Please find below our responses to the reviewer comments and concerns regarding manuscript EGUsphere-2025-3690 “The observed evolution of Arctic amplification over the past 45 years” submitted to *The Cryosphere*. Our responses are provided in red.

Respectfully,

Mark C. Serreze, and co-authors

REVIEWER #1

General Comments:

This study provides an overview on the seasonal and long-term change in Arctic amplification (AA) over the last several decades using ERA5 reanalysis and satellite-derived sea ice data. The authors introduce a metric called the “Local Amplification Anomaly” (LAA), which is used to diagnose how Arctic near-surface temperatures are changing relative to the global average on a point-by-point basis. In addition to this, they look at changes in low-level stability over the Arctic, again through season and time. Overall, this study highlights the tightly coupled and complex set of relationships between sea ice melt/growth, upper ocean heat accumulation, and near-surface AA ratios, with a focus on the importance of considering these interactions depending on the season.

Overall, the methods and results are logical, and the paper is particularly well-written. The authors did a great job in describing AA in very clear and concise language. I just have some additional thoughts, questions, and comments below, which I hope are useful in the revision process.

We thank this reviewer for these positive comments and the time and effort spent on the review.

Specific Comments:

1. My primary concern is related to the originality/novelty of the results for publication in The Cryosphere (journal’s reviewing criteria). At this stage, it is well understood now that the rate of AA differs by season across the Arctic, particularly because of different feedbacks like heat flux exchanges through the seasonal cycle of ice growth and melt. There have also been a few review papers on AA processes published in recent year (e.g., Henderson et al. 2021; Previdi et al. 2021; Taylor et al. 2022, Esau et al. 2023) and studies that have quantified an updated calculation of the AA ratio. I think there are a few new results nicely described here for the seasonal and decadal evolution of regional AA, so the authors should more clearly highlight the purpose and these new contributions in the introduction of the paper (such as around L44-54) relative to existing earlier work on Arctic change.

   We thank the reviewer for bringing these papers to our attention. We have now briefly described and cited these papers in the introduction. The paper by Esau et al (2023) is particularly valuable in highlighting some of the impacts of AA on Arctic terrestrial and marine ecosystems. Additionally, we have also added text to point out what is new in our study and to set it apart from previous work.

2. This cautionary comment is acknowledged in a few places, such as L296-303, but I still have some hesitation around showing only results from ERA5. I understand that a comparison of observational/reanalysis datasets is not within the scope of this paper, but I still think it is necessary for a quick comparison for the temperature results given that ERA5 does have numerous biases (which could even be reflected in trend data) (Wang et al. 2019; Yu et al. 2021; Tian et al. 2024). One suggestion would be to show the seasonal decomposition of decadal AA, similar to Figures 3-4, in a supplement figure using a station-based gridded dataset (such as Berkeley Earth, or others).

   Thank you for bringing these studies to our attention. We acknowledge that we were remiss in not adequately reviewing papers discussing bias in ERA5. We added the following text to Section 2 and return to the issue of biases later in the paper:

   "Our results must be viewed within the context of known problems in ERA5, one being a warm bias in 2-meter air temperature over the Arctic (Yu et al., 2021; Tian et al., 2024). Compared to an extensive set of matching drifting observations, Yu et al. (2021) found ERA5 to have a mean bias of 2.34 ± 3.22 °C in 2-meter air temperature, largest in April and smallest in September. Interestingly, surface (skin) temperature biases were found to be negative (−4.11 ± 3.92 °C overall), largest in December and smaller in the warmer months, although the magnitudes might be overestimated by the location of the surface temperature sensors on the buoys, which may have been affected by snow cover. While we are largely dealing in this paper with anomalies, rather than absolute values, our comparisons between Arctic and global anomalies may be influenced by the fact that biases at the global scale are different. Wang et al. (2019) found that compared to the earlier ERA-I effort, ERA5 has a larger warm bias at very low temperatures (< -25°C) but a smaller bias at higher temperatures. ERA5 has higher total precipitation and snowfall over Arctic sea ice. The snowpack in ERA5, results in less heat loss to the atmosphere and hence thinner ice at the end of the growth season, despite the warm bias."

   In addition to adding this text highlighting biases in ERA5, we have performed the same analysis as done with ERA5 using the Berkeley Earth Surface Temperature (BEST) dataset. We have added verbiage in the paper around this analysis as well as adding supplemental figures and the analysis shown in Table 1 with BEST data. In Section 2, we added:

   "To further address biases in ERA5, analysis was also performed using the 'Berkeley Earth Surface Temperatures' gridded surface temperature data (Rohde and Hausfather, 2020; Available for download from: https://berkeleyearth.org/data/). This dataset extends back to 1850, combining both 2m temperatures over land as well as sea surface temperatures to create a global, gridded observational dataset to which reanalysis data can be compared."

3. Changes in surface heat fluxes are mentioned throughout the study as supporting the evolution of events over time, including the association between near-surface air temperature, static stability, and sea-ice anomalies. I do think it would strengthen the results to actually show how turbulent heat fluxes unfold. If this additional analysis is not possible, please more clearly refer to other studies that have analyzed this data in observations/reanalysis.

   Thank you for this suggestion. This analysis has been performed, and the results have been added to the paper.

Technical Comments:

1. L11; Spelling for "evolution"

   Typo fixed.

2. L15; Spelling for "anomalies"

   Typo fixed.

3. L59; Space in front of surface parameters.

   Fixed.

4. L70-73; Is this point still actually under-acknowledged in the literature on Arctic change?

   We have clarified as follows: *"A key, but in our view, under-appreciated aspect of AA in our study is its strong seasonality - under-appreciated not that it exists but in the sense that processes at work during summer over the Arctic Ocean, when AA is small, set the stage for understanding the strong imprints of AA during autumn and winter."*

5. L74-74; What is the statistical test used here and throughout the analysis?

   The statistical test used was an ordinary least square regression. This has been added to the corresponding Figure captions.

6. L112; "Still[,] positive 2-meter"

   Comma added.

7. L219-2020; Though this could be a product of internal variability and only looking at 5 years, compared the full decade.

   The sentence starting *"This is consistent with…"* was meant to refer to the entire time series of mostly weaker anomalies, not that last 5 years. Therefore, we have flipped the order of these two sentences. That said, as the reviewer suggests, the importance of internal variability is obviously more prominent in 5 years than 10, so we also now mention that the 3°C anomalies for the 2020-2024 period may "represent short-term internal variability".

8. L227; "on" to "in"

   Changed as suggested.

9. L228-230; Could a reference be added here? (e.g., https://nsidc.org/learn/ask-scientist/why-use-1981-2010-average-sea-ice)

   The reference (Scott, M., 2022) has been added.

10. L289; Spelling for "Barents"

    The "t" has been restored.

11. L336-338; Could this sentence be reworded to improve clarity?

    This sentence has been reworded.

Figures/Tables:

1. All map Figures; Could the labels for the lines of longitude be reduced in frequency? Sometimes the text overlaps and are difficult to read, along with too many dashed lines over the actual data contours.

   This has been done.

2. All Figures; Could units and labels be added to the colorbars? This helps ensure greater accessibility for interpreting the results.

   This has been done.

3. All Subplot Figures; Could letters be added (e.g., a, b, c, d) next to each subplot to make it easier to refer to the figures in the text?

   This has been done.

4. Figure 1 and Elsewhere; Please define all acronyms (e.g., DJF, MAM, T2M)

   This has been done.

5. Figure 2; I think it is showing September trends again on the right side.

   The correct figure is in the paper now.

6. Table 1; Please indicate units.

   Units have been added.

7. Figure 7; Could the colormap be changed here to a perpetually uniform, colorblind-friendly one that is more accessible to TC readers? (Hawkins, E. (2015). Scrap rainbow colour scales. Nature, 519(7543), 291-291.)

   The figure has been remade with a more colorblind-friendly colormap.

Reviewer's References:

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Yu, Y., Xiao, W., Zhang, Z., Cheng, X., Hui, F., & Zhao, J. (2021). Evaluation of 2-m air temperature and surface temperature from ERA5 and ERA-I using buoy observations in the Arctic during 2010–2020. Remote Sensing, 13(14), 2813

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