Atmos. Chem. Phys. Discuss., 5, S2226–S2232, 2005
www.atmos-chem-phys.org/acpd/5/S2226/
European Geosciences Union

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Tropopause referenced ozone climatology and inter-annual variability (1994–2003) from the MOZAIC programme" *by* V. Thouret et al.

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Received and published: 23 August 2005

The paper presents ozone data of a unique data coverage in space and time, which was not available for the scientific community so far. The seasonal cycles and time series reveal interesting details which improve our knowledge about the distribution and evolution of ozone in the UTLS. The relationhip between ozone anomalies and teleconnection patterns in different layers of the UTLS is interesting as it stands, even if the causes remain unclear. The analysis highlights the strengths of tropopause related coordinates in the UTLS region for these kind of studies, which I really appreciate.

The paper is fluently written, albeit some statements in section 6.1 could be sharpened (see specific comments). There is only one major point concerning the calculation of the stratospheric mean ozone values, which should be clarified.
I think, this is a good paper and I highly recommend it for publication in ACP after the following points have been addressed.

Specific comments:

In Fig.3 strong gradients along meridians are apparent exhibiting a rather sharp transition in the subtropics (e.g. ranging from about 50 ppbv of ozone at 35-40N to more than 300 ppbv at 65N in summer, but the pattern is evident during all seasons). According to the authors' analysis these values occur between 15-45 hPa above the local tropopause (layer#4 according to Fig.1). The authors interpret this as the '...meridional gradient characterizing the ozone distribution in the LS...' (p.5449, l.23). The observation of such a strong ozone gradient within the lowermost stratosphere might not be surprising when analyzing ozone columns or mixing ratios on isobaric or isentropic surfaces, which cross the tropopause, but considering the chosen tropopause related coordinate system this is not obvious to me (see also e.g. Logan, 1999: Fig.13 indicates no latitudinal tendency at the thermal tropopause (i.e. above 2PVU), roughly corresponding to the interface of your layer#3 and #4. See also Fig.8 and Fig.10 therein). Furthermore, it surprises me a little bit to find mean ozone values lower than 100 ppbv at 15-45 hPa above the tropopause over such a broad range of longitudes.
Possibly these observations might be an artefact of the method, since only the vertical distance relative to the local tropopause is considered. The dynamical tropopause often exhibits steep (sometimes vertical) gradients, in particular when approaching the subtropics. Thus, an aircraft, which is flying in the stratosphere above a sloping 2PVU surface, can still be in close horizontal proximity to that surface. In such cases

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air parcels will be classified as being stratospheric (layer#4 or #5), although their history and chemical composition are 'tropopause-like' (layer#3) and they belong to the tropopause mixing layer. In perticular, when calculating mean stratospheric ozone values and anomalies, this will introduce a tropospheric bias to the stratospheric data. The further south the measurements the more frequent this situation might have occurred since one approaches the region of the subtropical jet. Note, that according to Fig.3 the region of low ozone values seems to be related to the subtropics.
I suggest to try the following: When calculating lower stratospheric mean ozone, the southern boundaries of the US- and European domains could be shifted to the north by at least 5°, which would exclude a large part of the tropospheric bias.
Note, that this could potentially improve the significance of the NAM analysis when later on using these modified stratospheric ozone values.
Alternatively, you could check this with a figure like Fig.3, but with PV (or CO) instead of ozone. A similar (opposite) latitudinal tendency of PV (CO) as observed for ozone within the lowermost stratosphere could be a further indication that your stratospheric mean values are possibly biased or strongly affected by short term mixing processes related to the jet.

Minor remarks:

p. 5442: According to p.5460, l.14ff. extreme NAM values are much better anticorrelated to the ozone anomalies, than the whole data set. This should be added to the abstract (p.5442 l25/26: '.. found between ozone and the extremes of the Northern...').

p. 5447, l. 10: A more recent seasonal overview on the tropopause mixing layer based on observations was obtained during the SPURT project using a very similar 2PVU-based coordinate system (Hoor et al., 2004 instead of 2002, see also p. 5454, l.7).

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p. 5449, para. 5.1, and Fig.3: Why is the level 15-45 hPa above the local tropopause (layer#4) selected for Fig.3 and not the region above 45 hPa (layer#5)? In the following paragraph 5.2 layer#5 is defined as being typical for the lowermost stratosphere and this definition is kept for the rest of the paper. I guess, mean stratospheric ozone values are also calculated according to that redefinition without layer#4. Thus, it would be consequent to plot in Fig.3 those ozone data, which are relevant for the rest of the paper (layer#5).

p. 5450, l.22-24: Is this still the case with redefined boundaries (major comment)?

p. 5451, l. 25ff: The discussion of Fig.6 (containing the same measurements as Fig. 5c?) is somewhat short. If you want to discuss it, you should compare it to similar results (Zahn et al., ACPD, 2004), albeit these have never been revised.

p. 5452, l.14-15: I suggest to recalculate lower stratospheric mean ozone values over Europe and Eastern US considering different southern boundaries (See major point).

p. 5452, l.15-17: I don't understand the sentence ('the advantage'?).

p. 5453, l.5: Can the observed increase rate really be driven by a maximum in the center of the time series? Compare also Table 1, indicating the strongest UT ozone trend over Iceland, but according to Fig. 7/10 the anomaly seems only to be weak.

p. 5453, l.18ff. (also Fig.11/12): How does the UT-cycle over Iceland look like, since at least the trend seems to be strongest and significant (comp. Table.1)?

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p. 5453, l.18-23: The paragraph is somewhat difficult to read, since it could be interpreted as a lag between Europe and the US instead of a temporal comparison within each domain.

p. 5454, last para: The discussion of the LS anomalies is somewhat confusing, since the message is not clear. Do you want to highlight differences or similarities between 1998/99 and 2001/02 as well as between UT and LS? I think it is interesting to see the different grouping of cycles in the Europe LS compared to the Europe UT.

p. 5455, l.5 ff.: When discussing possible explanations for the observed UT ozone anomalies (ENSO related biomass burning) an additional ozone source could be enhanced transport from the stratosphere (e.g. Zeng and Pyle, 2005).

p. 5456, l.13 ff: If reduced transport of ozone-poor air from the troposphere to the stratosphere has caused the observed stratospheric ozone anomaly, then one could expect a decrease of stratospheric CO, which is also available from MOZAIC. It would be interesting to check for that.

p. 5457, l.1: '...Nothing is noticeable in 1999.'? At least the European LS-ozone cycle for 1999 (Fig.9,13) as well as the anomalies (Fig.8,10) suggest similar deviations in early 1999 and 1998 (see also Fig.17).

Technical remarks:

Table 1: The analyzed regions are given as coordinates in a table. Please mark the

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regions also in one of the maps (eg. Fig.2), to visualize the relation between data and selected regions (see major point).

Fig.2/3: It is difficult to differentiate between ozone levels due to the color code. It would be helpful to reduce the number of intervals to 10-15.

Fig. 5/7/8/9/10: A common time axis style would facilitate comparing the different figures, in particular Fig.8/9/10 are hard to read and have 1.5 years major ticks.

p.5442, l.13: 'Moreover' instead of 'more over'
p.5448, l.11: comma after 'However'
p.5448, l.22: comma after 'both'
p.5449, l.2: Incomplete sentence?
p.5450, l.20: add something like 'in the discussion of' instead of 'with'
p.5450, l.28: remove 'real'
p.5456, l.21: add '...would lead to more 'stratospheric' ozone in 1998....'

p.5460, l.14: remove line break

References:

Logan, J.: An analysis of ozonesonde data for the troposphere: Recommendations for testing 3-D models and development of a gridded climatology for tropospheric ozone, JGR 104 (D13), 16115-16149, 1999.

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extent of extratropical TST derived from in-situ CO measurements during SPURT, ACP, 4, 1427-1442, 2004.

Zeng, G. and A. Pyle: Influence of El Nino Southern Oscillation on stratosphere/troposphere exchange and the global tropospheric ozone budget, GRL, 32, L01814, doi: 10.1029/2004GL021353, 2005.).

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