THE VENETO REGION MODELLING SYSTEM FOR AIR QUALITY ASSESSMENT

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INTRODUCTION

Local topography and meteorological conditions over the Po valley, as well as natural and anthropogenic emissions, make this area one of the most polluted in Europe especially regarding the concentrations of secondary pollutants as ozone and PM10. The Veneto region covers the east part of the Po valley and is bounded by the Alps to the north and the Adriatic Sea to the east. Trans-boundary pollution exchange with the Lombardy and Emilia-Romagna regions in the west and south direction respectively could play an important role for the air quality state. Moreover, the air quality situation in the Venice Lagoon is worsen by the presence of Porto Marghera, one of the most heavily industrialized Italian areas and an active commercial port.

CALMET model (version 5.5) (*Scire et al*., 2000) is used to produce the meteorological input fields. The domain covers most of the Veneto region on a 50x42 horizontal mesh with 4x4 km^2 resolution. Vertically CALMET is initialised with 10 levels from the surface to 3000m height. On the same grid, CAMx (version 4.0) (*ENVIRON International Corporation*, 2004) is used for the dispersion of primary and photochemical compounds, primary and secondary aerosol. The chemical mechanism used is the Carbon Bond IV with heterogeneous chemistry. The modelling system has been run for one year starting the 1st of July 2004. The concentration and deposition fields of the regulated primary and secondary pollutants and nutrients have been computed and compared with measurements (air quality monitoring stations and bulk deposition campaign measurements).

MODELLING SYSTEM SETUP

The Veneto Region modelling system for air quality assessment comprises an integrated Bottom-Up and Top-Down emission inventory. The national Top-Down emission inventory (*Liburdi et al.*, 2004), at province level in space and at activity level on emission sources (SNAP'97 nomenclature), have been disaggregate to municipality level (*Gnocchi et al.*, 2005, *Gnocchi et al.*, 2006). The proxy variables used in the disaggregation have been tailored for each sector. Emissions are distributed over a regular grid based on the land-use, i.e. residential combustion is distributed over urban areas, and temporally (*Maffeis at al.*, 2004) and chemically disaggregated.

Table 1. Regional Emission Inventory and share of the main emission sectors.

Pollutant	Emissions (tons/yr)	Sector 1	Sector 3	Sector 6	Sector 7	Sector 8
PM10	15850	9%	19%	0%	29%	15%
VOC	130457	0%	1%	42%	34%	8%
NOx	128518	18%	14%	0%	44%	14%
SO2	110542	80%	13%	0%	1%	1%

The major point emissions belonging to industrial SNAP sectors (1, 3, 4, 6 and 9) have been collected in a Bottom-Up inventory. Lastly a mixed Top-Down and Bottom-Up inventory (*Gnocchi et al.*, 2005, *Gnocchi et al.*, 2006) is used in the modelling system. The annual emissions and the share of the SNAP sectors is presented in the self-explanatory table 1.

CALMET model is employed to blend together data coming from 32 surface stations (of which 9 synoptic), 1 off shore station and 3 radio-sounding stations and provides CAMx with the hourly temperature field, the horizontal wind, and the vertical diffusivity (following CALGRID method, *Yamartino et al.*, 1989) at every grid cell. Furthermore, pressure and water vapour content are directly computed by interpolation of radio-soundings data while ad-hoc processors interpolates synoptic cloud data and produces three-dimensional cloud input fields. The meteorological processor has been tuned to best represent the meteorological fields in the domain of interest (*Sansone et al.* 2005, *Pernigotti et al.* 2005).

Boundary and initial condition are given by CHIMERE output from Prev'air system (http://prevair.ineris.fr) with 0.5° of resolution (roughly a 30x50 Km^2 mesh). Initial conditions consist of a single 3D field of the species modelled by CAMx while the top condition for each chemical specie is constant both in space and time.

CAMx requires data of ozone column level, atmospheric turbidity and chemical photolysis rate. Data are downloaded from the NASA web and ftp sites (http://aeronet.gsfc.nasa.gov and ftp://toms.gsfc.nasa.gov/pub/eptoms/data/ozone). A 5D table of photolysis rates is obtained from the TUV model for each of the six photochemical reactions included in CAMx chemical mechanism. The five dimensions of the table are: ozone column level, turbidity level, albedo, solar zenith angle and height.

MODEL PERFORMANCE

In this section we focus the discussion on the pollutants that are critical for the air quality in the Veneto region namely nitrogen oxide, ozone and particulate matter while the deposition data regard sulphates and nitrates. The model performance is evaluated by means of comparison between the data from monitoring stations and the model results in 16 points of the domain for gas species (visible in fig. 1 and 2), 12 points for particulate matters and 3 points near the Venice Lagoon for the deposition.

Ground concentrations

The annual average concentration of NO_2 is very well captured in the space by the modelling system (fig.1). The hot spots for NO_2 are located in the urban areas with a peak concentration near the Venice lagoon due to also intense industrial and port activities. The maximum summer ozone concentrations (fig. 2) generally occur above the sea and in the western part of the domain with minimum concentrations over the industrial area in Venice, due to O_3 consumption by "fresh" nitrogen emissions. Again the special variability and the absolute value of mean daily maximum concentration is well reproduced by the model.

Table 2. Correlation coefficients between measures and model estimate at 16 sites in the Veneto Region for NO_2 and O_3 and 11 sites for PM10.

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
NO_2	0.50	0.48	0.60	0.58	0.54	0.36	0.40	0.63	0.52	0.49	0.44	0.38	0.34	0.54	0.30	0.37
O_3	0.73	0.76	0.84	0.85	0.83	0.78	0.76	0.84	0.80	0.73	0.83	0.82	0.87	0.74	0.81	0.60
PM10	0.65	0.68	0.49	0.51	0.70	0.67	0.68	0.62	0.46	0.56	0.45					

In terms of temporal modulation of the concentration, NO_2 shows a relatively weak correlation for some stations. Most of the correlation coefficient lay between 0.4 and 0.6. The reason is to be sought in the temporal modulation of the diurnal mixing and emissions. In the real world the hour of peak emission changes between summer and winter due to the shift of human habit. On top of that the mixing has an abrupt transition at sunrise and sunset due to the change in the mixing schemes implemented in CALMET at the transition hours. The abrupt change in the mixing can lead to an abrupt change in the ground concentration particularly evident for primary species with sharp horizontal gradient in the emissions as NOx and SO_2. This temporal shift has a lesser impact on secondary species like ozone which has a high degree of correlation with model results (tab. 2).

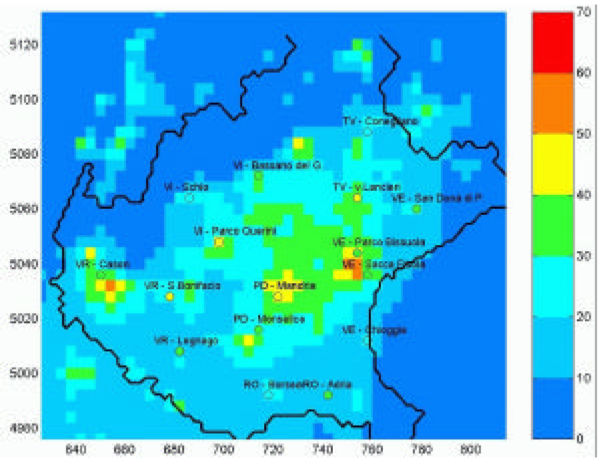

Fig 1: Annual mean concentration of NO_2 as in the model simulation superimposed to the annual mean measurements (filled dots).

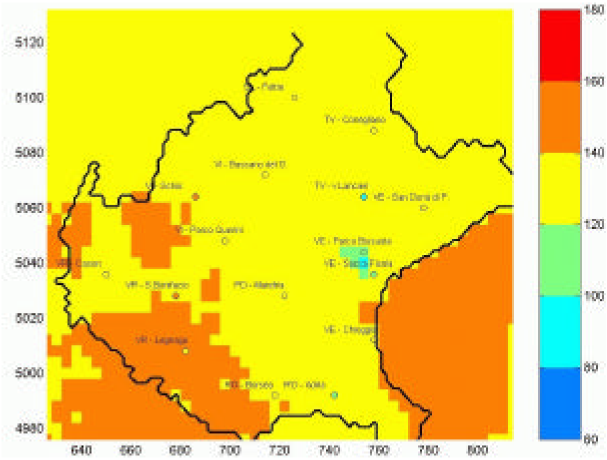

Fig. 2: Daily maximum O_3 concentration averaged for five summer months July-August-September 2004 and May-June 2005 superimposed to the measurements (filled dots).

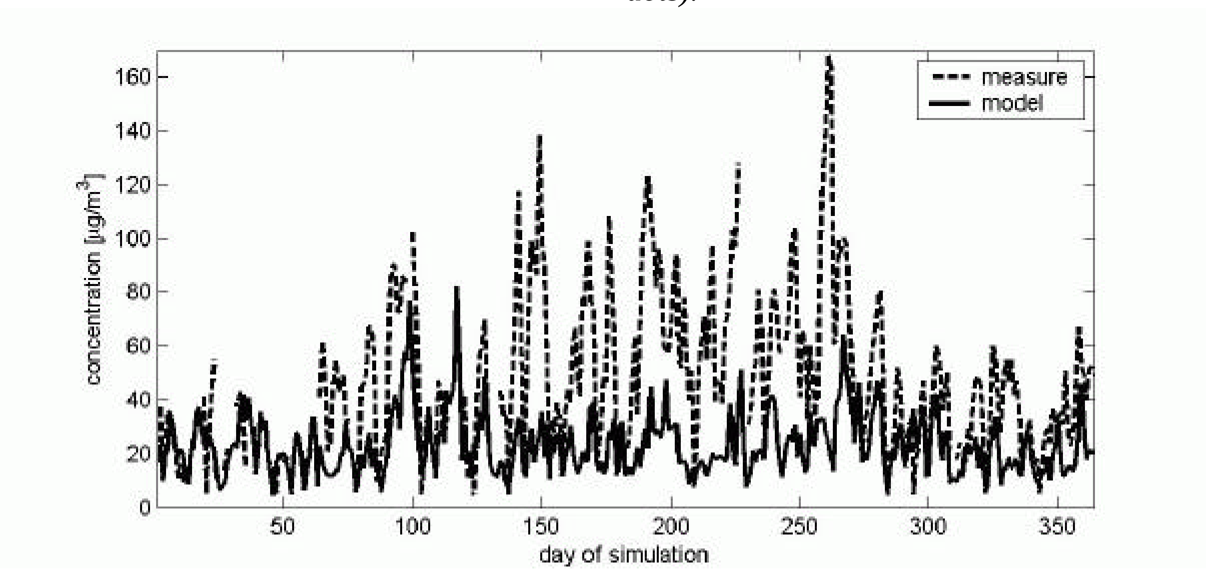

Fig. 3: PM10 concentration at VR-Cason station (Rural Background) in the western corner of the domain as reported by the monitoring station (dashed line) and the model (solid line).

In terms of PM10 the model underestimates the ground concentration in wintertime (fig. 5). The underestimation is on an average around 50%. A number of reasons are responsible for the underestimation, some of them common to state-of-the-art particulate models (another Italian example of state-of-the-art chemical modelling is given in *Deserti et al.*, 2006): lack of processes resolved by the chemical scheme, low level concentration in the boundary conditions, lack of emission processes as re-suspension of particles from soil, roads and sea spray. Despite the lack of processes and input data, PM10 time variability is sufficiently well represented in some measuring sites and can reach correlation coefficients as high as 0.7 (tab. 2).

Deposition data

Three bulk deposition collectors have been placed near or inside the Venice Lagoon. S.Fisola site is in Giudecca Island inside the lagoon, Lissa is inside the urban are of Mestre facing the lagoon and Malcontenta is localized downwind the industrial area of Marghera and the port. Six monthly campaigns in S.Fisola and twelve in Lissa and Malcontenta sites have been performed. These measurements have been compared to the model simulation.

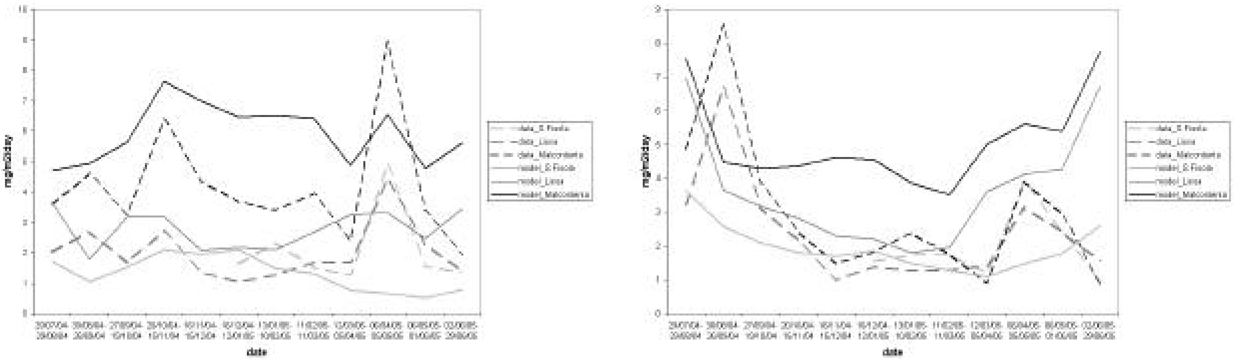

Fig 4: Sulphur (left) and nitrogen (right) daily mean deposition in three sites (dashed lines) for twelve monthly campaigns (x axis) compared to the model estimate (solid lines).

Fig. 4 and 5 illustrate the comparison between the daily mean deposited sulphur (fig. 5) and nitrogen (fig. 5). The dashed lines indicate the measurements and the solid lines indicate the model estimates. Dissolved gasses and deposited particulate matter have been normalized to the molecular weight of sulphur and nitrogen for a fair comparison with the data. The model capture with a discrete resolution (sulphur particularly) both values and spatial variation of the bulk deposition for both sulphur and nitrogen and its spatial variability. In fact the Malcontenta site presents a higher deposition compared to the other two sites. This variability is present both in the measures and in the model (fig. 4). However, in the nitrogen case the deposition is similar in the three measurement sites while the model estimates an higher deposition in Malcontenta site relative to the other two locations (tab. 3). Lastly the model simulation will be used to estimate the load of nutrients coming from the atmosphere and draining into the lagoon catchment's area.

Table 3. Twelve months average deposition (six months for S.Fisola) in micrograms/m^{-2}/day

Deposition (mg/m^{-2}/d^{-1})	Sulphur S. Fisola	Sulphur Lissa	Sulphur Malcontenta	Nitrogen S.Fisola	Nitrogen Lissa	Nitrogen Malcontenta
Measure	2.1	2.0	4.2	1.9	2.4	3.0
Model	1.1	2.8	5.9	1.7	3.6	5.1

CONCLUSIONS

The Veneto Region modelling system for air quality has been validated with measurements using one year of model simulation. While a satisfying level of correlation between model and measurements for all pollutants has been reached, some challenges are still open to drive future improvements: O_3 summer peak underestimation, tendency to overestimate the NO_2 at nighttimes and PM10 underestimation; a reasonable estimation of the magnitude of the deposition field with a somewhat overly-marked model spatial variability. The annual simulation presented in this paper allows for the estimation the atmospheric contribution of the pollution load on the Venice Lagoon. This estimation is useful to policy-makers and provides them with sound scientific advice in their decision regarding nutrition load regulation in the Venice Lagoon environment. Furthermore the modelling system will be used to assess the contribution of the various emission sources to the air pollution in this region and the relative contribution of the atmosphere respect to the other means (water and soil) in terms of nutrients deposition in the Venice Lagoon. Further improvements will regard: inventory completeness (particularly for PM), implementation of a prognostic meteorological model, sensitivity studies on model performance.

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