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Snow metamorphism observed using time-lapse tomography: new emerging pictures and concepts

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In many climates dry snow metamorphism is the motor of the continuous change in physical properties of the snowcover during a longer period in winter. We observed the changes in snow under different conditions of temperature gradients (vanishing, constant, oscillating) using time-lapse micro-tomography. Settlement, thermal conductivity, vapor mass flux and structural change were visualized and calculated using instrumented sample holders. The experiments show that for vanishing temperature gradients (i.e. isothermal conditions) metamorphism is well described by collective, isotropic coarsening dynamics of ice crystals. As soon as a constant, unidirectional temperature gradient is externally applied, crystal growth is accelerated and becomes anisotropic. Additionally, in contrast to isothermal metamorphism, an external temperature gradient causes the grains to recrystallize completely at a rate which is much higher than the structural growth rate. We observed that the evolution of the crystal shape is intimately linked to the temporal and spatial stability of the diffusion field. Morphological growth instabilities such as depth hoar are thus not only influenced by temperature and temperature gradients, but also by a changes in the crystal environment which may be induced either by re-crystallization or by settling. Finally, we address metamorphism under the influence of an oscillating temperature gradient which is relevant to metamorphism in the presence of diurnal oscillations of air temperature. We found that the oscillation frequency is very important for the structural evolution of snow. While the latter aspect seems to be difficult to observe in nature, time-lapse tomography gives us a much more dynamic and multi-faceted idea how snow is evolving.