

# First results of a long-term simulation of photochemical smog in Northern Italy

A contribution to subproject SATURN

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## Summary

Ozone is considered one of the most significant pollutants with respect to the potential impacts to human health and natural ecosystems, both in terms of critical episodes and as long-term exposures. Consequently, in order to assess the comprehensive effects of photochemical pollution, not only ozone peak concentrations need to be examined, but also ozone exposures on “seasonal” scale need to be quantified. Modelling systems can represent suitable tools for this purpose, allowing both to study photochemical pollution and to analyse and assess appropriate emissions reduction strategies.

In this study an integrated modelling system has been developed in order to perform a climatological simulation of photochemical pollution. The proposed system is made up of some chief modules: the meteorological model CALMET, the emission evaluation model POEM and two transport-chemical models, CALGRID and STEM-FCM. The modelling system has been applied in Northern Italy over a domain including the whole of Lombardia Region, characterised by complex terrain, high urban and industrial emissions and a close road network. Initial and boundary conditions for the domain under study are obtained by means of a nesting procedure from the EMEP Lagrangian Photooxidant Model. The system has been preliminary applied over the period May-July 1996, in order to assess the model capability to actually reconstruct the different peculiar features of pollutant concentrations. Some representative air quality stations have been selected from the Lombardia Region monitoring network by using a clustering analysis technique to evaluate simulation results. Comparison has pointed out a quite good agreement between computed and measured ozone concentrations both in urban and rural areas.

## Introduction

Tropospheric ozone may have adverse effects on human health, materials and ecosystems. Impacts can be related to peak concentrations developing during episodes, but also to long-term exposures. In order to reduce ozone and photochemical smog, appropriate emissions reduction strategies need to be implemented. Modelling system can be an useful tool in evaluating the effectiveness of emissions reduction policies. Recent works (Hogrefe *et al.*, 2001, Tarasson *et al.*, 2001) point out the importance to perform policies analysis on a “climatological” basis rather than focusing on a single critical episode. This approach allows to better evaluate model performances (Hogrefe *et al.*, 2001) and also to quantify policies effects respect to long-term air quality standards.

Lombardia Region, located in Northern Italy, is often affected by severe photochemical and particulate pollution episodes, mainly during summer season. This is due to both anthropogenic and meteorological effects. In fact Lombardia region is very industrialised and populated and it is characterised by strong urban, industrial and traffic emissions; moreover, due to the presence of the Alps, often exhibits weak circulation and stagnant conditions.

In this paper, the first results of long-term simulation performed over this domain by means of two regional photochemical models are presented.

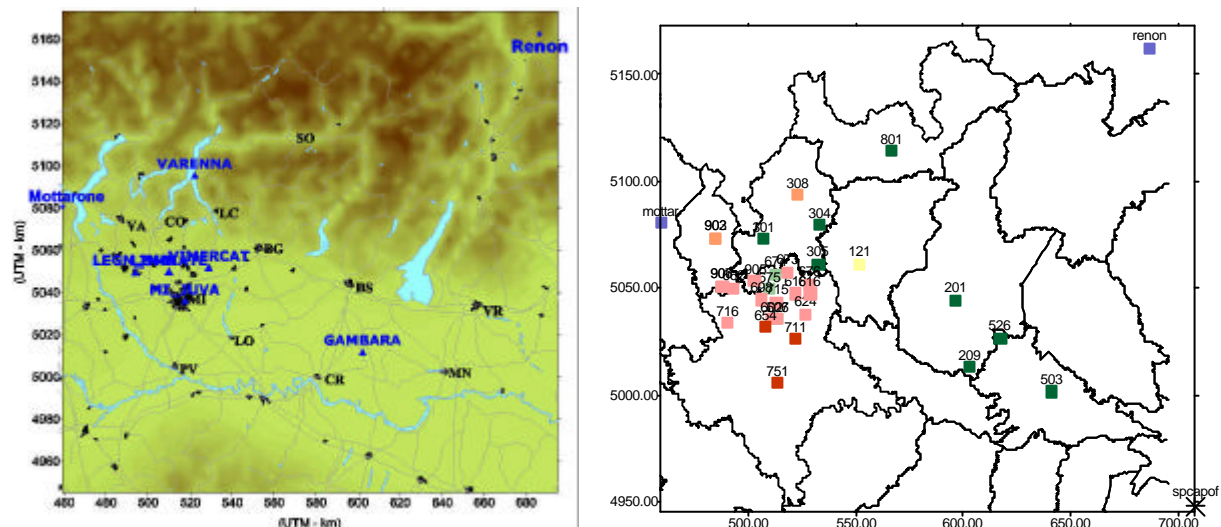
## Objectives

The first aim of this work is the development of a modelling tool able to perform “climatological” photochemical simulations. Then the modelling system has been applied to reproduce long-term ozone concentrations over a wide area, generally not covered with measurements. Since over the area ozone estimations by means of large scale models are available too, obtained results could be also used for an intercomparison exercise between models dealing with different spatial resolution.

## Activities

The implemented modelling system includes 3D meteorological model CALMET (Scire *et al.*, 1999), a flexible emissions evaluation model POEM (Catenacci *et al.*, 1999) and two photochemical transport models: CALGRID (Yamartino *et al.*, 1992) and STEM-FCM (Silibello *et al.*, 2001).

The computational domain (Figure 1) covers an area of 240x232 km<sup>2</sup>, including the whole of Lombardia Region as well as rural areas in Po Valley, the Central Alps (reaching 4000 m) and portions of Southern Switzerland.



**Figure 1:** The simulation domain with the selected stations (left). Available air quality stations classified by means of cluster analysis (right)

3D wind fields have been reconstructed by CALMET, merging background field supplied by ECMWF model with observations. Meteorological preprocessors have been also applied to estimate temperature fields as well as turbulence parameters. The emission model POEM (*Pollutant Emission Model*) is specifically designed to produce present and alternative emission fields. The road transport, agriculture and biogenic emissions are estimated by means of a *bottom-up* approach, while the emissions due to other source categories are computed disaggregating the CORINAIR90 data set, updated by the last available Italian CORINAIR report (1994). The road traffic emissions are estimated up to 1996.

Two Eulerian three-dimensional chemical-transport models have been applied: CALGRID and STEM-FCM. Both models use an accurate advection-diffusion scheme in terrain-following coordinates with variable vertical spacing and implement the SAPRC90 chemical mechanism (Carter, 1990).

The studied area has been horizontally subdivided into 60 × 58 cells, with a resolution of 4 km. Vertical domain extends up to 3900 [m agl], subdivided into 11 layers of growing

thickness. Initial and boundary conditions for the domain under study are obtained by means of a nesting procedure from the EMEP Lagrangian Photooxidant Model (EMEP, 1999). Models have been run for the period May-June 1996 supplying hourly concentration fields. Ozone time series from the air quality networks have been analysed by using a clustering analysis technique to evaluate similarity in terms of levels and temporal variability (frequency and peak distribution, daily shape). Starting from obtained results, a reduced set of 8 representative monitoring stations have been selected to compare estimated concentrations with measurements (Figure 1).

## Results

Figure 2 shows the 3-months average ozone concentrations fields estimated at ground level by STEM-FCM and CALGRID. Maps evidence that highest mean concentrations take place outside the urban areas both in the northern and southern part of the domain.

Figure 3 reports the comparison for 3-months average concentration, while figure 4 shows the comparison among measured and simulated mean day as an average for 4 urban and 2 remote stations. Both models reasonably agree with measured data, in terms of the reproduction both of daily patterns and mean concentrations.

The largest differences with respect to measured data come from an overestimation of the mean value at Gambara station, probably descending from an inadequate temporal modulation of boundary concentration in SE part of the domain. Moreover, in urban context, STEM reveals an underestimation of both diurnal peak concentration and mean value. This could be due to an underestimation of vertical dispersion and, consequently, to an overestimation of  $O_3$  titration due to  $NO_x$  emissions.

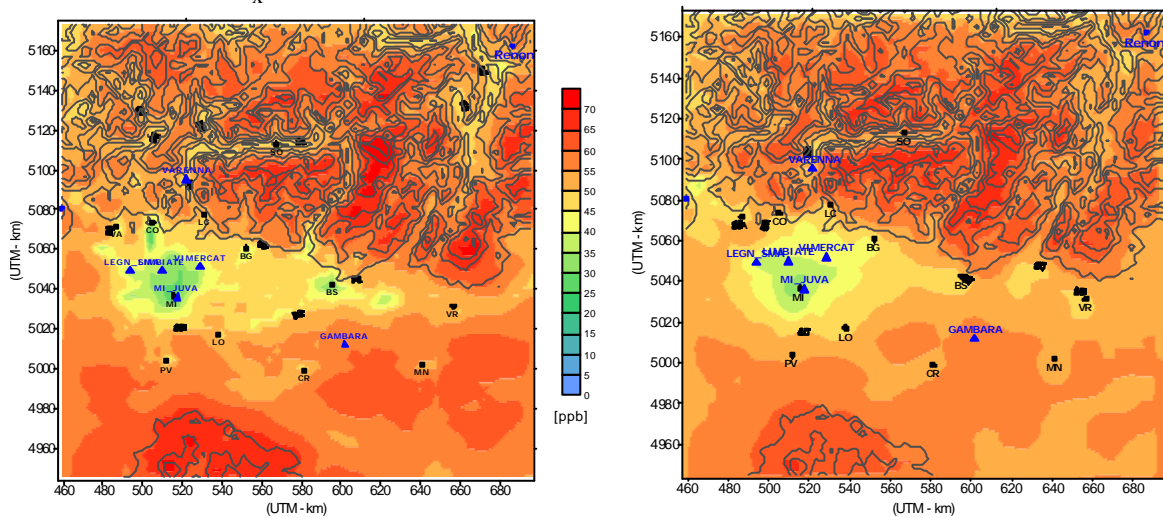


Figure 2: 3-Months average ozone concentration estimated by: STEM -FCM (left) and CALGRID (right).

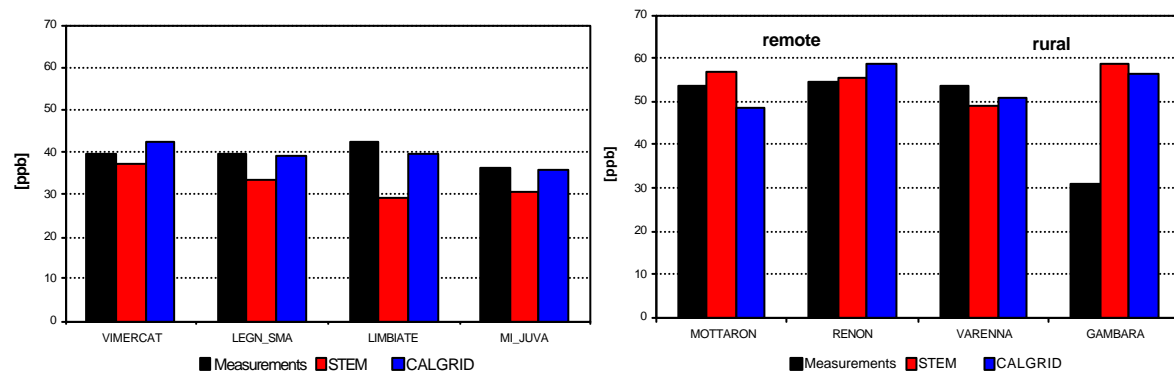
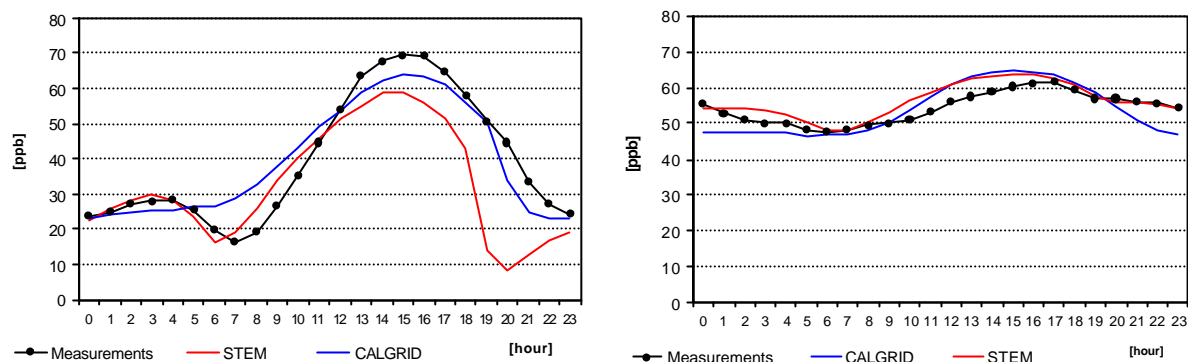


Figure 3: 3-Months mean value at urban sites (left); remote and rural sites (right).



**Figure 4:** Comparison with measurements: mean day at urban sites (left) and remote sites (right).

## Conclusions

An integrated modelling system for the long-term analysis of photochemical pollution has been preliminary applied to a summer period (May-July 1996) over Lombardia Region (Northern Italy). The system integrates meteorological and emissions pre-processors as well as two transport-chemistry models: CALGRID and STEM-FCM. Simulation results over the summer period have been compared with air quality data, pointing out a quite good agreement between computed and measured ozone concentrations.

Further analysis of results will be performed, in order to compare simulated fields with large scale models evaluations and also with maps of measured ozone concentrations and critical levels, derived by using spatial interpolation methods. Moreover sensitivity analysis on meteorological fields, boundary conditions and chemical mechanisms will be carried out to improve obtained results.

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## **Aims for next year (i.e. 2002) and list of publications in 2001**

The activity will be focused on performing long-term simulation of photochemical pollution over Lombardia region, with the following particular aims:

- evaluation of long term exposure indexes and comparison with observations;
- CALGRID, STEM II models inter-comparison;
- sensitivity analysis.

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