Plate 3.11 Mean Snow Depths, 1983–2002

Introduction

If temperatures are sufficiently low, precipitation will fall in the form of snow. In the Alps, above 2000 m over 70 % of the precipitation is snow, at 1500 m it is barely 45 % and at 500 m it is only around 15 % [1].

Large parts of Switzerland are covered by a solid layer of snow for many months. The thickness of this snow cover depends on various factors such as season or altitude, which means that it can vary considerably within a short distance and between one region and another (see plate 3.6).

The depth of the snow cover is measured and analysed at around 300 stations. These spot measurements are then extrapolated to larger areas to estimate the depth of snow in places where no measurements are available. Maps of snow depth are an important basis for avalanche warnings, although they are also important for tourism in relation to snow reliability, for setting up hydrological models and for nivo-climatic studies [5].

The present plate is based on a calculation method used to map the distribution of snow depth in Alpine regions [1].

Data

The basic data were obtained from the measuring network run by the Swiss Federal Institute for Snow and Avalanche Research Davos (SLF) and from MeteoSwiss (Federal Office of Meteorology and Climatology) (see plate 3.1[2]) [4]. All the stations that were chosen lie within a representative, horizontal field. They provide only snow depth figures for that field, i.e. for the flat area. Factors such as gradient, exposition, wind and vegetation cover (particularly forest) that may have a significant influence on the pattern of snow cover have not been taken into account.

For this study we chose to use the 20-year measuring period from 1983 to 2002, when relatively little snow fell compared to the rest of the 20th century. Between 1983 and 2002, at altitudes below 1000 m there was 20 to 40 % less snow, depending on the month, than in the preceding decades. At high altitudes (above 2000 m) the percentage variation was less marked [1,2].

Since we need to draw conclusions for larger areas, it is important to use as dense a network of stations as possible, in particular at higher altitudes. For this reason automatic stations in the high Alps, from which data have been obtained only since the mid-1990s, were included (see table 1). The data from these stations were compared with simultaneously measured long-term data series and converted for the period used here, namely 1983 to 2002. Data from a total of 173 stations were used [1].

Regional extrapolation

To obtain a regional picture of mean snow depth, an approach was used which takes into account both the dominant influence of altitude on snow depth and local and regional characteristics [1]. This approach basically comprises two steps, the results subsequently being combined:

1) The snow depth is influenced first and foremost by the altitude at a particular site. This correlation is described using two linear functions that apply to the whole of the country and that are differentiated by altitude; the result is an estimated snow depth. Using a digital elevation model, this so-called basic value (G) is calculated for each grid point. The spatial resolution of the grid points is 1 km • 1 km.

2) The compensation value (A) accounts for regional deviations from the model for the whole of the country. To obtain this value, the difference between the effective measured depth and the calculated basic value is determined for the three measuring stations closest to the grid point for which the snow depth is to be estimated. These differences are then applied to the grid point, weighted for distance:

$$A_j = \frac{h_j}{\sum_{i=1}^{3}\left(\frac{1}{d_{ji}}\right)} * \sum_{i=1}^{3}\left[\frac{1}{d_{ji}}\frac{(HS_i - G(h_i))}{h_i}\right]$$

where:

A_j: compensation value at grid point [cm]

h_j: altitude of grid point [m]

d_{ji}: distance between grid point and measuring station [km]

HS_i: effective snow depth measured at the measuring station [cm]

$G(h_j)$: snow depth at the measuring station according to the model; basic value [cm]

h_i: altitude of measuring station [m]

j: grid point 'j'

i: measuring station 'i'

The snow depth can be obtained by adding the basic value and the compensation value. Using this regionalisation approach, other parameters that are closely linked to altitude can also be estimated, e.g. depth of new snow, maximum snow depth and total water equivalent of the snow cover, as well as air temperature or precipitation.

Snow depths in Switzerland

The maps show the mean winter value (November–April) providing an overview of the spatial distribution of snow depths, as well as mean values for the months of December, February and April, which give an idea of changes in snow depth over the winter period.

Winter (November–April): This map shows firstly the marked correlation between snow depth and altitude. Secondly, the long-term mean values reveal considerable regional differences. In general, from the Bedretto Valley and the Gotthard and Grimsel regions across to the Alps in the cantons of Glarus and St. Gallen, there was around 20 to 70 % more snow than the national average for the altitudes in question. There was relatively little snow in the southern valleys of the Valais, the Surselva, the central Grisons and the Engadine.

December: The correlation between snow depth and altitude is already clear at the beginning of the winter. The Alpine foothills (above 800 m) already have 10 to 30 cm of snow and are thus quite distinct from the Central Lowlands, which have less than 10 cm. The mean snow depth for the high Alps, with the exception of the Gotthard and Grimsel regions and the peaks of the eastern part of the Valais, is hardly over 150 cm.

February: Most parts of Switzerland have a solid snow cover. Below 1500 m, this is the month when snow depths are at their greatest. The maximum snow depths, namely over 250 cm, are to be found in the Gotthard and Grimsel regions.

April: The snow has already disappeared in the Central Lowlands and in many Alpine valleys. In areas over 2000 m the maximum snow depth is reached only in April, which explains the fact that the steepest gradients of snow depths are also seen at this time. Above approximately 2800 m snow depths of over 3 m are frequent.

The maps showing spatial distribution of snow depths correspond to those in the SIA (Swiss Association of Engineers and Architects) norms [3] as well as the precipitation maps for the European Alps (see plates 2.6, 2.7), which are based on different regionalisation methods.

Regional distribution of snow depths

By mapping the compensation value, the regional climatic differences in the distribution of snow depths can be determined. Areas can be identified with above-average or below-average snow depths in comparison with mean values for the whole of the country (fig. 1).

The maps reveal an arc of greater snow depths that stretches from the northern Tessin across the Gotthard and Grimsel regions, the Goms (eastern part of the Valais), central Switzerland and the Glarus Alps to the Toggenburg and the Alpstein. Other areas that receive considerable amounts of snow include the Prättigau, the Chablais, the Saanenland and the Bernese Alpine foothills. Areas with less snow than the national mean include the southern valleys of the Grisons, the Engadine, the central Grisons and the Surselva, the Jungfrau and Aletsch regions, and the part of the Valais south of the R. Rhone. The explanation for this is that the prevailing weather systems that bring precipitation come in from the north or south and consequently result in large quantities of snow on the northern or southern limits of the Alps, while their effects are less marked in the inner-Alpine areas. Since the principal north and south precipitation patterns overlap in the Gotthard area the greatest depth of snow can be found here.

Since basically in December not much snow has fallen, the regional differences in snow depth barely exceed 50 cm, while in February and April the differences are greater. In the Engadine and the southern valleys of the Valais, for example, there is considerably less snow in February and April than the national mean for the corresponding altitude. At the same time, the snow depth on the northern slopes of the Alps is already above the mean in many places [1].

Time series

Various SLF stations have long-term time series for snow depths of up to 70 years [4]. Figure 2 shows the time series for the winter months of November to April. Although the stations at the Weissfluhjoch (2540 m), Davos (1560 m) and Küblis (810 m) are within 10 km of each other, they cover a broad range of different altitudes. The diagrams corroborate the rise in snow depth with increasing altitude; they also reveal, however, the varying climatic conditions at the different altitudes. While the 5-year moving means for the Davos and Küblis stations show a marked decrease since the beginning of the 1980s, such a trend cannot be seen in the figures for the Weissfluhjoch station, where snow depths are tending to increase [1,2].

The stations at Trüebsee (1770 m), Zermatt (1600 m) and Zuoz (1710 m), which are all at a similar altitude, lie in different climatic areas. The time series for their snow depths illustrate the regional differences in snow conditions within the Alps. Figures for the station at Trüebsee illustrate the fact that the northern Alps and the Alpine foothills receive a lot of snow compared with the inner-Alpine valleys such as Zermatt in the Mattertal and Zuoz in the Engadine. The moving means for these three time series also show a marked decrease in snow depths since the beginning of the 1980s due to prevailing temperatures.

For all six stations there is a considerable variation in snow depths from one year to the next. These variations can amount to 350 % of the long-term mean value, which only serves to illustrate the complexity of mountain climatology.

References

[1] **Auer, M. (2003):** Regionalisierung von Schneeparametern – Eine Methode zur Darstellung von Schneeparametern im Relief. Publikation Gewässerkunde Nr. 304, Bern.

[2] **Laternser, M. (2002):** Snow and avalanche climatology of Switzerland. Diss. ETH No. 14493, Zürich.

[3] **SIA (2004):** Grundlagen der Projektierung von Tragwerken; Einwirkungen auf Tragwerke: Bemessungsbeispiele zu den Normen SIA 260 und 261. Schweizerischer Ingenieur- und Architektenverein SIA, Zürich.

[4] **SLF (2002):** Schnee und Lawinen in den Schweizer Alpen Winter 1997/98. Winterbericht Nr. 62, Eidgenössisches Institut für Schnee- und Lawinenforschung, Davos.

[5] **Witmer, U. (1984):** Eine Methode zur flächendeckenden Kartierung von Schneehöhen unter Berücksichtigung von reliefbedingten Einflüssen. Geographica Bernensia G21, Bern.