Review of ACP MS No.: acp-2015-1004

Title: What Controls the Low Ice Number Concentration in the Upper Troposphere?
Author(s): C. Zhou, J. E. Penner, G. Lin, X. Liu, and M. Wang

General Comments:

The authors are thanked for their detailed and informative answers/results regarding the questions asked by this reviewer (in both the initial review and in the "2nd review" or "addendum"). Regarding the answer to the first question, the answer makes sense provided pre-existing ice was assumed in all simulations shown in Fig. 1 of the author responses (the response seemed to imply that pre-existing ice was assumed).

The only outstanding issue concerns the 3rd answer from the authors that concerns the assumption of pre-existing ice. It is fine to make this assumption as many other investigators are doing so, but since the paper is focused on TTL cirrus, the paper should include some explanation on why it makes sense to assume pre-existing ice in the case of TTL cirrus. This is particularly important since TTL cirrus are generally above the zone of anvil cirrus and residual ice crystals from decaying anvils should not generally be a source of pre-existing ice in TTL cirrus. So from where does this pre-existing ice affecting TTL cirrus come from?

In specific response to the 3rd answer from the authors regarding the initial review, it should be noted that in Diao et al. (2015), the ice nucleation zone was generally at the thermal tropopause, or just above it (e.g. see Fig. 13). The author's argument that ice crystals were advected into the nucleation zone from adjacent cirrus that were not sampled (in the Diao et al. study), thus introducing "pre-existing ice" into the nucleation zone (or adjacent cirrus advecting ice into an ISSR, creating an "apparent" nucleation zone), appears to be a weak argument. As the in situ measurements in Diao et al. (2015) show, there were no cirrus above the ice nucleation zone (i.e. above the thermal tropopause). For ice to be advected into the nucleation zone, it would need to be advected primarily from regions below the tropopause, which appears rather unlikely. Although the tropopause height varies in relation to distance from the jet core, upper troposphere winds follow the isobars and it is thus not likely for ice to advect from a higher to lower altitude along this tropopause surface. For the in situ cirrus sampled in Diao et al. (GRL 2013, 2014; JGR 2015), the pre-existing ice assumption is not well supported.

While the nucleation zone was generally at the tropopause in Diao et al. (2015), there were a number of exceptions to this, and for those cases pre-existing ice appears somewhat more likely for the reasons the authors have mentioned.

The pre-existing ice assumption does appear valid for liquid origin cirrus as described in Krämer et al. (ACP, 2016) and Luebke et al. (ACPD, 2015). These cirrus form as liquid cloud droplets from lower levels are advected into and freeze in the "cirrus zone" ($T < 235$ K) via a conveyer belt of rising air associated with mid-latitude frontal systems or via strong updrafts associated with deep convection (i.e. anvil cirrus). It is very likely that ice crystals produced by these freezing cloud droplets will vigorously compete for water vapor among pre-existing ice particles. Under such conditions heterogeneous ice nucleation (het) should be strongly favored. Het may also dominate in most in situ cirrus, but perhaps not due to pre-existing ice.

Final recommendation: Although the authors and this reviewer may differ on the pre-existing ice assumption, this paper is still a valuable study worthy of publication in ACP.