P3.18 SNOW GAUGE PERFORMANCE DURING THE DENVER BLIZZARDS OF DECEMBER, 2006

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1. INTRODUCTION

On December 20, 2006, a major snow storm affected northeastern Colorado accompanied with blizzard conditions and depositing as much as four feet of snow over the Denver metropolitan area. Eight days later on December 28, 2006, a second major snow storm affected the area accompanied by blizzard conditions and depositing an additional three feet of snow over the Denver area. Snow gauges deployed at the National Center for Atmospheric Research's (NCAR) Marshall test site captured both events as well as snow gauges deployed at the Denver International Airport (DIA).

The Marshall site consisted of GEONOR gauges in single and double Alter shields. A GEONOR gauge was also setup inside a Double Fence Intercomparison Reference (DFIR) shield which is recognized as a standard for comparison by the World Meteorological Organization (WMO) (Goodison et al., 1998) In addition to the GEONOR gauges, the Marshall site was also equipped with a Hotplate snow gauge.

Like the Marshall site, the DIA site was equipped with a GEONOR in a DFIR shield. Additionally, it was equipped with an OTT gauge of the same design as the OTT gauge used with the National Weather Service Automated Surface Observing System (ASOS). This gauge is also known as the All Weather Precipitation Accumulation Gauge (AWPAG) sensor on ASOS and has a Tretyakov-style shield surrounding it.

An analysis of the various gauges performances during these high-wind events is presented along with the transfer functions that were derived to correct each gauge/shield combination for wind effects.

2. SNOW GAUGE ANALYSIS

The December 20th snow storm had wind speeds throughout much of the event sustained between six and twelve meters per second (Figure 1). Though not quite as high, the December 28th snow storm had wind speeds ranging from four to ten meters per second throughout most of the event (Figure 2). These high winds, combined with the relatively long event times of each storm (30 hours and 12 hours respectively) provided a unique opportunity to examine the performance of each snow gauge/shield combination under blizzard conditions. For each case, one-minute data is presented from both the gauge and the wind sensor.

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2.1 SINGLE AND DOUBLE ALTER COMPARISONS

An initial comparison of the raw data from the Marshall GEONORs shows a clear under-catch problem associated with the single and double Alter-shielded GEONORs for both the December 20th and December 28th events (Figures 1 and 2). Since wind speed data at gauge height was collected throughout both events, the following correction factor was used based on Rasmussen et al., 1999.

$$CR = (100 + (WS * \sigma))/100$$

Where CR is the catch ratio, WS is the wind speed at gauge height and σ is the wind speed dependent coefficient unique to each gauge/shield combination. No averaging of the data was used for the transfer function and the correction factor was applied to the raw accumulation values as the inverse of the ratio. Additionally, the correction factor was only applied to the data if the ambient air temperature was less than four degrees Celsius.

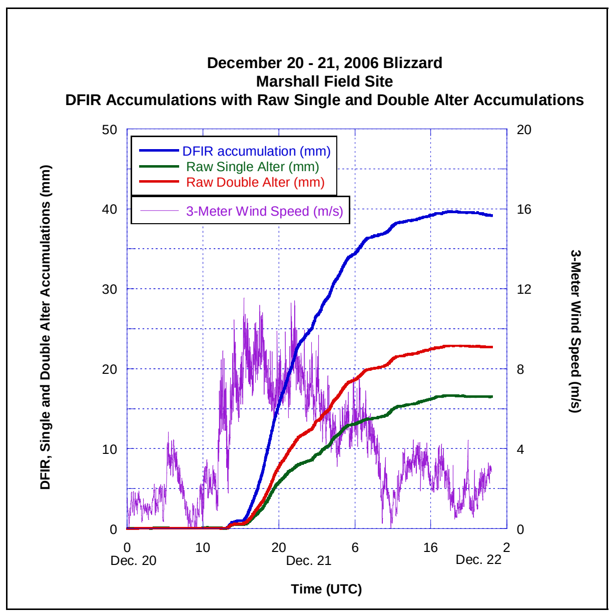

Figure 1 – Raw accumulations from the DFIR, single and double Alter-shielded GEONORs for December 20, 2006.

When applying the correction factor to the GEONOR in the single Alter, the optimum value for σ was determined to be -7.6. Figures 3 and 4 show the single Alter-shielded GEONOR matching the DFIR GEONOR much more closely once the transfer function has been applied though the single Alter GEONOR still falls short of the DFIR GEONOR accumulations for the December 20th event.

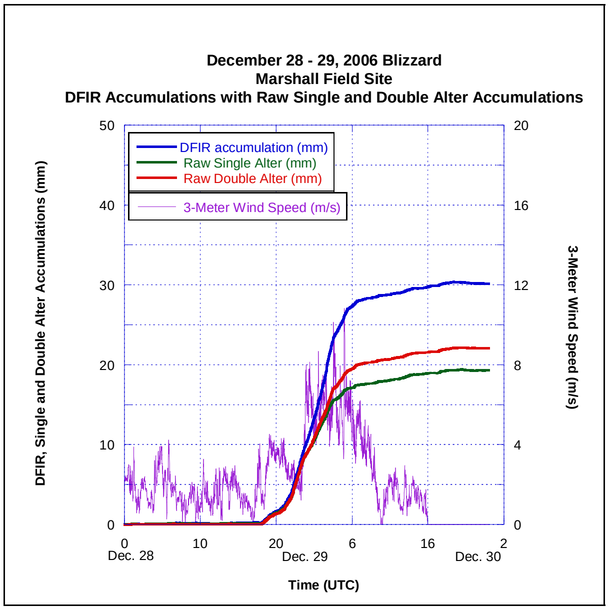

Figure 2 – Raw accumulations from the DFIR, single and double Alter-shielded GEONORs for December 28, 2006.

The correction factor for the double Alter-shielded GEONOR has an optimum value for σ of -6.5. Figures 5 and 6 show the double Alter-shielded GEONOR matching the DFIR GEONOR much more closely than the corrected single Alter-shielded GEONOR once the transfer function has been applied.

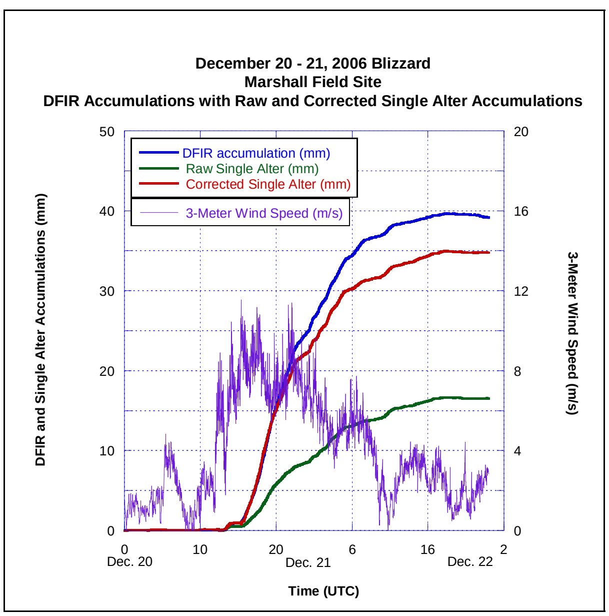

Figure 3 – Raw and corrected accumulations for the single Alter-shielded GEONOR for December 20, 2006.

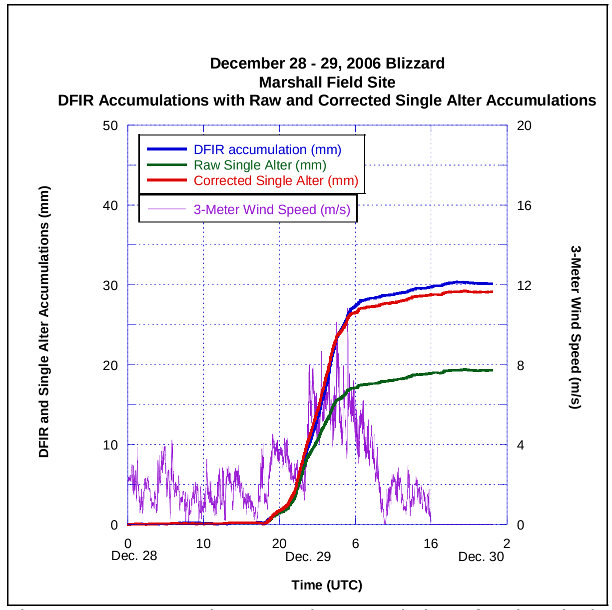

Figure 4 – Raw and corrected accumulations for the single Alter-shielded GEONOR for December 28, 2006.

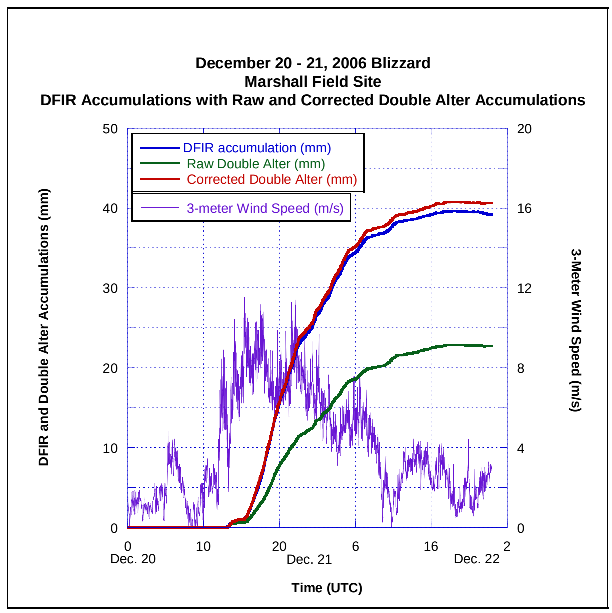

Figure 5 – Raw and corrected accumulations for the double Alter-shielded GEONOR for December 20, 2006.

2.2 OTT COMPARISONS

As with the single and double Alter-shielded GEONORs, the raw data from the OTT shows an undercatch of accumulation as compared to the GEONOR in the DFIR (Figures 7 and 8). One-minute data was also collected from the OTT as was wind speed at gauge height at the DIA field site.

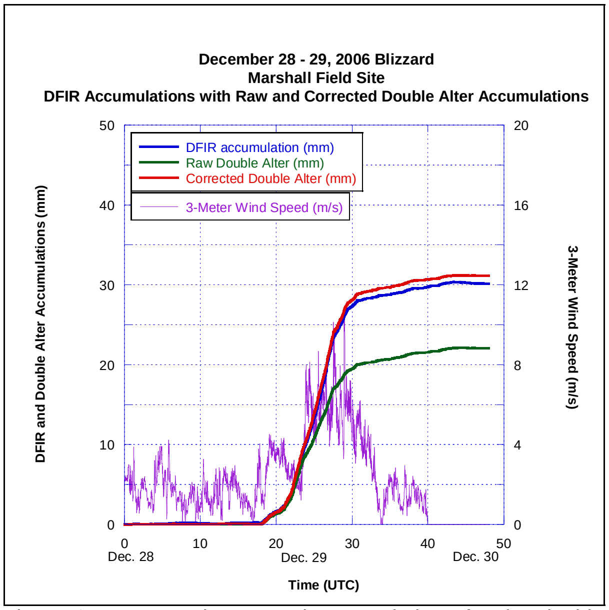

Figure 6 – Raw and corrected accumulations for the double Alter-shielded GEONOR for December 28, 2006.

Using a correction factor similar to the single and double Alter-shielded GEONORs, the optimum value for σ was found to be -5.5 for the OTT. Corrected accumulations for the OTT are shown in Figures 7 and 8. While not quite as good as a GEONOR in a double Alter shield, the accumulation for the OTT is significantly improved after application of the transfer function.

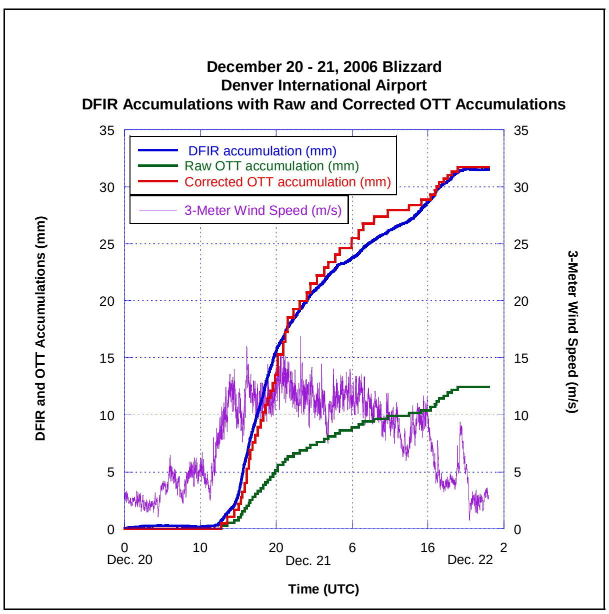

Figure 7 – Raw and corrected accumulations for the OTT for December 20, 2006.

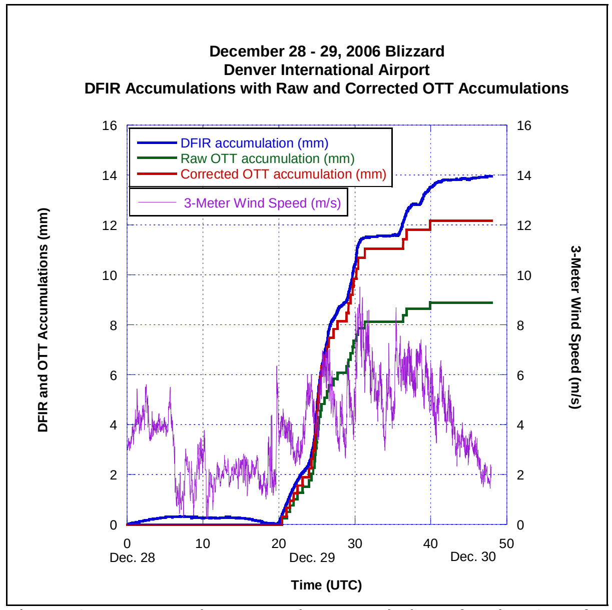

Figure 8 – Raw and corrected accumulations for the OTT for December 28, 2006.

2.3 HOTPLATE COMPARISONS

Unlike the GEONOR and OTT gauges, the hotplate gauge is calibrated to account for wind speed corrections and thus the data needs no correction. A comparison of the hotplate data for both events shows the hotplate to be highly correlated to the GEONOR in the DFIR for both the December 20th and December 28th events (Figures 9 and 10). No additionally correction was calculated for the hotplate.

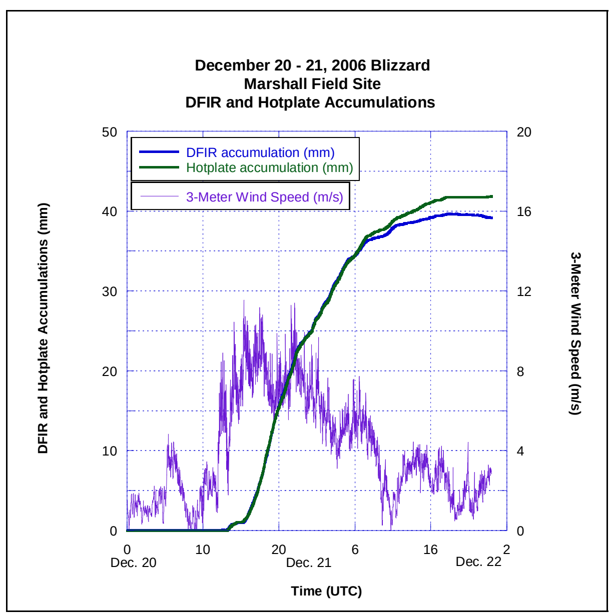

Figure 9 – Hotplate and DFIR/GEONOR accumulations for December 20, 2006.

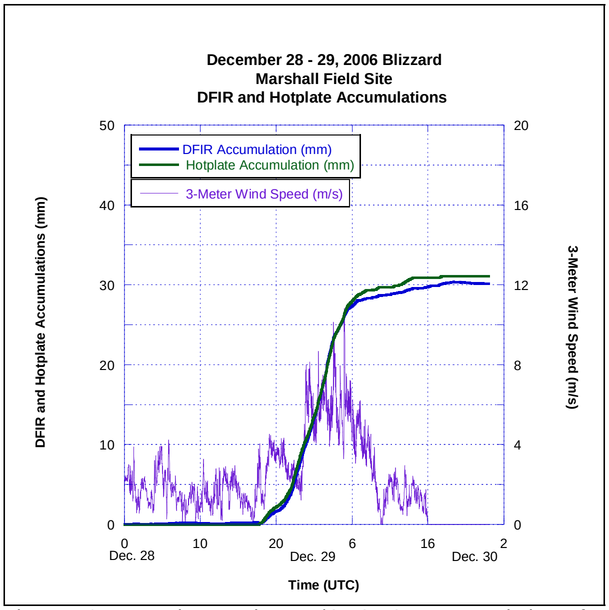

Figure 10 – Hotplate and DFIR/GEONOR accumulations for December 28, 2006.

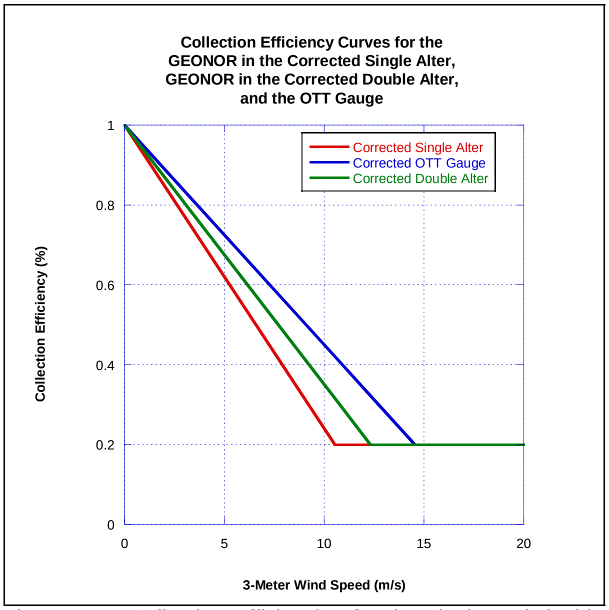

Figure 11 – Collection Efficiencies for the single and double Alter-shielded GEONORs and the OTT gauge as a function of wind speed.

3. SUMMARY AND DISCUSSION

It has been shown that a single or double Alter-shielded GEONOR by itself does not collect as much snow as the GEONOR in a DFIR due to wind under-catch. The same is true of the OTT gauge in the Tretyakov-style shield. A transfer function has been derived for each of these gauge/shield combinations that yields accumulation values that closely match those of the GEONOR in the DFIR. The transfer functions used for the single and double Alter-shielded GEONORs have been tested and shown to work at lower wind speeds, though that data is not presented in this study. Further analysis is needed to confirm that the transfer function derived for the OTT will work at lower wind speeds.

Figure 11 shows the collection efficiencies of the three corrected gauge/shield combinations as a function of wind speed. The single Alter-shielded GEONOR has the lowest collection efficiency and the OTT has highest. Collection efficiencies for the gauges was cut off at 0.2 (or 20%).

It is worth noting that the hotplate snow gauge needed no additional correction as the instruments internal algorithm takes into account the change in collection efficiency with wind speed and corrects the data before output.

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