Response to Reviewer #1

Corresponding author: Yusuke Hiraga
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We sincerely thank the reviewer for the careful and constructive evaluation of our manuscript. We appreciate the reviewer's recognition of the strengths of the study, particularly the increasing trend in AR frequency over northwestern Japan and the role of PW in distinguishing QSLRB-associated and non-QSLRB events.

We carefully considered all of the comments. In the revised manuscript, we have primarily addressed the reviewer's concerns by clarifying the scope of our analyses, moderating statements that could imply independent or causal effects, explicitly describing the statistical methods, clarifying the temporal coverage of the QSLRB analysis, and incorporating the suggested references.

We have intentionally not introduced several new analyses requested by the reviewer, such as multiple-comparison corrections, partial correlations or multiple regression, quantitative SOM skill metrics, vertical velocity/geopotential-height composites, or lagged correlation analyses. Instead, we have clarified what can and cannot be concluded from the existing analysis and have explicitly identified these analyses as directions for future work. We believe that this approach better reflects the scope of the present study while avoiding overinterpretation of the results.

General Comments

The paper shows that IVT alone is not enough to explain heavy rainfall from ARs in Japan, using SOM based AR classification, Huber regression residual grouping, and a QSLRB overlap analysis. The Mann Kendall trend result (AR frequency rising in northern Japan) and the finding that PW separates QSLRB from non QSLRB events are the strongest parts of the paper. But the statistics connecting Figure 4 and 5 to the paper's main claim are not strong enough to support how confidently the claim is stated. The paper also never looks at vertical circulation structure even though its own explanation depends on convergence and lifting. And the AR to rainfall relationship is only checked as same window overlap, with no check for whether rainfall happens before, during, or after AR landfall. Major revision is recommended.

Response:

Thank you for this careful overall assessment. We agree that the statistical comparisons in Figures 4 and 5 and the temporal overlap analysis do not by themselves support strong claims concerning independent or causal mechanisms.

Accordingly, we have substantially revised the interpretation of these results. In particular, we now describe the Figure 4 results as exploratory associations, rather than independently established controlling factors. We also clarify that the IVT-based residual classification does not isolate the independent contribution of moisture-related variables such as PW.

Furthermore, we have moderated the discussion of convergence and orographic lifting because the present study does not directly diagnose the three-dimensional vertical circulation. We have also clarified that the temporal-overlap approach used for the QSLRB analysis cannot establish temporal precedence.

Finally, we have incorporated the studies suggested by the reviewer, including Pandidurai et al. (2026), which explicitly examines the sequential evolution of moisture transport, moisture convergence, and heavy rainfall, as well as the three studies suggested in Minor Comment 7 concerning moisture sources, extreme-rainfall organization, and high-temporal-resolution moisture-budget information.

Major Comments

Major Comment 1

1. In lines 219-238, Figure 4. Ten separate tests are run (IVT, PW, CAPE, CIN, MVIMC, RH500, latitude, duration, overlap, elevation) on groups of 46 and 50 events, with no correction for running that many tests at once. At a 0.05 significance level across 10 tests, you would expect about one false positive purely by chance. Five out of ten come back significant here. Without a correction such as Bonferroni or FDR, this result cannot be trusted as strongly as the paper treats it, and it is central to the main claim of the abstract.

Response:

Thank you for highlighting this important statistical issue. We agree that multiple testing increases the possibility of false-positive findings and that the original wording placed too much emphasis on the nominal significance of individual variables.

We have therefore not applied a post-hoc Bonferroni or FDR correction, because the present analysis was designed as an exploratory event-group comparison rather than as a formal hypothesis-testing framework for ten independent hypotheses. Instead, we now explicitly refer to the reported p-values as nominal p-values and state that the results should be interpreted as exploratory associations.

Most importantly, we have removed wording suggesting that the statistically significant variables independently “explain” the higher rainfall efficiency. The Abstract, Figure 4 discussion, Discussion, and Conclusion have all been revised consistently to avoid overstatement.

Revisions in the Manuscript:

Original manuscript lines 17–23 — Abstract

The original Abstract stated that rainfall intensity was “primarily modulated” by several factors.

Revised text:

“IVT explains a substantial portion of the overall relationship ($R = 0.71$), but considerable variability remains among events with similar IVT. Within our event-based residual-group comparison, enhanced rainfall efficiency is associated with stronger moisture convergence, lower convective inhibition, higher mid-level humidity, and higher landfalling elevation. These results indicate that synoptic moisture transport alone does not fully determine rainfall efficiency and that the thermodynamic and geographical environment also contributes to event-to-event variability.”

Original manuscript lines 219–238 — Figure 4 discussion

The original statements that the significant variables “explain” the higher precipitation efficiency and that MVIMC and elevation are primary/decisive factors have been weakened.

Revised text:

“Several environmental variables show nominally significant differences between the two residual groups, including moisture convergence, convective inhibition, mid-level humidity, mean latitude, and elevation. These differences indicate that rainfall efficiency varies with the dynamical, thermodynamic, and geographical environment in addition to the magnitude of moisture transport. Because multiple comparisons were performed and the variables are physically coupled, these results should be interpreted as exploratory associations rather than as independently established effects.”

Major Comment 2

2. In lines 198-217. The way events are split into positive and negative residual groups may already guarantee part of the result. IVT and PW are physically related to each other. When you regress rainfall on IVT and look at what is left over, you also remove any effect that comes from things correlated with IVT, including PW. So, the finding that "PW shows no difference between groups" (line 222) might just be a side effect of how the groups were built, not real evidence that PW does not matter. The authors should report the correlation between IVT and PW directly, and discuss whether their method could even detect a PW effect if one existed.

Response:

Thank you for this important methodological observation. We agree that the construction of the residual groups conditions the analysis on the IVT–precipitation relationship and therefore affects the interpretation of other moisture-related variables.

In particular, we agree that the absence of a statistically significant PW difference between the residual groups should not be interpreted as evidence that PW does not contribute to rainfall efficiency. Because PW is physically related to the integrated moisture transport environment represented by IVT, part of its influence may already be represented in the baseline IVT–precipitation relationship.

We have therefore revised the corresponding statement in Figure 4. We have not introduced a new direct IVT–PW correlation analysis in the revised manuscript, and we now explicitly acknowledge that the present residual approach cannot independently isolate the contribution of PW.

Revisions in the Manuscript:

Original manuscript lines 198–217 — IVT-based residual-group methodology

We retained the Huber-regression residual classification but clarified its interpretation.

Revised/additional text:

"The residual-group analysis is designed to identify environmental characteristics associated with deviations from the IVT–precipitation relationship. Because moisture-related variables such as PW are physically related to IVT, the residual classification does not isolate their independent contributions."

Original manuscript lines 219–224 — Figure 4 discussion

The original statement that the absence of a PW difference "confirms" that total column water vapor does not drive the rainfall contrast has been removed.

Revised text:

"IVT and PW do not show statistically distinguishable differences between the two residual groups. However, because the residual grouping is constructed from the IVT–precipitation relationship, the contribution of moisture availability represented by PW may be partly incorporated into the IVT-based relationship. Therefore, the absence of a significant PW difference in this comparison should not be interpreted as evidence that PW has no effect on rainfall efficiency."

Major Comment 3

3. In lines 219-238. MVIMC, CIN, RH500, elevation, and latitude are treated as five separate independent factors, but some of these are likely connected. Higher elevation naturally increases convergence through orographic lifting, so elevation and MVIMC may be reflecting the same physical process rather than two separate ones. A partial correlation or multiple regression is needed before listing both as separate conclusions (lines 326 to 328).

Response:

We agree with the reviewer that these environmental variables are physically coupled and should not be interpreted as statistically independent factors.

The underlying analysis included pairwise correlation and VIF diagnostics, which indicated substantial interrelationships among several predictor variables. These diagnostics support the reviewer's concern that the present group-wise comparisons cannot establish the independent contribution of MVIMC, CIN, RH500, latitude, and elevation.

We have revised the manuscript so that these variables are presented as **c**oupled environmental characteristics associated with enhanced rainfall efficiency, rather than as independently established controlling factors.

Revisions in the Manuscript:

Original manuscript lines 219–238 — Figure 4 discussion

The individual variables are no longer presented as independent factors.

Revised text:

"Because these environmental variables are physically interrelated, the differences between the residual groups should be interpreted as coupled environmental characteristics associated with enhanced rainfall efficiency rather than as evidence of independent effects."

Original manuscript lines 326–328 — Discussion

The previous statement implying independent "necessity factors" has been replaced.

Revised text:

"The environmental variables examined here are not independent; pairwise correlations and variance inflation factors in the underlying analysis indicate substantial interrelationships among several predictors. Therefore, the present group-wise comparisons identify environmental characteristics associated with rainfall-efficiency differences, but do not establish their independent contributions."

Major Comment 4

4. In lines 141-143. The choice of a 2 by 2 SOM grid is only explained in words, not backed by numbers. Since Cluster D at 44.7 % of events (line 143) is the basis for the whole climatology section, the grid size choice needs a quantitative check, such as quantization error or topographic error across different candidate grid sizes.

Response:

Thank you for this comment. We agree that quantitative SOM diagnostics could provide an additional objective basis for determining the optimal grid size.

In the present study, however, the SOM was intended primarily to identify physically interpretable and distinct AR trajectory patterns. The 2 × 2 configuration was selected after testing multiple configurations because it provided clear physical separation while avoiding excessive fragmentation of the event population.

We have clarified that the 2 × 2 configuration represents a physically motivated classification, rather than a uniquely optimal statistical solution.

Revisions in the Manuscript:

Original manuscript lines 141–143 — Section 3.1.1

The rationale for the 2 × 2 SOM configuration has been clarified.

Revised text:

"After testing multiple SOM configurations, a 2 × 2 node structure was selected because it provided physically interpretable and distinct AR trajectory patterns while avoiding excessive fragmentation of the event population. The selected configuration should therefore be regarded as a physically motivated classification rather than as a uniquely optimal SOM resolution."

Major Comment 5

5. In Section 3.1 and 3.2, Figures 1, 5, 6. All circulation analysis in the paper is based only on IVT composites. The discussion (lines 288 to 297) argues that convergence and low CIN drive rainfall, but this is inferred from a single CIN number rather than shown directly. Adding vertical velocity and geopotential height anomaly composites at 500 hPa and 850 hPa for the positive and negative residual groups, alongside the existing IVT panels, would let the authors actually show this mechanism instead of inferring it. This kind of analysis is used in Pandidurai et al. (2026), https://doi.org/10.1002/joc.70462.

Response:

Thank you for this constructive suggestion. We agree that vertical velocity and geopotential-height anomaly composites would provide a more direct diagnosis of the three-dimensional circulation associated with heavy rainfall.

We have revised the interpretation so that the existing results are not presented as a direct diagnosis of vertical circulation or as proof of a specific lifting mechanism.

We have also incorporated Pandidurai et al. (2026) into the Discussion as an example of a process-oriented approach that explicitly examines the sequential evolution of moisture transport, moisture convergence, and rainfall. Their results demonstrate the usefulness of combining moisture transport, moisture budget, and temporal evolution to identify precursor processes.

Revisions in the Manuscript:

Original manuscript lines 288–297 — Discussion

The original statements concerning the “decisive role” of landfalling elevation and the causal interpretation of convergence have been moderated.

Revised text:

“The present analysis identifies enhanced moisture convergence and favorable thermodynamic and geographical conditions as characteristics associated with higher rainfall efficiency. However, the present circulation analysis does not directly diagnose the three-dimensional vertical circulation, and therefore the dynamical mechanisms underlying these associations cannot be fully separated here. Process-oriented analyses that combine moisture transport, moisture convergence, vertical circulation, and their temporal evolution, such as those presented by Pandidurai et al. (2026), would provide a useful framework for further investigating these relationships.”

Major Comment 6

6. In lines 96-128 and 245-248. The relationship between ARs and rainfall is only checked through overlap in time and space (lines 96-99, 127-128), never through timing offset. Since both ARs and QSLRBs last several hours on average (Figure 2b shows 10 to 13.5 hours), simple overlap cannot tell apart rainfall that happens at the same time as the AR from rainfall that happens as a delayed response, for example moisture building up first and heavy convection organizing later. The authors should compute a lag relationship, either a cross correlation or a distribution of the time gap between peak rainfall or QSLRB onset and AR axis passage, going out to at least 48 hours given the six hourly resolution of the data. This should be done separately for each SOM cluster and for QSLRB versus non QSLRB events before combining everything, because pooling all 479 events together first could hide a real lag if different AR types behave differently. This connects to the sequential moisture approach in Pandidurai et al. (2026), cited above in M5.

Response:

We agree that the temporal-overlap criterion cannot distinguish between simultaneous conditions and a delayed response of precipitation to moisture transport.

The present study was designed to characterize environmental conditions associated with AR-related precipitation during the event period rather than to establish temporal precedence. Thus, we have removed wording that could imply that PW is a temporal precursor and have explicitly identified the absence of lead–lag analysis as a limitation of the current event-based framework.

We have also cited Pandidurai et al. (2026), which provides an example of a sequential moisture-analysis framework in which IVT strengthening, moisture convergence, and peak rainfall are examined in their temporal sequence.

Revisions in the Manuscript:

Original manuscript lines 96–128 — AR/QSLRB association methodology

The temporal-overlap definition has been retained because it is appropriate for the scope of the present event-association analysis. We have clarified its interpretation in the Discussion rather than implying temporal causality.

Original manuscript lines 245–248 — QSLRB results

The original wording:

"a higher background concentration of PW in the target region is a critical precursor for QSLRB development"

has been revised.

Revised text:

"PW showed a statistically distinguishable difference between QSLRB-associated and non-QSLRB events in the rainfall-matched comparison, suggesting that a moisture-rich atmospheric environment is an important characteristic of QSLRB-associated ARs."

Original manuscript lines 378–387 — Discussion / limitations

The temporal limitation is stated once in the consolidated limitations paragraph:

"Because the AR characteristics and precipitation are evaluated over temporally overlapping event periods, the present analysis does not distinguish conditions that precede rainfall from those occurring concurrently with or following rainfall. Future work using higher-temporal-resolution observations and lagged analyses would be useful for examining the temporal evolution of moisture transport, convergence, and precipitation."

Minor Comments

Minor Comment 1

1. Lines 218 to 221: The sentence describing what Figure 4 shows is repeated almost word for word right after itself. Remove the duplicate.

Response:

Thank you for pointing this out. We have removed the duplicated sentence.

Revisions in the Manuscript:

Original manuscript lines 218–221

The repeated description of Figure 4 was removed.

Minor Comment 2

2. Lines 65 to 68: "we utilized a suite of ERA5 based variables and indices except for precipitation" is awkward. Consider "excluding precipitation, which came from RA data instead."

Response:

Thank you for the suggestion. We agree and have revised the wording for clarity.

Revisions in the Manuscript:

Original manuscript lines 65–68

Revised text:

"We utilized a suite of ERA5-based variables and indices, excluding precipitation, which was obtained from the Radar–AMeDAS dataset."

Minor Comment 3

3. Lines 219, 260 (Figure 4, Figure 5c): The statistical test used to get the p values is never named. Since the paper already points out that rainfall data has heavy tails and uses Huber

regression for that reason (lines 108 to 111), using a plain t test elsewhere would be inconsistent. State and justify whichever test was used.

Response:

Thank you for this comment. We agree that the statistical test should be explicitly identified.

The group comparisons were performed using Welch's t-test, which does not assume equal variances between the two groups. We have now explicitly stated this in the manuscript.

The Huber regression and Welch's t-test have different purposes in the analysis. Huber regression is used to characterize the IVT–precipitation relationship while reducing the influence of extreme residuals, whereas Welch's t-test is used to compare environmental variables between the resulting groups.

Revisions in the Manuscript:

Original manuscript lines 219 and 260

We added the statistical-test information to the descriptions of the group comparisons.

Revised text:

"Differences in the environmental variables between the two residual groups were evaluated using Welch's t-test, which does not assume equal variances between the two groups."

The same statistical test is used for the QSLRB-associated versus non-QSLRB comparison.

Minor Comment 4

4. Line 232: "Landfalling Elevation" is never clearly defined. Is it the elevation at the point where the AR axis meets the coast, or the average terrain elevation across the AR footprint? Needs one clarifying sentence.

Response:

Thank you for pointing this out. We agree that the definition of this variable should be clarified.

In the event-based analysis, the physical variables are spatially averaged over the intersection between the AR footprint and northwestern Japan. Surface elevation is derived from ERA5 geopotential and represents the terrain environment associated with the AR footprint in the target region.

Revisions in the Manuscript:

Original manuscript line 232

Revised/additional text:

"Surface elevation was derived from the ERA5 geopotential by dividing by the standard gravitational acceleration and was used as a first-order representation of the terrain elevation associated with AR landfall."

This wording is intended to clarify that "Landfalling Elevation" does not represent the elevation of a single AR-axis/coast intersection point.

Minor Comment 5

5. Lines 51, 172, 320 and reference list: The name "Hirockawa" is used throughout, but the more common spelling in the AR and QSLRB literature is "Hirokawa." Worth checking if this is correct or a repeated typo.

Response:

Thank you for pointing this out. We carefully checked the author name and confirmed that the correct spelling is Hirockawa.

We therefore retain "Hirockawa" throughout the manuscript and reference list.

Revisions in the Manuscript:

Original manuscript lines 51, 172, 320, and reference list

The spelling was checked and confirmed as Hirockawa. No change was necessary.

Minor Comment 6

6. Lines 245 to 250: State clearly that the QSLRB analysis only covers 2006 to 2023 because of the RA data limits, while the residual group analysis in section 3.2.1 covers a different period. This is currently left unstated.

Response:

Thank you for this comment. We agree that the temporal coverage of the two analyses should be explicitly distinguished.

The QSLRB analysis is restricted to 2006–2023, corresponding to the availability of the Radar–AMeDAS precipitation dataset. We have added this information to the manuscript.

Revisions in the Manuscript:

Original manuscript lines 245–250

Added text:

"The QSLRB analysis was restricted to the 2006–2023 period, corresponding to the availability of the Radar–AMeDAS precipitation dataset used for this analysis."

Minor Comment 7

7. The authors note that the causes behind shifting AR tracks remain unclear (lines 315–317). One direction for future work would be tracing moisture sources for landfalling AR events and using higher time resolution moisture budget datasets to better capture the fine-scale convergence signal discussed as central to rainfall efficiency in Section 3.2.1. Relevant studies include: https://doi.org/10.1029/2026EF008305, https://doi.org/10.1029/2026GL121973, and https://doi.org/10.1038/s41597-025-06044-y.

Response:

Thank you for this valuable suggestion. We agree that moisture-source attribution and higher-temporal-resolution moisture-budget analyses would provide an important extension of the present study.

We have therefore incorporated all three references suggested by the reviewer into the revised manuscript. Specifically, Raghuvanshi and Agarwal (2026a) provides a framework for moisture-source attribution of synchronized extreme precipitation, Raghuvanshi and Agarwal (2026b) demonstrates the relevance of preceding rainfall, low-pressure anomalies, and moisture convergence to extreme-rainfall predictability, and Raghuvanshi and Agarwal

(2025) provides an hourly dataset of moisture-budget components that can support higher-temporal-resolution process analysis.

These studies are cited as motivation for future work rather than as direct evidence for the mechanisms identified in the present study.

Revisions in the Manuscript:

Original manuscript lines 315–317 — Discussion / future work

The original future-work statement has been expanded.

Revised text:

“Future studies should further examine the moisture sources and temporal evolution of AR-related precipitation using moisture-source attribution and higher-temporal-resolution moisture-budget datasets. Recent studies have demonstrated the potential of moisture-source attribution for identifying distinct moisture-transport pathways associated with extreme precipitation (Raghuvanshi and Agarwal, 2026a) and of event-based approaches for identifying preceding rainfall, circulation anomalies, and moisture convergence associated with extreme rainfall (Raghuvanshi and Agarwal, 2026b). In addition, the hourly moisture-budget dataset developed by Raghuvanshi and Agarwal (2025) provides an example of the higher-temporal-resolution information that could be useful for resolving fine-scale moisture convergence. Such approaches could help clarify the relative timing and contribution of moisture transport, moisture convergence, vertical circulation, and precipitation development.”

Additional revisions to improve consistency of interpretation

In addition to the point-by-point revisions above, we conducted a focused review of the manuscript for statements that were stronger than supported by the present analysis.

1. Abstract

Original manuscript lines 17–23

The Abstract previously stated that rainfall intensity was “primarily modulated” by a combination of strong moisture convergence, low CIN, and orographic enhancement.

This has been replaced with the more cautious wording:

“IVT explains a substantial portion of the overall relationship (R = 0.71), but considerable variability remains among events with similar IVT. Within our event-based residual-group comparison, enhanced rainfall efficiency is associated with stronger moisture convergence, lower convective inhibition, higher mid-level humidity, and higher landfalling elevation. These results indicate that synoptic moisture transport alone does not fully determine rainfall efficiency and that the thermodynamic and geographical environment also contributes to event-to-event variability.”

2. Figure 4 and Discussion

Original manuscript lines 219–238

Expressions such as:

- “highly significant differences that explain”
- “primary driver”
- “decisive mechanism”
- “primarily governed”

have been removed or softened.

The revised interpretation emphasizes that these are **statistical associations among physically coupled environmental variables**.

3. QSLRB interpretation

Original manuscript lines 245–250 and 320–325

The original wording described PW as the “primary differentiator” and “critical precursor.”

This has been revised to:

“PW showed a statistically distinguishable difference between QSLRB-associated and non-QSLRB events in the rainfall-matched comparison, suggesting that a moisture-rich atmospheric environment is an important characteristic of QSLRB-associated ARs.”

Thus, the result is retained, but the wording no longer implies that PW has been demonstrated to be an independent temporal precursor.

4. Discussion and Conclusion

Original manuscript lines 326–328 and 407–414

The original expressions "decisive role," "primary necessity factor," "specific necessity factors," and "sole significant differentiator" have been revised.

Revised Conclusion text:

"AR precipitation efficiency is associated with environmental conditions beyond the magnitude of moisture transport, including moisture convergence, convective inhibition, atmospheric humidity, and terrain elevation. These characteristics should be interpreted as coupled environmental conditions associated with enhanced rainfall efficiency rather than as independently established causal factors."

For QSLRBs, the conclusion has similarly been moderated:

"PW showed a statistically distinguishable difference between QSLRB-associated and non-QSLRB events under the rainfall-matched comparison, suggesting that a moisture-rich atmospheric environment is an important characteristic of QSLRB-associated ARs."

Consolidation of limitations

Original manuscript lines 378–387

We agree that the manuscript should not repeatedly state the same limitation in multiple sections. Therefore, rather than repeating the limitations separately in the responses to Major Comments 2, 5, and 6, we have consolidated the relevant methodological limitations into the existing Discussion/limitations section.

Revised text:

"The interpretation of the present event-based analysis is subject to several limitations. Because the residual groups are defined from the IVT–precipitation relationship, environmental variables physically related to IVT may partly contribute to the baseline

relationship, and the residual-group analysis is therefore not intended to isolate independent effects of individual moisture-related variables. In addition, the circulation analysis is primarily based on IVT composites and scalar environmental variables and does not directly diagnose the three-dimensional vertical circulation. Finally, because the AR characteristics and precipitation are evaluated over temporally overlapping event periods, the present analysis does not distinguish conditions that precede rainfall from those occurring concurrently with or following rainfall. Future studies using higher-resolution atmospheric datasets, direct circulation diagnostics, moisture-source attribution, and lagged analyses would be useful for examining the temporal and physical processes linking ARs to localized extreme precipitation."

This consolidated paragraph is intended to avoid repetition while making the three principal methodological limitations identified by the reviewer explicit.

References added in response to Reviewer #1

The following papers specifically suggested by the reviewer have been incorporated into the manuscript:

1. **Pandidurai, D., Raghuvanshi, A. S., Agarwal, A., & Trigo, R. M. (2026).** Sequential Moisture Dynamics Driving Multi-Day Flood-Producing Rainfall Across India. *International Journal of Climatology*, e70462. https://doi.org/10.1002/joc.70462.
2. **Raghuvanshi, A. S., & Agarwal, A. (2026a).** Moisture Source Attribution of Synchronized Extreme Precipitation Communities During the Indian Summer Monsoon. *Earth's Future*, 14, e2026EF008305. https://doi.org/10.1029/2026EF008305.
3. **Raghuvanshi, A. S., & Agarwal, A. (2026b).** Network Divergence Reveals Predictable Pathways of Extreme Rainfall in Central India. *Geophysical Research Letters*, 53, e2026GL121973. https://doi.org/10.1029/2026GL121973.
4. **Raghuvanshi, A. S., & Agarwal, A. (2025).** An Hourly Dataset of Moisture Budget Components Over the Indian Subcontinent (1940–2024). *Scientific Data*, 12, 1770. https://doi.org/10.1038/s41597-025-06044-y.

We thank the reviewer again for these constructive suggestions. We believe that the revised manuscript now more clearly distinguishes the observational associations identified by the present analysis from mechanisms that require further process-oriented investigation. The revisions also clarify the methodological scope of the study and reduce the possibility of overinterpreting individual statistical differences as independent causal factors.