ADVANCING ACCESSIBILITY IN AVALANCHE FORECASTING STRATEGIES FOR INTERPRETING GEOSPATIAL DATA

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ABSTRACT: Building on prior work presented in Visually Impaired Forecasting and Accessible Software (Rettie, 2023), this paper examines advances in accessibility within avalanche forecasting tools.

Public forecasts in Canada and Colorado are produced using the AvID 2.0 platform, which introduced flexible forecast boundaries that can be redrawn as conditions evolve. An enhanced accessibility mode allowed a visually impaired forecaster to use all the features with a screen reader instead of the map-based interface used by sighted forecasters.

Over the past three years, the techniques developed for the enhanced accessibility mode in AvID 2.0 have been extended to tools supporting the diverse data sources used in avalanche hazard assessment, including weather stations, avalanche observations, meteogram weather forecasts, and snowpack model dashboards. Each of these tools presents highly spatial or graphical data that are traditionally inaccessible to screen reader users. The primary strategy is to systematically convert spatial data into structured, navigable table formats that retain the relationships and context needed for hazard analysis.

While this approach has proven effective for some complex datasets, its applicability is limited, and certain data is still not practical to interpret in this format. Key examples include highly visual data streams such as map-based synoptic weather products and avalanche photos, neither of which can be effectively represented in tabular form.

This paper presents the current strategies for making geospatial data accessible to screen reader users and identifies key forecasting resources that remain difficult to navigate. It then explores potential solutions to address these accessibility gaps, including the use of AI to interpret and summarize primarily visual data in a text-based format.

KEYWORDS: Screen Reader, Accessibility, Snowpack Models, Meteograms, Forecasting.

1. INTRODUCTION

Avalanche forecasting relies on the interpretation of datasets, including weather observations, weather models, snowpack models, and avalanche observations. Increasingly, these data are accessed through primarily visual interfaces and dashboards. These visual data resources allow forecasters to identify patterns and relationships across space and time. While these visual representations provide an efficient means of communicating complex information, they can create significant barriers for forecasters who access digital information using a screen reader.

Screen readers primarily interpret text and structured interface elements and generally cannot communicate the information contained within maps, graphics, and images. Consequently, making avalanche forecasting software accessible requires more than providing access to interface controls; the data set must also be presented in a format that can be interpreted without vision. This is particularly challenging for geospatial data. Previous work presented in Visually Impaired Forecasting and Accessible Software (Rettie, 2023) demonstrated how these barriers could be addressed within the AvID 2.0 forecast publishing platform by converting geospatial data into table-based formats.

Daily forecasting work completed within the AvID 2.0 platform represents a relatively small component of the workflow. Through operational experience over the past three years, several other accessibility gaps have been identified in the workflow.

The work presented here describes how similar accessibility strategies have been applied to the

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broader suite of tools used in avalanche forecasting as well as the limitations in this approach and potential future solutions to accessibility gaps.

2. DESIGN PROCESS

Enhanced accessibility modes were developed through an iterative process based on operational use, observation, testing, and feedback. Rather than attempting to identify all accessibility requirements during the initial design of each application, accessibility gaps were identified through daily use of existing forecasting tools with a screen reader. When a barrier was encountered, the underlying problem was considered in terms of both access to the interface and access to the information itself. Summaries of these challenges, along with potential design solutions, were provided to Avalanche Canada's in-house software developers. Prototype solutions were then incorporated into the dashboards and evaluated through continued operational use. This cycle of identifying barriers, implementing changes, and testing the resulting interface allowed the enhanced accessibility modes to evolve in response to the practical requirements of forecasting work.

An iterative approach was particularly important because limited practical guidance was available for making highly spatial, map-based forecasting applications accessible to screen reader users. Established accessibility guidelines, such as Web Content Accessibility Guidelines (W3C, 2023), could address many interface elements but did not provide direction for communicating the spatial relationships normally conveyed through maps and graphics. Consequently, many of the approaches described here were developed through trial, operational testing, and refinement rather than through the direct application of established design patterns.

The development process focused primarily on determining how information normally communicated visually could be reorganized without losing the temporal, spatial, and operational context required for hazard assessment. The approach developed previously for AvID 2.0 provided the starting point, with visual and geospatial information converted where possible into structured, screen-reader-navigable tables. As increasingly complex datasets were considered, this approach was expanded to include filtering, location information, grouping of related data, and text-based summaries. The objective was not necessarily to reproduce the visual interface directly, but to provide access to the same underlying information in a format that could be efficiently interpreted using a screen reader.

This process was applied to four of Avalanche Canada's forecasting dashboards: avalanche observation, weather station, meteogram weather forecast, and snowpack model.

3. PRODUCTS

The first new forecasting tools to feature enhanced accessibility were avalanche observation and weather station dashboards. This underlying data displayed in these dashboards are simple tables, so lessons learned from the AvID 2.0 project were relatively easy to implement in the development of these tools. Later the snowpack model and meteogram weather forecast dashboards received enhanced accessibility. A similar table-based approach was taken for these tools, but development of enhanced accessibility had greater difficulty as the data is inherently multidimensional and more complex.

The primary difference between the standard and enhanced accessibility mode within the weather station and avalanche observation dashboards is the removal of uninterpretable visual data. This is an effective approach for these data sets as the data can be presented in its entirety in a table-based format (Fig. 1).

Source	Metadata		Air Temperature (°C)				RH …	Rad…	Wind (km/h,°)								Snow (cm)						
									Speed			Gust			Direction		Height		Combine	Sum	Δ	R…	S…
Name	Elevation (m)	Owner	Pres	Min	Max	Δ	Pres	Sky	Pres	Avg	Max	Pres	Avg	Max	Pres	Avg	HS	H…	Total	Total	Total	M…	S…
Aster Lake	2320	Alberta Parks	-2	-8	3	6	31		7	6	10	20	23	37	138	139	227		1	2	0	0	
Highwood Pass	2215	Alberta Parks	-4	-10	4	4	55		0	3	6	7	16	31	350	58	153		2	4	0	1	
Mount Odlum	2090	Alberta Governm																					
Conrad Glacier	2599	BCMoE	-6	-13	-6	7											~~242~~		~~12~~	~~23~~	~~0~~	~~9~~	
Black Forest	1930	CMH Bugaboos																					
Rocky	1900	CMH Bobbie Bu															390	30					
BU Lodge	1510	CMH Bugaboos	-4	-6	2	6		CLR	15	8	15				270	270	116	0	0				
BB Lodge	1365	CMH Bobbie Bu	-4	-4	5	9		CLR	15	8	15				180	180	130	0	0				
Farnham Wx Plot	2666	RK Heliski Panc																					
Goldie Auto Wx	2454	Panorama	-8	-11	-6	2	68		25	24	25	26	25	26	250	220							
Little Dragon	2380	BCMoTI	-5	-11	-2	6	43		6	10	19				312	304							
Panorama Summit	2375	Panorama Ski R	-5	-11	-1	6			18	18	22				234	236	159		2	4	0	1	
Panorama Mountai…	2356	Ski resort															158						
Summit Weather Plot	2356	Panorama	-6	-10	3	-1		FEW	15	8	15				270	270	157	8	0				
FIS Wx Plot	2336	RK Heliski Panc																					
Rosie's Study Plot	2304	RK Heliski Panc																					
Little Dragon Snow	2250	BCMoTI	-3	-9	3	7											138		1	1	0	1	
Springs Creek	2250	Toby Creek Adve	-3	-9	-1			FEW	15	15	15				225	225	170	10	0				

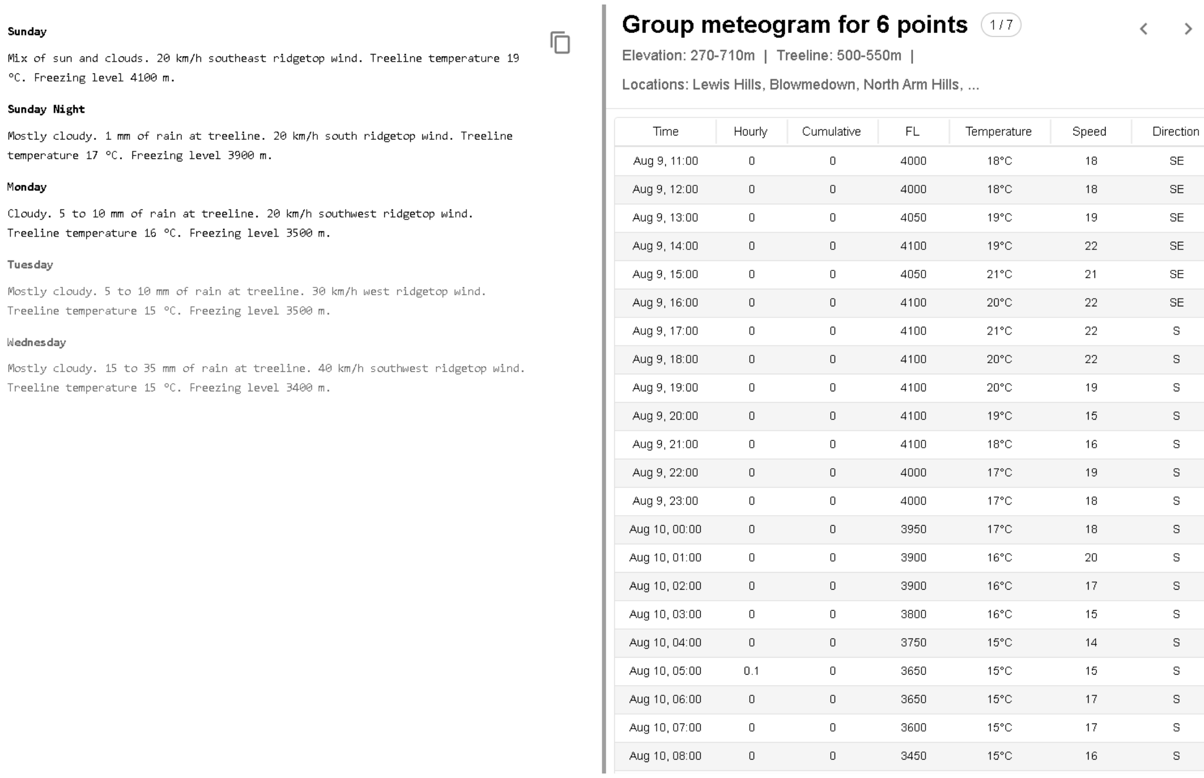
Figure 1: Weather station dashboard with enhanced accessibility.

When navigating the table with a screen reader, column or row information is communicated along with the value. For example, when navigating through the weather station column the screen reader simply reads the name of the station. To analyze the data from the station the user would then navigate across the row, as the screen reader cursor moves to a new column it will read out the column heading followed by the value in the cell. Rather than visually scanning the table, the forecaster moves between cells using keyboard commands while the screen reader communicates the value and its associated row or column heading.

The enhanced accessibility mode in the meteogram weather dashboard presents the same underlying forecast data in a structured table, with time represented by rows and individual weather variables organized into columns (Fig. 2). This allows a screen reader user to navigate through the forecast chronologically or compare individual variables. Tables are available for the group ensemble meteogram for multiple points in a region, as well as each of the individual points that exist within the region. The name of each point contained in the group meteogram is listed along with the latitude and longitude of the point.

In addition to the detailed hourly data, a text-based summary provides an overview of expected conditions for each forecast period. Variables important to avalanche forecasting, including precipitation amounts, ridgetop wind speed and direction, treeline temperature, and freezing level, are combined into concise statements. The two formats complement each other: the text summary supports rapid identification of significant weather trends, while the table provides access to the higher-resolution data required for more detailed analysis.

This approach retains much of the temporal and spatial context contained in the original graphical meteogram while allowing the information to quickly be accessed and interpreted using a screen reader.



Sunday

Mix of sun and clouds. 20 km/h southeast ridgetop wind. Treeline temperature 19 °C. Freezing level 4100 m.

Sunday Night

Mostly cloudy. 1 mm of rain at treeline. 20 km/h south ridgetop wind. Treeline temperature 17 °C. Freezing level 3900 m.

Monday

Cloudy. 5 to 10 mm of rain at treeline. 20 km/h southwest ridgetop wind. Treeline temperature 16 °C. Freezing level 3500 m.

Tuesday

Mostly cloudy. 5 to 10 mm of rain at treeline. 30 km/h west ridgetop wind. Treeline temperature 15 °C. Freezing level 3500 m.

Wednesday

Mostly cloudy. 15 to 35 mm of rain at treeline. 40 km/h southwest ridgetop wind. Treeline temperature 15 °C. Freezing level 3400 m.

Group meteogram for 6 points 1 / 7

Elevation: 270-710m | Treeline: 500-550m |

Locations: Lewis Hills, Blowmedown, North Arm Hills, ...

Time	Hourly	Cumulative	FL	Temperature	Speed	Direction
Aug 9, 11:00	0	0	4000	18°C	18	SE
Aug 9, 12:00	0	0	4000	18°C	18	SE
Aug 9, 13:00	0	0	4050	19°C	19	SE
Aug 9, 14:00	0	0	4100	19°C	22	SE
Aug 9, 15:00	0	0	4050	21°C	21	SE
Aug 9, 16:00	0	0	4100	20°C	22	SE
Aug 9, 17:00	0	0	4100	21°C	22	S
Aug 9, 18:00	0	0	4100	20°C	22	S
Aug 9, 19:00	0	0	4100	20°C	19	S
Aug 9, 20:00	0	0	4100	19°C	15	S
Aug 9, 21:00	0	0	4100	18°C	16	S
Aug 9, 22:00	0	0	4000	17°C	19	S
Aug 9, 23:00	0	0	4000	17°C	18	S
Aug 10, 00:00	0	0	3950	17°C	18	S
Aug 10, 01:00	0	0	3900	16°C	20	S
Aug 10, 02:00	0	0	3900	16°C	17	S
Aug 10, 03:00	0	0	3800	16°C	15	S
Aug 10, 04:00	0	0	3750	15°C	14	S
Aug 10, 05:00	0.1	0	3650	15°C	15	S
Aug 10, 06:00	0	0	3650	15°C	17	S
Aug 10, 07:00	0	0	3600	15°C	17	S
Aug 10, 08:00	0	0	3450	15°C	16	S

Figure 2: Meteogram weather dashboard with enhanced accessibility mode.

Like the meteogram weather dashboard, the enhanced accessibility mode within the snowpack model dashboard presents model output in a structured table. Model locations are organized into rows, while snowpack and weather variables are presented in columns (Fig. 3a). This structure allows a user to navigate across a row to examine multiple variables at a specific model location or move through a column to compare the same variable across multiple locations. Data available within the table include snow depth, and hazard metrics for new snow, wind, persistent weak layer and wet-snow problems.

Snowpack model cluster data can also be viewed in a table format (Fig. 3b). Data is displayed with a row for each cluster and columns for the sub regions contained within the cluster and relevant snowpack characteristics.

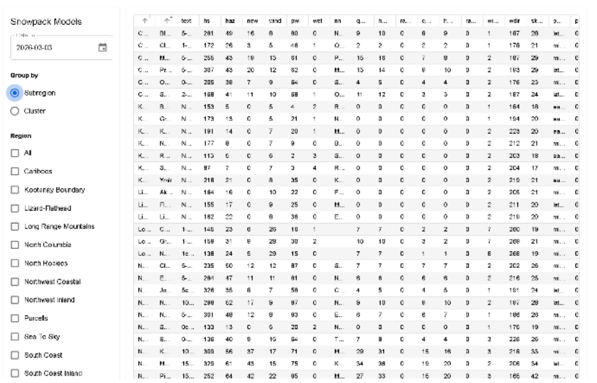


Figure 3a: Snowpack model dashboard presenting model data for individual locations with enhanced accessibility.

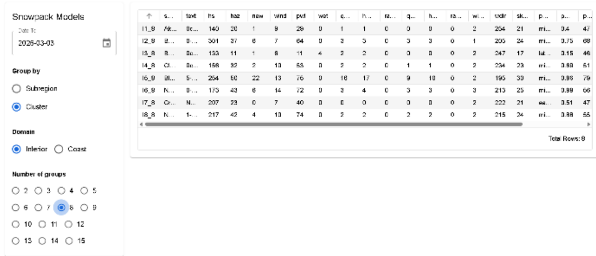


Figure 3b: Snowpack model dashboard presenting model data for clusters with enhanced accessibility.

Data in these dashboards can be selected by date, grouped by subregion or cluster, and filtered to individual forecast regions. This is particularly important when working with a large dataset, as it allows a screen reader user to reduce the amount of information presented and focus on locations relevant to the hazard assessment. By combining filtering with structured tabular output, a large dataset that would otherwise be explored primarily through a map or graphical interface can be analyzed queried and compared using a screen reader.

The enhanced accessibility mode can be toggled on and off within the dashboard settings. Allowing both sighted and vision impaired users to access information in the format that is most interpretable to them.

These developments demonstrate that a table-based approach can provide effective screen reader access to a wide range of data used in avalanche forecasting. The relative simplicity of adapting weather station and avalanche observation data contrasts with the greater challenge of representing inherently graphical and spatial datasets such as meteogram weather forecasts and snowpack model output. In these more complex applications, structured tables, filtering, location information, and text summaries preserve the temporal and spatial context required for hazard assessment while also increasing efficiency of screen reader interpretation.

4. LESSONS AND RECOMMENDATIONS

The development of enhanced accessibility across Avalanche Canada's forecasting tools has identified several principles that may be useful when designing other data-intensive applications for screen reader users. A key lesson is that accessibility does not require replacing the standard visual interface. Instead, enhanced accessibility can provide an alternative representation of the same underlying data, with users able to toggle between standard and enhanced modes. This approach allows accessibility improvements to be incorporated without reducing the functionality available to sighted users and creates flexibility for users who may benefit from elements of both interfaces.

An additional challenge is that accessibility requirements vary considerably between users, making it difficult for a single enhanced accessibility mode to address all potential barriers. The enhanced accessibility modes described in this paper were developed to support screen reader use and should not be interpreted as a comprehensive accessibility solution. Other requirements may be better addressed independently; for example, colour-vision accessibility within Avalanche Canada applications has been supported through an alternative colour palette rather than incorporated into the enhanced accessibility mode. This suggests that accessible application design may be better approached as a collection of complementary options that users can configure according to their needs rather than as a single universal accessibility mode.

For large or complex datasets, providing access to the raw data alone may not be sufficient for efficient analysis with a screen reader. Navigating hundreds of table cells with a screen reader can make it difficult to recognize the broad patterns that a sighted forecaster may identify quickly from a graph or map. A useful approach is to provide information at multiple levels of detail. A concise text summary should first communicate the major patterns, trends, and changes within the dataset, allowing the user to develop an overall understanding before navigating the detailed table. The meteogram dashboard demonstrates this approach by summarizing precipitation, wind, temperature, and freezing level for each forecast period while retaining the hourly table for more detailed analysis.

This approach reflects the broader "overview first, details on demand" design principle (Shneiderman, 1996) and may benefit all forecasters, not only screen reader users. As datasets increase in size and complexity, emerging approaches such as Retrieval-Augmented Generation (RAG) may provide another means of generating an initial text-based overview from large datasets while retaining access to the underlying source data. Such summaries could provide a useful starting point for analysis.

A map allows a sighted user to visually limit their attention to a geographic area, whereas a screen reader may otherwise encounter the dataset as a long sequence of locations. Spatial filtering should reflect the geographic units used during hazard assessment rather than simply reducing the size of the dataset. For example, a forecaster may begin by filtering snowpack model data to the cluster containing the region being assessed to identify trends or patterns. Then examine the individual subregions. This creates a progression from regional patterns to local variability that parallels the way a sighted forecaster may progressively examine areas on a map. Accessible applications should therefore provide meaningful spatial filters that reflect how the data are used. The snowpack model dashboard demonstrates the value of this approach by allowing data to be selected by date, grouped by subregion or cluster, and filtered to individual forecast regions. Filtering reduces the amount of information that must be navigated and allows the screen reader user to progressively move from a regional overview toward locations requiring a deep dive.

Geospatial context should also be attached directly to tabular information rather than relying on a separate map to establish where observations or model points are located. At a minimum, locations should have meaningful names and coordinates, as demonstrated in the group meteogram where each point is identified by name, latitude, and longitude. The objective is to create enough spatial context that relationships between locations and relevant data can be understood without viewing them on a map.

The iterative development process used for these tools demonstrates the importance of evaluating accessibility through operational use rather than relying exclusively on accessibility standards or pre-release testing. The enhanced modes described in this paper were developed by identifying barriers during daily forecasting work, communicating those barriers and potential solutions to software developers, implementing changes, and then evaluating those changes during continued operational use. This process identified accessibility problems that may not have been apparent during initial software design and allowed solutions to evolve alongside the forecaster's understanding of how the information could most effectively be interpreted with a screen reader.

5. LIMITATIONS

Highly visual data streams, such as map-based synoptic weather products and avalanche photos, present a greater accessibility challenge because their value is derived from complex spatial relationships, patterns, and visual context rather than simple numerical values. As the saying goes "A picture is worth a thousand words". On a synoptic weather map, the position and shape of pressure systems, fronts, precipitation, and other features relative to one another are fundamental to interpretation. Similarly, avalanche photographs contain information about terrain, avalanche character, size, weather, and surrounding conditions that cannot be adequately described through a series of predefined fields.

Artificial intelligence (AI) image interpretation provides a potential approach for addressing this accessibility gap. AI systems can interpret an image and communicate its contents through text, potentially allowing a screen reader user to query visual information that would otherwise be inaccessible. For synoptic weather products, this includes identifying major pressure systems, fronts, precipitation areas, and broad spatial patterns and describing their locations. For avalanche photographs, AI could potentially describe visible terrain and avalanche characteristics and provide a structured summary of features relevant to hazard assessment.

For example; when Chat GPT 5.6 Sol was given the photo in Fig. 4 and the following prompt "Describe the size, character, and likely trigger type of the avalanche in the photo. Include a confidence rating of your answer." It produced this image interpretation:

The photo appears to show an avalanche that released from the upper alpine slope near the ridgeline and ran a substantial distance through the central gully.

- *Size: Approximately Size 2 (D2), potentially approaching Size 2.5. The avalanche appears to have travelled several hundred vertical meters and produced a substantial debris deposit confined within the gully. Exact sizing is uncertain because there is no definitive scale or information about debris depth.*
- *Character: Most consistent with a dry slab avalanche. There appears to be a broad release area in the upper start zone, with the avalanche subsequently channelled into the gully. From the photograph alone, I cannot reliably determine whether it involved a storm slab, wind slab, or persistent weak layer.*
- *Likely trigger: Natural appears most likely. I do not see obvious evidence of a skier/snowmobile track, explosive trigger, or other artificial trigger in the start zone. However, absence of visible evidence is not sufficient to establish a natural trigger, so this remains an inference.*
- *Confidence: Moderate (~65%) for the overall interpretation. I have relatively high confidence that this is a slab avalanche and moderate confidence in the approximate size. Confidence in the trigger is low, because trigger type generally cannot be established from this photograph alone.*

Figure 4: A size 3, naturally triggered wind slab avalanche.

This interpretation is not entirely accurate, but it is generally accurate. The avalanche was a size 3 wind slab, while AI failed to accurately determine the size and character, it was close in this assessment and offered good rational and identification of its uncertainties. It was however correct that the avalanche was triggered naturally. An avalanche expert may have noticed the lack of snow on the trees and been able to narrow their assessment of avalanche character. They may also have assumed that the debris did not stop at the edge of the photo and therefore leaned towards a larger avalanche size.

The application of AI to forecasting introduces important limitations. AI-generated interpretations may omit relevant features, misinterpret visual information, or describe uncertain information with inappropriate confidence. AI image interpretation should therefore only be considered an accessibility aid at this time. Further development and evaluation are needed to determine where these tools can reliably improve access to visual forecasting data and how their output can be incorporated into operational workflows.

6. CONCLUSION

The development of enhanced accessibility across Avalanche Canada's forecasting tools demonstrates that complex datasets can often be made accessible to screen reader users without changing the underlying information available to sighted forecasters. Building on the approach developed for AvID 2.0, structured tables, filtering, text summaries, and location information have been successfully applied to weather station observations, avalanche observations, meteogram forecasts, and snowpack model outputs. Importantly, these developments have been driven by operational use, with accessibility gaps identified through daily forecasting workflows and subsequent improvements informed by direct feedback.

The effectiveness of this approach depends largely on the nature of the underlying data. Information composed of numeric values can generally be reorganized into structured tables while retaining much of the context required for hazard assessment. As datasets become increasingly graphical or image-based, translating them into tables becomes less effective. Synoptic weather maps and avalanche photographs demonstrate an important boundary of the current approach: their usefulness comes not only from individual pieces of information, but from visual patterns and relationships that are difficult to reproduce in an accessible format.

Emerging technologies, particularly AI, may provide new opportunities to address these remaining barriers by translating visual information into text and allowing users to interactively query images and maps. At present, limitations in reliability, completeness, and uncertainty mean that these technologies should supplement rather than replace established forecasting information and professional interpretation. Continued evaluation within operational workflows will be important to determine where these tools can provide meaningful and reliable improvements in accessibility.

Accessible avalanche forecasting software is not achieved by simply making an interface compatible with a screen reader. Accessibility requires consideration of how the information is displayed while maintaining the context necessary for professional interpretation. The progress made since the initial AvID 2.0 work demonstrates that accessibility can be incorporated into highly specialized forecasting systems, while the remaining gaps provide opportunities for continued development as new methods of interpreting and communicating visual information become available.

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