EULERIAN MODELLING APPLICATION FOR A HIGHWAY AIR QUALITY IMPACT ASSESSMENT

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Abstract: This study presents the results obtained using a modelling system to assess the impact of a new highway (about 33 km long) in the central part of the Veneto Region (Passante Project). Within this project the modelling system is a part of a more complex integrated Air Quality assessment tool that includes also monitoring activities.
The modelling system has been run for a whole year both for the baseline scenario referred to the *ante operam* situation and for the future scenario with the highway in its operational phase, in order to obtain the annual pollutant level statistics required by the European Air Quality Legislation.

Key words: *Air quality assessment, euleriano modelling, traffic emissions, FARM.*

INTRODUCTION

The "Passante di Mestre", the blue line in Figure 1, is a new highway, part of the A4 Italian motorway, in the Eastern area of the Veneto Region, opened to traffic at the beginning of 2009. About 33-km long, it allows the West-East long-distance traffic between Turin and Trieste and torward Eastern Europe to by-pass the "Tangenziale di Mestre" (green line in Figure 1), the local beltway of the Venice mainland. In this way, the Mestre ring road, formerly driven by 150000-170000 vehicles per day, is now used by local traffic among the three towns of Padua, Treviso and Venice.

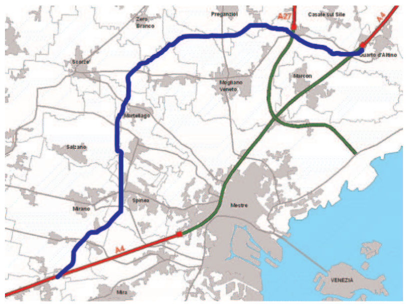


Figure 1: Mestre – Venice road system

The atmospheric modelling system described in this study allows to conduct a scenario analysis of the air quality state based on hypotheses about the traffic fluxes induced by the new route on the whole road network around Mestre. Together with the monitoring network, it is also a tool used by the Veneto Region Environmental Protection Agency (ARPAV) to assess the new highway impact on the air quality.

MODEL AND SIMULATIONS

The atmospheric modelling system (AMS) consists of four subsystems used respectively to reconstruct flows and related turbulence parameters, apportion data from the emission inventories to grid cells, perform air quality simulations over the selected domain and compute air quality indicators required by the EC directives. The AMS is based on FARM model (Flexible Air quality Regional Model, Silibello *et al.*, 2008; Gariazzo *et al.*, 2007) that has been applied with the SAPRC-90 (Carter, 1990) chemical mechanism and the aero3 modal aerosol scheme implemented in CMAQ framework (Binkowski, 1999; Binkowski and Roselle, 2003). Time varying boundary conditions for all modelled species on the regional domain have been derived from the corresponding three-dimensional fields coming from PREV'AIR system based on CHIMERE chemistry-transport model (http://prevair.ineris.fr/en/modele.php).
Meteorological fields needed by FARM model have been provided by means of the diagnostic model SWIFT/MINERVE (Desiato *et al.*, 1998) using local data coming from the regional meteorological network.
The meteorological fields together with land cover information (e.g. roughness length) and chemical species characteristics (gas reactivity), have been then used by interface module GAP/SURFPRO (Finardi *et al.*, 2008; FUMAPEX, 2006) to produce dry deposition velocities and turbulent diffusivity fields needed by FARM.

Domain

The modelling system has been applied on a 60 x 50 km^2 domain (map in Figure 2), with a 1-km horizontal resolution, including, besides the Mestre-Venice urban system, also the larger Padua – Treviso – Venice urban area, involved in the road network reorganization. The horizontal resolution choice is the result of a balance between a quite detailed description of the emission line sources and the computational time.

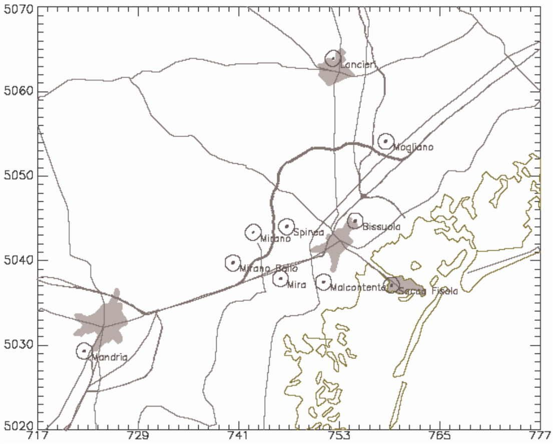
Meteorological scenario

In order to obtain the long term pollutant level statistics (annual mean, number of exceedances per year of the different limit values) provided by the European Air Quality legislation (Directive 2008/50/EC), the simulations have been applied for a whole base case year (2005).
The meteorological module has been fed by observed data from 20 meteorological surface stations, 1 off shore station, 3 radio-sounding stations and 1 SODAR. The same meteorological fields are used to drive the dispersion module for both the base case and the future scenario.

Emission scenarios analysis

The emissions coming from diffuse sources over the considered domain were derived from the national emission inventory for the year 2000 (APAT, 2004), except from traffic, not covered by a specific road network, that was also projected to the simulated year using national trends differentiated for each pollutant and activity . A more complete approach has been adopted to estimate emissions coming from major industrial facilities and traffic over the investigated area. The former have been estimated on the basis of an exhaustive inventory performed by the Regional Environmental Agency that includes major facilities present in the area: thermal power plants, refineries and cement factories (Gnocchi *et al.*, 2005). As for traffic emissions, the availability of detailed data (flows and velocities for different kind of vehicles: motorcycles, cars, light and heavy duty vehicles, trucks and buses), coming from a traffic assignment model applied on a road network made up of more than 6000 links has suggested the use of TREFIC model (Nanni and Radice, 2004) to estimate such emissions. The road network covers a large part of the investigated area (Venice and adjacent provinces) while the emission model implements COPERT III (Ntziachristos and Samaras, 2000) approach and includes IIASA emission factors for the treatment of PM (IIASA, 2001).

Two traffic scenario were analyzed: first, the traffic volumes on the existing network were updated from 2000 to 2005 on the basis of the current annual traffic increment rate observed at four counting sections (+1.85%); second, the increment on the existing network was extended to 2008, the “Passante” source was added to the network and foreseen modifications to traffic volumes of existing network have been applied. These last consisted essentially in an increase of private traffic (+53%) in the first link of the “Tangenziale di Mestre”, a decrease of commercial traffic (about -10%) in the remaining links of it and a general decrease of traffic along three other major roads (“Miranese”, “Castellana”, “Terraglio” - between –11% and –53% -). The fleet distribution used for 2005 comes from real local statistics. They were extrapolated to 2008 on the basis of the national market trends also referred to 2005.



Station	Type
Bissuola (Mestre) Lancieri (Treviso) Mandria (Padua) Saccafisola (Venice) Mogliano Mirano	urban background
Mira Spinea	urban traffic
Malcontenta	industrial

Figure 2: Left: model domain and location of monitoring sites. Right: characteristics of the monitoring sites considered in the study.

MODEL PERFORMANCE

In this study the discussion is focused on two pollutants that are critical for the air quality in the Veneto Region namely nitrogen dioxide and particulate matter. For both of them, the current European legislation mirrored in the Italian legislation prescribes that the annual mean of concentration value shouldn’t exceed the value of 40 $\mu g/m^3$.

The model performance is evaluated by comparing the monitoring stations data available for the year 2005 (7 stations for NO_2 and 5 stations for PM10 inside the model domain, see station location and characteristics in Figure 2) and the model results for the base case.

In Tab.1 estimated and measured annual mean concentrations are shown for both NO_2 and PM10; statistical parameters are based on annual series of hourly concentrations for NO_2 and daily concentrations for PM10.
The annual mean concentrations are represented by scatter plots in Figure 3.

Table 1: Comparison between model results and measured data: statistical parameters based on annual series of hourly (NO_2) or daily (PM10) data.

	NO₂					***PM10***				
Station	**Model [µg/m³]**	**Meas. [µg/m³]**	**Bias [µg/m³]**	**St. Dev. [µg/m³]**	**Correl.**	**Model [µg/m³]**	**Meas. [µg/m³]**	**Bias [µg/m³]**	**St. Dev. [µg/m³]**	**Correl.**
Bissuola						35.6	47.7	-9.0	26.3	0.79
Lancieri	30.7	38.9	-7.8	21.9	0.58	29.5	44.7	-13.0	24.5	0.77
Mandria	40.5	41.4	-0.6	23.6	0.61	42.3	52.1	-4.2	25.7	0.69
Sacca Fisola	31.3	35.0	-3.7	22.7	0.55	36.4	40.4	-3.6	22.1	0.70
Mogliano						30.8	42.8	-8.2	24.5	0.73
Mirano	33.8	35.8	-1.9	22.7	0.71					
Mira	36.2	42.9	-6.0	29.7	0.63					
Spinea	34.0	39.8	-9.6	23.0	0.53					
Malcontenta	36.9	46.0	-9.3	27.2	0.67					

The annual mean concentration of NO_2 exceeds the limit value of 40 µg/m^3 at the sites of Mandria, along the Padua ring road, Mira, along the A4 motorway, and at the industrial site of Malcontenta. At the other sites, the NO_2 levels are a little lower than the legal limit. At all monitoring stations the PM10 annual mean concentration is above the legal limit of 40 µg/m^3. The model presents a generalized light tendency to underestimate the measured values, the uncertainty is well between ±30% for NO_2 and between ±50% for PM10, as the EU directive prescribes for annual averages model estimates.

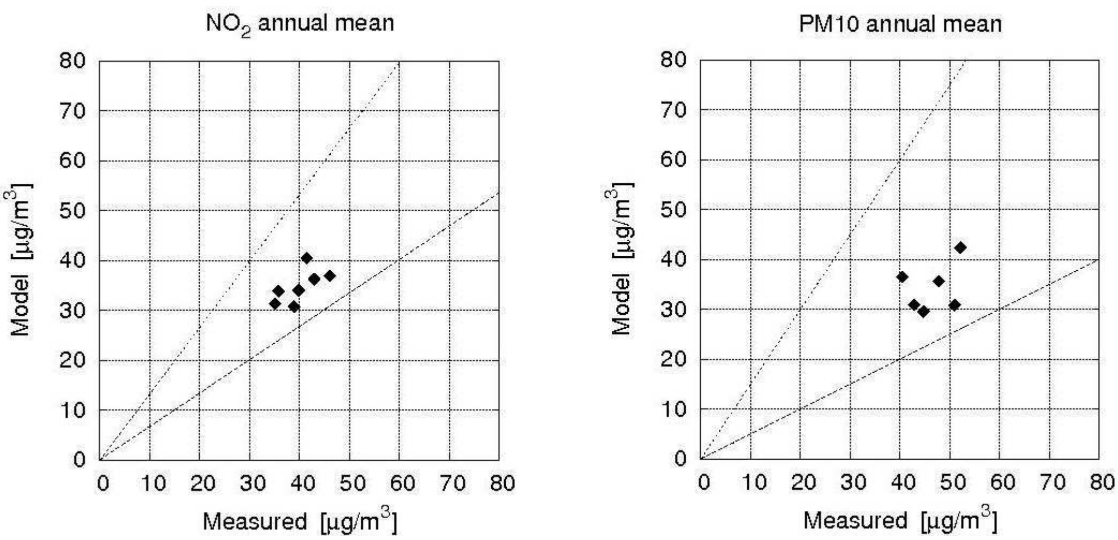


Figure 3: Comparison between measured (abscissa) and model estimated (ordinate) annual mean concentration of NO_2 (left) and PM10 (right) at the monitoring stations. The dotted lines correspond to a difference of ± 30% between model and measures data for NO_2, and ± 50% for PM10, as EU requires for model estimates.

IMPACT ANALYSIS

Figure 4 shows annual mean concentration maps for NO_2 (left panel) and PM10 (right panel): at the top panels the base scenario, in the middle the future ones and at the bottom the difference between the future and the base ones. In the difference maps, positive values mean an increase in concentrations for the future scenario. In all the maps the road system and the coastline are represented as well.

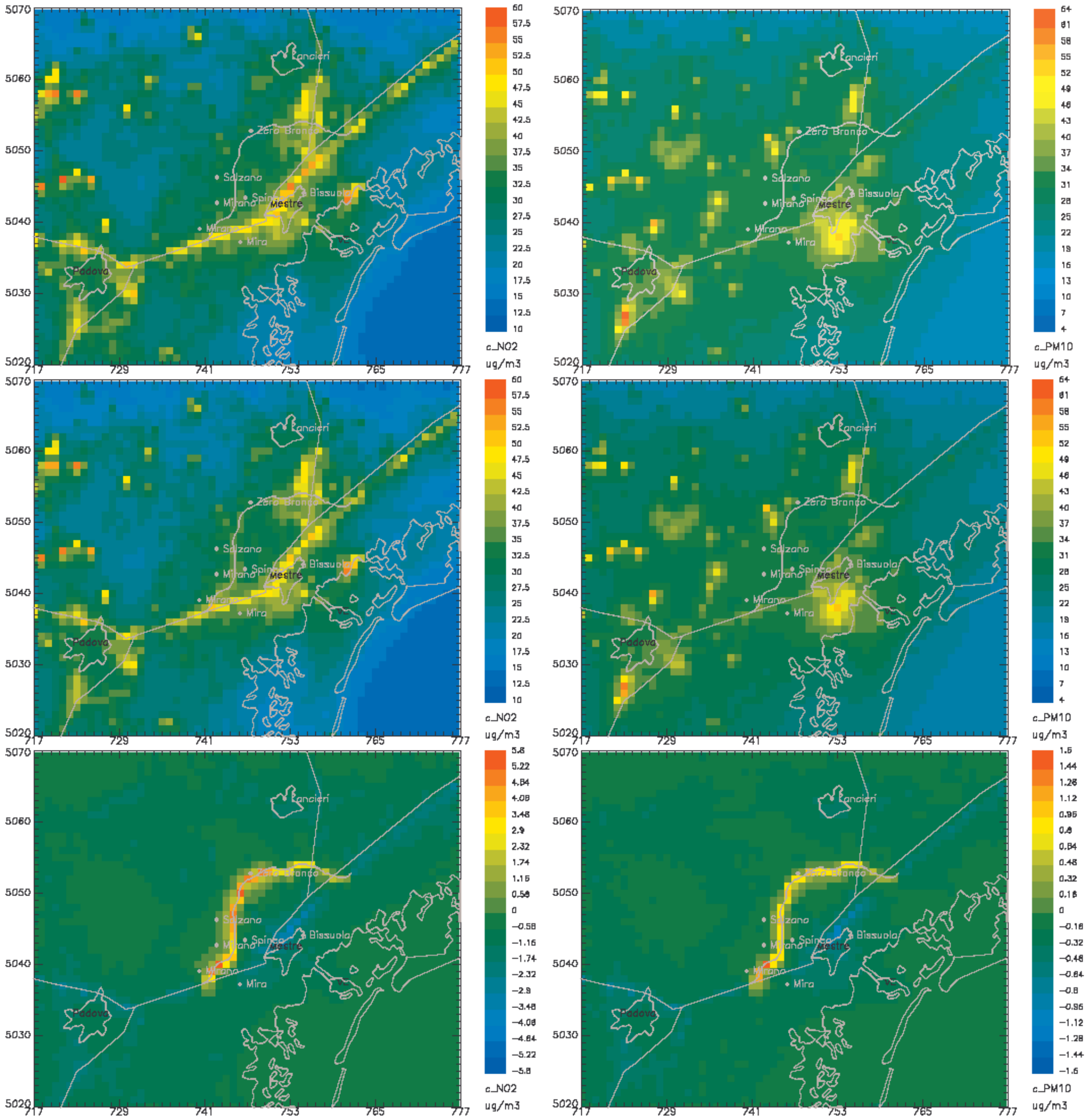


Figure 4. NO_2 (left) and PM10 (right) concentration maps for base case (top), future scenario (middle) and difference between future and base scenarios (bottom).

In the base scenario map, NO_2 records the highest concentrations along the Mestre ring road. High concentrations, exceeding the annual limit value, are calculated along the Padua ring road and at the Venice airport as well. In the difference map the increase in concentration values along the new highway is stronger than the decrease along the Mestre ring road.
For PM10 highest concentrations, exceeding the annual limit value, are calculated at South of Padua and in the urban area of Mestre. As previously commented for NO_2, the PM10 difference map records a stronger increase along the new highway than the decrease along the Mestre ring road.

In Figure 5 the percentage differences between future and base scenarios at the monitoring sites are plotted. For NO_2 (left panel) the graph highlights how all the sites, even those located along the new highway, have a decrease in concentrations. The increases previously commented for the maps are in fact confined in a narrow line along the road. As far as PM10 is concerned, the sites in the surroundings of the urban area of Mestre (Bissuola), Venice (Sacca Fisola) and Padua (Mandria) shows a decrease, while the site along the new highway (Mogliano) shows an increase.

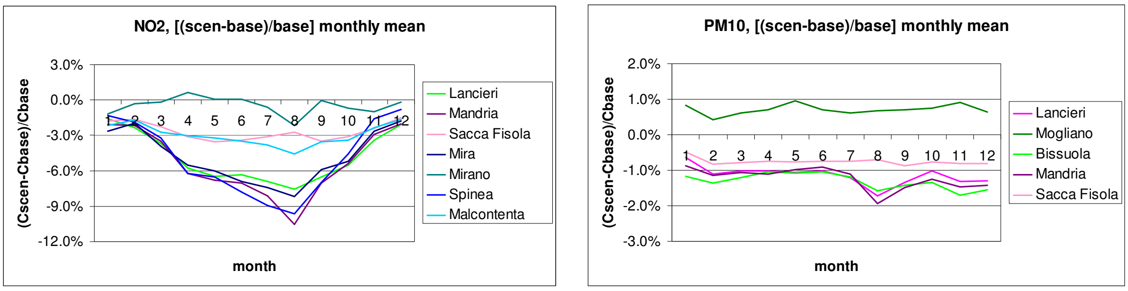


Figure 5. Scenario percentage differences for monthly means concentration (NO_2 left, PM10 right) at monitoring sites.

CONCLUSIONS

This work confirms the capability of modelling techniques to reconstruct a base case scenario (year 2005, assessment) and to evaluate the impact of important infrastructures on air quality levels (future scenario, management). The comparison between observed and estimated NO_2 and PM10 concentrations for the base case scenario evidences a good agreement confirming the use of the adopted modelling system to estimate the impact of “Passante di Mestre” opera on surrounding areas.

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