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Interactive comment on “A PV-based determination of the transport barrier in the Asian summer monsoon anticyclone” by F. Ploeger et al.

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General comment:

We thank the reviewer for her/his careful consideration of the manuscript and her/his well thought-out comments, which significantly helped to improve the paper. In the following, we address all comments and questions raised (Reviewer’s comments in italics). Text changes in the manuscript are highlighted in red (except minor wording changes). Main changes concern: (i) an extended discussion of the evaluation of the PV-gradients and the related transport barrier over the season and potential relations to convective activity (including ozone, mean age, OLR and diabatic heating rates in the revised Fig. 12) in section 5, (ii) a critical discussion of the leakiness of the diag-

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nosed barrier (discussion), (iii) an extended discussion of MLS observations and the comparison between model and MLS (discussion, including a new Fig. 14), and (iv) shifts of the old section 6 to the appendix, of the discussion of the layer where our criterion is applicable to section 4, and of the discussion of the anticyclone location probability to the new section 6.

Issue 1: The authors have done a wonderful job of describing their analysis with examples from a particularly good case that occurred July 6 2011. They have also performed analysis over 3 summer seasons as demonstrated by Table 1 and Fig. 11 (although this figure only shows 1 season). However, the paper relies too heavily on the July 6 analysis. This applies to the discussion of Figs. 3, 12, and 13 that should, in my opinion, relate seasonal data and not just values from 1 day. Fig. 3 is important because it demonstrates that results from CLaMS (the transport model) agree with MLS data. The agreement between models and satellite data can be very fickle; one might get great agreement one week and terrible the next. It is therefore important to provide the reader with a more thorough indication of how good the agreement actually is. For the early figures, it is appropriate to focus on July 6. The analysis afterward (Figs. 11-13) is essentially a demonstration of how good the ‘barrier model’ is and should not be restricted to July 6. However, after showing seasonal data in Fig. 11, the authors return to the July 6 analysis for Fig. 12 and 13. I think that these figures should show seasonal results. In addition, Fig. 11 should have two more panels: one for O3 and one for age of air.

The reason to focus on one single day (6 July 2011) for large parts of the paper was to describe the methodology as simply and clearly as possible. However, as Reviewer 1 (and also Reviewer 3) points out, the discussion of how “good” the diagnosed barrier is, should not be restricted to this single date. Indeed, we showed seasonal data already in the draft for the PV-gradient and CO-gradient (old Fig. 11). This figure now includes also ozone and mean age, as suggested by the Reviewer. Furthermore, we now present the ozone-gradients from MLS for the entire summer season (new Fig.

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14), and discuss the agreement with the CLaMS model and possible shortcomings in Sect. 5. Comparison of tracer maps shows good agreement between CLaMS and MLS ozone and CO throughout the summer, similar to the case in Fig. 2 (see also Pommrich et al., 2014). Concerning the gradients, good agreement is only found for parts of the season (beginning and mid-end of July). However, the disagreements in the exact location of maximum gradients (e.g., during August) are not unexpected, due to very different resolution of the model and MLS observations (e.g., the model has a vertical resolution of about 400m around the tropopause, whereas MLS has about 3 km). This fact demonstrates the need for high resolution measurements in the Asian monsoon region.

The characteristic of the transport barrier to be best detectable at 380 K holds for the whole summer season. However, we think that showing plots like Fig. 11 (old version) also for other levels than 380 K would overfill the paper with unnecessary material. Therefore, we kept the old version of Fig. 13 (old version), but present the respective part at an earlier place in the paper (end of section 4), and improved the corresponding text.

Issue 2: This issue concerns the use of the term ‘barrier’. This term is widely used in the literature and, so, I understand why the authors might choose to use it as well. However, I think it is misleading and the maps in Fig. 9 seem to support this contention. I would prefer it if the authors referred to the PV gradient as a diagnostic of how strong (or weak) cross-gradient transport is likely to be – the stronger the PV gradient, the weaker cross-gradient transport is. The reason that the term ‘barrier’ is not appropriate is because it invokes the concept of an external restriction on the flow (e.g., a wall) and of causality. However, PV and cross-gradient transport are both merely related properties of the circulation; they are highly correlated but neither causes the other to occur.

We totally agree with the Reviewer’s view. However, we would keep the term “barrier”, which is indeed usually used in the literature as Reviewer 1 also remarks, to have

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some simple terminology. We discuss the term “barrier” now briefly at the end of the introduction and more extensively in the discussion (see also our reply to Reviewer 2/Major comment 1).

Specific and technical comments:

Page 10594, line 25: *Regarding ‘the linear response . . .’. One obtains a strong anticyclone over Asia as the linear response to low-level convective heating associated with the Asian monsoon. However, the anti-cyclone has nonlinear components. I suggest rewording the is sentence to reflect that fact.*

Sentence has been reworded!

Page 10595, line 5: *Remove ‘characterized’.*

Done.

Page 10595, lines 24-25: *Here and throughout the text, the authors use ‘has been’ where ‘was’ is appropriate. ‘Has been’ should be used when something started in the past and continues into the present. In this particular case, the use of PV gradients originated at a particular time in the past – it is not continually being originated. Change ‘has been’ to ‘was’.*

We corrected all cases pointed out by the Reviewer and carefully checked the text again for further mistakes.

Page 10595, line 26: *Change ‘In fact, the’ to ‘This’*

Done.

Page 10595, lines 26-27: *Change ‘relies on the characteristics of PV being an approximately conserved quantity’ to ‘relies on the fact that PV is approximately conserved’*

Done.

Page 10597, line 2: *Change ‘for suppressed’ to ‘of suppressed’*

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Done.

Page 10597, line 2: *Change 'has been' to 'was'*

Done.

Page 10597: *'Age of air' should be defined here. Section 3: Why not show CO from MLS?*

Age of air is defined now - Thanks for pointing this out to us. MLS CO has a worse vertical resolution (about 4.5km) compared to MLS ozone (about 3km), in the region of interest. As the transport barrier is only detectable in a small vertical layer around the tropopause, MLS ozone is clearly advantageous over MLS CO for our purpose. This is stated now at the end of Sect. 2.

Page 10599, lines 10-11: *Change 'has been' to 'was'*

Done.

Page 10599, line 16: *Change 'has been' to 'was'*

Done.

Page 10600, line 5: *Change 'has been' to 'was'*

Done.

Page 10600, line 8: *Change 'barrier of the subtropical jet' to 'barrier for the subtropical jet'*

Done.

Page 10600, line 14: *Change 'has been' to 'was'*

Done.

Page 10600, line 16: *Change 'change of our results' to 'change to our results'*

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Done.

Page 10600, line 17: *Change 'In analogy to' to 'Following'*

Sentence changed, as suggested by Reviewer 3.

Page 10600, line 18: *Delete 'in the following' (within parentheses)*

Done.

Page 10601, lines 27-28: *The statement that ' barrier is located . . . in the latitude range of decreasing circulation' seems to contradict Fig. 7, which shows that circulation increases with equivalent latitude. Please clarify.*

This sentence was indeed not well written. We meant to say that the barrier needs to be located in the region where the circulation decreases when moving away from the anticyclone center (hence, with decreasing monsoon equivalent latitude). The sentence has been reworded.

Page 10604, line 19: *Change 'has been' to 'was'*

Done.

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