SNOW CHARACTERIZATION BY FACET NUMBER AND SIZE FROM SNOW PIT WALL PHOTOGRAPHS

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ABSTRACT: Faceted snow within a natural snowpack often weakens its stability, with depth hoar being a prime example for a persistent weak layer. Traditionally, possible weak layers are detected by hand measurements of snow properties like snow hardness, density, grain size and grain shape. In recent years, several techniques have been developed to determine snow grain size by diffuse reflectance measurements at near-infrared wavelengths in the laboratory and in the field. However, it has not been possible to gather additional information about grain shape. Here, we present first steps towards a possible measurement method to detect facet number and size within the snow. The method involves taking a picture of a snow pit wall with a flash without additional natural or artificial lighting to guarantee directional lighting within a small angle of incidence. After filtering, number, size and distribution of specular highlight pixels then indicate regions of faceted or rounded snow. We find a qualitative agreement between our measurements and expected results for three snow types: Depth hoar, faceted crystals and small rounded grains from wind-pressed snow.

1. INTRODUCTION

Snow grain type is one of the major properties recorded in a snow profile as the snow stratigraphy determines the stability or instability of the present snowpack. Persistent weak layers within a snow cover where dry slab avalanches initiate are composed of snow types with planar faces in contrast to snow with a rounded structure. Snow types that form these weak layers are faceted crystals, surface and depth hoar (Schweizer et al., 2003).

Hence, one crucial observation for avalanche forecasting is the distinction between snow which is mainly composed of facets and rounded snow grains or crusts. In recent years, optical measurements of snow have been performed to quantify snow and ice properties like grain size, density and light absorption by diffuse reflectance and transmittance measurements (Warren et al., 2006; Matzl and Schneebeli, 2006; Gallet et al., 2009; Gergely et al., 2010). Here, multiple scattering within the snow cover is analyzed to determine physical properties which are integrated properties over a snow volume of several cm^3 depending on the wavelength of the used illumination and the snow type. However, it has not been possible to gain information on grain shape from these methods.

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In our study, we present first steps towards a snow profile analysis using facet number and size as the discriminating factors for snow stratigraphy. The method is based on simple snow pit wall photographs. Theory and methodology are explained in the next section. Then, first test results of a snow pit wall are shown. This leads to an outlook for this preliminary study, which are necessary for a detailed and quantitative analysis.

2. SNOW PIT WALL PHOTOGRAPHY

Our measurement method is based on specular reflections from planar ice-to-air interfaces within the snow. These reflections are detected by a digital camera.

2.1 Theory

In contrast to diffuse reflectance of snow specular reflection highlights are caused by a mirror-like reflection of light at an air-to-ice interface. This is a single reflection event at the ice surface and not multiple scattering within a snow volume.

If the angle of incident parallel light is equal to the viewing angle of the observer with respect to the reflecting surface a bright specular highlight is visible. For all other viewing directions only the diffuse background reflectance from multiple scattering within the snow can be detected.

Accordingly, we expect to find more and larger specular highlights for snow types with large planar faces than for snow types consisting mainly of rounded ice structures.

2.2 *Method*

The experimental setup is shown in Figure 1. An image of a snow pit wall is taken by a digital camera with flash while the surrounding light is blocked by a black cover. Another image of a homogeneously reflecting standard surface can be used for normalization.

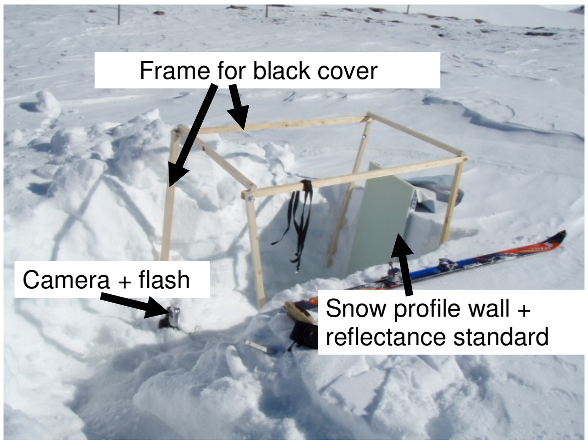

Figure 1: Experimental setup for snow pit wall photography in the field.

The flash serves as a source of directional light. Although a camera flash does not emit perfectly parallel light we found it to be sufficient and simple to use for our test measurements.
For the analysis the RGB images are first converted to greyscale images. Illumination inhomogeneities are corrected by dividing the pixel intensities of the snow pit wall image by the respective values of the image taken of the homogeneous standard material.
Then, an image of the diffuse background reflectance is obtained by a morphological opening of the normalized intensity image. The size of the structure element to perform the opening is chosen manually so that the biggest visible specular highlight of the normalized image is just removed. This background image is then subtracted from the normalized image to obtain an image which only shows the intensity differences to the diffuse multiple-scattering background.
Finally, a binary image is created by thresholding. Here, black represents the pixels of diffuse background reflectance while the specular highlights show up in white. Like the structure element size for opening, the threshold intensity of the difference image is chosen manually. Number and size of the highlighted regions can then be analyzed.

3. TEST RESULTS

Our measurement method is based on the detection of planar ice faces within the snow by taking just one picture from one viewing direction. Obviously, with one picture only a small fraction of the total number of planar faces can be detected. Nevertheless, if the distribution of these facets within the snow is isotropic one image can reproduce this distribution accurately.
Even for our depth hoar sample we found that the planar faces were indeed distributed approximately isotropically due to the complex vapor flux throughout the 3-dimensional snow structure. A micro-computed tomography image of depth hoar with highlighted facets is shown in Figure 2.

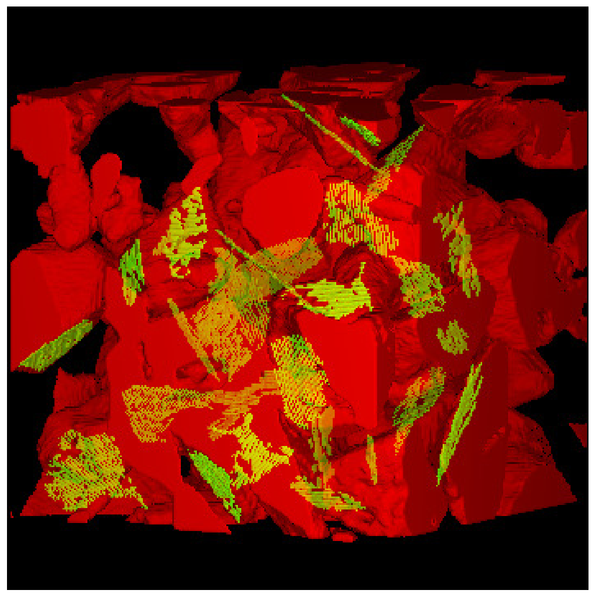

Figure 2: Micro-computed tomography image of a 3 x 3 x 3 mm^3 snow sample. Ice is shown in red, planar ice faces are highlighted in green. Facets were visualized by curvature thresholding.

Results of one snow pit wall image are presented in Table 1. Generally, the fraction of specular highlights of the total number of pixels is very small. However, this is a reasonable result considering the low percentage of facets overall (Figure 2) and the very confined angular resolution due to only taking one single camera image of the snow pit wall.
As expected, depth hoar contains the largest detected facets, on average as well as with regard to maximum size. The surprisingly high number of maximum and mean specular highlight area for wind-pressed snow, which consisted of small rounded grains, is probably due to one stray larger faceted crystal which was deposited on the snow

Table 1: Area A of specular highlights for 3 snow types of one single snow pit wall photograph. Snow types were assigned from additional hand measurements. Maximum and mean number of pixels of contiguous specular highlight regions are denoted A_max and A_mean, respectively.

	Depth hoar	Faceted crystals	Wind-pressed
A_max [px]	29	14	22
A_mean [px]	2.8	2.1	2.2
A [%]	0.06	0.07	0.02
A > 1 px [%]	0.025	0.03	0.006

pit wall within the wind-pressed layer while digging the snow profile. The second-largest detected highlight area is only 7 pixels while the analysis of the snow type 'faceted crystals' showed several detected highlights with an area of more than 7 pixels.

For all 3 snow types specular highlights of a size of 1 pixel were by far the most common. So, the mean specular highlight pixel number is still within 30 % of each other.

'A' and especially 'A > 1 px' (specular highlights with an area of more than 1 pixel) are a better measure for how many facets are present within the analyzed snow profile region.

For quantifying the size of the facets A_max can give reasonable results once the snow pit wall is prepared carefully and no stray snow from other regions is deposited within the analyzed snow profile.

Choosing other parameters which are easily derived from the area of the specular highlights like a diameter for equivalent spheres or an ellipsis major axis length does not alter our results and possible interpretations significantly.

But, we found that thresholding (see Section 2.2) can have a significant effect on the results. If the threshold is chosen too high larger contiguous regions of specular highlights which can already be identified visually in the original image shrink excessively. If the threshold value is chosen too low intensity variations which are not caused by specular highlights (like variations due to small ridges and grooves in the snow pit wall) are falsely recognized as such and thus attributed to facets which are not present in the photographed snow profile. However, in between the two extremes the choice of the threshold only has a minor effect on the parameters presented in Table 1.

4. CONCLUSIONS AND OUTLOOK

We have presented first results of one snow pit wall image analysis for three snow types to deduce facet number and size from estimating the area of specular highlights in the image.

While a quantitative interpretation is not yet possible measurements and expectations agree qualitatively. A more detailed analysis especially for the extreme values of the measured highlight area could reveal more quantitative information.

On the experimental side, the next step is a measurement of a snow pit wall cut from well-described homogeneous snow layers. Snow samples can then be taken and analyzed by micro-computed tomography to compare those measurements to the specular highlights detected in the snow pit wall photograph.

5. ACKNOWLEDGEMENTS

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