Numerical study of the air quality in the city of Sofia – some preliminary results

Ivelina Georgieva[1], Georgi Gadzhev[1], Kostadin Ganev[1], Maria Prodanova[2], Dimiter Syrakov[2], Nikolay Miloshev[1]

1 National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria
2 National Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences, Sofia, Bulgaria
Contacts: iivanova@geophys.bas.bg, ggadjev@geophys.bas.bg, kganev@geophys.bas.bg, maria.prodanova@meteo.bg, Dimiter.Syrakov@meteo.bg, miloshev@geophys.bas.bg

1. INTRODUCTION

Recently extensive studies for long enough simulation periods and good resolution of the atmospheric composition status in Bulgaria have been carried out using up-to-date modelling tools and detailed and reliable input data (Gadzhev et al. 2011 a,b, 2012, 2013 a,b,c,d). The next step in atmospheric composition climate studies is performing simulations in urban scale. The simulations aim at constructing of ensemble, comprehensive enough as to provide statistically reliable assessment of the atmospheric composition climate of the city of Sofia – typical and extreme features of the spatial/temporal behaviour, annual means and seasonal variations, etc. Some extensive numerical simulations of the atmospheric composition fields in the city of Sofia have been recently performed.

2. MODELING TOOLS

The simulations are carried out with the US EPA Models-3 System:

WRF (Shamarock et al. 2007) used as meteorological pre-processor;

CMAQ - the Community Multiscale Air Quality System (Byun et al., 1998, Byun and Ching, 1999) - the Chemical Transport Model (CTM)

SMOKE - the Sparse Matrix Operator Kernel Emissions Modelling System (CEP, 2003) – the emission pre-processor.

3. INPUT DATA

Meteorological data

NCEP Global Analysis Data with 1°×1° resolution WRF and CMAQ nesting capabilities are applied for downscaling the simulations to a 1 km step for the innermost domain (Sofia).

Emission data

The national emission inventory is used as an emission input for Bulgaria, while outside the country the emissions are taken from the TNO with 0.25°x0.125° in 10 SNAP categories (A. Visschedijk et all., 2007). The biogenic emissions of VOC are estimated by the model SMOKE.

Period

The simulations were performed day by day for a period of 7 years – from 2008 to 2014.

5 nested domains for WRF

D1 (Europe) – 81 x 81 km
D2 (Balkan peninsula) – 27 x 27 km
D3 (Bulgaria) – 9 x 9 km
D4 (Sofia municipality) – 3 x 3 km
D5 (Sofia city) – 1 x 1 km

4 nested domains for CMAQ

D2 (Balkan peninsula) – 27 x 27 km
D3 (Bulgaria) – 9 x 9 km
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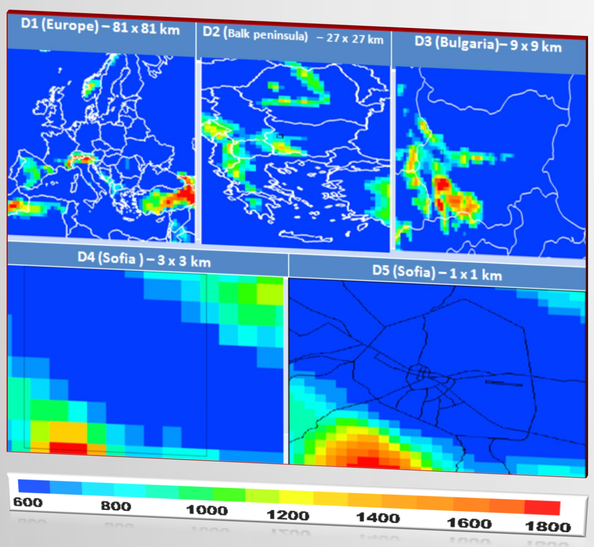
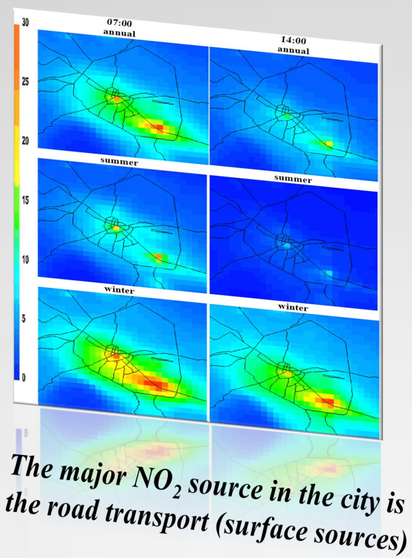
D5 (Sofia city) – 1 x 1 km

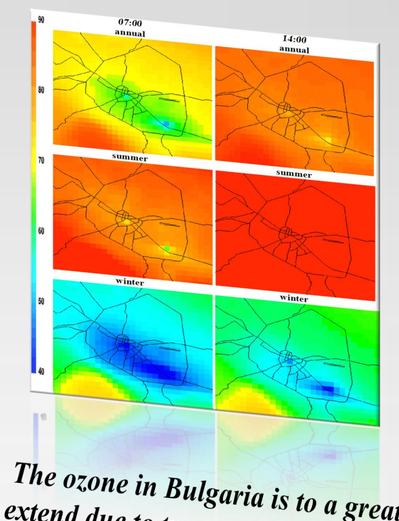


4. RESULTS, COMMENTS

Figure 1: Surface NO_2 and O_3 "typical" annual, summer and winter concentrations [μg/m³] at 07:00 and 14:00 GMT

SURFACE CONCENTRATION





The major NO_2 source in the city is the road transport (surface sources)

✓ Higher NO_2 concentrations early in the morning and smaller at noon.

✓Bigger winter NO_2 concentrations than in summer, or the annually averaged

✓The maximal concentrations are formed in the city centre and along the boulevard with most busy traffic

The ozone in Bulgaria is to a great extend due to transport from abroad (Gadzhev et al. (2012, 2013 a,b,c,d))

✓Smaller O3 concentrations early in the morning than at noon (less intensive transport from higher levels)

✓ Higher O3 concentrations at daytime and during the Summer

✓O_3 gaps in the regions, where the NO_2 concentrations are large (the ozone photochemistry)

✓The NO_2, PM_{10} and $PM_{2.5}$ concentrations at "Kopitoto" are much smaller as those at "Orlov most"

✓The O_3 concentrations at both sites are of similar values

✓For the "Orlov most" site the O_3 concentrations reach maximum around noon, when NO_2 and PM concentrations tend towards local minimum

✓On the contrary for the "Kopitoto" site the NO_2 concentrations reach maximum around noon

✓The PM_{10} and $PM_{2.5}$ concentrations at "Kopitoto" do not have such a significant diurnal variations

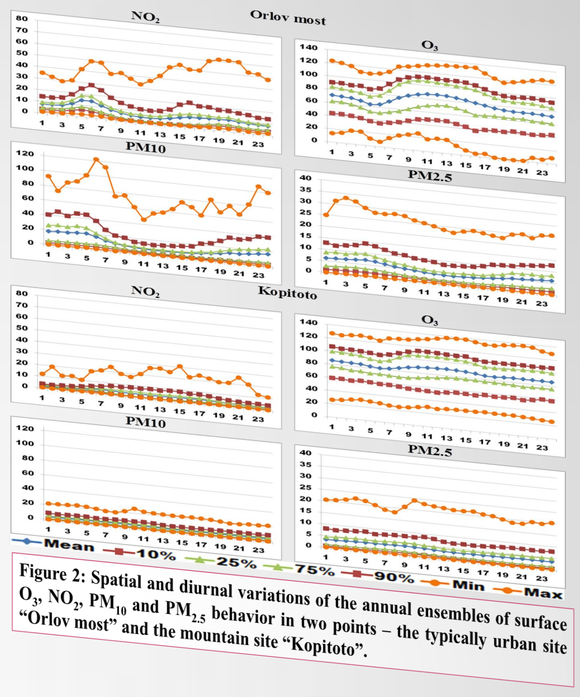
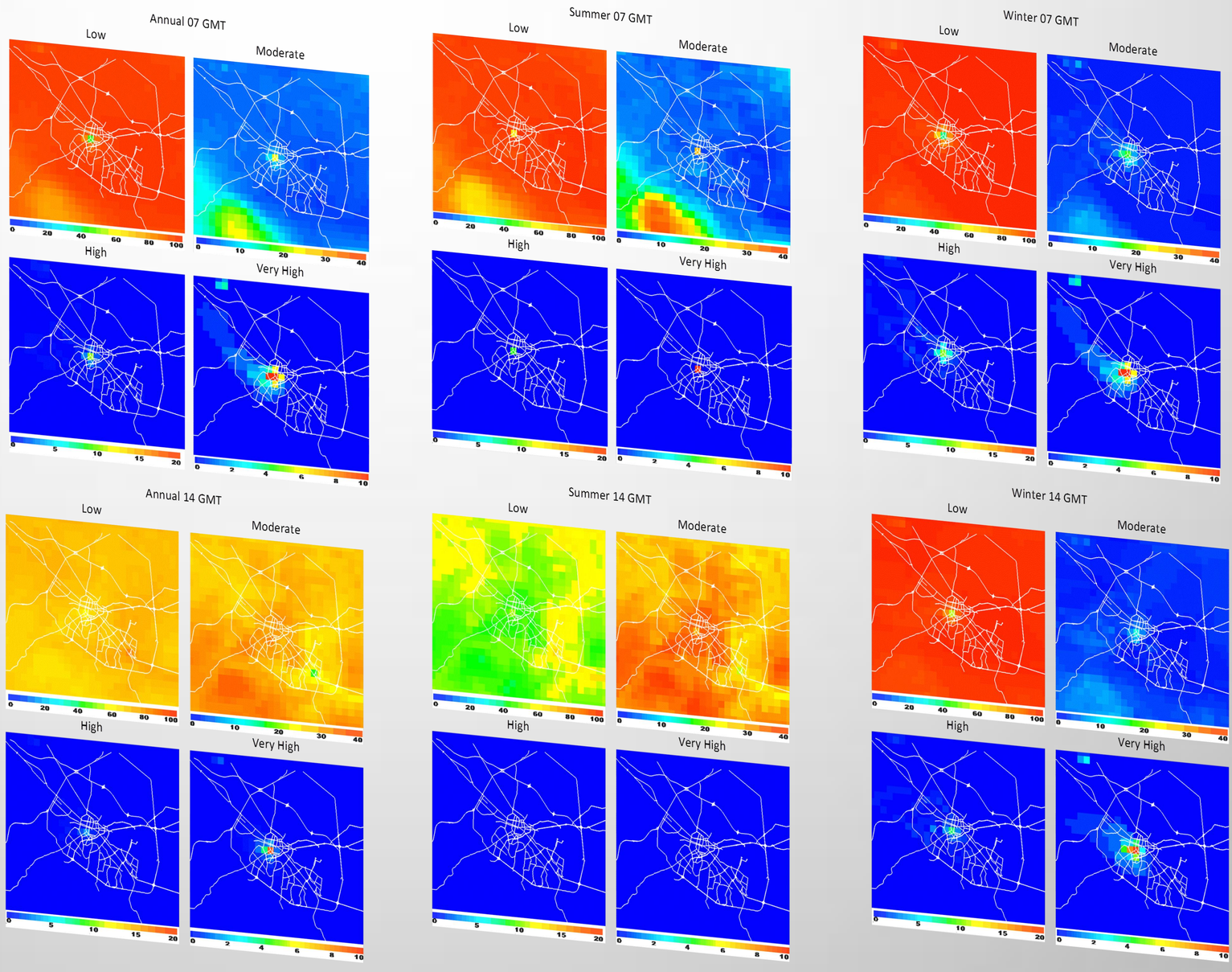


Figure 2: Spatial and diurnal variations of the annual ensembles of surface O_3, NO_2, PM_{10} and $PM_{2.5}$ behavior in two points – the typically urban site "Orlov most" and the mountain site "Kopitoto".

BEHAVIOUR OF THE AQI OVER SOFIA

Figure 3: Plots of seasonal (summer and winter) and annual of the percent recurrence of the AQI in the "Low", "Moderate" and "High" bands over Sofia at 07:00 and 14:00 GMT



Almost everywhere the recurrence of the AQI from the "Low" band is close to 100%, except in the city centre.

The recurrence of the AQI from the "Moderate" band is relatively high :
• up to 20% in the morning in the centre of the city at winter - due to the high NO2 values
•the recurrence over Vitosha is higher in the morning at summer compared to the winter case.
•recurrence of AQI from the "Moderate" band reaches 40% everywhere at summer, obviously due to the high ozone levels.

The recurrence of cases with most polluted air ("Very High" band) is about 10% - nearby the Russian memorial) at both chosen hours. The high recurrence of AQI from "Very High" ranges in the city centre is probably due to surface sources (road transport) and the atmospheric stability, which cause high NO2 concentrations early in the morning.

5. CONCLUSIONS

The main results from the present study can be summarized in the following way:

• The obtained concentration fields display well manifested seasonal and diurnal course in good qualitative agreement with the emission courses and the atmospheric stability influence;

• Highest NO_2 and $PM_{2.5}$ concentrations, as should be expected, are formed in the city centre an along the most busy streets and roads;

• The behavior of the surface ozone is more complex: the ozone in Bulgaria is to a great extent due to transport from abroad. Because of less intensive transport from higher levels, the ozone concentrations early in the morning are smaller than at noon. The other is, the ozone photochemistry, which explains both the higher O_3 concentrations at daytime and during the summer and the O_3 gaps in the regions, where the NO_2 concentrations are large. In general the highest ozone concentrations are obtained away from the city centre, even in the Vitosha mountain;

The AQI analysis shows that the air quality status of Sofia is rather good (evaluated with a spatial resolution of 1km) - the recurrence of high AQI values is close to zero. All the simulations show that AQI status in the capital of Bulgaria falls in "Low" and "Moderate" categories.

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