Plate 3.5 Extreme Accretion of the Snow Cover

Introduction

The Swiss Federal Institute for Snow and Avalanche Research (FISAR), organised as a branch of the Swiss Federal Institute for Forest, Snow and Landscape (WSL), is responsible for research in the field of snow and avalanches. In addition, the FISAR is charged by the WSL to provide the avalanche warning service within Switzerland as well as information about avalanche danger for the general public. For this purpose the FISAR maintains an observation network including comparative stations and measuring points (cf. map 3.1). The people working with the stations obtain basic information every day concerning the most important weather and snow parameters and pass it on to the central station on the Weissfluhjoch above Davos. The stations with the longest available observations have been in operation for over 50 years. The network has been enlarged considerably over the years. At present the measurement data is collected by around 100 stations in the Swiss Alps, which means that each station covers an area of 250 km^2. Ninety-three stations have at their disposal measurement series covering more than 15 years. The analyses described below are based solely on the FISAR data and do not use information from measurement series from other networks, such as those from the Swiss Meteorological Institute.

The estimation of avalanche danger is based principally on analyses of the following four parameters: new snow, wind, temperature and stratigraphic structure of the snow cover; for obvious reasons, the last parameter is obtained only twice per month instead of daily from representative test areas for each station using so-called snow profiles. For preparing the Avalanche Bulletins [4], which are an important component of the short-term avalanche warning system, the necessary data must be made available at short notice. It is also processed and stored in the so-called snow database, extracts from which are published annually in the Winter Report [3]. With the help of statistical avalanche warning models, historical meteorological and snow conditions are sought which are similar to those prevailing at the time, so that conclusions can be drawn as to the probable avalanche danger and activity level based on previous events. Analyses such as those described in the present map of the «Hydrological Atlas» constitute a basis for the design of long-term protection against avalanches and are also used in climatic studies of the Alps. Guidelines have been drawn up for designing avalanche defence works in the release zone [2]. In addition, engineers will take into account extreme snow loads according to norm 160 [5] of the regulations drawn up by the Swiss Association of Engineers and Architects (cf. map 3.2).

Snow fall period, depth of new snow and total snow depth

The depth of new snow in each 24-hour period is determined from the snow deposited on an exposed measuring table, the table being cleared after each morning's measurement. An episode of snow fall may extend over several days with new snow on the measuring table every morning. As soon as there is one day with no new snow or less than 0.5 cm the period of snow fall is considered over. The duration of a snow fall period indicates the length of the precipitation period, although it is always possible that there are short intervals without new snow during the snow fall period.

The total amount of new snow during a snow fall period indicates the intensity of the precipitation. On the other hand, the accretion value, i. e. the difference in total snow depth between the day immediately before the snow fall period starts and the day with the greatest total snow depth during the snow fall period, provides important information concerning compaction and thus also temperatures during the snow fall period. New snow does not simply accumulate on top of the existing snow cover; its own weight helps considerably to compact the old snow cover, which in turn can have a decisive influence on avalanche activity. During longer periods of snow fall an equilibrium is often established by about three to five days after which the total snow depth remains more or less unchanged. The representation of extreme events was therefore limited to the largest annual amount of new snow over a 3-day period (HN_3) and the highest annual values for accretion of the snow cover over a 3-day period (ΔHS_3). These values were extrapolated using the Gumbel distribution to provide the mapped 100-year return period data.

Regional analyses

The two parameters HN_3 and ΔHS_3 were spatially interpolated on the basis of the stations included on the map, using a method commonly applied in meteorology [1]. Missing values were interpolated on the basis of data from neighbouring stations; this was necessary for only 3 % of the values. Before being interpolated the values per FISAR region were adjusted to a common altitude of 2000 m using linear regression. Taking the mapped adjustment factors for each region it is possible to calculate the two parameters for any altitude between 1000 m and 2500 m. The table gives values for the altitude of the station and adjusted values for an altitude of 2000 m. Owing to generalisation when the data were interpolated, one or two of the values in the table adjusted for 2000 m lie slightly outside the range of value plotted.

On the map of the 100-year 3-day totals of new snow, the Simplon area and the western part of the Ticino with extreme 3-day values of over 280 cm clearly stand out against the other parts of the country. The values for the Great St. Bernard area and the Upper Engadine are relatively low (< 160 cm).

The map of the 100-year 3-day totals for accretion of the snow cover provides information on the distribution of the decisive release factors used in calculating flowing snow avalanches. The return period of 100 years is suitable for most planning purposes. The altitude of 2000 m was selected because the main avalanche release zones are situated in this altitude. In order to describe one single avalanche comprehensively it is also necessary to take into account local wind conditions, the aspect of the slope and the nature of the subsoil. It should be noted that even in areas with quite low accretion values of snow cover massive avalanches can take place. It is consequently the structure of the snow cover, i.e. the degree of tension and compactness of the individual layers of snow, which plays a decisive role.

Periods of extreme snow fall

For the seven selected stations, the diagrams of snowfall periods where new snow totals exceed 50 cm clearly illustrate the climatic influence of the Alps. It is clear, for example, that conditions on the northern side of the Alps (Grindelwald, Trüebsee and Braunwald stations) are very different from those prevailing in areas within the Alps (Zermatt, Zuoz). Analysis shows that on average each winter there are six snow fall periods with over 50 cm of new snow at the Trüebsee station, whereas the station in Zuoz experiences only one such snow fall period.

It is not possible to identify a statistically significant trend over the last 50 years in the annual frequency of such extreme conditions; over the past few years, however, extreme conditions have been seen more frequently towards the spring, especially in the Valais and the northern part of the Grisons.

Extreme value statistics

The Extreme Value Type I distribution (EVI or Gumbel) is quite suitable for the extrapolation of annual extreme events based on measurement series of more than 15 years. The extrapolation method used becomes more reliable as the duration of the observation period increases. As detailed analyses have shown [6], it is not essential that all measurement series cover the same period of time. Map 2.4 indicates the extreme value statistical method used. For purposes of clarity the individual values have not been included in the frequency diagrams. Certain stations were selected for inclusion within the framework of the Atlas. The complete set of diagrams relating to the data analysed from all 93 stations can be obtained from the FISAR.

References

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