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EFFECT OF THE LONG-RANGE TRANSPORT ON THE AIR QUALITY OF BUDAPEST

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Abstract: SO_2, NO_2 and Particulate Matter (PM) are air pollutants, generated by a variety of human activities and can travel long distances in the atmosphere and cause a wide range of air quality problems in Europe. The influence of transboundary and national contributions in PM concentrations in Central-European cities could be dominant, and only a little improvement can be expected from local control policies. The air quality of Budapest is determined mainly by the local residential heating and traffic emissions combined with the meteorological conditions. Sometimes the impact of the transboundary sources can be negligible especially under special meteorological conditions when the local effects determine the air quality of Budapest, but sometimes it could be responsible for the formation of air pollution episodes. In this research the effect of long-range transport on the air quality of Budapest was analyzed in details, using the outputs of EMEP chemical transport model.

Key words: *long-range transport, EMEP chemical transport model, urban air quality, emission*

INTRODUCTION

Many types of air pollutants have been observed to travel far from their sources causing air quality problems. The potential of a pollution for long-range transport, sometimes referred to as its characteristic travel distance or spatial range, depends not only on its real physico-chemical properties, but also on its mode and point of release to the environment. This process becomes relevant only when the transported chemical material has some harmful effect on human health or on ecosystems far from its source.

Atmospheric emissions of SO_2 result mainly from the combustion of sulphur containing coal and other fossil fuels, but the contributions from volcanoes and the biogenic precursor dimethyl sulphide are non-negligible (Benkovitz, et al, 2004) either. Air pollution by long-range transported SO_2 globally is not a recent problem, but locally it can cause serious trouble. Long-range transport of SO_2 from east Asia to the Pacific have been most intense during springtime because of strong westerly winds (Tu, Fang Huang, et al. 2004).

The dominant sources of nitrogen oxides are anthropogenic emissions from combustion processes in transportation, power plants, industry and agricultural biomass burning, as well as natural sources such as lightning emissions, natural biomass burning and microbial soil emissions. The lifetime of NO_2 in the planetary boundary layer amounts to a few hours, depending on the strength of solar irradiation and on the available radical species. This, combined with low wind speeds near the surface, makes long-range transport of anthropogenic NO_2 in the planetary boundary layer very unlikely. However its lifetime is up to a week in the middle and upper troposphere. More and larger plumes are emitted in winter, when the lifetime of NO_2 is long, anthropogenic emission rates are especially high and meteorological conditions are favorable with frequent cold fronts and cyclones. Arctic is likely to be one of the most sensitive regions to the effects of altered atmospheric and oceanic chemistry due to NO_2 long-range transports (Zien, et al. 2014).

PM_{10} particles mainly originate from sea salt, soil dust resuspension, construction/demolition, non-exhaust vehicle emissions, and industrial fugitives, whereas $PM_{2.5}$ and $PM_{0.1}$ particles are mainly produced by combustion processes, forest fires and transformation of gaseous species. The lifetime of smaller size particles can range from days to weeks, while bigger particles have a lifetime of hours to days. This is the reason while there has been certain evidence that long-range transport of fine aerosol particles over distances crossing national borders and could have essential effect on air quality in urban areas in Europe (Moreno, et al., 2005). Many scientific articles described the long-range transport of

particulate matter which have a significant impact on PM_{10} levels in big European cities while strong local sources could tend to mask long-range transport influences (Borge, et al. 2007).
In Central Europe the effect of the long range transport determine the air quality of the big cities like Budapest. The location of Budapest is not favorable, since polluted air arrive from any direction by the wind. There are some notable industrial areas like Po valley and the south part of Poland which play critical role in the air quality of Budapest. These facts portend that the qualitative analysis of the long range transport is essential in order to distinguish the effect of the local and distant sources, and to create effective air quality plan to make the air quality of the capital of Hungary healthier.

In this work, the effect of the long-range transport of SO_2, NO_2 and Particulate Matter (PM) was analyzed in detail using the results of EMEP chemical transport model. The results will show how important this effect is and how we will able to put this information into an air quality forecasting system.

METHOD
Based on scientific results mentioned above, it was very important to begin the development of chemical transport models with investigating the long-range transport of the air pollutants. A representative of these types of models is the EMEP Eulerian long-range transport model (Simpson, et al. 2012). The model is an important tool to analyze both acidification and photo-oxidant activities in the air. Determining the effect of the long range transport of different hazardous materials on the air quality of Budapest the EMEP chemical transport model was used. Applying the results of this chemical transport model only the yearly average of this effect could be analyzed. The results will show how this effect is important and how we will able to put this information into an air quality forecasting system.

The current version of the EMEP model working on a polar-stereographic projection, true at 60 N, has commonly been used, with grid-size of 50 km×50 km at 60 N. The standard domain has changed somewhat over the years, and was enlarged towards Eurasia in 2007. The model currently uses 20 vertical levels from the surface to the top of the model domain (currently: 100 hPa, 15 km). The 15 km high air column is divided into 20 levels in a form that the lower layer (3 km), which is relevant in the mixture of air pollutants, includes 10 levels, allowing the detailed examination of this air layer. The EMEP model uses a chemical pre-processor to convert lists of input chemical species and reactions to differential equations in Fortran code. The default chemical scheme, which is used in the open source version of the EMEP model, is the EmChem09. This chemical scheme describes 137 reactions and 26 photochemical reactions between 72 chemical species. The model calculates the dry and wet deposition of the chemistry substances. The dry deposition flux is determined by using the deposition velocity, while the wet deposition processes include both in-cloud and sub-cloud scavenging of gases and particles.

The standard emissions input required by EMEP model consists of gridded annual national emissions of sulphur dioxide (SO_2), nitrogen oxides ($NOx = NO+NO_2$), ammonia (NH_3), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), and particulates ($PM_{2.5}$, and PM_{coarse}, the latter being the coarse aerosol fraction, PM_{10}-$PM_{2.5}$). The particulate matter categories can be further divided into elemental carbon, organic matter, and other compounds as required. Emissions can be from anthropogenic sources (burning of fossil and biomass based fuels, solvent release, etc.), or from natural sources such as foliar VOC emissions or volcanoes.

The EMEP model has been adapted to run with meteorological fields calculated by a number of numerical weather prediction models, like the ECMWF IFS. Beginning from 2001, the data of the ECMWF IFS are available for forecasts with $0.125° \times 0.125°$ horizontal grid length and 137 vertical levels, and this model became the default meteorological driver.

RESULTS
The amount of pollutants emitted in one location and the fraction that finally reaches a certain downwind location dependents on three factors: (i) the quantity of the pollutant emitted or produced at the source, (ii) the meteorological conditions that transport the pollution from one continent to another, and (iii) the physical and chemical transformation processes that modify the quantity and composition of the pollution during transport that lasts from days to weeks. The aim of our work was determining the effect of the long

range transport on the air quality of Budapest. This information could be very important when an air quality forecast system is being developed. Without these information the forecasted values of different pollutants could be underestimated. The special output of the EMEP chemical transport model was used: the yearly grid-to-grid source-receptor calculations by country for deposition of sulphur and nitrogen, and concentrations of particulate matter (PM). To evaluate the year to year temporal variability of the long range transport the model results between 2000 and 2013 were analyzed.

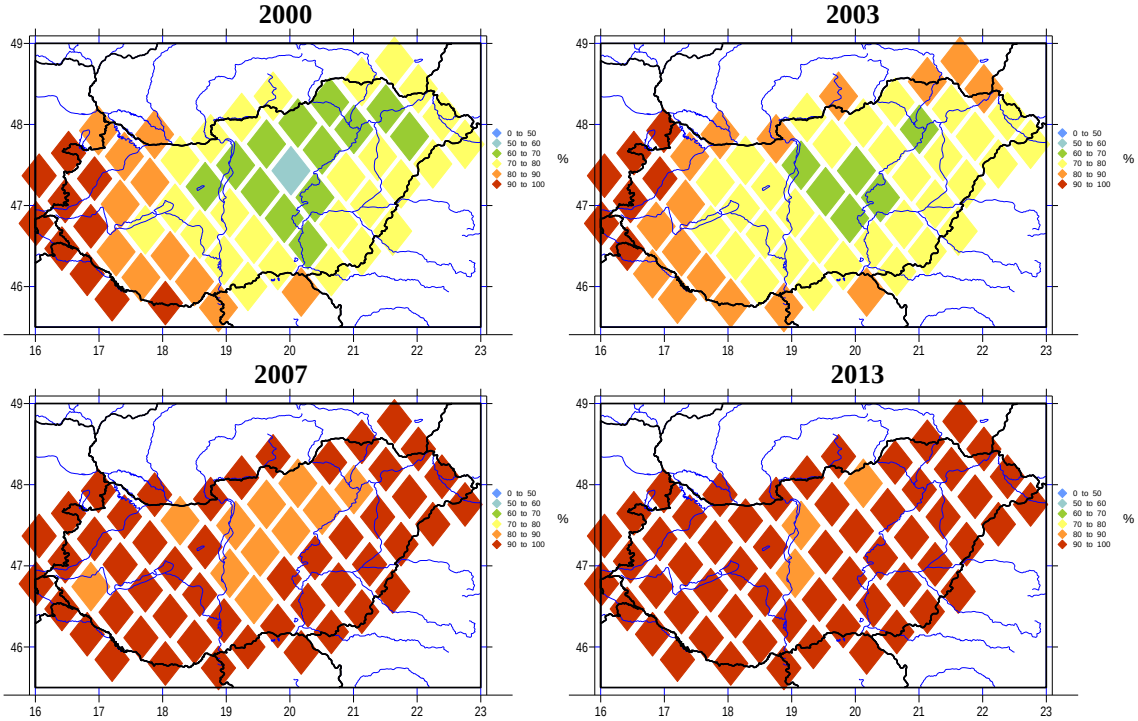

Figure 1. Fraction of transboundary contribution to SO_x deposition in Hungary (unit %)

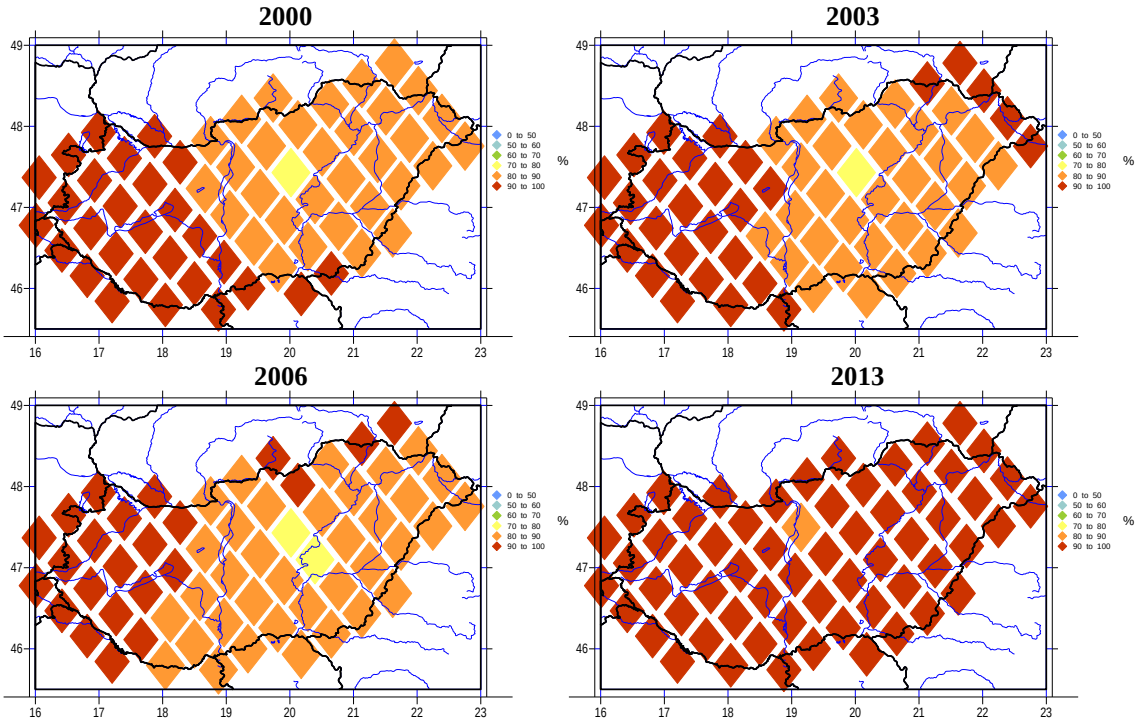

Figure 2. Fraction of transboundary contribution to NO_x deposition in Hungary (unit %)

In Figures 1-3. the results of model calculations are shown in mapped format, indicating the fractions of transboundary contributions to sulphur and nitrogen deposition, as well as PM_{10} concentration, respectively. The effect of the long-range transport shows significant spatial variability, the most important part is at the western frontier of Hungary, and the smallest one is in the central part of the country.

Considering the deposition of SO_x and NO_x the picture was changed remarkably in the last 14 years. After 2007, the deposition of oxidised sulphur and nitrogen in Hungary are determined mainly by the transboundary sources. The quantity of this effect is larger than 90%, and it is smaller only in the surrounding area of Budapest.

In case of PM_{10} the situation is somewhat different, as the effect of the long range transport shows a continuously decreasing tendency. The multiyear variation is mainly explained by changes in the PM_{10} emission of Hungary. In the years when the emission of Hungary was decreased significantly the proportion of the long-range transport increased slightly. Unfortunately, the emission of PM_{10} was not decreased in Hungary as much as it decreased in Europe.

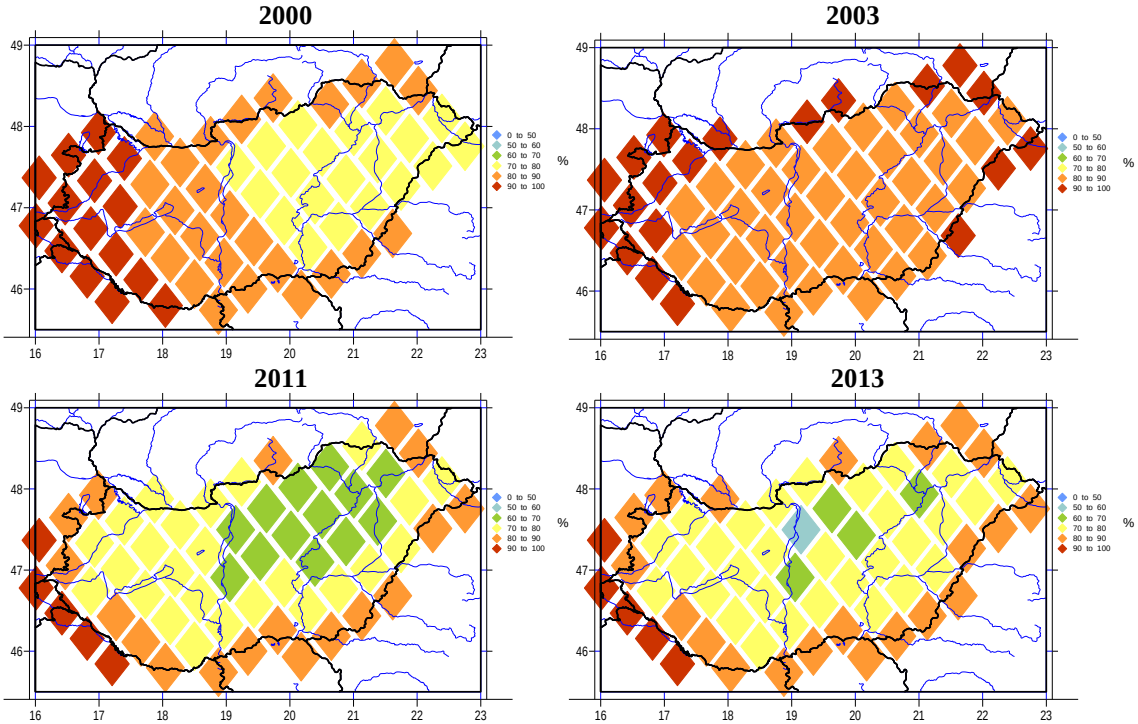

Figure 3. Fraction of transboundary contribution to PM_{10} concentration in Hungary (unit %)

In Figure 4, the temporal variation of fractions of transboundary contribution to SO_x and NO_x deposition and PM10 concentration in Budapest is presented. Based on the results gained from model calculations, it can be stated, that a significant increase of transboundary contribution can be seen for sulphur, while transboundary contribution to PM10 concentration in Budapest tended to decrease during 2000-2013.

The temporal variation can mainly be explained by changes in the rate of emission in Hungary, especially in the surrounding area of Budapest and in Europe. During the period, when the emission of Hungary decreased significantly, the proportion of the long-range transport increased slightly.

The emission of SO_x dramatically decreased in Hungary until 2005, then there was a gradual decline. Parallel to this, the emission of SO_x in Europe decreased continuously. This is the reason why the effect of the long-range transport increased significantly until 2005, and then it was changed only slightly.

The situation in case of NO_x is different, because the emission of NO_x continuously decreased both in Hungary and in Europe. This is the reason why the fractions of transboundary contribution to NOx deposition is around 85% during the 14 years investigated.

In the last decade the emission of the PM_{10} in Europe continuously decreased while in case of Hungary the emission was rather stagnant with a fluctuation of ±20%. This situation explains, that the fraction of transboundary contribution to PM_{10} concentration in Budapest continuously decreases.

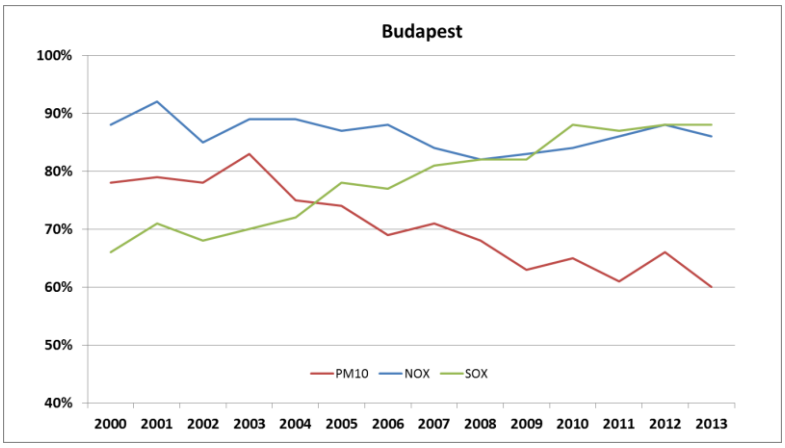

Figure 4. Fraction of transboundary contribution to SO_x and NO_x deposition and PM_{10} concentration in Budapest (unit %)

CONCLUSION

In this work the effect of the long range transport on the air quality of Budapest and surrounding area was determined using the outputs of EMEP chemical transport model. It was determined that the effect of the transboundary sources on the air quality of Budapest is essential, its fraction is higher than 60% in all three pollutants' cases. These results are proving, that without boundary conditions calculated by a global chemical transport model, an air quality forecasting model is unable to produce realistic air quality forecasts for the area of Budapest.

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