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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The effect of ENSO activity on lower stratospheric water vapor" *by* F. Xie et al.

F. Xie et al.

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We appreciate for all the helpful comments. The comments have been carefully addressed and our replies are summarized below:

General Comments: I think there is a sufficient amount of new results in this paper to warrant publication, after the authors significantly strengthen the arguments, address some possible data interpretation errors, and clean up the figures, as detailed below. Also, Section 4, on the integrated effect of ENSO events on stratospheric temperature and water vapor, is particularly weak. First of all, it is unclear to me why you would want to examine the integrated effect of ENSO events, rather than just the separate effects of El Nino and La Nina events. You need to give the rationale. In addition, according to your discussion on p.4152, El Nino and La Nina events influence stratospheric water

vapor through different mechanisms. So isn't it inappropriate to combine them in an analysis of the integrated effect? Furthermore, the paragraph on long-term trends contains only a cursory mention of analysis results without presenting any numerical or graphical results. I recommend that Section 4 be significantly revised or possibly omitted. The paragraph on long-term trends could perhaps be moved to the "Summary and conclusions" section to serve as a discussion of possible future work. Although you do a good job of citing relevant literature in the Introduction, I think the paper needs more background to help the reader understand why the analysis reported here is relevant. For example, you might want to briefly summarize the observed frequency and magnitude of El Nino and La Nina events in the past and projected future variability, and explain that your analysis contributes potentially to better understanding of why stratospheric water vapor has varied in the past and how it might vary in the future.

1) Thanks for the good suggestions to the structure of our paper. The Section 4 (in ACPD version) has been deleted and the discussions on long-term water vapor trends has been moved to the "Summary and conclusions" in the revised paper.

2) The introduction has been improved. Thanks.

Specific Comments: 1. p.4144, lines 18-22: You describe the NCEP reanalysis2 data set here, but you don't actually show any results based on that data set, except for a brief mention at the end of Section 4. You should revise the text here.

The analysis of NCEP reanalysis2 data has been abandoned and ERA-interim data was analyzed in the revised paper instead.

2. p.4145-4146: You discuss to a certain extent the caveats of using reanalysis data to study stratospheric water vapor, and explain that you use MLS and HALOE data to cross-check the robustness of the reanalysis-based results. However, I'm not fully convinced that the robustness of the results for the earlier decades can be confidently inferred based on the satellite data, which only start in 1993 and have large uncertainties. I think you need to provide a more extensive assessment of the robustness or

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validity.

In the revised paper, we abandoned ERA-40 reanalysis and used ERA-Interim dataset instead to redo the analysis of the lower stratospheric water vapor and tropopause temperature anomalies in ENSO events. ERA-Interim dataset assimilates the new model outputs and satellite observations, with a 1.5o x 1.5o horizontal resolution and relatively high vertical resolution in the tropical tropopause region (Simmons, et al., 2007a; Simmons, et al., 2007b; Uppala, et al., 2008). This dataset includes the time range of MLS dataset (ERA-Interim: 1989-2010; MLS: 2005-2010). We can see from revised Fig. 1 (Please see the Supplement) that the distributions of the stratospheric water vapor in the two datasets are overall in agreement. We also analyzed the data from a 30-year model simulation performed with a chemistry-climate model and got the similar results

3. p.4146, lines 5-6 and 23-26: The coarse vertical resolution of the reanalysis model around the tropopause doesn't allow for precise investigation of temperature effects on troposphere to stratosphere transport of water vapor. I think you should include some discussion of the uncertainties associated with this coarse resolution.

The ERA-Interim dataset used in the revised paper has higher vertical resolution than ERA-40 reanalysis. The vertical resolution of ERA-Interim dataset is about 1-2 km and the vertical resolution of the satellite observations is also about 1-2 km (e.g., MLS and HALOE data). We think that using of ERA-Interim data instead of ERA-40 reduces uncertainties to some extent. We agree on your point that uncertainties always exist for any datasets currently available, but we don't see how further verification of water vapor data is possible.

4. p.4148, lines 23-27: You state that "The vertical velocity fields during ENSO events (Fig. 3f) show a strong upward motion around the middle and eastern Pacific, and a relatively weak upward motion over the western Pacific and Indian Ocean in ENSO situations suggesting that vertical transport of water vapor is stronger over the middle

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and eastern Pacific than that over the western Pacific and Indian Ocean during ENSO events." But Fig. 3f seems to me to show the opposite: The vertical velocities are quite weak in the middle and eastern Pacific (in some locations even slightly negative) while they are much stronger over the western Pacific and Indian Ocean. If I'm correct, you'll need to revise the discussion in the rest of the paragraph as well, proposing a new explanation for the water vapor anomalies that extend well above the 390K isentropic surface over the middle and eastern Pacific. Also, do the regional differences in vertical transport also exist during non-ENSO periods? Since you don't mention the non-ENSO periods, one (including myself) might wonder why the differences are only limited to El Nino and La Nina periods and not the neutral ones.

1) Figs. 3e and 3f have been revised. The detailed explanations are added to the revised paper as following:

"It is interesting that the effect of ENSO on the water vapor over the western Pacific and Indian Ocean is most pronounced bellow 420 K isentropic surface while over the middle and eastern Pacific significant water vapor anomalies can be noted well above 420 K isentropic surface. Figs. 3e and 3f further shows the temperature anomalies on 380 K isentropic surface and vertical water vapor flux averaged between 380-420 K isentropic surfaces. Here, the vertical water vapor flux is defined as w*q following Gettelman and Holton [2000], with w and q being vertical velocity and water vapor mass mixing ration, respectively. Fig.3e and Fig.3f indicate that the temperature ENSO anomalies over the middle and eastern Pacific are much larger than the anomalies in the western Pacific and Indian Ocean, consequently, the water vapor ENSO anomalies over the middle and eastern Pacific are much larger than those over the western Pacific and Indian Ocean on the same isentropic surface. We can also see that positive temperature anomalies at 380 K isentropic surface are not always accompanied by upward water vapor flux. However, it is apparent that both the downward and upward transport of water vapor are stronger over the middle and eastern Pacific than over the western Pacific and Indian Ocean at lower stratosphere during ENSO events. This may be the

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possible reason that water vapor anomalies over the middle and eastern Pacific can be noted well above the 420 K isentropic surface."

2) In revised Fig. 3e and 3f, the water vapor vertical fluxes are shown instead of vertical velocities. We found that the spatial pattern of water vapor vertical transport in non-ENSO conditions is similar with in ENSO situation. However, the vertical transport of water vapor in non-ENSO conditions is stronger than that in El NinËIJo events but weaker than that in La NinËIJa events. The regional differences in the vertical water vapor flux along the tropical longitudes look to relate with the pattern of the Walker circulation in ENSO situations (Webster and Chang, 1988).

5. p.4149: You use the 2005–âĂŘ2010 MLS water vapor record to help assess ENSO effects; were there any complete La Nina events during that period? Perhaps only one? You should report how many La Nina (and El Nino) events occurred during the period and note that the small number of events may not be representative of a longer-term climatology. This is a good point. The MLS dataset spans 19 El NinËIJo events, 15 La NinËIJa events and 38 neutral events. We agree that small number of events may not be representative of a longer-term climatology. But they can still provide with us more confidence in the results obtained from ERA-interim data which spans a longer time period. The above points are clarified in the revised text.

6. p.4150, lines 18-21: You state that the HALOE data do not exhibit moistening in the lower stratosphere between 5S-5N during El Nino events. However, the data actually exhibit slight moistening between 100 and 80 hPa. The region below 100 hPa is generally not stratospheric so you should exclude it from the discussion.

Due to too many missing values in HALOE data in the tropical lower stratosphere, the analysis of HALOE data was deleted in the revised paper.

7. p.4152, lines 19-27: You should explain how enhanced upwelling can overcome the limit on water vapor mixing ratio placed by cold tropopause temperatures and lead to higher stratospheric mixing ratios. The answer is not obvious.

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Enhanced upwelling could deposit more water into the stratosphere, perhaps as ice or cloud liquid, so there doesn't need to be a higher tropopause temperature for stratospheric water to increase. This point is added in the revised text.

8. p.4153-4154: Why do you discuss temperature anomalies in the middle stratosphere? Only tropopause temperatures are relevant for stratospheric water vapor anomalies.

Good point. The discussions of temperature anomalies in the middle stratosphere were deleted in the revised text.

TECHNICAL CORRECTIONS: 1. p.4144, lines 17-21: References for these two reanalysis data sets would be helpful.

Relevant references were added in the revised paper.

2. p.4145, line 1: This is the first mention of the acronym "ONI" other than in the Abstract, so you should define it (spell it out) here.

Done.

3. p.4145 and p. 4152: You refer to "normal" ENSO conditions. I believe the term "neutral" is more standard terminology.

Changed.

4. Figure 1: The text above the four plots is nearly illegible. The font size for the text next to the color bars could be increased too. Please make similar changes for the other figures as well.

The text in all figures has been revised.

5. Figure 4: The caption incorrectly reverses the definitions of the dashed and dotted lines, dashed should correspond to the Southern Hemisphere, etc.

Corrected. Thanks.

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6. Figure 5: The bottom axes in these plots seem incorrect: isn't 0 degree longitude supposed to lie at the left edge of the plots rather than at the center?

Corrected. Thanks.

7. 5a and b are difficult to compare with Fig. 2b and d since the former represent different values using colors while the latter use contour lines. I suggest making them consistent.

The two figures have been made consistent.

5c and d cannot be exactly compared with Fig. 3a-b and 3c-d since the former show the average over 25N-25S while the latter cover the ranges 25-2.5N and 2.5-25S, skipping the region between 2.5N and 2.5S. Furthermore, the two sets of plots cover slightly different altitude ranges, i.e. 370-450 K vs. 360-440 K. Please try to make them consistent.

The average areas in the two figures are consistent in the revised figure.

5e and f display different units on the vertical axis (pressure hPa) from 4a and b (potential temperature K).

The units on the vertical axis of Fig. 5e and 5f are made consistent with those in Fig 4c and 4d.

4. p.4152 (and throughout the paper): The frequent use of the "/" symbol, in phrases like "El Nino/La Nina" and "weaken/enhance", makes the text difficult to read. It would be helpful to replace this wording, at least some of the time, with sentences in which you discuss the two items separately.

This bad writing is improved as much as possible.

5. p.4154, line 10: The word "recorder" should be changed to "records". Corrected

6. p.4154, line 12: I think "ineligible" should be changed to something similar to "impor-

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tant".

Changed

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/11/C4254/2011/acpd-11-C4254-2011-supplement.pdf

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Interactive comment on Atmos. Chem. Phys. Discuss., 11, 4141, 2011.