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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Simulation of convective moistening of extratropical lower stratosphere using a numerical weather prediction model" *by* Zhipeng Qu et al.

Anonymous Referee #2

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1 Content

This manuscript describes model simulation of an overshooting convective event occurred in 2013 over North America. The simulation are performed with different setups and resolutions. The authors found an moistening of the lower stratosphere by the overshooting convection. They further concluded from the detailed model simulation that the main processes for moistening are breaking gravity waves induced by the convection and sublimation of ice crystals. In addition, the simulations are compared to aircraft in-situ measurements and satellite observations.

2 Overall impression and rating

The overall impression of the manuscript is good. The manuscript is well structured and the text is easy to understand. The simulations and process interpretation are an important contribution to the community. For these reasons, I recommend publication in ACP after minor revisions.

3 Specific comments/questions:

- Page 1, line 4: Maybe add here Riese et al. 2012. They showed also how small change in water vapor due to mixing processes change the radiative budget of the UTLS.
- Page 2, line 24: Isentropic transport of water vapor due to planetary wave activity is also an important transport mechanism for transporting tropical tropospheric air into the lower extra-tropical stratosphere (see e.g. McIntyre and Palmer, 1983; Waugh, 1996; Homeyer and Bowman, 2012). I recommend to include this mechanism also in the manuscript to complete all transport pathways.
- Page 2, line 33: I recommend to add the paper of Lee et al., 2019. They performed also high resolution model simulation of an overshooting event in the Asian monsoon region and showed how the moistening occurred and how the hydrated air was transported in the lower stratosphere.
- Page 4, line 34: In summer times the standard value in the extra-tropical lower stratosphere is more 5 ppmv (see Zahn et al. 2014 Figure 5). I would recommend to change the text from 4 to 5 ppmv.
- Page 6, line 21: Here you state the time of Fig. 4 to be at 19:49. In the figure caption it is stated 19:46. Please correct one of these times.

- Where there any cloud instrumentation aboard the ER-2 for measuring cloud number concentration or IWC? If yes, did you check if there were still ice crystals present at flight altitude in the domain B. That would be interesting to see, because than the ice crystals would have been transported over a longer distance in the stratosphere. This transport is shown by the Lee et al. 2019 and it would be interesting to see, if it occurred also in your case.
- Page 9, lines 5-10: Maybe it is worth a mention that the averaging kernels of limb sounders like MLS smear out the strong vertical gradient in water vapor at the tropopause (Hegglin et al.,2013).
- Page 9: The comparison between GEM and MLS is not really done in a balanced way. The difference is partly larger (> 100%) than the baises which are reported in the literature. This strong differences can be hardly explained by just mentioned the possible bias of MLS water vapor. It could also be a result of the model simulation. For example, warmer temperatures in comparison to MLS could lead to slower ice crystal growth and thus less dehydration and thus higher gas-phase water, which could be transported into the lower stratosphere.

Can you please comment on the following questions and suggestions:

- Which Version of MLS data are you using (this would be also nice to mention in the text)?
- Did you applied the averaging kernels of MLS onto the GEM profile ? Otherwise a fair comparison is barely possible. Why not using the exact location of MLS and applying the averaging kernels?
- Why are the profiles of water vapor (panel a/c/e) and also temperature (panel b/d/f) so different ? They should both represent air masses moving from domain a to domain b as shown by the trajectories. It

seems that the situation is strongly variable. Can please discuss in the text about the standard deviation of the mean profiles to get a better feeling on the variability.
- For better understanding of the deviation between GEM and MLS, I would also recommend to add the location of the MLS profile also into the map in Figure 7.

- Figure 8: You show some parameters of an individual trajectory in this figure. The water vapor amount with ~20 ppmv is quite high and the temperatures are cold between 203-206K, which could create conditions with supersaturation wrt. ice. and therefore additional ice formation. Do you see any signs of ice formation in the lower stratosphere along these trajectories? This could be important, because it could partly dehydrate the previously hydrated air masses.
- Page 10-11: For me it is not clear, which part of the equation 5 account for ice sublimation/transport ? Because in the equation only q, which stands for water vapor, is considered. Can you please better explain how you estimated the change due to advection and ice sublimation as stated in lines 16-20.
- Page 12-14: Where does the sublimation occurs in the hight resolution models ? Is it directly in the overshoot or are the ice crystals first mixed into the lower stratosphere by wave breaking and small scale mixing and than sublimate ? Which brings me to a further question, if ice crystals are transported along the trajectories in the lower stratosphere ? Perhaps, you can add this information also into the manuscript.
- Page 13/14: What does a negative sublimation tendency mean ? I would guess it is additional ice formation or particle growth. Or is it both ?
- Page 14: I agree with your conclusion that ice sublimation occurs less pronounced in the high resolution model because of existence of ice crystals mostly

in the overshooting core. In the relative humidity distribution (Figure 12 b) I would expect higher fraction of IWC in the sub-saturated region (Rhi < 1) for the low resolution compared to the high resolution, if there is a much higher sublimation rate. Do you have an explanation for the agreement of IWC distribution in sub-saturation for all three model setups ?

4 Technical comments/suggestions:

- Page 8, line 8: Citation should be Vömel et al.
- Page 14, line 9: It is more common to use the term supersaturated instead of oversaturated.
- Figure 2: Can you please include the date of the ER-2 measurements into the figure caption.
- Figure 4: The comprehensibility of the vertical wind speed in panel d would be better, if you choose a color scale centered with the color white at the value of 0 and with positive/negative values in two different colors (e.g. red and blue).
- Figure 5: Same suggestion above for panel c and d.
- Figure 12, caption: "relative humidity" instead of "relatively humidity"

5 References:

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