Tipping Bucket Assembly for Snow Lysimeters

Installation and Use

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Introduction

The **snowmetrics** tipping buckets were designed and manufactured to provide the best available event runoff data over a long period of time. The tipping bucket mechanism consists of a double catchment bucket system held between two plates that allows continuous filling and dumping of flow while counting the number and registering the time stamp of the known collection volume. A funnel on top of the apparatus collects the flow and directs it into the empty side of the bucket. When the first side fills to a critical volume, the weight of the collected fluid causes the mechanism to tip away from the center of the funnel and this side spills its load. The other side of the bucket mechanism immediately begins to fill and the process repeats. When either bucket tips, a magnetic reed switch temporarily closes and an event logger records the time stamp of each switch closure. Water from the spilling bucket simply falls to the enclosure floor and is routed out of the structure via a subterranean drain.

The buckets are of adequate size to handle maximum snowmelt rates in a variety of snow climates, but must also be sized for the collection pan. We have found that the bucket size we use (approximately 500 cc or 0.5 L) is well suited to most snowmelt applications in maritime and continental snow regimes.

Materials and construction

All materials are selected to minimize metal corrosion through galvanic action common in moist environments. The bucket and axel are constructed with 304 stainless steel, the support structure is 6061-T6 aluminum, and all fasteners are solid brass or stainless steel. These metals work well in wet places and work well together. Axel bushings are plastic or nylon to maximize smooth movement and resist wear and corrosion. Figure 1 shows a tipping bucket assembly with labeled parts, less the funnel apparatus.

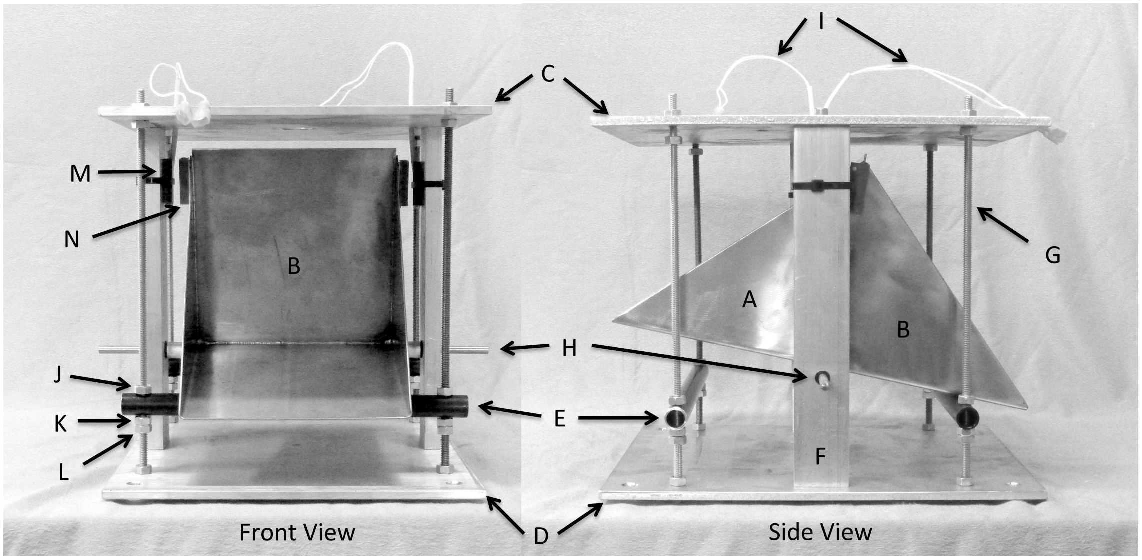
Critical joints in the bucket assembly are all welded, checked for weld quality, and leak tested. All other materials and construction are designed well above the needed specifications for the application to ensure long life and robust data collection. Some of these units have been in use in harsh environments for over a decade without failure.

Maintenance

These **snowmetrics** tipping bucket units should require very little maintenance. Annual cleaning is a good idea, particularly if the collection pan supplying melt water collects and transfers dirt, vegetative matter, or other debris. A toothbrush and warm, soapy water are adequate. Do not use solvents. Make sure the bucket unit moves freely. Balance it in the center, then be sure that very little pressure will cause a tip in either direction. Make sure there is nothing sticky or adhesive accumulating between the bucket bottom and the stop bar.

The reed switch (Figure 1, M) is the most likely point of failure, although these too should last for many years. Two reed switches are mounted on each tipping bucket assembly to reduce the chances of data loss. Experience has shown that redundancy is a good idea due to occasional logger failure, rather than tipping bucket or switch failure. If you do need to replace the switches, they can be found at local hardware stores or electrical shops. Cut the zip tie, peel the old switch off, clean the surface, and apply a new sticky back to mount the replacement. Make sure both the magnet and the reed portion of the switch are aligned properly. Replace the zip tie as an added precaution. Be sure that the switch is oriented with the wires pointing downward.

Freezing may destroy the bucket assembly. In particular, if significant water is allowed to freeze *in situ* in the buckets, the welded seam that seals the back wall divider into the bucket assembly may be compromised. Every attempt should be made to *not* allow water to freeze in the buckets.



A. Tipping bucket – side A
B. Tipping bucket – side B
C. Top plate
D. Bottom plate
E. Stop bars
F. Support arm
G. Support rods
H. Bucket axel
I. Wires to event logger
J. Top lock nut
K. Stop bar adjusting nut
L. Bottom locking nut
M. Reed switch
N. Magnet

Figure 1. Tipping bucket assembly – front and side view, without funnel assembly.

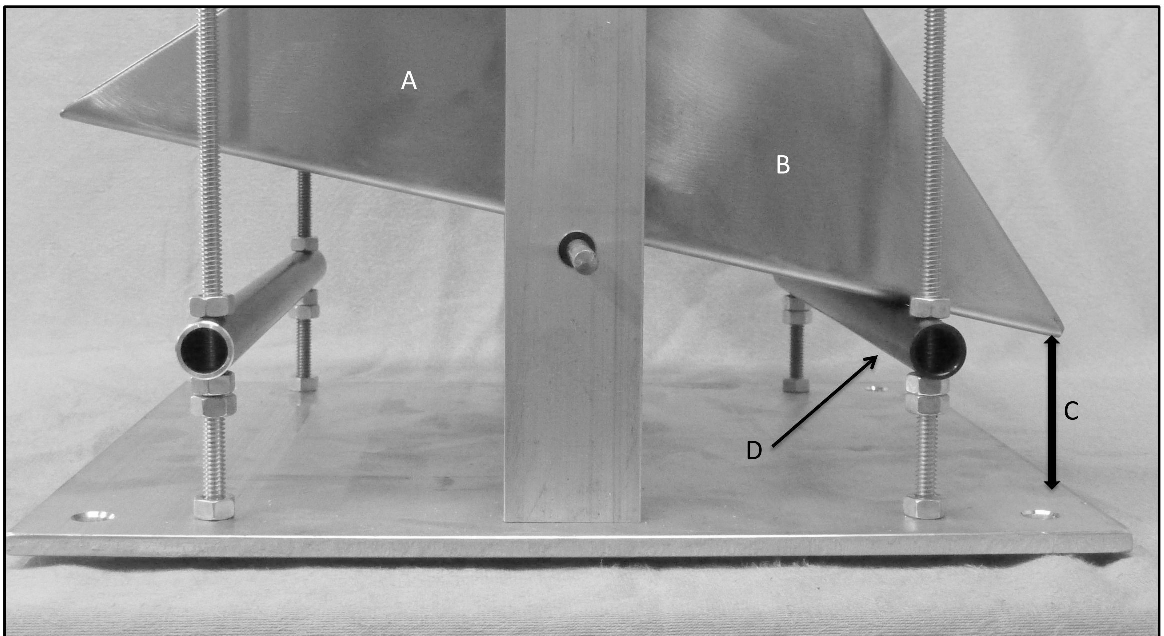
Tipping bucket assembly

The **snowmetrics** tipping buckets come preassembled with the exception of the collection funnel. The funnel unit has two parts; the collector and the threaded bushing that holds the funnel in place. Teflon tape should be applied to the bushing threads before assembly. Place the funnel over the large hole in the top plate and thread the bushing from the bottom side of the top plate into the funnel unit. Tighten the bushing as tight as possible by hand, then a couple more turns holding the bushing with channel locks or vise grips. Be very careful not to crush the bushing with the tools – it is just plastic!

The buckets can be adjusted to a desired tip volume between 250 and 600 cc. We adjust the assembly to have an approximate tipping volume of 500 cc. Depending on your application, you should check the initial calibration and adjust it to your need in your indoor laboratory before installing in the field. Note that you should do a careful check on the actual tipping volume once final installation is completed.

Adjusting bucket volume

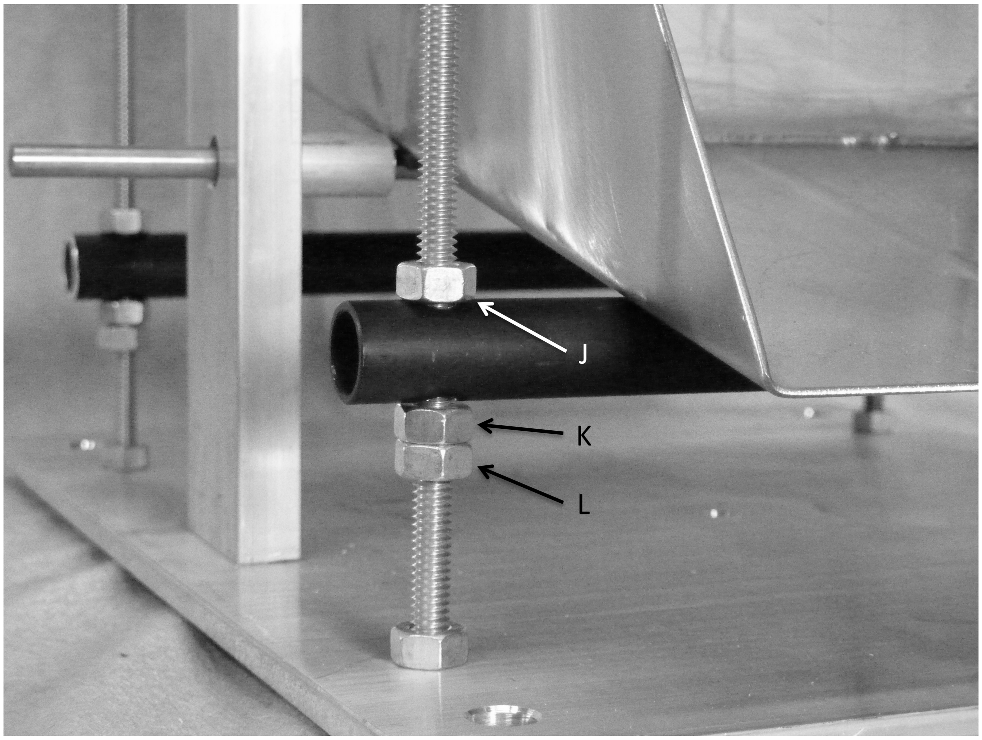
The tipping bucket volume is adjusted by raising or lowering the stop bar. This adjustment is accomplished by moving the brass nuts on the support rods upward or downward. Note that adjusting the stop bar on the opposite side of the bucket in question controls the volume, e.g. raise or lower the stop bar on side B to control the tipping volume on side A (Figure 2). Before moving the stop bar, loosen the top locking nuts on the stop bar support rods (Figure 3, J). Then unlock the two nuts below the stop bar (Figure 3, K and L), using two wrenches to separate. Note that if you try to move the lower nuts with one wrench, without unlocking them, you will destroy the threads on the brass support rods and further adjustment will be impossible. Loosen the nuts to the appropriate heights, move the stop bar, snug the nut on top (J) and bottom (K) of the stop bar and check your calibration. If the calibration volume is not correct, repeat adjustments and measure volume again. If it is correct, carefully tighten the bottom lock nut (L) against the adjustment nut (K) and snug the top nut (J) downward on the top bar. Do not over-tighten any of the nuts. Brass is, by nature, a soft metal and you will compromise the nut or the rod threads if you are too vigorous. The height of the stop bar is not likely to be the same on both sides of the assembly for similar tipping volumes because the axel position on the bucket is approximate and the exact side-to-side weight on the bucket will differ between sides.



A. Bucket, side A
B. Bucket, side B
C. Critical height for bucket A volume adjustment
D. Stop bar for bucket A volume adjustment

Figure 2. Stop bar and buckets. Distance C controls volume in bucket A.

Note that it is very difficult to get exact volume (e.g. 500 cc). More likely, your volume will differ slightly. For most applications, this does not matter as you will be integrating the rate over time and the cc volume is irrelevant as volumes accumulate (liters/hour or liters/day). It is however, important to know the volume that is accumulated for each tip, and it is important to know how many tips occur.



J. Stop bar upper lock nut
K. Stop bar adjustment nut
L. Stop bar lower lock nut

Figure 3. Detail of stop bar adjustment and locking assembly.

Calibrating bucket volume

Tipping volume can be measured for calibration by two simple methods. Both of these methods should allow you to determine the tipping volume with an error of plus or minus 5 cc, if you take 5-10 measurements for each side and use the mean value. This should be performed twice a year – once near the beginning of the melt season and again at the end of flow. If you suspect that the assembly has moved for any reason, check the calibration. It is a good idea to mark both buckets with an A and B, or 1 and 2, so you can keep track of which is which.

Method 1 – Volume
Use a graduated cylinder to pour the bulk of the volume into the bucket, and then add additional volume with a 50 cc or 60 cc syringe capable of accurately measuring small volumes. For example, if you want to calibrate to a 500 cc tipping volume, fill the bucket with 450 cc of water from the graduated cylinder, and then slowly add another portion with the syringe, carefully noting the actual volume necessary to create the tip. Adjust the stop bar height if necessary to change the tipping volume.

Method 2 – Weight
Carefully collect the bucket discharge in a Ziploc bag when it tips and weigh the bag (remove the tare weight of the Ziploc). Remember that 1 cc weighs 1 gram and then calibration is very straightforward.

If you wish to change the tipping volume significantly, use the graph in Figure 4 to obtain a rough adjustment, then follow detailed adjustment procedures and calibration outline above. The equation for approximate calibrations is:

$$V = -108\,H + 800$$

where V is bucket volume (cm^3 or cc), and H is height (cm) from base plate to opposite-side bucket lip (see Figure 2). The coefficients have been rounded to a reasonable number of significant digits and for the intended approximation. To solve this equation for the height to produce a specific volume:

$$H = \frac{800 - V}{108}$$

The exact mathematical relationship between V and H will change for each bucket assembly due to geometry and balance of each unit. These equations and the graph in Figure 4 are useful for approximate settings, but careful calibration through fine-tuning is needed for each unit.

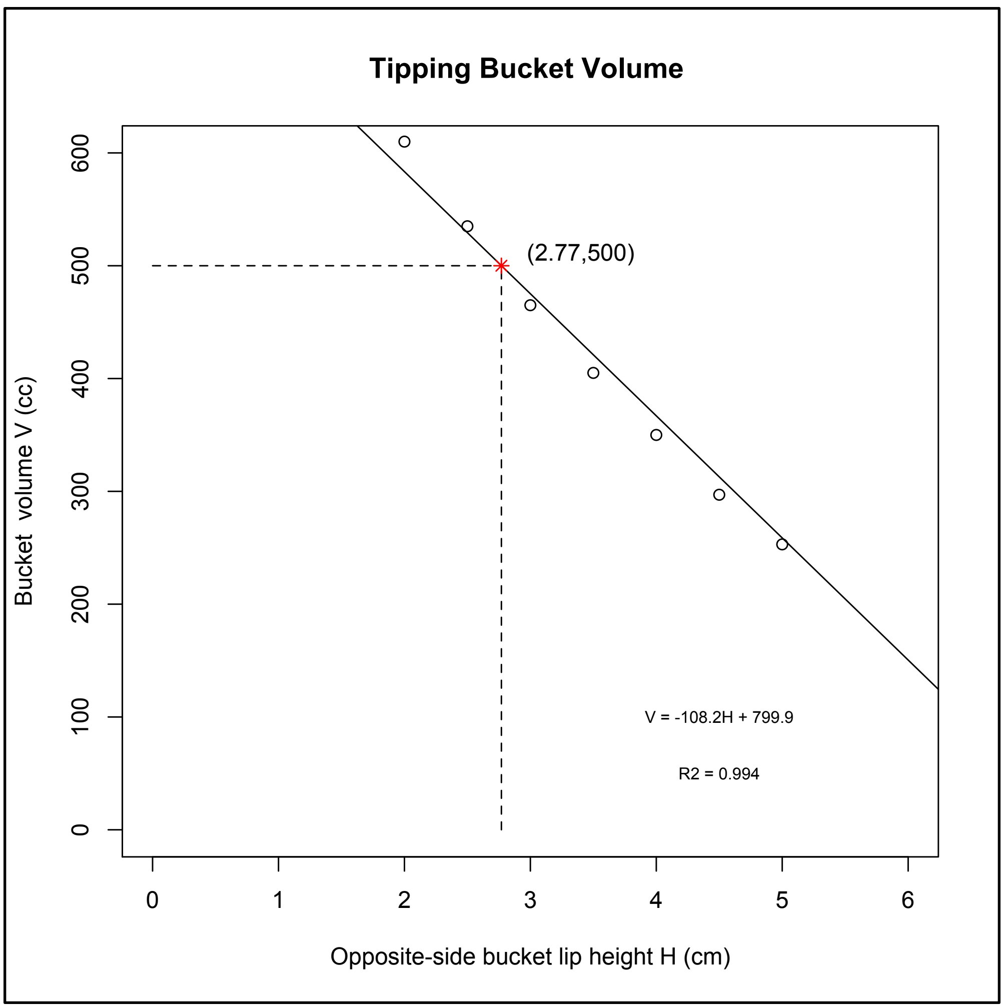


Figure 4. Bucket volume versus opposite-side bucket edge height.

Installing a ground plate

There are many different configurations and structures that can be used for mounting the tipping bucket assembly in place. We will refer to them generically hereafter as the “ground plate”, although they may have no resemblance to a plate.

The most important aspect of the ground plate is that it should be as immobile as possible. Neither vertical nor horizontal displacement is acceptable and both may compromise measurements. Loose or wiggly structures also seriously degrade measurements. A concrete pad would be the best scenario, but is seldom feasible for field installations. Driving metal stakes or rods into the ground is a good alternative, coupled with a firmly attached structure to which one mounts the tipping bucket assembly. Attempt to drive stakes or rods to a point below the freezing depth in the soil. The structure can be a well-fabricated wooden or welded metal frame. The ground plate should shed water unimpeded. Note that the ground plate itself does not need to be level. However, it should be as level as is reasonably possible. Final leveling is done by fine-tuning the tipping bucket assembly using the mounting or leveling studs (detailed below).

One design is shown in Figure 5. To mount this unit, place it on the flat ground surface, place the metal rods in the rod tubes, pound each one in as far as needed or possible, slide the frame up the rods to the desired height. Fix in place with the set bolts. Check for level and readjust if necessary. Mount the tipping bucket assembly to the frame as detailed below.

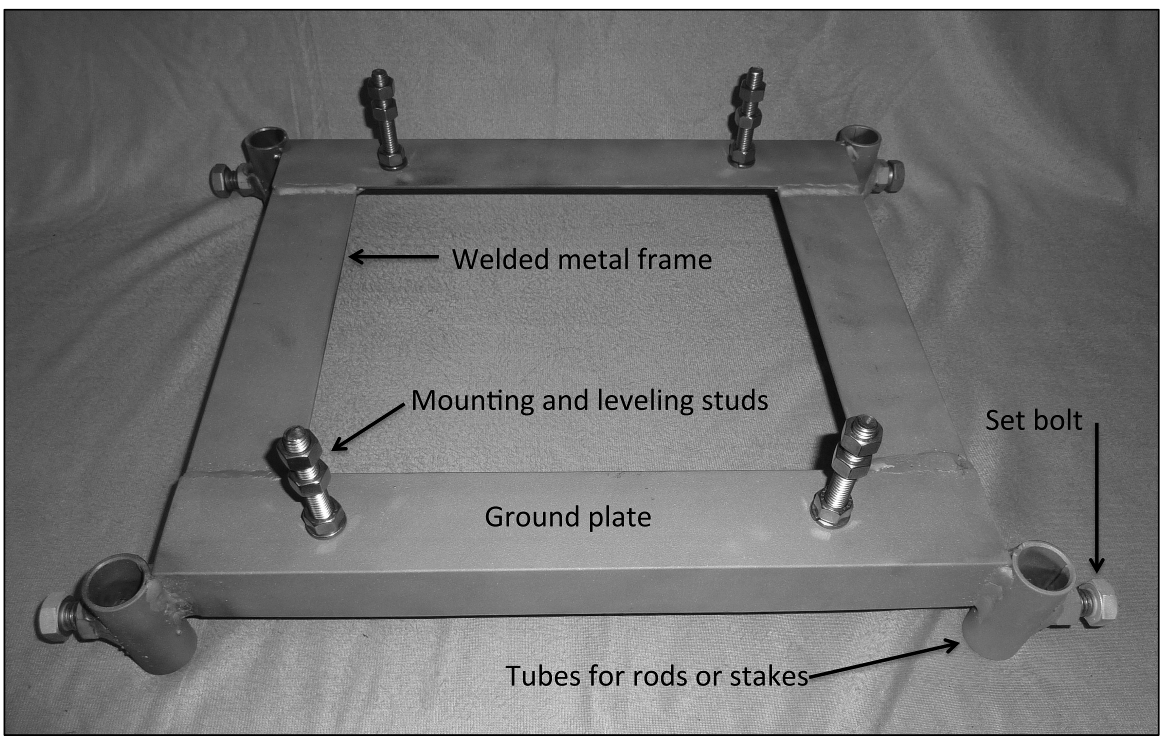


Figure 5. Ground plate for tipping bucket assembly.

Mounting and leveling the tipping bucket assembly

Mount the tipping bucket assembly on the ground plate using the four 3/8" holes in the corners of the base plate. Stainless steel bolts with fully threaded shanks work well for this purpose. Mount the bolts as shown in Figure 6. If the studs are mounted to a wooden ground plate, use large washers on both sides of the wood to minimize movement and adjustment problems. The lower nut (R) in Figure 6 locks the adjustment stud in place, the middle nut (Q) levels the tipping bucket unit, and the top nut (P) locks the tipping bucket unit in place once it is leveled.

1) Tighten all four R nuts,
2) adjust all Q nuts so the unit is level using a bubble level,
3) tighten all P nuts to lock the unit in place after final adjustment, and
4) recheck the level on unit, and repeat adjustment if necessary.

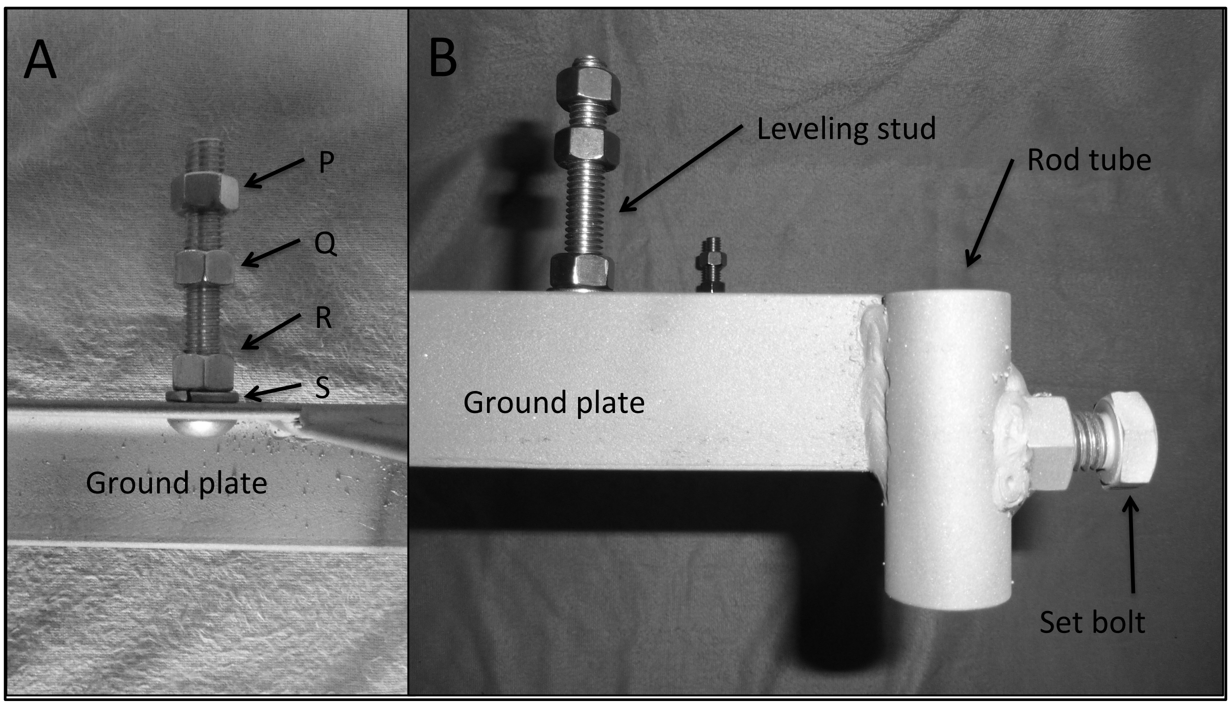


Figure 6. Detail of ground plate: A) Leveling stud with lock washer (S), bottom lock nut (R), leveling nut (Q), top lock nut (P); B) rod tube and set bolt to attach ground plate to ground support rods.

Keeping your unit level is probably one of the easiest and most important parts of collecting quality data. Bubble, or bull's eye, levels are inexpensive, accurate, and perfect for this application. Place a bubble level on the top plate close to one of the vertical support arms, as this is likely to be the most level portion of the unit (Figure 7). Minor deformation may occur in the top plate closer to the ends and corners so these areas may not be level. It is suggested that the level is checked at least twice a year to see if mounting settlement or any other disturbance causes problems in the orientation. Check and adjust if necessary. It is worth just leaving a bubble level on each unit all the time as a quick regular check can be performed with each visit to the site.

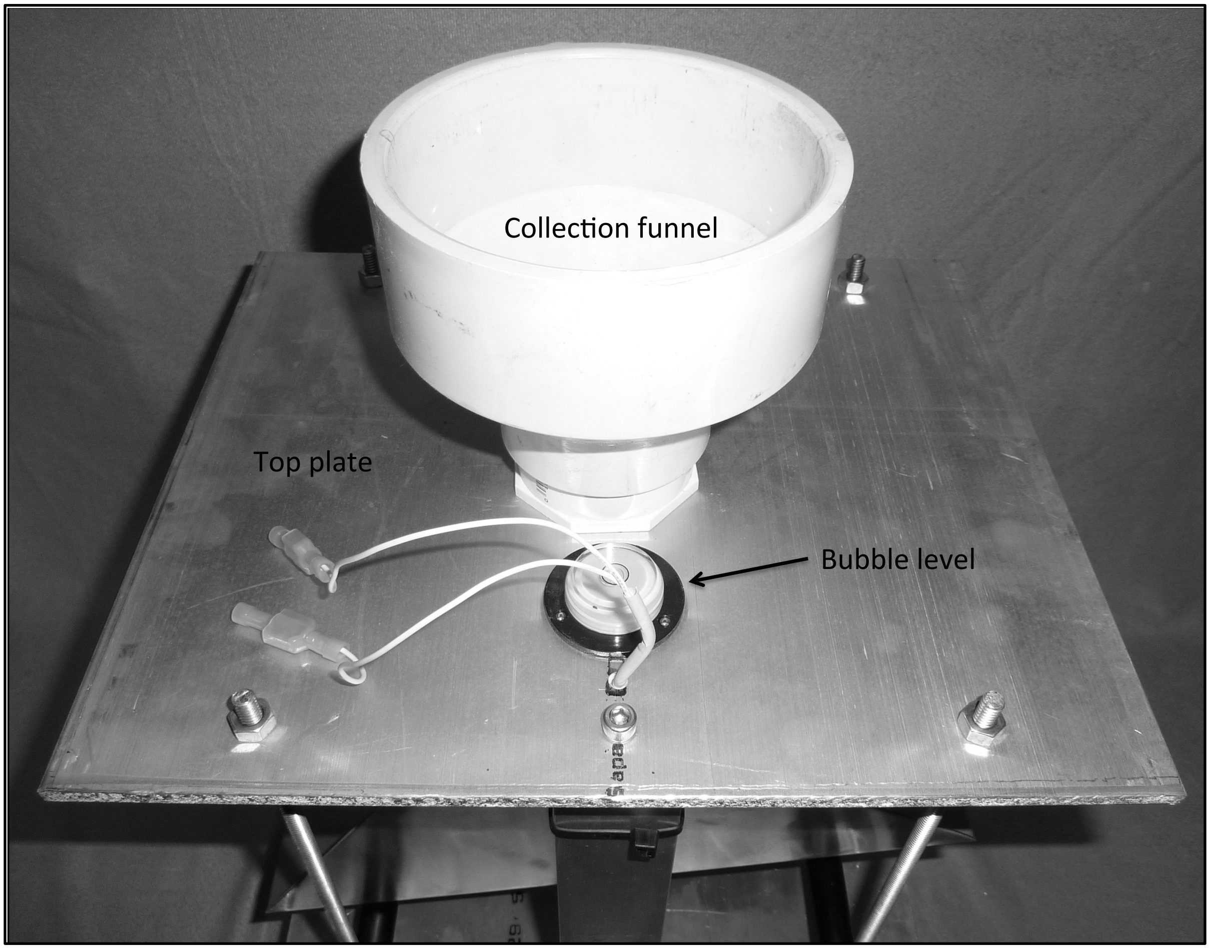


Figure 7. Proper bubble level placement for leveling tipping bucket assembly.

Data loggers or event counters

The tipping bucket assembly is pre-wired and ready to hook up to a data recorder. Spade connectors are included for easy installation and to allow removal of the event logger or data logger without needing to rewire the entire unit. Pairs of like terminals (male or female) are found on each reed switch so the same side is always hooked up to the same event logger or channel on the data logger. Simple event loggers may be used with the snowmetrics tipping bucket assembly. Alternatively, if a data logger is available or close at hand for other reasons, such as a meteorological station, events may be recorded using the logger by including the correct code in the logger's program. Contact the manufacturer of your data logger for details.

Data processing

Examine time series data plots carefully. Rapid melt rate with a 5 m^2 collection pan will fill a 500 cc bucket in approximately 40 seconds. If the data show double tips, that is tips very close together in time, it is necessary to filter the data to get rid of the second false tips. A simple filtering algorithm that examines at the differences in the time stamps will allow proper removal of bad data. Set the threshold to 30 seconds or less, based on your observations of maximum tip rates at your site. Any repeat tips (events) that occur under the threshold time are bogus and are removed. Fluctuation or vibration of the reed when the magnet passes by the reed switch causes this problem. We have not found an inexpensive switch that alleviates this problem completely. It is important to beware of the issue and correct for it.

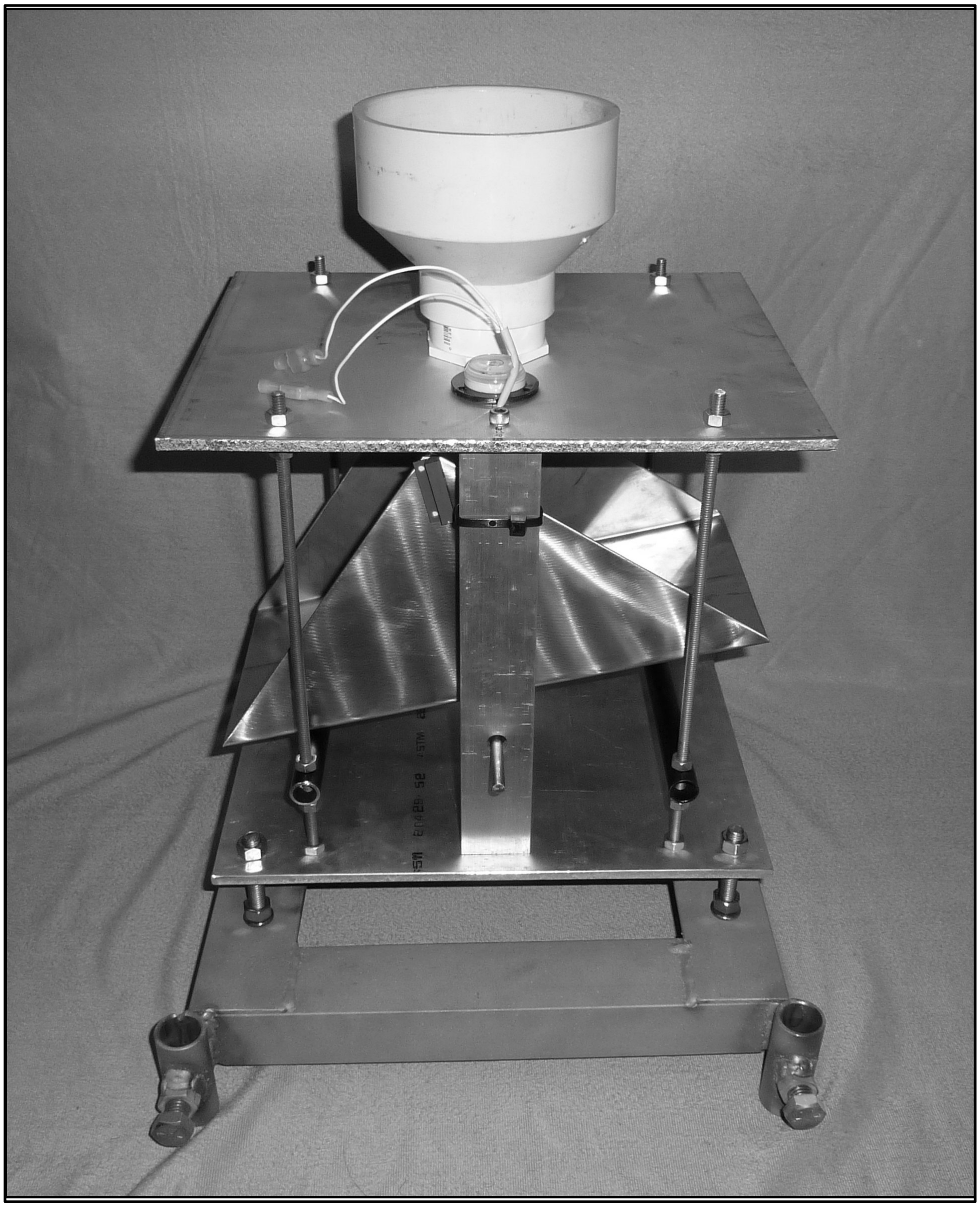


Figure 8. Final tipping bucket assembly with funnel unit and ground plate attached.

Tools needed for installation

Tipping bucket assembly

Bubble level
7/16" wrench (two of these)
Teflon tape

Ground plate assembly

6 lb sledge hammer
Wrenches or tools to secure plate to ground rods
Shovel