Isentropic transport and mixing between the tropical UTLS and the extratropical stratosphere as observed by in-situ measurements of long-lived trace gases

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Introduction

During several field campaigns the University of Frankfurt's "High Altitude Gas AnalyzeR" (HAGAR) measured N_2O, CH_4, CO_2 CFC-12, CFC-11, H-1211 and SF_6 within the tropical UTLS region on board the M55 Geophysica high altitude aircraft. Ozone was obtained by the Fast Ozone ANalyzer (FOZAN).

During the "Tropical Convection, Cirrus and Nitrogen Oxides Experiment II" (TroCCiNOx II) aircraft campaign, which took part in January/February 2005 in southern Brazil, our in-situ measurements of long-lived trace gases indicate frequent quasi-horizontal transport and mixing in the sub-tropical UTLS, both across and above the tropopause.

CLaMS simulations from a long-term model run, as well as comparisons with other tropical aircraft campaigns (APE-THESEO, SCOUT-O3-Darwin and AMMA-SCOUT-O3) are presented in order to place our observations into a climatological context.

One very pronounced mixing event close to the Equator on Jan 23[d] 2005 is examined in detail using back-trajectories and CLaMS model simulations.

Signals of isentropic mixing in tracer measurements

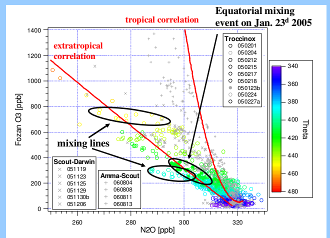

Fig. 3: Ozone-N_2O correlation colour-coded by potential temperature for TroCCiNOx (other campaigns shown as grey symbols)

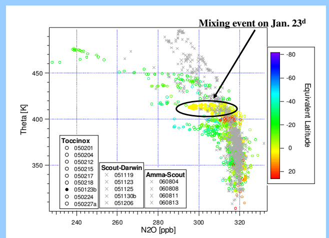

Fig. 4: The vertical distribution of N_2O colour coded by equivalent latitude for TroCCiNOx (other campaigns shown as grey symbols)

During TroCCiNOx, tracer mixing ratios ranging from typical tropical to typical mid-latitude values, often over short flight distances, indicate active isentropic mixing, sometimes deep into the tropical UTLS, on Jan. 23[d] even up the equator. Events of isentropic mixing are apparent as mixing lines in the tracer-tracer correlations (Fig. 3).

The tracer distribution generally does not correlate well with the equivalent latitude, presumably due to the presence of small scale features and active irreversible mixing (Fig. 4).

Climatology of the N_2O - O_3 correlation and comparison with CLaMS model

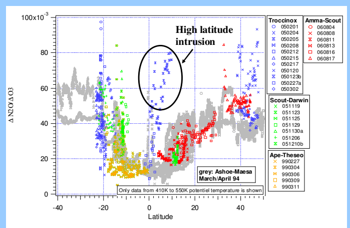

Fig. 5: Slope of the N_2O-O_3 correlation ($\Delta N_2O/\Delta O_3$) of stratospheric air as a function of latitude as observed in various aircraft campaigns.

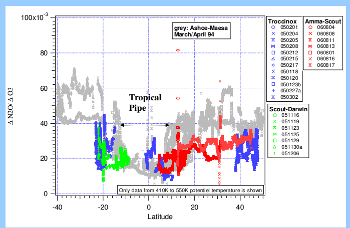

Fig. 6: Slope of the N_2O-O_3 correlation ($\Delta N_2O/\Delta O_3$) of stratospheric air versus latitude as simulated in a long-term run of the CLaMS model (coloured symbols; grey symbols as in Fig. 5).

Observations from four tropical and subtropical Geophysica campaigns (coloured) as well as previous data from the NASA ER-2 ASHOE/MAESA campaign (grey) show a sharp step in the correlation slope across the subtropical barrier. First results from a recent long-term (5-year) simulation of the CLaMS model using simplified chemistry show this feature as well, albeit less pronounced. TroCCiNOx observations and simulations (blue) exhibit a highly variable correlation slope indicating a region of active transport and mixing across the subtropical barrier.

Conclusions:

- The summer subtropical lower stratosphere over Brazil appears to be a region where vigorous large-scale meridional transport and irreversible mixing across the subtropical barrier was common during the campaign period.
- First results from a recent long-term (5-year) simulation of the CLaMS model using simplified chemistry qualitatively reproduce the climatological tracer structure across the subtropical barrier as well as the presence of active mixing in the TroCCiNOx-II observation region.
- Individual mixing features are well distinguished in the tracer observations. It is shown that a pronounced intrusion of extratropical air into the equatorial region observed on Jan. 23[d] 2005 is well reproduced in the CLaMS model simulations.

Atmospheric transport context for TroCCiNOx

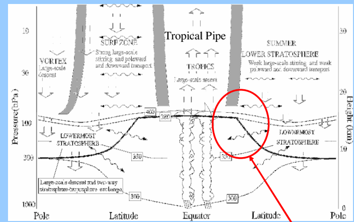

Fig.1: WMO '99 transport schematics

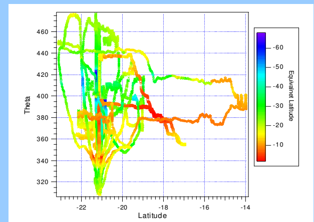

Fig.2: Equivalent latitude along the M55 flight tracks during TroCCiNOx-II

The lower stratosphere over Araçatuba, Brazil, was not situated within the stratospheric tropical pipe, but just south of the subtropical barrier (Fig. 1).

The observation region of TroCCiNOx was often influenced by the subtropical jet and thus dynamically very active.

Although most flights were performed in the latitude band between 23°S and 18°S the TroCCiNOx-II flights covered a large range of equivalent latitudes from 65°S to 5°S (Fig. 2).

Case study of Jan. 23[d] 2005

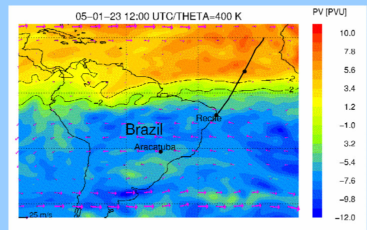

Fig. 8: The field of potential vorticity on Jan. 23[d]. The black line indicates the flight path and the black dot where the extratropical tracer signatures have been found.

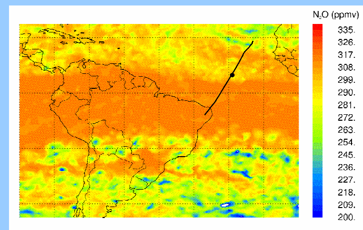

Fig. 9: Field of N_2O as calculated by the CLaMS long-term run. The black line indicates the flight path and the black dot the position of the observed extratropical tracer signature.

One prominent intrusion of extratropical air over the Atlantic, close to the Equator, has been observed on the transfer flight of Jan. 23[d].

The PV-map in Fig. 8 as well as the field of N_2O from the CLaMS long-term run show patches of extratropical air masses that are transported towards the equator.

The vertical cross section along the flight path (Fig. 10) shows the measured structure between 400K and 415K potential temperature at around 9:00 UTC.

Back-trajectories calculated with the NOAA HYSPLIT model (Fig.11) confirm that between five and eight days earlier air from high latitudes had been transported into the equatorial region.

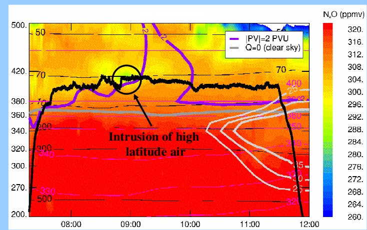

Fig. 10: Vertical cross-section of N_2O along the flight path as calculated by CLaMS.

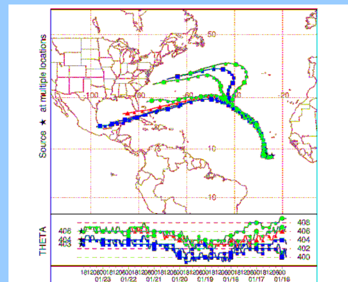

Fig. 11: 192h-back-trajectories calculated by the NOAA HYSPLIT Model.

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Acknowledgements

This research project was supported by the European Union. We would also like to thank the M55-Geophysica pilots and crew.