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The use of stable water isotopes as tracers for air-sea interactions induced by large-scale cold and warm advection associated with extratropical cyclones

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Weather systems shape the atmospheric water cycle on the synoptic timescale. Due to the passage of extratropical cyclones and their associated frontal systems, cold and warm air masses are advected and can be observed as cold-air outbreaks in the cold sector or atmospheric rivers in the warm sector. The advection of air masses induces moisture fluxes between the ocean and the atmosphere such as evaporation, precipitation and water vapour deposition. A climatological analysis of the importance of cold and warm advection for freshwater fluxes done with the ERA-Interim dataset reveals that a large share of the atmospheric moisture turnover is associated with cold advection.

Measuring and monitoring the atmospheric water cycle is a challenge, especially turbulent fluxes are difficult to measure over the ocean. A very useful tool to investigate water cycling and trace moist atmospheric processes are stable water isotopes (SWIs). Isotopic fractionation during phase changes and molecular diffusion processes leave a distinct fingerprint in SWIs of atmospheric moisture. SWIs thus provide important insights into moist processes associated with extratropical cyclones.

Here, we present in situ measurements of SWIs in atmospheric water vapour in the marine boundary layer (MBL) during the Antarctic Circumnavigation Expedition in combination with radio sonde profiles, micro rain radar measurements and ECMWF analyses. A quasi-climatological composite analysis of SWIs in atmospheric water vapour is conducted and exemplified by two case studies. Hereby, we focus on the specific air-sea interaction and SWI signals that occur in the MBL during contrasting large-scale conditions characterized by cold and warm air advection, respectively. The MBL during cold or warm air advection is characterized by distinct air-sea moisture gradients and vertical mixing. The second-order isotope variable deuterium excess shows high/low values in the cold/warm sector, respectively, of extratropical cyclones due to the opposing moisture fluxes and non-equilibrium fractionation in the two sectors.

This study demonstrates the use of SWI measurements in the MBL for gaining a better understanding of turbulent moisture fluxes and air-sea interaction that occur during the passage of synoptic scale weather systems.