Snow Measurement Guidelines
for
National Weather Service
Surface Observing Programs

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
National Weather Service
Office of Climate, Water and Weather Services
Silver Spring, MD 20910

September 2013

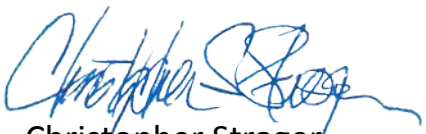
Preface

Snowfall and snow depth and their water equivalent are some of the most difficult, but important, weather elements to measure in an accurate, consistent manner. Snow has a profound effect on the national economy. Large snowstorms can paralyze large metropolitan areas and even isolate entire regions for days, affecting millions of people and resulting in loss if lives and billions of dollars. On the other hand, winter recreational activities that depend on snow generate tens of billions of dollars of revenue and melting western-mountain snowpack provide beneficial moisture for human and agricultural consumption during the summer.

Effective use of snow data can result in more efficient decision making that affects many sectors of our economy, and in the process, save millions of dollars. Snow data are used by a wide variety of users, including National Weather Service (NWS) weather and hydrologic forecasters, climate researchers, water resource managers, construction engineers, plow operators, airport managers, winter resort managers, farmers, and many others.

Given the increasing importance of snowfall and snow depth measurements for the diverse applications noted above, there has been a commensurate increase in the concern for the accuracy and consistency of these measurements that make up the "official" national database.

These guidelines were prepared by the NWS Office of Climate, Water and Weather Services for use by all NWS observing programs. These are meant to clarify previous snow measuring guidelines as well as provide a consistent method of measurement throughout the NWS and that may be used outside of the NWS for other networks.



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September, 2013

Contents

1. General

The following guidelines were developed from previously existing National Weather Service (NWS) procedures, Federal interagency standards, and input from climatologists, snow specialists, weather observers, and data users.

Requirements for making accurate snowfall observations are different than other elements such as temperature and precipitation. Snowfall measurements between the official observation times may be required to make an accurate 24-hour total snowfall measurement.

It is essential for all observers to understand the importance of taking standard measurements in the prescribed consistent manner. Inconsistent observing and reporting methods result in incompatible data that can result in profoundly incorrect differences between stations and observers.

2. Each Season Before the First Snow Falls or Before a Snow Event

Review these instructions for measuring snow. It is easy to forget what needs to be measured, especially in those parts of the country where snow falls infrequently.

2.1. Siting your snow measurement board

At the beginning of each snowfall/freezing season or before the snowfall/freezing precipitation event (in regions of the country where snow rarely falls), remove the funnel and inner measuring tube of the manual rain gauge to expose the outer cylinder so that it can more accurately catch frozen precipitation. Put your snow measurement board (SMB) out and mark its location with a flag or some other indicator so it can be found after a new snowfall. The SMB should be located in the vicinity of your station in an open location. Find an area where wind effects and drifting are minimized and far enough away from buildings or trees where snow blowing off of higher structures is unlikely to fall onto your SMB.

2.2. If an official snow measurement board is not available

If an official NWS snow measurement board is not available you can make your own board following the instructions below. You can also purchase a SMB from a commercial supplier. As a last resort, snowfall observations can be taken without a measurement board on grassy or elevated surfaces using the guidelines described in section 3.1.

To make your own SMB, first acquire a 24 inch x 24 inch piece of plywood. A thickness of 3/8 inch to ½ inch is recommended to reduce the likelihood of having it blow away. For greater durability it is best to use exterior or marine grade plywood. Paint the plywood on both sides and all edges with a flat, white paint.

2.3. Equipment and Siting Review

2.3.1. Make sure your snow measuring equipment is in good working order before the snow season.

2.3.1.1. Snow Measuring Stick – The numbers should be easy to read and marked in measures of tenths of an inch.

2.3.1.2. Rain Gauge (for snow water equivalent) – There should be no cracks or leaks in either the measuring tube or the overflow can. Check for leaks by filling both the outer cylinder and inner tube with water.

2.3.2. Evaluate the exposure of your Snow Board as referenced in Section 2.1

2.3.2.1. Avoid structures and obstructions that could affect the wind patterns in the surrounding area. You should re-evaluate this once the snow has fallen to make sure your observing location is in the best area of snowfall uniformity.

2.3.2.2. Determine a clear and safe path to take snow measurements so the remainder of the area stays as undisturbed as possible.

2.3.2.3. The area should remain clear of snow removal or snow storage activity as snow accumulates.

3. <u>Measuring and reporting solid precipitation</u>

Four values should be measured when reporting solid precipitation. They are:

- *Snowfall:* Maximum amount of new snow that has fallen since the previous observation.

- *Snow Depth:* The total depth of snow (including any ice) on the ground at the normal observation time. The snow depth includes new snow that has fallen combined with snow already on the ground.

- *Snowfall Water Content* (also known as Water Equivalent): The water content of new snowfall since the previous day's observation.

- *Snow Depth Water Content*: The water content of new and old snow on the ground measured by taking a core sample.

Water content measurements are addressed in section 4.

Your observation should be reported via your established reporting method. For example, NWS Cooperative Observers should use WxCoder III or IV-ROCS.

3.1. Snowfall

It is essential to measure snowfall (and snow depth) in locations where the effects of blowing and drifting are minimized. Measuring in a location where snow accumulates uniformly simplifies all other aspects of the observation and reduces opportunities for error. In open areas where windblown snow cannot be avoided, take a number of measurements in different locations to report a representative measurement (typically 3 or more measurements). The multiple measurements should be averaged together to obtain an accurate measure of the snow that fell. The measurements should not include the largest drifts or areas that have had snowfall drastically reduced by the wind. In heavily forested locations, try to find a clearing where snow is free to fall without being caught in the tree canopy.

- Measurements beneath trees are inaccurate because snow can accumulate on tree branches and never reach the ground.
- Areas that are shaded from the sun (e.g., on the north side of building) are acceptable sites for measuring snowfall if winds are not blowing in a direction likely to blow snow off of roofs and artificially inflate the snowfall total.
- If a SMB is not available, snowfall can be measured on the ground. As a last resort measurements can be made on surfaces such as a picnic table or a wooden deck as long as the observing location is not near a building where snow blowing off the roof is likely to accumulate and artificially inflate the amount of snow that fell.
    - Be aware that it is possible that in such locations wind may blow snow off elevated surfaces, which would result in artificially low measurements.
    - Measurements taken on grass can leave air space below the bottom layer of snow, particularly early in the season and when there was no previous snow on the ground. Measuring all the way to the ground can inaccurately inflate the snow depth amount.

Snowfall is the accumulation of new snow and ice (ice pellets [sleet], graupel, snow pellets) since the last observation, prior to melting or settling. Measure snowfall to the nearest 0.1 (one-tenth) inch. The measurement should be made as soon as possible after the snow ends in order to capture how much accumulated.

The observer should be aware that wind-blown snow can accumulate on a SMB even though no snow has fallen. It should not be reported as snowfall. Only report actual snowfall amounts.

3.1.1. Once-per-day snowfall measurements

Observers in networks such as the NWS Cooperative Observer Program network are typically required to take measurements only once per day. The SMB should be cleared at the end of the 24-hour period in preparation for measuring snowfall during the next observing period.

Measure the maximum depth of snow that has accumulated on your snow measurement board (or other approved surface) since the previous snowfall observation. This measurement should reflect the greatest accumulation of new snow observed (in inches and tenths, for example, 3.9 inches) within the past 24 hours even if this total occurs at a time preceding the regularly scheduled observation time.

For example: Snow begins to fall at 10:00 a.m., accumulates to 4.2 inches by 3:00 p.m. and then stops. Ideally, this is when you should measure the snow. The snow begins melting and settling such that by your observation the next morning you only have 2.6 inches of snow on your snow board. The correct number to report for your 24-hour snowfall is 4.2 inches - the accumulation prior to melting and settling.

3.1.2. What to do if you are not available to take measurements throughout the snow event

Due to work or other commitments you may not be available to measure snow when it ends or before your regular observation time. In these cases use your best estimate, based on a measurement of snowfall at the time of observation along with knowledge of what took place in the last 24 hours. Input may be obtained from other people who were near the station during the snow event. If your observation is not based on direct measurement, record in your remarks “snow amount based on estimate.”

3.1.3. How to handle short events or multiple events in a 24-hour period

While acknowledging there is no perfect way of measuring snowfall, the following best practice accommodates the observer while ensuring the best consistency. If the snow event ends well before the end of the 24-hour observing period make the 24-hour measurement at the end of the snow event, if possible. For example if the snow event ends at 1PM, make the snowfall measurement at that time. If snow falls later in the 24-hour period an additional measurement can be made but report only the largest accumulated snowfall total. No matter how many times it snows during the 24-hour period report only the SINGLE highest snowfall amount that accumulated on the SMB. Only clear the snowboard at the end of the 24-hour observing period. If you cannot take a measurement at the end of the snow event, measure it as soon as possible after the event ends and no later than the official observation time. See Figure 1 as an example.

If snow continually melts as it lands and accumulation never reaches 0.1 inches on your measuring surface, record the snowfall as a trace (T), and record in your remarks that the "snow melted as it landed."

Figure 1

3.1.4. Measuring snowfall once every 6 hours

YOUR SERVICING NWS OFFICE WILL LET YOU KNOW IF YOU ARE REQUIRED TO TAKE 6-HOURLY MEASUREMENTS. OTHERWISE ONLY TAKE 24-HOUR MEASUREMENTS.

The following procedures should be followed for observers required to take observations every 6 hours. This is often the case for observers at major airport locations. If you take your observations at this frequency, make sure that you clear your SMB no more frequently than every 6 hours. Record the frequency of observation during the 24-hour period in the comments section of your report. Sum the 6-hour observations to obtain the daily snowfall measurement and report that total at the normal observation time.

Never add more than four 6-hourly observations to determine your 24-hour snowfall total. If you add more than four observations it could inaccurately inflate the snowfall total. Because it is not possible for most observers to take snowfall measurements every hour, this standard practice of providing 6 hours between snowfall measurements during a snow event ensures a standard length of time for snow to settle between measurements and helps ensure consistency and uniformity among stations. Note however that if snowfall stops before the end of a 6-hour period that you should measure the total as the greatest amount, even if it occurs before the end of the 6-hour period.

3.1.5. Special Circumstances

Freezing rain: Glaze ice that forms when liquid precipitation freezes on contact with the surface should never be reported as snowfall. This precipitation should be reported as liquid precipitation.

Measuring windblown snow: In open areas where windblown snow cannot be avoided, several measurements in areas away from your normal observing location will be necessary to obtain an average depth. The measurements should not include the largest drifts or artificial snow piles (e.g., from snowplows or shoveling near cleared walkways or driveways), nor should they include areas that have been scoured clean by the wind. The goal is to obtain a representative measurement of the average depth of new snowfall.

Mixed Precipitation: If snow or sleet is mixed with rain and doesn't actually accumulate on the ground, report the melted precipitation in the gauge as the daily precipitation, and a Trace of new snow. Make a note in remarks “snow and sleet mixed with rain but melted as it landed”.

If snow and rain are mixed and there is snow that accumulates, report the precipitation (melted) in the gauge as your daily precipitation, and report the maximum accumulation of the new snow as Snowfall. If the snow is likely to melt before the official observation time, it is best to measure the depth of the new snow as soon as possible after the snow ends before it has a chance to melt. Be sure to include that you had mixed precipitation in your comments.

In some situations you may have measurable snow of a couple of tenths, but the snow in the rain gauge only melts down to a Trace. This can happen when the snow is very dry and/or it is windy. Note that if you observe any amount of snowfall, even a trace, you must report at least a trace of precipitation.

3.2. Snow Depth

Snow depth measurements are taken as long as there is snow on the ground. Determine the total depth of snow, sleet, or ice on the ground. This is a combination of snowfall (if snow has fallen

during the observing period) and snow that was already on the ground. This observation is taken once a day at the scheduled time of observation with a measuring stick. Sometimes it is taken by measuring the total depth of snow on exposed ground at a permanently mounted snow stake.

3.2.1. Making the most accurate snow depth measurements

Very often, snow depth needs to be determined by using a measuring stick to take, and then average, several depth readings. This is generally done within 100 yards (300 feet) of the official observing location and is often necessary because snow depth can vary in the vicinity of an observing location due to shaded and non-shaded areas, and because wind-blown snow can create areas of greater and lesser depth*.

In addition, in hilly or mountainous terrain you will be faced with the situation where no snow is observed on south-facing slopes while snow, possibly deep, remains in shaded or north-facing areas. Under these circumstances, you should use good judgment to visually average and then measure snow depths in exposed areas within several hundred feet surrounding the weather station. For example, if half the exposed ground is bare and half is covered with 6 inches of snow, the snow depth should be entered as the average of the snow readings, or 3 inches.

- When, in your judgment, LESS THAN 50 PERCENT of the exposed ground is covered by snow, even though the covered areas have a significant depth, the snow depth should be recorded as a trace (T). Make a note of the range of depths of the remaining snow in the comments.
- When no snow or ice is on the ground in exposed areas within 100 yards (300 feet) of your normal observing location, record a “0”.
- When strong winds have blown the snow, take several measurements where the snow was least affected by drifting and average them. If exposed areas are blown free of snow while others have drifts, again try to combine visual averaging with measurements to record your representative value for snow depth. (noting that if more than half of the ground is snow-free only a trace should be reported)

* Measurements should not be taken from rooftops, paved areas, or other surfaces that are likely to be warmer than natural surfaces.

3.2.2. Properly reporting snow depth

When using a measuring stick, make sure the stick is pushed vertically into the snow until the bottom of the stick rests on the ground. Do not mistake an ice layer or crusted snow as ground. The measurement should reflect the average depth of snow, sleet, and glaze ice on the ground in areas not disturbed by human activities (e.g., no artificial piles of snow).

Be aware that measurements taken on grass can leave air space below the bottom layer of snow, particularly early in the season and when there was no previous snow on the ground. Measuring all the way to the ground can inaccurately inflate the snow depth amount. If you suspect this may have occurred, carefully clear a small patch of snow away so you can see the snow layer on top of the grass. Measure from the bottom of the snow layer to the top of the layer. You may have to repeat this in several areas to obtain a representative snow depth.

After you have made your snow depth measurements, average the measurements to obtain a single number for snow depth. Report snow depth to the nearest whole inch, rounding up when one-half inch increments are reached. For example: 0.4 inches of snow on the ground should be reported as a trace (T), 1.3 inches should be reported as 1 inch, 3.5 inches should be reported as 4 inches. Be aware that when taking measurements over grassy surfaces that air space might be present within the grass. If necessary reduce the snow depth reading by an appropriate amount.

3.2.3. Special Circumstances

At times an ice layer may form on the top of snow. In such circumstances creativity may be needed to make a snow depth measurement. Some observers have resorted to the use of a saw to cut through the ice. Personal safety is paramount. If attempted, personal protective gear should be worn.

4. Measuring and reporting the water content of snowfall and snow depth

Forecasters need to know the amount of the water content of new snowfall. They also need to know the water content of the total snow on the ground. Measurements of the water content of snowfall are taken once per day at the normal observation time when snow has fallen within the past 24 hours. Measurements of the water content of snow depth are taken as frequently as once a day to no less often than once a week. Your servicing NWS office will provide guidance on when to take snow depth water content measurements. The precipitation gauges referred to in the following are assumed to be either the 8-inch or the 4-inch diameter models. Both have the same component parts, e.g. funnel, inner measuring tube, and outer cylinder.

4.1. Snowfall Water Content

This measurement is made by melting the snow that has fallen in the precipitation gauge and measuring the liquid as is done for rainfall.

Water content also can be measured by taking a core sample of the snowfall from the SMB or other measurement surface. When all the precipitation fell as snow and was not subject to melt, measurements from core samples often provide a more accurate measure than those based on snow that accumulated within the precipitation gauge, particularly when snowfall was

accompanied by windy conditions (section 4.1.2). Observers are encouraged to take core samples unless the snow on the board is not representative of the actual amount that fell (e.g., if melting has occurred since the snow stopped falling or when mixed precipitation fell and caused snowmelt from the board).

4.1.1. Making water content measurements of snowfall

Measure the water content of snowfall since the previous day's observation. Melt the contents of your gauge using either of two acceptable methods.

1. Add a measured amount of warm water to melt the snow in the gauge. (Make sure you accurately measure the amount of warm water added before pouring it into the gauge by using the inner tube and rain measuring stick as described below.) Then, when you take your liquid measurement as described below, subtract the amount of warm water added from the total liquid measurement to get your final liquid water content of the snowfall, or

2. Bring the gauge inside your home and wait until the snow melts.

Following action 1 or 2 above, pour the liquid through the funnel and into the smaller inner measuring tube. Measure the amount to the nearest .01 inch just as you do when measuring rainfall (use the NWS-provided measuring stick when observing with an NWS 8-inch rain gauge). Do not measure the melted precipitation directly in the large outer cylinder of the gauge. Make sure the inner measuring tube cannot fall over when pouring the liquid back into it. If the melted water (including any added warm water) cannot fit into the measuring tube all at one time, empty the full measuring tube (after recording the liquid total) then pour the remaining liquid from the large outer cylinder into the emptied measuring tube. Add the multiple measurements of water content and report as precipitation.

4.1.2. Taking a core sample of snowfall

As winds increase, gauges collect less and less of the precipitation that actually falls. Generally speaking, the stronger the wind and the drier the snow, the less is captured in the gauge. If you believe the snow that fell did not fully accumulate in the gauge you can measure the water content by taking a core sample of snow from your SMB. Or, if you have determined your snowfall average from a location other than your SMB, take the core sample from a spot in the vicinity of your snowfall measurement. If necessary take measurements from several locations and average them to make a representative observation.

Start with a clean and empty outer cylinder. Use the outer cylinder to take a sample of new snowfall from your SMB or other observing location. This is sometimes referred to as "take a

core" or "cut a biscuit". Follow the procedures described in Section 4.2.1, 'Procedures for Taking a Core Sample'.

4.1.3. Reporting snowfall water content

After the core sample is collected, the snow melted, and the liquid amount measured following the procedures described above, compare the total measured from the snow in the gauge with the total from the core sample and report the highest total as precipitation. Put the lower value in Remarks.

4.2. Snow Depth Water Content

This measurement is made by taking a core sample of snow, melting the snow, and measuring the amount of liquid. This is similar to the procedure for measuring water content of snowfall, but it involves taking a core sample from the total snow on the ground (new snow that has fallen within the past 24 hours plus any old snow remaining on the ground). In areas of the country where snowpack continues to build during the winter this becomes more difficult as the amount of snow on the ground increases and ice layers begin to form at the bottom or within the snowpack.

4.2.1. Procedures for Taking a Core Sample

A common but difficult method for collecting a core sample of snow is to invert the outer cylinder of your rain gauge. It is far easier to obtain a core reading using a 4 inch diameter gauge, especially if the snow depth is less than 20 inches. If an 8 inch gauge is used for official observations, a 4 inch gauge can still be used to take core samples.

Take a core sample after you have measured snow depth from the same location. For example, if you determined the total depth of the new snow is 4 inches, then take your core sample from an area where the depth of new snow is 4 inches.

Capture a core by inverting the outer gauge cylinder and pushing straight down into the snow.

Use something thin and sturdy to slide under the cylinder (e.g., aluminum flashing, spatula, clip board). Then melt and measure the snow collected in accordance with Section 4.1.1.

A core sample can also be taken by the same method listed above using the inner 2-inch gauge of an 8 inch gauge. However, the measurement of the water can only be taken to the nearest 0.1 inch.

Reporting water content snow depth

The water content of the snow depth will be reported in accordance with the directions provided by the observing program you are reporting to.