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Article

Impact of aircraft NO_x emissions. Part 1: Interactively coupled climate-chemistry simulations and sensitivities to climate-chemistry feedback, lightning and model resolution

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Abstract

Simulations with the fully coupled climate-chemistry model E39/C suggest that the 1990 aircraft NO_x emissions contributed substantially to the Northern Hemisphere NO_x (30–40%) and ozone (3–4%) tropospheric burdens. Ozone production rates are increased by air traffic NO_x emissions in the mid- and upper troposphere, whereas ozone loss rates are increased in the lower troposphere but decreased at cruise altitudes. The latter reduction results from increased tropospheric NO and NO_2 concentrations and a change in the OH:HO_2 ratio at cruise altitudes. Sensitivity studies showed that feedback processes between chemical species and dynamics are not altered significantly by air traffic. However, the results are sensitive to the lightning NO_x emission patterns, the vertical resolution of the model at tropopause altitudes, model domain, and maximum flight level.

Zusammenfassung

Simulationen mit dem vollständig gekoppelten Klima-Chemie Modell E39/C zeigen einen deutlichen Beitrag von Flugzeug-NO_x-Emissionen zum troposphärischen NO_x- (30–40%) und Ozongehalt (3–4%). Ozonproduktionsraten erhöhen sich durch den Luftverkehr in der mittleren und oberen Troposphäre. Hingegen verstärken sich Ozonverlustraten in der unteren Troposphäre und verringern sich im Flugniveau. Letzteres ergibt sich aus einer Erhöhung der NO- und NO_2-Konzentrationen in der Troposphäre und einer Änderung des OH:HO_2-Verhältnisses. Sensitivitätsstudien zeigen, dass Rückkopplungsprozesse zwischen chemischen Spurenstoffen und der atmosphärischen Dynamik sich durch den Flugverkehr nicht signifikant ändern. Jedoch zeigen die Ergebnisse eine Sensitivität gegenüber NO_x-Emissionsmustern von Blitzen, der vertikalen Modellauflösung im Tropopausenniveau, der Ausdehnung des Modellgebietes und der maximalen Flughöhe.

1 Introduction

Emissions of NO_x from aircraft have the potential to modify significantly ozone (O_3) concentrations in the troposphere, and especially in the tropopause region (PENNER et al., 1999). A change in ozone affects radiative forcing dominantly in the tropopause region because of the low temperatures there (WANG and SZE, 1980). In recent years, several modelling studies investigated the effect of air traffic upon the chemical composition of the atmosphere. BRASSEUR et al. (1998) calculated maximum ozone increases due to aircraft emissions between 0.6 and 3.9% based on simulations from 4 models. VALKS and VELDERS (1999) calculated an ozone change of about 2.5 to 3.5% and 3.5 to 4.7% for 1990 and 2015, respectively. For a 2015 scenario, the IPCC (PENNER et al., 1999) reported results for ozone changes of between 5 and 10% in a comparison of 6 models. This wide range of values shows that there are uncertainties in the models partly resulting from deficiencies in the simulation of the upper troposphere NO_x distribution, which is mainly controlled by lightning, aircraft and surface emissions, transported by convection or large scale ascent (e.g. GREWE et al., 2001).

The models used in recent assessments (PENNER et al., 1999; BRASSEUR et al., 1998) all suffer from some deficiencies. Most models concentrate on tropospheric chemistry only and the transition from the troposphere to the stratosphere is only insufficiently resolved (i.e. vertical resolution ~2 km). The tropospheric chemistry schemes often ignore non-methane hydrocarbon (NMHC) chemistry. In addition, some important processes are only poorly quantitatively known, e.g. NO_x emissions by lightning, mass transport by convection.

Here, we present simulations with the new ECHAM/CHEM model version E39/C (HEIN et al., 2001). An older version has already been used in the recent assessments. The upgrades include higher horizontal and vertical resolutions, and interactive coupling of chemistry, radiation, photolysis, clouds, wash-out, and lightning. The

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