Answers to Referee #1: Xiaohong Liu, xiaohong.liu@tamu.edu

Thank you for the additional comments and the helps with improving the quality of this manuscript! Please find the responses below to each of the comments.

Referee comments:

I appreciate the authors to make good efforts to address my comments on the manuscript, particularly improving the introduction to the model parameterizations, and quantifying the uncertainty of the FFD parameterization, and testing the third SIP process (ice-ice collisional breakup (CB)). While the manuscript is in a good shape for acceptance, I still have some minor comments/corrects before the publication.

1. Line 94, "particles sizes" -> "particle sizes".

Thank you! Corrected.

2. Line 142. "Because of this, each ice category in P3 can represent any type of ice-phase hydrometeor (with the limitations of a bulk scheme)." This sentence is a bit confusing. Can you be clear here what the limitations a bulk scheme are?

Thank you for the comment, we adjusted the phrase as:

"Because of this, each ice category in P3 can represent any type of ice-phase hydrometeor, although, as in any bulk scheme, ice categories in P3 remain constrained by assumed PSD parameters type and the number of prognostic moments."

3. Line 158-159. "..., immersion/contact freezing of cloud droplets and rain drops (see Morrison and Milbrandt, 2015), ..." Can you give some detail of treatment of immersion/contact freezing based on Morrison and Milbrandt, 2015? Is it dependent on aerosol, or only on temperature?

We modified the phrase as:

"…, immersion/contact freezing of cloud droplets and rain drops (temperature-dependent following Bigg (1953) with parameters from Barklie and Gokhale (1959)), …"

Two references are added:

Barklie, R. H. D., and Gokhale, N. R.: The freezing of supercooled water drops. Alberta hail, 1958, and related studies, McGill University Stormy Weather Group Sci. Rep. MW-30, Part III, 43–64, 1959.

Bigg, E. K.: The supercooling of water. Proc. Phys. Soc., 66B, 688–694, doi:10.1088/0370-1301/66/8/309, 1953.

4. Line 159. "heterogeneous nucleation via condensation freezing and deposition (Cooper, 1986)," please rewrite this to something like: condensation freezing of cloud droplets and rain drops (?) and deposition nucleation.

We changed the phrase to: "Heterogeneous nucleation through condensation freezing of cloud droplets and rain drops, and deposition nucleation (Cooper, 1986)."

5. Figure 3. As I mentioned in the first round of my review, the unit (Y-axis) of Ni seems not correct. Currently it reads as 0-5 m^-3, while it should be 10^0 - 10^5 m^-3, if I understand correctly. This also applies to other similar figures.

Sorry that we missed this point! Thank you again for mentioning it! Fig. 3 and 13 are now updated.

6. Line 486-517. You talk about the heterogeneous nucleation (condensation freezing/deposition ice nucleation) for the importance of comparing the modeled and observed T - Ni histogram (Figure 18) in this flight and also include the red open circles from Cooper 1986. How about the role of immersion/contact freezing of cloud droplets and rain drops? In mixed-phase clouds, immersion/contact freezing could dominate the ice nucleation based on previous studies.

We agree that immersion and contact freezing are another source which could explain the higher Ni values compared to the Cooper (1986) line (small red dots). We adjusted the paragraphs as:

“One possible reason for the fairly accurate Ni values in the F20-BASE simulation is that in this stratiform case Ni is likely governed by the heterogeneous nucleation process, with SIP playing a relatively less important role. In the F20-BASE simulation, most Ni values between –15°C and –25°C (T of the maximal flight altitude for Flight 20 at ~6.4 km) are higher than the parameterized Ni due to condensation freezing/deposition ice nucleation (lower half of the small red cycles in Figure 18a) within the same temperature range, but lower than the parameterized Ni for colder temperatures (upper half of the small red cycles in Figure 18a). Ice particles formed at temperatures below –25°C through condensation freezing/deposition ice nucleation may gradually fall to warmer, lower-altitude regions, thereby contributing to higher Ni compared to the parameterized Ni. Another possible source of the enhanced Ni is immersion and contact freezing. Additionally, simulated results from F20-BASE (Figure 18a) show a gradual decrease in Ni with increasing temperature, underscoring the effect of ice particle aggregation.”

“In the observed Ni frequency distribution (Figure 18d), two distinct clusters are apparent. One cluster (indicated by the large red circle) aligns closely with the parameterized Ni line, suggesting the influence of condensation freezing/deposition ice nucleation. The second cluster, which exhibits higher Ni values below –20°C, may indicate the influence of immersion and contact freezing, as well as the presence of falling ice particles originating from higher altitudes, regions that were not directly observed due to the flight's altitude limitations. The higher Ni values may also result from the effects of SIP. However, Ni gradually decreases with increasing temperature. Unlike the F20-HMgc-FFDh (Figure 18b) and F20-HMgc-FFDl-CB (Figure 18c) cases, there is no distinct ‘protruding’ cluster (green circles in Figure 18b, 18c) that would indicate a sudden Ni increase at lower altitudes due to SIP. Thus, ice formation in warmer regions (lower altitudes) in Figure 18c is likely dominated by heterogeneous nucleation, although the influence of SIP cannot be ruled out.”