Time-lapse Diffraction Contrast Tomography of snow temperature gradient metamorphism

Rémi Granger∗1,2, Frédéric Flin2, Wolfgang Ludwig3, Ismail Hammad3, Christian Geindreau1, Sabine Rolland du Roscoat1, Armelle Philip4, Fabien Lahoucine5, Philippe Lapalus2, Laurent Pézard2, Jacques Rouille5, Alexis Burr4, Anne Dufour2, Pascal Hagenmuller2, Isabel Peinke2, and Paul Tafforeau3

1Univ. Grenoble Alpes, CNRS, Grenoble INP†, 3SR, F-38000 Grenoble, France
2Univ. Grenoble Alpes, Université de Toulouse, Météo-France, CNRS, CNRM, Centre d’Études de la Neige, 38000 Grenoble
3ESRF, BP 220 38043 Grenoble Cedex, France
4Univ. Grenoble Alpes, CNRS, IRD, Grenoble INP, IGE, 38000, Grenoble, France
5Concept Soudure, Echirolles, France

Keywords: X-ray Diffraction Contrast Tomography (DCT), snow, crystal growth, cryogenic cell

Summary: In order to bring clarifications on effects of crystalline orientations of ice grains in snow during temperature gradient metamorphism, time-lapse diffraction contrast tomography was applied to observe individual grains and access their crystallographic orientation while they undergo metamorphism.

INTRODUCTION

Snowpack is a layered porous media resulting from the accumulation of snowflakes. This is made of ice, air and sometimes liquid water. The snow microstructure constantly evolves with time, due to ice redistribution by sublimation/condensation and diffusion of water vapor in the pore space. These transformations are called metamorphism of snow. The driving mechanism of these transformation depends on the amplitude of the temperature gradient the snowpack is subject to. Particularly, when the snowpack is subject to a strong temperature gradient, the gradient of water vapor density at saturation implies a flux of water vapor from higher temperatures to lower temperatures. This flux may be relatively important so that ice crystals grow kinetically. In that case, facets and hexagonal shapes appear in the microstructure of the snowpack. Those shapes are the direct expression of the hexagonal crystalline structure of ice. Currently, an open question has raised interest in the snow science community [2]: Does the crystalline orientation of an ice crystal relative to the temperature gradient direction has an importance in the evolution of this crystal? Indeed, at a given temperature, growth rate is in general different between basal and prismatic facets. So it may be possible that grains presenting a favorable orientation relative to the main flux grow preferentially. X-ray microtomography is now a method of choice for studying snow microstructure and its evolution. However, common tomographic techniques use absorption contrast and give no information on the crystalline orientation of the ice grains.

EXPERIMENTAL METHOD

Here, we applied time-lapse Diffraction Contrast Tomography (DCT) [1] to temperature gradient snow metamorphism. DCT has already been applied for one study on snow [3]. However, it is the first study reporting time series of DCT images on snow metamorphism. The experiment was performed with synchrotron radiation at ID19 beamline of the European Synchrotron Radiation Facility (Grenoble, France). Temperature environment of the snow sample was controlled using a modified version of CellDyM cryogenic cell [4]. This cell consists in a cylindrical sample holder, placed between two copper columns whose temperature at their boundaries can be controlled using peltier modules. The whole assembly is placed in a vacuum chamber that thermically insulates the sample (see figure 1a). This permit to control temperature conditions over the sample. A temperature gradient of 34 °C/m at -2.1 °C was imposed for 2 days.

†Institute of Engineering Univ. Grenoble Alpes
∗e-mail: remi.granger@3sr-grenoble.fr
RESULTS

During the metamorphism, faceted crystals appear and are visible at the final stages of the experiment. Disappearance of smaller grains occurs while bigger crystals grow. Computations on absorption tomography images permit to follow evolution of curvature distribution, density and specific surface area. Shape and crystalline orientations for most of the grains have successfully been retrieved all along the experiment and boundaries between grains can be observed. In addition, evolution of the fabric has been followed.

References


Figure 1: (a) Scheme of the experimental setup. (c) Snow microstructure obtained with traditional tomography at initial and final state, colormaps correspond to mean curvature. (d) Grain map obtained with diffraction contrast tomography at initial and final state, different colors refer to different grains differentiated by their crystalline orientation. Black bar correspond to 1 mm.