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The influence of below-cloud processes on short-term variations of stable water isotopes in surface precipitation

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Precipitation evaporation is an important part of the atmospheric water cycle. Evaporating precipitation can significantly reduce the precipitation amount, thereby moisten below-cloud air and feed back on the dynamics of a weather system by evaporative cooling of the surrounding air. Stable water isotopes (SWI) are widely applied as physical tracers in the atmospheric water cycle. The isotopic signal in vapour or precipitation is related to meteorological conditions and processes along the transport path of atmospheric moisture. This includes also the processes acting on precipitation during the way from the cloud to the surface, the so-called below-cloud processes. Of most interest are thereby precipitation evaporation and interaction between falling precipitation an the surrounding vapour. These processes leave a distinct isotopic fingerprint on water vapour and precipitation, which can help to quantify different processes from observations.

In this contribution, we present parallel high-frequency measurements of SWI in near-surface vapour and precipitation for selected rain events in Switzerland to identify the driving mechanisms of isotopic variability on the sub-event time scale and demonstrate the influence of below-cloud processes. Rain in comparison with near-surface vapour is on average depleted by 5.4‰ in δ^2H, which indicates incomplete equilibration, and lower by 4.6‰ in d-excess, which underlines the presence of rain evaporation. A new reference frame ($\Delta\delta\Delta d$-space) for the interpretation of rain samples is introduced, which displays the isotopic difference between rain and near-surface vapour for δ^2H and d-excess.

The SWI measurements in near-surface vapour and precipitation are compared to simulations with a below-cloud interaction model fed with meteorological observations. We demonstrate that the combination of measurements with model simulations has the potential to quantify precipitation evaporation, to constrain local atmospheric conditions and to validate atmospheric models during rain events.