Compound intense warming and precipitation events in the Patagonian Icefields and the Antarctic Peninsula Ice Sheet - Part 1: Event frequency, atmospheric circulation and impacts on glacier surface

1. General comments

The manuscript by Torres et al. (2026) investigates the concurrent occurrence of intense warming events (IWEs) over the Patagonian Icefields and intense precipitation events (IPEs) over the Antarctic Peninsula Ice Sheet, associated with atmospheric rivers (ARs), during the austral summers of 1980-2022. Using simulations from the Modèle Atmosphérique Régional (MAR), ERA5 reanalysis data, and meteorological observations, the authors identify 127 days of concurrent IWE and IPE occurrence, associated with a dipole atmospheric circulation pattern and contrasting surface energy and mass balance responses in the two regions.

The topic is relevant to the scope of *The Cryosphere*, and investigating atmospheric connections between these regions represents a potentially valuable contribution. The combination of high-resolution regional climate simulations with synoptic and glaciological analyses is a strength of the study.

However, several issues require clarification or further investigation, particularly the rationale for selecting the specific types of extreme events, the procedures used for event identification and classification, the interpretation of atmospheric circulation mechanisms, and the robustness of the conclusions regarding their glaciological impacts. It is also important to distinguish results that follow directly from the event selection criteria from those that reveal characteristics specifically associated with concurrent events.

2. Specific comments

2.1. Rationale for selecting IWEs over Patagonia and IPEs over the Antarctic Peninsula (Introduction, lines 76-108)

The Introduction does not sufficiently justify why the authors investigate IWEs over Patagonia and IPEs over the Antarctic Peninsula, rather than examining both types of extremes in both regions. The manuscript itself acknowledges that intense warming and precipitation can occur in both regions, and the results show substantial positive temperature anomalies over the Antarctic Peninsula. I recommend explicitly stating the physical hypothesis underlying this selection and considering a complementary analysis of IWEs and IPEs in both regions to determine whether the identified circulation pattern is specific to the selected combination of extremes.

2.2. Definition of compound events and statistical significance of their co-occurrence (Sect. 4.2, lines 215-238; Figs. 3 and 4)

The authors identify 127 days of concurrent IWEs and IPEs and report that 80% of compound events last one day, 16% last two days, and 4% persist for three or more days. However, the

methodology used to group consecutive days into independent events should be clarified, and the total number of independent compound events should be explicitly reported. Furthermore, it would be important to assess whether the observed co-occurrence frequency is significantly higher than expected from the individual event frequencies, accounting for temporal persistence.

2.3. Interpretation of results conditioned on event selection (Sects. 4.2-4.4, lines 215-345; Figs. 4 and 6-8)

Positive temperature anomalies over Patagonia and enhanced precipitation over the Antarctic Peninsula are expected from the event identification criteria themselves. I recommend distinguishing these results from those representing independent characteristics of event co-occurrence. A comparison between concurrent events and IWE-only and IPE-only days would help identify which atmospheric circulation patterns and glaciological impacts are specifically associated with compound events.

2.4. Rossby wave propagation

The map projection used in Fig. 5 makes it difficult to identify the potential source region and propagation pathway of the Rossby wave train. I recommend using a geographical domain that more clearly illustrates its propagation across the Southern Hemisphere. It is also necessary to clarify how the time-lagged composites were constructed (Sect. 3.4, lines 190-195; Fig. 5, lines 255-258), considering that the events have different durations.

2.5. MAR validation and representativeness of observations (Sects. 2.1, 4.1, and 5.1, lines 110-125, 210-215, and 390-410; Fig. 2)

The model validation is based on three stations in Patagonia and two on the Antarctic Peninsula (lines 110-125), all located at relatively low elevations and therefore not necessarily representative of conditions over higher-elevation glacierized areas. Furthermore, IPE validation considers only liquid precipitation, whereas event identification is based on total precipitation, including rainfall and snowfall. I recommend discussing these limitations, clarifying potential elevation differences between the stations and their corresponding MAR grid cells, and moderating the conclusions regarding the model's ability to reproduce extreme events throughout the glacierized areas of both regions.

2.6. Calculation of percentage contributions to accumulation and ablation (Fig. 9, lines 340-347)

The procedure used to calculate the percentage contributions shown in Fig. 9 is not described in the Methods section. The authors should clarify whether the denominator corresponds to annual totals or only to the extended austral summer, which MAR components were used to define accumulation and ablation, how spatial aggregation was performed, and whether absolute values

or anomalies were considered. It is important to distinguish surface melt from actual mass loss, given the potential for meltwater retention and refreezing within the snowpack. I recommend including an equation describing the calculation.

2.7. Classification of low-IVT and high-IVT events (Sect. 4.5, lines 348-355; Table 3)

The classification based on the 75th percentile of IVT is introduced in the Results section, but important methodological details remain unclear. The authors should specify how IVT was spatially and temporally aggregated to characterize each event (e.g., spatial mean or maximum, daily mean or maximum) and whether the 75th percentile was calculated separately for the IPE-AR and IWE-IPE-AR samples or using a common reference distribution. These methodological details should be included in the Methods section.

2.8. Influence of IVT intensity and statistical interpretation (Sect. 4.5, lines 348-380; Table 3)

The conclusion that IVT intensity plays a secondary role is supported by generally small effect sizes and the absence of statistically significant differences for several variables between low-IVT and high-IVT categories. However, these results do not necessarily establish that IVT intensity has a limited physical influence relative to large-scale atmospheric circulation. I recommend examining the relationships between continuous IVT values and precipitation, temperature, surface melt, and surface mass balance (SMB), or otherwise moderating this conclusion. The authors should also clarify whether temporal dependence between consecutive days was considered in the Mann-Whitney U tests and report the numerical Cliff's delta values in Table 3, rather than only qualitative effect-size categories.

2.9. Scope of the conclusions and original contribution (Sect. 6)

The conclusions should more clearly distinguish findings directly supported by the analyses from proposed physical interpretations, avoiding stronger causal claims than the evidence allows. In addition, I recommend emphasizing the original contribution of the study by clarifying what new insights emerge from the joint analysis of concurrent extreme events, atmospheric circulation, and glaciological responses in Patagonia and the Antarctic Peninsula, particularly in relation to previous studies.

3. Technical corrections

1. Lines 23-33 (Abstract): Use “extended austral summer (November-March)” and revise the wording describing positive SMB anomalies over the Antarctic Peninsula.
2. Lines 102-103 (Introduction): Correct the grammatical construction beginning with “Understanding common large-scale circulation patterns...”. Consider adding “how” after “Understanding” to clarify the intended meaning.

3. Line 140 (Sect. 2.2): Specify which years of the MAR simulations were discarded as model spin-up.
4. Line 186 (Sect. 3.3): Correct the subsection title, which incorrectly repeats the title of Sect. 3.2.
5. Lines 160, 188, and 336: Ensure consistency in the climatological reference periods, reported as 1980-2020 and 1981-2020.
6. Lines 239 (Sect. 4.2): Correct “Ars” to “ARs”.
7. Lines 255-300 (Figs. 5-8): Specify in the captions that the 127 days correspond to concurrent IWE, IPE, and AR occurrence, and distinguish event days from independent meteorological episodes.
8. Throughout the manuscript: Standardize event terminology, abbreviations, units, and heat flux sign conventions.