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Manual measurement of snow water equivalent

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Manual measurement of snow water equivalent

Mesure manuelle de l'équivalent en eau de la neige

Manuelle Messung des Schneewasseräquivalents

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Foreword

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Introduction

Snow water equivalent (SWE) measurements

Snow water equivalent (SWE), also called “water equivalent of snow”, is the depth of water that would be obtained by melting the snowpack in a given area, and is normally expressed in millimetres. In other words, SWE corresponds to the mass of snow over a given area.

Measurements of SWE in snowpack, and new snow, improve the estimation of winter precipitation, especially in areas with a sparse network of meteorological stations. The measurements are mainly made for the purpose of estimating the spatial distribution of the total water content in catchment areas, as knowledge of the SWE in river basins is fundamental for estimating the expected snowmelt runoff.

Information about snow accumulation and daily melt rate is essential in flood forecasting during the snowmelt season. SWE is also used in avalanche theory and forecasting, as well as for risk assessment of heavy snow loads. Furthermore, the data is important in glaciological mass balance studies and climate monitoring. The melt from polar ice sheets is a major factor in sea level rise.

Methods and instruments, which have been developed for determination of SWE, are listed in Annex A.

Manual SWE measurements

The first station networks with manual SWE measurements were established in the early 20th century at meteorological institutes in North America and Europe. Today the measurements are made routinely at federal and national meteorological and hydrological institutes, within the hydropower industry, and by universities, in cold climate countries all over the world. Annex B shows a list of manual SWE measuring bodies in Europe.

Automized methods have been developed to be used in remote areas, as well as to enable continuous recording, but manual measurements are still more common, as they can provide high quality data for a relatively low capital cost. The importance of manual measurements is also reflected in their use as reference to other SWE measuring methods.

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1 Scope

This Technical Report defines the requirements for manual measurements of SWE over land, see ice and glaciers, under natural environmental conditions, and shows methods for calculating the spatial distribution of the data. It includes measurements with snow tubes, core drills and density cutters.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

Note 1 to entry Primarily 'The International Classification for Seasonal Snow on the Ground' (UNESCO), 'Cryospheric Glossary' (NSIDC) and 'Glossary of Meteorology' (AMS) has been used as reference.

2.1
ablation
removal of material from the surface of an object by vaporization, chipping, or other erosive processes. In this case the opposite of *snow accumulation*

2.2
blowing snow
an ensemble of snow particles raised by the wind to moderate or great heights above the ground; the horizontal visibility at eye level is generally very poor

Note 1 to entry See also *drifting snow*.

2.3
condensation
the change of the physical state of matter from gaseous phase into liquid phase (opposite of *evaporation*)

2.4
deposition
(1) a process by which water vapour is deposited as ice without first forming liquid water (opposite of *sublimation*)

(2) the process by which snow is deposited on the ground either with or without wind action

Note 1 to entry As a result, stationary snow deposits such as snow dunes, *snowdrifts*, or the *snow cover* itself may form.

2.5
drifting snow
snow raised from the *snow surface* by the wind to a height of less than 2 metres; it does not restrict horizontal visibility at 2 metres or more above the surface

Note 1 to entry See also *blowing snow*.

2.6
evaporation
vaporization of a liquid that only occurs on the surface of a liquid, at temperatures below the boiling point (opposite of *condensation*)

2.7
firn
well-bonded and compacted snow that has survived the summer season, but has not been transformed to *glacier* ice

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Note 1 to entry Typical *densities* are 400 - 830 kg·m^{-3}. Thus firn is the intermediate stage between snow and glacial ice where the pore space is at least partially interconnected. Firn usually results from both melt-freeze cycles and compaction by overload, or from compaction alone, as in inland Antarctic snow.

2.8
glacier
a mass of land ice formed by the further *recrystallization* of *firn*, normally flowing continuously from higher to lower elevations

2.9
new snow
recently fallen snow in which the original form of the ice crystals can be recognized

Note 1 to entry This is usually the snow which has accumulated on a snow board during the standard observing period of 24 hours.

2.10
old snow
deposited snow whose transformation into *firn* is so far advanced that the original form of the ice crystals can no longer be recognized

2.11
recrystallize
to crystallize again, i.e., to form into new crystals

2.12
redistribution
distribution of previously *deposited snow* that was *eroded* and transported by the wind

Note 1 to entry Redistribution features such as *snowdrifts* are usually formed from densely packed and friable snow.

2.13
perennial snow
snow persisting for an indefinite time longer than one year

Note 1 to entry See also *seasonal snow*.

2.14
seasonal snow
snow that accumulates during one season and does not last for more than one year

Note 1 to entry See also perennial snow.

2.15
snow accumulation
all processes that add mass to the *snow cover*, i.e. typically solid and liquid precipitation, ice *deposition* from atmospheric water vapour, and snow deposited by wind, *avalanches*, etc. (opposite of *ablation*)

2.16
snow avalanche
mass of snow which becomes detached and slides swiftly down a slope

Note 1 to entry Large snow avalanches may contain rocks, soil, vegetation, and/or ice.

2.17
snow board
in this case a specially constructed board used to identify the surface of snow that has been recently covered by *snowfall*

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2.18
snow core
a *sample of snow*, either just the freshly fallen snow or the combined old and new snow on the ground, obtained by pushing, or drilling, a cylinder down through the *snow layer* and extracting it

2.19
snow course
an established line, or transect, of measurements of SWE across a snow covered area in a representative terrain, where appreciable amounts of snow accumulates

2.20
snow cover
in general, the *accumulation of snow* on the ground surface, and in particular, the areal extent of snow-covered ground; term to be preferably used in conjunction with the climatologic relevance of snow on the ground

Note 1 to entry See also *snowpack.*

2.21
snow creep
a continuous, slow downhill movement of a snow layer

2.22
snow density
the mass per unit volume of snow

Note 1 to entry Sometimes total and dry snow densities are measured separately. Total snow density encompasses all constituents of snow (ice, liquid water, and air) while dry snow density refers to the ice matrix and air only.

2.23
snow depth
the total height of the *snowpack*, measured vertically from the base to the *snow surface*

Note 1 to entry The slope-perpendicular equivalent of snow depth is the *snowpack thickness*.

2.24
snow distribution
spatial and temporal variability of snow cover affected by *snowfall*, wind speed, elevation, topography, vegetation and ablation

2.25
snow erosion
the process by which the surface of the *snow cover* is worn away, primarily by the action of wind

Note 1 to entry Wind erosion is a very important factor in the *redistribution* of snow.

2.26
snow height
the vertical distance from a base to a specific level in the snow, or to the *snow surface*

Note 1 to entry Ground surface is usually taken as the base, but on *firn* fields and *glaciers* it refers to the level of either the *firn* surface or *glacier* ice. Height is used to denote the locations of layer boundaries but also of measurements such as snow temperatures relative to the base. Where only the upper part of the *snowpack* is of interest, the *snow surface* may be taken as the reference. This should be indicated by using negative coordinate values. *Snow depth* is the total height of the *snowpack*.

2.27
snow layer

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a layer of ice crystals with similar size and shape

2.28
snow load
the downward force on an object or structure caused by the weight of *accumulated snow*

2.29
snow metamorphism
the transformation that the snow undergoes in the period from *deposition* to either melting or passage to glacial ice

Note 1 to entry Meteorological conditions as well as mechanical or gravitational stresses are the primary external factors that affect snow metamorphism.

2.30
snow pit
in this case a pit dug vertically into the *snowpack* where *snowpack stratigraphy* and characteristics of the individual *snow layers* are observed

Note 1 to entry See also *snow profile*.

2.31
snow profile
a *stratigraphic* record of the *snowpack* including characteristics of individual *snow layers*, usually performed in *snow pits*

2.32
snow sample
in this case a sample of snow with a defined volume extracted from the *snowpack*

2.33
snow sampler
an instrument used for the collection of *snow samples* in an undisturbed *snowpack*

2.34
snow season
the time period when the ground usually is covered by snow

2.35
snow surface
the uppermost part of the snow cover, forming the interface to the atmosphere

2.36
snow survey
the process of determining snow parameters, most often depth and density, at representative points, usually along a *snow course*

2.37
snow water equivalent (SWE)
the depth of water that would result if a certain amount of snow melted completely

Note 1 to entry It can represent the *snow cover* over a given region or a confined snow sample over the corresponding area. The snow water equivalent is the product of the *snow height* and the *snow density* divided by the density of water. It is typically expressed in millimetres of water equivalent, which is equivalent to kilograms per square metre or litres of water per square metre.

2.38
snowdrift

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a mound or bank of snow deposited as sloping surfaces and peaks, often behind obstacles, irregularities, and on lee slopes, due to eddies in the wind field. (See also *deposition*)

2.39
snowfall
the quantity of snow falling within a given area in a given time

2.40
snowpack
the *accumulation* of snow on the ground at a given site and time; term to be preferably used in conjunction with the physical and mechanical properties of the snow

Note 1 to entry See also *snow cover*.

2.41
snowpack stratigraphy
the definition and description of the stratified, i.e. layered *snowpack*

Note 1 to entry See also *snow profile*.

2.42
snowpack thickness
the total height of the *snowpack*, measured perpendicularly from base to snow surface, i.e. at right angle to the slope on inclined *snow covers*

Note 1 to entry When observers report thickness, they should also include the slope angle with respect to either the *snow surface* or a layer within the *snowpack*, e.g., the bed surface of an avalanche. The slope-vertical equivalent of *snowpack* thickness is the *snow depth*.

2.43
sublimation
the change of state of matter from solid phase to gaseous phase without entering liquid phase (opposite of *deposition*)

3 Symbols

The symbols used in this technical report are given in Table 1.

Table 1 — Symbols

Symbol	Quantity	Most common units
SWE	Snow water equivalent	m, mm
D	Snow depth	m, cm
m	Mass	kg, g
ρ	Density	$kg \cdot m^{-3}$, $g \cdot cm^{-3}$
V	Volume	m^3, cm^3
A	Area	m^2, cm^2

4 Objective

4.1 Spatial estimation of SWE

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