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The role of vegetation for tropospheric ozone balance: possible changes under future climate conditions

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Ozone (O_3) is a phytotoxic trace gas in the troposphere where it is photochemically produced from volatile organic compounds (VOCs) and nitrogen oxides (NO_x). The dominant sink of O_3 in the air over areas with dense plant cover is dry deposition on plant surfaces. However, plants can also contribute to photochemical O_3 formation because they emit biogenic VOCs (BVOCs).
In this study, the role of vegetation for tropospheric ozone balance was investigated by considering the following processes: O_3 depletion by dry deposition on plant surfaces, O_3 depletion by gas phase reactions with plant emitted BVOCs, and photochemical O_3 production from these BVOCs. Furthermore, drought and heat stress were applied to the plants, and the stress-induced changes of plant performance and the subsequent changes regarding the tropospheric ozone balance were investigated.
Dry deposition of O_3 in unstressed plants was dominated by O_3 uptake through the plants stomata with negligible losses on cuticle and stem. For strong BVOC emitters, O_3 destruction by gas phase reactions with BVOCs was significant at low NO_x conditions. Switching from low NO_x to high NO_x conditions led to O_3 production. A ratio of O_3 formation rates over BVOC loss rates was measured for α-pinene as single BVOC and for BVOC mixtures emitted from real plants. For O_3 formation under BVOC limited conditions, this ratio was in the range of 2–3 ppb/ppb. The ratio of O_3 uptake/BVOC emission reflects the capability of a plant as a potential source of O_3, while NO_x concentrations and the BVOC/NO_x ratio determine whether the emitted BVOCs act as an additional sink or a source of O_3.
O_3 uptake rates and BVOC emission rates are affected by environmental variables such as temperature, light intensity and stresses to plants. The impacts of these variables on the two processes are different and thus the capability of a plant to be a source of O_3 is also affected. As future climate change will bring more and intense heat waves and elongated drought periods we focused on evaluating the impact of drought and heat stress on the ozone balance. With the application of moderate drought, the capability of a plant to be a source of O_3 increased; under conditions of severe drought the impact of plants in the O_3 balance decreased to almost zero. Moderate increase of temperature increased the role of plants as potential O_3 source. However, when temperature exceeded the threshold causing irreversible damage to plants, different impacts were observed. For plants without storage pools, decreases of BVOC emissions were found to attenuate their role as a potential O_3 source. For plant species with storage pools, increasing emissions enhanced their role as O_3 precursors under high NO_x conditions.