4.3 THE NEW PRECIPITATION ALGORITHM FOR THE THREE-WIRE GEONOR GAUGE OF THE U.S. CLIMATE REFERENCE NETWORK -- OBJECTIVES, DESCRIPTION AND PERFORMANCE

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1. INTRODUCTION

The U. S. Climate Reference Network (USCRN) forms the backbone for climate monitoring in the U. S. Its two main components are observations of temperature and precipitation. The precipitation is collected in a Geonor weighing gauge outfitted with three transducer/wire combinations for depth measurement. By utilizing the measurement from these three wires an accurate and reliable estimation of precipitation amount is obtained. In the near future the depth measurements from the network sites will be available at 5-minute intervals. This paper discusses the development of a new algorithm for estimation of the precipitation from these depth measurements. It is designed to replace the presently used algorithm and alleviate some of its deficiencies. The paper will discuss the objectives and how they are met with example cases. Some overall comparison statistics with other gauges will also be shown.

2. THE GEONOR GAUGE

The Geonor precipitation gauge (see Figure 1) used at the CRN sites is outfitted with three transducer/wire combinations for depth measurement. The transducers cause the wires to vibrate and appropriate samples of their frequency measurements are used to determine the depth through a wire-dependent quadratic equation. The combination of three depth estimations is used by the algorithm discussed in this paper to determine the precipitation for the gauge.

Figure 1. Geonor precipitation gauge, showing housing, bucket, and transducer/wire.

The gauge is surrounded by a double fence as shown in Figure 2. The effectiveness of this fence arrangement in capturing precipitation is the subject of another paper. The gauge is installed with a heater described in NOAA Technical Note NCDC No. USCRN-04-1, Inlet Heater for USCRN Weighing Precipitation Gauge.

The Geonor depth measurements from the presently operational CRN sites are at 15 minute intervals. At the test sites at Sterling, VA and Johnstown, PA, the measurements are at a 1 minute interval. In the future, the Geonor depths at CRN sites will be taken at a 5 minute interval.

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The new precipitation algorithm, while suitable for any interval, was developed with 5 minutes as the basic time interval. Testing was performed for the operational CRN sites using data every 15 minutes, while the data were extracted every 5 minutes for Sterling and Johnstown.

Figure 2. Double fence (DFIR) surrounding the Geonor precipitation gauge.

3. CHARACTER OF THE MEASUREMENTS

3.1 Ideal Data

Ideally, the depth measurements would be the same from all three wires, would be constant in the absence of precipitation (with oil preventing evaporation), would not respond to wind or temperature changes, and would increase synchronously by the amount of precipitation falling into the gauge. This ideal is never absolutely met, but many of the measurements are close to this ideal. Figure 3. shows individual wire depths for Sterling, VA for 5-13 December (days 340-348). The changes in all three wires are nearly synchronous and constant between precipitation events. The amount of the difference of absolute depth between the wires is normal and remains nearly constant with depth change.

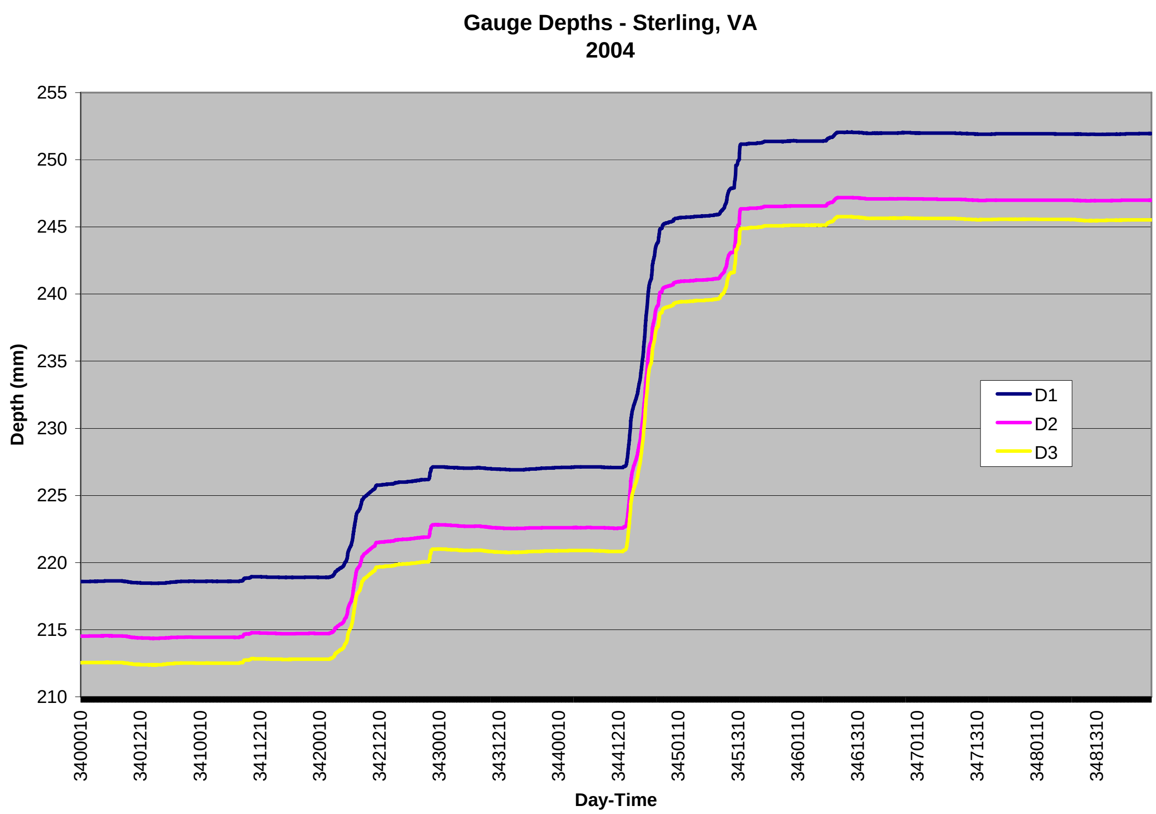

Figure 3. Individual wire depths for Sterling, VA for 2004, days 340 through 348

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3.2 Problem Data

There are many ways in which depth measurements can be problematic for a precipitation algorithm. The first example (Figure 4) of problem data shows a precipitation event superimposed on very noisy data with a large diurnal signal in one of the wires. The data are for Tuscon, AZ for 1-16 February 2005. These con, AZ for 1-16 February 2005. These data, and any similar data with large amplitude noise, present a challenge for development of the precipitation algorithm. Another particularly problematic situation for a precipitation algorithm is the occurrence of very light precipitation. In such a case, the algorithm must be able to compare the present depths with those from possibly several hours previous. An example will be given later to show how well the new algorithm behaves in light precipitation.

Naturally, the precipitation algorithm must be able to filter out extraordinary events such as gauge emptying, addition of liquids to the gauge to prevent freezing, evaporation or calibration, and wire breakage. At the same time, large precipitation events must be accurately captured. With this in mind, the next section lists the objectives and design for the new precipitation algorithm.

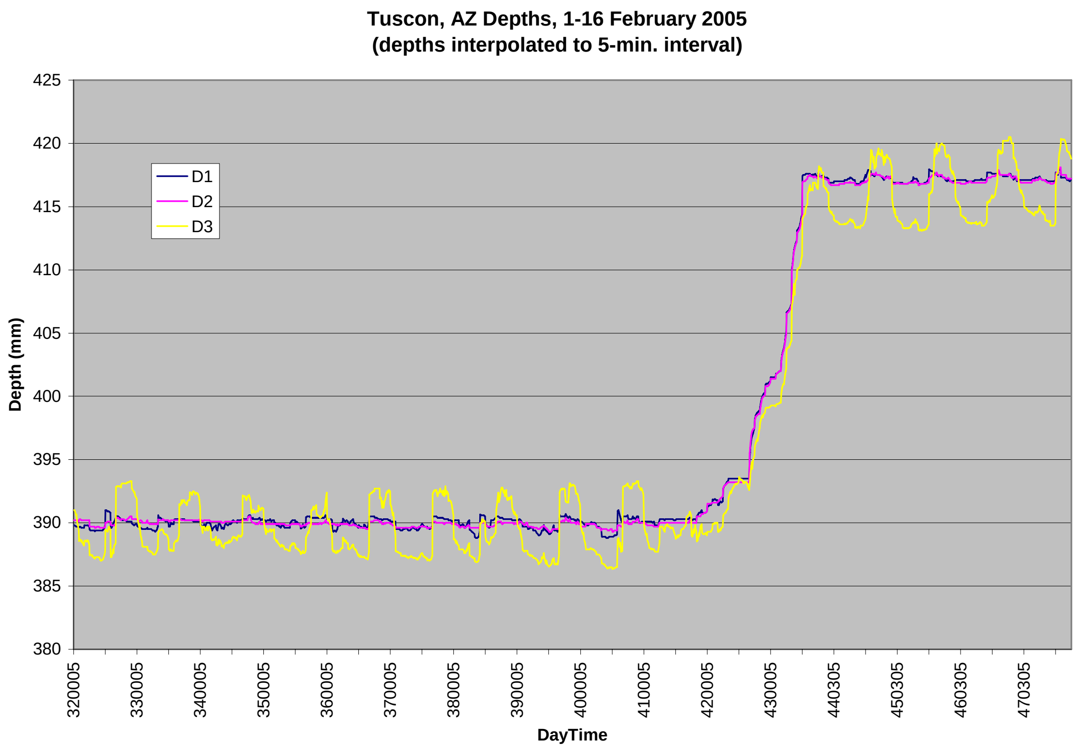

Figure 4. Wire depths for Tuscon, AZ for 1-16 February 2005, showing a precipitation event, individual wire noise, and a large amplitude diurnal variation in one wire.

4. THE NEW PRECIPITATION ALGORITHM

The primary objectives of the new precipitation algorithm are: 1) to minimize false reports due to depth drift or 'noise', 2) to capture as much light precipitation as possible, 3) to calculate the most accurate value of precipitation by an intelligent decision on which wire depths are useable, and 4) to eliminate from precipitation amounts any effects of gauge emptying, adding of antifreeze and/or oil, addition of liquid for gauge calibration, or from wire breaks. The calculations must be performed in such a way as to allow retrospective calculation.

4.1 Description of the Precipitation Algorithm

There is a single amount of liquid in the Geonor bucket, and yet there are three trandeucer/wire measurements of the depth. This suggests that each wire should be treated independently in calculations until combined in a final estimate of the precipitation.

The first step in this process is to establish for each wire a reference level for the depth. This reference level serves as a basis for calculation of any depth changes. Consider first a period of time without precipitation. In such a period, it is necessary to determine the onset of precipitation. If the depth data were ideal, it would only be necessary to use the previous time level of depth for this reference level, adding together any increases. But, in the presence of possible noise, light precipitation, or diurnal or other drift, it is best to use an average of past depth measurements as the reference level and only count as precipitation increases above a small limit (0.2 mm). During precipitation events, the previous depth of the wire is used as the reference level, thereby capturing any additional precipitation above the lower limit. This reference level is used for two hours following precipitation.

During the averaging of depths for the determination of the reference level, tests are made to guarantee that the depths and changes of depth are within the proper range.

The data from CRN sites are transmitted to NCDC in three hour groups—the present hour and the two previous hours. This redundancy guarantees near-100% receipt of the data. It also allows the depth reference level for each wire to be calculated from information from two hours in the past. Experiments show that this is sufficient to filter much, but not all, of the noise in the depth measurements.

The next step is to calculate the depth change from the reference level for each wire. The depth changes must be greater than zero and less than an amount consistent with maximal precipitation rates to be further considered. If these depth changes are consistent between the wires and of sufficient magnitude, then they may be used confidently in computing any precipitation. Therefore, the next step is to compare depth changes between pairs of wires.

Logic determines which wires to use in further computations. There are 3 pairs of wires to be compared; each pair is determined to be either "close" or "far", depending on whether its depth change is less than, or greater than, a certain threshold. There are 4 possibilities for how many of these 3 pairs are "close", shown in Table 1.

Table 1. Decision for which wires to use.

# close	# far	**Which Wires to Use**
3	0	Use all 3
2	1	Use the 1 close to two others
1	2	Use the 2 close to each other
0	3	Use none. Report a 0.

The precipitation amount is the average of the depth changes from the reference levels for the wires which pass these checks.

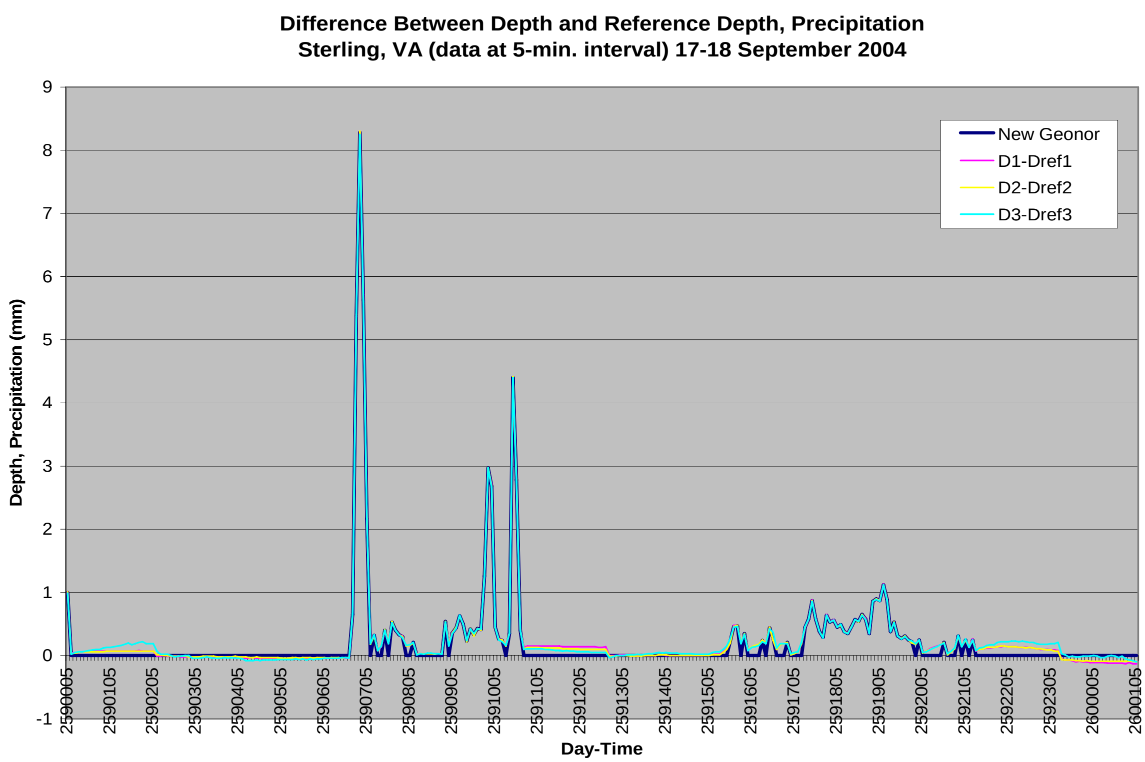

Figure 5. The difference between individual wire depths and their reference level for Sterling, VA.

It is possible in cases of large precipitation rates that none of the wires passes the necessary checks because of increased inter-wire depth change differences. In this case, special logic allows further consideration of the data to determine which wires, if any, to use in the precipitation calculation. A more complete description of the algorithm may be found in NOAA Technical Note NCDC No. USCRN-05-1, Calculation of Official USCRN Precipitation from (Geonor) Weighing Precipitation Gauge.

4.2 Examples of Precipitation Algorithm Behavior

Figure 5. shows any precipitation amount and how the reference level for each wire differs from the depth, both during precipitation events and non-precipitating times. The data for the calculations were extracted from the Sterling, VA depths at a 5 minute interval for parts of 17-18 September 2004 (days 261-262). During the periods of precipitation, the precipitation amount

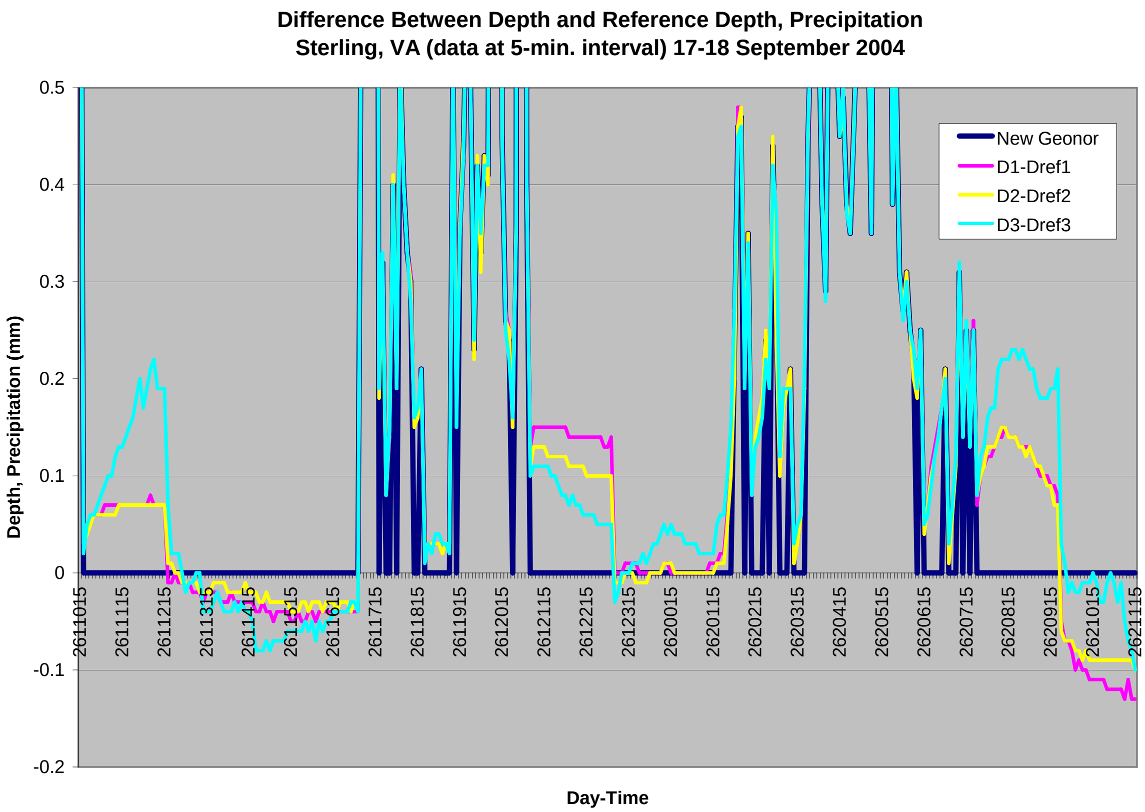

Figure 6. The difference between individual wire depths and their reference level for Sterling, VA.

and the difference between the depth and the reference level are nearly identical and the plots are on top of each other. During non-precipitating periods (heavy blue curve at zero), the three wire depth, reference level differences show variations from each other.

Figure 6 shows the detail of the data in Figure 5 for small values of the precipitation and differences of wire depth levels from their reference levels. Consider these differences in some more detail. At the first time plotted there is precipitation and the three plots overlap. Between 2611015 (day 261, 1015 UTC) and 2611650 there is no precipitation diagnosed, but the wire 3 difference meets or exceeds 0.2 mm, the limiting value for precipitation, at three times between 1140 UTC and 1200 UTC. The other two wires show differences from their reference levels of 0.07 mm. There is likely very light precipitation falling during part of this time, but it is too small to be diagnosed confidently. A wetness sensor installed at this station confirms that light rain fell part of this time. At 1240 UTC the differences fall to zero or below; precipitation has definitely ceased.

There are two other periods in which the depth minus reference level differences were between zero and 0.2 mm—both immediately following diagnosed precipitation. Comparison with the wetness sensor (not shown) shows that very little actual precipitation was lost. Note that at two hours following each precipitation event, the depth minus reference level differences step down to zero. This is due to the way in which the reference level is calculated: for two hours immediately following precipitation, the depth at the end of the precipitation is the reference level while for periods exceeding two hours after precipitation ceases, the reference level is a two-hour average of the depth.

Figure 7 shows accumulated depth differences and accumulated precipitation for Lafayette, LA for 2 March 2005. The depths for wires 1 and 2 (D1 and D2) are so close to the accumulated precipitation by the new algorithm (SUMNOFF) that they do not generally show. The depth increase of wire three (D3) is a little greater than SUMNOFF at the end of the period of precipitation, while the accumulated precipitation by the tipping gauge (SUMTIP) is a little smaller.

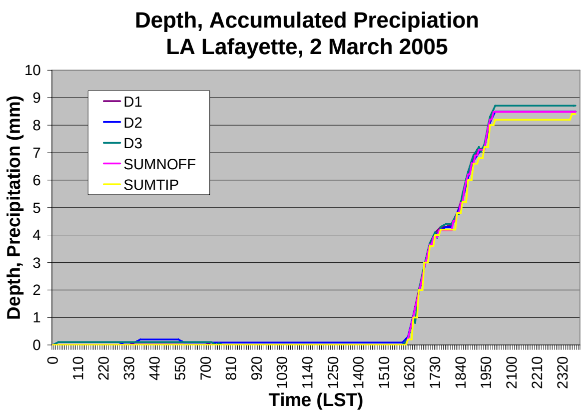

Figure 7. Individual wire depth changes from initial time (D1, D2, D3), accumulated new precipitation (SUMNOFF), and accumulated tipping gauge precipitation (SUMTIP) for Lafayette, LA on 2 March 2005.

We next consider a comparison of the new precipitation algorithm and the tipping gauge over a three month's time. Figure 8 shows the Geonor wire depths (D1, D2, D3), accumulated new precipitation (SNOFF), and accumulated precipitation by the tipping gauge (STIP) for Johnstown, PA for the period of 1 August to 31 October 2004. Note that only times are included when either the Geonor or tipping gauge had precipitation. In the middle of the period the Geonor gauge was emptied; this event gave no difficulty for the new precipitation algorithm. The tipping gauge and Geonor precipitation amounts were very close to each other for the full month.

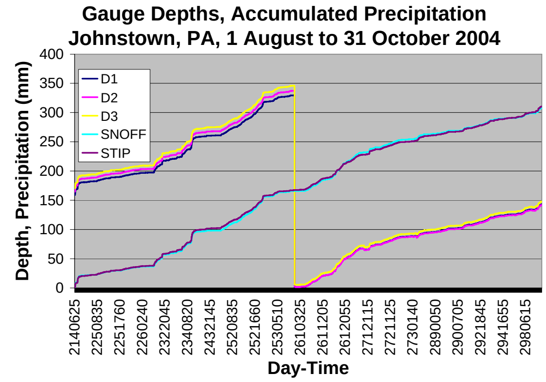

Figure 8. Accumulated precipitation by the new algorithm (SNOFF), accumulated precipitation by the tipping gauge (STIP), and Geonor wire depths (D1, D2, D3) for Johnstown, PA for 1 August to 31 October 2004.

Figure 9 shows similar plots for Sterling, VA for 1 August to 31 October 2004. The depth values show a number of dips during the month with, properly, no response in the accumulated precipitation. The Geonor and tipping gauge precipitation reasonably track each other for the full period, but with the Geonor total lagging a bit behind.

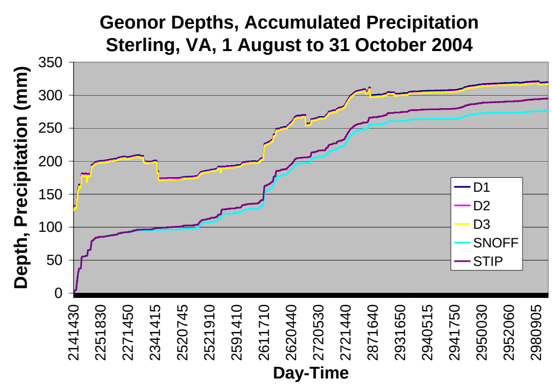

Figure 9. Accumulated precipitation by the new algorithm (SNOFF), accumulated precipitation by the tipping gauge (STIP), and Geonor wire depths (D1, D2, D3) for Sterling, VA for 1 August to 31 October 2004.

5. LIMITATIONS TO THE NEW ALGORITHM

There are a few remaining limitations to the absolute accuracy of the new precipitation algorithm. The first is its sensitivity to large-amplitude noise that is coincident between wires. This was particularly noticeable at stations like Tuscon, AZ and Redding, CA which have had very noisy wire(s), but long periods without precipitation. Two developments are nearly eliminating this problem. First, noisy wires are being replaced with station maintenance. Also, wetness gauges are being installed at all stations during their scheduled annual maintenance visit. The wetness gauge is shown to work well under most all weather conditions.

The second limitation to the accuracy of the algorithm is for very light precipitation. The two-hour averaging period for determination of the reference level limits the precipitation rate that can be computed to greater than 0.2 mm/hr. This condition can likely be relaxed by after-the-fact recalculation of the precipitation, using data from a period of time of a day or longer, thus allowing more sophisticated noise removal and detection of smaller depth increases. At the same time, there would be the possibility of removing the diurnal signal.

6. SUMMARY

This paper discussed the character of observations from the Geonor precipitation gauges installed at the USCRN sites. The depth measurements at times show difficulties for the development of an accurate precipitation algorithm—noisy depths, diurnal variations, and large variations not due to precipitation. The characteristics of the new precipitation algorithm were outlined and its performance discussed. It is found to perform well in comparison to tipping gauges at the Sterling, VA and Johnstown, PA test sites. A number of ways in which the gauges and performance of the algorithm could be further improved were discussed.

REFERENCES

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Hall, Mark E, Edwin May, 2004: NOAA Technical Note NCDC No. USCRN-04-1, Inlet Heater for USCRN Weighing Precipitation Gauge. (This paper can be obtained from: ftp://ftp.ncdc.noaa.gov/pub/data/uscrn/documenttion/program/technotes/TN04001GeonorHeater.pdf)