



## **Vertical and long-range transport of trace gases and aerosols: Recent results from the airborne CONTRACE, TROCCINOX, and ITOP field campaigns**

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During research flights in the mid and upper troposphere polluted layers are frequently observed. The age spectra range from very fresh layers mainly transported by nearby deep convection - to  $\sim 1$  week aged layers uplifted by warm conveyor belts and transported in the jet stream from one continent to another.

Results from in situ measurements in thunderstorm anvils are presented. Airborne measurements ( $\text{CO}$ ,  $\text{O}_3$ ,  $\text{NO}$ ,  $\text{NO}_y$ ,  $\text{J}(\text{NO}_2)$ , aerosol particles) have been carried out in the midlatitudes during the CONTRACE field experiment over Europe in summer 2003, and in the subtropics/tropics during the TROCCINOX field experiment over Brazil in winter 2004 and 2005. Especially in the anvil outflow in the midlatitudes a distinct influence from boundary layer pollution is observed in the anvil outflow. Concerning  $\text{NO}_x$  ( $=\text{NO}+\text{NO}_2$ ) in the anvil outflow about 1/3 is transported from the boundary layer and 2/3 is produced by lightning. In contrast deep convection over Brazil mainly contained  $\text{NO}_x$  produced by lightning and the influence from anthropogenic pollution was low. The  $\text{NO}_x$  mass flux in observed anvil outflows was estimated and compared to model results. The amount of lightning-produced  $\text{NO}_x$  varied between 2-10 Tg(N)/yr. In some cases a production of ultra-fine particles was observed in the anvil outflow.

In comparison to polluted layers uplifted by deep convection on the mesoscale, the extension of polluted layers, uplifted by warm conveyor belts ahead of cold fronts, is much wider and reaches synoptic dimensions. The long-range transport of pollutants from North America (NA) to Europe (EU) has been investigated during the CON-TRACE and ITOP field experiments over EU in winter 2001 and summer 2004, respectively. Especially in winter the storm track over the Atlantic was well developed and a distinct amount of NA pollution was rapidly transported to EU and even reached surface levels in some cases. For the forecast and analysis of these events chemical transport models were essential. CO was used as a tracer in the models for the pollution transport. Backward modeling with a Lagrangian particle dispersion model was an essential tool to track the polluted layers back to their source region. Even during the winter field campaign a positive O<sub>3</sub>-CO correlation was observed in some of the NA pollution plumes over EU. The observations indicate that the enhanced levels of ozone were already produced near the source region over the eastern U.S. and not during the transit. During the summer field campaign ITOP the polluted layers observed over EU mainly contained signatures from forest fire emissions from Alaskan and Canadian wild fires. A Lagrangian transport case of the New York –Boston plume to Ireland was observed. On the average ozone was slightly enhanced by 10-20 nmol/mol in the polluted layers in comparison to the background.