Reviewer 1:

As a reviewer, after carefully evaluating the revised manuscript, the authors' responses, and the comments from the other reviewer, I find that while the authors have made noticeable efforts in incorporating statistical tests and expanding textual discussions, the core scientific and methodological flaws raised in the previous round remain unresolved. I completely share the reservations expressed by Reviewer 2; the current revisions appear to be statistical and rhetorical patchworks that gloss over fundamental vulnerabilities in the underlying physical mechanisms.

We sincerely thank the reviewer for the careful evaluation of the revised manuscript and for highlighting the remaining concerns. We regret that our revisions did not fully address the reviewer's expectations.

We acknowledge that the limited availability of observations is an inherent challenge in the study of extreme events. Such events, by definition, are rare, which restricts the size of the available datasets and limits the extent to which broad statistical generalizations can be made. Recognizing this limitation, we have further revised the manuscript to present our findings explicitly as case-study evidence applicable to the specific extreme events analyzed, rather than as universally generalizable conclusions. We have carefully modified the discussion throughout the manuscript to avoid overgeneralization and to emphasize the scope and limitations of our results.

In addition, to improve the robustness of the analysis for Southern Hemisphere-origin events, we expanded the dataset by analyzing 47 "strong" events. This larger sample provides a more solid statistical basis for the conclusions related to this subset of events while remaining consistent with the observational constraints inherent to extreme-event research.

Although we recognize that some limitations cannot be completely eliminated due to the nature of the available observations, we believe that the revised manuscript now presents the results with an appropriate level of caution, clearly defining their applicability and avoiding claims beyond what the data can support.

First, regarding the extremely limited sample size (5 events in the Southern Hemisphere and 6 in the Northern Hemisphere), the composite analysis is highly susceptible to the leverage of a single outlier event, as pointed out by Reviewer 2. Although the authors introduced statistical remedies such as balanced resampling and bootstrap testing, these methods cannot inherently eliminate the structural bias embedded in such a tiny dataset. Without quantitatively isolating the dominant impact of individual extreme events, these statistical adjustments fail to cure the Achilles' heel of a weak data foundation, leaving the robustness and representativeness of the conclusions highly questionable.

We appreciate the reviewer's concern regarding the limited sample size and the potential influence of individual cases on the composite results. To directly address this issue, we performed an additional analysis using the full set of 47 "strong" SH events, rather than only the subset of "very strong" events. The resulting composite exhibits a circulation pattern that is highly consistent with that obtained for the "very strong" events, characterized by a pressure gradient between an anomalous anticyclonic center and an anomalous cyclonic center over the South Pacific, oriented along a southwest–northeast (SW–NE) axis. As expected, the pressure gradient is somewhat weaker than in the composite based solely on the "very strong" events, but the overall spatial structure and orientation remain essentially unchanged. The close agreement between the composites derived from the larger sample and from the subset of very strong events indicates that the identified large-scale circulation pattern is not controlled by a few individual events or outliers, but instead represents a robust feature of SH strong events. This additional analysis therefore provides independent evidence that the main physical mechanism proposed in the manuscript is not an artifact of the limited sample size.

We have added a paragraph to the Discussion about the "strong" events originated in the SH (L487-L493). In addition, we have included Table S7 in Supporting Information, which lists the 47 “strong” SH events considered in this analysis, together with Fig. S28, which shows the SLP composite of these events.

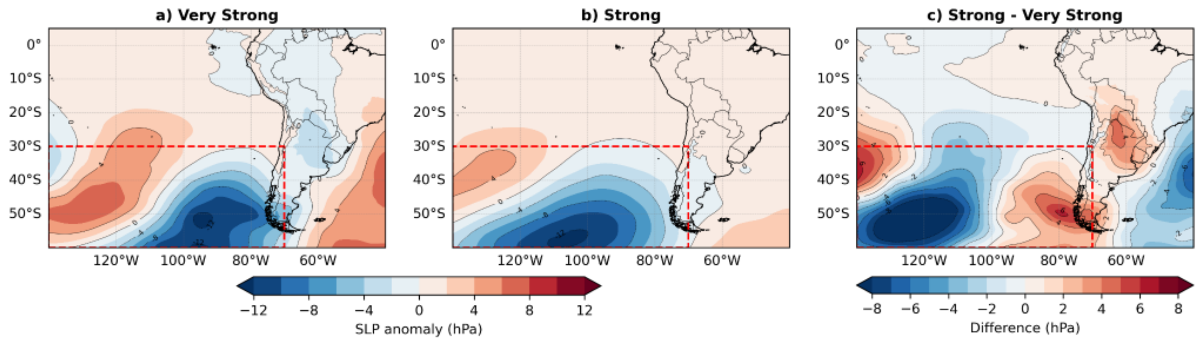

Figure S28. Composite sea-level pressure (SLP) anomalies (hPa) for SH extreme swell events. (a) Very strong events, (b) strong events, and (c) their difference (strong minus very strong).

L487- 493: “To expand the sample size of events, 'strong' swell events originating in the SH were also explored alongside the most extreme cases. For this subset (Table S7 - Supporting Information), the atmospheric composite displays a circulation pattern similar to that of the 'very strong' events, albeit characterized by a weaker pressure gradient (Fig S28 - Supporting Information). When examining flow analogues individually for each event, higher inter-event variability emerges, reflecting a greater influence of internal climate variability—resembling the behaviour observed in NH events. Nonetheless, a substantial proportion of these strong events still exhibit a present-day wind intensification alongside a shift toward a positive SAM phase, confirming that this dominant forcing persists across a broader set of events (Fig S29 - Supporting Information).”

Second, the attribution mechanism for the Northern Hemisphere (NH) events suffers from a severe logical fracture, which further validates Reviewer 2's skepticism regarding the validity of the analogue analysis. Out of the 6 NH events, half show intensification under global warming while the other half show weakening. The authors attribute this divergence to the countervailing effects of internal modes like PDO and ENSO, ultimately sheltering their argument under the IPCC's "low confidence" conclusion. This line of reasoning precisely exposes the limitation of the proposed framework: if internal climate variability can so easily mask or reverse the global warming signal, the core thesis concerning the regulation of Peru's extreme swells by global warming lacks sufficient certainty and persuasion in the NH, failing to deliver a unified and lucid physical picture.

We thank the reviewer for this comment. We acknowledge that the NH events do not exhibit a uniform response under present-day climate conditions. However, we would like to clarify that the analogue-based attribution framework employed here, which is widely used in event attribution studies, evaluates each event individually rather than seeking a single deterministic response across all events. Consequently, differences in the attribution signal between events are expected and reflect the combined influence of anthropogenic climate change and internal climate variability on event-scale processes.

For the NH events, the contrasting responses do not represent a logical inconsistency of the methodology but rather illustrate the complexity of the mechanisms governing these extreme swells. In particular, large-scale modes of climate variability, such as ENSO and the PDO, can modulate the atmospheric circulation patterns responsible for these events, either reinforcing or offsetting the thermodynamic effects associated with global warming. This event-to-event variability is consistent with the current understanding reported in the IPCC, which assesses the confidence in detecting anthropogenic influences on some types of extratropical storm activity as low.

We agree that these results do not support a single, unified response for NH-origin events. For this reason, we have revised the manuscript to explicitly present these findings as event-specific attribution results rather than evidence of a generalized NH response. The manuscript now emphasizes that the attribution of NH extreme swells remains conditional on the characteristics of each event and the background state of the climate system. We believe this revised framing more accurately reflects both the capabilities and the limitations of the methodology and avoids overgeneralization beyond what the available evidence can support.

Finally, the dynamical link between large-scale circulation anomalies and actual coastal hazards remains fractured. The near-shore wave validation using ERA5 data, hastily added to the discussion section, is superficial. It fails to quantitatively resolve the complex physical processes—such as wave-current interactions and shallow-water deformation—that swells experience during their multi-thousand-kilometer propagation. The sensitivity experiments also stop short at merely proving that "timing inaccuracies do not matter," failing to establish a rigorous, closed dynamical chain from open-ocean generation to coastal transmission.

In summary, the scientific conclusions of the revised manuscript still rest upon highly uncertain derivations, and the critical deficiencies flagged by both reviewers persist.

We agree that wave transformation processes occurring during nearshore propagation, including wave-current interactions, refraction, shoaling, and other shallow-water effects, are important for determining the final coastal impact of swell events. However, we would like to clarify that these processes are beyond the scope of the present study.

The primary objective of this work is to investigate the atmospheric and oceanic conditions associated with the generation of extreme swell events and to assess how the large-scale mechanisms responsible for their formation are influenced under present-day and past climate conditions. Our attribution analysis is therefore focused on the origin of the events rather than on the detailed propagation and transformation of swell waves within the coastal zone.

The comparison with ERA5 wave fields near the Peruvian coast was included solely as an independent consistency check to verify that the simulated large-scale swell signals are represented near the coast. It was not intended to constitute a comprehensive coastal wave propagation or hazard assessment.

Reviewer 3:

The paper presents an assessment of the dynamics causing extreme swell along the Peruvian coast. It uses the flow analogue method to investigate if the atmospheric circulation patterns have changed through time.

1. I would like to highlight that analogues from observations/reanalysis alone cannot be used to attribute changes to anthropogenic climate change. I quote from my own paper (https://www.sciencedirect.com/science/article/pii/S2212094726000496):

It is important to note that differences between past and present composites are not necessarily caused by forced changes, such as anthropogenic greenhouse gas forcings. The differences may be due to internal variability, land-use or aerosol changes, or could be statistical artefacts due to the small sample size or a lack of good analogues. We cannot attribute the changes from these results alone, but they can be used to support attribution statements derived from other methods.

Therefore I would suggest that conclusions point 4 is rewritten to account for this. It would be beneficial to also reframe Line 435, though the inclusion of 'partly' does already help. Perhaps it could be highlighted that further work including flow analogues in GCMs of the past and future could lead to an attribution of the changes.

We thank the reviewer for this important comment and for sharing the relevant passage from their own work. We fully agree that circulation analogues derived from reanalysis alone cannot, by themselves, attribute changes to anthropogenic forcing, and we have revised the manuscript throughout to ensure this distinction is made explicit and consistently maintained.
Specifically, we reframed the Abstract, Objectives, and Section 2.4 (Methods) to describe the analogue framework as assessing whether surface winds have changed between periods, with anthropogenic forcing discussed as a plausible contributor. In Sections 3.1.3 and 3.2.3 (Results), we revised the language around the counterfactual reconstructions to avoid attributing period differences directly to "climate change". In the Discussion, we cite the reviewer's own recent paper (Thompson et al., 2026) to support this point, and revised the closing summary to remove language implying a self-assigned IPCC-style confidence level, stating instead that the SH signal offers supportive, rather than conclusive, evidence of anthropogenic influence. Conclusions point 4 and Line 435 have been rewritten accordingly, framing the SH signal as consistent with — rather than directly caused by — the SAM trend and its documented anthropogenic drivers.
We also thank the reviewer for the suggestion regarding flow analogues in GCMs; we agree this is a valuable path toward formal attribution and have added this as a direction for future work in the Discussion (L548-L552).

L548 – 552: "Future work should extend the flow-analogue framework beyond the observational record by applying it to large ensembles of climate model simulations under historical and future forcing scenarios. Such an approach would enable a formal attribution of the circulation changes identified here by separating the dynamical and thermodynamical responses to different external forcings, thereby providing a more robust assessment of the role of anthropogenic climate change in modulating the atmospheric conditions that generate extreme swell events along the Peruvian coast."

Conclusion point 4: "Flow-analogue reconstructions indicate that surface winds during SH extreme-wave events have strengthened in recent decades, associated with enhanced synoptic pressure gradients. This intensification coincides with the recent trend toward more positive SAM phases—itself linked in the literature to ozone depletion and greenhouse-gas forcing—which favours stronger westerlies across the high-latitude South Pacific. This pattern is consistent across all SH events *except E3, pointing to anthropogenic forcing as a plausible contributor to the SH signal, alongside internal climate variability."*

2. For SH, 'very strong' observed events are used, whereas for NH there are only 'strong' events. I understand this is simply what is in the observational record. It would be interesting to see the analogue assessment repeated for the 'strong' SH events to see if less conclusive findings are shown (as in the NH). Alternatively, a comment in the discussion on the difference in results from SH and NH and how that could be linked with the very strong / strong event types would be useful.

We thank the reviewer for this suggestion. We have now repeated the analogue assessment for the 47 "strong" SH events. As expected, these events exhibit greater heterogeneity, with the influence of natural variability varying more substantially from one event to another. This variability stems from differences in the dominant climate mode and its active phase during each event, alongside minor shifts in source-region locations. For example, there are 17 events in which the ENSO index shows a significant increase between the two periods, which contributes to weaker winds across all or part of the event source region.
Nevertheless, of the 47 events, 29 show an intensification of the 10-m wind in the recent period (1987–2024) relative to 1950–1986, and there is also a stronger predominance of the positive phase of the SAM in the recent period (30 of 47 events), which tends to intensify the 10-m wind over all or part of the event source region. This is consistent with the results obtained for the "very strong" events, suggesting that the main finding is robust even when the event selection criterion is relaxed.
We have added a paragraph to the Discussion about the "strong" events originated in the SH (L487-L493) and added the Fig. S29 to the Supporting Information.

L487- 493: "To expand the sample size of events, 'strong' swell events originating in the SH were also explored alongside the most extreme cases. For this subset (Table S7 - Supporting Information), the atmospheric composite displays a circulation pattern similar to that of the 'very strong' events, albeit characterized by a weaker pressure gradient (Fig S28 - Supporting Information). When examining flow analogues individually for each event, higher inter-event variability emerges, reflecting a greater influence of internal climate variability—resembling the behaviour observed in NH events. Nonetheless, a substantial proportion of these strong events still exhibit a present-day wind intensification alongside a shift toward a positive SAM phase, confirming that this dominant forcing persists across a broader set of events (Fig S29 - Supporting Information)."

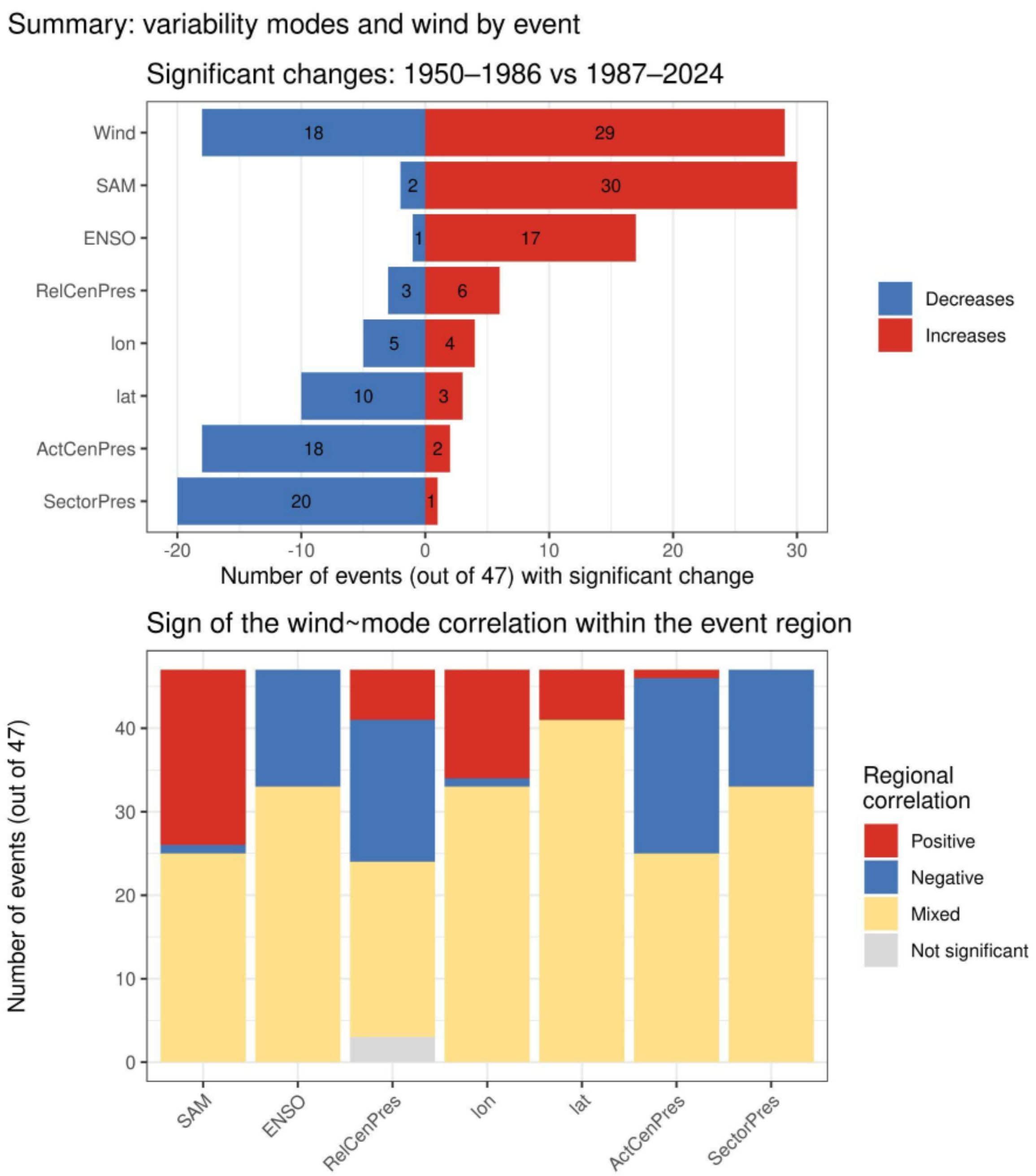

Figure S29. Summary of changes in variability modes and surface winds across the 47 strong Southern Hemisphere (SH) events. **Top:** Number of events (out of 47) exhibiting statistically significant differences between the early (1950–1986) and recent (1987–2024) periods for each variable, separated into decreases (blue) and increases (red): 10-m wind speed, the Southern Annular Mode (SAM), the El Niño–Southern Oscillation (ENSO) index, and the four Amundsen Sea Low (ASL) indices (ActCenPres, SectorPres, RelCenPres, and central-pressure longitude and latitude). **Bottom:** Sign of the temporal correlation between each MJJAS variability-mode index and 10-m wind speed, evaluated at each grid cell within the source region identified for that event. For every event, the correlation is classified as positive (red) or negative (blue) if the sign is consistent across the region, mixed (yellow) if both signs occur within the region, or not statistically significant (grey). Bars show, for each mode, the number of the 47 events falling into each category.