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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Overshooting of clean tropospheric air in the tropical lower stratosphere as seen by the CALIPSO lidar" *by* J. P. Vernier et al.

Anonymous Referee #3

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Review of the paper " Overshooting of clean tropospheric air. . . " by J. P. Vernier et al.

The paper presents the time evolution of aerosols in the tropical upper troposphere-lower stratosphere (UTLS) as measured by the spaceborne CALIOP instrument aboard the CALIPSO satellite. Low amounts of aerosol scattering ratios (SRs) propagate in the Northern Hemisphere (NH) winter from 14 to 20 km in a time frame (1-4 months) much more rapid than the expected slow ascent mechanism as broadly accepted in the Troposphere-to-Stratosphere Transport. The mechanism of clean aerosol air to propagate so rapidly in the UTLS is explained to be caused by overshooting towers, particularly marked in the southern tropics. In the northern tropics, overshooting tow-

ers and horizontal mixings tend to reload clean air into aerosols. Based upon these assumptions, the air flux from the troposphere to the stratosphere is estimated to be 5-20 times larger than the slow ascent by radiative heating. Consequently, the conclusions are that the convective overshooting mechanism is far from being negligible at global scale over the tropics.

This paper is very well written and, as based upon a very good quality data set from CALIOP/CALIPSO, shows a vertical propagation of air (clean air) much more rapid than the slow ascent by radiative heating. In my opinion, this is already excellent. I am very well convinced by the study over the Southern Hemisphere (SH) tropics, that is very robust, and I am keen in accepting the very challenging conclusions of the paper. But I have two main concerns (that will be detailed below). First of all, I am much less convinced by the interpretations of this apparent fast vertical motion, I mean the differences or the lack of differences between NH and SH tropics. There is indeed an asymmetry between NH and SH tropics, both in overshooting intensity and aerosol loading, and, although the explanation seems robust to interpret the temporal evolution of SRs in the SH, it cannot (in my opinion) explain the evolution of SRs in the NH. My second concern is the calculation of the flux between troposphere and stratosphere by considering the measured SR-1 as proportional to an aerosol mixing ratio, and the possibility of missing loss paths in the model, thus estimating an upper limit of the flux intensity. Thus, I can recommend the publication of this paper in ACP once the points listed below are obviously stated.

Major points

1. Convective overshooting

a) In order to underpin the fast vertical motion, I would draw on Fig. 1 an incurved vertical line starting at least on JAN-FEB 2008 (eventually on FEB 2007 and 2009) that will follow the propagation of the clean air from $\sim$14 to $\sim$20 km. Over this line, I would draw a line symbolizing the slow ascent by radiative heating, as on Fig. 2. This will help again stressing that the propagation of clean air from CALIOP in much more rapid that slow ascent.

b) On Fig. 3 (left), the minimum in CALIOP SR around 19 km does NOT coincide with any minimum of aerosol mixing ratio from balloon-borne OPC (minimum from 14 to 19 km). It is fine for BKS measurements (same units) showing a minimum around 19 km. Is this related to the fact that you compare two different quantities, CALIOP SRs and OPC mixing ratios?

c) Fig. 4 : the 6 boxes absolutely needs to be enlarged and eventually the colours will need to be modified. It is impossible to detect the fine structures of less clean air around 16 km in the NH in APR-JUL, unless zooming a PDF file on a screen. Also, the Colour Chart is missing.

d) I really cannot understand Fig. 5, although I spent several days on it. If I consider CALIOP/TRMM measurements in the SH (lower panel), the convective overshooting period is in phase with the propagation of a minimum CALIOP SR, starting in November. As on Fig. 1, you could eventually draw the vertical displacement of the miminum of SRs compared to the slow ascent calculations. This is obvious. Now I consider the same Figure, but for measurements in the NH (upper panel). Although the TRMM overshoots are 6-month out-of-phase compared to be SH, the CALIOP SR time evolutions at different altitudes in the NH are completely consistent with the one in the SH. I understand you can have horizontal transport and the propagation of (clean or polluted) air from one hemisphere to the other, but I am puzzled by the fact that 1) there is no phase shift if the SR evolution between the two hemispheres, and above all, 2) SR evolution is the same considering either SH or NH tropics. This is the main weakness of the paper, namely explaining why SRs in the SH and NH tropics behave consistently despite the fact that AODs and overshoots strongly differ.

e) Now, we examine whether air lifted in the convective overshoots is poor or enriched in aerosols. Again, Fig. 6 is quite small and would require an enlargement. Anyway,

on my screen zooming the PDF file, we can notice that associated with the overshoots, and particularly over the African continent, is a minimum in aerosol optical depths. Is this an issue to be raised regarding the sampling of the CALIPSO vs. TRMM measurements, namely a lack of CALIPSO data or actually a minimum in AOD?

f) I understand there is slightly more AODs in the NH compared to the SH in the vicinity of the convective overshootings. Then, an Aerosol Index is calculated. This is indeed a good idea. Unfortunately, Fig. 7 shows the time evolution of the AI considering the whole tropical band, 20°S-20°N. You absolutely need to consider the two bands (NH and SH tropics) and eventually the global tropics since at this stage, I do not really know why SRs behave similarly in the NH and the SH. Furthermore, on this Fig., CALIPSO SRs and AIs seem not to be sampled in the same interval: 15 days for SR, and 30 days for AI. This should be stated or calculated using the same time sampling. Finally, I cannot understand the sentence "The minimum observed, delayed by 2 months…", and more generally, all the paragraph starting Page 173 Line 22.

2. Aerosol mixing ratio

I am not a specialist in aerosols, but all the discussions related to the impact of overshooting at the global scale (Section 4.2) depends on 1) the fact that you suppose (SR-1) to be proportional to an aerosol mixing ratio, and 2) a conceptual model describing the mass flux conservation in terms transport processes. First of all, you have to clearly specify why the proportionality assumption is valid in this particular context. What kind of approximations you perform? Note for instance the differences in SRs and mixing ratios in Fig. 3. Secondly, the conceptual model refers to a sort of long-lived species since only transport processes are taken into account. In my opinion, aerosols cannot be considered as long-lived species, since several processes can alter its evolution (wash out, sedimentation, nucleation, etc.). My understanding of the calculation performed is that, by only considering transport terms, you get rid of other loss terms, that can eventually be negligible, I can admit this point but we do not know. This needs to be developed or discussed. At that stage, I would consider these calculations as an upper limit of the troposphere-to-stratosphere mass flux, explaining why the figures are so big (up to 20 times) compared to values from radiative calculations.

Minor points

P. 169, L. 1: write “do not” instead of “don’t”

P. 172, L. 18: you should remove the first “WV”

P. 172, L. 26: should be “anticorrelated”

P. 174, L. 11: “beta-aero” and “beta-mol” are not defined

P. 175, L. 18: the reference “Pommereau et al., 2010” is not present is the Reference List.

P. 185, Caption of Fig. 1, remove one “after”.

P. 186. Fig. 2, as proposed in Fig. 1, I would draw one line (maximum of 3) showing the evolution of the clean air bubbles along the vertical in FEB 2007, 2008, and 2009.

P. 189, Fig. 5, again I would draw a vertical line showing the vertical displacement of the clean air parcels in the SH and NH tropics. Eventually, show the radiative heating calculations.

P. 191, to be split into 2 or 3 Figs.: NH, SH and global tropics.

P. 192, Fig. 8: y label is missing, I guess “height”, together with the x label and values.

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