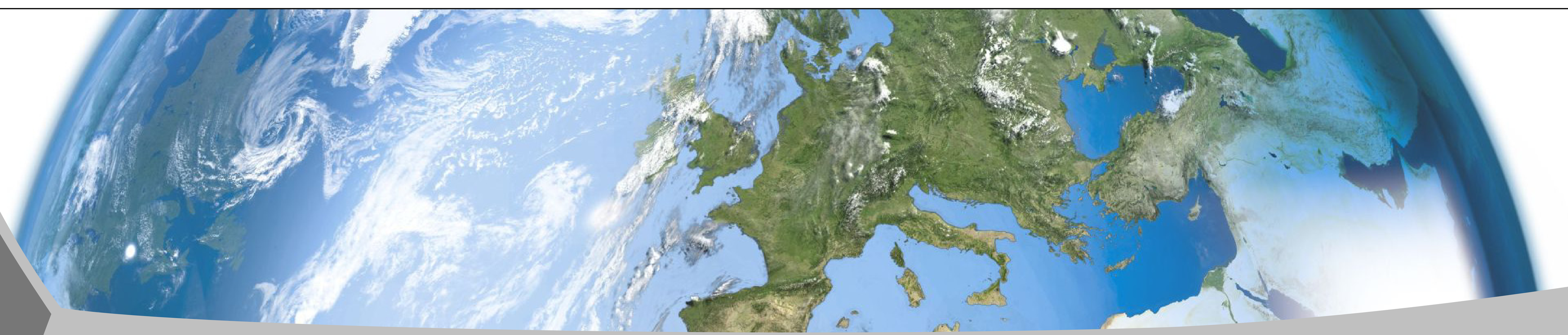

DLR

DKRZ – Project 80
Climate effects of emissions from the transport sector

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Introduction

In this project, the climate impact of emissions from the transport sector is investigated. Land-based transport, shipping, and aviation cause changes in atmospheric composition which result in a significant influence on the climate system. We use numerical simulations to study these effects. Different types of models are applied and further developed in order to determine the impacts of both CO_2 and non-CO_2 emissions. A special focus, however, is on the investigation of non-CO_2 emission effects since the uncertainties in this field are comparatively high. The specific subjects of the project are:

- Effects of global emissions from the individual transport sectors on atmospheric aerosol and related effects on clouds and radiation.
- Effects of nitrogen oxides emissions on the global abundances of ozone and methane.
- Aviation-induced cloudiness: Contrail cirrus.
- Climate sensitivity analysis for all important non-CO_2 radiative forcing contributions from transport-related emissions.
- Development of the simplified response model TransClim for efficient evaluation of measures to mitigate climate change.

Effects of aerosols from the transport sector on atmosphere and climate

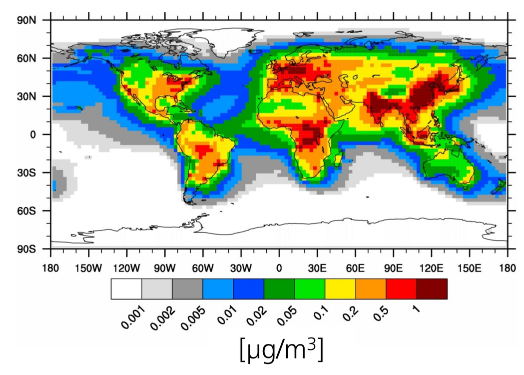
Major subjects

Further development and application of the global aerosol-climate model EMAC/MADE in order to quantify:

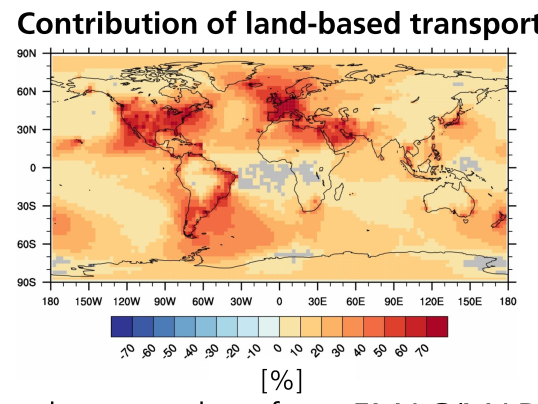
- effects of the individual transport sectors on the distribution and properties (particle sizes, composition, optical properties, etc.) of the global atmospheric aerosol,
- related effects on clouds at different altitudes (warm clouds and cirrus),
- related effects on the Earth's radiation budget,
- effects of mitigation measures.

Example

Soot concentration at Earth's surface



Contribution of land-based transport

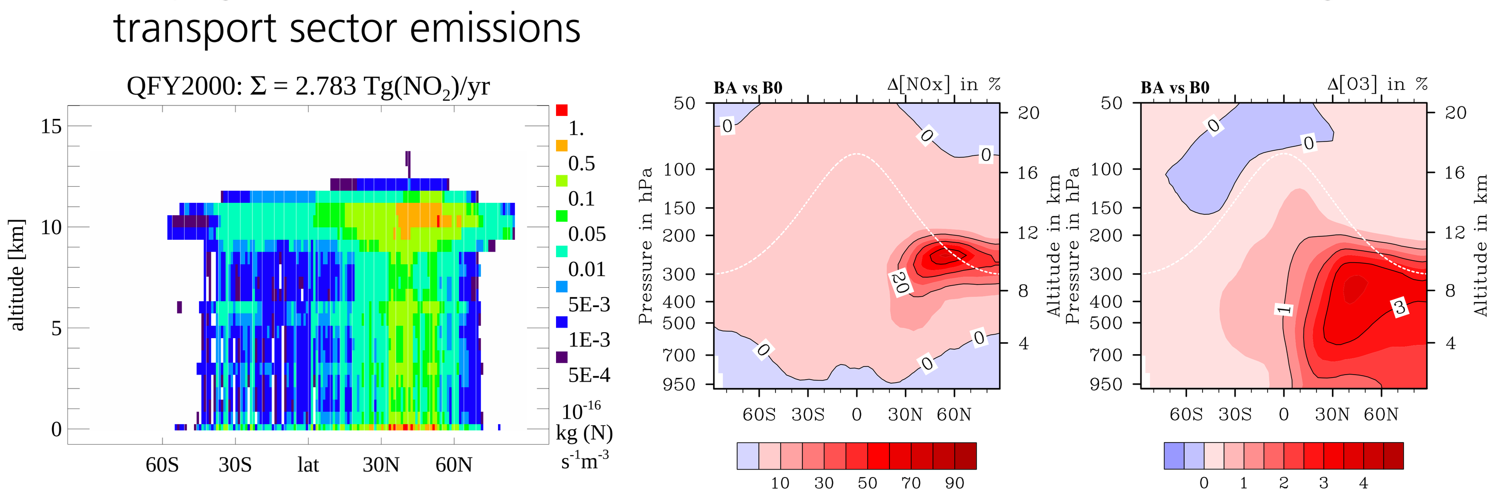


Annual mean values from EMAC/MADE simulations based on year 2000 emissions.

Effects of transport emissions on atmospheric chemistry

Parts of the DLR projects CATS (Climate Compatible Air Transport System) and VEU (Verkehrsentwicklung und Umwelt) are dedicated to study the impact of gaseous emissions (e.g. NO_x) on atmospheric trace gases that affect the Earth's radiation budget (e.g. O_3, CH_4). Transport emissions enter the model as offline inventories here. We vary the inventories or chemical parameterisations within a series of global simulations (EMAC in QCTM mode). The resulting differences in chemical species between the simulations provide insights into the:

- Effects of different mitigation measures = different emission inventories
- Propagation of model uncertainties on estimates of radiative forcing from transport sector emissions



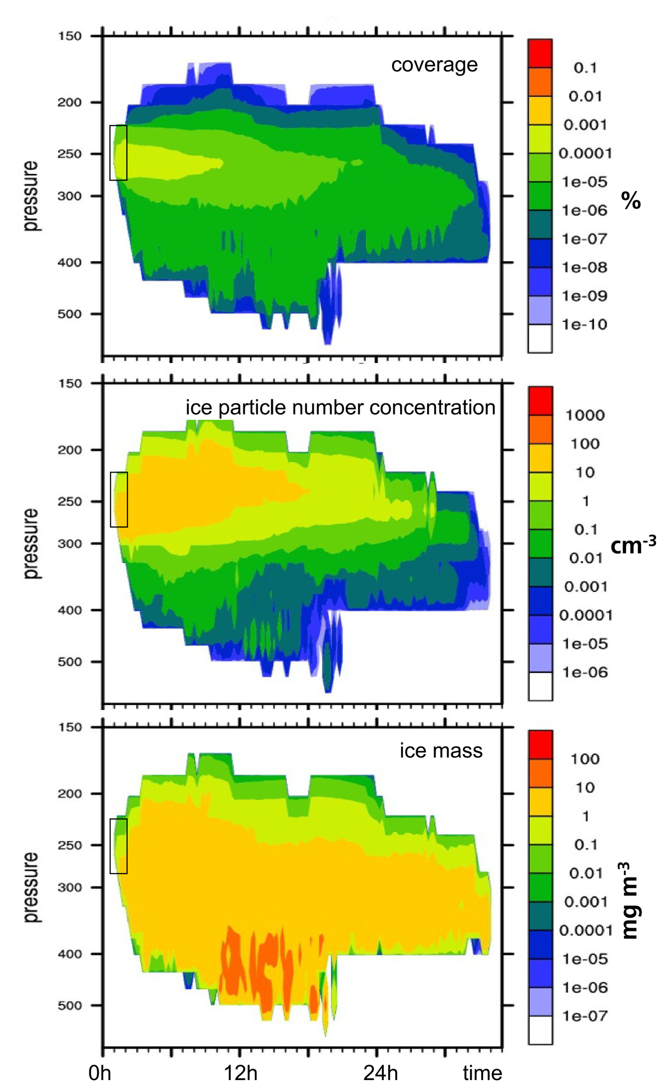
Aviation NO_x inventory, and differences in annual zonal mean NO_x and O_3 between an EMAC simulation with aircraft emissions (BA) and one without (B0).

Aviation-induced cloudiness: Contrail cirrus

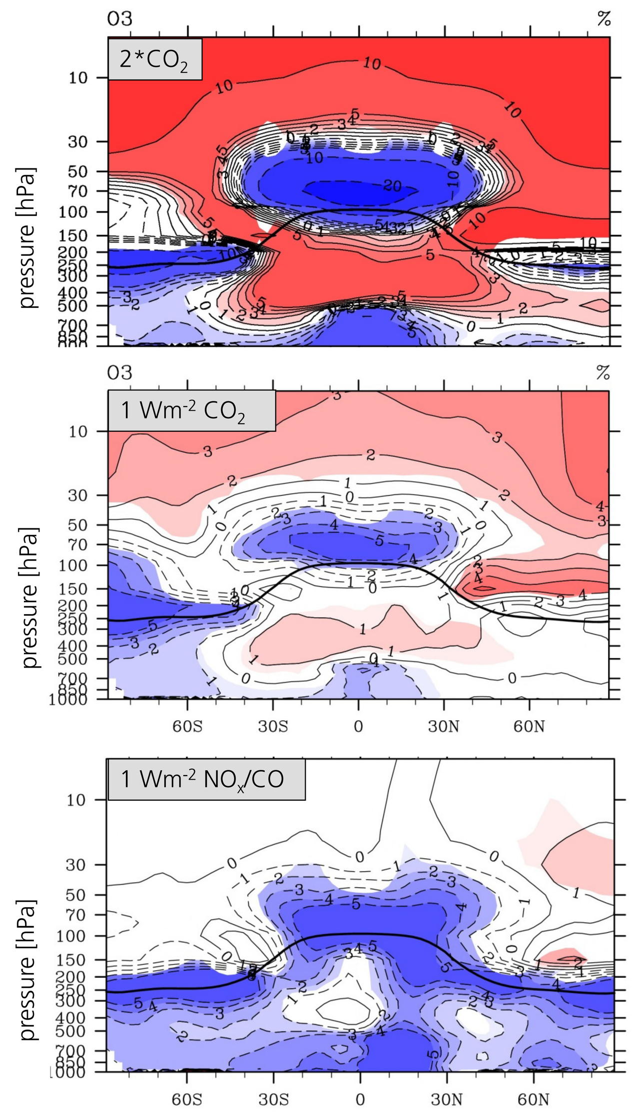
Within the BMWi project FAIR und the EU project AHEAD we estimate the impact of different aircraft fuels and propulsion systems on the contrail cirrus radiative forcing. The use of biofuels is supposed to generate fewer soot particles, affecting microphysical properties of contrail cirrus and life time.

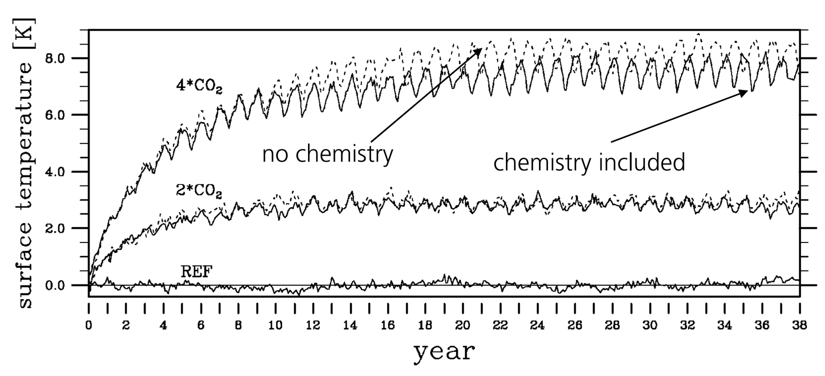
→Development of a contrail cirrus parameterization in ECHAM5-HAM including a microphysical 2-moment-scheme.

The figure shows the temporal evolution of contrail cirrus when prescribing air traffic at 250 hPa for 1 hour (black box). Contrail cirrus coverage quickly reaches its maximum and subsequently decreases slowly; ice particles sediment quickly but concentrations are largest at upper levels; ice mass is largest at lower levels due to the larger amount of water vapor available for deposition.



Climate sensitivity and feedbacks





Equilibrium climate change simulations using a chemistry-climate model (here: EMAC) allow to quantify feedbacks that occur through interactions between the physical climate system and radiatively active chemical tracers. These feedbacks are neglected in conventional climate models without chemistry, yet they have a non-negligible influence on the model's climate sensitivity (see figure above).

Radiative feedbacks via ozone have a damping influence on climate sensitivity in CO_2 simulations. A characteristic ozone feedback pattern shows up, featuring dynamically induced ozone decrease in the lowermost tropical stratosphere (top and mid left). The negative ozone radiative feedback is closely connected with an additional negative feedback via stratospheric water vapour; both together induce a radiative feedback between −0.05 and −0.06 $Wm^{-2}K^{-1}$.

The negative ozone radiative feedback is further enhanced if the radiative forcing originates from enhanced NO_x and CO surface emissions via O_3 changes (bottom left).

Climate-chemistry-response model TransClim

Introduction:

- Surface emissions (NO_x, CO, NMHC) induce atmospheric ozone changes.
- Assessment of mitigation options and optimisation of surface traffic requires a fast modelling capability to assess numerous options.

Objective:

- Establish a response function which estimates the effects of emission changes on atmospheric composition and climate change.

Methodology:

- Numerous simulations with EMAC/Tagging of emission variations and the impact on the contribution of individual sectors to ozone, methane etc.
- Derive a response surface based on these EMAC simulations.

First results:

- First step: Investigate effects from reductions in road traffic NO_x emissions.
- Only small ozone changes occur, since the ozone productivity increases and other sources' contributions increase and compensate for the large reduction of the road traffic ozone contribution.