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CHARACTERIZING THE IMPACT OF URBAN SOURCES IN RUSSIA ON AIR POLLUTION IN NORTHERN EUROPE

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1. INTRODUCTION

Air pollutants emitted into the atmosphere (CO, SO2, NO_X, NH_3, VOCs, and PM) are known to have direct and indirect effects on human health and also known to be harmful when deposited into sensitive terrestrial or aquatic ecosystems. Nitrogen compounds can cause an oversupply of nutrient in soils and water bodies. CO, NO_X and VOCs contribute to the formation of ground-level ozone (O3), which can trigger serious respiratory problems. Since ozone is formed in the atmosphere by reactions between CO, NO_X and VOCs in the presence of heat and sunlight, high concentrations of ground-level ozone are thus a major concern during the summer months. Fine particulate matter with a diameter size below 2.5 micrometer (PM2.5) is now generally recognized to be the main threat to human health from air pollution. Therefore, accurate assessment of air quality on a regional scale and understanding the contribution of various sources is critical for developing mitigation strategies to improve air quality and protect human health.

In Europe (EU), emissions of many air pollutants fell substantially since 1990, resulting in improved air quality over the region. Presently, more than 2,300 air quality monitoring stations are operating in Europe. However, ambient concentrations of PM and ozone in the air have not shown any improvement since 1997, despite of the decrease in emissions. This might be due to meteorological variability and growing long-distance transport of pollutants. Chemical transport models are among the primary tools used by air quality managers to assess the impact of anthropogenic emissions on air quality in Europe. However, relative contribution of emissions from Russia still remains a main source of uncertainty in model simulations. Emission inventories typically don't provide adequate information on emission sources in Russia. Also, air quality monitoring data in Russia are very limited, which creates a challenge for model evaluation. Currently, Russia is not fully integrated in international programs on air pollution. This study is a first attempt to use air quality modeling in characterizing the impact of anthropogenic emissions from urban sources in Russia on air pollution in Northern Europe.

2. ANALYSIS OF MONITORED AIR QUALITY CONCENTRATIONS IN RUSSIA

The number of air quality monitoring stations that can be used to estimate regional levels of air pollution in central and north-western parts of Russian Federation is limited. For example, in 2008, there were only four monitoring stations in Russian Federation, and no stations in the north-western region of Russia. On the other hand, there is a large number of monitoring stations in urban areas designed to provide air quality information in highly populated areas. 248 cities in Russia have air quality stations that monitor levels of concentrations of multiple air pollutants. Observations show that observed concentrations exceed the standards in many cities across the country.

Trends of measured air quality concentrations from the Russian Federal Service for Hydrometeorology and Environmental Monitoring network for the period of 2004 to 2008 are shown in Table 1. As can be seen from the table, concentrations of several pollutants (PM, NO_2, and Formaldehyde) have increased over the 4-year period [*Overview of the environmental statement and pollution in Russian Federation in 2008. Roshydromet*].

Observations show that levels of air quality concentrations remain high. More than 67% of Russian cities (or 56.3 millions of people) show high levels of air pollution, whereas only 19% of cities show low levels of pollutant concentrations. People living in two largest urban areas of Russia, St. Petersburg and Moscow (i.e. 10% of the entire population of Russian Federation) are exposed to high levels of air pollution concentrations. There is a concern that high levels of air pollution could

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have a significant impact on human health in Russia.

Table 1. Relative change in observed air quality concentrations in urban areas of Russia from 2004 to 2008.

Air Pollutant	Number of cities	Relative change in concentrations (%)
PM	220	+4,2
SO2	232	-8,5
NO2	237	+5,1
NO	136	-7,4
CO	203	-3,7
Benzopyrene	171	-24,0
Formaldehyde	153	+12,5

According to the state statistics of Russian Federation, children morbidity increased by 20% from 2000 to 2008 [*Federal State Statistics Service*]. Figure 1 shows an increase of various health outcomes for the eight-year period from 2000 to 2008. There is a significant increase (more than 20%) of respiratory symptoms that can be correlated to unhealthy levels of air pollution in Russia.

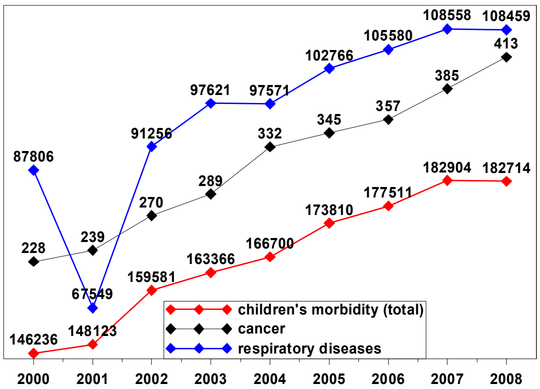

Figure 1. Children's morbidity (age 0 to 14) for the period of 2000–2008.

3. MODELING AIR QUALITY CONCENTRATIONS IN THE NORTH-WEST REGION OF RUSSIAN FEDERATION

St. Petersburg is the third largest city in Europe with population of 5.4 million people and area of 11,600 square kilometers. Therefore, accurate estimates of emissions for St. Petersburg is critical for air quality modeling. Mobile sources is one of the most significant sources of emissions in St. Petersburg. For the period from 2004 to 2008, there has been a strong increase in number of cars in St. Petersburg. As can be seen from the Figure 2, the increase in number of vehicles is about 10% per year.

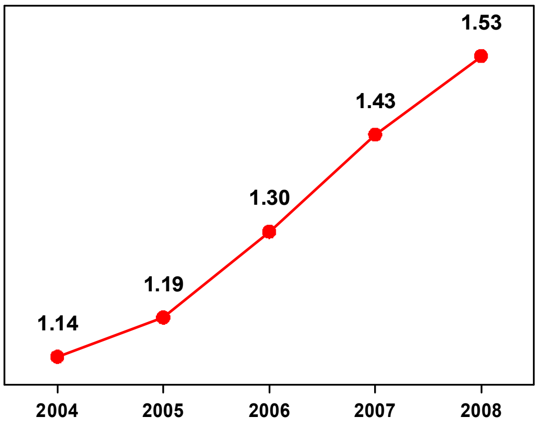

Figure 2. Number of vehicles (in millions) in St. Petersburg from 2004 to 2008.

In this study, we used CMAQ [*Byun, D.W. and K. Schere, 2006*] to simulate air quality concentrations in the north-western region of Russia. The modeling domain covered an area of 800 x 800 km encompassing St. Petersburg, north-western part of Russian Federation and neighboring states, as shown in Figure 3.

Emission inputs were based on official inventory data for Russian Federation. VOC point sources inventory for Saint-Petersburg is given in Figure 4. Figure 5 shows distribution of mobile sources of NOx.

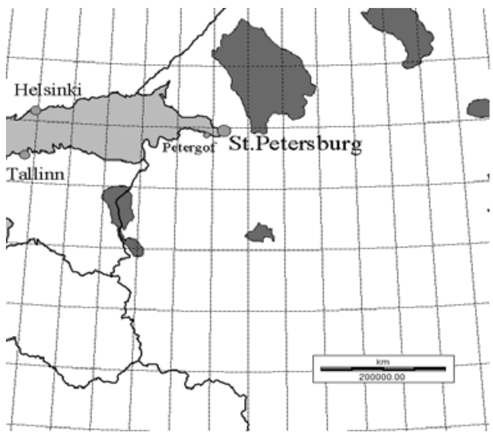

Figure 3. Modeling domain.

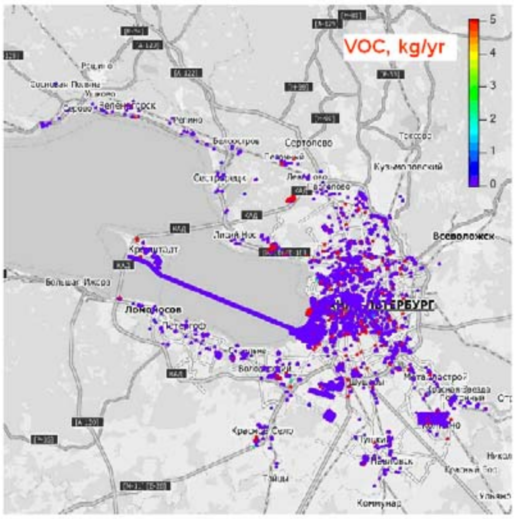

Figure 4. VOC point sources inventory for Saint-Petersburg.

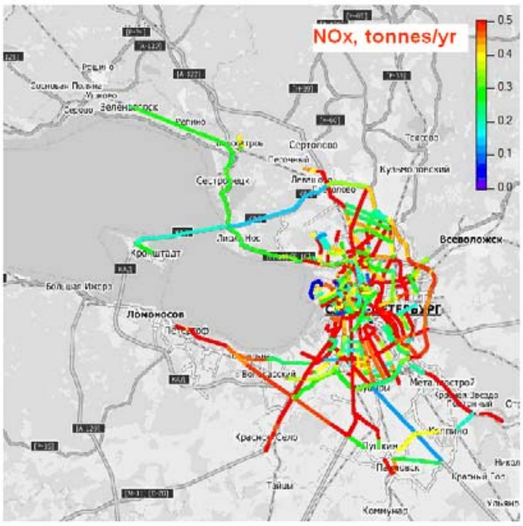

Figure 5. NOx mobile sources inventory for Saint-Petersburg.

To account for seasonal and diurnal variability in emissions, we applied temporal profiles derived from CO and NO2 observations in St. Petersburg to annual emission estimates

Meteorology was simulated by WRF and emission inputs prepared by SMOKE emissions modeling system. We also used vertical profiles of measured concentrations from EMEP, NOAA (NOAA ESRL/GMD CCGG, NDACC, and SPBU field measurements to specify initial and boundary conditions. The simulation period was January – March 2006, when elevated levels of air pollution were observed.

We compared model results with observed CO total column and NO2 tropospheric column data from Saint-Petersburg State University filed measurements. The monitoring site was located in Peterhof, in the suburbs of St. Petersburg (59.88 lat., 29.83 lon). A comparison shows a good agreement between model results and observations (Figure 6).

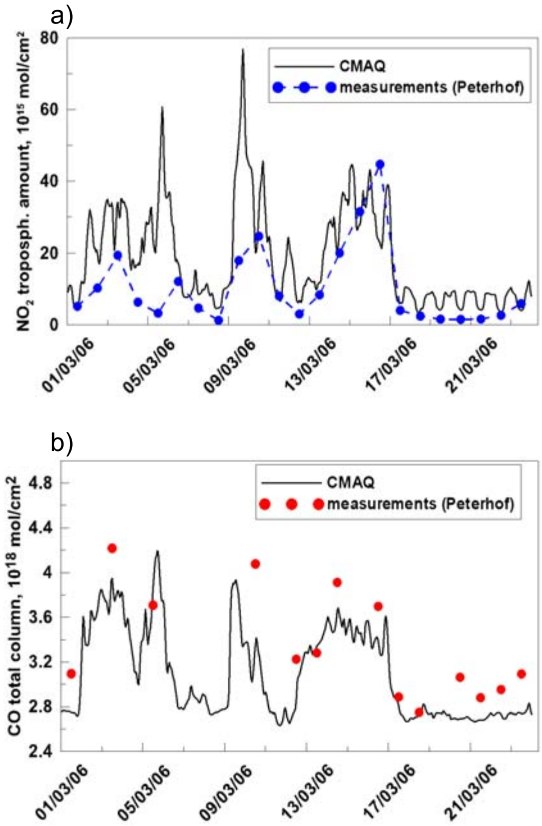

Figure 6. Comparison of modeled and observed NO2 troposheric column (a) and CO total column (b).

Model results indicate that the impact of anthropogenic emissions from St. Petersburg on levels of air pollution can quite high, about 40% contribution for average values of CO total column amounts. For NO2 tropospheric column, the contribution could be even more significant – up to 20 times higher as compared to its background levels. This could be an important factor to consider when measuring ambient levels of background concentrations and columns near large metropolitan areas such as St. Petersburg or Moscow. Our results indicate that CO and NO2 concentrations in the lower 500 m layer could be

10 to 20 times higher than typical background concentrations because of the impacts of anthropogenic sources from big cities. Model results show that the impact could be noticeable at long distances, up to 300 km or so (Figures 7 and 8). This should be taken into account when modeling air quality impact on a regional scale, considering the fact that the distance from St. Petersburg and neighboring states (Estonia and Finland) is only 150 km. Therefore, the accuracy in emission estimates for all major cities in the modeling domain (St. Petersburg, Tallinn, and Helsinki) should be comparable.

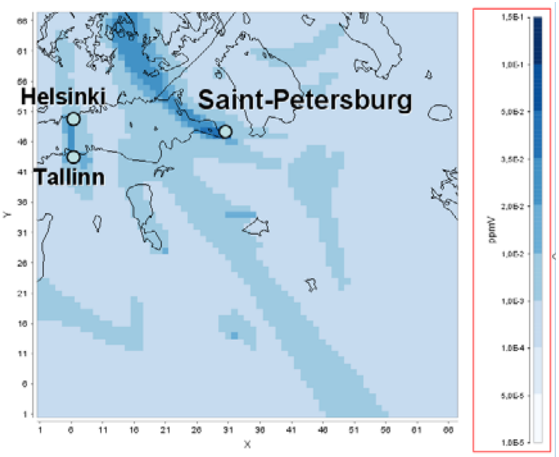

Figure 7. NO2 concentration field (01 February, 2011).

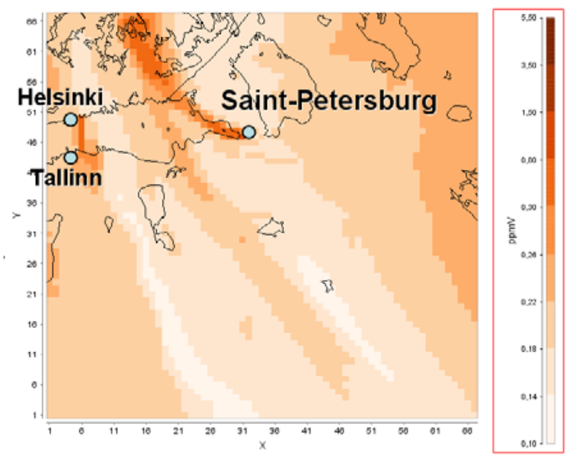

Figure 8. CO concentration field (01 February, 2011).

The results of model sensitivity simulations indicated that the impact of emissions from St. Petersburg could result in increase of concentrations of by 0.3 ppm for CO, 20 ppb for NO2, and 2 ppb SO2 at 150 km distance, and 0.12 ppm for CO, 10 ppb for NO2, and 0.8ppb for SO2 at 300 km distance (which is a similar distance to Tallinn and Helsinki).

Note, that westerly flow is dominant for this area, therefore, the probability of the transport of air pollution from St. Petersburg to Northern Europe is low.

4. CONCLUSIONS

Air quality modeling can be a very useful tool in estimating the levels of air quality concentrations in the north-western region of Russia, where observational network is limited. The modeling is also a key in connecting emissions sources and ambient concentrations, and understanding the impact of various sources on air quality. In this study, we use CMAQ air quality model in characterizing the impact of anthropogenic emissions from urban sources in Russia on air pollution in Northern Europe. Concentrations of key air pollutants (CO, NO2, O3 and PM) were simulated for the period of January – March of 2006. We used WRF to simulate meteorology, and SMOKE to prepare emission inputs using the official emission inventory for Russian Federation. CMAQ results were compared with the ground-based measurements of NO2, CO and O3 at Saint-Petersburg and its suburbs. Our analysis indicates that temporal behaviors of simulated and observed concentrations of CO and NO2 are similar. We found that Saint-Petersburg is the most significant factor impacting air quality in the North-Western region of Russia. Specifically, concentrations of NO2 and CO within the lower layer in the troposphere may exceed background concentrations by 20 and 6 times (correspondingly) for St. Petersburg and its suburbs. Model results suggest that anthropogenic emissions from Saint-Petersburg can impact levels of pollutant concentrations more than 300 km away from megacity (e.g. in border countries Finland and Estonia).

ACKNOWLEDGEMENTS

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