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Final Report: Operational Testing of Various Precipitation Sensors in Support of the United States Climate Reference Network (USCRN)

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U.S. DEPARTMENT OF COMMERCE
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National Oceanic and Atmospheric Administration
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National Climatic Data Center
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Asheville, NC 28801-5001

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Executive Summary

The U.S. Climate Reference Network (USCRN) is a NOAA sponsored network that is being implemented to provide climate data for climate monitoring and other applications. Reliable, high-quality precipitation data are necessary to detect climate change and to validate climate projections and climate models. Over 100 CRN sites will be installed nationwide according to present plans. The National Climatic Data Center (NCDC) conducted field tests from November 2003 through April 2005 to evaluate various precipitation gauges and shields in support of the CRN network These tests were conducted at NOAA/National Weather Service (NWS) research sites at Sterling, Virginia, and at Johnstown, Pennsylvania. Precipitation gauges evaluated included: the Geonor, Frise, Ott Pluvio All Weather Precipitation Accumulation Weighing Gauge (AWPAG), Hydrologic Services LTD Tipping Bucket Gauge (TB3) and nonrecording 8-inch gauges. Various shields were evaluated, including the Alter, Tretyakov, SDFIR (Small Double Fence Inter-Comparison Reference) and the Large DFIR.

At Sterling, for all observations, the Geonor gauge caught less precipitation than the Ott and the TB gauges. It is apparent that gauges with an Alter shield and Tretyakov shield performed better if combined with the Small DFIR or the Large DFIR. The TBs over caught by 1 to 2 percent. The Otts over caught up to 3 percent. The 8-inch manual gauges all under caught significantly (due to manual reporting procedures); however, the Alter shielded gauges caught 5 percent more precipitation than the unshielded gauge. The Frise gauges with ASOS (Automated Surface Observing System) vinyl shields did not do as well as the TBs with Alter shields (both tipping bucket gauges). The Frise gauges under caught compared to Geonor #1 by 3 to 4 percent. Ott 706, with a SDFIR, did slightly better than Ott 705 and 704, which have just Tretyakov shields. For warm season data (May-October) nearly all gauges were better than the Geonor. The TBs ranged from +3 to +6 percent, the Frises from +2 to +4 percent, and the Otts from 0 to +3 percent. The 8-inch manual gauges improved accuracy by 4 to 8 percent. For cold weather data (November – April), the situation changes significantly. The Frises are off by -7 percent, the TBs at 0 to -1 percent, while the Otts ranged from +1 to + 3 percent. The 8-inch manual gauges slip to -16 to -24 percent compared with the Geonor gauge.

At Johnstown, for all data, the Geonor gauge performed better than other gauges. The Frise gauge under caught compared with the Geonor by 8 percent. The TB under caught by 13 percent. The Otts under caught by 2 to 8 percent. The 8-inch manual gauges, while under-performing overall due to manual procedures, clearly show the benefit of shields on gauges. While these gauges catch nearly the same amounts during the warm season, during cold season the shielded gauges catch 4 to 6 percent more than the unshielded 8-inch gauge. During the warm season at Johnstown, except for TB, all recording gauges are within 1 to 2 percent of each other. During the cold season, the Frise (with an ASOS shield) had a deficiency of 13 percent, while the TB (Alter shield) had a deficiency of 18 percent. Ott 729 (with a SDFIR) had a deficiency of 2 percent, while Ott 722 and 726 (no SDFIRs) had deficiencies of 11 percent.

During short bursts of high intensity precipitation (5 and 60 minutes), the Geonor/Alter/SDFIR combination under catches Ott/Tret/SDFIR under all conditions, i.e., rain and snow, and low and higher wind categories. At winds above 3 m/s or so, the Ott/Tret combination starts to fall behind the Ott/Tret/SDFIR a few percentage points in rain and quite significantly in snow. Ott/Tret also falls substantially behind the Geonor/Alter/SDFIR in snow at these higher winds.

It is very difficult to accurately measure precipitation, especially under all temperature and wind conditions. Solid precipitation events are a problem for all gauges, but are especially difficult for tipping bucket gauges (TB and Frise). Precipitation measurement errors increase for all gauges as the wind speed increases and the temperature decreases. Various shielding combinations all provide varying beneficial protection for the gauges. Weighing gauges (Geonor and Ott) generally do better for conditions involving solid events. False reports by the Geonor gauge have been a problem in the past, but processing software has resolved that issue to a very great extent. Considering all the above and the gauge/shield combinations evaluated, the Geonor gauge combined with the Alter shield and SDFIR would seem to provide a good opportunity for obtaining accurate and reliable precipitation measurements under most climatic conditions. The Geonor gauge performed reliably for 18 months under varying climatic conditions and, on average, met or exceeded the performance of the other test gauge configurations.

1. Introduction

The U.S. Climate Reference Network (USCRN) is a NOAA sponsored network that is being implemented to provide climate data for climate monitoring and other applications. Reliable, high quality precipitation data are necessary to detect climate change and to validate climate projections and climate models. Approximately 100 CRN sites are being installed nationwide. The National Climatic Data Center (NCDC) has conducted field tests of various precipitation gauges and shields in support of the CRN network since November 2003. These tests have been conducted at NOAA/National Weather Service (NWS) research sites at Sterling, Virginia, and at Johnstown, Pennsylvania. Precipitation gauges evaluated include the Geonor, Frise, Ott AWPAG, TB3 and nonrecording 8-inch gauges. The Geonor and Ott gauges are weighing gauges, while the Frise and TB3 are tipping bucket gauges. Various gauge shields were evaluated and included the Alter, Double Alter, Tretyakov, SDFIR (Small Double Fence Inter-Comparison Reference) and the Large DFIR.

Results of gauge and gauge/shield comparisons are presented by total precipitation and differentiated by warm and cold season. Comparisons for short duration 60-minute maxima are presented and are also differentiated by warm and cold seasons as well as wind speed. The performance of the Geonor gauge, selected as the primary CRN gauge, is of particular interest. A table of site gauge configurations is included. This report is the final report of the study and will summarize all precipitation events at both Sterling and Johnstown for the previous 18 months. There are 18 monthly reports and a separate report on wind speed and gauge ratios.

There are five primary areas of evaluation: 1) overall comparison of the Geonor gauge to the other test gauges and an intercomparison of all test gauges for the entire test period (18 months); 2) the evaluation of gauge functioning during warm and cold seasons; 3) examination of the various gauge/shield combinations; 4) an evaluation of gauge functioning under high-intensity, short-term events (60 minutes) with emphasis on categorizing the data by solid or liquid and by high or low wind speeds; and 5) a brief examination of temperature and wind speed on gauge comparisons. The following data, analysis, and discussions address these areas.

2. Data and Procedures

Precipitation, wind and temperature data at one-minute intervals were collected at the two test sites, Johnstown and Sterling. Data were collected from November 2003 through April 2005. Data were summarized and processed in 24-hour totals. Average wind speed, temperature, wind gust and precipitation totals for each 24-hour period were calculated and analyzed by month. The maximum precipitation totals for 60- minute periods were calculated and precipitation totals were further summarized for “warm” periods (May – October) and for “cold” periods (November – April). Since the Geonor gauge has been selected as the standard precipitation gauge for the CRN, precipitation totals for all gauges were compared to the Geonor gauge by calculating the ratio of gauge catch to Geonor catch. Table 28 lists the individual equipment at each site. All recording gauges were heated to ensure satisfactory cold weather operations. During the warm season, the month of June 2004 had to be eliminated from the analysis at both Johnstown and Sterling because of overflow problems with the Geonor gauges. Also, for the cold season totals, two days in November 2003 and 17 days in November 2004 had to be eliminated from the analysis at Sterling because of problems with Ott 706. At Sterling, some early data in November 2003 were included in the mass plot but not in the table analysis, so the mass plot appears slightly higher than the table totals.

3. Results

Section 7, Table 28 provides individual gauge configurations that are important in understanding and comparing precipitation totals for various gauges. Many conclusions that have been demonstrated in other studies are reinforced here (**See Section 8, Pg 60: References).** For example, tipping bucket gauges are less effective in solid precipitation events than are weighing gauges. Heating of a tipping bucket gauge to keep it functional in below freezing environments is very difficult to do effectively. Wind causes significant precipitation measurement errors. The higher the wind speed the greater the error. Solid precipitation is affected by wind much more than liquid precipitation; therefore, wind-caused errors are much greater for solid than liquid precipitation. Shields are effective in reducing catch errors due to turbulence, especially in solid precipitation events. The SDFIR and DFIR provide added gauge protection when added to the Alter or Tretyakov shields. The Geonor gauge and the Ott gauge were both effective in environments at Johnstown and Sterling. The Geonor tended to catch less at Sterling, while it tended to catch more at Johnstown. As Johnstown has a more severe climate (i.e., more wind and more solid events) this would seem to bode well for the Geonor. However, the reasons for the Geonor to routinely under catch and/or over catch at the different locations have not been clearly identified. Also, a more detailed analysis of gauge ratios, including confidence intervals and tests of significance (Z tests) for short duration, high intensity events follows in Section 3.3 of this report.

3.1 Sterling Data

At Sterling, for all data, the Frise gauges under caught by 3 to 4 percent compared to Geonor 1. The TBs over caught by 1 and 2 percent. The Otts over caught by 0 to 3 percent. The 8-inch manual gauges all under caught significantly (due primarily to manual reporting procedures), but it should be noted that the Alter shielded gauges caught 5 percent more precipitation than the unshielded gauge. The Frise gauges with ASOS shields did not fare as well as the TBs with Alter shields. Ott 286 and 706, with a DFIR and SDFIR, did slightly better than Ott 705 and 704, which have just Tretyakov shields.

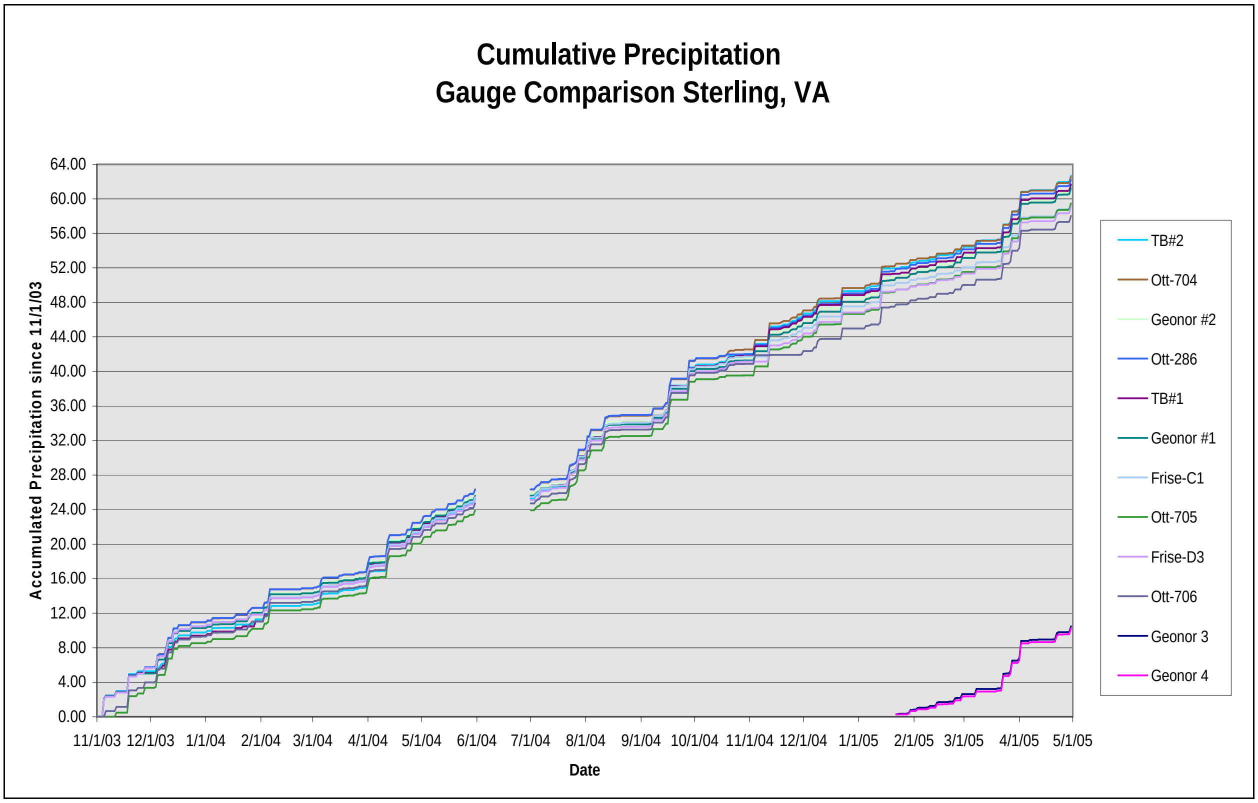
At Sterling, for warm season data, nearly all gauges improved as compared with the Geonor. The TBs ranged from +3 to +6 percent, the Frises from +2 to +4 percent, and the Otts from 0 to +3 percent. The 8-inch manual gauges improved by 4 to 8 percent.

For cold weather data, the situation changes. The Frises are at -7 percent, the TBs at 0 to to -1 percent, while the Otts ranged from +1 to + 3 percent. The 8-inch manual gauges slip to -16 to -24 percent compared with the Geonor gauge. Again, the benefit of the Alter shield is apparent with the shielded 8-inch gauges over catching the unshielded manual gauge by 7 to 8 percent. Also, Ott 286 has a DFIR while Ott 706 has a SDFIR. Ott 286 had an over catch of 2 percent, while Ott 706 had an over catch of 3 percent. So, the double fence enclosure provides additional gauge protection with little apparent difference between the DFIR and the SDFIR. Refer to the following table for gauge comparisons with all the test gauges.

Table 1. Data Table at Sterling, VA, for precipitation events (precipitation in inches). Totals and averages, as appropriate, are tabulated. Ratios, as shown in the table, are for total precipitation.

Sterling- Nov 2003-Apr2005 **(All data)**	cum TB#1-inch A	cum Geonor #1 A+S	cum TB#2 S	cum Geonor #2 A+S	cum Frise-C1 V	cum Frise-D3 V	cum Ott-286 T+D	cum Ott-705 T	cum Ott-704 T	cum Ott-706 T+S	cum 8"N A	cum 8"S A	cum 8" unshiel U
Precip totals	56.65	56.29	57.52	56.5	54.61	54.2	57.16	56.49	57.48	58.02	48.06	48.11	45.25
Ratio compared to Geonor1(A+S)	1.01	1.00	1.02	1.00	0.97	0.96	1.02	1.00	1.02	1.03	0.85	0.85	0.80
Difference in Ratios	0.01	0.00	0.02	0.00	-0.03	-0.04	0.02	0.00	0.02	0.03	-0.15	-0.15	-0.20
ratio with TB#1(A)	1.00	0.99	1.02	1.00	0.96	0.96	1.01	1.00	1.01	1.02	0.85	0.85	0.80
ratio with TB#2 (S)	0.98	0.98	1.00	0.98	0.95	0.94	0.99	0.98	1.00	1.01	0.84	0.84	0.79
ratio with Ott286 (T+D)	0.99	0.98	1.01	0.99	0.96	0.95	1.00	0.99	1.01	1.02	0.84	0.84	0.79
ratio with Ott705 (T)	1.00	1.00	1.02	1.00	0.97	0.96	1.01	1.00	1.02	1.03	0.85	0.85	0.80
ratio with Ott706 (T+S)	0.98	0.97	0.99	0.97	0.94	0.93	0.99	0.97	0.99	1.00	0.83	0.83	0.78
ratio with Frise C1 (V)	1.04	1.03	1.05	1.03	1.00	0.99	1.05	1.03	1.05	1.06	0.88	0.88	0.83
ratio with Geonor 2 (A+S)	1.00	1.00	1.02	1.00	0.97	0.96	1.01	1.00	1.02	1.03	0.85	0.85	0.80
		**											
Sterling- May-Oct 2004 **(Warm Season)**													
Precip totals	20.18	19.51	20.71	19.67	20.32	19.99	19.54	19.51	20.06	20.04	17.36	17.34	17.25
Ratios compared to Geonor 1	1.03	1.00	1.06	1.01	1.04	1.02	1.00	1.00	1.03	1.03	0.89	0.89	0.88
Difference in Ratios	0.03	0.00	0.06	0.01	0.04	0.02	0.00	0.00	0.03	0.03	-0.11	-0.11	-0.12
ratio with TB#1	1	0.97	1.03	0.97	1.01	0.99	0.97	0.97	0.99	0.99	0.86	0.86	0.85
ratio with TB#2	0.97	0.94	1.00	0.95	0.98	0.97	0.94	0.94	0.97	0.97	0.84	0.84	0.83
ratio with Ott286	1.03	1.00	1.06	1.01	1.04	1.02	1.00	1.00	1.03	1.03	0.89	0.89	0.88
ratio with Ott705	1.03	1.00	1.06	1.01	1.04	1.02	1.00	1.00	1.03	1.03	0.89	0.89	0.88
ratio with Ott706	1.01	0.97	1.03	0.98	1.01	1.00	0.98	0.97	1.00	1.00	0.87	0.87	0.86
ratio with Frise C1	0.99	0.96	1.02	0.97	1.00	0.98	0.96	0.96	0.99	0.99	0.85	0.85	0.85
ratio with Geonor 2	1.03	0.99	1.05	1.00	1.03	1.02	0.99	0.99	1.02	1.02	0.88	0.88	0.88
		***											
Sterling- Nov 03-Apr04 and Nov 04-Apr05 **(Cold Season)**													
Precip totals	36.47	36.78	36.81	36.83	34.29	34.21	37.62	36.98	37.42	37.98	30.7	30.77	28
Ratios compared to Geonor 1	0.99	1.00	1.00	1.00	0.93	0.93	1.02	1.01	1.02	1.03	0.83	0.84	0.76
Difference in Ratios	-0.01	0.00	0.00	0.00	-0.07	-0.07	0.02	0.01	0.02	0.03	-0.17	-0.16	-0.24
ratio with TB#1	1	1.01	1.01	1.01	0.94	0.94	1.03	1.01	1.03	1.04	0.84	0.84	0.77
ratio with TB#2	0.99	1.00	1.00	1.00	0.93	0.93	1.02	1.00	1.02	1.03	0.83	0.84	0.76
ratio with Ott286	0.97	0.98	0.98	0.98	0.91	0.91	1.00	0.98	0.99	1.01	0.82	0.82	0.74
ratio with Ott705	0.99	0.99	1.00	1.00	0.93	0.93	1.02	1.00	1.01	1.03	0.83	0.83	0.76
ratio with Ott706	0.96	0.97	0.97	0.97	0.90	0.90	0.99	0.97	0.99	1.00	0.81	0.81	0.74
ratio with Frise C1	1.06	1.07	1.07	1.07	1.00	1.00	1.10	1.08	1.09	1.11	0.90	0.90	0.82
ratio with Geonor 2	0.99	1.00	1.00	1.00	0.93	0.93	1.02	1.00	1.02	1.03	0.83	0.84	0.76
A=Alter, S=SDFIR, D=DFIR, T=Tretyakov, V=ASOS Shield, U=Unshielded													

Figure 1. Cumulative Precipitation Gauge Comparison, Sterling, VA.



3.2 Johnstown Data

At Johnstown, for all data, the Frise gauge under caught compared with the Geonor by 8 percent. The TB under caught by 13 percent. The Otts under caught by 2 to 8 percent. The 8-inch manual gauges, while under performing overall due to manual procedures, clearly show the benefit of shields on gauges. While these gauges catch nearly the same amounts during the warm season, during cold season the Alter shielded 8-inch nonrecording gauges catch 4 to 6 percent more than the unshielded 8-inch gauge. During the warm season at Johnstown, except for TB, all recording gauges are within 1 to 2 percent of each other.

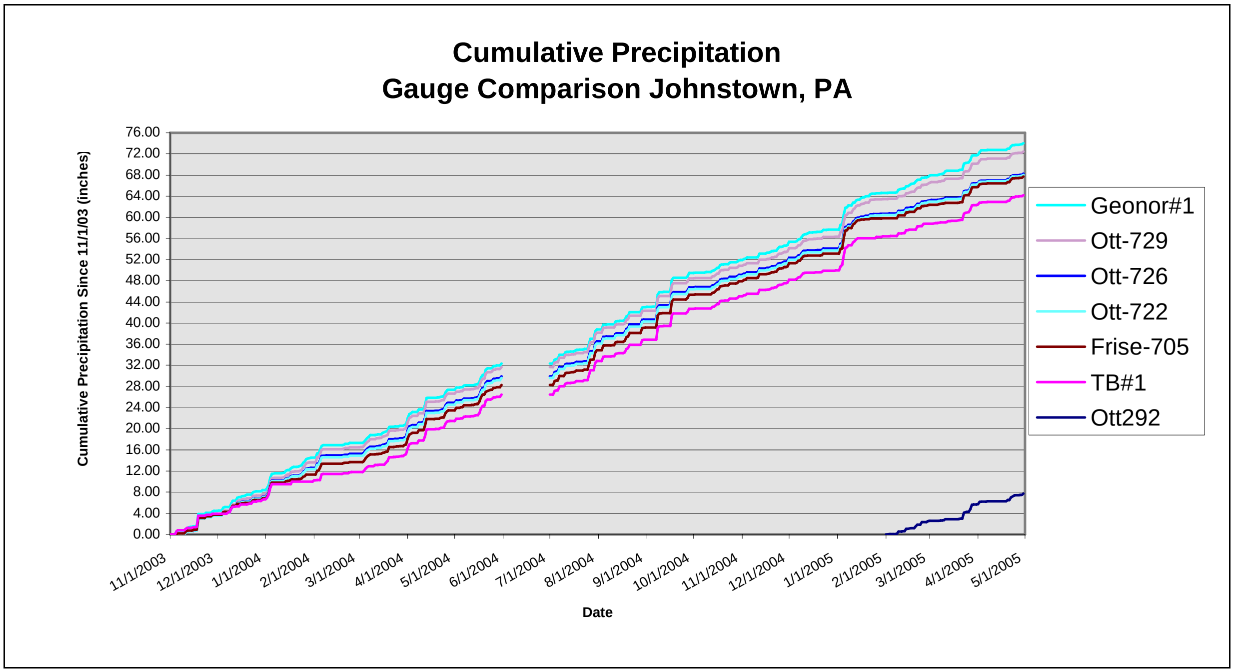
The most interesting data are from the cold season. Comparing tipping bucket gauges, the Frise (ASOS shield) had a deficiency of 13 percent while the TB (Alter shield) had a deficiency of 18 percent. Ott 729 (with a SDFIR) had a deficiency of 2 percent while Ott 722 and 726 (no SDFIRs) had deficiencies of 11 percent. Apparently, the SDFIR reduced the error in catch by about 9 percent and again is good evidence as to the value of the SDFIR. Also, the 8-inch manual gauges again show the effectiveness of the Alter shield in solid events. 8N (North) and 8S (South) (both with Alters) had errors of 53 and 51 percent, while 8U (Unshielded) had an error of 57 percent.

Table 2. Data Table at Johnstown, PA, for precipitation events (precipitation in inches). Totals and averages, as appropriate, are tabulated. Ratios, as shown in the table, are for total precipitation.

Johnstown- Nov 2003-Apr2005 **(All Data)**	cum-in TB#1 A	cum Geonor#1 A+S	cum Frise-705 V	cum Ott-726 T	cum Ott-722 T	cum Ott-729 T+S	cum 8"N A	cum 8"S A	cum 8"u
Precip totals	64.2	74.02	67.73	68.26	68.05	72.45	34.26	34.83	31.84
Ratio compared to Geonor(A+S)	0.87	1.00	0.92	0.92	0.92	0.98	0.46	0.47	0.43
Difference in Ratios	-0.13	0.00	-0.08	-0.08	-0.08	-0.02	-0.54	-0.53	-0.57
ratio with Ott 729 (T+S)	0.89	1.02	0.93	0.94	0.94	1.00	0.47	0.48	0.44
ratio with Ott 726 (T)	0.94	1.08	0.99	1.00	1.00	1.06	0.50	0.51	0.47
ratio with TB (A)	1	1.15	1.05	1.06	1.06	1.13	0.53	0.54	0.50
ratio with Frise (V)	0.95	1.09	1.00	1.01	1.00	1.07	0.51	0.51	0.47
	***								
Johnstown- May-Oct 2004 **(Warm Season)**									
Precip totals	23.58	24.56	24.47	24.23	24.23	24.17	10.86	10.83	10.64
Ratios compared to Geonor	0.96	1.00	1.00	0.99	0.99	0.98	0.44	0.44	0.43
Difference in Ratios	-0.04	0.00	0.00	-0.01	-0.01	-0.02	-0.56	-0.56	-0.57
ratio with Ott 729	0.98	1.02	1.01	1.00	1.00	1.00	0.45	0.45	0.44
ratio with Ott 726	0.97	1.01	1.01	1.00	1.00	1.00	0.45	0.45	0.44
ratio with TB	1	1.04	1.04	1.03	1.03	1.03	0.46	0.46	0.45
ratio with Frise	0.96	1.00	1.00	0.99	0.99	0.99	0.44	0.44	0.43
	**								
Johnstown-Nov 03-Apr 04 and Nov 04-Apr 05 **(Cold Season)**									
Precip totals	40.62	49.46	43.26	44.03	43.82	48.28	23.4	24	21.2
Ratios compared to Geonor	0.82	1.00	0.87	0.89	0.89	0.98	0.47	0.49	0.43
Difference in Ratios	-0.18	0.00	-0.13	-0.11	-0.11	-0.02	-0.53	-0.51	-0.57
ratio with Ott 729	0.84	1.02	0.90	0.91	0.91	1.00	0.48	0.50	0.44
ratio with Ott 726	0.92	1.12	0.98	1.00	1.00	1.10	0.53	0.55	0.48
ratio with TB	1	1.22	1.06	1.08	1.08	1.19	0.58	0.59	0.52
ratio with Frise	0.94	1.14	1.00	1.02	1.01	1.12	0.54	0.55	0.49

A=Alter, S=SDFIR, D=DFIR, T=Tretyakov, V=ASOS Shield, U=Unshielded

Figure 2. Cumulative Precipitation Gauge Comparison, Johnstown, PA.



3.3 Analysis of Short Duration Events

The 18 months of data at Sterling and Johnstown were examined to determine the periods of highest intensity precipitation events. As a result, approximately 54 hours of data at Sterling and approximately 50 hours of data at Johnstown were examined in much greater detail.

3.3.1 Sterling Data

During liquid events, the two Geonors/Alter/SDFIR under catch the Ott gauges regardless of shielding by 2-4 percent in lower wind cases and 0-2 percent in higher wind cases. The two Otts/Tret are about equal in catch with the Ott/Tret/SDFIR in low winds, but fall behind by 1-2 percent in the higher wind category. It appears then, that increased catch of some 2 percent is attributable to the SDFIR alone as winds rise above 4 m/s or so. At truly high winds, under catch would likely increase further. The Tipping Bucket/SDFIR (TB/SDFIR) exceeds the TB/Alter combination by 1-2 percent and both under catch by 4-5 percent in higher winds compared with the Geonor. The two Frise/ASOS shield (Frise) combinations under catch all other Ott/Geonor shield combinations by 2-6 percent in low winds and 5-8 percent in the higher wind category.

Unfortunately, for solid events, there are only a handful of lower wind cases and no truly high winds to go with them. Arbitrarily stratifying the 12 cases into “lower wind” and “higher wind” categories yields an unsatisfactory result in that “higher wind” ranges only from 1.79 – 2.74 m/s. Combining the 12 cases shows the Geonors averaging 0.83 inches, the Ott/SDFIR 0.84 inches and the Otts/Tret averaging 0.83 inches, while the two Frises record 0.77 inches. The Frise lag appears to accelerate as winds exceed 2 m/s. The TBs are unavailable in 10 of the 12 events.

Table 3. Sterling, VA, test site data.

STERLING VA TEST SITE DATA
SELECTED LIQUID PRECIPITATION CASES

SHIELD	SDFIR/A	A. SDFIR/A	SDFIR	SDFIR/T	ALTER	ASOS	ASOS	TRET (5/60 MINUTE MAXIMA)	TRET	DFIR	AVG TMP C	AVG WND M/S	
GAUGE	GEO 1	GEO 2	TB2	O706	TB1	FR 1	FR 2	O705	O704	O754/286			
DATE													
11/5/2003	0.98	0.97	0.98	MM	0.94	0.95	0.94	MM	MM	0.99	20.05	2.25	
3/6/2004	0.07	0.07	0.06	0.05	0.06	0.06	0.05	0.07	0.06	0.06	15.166	1.48	
3/6/2004	0.37	0.37	0.37	0.35	0.37	0.33	0.35	0.35	0.36	0.35	15.08	0.96	
3/16/2004	0.07	0.09	0.1	0.08	0.09	0.08	0.08	0.08	0.08	0.08	2.06	1.95	
4/1/2004	0.2	0.2	0.21	0.2	0.21	0.19	0.19	0.2	0.2	0.19	7.58	2.12	
4/12/2004	0.21	0.21	0.26	0.22	0.21	0.2	0.2	0.22	0.22	0.2	7.65	2.92	
5/16/2004	0.26	0.29	0.31	0.27	0.26	0.28	0.25	0.29	0.28	0.28	19.84	2.7	
5/16/2004	0.44	0.44	0.46	0.46	0.43	0.44	0.41	0.46	0.46	0.46	19.6	1.48	
5/31/2004	0.39	0.4	0.35	0.39	0.36	0.41	0.4	0.41	0.4	0.39	17.57	5.39	
5/31/2004	0.46	0.46	0.42	0.47	0.43	0.49	0.49	0.49	0.48	0.47	21.01	2.06	
6/5/2004	0.41	0.42	0.44	MM	0.44	0.41	0.39	0.43	0.43	0.42	14.89	2.17	
6/11/2004	0.21	0.2	0.22	0.21	0.21	0.2	0.19	0.21	0.21	0.21	15.15	1.56	
7/23/2004	0.13	0.13	0.14	0.13	0.14	0.13	0.13	0.14	0.15	0.14	23.7	1.67	
7/23/2004	0.79	0.82	0.87	0.84	0.83	0.83	0.82	0.85	0.84	0.85	24.48	2.27	
7/28/2004	0.36	0.39	0.37	0.39	0.36	0.35	0.32	0.38	0.37	0.37	21.84	4.09	
7/28/2004	1.28	1.31	1.29	1.28	1.23	1.19	1.17	1.3	1.27	1.28	21.16	1.64	
8/2/2004	0.25	0.24	0.24	0.26	0.25	0.24	0.24	0.25	0.25	0.26	22.48	3.46	
8/2/2004	1.29	1.29	1.31	1.35	1.29	1.25	1.26	1.33	1.35	1.34	23.02	3.31	
8/12/2004	0.29	0.29	0.27	0.37	0.24	0.26	0.26	0.29	0.32	0.29	19.33	4.8	
8/12/2004	0.68	0.68	0.67	0.71	0.66	0.68	0.68	0.71	0.7	0.7	19.5	2.16	
9/17/2004	0.35	0.35	0.32	0.32	0.34	0.32	0.33	0.31	0.32	0.35	23.13	4.68	
9/17/2004	0.92	0.92	0.92	0.94	0.9	0.87	0.89	0.95	0.94	0.94	23.93	3.544	
9/28/2004	0.15	0.15	0.16	0.19	0.17	0.15	0.16	0.16	0.16	0.17	19.86	1.68	
9/28/2004	0.46	0.46	0.46	0.46	0.45	0.43	0.43	0.45	0.46	0.46	19.49	3.85	
10/2/2004	0.11	0.11	0.11	0.11	0.12	0.11	0.11	0.12	0.11	0.11	21.59	0.73	
10/2/2004	0.26	0.26	0.29	0.29	0.28	0.29	0.28	0.29	0.3	0.29	22.58	0.88	
10/20/2004	0.11	0.11	0.12	0.11	0.11	0.1	0.1	MM	0.11	MM	10.94	1.17	
11/4/2004	0.23	0.25	0.25	0.23	0.24	MM	MM	0.24	0.24	0.24	6.68	1.29	
11/12/2004	0.24	0.23	0.24	MM	0.24	0.22	0.23	0.24	0.24	0.24	7.62	1.72	
12/9/2004	0.18	0.18	0.19	0.18	0.19	0.18	0.18	0.18	0.18	0.18	5.9	0.54	
12/23/2004	0.29	0.31	0.26	0.3	0.27	0.25	0.3	0.29	0.29	0.3	15.11	5.63	
12/23/2004	0.71	0.75	0.71	0.73	0.69	0.71	0.66	0.73	0.74	0.74	13.81	4.42	
1/14/2005	0.27	0.27	0.26	0.28	0.26	0.26	0.26	0.28	0.28	0.28	14.15	4.26	
1/14/2005	0.83	0.84	0.81	0.84	0.81	0.82	0.81	0.85	0.85	0.84	13.99	2.77	
3/8/2005	0.17	0.16	0.17	0.17	0.17	0.16	0.17	0.17	0.17	MM	9.3	2.7	
3/23/2005	0.05	0.05	0.06	0.06	0.06	0.05	0.06	0.05	0.05	MM	5.3	1.39	
3/23/2005	0.29	0.3	0.31	0.31	0.31	0.29	0.29	0.3	0.3	MM	5.42	2	
3/28/2005	0.46	0.45	0.43	0.45	0.44	0.37	0.4	0.44	0.45	MM	5.18	3.35	
4/2/2005	0.14	0.13	0.11	0.13	0.13	0.12	0.13	0.14	0.14	MM	10.39	7.74	
4/2/2005	0.63	0.62	0.57	0.63	0.6	0.57	0.57	0.62	0.62	MM	9.73	4.22	
4/30/2005	0.13	0.12	0.14	0.13	0.13	0.12	0.13	0.13	0.13	MM	11.88	0.52	
TOTAL	16.12	16.29	16.23	14.89	15.92	15.36	15.31	15.4	15.51	14.47			
RATIO	1	1.01	1.01		0.99								
ADJ RATIO*	1	1.01	1.01	1.03		0.97	0.96	1.02	1.02	1.02			

STERLING VA TEST SITE
SELECTED SOLID PRECIPITATION CASES — 5/60 MINUTE MAXIMA

DATE	GEO 1	GEO 2	TB2	O706	TB1	FR 1	FR 2	O705	O704	O754/286	AVG TMP C	AVG WND M/S	
12/5/2003	0.04	0.04	0.02	0.04	0.02	0.04	0.04	0.05	0.04	0.05	-1.91	1.99	
12/5/2003	0.19	0.19	0.08	0.17	0.08	0.16	0.16	0.18	0.17	0.17	-0.788	1.79	
1/25/2004	0.02	0.02	MM	0.02	MM	0.02	0.02	0.02	0.02	0.02	-8.99	1.03	
1/25/2004	0.13	0.13	MM	0.15	MM	0.13	0.14	0.15	0.14	0.15	-9.02	0.92	
1/27/2004	0.1	0.08	MM	0.06	MM	0.06	0.05	0.06	0.06	0.06	-4.87	MM	
2/3/2004	0.03	0.04	MM	0.03	MM	0.03	0.03	0.03	0.03	0.03	0.523	2.2	MIXED
2/3/2004	0.17	0.19	MM	0.18	MM	0.17	0.16	0.18	0.18	0.18	0.54	2.16	MIXED
1/30/2005	0.01	0.01	MM	0.01	MM	0.01	0.02	0.01	0.01	0.02	-1.575	0.4	
1/30/2005	0.06	0.06	MM	0.07	MM	0.06	0.06	0.07	0.06	0.06	-1.47	0.6	
2/24/2005	0.01	0.01	MM	0.01	MM	0.01	0.01	0.01	0.01	MM	-2.74	2.3	
2/24/2005	0.05	0.05	MM	0.05	MM	0.04	0.04	0.04	0.05	MM	-2.67	2.74	
2/28/2005	0.01	0.01	MM	0.02	MM	0.01	0.01	0.01	0.02	MM	-0.8	1.38	
2/28/2005	0.1	0.09	MM	0.09	MM	0.09	0.08	0.09	0.09	MM	-0.83	1.39	
TOTAL	0.92	0.92		0.9		0.83	0.82	0.9	0.88				
RATIO	1	1		0.98		0.9	0.89	0.98	0.96				

ADJ. RATIO IS THE RATIO AFTER SUBTRACTING GEONOR TOTALS FROM THE CORRESPONDING MISSING EVENTS.

COMMENT:
IN RAIN GEO/SDFIR UNDERCATCHES OTT/SDFIR BY 2-3%
TB/ALTER UNDERCATCHES TB/DFIR BY 2% IN RAIN
OTT/SDFIR VS OTT/TRET DIFFERENCE NEGLIGABLE IN RAIN
FRISE/ASOS UNDERCATCHES GEONOR/SDFIR 3-4% R 3-5%

IN SNOW, SIGNS REVERSE WITH OTT/SDFIR UNDERCATCH GEONOR/SDFIR BY 2% AND OTT/TRET BY 2-4%

Table 4. Sterling, VA, test site data.

STERLING VA TEST SITE DATA

	LOWER WIND		SELECTED LIQUID PRECIPITATION CASES					5/60 MINUTE MAXIMA			AVG TMP	AVG WND
SHIELD	SDFIR/A	SDFIR/A	SDFIR	SDFIR/T	ALTER	ASOS	ASOS	TRET	TRET	DFIR	C	M/S
GAUGE	GEO 1	GEO 2	TB2	O706	TB1	FR 1	FR 2	O705	O704	O754/286		
4/30/2005	0.13	0.12	0.14	0.13	0.13	0.12	0.13	0.13	0.13	MM	11.88	0.52
12/9/2004	0.18	0.18	0.19	0.18	0.19	0.18	0.18	0.18	0.18	0.18	5.9	0.54
10/2/2004	0.11	0.11	0.11	0.11	0.12	0.11	0.11	0.12	0.11	0.11	21.59	0.73
10/2/2004	0.26	0.26	0.29	0.29	0.28	0.29	0.28	0.29	0.3	0.29	22.58	0.88
3/6/2004	0.37	0.37	0.37	0.35	0.37	0.33	0.35	0.35	0.36	0.35	15.08	0.96
10/20/2004	0.11	0.11	0.12	0.11	0.11	0.1	0.1	MM	0.11	MM	10.94	1.17
11/4/2004	0.23	0.25	0.25	0.23	0.24	MM	MM	0.24	0.24	0.24	6.68	1.29
3/23/2005	0.05	0.05	0.06	0.06	0.06	0.05	0.06	0.05	0.05	MM	5.3	1.39
3/6/2004	0.07	0.07	0.06	0.05	0.06	0.06	0.05	0.07	0.06	0.06	15.166	1.48
5/16/2004	0.44	0.44	0.46	0.46	0.43	0.44	0.41	0.46	0.46	0.46	19.6	1.48
6/11/2004	0.21	0.2	0.22	0.21	0.21	0.2	0.19	0.21	0.21	0.21	15.15	1.56
7/28/2004	1.28	1.31	1.29	1.28	1.23	1.19	1.17	1.3	1.27	1.28	21.16	1.64
7/23/2004	0.13	0.13	0.14	0.13	0.14	0.13	0.13	0.14	0.15	0.14	23.7	1.67
9/28/2004	0.15	0.15	0.16	0.19	0.17	0.15	0.16	0.16	0.16	0.17	19.86	1.68
11/12/2004	0.24	0.23	0.24	MM	0.24	0.22	0.23	0.24	0.24	0.24	7.62	1.72
3/16/2004	0.07	0.09	0.1	0.08	0.09	0.08	0.08	0.08	0.08	0.08	2.06	1.95
3/23/2005	0.29	0.3	0.31	0.31	0.31	0.29	0.29	0.3	0.3	MM	5.42	2
5/31/2004	0.46	0.46	0.42	0.47	0.43	0.49	0.49	0.49	0.48	0.47	21.01	2.06
4/1/2004	0.2	0.2	0.21	0.2	0.21	0.19	0.19	0.2	0.2	0.19	7.58	2.12
8/12/2004	0.68	0.68	0.67	0.71	0.66	0.68	0.68	0.71	0.7	0.7	19.5	2.16
6/5/2004	0.41	0.42	0.44	MM	0.44	0.41	0.39	0.43	0.43	0.42	14.89	2.17
2/3/2004	0.03	0.04	MM	0.03	MM	0.03	0.03	0.03	0.03	0.03	0.523	2.2
11/5/2003	0.98	0.97	0.98	MM	0.94	0.95	0.94	MM	MM	0.99	20.05	2.25
7/23/2004	0.79	0.82	0.87	0.84	0.83	0.83	0.82	0.85	0.84	0.85	24.48	2.27
	7.87	7.96	8.1	6.42	7.89	7.52	7.46	7.03	7.09			
RATIO	1	1.01										
ADJ RATIO *			1.03	1.03	1.01	0.98	0.98	1.04	1.03			

ADJ. RATIO IS THE RATIO AFTER SUBTRACTING GEONOR TOTALS FROM THE CORRESPONDING MISSING EVENTS.

HIGHER WIND SELECTED LIQUID PRECIPITATION CASES 5/60 MINUTE MAXIMA

SHIELD / GAUGE	SDFIR/A GEO 1	SDFIR/A GEO 2	SDFIR TB2	SDFIR/T O706	ALTER TB1	ASOS FR 1	ASOS FR 2	TRET O705	TRET O704	DFIR O754/286	AVG TMP C	AVG WND M/S
5/16/2004	0.26	0.29	0.31	0.27	0.26	0.28	0.25	0.29	0.28	0.28	19.84	2.7
3/8/2005	0.17	0.16	0.17	0.17	0.17	0.16	0.17	0.17	0.17	MM	9.3	2.7
1/14/2005	0.83	0.84	0.81	0.84	0.81	0.82	0.81	0.85	0.85	0.84	13.99	2.77
4/12/2004	0.21	0.21	0.26	0.22	0.21	0.2	0.2	0.22	0.22	0.2	7.65	2.92
8/2/2004	1.29	1.29	1.31	1.35	1.29	1.25	1.26	1.33	1.35	1.34	23.02	3.31
3/28/2005	0.46	0.45	0.43	0.45	0.44	0.37	0.4	0.44	0.45	MM	5.18	3.35
8/2/2004	0.25	0.24	0.24	0.26	0.25	0.24	0.24	0.25	0.25	0.26	22.48	3.46
9/17/2004	0.92	0.92	0.92	0.94	0.9	0.87	0.89	0.95	0.94	0.94	23.93	3.544
9/28/2004	0.46	0.46	0.46	0.46	0.45	0.43	0.43	0.45	0.46	0.46	19.49	3.85
7/28/2004	0.36	0.39	0.37	0.39	0.36	0.35	0.32	0.38	0.37	0.37	21.84	4.09
4/2/2005	0.63	0.62	0.57	0.63	0.6	0.57	0.57	0.62	0.62	MM	9.73	4.22
1/14/2005	0.27	0.27	0.26	0.28	0.26	0.26	0.26	0.28	0.28	0.28	14.15	4.26
12/23/2004	0.71	0.75	0.71	0.73	0.69	0.71	0.66	0.73	0.74	0.74	13.81	4.42
9/17/2004	0.35	0.35	0.32	0.32	0.34	0.32	0.33	0.31	0.32	0.35	23.13	4.68
8/12/2004	0.29	0.29	0.27	0.37	0.24	0.26	0.26	0.29	0.32	0.29	19.33	4.8
5/31/2004	0.39	0.4	0.35	0.39	0.36	0.41	0.4	0.41	0.4	0.39	17.57	5.39
12/23/2004	0.29	0.31	0.26	0.3	0.27	0.25	0.3	0.29	0.29	0.3	15.11	5.63
4/2/2005	0.14	0.13	0.11	0.13	0.13	0.12	0.13	0.14	0.14	MM	10.39	7.74
	8.28	8.37	8.13	8.5	8.03	7.87	7.88	8.4	8.45			
RATIO	1	1.01	0.98	1.03	0.97	0.95	0.95	1.01	1.02			

COMMENT
TB RATIOS DROP 4-5 % LOW WIND TO HIGH WIND CATEGORY
OTTS NO SDFIR DROP 1-3 % IN HIGHER WINDCATEGORY
GEONORS UNDERCATCH OTTS 1-2% NO MATTER SHIELDING OR WIND REGIME
GEONORS UNDERCATCH REDUCES AS WIND INCREASES.
FRISE DROPS 3% CATCH LOW WIND TO HIGH WIND CATEGORY

Table 5. Sterling, VA, test site data.

	SRDC	LOWER WIND SELECTED SOLID PRECIPITATION CASES 5/60 MINUTE MAXIMA										
1/30/2005	0.01	0.01	MM	0.01	MM	0.01	0.02	0.01	0.01	0.02	-1.575	0.4
1/30/2005	0.06	0.06	MM	0.07	MM	0.06	0.06	0.07	0.06	0.06	-1.47	0.6
1/25/2004	0.13	0.13	MM	0.15	MM	0.13	0.14	0.15	0.14	0.15	-9.02	0.92
1/25/2004	0.02	0.02	MM	0.02	MM	0.02	0.02	0.02	0.02	0.02	-8.99	1.03
2/28/2005	0.01	0.01	MM	0.02	MM	0.01	0.01	0.01	0.02	MM	-0.8	1.38
2/28/2005	0.1	0.09	MM	0.09	MM	0.09	0.08	0.09	0.09	MM	-0.83	1.39
TOTAL	0.33	0.32		0.36		0.32	0.33	0.35	0.34	N/A		
RATIO	1	0.97		1.09		0.97	1	1.06	1.03			
	SRDC	HIGHER WIND SELECTED SOLID PRECIPITATION CASES 5/60 MINUTE MAXIMA										
12/5/2003	0.19	0.19	0.08	0.17	0.08	0.16	0.16	0.18	0.17	0.17	-0.788	1.79
12/5/2003	0.04	0.04	0.02	0.04	0.02	0.04	0.04	0.05	0.04	0.05	-1.91	1.99
2/3/2004	0.17	0.19	MM	0.18	MM	0.17	0.16	0.18	0.18	0.18	0.54	2.16
2/3/2004	0.03	0.04	MM	0.03	MM	0.03	0.03	0.03	0.03	0.03	0.52	2.2
2/24/2005	0.01	0.01	MM	0.01	MM	0.01	0.01	0.01	0.01	MM	-2.74	2.3
2/24/2005	0.05	0.05	MM	0.05	MM	0.04	0.04	0.04	0.05	MM	-2.67	2.74
TOTAL	0.49	0.52		0.48		0.45	0.44	0.49	0.48			
RATIO	1	1.06		0.98		0.92	0.9	1	0.98			

COMMENT
LOWER WINDS: GEONORS/SDFIR UNDERCATCH OTT/SDFIR 9-12% & OTTS/TRET BY 3-9%
HIGHER WINDS: REVERSAL-OTT/SDFIR UNDERCATCHES GEONORS/SDFIR 2-8%
HIGHER WINDS: OTTS/TRET UNDERCATCH GEONORS/SDFIR IR .97/1.01 = 4%
LOWER WINDS: OTTS/TRET UNDERCATCH OTT/SDFIR 3-6%
HIGHER WINDS: OTTS/TRET 0-1% MORE CATCH THAN OTT/SDFIR
FRISES DROP 5-10% FROM LOWER WINDS TO HIGHER

3.3.2 Johnstown Data

During liquid events, Ott/SDFIR and Ott/Tret catch substantially the same in both wind categories. The Geonor and Frise gauges under catch the Otts by 3-6 percent regardless of Ott shielding or wind category, with no trends evident. The TB under catches the Otts by 3-4 percent in lower winds and 9-11 percent in the higher wind category.

For solid events, again, there is a paucity of events. Even so, some interesting trends begin to appear. The Geonor under catch continues, amounting to 0-3 percent vs. Ott/Tret and 5-8 percent vs. Otts/SDFIR in the lower wind category. Here, Otts/Tret lag Otts/SDFIR by an average of 4 percent (1.3/1.36 inches). In winds above 2.8 m/s, the Otts/Tret begin to significantly under catch Otts/SDFIR and Geonor/SDFIR, averaging a loss of 23 percent (.44/.57 inches) and 19 percent (.22/.27 inches), respectively. It is logical to assume that the SDFIR makes a substantial difference here. The Geonor vs. Ott/SDFIR under catch also widens to 11-17 percent from the aforementioned 5-8 percent as winds increase. This difference must be attributable to gauge/shield performance, since they both have SDFIR. Frise under catches all other combinations in use, 11-19 percent in low winds and plunges to 41 percent vs. the Geonor and averages 56 percent against the Otts/SDFIR. Again, the TB is unavailable under these conditions.

Table 6. Johnstown, PA, test site data.

JOHNSTOWN PA TEST SITE

SELECTED LIQUID PRECIPITATION CASES

SHIELD GAUGE DATE	SDFIR/ALT GEO	SDFIR/TR O 729	SDFIR/TR O755/725	ALTER TB	ASOS FRISE	TRET O 722	TRET O 726	AVG TMP C	AVG WND M/S
11/19/2003	0.18	0.18	0.18	0.17	0.17	0.18	0.19	13.09	2.95
11/19/2003	0.75	0.77	0.77	0.7	0.71	0.77	0.79	12.93	3.36
12/10/2003	0.07	0.07	0.06	0.06	0.06	0.07	0.07	4.89	4.49
12/10/2003	0.3	0.32	0.32	0.29	0.31	0.32	0.32	4.92	3.32
1/4/2004	0.2	0.21	0.21	0.21	0.21	0.21	0.21	3.019	1.75
1/5/2004	0.18	0.18	0.19	0.18	0.18	0.19	0.19	4.09	2.31
3/20/2004	0.27	0.29	0.29	0.27	0.29	0.29	0.29	6.61	3.05
4/1/2004	0.17	0.16	0.16	0.15	0.16	0.17	0.17	4.19	3.76
4/13/2004	0.44	0.44	0.43	0.43	0.43	0.44	0.44	2.34	1.49
5/18/2004	0.38	0.38	0.38	0.36	0.37	0.38	0.39	15.75	2.58
5/21/2004	0.55	0.55	0.55	0.5	MM	0.56	0.56	16.26	4.3
6/11/2004	0.2	0.2	MM	0.2	0.19	0.2	0.2	17.07	1.94
6/16/2004	0.61	0.75	MM	0.73	0.72	0.76	0.76	20.55	1.82
6/22/2004	0.22	0.25	MM	0.23	0.25	0.25	0.25	19.11	3.68
7/4/2004	0.37	0.39	MM	0.35	0.36	0.39	0.39	18.75	3.55
7/4/2004	0.58	0.6	MM	0.55	0.57	0.6	0.6	20.06	1.99
7/7/2004	0.3	0.3	MM	0.26	0.29	0.3	0.3	19.13	5.86
7/7/2004	0.8	0.82	MM	0.72	0.79	0.83	0.83	19.56	3.92
7/26/2004	0.1	0.1	MM	0.1	0.1	0.1	0.1	18.21	0.99
7/26/2004	0.4	0.39	MM	0.39	0.38	0.39	0.4	18.12	0.69
7/30/2004	0.6	0.6	MM	0.57	0.56	0.61	0.6	20.4	1.1
8/4/2004	0.43	0.44	MM	0.42	0.43	0.44	0.44	17.87	2.62
8/29/2004	0.68	0.69	MM	0.65	0.69	0.71	0.7	19.81	1.72
9/8/2004	0.4	0.42	MM	0.39	0.39	0.42	0.42	18.3	3.31
9/17/2004	0.31	0.3	MM	0.28	0.31	0.31	0.32	15.04	5.34
10/13/2005	0.05	0.06	MM	0.06	0.06	0.05	0.05	8.1	2.93
10/13/2004	0.18	0.2	MM	0.2	0.2	0.2	0.2	8.35	2.62
10/18/2004	0.14	0.15	MM	0.14	0.15	0.15	0.15	6.9	2.84
11/12/2004	0.11	0.11	0.1	0.1	0.1	0.1	0.1	2.46	2.71
11/24/2004	0.09	0.09	0.09	0.08	0.09	0.09	0.09	9.62	4.11
12/1/2004	0.17	0.18	0.17	0.16	0.17	0.18	0.17	8.54	4.53
12/10/2004	0.21	0.2	0.21	0.2	0.2	0.21	0.21	4.28	0.95
2/9/2005	0.16	0.17	0.18	0.17	MM	0.18	0.18	5.52	4.57
4/2/2005	0.12	0.13	0.13	0.12	0.13	0.13	0.12	5.75	2.38
4/22/2005	0.2	0.21	MM	0.2	0.2	0.21	0.21	7.44	2.33
TOTAL	10.92	11.3		10.59	10.22	11.39	11.41		
RATIO	1	1.03		0.97		1.04	1.04		
ADJ RATIO					1				

JOHNSTOWN PA TEST SITE

SELECTED SOLID PRECIPITATION CASES

DATE	SDFIR/ALT GEO	SDFIR/TR O 729	SDFIR/TR O755/725	ALTER TB	ASOS FRISE	TRET O 722	TRET O 726	AVG TMP C	AVG WND M/S
1/14/2004	0.09	0.09	0.09	MM	0.08	0.08	0.09	-5.21	2.43
1/17/2004	0.07	0.07	0.07	MM	0.06	0.07	0.07	-6.34	1.31
1/25/2004	0.15	0.18	0.14	MM	0.09	0.14	0.14	-13.91	2.57
2/3/2004	0.04	0.04	0.05	0.01	0.04	0.04	0.04	-4.36	2.83
2/3/2004	0.14	0.15	0.14	0.2	0.13	0.14	0.15	-3.54	2.285
2/6/2004	0.02	0.02	0.09	MM	0.02	0.03	0.07	-3.89	4.85
2/6/2004	0.15	0.16	0.17	MM	0.14	0.15	0.16	0.518	2.5
3/8/2004	0.11	0.13	0.06	MM	0.05	0.07	0.07	-2.08	4.09
1/5/2005	0.03	0.04	0.03	0.03	0.03	0.03	0.03	-0.56	MM
1/5/2005	0.18	0.18	0.18	0.17	0.19	0.18	0.18	-0.56	MM
1/6/2005	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.587	MM
2/24/2005	0.04	0.04	0.06	MM	0.06	0.06	0.05	-5.65	1.91
3/11/2005	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-3.56	3.49
3/11/2005	0.05	0.06	0.06	0.01	0.03	0.03	0.03	-3.57	3.35
4/24/2005	0.04	0.04	MM	0.01	0.01	0.02	0.02	-0.09	5.41
TOTAL	1.17	1.25	1.2		0.99	1.1	1.16		
RATIO	1	1.07	1.06		0.85	0.94	0.99		

COMMENT: GEONOR UNDERCATCHES OTTS 3-4 % REGARDLESS OF SHIELDING IN RAIN
TB/ALTER UNDERCATCH 3% COMPARED TO GEONOR/DFIR DFIR IN RAIN
FRISE/ASOS SHIELD 1:1 RATIO WITH GEONOR/DFIR IN RAIN
IN SNOW GEONOR/DFIR UNDERCATCHES OTT/DFIR BY 7% 6-7%
IN SNOW OTT/TRET UNDERCATCH OTT/DFIR BY 1-(BY 7-13%

Table 7. Johnstown, PA, test site data.

			JOHNSTOWN PA TEST SITE				5/60 MINUTE MAXIMA		
		LOW WIND	LIQUID PRECIPITATION CASES					AVG TMP	AVG WND
GAUGE	GEO	O 729	O755/725	TB	FRISE	O 722	O 726		
SHIELD	SDFIR/ALT	SDFIR/TR	SDFIR/TR	ALTER	ASOS	TRET	TRET	C	M/S
DATE									
7/26/2004	0.4	0.39	MM	0.39	0.38	0.39	0.4	18.12	0.69
12/10/2004	0.21	0.2	0.21	0.2	0.2	0.21	0.21	4.28	0.95
7/26/2004	0.1	0.1	MM	0.1	0.1	0.1	0.1	18.21	0.99
7/30/2004	0.6	0.6	MM	0.57	0.56	0.61	0.6	20.4	1.1
4/13/2004	0.44	0.44	0.43	0.43	0.43	0.44	0.44	2.34	1.49
8/29/2004	0.68	0.69	MM	0.65	0.69	0.71	0.7	19.81	1.72
1/4/2004	0.2	0.21	0.21	0.21	0.21	0.21	0.21	3.019	1.75
6/16/2004	0.61	0.75	MM	0.73	0.72	0.76	0.76	20.55	1.82
6/11/2004	0.2	0.2	MM	0.2	0.19	0.2	0.2	17.07	1.94
7/4/2004	0.58	0.6	MM	0.55	0.57	0.6	0.6	20.06	1.99
1/5/2004	0.18	0.18	0.19	0.18	0.18	0.19	0.19	4.09	2.31
4/22/2005	0.2	0.21	MM	0.2	0.2	0.21	0.21	7.44	2.33
4/2/2005	0.12	0.13	0.13	0.12	0.13	0.13	0.12	5.75	2.38
5/18/2004	0.38	0.38	0.38	0.36	0.37	0.38	0.39	15.75	2.58
8/4/2004	0.43	0.44	MM	0.42	0.43	0.44	0.44	17.87	2.62
10/13/2004	0.18	0.2	MM	0.2	0.2	0.2	0.2	8.35	2.62
11/12/2004	0.11	0.11	0.1	0.1	0.1	0.1	0.1	2.46	2.71
	5.62	5.83		5.61	5.66	5.88	5.87		
RATIO	1	1.04		1	1.01	1.05	1.04		
		HIGHER WIND LIQUID PRECIPITATION CASES					5/60 MINUTE MAXIMA		
10/18/2004	0.14	0.15	MM	0.14	0.15	0.15	0.15	6.9	2.84
10/13/2005	0.05	0.06	MM	0.06	0.06	0.05	0.05	8.1	2.93
11/19/2003	0.18	0.18	0.18	0.17	0.17	0.18	0.19	13.09	2.95
3/20/2004	0.27	0.29	0.29	0.27	0.29	0.29	0.29	6.61	3.05
9/8/2004	0.4	0.42	MM	0.39	0.39	0.42	0.42	18.3	3.31
12/10/2003	0.3	0.32	0.32	0.29	0.31	0.32	0.32	4.92	3.32
11/19/2003	0.75	0.77	0.77	0.7	0.71	0.77	0.79	12.93	3.36
7/4/2004	0.37	0.39	MM	0.35	0.36	0.39	0.39	18.75	3.55
6/22/2004	0.22	0.25	MM	0.23	0.25	0.25	0.25	19.11	3.68
4/1/2004	0.17	0.16	0.16	0.15	0.16	0.17	0.17	4.19	3.76
7/7/2004	0.8	0.82	MM	0.72	0.79	0.83	0.83	19.56	3.92
11/24/2004	0.09	0.09	0.09	0.08	0.09	0.09	0.09	9.62	4.11
5/21/2004	0.55	0.55	0.55	0.5	MM	0.56	0.56	16.26	4.3
12/10/2003	0.07	0.07	0.06	0.06	0.06	0.07	0.07	4.89	4.49
12/1/2004	0.17	0.18	0.17	0.16	0.17	0.18	0.17	8.54	4.53
2/9/2005	0.16	0.17	0.18	0.17	MM	0.18	0.18	5.52	4.57
9/17/2004	0.31	0.3	MM	0.28	0.31	0.31	0.32	15.04	5.34
7/7/2004	0.3	0.3	MM	0.26	0.29	0.3	0.3	19.13	5.86
TOTAL	5.3	5.47		4.98	4.56	5.51	5.54		
RATIO	1	1.03		0.94	0.99	1.04	1.05		

COMMENT
TB AND FRISE LOSE CATCH OF 2-6 % IN HIGHER WIND GATEGORY
GEONOR UNDERCATCHES OTTS IN DFIR OR NOT. 3-5%
OTT/SDFIR UNDERCATCH OTTS/TRET BY 1-2%

			SELECTED SOLID PRECIPITATION CASES						
1/14/2004	0.09	0.09	0.09	MM	0.08	0.08	0.09	-5.21	2.43
1/17/2004	0.07	0.07	0.07	MM	0.06	0.07	0.07	-6.34	1.31
1/25/2004	0.15	0.18	0.14	MM	0.09	0.14	0.14	-13.91	2.57
2/3/2004	0.14	0.15	0.14	0.2	0.13	0.14	0.15	-3.54	2.285
2/3/2004	0.04	0.04	0.05	0.01	0.04	0.04	0.04	-4.36	2.83
2/6/2004	0.15	0.16	0.17	MM	0.14	0.15	0.16	0.518	2.5
2/6/2004	0.02	0.02	0.09	MM	0.02	0.03	0.07	-3.89	4.85
3/8/2004	0.11	0.13	0.06	MM	0.05	0.07	0.07	-2.08	4.09
1/5/2005	0.03	0.04	0.03	0.03	0.03	0.03	0.03	-0.56	MM
1/5/2005	0.18	0.18	0.18	0.17	0.19	0.18	0.18	-0.56	MM
1/6/2005	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.587	MM
2/24/2005	0.04	0.04	0.06	MM	0.06	0.06	0.05	-5.65	1.91
3/11/2005	0.05	0.06	0.06	0.01	0.03	0.03	0.03	-3.57	3.35
3/11/2005	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-3.56	3.49
4/24/2005	0.04	0.04	MM	0.01	0.01	0.02	0.02	-0.09	5.41
TOTAL	1.17	1.25	1.2		0.99	1.1	1.16		
RATIO	1	1.07		N/A	0.85	0.94	0.99		
ADJ RATIO			1.06*						

* AFTER DEDUCTING 4/24/05 GEONOR TOTAL

COMMENT:
OTTS/TRET UNDERCATCH OTT/SDFII SDFIR 7 TO 13%
GEONOR/SDFIR UNDERCATCHES OTTS/SDFIR 6-7%
FRISE/ASOS UNDERCATCH 15% VS GEONOR/SDFIR AND 21-22% VS OTTS

Table 8. Johnstown, PA, test site data.

SOLID PRECIPITATION IN LOW WINDS									
1/17/2004	0.07	0.07	0.07	MM	0.06	0.07	0.07	-6.34	1.31
2/24/2005	0.04	0.04	0.06	MM	0.06	0.06	0.05	-5.65	1.91
2/3/2004	0.14	0.15	0.14	0.2	0.13	0.14	0.15	-3.54	2.285
1/14/2004	0.09	0.09	0.09	MM	0.08	0.08	0.09	-5.21	2.43
2/6/2004	0.15	0.16	0.17	MM	0.14	0.15	0.16	0.518	2.5
1/25/2004	0.15	0.18	0.14	MM	0.09	0.14	0.14	-13.91	2.57
TOTAL	0.64	0.69	0.67		0.56	0.64	0.66		
RATIO	1	1.08	1.05		0.88	1	1.03		
SOLID PRECIPITATION IN HIGHER WINDS									
2/3/2004	0.04	0.04	0.05	0.01	0.04	0.04	0.04	-4.36	2.83
3/11/2005	0.05	0.06	0.06	0.01	0.03	0.03	0.03	-3.57	3.35
3/11/2005	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-3.56	3.49
3/8/2004	0.11	0.13	0.06	MM	0.05	0.07	0.07	-2.08	4.09
2/6/2004	0.02	0.02	0.09	MM	0.02	0.03	0.07	-3.89	4.85
4/24/2005	0.04	0.04	MM	0.01	0.01	0.02	0.02	-0.09	5.41
TOTAL	0.27	0.3	0.27		0.16	0.2	0.24		
RATIO	1	1.11			0.59	0.74	0.89		
ADJ RATIO			1.17						

COMMENT
LOW WIND CASES: GEONOR/SDFIR UNDERCATCHES OTTS/SDFIR 5-8%
HIGHER WIND CASES: GEONOR/SDFIR UNDERCATCHES OTTS/SDFIR 11-17%
LOW WIND CASES : OTTSTTS/TRET UNDERCATCH OTTS/SDFIR BY FIR 1.3/1.36 = 4%
HIGHER WIND CASES: GIOTT/TRET UNDERCATCHES OTT/SDFIR R BY .44/.57 = 23%
LOW WIND CASES: FRISE/ASOS UNDERCATCH GEONOR/SDFIR BY 12%
HIGHER WIND CASES FRISE/ASOS UNDERCATCH PLUNGES TO 41%

With only 24 snow cases, results here are based on a small sample, and statistical relevance is difficult to establish. Nonetheless, the trends that become evident are consistent with those found by many other researchers. During these shorter bursts of precipitation (5 and 60 minutes) the Geonor/Alter/SDFIR combination under catches Ott/Tret/SDFIR under all conditions, i.e., rain and snow, and low and higher wind categories. At winds above 3 m/s or so, the Ott/Tret combination starts to fall behind the Ott/Tret/SDFIR a few percentage points in rain, and quite significantly in snow. Ott/Tret also falls substantially behind the Geonor/Alter/SDFIR in snow at these higher winds. It should be noted here that winds covered by these events are by no means “high,” as maximum winds for all snow cases is only 5.41 m/s. These determinations should be considered when decisions are taken regarding non-use of SDFIR in snow country and, especially in Alaska. The poor performance of the Tipping Bucket in snow limits its usefulness as backup in those places where snow is a major contributor to annual precipitation. In rain, the TB/Alter and TB/Alter/SDFIR compare well with the Otts and Geonors at low wind speeds; as winds increase, catch starts to fall behind by 4-6 percent. There are no data in this study that would indicate how these backup units would perform at, say, 10 m/s or higher. The Frise/ASOS shield combination exhibits serious shortcomings under various snow and higher wind rain scenarios.

3.4 Number of Days of Precipitation at Johnstown and Sterling

The number of days of recorded precipitation at Sterling and Johnstown from November 2003 to April 2005 are shown in the following table.

Table 9. Number of days with recorded precipitation, November 2003 to April 2005.

Number of Days With Recorded Precipitation- Nov 03 to Apr 05			
Month	**Sterling**	**Johnstown**	**Total**
Nov '03	9	16	25
Dec	14	25	39
Jan '04	14	25	39
Feb	5	8	13
Mar	13	18	31
Apr	15	15	30
May	17	16	33
Jun	13	15	28
Jul	16	12	28
Aug	10	16	26
Sept	11	9	20
Oct	10	12	22
Nov	14	16	30
Dec	8	15	23
Jan '05	14	22	36
Feb	11	15	26
Mar	10	21	31
Apr	10	13	23
Total	214	289	503

3.5 Geonor False Reports/Wetness Sensor Summary

The Vaisala Rain Detector was used at both sites to determine when the Geonor gauges reported false events. This rain detector, or wetness sensor as it was called, was quite successful in identifying false data and providing a technique for removing that data from the data base. During the course of the study, however, false reports rates for the Geonor gauges at Sterling were .90 and .75 percent, and at Johnstown, .47 percent. However, processing software combined with the wetness sensor does eliminate the false report as a significant issue. Further testing and analysis will be made for utilizing the wetness sensor.

Table 10. False reports by date.

False Reports by Date	Sterling				Johnstown	totals
	Geo1	Geo2	Geo3	Geo4	Geo	
Nov	13	13				2
Dec						
Jan '04	3,16,24,	15,24,28				6
Feb	2,12,16 20,23,29	2,14,16 23,28,29			1,8,11 13,15,27	18
Mar	1,9,14, 23,24,29	1,13,23, 24,29			2	12
Apr	16,17,18 19,28	16,17,18 19,21,24 (2)				12
May	5,6,11,12, 13,14,23,24	5,6,11,12, 13,14,23,24			4,6	18
June	7,8,9,10					4
July					21,25	2
August					2,3,9,17, 23,24,27	7
Sept					3,4,10,20, 22,23	6
Oct	25,30	30			11,12,28	6
Nov					10	1
Dec					20,25	2
Jan '05	27	18,28	21(2),26(3) 27,28			10
Feb	1,2,6,7,11	6,19	2,5,7,8,11,12		27	14
Mar	9,15,18(2), 30	9		30	14,30	9
April	5,6,9,10,11, 14-18,28	5,9-11,14, 16-19,28	5,9,10,16,17, 19,28	5,9,10,13,14, 15,18,19,28	5,12,14,17	41
Totals	57	46	20	10	37	170

Table 11. False reports as a percentage of precipitation.

False reports as a percentage of precipitation							
	Nov '03	Dec	Jan '04	Feb	Mar	Apr	May
Geo 1 Sterling	0.2	0	1.7	6	3.2	0.8	2.1
Geo 2 Sterling	0.2	0	1.7	5.7	2.5	1.4	2.1
Geo Johnstown	0	0	0	5.9	0.3	0.2	0.4
	June	July	August	Sept	Oct	Nov	Dec
Geo 1 Sterling	2.5	0	0	0	1.6	0	0
Geo 2 Sterling	0	0	0	0	0.8	0	0
Geo Johnstown	0	0.3	1.6	0.9	2.4	0.4	0.7
	Jan '05	Feb	Mar	Apr	Overall		
Geo1 Sterling	0.3	2.7	1.2	2.6	0.9		
Geo2 Sterling	0.6	1.1	0.3	2.5	0.75		
Geo3 Sterling	9	12.5	0	1.8	1.9		
Geo4 Sterling	0	0.5	0.3	2.2	1.1		
Geo Johnstown	0	0.3	0.5	1.8	0.47		

3.6 Additional Gauge Comparison Ratios, Confidence Intervals and Z tests for Short Duration Events

The following tables and graphs compare all gauges with each other during short duration events as identified in Section 3.3. Data cover approximately 54 hours from Sterling and 50 hours from Johnstown. Analyses include the number of events, comparison ratios (a ratio based on total sums of all events, and a second ratio which is the average of the ratios of individual events), standard deviations, 95 percent confidence intervals and the Z test. The null hypothesis of the Z test is that the mean catch of the two gauges being compared are equal. If the Z value is greater than 1.96 or less than -1.96 , then the null hypothesis is rejected. If the Z value is between 1.96 and -1.96, then we fail to reject the null hypothesis. For the Z test, confidence intervals or standard deviations to be valid, the number of events (column NIJ) should be about 30 or more to ensure a normal population. Therefore, in many cases in the following tables, **events are fewer than 30, so statistics for those comparisons should be viewed with caution.** High wind is defined as all events occurring above the average wind speed for all events; low wind is all events occurring at wind speeds below the average.

The following 14 tables (numbered 12 through 25) provide the following: All data, all liquid precipitation, all solid precipitation, liquid high wind, liquid low wind, solid high wind, and solid low wind. The first seven tables are for Sterling; the next seven are for Johnstown. These tables provide information to make inter-comparisons between all the test gauge types for a variety of precipitation and wind conditions. As would be expected, solid precipitation and higher wind conditions increase variability between gauges. Also, the vulnerability of tipping bucket gauges in solid precipitation situations becomes more evident.

At Sterling, for all data, the standard deviation (a measure of variation, in this case, when comparing ratios of individual events) is greatest between Ott 754 and TB1 (.309). Ott

754 has a Tretyakov and DFIR for protection while TB1 has just an Alter shield. For liquid data only, the standard deviation is greatest between Ott 706 and TB 2 (.106). Ott 706 has a Tretyakov and SDFIR for protection while TB2 has just the SDFIR. For solid precipitation only, the standard deviation is greatest between Ott 754 and Geo1 (.359). Ott 754 has the Tretyakov and DFIR while Geo1 has an Alter and SDFIR. However, it should be noted that the number of solid events at Sterling was relatively small.

At Johnstown, for all data, the standard deviation is greatest between Ott755 and TB1 (1.245). Ott 755 has a Tretyakov and SDFIR while TB1 has just an Alter shield for protection. For liquid precipitation only, the standard deviation is largest between TB1 and the Geonor gauge (.077). TB1 has an Alter while the Geonor has an Alter and SDFIR for protection. For solid precipitation only, the standard deviation is largest when comparing the Ott 755 and TB 1 (2.075).

Table 12. Sterling, all data.

Sterling - All Data								
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
GEO 2	GEO 1	54	1.01	1.012	0.076	0.863	1.16	0.03
TB2	GEO 1	43	0.999	0.998	0.16	0.684	1.312	-0.004
O706	GEO 1	51	1.025	1.037	0.172	0.699	1.375	0.068
TB1	GEO 1	43	0.98	0.98	0.139	0.708	1.253	-0.064
FR 1	GEO 1	53	0.963	0.959	0.085	0.793	1.125	-0.11
FR 2	GEO 1	53	0.96	0.977	0.174	0.635	1.319	-0.12
O705	GEO 1	52	1.022	1.018	0.091	0.839	1.196	0.063
O704	GEO 1	53	1.021	1.028	0.156	0.723	1.334	0.059
O754/286	GEO 1	42	1.021	1.041	0.176	0.696	1.386	0.061
GEO 1	GEO 2	54	0.99	0.994	0.069	0.859	1.128	-0.03
TB2	GEO 2	43	0.988	0.987	0.145	0.702	1.271	-0.037
O706	GEO 2	51	1.013	1.026	0.172	0.689	1.363	0.036
TB1	GEO 2	43	0.97	0.97	0.134	0.708	1.232	-0.097
FR 1	GEO 2	53	0.955	0.95	0.073	0.807	1.094	-0.136
FR 2	GEO 2	53	0.951	0.969	0.172	0.632	1.306	-0.147
O705	GEO 2	52	1.011	1.007	0.087	0.838	1.177	0.03
O704	GEO 2	53	1.009	1.019	0.155	0.714	1.323	0.027
O754/286	GEO 2	42	1.007	1.021	0.177	0.674	1.367	0.019
GEO 1	TB2	43	1.001	1.043	0.274	0.506	1.58	0.004
GEO 2	TB2	43	1.012	1.051	0.268	0.525	1.577	0.037
O706	TB2	40	1.029	1.065	0.252	0.572	1.558	0.086
TB1	TB2	43	0.981	0.987	0.062	0.866	1.108	-0.06
FR 1	TB2	42	0.968	1.002	0.237	0.538	1.465	-0.102
FR 2	TB2	42	0.965	1.006	0.24	0.536	1.476	-0.112
O705	TB2	41	1.026	1.079	0.308	0.475	1.682	0.08
O704	TB2	42	1.024	1.058	0.241	0.585	1.531	0.073
O754/286	TB2	35	1.019	1.077	0.317	0.455	1.699	0.056
GEO 1	O706	51	0.976	0.986	0.147	0.698	1.274	-0.068
GEO 2	O706	51	0.987	0.995	0.132	0.736	1.253	-0.036
TB2	O706	40	0.972	0.973	0.149	0.68	1.265	-0.086
TB1	O706	40	0.954	0.956	0.136	0.691	1.222	-0.142
FR 1	O706	50	0.939	0.937	0.1	0.741	1.132	-0.173
FR 2	O706	50	0.936	0.954	0.175	0.611	1.296	-0.181
O705	O706	50	0.997	0.995	0.114	0.771	1.219	-0.009
O704	O706	51	0.996	0.996	0.059	0.88	1.112	-0.013
O754/286	O706	39	0.995	1.027	0.174	0.685	1.368	-0.014
GEO 1	TB1	43	1.021	1.056	0.264	0.539	1.573	0.064
GEO 2	TB1	43	1.031	1.065	0.262	0.552	1.578	0.097
TB2	TB1	43	1.019	1.017	0.066	0.888	1.147	0.06
O706	TB1	40	1.049	1.08	0.248	0.594	1.565	0.142
FR 1	TB1	42	0.986	1.014	0.23	0.563	1.466	-0.044
FR 2	TB1	42	0.983	1.018	0.228	0.571	1.465	-0.054
O705	TB1	41	1.044	1.09	0.301	0.501	1.68	0.133
O704	TB1	42	1.042	1.072	0.234	0.612	1.531	0.128

O754/286	TB1	35	1.044	1.097	0.309	0.491	1.702	0.13
GEO 1	FR 1	53	1.038	1.053	0.114	0.829	1.277	0.11
GEO 2	FR 1	53	1.048	1.059	0.089	0.884	1.234	0.136
TB2	FR 1	42	1.033	1.032	0.147	0.744	1.319	0.102
O706	FR 1	50	1.065	1.084	0.161	0.769	1.4	0.173
TB1	FR 1	42	1.014	1.015	0.134	0.752	1.279	0.044
FR 2	FR 1	53	0.996	1.018	0.151	0.722	1.315	-0.011
O705	FR 1	51	1.061	1.062	0.06	0.943	1.18	0.167
O704	FR 1	52	1.06	1.074	0.144	0.793	1.356	0.164
O754/286	FR 1	41	1.05	1.073	0.158	0.763	1.383	0.138
GEO 1	FR 2	53	1.042	1.05	0.176	0.705	1.395	0.12
GEO 2	FR 2	53	1.051	1.055	0.146	0.769	1.341	0.147
TB2	FR 2	42	1.037	1.029	0.153	0.728	1.329	0.112
O706	FR 2	50	1.068	1.076	0.175	0.732	1.419	0.181
TB1	FR 2	42	1.017	1.011	0.131	0.755	1.267	0.054
FR 1	FR 2	53	1.004	0.995	0.095	0.808	1.182	0.011
O705	FR 2	51	1.064	1.056	0.115	0.83	1.282	0.177
O704	FR 2	52	1.063	1.068	0.168	0.738	1.398	0.174
O754/286	FR 2	41	1.059	1.062	0.064	0.937	1.187	0.162
GEO 1	O705	52	0.979	0.993	0.117	0.764	1.221	-0.063
GEO 2	O705	52	0.99	1.001	0.096	0.813	1.188	-0.03
TB2	O705	41	0.974	0.968	0.152	0.671	1.265	-0.08
O706	O705	50	1.003	1.023	0.164	0.701	1.345	0.009
TB1	O705	41	0.958	0.954	0.139	0.681	1.227	-0.133
FR 1	O705	51	0.943	0.945	0.051	0.844	1.045	-0.167
FR 2	O705	51	0.94	0.964	0.163	0.643	1.284	-0.177
O704	O705	52	0.999	1.014	0.15	0.72	1.308	-0.004
O754/286	O705	41	0.994	1.013	0.163	0.694	1.332	-0.016
GEO 1	O704	53	0.98	0.989	0.127	0.741	1.238	-0.059
GEO 2	O704	53	0.991	0.997	0.11	0.782	1.212	-0.027
TB2	O704	42	0.976	0.975	0.14	0.702	1.249	-0.073
O706	O704	51	1.004	1.008	0.062	0.887	1.129	0.013
TB1	O704	42	0.959	0.96	0.127	0.711	1.209	-0.128
FR 1	O704	52	0.944	0.941	0.081	0.783	1.1	-0.164
FR 2	O704	52	0.941	0.959	0.172	0.623	1.295	-0.174
O705	O704	52	1.001	0.999	0.093	0.817	1.181	0.004
O754/286	O704	41	0.998	1.027	0.162	0.709	1.346	-0.006
GEO 1	O754/286	42	0.979	0.982	0.143	0.701	1.263	-0.061
GEO 2	O754/286	42	0.993	1	0.125	0.755	1.244	-0.019
TB2	O754/286	35	0.982	0.972	0.158	0.663	1.282	-0.056
O706	O754/286	39	1.005	0.991	0.109	0.777	1.205	0.014
TB1	O754/286	35	0.958	0.95	0.14	0.675	1.225	-0.13
FR 1	O754/286	41	0.953	0.944	0.087	0.774	1.114	-0.138
FR 2	O754/286	41	0.945	0.945	0.055	0.838	1.052	-0.162
O705	O754/286	41	1.006	1.002	0.093	0.819	1.185	0.016
O704	O754/286	41	1.002	0.987	0.09	0.81	1.164	0.006

Table 13. Sterling, VA, all liquid precipitation.

Sterling-	All Liquid							
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
GEO 2	GEO 1	41	1.011	1.011	0.058	0.898	1.125	0.034
TB2	GEO 1	41	1.007	1.024	0.11	0.809	1.239	0.022
O706	GEO 1	38	1.028	1.029	0.091	0.85	1.208	0.082
TB1	GEO 1	41	0.988	1.005	0.08	0.849	1.162	-0.04
FR 1	GEO 1	40	0.967	0.967	0.069	0.831	1.102	-0.107
FR 2	GEO 1	40	0.963	0.971	0.078	0.818	1.124	-0.117
O705	GEO 1	39	1.025	1.027	0.048	0.933	1.12	0.076
O704	GEO 1	40	1.024	1.024	0.054	0.918	1.131	0.075
O754/286	GEO 1	33	1.023	1.023	0.054	0.918	1.128	0.071
GEO 1	GEO 2	41	0.99	0.992	0.05	0.893	1.09	-0.034
TB2	GEO 2	41	0.996	1.012	0.088	0.839	1.186	-0.012
O706	GEO 2	38	1.015	1.018	0.095	0.833	1.203	0.045
TB1	GEO 2	41	0.977	0.995	0.073	0.851	1.139	-0.074
FR 1	GEO 2	40	0.958	0.958	0.06	0.841	1.076	-0.137
FR 2	GEO 2	40	0.954	0.963	0.08	0.807	1.12	-0.147
O705	GEO 2	39	1.012	1.016	0.05	0.918	1.114	0.039
O704	GEO 2	40	1.012	1.014	0.059	0.898	1.131	0.038
O754/286	GEO 2	33	1.008	1.004	0.056	0.894	1.114	0.026
GEO 1	TB2	41	0.993	0.987	0.1	0.791	1.183	-0.022
GEO 2	TB2	41	1.004	0.995	0.087	0.824	1.167	0.012
O706	TB2	38	1.022	1.012	0.106	0.804	1.221	0.066
TB1	TB2	41	0.981	0.986	0.063	0.862	1.111	-0.062
FR 1	TB2	40	0.961	0.952	0.08	0.795	1.109	-0.125
FR 2	TB2	40	0.958	0.956	0.092	0.775	1.137	-0.135
O705	TB2	39	1.018	1.012	0.091	0.834	1.19	0.055
O704	TB2	40	1.017	1.008	0.089	0.833	1.182	0.053
O754/286	TB2	33	1.01	1.002	0.08	0.845	1.159	0.032
GEO 1	O706	38	0.973	0.98	0.094	0.795	1.164	-0.082
GEO 2	O706	38	0.985	0.991	0.097	0.8	1.182	-0.045
TB2	O706	38	0.979	0.998	0.101	0.8	1.197	-0.066
TB1	O706	38	0.96	0.981	0.084	0.817	1.146	-0.122
FR 1	O706	37	0.94	0.944	0.082	0.783	1.104	-0.185
FR 2	O706	37	0.938	0.947	0.066	0.818	1.075	-0.191
O705	O706	37	0.997	1.004	0.09	0.828	1.179	-0.01
O704	O706	38	0.997	1	0.064	0.875	1.125	-0.01
O754/286	O706	30	0.994	0.998	0.066	0.869	1.127	-0.018
GEO 1	TB1	41	1.013	1.001	0.076	0.852	1.149	0.04
GEO 2	TB1	41	1.023	1.01	0.075	0.863	1.157	0.074
TB2	TB1	41	1.019	1.018	0.068	0.886	1.15	0.062
O706	TB1	38	1.041	1.028	0.105	0.823	1.233	0.122
FR 1	TB1	40	0.98	0.965	0.068	0.832	1.098	-0.065
FR 2	TB1	40	0.976	0.968	0.063	0.846	1.091	-0.075
O705	TB1	39	1.036	1.024	0.073	0.881	1.168	0.11
O704	TB1	40	1.035	1.022	0.077	0.871	1.174	0.108

O754/286	TB1	33	1.036	1.023	0.063	0.899	1.147	0.108
GEO 1	FR 1	40	1.035	1.04	0.074	0.894	1.186	0.107
GEO 2	FR 1	40	1.044	1.048	0.067	0.915	1.18	0.137
TB2	FR 1	40	1.04	1.058	0.088	0.885	1.231	0.125
O706	FR 1	37	1.064	1.068	0.098	0.876	1.26	0.185
TB1	FR 1	40	1.021	1.041	0.071	0.902	1.18	0.065
FR 2	FR 1	40	0.997	1.006	0.067	0.875	1.137	-0.01
O705	FR 1	38	1.059	1.063	0.05	0.964	1.161	0.178
O704	FR 1	39	1.06	1.062	0.059	0.946	1.178	0.178
O754/286	FR 1	32	1.048	1.046	0.051	0.947	1.146	0.143
GEO 1	FR 2	40	1.038	1.037	0.087	0.865	1.208	0.117
GEO 2	FR 2	40	1.048	1.045	0.092	0.866	1.225	0.147
TB2	FR 2	40	1.044	1.055	0.1	0.859	1.251	0.135
O706	FR 2	37	1.066	1.062	0.084	0.897	1.227	0.191
TB1	FR 2	40	1.024	1.037	0.065	0.91	1.164	0.075
FR 1	FR 2	40	1.003	0.998	0.065	0.871	1.126	0.01
O705	FR 2	38	1.062	1.06	0.084	0.896	1.225	0.186
O704	FR 2	39	1.063	1.059	0.071	0.92	1.198	0.186
O754/286	FR 2	32	1.057	1.057	0.054	0.951	1.163	0.169
GEO 1	O705	39	0.976	0.976	0.046	0.886	1.067	-0.076
GEO 2	O705	39	0.988	0.987	0.051	0.888	1.086	-0.039
TB2	O705	39	0.982	0.996	0.09	0.82	1.172	-0.055
O706	O705	37	1.003	1.004	0.085	0.837	1.171	0.01
TB1	O705	39	0.966	0.981	0.072	0.841	1.121	-0.11
FR 1	O705	38	0.944	0.943	0.044	0.858	1.028	-0.178
FR 2	O705	38	0.941	0.949	0.072	0.807	1.09	-0.186
O704	O705	39	1	0.999	0.036	0.928	1.07	0
O754/286	O705	32	0.995	0.991	0.046	0.902	1.081	-0.015
GEO 1	O704	40	0.976	0.979	0.053	0.875	1.083	-0.075
GEO 2	O704	40	0.988	0.989	0.059	0.873	1.106	-0.038
TB2	O704	40	0.983	1	0.089	0.826	1.174	-0.053
O706	O704	38	1.003	1.004	0.066	0.876	1.133	0.01
TB1	O704	40	0.966	0.984	0.072	0.843	1.124	-0.108
FR 1	O704	39	0.944	0.944	0.05	0.846	1.042	-0.178
FR 2	O704	39	0.941	0.949	0.066	0.819	1.079	-0.186
O705	O704	39	1	1.003	0.038	0.927	1.078	0
O754/286	O704	32	0.996	0.994	0.036	0.923	1.065	-0.013
GEO 1	O754/286	33	0.977	0.98	0.053	0.876	1.084	-0.071
GEO 2	O754/286	33	0.992	0.999	0.057	0.887	1.111	-0.026
TB2	O754/286	33	0.99	1.005	0.089	0.831	1.179	-0.032
O706	O754/286	30	1.006	1.007	0.07	0.869	1.144	0.018
TB1	O754/286	33	0.965	0.981	0.061	0.861	1.101	-0.108
FR 1	O754/286	32	0.954	0.958	0.045	0.869	1.047	-0.143
FR 2	O754/286	32	0.946	0.948	0.048	0.855	1.042	-0.169
O705	O754/286	32	1.005	1.011	0.048	0.918	1.104	0.015
O704	O754/286	32	1.004	1.008	0.037	0.935	1.08	0.013

Table 14. Sterling, all solid precipitation.

Sterling- All Solid								
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
GEO 2	GEO 1	13	1	1.012	0.115	0.785	1.238	0
TB2	GEO 1	2	0.435	0.461	0.039	0.383	0.538	-0.284
O706	GEO 1	13	0.978	1.06	0.303	0.467	1.653	-0.016
TB1	GEO 1	2	0.435	0.461	0.039	0.383	0.538	-0.284
FR 1	GEO 1	13	0.902	0.934	0.117	0.704	1.164	-0.074
FR 2	GEO 1	13	0.891	0.997	0.324	0.362	1.632	-0.083
O705	GEO 1	13	0.978	0.991	0.159	0.679	1.302	-0.016
O704	GEO 1	13	0.957	1.041	0.3	0.453	1.629	-0.032
O754/286	GEO 1	9	0.987	1.106	0.359	0.403	1.81	-0.009
GEO 1	GEO 2	13	1	1	0.107	0.791	1.21	0
TB2	GEO 2	2	0.435	0.461	0.039	0.383	0.538	-0.284
O706	GEO 2	13	0.978	1.051	0.298	0.466	1.636	-0.016
TB1	GEO 2	2	0.435	0.461	0.039	0.383	0.538	-0.284
FR 1	GEO 2	13	0.902	0.926	0.1	0.73	1.122	-0.073
FR 2	GEO 2	13	0.891	0.987	0.317	0.365	1.608	-0.082
O705	GEO 2	13	0.978	0.982	0.147	0.694	1.27	-0.016
O704	GEO 2	13	0.957	1.032	0.295	0.454	1.61	-0.032
O754/286	GEO 2	9	0.974	1.083	0.36	0.378	1.788	-0.019
GEO 1	TB2	2	2.3	2.188	0.188	1.82	2.555	0.284
GEO 2	TB2	2	2.3	2.188	0.188	1.82	2.555	0.284
O706	TB2	2	2.1	2.062	0.063	1.94	2.185	0.252
TB1	TB2	2	1	1	0	1	1	0.252
FR 1	TB2	2	2	2	0	2	2	0.236
FR 2	TB2	2	2	2	0	2	2	0.236
O705	TB2	2	2.3	2.375	0.125	2.13	2.62	0.298
O704	TB2	2	2.1	2.062	0.063	1.94	2.185	0.252
O754/286	TB2	2	2.2	2.312	0.188	1.945	2.68	0.283
GEO 1	O706	13	1.022	1.005	0.242	0.53	1.479	0.016
GEO 2	O706	13	1.022	1.005	0.201	0.61	1.4	0.016
TB2	O706	2	0.476	0.485	0.015	0.456	0.514	-0.252
TB1	O706	2	0.476	0.485	0.015	0.456	0.514	-0.252
FR 1	O706	13	0.922	0.916	0.137	0.648	1.184	-0.058
FR 2	O706	13	0.911	0.973	0.324	0.338	1.607	-0.066
O705	O706	13	1	0.97	0.163	0.651	1.289	0
O704	O706	13	0.978	0.984	0.041	0.904	1.064	-0.016
O754/286	O706	9	1.014	1.123	0.324	0.487	1.759	0.009
GEO 1	TB1	2	2.3	2.188	0.188	1.82	2.555	0.284
GEO 2	TB1	2	2.3	2.188	0.188	1.82	2.555	0.284
TB2	TB1	2	1	1	0	1	1	0.284
O706	TB1	2	2.1	2.062	0.063	1.94	2.185	0.252
FR 1	TB1	2	2	2	0	2	2	0.236
FR 2	TB1	2	2	2	0	2	2	0.236
O705	TB1	2	2.3	2.375	0.125	2.13	2.62	0.298
O704	TB1	2	2.1	2.062	0.063	1.94	2.185	0.252

GEO 1	FR 1	13	1.108	1.093	0.184	0.733	1.454	0.074
GEO 2	FR 1	13	1.108	1.094	0.13	0.84	1.348	0.073
TB2	FR 1	2	0.5	0.5	0	0.5	0.5	-0.236
O706	FR 1	13	1.084	1.13	0.263	0.614	1.646	0.058
TB1	FR 1	2	0.5	0.5	0	0.5	0.5	-0.236
FR 2	FR 1	13	0.988	1.057	0.278	0.511	1.603	-0.008
O705	FR 1	13	1.084	1.058	0.083	0.896	1.22	0.057
O704	FR 1	13	1.06	1.111	0.265	0.592	1.631	0.041
O754/286	FR 1	9	1.088	1.169	0.305	0.572	1.766	0.058
GEO 1	FR 2	13	1.122	1.091	0.318	0.468	1.713	0.083
GEO 2	FR 2	13	1.122	1.086	0.245	0.606	1.565	0.082
TB2	FR 2	2	0.5	0.5	0	0.5	0.5	-0.236
O706	FR 2	13	1.098	1.115	0.31	0.508	1.723	0.066
TB1	FR 2	2	0.5	0.5	0	0.5	0.5	-0.236
FR 1	FR 2	13	1.012	0.986	0.155	0.682	1.29	0.008
O705	FR 2	13	1.098	1.043	0.177	0.696	1.39	0.066
O704	FR 2	13	1.073	1.097	0.312	0.486	1.709	0.05
O754/286	FR 2	9	1.088	1.079	0.089	0.904	1.253	0.058
GEO 1	O705	13	1.022	1.042	0.211	0.628	1.457	0.016
GEO 2	O705	13	1.022	1.042	0.163	0.723	1.362	0.016
TB2	O705	2	0.435	0.422	0.022	0.379	0.466	-0.298
O706	O705	13	1	1.076	0.281	0.525	1.628	0
TB1	O705	2	0.435	0.422	0.022	0.379	0.466	-0.298
FR 1	O705	13	0.922	0.951	0.069	0.815	1.086	-0.057
FR 2	O705	13	0.911	1.007	0.295	0.429	1.585	-0.066
O704	O705	13	0.978	1.06	0.289	0.495	1.626	-0.016
O754/286	O705	9	0.987	1.089	0.325	0.452	1.727	-0.009
GEO 1	O704	13	1.045	1.021	0.236	0.558	1.483	0.032
GEO 2	O704	13	1.045	1.021	0.194	0.641	1.401	0.032
TB2	O704	2	0.476	0.485	0.015	0.456	0.514	-0.252
O706	O704	13	1.023	1.018	0.047	0.927	1.11	0.016
TB1	O704	2	0.476	0.485	0.015	0.456	0.514	-0.252
FR 1	O704	13	0.943	0.932	0.136	0.665	1.199	-0.041
FR 2	O704	13	0.932	0.989	0.322	0.358	1.619	-0.05
O705	O704	13	1.023	0.988	0.173	0.65	1.326	0.016
O754/286	O704	9	1.042	1.147	0.312	0.536	1.757	0.028
GEO 1	O754/286	9	1.014	0.988	0.292	0.416	1.561	0.009
GEO 2	O754/286	9	1.027	1.001	0.247	0.518	1.484	0.019
TB2	O754/286	2	0.455	0.435	0.035	0.366	0.504	-0.283
O706	O754/286	9	0.986	0.941	0.178	0.591	1.29	-0.009
TB1	O754/286	2	0.455	0.435	0.035	0.366	0.504	-0.283
FR 1	O754/286	9	0.919	0.895	0.154	0.592	1.197	-0.058
FR 2	O754/286	9	0.919	0.933	0.073	0.79	1.075	-0.058
O705	O754/286	9	1.014	0.969	0.174	0.628	1.311	0.009
O704	O754/286	9	0.959	0.915	0.16	0.602	1.228	-0.028

Table 15. Sterling, liquid, high wind.

Sterling- Liquid High Wind								
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
GEO 2	GEO 1	18	1.011	1.009	0.046	0.918	1.099	0.028
TB2	GEO 1	18	0.982	0.98	0.101	0.782	1.178	-0.046
O706	GEO 1	18	1.027	1.027	0.072	0.885	1.169	0.067
TB1	GEO 1	18	0.97	0.964	0.042	0.883	1.046	-0.077
FR 1	GEO 1	18	0.95	0.944	0.064	0.818	1.071	-0.126
FR 2	GEO 1	18	0.952	0.951	0.043	0.866	1.036	-0.123
O705	GEO 1	18	1.014	1.013	0.046	0.922	1.104	0.036
O704	GEO 1	18	1.021	1.018	0.04	0.94	1.097	0.052
O754/286	GEO 1	14	1.023	1.02	0.028	0.965	1.076	0.054
GEO 1	GEO 2	18	0.989	0.994	0.045	0.906	1.081	-0.028
TB2	GEO 2	18	0.971	0.972	0.09	0.796	1.147	-0.073
O706	GEO 2	18	1.016	1.02	0.075	0.873	1.166	0.039
TB1	GEO 2	18	0.959	0.958	0.057	0.846	1.07	-0.104
FR 1	GEO 2	18	0.94	0.937	0.055	0.829	1.044	-0.154
FR 2	GEO 2	18	0.941	0.944	0.057	0.833	1.056	-0.151
O705	GEO 2	18	1.004	1.005	0.045	0.916	1.094	0.009
O704	GEO 2	18	1.01	1.011	0.048	0.916	1.106	0.024
O754/286	GEO 2	14	1.004	0.998	0.036	0.928	1.069	0.01
GEO 1	TB2	18	1.018	1.031	0.1	0.834	1.228	0.046
GEO 2	TB2	18	1.03	1.037	0.089	0.863	1.212	0.073
O706	TB2	18	1.046	1.057	0.111	0.839	1.274	0.112
TB1	TB2	18	0.988	0.992	0.082	0.831	1.152	-0.031
FR 1	TB2	18	0.968	0.97	0.082	0.808	1.131	-0.08
FR 2	TB2	18	0.969	0.98	0.105	0.774	1.185	-0.077
O705	TB2	18	1.033	1.041	0.089	0.867	1.216	0.082
O704	TB2	18	1.039	1.048	0.093	0.865	1.231	0.097
O754/286	TB2	14	1.028	1.028	0.092	0.847	1.209	0.064
GEO 1	O706	18	0.974	0.978	0.062	0.856	1.1	-0.067
GEO 2	O706	18	0.985	0.986	0.065	0.859	1.112	-0.039
TB2	O706	18	0.956	0.956	0.098	0.764	1.149	-0.112
TB1	O706	18	0.945	0.944	0.08	0.788	1.101	-0.143
FR 1	O706	18	0.926	0.923	0.078	0.77	1.075	-0.192
FR 2	O706	18	0.927	0.93	0.076	0.782	1.078	-0.19
O705	O706	18	0.988	0.989	0.06	0.872	1.107	-0.03
O704	O706	18	0.994	0.994	0.042	0.912	1.076	-0.015
O754/286	O706	14	0.989	0.984	0.068	0.851	1.117	-0.027
GEO 1	TB1	18	1.031	1.039	0.049	0.943	1.136	0.077
GEO 2	TB1	18	1.042	1.048	0.065	0.921	1.175	0.104
TB2	TB1	18	1.012	1.016	0.089	0.842	1.19	0.031
O706	TB1	18	1.059	1.069	0.12	0.833	1.305	0.143
FR 1	TB1	18	0.98	0.98	0.067	0.849	1.111	-0.049
FR 2	TB1	18	0.981	0.988	0.059	0.872	1.103	-0.046
O705	TB1	18	1.046	1.052	0.062	0.93	1.173	0.112
O704	TB1	18	1.052	1.059	0.076	0.909	1.208	0.127

O754/286	TB1	14	1.052	1.059	0.055	0.951	1.167	0.117
GEO 1	FR 1	18	1.052	1.064	0.074	0.919	1.209	0.126
GEO 2	FR 1	18	1.064	1.072	0.067	0.941	1.203	0.154
TB2	FR 1	18	1.033	1.039	0.091	0.86	1.218	0.08
O706	FR 1	18	1.08	1.092	0.103	0.89	1.295	0.192
TB1	FR 1	18	1.02	1.025	0.069	0.891	1.16	0.049
FR 2	FR 1	18	1.001	1.011	0.067	0.879	1.142	0.003
O705	FR 1	18	1.067	1.075	0.056	0.966	1.185	0.162
O704	FR 1	18	1.074	1.082	0.069	0.948	1.217	0.177
O754/286	FR 1	14	1.059	1.062	0.057	0.95	1.174	0.132
GEO 1	FR 2	18	1.051	1.054	0.048	0.96	1.148	0.123
GEO 2	FR 2	18	1.062	1.063	0.066	0.934	1.192	0.151
TB2	FR 2	18	1.032	1.033	0.113	0.81	1.255	0.077
O706	FR 2	18	1.079	1.083	0.102	0.884	1.282	0.19
TB1	FR 2	18	1.019	1.016	0.058	0.902	1.131	0.046
FR 1	FR 2	18	0.999	0.994	0.064	0.869	1.119	-0.003
O705	FR 2	18	1.066	1.067	0.06	0.95	1.184	0.159
O704	FR 2	18	1.072	1.073	0.064	0.947	1.199	0.174
O754/286	FR 2	14	1.065	1.067	0.05	0.969	1.165	0.145
GEO 1	O705	18	0.986	0.99	0.047	0.897	1.082	-0.036
GEO 2	O705	18	0.996	0.997	0.047	0.905	1.089	-0.009
TB2	O705	18	0.968	0.967	0.082	0.806	1.128	-0.082
O706	O705	18	1.012	1.015	0.071	0.876	1.154	0.03
TB1	O705	18	0.956	0.954	0.056	0.844	1.064	-0.112
FR 1	O705	18	0.937	0.932	0.048	0.839	1.026	-0.162
FR 2	O705	18	0.938	0.94	0.054	0.835	1.045	-0.159
O704	O705	18	1.006	1.006	0.029	0.95	1.063	0.015
O754/286	O705	14	1.001	1.002	0.048	0.907	1.097	0.003
GEO 1	O704	18	0.98	0.984	0.039	0.906	1.061	-0.052
GEO 2	O704	18	0.991	0.991	0.048	0.897	1.085	-0.024
TB2	O704	18	0.962	0.962	0.087	0.792	1.132	-0.097
O706	O704	18	1.006	1.008	0.045	0.92	1.096	0.015
TB1	O704	18	0.95	0.949	0.06	0.831	1.066	-0.127
FR 1	O704	18	0.931	0.927	0.057	0.816	1.039	-0.177
FR 2	O704	18	0.933	0.935	0.055	0.826	1.044	-0.174
O705	O704	18	0.994	0.995	0.027	0.941	1.048	-0.015
O754/286	O704	14	0.996	0.996	0.046	0.906	1.085	-0.01
GEO 1	O754/286	14	0.977	0.981	0.028	0.927	1.035	-0.054
GEO 2	O754/286	14	0.996	1.003	0.035	0.934	1.072	-0.01
TB2	O754/286	14	0.973	0.982	0.104	0.778	1.186	-0.064
O706	O754/286	14	1.011	1.022	0.081	0.863	1.18	0.027
TB1	O754/286	14	0.95	0.947	0.048	0.854	1.04	-0.117
FR 1	O754/286	14	0.945	0.944	0.05	0.845	1.043	-0.132
FR 2	O754/286	14	0.939	0.939	0.044	0.852	1.027	-0.145
O705	O754/286	14	0.999	1.001	0.047	0.908	1.093	-0.003
O704	O754/286	14	1.004	1.006	0.047	0.914	1.099	0.01

Table 16. Sterling, liquid, low wind.

Sterling- Liquid Low Wind								
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
GEO 2	GEO 1	24	1.011	1.027	0.09	0.85	1.204	0.023
TB2	GEO 1	23	1.033	1.059	0.104	0.855	1.262	0.069
O706	GEO 1	21	1.029	1.03	0.103	0.828	1.232	0.051
TB1	GEO 1	23	1.006	1.038	0.088	0.866	1.209	0.013
FR 1	GEO 1	23	0.984	0.986	0.066	0.857	1.115	-0.032
FR 2	GEO 1	23	0.976	0.988	0.092	0.808	1.169	-0.048
O705	GEO 1	22	1.037	1.037	0.045	0.948	1.126	0.07
O704	GEO 1	23	1.029	1.028	0.062	0.906	1.15	0.055
O754/286	GEO 1	20	1.023	1.024	0.065	0.897	1.151	0.047
GEO 1	GEO 2	24	0.989	0.98	0.072	0.839	1.121	-0.023
TB2	GEO 2	23	1.023	1.044	0.073	0.901	1.187	0.047
O706	GEO 2	21	1.013	1.004	0.121	0.767	1.24	0.023
TB1	GEO 2	23	0.996	1.024	0.071	0.885	1.164	-0.008
FR 1	GEO 2	23	0.975	0.966	0.073	0.824	1.109	-0.05
FR 2	GEO 2	23	0.968	0.969	0.101	0.771	1.167	-0.066
O705	GEO 2	22	1.022	1.013	0.077	0.862	1.163	0.042
O704	GEO 2	23	1.014	1.005	0.085	0.838	1.172	0.027
O754/286	GEO 2	20	1.011	0.995	0.086	0.826	1.164	0.022
GEO 1	TB2	23	0.968	0.953	0.086	0.785	1.121	-0.069
GEO 2	TB2	23	0.978	0.963	0.07	0.825	1.1	-0.047
O706	TB2	20	0.992	0.973	0.084	0.808	1.137	-0.014
TB1	TB2	23	0.974	0.982	0.043	0.898	1.067	-0.056
FR 1	TB2	22	0.954	0.937	0.075	0.79	1.084	-0.097
FR 2	TB2	22	0.946	0.937	0.075	0.789	1.085	-0.114
O705	TB2	21	1	0.987	0.085	0.821	1.153	0
O704	TB2	22	0.992	0.975	0.07	0.838	1.112	-0.017
O754/286	TB2	19	0.995	0.983	0.063	0.859	1.106	-0.011
GEO 1	O706	21	0.972	0.982	0.113	0.761	1.203	-0.051
GEO 2	O706	21	0.988	1.012	0.137	0.745	1.28	-0.023
TB2	O706	20	1.008	1.036	0.088	0.862	1.209	0.014
TB1	O706	20	0.981	1.014	0.073	0.871	1.158	-0.035
FR 1	O706	20	0.96	0.966	0.079	0.81	1.121	-0.072
FR 2	O706	20	0.953	0.964	0.049	0.868	1.061	-0.084
O705	O706	20	1.008	1.016	0.106	0.808	1.225	0.014
O704	O706	21	1	1.005	0.076	0.856	1.154	0
O754/286	O706	17	1	1.01	0.059	0.893	1.126	0
GEO 1	TB1	23	0.994	0.97	0.079	0.816	1.125	-0.013
GEO 2	TB1	23	1.004	0.981	0.069	0.846	1.116	0.008
TB2	TB1	23	1.027	1.02	0.044	0.933	1.107	0.056
O706	TB1	20	1.019	0.991	0.069	0.855	1.127	0.035
FR 1	TB1	22	0.979	0.953	0.066	0.823	1.083	-0.044
FR 2	TB1	22	0.971	0.953	0.061	0.833	1.073	-0.06
O705	TB1	21	1.023	1.001	0.074	0.855	1.147	0.046
O704	TB1	22	1.016	0.992	0.064	0.867	1.118	0.031

O754/286	TB1	19	1.021	0.997	0.056	0.887	1.106	0.043
GEO 1	FR 1	23	1.016	1.019	0.067	0.887	1.151	0.032
GEO 2	FR 1	23	1.025	1.041	0.086	0.872	1.211	0.05
TB2	FR 1	22	1.048	1.074	0.083	0.912	1.236	0.097
O706	FR 1	20	1.042	1.043	0.085	0.876	1.209	0.072
TB1	FR 1	22	1.021	1.054	0.07	0.916	1.192	0.044
FR 2	FR 1	23	0.992	1.002	0.065	0.875	1.129	-0.016
O705	FR 1	21	1.049	1.049	0.042	0.967	1.131	0.091
O704	FR 1	22	1.043	1.043	0.042	0.96	1.126	0.079
O754/286	FR 1	19	1.037	1.032	0.041	0.952	1.112	0.074
GEO 1	FR 2	23	1.024	1.022	0.105	0.815	1.228	0.048
GEO 2	FR 2	23	1.034	1.044	0.121	0.808	1.281	0.066
TB2	FR 2	22	1.057	1.074	0.083	0.911	1.237	0.114
O706	FR 2	20	1.049	1.04	0.055	0.931	1.148	0.084
TB1	FR 2	22	1.03	1.054	0.065	0.926	1.181	0.06
FR 1	FR 2	23	1.008	1.002	0.064	0.876	1.128	0.016
O705	FR 2	21	1.058	1.052	0.099	0.858	1.245	0.106
O704	FR 2	22	1.051	1.044	0.073	0.901	1.187	0.093
O754/286	FR 2	19	1.049	1.047	0.055	0.939	1.156	0.097
GEO 1	O705	22	0.964	0.966	0.042	0.885	1.048	-0.07
GEO 2	O705	22	0.979	0.994	0.09	0.818	1.17	-0.042
TB2	O705	21	1	1.02	0.089	0.846	1.194	0
O706	O705	20	0.992	0.994	0.093	0.811	1.176	-0.014
TB1	O705	21	0.977	1.004	0.075	0.857	1.152	-0.046
FR 1	O705	21	0.953	0.955	0.037	0.882	1.028	-0.091
FR 2	O705	21	0.946	0.958	0.083	0.795	1.122	-0.106
O704	O705	22	0.993	0.993	0.04	0.915	1.07	-0.014
O754/286	O705	19	0.988	0.984	0.041	0.904	1.064	-0.023
GEO 1	O704	23	0.972	0.976	0.06	0.858	1.094	-0.055
GEO 2	O704	23	0.986	1.003	0.096	0.815	1.192	-0.027
TB2	O704	22	1.008	1.031	0.078	0.879	1.183	0.017
O706	O704	21	1	1.001	0.077	0.849	1.153	0
TB1	O704	22	0.984	1.012	0.068	0.879	1.145	-0.031
FR 1	O704	22	0.959	0.961	0.038	0.886	1.035	-0.079
FR 2	O704	22	0.952	0.963	0.071	0.823	1.102	-0.093
O705	O704	22	1.007	1.009	0.044	0.924	1.095	0.014
O754/286	O704	19	0.995	0.993	0.026	0.942	1.044	-0.009
GEO 1	O754/286	20	0.977	0.981	0.064	0.855	1.107	-0.047
GEO 2	O754/286	20	0.989	1.013	0.099	0.819	1.208	-0.022
TB2	O754/286	19	1.005	1.022	0.07	0.884	1.16	0.011
O706	O754/286	17	1	0.994	0.055	0.886	1.101	0
TB1	O754/286	19	0.98	1.007	0.058	0.894	1.12	-0.043
FR 1	O754/286	19	0.964	0.97	0.038	0.897	1.044	-0.074
FR 2	O754/286	19	0.953	0.958	0.049	0.862	1.053	-0.097
O705	O754/286	19	1.012	1.018	0.045	0.93	1.107	0.023
O704	O754/286	19	1.005	1.008	0.026	0.956	1.06	0.009

Table 17. Sterling, solid, high wind.

Sterling-	Solid High Wind							
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
GEO 2	GEO 1	6	1.061	1.075	0.123	0.834	1.317	0.032
TB2	GEO 1	2	0.435	0.461	0.039	0.383	0.538	-0.284
O706	GEO 1	6	0.98	0.992	0.049	0.897	1.088	-0.011
TB1	GEO 1	2	0.435	0.461	0.039	0.383	0.538	-0.284
FR 1	GEO 1	6	0.918	0.94	0.085	0.773	1.107	-0.044
FR 2	GEO 1	6	0.898	0.931	0.081	0.772	1.089	-0.056
O705	GEO 1	6	1	1.009	0.134	0.746	1.273	0
O704	GEO 1	6	0.98	0.992	0.049	0.897	1.088	-0.011
O754/286	GEO 1	4	1	1.051	0.129	0.798	1.304	0
GEO 1	GEO 2	6	0.942	0.941	0.094	0.757	1.124	-0.032
TB2	GEO 2	2	0.435	0.461	0.039	0.383	0.538	-0.284
O706	GEO 2	6	0.923	0.932	0.09	0.756	1.108	-0.043
TB1	GEO 2	2	0.435	0.461	0.039	0.383	0.538	-0.284
FR 1	GEO 2	6	0.865	0.881	0.095	0.696	1.067	-0.077
FR 2	GEO 2	6	0.846	0.872	0.095	0.685	1.059	-0.089
O705	GEO 2	6	0.942	0.949	0.161	0.634	1.264	-0.032
O704	GEO 2	6	0.923	0.932	0.09	0.756	1.108	-0.043
O754/286	GEO 2	4	0.935	0.961	0.182	0.604	1.317	-0.04
GEO 1	TB2	2	2.3	2.188	0.188	1.82	2.555	0.284
GEO 2	TB2	2	2.3	2.188	0.188	1.82	2.555	0.284
O706	TB2	2	2.1	2.062	0.063	1.94	2.185	0.252
TB1	TB2	2	1	1	0	1	1	0.252
FR 1	TB2	2	2	2	0	2	2	0.236
FR 2	TB2	2	2	2	0	2	2	0.236
O705	TB2	2	2.3	2.375	0.125	2.13	2.62	0.298
O704	TB2	2	2.1	2.062	0.063	1.94	2.185	0.252
O754/286	TB2	2	2.2	2.312	0.188	1.945	2.68	0.283
GEO 1	O706	6	1.021	1.01	0.052	0.908	1.112	0.011
GEO 2	O706	6	1.083	1.084	0.119	0.851	1.318	0.043
TB2	O706	2	0.476	0.485	0.015	0.456	0.514	-0.252
TB1	O706	2	0.476	0.485	0.015	0.456	0.514	-0.252
FR 1	O706	6	0.937	0.948	0.071	0.809	1.086	-0.034
FR 2	O706	6	0.917	0.938	0.074	0.793	1.084	-0.045
O705	O706	6	1.021	1.018	0.132	0.76	1.276	0.011
O704	O706	6	1	1	0	1	1	0.011
O754/286	O706	4	1.024	1.062	0.108	0.85	1.275	0.013
GEO 1	TB1	2	2.3	2.188	0.188	1.82	2.555	0.284
GEO 2	TB1	2	2.3	2.188	0.188	1.82	2.555	0.284
TB2	TB1	2	1	1	0	1	1	0.284
O706	TB1	2	2.1	2.062	0.063	1.94	2.185	0.252
FR 1	TB1	2	2	2	0	2	2	0.236
FR 2	TB1	2	2	2	0	2	2	0.236
O705	TB1	2	2.3	2.375	0.125	2.13	2.62	0.298
O704	TB1	2	2.1	2.062	0.063	1.94	2.185	0.252

O754/286	TB1	2	2.2	2.312	0.188	1.945	2.68	0.283
GEO 1	FR 1	6	1.089	1.073	0.105	0.868	1.278	0.044
GEO 2	FR 1	6	1.156	1.148	0.123	0.907	1.39	0.077
TB2	FR 1	2	0.5	0.5	0	0.5	0.5	-0.236
O706	FR 1	6	1.067	1.062	0.088	0.889	1.235	0.034
TB1	FR 1	2	0.5	0.5	0	0.5	0.5	-0.236
FR 2	FR 1	6	0.978	0.99	0.022	0.947	1.033	-0.011
O705	FR 1	6	1.089	1.072	0.091	0.893	1.252	0.044
O704	FR 1	6	1.067	1.062	0.088	0.889	1.235	0.034
O754/286	FR 1	4	1.075	1.093	0.094	0.908	1.277	0.041
GEO 1	FR 2	6	1.114	1.083	0.1	0.888	1.279	0.056
GEO 2	FR 2	6	1.182	1.16	0.123	0.919	1.401	0.089
TB2	FR 2	2	0.5	0.5	0	0.5	0.5	-0.236
O706	FR 2	6	1.091	1.073	0.091	0.894	1.252	0.045
TB1	FR 2	2	0.5	0.5	0	0.5	0.5	-0.236
FR 1	FR 2	6	1.023	1.01	0.023	0.965	1.056	0.011
O705	FR 2	6	1.114	1.083	0.093	0.901	1.266	0.056
O704	FR 2	6	1.091	1.073	0.091	0.894	1.252	0.045
O754/286	FR 2	4	1.103	1.109	0.092	0.928	1.291	0.055
GEO 1	O705	6	1	1.008	0.134	0.745	1.272	0
GEO 2	O705	6	1.061	1.082	0.173	0.744	1.421	0.032
TB2	O705	2	0.435	0.422	0.022	0.379	0.466	-0.298
O706	O705	6	0.98	0.999	0.133	0.739	1.259	-0.011
TB1	O705	2	0.435	0.422	0.022	0.379	0.466	-0.298
FR 1	O705	6	0.918	0.939	0.074	0.793	1.084	-0.044
FR 2	O705	6	0.898	0.93	0.076	0.78	1.079	-0.056
O704	O705	6	0.98	0.999	0.133	0.739	1.259	-0.011
O754/286	O705	4	0.977	0.986	0.024	0.939	1.033	-0.013
GEO 1	O704	6	1.021	1.01	0.052	0.908	1.112	0.011
GEO 2	O704	6	1.083	1.084	0.119	0.851	1.318	0.043
TB2	O704	2	0.476	0.485	0.015	0.456	0.514	-0.252
O706	O704	6	1	1	0	1	1	-0.252
TB1	O704	2	0.476	0.485	0.015	0.456	0.514	-0.252
FR 1	O704	6	0.937	0.948	0.071	0.809	1.086	-0.034
FR 2	O704	6	0.917	0.938	0.074	0.793	1.084	-0.045
O705	O704	6	1.021	1.018	0.132	0.76	1.276	0.011
O754/286	O704	4	1.024	1.062	0.108	0.85	1.275	0.013
GEO 1	O754/286	4	1	0.966	0.114	0.742	1.189	0
GEO 2	O754/286	4	1.07	1.077	0.19	0.704	1.449	0.04
TB2	O754/286	2	0.455	0.435	0.035	0.366	0.504	-0.283
O706	O754/286	4	0.977	0.95	0.087	0.78	1.12	-0.013
TB1	O754/286	2	0.455	0.435	0.035	0.366	0.504	-0.283
FR 1	O754/286	4	0.93	0.921	0.074	0.777	1.066	-0.041
FR 2	O754/286	4	0.907	0.908	0.073	0.764	1.052	-0.055
O705	O754/286	4	1.023	1.015	0.025	0.965	1.065	0.013
O704	O754/286	4	0.977	0.95	0.087	0.78	1.12	-0.013

Table 18. Sterling, solid, low wind.

Sterling- Solid Low Wind								
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
GEO 2	GEO 1	6	0.97	0.983	0.037	0.91	1.056	-0.014
O706	GEO 1	6	1.091	1.203	0.368	0.482	1.925	0.04
FR 1	GEO 1	6	0.97	0.983	0.037	0.91	1.056	-0.014
FR 2	GEO 1	6	1	1.146	0.391	0.38	1.913	0
O705	GEO 1	6	1.061	1.037	0.094	0.852	1.222	0.026
O704	GEO 1	6	1.03	1.163	0.378	0.422	1.904	0.013
O754/286	GEO 1	4	1.136	1.288	0.416	0.474	2.103	0.047
GEO 1	GEO 2	6	1.031	1.019	0.041	0.937	1.1	0.014
O706	GEO 2	6	1.125	1.22	0.356	0.522	1.918	0.053
FR 1	GEO 2	6	1	1	0	1	1	0.053
FR 2	GEO 2	6	1.031	1.161	0.379	0.418	1.904	0.014
O705	GEO 2	6	1.094	1.053	0.076	0.905	1.202	0.04
O704	GEO 2	6	1.062	1.179	0.368	0.458	1.901	0.027
O754/286	GEO 2	4	1.136	1.288	0.416	0.474	2.103	0.047
O754/286	O706	6	0.917	0.889	0.194	0.508	1.27	-0.04
GEO 1	O706	6	0.889	0.871	0.177	0.524	1.217	-0.053
TB2	O706	6	1	1	0	1	1	-0.053
TB1	O706	6	0.889	0.871	0.177	0.524	1.217	-0.053
FR 1	O706	6	0.917	1.03	0.462	0.124	1.936	-0.04
FR 2	O706	6	0.972	0.917	0.186	0.551	1.282	-0.013
O705	O706	6	0.944	0.965	0.054	0.859	1.071	-0.026
O704	O706	4	1	1.214	0.457	0.318	2.111	0
O754/286	FR 1	6	1.031	1.019	0.041	0.937	1.1	0.014
GEO 1	FR 1	6	1	1	0	1	1	0.014
TB2	FR 1	6	1.125	1.22	0.356	0.522	1.918	0.053
TB1	FR 1	6	1	1	0	1	1	0.053
FR 1	FR 1	6	1.031	1.161	0.379	0.418	1.904	0.014
FR 2	FR 1	6	1.094	1.053	0.076	0.905	1.202	0.04
O705	FR 1	6	1.062	1.179	0.368	0.458	1.901	0.027
O704	FR 1	4	1.136	1.288	0.416	0.474	2.103	0.047
O754/286	FR 2	6	1	0.946	0.224	0.508	1.385	0
GEO 1	FR 2	6	0.97	0.926	0.199	0.536	1.316	-0.014
TB2	FR 2	6	1.091	1.144	0.442	0.277	2.011	0.04
TB1	FR 2	6	0.97	0.926	0.199	0.536	1.316	-0.014
FR 1	FR 2	6	1	1	0	1	1	-0.014
FR 2	FR 2	6	1.061	0.977	0.222	0.542	1.412	0.026
O705	FR 2	6	1.03	1.104	0.447	0.227	1.981	0.013
O704	FR 2	4	1.042	1.018	0.031	0.957	1.078	0.016
O754/286	O705	6	0.943	0.972	0.088	0.801	1.144	-0.026
GEO 1	O705	6	0.914	0.954	0.065	0.826	1.082	-0.04
TB2	O705	6	1.029	1.167	0.373	0.436	1.897	0.013
TB1	O705	6	0.914	0.954	0.065	0.826	1.082	-0.04
FR 1	O705	6	0.943	1.113	0.4	0.329	1.897	-0.026
FR 2	O705	6	1	1	0	1	1	-0.026
O705	O705	6	0.971	1.132	0.392	0.364	1.9	-0.013
O704	O705	4	1	1.214	0.457	0.318	2.111	0
O754/286	O704	6	0.971	0.923	0.197	0.538	1.309	-0.013
GEO 1	O704	6	0.941	0.905	0.183	0.546	1.263	-0.027
TB2	O704	6	1.059	1.04	0.062	0.917	1.162	0.026
TB1	O704	6	0.941	0.905	0.183	0.546	1.263	-0.027
FR 1	O704	6	0.971	1.065	0.454	0.175	1.955	-0.013
FR 2	O704	6	1.029	0.956	0.213	0.539	1.373	0.013
O705	O704	6	1	1	0	1	1	0.013
O754/286	O754/286	4	0.88	0.842	0.205	0.441	1.243	-0.047
GEO 1	O754/286	4	0.88	0.842	0.205	0.441	1.243	-0.047
TB2	O754/286	4	1	0.917	0.25	0.427	1.407	0
TB1	O754/286	4	0.88	0.842	0.205	0.441	1.243	-0.047
FR 1	O754/286	4	0.96	0.983	0.029	0.927	1.04	-0.016
FR 2	O754/286	4	1	0.917	0.25	0.427	1.407	0
O705	O754/286	4	0.92	0.858	0.209	0.449	1.267	-0.031
O704	O754/286	4	1	1	0	1	1	-0.031

Table 19. Johnstown, all data.

Johnstown- All Data

NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
O 729	GEO	50	1.038	1.042	0.085	0.876	1.208	0.101
O755/725	GEO	31	1.026	1.136	0.631	-0.1	2.372	0.044
TB	GEO	43	0.967	0.936	0.216	0.513	1.359	-0.091
FRISE	GEO	48	0.985	0.963	0.182	0.607	1.32	-0.039
O 722	GEO	50	1.033	1.018	0.155	0.713	1.322	0.088
O 726	GEO	50	1.04	1.057	0.37	0.331	1.783	0.105
GEO	O 729	50	0.963	0.966	0.076	0.817	1.114	-0.101
O755/725	O 729	31	0.996	1.108	0.64	-0.148	2.363	-0.006
TB	O 729	43	0.934	0.905	0.208	0.498	1.312	-0.184
FRISE	O 729	48	0.948	0.931	0.19	0.559	1.303	-0.139
O 722	O 729	50	0.995	0.983	0.17	0.65	1.317	-0.013
O 726	O 729	50	1.002	1.023	0.381	0.277	1.769	0.004
GEO	O755/725	31	0.975	0.975	0.224	0.536	1.413	-0.044
O 729	O755/725	31	1.004	1.015	0.278	0.47	1.561	0.006
TB	O755/725	24	0.937	0.909	0.241	0.437	1.381	-0.109
FRISE	O755/725	29	0.933	0.906	0.174	0.564	1.247	-0.112
O 722	O755/725	31	0.988	0.965	0.159	0.653	1.277	-0.022
O 726	O755/725	31	1.002	0.98	0.118	0.748	1.212	0.003
GEO	TB	43	1.034	1.252	0.857	-0.429	2.932	0.091
O 729	TB	43	1.07	1.306	0.957	-0.57	3.183	0.184
O755/725	TB	24	1.067	1.406	1.245	-1.034	3.847	0.109
FRISE	TB	41	1.029	1.142	0.55	0.063	2.22	0.073
O 722	TB	43	1.073	1.188	0.547	0.116	2.26	0.19
O 726	TB	43	1.076	1.189	0.546	0.119	2.259	0.197
GEO	FRISE	48	1.015	1.116	0.479	0.178	2.055	0.039
O 729	FRISE	48	1.055	1.167	0.514	0.16	2.174	0.139
O755/725	FRISE	29	1.072	1.219	0.654	-0.062	2.5	0.112
TB	FRISE	41	0.972	0.953	0.178	0.604	1.302	-0.073
O 722	FRISE	48	1.048	1.079	0.181	0.724	1.435	0.121
O 726	FRISE	48	1.055	1.123	0.389	0.361	1.885	0.138
GEO	O 722	50	0.968	1.012	0.207	0.607	1.417	-0.088
O 729	O 722	50	1.005	1.057	0.25	0.567	1.546	0.013
O755/725	O 722	31	1.013	1.099	0.395	0.324	1.873	0.022
TB	O 722	43	0.932	0.916	0.18	0.564	1.269	-0.19
FRISE	O 722	48	0.954	0.945	0.109	0.731	1.159	-0.121
O 726	O 722	50	1.006	1.029	0.19	0.656	1.401	0.017
GEO	O 726	50	0.962	1.002	0.222	0.567	1.436	-0.105
O 729	O 726	50	0.998	1.047	0.264	0.529	1.565	-0.004
O755/725	O 726	31	0.998	1.043	0.196	0.658	1.427	-0.003
TB	O 726	43	0.93	0.914	0.174	0.573	1.256	-0.197
FRISE	O 726	48	0.948	0.936	0.146	0.651	1.222	-0.138
O 722	O 726	50	0.994	0.988	0.089	0.813	1.163	-0.017

Table 20. Johnstown, all liquid.

Johnstown- All Liquid								
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
O 729	GEO	35	1.035	1.036	0.061	0.917	1.155	0.1
O755/725	GEO	17	1.016	1.01	0.064	0.884	1.135	0.029
TB	GEO	35	0.97	0.976	0.077	0.825	1.128	-0.089
FRISE	GEO	33	1.001	1.005	0.073	0.861	1.149	0.003
O 722	GEO	35	1.043	1.038	0.056	0.927	1.148	0.123
O 726	GEO	35	1.045	1.037	0.055	0.929	1.146	0.128
GEO	O 729	35	0.966	0.968	0.053	0.864	1.072	-0.1
O755/725	O 729	17	0.998	0.991	0.049	0.896	1.086	-0.004
TB	O 729	35	0.937	0.942	0.043	0.858	1.026	-0.189
FRISE	O 729	33	0.966	0.97	0.036	0.9	1.04	-0.097
O 722	O 729	35	1.008	1.003	0.038	0.927	1.078	0.023
O 726	O 729	35	1.01	1.003	0.044	0.916	1.089	0.029
GEO	O755/725	17	0.984	0.995	0.066	0.865	1.124	-0.029
O 729	O755/725	17	1.002	1.011	0.053	0.908	1.115	0.004
TB	O755/725	17	0.939	0.946	0.034	0.879	1.013	-0.112
FRISE	O755/725	15	0.97	0.981	0.026	0.929	1.032	-0.049
O 722	O755/725	17	1.011	1.019	0.042	0.938	1.101	0.02
O 726	O755/725	17	1.016	1.018	0.047	0.926	1.11	0.028
GEO	TB	35	1.031	1.03	0.076	0.881	1.179	0.089
O 729	TB	35	1.067	1.064	0.048	0.969	1.159	0.189
O755/725	TB	17	1.065	1.058	0.038	0.984	1.133	0.112
FRISE	TB	33	1.03	1.032	0.045	0.944	1.119	0.083
O 722	TB	35	1.076	1.066	0.062	0.946	1.187	0.212
O 726	TB	35	1.077	1.066	0.063	0.942	1.19	0.217
GEO	FRISE	33	0.999	1	0.07	0.863	1.136	-0.003
O 729	FRISE	33	1.035	1.032	0.04	0.955	1.11	0.097
O755/725	FRISE	15	1.031	1.021	0.028	0.966	1.075	0.049
TB	FRISE	33	0.971	0.971	0.041	0.89	1.052	-0.083
O 722	FRISE	33	1.042	1.033	0.05	0.934	1.132	0.116
O 726	FRISE	33	1.044	1.033	0.056	0.923	1.143	0.121
GEO	O 722	35	0.959	0.966	0.05	0.869	1.064	-0.123
O 729	O 722	35	0.992	0.999	0.043	0.915	1.083	-0.023
O755/725	O 722	17	0.989	0.982	0.036	0.911	1.054	-0.02
TB	O 722	35	0.93	0.941	0.06	0.823	1.059	-0.212
FRISE	O 722	33	0.96	0.971	0.052	0.869	1.072	-0.116
O 726	O 722	35	1.002	1	0.021	0.959	1.041	0.005
GEO	O 726	35	0.957	0.967	0.049	0.871	1.062	-0.128
O 729	O 726	35	0.99	0.999	0.048	0.905	1.094	-0.029
O755/725	O 726	17	0.984	0.985	0.043	0.9	1.069	-0.028
TB	O 726	35	0.928	0.941	0.061	0.821	1.062	-0.217
FRISE	O 726	33	0.958	0.971	0.057	0.86	1.083	-0.121
O 722	O 726	35	0.998	1	0.022	0.958	1.043	-0.005

Table 21. Johnstown, all solid.

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Johnstown- All Solid								
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
O 729	GEO	15	1.068	1.057	0.123	0.817	1.297	0.062
O755/725	GEO	14	1.062	1.29	0.912	-0.498	3.078	0.058
TB	GEO	8	0.907	0.759	0.431	-0.086	1.604	-0.049
FRISE	GEO	15	0.846	0.871	0.286	0.311	1.432	-0.145
O 722	GEO	15	0.94	0.971	0.264	0.453	1.488	-0.056
O 726	GEO	15	0.991	1.104	0.669	-0.207	2.414	-0.008
GEO	O 729	15	0.936	0.959	0.112	0.74	1.178	-0.062
O755/725	O 729	14	0.992	1.249	0.932	-0.578	3.076	-0.008
TB	O 729	8	0.875	0.743	0.437	-0.114	1.6	-0.069
FRISE	O 729	15	0.792	0.845	0.319	0.22	1.47	-0.204
O 722	O 729	15	0.88	0.938	0.3	0.35	1.527	-0.117
O 726	O 729	15	0.928	1.071	0.689	-0.28	2.422	-0.07
GEO	O755/725	14	0.942	0.951	0.323	0.317	1.584	-0.058
O 729	O755/725	14	1.008	1.021	0.41	0.217	1.824	0.008
TB	O755/725	7	0.923	0.82	0.43	-0.023	1.663	-0.042
FRISE	O755/725	14	0.817	0.825	0.223	0.389	1.262	-0.186
O 722	O755/725	14	0.9	0.898	0.214	0.478	1.318	-0.1
O 726	O755/725	14	0.95	0.935	0.157	0.628	1.242	-0.05
GEO	TB	8	1.102	2.22	1.665	-1.044	5.484	0.049
O 729	TB	8	1.143	2.368	1.879	-1.315	6.051	0.069
O755/725	TB	7	1.083	2.251	2.075	-1.815	6.318	0.042
FRISE	TB	8	1	1.596	1.134	-0.627	3.819	0
O 722	TB	8	1.02	1.72	1.115	-0.466	3.905	0.01
O 726	TB	8	1.041	1.726	1.11	-0.449	3.901	0.019
GEO	FRISE	15	1.182	1.372	0.792	-0.18	2.925	0.145
O 729	FRISE	15	1.263	1.462	0.845	-0.193	3.118	0.204
O755/725	FRISE	14	1.224	1.431	0.893	-0.319	3.181	0.186
TB	FRISE	8	1	0.877	0.385	0.122	1.632	0
O 722	FRISE	15	1.111	1.181	0.291	0.611	1.751	0.089
O 726	FRISE	15	1.172	1.322	0.647	0.053	2.59	0.137
GEO	O 722	15	1.064	1.118	0.347	0.438	1.798	0.056
O 729	O 722	15	1.136	1.192	0.421	0.365	2.018	0.117
O755/725	O 722	14	1.111	1.24	0.555	0.153	2.328	0.1
TB	O 722	8	0.98	0.807	0.378	0.065	1.549	-0.01
FRISE	O 722	15	0.9	0.887	0.165	0.562	1.211	-0.089
O 726	O 722	15	1.055	1.095	0.336	0.437	1.754	0.048
GEO	O 726	15	1.009	1.084	0.385	0.329	1.84	0.008
O 729	O 726	15	1.078	1.157	0.458	0.26	2.055	0.07
O755/725	O 726	14	1.053	1.113	0.272	0.581	1.646	0.05
TB	O 726	8	0.961	0.795	0.36	0.09	1.5	-0.019
FRISE	O 726	15	0.853	0.859	0.228	0.412	1.306	-0.137
O 722	O 726	15	0.948	0.959	0.155	0.655	1.264	-0.048

Table 22. Johnstown, liquid, high wind.

Johnstown- Liquid High Wind								
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
O 729	GEO	18	1.032	1.041	0.059	0.926	1.156	0.062
O755/725	GEO	10	1.022	1.009	0.07	0.871	1.147	0.029
TB	GEO	18	0.94	0.957	0.082	0.797	1.117	-0.119
FRISE	GEO	16	0.993	1.007	0.08	0.85	1.163	-0.012
O 722	GEO	18	1.04	1.04	0.042	0.957	1.122	0.076
O 726	GEO	18	1.045	1.043	0.041	0.963	1.123	0.087
GEO	O 729	18	0.969	0.964	0.052	0.861	1.066	-0.062
O755/725	O 729	10	0.996	0.986	0.05	0.888	1.084	-0.005
TB	O 729	18	0.91	0.918	0.038	0.844	0.992	-0.182
FRISE	O 729	16	0.96	0.966	0.043	0.882	1.05	-0.074
O 722	O 729	18	1.007	1.001	0.045	0.913	1.09	0.014
O 726	O 729	18	1.013	1.004	0.051	0.905	1.104	0.025
GEO	O755/725	10	0.978	0.996	0.073	0.853	1.139	-0.029
O 729	O755/725	10	1.004	1.017	0.056	0.907	1.127	0.005
TB	O755/725	10	0.921	0.931	0.029	0.874	0.989	-0.11
FRISE	O755/725	8	0.961	0.979	0.029	0.923	1.036	-0.044
O 722	O755/725	10	1.014	1.031	0.051	0.93	1.131	0.019
O 726	O755/725	10	1.022	1.033	0.05	0.935	1.131	0.029
GEO	TB	18	1.064	1.052	0.082	0.892	1.212	0.119
O 729	TB	18	1.098	1.091	0.044	1.005	1.177	0.182
O755/725	TB	10	1.086	1.075	0.033	1.01	1.14	0.11
FRISE	TB	16	1.058	1.057	0.043	0.973	1.141	0.1
O 722	TB	18	1.106	1.092	0.07	0.955	1.23	0.196
O 726	TB	18	1.112	1.096	0.071	0.956	1.235	0.207
GEO	FRISE	16	1.007	0.999	0.076	0.85	1.149	0.012
O 729	FRISE	16	1.042	1.038	0.048	0.944	1.132	0.074
O755/725	FRISE	8	1.041	1.022	0.031	0.961	1.083	0.044
TB	FRISE	16	0.945	0.947	0.039	0.872	1.023	-0.1
O 722	FRISE	16	1.046	1.034	0.067	0.902	1.166	0.081
O 726	FRISE	16	1.053	1.038	0.072	0.897	1.178	0.092
GEO	O 722	18	0.962	0.963	0.038	0.889	1.037	-0.076
O 729	O 722	18	0.993	1.001	0.052	0.9	1.103	-0.014
O755/725	O 722	10	0.986	0.972	0.044	0.885	1.059	-0.019
TB	O 722	18	0.904	0.92	0.073	0.778	1.062	-0.196
FRISE	O 722	16	0.956	0.972	0.07	0.834	1.109	-0.081
O 726	O 722	18	1.005	1.003	0.021	0.963	1.044	0.011
GEO	O 726	18	0.957	0.96	0.037	0.888	1.032	-0.087
O 729	O 726	18	0.987	0.999	0.057	0.888	1.11	-0.025
O755/725	O 726	10	0.979	0.97	0.043	0.885	1.055	-0.029
TB	O 726	18	0.899	0.917	0.073	0.774	1.061	-0.207
FRISE	O 726	16	0.95	0.969	0.073	0.825	1.112	-0.092
O 722	O 726	18	0.995	0.997	0.021	0.957	1.038	-0.011

Table 23. Johnstown, liquid, low wind.

Johnstown- Liquid Low Wind								
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
O 729	GEO	17	1.037	1.031	0.062	0.909	1.153	0.081
O755/725	GEO	7	1.006	1.011	0.054	0.905	1.117	0.008
TB	GEO	17	0.998	0.997	0.067	0.866	1.128	-0.004
FRISE	GEO	17	1.007	1.004	0.067	0.873	1.135	0.016
O 722	GEO	17	1.046	1.035	0.068	0.901	1.169	0.1
O 726	GEO	17	1.044	1.031	0.067	0.901	1.162	0.096
GEO	O 729	17	0.964	0.973	0.053	0.869	1.078	-0.081
O755/725	O 729	7	1	0.999	0.045	0.91	1.088	0
TB	O 729	17	0.962	0.967	0.032	0.905	1.03	-0.084
FRISE	O 729	17	0.971	0.974	0.027	0.921	1.027	-0.065
O 722	O 729	17	1.009	1.004	0.03	0.946	1.062	0.019
O 726	O 729	17	1.007	1.001	0.036	0.931	1.071	0.015
GEO	O755/725	7	0.994	0.992	0.055	0.885	1.1	-0.008
O 729	O755/725	7	1	1.003	0.047	0.911	1.096	0
TB	O755/725	7	0.97	0.967	0.03	0.909	1.025	-0.04
FRISE	O755/725	7	0.982	0.982	0.022	0.938	1.025	-0.024
O 722	O755/725	7	1.006	1.003	0.008	0.987	1.019	0.008
O 726	O755/725	7	1.006	0.996	0.032	0.934	1.058	0.008
GEO	TB	17	1.002	1.007	0.061	0.887	1.127	0.004
O 729	TB	17	1.039	1.035	0.035	0.967	1.103	0.084
O755/725	TB	7	1.031	1.035	0.032	0.973	1.097	0.04
FRISE	TB	17	1.009	1.007	0.031	0.947	1.068	0.019
O 722	TB	17	1.048	1.039	0.033	0.974	1.104	0.103
O 726	TB	17	1.046	1.035	0.031	0.975	1.096	0.099
GEO	FRISE	17	0.993	1	0.063	0.878	1.123	-0.016
O 729	FRISE	17	1.03	1.028	0.029	0.97	1.085	0.065
O755/725	FRISE	7	1.019	1.019	0.023	0.973	1.065	0.024
TB	FRISE	17	0.991	0.994	0.03	0.935	1.052	-0.019
O 722	FRISE	17	1.039	1.031	0.026	0.981	1.082	0.084
O 726	FRISE	17	1.037	1.028	0.035	0.959	1.097	0.08
GEO	O 722	17	0.956	0.97	0.06	0.852	1.087	-0.1
O 729	O 722	17	0.991	0.997	0.031	0.936	1.057	-0.019
O755/725	O 722	7	0.994	0.997	0.008	0.981	1.012	-0.008
TB	O 722	17	0.954	0.964	0.031	0.903	1.024	-0.103
FRISE	O 722	17	0.963	0.97	0.024	0.923	1.017	-0.084
O 726	O 722	17	0.998	0.997	0.021	0.955	1.038	-0.004
GEO	O 726	17	0.957	0.973	0.058	0.86	1.087	-0.096
O 729	O 726	17	0.993	1	0.037	0.927	1.073	-0.015
O755/725	O 726	7	0.994	1.005	0.034	0.939	1.071	-0.008
TB	O 726	17	0.956	0.967	0.029	0.911	1.023	-0.099
FRISE	O 726	17	0.964	0.974	0.035	0.905	1.043	-0.08
O 722	O 726	17	1.002	1.004	0.022	0.96	1.047	0.004

Table 24. Johnstown, solid, high wind.

Johnstown- Solid High Wind								
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
O 729	GEO	6	1.111	1.064	0.09	0.887	1.24	0.046
O755/725	GEO	5	1.174	1.699	1.422	-1.089	4.487	0.073
TB	GEO	4	0.286	0.425	0.333	-0.227	1.077	-0.408
FRISE	GEO	6	0.593	0.717	0.3	0.129	1.306	-0.207
O 722	GEO	6	0.741	0.873	0.34	0.206	1.54	-0.127
O 726	GEO	6	0.889	1.206	1.044	-0.84	3.252	-0.052
GEO	O 729	6	0.9	0.947	0.076	0.798	1.095	-0.046
O755/725	O 729	5	1.038	1.642	1.452	-1.203	4.488	0.017
TB	O 729	4	0.267	0.417	0.339	-0.247	1.08	-0.412
FRISE	O 729	6	0.533	0.689	0.319	0.064	1.315	-0.246
O 722	O 729	6	0.667	0.84	0.367	0.12	1.559	-0.169
O 726	O 729	6	0.8	1.173	1.063	-0.911	3.257	-0.098
GEO	O755/725	5	0.852	0.938	0.519	-0.08	1.955	-0.073
O 729	O755/725	5	0.963	1.038	0.632	-0.201	2.277	-0.017
TB	O755/725	3	0.25	0.456	0.385	-0.299	1.211	-0.354
FRISE	O755/725	5	0.556	0.671	0.276	0.129	1.213	-0.269
O 722	O755/725	5	0.667	0.76	0.308	0.156	1.364	-0.189
O 726	O755/725	5	0.815	0.849	0.225	0.408	1.29	-0.101
GEO	TB	4	3.5	3.5	1.5	0.56	6.44	0.408
O 729	TB	4	3.75	3.75	1.785	0.251	7.249	0.412
O755/725	TB	3	4	4	2.16	-0.234	8.234	0.354
FRISE	TB	4	2.25	2.25	1.299	-0.296	4.796	0.219
O 722	TB	4	2.5	2.5	1.118	0.309	4.691	0.284
O 726	TB	4	2.5	2.5	1.118	0.309	4.691	0.284
GEO	FRISE	6	1.688	1.811	1.075	-0.296	3.919	0.207
O 729	FRISE	6	1.875	1.933	1.106	-0.234	4.1	0.246
O755/725	FRISE	5	1.8	1.99	1.3	-0.558	4.538	0.269
TB	FRISE	4	0.444	0.646	0.355	-0.051	1.342	-0.219
O 722	FRISE	6	1.25	1.317	0.367	0.597	2.036	0.089
O 726	FRISE	6	1.5	1.65	0.901	-0.117	3.417	0.168
GEO	O 722	6	1.35	1.317	0.461	0.413	2.222	0.127
O 729	O 722	6	1.5	1.421	0.545	0.352	2.489	0.169
O755/725	O 722	5	1.5	1.621	0.794	0.065	3.178	0.189
TB	O 722	4	0.4	0.521	0.291	-0.049	1.091	-0.284
FRISE	O 722	6	0.8	0.813	0.197	0.426	1.201	-0.089
O 726	O 722	6	1.2	1.222	0.497	0.248	2.196	0.08
GEO	O 726	6	1.125	1.254	0.562	0.153	2.355	0.052
O 729	O 726	6	1.25	1.357	0.643	0.097	2.617	0.098
O755/725	O 726	5	1.227	1.279	0.394	0.506	2.051	0.101
TB	O 726	4	0.4	0.521	0.291	-0.049	1.091	-0.284
FRISE	O 726	6	0.667	0.75	0.279	0.203	1.297	-0.168
O 722	O 726	6	0.833	0.905	0.213	0.487	1.322	-0.08

Table 25. Johnstown, solid, low wind.

Johnstown- Solid Low Wind								
NAME(I)	NAME(J)	NIJ	RATIO	RATIO_ME	STD DEV	CONF_INT	CONF_INT	Z
O 729	GEO	6	1.078	1.056	0.071	0.917	1.196	0.067
O755/725	GEO	6	1.047	1.094	0.191	0.72	1.469	0.042
TB	GEO	1	1.429	1.429	0	1.429	1.429	8.608
FRISE	GEO	6	0.875	0.951	0.27	0.422	1.481	-0.12
O 722	GEO	6	1	1.054	0.204	0.654	1.453	0
O 726	GEO	6	1.031	1.054	0.099	0.859	1.248	0.028
GEO	O 729	6	0.928	0.951	0.06	0.833	1.068	-0.067
O755/725	O 729	6	0.971	1.046	0.222	0.611	1.48	-0.027
TB	O 729	1	1.333	1.333	0	1.333	1.334	7.858
FRISE	O 729	6	0.812	0.915	0.295	0.336	1.493	-0.185
O 722	O 729	6	0.928	1.006	0.231	0.554	1.459	-0.069
O 726	O 729	6	0.957	1.005	0.136	0.737	1.272	-0.04
GEO	O755/725	6	0.955	0.937	0.133	0.676	1.197	-0.042
O 729	O755/725	6	1.03	0.994	0.183	0.635	1.353	0.027
TB	O755/725	1	1.429	1.429	0	1.429	1.429	8.608
FRISE	O755/725	6	0.836	0.857	0.111	0.64	1.074	-0.167
O 722	O755/725	6	0.955	0.962	0.054	0.856	1.068	-0.044
O 726	O755/725	6	0.985	0.974	0.073	0.83	1.118	-0.014
GEO	TB	1	0.7	0.7	0	0.7	0.7	-8.608
O 729	TB	1	0.75	0.75	0	0.75	0.75	-7.858
O755/725	TB	1	0.7	0.7	0	0.7	0.7	-8.608
FRISE	TB	1	0.65	0.65	0	0.65	0.65	-8.877
O 722	TB	1	0.7	0.7	0	0.7	0.7	-8.608
O 726	TB	1	0.75	0.75	0	0.75	0.75	-7.858
GEO	FRISE	6	1.143	1.129	0.292	0.557	1.7	0.12
O 729	FRISE	6	1.232	1.209	0.395	0.435	1.983	0.185
O755/725	FRISE	6	1.196	1.19	0.177	0.843	1.537	0.167
TB	FRISE	1	1.538	1.538	0	1.538	1.539	8.877
O 722	FRISE	6	1.143	1.145	0.192	0.769	1.521	0.125
O 726	FRISE	6	1.179	1.163	0.21	0.751	1.575	0.151
GEO	O 722	6	1	0.977	0.146	0.69	1.264	0
O 729	O 722	6	1.078	1.036	0.187	0.669	1.403	0.069
O755/725	O 722	6	1.047	1.043	0.061	0.924	1.162	0.044
TB	O 722	1	1.429	1.429	0	1.429	1.429	8.608
FRISE	O 722	6	0.875	0.894	0.122	0.654	1.133	-0.125
O 726	O 722	6	1.031	1.016	0.093	0.835	1.197	0.029
GEO	O 726	6	0.97	0.957	0.084	0.792	1.122	-0.028
O 729	O 726	6	1.045	1.014	0.142	0.737	1.292	0.04
O755/725	O 726	6	1.015	1.033	0.084	0.869	1.197	0.014
TB	O 726	1	1.333	1.333	0	1.333	1.334	7.858
FRISE	O 726	6	0.848	0.888	0.163	0.569	1.208	-0.151
O 722	O 726	6	0.97	0.993	0.1	0.797	1.19	-0.029

The following figures compare the Geonor, Frise and Ott gauges to other gauges for the previously defined short duration events. Ratios are plotted along with associated error bars. Plots are for "all events" and "all liquid events" because those categories had sufficient events to make the statistics more reliable.

Figure 3. Sterling, all-liquid events; ratio to Geonor 1.

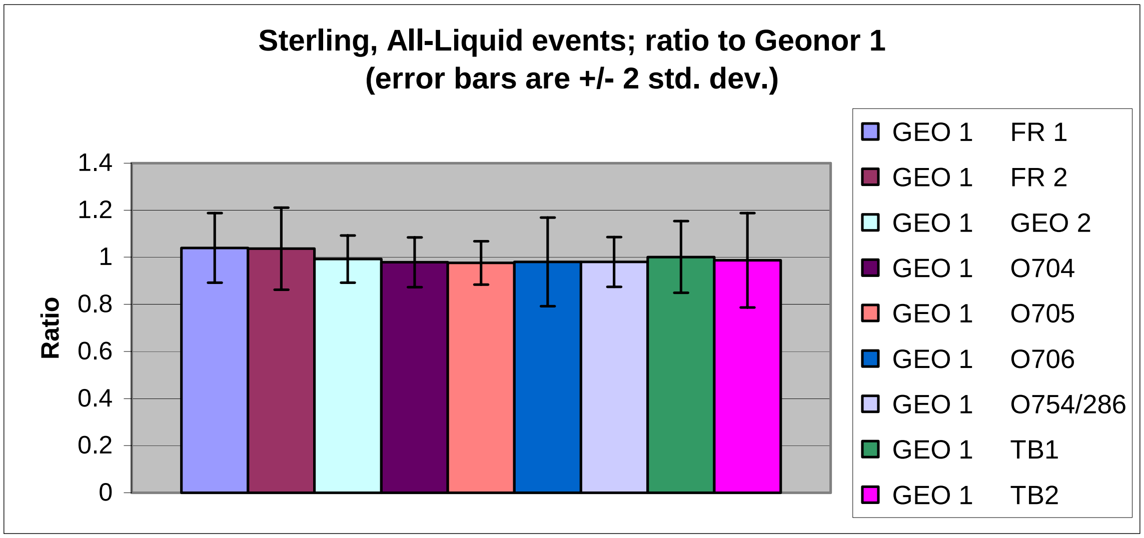


Figure 4. Johnstown, all-liquid events, ratio to Geonor.

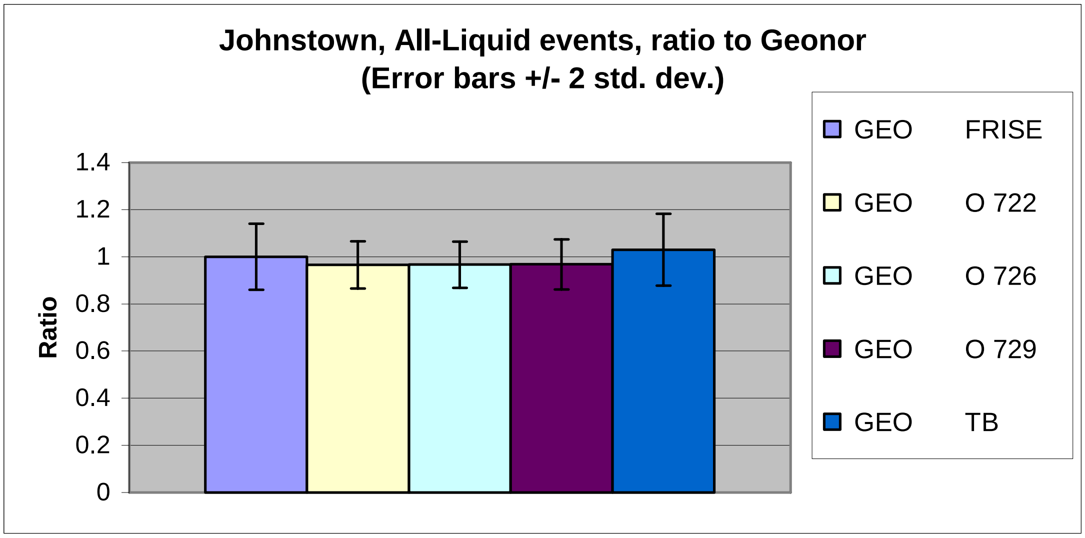


Figure 5. Sterling, all events, ratio to Geonor 1.

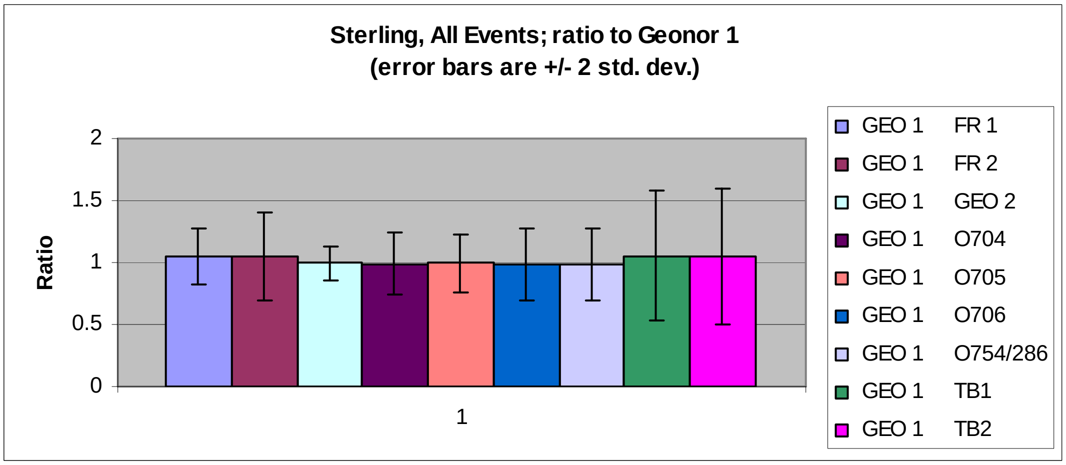


Figure 6. Johnstown, all events, ratio to Geonor.

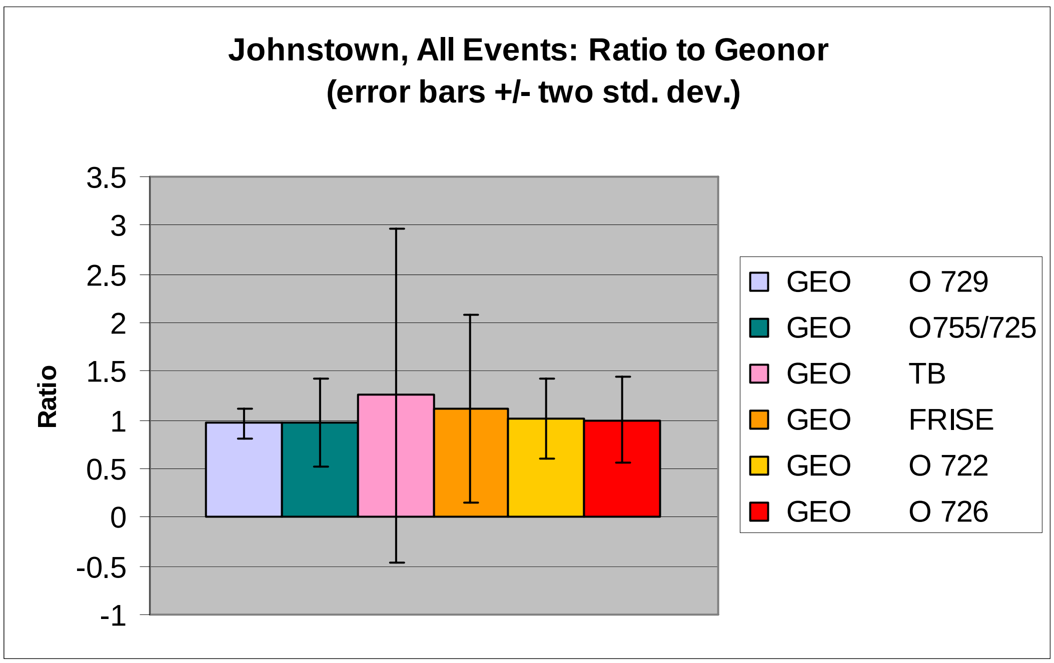


Figure 7. Sterling, all events, ratio to Frise 1.

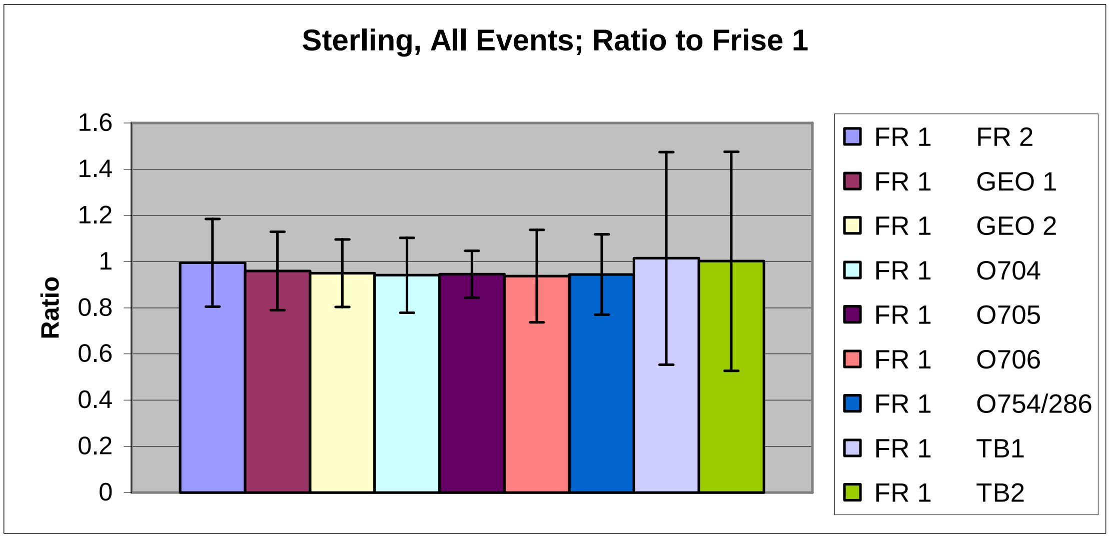


Figure 8. Sterling, all-liquid events, ratio to Frise 1.

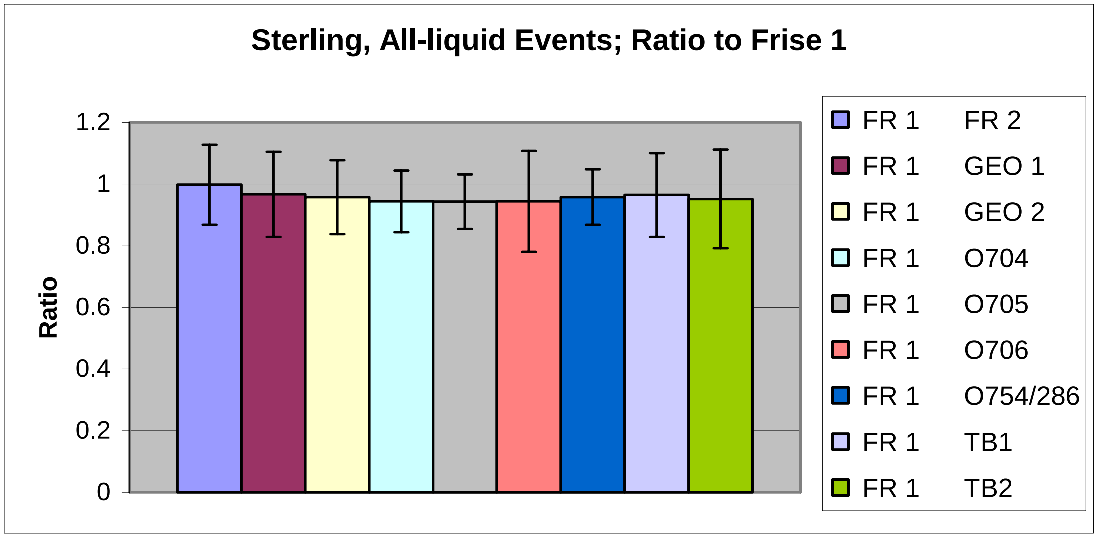


Figure 9. Johnstown, all events, ratio to Ott 729.

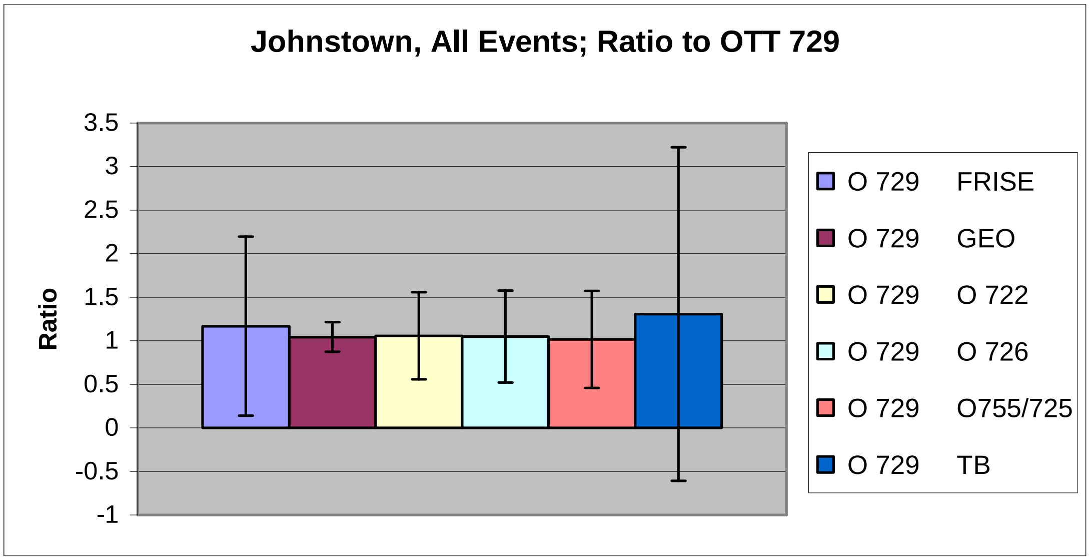
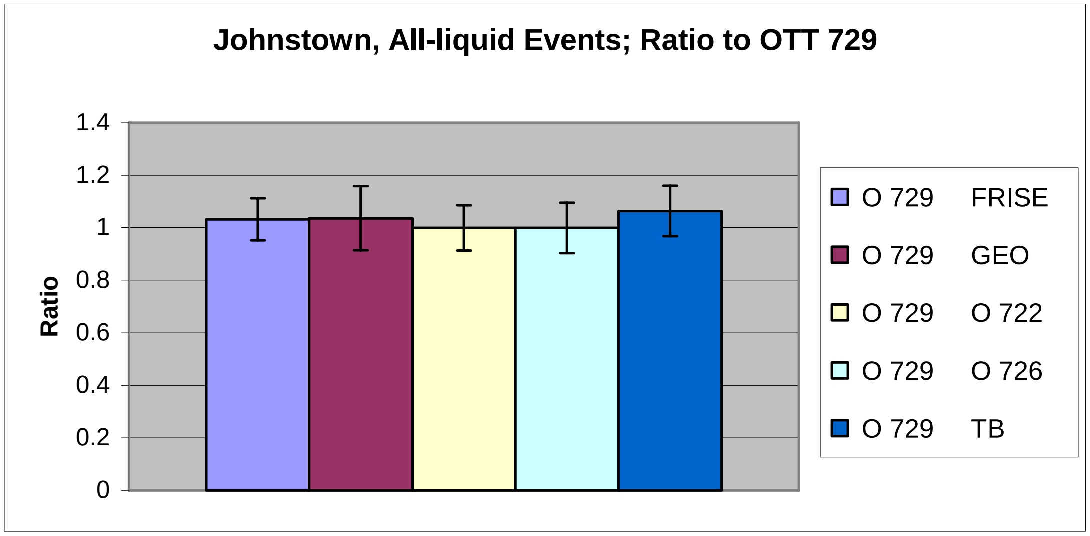


Figure 10. Johnstown, all-liquid events, ratio to Ott 729.



As described for the previous tables, the following six tables (Tables 26-31) compare all gauges with each other for all data during short duration events as identified in Section 3.3. Analysis includes the number of events, comparisons based on **gauge catch differences** (not ratios as in the previous tables), standard deviations, 95 percent confidence intervals, and the Z test.

The greatest variation for all data at Sterling using gauge catch differences is between FR2 and TB2 (.036). FR2 has an ASOS vinyl shield while TB2 has the SDFIR for protection. For Johnstown, the greatest variation is between Ott 722 (and Ott 726) and TB2 (.026). Ott 722 and Ott 726 each have the Tretyakov shield while TB has the Alter shield.

When looking at liquid precipitation only, at Sterling, the greatest variation using gauge catch differences was again between FR2 and TB2 (.033). At Johnstown, the greatest variation was between Geonor and TB (.03).

For solid precipitation, at Sterling, the greatest variation was between the tipping buckets (TB1 and TB2) and the Geonors (1 and 2) at .045. At Johnstown, the greatest variation was between the TB and Ott755 at .033.

Table 26. Sterling, all data, differences

Sterling -	**All Data**									
NAME(I)	NAME(J)	NIJ	DIFF	DIFF_MN	STD-DEV	CONF-I	N	TERVAL		Z
GEO 2	GEO 1	54	0.17	0.003	0.012 (	-0.021	,	0.027	)	0.053
TB2	GEO 1	43	-0.02	0	0.031 (	-0.061	,	0.06	)	-0.007
O706	GEO 1	51	0.38	0.007	0.02 (	-0.032	,	0.047	)	0.125
TB1	GEO 1	43	-0.33	-0.008	0.025 (	-0.057	,	0.041	)	-0.117
FR 1	GEO 1	53	-0.62	-0.012	0.025 (	-0.06	,	0.037	)	-0.199
FR 2	GEO 1	53	-0.68	-0.013	0.024 (	-0.06	,	0.034	)	-0.22
O705	GEO 1	52	0.35	0.007	0.018 (	-0.028	,	0.041	)	0.115
O704	GEO 1	53	0.33	0.006	0.017 (	-0.027	,	0.039	)	0.108
O754/286	GEO 1	42	0.32	0.008	0.017 (	-0.025	,	0.041	)	0.108
GEO 1	GEO 2	54	-0.17	-0.003	0.012 (	-0.027	,	0.021	)	-0.053
TB2	GEO 2	43	-0.19	-0.004	0.029 (	-0.061	,	0.052	)	-0.066
O706	GEO 2	51	0.2	0.004	0.02 (	-0.036	,	0.044	)	0.065
TB1	GEO 2	43	-0.5	-0.012	0.027 (	-0.064	,	0.041	)	-0.176
FR 1	GEO 2	53	-0.77	-0.015	0.025 (	-0.064	,	0.034	)	-0.246
FR 2	GEO 2	53	-0.83	-0.016	0.028 (	-0.07	,	0.038	)	-0.266
O705	GEO 2	52	0.17	0.003	0.015 (	-0.027	,	0.033	)	0.055
O704	GEO 2	53	0.15	0.003	0.016 (	-0.029	,	0.035	)	0.049
O754/286	GEO 2	42	0.1	0.002	0.016 (	-0.03	,	0.034	)	0.033
GEO 1	TB2	43	0.02	0	0.031 (	-0.06	,	0.061	)	0.007
GEO 2	TB2	43	0.19	0.004	0.029 (	-0.052	,	0.061	)	0.066
O706	TB2	40	0.43	0.011	0.03 (	-0.049	,	0.07	)	0.155
TB1	TB2	43	-0.31	-0.007	0.019 (	-0.045	,	0.03	)	-0.109
FR 1	TB2	42	-0.52	-0.012	0.032 (	-0.076	,	0.051	)	-0.184
FR 2	TB2	42	-0.57	-0.014	0.036 (	-0.083	,	0.056	)	-0.203
O705	TB2	41	0.4	0.01	0.027 (	-0.044	,	0.063	)	0.145
O704	TB2	42	0.37	0.009	0.027 (	-0.043	,	0.061	)	0.133
O754/286	TB2	35	0.27	0.008	0.027 (	-0.046	,	0.061	)	0.098
GEO 1	O706	51	-0.38	-0.007	0.02 (	-0.047	,	0.032	)	-0.125
GEO 2	O706	51	-0.2	-0.004	0.02 (	-0.044	,	0.036	)	-0.065
TB2	O706	40	-0.43	-0.011	0.03 (	-0.07	,	0.049	)	-0.155
TB1	O706	40	-0.7	-0.017	0.03 (	-0.075	,	0.04	)	-0.256
FR 1	O706	50	-0.95	-0.019	0.028 (	-0.075	,	0.037	)	-0.316
FR 2	O706	50	-0.99	-0.02	0.029 (	-0.077	,	0.037	)	-0.331
O705	O706	50	-0.05	-0.001	0.015 (	-0.031	,	0.029	)	-0.016
O704	O706	51	-0.07	-0.001	0.011 (	-0.023	,	0.02	)	-0.023
O754/286	O706	39	-0.07	-0.002	0.016 (	-0.033	,	0.029	)	-0.024
GEO 1	TB1	43	0.33	0.008	0.025 (	-0.041	,	0.057	)	0.117
GEO 2	TB1	43	0.5	0.012	0.027 (	-0.041	,	0.064	)	0.176

TB2	TB1	43	0.31	0.007	0.019 (	-0.03 ,	0.045)	0.109
O706	TB1	40	0.7	0.017	0.03 (	-0.04 ,	0.075)	0.256
FR 1	TB1	42	-0.22	-0.005	0.027 (	-0.058 ,	0.047)	-0.079
FR 2	TB1	42	-0.27	-0.006	0.026 (	-0.057 ,	0.044)	-0.098
O705	TB1	41	0.66	0.016	0.027 (	-0.037 ,	0.069)	0.243
O704	TB1	42	0.64	0.015	0.025 (	-0.034 ,	0.065)	0.234
O754/286	TB1	35	0.62	0.018	0.025 (	-0.032 ,	0.067)	0.229
GEO 1	FR 1	53	0.62	0.012	0.025 (	-0.037 ,	0.06)	0.199
GEO 2	FR 1	53	0.77	0.015	0.025 (	-0.034 ,	0.064)	0.246
TB2	FR 1	42	0.52	0.012	0.032 (	-0.051 ,	0.076)	0.184
O706	FR 1	50	0.95	0.019	0.028 (	-0.037 ,	0.075)	0.316
TB1	FR 1	42	0.22	0.005	0.027 (	-0.047 ,	0.058)	0.079
FR 2	FR 1	53	-0.06	-0.001	0.015 (	-0.031 ,	0.029)	-0.02
O705	FR 1	51	0.92	0.018	0.023 (	-0.027 ,	0.063)	0.307
O704	FR 1	52	0.91	0.018	0.023 (	-0.028 ,	0.063)	0.302
O754/286	FR 1	41	0.71	0.017	0.023 (	-0.029 ,	0.063)	0.243
GEO 1	FR 2	53	0.68	0.013	0.024 (	-0.034 ,	0.06)	0.22
GEO 2	FR 2	53	0.83	0.016	0.028 (	-0.038 ,	0.07)	0.266
TB2	FR 2	42	0.57	0.014	0.036 (	-0.056 ,	0.083)	0.203
O706	FR 2	50	0.99	0.02	0.029 (	-0.037 ,	0.077)	0.331
TB1	FR 2	42	0.27	0.006	0.026 (	-0.044 ,	0.057)	0.098
FR 1	FR 2	53	0.06	0.001	0.015 (	-0.029 ,	0.031)	0.02
O705	FR 2	51	0.97	0.019	0.026 (	-0.032 ,	0.07)	0.325
O704	FR 2	52	0.96	0.018	0.025 (	-0.031 ,	0.068)	0.32
O754/286	FR 2	41	0.83	0.02	0.026 (	-0.03 ,	0.071)	0.285
GEO 1	O705	52	-0.35	-0.007	0.018 (	-0.041 ,	0.028)	-0.115
GEO 2	O705	52	-0.17	-0.003	0.015 (	-0.033 ,	0.027)	-0.055
TB2	O705	41	-0.4	-0.01	0.027 (	-0.063 ,	0.044)	-0.145
O706	O705	50	0.05	0.001	0.015 (	-0.029 ,	0.031)	0.016
TB1	O705	41	-0.66	-0.016	0.027 (	-0.069 ,	0.037)	-0.243
FR 1	O705	51	-0.92	-0.018	0.023 (	-0.063 ,	0.027)	-0.307
FR 2	O705	51	-0.97	-0.019	0.026 (	-0.07 ,	0.032)	-0.325
O704	O705	52	-0.02	0	0.009 (	-0.018 ,	0.018)	-0.006
O754/286	O705	41	-0.08	-0.002	0.011 (	-0.023 ,	0.019)	-0.028
GEO 1	O704	53	-0.33	-0.006	0.017 (	-0.039 ,	0.027)	-0.108
GEO 2	O704	53	-0.15	-0.003	0.016 (	-0.035 ,	0.029)	-0.049
TB2	O704	42	-0.37	-0.009	0.027 (	-0.061 ,	0.043)	-0.133
O706	O704	51	0.07	0.001	0.011 (	-0.02 ,	0.023)	0.023
TB1	O704	42	-0.64	-0.015	0.025 (	-0.065 ,	0.034)	-0.234
FR 1	O704	52	-0.91	-0.018	0.023 (	-0.063 ,	0.028)	-0.302
FR 2	O704	52	-0.96	-0.018	0.025 (	-0.068 ,	0.031)	-0.32
O705	O704	52	0.02	0	0.009 (	-0.018 ,	0.018)	0.006
O754/286	O704	41	-0.03	-0.001	0.01 (	-0.02 ,	0.018)	-0.01
GEO 1	O754/286	42	-0.32	-0.008	0.017 (	-0.041 ,	0.025)	-0.108
GEO 2	O754/286	42	-0.1	-0.002	0.016 (	-0.034 ,	0.03)	-0.033
TB2	O754/286	35	-0.27	-0.008	0.027 (	-0.061 ,	0.046)	-0.098
O706	O754/286	39	0.07	0.002	0.016 (	-0.029 ,	0.033)	0.024
TB1	O754/286	35	-0.62	-0.018	0.025 (	-0.067 ,	0.032)	-0.229
FR 1	O754/286	41	-0.71	-0.017	0.023 (	-0.063 ,	0.029)	-0.243
FR 2	O754/286	41	-0.83	-0.02	0.026 (	-0.071 ,	0.03)	-0.285
O705	O754/286	41	0.08	0.002	0.011 (	-0.019 ,	0.023)	0.028
O704	O754/286	41	0.03	0.001	0.01 (	-0.018 ,	0.02)	0.01

Table 27. Sterling, liquid only, differences

Sterling- Liquid, Differences								
NAME(I)	NAME(J)	NIJ	DIFF	DIFF_MEA	STD DEV	CONF_INT	CONF_INT	Z
GEO 2	GEO 1	41	0.17	0.004	0.013	-0.021	0.03	0.06
TB2	GEO 1	41	0.11	0.003	0.026	-0.049	0.054	0.039
O706	GEO 1	38	0.4	0.011	0.021	-0.031	0.052	0.148
TB1	GEO 1	41	-0.2	-0.005	0.02	-0.044	0.034	-0.072
FR 1	GEO 1	40	-0.53	-0.013	0.027	-0.067	0.04	-0.193
FR 2	GEO 1	40	-0.58	-0.014	0.026	-0.065	0.036	-0.212
O705	GEO 1	39	0.37	0.009	0.018	-0.025	0.044	0.138
O704	GEO 1	40	0.37	0.009	0.017	-0.024	0.042	0.137
O754/286	GEO 1	33	0.33	0.01	0.016	-0.021	0.041	0.125
GEO 1	GEO 2	41	-0.17	-0.004	0.013	-0.03	0.021	-0.06
TB2	GEO 2	41	-0.06	-0.001	0.024	-0.049	0.046	-0.021
O706	GEO 2	38	0.22	0.006	0.022	-0.038	0.049	0.081
TB1	GEO 2	41	-0.37	-0.009	0.023	-0.054	0.036	-0.133
FR 1	GEO 2	40	-0.68	-0.017	0.028	-0.071	0.037	-0.246
FR 2	GEO 2	40	-0.73	-0.018	0.03	-0.078	0.041	-0.266
O705	GEO 2	39	0.19	0.005	0.016	-0.027	0.037	0.07
O704	GEO 2	40	0.19	0.005	0.018	-0.03	0.04	0.07
O754/286	GEO 2	33	0.12	0.004	0.017	-0.029	0.037	0.045
GEO 1	TB2	41	-0.11	-0.003	0.026	-0.054	0.049	-0.039
GEO 2	TB2	41	0.06	0.001	0.024	-0.046	0.049	0.021
O706	TB2	38	0.32	0.008	0.028	-0.047	0.064	0.119
TB1	TB2	41	-0.31	-0.008	0.02	-0.046	0.031	-0.112
FR 1	TB2	40	-0.62	-0.015	0.029	-0.072	0.041	-0.225
FR 2	TB2	40	-0.67	-0.017	0.033	-0.081	0.047	-0.245
O705	TB2	39	0.27	0.007	0.023	-0.039	0.053	0.101
O704	TB2	40	0.26	0.007	0.024	-0.04	0.053	0.096
O754/286	TB2	33	0.15	0.005	0.023	-0.042	0.051	0.056
GEO 1	O706	38	-0.4	-0.011	0.021	-0.052	0.031	-0.148
GEO 2	O706	38	-0.22	-0.006	0.022	-0.049	0.038	-0.081
TB2	O706	38	-0.32	-0.008	0.028	-0.064	0.047	-0.119
TB1	O706	38	-0.59	-0.016	0.028	-0.07	0.039	-0.221
FR 1	O706	37	-0.88	-0.024	0.031	-0.085	0.038	-0.333
FR 2	O706	37	-0.91	-0.025	0.032	-0.088	0.038	-0.346
O705	O706	37	-0.05	-0.001	0.017	-0.036	0.033	-0.018
O704	O706	38	-0.05	-0.001	0.012	-0.026	0.023	-0.018
O754/286	O706	30	-0.08	-0.003	0.017	-0.037	0.032	-0.031
GEO 1	TB1	41	0.2	0.005	0.02	-0.034	0.044	0.072
GEO 2	TB1	41	0.37	0.009	0.023	-0.036	0.054	0.133
TB2	TB1	41	0.31	0.008	0.02	-0.031	0.046	0.112
O706	TB1	38	0.59	0.016	0.028	-0.039	0.07	0.221
FR 1	TB1	40	-0.32	-0.008	0.023	-0.054	0.038	-0.118
FR 2	TB1	40	-0.37	-0.009	0.022	-0.052	0.034	-0.137
O705	TB1	39	0.53	0.014	0.024	-0.033	0.06	0.2
O704	TB1	40	0.53	0.013	0.023	-0.032	0.058	0.198

O754/286	TB1	33	0.5	0.015	0.022	-0.029	0.059	0.191
GEO 1	FR 1	40	0.53	0.013	0.027	-0.04	0.067	0.193
GEO 2	FR 1	40	0.68	0.017	0.028	-0.037	0.071	0.246
TB2	FR 1	40	0.62	0.015	0.029	-0.041	0.072	0.225
O706	FR 1	37	0.88	0.024	0.031	-0.038	0.085	0.333
TB1	FR 1	40	0.32	0.008	0.023	-0.038	0.054	0.118
FR 2	FR 1	40	-0.05	-0.001	0.017	-0.035	0.032	-0.019
O705	FR 1	38	0.85	0.022	0.025	-0.027	0.071	0.323
O704	FR 1	39	0.86	0.022	0.025	-0.027	0.072	0.324
O754/286	FR 1	32	0.65	0.02	0.025	-0.03	0.07	0.251
GEO 1	FR 2	40	0.58	0.014	0.026	-0.036	0.065	0.212
GEO 2	FR 2	40	0.73	0.018	0.03	-0.041	0.078	0.266
TB2	FR 2	40	0.67	0.017	0.033	-0.047	0.081	0.245
O706	FR 2	37	0.91	0.025	0.032	-0.038	0.088	0.346
TB1	FR 2	40	0.37	0.009	0.022	-0.034	0.052	0.137
FR 1	FR 2	40	0.05	0.001	0.017	-0.032	0.035	0.019
O705	FR 2	38	0.89	0.023	0.028	-0.032	0.079	0.34
O704	FR 2	39	0.9	0.023	0.027	-0.03	0.076	0.341
O754/286	FR 2	32	0.77	0.024	0.028	-0.03	0.079	0.298
GEO 1	O705	39	-0.37	-0.009	0.018	-0.044	0.025	-0.138
GEO 2	O705	39	-0.19	-0.005	0.016	-0.037	0.027	-0.07
TB2	O705	39	-0.27	-0.007	0.023	-0.053	0.039	-0.101
O706	O705	37	0.05	0.001	0.017	-0.033	0.036	0.018
TB1	O705	39	-0.53	-0.014	0.024	-0.06	0.033	-0.2
FR 1	O705	38	-0.85	-0.022	0.025	-0.071	0.027	-0.323
FR 2	O705	38	-0.89	-0.023	0.028	-0.079	0.032	-0.34
O704	O705	39	0	0	0.01	-0.019	0.019	0
O754/286	O705	32	-0.07	-0.002	0.012	-0.026	0.021	-0.027
GEO 1	O704	40	-0.37	-0.009	0.017	-0.042	0.024	-0.137
GEO 2	O704	40	-0.19	-0.005	0.018	-0.04	0.03	-0.07
TB2	O704	40	-0.26	-0.007	0.024	-0.053	0.04	-0.096
O706	O704	38	0.05	0.001	0.012	-0.023	0.026	0.018
TB1	O704	40	-0.53	-0.013	0.023	-0.058	0.032	-0.198
FR 1	O704	39	-0.86	-0.022	0.025	-0.072	0.027	-0.324
FR 2	O704	39	-0.9	-0.023	0.027	-0.076	0.03	-0.341
O705	O704	39	0	0	0.01	-0.019	0.019	0
O754/286	O704	32	-0.06	-0.002	0.01	-0.022	0.019	-0.023
GEO 1	O754/286	33	-0.33	-0.01	0.016	-0.041	0.021	-0.125
GEO 2	O754/286	33	-0.12	-0.004	0.017	-0.037	0.029	-0.045
TB2	O754/286	33	-0.15	-0.005	0.023	-0.051	0.042	-0.056
O706	O754/286	30	0.08	0.003	0.017	-0.032	0.037	0.031
TB1	O754/286	33	-0.5	-0.015	0.022	-0.059	0.029	-0.191
FR 1	O754/286	32	-0.65	-0.02	0.025	-0.07	0.03	-0.251
FR 2	O754/286	32	-0.77	-0.024	0.028	-0.079	0.03	-0.298
O705	O754/286	32	0.07	0.002	0.012	-0.021	0.026	0.027
O704	O754/286	32	0.06	0.002	0.01	-0.019	0.022	0.023

Table 28. Sterling, solid, differences

Sterling, Solid, Differences								
NAME(I)	NAME(J)	NIJ	DIFF	DIFF_MEA	STD DEV	CONF_INT	CONF_INT	Z
GEO 2	GEO 1	13	0	0	0.009	-0.017	0.017	0
TB2	GEO 1	2	-0.13	-0.065	0.045	-0.153	0.023	-1.138
O706	GEO 1	13	-0.02	-0.002	0.015	-0.03	0.027	-0.067
TB1	GEO 1	2	-0.13	-0.065	0.045	-0.153	0.023	-1.138
FR 1	GEO 1	13	-0.09	-0.007	0.013	-0.032	0.018	-0.309
FR 2	GEO 1	13	-0.1	-0.008	0.016	-0.04	0.024	-0.348
O705	GEO 1	13	-0.02	-0.002	0.014	-0.029	0.026	-0.065
O704	GEO 1	13	-0.04	-0.003	0.013	-0.029	0.023	-0.134
O754/286	GEO 1	9	-0.01	-0.001	0.017	-0.035	0.033	-0.038
GEO 1	GEO 2	13	0	0	0.009	-0.017	0.017	0
TB2	GEO 2	2	-0.13	-0.065	0.045	-0.153	0.023	-1.138
O706	GEO 2	13	-0.02	-0.002	0.011	-0.023	0.02	-0.066
TB1	GEO 2	2	-0.13	-0.065	0.045	-0.153	0.023	-1.138
FR 1	GEO 2	13	-0.09	-0.007	0.01	-0.026	0.013	-0.305
FR 2	GEO 2	13	-0.1	-0.008	0.014	-0.034	0.019	-0.343
O705	GEO 2	13	-0.02	-0.002	0.01	-0.022	0.019	-0.065
O704	GEO 2	13	-0.04	-0.003	0.009	-0.021	0.015	-0.133
O754/286	GEO 2	9	-0.02	-0.002	0.013	-0.028	0.024	-0.074
GEO 1	TB2	2	0.13	0.065	0.045	-0.023	0.153	1.138
GEO 2	TB2	2	0.13	0.065	0.045	-0.023	0.153	1.138
O706	TB2	2	0.11	0.055	0.035	-0.014	0.124	1.087
TB1	TB2	2	0	0	0	0	0	0
FR 1	TB2	2	0.1	0.05	0.03	-0.009	0.109	1.054
FR 2	TB2	2	0.1	0.05	0.03	-0.009	0.109	1.054
O705	TB2	2	0.13	0.065	0.035	-0.004	0.134	1.284
O704	TB2	2	0.11	0.055	0.035	-0.014	0.124	1.087
O754/286	TB2	2	0.12	0.06	0.03	0.001	0.119	1.265
GEO 1	O706	13	0.02	0.002	0.015	-0.027	0.03	0.067
GEO 2	O706	13	0.02	0.002	0.011	-0.02	0.023	0.066
TB2	O706	2	-0.11	-0.055	0.035	-0.124	0.014	-1.087
TB1	O706	2	-0.11	-0.055	0.035	-0.124	0.014	-1.087
FR 1	O706	13	-0.07	-0.005	0.006	-0.018	0.007	-0.244
FR 2	O706	13	-0.08	-0.006	0.007	-0.021	0.008	-0.281
O705	O706	13	0	0	0.006	-0.011	0.011	0
O704	O706	13	-0.02	-0.002	0.004	-0.009	0.006	-0.068
O754/286	O706	9	0.01	0.001	0.006	-0.01	0.012	0.038
GEO 1	TB1	2	0.13	0.065	0.045	-0.023	0.153	1.138
GEO 2	TB1	2	0.13	0.065	0.045	-0.023	0.153	1.138
TB2	TB1	2	0	0	0	0	0	0
O706	TB1	2	0.11	0.055	0.035	-0.014	0.124	1.087
FR 1	TB1	2	0.1	0.05	0.03	-0.009	0.109	1.054
FR 2	TB1	2	0.1	0.05	0.03	-0.009	0.109	1.054
O705	TB1	2	0.13	0.065	0.035	-0.004	0.134	1.284
O704	TB1	2	0.11	0.055	0.035	-0.014	0.124	1.087

O754/286	TB1	2	0.12	0.06	0.03	0.001	0.119	1.265
GEO 1	FR 1	13	0.09	0.007	0.013	-0.018	0.032	0.309
GEO 2	FR 1	13	0.09	0.007	0.01	-0.013	0.026	0.305
TB2	FR 1	2	-0.1	-0.05	0.03	-0.109	0.009	-1.054
O706	FR 1	13	0.07	0.005	0.006	-0.007	0.018	0.244
TB1	FR 1	2	-0.1	-0.05	0.03	-0.109	0.009	-1.054
FR 2	FR 1	13	-0.01	-0.001	0.006	-0.013	0.011	-0.036
O705	FR 1	13	0.07	0.005	0.007	-0.009	0.02	0.239
O704	FR 1	13	0.05	0.004	0.005	-0.006	0.013	0.176
O754/286	FR 1	9	0.06	0.007	0.007	-0.006	0.02	0.236
GEO 1	FR 2	13	0.1	0.008	0.016	-0.024	0.04	0.348
GEO 2	FR 2	13	0.1	0.008	0.014	-0.019	0.034	0.343
TB2	FR 2	2	-0.1	-0.05	0.03	-0.109	0.009	-1.054
O706	FR 2	13	0.08	0.006	0.007	-0.008	0.021	0.281
TB1	FR 2	2	-0.1	-0.05	0.03	-0.109	0.009	-1.054
FR 1	FR 2	13	0.01	0.001	0.006	-0.011	0.013	0.036
O705	FR 2	13	0.08	0.006	0.008	-0.01	0.023	0.276
O704	FR 2	13	0.06	0.005	0.007	-0.01	0.019	0.213
O754/286	FR 2	9	0.06	0.007	0.007	-0.006	0.02	0.239
GEO 1	O705	13	0.02	0.002	0.014	-0.026	0.029	0.065
GEO 2	O705	13	0.02	0.002	0.01	-0.019	0.022	0.065
TB2	O705	2	-0.13	-0.065	0.035	-0.134	0.004	-1.284
O706	O705	13	0	0	0.006	-0.011	0.011	0
TB1	O705	2	-0.13	-0.065	0.035	-0.134	0.004	-1.284
FR 1	O705	13	-0.07	-0.005	0.007	-0.02	0.009	-0.239
FR 2	O705	13	-0.08	-0.006	0.008	-0.023	0.01	-0.276
O704	O705	13	-0.02	-0.002	0.007	-0.015	0.011	-0.067
O754/286	O705	9	-0.01	-0.001	0.006	-0.012	0.01	-0.037
GEO 1	O704	13	0.04	0.003	0.013	-0.023	0.029	0.134
GEO 2	O704	13	0.04	0.003	0.009	-0.015	0.021	0.133
TB2	O704	2	-0.11	-0.055	0.035	-0.124	0.014	-1.087
O706	O704	13	0.02	0.002	0.004	-0.006	0.009	0.068
TB1	O704	2	-0.11	-0.055	0.035	-0.124	0.014	-1.087
FR 1	O704	13	-0.05	-0.004	0.005	-0.013	0.006	-0.176
FR 2	O704	13	-0.06	-0.005	0.007	-0.019	0.01	-0.213
O705	O704	13	0.02	0.002	0.007	-0.011	0.015	0.067
O754/286	O704	9	0.03	0.003	0.005	-0.006	0.013	0.114
GEO 1	O754/286	9	0.01	0.001	0.017	-0.033	0.035	0.038
GEO 2	O754/286	9	0.02	0.002	0.013	-0.024	0.028	0.074
TB2	O754/286	2	-0.12	-0.06	0.03	-0.119	-0.001	-1.265
O706	O754/286	9	-0.01	-0.001	0.006	-0.012	0.01	-0.038
TB1	O754/286	2	-0.12	-0.06	0.03	-0.119	-0.001	-1.265
FR 1	O754/286	9	-0.06	-0.007	0.007	-0.02	0.006	-0.236
FR 2	O754/286	9	-0.06	-0.007	0.007	-0.02	0.006	-0.239
O705	O754/286	9	0.01	0.001	0.006	-0.01	0.012	0.037
O704	O754/286	9	-0.03	-0.003	0.005	-0.013	0.006	-0.114

Table 29. Johnstown, all data, differences

Johnstown- All Data								
NAME(I)	NAME(J)	NIJ	DIFF	DIFF_MN	STD-DEV	CONF-I N	TERVAL	Z
O 729	GEO	50	0.46	0.009	0.021	(-0.032 ,	0.051)	0.223
O755/725	GEO	31	0.14	0.005	0.018	(-0.031 ,	0.04)	0.11
TB	GEO	43	-0.38	-0.009	0.03	(-0.067 ,	0.049)	-0.201
FRISE	GEO	48	-0.17	-0.004	0.024	(-0.051 ,	0.044)	-0.086
O 722	GEO	50	0.4	0.008	0.024	(-0.04 ,	0.056)	0.192
O 726	GEO	50	0.48	0.01	0.025	(-0.039 ,	0.058)	0.23
GEO	O 729	50	-0.46	-0.009	0.021	(-0.051 ,	0.032)	-0.223
O755/725	O 729	31	-0.02	-0.001	0.02	(-0.041 ,	0.039)	-0.016
TB	O 729	43	-0.78	-0.018	0.024	(-0.064 ,	0.028)	-0.403
FRISE	O 729	48	-0.62	-0.013	0.021	(-0.054 ,	0.028)	-0.306
O 722	O 729	50	-0.06	-0.001	0.013	(-0.027 ,	0.025)	-0.028
O 726	O 729	50	0.02	0	0.015	(-0.029 ,	0.03)	0.009
GEO	O755/725	31	-0.14	-0.005	0.018	(-0.04 ,	0.031)	-0.11
O 729	O755/725	31	0.02	0.001	0.02	(-0.039 ,	0.041)	0.016
TB	O755/725	24	-0.31	-0.013	0.024	(-0.06 ,	0.034)	-0.263
FRISE	O755/725	29	-0.33	-0.011	0.019	(-0.048 ,	0.025)	-0.289
O 722	O755/725	31	-0.07	-0.002	0.013	(-0.028 ,	0.024)	-0.054
O 726	O755/725	31	0.01	0	0.01	(-0.019 ,	0.019)	0.008
GEO	TB	43	0.38	0.009	0.03	(-0.049 ,	0.067)	0.201
O 729	TB	43	0.78	0.018	0.024	(-0.028 ,	0.064)	0.403
O755/725	TB	24	0.31	0.013	0.024	(-0.034 ,	0.06)	0.263
FRISE	TB	41	0.3	0.007	0.02	(-0.031 ,	0.046)	0.162
O 722	TB	43	0.81	0.019	0.026	(-0.032 ,	0.069)	0.414
O 726	TB	43	0.84	0.02	0.026	(-0.031 ,	0.07)	0.429
GEO	FRISE	48	0.17	0.004	0.024	(-0.044 ,	0.051)	0.086
O 729	FRISE	48	0.62	0.013	0.021	(-0.028 ,	0.054)	0.306
O755/725	FRISE	29	0.33	0.011	0.019	(-0.025 ,	0.048)	0.289
TB	FRISE	41	-0.3	-0.007	0.02	(-0.046 ,	0.031)	-0.162
O 722	FRISE	48	0.54	0.011	0.015	(-0.019 ,	0.041)	0.264
O 726	FRISE	48	0.62	0.013	0.018	(-0.022 ,	0.048)	0.303
GEO	O 722	50	-0.4	-0.008	0.024	(-0.056 ,	0.04)	-0.192
O 729	O 722	50	0.06	0.001	0.013	(-0.025 ,	0.027)	0.028
O755/725	O 722	31	0.07	0.002	0.013	(-0.024 ,	0.028)	0.054
TB	O 722	43	-0.81	-0.019	0.026	(-0.069 ,	0.032)	-0.414
FRISE	O 722	48	-0.54	-0.011	0.015	(-0.041 ,	0.019)	-0.264
O 726	O 722	50	0.08	0.002	0.008	(-0.014 ,	0.017)	0.037
GEO	O 726	50	-0.48	-0.01	0.025	(-0.058 ,	0.039)	-0.23
O 729	O 726	50	-0.02	0	0.015	(-0.03 ,	0.029)	-0.009
O755/725	O 726	31	-0.01	0	0.01	(-0.019 ,	0.019)	-0.008
TB	O 726	43	-0.84	-0.02	0.026	(-0.07 ,	0.031)	-0.429
FRISE	O 726	48	-0.62	-0.013	0.018	(-0.048 ,	0.022)	-0.303
O 722	O 726	50	-0.08	-0.002	0.008	(-0.017 ,	0.014)	-0.037

Table 30. Johnstown, liquid, differences

Johnstown, Liquid Only, Differences								
NAME(I)	NAME(J)	NIJ	DIFF	DIFF_MEA	STD DEV	CONF_INT	CONF_INT	Z
O 729	GEO	35	0.38	0.011	0.024	-0.037	0.059	0.22
O755/725	GEO	17	0.07	0.004	0.011	-0.017	0.025	0.068
TB	GEO	35	-0.33	-0.009	0.03	-0.068	0.049	-0.199
FRISE	GEO	33	0.01	0	0.024	-0.047	0.048	0.006
O 722	GEO	35	0.47	0.013	0.026	-0.037	0.064	0.27
O 726	GEO	35	0.49	0.014	0.026	-0.037	0.065	0.281
GEO	O 729	35	-0.38	-0.011	0.024	-0.059	0.037	-0.22
O755/725	O 729	17	-0.01	-0.001	0.006	-0.013	0.012	-0.01
TB	O 729	35	-0.71	-0.02	0.022	-0.063	0.023	-0.419
FRISE	O 729	33	-0.36	-0.011	0.015	-0.04	0.018	-0.214
O 722	O 729	35	0.09	0.003	0.006	-0.009	0.014	0.051
O 726	O 729	35	0.11	0.003	0.007	-0.012	0.018	0.062
GEO	O755/725	17	-0.07	-0.004	0.011	-0.025	0.017	-0.068
O 729	O755/725	17	0.01	0.001	0.006	-0.012	0.013	0.01
TB	O755/725	17	-0.27	-0.016	0.018	-0.051	0.02	-0.27
FRISE	O755/725	15	-0.11	-0.007	0.015	-0.036	0.022	-0.12
O 722	O755/725	17	0.05	0.003	0.005	-0.006	0.012	0.048
O 726	O755/725	17	0.07	0.004	0.007	-0.009	0.018	0.066
GEO	TB	35	0.33	0.009	0.03	-0.049	0.068	0.199
O 729	TB	35	0.71	0.02	0.022	-0.023	0.063	0.419
O755/725	TB	17	0.27	0.016	0.018	-0.02	0.051	0.27
FRISE	TB	33	0.3	0.009	0.016	-0.022	0.04	0.186
O 722	TB	35	0.8	0.023	0.024	-0.024	0.07	0.468
O 726	TB	35	0.82	0.023	0.025	-0.026	0.073	0.479
GEO	FRISE	33	-0.01	0	0.024	-0.048	0.047	-0.006
O 729	FRISE	33	0.36	0.011	0.015	-0.018	0.04	0.214
O755/725	FRISE	15	0.11	0.007	0.015	-0.022	0.036	0.12
TB	FRISE	33	-0.3	-0.009	0.016	-0.04	0.022	-0.186
O 722	FRISE	33	0.43	0.013	0.016	-0.018	0.044	0.254
O 726	FRISE	33	0.45	0.014	0.018	-0.021	0.048	0.265
GEO	O 722	35	-0.47	-0.013	0.026	-0.064	0.037	-0.27
O 729	O 722	35	-0.09	-0.003	0.006	-0.014	0.009	-0.051
O755/725	O 722	17	-0.05	-0.003	0.005	-0.012	0.006	-0.048
TB	O 722	35	-0.8	-0.023	0.024	-0.07	0.024	-0.468
FRISE	O 722	33	-0.43	-0.013	0.016	-0.044	0.018	-0.254
O 726	O 722	35	0.02	0.001	0.006	-0.011	0.012	0.011
GEO	O 726	35	-0.49	-0.014	0.026	-0.065	0.037	-0.281
O 729	O 726	35	-0.11	-0.003	0.007	-0.018	0.012	-0.062
O755/725	O 726	17	-0.07	-0.004	0.007	-0.018	0.009	-0.066
TB	O 726	35	-0.82	-0.023	0.025	-0.073	0.026	-0.479
FRISE	O 726	33	-0.45	-0.014	0.018	-0.048	0.021	-0.265
O 722	O 726	35	-0.02	-0.001	0.006	-0.012	0.011	-0.011

Table 31. Johnstown, solid only, differences.

Johnstown, Solid Only, Differences								
NAME(I)	NAME(J)	NIJ	DIFF	DIFF_MEA	STD DEV	CONF_INT	CONF_INT	Z
O 729	GEO	15	0.08	0.005	0.01	-0.013	0.024	0.263
O755/725	GEO	14	0.07	0.005	0.024	-0.042	0.052	0.254
TB	GEO	8	-0.05	-0.006	0.029	-0.063	0.051	-0.193
FRISE	GEO	15	-0.18	-0.012	0.022	-0.055	0.031	-0.636
O 722	GEO	15	-0.07	-0.005	0.014	-0.031	0.022	-0.244
O 726	GEO	15	-0.01	-0.001	0.019	-0.037	0.036	-0.034
GEO	O 729	15	-0.08	-0.005	0.01	-0.024	0.013	-0.263
O755/725	O 729	14	-0.01	-0.001	0.03	-0.059	0.057	-0.034
TB	O 729	8	-0.07	-0.009	0.028	-0.065	0.047	-0.267
FRISE	O 729	15	-0.26	-0.017	0.03	-0.076	0.041	-0.873
O 722	O 729	15	-0.15	-0.01	0.02	-0.049	0.029	-0.497
O 726	O 729	15	-0.09	-0.006	0.024	-0.053	0.041	-0.295
GEO	O755/725	14	-0.07	-0.005	0.024	-0.052	0.042	-0.254
O 729	O755/725	14	0.01	0.001	0.03	-0.057	0.059	0.034
TB	O755/725	7	-0.04	-0.006	0.033	-0.07	0.059	-0.16
FRISE	O755/725	14	-0.22	-0.016	0.021	-0.057	0.026	-0.831
O 722	O755/725	14	-0.12	-0.009	0.017	-0.042	0.025	-0.444
O 726	O755/725	14	-0.06	-0.004	0.01	-0.025	0.016	-0.22
GEO	TB	8	0.05	0.006	0.029	-0.051	0.063	0.193
O 729	TB	8	0.07	0.009	0.028	-0.047	0.065	0.267
O755/725	TB	7	0.04	0.006	0.033	-0.059	0.07	0.16
FRISE	TB	8	0	0	0.029	-0.056	0.056	0
O 722	TB	8	0.01	0.001	0.025	-0.048	0.051	0.038
O 726	TB	8	0.02	0.003	0.022	-0.041	0.046	0.075
GEO	FRISE	15	0.18	0.012	0.022	-0.031	0.055	0.636
O 729	FRISE	15	0.26	0.017	0.03	-0.041	0.076	0.873
O755/725	FRISE	14	0.22	0.016	0.021	-0.026	0.057	0.831
TB	FRISE	8	0	0	0.029	-0.056	0.056	0
O 722	FRISE	15	0.11	0.007	0.013	-0.019	0.034	0.393
O 726	FRISE	15	0.17	0.011	0.018	-0.024	0.046	0.601
GEO	O 722	15	0.07	0.005	0.014	-0.022	0.031	0.244
O 729	O 722	15	0.15	0.01	0.02	-0.029	0.049	0.497
O755/725	O 722	14	0.12	0.009	0.017	-0.025	0.042	0.444
TB	O 722	8	-0.01	-0.001	0.025	-0.051	0.048	-0.038
FRISE	O 722	15	-0.11	-0.007	0.013	-0.034	0.019	-0.393
O 726	O 722	15	0.06	0.004	0.011	-0.017	0.025	0.209
GEO	O 726	15	0.01	0.001	0.019	-0.036	0.037	0.034
O 729	O 726	15	0.09	0.006	0.024	-0.041	0.053	0.295
O755/725	O 726	14	0.06	0.004	0.01	-0.016	0.025	0.22
TB	O 726	8	-0.02	-0.003	0.022	-0.046	0.041	-0.075
FRISE	O 726	15	-0.17	-0.011	0.018	-0.046	0.024	-0.601
O 722	O 726	15	-0.06	-0.004	0.011	-0.025	0.017	-0.209

3.7 Overall Gauge/Shield Performance

The need to provide gauge shielding is readily apparent in the data from both Sterling and Johnstown. The Tretyakov, Alter, ASOS and SDFIR all provide beneficial shielding for the gauges, although there are advantages and disadvantages with each. At Johnstown, Ott 729 (Tretyakov/SDFIR) caught -2 percent less than the Geonor, while Ott 726 and 722, each with just Tretyakov shields, caught -11 percent less during the cold season. Thus, the SDFIR would appear to have increased solid precipitation catch at Johnstown by about 9 percent during solid events. The 8-inch nonrecording gauges also provide useful shield information. 8"N and 8"S both have Alter shields. They had solid precipitation catch deficiencies of -53 and -51 percent as compared with the Geonor. 8"U has no shield and had a deficiency of -57 percent. The Alter shield, by itself, resulted in an increase in catch of 4 to 6 percent.

At Sterling, it is possible to make several interesting shield comparisons. Ott 286 and 706 have Tretyakov shields plus the SDFIR. Ott 704 and 705 have only the Tretyakov shields. Ott 286 and 706 had a plus ratio for cold season of +2.5 percent, while Ott 704 and 705 have a plus ratio of 1.5 percent. Thus, the SDFIR seems to have provided an addition catch factor of about 1 percent. It should be remembered that even though this is cold season data, at Sterling actual solid precipitation events are minimal as compared with Johnstown. TB1 has an Alter shield while TB2 has a SDFIR. For the cold season, TB1 had a comparison ratio of -1 percent while TB2 had 0 percent. Again, the SDFIR seems to have provided slightly more solid precipitation protection than the Alter by itself. Looking at the 8-inch nonrecording gauges, 8"N and 8"S have Alter shields while 8"U has no shield. For the cold season, the 8-inch shielded gauges caught -16.5 percent less as compared to the Geonor, while the unshielded 8" gauge caught -24 percent less. The Alter shield alone provided an additional catch of nearly 8 percent.

The ASOS shield, which is on the Frise gauge and is a vinyl shield, can be compared to the Alter which is on the TB gauge. Both gauges are tipping buckets, so the major difference is with the shields. At Sterling, during the cold season, the Frise gauges caught -7 percent less than the Geonor, while the TB1 caught -1 percent less. So, is the additional catch by the TB gauge due to the Alter shield, or due to more efficient functioning of the gauge itself? At Johnstown, the Frise caught -13 percent less, while the TB was at -18 percent. Thus, the results for the vinyl ASOS shield versus the metal Alter shield during the cold season were mixed.

3.8 Temperature, Wind Speed and Gauge Ratios at Sterling and Johnstown

This section relates gauge ratios to wind speed and temperature. Multiple events were selected for each site (11 events at Sterling and 10 at Johnstown). The figures below demonstrate the effect of average wind, wind gusts, and temperature on the average ratios of various gauges (TB, Frise and Ott) as compared to the Geonor gauge. In general, while temperature and wind events were not extreme, minimal changes in gauge ratios were observed. At Johnstown, some drop off in gauge ratios were apparent for wind above 4 mps, while at Sterling there was no significant drop off up to 3 mps. Gauge ratios were generally greater than 1 at Sterling and less than 1 at Johnstown.

Figure 11. Sterling Temperature and Wind Characteristics for Events

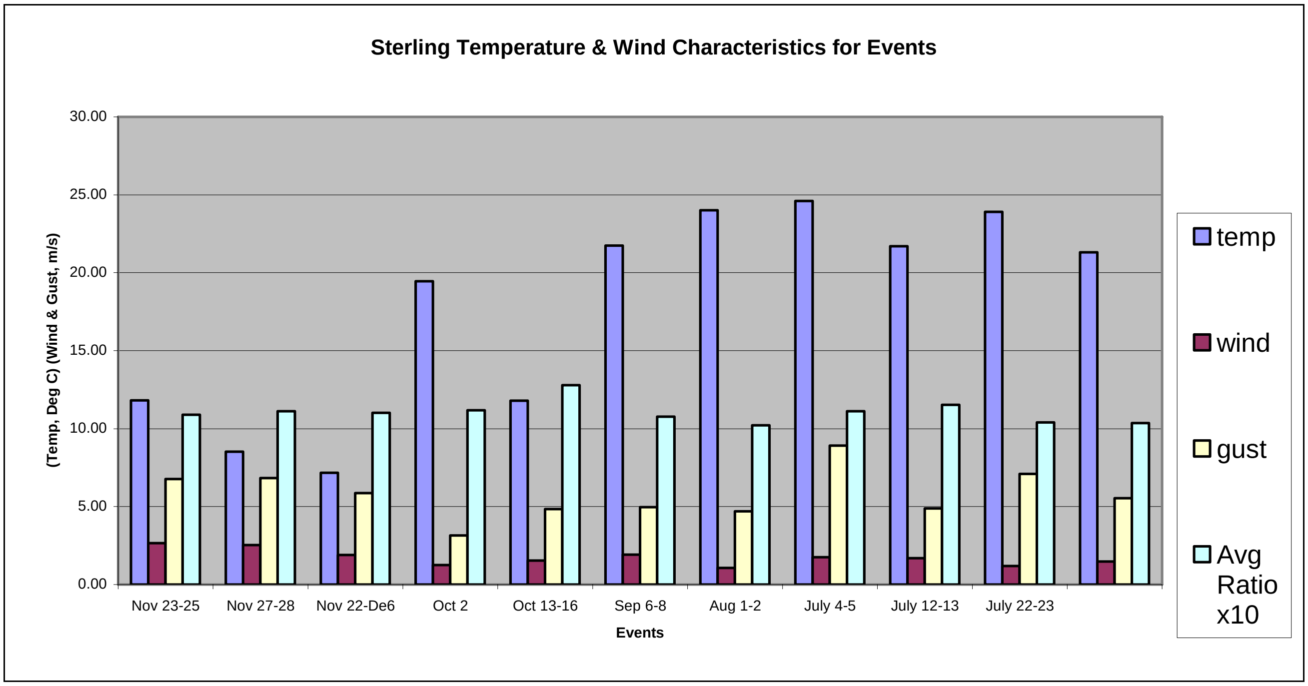


Figure 12. Sterling, ratios vs. wind speed.

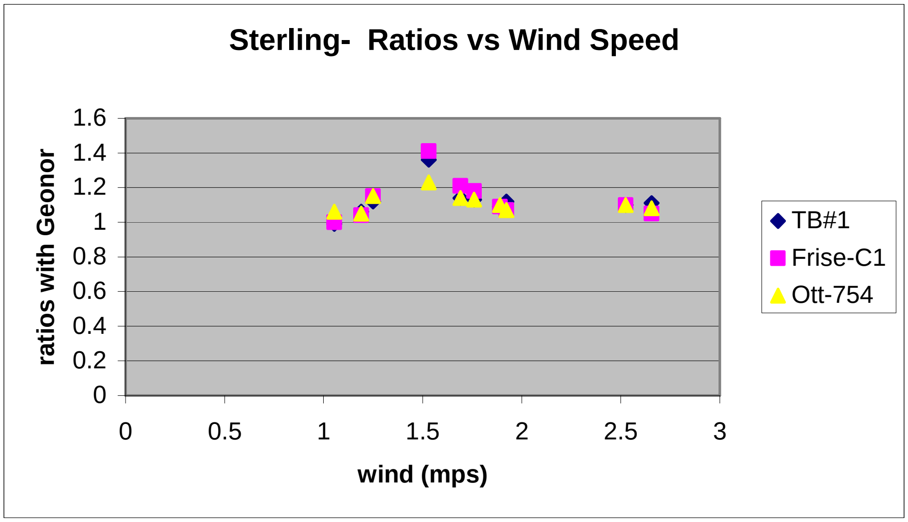


Figure 13. Sterling, ratios vs. wind gusts.

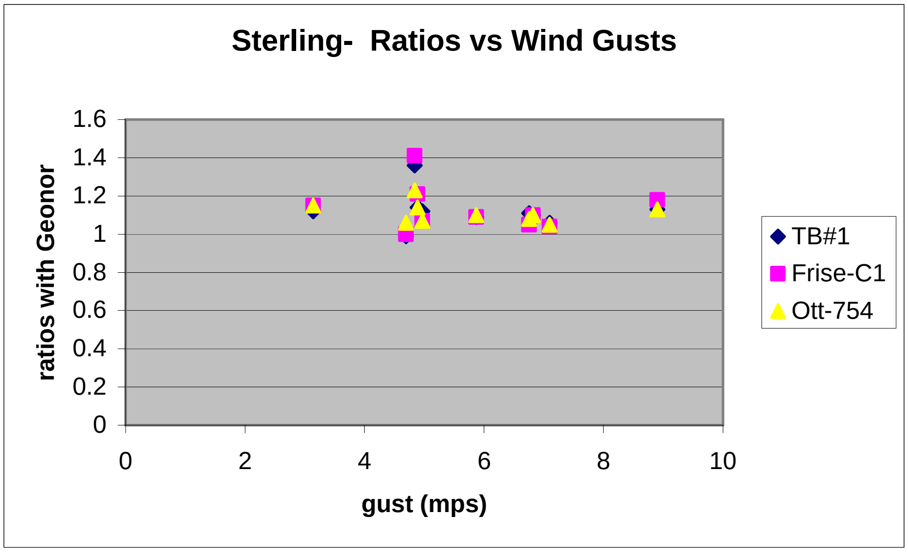


Figure 14. Sterling, ratios vs. temperature.

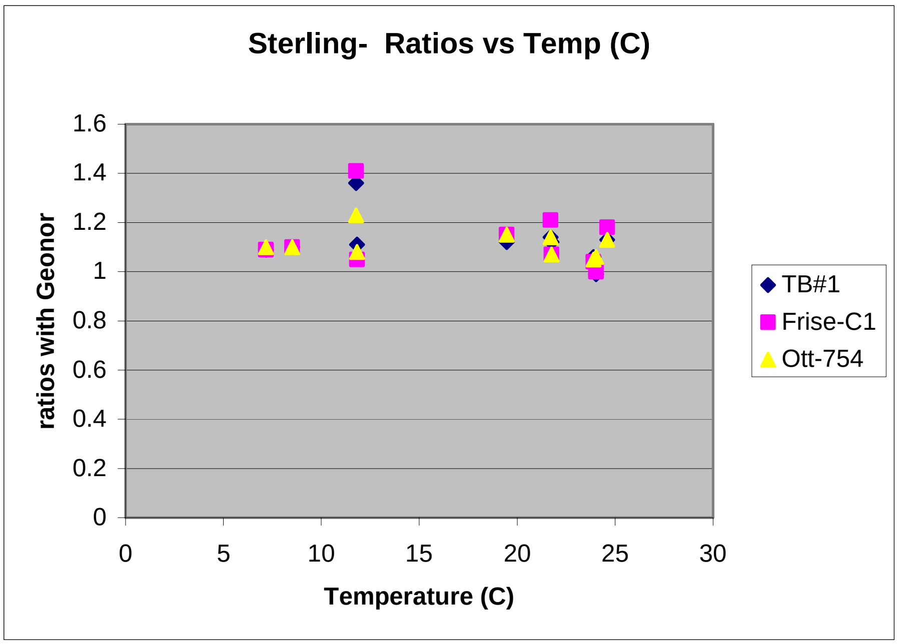


Figure 15. Johnstown Temperature and Wind Characteristics.

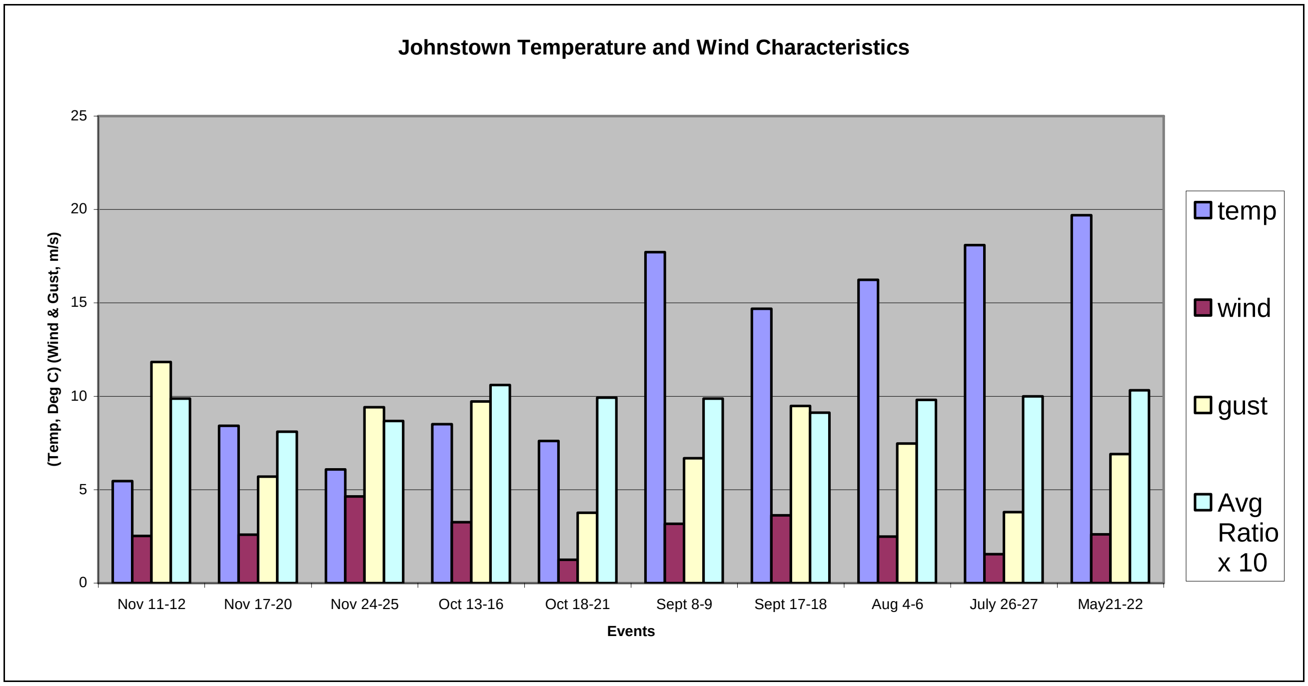


Figure 16. Johnstown, ratios vs. wind speed.

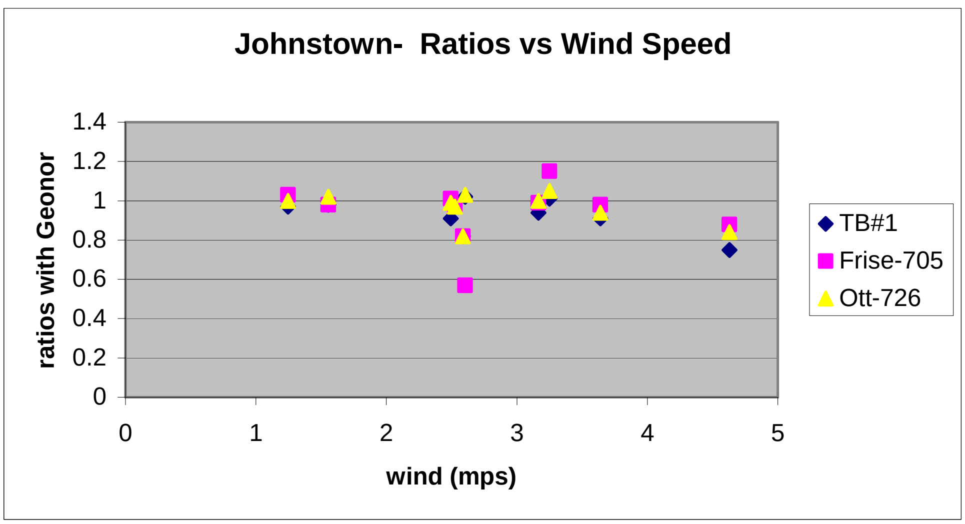


Figure 17. Johnstown, ratios vs. wind gusts.

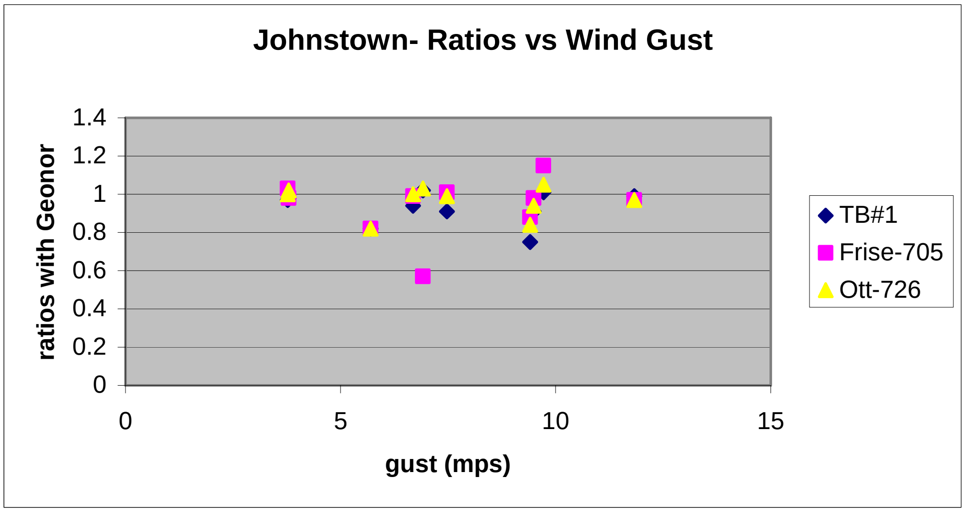
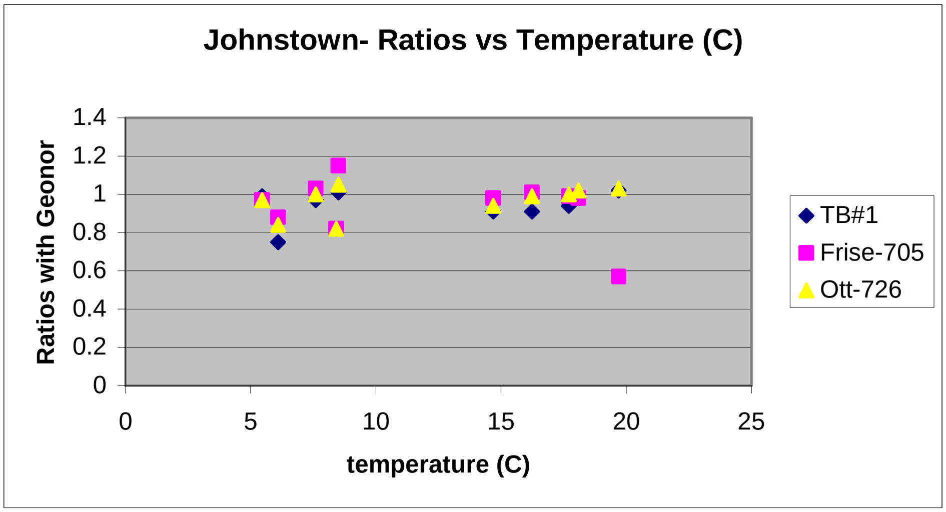


Figure 18. Johnstown, ratios vs. temperature.



4. Discussion

In order to make reliable and "true" precipitation measurements, several requirements must be met. First, a reliable and accurate gauge must be utilized. The gauge should be easily maintained, present a minimal obstacle to the airstream, and be able to function in all environments. Second, a site must be selected carefully. The site should represent the surrounding area, be level, free of individual obstacles and, if possible, provide natural gauge protection. Finally, the gauge must be combined with a suitable shield. The purpose of a gauge shield, regardless of the type, is to enable the gauge to accurately and reliably make a "true" catch of precipitation. To accomplish this, the shield must reduce horizontal wind flow around the gauge thus reducing turbulence in the vicinity of the gauge orifice. If turbulence around and over the gauge orifice can be reduced to near zero under all conditions, reliable and accurate precipitation measurements can be made.

Precipitation gauge comparison studies generally assume that the gauges which catch the "most" precipitation are functioning the best. In general, this is usually true. However, other factors must be considered. Are the gauges located close to each other and at the same heights? Do the gauge locations honestly represent the surrounding microclimate? Are the gauges similarly protected? Is the surrounding area level and free of individual obstacles? In the case of Johnstown and Sterling, these sites were carefully selected and, therefore, the requirements for good gauge comparisons have been met. The exception in this study is that the different test gauges have different shields. So, the gauge comparisons herein necessarily reflect not only the physical operation of the individual gauges, but also the combined effect of the shield and the gauge.

In general, the Geonor gauge caught slightly less precipitation at Sterling and slightly more at Johnstown as compared with the tipping bucket gauge TB3 and the Ott weighing gauges (see Figures 1 and 2). The reason for this is not readily apparent. Part of the answer may be that the Johnstown climate is somewhat more severe (i.e., higher average wind speeds and colder temperatures) as compared to the Sterling site. The tipping bucket gauges demonstrated their ability to function well in most liquid precipitation and low wind events but showed their vulnerability during solid events, high wind and high intensity events. During solid events, the tipping bucket gauges generally under reported significantly and had problems with timing (e.g., solid events were often reported the next day after melting had occurred). All the Ott gauges performed reasonably well in all environments, and with the Tretyakov shield and SDFIR compared well to the Geonor gauge. The Alter shield, on both the TB and nonrecording gauges, showed its effectiveness, especially in solid events. The Alter shield has the added advantage of swinging metal leaves that will not become "capped" in high intensity, wet, solid events.

5. Conclusions

It is obvious from this study, and has been shown in numerous similar studies, that it is difficult to accurately measure precipitation under all temperature and wind conditions. Solid precipitation events are especially difficult for tipping bucket gauges. Increased wind speed increases turbulence around the gauge orifice and thus reduces gauge catch efficiency for all gauges. Precipitation measurement errors increase for all gauges as the wind speed increases and the temperature decreases. Weighing gauges generally do better for conditions involving solid events. Heating of gauges, if not carefully done, can increase measurement errors due to evaporation and "chimney" effects at the gauge orifice. Proper site requirements are paramount when installing gauges for maximum accuracy and reliability. False reports by the Geonor gauge were a problem, but processing software seems to have resolved that issue. However, considering all the above, the Geonor gauge, combined with the Alter shield and SDFIR, or possibly the Double Alter, would seem to provide a good opportunity for obtaining accurate and reliable precipitation measurements under all conditions. The Geonor gauge performed reliably for 18 months under varying climatic conditions and, on average, met or exceeded the performance of the other test gauge configurations.

6. Recommendations

Further refinement of gauge/shield comparisons would benefit from additions to the test fields. Some of those additions would include:

- Installation of Double Alter shields to define operating characteristics with the DFIR and the SDFIR.

- Cross comparisons of primary gauges (Geonor and Ott) with the Tretyakov and Alter shields. For example, install an Ott gauge with the Alter shield and a Geonor with a Tretyakov shield. There is some question as to how the Alter and Tretyakov shields really function as compared to each other.

- Liquid precipitation events are fairly well understood with regard to gauge/shield functioning. Solid precipitation events need further refinement. Unfortunately, Johnstown and, especially, Sterling have relatively few solid events. Installation of test gauges in more severe climates in terms of temperature and wind would be very helpful. Suggested locations would be the upper Midwest or Alaska.

- Additional gauge installations such as the Vaisala precipitation gauge should be ongoing as future gauge development may warrant.

- Continued evaluation of the "wetness sensor."

- Continued collection of data from current gauges and test sites to increase the number of precipitation events so that the resulting statistics will be more robust.

7. Site Gauge Configurations

Table 32. Site/Gauge Configurations

Gauge Configurations at Sterling and Johnstown

Location	gauge	shield	orifice dia inches	increment	type	notes
Johnstown						
	Ott729	Tretyakov and SDFIR	6.28	.01 in	weighing	
	Ott726	Tretyakov	6.28	.01 in	weighing	
	Ott725	Tretyakov and SDFIR	6.28	.01 in	weighing	was #755, changed Jan 05 removed, 4/16/05
	Ott722	Tretyakov	6.28	.01 in	weighing	
	TB1	Alter	7.9	.2mm	tipping bucket	metric
	Geonor	Alter/SDFIR	6.28	.25mm	weighing	metric
	Frise	ASOS	12	.01 in	tipping bucket	
	8"	see notes	8	.01 in	non-recording	Four gauges, 2 with Alters, 1 unshielded and 1 in a DFIR
	Ott 292	Tretyakov			started about 2/1/05, gauge has experimental wind shield (fence) on 3 sides Moved to DFIR on 4/16/05	
	Frise 995	ASOS	12	.01 in	Installed 4/16/05	
Sterling						
	TB1	SDFIR	7.9	.2mm	tipping bucket	metric
					Had Alter, moved to SDFIR Jan 2005	
	TB2	SDFIR	7.9	.2mm	tipping bucket	metric
					Both TBs moved inside SDFIR on 1/18/05	
	Ott286	Tretyakov and DFIR	6.28	.01 in	weighing	orifice 5" higher than other Otts Moved to DFIR on Oct 26,'04 Formerly 754, changed to 286 on 1/18/05
	Ott705	Tretyakov	6.28	.01 in	weighing	
	Ott704	Tretyakov	6.28	.01 in	weighing	
	Ott706	Tretyakov and SDFIR	6.28	.01 in	weighing	
	Geonor1	Alter and SDFIR	6.28	.25mm	weighing	metric
	Geonor2	Alter and SDFIR	6.28	.25mm	weighing	metric
	Geonor 3	Double Alter	6.28	.25mm	weighing	Started 1/20/05
	Geonor 4	Double Alter	6.28	.25mm	weighing	Started 1/20/05
	FriseC1	ASOS	12	.01 in	tipping bucket	
	FriseD3	ASOS	12	.01 in	tipping bucket	
	8"	see notes	8	.01 in	non-recording	same as at Johnstown

Table 33. Equipment Descriptions

Brief Equipment Descriptions:	
Geonor gauge:	This is the Geonor T-200B weighing gauge which was designed in cooperation with the Norwegian Meteorological Institute. Precipitation amounts are determined by means frequency changes in three vibrating support wire transducers. This is the standard CRN precipitation gauge and will be added to the modernized COOP Network.
TB gauge:	Hydrologic Services, LTD siphoning tipping bucket precipitation gauge. This gauge is used as a secondary backup for the Geonor at some locations.
Ott gauge:	Ott Pluvio "All Weather" weighing gauge (AWPAG) manufactured by Vaisala. This gauge is being added to ASOS and COOP sites.
8 Inch gauge:	The standard NWS nonrecording 8 inch diameter gauge. Precipitation is measured manually with a measuring stick.
Frise gauge:	This is the standard ASOS tipping bucket manufactured by Frise Engineering Co. of Baltimore.
Alter shield:	The standard NWS gauge shield consisting of swinging vertical metal leaves which are mounted around and slightly above the gauge orifice . Diameter is 4 feet with 32 leaves each app. 16 inches long.
Double Alter:	Same as standard Alter with an outer ring app. 8 feet in diameter and an inner ring 4 feet in diameter.
Tretyakov shield:	This shield has fixed metal leaves around the gauge which flare out at orifice level similar to upturned trumpet.
DFIR:	The Double Fence Intercomparison Reference consists of two concentric octagonal rings of vertical lath fencing surrounding the gauge. Outer circle is 40 feet in diameter while the inner circle is 13 feet in diameter.
SDFIR:	The Small DFIR is similar to the DFIR except outer ring is approximately 25 feet in diameter.
ASOS shield:	Similar to an Alter shield except the leaves are fixed and are made of vinyl fabric.
Wetness Sensor:	Vaisala Rain Detector, DRD11A. Determines presence of water on detector plate by a change in sensor voltage.

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