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Interactive Comment

Interactive comment on "Highly resolved observations of trace gases in the lowermost stratosphere and upper troposphere from the Spurt project: an overview" *by* A. Engel et al.

A. Engel et al.

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General comments to all reviews

Some referees have asked to see the raw data, i.e. data which have not in any way been plotted vs. a model coordinate (like eq. lataitude). The reason that this has not been done is that it is necessary to include some kind of tropopause information in order to structure that data. Unfortunately (see below) no continuous tropopause information is available for the SPURT data, as no temperature profiler measurements are available. A direct representation of the data (e.g. plotted vs. altitude, pressure or potential temperature) gives very little information, as there is very much scatter due to the meteorological variability. In order to make this clear, we have decided to show some raw data from a single campaign plotted vs. different coordinates. This is included in the introduction to section 5 as follows:

In the frame of the SPURT project a large number of data has been collected in the UT/LMS for a wide range of tracers. For many tracers (e.g. N_2O, SF_6, CO_2) the observed variabilities are very small. It should also be noted that the LMS is a dynamically very active region. Representing the data in classical co-ordinate systems does not show the features of the typical distributions. This is illustrated in Figure 5, where the distribution of N_2O measured during campaign S8 is plotted vs. pressure, potential temperature, potential vorticity and Theta above the local tropopause (note that the local tropopause is calculated form the ECMWF data). It is clearly visible that the complete range of N_2O values observed is present at all pressures below about 250 hPa and all potential temperatures above about 340 K. A systematic structure is only clear when using PV or Theta above the local tropopause as vertical coordinates, i.e. vertical scales which hold some tropopause information. Therefore, in order to give an overview of the data collected during SPURT, the measurements .....

A further point was, that SPURT, due to the short time period covered, can not provide a climatology. We absolutely agree to this point. We did not intend to make this statement. We have rephrased on p. 5086, l. 6-7 as follows:

In contrast, SPURT was designed to establish a comprehensive data set with good seasonal and latitudinal coverage of the LMS, which could in the future and in combination with data from other sources lead towards a climatology of the air mass composition in the UT/LMS, rather than to focus on special events which could introduce a bias in the results obtained.

Reviewer 1

This Reviewer has made two general remarks. We agree to both of these. However, especially the first comment, i.e. to plot in a delta(z) vs. latitude space, is problematic,

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since we do not have observed tropopauses along the flight track, because the Learjet unfortunately does not have a temperature profiler. Actual observations of vertical temperature profiles are only observed during take of and landing of the aircraft. It is therefore not possible to plot vs. an observed tropopause, which is why we have chosen to display the data in eq. lat. theta coordinates. We recognise that this coordinate system will only display the general features of the distributions. As it is the aim of this paper to present an overview of the data gained during SPURT, we think that this is an adequate frame of reference. As noted by the reviewer, an observed tropopause would be necessary for another approach. This is, unfortunately, not available. The second general comment is concerned with missing references, or the claim of discovery of already well known phenomena. We are by no means claiming that all the phenomena discovered during SPURT are new. This is detailed in the reply to the specific observations.

p 5084, l 9-26: The reference to the paper by Rosenlof et al. (1997) is given, with an upper limit of 450 K for the tropically controlled transition layer. Papers by Hintsa et al. (1994) and Boering et al. (1994) are also referenced. Concerning the question of the stratospheric overworld, we would prefer to stay with the definition given in e.g. Holton et al. (1995), the overworld is the region above 380 K in which the isentropes lie entirely in the stratosphere. Therefore, we consider the tropically controlled transition layer as part of the overworld. We have found no conclusive indication of a lower boundary of the overworld in the other papers. This section has therefore not been changed.

p 5087, 3: It is mentioned in the manuscript, that the north-south excursions are largely reversible. We do not state that Rossby waves do not lead to mixing. However, an air parcel which is transported from high latitudes to mid latitudes does not immediately take up the chemical characteristics of mid latitudes.

p 5087, 15: the use of the word mixing is somewhat unspecified here. We have chosen to rephrase as follows: The mixing of air masses with different chemical characteristics (e.g. tropospheric and stratospheric), down to scales below the resolution of the

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observations, leads to changes in correlations between trace species which can be investigated with the SPURT data set.

p 5099, 5-6: As no tropopause observations are available (see above), this statement is based on the ECMWF model. This is stated clearly now in the paper as follows: Over south-western Europe the ECMWF data show a richly structured tropopause with slowly evolving filaments of tropospheric and stratospheric air.

p 5099, 15-25: As mentioned above, the main idea of this paper is to give an overview of the general distribution of the data. As the variability is lowest in the theta-eq.lat coordinate system, we have chosen to use this coordinate system.

p 5100, p 5-18: The surface mixing ratios from the CMDL network (N.H. mean) are similar to our observations. We have not observed significantly reduced N_2O values in the upper troposphere with respect to the surface mixing ratios. The data from the CMDL network are also given as a reference now.

p 5101, 4-18: The remark is correct; N_2O is a long lived tracer, whereas Ozone is not. However, the chemical lifetime of odd oxygen (Ox) is quite long in the lowermost stratosphere, where it is considered to be under dynamical control. The chemical lifetime of O_x in the lowermost stratosphere is now discussed in the ozone subsection as follows: Ozone is not an inert tracer in the lowermost stratosphere, like e.g. N_2O. Yet the chemical lifetime of the odd oxygen O_x- family is well above 1 year in the lower stratosphere below 20 km (see e.g. Brasseur and Solomon, 1986). Therefore the distribution of ozone in the lowermost stratosphere is dominated by transport rather then chemistry.

p 5103, 16-27: see remark given under General: we do not have enough tropopause observations.

p 5104, 10-22: A reference to the Figure 6 in the paper by Tuck et al. mentioned by the reviewer was added and the fact that species with different lifetimes reveal different information: Species with different lifetimes can give information on different chemical

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and transport processes (see e.g. Tuck et al., 2004).

p. 5104, 20-23: While we agree in principal to this point (e.g. when using correlations or investigating variabilities), the view adopted here (i.e. using the Theta/Eq. Lat. coordinate system), allows to eliminate a lot of scatter from the data. As this paper should give an overview of the available data and the seasonality in the data, this is exactly what was intended. Other papers will hopefully use the SPURT data set in the way suggested by the reviewer.

p 5105, 5-22: to make clear that we are not claiming discovery of all what is mentioned here, we have rephrased by changing from reveal (line 10) to confirm.

Technical points: We have corrected all the technical points according to the suggestions of the reviewer

Referee 2

The reference to the possibility of pyro-convective input in the lowermost stratosphere has been added: .. therefore not necessarily an indication of transport across the extratropical tropopause. In addition, recent observations and model studies (Fromm et al., 2000, Wang et al., 2003, Wang et al., 2004) have revealed that pyro convection or high reaching convection in large storms can transport air from the mid latitude boundary layer to the lowermost stratosphere in a very short time.

Indeed, significantly contribute is what is meant. This has been stated more clearly now by changing the wording from largely contribute to significantly contribute. . This referee further suggests to include a data table in the paper, as some aspects are hard to see in the plots. This may indeed be true, yet due to the large amount of data, such a table would be very large. As noted in the paper the raw data are freely available for download, so those who intend to work further with these are encouraged to get the data and calculate the averages.

Referee 3

This referee suggest to include the visualisation relative to the observed tropopause. See the discussion of a similar comment by referee 1: unfortunately the observed tropopause has a very bad resolution, as we usually only observe it during take-off and landing. The referee also suggests to add some correlation-plots. We have not included any correlation data (see discussion above), as it was our intention to give an overview of the data available. These correlations will be used in specific papers.

The reviewer suggest to include a direct correlation plot between the two N_2O observations. This plot is actually in the paper (Figure 3). The further suggestion to include a figure showing the measurement are in a latitude altitude reference frame including the tropopause is of course possibly for single flights (and such plots are available on the web site). In order to give an overview of the campaign with its 36 flights, such a representation would not be possible. In fact the data plots in eq. lat -theta space give a very good idea on the observed range. A paper on the meteorology during the SPURT campaigns is in preparation. Therefore the reader is referred to this paper and the web site for detailed information on the meteorology.

Specific comments:

we have changed as follows:

p. 5083., l. 25: above the tropopause, a layer, called the mixing layer by Fischer et al., (2000), is found where trace gases show intermediate values between typical tropospheric values and typical stratospheric values.

p. 5083., l. 27: - -p. 5084, l.2: In agreement with this, the observed seasonal variability of ozone changes rapidly above the tropopause. Brunner et al., (2001) found a typical upper tropospheric cycle at the lower boundary of this layer (i.e. on the 2 PVU potential vorticity surface), while a typical stratospheric ozone seasonality was observed at the upper limit of this layer (i.e. at about 3.5 PVU).

p. 5084., l. 9.: Boering et al. (1996) found a similar behaviour for CO2, where the

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seasonality in CO_2 mixing ratios is due to the tropospheric seasonality.

p. 5084., l. 25-29: there are many examples in the literature where trace gas budgets in the LMS have been calculated, using a stratospheric and a tropospheric fraction (e.g. Ray et al., 1999). Basically, this is also the picture given in Holton et al., (1995). We have rephrased as follows: In order to explain the trace gas compositions in the lowermost stratosphere, all the transport pathways described above have to be taken into account.

p. 5085., l. 2: dynamically

l. 4: than into the overworld stratosphere.

l. 5.: The referee is correct. We have omitted this sentence

p. 5086., l. 6.: agreed, see general comment above.

p. 5093.: l. 16: the details of the ECMWF data used are now given. Operational ECMWF analyses with 3 hrs time resolution, 60 layers and a 1.0 degree resolution are used.

p. 5101., l. 7: We can not agree to this point. While it is clear that the representation of the tropospause in ECMWF (and other) meteorological data is not satisfactory, it is certainly not meaningless. The fact that the SPURT data often show a very good correlation to PV, clearly shows that these values are not meaningless.

p. 5101., l. 10 and 11.: This seasonal variation is generally smaller at 5-6 km, which is considered to be representative of the free troposphere, since it is rather weakly influenced by small scale anomalies of the tropopause height and by local emissions of O_3 precursors that generally take place in the boundary layer (Fischer et al., 2005).

p. 5105., l. 16-17: It is stated that transport can occur isentropically or via the tropically controlled transition layer. We do not state that it does so (as this is not distinguishable in the result). We have rephrased in order make clear that we do not state that either of

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the transport pathways is actually the dominant one: Isentropic transport (e.g. through exchange near the sub-tropical tropopause break) or transport via the tropically controlled transition layer (Rosenlof et al., 1997) in the extratropical lower stratosphere could explain these observations.

Referee 4

This referee has two comments. The first comment is concerned with the word climatology. This is addressed above. The second point is the request to give characteristics of each gas. We believe that it would really be beyond the scope of this overview paper to include explanations on the characteristics of each gas. The chapters showing the distributions do indeed give some brief explanations on the characteristics of each gas, e.g. explaining whether it is a long lived or short lived gas, whether it has a strong atmospheric trend and which processes influence this gas. Again, the reviewer addresses the point of of using equivalent latitude theta coordinates. See general comment concerning this point.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 5081, 2005.