SPECIALIZED PROBALISTIC MOUNTIAN WEATHER FORECASTS IN SUPPORT OF SNOW SAFETY AND AVALANCHE MITIGATION EFFORTS

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ABSTRACT: The National Weather Service (NWS) Weather Forecast Office (WFO) in Salt Lake City has a longstanding public-private partnership with the Utah Department of Transportation (UDOT) Avalanche Program, the Utah Avalanche Center, as well as Alta and Snowbird Snow Safety teams to provide a highly specialized twice-daily mountain weather forecast for heavily trafficked and avalanche-prone Little Cottonwood Canyon and Provo Canyon. The NWS aims to work closely with core partners to deliver user-specific, actionable forecasts that provide value to their operational decision-making.

A novel, fully probabilistic mountain weather forecast communicates the range of potential outcomes for a range of forecast variables and communicates valuable uncertainty in timing and intensity. Robust statistics back each probabilistic field, leveraging the extensive amounts of ensemble forecast information available. This forecast product is unique in its collaborative design through input and feedback from the end-user, the ability of the forecaster to shift the probabilistic output while maintaining valuable uncertainty information, and the ability to automate the product allowing for the future expansion to other locations of interest across Utah and beyond. This next-generation probabilistic mountain weather forecast serves as a template that aims to improve our level of service across the board.

KEYWORDS: weather forecast, probabilistic forecast, operational forecast, national weather service, decision support, bias correction

1. INTRODUCTION

Weather forecasts have long been an integral part of decision-making for snow safety professionals and avalanche mitigation teams. Existing snowpack and ongoing changes in temperature, wind, and new snowfall all contribute to the evolving avalanche hazard. To borrow from the Utah Avalanche Center's "Anatomy of a Forecast," "If snowpack is the carpenter that builds an avalanche, weather is the architect". A high-quality specialized weather forecast can increase efficiency for decision-makers and lead to wider margins of safety when it comes to daily operations and movement on snow.

The National Weather Service (NWS) produces twice-daily routine weather forecast packages for its core partners and the general public. While sufficient for some users, the currently available suite of forecast products and services may fall short for highly specialized applications. probabilistic forecast information and working closely with core partners to deliver user-Recently, the NWS has embraced the Modernized Forecast Operations Concept (MFOC), which involves leveraging specific, actionable forecasts that provide value to their operational decision-making.

Weather forecasts provided by the National Weather Service exist on a 2.5 to 5 km grid across terrain elevations that vary greatly within this technical constraint. Generally, point forecasts for finite, specific mountain sites and avalanche start zones produced by a live, human forecaster do not exist. Additionally, these gridded forecasts provide a single 'deterministic' outcome rather than a probabilistic approach suited to convey the inherent uncertainty.

The mountain weather forecast provided by the National Weather Service in Salt Lake City in its various iterations from casual to formal over the past four decades has proven invaluable in working to fill this gap. Dynamic environments require dynamic solutions, and while this program has proven beneficial to snow safety partners of the Salt Lake City Weather Forecast Office (WFO), caution should be taken in applying a one-size-fits-all approach to supporting snow safety partners in other areas.

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2. DEVELOPMENT

The National Weather Service's long-standing relationships with Utah's snow safety professionals has led to a greater understanding of their specific operational needs. The early days of the mountain weather forecast begun with a casual, unscheduled, but routine daily phone call from avalanche forecasters in Little Cottonwood Canyon, as early as the mid-1970s. Over time, the desire for a specialized mountain weather forecast for snow safety professional from the NWS WFO in Salt Lake City grew, with calls coming in from neighboring ski areas in Big Cottonwood Canyon as well as from the Utah Department of Transportation (UDOT) Avalanche Program in Provo Canyon.

A more formal product was adopted with the uptake of the internet in the early 2000s, with the novel web-based mountain weather forecast product enabling greater consistency in the information provided to end-users (Figure 1).

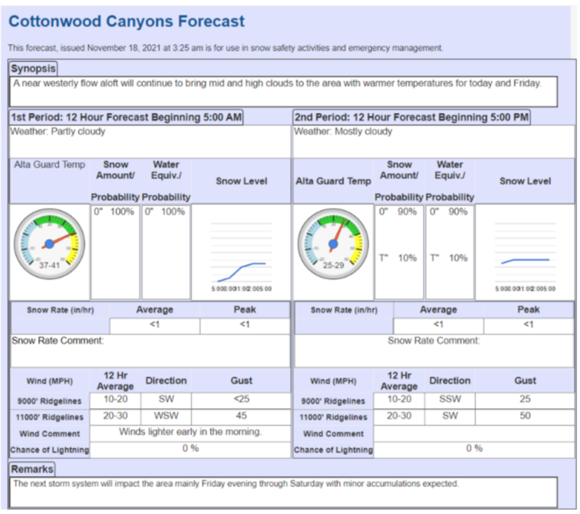

Figure 1. Sample of the Legacy Cottonwood Canyons Forecast. A "Synopsis" section provides the meteorologist generated discussion of weather conditions over the next 24 hours. Then the forecast is divided into left, the first 12-hour period, and right, the second 12-hour period. Each period then contains, max or min temperature, snow level, snow rate, subjective two-bin snow, and snow water equivalent forecasts, as well as wind and lightning forecasts.

Furthermore, the introduction of a web-based form for snow safety professionals to submit and aggregate high-quality daily weather observations allowed for the verification of prior forecasts, allowing meteorologists at WFO SLC to calibrate and improve the accuracy of the forecast over time.

An additional challenge inherent in forecasting weather, as well as avalanches, is the inherent use of words that convey an inaccurate level of certainty: supposed to, going to, forecasted to, and will. Subjective probabilistic language makes some attempt at quantifying the uncertainty in outcomes, though still falls short, with significant overlap between actual outcomes, perceived probability, and words of subjective probability: slight chance, chance, likely, as well as isolated, scattered, and areas of (Ripberger et al. 2022; Tart 2018).

Snow safety professionals are well-versed in communicating and understanding uncertainty, and as numerical weather prediction advanced, the ability to for meteorologists to provide a range of possible outcomes with greater scientific accuracy grew. An attempt to condense this information led to a 12-hour, two-bin forecast with a "most likely" outcome (>60%) and a "least likely" outcome (<40%), each expressed as a range of snowfall and water equivalent forecast. However, these probabilities were determined by the forecaster, and while providing some numeric output, these probabilities remained subjective at their core.

2.1. <u>*Cooperative Iteration*</u>

With the goal of a specialized weather forecast designed to meet snow safety professionals' needs, the NWS WFO in Salt Lake City worked closely with the Utah Avalanche Center, UDOT Avalanche Program, and Alta and Snowbird Ski Areas in developing the forecast parameters and layout of the new probabilistic mountain weather forecast. Fully probabilistic forecasts of temperature, snow level, snow-liquid-ratio, and wind speed were added (previously provided as single-value 'most likely' forecasts), as well as hourly timeseries forecasts for each parameter.

Providing fully probabilistic information may not be the most efficient dissemination tactic for a briefing-style product, suggesting the need for a blended approach between subjective language and objective numeric output. Thus, the next-generation forecast employs scenario-based language based in amounts at specific snow and water equivalent forecast percentiles: most likely (25^{th} to 75^{th}), high end (95^{th}), and low end (5^{th}).

On unanimous request, the forecast snowfall intensity was updated from an average and maximum rate during the 12-hour forecast period to an hourly average and maximum precipitation intensity. This allows not only the peak precipitation rate to be quickly and easily identified, but also when it may happen, if there are multiple peaks in precipitation intensity, and if there is uncertainty in the onset time and duration of the highest precipitation rates.

The modernized mountain weather forecast (Figure 2) provided by the SLC WFO will be generated alongside the legacy mountain weather forecast for winter 2023-24.

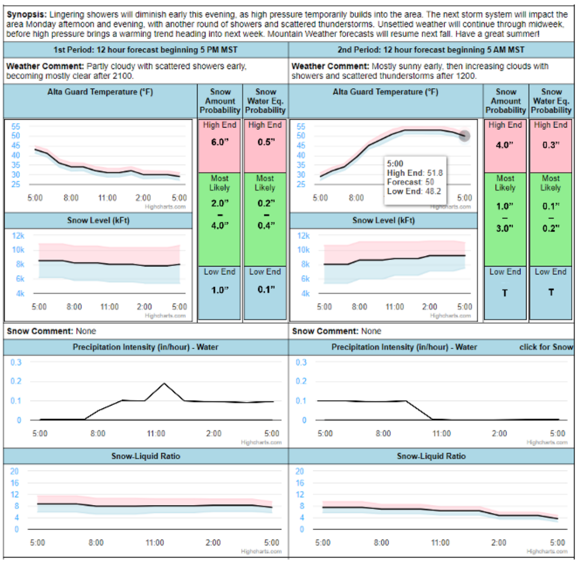

Figure 2. Sample of the Modernized Cottonwood Canyons Forecast. A "Synopsis" section provides the meteorologist generated discussion of weather conditions over the next 24 hours. Then the forecast is divided into left, the first 12-hour period, and right, the second 12-hour period. Each period then contains, probabilistic temperature, snow level, precipitation intensity, snow to liquid ratio, snow amount, and snow water equivalent forecasts.

Feedback will be actively collected, and with the modernized product in beta, changes may be implemented over the course of the winter, with Utah's snow safety partners, especially the Utah Avalanche Center and Utah Department of Transportation directly assessing the usability of the service. This type of cooperative and iterative development of a probabilistic, partner-driven forecast product is at the forefront of the NWS's mission and vision for the future and is being prioritized as such.

2.2. Weather Prediction Center Snowfall

The NWS Weather Prediction Center (WPC) produces a probabilistic snowfall forecast on a 5km grid across the entire continental United States and is leveraged as a starting point for this specialized probabilistic mountain weather forecast. The WPC has been producing the probabilistic portion of the snowfall forecast in an automated fashion since the 2013-2014 winter, although the methodology has been refined over time. In its current form, the probabilistic snowfall forecast is generated using a 61-member ensemble, including 25 randomly selected European Center for Medium-Range Weather Forecasts (ECMWF) ensemble members, and 10 Global Forecast System (GFS) members, among others, all of which are downscaled using the PRISM climatology (Daly et al. 2008) to the forecast resolution.

In addition, the WPC also produces a deterministic snowfall forecast which can be influenced by a meteorologist. To produce the suite of probabilistic snowfall forecasts, a binormal probability distribution (Toth and Szentimrey 1990) is used in which the deterministic forecast is set as the mode of distribution, and the placement of the deterministic forecast in that probabilistic space determines the skewness of the distribution. This fit is done at all grid points, so that the probabilistic distribution will vary across the country, grid point by grid point.

This forecast is produced for the first 72 hours of the forecast, with the NWS Weather Forecast Offices (WFOs) receiving the 5, 10, 25, 75, 90, and 95th percentiles for each 12-hour period, in addition to the deterministic WPC forecast, all of which is downscaled to a 2.5km forecast grid at the WFO. The WFO may then make finer scale adjustments to the deterministic forecast, typically leveraging local expertise to adjust for known biases and mesoscale effects. This final deterministic forecast is then once again used to mode-match the binormal distribution, resulting in one last refinement of the probabilistic snowfall forecast.

This approach has generally proven to be well calibrated across the country and serves a reliable addition to NWS messaging of the inherent uncertainty in snowfall event forecasting. However, in researching this dataset for use in this specialized forecast, an under-dispersive bias, particularly on the high-end of the distribution (Figure 3), was discovered particularly across the intermountain west and lake-effect belts near the Great Lakes.

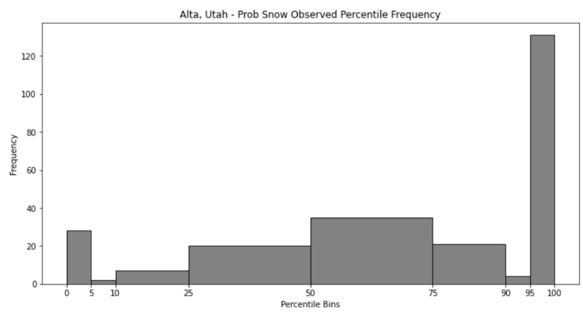

Figure 3. Frequency in which the Alta, UT snow observation verified in each probability bin of the probabilistic snowfall forecast. Under-dispersion is generally noted by the higher-frequency than expected at the tails of the distribution, however this under-dispersion is much worse on the high end, meaning that the observation is coming in higher than the 95th percentile forecast more often that expected.

The WPC is investigating a refinement to their methodology, which shows promise to increase the dispersiveness and reliability of the probabilistic forecast for these regions.

3. METHODOLOGY

No pre-existing solution exists to meet the needs of forecasting mountain weather with the level of specificity and at the terrain resolution necessary to meet the needs of most snow safety professionals operating in these environments (Alcott 2015). To provide a valuable service to snow safety professionals, a blend of operational and experimental techniques has been implemented to leverage the existing suite of model output, observation networks and manual observation datasets to produce a higher quality forecast.

3.1. The National Blend of Models

The National Blend of Models (NBM) is an effort by the NWS to produce a nationally consistent and skillful suite of calibrated forecast guidance, which leverages as many as 100 ensemble members in the first 48 hours of the forecast, including both NWS and non-NWS models (Hamill et al. 2017). The NBM continues to evolve toward a more robust fully probabilistic dataset, which is rapidly expanding the capability of the NWS to use probabilistic weather forecast information to better serve its core partner group (Hamill, Stovern and Smith 2023).

For many of the important forecast elements in this specialized forecast (including temperature, snow-to-liquid ratio, and snow level), the NBM serves as the backbone for the first guess deterministic forecast, as well as the distribution of those parameters. While the NBM provides an excellent starting point, the challenges of forecasting in complex terrain still provide ample opportunity for the human meteorologist to influence the forecast and account for known biases or mesoscale effects. The WFO meteorologists adjust the 2.5km deterministic, gridded forecast over a large spatial area as needed to account for such effects applying local knowledge to the forecast. This final deterministic gridded forecast, combined with probabilistic information from the NBM, serves as the starting point for the point-specific specialized mountain weather forecast. The meteorologist may then refine the forecast further to provide the highest possible quality point-specific forecast in support of snow safety and avalanche mitigation efforts.

3.2. Forecasting Snow Water Equivalent

Based on input from multiple snow safety partners, an effort is being made to reshape the forecast process from one that explicitly forecasts snowfall amounts as the starting point to one that forecasts the snow water equivalent as one of three components to produce a snowfall amount.

Under this methodology, the final probabilistic forecast snowfall amount is produced from the initial probabilistic snow water equivalent forecast in combination with explicit, probabilistic, forecasts of the rain/snow level and snow-liquid-ratio. This will bring a significant improvement over the current method employed in the legacy mountain weather forecast produced by WFO SLC, which works backwards to derive the probabilistic snow water equivalent forecast from the initial probabilistic snowfall forecast. This often leads to moderate biases in the final snow water equivalent (as the driver of realized impacts) even when the snowfall amounts verify.

Given that even small magnitude forecast errors in the underlying components of water equivalent, snow level, and snow ratio can compound to produce much larger errors in the final snowfall forecast, ensuring that the forecast for snow water equivalent is as accurate as possible lends greater credibility to the forecast, and makes the product multitudes more useful to the snow safety professional who must consider the impacts of the precipitation forecast on the snowpack.

3.3. Wind Forecasts in Complex Terrain

While the NBM serves as an overall excellent starting point for many essential forecast variables, wind in complex terrain remains a unique challenge. Users of the specialized mountain weather forecast expect a mid-elevation wind forecast (~2700 meters) and a high ridgeline wind forecast (~3300 meters) (Figure 4). The NBM largely handles the mid-elevation wind forecast reasonably well, where it can be provided to the meteorologist as a starting point for the forecast and then adjusted as needed based on local knowledge. However, the NBM was not designed to capture sub-grid-scale maxima in wind observations such as those weather stations that report from the tops of 3300-meter mountains but are critical to the snow safety user group.

Fortunately, the University of Utah has supported research to forecast winds for these high-elevation mountain ridgelines. The technique that has been around the longest is a perfect-prognostic linear regression approach developed around 2010 which leverages multiple levels of wind and stability information from a forecast model profile of the atmosphere. The NWS leverages this linear regression approach to calculate the forecasted wind speed and wind gust from 4 model cycles of the GFS and North American Mesoscale Forecast System (NAM), which are available every 6 hours, resulting in a time-lagged and two-system ensemble forecast. Additional spread in the forecast is introduced by leveraging the probabilistic wind forecast from the NBM, allowing for a fully probabilistic forecast of wind speed and wind gust that is tuned to the high elevation ridge top locations. This forecast is delivered to the meteorologist as a starting point for the specialized mountain weather forecast, and the meteorologist may still make additional adjustments based on local expertise for the final forecast.

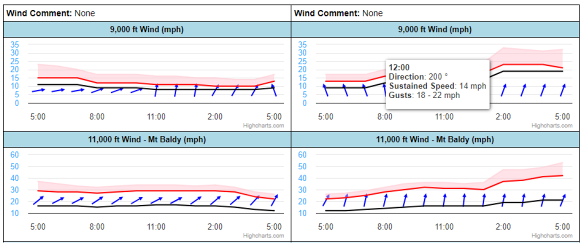

Figure 4. The wind forecast for 2700m (9,000 ft) wind and gusts (top) and 3300m (11,000 ft) ridgetop wind and gusts (bottom). Black line is sustained wind speed, blue arrows indicate direction, red line indicates most-likely wind gust and red shading indicates 90th percentile wind gust.

3.4. Machine Learning Applications

Machine Learning/Artificial Intelligence techniques provide a more flexible and adaptable solution to removing bias or error present in mountain weather forecasts for specific locations with long-standing high-quality datasets (Roebber et al. 2007). While applications of these techniques to improve mountain weather forecasts are somewhat new and actively a subject of academic research and experimentation in the private sector, some early results have proven promising.

Within the Department of Atmospheric Science at the University of Utah in Salt Lake City, work is being done to leverage the unique length and quality of the Alta Ski Area observational dataset and novel machine learning techniques. The result is a more reliable point forecast for upper Little Cottonwood Canyon with anecdotally improved accuracy in temperature, snow ratio, and wind speed forecasts. Work is ongoing to quantify these results and provide metrics of how well the novel forecast products perform against existing techniques.

Recently, the University of Utah has developed an updated version of the high elevation ridgeline wind forecast using a machine learning algorithm. This shows promise and may be considered for replacing the linear regression method in future iterations of this specialized forecast.

3.5. Role of the Forecaster

In sprit of the original mountain weather forecast that begun as casual phone conversations between those responsible for avalanche hazard mitigation in upper Little Cottonwood Canyon and the meteorologists at the NWS WFO in Salt Lake City, the forecast discussion and human involvement in the forecast process remains the soul of this product. The twice-daily issuance of the mountain weather forecast is always accompanied by a synopsis covering the details, nuances, and uncertainty of the near-term forecast (0 – 24 hours) as well as remarks covering any impactful weather or trends through the remainder of the short- and long-term forecast period. Additionally, a coarse storm total snow water equivalent and snowfall forecast accompany the remarks, highlighting an ongoing or upcoming storm cycle along with expected duration with most likely start and end times for the event.

Users of the mountain weather forecast continually state that the forecast discussion and remarks are often the most critical part of the product and an invaluable tool in their decision-making. The discussion can lend insight into a meteorologists' confidence in that issuance of the weather forecast, as well as help the snow safety professional in understanding nuances in the forecast including alternate scenarios that may deviate greatly from what is included in the objective, numeric forecast. For the meteorologist, free text allows an opportunity to highlight parts of the numeric forecast which may be especially impactful and/or uncertain, as well as include relevant information that is not normally included as part of the routine forecast package such as the inclusion of precipitation types such as graupel or hail, and the nature of precipitation such as convective or stratiform.

As the modernized mountain weather forecast moves towards a more statistically robust format and 'first guess', the human forecaster retains the ability to modify the final output. While the legacy product allowed explicit editing and entry of values for each parameter, the updated product encourages modifying the 'most likely' value and adjusting the maximum/minimum values as needed to reshape the probability distribution rather than generate new numbers entirely. In doing so, the forecaster can assure that hard-to-correct biases from issues in modeling or those introduced due to the weather pattern or flow direction are accounted for, while maintaining a robust statistical basis to the probabilistic forecast. The reduction of workload enabled by the improved 'first guess' then enables the forecaster to divert more time and attention to directly supporting snow safety partners through the discussion, remarks, and directly through phone conversations and remote briefings.

4. DISCUSSION

The long-standing mountain weather forecast provided by the National Weather Service Weather Forecast Office in Salt Lake City has played a central role in getting timely, accurate, and specialized information to snow safety professionals in the Cottonwood Canyons and Provo Canyon for multiple decades. The current iteration of the product is the result of evolution from casual phone conversations between meteorologist and avalanche forecaster, to a simple 'most likely' forecast, to one of the earliest documented routine specialized probabilistic forecasts issued by the NWS.

The next generation of the mountain weather forecast adopts a fully probabilistic approach and adds a wealth of information through the visualization of hourly forecasts as timeseries and the inclusion of both most likely and reasonable worst-case scenario forecasts, all quickly and easily discernable. Developed in close coordination with core snow safety partners, the product prioritizes information delivered in a format that directly meets their needs.

Ensuring the meteorologist continues to have a fully involved role in this forecast product that now leverages more robust ensemble forecasts and statistical output on the backend preserves trust in the forecast. Furthermore, the more subjective free-text synopsis and remarks provided by the meteorologist have been called invaluable and allow the users of the mountain weather forecast to better understand the complexities and uncertainties that are presented in the objective, numeric forecast, and get a sense of the meteorologist's own level of innate confidence in the forecast.

Leveraging tools such as the National Blend of Models (NBM), a truly probabilistic and statistically robust point forecast of temperature, snow level, snow ratio is made possible. While no numerical weather forecast is perfect, the multi-model ensemble that is the NBM provides a better 'first guess' for the forecast than has been previously available, bringing the initial quality of the mountain weather forecast to a higher level than previously possible. In leveraging additional machine learning and statistical regression techniques (Alcott and Steenburgh 2010) trained on and calibrated specifically for upper Little Cottonwood Canyon and the ridgeline north of Provo Canyon, better initial forecasts of snow water equivalent, wind speed, and wind direction are also made possible. Lastly, high-resolution numerical models give additional insight into the potential onset time of precipitation and heightened precipitation intensity, as well as identify the most likely and reasonable worst-case scenario precipitation rates.

With this information compiled into an easy-to-use briefing style product and accompanied by the free-text discussion, the mountain weather forecast provided by the NWS WFO in SLC stands out as a unique and high-quality tool ideal for streamlined use within an avalanche forecaster's workflow.

4.1. <u>Verification and Usability</u>

Ad-hoc verification of the legacy mountain weather forecast from 2005 through 2023 (Table 1) highlights similar performance as noted in the WPC probabilistic snowfall forecast with a modest low bias across the forecast dataset against snowfall observations from Alta Ski Area's Collins Snow Study Plot. Of note, while significant underforecasts were observed, no significant overforecasts exist in the record. Given the model forecasts used to populate the first guess tend towards under dispersive on the upper end with most forecasts verifying above the 95th percentile, this is expected behavior.

Over time, it is expected that snow safety professionals utilizing the forecast will note and correct for this slight low bias, which has been confirmed in conversations with core partners in upper Little Cottonwood Canyon. The issue for the meteorologist is one of an anchoring bias, where it is difficult to present a forecast that exceeds the bounds of a calibrated ensemble forecast and probabilistic output without overwhelming evidence that the range of forecasts does not truly encompass the most likely outcome. In short, this is most likely a factor of the model underestimating terrain elevation due to high topographic complexity in relatively coarse grid spacing, and beyond the scope of this work to remedy.

Instilling some degree of confidence in the reliability of the forecast, over the 18-year dataset, 77.8% of events verified somewhere within the two-bin probability forecast, with more than half of the forecasts falling, appropriately within the High Bin (>60%) and as high as 63% of forecasts falling within the High Bin some years. Appropriately, 25.6% of forecasts fell within the Low Bin (<40%) with as many as 38% and as few as 13% of forecasts falling within the low bin. Proportionally, this is the expected behavior of the two-bin probability, however, given the subjective nature of how these probabilities have been derived, there is ample room for improvement. The underdispersive nature of the forecast is also noted in that, on average, 21.9% of forecasts on miss the observed amount entirely, and as many as 4% of forecasts missed the observed amount by an underforecast of greater than 15.24 cm (6").

While the range or width of each bin (e.g., 15.3 - 25.4 cm or 6 - 10") is not archived, it is likely that the perceived desire for a more precise forecast leads to narrower bins and more frequent cases where forecasts verify above or below the two bins. With the move to the more statistically robust three-bin probabilities in the modernized mountain weather forecast product, it is expected that the number of forecasts falling outside the presented ranges will decrease.

Currently, insufficient data exists to verify the new, more robust probabilistic snow and snow water equivalent forecasts. Given the ability to verify across the entire probability density function as well as the three-bin probability based on the 5^{th}, 25^{th}, 75^{th}, and 95^{th} percentiles, verification of the modernized forecast should lead to greater insight into solving remaining forecast challenges.

n = 3060	High Bin	Low Bin	Outside
Average	52.2%	25.6%	21.9%
Maximum	63.0%	38.0%	33.0%
Minimum	40.0%	13.0%	5.0%
	Overforecast	**Underforecast**	**Significant Underforecast**
Average	9.3%	12.8%	0.7%
Maximum	20.0%	22.0%	4.0%
Minimum	0.0%	4.0%	0.0%

Table 1. Verification of the 12-hour forecast snow amount against observed snowfall at Alta Ski Area Collins Snow Study Plot from Oct 1 – Mar 20, 2005 – 2023 for events greater than 5.1 cm (2"). In a two-bin probability forecast, High Bin represents the high confidence (>60%) scenario, Low Bin represents the low confidence (<40%) scenario. Overforecasts verify above either bin, underforecasts verify below either bin, and a significant underforecast is a miss of > 15.24 cm (6"). No significant overforecasts were observed.

5. FUTURE WORK

The WFO at Salt Lake City will continue to work closely with its snow safety partners across the state to develop the modernized mountain weather forecast, actively collecting feedback, performing verification, and iterating upon its current design. There is desire to see this product expanded to other locations outside of Little Cottonwood Canyon and Provo Canyon, and with a better 'first guess' behind the forecast, it may become feasible to automate the generation of the product. However, noting that the meteorologists' input and discussion are said to be the greatest value of the product, caution is being taken not to release an inadequate product.

At the national level, the NWS is working on a product known as Avalanche Weather Guidance (AVG). Currently, this text-based hourly forecast product (Figure 5) does not receive any direct input from a meteorologist but serves as an automated and consistently formatted stopgap and starting point for offices that do not currently provide weather forecast support for their local snow safety professionals. Some offices have augmented the AVG with a written forecast discussion, which has been well received by these partners where it has so far been implemented. Efforts to build out the AVG based on partner feedback are ongoing.

No Active Alerts | Tabular Forecast | Graphical Forecast

DATE	TUESDAY 11/09								WEDNESDAY 11/10								
TIME (LT)	06	09	12	15	18	21	00	03	06	09	12	15	18	21	00	03	06
CLOUD COVER	OV	OV	OV	OV	OV	OV	OV	OV	OV	BK	SC	BK	BK	BK	BK	BK	OV
CLOUD COVER (%)	90	100	100	95	95	95	90	90	75	60	50	55	60	55	55	65	80
TEMPERATURE	31	31	29	28	28	29	29	28	27	24	24	22	22	25	26	27	27
MAX/MIN TEMP					32				23				26				23
WIND DIR	S	S	S	SW	SW	W	W	W	W	W	W	W	W	SW	SW	SW	S
WIND (MPH)	16	14	13	14	16	16	14	14	13	16	17	14	12	11	11	12	12
WIND GUST (MPH)																	
PRECIP PROB (%)	10	80	100	100	90	90	90	60	50	20	20	20	20	20	20	20	50
PRECIP TYPE		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
12 HOUR QPF					0.38				0.36				0.04				0.02
12 HOUR SNOW					3.2				3.1				0.4				0.2
12 HOUR ICE					0.00				0.00				0.00				0.00
SNOW LEVEL (KFT)	7.7	7.6	7.4	7.7	7.9	7.7	7.4	7.2	6.7	6.1	5.9	5.9	5.6	6.0	6.1	6.0	6.2

Forecast Issued: Tue Nov 9 3:24am

Figure 5. Avalanche Weather Guidance (AVG) Tabular Forecast product provided to NWS WFOs from the national level as a starting point.

ACKNOWLEDGEMENTS

A tremendous thank you to all of Utah's snow safety professionals who continue to share their highly reliable snow and water amount observations with the Utah Avalanche Center and the National Weather Service, making forecast verification and research projects possible, elevating the quality of future mountain weather forecasts in turn.

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