Reply on RC4 and RC5

Major/clarifying comments:

Q: The AR identification is based on Guan and Waliser (2024), who also employ a Lagrangian tracking framework. According to their tracking methodology, the Siberian AR event and the Atlantic AR event appear to be merged into a single AR event (if my understanding is correct). However, throughout the manuscript the two events are described as separate ARs. It would be helpful to include a brief clarification explicitly stating that, under the Guan–Waliser AR algorithm, these two ARs are identified as a single merged event, while they are analyzed separately in this study.
A: We thank the reviewer for this comment. The tARget algorithm identifies AR objects at individual time steps and tracks each AR object through space and time, with two AR shapes at adjacent time steps that spatially overlap being regarded as belonging to the same life cycle (Guan and Waliser, 2024). In this Lagrangian framework, the Eurasian and Atlantic ARs are tracked as individual objects until a merger occurs, i.e. an AR shape is identified that overlaps with the spatial footprints of both/multiple ARs from the previous time step. At this point, tARget v4 continues the life cycle of the AR that most closely matches the new shape and terminates the other. This results in a single merged AR object being identified over the Arctic during the latter stages of the life cycle.

Because the two ARs have different synoptic drivers, moisture origins, and regional impacts, we study them as separate events during their earlier stages and note that they subsequently merge in the Arctic. We have added a clarifying sentence to the methods section: '*As the two ARs merge over the central Arctic in the latter stages of their lifetimes, the tARget tracking algorithm identifies them as a single AR object for those time steps.*' See lines 163-164 on page 6.

Q: Regarding Figure 3: In April, decreases in net shortwave radiation associated with ARs can also contribute to the net surface energy budget (SEB), in addition to enhanced net longwave radiation (Zhang et al., 2025). It would be helpful to discuss the contribution of net shortwave radiation to net SEB, as net shortwave radiative appears to decrease during the two AR events shown in Figure 3e, which may help explain the slight decrease on net SEB on April 16.
In addition, prior to the arrival of the Siberian AR, net longwave radiation, 2-m temperature (T2m), precipitation, 2-m specific humidity (Q2m), and net SEB already show increases, while during the Siberian AR itself the net longwave radiation remains relatively steady. Could the authors please elaborate on the atmospheric conditions preceding the arrival of the Siberian AR that may explain these features?

I also suggest computing T2m, precipitation, Q2m, and surface energy budget components (including longwave, shortwave, sensible, and latent heat fluxes) from ERA5 and comparing them with the MOSAiC in situ observations shown in Figure 3. This comparison could help readers to appreciate a broader spatial context and allow for an assessment of the consistency between the reanalysis and the MOSAiC observations.
A: We thank the reviewer for this comment and agree that the SEB components in Fig. 3 would benefit from further clarification. We have addressed the three points as follows: First, regarding the role of net shortwave radiation to the SEB, the slight decrease in net SEB during the second half of 16 April may be explained by the diurnal cycle of net shortwave radiation, as net longwave radiation and turbulent fluxes remained fairly steady during this period. We have added the following to the revised manuscript: '*Together with a reduced amplitude of the diurnal cycle of net shortwave radiation, the enhanced net longwave radiation suggests an increase in cloud cover. (…) As during the Eurasian AR, reduced net shortwave radiation is observed.*' See lines 238-254 on pages 10-11.

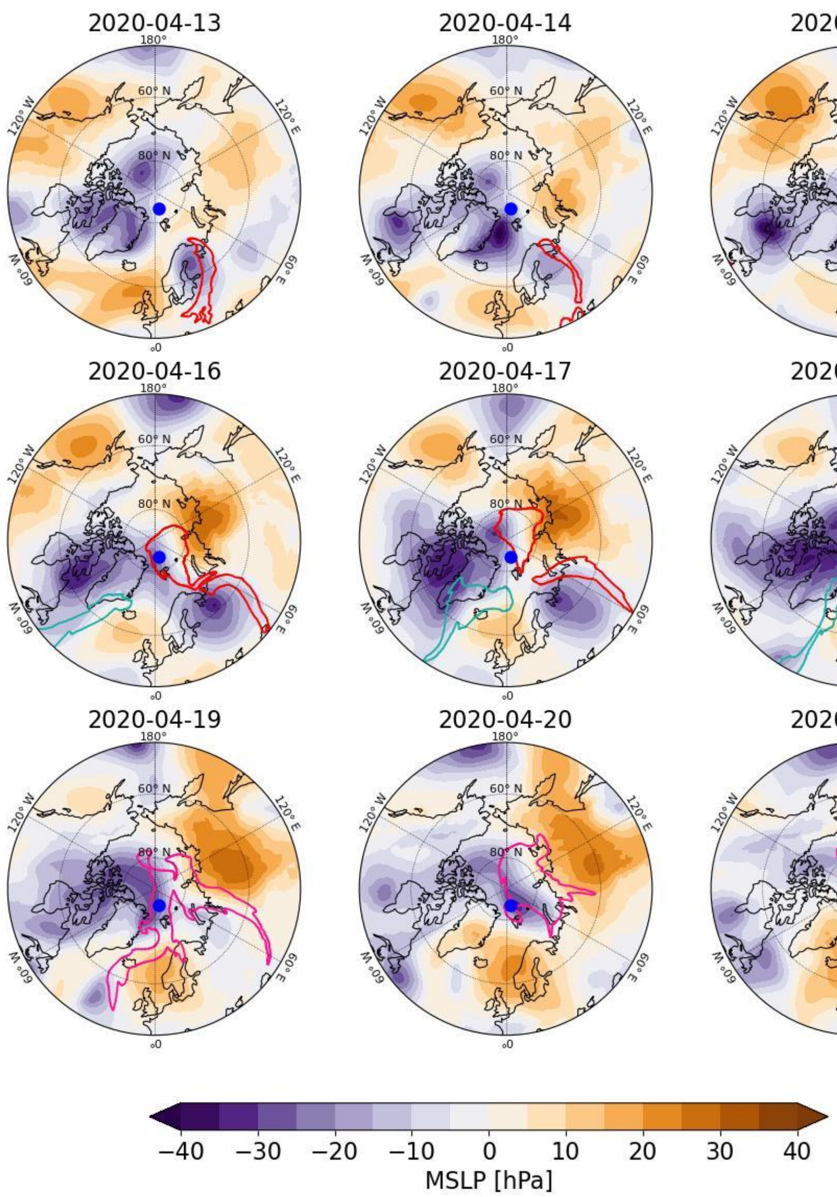
Secondly, regarding the atmospheric conditions leading up to the arrival of the Eurasian AR, we have complemented the description of Fig. 3 with the following: '*Notably, the rise in T2m, WS10m, Q2m, and SEB begins 1-2 days prior to the AR reaching the MOSAiC site and indicates that the airmasses associated with the AR were gradually influencing surface conditions before its core arrival.*' See line 240-242 on page 11.

Finally, we appreciate the suggestion to compare ERA5 with the MOSAiC observations. However, a full evaluation of ERA5 against the in-situ MOSAiC observations would be beyond the scope of the present study, which focuses on the large-scale characteristics and impacts of the AR events. A detailed reanalysis validation would shift the paper away from this central aim. For this reason, we decide not to carry out such a comparison.

Minor comments:

Q: Lines 19–22: I recommend citing the canonical AR definition paper by Ralph et al. (2018).
A: We have added a reference to Ralph et al. (2018).

Q: Figure 1: Please consider using two distinct colors to clearly differentiate the Siberian AR from the Atlantic AR.
A: Thank you for this comment. Changing the colours of the AR outlines in Fig. 1 has also been suggested by referee #1 and we have selected three different colours to indicate (1) the Eurasian AR, (2) the Atlantic AR and (3) the merged AR (see below). The figure caption now reads: '*Red (teal) contours outline the shapes of the Eurasian (Atlantic) AR at 12:00 UTC of the respective days diagnosed from the tARget database. After the ARs merge, the contours are shown in pink.*'



Q: Figure 3 (title): Please specify that the in-situ observations refer to measurements from RV Polarstern.

A: The figure caption has been modified to '*MOSAiC in-situ observations taken at RV Polarstern for 11-23 April 2020.*'

Q: Line 145 (Section 2.5): Please provide additional details on the Lagrangian Analysis Tool (LAGRANTO v2.0) used in the parcel tracking analysis.

A: We agree that additional detail on the Lagrangian Analysis Tool (LAGRANTO v2.0) improves clarity in the Methods section. Following this comment and a related remark by reviewer #1, we have added the following sentence to better describe its capabilities and justify its use: *'While tARget v4 (see Sect. 2.4) includes Lagrangian feature tracking, it is limited to tracking the displacement of ARs over time, i.e. the propagation of a coherent* *pattern, which may move at a different speed and direction than the underlying airflow. LAGRANTO v2.0, by contrast, conducts air parcel tracking, computing full 3-D kinematic trajectories of individual air parcels that are essential for assessing sources and sinks of heat and moisture.'* See lines 169-171 on page 6.

Q: Lines 343–345: Figure 12 shows nTnθ, but the text refers to nTpθ. Please correct this inconsistency.

A: We thank the reviewer very much for pointing out this mistake. Fig. 12 shows nTpθ parcels that reach the central Arctic analogously to Fig. 9 for east Greenland. We have corrected the figure caption to read: '*Same as Fig. 9 but for 7-day back trajectories of nTpθ parcels from Fig. 10.*'

References:

Zhang, C., Cassano, J. J., Seefeldt, M. W., Wang, H., Ma, W., and Tung, W.: Quantifying the impacts of atmospheric rivers on the surface energy budget of the Arctic based on reanalysis, The Cryosphere, 19, 4671–4699, https://doi.org/10.5194/tc-19-4671-2025, 2025.

Guan, B. and Waliser, D. E.: A regionally refined quarter-degree global atmospheric rivers database based on ERA5, Scientific Data, 11, https://doi.org/10.1038/s41597-024-03258-4, 2024.

Ralph, F. M., Dettinger, M. C. L. D., Cairns, M. M., Galarneau, T. J., and Eylander, J.: Defining "Atmospheric river": How the glossary of meteorology helped resolve a debate, B. Am. Meteorol. Soc., 99, 837–839, https://doi.org/10.1175/BAMS-D-17-0157.1, 2018.