Review of the paper "**Impact of Ice Multiplication on the Cloud Electrification of a cold-season thunderstorm: a numerical case study**" by Jing Yang et al.

General Comments:

Yang et al studied the role of three secondary ice production (SIP) mechanisms on cloud electrification in a simulated thunderstorm that was developed during the cold season. They implemented three major SIP mechanisms in the WRF model with fast SBM microphysics along with inductive and non-inductive charging mechanisms. Overall, the effect of SIP mechanisms on electrification is an important topic for the scientific community. However, in the current format, the paper needs major revision. Authors need to improve most of the sections including model validation, Analysis, implementation of SIPs, etc. I have enlisted specific and minor comments below.

Specific comments:

1) In the present study model validation is only based on spatial distribution radar reflectivity and temporal evolution flash rates. Since the study considers 3 major SIP processes, to what extent does the model agree with the observed number of concentrations of ice particles? How well does the model simulate the liquid water mass/content and vertical velocities? All these microphysical properties are of great importance for lightning. Comparison of some of these microphysical properties with the observation will be helpful for readers to understand the accuracy of the model. It will be good to compare the vertical distribution of radar reflectivity from the model with observations. If available, surface precipitation can be compared to show the robustness of model simulations.

2) Even with radar reflectivity plots, contour levels are different in observations and model, which makes it difficult to compare. To what extent does the simulated radar reflectivity is

in agreement with observations when all SIP processes are active? It will be good to present some statistical analysis.

3) Based on my knowledge, in most of the previous studies, ice-ice collision is a major SIP mechanism in deep convective clouds when compared with rime-splintering and drop shattering (e.g. Phillips and Patade 2022). This is because rime-splintering and drop shattering are active over a limited range of temperatures. The authors need to mention the reasons behind less active ice ice collision in the simulated case. What are the factors that resulted in high secondary production by rime-splintering and drop shattering when compared with ice-ice collisions? What are the major differences in the microphysical processes of wintertime thunderstorms and summertime thunderstorms? There should be some discussion on the relative role of SIP in modulating ice number concentration and hence cloud electrification.

4) It is important to show the rates of three SIP processes implemented in the model. Or at least the concentration of ice resulting from each SIP mechanism in 3SIP simulations can be shown. Time height evolution of ice particle number concentration from each of the SIP mechanisms will help to understand their relative importance in altering total ice number concentration. Authors have shown time height evolution of mass mixing ratios, however, changes in ice number concentration are very important as far as the role of SIP is concerned.

5) In Figure 8, temporal variation of ice/snow showed that there is not much effect of individual SIP process on ice/snow concentration, however when all SIPs were considered the concentration was boosted. What are the physical mechanisms behind it? I expect a significant increase in ice/snow concentration as a result of SIP in the simulations where a single SIP is considered if that mechanism is important.

6) A few details of the implementation of SIP in the model are needed. What was the diameter of the tiny fragments that resulted from mode 1 in drop shattering? What kind of collisions were considered for collisional breakup mechanisms? In which category the resulting fragments were added?

7) There is no information about the radar data e.g. which radar was used, what are the data corrections etc. Similarly, there is not much information available about lightning data.

8) Line 378: if ice ice collision was less active what are the reasons behind the enhancement in the flash rate?

9) What are the mechanisms behind the improvement in the temporal distribution of flash rate in 3SIP simulations?

10) Authors should check the manuscript carefully for grammar and language corrections. In many places, articles are missing or not used properly.

Technical corrections/Minor comments:

1. What was the cloud base height and temperature of simulated clouds?

2. Figure 1 captions: The time mentioned in the caption does not match that mentioned in the plots. Also, plots 1a and 1b are supposed to be 500 mb geopotential height, isotherms and wind barbs, but on plot b the mentioned height is 850 hpa. The same mistake is with plots c and d.

3. Figure 7: What are the averaging conditions for incloud points shown in time height plots?

4. Figure 7 captions: The names of sensitivity studies mentioned in the captions “SBM-0SIP Simulation; SBM-1SIP SimulationSBM-2SIP Simulation; SBM-3SIP” do not match the names on the plot. Please correct it according to the sensitivity tests mentioned in the text earlier.

5. Line 11: in a thunderstorm **that** occurred ;

6. Line 11: **are** investigated …
7. Line 40: correct lighting to lightning
8. Line 55: Phillips et al. 2020
9. Line 67: studies **that** highlighted ….
10. Line 95: warm **mois**t ..
11. Line 111: Fig.3a not 2a
12. Line 113: Fig 3c not 2c
13. Line 124: Figure 4 not 3
14. Line 124: **a** two-way nested
15. Line 127: spin-up
16. Line 140: Incomplete sentence
17. Line 140: at **temperatures** colder than
18. Line 144: it can also **be** active …
19. Line 204: change "With all the three SIP processes implement" to "With all implemented"
20. Line 217: units should be g kg-1 and not g ks-1
21. Line 232: there **are** …
22. Line 235: graupel mixing **ratio** …

23. Line 245: correct quicky to quickly
24. Line 281: result**s** in changes in the

25. Line 318: delete the before that
26. Line 329: cross-section
27. Line 380: implemented
28. Line 407: replace continued by continue
29. Line 408: change falling to it falls
30. Line 414: change on to in
31. Line 469: Define RAR and RAR_c