Response to Reviewer #2

Thank you for your comprehensive and valuable comments and suggestions, which we have carefully considered. We very much appreciate your thoughts and time; your ideas really improved and enriched the manuscript! Please look at our responses and the revised manuscript.

The text of your review is copied below in *Calibri black font italic style*; our replies are given in black style.

Reviewer #2:

An extensive analysis of low-level airborne observations of near-surface thermal-infrared net irradiance (TNI) conducted in the Arctic is presented in the article "Effects of variable, ice-ocean surface properties and air mass transformation on the Arctic radiative energy budget". The study explores the complex interplay between sea ice concentration, cloud properties, surface albedo and atmospheric thermodynamics, shedding light on the radiative transfer and thermodynamic processes occurring in the marginal ice zone (MIZ) and surrounding areas. The article addresses the critical knowledge gap regarding the understanding of near-surface thermal-infrared net irradiance in the Arctic, particularly in the MIZ. Several noteworthy findings are presented. Firstly, the study reveals four distinct modes of near-surface TNI in the MIZ. Furthermore, the authors observe a seasonal shift in the TNI field above homogeneous sea ice, characterized by more negative net irradiances and increased occurrence of cloudy states in summer compared to winter. This shift is attributed to the non-linearity of the Planck emission. Moreover, the authors highlight the importance of considering the thermodynamic profiles and stability in both cloudy and cloud-free conditions, as these factors significantly impact the TNI. The amount and quality of data evaluated in chapter 4 ("Cloudy and cloud-free modes of thermal-infrared net irradiance (TNI)") is impressive and the conclusions comprehensible and interesting.

Naturally, there is much less data for the analysis in chapter 5 ("Impact of synoptically driven meridional air mass transports on thermal-infrared radiation at the surface") and the conclusions on the individual case studies are more speculative here. While the publication mentions diverging and variable estimates from satellites, models, and observations, there is limited comparison or discussion of the findings in relation to existing literature. How could more robust statements be made here in the future in order to get similar TNI values from remote sensing, models and in situ observations?

The research presented in this article carries significant implications for our understanding of radiative transfer and thermodynamic processes in the Arctic. The findings provide valuable insights into the complexities of TNI in the MIZ and its relationship with sea ice dynamics. Publication is recommended and addressing the above-mentioned minor points of criticism would further strengthen the study.

Reply:

The first part of the reviewer's comment is about placing the findings in relation to existing literature. The paper has attempted to do so by mentioning some of the key observations over sea ice from the past, such as from SHEBA and N-ICE2015, as well as incorporating some data from those campaigns into the analysis as direct context for the ACLOUD and AFLUX measurements. There are relatively few of these measurements that can be used as context. The MOSAiC data are one potential new source, although analysis of that data is still underway and will be published in the future.

The second part of the reviewer's comment specifically asked if more robust statements could be made in the future to get similar TNI values from different perspectives. We interpret this statement as asking how we can better achieve consistency across the different perspectives on TNI. Indeed, this is an important goal and one of the motivations for making the aircraft-based measurements that are the subject of this paper. These observations are relatively unique and offer good potential to evaluate how both models and satellite retrievals represent the TNI across the ocean-ice interface transition zone, including their representation of the different states of the TNI distribution. Achieving this consistency is a long-term process that will require further observations, detailed intercomparisons, more sophisticated model-process diagnostics, and further refinement of satellite retrieval approaches as well as model parameterizations. While that work is surely beyond the scope of this paper, we have added some statements to the last paragraph of the paper that express the need for this important future research.

Reviewer #2: *Figure 8 change F_ter,net --> F_tin*

Reply: Thanks for carefully reading the text, we have changed $F_{\mathrm{ter,net}}$ to $F_{\mathrm{tir,net}}$

Reviewer #2: *Figure 9 – seems a bit cluttered and confusing to me. Showing simulated thermal-infrared downward irradiances for clear sky conditions adds little value.*

Reply: The cloud-free values along the flight path are used to obtain an appropriate baseline. However, we agree with the comment of the reviewer, which was also made by reviewer #1. Therefore, we have skipped the results of the simulations for cloud-free conditions. Instead, we have added two panels of downward and upward irradiances to this figure, which simplifies interpretation.