A modelling case study of a large-scale cirrus in the tropical tropopause layer

February 13, 2016

We would like to thank the reviewer for the insightful evaluation of our work. Please find below our point-by-point reply.

1. ***Reviewer*** — This paper describes simulations of a specific TTL cirrus event and provides useful insight into TTL cirrus physical processes and impacts on water vapor. The paper is interesting and well written. The paper should ultimately be suitable for publication in ACP, but I would like the authors to consider the following comments and suggestions. In particular, I would like to see more details about the WRF microphysics parameterizations used and the simulated cloud microphysical properties.

   Authors — We agree with the referee that a description of the microphysics is necessary. This has been done following the referee's suggestion in the Model description section (see also below). Also, to briefly address the sensitivity on specific microphysical parameters in the reference Thompson scheme, we have added a short discussion on those in subsection 4.2 on and one associated additional figure.

2. ***Reviewer*** — 1. Page 31091, first partial sentence: Suggest citing Wang et al. (1996, JGR). This paper reported SAGE measurements of TTL cirrus which provided the first indication of their high occurrence frequency.

   Authors — Thank you for pointing out this reference, which we have added.

3. ***Reviewer*** — 2. Page 31091, lines 2-4: I think the extents to which TTL cirrus radiative heating affects the temperature and upwelling are not well known. What is clear is that the clouds affect the TTL thermal budget.

   Authors — We agree. We have added a 'potentially' to this sentence to emphasize that it is a bit speculative.

4. ***Reviewer*** — 3. Page 31095, lines 6-7: Somewhere prior to this point (perhaps in the model description section), the authors should describe the ice nucleation scheme in the Thompson parameterization. Does the nucleation parameterization require substantial ice super- saturation for ice production (which would be consistent with homogeneous freezing of aqueous aerosols)? Are treatments of heterogeneous nucleation included? Are

mass- dimensional relationships used based on observations of cirrus at TTL temperatures or extrapolations from warmer temperatures?

Authors — A paragraph describing the microphysical assumptions in the Thompson scheme has been added in the text, on p6-7 of the revised manuscript. As explained, the parameterization involves a threshold supersaturation for nucleation to occur, which is much lower than the thresholds that would be relevant for homogeneous nucleation in a (single) air parcel. It could be interpreted as heterogeneous nucleation, but above all it is consistent with the scales of mesoscale modelling, i.e. it would produce unrealistic results to wait for the average supersaturation over a 10 km x 10 km x 300 m grid box to reach levels of 60% before triggering nucleation.

5. ***Reviewer*** — 4. Page 31095: What about the sensitivity of the ATB to ice crystal size distribution? I would hope that some comparison between the simulated effective radii and aircraft observations (Lawson et al., 2008; Kramer et al., 2009) is provided somewhere in the paper.

   Authors — We have added a sentence mentioning the sensitivity to ice crystal size distribution; however, as now specified in the text, we have not carried any sensitivity study on this parameter to keep the consistency with the assumptions inside the microphysical code. See answer to the next question regarding the comparison with previous aircraft observations.

6. ***Reviewer*** — 5. Page 31096, lines 12-14: Despite the lack of microphysical cloud property observations for this particular cirrus event, it would still be useful to present the simulated cloud microphysical properties (ice water content, ice concentration, ice crystal size) and compare with statistics from previous observations (Lawson et al. and Kramer et al.).

   Authors — We have added a Table (Table 2) summarizing the bulk microphysical properties of our cirrus field. We have also added near the end of section 2.3 a paragraph mentionning the comparison with Lawson et al. (2008) and Kramer et al. (2009).

7. ***Reviewer*** — 6. Page 31106, lines 4-5: The authors should also mention the Dinh et al. papers suggesting that radiative heating-induced internal cloud dynamics has a large impact on TTL cirrus evolution.

   Authors — We have added the reference to those papers in this section.

8. ***Reviewer*** — 7. Page 31108, lines 10-20: In the discussion of cloud radiative heating rates for the simulated TTL cirrus system, it would be useful to know how typical the simulated cloud properties are for TTL cirrus. As suggest above, a comparison between the simulated microphysical properties and the typical values reported by Lawson et al. (2008) would be helpful in this respect.

   Authors — We agree. At this point in the text, we have added a reference to the relevant section of the manuscript that compares the microphysical properties of our cirrus to observations.

9. ***Reviewer*** — 8. Page 31108, lines 24-25: It would be more accurate to say "...the magnitude of wind shear was found to be an important factor affecting the buildup of cloud-scale circulations..."

   Authors — Corrected

10. ***Reviewer*** — 9. Pages 31109-31110: The authors make an important point here: that radiatively- induced cloud vertical motions have little impact on the cirrus evolution because (1) the lifetime of air parcels in the cloud system is too short, and (2) the induced vertical motions would be comparable to or smaller than the typical mesoscale motions present. Perhaps it would be worth mentioning this result in the abstract.

    Authors — We have adopted the reviewer's suggestion and added a sentence in the abstract.

11. ***Reviewer*** — Figure 10: Most people working in the TTL clouds and water vapor field use ppmv. Figure 10 would be easier to quantitatively interpret if the authors used ppmv rather than ppmm.

    Authors — We have adopted the reviewer's suggestion and changed the units.