



EVALUATION OF THE PERFORMANCE OF CHIMERE CHEMICAL TRANSPORT MODEL IN FOG SITUATIONS OVER HUNGARY

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ABSTRACT

Air pollution is a serious environmental problem in Hungary. Primarily during winter and fall seasons, episodes of poor air quality related to high concentrations of particulate matter are frequent, especially in the eastern part of the country. These situations are often connected to special meteorological conditions which hinder the mixing and dilution of air pollutants. Such a situation occurred at the end of January 2017 when a cold air cushion evolved over Hungary, leading to foggy weather, very low temperature conditions and high surface PM₁₀ concentrations. Chemical transport model (CHIMERE) calculations have been carried out to evaluate this smog episode. At first a sensitivity analysis was made to determine the most important meteorological parameters affecting the concentration fields that we obtain as results of the chemical transport model simulations. The following aim was to examine the meteorological background which could contribute to the developing of the smog situation. Imprecisions in meteorological data can cause significant inaccuracies in the calculated gas and aerosol concentrations. The mass concentrations have been compared with measured PM₁₀ concentrations for the validation of the simulation results.

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INTRODUCTION

A key issue regarding air quality research in the Carpathian Basin is to identify the sources of aerosol particles and the influencing meteorological factors that may lead to increased concentrations of particulate matter (PM), which is the most frequent constituent of smog episodes in Hungary. Data in emission inventories have improved significantly in Europe in the latest years, however, the quantitative contributions of different sources (e.g. domestic heating and automobile exhaust) to the total emission are still highly uncertain. In addition to the uncertainties in anthropogenic emission data, another difficulty lies in our limitation in the accurate understanding of the connection between local meteorological conditions and the environmental concentrations of pollutants. Analysis of local and regional meteorology – including wind speed, wind direction, atmospheric stability and precipitation – is crucial to completely understand the processes responsible for the spatial and temporal distribution of PM in all geographic regions [1] [3]. The situation is further complicated by the fact that apart from being emitted directly, PM can also form in the atmosphere when gaseous pollutants undergo transformation to yield secondary inorganic particles [2], and this complexity adds to the importance of meteorology in air pollution analyses. In this study we present a few examples to show how meteorological variables affect the distribution of PM concentrations in the Carpathian Basin and then we summarize an analysis of a smog situation that happened under special meteorological conditions at the end of January 2017.

THE COLD AIR CUSHION

A cold air cushion is a special meteorological situation that is related to inversion in the upper atmosphere and it is coupled with very low surface air temperatures. It most frequently evolves in areas that are surrounded by chains of mountains. Anticyclonic events trigger the development of cold air cushions as they foster downward motions in the air. By serving as a barrier for mixing motions, inversion causes the air to stabilize and it hinders the movement of the air mass out of the basin. This effect is enhanced by the presence of the surrounding mountains. Low temperatures boost residential heating and in the absence of sufficient mixing and dilution, pollutants of anthropogenic origin accumulate rapidly and concentrations can easily reach levels that are considered harmful for the health.

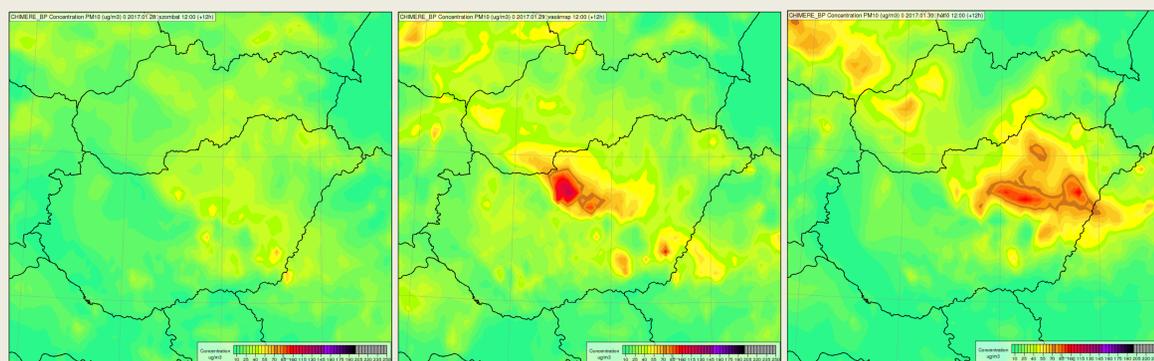


Figure 2. PM₁₀ in the Carpathian Basin at 12 UTC from 28 to 30 January 2017.

DISCUSSION

The ability of the model to describe a smog situation in a realistic way lies both in precise emission data and in an accurate weather forecast. In the smog situation examined here, wind speed had a crucial role. In the absence of a considerable wind, the amount of pollutants in the air increases rapidly. Since wind speed strongly affects the dilution of pollutants in the air and in model simulations, the inaccuracies in modelled wind speed data could probably largely contribute to the inaccuracies in PM₁₀ concentration fields calculated by CHIMERE. Another factor which the model was unable to take into account, is the increase in the anthropogenic emission compared to the inventory, which occurred as a consequence of the very low temperature conditions.

THE EFFECT OF METEOROLOGY

The transport and dilution of pollutants emitted into the atmosphere is mainly driven by the actual meteorological conditions. Based on a unified emission inventory, a sensitivity analysis that is carried out with real meteorological data describing different weather patterns reflects the effects of meteorological variables well. In this work we demonstrate the effects of wind speed and precipitation (Figure 1). Results of our analysis suggest that in cases when wind speed remains low and there is no precipitation, conditions are favourable for PM₁₀ to accumulate, while in the presence of rain and strong winds concentrations dissipate quickly.

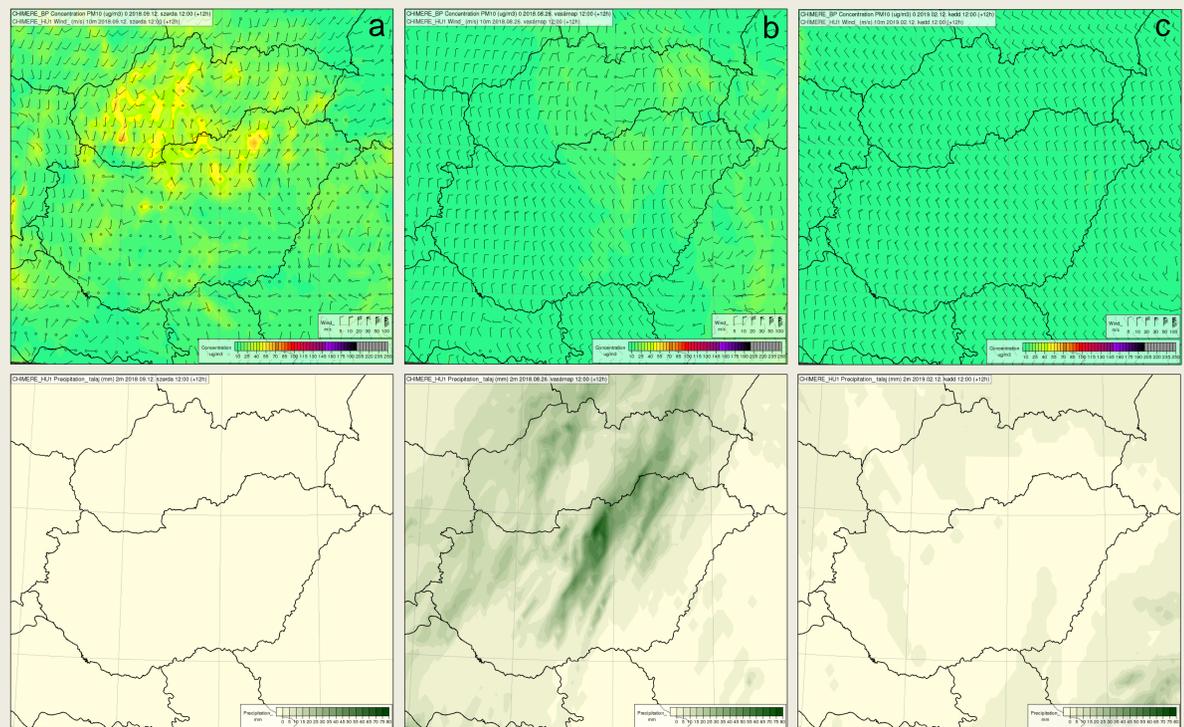


Figure 1. PM₁₀ and wind speed (top) and precipitation (bottom) fields in the Carpathian Basin under different weather patterns: a) a dry day with low wind speed, b) a day with a large amount of precipitation and c) a day with strong winds. The maps show the 12 UTC situation.

A SPECIAL SMOG SITUATION IN HUNGARY

At the end of January 2017 a cold air cushion evolved over Hungary. Temperatures dropped well below -10°C for the nights throughout the whole country. On account of a lower level inversion, planetary boundary layer height remained below 200 m, winds were light and the air stabilized. This unfavourable meteorological situation led to high concentrations of PM₁₀. Concentrations started to rise on 18 January and reached a peak at the end of the month. We used the CHIMERE chemical transport model to simulate the transport and chemical transformation of air pollutants during this smog episode. The model domain covered the Carpathian Basin with a resolution of 0.1° (roughly 10 km). For the input anthropogenic emission data the EMEP database was used with a 0.1° spatial resolution. Input meteorology for the model calculations was provided by the AROME numerical weather prediction model. Figure 2 shows the distribution of PM₁₀ concentrations in the Carpathian Basin at 12 UTC from 28 January to 30 January.

RESULTS

Simulation results suggest that in this very special meteorological situation the model in some areas underestimated the real concentration values considerably. PM₁₀ pollution was extremely high in the Sajó Valley, in the vicinity of the city of Miskolc, with the highest measured 1-hour average concentrations above 500 µg/m³. Figure 3 shows time series of PM₁₀ measured at different stations in Miskolc and Budapest and modelled values for grid points located in the territory of the individual cities. The model significantly underestimated the measurements around Miskolc, in the case of Budapest, however, we found that the simulation results were much closer to the measured values.

CONCLUSIONS

In this study we presented a few examples for the way meteorological variables affect the transport and dilution of PM in the atmosphere and investigated a special meteorological situation that occurred in the Carpathian Basin and led to increased environmental concentrations of PM₁₀. We demonstrated how strongly wind speed and precipitation contribute to the dilution of particles in the air, while in low wind and dry weather conditions pollutants accumulate rapidly. At the end of January 2017 a cold air cushion evolved over Hungary that involved very low temperature conditions, a low planetary boundary layer height, light winds and stable air. The consequence was a smog period with high PM₁₀ concentrations that in some areas exceeded the 500 µg/m³ value. Model calculations were carried out in order to simulate the smog episode using the CHIMERE chemical transport model and AROME weather forecast data. We found that in this very special case the model significantly underestimated the measured values in certain areas, probably as a result of the inaccuracies in weather data and the enhanced intensity of residential heating which the model could not take into account. This analysis suggests that local meteorology has a crucial role in the accuracy of air pollution modelling.

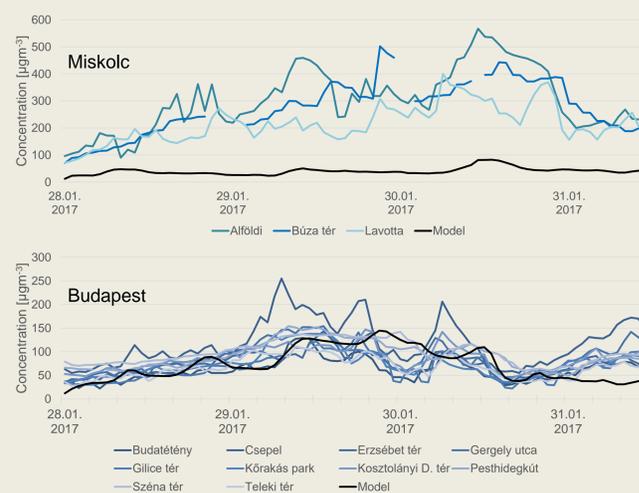


Figure 3. Measurement time series of PM₁₀ at different stations in Miskolc and Budapest (blue) and model simulation results (black) for grid points located in the areas of the cities from 28 to 31 January.