ASSESSMENT OF TRANSBOUNDARY POLLUTION ROLE IN TROPOSPHERIC OZONE ACCUMULATION PROCESS BY FACTOR SEPARATION ANALYSIS

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1. METHODOLOGY

The definition of efficient ozone control strategies is a complex task for an Air Quality Manager, because ozone formation is a strongly nonlinear process, and it can be locally produced or due to transboundary phenomena.
To support the Air Quality Manager in this task, the factor separation technique [3] can be applied. Such method allows to assess the impact of a single factor in a nonlinear system as well as the interaction between that factor and others, processing deterministic model simulations [6].

In this study the technique is addressed to identify and quantify the role of anthropogenic and biogenic emissions on ozone concentration levels, as well as the interactions among such sources and the pollutant masses transported inside the study domain (i.e. the boundary condition effects). The methodology has been applied processing the simulations performed by GAMES photochemical modelling system [7].

2. FACTOR SEPARATION TECHNIQUE

To evaluate the contribution of relevant factors and the interactions among them in a particular physical non-linear process, as the pollution formation and transport in atmosphere, the factor separation method can be applied [3].

Let's consider the three factors A (anthropogenic emissions), B (biogenic emissions) and C (boundary conditions), and *F={A,B,C}*.

Denoting with f_{tot} , f_0, f_i, (with *i* in *F*), the simulations including all the factors, none of the factors and factor *i* only respectively, the pure contribution of factor *i* (f_i'), can be isolated as follows:

$$f_0' = f_0$$

$$f_i' = f_i - f_0 \qquad i \in \{A,B,C\}$$

Note that the term f_i' represents the fraction of the considered process completely ascribed to factor *i*, while f_0 is the term independent from *i*. The double mutual interaction among 2 factors, i.e. is given by:

$$f_{ij}' = f_{ij} - (f_i + f_j) + f_0$$

$$i, j \in F, i \neq j$$

The triple interaction is expressed as:

$$f_{tot}' = f_{tot} + \sum_{i \in F} f_i - \sum_{\substack{i,j \in F \\ j \neq i}} f_{ij} - f_0$$

In this way, the simulation including all the involved factors (f_{ABC}) in terms of pure and sinergic contributions, can be subdivided as shown in the following equation:

$$f_{tot} = f_{tot}' + \sum_{i \in F} f_i' + \sum_{\substack{i,j \in F \\ j \neq i}} f_{ij}' + f_0'$$

As introduced by [6], the total impact (TI_i) of a specific accounted factor *i* is defined as the sum of all pure contribution and synergic terms in which *i* appears. The total impact of the three factors considered in this study can be represented as follows:

$$TI_i = f_{ijk}' + f_i' + \sum_{\substack{i,j \in F \\ j \neq i}} f_{ij}' = f_{ijk} - f_{jk}$$

The terms in the previous equations, used to calculate pure and sinergic effects, are shown in Table 1, where the eight simulations performed in this study are listed.

Simulations	Anthropogenic emissions	Biogenic emissions	Boundary conditions
f_o	-	-	-
f_A	x	-	-
f_B	-	x	-
f_C	-	-	x
f_{AB}	x	x	-
f_{AC}	x	-	x
f_{BC}	-	x	x
f_{ABC}	x	x	x

Table 1: The eight deterministic model simulations performed.

3. CASE STUDY

This study focuses on a northern Italy region (Figure 1). Bounded north by Alps, it covers a large part of the Po Valley, presenting an agricultural area in the southern part, along the Po River, and a densely urbanized area in the central part. In northern Italy there are regularly high ozone level concentrations (Figure 1 right). Moreover, the domain is ruled by NOx chemical regime in Northern part of the domain, and VOC chemical regime in the central flat area [2].

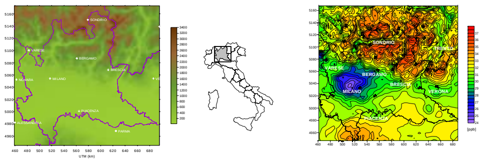

Figure 1: The simulation domain (on the left and centre), and the ground level ozone mean value distribution, computed over a 6-months period [ppb] (on the right).

3.1. GAMES SYSTEM DESCRIPTION

GAMES (Figure 2) consists of the CALMET meteorological model [4], the emission model POEM-PM [1], the photochemical model CALGRID [5], the boundary and initial condition module BICM and the system evaluation tool SET.

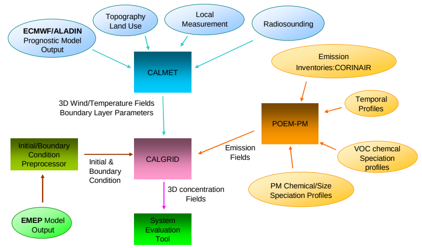

Figure 2: The GAMES modelling system.

3.2. SIMULATION SET UP

GAMES system has performed seasonal simulations (April-September 1996). The selected area is 240X232 km^2 wide and it has been subdivided with a horizontal grid resolution of 4X4 km^2 , with 11 vertical variable layers (20, 45, 80, 130, 230, 400, 650, 1000, 1700, 2800 and 3900 m a.s.l.).

4. RESULTS AND DISCUSSION

A first evaluation of the weight of boundary conditions and emission sources is shown analyzing the pure impact of each factor on the ozone concentration level (Figure 3). Such maps pointed out that the contribution of each factor is always positive, with higher values due to anthropogenic emissions and boundary conditions. Further, the lower bound of boundary condition pure contribution is higher (24 ppb) than the emission source ones (about 10 ppb).

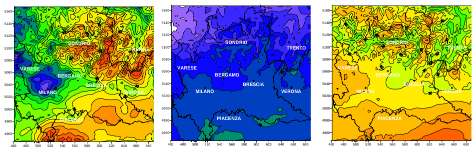

Figure 3: Pure anhtropogenic, biogenic and boundary conditions effects, respectively from left to right

As the analysis performed by means of the pure contribution does not account the nonlinearity among the factors, to evaluate the complete contribution of each factor on the mean ozone concentrations the total impact has been computed.

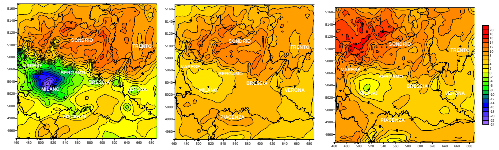

Figure 5: Total anhtropogenic (TI_A), biogenic (TI_B) and boundary conditions (TI_C) effects, respectively from left to right

The total impact of anthropogenic emissions (TI_A) ranges between -24 ppb to 16 ppb. Negative values, i.e. ozone reduction, are estimated over Milan metropolitan area characterized by high NOx anthropogenic emission and VOC-limited regime.

The biogenic contribution (TI_B), mostly positive, presents the maximum impact in the correspondence of the high biogenic emission areas, i.e. the Alpine region and along the Po river, in domain southern part.

The map showing the boundary condition total impact (TI_C) highlights that: (1) the positive contributions are quite similar to the anthropogenic and biogenic ones; (2) TI_C is null in correspondence of Milan; (3) the urbanized area between Milan and Verona is characterized by a modest impact (only few ppbs); (4) the highest impact is found in the NW part of the domain, in correspondence of Switzerland area.

5. CONCLUSIONS

GAMES modelling system has been applied to assess the influence of boundary conditions and emissions on tropospheric ozone formation and accumulation processes.

This analysis represents a useful tool for regional authorities interested in developing plans for ozone reduction, allowing to deduce the following evidences:

• the biogenic impact is positive in all the domain, meaning that this contribute cannot be neglected in planning an air quality strategy;

• in the northern part of the domain, an area characterized by low precursor emissions, ozone is equally produced by transboundary processes, the urban plumes transported by mountain - valley breezes, and biogenic emissions;

• control strategies based on local anthropogenic emission reduction measures may be effective in the central urbanized area, but they have limited effectiveness in northern part of the domain, requiring the implementation of transnational policies.

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6. ACKNOWLEDGMENTS

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