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Atmospheric Chemistry and Physics Discussions

# *Interactive comment on* "Correlation among cirrus ice content, water vapor and temperature in the TTL as observed by CALIPSO and Aura/MLS" *by* T. Flury et al.

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The authors thank the referees for their work and constructive comments on the article. Please find our answers to major comments in the beginning followed by minor comments at the end.

Answers to the major comments of referee 1:

Comment 1: Time sampling and diurnal effects. There are known diurnal patterns in tropical convection with significant land/ocean differences. The satellite data are obtained with sun-synchronous orbits and this could have a significant impact on the interpretation. For temperatures, it was not clear whether the daily values were synched



with the satellite overpasses or whether these were diurnal averages, and if so, how they were computed. The paper should address the expected impact of the cloud and water vapor measurement sampling (same time at every latitude, throughout the year) and whether there may be any biases introduced and how large these might be.

Answer: The first study that correlates temperature with water vapor will be done with MLS measurements solely (figure 1) in the revised article instead of using NCEP temperatures. There will thus be no issue about diurnal effects since the used profiles were recorded at the same local time. As part of the A-Train sun-synchronous satellite constellation Calipso and Aura have very similar sampling times that differ by about 15 minutes. The correlation of IWC and H2O is based on seasonal averages of nighttime CALIOP measurements and seasonal averages of MLS H2O. Since the main regions of interest lie over the ocean diurnal effects in convection do not play a major role because there are no significant diurnal variations of convection over ocean (Hong et al., Effect of cirrus clouds on the diurnal cycle of tropical deep convective clouds, JGR 2006). Furthermore cirrus clouds are long lived and remain during night even if created during daytime. Cloud convective- and diurnal variations are too fast in terms of time scale in comparison with our interest in seasonal variations. However your remark about diurnal variations could help explain why the correlation of IWC and H2O is better over ocean than over land in the tropics.

Comment 2: NCEP temperatures. There is the obvious question of why NCEP temperatures are used when MLS has measurements simultaneous with water vapor. If NCEP is preferred for good reasons, then it is important to include some discussion and details on the accuracy, etc. and whether it is sufficient for the purposes of this investigation or whether there are any known systematic or seasonally varying biases.

Answer: Thank you for this issue. NCEP temperatures were a remnant from the beginnings of the study. In the revised version we will show the correlation of T and H2O with solely MLS data and leave out NCEP. The results are very similar and do not alter the bottom line of the article.

Comment 6: "The ascent of TTL air is predominantly regulated by cirrus clouds ..." It is not clear that cirrus heating necessarily dominates the mass flux. There is net radiative heating and ascent of air in clear regions as well. What is needed is a precise accounting of the mass flux in the cloudy versus clear regions, and a weighting by area in order to assess the relative contributions. Has such an analysis been done?

Answer: We wanted to point out the importance of cirrus clouds in TTL processes but of course temperature plays a major role too, since 100 hPa T is about 5 K warmer in JJA than in DJF. We will adapt the sentence. No analysis has been made that accounts for ascent budgets in this study.

Comment 11: The explanation for why H2O and cirrus are positively correlated in the monsoon regions over Asia and Central America is not clear to me. First, is there abundant evidence for a persistent, elevated tropopause preferentially over these regions during JJA? There could be more discussion and references to help flesh this out. Second, how would this translate into a shift from an anticorrelation to a positive correlation? The details are not obvious to me.

Answer: To answer this question we scrutinized H2O, IWC, T and Rhi data from MLS and CALIOP and looked at the seasonal cycle in two distinctive regions at 100 hPa. The first region spans Indonesia and parts of the western Pacific (8S-8N,104E-144E) where H2O and IWC are anticorrelated (Blue in Figure 4). The second is the Indian monsoon region (16N-20N, 72E-128E) where H2O and IWC are correlated (Red in Figure 4). The difference of the respective seasonal cycles in IWC and T may explain the differences in correlation. There is a more pronounced seasonal cycle of convection in the monsoon region than there is inside of 8S-8N. IWC at 100 hPa is elevated from July to October and disappears almost entirely in DJF. Thus, convection brings ice and water vapor to 100 hPa in summer whereas ice disappears in winter. Over Indonesia ice is present throughout the year at 100 hPa. There is also a significant difference in the seasonal cycle of temperature between the two regions. Over Indonesia it is about 3K colder and the amplitude of the seasonal cycle is about 2 K, whilst it is only 1 K over



the Indian monsoon region. During the season of high IWC, relative humidity and water vapor are both elevated over the monsoon region, which is opposite to the situation over Indonesia. MLS temperatures show, that the cold point tropopause is higher over the monsoon region. During JJA it is around 85 hPa over the Indian monsoon region whereas it is around 95 hPa over Indonesia. We wanted to express that during the monsoon season the 100 hPa level is not on top of convection but inside and water vapor and ice are correlated within convection. Basically the results at 100 hPa over the monsoon region (positive correlation) are similar to what we get over Indonesia at lower altitudes (200 hPa for instance). We agree that we could have described it in a different way, what will be done in the adapted manuscript.

Comment 15: p.9 last sentence: I suspect what is meant here is that if total water in the TTL is approximately constant in the tropical, seasonal mean, then the mean flux of water into the TTL from below is approximately constant. I think this is correct only provided that the mean transport of water *out* of the TTL and into the lower stratosphere is also constant. Also, this sentence seems to imply that convection does not have a strong seasonal cycle, which is not exactly true. Moist convection refers to many things, and the vertical transport of total water is only one diagnostic.

Answer: We agree that fast processes such as the flux of water into the TTL have a seasonal cycle. But the updraft and downdraft fluxes are largely balanced in a short time scale. Inside the tropics convection shows no strong seasonal cycle but the altitude of detrainment does. A possible explanation for the conservation of total water at 100 hPa could be enhanced horizontal transport into the TTL when the flux from below decreases. This is possible during the Monsoon season from July to October.

Answers to minor comments. Please find the referee comments in the corresponding file.

1. Sentence adapted. Water vapor cools the TTL (Gettelman, JGR 2004).

2. Adapted

3. high -> strong

4. with -> to

5. Adapted

8. Adapted

9. Sentence removed

10. Adapted

12. Calipso is much better in detecting thin cirrus ice particles than MLS due to the different measurement technique. Calipso uses a LIDAR and determines the intensity of the backscattered light which is a function of (ice) particles.

14. corrected

16. Interesting for a more thorough investigation in a future study but beyond the scope of the current one.

17. Done. 1 ppm more in monsoon regions than outside at same latitude

18. See 15

19. Models are not the main point of study, but a difference was noticed and should be made public in order to stimulate future studies.

20. Subject of future investigation and beyond the scope of the current study.

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Interactive comment on Atmos. Chem. Phys. Discuss., 11, 25037, 2011.