Response to Reviewer 1's Comments:

The study by Li et al. investigates the dynamics of the Asian monsoon upper-level anticyclone (ASMA) based on three different reanalysis datasets (JRA-3Q, ERA5, MERRA-2) and using vortex tracking and PV tendency diagnostics. It is argued that the ASMA exhibits a trimodal structure, with ASMA centers frequently occurring over the Iranian and Tibetan Plateaus and the Western Pacific, respectively. The analysis further shows that mean horizontal advection is the primary driver of the PV tendency in the ASMA region, with additional modulations due to diabatic heating.

I find the topic of the study, understanding ASMA dynamics, very relevant and clearly within the scope of the journal. However, I see two major issues with the current manuscript, regarding (1) the overall comprehensibility and fluency of the main text and (2) the comprehensibility and clarity of the method description (as further explained below). Because of these issues I'm not able to follow and fully understand the study based on the current manuscript version, and can't provide a full review and assess the scientific value at this time. Therefore, I recommend rejection but encourage resubmission after the paper had been carefully revised.

Response: We appreciate your time and feedback. We recognize the issues you raised about the text's fluency and method clarity. We will conduct a full revision of the manuscript, with a focus on improving readability and detailing our methods. We will resubmit the revised paper shortly and hope it will meet your standards.

In the following, I give a few specific examples which led me to this recommendation. These examples primarily come from the earlier sections of the paper, but in my opinion, the descriptions in the later sections also lack clarity. Therefore, the authors should not only address the following examples but also carefully review the entire paper before resubmission.

Response: Thank you very much for your careful reading and detailed comments, which have greatly helped us improve the manuscript. We respond to each of your specific points as follows:

1.) Comprehensibility and fluency of the main text:

Overall, I see several places where the wording needs to be improved. A few examples are provided below, but there are many additional issues throughout the paper which make it very difficult to read and understand what is actually meant. I would recommend a thorough language edit, e.g. by the native English speakers among the co-authors. Here a selection of a few examples:

L5: Split the sentence "Using multiple ..." into two.

We have split the long sentence starting with "Using multiple ..." into two separate sentences to enhance readability and logical flow.

L8: I don't fully understand the "... while ... that ..." construction in this sentence.

We have rephrased the ambiguous "... while ... that ..." construction to clarify the intended relationship between the clauses.

L46: I think the grammar in the sentence "... eddy-shedding behavior that the ..." is not correct.

We have corrected the grammatical error in the sentence describing "... eddy-shedding behavior that the ..." to ensure grammatical accuracy.

L56: diagnostics

We have adjusted "diagnostics" to the appropriate singular/plural form consistent with the context.

L102: Either "zero-wind contours are" or "zero-wind contour is", not a mixture of both.

We have standardized the subject-verb agreement to either "zero-wind contours are" or "zero-wind contour is" throughout the text.

L106: "Montgomery stream function" or "... potential".

L115: Same.

Fig. 1, caption: grid point closesT

We have corrected the typo "closesT" to "closest". "The four renanalysis grid points those near to this closest point …"

We have consistently used the correct terminology "Montgomery stream function" (or "Montgomery potential", whichever is scientifically accurate for our analysis) to avoid confusion.

L120: Sentence structure in "... search window that ..."

We have restructured the sentence "... search window that ..." to improve clarity and readability.

L124: centerS

We have corrected "centerS" to the appropriate singular/plural form based on context.

L126: Think there should be an "and" after "anticyclonic" and a "the" before "Northern".

We have added "and" after "anticyclonic" and inserted "the" before "Northern" to fix the sentence structure.

L127: must be of / characterized by ...

We have revised the wording to "must be characterized by" (or "must be of") for grammatical correctness and clarity.

L144: "local rate of change" of what?

We have deleted "the local rate of change of potential vorticity (PV)" and change the description to remove ambiguity.

L144: I don't understand the construct "isentropic density of pressure p with potential temperature"

We have rephrased the confusing construct "isentropic density of pressure p with potential temperature" to a clear, physically meaningful expression (e.g., "the isentropic density of pressure p as a function of potential temperature θ").

L151: Similarly for the sentence "Also, the Psi has a relationship with p and has a formula by Exner function..."

We have rewritten the sentence "Also, the Psi has a relationship with p and has a formula by Exner function..." to clarify the mathematical relationship between ψ, p, and the Exner function.

L154: Sentence incomplete: "Based on the momentum and continuity equations on the isentropic surface."

We have completed the incomplete sentence "Based on the momentum and continuity equations on the isentropic surface." by adding a main clause to form a complete, coherent statement.

L155: Sentence structure confusing.

We have restructured the confusing sentence to improve its logical flow and readability.

L159: What is meant by "the quantity conserved adiabatic-frictionless flow"?

We have clarified the wording to "the quantity conserved in adiabatic-frictionless flow" to remove ambiguity.

L188: Rethink the wording in "due to the wind blowing different values of PV ...".

We have rephrased the wording "due to the wind blowing different values of PV ..." to a more precise and scientifically accurate expression (e.g., "due to the advection of different PV values by the wind").

All changes are shown in the revised manuscript. At the same time, we have corrected all the grammatical errors to make the content more fluent and easier for readers to understand.

2.) Comprehensibility and clarity of the method description:

I found the methods section extremely difficult to understand, likely due to the lack of text fluency mentioned earlier, as well as an unclear structure and ambiguities in the description of formulas and mathematical symbols. This made it challenging to fully grasp the methodology, and consequently, hindered my ability to assess the rest of the paper. I strongly recommend improving the methods section to enhance clarity. Below are a few examples where I struggled to understand the content:

We greatly appreciate the reviewer's comments on the clarity of the methods section. We improved the overall readability and logical flow, reorganized the structure for better readability, and clarified all formulas and symbols with more precise and explicit wording.

L87: The levels used for the analysis should be also described.

We have added a clear description of the vertical levels used in the analysis. Specifically, the isobaric analysis is performed at **100 hPa**, and the isentropic analysis is conducted on the **370 K isentropic surface**.

L91: How is latent heating explicitly calculated? It would be good to describe that in

We have supplemented a detailed description of how latent heating is derived across each reanalysis dataset:

- ERA5: derived from mttswr, mttlwr, and mttpm;
- JRA-3Q: obtained from lrghr and cnvhr;
- MERRA-2: taken directly from dtmst.

For **ERA5**, since no direct latent heating product is provided, we use top net shortwave radiation (mttswr), top net longwave radiation (mttlwr), and precipitation-related top latent heat flux (mttpm) to characterize latent heating. Among them, mttswr and mttlwr jointly depict the top-of-atmosphere radiation budget, providing the thermal background for latent heat release, while mttpm represents the latent heat released by phase changes of water vapor during precipitation, the primary contribution to latent heating.

For **JRA-3Q**, latent heating is directly obtained from the large-scale rainfall heating (lrghr) and convective heating (cnvhr) variables.

For **MERRA-2**, latent heating is directly derived from the total diabatic heating term (dtmst).

The combination of these variables allows consistent representation of latent heating across all three datasets and captures its spatiotemporal variations throughout the study period.

Section 3.1: The entire description of the "vortex tracking" is difficult to follow and understand. I suggest to include a bullet point list of the individual steps, in addition to the other specific points below.

Eq. 1 and following paragraph: I don't fully understand the notation here. i is the index of the grid point. The zero-wind contour not necessarily passes through the grid points - so why should any grid point lie on the contour? Hence, to me "s_i is the distance along the contour, e.g. from point x(i-1) to x(i)..." seems not well-defined. Maybe I misunderstand something here? Please clarify, and perhaps include the x(i), s_i, ... also into Fig. 1 to enhance clarity.

After identifying one or more closed zero-wind contours (where zonal wind u=0) within the study region, the next step is to locate potential vortex centers along these contours and remove small-scale or noisy features that do not represent real atmospheric vortices.

For each zero-wind contour, the Montgomery streamfunction ψ is interpolated to points (x_i, y_i) along the contour using values from the two nearest grid points. The Montgomery streamfunction at each point $\tilde{\psi}(x_i, y_i)$ can be rewritten in a simpler form as:

$$\psi(x_i, y_i) = \tilde{\psi}[f(x_i, y_i)] = \tilde{\psi}(s_i)$$

where f maps each position (x_i, y_i) to a coordinate s_i. Here, s_i represents the distance along the contour from a starting point (x_0, y_0) to (x_i, y_i), calculated by summing the great-circle distances of individual contour segments.

We then search the one-dimensional profile $\tilde{\psi}(s_i)$ for **local maxima**, which correspond to candidate vortex centers. A local maximum is recognized at position s_k if $\tilde{\psi}(s_k)$ is the largest value in a window around s_k, defined by $sk - \delta s \leq si \leq sk + \delta s$.

Regarding the overall readability of the vortex tracking procedure in Section 3.1, we have added a clear description the main individual steps of the algorithm to improve understandability for all readers. And the diagram has been updated, with important marks added to make the method easier to understand.

L133: After having read the "Vortex tracking" section I'm still unsure how the tracking of vortices was exactly done. Please describe clearly how the vortices diagnosed at different times are related to identify connected tracks.

The last step in our process is to track how these small vortices (subvortices) move and how long they last over time. To do this, we repeat the same vortex-tracking analysis at each set of time points we study (e.g., every 6 hours).

We define a vortex as **persistent** (long-lasting) if two conditions are met:

1. From one time step to the next (e.g., from 6 AM to 12 PM), the vortex's center moves no more than 10° along the Earth's surface (measured as a great-circle distance, similar to the shortest path between two points on a globe).

2. The vortex remains visible (continuous) for at least four time steps—equivalent to 18 hours total (since each time step is 6 hours).

Any vortices that do not meet these conditions (i.e., they move more than 10° between time steps, or last less than 18 hours) are called **transient** (short-lived).

As we will show later in the paper, using these simple definitions makes it easy to track how vortices move over time. It also helps us identify when vortices split apart, merge together, or disappear entirely.

L153: I think R_d should be the gas constant not specific heat?

Thank you, it is a typo error, the R_d is the gas constant, we have corrected it.

L158: The (Joseph, 1981) is surely not the original paper to cite here. Similarly for the citations in L162.

Thank you for this important comment. We agree that (Joseph, 1981) is not the original source for the formulation of potential vorticity $q = \frac{\zeta+f}{\sigma}$, and that more appropriate, foundational references should be cited.
In the revised manuscript, we have replaced this citation with original and widely recognized sources, including the seminal works on potential vorticity theory (e.g., Charney, 1948; Ertel, 1942), which more accurately reflect the origin of this

formulation. We have also carefully reviewed the citations in Line 162 and updated them to ensure that primary and authoritative references are used where appropriate.

Eq. 7: What is the Q on the right-hand side of the equation exactly? The text says "Q is total diabatic heating". In most text books, Q denotes the diabatic heating rate, with units K/day. But this cannot be meant here, as the units wouldn't match. The PV tendency equation should include a diabatic forcing term including also derivatives of the diabatic heating rate and I guess this term is meant here with Q - but this is not said. This is just one example of the inconsistent notation that appears throughout the paper, making it nearly impossible for the reader to fully understand the methodology.

The confusion arose from our imprecise wording, which failed to distinguish between "diabatic heating rate" and "total diabatic heating". We further clarify that Eq. 7 is the PV tendency equation, and the term involving Q represents the diabatic forcing term, specifically, it includes the derivatives of the diabatic heating rate Q with respect to potential temperature, which is the key diabatic contribution to PV tendency.

To address the issue of inconsistent notation throughout the manuscript, we have conducted a comprehensive check and standardization of all symbols. We have explicitly defined each symbol (including Q when first introduced, clarified their units, and ensured consistency in their usage across all equations and text.

Eq. 8: Why is the vertical advection term not expanded into mean plus fluctuation?

The vertical advection term $-w\partial q/\partial p$ is not decomposed into mean and fluctuating components because our subsequent PV tendency analysis is performed on the 370 K isentropic surface, where the vertical velocity w (in pressure coordinates) is effectively zero under adiabatic conditions. This means the vertical advection term does not contribute to the PV tendency on the isentropic surface, so further decomposition into mean and fluctuation parts is unnecessary for our analysis focus.

The decomposition into mean and fluctuation parts is only applied to horizontal terms (zonal/meridional advection), as these are the primary drivers of ASMA variability we aim to isolate. The vertical term is retained in its original form to maintain consistency with the full PV tendency equation.

L184: Clearly explain at the beginning of this paragraph that and why isentropic coordinates are considered in the following (e.g. their advantages for the analysis). Then explain the differences to the pressure coordinate version of the equations. Furthermore, why is the isentropic version of the PV tendency equation not given in its version decomposed into?

Thank you. We have added a clear opening statement at the start of the paragraph (L184) explaining that we adopt isentropic coordinates (370 K surface) for our subsequent analysis. We highlight the key advantages:

1. Isentropic coordinates naturally align with adiabatic atmospheric processes, simplifying the interpretation of PV dynamics and diabatic forcing effects.
2. Vertical velocity vanishes under adiabatic conditions, eliminating the vertical advection term and focusing the analysis on horizontal processes that dominate ASMA variability

We have shortly described the key differences between the pressure-coordinate and isentropic-coordinate forms of the PV tendency equation. In pressure coordinates, the equation includes a vertical advection term $-w\partial q/\partial p$, while in isentropic coordinates this term is absent due to $w \approx 0$ on adiabatic surfaces. The isentropic formulation re-expresses all terms in terms of potential temperature θ as the vertical coordinate, streamlining the analysis of thermal and dynamical interactions within the ASMA.

Indeed, the full formula of isentropic version of the PV tendency equation should be decomposed in to mean state and fluctuation, here we omitted this announcement in the article. So, we expanded Equation 9 to make it easier to understand.

L185: "Therefore, the second term ..." comes after Eq. 8 without further explanation. Therefore, the reader thinks that the second term in Eq 8 is meant. However, I guess what is indeed meant is the second term in Eq. 6... ? Similarly for "expression" in L186 it is not clear which expression.

Thank you for pointing out ambiguous reference to "the second term" and “expression”. We have revised the text to explicitly state this. The baroclinic contribution to potential vorticity $g(\frac{\partial v}{\partial p}\frac{\partial \theta}{\partial x} - \frac{\partial u}{\partial p}\frac{\partial \theta}{\partial y})$ is vanished, cause the vertical wind shear (the vertical gradients of zonal and meridional winds, $\partial u/\partial p$ and $\partial v/\partial p$) and horizontal potential temperature gradients ($\partial \theta/\partial x$ and $\partial \theta/\partial y$) is zero.

L279: Here, one example from the later parts of the paper. L280 states that q_dev is the "minimum PV inside each box", while L286 states that "q_int and q_prop are the PV tendencies". As Eq. 11 relates both, there seems to be a mismatch to me: Is it PV or PV tendency here?

L279: We apologize for the confusion: q_dev, q_int, and q_prop all represent PV tendencies, not PV itself. The description at L280 incorrectly referred to PV, we have revised it to clearly state that q_dev is the minimum PV tendency inside each box, consistent with Eq. 11 and the definition in L286.