UAV BASED WORKFLOW FOR FAST AND ACCURATE HS AND SNOW DISTRIBUTION IN HIGHWAY AVALANCHE FORECASTING

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ABSTRACT: Aerial remote sensing can provide important insights in the distribution of snow which is of importance for avalanche forecasting. We tested the use of a low-cost UAV on several use cases, including location and effect of shots and removal of snow from roads and highways. We found that the Digital Elevation Models allowed for measuring changes of snow surfaces with a precision in the ~10 - 20 cm range depending on the weather and snow surface conditions. For all use cases this resulted in the acquisitions of actionable data to guide avalanche forecasting activities. The low price and ease-of-use including preprogrammed automated missions combined with cloud based analysis and data sharing makes the tested UAV workflow a valuable forecasting tool.

KEYWORDS: remote sensing, UAV, snow depth, avalanche forecasting

1. INTRODUCTION

Avalanche forecasting is complex and data of snow distribution plays in important role in many decision-making processes. There are various ways to acquire these data, ranging from snow probing to more technological advanced techniques like aerial remote sensing. In this paper we present the results of a study where a small Uncrewed Aerial Vehicle (UAV) was used to remotely obtain data on snow distribution in various use cases. The workflow consists of the sequential acquisition of aerial data sets of areas of interest, such as avalanche start zones, and compare changes in Digital Elevation Models (DEMs) constructed of this data using photogrammetry. Through subtracting one DEM from another, i.e., DEM differencing, we can look at the change of HS through time. This can be between the barren ground and snow on DEM giving the absolute HS, but it can also be used to quantify snow displacement and shot positioning to guide future adjustments. We tested our workflow in the field on a variety of use cases to assess how well we can locate changes in HS snow.

2. MATERIAL AND METHODS

2.1 Study site

We conducted surveys at Washington Pass and Stevens Pass. Washington Pass was visited between 17-19 April 2023 and Stevens Pass was visited during 20-21 April 2023. At Washington Pass we mapped the avalanche chutes Liberty Bell 2 and 3 and a stretch of HW20 before and after avalanche control with a Howitzer. At Stevens Pass we mapped Greg's Meadow and Shot 6 before and after the Avalanche Guards (Remote Avalanche Control Systems) were used to initiate controlled avalanches.

2.2 UAV and flight parameters

We selected a light-weight quadcopter Autel EVO 2 RTK UAV (https://shop.autelrobotics.com/pages/evo-ii-rtk-series) for aerial mapping for several reasons. It has ~30 minutes flight time and provides reliable and safe flights at low temperatures. Because of its relatively low weight and small size it is well suited for launching and landing in areas with limited space, such as mountain tops and roadsides. It is equipped with a high precision GNSS receiver and is RTK enabled which allows for cm-level positioning which is required for the construction of accurate maps by means of photogrammetry without the need for Ground Control Points. We worked with five spare batteries which were kept warm before being used.

Flight elevation was approximately 75m above ground level and the forward overlap 80% and side overlap 60% with a nadir camera position. The missions required one to two flights. We used UgCS software (www.ugcs.com) for mission planning as it allows terrain following based on an external elevation model. Flight speed was automatically calculated by UgCS.

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2.3 PPK processing and Photogrammetry

We used a Post Processing Kinematics (PPK) workflow for high accuracy geotagging of the images using REDToolBox (www.redcatch.at/redtoolbox) and Emlid Studio (https://docs.emlid.com/emlid-studio/). The output is a text file with accurate locations of the camera positions or updated georeferenced photos (depending on the software used) which is the input for photogrammetry. Due to unforeseen circumstances our Emlid RS2 GNSS base station and survey set were held up at the border and were unavailable in the field. As a substitute we used the base stations of the NOTA GNSS network available through the UNAVCO portal (https://www.unavco.org), with station P434 for Stevens Pass and P413 for Washington Pass.

We used Agisoft Metashape (www.agisoft.com) for photogrammetry. Agisoft Metashape is an advanced desktop program which a high level of user control.

3. RESULTS

Most use case require sequential DEMs to look at changes in HS. With the bare grounds DEMs still to be collected at the time of writing we will focus on the following two scenarios.

3.1 Shot location and effect

We focus of pre and post deployment of the Avalanche Guard at Greg's Meadow. Figure 1 shows an orthomap and DEM before (top panel) and after the shot (bottom panel).

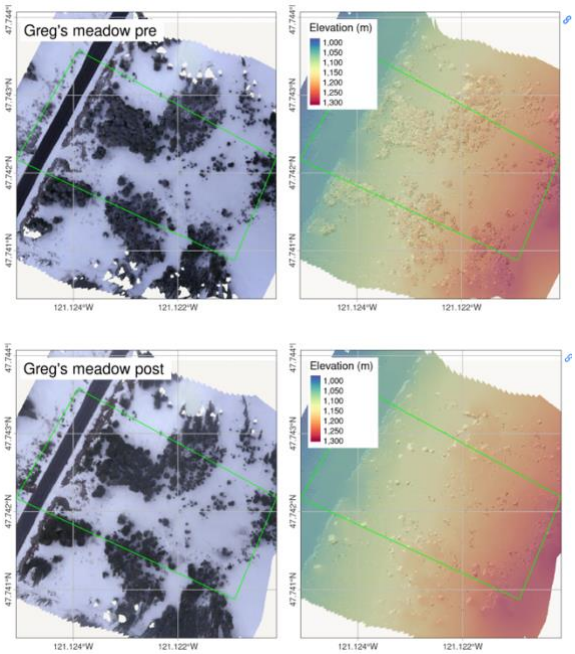


Figure 1 Orthomap and DEM of Greg's Meadows pre and post shot deployment.

The placement of the shot is visible in the orthomap and the exact location can be determined accurately. The difference between the two DEMs is not reliable because it was snowing during the mission after the shots of the Avalanche Guard.

3.2 Road and rail snow removal

The efficiency of measuring HS on seasonally closed passes was tested at Washington Pass. We surveyed a stretch of ~550m in length which was partially cleared. This is illustrated in Figure 2, where during the first flight (DEM 1) the first 220m of the road was covered, subsequently a large increase in HS is visible which is due to avalanche debris and the rest of the DEM is cleared road. The second flight (DEM 2) was taken once the road was cleared and hence represents the road surface.

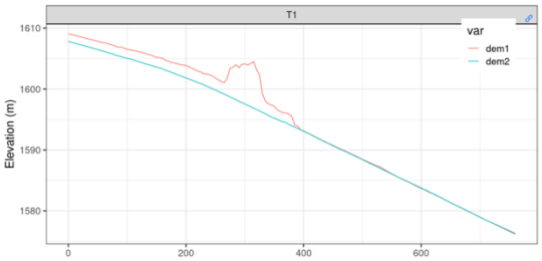


Fig 2. Altitude of the surface on the road. DEM 1 was collected with partial snow removal and DEM 2 after snow removal (the road surface).

Figure 3 shows the area of the avalanche debris in more detail. The left panel shows the avalanche debris presents and the road covered. The central panel shows the road partially cleared. The difference in DEMs between the two states represented in the right panel (post - pre). The dark blue color represents the large volume of avalanche debris removed.

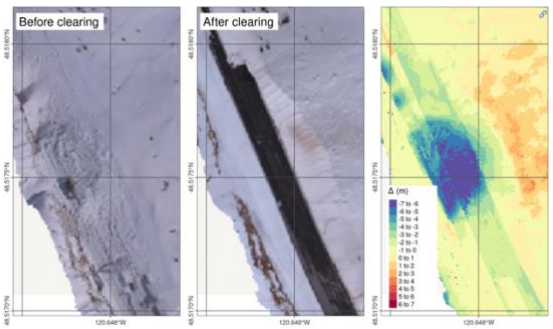


Figure 3. Orthomap of the road covered in avalanche debris (left) and partially removed (central). The right panel is the difference between the post and pre DEMs with increasing intensity of blue representing an increasing amount of debris removed.

4. CONCLUSIONS

We collected UAV based images which we used to construct DEMs and orthorectified maps to look at changes of HS. The placement of RACK shots were visible in the orthomaps and the exact coordinates can be easily extracted in GIS software. This can be useful to assess the effects of the shots and guide future adjustments. The snow displacement after the impact is visible after DEM differencing. Similarly, we can clearly see the avalanche debris on Washington Pass and the effects of snow removal. The HS on the road can be extracted and with the with an estimate of the volume of snow to be removed can be made. This can be very useful for determining the amount of labor and equipment required to clear the pass of snow in spring.

An important limitation of our study is that we had to use the NOTA network base, which especially for Washington Pass was quite far away. We planned and highly recommend using a local GNSS stations and include several Ground Check Points in the surveyed area.

Secondly, the weather conditions can affect the quality of the data collected. For example, the data set post blast of Greg's Meadow at Washington Pass was taking during snow fall which greatly negatively affected the photogrammetry process and hence our ability to quantify the effects of the impact.

Our study shows that data collected with low-costs easy to fly UAVs can be used to provide useful data products to inform avalanche forecasting. We believe that the potential can extend beyond the use cases investigated here and applies to many scenarios involving changes in HS.

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