International Commission for the Hydrology of the Rhine Basin (CHR)

Annual Report of the CHR 2015

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International Commission for the Hydrology of the Rhine Basin

Internationale Kommission für die Hydrologie des Rheingebietes

The International Commission for the Hydrology of the Rhine Basin (CHR) works within the framework of the International Hydrologic Programme (IHP) of UNESCO and the Hydrology and Water Resources Programme (HWRP) of the World Meteorological Organisation (WMO). It is a permanent, independent, international commission and has the status of a foundation, which is registered in the Netherlands. The following scientific and operational hydrological institutions of the Rhine basin are members of the commission:

- Federal Ministry of Agriculture, Forestry, Environment and Water Management, Department IV/4 – Water Supply (Hydrography), Vienna, Austria,
- Office of the State of Vorarlberg, Department VIId – Water Management, Bregenz, Austria,
- Federal Office for the Environment, Bern, Switzerland,
- IRSTEA, Antony, France,
- IFSTTAR, Nantes, France,
- Federal Institute for Hydrology, Koblenz, Germany,
- Hessian State Office for Nature Conservation, Environment and Geology, Wiesbaden, Germany,
- IHP/HWRP Secretariat, Federal Institute for Hydrology, Koblenz, Germany
- Administration de la Gestion de l’Eau, Luxembourg,
- Deltares, Delft, Netherlands,
- Rijkswaterstaat – Traffic and Water Management, Lelystad, Netherlands.

1. Hydrologic overview for the Rhine drainage basin

Meteorological characteristics

Austria, Source: Central Institution for Meteorology and Geodynamics (Zentralanstalt für Meteorologie und Geodynamik, ZAMG)
The year 2015 is, after 2014, the second warmest in Austria since the beginning of instrumental recording in 1768, with a deviation from the average for 1981-2010 of +1.5 °C (Figure 1). It was not only particularly warm in the past year but also poor in precipitation over wide areas. Austria-wide, 10% less precipitation fell in comparison to the long-term average. Thus, 2015 is one of the twenty driest years since the beginning of the nationwide precipitation recording in 1858. Large parts of Upper Austria, western Lower Austria and the industrial quarter saw a total of 22 to 40 percent less precipitation. Seven to 22 percent less precipitation fell in large parts of the country. Balanced amounts of precipitation came together in the Rhine Valley, Tyrolean Oberland, along the Hohe Tauern, in parts of Carinthia and in the upper Murtal. Since the beginning of records in 1925, 2015 was the fifth sunniest year in Austria. In the area average, the sun shone, nationwide, 10 percent longer than in the long-term average.

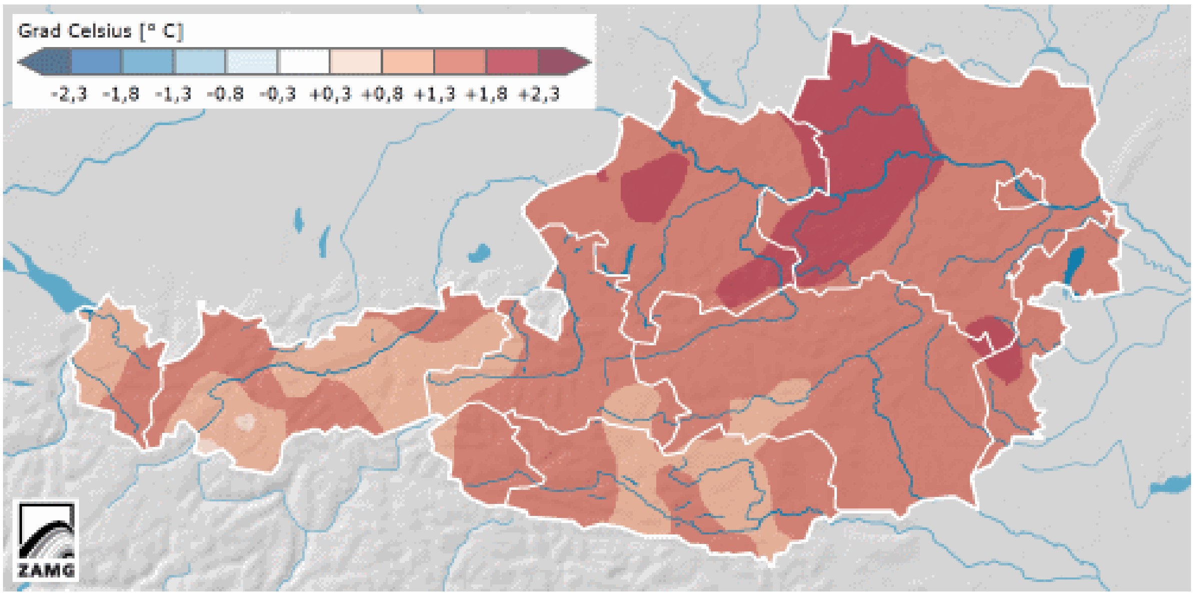


Figure 1: Temperature in Austria in 2015: Temperature deviation from the long-term average 1981-2010. Source ZAMG

Meteorological characteristics for the Austrian Rhine basin
The annual precipitation average was between 80 and 95% of the long-term average value in the Austrian part of the Rhine drainage basin. In January, April and May, the precipitation total was above the long-term average for these months; that of September was average. Otherwise, the monthly precipitation totals were below average (see Figure 2). In the Austrian Rhine drainage basin, the annual average of the air temperature was approx. 1.4 °C above the long-term average.

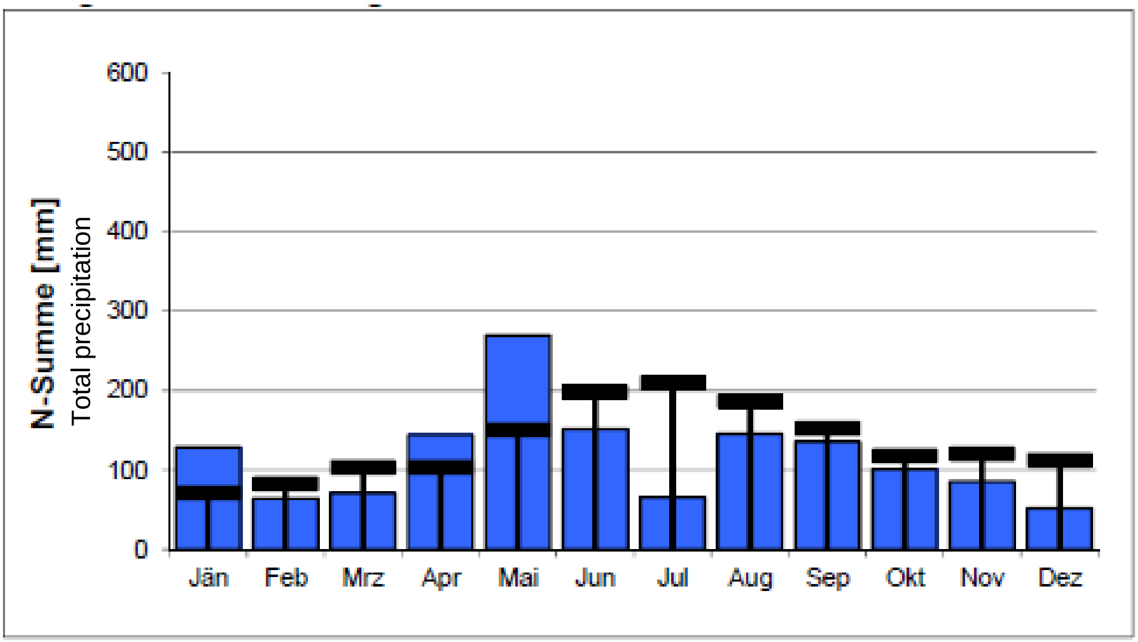


Figure 2: Monthly precipitation totals in 2015 (blue bars) compared to the long-term monthly averages at the Bregenz Altreuteweg measuring station

Switzerland, Source: MeteoSchweiz
In the first half of January, the weather in Switzerland was governed predominantly by mild westerly and south-westerly currents. North-westerly and northerly currents brought winter back to Switzerland in the second half of January. February turned out wintry with widespread below-average temperatures and snowfalls with deep accumulation on both sides of the Alps. Despite a cold February, the winter in Switzerland was too mild overall, with an excess of 0.7 degrees compared to the 1981–2010 standard.

After several foggy and damp days at the beginning of the month, March delivered glorious high-pressure weather until mid-month. It ended in late-wintry fashion with snow as low as 600 m and stormy conditions on both sides of the Alps. April brought Switzerland primarily calm, sunny and mild spring weather.

At the transition from April to May, a very precipitation-rich period set in. Inside of six days, around 100 mm of rain fell on average over the whole of Switzerland. The largest amounts fell in the Lower Valais, in the Vaudois Alps and in the neighbouring Bernese Oberland. Higher altitudes in these areas received 200 mm precipitation and more. With additional heavy precipitation mid-month, the end result at multiple measurement stations was the most precipitation-rich May since the beginning of measurement, especially in the western Alps and in the Bernese Oberland.

The Swiss summer goes down as the second warmest, after 2003, in the 152-year measurement history. July was widely the hottest month since the beginning of measurement on the south side of the Alps, in Engadine, in Valais and in western Switzerland. From July 1 to July 7, 2015, Switzerland experienced one of the most extreme heat weeks. At the end of this week, Geneva registered the highest temperature ever measured on the north side of the Alps with 39.7 degrees. On the south side of the Alps, the high heat continued from mid-July.

The summer already delivered widespread, significantly below-average precipitation amounts. The lack of precipitation continued in the fall. Above-average precipitation amounts in large areas fell only in September, this entirely in the west of Switzerland as well as in

Ticino and in Grisons. In October generally below-average amounts fell, and the first three weeks of November remained, largely, precipitation-free throughout Switzerland. In the end, the south side of the Alps experienced a record lack of precipitation for the period November-December. In Lugano and Locarno-Monti, only 0.8 mm of precipitation fell; normal would be 200 to 250 mm.

The persistent, extremely mild and practically precipitation-free high-pressure weather lead to a pronounced early winter lack of snow throughout Switzerland.

Table 1: Annual values for 2015 at selected MeteoSchweiz measurement stations compared to the 1981-2010 standard

Station	**Elevation a.s.l.**	**Temperature (°C)**			**Sunshine duration (h)**			**Precipitation (mm)**		
		Average	**Standard**	**Dev.**	**Total**	**Standard**	**%**	**Total**	**Standard**	**%**
Bern	553	10.0	8.8	1.2	2077	1682	123	768	1059	73
Zurich	556	10.6	9.4	1.2	1946	1544	126	918	1134	81
Geneva	420	11.6	10.6	1,0	1996	1828	109	686	1005	68
Basel	316	11.7	10.5	1.2	1945	1637	119	645	842	77
Engelberg	1036	7.8	6.4	1.4	1500	1350	111	1435	1559	92
Sion	482	11.5	10.2	1.3	2249	2093	107	500	603	83
Lugano	273	13.8	12.5	1.3	2302	2069	111	1232	1559	79
Samedan	1709	3.4	2.0	1.4	1957	1733	113	626	713	88

Standard = Long-term average for 1981-2010
Dev. = Deviation of the temperature from the standard
% = Percent in relation to standard (standard = 100%)

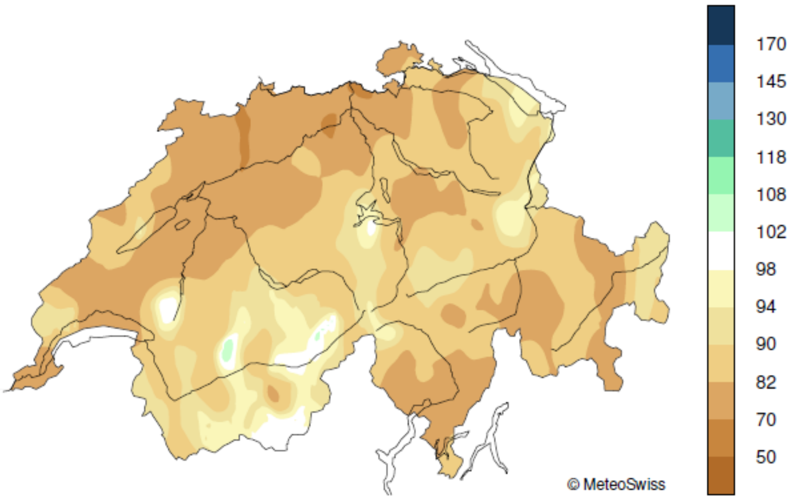


Figure 3: Annual precipitation totals for Switzerland in 2015 in percentages of the standard (1981-2010).

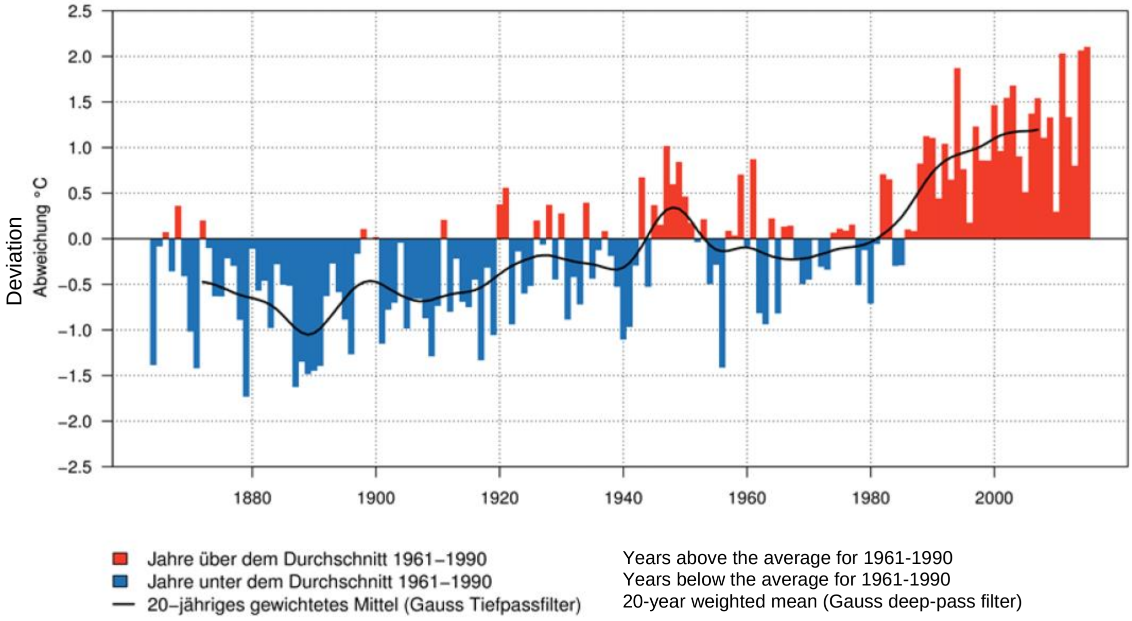
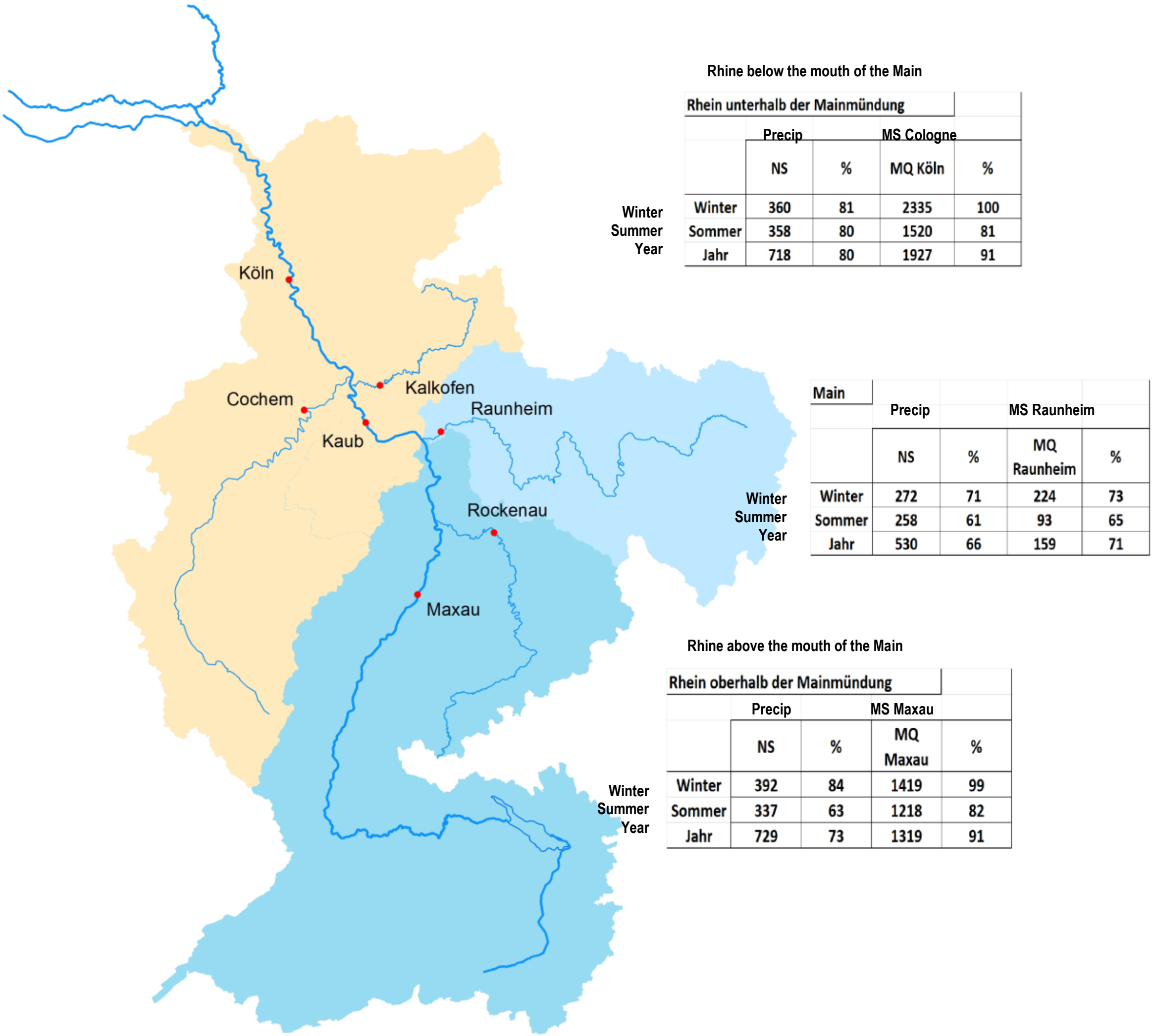


Figure 4: The annual temperature deviation in Switzerland in the year 2015 from the long-term average (reference period 1961-1990). The too-warm years are shown in red, the too-cold years in blue. The black line shows the temperature profile averaged over 20 years.

Germany, Source: German Meteorological Service (Deutscher Wetterdienst, DWD)
Viewed worldwide, the average temperature of the calendar year 2015 broke a new heat record. In Germany, 2015 represents, along with 2000 and 2007, the second-warmest year since the beginning of regular weather records in 1881; during this year, it was predominantly too hot and too dry throughout Germany. The relative deviations of the precipitation amounts for the federal territory showed a significant north-south differential in the observation period. At the Rhine, this means that the southern drainage basin to the mouth of the Main showed an average precipitation amount of approx. 73% of the long-term observed precipitation amount of the 1981-2010 series; north of that area, it was 80%. The driest, seen relatively, was the Main drainage basin section with only about 2/3 of the normal basin precipitation total (cf. Figure 5 with tables).



Rhine below the mouth of the Main

Rhein unterhalb der Mainmündung		Precip		MS Cologne	
		NS	%	MQ Köln	%
Winter	Winter	360	81	2335	100
Summer	Sommer	358	80	1520	81
Year	Jahr	718	80	1927	91

Main		Precip		MS Raunheim	
		NS	%	MQ Raunheim	%
Winter	Winter	272	71	224	73
Summer	Sommer	258	61	93	65
Year	Jahr	530	66	159	71

Rhine above the mouth of the Main

Rhein oberhalb der Mainmündung		Precip		MS Maxau	
		NS	%	MQ Maxau	%
Winter	Winter	392	84	1419	99
Summer	Sommer	337	63	1218	82
Year	Jahr	729	73	1319	91

Figure 5: Rhine drainage basin. Comparison of the basin precipitation totals and discharge averages in the discharge year 2015 with the long-term average 1981/2010
(Source: DWD / monthly weather reports 2015)

Especially in the summer half-year with basin precipitation averages of 63% south of the mouth of the Main and even just 61% in the Main basin, a significant deficit, compared to the long-term observed precipitation, was to be recorded. The long-term monthly average in the hydrologic year was exceeded above the mouth of the Main and in the Main basin only in January, below the mouth of the Main also in August and September. In the entire Rhine drainage basin, February, May, July and October turned out significantly too dry, with relative precipitation amounts of 50% (see Figure 6a).

In the precipitation division between winter and summer half-years, the seasonal precipitation statistic showed a surplus of the winter precipitation share at Upper Rhine and Main with 52% to 48% on average compared to the long-term observed precipitation total of the series 1981/2010 (winter 47%, summer 53%). Below the mouth of the Main, the ratio corresponded to the long-term calculated values at 50:50. For the winter half-year, a precipitation total of 346 mm (81%) was recorded in the entire Rhine basin; the summer half-year, with 325 mm

(69%), recorded a value that was significantly too low compared to the long-term averaged precipitation total for this period.

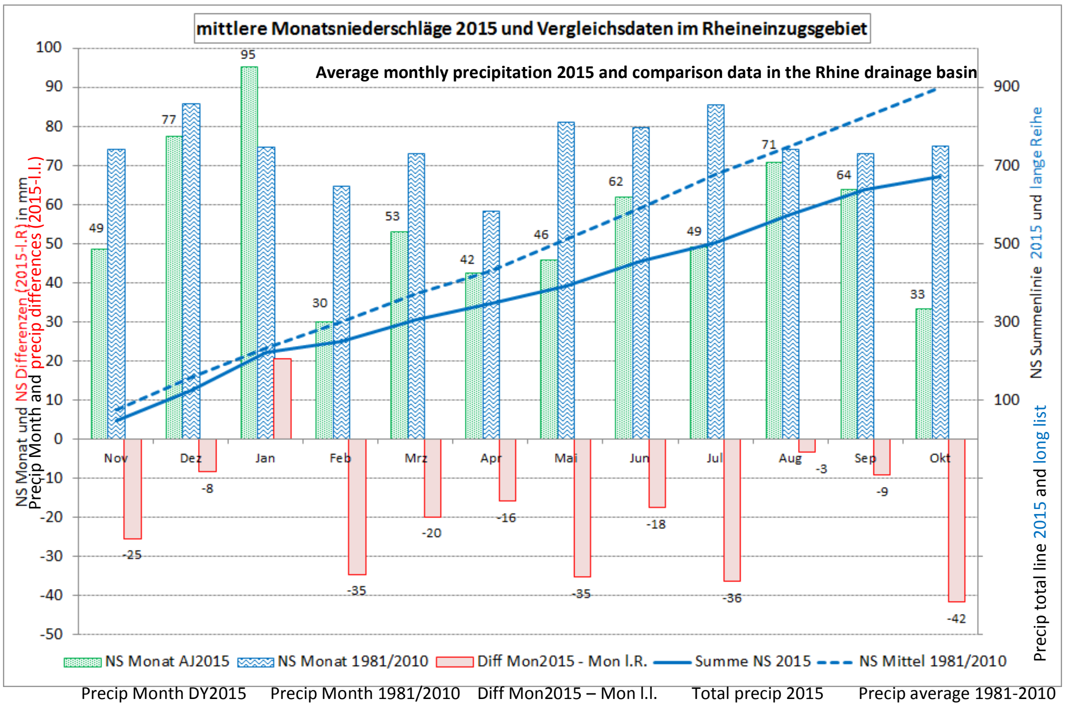


Figure 6a: Rhine drainage basin. Comparison of the monthly basin precipitation totals in the discharge year 2015 to the long-term averages 1981/2010 (Source: DWD / monthly weather reports 2015)

At the beginning of the discharge year (Nov-Jan) and in July and August, the deviations of the monthly temperature averages were on average almost 2°K above the reference period 1981/2010. The basic characteristic determined for the entire federal republic was also, as shown in Figure 6b for the example of the Cologne measurement station, significant despite minimal differences for the German Rhine basin.

Average monthly precipitation in the Rhine basin below the mouth of the Main
and average air (AT) and water (WT) temperatures in Cologne in the discharge year 2015

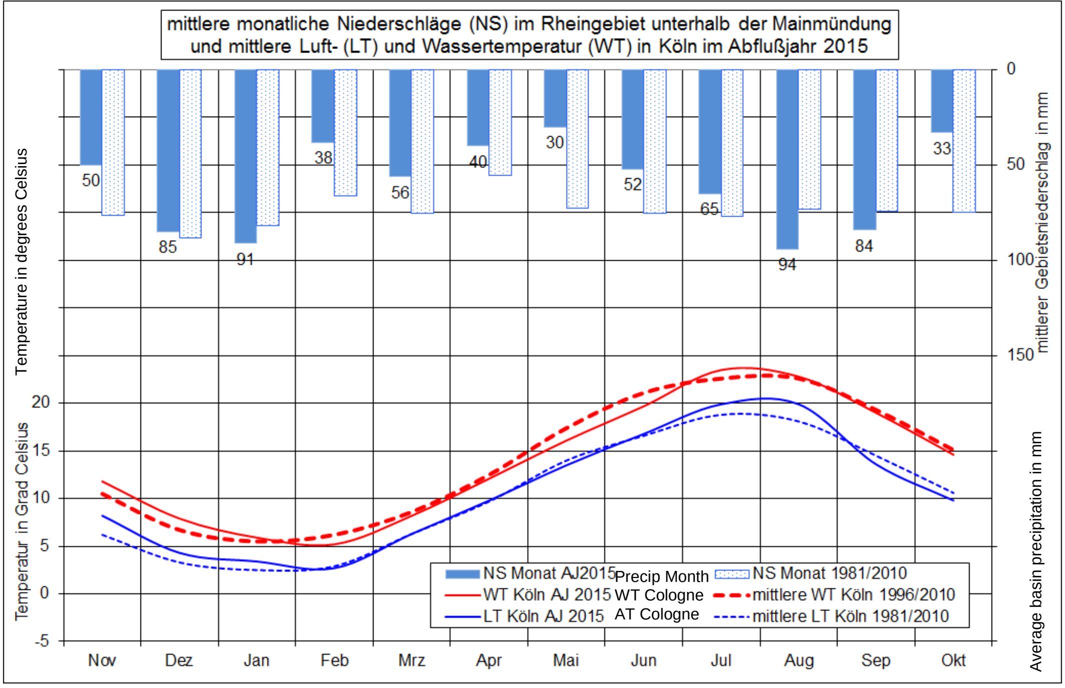


Figure 6b: Rhine drainage basin/example station Cologne. Comparison of the monthly temperature and precipitation data in the discharge year 2015 compared to the long-term average 1991/2010
(Data sources: AT and precip – German Meteorological Service, WT – Federal Waterways and Shipping Administration)

Netherlands, Source: Royal Netherlands Meteorological Institute (Koninklijk Nederlands Meteorologisch Instituut, KNMI)
The average annual temperature at the De Bilt station reached a value of 10.9 °C in 2015, compared to a normal of 10.1 °C. Thus, 2015 was the fifth-warmest year since 1901. For a long time, it looked unlikely that 2015 would go down in history as ‘very warm’.

The winter months January and February were both fairly mild. Spring was, overall, rather cool, especially through a cool month of May. The summer proceeded fairly warm. From June 30 through July 5 inclusive, there was talk of a heat wave. On July 2, the highest temperature of the year was measured in Maastricht at 38.2 °C, just below the record of 38.6 °C from 1944. Fall began cold. September had not been so cold since 2001. October was also a properly cold month. Nevertheless, the fall ended extremely mild. November was the second-warmest November month for over a century. December was by far the warmest December month since the beginning of regular temperature observations in 1706. The average temperature in December reached a value of 9.6 °C, even higher than the normal value for April (see Figure 7).

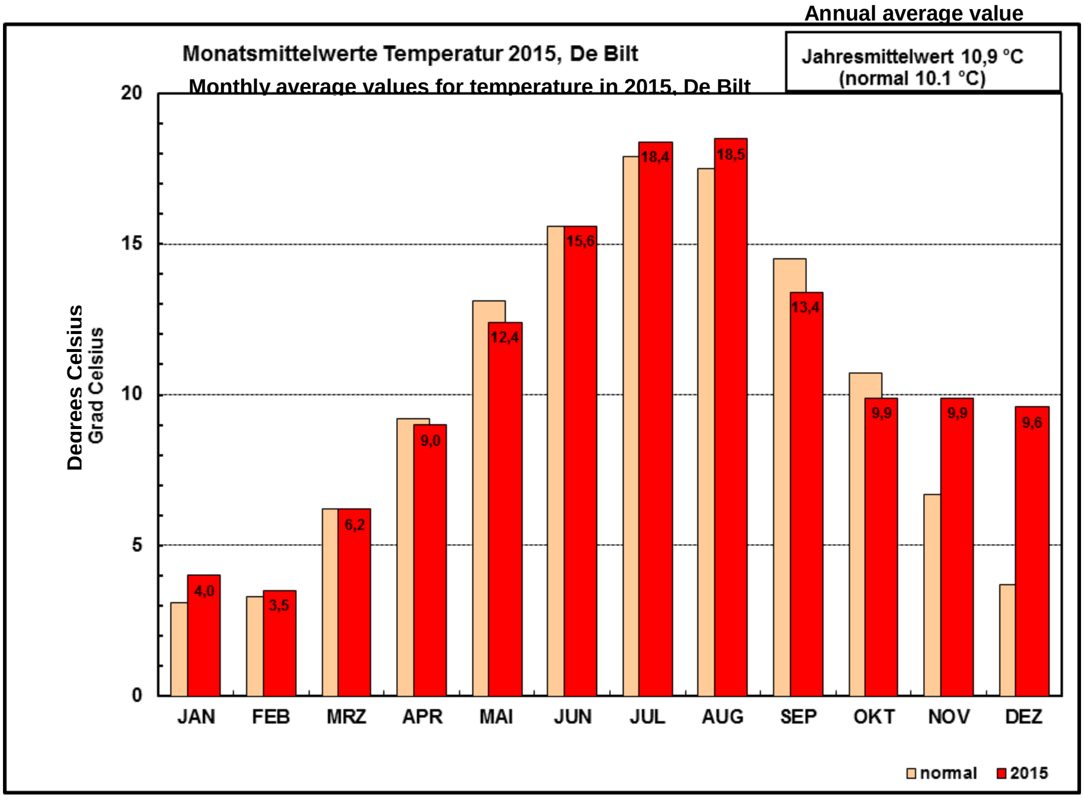


Figure 7: Monthly average values of the temperature at the De Bilt station in 2015 compared to long-term (1981-2010) average (Source: KNMI)

On average, 1894 hours of sunshine were recorded in the Netherlands in the past year, and thus 2015 was a very sunny year. Normally the sun shows itself for 1639 hours (in comparison to the long-term average value for 1981-2010).

The average precipitation amount was 831 mm in the past year. The long term average value is 847 mm. The regional differences were nevertheless very large. Above all, the central part of the Netherlands was very wet with 1000 mm, compared to which 2015 was a very dry year for the southeast of the country with 632 mm (see Figure 8).

Wet months with an average value of 100 mm or more were January, August and November. In January it was not only wet but also consistently stormy. On 16 days, especially in the coastal areas, strong wind gusts of over 75 km/h occurred. Also notable was the strong summer storm that made its way across the country from the southwest to the northeast.

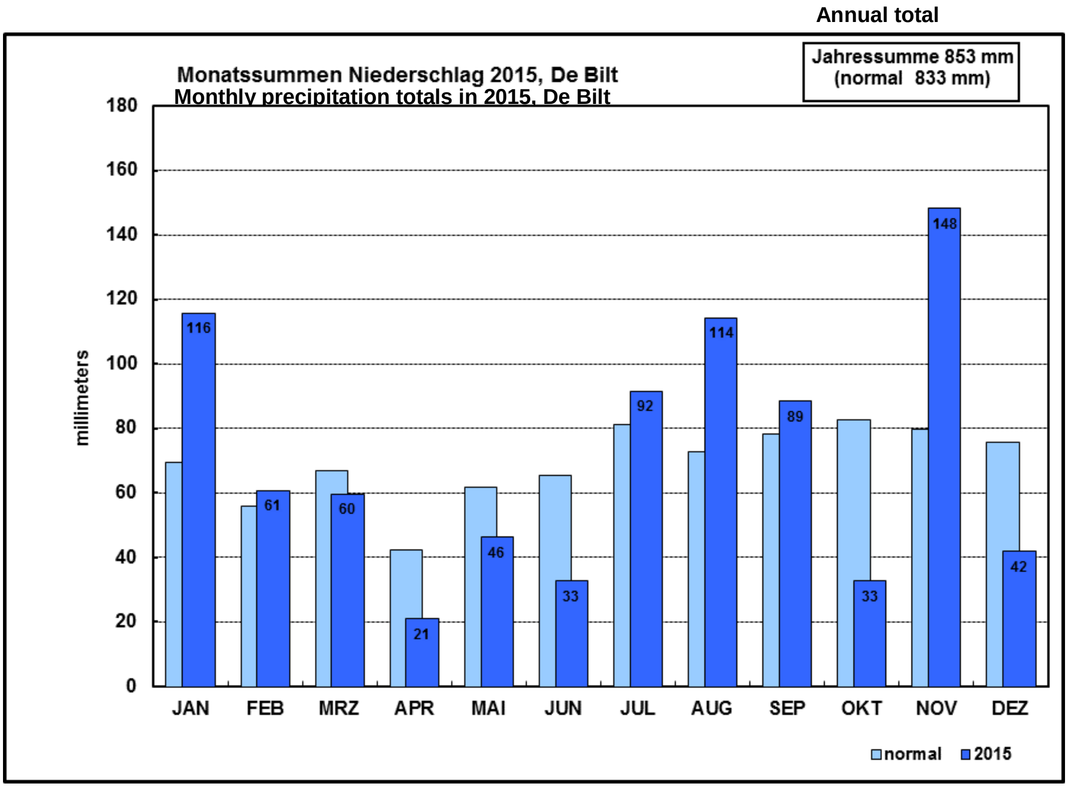


Figure 8: Monthly totals of precipitation at the De Bilt station in 2015 compared to the long-term (1981-2010) average value (Source: KNMI)

Snow and glaciers

Source: Snow: WSL-Institute for Snow and Avalanche Research SLF
Glaciers: Geographic Institute of the University of Fribourg and Laboratory for Hydraulics, Hydrology and Glaciology (Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, VAW)

January was precipitation-rich in the South and in Engadine; otherwise, the precipitation amounts were average. The first half of January was as mild as springtime and the snow line was significantly above 2000 m a.s.l. in some places. In the second half of January, however, winter returned with multiple cold fronts and snow was constantly falling, even in the midlands and in Jura. At the end of the month, there were then significant snow amounts even in the west and north.
The snowfalls in February were far above average in the south, slightly below average in the north. A lot of snow fell primarily in Upper Valais, in the area of the central Alpine divide and in northern Ticino, especially due to a strong snowfall in mid-February.
March was indeed characterised by lots of sun in the north. Thanks to the snowfalls at the beginning of the month and especially due to a large snowfall at the end of the month in the west and north, however, average or slightly above-average snow depths were reached.

April brought average snowfalls only in the pre-Alps. Especially in the south, very little precipitation fell and there was at times a risk of forest fire.

May was characterised at the beginning of the month by intensive precipitation in the western and northern Alps. Because the snow line was mostly high, the snow still on the ground was melted by the snow. With melt rates thereby increased, the result was very high runoff and also flooding. The flood situation was able to calm down thanks to sunny and dry weather until mid-month. A lot of snow fell again in the middle of the month on the southern slopes of the Alps and from 18 to 22 May in the central and eastern Alps, but it melted again rapidly.

In the hydrologic year 2014/15, the mass balance was taken at 21 Swiss glaciers. Average snow levels on the glaciers were able to be determined in mid-April. The snow melt did not set in until the beginning of the hot period in July. However, the hot and stable summer weather, which persisted with only few interruptions until mid-August, then led to unusually strong melting. A marked cooling and new snowfall in the second half of August and in September finally ended this phase of stark loss of the glaciers.

The difference of the mass balance from glacier to glacier was particularly large in 2015. The least dramatic turned out to be the melting with an average ice thickness lost of around 70 cm in southern Valais. By contrast, the glaciers between Bernese Oberland and Valais suffered very strongly. Extreme thickness losses of more than 250 cm could be detected. For most of the glaciers in Switzerland, both on the northern and on the southern sides of the Alps, the thickness losses were between 100 and 200 cm. Smaller glaciers at lower elevations, on which the winter snow had already completely melted away in the month of July, were most strongly affected by the hot period.

On all glaciers of Switzerland carried over, an estimated loss of volume of 1300 million cubic metres of ice results for the hydrologic year 2014/15. This corresponds to a reduction of the current remaining total glacier volume by almost 2.5 percent. Although the glacier melt was clearly above average, the record values of the hot summer of 2003 were not reached. The mass balance of the Swiss glaciers now lies in a similar range as in the likewise very negative years 2006 and 2011.

Hydrologic situation in the Rhine basin in the year 2015

Water levels of the large lakes in the drainage basin of the Rhine

Austria

At Lake Constance, the water level at the Bregenz gauge remained above the respective long-term daily average value from the beginning of the year until June 28, with the exception of four days in June. In the second half of the year, the water level was almost always below the average value of the calendar day. The above-average precipitation in January, in conjunction with the positive temperatures in the first half of the month and the large amounts of precipitation in May, led to an above-average seasonal water level until mid-June. The below-average precipitation totals in the months June to December caused the below-average water levels until the end of November, compared to the observation series 1864-2013 (see Figure 9).

GAUGE STATION BREGENZ – LAKE CONSTANCE
Water level movement from 1864 – 2013 (150 years)
Gauge zero point: 392.14 m above sea level

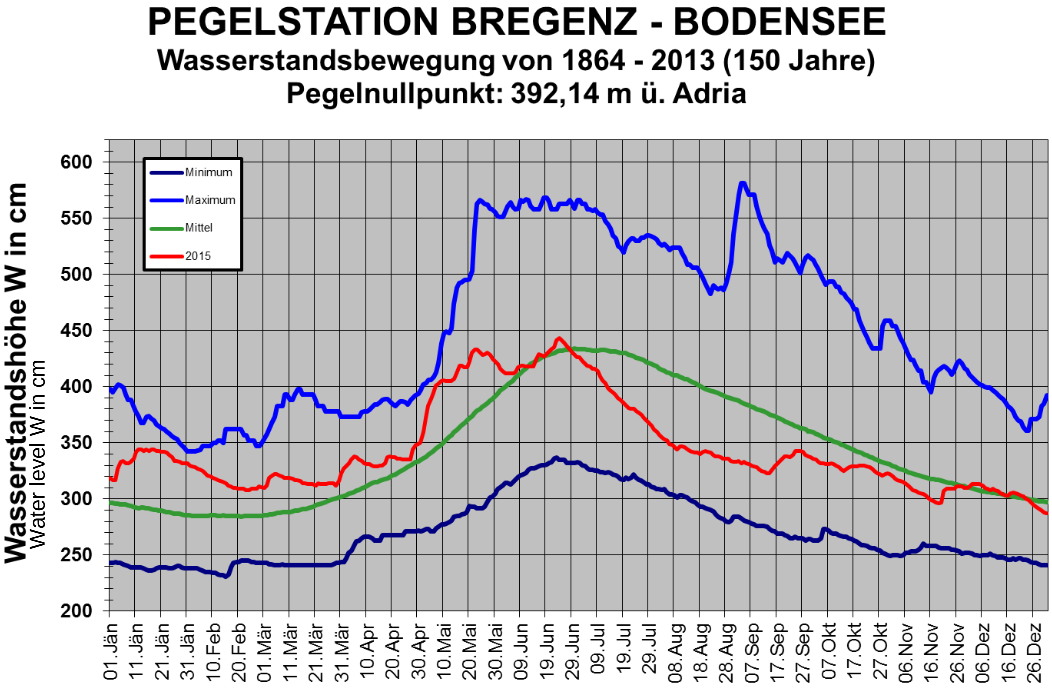


Figure 9: Hydrograph of the water level in Lake Constance at the Bregenz gauge in (red curve) compared to long-term lows, highs and average values of the period 1864 – 2013

Switzerland
At the larger lakes in Switzerland, the annual average values of the water level in general differed only a few centimetres from the long-term average values. Short-term swings often level out when viewed over the entire year. That was also not very different in 2015. For the most part, the levels this year were a few centimetres below the norm; at a couple of lakes, they were barely above average. Worth noting, with large negative differences, are Lake Lugano (-8 cm), Lake Zug (-9 cm) and the Walensee (-13 cm). With a large positive difference of 12 cm, Lake Constance was an outlier this year.

At the end of last year and the beginning of this year, Lake Constance had a relatively high water level. In January it was up on average almost 50 cm, and in February it was still more than 30 cm above the corresponding long-term normal values. Lake Neuchatel and Lake Geneva started at a normal level for the time of year. While the monthly average of Lake Neuchatel and Lake Geneva followed the long-term average values in the second half of the year, significantly below-average levels were registered at Lake Constance from July to September.

New monthly high values occurred in May. At Lake Neuchatel and Lake Geneva, the average water level was about 30 cm above the long-term average values. At Lake Neuchatel, the high level of May 8, with 430.44 m a.s.l., was not only a record for May (previously 430.05 m a.s.l. in 1999), but also an overall record for the lake (previously 430.27 m a.s.l. in August 2007). The level of the lake has never been higher since the second Jura water correction.

The long period of low precipitation in the second half of the year did not express itself overall with very low water levels. This is due to – especially at Lake Constance – the relatively high level after the May floods. The water level of Lake Constance was high for the time of year at the beginning of summer and therefore did not fall below the 5% quantile boundary even after a long time of constant retreat. The regulated Lake Zurich could not profit from this effect. From mid-July on, the water level moved constantly into the range of seasonal low values. For August, September and November, there were new monthly minimums in this year at Lake Zurich.

Water levels and discharges of river water

Austria

The discharges of the most important tributaries to Lake Constance varied in 2015. The annual load compared to the long-term average was

- 89% for the Bregenzerach (MQ 2015 = 41.3 m³/s, long-term MQ = 46.5 m³/s);
- 90% for the Dornbirnerach (MQ 2015 = 6,35 m³/s, long-term MQ = 7,04 m³/s);
- 96% for the Alpenrhein (MQ 2015 = 221 m³/s, long-term MQ = 231 m³/s).

Switzerland

The annual average of discharge of the large river basins corresponded at the Rhone as far as Lake Geneva, at Ticino, Inn and Alpenrhein roughly to the average of the standard period 1981-2010. The discharges of the Aare, Reuss, Limmat, Thur and Doubs were 10 to 15% below the long-term average. On the Birs and Maggia, only three quarters of the usual amounts were discharged. In the mid-sized discharge basins, one sees the influence of snow and glacier melt. Basins with a marked glaciations achieved average or even above-average discharge amounts despite modest precipitation amounts. The Saltina, the Massa and the Reuss at Andermatt exceeded the norm by about 15%, the Rosegbach by more than 30%.

The discharge amounts in many areas of western Switzerland and the midlands were in the range of 70 to 90% of the normal amounts. The drainage basins with normal discharges (90 to 110%) are in Bernese Oberland, in the central and eastern Pre-Alps, in Ticino and in Engadine. In some basins, the average annual discharges consist of a wet first half-year and a dry second half-year. This dichotomy of the year can be shown especially well on the Aare, the Reuss and the Limmat, but also at the Emme, the Thur and the Muota. On the Thur at Andelfingen, nearly 20% more water was discharged from January to June than in the long-term average. From July to December, however, it was less than half the usual amount.

The most striking months of the first half of the year were January and May, with discharges at times massively higher than in the long-term average. A storm front that crossed from the north toward the Alpine region in the first days of the year brought a great deal of moisture and also very mild air to Switzerland. The precipitation, in combination with the snow melt led to strong rises of the water levels in northern and north-western Switzerland. The standout event of the first half of the year, however, was the flood of the beginning of May. On the Aare, Reuss, Limmat and also on the Rhine, the discharges in May formed the highest, monthly values of the year.

The unusually low precipitation in the second half of the year led to below-average discharges being registered every month from July to December at many measurement stations. In some basins, the monthly values from July on never rose above 80% of the long-term averages.

From July to December, especially on the north side of the Alps, there were new low water records in every month. Noteworthy is the month of November, in which new record monthly lows were measured in the midlands east of the Aare at numerous measurement stations.

With regards to flooding, 2015 was uneventful. Apart from the flood at the beginning of May, only a few noteworthy flood events occurred. The event at the beginning of the year on the north side of the Alps brought new monthly highs *inter alia* on the Sorne, on the Töss and on the Glatt at Herisau. The flood in May was by far the largest of the year. More than a dozen measurement station between Lake Geneva and Birs registered a new May high.

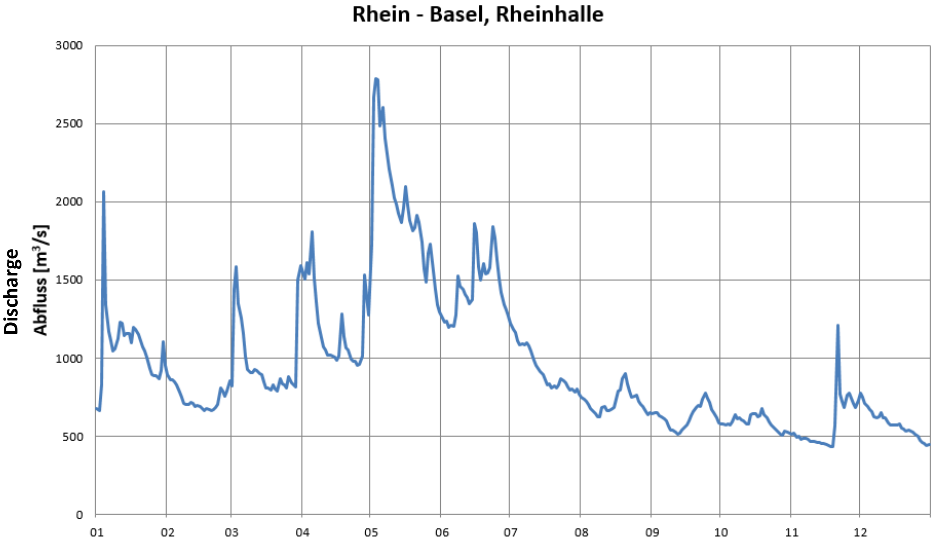


Figure 10: Discharge hydrograph at the Rhine – Basel gauge, Rheinhalle in 2014 (provisional data)

Germany

The discharge behaviour in the discharge year 2015 (illustrated in the hydrograph presentations of Figures 11 through 16) turned out to be very balanced on the Rhine into June. High and low water extremes were absent; only in Cologne did the lowest discharges fall below the monthly average (mMNQ) on 7 days. At the beginning of July, an extraordinary low water period emerged for the entire drainage basin. As a result, the hydrographs fell at all measurement stations continually until the end of the observation period in October; here the lowest monthly discharges were detected at the most measurement stations.

There were regional differences in the discharge volumes of the Rhine and its tributaries. In relation, the Rhine showed a slight surplus in the 8-month average Nov. 2014/Jun. 2015 above the long-term average of the periods 1931/2011 in the amount of +6%; this positive difference turned out to be even more significant with respect to the Mosel (Cochem gauge) with +23%. By contrast, the level at the Neckar (Rockenau gauge) had to be recorded as falling slightly below the long-term 8-month average with around -5%, compared to which the level at the Main (Raunheim gauge) was actually very significantly below the reference value by 29%.

For the period from July to October, a significant deficit of 34% on average for all months at all measurement stations was recorded, again with the exception of the Mosel (Cochem gauge); here only 28% of the long-term discharge amounts calculated for these months flowed into the Rhine. At the measurement stations of the Rhine, levels continually fell below the average monthly lowest values (mMNQ) at the Maxau and Kaub station in the period from July to October, in Cologne with the exception of 4 days, at Neckar and Main very frequently, on the Mosel almost always except for 7 days in September.

The annual MQs at the measurement stations in the Rhine were between 5 and 9% below the long-term annual averages in 2015 (cf. Tab. 2). At the Neckar, Rockenau measurement station, the MQs were narrowly missed by 12%; the Main recorded a significant deficit at the Raunheim gauge with 29%. At the Cochem station, Mosel, the MQ2015 is 85% compared to that calculated from the long list (1931-2011), yet it is apparent that there 89% of the total annual amount was already discharged in the first 7 months alone.

The ratio of the winter to summer MQ shows significantly the effect for the Rhine, with the addition of the drainage basin area, of the tributaries from the uplands. In Maxau the average discharge in the winter half-year was still just below that calculated for the summer; by Cologne, the summer share dropped to 39%. For the dam-regulated tributaries Neckar and Main, on average, 71% of the total annual discharge were to be measured at the Rockenau and Raunheim gauges in the winter half-year (Nov-Apr). On the Mosel, a significant overbalance of the winter half-year discharge totals was to be recorded with 82% of the total discharge (cf. Tab. 2).

Table 2: Comparison of the mean discharges (MQ) for selected gauges in the Rhine basin

Gauge	MQ			MQ 2015		
	2015	1931-2011	MQ 2015 to MQ long list [%]	Winter	Summer	% W/S
Maxau (Rhine)	1186	1253	95	1212	1159	51/49
Rockenau (Neckar) * 1951-2011	121	137*	88	171	71	71/29
Raunheim (Main) * 1981-2011	159	225*	71	224	93	71/29
Kaub (Rhine)	1539	1653	93	1723	1356	56/44
Cochem (Mosel)	267	314	85	437	97	82/18
Cologne (Rhine)	1927	2110	91	2335	1520	61/39

The ratio of the shortfall days of the winter or summer MQ was balanced at the Rhine gauge at Maxau with 120 to 121 days; in Kaub it was 110 to 129 and in Cologne 90 to 146 days. At the tributaries, the shortfalls for the observation period at the Neckar and Mosel were at 278 and 247 days respectively, at the Main even at 300 days, the respective largest share of which was allotted to the summer half-year with 176 days at the Neckar; at the Main this was 184 days and 117 days at the Mosel.

Noteworthy shortfalls of the average annual lowest discharges (MNQ) were recorded in the entire Rhine drainage basin in the summer half-year, with 19 days in Cologne and at the Main and with 73 days at the Mosel (Cochem). The lowest values fell below the monthly average (mMNQ) at the measurement stations of the Rhine on average on 123 days in the summer half-year, at the tributaries: Neckar only on 91 days (winter 12, summer 79), Main on 183 (winter 60, summer 123) and at the Mosel on 144 days (winter 22, summer 122).

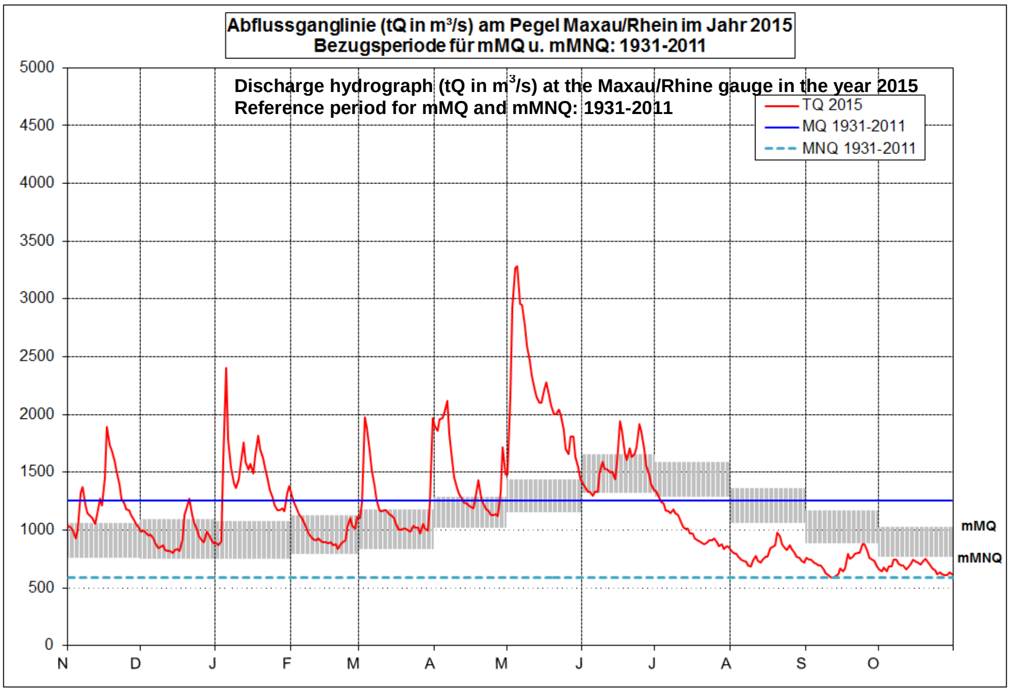


Figure 11: Discharge hydrograph (tQ) at the Maxau (Rhine) gauge in 2015 in m³/s (Reference period for MQ, mMQ and mMNQ: 1931-2011 timeframe)

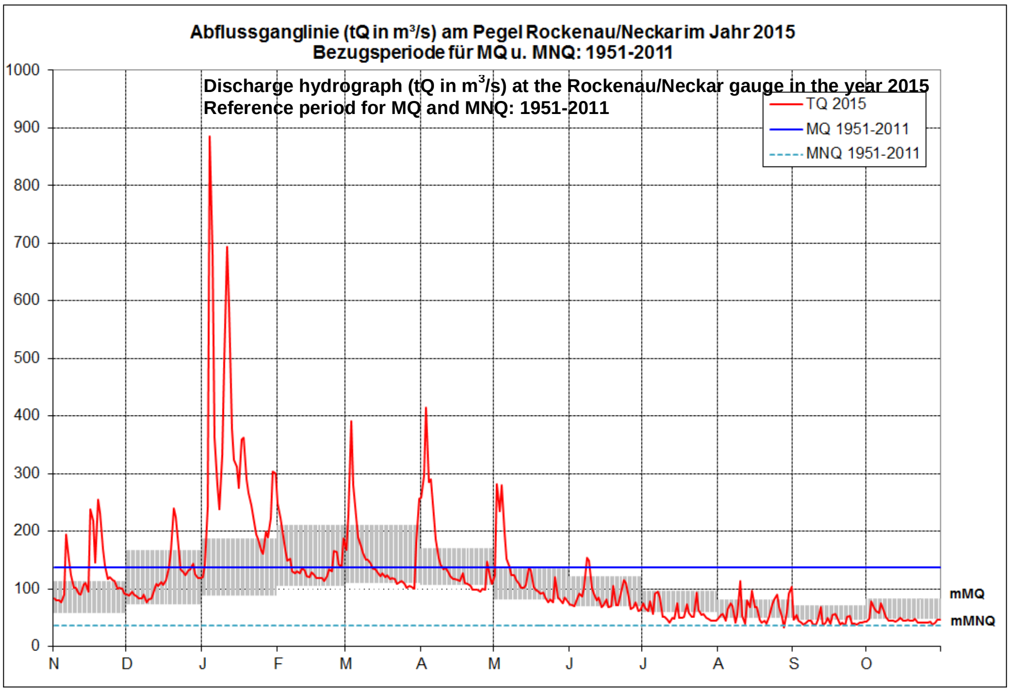


Figure 12: Discharge hydrograph (tQ) at the Rockenau (Neckar) gauge in 2015 in m³/s (Reference period for MQ, mMQ and mMNQ: 1951-2011 timeframe)

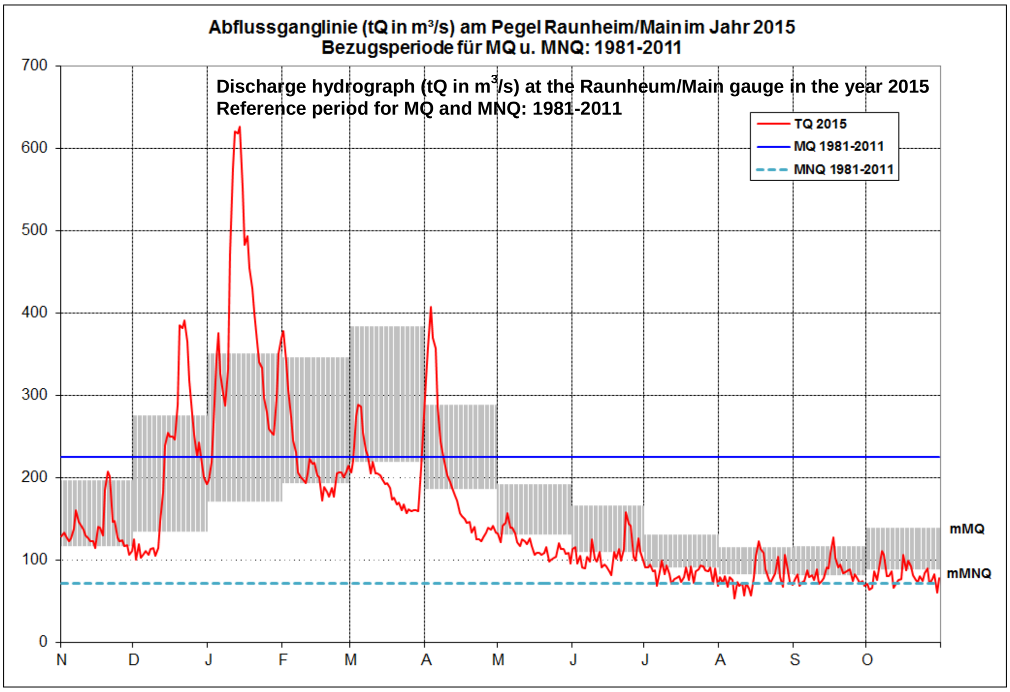


Figure 13: Discharge hydrograph (tQ) at the Raunheim (Main) gauge in 2015 in m³/s (Reference period for MQ, mMQ and mMNQ: 1981-2011 timeframe)

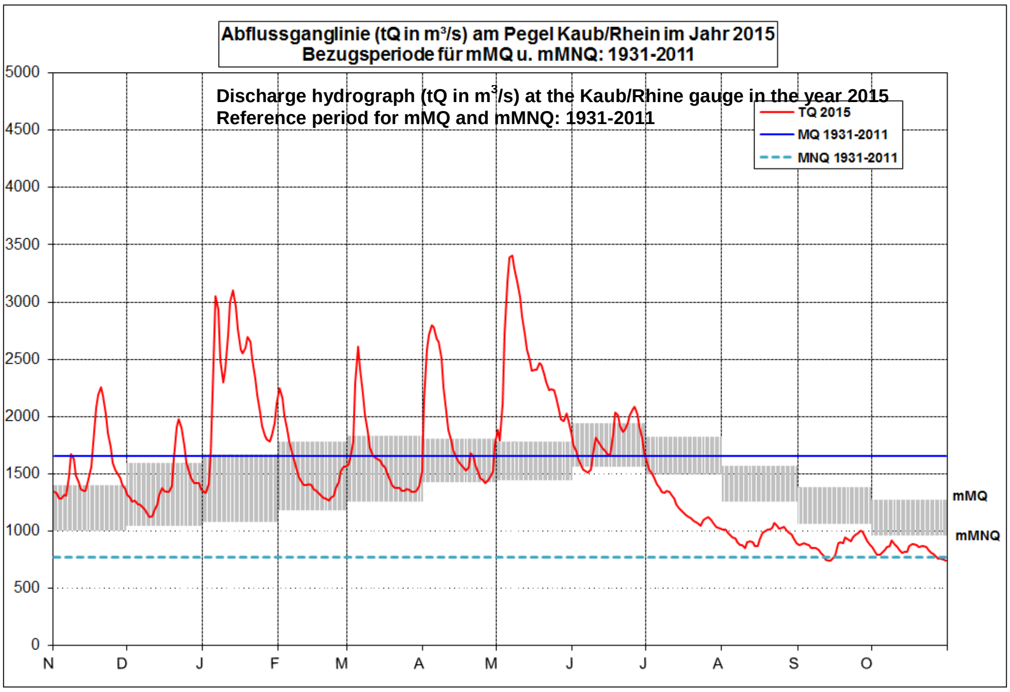


Figure 14: Discharge hydrograph (tQ) at the Kaub (Rhine) gauge in 2015 in m³/s (Reference period for MQ, mMQ and mMNQ: 1931-2011 timeframe)

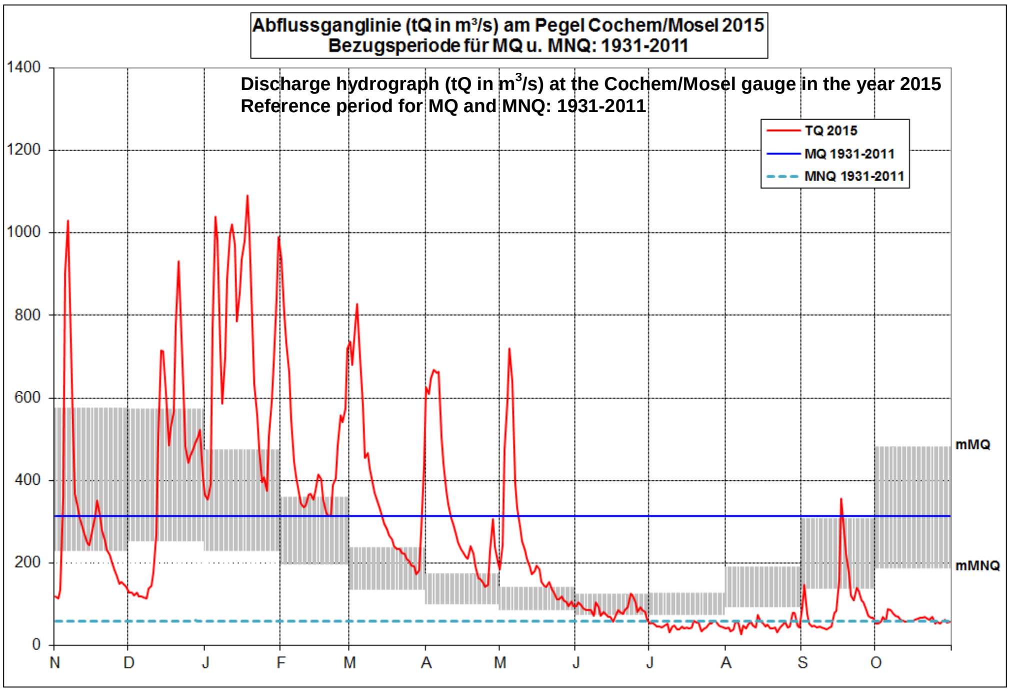


Figure 15: Hydrograph (tQ) at the Cochem (Mosel) gauge in 2015 in m³/s (Reference period for MQ, mMQ and mMNQ: 1931-2011 timeframe)

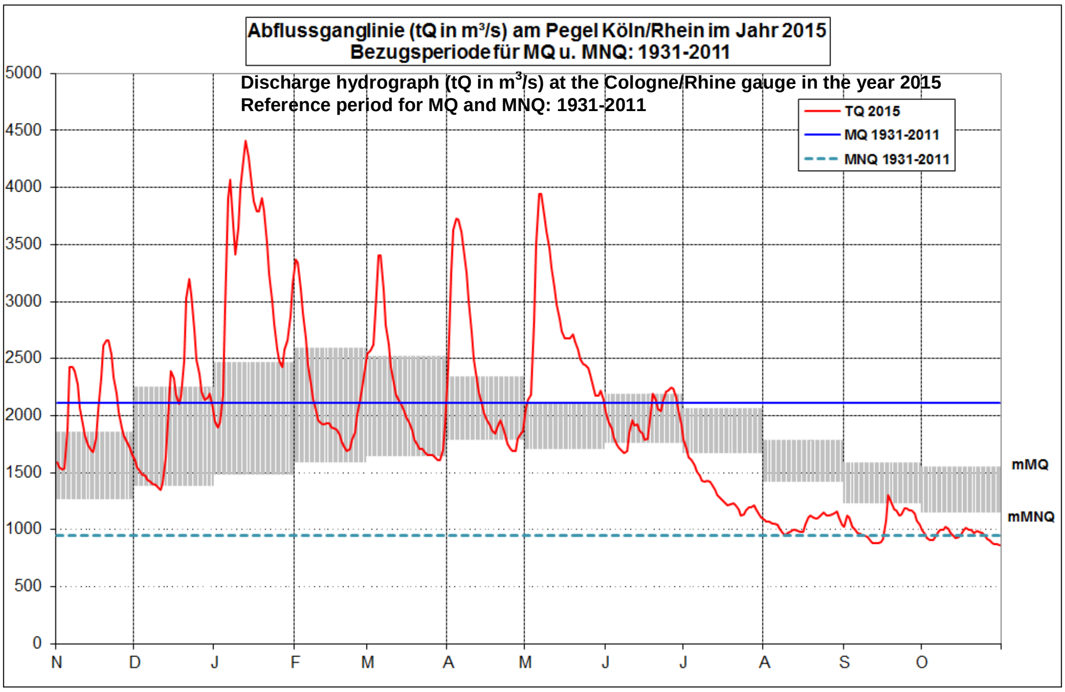


Figure 16: Discharge hydrograph (tQ) at the Cologne (Rhine) gauge in 2015 in m³/s (Reference period for MQ, mMQ and mMNQ: 1931-2011 timeframe)

Netherlands

Because of the relatively normal precipitation and snowmelt amounts in the drainage basin of the Rhine in the first half of the year, only a few discharge situations above the long-term average value occurred at the Lobith gauge. The highest discharge wave was in January 2015 with a crest value of 4625 m^3/s (12.35 m +NAP) on January 14 (see Figure 17). Discharge waves of this type normally occur multiple times a year.

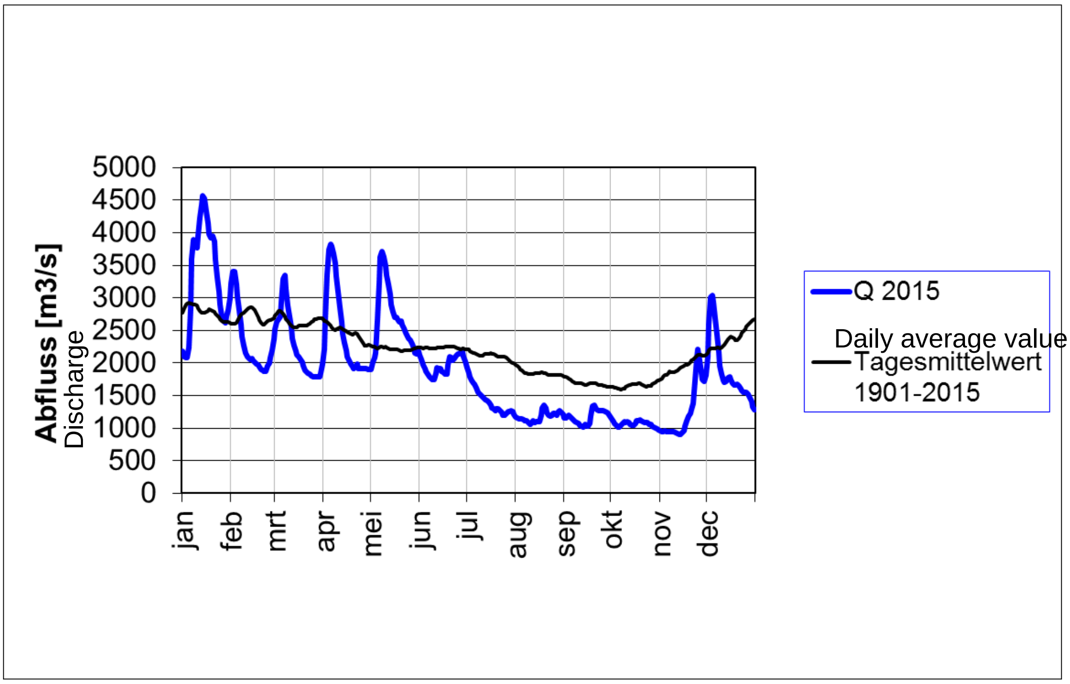


Figure 17: Discharge hydrograph (tQ) at the Lobith gauge (Rhein) in the year 2015 in m³/s and daily average value: 1901-2015 timeframe

With regard to low water, 2015 was an unusual year for the Netherlands, which involved the duration of the low water period. In the months July to November, the longest uninterrupted low water period since the beginning of measurements occurred with 134 days. The lowest discharge was measured at the Lobith gauge with 888 m^3/s on November 14.

Water Temperatures

Austria

The annual average of the water temperature of Lake Constance was 13.3° C, 1.4°C above the long-term average value of 11.9 °C (Figure 18).

Lake Constance Bregenz Harbour Daily Water Temperature Average
Annual hydrograph for 2015 compared to high, low and average of the years 1976 to 2014

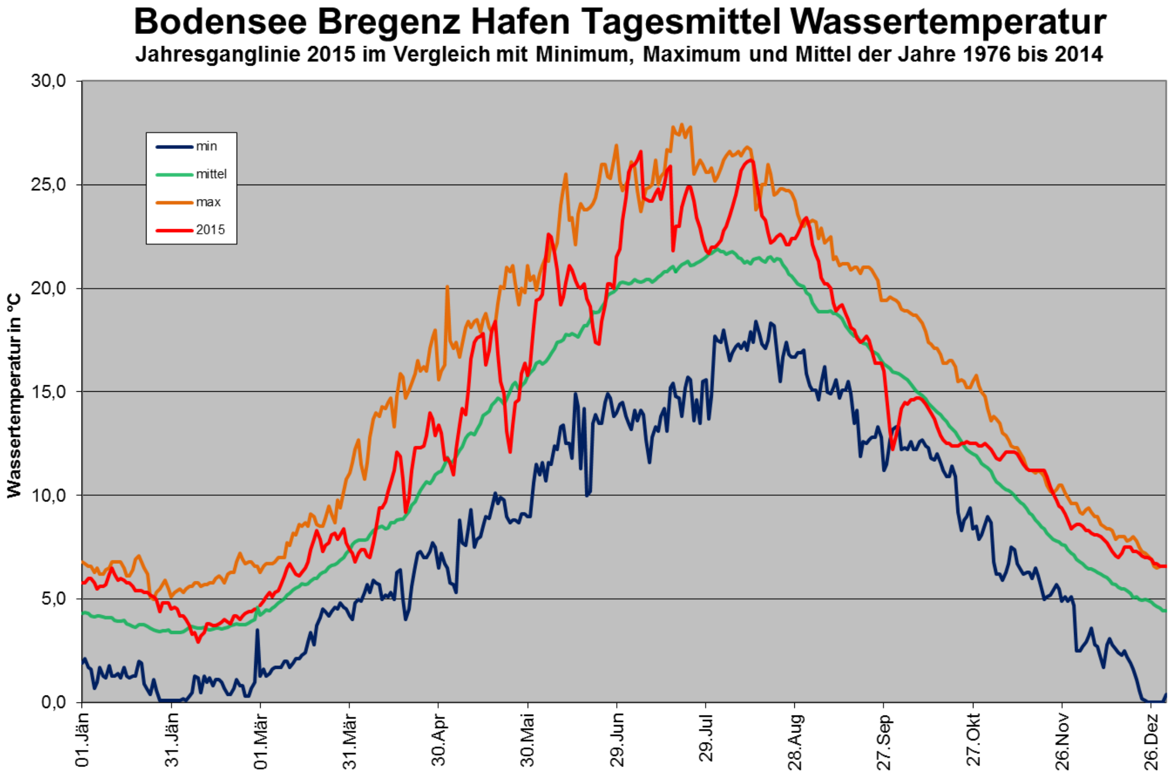


Figure 18: Hydrograph of the water temperature of Lake Constance at the Bregenz gauge in 2015 (red curve) in comparison with long-term lows, highs and average values of the years 1976-2014

Switzerland

After, unusually, many new highs of the annual average values were recorded in the years 2011 and 2014 for the water temperatures, the year 2015 was characterised by fewer rises above the annual average of the stations. On the one hand, spring was indeed mild but also had high precipitation, which led to a normal temperature behaviour for the rivers. By contrast, a distinct hot period did not set in until July. The resulting increase of the water temperature, which was sometimes strong, was continually broken by disruptions, as it was also in the later course of the summer and fall. Marked cyclical temperature behaviours thereby formed with high maximum and subsequent fall to below the long-term average or even lowest temperature. Only the more sustained period of fine weather in the fall and winter led to relatively undisturbed hydrographs with increased water temperature.

The year 2015 was characterised in July by an unusual hot period. As a result, new high values were recorded in many rivers. At some measurement stations, new record highs for July or even absolute highest temperature values in the 30- to 40-year average series were registered. It had never been as warm in July in the last 40 years as it was, for example, along the Aare at the measurement stations at Thun and Bern or even along the Reuss at Lucerne and Mellingen. The water temperatures in the Alpine drainage basins, affected by the snow and glacier melts, remained significantly lower than in the midlands. Isolated storms and cold fronts provided cooler weather and a significant reduction of the water temperatures in widespread areas. This led to marked cyclical temperature behaviour into the fall, especially in the Rhine drainage basin.

Germany

The average of the water temperatures (WT) recorded for the observation period was 0.15 °K below the long-term calculated annual average at the Kaub measurement station with 13.8 °C; at the Cologne gauge, the recorded value of 14.0 °C fell below the average by 0.1 °K. The largest deviations of the monthly average, each falling below the average values, were recorded at the Kaub station in May and in Cologne in June with -1.4 °K in each case; the largest positive deviation from the monthly average was recorded in July in Kaub and in November in Cologne with 1.3 °K in each case. The maximum negative deviation for the daily values was -3.2°K in Kaub and -3.6 °K at the Cologne station, each at the end of June; the largest positive deviation occurred in Kaub with 3.0 °K in August, in Cologne with 2.7 °K on Christmas Eve, Dec. 24, 2014.

Over the course of the year of the WT measured daily at the selected measurement stations, the daily average was approx. 14 °C at the beginning of the discharge year and then fell until the beginning of February, where they then reach the lowest point for Kaub with 3.6 °C and for Cologne with 4.2 °C. They increased with constant starts and stops until they constantly climbed from the beginning of July (with a small decrease at the end of July); the highest daily value was then reached in mid-August with an average of 25.5°C. The water temperatures then fell until the end of October to an average value of 13°C.

Overall, an erratic behaviour of the water temperatures emerged over the entire observation period, characterised by frequent deviations from the long-term observed average values, especially for the period from mid-May to the beginning of September. For the months April to June, the average differed from the long-term observed average values by -1°K, for July and August by +0.5°K and for the last two months by -0.5°K.

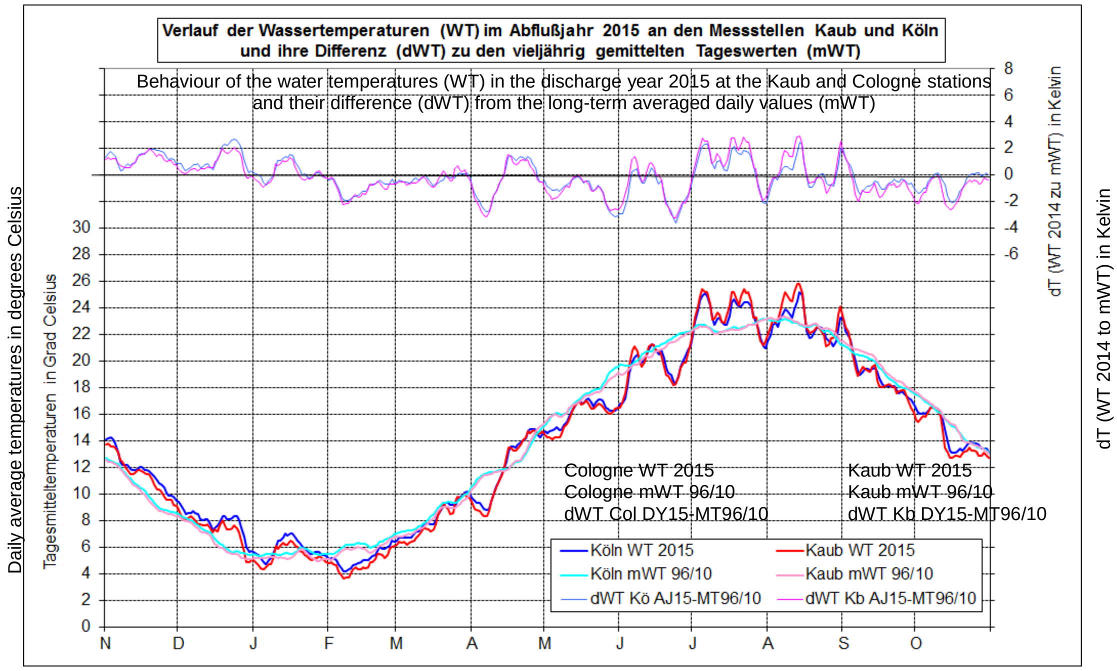


Figure 19: Water temperatures compared to the long-term average values

Netherlands

At the Lobith gauge, the average of the water temperature was 13.9 °C, about 0.8 °C above the long-term (1961-2015) calculated annual average value (see Figure 20). Since 1908, the average water temperature was higher in nine years.

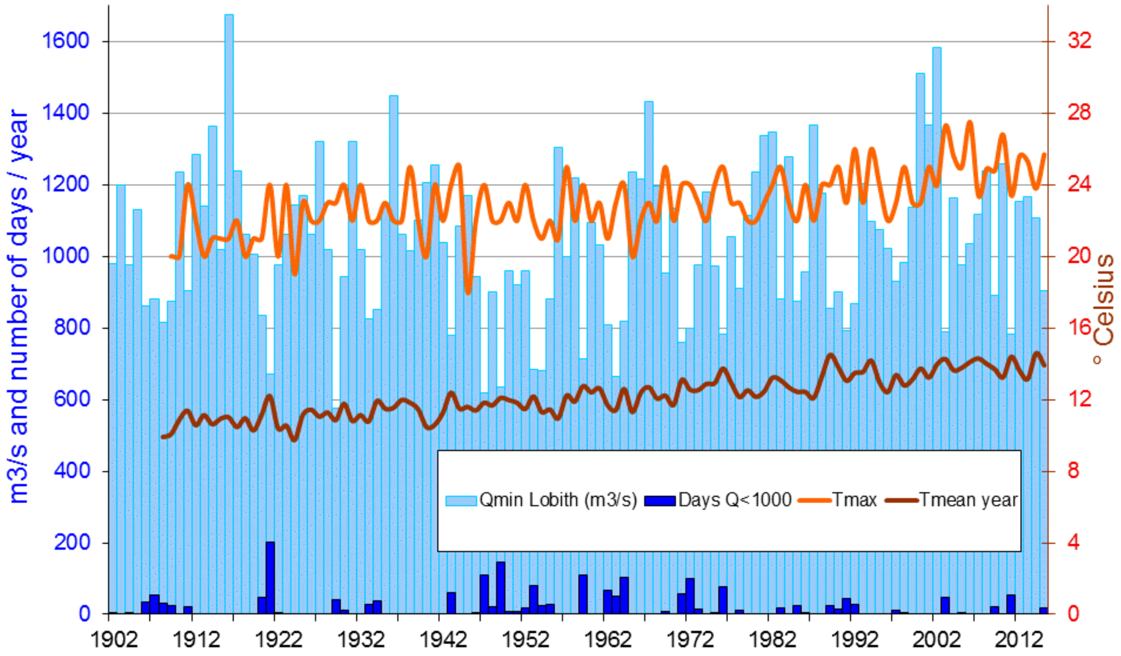


Figure 20: Average and maximum water temperatures at the Lobith/Rhein gauge

Groundwater

Austria

The low precipitation totals, especially of the second half of the year, resulted in below-average groundwater levels in the second half-year of 2015. At some measurement stations, the lowest groundwater levels since the beginning of measurement were measured.

Switzerland

The year 2015 began with normal groundwater levels and spring discharges throughout the country. In January, above-average precipitation amounts for this month fell in large parts of Switzerland. While in February on the south side of the Alps, heavy precipitation led to further precipitation amounts that were significantly above average, this month was relatively dry on the north side of the Alps. So in March normal groundwater levels and spring discharges were to be observed with uneven tendency across the country.

At the beginning of May, unusually high precipitation amounts fell in the Alps and on their north side, which as a result of the flood in Lower Valais, in western Switzerland and in eastern Switzerland led to an increase of the groundwater levels along the rivers. Due to the overall high-precipitation month, the groundwater levels were generally high and springs also showed an increased discharge.

The persistent dryness from June on only had a small effect on the groundwater resources of Switzerland at first thanks to the high starting groundwater levels and spring discharges at the beginning of the dry period. Unconsolidated aquifers along the large rivers from the Alps also profited from the large river water infiltration due to the unusually high glacier melt during the hot month of July. So in August sinking groundwater levels and spring discharges were indeed to be recorded, but they were mostly still within the normal range.

Due to the persistent dryness, groundwater levels and spring discharges sank further. Thus, on the north side of the Alps, they were generally low at the beginning of November and showed a declining tendency. On the south side of the Alps, by contrast, normal groundwater levels were still to be observed as a result of the average to above-average precipitation amounts in September and October.

Only individual local aquifers in the Alps and in the Neuchatel and Bernese Jura were able to profit from the sometimes extensive precipitation at the end of November. Due to the dry December, normal to low groundwater levels and spring discharges were to be recorded on the north side of the Alps at the end of 2015.

Suspended Sediments

Austria

Correlative to the below-average precipitation total in the Lake Constance drainage basin, the suspended sediment load to Lake Constance in 2015 was also less than the suspended sediment load of the previous year.

Germany

To obtain an overview of the suspended sediment loads, the data of the measurement stations at Maxau (Rhine-km 362.3) for the Upper Rhine and Weißenthurm (Rhine-km 608.2) for the area of the lower Middle Rhine/Lower Rhine (below the largest tributaries) were evaluated; on this, cf. also Figures 21a and 21b.

Extreme peak values in daily loads are caused in the summer by strong rain events and in the winter by the onset of thaws.

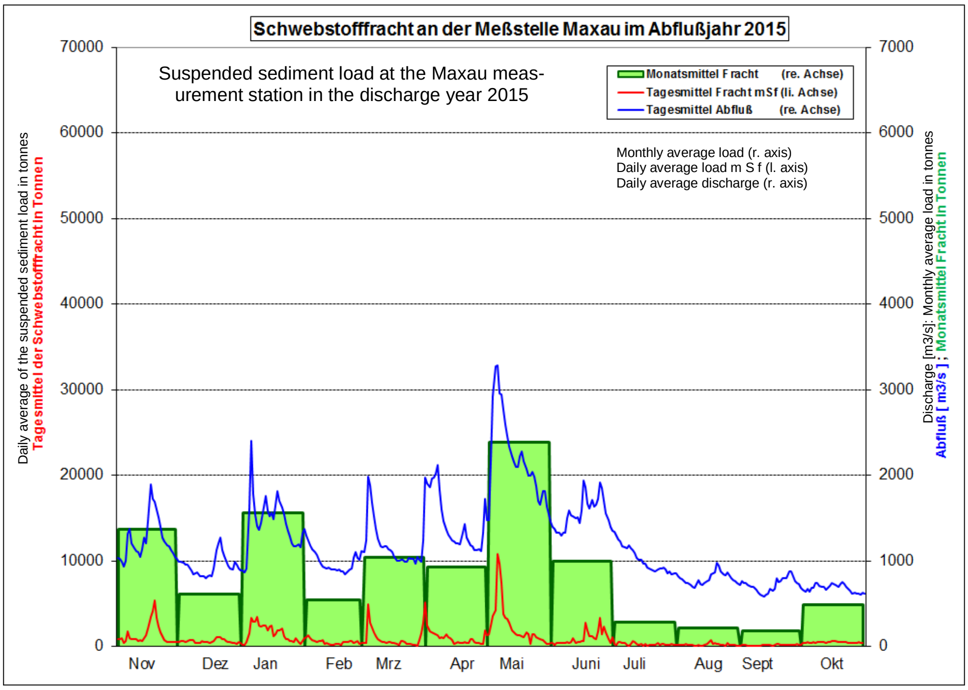


Figure 21a: Maxau suspended sediment measurement station, Rhine-km 362.3

In Maxau the total annual suspended sediment load was 322,008 t; this corresponds to about 25 % of the long-term average of the reference period 1965/2007.

The highest monthly suspended sediment transport was measured at the Maxau station in May 2015 with 73,966 t (daily average: 2,386 t), which corresponds to approx. 23% of the total annual load; the lowest monthly suspended sediment load was recorded in September 2015 with only 5,204 t (173 t/day).

For the daily loads, the lowest daily load at the Maxau station was recorded on August 13 with 62 t at an average discharge of 718 m³/s, and the highest daily load with 10,769 t at an average daily discharge of 3,280 m³/s on May 5.

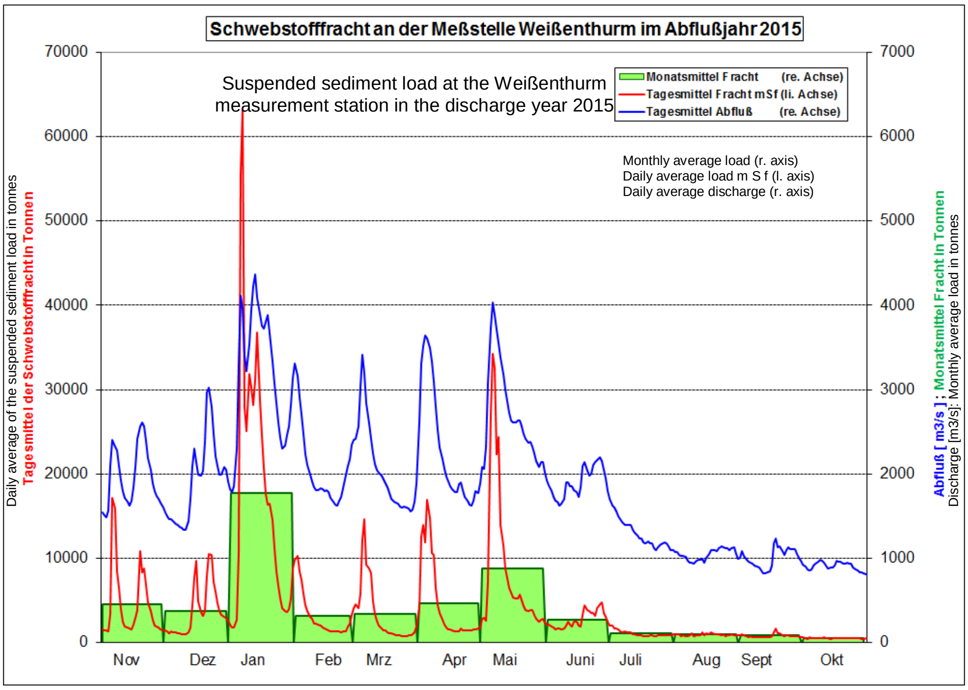


Figure 21b: Weißenthurm suspended sediment measurement station, Rhine-km 608.2

In Weißenthurm (Rhine-km 608.2; the Andernach gauge at Rhine-km 613.8 is used here as the reference gauge for determining the discharges), an annual suspended sediment load of 1,591,050 t was calculated; this corresponds to roughly 52 % of the long-term average of the reference period 1965/2007.

The highest monthly suspended sediment transport was measured at the Weißenthurm station in January 2015 with 549,601 t (daily average: 17,729 t), this at an average monthly discharge (MQ) of 3180 m³/s; the lowest was only 16,104 t in October 2015 (MQ = 907 m³/s).

The lowest daily load at the Weißenthurm station was recorded on October 14, 2015, with 425 t at an average discharge of 890 m³/s. By contrast, the highest daily load was 63,198 t on January 7, 2015 (at an average daily discharge of approx. 3,950 m³/s).

Explanation of the suspended sediment data:
Because suspended sediment measurements could not be carried out on all days in the hydrologic year 2015 at the Weißenthurm measurement station due to a staff shortage at the responsible Federal Waterways and Shipping Administration (WSA), the daily loads were calculated from the data series at the measurement stations at Koblenz/Rhine (permanent measurement station for turbidity), Cochem/Mosel (permanent measurement station for turbidity) and Kalkofen/Lahn (daily scoop samples) and added together and daily values for the concentration in Weißenthurm calculated from the daily totals using the discharge series at Andernach.

2. Activities of the International Commission for the Hydrology of the Rhine Basin (CHR) in the year 2015

The CHR met twice in 2015, on March 26 and 27 in Lyons (France) and on September 16 and 17 in Kinderdijk (Netherlands).

Personnel changes within the CHR
Mr. Johannes Cullmann accepted the post of Director of the Department of Climate and Water at the WMO in Geneva on October 12, 2015. He has thereby taken his leave as representative of the German IHP/HWRP Secretariat in the CHR.
Mr. Siegfried Demuth has left the UNESCO Secretariat in Paris at the end of 2015. He has taken over the leadership of the IHP/HWRP Secretariat within the BfG. Mr. Demuth is thus the German representative of the IHP/HWRP Secretariat in the CHR.

The new representative of France in the CHR, Mr. Eric Gaume of the Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux – IFSTTAR in Nantes, participated for the first time in the CHF meeting in September 2015.

Activities in the CHR projects
Sediment
The CHR support the 'From the Source to the Mouth – A Sediment Balance of the Rhine' project carried out by the BfG and the University of Aachen. The project was completed at the end of 2014 and the project results were presented in a seminar in March 2015. The project report will be completed in the course of the year 2016 and should be published within the green CHR series in two languages (German and English).

ASG-Rhine: Contribution of snow and glacier melts to the Rhine discharges
In the 75th meeting of the CHR in Lyons, Mr. Belz of the Federal Institute for Hydrology reported on the progress of the project, as did Ms. Stahl of the University of Freiburg in the 76th meeting in Kinderdijk.
The first phase of the project was completed in 2015. The results were presented in November in a workshop with around 40 participants.
The final report will be completed (in two languages: German and English) in 2016.
A potential second phase focuses on the possible future contribution of snow and glacier melts under the influence of climate changes. Decisions will be taken in 2016 regarding the execution of the second phase.

Lake Constance as water reservoir – a literature survey
The CHR have commissioned the Technische Universität Munich to conduct an evaluative-analytical literature survey. The concept report of this study was distributed in the internal CHR circle in 2015. The CHR's acceptance will be discussed in 2016, after which the document can be forwarded to external interested parties for the purpose of commentary with the approval of all members.

Climate changes
In various countries neighbouring the Rhine, new climate scenarios were created. In the 75th meeting of the CHR, it was agreed that Deltares create an overview of the existing and planned climate scenarios. This overview was presented in the 76th meeting of the CHR by Ms. Sperna-Weiland of Deltares. The following conclusions were drawn:

- The level of detail of the information varies by country;

- Not all countries work with the CMIP5 datasets;
- Some countries work with the CMIP5 datasets with special focus on the Rhine.

It was agreed that a new project group be set up with the task of preparing a seminar.

Socio-economic influences on the low-water system of the Rhine

During the symposium organised in March 2014, the topic was discussed further in the 75th and 76th meeting of the CHR. Mr. Ruijgh (Deltares) has designed a quick-scan analysis of the available data and projects. The idea is to organise a project similar to the RheinBlick2015 Project.

Within the BfG, the project 'Water Management 2050' has been running since June 2015. This project was presented in the 75th meeting of the CHR by Mr. Nilson (BfG). WM2050 could supply valuable information for the planned CHR socio-economics project.

Collaboration with other organisations

There are plans for a second Rhine-Mekong workshop. The content and financial bases of a potential cooperation with the Mekong River Commission will be discussed further in 2016.

Events organised by the CHR

In March 2015, the CHR in Lyons organised a two-day seminar entitled 'From the Source to the Mouth, a Sediment Balance of the Rhine'. The seminar was the conclusion of the joint research project of the Federal Institute for Hydrology and the RWTH University of Aachen, in which a sediment balance of the Rhine from the source to the mouth, differentiated by grain fractions, was created. In the seminar, the sediment balance was presented on the basis of the various thematic areas and holes in the research and uncertainties were discussed. The presentations are available on the website at: www.chr-khr.org/en/calendar.

In November 2015, the CHR in Viktorsberg/Austria organised the two-day workshop 'ASG-Rhine Snow & Glacier – Discharge Share from Snow and Glacier Melts in the Rhine and Its Influence against the Background of Climate Change'. In the workshop, the tasks and results were presented by the partners in the ASG research project and certain guest contributions. These presentations are also available on the CHR website.