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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Where do the air masses between double tropopauses come from?" *by* A. C. Parracho et al.

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Response to general comments by reviewer #2:

1. We think that the title of the paper is appropriate because the analysis is based on the history of the particles that reach the double tropopause layers.

   1) The longitude and latitude of the centroid position of all particles, at each instant, were used to access the spatial difference in the origin of the particles that reach the domain. However, the mean PV and the fraction of tropospheric particles, at each instant, were calculated considering the PV and the tropopause height at the position of each particle.

   2) We analysed the month of January because the frequency of DT occurrence in the Northern Hemisphere is higher in winter (December-February) (Añel et al., 2008; Peevey et al., 2012; Randel et al., 2007b). An analysis of a shorter 10-year period for the month of March (not discussed in the paper) has revealed results that are consistent with those obtained for January. This information is now given in the paper.

   It is difficult to establish a relationship between our results and those of *Homeyer and Bowman* (2013). The frequency of DT occurrences in the Northern Hemisphere is higher in winter (December-February) whereas the wave-breaking frequency in the 350–400 K potential temperature range shows a strong peak in the summer (*Homeyer and Bowman* , 2013, page 614).

2. The analysis of PV distribution has been repeated excluding the backward trajectory instants for which the nearest grid point to the centroid trajectory has a DT (as done for the analysis of the fraction of tropospheric particles). The results do not change qualitatively, as would be expected from Fig. 6, which suggests that the PV remains approximately constant along the trajectories.

   We don't see how the suggestion given in the last sentence of this comment would be implemented. However, the newly added section on "Composites of static stability and zonal wind" may address, partially at least, the reviewer's concern.

3. Figure 1 now includes the mean wind speed climatology for January. The new section on "Composites of static stability and zonal wind" also gives some information on the zonal asymmetry in the occurrence of meridionally extended intrusions of tropical tropospheric air into the lower extratropical stratosphere, like those analysed by Pan et al. (2009) and *Homeyer et al.* (2011).

4. The notation has been revised so that it now remains coherent throughout the paper. Furthermore, the criteria for the selection of single and double tropopause

events have been made less restrictive and their description has been simplified.

Response to specific comments:

Page 1352, line 20: In the upper troposphere and lower stratosphere (300–100-hPa layer) the vertical model resolution (separation between isobaric levels) is in the range ∼700–1200 m, whereas in the reanalysis the vertical resolution is in the range ∼ 700–1600 m. These are very low resolutions compared with that of radiosonde data. Therefore, the tropopause pressure was determined using an algorithm that is similar to that used by Birner (2010b). The algorithm is well tested in the literature and implements the WMO definition of the tropopause to a level p_{TP} linearly interpolated on p^{κ}, where $k = R/C_p$.

Page 1353, Section 2.2: As we explain in the paper "Eight domains were placed northward of the maxima of DT occurrence, six domains were placed along the maxima, and the remaining six domains were placed southward of the maxima of DT occurrence. These domains were chosen to sample regions with different frequencies of occurrence of DTs, and the choice of their locations was somewhat arbitrary. However, the results discussed in the following sections show that there is regional consistency between the domains, and that the conclusions would have been the same had other domains been chosen."

Page 1353, equations 1 & 2: In section 2.2 we have clarified that equations 1 and 2 were applied to each domain: "The means were calculated for each domain separately and considering only the instants with DT profiles."

Page 1354, lines 20-23: The FLEXPART domains for particle release are four-dimensional (space and time) boxes. When running FLEXPART we define the

center $(x_0, y_0, z_0; t_0)$ and the boundaries of the boxes. In our simulations the time boundaries are $t_0 - 3$ h and $t_0 - 3$ h.

Page 1355, lines 11-12: We have clarified that it is the first tropopause.

Page 1355, line 26: The notation has been revised, so that it now remains coherent throughout the paper.

Page 1356, lines 1-4: As previously mentioned, the criteria for the selection of single an double tropopause events have been made less restrictive and their description has been simplified.

Homeyer et al. (2013) compared the tropopause altitude obtained from the GFS analysis with that determined from radiosonde data. Both tropopause levels were calculated using the WMO definition. The root-mean-square differences between the radiosonde observations and the gridded analysis are ∼600 m. This value is comparable to the resolution of the GFS vertical grid, which is ∼500 m.

Page 1356, line 16: The notation has been clarified.

Page 1356, lines 17-18: The text has been clarified.

Page 1357, lines 1-3: The text has been changed accordingly.

Page 1357, lines 7-13: We believe that the text is now more clear.

Page 1362, Section 3.3: We have repeated the analysis retaining only the final trajectory time (i.e., 10 days prior) and the distribution of the fraction of tropospheric particles remained qualitatively the same.

Figures 2 & 6: We now use darker colors to represent the mean trajectories in Figs. 3 and 6.

The work of *Homeyer et al.* (2011) has been referred.

A copy of the revised manuscript is attached as a supplement file to the responses to reviewer #1.

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