We thank the reviewer for their useful comments on our manuscript. Below we provide detailed response to your comments. In the following, the comments of the reviewer are presented in *italic blue*. Our responses are in normal black font. Changes to the text are in red.

*Comment 1:*
*From my understanding of the manuscript, I do not believe that the primary conclusion ". . . most of the convectively moistened air is then transported to the center of the NA anticyclone and the anticyclonic structure helps maintain high water vapor content there." is necessarily supported by the evidence provided. What is shown is that there is an offset between the region that corresponds to the authors chosen metric of deep convection, and the region of maximum H2O anomaly as measured by MLS.*

*Even if one accepts the chosen convective proxy, there seems to be another plausible explanation for this geographic mismatch. Air simply resides in the Southern US region for a longer period before being transported downwind to other longitudes, and therefore has greater convective moisture efficiency. Thus, it is not clear to me to that transport from higher latitudes is required. The claim that can easily be made is that there is a strong correlation between air that has a long residence time over NA and air with a large H2O anomaly.*

We agree that we need to show more analysis to support the conclusion, so we will add a new row to Fig. 3 in the paper; the revised figure is shown below. To produce the new row (the fourth one), we take MLS observations that our back-trajectory analysis shows were convectively enhanced and show the location where those trajectories encountered convection. We find that most of the convective encounters happened over the regions where GridRad data show deep convection is most frequently occurring. This supports our conclusion that the offset between convection and high water vapor is due to transport.

We acknowledge that we cannot rule out a contribution from unobserved convection in regions of high water vapor, but we see no evidence to support that.

In the revised text, we will add this row to Fig. 3 in the paper and insert a paragraph after line 118:

> We identify the locations where parcels encounter deep convection in the back trajectories and grid the number of trajectories encountering convection into 2° x 2° boxes (Fig. 3J-L). Most of the locations of convective encounters occur over the region where NEXRAD data show deep convection frequently occurs, e.g., over the Central Plain region, and over Florida during August. The geographical distribution of convective encounters does not match with the convective influence ratio, indicating that convective moisture is transported to the region of high water vapor by the dynamics of the monsoon.

*Comment 2:*
*I am also skeptical about the relevance of the fact that in June the back trajectories travel through very cold regions. These are back trajectories, so these low temperatures are influencing the parcels before they are moistened by the deep convection.*
*Perhaps the authors are suggesting that these parcels are moistened over the US,*

*travel to the tropics, and then come back to the US, but I would have thought that such a trajectory path would only be followed by only a very small fraction of parcels and the authors have provided no evidence to the contrary.*

Yes, our argument is that parcels encounter deep convection over the US, travel to the (sub)tropics, are dehydrated along the way, and then travel back over the US. However, as the reviewer correctly suggested, only a minority of parcels take this path. If we regard 20°N-20°S as the tropics, then 33%, 13%, and 9% of the convectively influenced parcels follow this pathway during June, July, and August over 2005-2016, respectively. This reflects the fact that the monsoon circulation is weaker during June, and so a small but important fraction of parcels can follow this path; during July and August, when the monsoon is better established, this pathway is nearly shut off.

As we argue in the paper, year-to-year variations around these average values are responsible for observable variations in water vapor. During June 2011, 44% of the convectively influenced parcels traveled to the tropics, while during June 2010, only 20%. Per the Clausius-Claperyon equation, a 1-K change in minimum temperature will change water vapor by 20% at TTL temperatures. So, 20% of the parcels in 2011 experiencing temperatures a few degrees colder than those in 2010 (as suggested by Fig. 6 of the original paper) can change the water vapor over the monsoon region by the amount observed.

However, we acknowledge that our text could be clearer. We will make the following change to the text:
Line 137 - The second reason is also connected to the changing dynamics during June, July, and August. Parcels tend to travel to lower latitudes during June (Fig. 4a). 33% of the convectively moistened parcels travels to the tropics (20°N-20°S) during June, and 13% during July and 9% during August. Traveling to the tropics leads them to experience colder temperatures at 100 hPa (Fig. 4b). As a result, the median of the water vapor mixing ratio of the parcels that stays in the mid-latitudes is 5.98 ppmv, while it is 5.36 ppmv for those parcels that travels to the tropics. This means that convectively moistened air experiences subsequent dehydration more frequently in June than in later months (Randel et al., 2015).

*Additional comment 1:*
*Abstract line 8– I'm not sure what the "hypothesis" is, nor is there a particular need to mention or have one.*

Changes have been made in the text: We have replaced "Our hypothesis" with "This".

*Additional comment 2:*
*Line 52 – The convective radar data play a fundamental role in this paper. Although the reference to Cooney et al. is good, please devote a few lines to describing the reflectivity observations and what they mean. For instance, is a reflectivity Zn over 10 dBz a well-accepted value for tropopause overshooting convection?*

Changes have been made in the text:

Line 52 - Cooney et al. (2018) used GridRad data to calculate the deep convective echo top, and found out a highest level that the reflectivity over 10 dBz is a representative threshold that balances the sensitivity and noise. In our analysis, we also use this strategy and identify deep convection as observations of reflectivity over 10 dBz.

*Additional comment 3:*
*Figure 1 – I understand that in panel 'A' different very different quantities are being plotted, but just putting a y-axis that says "normalized" is unacceptable. There needs to be some way for the reader to connect the plotted value with a physical quantity (ppmv, fractional occurrence of convection, etc.). Also, the two reddish lines in panel 'A' (apparently one is orange) are very difficult to distinguish.*

Fig. 1A has been revised. We now have multiple y-axes, with each showing the values of each physical quantity. A green line replaces the orange line, which should improve the figures clarity. The revised Fig. 1 is shown below.

*Additional comment 4:*

*Figure 3 – This is an interesting figure, and the fact that the convective influence ratio looks not dissimilar from the MLS H2O anomaly is very interesting. The black line single value GridRad contour is useful because it makes it easier to see the offset between the maximum convection and the maximum H2O anomaly, and if this specific convection contour represented all convection, then one would be forced into the conclusion presented by the authors, i.e. that high H2O air is being transported from these regions to the lower latitude regions. But there is nothing special about the specific convection level contour that the authors have chosen. While some of the moist air may have been brought down from the North, some of the moistening in the Southern US is almost certainly caused by local convection in this region. This figure therefore include a full row showing a color contour of the convective occurrence by month throughout the US.*

We agree that there is nothing special about the 1e-5 contour. We have therefore taken the reviewer's suggestion and added a row with the maps of convective occurrence over the NA.

Changes have been made in the text:

Line 106: From June to August every year, deep convection frequently occurs during boreal summer, especially over the central US (Fig.3A-C, see also Cooney et al. (2018)). The water vapor mixing ratio over NA also shows positive anomalies relative to the zonal mean (Fig. 3D-F). However, there is a discrepancy between the spatial distribution of the water vapor anomaly and deep convective occurrence: The deep convection occurs mainly over the Central Plains region, centered around 40°N. Large positive water vapor anomalies are observed over a broader longitude range south of 40°N latitude.

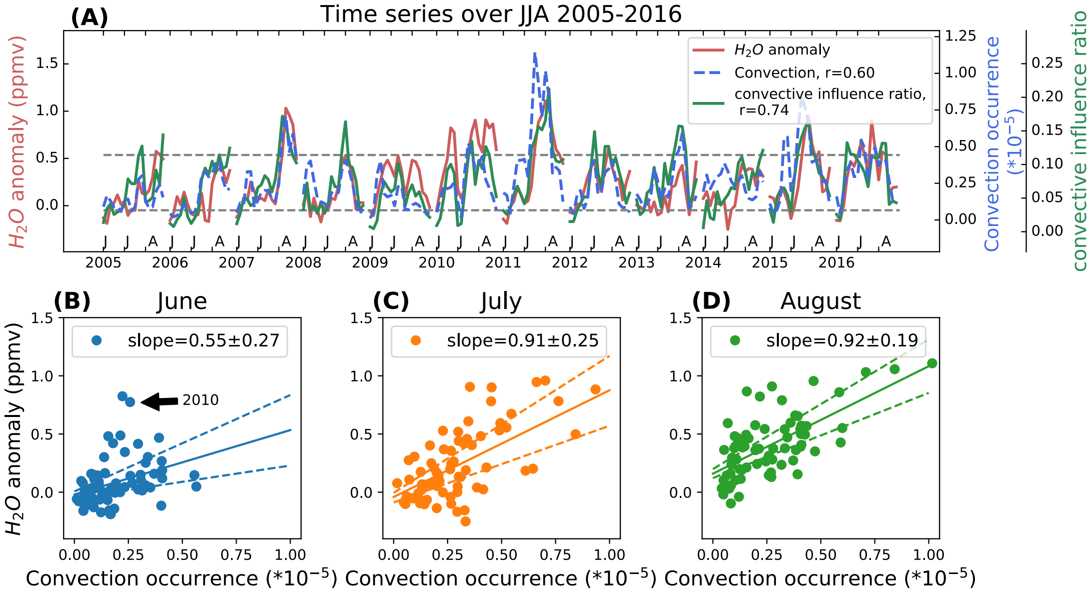


Figure 1. (A) Time series of ~~normalized~~ 100-hPa (red line) MLS water vapor anomaly (zonal mean removed), (blue line) convective occurrence from GridRad, and (green line) the convective influence ratio in the back trajectory experiments. All data are 5-day averages over the NA region (25°N-50°N, 70°W-130°W) during June, July, August 2005-2016. For the convective frequency, we use linear interpolation to estimate the value at 100 hPa. The convective influence ratio is the fraction of the MLS observations that encounter deep convection, as determined by the back trajectory calculations. (B-D) Joint distribution of convection and water vapor time series during 2005-2016 divided into (B) June, (C) July, and (D) August. Solid lines show the linear fit, and dashed lines show the 95% significant level margin of error of the slope bar (accounting for auto-correlation). To account for the time for the water vapor to spread out, each data point is a 10-day average of convection, with water vapor averaged over the last five days of the averaging period for convection.

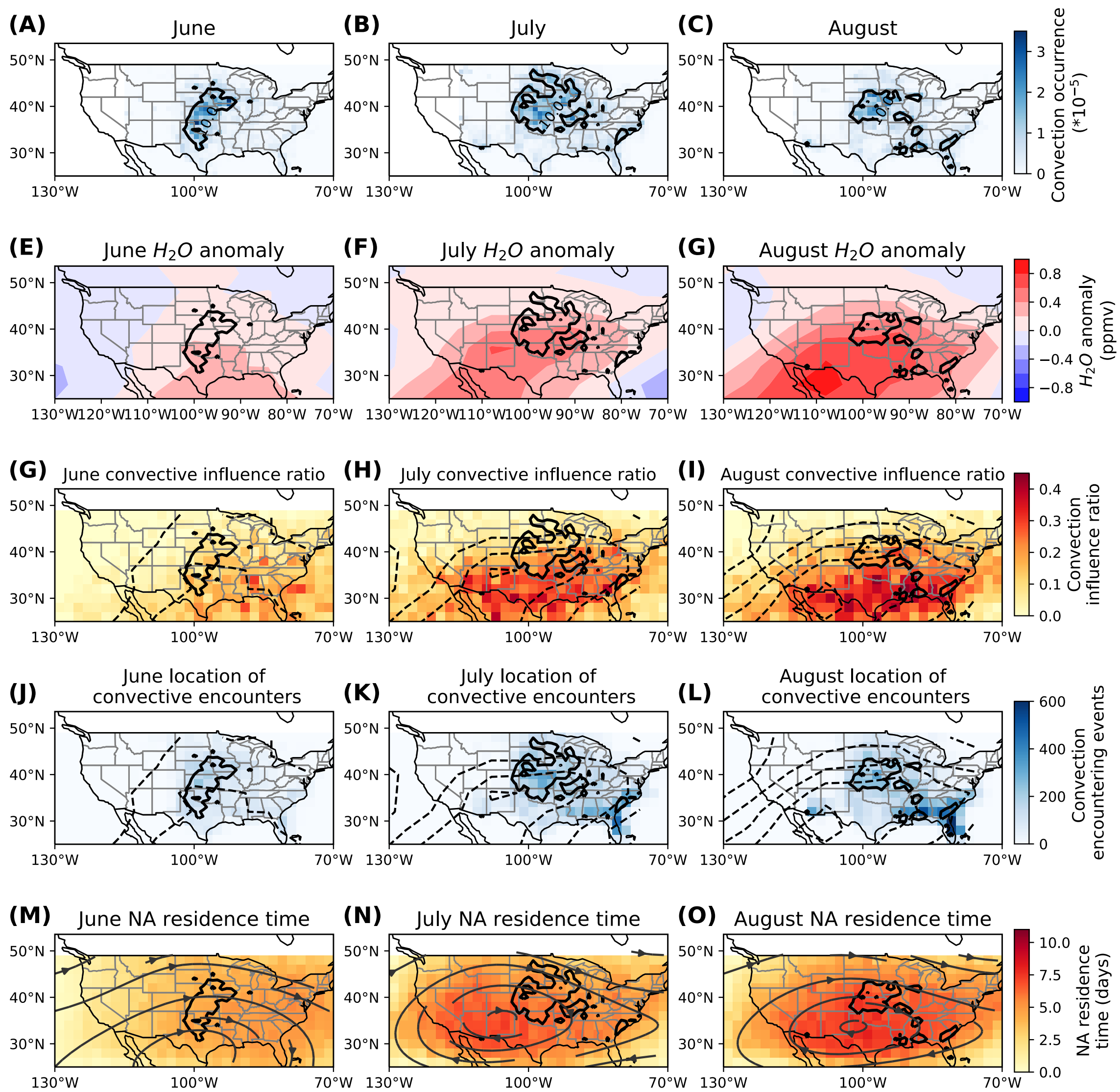


Figure 3. (Top row) Distribution of the 100-hPa GridRad deep convection occurrence averaged over 2005-2016 in (A) June, (B) July, and (C) August. The black contour in each panel (repeated in each row) is the $10^{-5}$ contour of GridRad convective occurrence, averaged over that month. (Second row) Geographical distribution of the MLS 100-hPa water vapor anomaly (after removal of the zonal mean), averaged over 2005-2016 in (D) June, (E) July, and (F) August. (Third row) Geographical distribution of the convection influence ratio over the NA region during (G) June, (H) July and (I) August 2005-2016. The black dashed contour (repeated in each panel) is the

water vapor anomaly contours matching the shading in the corresponding upper panel. (Fourth row) Location where convectively influenced parcels encounter convection during 2005-2016 (J) June, (K) July and (L) August; (Bottom row) Geographical distribution of the parcel time spent over the NA region during (M) June, (N) July, and (O) August. (The stream lines are horizontal velocities interpolated onto 100 hPa using the cubic spline method from ERAi data averaged over the same period.

**References**

Cooney, J. W., Bowman, K. P., Homeyer, C. R. and Fenske, T. M.: Ten Year Analysis of Tropopause-Overshooting Convection Using GridRad Data, J. Geophys. Res. Atmos., 123(1), 329–343, doi:10.1002/2017JD027718, 2018.

Randel, W. J., Zhang, K. and Fu, R.: What controls stratospheric water vapor in the NH summer monsoon regions?, J. Geophys. Res. Atmos., 120(15), 7988–8001, doi:10.1002/2015JD023622, 2015.