FORECAST AND REAL TIME AIR QUALITY MODELING SYSTEMS FOR ROME METROPOLITAN AREA: DESCRIPTION AND PRELIMINARY PERFORMANCE EVALUATION

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Forecast and Real time modeling air quality system:

• As provided by the air quality *Directive 2008/50/CE*, modelling is considered a powerful tool to assess and manage air quality (AQ)

• In Italy, to date, only few Regional Environmental Protection Agencies (ARPAs) have implemented models to integrate information coming from air quality monitoring networks and support the definition of measures to reduce health impact of air pollution

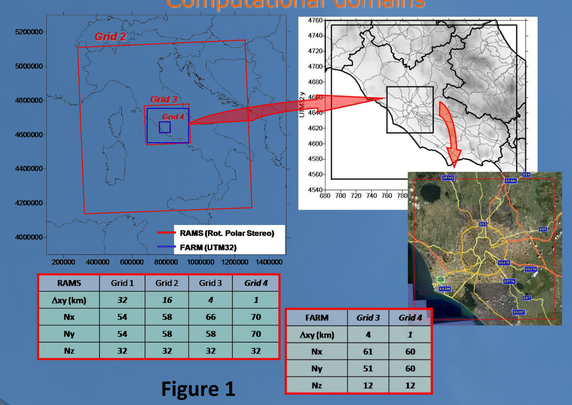
Would Forecast and Real time air quality modeling become an important support instrument to Environmental Protection Agencies (ARPAs) ?

Conclusion

• At high resolution **(1 km)** over Rome urban conglomeration, the quality of the **Forecast** and **Nowcast** results are comparable and **both** well reproduce pollutants trends for the considered period.
• During wintertime, very good results have been obtained for **PM10** and **PM2.5** daily average values.
• At resolution of **4 Km** over Lazio Region domain, the forecast system predictions **underestimate** the observations, while the NRT system **maintains** a very good concordance with experimental data for **NO_2**, whose measurements are directly assimilated, but not for **PM10**, which is not assimilated
These results highlight the importance to improve emissions characterization outside Rome area.

Modelling Systems

Computational domains



RAMS	Grid 1	Grid 2	Grid 3	Grid 4
Δxy (km)	32	16	4	1
Nx	54	58	66	70
Ny	54	58	58	70
Nz	32	32	32	32

FARM	Grid 3	Grid 4
Δxy (km)	4	1
Nx	61	60
Ny	51	60
Nz	12	12

Figure 1

Forecast System:

- Emission pre-processing system: EMMA
- Prognostic non-hydrostatic meteorological model RAMS
- Interface module for the estimation of dispersion parameters: GAP/SurfPRO
- Chemical Transport Model (CTM) : FARM
- Produces a 72 hours forward prediction on a daily basis

Near Real Time:

- Emission pre-processing system: EMMA
- Prognostic non-hydrostatic meteorological model RAMS
- Interface module for the estimation of dispersion parameters: GAP/SurfPRO
- Chemical Transport Model (CTM) : FARM
- Assimilation performed with the Successive Correction Method, that takes into account O_3, NO_2, Benzene, CO and SO_2 measurements from 34 regional monitoring stations
- Produces air quality analyses every 3 hours

Statistical Analysis

The AQ System verification lasts the period from August to December 2009 and is mainly devoted to verify the modelling system capability to reproduce the observed concentration of major pollutants, their time variations and to forecast relevant air pollution episodes. The comparison with observations has been extended to the regional-background and metropolitan domains (Figure 1) to identify resolution effects and possible influence of emissions treatment over the nested domains.

Measures of bias

$$MB = \frac{1}{N}\sum_{i=1}^{N}(C_{mi} - C_{oi})$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(C_{mi} - C_{oi})^2}$$

$$NME = \frac{\sum_{i=1}^{N}|C_{mi} - C_{oi}|}{\sum_{i=1}^{N} C_{oi}} 100\%$$

$$NMB = \frac{\sum_{i=1}^{N}(C_{mi} - C_{oi})}{\sum_{i=1}^{N} C_{oi}} 100\%$$

Forecast evaluation metrics

Accuracy (%)	Percent of forecast that were correct	100 (A+D)/(A+BC+D)
False Alarm Rate (FAR) (%)	Percent of forecasted exceedances that did not occur	100 B/(B+D)
Probability of Detection (POD) (%)	Percent of observed exceedances that were forecasted correctly	100 D/(C+D)
Critical Success Index (CSI) (%)	Measures how well high events are predicted (not influenced by number of correct non-exceedance forecasts)	100 D/(B+C+D)

where: A: Model correctly predicted no exceedance, B: Model predicted an exceedance that did not occur; C: Model failed to predict an exceedance that occurred, D: Model correctly predicted an exceedance

In the following table (Table 1) are reported the standard and widely used measures of bias and the forecast evaluation metrics used to evaluate the performances of the two modelling systems

Station	Forecasting System 1 km PM10			
	MB	NMB	RMSE	NME
Preneste	-1,3	-4,5	8,9	24,0
Bufalotta	3,2	14,1	9,6	31,8
Cinecittà	-5,4	-17,8	10,2	26,0
Ada	2,7	11,3	8,2	27,6

Table 2. Discrete Statistic for November – December 2009, PM10
The statistics refer to stations located inside Roma urban area and show the good agreement with observations of PM10 results for the Forecasting System. Negative and positive values of MB denote the difference between roadside and urban background stations. RESOLUTION : 1 Km

Station	Forecasting System 4km NO_2				NRT System 4km NO_2			
	MB	NMB	RMSE	NME	MB	NMB	RMSE	NME
Cassino	-33,5	-65,4	39,5	66,9	-7,2	-13,9	19,2	18,9
Latina Scalo	-40,8	-81,0	49,1	81,3	4,9	9,6	11,5	17,3
Latina Tasso	-40,8	-82,2	49,5	82,2	12,1	23,4	19,0	28,9
Rieti	-28,6	-80,0	36,7	80,6	3,7	9,9	11,8	23,2
Leonessa	-16,2	-86,1	21,8	86,1	0,7	3,4	13,1	27,7

Table 4. Discrete Statistic for November –December 2009, NO2.
Table 4 shows results obtained for different stations located far from Rome at rural background, urban background and traffic locations, in term of model performances statistical indicators. The values of RMSE for NO_2 confirm the large discrepancies already observed for the forecast system and the relevant improvement provided by data assimilation. RESOLUTION : 4 Km

Station	Accuracy (%)	FAR (%)	POD (%)	CSI (%)
Preneste	78	60	100	40
Bufalotta	76	88	100	13
Cinecittà	83	50	60	38
Ada	82	83	100	17

Table 3. Categorical Statistic for December 2009, PM10, Forecast System, Resolution 1 Km
The system is characterized by an elevated Accuracy in every considered month. This parameter is influenced by the high number of correctly forecasted non exceedances and for this reason it is important to pay attention to the interpretation of this index in the evaluation of a forecasting system performances. The POD values are very high but in many cases the FAR index too, this is the reason for what the CSI is low. It can also be noticed the variation of some parameters like FAR and CSI among the different considered stations. This behaviour can be attributed partially to the moderately polluted situations when concentration limits are exceeded only in some of the monitoring stations. These conditions are quite hard to forecast because the threshold values can be exceeded locally for a few μg/m³ of concentration. Moreover, when exceedances are forecasted in wrong position, while the forecast can still be considered positively, its contribution to FAR and CSI will decrease performance indicators values. RESOLUTION : 1 Km

Comparison Model Systems and Measurements

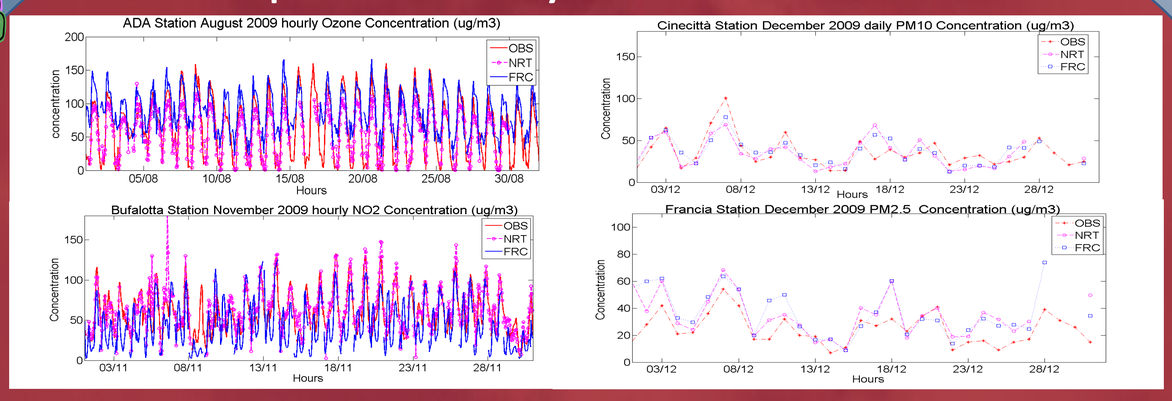


Figure 2. Temporal Series comparisons for NO_2, O_3, PM10 and PM2.5: Red indicates measurements, blue forecast system results and magenta NRT system results in the inner high resolution (1 km) domain.

Both Forecast and Nowcast well reproduce the pollutants trends : (Fig.2)

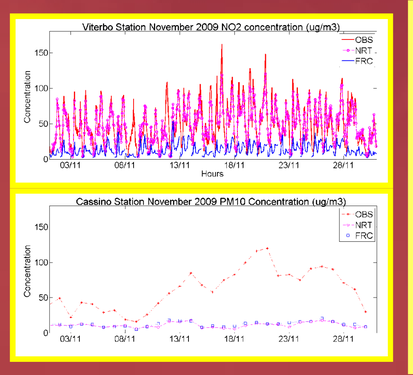


Figure 3

Figure 3. Temporal Series comparisons for NO2 and PM10: Red indicates measurements, blue forecast system results and magenta NRT system results in the outer low resolution (4 km) domain. To understand the quite different results obtained for Rome (Fig 2) and the surrounding region, it has to be reminded that Rome is the only large city in the area and all the remaining towns, where monitoring stations are located, have sub-grid size at the resolution of 4x4 km² and are surrounded by countryside. Nonetheless, monitoring stations are normally sited within town centres and nearby roads, making the reproduction of their measurements even more difficult

The monthly mean concentrations maps of NO_2 (Lazio region) and PM10 (Rome urban area) produced by the NRT system for November 2009 are shown in Figure 4. For NO2, the NRT system qualitatively describes the areas where higher concentrations are observed and provides values very close to the observed ones. This feature is shown by PM10 map too for Rome urban area, even if PM observed data have been not assimilated

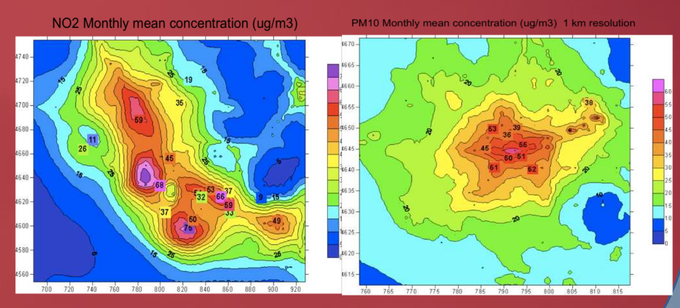


Figure 4