Plate 2.5 Extreme Regional Precipitation of Varying Duration and Return Period

Introduction

Precipitation is an areal phenomenon, limited in extent and duration. The area covered by a precipitation event, its duration, and its depth and spatial distribution are determined by the processes of precipitation generation in the atmosphere, and their horizontal movement and evolution.

The most accurate way of recording the precipitation depth is still measurement by means of gauges installed at fixed locations (cf. map 2.1). The principal way of characterising precipitation regimes is therefore through data obtained from these series of point measurements (cf. maps 2.2, 2.4, 2.4[2]), which include the dimensions, depth and duration. In view of the random and systematic spatial variability of precipitation of a certain duration, point measurements can only be representative of the location of the gauge and the immediate vicinity, the extent of which depends on local topography and the precipitation process, but is less than 100 km^2. Generally, precipitation depth for areas larger than approximately 30 km^2 have to be deduced by averaging the point measurements over the area in question. This means that, in addition to the two dimensions of depth and duration, the surface is also of significance when describing regional precipitation depths.

Precipitation depths of a given duration in any defined area have a maximum and a minimum (cf. for example fig. 1). Areal precipitation determined for increasingly large concentric areas around the maximum results in characteristical decreasing curves, known as depletion curves, which can be represented in various ways (figs. 2, 3 and 4).

Bases and Methods

The analysis [1] from which the present map has been drawn up is based on the precipitation gauging networks of the Swiss Meteorological Institute (cf. map), and uses hourly resolution measurements. The values from stations where measurements are recorded only on a daily basis have been subdivided into hourly values using hourly measurements from the ANETZ stations. Data for the period 1981–1993 were thus available for the analysis. The depletion curves for areal precipitation were determined for eight non-calendar duration classes of between 3 and 72 hours.

The presence and the orientation of the Alps generate varying precipitation conditions. The area covered by Switzerland was accordingly divided into eight zones (cf. map) and the depletion characteristic per duration class for each zone was investigated. In the Valais, a distinction was made between zone 4, which is influenced from the WSW to NW, and zone 5, where cyclonic heavy precipitation comes solely from the SW to SE. Similarly, south of the Alps, it was necessary to distinguish between the Camedo area (zone 6) and the remaining part (zone 7). The Bergell (Bregaglia) and Poschiavo valleys show equally autonomous characteristics, but it was not possible to carry out an analysis on account of their location, size and the special characteristics of the gauging network (cf. also «Application»).For the analysis, the heaviest areal precipitation in each zone and each duration class up to the total duration of the event was used. A depletion curve can be drawn for each event. For this purpose, areal precipitation was always determined from the centre of the «meteorological» precipitation field, i.e. independent of hydrological catchments. The 26 most intensive precipitation events per zone and per duration class were used for the statistical analyses in figures 2 and 3. The resulting depletion curves were estimated using the «Weibull-3» distribution.

Results

Figure 1 shows the atmospheric conditions of the most extreme cyclonic precipitation events for the period 1977 to 1994 and the spatial precipitation distribution. The horizontal pressure patterns and their vertical stratification are very much simplified in order to indicate the main air flow characteristics. The precipitation fields show that the most extreme cyclonic precipitation in and on the southern flank of the Alps occurs only with air flows coming towards the Alps. North of this massif, extreme precipitation usually occurs independently of topography. Figures 2, 3 and 4 show depletion curves per zone for selected durations. The abscissae in the diagram all represent divisions of 5000 km^2; if zones are smaller, the curves have been drawn to the size of the zone. The ordinates have either been adjusted to the depths [mm] according to duration (figs. 2 and 4) or based on standardised scale (fig. 3). For areas of up to around 300 km^2, the curves for periods of 3 and 6 hours are determined by showers. Larger areas and all longer periods (> 12 hours) are dominated by cyclonic precipitation. In zone 3 it was not possible to use showers in a representative way with the existing gauging network owing to the topographical complexity, with the result that the 3-hour absolute depletion curves are shown only for areas larger than 300 km^2 (fig. 2). Relative curves could not be determined (not even for durations of 6 hours) because of the missing initial value of the curve (fig. 3).

As the duration period increases, the depletion curves systematically flatten out. This is especially obvious in the relative representation (fig. 3, e.g. zone 1). For precipitation periods of over 24 hours the shape of the curves changes only very slightly. For small areas, however, values drop dramatically over short periods (e.g. 3 hours); this reflects the rapid decrease in precipitation, in the case of showers, from the centre to the edge of the area. Heavy precipitation over a longer period covers larger areas, which means that the depletion curves are accordingly flatter.

The depletion curves proved to be independent of the return period. For this reason, figure 3 gives only one curve for each zone and duration class. The sequential pattern of the curves relating to duration in each diagram (zone) is barely differentiated in the Alpine zones 4, 5 and 8 owing to the particular precipitation conditions. The pattern is partly «distorted» in the other zones because of the short period of reference. Only duration classes of 3 to 48 hours are shown for zone 8 (Engadine). Reliable results could not be obtained for longer periods owing to a lack of suitable data.

Application

The depletion curves do not represent the decrease in areal precipitation in an actual precipitation field but instead show, for each area size, the absolute areal precipitation (figs. 2 and 4) or the relative depletion factor (fig. 3). The diagrams include, in particular, the following information:

1) The enveloping curves describe the largest recorded areal precipitation in the reference period for each area size (fig. 4). These are shown for purposes of comparison.

2) The absolute depletion curves (fig. 2) depict the meteorological areal precipitation for selected return periods for an area and duration of particular interest.
   Example: For a duration of 12 hours and a surface area of 500 km^2 the 50-year meteorological precipitation is 91 mm in zone 1 (west) and 102 mm in zone 3 (east).
   For application to a hydrological catchment it should be borne in mind that the value for areal precipitation in the catchment will be overestimated, since the probable depth depends not only on the frequency of fields with heavy precipitation but also on the location of the catchment in these fields (cf. case A2).

3) The relative depletion curves (fig. 3) give an areal reduction factor (AF) for each zone, duration period and area size, which represents the ratio of the areal precipitation to the point value at the centre of the precipitation field. Either the value at the centre of an event (case A) or a point value of a certain return period as shown in map 2.4[2] (case B) can be used.

Case A: Here either the meteorological areal precipitation P for a given event (case A1) or precipitation P' in a catchment (case A2) can be determined.
In case A1 the AF factor can be applied direct to the highest value observed at a gauging station in the centre of the heavy precipitation field.
Example for zone 1: With a 12-hour duration of precipitation of 100 mm in the centre of the field the regional precipitation for an area of 600 km^2 can be estimated as $P = 100 \bullet 0.71 = 71$ mm.

In case A2 the distance between the station with the heaviest precipitation in the given catchment and the station with the highest value (the centre of the heavy precipitation field) must also be taken into account. The reduction should only be applied from area size $F = \pi \bullet r^2$ onwards.
Example for a catchment with an area of $F = 600\ km^2$ and a highest precipitation value in the catchment of 50 mm (duration = 12 hours): If the distance r is 12 km, the reduction factor must be taken into consideration only from an area of 452 km^2 ($\pi \bullet 12^2$) on. Where F = 452 km^2, AF = 0.74; for (452+600) = 1052 km^2, AF = 0.67, thus for a catchment of 600 km^2 $P' = 50 \bullet 0.67/0.74 = 45$ mm. In view of the analysis concept and the deviation of the field from a circular form, these estimations each represent upper values.

Case B: Point precipitation values from map 2.4[2] are used for estimating areal precipitation in a catchment for given return periods: in zones 1, 2, 4, 6, 7 and 8 the basis is the point value which shows the highest amount in the catchment in relation to a certain return period. The AF for the catchment area can be applied direct to this value.

In zones 3 and 5 the fields of heavy precipitation are of the «19.7.1987» type (zone 3) and the «24.9.1993» type (zone 5) (fig. 1). The method described for case A2 can be used in both zones for precipitation durations above 6 hours. The distance has to be measured from Hinterrhein (station no. 280) for zone 3 and Binn (station no. 7100) for zone 5.

AFs for zone 7 are recommended for estimating areal precipitation in the Bergell (Bregaglia) and Poschiavo valleys.

Bibliografia

[1] **Grebner, D., Roesch, Th. (1998):** Flächen-Mengen-Dauer-Beziehungen und mögliche Niederschlagsgrenzwerte in der Schweiz. Schlussbericht NFP 31, Zürich.