

Microstructural Characterization of Snow Metamorphism using X-ray Computed Micro-Tomography

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Snow is a porous material, existing in nature as one of the morphologies of ice. Most snow properties are closely linked to the microstructure of a snowpack. Some properties, e.g. the optical properties of a snowpack, are primarily determined by the ice grains themselves [1, 2]. Other properties, e.g. the thermal conductivity of a snowpack, strongly depend on the bonds between adjacent ice grains [3]. Additionally, lying between the lower atmosphere and the ground, snow plays an important role in the exchanges in mass, heat and chemicals between systems. Therefore, in order to understand the snow properties and the impact of their changes on other geophysical systems, it is crucial to effectively characterize the snow microstructure and its evolution over time.

There has been considerable research on snow morphology, largely using optical microscopy, [the images produced are of](#) low resolution and involve destructive specimen preparation. By using X-ray computed micro-tomography, three-dimensional (3D) renderings of the internal structure of a snowpack can be obtained without physically sectioning the sample. Thus, the structural evolution can be examined both in space and time.

For this project, a Skyscan 1172 X-ray computed micro-tomograph (Micro-CT) in a -10°C cold room was used (Fig. 1). To obtain 3D images and evaluate structural parameters, four sequential steps [needed](#) to be carried out including projection image acquisition, gray-scale cross-sectional image reconstruction, binary image conversion, and 3D rendering creation. Micro-CT imaging is based on X-ray attenuation. Typically, a 40 kV accelerating voltage at a current of 250 μA is used for snow, which yields [detailed](#) contrast between ice and air [4]. An example of the 3D image of an $8 \times 8 \times 8 \text{ mm}^3$ cubic snow specimen is shown in Fig. 2, which was acquired using [a](#) 15 μm image pixel size. The volume fraction of ice and the specific surface area of the ice matrix, [were](#) measured using the Micro-CT, [and](#) are $\sim 11\%$ and 25 mm^{-1} , respectively. In order to examine the structural changes of snow samples over time, periodic observations were performed. Images of [a single](#) snowflake were extracted during post image processing [for](#) comparison, [the example](#) shown in Fig. 3, [is](#) a snow specimen [which](#) was maintained at -5°C for 31 days and periodically examined. As time increased, the crystal gradually lost its fine structure by mass transport mostly from convex areas to hollow depressions. Small branches breaking apart from the central structure [were](#) also observed [5].

References

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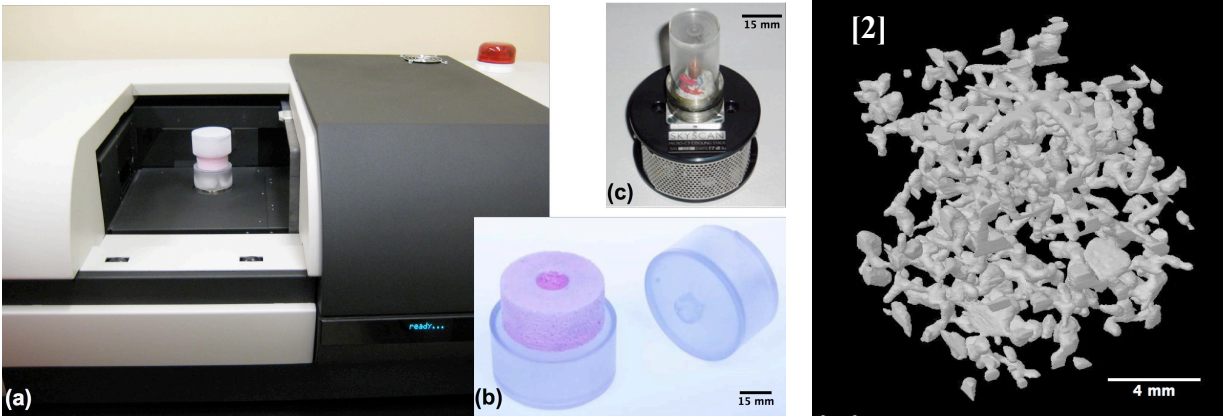


Fig. [1] Images showing the Micro-CT setup: (a) the Skyscan 1172 micro-CT with a specimen mounted on the rotation stage inside the chamber, (b) lab-constructed specimen holder, and (c) the micro-CT cooling stage. [2] 3D Micro-CT image of an $8 \times 8 \times 8 \text{ mm}^3$ cubic snow specimen, which was acquired using $15 \mu\text{m}$ image pixel size.

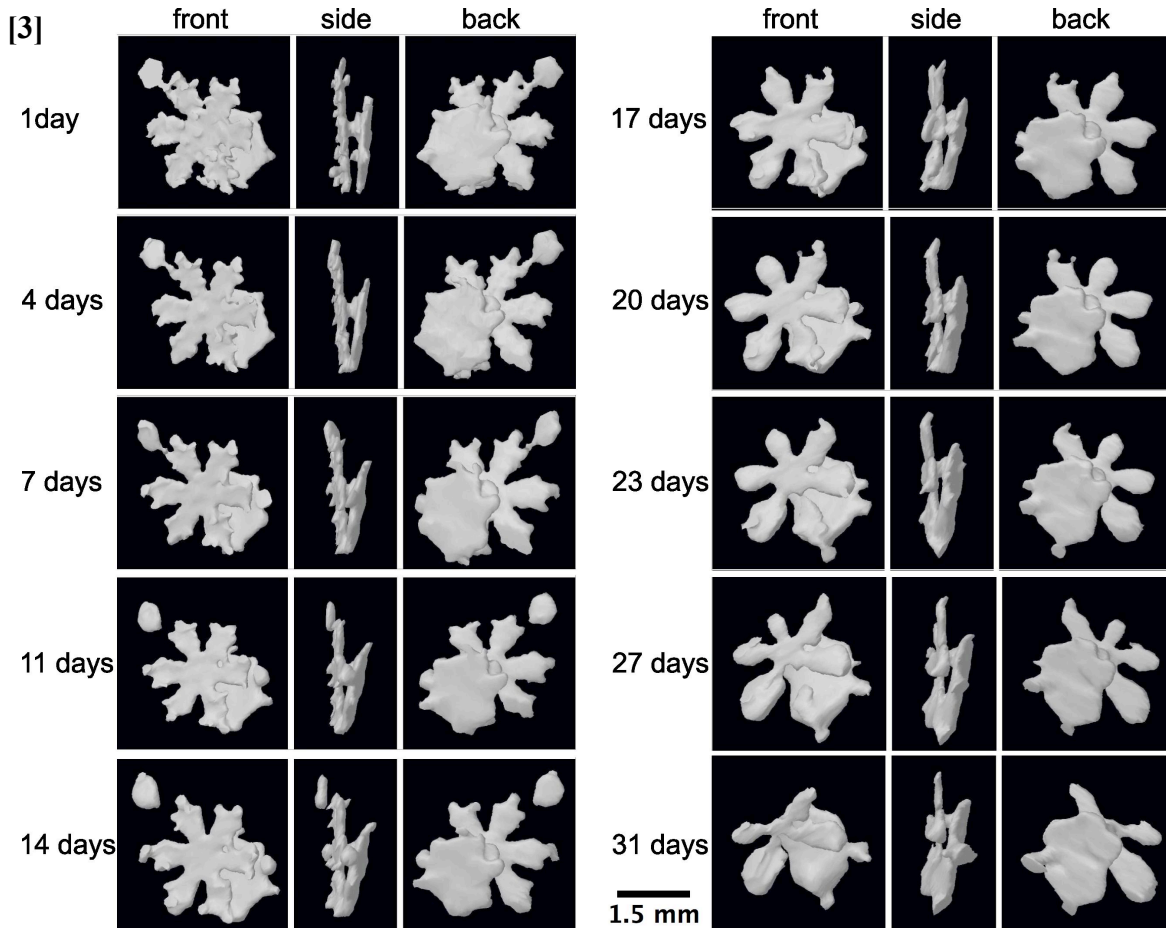


Fig. [3] 3D time-series Micro-CT images of an individual snowflake showing structural changes observed from different direction as it evolved at -5°C over a period of 31 days.