H13-47
AIR QUALITY FORECASTING SYSTEM IN A DOLOMITIC VALLEY: PERFORMANCE COMPARISON BETWEEN EXPECTED AND MEASURED DATA.

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Abstract: An air quality forecasting system named SKYNET was designed for the Belluno Valley, a mountainous area located in the Dolomites mountain range. ARPAV Belluno Department performed a local emission inventory based on a bottom-up approach with particular detail on the estimation of domestic heating contribution, which was investigated through the use of more than 5000 questionnaires submitted to the population. The model has been tested in a winter period of 4 months by comparing the PM10 and NO_2 forecasts for following 48 hours with the experimental data derived from two air quality stations located in Belluno and Feltre urban areas. The SKYNET performances have been evaluated with statistical indexes, and the results are overall good for both the stations. There is a particular agreement in the Belluno area, while the model reveals the tendency to under-predict the PM10 values in Feltre. The information generated by the model and a precise knowledge of the emission sources derived from the bottom-up inventory allowed to create an experimental air quality forecasting bulletin tested on a two month period, which gave reliable predictions both in Belluno (80%) and Feltre (71%).

Key words: *air quality forecasting, meteorological modelling, air quality forecasting bulletin, alpine valley.*

1. INTRODUCTION

Air quality forecasting is one of the requirements of the new Air Quality Framework Directive (2008/50/CE). This directive on ambient air quality and cleaner air for Europe was adopted on April 14, 2008 and sets a particular focus on the introduction of modelling as a necessary tool for Air Quality Assessment (AQA) and Air Quality Management (AQM). It states rigid air quality standards, along with the obligation to inform the population through clear and direct advice about actual or predicted exceedances of alert thresholds. This new context leads to the designation of an air quality forecasting system called SKYNET for the Belluno Valley, which is located in the Dolomites mountain range, a new UNESCO heritage site.

The Belluno Valley is an asymmetrical and large basin surrounded by Prealpi and Dolomites mountain range, crossed by the Piave river which passes through the Prealpi mountains to arrive in the Po Valley. This zone is characterized by a high level of natural beauty, with a national park of 32,000 ha and a low anthropic level. The main urban areas are Belluno (36,000 inhabitants) and Feltre (19,000 inhabitants).

In this context, meteorology is one of the most important determinant factors. The Belluno basin boundary layer often appears like a dense and stagnant "lake" where strong air stagnation is often disconnected with free atmosphere flow. A microscale wind study shows a very high frequency of persistent air stagnation, especially during the cold season when aerological conditions determine a critical concentration of fine dust in the low atmosphere. Many winter days are marked by a very low wind speed (89% hours under 0.5 m/s in winter at Feltre and 69% at Belluno) and fog episodes. Furthermore, as a consequence of strong temperature inversion profile, the vertical dispersion is not possible.

In the last period, air quality stations in the valley failed to comply with the maximum number (35) of exceedances of PM10 daily human health protection limit (50 $\mu g/m^3$) and recorded high levels of B(a)P repeatedly higher than the legal limit (1 ng/m^3). Due to these critical aspects, it is mandatory to investigate the pollutants origins and dispersion by means of a modelling system and an accurate emission inventory.

2. THE ATMOSPHERIC EMISSION INVENTORY IN THE BELLUNO VALLEY

An atmospheric emission inventory is an essential tool to recognize the pressures acting on a territory. At the same time, it is an instrument that can be used in numerical dispersion models to study future scenarios.

Therefore ARPAV Belluno Department performed a local inventory based on bottom-up approach. A special attention has been paid on industrial processes, road traffic and domestic heating, even though the database includes off-road means (farming and railways) and other sources.

In the valley there are about 150 factories submitted to periodical chemical analysis, and the 20 most important activities performed about 90% of TSP (Total Suspended Particles) from industrial sector. In order to estimate the traffic contribution, about 60 roads in the valley have been considered to obtain mean hourly traffic flows.

Particular detail was dedicated to the estimation of domestic heating contribution, which was investigated through the use of more than 5000 questionnaires submitted to the population. Data concerning fuels and combustors, with particular reference to firewood, were obtained.

In respect to PM10 pollution, domestic heating plays a very important role, and wood combustion stands out among combustibles (Figure 1). In fact, more than 80% of families use almost only a stove for heating, with a great number of traditional stove plants characterized by a low combustion efficiency and high emissions (Figure 2). On the other hand, road traffic and industry are the main sources for NO_2 emissions.

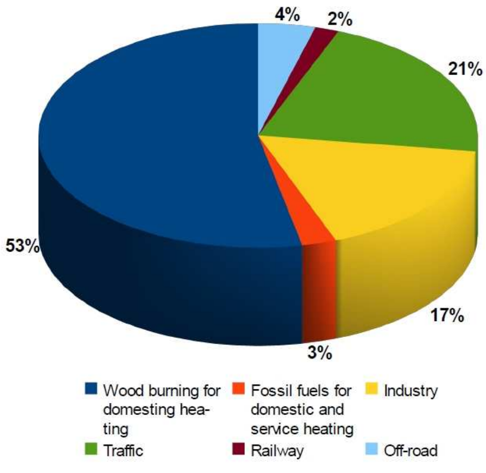

Figure 1. PM10 emission inventory (yearly amount of 386.6 Mg/y)

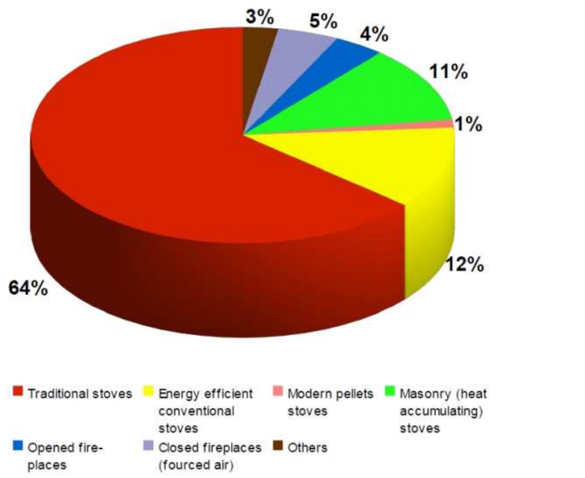

Figure 2. Contribution of various combustors to yearly PM10 emission (205.8 Mg/y) from biomass burning for domestic heating

3. MODELLING SYSTEM CHARACTERISTICS

The Air Quality Forecasting System (AQFS) SKYNET is realized through modelling system built by 4 modules:

5. prognostic meteorological model RAMS for synoptic weather downscaling, description of local scale atmospheric flow and providing the meteorological fields.
6. interface module SWIFT/GAP/SurfPRO for estimation of atmospheric turbulence and dispersion parameters
7. emission processor EMMA (Emission Manager) to provide gridded emissions of the pollutants starting from the emission inventory
8. Eulerian Chemical Transport (CTM) model FARM (Flexible Air quality Regional Model, Silibello *et al.*, 2008; Gariazzo *et al.*, 2007) to describe transport, dispersion, deposition and chemical reactions of pollutants to perform air quality simulations over the selected domain

The entire architecture system is shown in Figure 3.

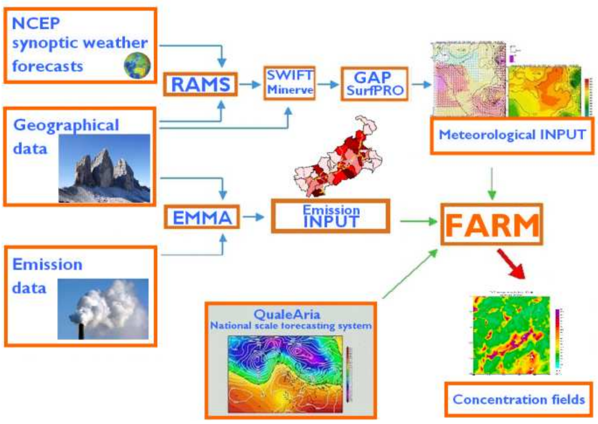

Figure 3. The AQFS system architecture.

SKYNET has been operational since June 2009 and after several evolutions, it found its standard configuration in November 2009. Therefore, for data analysis it has selected the time period November 2009 – February 2010.
The AQFS (Air Quality Forecasting System) works on a computational domain of 66 x 67 cells at 1 km of horizontal resolution and 10 vertical levels. This fine resolution run allows a good description of all sources acting in the zone.

The meteorological fields that are necessary to realize air quality forecast come from numerical weather predictions provided by the United States meteorological service (NCEP). Mesoscale and local scale meteorological fields are achieved applying the non-hydrostatic meteorological model RAMS, by using 4 nested computional grids with 32, 16, 4 and 1 km space resolution. On a daily basis, RAMS provides hourly 3D forecast for the meteorological fields that cover two days forward. The boundary conditions are provided by a national-scale forecasting system QualeAria - http://www.aria-net.eu/QualeAria/ - which is part of Chemical Weather Forecast Network promoted by COST ES0602 Action – see http://www.chemicalweather.eu/.

EMMA computed gridded hourly emission rates of all emission data available for AQFS by using specific cartographic thematic layers and time modulation profiles (yearly, weekly and daily) and non-methanic hydrocarbon speciation profiles.
Finally, FARM has been applied with the SAPRC-90 (Carter, 1990) chemical mechanism and the aero3 model aerosol scheme implemented in CMAQ framework (Binkowski, 1999; Binkowski and Roselle, 2003).
In the following figure (Figure 4) the 4 nested grids adopted by RAMS model and the target computational domain considered by FARM are shown.

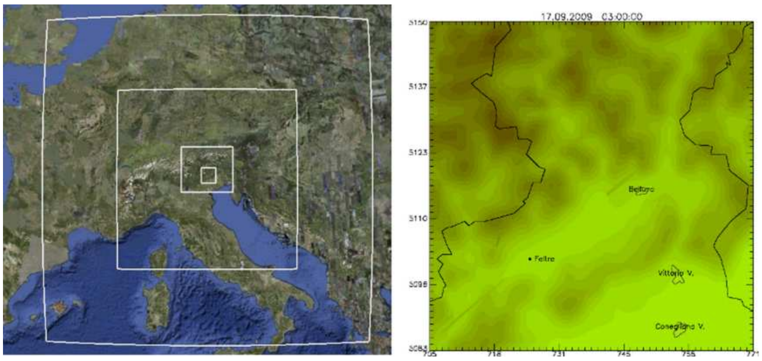

Figure 4. The 4 nested grids adopted by RAMS and the computational domain considered by FARM.

SKYNET, equipped with automatic procedures to collect data, run models and generate output results, runs on a daily basis in order to produce air quality forecasts for current day (+24 hr) and the following one (+48 hr). Hourly concentration fields are so produced for the main atmospheric pollutants specified by the European Directive. Then, they are submitted to a sequence of post-processing tools with statistical comparisons.

4. MODELLING SYSTEM PERFORMANCES

The forecasts from +24hr and +48hr runs produced by the AQFS have been compared with experimental data collected by two urban background stations at the bottom of the valley, Belluno and Feltre.
Since PM10 and $NO_{2,}$ are the most important atmospheric pollutants during the cold season they have been considered for evaluation of the forecast system. The SKYNET performances have been evaluated using some statistical indexes among the ones that are most frequently used in model evaluation studies: mean bias (MB), fractional bias (FB), index of agreement (d), root mean square error (RMSE), normalized standard deviation (NSD) and factor two (F2). The table 1 reports the results of the statistical indexes applied for PM10 and NO_2.

Table 1. AQF modelling system performances in the period (nov.09-feb.10); +24 and +48 runs are considered distinctly.

		MB	FB	d	RMSE	NSD	F2
Belluno	PM10+24	10.35	0.33	0.47	18.55	0.52	0.84
	PM10+48	9.66	0.32	0.46	17.88	0.60	0.85
Feltre	PM10+24	18.35	0.53	0.44	25.13	0.47	0.68
	PM10+48	18.47	0.57	0.50	25.29	0.45	0.70
Belluno	NO_2+24	1.60	0.04	0.75	17.61	1.30	0.98
	NO_2+48	1.41	0.04	0.75	17.78	1.31	0.99
Feltre	NO_2+24	-2.52	-0.08	0.55	20.86	1.42	1.28
	NO_2+48	-2.14	-0.07	0.56	20.70	1.40	1.27

A first overall evaluation shows a very similarity in the results between +24hr and +48hr runs, proving the low influence of initial condition in the simulations and a good agreement of meteorological predictions in this winter period.
For PM10, Belluno shows better results with higher values of *d* and *F2* indexes and lower *RMSE* both +24 and +48 while *FB* are included in -0.5 and 0.5 gap only in Belluno area.
It's possible to notice that the model simulates NO_2 in a better way for both stations, with a very good agreement shown by limited values of *MB*, good d values and *FB* values very close to zero.
As seen in the statistical indexes summary, the model reproduces better PM10 concentrations in Belluno than Feltre and this trend is confirmed by the box plot graphics (Figure 5). AQFS tends to under-estimate the observed values in Feltre zone, in particular fails to simulate the peaks concentrations. This is probably due to a difficulty in reproducing the very low wind fields that characterized this part of the Belluno Valley.
NO_2 comparisons (Figure 6) reveal a better agreement with the observations, phenomenon common to both the stations.

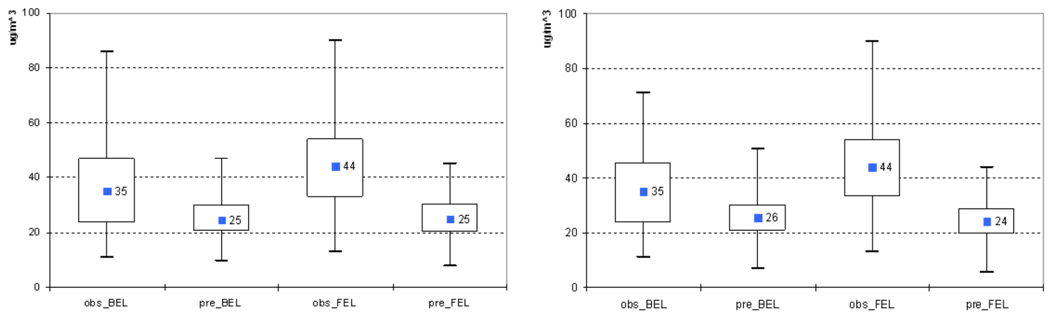

Figure 5. Box plots of the comparisons between PM10 observed data (obs) and PM10 predicted data (pre) for +24 runs (left) and +48 (right).

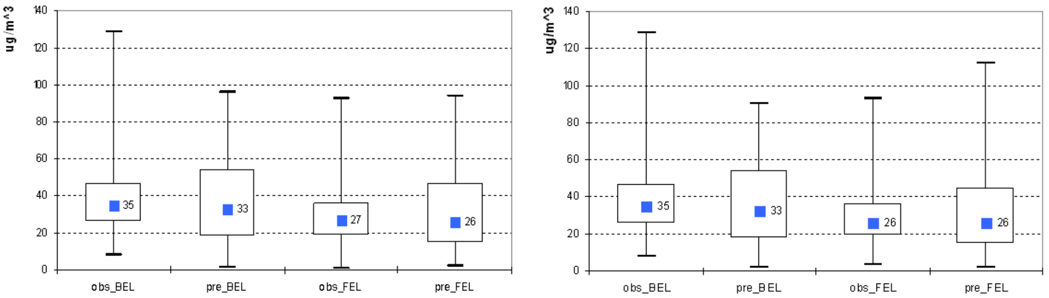

Figure 6. Box plots of the comparisons between NO_2 observed data (obs) and NO_2 predicted data (pre) for +24 runs (left) and +48 (right).

A more accurate evaluation of the model system is able to confirm a general similarity between measured and predicted data for daily averages of NO_2, as seen in Figure 7, where the red lines represent the acceptability limits provided for European legislation in the modelling field.

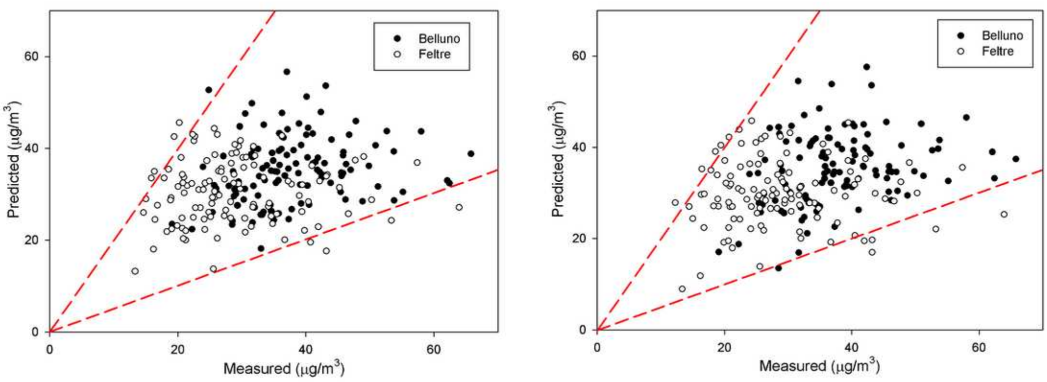

Figure 7. Scatter plots of daily averages NO_2 , +24 (left) and +48 (right).

5. THE AIR QUALITY FORECASTING BULLETIN

An experimental air quality forecasting bulletin has been produced in the period Jan.10 – Feb.10 using SKYNET associated with other systems acting on national scale and by using data from sodar and radiometer sited in Feltre.

It has been possible to observe that the System reliability is strictly linked to the experience of the forecaster and the obtained performances gave us good results both for Belluno and Feltre. In particular, for Belluno the correct forecasts for following day arrive at 80% of cases, while for Feltre performances arrive at 71%. The most critical conditions to evaluate were some snowy episodes. In fact, in some cases they caused pollutant concentrations to fall, in other cases they led to a stability, while in some other cases a following quick increase of PM10 concentrations in the entire Belluno Valley was observed. These conditions might be explained by some meteorological parameters such as very low wind (9.5 km/day), heavy inversions and high humidity (more than 90%).

6. CONCLUSIONS

SKYNET has proved to be a useful and valuable tool to increase the knowledge of the dynamics of air quality in Belluno Valley. The most important factors that seriously affect the air quality in the valley are the meteorological factors, which created some problems to the model because of the almost total absence of wind in some areas of the valley associated with a considerable orographic complexity.

All the main air quality indicators confirm a good performance of modelling predictions compared with experimental measures for the two evaluated pollutants. The correct reproduction of major air pollution episodes in the cold season is the most critical aspect that needs more studies and the implementation of AQFS is strictly linked to the improvement of accuracy of the meteorological modelling and dispersion parameterisations.

The use of the information generated by the model and a precise knowledge of the emission sources deriving from a bottom-up inventory allowed us to create an air quality forecasting bulletin which gave reliable predictions both in Belluno (80%) and Feltre (71%).

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