Review of "Contrasting Impacts and Mechanisms of Clustered versus Isolated Summer Atmospheric Rivers on Arctic Sea Ice Melt" by Wang

This manuscript investigates two atmospheric river (AR) cases associated with substantial summer Arctic sea ice decline: an isolated AR event in August 2012 and a successive AR event in July 2020. The author links differences in surface energy component changes to these two AR events and further argues that future Arctic conditions may become increasingly characterized by clustered AR events similar to those observed in July 2020.

The two AR cases examined here have already been documented in detail by Li et al. (2024), although that study did not explicitly distinguish between isolated and clustered AR events. Therefore, the topic of comparing isolated and clustered ARs is potentially interesting and could provide additional scientific insight. However, the manuscript currently contains substantial serious scientific and presentation issues that prevent its conclusions from being adequately supported by the analyses presented. In its current form, I would recommend rejection.

First, several figures, particularly those supporting Sections 3.2 and 3.3, are not fully consistent with the corresponding text and do not clearly support the main conclusions of the manuscript. As a result, many of the arguments and interpretations appear insufficiently supported, making it difficult to assess the validity and significance of the conclusions.

Second, the manuscript lacks scientific rigor in several places. Numerous statements extend well beyond what can be directly inferred from the presented figures, yet these interpretations are often not supported by appropriate literature references or additional analyses. Consequently, it is difficult to distinguish between evidence-based findings and speculative discussion.

Third, the overall organization of the manuscript is confusing. Atmospheric rivers are discussed extensively before they are clearly identified and introduced. For example, Section 3.1 frequently refers to ARs, yet the reader is not shown when and where these AR events occurred. Even in Section 3.2, the distinction between isolated and clustered AR events is not clearly illustrated in the figures. A figure showing the timing, location, evolution, and classification of the detected AR events should be presented clearly in the manuscript to provide the necessary context for the subsequent analyses and discussion.

In addition, while the manuscript acknowledges the use of Gemini for language editing, the text contains numerous broad interpretations that lack supporting references. All scientific statements and conclusions should be supported either by evidence presented in the manuscript (such as the figures) or by appropriate citations from the literature.

Major Comments

1. Abstract and Introduction

The manuscript focuses on two case studies (2012 and 2020), yet this is not clearly stated in either the Abstract or the Introduction. Both sections create the impression that a climatological or systematic analysis of isolated and clustered Arctic ARs is being conducted. For example, the Abstract does not explicitly state that the study is based on only two events, and several of the broader conclusions presented there do not appear to be adequately supported by such a limited case study. Similarly, the statement in the Introduction, "This study aims to provide a systematic comparison of the impacts and mechanisms of clustered versus isolated summer ARs on Arctic sea ice melt," suggests a comprehensive or climatological investigation rather than an analysis of two individual case studies. The scope of the study should therefore be clarified from the outset, and the conclusions should be framed consistently with the case-study nature of the analysis in the Abstract.

Additionally, the Introduction requires substantially more citations to support many of its statements. Examples include:

Lines 20–21: Citation needed for the statement that Arctic warming is approximately four times the global mean.

Lines 28–29: Citation needed for the discussion of ice-albedo feedback.

Line 46: Citation needed for AR influences on sea ice through dynamic and thermodynamic pathways.

Additional citations are needed throughout the Introduction wherever established scientific understanding is discussed.

2. Data and Method:

The sea ice concentration (SIC) data are not described. Similar to ERA5, SIC data should be introduced in Section 2.

IVT Calculation: ERA5 pressure-level data are interpolated from 137 hybrid sigma/model levels. In the Arctic, surface pressure can be substantially lower than 1000 hPa over elevated terrain (e.g., Greenland). Therefore, integrating IVT from 1000 hPa to 300 hPa may omit part of the atmospheric column in some regions. Please justify this choice. It may be more appropriate to integrate from the surface pressure to 300 hPa.

The AR identification and tracking algorithm is not described clearly. Additional details regarding the AR detection and tracking methodology are needed to enable readers to understand and evaluate the analysis. For example: What is the exact domain of the target sector (e.g., East Siberian Sea)? Are thresholds applied at individual grid points or based on a regional mean? If a regional mean is used, please clearly define the domain. Does "local summer climatology" refer to JJA climatology? Does "local" refer to grid-point climatology or regional climatology? Please verify the threshold value of 200 kg m^{-1} s^{-1}.

Regarding section 2.3.2: Is there a spatial-overlap criterion used to connect AR features between time steps? Or are events defined solely by their occurrence within the target domain? A figure showing the analysis domain would greatly improve clarity.

3. Figures

Figure 1: Is Figure 1 based on spatial averages over the Arctic? If so, please clearly define the Arctic domain (e.g., north of 60°N, 70°N, etc.). Does the net surface energy flux anomaly represent summer-only values or annual values?

Lines 143–144: The statement that "the net surface energy flux remained close to its climatological baseline" is not obvious from Figure 1. If anomalies are shown, values close to climatology would be expected to remain near zero.

Many statements in Section 3.1 are not adequately supported by Figure 1 alone. Examples include:

- "episodic atmospheric forcing ... was often insufficient to cause basin-wide ice retreat"
- "the Arctic is no longer a system governed by slow seasonal changes"
- "synoptic-scale energy pulses dictate the summer minimum"
- "the cumulative impact of Atmospheric Rivers and reduced surface reflectivity"

Figure 2: Please specify whether this figure represents:

- a monthly mean,
- a composite average,
- a daily average, or
- a specific event period.

Figure 3: The figure caption does not clearly indicate the averaging period. Is this:

a July 2020 composite, summer-season composite, or a specific event?

Figures 4-8 contain inconsistencies between the figure captions and the displayed content.

Specific comments:

The manuscript repeatedly refers to "code" throughout the text (e.g., Lines 112, 123, 127, and elsewhere). The code is merely a tool used to perform the analysis and is not itself a scientific result. References to the code should be minimized unless directly relevant to reproducibility.

Line 37: There is an extra question mark ("?").

Line 97: LHF and SHF are used before being defined.

Lines 136–137: Please provide a citation for the phrase "canary in the coal mine."

Lines 172–175: Citation needed for "a classic manifestation of Arctic atmospheric blocking." Please also explain the terms "dynamic pump" and "dynamic corridor."

Lines 179–181: Please provide the corresponding figure for the 2012 case.

Lines 184–187: Evidence supporting these conclusions is not apparent.

Line 191: Where are the clustered AR events identified in the figures?

Lines 191–193: Citation needed for "radiative-dynamic coupling."

Lines 195–197: Where is the evidence that warm-air advection increased atmospheric emissivity?

Lines 198–204: The discussion refers to late July 2020, but this period is not clearly shown in Figure 2.

Lines 209–212: Citation needed.

Lines 213–214: IWV is discussed but not shown.

Line 223: Please provide vertical temperature profiles to support the claim of a strong temperature inversion.

Lines 226–227: Please provide supporting evidence.

Lines 232–235: Additional evidence or literature support is needed.

Lines 248–259: Additional evidence or literature support is needed.

Line 262: Figure 4a is not a time series.

Section 3.2.1 discusses "three distinct, high-intensity pulses," but no figure clearly demonstrates these pulses.

Line 276: Figure 4b does not appear to show Qnet.

Line 312: Figure 6a does not appear to show the DLR anomaly for the 2012 peak event.

Line 397: Figure 5a does not appear to show albedo.

Line 419: Please provide references supporting the statement that "the frequency of stagnant blocking patterns is projected to rise."

Line 440: The Data and Code Availability section should provide a more complete and detailed description of the datasets and code used in the study.

References:

Li, L., Cannon, F., Mazloff, M. R., and others: Impact of atmospheric rivers on Arctic sea ice variations, The Cryosphere, 18, 121–137, https://doi.org/10.5194/tc-18-121-2024, 2024.