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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Lagrangian simulations of the transport of young air masses to the top of the Asian monsoon anticyclone and into the tropical pipe" *by* Bärbel Vogel et al.

Anonymous Referee #1

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This manuscript uses back trajectories and full 3D CLaMS simulations in conjunction with MIPAS HCFC-22 measurements to elucidate the transport pathway of air masses emitted in defined boundary layer regions through the Asian summer monsoon anticyclone and into the tropical pipe. The modeling tools and measurements are well suited to the investigation, the analysis is generally well thought out and well executed, and the findings will certainly be of interest to the journal readership. I do, however, have a number of substantive comments that I would like to see addressed before the paper is accepted for publication in ACP.

Specific substantive comments and questions:

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Discussion paper

Sections 2.2 and 3.2.1: 40 days seems like a very long period for trajectory calculations. I realize that CLaMS 40-day trajectories have been published previously, but nevertheless I think that a sentence or two on how much error has accumulated over the course of such long trajectory calculations would be appropriate, either in Section 2.2 or in Section 3.2.1.

Section 2.4: I miss in the description of the MIPAS HCFC-22 any information about the accuracy, precision, or horizontal or vertical resolution of the measurements. Some discussion of the data quality is warranted to help evaluate the comparisons with CLaMS results later in the manuscript. This information may be contained in the paper by Chirkov et al., but some basic data quality information needs to be included here as well for the convenience of the reader. See related comment below.

P7, L29 – P8, L11: These paragraphs are confusing, because the first sentence (P7, L29), as well as the subsection title, refer to transport of emission tracers to "the top of the Asian monsoon anticyclone", yet Figure 2 (top row) and the related discussion focus on 360 K, which is obviously not at the top of the anticyclone. It may be that the discussion begins with 360 K because that level is where regions "inside" and "outside" the anticyclone are defined, which seems to be what is implied by the sentence in P8, L9-10, but if so then that motivation needs to come earlier in the paragraph to set the stage. Moreover, if that is the case, then I am confused by that as well – why define inside/outside the anticyclone at a single level, rather than at each considered level, since the shape of the anticyclone changes considerably with height? And Fig. 3 defines the anticyclone by the 20% contour of the India/China tracer at 380 K (not 360 K). So this entire discussion needs to be clarified.

P8, L15: To my eye, it looks as though fractions as high as 40% extend lower than 350 K, down to at least 340 K, if not lower.

P8, L20-21: It is not clear exactly which regions are being referred to for these values; in particular, in some areas (~310-330 K, 10N) fractions from the tropical adjacent

regions much higher than 10%-40% are seen.

P8, L28-29: First, the region “inside the anticyclone” is referred to here, but it is not possible for the reader to identify where the anticyclone boundary falls at different altitudes in the cross sections of Fig. 2. The authors should think about how to convey information about the approximate location of the anticyclone in these panels. Second, it is stated that near the tropopause the fraction from the tropical adjacent regions reaches as high as 35%, but I am not sure exactly where is being referred to, as most TAR fractions in the vicinity of the monsoon in Fig. 2d are no larger than 25-30%.

P9, L11-25: I agree that the HCFC-22 data show good agreement with the India/China emission tracer and that they are a very useful element of the analysis. However, Fig. 3 reveals quite a few stray data points well outside the anticyclone that also have elevated HCFC-22 abundances. As mentioned earlier, the precision of an individual data point should be given so that the agreement in Fig. 3 can be fully evaluated. It seems to me that the enhancement in the thin filament (L15) does not particularly stand out in the measurements; indeed, in the absence of the CLaMS results to guide the eye, it likely would be overlooked altogether. Likewise, the measured enhancements at the top of the anticyclone above the tropopause (L20) are also fairly modest; in fact, they are not much different from other high MIPAS points well away from where CLaMS indicates a signal (e.g., at the EQ at 370 K, at 5N at 420 K, and at 30N at 430 K). It might help to also overlay on these plots (both the map and the cross sections) a solid contour highlighting a selected HCFC-22 mixing ratio. Although the “dot plots” are very valuable for representing the sampling of the MIPAS measurements, they do make it more difficult to get an impression of the overall morphology. Overlaying one specific contour from a gridded HCFC-22 field might strengthen the case for good agreement with the modeled tracer. Finally, although I do see a steep vertical gradient in the HCFC-22 data from $\sim$350 to 360 K in the $\sim$25-40N region, I do not see a corresponding signature in the India/China tracer in that region (L25); there is a steep gradient in that tracer in Fig. 2g, but at altitudes below 350 K, so the patterns in the 350-360 K region

are not really that similar.

P10, L6-11: Again, this discussion refers to “within” and “in the core of” the anticyclone, so some means of delineating exactly where that region is at each level is needed. In Fig. 3, the 20% contour for the India/China tracer is used to approximate the boundary of the anticyclone at 380 K, but what about at the higher levels shown in Fig. 4? How is the reader to gauge that the largest contributions of both emission tracers are found within the anticyclone at 400 K but around its edge at 420-460 K, as stated here? In fact, I am not convinced that either statement is true: the eastern lobe of the anticyclone ($\sim$100E) shows the largest fractions of the TAR tracer along what looks to me more like the edge of the anticyclone at 400 K, whereas the largest values of both tracers seem to be concentrated in the core region at that longitude at 420 K.

P10, L16-19: How were the percentages of young air masses for the selected air parcels chosen? In the absence of any explanation these values seem arbitrary. Are these trajectories initiated from the entire region within the defined lat/lon boxes? I’m wondering if these percentages can be related to the values shown for the India/China tracer in Fig. 4.

P10, L22-23: How consistent are the trajectory results, which indicate that the Tibetan Plateau and the western Pacific are preferred regions for fast uplift, with prior studies (in other words, some citations would be appropriate here).

P10, L24-26: Is there a reason that the corresponding plots for the eastern lobe of the anticyclone were not shown in Fig. 5, as they were in Fig. 6? I would have thought that they would be relevant to the discussion here.

P11, L14-26: What exactly is meant by “substantial” upward transport (L14)? Does “substantial” mean 0.5 K/day, 1 K/day, or?? It would be better to be more quantitative. In addition, here the discussion is cast in terms of heating rate (K per day), whereas Fig. 7 and Fig. A1 show the change in potential temperature (in K) along 20-day trajectories, making the reader do the (admittedly easy) math. Once the meaning of

"substantial" is established, it would be better to qualify the transport experienced by air parcels grouped in filaments as being "substantial" or "strong" (L16) – filamentary structure is not present everywhere that air parcels have experienced some uplift. I also think it would be better to say "largely", rather than "only", in L26 because there are red dots outside the monsoon region, especially in July and August.

P12, L11: It might be good to explain why the emphasis has shifted from the tropical adjacent regions examined in previous figures to Southeast Asia specifically in Fig. 9, especially since Fig. 12 shows that the TPO also makes a substantial contribution to the air at 550 K.

P12, L14-17: It is stated that an enhanced signal from Southeast Asia of up to 25% (L14 and L17) is seen around 550 K for the S07 pulse, but as far as I can tell from Fig. 9, the largest S07 enhancement (at ∼10S) is only ∼12%, not 25%.

P12, L27-28: I do think it is important to point out the uncertainties in the reanalysis heating rates, as done in these lines. However, the way this paragraph ends leaves the reader hanging a bit. What is the take-away message? Can we trust the results in Fig. 10 or not? What are the possible implications for the 'upward spiraling range'?

P12, L29: It is stated that Fig. 11 shows the same cross sections as Figs. 8 and 9. The latter two figures, however, show results only for the eastern lobe (90E), whereas Fig. 11 also shows the cross section for 30E. Although we have some information about S08 in that region from Fig. 2, we do not get the full picture from that figure, and thus we have little to compare to the left panel of Fig. 11. I note that, in terms of major features, the HCFC-22 results look quite similar at 30E and 90E. Is that also the case for the CLaMS results, that is, do the corresponding plots at 30E look similar to those in Figs. 8 and 9? If so, then that should be mentioned, and perhaps the left panel of Fig. 11 should also be omitted. If not, discussion of the differences should be included.

P16, L3-4: Has evidence for a coherent signature of the existence of the anticyclone and influence of monsoon air up to altitudes as high as 460 K been reported previously?

It seems to me that this may be an important finding that has been underemphasized in this manuscript.

P26, Fig. 2: Perhaps it would make the maps in the top row too cluttered, but I think it would be helpful to draw on them a horizontal line at 25N and vertical lines at 30E and 90E to orient the reader for the cross sections in the bottom panels. In addition, I understand that a common color bar is used for all panels in this figure, and I agree that that is probably the best approach, and I further agree that extending the color bar to 100% is appropriate for the cross sections. However, I note that employing such a color bar renders some of the features in the maps less prominent. For example, the filament at 50E seen so clearly at 380 K in Fig. 3, where the tracer color bar extends only to 50%, is nearly invisible in Fig. 2 but might show up well if the color bar range were reduced. I am not suggesting that the color bar should necessarily be changed, merely pointing out the issue.

P27, Fig. 3: I found the figure layout and accompanying discussion hard to follow. Here the latitude-theta cross section at 30E comes first, then the one at 90E, and finally the longitude-theta cross section, which is essentially opposite to the order followed in Fig. 2. It would make it easier to compare the CLaMS and MIPAS results if Fig. 3 were configured as a single-column figure following the same layout as Fig. 2 (with an extra panel at the top for the India/China tracer and the MIPAS panels corresponding to those in Fig. 2 below). In addition, I do not understand why only in Fig. 2 are the panels labelled. Panel labels would be helpful in Fig. 3 and all other multi-panel figures as well. This would simplify referencing the figures in the text, eliminating the need to always point to top, middle, bottom, left, right, etc.

P31, Fig. 7: Again, I think this figure would work better laid out in a single column. In addition, I find the transition between upwelling and downwelling in these maps awkward – the zero value of delta(theta) lies between two pale blue colors, and thus cannot be readily identified.

Minor points of clarification, wording suggestions, and grammar / typo corrections:

P1, L9: To avoid any possibility of confusion, I think “boundary sources” should be “boundary layer sources”; also in this line “transport pathway” should just be “transport”

P2, L1: I think it would be better to add “and is” between “summer” and “associated”

P2, L9: a large variability –> large variability; anticyclone reaching –> anticyclone, which reaches

P2, L13: referred –> referred to

P3, L7-8: relation . . . influence –> relationship . . . influences

P3, L11-12: with observations of global . . . measurements of the –> with global . . . measurements from the

P3, L25: the the –> the; between 360 K –> from 360 K

P3, L33: as –> us

P4, L5: at top –> at the top

P5, L27: having “Tropical AR” in quotes and bold font gives the reader the impression that this is an important acronym that will be used again, whereas “tropical adjacent regions” is always written out in full in the text. “Tropical AR” seems to be used only in figure labels; in Table 1 this area is referred to as “TAR”. It would be better to be more consistent in the usage.

P6, L5: an added –> added

P6, L22-23: associated to –> associated with; delete “anymore”

P6, L26: Asia –> Asian

P7, L6 and also L8: synoptical –> synoptic

P7, L26: the 18 August –> 18 August

P8, L1: and for the –> and that for the

P8, L6-8: the lack of strong tracer gradients on the equatorward side of the anticyclone has been noted several times, so some references to previous work would be appropriate here.

P8, L15: low values of the tropical adjacent regions –> low fractions from the tropical adjacent regions

P8, L24-25: this wording is confusing. It would be clearer to say: “At 90E (Fig. 2c), a layer of young air masses with enhanced India/China fractions extends well above the thermal tropopause, with values as high as 20% up to 420 K.”

P9, L4-5: “in particular” is repeated twice in these lines, thus “restricted regions, such as” would be better. In addition, this point was made previously not only in Section 1 as noted, but also in Section 2.4 (P6). It may not be necessary to provide this information three times, so the authors might consider deleting it from Section 2.4.

P9, L9: delete “percentages of”; are marked –> is marked on the cross sections

P9, L18: mode –> modes; also, I feel it would be more appropriate to say “broadly consistent”

P9, 26: it would be clearer to say “smaller” rather than “lower” mixing ratios (since this sentence also talks about “below” and “above”)

P10, L6-8: Restructuring this sentence would make it easier to interpret: “At 380 K, the highest fractions of air from India/China and from the tropical adjacent regions are found in the core of the anticyclone and at its edge, respectively.”

P10, L10: “vertical upward” is redundant in this context; use one or the other, not both

P10, L15: started –> starting; mode –> modes

P10, L26: upward transport –> vertical transport (to avoid repeating “upward”)

P10, L27: part –> parts

P10, L29: western and eastern part –> western and eastern parts of the anticyclone

P10, L30: “vertical upward” – same comment as above

P11, L10: mode –> modes

P11, L11: to what does “in this region” refer? The tropics, or 360 K, or ???

P11, L18: mode –> modes

P11, L29: the Appendix A –> Appendix A

P12, L7: boundary regions –> boundary layer regions

P12, L9: winter time –> winter

P12, L10: boundary emissions –> boundary layer emissions

P12, L17: larger as –> larger than; also delete “(Winter 07/08 pulse)” after “tracer”

P12, L18: winter time –> winter

P12, L23: analysis –> reanalysis

P12, L26: tropopause which again are –> tropopause, which in turn are

P12, L29: longitude –> latitude

P12, L32: from Summer –> from the Summer

P12, L34: Asia –> Asian

P12, L31: it might be good to add “just” here: “a combination of just two signals”, to make a stronger contrast

P13, L1: winter time –> winter

P13, L4: velocity –> velocities; summer time –> summer

P13, L6: exists; that –> exist that

P13, L11: This point was already made in Figs. 8 and 9; thus it would be better to refer back to those figures here than to point ahead to Fig. 12, which is not introduced until the following paragraph.

P13, L12: boundary –> boundary layer

P13, L26: highest –> largest

P13, L30: boundary emission –> boundary layer emission

P14, L3: the the –> the

P14, L7: contribute to a lower –> contribute a smaller

P14, L8: CLaMS –> the CLaMS; include –> includes

P14, L30: the the –> the

P15, L17: is already –> has already been

P16, L20: 1 K per day - 1.5 K per day –> 1-1.5 K per day (as done everywhere else in the paper)

P16, L22-30: these lines are a bit garbled. First, it is odd to have a 1-sentence paragraph (L22-24). Second, L30 starts with "Further" but then repeats verbatim the sentence in L23-24. These sentences need to be merged / rearranged / rewritten. Third, the sentence in L25-26 is hard to read. It would be clearer to say: "Thus, within the upward spiralling range above the anticyclone, young air masses from along its edge originating in the tropical adjacent regions are mixed with air masses from inside the anticyclone mainly originating in India/China." Finally, L29: consisted –> consistent

P17, L2-5: It is stated that fresh emissions from the 2008 monsoon season do not contribute to the distribution within the tropical pipe at 550 K. However, emissions from that season would eventually reach 550 K, so this statement needs to be qualified

in some way (for example, by adding “before October 2008” or something similar). Similarly, it might be good to add “in October 2008” after “550 K” in L5.

P17, L8: here too I think it would be better to delete “pathway”

P17, L13-14: region air masses from the tropical adjacent regions (Southeast Asia/tropical Pacific/northern Africa/northwestern Pacific) are transported in a substantial percentage by this pathway into the tropical pipe –> region, a substantial percentage of air masses from the tropical adjacent regions (Southeast Asia/tropical Pacific/northern Africa/northwestern Pacific) is transported by this pathway into the tropical pipe

P26, Fig. 2 caption: Rather than “first” and “second”, it may be better to refer to the tropopauses as “primary” and “secondary”. Also, in the last sentence, “percentages” should be deleted, and “(cross sections)” should be added after “white lines”.

P27, Fig. 3 caption: thick black or grey lines –> thick black (maps) or grey (cross sections) lines

P29, Fig. 5 caption: reversed –> back; single –> successive

P30, Fig. 6 caption: reversed –> back

P31, Fig. 7 caption: are shown –> is shown; 1st row –> 1st panel; rows –> panels

P32, Fig. 8 caption: again, “primary” and “secondary” may be better than “first” and “second”

P33, Fig. 10 caption: again, “primary” and “secondary” may be better than “first” and “second”

P34, Fig. 11 caption: eastern mode (80E-100E) –> eastern (80E-100E) mode

P35, Fig. 12 caption: (1) this would be easier to read if “(top)” were moved to before “The contribution” in L1 and “(bottom)” were moved to before “The contribution” in L5.

(2) “by October 2008” should be added at the end of “550 K” in L4. (3) “The contribution of the three time pulses” –> The contributions of the time pulses” (it is confusing to say three since only two are shown). (4) in the legend of the figure itself, “Residual” should be “Residual surface” to be consistent with the text.

P36, Fig. 13 caption: transport pathway –> transport

P38, Fig. A2: In the legend, Residual –> Residual surface

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