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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Enhanced Stratospheric Water Vapor over the Summertime Continental United States and the Role of Overshooting Convection" *by* Robert L. Herman et al.

Anonymous Referee #1

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This paper presents an interesting analysis that links anomalously high stratospheric water vapor mixing ratios measured over the central United States to convection-induced overshooting cloud tops via model-calculated back trajectories of air parcels. High levels of stratospheric water vapor were measured during three flights of the NASA ER-2 aircraft as part of the SEAC4RS mission in August 2013. Trajectories from the FLEXPART model, initiated at the times and locations of the high water vapor measurements and stepped back in time, show convincing spatiotemporal intersections with overshooting cloud tops identified from GOES infrared imagery of cloud brightness temperatures.

This paper is fairly well written but could use some "cleaning up" of the language and

presentation. The methods and conclusions are sensible and the content is appropriate for Atmospheric Chemistry and Physics. I suggest it be published after some minor but important revisions.

Major Comment:

In my opinion this paper could easily stand alone if all Figures and in-depth discussions of Aura MLS stratospheric water vapor measurements were omitted. The vast majority of scientific conclusions can be made without the broader picture provided by the MLS data. The one significant contribution of MLS data to this paper is to show the low frequency of occurrence of anomalously high stratospheric water vapor mixing ratios over the North American monsoon region. However, this conclusion, based on MLS water vapor data, was already published by Schwartz et al. (2013, Geophy. Res. Lett.). There are also some difficulties translating between the aircraft and MLS results because of the presumably different mixing ratio thresholds used to identify "enhanced" water vapor for each. Intuitively the MLS threshold needs to be lower because of the much coarser vertical and horizontal resolution of MLS retrievals. See my comments below regarding this issue.

I will leave it up to the authors if they want to retain or omit the MLS data in their paper. I don't think its presence detracts from the main objectives of this paper, but I also think it doesn't contribute much to them.

Minor Comments:

Figure 1 and Caption. "Each monthly histogram is normalized to unity over mixing ratio" needs further explanation. I went back to the Schwartz et al. (2013) paper for clarification and found the exact same statement. For me, to normalize each monthly histogram one would divide the population of each mixing ratio bin by the entire population or the population of the bin containing the mode or mean of the distribution. Assuming a somewhat Gaussian distribution, the normalization the mode or mean bin population would produce numbers near one and zero for the most and least populated bins (most and least probable in a PDF), respectively. This is how I interpret Figure 1 even though I don't understand "normalized to unity over mixing ratio" and the units on the color bar are ppmvˆ-1. What am I missing here?

Also for Figure 1, the vertical lines are not "dashed" and the gray shading is too light, at least for my eyes.

The paper uses three vertical coordinates and doesn't tie them together very well. The introduction focuses on potential temperatures, everything pertaining to Figures 1-4 is discussed and shown in pressure coordinates, then Figures 5-7 are presented in altitude coordinates. Are the profiles in Figures 4-7 entirely in the lowermost stratosphere or do they extend into the overworld (or upper troposphere for that matter)? Profiles in Figures 4 extend from 150 to 50 hPa but in Figure 5a (same profiles) span 15.5 to 18.5 km. Are the axis ranges of these two Figures the same in terms of vertical span? I understand the need to discuss stratospheric layers in terms of potential temperature (introduction), but why can't everything else be presented uniformly using either pressure or altitude coordinates (or both together)? It would make the discussion and Figures much more intelligible.

Though the phrase "enhanced water vapor" appears in the paper's title and is used frequently throughout the paper, it is never defined for the aircraft measurements. Presumably there is a mixing ratio threshold used to identify air parcels with enhanced water vapor? The abstract may indirectly imply, likely incorrectly, that "enhanced" mixing ratios measured from aircraft are those >10 ppmv. Adding to the mystery are the blue markers in panels (a) of Figures 5-7 that represent the "enhanced H2O region" but range well below 5 ppmv. What exactly is the threshold for "enhanced" water vapor measured from the aircraft? Why are there mixing ratios <5 ppmv in regions of enhanced water vapor? This is quite confusing and requires some important clarification in the paper.

Is it appropriate to try to combine information from MLS and aircraft-based detections of

"enhanced" water vapor in this paper when their thresholds are probably very different? Figure 3 shows only 13 instances where MLS retrievals at 100 hPa during Jul-Aug 2013 exceeded 8 ppmv. Is this the threshold for MLS-detected "enhanced" water vapor? Given the greatly different vertical and horizontal resolution of the MLS and aircraft measurements, how can the MLS findings be integrated with the aircraft-based results that follow? I don't think they can. What does a MLS retrieval of 8 ppmv with a 3-km averaging kernel width translate to for the in situ aircraft measurements? Figures 1-3 contribute to only one conclusion drawn in this paper: that MLS retrievals at 100 hPa over the NAM region during Jul-Aug rarely exceed 8 ppmv. In my opinion that is a secondary (and already published) conclusion compared to the dominant conclusion of this paper that enhanced stratospheric water vapor measured over the NAM region during Jul-Aug 2013 can be traced back to convection-induced overshooting cloud tops.

Editorial Comments:

Line 58: please give the lowermost stratosphere a rough lower limit (in potential temperature) otherwise this implies it extends down to the surface. "Commonly" suggests these mechanisms are highly probably pathways for tropospheric water vapor to reach the stratosphere, which they are not.

Line 62: Please make it clear that ice (not elevated water) is transported into the stratosphere where it sublimates and produces "enhanced" water vapor mixing ratios.

Line 63: Here and elsewhere "stratospheric overworld" (defined in Line 45) has now become the "overworld stratosphere".

Line 66: Ice does not "bypass" the cold trap, it is unaffected by it.

Line 67: Suggested paragraph break before "Paraphrasing".

Line 81: "are limited by their horizontal and vertical resolution in detecting fine-scale three-dimensional variations in water vapor ..."

Line 101: "Instruments on the NASA ER-2" – which instruments and what was measured that allows you to conclude that "the aircraft intercepted convectively-influenced air"?

Line 107: "measures daily global atmospheric profiles" sounds like one gigantic profile is measured each day. How about "measures ∼3500 profiles around the globe each day of atmospheric species ..."

Line 118: Aren't "the decadal histogram" and "the previous multi-year MLS record" the same thing in Figure 2? Don't you want to compare and contrast the histogram of 2013 with the histogram of 10-year mean values? Figure 2 would be a great place to visually show (as a vertical line) the threshold for "enhanced" MLS water vapor.

Line 120: You have the histograms so why say "rare" when you can be quantitative?

Line 122: At least 3 of the white circles in Figure 3 are near the west coast of Mexico, not Central America.

Line 146: What is the spatial resolution (horizontal and vertical) of the convective storm information used to link "enhanced" water vapor to overshooting tops? Later (Line 503) you say that the OT data are "high resolution" but the spatial resolution is never described.

Line 156: What was the time step interval for back trajectory calculations?

Line 158: How were these tolerances chosen? Do they have any relationship to the spatial resolution (horizontal and vertical) of the convective storm information?

Line 164: You already wrote about initializations (Line 153). This statement is again repeated in Line 180.

Line 169: It would be beneficial to include the lats/lons of these sites.

Line 173: Same comment as for Line 58.

Line 182: This information is already in the Figure Captions.

Line 184: In Figures 5-7, panels (b) and (c), the green markers show "near coincidences" (within the tolerances listed in Line 158) between back trajectories and OTs, while red squares show "coincidences". What are the criteria for "coincidences"?

Line 191: In Figure 5b there are many green markers in western Mexico, so why is this location not listed?

Line 198: In Figure 5d there are many red markers depicting transit times >6 days, but here you claim domination by transit times of "two to five days".

Line 205: TX, OK and AR are in the "South Central" U.S.

Line 216: Define MCC as mesoscale convective complex

Line 227: Earlier you stated that back trajectories were initialized for every measurement of enhanced water vapor. Now, "Example" infers that this was done only for a subset. Did "all" (Line 228) of the back trajectories connect to OTs? Really? All?

Line 230: Figure 7b shows there were influences from storm systems in South Central Canada as well.

Line 235: "leaving behind" should be "producing"

Line 238: "propel water" gives the wrong impression while "loft ice" is more accurate.

Line 239: "the enriched delta-D isotopic signature" needs a bit more explanation, including a mention of the isotope itself, HDO.

Line 246: "The water is almost certainly injected in the ice phase" needs support. I suggest you combined this paragraph with all or some of the previous paragraph that provides such support.

Line 252: "from a long (200 km) path through the atmosphere" also needs to include information about the vertical resolution. The qualitative statement "may be enhanced even more" is the basis for my argument that the MLS and aircraft results cannot be meaningfully integrated together in this paper.

Line 254: what percent of the 10 years of MLS observations show enhanced water?

Line 261: Which “monsoon region”?

Figure 2: Caption: “ten year mean for 2004 through 2013.”

Figure 3: Caption: “Average Aura MLS 100-hPa”

Figure 4: Colored markers are not “retrievals” from the aircraft, they are the actual aircraft measurements. Why do multiple aircraft profiles produce only one profile convolved with the MLS averaging kernels? Without strongly magnifying this Figure I can’t tell the difference between the MLS profiles and the convolved aircraft profile. I suggest omitting the convolved aircraft profile in each panel. It does shows that the averaging kernels smooth the aircraft profiles, but isn’t that exactly what one would expect anyway? Also, the black asterisks showing MLS retrieval locations on flight track maps are difficult to distinguish from black map lines. Perhaps larger gray symbols “x” or “+” would stand out more? And the “line” mentioned in the caption, is this the horizontal line in each “Flight Altitude” (should be “Pressure”) vs UTC hour panel indicating the time range of measurements shown in the profiles? This Figure would be an ideal place to visually show (as a vertical line in each profile panel) the threshold for aircraft “enhanced” water vapor.

Figure 5: These comments apply to each of Figures 5-7: In panels (a), the captions claim the blue markers denote “enhanced water measurements” (which range below 5 ppmv) while in the panel (a) legends the blue markers are said to represent the “Enhanced H2O region”, which must be something quite different from “enhanced water vapor” measurements. This distinction needs to be clarified in the paper by defining exactly what is meant by the terms “enhanced water measurements” and “enhanced H2O region”.

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