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Atmospheric Chemistry and Physics Discussions



# *Interactive comment on* "Observations of convective cooling in the tropical tropopause layer in AIRS data" *by* H. Kim and A. E. Dessler

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We are thankful to the reviewer for the detailed comments and recommendations. Here is a list of major modifications, and answers to specific comments are listed below.

1. We have added an example of a convective event to show how each convective stage is determined (Fig. 1).
2. Figures 3 and 4 were also modified to include error bars.
3. We have clarified arguments on the sensitivity test.
4. We have modified equations for the calculation of turnover time.

**Reviewer:** First, the authors sort events by convective onset relative to observation

time in figure 2. Where is stage 4 on figure 2? The authors need to explain in a bit more detail how it relates to Figure 1. In the later stages (4-5) the temperature anomalies decay in figure 1, and yet for longer durations the potential temperature anomalies appear larger in figure 2. Where are the events in stages 4-5 in figure 2? Also, it would be useful to put error bars on the symbols in figure 2 so the reader has some sense of the confidence interval here.

**Answer:**
- We have added error bars to show the confidence level of calculation.
- In Fig. 3 (the cooling rate plot), stage 4 and 5 are not shown. This plot is intended to calculate the speed of cooling from the beginning of convection to the most active stage. The effect of the decay, in stages 4 and 5, is not considered. The large potential temperature anomalies in longer durations are cases of very strong convection still in stage 3. Events in stage 4 and 5 show small potential temperature anomalies than those in stage 3.

**Reviewer:** Second: Figure 3 could use some error bars as well. This figure shows that for a range of cloud threshold temperatures and fractions, there is no sensitivity in the calculation to the depth of convection or its extent. Is this expected from theory? It seems like there should be some relationship here if the convection is causing the cold temperatures? If not, is it possible that the cold temperatures might actually help cause the convective penetration? In figure 2 the average temperature before convective onset is 1-2K colder than the mean. For example, one likely mechanism is that temperature changes associated with Kelvin waves and the Madden Julian Oscillation might cool the upper troposphere by several degrees kelvin as observed, and the associated instability affects convection. I do not think this can be ruled out from this data, given that there does not seem to be a relationship between the strength of convection and the temperature anomalies.

**Answer:**
- We have added error bars.



**ACPD**

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Interactive Comment

- We have clarified arguments about the sensitivity test. Theoretically, it is true that the intensity of convection is associated with the amount of convective cooling. However, we would like to note that the amount of convective cooling is more directly related to the duration of deep convection than to an instantaneous change of convective intensity.

**Reviewer:** Third, the discussion on page 7623 to me seems very confusing, and I do not actually follow the math.

**Answer:**
- We agree. We have revised those equations as the reviewer suggested.

**Reviewer:** Finally, the subsequent analysis here could be clarified, and should cite some additional work. You should probably note that this is a lower limit on the convective turnover time, because it assumes the direct injection of air is responsible for all of the observed cooling, which is likely not the case. For example, from figures 1 2, the preconvective environment in stage 1 is 1-2 K colder than the mean. Also, it is likely that radiative cooling from anvil clouds, cirrus clouds and the large scale dynamic response to convection has some impact (as indicated by Sherwood (2003)). It would be useful to note also the turnover time / mass flux estimates of Kupper et al (2004) and Gettelman et al (2002) here as well. Given the level of 208K for the clouds (something like 14.5km or lower if the clouds are cooler than their environment), your estimates appear to be within the range of previous work. It looks like perhaps your estimates are on the high side of a mass flux, or the short side of a timescale, which would be expected from the method.

**Answer:**
- We agree. We have mentioned that this turnover time estimation is likely a lower limit. We also included the mass flux estimates of Kupper et al (2004) and Gettelman et al (2002).

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Interactive comment on Atmos. Chem. Phys. Discuss., 4, 7615, 2004.