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METEOROLOGICAL ELEMENTS USED IN THE NUMERICAL FORECAST OF PM_{10} OVER THE ROMANIAN TERRITORY

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Abstract. Pollutants in large amounts may not only cause severe health problems and damage crops, but may also represent one of the main causes of global warming. Air quality numerical models are very useful tools in forecasting air pollutants transport and spread. Consequently, this paper analyzes the regional concentration of PM_{10} (a geographical domain representative of Romania's territory), by using the numerical air quality forecasting model: WRF-CHEM version 3.5. The respective model has been applied on a Romania-centered upon geographical area, for both the two months representative of the warm and cold seasons (June and January 2013, respectively), at a spatial resolution of 10 km, with a 24 hours' anticipation. For the WRF-CHEM chemistry module to be initiated, values of PM_{10} emissions were extracted from the TNO (*Nederlandse Organisatie voor toegepast natuurwetenschappelijk onderzoek*, www.tno.nl) database for 2009. The meteorological parameters required by the weather forecast model were obtained from the numerical output of the ECMWF (www.ecmwf.int) global model. All these meteorological parameters are very important for air quality simulations, especially wind profiles, which are very important assessment tools since they determine where pollutants are transported, and air-temperature as it may largely influence the speed of chemical reactions in the atmosphere. The vertical diffusion is strongly linked to the height of the mixing layer and influences the exchange between the ground layers and the open troposphere. In order to highlight the quality of the numerical forecasts for PM_{10} from the WRF-CHEM model, the results obtained were compared to the measurements obtained through gravimetric methods (average daily values of PM_{10}). Hence, specific measurements were provided by the National Environmental Protection Agency (ANPM).

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1. Introduction

Over the last years, air quality issues have become a particular concern for the scientific community, especially if taking into consideration that air pollution still remains the environmental risk factor which causes premature death in Europe (EEA, 2014). In this respect, real-time air quality forecasting is a response to these needs, reflecting the understanding of physical processes which take place into atmosphere (Žabkar et. al., 2015). Moreover, air pollution can affect ecosystems and the climate system and can modify cloud properties by aerosol indirect effect (Meij et al., 2008).

PM_{10} particles can lead to reduced visibility, adverse health effects and may adversely influence the heat balance of the Earth. The airborne particles also play an important role in spreading reproductive materials and pathogens (pollen, bacteria, spores, viruses, etc.) as well as various other biological organisms (Shiraiwa et. al., 2012). The total number concentration, chemical composition and size distribution of an aerosol population depend on the location (urban or rural; continental or marine) as well as on the season and time of the day (e.g. Poschl, 2005).

Meteorological parameters are very important tools in air quality simulations. Out of them, wind profiles and air-temperature are the most important ones since they determine where pollutants are transported, in the first case, and the speed of chemical reactions in the air, in the second case. The vertical diffusion is, moreover, strongly linked to the height of the mixing layer and directly influences the exchanges between the ground layers and the open troposphere.

At national level, agglomerations (zones with a population exceeding 250,000 inhabitants, or, where the population is equal to 250,000 inhabitants or less, with a density of 3,000 inhabitants per km^2), were defined, together with zones for air quality assessment and management. The National Air Quality Monitoring Network (NAQMN) was established between 2005 and 2007, by taking into consideration the criteria established by the European directives[3]. The air quality data received from all the fixed monitoring stations as well as the meteorological data are sent both to the local centers and to panels for public display.

The paper is structured as follows: section 2 describes the data and methods used in the numerical forecast of PM_{10} over the Romanian territory, while section 3 outlines the results. Section 4 summarizes the conclusions.

2. Data and methods

This study is mainly based on the numerical air quality forecasting model WRF-CHEM (*Weather Research and Forecasting* model coupled with *Chemistry* module), version 3.5. This model was operated at a 10 km horizontal resolution,

[3] http://acm.eionet.europa.eu

on a Romania's centered upon geographic area (Figure 1), for the two months representative of the warm and cold seasons (June and January 2013, respectively*)*.

The model was integrated for a forecast period of 24 hours. The WRF (*Weather Research and Forecasting*) model is mainly designed for operational forecasting and includes a chemical module with which it is fully coupled (*WRF-CHEM*), (Xuexi et al., 2006). However, the WRF and WRF-CHEM models differ mainly in terms of chemistry. From this point of view, as compared to WRF, the WRF-CHEM model needs additional gridded input data linked to emissions.

The integration domain of WRF-CHEM module includes 161x161 grid points, with 35 vertical layers and a running time of 2 hours and 30 minutes for 24 hours of forecast. The testing period taken into consideration in the present study is represented by January 2013.

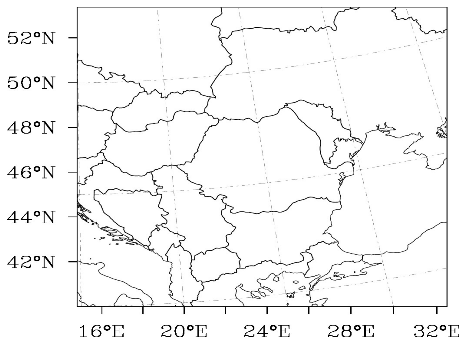


Figure 1. WRF-CHEM integration domain

The lateral and boundary conditions for the chemistry module are represented by the values of PM_{10} emissions from the TNO (*Nederlandse Organisatie voor toegepast natuurwetenschappelijk onderzoek*, www.tno.nl) database for 2009. The emissions from the TNO database were processed in 2 stages: the first step consisting in the transformation of the values from tons/ year in micrograms/ m^3, thus resulting the monthly averages for each day of the week in a regular grid of TNO database; the second step comprising the interpolation of the regular grid of the TNO database into the grid of the model WRF-CHEM (monthly average for each day of the week).

On the other hand, in order for the weather forecast model to be initialized, there were used some meteorological parameters obtained from the numerical output of the *European Center for Medium Range Weather Forecasting* (**ECMWF**) Global Model. Subsequent ECMWF numerical model forecasts were obtained by means of specialized scripts from the MARS database[4]. The most important parameters which were integrated in the above-mentioned model are presented in the table below (Table 1).

Table 1. Meteorological parameters used for calibration

Surface level parameters	**Pressure level parameters for levels between 1,000hPa and 500hPa**
surface 10 meter U wind component	specific humidity
surface 10 meter V wind componen	relative humidity
surface 2 meter dew point temperature	temperature
surface 2 meter temperature	U velocity
surface mean sea level pressure	velocity
surface snow depth	geopotential height

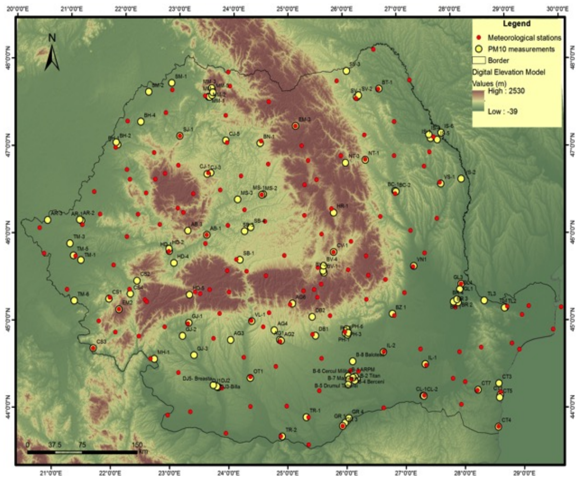


Figure 2. Map showing the position of the meteorological stations (red dots) and PM10 ground measurement (yellow dots)

In order to highlight the quality of the numerical forecasts for PM_{10} from the WRF-CHEM model, the results were compared to the measurements obtained through the gravimetric method (average daily values of PM_{10}), available at the ground stations (Figure 2).

4 http://www-mars.lmd.jussieu.fr/mars/access.html

The specific measurements were provided by the *National Environmental Protection Agency* (NEPA), while the meteorological data were extracted from the *Romanian National Meteorological Administration* database (160 synoptic stations available, also presented in Figure 2).

3. Results

The figures bellow (Figures 3 and 4) show the mean values in 24 hours, of PM_{10} concentrations, for two days in January and June, respectively. It can be

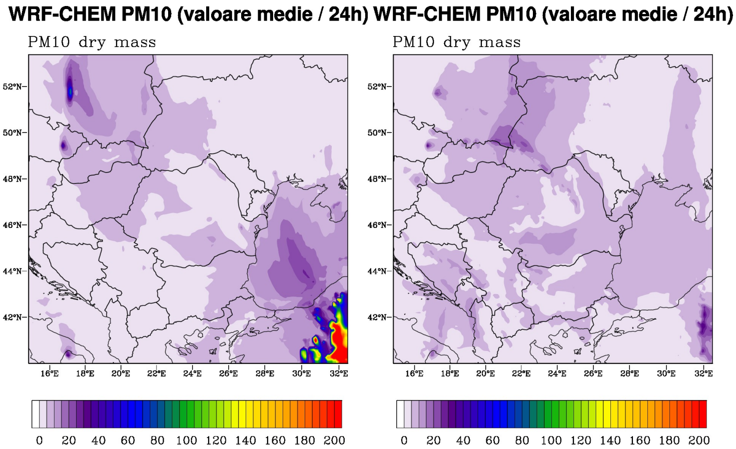


Figure 3. The medium values in 24 hours of PM10 for the day of 12 January 2013 (left) and 13 January 2013 (right)

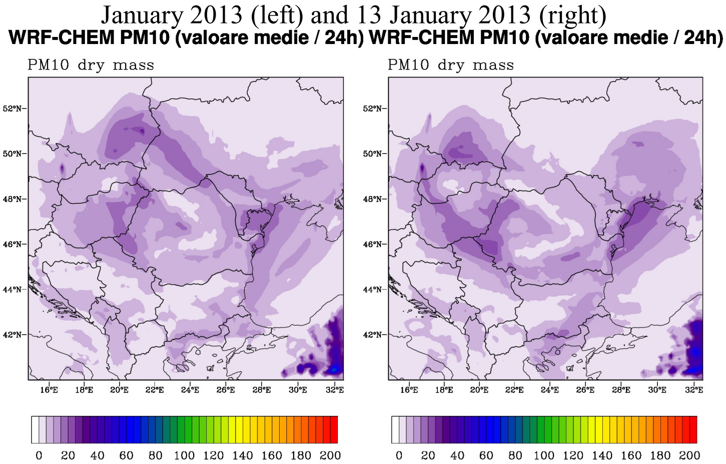
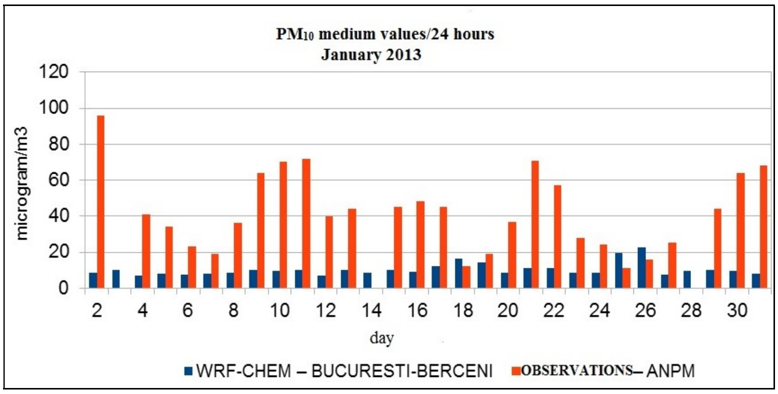


Figure 4. The medium values in 24 hours of PM10 for the day of 7 June 2013 (left) and 6 June 2013 (right)

noticed that on 13 January, as compared to 12 January, the PM_{10} values reach levels of about 30 micrograms/m^3 in most regions of the Romanian territory. For the summer month, the values are higher, reaching up to 40 micrograms/m^3 especially in the Western and Black Sea regions (6 June).



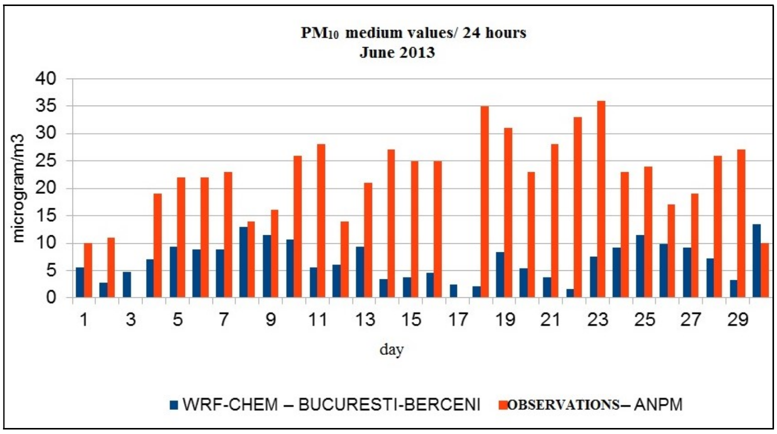
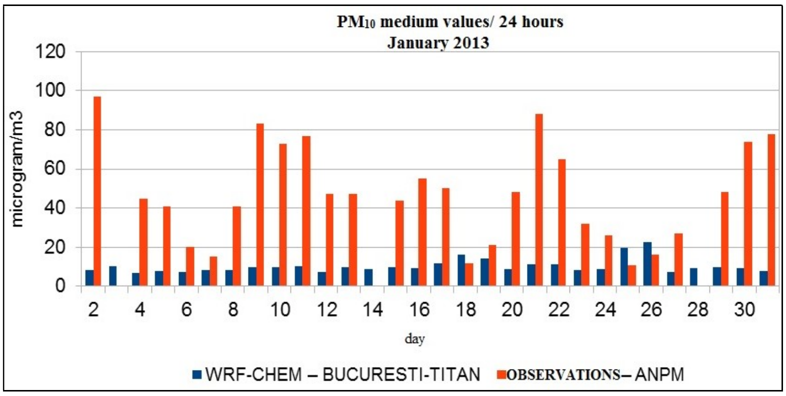


Figure 5. Comparison between medium values/24h of PM_{10} concentrations derived from WRF-CHEM model and observational data, at monitoring station Bucureşti-Berceni

By analyzing the graphics above, it can be noticed that the model generally tends to underestimate the forecast concentrations of PM_{10} as compared to observations, mostly during the summer season. In winter, the model results show a significantly higher accordance with observational data, the maximum values of PM_{10} reaching up to 100 micrograms/m^3.

For the Bucureşti-Titan station, the results indicate the same tendency as the WRF-CHEM model, mainly underestimating the PM_{10} concentrations especially in summer. The maximum values in June reach up to 40 micrograms/m^3 (Figure 6).



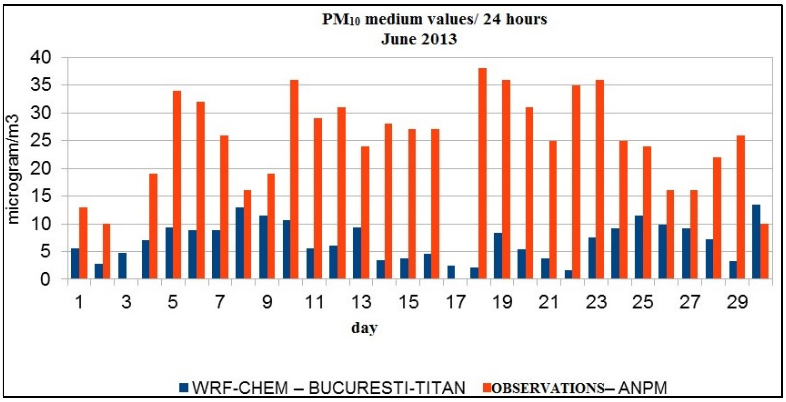


Figure 6. Comparison between medium values/24h of PM_{10} concentrations derived from WRF-CHEM model and observational data, at monitoring station Bucureşti-Titan

For June, at both stations analyzed, unlike January, the average values of PM_{10} model results are closer to the observation data values.

4. Conclusions

In the present paper, the air quality model WRF-CHEM was integrated at a horizontal resolution of 10 km for the entire Romanian territory. The model was evaluated for one winter month (January 2013) and one summer month (June 2013).

The study of two selected days from January show that the 24 hours' mean values of PM_{10} concentrations which were forecast by the model, reach levels of 30 micrograms/m^3 in most regions of the Romanian territory.

For June, the forecast values for 24 hours' mean PM_{10} concentrations are higher, reaching up to 40 micrograms/m^3. This is valid especially for the Western part of the country and the Black Sea region.

The WRF-CHEM model displays a general tendency to underestimate the forecast values for PM_{10} as compared to the observation data obtained from NEPA, for both months analyzed.

Similar to the results obtained in the previous studies conducted by Hirt et. al. (2012, 2013, 2014) and Bocquet et. al. (2015), during the summer months the model forecast shows better results. This behavior can be due to the fact that, in winter, higher PM_{10} concentrations are caused by the inversion layers which are not very accurately represented by the model.

This study showed only an initial analysis of the whole performance run by the WRF-CHEM model in forecasting PM_{10} concentrations over the Romanian territory. Further improvements on the numerical forecast of the WRF-CHEM model for PM_{10} particulates could be achieved by consequently assimilating various types of PM_{10} observational data, such as ground measurements, different types of satellite products and so on. Other improvements can also be obtained by using initial meteorological conditions at a higher resolution, in order to have a better description of the atmospheric conditions which play an important part in the transport and chemical reaction speed of different pollutants.

References

A. de Meij, P. Thunis, B. Bessagnet, C. Cuvelier, 2008 - *The sensitivity of the CHIMERE model to emissions reduction scenarios on air quality in Northern Italy*. Atmospheric Environment 43, 1897–1907

Bocquet, M., 2012 - *Parameter field estimation for atmospheric dispersion: Applications to the Chernobyl accident using 4D-Var*, Q.J. R. Meteorol. Soc., 138, 664-681

European Environment Agency*, 2014 - Air quality in Europe — 2014 report, ISSN 1977-8449*

Hirtl M., Mantovani S., Krüger B.C., and Triebnig G., 2012 **-** *AQA-PM: Extension of the Air-Quality model for Austria with satellite based Particulate Matter estimates. Geophysical Research Abstracts Vol. 14, EGU2012-1846, 2012 EGU General Assembly 2012*

Hirtl M., Mantovani S., Krüger B.C., Triebnig G. and Flandorfer Claudia, 2013 - *AQA-PM: Extension of the Air-Quality Model For Austria with Satellite based Particulate Matter Estimates, Geophysical Research Abstracts Vol. 15, EGU2013-3915, 2013 EGU General Assembly 2013*

Poschl, U., 2005 - *Atmospheric Aerosols: Composition, Transformation, Climate and Health Effects. Angew. Chem. Int. Ed., 44, 7520 – 7540*

Žabkar R., Honzaka L., Skok G., Forkel R., Rakovec J., Ceglar A., Žagar N., 2015 - *Evaluation of the high resolution WRF-Chem (v3.4.1) air quality forecast and its comparison with statistical ozone predictions.* IN: Geosci. Model Dev., 8, 2119–2137

Shiraiwa M., Selzle K., Pöschl U., 2012 - *Hazardous components and health effects of atmospheric aerosol particles: reactive oxygen species, soot, polycyclic aromatic compounds and allergenic proteins.* IN: Free Radic Res. 2012 Aug; 46(8):927-39. Epub 2012 Apr 23

Xuexi Tiea, Sasha Madronicha, GuoHui Lib, Zhuming Yingc, Renyi Zhangb, Agustin R. Garciad, Julia Lee-Taylora, Yubao Liua, 2006 - *Characterizations of chemical oxidants in Mexico City: A regional chemical dynamical model (WRF-Chem) study*. IN: Atmospheric Environment Volume 41, Issue 9, Pages 1989–2008.