Interannual variability of residence time in the TTL

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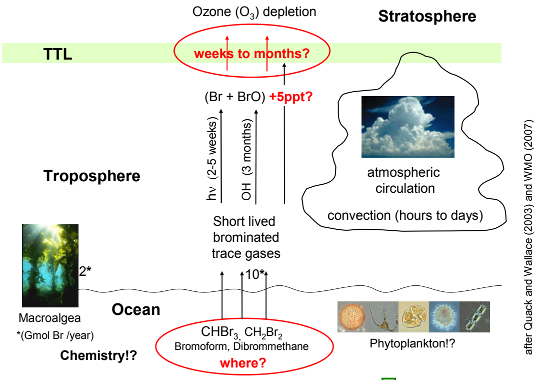
Motivation

The tropical tropopause layer (TTL) is the main entrance region for trace gases traveling from the troposphere into the stratosphere. The dynamical and microphysical processes in this region affect the trace gas content and variability in the stratosphere, which are controlled by the temperature history and the amount of water vapour of the air parcels, their residence time in the TTL and the geographical distribution of their individual transition into the stratosphere. A better representation of these factors in transport models will also help to clarify which role very short lived substances (VSLS) like oceanic bromocarbons could play in depleting stratospheric ozone (WMO, 2007).

Multi-year calculations of quasi-isentropic trajectories have been carried out to investigate the residence time in the upper part of the TTL. For this purpose we have developed an alternative approach to better constrain the vertical velocities in trajectory models of this region: a reverse domain filling trajectory model driven by diabatic heating rates (Q) from the ECMWF's radiative transfer model (Krüger et al., 2008).

In this study we concentrate on the residence time (τ) between 400K and the Lagrangian Cold Point (LCP) layer during northern hemispheric winter months (DJF), which show the lowest temperatures during the seasonal cycle and hence the lowest stratospheric water vapour mixing ratios. The LCP is important for VSLS as it marks the transition, where air parcels reach the stratosphere and it determines how much water vapour they will contend. The duration time and the amount of water vapour of air parcels within the TTL before and after that cold point affect the chemical life times and processes of VSLS reaching the stratosphere. Here we will focus in particular on the spatial and temporal variability of the residence time as these are important for long-term transport studies of VSLS and thus also for the stratospheric ozone chemistry.



Method and Data

Recent papers addressing the residence time in the TTL used the noisy and too high vertical winds from data assimilations in the stratosphere (Füglistaler et al., 2004, Levine et al., 2007, Berthet et al., 2007).

Alternative approach

- Diabatic heating rates (Q) are used as vertical velocity in a quasi-isentropic trajectory model instead of the noisy and strong vertical winds (e.g. Manney et al., 2005, Upalla et al., 2005).
- Transport: Lagrangian approach, the real history of the air parcel pathway is taken (trajectory calculations). The heating rates are calculated off-line from the ECMWF radiation code.
- Meteorological input: ERA40/ op ECMWF data on 60 model levels
  - 2°x2° grid from T106, 6 hourly, (~0.8 km vertical resolution in TTL)
  - trajectories: u, v, Q or w, T, gH, p
  - heating rate calculations: T, p, clouds, surface log p, O_3 and H_2O from ECMWF data sets (GHG increasing with time, aerosol climatology)
- Trajectories calculations:
  - backward for 3 months (DJF) from 28. February to 1. December
  - started on 400K (~18km altitude)
  - based on ERA40: for 40 years from 1962/1963 to 2001/2002
  - based on opECMWF: for 5 years from 2000/2001 to 2004/2005
- Modular tool: can use heating rates or vertical winds on model levels:
  - opECMWF using heating rates/vertical wind: opECMWF+hrates/opECMWF+3dwind
  - ERA40 using heating rates: ERA40+hrates
  - opECMWF/ERA40 using ozone climatology for the heating rate calculations: opECMWF O3clim+hrates/ ERA40 O3clim+hrates

Large uncertainty for residence time

Residence time in the upper part of the TTL (WMO, 2007)

2000/01 DJF:	ERA40 data	**20 days for the 360-380K layer** (Füglistaler et al., 2004)
	opECMWF data	**20 days for the 360-380K layer** (Levine et al., 2007)
1999-2001:	1D model using radiosonde data	**80 days for the 360-380K layer** (Folkins and Martin, 2005)

Krüger et al. (2008) using diabatic heating rates:

2000/01 DJF:	ERA40 data	**38 days for 360-380K layer**
	opECMWF data	**48 days for 360-380K layer**
2001/02 DJF:	ERA40 data	**40 days for 360-380K layer**
	opECMWF data	**36 days for 360-380K layer**

Key questions:

1. **How fast is the large-scale ascend/ residence time in the TTL?**
2. **Which role does spatial and temporal variability play in the TTL?**
3. **How large is the interannual variability of residence time in the TTL?**

Future work

New project at IFM-GEOMAR

Very Short Lived Bromine species in the ocean and their transport pathways into the stratosphere (**TransBrom**)

With a new transport model and hot-spot measurements of marine source gases in the Western tropical Pacific we want to investigate the real contribution of marine emissions to the stratospheric bromine content.

Job announcement
1 PhD position starting in 2009!

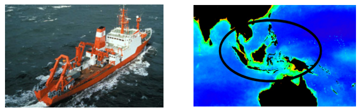
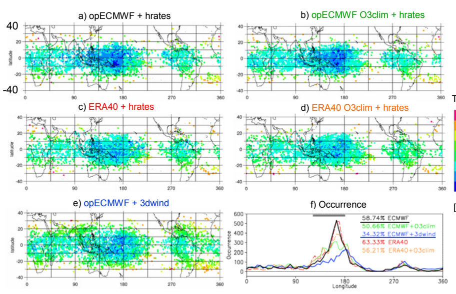


Figure 1: The ship campaign takes place onboard of the research vessel Sonne (left) and is planned for the tropical western Pacific (right) during NH winter 2009/2010.

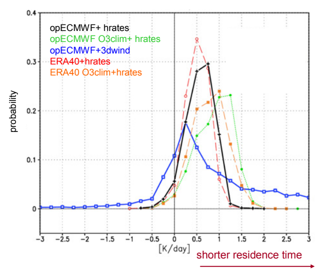
LCP, vertical ascend and residence time using different observational data sets – Lagrangian case study for DJF 2001/2002

Lagrangian cold point (LCP) temperature

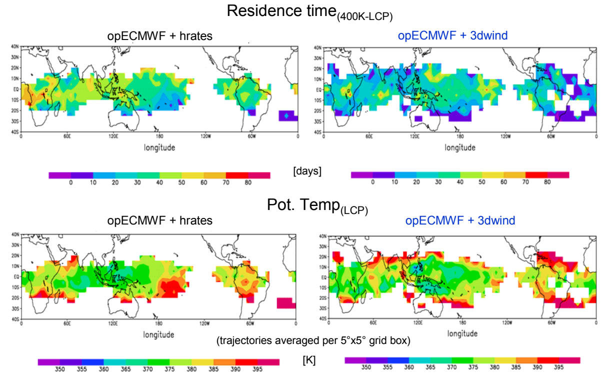


For the calculations based on opECMWF heating rates, 59% of all LCPs lie in the West Pacific (between 120° to 180°E), while for the calculations based on opECMWF vertical winds only 34% of the LCPs lie in this region.

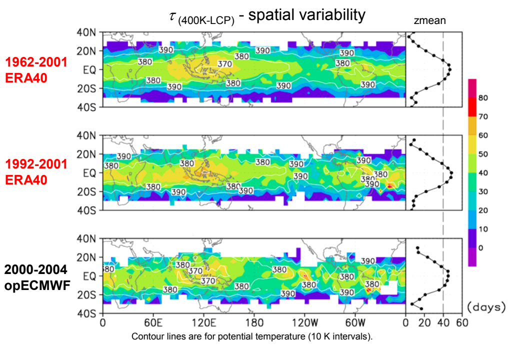
PDF of vertical ascend



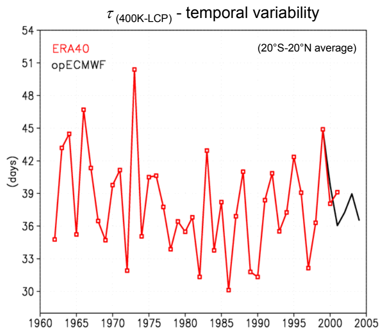
$\bar{Q}_{400K-LCP}$ - averaged vertical ascend for 400K-LCP:
opECMWF + heating rates 0.56 K/day
opECMWF + vertical winds 0.81 K/day
(Mc Farlane et al, 2007: 0.5 K/day ~17km)
(March to December 1999 and February to July 2000)



Interannual variability of residence time (DJF) in the TTL



In the tropical belt (20°S-20°N) the residence time varies locally between 20 and 70 days for the different periods and data sets. Maximum residence time is analysed for the maritime continent during the 1992-2001 period, based on ERA40 analysis



The residence time, averaged over 20°S to 20°N, shows a high interannual variability. Longer/shorter residence time seems to be connected with periods of weakened/ enhanced wave driving in the extratropics.

Conclusions

The DJF 2001/2002 case study shows that:

- The geographical distribution of LCP is very robust and does not seem to be much affected by using heating rates compared to vertical wind.
- However, differences in the density of trajectories, distribution of Q and in residence time are large. These are important for troposphere-stratosphere transport processes and particularly for the chemistry of VSLS in the TTL.

For the interannual variability of residence time in upper part of the TTL (400K-LCP layer) the following new results are derived:

- The residence time is depending on the height of the LCP, which varies over time and between the used data sets. A higher LCP corresponds to a shorter residence time (also shown for the case study).
- The residence time is showing a spatial varying pattern with the longest residence time over the maritime continent during the 1990s.
- The interannual variability of residence time is highly varying from 30 up to 51 days between 1962/1963 and 2004/2005.
- We analyse an amplification of the residence time in the 1990s during the period of less wave driving in the NH extratropics (ERA40). After the late 1990s the residence time reduces (opECMWF), which leads to a faster supply and different ratios of VSL primary and secondary source gases.

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