River water stable isotopes on each side of the continental divide in Montana

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Abstract

Surface water bodies such as rivers and lakes have shown significant differences in hydrogen (δD) and oxygen ($\delta^{18}O$) isotopic signatures. They dominantly reflect precipitation δD and $\delta^{18}O$ values and evaporation. Precipitation δD and $\delta^{18}O$ values are further influenced by elevation and local climate as well as the origin and trajectory of the water vapor producing the precipitation events. In this study, we examine the relationship between elevation, vapor trajectory, relative humidity (RH) and δD, $\delta^{18}O$ and d-excess values from 68 river water samples on each side of the continental divide in Montana. Our data were collected in 2017 and 2021 summers and covered different areas in the two years. Rain vapor trajectory analysis show that moisture in the study area were from several sources. The isotope data from the west in 2017 and east in 2021 show decreases as elevation increases, suggesting the influence of regional topography on precipitation and thus river water isotope values. River waters in eastern Montana have low d-excess, associated with low relative humidity, suggesting significant evaporation. The isotope values from the east in 2017 and west in 2021 do not show statistically significant correlation with elevation, suggesting dominance of snowmelt during the sampling season.

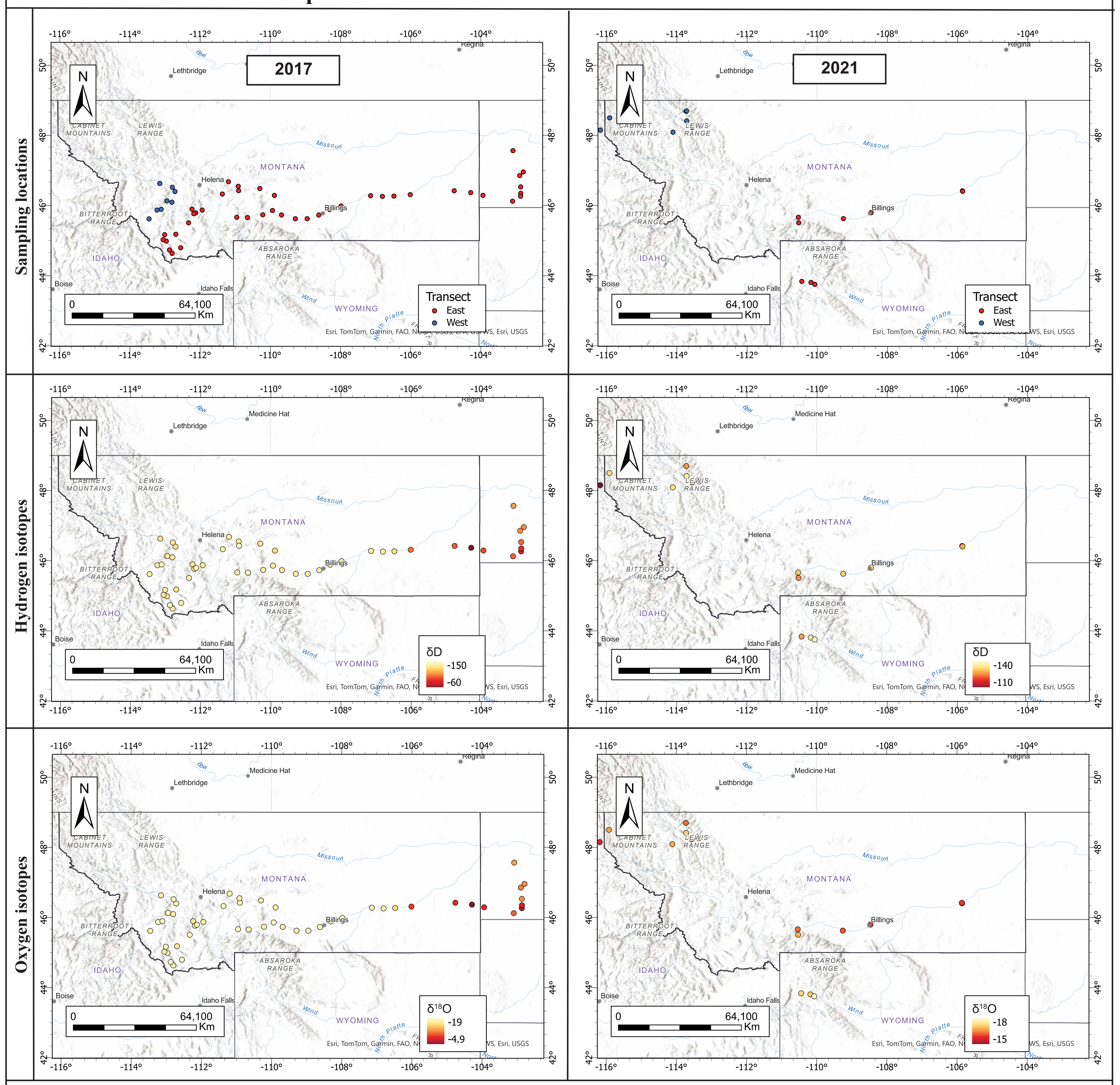
Objective

Understand the effects of RH, moisture source and elevation on the river water δD and $\delta^{18}O$ values in Montana

Methodology

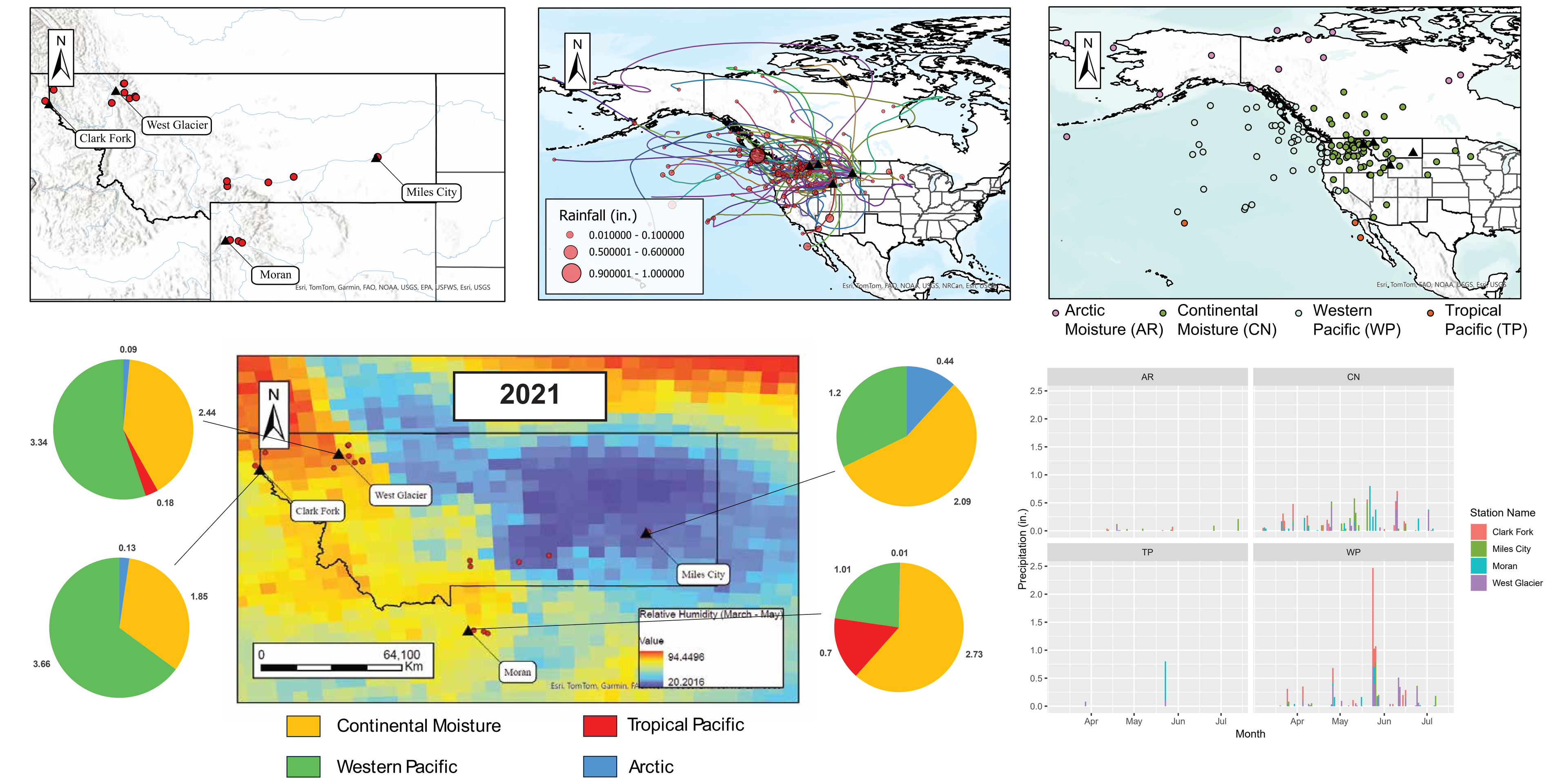
Collection of river water samples in Teflon tubes at various elevations to the each side of the continental divide in Montana.
Analysis of water δD and $\delta^{18}O$ in per mil (‰) values using a Picarro L2120-i CRDS
Calculation of d-excess using the the formula - *d-excess (‰) = δD - 8*δ¹⁸O* (Froelich et al., 2002)
Construction of RH maps using the North America Regional Re-analysis (NARR) dataset
HYSPLIT modelling of precipitation in nearby NOAA precipitation stations for moisture trajectories (Zhu et al., 2018)
Comparison of our river water δD and $\delta^{18}O$ values to published precipitation δD and $\delta^{18}O$ values

Spatial distribution of river water δD and $\delta^{18}O$ values

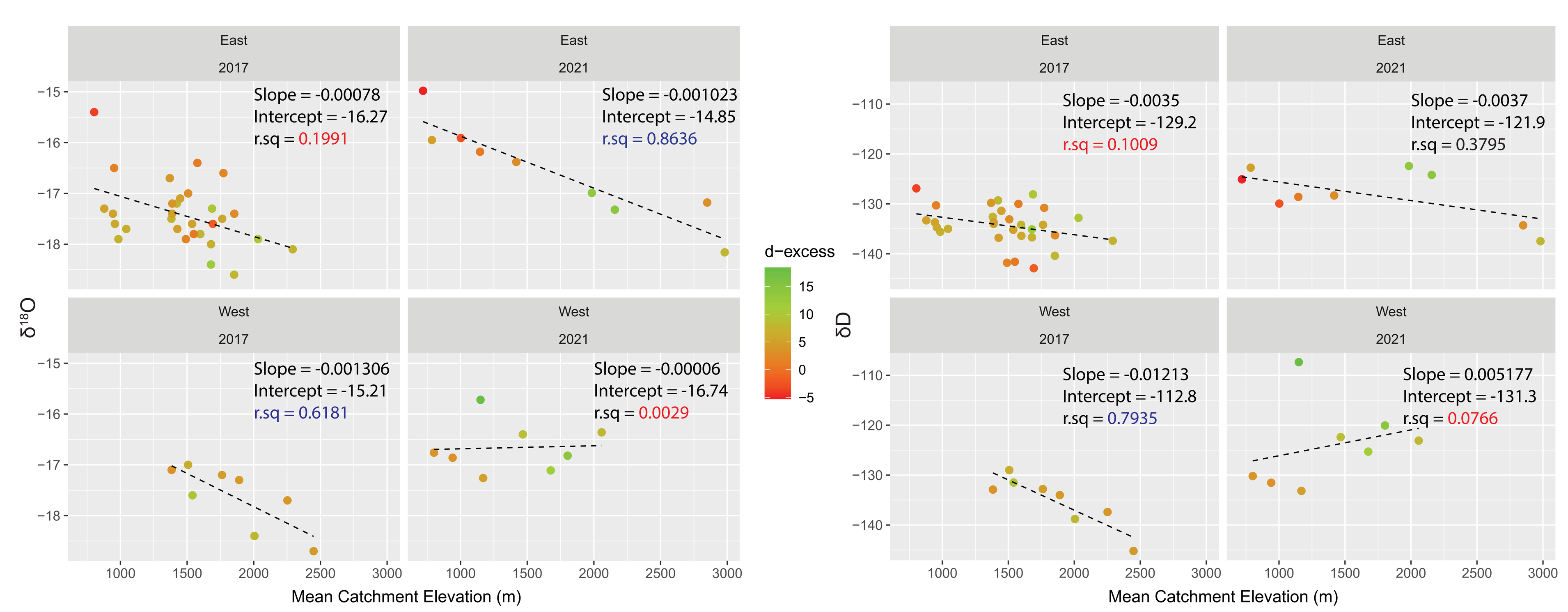


Similar patterns of δD and $\delta^{18}O$ values in both sampling seasons with values increasing towards the east

Trajectory analysis of rain producing vapor and moisture source determination



Correlation of δD and $\delta^{18}O$ values with elevation and d-excess



Results and Discussion

The δD and $\delta^{18}O$ values (in ‰) of river water range between -145.2 to -60.0 and, -18.7 and - 4.9 respectively. The western US being dominated by orographic rainfall, should see regional topography exert a major control on these values. Precipitation δD and $\delta^{18}O$ values should lower values with increasing elevation (Rowley, 2007), which should be reflected in the river waters. A departure from this relationship would be produced by external factors like relative humidity, input from re-evaporated continental moisture, and multiple moisture sources contributing to the precipitation.

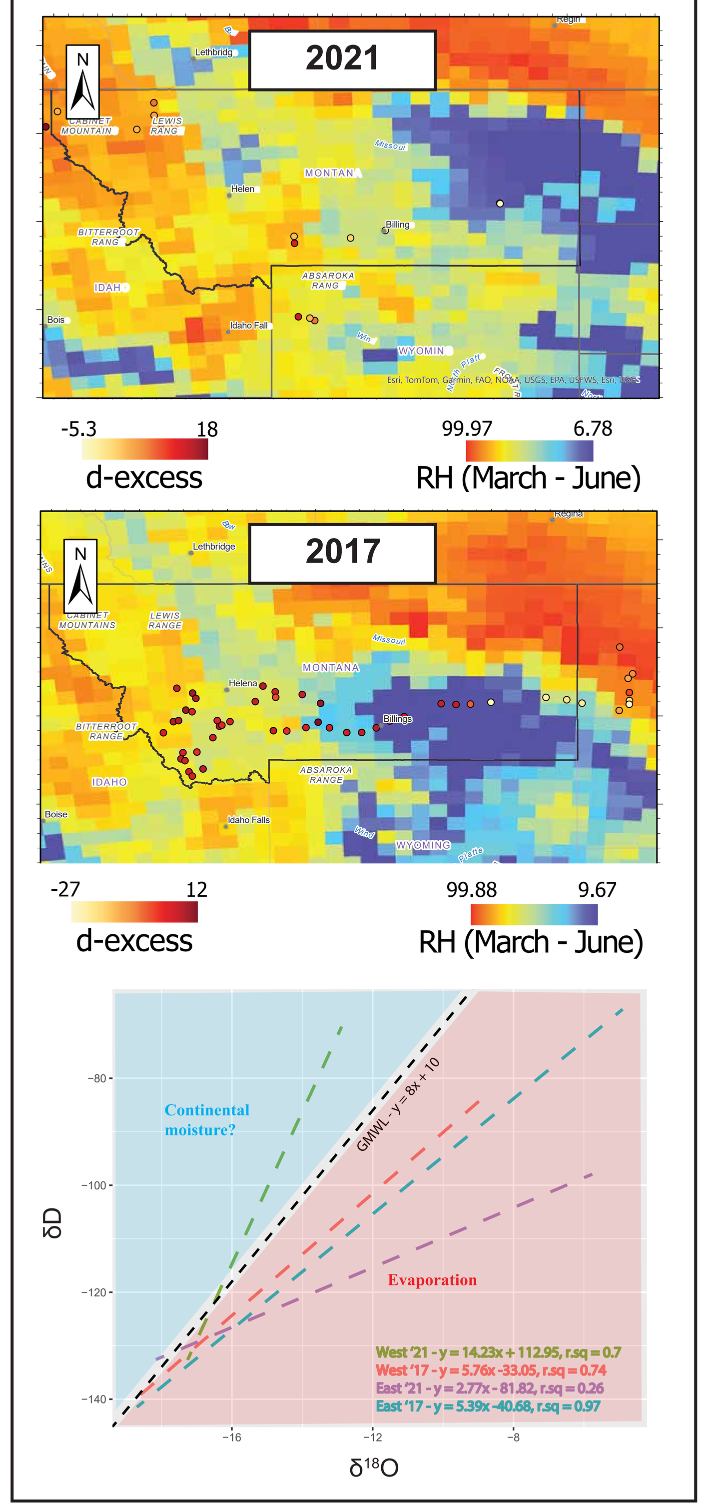
The river water δD and $\delta^{18}O$ values show shallow slopes across all transects across the two sampling seasons, when correlated to precipitation catchment elevations. A statistically significant (>0.5) correlation factor (r.sq) in the west in 2017 and the east in 2021 suggests that regional topography is the dominant factor influencing the precipitation and hence the river water δD and $\delta^{18}O$. However, the low r.sq shows that δD and $\delta^{18}O$ values are not majorly controlled by the elevation in the east in 2017 and the west in 2021, and there are secondary factors affecting the values.

Moisture trajectories modelled using HYSPLIT systems with NOAA meteorological data show that there are dominantly two common precipitation sources, the western Pacific and continental moisture bringing rain to the region with minor contributions from the tropical pacific to the South and the Arctic to the East. Rainfall events from different sources would have different δD and $\delta^{18}O$ values, adding variation in the river water δD and $\delta^{18}O$ values.

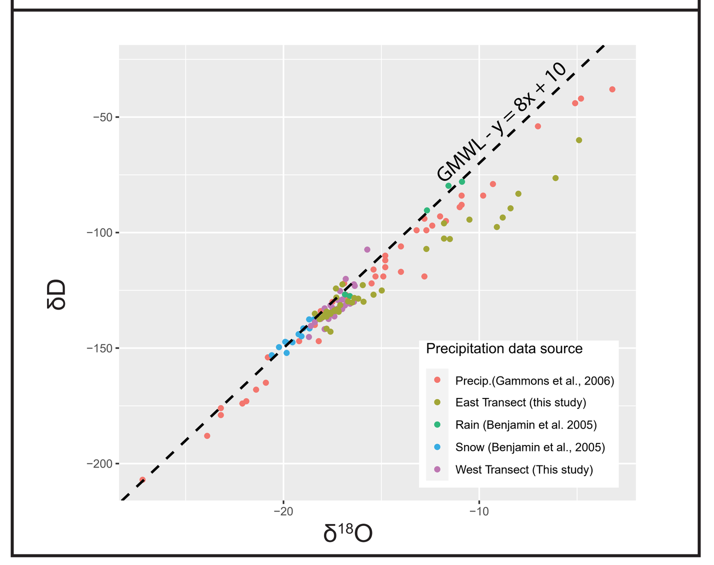
Evaporation is a significant factor affecting the river water δD and $\delta^{18}O$ values, increasing towards the east of Montana. Low RH values in the eastern part of Montana show that the region is very dry, with increased evaporation being reflected in the low d-excess values of the river waters. The moisture sources also point to increased contribution of continental moisture towards the east. This should bring up the d-excess values, but evaporation seems to be more dominant, leading to overall low d-excess values in the eastern part of Montana in both sampling seasons.

The poor correlation of the water δD and $\delta^{18}O$ values and elevation in the east in 2017 and the west in 2021 also suggests that the river water were not fed by precipitation in the region, but were dominated by snowmelt, causing the δD and $\delta^{18}O$ values to have similar values across all elevations.

Evaporation - d-excess and RH



Precipitation and river water



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