Experimental validation of MAP 3D environmental data in NE region of Romania-Iasi area

M.M. Cazacu[1], A. Timofte[1,2], D. Dimitriu[1] and S. Gurlui[1]

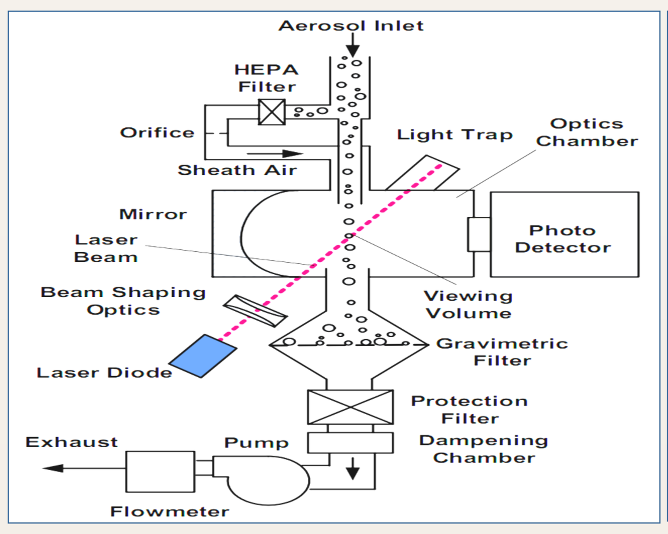
"Al. I. Cuza" University of Iasi, Faculty of Physics, 11 Carol I Blvd., 700506 Iasi, RO,
National Meteorological Administration, Regional Forecast Center Bacău, 1 Cuza Voda Str., 600274 Bacău, RO

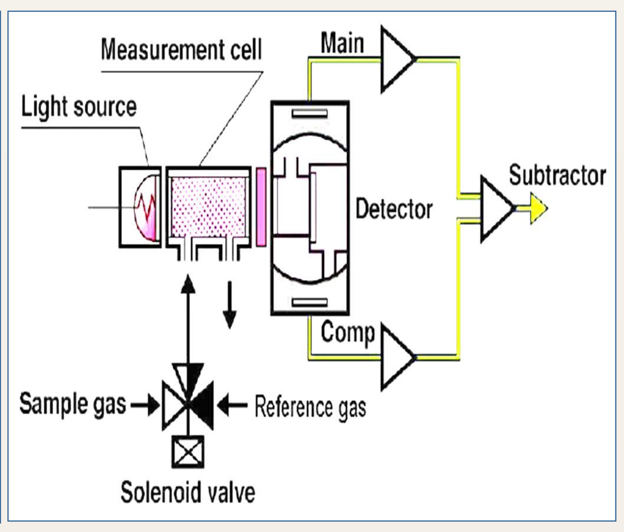
Context …

MAP 3D is the acronym for "Mesoscale Air Pollution 3D modelling"; it was developed at the EFLUM laboratory (EPFL). This tool is a permanent modelling system which provides daily forecast of the local meteorology and the air pollutant (gases and particles) concentrations (http://map3d.iucn.org/). In this study we intend to compare the MAP 3D forecasted environmental data and experimental data measured in Iasi area. We will study, compare and correlate data on Ozone, PM 10 concentration; and meteorological data- temperature (0C) and relative humidity (%). Measurements data were obtained using air-monitoring devices HORIBA APNA-350 E, DustTrak Aerosol Monitor 8520. Data on temperature and relative humidity were correlated with meteorological data from Iasi Weather Station.

Experiment …

Figures 1, 2: . Experimental device: Dust Trak Aerosol Monitor and HORIBA O_3 Monitor.





•MAP 3D is an instrument of modelling by means of which a local meteorological forecasts can be made and also a forecasts for the atmospheric pollutants (gases and particles) as well as their local concentration. Our case study aims to compare the forecasted data by MAP 3D and the data measured in the city of Iasi. We shall study, compare and correlate the data concerning the ozone concentrations, oxides of nitrogen, dust particles (PM 10 and PM 2.5) and the meteorological data (the temperature and the relative humidity).
•The data shown by measurements were obtained by means of air monitoring devices HORIBA APNA-350 E, DustTrak Aerosol Monitor – model 8520. The experimental devices of the two apparatus are given in figures 1 and 2. Particle sizer principle is based on the scattering of the light (see Mie scattering theory) upon the different particle]. Thus, the aerosol is drawn into the sensing chamber in a continuous stream using a diaphragm pump. Part of the aerosol stream is split ahead of the sensing chamber and passed through a HEPA filter and injected back in to the chamber around the inlet nozzle as sheath flow.
•The remaining flow, called the sample flow passes through the inlet entering the sensing chamber where is irradiated by a laser diode. The laser radiation passes through a collimating lens and then through a cylindrical lens to create a thin sheet of light. A gold coated spherical mirror captures a significant fraction of the light scattered by the particles and focuses it on to a photo detector. The electrical signal response of photo detector is proportional to the mass concentration of the aerosols. The electrical signal is multiplied by a calibration constant which is determined from the ratio of a known mass concentration of the test aerosol to the voltage response of the same photometers that respond linearly to mass concentration. The scattered light depends on the size distribution of the aerosol, refractive index, shape factor and density of the aerosol.
•The ultra-violet-absorption method (NDUV) based on the effect that ozone absorbs ultraviolet energy at 254 nm is integrated in the HORIBA APOA-370E for O3 monitoring, presented in Figure 2. The UV light available for detection is proportional to the amount of ozone in the sample chamber.
•Averaging intervals of 60 minutes are automatically logged with the data acquisition systems

The data concerning temperature and relative humidity shall be correlated with the data from the meteorological station at Iasi. The data base of the MAP 3D for the Iasi area, has data starting from the 21st of May 2010, therefore in our case study we shall compare the data for temperature and relative humidity for the interval the 21st of may- the 19th of July respectively the 21st of May- the 31st of July 2010. For the rest of the data, Ozone [ppb], PM10 [microg/m3] and PM2.5 [microg/m3] concentrations, the comparison was made for the time period: 27th of August – 17th of September 2010 and 18th 29th of August 2010, respectively).

Results

1. A comparison between daily temperatures and the humidity recorded by the meteorological station (experimental) and MAP 3D modelling are given in Figures 3 and 4. Preliminary results show a very good concordance prediction both qualitative and quantitative of the model concerning the temperature profiles in range of May-July period. Not the same results were obtained when we take into account the profiles of the humidity. Already there is a qualitative evolution of the two sets of compared data (experimental and model), the recording experimental data shows values of H2O vapours density much higher than predicted by the model. As we will see in the following, these results correlated with other physico-chemical phenomena, involves changes into the dynamics of the ozone concentration (see the interval 7-9 September). The weather conditions (temperature, rain, humidity) influence the distribution concentration of the main pollutants.

2. No any correlation has been obtained in case of the dusty PM10 particles (Figure 5). These results may be explained by taking into account the none-predicted supplementary pollutant sources (in the model) present in the vicinity of the Dust Trak Aerosol Monitor (the measures have been recorded near the University building where important site construction area is opening).

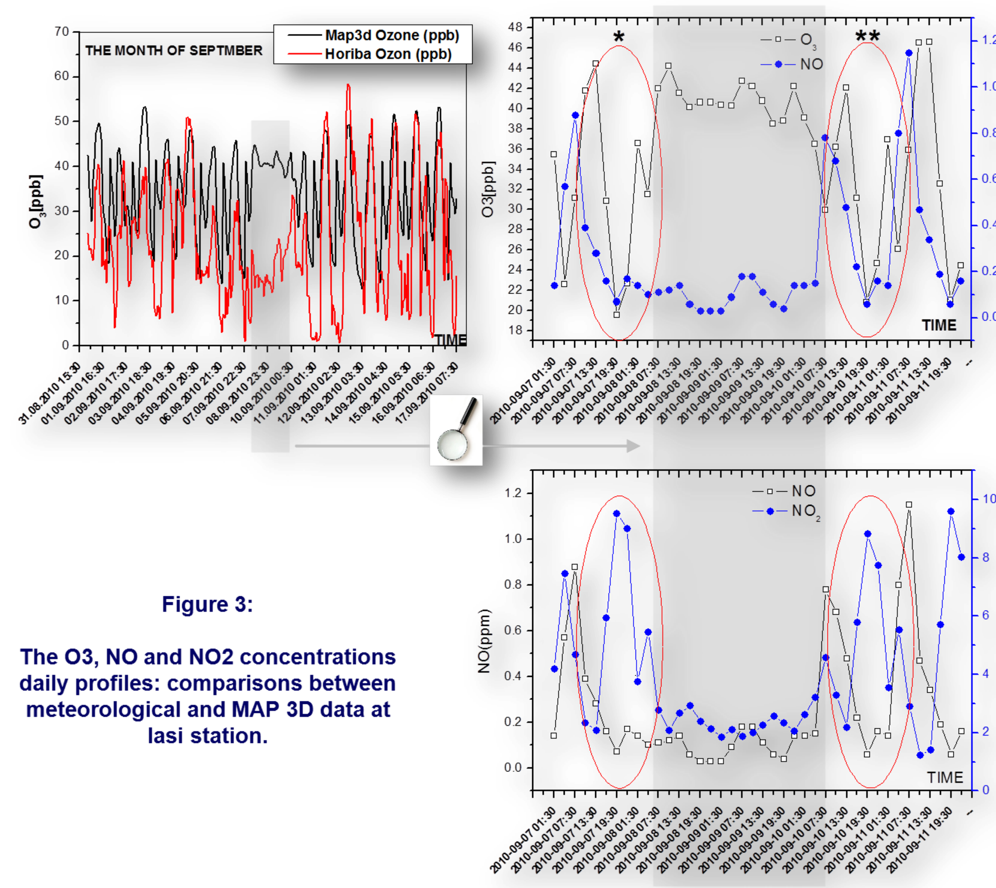


Figure 3:

The O3, NO and NO2 concentrations daily profiles: comparisons between meteorological and MAP 3D data at Iasi station.

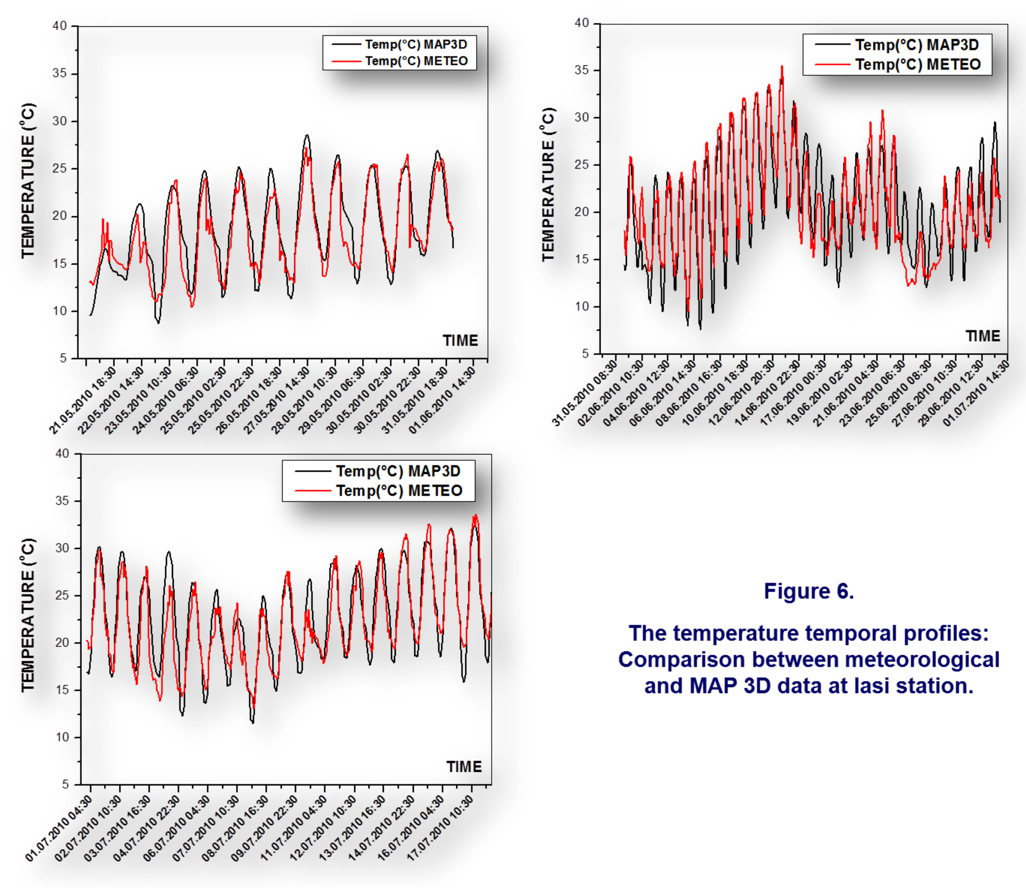


Figure 6.

The temperature temporal profiles: Comparison between meteorological and MAP 3D data at Iasi station.

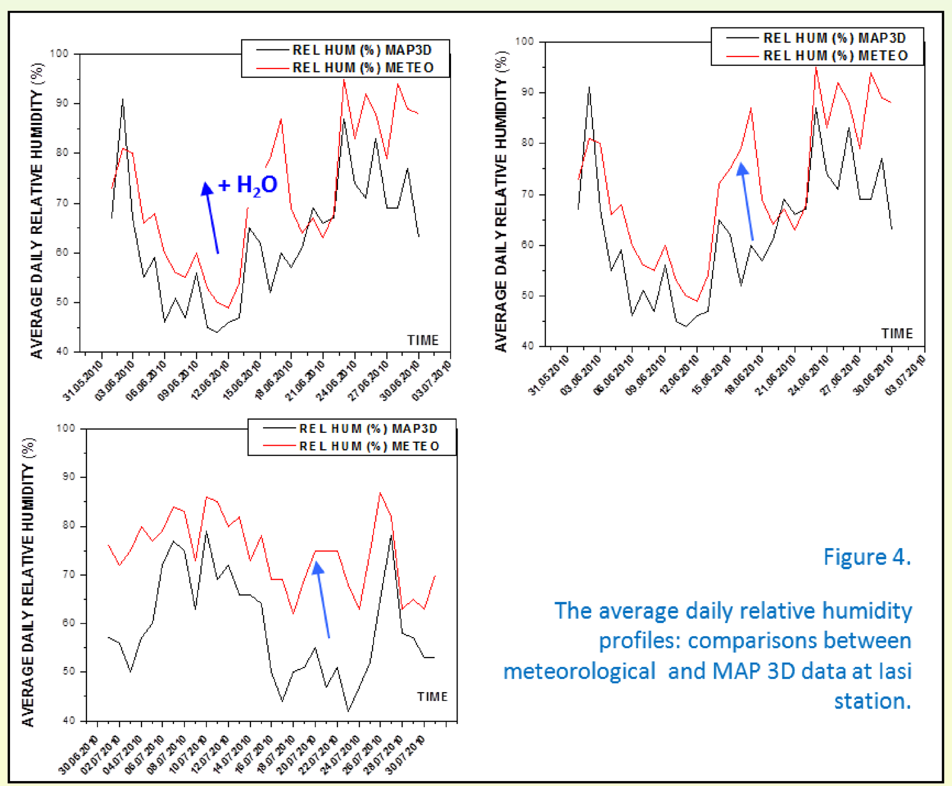


Figure 4.

The average daily relative humidity profiles: comparisons between meteorological and MAP 3D data at Iasi station.

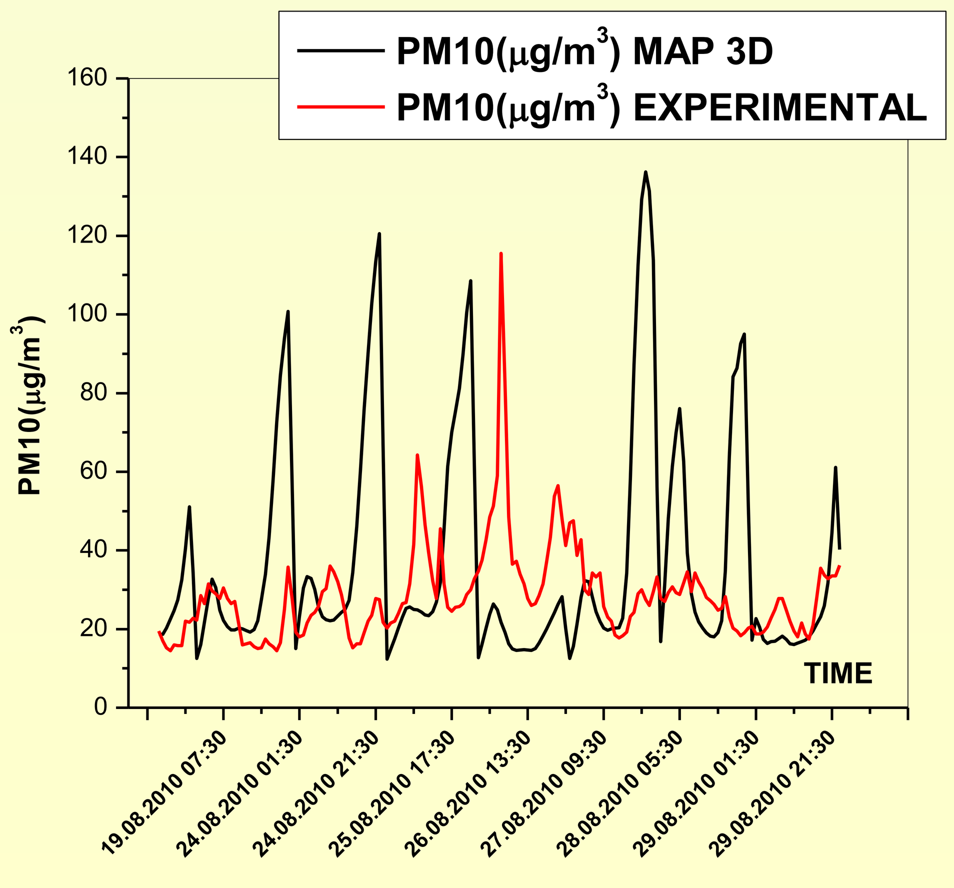


Figure 5. The PM 10 particle concentrations daily profiles: comparisons between experimental and MAP 3D data at Iasi station

In Figure 6 the O3, NO and NO2 profiles are shown. The comparison between meteorological and MAP 3D data evidenced generally qualitative and quantitative good concordances except the region of September 8 (7:30 UTC) -9 (7:30 UTC). In this period an almost constant profile of the ozone are evidenced and the oxides of nitrogen, NO and NO2 have small values. MAP3D shows a reduction of the PM particle concentrations, too (not indicated in the figure). Figure 6 shows some interesting results: ratio of NO and NO2 with maximums in the evening at 19:30 UTC and the ozone dynamics concentrations. As result from Figure 6, the NO2 density is in abundance in the evening, at 19:30 UTC on 7 and 10 September, respectively by contrast of NO - a small concentration. These observations are explained by taking into account the following. The increase in NO2 is possible due to increased pollution during day, witch reflects in the evening hours. At twilight, NO2 density depends on NO and controlled by the following reactions

$$NO + O_3 \rightarrow NO_2 + O_2$$
$$NO_2 + h\nu \rightarrow NO + O$$
$$NO_2 + O \rightarrow NO + O_2$$

During evening twilight hours, the rapid decreases in the rate of photolysis of NO2 and the abundances of atomic oxygen lead to conversion of NO into NO2 and the total number of NO2 molecules can increase substantially at evening ours (see 19:30 UTC – Figure 1). During the night NO2 can be oxidized by O3 to form NO3 – a strong atmospheric oxidant and precursor to the formation of N2O5 as following:

$$NO_2 + O_3 \rightarrow NO_3 + O_2$$
$$NO_3 + NO_2 + M \leftrightarrow N_2O_5 + M$$

During the day N2O5 molecules can be photolyzed to regenerate NO2,

$$[NO_3 + h\nu(\lambda < 700nm)] \rightarrow NO + O_2$$
$$[NO_3 + h\nu(\lambda < 580nm)] \rightarrow NO_2 + O$$

Also, during the day but not only, tropospheric NO2 plays a key role in both stratospheric and tropospheric chemistry. Ozone, one of the most extensively measured trace gases, is generated in troposphere by photolysis of the NO2:

$$[NO_2 + h\nu(\lambda < 420nm)] + O_2 \rightarrow NO + O_3$$

On the other hand, as meteorological data shows, at Iasi station rain in days of 8, 9 and 10 September 2010. This is evidenced too by the high humidity (see Figure 4). The nitric acid may be formed in the presence of nitrogen dioxide and water, as following:

$$3NO_2 + H_2O \rightarrow NO + 2HNO_3$$

The presence of atmospheric front over the investigated region decreases the sun flux radiation but increases the concentration of the water vapours. According to the eqs. (8, 9), it results that in these meteorological conditions the concentration of nitrogen dioxide molecules reduces and, as result the ozone concentration is reduced, too. Figure 6 shows that in case of experimental data the percent of the humidity are higher that in MAP 3D. Thus, we explain the difference of the ozone molecules density region in the troposphere (red line) versus MAP 3D (dark line).

Conclusions

1. In order to investigate the dynamics of the air pollutants in the Romanian, Iasi county region, both through experimental and model (MAP 3D), preliminary investigations have been performed.
2. The atmosphere molecules concentrations (O3, NO, NO2, etc) and meteorological data (temperature, humidity) have been used. Both the experimental results and MAP 3D shows that NO2 molecules play a key role in the tropospheric chemistry. Generally, the two sets of data are qualitatively in good agreement except the profiles of the dust particles that can be explained by presence of supplementary sources of regional pollutants.
3. Influence of the meteorological conditions upon the ozone molecules density at the ground level has been evidenced. The explanation may be in relation with the high degree of the humidity that reduces the concentration of nitrogen dioxide molecules and, consequently, the ozone molecules density is influenced.

Acknowledgement. This work was supported by ROmanian NETwork LIdar project (ROLINET) and Romanian Atmospheric Observatory 3D project (RADO). Special thanks to Mrs. Gina Tiron from National Meteorological Administration, Regional Meteorological Centre Moldova Iasi.