Reviewer 2

First of all, I would like to apologize for the long delay in providing the review of the manuscript.
The authors investigate the linkages between atmospheric rivers and humid heat across the United States. For that, they use MERRA-2-based Guan-Waliser AR-detection algorithm and also daily maxima of 2-m wet-bulb temperature.
The manuscript is usually well written and the methodology is sound even if some points are not that clear. In my opinion, the manuscript can be accepted after minor revision mentioned below.

We appreciate the Reviewer's input, and recognize that all of us are overburdened with these sorts of tasks. We are glad for the overall positive assessment and respond to the Reviewer's specific concerns below, which have been helpful in validating our results and clarifying our thinking, thus improving the manuscript considerably (both through revising the text and through the addition of several new supplemental figures). Please find below further details on what we have changed and added (text in red). Quoted reviewer commenters are in *italics*, and our responses are in bold.

Even though the authors acknowledge the fact that AR have different phenomenology, I was wondering if the authors can enlarge the introduction relatively to that matter. In addition, can the authors also comment on the different between AR in the cold and warm season? And also, the different types of ARs that can reach different areas of the US?

We have added several more references on different types of ARs, especially about cold versus warm season varieties and regional distinctions, and have expanded this part of the introduction accordingly. The revised text reads:
"ARs can be further divided along dimensions including moisture versus wind-dominated (Gonzales et al. 2020), transient versus quasi-stationary (Park et al. 2023), and tropical versus extratropical (Reid et al. 2022), as well as other distinct regional characteristics — all differences which affect ARs themselves and their impacts (Park et al. 2021; Guan & Waliser 2019; Nayak & Villarini 2017). This variety of systems falling under a single broad heading is also the case for other important climate phenomena, such as droughts (Haile et al. 2019). Although the first-described and best-known AR types occur in the extratropical cold season, warm-season varieties can have a substantial imprint on regional hydroclimate (Slinskey et al. 2020). To take North America as an illustrative case, about half of summer extreme-precipitation days in the Eastern and Central US are caused by ARs. Summer ARs over the US originate from the Pacific Ocean or (especially) the Gulf of Mexico, and tend to be weaker but wetter than their cold-season counterparts due to the higher temperatures and associated background water-vapor quantities (Slinskey et al. 2020; Neiman et al. 2008)."

Section 2.1. the authors mentioned that they used 6-hourly data from MERRA-2, however in section 2.3 they mentioned that the use of hourly data for computing the 2-m wet-bulb temperature. I am assuming that the data here also comes from MERRA-2.

Yes, all the data is from MERRA-2. It has hourly data available for some variables, but the AR algorithm was only processed every 6 hours (there is relatively little hour-to-hour change in ARs). We have adjusted a few words in Sections 2.1, 2.2, and 2.3 to ensure these descriptions are clear and self-consistent.

Fig 1. Can you please put the name of the regions inside them? In the preset version is not very readable.

To improve the readability of Figure 1, we have added arrows connecting the region labels (near each inset plot) to the corresponding region on the main map. We feel this is a good solution because it avoids having duplicate labels which might be confusing or cluttered:

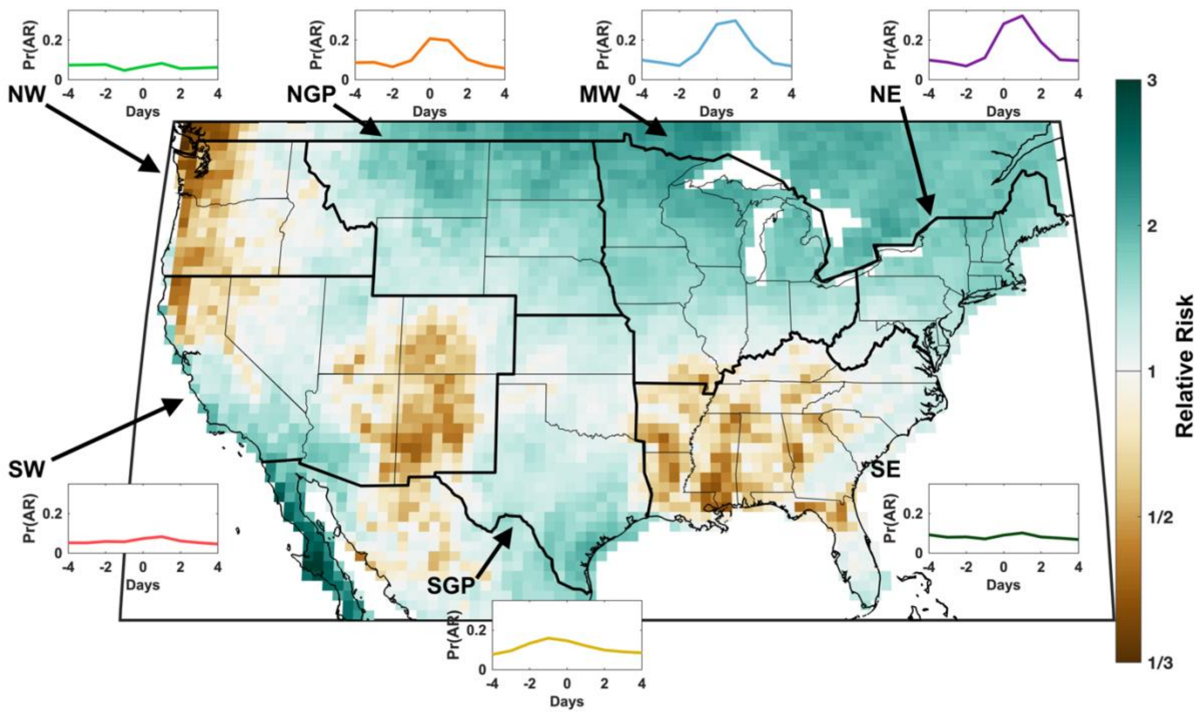


Fig 1. Caption - Authors need to add the information regarding the relative risk. Higher values correspond to higher risk?

We have expanded the Figure 1 caption to include this information:
"Relative risk > 1 corresponds to a risk larger than that expected by chance."

Section 2.3 Can the authors expand the explanation regarding the computation of the percentiles? Did you compute the percentile after or before the 30-day smoothing? In addition, *can the authors include a figure in the supplementary material explaining 3 days highest Tw value? And also, the difference between "regional" and "regional peak"?*

The percentiles were actually computed later and independent of the smoothing, so the revised text removes mention of smoothing altogether:
"We compute Tw percentiles for each day at each gridcell against the climatology of the surrounding 30 days, then define a 'humid-heat day' as a day with Tw above the 95th percentile."

The percentiles are computed from a 30-day block surrounding each day (comprised of 30 days x 41 years = 1,230 days).

A definition figure is a good suggestion. We have created one as Figure A1, and we direct interested readers to it in Section 2.3. It is reproduced here for convenience:

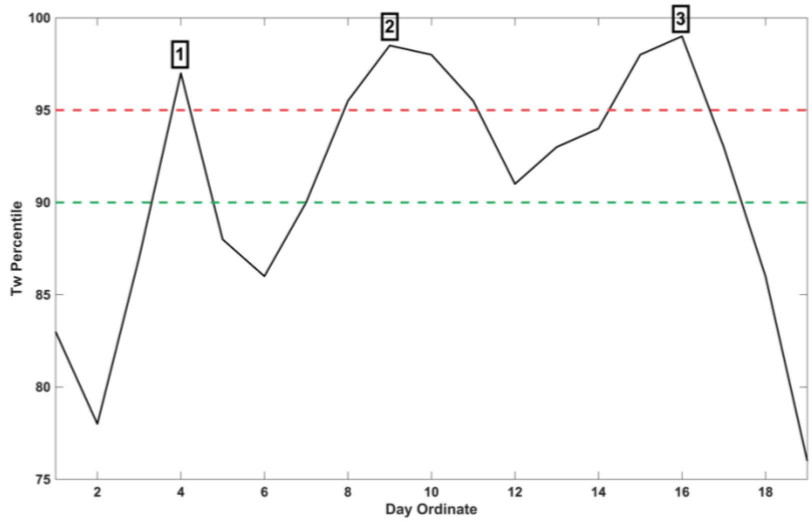


Figure A1: Illustration of the definition of a peak heat-stress day. Days marked 1 and 2 satisfy the requirements of having the highest Tw value within 3 days on either side, as well as Tw having been below the 90th percentile within the preceding 3 days, while day 3 does not. As stated in the text, these requirements can apply to data from an individual gridcell or to a regional (spatial) mean.

Section 2.4 Did the authors use the axis of the AR, or the area of the AR? If you use the area provided by the Guan-Waliser AR-detection algorithm, then I don´t understand that a grid cell should be 100km from an AR.

Section 2.4 refers to distance from the edge of an AR. In other words, the gridcell in question could be within an AR, or no more than 100 km from its edge. We have rewritten and expanded this description:
"We define as 'interaction' between ARs and humid heat those cases where humid-heat days at a gridcell occur within 1 day and 100 km of an AR. Spatially, this means a gridcell could be included within an AR, or the edge of an AR is no more than 100 km away; temporally, it means the spatial criterion is satisfied on the day before, the day after, or the same day as a humid-heat day."

I am just wondering if having a new sub-section with a case study would also benefit the potential readers to better understand the methodology?

We believe that the new Figure A1 showing the peak-day definition, as well as the various text revisions prompted by the Reviewer's helpful comments, mean that a methodology-oriented example figure would not be of great additional value.

Section 3.1. L160 onwards. You could add a figure on characterizing the different ARs that strike the different regions? It would help a lot in understanding the results. Are they associated with Extra-tropical cyclones? They are wind vs humidity driven?

Thanks to this suggestion, we have added Figures A10 and A11 (copied at the bottom of this Response document). These figures show that summertime ARs in each region tend to occur between a surface low to the northwest and a surface high to the east or southeast, as is also often the case in winter (Ralph et al. 2020). The ARs are generally colocated with areas of high precipitation likelihood and high IVT. Combined with the composite map of summertime ARs affecting each region created by Slinskey et al. 2020, their Figure 6, we see that US ARs east of the Rocky Mountains tend to track along the western and northern periphery of the North Atlantic Subtropical High [NASH]. Several of these points are mentioned in the revised text:

"Simultaneously, this flow is also often manifest as an amplified state of the warm-season Great Plains Low-Level Jet, itself often enhanced by proximity to the North Atlantic Subtropical High (Zhou et al. 2020; Budikova et al. 2010). Our work ties this mechanistic view to the detailed regional statistics of Zhang and Villarini (2020) by showing that southerly low-level flow in the Midwest is frequently classified as an AR, and that these ARs mostly occur on the west or north flank of a ridge, resulting in precipitation that tends to lag humid heat because of the usual eastward motion of mid-latitude weather systems (Figure 5)."

"In much of the US, we find that warm-season ARs are often associated with preceding humid heat, and more specifically with a heat-then-flood timeline — a relationship that derives from the typical orientations and trajectories of mid-latitude synoptic weather systems, with AR-related IVT progressing from southwest to northeast between a surface low and high (Ralph et al. 2020). Heat followed by heavy precipitation is consistent with earlier results for multiple seasons and for several temperate climate zones including the Midwest (Zhang & Villarini 2020; Sauter et al. 2023)."

The revised Discussion also notes other regional differences in ARs and how they are likely influencing our results:

"The tendency for ARs and humid heat to be distinct hazards in certain regions (Figure 1) can be understood through analyses of this sort. Considering first the Northwest, humid-heat days there are in fact mostly hot and dry, driven by processes (sensible heating, warm-air advection) antithetical to those associated with ARs (Raymond et al. 2017). Despite the exceptional anomalies involved, the above example, specifically the geographic offset between landfall location and peak temperature anomaly, may be illustrative in this regard. A valuable reduction of joint risk is also apparent for the Southeast and Southwest. In the Southeast, it may be linked to the dynamics of the summertime westward expansion of the North Atlantic Subtropical High (Luo et al. 2021), which would also explain why humid heat is most unlikely near strong ARs there; in the Southwest, this joint-risk reduction may stem from the diffuse and sporadic nature of North American Monsoon moisture incursions generally not meeting the Guan-Waliser AR definition (Slinskey et al. 2020; Guan & Waliser 2019; Adams & Comrie 1997)."

In other words, across the US there are several distinct and well-described seasonal features that can be classified as ARs when the associated moisture transport is large and organized into sufficiently long and narrow bands. For this reason, the final paragraph of the Discussion intentionally mentions ARs' characteristic features of IVT and precipitation without specifying more closely, because the details of how these are achieved in a meteorological sense vary substantially by region.

Classification of ARs associated with humid heat, by for example moisture versus wind dominated, is a great idea for exploration, but in this manuscript format we consider it beyond the scope of our focus.

2 Why the risk decreases if you go to the higher AR categories in some regions (eg. NGP, SGP and SE?)?

We hypothesize that this feature is partly due to the mutually exclusive nature of processes that lead to humid heat and to strong ARs in these regions, and partly due to sample-size effects. In the Southeast, for example (original Figure A5), the maximum humid heat occurs distinctly south of the maximum IVT and precipitation likelihood. In Figure 2, and in our analysis overall, we would say that our results are most easily interpretable east of the Rocky Mountains. We added a clause to note this in introducing Figure 2:
"Separating strong ARs from weak-to-moderate ones shows an enhancement of AR/humid-heat interaction probability with increasing AR intensity for the Southwest, Midwest, and Northeast, though with some uncertainty due to sample-size effects (Figure 2a)."

And also in the Discussion:
"A valuable reduction of joint risk is also apparent for the Southeast and Southwest. In the Southeast, it may be linked to the dynamics of the summertime westward expansion of the North Atlantic Subtropical High (Luo et al. 2021), which would also explain why humid heat is most unlikely near strong ARs there"

I like figure 4. Maybe the authors can explain the physical process behind the heat conditioned on precipitation and IVT?

Our best understanding of Figure 4 is that precipitation, IVT, and humid heat are all well-correlated in the northern tier of the country. IVT is the more important variable, but analyzing humid heat via ARs adds more value than either one, probably due to nonlinear interactions e.g. (re-)evaporation of precipitation. The Western US feels influences from systems such as the North American Monsoon that are not necessarily well suited to the AR

definition that is used here (although this definition is used globally and in many studies). We agree the physical processes involved are interesting and worthy of further exploration, as we now also state in the Discussion:
"This integration of likely nonlinear effects also helps explain why the interaction signal tends to be stronger for stronger ARs, even when controlling for ridge amplitude. However, the exact physical mechanisms involved remain uncertain and a worthy subject for exploration."

Regarding the Midwest, is this a proper AR feature, or more related with an LLJ feature? At least in late winter some of the AR there are associated with a extra-tropical cyclone : https://blog.weather.us/atmospheric-river-to-bring-heavy-rain-and-possible-flooding-to-parts-of-the-east-coast-later-this-week/

We agree that the Midwest and indeed all of the US east of the Rocky Mountains experience ARs that are rather different than the classic oceanic ones which affect the US West Coast, Portugal, etc. This variety of ARs (which are all classified as such according to the Guan-Waliser algorithm) is discussed in several papers, including Slinskey et al. 2020, Gimeno et al. 2021, Ralph et al. 2020, and Reid et al. 2022 (doi: 10.1175/jcli-d-21-0606.1). We have added manuscript text that cites these papers' description of how features such as active monsoon patterns or the Great Plains Low-Level Jet can exhibit AR-like characteristics despite quite diverse driving mechanisms. Later in the discussion, we have also added a reference to Higgins et al. 1997 to direct interested readers to another authoritative source on the subject:
"An important area for future work will be interrogating this AR-mediated humid heat/precipitation connection more directly, including at the subdaily timescale, as well as the extent to which it can be considered a direct signature of the Great Plains Low-Level Jet (Higgins et al. 1997)."

As we are focused on summer, extratropical cyclone activity is considerably weaker and less frequent, and circulations associated with the North Atlantic Subtropical High dominate AR activity east of the Rockies (Slinskey et al. 2020, Zhou et al. 2020) — see earlier response.

Regarding my point 8) and considering all the information provided in the manuscript, what is missing are the composites (SLP, GPT500, other variable ??) of the AR days for each one of the regions.

Following this excellent suggestion, composites of AR days unconditioned on any humid-heat categorization have now been produced as Figures A10-11. Figure A10 shows AR probabilities and Z500 anomalies, while Figure A11 shows IVT and precipitation percentiles. They are relevant to several responses in the document, as stated above, so please refer to those passages for our interpretation (as much as fits in the space available).

The new figures are reproduced here:

Figure A10: Composite of AR probabilities (contours) and Z500 anomalies (shading) for all AR days at the central gridcells of each region. Light (dark) green contours indicate AR probabilities >50% (>80%), while light red (dark red) shading indicates Z500 anomalies >25 m (>50 m) and light blue (dark blue) shading indicates Z500 anomalies <-25 m (<-50 m).

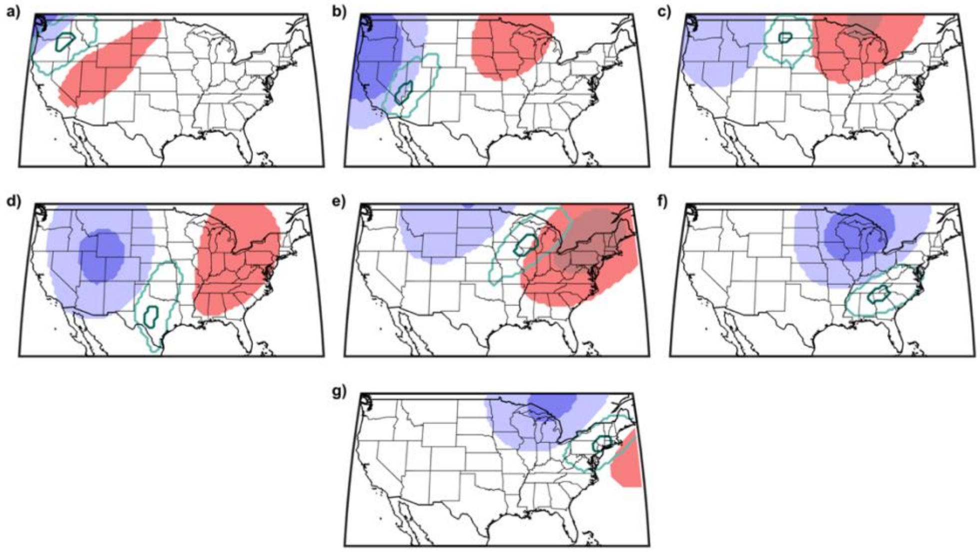
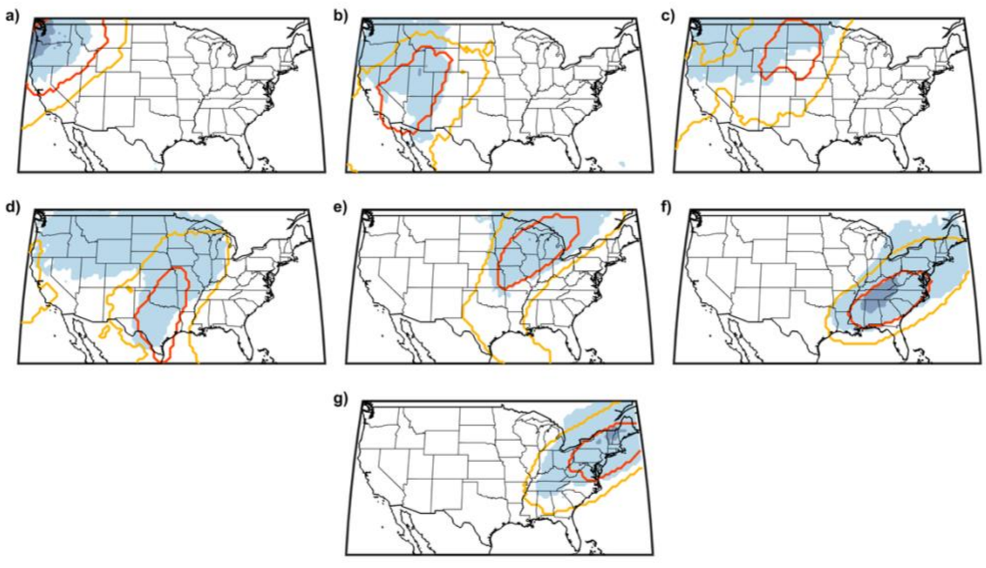


Figure A11: Composite of IVT percentiles (contours) and precipitation percentiles (shading) for all AR days at the central gridcells of each region. Orange (red) contours indicate IVT percentiles >70th (>85th), while light blue (dark blue) shading indicates precipitation percentiles >60th (>80th). These values are chosen to best highlight the regions of interest.



[As a reminder, composite AR days intersected with regional peak humid-heat days have already been plotted in Figure 5 and Figures A2-7.]

New references:

Gonzales, K. R., Swain, D. L., Barnes, E. A., and Diffenbaugh, N. S.: Moisture- versus wind-dominated flavors of atmospheric rivers, Geophys. Res. Lett., 47, e2020gl090042, doi:10.1029/2020gl090042, 2020.

Haile, G. G., Tang, Q., Li, W., Liu, X., and Zhang, X., Drought: Progress in broadening its understanding, WIREs Water, 7, e1407, doi:10.1002/wat2.1407, 2019.

Higgins, R. W., Yao, Y., Yarosh, E. S., Janowiak, J. E., and Mo, K. C.: Influence of the Great Plains Low-Level Jet on summertime precipitation and moisture transport over the Central United States. J. Clim., 10, 481-507, doi:10.1175/1520-0442(1997)010<0481:iotgpl>2.0.co;2, 1997.

Park, C., Son, S.-W., and Guan, B.: Multiscale nature of atmospheric rivers, Geophys. Res. Lett., 50, e2023gl102784, doi:10.1029/2023gl102784, 2023.

Reid, K. J., King, A. D., Lane, T. P., and Hudson, D.: Tropical, subtropical, and extratropical atmospheric rivers in the Australian region, J. Clim., 35, 2697-2708, doi:10.1175/jcli-d-21-0606.1, 2022.

Zhou, W., Leung, L. R., Song, F., and Lu, J.: Future changes in the Great Plains Low-Level Jet governed by seasonally dependent pattern changes in the North Atlantic Subtropical High, Geophys. Res. Lett., 48, e2020gl090356, doi:10.1029/2020gl090356, 2020.