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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Water vapor increase in the northern lower stratosphere by the Asian monsoon anticyclone observed during TACTS/ESMVal campaigns" *by* Christian Rolf et al.

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The authors thank reviewer #1 for the many fruitful comments which were helpful to improve the paper. All changes to the paper are highlighted in red color. Point by point answers to your comments are reported below.

Major comments

- *- I think it is necessary to include more background in the introduction. This may include, but not limited to, characteristics of the monsoon anticyclone and why*

the transport in and near the Asian monsoon anticyclone is important in global scale circulation.
We included more information about the Asian monsoon and to transport pathways to better introduce the background and to motivate this study. For example, we now discuss the papers by Randel and Jensen, 2013, Ungermann et al. 2016.

- *- It is not clear what the scientific goals are. Why is the quantitative analysis of changes in the water vapor amount in the extra-tropical lower stratosphere important? Is 10*
We added more information about water vapor and motivate why the knowledge about small changes of water vapor concentration in the UTLS are important for global climate like the study by Solomon et al. 2010.

- *- Also, explain why in-situ measurements of chemical species are necessary and unique in this study compared to the previous studies. What are the limitations of using satellite measurements of water vapor in this type of study?*
We already explained that especially satellites, like limb sounders, have a coarse vertical resolution. We added a sentence to the introduction to stronger motivate the use of in-situ instrumentation: Especially in the tropospause region this coarse resolution can smooth the strong vertical gradient of water vapor at the tropopause and may lead to both an over- or underestimation of the water vapor concentration in the lower stratosphere. Here, we present high resolution and precise in-situ water vapor and methane measurements in the northern lower stratosphere performed in August and September 2012.

- *- Explain why water vapor and methane are used and what we can learn from those. What are the lifetimes of water vapor and methane in the troposphere and strato- sphere? What other species were measured during the field campaign?*
First, water vapor is a major green house gas and the variablity of water vapor at tropopause altitudes has a strong impact on surface climate (Solomon et al.

2010, Riese et al. 2012). This is a major motivation of our study which is now included in the introduction. Second, Methane has a long lifetime of around 8.9 years in the troposphere and even longer in the lower stratosphere (Wuebbles et al. 2002), whereas water vapor has a very short life time of about 9 days (Hartmann 2015) due to its strong temperature dependence. Therefore water vapor is very variable with respect to transport history, in contrast to methane. This is also the reason why methane shows a stronger correlation to the MON tracer compared to water vapor. Both correlation coefficients are now included in the text. In addition, both trace gases are important green house gases and small changes in their concentration in the UTLS have strong climatic relevance. We included now the life times and more motivation concerning the choice of trace gases in the introduction and section 3.3.

- *- Why is CLaMS used here? What is unique about this model? And are there any modeling studies on the similar subject?*
  For the scientific issues addressed here, a model is required that provides a good resolution in the UTLS and, in particularly, describes well quasi-isentropic transport in the UTLS as well as transport in the presence of strong tracer gradients. Due to its Lagragian transport on isentropic surfaces with a physically based mixing scheme (that avoids the classic problem of numerical diffusion in Eulerian transport schemes) CLaMS is indeed very well suited for the scientific questions addressed in our paper. CLaMS is indeed widely used like Vogel et al., ACP, 2015, Vogel et al., ACP, 2016, Ploeger et al., JGR, 2013, Pommrich, GMD, 2011, Pommrich, GMD , 2014, Vogel et al., JGR, 2012, Konopka et al., ACP, 2010, Hoppe et al., GMD, 2014. Some (not all) of these studies are now cited in the text.

- *- Writing can be improved. Careful selection of words should help clarifying some of the ideas. I think simple grammatical errors can easily be avoided by putting more effort into proof reading.*

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Discussion paper

We agree with the reviewer and thank her/him for the many good and helpful suggestions. We carefully checked the writing and sent this manuscript to the language office at our institution for proof reading by a native speaker.

Specific comments

- *- P1, L1 – from Asia -> locally*
  Changed.
- *- P1, L2 – water vapor (H2O) of about 0.5 ppmv (11*
  Changed.
- *- P1, L4 – 'by in-situ instrumentation in the northern hemisphere' is redundant*
  Changed.
- *- P1, L4 – What are the full names of TACTS and ESMVal?*
  We added the full names in the text of Section 2. We think in the abstract, is not the right place resolve acronyms of minor importance.
- *- P1, L5 – this water vapor and methane increase -> the increased water vapor and methane, with the help of -> using*
  Changed.
- *- P1, L6 – transport model (CLaMS)*
  Changed.
- *- P1, L9 – influence of air. . .region. -> influence due to the Asian monsoon anticyclone.*
  Changed.
- *- P1, L10 – remove 'between'*
  Changed.

- *- P1, L15 – gases like water vapor and methane -> gases, such as, water vapor and methane,*
  Changed.
- *- P1, L19 – with a low -> with low*
  Changed.
- *- P2, L3 – 'higher values. . .temperature' – The meaning of this is not clear.*
  Changed.
- *- P2, L10 – by a potential -> by strong potential*
  We did not add the word strong, because the transport barrier is often rather leaky as shown in Ploeger et al. 2015 and the gradient is much lower than at the polar vortex for example.
- *- P2, L15 (and others) – Eddy shedding -> eddy shedding*
  Changed.
- *- P2, L18 – AURA-MLS -> the Aura Microwave Limb Sounder (MLS)*
  Changed.
- *- P2, L22 – . . .altitude range -> add a few references here.*
  Changed.
- *- P2, L27 – This study bases on -> This study is based on the (or In this study, the data collected. . . are analyzed. . .)*
  Changed.
- *- P2, L27 – Also what other species were measured during TACTS and ESMVal?*
  There were other species like CO, N2O, and O3 measured during TACTS and ESMVal. The results are published in Müller et al. 2016. In this study, we particularly highlight the importance of the water vapor transport associated to the AMA.

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Discussion paper

- *- P2, L28 (and others) – northern hemisphere -> Northern Hemisphere*
  Changed.

- *- P2, L33 – A reference for CLaMS is necessary here. Also, why is CLaMS perfect for this type of research?*
  We included a reference in the text and put more information as well as a brief motivation in the sub section about CLaMS. See also the answer to your general comment #5.

- *- P3, L1 – location -> locations*
  Changed.

- *- P3, L5 – bases -> is based*
  Changed.

- *- P3, L11 – The full name for TRIHOP should be given here. Also bases -> is based*
  Both is changed.

- *- P3, L20 – is driven by ERA-Interim -> is driven by the European Reanalysis (ERA)- Interim*
  Changed.

- *- P3, L22 – What are the definitions of "emission tracers"?*
  The "emission tracers" are artificial tracers with no chemical depletion, but are transported within the atmosphere. During this transport mixing is applied, thus these tracers can be diluted by emission tracers from different source regions. More information can be found in the cited literature of Vogel et al. 2015 and 2016.

- *- P3, L24 – concentrations -> concentration*
  Changed.

- *- P3, L27 – I do not think PV is measured by the MLS.*
  You are right. We changed the text according to your suggestion.

- *- P3, L27 – proxy -> proxies, allow for transport -> allow transport*
  Changed.

- *- P3, L29-30 – Either add references here or explain how this can be done.*
  Beside the Asian monsoon e.g. typhoons can uplift air masses from the ground into the upper troposphere in the vicinity of the monsoon system. These air masses are dragged by the AMA and loop around the the outer part. A reference is added to the text.

- *- P3, L30 – regions are -> regions considered are*
  Not changed. Because this are the important source regions found in Vogel et al. 2016.

- *- P4, Table 1 – A map can be added here. Or this table can be replaced by a map.*
  We decided to skip the map, because it is already published in the Vogel et al. 2015 and Vogel et al. 2016 and would not provide more information than the table.

- *- P4, L3-4 – that these. . .stratosphere -> that these regions do not make a significant contribution to the lower stratosphere*
  Changed.

- *- P4, L7-8 – In contract to three -> In contrast to the three, temperature development -> changes in the temperature*
  Changed.

- *- P4, L8 – A reference is needed at the end of this sentence.*
  We mitigated the formulation of this sentence to: However, the position of an

air parcel and the changes in the temperature along the trajectory can be tracked with sufficient accuracy over several days or even weeks. In Addition, we included two studies of Vogel et al. 2014 and Rolf et al. 2015 which sucessfully used long trajectories.

- *- P4, L10 – remove 'of the ECMWF'*
  Changed.
- *- P4, L22 – 'the tropical Pacific' – I am not sure if this has been mentioned previously.*
  It is mentioned in the Section 2.3, where the contributing artifical tracer source regions are stated. Nothing changed here.
- *- P5, L1 – 'reinforce the hypotheses' – What does this mean?*
  We rephrased the text to make it more clear.
- *- P5, L6 – Figures 1a and b -> Figures 1a and 1b (also P9, L8)*
  Changed.
- *- P5, L7 – along equivalent latitude -> along the equivalent latitude. Also explain how 'equivalent latitude' is defined.*
  Changed and we added "PV based" as definition for equivalent latitude.
- *- P5, L8 – What does 'tropospheric influenced air' mean? Does this mean the air is mixed with tropospheric air?*
  Yes, exactly. In this case we mean stratospheric airmasses which are influenced by tropospheric airmasses by mixing. We rephrased the text to make it more clear.
- *- P5, L11 – have a similar. . .extent. . . -> have similar vertical and horizontal extents*
  Changed.

- *- P5, L16 – at a PV value -> at PV values, remove 'in the time'*
  Changed.

- *- P5, L19 – All air -> All the air*
  Changed.

- *- P5, L22 – The distribution -> The frequency distribution*
  Changed.

- *- P5, L25 – vapor concentration -> vapor concentration between the two phases*
  Changed.

- *- P5, L28 – It might be easier to refer a figure in Vogel at al., instead of a page number.*
  You are right, we changed the reference to the Figure instead of the pape.

- *- P5, L32 – Figures 2a, b -> Figures 2a and 2b*
  Changed.

- *- P5, L33 – remove 'relatively'*
  Changed.

- *- P6, Figure 1 – a)-d) can be written on the top left instead of bottom left (also in other figures).*
  Changed.

- *- P6, L3 – Figure 2d) -> Figure 2d*
  Changed.

- *- P6, L4 – from phase 2 to phase 1 -> from phase 1 to phase 2*
  Changed.

- *- P8, L2 – enhancements -> enhancement*
  Changed.

- *- P8, L5 – Only few -> Only a few*
  Changed.

- *- P8, L7 – Explain what 'core region' means.*
  The core region of the scatter plot is defined by the 75% percentile of the frequency distribution (black contour). It is now written in the text.

- *- P8, L10 – 'the slope of' – A linear regression line can be added in Fig. 3a.*
  We added a linear regression to the plot to better highlight the slope of the correlation.

- *- P8, L18 – What does 'the imprint on water vapor' mean here?*
  It is directly connected to the sentence before. "The amount of water vapor which is transported from the troposphere into the stratosphere is strongly coupled with the Lagrangian cold point (LCP), where typically the water vapor is dehydrated close to the saturation mixing ratio by ice crystal formation and subsequent sedimentation. Thus, the amount of water vapor in these air masses is nearly preserved after passing the LCP in the tropical, sub-tropical and mid-latitude stratosphere." The imprint means the minimum saturation mixing ratio along the temperature. We make it clear by changing the wording to "these imprint".

- *- P9, L1 – that Eddy shedding -> that the eddy shedding*
  Changed.

- *- P9, L5 – A reference can be added at the end of this sentence.*
  We added two references which address this point.

- *- P10, L2 – between both phases -> from phase 1 (Aug) to phase 2 (Sep)*
  Changed.

- *- P10, L7 – model study of -> modeling study of*
  Changed.

- *- P10, L20 – gives observational -> gives an observational*
  Changed.

References:

- Hartmann, Dennis: Global Physical Climatology (Second Edition), Elsevir, ISBN: 978-0-12-328531-7,p. 399, 2015

- Hoppe, C. M., Hoffmann, L., Konopka, P., Grooß, J.-U., Ploeger, F., Günther, G., Jöckel, P., and Müller, R.: The implementation of the CLaMS Lagrangian transport core into the chemistry climate model EMAC 2.40.1: application on age of air and transport of long-lived trace species, Geosci. Model Dev., 7, 2639-2651, https://doi.org/10.5194/gmd-7-2639-2014, 2014.

- Konopka, P., Grooss, J. U., Günther, G., Ploeger, F., Pommrich, R., Müller, R., and Livesey, N.: Annual cycle of ozone at and above the tropical tropopause: observations versus simulations with the Chemical Lagrangian Model of the Stratosphere (CLaMS), Atmospheric Chemistry and Physics, 10, 121–132, https://doi.org/10.5194/acp-10-121-2010, 2010.

- Müller, S., Hoor, P., Bozem, H., Gute, E., Vogel, B., Zahn, A., Bönisch, H., Keber, T., Krämer, M., Rolf, C., Riese, M., Schlager, H., and Engel, A.: Impact of the Asian monsoon on the extratropical lower stratosphere: trace gas observations during TACTS over Europe 2012, Atmospheric Chemistry and Physics, 16, 10 573–10 589, https://doi.org/10.5194/acp-16-10573-2016, 2016.

- Ploeger, F., Günther, G., Konopka, P., Fueglistaler, S., Müller, R., Hoppe, C., Kunz, A., Spang, R., Grooß, J. U., and Riese, M.: Horizontal water vapor transport in the lower stratosphere from subtropics to high latitudes during boreal summer, Journal of Geophysical Research- atmospheres, 118, 8111–8127, https://doi.org/10.1002/jgrd.50636, 2013.

- Ploeger, F., Gottschling, C., Griessbach, S., Grooß, J. U., Günther, G., Konopka, P., Müller, R., Riese, M., Stroh, F., Tao, M., Ungermann, J., Vogel, B., and von Hobe, M.: A potential vorticity-based determination of the transport barrier in the Asian summer monsoon anticyclone, Atmospheric Chemistry and Physics, 15, 13 145–13 159, https://doi.org/10.5194/acp-15-13145-2015, 2015.

- Pommrich, R., Müller, R., Grooß, J.-U., Konopka, P., Günther, G., Pumphrey, H.-C., Viciani, S., D'Amato, F., and Riese, M.: Carbon monoxide as a tracer for tropical troposphere to stratosphere transport in the Chemical Lagrangian Model of the Stratosphere (CLaMS), Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmdd-4-1185-2011, 2011.

- Pommrich, R., Müller, R., Grooß, J. U., Konopka, P., Ploeger, F., Vogel, B., Tao, M., Hoppe, C. M., Günther, G., Spelten, N., Hoffmann, L., Pumphrey, H. C., Viciani, S., D'Amato, F., Volk, C. M., Hoor, P., Schlager, H., and Riese, M.: Tropical troposphere to stratosphere transport of carbon monoxide and long-lived trace species in the Chemical Lagrangian Model of the Stratosphere (CLaMS), Geoscientific Model Development, 7, 2895–2916, https://doi.org/10.5194/gmd-7-2895-2014, 2014.

- Randel, W. J. and Jensen, E. J.: Physical processes in the tropical tropopause layer and their roles in a changing climate, Nature Geoscience, 6, 169–176, https://doi.org/10.1038/ngeo1733, 2013.

- Riese, M., Ploeger, F., Rap, A., Vogel, B., Konopka, P., Dameris, M., and Forster, P.: Impact of uncertainties in atmospheric mix- ing on simulated UTLS composition and related radiative effects, Journal of Geophysical Research-atmospheres, 117, D16 305, https://doi.org/10.1029/2012JD017751, 2012.

- Rolf, C., Afchine, A., Bozem, H., Buchholz, B., Ebert, V., Guggenmoser, T., Hoor, P., Konopka, P., Kretschmer, E., Müller, S., Schlager, H., Spelten, N., Suminska-Ebersoldt, O., Ungermann, J., Zahn, A., and Krämer, M.: Transport of Antarctic stratospheric strongly dehy- drated air into the troposphere observed during the HALO-ESMVal campaign 2012, Atmospheric Chemistry and Physics, 15, 9143–9158, https://doi.org/10.5194/acp-15-9143-2015, 2015.

- Solomon, S., Rosenlof, K. H., Portmann, R. W., Daniel, J. S., Davis, S. M., Sanford, T. J., and Plattner, G. K.: Contributions of Stratospheric Water Vapor to Decadal Changes in the Rate of Global Warming, Science, 327, 1219–1223, https://doi.org/10.1126/science.1182488, 2010.

- Ungermann, J., Ern, M., Kaufmann, M., Muller, R., Spang, R., Ploeger, F., Vogel, B., and Riese, M.: Observations of PAN and its con- finement in the Asian summer monsoon anticyclone in high spatial resolution, Atmospheric Chemistry and Physics, 16, 8389–8403, https://doi.org/10.5194/acp-16-8389-2016, 2016.

- Vogel, B., Günther, G., Müüller, R., Grooß, J. U., Afchine, A., Bozem, H., Hoor, P., Krämer, M., Müller, S., Riese, M., Rolf, C., Spel- ten, N., Stiller, G. P., Ungermann, J., and Zahn, A.: Long-range transport pathways of tropospheric source gases originating in Asia into the northern lower stratosphere during the Asian monsoon season 2012, Atmospheric Chemistry and Physics, 16, 15 301–15 325, https://doi.org/10.5194/acp-16-15301-2016, 2016.

- Vogel, B., Günther, G., Müller, R., Grooß, J. U., and Riese, M.: Impact of different Asian source regions on the composition of the Asian monsoon anticyclone and of the extratropical lowermost stratosphere, Atmospheric Chemistry and Physics, 15, 13 699–13 716, https://doi.org/10.5194/acp-15-13699-2015, 2015.

- Vogel, B., Günther, G., Müller, R., Grooß, J. U., Hoor, P., Krämer, M., Müller, S., Zahn, A., and Riese, M.: Fast transport from Southeast Asia boundary layer sources to northern Europe: rapid uplift in typhoons and eastward eddy shedding of the Asian monsoon anticyclone, Atmospheric Chemistry and Physics, 14, 12 745–12 762, https://doi.org/10.5194/acp-14-12745-2014, 2014.
- Wuebbles, D. J. and Hayhoe, K.: Atmospheric methane and global change, Earth-science Reviews, 57, PII S0012–8252(01)00 062–9, https://doi.org/10.1016/S0012-8252(01)00062-9, 2002.

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