Responses to Referee 1

Our responses in italics. In the revised manuscript, all changes (except minor technical corrections) are highlighted in red.

General comments

This manuscript proposes a procedure for building climatologies of jets and for mapping fields (e.g. from satellite data) with respect to the jet location in the horizontal and the vertical. It shows how it can be applied to a sample of data. Overall, the research and methodology presented in this manuscript is sound and very relevant to the current research in the field of UTLS. Although the manuscript reads well and the methodology is carefully described, the text insists too much on promoting the advantages of the framework proposed, while discussions on its limitations are almost absent. Other methods are mentioned without proper account of their strengths and limitations. To my opinion, the manuscript's text needs to be re-balanced, including proper discussions of the limitations of the proposed method and the strengths and limitations of the existing methods it is compared to (see specific comments). Apart from this balancing issue, the manuscript represents an exciting, original work and is clearly relevant to the field.

We thank the referee for his/her helpful comments. Both referees remarked on the lack of balance between the treatment of the new jet-coordinate view that we are presenting here and existing frameworks used to view the extra-tropical UTLS. It was never our intention to dismiss the value of those methods, but we appear to have been too enthusiastic in highlighting the added value of our new methods. We have revised the text throughout (and modified several of the figures, as discussed below and in the response to referee#2's comments) to not only give a more balanced view of different coordinate systems, especially EqL versus the jet coordinate, but also to highlight ways in which both frameworks can be used together to provide further insight into dynamics and transport around the UTLS jets. The largest changes are in the discussion of Figures 5 through 7, Figures 10 and 11 (now Figures 10 through 12), and in the Introduction and the Discussion and Conclusions sections. In the introduction, for example, we have modified the statement regarding the complications of using the EqL coordinate in the UTLS to read:

"In these regions, the O_3 field suggests mixing in a broad area between edge of the subvortex and the tropopause. At both levels, the jet is often discontinuous or may have multiple cores at some longitudes, with corresponding complexity in the PV contours; its strength also varies greatly with longitude. Equivalent latitude (EqL) calculated from PV is a very useful coordinate in the polar winter stratosphere where, since the circulation is organized by a single, simply-connected jet of relatively uniform strength around each EqL contour, it not only accurately segregates different air masses but also provides a complete description of the relationships of those air masses to the jet structure. In contrast, while an EqL coordinate still shows the boundary between different air masses in an average sense (around an EqL contour) in the UTLS, it can obscure the details of the relationships of those air masses to the complex, discontinuous system of jets, and associated variations in trace gas distributions and gradients around EqL contours."

In the conclusions section, the summary statement about trace gas distributions in different coordinate systems has been reworked as follows:

"The view of UTLS MLS O_3 data is compared using EqL and distance from the subtropical jet as horizontal coordinates in combination with several vertical coordinates. While both views show evidence of STE in the existence of O_3 values characteristic of the stratosphere well below the tropopause, the EqL/q view blurs the representation of the jet and the strong gradients (in PV, tropopause altitude, and O_3) crossing the jet core, and thus the relationship of that STE to the jets, wherein stratospheric O_3 values in the troposphere are concentrated poleward of and below the jets. The view using the subtropical jet core as both horizontal and vertical coordinates highlights the correlation between strong PV and tropopause height gradients and very strong O_3 gradients. The jet coordinates also highlight evidence of poleward transport across the top of the jet. Vertical coordinates relative to the tropopause are also valuable, especially in defining the strong trace gas gradients across the tropopause. For studies such as quantifying the geographic and temporal variability of large-scale trace-gas gradients across the tropopause, it may prove valuable to examine both tropopause- and jet-relative vertical coordinates in combination with the

horizontal jet coordinate, as well as using the EqL/tropopause framework to obtain a global picture."

Numerous other changes have been made throughout the text, which will be described in the responses to the referees' specific comments.

Specific comments

1. The jet catalogue excludes longitudes of weak jets. This exclusion is fine for the mapping of jets because its implications may be anticipated. However, when used to map satellite data, this exclusion leads a biased representation of the data when a correlation exists between the longitude of the strength of the jet and the satellite data. If such a correlation is absent, then it leads to a sub-sampling of the data, which arbitrarily reduces the statistical significance of the data. The authors argue that this framework gives an advantage because it allows to focus exclusively on regions of special interest. This argument hypothesizes that longitudes with strong jets are of higher interest than longitudes with weak jets. To my opinion, we do not have the knowledge today to ascertain this. Showing that this is indeed the case, would be a result in itself. In order to show that this is the case, the authors would need to provide a mapping of the satellite data in longitudes of weak jets as well. I suggest that the authors provide the maps of data in longitudes of weak jets as well, if possible. If any, I strongly recommend to add to Fig. 7 the quantities mapped in the EqL framework in the longitudes of strong winds only, with a corresponding discussion. This could give a hint on the implications of the selection made in the jet-relative framework. In any case, the manuscript needs a discussion on this issue, not only in the conclusion area, but also in the introduction.

We have reworked what was Figure 10 into two figures (Figures 10 and 11): The new figure 10 shows the data in EqL/theta coordinates mapped separately for the data points at longitudes that did and did not have a subtropical jet core identified. In fact, the mapping using only the strong jet regions is ***very*** *similar to that in the top panels of the original Figure 10, indicating that the inclusion of weak jet regions was, in this case, a minor factor. This figure also allows us to discuss the differences between strong and weak jet regions and hence demonstrate one way in which we can use our jet characterization within the EqL framework to get additional information on the differences between strong and weak jet regions.*

In Figure 7, we now show the EqL coordinate lines mapped using only the data at longitudes where a subtropical jet core was cataloged, hence including exactly the same subset of the data as the jet coordinate lines. The result of this change made very little difference in the results.

2. The methodology uses threshold values for the minimum jet strength and for the latitude distinguishing sub-tropical and polar jets. In studies which span a century, the jet stream may increase and shift in latitudes. These changes may affect the way satellite data are mapped using this jet catalogue. This issue needs to be addressed somewhere in the manuscript, such as in the conclusion section.

This issue naturally fits in Section 3.1, where we have added text noting that the fields we examined to "validate" the parameter choices span the 32 years of the MERRA reanalysis, and that our code is formulated so that all these parameters can easily be modified for special cases, or if we observe trends that warrant reconsideration of our selections.

3. The mapping of fields with respect to the jet offers an interesting perspective, since jets are known for their capacity to organise fields such as passive tracers in particular. However, away from the jet, passive tracers will become less organised by the jet and be subject to other dynamics. Hence, the mapping of a tracer with respect to the jet is expected to provide a sharp view close to the jet and to become blurred away from the jet. This needs to be addressed in the manuscript.

The discussion of Figures 5 and Figures 10–12 has been modified to make this point explicitly. In addition, we have carefully looked at the language used in describing all of the jet coordinate plots to ensure that we have *been specific about noting the range of influence of the jets.*

4. Fields mapped with respect to the jet location, using horizontal distances as x-axes , are shown from -60 to 30 (SH) or -30 to 60 (NH), spanning 90 degrees latitude (Figs 5, 6, 11, 12). It is clear that the number of data available at these latitudes decreases towards the pole because of the variation of the jet location. This also means that statistical significance of averages decreases towards the poles. The knowledge of statistical significance (or at least of the number of available data in each grid box) is essential to the interpretation of the averages presented in this manuscript. This aspect is omitted in the current manuscript and needs to be included. I strongly recommend to either overlay statistical significance on the appropriate figures, or to add graphs showing the number of available data.

Because we mapped the high-resolution GEOS-5 fields in Figures 5 through 7 on relatively coarse EqL/theta grids (the grids used are now specified in the figure captions), there are typically several hundred to several thousand points in each bin except along the edges of the mapping region. We have added to Figure 7 (in the PV panel where a standard deviation is not shown) lines showing the number of points in each bin shown for each coordinate combination, and discussion of the negligible impact of this on the comparisons.

5. The manuscript does not provide a balanced account of existing methods for mapping fields (EqL, PV, TH,...). It tries to convince the reader that the proposed methodology is better, but fails to discuss within what limits it is better, and for what type of focus. The manuscript seems to promote the proposed method as a generally better way of mapping fields. The above items suggest several limitations of this method that need to be discussed in the manuscript for a more balanced account of the strengths and limitations of the method itself. In addition, the current manuscript needs to be improved (at least in the introduction) to provide a more balanced account of other methods. In particular, the EqL framework is criticized because it fails at showing the strong peak in the PV gradient around the jet. This is inherent to the EqL framework, of course, and is not surprising. However, the EqL provides an interesting theoretical framework for understanding non-conservative transport, since PV has conservative properties. In my opinion, the framework proposed here shows a greater interest when compared with the EqL framework, such as in Fig. 5.

As noted in the response to the general comments, we have worked throughout the text to provide balance in the discussion of usage of Eql versus jet coordinates. One thing that we see as an important improvement in the revised manuscript is discussion of benefits of both using the jet catalog within the EqL coordinate framework to provide information on strong and weak jet regions, and using the comparisons between trace gas fields viewed in EqL and jet coordinates to make additional inferences about the processes at work.

6. In Fig. 7, center panel, the standard deviation of Hor PV Gradient in EqL is higher than the one in the jet-relative coordinate system. I am surprised. I wonder whether this is not just an artefact due to the number of data used in these standard deviations. Indeed, since the EqL loses the longitudinal dimension, the number of data used to calculate the standard deviation must be simply the number of times. On the other hand, the numbers of values used in the standard deviations using the jet-coordinate include the longitudes and the time, ie a much larger number of values. Comparing standard deviations with such a difference in the number of samples is misleading in this context.

As per the response to point 4, the number of points in the bins is so large in all cases that the effects on the standard deviations are negligible; this is now discussed in the text. In fact, the EqL/theta and jet/jet coordinates have comparable numbers of points in each bin, while the jet/theta coordinate has many fewer – the fact that the jet/jet and jet/theta coordinates show very similar standard deviations indicates that the number of points in each bin is not a large factor in the differences, as is now stated in the text.

7. Fig. 8, top panel: Is this the correct figure? The x-axis says "windspeed difference from max", and the axis ranges from -60 to +60. How can you have winds 60m/s larger

than the max wind?

We apologize for the confusion here – the figure was "chopped up" in the ACPD production process, so that some of the x-axis labels were not associated with the correct plots, and I did not notice it soon enough to correct it.   However, the negative values in the plot with windspeed difference from the max simply indicate that those are values at locations equatorward of the jet, whereas the positive values are for values poleward of the jet, as is now stated in the figure caption.

8. It is argued through the paper that effort is made to automate the search for the jet center(s) using what the human eye would see as a reference. Why would the human eye be such a good reference?

The human eye and visual processing circuitry are well-known to be extremely good at pattern recognition; we have added two citations to this effect where this objective is first discussed in the text (Section 3.1).

Technical corrections

l. 41: remove first bracket

Done.

l. 206: decrease between them: do you mean in straight line? clarify.

Yes, in a straight line – this has been clarified.

l. 281: remove last bracket

Done.

l. 379: last "2005" should be "2009"

Done.

l. 406: define EqL

EqL had already been defined (on line 97 of the manuscript the reviewer appears to have been looking at).

l. 412-413: Undulating flows, ie with conservative waves, should be well described with conservative quantities, such as PV or TH. Complex jets may make the jet-relative framework less relevant. Clarify.

We have reworded this to clarify that we were not talking about non-conservation of PV, but rather trying to convey that we don't get a focus on the jets because the EqL coordinate averages together regions with very different jet characteristics. This paragraph from the revised paper is quoted above in our response to the general comments.

l. 456-457: This suggests that the jet-relative coordinate system is less relevant fare away from the jet.

Indeed it does, and we have added a comment to that effect in the text.

l. 469: Is this really an advantage?

Throughout the text, including here, we have worked to remove language such as "advantage" that implies a value judgment in favor of stating specifically what it allows us to do or see.

l. 524: weakly positive equatorward, not poleward

Corrected.

l. 534: why would transport be more interesting near strong jet cores than elsewhere?

It is, arguably, not inherently more interesting there, and we did not, even in the original manuscript, state that it was. It is simply that it is one region that is interesting, and this paper focuses on transport in that particular region.

l. 545: with a plot

Corrected.

l. 562: The strongest

Corrected.

l. 565: I do not understand this statement.

We have reworded this to say that the strong ozone gradients are in accord with the role of the jets as a transport barrier.

l. 636: latitudinal

Corrected.

l. 657-658: I am surprised that MLS can see below the tropopause

The MLS UTLS ozone (as well as CO, HNO3 and H2O) measurements have been extensively validated. We have added a reference here to the validation paper on UTLS ozone and CO. In addition, we included Figure 9 in the paper specifically for the purpose of demonstrating that the MLS ozone measurements in the UTLS are useful for the analyses we show following that.

l. 763: "undiluted": what do you mean?

We have changed this phrase to read "…by focusing on regions influenced strongly by a jet"

Fig. 9: Is this figure really useful?

It was included to demonstrate the utility of the MLS ozone data in the UTLS. Since this referee questioned that utility in a previous comment, we have elected to retain it.