16th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
8-11 September 2014, Varna, Bulgaria

EVALUATING THE PERFORMANCE OF WRF-CMAQ MODELS IN BULGARIA BY MEANS OF THE DELTA TOOL

Emilia Georgieva, Dimiter Syrakov, Maria Prodanova, Iglika Etropolska, Kiril Slavov

National Institute of Meteorology and Hydrology- Bulgarian Academy of Sciences, Sofia, Bulgaria

Abstract: Model evaluation is performed based on 1 year of simulations for 2013 and on data from about 25 stations of the national air quality monitoring network. The DELTA tool, developed within the EU FAIRMODE initiative, is used to analyse model results focussing on 8-hour mean maximum daily ozone levels, hourly nitrogen dioxide values, and daily particulate matter (PM10) concentrations. Model performance is found to be good for ozone, especially at rural sites, but unsatisfactory relevant to NO2 and PM10. Possible ways for improvement are discussed.

Key words: *air quality assessment, EU limit values, model evaluation*

INTRODUCTION

The air quality model system WRF-CMAQ is the backbone of the Bulgarian Chemical Weather Forecasting and Information System (BgCWFIS), version 2, developed in the last two years. BgCWFIS is running in operational mode at the National Institute of Meteorology and Hydrology in Sofia (NIMH) providing daily 72-hour forecast for the fields of surface concentration of 4 key pollutants – particulate matter, nitrogen dioxide, sulphur dioxide and ozone. The simulations over the whole territory of Bulgaria are performed with 9 km horizontal resolution, while for the region of Sofia downscaling to 1km was recently established.

Although the system was not developed intentionally for air quality assessment in the frame of the EU Air Quality Directive (AQD), by the moment already one year of simulations are available, and thus some initial model performance evaluation can be taken over.

The purpose of this study is to evaluate the performance of BgCWFIS using surface data from the national air quality monitoring network for the year 2013 and focusing on mean daily PM10, 8-hour mean maximum daily O3 and hourly NO2 concentrations. The tool for this analysis is the software package "DELTA", developed in the framework of the EU initiative FAIRMODE (Thunis et al., 2011). DELTA Version 3, that considers observation uncertainty in model performance indicators (Thunis et al., 2012), is applied in order to give insight into the main shortcomings of BgCWFIS related to model assessment of air quality in Bulgaria.

THE MODEL SYSTEM

The simulations in this study are made by the Bulgarian multi-domain Chemical Weather Forecasting and Information System (Syrakov et al., 2013a,b). The forecast period is 3 days starting at 00 UTC each day and the forecast regions are 5: Europe, Balkan Peninsula, Bulgaria, Sofia Region and Sofia City. The nesting approach is used increasing the space resolution from 81 km (Europe) to 1 km (Sofia City). The forecasted pollutants are SO2, NO2, Ozone and PM10. The System is fully automated. It is based on the well known models WRF (Meso-meteorological Model) and the US EPA dispersion model CMAQ (Chemical Transport Model). The WRF model is driven by the US NCEP Global Forecast System data (1°×1° space and 6 h time resolution). As emission input the TNO data are used for the two biggest domains. For the 3 Bulgarian domains the current emission inventory prepared by Bulgarian environmental authorities is exploited. More detailed description of the system can be found at the

NIMH-BgCWFIS web-site: http://www.meteo.bg/en/cw, where also maps of forecasted pollutants are uploaded. Only results for Bulgaria region (9 km resolution) are used in this study.

MONITORING DATA

Data from the national air quality monitoring network, maintained by the Bulgarian Executive Environment Agency with the Ministry of Environment and Water, are used in this study. For 2013 observations from 33 stations were available. The number of stations per pollutant is shown in Table 1.

Table 1. Number of stations and data availability (%) for 2013

	NO2 hourly	**O3 hourly**	**PM10 daily**
Number of all stations with measurements	26	22	31
Number of background stations with measurements	21	17	23
Number of valid background stations (more than 75 % of data)	18	16	18

The stations are mostly located in urban areas. In view of the model grid resolution only background stations have been selected for the study. There are only two rural stations (dark dots in Figure 1), both of them in mountain regions.
The built–in check integrity tool in DELTA turned out to be very useful in highlighting outliers in observational data and eliminate suspicious stations from further analysis.

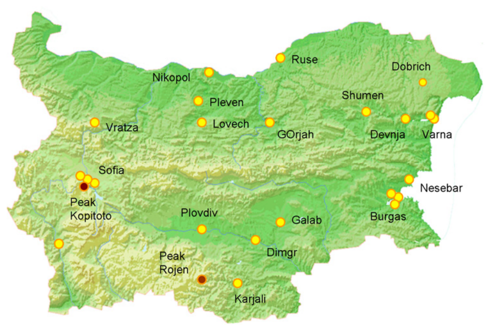

Figure 1. Location of background air quality monitoring stations used in this study. Dark dots indicate the two rural (mountain) stations: peak Kopitoto (1323 m a.s.l.) near Sofia and the remote "Peak Rojen" (1750 m a.s.l.)

RESULTS AND DISCUSSION

Figure 2 gives an overview of model performance for maximum daily 8-hour mean ozone (8hDMax) during the whole year (left) and for the summer period (right). From the available 33 stations only 16 have sufficient data; they are represented with different symbols where colours indicate the region of the station. In general, the model overestimates observations in all regions on annual basis (positive bias), and has problems with correlation, so that only 31% fulfil the DELTA model quality objective (MQO). Two of the stations in the green area are rural mountain sites ("Kopitoto" near Sofia and Peak "Rojen" in southern Bulgaria). During summer the model fulfils the criteria at all stations but problems with standard deviation (lack of amplitude) are evident for stations in Sofia and western Bulgaria, while deficit in correlation is noticed mainly at stations from the east-southeast part of the country.

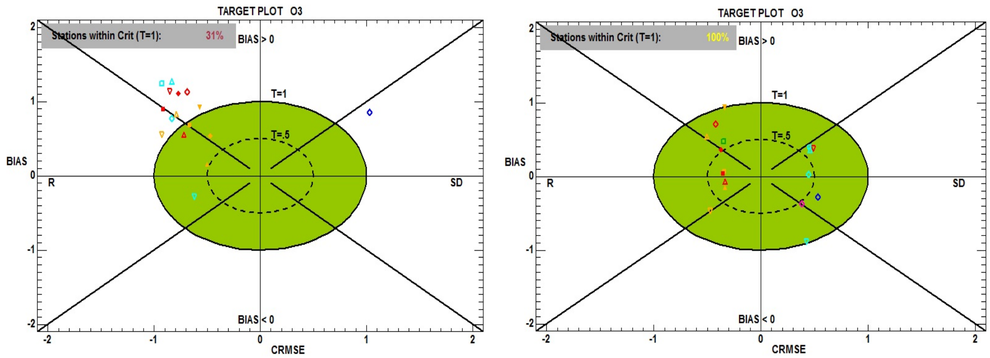

Figure 2. Target diagram for O3 8hDMax concentrations for the whole year (left) and for the summer only (right)

Figure 3 shows mean observed and modelled values at single stations (left) and gives some information on the correlation coefficient on the ModelPerformanceCriteria (MPC) plot (right). Mean values of O3 8hDMax by observations and model are 73 μgm^{-3} and 93 μgm^{-3}, the highest correlation coefficient is for the rural remote station "Rojen" – 0.72.

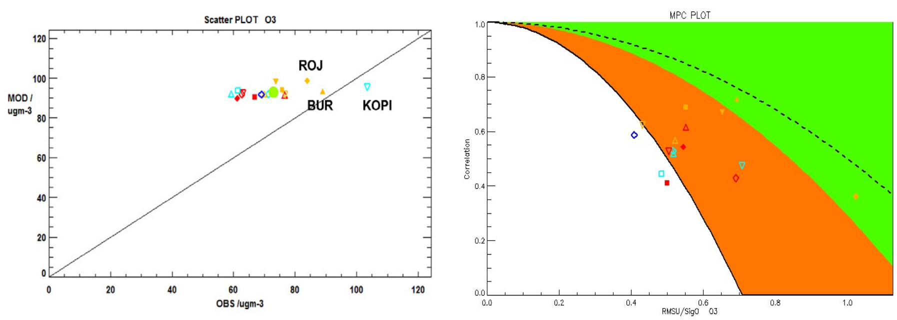

Figure 3. Scatter plot for O3 8hDMax concentrations for the whole year (left) and MPC (right) with symbols representing each station. The symbols identify stations with higher ozone levels: ROJ="Peak Rojen", KOPI – the mountain station "Kopitoto", and BUR – the urban station Burgas "Meden Rudnik"

NO2 concentrations are underestimated at all stations, as shown on Figure 4, more significant in large cities (Sofia, Varna, Plovdiv) (symbols outside the green area). 61% of the stations fulfil the target criterion. Mean annual NO2 value averaged by observations is 13.9 μgm^{-3}, while the model simulates 2.9 μgm^{-3}.

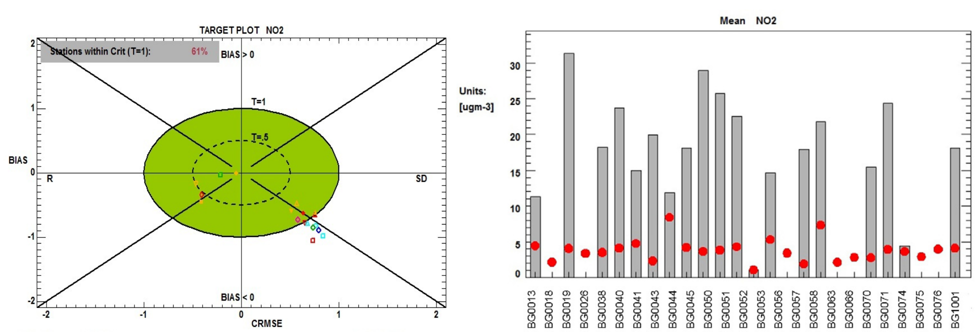

Figure 4. Target diagram for NO2 hourly values (left) and Bar plot with mean annual values - observed (bars) and modelled (dots) at individual stations and in average (right)

NO2 underestimation is probably due to the coarse model resolution relative to the scale of the typical emission sources for NO2 (street level).

Observed daily mean PM10 concentrations are significantly higher than the modelled ones (Figure 5, left). The observed annual mean, averaged over all 18 valid background stations, is 39 μgm^{-3}, while the simulated value is 4 times lower. This significant underestimation might be attributed to the coarse model resolution and lacks in emission inventories at local level especially in winter. Figure 5 (right) shows that the model does not capture differences winter–summer in the main urban areas. The difference in observations varies in the range from 15 μgm^{-3} (at the coastal cities Varna and Burgas) to 70 μgm^{-3} at Plovdiv, while the model simulates similar difference at all stations at about 5 μgm^{-3}.

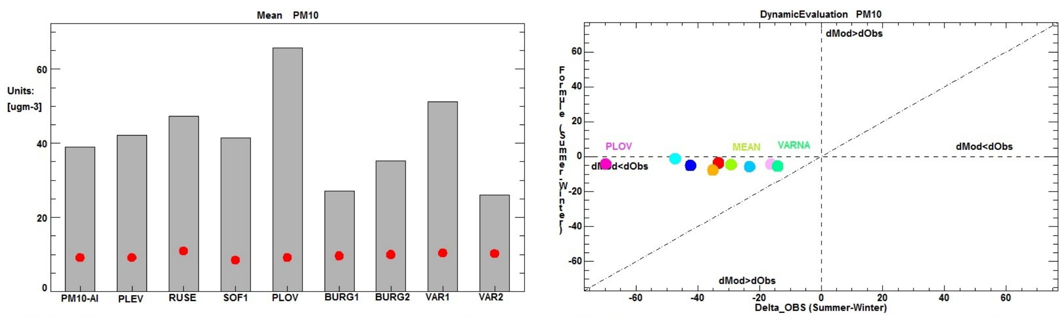

Figure 5. PM10 mean modelled and observed (left). First column refers to values averaged over all stations, the next columns refer to some large urban areas; Differences in summer-winter observed and simulated values (right), where dots represent the same stations as on the left diagram

The PM10 target plot (Figure 6) shows that the main deficit in model values is related to amplitude (standard deviation). The mean correlation coefficient for the 18 stations with sufficient data is 0.36 and is lower than the value for urban background stations (0.44) reported by Thunis et al., 2012.

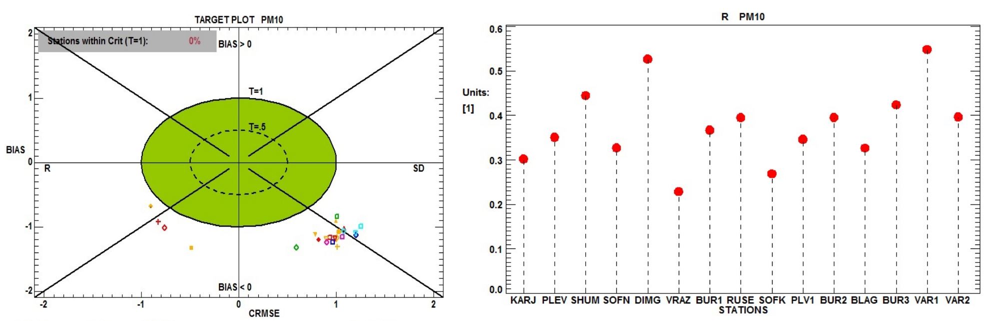

Figure 6. Target plot PM10 daily mean concentrations in 2013(left);
R correlation coefficient for stations of the right part of target plot (right)

CONCLUSIONS

BgCWFIS model results have been compared to observations from 25 background stations in Bulgaria. Model performance for O3 is better than for PM10 and NO2. The model tends to overestimate 8h mean daily max O3 concentrations, more evident during winter. The best model results are found for the 2 rural stations (mountain stations) and for one of the coastal stations. The grid resolution of 9 km might be an explanation for better performance at rural sites. Only 31% of the stations fulfil the DELTA MQO (DMQO). The correlation coefficient varies between 0.43 and 0.72, but at half at the stations the correlation problems are indicated. For NO2 61% of the stations fulfil the DMQO, however observations are underestimated and model weakness in representing amplitude is noticed. Daily PM10 values are also underestimated by the model, the target diagram indicates model problems both for correlation and amplitude and DMQO is not fulfilled at any station. Part of bad model results for daily PM10 might be attributed to uncertainty of emissions in the winter period and model emission profiles, as well as to insufficient representation of local meteorological effects (thermal inversion) within the model. However, for this study part of the error is related to some observation data shortcoming found in daily mean values.

Exceedance of daily limit PM10 value at majority of the stations in Bulgaria is well known problem (EEA Report, 2013). For 2011, 100% of the urban population was exposed to concentrations above the reference level and the trend of high mean annual concentrations is maintained, (EEA Bulgaria Factsheet, 2013). Thus, providing more accurate model results for the country is actual and very challenging task.

Further studies will be focussed on model grid resolution and questions related to observation representativeness.

Acknowledgments
The Executive Environment Agency - Bulgarian Ministry of Environment and Water is acknowledged for providing air quality data.

REFERENCES

EEA Report: Air quality in Europe — 2013 report, European Environment Agency Report 9/2013, ISBN 978-92-9213-406-8, 107 pp. , http://www.eea.europa.eu/publications/air-quality-in-europe-2013.

EEA Bulgaria Factsheet: Air pollution fact sheet 2013-Bulgaria, EEA-2103, 22 pp., http://www.eea.europa.eu/themes/air/air-pollution-country-fact-sheets.

Syrakov D., M. Prodanova, I. Etropolska, K. Slavov, K. Ganev, N. Miloshev, and T. Ljubenov, 2013a: A Multy-Domain Operational Chemical Weather Forecast System, in. Lirkov I., S. Margenov, and J. Wan´siewski (Eds.): LSSC 2013, LNCS v.8353, pp. 413-420, Springer-Verlag, Berlin, Heidelberg.

Syrakov D., M. Prodanova, K. Slavov, I. Etropolska, K. Ganev, N. Miloshev, T. Ljubenov, 2013b: Bulgarian System for Air Pollution Forecast, Journal of International Scientific Publications ECOLOGY & SAFETY, Volume 7, Part 1 (http://www.science-journals.eu), ISSN: 1313-2563, pp.325-334.

Thunis P., E. Georgieva, S. Galmarini, 2011: A procedure for air quality models benchmarking. http://fairmode.jrc.ec.europa.eu/document/fairmode/WG1/WG2_SG4_benchmarking_V2.pdf

Thunis P., Pederzoli, A., Pernigotti, D., 2012: Performance criteria to evaluate air quality modeling applications., *Atmospheric Environment*, **59**, 476-482.