Atmos. Chem. Phys. Discuss., 10, C12630–C12637, 2011
www.atmos-chem-phys-discuss.net/10/C12630/2011/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "On the behaviour of the tropopause folding events over the Tibetan Plateau" *by* X. L. Chen et al.

X. L. Chen et al.

chen24746@itc.nl

Received and published: 21 January 2011

We would like to sincerely thank Reviewer 2 for her/his encouraging comments. We have revised our manuscript and addressed your comments point by point. The mentioned literatures are really helpful to this work and have been studied as well.

Comment: Lack of new findings: The paper may represent an analysis of the structure of the UT/LS above the Tibetan Plateau, but it does not report "new findings" on the UT/LS. The tropopause related processes the author described are well known and documented in literature. Further, the difference in frequency of double tropopauses before and during the monsoon season, is not a new finding. It rather reflects the difference in dynamics dependent on season.

Response: Although the results maybe considered not really 'new', to our knowledge, this paper should be the first one on systematic analysis of UTLS above the Plateau. Previous studies have proven that the STE over the Plateau contribute a large amount to Northern Hemisphere STE. From this point, we think that variation of UTLS deserves to be studied in more depth. Such work was not possible without this dataset.

Comment: On page 23002 (line 17) the authors write "To further investigate the observed close relationship between the jets and tropopause folds above, we display the seasonal variation of the jets (Fig. 7) to explain seasonal differences in tropopause structure". First, this figure only shows the seasonal variation of the jet stream, it does not give any information on the relationship to tropopause folds!

Response: The seasonal variation of tropoause folds (shown by PV) has been plotted with the jets together. As you can see, in accordance with seasonal north-south movement of the jets, the tropopause folds also moves to north in summer from south in winter. The folds in winter are deeper than those in summer time when the jets are weaker than in winter time.

Comment: Second, the authors state this relationship as if they would be the first who have investigated tropopause folds and jet structure. There are many earlier publications, which show a coexistence between tropopause folds and jet streams (e.g. Shapiro, 1980), and the connection of double tropopauses with jet streams (e.g. Pan et al., 2009).

Response: Changed from "To further investigate the observed close relationship between the jets and tropopause folds above, we display the seasonal variation of the jets (Fig. 7) to explain seasonal differences in tropopause structure" to "Due to the close relationship between the jets and tropopause folds (Shapiro, 1980), we display the seasonal variations of the jets (Fig. 7) to explain seasonal difference in tropopause structure."

Comment: There are a lot of misleading terminologies and statements probably due to a lack of the understanding of background science. The subtropical jet stream does not cause tropopause folds above the plateau (page 22994, lines 23–24)! Of course, tropopause folds, jet streams and double tropopauses have some relations in the atmosphere, but the definitions are different. Double tropopauses are defined by the lapse rate criterion and the tropopause folds are usually dynamically defined by a fixed PV isoline. The authors also state, that they have observed tropopause folds as thermal MT events (e.g. page 22997, lines 4–6). It seems that they believe, “tropopause folds” and “multiple tropopauses” are the same.

Response: Thanks for enlightening us the relationships between jet, folds and multi-tropopause. We have revised several related contents and changed from “Section 4 explains dynamic tropopause folding which has been observed by radiosonde as thermal MT events.” to “Section 4 explains some tropopause foldings when the radiosondes have observed thermal MT events.”. This change has been also made in several parts of the paper.

Comment: The authors further use the terminology “simple tropopause” (e.g. page 22996, line 12), which is used in a wrong context.

Response: “simple tropopause” was revised to “single tropopause”; This change also was made in several parts of the paper.

Comment: On page 22999 (lines 29–31) the authors suggest the third tropopause (LRT3) as a stratospheric inversion layer and the first tropopause (LRT1) and second tropopause (LRT2) as tropospheric inversion layers. A tropopause is no inversion layer!

Response: As both referee suggested, we revise the sentence to ‘LRT3 doesn’t show this character suggesting itself as a stratospheric inversion layer (Añel et al. 2007; Gettelman and Forster, 2002). On the contrary, LRT1 and LRT2 should be attributed to tropospheric stable layers”.

Comment: The south–north movement of the jet streams does not cause the latitudinal

variation of tropopause folds (page 23003, lines 1–8).

Response: Due to the complex relationship between the jet and tropopause folds, the sentence of ‘The south-northward movements of the jet streams cause the latitudinal variation of tropopause folds, which finally determine the simple or multi tropopauses observed at the plateau stations.’ was revised to ‘The south-northward movements of the jet streams was accompanied by the latitudinal movement of tropopause folds, which influence the structure in UTLS. The variation of UTLS structure was reflected by the simple or multi tropopauses observed at the plateau stations.’

Comment: The tropopause folds are not the mean reason for the height variation of LRT1 in winter.

Response: We agree that the tropopause folds may not be the ‘main reason’ for the height variation of LRT1, but from our analysis we can conclude that the height variation of LRT1 from low to high at Gerze station is the result of latitudinal movement of folds. Please check the time series pictures of cross section and simultaneous LRT height variation in the figures of supplementary documents. When tropopause folds move to north of Gerze, the LRT1 is observed to be high. When the tropopause folds propogate above and south of Gerze, the LRT1 height is low. Thus we think the variation of tropopause folds influence the structures in UTLS, which finally influence the height variation of LRT1. This part of contents has been upgraded.

Comment: The discussion of the frequency of multiple tropopause events is problematic. The author cannot compare absolute values of frequencies of multiple tropopauses, calculated for the different Tibetan plateau sites, with those of other publications, such as Randel et al. (2007) or Añel et al. (2008). Randel and Añel used different data sets, with a different vertical and horizontal resolution, and their analysis represents a climatology on a larger time period.

Response: The frequency of GPS occultation in Randels is based on ’10 degree*30 degree’ horizontal bins’, the area of Tibetan Plateau is around one bine size. The resolution of ERA 40 MT frequency is about '1.5 degree*1.5 degree'. The horizontal resolution is not the main reason for their relative low values over the plateau. The critical problem is we have limited periods of observations, and use several stations to present the plateau. To make a more accurate evaluation, the shortage of our estimations will be discussed in conclusion and discussion section. The global distribution of MT in Añel et al. was interpolated from unevenly distributed radiosonde stations. This process should influence the final outputs over the Plateau. At the beginning, we communicated with Añel whether they could provide their function of tropopauses to us. Thus the comparison with Añel will be more reasonable. Due to unexplained reason, we can't get it. Then we had to develop our own code and uploaded it to ACPD, hoping other people will use the same standard code to study tropopauses. Secondly from vertical resolution, we think that the vertical resolution of their dataset are not as high as ours. We have asked Añel to send us the IGRA dataset over and around the plateau. After checking the data, we found a large number of the data only have information on mandatory levels (such as 500, 400, 300, 250, 200, 175 hPa et al.). We also recognize that both Randel and Añel provide us the mult-tropopause frequency from global distribution. Meanwhile, the frequency difference between us and theirs over the plateau exactly reminds us the frequency of multi-tropopause is really high. And this high frequency may reflect constantly folds occurring over there. Whether are there any other significant differences in MT frequencies still needs to be testified with more high resolution data of radiosonde. From our studies, we must recommend vigilance with reanalysis data and IGRA when using them to describe the structure of multi-tropopause over the plateau.

Comment: On page 22999 (lines 4–7) the authors state that the MT occurrences at the three Plateau stations for IOP1 are between 72% to 84%. I guess they calculated the sum of the frequency of the second and third tropopauses at the single stations. This value has no scientific meaning to me. The author cannot compare this value to the values of Randels Figure 9a. This figure represents the frequency of double tropopauses and does not contain any third tropopause. It shows the seasonal fre-

quency for 10*30o horizontal bins, so the author cannot directly compare his frequency of second and third tropopauses at three single latitude and longitude positions of the Plateau stations (Gerze, Nagqu, Litang) with Randels mean frequency. The author should reexamine the comparison with other publications.

Response: At first, I also believe the values in Randel's Figure 9a represent double tropopauses. But the figure titles write 'Multiple LRT'. I also wondered whether only two tropopause events are counted. But when I wrote email to ask Bill Randel, He answered 'three or more tropopause are included'. Then I believe his double tropopause definition actually includes 'three or more tropopause' events. But in my case, double-tropopause represents only two tropopauses, triple-tropopause represent three tropopauses (listed in table 2). The sum of double-tropopause and triple-tropopause frequency in our table 2 should be identical to Randel's 'double tropopauses'. Due to our short periods of data, it is not necessary any more to compare with other frequency of multi-tropopause over the Plateau.

Comment: Speculative reasoning: The discussion is too much speculative. Especially the discussion on the impact of stratospheric intrusions on the high ozone concentration in the upper troposphere (page 23002, line 11) needs some supporting scientific analyses or some convincing references. The impact of intrusions on the ozone concentration in the upper troposphere is too much speculative. The statement of the authors, that intrusions of stratospheric air with a high ozone concentration into the upper troposphere above the Tibetan Plateau would be a new explanation of the higher ozone in the upper troposphere in winter than in summer is not convincing (page 22994, lines 25–27, page 23002, line 11).

Response: The picture of pressure-longitude cross section has been added to show that the meridional folds dominate UTLS above the plateau. We have to concede that the effects of stratospheric intrusion on the vertical ozone content should be studied further in detail, as the photochemical, other transport processes and dry deposition may also contribute to ozone minimum. Thus we conclude with 'less intrusions of stratospheric air can be one reason for total ozone value above the plateau in winter higher than that in summer.' other than 'This effects cause total ozone value in winter higher than that of summer'; The lines 25-27 on page 22994 have been revised to 'The variations in the intrusions of high latitude stratospheric ozone rich air into the troposphere over the plateau can contribute partially to total column ozone in winter higher than that in summer.' , with other effects discussed in the last section.

Comment: Introduction: The introduction does not provide any description of the characteristics of the two mean features of the paper, the multiple tropopauses and the tropopause folds, in more detail. Concerning the tropopause folds there are some important publications (e.g. Shapiro, 1980, 1987). The author should also cite some analyses on the frequency of both double tropopauses and tropopause folds (summer to winter contrast), which already appeared in literature.

Response: The introduction structure has been adjusted with the first paragraph focus on the importance of STE over the plateau and scarcity of research on this subject. The second paragraph demonstrates the importance of Multi-tropopause and a gap between our estimation and other researches. The third paragraph shows tropopause folds coexisting with the jet should frequently happens over the plateau. The fourth paragraph relates the ozone minimum which has been studied in several ways to tropopause folds, which is rarely focused on. Paragraph five tells the radiosonde observation and what we have done with the dataset in paragraph six. In the introduction the significance of multi-tropopause and tropopause fold are also included. Thanks for your enlightening us the two features of the paper.

Comment: The authors should present a clear picture about their contribution in the context of the present science. They try to give some questions on the objectives of the paper (page 22996, lines 19–22), but these questions should be more precise and they are not properly answered in the paper.

Response: As Fu et al 2006 pointed out the Plateau region as an active STE area

(short-circuit and pathway), without knowledge on the structure of UTLS at this area, we think to diagnose the effects of the plateau on STE will not be built on solid ground. The study highlights the occurrence of MT events over the plateau. Another aspect is that nobody has ever tried to explain the ozone minimum phenomena from dynamic transport point of view. We also believe that the atmospheric heating caused by the plateau in some extent or in some way may influence the STE. In the future we think the questions will be studied further. So in this paper we'd like to delete the following contents: 'This study will focus on the following relevant issues. (1) What is the detailed UTLS structure over the TP? (2) What are the influences of the westerly jet on intrusions, and the intrusion of stratospheric air on the vertical ozone distribution, further on the total ozone over the plateau?'. The plateau provides us a natural platform to study the climate change signal under the environment of global change. And due to topography of the plateau, the atmospheric boundary layer can be easily coupled with the processes of upper layer. A very high boundary layer was discovered later, which we think has a close relation with the tropopause folds. Detailed contents were analyzed in another manuscript by us.

We have totally revised our manuscript and uploaded some more figures in order to help readers to easily understand this work.

Xuelong Chen on behalf of co-authors

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/10/C12630/2011/acpd-10-C12630-2011-supplement.zip

---

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 22993, 2010.