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CAPABILITIES OF THE BULGARIAN CHEMICAL WEATHER FORECAST SYSTEM EVALUATED WITH THE FAIRMODE-DELTA TOOL

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Abstract: The DELTA tool in forecast model has been applied to data for PM_{10} and O_3 in 2015. Modelled data were provided by the WRF-CMAQ system running operationally at NIMH-Sofia, observational data are from 25 background stations of the National Air Quality Monitoring network. Sensitivity tests of user input in DELTA on embedded statistical parameters (false alarm ratio, probability of detection, modelling quality indicators) have shown improvement with increasing measurement uncertainty, the time length of the forecast and impact of uncertainty flexibility option. The results show that the main modelling quality indicator is not fulfilling the requirement (less than 1) for no one of the selected pollutants. Better model performance is found for PM_{10} in northern Bulgaria and in the winter period; for ozone – southern Bulgaria and at the mountain stations.

Key words: *target diagram, modelling quality objectives, ozone, particulate matter*

INTRODUCTION

The Bulgarian Chemical Weather Forecasting and Information System (BgCWFIS), based on the WRF-CMAQ models, is running in operational mode at the National Institute of Meteorology and Hydrology in Sofia providing daily 72-hour forecast for the surface concentrations of key pollutants – particulate matter, nitrogen dioxide, sulphur dioxide and ozone over Bulgaria. The DELTA tool is a software, developed in the last few years within the EU - FAIRMODE (Forum for Air Quality Modelling in Europe) initiative (http://fairmode.jrc.ec.europa.eu/), as support to implementation of models under the EU Air Quality Directive (AQD, 2008). The performance of the modelling system relative to assessment of air quality for O_3 and PM_{10} applying the DELTA tool, was studied by Georgieva et al., 2015.

The purpose of this work is to evaluate the forecasting capabilities of BgCWFIS for the daily mean PM_{10} (PM10) and the maximum daily eight-hour mean ozone (8hDMax O3) using the updated version of the DELTA tool (ver.5.5) which includes criteria and plots for forecasting application (Janssen et al., 2017). The evaluation is based on paired data: surface data from the national air quality monitoring network for the year 2015 and modelled hourly concentrations, looking at statistical indicators embedded in DELTA for forecasting purposes – target plot, false alarms, probability of detection, summary statistics.

METHODOLOGY

The modelling system

The Bulgarian Chemical Weather Forecast System (Syrakov et al., 2013a, b) is based on the state of the art WRF-CMAQ model chain. The Weather Research and Forecasting model WRF v3.6.1 (Skamarock and Klemp, 2008) is used as meteorological pre-processor to the Community Multiscale Air Quality (CMAQ) model, v4.6 (Byun and Schere, 2006). The model was run over 3 nested domains – Europe (81km horizontal resolution), Balkan Peninsula (27 km), and Bulgaria (9 km). The initial meteorological conditions are provided by the National Centers for Environmental Prediction (NCEP) Global Forecast Model (GFS) with resolution of 1°x1° in space and 6 hours in time. The chemical boundary conditions over the mother domain (Europe) are set according to the CMAQ's BCON profiles. CMAQ was run with the predefined configuration "cb4_ae4_aq".

The emissions are based on the inventory provided by the Netherlands Organization for Applied Scientific Research (TNO) for 2009 (Kuenen et al., 2014); for Bulgaria national emission inventories for 2010 have been exploited. Results from model domain Bulgaria (9km) have been used here.

Observational data

The air quality monitoring stations are irregularly spread over the country, and mostly in urban regions; only two rural stations are available and they are located at mountain tops (Fig.1). Data for 2015 were available at 33 stations of different type. In view of the model grid resolution only background stations have been selected (25). The number of stations with data availability more than 75% is 22 for PM_{10} and 19 for O_3.

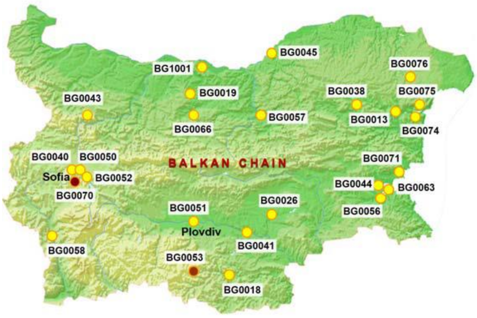

Figure 1. Location of background air quality monitoring stations used in this study, brown dots indicate two stations at mountain tops BG0070 (1321 m asl.) and BG0053 (1720m asl.)

The forecasting indicators in DELTA

The forecasting indicators and diagrams in DELTA v.5.5 are still in process of maturing (Janssen et al, 2017). The idea is to have consistence with the assessment diagrams and indicators, were measurement uncertainty (MU) has been introduced in defining modelling quality indicators and criteria. The target indicator for forecast is defined using normalization by a quantity representative of the “intra-day” variations, and model M^* values are transformed model forecast values to account for some tolerance due to measurement uncertainty:

$$\text{Target}_{\text{forecast}} = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(M_i^* - O_i\right)^2}}{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(O_{i-j} - O_i\right)^2}} \quad \text{with} \quad \begin{aligned} M_i^* &= \min(M_{\text{i}} + \text{MU}.O_{\text{i}}, O_{\text{i}}) \text{ if } M_i < O_i\,, \\ M_i^* &= \max(M_{\text{i}} - \text{MU}.O_{\text{i}}, O_{\text{i}}) \text{ if } M_i \geq O_i \end{aligned} \qquad (1)$$

The target indicator becomes one when the model forecast is as good as a persistent model. Values lower than one indicate better capabilities than the persistent model whereas values larger than one indicate poorer performances. The measurement uncertainty has now impact not only on the target indicator, but on forecasting parameters as false alarm, missed alarms, probability of detection. It leads also to different relations between modelled, observed and limit values, which are expressed via the so called ”flexibility options”, that are part of the user input.

RESULTS AND DISCUSSION

Sensitivity to user input

The user input for the forecast mode of DELTA ver. 5.5 has 3 main parameters: a) measurement uncertainty (MU) – can be arbitrarily put to a value <100% or be a variable, i.e. accessed as in the assessment mode; b) uncertainty flexibility option relate to cases when the LV is inside the MU range - conservative (MU at high end), caution (no MU), as model (MU at the uncertainty edge closer to the model); and c) time length of the forecast (day+1,+2 etc). The flexibility options treat the cases when observations are near the limit value (LV), and modify the alarms (values above LV) given by the model.

Sensitivity tests of different user input parameters for the Modelling quality Indicator (MQI), false alarm ratio (FAR) and probability of detection (POD) for daily PM10 (LV =50 μgm^{-3}) are shown in Table 1. Higher values of MU improve the selected statistics, for consistency with the assessment mode of DELTA the “MU variable” option has been chosen in this work. The time length also has effects on MQI. Previous evaluation of BgCWFS (Etropolski, 2015) have shown that for “d+1” the results are better than for the next days, so this option has been chosen further. The flexibility option has impact on detection of alarms (FAR and POD). Best results are obtained while using the option “as model’. Sensitivity test for

8hDMax O3 lead to similar conclusions. Further on, the flexibility option was set to “conservative” – POD is not as high as with option “as model” but it is linked to observations above the LV, no matter whether the model is underestimating or overestimating the observations.

Table 1. Sensitivity tests for PM10 and different user input parameters

	"d+1" and "conserv"			**"MU variable" and "d+1"**			**"MU variable" and "conserv"**		
	MU 10%	MU 50%	MU variable	conserv	caution	as model	d+1	d+2	d+3
MQI	1.82	0.96	1.42	1.42	1.42	1.42	1.42	1.05	0.94
FAR%	27	2	9	9	26	9	-	-	-
POD%	14	32	21	21	38	43	-	-	-

Particulate matter

Fig.2 shows results for the daily mean PM$_{10}$ over the entire year 2015. The MQI is more than 1 indicating that model performance, in general, is worse than the persistent one. Only for 3-4 stations located at mountain top or near the coast the target indicator is acceptable. The deficit of the model is in “missed alarms” values, as model values are underestimating observations. The averaged observed over all stations PM10 is 35.5 µgm^{-3} while the modelled one is 24.2 µgm^{-3}, respectively the average number of exceedances is respectively 58 and 11.

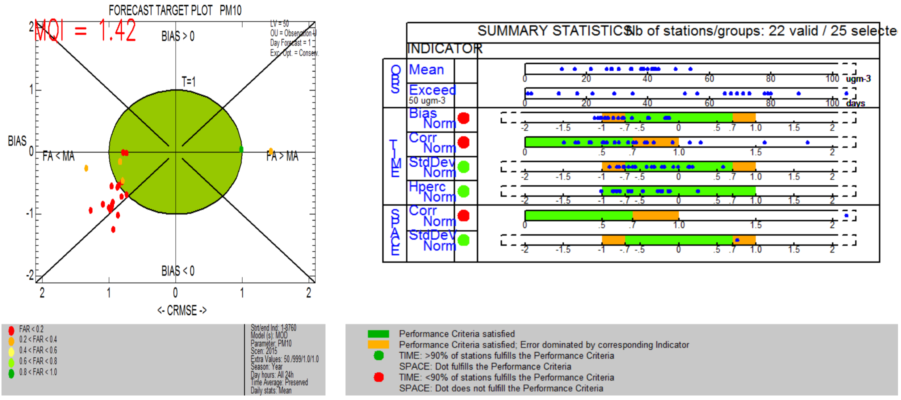

Figure 2. PM10 forecast indicators for year 2015: Target plot (left) and Summary Statistics Table (right)

Model performance for different regions (northern Bulgaria –NB, southern Bulgaria –SB, without the 2 mountain stations) and seasons (winter and summer) is summarised in Table 2. On regional basis better performance in terms of probability of detection is seen for NB, possibly due to better station representativeness in the relatively plain terrain of NB. On seasonal basis – the model seems to perform better in winter, when higher PM10 concentrations are observed and modelled, in summer the model does not simulate exceedances, while the observational data have values above the LV.

Table 2. DELTA results for mean daily PM10,
NB – northern Bulgaria (11 stations), SB-southern Bulgaria (12 stations)

	OBS µgm^{-3}	**MOD** µgm^{-3}	**MU** %	**MQI**	**POD** %	**FAR** %	**ExcComp Ind**
region				year			
all	37.64	25.02	12.58	1.42	21	9	0.64
NB	37.62	26.09	12.34	1.44	29	12	0.71
SB	37.66	24.03	12.77	1.37	15	3	0.61
				winter			
all	57.11	34.36	18.56	1.6	34	7	0.70
NB	54.11	37.97	17.01	1.67	43	11	0.71
SB	59.80	31.05	19.95	1.39	27	1	0.69

				summer			
all	27.90	17.55	8.31	2.38	0	-	-
NB	27.78	16.58	8.29	2.17	0	-	-
SB	28.00	18.44	8.32	2.33	0	-	-

Ozone

The MQI for 8h daily max ozone (Fig.3) is more than 1 (i.e. model performance, is worse than the persistent approach). The position of the dots suggest model problems with missed alarms and overestimation. Only the two mountain stations are in the green circle. Exceedances of the LV 120µgm^{-3} are observed at 12 stations, but the model simulates exceedances at all 19 valid stations.

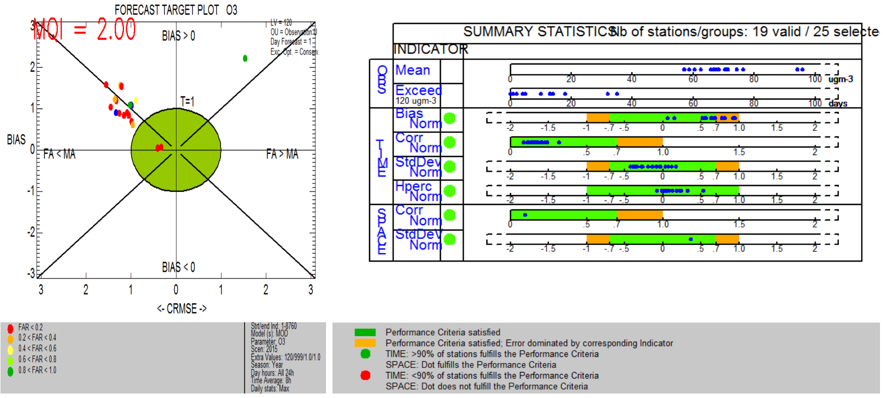

Figure 3 Ozone 8hDMAX forecast indicators for year 2015: Target plot (left) and Summary Statistics Table (right)

Table 3 summarises model performance for different regions, as in Table 2, adding also the two mountain stations (MNT). Despite model overestimation as suggested by the target diagram, POD is rather low (best in summer at mountain stations 48%). This is most likely due to overestimation of minimum (night-time ozone values). On regional basis the forecast model capabilities are better for the stations in southern Bulgaria, where also observed ozone values are higher than for northern Bulgaria.

Table 3. DELTA results for 8h daily max ozone,
NB – northern Bulgaria (7 stations), sB-Southern Bulgaria (10 stations), MNT-mountain (2 stations)

	OBS µgm^{-3}	**MOD** µgm^{-3}	**MU** %	**MQI**	**POD** %	**FAR** %	**Exc Comp Ind**
region				year			
MNT	95.09	95.68	20.14	0.35	32	0	0.66
NB	64.01	83.06	18.64	2.18	6	11	0.41
SB	67.62	83.57	18.86	1.98	18	2	0.57
				summer			
MNT	114.48	113.64	21.3	0.23	48	0	0.74
NB	85.64	98.41	19.59	1.98	6	0	0.54
SB	93.65	99.53	20.04	1.06	19	0	0.60

CONCLUSION

The DELTA tool in forecast mode shows that the Bulgarian Chemical Weather forecast modelling system performs worse than the persistent approach both for daily PM$_{10}$ and 8hDMAX ozone at the background stations in Bulgaria for 2015. The probability of detection of values above the limit value is on average about 20% for particulate matter, and about 19% for ozone. This indicator suggest also better performance for PM$_{10}$ in northern Bulgaria and the winter period, while for O$_3$ this is evident for the mountain stations and in southern Bulgaria. The sensitivity tests have shown that forecast indicators are very sensitive to user input options in DELTA, and the analysis has to be further extended with developments in DELTA forecast parameters. Although preliminary, the results mark some important issues to be further checked and improved in the modelling system - ozone overestimation, low variability of modelled values and effects of finer grid resolutions.

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