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Monitoring dry snow metamorphism from in-situ tomographic measurements

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Snow physical properties result from the complex 3D arrangement of ice and air at the micrometre scale, referred to as snow microstructure. Describing snow microstructure and predicting its temporal evolution are keys for snowpack models, such as CROCUS or SNOWPACK. Currently, the evolution laws of density and SSA in both models are not fully satisfactory, as shown by some model errors when compared to observations. For example, SSA of new snow simulated on CROCUS tends to decrease faster than what is observed experimentally, while the inverted density profile due to strong gradient metamorphism observed in arctic snowpacks is not captured by CROCUS. These limitations result partly from the fact that evolution laws were empirically derived from experimental time series covering a limited number of snow evolution scenarios, and whose temporal and spatial resolutions could be enhanced.

X-ray tomography has brought new insights into snow microstructure observation, enabling a quantitative assessment of its variations and a deeper understanding of the physical processes at the micrometer scale. While first measurements were made at room temperature and required to fix the microstructure evolution with impregnation, the use of micro-CT directly inside a cold lab offers the possibility to conduct extensive measurements of snow samples in a cold environment. In this work, we use micro-CT measurements to characterize the temporal evolution of microstructural properties of snow under dry snow metamorphism. To do so, we designed a snow-metamorphism cell to control the temperature at the upper and lower boundaries of a cylindrical snow sample of size 1.8 cm x 2 cm2. This cell can operate directly inside the tomograph and offers the possibility to conduct in-situ monitoring under various experimental conditions. We explored temporal evolutions for different initial snow types, mean temperatures, and temperature gradients ranging from isothermal condition up to 200 K/m. From the micro-CT measurements, we calculate the microstructure properties and analyze their temporal evolution. We also explore the relationships between characteristic lengths, such as ssa, correlation length, mean chord length, and curvature length. In this work, we present the preliminary results from a selection of experiments. The long-term objective is to produce highly resolved time-series with systematic variations of the experimental conditions, and to monitor the evolution of the snow microstructural properties in order to compare them to existing evolution laws and suggest improvements if needed.