Trace gas observations and their relation to the tropopause definition

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Abstract:

We use airborne in-situ observations of various trace gases obtained over the last 15 years to investigate the distribution of distinct species at the tropopause. Special focus will be given to ozone and CO in the tropopause region. We use only measurements during ascent and descent of the aircraft when vertical profiles of trace gases and tempertaure were obtained.

We use different definitions of the tropopause namely the thermal, an ozone gradient based and a Lagrangian definition.

To investigate downward mixing of ozone across the tropopause we use the anticorrelation of CO and ozone and the strengths of the correlation. We find that in the extratropics linear anticorrelations indicate ongoing mixing and irreversible ozone transport to 1000m below the ozone gradient derived tropopause, 1500m below the thermal tropopause. Below the anticorrelation is eroded.

Using CO at the tropopause we show that for the chemical composition at high latitudes isentropic transport within the troposphere plays an important role

Tropopause definition:

For the determination of the tropopause the following conditions have been applied:

only data from ascent or desent have been used:

dz/dt > 2.5 m/s

1) thermal TP: **dT/dz > -2 K/km**, and in layer 2 km above

2) ozonopause:**dO$_3$/dz > 60 ppbv/km,** and in layer 1km above

z > 5 km

O$_3$ > 40 ppbv

3) dynamical tropopause: **PV = 2 PVU**

4) Lagrangian tropopause

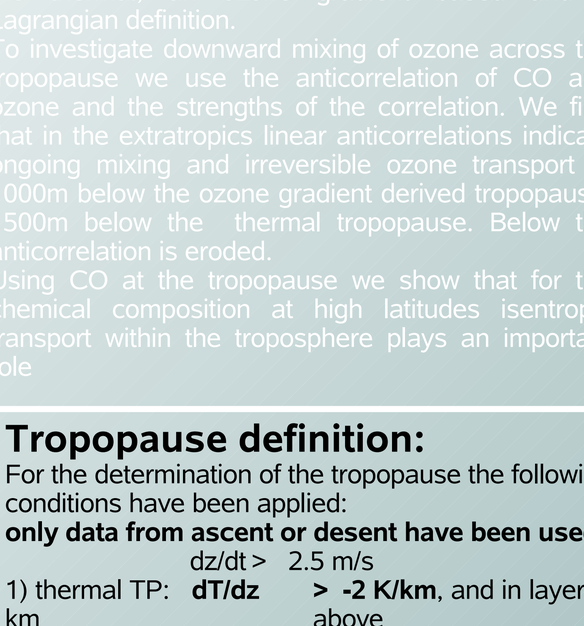


Fig.1: Proportion of trajectories arriving at a given equivalent latitude and potential temperature location that have encountered the boundary layer (z < 1km) within the previous 30 days. White contours show 1,2,4,8,12 PVU with 2 PVU in bold. The black line indicates the 20% contour (from Berthet et al, JGR, 2007: A Lagrangian perspective of the tropopause and the ventilation of the lowermost stratosphere).

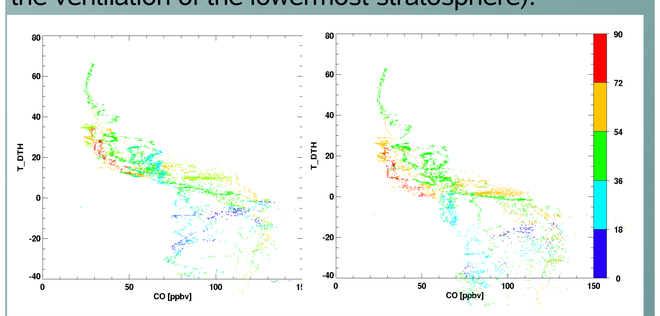


Fig.2: Vertical profiles of CO as a function of potential temperature relative to the dynamical tropopause (2PVU) **(left)** and **(right)** using a Lagrangian definition relative using the probability of encountering boundary layer air masses of 20% (comp. Fig.1).

Tab.1: Spearmans rho indicating the compactness of the CO distribution relative to the tropopause. Higher values for the ΔΘ definition of the tropopause indicate a better match of the observations to the respective tropopause definition than to the Lagrangian definition.

spearman's rho ρ

time	ΔΘ	χ=20%
Nov 2001	-0.62	-0.55
Jan 2002	-0.93	-0.93
May 2002	-0.94	-0.93
Aug 2002	-0.88	-0.85
Oct 2002	-0.86	-0.81
Feb 2003	-0.88	-0.88
April 2003	-0.95	-0.95
July 2003	-0.87	-0.83

Stratosphere to troposphere (STT)

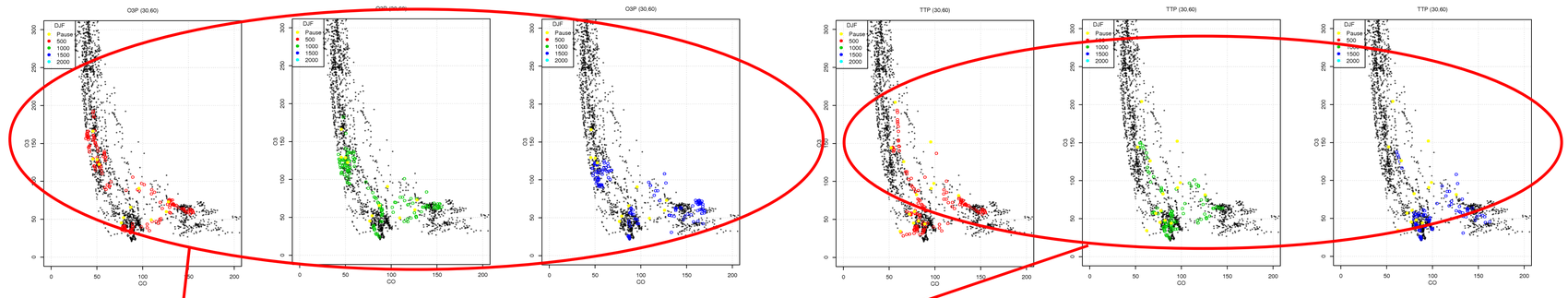


Fig.3: Scatterplots of CO and O_3 for DJF for 30-60N relative to the O_3-gradient derived tropopause (right) and the thermal tropopause (left). Different colors denote different distances to the local tropopause, yellow dots indicate the respective tropopause location.

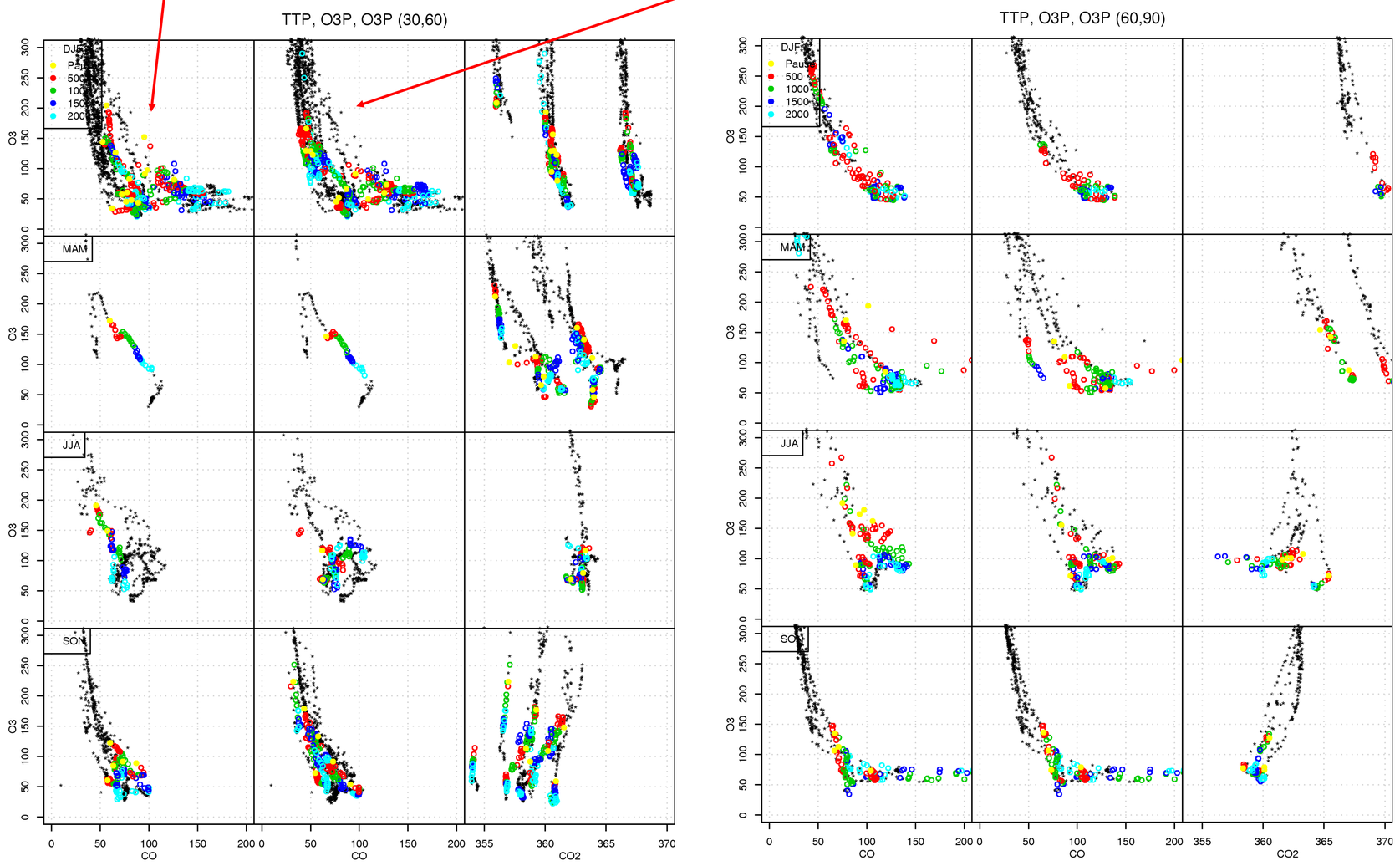


Fig.4: As Fig.3,but merged for different seasons (TTP: thermal tropopause, O3P: O_3-gradient derived tropopause) and CO_2-O_3 (only O_3-derived tropopause) for 30-60N (left) and 60-90N (right). Note the decreasing anti correlation of CO and ozone with increasing distance relative to the tropopause. The same effect for CO2 indicates that dynamical effects determine the decreasing anticorrelation rather than chemistry.

Troposphere to tropopause (TSTp)

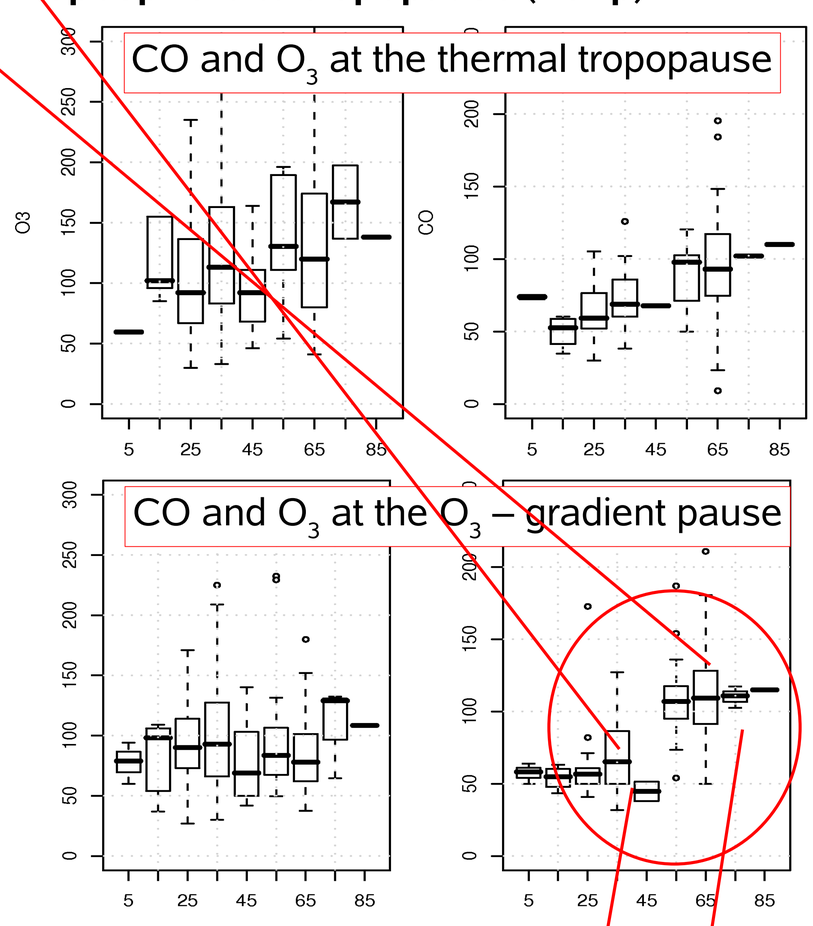
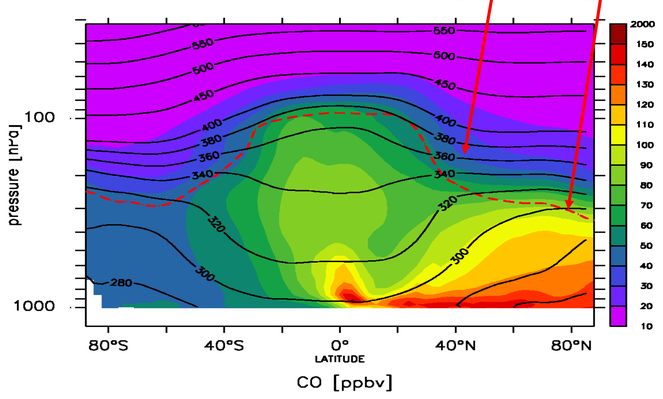


Fig.6: Latitudinal distribution of ozone (left) and CO (right) at the thermal (top) and the ozone gradient based tropopause (right). Note the clear separation of CO at the gradient based tropopause at 55N indicating to chemical regimes (Hoor and Hegglin, 2008). The different regimes correspond to regions of rapid transport from the boundary layer. High CO values at the tropopause in the extratropics are linked to isentropes which connect to the boundary layer (**see Fig below)**.



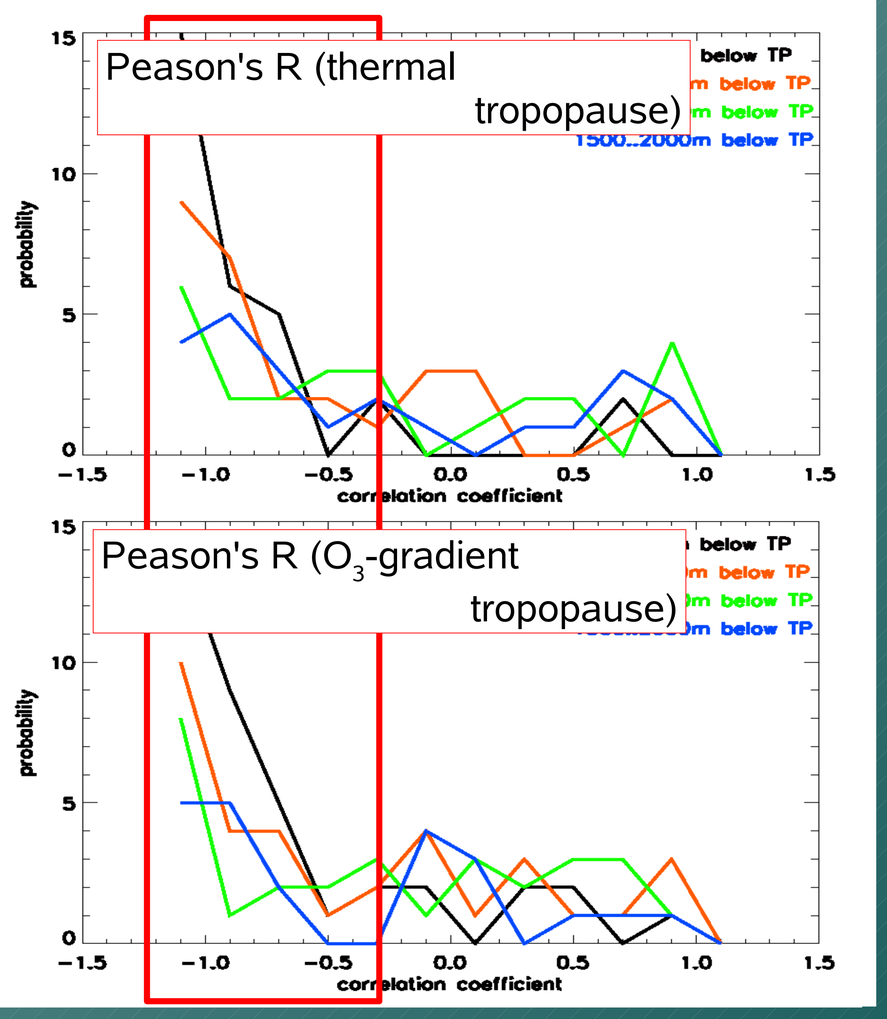


Fig.5: Correlation coefficient of the data in Figure 4 in steps of 500m below the tropopause (top: thermal tropopause, bottom: ozone gradient based). With increasing distance from the tropopause the correlation coefficient degrades indicating complete irreversible mixing of STE about 500 m below the tropopause.

Conclusions:

-**STT**: Downward is detectable up to 2000m below the tropopause

-degrading anticorrelation indicates complete mixing between 1000-2000m

-**TSTp**: CO at the ozone gradient based tropopause shows a bimodal distribution in agreement with Lagrangian models

-rapid isentropic transport from the boundary layer to tropopause altitudes at mid- and high latitudes cause high CO values distinct from the (sub)tropics

References:

Berthet et al., A Lagrangian perspective of the tropopause and the ventilation of the lowermost stratosphere, JGR, 2007.

Hoor and Hegglin, Trace gas distribution and tropopause definitions,in prep.