Citation: Seiz, G., Foppa, N., 2007. National Climate Observing System (GCOS Switzerland). Publication of the Federal Office of Meteorology and Climatology MeteoSwiss and ProClim, 92 p.

3.6 Snow cover

As well as playing a key role in the climate system, snow cover is a vital economic factor in sectors such as tourism, water management, hydropower, agriculture and transport. With long time series for snow variables, conclusions can be drawn concerning past and future regional trends.

§ Legal basis

Under the Federal Act on Meteorology and Climatology (MetG, SR 429.1), the federal authorities are required to record meteorological and climatological data throughout Switzerland and to provide weather hazard warnings. Under the Federal Ordinance on Meteorology and Climatology (MetV, SR 429.11), the implementing agency is the Federal Office of Meteorology and Climatology MeteoSwiss. Under the ETH Board Ordinance on Research Institutes of the ETH Domain (SR 414.161), the Swiss Federal Institute for Snow and Avalanche Research (SLF), as part of the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), is responsible for issuing avalanche warnings and information on the development of snow and avalanche conditions in Switzerland.

Measurements in Switzerland

The most important observations for snow climatology are snow depth, new snow depth, and water equivalent of new and total snow cover. Snow depth and new snow depth are recorded by measurement networks operated by the SLF, MeteoSwiss and other cantonal and private institutions.

The SLF network comprises both automatic and conventional stations (measuring points MS and comparison stations VG). At the roughly 100 conventional stations, the variables are measured manually by observers each day. Most of the stations are located at medium altitudes between 1000 and 2000 m a.s.l.

By contrast, the 39 automatic (ANETZ, now SwissMetNet) and 11 conventional (KLIMA) snow measurement stations operated by MeteoSwiss are evenly distributed across Switzerland, also covering altitudes below 1000 m a.s.l. Since 1996, the SLF and MeteoSwiss stations have been supplemented by the approx. 70 automatic stations of the Intercantonal Measurement and Information System (IMIS), located at altitudes between 2000 and 3000 m a.s.l. This network was established in cooperation with the FOEN under an intercantonal agreement.

At the 10 mountain stations of the automatic ENET network, observations required for avalanche warnings are jointly carried out by MeteoSwiss and the SLF. At about 75 % of the roughly 340 precipitation stations in the MeteoSwiss NIME network, daily measurements of total and new snow depth are carried out manually. Unlike at the conventional and automatic stations, these data are not recorded digitally. Satellite data are being used operationally to determine snow cover, e.g. from NOAA AVHRR (by the University of Bern) and Meteosat Second Generation (by MeteoSwiss).

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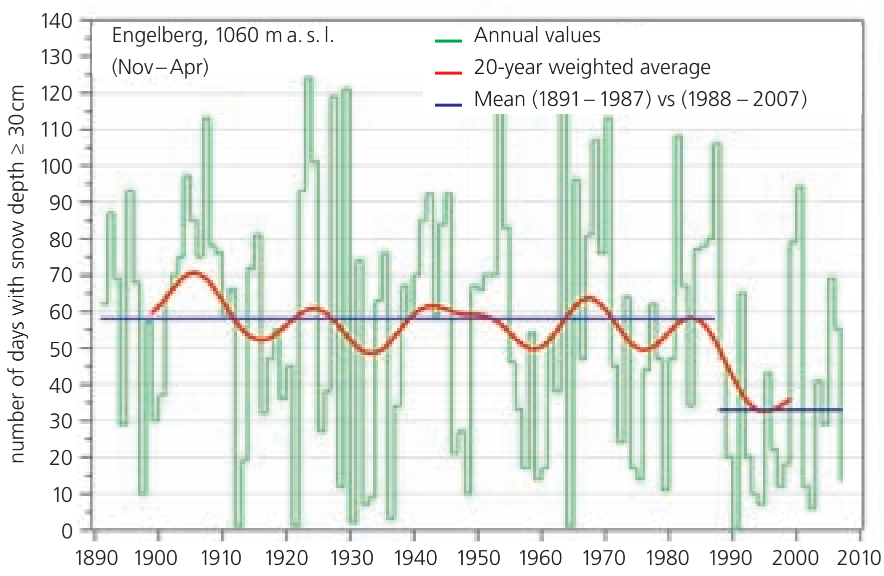
Snow depth
Long time series and their importance

Compared with the automatic measurement networks, the advantage offered by the conventional stations is that the available time series are sufficiently long for climatological purposes (> 50 years). In most cases, the most important measurement series for total snow depth are shorter than for new snow depth. This may be associated with the early initiation of precipitation measurements (→ 2.2 Precipitation). The longest total snow depth series go back to the 1890s – Säntis (1890), Engelberg (1890) and Davos (1896). At other stations, measurements also began around 1900, but the frequency of measurement varied widely from year to year and from station to station. At most sites, continuous observations of total snow depth began at the earliest in the 1930s (e.g. Weissfluhjoch, Trübsee, Andermatt, Ulrichen). Total snow depth has also been recorded since the 1930 at stations in a number of Swiss towns on the Central Plateau. However, given the high degree of variability in snow depth associated with small amounts of snow at this altitude, time series from these sites are difficult to interpret.

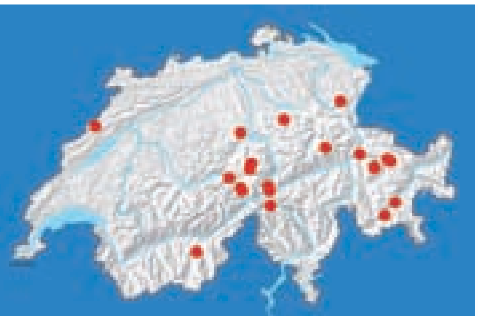
Data on snow depth were only recorded more or less regularly following the introduction of measurement instructions from 1893 onwards. In many cases, the data collected before 1930 are only available in the original analogue form and therefore require additional processing and digitization if they are to be used in analyses.

Snow cover in Engelberg 1891 – 2007

Days with snow depth of at least 30 cm for the November-April period



The development over time illustrates the clear decline of snow cover at valley elevations. The green curve shows the large natural fluctuations typical of snow cover. The 20-year average highlights a decrease in the number of snow days – from the late 1980s to the present – never previously observed since measurements began. In the winter of 1989/90, for example, a snow depth of 30 cm or more was not recorded on a single day. This decline over the past 20 years is also associated with a sharp decrease in the total number of winter snow days – an important figure for tourism – from 58 to only 33. The decrease in snow days observed at virtually all stations below 1300 m a.s.l. over the past 20 years is already having a major impact on winter tourism (Laternser and Schneebeli, 2003).



Stations with the longest and most important time series for snow depth (>50 years) and new snow depth (>100 years).

(Continued on page 52)

http://www.slf.ch/research/snowtrends/snowtrends-en.html
http://www.meteoswiss.admin.ch/web/en/services/data_portal/monitoring_networks.html

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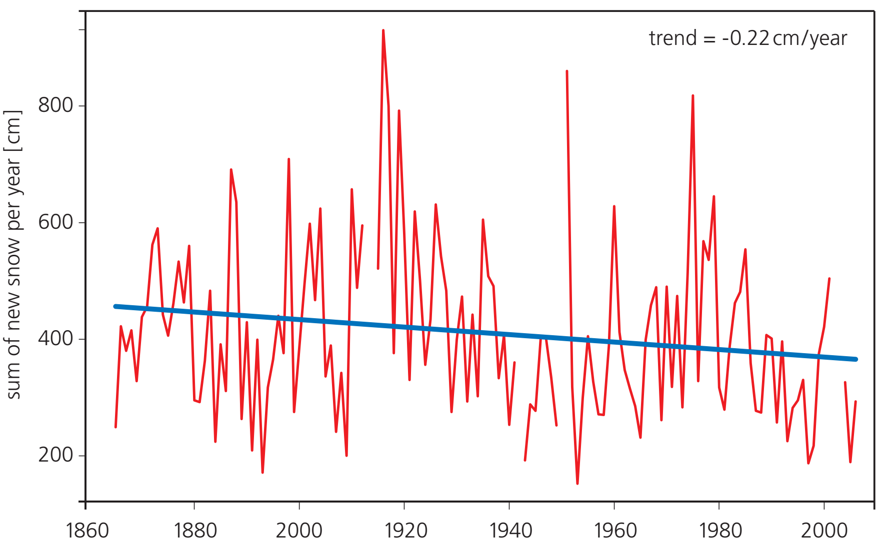
New snow
Long time series and their importance

Altogether 15 stations have new snow records dating back to the 19th century. Either MeteoSwiss or the SLF is responsible for these measurements. At 7 stations, new snow has been recorded since around 1880 – Sils Maria (1864), Guttannen (1877), Elm (1878), Lucerne (1883), Airolo (1885), Chur (1888) and Arosa (1890). The amount of new snow per day and the number of days with new snow are variables of climatological importance, making it possible to analyse the influence of warmer winter temperatures (i.e. more rain than snow) and the predicted increase in winter precipitation (i.e. more snow in summit regions). New snow depth is also important for avalanche warning operations, winter tourism and snow clearance services.

New snow in Sils Maria 1864 – 2006
Yearly total in cm



Yearly totals for new snow in Sils Maria, 1864–2006. The blue line illustrates the linear trend for the entire period. However, the trend of -0.22 cm total new snow per year is not statistically significant. Sils Maria has the longest new snow series available in Switzerland, going back as far as 1864. Measurements for 6 individual years are incomplete (1913, 1914, 1942, 1950, 2002 and 2003), with no data at all for 1913 and 1914. In the other cases, data for at least one winter month (December, January, February) are missing, so that it is not possible to calculate plausible yearly totals for new snow. The maximum yearly total (930 cm) was recorded in 1916, and the minimum (152 cm) in 1953.

Measurements in Switzerland (2)

Long-term data on snow water equivalents (SWE) are also of interest from an engineering perspective, as these values are used in construction standards (SIA NORM 261) for the maximum snow load on structural elements. The SWE is recorded by various institutions and measurement networks across Switzerland. Compared with measurements of snow depth, SWE is determined at a lower temporal resolution.

The first regular observations of SWE within a measurement network were carried out in 1943 by the ETH Zurich (Hydrology Division of the Laboratory of Hydraulics, Hydrology and Glaciology/VAW) in cooperation with the electricity sector. This network was subsequently largely integrated into the SLF network, and since then the sites concerned have served as comparison stations (VG). The SWE data collected at VG stations from 1943 onwards were digitized for the period 1943–1985. Since 1998, after an interruption of more than 10 years, data have again been recorded in digital form. At present, the water equivalent of the snow depth is determined by observers twice monthly at half of the roughly 80 VG stations. Measurements are mainly performed between November and April, and the data are digitally archived. Additional isolated measurements are carried out by hydropower plants and private companies, supported by Cryospheric Commission (EKK) of the Swiss Academy of Sciences (SCNAT). Thus, as part of the observation programme on the Claridenfirn and the Silvretta, Basodino, Gries and Aletsch glaciers, measurements of the water equivalent of accumulated firn are carried out in the spring with EKK support. As well as ground-based and conventional measurements of SWE, additional methods are used for research purposes: for example,

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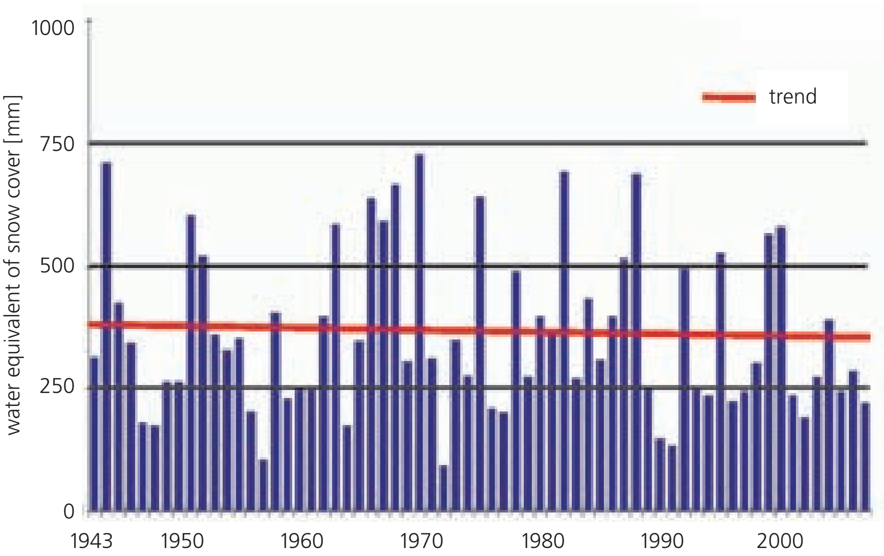
Snow water equivalent
Long time series and their importance

The SLF operates VG stations where measurements of SWE go back to the 1940s – Weissfluhjoch (1937), Davos (1947), Klosters (1948) and Zuoz (1951). Of particular importance with regard to total SWE are the various stations in the Wägital valley. They account for the world's longest SWE series for a catchment area (since 1943). The series includes 11 SWE and 28 snow depth sites where measurements are performed in the spring and the average SWE of the snowpack is determined for the catchment. This network, originally operated by the Hydrology Division of the VAW at the ETH Zurich, is now being run by Meteodat GmbH with financial support from the SLF. Meteodat GmbH is currently continuing the measurements carried out at the Garichte and Sihlsee stations since 1943.

Snow water equivalent in the Wägital 1943 – 2007

Area-averaged SWE in mm for the whole catchment as of 1 April



On the basis of point measurements at each site, the water reserves stored in the snowpack are combined into an area-averaged SWE as a function of elevation band. Variation in SWE can thus be shown for the entire catchment area. The red line shows the trend for the long-term average on 1 April. Winter precipitation at lower and medium elevations is likely in future to increasingly take the form of rainfall rather than snowfall. Among the consequences would be greater snowpack compaction (Rohrer et al., 1994). SWE is therefore expected to show a less pronounced negative trend with climate change than snow depth.

The longest water equivalent series go back to 1940: individual stations (green) and groups of stations in catchment areas (red: Wägital, Garichte, Sihlsee; blue: Alptal).

International integration

As part of the European avalanche warning system, snow data from stations close to the border are exchanged with foreign avalanche warning services. In the Alptal valley, hydrological and climatological studies have been carried out by the WSL on snow courses in various subalpine subcatchments for almost 40 years. Individual hydrological measurements form part of the NADUF programme (→ 3.1 River discharge). SWE values determined at 14 sites in the Alptal on a weekly to monthly basis serve as reference measurements for the validation of numerical models in the international Snow Model Intercomparison Project (SnowMIP2) conducted on behalf of the International Association of Cryospheric Sciences (IACS).

SWE is determined using equipment such as snow pillows, flat band cable sensors, microwave systems and gamma ray spectrometers.

Resources required

Continuation of the longest time series is largely assured. Whether certain long-term SLF series (including Engelberg) will be continued is uncertain, since the climatological measurement sites have been outsourced from the avalanche warning service and the current support by the FOEN and ETH is open. The valuable measurements in the Wägital catchment are only assured in the short term. To guarantee their continuation, additional financial resources will be required from 2008.

http://www.wsl.ch/forschung/forschungsprojekte/hydrology_subalpine_watershed/