2.7 Variability Coefficient of Precipitation Depth

The Maps 2.2 to 2.6 give an impression of the wide spatial variation of mean precipitation depths with a span of about 1500 mm in the annual values of the period 1961–1990; the areal average is 779 mm. However, besides spatial variability, knowledge of the *temporal variability* is essential in any water-resources planning issue, such as the establishment of a water balance or determination of the mean groundwater recharge. The length of the current internationally agreed 30-year reference period defined by WMO, is mainly due to the high variability of precipitation. In contrast to the discrete precipitation events, other weather elements like air temperature often have a distinct diurnal course dependent on sunshine, while their mean values over days, months, and years are much less variable in time than precipitation.

The Maps 2.2 to 2.6 show the mean values of the observation series of the reference period 1961–1990. However, single years, half-years, and months may deviate considerably from these mean values. When using mean values in hydrological computations, it is consequently necessary to know how wide the values may deviate on average from these mean values at a given site in single years, half-years, or months.

Often, the standard deviation s is used as a simple measure for the temporal scatter of an observation series around its mean value. The higher the precipitation depth, the higher is also this standard deviation. Mapping of the standard deviation would thus essentially reflect the spatial distribution of precipitation. Consequently, it is reasonable not to use s, but to standardise it with the arithmetic mean value and to express it as percentage. The variability coefficient V in percent is equal to the percentage standard deviation:

$$V = \frac{s}{\bar{x}} \cdot 100 \quad \text{with} \quad s = \sqrt{\frac{1}{n-1} \sum_{j=1}^{n} (x_j - \bar{x})^2}$$

with $\bar{x}$ being the mean value of the single elements x_j and n the number of values in the observation series. The standardisation gives a better area-related visualisation of the spatial variations of precipitation depths around the mean value due to different influences of weather types and orographic conditions. The values of the variability coefficient are always in the range from 0 to 100 percent.

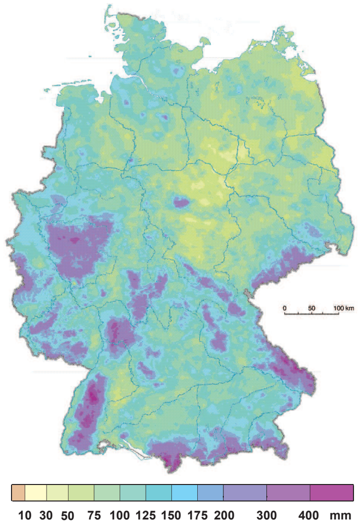

Fig. 1 Precipitation depth of the wettest month of the reference period 1961–1990: July 1980

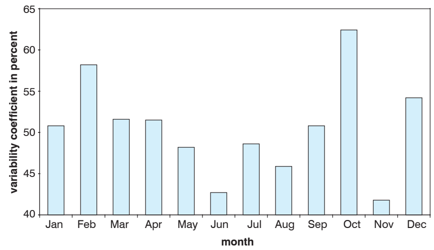

Fig. 3 Variability coefficient of the individual months in the reference period 1961–1990

Map Structures

Similar to the mean precipitation depths of the years and hydrological half-years shown in the Maps 2.2 to 2.6, the variability coefficient is computed for the years und hydrological half-years of the period 1961–1990. Additionally, the mean variability coefficient of the single months is determined.

Since the behaviour of the temporal precipitation variability is nearly independent of a correction of the systematic measuring error, all computations use uncorrected precipitation depth data. The grid representation is smoothed to eliminate station extremes.

Variability coefficient of the years

Map A shows the variability coefficient of the annual precipitation depths. The values of the grid cells range between 11 and 24 percent. In the north and the south of Germany, the temporal variations are the lowest, remaining below 14 percent, with minima in the North-German Lowland, on the Baltic Sea coast, and throughout the Alpine piedmont. In the Alps, the percentage standard deviation is only slightly higher at 16 percent.

Towards Central Germany, the variability coefficient increases and reaches its maximum in the eastern foreland of the Harz Mountains. Other maxima are located around Kassel, in the Lausitz (Lusatia), and around the uplands of Spessart, Odenwald, and Vogelsberg mountains. Here however, the ridges of the mountains do not show outstanding values as they do regarding the mean annual precipitation depths. For instance on higher ground in the Schwarzwald (Black Forest), the variability coefficient of annual precipitation depths is just as high as in the Oberrheingraben, with minor differences between the northern and the southern Black Forest. Also the Sauerland and Harz uplands differ only little from the surrounding lowland regions.

One reason for the little scatter of annual precipitation depths on the coasts is probably the balancing influence of the North Sea and the Baltic Sea with high humidity transport and subsequent precipitation fields. In Southern Germany, precipitation is usually less dependent on changing, weather-type related humidity fluxes as – especially in summer – precipitation there is mainly convective. Then precipitation is generated less by advective humidity transport than from the existing stationary humidity storage.

Variability coefficient of the months

In order to eliminate the annual variations of monthly precipitation depths, the variability coefficients of the months are not computed by relating the 360 months of the period 1961–1990 to a mean monthly distribution of precipitation, but the variability coefficients of the single months are first computed separately and then averaged.

To which extent monthly precipitation depths may vary in time is illustrated by the precipitation distribution during the month with the highest areal precipitation depth of the reference series – i. e. July 1980 (Figure 1) – and the month with the lowest one – i. e. February 1972 (Figure 2). The mean areal precipitation depth over Germany in February 1972 amounted to 10.8 mm and in July 1980 to 133.5 mm, i. e. more than the ten-fold.

Precipitation in the wet month of July 1980 is characterised by persistent western weather types and is exemplary for a monsoon-type summer month. The distribution of precipitation coincides nearly with the mean annual precipitation distribution (Map 2.2). Due to stemming on the windward sides of all mountains, these areas stand out with high precipitation depths. The drier regions lie on the leeward side of the Pfälzer Wald (Palatinate Forest), the Harz Mountains, the Black Forest, and in the Altmark. The span of the spatial variation reaches from 25 mm to more than 400 mm.

In the dry month of February 1972, southeasterly airflow prevailed over Germany, so that low-pressure areas with humid air masses could gain influence only over the extreme south-west and south of the country. Consequently, in February 1972 only the Sauerland Mountains, the south-west of Rheinland-Pfalz (Rhineland-Palatinate) and the Saarland, the southern Black Forest, and the eastern Alpine region received precipitation depths above 25 mm. With increasing continental character, precipitation depth decreases towards the east to less than 5 mm.

These two examples illustrate that the distribution of precipitation in single months may be very different. The distribution of the variability coefficients of the single months shown in Map B is very similar to the structure of the variability coefficients of the years. However, with 44 to 59 percent, the grid-cell values are markedly higher than the annual scatter.

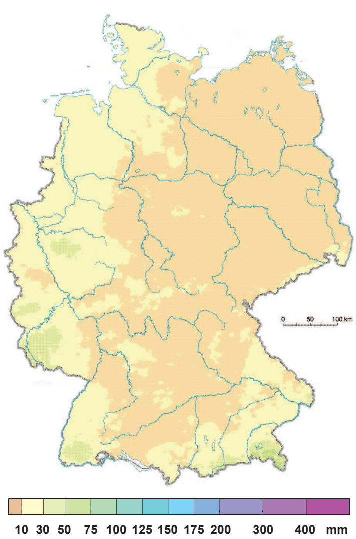

Fig. 2 Precipitation depth of the dryest month of the reference period 1961–1990: February 1972

The temporal variations of monthly precipitation depths are with more than 58 percent the highest in the driest regions in eastern Germany and in the lee of the Palatinate Forest. The causes are summer convective precipitation events such as the heavy rainfall in August 1978 over the Niederlausitz, which brought high monthly precipitation depths in otherwise rather dry areas. The wide variations in the Odra basin may also be due to rare extreme precipitation events during so-called Vb weather patterns. Other rare maxima occurred in the Bavarian Forest and in the southernmost part of Baden-Württemberg. As especially the months of February and October show very high variability coefficients in these regions (above 80 percent), extreme convective events alternating with little precipitation during persistent periods of high pressure may be the underlying cause.

In the German Alps, on the ridges of the uplands, and throughout Northwest Germany, the values of the monthly variability coefficient are around 48 percent. Prevailing westerly winds bring a rather balanced precipitation regime to Northwest Germany. In the hilly and upland regions, precipitation is intensified by uplift of air masses on the windward side of the obstacles. Here too, variations relative to the mean value are small.

Considering the variability coefficients of the single months in the reference period, one finds distinct differences in the course of the year. Figure 3 shows the mean variability coefficients of all grid cells of Germany for the single months. In the course of the year, November has the lowest scatter, followed by June. Conversely, precipitation depths vary strongly in October, with a second maximum in February. For instance, the monthly areal precipitation depths over Germany in the reference period range in October between 14 and 127 mm, but in November merely between 29 and 107 mm.

The shown yearly course of the variability coefficients of the months remains qualitatively preserved if considered over longer periods (e.g. 1900–1999), although the values are slightly smoothed. October remains the month with the widest scatter from year to year, June the one with least deviations. However, in the period 1900–1999, the mean variability coefficient of November is markedly higher (10 percent); March is similar with 5 percent. Therefore, precipitation conditions of the reference series 1961–1990 deviate in both months distinctly from those of the 100-year period 1900–1999.

Variability coefficient of the hydrological half-years

The Maps C and D show the variability coefficients of the hydrological half-years. In the summer half-year, the grid cells of the variability coefficient range between 12 and 29 percent. Like in the analysis of the years, one finds here minima in the north of Germany, especially around Bremen, as well as in the southern Alpine piedmont and in the Alps. The maxima are again located in Lusatia, in the eastern foreland of the Harz Mountains, in the Hessian Uplands, around Frankfurt/Main, and in the northern parts of Baden-Württemberg. In particular the minima of half-year variability coefficients are even more pronounced than those of the years, since precipitation generating processes which influence the distribution over the year are particularly dominant in summer.

With 15 to 30 percent, the variability coefficients of the hydrological winter half-years are somewhat higher than those of summer half-years. However, their distribution pattern is much different: Minima occur only in Lusatia and in Brandenburg and along the Middle Rhine between Koblenz and Köln (Cologne). Elsewhere the percentage standard deviation is relatively uniform around 22 percent. Maxima exist in the High Rhine region, in the upper and middle basin of the River Main, and north of the Harz Mountains.

In the summer half-years, the variability coefficient of precipitation increases from the north-west towards central Germany, to drop again southwestwards to the Alps. In the winter half-years, one observes an increase from the eastern parts of Germany to a maximum between the northern foreland of the Harz Mountains, the middle reach of the River Neckar, and the Fränkische Alb (Franconian Alb). Towards the western parts of the country and the northern Alpine piedmont, the values decrease again.

Practical Information

Because the Maps 2.2 to 2.4 show the mean precipitation depths of years and half-years, it is possible to compute the absolute scatter in mm around the mean value for these periods by multiplication with the variability coefficients of the Maps A, C, and D. The variability coefficients are also transferable in the same order of magnitude to the values of the corrected precipitation depths (Maps 2.5 and 2.6).

Decisive for the specific regional size of the variability coefficients is the period under consideration: The values of annual distributions range between 11 and 24 percent, those of summer half-years between 12 and 29 percent, of winter half-years between 15 and 30 percent, and finally of the months between 44 and 59 percent.

When mean precipitation depths are used for water-resources planning, their temporal variability must not be left out of account. In dependence on the issue in question and potential environmental risk factors, the whole span of variability coefficients around the mean value or even its station extremes may become relevant.