

Distribution of $\delta^{18}\text{O}$ and δD Values of Precipitation in Central Ohio

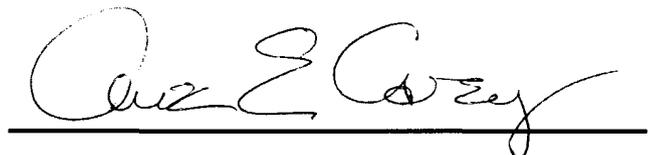
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By

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A handwritten signature in black ink, appearing to read "Anne E. Carey", is written over a solid horizontal line.

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Abstract

Stable isotopic analysis of precipitation collected from four sites in central Ohio indicate a small seasonal and spatial variation in $\delta^{18}\text{O}$ and δD , although the sites are not very geographically spread out and they are of similar elevation. The sites were classified as Byrd Polar Research Center (BPRC), which is in Columbus, Ohio, Galena, Clintonville, and Mansfield. Byrd Polar Research Center (Columbus, Ohio), Clintonville, Ohio, and Galena, Ohio did not have much variation in the mean $\delta^{18}\text{O}$ and δD values. BPRC had mean values of $\delta^{18}\text{O}$ and δD of -5.72‰ and -36.00‰ , respectively. Clintonville had mean values of $\delta^{18}\text{O}$ and δD of -5.16‰ and -31.99‰ , respectively. Galena had mean values of $\delta^{18}\text{O}$ and δD of -5.21‰ and -31.66‰ , respectively. Mansfield had $\delta^{18}\text{O}$ and δD values of -7.84‰ and -52.82 .

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1. Introduction

Stable isotopes are very useful when it comes to reconstructing paleoclimates (Bowen et al. 2011). Variations of $\delta^{18}\text{O}$ and δD in precipitation have been used in many different studies. The stable oxygen and hydrogen isotope values of precipitation demonstrate spatial variation (Bowen et al. 2003). Stable isotope analysis is an essential method in finding the source of precipitation events, keeping an eye on the rate of water loss, and dealing with water quality issues. Data that are collected over a certain period of time can be used in conjunction with knowledge on regional climate patterns and stable isotope hydrology can be used to distinguish surface water resource vulnerability to climate change (Bowen et al. 2003).

Atmospheric moisture comes primarily from oceanic regions that are closer to the equator. The $\delta^{18}\text{O}$ and δD of precipitation is high in regions where vapor is sourced to the atmosphere, and declines away from source regions in response to the progressive cooling of air masses and equilibrium fractionation between vapor and precipitation during rainout (Bowen et al. 2003; Dansgaard, 1964). Rainout can occur by a number a different processes, such as meridional transport, transport from oceanic to continental regions, orographic lifting, and convective processes. Extra variation of vapor isotope amounts can be the consequence of the contribution of evaporated or transpired meteoric water to atmospheric vapor (Kendall et al. 2001). Spatial variability in the $\delta^{18}\text{O}$ and δD amounts in precipitation suggests that source-region labeling, rainout effects, and recycling effects combine to affect air masses that distribute vapor over different geographic regions (Bowen et al. 2003). The $\delta^{18}\text{O}$ and δD of precipitation can be used as a representation of climactic conditions as larger precipitation amounts often produce lower $\delta^{18}\text{O}$ and δD amounts (Dansgaard, 1964).

This work uses stable isotopes of $\delta^{18}\text{O}$ and δD of precipitation in comparison to a local meteoric water line for central Ohio. Anion analysis was also performed to show the amount of inorganic solutes that was dissolved in the precipitation. This is pertinent information because the concentration of anions can help provide the source area of the rain.

2. Materials and Methods

2.1 Precipitation collection

Precipitation samples were collected in central Ohio at different time intervals during a rainfall event. Samples were collected at Byrd Polar Research Center (Columbus, Ohio), Galena, Ohio, Clintonville, Ohio, and Mansfield, Ohio. Figure 2 shows the location of the collection sites. Precipitation samples were collected in a plastic sampling container with a plastic funnel. The sampler was designed with two features to prevent evaporation of the sample or exchange with the atmosphere: A tube connected to the tip of the funnel extended down to the base of the sample so that a small amount of rain would seal the tube, thereby minimizing the surface area for evaporation to the atmosphere; and a short vent tube was fitted which allows for pressure equalization in the container. Precipitation samples were collected and analyzed for stable isotopes and anions. After collection, samples were transferred to 20 mL glass vials for isotope analysis and 20 mL plastic vials for anion analysis. The water samples were filled to the top and closed tightly with a screw cap to prevent evaporation. They were then placed into Ziploc plastic bags and stored in a refrigerator until it came time for analysis, which usually happened within a month of collection.

2.2 Stable Isotope Analysis

The stable isotope samples were analyzed for $\delta^{18}\text{O}$ and δD using a Picarro Liquid-Water Isotope Analyzer (LWIA) model L1102-*i* with auto injector. In order for the samples to be run by this instrument, they had to be pipetted into 2 mL vials. The pipette tip was changed with every sample to avoid contamination and every ten samples a duplicate was made. There were standards that were analyzed with every run. The standards that were used were dionized water aliquots from Florida ($\delta^{18}\text{O} = -2.3\text{‰}$; $\delta\text{D} = -12.3\text{‰}$), Ohio ($\delta^{18}\text{O} = -9.3\text{‰}$; $\delta\text{D} = -64.6\text{‰}$), Colorado ($\delta^{18}\text{O} = -17.0\text{‰}$; $\delta\text{D} = -129.0\text{‰}$), and Nevada ($\delta^{18}\text{O} = -14.2\text{‰}$; $\delta\text{D} = -106.0\text{‰}$).

2.3 Anion Analysis

Anion concentrations were analyzed by using the Dionex DX-120 ion chromatograph. Analyses were performed using the method of Welch et al. (1996). Duplicates were made at every ten samples.

3. Results

The $\delta^{18}\text{O}$ values of all the precipitation samples ranged from -16.61 to 4.06‰, with 168 out of 190 samples falling occurring between -1.00‰ and -10.00‰. Precipitation δD values ranged from -118.561‰ to 28.42‰. Precipitation collected at the Mansfield site has the lowest amount of mean $\delta^{18}\text{O}$ and δD values of -7.92‰ and -53.54‰, respectively, and were significantly different than values obtained for the other three sites. A complete table of the $\delta^{18}\text{O}$ and δD values from all four collection sites can be found in Table 1.

Precipitation that was collected at Byrd Polar, Clintonville, and Galena was analyzed for the concentration of anions. Chloride (Cl^-) and sulfate (SO_4^{2-}) were the anions within the samples. The concentrations were in units of mol/L. Table 6 shows the chloride and sulfate concentrations of the three locations. The mean concentrations of chloride and sulfate for Galena were $6.50\text{E-}06$ and $1.44\text{E-}05$, respectively. The mean concentrations of chloride and sulfate for Clintonville were $9.20\text{E-}06$ and $1.76\text{E-}05$, respectively. The mean concentrations of chloride and sulfate for Byrd Polar were $2.40\text{E-}05$ and $3.44\text{E-}05$, respectively. The mean concentrations obviously vary and the cause of that could be that Galena's first sample was collected in June, Clintonville's in May, and Byrd Polar's in July.

4. Discussion

Dansgaard (1964) was the first to identify that the $\delta^{18}\text{O}$ and δD values in precipitation were negatively correlated with temperature, latitude, and distance inland from the coast, elevation, and amount of precipitation. Figure 1 shows the $\delta^{18}\text{O}$ vs. δD values and plots all of these data along a local meteoric water line. Clintonville, BPRC, and Galena had very similar $\delta^{18}\text{O}$ and δD mean values indicated that there was little spatial variation among those three sites. Galena is fifteen miles from Clintonville and twenty-two miles from BPRC; Clintonville is only about three and a half miles from BPRC, which can explain why there is not much spatial variation between those three sites. Price et al (2008) conducted a study of precipitation collected from five locations in southern Florida that were limited in geographic coverage. The $\delta^{18}\text{O}$ and δD values from each of these five locations strongly varied spatially and seasonally. The reason these five sites had strong spatial and seasonal variations was that they came from different environments. They came from coastal Atlantic, inland, and the lower Keys. The

reason that BPRC, Clintonville, and Galena did not show much spatial and seasonal variations in their $\delta^{18}\text{O}$ and δD values was because they all have similar environments (climate, elevation, distance inland, etc.). Mansfield is about sixty miles North-East of Columbus and Clintonville and about forty-five miles North-East of Galena, which can account for the different $\delta^{18}\text{O}$ and δD mean values. Another characteristic of the precipitation that can be taken into account as to why Mansfield has different $\delta^{18}\text{O}$ and δD values could be that the samples were collected in a full year, over all of the seasons. The mean $\delta^{18}\text{O}$ and δD values for the fall and winter (October through February) were -9.26‰ and -61.48‰, respectively. The mean $\delta^{18}\text{O}$ and δD values for the spring and summer were -5.88‰ and -40.90‰, respectively. The precipitation that was collected in the winter months had much lower $\delta^{18}\text{O}$ and δD values which can explain why the mean $\delta^{18}\text{O}$ and δD values are so much lower than the other 3 sites.

Ion chromatography has been recognized as a useful approach for the determination of anions in many types of natural water, especially rain water (Tanaka et. al 2000). In Tanka et. al (2000), ion chromatography is used to monitor acid aerosols transported from mainland China to central Japan by the jet stream. There does not seem to be any patterns in the concentrations of chlorine and sulfate, just like this present study. The values of chlorine and sulfate from Galena, Clintonville, and Byrd Polar vary by day. On August 20th, Galena had chloride and sulfate concentrations of 1.75E-06 and 2.86E-05, respectively. Clintonville had chloride and sulfate concentrations of 2.29E-05 and 3.76E-05, respectively. Byrd Polar had chloride and sulfate concentrations of 7.28E-05 and 1.20E-04, respectively. Just two days later, on August 22nd, Galena had chloride and sulfate concentrations of 4.60E-06 and 8.73E-06, respectively. Clintonville had chloride and sulfate concentrations of 5.03E-06 and 2.07E-05, respectively. Byrd Polar had chloride and sulfate concentrations of 3.77E-06 and 1.16E-05, respectively. This

shows that there is no pattern in concentration of chloride and sulfate anions of precipitation on different locations that are not far apart.

4.1 Recommendations for Future Work

Longer studies need to be performed to determine if these values are consistent with every new year and at the same time of the year. Samples could be taken year round to have more data points to plot on a local meteoric water line. There are many other locations around central Ohio where samples could be collected. This experiment could be conducted in other areas of Ohio; it is not just limited to the central part of the state.

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Tables and Figures

Table 1 Summary of precipitation collection dates, latitude. Longitude, mean $\delta^{18}\text{O}$ and D for the four sites in Ohio.

Site	Latitude	Longitude	Collection dates	Mean $\delta^{18}\text{O}$ (‰)	Mean δD (‰)
Byrd Polar (Columbus)	40.003966	-83.03849	6/14/14- 10/29/14 4/30/14-	-5.72	-36.00
Clintonville	40.055607	-83.00909	10/14/14 5/28/14-	-5.16	-31.99
Galena	40.205225	-82.86539	10/14/14 10/18/12-	-5.21	-31.66
Mansfield	40.769102	-82.51282	11/17/13	-7.84	-52.82

Table 2 Identifier, dates, $\delta^{18}\text{O}$, and δD for samples collected in Clintonville

Identifier	$\delta^{18}\text{O}$ (‰)	δD (‰)
CVL14-01	-1.54	-6.55
CVL14-02	-3.79	-18.86
CVL14-03	-6.61	-43.93
CVL14-04	-5.22	-31.45
CVL14-05	-5.75	-34.81
CVL14-06	-5.93	-34.49
CVL14-07	-5.65	-39.84
CVL14-08	2.09	19.18
CVL14-09	-3.82	-15.07
CVL14-10	-3.54	-15.47
CVL14-11	-4.84	-24.43
CVL14-12	-4.28	-24.76
CVL14-13	-3.03	-16.03
CVL14-14	-4.86	-35.00
CVL14-15	-5.03	-28.79
CVL14-16	-2.43	-9.48
CVL14-17	-2.14	-5.16
CVL14-18	-3.14	-13.25
CVL14-19	-5.76	-41.20
CVL14-20	-10.72	-74.37
CVL14-21	4.06	28.42
CVL 14-22	-3.83	-25.80
CVL 14-23	-10.47	-75.49
CVL14-25 19 June 7am	-3.49	-13.32
CVL14-26 1700 June 20	-2.40	-11.37
CVL14-27 23 June overnight	-4.38	-24.07
CVL14-28 24 June 6-10pm	-3.98	-14.28
CVL14-29 25 June overnight	-7.18	-40.94
CVL14-30 25 June 6:45-7pm	-6.01	-42.03
CVL14-31 28 June 8-8:30pm	-5.27	-29.55
CVL14-32 July 1 overnight	-3.66	-15.80
CVL14-33 July 2 overnight	-2.14	-8.54
CVL14-34 July 2 6:15-6:45pm	-4.19	-29.81
CVL14-35 7 July 4:20-6pm	-3.31	-14.57
CVL14-36 7 July 6:10-6:30pm	-6.18	-41.43
CVL14-37 8 July overnight	-4.46	-24.49
CVL14-39 14 July 9-10pm	-9.36	-65.33
CVL14-40 19 July overnight	-4.87	-27.73
CVL14-41 19 July 8am-noon	-5.93	-38.31
CVL14-43 27 July 14 17:45	-4.58	-20.40
CVL14-47	-6.35	-33.88
CVL14-48	-3.50	-20.48
CVL14-49	-5.00	-32.35
CVL14-50	-4.26	-25.20
CVL14-51	-2.64	-6.81
CVL14-52	-0.91	4.00
CVL14-53	-9.21	-62.93
CVL14-53 6 Sep 2014 overnight	-3.02	-19.93
CVL14-54 2 Sep 2014 8am-6pm	-2.76	-21.28
CVL14-56 11 Sep 2014 overnight	-5.01	-31.77
CVL14-44 28 July 14 7am	-4.69	-31.24
CVL14-45 1 Aug 14 11:30am-1:15	-6.39	-37.62
CVL14-46 2 Aug 14 3pm	-4.81	-29.46
CVL14-57 30 Sept 14 11am-5pm	-3.76	-23.40
CVL14-58 Oct 6-7 2014 overnight	-13.07	-92.33
CVL14-59 7 Oct 14 9am-6 pm	-9.72	-66.76
CVL14-60 9 Oct 14 9am-5pm	-7.10	-56.14
CVL14-61 14 Oct 14 all day	-7.48	-51.90
CVL14-62 16 Oct 14 overnight	-11.20	-79.19
CVL14-63 18 Oct 14 noon-8pm	-14.29	-116.30
CVL14-64 20 Oct 14 11pm	-9.43	-65.46
CVL14-65 21 Oct 14 daytime	-6.95	-57.08
CVL14-66 28 Oct 14 mid afternoo	-5.88	-29.39
MEAN	-5.16	-31.99

Table 3 Identifier, dates, $\delta^{18}\text{O}$, and δD for samples collected in Columbus at Byrd Polar

identifier	$\delta^{18}\text{O}$ (‰)	δD (‰)			
Precip 6/2/14 1100	-3.56	-12.66			
BPRC-14-01	-3.38	-16.42			
14-24 18 June 14 @212	-2.20	-13.23			
BPRC-14-04 7/21/14	-5.62	-31.71			
BPRC-14-05 7/23/14	-2.95	-29.65			
BPRC-14-06 7/28/14	-4.30	-22.39			
BPRC-14-07	-7.76	-59.73			
BPRC-14-08	-7.98	-48.27			
BPRC-14-10	-6.76	-36.52			
BPRC-14-11	-5.11	-28.79			
BPRC-14-12	-5.16	-38.23			
BPRC-14-13	-3.87	-17.10			
BPRC-14-02	-3.94	-20.39			
BPRC-14-03 7/16/14	-8.93	-61.57			
BPRC-14-15 9/2/2014	-7.41	-49.17			
BPRC-14-16 9/11/14	-4.56	-31.07			
BPRC-14-17 10/1/14	-5.02	-28.49			
BPRC-14-18 10/6/14	-9.88	-66.39			
BPRC-14-19 10/13/14	-10.06	-73.33			
BPRC-14-20 10/28/14	-8.63	-60.49			
BPRC-14-21 10/29/14	-3.02	-10.41			
MEAN	-5.72	-36.00			

Table 4 Identifier, dates, $\delta^{18}\text{O}$, and δD for samples collected in Galena		
identifier	$\delta^{18}\text{O}$ (‰)	δD (‰)
GAL-14-01 5/28/14	-2.33	-7.27
GAL-14-02 6/4/14	-6.49	-40.66
GAL-14-03 6/8/14	-4.11	-25.42
GAL-14-04 6/8/14	-6.18	-38.40
GAL-14-05 6/10/14	-7.77	-53.73
GAL-14-06 6/10/14-6/11/14	-10.44	-75.81
GAL-14-07 6/18/14-6/19/14	-4.80	-22.18
GAL-14-08 6/20/14	-3.40	-13.95
GAL-14-09 6/23/14	-2.88	-13.91
GAL-14-10 6/23/14-6/24/4	-4.57	-23.94
GAL-14-11 6/24/14	-3.31	-12.35
GAL-14-12 6/24/14-6/25/14	-6.99	-39.09
GAL-14-13 7/7/4 4-4:30PM	-2.56	-9.94
GAL-14-14 7/7/14 6-6:30PM	-5.36	-26.34
GAL-14-15 7/18-7/19 overnight	-5.57	-31.18
GAL-14-16 7/23/14 7:30-8AM	-3.65	-28.72
GAL-14-17	-4.31	-25.42
GAL-14-18	-5.24	-27.86
GAL-14-19	-3.57	-19.93
GAL-14-20	-2.02	-17.03
GAL-14-21	-5.66	-33.39
GAL-14-23	-3.82	-18.90
GAL-14-24	-5.48	-32.20
GAL-14-25	-4.17	-20.30
GAL-14-26	-9.83	-66.77
GAL-14-27	-5.96	-36.37
GAL-14-28 9/2/14 3pm-4pm	-3.78	-28.93
GAL-14-29 9/11/14 3-4am	-5.15	-30.42
GAL-14-30 9/20/14 11-11:30pm	-0.77	-17.37
GAL-14-31 10/3/14 10am-11am	-6.15	-37.45
GAL-14-32 10/3/14 4pm-5pm	-12.72	-87.28
GAL-14-33 10/14/14	-7.68	-50.70
MEAN	-5.21	-31.66

Table 5 Dates, $\delta^{18}\text{O}$, and δD for samples collected in Mansfield		
identifier	$\delta^{18}\text{O}$ (‰)	δD (‰)
10/18/2012 R	-9.54	-67.92
10/19/2012 R	-15.23	-112.41
10/26/2012 R	-9.12	-52.92
10/27/2012 R	-12.93	-84.58
10/28/2012 R	-13.26	-86.33
10/29/2012 R	-16.61	-118.56
10/30/2012 R	-11.78	-80.79
10/31/2012 R	-10.71	-72.27
11/9/2012 R	-2.46	-11.03
11/12/2012 R	-8.28	-48.42
12/2/2012 R	-4.09	-12.13
12/5/2012 R	-4.85	-21.23
12/7/2012 R	-11.94	-84.09
12/9/2012 R	-7.74	-49.37
1/13/2013 S	-9.24	-62.31
1/28/2013 S	-12.30	-85.06
1/30/2013 R	-6.02	-35.14
2/5/2013 S	-15.80	-117.16
2/10/13 S	-7.89	-68.13
2/22/13 S	-9.34	-67.75
2/26/13 S	-11.02	-73.50
3/2/13 S	-13.40	-94.67
3/11/13 R	-7.21	-53.15
3/18/13 R	-10.99	-75.04
3/25/13 S	-8.71	-92.00
4/11/13 R	-3.88	-23.25
4/17/13 R	-0.81	-11.85
4/19/13 R	-5.14	-32.15
4/28/13 R	-3.08	-24.50
6/7/13 R	-1.33	-18.22
6/13/13 R	-5.03	-36.05
6/26/13 R	-2.39	-3.97
6/29/13 R	-7.02	-47.58
7/4/13 R	-8.45	-59.48
7/6/13 R	-5.34	-33.79
7/8/13 R	-6.13	-37.09
7/9/13 R	-6.14	-36.55
7/10/13 R	-7.70	-49.76
7/27/13 R	-2.84	-29.60
7/31/13 R	-4.43	-26.74
8/2/13 R	-7.56	-52.06
8/30/13 R	-5.98	-40.06
9/2/13 R	-3.19	-14.83
9/12/13 R	-6.90	-43.47
9/20/13 R	-7.53	-45.75
10/3/13 R	-8.03	-47.05
10/5/13 R	-4.32	-21.25
10/6/13 R	-8.73	-54.62
10/15/13 R	-5.88	-32.59
10/19/2013 R	-7.73	-60.56
10/19/2013 R	-7.69	-60.89
10/21/13 R	-8.92	-62.32
10/31/13 R	-7.79	-48.09
11/2/13 R	-12.90	-94.23
11/6/13 R	-5.21	-20.75
11/16/13 R	-8.55	-51.29
11/17/13 R	-9.67	-64.18
MEAN	-7.84	-52.82

Table 6 Shows the identifiers, dates and times, and the Cl ⁻ and SO ₄ ²⁻ values								
Mol/L	Cl ⁻	SO ₄ ²⁻		Cl ⁻	SO ₄ ²⁻		Cl ⁻	SO ₄ ²⁻
GAL-14-01	1.31E-05	1.94E-05	CVL14-18 15 May overnight	7.51E-06	1.64E-05	BPRC-14-01	7.51E-06	1.64E-05
GAL-14-02	4.57E-06	6.43E-06	CVL14-19 15 May	5.16E-06	1.08E-05	BPRC-14-02	5.16E-06	1.08E-05
GAL-14-03 6/6/14 11:45am-1pm	1.09E-05	2.17E-05	CVL14-20 17 May	3.62E-06	8.40E-06	BPRC-14-03 7/14/14	3.62E-06	8.40E-06
GAL-14-04 6/8/14 1-3pm	4.73E-06	1.68E-05	CVL14-22 10 June 14	4.14E-06	7.86E-06	BPRC-14-04 7/21/14	1.08E-05	2.12E-05
GAL-14-05 6/10/14 10-10:20pm	6.44E-06	1.74E-05	CVL14-23	9.28E-06	2.30E-05	BPRC-14-05 7/23/14	2.42E-05	2.56E-05
GAL-14-06 6/10-6/11/14 overnight	8.80E-06	2.72E-06	CVL14-25 19 June 7am	1.73E-06	1.18E-05	BPRC-14-06 7/28/14	1.28E-05	2.12E-05
GAL-14-07 6/18-6/19 overnight	3.79E-06	1.26E-05	CVL14-27 23 June overnight	1.15E-05	2.01E-05	BPRC-14-07 8/1/14	2.61E-05	2.27E-05
GAL-14-08 6/20/14 2:45-3:30pm	6.28E-06	9.29E-06	CVL14-28 24 June 6-10pm	1.55E-06	6.90E-06	BPRC-14-08 8/4/14	3.07E-06	2.30E-05
GAL-14-09 6/23/14 5:45-6pm	6.02E-06	2.32E-05	CVL14-29 25 June overnight	1.76E-06	1.06E-05	BPRC-14-09 8/11/14	1.31E-05	1.32E-05
GAL-14-10 6/23-6/24/14 overnight	4.38E-06	1.16E-05	CVL14-31 28 June 8-8:30pm	1.41E-06	1.55E-05	BPRC-14-10 8/13/14	9.11E-06	2.59E-05
GAL-14-11 6/24/14 6:30-7pm	3.42E-06	8.51E-06	CVL14-32 July 1 overnight	1.52E-05	8.48E-06	BPRC-14-11 8/20/14	7.28E-05	1.20E-04
GAL-14-12 6/24-6/25/14 overnight	1.34E-06	4.07E-06	CVL14-33 July 2 overnight	1.56E-05	3.67E-05	BPRC-14-12 8/22/14	3.77E-06	1.16E-05
GAL-14-13 7/7/14 4-4:30pm	9.28E-06	2.30E-05	CVL14-35 7 July 4:20-6pm	3.69E-07	1.85E-05	BPRC-14-13 10/6/14	6.68E-06	1.59E-05
GAL-14-14 7/7/14 6-6:30pm	1.73E-06	1.18E-05	CVL14-36 7 July 6:10-6:30pm	1.75E-06	2.86E-05	BPRC-14-15 9/2/14	7.60E-06	8.77E-06
GAL-14-15 7/18-7/19/14 overnight	1.15E-05	2.01E-05	CVL14-37 8 July overnight	1.23E-05	2.41E-05	BPRC-14-16 9/11/14	1.26E-05	2.82E-05
GAL-14-16 7/23/14 7:30-8am	1.55E-06	6.90E-06	CVL14-38 13 July 1:15-1:45pm	1.02E-05	1.57E-05	BPRC-14-17 10/1/14	1.66E-04	1.77E-04
GAL-14-17 7/26/14 4:30-6pm	1.91E-06	1.11E-05	CVL14-39 14 July 9-10pm	4.80E-07	1.30E-05	MEAN	2.40E-05	3.44E-05
GAL-14-18 7/27/14 2-2:30pm	1.41E-06	1.55E-05	CVL14-40 19 July overnight	1.23E-05	2.41E-05			
GAL-14-19 7/27/14 4-4:30pm	1.52E-05	8.48E-06	CVL14-42 9am-6pm 23July	1.02E-05	1.57E-05			
GAL-14-20 8/2/14 1:30-2pm	1.56E-05	3.67E-05	CVL14-43 27 July 5:45pm	4.80E-07	1.30E-05			
GAL-14-21 8/11/14 11-11:30am	3.69E-07	1.85E-05	CVL14-45 2 Aug 11:30am-1:15pm	5.19E-06	3.41E-05			
GAL-14-22 8/19-8/20/14 overnight	1.75E-06	2.86E-05	CVL14-46 2 Aug 3pm	7.21E-06	1.27E-05			
GAL-14-23 8/21/14	1.35E-05	1.85E-05	CVL14-47 11Aug 5-6am	1.87E-06	5.94E-06			
GAL-14-24 8/21/14 12-1pm	3.05E-06	2.01E-06	CVL14-48 11Aug 9am-9pm	5.98E-06	3.20E-05			
GAL-14-25 8/22/14	4.60E-06	8.73E-06	CVL14-49 20Aug overnight	2.29E-05	3.76E-05			
GAL-14-26 8/31/14	1.66E-06	2.49E-06	CVL14-50 8/21/14 afternoon	2.37E-06	4.64E-06			
GAL-14-28 9/2/14 3-4pm	5.27E-06	1.21E-05	CVL14-51 8/22/14 overnight	5.03E-06	2.07E-05			
GAL-14-29 9/11/14 3-4am	5.91E-06	1.37E-05	CVL14-52 8/31/14 overnight	1.19E-05	1.40E-05			
GAL-14-30 9/20/14 11am-4pm	1.04E-05	3.83E-05	CVL14-53 8/31/14 8am-noon	5.94E-07	1.99E-06			
GAL-14-31 10/3/14 10-11am	2.12E-05	8.70E-06	CVL14-54 9/2/14 8am-6pm	1.17E-05	2.30E-05			
GAL-14-32 10/3/14 4-5pm	1.82E-06	8.16E-06	CVL14-56 9/11/14 overnight	1.91E-05	1.18E-05			
MEAN	6.50E-06	1.44E-05	CVL14-57 9/30/14 11am-5pm	9.14E-06	3.48E-05			
			CVL14-58 10/6/14-10/7/14 overnight	7.30E-05	1.81E-05			
			CVL14-59 10/7/14 9am-6pm	1.04E-05	1.64E-05			
			MEAN	9.20E-06	1.76E-05			

Figure 1 O18 vs D values

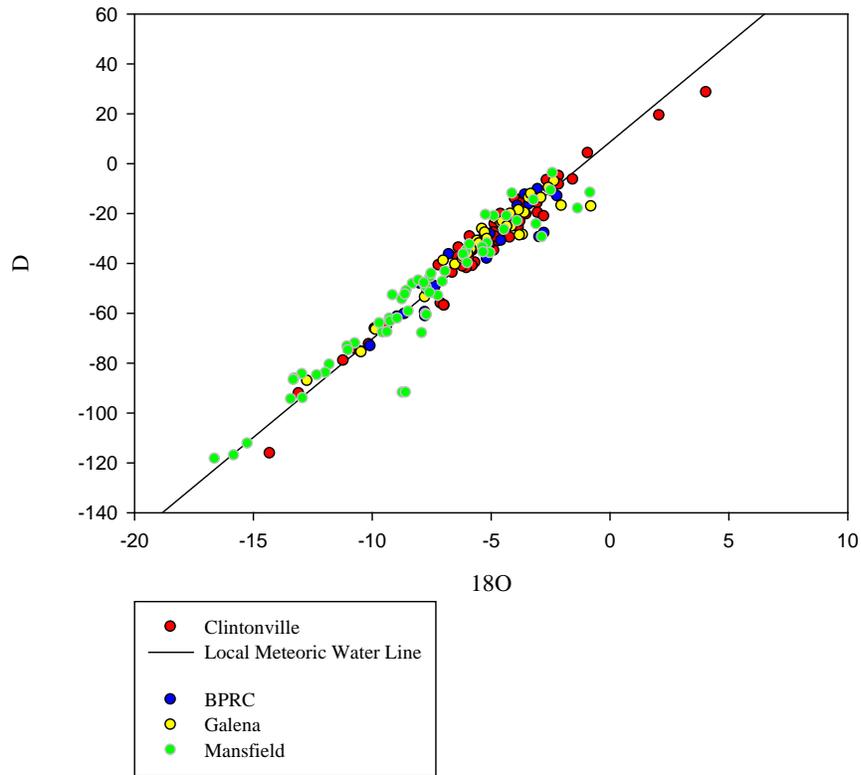


Figure 2. This figure shows the locations of the precipitation collection sites. The yellow marker is Mansfield, the blue marker is Galens, the red marker is Clintonville, and the green marker is Byrd Polar Research Center.

