Comments on WCD-2021-12

General comments

Unlike traditional monsoon that occurs in the tropics, the East Asian summer monsoon (EASM) is characterized as a subtropical monsoon, which is affected by both the tropical and mid-latitude dynamics. In this work, the authors introduce some methodologies to investigate role of the monsoonal southerlies and the extratropical northerlies in the seasonal progression of the EASM, with a focus on the Mei Yu stage. In particular, the authors employ a frontal detection algorithm that's based on the 850 hPa equivalent potential temperature gradient to identify the front position at 6-hourly frequency. They also introduce a Lagrangian method that illustrates backward trajectories of air masses arriving at East Asia during the seasonal march of the monsoonal rainfall. The authors show that the Mei-Yu stage is unique in that the Lagrangian method shows well separated air mass origin during this stage – cold extratropical air and warm tropical air converging in East Asia and form the Mei-Yu front. By comparing the high-lat years and low-lat years based on the front latitude during the climatological Mei Yu period (3rd dekad of June), the authors show that the extratropical northerlies are crucial in affecting the location and intensity of the Mei Yu front.

This manuscript is overall well-written, and the results are presented in a structured and clear style. The methodologies used in this study provide new angles to the EASM community, especially for studies on extreme events and rainfall variability at high-frequency timescales. What I like most about this paper is the authors provide a comprehensive analysis of key physical factors during the EASM rainfall stages, including atmospheric circulations (such as the subtropical jet and the western Pacific subtropical high), moisture transport, and origin of air masses. That said, I do find some analysis and interpretation a bit confusing or even misleading (see the specific comments for details). In summary, I think this paper could be a potential publication in WCD once the authors address these comments.

Specific comments/major comments

1. My biggest concern is that I would expect to see more in-depth discussion on the physical mechanisms based on the current title. However, the paper overall is descriptive and lack mechanistic insights. For example, although the authors did show the different air mass origins during each rainfall stages and compared the tropical flow vs. extratropical flow between high-lat and low-lat cases, the authors did not articulate how their results differ from previous findings on mechanism-level. In particular, Chiang et al. (2020) employed modeling approach and provided detailed discussion on interaction of tropical and extratropical flows on the seasonality of the EASM (their section 5 is specifically focused on this). Similarly, Figure 16 in this study looks quite similar to Figure 15 from Sampe and Xie (2010), but I don't see what new insights we learn from it. Maybe the authors could elaborate more. I would like to see more discussion on what new lessons that we learn from this study compared to previous studies asking similar questions such as Chiang et al. (2020) and others.
2. Section 2.2. Besides the pair of studies cited here (Li et al., 2018, 2019), Day et al. (2018) introduced an East Asian rainband detection algorithm based on precipitation, Dai et al. (2021) used the self-organizing map to define the seasonal rainfall stages in East Asia. And

there might be other methods out there in the literature. To provide more context, it is worthwhile briefly summarizing the algorithms that have been introduced in the literature on the EASM front detection, their pros and cons, and why the algorithm adopted in this study is an ideal approach. Further, could the authors introduce their algorithm in a more structured way in Lines 127-147, such as using numerated bullet points and maybe adding sub-title to illustrate the purpose for each point/step? It would also be helpful to show snapshots of the front detection at 6-hourly frequency for a "true" front case and a "false" front case. These efforts will help the readers to better understand the method.

3. Section 3.1. I'm a bit confused how the front progression shown in Figure 1 is produced. Are the front positions the average of the 6-hourly frontal detection from each dk? Or are they the results of applying the algorithm to the dk averaged theta_e gradient? It's unclear to me how the results from these two approaches would differ. Could the authors clarify?
4. Section 3.2. I agree that the four dekads are representative for the four stages, but how the four rainfall stages were decided at the first place? Is that based on the timing of these stages suggested from previous literature? Please clarify.
5. Section 4.1. Could the authors elaborate on the reasoning of analyzing the vertical cross-section along A-B? I would expect to see more evident signal from the extratropical flow, but they are absent in Figure 8. Supporting evidence is missing for the statement such as in Line 345 that "The advection of cool sub-tropical air is centred around 700-800 hPa"; in Line 364 that "This is in agreement with Figure 8c, displaying these different air masses impacting on the front from opposite sides." I agree that the theta_e contour clearly shows the warm versus cold air, but the wind pattern in the extratropics is too weak to support cold air advection. Do the results change if the authors analyze the cross-section along eastern China, say 105E, instead?
6. Lines 347-349 and Figure 9. Should we expect the position of the frontal position for each stage in Figure 9 match those shown in Figure 3? The spring, in particular, does not seem so. The spring front in Figure 9 is evidently further south compared to Figure 3.
7. Section 5. The comparison between high-lat and low-lat cases is interesting, but the wording here is misleading. The authors selected the high-lat and low-lat cases based on the front latitude during the climatological Mei-Yu period, i.e. the 3rd dekad of June. However, it is very likely that the seasonal evolution of the EASM front is different between the high-lat and low-lat cases (Chiang et al., 2017). Therefore, when describing the high-lat and low-lat results, it might not be accurate to directly refer that as the Mei-Yu in the high-lat and the low-lat. Specific comments related to section 5 are listed below.
    1) Line 393. Suggest rephrasing that these dekads refer to the climatological rainfall stages. Similarly, in Line 401, it might be more accurate to say "during the climatological Mei Yu period" or simply say "The precipitation patterns during the 3rd dekad of June." And in Line 408, suggest replacing "during the Mei Yu stage" with "during the climatological Mei Yu stage" or "during the 3rd dekad of June."
    2) Lines 396-400. A bit concerned about the statement on whether Figure 11 tells us the dependence between the rainfall stages from both cases. An alternative interpretation could be that, the fact that the blue dashed line and the red dashed line stay at the similar latitudes suggests a more stationary front from the low-lat

cases; in other words, the low-lat cases reflect years with longer Mei Yu (Chiang et al., 2017).

3) To further elaborate the point raised in Lines 398-400. It would be helpful to present the high-lat and low-lat versions of Figure 2 (the precipitation hovmoller diagram) in the paper. This will more clearly show the seasonal evolution of the EASM front from the two cases. The authors could also consider expanding their analysis on the STWJ, WPSH, and air mass origins to the four rainfall stages from both cases. This may provide a more complete picture on role of the tropical vs. extratropical flows on the progression of EASM front.
4) Line 410. Again, it is misleading to directly refer the pattern to the 'tripole', because the latter is captured by the leading mode of East Asian summer rainfall. It is more appropriate to say that the rainfall pattern resemble one phase of the tripole mode.
5) Line 413. To clarify, it is more precise to say that the termination of the Mei Yu has already taken place by the end of June.
6) Figures 13-15 suggest that high-lat cases are associated with stronger moisture transport from southerly flow, while the front in the high-lat cases presents a more northward progression and produces less intense rainfall. My take from these results is that the comparison between high-lat and low-lat highlight role of the extratropical air mass in affecting both front latitude (with strong extratropical air → southward or more stationary Mei Yu front) and rainfall intensity (with strong extratropical air → stronger convergence with the southerlies and thus more intense rainfall). The reason why I raise this is I think this is a good example to illustrate the authors original motivation: to figure out how the tropical and extratropical air control the EASM front movement. Further, I would interpret Figure 15 in a different way, compared to what the authors stated in Line 460-462. A more generalized lesson from the comparison between high-lat and low-lat is that it is the strength of the extratropical northerlies that determine the evolution of the front. Thus, compared to the tropical component, the extratropical component is more fundamental (or dominant) in the seasonal evolution, and when the extratropical component is weak, we see the high-lat patterns. No matter whether the authors agree or disagree with these points, I think it would be worth elaborating on what we learn about role of tropical vs. extratropical air from the comparison between the high-lat and the low-lat cases.

8. The authors argue for a crucial role of the South Asian Monsoon in influencing the EASM but did not provide specific references and underlying mechanisms. For example, for the introduction of the tropical influence on the EASM (Line 33 and Lines 41-49), could the authors elaborate more on the effect of the onset and progression of the South Asian monsoon? I find this part is vague and unsure through what physical processes the South Asian monsoon affects the EASM. Further, it is not convincing that the results presented in the current paper suggest the Bay of Bengal, instead of South China Sea, is the primary moisture source for eastern China. The moisture content of the southerly flow is relatively constant might be due to that air parcels both precipitates along the trajectory and picks up moisture from the warm moist ocean surface over the South China Sea. In this case,

there is indeed contribution from the South China Sea, it is just the total amount of water content keep unchanged.

Technical corrections/minor comments

1. End of Line 29. Suggest the authors replace “a large elevated landmass” with “TP”, which is more precise and concise in this context.
2. End of Line 32. Add references about the spring rainfall stage, for example, (Wu et al., 2007) and maybe others.
3. Line 38. Add reference on using the gradients of equivalent potential temperature to denote the front, for example, (Tomita et al., 2011). Also clarify whether and how the equivalent potential temperature is calculated, or whether it is directly downloaded from the ERA5 website.
4. Lines 41-49. Convection over western tropical Pacific and related “Pacific-Japan” pattern should not be ignored when considering tropical influence.
5. Line 66. This sentence reads odd. Suggest the authors rephrase the second half of the sentence to something like “…, that the EASM rapidly weakens and mid-summer rainfall dominates northeastern China.”
6. Lines 73-75. The mentioning of the “tripole mode” here is a bit misleading. I think it is worth citing the original reference of the tripole mode (Hsu and Lin, 2007) and clarify that the tripole mode was originally referred to the leading mode of East Asian summer rainfall at interannual timescale. Further, it is worth clarifying that Chiang et al. (2017) showed that rainfall anomalies during years with earlier Mei-Yu termination mimic one phase (i.e. more rainfall in northeastern China and southeastern China while less rainfall in central eastern China) of the tripole mode, not results in the tripole mode.
7. Lines 100-109. Could the authors rephrase or reorganize this part? It would make it easier for the readers to follow if the authors can explicitly explain what each section of sections 3-5 focuses on.
8. Line 113. Suggest changing the resolution to $0.25° \times 0.25°$.
9. Section 2.1. The paper by Tarek et al. (2020) specifically focused on its performance in North America. More discussion is needed on whether ERA5 dataset is a more useful or suitable source (compared to ERA-Interim) for studying the EASM.
10. Line 125. Clarify what does “n” refer to. And it should be “The algorithm used in Li et al. retains …”?
11. Section 2.4. Add units for IVT, IWV and the variables used for both calculations.
12. Line 202. The word “extending” is misleading, which may imply that there is southward rainfall migration when the pre-Meiyu stage starts. However, the rainfall appearing in the South China Sea is just a reflection of enhanced convection during that period.
13. The unit in Figure 3 caption should be mm/day?
14. Lines 296-297. More specifically and directly, it is the extratropical northerlies that prevent the southerly flow to march northward, and the strong extratropical northerlies have been argued to arise from the mechanical forcing from the TP on the SWTJ (Chen and Bordoni, 2014; Kong and Chiang, 2019).

15. Line 342. Rephrase “opposite sides” to “the tropical and the extratropical side.” The original wording is vague.
16. Line 466. Suggest adding “(the green contour in Figure 13)” at the end of the sentence.
17. Suggest adding a sub-plot showing low-lat minus high-lat in Figure 14. This will help to highlight the circulation difference in the extratropics.
18. Lines 503-510. I did not understand why the authors tried to draw analogies between the Indian summer monsoon and the EASM. Was the motivation to show that it is valid to apply the method, which was applied to the Indian Summer Monsoon in (Parker et al., 2016), to the EASM? If so, it might be more appropriate to put this part to Line 100.

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