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Aeolian snow transport induces airborne snow metamorphism with implications for snowpack physical properties

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Aeolian transport of snow is a cryospheric process prevalent in all snow-covered areas. It influences the energy and mass balance of these cold regions. Apart from the direct effects during the process, aeolian transport alters the snow's microstructure, leaving behind a wind-blown snow layer with different snowpack characteristics than before the wind event. For high-resolution climate modeling in snow-covered regions, it is thus important to incorporate the immediate and lasting effects of wind-induced aeolian snow transport for an accurate representation of the energy and mass balances of a snowpack. Apart from mechanical mechanisms such as fragmentation and aggregation of snow crystals, the metamorphic mechanism (sublimation and deposition of water molecules on the suspended snow particles) can alter the microstructure of snow during aeolian transport. It is difficult to predict the relative importance of the two mechanisms for the evolution of the microstructure of wind-blown snow, not least because the process is happening on the micro-scale but is unfolding on large spatial scales on the respective particle trajectories. Thus, it is difficult to observe.

However, metamorphic processes leave a fingerprint on the snow's composition of stable water isotopes whereas the mechanical mechanisms do not. Hence, monitoring the evolution of the stable water isotope signal of the snow can act as a macro-scale tracer for the metamorphic micro-scale processes. The stable water isotope signal can thus help to differentiate the processes at play during aeolian snow transport.

Here we show through observations of cold laboratory ring-wind tunnel experiments that aeolian transport of snow involves airborne snow metamorphism. We monitored the evolution of the microstructure and the isotopic composition of airborne snow through repeated sampling of snow from the air stream. In a total of 19 experiments we varied the temperature in a range of -20°C to -3°C and the transport times varied between 50 - 180 minutes. We find a rapid exponential decay in specific surface area (SSA) with transport time which reduces the SSA value to 35-70% of its starting value by the end of the experiments. Further, we observe a shift in the particle size distribution towards larger snow particles, both for the most abundant and maximum particle sizes with aeolian transport time. Simultaneously, the water isotope signature shows mainly an

enrichment in $\delta^{18}O$ and a decrease in d-excess which is a strong indicator for isotopic fractionation and thus evidence for the presence of metamorphic processes. Combining the results, we attribute the change in snow microstructure to airborne snow metamorphism. The unique combination of information on the isotopic composition and microstructure of airborne snow under well-constrained laboratory conditions can be used to develop parameterizations for the incorporation of airborne snow metamorphism in snow-process models.