VALIDATION AND SOURCE APPORTIONMENT ANALYSES OF CAMx MODEL OVER THE VENETO REGION AND VENICE LAGOON

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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, in the Venice Lagoon the air quality situation is worsen by the presence of Porto Marghera, one of the most heavily industrialized Italian areas and a commercially active port. Within this scenario it is important to assess the local, intra-regional and extra-regional sources of pollution responsible for both the population exposure in the nearby cities of Mestre and Venice and the critical load on the Venice Lagoon itself.

To inquire about these questions (meteorology, multi-scale phenomena, chemistry), the Comprehensive Atmospheric Model (CAMx) has been implemented over the Veneto region. Boundary conditions for the chemicals are given by CHIMERE model while the meteorological fields are driven by CALMET model. CAMx has been run over a test period in July 2004 and the validation of ozone model results against the air quality monitoring data has been performed. The different weight of local (Porto Marghera), regional (Veneto) and external emission contributions to ozone concentration have been estimated.

MODEL INPUT

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 a 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 to simulate the photochemical reactions. The chemical mechanism considered is the Carbon Bond IV without heterogeneous chemistry in order to improve the computational efficiency. No plume-in-grid is present since point source emissions are emitted at the ground level. This approximation will be reconsidered by making use of the bottom-up inventory in the Veneto region (*Gnocchi et al.*, 2005). A cloud-free and precipitation-free atmosphere is present at all times in the current experiments but both clouds and wet deposition will be included in future CAMx calculations.

Emissions

A top down approach (*Gnocchi et al.*, 2005) has been performed starting from an annual national emission inventory (*Liburdi et al.*, 2004) resolved at the provincial level in space (seven provinces corresponding to the main cities present in Veneto) and at activity level on emission sources (following SNAP'97 nomenclature). Regional emissions include 125 thousands tons per year of NOx and 130 thousands tons of VOC per year. The transport sector is the main nitrogen contributor with 45% of total emission; power plants are the second contributor with 20%, while solvent use and production is the first organic compound emitter (41%) followed by the transport sector (33%).

Annual emissions are disaggregated at the municipality level based on main sector dependent proxy variables. Gridding is performed based on the land-use: i.e. municipality emissions for each main sector are spatially distributed over the most suitable land-cover (e.g. residential combustion over urban areas). Finally annual grid cell emissions are temporally and chemically disaggregated according to profiles that vary the main sector, the province, the pollutant, the season, the day-type and the climatic zone (*Maffeis at al.*, 2004).

NOx daily emissions is presented in figure 1. The main urbanized and industrialized areas (NOx emitters) are distributed along an east-west line, following the A4 highway from Venice to Verona (fig. 1). The Alps to the north and the Adriatic Sea to the South East are the lowest (or null) NOx emitters (see also land-use in fig. 2). These areas are also the ones with highest VOC/NOx ratios (not shown) due to consistent biogenic organic compound emissions.

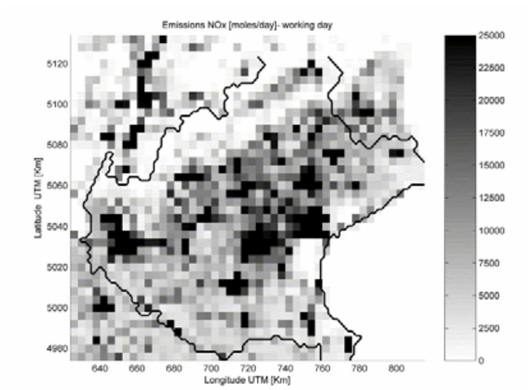

Figure 1: NOx daily emission (working day) mole/(day*cell) over the model domain.

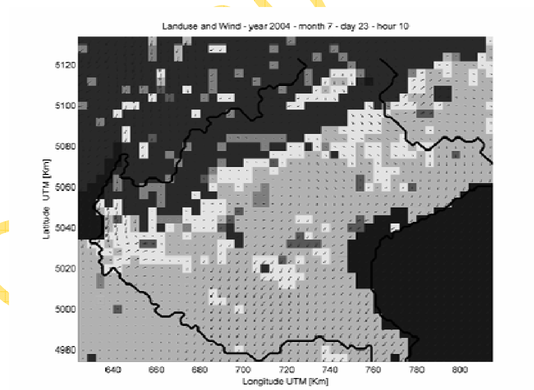

Figure 2: morning wind field (23/7/2004, 10am) over the land-use.

Meteorological fields

CALMET model is employed to blend together data coming from 32 surface stations (of which 9 synoptic), 1 sea station and 2 radiosonde stations and provides CAMx with the hourly temperature field, the horizontal wind (u, v), 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. In fig. 2, land-use and horizontal wind field at the surface are depicted for a morning hour on the 23rd July 2004.

Boundary, initial and top conditions

The output of the Chimere model gives the boundary, initial and top conditions for the CAMx experiments. The resolution of Chimere model is 0.5x0.5 degrees, which translates to roughly a 30x50 km resolution. Initial conditions consist of a single 3D field of the species modelled by Chimere while the top condition for each chemical specie is constant both in space and time. The boundary conditions, provided for every hour and at every vertical level, are averaged in the horizontal along each boundary to smooth the highly variable Chimere outputs and to facilitate the understanding of CAMx model dynamics.

Other inputs

CAMx requires data of ozone column level, atmospheric turbidity and chemical photolysis rate. TOMS ozone column measurements are downloaded from the NASA website while the second dataset is available through the Institute for Marine Sciences, Venice. 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 5D table is subdivided according to: ozone level, turbidity level, albedo, solar zenith angle and height.

VALIDATION

The twelve days simulation period in middle July 2004 presents a typical photochemical episode starting from a raining event (12-13th of July) followed by clear and warm days with high, but not exceptional, ozone concentrations. Two ozone peaks are present: the first (relative maximum) on the 17th and the second (absolute maximum) on the 23rd of July. The CALMET-CAMx modelling chain is able to follow correctly the daily ozone cycle and captures the decrease of daily peak concentration after the relative maximum on the 17th of July (fig. 3).

Eight monitoring stations have been chosen to be representative of the regional background, although some of them “feel” the influence of close fresh emissions: an evident example is VE-Bissuola, located in a green area in the centre of Mestre city. In this area the emissions are widespread and intense enough that a 4x4Km^2 grid-cell model is able to simulate the nigh-time NOx titration of ozone (fig. 3a).

A few stations show a nigh-time ozone peak, present both in model and measure data (eg: VR Cason station, fog. 3b); a more focused analysis is needed in order to determine the cause of this phenomenon possibly linked to a vertical break of the stable night-time boundary layer, a valley breeze transport from upper locations or a more complicated mechanism.

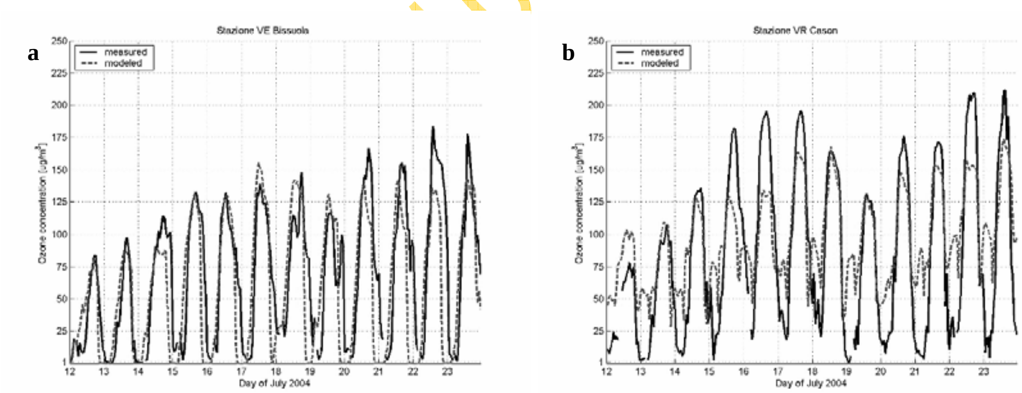

Figure 3: Model results and comparison with experimental data on eight monitoring stations for the simulation period from the 12th to the 23rd of July 2004.

The model performs the worst during the last two days (22 and 23) of the simulation where, at the location of some monitoring stations, the model is not able to reproduce the ozone build-up and it computes lower and late hourly maxima. At 5 pm, in fact, ozone model concentrations reach the maximum while measurements show a from 2 pm peak.

A group of statistical parameters (*Tesche, T.W. and F.L. Lurman*, 1990) are computed for the eight monitoring stations to evaluate model performance on the twelve days period from the 12th to the 23rd of July 2004 (table 1). All statistical parameters seem to be in a reasonable interval of values: correlation between measured and modelled ozone time series ranges between 0.7 and 0.9 with 0.81 average; NMBIAS and ASPP indicate an almost generalised underestimation of about 15% of both average (13 μg/m^3 the mean Gross Error) and peak ozone.

Table 1. Synthetic statistical performance of ozone simulation. The eight monitoring stations are reported in the same order as in figure 3 (left-right, top-bottom). ASPP (Accuracy of Spatially Paired Peak) is the percentage difference between hourly maximum.

Statistical parameter	1 - VR CASON	2 - VI BASSANO	3 - BL CITTA'	4 - TV CONEGLIANO	5 - VE BISSUOLA	6 - PD MANDRIA	7 - RO BORSEA	8 - VE FISOLA	AVERAGE
Correlation	0.85	0.79	0.75	0.84	0.72	0.90	0.83	0.80	**0.81**
Hourly maximum (μg/m^3)	212	248	192	228	184	240	231	167	
Average (μg/m^3)	82	107	78	91	68	83	97	69	**87**
ASPP	-18%	-20%	-9%	-12%	-15%	-25%	-15%	2%	**-16%**
Normalized Mean BIAS	-15%	-3%	-40%	-19%	15%	0%	-14%	-22%	**-11%**
Gross Error (μg/m^3)	13	3	31	17	10	0	14	15	**13**
Normalized Gross-Error	15%	3%	40%	19%	15%	0%	14%	22%	**15%**

SCENARIOS ANALYSIS

The different weight of local (Porto Marghera), regional (Veneto) and external (Lombardia, Emilia Romagna, Trentino and Friuli-Venezia-Giulia) emission contributions to ozone concentration have been estimated through five scenario runs on the same period with modified inputs for area emissions or boundary condition from the base run (Model 1) discussed above (Table 2). Model 2 is the evaluation of "local effect" where all NOx and VOC emissions of production and harbour activities in Porto Marghera and the city of Venice have been eliminated in a 16x16 Km^2 area. Model 3, 4 and 5 evaluate the different emissions contributions at the regional scale. In Model 4 all NOx and VOC emissions have been eliminated except for biogenic VOC while in Model 3 and Model 5 industrial activities and traffic are respectively omitted. Finally Model 6 has null NOx and VOC boundary conditions which roughly means: no primary coming from the outer areas.

Table 2. Scenarios definition

Scenarios	**Description**	**NOx reduction**	**VOC reduction**
1	Base simulation	-	-
2	Base simulation without "Porto Marghera" emissions	5.5%	7.2%
3	Base simulation without all industrial emissions	46.1%	48.7%
4	Base simulation without all anthropogenic emissions	100%	84.4%
5	Base simulation without all traffic emissions	52.6%	33.7%
6	Base simulation with zero VOC and NOx boundary conditions	-	-

At the regional level (fig. 4a), inner (Model 4) and outer (Model 6) precursor are equally important regarding ozone formation with about 10-15% average reduction in 8-hours mean peak value when such precursor are not included in the calculations. Such a small reduction of ozone in Model 4 and 6 implies the advection of ozone from the boundaries is a crucial process. Within the regional emissions the transport and industrial sector play a comparable roles in terms of regional ozone formation with a contribution of about 7% each. At the local level (fig. 4b), ozone formation is inhibited by the presence of the industrial activities in Porto Marghera due to the titration process of ozone with NOx. Without such activities it is estimated that the 8-hours mean ozone peak would increase of about 10-20% of today's value.

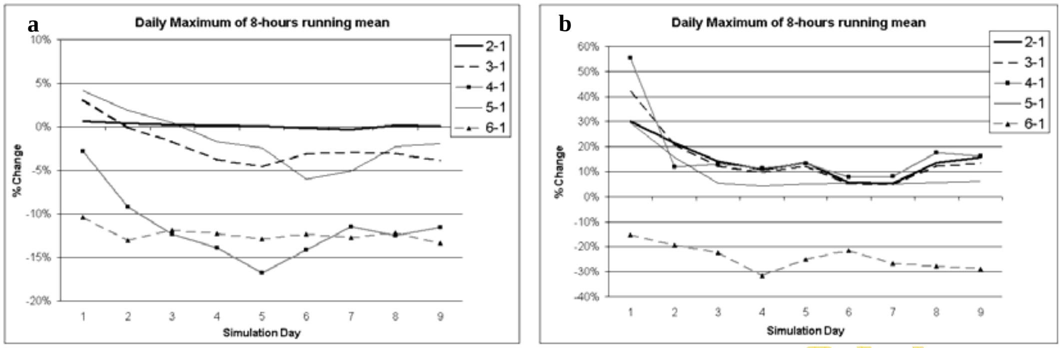

Figure 4: *Comparison of the five different scenarios (relative to the baseline scenario – model 1). Surface daily maximum of the 8-hours running mean for the whole Veneto Region (a) and Urban-Industrial Venice areas (b): ratio between scenarios (2-6) and the baseline (1).*

First results of CAMx process analysis tool is that vertical diffusion input from the above layer and dry deposition removal are the mail processes affecting, on the average, regional ozone concentration at ground; secondly chemistry and advection processes. Locally in Porto Marghera and Venice city, the main removal process is chemical titration with dry deposition playing a smaller but still significant role. Ozone precursors transport occurs mainly from the southern and eastern boundary of the domain considered both at regional and local levels.

ACKNOWLEDGMENTS

This work has been funded by the Veneto Region Authority (Project "SIMAGE I Lotto", 2002-2005).

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