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Isotopic anomalies in water vapor during an atmospheric river event at Dome C, East Antarctic plateau, controlled by large-scale advection and boundary layer processes

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On December 19-21, 2018, an atmospheric river hit the French-Italian Concordia station, located at Dome C, East Antarctic Plateau, 3 269 m above sea level. It induced an extreme surface warming (+ 15°C in 3 days), combined with high specific humidity (multiplied by 3 in 3 days) and a strong isotopic anomaly in water vapor (+ 15 ‰ for δ18O). The isotopic composition of water vapor monitored during the event may be explained by (1) the isotopic signature of long-range water transport, and by (2) local moisture uptake during the event. In this study we quantify the influence of each of these processes.

To estimate the isotopic composition of water vapor advected by long-range transport, we perform back-trajectories with the FLEXible PARTicle dispersion model FLEXPART. We retrieve meteorological conditions along different trajectories between the moisture uptake area and Concordia, and use them to compute isotopic fractionation during transport with the mixed cloud isotope model MCIM. While intermediate conditions along the trajectory do not seem to have a major impact on the final isotopic composition (less than 0.1 ‰), the latter appears sensitive to surface conditions (temperature, pressure and relative humidity) in the moisture uptake area (±5.1 ‰). As the event is characterized by the presence of liquid water clouds above Concordia, we show additional sensitivity tests exploring the impact of mixed phase clouds on the water vapor isotopic composition.

Finally, we perform a water vapor mass budget in the boundary layer using observations and simulations from the regional atmospheric model MAR, ran with and without drifting snow. The presence of mixed-phase clouds during the event induced a significant increase in downward longwave radiative fluxes, which led to high turbulent mixing in the boundary layer and to heavy drifting snow (white-out conditions). Using MAR simulations, we show that a significant part of the atmospheric water vapor originates from sublimation of drifting snow particles removed from the snowpack. Consequently, the isotopic signal monitored in water vapor during this atmospheric river event reflects both long-range moisture advection and interactions between the boundary layer and the snowpack. Only specific meteorological conditions driven by the atmospheric river, and their associated intense poleward moisture transport, can explain these strong interactions.