ESRF	**Experiment title:** Monitoring of the isothermal metamorphism of snow by absorption microtomography	**Experiment number:** ME-390
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Shifts: 12	**Local contact(s):** Xavier THIBAULT	*Received at ESRF:*

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Report:
A 3 month long experiment of isothermal metamorphism of dry snow was carried out in cold laboratory in order to obtain a collection of microtomographic images describing the evolution of the snow structure with time. The microtomographic samples were principally analyzed in terms of mean curvature distribution and specific surface area and provided an interesting database for the monitoring and modelling of isothermal metamorphism.

Experimental key points:
Complete information about the experimental method is available in a manuscript that was recently submitted to *Journal of Glaciology.*
Sample preparation:
A 0.5 x 1 m slab of recent snow was first collected in the field 15 hours after a snowfall (exterior temperature $-1°$ C, slab thickness 12 cm). To prevent sublimation and temperature gradient effects, the slab was stored in a closed styrodur box inside the cold room maintained at $-2 \pm 0.2°$ C. Till the end of the experiment, all manipulations were done in the cold room at this temperature. A three-centimeter wide core was sampled at increasing time intervals, ranging from 24 hours at the beginning to one week at the end of the experiment. Once sampled, each core was impregnated by 1 - chloronaphthalene and machined into the shape of a 9 x 9 mm cylinder for microtomograhic acquisition.
Microtomography:
3D images of snow samples were obtained by X-ray absorption microtomography using a new refrigerating cell developed at the ESRF. All images were obtained at 18-20 keV, with a voxel size of 4.91 μm. Due to air conditioning problems, the ambient dewpoint was unusually high ($T_d \sim 18°$ C) during the experiment. This amplified the air-tightness problems inside the cell, leading to icing and poor circulation of cold dry N_2 around the sample. This induced a partial melting of snow samples, although the copper base of the sample holder remained cold. In spite of careful manipulation, an attempt for de-icing the cryostat resulted in blocking a motor due to water infiltration. For future experiments, an accurate de-icing procedure should be realized using an appropriate protection (plastic receptacle mounted on the cell?).

Evolution of snow under isothermal conditions:
New algorithms for 3D image analysis (specific surface area, local mean curvature and anisotropy estimation) were developed and applied to the snow tomographic images obtained. This is presented in the following publication [1]:

3D geometric measurements of snow microstructural evolution under isothermal conditions

Abstract: Snow, from its fall until its full melting, undergoes a structural metamorphism that is governed by temperature and humidity fields. Among the many possible mechanisms that contribute to snow metamorphism, those that depend only on curvature are the most accessible to modeling. In this paper, techniques of volume data analysis adapted to the complex geometry of snow are introduced and then applied to experimental tomographic data coming from the isothermal metamorphism of snow near 0° *C. In particular, an adaptive algorithm of curvature computation is described. Present results on the evolution of specific surface area and anisotropy already show that such image analysis methods are relevant tools for the characterization of real snow microstructures. Moreover, the evolution of the curvature distribution with time provides valuable information for the developement of sintering models, same as a possible quantitative calibration of snow grain coarsening laws.*

Validation of a 3D microstructural model of snow isothermal metamorphism:
A 3D model that simulates the isothermal metamorphism of dry snow structures has been implemented. This model was experimentally validated by images from X-ray microtomography. The results have been published in [2]:

Full three-dimensional modelling of curvature-dependent snow metamorphism: first results and comparison with experimental tomographic data

Abstract: Snow, from its fall until its full melting, undergoes a structure metamorphism governed by temperature and humidity fields. Among the many possible mechanisms that contribute to snow metamorphism, those that depend only on curvature are the most accessible to modelling. The isothermal metamorphism of a dry snow sample near 0° *C is addressed in this work. Near* 0° *C, the vapor pressure of water is high: the metamorphism can be considered, in first approximation, as fully curvature-driven. This corresponds to neglect crystallographic orientation and diffusion-limited effects. Based on Kelvin's and Langmuir-Knudsen equations, a growth law of the ice phase can be analytically obtained. In this law, the variation of the local volume fraction is proportional to the difference between integral and local curvatures. A simple numerical model was implemented in three dimensions and applied on real tomographic images.*

References

[1] F. Flin, J. B. Brzoska, B. Lesaffre, C. Coléou and R. A. Pieritz, 3D geometric measurements of snow microstructural evolution under isothermal conditions, *Annals of Glaciology*, vol. **38**, in press.

[2] F. Flin, J. B. Brzoska, B. Lesaffre, C. Coléou and R. A. Pieritz, Full three-dimensional modelling of curvature-dependent snow metamorphism: first results and comparison with experimental tomographic data, *Journal of Physics D: Applied Physics*, vol. **36**, pp. A49-A54, 2003.