THREE-DIMENSIONAL SNOW: HOW SNOW REALLY LOOKS LIKE

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ABSTRACT: The three-dimensional structure of snow is difficult to see, because ice is highly transparent in the visible spectrum. An improved method of the reconstruction and visualization of snow structures has been developed. Using this method, the three-dimensional structure of snow samples with a sidelength of 1 to 30 mm can be reconstructed and visualized on the computer. Samples from all snow types have been reconstructed. In addition, also a few samples of layer interfaces have been investigated. 3-D reconstruction clearly shows the structural instability of such interfaces.

KEYWORDS: reconstruction of snow, methods of preparation

1. INTRODUCTION

Most physical and mechanical properties of snow depend on microstructure. The description of the microstructure of snow was until now limited to plane surface sections or thin-sections with classical, two-dimensional stereological methods. It was realized during the past years that the precise measurement of grains is of limited value to describe the properties in terms of microstructures, but that the connections, the so-called bonds, are of utmost importance. We developed during the past years a method to reconstruct the microstructure of snow efficiently. A typical section with 300 slices can be done within 2 hours.

2. SAMPLE PREPARATION

Snow samples are cast with colored dimethylphatalate. The dimethylphtalate is colored with 0.5% soot black. Snow and filler should be at a temperature of about -3°C. To prevent shrinkholes, it is recommended to cast the samples under vacuum. Size of samples is about 7 cm x 7 cm x 7 cm.

3. SLICING

The frozen samples are cut to the final size with a saw. The smallest dimension of the snow bonds determines the maximal size of a single sample. A bond should be represented by at least 2 pixels (in 2 dimensions).

The maximal size of samples that can be taken under these conditions is between 10 to 40 mm, assuming that images are taken with a digital camera with 1024 x 1024 pixel resolution.The illumination of the samples is crucial. The best contrast can be achieved with a completely diffuse illumination. The diffuse incident light is mostly absorbed by the transparent ice grains and reflected by the filler. Shrinkholes cause specular reflections which are difficult to correct. Using vacuum casting they can be avoided.

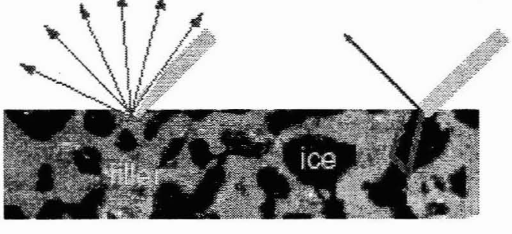

Figure 1: Principle of light reflection and adsorption in a snow sample filled with dimethylphtalate.

4. SEGMENTATION

The segmentation of the images is automated based on the histogram. An algorithm locates the peaks of the image histogram. Then a parabola is fitted between the peaks and the minimum calculated. This method is least influedend by local variations of the histogram and gives a stable estimate of the optimal threshold. The threshold separates ice and air.

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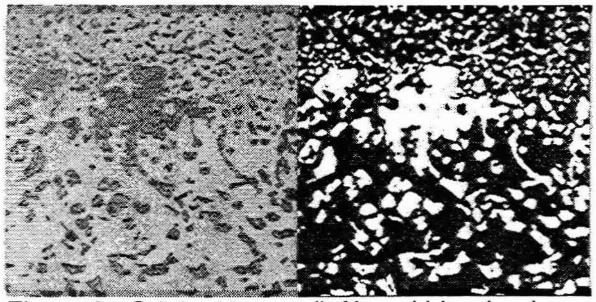

Figure 2: Original image (left) and binarized image (right). The new casting and illumination technique allows to discriminate small and large ice structures in the same image.

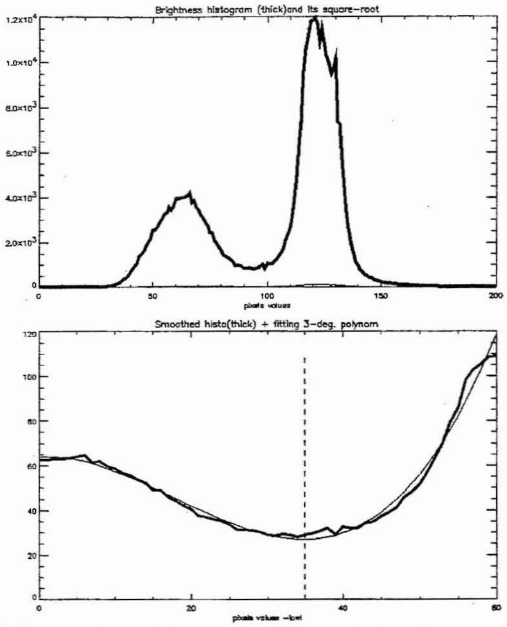

Figure 3: Histogram of the original image (top) and automatic selection of the best threshold (stippled vertical line) for binarization (bottom). With this algorithm variations in the darkness or intensity of illumination are automatically corrected.

5. RECONSTRUCTION

The binarized image is converted to equilateral volume elements (voxels). Unconnected elements can be removed. The data is stored in a byte array. Computer procedures have been developed using IDL (Research Systems Inc.). The 3-D snow structure is visualized using an isosurface algorithm.

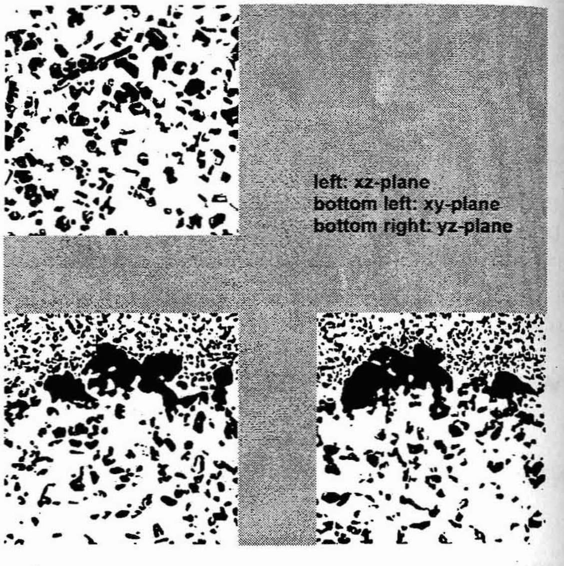

Figure 4: Real and virtual cuts through the reconstructed 3-D snow sample. The cut through the xy-plane is real, corresponding to the surface of the cut sample. The other cuts are calculated based on the reconstruction. The top xz-plane shows faceted crystals cut horizontally.

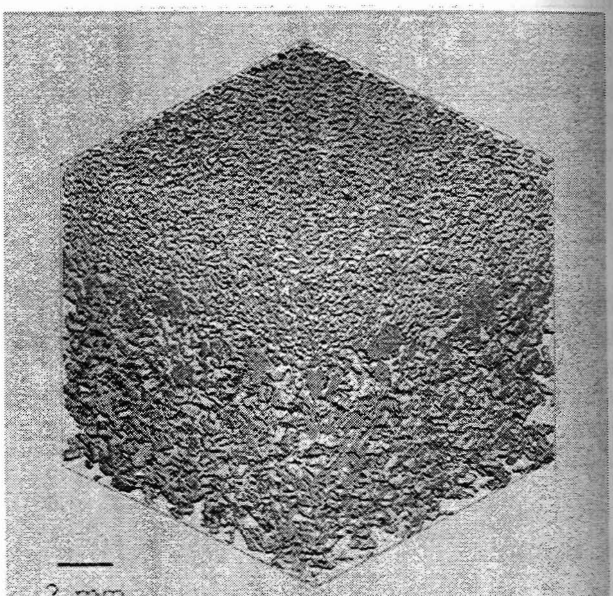

Figure 5: 3-D visualized snow sample. The sample consists of decomposed snow, melt-freeze crust and surface recrystallized faceted crystals (from top to bottom).