2.14 Mean Annual Climatic Water Balance

The *climatic water balance* (CWB) is defined as the difference between precipitation depth and the depth of potential evapotranspiration at a given site during a certain time period.

In general climatology, climate classifications are usually based on the weather elements “air temperature” and “precipitation depth”, from which e. g. the description of the aridity of the climate is derived, the so-called aridity index. However, in the context of water-resources management and hydrology, the climatic water balance is better suitable for the hydroclimatic characterisation of sites, areas or periods, because the (hydro-)climatic conditions are described directly by means of the water-balance effective elements “precipitation” or “potential evapotranspiration” in the dimension “mm”. Dependent on whether precipitation depth or potential evapotranspiration depth prevails in the considered period, the climatic water balance assumes positive or negative values and thus indicates *climate-induced* surpluses or deficits in the water budget and its regional distribution. Real evapotranspiration, or more precisely the balance between precipitation and real evapotranspiration, is determined by these hydroclimatic conditions and additionally by land use and soil conditions (Map 2.13).

It should be noted that the numeric values of the climatic water balance may differ considerably depending on the computation method used for input data. That is why the method used for computing potential evapotranspiration (Map 2.12) and precipitation depths (with/without correction) must be indicated in any climatic water balance figures. This problem will be treated in more detail in the Chapter “Practical Information”.

Map Structures

The Map 2.14 shows in form of grid cells the mean annual values of the climatic water balance computed as the difference between the gridded mean annual values of corrected precipitation depth (Map 2.5) and the gridded grass reference evapotranspiration (Map 2.12). The symbols of the 1-km² grid cells indicate different widths of the chosen classes. In the lower, sometimes negative range of balance values up to +100 mm, the span of a class is 50 mm. In the range between 100 mm and 400 mm, classes follow in 100-mm steps, and in the next range (climatic water balance up to 1000 mm) the class amplitudes are 200 mm wide. The range of high climatic water balances (> 1000 mm) is divided in 500-mm steps.

The mean annual totals of the climatic water balance decrease in the North-German Lowlands from some 300 mm on the North Sea coast south-eastwards to negative values. In the same direction, the mean distribution of precipitation depths shows a decrease, while the grass reference evapotranspiration increases. Over wide areas on the lower River Saale (north-eastern/ eastern Harz foreland), on the middle reach of the River Elbe, and in the Baruther Urstromland (glacial valley of Baruth), the yearly totals of grass reference evapotranspiration are higher in the long-term average than the corrected precipitation depths, so that the climatic water balances turn negative. The highest annual deficits, which are on average around -100 mm and reach in extremely dry years -400 mm, occur in the eastern foreland of the Harz Mountains, where also the lowest precipitation depths of Germany are recorded (Map 2.2). Other larger areas with negative mean annual balances are the Oderbruch and northwards the adjacent areas of the Uckermark hill country and the lower Oder valley, as well as in the south-west of Germany the Vorderpfälzer Tiefland and the Alzey hill country. In years with abundant precipitation, these dry areas record also positive annual values of the climatic water balance. In the 1961–1990 period, annual balances there were positive in 30 to 50 percent of the years.

In the north-east of Germany, especially in the Federal State of Brandenburg, the tight water balance is not only due to climatic precipitation and evapotranspiration conditions, but is influenced as well by the characteristics of the natural regions. A high areal share of natural and man-made waters (mining lakes, canals) as well as the groundwater-influenced lowland and marsh areas have high actual evapotranspiration values and usually negative water balances. Moreover, sandy soils with little water-storage capacity are common in this region, so that periods with little rainfall during the growing season do not provide sufficient supply of water to plants, whereas in times of abundant rainfall groundwater recharge is enhanced.

In upland regions and in the Alps, the average yearly balances are positive throughout, due to the high precipitation on the windward sides of the uplands and the decrease of evapotranspiration with growing elevation. The highest values of the climatic water balance are recorded on high ground of the uplands Westerwald, Harz, Schwarzwald (Black Forest) and the Alps with annual averages up to 2000 mm, which may be exceeded considerably in wet years. Even in years with precipitation far below the average, the annual climatic water balances remain in the positive range here. The warmer valleys, where precipitation is less abundant, show distinctly lower mean balance values in the mean regional distribution. Examples are the valley of the River Main (Schweinfurter Becken) and the above-mentioned precipitation-deficient area of Rheinhessen (Vorderpfälzer Tiefland, Alzey hill country) with a negative annual balance on average.

The regional differences in climatic precipitation and evapotranspiration conditions in Germany are also reflected in the inner-annual course of the climatic water balance. Table 1 lists the typical mean year and half-year values of the climatic water balance for some German regions at selected sites. The data in this table should be understood as orientation values, which may give an overview on the large-scale distribution of annual and seasonal climatic water balances. Because of the small-scale patterns of precipitation fields both in the mountains and in lowlands (Maps 2.2 and 2.4), considerable differences in the mean climatic water balances may be found already over relatively short distances. Climatic water balances that are directly related to certain sites or regions must take these structures into consideration by computing the balances with data measured at representative precipitation or weather stations.

In the summer half-year, positive (mean) balance values are restricted to the region near the North Sea coast, the Niederrheinisches Tiefland (Lower Rhine lowland), the Westfälische Tieflandsbucht (Westphalian lowland), and the Geestniederungen (geest regions) along the rivers Dümme, Ems, and Hunte. About 30 percent of the years show negative summer half-year values of the climatic water balance here, too. The mean monthly values assume negative values from May to July, although negative monthly balances can be expected in nearly all months (except November and December) whenever rain-deficient weather prevails.

Table 1 Mean year and half-year values of the climatic water balance (corrected precipitation minus grass reference evapotranspiration ET_0) in mm at sites in selected regions of Germany for the period 1961–1990

region	year	winter half-year	summer half-year
North-German Lowlands and individual regions			
Weser-Ems-Marsh	333	272	61
Weser-Aller-Lowland	165	204	-39
North-East-Mecklenburg	186	206	-20
Central Brandenburg	50	158	-108
Lausitzer Becken	4	109	-105
Eastern Harz Foreland	-65	75	-140
Alzeyer Hill Country	-62	81	-143
medium heights (about 400 m – 500 m a. s. l.)			
Westerwald	694	501	193
Thuringian Forest	745	523	222
Western Erzgebirge	492	330	162
Eastern Erzgebirge	282	218	64
Pre-Alpine Hill Country	655	324	331
uplands and mountains (about 1000 m – 1500 m a. s. l.)			
Harz	1754	1120	634
Erzgebirge	911	545	366
Black Forest	1828	1072	756
Bavarian Forest	1202	722	480
Allgäu	2296	1144	1152

In the North-German Lowland, a continuous transition associated with decreasing positive balance values in the winter half-year and increasing balance deficits in the summer half-year occurs with growing distance from the Atlantic Ocean and the North Sea coast. Negative mean balances of the summer half-year are recorded already in the Weser-Aller Lowland, in the Lüneburger Heide (Lüneburg Heath), and in the coastal region of the Baltic Sea. The whole lowland regions of Mecklenburg-Vorpommern (Mecklenburg-Western Pomerania), Brandenburg, Sachsen-Anhalt (Saxony-Anhalt), and Sachsen (Saxony) have negative summer half-year balances, with average values sometimes drastically below - 100 mm. The highest deficits in the summer half-year show values below -300 mm. In summers with abundant rainfall, positive half-year balances may be recorded too, what was the case in about one third of the years in the series 1961–1990.

The period with mean negative monthly balances in the inland lowlands lasts from April to September/October. The highest monthly balance deficits below -100 mm are recorded in the months from May to July. Negative monthly balances may occur throughout the year, provided dry weather prevails. In the rain shadow of the Harz Mountains and in the eastern regions of Brandenburg and Saxony, a few single years have negative balances also in winter half-years.

On middle and higher elevations of the uplands and the Alps, the climatic water balances of summer and winter half-years are all positive. Negative monthly balances occur here only rarely, however, they may be expected in all months of the year in uplands in the east, while they are restricted to the summer half-year on high ground of mountains in the west. In the uplands, the annual sums of the climatic water balance result on average by 60 percent from the values of the winter half-year and by 40 percent from those of the summer half-year. In the Alps, the contributions of both half-year sums to the annual value are on average equal.

Precipitation deficient valleys and leeward locations, such as the Alzey hill country or the Vorderpfälzer Tiefland show an annual course of the climatic water balance that is typical for regions of inland lowlands (see above). The transition from climates of maritime to continental influence is still distinct in the climatic water balances of the windward locations rich in precipitation. On comparable elevations, the values of years and half-years of the climatic water balance are on mountains in the west notably higher than in the east. The uplands show from west towards east an increase in the number of summer half-years with negative climatic balances or a prolongation of the period with onaverage negative monthly values. Exclusively positive half-year balances occur in the pre-alpine region. This precipitation-rich area on the windward side of the Alps has only exceptional cases of negative monthly balances. Typical phenomena in this region are abundant summer showers (Map 2.4), which cause high summer half-year balances – as they occur also on high ground of the Alps – reaching or even exceeding the balance figures of the winter half-year.

Practical Information

The climatic water balance has high temporal variability, which is due – just like its regional variability – mainly to the strong variations of precipitation depth. Potential evapotranspiration may be above or below the average in precipitation-deficient weather just like in weather with abundant rainfall. Consequently, the variability range of the climatic water balance is less than that of precipitation depth. Figure 1 shows the more than 100-year time series of annual climatic water balances at the weather station of Potsdam. The mean value of the most recent reference time series 1961–1990, that was used for the Hydrological Atlas, coincides here accidentally with that of the long series. The smoothed time series (Gaussian filter) allow to identify periods with higher or lower average values of the climatic water balance. The variability range of the climatic water balances of single years is around 500 mm. The highest and the lowest yearly totals of the climatic water balance observed at this station since the beginning of records in 1893 are also included in the 1961–1990 series (1981 and 1982). The time series of the annual balances shown has a slightly decreasing, though not significant trend.

Besides the temporal and regional references that are needed because of the variability of the climatic water balance, the computation method used must be indicated whenever balance values from different sources are compared. Especially older maps and classifications include data of the climatic water balance, which are based on potential evapotranspiration depths calculated according to Haude or Penman (with different empirical factors!) and on precipitation depth measurements which are usually not corrected. Table 2 shows by the example of the weather station Potsdam that the methods used for routine computations of potential evapotranspiration have considerable influence on the result of the balances. The use of non-corrected precipitation depths reduces the balance values in Table 2 additionally by 57 mm against the result gained under consideration of corrected precipitation data. The comparative calculations highlight that considerable misinterpretations may occur if the data used for the climatic water balance is not derived from a standardised basis.

Table 2 Mean year values of the climatic water balance CWB using different computation methods of potential evapotranspiration PET (station Potsdam, time series 1961–1990)
\# using uncorrected precipitation measurements
\## using corrected precipitation measurements

computation method	CWB# in mm	CWB## in mm
grass-reference evapotranspiration (Map 2.12)	-15	+42
Penman	-125	-68
Turc	+9	+66
Haude	-38	+19

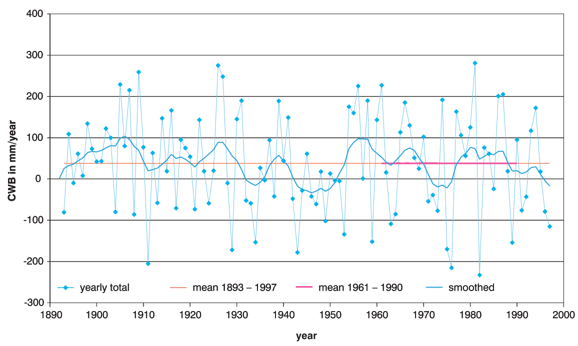

Fig. 1 Time-dependent curve of the climatic water balance ($CWB = P_{corr} - ET_0$) of Potsdam for the time series 1893–1997