Geomatics use in fieldwork for public avalanche forecasting: Yukon case study

Abstract:

In the winter of 2012 the Canadian Avalanche Center in collaboration with the Yukon Avalanche Association unveiled a new public avalanche forecast for the Yukon and Northern BC. The development of this program is detailed in a companion paper (Smith & Sharp, 2012). The Klondike forecast region is characterized by an absence of the data streams that traditionally form the foundation of regional public avalanche forecasting in Canada. A pilot field program was tasked with developing systems to gather, synthesize and communicate data on avalanche occurrences, trends in the snow pack, and local weather observations. This program faced a variety of operational challenges but also presented an exciting opportunity for experimentation and innovation.

This paper explores how geomatics provided effective solutions to overcoming some of the operational challenges faced by the field program. A geographic information system is described that was instrumental in cataloging resources, terrain photos, and information about recreational use in the forecast area. It also aided in the exchange of field observations between the local field team and the forecast team based in Revelstoke BC, over 2000 km away. In addition spatially track the field team's movements helped target observations and ensure a broad dispersion of data sampling.

After a successful first season, avenues for further development include: 1) calibrating and incorporating numerical snow pack simulation models to augment field data in the region; and 2) further developing the use of geomatics to analyze and categorize terrain in order to better target observations and improve operational efficiency.

1. Introduction

In the winter of 2012 the Canadian Avalanche Center (CAC) in collaboration with the Yukon Avalanche Association (YAA) unveiled a new public avalanche forecast region covering an area of Southwestern Yukon and Northwestern BC. The development of this program is detailed in a companion paper (Smith & Sharp, 2012). The CAC's Klondike forecast region lies at sixty degrees north and straddles the western edge of the border between British Columba and the Yukon Territory. Although its boundaries are still under refinement the region covers roughly 4000 square kilometers of the Boundary Range of the Coast Mountains. It is a region characterized by highly variable snow pack, relatively low user density, and an absence of the data streams traditionally relied upon to forecast avalanche hazard in Canada.

The CAC has been producing public avalanche forecasts for recreationalists in Western Canada for 20 years. These forecasts, written by forecasters based in Revelstoke, BC have traditionally been largely based on snow pack, weather and avalanche observations submitted by avalanche professionals from across the region through the InfoEx network. This approach has been demonstrated to produce forecasts that accurately capture local conditions, but its efficacy is dependent on data density (Jamieson et al. 2008). Typically five or more professional operations provide daily reports for each for the CAC's larger forecast regions. As a result, this standard operational model was not appropriate for the data-sparce Klondike region.. Adapting its operational model, a pilot project was undertaken with a field programme staffed by CAC employees based in Whitehorse run out of the CAC's forecast office in Revelstoke, 2000km to the south.

In its inaugural year the Klondike Field Program was staffed by two fulltime avalanche technicians. From December 2011 through May 2012 the field team spent three to four

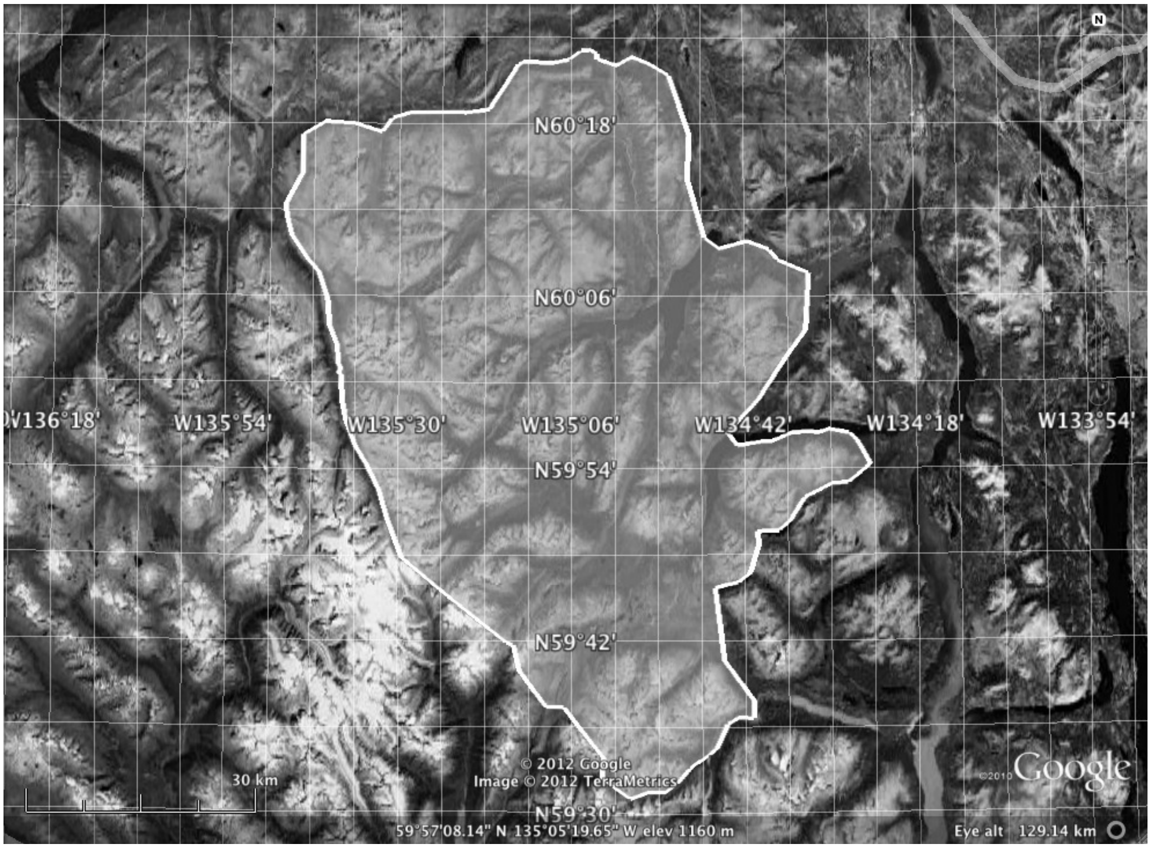

Fig 1. Klondike forecast region

days a week gathering snowpack, weather and avalanche observations which they forwarded daily to forecasters in Revelstoke. In addition, the team synthesized daily localized nowcasts of current conditions and avalanche hazard, enabling them to apply and communicate their cumulative knowledge of the region and local snowpack. Even with a dedicated team in the field the data density for the region was significantly lower than in the CAC's established regions to the south. The combination of grappling with data limitations, a new geographic region, and learning the spatial patterns of "avalanche climates" located within the region, we decided not to implement an Avalanche Forecast, similar to those produced for southern regions, during the first winter. Instead, a weekly Avalanche Conditions Summary was created. These summaries provide an overview of the current snowpack structure and avalanche problems across the region, supplemented by a description of the avalanche concerns expected in the coming days. The program's cruxes were:

- Building data density. Over the course of a four day shift one field team needed to gather a broad sampling of observations from across a 4000 square kilometer region.
- Overcoming spatial variability. The region is characterized by a high degree of spatial variability due to the transition from a maritime to continental climate, coupled with a strong wind regime.
- Communication. The field team needed to synthesize these observations and communicate a comprehensive nowcast of the avalanche danger in the region.

2. Yukon Forecast Region

The topography of the Yukon Forecast region is highly variable. The southern end of the region was sculpted by a period of heavily glaciation and is comprised of a complex assembly of peaks, deep U-shaped valleys and small glaciers. The north end of the region avoided this most recent glaciation and is characterized by rolling alpine plateaus broken by the occasional exposed batholith and split by a network of steep V-shaped valleys. The majority of summits of the region lie between 1800m and 2000m ASL and relief ranges from 800m to 1200m. Tree line is roughly 950m ASL and as a result alpine features dominate the landscape.

The typical winter weather pattern for the area is a strong south to southwest flow driven by the Aleutian Low. The forecast region lies along the boundary between the maritime arctic climate to the southwest and a continental arctic climate to the north. The topographical barrier of the Coastal Range often results in tight pressure gradients parallel to the Lynn Canal and resulting in strong south winds. In 2012, these winds were observed to be the primary modifier of the snow pack.

The region exhibits a high degree of spatial variability in snowpack over a small area. On average, Camp Fraser in the south of the region receives 689% more precipitation between October and May than Annie Lake 30 kilometers to the north which also typically experiences cooler temperatures (Water Resources Branch Environment Yukon, 2012). The region can be broken up into three distinct avalanche climates with a costal snowpack in the south of the region, a continental snowpack in the north and a classic transitional pack between the two (McClung & Schaere, 2002). Although it may be more accurate to think of these descriptors not in their classical sense but as quasi-snow climates, since each receive significantly less precipitation and dramatically cooler temperatures than the associated snow-climate further south.

3. Operational Challenges

The primary objective for the Yukon Field Team in the 2012 winter season was to gain familiarity with the region and to develop an effective data stream for the CAC's forecast office. This involved building a new program in a new area (new for both the field technicians and the Revelstoke based forecast team with little historical data available. The team faced three primary operational challenges:

a. The field team needed to quickly explore the region and become familiar with snow-climatic zones, the prevailing weather patterns, and character of avalanche problem across the area. This required an early-season focus on obtaining a broad sampling of observations from across the region from which trends to be geospatially extrapolated.
b. Daily operations were conducted out of a Yukon Highways Camp at Fraser BC. Phone and a low bandwidth Internet connection were the only communication channels available from this remote location. A lightweight communications system was required to facilitate the sharing of daily snowpack weather and avalanche observations with the forecast team. Ideally, this system would also allow the forecast team to frame these observations within their cumulative knowledge of the operational area.
c. With a small field team operating in a large forecast area, a tool was needed to help with operational planning and to maximize the teams efficiency in the field.

4. Geomatics Solutions

Since many of the operational challenges faced by the field team had a geospatial component, geometrics were identified early in the project as having a potentially powerful role in the program. A rudimentary geographic information system was designed and implemented in Google Earth by the field team to manage field observations and operational data with three primary goals in mind:

a. To provide a topographic framework in which to geospatially record observations, extrapolate trends from field data and capture the field teams cumulative knowledge of the area.
b. To facilitate in the communication of weather data, snowpack factors revealing structural weaknesses, and direct observations of instability such as avalanches or stability tests.

c. To aid in the visualization of spatially referenced data in order to facilitate operational planning.

It was identified this geospatially-referenced data set could be useful to advanced recreationalist in their decision-making. The system was designed so that field data could eventually be made available for public consumption.

4.1 Data Model

With limited historical data to import the onus was on the field team to populate the dataset. The team strived to geospatially reference data collected whenever possible. GPS locations were recorded for all field observations including graphs of full and test snow profiles, photographs of avalanche occurrences and videos of snow pack test. These observations were catalogued by region and date. A photographic terrain atlas was compiled using a GPS enabled camera. Terrain photographs were catalogued by region; drainage, feature and the aspect that they captured. The locations from were the photographs were taken was recorded in their metadata. Remote weather station telemetry was captured in time series graphs. Referenced by the GPS location of the weather station and catalogued by site. Daily operational activity was tracked using a mapping GPS: access and egress routes were saved as track files, trailheads, helicopter landings, and common field study sites were saved as points of interest. Observations of recreational usage were recorded and catalogued by region and drainage. Reported avalanche involvements were recorded with a GPS location whenever possible and catalogued according to date.

4.2 Implementation

The classes of data contained in this data set could all be geospatially referenced through vector objects. Google Earth was chosen as the best software alternative with which to implement the system in this pilot phase. It was identified as a free, vector based lightweight software package with sufficient functionality for the initial data model.

Field observations were referenced through points compiled in layers defined by the observation type. These points were typically linked to web hosted media files such as profile graphs, photographs or videos. The photographic terrain atlas was compiled in a layer of points representing the locations from which the photographs were taken. These points referenced web links to the photographs themselves. Web links to raw weather station telemetry and time series profiles were compiled into a layer of points representing the various weather stations available to the program. Operational resources and a log of operational activities were collected in additional layers in the system. Lines represented commonly used access and egress routes, and points represented and trailheads, helicopter landings and standard field sites. Whenever appropriate, these objects were supplemented with descriptions of the trail or site in their metadata. As the season progressed and the field team developed an understanding of recreational usage patterns across the region, usage observations were analyzed and polygons were drawn to represent high usage drainages. As the field teams understanding of the region developed, polygons were created to represent snow climatic zones across the region.

System data was uploaded and stored on the CAC's ftp server so as to be web accessible. The GIS was saved as a Google Earth *.kmz file that was also hosted on the CAC ftp server. This hosting model was chosen anticipation of making the system publically available. At the end of every field day the field team uploaded and catalogued newly connected data onto the server. To access the system a forecaster could either download the most recent version of the *.kmz file from the server and open it in locally with Google Earth or access the hosted file remotely through an online Google Maps portal.

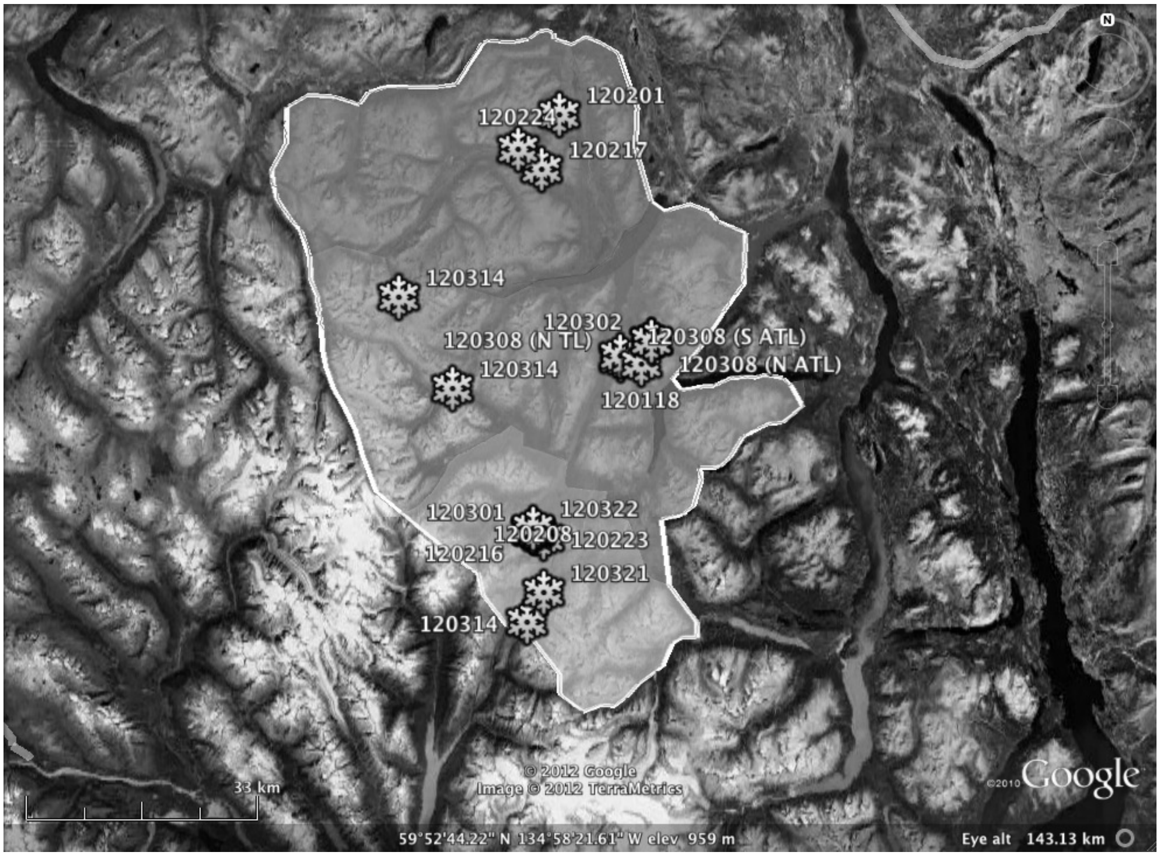

Fig 2. Sample system output: Klondike field team test profile locations from March and April 2012

5. Discussion

Although the system was a rudimentary and inelegant solution the team found it achieved all of its objectives, albeit with varying degrees of success. Over the course of the 2012 season a geospatially referenced data set was developed which eventually included 45 snow profiles, 20 videos of snow pit tests, pictures of 32 avalanche occurrences, a terrain atlas with over 300 photos, time series profiles for 3 remote weather stations, observations of recreational backcountry usage, records of avalanche involvements, and a log of operational activities. In compiling this data into a geographic information system a valuable communications tool was developed. The system allowed Revelstoke based colleagues with little direct knowledge of the region to visualize the topography of the terrain and character of the avalanche problem across the forecast area. The system also provided regional framework in which to interpret the field teams daily observations.

By aiding visualization the distribution of observations made across the region over the course of the season, facilitated a better understanding of the snowpack structure and weather patterns across an area, that was otherwise too vast to fully explore. In addition, the ability to define polygons representing areas of similar snowpack layering allowed the team to capture and communicate what they often observed to be dramatic variation in avalanche stability across the region.

Finally, as data populated the system over the course of the season, operational efficiency benefited. The ability to visualize the pattern of the field team's activities and more importantly identify areas of data scarcity ensured that fieldwork was effectively distributed across the region. The choice of Google Earth with its intuitive interface and limited complexity made for a simple workflow at the end of the day, in a facility limited bandwidth.

While the data model is sound, several shortcomings with the system became apparent. The simplicity for which Google Earth was chosen also limited the analytical ability of the system and over the course of the season the potential of the system out grew the functionality of the platform. Although it was decided during the design phase that vector representation of collected data would suffice, Google Earth's inability to deal with raster objects and perform terrain analysis on digital elevation models limited the functionality of the system.

Although hosting the systems data on the CAC's ftp server was an easy solution to implement, it came with management issues. Ftp hosting meant that both the Google Earth *.kmz file and system data could not be modified remotely but needed to be downloaded, edited and then uploaded again. This made the system vulnerable to data loss and corruption in a multi-user. Ftp hosting was initially chosen for the potential for the data to be made publically available. However, the data model as designed, did not have the ability to limit access to sensitive or private data and information privacy concerns with demographic information and avalanche involvement records, meant that the system has not yet been released

6. Conclusion

Overall, the system proved its worth to the Yukon Field Program in the 2012 season, but several shortcomings were also identified. Moving forward the system has room for development. Data management issues need streamlining and a solution needs to be developed to allow public access to selected datasets. Implementing the system on another software platform with the ability to handle raster objects would allow for an increased capability for terrain analysis such as the identification of areas with specific terrain characteristics where a particular weak layer may be expected to exist (Shea, 2011).

The data model itself could be developed to capture greater detail in the reporting of avalanche occurrences. For example, identifying, mapping, and monitoring frequent flyer avalanche paths would provide gauge to understand and compare avalanche cycles in this large region. The usefulness of the terrain atlas could be improved by implementing it as photographic overlays as opposed to points linked to images. Over the long term the vision for the system is to incorporate numerical model outputs such as GEM and SWarm overlays following the model implemented in Google maps API ARFI (Shea and Jamieson, 2010). Numerical snow pack models could also be implemented as they are refined and validated for data scarce regions such as the Klondike Forecast region (Bellaire, 2012). However, exploration in these directions would require a greater investment in time and resources.

The rudimentary geographic system designed and implemented by the Yukon field program in its inaugural year barely scrapes the surface of the potential of these technologies in public avalanche forecasting. The program found that the use even basic visualization assists in the process of communicating snow pack, weather and avalanche observations and their patterns. This in turn facilitates the synthesis of a large data set of observations into a cumulative understanding of the avalanche concerns across a region.

7. Acknowledgments

The CAC Klondike Field Program would not have had the success that it did in the 2012 field season with out the cooperation, support and hard work of both the Canadian Avalanche Center and Yukon Avalanche Association. In particular we are indebted to James Floyer and Penny Goddard for their feedback and encouragement through out this project.

We are especially grateful to the late Cora Shea for her pioneering working this field.

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