ABSTRACT: To improve our understanding of avalanche release processes, more accurate avalanche activity data are required. Usually, data on avalanche occurrences are obtained through visual observations from valley bottom at regular time intervals, for instance twice a day. Visual observations are not possible during periods of poor visibility, in remote locations or in hazardous situations. This results in inaccurate data and a bias towards larger avalanches, as these are more easily observed. To overcome these limitations, several remote avalanche detection methods, such as seismic or infrasonic monitoring have been developed. However, these methods can be relatively expensive and have not yet reached a level of reliability required for operational use. We propose a simple alternative using time-lapse photography. Time-lapse photography is a nonintrusive, inexpensive and safe technique that can be used to observe avalanche activity across large areas. It can also be used to measure changes in snow movement and deformation. We have used time-lapse photography to improve glide-snow avalanche forecasting by monitoring glide crack expansion. By counting the number of dark pixels in an area around a glide crack, changes in glide rates are measured. Our results show that time-lapse photography can be used to monitor snow glide rates simultaneously in several start zones and potentially provide insight into when, or if, a glide-snow avalanche will release. We have also used time-lapse photography to better understand processes involved in wet-snow avalanche release, by correlating avalanche occurrences with local meteorological data. Results show that onset of wet-snow avalanching typically occurs during the first period of prolonged above freezing temperatures. Furthermore, there typically is a lag of a few hours between the rise in snow surface temperature and the onset of avalanching. Overall, our results show that time-lapse photography can be used to improve our understanding of processes involved in avalanche formation, and ultimately, improve their forecasting.

KEYWORDS: Time-lapse photography, image processing, avalanche activity, glide-snow avalanche.

1 INTRODUCTION

One of the most striking properties of snow is its distinctive color. Snow wouldn't be snow if it wasn't white. The advantage of this is that when snow falls on the ground, it can easily be distinguished from the surface on which it fell. Time-lapse photography (TLP) is therefore an attractive monitoring method to investigate snow processes. Originally, TLP was developed as cinematographic technique to capture film frames at rates slower than they are replayed to show events much faster than they occur in real life. For research, TLP has been used to investigate various processes ranging from cloudiness to fluvial geomorphology (e.g. Holle et al., 1979; Dexter and Cluer, 1999). Time-lapse photography was also successfully applied to investigate the spatial and temporal patterns of snow distributions at various scales (e.g. Aschenwald et al., 2001; Parajka et al., 2012).

The main objective of this study is to investigate the potential and benefits of TLP for avalanche research. Accurate near real-time avalanche activity data are essential to improve our understanding of avalanche release processes. Usually, such data are obtained through visual observations from valley bottom, resulting in inaccuracies and a bias towards larger avalanches, as these are more easily observed. To overcome these limitations, several remote avalanche detection methods, such as seismic or infrasonic monitoring have been developed. However, these methods can be relatively expensive and have not yet reached a level of reliability required for operational use. We propose a simple alternative using TLP.

Over the last decade, technological advances have increased the supply of digital cameras and dramatically decreased their cost. Time-lapse photography has therefore become an inexpensive monitoring technique. In this paper we will describe two of the TLP systems we have been using for the last five years. Using several examples, we will then highlight the
benefits of using TLP to monitor avalanche occurrences and glide-snow avalanche release.

2 METHODS

2.1 Instrumentation

Starting in the winter of 2008-2009, we used TLP to monitor avalanche activity and glide crack expansion. We installed a first system in 2008 in an office at the SLF in Davos, Switzerland (Feick et al. 2012; van Herwijnen and Simenhois, 2012; Mitterer et al., 2011). The system consists of a digital camera (Nikon Coolpix 4300) connected to a Linux desktop computer. The camera is directed at the Dorfberg field site above Davos, a large SE facing slope where glide-snow and wet-snow avalanches often release (Figure 1a). Using gphoto2 (www.gphoto.org) we wrote a script running on the desktop computer to capture and store images at regular intervals. During the first four winters, images were taken every 15 minutes, while during the winter of 2012-2013, images were stored every two minutes.

We installed a second mobile system in 2009 at the more remote Wannengrat field site above Davos (van Herwijnen et al., 2010). This system consists of a solar powered camera (Canon Powershot A470) mounted in a protective housing on an automatic weather station at the top of a ridge at 2475 m.a.s.l. The camera is directed at a large NE to SE facing avalanche start zone to monitor avalanche activity (Figure 1b). Using CHDK (chdk.wikia.com), we wrote a script running on the SD card to capture and store images every 5 minutes. The images were then manually retrieved approximately every 10 days.

2.2 Image processing techniques

To analyse the time-lapse images we used methods based on 1) visual inspection, 2) dark pixel counting and 3) image correlation. For obvious reasons, images taken at night and during periods of poor visibility (e.g. fog or intense snowfall) could not be used.

Independent of the process under investigation, the first step in our analysis consisted of visually inspecting the images. While this is a relatively time consuming endeavour, it was necessary to remove images of poor quality. Furthermore, it allowed us to obtain accurate avalanche occurrence times (within the recording interval) or determine the first appearance of glide cracks.

To distinguish pixels with snow from those without snow, we used a method based on dark pixel counting (van Herwijnen and Simenhois, 2012). Using a pixel intensity threshold, dark pixels (without snow) and bright pixels (with snow) are discriminated. Using this simple technique, we investigated the expansion of glide cracks prior to glide-snow avalanche release.

Finally, with image correlation, we analyzed the displacement field in the images with a particle image velocimetry (PIV) algorithm (e.g. Reiweger et al., 2009). The PIV algorithm recognizes patterns on a digital image and tracks them over subsequent frames to obtain displacement measurements. We used PIV to determine the area of the snow cover which moved below glide cracks.

3 RESULTS AND DISCUSSION

3.1 Avalanche occurrences

The transition from winter conditions with dry-snow avalanching to spring conditions dominated by wet-snow avalanching generally starts on low to mid elevation southerly slopes. The Dorfberg field site is therefore well suited to study this transition and it has a well documented history of wet-snow avalanche activity. For the last five years, we have used TLP to monitor the onset of wet-snow avalanching (e.g. Mitterer et al., 2011). Our results show that the first wet-snow avalanche cycle typically coin-
decided with the first period of prolonged above freezing day-time temperatures (Figure 2). During the winter of 2008-2009 this was in early April, while during the winter of 2011-2012 wet-snow avalanching already started at the end of February. Note that during the winter of 2009-2010 there was no wet-snow avalanche activity at the Dorfberg site. We attribute this to the unusually warm winter with relatively little snow.

During the spring of 2013, from 28 February to 13 March, a relatively widespread wet-snow avalanche cycle occurred. Avalanche activity observed on the time-lapse images correlated well with snow surface temperature (top Figure 3), in line with recent studies on wet snow avalanches (Mitterer and Schweizer, 2013; Schmid et al., 2012). The detrended cross correlation (for details see Zebende, 2011) of avalanche activity and snow surface temperature shows that there were three typical time scales involved in this wet-snow avalanche cycle:

1. there was a lag time of about 5 hours between the onset of avalanche activity and rises in snow surface temperature;
2. there was a clear diurnal cycle and
3. there was a progressive relaxation of avalanche activity on the order of 4 days. Given the short investigation time period, our results are very preliminary. Nevertheless, they highlight the potential to improve our knowledge on processes involved in wet-snow avalanche formation using accurate avalanche activity data.

3.2 Glide crack expansion

Glide-snow avalanches typically release on slopes with relatively little ground roughness (e.g. grassy slopes or smooth rock faces). Since 2008, we observed numerous glide cracks using TLP, especially at the Dorfberg site in Davos. Many glide cracks appeared without resulting in avalanches and many glide avalanches re-

Figure 2: Air temperature from January to the end of April from 2009 to 2013. The first wet-snow avalanche cycle observed on the time-lapse images are highlighted with the colored boxes.

Figure 3: (top) Avalanche activity (N$_{av}$) and snow surface temperature (T$_{ss}$) with time. (bottom) Detrended cross correlation (DCCA) of N$_{av}$ and T$_{ss}$. The arrows indicate the three time scales involved in this wet-snow avalanche cycle.

Figure 4: Top: Two glide-snow avalanches released on 23 and 24 December 2012. Bottom: Changes in glide rates were tracked by counting the number of dark pixels around the glide crack for the first (left) and second (right) avalanche.
leased shortly after the appearance of a glide crack. During the winter of 2012-2013 we therefore increased the image recording rate to 2 minutes to better investigate glide-snow processes.

From 22 to 28 December 2012, relatively warm air moved over the European Alps. As a result of this event, two glide snow avalanches released on 23 and 24 December 2012 at the Dorfberg field site (top Figure 4). By counting the number of dark pixels in an area around the glide cracks, we observed an increase in glide rates shortly before the release of both avalanches (bottom Figure 4), similar to the results found by Stimberis and Rubin (2009) using a glide shoe. The advantage of using TLP is that several start zones can be monitored at once. Using image correlation, in some cases it was possible to estimate the total area of the snow cover which was gliding below the glide crack. Indeed, for a glide-snow avalanche which released on 26 December 2011, we were able to determine the contour of the snow slab that would release (Figure 5). The estimated slab contour, determined by using a threshold to distinguish actual movement from background noise, compared well with the actual release area (bottom right in Figure 5).

4 CONCLUSIONS

In this study we highlighted the usefulness of time-lapse photography for avalanche research. Clearly, TLP suffers from the same problems as conventional visual observations (i.e. impossible at night or when the visibility is limited). Nevertheless, it can provide valuable and novel insight into various processes related to avalanche formation.

Using visual inspection, dark pixel counting and image correlation, we showed that TLP can be used to investigate avalanche occurrence and glide crack expansion. Our results showed the potential to improve our knowledge on processes involved in wet-snow avalanche formation using accurate avalanche activity data from TLP. Furthermore, we showed that TLP could be a very useful tool for forecasting the release time and size of glide-snow avalanches.

5 REFERENCES


