Using Stable Isotopes and Fallout Radionuclides to Track Winter Precipitation

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Abstract

Under changing conditions of precipitation due to climate change and possible shifts in precipitation, having a baseline of precipitation sourcing for regions across the U.S. will become increasingly important. This baseline will be especially important for winter precipitation in snowfall regions such as the upper Midwest U.S. because snowpack is a crucial water source for rivers, lakes, aquifers and drinking water systems across the country. Using relative concentrations of oxygen's three stable isotopes (^{16}O, ^{17}O, and ^{18}O) and hydrogen's isotope deuterium (^{2}H) as tracers of precipitation is a method that can be used to track processes of precipitation formation and evaporation. Fallout radionuclides can also be effective tools for tracking precipitation events. Certain short-lived radionuclides, such as Lead-210 (^{210}Pb) and Beryllium-7 (^{7}Be), have a variety of uses in studying precipitation and atmospheric processes. We collected and planned to analyze local snow samples for stable isotopes and radionuclides throughout the winter and utilized this data along with pre-existing data from multiple collaborators at the University of Minnesota. This study assists in creating a baseline for isotopic composition in precipitation for the Twin Cities and Upper Midwest and creates a deeper understanding of the source conditions and spatial distribution of precipitation events. Future studies of precipitation tracking, specifically winter precipitation, are needed to set a baseline for the precipitation source conditions across multiple spatial scales.

Introduction

- Investigating water chemistry in precipitation is a very useful method to help explain many atmospheric and hydrological processes.
- Isotope tracers can track storms and the source conditions of precipitation events.
- Stable isotopes and fallout radionuclides are effective tools to trace precipitation events.
- Oxygen's (O) stable isotopes ^{16}O, ^{17}O, and ^{18}O and hydrogen's isotope, ^{2}H, can be used to track where the storm originated (This process is detailed in Figure 1).
- Lead-210 (^{210}Pb) and Beryllium-7 (^{7}Be) are radionuclides that can track air-mass type and atmospheric deposition.

Hypothesis

- By using stable isotopes in conjunction with fallout radionuclides, this study investigates the merits of using multiple isotope processes to track precipitation events. We hypothesize that the isotopic composition of precipitation events will follow the spatial trajectory calculated by the Vienna Standard Mean Ocean Water standard (or VMSOW), which can be seen in Figure 2.

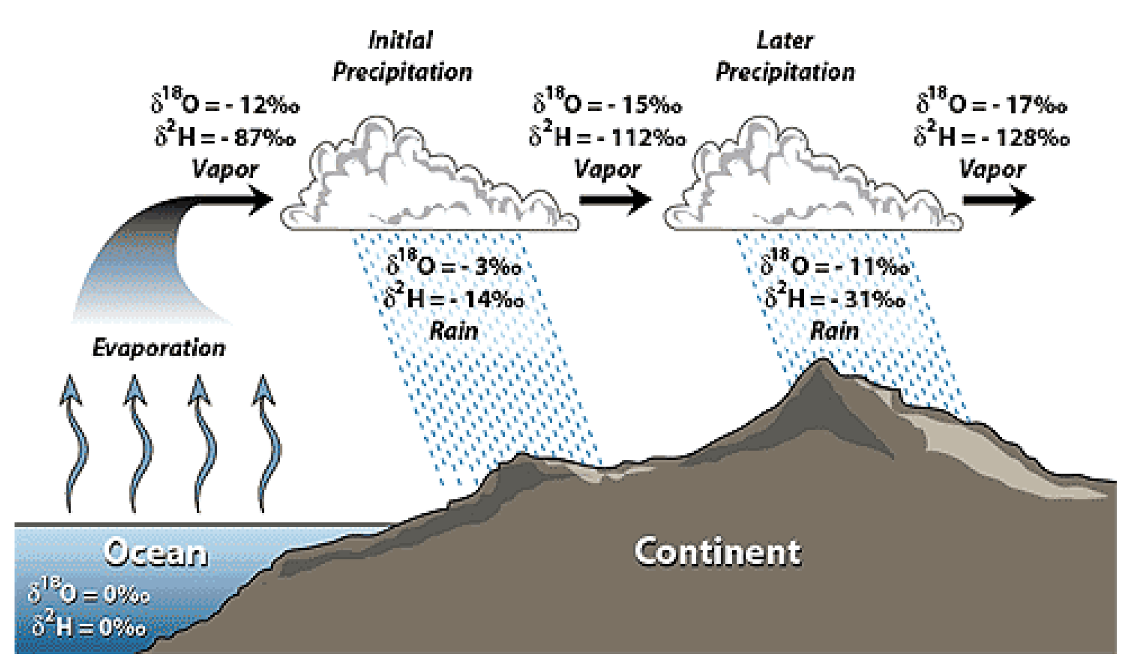

Figure 1: An illustration of how Oxygen's isotopes enrich in concentration

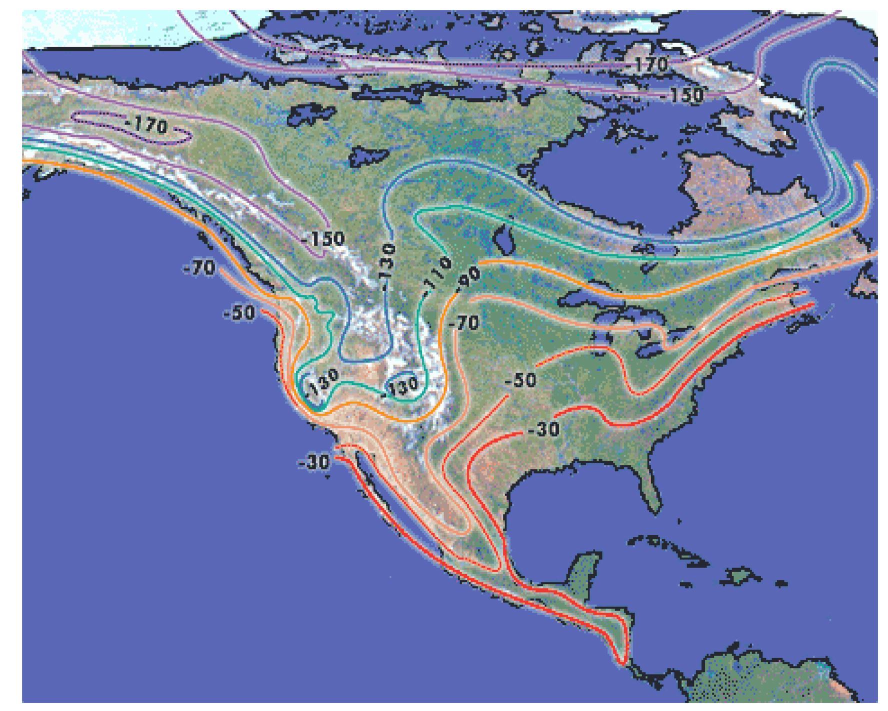

Figure 2: Map of the typical isotopic composition by region

Methods

- Samples were collected near the University of Minnesota St. Paul Campus in a snow collection gauge on an event-based basis from November 2019 through February 2020.
- The samples were then analyzed for fallout radionuclides and stable isotope composition (the sample process is pictured below in Figures 3-7)
- The stable isotope sample values are then compared to the international standard or VMSOW and each sample's isotopic composition can be traced to its source conditions.
- For the fallout radionuclide samples, the ^{210}Pb and ^{7}Be concentrations can be used to correlate the storm's air-mass type and to trace atmospheric deposition.

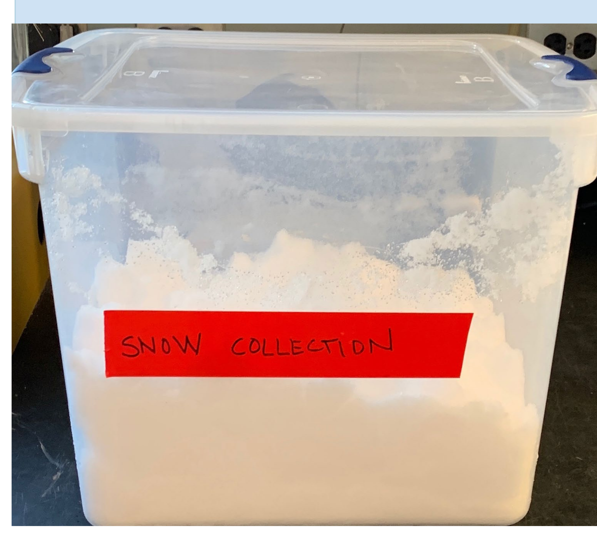

Figure 3: Freshly collected snow sample

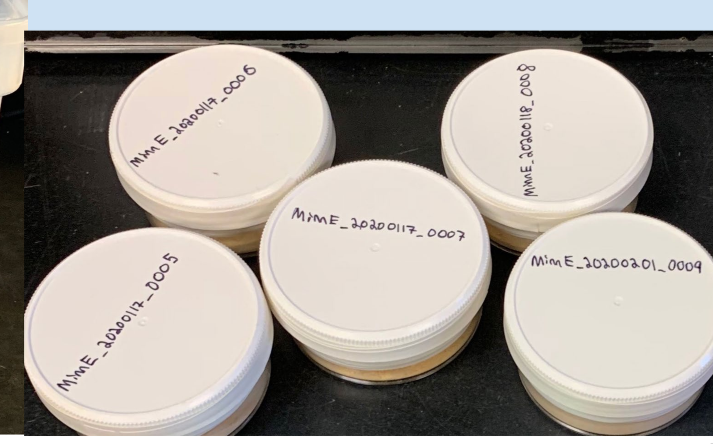

Figure 4: Radionuclide samples ready to be analyzed

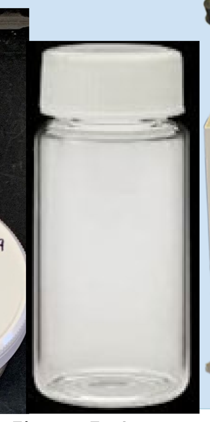

Figure 5: An example of a scintillation vial

Figure 6: Gamma Counter for ^{210}Pb and ^{7}Be

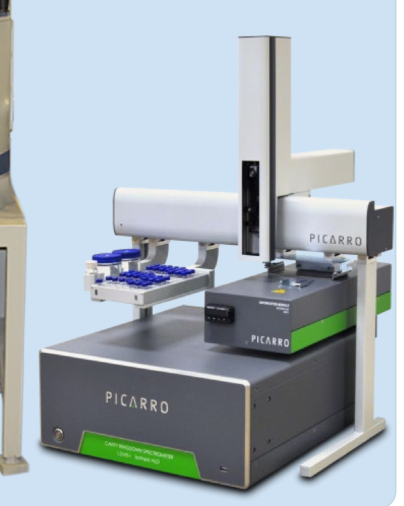

Figure 7: Isotope and Gas Concentration Analyzer

Discussion/Conclusion

- As climatic and hydrologic conditions further shift due to climate change, the importance of a baseline of precipitation sourcing is increasingly vital.
- Changes in seasonal precipitation and snow quantities in fall/spring may further alter the chemical composition of the precipitation.
- Tracking fallout radionuclides in conjunction with stable isotopes is a comprehensive method to track precipitation events due to the differing spatial scales and processes that each method can analyze, but it remains unclear the effectiveness of using the two processes on the same set of samples.

Results

- Unfortunately due to the Covid-19 pandemic, the collected samples were not able to be fully analyzed before the laboratory was shut down. Fortunately, these samples were able to be stored and will be analyzed in the next several months.
- These samples will be processed at a future date and will assist in forming a baseline for winter precipitation isotope composition in the Upper Midwest.

Future Directions

- Future studies should focus on the large-scale effectiveness of using fallout radionuclides along with stable isotopes to track precipitation.
- Further research is also necessary to analyze and track precipitation sourcing at multiple resolutions across the Upper-Midwest and beyond as climate change continues to intensify.
- Long term studies in snowpack dominant regions are needed to help inform future water resource decisions.
- Subsequent studies should concentrate on the seasonal variation of precipitation isotopic composition.

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