1.2 THE USE OF A WETNESS SENSOR IN PRECIPITATION MEASUREMENTS FOR THE U. S. CLIMATE REFERENCE NETWORK

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1. INTRODUCTION

The U. S. Climate Reference Network (USCRN) is a key element in climate monitoring for the United States. The stations in the network monitor temperature through redundant temperature readings and the precipitation by Geonor all-weather gauges. These gauges determine the depth of precipitation they hold by the vibration frequencies of three independent wires. Each wire is individually calibrated, with stable long-term behavior. However, there are small but significant variations in the wire vibrations and their implied precipitation depths, which are not related to precipitation.

This paper discusses the use of a wetness sensor to distinguish Geonor depth changes due to precipitation from those other causes. The precipitation from a Geonor gauge is determined by an algorithm which analyzes the implied depth changes of the three wires, makes a determination of the quality of measurement from each, and produces a single precipitation value. In a small number of cases, a non-zero value of precipitation is produced when other sources of information indicate a lack of precipitation. The recently installed wetness sensor is shown to provide a highly reliable source of this additional information. It is used to eliminate false precipitation from spurious depth changes, diurnal depth variations, and dew. Examples and statistics from USCRN sites are shown which indicate the wetness sensor's high value and reliability.

2. CHARACTERISTICS OF THE WETNESS SENSOR

The working principle of the wetness sensor is based on the detection of water on the active portion of the sensor plate. A heater is integrated in the sensor plate to dry out water droplets or any condensation. The wetness sensor used at CRN sites provides two numerical values. When there is no precipitation, the first value is about 1000 and is the rain on/off threshold channel. The second channel is the analog out and is proportional to the moisture level on the sensor plate and when dry reads about 3000. During precipitation, the first value drops crisply to about 30. The second value also drops, by an amount generally related to the precipitation intensity. Dew is eliminated from the sensor by application of sufficient heat.

Since only the distinction between precipitating and non-precipitating times is needed, only the rain on/off threshold channel is used for CRN site precipitation determination.

3. THE USCRN PRECIPITATION ALGORITHM FOR THE GEONOR GAUGE

The Geonor precipitation gauge is a weighing gauge, utilizing three wires whose vibration frequency is used to measure the depth of liquid in the gauge. While there is a single true depth of liquid in the gauge, the wires give independent measurement of its magnitude. The precipitation algorithm for the Geonor first determines which of the three wires is performing properly, and then uses those to determine the liquid depth.

Two conflicting factors must be balanced in the design of the algorithm which determines any precipitation amount from the individual implied wire depths, namely, the desire to capture all precipitation above a small threshold, and to avoid falsely determining precipitation when there is none. The algorithm designed for the Geonor gauge accomplishes these goals quite well, but not perfectly. The next section, describing the variations seen in the wire variations, will illustrate why this may not be done perfectly, thus pointing to the necessity of the wetness sensor to distinguish precipitating from non-precipitating periods. The rest of this section will describe in some detail the Geonor precipitation algorithm in use at the CRN sites.

The wire depths for the Geonor gauge at the CRN sites are available at 5-minute intervals. The processing is performed once an hour for overlapping 3-hour groups of data, with the precipitation from the last of the three hours the final value.

The first task of the precipitation algorithm is to establish a reference depth level for each of the three wires. Initially, the reference level is equal to the depth. Thereafter, if there was precipitation at the last time level, the reference level is equal to the previous depth. If there was precipitation within the last two hours, the reference level is unchanged from the last time level. Otherwise, the reference level is the average of the depth for the last two hours (or back to the initial time of the 3-hour time block). Naturally, there are checks on

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the reasonableness of the depths before they are used for reference level determination.

Next, the 5-minute change of depth from the wire reference levels is calculated for each wire. Then, the difference in depth change between pairs of wires is calculated. From these inter-wire depth change differences it is possible to determine which wires are performing within defined limits. Finally, for depth changes exceeding 0.2 mm, the precipitation is calculated as the average change in depth from the reference level for the properly operating wires.

Further description of the precipitation algorithm can be found in Calculation of Official USCRN Precipitation from (Geonor) Weighing Precipitation Gauge, NOAA Technical Note NCDC No. USCRN-05-1 by C. B. Baker, et al and in The New Precipitation Algorithm for the Three-wire Geonor Gauge of the U. S. Climate Reference Network—Objectives, Description and Performance by W. Collins, et al.

4. THE NATURE OF THE WIRE VARIATIONS AND FALSE PRECIPITATION REPORTS

The Geonor wires respond to several, only partially identified, sources. Major changes in wire depth are due to precipitation, the addition of antifreeze and oil, and the emptying of the gauge. Other sources of wire variations that are observed can be described as a diurnal variation, slow decreases from evaporation, and random sources, either correlated or uncorrelated between wires. The diurnal and random variations may show different amplitudes and timing between the three wires. Wire variations, not due to precipitation, which are of sufficient magnitude and correlated between two or more wires, can lead to spurious precipitation determination. The nature of the precipitation algorithm is such that if it is dry, as determined by the wetness sensor, and the algorithm produces precipitation, it will often lead to several consecutive time periods of false precipitation. This paper will refer to such a time period as a 'false report'.

Figure 1 shows a typical plot of individual wire variations, during a period without precipitation. The plot is for station NH Durham 2 N, for 1-8 July 2006. The individual wire variations are shown in the figure as D1, D2 and D3. Wires 2 and 3 have a fairly similar variation, while wire 1 shows a differing pattern. The diurnal signal is moderately strong, with an amplitude of about 0.5 mm. The evaporation over the eight day period amounts to about 1 mm. Neither the evaporation, nor any noise with short-term amplitude less than 0.2 mm is a problem for the precipitation algorithm. However, correlated changes between the wires of larger amplitude, may lead to false precipitation which must be eliminated by the use of the wetness sensor. During the period of the data in Figure 1, there were two such times: 1 July at 1135 UTC and 7 July at 1135 UTC. Both are associated with the diurnal wire variations.

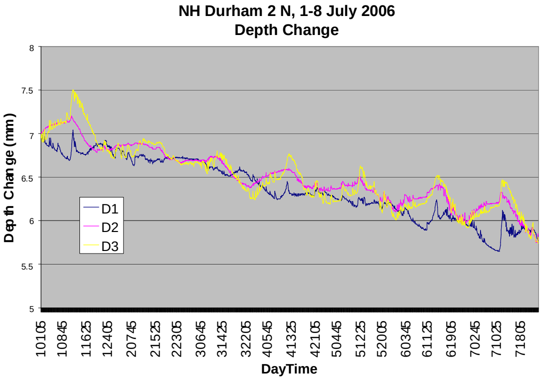

Figure 1. Individual wire depth changes for CRN site NH Durham 2 N, 1-8 July 2006.

5. EXAMPLES OF WETNESS SENSOR USE TO ELIMINATE FALSE PRECIPITATION REPORTS

The wetness sensor reliably distinguishes precipitating from non-precipitating times. Figure 2 shows the relative variation in wire depth and the accumulated precipitation for July 2006 for NH Durham 2N. At this vertical scale, the variations shown in Figure 1 for the first eight days of the month do not show well. But it is seen that the accumulated precipitation and the wire depths track well against each other. For this reason, and to be better able to see the wire variations, later figures will subtract the accumulated precipitation, as determined by the precipitation algorithm, and after use of the wetness sensor to remove false precipitation, from the individual wire depths. Figure 3 shows the depth change, minus the accumulated precipitation (D1MP, D2MP and D3MP), as well as the accumulated precipitation for July 2006 for NH Durham 2N. During the month there were 8 times of false precipitation reports. Figure 4 isolates 8-12 July to show greater detail for a period of time when there were 4 false

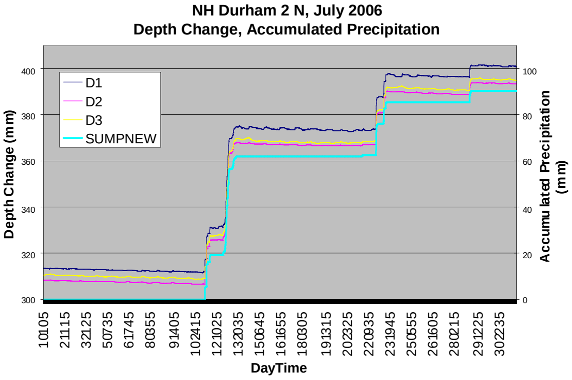

Figure 2. Individual wire depth changes and accumulated precipitation for CRN site NH Durham 2 N, 1-31 July 2006.

reports. Two of the false reports were associated with diurnal wire variations and the other two were during lulls in the precipitation, as shown by the wetness sensor, with sufficient wire variation to trigger the precipitation algorithm.

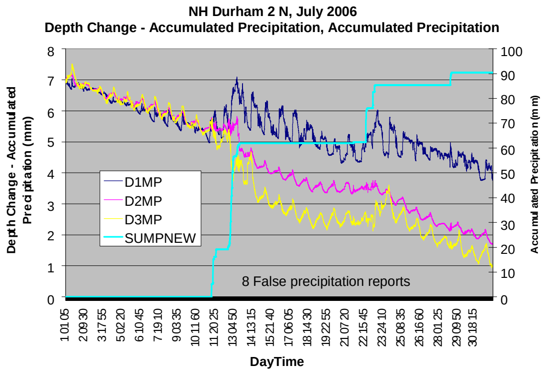

Figure 3. Individual wire depth changes minus accumulated precipitation and accumulated precipitation for CRN site NH Durham 2 N, 1-31 July 2006.

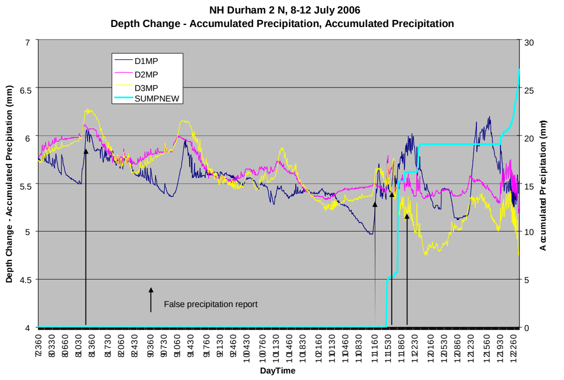

Figure 4. Individual wire depth changes minus accumulated precipitation (D1MP, D2MP, D3MP), accumulated precipitation (SUMPNEW), and times of false precipitation reports (shown by arrows) for CRN site NH Durham 2 N, 8-12 July 2006.

Another example of false reports is provided by MO Chillicothe 22 ENE for July 2006. Figure 5 shows the wire depth changes minus the accumulated precipitation, and the accumulated precipitation for the full month, while Figure 6 shows this same information for 18-21 July 2006. Figure 6 also shows with arrows the times of two false reports. For the full month, there were 26 false reports.

The false report at 1355 UTC on 18 July is caused by the synchronous increase in depth of the three wires. It is interesting that, with slightly different timing of the diurnal variation of the three wires, there were no false reports for 19 or 20 July. The false report at 1155 UTC on 21 July occurs just before a precipitation event as shown by the wetness sensor. This results from a slight timing difference between when the precipitation algorithm first senses precipitation and when the wetness sensor does so. The wetness sensor became “wet” at 1200 UTC and the precipitation algorithm produced 0.30 mm rain.

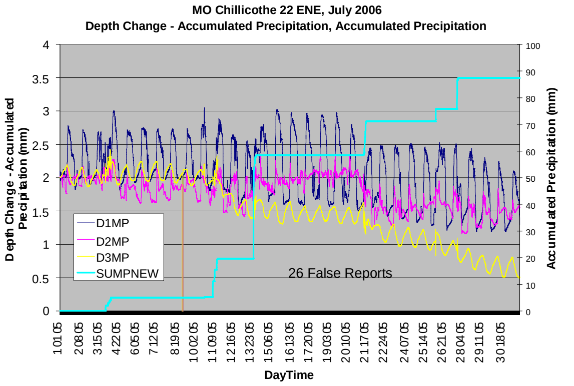

Figure 5. Individual wire depth changes minus accumulated precipitation and accumulated precipitation for CRN site MO Chillicothe 22 ENE, 1-31 July 2006.

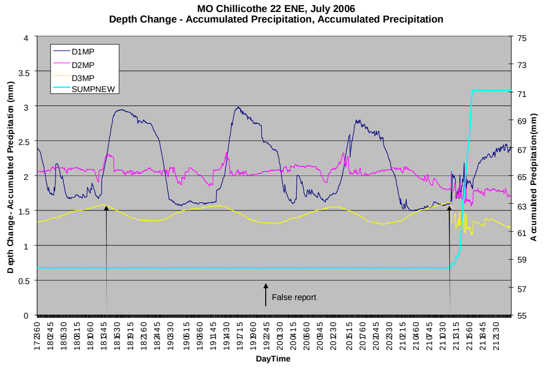

Figure 6. Individual wire depth changes minus accumulated precipitation (D1MP, D2MP, D3MP), accumulated precipitation (SUMPNEW), and times of false precipitation reports (shown by arrows) for CRN site MO Chillicothe 22 ENE, 18-21 July 2006

6. STATISTICS ON THE USE OF THE WETNESS SENSOR

The wetness sensor has been found to be extremely reliable in its determination of when there is precipitation. Out of 159 months of data, there were found to be only 27 instances (.002% of sensor readings) when the wetness sensor indicated “dry” and more than one precipitation gauge had a non-zero amount of precipitation. For May to July 2006, 66 CRN sites were examined to determine the number of false reports. The average monthly number of false reports was 3.4, but the distribution varies widely from 0 to 43. Figure 7 shows the distribution of false reports.

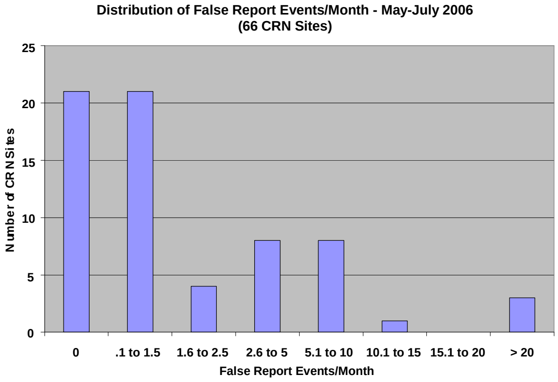

Figure 7. Distribution of false report events/month for 66 CRN sites.

It is seen that two-thirds of the stations have less than 1.6 false reports per month. Those with larger number appear to be predominantly associated with large, consistent diurnal variation in the wire depths. At present, the cause of the diurnal variation is under investigation.

7. CONCLUSIONS

The use of a wetness sensor at CRN sites for the determination of 'wet' and 'dry' periods was described. The wetness sensor was found to have little error in its discrimination between 'wet' and 'dry' times. This study shows that the precipitation algorithm is vulnerable to false precipitation from sufficiently large Geonor wire variations that are positively correlated, and that the wetness sensor is effective in removing this precipitation.

REFERENCES

Baker, C. Bruce, et al, 2005: Calculation of Official USCRN Precipitation from (Geonor) Weighing Precipitation Gauge, NOAA Technical Note NCDC No. USCRN-05-1, 27 pp. (This paper can be obtained from: ftp://ftp.ncdc.noaa.gov/pub/data/uscrn/documentation/program/technotes/TN5001GeonorAlgorithm.pdf)

Collins, William G., et al, 2005: The New Precipitation Algorithm for the Three-wire Geonor Gauge of the U. S. Climate Reference Network—Objectives, Description and Performance, 13th Symposium on Meteorological Observations and Instrumentation, 20-24 June, 2005, Savannah, GA., paper 4.3.