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Snow surface water isotope variability driven by vapor-snow exchange

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Observed variability in summer surface snow isotopic composition (δ^{18O}, δD) cannot solely be explained by precipitation events. This variability however, influences the overall summer isotope signal that is archived in ice cores. It is therefore important to explain the origin of such post-depositional modifications of the snow isotope signal to ensure an optimal interpretation of ice core isotope records. The continuous exchange of humidity between the atmospheric vapor reservoir and the snow surface through sublimation and deposition could be a key process. Yet, in the past, the surface humidity flux has been disregarded as influential for the formation of the isotope signal in snow based on the assumption of the absence of isotopic fractionation during sublimation. Here we show evidence of isotopic fractionation during snow sublimation through a combination of laboratory experiments, in-situ observations from the Greenland Ice Sheet, and snow surface modeling. We document substantial isotopic enrichment in the uppermost centimeters of snow induced by sublimation and find that the in-situ observed summer season temporal evolution of the snow surface isotopic composition (in between precipitation events) can be attributed to surface humidity fluxes. We further discuss the nature and the underlying physical process of fractionation during sublimation. Our results lead to an improved process understanding and necessitate the implementation of fractionation during the sublimation process in isotope-enabled climate models.