Manual Snow and Weather Observations

1.1 Introduction

Manual observations of snow and weather conditions are an important part of an avalanche forecasting operation. This chapter describes methods for making and recording these observations. Section 1.2 describes observation objectives. Section 1.3 outlines the recommended standard morning snow and weather observation. Sections 1.4 through 1.6 give important background information for planning and implementing observational schemes, Sections 1.7 and 1.8 discuss field observations, and Sections 1.9 through 1.27 describe how to observe and record individual parameters.

1.2 Objectives

Snow and weather observations represent a series of meteorological and snow surface measurements taken at a properly instrumented study plot or in the field (refer to Appendix D - Observation Sites for Meteorological Measurements). Observational data taken at regular intervals provide the basis for recognizing changes in stability of the snow cover and for reporting weather conditions to a meteorological office or regional avalanche center.

Sustained long-term data sets of snow and weather observations can be used to improve avalanche hazard forecasts by statistical and numerical techniques. They also serve to increase climatic knowledge of the area. Observations should be complete, accurate, recorded in a uniform manner, and made routinely. Following an established protocol increases the consistency in the data record, reduces error, and increases the potential for useful interpretation of the data.

Figure 1.1 Alpine weather station in the Colorado Rocky Mountains (photograph by Kelly Elder).

1.3 Standard Morning Snow and Weather Observation

Operations that include an avalanche forecasting program typically observe and record a set of weather and snow parameters daily. These observations should be made at about the same time each day and between 4 am and 10 am local standard time. Many operations will need to observe these parameters more than once per day. A set of suggested fields to observe and record, and a brief explanation are listed below. Detailed information on each of these parameters is available in the sections that follow. Sections that are marked with a ✧ contain information on the parameters listed below. An example record sheet appears in Figure 1.2.

1) *Observation Location*– record the location of the observation site or nearest prominent topographic landmark (mountain, pass, drainage, avalanche path, etc.), political landmark (town, road mile, etc.), or geographic coordinates (latitude/longitude or UTM). If the measurements are made at an established study site, record the site name or number.
2) *Elevation* (ASL)– record the elevation of the observation site in feet (meters) above sea level.
3) *Date* – record the date on which the observation is being made (YYYYMMDD).
4) *Time* – record the local time on the 24-hour clock (0000 – 2359) at which the observation began.
5) *Observer* – record the name or names of the personnel that made the observation.
6) *Sky Conditions*- record the sky conditions as Clear, Few, Scattered, Broken, Overcast, or Obscured (Section 1.12).
7) *Current Weather* – record the precipitation type and rate using the scale and data codes in Section 1.13.
8) *Air Temperature* – record the 24-hour maximum, minimum, and current air temperature to the nearest 0.5 °C (or whole °F) (Section 1.14).
9) *Snow Temperature 20 cm* (or 8 in) – record the snow temperature 20 cm (or 8 in) below the snow surface (Section 1.17).
10) *Surface Penetration* – record the surface penetration to the nearest whole centimeter (or 0.5 inch) as described in Section 1.18.
11) *Total Snow Depth* – record the total depth of snow on the ground to the nearest whole centimeter (or 0.5 inch) (Section 1.20).
12) *24-hour New Snow Depth* – record the depth of the snow that accumulated during the previous 24-hours to the nearest whole centimeter (or 0.5 inch) (Section 1.21).
13) *24-hour New Snow Water Equivalent* – record the water equivalent of the snow that accumulated during the previous 24-hours to the nearest 0.1 mm (or 0.01 inch) (Section 1.22).
14) *24-hour Liquid Precipitation*- record the depth of the liquid precipitation that accumulated during the previous 24 hours to the nearest 0.1 mm (or 0.01 inch) (Section 1.24).
15) *Wind Direction* – observe the wind for at least two minutes and record the average wind direction or use an automated measurement. Record wind direction as N, NE, E, SE, S, SW, W, or NW. If an automated measurement is used, record to the nearest 10 degrees (Section 1.26).
16) *Wind Speed* – observe the wind for at least two minutes and record the average wind speed using the indicators in Section 1.26, or use an automated measurement.
17) *Maximum Wind Gust*- observe the wind for at least two minutes and record the speed of the strongest wind gust, or use an automated measurement. For an automated measurement record the time that the wind gust occurred (Section 1.26).

1.4 Manual versus Automated Observations

Observation networks for avalanche forecasting programs usually involve at least one set of manual observations and one or more automated weather stations. Manual observations can be used to maintain a long-term record and observe and record data not amenable to sensing by automated systems. Automated observations provide unattended continuous weather (and some snowpack) information about a certain region or regions within a forecast or ski area. Automated weather stations can be co-located at study sites where manual weather observations and/or snowpack observations are collected. Programs that maintain a study plot should use data from automated weather stations to augment and not replace manual observations. The following chapter discusses how to make and record manual observations. Details regarding automated snow and weather observations appear in Appendix E.

1.5 Time Periods for Manual Snow and Weather Observations

Observations taken at regular daily times are called *standard observations*. Manual observations are typically carried out in 24-hour, 12-hour, or 6-hour intervals. Data collected at 6-hour intervals beginning at 0000 hours Greenwich Mean Time (also termed Coordinated Universal Time (UTC) or Zulu time (Z)) will conform to climatic data sets. Avalanche forecasting operations typically make two standard observations each day at 0700 and 1600 hours local time, when a 12-hour interval is not possible. The type of operation and availability of observers may necessitate different frequencies and times. In regions that observe Daylight Savings Time, schedules should be adjusted so that the observation time does not change (i.e. use local standard time when recording observations). If observations are made on a 24-hour interval, it is best to make that observation in the morning.

Observations taken between the standard times are referred to as *interval observations*. They are taken when the snow stability is changing rapidly, for example, during a heavy snowfall. Interval observations may contain a few selected observations or a complete set of observations.

Observations taken at irregular times are referred to as *intermittent observations*. They are appropriate for sites that are visited infrequently; visits will typically be more than 24 hours apart and need not be regular (i.e. in a heli-ski operation). Intermittent observations may contain a few selected observations or a complete set of observations. In highway operations, intermittent observations often include *shoot* or *storm* observations to coincide with timing of avalanche control missions or the start and end of particular storm cycles (see Figure 1.2 for sample of field book entry).

It is common for avalanche forecasting operations to collect information for an individual storm event. Observations of snowfall, temperature changes, wind direction and speed, and avalanche activity can be observed for a particular *storm unit*. A storm unit is typically a qualitative increment based on precipitation rates or meteorological events. Operations that choose to use a storm unit may also find it useful to develop a quantitative storm unit definition.

1.6 Equipment for Manual Standard Observations

A snow and weather study plot usually contains the following equipment:

- Stevenson screen for housing thermometers (height adjustable)
- Maximum thermometer
- Minimum thermometer
- One or more snow boards with 1 m (~ 3 ft) rods and base plate with minimum dimensions of 40 cm x 40 cm (~ 15 in) and appropriate labels (Figure 1.4)
- Snow stake, depth marker (graduated in cm (in))
- Ruler (graduated in cm (in))
- Snow sampling tube and weighing scale (graduated in grams or water equivalent), or precipitation gauge
- Large putty knife or plate for cutting snow samples
- Field book and pencil (water resistant paper)

The following additional equipment is useful:

- Hygrothermograph located in a Stevenson screen (Figure 1.3)
- Recording precipitation gauge or rain gauge
- Additional snow boards
- First section of a Ram penetrometer
- Barograph (in the office) or barometer/altimeter
- Anemometer at a separate wind station with radio or cable link to a recording instrument
- Box (shelter) for the equipment
- Small broom
- Snow shovel

Note: In some cases the weather sensors listed above have been linked to data loggers where, in most instances, comparable data may be obtained (see Appendix E). However, a broken wire or power outage may render automated data useless, so manual observations are still preferred as a baseline.

1.7 Field Book Notes

There are many good and different methods for taking field notes. Following these general practices will ensure that quality data are collected (see Figure 1.2 for example).

- Do not leave blanks. If a value was not observed, record N/O for not observed.
- Only write “0” when the reading is zero, for example, when no new snow has accumulated on the new snow board.
- Only record values that are actually observed.

1.8 Field Weather Observations

Heli-ski guiding, ski touring and similar operations often observe general weather conditions in the field. These observations may serve as an interval measurement, accompany a snow profile, or serve to document conditions across a portion of their operational area. The records should describe some of the parameters listed in this section, but field reports should be made as a series of comments so as not to be confused with observations taken at a fixed weather station. Maximum and minimum temperatures cannot be observed but a range in present temperatures can be reported. Field observations should specify the elevation range and the time, or time range, from where the observations were taken. Common field observations typically include: time, location, elevation, sky cover, wind speed and direction, air temperature and precipitation type and rate. Field weather observations that are estimates and not measurements should be recorded with a tilde (~) to denote that the value is approximate.

1.9 Location ✧

Record the location and elevation, or study plot name, at the top of the record book page.

1.10 Date ✧

Record the year, month and day. Avoid spaces, commas etc., i.e. December 5, 2001, is noted as 20011205 (YYYYMMDD). This representation of the date is conducive to automated sorting routines.

1.11 Time ✧

Record the time of observation using a 24-hour clock (avoid spaces, colons etc.) (i.e. 5:10 p.m. is noted as 1710). Use local standard time (i.e. Pacific, Mountain, etc. as appropriate). Operations that overlap time zones should standardize to one time.

1.12 Sky Condition ✧

Classify the amount of cloud cover and record it using the definitions in Table 1.1. Observers may select a separate data code for each cloud layer or one code for the total cloud cover.

Table 1.1 Sky Condition

Class	Symbol	Data Code	Definition
Clear	○	CLR	No Clouds
Few	◷	FEW	Few clouds: up to 2/8 of the sky is covered with clouds
Scattered	⦶	SCT	Partially cloudy: 3/8 to 4/8 of the sky is covered with clouds
Broken	⦷	BKN	Cloudy: more than half but not all of the sky is covered with clouds (more than 4/8 but less than 8/8 cover)
Overcast	⊕	OVC	Overcast: the sky is completely cov-ered (8/8 cover)
Obscured	⊗	X	A surface based layer (i.e. fog) or a non-cloud layer prevents observer from seeing the sky

Valley Fog/Cloud

Where valley fog or valley cloud exists **below** the observation site, estimate the elevation of the top and bottom of the fog layer in feet (meters) above sea level. Give the elevation to the nearest 100 ft (or 50 m). Data code: VF.

Example: Clear sky with valley fog from 7,500 to 9,000 ft is coded as CLR VF 7500-9000.

Thin Cloud

The amount of cloud, not the opacity, is the primary classification criterion. Thin cloud has minimal opacity, such that the disk of the sun would still be clearly visible through the clouds if they were between the observer and the sun, and shadows would still be cast on the ground. When the sky condition features a thin *scattered*, *broken* or *overcast* cloud layer then precede the symbol with a dash.

Example: A sky completely covered with thin clouds is coded as -OVC.

1.13 Precipitation Type, Rate, and Intensity ✧

The amount of snow, rain, or water equivalent that accumulates during a time period will help forecasters determine the rate and magnitude of the load increase on the snowpack. In this document, *Precipitation Rate* refers to an estimate of the snow or rain rate. *Precipitation Intensity* is a measurement of water equivalent per hour.

Procedure

Precipitation Type

Note the type of precipitation at the time of observation and record using the codes in Table 1.2.

Table 1.2 Precipitation Type

Data Code	Description
NO	No Precipitation
RA	Rain
SN	Snow
RS	Mixed Rain and Snow
GR	Graupel and Hail
ZR	Freezing Rain

Precipitation Rate

Use the descriptors listed in Table 1.3 to describe the precipitation rate at the time of observation. Record the estimated rate with the appropriate data code in Table 1.3.

Table 1.3 Precipitation Rate

Data Code	Description	Rate
Snowfall Rate (this system is open-ended; any appropriate rate may be specified)		
S –1	Very light snowfall	Snow accumulates at a rate of a trace to about 0.5 cm (~ 0.25 in) per hour
S1	Light snowfall	Snow accumulates at a rate of about 1 cm (~ 0.5 in) per hour
S2	Moderate snowfall	Snow accumulates at a rate of about 2 cm (a little less than 1 in) per hour
S5	Heavy snowfall	Snow accumulates at a rate of about 5 cm (~ 2 in) per hour
S10	Very heavy snowfall	Snow accumulates at a rate of about 10 cm (~ 4 in) per hour
Rainfall Rate		
RV	Very light rain	Rain produces no accumulation, regardless of duration
RL	Light rain	Rain accumulates at a rate up to 2.5 mm (0.1 in) of water per hour
RM	Moderate rain	Rain accumulates at a rate between 2.6 to 7.5 mm (0.1 to 0.3 in) of water per hour
RH	Heavy rain	Rain accumulates at a rate of 7.5 mm (0.3 in) of water per hour or more

Precipitation Intensity

Use measurements of rain or the water equivalent of snow to calculate the precipitation intensity with the following equation:

$$PI\left(\frac{\text{mm}}{\text{hr}}\right) = \frac{\textit{water equivalent of precipitation}\ (\text{mm})}{\textit{duration of measurement period}\ (\text{hr})}$$

Record the results with the data code PI and the measured value in millimeters (inches) of water.

Note: PI values are assumed to be in millimeters. Use the symbol " to signify when inches are used

Example: A precipitation intensity of one half inch per hour would be coded as PI0.5".

1.14 Air Temperature ✦

Temperature is measured in degrees Celsius (abbreviated °C) (°F). The standard air temperature should be observed in a shaded location with the thermometer 1.5 m above the ground or snow surface. At a study site, thermometers should be housed in a Stevenson screen and the lower edge of the screen should be 1.2 to 1.4 meters above the ground or snow surface (Figure 1.3).

Procedure

a) Read the maximum thermometer immediately after opening the Stevenson screen.
b) Read the present temperature from the minimum thermometer, and read the minimum temperature from the minimum thermometer last.
c) Read temperature trend and temperature from the thermograph.

At the end of the temperature observation:

d) Remove any snow that might have drifted into or accumulated on top of the screen.
e) Reset the thermometers after the standard observations (refer to Appendix D).
f) If the Stevenson screen is fitted with a height adjustment mechanism ensure that the screen base is in the range of 1.2 to 1.4 m above the snow surface. *[Note: In heavy snow climates where daily access of the site is not always possible, the Stevenson screen may be mounted on top of a (chair) tower to prevent burial. However the height of the screen should be noted in the metadata.]*
g) Check that the screen door still faces north if any adjustments are made.

Note: Read all air temperatures from thermometers to the nearest 0.5 °C (or whole °F).

If there is snow on the thermometer it should be brushed off prior to reading the instrument and noted in the comment section.

1.14.1 Air Temperature Trend

If available, read the air temperature from the thermograph and record to the nearest whole degree. Use an arrow symbol to record the temperature trend shown on the thermograph trace over the preceding three hours.

Table 1.4 Temperature Trend

Symbol	Data Code	Description
↑	RR	Temperature rising rapidly (> 5 degree increase in past 3 hours)
↗	R	Temperature rising (1 to 5 degree increase in past 3 hours)
→	S	Temperature steady (< 1 degree change in past 3 hours)
↘	F	Temperature falling (1 to 5 degree decrease in past 3 hours)
↓	FR	Temperature falling rapidly (> 5 degree decrease in past 3 hours)

Note: Table 1.4 assumes the use of the Celsius temperature scale. Operations that use the Fahrenheit temperature scale should use a threshold of 10-degrees (rather than 5-degrees) for rapid temperature changes.

Location	Never Summer Site #4, 8,300'					
Observer	MA	EL	BS	NW	RP	BK
Date	20030210	20030211	20030212	20030213	20030214	20030215
Time, Type (Std, Int)	0530, S	2330, I	1130, I	1630, S	0530, S	1630, S
Sky	○	⊗	- ⊕	OVC	⊕	CLR
Precip Type/Rate	None	S-1	S1	S3	RL	None
Max Temp (°C)	-2.5	-3.0	-3.0	-1.5	1.0	0.0
Min Temp (°C)	-7.0	-6.0	-4.5	-4.0	-4.0	-11.0
Present Temp (°C)	-6.5	-3.0	-4.0	-1.5	0.0	-10.0
Thermograph (°C)	-7	-3	-4	-1	-0	-10
Thermograph Trend	↗	→	↗	↗	→	↘
20 cm Snow Temp (°C)	-10	-6	-5	-4	-4	-6
Relative Humidity (%)	78	86	96	98	100	67
Interval (cm) HIN	0	T	10	12	4	0
Standard (cm) H2D	0	T	10	12	15	0
New (cm) HN24	0	T	10	12	15	14
Storm (cm), C=cleared HST	0	T	10	20	21	19,C
Snow depth (cm) HS	223	222	231	239	241	239
New water (g)	N/O	N/O	33.6	42	67	0
New water (mm)	N/O	N/O	8	10	16	0
Density (kg/m³)	N/O	N/O	80	83	106	0
Rain gauge (mm)	N/O	N/O	N/O	N/O	3	N/O
Precip gauge (mm)	60	60	67	77	82	82
Foot Pen (cm)	35	35	45	50	50	45
Ram Pen (cm)	40	39	47	55	55	48
Surface Form / Size (mm)		PP/0.3	PP/0.3	PP/0.3	WG/0.3	DF/0.3
Wind Speed / Direction	L, E	Calm	M, SE	L, S	L, SW	M, E
Blowing Snow Extent / Dir	None	None	None	M, S	Prev	U
Barometric Pressure (mb)	852	847	817	813	833	843
Pressure Trend	↘	↘	↓	→	↗	→
Comments						

Figure 1.2 An example of a record sheet of a standard observation.

Figure 1.3 Thermograph housed in a Stevenson screen (photograph by Kelly Elder).

1.15 Relative Humidity (RH)

Read the relative humidity to the nearest one percent (1%) from the hygrograph or weather station output.

Note: The accuracy of relative humidity measurements decreases at low temperatures. Furthermore, the accuracy of any mechanical hygrograph is unlikely to be better than five percent (5%) but trends may be important especially at high RH values. Refer to Appendix D for information on exposure issues and relative humidity measurements.

Depending on location, humidity measurements may be more relevant from mid-slope or upper-elevation sites than from valley-bottom sites.

Hygrographs should be calibrated at the beginning of each season, mid season, and after every time the instrument is moved. Calibration is most important when data from multiple instruments are compared with each other. The simplest calibration method is to make a relative humidity measurement near the Stevenson screen with a psychrometer (aspirated or sling). Calibration should be done midday or at a time when the air temperature is relatively stable. Psychrometer measurements are easier to perform when the air temperature is near or above freezing.

1.16 Barometric Pressure at Station

The SI unit for pressure is the pascal (Pa). For reporting weather observations, barometric pressure should be recorded in millibars (1 mb = 1 hPa = 100 Pa, see Appendix B). The recommended English unit for barometric pressure is inches of mercury (inHg). Conversions from other commonly used pressure units to millibars and inches of mercury are listed in Appendix B.

A variety of instruments including barographs, barometers, altimeters, and electronic sensors can be used to obtain a measure of the barometric pressure. Absolute pressures and/or pressure trends are valuable for weather forecasting.

1.16.1 Pressure Trend

Use an arrow symbol to record the pressure tendency as indicated by the change of pressure in the three hours preceding the observation.

Record the change in barometric pressure in the past three hours.

Table 1.5 Pressure Trend

Symbol	Data Code	Description
↑	RR	Pressure rising rapidly (>2 mb rise per hour)
↗	R	Pressure rising (<2 mb rise per hour)
→	S	Pressure steady (<1 mb change in 3 hours)
↘	F	Pressure falling (<2 mb fall per hour)
↓	FR	Pressure falling rapidly (>2 mb fall per hour)

1.17 20 cm Snow Temperature (T20) ✧

Dig into the snow deep enough to allow access to an area 20 cm (or 8 in) below the surface. Cut a shaded wall of the pit smooth and vertical. Shade the snow surface above the area where the sensor will rest in the snow. Cool the thermometer in the snow at the same height, but a different location, at which the measurement will be taken. Insert the thermometer horizontally 20 cm (or 8 in) below the snow surface and allow it to adjust to the temperature of the snowpack. Once the sensor has reached equilibrium, read the thermometer while the sensor is still in the snow.

Record snow temperature to the nearest degree or fraction of a degree based on the accuracy and precision of the thermometer.

1.18 Surface Penetrability (P) ✧

An indication of the snowpack's ability to support a given load and a relative measure of snow available for wind transport can be gained from surface penetrability measurements. There are several common methods for examining surface penetration. Ram penetration is the preferred method of observation because it produces more consistent results than ski or foot penetration. When performing foot or ski penetration on an incline, average the uphill and downhill depths of the track.

Procedure

Ram Penetration (PR)

Let the first section of a standard ram penetrometer (cone diameter 40 mm, apex angle 60° and mass 1 kg) penetrate the snow slowly under its own weight by holding it vertically with the tip touching the snow surface and dropping it. Read the depth of penetration in centimeters.

Foot Penetration (PF)

Step into undisturbed snow and gently put full body weight on one foot. Measure the depth of the footprint to the nearest centimeter (or whole inch) from 0 to 5 cm and thereafter, to the nearest increment of 5 cm (or 2 in).

> *Note: The footprint depth varies between observers. It is recommended that all observers working on the same program compare their foot penetration. Observers who consistently produce penetrations more than 10 cm (or 4 in) above or below the average should not record foot penetrations.*

Ski Penetration (PS)

Step into undisturbed snow and gently put full body weight on one ski. Measure the depth of the ski track from its centerline to the nearest centimeter (or whole inch) from 0 to 5 cm and thereafter, to the nearest increment of 5 cm (or 2 in).

Note: Ski penetration is sensitive to the weight of the observer and the surface area of the ski.

1.19 Form (F) and Size (E) of Surface Snow

Record the form and size in millimeters of snow grains at the surface using the *International Classification for Seasonal Snow on the Ground*, (Fierz and others, 2009) basic classification (Table 1.6).

Experienced observers may use the crust subclasses (Table 1.7) to discriminate between various types of surface deposits and crusts (refer to Appendix F for more detailed information about grain forms).

Table 1.6 Basic Classification of Snow on the Ground

Symbol	Basic Classification	Data Code
+	Precipitation Particles (New Snow)	PP
◎	Machine Made Snow	MM
/	Decomposing and Fragmented Particles	DF
●	Rounded Grains (monocrystalline)	RG
□	Faceted Crystals	FC
∧	Depth Hoar	DH
∨	Surface Hoar	SH
○	Melt Forms	MF
▬	Ice Formations	IF

Note: Modifications to Fierz and others, 2009:

*The use of a subscript "r" modifier is retained to denote rimed grains in the Precipitation Particles (PP) class and its subclasses except for **gp**, **hl**, **ip**, **rm**, and all of Decomposing and Fragmented Particles (DF) class (Example: PP-r).*

Subclasses for surface hoar are listed in Appendix F.

Table 1.7 Surface Deposits and Crusts Subclass

Symbol	Classification	Data Code
∀	Rime	PPrm
=	Rain crust	IFrc
−	Sun crust, Firnspiegel	IFsc
●	Wind packed	RGwp
○○	Melt freeze crust	MFcr

1.20 Height of Snowpack (HS) ✧

The height of the snowpack should be measured at a geographically representative site preferably within 100 meters (or 300 ft) of the weather study plot. A white stake graduated in centimeters (inches) should be placed at the site. It is best to preserve an area with a radius of about 3 m (or 10 ft) around the snow stake for measurements. Ideally the snow in this area is not disturbed during the winter. Try not to walk through the area and leave naturally forming settlement cones and depressions in place.

Procedure

From a distance of about 3 m (or 10 ft) look across the snow surface at the snow stake. Observe the average snow depth between your position and the stake to the nearest centimeter (or 0.5 inch). Try not to disturb the snow around the stake during the course of a winter season.

Note: HS values are measured vertically (i.e. line of plumb).

1.21 Height of New Snow (HN24) ✧

The new snow measurement in the standard morning observation uses a 24-hour interval. Many operations will find it useful to observe snow fall on more than one interval. However, the 24-hour interval snow board should only be used for 24-hour observations. Additional snow boards should be added for additional observations as necessary. It is highly recommended that both 24-hour and Storm intervals be observed by operations that maintain a study plot. Other commonly used intervals appear in the Snow Board Naming Convention Section 1.21.1.

New snow measurements should be made on a snow board (Figure 1.4). The base plate should have minimum dimensions of 40 cm x 40 cm (or 15 in x 15 in), with an attached rod of 1 m (or 3 ft) in length. Larger boards (60 cm x 60 cm) provide more room to make measurements. The base plate and rod should be painted white to reduce the effects of solar heating.

Procedure

Use a ruler graduated in centimeters (or inches) to measure the depth of snow accumulated on the snow board. Take measurements in several spots on the board. Calculate the average of the measurements and record to the nearest cm (in). Record “T” (signifying a trace) when the depth is less than 1 cm (or 0.5 in), or when snow fell but did not accumulate. If there is no new snow record zero. Do not consider surface hoar on the boards as snowfall; clear off hoar layer after observation. If both rain and snow fell it should be noted in the remarks.

The sample on the snow board can also be used to measure the water equivalent of new snow (Section 1.22). Once the observations are complete, redeposit the snow in the depression left by the snow board, adding additional snow if necessary to reposition the board level with the surrounding snow surface.

Note: If the snow board was not level the measurement should be made normal to the surface of the board.

1.21.1 Snow Board Naming Conventions

The following convention can be used to identify snow boards used for different interval measurements.

HN24 – 24-hour Board: The HN24 board is used to measure snow that has been deposited over a 24-hour period. It is cleared at the end of the morning standard observation.

HST – Storm Board: Storm snowfall is the depth of snow that has accumulated since the beginning of a storm period. The storm board is cleared at the end of a standard observation prior to the next storm and after useful settlement observations have been obtained. The symbol "C" is appended to the recorded data when the storm board is cleared.

H2D – Twice-a-Day Board: An H2D board is used when standard observations are made twice a day. In this case both the HN24 and H2D boards should be cleared in the morning and then the H2D board is cleared again in the afternoon.

HSB – Shoot Board*:* The shoot board holds the snow accumulated since the last time avalanches were controlled by explosives. The symbol "C" is appended to the recorded data when the shoot board is cleared.

HIN – Interval Board: An interval board is used to measure the accumulated snow in periods shorter than the time between standard observations. The interval board is cleared at the end of every observation.

HIT – Intermittent Board: Snow boards may be used at sites that are visited on an occasional basis. Snow that accumulates on the board may result from more than one storm. The intermittent snow board is cleared at the end of each observation.

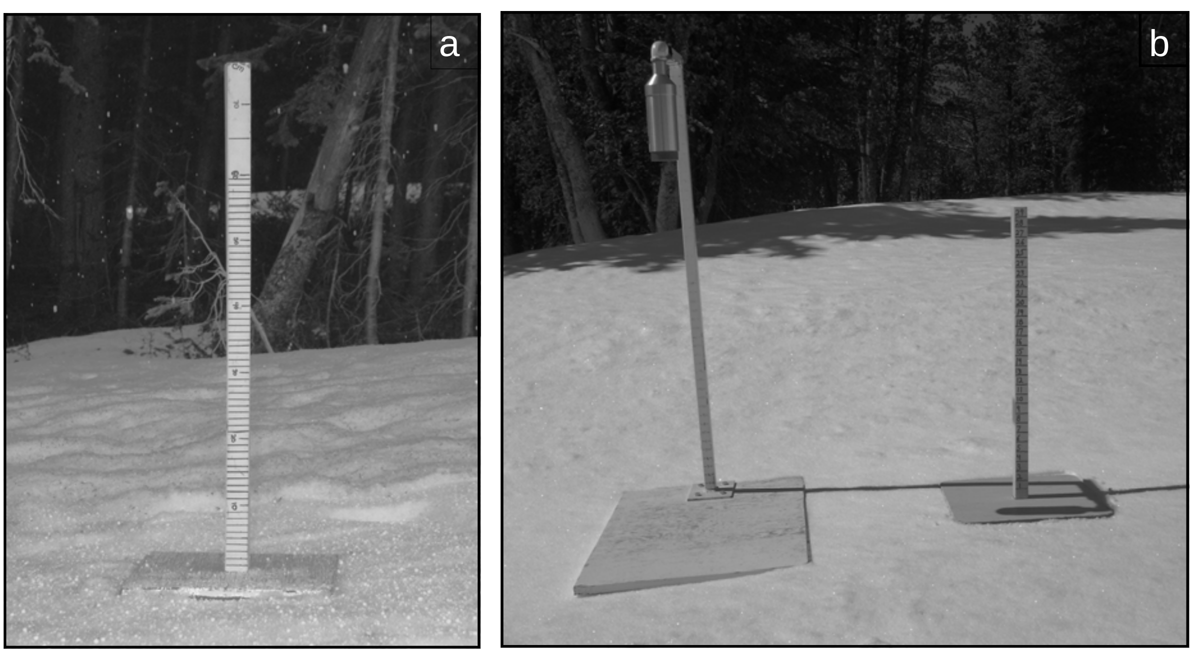

Figure 1.4 a) Snow board graduated in centimeters b) Automated snow board and snow board graduated in inches (photographs by Tom Leonard).

1.22 Water Equivalent of New Snow (HN24W) ✧

The water equivalent is the depth of the layer of water that would form if the snow on the board melted. It is equal to the amount of liquid precipitation. The standard morning observation includes the water equivalent of the new snow on a 24-hour interval. The same snow board used for a 24-hour or other interval measurement should be used to calculate the water equivalent. There are several suitable methods for making this measurement. Three different methods are described in the following section.

Procedure

Use one of the following methods to calculate the water equivalent of the new snow. Record the value to the nearest 0.1 mm (or 0.01 in). Make several measurements and report the average value. Record "T" (signifying a trace) when the snow depth is less than 1 cm (or 0.5 in). If there is no new snow record a zero. Do not consider surface hoar on the boards as snowfall; clear off hoar layer after observation.

Snow Board Tube and Weighing Scale

a) Cool the measurement tube in the shade prior to making the measurement
b) Hold the tube vertically above the surface of the snow on the snow board
c) Press the tube into the snow at a slow and constant rate until it hits the base plate of the snow board
d) Record the height of the snow sample in the tube
e) Remove the snow next to one side of the tube with a large putty knife or scraper
f) Slide putty knife under the tube and remove the sample from the board
g) Weigh the sample and read the water content from the scale or use the equation listed below
h) Repeat and record the average of several measurements to the nearest 0.1 mm (or 0.01 in)

Melting the Snow Sample

The water equivalent of the new snow can be obtained by melting a sample of snow and measuring the resulting amount of melt water. The height of the melt water in mm (in) is the water equivalent of the sample. When using this method, the base area of the snow sample and the melted sample must remain the same.

Indirect Method:

The water equivalent of snow can also be obtained by weighing a snow sample of known cross-sectional area. Water equivalent is calculated by using the following equation.

$$H2DW\,(\mathrm{mm}) = \frac{mass\ of\ snow\ sample\ (\mathrm{g})}{area\ of\ sample\ tube\ (\mathrm{cm}^2)} \times 10$$

This method is commonly used by avalanche operations because of its ease (Note: 1 cm^3 of water has a mass of 1 g). The expanded equation is in Appendix B, Section B.5.

1.23 Density of New Snow (ρ)

Density is a measure of *mass* per unit *volume*; density is expressed in SI units of kg/m^3. It is also common for avalanche operations to discuss snow density in percent water content per volume. Calculations of both quantities are described below. Data records of snow density should be recorded in units of kg/m^3. The Greek symbol ρ (rho) is used to represent density.

Calculate density as follows:

Divide the mass (g) of new snow by the sample volume (cm^3) and multiply by 1000 to express the result in kilograms per cubic meter (kg/m^3). Record as a whole number (i.e. 120 kg/m^3).

$$\rho\left(\frac{\mathrm{kg}}{\mathrm{m}^3}\right) = \frac{mass\ of\ snow\ sample\ (\mathrm{g})}{sample\ volume\ (\mathrm{cm}^3)} \times 1000$$

For measurements from standard observations:

$$\rho\left(\frac{\text{kg}}{\text{m}^3}\right) = \frac{H2DW\ (\text{mm})}{H2D\ (\text{cm})} \times 100$$

The density of a snow sample is often communicated as a dimensionless ratio or percent. Calculate this ratio by dividing the height of the water in a snow layer by the height of the snow layer and then multiply by 100 (e.g. 10 cm of snow that contains 1 cm of water has a water content of 10%).

This ratio can also be calculated by dividing the density of the snow (kg/m^3) by the density of water (1000 kg/m^3) and multiplying by one hundred. Using the density of water allows for an easy calculation by moving the decimal one space to the left (i.e. 80 kg/m^3 = 8%).

$$\%\,water = \frac{water\ equivalent\ of\ snow\ sample\ (\text{mm})}{height\ of\ snow\ sample\ (\text{mm})} \times 100$$

$$\%\,water = \frac{water\ equivalent\ of\ snow\ sample\ (\text{mm})}{height\ of\ snow\ sample\ (\text{cm})} \times 10$$

$$\%\,water = \frac{water\ equivalent\ of\ snow\ sample\ (\text{in})}{height\ of\ snow\ sample\ (\text{in})} \times 100$$

1.24 Rain ✦

There are a variety of commercial rain gauges available. The standard rain gauge is made of metal and has an 8-inch (~20 cm) orifice (Figure 1.5). However, good results can be obtained with commercially manufactured 4-inch (~10 cm) diameter plastic gauges. The gauge should be mounted at the study site (see Appendix D for site guidelines). If a mounted gauge is not available, an 8-inch (~20 cm) gauge may be placed on the snow board prior to a rain event.

Procedure

Measure the amount of rain that has accumulated in the rain gauge with the length scale on the gauge or a ruler. Record the amount to the nearest 0.1 mm (or 0.01 in). Empty the gauge at each standard observation.

Figure 1.5 Precipitation gauge with Alter shield (photograph by Tom Leonard).

1.25 Accumulated Precipitation

Accumulated precipitation gauges collect snowfall, rainfall and other forms of precipitation and continuously record their water equivalent. There are a variety of commercial gauges (both manual and automated) available.

Procedure

Record the amount of precipitation accumulated in the recording precipitation gauge to the nearest tenth of a millimeter (0.1 mm) (or 0.01 of an inch). The amount of precipitation that fell during a single event can be obtained by taking the difference between the present reading and the previous reading.

1.26 Wind ✧

Both *estimates* and *measurements* of wind speed and direction are useful to observe and record. However, it is important to distinguish between the two types of observations. Measurements are made with an instrument located at a fixed point. Estimates are made without instruments or with hand-held instruments, and typically represent wind in a local area rather than at a fixed point.

Procedure

Estimated Wind Speed

For the standard morning observation, an estimate of the wind speed can be obtained by observing for two minutes. Use the indicators in Table 1.8 to determine the categorical wind speed, and the data codes to record average conditions during the observation period.

Estimated Maximum Wind Gust

Estimate the maximum wind speed during the observation period. Record the estimated speed to the nearest 2 m/s (or 5 mi/hr).

Measured Wind Speed

The SI unit for wind speed is meters per second (miles per hour). Refer to Appendix B for unit conversions.

Measured Maximum Wind Gust

Record the speed and time of occurrence of the maximum wind gust.

Table 1.8 Wind Speed Estimation

Class	Data Code	km/h	m/s	mi/hr	Typical Indicator
Calm	C	0	0	0	No air motion. Smoke rises vertically.
Light	L	1-25	1-7	1-16	Light to gentle breeze; flags and twigs in motion.
Moderate	M	26-40	8-11	17-25	Fresh breeze; small trees sway. Flags stretched. Snow begins to drift.
Strong	S	41-60	12-17	26-38	Strong breeze; whole trees in motion.
Extreme	X	>60	>17	>38	Gale force or higher.

Note: The indicators used to estimate the wind speed are established by rule of thumb. Observers should develop their own relationships specific to their area.

Wind estimates (speed and direction) should be averaged over a two-minute period prior to the observation.

Since wind speed classes are determined by an estimate, mi/h categories can be rounded to the nearest 5 mi/h.

Estimated Wind Direction

During a two-minute period, note the direction **from** which the wind blows. The wind direction can be recorded using the compass directions listed in Table 1.9. Do not record a direction when the wind speed is zero (calm).

Measured Wind Direction

Measured wind direction for standard observations should be rounded to the nearest 10 degrees (i.e. 184 degrees (just beyond south) is coded as 180). Forty-five degrees (northeast) is coded as 050. Archived wind direction data from an automatic weather station can be stored as a three digit number.

Table 1.9 Wind Direction

Direction	N	NE	E	SE	S	SW	W	NW
Degrees	0	45	90	135	180	225	270	315

1.27 Blowing Snow

Estimate the extent of snow transport (Table 1.10) and note the direction **from** which the wind blows to the closest octant of the compass (Table 1.11). The observer should also note the location and/or elevation of the wind transport (e.g. valley bottom, study site, ridgetop, peaks, 11,000 ft, 3000 m, etc…).

Table 1.10 Extent of Blowing Snow

Data Code	Description
None	No snow transport observed.
Prev	Snow transport has occurred since the last observation but there is no blowing snow activity at the time of observation.
L	Light snow transport.
M	Moderate snow transport.
I	Intense snow transport.
U	Unknown as observation is impossible because of darkness, cloud, or fog.

Record wind direction as indicated by blowing snow.

Table 1.11 Direction of Blowing Snow

Direction	N	NE	E	SE	S	SW	W	NW
Degrees	0	45	90	135	180	225	270	315

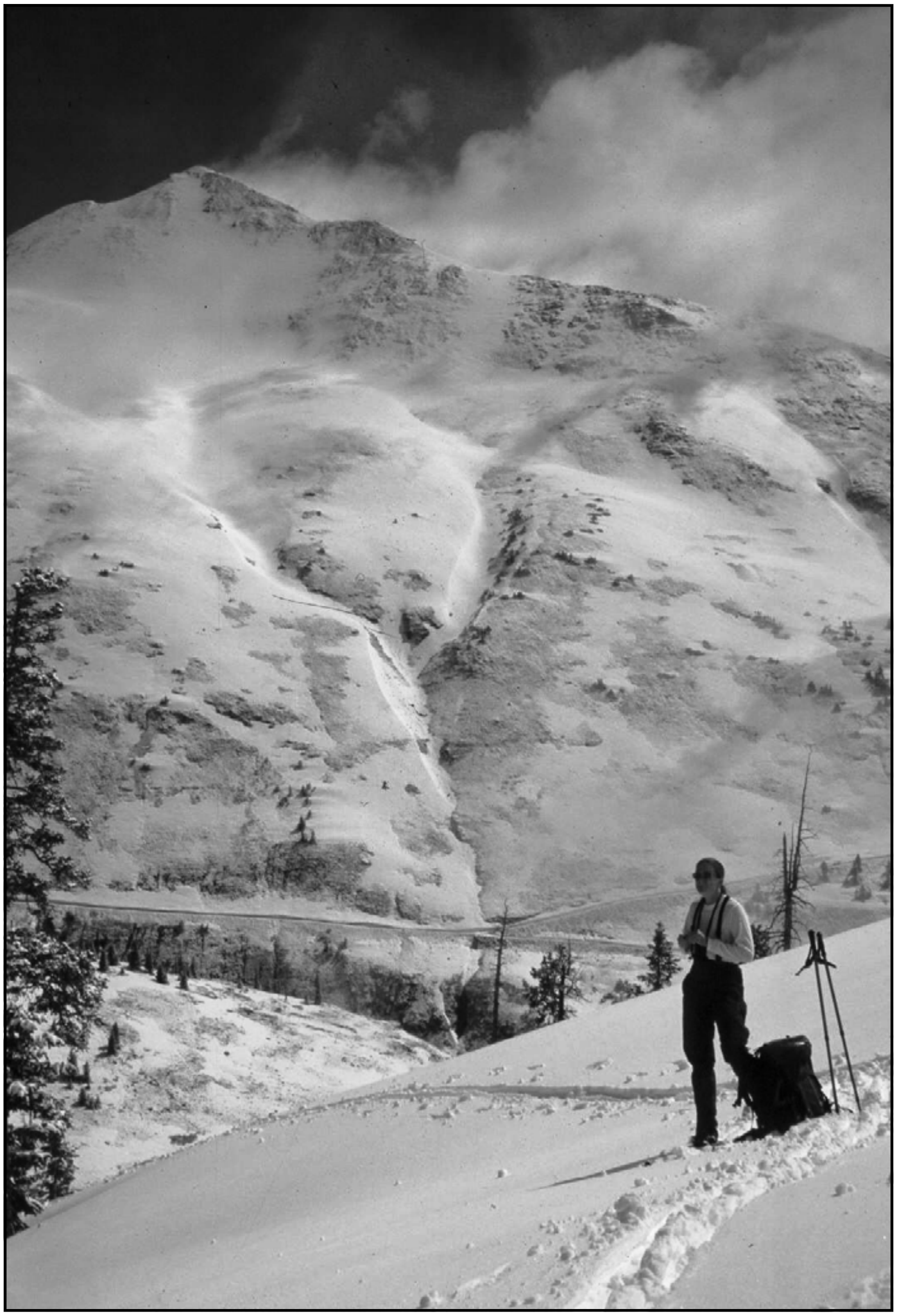

Figure 1.6 Wind transport of snow along a mountain ridgeline (photography by Andy Gleason).