EGU2020-15241
https://doi.org/10.5194/egusphere-egu2020-15241
EGU General Assembly 2020
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Multi-year water vapor isotopes (δ18O/ δ2H) reveal dynamic drivers of moisture source and transport in the Barents Region

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Stable isotope ratios ($\delta^{18}O$ and $\delta^{2}H$) in precipitation ($_P$) and atmospheric water vapor ($_V$) can provide mechanistic information about water cycle processes such as moisture evaporation, transport and recycling dynamics. Such insight is valuable in the Arctic where declining sea ice is amplifying atmospheric temperature and humidity, leading to complex seasonal patterns of synoptic climate and atmospheric moisture transport. Here, we present two years of continuous water vapor isotope data from Pallas-Yllästunturi National Park, northern Finland, to investigate moisture source and transport processes in the Barents Region of the Arctic. High-resolution (1-sec) measurements obtained between December 2017 and December 2019 are coupled with on-site automated weather station data – including air temperature, humidity, solar flux, wind speed and direction – as well as event-based precipitation sampling and stable isotope data over the same interval. Over the two-years, mean vapor $\delta^{18}O_V$, $\delta^{2}H_V$ and *d-excess*$_V$ values are -24.50‰, -181.49‰ and 14.49‰, respectively. These values are strongly correlated and define a local vapor line for Pallas where $\delta^{2}H_V = 7.6 \times \delta^{18}O_V + 5.9$ (R^2=0.98). We observe a mean offset of 10.9 ‰ between Pallas $\delta^{18}O_V$ and $\delta^{18}O_P$, and *d-excess* is -4.8 ‰ lower in $\delta^{18}O_P$. There is a larger offset between vapor and precipitation *d-excess* during summer (-8.4‰) compared to winter (0.1‰) that may reflect varying fractionation coefficients between solid and liquid cloud-precipitation phases. The timeseries exhibits strong seasonality characterized by lower $\delta^{18}O_V/\delta^{2}H_V$ and higher *d-excess* during winter, and the reverse during summer. In winter these broad patterns are primarily driven by synoptic-scale processes that influence the source and transport pathway of atmospheric moisture, and three dominant oceanic evaporative source regions are identified: the Barents, Norwegian, and Baltic Seas. Yet on diurnal timescales we observe distinct summer diel cycles that correlate with local fluctuations in specific humidity (q). These seasonal relationships are explored in context of spatial-temporal patterns in sea ice and snow cover distribution, as well as evapotranspiration processes across northern Eurasia. Finally, to better understand how current changes in the Arctic hydrologic cycle relate to inherent variability of the polar jet stream and related synoptic-scale weather, our isotope data are examined in context of dynamic circulation modes of the North Atlantic Oscillation (NAO) and Arctic Oscillation (AO).