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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Annual cycle of water vapour in the lower stratosphere over the Indian Peninsula derived from Cryogenic Frost-point Hygrometer observations" *by* Maria Emmanuel et al.

Anonymous Referee #1

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General comments:

This study presents the water vapor profiles measured by the balloon-borne Cryogenic Frostpoint Hygrometer (CFH) in the upper troposphere and lower stratosphere (UTLS) over two stations in India during the period from February 2015 to January 2016. Their figures show that the CFH measurements have sufficient quality to discuss the nature of water vapor in the UTLS, in particular, the tape recorder signals observed at the two launching stations are very impressive. However, I think that the current manuscript lacks some essential and key points to understand and interpret the observational re-

sults. In my opinion, the required components are 1) employment of the saturation water vapor mixing ratio, 2) understanding a concept of three-dimensional transport in the UTLS, 3) presentation of the value to use the column integrated water vapor amount, and 4) presentation of the value to focus on the upward propagating signal in the water vapor mixing ratio difference between the two launching stations. The specific comments, including above four points, are described bellow.

Specific major comments:

1) The atmospheric pressure logarithmically changes with altitude. This is one of the reasons why we usually use the "mixing ratio" for our analysis because of its conservative property in vertical movement of the atmosphere. If one air parcel moves to upward, its air pressure, water vapor pressure, absolute humidity [mg/mˆ3] which the authors employ in the manuscript, must change, however, the water vapor mixing ratio never change without the occurrence of dehydration or hydration or mixing it with surrounding air mass. Therefore, when we want to discuss the water vapor and the dehydration, in particular in the tropical UTLS, we usually employ the minimum saturation water vapor mixing near the cold point tropopause (CPT), but not temperature at the CPT, to compare the observed water vapor mixing ratio. For example, here we consider two air parcels (parcel_1 and parcel_2), one has the temperature (T_1) and pressure (p_1) at altitude (z_1), and another has (T_2) and (p_2) at (z_2), and we assume parcel_1 locates higher altitude than parcel_2 (z_1 > z_2). If T_1 and T_2 are the same value, the two produce the same saturation water vapor mixing ratios (p_wv1 and p_wv2). However, the two situations produce different saturation water vapor mixing ratios (SMR_1 and SMR_2) because they are obtained from SMR_1 = p_wv1/p_1 and SMR_2 = p_wv2/p_2 under the condition of p_1 < p_2. This fact imposes the employment of the minimum SMR (SMRmin) near the CPT (the altitude where produces the SMRmin does not always agree with the CPT) on the current manuscript to discuss dehydration or hydration, in particular, in the following parts. Figure 1, Figure 3 (Could you include symbols showing the mean SMRmin at the altitude where they

produce in the same color scale to water vapor?), Figure 5b, Figure 6a, Discussions in Page5 Line27-Page6 Line2, Page7 Line20-30, the first paragraph in Page8, and Page11 Line21-24.

2) Though the authors cite some articles (e.g., Randel and Park, 2006; Park et al., 2007) addressing the Asian summer monsoon (ASM), a modern concept of the ASM is not sufficiently reflected in the interpretation of the results obtained from the current study. To grasp the concept, I think Figure 14 of Park et al. (2009) and Ploeger et al. (2017) may be helpful. They present the pictures involved in the ASM that consists rapid vertical transport by convections, horizontal transport by anticyclonic circulation at the UTLS, and slow ascent in the tropical stratosphere by the BDC. After considering those transport mechanisms involved in the ASM, I basically agree the interpretation that the water-rich air mass at higher altitude than that of the CPT observed over Hyderabad during ASM season, which might be transported from the region over Bay of Bengal (BoB) after it is hydrated by convections. It likely occurs, I think. But, if so, I think the infrared data around BoB (as well as other upstream regions of the anticyclonic circulation) should be additionally shown together with the horizontal wind field at just above the CPT altitude.

3) I could not find the reasonable reason why the authors employ the column integrated water vapor in the LS (IWV_LS) in the current manuscript. The IWV_LS is mainly discussed in the text in Page7 Line7-20 and the discussion about its difference between the two launching site is connected to local processes. I think it could not provide scientific discussions unless the concept of three-dimensional transport associated with the ASM is accurately introduced as described in the previous comment. On the other hand, in my opinion, if the authors successfully determine some indicator to quantify the hydration amount above the CPT altitude (strictly the SMRmin altitude) caused by local convection and/or ASM (for example, to calculate the vertical integration of the water "increment" from the local SMRmin, etc.) and if the observed water vapor profiles can be quantitatively interpreted in connection with hydration processes using the

indicator (for example, to show the relationship between the amount of the indicator and the ice water content in the convective overshooting clouds, etc.), such study may provide an new insight to understand the role of ASM on the stratospheric water vapor.

4) The authors focus on the upward propagating signal in the water vapor mixing ratio difference between the two launching stations in Figure 8. But I could not identify such propagating signal in the figure. On the other hand, Figure 9, indeed, clearly shows such upward propagating signal. This signal, however, can be simply produced by lager and smaller amplitudes of the tape recorder over Trivandrum and Hyderabad, respectively. Such interpretation is likely reasonable to me because Trivandrum locates nearer the center of the tropical pipe in the stratosphere than Hyderabad. How do you think about this opinion? You can check it by making some figures which show the meridional (latitude-altitude cross-section) distribution of water vapor mixing ratio over a meridian line across India (for example 80degE) for every month by using MLS data (like as Figure 1 in Ploeger et al., 2017).

References Park, M., W. J. Randel, L. K. Emmons, and N. J. Livesey (2009), Transport pathways of carbon monoxide in the Asian summer monsoon diagnosed from Model of Ozone and Related Tracers (MOZART), J. Geophys. Res., 114, D08303, doi:10.1029/2008JD010621.

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