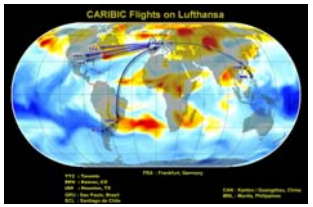
Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft
Institut für Physik der Atmosphäre

Airborne nitrogen oxides observations from CARIBIC

H. Ziereis[1], P. Stock[1], H. Schlager[1], U. Schumann[1], C.A.M. Brenninkmeijer[2], P. Jöckel[2], F. Slemr[2], A. Zahn[3], M. Hermann[4]

NO and NO_y Measurements on CARIBIC



Flight routes of CARIBIC overlaid with an ECHAM5/MESSY computer simulation of a typical carbon monoxide distribution at flight altitude (MPI-C).

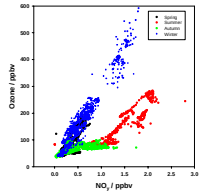
A large, systematic set of airborne in situ measurements of nitrogen oxide (NO) and the sum of all reactive nitrogen species (NO_y) has been performed in the tropopause region . These data are routinely acquired by the CARIBIC project (Civil Aircraft for the Regular Investigation of the Atmosphere Based on an Instrument Container). Since December 2004 NO and NO_y data have been obtained on a monthly basis during more than 130 flights using a Lufthansa Airbus A340-600.

Most of the CARIBIC flights have been performed between Germany and South America (Sao Paulo and Santiago de Chile) and between Germany and the East Asia (Guangzhou and Manila). Additionally there have been flights to destinations in North America.

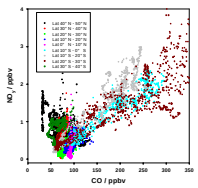
Nitrogen oxides play a key role in atmospheric photochemistry, particularly in controlling the cycling of OH and the production of ozone in the upper troposphere and lower stratosphere (UTLS). The budget of nitrogen oxides in the UTLS is controlled by a variety of different sources and processes, chiefly: long-range transport, lofting from the boundary layer, lightning, and air traffic.

In this study the nitrogen oxide data are analysed along with species as CO, O_3, aerosol particles, and others. The large scale distribution of NO and NO_y in the UTLS is presented. Tracer correlations are used to investigate the contribution of different sources on the nitrogen budget. Attempts have been made to assess the seasonal variation of nitrogen oxides in the probed UTLS region. Nitrogen oxides data obtained during the 2002 measuring period (CARIBIC Phase I) are compared with the simulations of the global atmospheric chemistry general circulation model ECHAM5/MESSy. Further analyses will exploit the wide range of concurrent measurements of trace gases and aerosol.

Trace gas correlations

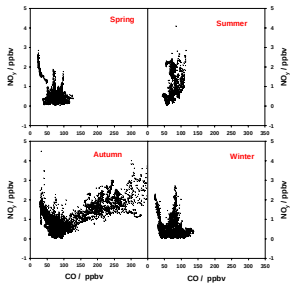


Ozone versus NO_y for all CARIBIC flights to America. Data are given for the latitude bin between 30 and 40°N and for all four seasons.

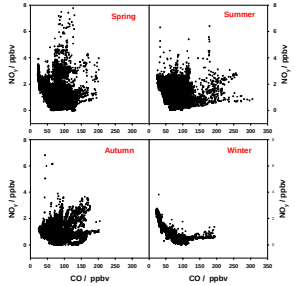


NO_y versus CO for all CARIBIC flights to America. Data are given for different latitude bins for autumn.

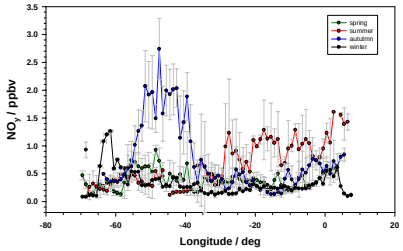
Flights to America



Flights to Asia

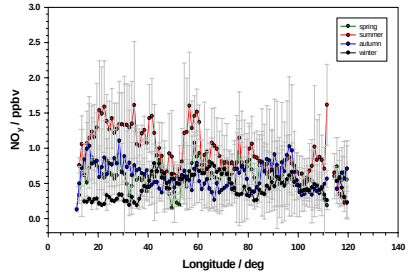


Longitudinal NO_y distribution - Seasonal variation



South America

Between February 2005 and March 2006 eight missions were performed between Germany and South America (Sao Paulo and Santiago de Chile).
About 300 000 NO_y data points have been obtained.



Asia

Between Mai 2005 and December 2007 19 missions were performed between Germany and Asia (Guangzhou and Manila).
About 600 000 NO_y data points have been obtained.

Signatures of air traffic emissions

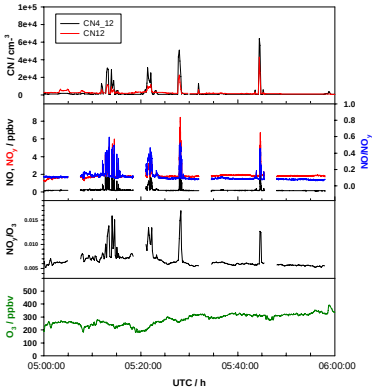
During the CARIBIC flights signatures of air traffic emissions are frequently observed. Typically, aged aircraft plumes can be recognized by sharp enhancements in NO_x, NO_y and fine particles. The time scale of these enhancements are of the order of a few to a few tens of seconds. The NO/NO_y ratio shows that nearly all NO_y during these events is made of NO indicating the young age of these emissions.

The emission index for CN-particles can be calculated from the known emission index for NO_x:

$$EI(CN)=EI(NOx)*NA/MNOx*p0*T/(NL*p*T0)*\Delta NCN/\Delta[NOx]$$

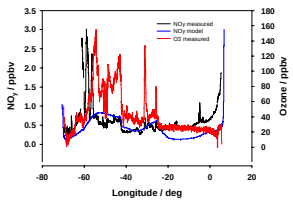
EI(CN)	emission indes for CN [number/kg fuel]
EI(NOx)	emission index for NOx [g/kg fuel]
p0,T0	pressure, temperature at standardconditions
p,T	pressure, temperature
MNOx	molecular mass of NOx
NA,NL	Avogadro, Lodschmidt number
ΔNCN, ΔNOx	enhancements in NOx and CN

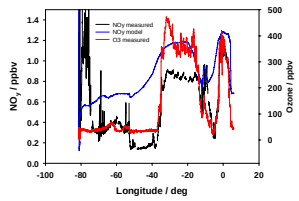
Taking a typical emission index for NO_x a CN-emission index of the order of $3*10^{17}$ /kg fuel can be derived from these measurements.



Signatures of air traffic emissions during the flight on June 21, 2007 from Frankfurt to Guangzhou over Northern China.

Comparison with model simulations





NO_y observations made during the CARIBIC I phase are compared to simulations of the global atmospheric chemistry general circulation model ECHAM5/MESSy.

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in der Helmholtz-Gemeinschaft
Institut für Physik der Atmosphäre
http://www.dlr.de/ipa
[2] Max-Planck-Institut für Chemie, Mainz; [3] Forschungszentrum Karlsruhe; [4] Institut für Troposphärenforschung, Leipzig