Plate 2.4 Extreme Point Rainfall of Varying Duration and Return Period

Introduction

Extreme floods are caused by intense rainfall, particularly in smaller catchments. Such rainfall represents one of the most significant factors leading to soil erosion and mass movements such as land slides and creep processes. Models have been developed allowing an estimation of both the extent and frequency of such phenomena, provided the frequency of extreme precipitation events is known. However, only in exceptional cases is it possible to predict the place, time and extent of flooding or mass movements.

For 2.33 and 100 year return periods, the four maps show the depths of extreme point rainfall of durations of 1 hour and 24 hours. By means of these four basis values, point rainfall of varying return period and duration can be estimated for any point and place. Additional information on the type of distribution function and the temporal range of interpolation and extrapolation, however, is required. This information is presented on a complementary map.

Depth of point rainfall and return period

For sites equipped with rain gauges, depths of point rainfall were determined by a frequency analysis of the measurement values [5]. These stations lay the groundwork for spatial data interpolation by the Kriging method. Only rainfall values (precipitation in liquid form) are considered; for mixed precipitation (rain/snow) the fraction of snow that did not melt during the measurement interval was subtracted. For stations lacking observational indications, the snow part was estimated on the basis of an altitude- and region-dependent regression equation [2,5]. It is assumed that above 3500 m a.s.l. no precipitation falls as rain, and therefore no interpolations were made at such altitudes.

The return period indicates in what number of years, on average, a particular rainfall depth is met or exceeded. This estimated value depends on both the distribution function and the method of parameter assessment.

The rainfall depth assigned to a particular precipitation duration equals the amount of rain measured during the relevant period. It does not take into account any possible interruptions in the rainfall.

Method

The 503 daily storage gauge stations, maintained by the Swiss Meteorological Institute and other institutions within and outside of Switzerland, make up the database for 24-hour values (cf. map 2.1). According to [4], these data, read at a precise time every day, have to be multiplied by a factor of 1.143 in order to obtain effective 24-hour maxima.

The one-hour values are ascertained from data of 63 pluviograph stations. With few exceptions, these sites are identical to those of the daily storage gauges. For sites lacking a pluviograph, the one hour values were extrapolated by means of a graphical regression based on the daily storage gauge.

For about 200 stations it was possible to analyse gauging series of the years 1901 to 1970; for the remaining stations, the gauging series available at the time of evaluation (1976–1983) were considered with a minimum span of 30 years. As a rule, the yearly maxima were analysed by means of extreme value statistics. As a distribution function, the Extreme Value Type I distribution (EVI; Gumbel) or the Extreme Value Type II distribution (EVII; log-Gumbel or Fréchet) was preferred. The investigation results are published in [5].

Extensive analyses by means of multivariate statistical methods did not reveal any significant dependency of intense rainfall values on physiographic characteristics. This fact allowed an interpolation of intense rainfall values without regard to the relief. For physical reasons, however, this apparent independence is not plausible.

Interpolation was carried out by means of the Point Kriging method. For practical reasons, calculations were based on a variogram, uniform for the whole basin investigated, without nugget effect, for any precipitation duration and return period. The measurement stations were assumed to be equal and representative of areas beyond the sites. To construct the isolines, the values of the ten closest measurement stations were interpolated on a grid of 1 km, calculating the grid point value as a weighted arithmetic mean. The weights of the nearby stations depend on their spatial position and are determined from the variogram. Subsequently, a computerised plot of the isolines and, when required, a graphical smoothing of the curves follows. The interpolation algorithm leads to a reproduction of the values at the measurement sites. As a result, the minima and maxima usually occur close to the measurement sites. Only a denser network could provide more accurate information on the exact spatial position of the extremes. At some sites, the isolines were smoothed for purposes of the graphical resolution capacity [1].

Use

It is to be emphasised that the maps focus on the estimation of point rainfall. It is not admissible, for example, to determine extreme areal precipitation from a planimetric shaping of the isolines. By transferring the point values to hydrological basins, decreasing curves have to be considered such as those developed by [3].

The practical application is explained by the following two examples. Complementary details can be found in [5]. The following terms are used (cf. fig. 1–3):

A: 1-hour-value on 100-year return period (mm) or (mm/h)

B': 24-hour value on 100-year return period (mm)

B: 24-hour-intensity-value on 100-year return period (mm/h); B = B'/24

C: 1-hour-value on 2.33-year return period (mm) or (mm/h)

D': 24-hour-value on 2.33-year return period (mm)

D: 24-hour-intensity-value on 2.33-year return period (mm/h); D = D'/24

t: measurement interval (h)

T: return period (years)

$x_{t,T}$: precipitation depth (mm) of a T-yearly event on a time interval of t hours

$i_{t,T}$: mean intensity (mm/h) of a T-yearly event on a time interval of t hours

ln(x): natural logarithm

exp(x): e^x

Example 1

For the coordinate axes 700/200 (south-east of Schwyz) the depths of point rainfall for one hour and twenty-four hours on a 50-year return period are required:

For the given position, the values A, B', C and D' are taken from the corresponding maps. From the complementary map we deduce that the EVII distribution has to be applied. For didactic reasons, however, the solutions to both distribution functions are given here.

Solution to the EVI distribution:

$$x_{1,T} = 1.14 \cdot C - 0.14 \cdot A + \frac{A - C}{4.02}\left[-\ln\left(-\ln(1 - \frac{1}{T})\right)\right]$$

$$x_{24,T} = 1.14 \cdot D' - 0.14 \cdot B' + \frac{B' - D'}{4.02}\left[-\ln\left(-\ln(1 - \frac{1}{T})\right)\right]$$

With the values A = 80 mm, B' = 175 mm, C = 25 mm and D' = 77 mm read off the map, the one-hour-value on a 50-year return period comes to $x_{1,50}$ = 70 mm and the 24-hour-value on a 50-year return period to $x_{24,50}$ = 158 mm (Fig. 1).

Solution to the EVII distribution:

$$x_{1,T} = \exp\left\{1.14 \cdot \ln C - 0.14 \cdot \ln A + \frac{\ln\frac{A}{C}}{4.02}\left[-\ln\left(-\ln(1 - \frac{1}{T})\right)\right]\right\}$$

$$x_{24,T} = \exp\left\{1.14 \cdot \ln D' - 0.14 \cdot \ln B' + \frac{\ln\frac{B'}{D'}}{4.02}\left[-\ln\left(-\ln(1 - \frac{1}{T})\right)\right]\right\}$$

With the same basis values A, B', C, and D', we obtain $x_{1,50}$ = 66 mm and $x_{24,50}$ = 152 mm (Fig. 2).

Example 2

The rain intensity diagram is to be derived for the same position:

Again the values A, B', C and D' are necessary as well as the type of distribution function. The following auxiliary values are then calculated:

B = B'/24

D = D'/24

a = 0.315 * ln(B/A)

b = 0.315 * ln(D/C)

With y(T) = -ln(-ln(1-1/T)), assuming the EVI distribution:

$$i_{t,T} = C \cdot t^b + 0.248\,(A \cdot t^a - C \cdot t^b)\,(y(T) - 0.577)$$

Assuming the EVII distribution:

$$i_{t,T} = C \cdot t^b \cdot \exp\left(0.248\ (\ln\frac{A \cdot t^a}{C \cdot t^b})\ (y(T) - 0.577)\right)$$

Illustrated by this example, the 24-hour-intensity-value on a 50-year return period is $i_{24,50}$ = 6.6 mm/h (EVI, cf. fig. 3). The relevant inter- and extrapolation code determined by means of the complementary map shows within what range of the rain intensity diagram the points of equal return periods can be joined by a straight line. In this example, the straight lines can be interpolated within 10 minutes and 24 hours.

References

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