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Interactive comment on "Confinement of air in the Asian monsoon anticyclone and pathways of convective air to the stratosphere during summer season" *by* Bernard Legras and Silvia Bucci

Anonymous Referee #1

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General:
This a very important and well-written paper and should be published by ACP. However, it is too long. It took me a few days to read and understand all details. I would recommend to include everything related to the "simple model" into a second paper. There is also some potential to shorten the remaining material (see below). There are still few major points which can certainly be clarified.

Major points

- "...The ERA5 diabatic and kinematic results differ not as much from each other than the respective results for ERA-Interim...". An important question is, if this is because the frequency of the data rather than data quality (less noise) became better for ERA5 if compared with ERA-Interim? Thus, if for ERA5 the data frequency would be reduced from 1 hour to 6 hour, would we also get similar large differences between the diabatic and kinematic calculations?
- You do not talk too much about the tropopause, especially as a vertical transport barrier during slow ascent of the spiraling trajectories. Because I do not see any effect of such a barrier in your results, I would recommend to mention this point in your discussion/conclusion or maybe even in the the abstract, i.e. something like: "tropopause is not a transport barrier for the vertically ascending trajectories..."
- This trajectory-based study with "true" convective clouds is very impressive and technically extremely well done. However, this is only an extremely model-based view of transport without any comparison with observations. Because of this, the picture of spiraling trajectories is a biased picture of reality (in the same way like "chimney", "conduit" or "blower"). Maybe the authors would like to re-consider this point.
- Horizontal confinement versus vertical transport. You derive some numbers showing that the horizontal confinement of the anticyclone is relatively weak (compared with the circulation rate). I am not convinced that the e-folding times derived from figure 7 really quantify the erosion rate, i.e., bi-directional crossing of air parcels across the vortex edge, a process that is typically believed to define the horizontal confinement (see also the minor comments).
- The 1d model is a great mathematical tool to put many things together and to create a simply 1d picture. But it is too much for this paper. Maybe to divide the whole material into two parts would help.

Minor comments:

- P1, L24
  "due to a dominant radiative cooling" - not clear. Ascending motion means increase of the potential temperature of the considered air parcel. This means absorption of energy or warming. Maybe you should clarify this point.

- P2 L20-25
  In your abstract you write: "We find no trace of a vertical conduit above convection over the Tibetan plateau": Maybe you should discuss in this paragraph also the concept of conduit and the related literature (mainly Bergman at al. papers). Furthermore, you discuss the concepts of "chimney" and "spiraling ascent" as two "extreme views". Please do not forget that the concept of "spiraling ascent" (which you seem to like more) is strongly related to long-term (40 days or more) and non-mixing trajectories. This is also a strong idealization, without any experimental confirmation in the observed tracers.

- P2 L34
  "We also focus on reconciling previous studies...": This is for me too strong. The presented study including the 1D-model, does not contain any comparison with the experimental data. With the 1D-model you can get a different perspective on the presented, 3d-trajectory-based results. However, as mentioned above, I would recommend to have a separate paper describing the 1D model.

- P3 L21
  Maybe you can finish the sentence in L21: "...at a 0.25^0 horizontal resolution.", skip the lines 22 and 23 and follow with "The data are availably..." FullAMA will be explained in section 2.3.

- P3 L29
  ...cloud radiative heating (CRH) : Is it calculated as "all sky heating" - "clear sky

heating"?. It would be nice to mention it either in the text or in the caption of Figure 1. The green contour for ERA5 around the the equator between 17.5 and 20 km looks strange for me.

- P4 L10
  Are both terms: "latent heat" and "vertical heat diffusion" really available in both reanalysis products ERA-Interim and ERA-5?

- P4 L12-13
  I think, Ploeger et al., 2017 does not initialize the tracers in the boundary layer but above theta=360 K. Please reformulate.

- P4 L14
  ...converges rapidly to the (clear sky) radiative heating rate as a...

- P4 L19
  ...for several levels during summer 2017...

- P4 L19

- P5 L2
  S2 Montgomery potential. I did not find the derivation of (1) in Nakamura at al., 1995. Maybe this is the wrong citation or you should reference more exactly the used equation.

- P5 L 5
  Sattellitte - please correct

- P5 L 11
  in the FullAMA domain...?

- P5 L21
  "For each of these cloud pixels"...maybe better: "For each of the selected cloud pixels"
- P5 L27
  "...version is labeled EAZ. Additional two integrations..." - sounds better for me
- P5 L34
  "every 15' and 20": I would mention that this is the temporal resolution (see also L8)
- P6 L13-14
  It would be nice to know how the units of the convective impact factor shown e.g. in Fig. 2 (day^2/K) can be derived from your impact density
- P6 L18-20
  ...do not understand. sorry
- P6 L23
  "The impact can also be stratified according to": I am not sure that this is the best English formulation. Maybe "spectral-resolved with respect to age", however,"stratified" is certainly shorter
- P7, L2
  "...and decays from 0.88 at 350K to 0.52 at 420K"
  0.5 at 420K is really small. It means that only 50% of the convective sources in the FullAMA region are correctly counted. However, we are more interested in the air masses entering the stratosphere through the anticyclone and not through the FullAMA region. Maybe it would be better to calculate the accumulated impact for the AMACore rather than for the FullAMA region.

- Figure 3
  The used notation in this figure should be the same as in the main text (AMA $\rightarrow$ FullAMA, ("max global" and "max ERAI" is the same, maybe "max global (ERAI)", and the same with the $\sum$...)
- P 8 L 21
  ...Figure 4, bottom panel shows the distribution....
- P 8 L 22
  You can use your abbreviation AMACore...
- P 8 L 29
  ...propagates inside the FullAMA (?) domain from the sources...
- P 8 L 34
  Supplement: S3 is not used in the main text. Nevertheless it is interesting Maybe you can couple it with your main text.
- P 8 L 34, Supplement S4
  "The normalized impact then becomes an age spectrum...". In this definition of the age spectrum, mixing is not included. Although I know that this concept follows the idea of "irreducible air parcels" (e.g. Schoeberl et al., 2000), however, this is not the way how the age spectrum should be defined by integral operator replacing the full 3d advection-diffusion equation.
- P 9 L 8-9
  "As the vertical velocities are ascending everywhere" - All sky radiation in Fig. 4 shows negative values below 360 K both for ERA-I and ERA-5...? You mean the total diabatic heating rates and w in the kinematic case which are shown in S5? "must is located" - must be located.

- Main text + supplement
  It seems that there are few good arguments supporting the kinematic approach to quantify the impact density at 340 and 350 K levels (descending branches of the Hadley and of the Hadley-Walker circulations). Maybe it is better to start your arguments with ERA-Interim (Figs. S9 and S10, where these branches are more visible) and continue with ERA-5 (Figs. S7 and S8). I also think that the partition of text (and arguments) between the main text and the supplement can be improved.

- P 9 L 17
  Once again, this is for me not the clean definition of the age spectrum (see above)

- P 9 L 19
  "The fastest propagation by EAD....while the slowest propagation by EID" - I think EAD and EID should be exchanged

- Figure 8
  The colors are not explained. Also it is not clear if the total impact is calculated for FullAMA or AMACore ?

- P 9 L 34
  What did you assume for A? According to your equation, $A = 1/(0.69\alpha)$, it will lead to $A = 0.109$ K/day. I do not see in Figure 4b that this is the mean value of the diabatic ascent. On the other hand, you use in your 1d model values of $A = 1$ K/day. Please clarify

- P 9 L 34
  I am also not really convinced that $\alpha = 13.3$ day derived from Figure 7 can be understood as the erosion rate. Clear, the number of convective air parcels is becoming smaller with the altitude because, as you show, the total convective impact decreases with the altitude. But it is not clear, if these air parcels stay e.g.

at the (inner) edge of the anticyclone (with low diabatic heating rates) or really cross this edge and move, roughly isentropically, into the regions outside of the anticyclone (such crossing of the edge could be interpreted as the erosion of the anticyclone).

- P 9 L 34
  If your calculation is correct, you get a picture of "upward spiraling air within a chimney" crossing the tropopause and maybe crossing the edge of the anticyclone (see above). The latter behavior, above the tropopause, is sometimes denoted as a blower.

- P 10 L6-24
  This part of the text is very similar to the discussion on page 9, L8-15. The figures 8 and 9 are almost the same like figures S7 and S8 discussed before. I think, the logic can be improved here. An idea for the sensitivity study would be to check how your results (total impact) will change if you confine your region from FullAMA to AMACore defined by different values of the Montgomery stream function.

- Figure 10
  The characters of the potential temperature values in the last column are too small I also think that this figure can be moved to the supplement.

- P 11 L4
  ...contribution of sources as the altitude rises...

- General
  In all your pictures it is difficult to localize the Tibetan Plateau.

- Figure 11
  Left column: This is a very nice way to show how the spiraling stars in the center

of the anticyclone (or spiraling within the chimney). Right column: why you do not use the same color bars like in the left column. I would expect the same spatial distribution of the mean age like in the left column. Because of this, figures (h) and (j) look very confusing for me.

- P 11 L32
  maybe: ...in reanalysis-based cloud properties and...
- P 12 L30-37
  Here I lost your way of arguments. Maybe a stronger relation to the lines in the table and more small-steps explanation of the numbers (like 2.57, 0.41 or "inverted contribution") would help
- P 13 L 13
  You should give here the definition of $S = S_0 \exp -\beta....$
- P 13 L 23
  "Consequently, the distribution of convective sources..." I thought that this distribution is prescribed by S. Maybe you mean the distribution of air parcels originating from the convective sources
- P 14 L 5
  I think, the figure S12 is so important to understand the 1d-model that it cannot be moved to the supplement. By the way, I did not find at which level all the distributions are shown in figure S12.
- P 14 L 5
  Parameter α describing the erosion rate. It is not clear if this parameter in the 1d-model is the same like that introduced in 3.2. The numbers seem to be very different. In relation to the 1d-model you do not introduce it in the main text and even in the supplement you do not say what is the basic value of α (S9 L8-10).

- P 14 L 19
  "...provide a consistent description.." - see my first main comment
- P 14 L 31
  "...leaky circulation..." - I do not see a good proof of this statement (see my comments above)
- P 15 L 1-2
  "...As the level rises, the confined Asian monsoon is more and more diluted..." - same type of problem. See also abstract: "The contrast is reduced by dilution...". Which type of dilution: in-mixing of old stratospheric air into the anticyclone? But you do not have any proof of that.
- P 15 L 18
  "...rather than concentrated in a narrow pipe." - It means for me, it is certainly not a conduit but much more a chimney, with some upward spiraling air inside.

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