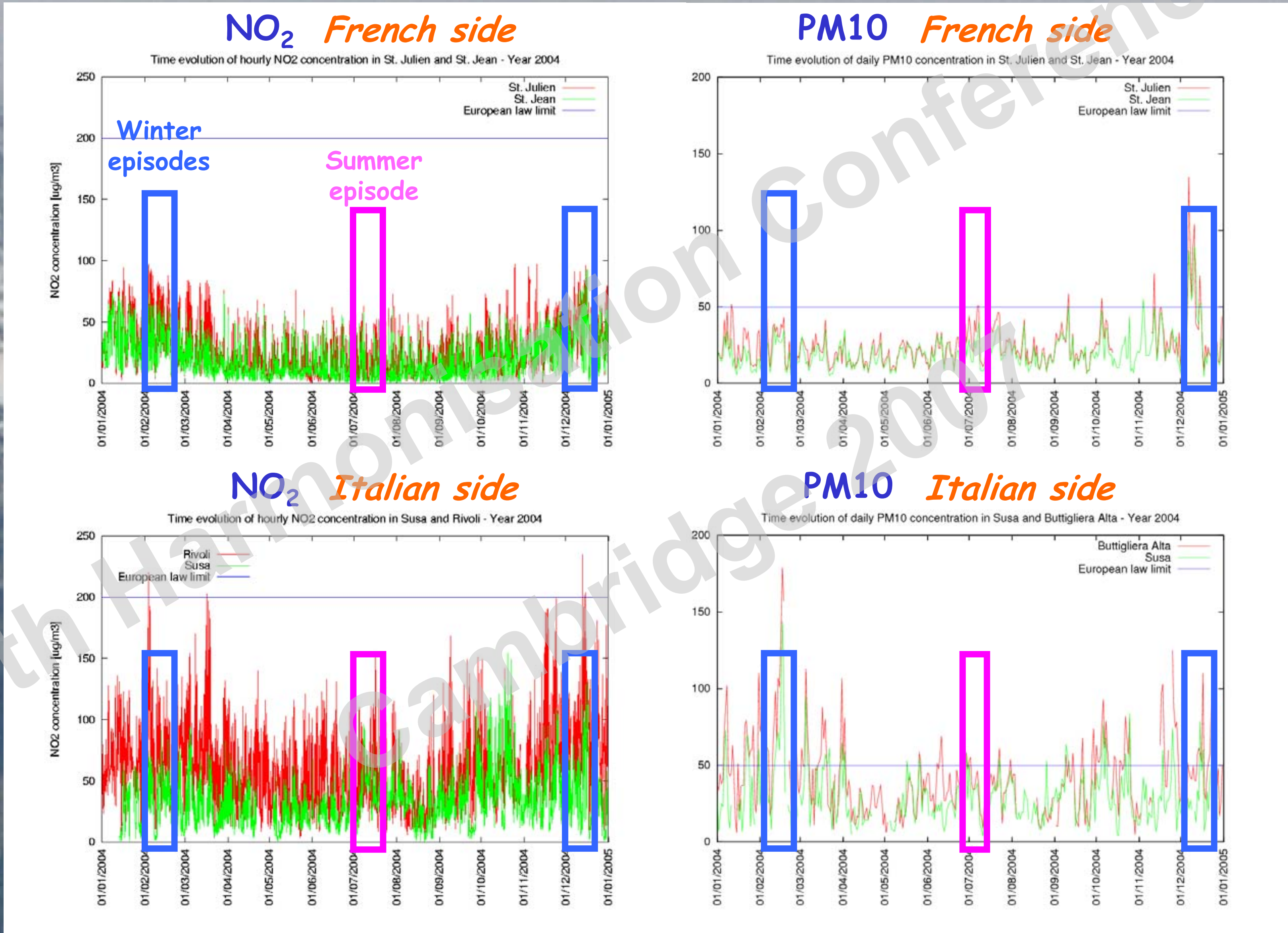
   NO_2 and PM10

2. individuation of critical episodes, characterized by high pollutant concentrations and a well marked period

3. meteorological characterization of the episodes through wind speed and temperature, surface fields and profiles.

4. consequent identification of:
   - Summer episode: 3 – 13 July
   - Winter episodes: 10 – 20 December and 8 – 18 February

Selection of periods

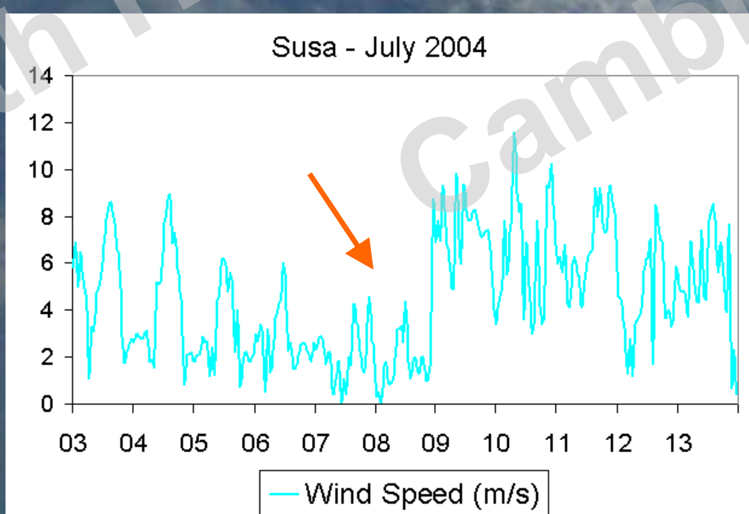


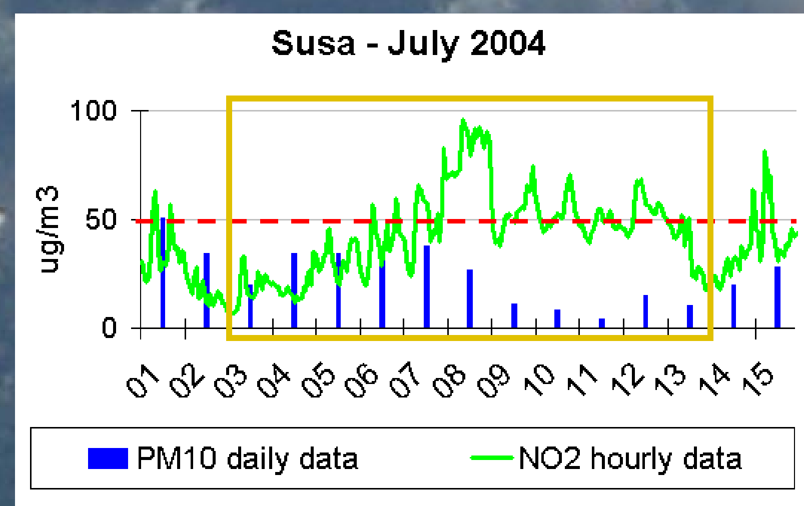
Meteorological characterization of the episodes

To confirm the choice of the episodes, we looked at the meteorological conditions.

The selected periods were generally characterized by atmospheric high pressure, no perturbation and consequent absence of precipitation.

We analyzed in details the wind speed time evolution at the surface and the temperature vertical profile in PBL during the PM10 highest concentration day.





ISAC-TO RMS modelling system

RAMS

Atmospheric circulation model (Regional Atmospheric Modeling System, Pielke et al., 1992)

Fields of WIND, TEMPERATURE, T.K.E., K (3 D)
TOPOGRAPHY, SURFACE FLUXES (2 D)

MIRS

Boundary layer parameterisation interfacing code (Method for Interfacing RAMS and SPRAY, Trini Castelli and Anfossi, 1997, Trini Castelli, 2000)

Fields of WIND, K, SKEWNESS, KURTOSIS, σ & T_L (3 D)
TOPOGRAPHY, PBL height (2 D)

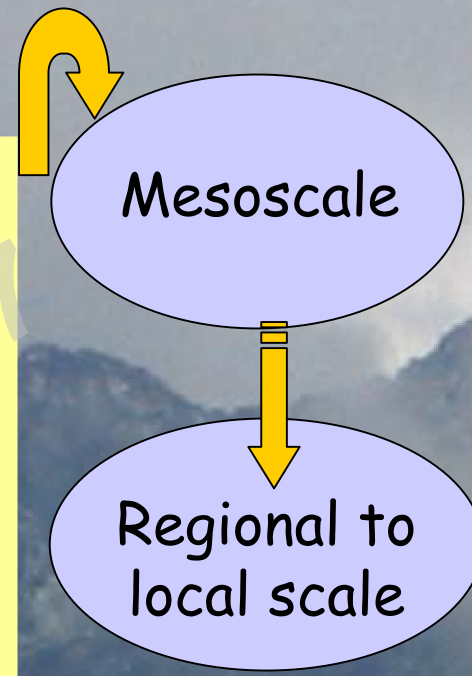
SPRAY

Lagrangian particle dispersion model (Brusasca et al., 1989, Anfossi et al., 1998, Tinarelli et al. 2000, Ferrero et al. 2001)

Fields of PARTICLE POSITIONS
G. L. CONCENTRATION

RAMS-MIRS configuration

Simulation of the meteo fields using the prognostic code RAMS up to 1 km resolution, 4 nested domains



grid 1: 1088 lon x 1088 lat km^2	64 km horizontal resolution
grid 2: 562 lon x 464 lat km^2	16 km horizontal resolution
grid 3: 197 lon x 132 lat km^2	4 km horizontal resolution
grid 4: 101 lon x 81 lat km^2	1 km horizontal resolution

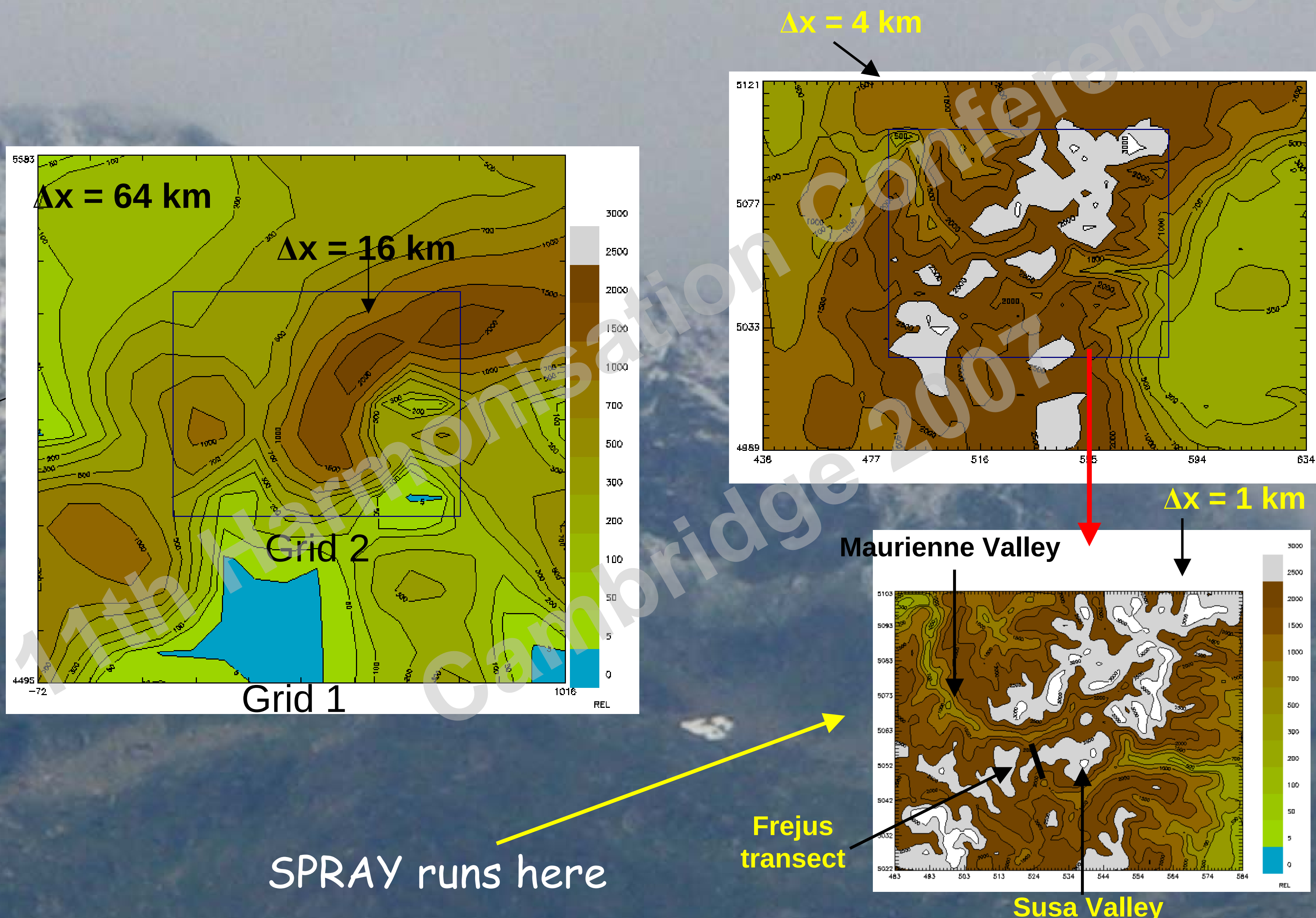
Vertical grid: 27 vertical stretched layers (0 –17500 m),
first layer 50 m depth (first level at 24 m)

RAMS is initialised with the ECMWF (0.5^o lat/lon) analysis fields.

Nudging at the lateral boundaries of the outer grid every 6 hours.

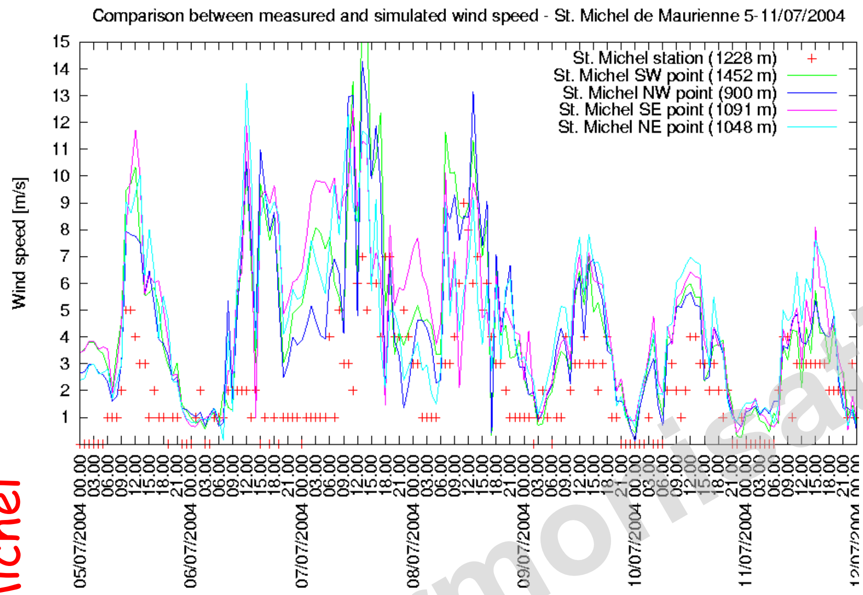
focus on the valleys for dispersion modelling of traffic emissions on main roads (highway and national roads)

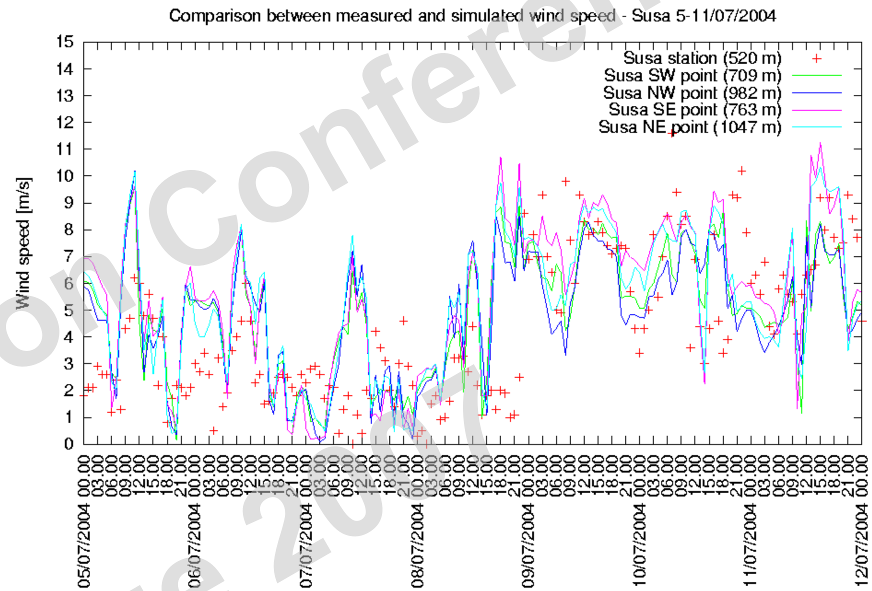
RAMS-MIRS Simulation Domains

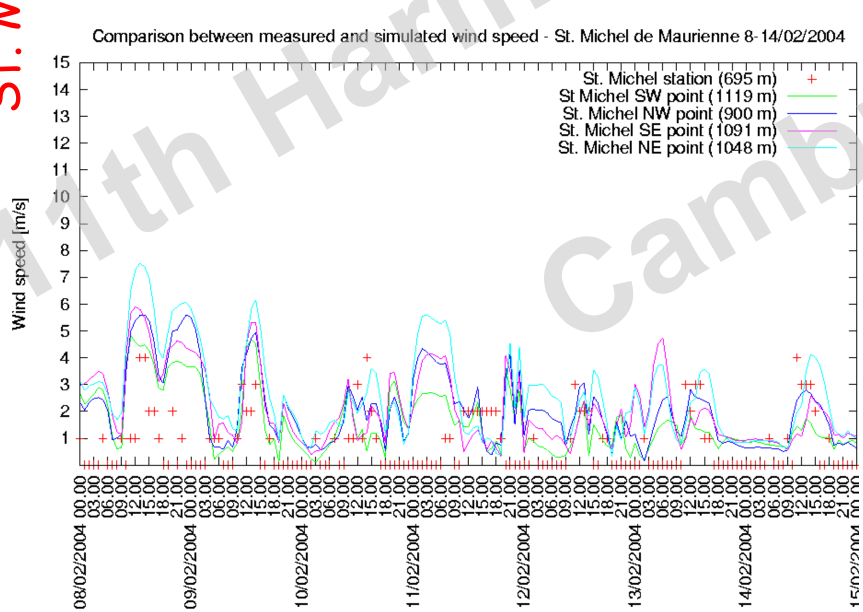


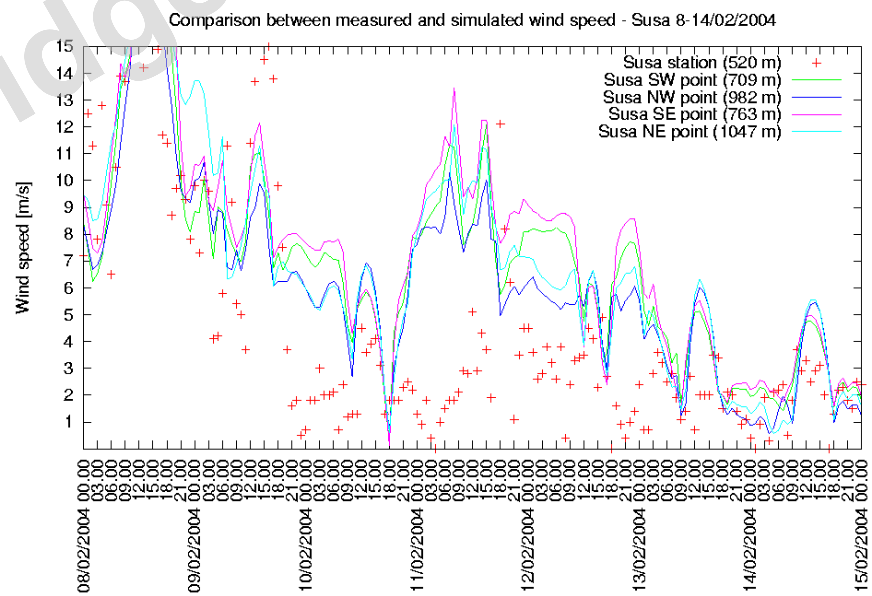
Comparison observed/predicted wind speed in the valley

St. Michel





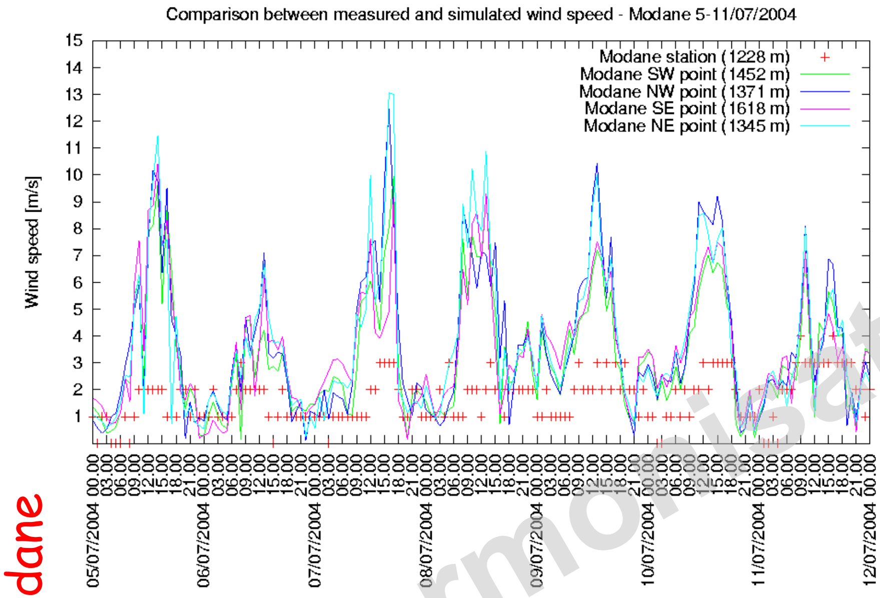


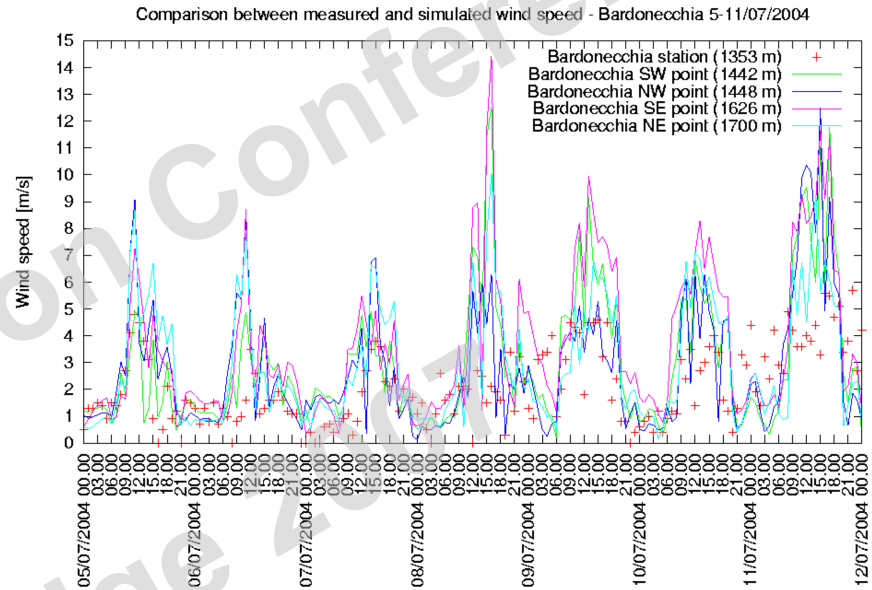


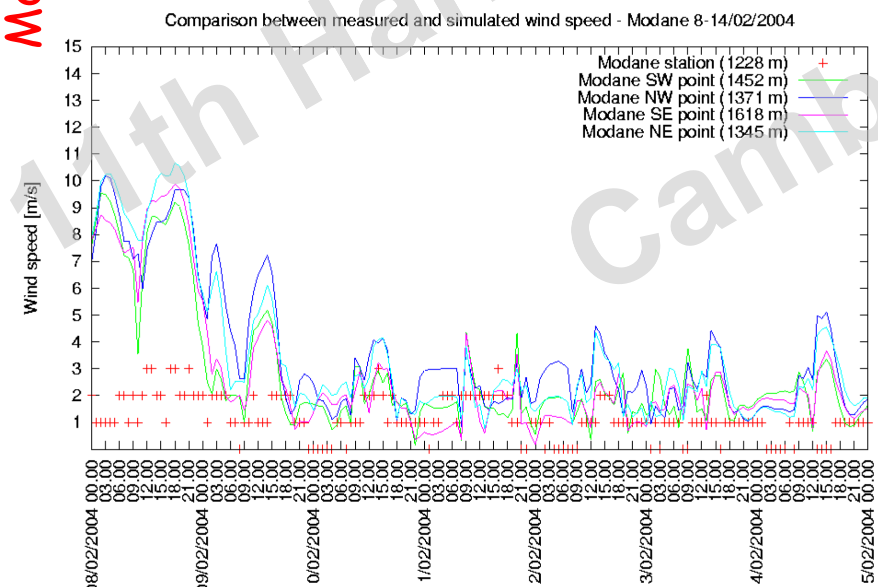
Susa

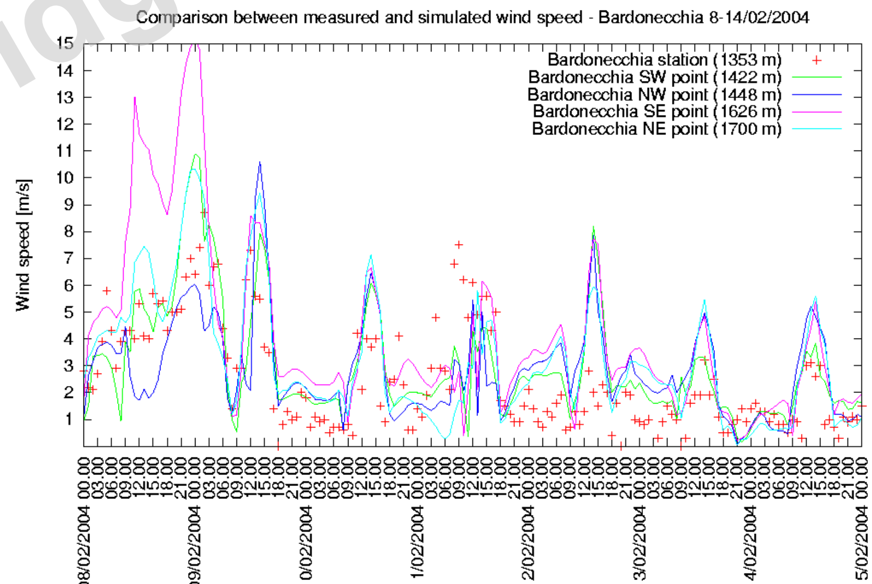
Comparison observed/predicted wind speed at Frejus tunnel

Modane









Bardonecchia

Spots of 'science': some critical items for atmospheric modelling

Sensitivity of the simulations to a proper modelling of the surface temperature in highly complex terrain, especially in Winter time.

The initial profile of temperature and humidity in the soil represent the triggering-start of the soil model, part of the 'engine' of the surface layer and boundary layer physical processes.

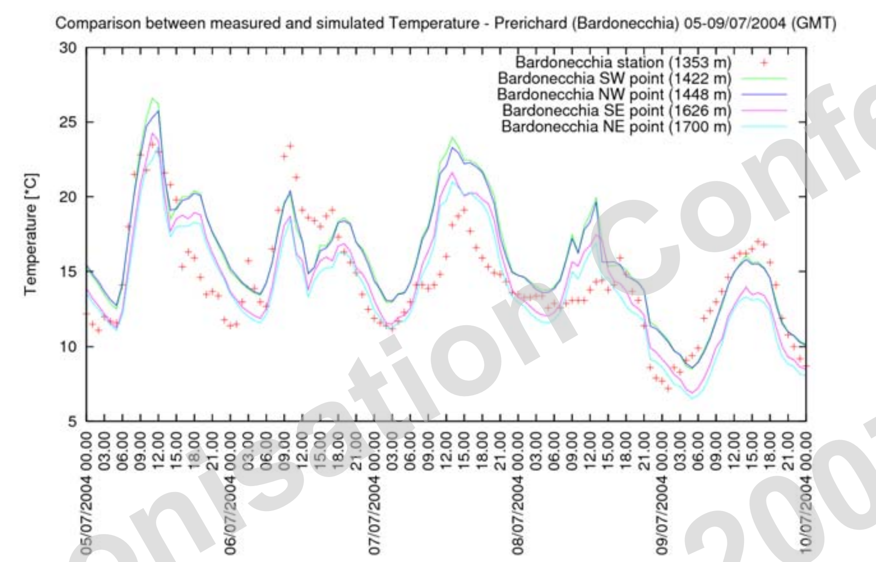
Lack of observed data and information about the soil thermodynamical variables is one of the limits which can affect the performances of the numerical models: more 'dramatic' for Winter periods, not yet optimal information on snow coverage

1st try: initial soil profiles of temperature and humidity from values extracted by the ECMWF analyses,

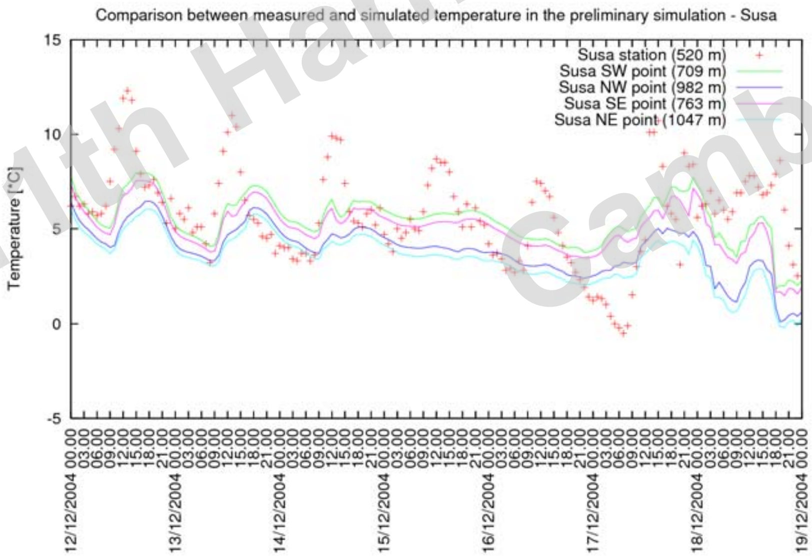
2nd try: using a constant profile of humidity with lower values than the ECMWF ones (ex. RH = 25 %)

Spots of 'science': some critical items for atmospheric modelling

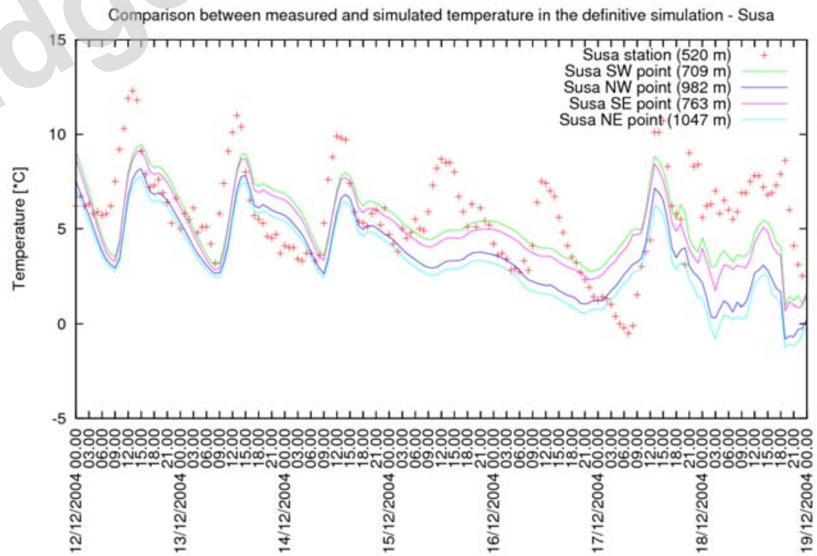
July



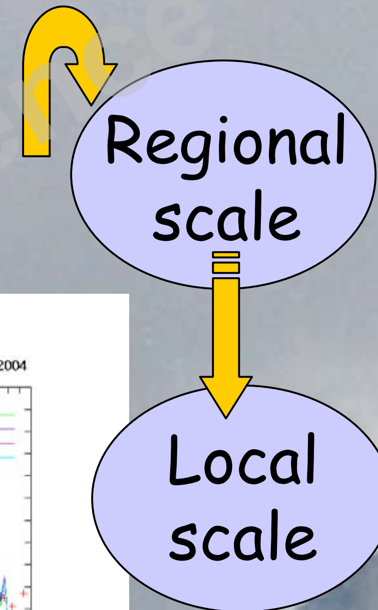
December 1st try



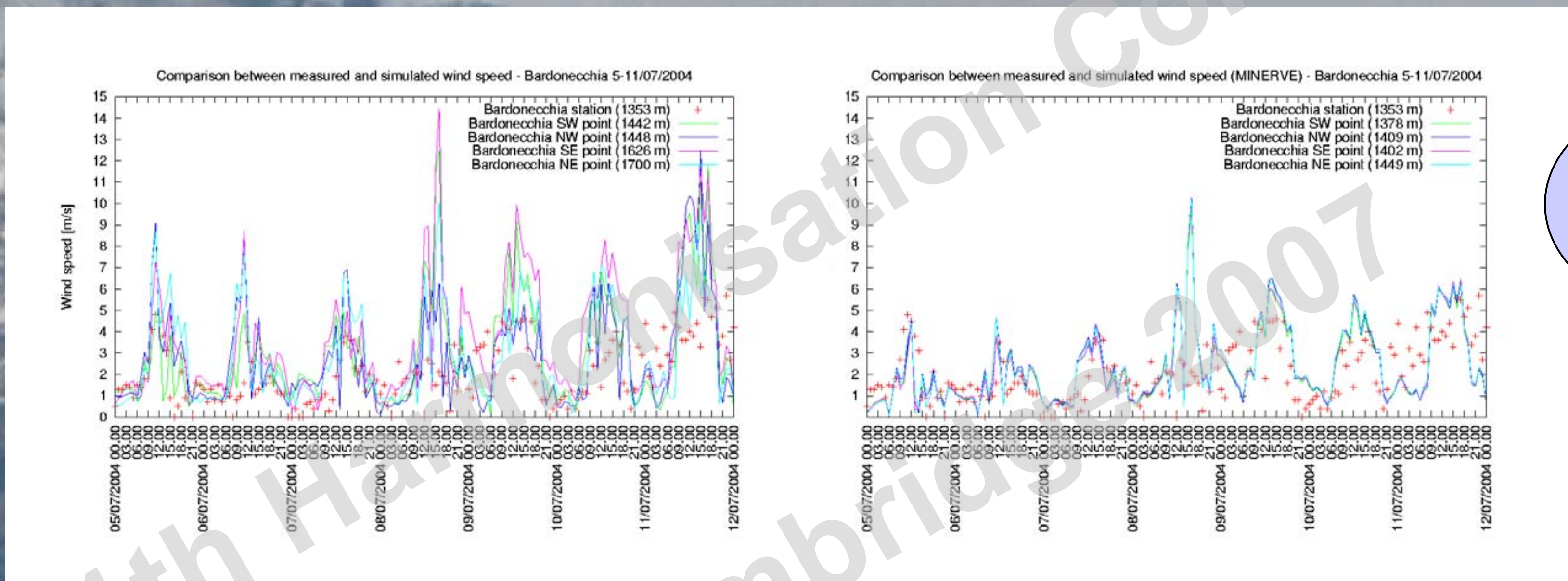
December 2nd try



Downscaling from RMS to MINERVE mass consistent model



Simulation of the meteo fields using the diagnostic code MINERVE up to 100 m resolution, in subdomains

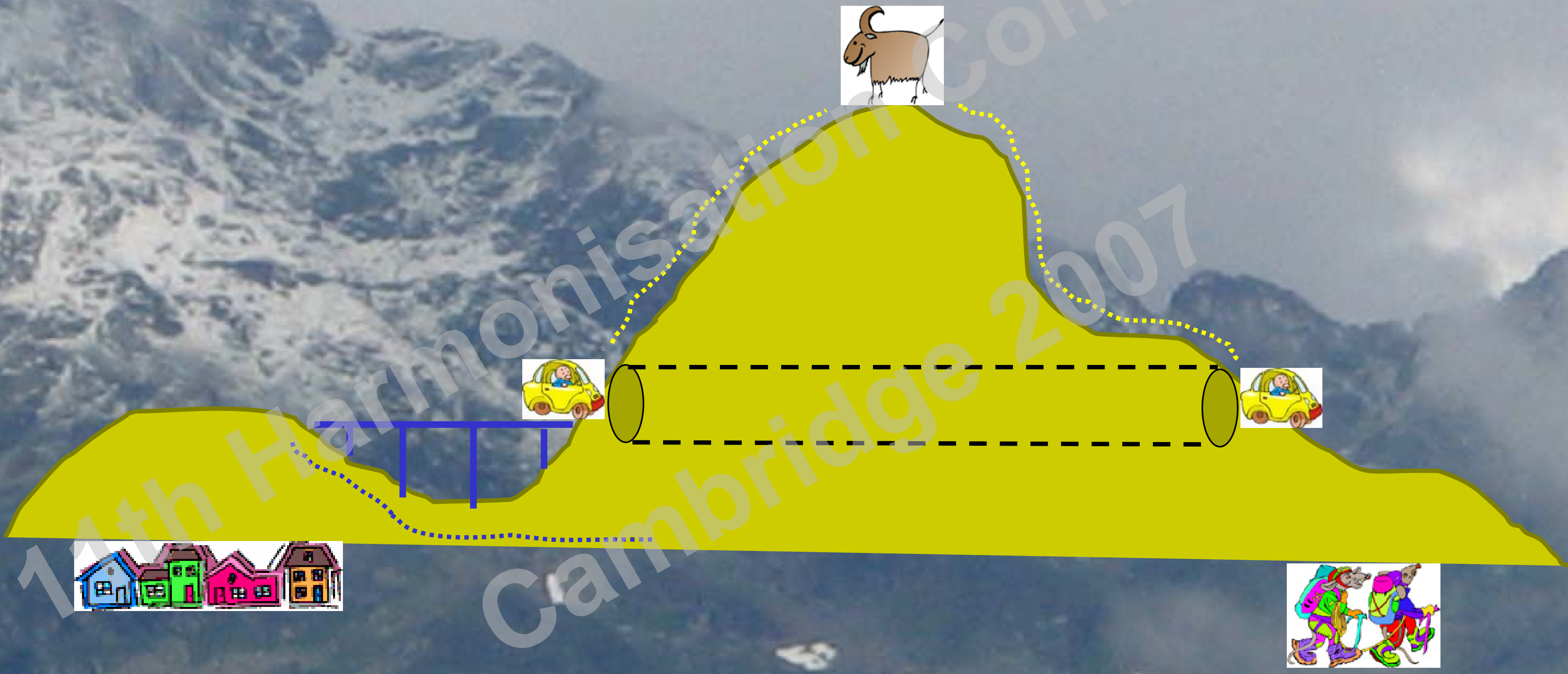


MINERVE gets as input the hourly RAMS 3D gridded dynamical and thermal fields and…

- interpolates the mean input fields on its 3D computational domain
-performs and objective analysis: application of mass conservation in every domain cell

Sub-grid 1:Susa valley 20 x 15 km, 100 m resolution
Sub-grid 2: Maurienne valley 20 x 20 km, 100 m resolution
Vertical grid: 27 vertical stretched layers (0 –8000 m), *1st level 10 m*

Spots of 'science': some critical items for dispersion modelling

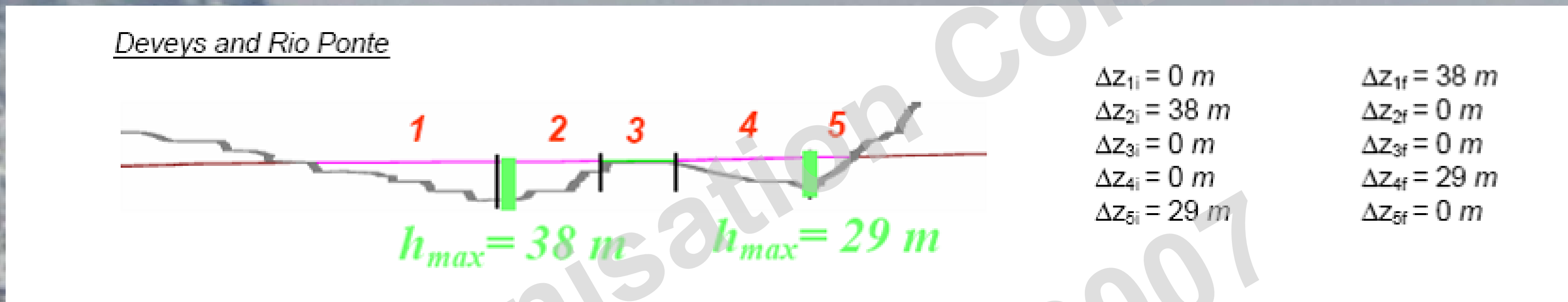


Accounting for the presence and effect of viaducts and tunnels

Spots of 'science': some critical items for dispersion modelling

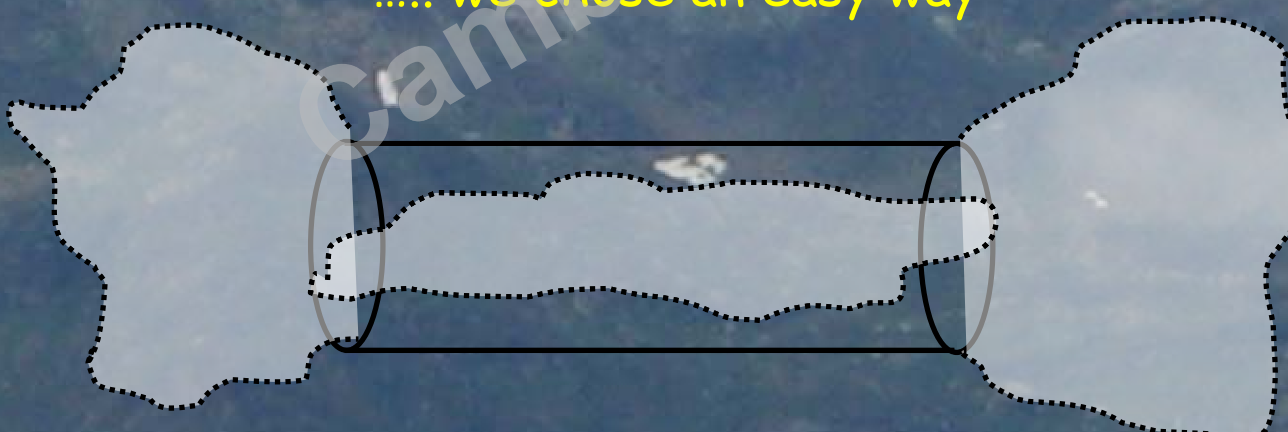
Viaducts: introduced in emission file by ARPA for the Italian side

2D (x,y) emission segments corresponding to viaducts (l > 20 m) are rearranged as 3D (x,y, Δz) segments ascribing them a height Δz over the topography → input to SPRAY



Tunnels: included in emission data through ALPNAP_Emix processing module at ISAC : **how to do it...?**

..... we chose an easy way



Check the effect of tunnels in RMS (1 km res.) and MMS (100 m res.)

NO tunnel case: the emission road segments lay on the topography

I-A case : the tunnel emitted mass is attributed to the first emission-segments adjacent to the two entrances (50 m in case of Frejus!!)

Distributed Case: the tunnel emitted mass is attributed to *n* emission-segments starting from the tunnel entrances up to cover about the 10% of the tunnel length (~ 1000 m in case of Frejus!!)

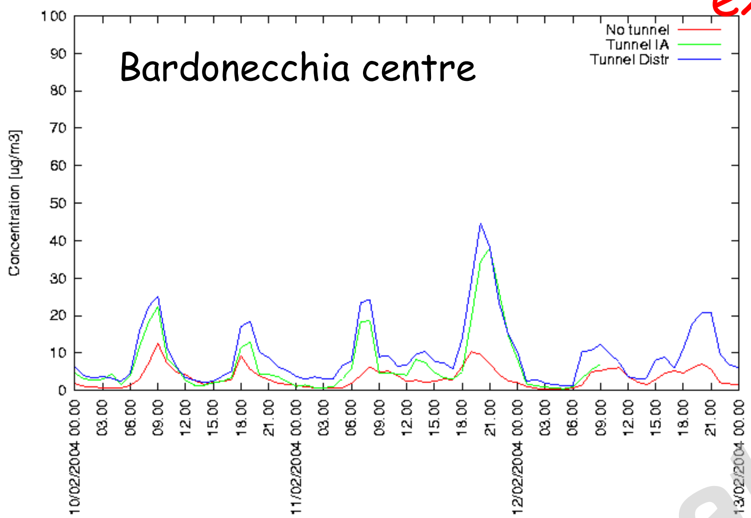
In MSS also

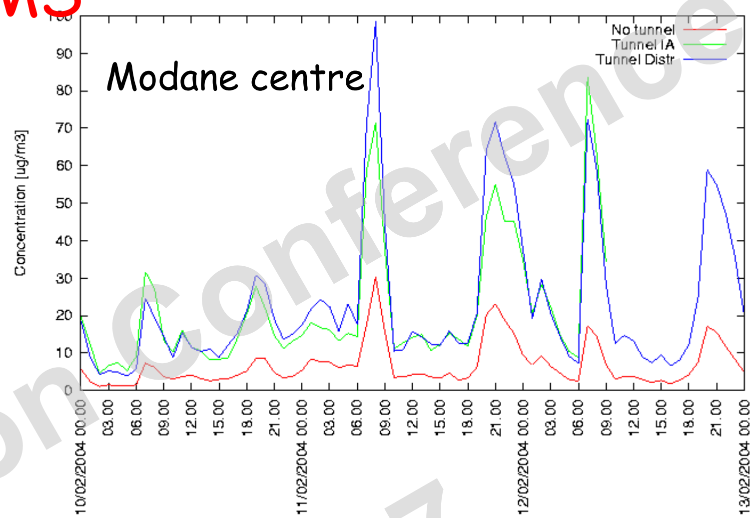
Defined-range case: the tunnel emitted mass is attributed to emission-segments adjacent to the tunnel entrances with the criteria… (*inspired by literature*)

Tunnel length < 1000 m ➔➔ Segment length = 50 m
Tunnel length 1000 ÷ 5000 m ➔➔ Segment length = 100 m
Tunnel length > 5000 m ➔➔ Segment length = 200 m

Emission boxes at tunnel entrances:
40 m cross-road (2 highway lanes) x 20 m height x segment-length m along-road.

ex. RMS





- consistent differences (as expected…) in concentration at locations in proximity of the tunnels when including or not their presence

- at 1 km res., not remarkable differences between the I-A and Distributed cases

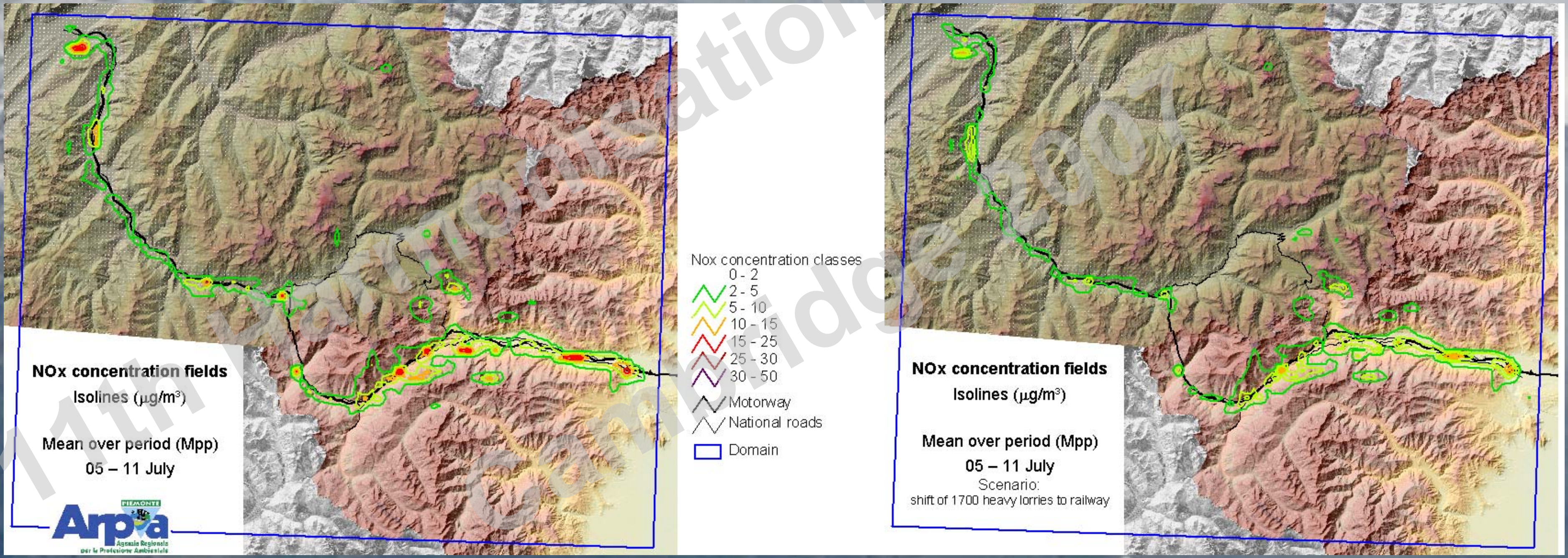
- at 100 m res., analogous behaviour between I-A case (50 m at Frejus) and Def-range case (200 m at Frejus)

-at 100 m res.: sensible differences between the Distributed case and others

Final choice: keep the 'defined-range' configuration to have a more realistic representation of tunnels' impact: modulation as function of their length, that is their emitted mass

Providing concentration data for impact assessment

MEAN concentrations over the all simulated period

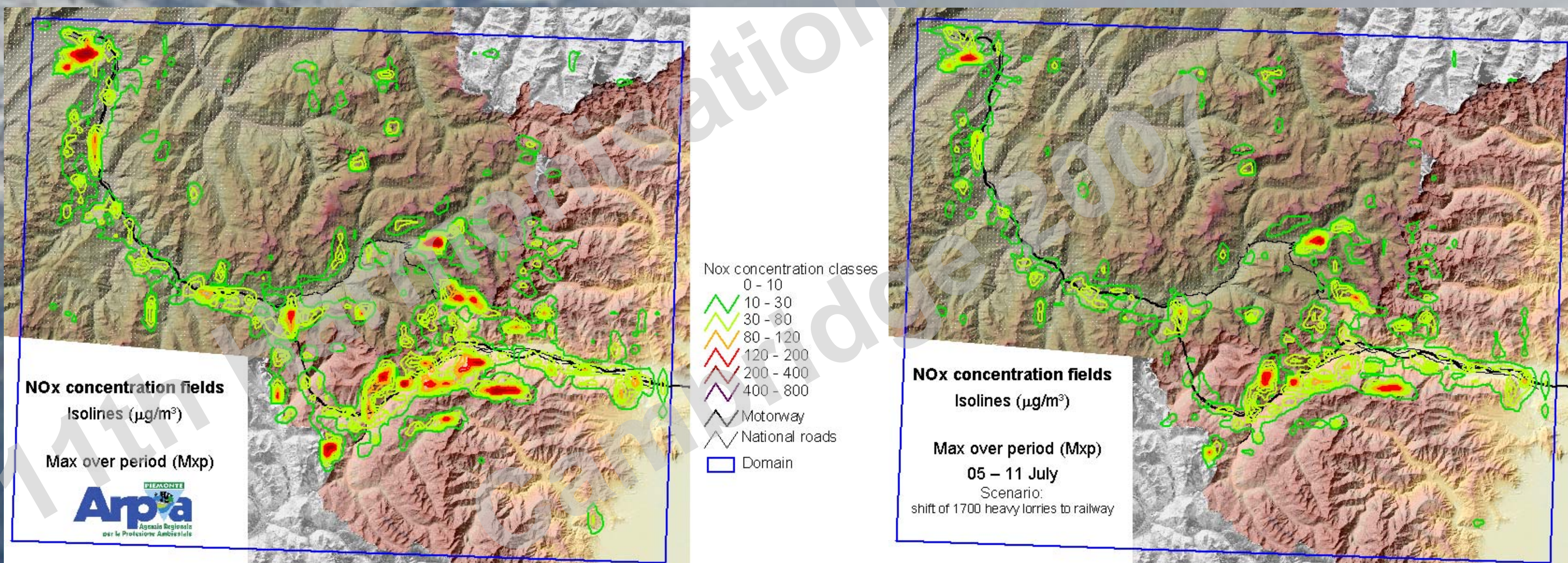


2004 emission dataset 'future scenario': - 1700 HL

(national roads + highway)

Providing concentration data for impact assessment

MAXIMUM concentrations over the all simulated period



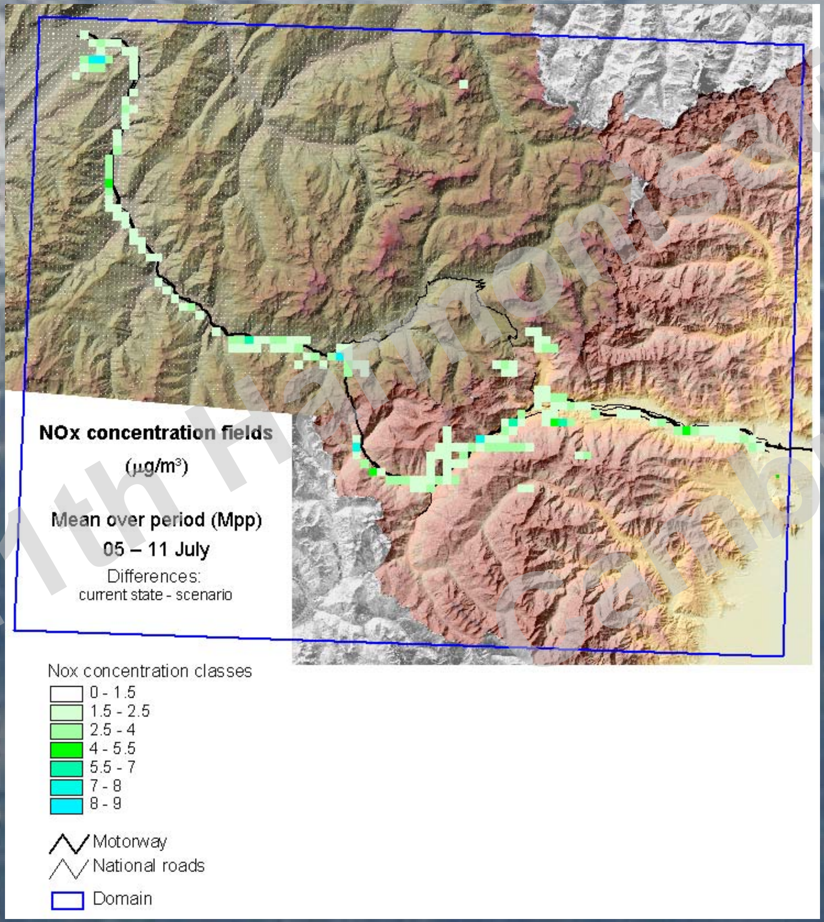
2004 emission dataset 'future scenario': - 1700 HL

(national roads + highway)

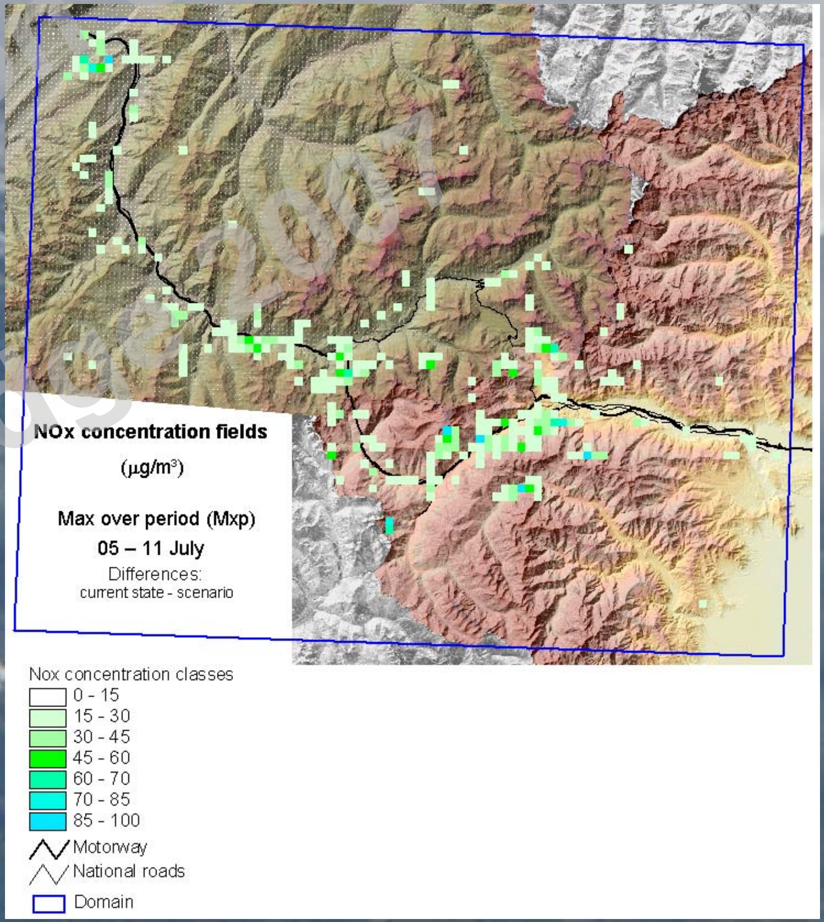
Providing concentration data for impact assessment

Differences between 2004 and 'future' scenarios' concentrations

mean



maximum



Conclusions

The peculiarity of meteorological and dispersive characteristics in highly complex and inhomogeneous terrain affect the dispersion of road traffic pollutant.

It is necessary to apply or develop properly sophisticated models able to reproduce this level of complexity.

The prognostic modelling system RMS was used in the frame of ALPNAP Project, for a detailed reproduction of the atmospheric circulation in West Frejus transect area. A further downscaling from the regional to the local scale was performed with mass-consistent model MINERVE. Some specific critical items were discussed

This kind of analysis allowed identifying the most critical zones for the air pollution impact and the information was then transferred to the impact assessment.

The methodology proposed was proved to be efficient to simulate (and forecast) meteorology and dispersion in highly complex and inhomogeneous terrain


Questions?