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Interactive Comment

Interactive comment on "Observationally derived transport diagnostics for the lowermost stratosphere and their application to the GMI chemistry and transport model" *by* S. E. Strahan et al.

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Summary: This paper presents several very interesting diagnostics for a comprehensive process-oriented validation of CCMs and CTMs in the upper troposphere/lower stratosphere (UTLS) and their application to the GMI CTM. It hence is a valuable contribution to ongoing validation activities within the different communities (e.g. QUANTIFY or CCMVal). However, the presentation and discussion of some diagnostics should be improved following the comments and suggestions below before I can recommend final publication in ACP.

Specific comments:

1. Introduction: I suggest rewriting the introduction in a more succinct way, as was likewise pointed out by reviewer 3. The first paragraph could be either omitted or should be substantially shortened and placed behind the description of the LMS and the discussion of the different transport pathways influencing its tracer composition. In its current form, the introduction leads the reader into a wrong direction of what will be the focus of this paper.

The second paragraph further lacks references to the most recent literature about extratropical stratosphere-troposphere exchange (STE). It is too much of a simplification to reduce the processes evaluated by the presented diagnostics to the wave driven circulation and the monsoon circulation. There is observational evidence from a wealth of recent aircraft measurements that other (non-isentropic) stratosphere-troposphere exchange processes such as gravity wave breaking [Witheway et al., 200x], deep convection [Poulida et al., 1996; Fischer et al., 2000; Hegglin et al., 2004], pyro-convection [Fromm et al., 2000; Ray et al., 2004], tropopause folding events [Danielsen et al., 1968], among others strongly influence LMS tracer distributions. All these processes will have considerable impact on the shape of the CO-O3 correlation but also on the CO2 seasonal cycle and its height dependence - which then are both diagnostics to test the depth of the mixed layer, better to be referred to as the extratropical transition layer (ExTL).

While the title of the paper suggests that the presented diagnostics are derived for the LMS (the region between the extratropical tropopause and the 380 K isentrope), the authors talk about the UT/LMS in the introduction, and finally diagnostics are also used for the LS. It is a good idea to validate the transport characteristics up to the lower stratosphere since transport through this region and into the LMS is crucial to the tracer composition found in the LMS. I hence suggest using the terminology ‘UTLS’ and to be consistent throughout the paper.

3. Transport diagnostics

3.1 Transport up to and through the tropical tropopause

Figure 2: Panel A: I guess the black line depicts the average of the model surface forcing at Mauna Loa and Samoa which are prescribed by ground-based observations. The figure caption fails to make this clear or isn't consistent with the text. Please improve. Also add which years are shown to make it obvious to the reader that the same years are used as in the study of B96. Does the lagged surface cycle agree with the measurements of B96 at the tropical tropopause? The discussion would be more convincing if the measurements could be shown as well. Why can't we see an expected annual increase of 1 ppmv for the CO2 surface mixing ratios?

P1456 p11: The reference to Hoor et al. [2004] is confusing in this place since all the results refer to B96. It fits better at the end of the discussion of the results of B96 and with an indication how the work of Hoor et al. [2004] relates to the results of B96.

3.2 The seasonally-varying composition of the lowermost stratosphere

The structure of this section might be improved by taking out the data descriptions into a separate section and add some more information. There is introduction material given about CO (e.g. reference to Schoeberl et al. [2006]) though this tracer is only used in the next section 3.3 which is confusing.

P1456 l23: Please add Krebsbach et al. [2006] and Hegglin et al. [2006] to these references since they used very similar diagnostics resulting in the same conclusions.

P1457 l8 For every model-measurement comparison it is important to provide information about possible sampling biases. The observation periods and the geographical latitude ranges of each data set used in this study should be indicated in the data description. Also, over which time period does MLS provide global coverage?

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I suggest changing this title. The evaluation extends down into the LMS and the same range is considered for the O3 diagnostic in the next subsection though there you just use 'O3' as title.

Figure 3: Please add a colorbar to the PDFs. Also provide a description of how the PDFs were calculated. Are they normalized? Do they reflect area-weighted measurements? This is often necessary though dependent on the sampling pattern of the used satellite [cf. Sparling 2000]. Are the MLS, SPURT, and ER-2 data further also restricted to the same geographical latitude range (70°N -88°N)? If not: the SPURT data covered a geographical latitude range between 30°N and 75°N. It is not obvious to me why you have chosen them for comparison at high latitudes. The high bias of the data in winter might just reflect a sampling bias towards low latitudes where we expect higher N2O mixing ratios due to the meridional gradient in long-lived tracer distributions in the LMS.

I further suggest splitting the presentation of this diagnostic into LS and LMS data. In the current form the reader cannot tell if the model really agrees well with the measurements in the LMS. Hegglin et al. [2006] showed that the use of O3 (or N2O) vertical profiles relative to the tropopause reveals a strong seasonal cycle with high (low) values in winter and low (high) values in summer, respectively. You might consider using this evaluation as a diagnostic which would account better for the characteristics of the LMS tracer distributions strongly influenced by the height of the tropopause.

P1458 l10-15: Strong horizontal mixing through the breaking of planetary waves is expected to lead to a homogenization of tracers along isentropes [cf. Plumb and Ko, 1996]. Due to strongest wave activity during late autumn/early winter, one hence would expect less variability of tracers along isentropes, what is indeed happening in the surf zone. Only the presence of a mixing barrier, i.e. the polar vortex, can explain the observed higher variability through the creation of a different transport and/or chemical regime. Is this what you meant by the 'vortex wobble'? Please also clarify the statement 'strong horizontal mixing in spring causes breakdown of the vortex and homogenization of the extratropics'. It might be more appropriate to say 'The breakdown of the vortex

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in late winter/early spring finally permits the homogenization of the tracer distributions in the extratropics'.

P1459 l5 The presence of a strong meridional gradient in the N2O tracer distribution even in summer/autumn as seen in the equivalent latitude-potential temperature plots implies the presence of a mixing barrier as discussed by Hoor et al. [2004]. This contradicts Chen [1995], please comment.

O3

Please add Logan et al. [1999] to the references here, who suggested the use of seasonal cycles of O3 data at different levels derived from radiosondes for model validation in the lower stratosphere.

3.3 Stratosphere-troposphere coupling at the extratropical tropopause

The diagnostics presented in this section are very valuable, nevertheless I suggest adding the measurements to Figure 7 and 8 in order to allow the reader direct comparison.

There is also a new paper by Pan et al., proposing a set of diagnostics for evaluating chemistry-climate models in the extratropical tropopause region which is just about to appear in JGR. It would make sense for the community to include this paper into the reference list, since it looks at the mixed layer using the H2O-O3 correlation, therefore addressing another important issue of the influence of transport on tracer distributions in this region.

4. Diagnostics summary

In Table 1, a reference to Pan et al. [2004] or Pan et al., in press, should also be included for the consistent thickness of the mixed layer, and the reference to Hegglin et al. [2006] for the diagnostic using O3 and N2O isopleths following the tropopause.

P1463 l20: Add the references Hoor et al. [2004] and Hegglin et al. [2006]

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P1463 l4: The too strong exchange with the extratropics between 380 and 420 K might also lead to the attenuation seen in the O3 seasonal cycle at midlatitudes.

P1464 l27: I cannot see that the seasonal cycles in O3 match the MLS data 'extremely well'. The difference at high latitudes at 350K is quite remarkable (up to 25%).

Technical comments:

P1454 l17: please specify the lower boundary of the vertical resolution in the LMS instead of saying 'is 1 km or less'.

P1454 l26: correct 'A GCM that correctly simulates'

P1455 l10: remove 'and' after 'tropical LS'.

P1455 l20: remove 'only' after 'diminished amplitude by'

P1455 l24: remove 'a little' before 'too rapid' (since the attenuation is between 20 and 40%, which should not be understated).

References: Please add the SRef-IDs of the cited ACP papers.

Additional references:

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