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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Delivery of halogenated very short-lived substances from the West Indian Ocean to the stratosphere during Asian summer monsoon" *by* Alina Fiehn et al.

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We would like to thank Reviewer 1 for the comments to improve the manuscript. Below, you find our answers to the specific points. The reviewer's comment is marked with 'RC:' and is enclosed in quotes, our answer in normal font.

RC: "Summarizing, the paper is well-written and presents an important contribution to our understanding of transport of the short-lived species from the boundary layer over the West Indian Ocean into the stratosphere. It should be published after some minor revisions."

We thank the reviewer for this very positive review.

Answers to the specific comments of the reviewer:

RC: "This leads to my first critical remark: The authors claim, that the value of 17 km height for the location of the tropopause represents the average cold point tropopause during the cruise and for the whole tropical region. [. . .] But why not using a tropopause location computed from the ERA Interim data, the same data underlying the transport calculation? I am not doubting the general location of the maximum entrainment areas, but using the ERA Interim based tropopause would be much more convincing and more consistent."

We tested several definitions for stratospheric entrainment for our trajectory runs. Flexpart includes the lapse rate tropopause (LRT) calculation after the WMO (1957) definition. Using our Flexpart/ERA-Interim trajectory runs this tropopause lies lower (14 15 km, see Fig. R1 below) than the one we observed during the cruise (17.0 km Fig S2 from paper) and the one inferred from satellite measurements during JJA at the equator (LRT 16.2 km, cold point tropopause (CPT) 16.7 km (Munchak and Pan, 2014)). In the Asian monsoon anticyclone the tropopause lies even higher between 17.2 (LRT) and 17.6 km (CPT) height for a 4 year mean (Munchak and Pan, 2014). A temperature threshold of 192 K (average CPT temperature over the Indian monsoon region in JJA (Kim and Son, 2012)) lead to a tropopause height around 16.5 km (Fig. R1). Thus, we decided to use 17 km height as a conservative approximation to the tropical tropopause height over the Indian Ocean and Asia during boreal summer and added other entrainment altitudes (13, 15, 18 km) in the supplementary material.

RC: "Speaking of this, ERA Interim provides much higher horizontal resolution than used. Why not using it for better, more accurate trajectory results, better resolved convection and better tropopause location? Even the Flexpart parameterizations for vertical transport and convection could benefit from this."

The spatial resolution of the current available ECMWF reanalysis from 1979 onwards, ERA-Interim, is approximately 80 km in grid space (T255 triangular truncation) on 60 vertical levels from the surface up to 0.1 hPa. Thus the chosen 1ËŽx1ËŽ grid resolution (111 km at the equator) is very close to the original model resolution. Higher spatial and vertical resolution ECMWF data is only available from the operational model with T1279 and L137 (since 2010 and 2013 respectively). However, the high resolution operational model was not suitable for our study on a longer interannual time series due to regular changes of the operational ECWMF weather model in order to improve the forecast.

RC: "To investigate more on stratospheric entrainment and the role of the West Indian Ocean a third forward trajectory model run is started with domain filling trajectories from a rectangular area over the area of interest (Indian Ocean setup). In this context now VSLS tracers are used, which undergo an exponential decay according to certain tropical tropospheric life times. This is in contrast to the vertical life time profile used for the simple OASIS setups, and I am not sure, why there are two different life times used. May be the authors can comment on this."

The two calculation methods differ slightly from each other in their timing of the calculation of compound decay. For the first method, the VSLS emissions are attached to the trajectories and the decay is calculated online with the model. The height of the particle position is known and can be used for determination of lifetime according to the vertical profile. For the second approach, the VSLS tracer transport is attributed to a trajectory after the model has been run by considering the transport time. We added the following explanatory sentence in line 264: "The use of VSLS tracers allows us to evaluate one model run for different compounds with varying lifetimes."

RC: "There is one more remark about the investigations with respect to the spatial variability of the stratospheric entrainment: In line 502 the definition of two core entrainment areas are mentioned, which are assumed to be evenly sized (and are shown in Fig. 6). It should be noted that these two regions may be evenly sized in grid space (that is 20 x 25 degrees), but not in area. Furthermore just by looking at the plots, one could think of moving the core entrainment box for the local convection 5 degrees more

to the east for a better capture of entrainment. But maybe these boxes are chosen to be similar to Chen et al. (2012). If this is the case, it should be mentioned."

Thanks for this comments. Yes it is true. Geographically, the entrainment areas are not evenly sized. We reformulated to "... and to be evenly sized in grid space" in line 502. The entrainment areas were not chosen to be similar to Chen et al. (2012). We will furthermore move the Local Convection entrainment area 5ËŽ to the east. This will also lead to changes in Fig. 6, Table 6 and the numbers in Sect. 4.2.

RC: "In the last part of the study the simulation with the Indian Ocean setup is extended to 16 years to specify inter-annual variability. To quantify the influence of different transport regimes (local convection and Asian monsoon) on the total entrainment, the respective time series are correlated by using Pearsons correlation coefficient. It should be noted, that for all values not -1 or 1 Pearsons r is not meaningful, as long as there is no linearity between the two times series and/or if the values are not normally distributed. If there is a linear relationship, than correlation coefficients of 0.54 and 0.56 only explain 29% and 32% of the observed variance, meaning that roughly 70% of the variance is not explained. Even for a value of 0.87 (as for CH3I) just 75% of the variance are explained. To decide, whether these values are significant, you need to do a t test. A much more robust method, which does not imply linearity, but only monotonicity is Spearman's rank correlation coefficient. There is a similar method introduced by Kendall. I would recommend to use one of these rank correlation coefficients, which is fairly easy to do, but would give more meaningful results."

Thanks for this discussion. We checked all our time series for normal distribution. They are normally distributed and thus Pearson correlations can be applied. Then we calculated p-values to infer the significance of the correlations in Table 6. We marked all 95% significant correlations in bold face. We also calculated the Spearman's rank correlation coefficients. These differed less than 0.1 from the Pearson correlation coefficients and thus we would like to continue using the Pearson correlation.

RC: "The values shown in figure 6 are labeled as tracer density (given in percent). Is this meant to be the same as tracer entrainment?"

Yes, it is meant to be tracer entrainment, but the relative distribution of this tracer entrainment. So it could also be named relative tracer entrainment, or entrainment density. We changed the label in Fig. 6 to “entrainment density”.

Citations Kim, J., and Son, S.-W.: Tropical Cold-Point Tropopause: Climatology, Seasonal Cycle, and Intraseasonal Variability Derived from COSMIC GPS Radio Occultation Measurements, Journal of Climate, 25, 5343-5360, 10.1175/jcli-d-11-00554.1, 2012. Munchak, L. A., and Pan, L. L.: Separation of the lapse rate and the cold point tropopauses in the tropics and the resulting impact on cloud top-tropopause relationships, Journal of Geophysical Research: Atmospheres, 119, 7963-7978, 10.1002/2013jd021189, 2014. WMO: Definition of the tropopause, WMO Bull., 6, 136, 1957.

Figure R1: Height of trajectories at entrainment locations using different tropopause definitions. Dashed lines show the lapse rate tropopause from ERA Interim, and solid lines the height of trajectories reaching temperatures below 192 K. 30SN means stratospheric entrainment between 30°S and 30°N and so on.

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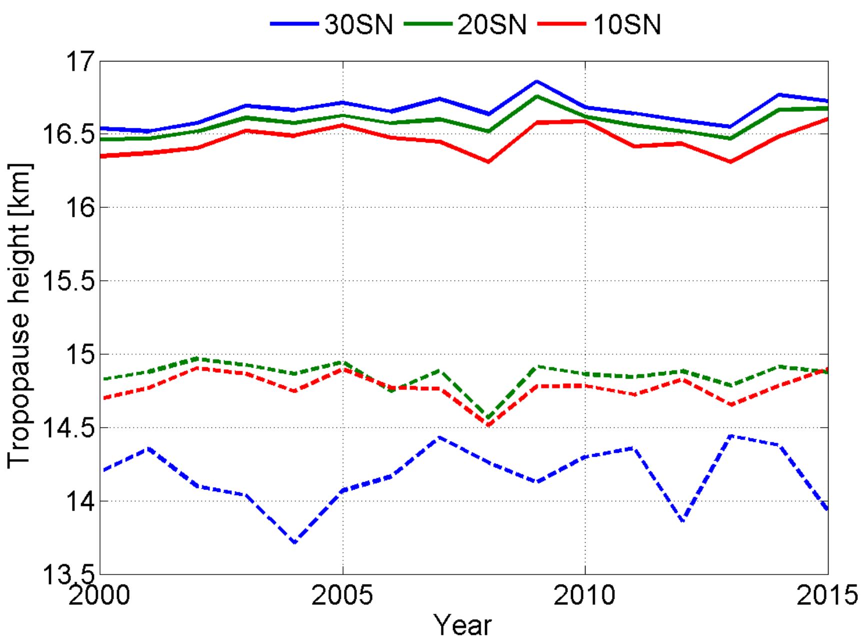

Fig. 1.