THE AVID PROJECT: COLLABORATIVE SOLUTIONS TO AVALANCHE FORECASTING CHALLENGES

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ABSTRACT: This article presents a case study examining an internal software development project that started at Avalanche Canada (AvCan) and evolved into an international, multi-jurisdictional success story in cooperation and collaboration: The Avalanche Information Distribution System (AvID). The project involves multiple agencies with different perspectives, requirements, expertise, and approaches, resulting in the creation of innovative new software products with unique workflows that meet the needs of avalanche forecasters in a variety of contexts. This approach offers a road map for partners with similar goals to cooperate and overcome financial, technical, and conceptual challenges in product development.

In the last 24 months, the AvID project produced several products currently used in production, including AvIDfx, the public avalanche forecasting software used by all public avalanche forecasting programs in Canada and the Colorado Avalanche Information Center (CAIC); AvIDhx, the CAIC Highway Avalanche Forecasting platform; and AvIDdx, a suite of forecaster support tools comprising the snowpack modelling visualization tool, the Mountain Information Network (MIN) public observations viewer, a weather observations dashboard, and a prototype avalanche observations dashboard. Finally, the paper reviews ideas for the future, including new features for existing products, additional new applications, and adjunct benefits for users who rely on public hazard and risk information to assess and manage avalanche risk.

KEYWORDS: AvID, Avalanche Forecasting, Forecasting Software

1. INTRODUCTION

In response to eight fatal accidents in the first seven weeks of 2008, AvCan conducted a critical review of its forecasts. The review found that essential messages were obscured in lengthy, text-based formats. Simultaneously, the Conceptual Model of Avalanche Hazard was in its early stages (Statham 2008), and research into public risk communications was initiated. This led to the development of Parks Canada's new AvalX forecasting software under the leadership of Grant Statham (Statham et al., 2012). With the launch of AvalX, a significant shift occurred in the way public forecasts were presented. Traditional text-based forecasts were replaced with graphical, icon-driven formats featuring concise, standardized language and the technical text details moved to the background.

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In 2015, AvCan began conceiving the next generation of forecasting software. Initially, for this project, AvCan hired a major contract design and development firm. However, this method proved costly and left us with limited control over the process. The firm lacked the context associated with our operations, and consequently, the outcomes didn't align with our vision.

Ultimately, this led us to a pivotal change: adopting modern "Agile" project management methodologies (Nakazawa and Tanaka, 2016) with a mostly in-house development team. It fundamentally transformed our perspectives on product development, as well as the scope and complexity of the projects we are able to take on. In the fall of 2019, AvCan launched AvIDfx v1, a modular avalanche forecasting application with various components that could be easily updated, replaced, or re-purposed to accommodate new future developments in forecasting procedures and changes in public-facing products. The AvID project also produced preliminary prototype versions of visualization tools for weather station data and avalanche occurrence observations. In 2020, we integrated AvCan's long-standing snowpack modelling application.

In the spring of 2021, we commenced work on a major update to the forecasting software, AvID v2. By that time we had an internal, full-stack design and development team, augmented with project managers and forecasting staff. This integrated group was able to quickly and efficiently design and build high-quality software based on user needs and feedback.

While there's no shortage of anecdotes about the challenges avalanche centres have encountered when engaging external software developers, our focus here is to highlight what worked for us. We share this not only as evidence of a successful strategy but also as a catalyst for broader discussions and collaborations within our community.

2. COLLABORATION IN AN AGILE ENVIRONMENT

After the release of AvID v1, AvCan approached the CAIC to discuss a partnership aimed at developing customized software tailored to the unique requirements of both organizations. A shared vision began to emerge through a series of brainstorming sessions, breakout discussions, and informal conversations. This partnership was formalized in July 2021 with a five-year agreement. Key CAIC staff were integrated with AvCan's team, adding significant funding, expertise, knowledge, and experience to the AvID project.

Both organizations shared a common desire to move away from large, static forecast regions. These static regional forecast areas often necessitated the use of complex, confusing text descriptions to address the inherent spatial variability of avalanche conditions within the regions with fixed boundaries. The idea was to move to a dynamic system that could adapt forecast regions to changing conditions by first delineating small areas that tend to have less spatial variability and then grouping these into larger, homogenous regions as conditions change. We hypothesized that once the underlying logic of this system was established, it might eventually give way to a high-resolution gridded forecast system, like those used in weather forecasting. This common goal became the first collaborative, co-development project of the new partnership.

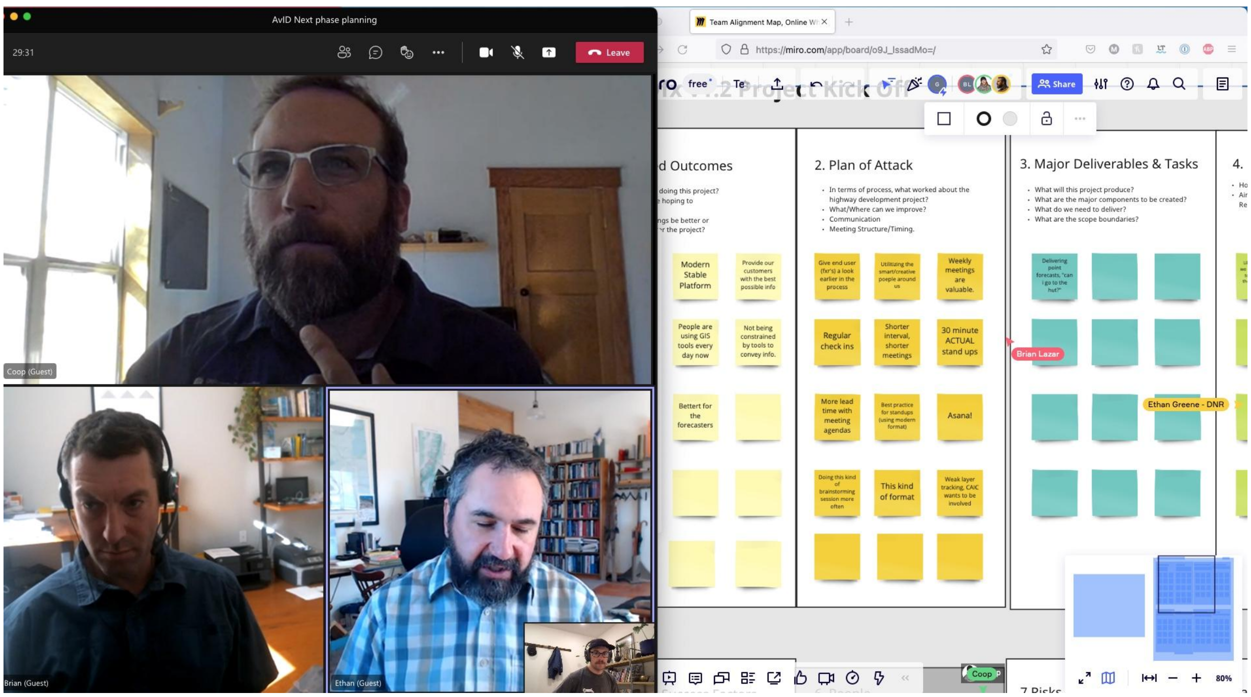
A dynamic forecasting system is a deceptively simple idea, but deeper investigation revealed a number of technical and workflow challenges that this system would need to address. It's natural to want to address all these challenges before we start building, mirroring traditional waterfall project management methodologies. Yet, software development calls for a more agile and adaptive approach. Our experience has been that solutions conceived in the early planning stage of a software project tend to be unnecessarily complex, overly engineered, and often lack a crucial piece of logic. It's hard to anticipate everything that will be relevant. We don't have perfect foresight, and some things can only be discovered by doing rather than planning. In this spirit, we started development without having solutions to every challenge. While that may seem counterintuitive to traditional project managers, this is where Agile project management methodology shines (Nakazawa and Tanaka, 2016).

Agile methodologies are a set of principles for software development under which requirements and solutions evolve through the collaborative effort of cross-functional teams. Embarking on the AvID v2 build project, we knew the end goals, but not all the solutions. We tackled this by dividing the goals into smaller tasks. We captured and estimated these tasks in a Kanban-style project management tool, which is critical to coordinating Agile development (Nakazawa and Tanaka, 2016). A Kanban tool offers insight into ongoing tasks, resource capacity, and the present workflow.

A key element of success was to create a basic version of the software early in the development cycle and then test and refine it over time based on feedback and new emergent insights. As development progressed, we garnered a more comprehensive understanding of the complexities involved, which allowed for a clearer and more defined vision of the product to emerge. This ranged from insights about how to best structure the source code, to the intricacies of how region boundaries were determined from smaller subregion building blocks. Further on, this process led to discovering ways to improve weak layer tracking tools, as well as several other updates that would have otherwise been difficult or impossible to foresee.

Agile embeds primary stakeholders into the development process. This allows for operational forecasters, supervisors, and managers to be fully integrated into the design, development, and testing of software products. Their full inclusion in the process allows designers, developers, and project managers to better understand user needs. In the specialized field of avalanche forecasting, conveying the intricacies to those unacquainted with winter recreation can be a formidable task. It's not enough to just have experts from different fields–their knowledge must be tailored to fit the specific challenges of avalanche forecasting. While new perspectives are valuable, we've found that understanding the nuances of this discipline is essential for effective product design and development.

The design, development, and testing of AvID v2 was completed almost entirely by in-house staff and partners. Although not everyone on the team was an avalanche professional, everyone was deeply integrated in the AvCan/CAIC ethos. The team's passion for winter backcountry travel aligns with AvCan and CAIC's mission and provides them with first-hand end user experience. As they themselves rely on forecast products for their own winter backcountry travel, this provides the development team with a level of context that would be very difficult to achieve using external contractors.



Collaborators discussing during a virtual Agile planning session, laying the groundwork for future development.

3. DEVELOPMENT & CHALLENGES

In Agile development, we embrace uncertainty, acknowledging that some of the most significant challenges lie ahead, yet to be solved. In developing AvID v2, one of the most formidable hurdles was figuring out how to present dynamic regional avalanche information in an easily understandable and accessible manner for the public. Initially, we weighed two design alternatives: A) eliminating region names to adopt a meteorological-style mapping approach where defined areas are unnamed and dynamically alterable; and B) preserving the names for the smallest sub-regions, so that users could familiarize themselves with these areas, then use the website to identify which larger, dynamic region would encompass the sub-regions they are familiar with.

After collaborative team deliberations, and with visualization and design input from our partner, Simon Fraser University (SFU), we chose to modernize the traditional practice of requiring users to memorize local forecast region names. We opted to eliminate these names altogether, providing users with a flexible, more intuitive way to interact with our forecasting tools. Our aim is to make forecasting products accessible to an audience that varies widely in expertise. Introducing new region names would require a massive educational effort for users to memorize these regions. Further, these regions are likely to change shape in the future as our knowledge about them and how to use this new forecasting system evolves. This decision protects against the disruption of end users having to learn new geographic regions that could occur if we later needed to change region shapes. Looking ahead, as we integrate more advanced modelling and artificial intelligence into our forecasting process, we view our current system as a stepping stone. The eventual goal is a transition toward granular, grid-based systems that can capture avalanche conditions with high-resolution and thus address the challenges of spatial variability. Our choice to eliminate region names makes this system more resilient in the face of an uncertain and changing future.

Adopting a nameless region system gave rise to new challenges. How would users orient themselves and navigate using the map? We needed to ensure that our designs did not overly depart from our prior systems, avoiding drastic deviations that would require significant user education. At the same time, we knew our system needed new features to support users navigating to the hazard information associated with the spatial locations that they were interested in. We needed an incremental approach to avoid costly education efforts while at the same time leveraging the best available knowledge for spatial navigation aids in contemporary mapping systems to ensure users won't get lost using the new system. We also needed to improve accessibility to be in accordance with web content accessibility guidelines (WCAG 2.1, 2018).

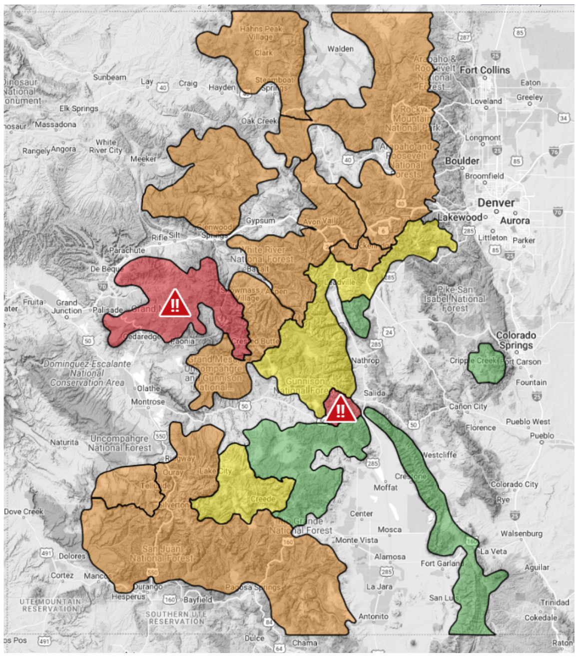
With this in mind, we developed a solution that built upon the existing interactive map navigation approaches that both AvCan and CAIC had used with fixed regions. As with our older system, the new interactive maps follow effective visualization design principles to ensure users are able to easily navigate to information of interest (Shneiderman, 1996). Users land on a page displaying an interactive map with a provincial overview of the highest danger ratings delineated within dynamic region boundaries. To access comprehensive forecast information, users can simply click on a region or search for a location, which opens a side panel with the forecast for that location.

In addition to conventional zooming, panning, and clicking, we added a search bar to better support end users navigating in our new system and to allow them to look for place names they are already familiar with. Places include political names as well as geographic names. For instance, querying “Whistler, BC” navigates the map to the corresponding location. Such search features are a staple of the widely used modern mapping applications like Google Maps (Google, 2023) or Apple Maps (Apple Inc., 2023). Again, in keeping with our intent to reduce the overall amount of additional education, we chose to add a navigation feature that users were likely already familiar with while leveraging their existing knowledge of localities and place names.

After our product launched and end users were engaging with the new flexible forecast system, we became aware that users were spending more time navigating to the forecast than in our prior system. Whereas in the past, a forecast was associated with a fixed region, and thus a specific URL could simply be bookmarked, our new dynamic system did not support this bookmarking feature. To address this issue, we quickly adapted and launched a new feature that embeds latitude and longitude coordinates into the website URLs. This allows users to bookmark a specific location on our map; accessing the bookmarked page in the future serves whatever forecast applies to this location, even if region boundaries have changed.

One feature that received mixed reviews was a tooltip-based legend. Users who didn’t need this information found it distracting and an impediment. While it can be easily turned off, this adds extra steps, which some found frustrating. This serves as an example of how, even with our best intentions, not every implementation will be perfect upon initial release. We are currently in the process of improving this as well as other features, highlighting our newfound capacity to be nimble, adapt, and utilize user feedback to continually refine our products.

It's worth noting that collaboration in this context is not merely about pooling financial resources but improving the core product for forecasters and public users. Incorporating a diverse set of intelligent perspectives inherently enriches the



CAIC's dynamic avalanche forecast regions during a busy mid-winter day in Colorado.

ideation process, yielding more refined and effective solutions. This case exemplifies how Agile's approach to collaboration significantly enhanced the project, taking it in directions that AvCan alone may not have conceived. Incorporating feedback from a diverse range of operational contexts enhances the adaptability of our products across different sectors within our industry.

Having surmounted the major design and logistical challenges, we continued with development, rigorous user testing, and eventually, training on the new system. By fall of 2022, AvIDfx v2 launched with dynamic forecast regions, enabling the geospatial approach to displaying forecasts to the public. Both apps proved highly stable, exhibiting no significant bugs, and reliably served the CAIC, AvCan, Parks Canada's four mountain parks, Kananaskis Country, and Avalanche Quebec throughout the winter of 2022/23.

4. AVID: ESSENTIALS OF THE CURRENT PLATFORM

AvID provides a forecasting platform flexible enough to accommodate a variety of geospatial forecasting applications. The full suite of tools can cater to both complex and dynamic regions, as well as simpler, static regions. Less complex or more traditional applications may use only a subset of tools and/or use them in a more simplified manner.

AvIDfx currently supports the creation of four backcountry products: avalanche forecasts, regional avalanche discussions, special products (e.g., watches, warnings, and special avalanche advisories), and weak layer tracking. Each of these products can be tailored for a specific geographical area and timeframe, with their configurations determined by the forecaster(s). For example, AvCan and the CAIC have adopted a dynamic forecast region approach, where forecast "zones" or boundaries change based on conditions, grouping similar conditions into a contiguous forecast region. Conversely, operations with fixed forecast regions can set up their maps once and use the same configuration throughout the season. Forecast products are built out of a set of discrete, non-overlapping polygons. This allows forecasters to easily nest products within one another or cover multiple products with another (i.e., a warning that covers two forecast zones).

AvIDhx is an avalanche forecasting application that supports the CAIC's highway forecasting and risk mitigation program. This application was actually released prior to AvIDfx v2, and its development was a condition of CAIC's involvement in the project. While AvCan does not have a highways program, many of the modules designed for AvIDhx v1 formed the foundations of the work done on AvIDfx v2. The iterative nature of Agile software development and modular architecture of AvID allowed a complete rebuild of this application on the v2 platform in under two months – allowing highway forecasters to benefit from the improved workflows and features of the backcountry forecasting application.

AvIDdx is a collection of forecaster support tools that include:

- Snowpack modelling visualization
- Mountain Information Network (public observations) viewer

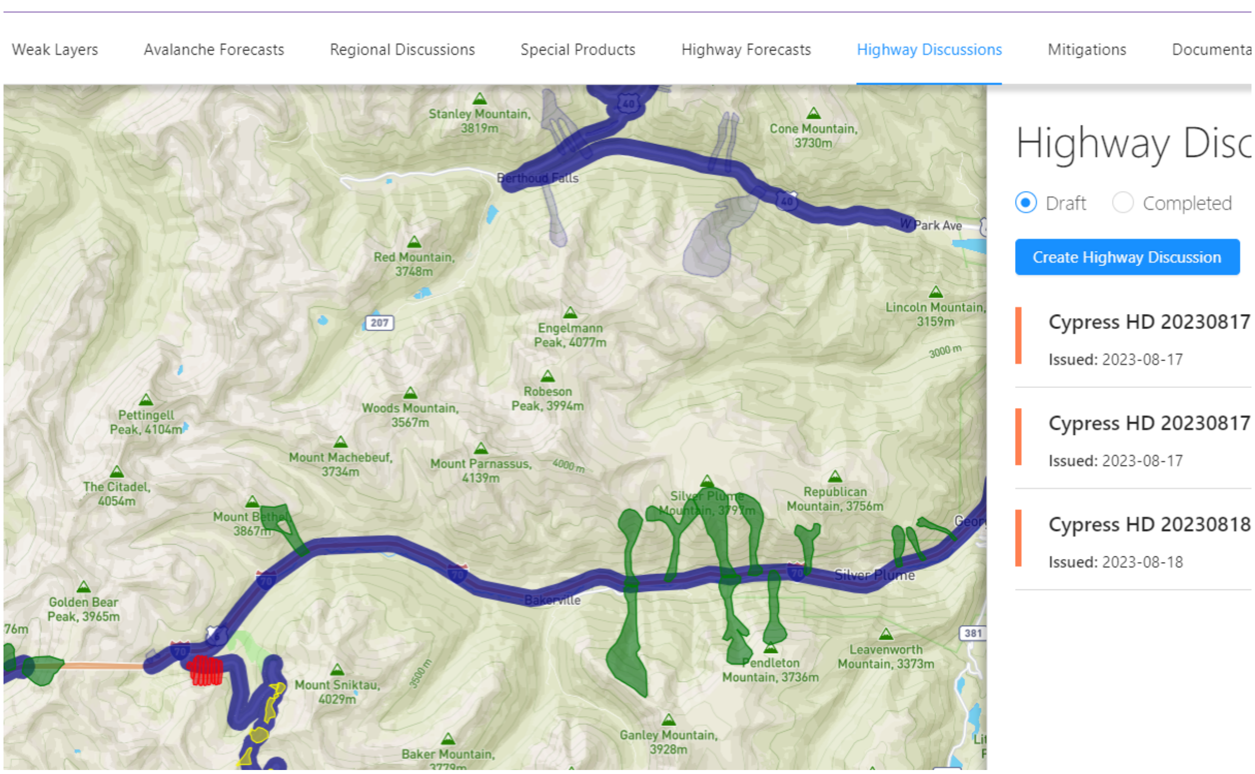
- Weather observations dashboard
- Avalanche observations dashboard

These tools are designed to streamline the task of avalanche forecasting. While already operational, most of these tools are still under active development and are the focus of our future development work.

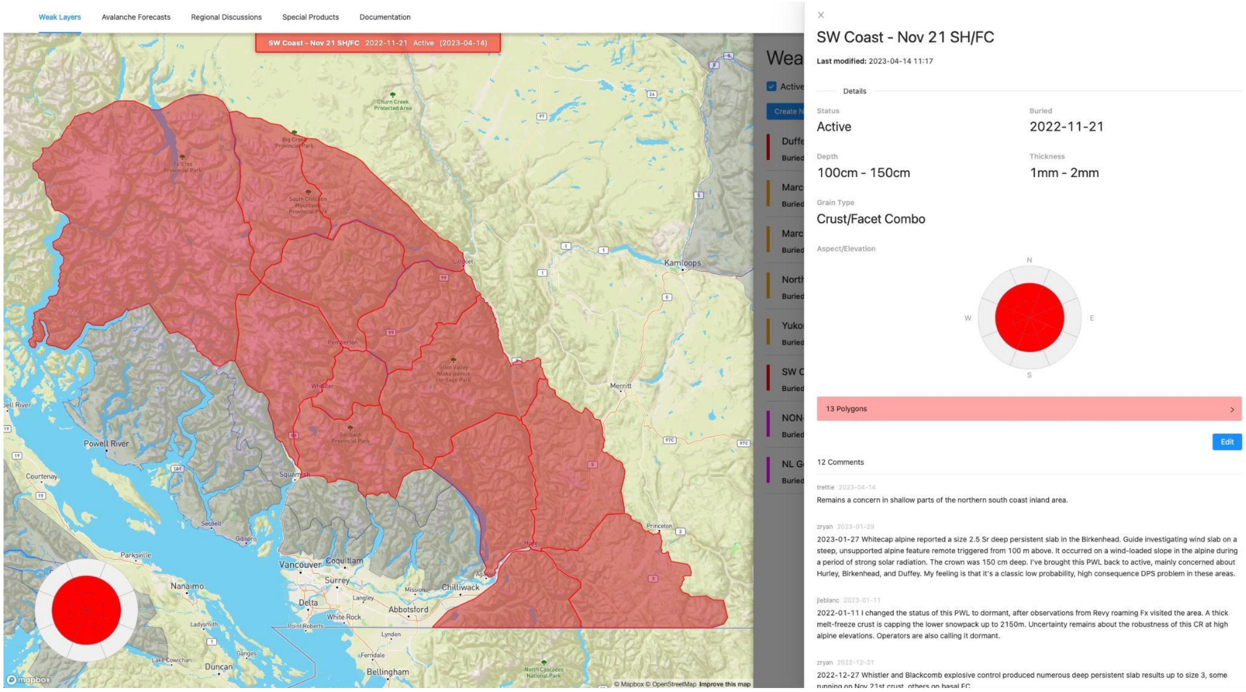
5. FUTURE DEVELOPMENT

Building upon ideas from Floyer et al. (2016), development work continues on a suite of visualization tools for observations of avalanche occurrences, weather actuals from automated weather stations, snowpack modelling, as well as tools to improve team communication and collaboration. Work is also being done to improve the way avalanche hazard information is communicated to the public. Each of these aspects will be discussed in more detail below.

Collaborative research with the Vancouver Institute for Visual Analytics at SFU brought to light certain limitations with the tools forecasters used to view data, such as tables, basic charts, and overlaying data on maps. This prompted the early design and creation of two new visualization tools, both of which have seen operational uptake by forecasting staff at AvCan. These tools serve distinct purposes: one is to visualize avalanche observation data, and the other is to visualize automated weather station data. Their main objective is to enable forecasters to discern spatial, temporal, and more abstract patterns within avalanche reports and weather telemetry. Given the heterogeneity and uncertainty inherent in both avalanche reports and weather station data, novel visualization approaches were required. We plan to refine these prototypes and extend these principles to develop new visualization tools for all the primary data sources used by forecasters. These future production tools will integrate knowledge derived from research evaluating how forecasters reason and conduct hazard assessments. This integration aims to ensure that we deliver valuable new capabilities without compromising the integrity of the forecasting process (Nowak and Bartram, 2023; Nowak et al. 2020; Nowak and Bartram, 2022).



AvIDhx's intuitive forecaster home screen, centralizing tools and insights for efficient hazard assessments.

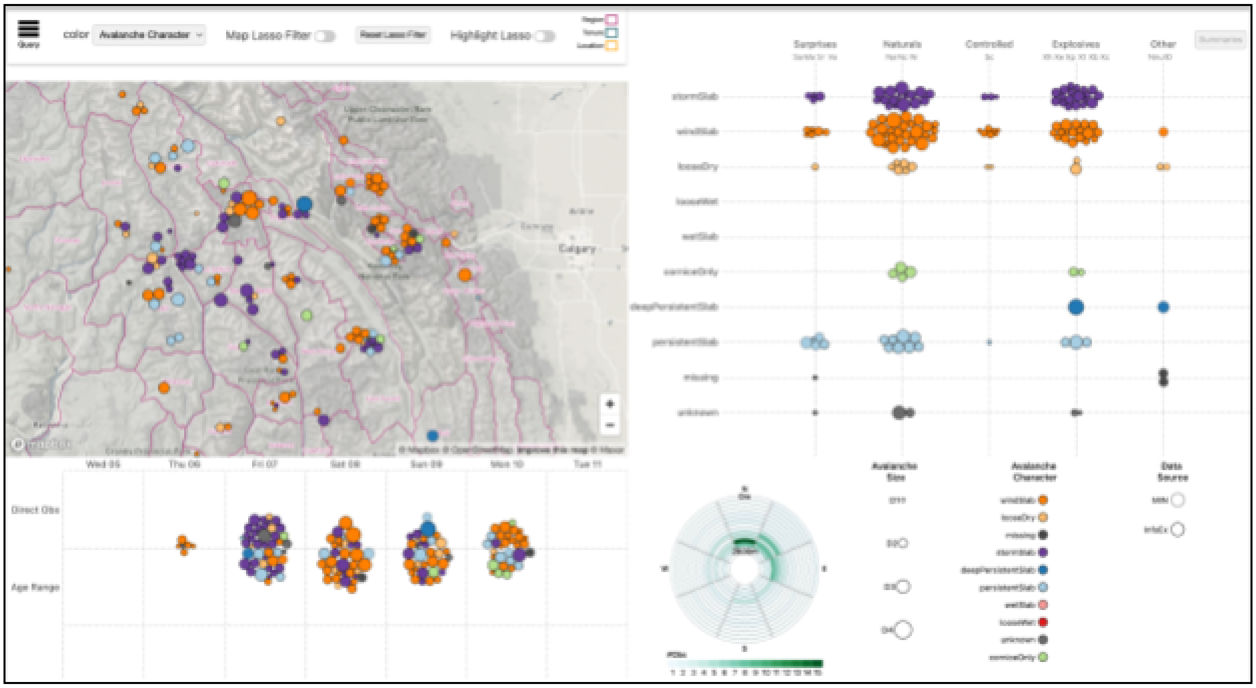


Display from AvIDfx's Weak Layer Tracking Module, showcasing an early-season persistent weak layer in British Columbia's Coast Mountains

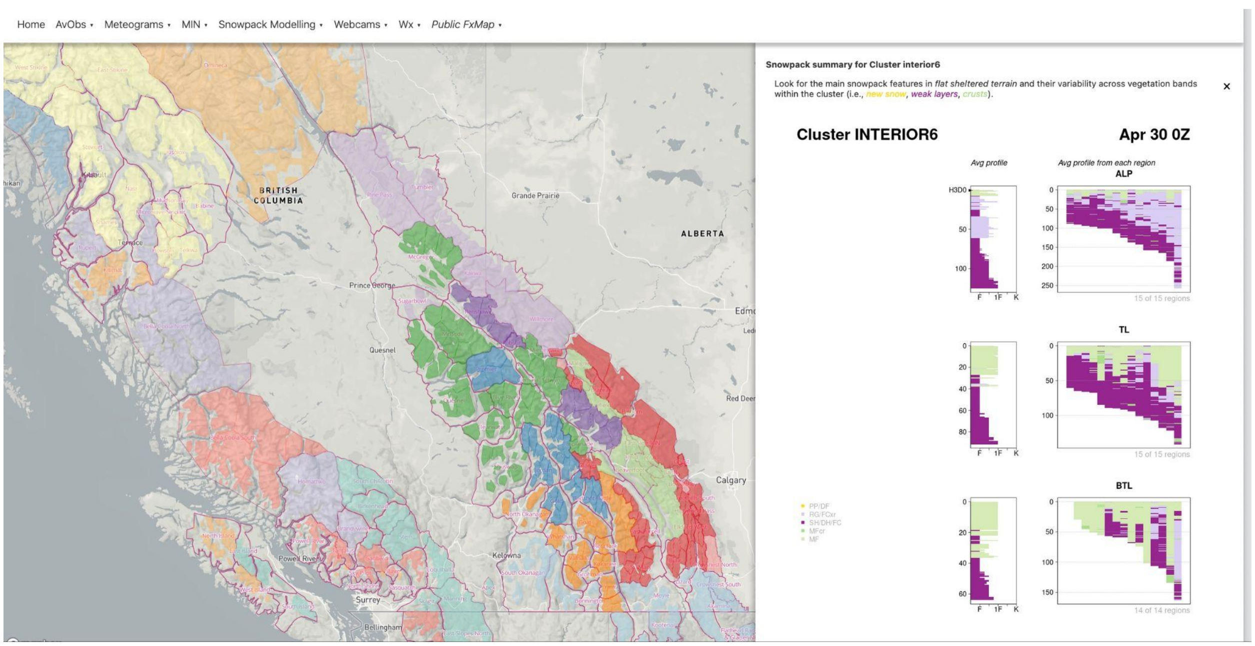
The introduction of improved tools for snowpack modelling data provides a critical new information source for forecasters to use in conjunction with traditional data sources. Most observation data comes in discrete and discontinuous points. By contrast, AvCan's snowpack models offer a more continuous spatial perspective, providing a broader framework and supplemental aid for synthesizing all relevant information into a coherent mental model. The use of snowpack models at AvCan is the outcome of more than a decade of research involving multiple research labs (Horton et al., 2023). As part of AvID's long-term vision of a platform providing unified access to multiple data streams, the AvID Project has made substantial investments in the necessary infrastructure for operating and using models. Numerous iterations of visualization prototypes have led to an operational tool that presents modelled snowpack data alongside other types of observational data sources (Horton et al., 2020). Future production tools will undergo further refinement based on operational experience, empirical studies validating snowpack model accuracy, and opportunities for integration with other products, such as model-recommended forecast region boundaries and gridded forecasts.

Our research collaborations with SFU have also highlighted the need for tools aimed at improving communication and collaboration within forecasting teams, particularly around shift changes (Nowak et al., 2023). We are actively developing tools to facilitate a smoother hand-off during shift changes to ensure effective continuity of hazard assessments among forecasters. Specifically, we are exploring ways to streamline the process of gathering various contextual information relevant to transferring hazard assessments during shift changes. Our aim is to enhance the transparency and accessibility of communications, providing a rationale for assessment decisions by capturing the supporting evidence used in the process.

Finally, AvID will also make improvements to the way avalanche hazard information is conveyed to the public. In keeping with AvID's agile and empirically informed approach, new developments in public-facing products will be based on the best available knowledge for designing such products and will be rigorously and continuously tested to ensure they are



Prototype avalanche observation dashboard developed collaboratively by Avalanche Canada and Simon Fraser University.



AvID's snowpack modelling dashboard

effective and to inform future design improvements. It is important to acknowledge that our community possesses graphical literacy. From complex meteorological visualizations to graphical snow profiles, we employ a rich visual language, and we continue to innovate by creating novel visualization products for forecasters.

Many of these tools require considerable training and background knowledge to use appropriately. While it may be tempting to simply present expert-facing products to the public or look to adjacent disciplines for common conventions, this is not without risk. For instance, scientific hurricane visualizations commonly used in meteorology for public communications often confuse the public and lead to predictable misinterpretations (Ruginski, 2016). Without the appropriate background information, individuals tend to choose the first interpretation that seems logical to them, potentially resulting in misinformed and consequential decision-making. Fortunately, there is a rich wealth of knowledge about effective communication methods to address a range of expertise levels more reliably. From foundational principles regarding how humans perceive and infer meaning from basic visual information (Ware, 2008) to cross-cultural studies demonstrating commonalities in how humans use symbols and signs to communicate (Tversky, 2011), there is a high degree of predictability and generality in how humans interpret visual information. We should leverage these insights in avalanche risk communication products. However, any approach needs to be tailored to the avalanche context and rigorously examined to determine its effectiveness.

6. CONCLUSION

The success of delivering highly complex, adaptable avalanche forecasting tools to multiple agencies underscores the power of Agile methodologies and thoughtful collaborations in software product design and development. Agile's iterative problem-solving proved to be useful in navigating complex issues. The approach was enriched by the concerted efforts of a tightly-knit development team, operational forecasting staff, and seasoned project managers. Our partnership with collaborators like the CAIC, coupled with our continuous engagement with researchers at SFU, diversified our expertise and improved our ability to solve complex problems. It also offered the practical advantage of sharing costs. We acknowledge that there is much to learn and many challenges ahead, but we remain optimistic that our ongoing collaborative efforts will provide a solid foundation for the continued refinement of AvID. This, in turn, will enhance its ability to meet the evolving needs in avalanche risk assessment, both now and in the future.

REFERENCES

Apple Maps, 2023: Available at: https://www.apple.com/maps/, last access: 7 September 2023.

Floyer, J., Klassen, K., Haegeli, P., and Horton, S.: Looking to the '20s: Computer-assisted avalanche forecasting in Canada, Proceedings of the International Snow Science Workshop, CO, 1245-1249, 3-7 October 2016.

Google Maps, 2023: Available at: https://maps.google.com, last access: 7 September 2023.

Horton, S., Nowak, S., and Haegeli, P.: Enhancing the operational value of snowpack models with visualization design principles, Nat. Hazards Earth Syst. Sci., 20, 1557–1572, https://doi.org/10.5194/nhess-20-1557-2020, 2020.

Horton, S., Haegeli, P., Klassen, K., Floyer, J., and Helgeson, G.: Adopting snowpack models into an operational forecasting program: Successes, challenges and future outlook, Proceedings of the International Snow Science Workshop, Bend, OR, 8-13 October 2023.

Nowak, S., Bartram, L., and Haegeli, P.: Designing for ambiguity: Visual analytics in avalanche forecasting, 2020 IEEE Visualization Conf., 81-85, https://doi.org/10.1109/VIS47514.2020.00023, 2020.

Nowak, S. and Bartram, L.: I’m Not Sure: Designing for Ambiguity in Visual Analytics, Graphics Interface 2022 Conf., 2022.

Nowak, S. and Bartram. L: Designing for Ambiguity in Visual Analytics: Lessons from Risk Assessment and Prediction, To appear in 2023 IEEE Visualization Conf., OSF [preprint], https://osf.io/y35u4/, 2023.

Rigby, D. K., Sutherland, J., and Takeuchi, H.: Embracing Agile: How to Master the Process That's Transforming Management, Harvard Bus. Rev., 94, 40–50, May 2016.

Ruginski, I. T., Boone, A. P., Padilla, L. M., Liu, L., Heydari, N., Kramer, H. S., and Creem-Regehr, S. H.: Non-expert interpretations of hurricane forecast uncertainty visualizations, Spatial Cognition & Computation, 16, 154-172, https://doi.org/10.1080/13875868.2016.1138117, 2016.

Shneiderman, B.: The eyes have it: A task by data type taxonomy for information visualizations, Proc. 1996 IEEE Symp. Visual Languages, Boulder, CO, 336–343, https://doi.org/10.1109/VL.1996.545307, 3–6 September 1996.

Statham, G.: Avalanche hazard, danger and risk - A practical explanation, Proceedings of the International Snow Science Workshop, Whistler, BC, 224-227, 21–27 September 2008.

Statham, G., Campbell, S., and Klassen, K.: The Avalx public avalanche forecasting system, Proceedings of the International Snow Science Workshop, Anchorage, AK, 165-171, 16-21 September 2012.

Tversky, B.: Visualizing Thought, Topics in Cognitive Science, 3(3), 499 535, 2011.

Ware, C.: Information Visualization: Perception for Design, Morgan Kaumann, 2004.

WCAG (Web Content Accessibility Guidelines) 2.1, 2018: Accessed from https://www.w3.org/TR/WCAG21, last access: 7 September 2023.

Nakazawa, S. and Tanaka, T.: Development and Application of Kanban Tool Visualizing the Work in Progress, 2016 5th IIAI Int. Cong. Advanced Applied Informatics, Kumamoto, Japan, 908-913, doi: 10.1109/IIAI-AAI.2016.156, 2016.