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Using continuous measurements of near-surface atmospheric water vapor isotopes to document snow-air interactions

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Water stable isotope data from Greenland ice cores provide key paleoclimatic information. However, post-depositional processes linked with snow metamorphism remain poorly documented. For this purpose, a monitoring of the isotopic composition δ18O and δD at several height levels (up to 13 meter) of near-surface water vapor, precipitation and snow in the first 0.5 cm from the surface has been conducted during three summers (2010-2012) at NEEM, NW Greenland.

We observe a clear diurnal cycle in both the value and gradient of the isotopic composition of the water vapor above the snow surface. The diurnal amplitude in δD is found to be $\sim$15‰ The diurnal isotopic composition follows the absolute humidity cycle. This indicates a large flux of vapor from the snow surface to the atmosphere during the daily warming and reverse flux during the daily cooling. The isotopic measurements of the flux of water vapor above the snow give new insights into the post depositional processes of the isotopic composition of the snow.

During nine 1-5 days periods between precipitation events, our data demonstrate parallel changes of δ18O and d-excess in surface snow and near-surface vapor. The changes in δ18O of the vapor are similar or larger than those of the snow δ18O. It is estimated using the CROCUS snow model that 6 to 20% of the surface snow mass is exchanged with the atmosphere. In our data, the sign of surface snow isotopic changes is not related to the sign or magnitude of sublimation or deposition. Comparisons with atmospheric models show that day-to-day variations in near-surface vapor isotopic composition are driven by synoptic variations and changes in air mass trajectories and distillation histories. We suggest that, in-between precipitation events, changes in the surface snow isotopic composition are driven by these changes in near-surface vapor isotopic composition. This is consistent with an estimated 60% mass turnover of surface snow per day driven by snow recrystallization processes associated with temperature gradients near the snow surface. Our findings have implications for ice core data interpretation and model-data comparisons, and call for further process studies.

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