EVALUATION OF THE EFFECTS OF THE NATIONAL EMISSION REDUCTION STRATEGIES FOR YEARS 2020-2029 AND AFTER 2030 ON THE SULPHUR AND NITROGEN SURFACE CONCENTRATIONS ON THE TERRITORY OF BULGARIA

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Abstract: Complying the EU Directive 2016/2284, Bulgaria developed national emission reduction strategies for years 2020-2029 and after 2030. Evaluation of the effects of these strategies on the Sulphur and Nitrogen surface concentrations on the territory of Bulgaria is the objective of the present study. The studies are performed applying computer simulations. The simulations are performed with the US EPA Models-3 System: Meteorological model WRF; Emission model SMOKE; Atmosphere Composition Model CMAQ for the period 2008 – 2014. The provided model simulations are with horizontal resolution 9 kilometers for the region of Bulgaria. The NCEP Global Analysis Data meteorological background with 1°x1° resolution is used as a meteorological background. The models nesting capabilities were applied to downscale the simulations to 9 km resolution for Bulgaria. Five emission scenarios are considered: 2005 emissions (reference period), 2020-2029 emissions projected with existing measures (WEM) and with additional measures (WAM), projected after 2030 WEM and WAM emissions. The comparison of the concentrations, simulated with the different scenarios makes it possible to evaluate the effect of the national emission reduction strategies.

INTRODUCTION

The present paper presents part of the results obtained in the frame of an extensive study of the effects of different emission reduction scenarios on the air quality in Bulgaria. The set of models applied for atmospheric composition simulations is the same used in the operational Bulgarian Chemical Weather Forecast and Information System. Thus, the obtained results are fully compatible with the operational chemical weather forecast. The models are also widely used in air pollution modelling, so the obtained computer simulation results are in harmony with evaluations made for other regions. Air pollution forces many countries to take action to mitigate its adverse effects on human health and ecosystems. There is already a large amount of direct and indirect data connected to the air quality from the different surface and satellite-based observing systems. However, we need to track the various processes involved in the composition, transport, and transformation of the air pollutant species, which will help us better understand their distribution at different spatial/temporal scales. These tasks are performed by air quality modeling systems, as we use US EPA Models 3 System for modeling the air quality in our country - Bulgaria.

The main goal of this work is to make a comparison between Nitrogen (NO_2) and Sulfur (SO_2) dioxide surface concentrations, simulated with the different emission reduction scenarios (with and without measures) and the reference period (with emission for 2005), in Bulgaria.

METHODOLOGY

Based on 3D modelling tools, an extensive database was created and used for different studies of atmospheric composition. The simulations were based on the US EPA Model-3 system. -

WRF – THE WEATHER RESEARCH & FORECASTING MODEL, used as meteorological pre-processor;

CMAQ: The Community Multiscale Air Quality Modeling System, CMAQ v.4.6 - Community Multi-Scale Air Quality model (CMAS) the Chemical Transport Model (CTM), and

Sparse **M**atrix **O**perator **K**ernel **E**missions (SMOKE) Modeling System, the emission model in the system.

The models in the system were adapted and validated for Bulgaria. The studies are performed by applying computer simulations for a 7-year period (2008 – 2014). The provided model simulations are with a horizontal resolution of 9 kilometers for the territory of Bulgaria. The large-scale (background) meteorological data used were from the 'NCEP Global Analysis Data' with a horizontal resolution of 1ºx1º. Using the **'nesting'** capabilities of the models, a resolution of 9 km was achieved for the territory of Bulgaria (Fig.1). The resolution of the mother domain (Europe) is 81 km, and two other domains are nested in it and in each other – Balkan Peninsula (27 km resolution) and Bulgaria (9 km), as shown in Figure 1.

TNO inventory is exploited for the territories outside Bulgaria in the mother domain. For the Bulgarian domain, the National inventory as provided by Bulgarian Executive Environmental Agency is used.

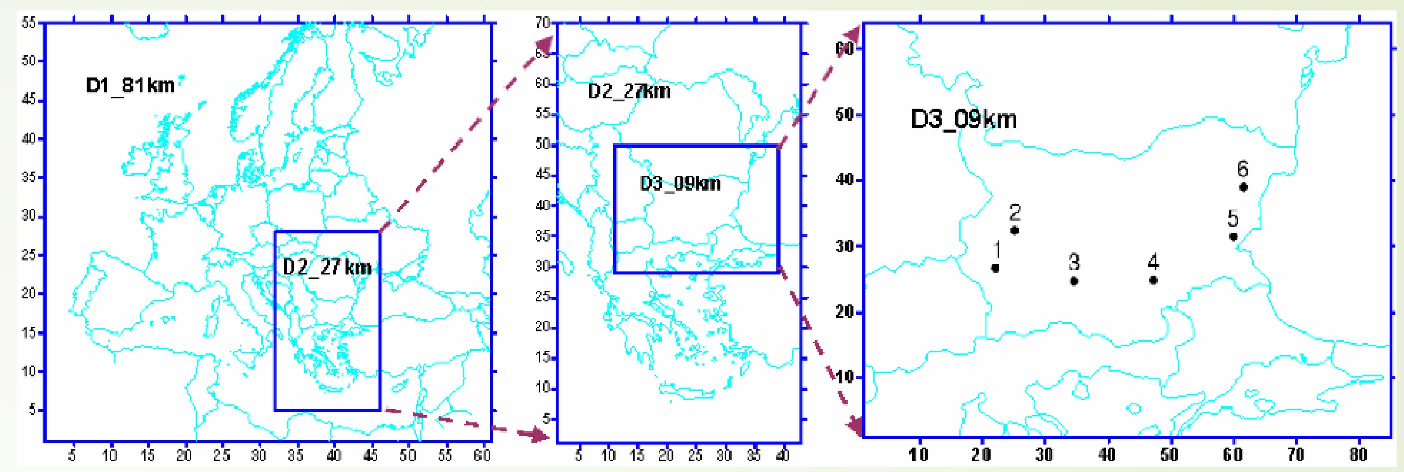

Figure 1. Model domains: Downscaling from domain Europe (81 km) to domain Bulgaria (09 km) and pointed location of some industrial zones in Bulgaria – 1 - TPP Bobovdol, 2 – Sofia city, 3 – Plovdiv city, 4 - TPP Maritsa Iztok, 5 – Burgas city, 6 - Devnya Industrial Area.

Every EU member state (According to the legislation) has to report the set of emission projections scenarios (EEA Technical report No 4/2015): projections scenario 'with existing measures' (WEM) means projections of anthropogenic Greenhouse Gas (GHG) or air pollutant emissions by sources that encompass the effects of currently implemented or adopted policies and measures; projections scenario 'with additional measures' (WAM) means projections of anthropogenic GHG or air pollutant emissions by sources that encompass the effects of policies and measures which have been adopted and implemented, as well as planned policies that are judged to have a realistic chance to be adopted and implemented in the future;

In the paper, four emission scenarios are considered for two periods, 2020-2029 and after 2030, with existing measures (WEM) and with additional measures (WAM), and the results are compared with the reference period (Ref 2005). It should be clear that only the Bulgarian emissions for 2020-2029 and 2030 have been modified according to the forecast scenarios.

The considerations and conclusions in the paper are based on simulated SO_2 and NO_2 surface concentrations on the territory of Bulgaria. Comparing the concentrations simulated with the different scenarios makes it possible to evaluate the effect of the national emission reduction strategies (EU Directive 2016/2284).

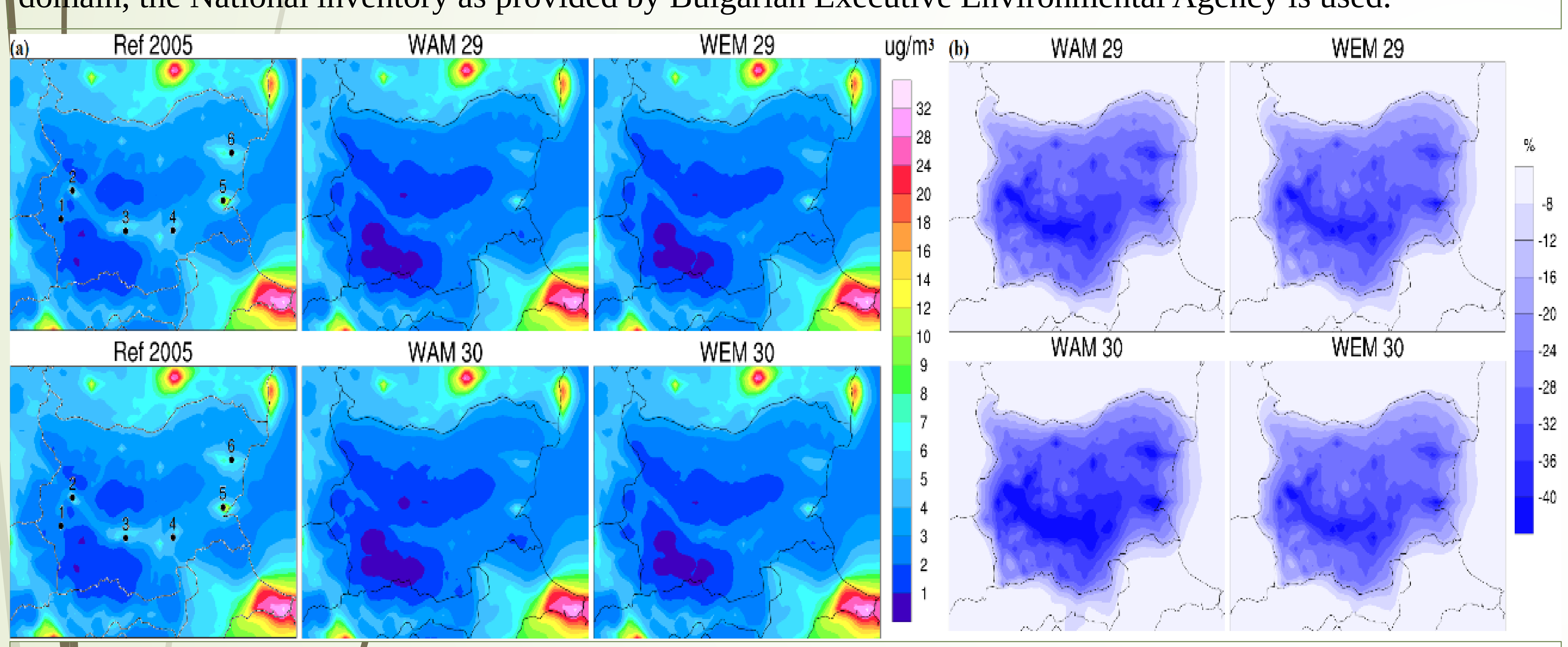

Figure 2. (a) Annually averaged NO_2 surface concentrations [µ/m[3]] for Ref 2005, WEM 2029, WAM 2029, WEM 2030, WAM 2030 emissions scenarios and (b) NMB of the NO_2 surface concentrations [%] for WEM 2029, WAM 2029, WEM 2030, WAM 2030 emissions scenarios compared to the Ref 2005.

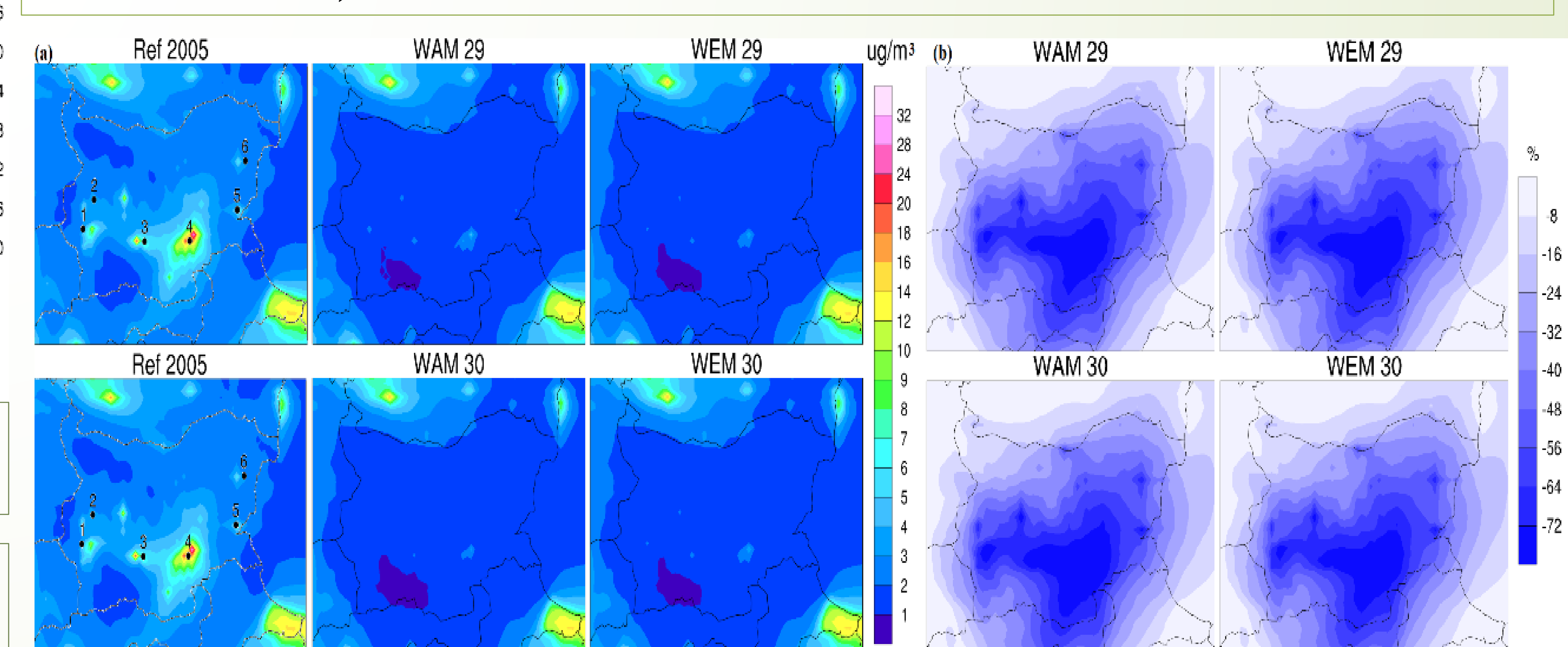

Figure 3. (a) Annually averaged SO_2 surface concentrations [µ/m[3]] for Ref 2005, WEM 2029, WAM 2029, WEM 2030, WAM 2030 emissions scenarios and (b) NMB of the SO_2 surface concentrations [%] for WEM 2029, WAM 2029, WEM 2030, WAM 2030 emissions scenarios compare to the Ref 2005.

RESULTS

The Normalized Mean Bias noted as NMB was used for comparison of the effect of different scenarios. The notions in these equations are i - ith value, S - the scenario output (WEM/WAM) for the selected period (2020-2029, 2030), and R - the output for the Reference period (2005).

$$NMB = \frac{\sum_i S - \sum_i R}{\sum_i R} * 100[\%]$$

Figure 2 presents the results from numerical experiments about NO_2 surface concentrations for different scenarios and the comparison with the results from the reference period 2005 and calculated NMB. According to these results, we can say that not only the measures for reductions of emissions worked, but also clearly see which scenario gives better results. Figure 3 presents the results of the SO2 for the different scenarios. Here, the effects of the emission reduction on SO2 surface concentrations are very well expressed, and the differences with Ref 2005 are obvious. Again, all the scenarios show better results according to the reference period.

CONCLUSIONS

The numerical experiments about NO_2 surface concentrations for different scenarios show:
- the results from all scenarios have a difference with reduction tendency in comparison with the reference period 2005;
- the NO_2 surface concentrations are reduced for all the WEM/WAM scenarios according to the Reference 2005, but the scenario WAM 2030 shows better results for the whole territory of Bulgaria;
- all the biases are with a negative sign and show that all the scenarios have smaller concentrations compared with the reference period and emissions for 2005;
- all the measures show a positive effect of reduction of emissions and lead to a reduction of NO_2 surface concentrations;
- the reduction over the whole domain is about 25 % and about 40% for some areas in the southwest part of the country;
- the WAM scenarios show a more significant reduction for both selected periods, and also, the WAM 2030 is clearly the one with the most sound effect.

The numerical experiments about SO_2 surface concentrations for different scenarios show:
- the effects of the emission reduction on SO_2 surface concentrations are even better expressed, and the differences with Reference 2005 are obvious;
- all the scenarios show better results according to the reference period, which shows that all the scenarios of reduction of the emission lead to a decrease in the SO_2 concentrations;
- the better results are demonstrated by the WAM 2030 scenario compared with the reference period 2005 and also compared with other scenarios;
- the bias of the SO_2 concentrations also has a negative sign, and the percentage of reduction is very well expressed and shows very good results for taking measures;
- the reduction reaches 50% almost over the whole territory of the country and for all scenarios;
- a reduction of 70% is achieved for some areas in the southwest part.

For all the results, we can conclude that more stringent measures lead to more effective results, whereas this study is about the WAM scenario.

ACKNOWLEDGEMENTS

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