CityZen

megaCITY - Zoom for the Environment

Collaborative Project

7th Framework Programme for Research and Technological Development

Cooperation, Theme 6:

Environment (including Climate Change)

Grant Agreement No.: 212095

Deliverable D1.6.2, type R

Evaluation of current state of modelled ozone and PM in the Po Valley

Due date of deliverable:	project month 22
Actual submission date:	project month 28

Start date of project: 1 September 2008 Duration: 36 months

Name of lead beneficiary for this deliverable: CNR-ISAC

Scientist(s) responsible for this deliverable: Alberto Maurizi, Felicita Russo, Francesco Tampieri

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Evaluation of current state of modelled ozone and PM in the Po Valley

Introduction

Due to its strategical role in the Italian economy and to the high population density, the Po Valley area has been subject of many studies concerning weather and air quality. Moreover, the topographical features of the Valley, surrounded to the South, the West and the North by high mountain ranges, give rise to a local climate characterised by low wind speeds, enhanced diurnal cycle and also by severe haze and fog conditions. The Po Valley is also characterized by a high pollution level, due manly to a dense transportation traffic along the main connection highways and to industrial activity. Using models to study air quality in this region can also help understanding the influence that the Pollution from the Po Valley can have on the surrounding european regions, which is one of the goals of the CityZen project.

The report is organised as follows.

In Section 1 some details of the numerical experiment are described.

In Section 2 the main features of the database containing concentration measurements are presented.

In Section 3 the results of the statistical comparison between model and data are reported and discussed.

In Section 4 a brief summary of the work done for this report and a comparison of the results with previous studies is presented.

1. Details of the numerical experiment

The model BOLCHEM (Mircea et al-ae-2008), an atmospheric dynamic and composition model in which meteorology and chemistry are coupled online, has been run at a resolution of about 50x50 km^2 over an European area (coordinate) for the year 2007.

This run is part of the 10yr trend experiment made in the frame of Cityzen project. Boundary conditions for the meteorology are supplied by ECMWF; for gas and particle concentration boundary conditions are set to climatological values. Emissions prepared for Cityzen project by INERIS are used.

The model concentrations for O_3 and PM10 (from here on indicated by PM) have been interpolated at the coordinates of the Po Valley Airbase station (see the next Section) in order to produce time series for comparison, with the same time resolution as for the observed time series.

2. Main characteristics of the data set (AirBase) used for the analysis

The data used for the comparison are obtained from AirBase. A complete description of the data base can be found at the website http://www.eea.europa.eu/data-and-maps/data/airbase-the-european-air-quality-database-2. For this study, time series of O_3 and PM concentration (respectively, with hour and day time resolution) in stations located in the Po Valley are used. A complete list of the stations used is reported in the tables in the Appendix 1, and their geographical locations are shown in Figure 1.

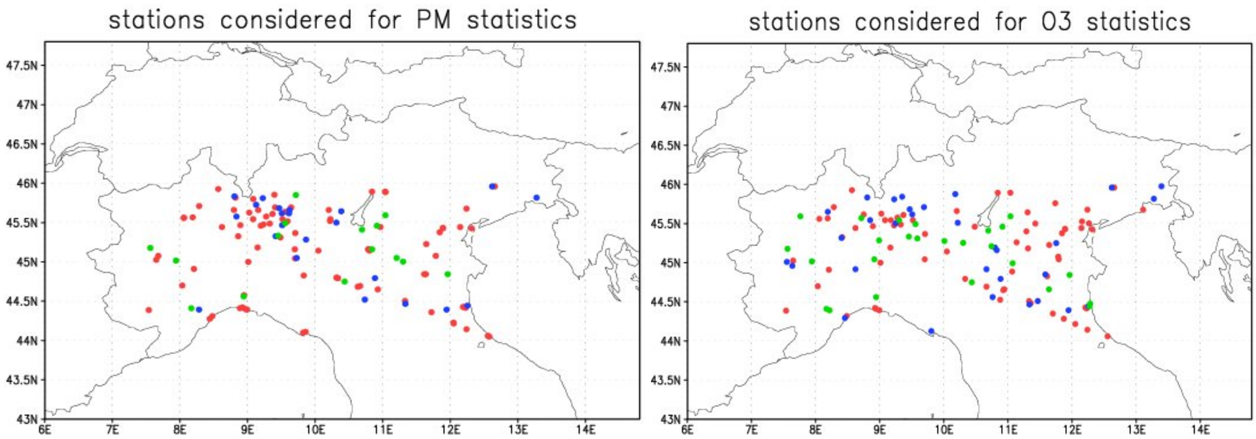

Figure 1: Locations of the stations used for the statistics. The red symbols refer to urban sites, blue symbols to suburban sites and green symbols refer to rural sites.

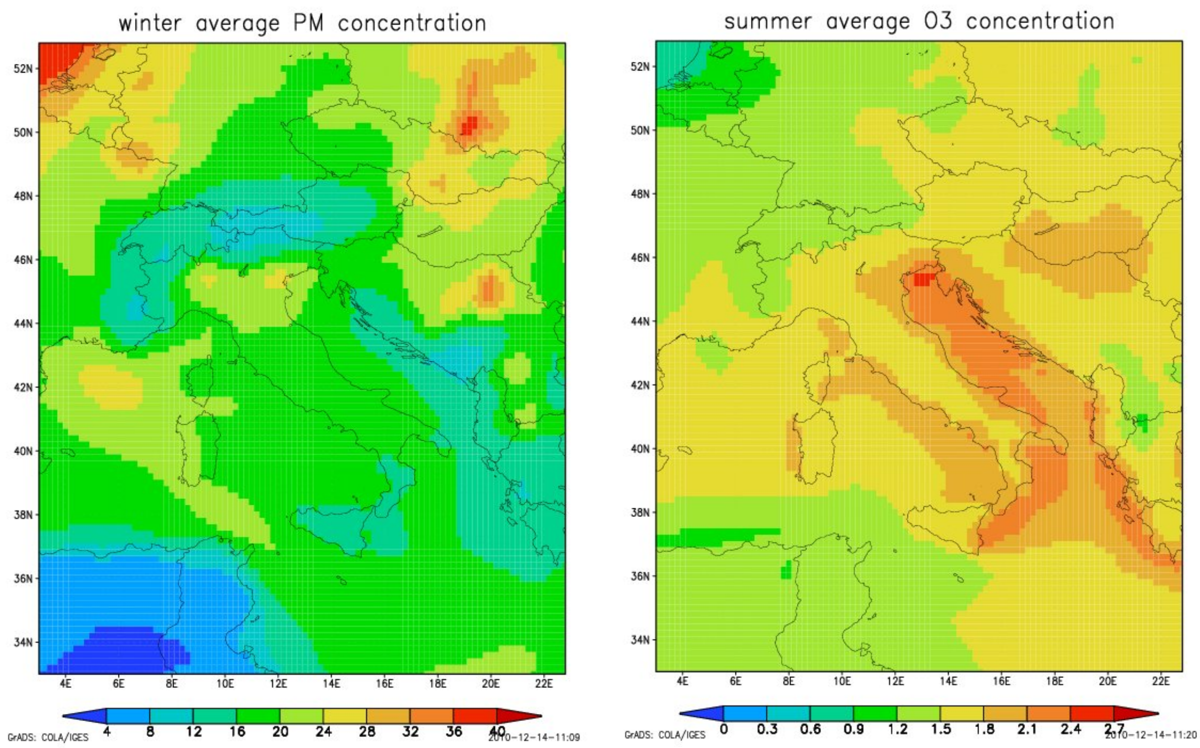

Figure 2: Example of the average spatial distribution of the lowest level PM and O3 near the Po Valley during the seasons when both concentrations are maxima. Units are micromol per m^3 for PM and microg per m^3 for O_3.

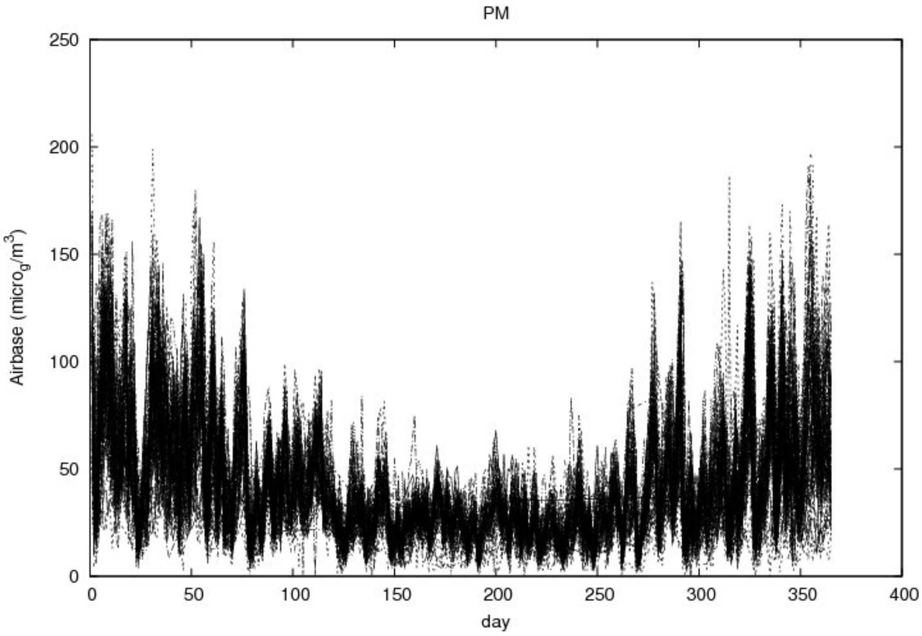

Figure 3: seasonal variations of the PM concentration in the Po Valley as measured by the Airbase stations. The graphic includes all the available stations used in this study. As expected the PM concentration is maximum during winter and minimum during the summer and the largest variability is present during winter.

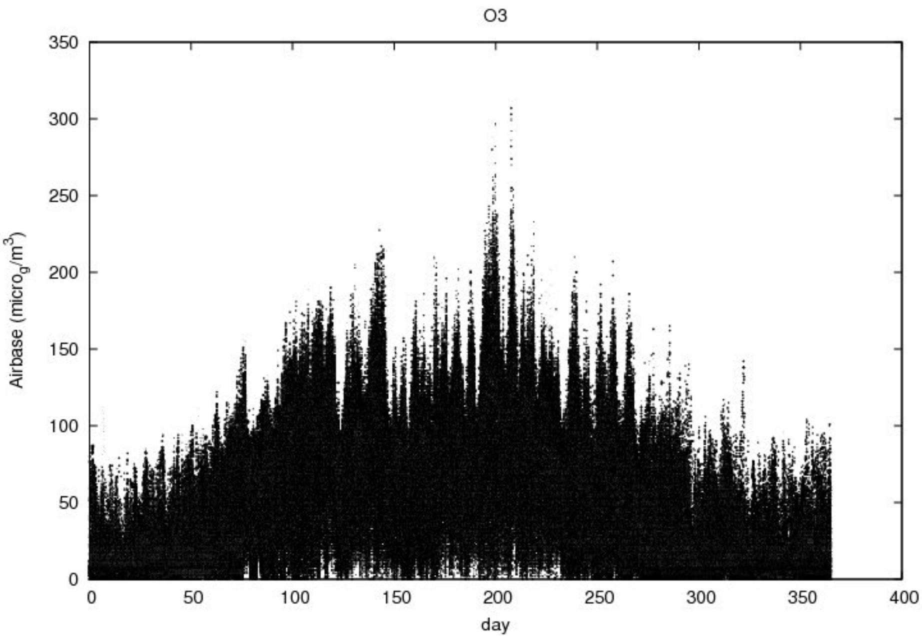

Figure 4: seasonal variations of the O_3 concentration in the Po Valley as measured by the Airbase stations. The graphic includes all the available stations used in this study. As expected the O_3 concentration is minimum during winter and maximum during the summer where it presents also the largest variability.

3.Comparison model/data

In order to compare model fields with station data it was necessary to interpolate the model fields at the stations measuring positions. Therefore two separate statistics were carried out: one for the PM and one for the O_3. For each of these two species we performed statistics separating data based on season (all year, spring, summer, fall and winter) and based on the type of station (all stations, urban, suburban and rural). The statistical quantities used for the analysis are:

the mean error:

$$\frac{\sum_{i=1,N}\sum_{j=1,D}(C_A(i,j)-C_B(i,j))}{N*D}$$

and the root mean square:

$$\sqrt{\frac{\sum_{i=1,N}\sum_{j=1,D}\left(C_A(i,j)-C_B(i,j)\right)^2}{N*D}}$$

where C_A is the species concentration as measured by Airbase, C_B is the concentration modelled with BOLCHEM, N is the number of the stations considered and D is the number of days/hours included.

We also report the correlation and the ensemble size (N*D), which gives a measure of the relative statistical significance of each set of data analysed.

These statistical quantities allow to represent the statistics of each subset of data in a synthetic manner, as shown in Figure 5 and Figure 6. From this overview we can easily notice the large seasonal dependence of both the mean error and the root mean square error for PM and O_3.

In particular the O_3 presents an inversion of sign in the mean error during the summer, while the mean error for the PM is always positive.

Another feature to notice is the inverted seasonal dependence in the root mean square for the PM (the root mean square error has a minimum value during summer) and the O_3 (the root mean square error is maximum during summer). This is contextual to the fact that O_3 concentration and its variability are higher during summer while PM concentration and its variability are higher during winter, as shown in Figure 3 and 4.

The behaviour of the correlations is highly different for PM and O_3. In fact in the case of PM they do not show an evident seasonal and station dependency, and are always around 30%. On the other hand in the case of O_3 they show a significant seasonal variation, from 70% during fall to 30% during winter. The PM correlation is expected to be always lower than O_3 since the latter is more reactive and mixable than the first and therefore being able to model PM concentration at the same space-time resolution as that of the station is on average more challenging.

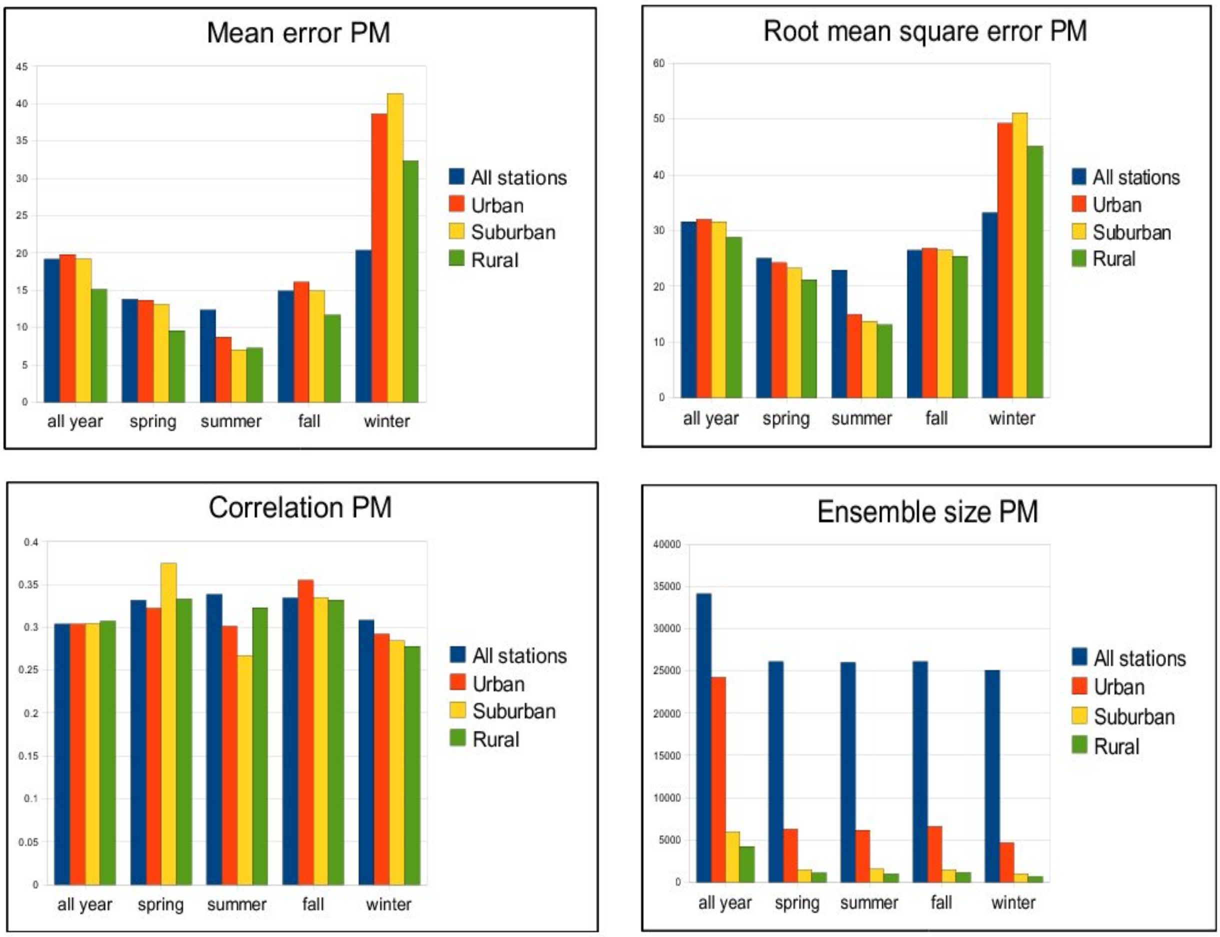

Figure 5: Overview of the statistics for the PM comparison. Upper left panel shows the mean error for the 4 station types and the 5 seasonal groups. The upper right panel shows with the same plot style the root mean square error. The lower left panel and the lower right panel show respectively the correlation between Airbase data and BOLCHEM simulation and the corresponding ensemble size.

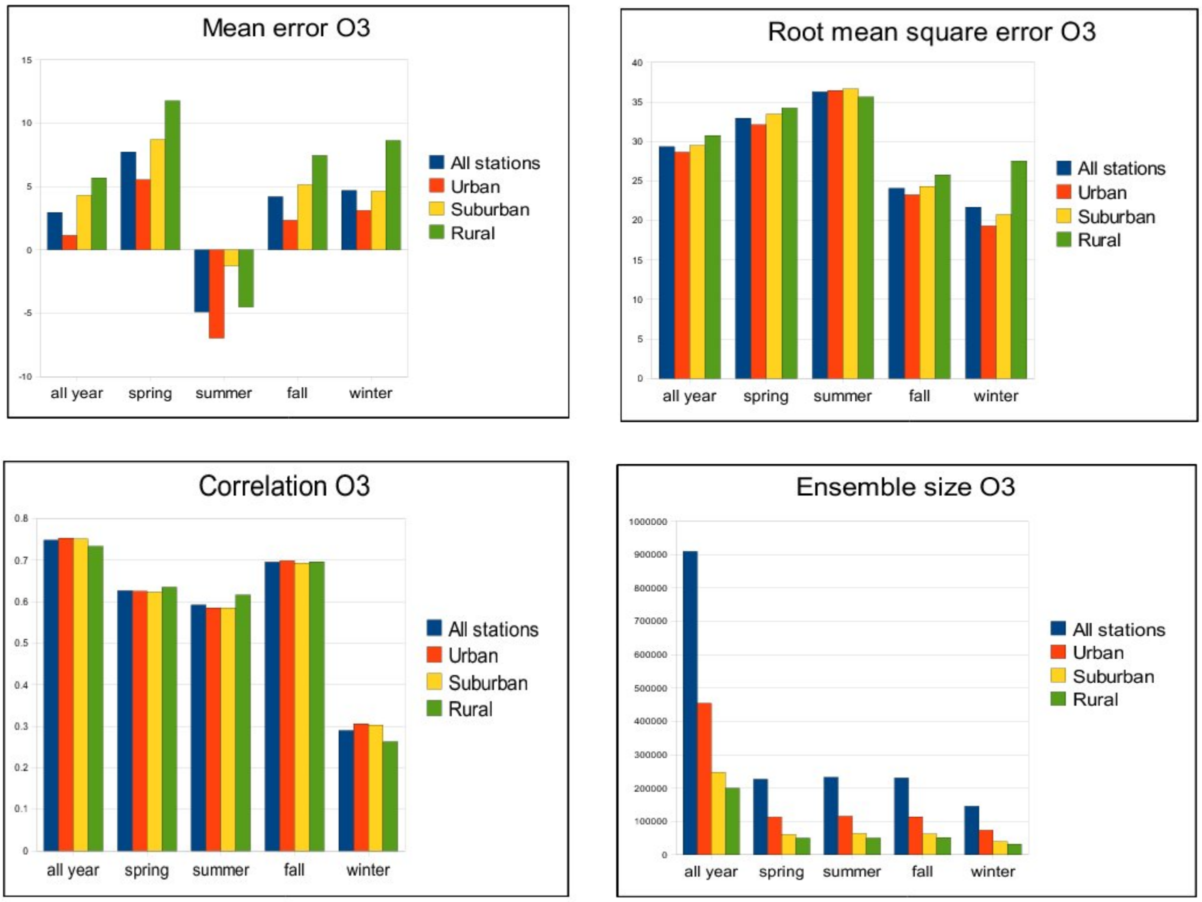

Figure 6: Overview of the statistics for the O_3 comparison. Upper left panel shows the mean error for the 4 station types and the 5 seasonal groups. The upper right panel shows with the same plot style the root mean square error. The lower left panel and the lower right panel show respectively the correlation between Airbase data and BOLCHEM simulation and the corresponding ensemble size. Notice that the size of the datasets that were available in the case of O_3 are much larger than in the case of PM. The reason is that the PM data are daily averages, while the O_3 data are hourly averages.

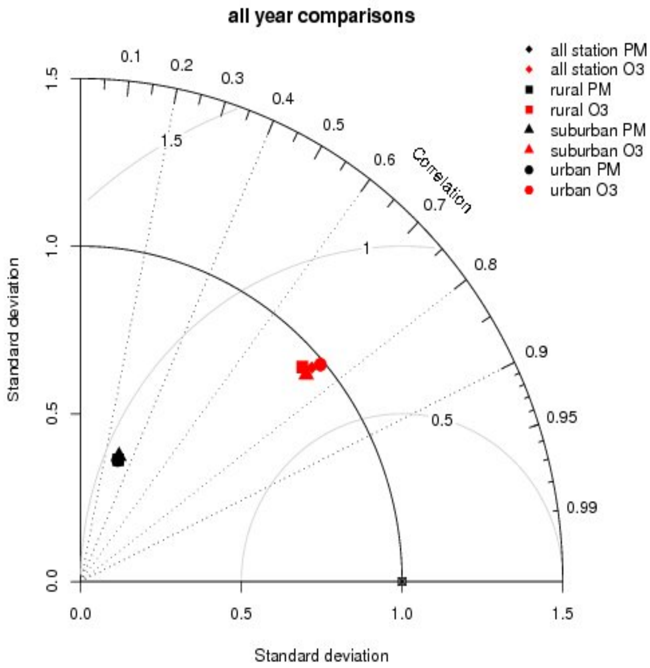

Figure 7: Taylor diagram of the PM and O_3 comparisons relative to the entire 2007 and for the different station types. The O_3 comparisons are significantly better than the PM comparisons for all the station types.

Another effective way of looking at these statistics is the Taylor diagrams like the ones shown in Figure 7, Figure 8 and Figure 9. Figure 7 shows the Taylor diagram relative to the dataset in which all the available data were included and for each type of stations both for PM and O_3. From this picture it is clearly evident that the model compares with data in the case of O_3 significantly better than in the case of PM independently on the type of station.

In Figure 8 and Figure 9 the dataset have been separated by season. From the comparison between these 4 panels we can conclude, as we already noticed, that the PM data during winter compares better with the model that in the other seasons and it does not depend significantly on the station type. On the other hand the O_3 model simulation is in better agreement with the data during fall, where the correlation is higher. One interesting feature to notice is the spread of the points relative to different station types. In the PM comparison the spread is higher during the summer while for the O_3 the spread is higher in winter. This is coincidental to the fact that these seasons are those characterized by a respective concentration minimum for the two species as seen in Figures 3 and 4.

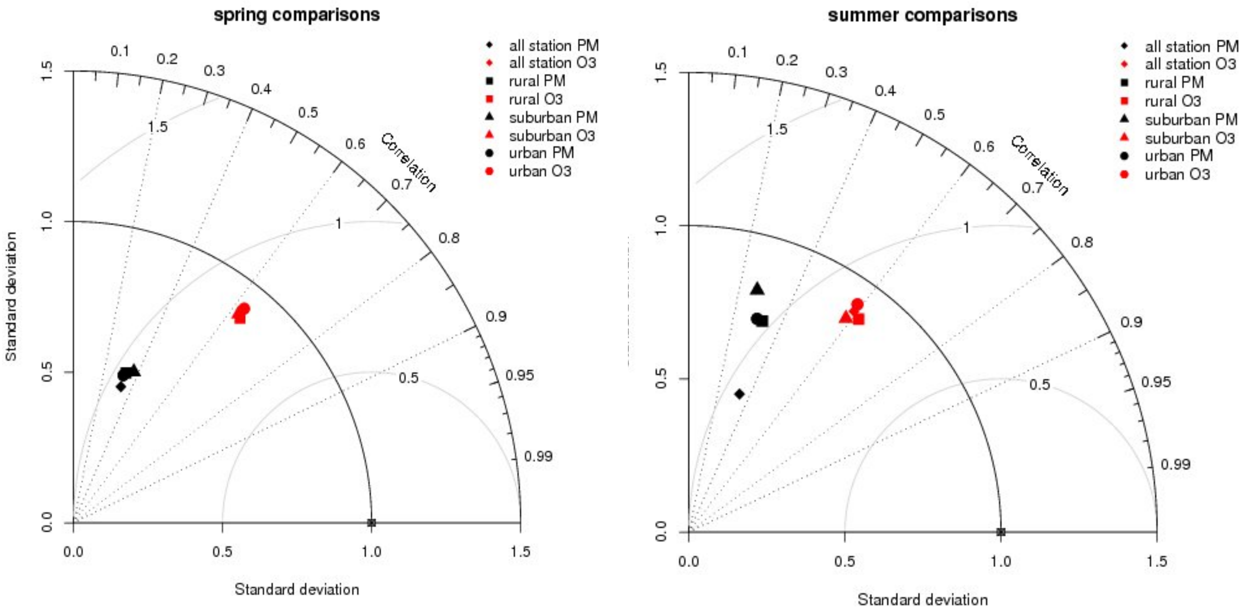

Figure 8: Taylor diagram of the spring dataset and the summer dataset. The O_3 comparisons are, in both datasets, better than the PM comparisons.

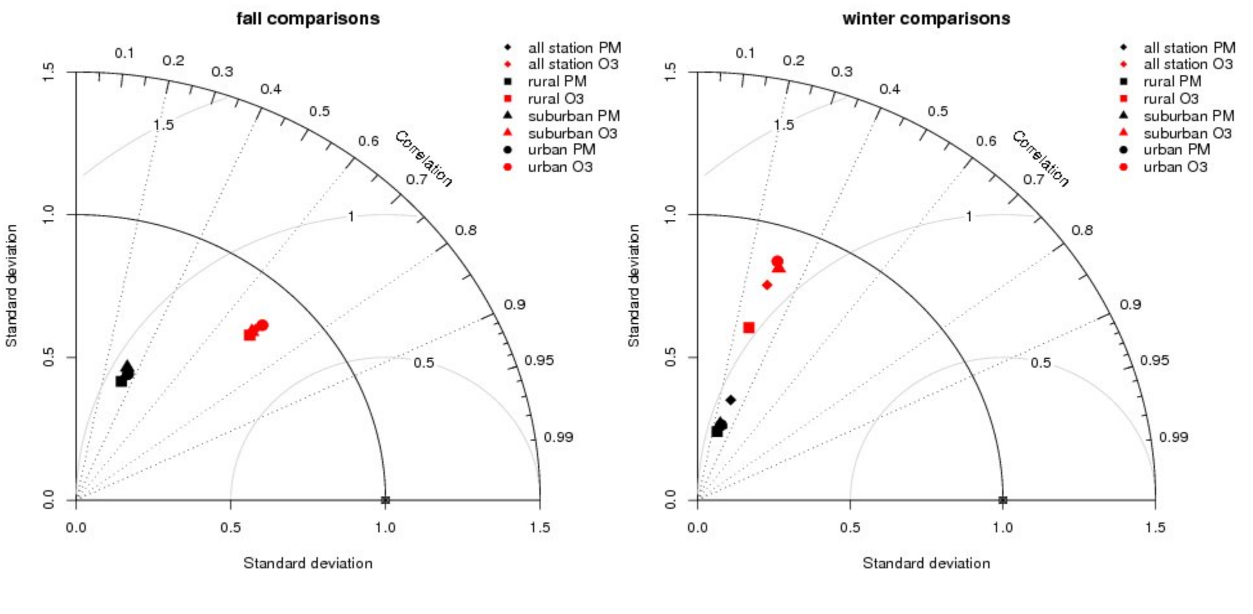

Figure 9: Taylor diagrams of the fall and winter datasets where it is evident that that the O_3 fall conparison is better than the PM fall comparison but also that the PM winter comparison is better than the O_3 winter comparison.

4.Conclusions

We presented one year of comparisons between BOLCHEM regional model and the Airbase data measured during 2007. The Airbase stations used were 106 for the PM and 118 for the O_3, each falling into three different air quality categories: urban, suburban and rural. We performed statistics both for the entire dataset and by dividing it by season. In general the mean difference between BOLCHEM and the data showed a significant seasonal dependence and the root mean square error is largest when the individual average concentrations of the species are largest (Figure 3,4, 5 and 6). The values of correlations both for PM and O_3 are in agreement with the values found in a previous study by Thunis et al., 2009. Moreover the results obtained here are in agreement with the state of the art of modeling as it is shown in the work done within the GEMS project (http://gems.ecmwf.int/).

Appendix 1:

station name	longitude (deg)	latitude (deg)	altitude (m)
IT0741A	10.3	45.25	51
IT0842A	10.01	45.28	61
IT0920A	12.27	44.44	0
IT0921A	12.28	44.48	0
IT0988A	7.76	45.59	371
IT1121A	7.56	45.18	337
IT1174A	8.99	45.29	100
IT1178A	8.94	44.56	80
IT1179A	11.96	44.84	-2
IT1188A	10.74	45.21	29
IT1233A	8.22	44.39	400
IT1288A	9.59	45.31	64
IT1343A	10.91	45.46	91
IT1387A	11.3	45	12
IT1388A	10.69	45.41	113
IT1392A	11.2	45.05	14
IT1418A	9.45	45.33	83
IT1451A	11.64	44.66	11
IT1460A	8.71	45.57	205
IT1464A	9.56	45.49	115
IT1519A	8.17	44.41	390
IT1522A	7.94	45.02	280
IT1672A	10.43	44.75	1020
IT1736A	8.92	45.04	74
IT1812A	9.3	45.54	1192
IT1848A	11.04	45.59	824
IT1865A	11.07	44.99	16
IT1867A	10.84	45.16	24

Table 1: list of the Airbase stations in a rural environment used in the comparison.

station name	longitude (deg)	latitude (deg)	altitude (m)
IT0267A	9.41	45.33	80
IT0186A	11.58	44.85	7
IT0510A	11.94	44.39	19
IT0558A	9.51	45.47	101
IT0559A	9.62	45.66	207
IT0638A	11.75	45.25	10
IT0710A	10.76	44.56	135
IT0732A	8.8	45.83	382
IT0742A	10.39	45.64	345
IT0757A	12.25	44.44	4
IT0822A	13.28	45.82	3
IT0840A	9.86	45.28	70
IT0846A	10.31	45.5	147
IT0902A	9.22	45.81	323
IT0903A	10.73	44.52	150
IT0929A	10.66	44.92	22
IT1017A	9.25	45.5	122
IT1088A	9.69	45.71	290
IT1112A	12.62	45.96	29
IT1120A	7.55	45.01	268
IT1125A	7.64	44.96	232
IT1144A	8.46	44.29	16
IT1152A	10.88	44.79	25
IT1161A	11.33	44.47	260
IT1165A	11.46	44.51	40
IT1168A	13.39	45.98	62
IT1203A	8.85	45.54	184
IT1232A	8.28	44.39	330
IT1245A	8.19	45.65	485
IT1385A	10.18	45.88	226
IT1393A	10.82	45.16	25
IT1454A	9.73	45.05	61
IT1459A	8.83	45.58	206
IT1463A	9.61	45.62	182
IT1465A	10.22	45.51	70
IT1466A	9.51	45.62	187
IT1648A	9.13	45.73	320
IT1662A	9.8	44.13	54
IT1734A	9.35	45.84	237
IT1830A	8.62	44.92	91
IT1866A	10.8	45.19	30
IT1876A	9.47	45.68	273
IT1878A	8.4	45.32	131

Table 2: list of the Airbase stations in a suburban environment used in the comparison.

name	lon (deg)	lat (deg)	alt (m)		name	lon (deg)	lat (deg)	alt (m)
IT0187A	11.61	44.84	8		IT1061A	11.31	45.64	240
IT0439A	12.15	45.44	6		IT1065A	11.74	45.76	114
IT0440A	12.15	45.53	12		IT1087A	9.7	45.04	61
IT0448A	12.31	45.43	1		IT1099A	12.66	45.96	28
IT0466A	9.22	45.48	122		IT1104A	9.15	45.18	77
IT0469A	7.68	45.08	210		IT1105A	10.34	44.79	55
IT0524A	9.52	45.54	133		IT1141A	12.21	44.43	4
IT0544A	9.83	44.83	210		IT1143A	8.44	44.28	2
IT0554A	7.65	45.03	220		IT1155A	11.04	45.89	208
IT0591A	11.04	45.89	200		IT1159A	11.33	44.5	54
IT0594A	10.22	45.54	149		IT1160A	11.33	44.51	40
IT0640A	11.89	45.43	12		IT1167A	13.11	45.68	2
IT0659A	11.43	45.5	63		IT1204A	12.23	44.42	4
IT0684A	10.63	44.68	60		IT1214A	11.79	45.04	3
IT0705A	9.2	45.46	122		IT1215A	11.78	45.08	7
IT0706A	9.33	45.49	123		IT1246A	8.19	45.57	273
IT0707A	9.64	45.69	249		IT1247A	8.06	45.56	405
IT0709A	10.8	45.14	18		IT1247A	8.06	45.56	405
IT0727A	11.06	44.89	18		IT1286A	9.49	45.31	80
IT0740A	10.2	45.66	274		IT1287A	9.7	45.16	58
IT0743A	10.48	45.46	188		IT1336A	10.96	45.44	62
IT0753A	10.84	45.89	73		IT1340A	11.29	45.4	30
IT0764A	8.8	45.66	238		IT1342A	11.13	45.26	21
IT0770A	9.08	45.54	160		IT1452A	12.05	44.23	28
IT0771A	9.08	45.8	201		IT1453A	11.84	45.38	13
IT0776A	9.4	45.85	214		IT1457A	9.82	44.1	3
IT0777A	9.41	45.69	292		IT1480A	10.88	44.53	110
IT0778A	9.59	45.52	125		IT1510A	8.57	45.93	197
IT0804A	10.33	44.79	60		IT1518A	8.62	45.44	159
IT0837A	9.56	45.64	190		IT1523A	8.21	44.91	149
IT0839A	9.71	45.37	79		IT1524A	8.03	44.7	164
IT0854A	8.93	44.42	105		IT1529A	7.54	44.39	551
IT0856A	8.94	44.41	45		IT1532A	8.28	45.71	345
IT0858A	8.99	44.39	85		IT1533A	8.42	45.33	131
IT0892A	11.36	44.48	73		IT1535A	11.31	45.18	25
IT0895A	12.19	44.43	4		IT1544A	9.86	44.11	3
IT0909A	8.86	45.33	107		IT1588A	8.82	45.82	388
IT0912A	9.16	45.19	77		IT1590A	12.24	45.68	15
IT0940A	10.66	44.69	50		IT1649A	10.31	44.8	55
IT0963A	12.26	45.5	1		IT1650A	9.02	45.63	212
IT0976A	11.64	45.23	11		IT1670A	12.24	44.14	37
IT0995A	9.17	45.54	146		IT1692A	9.24	45.48	122
IT1010A	8.89	45.47	138		IT1698A	8.97	44.4	75
IT1018A	10.94	44.66	30		IT1699A	8.89	44.41	5
IT1023A	11.61	44.83	9		IT1706A	8.48	44.31	14
IT1024A	11.64	44.84	6		IT1735A	9.01	45	90
IT1026A	8.95	44.58	80		IT1737A	10.22	45.52	70
IT1027A	11.7	44.35	45		IT1739A	10.05	45.14	45
IT1029A	11.72	44.36	42		IT1743A	9.27	45.58	162
IT1030A	11.87	44.28	35		IT1771A	10.93	44.65	34
IT1034A	9.16	45.66	221		IT1868A	10.8	45.16	22
IT1035A	9.37	45.61	194		IT1869A	10.78	45.16	19
IT1043A	12.55	44.06	6		IT1873A	8.75	45.62	215
IT1044A	12.58	44.05	3		IT1880A	11.89	45.43	11
IT1048A	12.05	44.22	29		IT1883A	8.49	44.32	55
IT1052A	12.24	44.14	33					

Table 3: list of the Airbase stations in a urban environment used in the comparison.

References:

Mircea, M., M. D'Isidoro, A. Maurizi, L. Vitali, F. Monforti, G. Zanini, and F. Tampieri, 2008: A comprehensive performance evaluation of the air quality model bolchem to reproduce the ozone concentrations over italy. *Atmospheric Environment,* 42,1169-1185.

Thunis P., G. Tracchini, L. White, G. Maffeis and M. Volta, Air pollution and emission reductions over the Po-valley: Air quality modeling and integrated assessment, *18th World IMACS/MODSIM Congress, Cairns, Australia 13-17 July 2009.*