# WMO SOLID PRECIPITATION MEASUREMENT INTERCOMPARISON AT SLEEPERS RIVER RESEARCH WATERSHED

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ABSTRACT

The U.S. Army Cold Regions Research and Engineering Laboratory is a member of the World Meteorological Organization (WMO) group tasked with evaluation of solid precipitation measurement procedures and instrumentation. The NOAA/CRREL Sleepers River Watershed in Danville, Vermont, was selected as the site for these tests in 1986, and precipitation gauges and supporting meteorological instrumentation were installed in the fall of 1986. This paper gives descriptions of the precipitation gauges evaluated and preliminary results obtained for a few snowstorms that occurred during the first winter of operation.

## Introduction

This paper addresses a long-term problem, that of measuring wintertime solid precipitation accurately. According to a paper by Larson[1,2] the problem of developing an accurate error-free, unbiased gauge for measuring precipitation has existed since the 13th Century AD, when the Chinese were concerned with the problem. Some of the more modern problems with precipitation measurement techniques are described by Rinchart[3]. The objectives of this report are (1) to discuss the first year's operation of the World Meteorological Organization (WMO) evaluation project established at the Sleepers River Research Watershed located in North Danville, Vermont, for the intercomparison of solid precipitation measuring techniques, and (2) to describe the testing and evaluation of a rapid response precipitation gauge developed by CRREL and a commercial optical precipitation gauge modified to operate in snowfall. The WMO program continues for five years, and a number of types of precipitation gauges are being tested at over 15 countries worldwide. After evaluation a gauge will be selected as the WMO standard for measurement of wintertime solid precipitation. Figure 1 is a site plan showing locations of the gauges and supporting meteorological instrumentation installed at the Town Line Site W-3 at the Sleepers River Watershed.

Supporting meteorological instrumentation was installed in close proximity to the site to measure wind speed and direction, air temperature, dew point, solar radiation and accumulated snow depth. Snow property measurements and routine snow course measurements were made nearby. The snow property measurements included density, temperature, hardness, crystal type and depth of each new snowfall. These measurements are needed to assist in verification of water equivalents measured by the independent gauges.

## Site Description

The North Danville W-3 test site is located near the eastern edge of a 6-ha clearing (see Anderson[4] for a detailed site description). The forest is generally about 200 m from the center of the selected site area. The surrounding first 75 m of terrain is generally

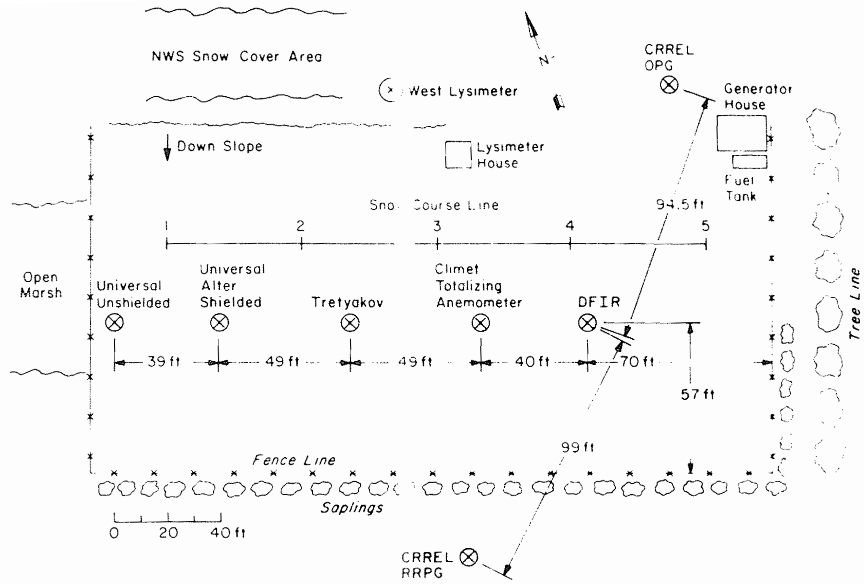



Figure 1. Site plan for Town Line Site W-3.

free of vegetation tall enough to protrude above the midwinter snow cover. Beyond 75 m there are scattered small conifers. The central portion of the site was graded prior to the installation of instruments. The site is very flat, with a slight slope to the south, and meets site criteria given in the WMO report[5]. This results in a very uniform snow cover over the site area. However, during windy periods the snow tends to blow off this area. The prevailing winds in winter are from a westerly direction.

Precipitation Gauges

During this first winter of testing five conventional snow gauges and two gauges under development by CRREL were installed for the intercomparison studies. The gauges installed were:

1. Double-fenced international reference (DFIR) gauge (Fig. 2a)
2. Tretyakov gauge (Fig. 2b)
3. Universal unshielded gauge (Fig. 2c)
4. Universal shielded gauge (Fig. 2d)
5. Rapid response precipitation gauge (RRPG) (Fig. 2e)
6. Optical snow gauge (Fig. 2f)

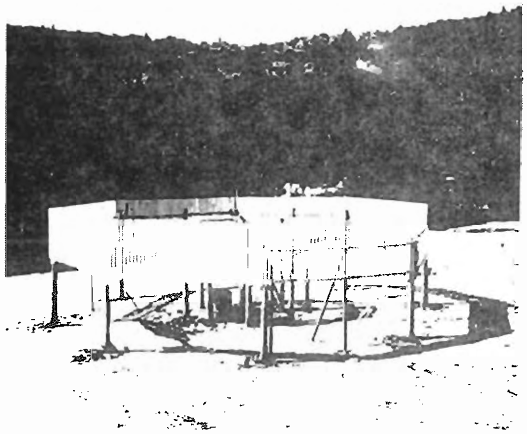
Site preparation, gauge descriptions and installation procedures for gauges 1-4 above are also given in the WMO Report[5] furnished to all participants. Gauges 5 and 6 are described in a report written by Koh and Lacombe[6].

Meteorological Sensors

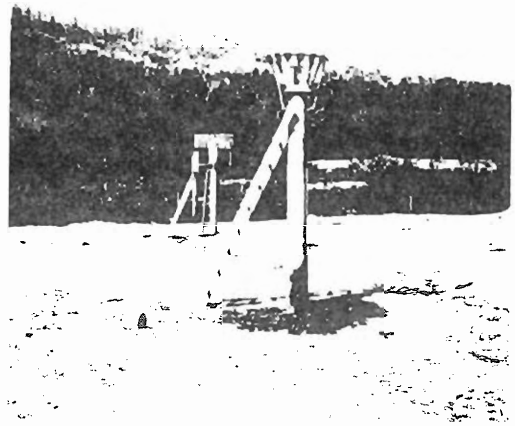
Meteorological sensors installed at the Town Line site are the normal routine NOAA station instruments (Anderson et al.[4]). These measurements are for reference or backup to the site-specific sensors installed by CRREL for the purpose of this experiment. Meteorological sensors installed by CRREL are listed in Table 1.

Table 1. Meteorological Sensors.

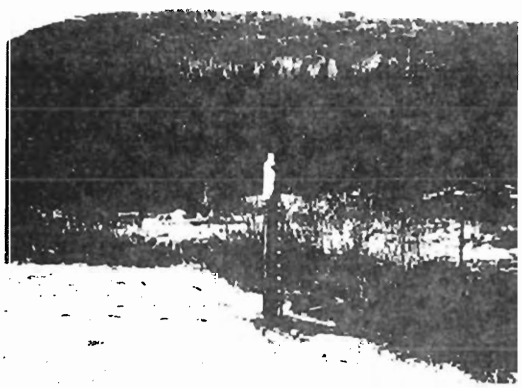
| Parameter | Type of Sensor | Range | Accuracy |
|---|---|---|---|
| Wind speed/wind direction | Propeller/vane | 0-60 m/s | ± 1% |
| Water equivalent | Automatic weighing | 0-150 mm | ± 0.1 mm |
| Short-wave solar radiation | Radiometer/pyranometer | 0.3-3 µm | ± 1% |
| Long-wave solar radiation | Radiometer/pyrgeometer | 3-50 µm | ± 1% |
| Air temperature | 100 OHM PRT | -45 to +66°C | ± 1°C |
| Dewpoint | 100 OHM PRT (L1CL Bobbin) | -45 to +66°C | ± 1°C |



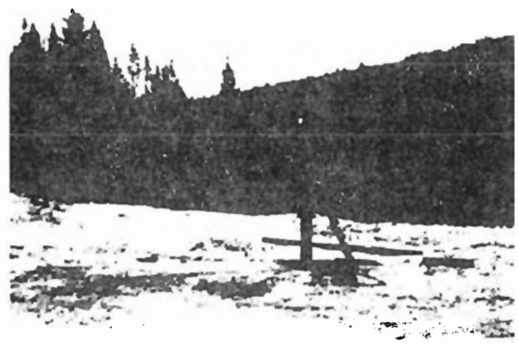
a. Double-fenced international reference (DFIR) gauge.



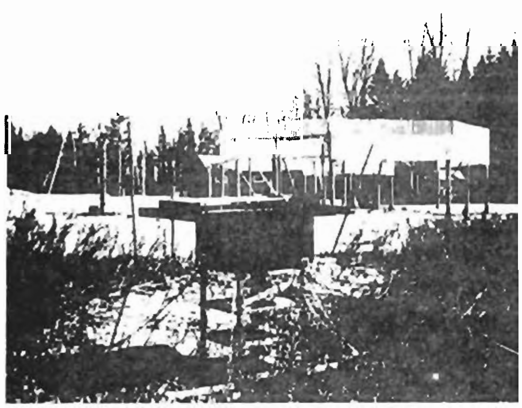
b. Tretyakov gauge.



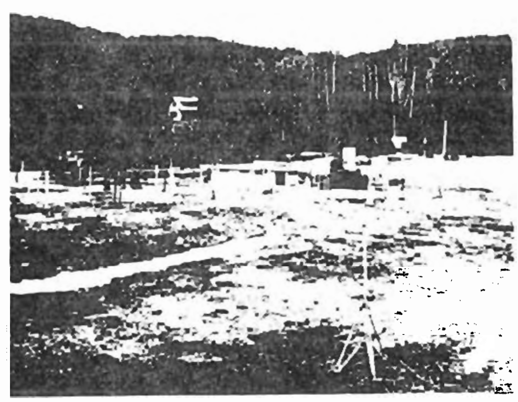
c. Universal unshielded gauge.



d. Universal shielded gauge.



e. Rapid response precipitation gauge (RRPG).



f. Optical gauge with standard 8-in. gauge in background.

Figure 2. Precipitation gauges.

These meteorological sensors were interfaced to a Kaye Data Logger and all hourly data were stored on floppy disks. Disk data were fed to the CRREL computer and the first year's data were stored for further analysis.

Snowstorm Data Presented

Total precipitation amounts were recorded for the five intercomparison gauges for the winter of 1986-1987. Correlation coefficients for water equivalents of each gauge, as compared to the DFIR gauge, for the entire winter are presented in Figures 3 and 4. For those gauges having more rapid response or recording capability (which includes the CRREL gauges), intercomparisons are given for the 1 March 1987 snowstorm in Figure 5.

Analysis

Table 2 gives a tabulation of total water equivalent and calculated snow density for two major storms. Snow density was calculated as follows:

$$\text{Cal. Density} = \frac{\text{W.E. (mm)}}{\text{Total snowfall (mm)}}$$

The calculated snow density is useful for comparison of each gauge's W.E. catch to the measured surface layer snow density. From comparisons in Table 2 it can be discerned that, for the 11 to 12 January storm, the Tretyakov gauge collected the least amount of W.E. for the storm (22 mm) and this leads to a lower calculated snow surface density of 0.057 g/cm$^3$. The calculated surface densities of all gauges averaged 0.074 g/cm$^3$ for this storm or 0.030 g/cm$^3$ below the measured density. Table 2 also gives the data for the 1-3

Table 2. Performance Comparison for Six Snow Gauges.

SNOWSTORM, 11 and 12 JANUARY 1987

Total snowfall = 386 mm Average wind speed 3 m/s Wind direction = West

Measured snow density on ground = 0.104 g/cm$^3$

Total Water Equivalent and Cal. Density

| DFIR | | Tretyakov | | Universal Shielded | | Universal Unshielded | | 8 in. STD | | RRPG |
|---|---|---|---|---|---|---|---|---|---|---|
| Amt (mm) | Den. (g/cm$^3$) | Amt (mm) | Den. (g/cm$^3$) | Amt (mm) | Den. (g/cm$^3$) | Amt (mm) | Den. (g/cm$^3$) | Amt (mm) | Den. (g/cm$^3$) | |
| 25.1 | 0.065 | 22.0 | 0.057 | 34.3 | 0.089 | 29.2 | 0.076 | 32.5 | 0.084 | N/A |

Average catch all gauges = 28.6 mm

SNOWSTORM, 1,2,3 MARCH 1987

Total snowfall = 221 mm* Average wind speed 1.8 m/s Wind direction = SE and West

Measured snow density on ground = 0.131 g/cm$^3$

Total Water Equivalent and Cal. Density

| DFIR | | Tretyakov | | Universal Shielded | | Universal Unshielded | | 8 in. STD | | RRPG | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Amt (mm) | Den. (g/cm$^3$) | Amt (mm) | Den. (g/cm$^3$) | Amt (mm) | Den. (g/cm$^3$) | Amt (mm) | Den. (g/cm$^3$) | Amt (mm) | Den. (g/cm$^3$) | Amt (mm) | Den. (g/cm$^3$) |
| 30.9 | 0.140 | 30.6 | 0.138 | 27.4 | 0.124 | 26.1 | 0.118 | 29.5 | 0.133 | 24.8 | 0.112 |

Average catch, all gauges = 28.2 mm

* Freezing rain and sleet accompanied portions of this storm.

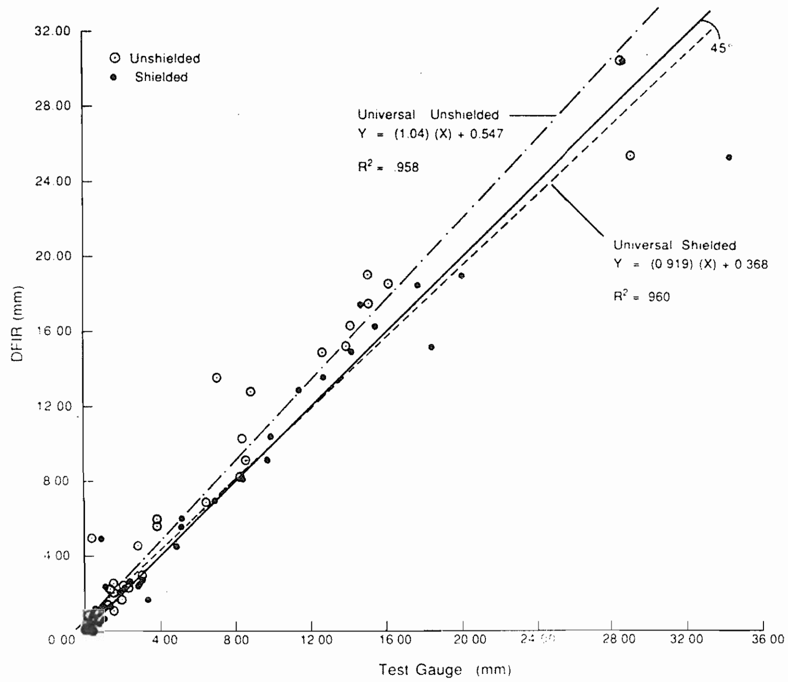



Figure 3. Correlation between DFIR gauge and Universal shielded and unshielded gauges.

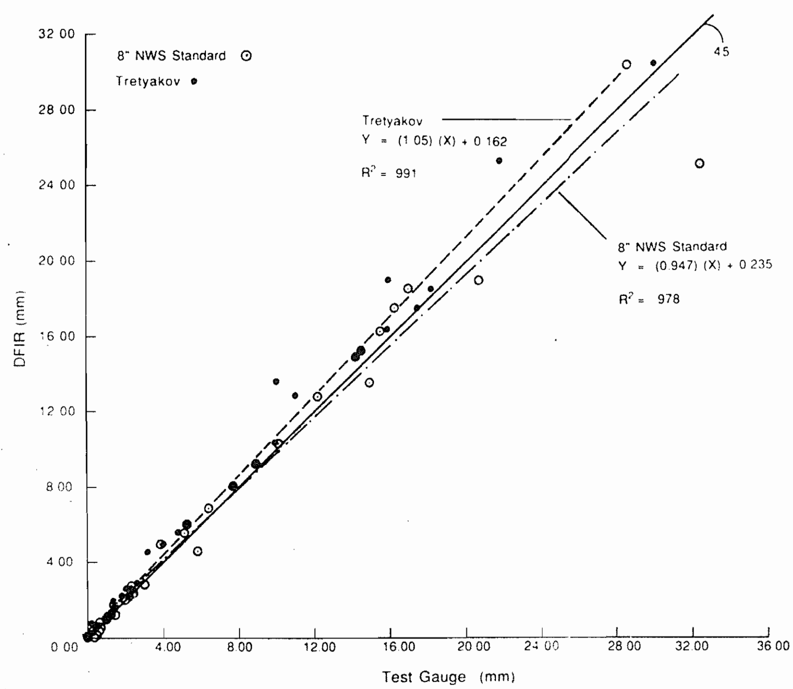



Figure 4. Correlation between DFIR gauge and Tretyakov and 8-in. standard gauges.

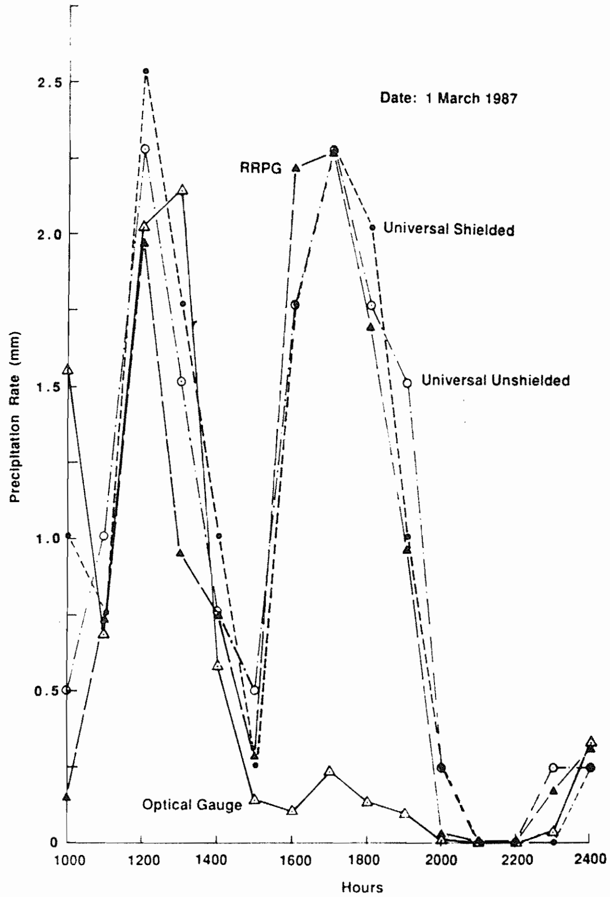



Figure 5. Hourly precipitation rate for four rapid response gauges.

March storm and shows that the RRPG gauge and the National unshielded gauge give the lowest catch and calculated densities of 24.8 mm and 0.112 g/cm³, and 26.1 mm and 0.117 g/cm³, respectively. However, the calculated surface densities average 0.128 g/cm³ for this storm or 0.003 g/cm³ below the measured density, which is extremely close. The larger departure for the calculated density for the 11-12 January storm is possibly explained by the fact that the snow density surface layer measurement was made 12 hr after the storm. The density for the March storm was made immediately after the storm ended. Metamorphic densification of the surface layer can result in an increase to 0.10 g/cm³ or more in a 12-hr period from the time of deposition.

Correlation coefficients for the overall winter (all data) daily total water equivalent are tabulated in Figures 3 and 4. The regression analysis shows that when each gauge was compared to the DFIR gauge, $R^2 = 0.991$ for the Tretyakov, 0.978 for the 8-in. NWS standard, 0.960 for the universal shielded and 0.958 for the universal unshielded. This analysis of W.E. data indicate that the Tretyakov and 8-in. standard gauges compare more favorably to the DFIR gauge than either of the universal shielded or unshielded gauge.

Hourly data were recorded for the two universal gauges as well as for the two CRREL gauges (RRPG and optical). One example of a comparison of the precipitation rate (mm/hr) is given for these gauges in Figure 5. The plots show that the hourly precipitation rate for the gauges compared favorably for the 14-hr experiment, except for the optical gauge between 1500 and 2000 hr. The reason for the differences in the optical gauge data was that it did not operate correctly during freezing rain and sleet over this 5-hr period, as it was specifically modified to monitor snowfall.

## CONCLUSIONS

1. In this fairly light wind regime at Danville, Vermont, this first winter's data show limited differences between gauge catches for daily or storm totals if analyzed for an entire winter's catch.

2. The slightly greater gauge width for shielded 8-in. orifice gauges than for the DFIR might account for some of the slightly greater difference in comparison to the universal gauge data.

3. Accumulated hourly precipitation rate data are needed for final determinations of precipitation accuracies for each station, especially to eliminate periods of rain, sleet and/or freezing rain.

4. Snow surface layer density measurements and total snowfall amount measurements on a standard snow board for measuring depth must be made immediately at the end of each storm. This is necessary to accurately calculate water equivalent values for comparison to each gauge's total catch and the measured surface snow density.

## REFERENCES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