Summary:

The manuscript “Distinct effects of several ice production processes on thunderstorm electrification and lightning activity” simulates three idealized storms, specified by the cloud base temperature and depth of the warm-phase layer, to assess the influence of aerosol concentration (CCN and INP) and three SIP processes (Hallett-Mossop rime splintering, raindrop shattering by freezing, and collision ice breakup) on cloud microphysics (ice crystal number concentration, cloud water content, graupel mass) and on electrification/lightning activity (charging rate on graupel, total number of flashes, and time of the first flash). The main results include an increase in lighting activity with the increase of CCN concentration up to a threshold as found in previous studies, but here it is shown that this threshold value varied depending on the INP concentration and type of storm. Each SIP process impacted the cloud electrification and lighting activity differently depending on the thickness of the cloud’s warm-phase. The results also highlight that activating SIP processes in the simulations impacted more dramatically the lightning activity than varying/adjusting aerosol concentrations (CCN or INP). In general, the study is well-structured and presents valuable and relevant contributions within the scope of ACP, but there are some inconsistencies mainly in sections 3 and 4. My comments are included below.

General Comments:

- **Aerosol concentration and SIP process for control run**
  In line 176, it is mentioned that the aerosol concentrations were kept constant at N_CCN = 1000 cm^-3 and N_INP = 10 L^-1 when analyzing the impact of the SIP processes. Why were these values chosen? Was there an additional evaluation to arrive at these values? Was this choice made based on a paper? If so, I recommend including the citation. CCN concentration of 1000 cm^-3 could be considered part of the high range of CCN concentration (Mansell and Ziegler, 2013). If not, I suggest including, mentioning or highlighting what would be realistic values or range of values for the three types of storms, since the chosen sensitivity range spans a more extensive range not explored by other studies as mentioned in lines 165-174. Additionally, in line 174, why only the HM process is activated in the first set of simulation varying aerosol concentrations? Could the reasoning for this decision also be included?

- **Charge separation parameterization**
  In line 163, the authors state that “... the non-inductive charge separation is parameterized following Takahashi (1978)...” Although it is mentioned in line 528 “... there is still no consensus on the parameterization of the non-inductive

process, and several existing parameterizations should be tested." I expected the manuscript to provide more detail on the implementation of this parameterization and to discuss the potential implications its selection may have on the results. This is particularly important given that the Saunders and Peck (1998) scheme is widely used and has been shown to also successfully reproduce inverted-polarity charge structures, as demonstrated by for example by Kuhlman et al. (2006).

- **Charge density instead of just the charging rate on graupel**
  Figures 3 and 9 only present the charging rate on graupel, but this information alone does not provide a clear indication of the storm's overall charge structure. I would strongly suggest providing cross-sectional plots of the charge density to reduce ambiguity in the interpretation and validation of the results. Additionally, Figure 1 presents only the thickness of the warm, mixed and cold-phase regions of the three idealized storms. It would be beneficial to include additional context of the simulation results such as plots of the simulated radar reflectivity to illustrate how these storms evolve and to better connect to the idealized setups.

- **Comparison with Phillips and Patade (2022)**
  The results for the cold case are compared with those of Phillips and Patade (2022), showing consistency on the importance of the CIBU process, as noted in line 516: "This is consistent with Phillips and Patade (2022) results for a cold-base thunderstorm in which HM and RDSF are almost inactive."
  There are more details in the introduction from Phillips and Patade (2022) and the effect of CIBU on CWC in line 66 "Phillips and Patade (2022) found that the most active SIP process was breakup during ice-ice collisions. This process, acting as a sink of liquid water content, has the ability to alter the polarity of the charge Graupel acquires and, consequently, the electric charge structure."
  However, in line 437 and referring to figure 12 the manuscript states that: "The COLD case does not show any impact of the SIP processes on the average CWC profile in the early cloud electrification stage... As cloud electrification starts during the development stage of the cloud, SIP processes have not yet consumed CWC." The comparison as currently presented appears to lack consistency. I recommend revising the text and revisiting the simulation/analysis to address potential contradictions of the results also within the manuscript and ensure a clearer discussion.

Specific Comments:

Abstract

- Line 13: What impact on electrification is this referring to? Is it regarding the polarity, the charge magnitude, number of flashes, …?

1 Introduction

- Suggest include citations for the sentences starting in lines 20 and 21.

2.1.1 Microphysical scheme

- In lines 101 and 105, the authors introduce abbreviations for the SIP processes: collisional ice break-up as CIBU and raindrop shattering freezing as RDSF. But in line 99, there is no mention of the abbreviation of the Hallett-Mossop process as HM. Additionally to maintain consistency, in line 315 and 505, this process is referred to as rime splintering, when throughout the manuscript HM process has been used. This term could be introduced in line 99 as well.

- In lines 108-118, the manuscript provides implemented equations, expressions and values for the RDSF process. But the same treatment is not given to the other SIP processes HM and CIBU. Is there a reason for expanding the explanation just for RDSF and not the other processes? Was the RDSF implementation different from the cited studies?

- The units for INP concentrations are given in L^_1, but in line 172, a reference from concentrations used in another study are given in cm^-3. Writing the concentrations in the same units would help the reader to compare the range and values considered.

Results: Sections 3 and 4

- Recommend maintaining a structure in the results sections 3 and 4.
  In section 3, it is presented the following subsections:
  3 Aerosol impact on cloud electrification and lightning activity
  3.1 Electrical activity
  3.2 Microphysical structure of the storms
  3.2.1 Cloud water content
  3.2.2 Ice crystal concentration
  3.2.3 Graupel mass
  3.3 The relationship between aerosols, microphysics and electrification

  In section 4, they are:

4 Effect of secondary ice production on cloud electrification and lightning activity
4.1 Electrical activity
4.2 Microphysics
4.2.1 Ice crystal number concentration
4.2.2 Cloud water content
4.2.3 Graupel mass
4.2.4 The relationship between SIP processes, microphysics and electrification

So, the subsection titles and the order they appeared are modified from what was in section 3. Recommend keeping this consistent.

- In line 190: "... we will focus on the modification of the electrical activity and of the microphysics of each idealized case due to the sensitivity tests rather than on the differences between the three cases with the same aerosol concentration and SIP process conditions." But, in line 373 the results are compared across storms under the same set of conditions: "This enhancement is 7 times higher in the WARM case than in the MID-WARM case. " How much are their respective increases compared to just HM or HM+CIBU?

- In line 268, when referring to the Takahashi diagram, I would suggest citing the paper, since there are a couple of Takahashi's papers in the References section.

- There are several mentions of high and low values for N_CCN and N_INP but the range is only specified later in the section. I would suggest making it more clear at the beginning of the section or on the sensitivity test section the ranges for low, medium and high N_CCN and N_INP.

- For the warm case, what is the range that the HM process is maximum/most intense, since the following sentences seem to disagree? In line 315: "That is why the HM process is the most intense for intermediate values of N_CCN in the WARM and MID-WARM cases." But in line 309: "For the WARM and COLD cases, the HM process rate is maximum for high N_INP (≥ 100 L^−1) and high N_CCN (≥ 5000 cm^−3)."

- Line 325: "It suggests graupel mass is not a limiting ingredient for cloud electrification, but it can modulate the amplitude of the charge exchanged during the non-inductive process." I would recommend explaining this better as it is not clear to me the results are suggesting this.

- There are numerous instances where the word “whatever” is used. I would recommend replacing it with “regardless of” or “independent of”.

- Line 338: “The formation is accelerated but the intensity is weaker leading to a lower graupel mass at high N_INP.” The intensity of what is being referenced here?

- Lines 378-380. These sentences could be combined to avoid repetition.

- Line 395: “In the WARM case, the HM process tendency is identical for the two pairs of simulations HM and HM+CIBU (6.5 x 10^9 kg^−1 s^−1), and HM+RDSF and ALLSIP (7.1 and 7.2 x 10^9 kg^−1 s^−1)...” 7.1 and 7.2 are not identical values.

- Is the result in line 397: “The CIBU process is very efficient in producing ice crystals over the whole mixed and cold cloud depth, leading to an increase of ice crystal number concentration by around two orders of magnitude (green and blue lines in Fig. 11a).” in comparison to NOSIP or HM simulation?

- Line 399: “RDSF is the most efficient SIP in this storm; it induces a maximum of 1000 L^−1 (orange line in Fig. 11a).” What altitude and/or temperature does this correspond to?

- Line 400: “Despite being the most active at -15degC, the RDSF process results in high N_i throughout the whole mixed and cold cloud depth...” There is not an isotherm line for -15 degC, so what altitude does it correspond to?

- Line 402: “When the three SIP processes are active (ALLSIP), they add up to produce mean ice crystal number concentration that reaches a maximum of 1500 L^−1.” Is this maximum ice crystal concentration at the same altitude of the 1000 L^_1 peak for process RDSF (line 399)?

- Is “the HM+RDSF simulation presents lower values of ice crystal concentration along the vertical profile” in line 410 a comparison to the lower values in the HM+CIBU simulations?

- Line 413: “Actually, RDSF needs a deep warm-phase cloud depth and a moderate updraft which will help raindrops to grow and to be lifted up to the right temperature region (Sullivan et al., 2018)” what is the right temperature region?

- Line 414: “Interestingly, in the ALLSIP simulation, the RDSF process 415 tendency is tripled compared to the HM+RDSF simulation.” This refers to figure 10b, right? Add it here.

- Line 421: They increase the mean ice crystal number concentration by up to a factor of 1000 in the temperature range in which they are active.” What is this temperature range?

- Line 428: “In the MID-WARM case, CWC is higher in the NOSIP simulation than in all simulations where SIP processes are activated near the 0degC isotherm.” It looks like it is activated until close to -10degC isotherm.

- Line 439: “... the non-inductive charging process only occurs at high altitude (between 7.5 and 11 km), where ice crystals are available…” Figure 9 shows charge separation occurring for ALLSIP simulation from 5 km altitude.

- In line 473, what does “different cloud electrification onsets” mean?

- Do the plots in Figure 4 for N_CCN = 1000 cm^-3 (black line), N_INP = 10 L^_1 (third row) match the ones for Figure 12 with HM process (black line)? Could this correspondence of control cases be included in the manuscript?

5 Conclusions

- Line 491: “As for the HM process, it is maximum at intermediate or high N_CCN levels (1000 - 10,000 cm^−3)” Is maximum at producing ice crystals? Also, inconsistent definition for the high range of N_CCN in line 308.

- Lines 497-500. Combine sentences to avoid repetition.

- Line 500: “Mansell and Ziegler (2013) attributed the decrease of lightning activity with NCCN to the HM process…” A decrease is observed once the threshold value is exceeded?

- Line 503: “Thus, both particles has to be taken into account to ...” Adjust to: Both aerosol particles have to be …