MODEL BASED YEARLY AIR QUALITY EVALUATION ON PIEMONTE REGION

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INTRODUCTION

The Environment Council (EC) has been introduced a series of Directives to control levels of certain pollutants and to monitor their concentrations in the air: the Framework Directive 96/62/EC on ambient air quality assessment and management and its daughter directives, which set the numerical limit values, or in the case of ozone, target values for each of the identified pollutants in ambient air. The Framework Directive and the first Daughter Directive (1999/30/EC, setting limit values for NOx, SO_2, Pb and PM10) introduce, for the first time in European air quality directives, the combined use of monitoring data, emission inventories and modelling techniques in assessment and management of air quality. The availability of a detailed regional inventory covering anthropogenic and natural sources at the detail of individual municipalities, main road axes and relevant point sources (INEMAR[12]) and of an adequate air monitoring network[13] has induced the Regional Authorities (Regione Piemonte and ARPA Piemonte) to implement, in cooperation with ARIANET s.r.l., a multi pollutant eulerian Atmospheric Modeling System (AMS) to support the air quality assessment and management (e.g.: production of spatial distribution maps, assessment of the contributions of various sources and source categories to exceedences of limit values from; evaluation of the effectiveness of emission control strategies on air quality levels).

A similar system is also implemented and applied in the MINNI project (Integrated National Model in support to the International Negotiation on air pollution, Zanini *et al.* 2004) to provide to the RAINS-Italy Integrated Assessment Model the necessary atmospheric transfer matrices. In this context the AMS has been applied for the 1999 reference year to the Italian domain at an horizontal resolution of 20 km. Emissions, meteorology and pollutant (primary and secondary) concentrations hourly fields produced within the MINNI project may be used to perform nested simulations over the Piemonte region for the year 1999 (Figure 1). In the next sections a description of the AMS and the procedure adopted to perform the regional simulation from the national one are given and the main results obtained in this study are discussed.

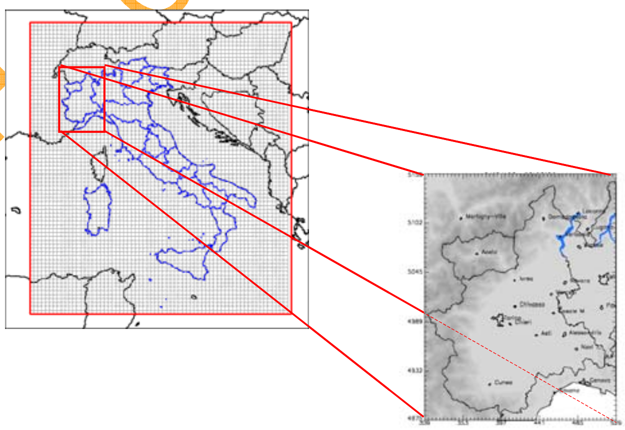

Fig. 1; Nesting from MINNI fields to Piemonte region.

[12]http://extranet.regione.piemonte.it/ambiente/aria/
[13]http://www.sistemapiemonte.it/ambiente/srqa/

MODELLING SYSTEM AND NATIONAL CONTEXT

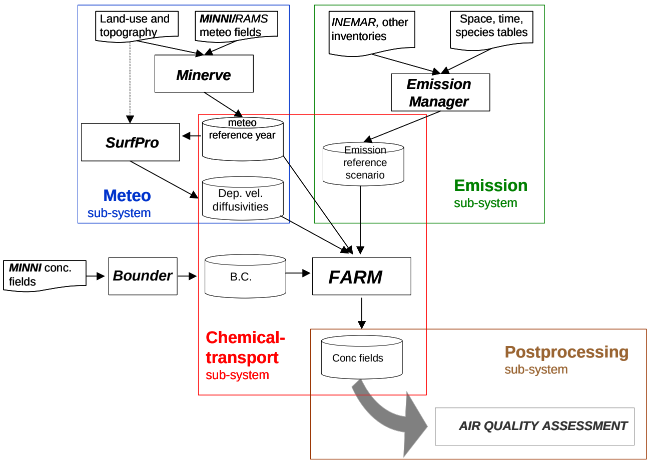

Fig. 2; AMS used to perform air quality evaluation over Piemonte region from MINNI project.

A description of the AMS used to reconstruct air quality maps over the Piemonte region is shown in Figure 2. The AMS include four subsystems respectively used to reconstruct flows and related turbulence parameters; to apportion data from the emission inventories to grid cells, to perform air quality simulations over the selected domain and to compute the air quality indicators required by the EC directives. The AMS is based on FARM model (Flexible Air quality Regional Model, De Maria *et al., 2005;* Silibello *et al.*, *2005*) that has been derived from STEM-II code (Carmichael *et al.*, 1991) and may implement different gas-phase chemical mechanisms and two aerosol modules: the *aero3* modal aerosol module implemented in CMAQ framework (Binkowski *et al.*, 1999) and a simplified bulk aerosol module (*aero0*) based on the approach adopted by the EMEP Eulerian Unified model (EMEP, 2003).

REGIONAL APPLICATION

The extension of the target domain is 220 x 284 km^2 (Figure 1) with an horizontal resolution equal to 4 km that represent a good compromise between the representation of terrain and emission inhomogeneities and the computational time needed to perform yearly simulations. For this application FARM model has been applied, coherently with MINNI project, with the SAPRC-90 (Carter, 1990) chemical mechanism and the *aero0* aerosol module.
Following procedure has been adopted to perform the air quality simulations over Piemonte region from MINNI national-scale fields. Meteorological fields estimated by RAMS model (Cotton *et al.*, 2003) have been diagnostically adapted to the regional complex topography and roughness using MINERVE processor (Aria Technologies, 2001). The regional scale meteorological fields together with land cover information (e.g. roughness length) and chemical species characteristics (gas reactivity) have been then used by SURF*PRO* processor (Arianet, 2004) to produce dry deposition velocities and turbulent diffusivities fields needed by FARM. Boundary conditions for all modelled species on the regional domain have been derived from the corresponding three-dimensional fields of the national simulation; in such way the regional-scale simulation takes also into account the influence of sources located outside the selected domain. Hourly gridded and chemically speciated model input has been prepared from the detailed regional emission inventory (INEMAR) integrated with data from national and international (EMEP) inventories of surrounding areas falling in the modelling domain. Figure 3 gives an example of NO emissions coming from diffuse and point sources on the computational domain.

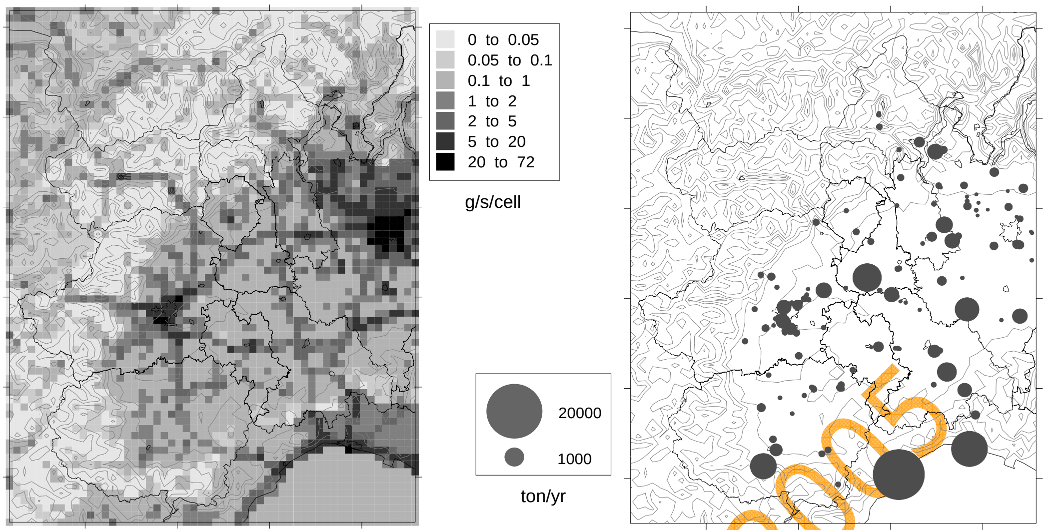

Fig. 3. Examples of NO input emissions on the computational domain: diffuse (left) and point sources (right).

RESULTS AND DISCUSSION

The whole year 1999 has been simulated over the selected domain and simulated concentrations have then been verified against the operational monitoring network data. An example of this procedure is given in Figure 4 where scatterplots of yearly averaged modelled concentrations of NO_2, SO_2 and O_3 against observed values are shown. The analysis of this figure evidence the capability of the modelling technique to reproduce measured values: the uncertainty of this assessment method is generally between ±50% for the selected species. The limited number of PM10 and benzene measurement sites available during 1999 does not permit a full verification of the AMS for these species that will be postponed to more recent years applications, currently ongoing, for which more experimental data are available. As for CO, the adopted horizontal resolution (4 km) does not permit such analysis for this species because of the location of the monitoring sites clearly influenced by nearby traffic emissions.

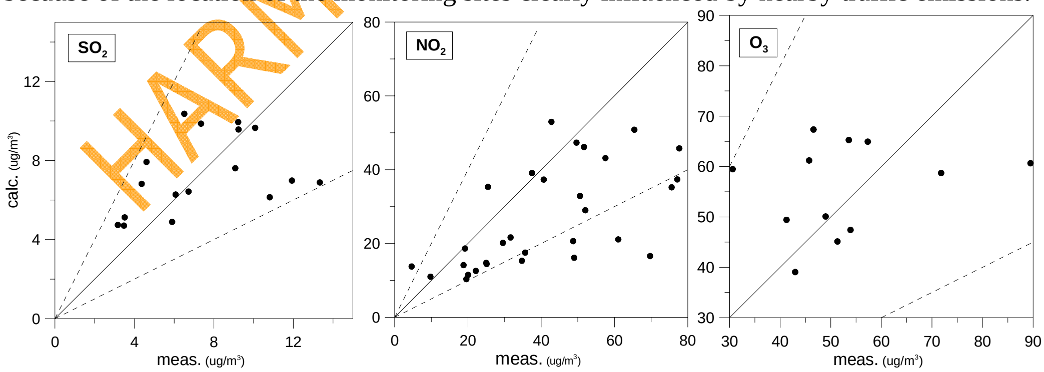

Fig. 4; Comparison between observed (abscissa) and estimated (ordinate) yearly averaged concentrations [$\mu g\ m^{-3}$].

In a further phase, spatial distribution maps of air quality target values for the protection of human health and the environment have been produced. An example is given in Figure 5 reporting modelled NO_2 year averages (target value: 40 µg m^{-3}) and number of days for which maximum ozone daily 8-hour means exceed the value of 120 μg m^{-3} (target value: no more than 25 days per calendar year). Such maps allow to locate the zones with concentrations of pollutants exceeding limit values and on which, according to 96/62/EC Directive, action plans have to be developed. The analysis of Figure 5 evidence unattainment areas for nitrogen dioxide mainly within Turin and Milan urban cores and covering the eastern part of the regional territory as well as northern to Turin urban area for ozone.

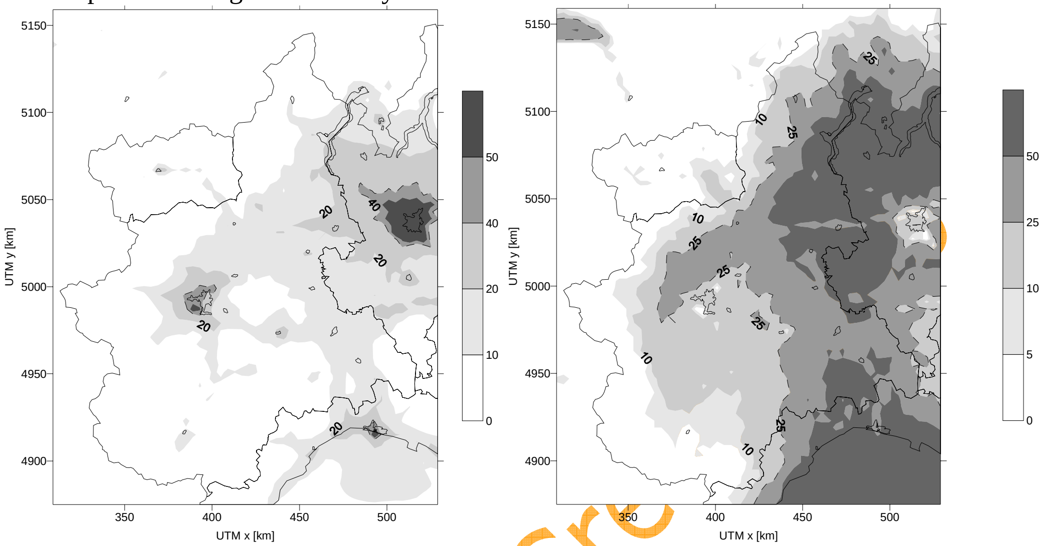

Fig. 5; NO_2 yearly averages (left) and the number of days for which maximum ozone daily 8-hour means exceed the value of 120 mg m^{-3} (right).

The limited number of PM10 experimental sites available during 1999 make even more significant the information provided by the AMS since this pollutant represent one of the most relevant environmental concern in Po Valley especially during wintertime when thermal inversion and frequent calm conditions generally lead to elevated particulate levels. Figure 6 show the number of days for which daily PM10 means exceed the value of 50 μg m^{-3} (target value: no more than 35 days per calendar year from 1/1/2005 and 7 days from 1/1/2010). The analysis of this map evidence critical areas within Turin and Milan urban cores; the estimated number of exceedances is although lower than those provided, in more recent years, by the regional air quality monitoring networks. This underestimation of PM10 levels may be attributed to a number of factors: uncertainties in the emission inventory, overestimation of fluxes within the modelling area (diagnostic adaptation to the regional territory of national-scale meteorological fields estimated by RAMS model) and to the adopted aerosol modelling approach, not including condensation of organic gases on the atmospheric particulate and resuspension processes.

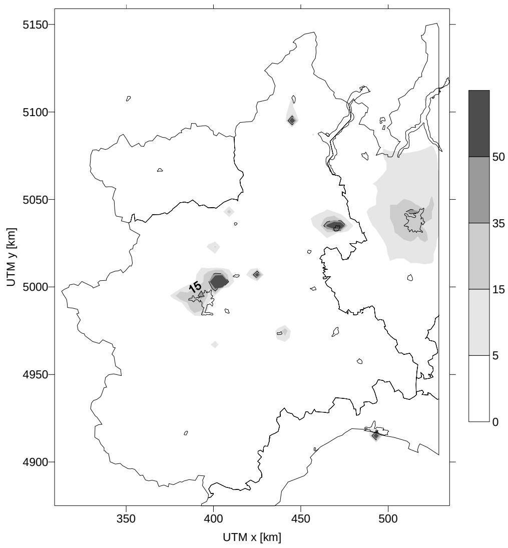

Fig. 6; Number of days for which daily PM10 means exceed the value of 50 mg m^{-3}.

CONCLUSIONS

The results obtained in this study confirm the importance of air pollution modelling in assessment and management of regional air quality. The complementary use of state-of-science photochemical models (adequately fed by meteorological drivers and detailed regional emission inventories) and measurements provided by the air quality networks allows in fact to obtain an adequate description of the spatial distribution of atmospheric pollutants and to identify, according to EU Directives, unattainment areas for which action plans have to be developed. This study has evidenced that environmental concern in Piemonte region is related to ozone in large portions of the territory, and to nitrogen dioxide and to PM_{10} generally during the winter season around main urban areas.

These results encourage the application of the AMS to more recent years and its use to investigate the impact of future emission control strategies on air quality. In this perspective emission scenarios related to vehicular traffic and domestic heating sectors have been recently investigated. Moreover, year 2004 is also being simulated, with the introduction of some variations mostly related to data feeding, setting the basis for a regular year-by-year use of the AMS for air quality assessment.

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