# SIMULATION OF AIR POLLUTION IN THE CROSS-BORDER REGION BULGARIA – TURKEY

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**Abstract**: The Bulgarian Chemical Weather Forecast System, based on WRF-CMAQ models is applied with 9km resolution for air pollution simulations in the cross-border region Bulgaria-Turkey, known for its natural parks with rich biodiversity and tourism activities in summer. Model results are compared to observations from 5 surface stations focussing on PM10, O3, NO2 and SO2 in February and June 2014. The preliminary analysis based on evaluation of some main statistics (mean, correlation, temporal variation) reveals that the model system performs well for ozone in summer, while PM10 and NO2 concentrations are underestimated. The result indicate some of the air quality problems of the region – high ozone in summer, high SO2 values in parts of the Turkish territory in winter and high PM10 daily mean concentrations in winter.

***Key words:*** *air quality assessment, cross-border region, model evaluation*

## INTRODUCTION

The region investigated is located in South–Eastern Europe, at the south-eastern part of the Balkan Peninsula and includes the districts of Burgas in Bulgaria and Kirklareli in Turkey. The population density is very low, about 53 inhabitants per km$^2$. The major part of the population lives in the bigger towns, while the small villages along the Bulgarian Black Sea coast become more populated during the summer season. Several protect areas and natural parks are placed in the region, e.g. the Strandja Nature Park in Bulgaria (the largest protected area in the country) and the Saka Lake Nature Reserve with the İğneada Longoz Forests near in Turkey. The region is characterized by rich biodiversity and for its flora and fauna is treated as unique in Europe.

For the preservation of the main assets of this region (natural parks, tourism and recreation, cultural heritage places) it is necessary to know the threads posed by air pollution. As a first step towards a joint survey on air quality in the area, a project funded by EU through the Bulgarian Turkey IPA cross-border Progamme has been started in January 2014 (http://saap4future.ecobg.org/). One of the activities is numerical simulation of ground concentrations of main pollutants for specific meteorological situations.

The main objective of this work is to present and discuss preliminary results on the simulation of PM10, NO2, O3 and SO2 for the months of February and June 2014, comparing modelled values to observational ones at 5 stations.

## THE MODEL SYSTEM

The simulations in this study are made by Bulgarian Multi-domain Chemical Weather Forecast 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 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 is 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 (a PDF file) is present in its web-site: http://www.meteo.bg/en/cw, where one can find hourly forecasts for all domains and pollutants. Only results for Bulgaria region (9 km resolution) is used in this study.

## MONITORING DATA

Air quality stations in the cross-border area are operated by the regional environmental agency in Burgas, Bulgaria and by the Turkish Ministry of Environment (Edirne and Kirklareli), Figure 1.

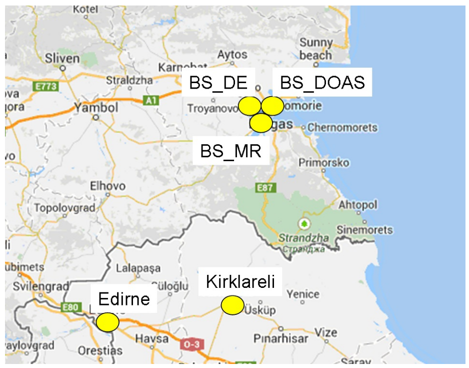


**Figure 1.** Location of the air quality monitoring stations. The three stations in Bulgaria are in Burgas BS_DE (Dolno Ezerovo), BS_MR(Meden Rudnik), BS_DOAS (DOAS station )

All stations are situated in urban areas - most populated is Burgas (about 200.000 inhabitants), Edirne (about 150.000 inhabitants) and Kirklareli about 100.000 inhabitants. The stations in Burgas are classified as background suburban, the main distance among them is about 7 km. Thus all 3 Burgas station are included in one model grid cell. One of the stations (BS_DE) is situated not far away from the industrial area of "LUKOIL Neftohim Burgas" - the biggest company on the Balkan Peninsula in terms of crude oil processing capacities. The Edirne station is near an international highway.

Table 1 summarizes the observed pollutants and the data availability for February and June 2014.

**Table 1.** Monitored pollutants and their availability (%) for two months in 2014

| Station | February 2014 | | | | June 2014 | | | |
|---|---|---|---|---|---|---|---|---|
| | NO2 | O3 | SO2 | PM10 | NO2 | O3 | SO2 | PM10 |
| Kirklareli | - | - | 72% | 92% | - | - | 97% | 96% |
| Edirne | - | - | 96% | 94% | - | - | 46% | 54% |
| Burgas_DE | 100% | 100% | 72% | - | 99% | 99% | - | 97% |
| Burgas_MR | 100% | 100% | 100% | 100% | - | 100% | 100% | 95% |
| Burgas_DOAS | - | - | - | - | 94% | 98% | 98% | - |

## RESULTS AND DISCUSSION

### Ozone

Ozone measurements are available only at the 3 near coast stations in Bulgaria. The temporal variation of observed daily max (DMAX) O3 values is similar at the three stations. Figure 2 shows that in June observed values are significantly higher at one of the Burgas stations, BS_DOAS. Emissions from traffic might contribute to lower ozone at the other two stations. The model does not “see” the difference among the stations, which is expected since all stations belong to one and the same model cell. However, the model reproduces quite well the temporal variation and magnitude at BS_DOAS, indicating that this station is representative in view of model resolution.

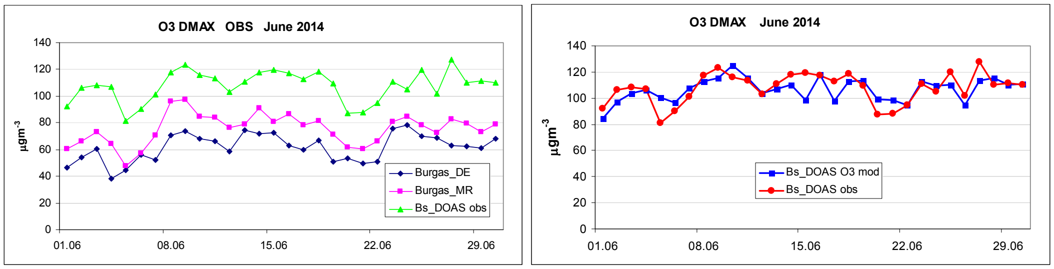


**Figure 2.** O3 daily max concentrations in June 2014: left - observed at the three Burgas stations; right - observed and modelled at the station Bs_DOAS

In general, the model overestimates daily max ozone concentrations by 20% to 60% (Figure 3). This overestimation is especially noticed at the station BS_DE, placed near industrial area. The reason might be in lack of modelled emissions.

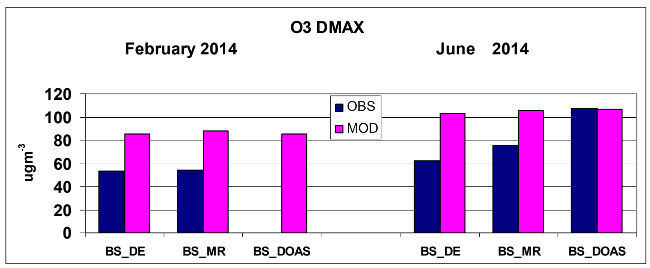


**Figure 3.** O3 daily max - monthly mean concentrations at the three Burgas stations: left – for February 2014, right – for June 2014

The diurnal variation of hourly O3 concentrations, as shown in Figure 4 for one of the stations, is characterized by model overestimation, significant during night–time hours in June. The correlation coefficient for February is 0.4, but for June reaches 0.7.

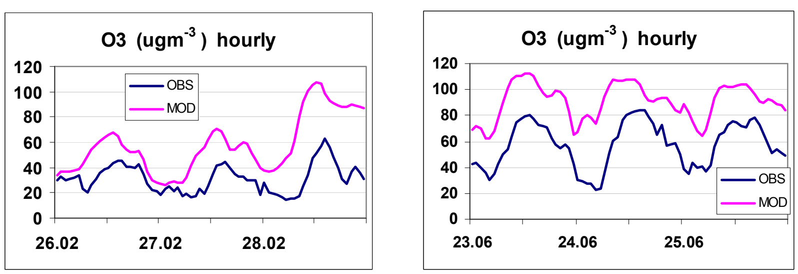


**Figure 4.** Diurnal variation of O3 daily max at the station BS_MR: left – for 3 days in February 2014, right – for 3 days in June 2014

**Nitrogen dioxide**

Hourly NO2 concentrations are also available only at the Bulgarian stations. The maximum observed hourly values for both months are about 70-80 $\mu gm^{-3}$, and thus well below the EU limit hourly value of 200 $\mu gm^{-3}$. For the station BS_DE the model overestimates maximum hourly values, but for the other station a significant underestimation is noticed (Figure 5). The model data at the stations differ more than for the other pollutants, reflecting the non-uniform character of NO2 fields in this area. The oil refinery near BS_DE is one of the main emission sources of nitrogen oxides.

Based on mean monthly values model underestimation is about 50%. This might be the reason for the higher ozone levels, produced by the model. The correlation coefficient is about 0.4 in June and lowers for February.

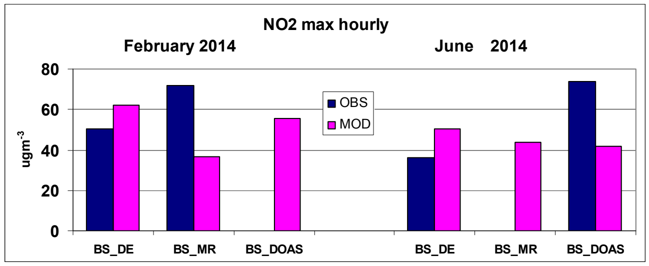


**Figure 5.** NO2 hourly max concentrations at the three Burgas stations: left – for February 2014, right – for June 2014

### Sulphur dioxide

Figure 6 shows the temporal variation of daily mean SO2 concentrations (observed and modelled) in February. The highest mean daily (127 µgm$^{-3}$) and mean monthly values SO2 (67 µgm$^{-3}$) are observed at Edirne, most likely due to the fossil fuel used for heating. The other Turkish station (Kirklareli) and the Burgas stations provide significantly lower values (mean monthly of 17 µgm$^{-3}$ at BS_MR and 9 µgm$^{-3}$ at BS_DE). Modelled concentrations are underestimated by 2 to 6 times, nevertheless the model captures high pollution events in the first week and at the end of the month, highest correlation coefficient (0.5) is obtained for Edirne and BS_DE in February. The underestimation at the stations in Turkey is probably due to shortcomings in modelled emissions.

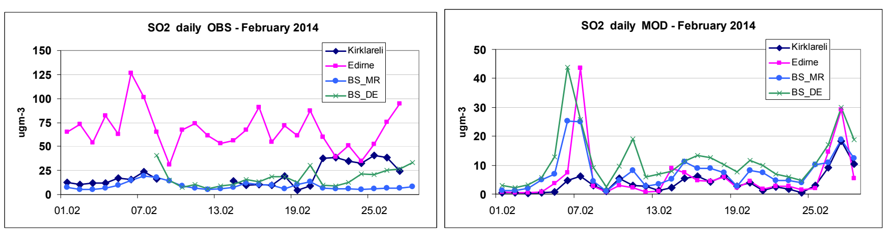


**Figure 6.** SO2 daily mean concentrations in February 2014: left – observed; right - modelled at 4 stations

### Particulate Matter PM10

In February observed daily mean PM10 concentrations are significantly higher at Kirklareli and Edirne (well above the EU limit value of 50 µgm$^{-3}$), than in BS_MR, (Figure 7). The model underestimates these concentrations by 3 to 5 times, probably due the representation of local emissions in the model. However, the model captures well some of the pollution episodes at the Turkish stations, the correlation coefficient for Kirklareli data is 0.56, for Edirne - 0.59, while lower at BS_MR – 0.3.

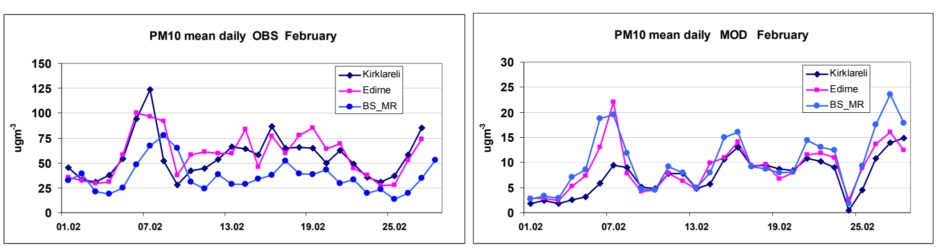


**Figure 7.** PM10 daily mean concentrations in February 2014: left – observed; right - modelled at 3 stations

In June the observed PM10 mean daily concentrations have similar temporal variation at Kirklareli, Edirne and BS_DE (Figure 8). Despite the vicinity of the two Burgas stations, there is noticeable difference in the magnitude of observed PM10, BS_DE near the oil refinery has higher values. The model underestimates (by about 2 times) daily mean concentrations and produces almost the same values and pattern at all stations with very low correlation coefficient of about 0.2.

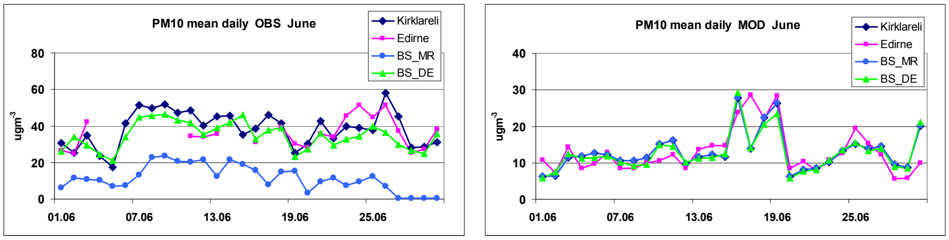


**Figure 8.** PM10 daily mean concentrations in June 2014: left – observed; right - modelled at 4 stations

## CONCLUSIONS

This work presents some results from the first joint air pollution study in the cross-border region Bulgaria-Turkey, a region known for its natural parks with rich biodiversity and tourism activities in summer. The main emission sources are located to the "outer limits" of the cross-border, where also the biggest urbanized areas are found (Burgas, Edirne and Istanbul). Model results obtained with the WRF-CMAQ system with 9 km resolution have been compared to observation data at 3 Bulgarian and 2 Turkish stations focussing on daily men PM10, daily max O3, hourly NO2 and daily mean SO2 in February and June 2014.

The analysis of observations indicates some of the air quality problems of the region – high ozone in summer near the Black Sea coast, high SO2 values in parts of the Turkish territory in winter and high PM10 concentrations in winter, often exceeding the EU daily mean limit value of 50 $\mu gm^{-3}$. The model system performs well for ozone in summer, while PM10 and NO2 concentrations are underestimated. The model system underestimates the high SO2 concentrations at Edirne in February, but captures the SO2 peaks in the temporal evolution.

The model deficit in simulating NO2 and PM10 is most likely due to representations of local emissions. Further efforts are needed also in representing the model emissions for the Turkish part of the area.
In order to understand model behaviour relative to O3 (overestimation during night-time) more detailed analysis are required involving also meteorological variables.

We believe that these preliminary results on applying modelling for analysing the air quality in the cross border area provide the basis for further joint studies.

**Acknowledgments**
This study was performed in the framework of project № 2007CB16IPO008-2013-3-025 (SAAP4FUTURE), funded by EU through the Bulgaria Turkey IPA cross border Programme CCI No. 2007CB16IPO008.

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