

## ***Interactive comment on “A model of HDO in the tropical tropopause layer” by A. E. Dessler and S. C. Sherwood***

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### General Comments

This paper addresses an issue of considerable current interest and controversy, namely the mechanism for dehydration of air entering the stratosphere. The authors believe that processes associated with convective towers that overshoot their levels of neutral buoyancy within the tropical tropopause layer (TTL) can account for the observed stratospheric aridity. They show that a simple convective parcel model can, under suitable assumptions, reproduce both the observed water vapor mixing ratio distribution and the observed underpletion (and near uniformity with height in the upper troposphere and lower stratosphere) of the water isotope HDO. Their paper thus makes a substantial case for the convective model for stratospheric dehydration, as opposed to

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models that depend on condensation and sedimentation processes occurring in high altitude cirrus.

The paper is a very provocative contribution, which should generate some interesting discussion. On the positive side, it is impressive that their simple two-column model is able to simultaneously predict reasonable vertical profiles in the tropical tropopause layer and lower stratosphere for water vapor, HDO, and ozone. On the other hand the model is highly parameterized, and requires a certain amount of somewhat arbitrary tuning to achieve these results. Perhaps more importantly, in the real world the tropical tropopause layer is subject not only to penetrative convection, but also is filled with rather long-lived cirrus clouds. Some of these are anvil clouds associated with convection, but others appear to be formed in-situ, independently of any underlying convection. It seems hard to believe that these ubiquitous cirrus do not play some role in stratospheric dehydration. In fact Danielsen, whom the authors fail to reference in this paper, argued a decade ago that dehydration could occur through processes that involved both overshooting convection and the cirrus anvils produced as a result of mixing and detrainment from convective turrets. Danielsen showed plausibly that such anvil clouds are not passive, but rather are destabilized by radiative heating at their bases and radiative cooling at their tops, providing vertical circulations within the anvil clouds that would loft the small ice crystals characteristic of these clouds, leading to reduced vertical gradients of species within the clouds as well as particle growth and sedimentation.

Danielsen also believed that net radiative heating would raise such clouds into the stratosphere, thus producing irreversible exchange. Later work showed that such heating tends to evaporate cirrus anvils rather than raising them to higher potential temperatures. Nevertheless, although the Danielsen model has not been borne out in detail, his focus on processes occurring within cirrus clouds is one that should not be ignored in a complete model of the TTL. Thus, although the present work may be regarded as an heroic effort, it is unlikely to be the whole story.

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## Specific Comments

p 4491, lines 2-3: This makes it sound like radiative heating causes air to ascend. As discussed by Yulaeva et al (1994), for example, dynamical forcing causes air to ascend in the Brewer circulation, thus causing adiabatic cooling to below radiative equilibrium, and a resulting radiative heating.

Yulaeva, E., J. R. Holton and J. M. Wallace, On the cause of the annual cycle in the tropical lower stratospheric temperature, *J. Atmos. Sci.*, 51, 169-174, 1994.

p. 4495, line 7: This assumption of a constant ice water = 4 times the water vapor in the clouds seems pretty arbitrary. I know that there isn't a lot of data, but Kelly et al. (1993), for example found quite a wide range (though their observations were not in the center of convective turrets, but rather in associated cirrus anvils).

Kelly, K., M. H. Proffitt, K. R. Chan, M. Loewenstein, J. R. Podolske, S. E. Strashan, J. C. Wilson and D. Kley, Water vapor and cloud water measurements over Darwin during the STEP 1987 tropical mission, *J. Geophys. Res.*, 98, 8713-8723, 1993.

p 4495, line 17: It is likely that descending cold parcels with collide with subsequent convective upwelling, producing enhanced mixing with air of differing characteristics. It is not clear how this may affect the results.

p 4495, line 21: Won't the mixed air still be saturated owing to ice evaporation? This sentence is unclear to me.

Figure 2: Why is there a departure from a monotonic decrease with height? Does this have something to do with the stability profile?

p 4496, lines 10-16: Yes, but in the real world cirrus anvils are formed, so aren't your assumptions pretty unrealistic here?

p4496, lines15-18: (also p4494 lines 20\_26) The assumption made here that the amount of overshoot is tuned to balance the assumed large-scale subsidence is a

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bit worrying given the poor current understanding of the so-called "stratospheric drain" which in any case seems to affect only a small region so that this assumption would seem to produce an overestimate of the overshooting mass on a tropics wide basis.

p4498, lines 5-6: It would be nice to know whether the "tuning" for the summer case was much different from the winter, and just how "similar" the results are. In summer much of the convection is over the American and African continents, where the "drain" assumption wouldn't apply.

p44501, lines 6-8: This picture of an ice crystal falling ~5 km while slowly evaporating seems unrealistic. It is also contrary to the model assumption mentioned on page 4496 of "instantaneous" evaporation.

p4503, lines 12-15: So are you arguing that a highly parameterized model is better than a real cloud model simply because there are fewer processes to disentangle? Seems a bit strange.

p4504, lines 11-15: Temperature variations associated with atmospheric waves such as gravity waves and Kelvin waves, would also produce subsaturated regions to facilitate evaporation.

p 4504, lines 17-19: Something is wrong with this sentence. Stripped to its essence it says that "...water vapor...wa.s...dehydrated..."

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