

Egusphere-2025-649 Review

The manuscript evaluates the impacts of certain SIP parameterizations on cloud microphysical representation in NWP models during mid-latitude storms over the continental US. The authors compare in situ observations from a couple of flights during the ICICLE field campaign with the Global Environmental Multiscale (GEM) model. The results show that HM, FFD SIP parameterizations significantly improve the simulated cloud ice number concentrations and ice water content compared to the base model without SIP. The authors also observed that High Ice Water Content (HIWC) in clouds can occur in midlatitude systems without strong convective conditions and obvious impacts from SIP.

General Comments

This is a well-written manuscript with clear objectives, descriptions of the observations and comparison of observations with model results. I also appreciate the effort to explain and address common pitfalls of FFD parameterizations on lines 170-182. The conclusions are generally supported by the observations and analysis presented. I have some minor revisions and comments, which I hope will clarify some missing details and add some much-needed discussion to the paper.

Minor comments

1. While the authors focus on the effects of the HM and FFD processes on ice number the IWC in clouds, can other SIP mechanisms such as ice-ice collisions and fragmentation also contribute/complement the HM and FFD processes? For example, Zhao and Liu (2021) showed that the addition of SIP process parameterization such as ice-ice collision fragmentation and droplet shattering during freezing can increase global ice water path by 20% in the CAM6 model. Is it possible that including other SIP process parameterizations may change the result that the F9-HMgc-FFD performs best compared to the BASE, and HMgr-FFD for Flight 9?
2. Line 390: The Flight 20 case is a little confusing. The authors mention that the system primarily consisted of stratiform clouds, but Fig. 12 suggests a deeper system with cloud top heights near 8-9 km above ground. Also, the method of ice formation is claimed to be primarily homogenous freezing and precipitation of ice particles from above. It isn't clear from Fig 12 radar data if such ice precipitation is

observed. Could the authors provide more details regarding the claim of Ni primarily from precipitating ice vs heterogeneous freezing within the storm system?

3. Line 425: Can the authors expand on the reasoning why storm system longevity might contribute to HIWC? Does a growing ice particle feel the storm system lifetime? At first thought, it should fall out of the cloud whenever it gets too heavy, and stronger updrafts should help it stay afloat longer and get bigger. This suggests that stronger updrafts may result in larger ice particles, yet Fig 19 suggests that larger ice particles were observed during weaker updraft conditions. Some explanation/clarification will better help the readers since these are very interesting results.
4. Line 435: Could HIWC be influenced by higher and lower aerosol number concentrations during the French Guiana, ICICLE F09 and F20 flights? Could aerosol cleansing during a longer storm increase supersaturation fluctuations to form bigger ice particles during F20?

Minor corrections

Line 113: How thick is the observed melting layer for F09 and F20? What is the model vertical resolution and is it able to resolve the melting layer for each grid size?

Line 149: Is this a typo? The HM peak is at -5 C, and also goes to 0 at -5 C, Should it be -8 C?

Line 164: What is numerical value with units of the max Nf rate at T = -12.5 C?

Line 173: The “which collect rain droplets” makes the sentence a little difficult to read.

Fig 2: Can the F09 track also be overlayed on this figure? It will help the reader locate flight observations, the storm system and model grid centers better.

Flight 224: “The simulated brightness temperature closely matches the GOES-16 observations.” With the naked eye, the GOES-16 temperature looks lower for the cloud system. Could you provide mean temp values for both for the cloud system?

Line 304: It isn't clear exactly where the enhancement is occurring in the figure. Could you add a box/arrow to point at the regions?

Line 315: Also unclear where the increase in IWC is to be seen. The scale is massive and the difference in shades of grey is tough to spot.