P3.16 DEVELOPMENT OF A TRANSFER FUNCTION FOR THE ASOS ALL-WEATHER PRECIPITATION ACCUMULATION GAUGE

*Jennifer M. Dover
Science Applications International Corporation
Sterling, VA 20166

1. INTRODUCTION

The heated tipping bucket (HTB) was the initial precipitation accumulation gauge when the Automated Surface Observing System (ASOS) was deployed. The sensor measures liquid accumulation, but is not designed to accurately measure freezing and frozen precipitation. The accurate measurement of all types of precipitation is an important part of weather observations. The National Weather Service (NWS) awarded a contract for design and development of an All-Weather Precipitation Accumulation Gauge (AWPAG) in 2001 to C.C.Lynch and Associates of Pass Christian, Mississippi, in partnership with Ott Hydrometry of Kempten, Germany.

The AWPAG specification requires comparability with a standard NWS 8-inch non-recording precipitation gauge with a single metal Alter shield. However, wind can significantly reduce precipitation catch, particularly when the precipitation is in the form of snow. This has resulted in the World Meteorological Organization (WMO) developing an internationally recognized reference windshield (Goodison, B.E, Louie, P.Y.T, and Yang, D., 1998), the Double Fence Intercomparison Reference (DFIR) which will improve precipitation gauge catch efficiency.

To assure that ASOS provides representative measurements of precipitation in all conditions, the NWS has undertaken a program to compare measurements of an ASOS production AWPAG with an 8-foot Alter shield to that of a production AWPAG installed inside a DFIR. In addition to testing a production AWPAG, additional AWPAGs with a Tretyakov shield inside an 8-foot diameter Alter shield were tested. Based on results from Dover (2002), this configuration should catch significantly more precipitation that the Tretyakov shields alone in wind-driven, snow conditions. However, as shown by Wade (2001), Larsen (2005), and Myers et al. (2005), all the tested configurations would be expected to catch less than the reference DFIR. Following an approach developed by the WMO, the measurements of an ASOS production AWPAG can be corrected to be in close agreement with the measurement inside the DFIR. The approach was to use wind speed, temperature, and knowledge of the precipitation type (information that is available from ASOS sensors) to derive the ratio of the two measurements. The equation so derived, referred to as the transfer function, can then be implemented on ASOS to provide more accurate real-time measurements of precipitation, even in wind-driven snow conditions.

Corresponding author address: Jennifer M. Dover, 43741 Weather Service Rd., Sterling, VA 20166;
E-Mail: Jennifer.dover@noaa.gov

2. TEST APPROACH

2.1 Test Location

Testing took place at the Johnstown, Pennsylvania test site operated by the NWS Sterling Field Support Center. One minute data were collected from all test sensors using a personal computer based data acquisition system. Data from all ASOS sensors at Johnstown were available for use in post-processing.

2.2 Sensors

2.2.1 Production AWPAG with Tretyakov shield

The production AWPAG with a Tretyakov shield (Production AWPAG) was the comparison sensor for this effort. It is a weighing gauge that collects precipitation as it falls through a 6.25 inch diameter orifice into a plastic storage container with a capacity of 56 inches of accumulation that includes antifreeze, which in some cases, can account for up to half of the liquid in the gauge. The storage container is continuously weighed and the weight is proportional to the catch amount. One AWPAG was installed with a Tretyakov shield at the test site as shown in Figure 1.

Figure 1 Production AWPAG

2.2.2 Production AWPAG with Tretyakov shield inside a DFIR

A DFIR containing an AWPAG with a Tretyakov shield (AWPAG DFIR) was the reference sensor for this test. The DFIR (Figure 2) consists of two vertical, concentric octagonal fences, with the outer fence measuring approximately 40 feet from apex to apex (diameter), and the inner fence measuring approximately 13 feet from apex to apex. The top of the outer fence is 108 inches above grade and the top of the inner fence is 88 inches above grade. Both fences use 60-inch long vertical slats configured for 50% porosity. One AWPAG with a Tretyakov shield was installed inside a DFIR at the test site.

Figure 2 DFIR

2.2.3 Production AWPAG with 8-foot diameter Alter shield

In addition to testing an AWPAG with a Tretyakov shield, two additional AWPAG's with a Tretyakov shield inside an 8-foot diameter Alter shield, one manufactured by OTT Hydrometry as shown in Figure 3 and one manufactured by the Atmospheric Turbulence Diffusion Division (ATDD), as shown in Figure 4, was tested at Johnstown, Pennsylvania.

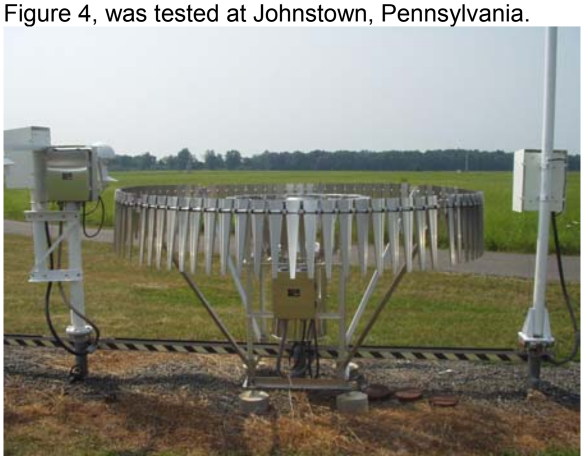

Figure 3 AWPAG Treyakov Alter (OTT)

Figure 4 AWPAG Treyakov Alter (ATDD)

3.0 TEST METHODOLOGY AND DATA ANALYSIS

The purpose of this test was to develop and validate a transfer function that provided a correlation between the reported precipitation of the production AWPAG with the 8-foot outer Alter shield and the AWPAG DFIR. This was accomplished by applying a transfer function to the initial accumulation. The transfer function was originally developed by the World Meteorological Organization (WMO), but was modified for use with the 8-foot outer alter. A second transfer function was developed by using a Least Squares Regression. The goal of this test was to improve catch in wind-driven snow conditions using a shield which could be installed around the production AWPAG on ASOS.

3.1 Modified WMO Transfer Function

The following Catch Ratio (CR) was used to adjust the precipitation in the AWPAG with the 8-foot Alter shield so that it is more representative of the actual precipitation recorded in the DFIR.

CR = 100-X*Ws+0.30*T

Ws = Wind Speed (orifice height) meters per second, which is a two-minute average updated every minute.
T = Temperature in °C, which is a five-minute average updated each minute.
X = Coefficient that is dependent on wind speed, temperature and shield
The WMO transfer function was developed using a coarser resolution, or daily temperature and wind speed data. The modified version of the WMO transfer function used a 15-minute average of the two-minute wind speed and five-minute temperature data to reduce the chances that the coefficient (X) would change rapidly. The CR was applied as the inverse of the ratio. The modified transfer function was only applied to the initial data if there was an accumulation in that minute and it was snowing, otherwise no adjustment was made.

3.2 Least Squares Regression Transfer Function

The following Catch Ratio (CR) was used to adjust the precipitation in the AWPAG with the 8-foot Alter shield so that it is more representative of the actual precipitation recorded in the DFIR.

$$CR = a1*T+(a2*\ln(W))/1.1+a3$$

W = Wind Speed (orifice height) knots, which is a two-minute average updated each minute.
T = Temperature in °F, which is a five-minute average updated each minute.
a1, a2, a3 = Coefficients derived by multiple regression
1.1 = factor used to improve the fit

3.3 Wind Speed at Gauge Orifice Height

The wind speed in the CR equation requires that it be measured from orifice level. Since ASOS wind height is measured at 10m, the orifice wind speed must be estimated using the following equation (Goodison, B.E, Louie, P.Y.T, and Yang, D., 1998):

$$Uh = [\log (h/ z_o)/(\log(H/ z_o))] \times UH$$

Uh= Wind speed (knots) at the height of the gauge orifice
h= height(m) of gauge orifice above ground
z_o= roughness length: 0.01m for winter
H= height(m) of the wind speed measuring instrument above ground, normally at 10m
UH= wind speed (knots) measured at the height H above ground

3.4 Data Analysis

Accumulation data from the AWPAG is reported in 0.01 inch increments. Internal algorithms filter out fluctuations in data due to wind pumping and temperature gradients that can lead to false positive reports and measurement inaccuracies.

4.0 RESULTS

Table 1 shows the differences between the tests, comparison and reference sensor for both uncorrected data (modified WMO transfer function not applied) and corrected data (modified WMO transfer function applied) as well as the catch for the 0.01 data. The column, “Catch Before”, refers to the catch before any transfer function was applied to it. The column, “Catch After”, refers to the catch after the modified transfer function was applied to it. The columns labeled “% of DFIR” refers to the percent of catch each configuration reported when compared to the DFIR.

It is important to note that the AWPAG Tretyakov with OTT Alter (SN 702) was increased by 32% over the production AWPAG, prior to any application of a transfer function. Even more dramatic are the results of the AWPAG Tretyakov with ATDD Alter, which increased the catch by 54% over the production AWPAG. The precipitation catch from the AWPAG Tretyakov with ATDD Alter (SN 715) was the closest to the AWPAG DFIR, both before and after the application of the transfer function. This gauge reported 31% below the AWPAG DFIR before the application of the transfer function, and 1% below after the transfer function was applied. The AWPAG Tretyakov’s with OTT Alter (SN 702 and SN705) reported 41% below the AWPAG DFIR before the application of the transfer function, and 19% and 12% below (respectively), after the transfer function was applied.

Sensor Number	Configuration	Catch Before	% of DFIR	Uncorrected Difference	Catch After	% of DFIR	Corrected Difference
198-comp	AWPAG Tretyakov	1.64	45	-2.01	2.27	62	-1.38
702-test	AWPAG Tretyakov with 8’ Alter (OTT)	2.17	59	-1.48	2.97	81	-0.68
705-test	AWPAG Tretyakov with 8’ Alter (OTT)	2.16	59	-1.49	3.21	88	-0.44
715-test	AWPAG Tretyakov with 8’ Alter (ATDD)	**2.52**	**69**	-1.13	**3.61**	**99**	-0.04
769-ref	AWPAG Large DFIR	3.65	--	--	--	--	--

Table 1 Sensor Differences of Liquid Water Equivalent
Note: The bold numbers indicate the best performers in each category – not including the DFIR gauge

Sensor Number	Configuration	Catch Before	% of DFIR	Uncorrected Difference	Catch After	% of DFIR	Corrected Difference
198-comp	AWPAG Tretyakov	2.33	49	-2.42	--	--	--
702-test	AWPAG Tretyakov with 8' Alter (OTT)	3.01	63	-1.74	5.02	105	0.27
705-test	AWPAG Tretyakov with 8' Alter (OTT)	2.96	62	-1.79	5.1	107	0.35
715-test	AWPAG Tretyakov with 8' Alter (ATDD)	**3.47**	**73**	-1.28	**4.97**	**104**	0.22
769-ref	AWPAG Large DFIR	4.75	--	--	--	--	--

Table 2 Sensor Differences of Liquid Water Equivalent
Note: The bold numbers indicate the best performers in each category – not including the DFIR gauge

Table 2 shows the same information as table 1, only the data is from the Least Squares Regression Transfer Function. The precipitation catch from the AWPAG Tretyakov with ATDD Alter (SN 715) was the closest to the AWPAG DFIR, before and after the application of the transfer function.

5.0 CASE STUDIES

During the 2006-2007 winter season, one 8-foot diameter Alter shield manufactured by ATDD and two manufactured by OTT were installed on production AWPAGs. The following is a case study from January 22, 2007 at the Johnstown, Pennsylvania, test facility. This case is similar to the overall results. The DFIR caught the most precipitation. The second highest catch was from the adjusted catch in the AWPAG Tretyakov with ATDD Alter shield.

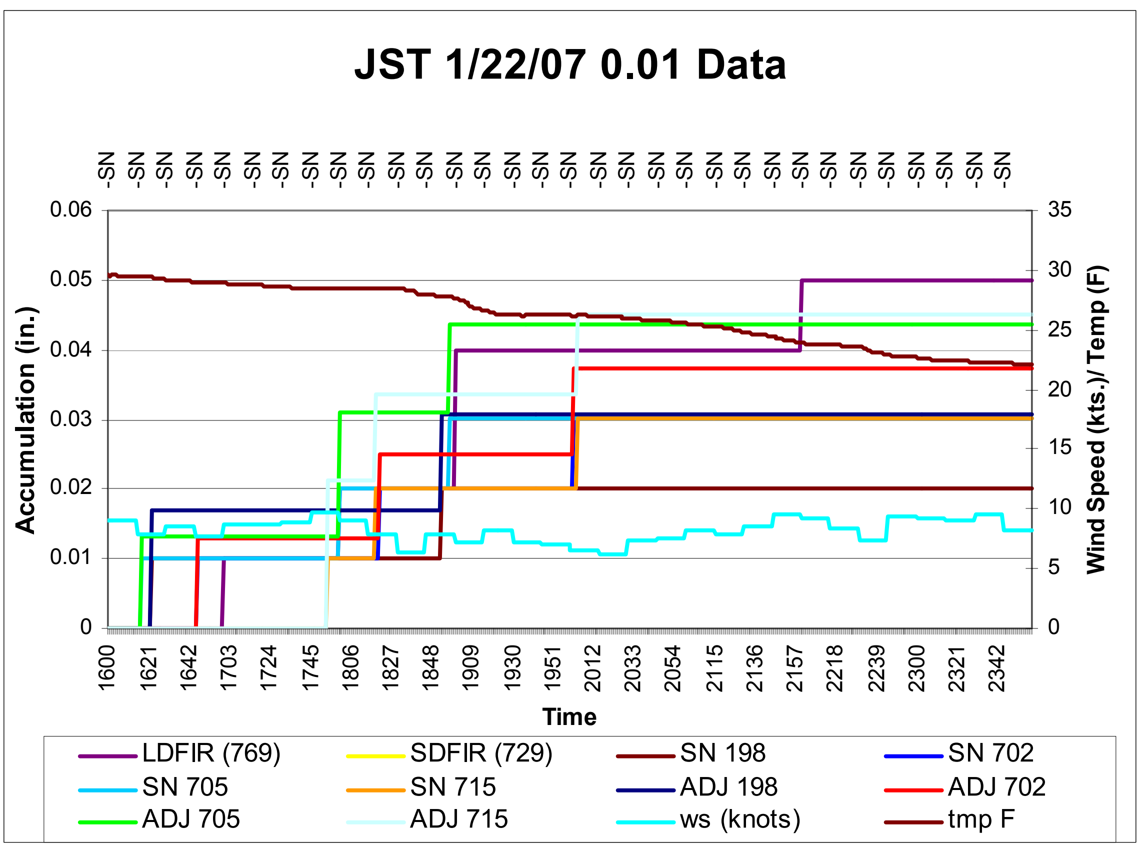

Figure 5 Precipitation catch from all gauges

6.0 CONCLUSIONS

In previous years, the production AWPAG with only the Tretyakov shield failed to catch any precipitation at all during some events. These events were typically high wind, light snow events where precipitation persisted for hours. The development of the transfer function can increase precipitation during some events, but there must be an initial precipitation catch in the gauge to correct. The addition of the AWPAG Tretyakov with 8-foot Alter shields dramatically improved catch in these events with high winds and light snow when compared to the standard AWPAG with only the Tretyakov shield, and therefore greatly improves the viability of using the transfer function.

The results from the modified version of the WMO transfer function showed that overall, the AWPAG Tretyakov with ATDD Alter (SN 715) was the closest to the AWPAG DFIR, both before and after the application of the transfer function. This gauge reported 31% below the AWPAG DFIR before the application of the transfer function, and 1% below after the transfer function was applied. The AWPAG Tretyakovs with OTT Alter (SN 702 and SN 705) reported 41% below the AWPAG DFIR before the application of the transfer function, and 19% and 12% below, respectively, after the transfer function was applied.

The results from the Least Squares Regression transfer function derived shows the adjusted precipitation catch from the two AWPAG Tretyakovs with OTT Alter was the highest, with SN 705 corrected to 5.1 inches and SN 702 corrected to 5.02 inches. The adjusted precipitation catch of the AWPAG Tretyakov with ATDD Alter shield SN 715 was 4.97 inches. Compared to the reference measurement in the DFIR of 4.75 inches, the corrected AWPAG Tretyakovs with OTT Alter over reported by 7%(SN 705) and 6%(SN 702), while the AWPAG Tretyakov with ATDD Alter over reported by 5%.

7.0 ACKNOWLEDGMENT

This work was sponsored by the National Weather Service ASOS Program under Contract Number 50-DGNW-6-90001. Opinions expressed in this paper are solely those of the authors, and do not represent an official position or endorsement by the United States Government.

We would like to thank Richard Lewis, NWS, Aaron Poyer, SAIC, Christopher Greeney, SAIC, and Robert Wnek, SAIC for observations that supported the evaluation for this testing period. We also wish to thank Richard Lewis and Michael Salyards, NWS, for their contribution to this test.

REFERNCES

Dover, J. and Winans, L.J., Evaluation of Windshields for use in the Automated Surface Observing System (ASOS); 6th Symposium on Integrated Observing Systems, 14-17 January 2002, Orlando, FL P.6.4.

Goodison, B.E., Louie, P.Y.T., and Yang, D., WMO Solid Precipitation Measurement Intercomparison, 1998.

Larsen, L.W., C.B.Baker, E.L.May, and H.Bogin, Operational Testing of Various Precipitation Sensors in Support of the United States Climate Reference Network, 13th Symposium on Meteorological Observations and Instrumentation, 19-23 June 2005, Savannah, GA, P4.4.

Myers, T.P., E.J., Dumas, M.E. Heuer, C.B. Baker, M. Hall, and W. Timz, Evaluation of a Double Alter Shield using Sonic Anemometers; 13th Symposium on Meteorological Observations and Instrumentation, 19 – 23 June 2005, Savannah, GA P.4.5.

Wade, C., and J. Cole, 2001, Final Report to CRN Management on the Snow Gauge and Windshield Evaluation Studies Conducted at NCAR from January to April 2001, NCAR Research Applications Program (RAP), 17 July 2001.