1.6 CONTINUED OPERATIONAL TESTING OF VARIOUS PRECIPITATION SENSORS AND PROTECTIVE SHIELDS IN SUPPORT OF THE UNITED STATES CLIMATE REFERENCE NETWORK (USCRN)

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1. INTRODUCTION

The U.S. Climate Reference Network (USCRN) is a National Oceanic and Atmospheric Administration (NOAA) sponsored network that is being implemented to provide data for climate monitoring and other applications. Reliable, high-quality precipitation data are necessary to detect climate change and to validate climate projections and models. Approximately 114 USCRN sites are being installed nationwide. NOAA's National Climatic Data Center (NCDC) has conducted field tests of various precipitation gauges and shields in support of the USCRN network since November 2003. These tests are being conducted at research sites at Sterling, Virginia, and at Johnstown, Pennsylvania. Precipitation gauges being evaluated include the Geonor, Frise, Ott, AWPAG, TB3, Vaisala and non-recording 8 inch gauges. The Geonor, Ott, and Vaisala gauges are weighing gauges; the Frise and TB3 are tipping bucket gauges. Various gauge shields are being evaluated. These include the Alter, Double Alter, Tretyakov, ASOS, SDFIR (Small Double Fence Inter-Comparison Reference), and DFIR (Double Fence Inter-Comparison Reference). A previous paper (Larson, 2005) summarized testing results through March 2005. This paper, which covers the test period from April 2005 through July 2006, updates the previous report. Several significant changes have been made since the initial paper, including the installation of the Vaisala gauge and additional Ott gauges. Results of gauge and gauge/shield comparisons are shown. Analysis of higher intensity precipitation events as well as long term totals is presented. The performance of the Geonor gauge, selected as the primary USCRN gauge, is of particular interest. Site layouts for both sites and equipment descriptions are included.

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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 April 2005 through July 2006. Data were summarized and processed in 24-hour totals. Average wind speed, temperature, wind gust and precipitation totals for each gauge for each 24-hour period were calculated and totaled by month. In addition, significant event totals were also calculated for each gauge. For this paper, precipitation totals were further summarized for "warm" periods (May – October) and for "cold" periods (November – April). Because the Geonor gauge has been selected as the standard precipitation gauge for the USCRN, precipitation totals for all gauges were compared to the Geonor gauge by calculating the ratio of gauge catch/Geonor catch. Table 5, at the end of this paper, lists the individual equipment and configurations at each site. Table 6 gives a general description of the equipment types. All recording gauges had heated orifices to ensure satisfactory cold weather operations. Ongoing necessary site additions and modifications are documented in Table 5.

3. RESULTS

3.1 Sterling

Data results for Sterling are shown in Table 1 and Figure 1. Note that the precipitation totals reflect the individual gauge and the associated shield. For total precipitation, all seasons, the Ott gauges caught less precipitation than the Geonor gauge by about 1 percent. The Frise gauges caught less compared with the Geonor gauge by 4.5 percent. Much of that could be attributed to tipping bucket difficulties in solid precipitation events. The TB gauges caught less than the Geonor by about 3.5 percent.

For warm season events, May-October, results change somewhat. The Ott gauges equaled the Geonor catch, while the Frise gauges still caught less than the Geonor by about 3.5 percent. The TB gauges caught less than the Geonor by about 3 percent. During cold season, November-April, both the Frise gauges caught less compared with the Geonor by about 8 percent, while the TB gauges caught about 6 percent less. The Otts caught about 4 percent less than the Geonor gauge.

The Geonors in Double Alters just about equaled Geonor in the Alter/SDFIR configuration for total precipitation and warm season catch, but trailed cold season catch by about 5 percent.

Sterling- Precipitation Test Study-April 2005-July 2006

Shield	temp	wind	gust	TB#1 SDFIR	Geonor #1 A/SDFIR	TB#2 SDFIR	Geonor #2 A/SDFIR	Frise-C1 ASOS	Frise-D3 ASOS	Ott-704 Tretyakov	Ott-706 T/SDFIR	Geonor 3 DblAlt	Geonor 4 DblAlt	Vaisala DblAlt*
	C	mps	mps	in	in	in	in	in	in	in	in	in	in	in
total/avg	14.49	1.65	5.28	56.54	60.31	59.45	60.09	57.05	57.68	59.62	59.67	60.05	59.5	24.96
ratio				0.94	1.00	0.99	1.00	0.95	0.96	0.99	0.99	1.00	0.99	0.96
cold	5.97	1.93	5.78	13.01	14.02	13.37	13.95	12.79	12.86	13.28	13.59	13.52	13.27	10.64
ratio				0.93	1.00	0.95	1.00	0.91	0.92	0.95	0.97	0.96	0.95	0.94
warm	19.5	1.48	4.98	43.53	46.29	46.08	46.14	44.26	44.82	46.34	46.08	46.53	46.23	14.32
ratio				0.94	1.00	1.00	1.00	0.96	0.97	1.00	1.00	1.01	1.00	0.97

*installed 12/05/05 (ratios adjusted)

Table 1. Sterling Data

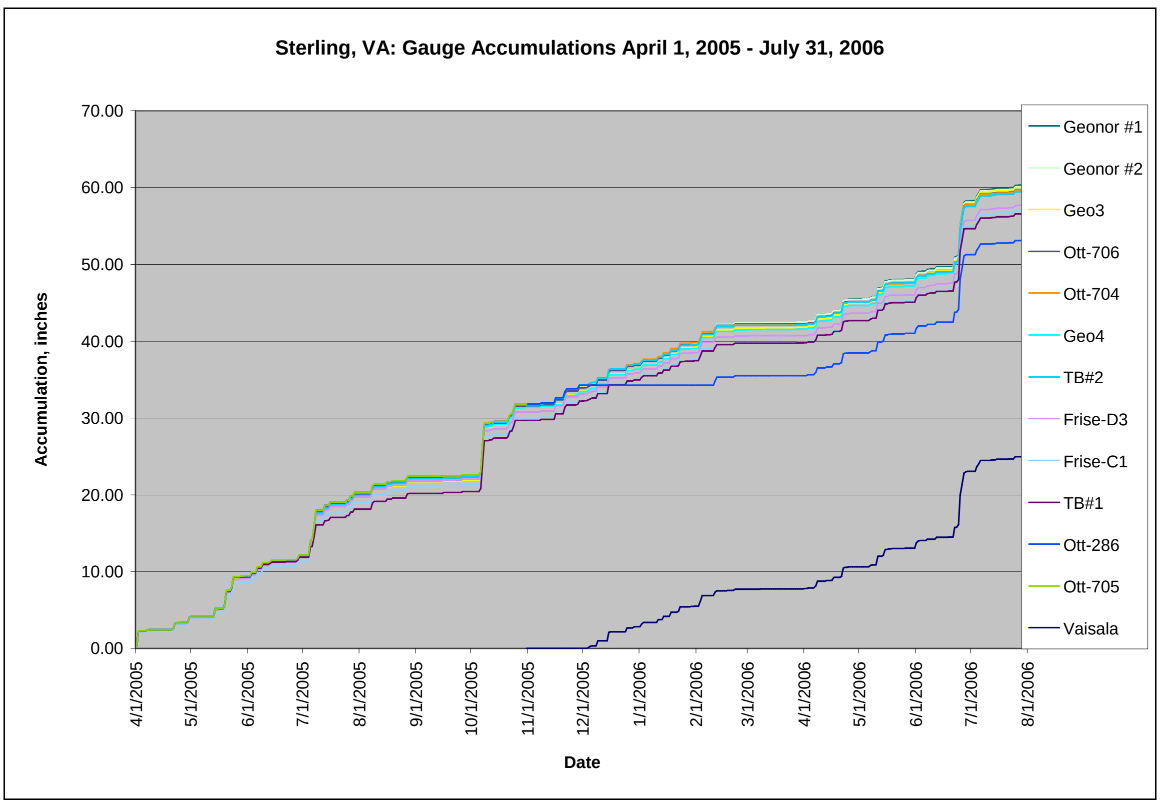

Figure 1. Sterling Mass Precipitation Plot

A Vaisala gauge was installed at Sterling on December 4, 2005, inside a Double Alter Shield. A question to be answered is how the Vaisala performs compared with the Geonor gauge. Geonor 3 and 4 are also inside Double Alters. Table 1 shows that compared with Geonor 1, the Vaisala gauge (Double Alter protected) has a ratio of .96 for total precipitation, .94 for mixed precipitation, and .97 for liquid only precipitation.

3.2 Johnstown

Data results for Johnstown are shown in Table 2 and Figure 2. At Johnstown, the Geonor gauge caught more precipitation than all other gauges consistently in every category. For all data, the Ott gauges caught less compared with the Geonor by about 5 percent. The Frise caught less by about 16 percent, while the TB caught less by about 19 percent.

For the warm season only, the Otts caught less by 3 percent, the TB less by 11 percent, while the Frise caught about 4 percent less than the Geonor. In the cold season, however, the statistics change even more. The Frise tipping bucket caught less by about 27 percent, the TB less by 30 percent, and the Otts less by 9 percent.

Johnstown- Precipitation Test Study- April 2005-July2006

shield	temp	wind	gust	TB#1 SDFIR	Geonor#1 A/SDFIR	Frise-705 ASOS	Ott-726 Tretyakov	Ott-722 Tretyakov	Ott-729 T/SDFIR	Ott292 T/DFIR	Frise995 ASOS
	C	mps	mps	in	in	in	in	in	in	in	in
total	10.63	3.39	9.21	43.77	53.26	47.81	47.76	48.20	50.99	51.16	45.93
ratio				0.82	1.00	0.90	0.90	0.91	0.96	0.96	0.86
cold	1.82	3.77	14.95	15.03	20.79	16.04	16.51	16.70	19.03	19.38	15.83
ratio				0.72	1.00	0.77	0.79	0.80	0.92	0.93	0.76
warm	15.9	3.16	5.95	28.74	32.47	31.77	31.25	31.50	31.96	31.78	30.10
ratio				1.00*	1.00	0.98	0.96	0.97	0.98	0.98	0.93

*adjusted for missing data

Table 2. Johnstown Data

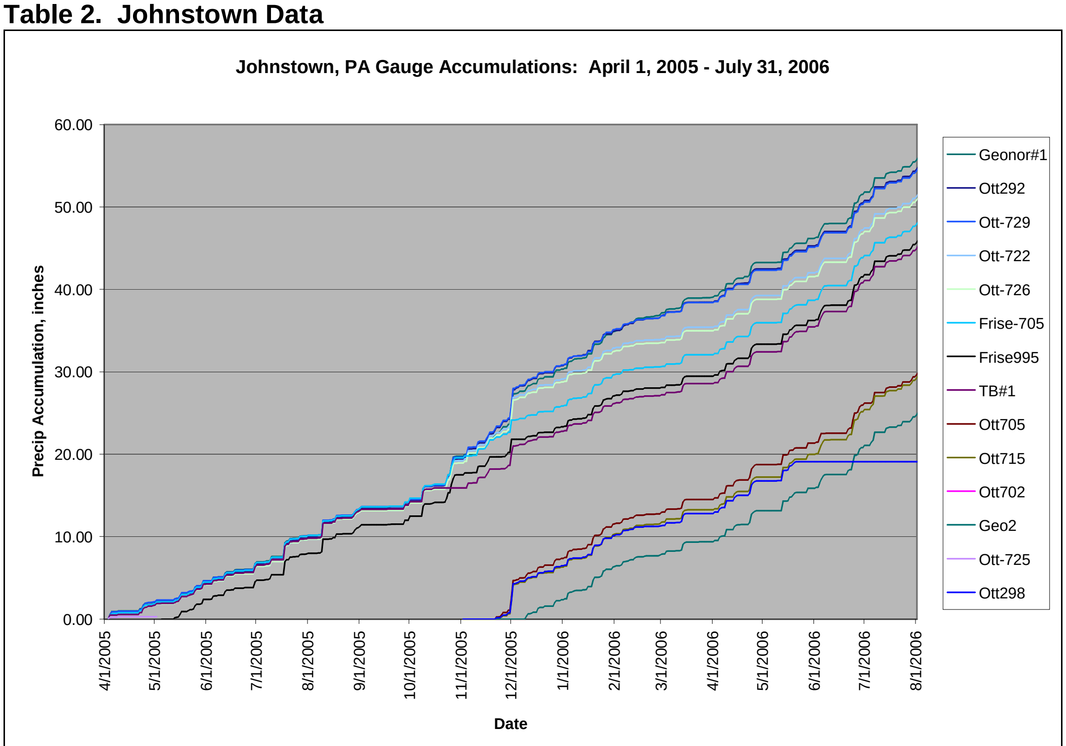

Figure 2. Johnstown Mass Precipitation Plot

3.3 Overall Gauge/Shield Performance

The need to provide gauge shielding is readily apparent in the data from both Sterling and Johnstown, especially for solid or mixed events. The Tretyakov, Alter, ASOS, DFIR, and SDFIR all provide beneficial shielding for the gauges, though there are advantages and disadvantages with each. At Johnstown, Ott 729 (Tretyakov/SDFIR) overall caught 4 percent less than the Geonor; Ott 726 and 722, each with just Tretyakov shields, caught 20 percent less for solid events. Thus, the SDFIR would appear to have increased solid precipitation catch at Johnstown by about 16 percent during solid events.

At Sterling, Ott 706 has a Tretyakov shield plus the SDFIR. Ott 704 has only a Tretyakov shield. Ott 706 under caught the Geonor by 3 percent while Ott 704 under caught by 5 percent for the cold season. Thus, the SDFIR seems to have provided an additional catch factor of about 2 percent. It should be remembered that even though this is cold season data, at Sterling actual solid precipitation events are minimal compared with Johnstown. Both TBs are protected by SDFIRs. For the cold season, TB1 under caught by 7 percent, while TB2 under caught by 5 percent. The additional under catch by the TBs is probably due to the heating required to ensure the gauge functions during cold weather.

The ASOS shield on the Frise gauge can be compared with the SDFIR, which protects the TB gauges. Both gauges are tipping buckets, so the major difference is with the shields. At Sterling, during the cold season, the Frise gauges caught 8 percent less than the Geonor, while the TBs caught 6 percent less. At Johnstown, during the cold season, the Frise caught 24 percent less than the Geonor, while the TB was at 28 percent less. Thus, the results for the ASOS shield versus SDFIR during cold season were mixed.

The SDFIR has been shown in this study to provide additional gauge protection. However, the SDFIR takes considerable effort to construct and maintain, and requires significant area to install. Therefore, it was decided, rather late in the study, to install several Geonor gauges with the Double Alter shields for comparison purposes. At Sterling, Geonor 3 and 4 were installed with the Double Alter. These two gauges were installed in late January 2005. From April 2005 to the end of July 2006, Geonor 3 and 4 caught, respectively, 60.05 and 59.5 inches of precipitation. By comparison, Geonor 1, with an Alter and SDFIR, caught 60.31 inches of precipitation. The Double Alter, therefore, caught slightly less precipitation than Geonor 1 by about .9 percent. It would appear that the Double Alter may be a reasonably good replacement for the SDFIR if that would be desired for reasons of limited area or other construction issues.

3.4 Gauge/Shield Performance During Heavier Precipitation Events

For purposes of this study, an “event” is defined as a period of precipitation totaling .25 inches or more, bounded by 60 consecutive minutes of no precipitation. Based on the 53 liquid events at Sterling during May 2005-July 2006, total gauge catch is quite similar between Ott and Geonor, no matter the shielding. Limited Vaisala data also shows good agreement with a tendency for the Vaisala to under catch by 1 to 2 percent. The TB shows good agreement as well. However, it is noteworthy and perhaps significant that where gauge height winds exceed 5 m/s (6/6/05 and 7/5/05 events) and 10m winds exceed 20 kts (7/5/05 deluge), the Otts consistently under catch the Geonors, no matter the shielding. The TBs show significant under catch in the three high wind events. The few snow events already show the effectiveness of the DFIR/SDFIR. The two Geonor gauges with Double Alters lag the two Geonors with Alter and SDFIR by 10 percent; the Ott with Tretyakov under catches the Ott/Tre/DFIR by about 12 percent. And, none of these cases involves winds above 5 m/s.

STERLING VA TEST SITE DATA EVENT LOG MAY 2005 THRU JULY 2006											
SHIELD ->>	SDFIR/ALTER	SDFIR/ALTER	DOUBLE ALTER	DOUBLE ALTEF	DFIR/TRI	TRET	TRET	SDFIR/TI	SDFIR/ALT	SDFIR	DBL ALT
GAUGE ->>	GEONOR 1	GEONOR 2	GEONOR 3	GEONOR 4	OTT 286	OTT 705	OTT 704	OTT 706	TB1	TB2	VAISA
		LIQUID PCPN EVENTS MAY '05 TO JULY '06									
NO. OF EVENTS	53	53	52	52	44	24	53	53	53	53	26
RATIO TO GEO1	1.00	1.00	1.01	1.00	1.00	1.01	1.01	0.99	0.93**	0.99	0.98
									** malfunction		
		HIGH WIND EVENTS MAY'05 TO JULY '06		(WINDS >5 M/S AT GAUGE LVL)					probable July 05		
NO. OF EVENTS	3	3	3	3	3	2	3	3	3	3	1
RATIO TO GEO1	1.00	1.01	1.01	1.02	0.95	0.97	0.96	0.94	0.78	0.85	0.96
		SNOW/MIXED EVENTS DEC '05 TO APR '06									
NO. OF EVENTS	3	3	3	3	MM	MM	3	3	3	3	1
RATIO TO GEO1	1.00	1.00	0.92	0.89	MM	MM	0.88	1.00	0.91	0.96	N/A

Note: "event" is defined as a precipitation period equal to or greater than 0.25 inches, bounded by 60 consecutive minutes of no precipitation.

Table 3. Precipitation Event Log, Sterling

JOHNSTOWN PA TEST SITE DATA EVENT LOG MAY 2005 THRU JULY 2006											
SHIELD >>	SDFIR/ALTER	DBL ALT	TRET	TRET	SDFIR/TR	DFIR/TR	SDFIR	TRET	SHIELDING		
GAUGE >>	GEONOR 1	GEO 2	OTT 726	OTT 722	OTT 729	0TT 292	TB 1	OTT 298	OTT702	OTT 705	OTT 715
		LIQUID PRECIPITATION CATCH									
NO. OF EVENTS	55	29	54	55	55	55	49	13	13	12	12
RATIO	1	0.98	1	1	1.01	1.01	0.97	1.01	1.01	1.02	1.01
		HIGH WIND CATCH FOR LIQUID PRECIPITATION									
NO. OF EVENTS	7	3	7	7	7	7	7	2	3	3	3
RATIO	1	1.05	1.01	1.03	1	1.02	0.93	1.1	1.08	1.09	1.12
		SNOW EVENT CATCH NOV 2005 TO APRIL 2006									
NO. OF EVENTS	6	5	6	6	6	6	5	5	5	5	5
RATIO	1	0.9	0.72	0.7	1.08	1.02	0.64	0.69	0.56	0.9	0.7

Note: "Event" is defined as a precipitation period equal to or more than 0.25 inches bounded by 60 consecutive minutes of no precipitation.

Table 4. Precipitation Event Log, Johnstown

At Johnstown, based on the 56 qualifying liquid precipitation events this period, the Geonor/Alter/SDFIR tends to under catch the Otts by 1 or 2 percent no matter the shielding. The Geonor/Double Alter under catches the Geonor/Alter/SDFIR by 2 percent in the 29 events in which they both functioned. The TB/SDFIR lags the Geonor #1 by 3 percent. High wind and solid or mixed events are insufficient for conclusions to be drawn, however a widely fluctuating catch appears with the non-SDFIR gauges lagging the SDFIR/DFIR gauges by 10 to as much as 45 percent in snow and mixed events. The six high wind cases show fair agreement, with fluctuations less than 4 percent, except for the Tipping Bucket which lags by 7 percent.

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 that catch the "most" precipitation are functioning the best. In general, this is usually true. However, other considerations come into play. Are the gauges located close to each other and at the same heights, so that they each accurately 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 protective 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.

The Geonor gauge with an Alter/SDFIR caught the most precipitation during all seasons at Sterling for the period April 2005-July2006. The situation was the same at Johnstown. During the cold season (November-April) the Geonor did even better at both sites with ratios decreasing for all other gauges compared with the Geonor. During the warm season (May-October), other gauges performed nearly as well as the Geonor in most cases. The Johnstown climate is somewhat more severe (i.e., higher average wind speeds and colder temperatures) compared with the Sterling site, so ratios compared with the Geonor worsened, especially for the tipping bucket gauges. The tipping bucket gauges demonstrated their ability to function well in average liquid precipitation events, but showed their vulnerability during solid events and high intensity events. During solid events, the tipping bucket gauges generally under reported significantly and had problems with timing. Solid events were often reported the next day after melting had occurred. All the Ott gauges with the Tretyakov shield and SDFIR compared well to the Geonor gauge. The Alter shield has shown its effectiveness, especially in solid events. The Alter shield has the added advantage of swinging metal leaves that do not become "capped" in high-intensity, wet, solid events. While not specifically demonstrated in this study, the Tretyakov has the potential for capping in heavy, wet solid events.

The situation changes somewhat when we look just at precipitation events. At Sterling, the Geonor and Ott gauges show similar results for total precipitation. The Vaisala gauge tends to under catch somewhat. However, when winds are significant, the Otts tend to under catch the Geonor gauge. Solid events show the effectiveness of the SDFIR and the DFIR. At Johnstown, however, the Geonor/Alter/SDFIR tends to under catch the Ott gauges no matter the shielding. Due to the limited number of high-wind and solid events, caution is needed in assessing gauge efficacy under these conditions.

5. CONCLUSIONS

It is obvious from this study, and it has been shown in numerous similar studies, that it is difficult to measure precipitation under all temperature and wind conditions. Solid precipitation events are 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 the tipping bucket, regardless of how carefully it is done, generally increases 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. However, considering all the above, the Geonor gauge, combined with the Alter shield and SDFIR, or possibly the Double Alter, would seem to provide the best opportunity for obtaining accurate and reliable precipitation measurements under all conditions. The Geonor gauge combined with an Alter shield and the SDFIR, or possibly the Double Alter, performed reliably for the period April 2005-July 2006 under varying climatic conditions and, on average, met or exceeded the performance of the other test gauge configurations.

It is important to remember that various gauge algorithms are used to determine precipitation amounts. Several of the gauges do not measure precipitation directly; this is especially true for the Geonor gauge. Thus, it is possible that gauge ratios would change if or when algorithms change. The effectiveness of various shields, however, would not change.

6. SITE CONFIGURATIONS AND EQUIPMENT DESCRIPTIONS

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	Tret lowered to orifice heigth 11/07/05
	Ott726 (Ott198)	Tretyakov	6.28	.01 in	weighing	Tret lowered to orifice heigth 11/07/05 Changed to Ott198 on 7/26/06
	Ott725	Tretyakov and DFIR	6.28	.01 in	weighing	was #755, changed Jan 05 removed, 4/16/05
	Ott722	Tretyakov	6.28	.01 in	weighing	Tret lowered to orifice heigth 11/07/05
	TB1	SDFIR	7.9	.2mm	tipping bucket	metric unheated in Alter until 12/05/05 heated in SDFIR after 12/05/05
	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 -769	Tretyakov and DFIR		0.01 in	weighing...started about 2/1/05, gauge has experimental wind shield (fence) on 3 sides Tret lowered to orifice heigth 11/07/05 Moved to DFIR on 4/16/05 Changed to Ott 769 on 8/806	
	Frise 995	ASOS	12	.01 in	tipping bucket......Installed 4/16/05	
	Ott298	Tret and 8'Alter	6.28	.01 in	weighing....Installed 11/07/05, single band 10" wide/ 1/16/06: band removed…Tret and 8' Dia Alter shield only	
	Ott702	Tret and 8'D Alter	6.28	.01 in	weighing...Installed 11/07/05,single band 1/16/06: band removed …outer shield installed 3/15/06	
	Ott705	Tret and 8'D Alter	6.28	.01 in	weighing...Installed 11/07/05,single band 1/16/06: (band removed) Tret and 8'd Alter	
	Ott715	Tret and 8'd Alter	6.28	.01 in	weighing...Installed 11/07/05,double band 1/16/06: (band removed) Tret and 8'd Alter	
	Geonor2	DA	6.28	.25mm	weighing	installed 12/05/05
	Note: all firmware (3.59) on Otts updated 11/18/05 (except Ott292) Note: Data from Otts 298,702,705,715 started on 11/21/05.					
Sterling						
	TB1	SDFIR	7.9	.2mm	tipping bucket Had Alter, moved to SDFIR Jan 2005 Alter removed when moved to SDFIR heated beginning 12/05/05	metric
	TB2	SDFIR	7.9	.2mm	tipping bucket Both TBs moved inside SDFIR on 1/18/05 heated beginning 12/05/05	metric
	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 Shield lowered to Orifice heigth on 11/8/05 removed 12/205 for testing reinstalled 2/08/06
	Ott705	Tretyakov	6.28	.01 in	weighing	
	Ott704	Tretyakov	6.28	.01 in	weighing	Shield lowered to orifice heigth on 11/08/05
	Ott706	Tretyakov and SDFIR	6.28	.01 in	weighing	Shield lowered to orifice heigth on 11/08/05
	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
	Vaisala	DA	8.9 in app.	.1mm	weighing	started 12/05/05, 400sqcm collecting area
	Note: Firmware updated to version 3.59 on 11/17/05 for Otts 704,286 and 706					

Table 5. Site Configurations

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 an 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.
Vaisala Gauge	Weighing gauge with load sensor. Orifice diameter of 8.9". Resolution of .1mm. Capacity of 25 inches. Overall dimensions: 37" high with a diameter of 16". Collecting area- 400 sq. cm

Table 6. Equipment Descriptions

Reference

Larson, Lee W., C. Bruce Baker, Edwin L. May, Hal Bogin, and Bill Collins, 2005: Operational testing of various precipitation sensors in support of the United States Climate Reference Network (USCRN), AMS 13 SMOI Conference, Savannah, Ga.