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Effects of the climate change on regional ozone dry deposition

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Abstract. This impact study investigates connections between the regional climate change and the tropospheric ozone deposition over different vegetations in Hungary due to the possible changes of atmospheric and environmental properties. The spatial and temporal variability of the dry deposition velocity of ozone was estimated for different time periods (1961–1990 for reference period and two future scenarios: 2021–2050 and 2071–2100). Simulations were performed with a sophisticated deposition model using the RegCM regional climate model results as an input. We found a significant reduction of the ozone deposition velocities during summer months, which predicts less ozone damage to the vegetation in the future. However elevated ozone concentration and changed plant physiology can compensate the effect of this reduction.

1 Introduction

Tropospheric ozone plays an important role in the formation of the photochemical air pollution and affects both vegetation and human health. Recently it has also been shown that the indirect radiative forcing of climate change through ozone effecting on the land carbon sink could be an important factor and can induce a positive feedback for global warming (Sitch et al., 2007; Klingberg et al., 2010).

Harmful effects of near surface ozone on different surfaces can be quantified by different flux-based metrics (e.g., Ashmore et al., 2004; Gerosa et al., 2009) derived from the ozone concentration and deposition velocity. Both terms, and therefore the ozone load, can be modified due to the effects of global warming. The deposition velocity of ozone depends on both atmospheric and other environmental (soil, vegetation, surface) properties. Spatial and temporal distributions of the deposition velocity can also be predicted based on the regional climate model results (e.g., Bartholy et al., 2008). According to changed climatic conditions and emission patterns of ozone precursors, the concentration of ozone will also change (Meleux et al., 2007; Langner et al., 2005). The main aim of this research is to explore the spatial and temporal variability of the dry deposition velocity of ozone over Hungary regarding to possible changes in the future based on regional climate model results.

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2 Model description

2.1 Input database

Regional Climate Model (RegCM) results are used for the input data of the ozone deposition model. RegCM has originally been developed at the National Center for Atmospheric Research (NCAR) and has been mostly applied to studies of the regional climate and the seasonal predictability around the world. The 3.1 model version has been adapted and used at the Eötvös Loránd University (Torma et al., 2008). The horizontal resolution of the model database is 10 km and the model domain is from 45.73° N to 48.70° N latitude and from 16.02° E to 23.04° E longitude. From the results of RegCM the following meteorological data are used in this study: average daily values of air temperature at 2 m, specific humidity at 2 m, u and v component of the horizontal wind at 10 m, root zone soil water content, total snow amount, incident solar energy flux, net absorbed solar energy flux, net infrared energy flux, surface air pressure. The Biosphere-Atmosphere Transfer Scheme's (BATS) land use categories are used (Fig. 1) in our study. Calculations for Hungary are performed for three time periods: two future scenarios for 2021–2050 and 2071–2100; and reference period (1961–1990). For the reference period calculations are made with the initial conditions obtained by the ECHAM global circulation model. These initial meteorological fields are used to compare future results to the reference period. Results with initial conditions from the ERA40 database are compared with the CRU climate database to verify the regional

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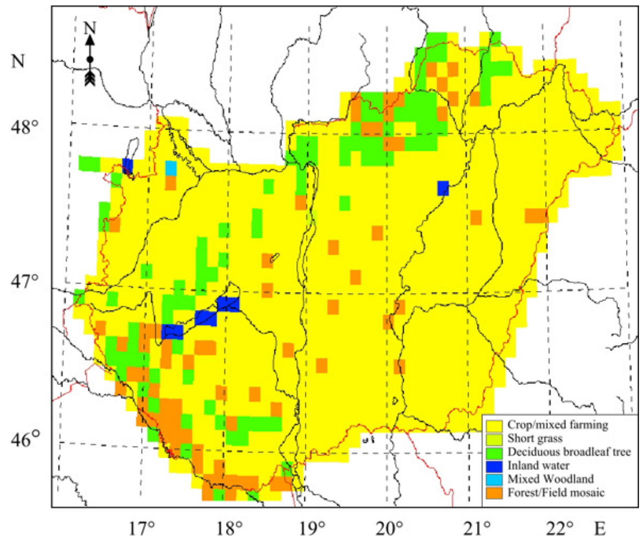

Figure 1. Land use categories over Hungary in RegCM-3 model.

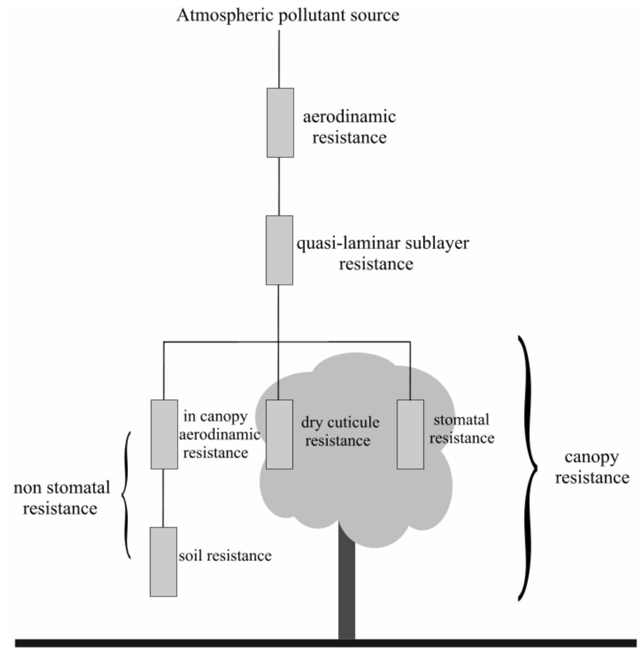

Figure 2. Calculation scheme of the resistance submodel.

climate model (Torma et al., 2008). In our study the comparison in changes of the ozone deposition velocity for the future are obtained by similar manner. This comparison is based on the fact that if the errors of a climate model are systematic, the right conclusions can be drown for the future using the results derived from ECHAM for the control period.

2.2 Deposition model

A sophisticated deposition model (Mészáros et al., 2009) is used to calculate the deposition velocity of ozone. The model has been developed at the Eötvös Loránd University, and it has been adapted and reconstructed for this specific task. The model uses a resistance analogy method in calculation of the deposition velocity. The scheme of the resistance model is depicted in Fig. 2. The parameterizations of the resistances in this model version are based on Zhang et al. (2003).

3 Results and conclusion

Using the results of the regional climate model as an input database of the deposition model based on daily values, a 30-yr averaged dry deposition velocity of ozone with its spatial and temporal variability is estimated over a Central European region including Hungary.

The spatial distribution of an average daily dry deposition velocity of ozone for each season in the control period (1961–1990) can be seen in Fig. 3. The highest values (up to 0.4 $cm\,s^{-1}$) occur in the summer period, the lowest ones in winter (around 0.1 $cm\,s^{-1}$). In spring and autumn, the deposition velocity varies around 0.2 $cm\,s^{-1}$. Yearly courses of the deposition velocity are similar for the three periods, but in the future a larger decrease is expected from May to August, while no considerable changes are found in other months (Fig. 4). The average values for the whole area are presented in this figure. According to the regional climate model results a major warming is expected for the far future in summer (+3.1 °C in average). For the near future this warming is 1.1 °C. In a warmer climate, the stomata of the plants are more closed to reduce water loss. Therefore, a decrease in the deposition velocity is expected for the future. In addition, the soil moisture and air temperature can also effect stomatal closure. The RegCM results show a decrease in precipitation over Hungary for the future. This drying and warming can cause decreased deposition velocities in our estimation.

The spatial variability of the changes in each season is presented in Fig. 5, where the relative differences of deposition velocities between the predicted (2021–2050 and 2071–2100, respectively) and the control periods are illustrated. The expected decrease in summer is higher in the Southern region than in the North. This decrease is due to the increasing stress factors on leaf stomata (higher temperature, relative humidity and soil moisture stresses). In the other seasons the changes are rarely greater than ±10%. In all seasons, a South-West – North-East axis can be found with a small decrease or increase of the deposition velocity in the North Eastern part of Hungary, and in general, larger decrease in the South, South-Western regions.

Figure 6 presents the average changes of the deposition velocity for each season. The magnitudes of the changes are larger for the period 2071–2100 except for spring. Larger changes are expected in summer, when a decrease of around

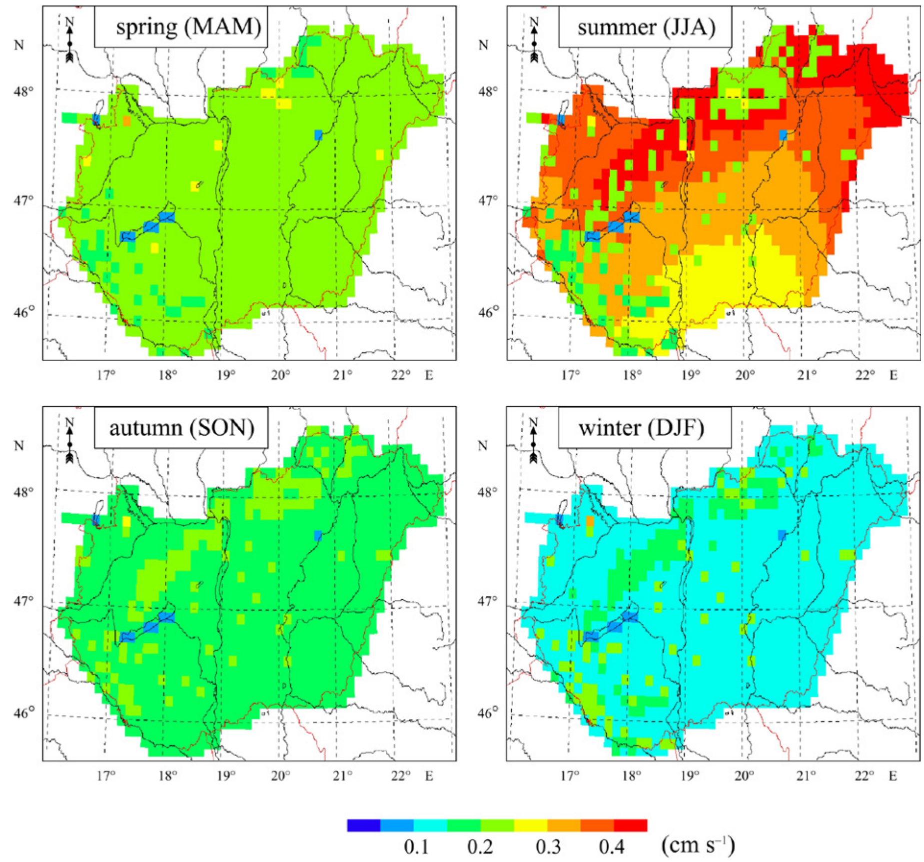

Figure 3. Average daily dry deposition velocity of ozone for different seasons in the control period (1961–1990) over Hungary.

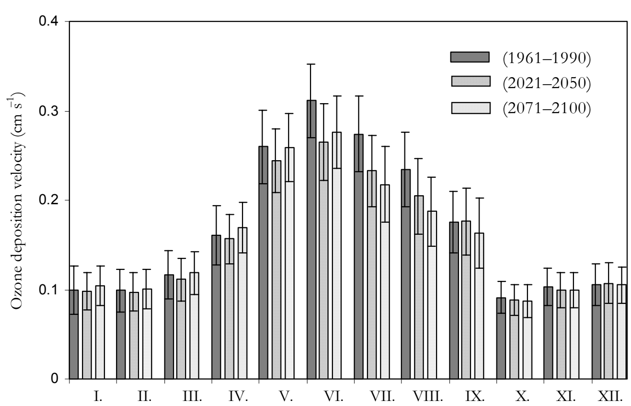

Figure 4. Average daily dry deposition velocity of ozone in each month for the following 30-yr periods: 1961–1990, 2021–2050, 2071–2100, (averages for all grid points; error bars are standard deviations).

12% and 14% is predicted in the values of the deposition velocity for the 2021–2050 and the 2071–2100 periods, respectively. A small increase of the deposition velocity is expected in winter for both future periods and in spring for the 2071–2100 period.

Based on these results, a lower deposition velocity is expected in the future in the vegetation period, which means a lower environmental load to vegetation assuming the same near surface ozone concentrations. However, the possible changes in ozone concentrations could modify these results. An expected increase of the ozone concentration may compensate or exceed the effect of the decreased deposition velocity. It must also be noted that these results correspond to Hungary (Central European region), and for other parts of Europe other changes in direction and magnitude might be expected, which require further investigations.

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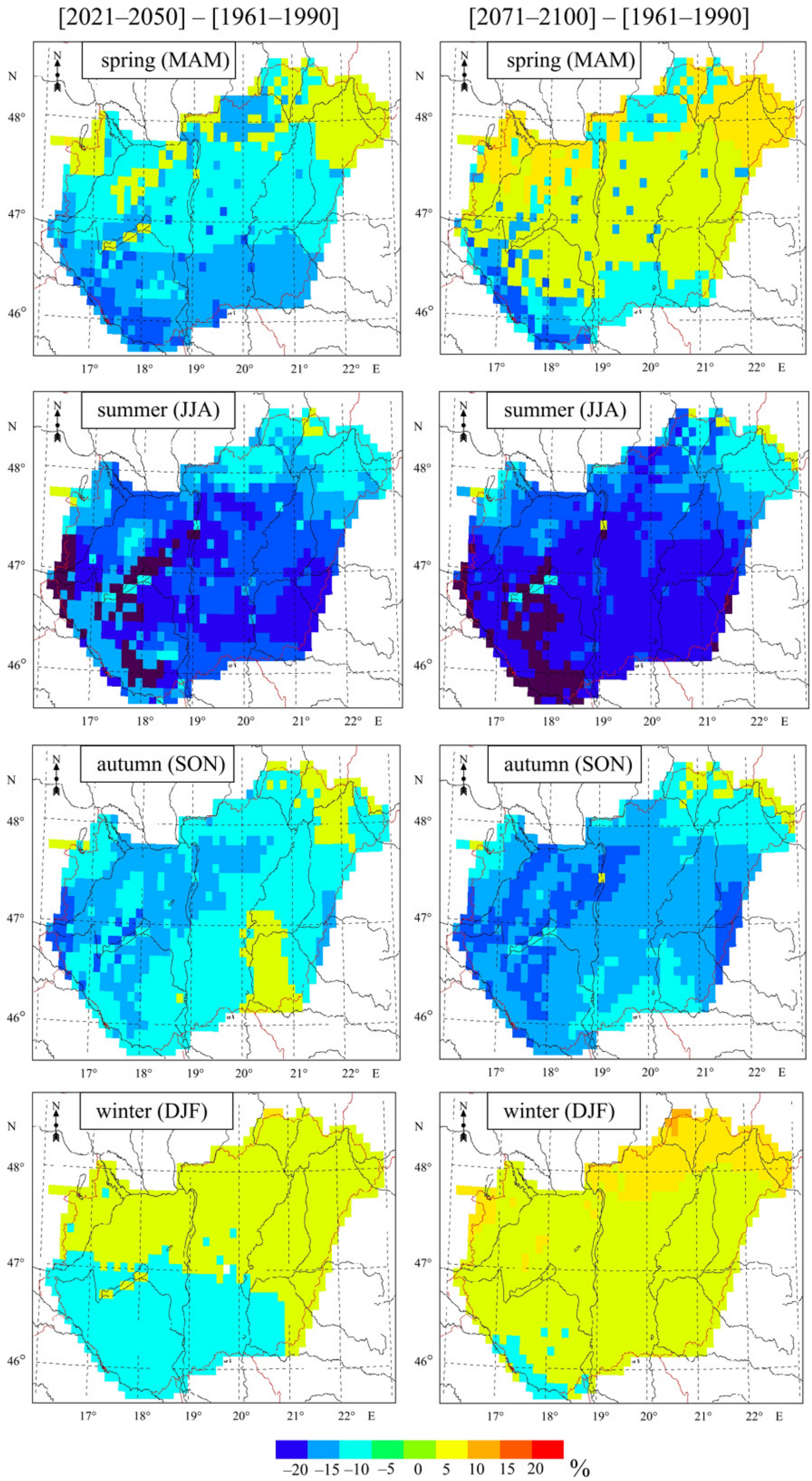

Figure 5. Spatial distribution of relative differences between ozone deposition velocities in each period for four seasons.

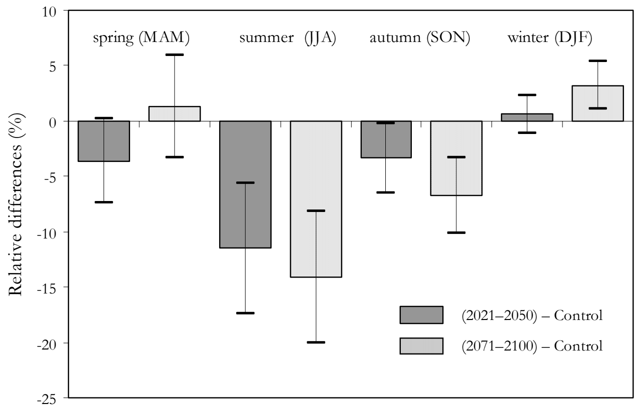

Figure 6. Averages and standard deviations of relative differences between ozone deposition velocities in each period.

References

Ashmore, M., Emberson, L., Karlsson, P. E., and Pleijel, H.: New directions: A new generation of ozone critical levels for the projection of vegetation in Europe, Atmos. Environ., 38, 2213–2214, 2004.

Bartholy, J., Pongrácz, R., Gelybó, Gy., and Szabó, P.: Analysis of expected climate change in the Carpathian Basin using the PRUDENCE results, Időjárás, 112, 249–264, 2008.

Gerosa, G., Marzuoli, R., Desotgiu, R., Bussotti, F., and Ballarin-Denti, A.: Validation of the stomatal flux approach for the assessment of ozone visible injury in young forest trees, Results from the TOP (transboundary ozone pollution) experiment at Curno, Italy, Environ. Pollut., 157, 1497–1505, 2009.

Klingberg, J., Engardt, M., Uddling, J., Karlsson, P. E., and Pleijel, H.: Ozone risk for vegetation in the future climate of Europe based on stomatal ozone uptake calculations, Tellus A, 63, 174–187, 2010.

Langner J., Bergström, R., and Foltescu, V.: Impact of climate change on surface ozone and deposition of sulphur and nitrogen in Europe, Atmos. Environ., 39, 1129–1141, 2005.

Meleux, F., Solmon, F., and Giorgi, F.: Increase in summer European ozone amounts due to climate change, Atmos. Environ., 41, 7577–7587, 2007.

Mészáros, R., Zsély, I. Gy., Szinyei, D., Vincze, Cs., and Lagzi, I.: Sensitivity analysis of an ozone deposition model, Atmos. Environ., 43, 663–672, 2009.

Torma, Cs., Bartholy, J., Pongrácz, R., Barcza, Z., Coppola, E., and Giorgi, F.: Adaptation of the RegCM3 climate model for the Carpathian Basin, Időjárás, 112, 233–247, 2008.

Sitch, S., Cox, P. M., Collins, W. J., and Huntingford, C.: Indirect radiative forcing of climate change through ozone effects on the land-carbon sink, Nature, 448, 791–794, 2007.

Zhang, L., Brook, J. R., and Vet, R.: A revised parameterization for gaseous dry deposition in air-quality models, Atmos. Chem. Phys., 3, 2067–2082, doi:10.5194/acp-3-2067-2003, 2003.