# Referee1

Many thanks to the reviewer for the comments which have helped to improve the clarity of the manuscript. In the following, we address all the points raised in the review (denoted by italic letters). Text changes in the manuscript are highlighted in red or blue.

***This manuscript examines the interhemispheric transport from the surface to upper troposphere / lower stratosphere in the other hemisphere using simulations from the CLaMS model. The manuscript contains material that is of interest to ACP readers, and I think contains some new results that warrant publication. However, major revisions are required to the manuscript before it is suitable for publication. As described below, there needs to be (1) improved referencing and discussion of previous studies, (2) more precise discussion of transport in lower stratosphere versus that in upper troposphere, and (3) clearer statements on what is new (as opposed to confirming previous studies).***

A. We thank the reviewer for being critical about our discussion of previous studies and statements on the results. We improve these discussions and statements in the revised manuscript as suggested by including more literature and comparisons with previous work and clarifying the statements regarding different altitude and findings.

## Major comments

(1) ***There needs be referencing and discussion of previous studies. This applies to both the description of the method and the results from your analysis.***

(a) ***There are many studies before Ploeger and Birner (2016) that have used boundary impulse or air mass fraction calculations (e.g., Holzer et al. 2003, Haine et al. 2008, Li et al. 2012, Orbe et al 2013, 2016). I think it is OK to refer to Ploeger and Birner (2016) for details of implementation used, but it needs to be acknowledged that others had developed similar methods and even some had used to look at similar transport problems (e.g. Orbe et al 2015, 2016). You might need to also discuss difference in implementation (see point 4 blow).***

A. More references are added in the revised version of the manuscript. The difference between the methods is also briefly explained on P4 L107-109 as "We apply the boundary impulse (time-) evolving response (BIER) approach to calculate the age spectrum G following Ploeger and Birner (2016), which is based on the boundary impulse response (BIR) method (e.g. Holzer et al., 2003; Haine et al., 2008; Li et al., 2012; Orbe et al., 2016), but evolves with time in a transient simulation using quasi-observational winds.".

(b) ***There are some previous relevant transport studies that are not referenced, e.g. Holzer 2009, Orbe et al 2015. Orbe et al (2015) is particularly relevant as it addresses the same issue, and direct comparisons can be made (eg. fig 3 in Orbe et al (2015) can compared with fig 1). The issue of direct comparisons also applies to some of the papers that are already referenced, e.g. compare fig 5 of Orbe et al. 2016 with fig 7 (more on this below). It is notable that the discussion section compares with previous studies, but only those by the authors of this manuscript.***

A. We agree that the mentioned papers are relevant for our study and extended the literature discussion as suggested. As the reviewer suggested, we compare now our Fig.1 with Fig.3 in Orbe et al (2015). We also directly compare our Fig.7 and Fig.8 with Fig.5 and Fig.7 in Orbe et al (2016). We discuss the similarities and explain the difference from previous work in the revised manuscript (P14, P17, and P18). More comparisons with the literature are also included in the "Discussion" section (P20 and P21).

(2) ***There needs to be more precise discussion of transport in lower stratosphere versus that in upper troposphere. In many cases I think statements on IHT apply for transport into southern lower stratosphere but it is not clear to me that they apply for IHT into the southern upper troposphere (or more generally southern troposphere). I think you need to separate into LS or UT, or maybe be clearer on the potential temperature surfaces that a certain result applies too. For example, do statement about magnitude of air from NH compared to SH hold for both the LS and UT?***

***I think this separation is particularly important as the majority of the Introduction (i.e. lines 26 to 75) discusses studies of inter-hemispheric transport within the troposphere (usually NH surface to SH surface), but most of the focus of this study is on transport into lower stratosphere, and it is not clear how relevant the results are for inter hemisphere tropospheric transport. In other words, the Introduction discusses in detail previous studies of troposphere to troposphere IHT but the results from this study are not put in context of these previous studies.***

A. We thank the reviewer for pointing to the differences between UT and LS transport and agree that some statements don't apply for both LS and UT. We revise the conclusions which are not applicable for both UT and LS. However, we refrain from separating into UT and LS as we regard the change from UT to LS more as a gradual transition than as a distinct boundary, in particular in the tropics within the tropical tropopause layer(TTL). We clarify this point in the revised version. Most of our conclusions apply to transport in the TTL. We don't investigate the IHT in the lower troposphere due to our model setup. We mainly focus on the IHT through the TTL region. Thus, our study can be understood as a complementary approach to that in Orbe et al., 2016, and we tried to make this complementary aspect clearer in the revised manuscript.

The studies cited in the introduction section from lines 26 to 75 are mainly for emphasizing the important role of inter-hemispheric transport in regulating the distribution of atmospheric compositions, we include few studies about the impact of inter-hemisphere transport on the stratosphere. Most of previous studies are related to the inter-hemispheric transport in the troposphere. Our main goal is to extend the research to stratosphere, which is also important due to the chemical, radiative, and climate effect of atmospheric species in the stratosphere. The transport within the lower troposphere (or from NH surface to SH surface) is beyond the scope of this paper. We revised the introduction section to make the structure of the manuscript more logical.

(3) ***There needs to be clearer statements on what is new and what is confirming previous studies. The abstract contains several statements on the variation in the transport, but are these new results? Given the overlap with previous studies and limited mention or detailed comparison with these studies it is not clear which of these statements are new and which are just confirming previous studies. I think it is a bit of both, and this needs to be made clearer.***

A. Detailed comparisons are included in the revised manuscript to clarify which results are new compared

to previous studies. We revise the statements mainly in the "Abstract" and "Conclusions" sections (P1 L12-14 and P22 L430-440). It is revised like "We confirm the important role of ASM and westerly ducts in the inter-hemispheric transport from the NH extratropics to the SH. Furthermore, we find that it is an interplay between the ASM and westerly ducts which triggers such cross-equator transport from boreal summer to fall in the UTLS between 350 K and 370 K." in the abstract.

(4) ***One aspect that I think is new is the lack of IHT during northern winter. However, I am not sure if this not an artifact of the experiment design.***

***The results show virtually no transport to 10S in Dec and May (Fig 7a, h) (and according to text same for Jan-Apr). line 270-). This is very surprising, and not what is seen in other studies. I think there are many studies that show there is some IHT during NH winter. The most direct comparison is probably Orbe et al. (2016). The BIR calculations shown in fig 5 of Orbe et al. (2016) shows transport during NH winter that is similar magnitude to the summer. The summer transport in lower panel fig 5 of Orbe et al. (2016) actually looks very similar to fig 7d-e (and shows transport in monsoon and ducts), but the winter transport is very different in this manuscript. This is a clear example of a case where current results are not compared with previous studies by other authors.***

***Is this because a differences in the transport within your model that in previous studies or is it the method used? I think it may be the latter, as the setting boundary layer values = 0 outside the source regions means that near-surface transport south from NH source region is removed, i.e. if air is transported south near the surface before being lifted into free troposphere it will not be included in your IHT. Whether this is the case or not, there needs to be some more discussion of the lack of winter IHT and the reason for this (and inconsistencies with previous studies).***

A. Thanks for this good remark! Yes, we think that the lack of IHT during northern winter is likely caused by the model setup in our simulations with the species set to zero in the boundary layer outside of the origin region, which eliminates the cross-equatorial transport from NH extratropical surface to the intertropical convergence zone (ITCZ) and then ascent over the tropics and SH subtropics. The suppressed convection in NH (sub)tropics in boreal winter can not lift the NH extratropical air to high altitude likely causing the lack of inter-hemispheric transport during winter. In our study, transport out of the NH extratropics and into the tropics in the lowest model layer is forbidden, and subsequent ascent is referred to as transport from the tropical surface. This is clearly a difference to the study by Orbe et al. (2016), but we don't think that one of the approaches can be regarded as better - they are just complementary, focusing on different aspects of transport. We include the comparison with previous studies and explanations of the differences in the revised manuscript.

(5) ***The potential interplay between the ASM and westerly ducts is I think one of the potentially new results. However, I think some care is needed in discussing this. The upper tropospheric westerly ducts are in NH winter and there are typically UT easterlies throughout the tropics in summer (as fig 9a,c shows), and I think most of previous studies on ducts and transport have focused on the winter. You are not seeing this winter transport so I don't think it is fair to say your results are in agreement in this regard (line 359). Also, the existence of summer-spring westerly ducts appears to be altitude dependent (Fig 9) and so interplay might apply in LS but not UT. Also, your statements regarding interplay between the ASM and westerly ducts could be misread to be saying the summer ASM interplay with winter westerly ducts.***

A. We agree that the coupling between the ASM and westerly ducts depends on the altitude and the season. The interaction between ASM and westerly ducts mainly drives the inter-hemispheric transport during autumn in the UTLS due to the coincidence of the westerly ducts and a significant amount of NH air at UTLS levels, which was transported upwards by the ASM during the previous months. This coupling effect plays an important role in the inter-hemispheric transport from summer to autumn at the altitude level between 350 K and 370 K. Our statements before, indeed might have been misleading and we revised the statements about the results and conclusions accordingly (P18, P19, and P22).

# Minor comments

(1) ***Figs 1-4: The changing of the scaling used for NH, SH and tropics between these figures gets confusing. I think a reader could very easily compare between columns without seeing this scaling, and once they see this in one figure they may assume similar in next figures (At least that is what I did). It might be better to have separate color bars for each column. Figures will look the same but will I think be clearer from multiple bars that scale differs.***

A. The colorbar for each source region is now included in the figures in the revised version.

(2) ***Fig 6 What are the contours in these plots? They differ between each panel. Shouldn't the climatology be the same in each column?***

A. The contours represent the mean age of air from each source region (NH extratropics, SH extratropics, and tropics) to the atmosphere, hence they are different in each column.

(3) ***Line 269 "lager"***

A. It's corrected.