Properties of the extra-tropical tropopause transition layer (ex-TL) from high-resolution O_3, CO, H_2O, acetone, and acetonitrile observations onboard the CARIBIC passenger aircraft

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The extratropical tropopause transition layer (ex-TL)

… names a layer sandwiched at the lower border by the tropopause and at the upper border by the unperturbed lowermost stratosphere (LMS) that is not influenced by recent in-mixing of tropospheric air. It is usually identified by linear or slightly curved correlations between a tropospheric tracer and a stratospheric tracer.

The nature as well as many properties of the ex-TL (seasonal variation, turnover time, short-term variability, convection-induced impact) are badly quantified, yet. Likewise, its relation to the recently discovered and meteorologically defined tropopause inversion layer (TIL) is not known, yet.

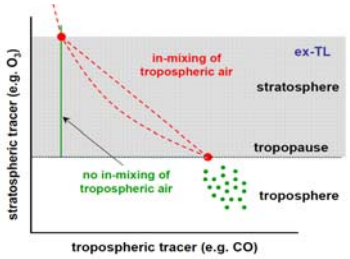

Fig. 1: *Schematic view of a typical tracer correlation around the extratr. tropopause*

CARIBIC

In CARIBIC a measurement container with 18 instruments is deployed once a month for four long-distance flights onboard an A340-600 of **Lufthansa**.

Almost 100 trace gases and aerosol parameters are measured at typical flight altitudes of 9-12 km. Since May 2005, more than 100 measurements flights were carried out.

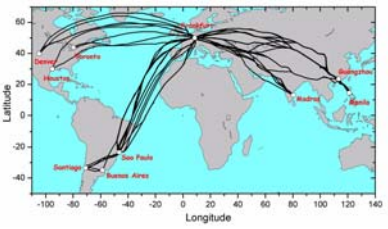

Fig. 2: *Flight paths May 2005 – July 2008*

The ex-TL during CARIBIC

Fig. 3 shows a typical O_3-CO correlation observed between China and Germany in February 2007.

The mixing line or ex-TL, resp., is clearly visible with a weak spatial difference (red line observed at 42°E, green line at 69°E, both at ~50°N). The mixing reservoirs a well-defined.

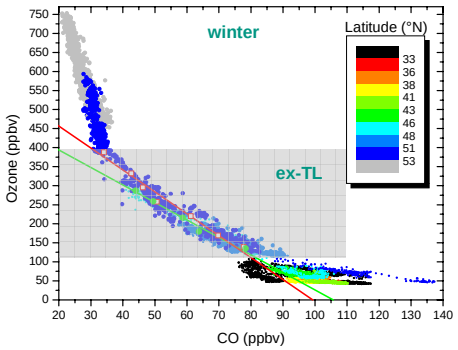

Fig. 3: *Correlation between O_3 and CO for a 11-hour flight (~10000 km) between South China and Germany at 10-12 km altitude*

Fig. 4 indicates a typical H_2O-CO correlation pattern observed in August 2006. The picture demonstrates that the mixing across the tropopause occurred along isentropic surfaces (lines). The blue data points characterize dry subtropical air, the black more humid high-latitude air. Note, the high H_2O m.r. in the ex-TL.

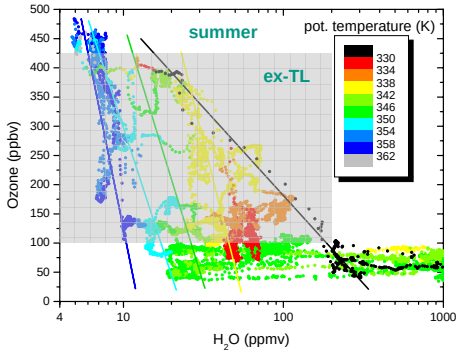

Fig. 4: *Correlation between O_3 and H_2O for a 11-hour flight from China to Germany.*

Fig. 5 shows the vertical profile of acetone relative to the tropopause for 4 flights in different seasons. There is a strong seasonal variation with highest acetone values and the highest variability in summer.

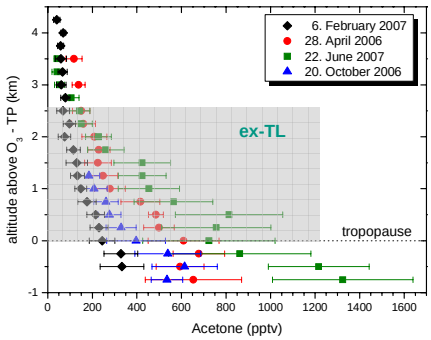

Fig. 5: *Vertical profiles of acetone observed in the mid-latitudes in different seasons.*

Vertical extension of ex-TL

The vertical extension of the ex-TL shows a seasonal variation, with ~1.6 km in winter and ~2.6 km in summer, see right Fig. 6a for CO.

For acetone (Fig. 6b) the high summer values are missing, which indicates that the air travel time from the tropopause to altitudes ~3km above the tropopause roughly amounts to the local lifetime of acetone of ~4 weeks.

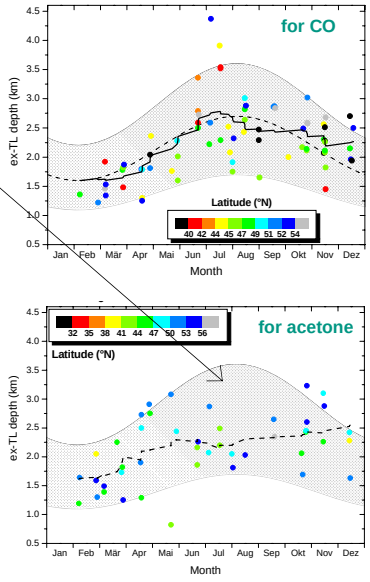

Fig. 6: *Vertical extension of ex-TL based on the correlation of O_3 with CO (a) and acetone (b). The dashed lines are running means, the shaded areas are sine functions that fit the data. No latitudinal gradient was resolved.*

Conclusion

Year-around tropospheric air mixes into the extra-tropical lowermost stratosphere and forms a mixing layer, the ex-TL, sandwiched between upper tropospheric and clean stratospheric air. Our H_2O data demonstrate that this in-mixing primarily occurs along isentropic surfaces (Fig. 4). A significant seasonal variation of the trace gas composition of the in-mixed air (Fig. 4, 5) and of the vertical extension of the ex-TL (Fig. 6) was observed. Based on the lifetime of acetone a mixing time to altitudes of 2-3 km above the tropopause of ~4 weeks was inferred. Further constraints on the ventilation of the lowermost stratosphere deliver trace gas climatologies, e.g. Fig. 7 for acetone.

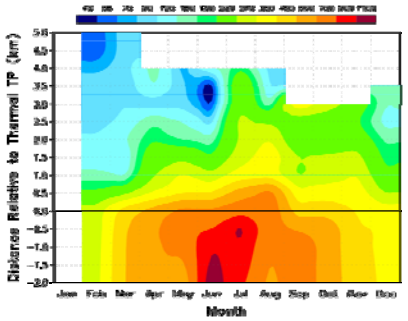

Fig. 7: *Seasonal variation of acetone around the tropopause inferred from the CARIBIC data 2005-2008. A strong seasonal variation is observed. In autumn the gradient across the tropopause is weak. Elevated acetone values remain in the lowermost stratosphere until ~November when the subsidence of clean, O_3-rich stratospheric air sets in.*