1.3 THE EFFECTS OF CONDENSATION ON THE OUTSIDE WALL OF A GEONOR PRECIPITATION GAUGE

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1. INTRODUCTION

The United States Climate Reference Network (USCRN) is dedicated to the production of highly accurate precipitation and surface temperature measurements. These two atmospheric variables are dominant indicators of climate. As a result, the USCRN takes every possible precaution to realize and mitigate effects that cause inaccuracies or false reporting of these two variables that are so important to the assessment of climate and climate variability. Here, we specifically deal with the case of false reporting as it relates to the accumulation of condensation on the outside wall of a weighing bucket rain gauge.

2. DATA

The data used in this study originated from testbed sites in Sterling, VA, and Johnstown, PA. For the Johnstown, PA, site, data were collected during the period January 1, 2004 through June 30, 2006. The Sterling, VA, data were collected from January 1, 2004 through April 30, 2006. The suite of instruments at each location included at least one Geonor Precipitation Gauge and one Tipping Bucket Rain Gauge (TB3). These two types of rain gauges are primarily used to compare the amounts of accumulated rainfall.

In this study, comparisons are made between the precipitation amounts collected from the Geonor and TB3, including a comparison of the ability to distinguish precipitating events from non-precipitating events. There is a different measuring mechanism associated with each rain gauge. For the TB3 mechanism, rain funnels into an orifice and once an incremental amount (0.01 inches) of precipitation has been collected, the bucket assembly tips. The measuring mechanism for the Geonor uses three vibrating wire gauges to continuously weigh the water in the collection system. In each case, a minimum change of .25mm (.01 inch) is required for precipitation to be reported.

Considering the differences in these measuring techniques and based on a preliminary analysis of data collected at the two testbed sites, we wanted to determine what physical processes were responsible for cases when the Geonor reports precipitation and the TB3 does not. We label this discrepancy as a false report.

3. ANALYSIS OF DATA

To begin our false report analysis, we looked at the pattern of discrepancies occurring at each testbed site. As seen in Figure 1, the highest frequency of false reports occurred at the Sterling site and during the evening and early morning hours at both. During these hours, the earth's surface experiences radiational cooling and as a consequence the air reaches relatively low temperatures in comparison to daytime highs.

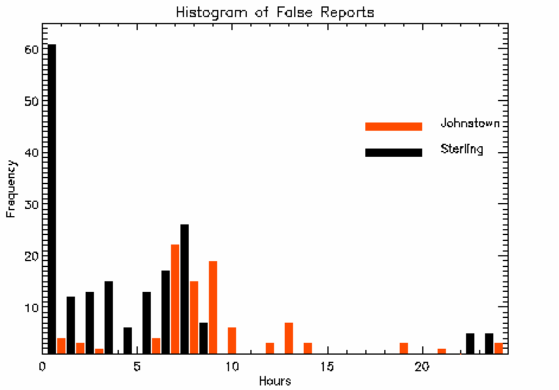

Figure 1. Histogram of Sterling and Johnstown False Reports.

When radiational cooling causes surface temperatures to reach the dewpoint, the air will become saturated and the water vapor in the air will begin to condense. This relationship caused us to look at the dewpoint temperatures and to correlate the time of these occurrences with the time of the false reports. However, since this variable is not measured at CRN stations we used dewpoint temperatures from collocated Automated Surface Observing System (ASOS) sites. As mentioned by Baker and Sun (2004), despite differences in reporting practices, solar radiation, infrared radiation, and ambient wind speed at two collocated sites, the temperature profiles of ASOS and USCRN data at the collocated sites show good agreement. To support this point, both ASOS and CRN temperature data and ASOS dewpoint data have been plotted in Figure 2.

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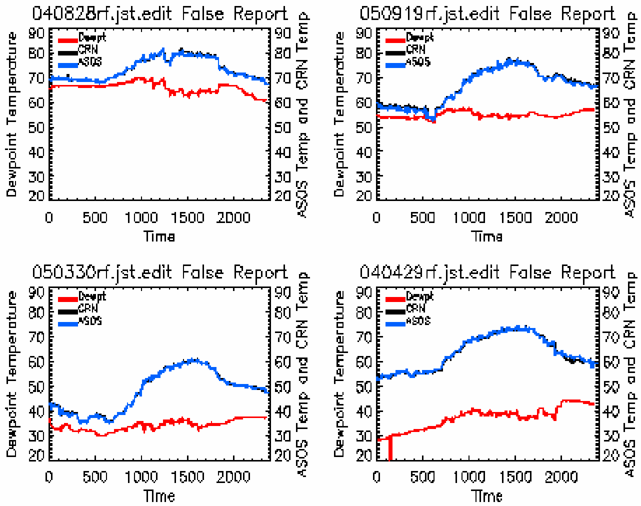

Figure 2. ASOS and CRN data

Although only four graphs are shown here, data were plotted for every day that the testbed sites experienced a false report. As shown in Table 1, the Johnstown data had no occurrences when the surface temperature dropped to or below the dewpoint temperature. For the Sterling site, only 6.32% of data points that were not missing, i.e did not contain -999.00 or 'M' values, fell to or below the dewpoint temperature.

Table 1. Temperature Characteristics at Testbed

Site	Data Points	Data Points with 999.00	Data Points with 'M'	Data Points not Missing	Data Points with Temp below Dewpt	Data Points not Missing %
JST	114969	1781	1731	111457	0	0%
STV	154080	15290	795	137995	8716	6.32%

Especially in the Johnstown case, these results indicate that radiational fog is not contributing to the condensate which may be forming on the outside wall of the weighing bucket. For this reason, condensate is likely to form as a result of low bucket temperatures that are at or below the dewpoint.

4. EXPERIMENT

To test the effects of low bucket temperatures on the formation of condensate on the outside wall of a Geonor rain gauge, we conducted a forced condensation experiment. We did this by loading one Geonor rain gauge bucket with 5 parts water and 2 parts ice. Then we looked at the change in frequency, hypothesizing that if condensate forms on the outside wall of the bucket the additional weight of the condensate would be displayed as an increase in frequency (or depth) as measured by the Geonor's 3 vibrating wires.

After adding ice to lower the bucket temperature, we had a strong temperature gradient. In this open system, heat was transferred to the bucket to melt the ice and it eventually raised the temperature of the water. Any condensate that originally formed on the outside wall of the bucket due to low bucket temperature was now evaporated due to the heat transfer into the bucket. As a consequence of this evaporation, the total mass of the bucket was decreased and the frequencies measured by the Geonor's three vibrating wires were expected to decrease as well.

After conducting our forced condensation experiment six times, we obtained results that didn't exactly agree with our hypothesis. Figure 3 and 4 are plots of the three vibrating wires once ice was added to the bucket. In the case of Figure 3, the bucket was first removed from the cradle of the rain gauge. Condensation occurred on the surface of the bucket rather quickly as indicated by the high frequency values that were measured at times less than 4500. Wires 1 and 3 showed fairly good agreement while wire 2 did not. There was an increase in frequency approximately between the times of 600-700 for all three wires(Figure 4). However, agreement with our hypothesis then stopped for wires 1 and 3. Wire 2 may be following our hypothesis fairly well. However, steep dips and rises didn't have a place in our hypothesis and as a result lack an explanation here.

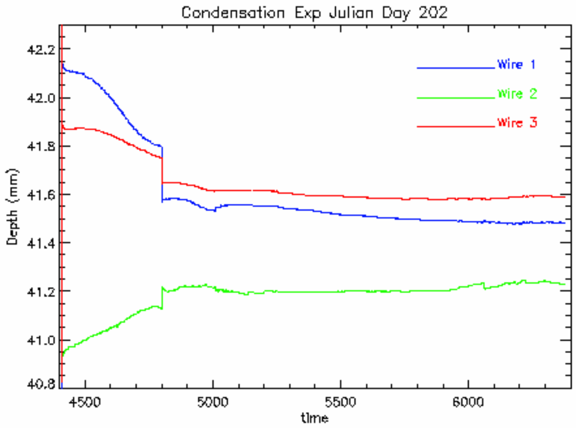

Figure 3. Forced Condensation Experiment 1

Since this experiment was conducted before sunrise, any condensation should have been uniformly distributed. During cases when we conducted this experiment during the daytime, we saw differences in the distribution of condensate on the bucket which was dependent on the solar zenith angle.

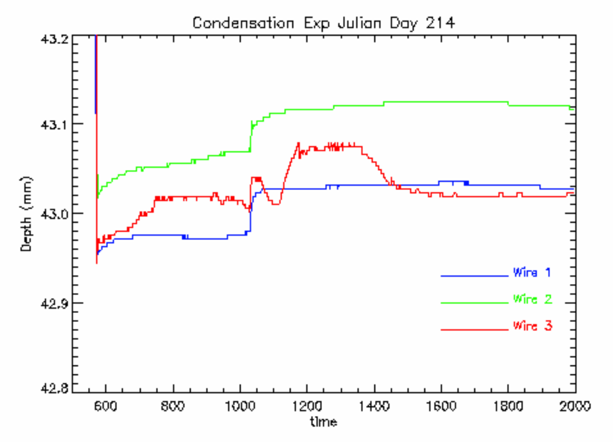

Figure 4. Forced Condensation Experiment 2

4.2 *Noise Effects*

After allowing the gauge to make measurements at a fixed depth, without adding any ice we see that noise also alters the output frequencies of the vibrating wires. As shown in Figure 5, wire 3 shows a noise dependency that follows the surface temperature profile. This is because the transducer is responding to the temperature gradient across the transducer housing. Although the change in wire 3 is not very pronounced, coupling this effect with the effects of condensate may produce a false report.

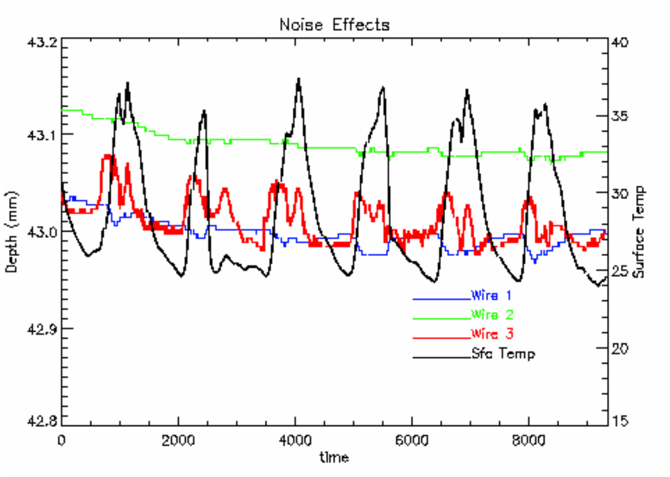

Figure 5. Noise in Vibrating Wires

5. MODEL

To continue to test our hypothesis, we seek to consider a theoretical model of dropwise condensate. Our first option in determining the cause of false reports and exactly how condensation and evaporation processes factor into this scenario would be a physical experiment, however, a numerical model proves to be of valuable use. We use this approach to determine the effects water vapor phase change processes can have on the Geonor weighing bucket rain gauge. Specifically, we plan to use a modified version of Nusselt's Condensation Theory.

6. CONCLUSIONS

At this time, we do not seek to draw conclusions from this research. There is ongoing work to further study the noise dependencies of the Geonor's vibrating wires using Nusselt's Condensation Theory to investigate the effects of condensation on the outside wall of the Geonor rain gauge bucket. Finally, we also seek to conduct additional forced condensation experiments under varying atmospheric conditions to continue to test the hypothesis of this work.

7. REFERENCES

B. Sun, and C. B. Baker, 2004: A comparative study of ASOS and CRN temperature measurements, Eighth Symposium on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface.

J. W. Rose, 1999: Condensation Heat Transfer, Heat and Mass Transfer, 35, 479-485.