The National Center for Atmospheric Research's Marshall Field: Winter Weather Precipitation Research

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Introduction

Boulder, Colorado is home to the National Center for Atmospheric Research's (NCAR) Marshall Field. At Marshall Field scientists create and test different types of precipitation gauges and apparatus. Marshall Field is a winter weather research site, so the scientists focus on solid precipitation measurements (snow and icing events). Snowfall measurements can be obtained simply by measuring snow depth with a yardstick, or by using more complex devices such as heated plates that measure the water content or evaporation rate of precipitation, yet results are not always consistent. Accurate snowfall measurements are important for determining snowpack and water availability.

In the West, a majority of the water supply comes from winter precipitation. Water managers generally use the April 1 snow water equivalent (SWE) to project future spring and summer streamflows, reservoir storage, and implications for water demand. Despite the SNOTEL and Snow Course networks monitored by the Natural Resources Conservation Service, a scarcity of precipitation gauges in the western U.S., particularly at higher elevations, leads to gaps in precipitation data collection (Groisman and Legates, 1994). In order to measure precipitation accurately in the western U.S. researchers need to improve the accuracy of solid precipitation measurements in order to develop a network of high quality precipitation gauges at varying elevations.

To determine accuracy of solid precipitation gauges, measurements are compared to a standard determined by the World Meteorological Organization (WMO). In 1985, attendees of the International Workshop on Correction of Precipitation Measurement recommended that the WMO fund a Solid Precipitation Measurement Intercomparison study. From 1986 to 1993, field studies were conducted in 13 countries. The goals of the field studies were to determine wind related errors, derive standards methods for adjusting measurements, and to create a reference (standard) observation method (Goodison et al. 1998). The Intercomparison study found that a large wind shield around precipitation gauges was needed to obtain the most accurate snow measurements, so this is the current reference method. However, the recommended wind shield is large (the wind fences are 12m (39.4 ft) and 4m (13.1 ft) in diameter) and not practical for many locations.

Researchers at Marshall Field in Boulder, Colorado are testing new gauges and other solid precipitation measurement techniques for improved accuracy and comparing them to measurements from gauges that use a large wind shield. This work will help establish the most accurate techniques and methodologies for measuring the snow water equivalent of solid precipitation events. They also conduct research on the effects of wind shields around precipitation gauges. This article describes several precipitation measurement devices currently being tested at Marshall Field: wind shields, weighing precipitation gauges, tipping buckets, and hotplate precipitation gauges.

Wind Shields

A wind shield is a barrier made of wooden or metal strips that prevents wind from blowing the precipitation over the top of the gauge. The Intercomparison study recommended the Double Fence (DFIR) wind shield, which is an octagonal double fence shield, as the accuracy standard (Figure 1a). Research has found that without a wind shield, gauges can under-estimate precipitation by 50% or more during windy events (Landolt et al. 2004). The diameter of a wind shield can also effect measurement. Wind shields that are too small can lead to downward forcing of precipitation and insufficient collection of the solid precipitation. Wind shields that are sufficiently large cause turbulence in the air flowing over the gauge rather than downward forcing and measurements closer to the accuracy standard set by the WMO (Landolt et al. 2004). Overall, most gauges benefit from the addition of a wind shield, however, there must be enough room around the gauge to add a sufficiently large wind shield.

Figure 1a. The standard wind shield as set by the WMO at Marshall Field (all photos are courtesy of Marshall Field Winter Weather Group at NCAR).

Weighing Precipitation Gauges

Weighing precipitation gauges measure precipitation amount and rate of accumulation by analyzing the resonating frequency of wires that hold up a bucket inside the gauge. As the weight of the precipitation in the gauge increases, the frequency of the wires will change. A data logger stores the frequencies at set time intervals (usually one minute), allowing for frequent accumulation and rate reports. During snow events, most weighing gauges have a heating element to melt snow and ice to calculate the snow water equivalent. Two types of weighing precipitation gauges being tested at Marshall Field include the Vaisala All Weather Precipitation gauge and the Geonor gauge (Figure 1b). The National Weather Service uses weighing precipitation gauges at all their Automated Surface Observing System sites.

The benefits of weighing gauges are that they are able to measure liquid and solid precipitation events. Also, when a weighing gauge is used with a wind shield, the measurements show accuracy similar to the WMO standards. However, weighing gauges are typically expensive and require a power source for both the data logger and the heating element. Researchers at Marshall Field have also found that snow can accumulate in the funnels leading to the collection bucket causing, inaccurate reports.

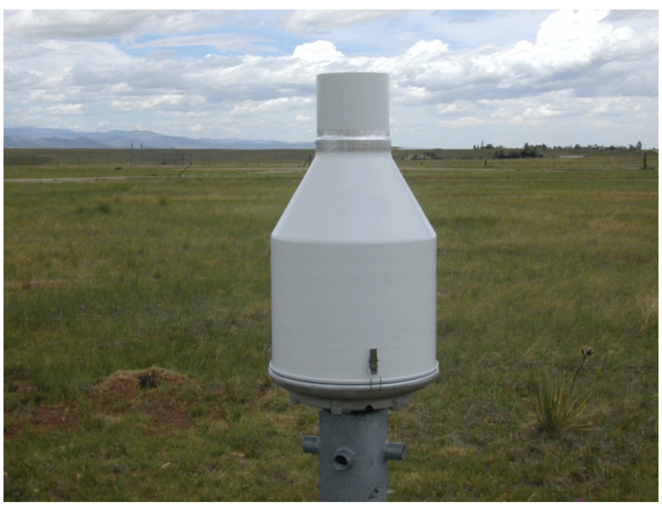

Figure 1b. A Geonor Gauge, which is an example of Weighing Precipitation Gauge.

Tipping Bucket Precipitation Gauges

Tipping buckets work similar to weighing precipitation gauges because they both collect precipitation through a heated funnel leading to a bucket (Figure 1c). Tipping buckets then send the precipitation to one of two smaller buckets. The buckets are on a pivot and work in a see-saw fashion; each time one bucket is filled with precipitation, it is triggered to tip the precipitation into a larger bucket. Each time a bucket is tipped, a sensor records the event. The number of times each bucket is tipped and the amount of time between each tip are used to calculate precipitation rate and total accumulation. The buckets are carefully calibrated to determine how much precipitation will trigger the bucket to tip.

Like the weighing precipitation gauge, the tipping bucket has accuracy similar to the WMO standard when it is used with a wind shield. Tipping buckets need a heating element (or antifreeze) and a power source. However, researchers at Marshall Field have found that tipping buckets freeze more often than other types of gauges during solid precipitation events even with a heating element. Also, if an event ends before a bucket is triggered to tip, that amount of precipitation remaining in the bucket will not be included in the total accumulation. Each bucket holds approximately 0.001 inch of precipitation, so the amount not recorded may be small, but can lead to errors in accumulation.

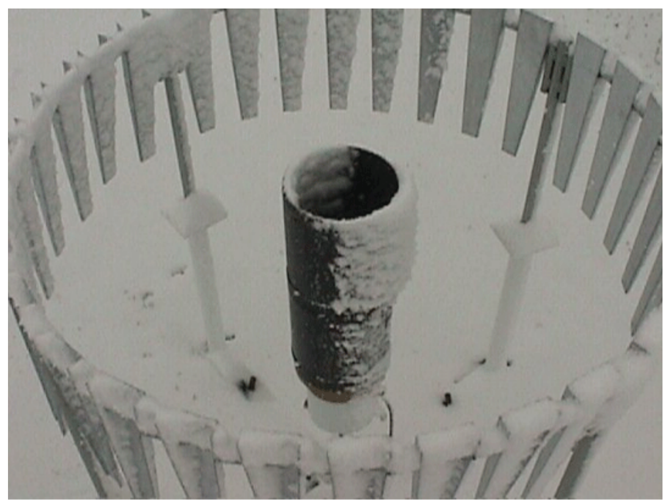

Figure 1c. A Tipping Bucket Precipitation Gauge.

Hotplate Precipitation Gauges

Hotplate gauges consist of two plates, one on top of the other, both heated to 90˚C (194˚F) (Figure 1d). As snow falls onto the top plate, the plate cools. The hotplate gauge then measures the time it takes to evaporate the precipitation off the gauge and heat back up to 90˚C. The bottom plate is heated to the same temperature as the top plate and is able to factor out cooling due to wind. The difference between the power required to heat the top plate compared to the bottom plate is proportional to the precipitation rate. Scientists at Marshall Field are testing several hotplate gauges manufactured by Yankee Environmental Systems, Inc.

On the Web

- For more information about the different types of gauges studied at Marshall Field, visit their web page at: http://www.rap.ucar.edu/projects/winter/sites/MAR1/
  More detailed data about the instrumentation, realtime webplots, and contact information are all available on the web page.

The benefits of hotplate precipitation gauges are that they do not have moving parts, they do not require a wind shield, they do not require anti-freeze, and they provide fairly accurate data as compared to the WMO standards. However, hotplate gauges are expensive, do not always perform as well in high wind events, and they do require a power source.

Figure 1d. A Hotplate Precipitation Gauge.

Conclusion

Accurate solid precipitation measurements are important for determining snowpack and water availability. A wide variety of gauges are tested and developed at NCAR's Marshall Field in order to improve accuracy of measurement. It is important to develop precipitation gauges that are smaller than the WMO standard DFIR wind shield, but most do require some type if wind shield and a power source. With continued research and development at Marshall Field, less expensive and more accurate solid precipitation gauges are being developed. Utilization of these gauges over a wide area and elevation range in the western U.S. can lead to more accurate precipitation measurements, which would be useful for water managers' annual projections and operations.

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Works Cited

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