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 #3

This is an interesting paper which explores the regional (or local) aspects of AA. Many studies will refer to the nature or impacts of Arctic change as a whole, but this manuscript delves a little deeper into the issue. The submission has the potential to make a significant contribution to the literature, but it is not quite there yet. Before I would be able to recommend acceptance, there are a number of issues which need to be addressed.

We thank the reviewer for this positive review and for their time and effort.

Lines 24 - : In this introductory survey and remarks it would be appropriate to mention the 'PAMIP' project …

Doug M. Smith, James A. Screen, Clara Deser, Judah Cohen, John C. Fyfe, Javier Garcia-Serrano, Thomas Jung, Vladimir Kattsov, … and Xiangdong Zhang, 2019: The Polar Amplification Model Intercomparison Project (PAMIP) contribution to CMIP6: Investigating the causes and consequences of polar amplification. *Geoscientific Model Development*, **12**, 1139-1164, doi: 10.5194/gmd-12-1139-2019.

Thank you for the suggestions. We have included this work in the introduction as: *"The Polar Amplification Model Intercomparison Project (PAMIP; Smith et al., 2019) further investigates the causes and consequences of polar amplification using a coordinated set of numerical model experiments, providing valuable insights into the mechanisms driving AA."*

Line 39: 'Graversen et al.' should be 'Graversen and Burtu'.

Fixed as suggested.

Line 45: Important additional rationale for this work is that the local characteristics of AA have broader implications. Beneficial here to support this by referencing study of Wenqin Zhuo, Yao Yao & co-authors, 2023: The key atmospheric drivers linking regional Arctic amplification with East Asian cold extremes. Atmosp. Res, 283, 106557, doi: 10.1016/j.atmosres.2022.106557 who demonstrate the AA regionality is important in producing very different remote influences, via teleconnection patterns, into the midlatitudes.

We thank the reviewer for this helpful suggestion. We have added a sentence to highlight the broader implications of regional Arctic amplification, citing Zhuo et al., (2023):

"The local characteristics of AA are important, as regional variations can produce different

remote influences, including midlatitude climate extremes (Zhou et al., 2023).”

Line 73: Better to write as ‘2’ and ‘5’.

Words have been changed to numbers here.

Line 80 (Figures): Showing the values of longitude at every 5 degrees makes these plots look unnecessarily busy. Much less frequent would be ample.

Also the headers on the plots should read ‘trend’ and not ‘change’

The caption reads … ‘Shading is used for trends significant at p<0.05’. This is confusing, especially as in the caption of Figure 2 the authors have (a better expression of) ‘Only trends significant at p<0.05 are shaded’. Be consistent and as clear as possible.

The preferred phrasing is now used for all figures with trends (Figure 1, 2, 8, and 9). The figures have been redone with the frequency of longitude labeling reduced, and the heading on the plots read ‘trend’ now rather than change.

Line 85: The authors must explain how they performed the statistical significance test. An additional aspect on this is that the parameters discussed here have considerable memory (autocorrelation). This has the effect of reducing the ‘effective’ number of data points and hence reduces to degrees of freedom. Please to allow for this also – see approach of Christopher S. Bretherton, Martin Widmann, Valentin P. Dymnikov, John M. Wallace and Ileana Bladé, 1999: The effective number of spatial degrees of freedom of a time-varying field. Journal of Climate, 12, 1990-2009, doi: 10.1175/1520-0442(1999)012<1990:TENOSD>2.0.CO;2.

We thank the reviewer for this comment. The statistical significance test for linear trends in sea ice concentration (% per decade) was performed using ordinary least squares regression test, and only trends significant at $p < 0.05$ are shaded for each grid point. While year-to-year autocorrelation in annual anomalies is minimal, spatial autocorrelation is present because neighboring grid points might not be independent. To account for this in a practical way, we focus on large contiguous areas with robust effect sizes, rather than isolated small pockets of significance, which are more likely influenced by spatial correlation. This approach emphasizes physically meaningful patterns while mitigating the influence of spatial autocorrelation, and we have clarified this in the Methods section.

Line 143: The third and fourth entries into the first column of Table 1 should be ‘2000-2009’ and ‘2010-2019’.

This has been corrected.

Lines 175-180: An interesting argument is made here. Note that in the three later decades shown in Figure 4 the AA over Eurasia is prominently negative. This ties in neatly with the Warm arctic-cold Eurasia (WACE) phenomenon (refence here Li, M., et al., 2021: Anchoring of atmospheric teleconnection patterns by Arctic Sea ice loss and its link to winter cold anomalies in East Asia. *Int. J. Climatol.*, **41**, 547–558). In line with the authors’ comments here regarding

the impact of the phase of the North Atlantic Oscillation in the earlier period, studies have shown that in more recent times other large-scale modes (such as Interdecadal Pacific Oscillation and the Atlantic Multidecadal Oscillation) have influenced the nature of the WACE pattern (see …

Luo, et al., 2022: The modulation of Interdecadal Pacific Oscillation and Atlantic Multidecadal Oscillation on winter Eurasian cold anomaly via the Ural blocking change. *Climate Dyn.*, doi: 10.1007/s00382-021-06119-7 and

Luo, B., D. Luo, and coauthors, 2022: Decadal variability of winter warm Arctic-cold Eurasia dipole patterns modulated by Pacific Decadal Oscillation and Atlantic Multidecadal Oscillation. *Earth's Future*, **10**, e2021EF002351, doi: 10.1029/2021EF002351). The paper will benefit from a more incisive argument along these lines on the structure of the Fig. 4 plots.

Thank you for pointing this out. We have added the following to the text*: "The observation that the last three time periods have negative LAA values over Eurasia is of interest through its apparent link with Warm Arctic-Cold Eurasia (WACE) phenomenon-while AA has become increasingly prominent, this has been attended by recent surface cooling over Eurasia, most evident in winter with considerable decadal variability. (e.g., Gong et al., 2017). The WACE phenomenon has garnered considerable attention over the past decades, and a suite of driving factors has been offered. An Urals blocking pattern has been identified as playing a strong role, and recent work has shown that decadal variability in the WACE phenomenon is mediated by phases of the Pacific Oscillation and the Atlantic Multidecadal Oscillation (e.g., Luo et al., 2022)."*

Line 183 (Figure 3): Figs. 3 and 4 present much more information than does Table 1. Perhaps consider deleting the Table as it contains lots of number. If you follow that, maybe also here show LAA Figs. covering spring and summer.

Also suggest 'LAA' rather than 'AA' in the headings of the sub-plots.

We will have to agree to disagree on this point; we feel that Table 3 provides valuable information. Note that changes have been made to Table 3 in response to other reviewer comments. However, the headings in the plots have been changed from 'AA' to 'LAA'.

Line 207: Support this point by also referencing Lee S, Gong T et al. (2017) Revisiting the cause of the 1989-2009 Arctic surface warming using the surface energy budget: Downward infrared radiation dominates the surface fluxes. Geophys. Res. Lett. 44: 10,654–10,661 doi: 10.1002/2017GL075375.

We have added this reference.

Lines 234-5: Why just October and December, when up till now you have been considering SON and DJF?

October is when there are particularly large heat fluxes from the ocean to atmosphere, while in December, most of these areas (apart from the Barents Sea) have re-frozen. We wanted to capture that contrast. We now note this in the text.

Line 251: Paper has been using ‘deg C’ up to here, and now ‘K’. Please revert to deg C here in the subsequent occurrences.

Everything has been changed to Kelvin for consistency.

Line 271 (Heading on Figures): Please to change ‘mb’ to ‘hPa’. (Similar for Figure 9).

This has been done.

Lines 276-286: reinforce these arguments by referencing paper of Simmonds et al. (2021 - Trends and variability in polar sea ice, global atmospheric circulations, and baroclinicity *Ann. NY Acad. Sci.* **1504** 167-86) showing strong decreases in the Brunt–Vaisalla frequency over the Artic and its broader region.

On this issue the B-V frequency is more strongly connected to the (thermo)dynamics than is ‘delta theta’. It also contains a ‘1/theta’ term which highlights the impact in the colder regions. Some words on this are warranted here.

Done as suggested. Thank you for making us aware of this study.

Lines 302-303: Valuable to mention in text here that Xin Wang and Jinping Zhao used three data sets, namely NCEP-R2, ERA5, and JRA-55, to make it explicit that ERA5 (as used here) was one of the sets.

Done.

Lines 412-413: Please to include full bibliographic details (volume, article number, …) here …

Liu Y, Zhang J (2025) Conductive heat flux over Arctic sea ice from 1979 to 2022. J. Geophys. Res. 130: e2024JC022062 doi: 10.1029/2024JC022062.

Full details added.

Lines 446-7: Reference is repeated. From context, I suspect authors meant to make Screen JA, Simmonds I (2010) Increasing fall-winter energy loss from the Arctic Ocean and its role in Arctic temperature amplification. Geophys. Res. Lett. 37: L16707 doi: 10.1029/2010GL044136 as ‘part b’.

The extra reference is now removed, and the “part b” version is now the only version.

More missing details in References …

Stroeve, J. C., Markus, T., Boisvert, L., Miller, J. and Barrett, A. 2014. 'Changes in Arctic melt season and implications for sea ice loss', *Geophys. Res. Lett.* **41**, 1216-1225, doi: 10.1002/2013gl058951,

Stroeve, J. and Notz, D. 2018. Changing state of Arctic sea ice across all seasons. Env. Res. Lett. 13, 103001. DOI: 10.1088/1748-9326/aade56. …

Please to check all reference informations carefully.

These two errors are fixed, and we went through the rest of the reference list, cleaning up a few more typos and omissions of details.