AVALANCHE FORECASTING ON THE VERGE: EPHEMERAL SNOWPACKS, CLIMATIC SHIFTS, AND THE EVOLUTION OF ARIZONA'S WINTERS

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ABSTRACT: Arizona seems an improbable ski locale given North America's mountainous geography, yet its high-elevation sky islands support multiple winter backcountry zones and several ski areas, served by two of the lowest-latitude avalanche centers in the country. The Kachina Peaks Avalanche Center (Arizona's only nonprofit avalanche center) serves a local user base accustomed to low-tide, variable, and ephemeral snowpacks relative to other western ranges, and the Sonoran Avalanche Center (the first for-profit avalanche center in operation) humorously raises user-group awareness of climate change and non-snow avalanche activity. The 2025–2026 season, characterized by near-average precipitation punctuated by extreme warm periods and mid-season rain events even at the highest elevations, raises a question with implications well beyond Arizona: was this an anomaly or a preview?

We examine historic patterns of winter snowfall, precipitation, temperature, and inter-storm intervals across Northern Arizona's forecast area to characterize the trajectory of ephemeral snowpack conditions in the Southwest. Our findings suggest that while a fully non-snow avalanche-forecasting future is not on the near-term horizon, the frequency of highly irregular snowpacks and extreme weather events that drive avalanche activity is rising. We emphasize that while the mechanics remain the same, the type, frequency, and distribution of historical patterns may be turning a new page. This finding supports the continued need for snow avalanche forecasting and outreach, while also pointing to the need for longer-term adjustments in operations and messaging.

Equally important, ephemeral and feast-or-famine snowpacks present a distinct risk communication challenge. Established literature on hazard perception suggests that infrequent, high-variance, and seasonally unstable hazards are systematically underweighted by the public, and that forecaster credibility is harder to build and sustain when "normal" conditions are themselves in flux. Thus, avalanche centers operating on the climatic margins are functioning as early case studies for the broader community when communicating risk under non-stationary winters — including how to frame uncertainty, sustain user engagement across lean seasons, and prepare the public for an eventual expansion into forecasts that include related recreational hazards (obstacles, access challenges, rain-on-snow events, or even debris flows) without eroding public attention to the core snow forecast.

KEYWORDS: Avalanche forecasting, climate change, risk communication, machine learning, snowpack variability

1. INTRODUCTION

Snow-based recreation in Arizona is driven by an ephemeral snowpack at moderate elevations, with only the highest peaks supporting a semi-consistent winter. The San Francisco Peaks (elevation ~3,840 m) are the dominant high-elevation range that supports common winter backcountry use, including backcountry skiing and snowboarding, which attracts a modest group of local recreationists. Within this area, avalanche hazard forecasting is supported by a local nonprofit, the Kachina Peaks Avalanche Center, which operates on a modest budget.

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Avalanche records for the region are spotty over time, with more coverage in modern times as the avalanche center has grown to produce full hazard ratings and more comprehensive, detailed avalanche records. This lack of historical records challenges our understanding of how avalanche activity and avalanche risk on the San Francisco Peaks are changing in response to anthropogenic-driven climate change. This is especially relevant to understand for our avalanche center, as changing avalanche conditions directly affect forecasting operations and organizational processes.

Given the incomplete historical avalanche records, we focus on characterizing the climatic trends experienced by the San Francisco Peaks

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over the last century. To do this, we hindcast historical data for a common forecasting SNOTEL site using historical observations from Pulliam Airport in Flagstaff, AZ. Based on these predictions, we investigate long-term climate trends and examine how these changes may influence avalanche activity, avalanche forecasting, and recreational exposure to avalanches on the San Francisco Peaks.

2. METHODS

Given the limited long-term historical snow and mountain weather records for the San Francisco Peaks, we focused on hindcasting historical data for a modern SNOTEL station at an elevation of 2963 m (9,720 ft) within the Inner Basin of the San Francisco Peaks (SNOTEL 927) (Table 1). The Inner Basin SNOTEL provides a modern weather observation record dating back to September 1997. To complement these modern records, we leverage historical data from the National Weather Service station USW00003103 at Pulliam Airport, at an elevation of 2,133 m (6,999 ft), which provides records dating back to September 1898. The distance between these two sites is ~22 km, and the elevation difference is 829 m (~2,721 ft).

Table 1. Description of sites used within the analysis.

	Inner Basin	Pulliam Airport
Station Name:	Inner Basin	Flagstaff Pulliam AP
Identifier:	SNOTEL 927	USW00003103
Elevation (m):	2,963	2,133
Start Date:	1997-10-01	1898-09-10
Role:	Response	Predictor

We applied a four-pass quality-control process to remove anomalies from SNOTEL data. Daily observations were discarded if depth >305 cm, implied SWE density <8%, depth >30.5 cm with SWE <1.27 cm, or if daily depth changed by >38 cm. This removed 1.09% of depth and 0.39% of SWE records. Daily temperatures with <12 hourly observations were set to missing to avoid range biases, limiting temperature analysis to 23 of 29 winters. Cleaned data were then compared using correlation. All modeling used U.S. Customary Units, as shown in Table 2.

SNOTEL data (NRCS Air and Water Database) and Flagstaff weather records (NOAA GHCN-Daily) were used to hindcast missing SNOTEL 927 observations for 1898–1997. We defined winter as October 1 to June 15 and trained a Long Short-Term Memory (LSTM) network to predict daily snow water equivalent (SWE), snow depth, temperature extremes, snowfall occurrence (>0.25 cm SWE gain), and SWE gains based on Flagstaff daily precipitation, temperatures, and clear-sky solar radiation.

The LSTM featured a 32-unit hidden layer and linear output. We trained it for 150 epochs (Adam optimizer, lr=0.01), minimizing masked mean squared error for continuous targets and binary cross-entropy for occurrence. Performance was evaluated via leave-one-winter-out (LOWO) cross-validation using standard metrics (NSE, RMSE, PBIAS, AUC, Accuracy, Precision, Recall, F1). We generated 10th–90th percentile prediction intervals by resampling day-matched LOWO residuals (300 draws/winter) to preserve serial correlation.

Secondary analyses examined long-term and 50-year trends in temperature, precipitation, and SWE. Storm cycles were defined as continuous precipitation periods, merging gaps of up to two dry days. We calculated inter-storm gaps for events delivering ≥0.89 cm of precipitation/SWE, further classifying them by site-specific size thresholds (Moderate, Large, Very Large). Finally, we compared interannual variability between the earliest (1898–1947) and most recent (1976–2025) 50 winters using an F-test on variance ratios, confirmed via Brown-Forsythe and 5,000-iteration permutation tests.

3. RESULTS

After quality control, Pulliam Airport and SNOTEL data correlated strongly for maximum and mean daily temperatures ($R^2 > 0.85$) but weakly for snow depth ($R^2 = 0.24$). This divergence, presumably driven by elevation-dependent melting and orographic effects, justifies using the LSTM model over simple linear regression.

The LSTM model demonstrated strong overall performance (Table 2). While predicting daily SWE gains from a lower-elevation site proved challenging (NSE_test = 0.546), accuracy improved substantially when evaluating storm-total SWE gains (NSE_test = 0.771).

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Table 2. Machine learning (LSTM) model performance across the training and testing splits. Storm totals are aggregated from the daily SWE-gain model; thus, there are no training fits.

Target	Units	N events	NSE (train)	NSE (test)	RMSE (test)	PBIAS (test) %
Daily SWE	in	7456	0.950	0.911	2.483	0.299
Daily snow depth	in	7228	0.968	0.882	8.234	2.839
Daily Tavg	F	5829	0.921	0.914	3.295	0.022
Daily Tmin	F	5829	0.832	0.817	4.852	0.037
Daily Tmax	F	5829	0.914	0.907	3.763	0.013
Daily SWE gain	in/day	7426	0.799	0.546	0.190	2.544
Storm-total SWE gain	in	499	NA	0.771	0.685	0.388

The hindcast reconstructions (1898–1899 onward) revealed multidecadal oscillations in temperature and SWE metrics (Figure 1). While these oscillations complicate long-term trend analysis, mean temperature showed a consistent, statistically significant increase across all periods. Temperatures rose by ~0.11°C per decade over the full record, accelerating to ~0.17–0.19°C per decade over the last 50 years, with the 2025–2026 season marking a global winter maximum. Temperature variance remained unchanged between the first and last 50-year periods (Figure 1A).

At the Inner Basin SNOTEL, full-record decreases in peak and seasonal SWE were not statistically significant. However, over the last 50 years, there have been clear declines, with an average loss of 5.59 cm (2.2 in) in seasonal SWE and 3.56 cm (1.4 in) in peak SWE per decade (Figure 1B/C). Interannual variability also increased significantly for seasonal SWE over the last 50 years (variance ratio = 1.52, $p = 0.004$), though peak SWE variance changes were non-significant ($p = 0.31$).

Finally, inter-storm gap periods lengthened—particularly recently—but these increases were not statistically significant (Figure 1D). Storm cycle size classes also showed no significant changes (Figure 1E), suggesting cycle sizes have remained consistent over the century-long record or are outside our detectable range.

4. DISCUSSION

The magnitude of change over time within the weather parameters is often sensitive to the period of time analyzed, with more recent cutoffs yielding steeper trends. Some of this reflects multidecadal variability operating on 40–60-year timescales, which a 128-year record spanning roughly two cycles cannot fully separate. Despite this challenge, three patterns emerged from the analysis. (I) Mean winter temperature increased significantly, at +.105°C (+0.19°F) per decade over the full record and +.194°C (+0.35°F) per decade over the last 50 winters. (II) Seasonal precipitation and SWE accumulation showed no trend across the full record, but SWE accumulation declined significantly over the last 50 winters (5.49 cm (-2.16 in) per decade, $p = 0.034$), and both became substantially more variable between seasons (standard deviation ratios of 1.69 and 1.52, $p < 0.005$). (III) Neither storm-size composition nor inter-storm gap period changed significantly. We further contextualize the possible impacts of these changes on avalanche activity and recreation.

4.1 Projected Avalanche Hazard

Continued warming will undoubtedly have a significant impact on future avalanche activity. One expected impact of this trend will be a shift in risk from dry-slab to wet-snow avalanches (Mayer et al., 2024), with intra-season weather patterns driving atypical midwinter shifts in avalanche types, possibly reducing the frequency of dry-slab avalanches over many decades. Similarly, this trend towards warming temperatures will likely increase snowpack cohesiveness throughout the season due to atypical warming periods, reducing dry-slab avalanche risk. However, arguments can be made that these increases may also raise the risk of dry-slab activity, especially in the near term, as factors such as rain-on-snow events, extreme temperature shifts, and melt-freeze crusts become more prevalent in the near- to moderate-term.

In addition to increasing temperatures, maintained but higher intra-season variability in snowfall will further complicate risk across seasons. This may materialize as an ephemeral snowpack, dominated by low-tide conditions at many elevations and aspects in which starting zones do not receive enough snow to generate significant, widespread avalanche activity and risk. Conversely, to offset these below-average seasons and maintain the average, above-average win-

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ters will inevitably create a deeper snowpack, expanding avalanche hazard across aspects and elevations. This scenario is already a major factor in our current pattern, where ephemeral snowpacks are very common on higher-elevation, sun-exposed slopes and at lower elevations across aspects during lackluster seasons. The avalanche risk is then transformed in deeper winters, with avalanche activity occurring across many aspects and elevations.

Such a scenario was observed during the recent (2025-2026) season, which was dominated by slightly below-average precipitation and above-average temperatures. The season began with a deep storm in early November, followed by a December warming period that created spring-like conditions and melted most snow on radiant aspects. Then two rain-on-snow events in late December and early January created an impenetrable ice crust across avalanche starting zones, so thick (~20 cms) it persisted into spring — transforming an optimistic season start into a suboptimal winter outcome.

Additional impacts of the rain events and subsequent ice crust occurred following a series of smaller storms that resulted in facets above the crust. Classically, these layers were buried by 5-7.6 cm (2-3 in) of SWE, facilitating numerous large persistent slab avalanches that failed above the rain crust on the faceted snow. The 2025-2026 season was recorded as the warmest winter to date, punctuated by a staggering ~1.94C (~ 3.5°F) increase above the projected average temperature. Thus, we hypothesize that within our forecast region, this season was a historic anomaly, but could potentially be considered more normative by future standards. If global warming continues at stable rates (without additional large-scale meteorological changes), this type of intermittent snow/rain winter could become the norm towards the end of the 21st century.

4.2 Changing Climate and Recreation

We hypothesize that these changes to the climate will inevitably impact recreational avalanche safety through three processes. (I) Avalanche hazard forecasting will face more rapid changes in snowpack and weather, requiring more frequent, data-informed assessments to maintain accuracy and robustness. (II) Increasing temperatures will drive atypical avalanche activity that may catch recreational skiers off guard. An example may be atypical wet slab activity during mid-winter periods or complex dynamics of persistent slab avalanche activity resulting from increased melt-freeze crusts, rain crusts, and/or unexpected slab softening from warm periods, driving atypical avalanche activity. (III) The tendency of boom-or-bust seasons will lead to overconfidence or normalization of risk during low-tide, low-avalanche-danger periods. While “boom” seasons will present further challenges, such as increased avalanche activity and increased risk-taking behavior due to scarcity mindsets.

These factors may become increasingly relevant for avalanche centers on the edge (and beyond) of the ephemeral snowpack margin. Possible adaptations may include improved weather station data collection, improved weather modeling, an increased emphasis on forecast uncertainty, increased field-based observations, and specific messaging related to a climate in flux.

4.3 *Risk Communication Under Non-Stationary Winters*

The forecasting challenges described above are only half the problem. The same conditions that make the snowpack harder to assess also degrade the environment in which our users learn. Avalanche terrain is already a "wicked" learning environment, one in which feedback is sparse, delayed, and systematically misleading, so that the absence of an avalanche is easily read as evidence of a sound decision rather than as a non-event (Hogarth et al., 2015; Hetland et al., 2025). Ephemeral, boom-and-bust snowpacks intensify this problem from both ends. Through a lean season, few or no avalanches are observed, hazard becomes cognitively unavailable (Tversky and Kahneman, 1973), and repeated uneventful travel through familiar starting zones accumulates as apparent evidence of safety — the familiarity and commitment mechanisms described by McCammon (2004). The risk is that this reasoning is not merely unsupported but inverted: working in the Southern Rockies, Peitzsch et al. (2026) found that the dominant driver of large-magnitude regional avalanche cycles shifted after 1988 from above-average snowfall years toward average- and below-average snow years. A low-tide season is not a safe season, but it is precisely the season in which our users are least likely to feel that it is not. At the other extreme, the compressed windows of good riding that follow a boom cycle concentrate exposure into a handful of days and invite scarcity-driven decisions. Here, the literature counsels some caution about how confidently we assert the mechanism: Mannberg et al. (2021) found that experimentally induced "powder fever" did not substantially degrade participants' hazard assessments, and Johnson et al. (2020) argue more broadly that the heuristic-traps framework was absorbed into avalanche education well ahead of the evidence supporting

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it. The behavioral pathway from scarcity to exposure in a boom-and-bust range remains, in our view, an open empirical question rather than a settled one.

A second and less-discussed challenge is that non-stationarity erodes the reference frame on which almost all avalanche messaging depends. Forecasters and educators lean heavily on comparative language - "normal for this time of year," "an unusual setup," "the deepest snowpack in years" - and that language presumes a stable distribution that a user and a forecaster share. Our results indicate that this presumption is weakening in Northern Arizona: seasonal SWE accumulation and precipitation became substantially more variable between seasons (standard deviation ratios of 1.69 and 1.52, $p < 0.005$), which is the avalanche-climatological expression of the broader loss of stationarity in hazard planning (Milly et al., 2008). Compounding this, users re-anchor quickly. Moore et al. (2019) showed that populations re-baseline what counts as a "remarkable" temperature anomaly within roughly two to eight years, meaning that a recreationist's sense of a normal Arizona winter is drawn from a window too short to register the trend our record documents. Terum et al. (2023) demonstrated experimentally that the perceived trend in conditions, not only their current level, shapes avalanche hazard perception — an effect with no obvious analog in current forecast products, which describe today rather than the trajectory. For a center on the ephemeral margin, this means credibility must be built on something other than an appeal to a norm that our users cannot reliably perceive and that our own record shows is moving.

We see three tractable opportunities. First, problem-based framing (Statham et al., 2018) is the natural vehicle for communicating atypical hazard — midwinter wet activity, rain crusts, persistent slabs above melt-freeze interfaces — because it describes hazard character rather than assuming a familiar seasonal arc. But its reach should not be assumed: Trachsel et al. (2023) found that users retained the danger level well (~90 %) while retention of the avalanche problem (~44 %) and correct application of its aspect and elevation (~24 %) were considerably weaker, and Morgan et al. (2023) found that roughly two-thirds of North American users interpret the danger scale as linear rather than exponential — a misreading that matters most during the rare High and Extreme days a boom cycle delivers to a user base that may go several seasons without seeing one. Plain-language travel and terrain advice measurably improves comprehension among users with little or no formal training (Fisher et al., 2022), which describes a large share of the audience a small, low-frequency center serves. Second, audience segmentation offers a way to reconcile the divergent needs of a committed local core and the intermittent, weather-chasing users who appear only in boom periods; the bulletin user typology of St. Clair et al. (2021) provides a tested framework for this. Third, and most directly relevant to a warming snowpack, explicit communication of forecast uncertainty has been shown to preserve user trust in the face of forecast error rather than undermining it (Joslyn and LeClerc, 2012). This is consequential because the hazard types our results project — wet-snow and rain-on-snow situations — are exactly those where operational prediction remains weakest, with poorly constrained release mechanisms, scarce liquid-water observations, and temperature-driven rules that generate frequent false alarms (Hendrick et al., 2023). Communicating that uncertainty candidly appears to be a better long-term strategy for a small center than projecting a confidence the underlying science does not yet support. We note that this is not a new question for our region: Lovejoy et al. (2006) raised the problem of sustaining an avalanche center through a drought season two decades ago, and Marino (2016) documented steady growth in KPAC product readership across seasons of widely varying quality, suggesting the audience persists even when the snowpack does not.

4.4 *Limitations to Study*

Although our study aims to understand the effects of climate change on avalanche activity, our avalanche occurrence datasets are not robust enough to address this question. Similarly, our high-elevation weather station data cover only a relatively recent period, which, if analyzed in isolation, may provide an incomplete picture of changes over time. Thus, to complete this analysis, we build a complex machine learning model to hindcast high-elevation SNOTEL parameters using a single local historic gauge. This process introduces several assumptions, including that the relationships between our historical data and the SNOTEL site are stationary. Additionally, several of the winters for which we produced hindcast data were outside the range of the training dataset, resulting from seasons with lower average temperatures or higher accumulated precipitation.

5. CONCLUSION

As we enter a period of unprecedented weather events (assuming it still snows), avalanche activity will undoubtedly be affected, making avalanche hazard assessments increasingly difficult, especially for small independent centers that lack

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large-scale infrastructure. In parallel, these changes will impact the behavior and knowledge of recreational users. Thus, it will be important to continue evidence-based forecasting operations and educational outreach programs, which may require additional financial resources, to continue to facilitate safe winter recreation in avalanche terrain.

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REFERENCES

Fisher, K. C., Haegeli, P., and Mair, P.: Travel and terrain advice statements in public avalanche bulletins: a quantitative analysis of who uses this information, what makes it useful, and how it can be improved for users, Nat. Hazards Earth Syst. Sci., 22, 1973–2000, https://doi.org/10.5194/nhess-22-1973-2022, 2022.

Hendrick, M., Techel, F., Volpi, M., Olevski, T., Pérez-Guillén, C., van Herwijnen, A., and Schweizer, J.: Automated prediction of wet-snow avalanche activity in the Swiss Alps, J. Glaciol., 69, 1365–1378, https://doi.org/10.1017/jog.2023.24, 2023.

Hetland, A., Hetland, R. A., Skille, T. T., and Mannberg, A.: Review article: A scoping review of human factors in avalanche decision-making, Nat. Hazards Earth Syst. Sci., 25, 929–948, https://doi.org/10.5194/nhess-25-929-2025, 2025.

Hogarth, R. M., Lejarraga, T., and Soyer, E.: The two settings of kind and wicked learning environments, Curr. Dir. Psychol. Sci., 24, 379–385, https://doi.org/10.1177/0963721415591878, 2015.

Johnson, J., Mannberg, A., Hendrikx, J., Hetland, A., and Stephensen, M.: Rethinking the heuristic traps paradigm in avalanche education: past, present and future, Cogent Soc. Sci., 6, 1807111, https://doi.org/10.1080/23311886.2020.1807111, 2020.

Joslyn, S. L. and LeClerc, J. E.: Uncertainty forecasts improve weather-related decisions and attenuate the effects of forecast error, J. Exp. Psychol.-Appl., 18, 126–140, https://doi.org/10.1037/a0025185, 2012.

Lovejoy, D. W., Dexter, L. R., and Tatsugawa, K.: Challenges to an avalanche center in a time of seasonal climate variability: a case study, in: Proceedings of the 2006 International Snow Science Workshop, Telluride, CO, USA, 683–690, 2006.

Moderow, A., Schauer, A., and Johnston-Bloom, A. Meteorological and snowpack properties associated with crust-adjacent weak layers. ISSW Proceedings, Bend, OR, https://www.cnfaic.org/wp-content/uploads/2024/09/Part-1-Literature-Review-08-13-2024.pdf, 2023.

Mannberg, A., Hendrikx, J., Johnson, J., and Hetland, A.: Powder fever and its impact on decision-making in avalanche terrain, Int. J. Env. Res. Pub. He., 18, 9496, https://doi.org/10.3390/ijerph18189496, 2021.

Marino, T. A.: Use of Google Analytics at the Kachina Peaks Avalanche Center, Arizona, in: Proceedings of the 2016 International Snow Science Workshop, Breckenridge, CO, USA, 1117–1120, 2016.

Mayer, S., Hendrick, M., Michel, A., Richter, B., Schweizer, J., Wernli, H., and van Herwijnen, A.: Impact of climate change on snow avalanche activity in the Swiss Alps, The Cryosphere, 18, 5495–5517, https://doi.org/10.5194/tc-18-5495-2024, 2024

McCammon, I.: Heuristic traps in recreational avalanche accidents: evidence and implications, Avalanche News, 68, 2004.

Milly, P. C. D., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z. W., Lettenmaier, D. P., and Stouffer, R. J.: Stationarity is dead: whither water management?, Science, 319, 573–574, https://doi.org/10.1126/science.1151915, 2008.

Moore, F. C., Obradovich, N., Lehner, F., and Baylis, P.: Rapidly declining remarkability of temperature anomalies may obscure public perception of climate change, P. Natl. Acad. Sci. USA, 116, 4905–4910, https://doi.org/10.1073/pnas.1816541116, 2019.

Morgan, A., Haegeli, P., Finn, H., and Mair, P.: A user perspective on the avalanche danger scale – insights from North America, Nat. Hazards Earth Syst. Sci., 23, 1719–1742, https://doi.org/10.5194/nhess-23-1719-2023, 2023.

Peitzsch, E. H., Martin, J. T., Greene, E. M., Eckert, N., Favillier, A., Konigsberg, J., Kichas, N., Stahle, D. K., Birkeland, K. W., Elder, K., and Pederson, G. T.: Changing drivers of regional large magnitude avalanche frequency throughout Colorado, USA, Nat. Hazards Earth Syst. Sci., 26, 1059–1074, https://doi.org/10.5194/nhess-26-1059-2026, 2026.

St. Clair, A., Finn, H., and Haegeli, P.: Where the rubber of the RISP model meets the road: contextualizing risk information seeking and processing with an avalanche bulletin user typology, Int. J. Disaster Risk Reduct., 66, 102626, https://doi.org/10.1016/j.ijdrr.2021.102626, 2021.

Statham, G., Haegeli, P., Greene, E., Birkeland, K., Israelson, C., Tremper, B., Stethem, C., McMahon, B., White, B., and Kelly, J.: A conceptual model of avalanche hazard, Nat. Hazards, 90, 663–691, https://doi.org/10.1007/s11069-017-3070-5, 2018.

Trachsel, J., Eberli, M., Grüter, S., Winkler, K., Lucas, C., Richter, B., and Techel, F.: Retention and use of avalanche forecast information: findings from field and online surveys, in: Proceedings of the 2023 International Snow Science Workshop, Bend, OR, USA, 974–981, 2023.

Tversky, A. and Kahneman, D.: Availability: a heuristic for judging frequency and probability, Cognitive Psychol., 5, 207–232, https://doi.org/10.1016/0010-0285(73)90033-9, 1973.

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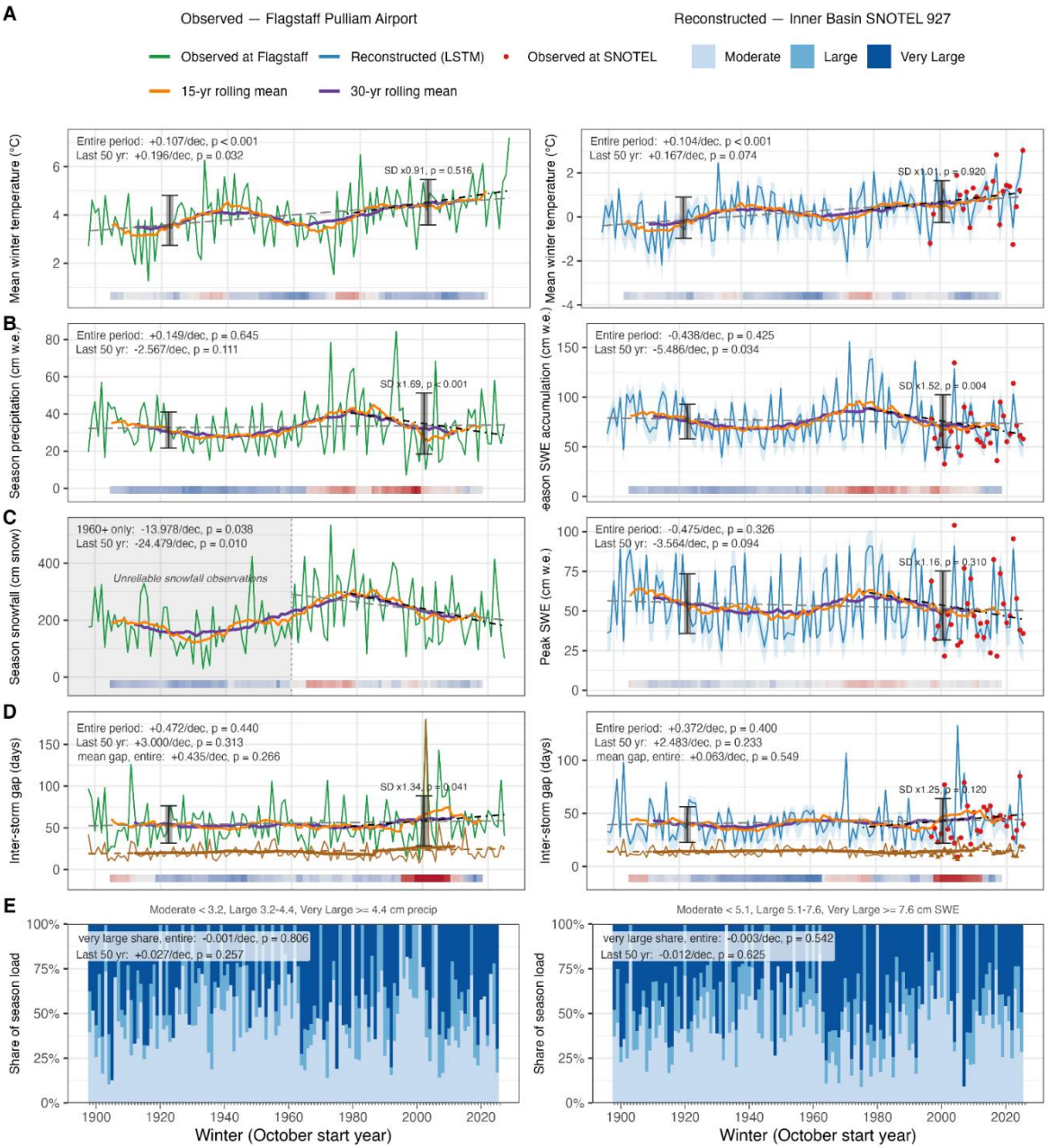


Figure 1. Observed Flagstaff weather (left) and LSTM-reconstructed Inner Basin snowpack (right), winters 1898–99 to 2025–26. Rows: (A) mean winter temperature; (B) season precipitation and SWE accumulation; (C) season snowfall and peak SWE; (D) longest inter-storm gap, with season mean gap in brown; (E) share of season storm load by storm size class. Shaded band = 80% prediction interval; red symbols = observed SNOTEL values (1997–2026). Orange and purple = 15- and 30-year centered rolling means (complete windows only). Grey long-dash = whole-period trend; black dot-dash = last 50 winters; both slopes per decade and p-values are annotated. The band beneath rows (A)–(D) shows the rolling 15-year standard deviation relative to that series' full-record standard deviation (blue = less variable, red = more); grey vertical bars span mean ± 1 SD for the earliest and most recent 50 winters, labelled with the ratio of standard deviations and its F-test p. Grey shading in (C) marks the pre-1960 period excluded from the snowfall trend for record inhomogeneity.

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