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Shifts: 3	**Local contact(s)**: W. Ludwig	*Received at ESRF:*

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Report:

Microstructural characterization and in-situ mechanical testing of snow

1. Introduction

The main goal of this study is to investigate the deformation mechanisms of snow loaded under uniaxial compression. In order to characterise all the microstructural aspects of the snow specimens which are relevant for subsequent numerical modelling work, Diffraction Contrast Microtomography (DCT) and Microtomography in absorption mode (µCT) were applied. The feasibility of the study was proved during experiment MA412 performed in august 2007.

- Diffraction Contrast Microtomography was used to characterise the grain microstructure at a given deformation stage. This technique gives access to the grain micro structure of polycrystalline materials in terms of 3D grain shapes and crystallographic orientations.
- Microtomography in absorption mode was used to monitor subtle changes in the snow microstructure that occur during the uniaxial deformation experiment.

Both techniques were applied using an optical set-up of 20.4 µm pixel size. The MA412 experiment showed that this size was a good compromise for both DCT and µCT scan analysis.

During the reported experiment, we analysed a laboratory processed specimen that exhibits large grain size (grains about 1 mm in diameter). Figure 1 shows some of the grains used to prepare the sample. The sample had a density of 0.65 g/cm^3 and was made up of about 200 grains in its original state.

2. Sample environment: cryogenic cell including a mobile piston for uniaxial compression

The cryogenic cell, developed by Météo France and LGGE, was improved and now prevents the sample from sublimating. Figure 2 shows the improved cold cell. During the 14 hours of the continuous operation, the temperature at the bottom part of the cell volume was -8°±0.5°C and -9°±0.5°C in the top part, close to the mobile piston. This low temperature gradient prevents the samples from sublimation and is close to classical laboratory conditions in cold rooms. By placing different weights on top of the piston, the sample can be loaded under uniaxial compression (constant load).

3. Compression test and experimental protocole

Figure 3 shows the deformation undergone by the sample during the experiment. A DCT scan of the sample in its initial stage was recorded. The load was applied by adding weights on the piston in three successive steps: 500g, 500g and 800g (see. Fig. 3). When 1% of deformation was reached a DCT scan was recorded after removing the weights (in order to avoid any deformation of the specimen during the scan). µCT were regularly recorded during the loading and unloading phases. The combination of the two techniques allows to follow precisely the microstructural changes of the sample.

4. Diffraction Contrast Tomography

Snow is a polycrystalline two phase material (air and ice). Provided some conditions on grain and sample size are fulfilled, DCT can be applied to reconstruct the 3D grain microstructure of snow by recording simultaneously the transmitted and the diffracted beams. In order to reconstruct the 3D grain shapes and the crystallographic orientations of the individual grains, this technique requires a relatively complex analysis procedure. Using the tools developed for MA412, we were able to reconstruct the grain structure for two DCT scans.

Figure 4 illustrates the results obtained for a given DCT scan: this is a mid horizontal section of the snow where the grain map obtained by DCT is superposed to the absorption one; black represents the pore phase (air); the grain c-axes orientations have been given a randomly chosen colour, except for the ice phase not yet oriented shown in white. Focusing on the top right cluster, the absorption map alone would indicate that only one snow grain is present, whereas the c-axis orientation map clearly shows the presence of three different ice grains. This information is a crucial input for micro-mechanical simulations of snow deformation.

Figure 5 shows 3D views of the sample for two different loading levels: a) initial; stage b) after the second 500g loading. These views clearly show that the sample height decreased during loading. More importantly, more grains than initially detected were found in the second DCT scan, which indicates that, unless there is a significant cracking activity, intragranular deformation has occurred. It also appears that some grain shapes have not been modified whereas their localisation and crystallographic orientation have changed. At this point of the analysis, we can not conclude on the possible occurrence of grain boundary sliding (GBS) vs intragranular deformation: GBS should result in a likewise rigid-body rotation of the grains, and, on the other hand, owing to the pronounced viscoplastic anisotropy of ice, intragranular deformation leads to a rotation of the crystal lattice.

5. Microtomography in absorption mode under compression

These data were used to investigate the microstructural changes undergone by the sample during loading. As expected the porosity decreased during loading, which corresponds to a compaction of the structure. This porosity evolution is a key point that can be used in two ways : it could either be introduced as such in mesoscale models that consider the mechanical properties as depending on the sole density (which is a crude approximation), or be used as a validation for micro-mechanical models that take into account the deformation of individual grains. The sample grains and bonds curvature evolution was also investigated. Figure 6 illustrates the results obtained for the initial stage. The next step will be to compare this curvature 3D-map to those which will be obtained for the different applied compression levels, whose data are currently processed.

6. Conclusion

During this experiment, we used an improved cold cell that prevent the sample from sublimating. The current study showed the feasibility of DCT on snow samples containing about 200 grains that were laboratory grown from natural snow. Structural changes have been observed and will now be more accurately quantified.

Figures

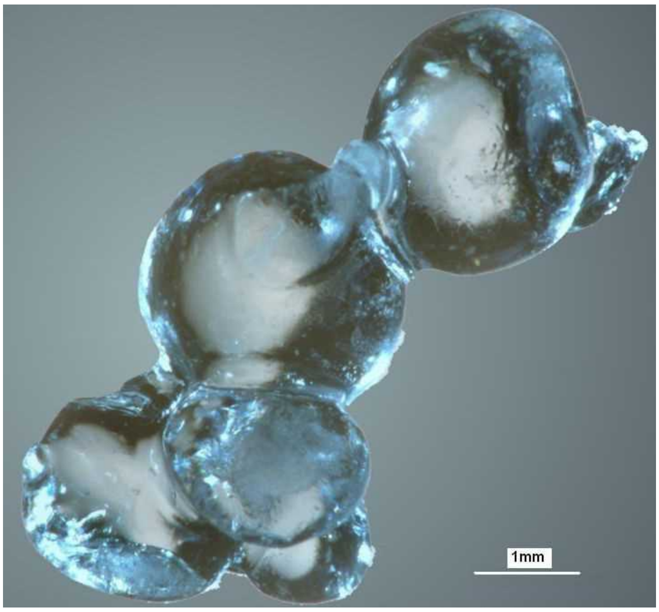

Figure 1: Laboratory processed large grained snow.

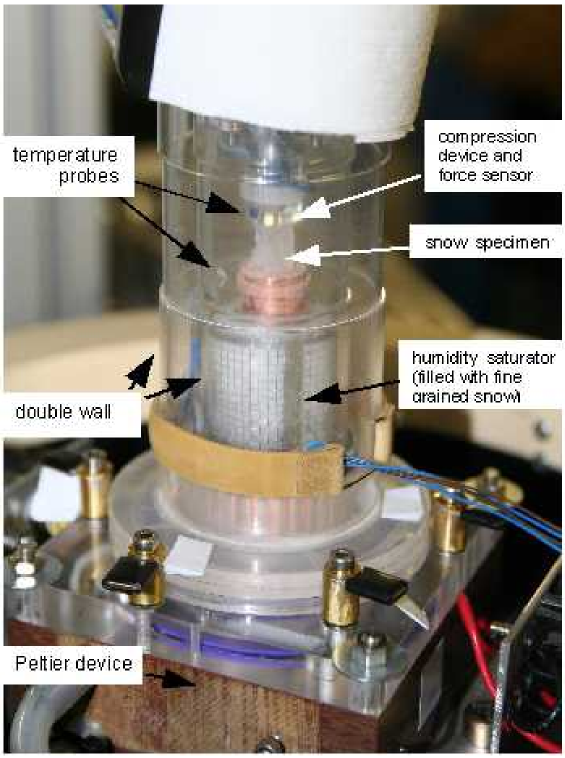

***Figure 2:** The improved cryogenic cell.*

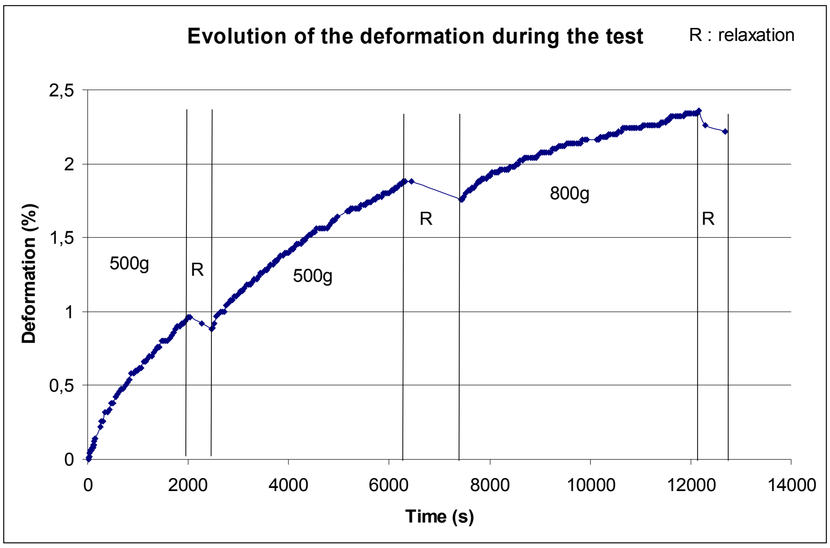

***Figure 3:** Deformation undergone by the snow sample during the MA-513 experiment*

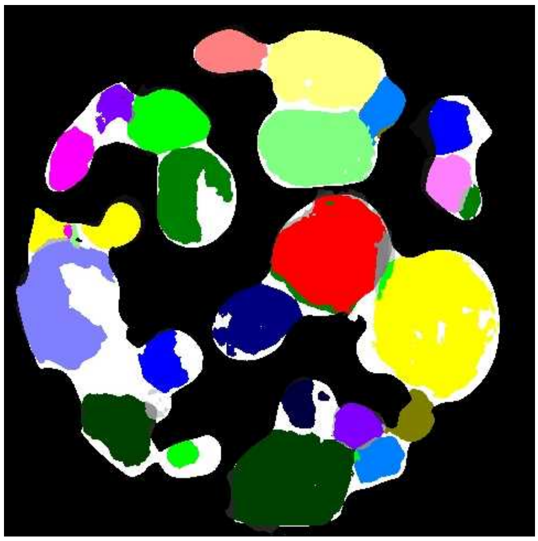

***Figure 4:** Mid horizontal section of the snow specimen tested during MA-513 (10mm in diameter).*

a) b)

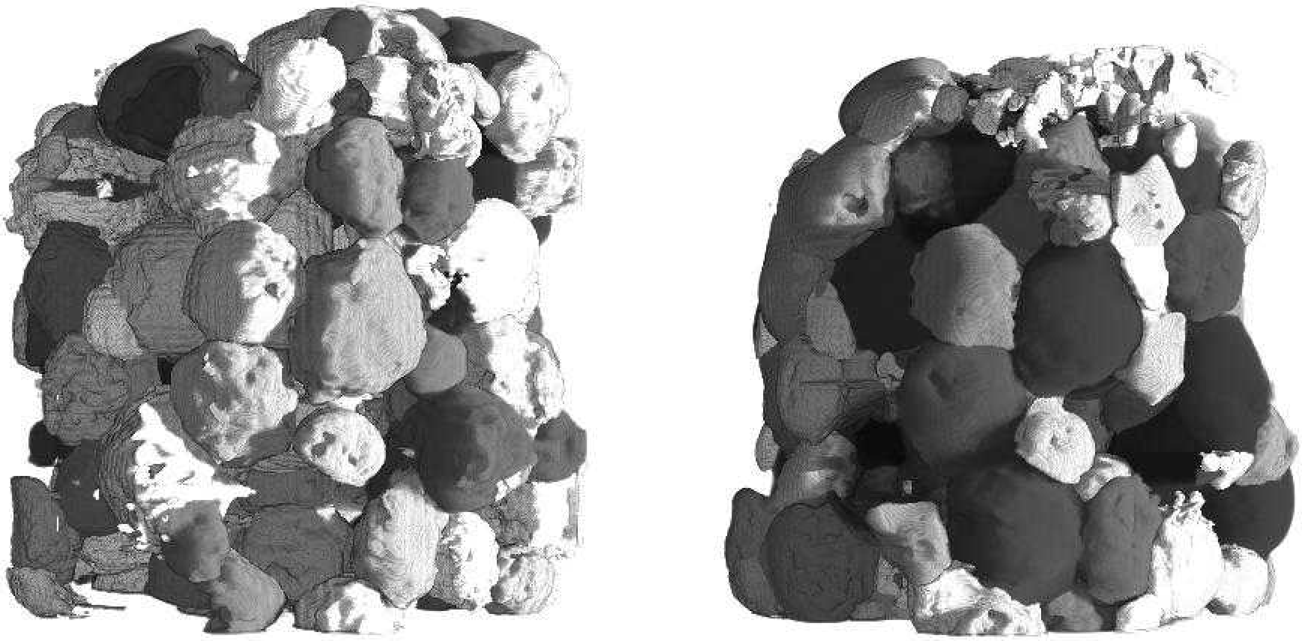

Figure 5: *3D views of the grain repartition in the snow sample (a) before the loading and (b) after the second 500g loading phase. The original sample size was 10 mm x 10 mm x 10.5 mm.*

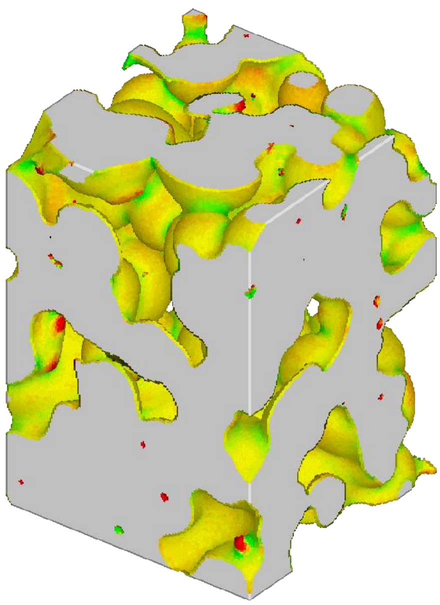

Figure 6: *3D map of the gaussian curvature; green represents the concave parts, red the convex ones. The volume is 3.06 mm x 3.06 mm x 4.28 mm.*