Flexible modelling System for Air Pollution Simulation and Control in Northern Italy

A contribution to subproject SATURN

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Summary
Northern Italy is often affected by severe photochemical and particulate pollution episodes in summer season. The development emission reduction strategies requires suitable modelling tools. An integrated system composed of a meteorological processor, an emission module and a transport model has been set up to perform such analysis. The system is able to include several chemical mechanisms and can be integrated with an aerosol processor both in the transport and emission module. Preliminary simulations of a selected episode characterised by high ozone levels have been realized with 4 different chemical mechanisms and the results obtained are presented.

Introduction

Northern Italy, characterised by a complex terrain, high urban and industrial emissions and a close road net, is often affected by severe photochemical and particulate pollution episodes, mainly during summer season. The main compounds inducing these reactions are NO_x and VOC coming from road traffic and industrial combustion plants. An essential role in the chemical process activation is played by high solar radiation and stagnating meteorological conditions. The cause-effect relation between precursors and photochemical pollutant is quite complex and non-linear, due to accumulation processes and to the large number of variables affecting the photo-oxidant production, including their integration and the consequent feedback multiple reactions.

Objectives

As a consequence of such complexity, the development of effective strategies of emission reduction requires suitable tools that allow to take into account all the variables involved in gas and aerosol phenomenology. In this work an integrated modelling system that can include several chemical mechanisms has been set up to support the analysis of such strategies.

Activities

The modelling system includes three main processors and postprocessing tools: a three-dimensional meteorological preprocessor CALMET (Scire et al. 1990), a flexible emission model POEM (Catenacci et al. 1998), and a photochemical model CALGRID-FCM. The emission processor POEM (POllutant Emission Model) has been specifically designed to produce present and alternative emission field estimates by means of an integrated *top-down* and *bottom-up* approach. POEM can be applied in particular to the Italian CORINAIR data and considers diffuse and main point sources coming from different activity sectors. The FCM interface has been implemented in the POEM to lump the emission splitted in the SAROAD classes into the chemical species needed by the chemical mechanism implemented in the photochemical model.

The photochemical model CALGRID (Yamartino et al., 1992) is an Eulerian three-dimensional model that implements an accurate advection-diffusion scheme in terrain-following co-ordinates with vertical variable spacing and a resistance-based dry deposition algorithm; the CALGRID chemical module uses SAPRC-90 mechanism (Carter 1990), including 54 chemical species with 129 reactions and the QSSA (Quasi Steady State Approximations) solver for the integration of kinetic equations. The CALGRID model has been modified to allow for changes in chemical schemes and this goal has been obtained implementing the Flexible Chemical Mechanism interface, FCM, (Kumar et al. 1995). The chemical mechanisms that have been implemented are:

- SAPRC-97 (Carter et al 1997) which considers 82 chemical species and 184 reactions.
- COCOH-97 (Durlak 2000) which is similar to SAPRC-97 but with condensable organic compounds yields and 2 dummy species (NH_3 and HCl).
- Carbon Bond IV (Gery et al. 1988) with 37 chemical species and 78 reactions.

The original integration solver of the CALGRID, the QSSA, has been substituted with the IEH solver (Sun et al. 1994). As the FCM makes possible to distinguish among fast and slow reacting species, the IEH integration method uses the implicit scheme LSODE (Hindmarsh 1980) to solve for the fast reacting species and an explicit second order scheme to solve the slow reacting species. The area under study (240x232 km^2, cell size 4x4 km^2) is located in Northern Italy and includes the Lombardia Region, with several cities as well as rural areas in Po Valley, most of central Alps and portions of Southern Swiss. This area is regularly affected by high ozone level, also due to the frequent stagnating conditions, especially during summer months. The episode chosen to be simulated as base-case for Lombardia is 1-5 June 1998 during the PIPAPO projects measurements campaign performed in the frame of SATURN and LOOP subprojects of EUROTRAC-2. During the selected period, values exceeding the health protection threshold have been recorded in many stations of the regional network.

Results

Urban air quality impact simulations have been performed with the 4 chemical mechanisms implemented for the base case reference meteorological and emission field in order to point out the differences between the schemes. Boundary and initial conditions have been determined from available measurements in the surroundings or from literature values, as well as the vertical profile, and have been assumed constant in time for all compounds except for ozone, NO and NO_2. When no data were available a default value of 1.0E-7 ppb has been assumed. The results obtained for ozone and NO are represented in figure 1 for an urban site and in figure 2 for a rural site.

As far as the urban site is concerned, all the mechanisms can obtain a good agreement between the ozone concentrations simulated and the experimental data. It must be evidenced that NO time concentrations obtained are generally higher than the measured concentrations except in some cases when a peak in NO has been detected: in this cases all the mechanisms show the same behaviour and are not able to reproduce such peaks. To explain this result let consider the figure 2 showing the NO time concentration for a rural site: in this case the model simulations show nighttime peaks in the NO concentrations that have not been detected in the experimental measurements and whose dynamic has a characteristic time very similar to the peaks measured in the urban site. It can be deduced that such discrepancies between model results and experimental data cannot be attributed to the photochemical model but only to the inputs and in particular the meteorological input. In fact the emission fields have a regular behaviour during the cycle of 24 hours that cannot explain the peaks only in some nights, so only a local meteorological effect that has not been reproduced by the meteorological processor is responsible for the high NO concentrations in the urban site. It can be noticed that during the last night in the urban site such local effect has been detected by the meteorological processor because a peak in NO concentration has been measured and has also been reproduced by the model. For the same reason the high NO concentrations in the rural site sometimes estimated can be attributed to the same effect that in this case has been estimated by the meteorological model but that it has not happened. Finally the results obtained for ozone in the rural site reproduce the measured values but not as well as in the urban site.

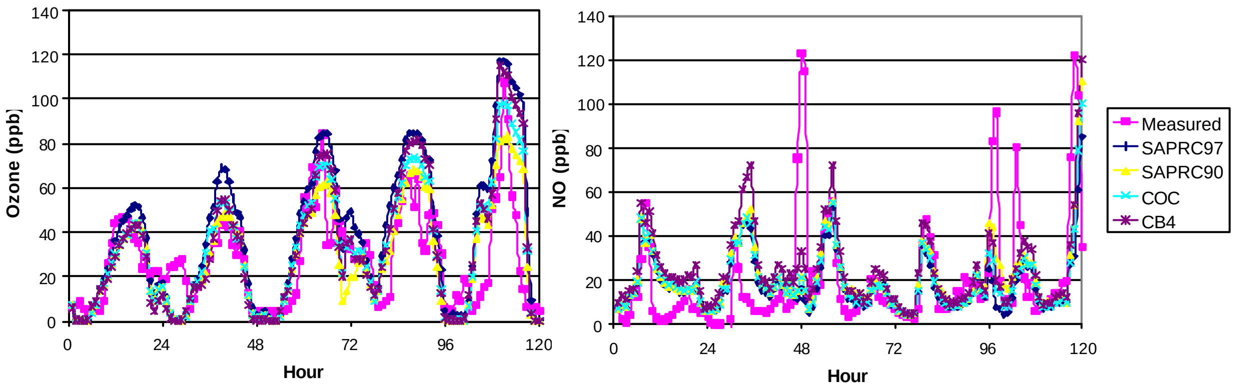

Figure 1: O_3 and NO time concentration for an urban site: Milano.

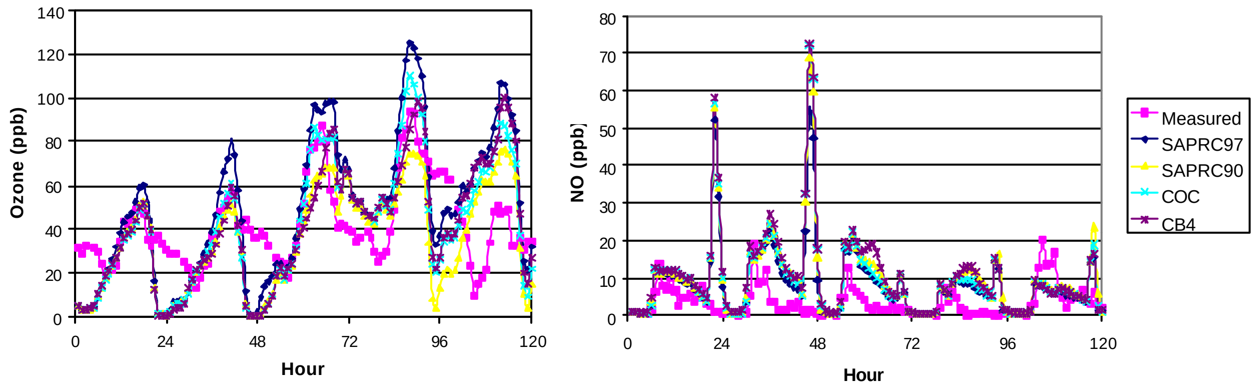

Figure 2: O_3 and NO time concentration for a rural site: Erba (CO)

In figure 3 comparison among the ozone fields evaluated by means of the 4 mechanisms at the same hour in the domain is shown. In each case the ozone concentration fields show the same distribution. It can be noticed that in the Milano zone the values obtained are lower than in the surrounding area due the higher emission of NO_x. Finally in the Northern and in the Southern zone of the domain the ozone concentrations tend to accumulate: this fact is due to a breeze effect produced by the mountains.

Conclusions

To evaluate the possible strategies of emissions reductions, a flexible and integrated modeling system has been realized. This system is composed of the CALGRID-FCM model, which has already been applied to the northern Italy, the POEM emission processor and the CALMET meteorological processor. This system can include several chemical mechanisms. First simulations have been obtained.

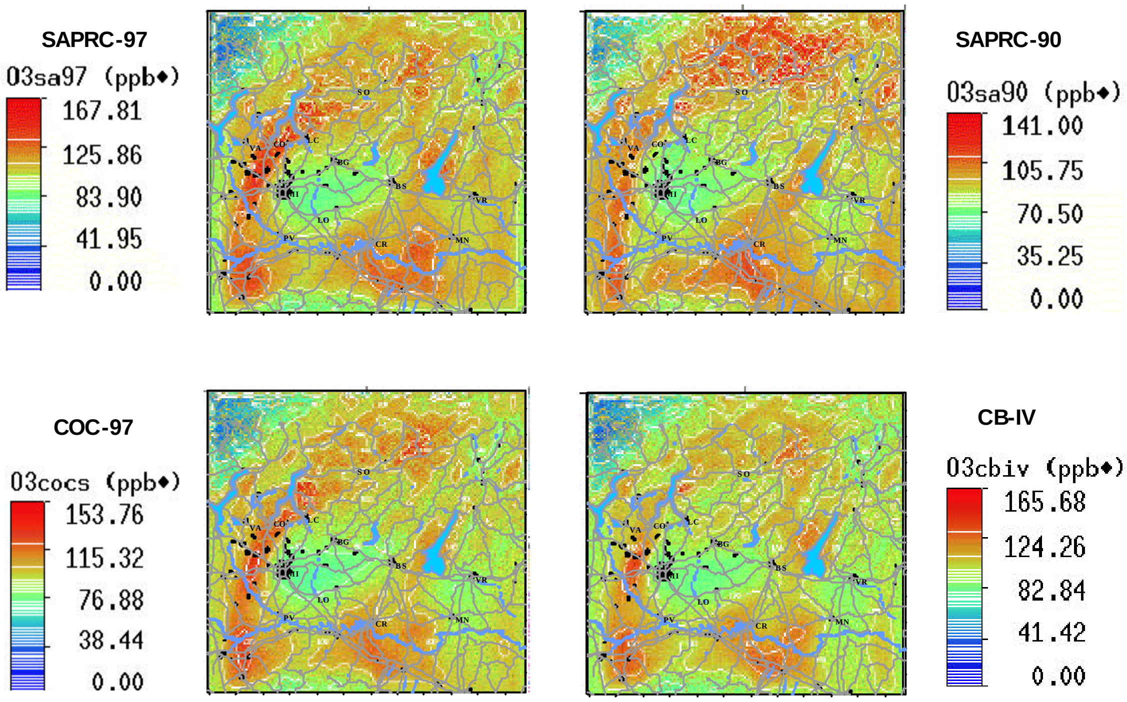

Figure 3: Comparison between the ozone fields obtained by the four mechanisms

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List of publications in 2001 and aims for 2002

The activity will be focussed on the sensitivity of the chemical mechanism to the inputs, on the evaluation of photochemical indicators to perform photochemical analysis of the domain. An aerosol processor will also be implemented in the transport model to evaluate the aerosol role in ozone photochemistry.

Decanini, E., Volta, M. "Integrated Gas-Aerosol phase Model System for Air Pollution Simulation and Control in Northern Italy ", Proceedings of the 10th International Symposium “Transport and Air Pollution”, September 17-19, 2001 – Boulder, Colorado. USA.