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Interactive comment on "A redistribution of water due to pileus cloud formation near the tropopause" *by* T. J. Garrett et al.

T. J. Garrett et al.

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We appreciate the reviewers comments as they have helped us to clarify the arguments we are trying to make.

General Comments

1. We fully agree with the reviewer's point that we need to find the right tone. Naturally, it is too early to say whether or not the process described is important, particularly based on the limited measurements obtained during CRYSTAL-FACE. Nonetheless, we believe pileus formation is an interesting process associated with some interesting physics in a interesting part of the atmosphere. We have

changed the title, as suggested to reflect that, in fact, it is convection that is initiating the described process, through the formation of pileus cloud.

2. The distinction between pileus and cirrus is artificial, as one is a subset of the other at cold temperatures. The question is more whether a pileus cloud is ephemeral, or whether it may linger. We show that in some circumstances, it may be expected to linger past the duration of the convective impulse that formed it. In this event, by definition, the pileus is cirrus.

3. We have tried to change the tone and clarity of the paper in the revised version.

Specific comments

1. We have changed the title to "Convective formation of pileus cloud near the tropopause"

2. We have changed the description of the TTL as suggested.

3. We have changed the wording of this paragraph to help the clarity. The point here is that the storm was extremely vigorous in a manner that would suggest deep convection (80 mm/hr is unusually high precipitation to be from shallow convection). A well-developed anvil tends to appear after the most vigorous stages of convection of ended.

4. We acknowledge the uncertainties, have left out reference to the stratosphere, and hopefully better explain the reasoning. Admittedly, it is a bit surprising that pileus cloud should exist so high, but it is quite possible if convection is pushing up a humid air layer temporarily.

5. The revised text tries to clarify the situation shown by Figure 2.

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6. The word “common” is in fact mentioned in the Garrett et al., (2004) paper on the basis, as stated in the introduction, that the phenomenon was observed on most flights. Examples from these flights are described throughout that paper. Nonetheless, we have quantified the number of cases described in the revision.

7. It’s a detail, but this paper couches the pileus hypothesis with word “suggests”, and the Garrett et al., 2004 paper couches the pileus hypothesis with the word “speculative” not “highly speculative” as quoted by the reviewer. Perhaps it is more speculative than we would think based on the discussion in section 4 of that paper. As a compromise, we change the phrase “These data suggested...” to “...led to the speculation...”

8. Garrett et al. states “we estimate the fractional contribution of convection to the TTC ranges up to 0.5” on p. D21203. We have put the sentence earlier so that it is more clear that it is from Garrett et al.

9. We have changed this paragraph considerably, deleting the reference to pileus cloud, and including more information about the relative locations of the TTL and anvil layers. We have added potential temperature to plot, from which it should be clear that TTL cirrus and anvil cirrus are of distinct characters. We now mention the hypothesis described by the reviewer in the text, and explain why a role for mixing makes more sense.

10. It is unlikely the 3K temperature difference would be due to gravity waves, as the signature would have to be fortuitously in the cold phase for the entire vertical and horizontal distance covered by the aircraft during its flight through the layer. The temperature measurements are consistent with the other mixed quantities (e.g. Q and delta-HDO) and are consistent with more general analyses described by Garrett et al., 2004.

11. As stated, this equation comes from dimensional analysis. Why there should be

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a timescale, as suggested by the reviewer, is unclear, however we have changed the text to provide more background on how the equation was derived.

12. We already have a schematic in Figure 9, so we would prefer not to add another that illustrates would is already shown in Fig. 9c. Rather we have attempted to better clarify what we are doing in the text and figures.

13. Changed from particle to particles

14. We have changed a fair bit of our description and discussion of Figure 4 to accomodate reviewer's concerns. Hopefully things are clearer.

15. We have restructured our presentation of the model results in Figure 5 to aid clarity.

16. Yes, the wrong figure was referenced.

17. The discussion is now in the text.

18. Well, of course, mixing isn't different if pileus are present, but the consequences are. Mixing without pileus formation represents simple transport of condensate to higher altitudes. The argument we are, at least, trying to make, is that this mixing enables a pileus cloud to linger where it would ordinarily just evaporate. Thus, an irreversible phase change has occured within TTL air. Also, just as anvil cirrus is a stratiform layer that is the product of detrainment of successive convective pulses, so would successive pileus formation ultimately form a stratiform layer in the TTL. This is what we think we are seeing in Figure 2. Admittedly this could have been explained better, which is what we have now tried to do in the revised version.

19. We now make it more clear we are talking about tropopause cirrus.

20. Yes, we mean larger updraft velocities. Changed.

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21. From the discussion of Figure 6, mixing would discourage evaporation of the pileus in the warm phase of the wave where it would ordinarily dip below saturation.

22. We have changed the figures and figure captions as suggested.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 8209, 2005.