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Interactive comment on "Seasonal cycles and variability of O_3 and H_2O in the UT/LMS during SPURT" *by* M. Krebsbach et al.

M. Krebsbach et al.

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We appreciate Eric Ray's assessment of the utility of our paper and his positive review. Point-by-point answers to his valuable questions, suggestions and comments are as follows (Referee comments are in **bold**):

p 7249, l 04: reverse the words "play" and "therefore"
words reversed

p 7249, l 12: "have a strong impact"
done

p 7250, l 10: reverse the words "measure" and "routinely"
words reversed

p 7252, l 08-10: I don't understand the sentence that starts "Similarly, the JOE instrument..." I think you mean that the JOE instrument only provides qualitative data at low altitudes but you should rewrite this sentence to more clearly state that.
No, on the contrary: Due to a too strong flow through the instruments' tubes at higher pressure levels, a bypass valve is used to avoid excess pressure. This valve is closed manually when the aircraft has reached a pressure altitude of about 400 hPa. The instrument provides high qualitative data only when the bypass valve is closed, i.e. above that pressure altitude (i.e. at pressure levels $<$400 hPa). We rephrased the following way:
Similarly, the JOE instrument provides high qualitative data at pressure altitudes above that pressure level (i.e. $<$400 hPa).

p 7257, l 13-14: You state that in the LMS a clear seasonal cycle in H_2O is present with maximum in summer and minimum in winter. But Figure 3 shows that May has lower H_2O compared to April. What's interesting about this is that O_3 is lower in May compared to April as well. So whatever caused the H_2O to be lower in May also resulted in lower O_3. Do you have any explanation for what might have caused this? Could it just be a sampling issue?
The decrease in H_2O from April to May is only partly correct, since the measurements were not performed in consecutive months: May in 2002 and April in 2003. Thus, we do not know the H_2O distribution in April 2002 or May 2003 (see first column in Table 1). If you consider the box plots Fig. 3 (and Fig. 2) in a chronological way, i.e. November (2001), January (2002), May (2002), August (2002), October (2002), February (2003), April (2003), July (2003), a clearer seasonal cycle is evident, indicating higher H_2O VMRs in 2003 than in 2002. Thus, though different meteorological conditions are en-

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countered during the single campaigns, the difference between April and May is more likely to be caused by interannual variability. We considered the discussed aspects above and rephrased the following way:
In the LMS (>4 PVU) a clearer seasonal cycle in H_2O than in the UT is apparent with a clear maximum during summer. This is in agreement with previous in situ and remote observations (e.g. Mastenbrook and Oltmans, 1983; Foot, 1984; Oltmans and Hofmann, 1995; Dessler et al., 1995; Pan et al., 1997; Stone et al., 2000). It is to note that the box plots in Fig. 3 (and also in Fig. 2) are not displayed chronologically in month (see labelling of abscissa). The measurements in February and April 2003 indicate higher H_2O VMRs in the LMS than in 2002, which is probably caused by interannual variability. Alongside, saturation is rare in the LMS, allowing H_2O-rich air to persist for a very long time period there. These aspects are part of current model studies with ClaMS (Chemical Lagrangian Model of the Stratosphere, Günther et al., in preparation). In contrast to O_3, with increasing PV the H_2O VMRs as well as the amplitude of the annual cycle decreases (note the logarithmic ordinate). This indicates a more pronounced seasonal cycle of H_2O in the lower LMS.

The Günther et al. paper in preparation is cited in a footnote:
Günther, G., Konopka, P., Krebsbach, M., and Schiller, C.: The quantification of water vapor transport in the tropopause region using a lagrangian model, in preparation, 2005.

We further included the month-year relation of measurements in the labelling of the abscissas in Fig. 2 and 3 and in the caption of Fig. 2.:
[...] Note the month-year relation given by the labelling of the abscissa.

p 7258, l 14: change to "...it is necessary to further investigate..."
changed

p 7258, l 24-25: I'm not sure why you say that the seasonal cycle in H_2O in the

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UT and LMS are not a priori expected to be in phase. In summer you have increased convection which brings high water vapor into the UT and a more porous tropopause barrier which brings the water into the LMS. In winter you have larger downward transport which brings low water into the LMS and a stronger tropopause barrier so less water enters from the UT. There is also less convection so you would expect lower water vapor in the UT. I'm just pointing out that qualitatively I would expect H_2O to have the same phase in the UT and LMS based on what we know from previous work.

We agree with that. Nevertheless, the H_2O VMRs in the LMS as measured during SPURT, are, however, yet in October comparable with the observed H_2O amount in January. Where does all the H_2O present in the LMS during summer go to towards winter/spring? Obviously, it mixes with descending H_2O-poor air entering the LMS from the overworld during winter/spring, and supplies from the UT are reduced due to the stronger tropopause barrier, as you mentioned above. But how can we explain the low H_2O VMRs yet in autumn? Since, once in the LMS, H_2O can only be removed from the LMS by relative unlikely freeze-drying there with subsequent sedimentation, we would expect to observe an integral effect of the H_2O content in the LMS, i.e. H_2O VMRs in autumn more comparable to those in summer than to those in winter. The observed low H_2O VMRs in autumn thus suggest a significant contribution of upper tropospheric (sub)tropical air which previously has entered the LMS (cf. also results of Hoor et al., 2005, GRL, 32, L07802, and Hegglin et al., 2005, ACPD, SRef-ID: 1680-7375/acpd/2005-5-8649). This is why we posed the statement. *We added the above mentioned references on p 7268, l 21.*

p 7262, l 11–12: I'm not sure what "kink" is referred to here.

We agree with that. We rephrased as follows for clarity:

The sharp local minima and maxima in the mean and median values in the Θ space (cf. Fig. 4 between 300 and 320 K), which are due to the varying location of the local tropopause, are significantly reduced or even absent when related to PV.

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p 7262, l 13–14: Why do you think the H_2O distribution is more compact when related to theta compared to PV in the summer? This seems worth making some comment about.

You are probably correct. We have not shown the whole PDFs for each season and each reference coordinate in detail for which it is referred to Krebsbach (2005). Consideration of these distributions leads to the given statement. The more permeable tropopause during summer allows a larger region around the tropopause to imbibe H_2O with not such strong vertical H_2O-gradients compared to the other seasons in that region. This significantly reduces the compactness of the PDFs around the tropopause, in particular when using the dynamical definition. Since the amount of H_2O in the air is strongly related to pressure and temperature, we thus would expect a relatively good correlation with Θ during summer (cf. Table 1), especially in the tropopause region. With increasing distance to the tropopause in the LMS, the spreading of H_2O relative to the bin of the reference coordinates will be reduced, and would thus not essentially pejorate the correlation coefficient.

p 7263, l 04: "intercomparisons provide evidence..."

changed; see also corresponding reply to Anonymous Referee ♯2

General comments:

We thank you for the stylistic remarks given which we have considered. We further fully agree that in the current print version Fig. 4–6 appear too small. Nonetheless, we keep the current sizes of Figures Fig. 4–6 due to space-saving, since (i) these are vector plots, making it possibly to enlarge them with the Acrobat Reader without loss of information and (ii) in the final version, Fig. 4 and 6 will be enlarged to the paper width and Fig. 5 will capture a whole page.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 7247, 2005.