Response to Comments of reviewer 1

The authors thank both reviewers for their constructive comments and suggestions, which have helped us to improve the quality of this paper both in sciences and writing. All comments are carefully considered and responded to. The response in black letters follows each comment in blue.

The authors' investigation into the amplification of longwave downward radiation by hygroscopic aerosols in an Arctic field site presents notably high radiative effect values. This Referee maintains a degree of skepticism and recommends a revision of the manuscript to address these concerns convincingly. The following points should be considered:

- **Comparison with Existing Studies:** Given the dramatic results, it's essential to compare and contrast these findings with existing literature. Are there any reported measurements or theoretical calculations in similar or relevant settings?

Answer: To our knowledge, no observations have been reported of additional infrared radiation released during aerosol wet growth. We hope that our observations will contribute to this gap. Under the condition of dry aerosol particles, our results are consistent with several literatures. And we have added the following sentences:

(L292) "Conversely, for non-hygroscopic aerosols, such as dust and black carbon, the ARE_{AW} is about 1.45 ± 2.00 Wm^{-2}, and close to previous studies, which does not change with RH (Spänkuch et al., 2000; Markowicz et al., 2003; Vogelmann et al.,2003; Lohmann et al., 2010)."

- **Robustness of Results:** In line with Referee 1's comments, additional effort is needed to ensure the robustness of the results. For example, while the authors discuss the distinctions between dry aerosol particles, wet aerosol particles, and cloud condensation nuclei, further elaboration is necessary.

Answer: Our study focuses on humidity levels below 100%, meaning we only discuss aerosols in their dry and wet states. We take aerosol in RH < 60% as dry states. When the environment becomes more humid (RH > 60%), a hygroscopic particle can absorb water, and its size grows, which can act as cloud condensation nuclei (CCN). This hygroscopic particle is defined as wet aerosol in our study. It is worth noting that since we focused on the infrared radiation effect of aerosols, the most notable distinction between the dry and wet states is that aerosols in the wet state (RH > 60%) exhibit enhanced infrared radiation.

And we added the following sentences to the introduction: (L54 - 57)" Our study focuses on humidity levels below 100%, meaning we only discuss aerosols in their dry and wet states. We take aerosol in RH < 60% as dry states. When the environment becomes more humid (RH > 60%), a hygroscopic particle can absorb water, and its size grows, which can act as cloud condensation nuclei (CCN). This hygroscopic particle is defined as wet aerosol in our study."

Clarity of Methods: The Methods section requires additional clarity. For instance, the introduction of "AREaw from FTS" measurements in section 4.1 that uses LBLDIS model calculations before the latter's formal introduction in the subsequent 4.2 section, creates ambiguity. The source of the evidence should be explicitly stated.

Answer: Corrected, we define the model in Section 4.1.(L164-166).

- **Precision in Terminology and Notation:** Equation 1 and its description warrant careful attention. The equation defines AREaw as the difference between all-sky and clear-sky values, yet the description refers to all scenes as "clear-sky" (no clouds), with the "clear-sky" term in the equation implying the absence of both clouds and aerosols. A revised notation and convention, possibly using the term "clean" for scenarios without aerosols, could enhance clarity.

Answer: Corrected, we have changed all the "clear-sky" to "clean-sky" referring to the conditions without aerosols and clouds.

- **Methodological Clarity and Validation:** The relationship between the various radiation methods introduced needs clarification. Are they complementary or intended for cross-checking? Additionally, the manuscript would benefit from a discussion of any validation efforts undertaken to bolster confidence in the results.

Answer: Added in the discussions part:

(L331 - 342) "FTIR and BSRN observations are operating on different spectral bands—FTIR focusing on the atmospheric window spectrum region and BSRN covering a broader infrared spectrum. It is worth noting that the estimation of the absolute radiation value from two observation methods is not comparable because of the different spectral range. However, if the cross-validation of these methods is needed, we can roughly compare them in terms of how many times they have grown in radiation from dry to wet aerosol. Both FTIR and BSRN observations consistently indicate that within the relative humidity range of 60% – 80%, aerosol wet growth results in an approximate 7 times increase in ARE compared to dry conditions. At high humidity (> 80%), the FTIR instrument can capture the infrared radiative enhancement by aerosol wet growth because of the small field of view (FOV = 3.3 mrad). In contrast, BSRN all-sky observation, which requires a completely cloud-free sky across the entire observation domain, is more susceptible to cloud contamination under high-humidity conditions. As a result, BSRN is limited in providing precise ARE values at higher humidity levels. This distinction highlights the strengths and limitations of each observational method under different atmospheric conditions."

More general comments that could be considered in the revision as well:

- **Extrapolation and Temperature Impact:** The manuscript's impact could be enhanced by extrapolating the local effects to a larger (regional or global) signal regarding longwave radiation effects. Furthermore, can the measurements provide

insights into the contribution of these aerosol effects to observed temperature changes nearby?

Answer: We acknowledge the importance of extrapolating the local effects observed in this study to larger regional or global scales to better understand the broader implications of aerosol longwave radiation effects. We are currently conducting model simulations for the recent 10 years to explore these regional and global impacts. However, as model simulations are very time consuming, we are still in the process of obtaining the first results. We plan to update this part of the work in future studies once the simulations are complete. These model results will also allow us to investigate the potential contribution of aerosol effects to observed temperature changes in the surrounding regions. We greatly appreciate your suggestion and have noted this as a key direction for future research.

- **Writing Style and Clarity:** The manuscript's readability could be improved. The use of numerous acronyms, while potentially common in this subfield, can hinder comprehension. Careful consideration of whether each acronym is necessary would enhance clarity. For example, the authors use "FTS" but maybe "FTIR" is more appropriate here?

Answer: Corrected. In the new version of our manuscript, we have used commonly recognized abbreviations wherever possible and minimized the use of unnecessary abbreviations.