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The climate impact of global transportation emissions: present-day effects and future scenarios

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Emissions from the transportation sectors, i.e., land-based transport, aviation and shipping, are one of the major drivers of climate change. Transportation is responsible for an important fraction of the anthropogenic emissions of the long-lived greenhouse gas CO_2 and also of short-lived species, such as nitrogen oxides (NO_x), volatile organic compounds (VOC), sulfur dioxide (SO_2) and particulate matter (PM). Short-lived emission components not only affect air quality but also have important climate effects. The emission of short-lived trace gases, in particular NO_x, carbon monoxide (CO), and VOC, result in climatically relevant perturbations of the greenhouse gases ozone and methane. The emission of aerosol particles (e.g., sulfuric acid or black and organic carbon particles) as well as aerosol precursor gases (e.g., SO_2) perturb the climate via modifications of clouds and radiation. Some of these effects contribute to global warming while others result in a negative climate forcing, i.e., a cooling effect, which - to some degree - counteracts the warming.

This contribution highlights results of the DLR transport research project TraK (Transport und Klima) where a comprehensive chemistry-climate model system was applied to consistently simulate the climate effects of all relevant short-lived emission compounds for all three transportation sectors, complemented by calculations of the climatic impact of the corresponding CO_2 emissions. For the first time, all transport-induced climate effects were quantified in a self-consistent manner to describe the impact of CO_2 as well as non-CO_2 emissions. The effects were calculated for the year 2015 as well as for 2050 in three future scenarios following the Shared Socioeconomic Pathways (SSPs) developed for the recent IPCC assessment report. The scenarios cover a large range of possible future developments, including a low emission case (SSP1-1.9), a middle-of-the-road scenario (SSP2-4.5) and a high emission case (SSP3-7.0). The results confirm the large importance of the non-CO_2 effects for all transportation sectors at present-day and reveal a high relevance of these effects in all considered future cases, even in the low emission scenario with drastic reductions of non-CO_2 transport emissions. This clearly reveals that, in addition to CO_2, non-CO_2 effects must be considered when designing and evaluating strategies for the energy transition in the transportation sectors.

The results of this study, including the developed modelling tools, are a valuable contribution to the evaluation of the climate benefits of mitigation strategies for the transportation sectors and other emission sources. In view of the energy transition this conference contribution will further present:

- concepts of modelling tools for assessing the climate effects of global and regional emissions from transportation and other sectors,
- concepts for evaluating the climate benefit of emission mitigation strategies, and
- further research needs in atmospheric and climate science to address relevant aspects of the energy transition.