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MODELLING THE AIR QUALITY IMPACT OF INDUSTRIAL EMISSIONS OVER A RIVERVALLEY IN THE CAMPANIA REGION, SOUTHERN ITALY

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Abstract. The air quality modelling system RAMS-CALMET-CALPUFF was used to simulate local meteorology and atmospheric dispersion of pollutants emitted from various industrial sources and from a highway located in a valley in southern Italy. The aim of the study is to support decision makers and stakeholders in the management of air quality in an industrial area where neither air quality nor meteorological parameters are routinely monitored. Model evaluation was performed in a period coincident with a field measurement campaign. Comparison between meteorological predictions and measured data showed the capabilities of the model system to reproduce the wind field complexity along the valley. Thediscrepancies shouldbe furtherinvestigatedwhen they havemore meteorological surface and vertical profile data. The simulations of different emission scenarios highlight the need to routinely monitor the concentrations of NOx and PM10.

Key words: *Valley, air quality, planning, mitigation, Campania*

INTRODUCTION

Industrial development poses both environmental threats along with economic advantages. Dispersion modelling studies are useful tools to support decision makers to address air quality problems in industrial areas where monitoring data are not available.

This study was promoted by the Province of Avellino (Campania Region, Italy) and a civil society organisation with the aim of assessing the impact on the atmosphere of a group of five industrial plants located on the bottom of a wide valley (Pianodardine) and whether the concentration of pollutants would justify actions in air quality management, at least for the regular monitoring of certain substances.

The study was conducted in two steps. Firstly, it was necessary to collect information on emission rates: both permitted emission levels and self-monitoring data were analysed and compared with each other and with Life Cycle Assessment methodology to identify effective mitigation strategies, then the air quality modelling system RAMS-CALMET-CALPUFF was used to simulate the atmospheric dispersion of pollutants and their impact on the ground.

As vehicular traffic another major source of air pollution in the area, for comparison, we decided to simulate the dispersion of pollutants from the highway that crosses the valley, through a rough estimate of the volume of heavy and light traffic.

STUDY AREA AND EMISSIONS

Pianodardine valley (around 40.9 N, 14.8 E, 290 m a.s.l.) is a wide valley along the SSW-NNE direction (Fig.1), surrounded by hills (many of them topping below 1000 m a.s.l., up to the maximum altitude of about 1350 m a.s.l.). The valley islocatedin the Provinceof Avellinoin the central-southern Italy.

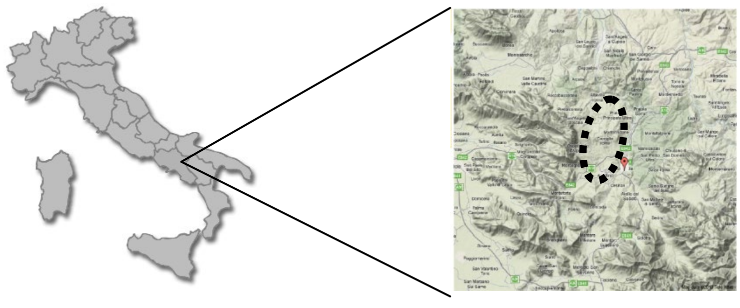

Figure 1. The study area. Pianodardine valley is marked with dots on the right .

Emissions come mainly from five industrial plants, from a highway and other local roads. Each industrial plant has a number of emission points. In this study, 82 stacks with significant emissions were considered. Table 1 summarized the average overall characteristics of each industrial plant. Two emission rates were considered: the first one derived from authorizations by the local authorities as the worst of cases, the other derived from self-monitoring.

Table 1. Stack characteristics and pollutants emission rates as resulted from permission (left column (p)) and from self-measured data (right column (s)).

Plant Code	LONG (N)	LAT (E)	Averaged stack height (m)	PM_{10} (gs^{-1})		NO_X (gs^{-1})		SO_2 (gs^{-1})		NMVOC (gs^{-1})	
				(p)	(s)	(p)	(s)	(p)	(s)	(p)	(s)
N	14.833	40.966	18.9	4.76	0.77	11.44	6.15	2.86	0.89	0.42	0.13
F	14.841	40.976	21.7	37.6	1.13	25.9	4.37	0.56	0.56	0	0
C	14.818	40.936	10.4	0.09	0.01	5.76	1.39	13.52	0.01	12.13	1.69
D	14.825	40.936	12.5	3.1	2.15	0.4	0.18	0	0	1.54	1.95
C	14.824	40.938	8.5	0.16	0.16	0.01	0.01	0.09	0.09	0.01	0.01

The differences between the two sets of data range from zero to a few orders of magnitude. The simulations with the most severe cases have been carried out to allow local authorities to assess the cumulative effect of the amount of permitted emissions.

With regard tothe emissionof pollutantsfromhighway traffic, the fluxes of heavy and light vehicles were estimated from raw data (Vehicle d^{-1} on the average of a year, and the rate of the flux of heavy and light vehicles per hour during the day) obtained from the highway company; the emission rate for each pollutant were obtained with the integration of flux data and emission factors from ETH inventory.

In the area there is neither a monitoring air quality network nor meteorological measurements. The only data available are for an experimental campaign carried out by the Regional Environmental Campania in March 2005 in 6 different positions with five days of continuous measurements at each point.

THE AIR QUALITY MODELLING SYSTEM

The study of air pollution in a valley involves many physical processes related to the peculiarity of meteorological and dispersive characteristics of such complex topography. Valleys may be affected by processes such as flow channelling, sheltering, cold-air pooling, drainage, slope flows, and plume impingement on higher terrain. Thus local circulations are superimposed on large scale motions, modifying the mean flow, the turbulence field and dispersion regimes. This requires a careful reconstruction of the 3-D wind field in which to simulate the transport and dispersion of pollutants.

The modelling system used in this study merges the prognostic meteorological model RAMS (Pielke et al., 1992), the micrometeorological model CALMET (Scire et al. 2000a) and the dispersion model CALPUFF (Scire et al. 2000b). RAMS wind fields are used as input for CALMET, which provides all boundary layer inputs needed in CALPUFF.

The simulations with RAMS were carried out in a two-way nested grid configuration with three grids in a polar stereographic coordinate system (Figure 2).

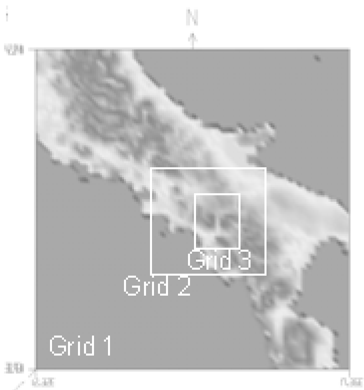

Figure 2. Modelling domain and the three meteorological nested grids.

The coarsest grid (grid1 in Figure 2) has a resolution of 30x30 horizontal grid points with a grid spacing of 16 km; the medium grid (grid 2, Figure 2) has a resolution of 34x42 horizontal grid points and a grid spacing of 4 km. The inner grid has a resolution of 34x42 horizontal grid points with a grid space of 1km. The atmosphere is vertically divided into 25 levels of different thicknesses, ranging from 100 m near the surface, gradually stretching up to a maximum of 1000 m at the top. Initial and boundary conditions have been based on mesoscale analyses produced by means of the RAMS pre-processor ISAN, (Isentropic Analysis System (ISAN). ISAN implements an optimal interpolation method based on Barnes algorithm. Analyzed fields are based on the ECMWF grid data available every 6 hours with a horizontal space resolution of 0.5 degrees. Horizontal domains and grid sizes were designed taking into account both computational time limitations and the capability of the model to resolve essential mesoscale and local features over the area.. RAMS wind field over the inner grid were then ingested by the CALMET pre-processor CALRAMS to be used ad as input for CALMET model which ran in UTM coordinate system. The domain size and grid spacing specifications are provided in Table 2

Different periods in 2005 were simulated. Here, we present the results for the period 1-15 march 2005 in which some experimental data were availablefor comparison.

MODEL RESULTS

Meteorological simulations

Results from model evidence how due to channelling, winds tend to follow the valley orientation with a marked diurnal/nocturnal cycle. At night, cold downslope winds blow down the sidewalls, while during the morning the valley atmosphere becomes coupled with the atmosphere above the valley.Calm wind conditions along the valley area highly frequent during the first part of day, increasing ground level pollutant concentration. Figure 3 shows an example of the flow pattern at ground obtained with the meteorological model at 8:00 UTC on 3 March 2005.

Table 2. Main characteristics of the domains used in RAMS and of the one used in CALMET and CALPUFF models. Lx, Ly and Lz are domain sizes in the x, y and z directions, respectively. Nx, Ny and Nz are the number of mesh points in the x, y and z directions, respectively. Dx and Dy are the mesh spacing in the x and y directions, respectively.

	Nx	Ny	Nz	Dx (km)	Dy (km)	Lx (km)	Ly(km)	Lz(km)
Rams Grid 1	30	30	25	16	16	480	480	13
Rams Grid 2	34	42	25	4	4	136	168	13
Rams Grid 3	34	42	25	1	1	34	42	13
Calmet/Calpuff	56	74	10	0.5	0.5	28	37	3

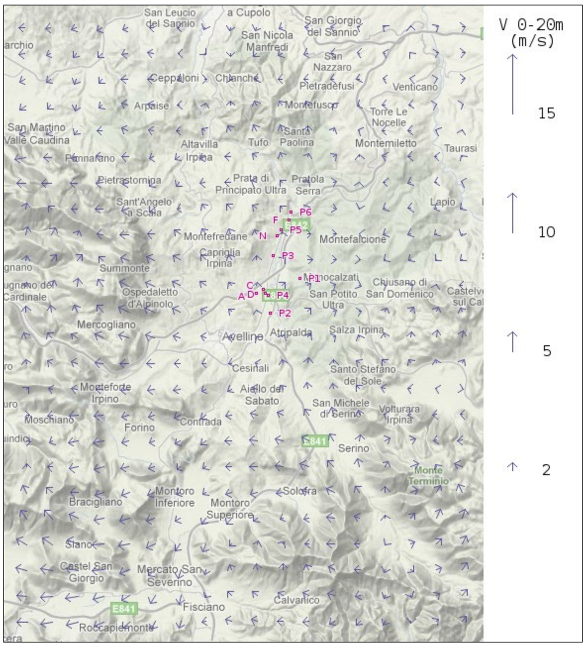

Figure 3.Horizontal wind vectors at ground as simulated by the meteorological models at 8:00 UTC on 3 March 2005. Squares indicate the positions of industrial plants, P1-P6 indicate the position of monitoring samples during the whole field campaign.

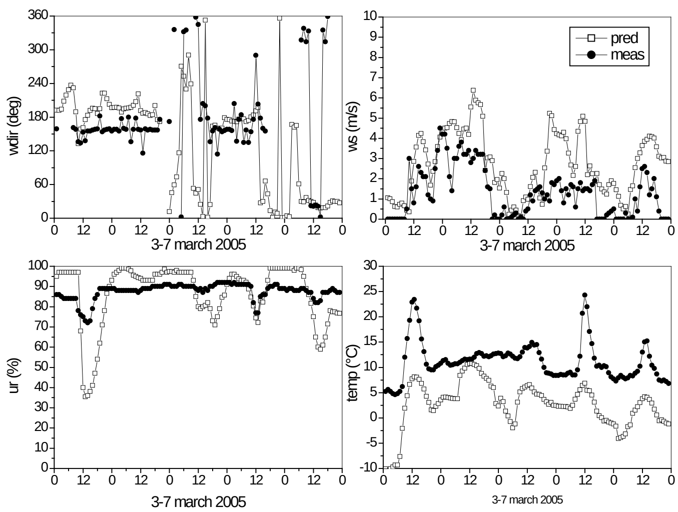

Figure 4. Temporal variation of near surface wind speed (ws) (m s−1), wind direction (wdir) (deg), temperature (temp) (°C) and humidity (ur)

(%) at the P4 site for the period 3-7 marzo 2005.

Figure 4 shows a comparison between model predictions and measured data at the P4 site for the period 3-7 march 2005 for wind direction and speed, temperature and humidity. To evaluate the model performance over the considered period, we used the following statistical indices for wind speed, humidity and temperature (Hanna and Yang, 2001): the mean bias as an absolute as well as arelative value, the root mean square error, the correlation coefficient. Due to the rotating scale of the wind direction, only absolute indices were considered for wind direction.

Table 3. Meteorological model performance measures forhourly average wind speed, wind direction and temperature atthe surface.

Statistical indexes	
Wind speed MB	-1.4
Wind speed fb	-0.7
Wind speed nmse	0.93
Wind speed cor	0.72
TemperatureMB	8.53
Temperature fb	1.23
Temperature nmse	2.83
Temperature cor	0.72
Humidity cor	0.642
WdirMB	5
Wdir rmse	29.3

Results evidence an acceptable agreement between predicted and measured wind direction. A high correlation between measured and predicted wind speed is also evident even if with a clear tendency of model to underestimate the measured data. Temperature corresponds quite poorly to the measurements.Model tends to underestimate data during the whole period, probably due to both to the insufficient spatial resolution of meteorological models and to the scarce representativeness of measured data. This has been confirmed by analysing the minimum/maximum temperature measured at three agro-meteorological stations in anearby area which values are more closer to the predictions. Discrepancies may also be due to the microphysics scheme adopted in RAMS and this explains also the differences in the humidity field. The scarcity of surface measured data and the lack of vertical profiles of meteorological variables make it difficult a deeper model evaluation.

Dispersion simulation

Simulations with Calpuff have been performed for all pollutants. Figure 5 shows the ground level concentration of NOx averaged over the 1-15 march 2005 period, considering both permitted and self-controlled emission data. Figures shows as pollutants distribute along the axis the valley with maximum average values ranging between 10 μgm^{-3} considering self-controlled emission data and 30 μgm^{-3} considering permitted emissions. The NOx pattern obtained by simulating the emissions from the highway crossing the valley evidences how the impact of the motorway is comparable with the same order of magnitude, but obviously with different spatial distribution.

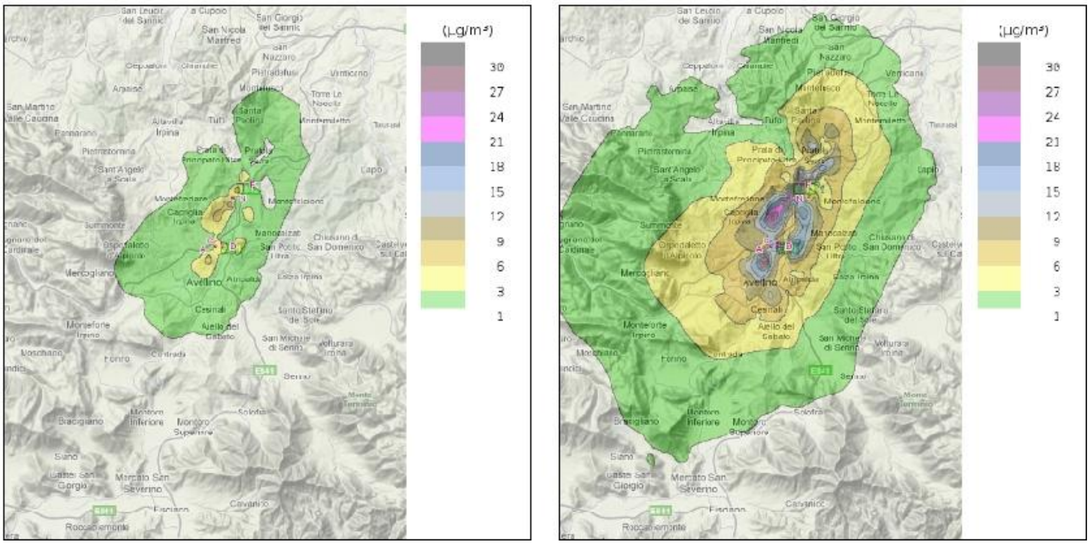

Figure 5 Average Ground level concentration of NOx averaged over 1-15 march 2005. Left: self-monitored input data set. Right: permission (worst case scenario) input data set.

CONCLUSIONS

Numerical simulations were performed to simulate the impact of several industrial sources and a highway in a valley in southern Italy, where neither air quality nor meteorological parameters are routinely monitored.

Model evaluation was performed in a period coinciding with an experimental campaign made during the 2005.The comparison between meteorological predictions and the few measured data has shown the capabilities of the RAMS/CALMET/CALPUFFmodeling system to reconstruct the wind field along the valley. Major discrepancies occurred for temperature with a clear tendency of the model to underestimate the measurements. The complexity of topography and its influence on the mean flow suggests the need to have available more meteorological surface and vertical profile data.

In order to provide information to decision makers and stakeholders, the impact of different emission scenarios (authorized emissions, emissions on the basis of self-monitoring) was simulated in different seasons. Significant differences occurred for each pollutant. The worst case scenario has helped to identify as NOx and PM_{10} can reach critical levels especially in unfavourable meteorological conditions for air pollution dilution. Moreover, the impact of the highway traffic has been roughly simulated, making it clear that the industrial sector and vehicle traffic atmospheric loads may be of the same order of magnitude, even if with different spatial distribution.

The overall work has provided practical recommendations to equip the area with monitors for both meteorological parameters and concentrations of NOx and PM_{10} , since industrial and vehicle (from both highway and local roads) emissions, added to domestic sources, may potentially infringe air quality standards. Local authorities, entrepreneurship and civil society have been provided a conceptual instrument useful to understand that the atmosphere does not have an unlimited capacity to dilute pollution, and to plan the implementation of mitigation strategies and technologies in achieving the goal of sustainable air quality standards.

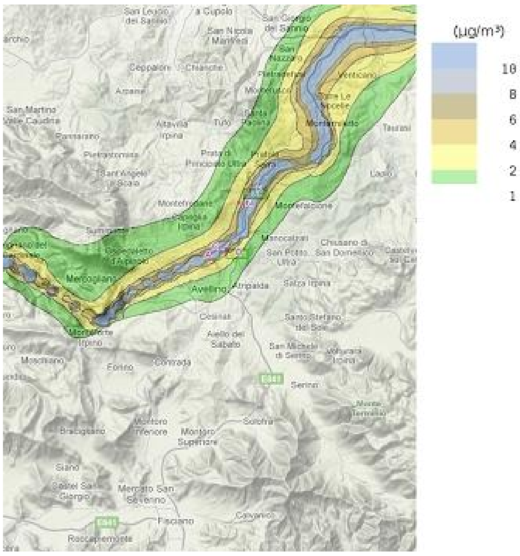

Figure 6 Map of NOx concentrations as simulated by the modelling system averaged over 1-15 march 2005.

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