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IMPACT OF THE AIR POLLUTION ON THE QUALITY OF LIFE AND HEALTH RISKS IN BULGARIA

Ivelina Georgieva [1] and Vladimir Ivanov [1]

[1] National Institute of Geophysics, Geodesy and Geography – Bulgarian Academy of Sciences, Sofia, Bulgaria

Abstract: The air is the living environment of human beings and obviously the atmospheric composition has a great importance for the quality of life and human health. Air Quality (AQ) is a key element for the well-being and quality of life of European citizens.

The objectives of the present work is performing reliable, comprehensive and detailed studies of the impact of lower atmosphere composition on the quality of life and health risks for the population in Bulgaria.

The study of AQ is based on atmospheric composition numerical simulations. This is a fruitful approach, which will helps better understanding of the part which different processes and transport scales play in Air Environment formation.

The Air Quality Index (AQI) provides an integrated assessment of the impact of air pollutants on human health and is calculated on the basis of the concentration of various pollutants obtained from measurements or numerical modelling.

The following set of models was applied as basic tool for 3D simulations - US EPA Models 3 System: WRF - PSU/NCAR 6-th generation meso-meteorological model; CMAQ – model of transport and chemical transformations. SMOKE – emission pre-processor. The models “nesting” abilities were utilized for downscaling the simulations to a 9 km resolution for Bulgaria.

The simulations were carried out for a 7 year period (2008 - 2014) thus providing quite a comprehensive ensemble of surface atmospheric composition fields, respectively AQI. The diurnal variations of the recurrence spatial distribution of different classes of the AQI are demonstrated and discussed in the present work.

Key words: *air quality, ensemble of numerical simulation, air quality indices, quality of life, health risks*

INTRODUCTION

The AQ is a key element for the well-being and quality of life of European citizens. An association between the increased incidence of respiratory, cardiovascular, neoplastic diseases, the reduced life expectancy and air pollution has been robustly established (Brunekreef B and Holgate S., 2002), (Atkinson et al., 2012). According to the World Health Organization (WHO, 2000, 2005), between 2.5 and 11% of the total number of annual deaths are due to air pollution. Current legislation (Directive 2002/3/2008 EC) requires informing the public on AQ, assessing air pollutant concentrations throughout the whole territory of Member States and indicating exceedances of limit and target values, forecasting potential exceedances and assessing possible emergency measures to abate exceedances using modelling tools.

The objective of the present study is calculation of the Air Quality (AQ) impact on human health and quality of life in Bulgaria. The AQ impact is evaluated in the terms of the Air Quality Indices (AQI), which give an integrated assessment of the impact of several pollutants and an integral characteristic directly measuring the effects on human health. In the current study the AQI evaluations are based on extensive computer simulations of the AQ in Bulgaria, which makes it possible to reveal the climate of AQI spatial/ temporal distribution and behaviour, using up-to-date modelling tools and detailed and reliable input data.

METHODOLOGY

Air Quality Indices: The AQI provides an integrated assessment of the impact of the air pollution on human health and is based on the concentration of various pollutants obtained from measurements or numerical modelling. One of the most commonly used indices is the UK Daily Air Quality Index (de Leeuw and Mol, 2005), also used in Bulgaria (Syrakov et al., 2012, 2013), (Georgieva, 2014), (Georgieva et al., 2015, 2017). This index has 10 points, grouped into 4 bands: Low, Moderate, High and Very High. Each band contains 3 indices (Table 1) except AQI 10 which defines the Very High band. The AQI is based on the concentrations of O_3, NO_2, SO_2, CO and PM_{10}. The breakpoints between index values are defined for each pollutant separately and the overall index is defined as the maximum value of all. Health descriptor for at-risk groups and the population are attached to each of the bands. The reference levels and Health Descriptor are based on health-protection related limit, target values set by the EU or by WHO.

Table 1: Air quality indices and their health impact (de Leeuw and Mol, 2005).

Banding	Value	Health Descriptor
Low	1–3	Effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants
Moderate	4–6	Mild effects, unlikely to require action, may be noticed amongst sensitive individuals.
High	7–9	Significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be needed (e.g. reducing exposure by spending less time in polluted areas outdoors). Asthmatics will find that their 'reliever' inhaler is likely to reverse the effects on the lung.
Very High	10	The effects on sensitive individuals described for 'High' levels of pollution may worsen.

Air quality computer simulations: The AQI evaluations are based on extensive computer simulations of the AQ in Bulgaria carried out with good resolution using up-to-date modelling tools and detailed and reliable input data (Gadzhev et al., 2011 a, b, 2012, 2013 a, b, 2014 a, b). All the simulations are based on the US EPA Model-3 system: **WRF** (Shamarock et al., 2007) used as meteorological pre-processor; **CMAQ** (Byun at al., 1998), (Byun and Ching, 1999), being the Chemical Transport Model (CTM) and **SMOKE** (CEP, 2003) – the emission pre-processor of the system.

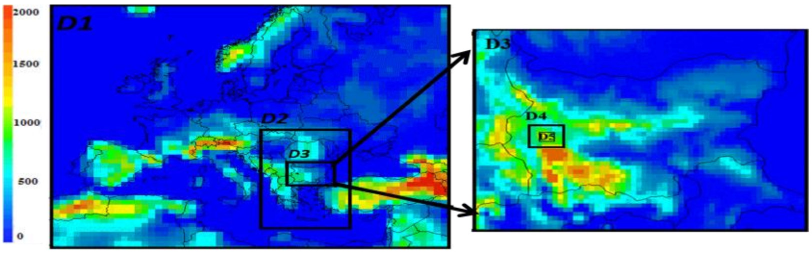

Figure 1. Model domains - D1-81x81 km (Europe), D2- 27x27 km (Balkan Peninsula), D3- 9x9 km (Bulgaria), D4-3x3 km (Sofia municipality) and D5- 1x1 km (Sofia city).

Meteorological data: The large scale (background) meteorological used is the NCEP Global Analysis Data with 1º×1º resolution. The WRF/CMAQ nesting capabilities are applied for downscale the simulations to a 9 km horizontal resolution for Bulgaria. The simulations are carried out for 5 nested domains (Figure 1), where the innermost domain is D5 - Sofia city (1km horizontal grid resolution) and some of the results for this domain are present in (Georgieva et al., 2015, 2017). The current paper presents results for the domain D3 - Bulgaria with 9 km horizontal grid resolution.

Emission data: The TNO high resolution inventory is exploited with resolution 0.25°×0.125° (about 20×15 km). The inventory is produced by proper disaggregation of the EMEP 50-km inventory data base (Vestreng, 2001), (Vestreng et al., 2005). The national emission inventory was used as an emission input for Bulgaria. The simulations are performed for 7 years (2008 to 2014). The biogenic emissions of VOC are estimated by the model SMOKE. (Schwede et al., 2005), (Syrakov et al., 2013).

RESULTS

The simulations aimed at constructing of ensemble of daily simulations for a large period (2008 - 2014). The results from the computer simulations are presented for the domain Bulgaria (9x9 km).
In the first place should be noted some areas from the territory of Bulgaria (Figure 2) for which the simulation results are discussed in the paper.

1 - Sofia
2 - Rozhen
3 - Stara Zagora
4 - Varna
5 - TPP Bobov dol
6 - TPP Maritza Iztok
7 - Rila mountain
8 - Pirin mountain
9 - Rodopy mountain
10 - Balkan Mountain
11 - Vitosha mountain

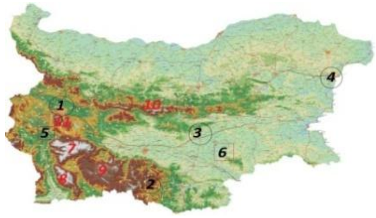

Figure 2: Location of some remarkable points: 1-Sofia the capital of Bulgaria, 2 - Rozhen presents the mountain area in the Rila-Rhodopy mountain array, 3 - Stara Zagora is the 5th largest city in Bulgaria, placed near to Thermal Power Plant (TPP) Maritza Iztok, 4 - Varna is situated on the coast line of the Black Sea, 5 - TPP Bobov dol and 6 - TPP Maritza Iztok., 7-10 - Bulgarian mountains (Rila, Pirin, Rodophy, Balkan and Vitosha).

Percent recurrence of the AQI in the "Low", "Moderate", "High" and "Very High" bands over territory of Bulgaria: Figures 3 demonstrate the spatial and diurnal variation of the annual recurrence of different AQI categories for chosen hour at noon - 13:00 GMT. The picture shows the sum of recurrences of the AQI in each range - Low, Moderate and High range. In the Low range the air is most clean, so high recurrence values mean more cases with clean air and lower recurrence values mean less cases with clean air (worse AQ status). In the other 3 plots (Moderate, High and Very High ranges) - high recurrence values means less favourable and respectively bad AQ status.

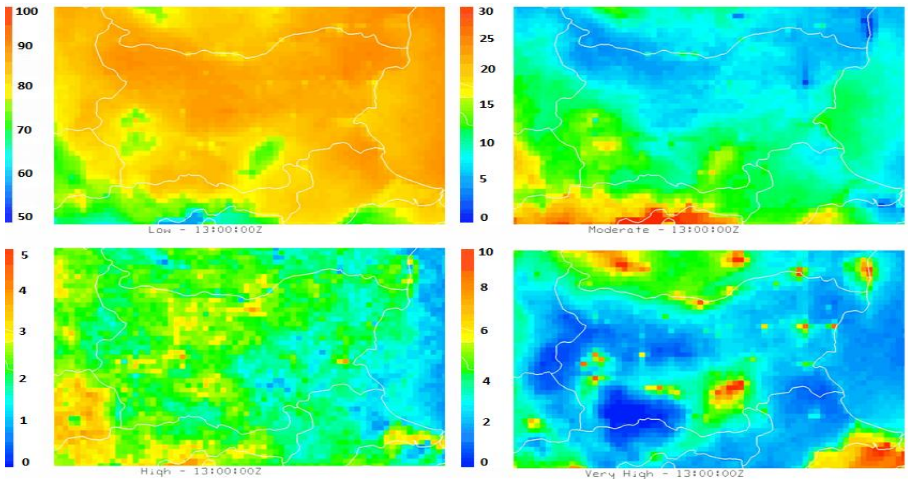

Figure 3. Annual plots of the recurrence [%] of the AQI - Low, Moderate, High and Very High bands in Bulgaria.

In that map of the Low range (upper left) recurrence it can be seen that Sofia and the Power plants (Maritza Iztok and Bobov dol) are the places with most polluted air with about 70% recurrence. Also it can be seen that in the regions over the highest part of the mountains mostly near Rozhen the Moderate range AQI (upper right) recurrence is pretty high. This is due to the high ozone concentrations and the ozone pollution there. The ozone in Bulgaria is to a great extend due to transport from abroad (Gadzhev et al., 2012, 2013 a, b). This is one of the reasons, together with the ozone photochemistry reactions, why the ozone concentrations early in the morning are smaller than at noon (less intensive transport from higher levels). In this range the lowest AQI status is near Sofia and Stara Zogora, TPP Maritza Iztok. For the High band (bottom left) the recurrences are not so high, about 3-5% mostly in the biggest cities. In Very High range (bottom right) recurrences during the whole day also biggest cities and power plants are well displayed. The maximum values are at night and this is probably due to the weather conditions (atmospheric stability) and Power Plants/domestic heating working regime. Off course this picture presents only the annual cases and the results are different for different seasons.

Annually averaged diurnal variations [%] of the dominant pollutant: The graphics that demonstrate the annual recurrence of the dominant pollutant are present in Figure 4 for the 4 bands. The considered pollutants - NO_2, O_3, SO_2 and PM are present in different colours. The pollutants that dominate (determine the AQI) in the Low range are O_3 and NO_2. In Moderate range dominates SO_2 followed by the O_3. In the High range dominates primarily SO_2 followed by PM concentrations, but for Very High range except SO_2 the second dominant pollutants are NO_2 and PM. Of course here again the seasonal cases differ from the annually averaged graphics and the dominant pollutants are different for different band with well displayed seasonal and diurnal course.

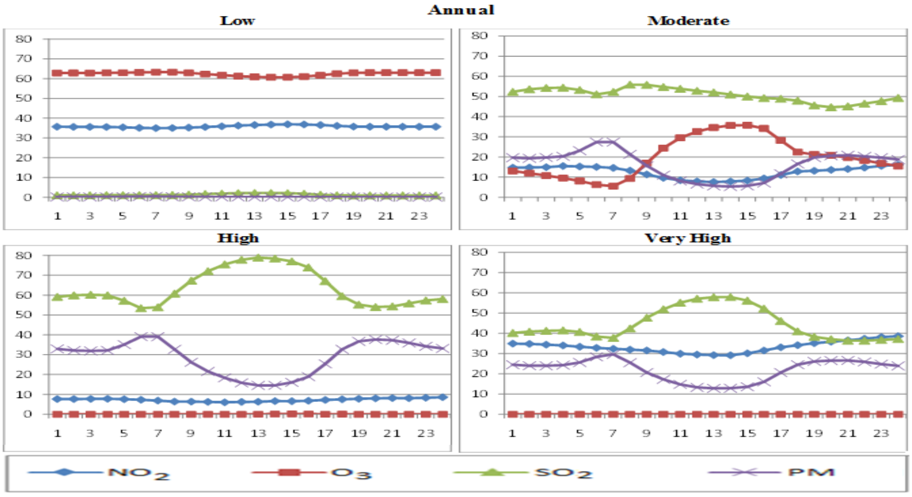

Figure 4. Annual Diurnal variations [%] of the dominant pollutant.

CONCLUSIONS

The general conclusion that can be made is that the AQ status of Bulgaria is rather good (evaluated with a spatial resolution of 9 km). AQI falls mostly in Low and Moderate bands. The recurrence of cases with Very High pollution is almost 15% mostly at TPPs and biggest city in the country. Apart from general features the climatic behaviour of the AQI probabilities is rather complex with significant spatial, seasonal and diurnal variability. The areas with slightly worse AQ status are not necessarily linked with the big pollution sources. Wide rural and even mountain regions can also have significant probability for AQI from the Moderate range. The recurrence of the AQI from the High range is almost negligible, except for some small areas linked mostly to the TPPs in the cold periods of the year. The dominant pollutants that determined the AQI and AQ status in Bulgaria are different for different bands with well displayed seasonal and diurnal course. In general we can say that: In Low range dominate O_3 and NO_2; In Moderate range dominate O_3 and SO_2; for the High and Very High range dominates SO_2, except in cold months, where dominates NO_2.

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