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

Annual report of the CHR 2017

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Photo front page: Ship encounter at the Loreley rock. Source: German Federal Institute of Hydrology

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Internationale Kommission für die Hydrologie des Rheingebietes
International Commission for the Hydrology of the Rhine basin

The International Commission for the Hydrology of the Rhine basin (CHR) works within the framework of the International Hydrological Programme (IHP) of UNESCO and the Hydrology and Water Resources Programme (HWRP) of the World Meteorological Organization (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 Sustainability and Tourism, Division I/4 (Hydrography), Vienna, Austria,
- Office of the Federal State of Vorarlberg, Division VII d - Water Management, Bregenz, Austria,
- Federal Office for the Environment, Bern, Switzerland,
- IRSTEA, Antony, France,
- IFSTTAR, Nantes, France,
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- IHP/HWRP Secretariat, Federal Institute of Hydrology, Koblenz, Germany
- Luxembourg Water Management Authority, Luxemburg,
- Deltares, Delft, Netherlands,
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1. Hydrologic overview for the Rhine basin

Meteorological characteristics

Austria, Source: Central Institute for Meteorology and Geodynamics (ZAMG)
2017 was the sixth warmest year in Austria since the beginning of instrumental recording in 1768 (Figure 1), with a deviation of +0.9°C from the temperature average between 1981 and 2010. 2017 had ten warm months above average and only two that were too cold.

The precipitation rate in the Austrian area was stable, but there were significant regional differences. From Vorarlberg to the Mostviertel, as well as in Carinthia and Upper Styria, there were stable conditions and as much as a 30 percent higher precipitation. At certain points precipitation was as much as 45 percent higher compared to an average year. Along and north of the Danube, in the Vienna Basin, in Burgenland and in Southern Styria there was a consistently lower amount of precipitation than with the climatological average. Here, the total amount of precipitation over the course of the year was 10 to 25 percent lower (see Figure 2).

The year 2017 was characterised by an above-average amount of sunshine. In the area there was 11 percent more measured hours of sunshine in Austria compared to the climatological average. This makes 2017 into one of the 10 sunniest since 1925.

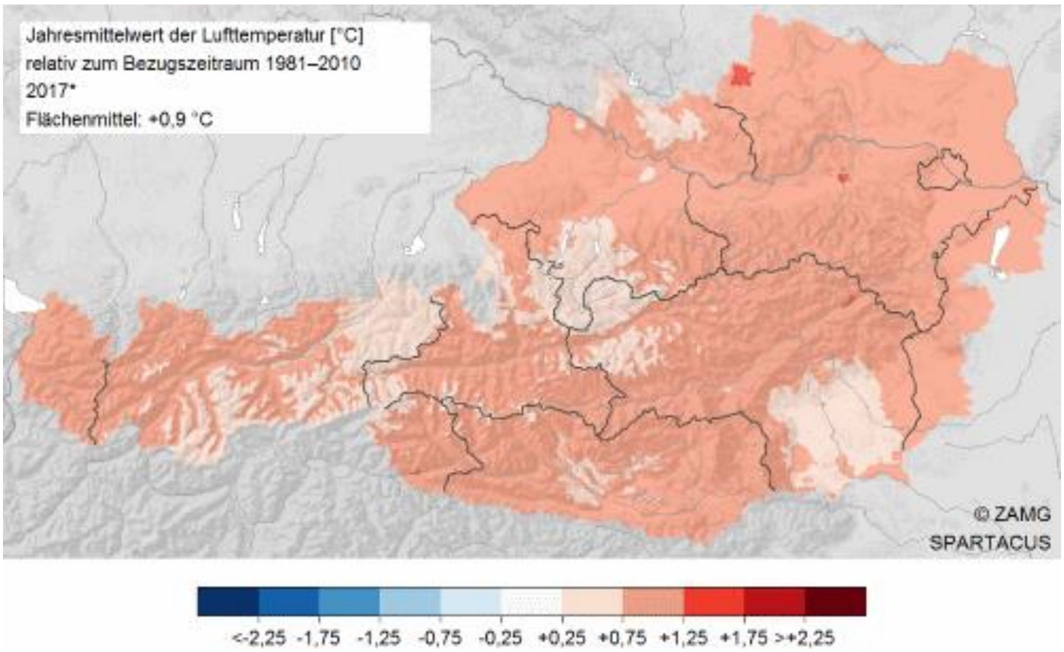
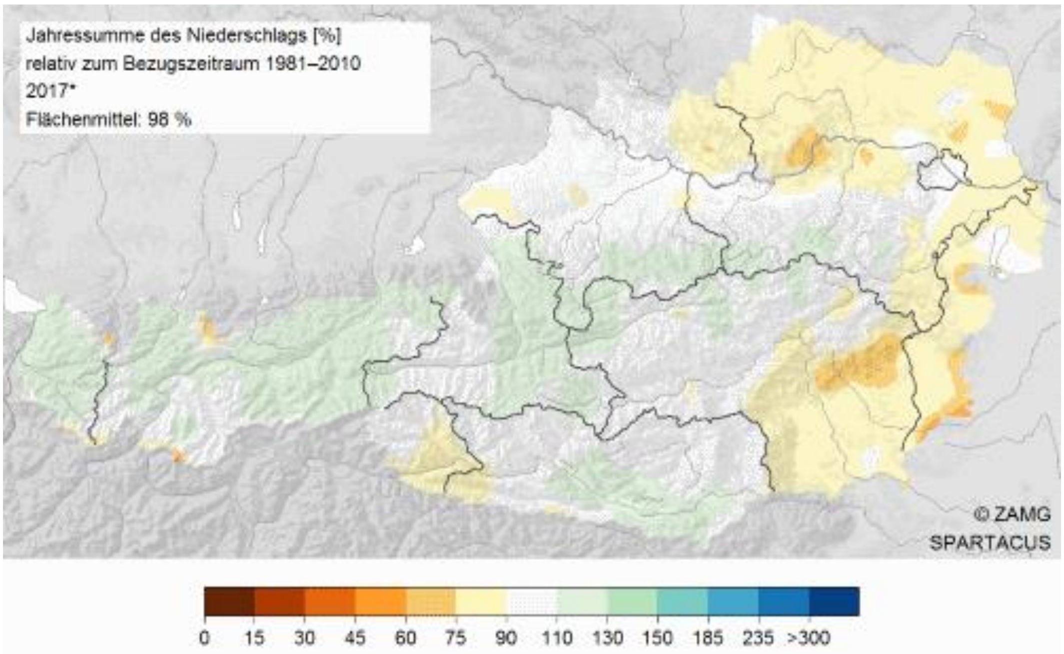


Figure 1: Temperature in Austria in 2017: temperature deviation from the long-term average 1981-2010. Source ZAMG

The snow conditions during the winter of 2016/2017 were consistently below average until into March. That was partly because, although January had been very cold, there was little precipitation. In February and March it was too dry and too warm for stable snow conditions.



Figures 2: Precipitation for Austria in 2017: Deviation of precipitation from the long-term average 1981-2010. Source ZAMG

Meteorological characteristics for the Austrian Rhine area. Source: Office of the Federal State of Vorarlberg

The annual precipitation total in the Austrian part of the Rhine basin area was 120% of the long-term average. Except for the months of May and June, the individual monthly precipitation totals were average or above average (see Figure 3). The average annual air temperature was about 1.0°C higher than the long-term average in the Austrian Rbine basin area.

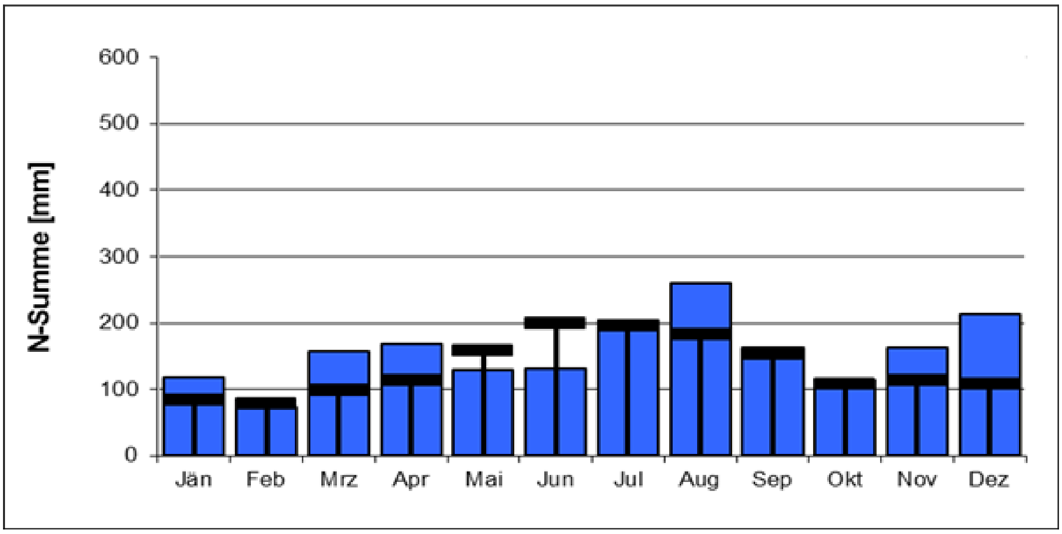


Figure 3: Monthly precipitation totals in 2017 (blue bars) in comparison with long-term monthly averages at the Bregenz Altreuteweg measuring station

Switzerland, Source: Federal Office of Meteorology and Climatology (MeteoSwiss)
January 2017 produced an unusually low monthly average of -2.9 degrees. The last time the northern-alpine January was colder, was in the year 1987. On February 23, extremely mild air masses arrived in Switzerland, accompanied by stormy south-westerly winds. Winter precipitation between December 2016 and February 2017 was, as national average, only half of the 1981–2010 standard. In western Switzerland and Valais, precipitation was only 30 to 50% of the usual amount of precipitation: The western part of Switzerland recorded the lowest winter precipitation in the region in 45 to 55 years.

Switzerland experienced the third warmest spring since measurements began in 1864. The mild weather in March and early April gave the vegetation a strong growth boost. Between April 20 and 21, strong night frosts then undid a lot of this. On April 26, cold air from the north brought winter conditions on the north side of the Alps. Between April 27 and 29, greater amounts of fresh snow fell along the northern slopes of the Alps and in the Alps.

The third warmest spring was followed by the third warmest summer since measurements began. Warmer were so far only the Summer 2003 and 2015. Especially the beginning of the summer was hot. June was characterised by a persistently high temperature and a five-day heat wave in the second half of the month. July was slightly warmer than the standard and went without much heat. In August, the hot summer weather returned. On the evening of the 1st and in the night of the 2nd of August, heavy thunderstorms with hail and strong squalls erupted on the northern side of the Alps. In the early morning of August 2 the path of the thunderstorm on the northern edge of Switzerland led to a new Swiss rain record: Between 02:40 am and 02:50 am, 36.1 mm of rain fell at the measuring station in Eschenz. The previous ten-minute record stood at 33.6 mm, on August 29, 2003 in Locarno-Monti.

Autumn showed very unstable weather. September was remarkably cool, especially in the mountains. The early winter weather continued during the first days of October. During mid-October a high-pressure system dominated for 10 days. On the southern side of the Alps, the fair-weather period lasted 20 days. There was hardly any precipitation throughout October. The frequent northerly föhn contributed to the dry weather.

In November, snow fell repeatedly at lower altitudes at the northern side of the Alps. Up to the first days of December, there was also temporarily a snow layer of a few centimetres in the midlands. In December a lot of snow fell in the mountains. Shortly after the middle of the month, more than 170% of normal snowfall lay spread across the Alps.

Table 1: Annual values for 2017 at selected MeteoSwiss stations compared to 1981-2010 standard

Station	Altitude a.s.l.	Temperature (°C)			Sunshine duration (h)			Precipitation (mm)		
		Average	Standard	Dev.	Total	Normative	%	Total	Normative	%
Bern	553	9.7	8.8	0.9	2006	1683	119	854	1059	81
Zurich	556	10.2	9.4	0.8	1828	1544	118	1107	1134	98
Geneva	420	11.3	10.6	0.7	2090	1768	118	693	1005	69
Basel	316	11.4	10.5	0.9	1844	1590	116	765	842	91
Engelberg	1036	7.2	6.4	0.8	1491	1350	110	1727	1559	111
Sion	482	11.4	10.2	0.8	2231	2093	107	567	603	94
Lugano	273	13.5	12.5	1.0	2416	2067	117	1509	1559	97
Samedan	1709	2.7	2.0	0.7	1914	1733	110	710	713	100

Standard = Long-term average 1981-2010
Dev. = Temperature deviation from the standard
% = Percentage in relation to the standard (standard = 100%)

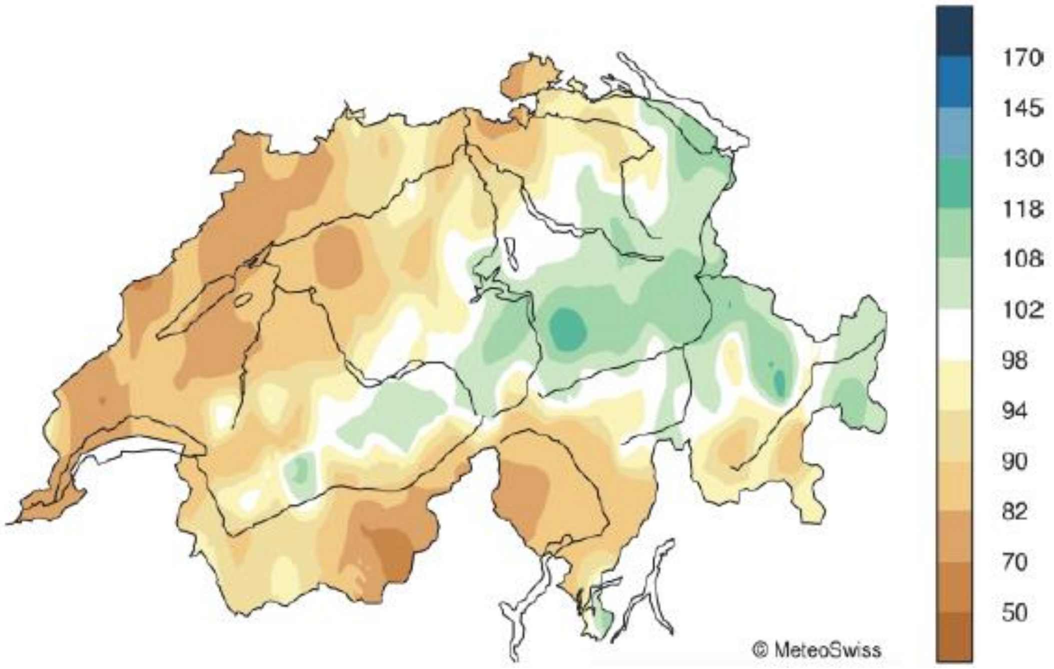


Figure 4: Annual precipitation total for Switzerland in 2017 as a percentage of the standard (1981-2010).

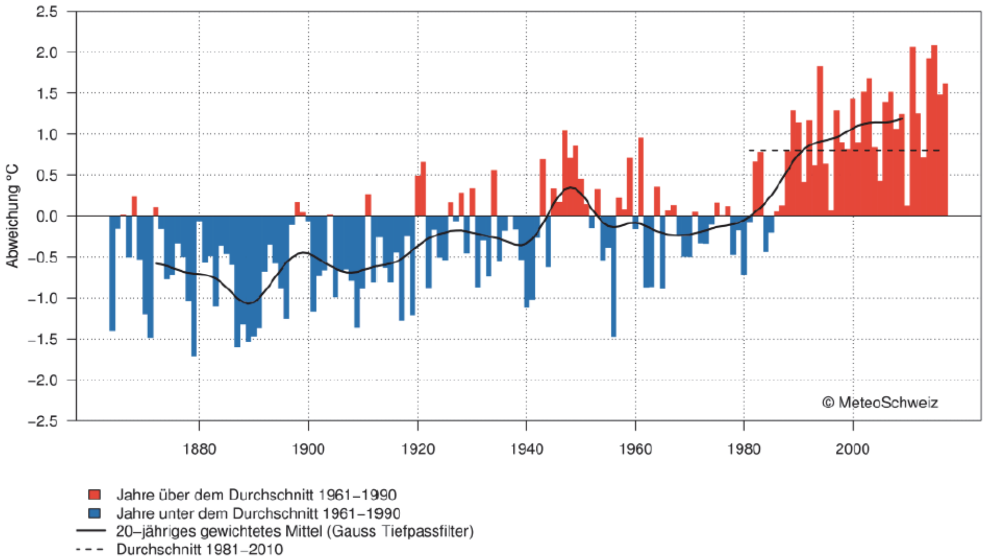
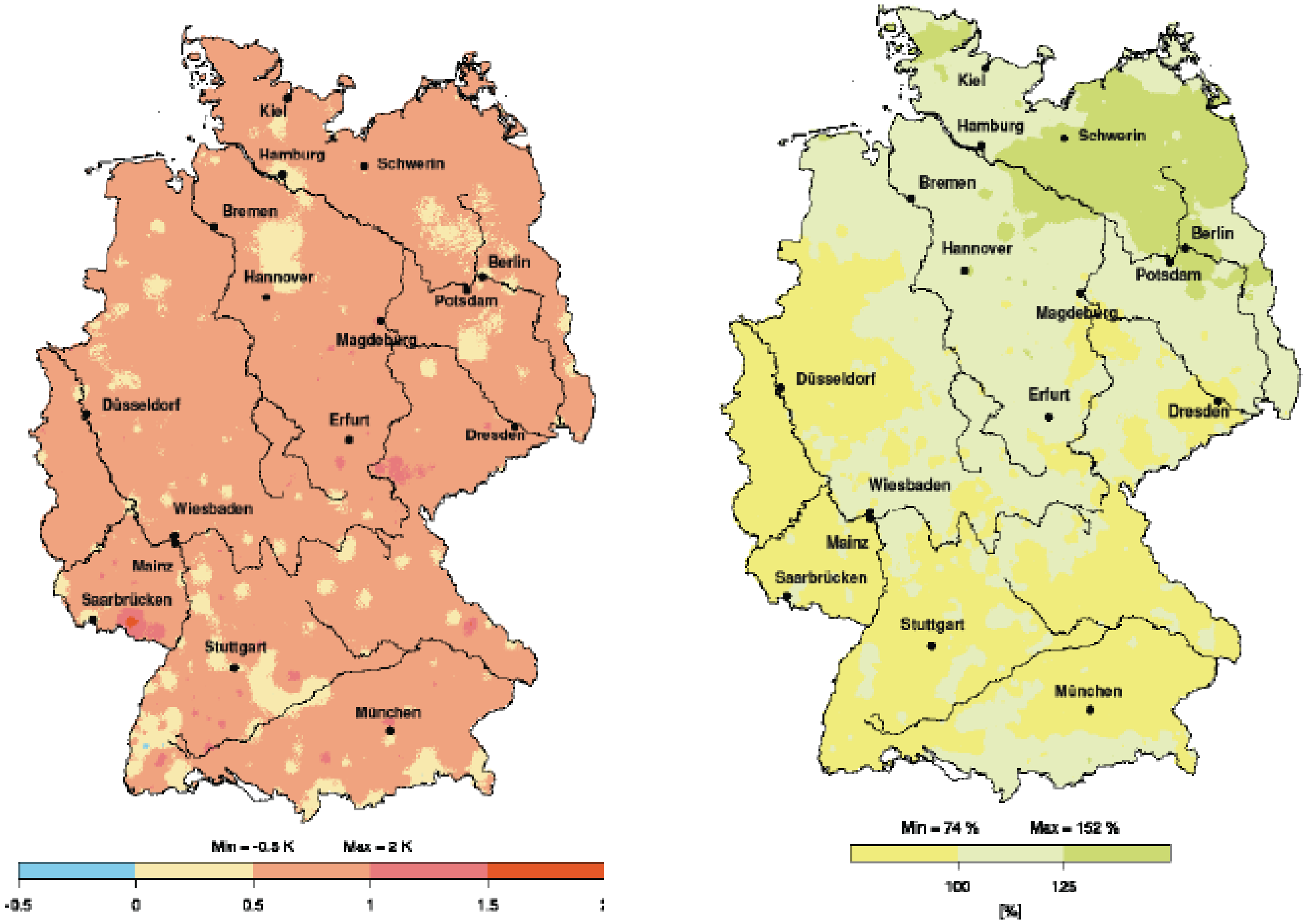


Figure 5: Annual temperature deviation in Switzerland for 2017 from the multi-year average (reference period 1961-1990). The too-warm years are shown in red, the too-cold years in blue. The black line shows the temperature profile averaged over 20 years.

Germany, Source: German Weather Service (DWD)
Overall, the 2017 calendar year was again particularly warm. This was also true for Germany: As Map 1a shows, average temperatures in almost all regions were above the normal values for the reference period 1981-2010. Concretely, this was on average 9.6°C, so 0.7 K more than during the reference period 1961-1990.

The annual precipitation totals (see Map 1b) north of a line Berlin-Hannover were significantly above the normal values of the reference period, and south of it (therefore also in large parts of the Rhine basin area) around the normal value.

(Source: DWD / Annual report 2017).



Figures 6a and 6b: Germany: Deviations of the average air temperatures (Map 1a, left, in K) and the precipitation totals (Map 1b, right, in %) in the calendar year 2017 compared to the long-term average 1981-2010
(Source: DWD/Weather report EXPRESS Annual report 2017)

The relative deviations of the amount of precipitation for the German Rhine basin in the discharge year 2017 (Nov 2016-Oct 2017) showed a "dry trend" in the first eight months of the observation period. This means, that during the last third (Jul-Oct) of the discharge year, the precipitation total of 362 mm was 47% of the total annual precipitation, at an annual precipitation total of 764 mm.

For the Rhine, above and below the estuary of the Main, the seasonal precipitation statistics showed, in the comparison between hydrological winter and summer months (Nov-Apr or May-Oct) with an average of 36% to 64%, a significantly higher amount of precipitation for the summer months. For the Main basin the distribution was even 31% to 69%. Overall, a precipitation total of 263 mm was measured for the winter months for the Rhine basin, and in the summer months it was 501 mm. However, the calculated average annual precipitation of 85% for the entire Rhine basin during the observation period is lower than the average.

When considering the monthly precipitation in comparison to the long-term monthly average values, the months of November to June and October experienced a significant deficit of between 6 and 70 mm. The minimum monthly precipitation of only 14 mm occurred in December. An exceeding with 50-5 mm of the long-term observed monthly precipitation totals was measured in the period from July to September. The peak value with 136 mm in monthly totals was measured in July (172%). (see Figure 7.a).

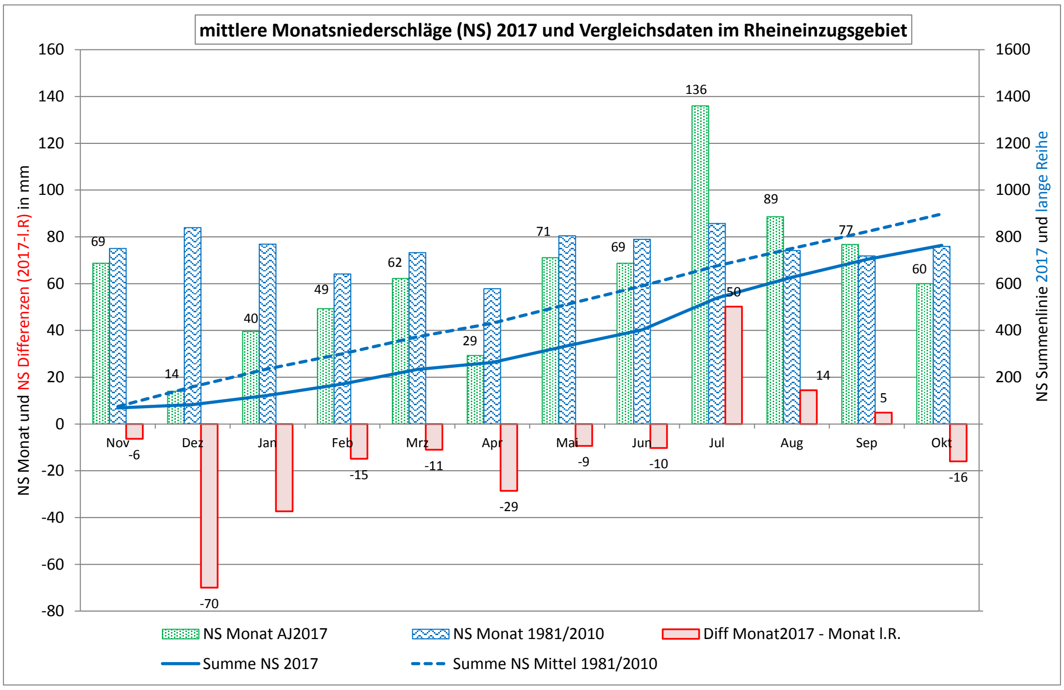


Figure 7.a: German Rhine basin area: Comparison of the monthly area precipitation totals in the discharge year 2017 versus the long-term average 1981-2010 (Source: DWD/Monthly weather reports 2017)

With respect to the average annual temperature of 9.4°C, the discharge year 2017 can be classified as a very warm year. At the measuring station Cologne, the annual average was 11.1°C with a deviation of +0.8 K compared to the climate reference period 1981-2010, where a deviation was measured of +1.2 K during the summer months. During the months of February, March and June 2017 (+2.8 up to 3.0 K) the monthly averages were exceeded significantly. With of 7.2°C throughout the country, the highest monthly March average since the beginning of systematic measurements in 1881 has been observed. With -2.6 K, the monthly average was significantly lower in January.
(see Figure 7.b).

The monthly water temperatures measured at the gauge in Cologne showed a fairly stable behaviour; there were neither ice conditions nor warming to more than 23°C. The monthly deviations from the long-term average values were, with the exception of January (-2.1K), consistently around +/- 1K. This pattern did not hold for the calculated monthly average of the air temperatures; here it fell significantly below the average, by -2.6K in January. During the further course of the discharge year, in February, March as well as June and October, the monthly average rose significantly by over 2.8K. (Figure 7.b).

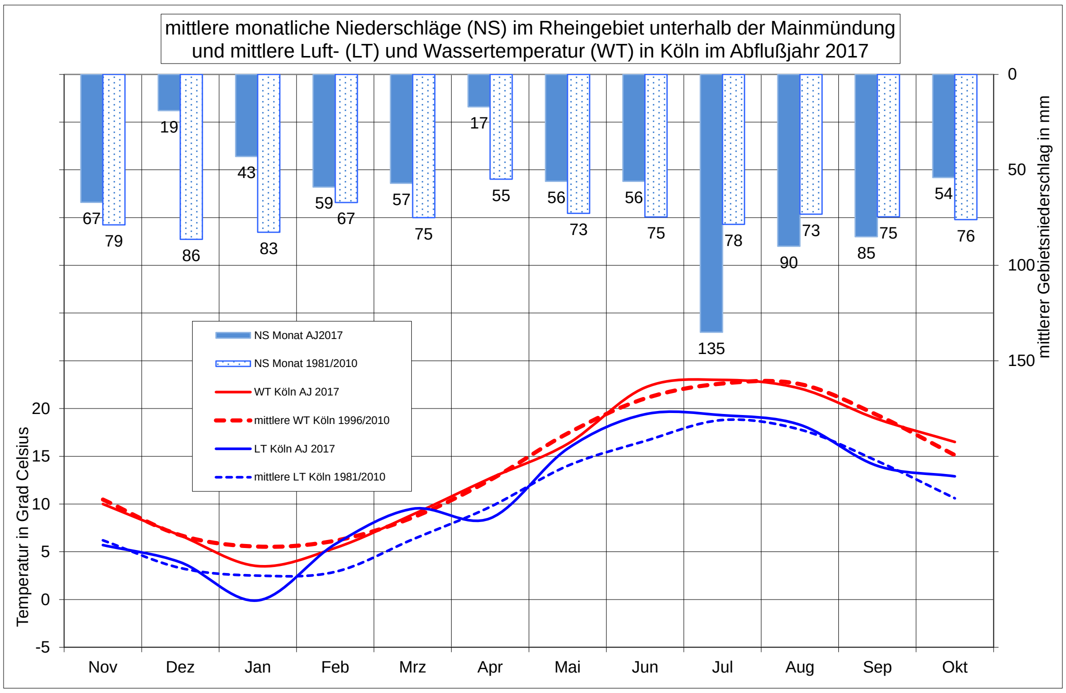


Figure 7.b: Rhine basin/Example station Cologne: Comparison of the monthly temperature and precipitation data in the discharge year 2017 compared with the long-term average (Data sources LT and NS: DWD; WT: WSV)

Netherlands, Source: Royal Netherlands Meteorological Institute (KNMI)

2017 was, with an average temperature at the De Bilt station of 10.9°C, the fourth very warm year in a row. Like the three previous years, 2017 also ended up among the 10 warmest years since observations began. This picture fits the trend of a warming climate.

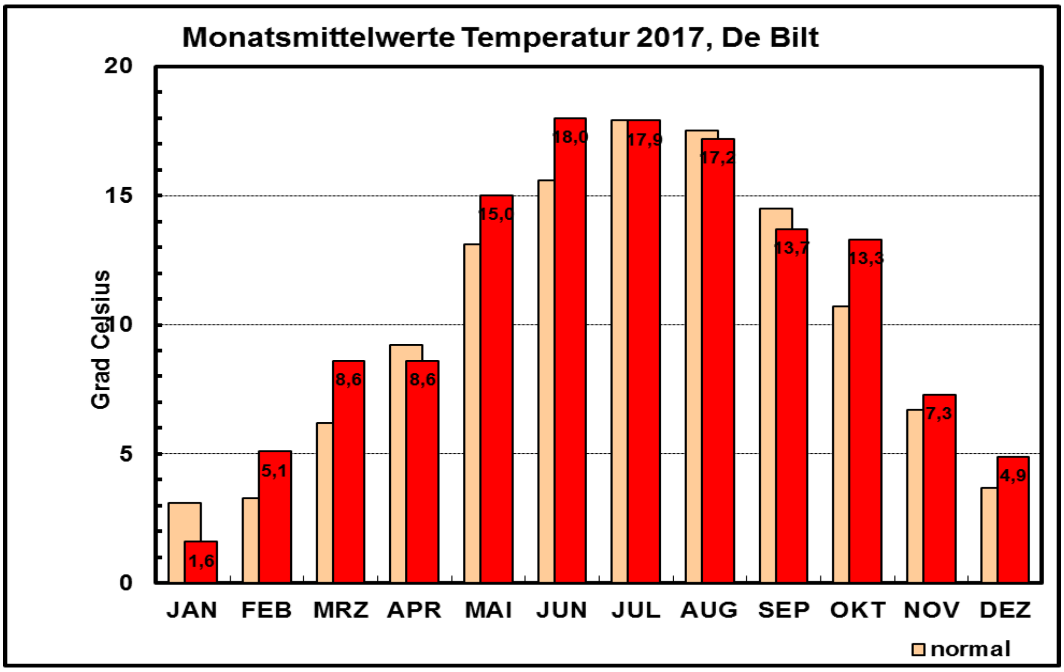


Figure 8: Monthly average temperatures at the De Bilt station in 2017 compared to long-term (1981-2010) averages (Source: KNMI)

January was cold with an average temperature of 1.6°C, and February, with 5.1°C, was particularly mild. Spring was very mild overall, but it showed two faces. March was unusually warm, while April was too cold. Frost around April 20 caused a lot of damage in fruit farming. May was extremely warm. The last 10 days of the month were summer like. On May 29 a temperature of 33.5°C was measured in the south of the country. This temperature belongs among the highest temperatures that were ever measured in this season in the Netherlands. The summer weather continued in June. With an average temperature of 18.0°C this month came in a split first place of the warmest June months since 1901. Summer was overall warm and finished in 10th place in the series of warm summers since 1901.

With an average of 1763 hours of sunshine, 2017 was very sunny. The long-term average is around 1639 hours.

With an average of 862 mm of precipitation, 2017 was a bit wetter than normal. The long-term average is 847 mm. The southeast of the country was a bit dryer than normal, while the north, the middle, the west and above all the southwest got more than average precipitation.

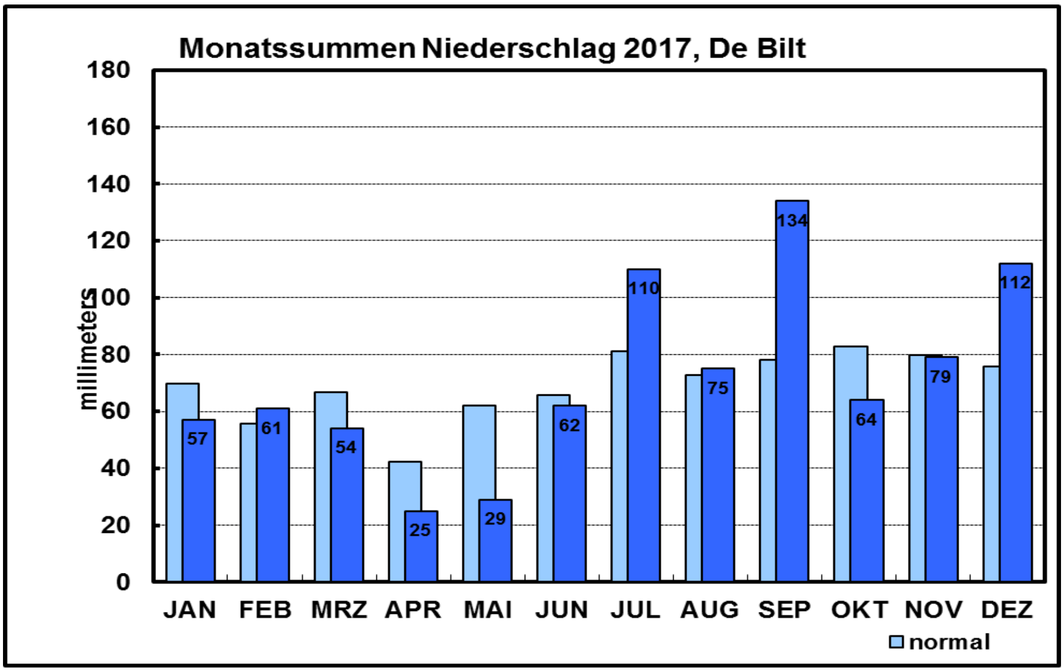


Figure 9: Monthly precipitation totals at the De Bilt station in 2017 compared to the long-term (1981-2010) averages (Source: KNMI)

There were only a few days with snow and the snow remained in most places only a few days. There were snow days on the12th and 13th of February (5 to 12 cm) and from the 8th to the 11th of December (10 to 15 cm). In the middle of the country, a snow cover of more than 30 cm temporarily accumulated in mid-December.

Snow and glaciers

Source: Snow: WSL - Institute for Snow and Avalanche Research SLF
Glaciers: Department of Geography at Fribourg University and Laboratory of Hydraulics, Hydrology and Glaciology (VAW)

October 2016 was relatively cold and unstable. After two onsets of winter weather with heavy snowfalls in the first half of November in the north and west, a persistent southerly air flow in the second half of November brought heavy precipitation on the southern slope of the Alps. The föhn then following for several days let the snow melt again even at great altitudes. In December the snow was slow to appear. It was the driest and snowiest December in Switzerland since measurements began in 1864.

The long-awaited snow fell only by early January 2017 and in the following weeks. In the north it was the coldest January in 30 years. As a result, there was snow even in lower-lying areas and on the northern edge of the Alps and in the midlands Thanks to the cold and the fog, a thin snow cover later remained for weeks. Snow fell in the Alps during the first three weeks of January, especially in the north and west. With a strong föhn, the snow melted in the lower-lying areas of the north. In the south, the extreme drought also continued in January.

Precipitation occurred repeatedly in the first two weeks of February. For a short time, it snowed even at low-lying areas. However, often it also rained up to 2000 m a.s.l. With totals of up to 80 cm, snowfall in higher-lying areas of the south and west was heaviest. In the second half of February there had then also fallen little snow in the north at high-lying areas.

The relatively high amounts of precipitation in the first half of March were responsible, that March was the only month that was above average wet or, depending on the altitude, saw a lot of snow in many areas. In the second half of March snow fell on the northern slopes of the Alps, in the south and in westerly Ticino above 2200 to 2500 m a.s.l. Because it was warm and because of the again high snow line limit, the snow cover at the end of March, on the northern slopes below about 2400 m a.s.l., on the southern slopes below about 2800 m a.s.l., was soaked and the snow melted away quickly, so a small number of stations saw such an early disappearance of snow as never before since measurements began.

The first half of April was unstable. From the middle of the month it cooled down again markedly and winter returned late. In the third week of April snow fell in high-lying areas in the north of the eastern Bernese Oberland until Nordbünden. At the end of the month there was widespread snowing, most heavy in the south.

In the first half of May it snowed repeatedly in high-lying areas. Mid-May the snow cover in the high mountains as well as on northern slopes above about 2500 m a.s.l., began to get soaked. It quickly lost mass in the second half of May.

The combination of the extremely small amounts of snow during early winter and the early disappearance of snow led to it in the winter months of 2016/17, that the thickness and duration of the snow cover in higher-lying areas was as low as had not been seen for a long time. Especially smaller glaciers were partly completely devoid of snow and ice in July. If September had not brought a protective snow layer on the glaciers, the loss of ice would have been even greater.

The glacial mass balance was determined for 20 Swiss glaciers in September 2017. The ratio of growth due to snow loss due to melts was again strongly negative. The summer of 2017 is characterised by significantly above-average losses in all regions of Switzerland. In many places, the glacier tongues disintegrate due to ongoing melts. The greatest losses have occurred with the glaciers between the western Bernese Oberland and Valais (Glacier de Tsanfleuron, Glacier de la Plaine Morte, Griesgletscher) with a decrease in average ice thickness of 2 to 3 m. On most other glaciers as well, the losses were, with an average thickness decrease of 1 to 2 m, very substantial. The thickness of the Rhone glacier and other glaciers in the Gotthard area, with a good one meter, decreased the least. This is due to more winter snow and some snowfall in the summer, which slowed the melting temporarily.

Applied to all glaciers in Switzerland, this means an estimated loss of volume of around 1500 million cubic metres of ice for the hydrological year 2016-2017. This would be enough, to fill an individual 25-meter swimming pool with glacier water for every Swiss household! The currently still present ice volume has declined by about 3% this year. During the summer of 2017 the melts of the glaciers was extreme - throughout Switzerland, the glaciers lost even more ice than in the hot summer of 2015 and about the same amount as in 2011. However, the record losses of 2003 were not quite reached. The measurements of the glacier melts for 100 years on the Claridenfirn in Glarnerland confirm it: 2017 belongs to one of the three most actively melting years.

Hydrological situation in the Rhine basin in the year 2017

Water levels of the large lakes in the Rhine basin

Austria

At the beginning of the year and during January, the water level of Lake Constance was slightly below the long-term average level for the respective calendar day. In February and March, above-average water levels due to melting of snow and during April to mid-May values were measured in the range of the average level. The below-average amounts of precipitation during May and June then led to below-average water levels by the end of August. From the September 2 onwards, the water level until the end of the year was above the average level for the respective calendar day of the reference period 1864-2013. (see Figure 10).

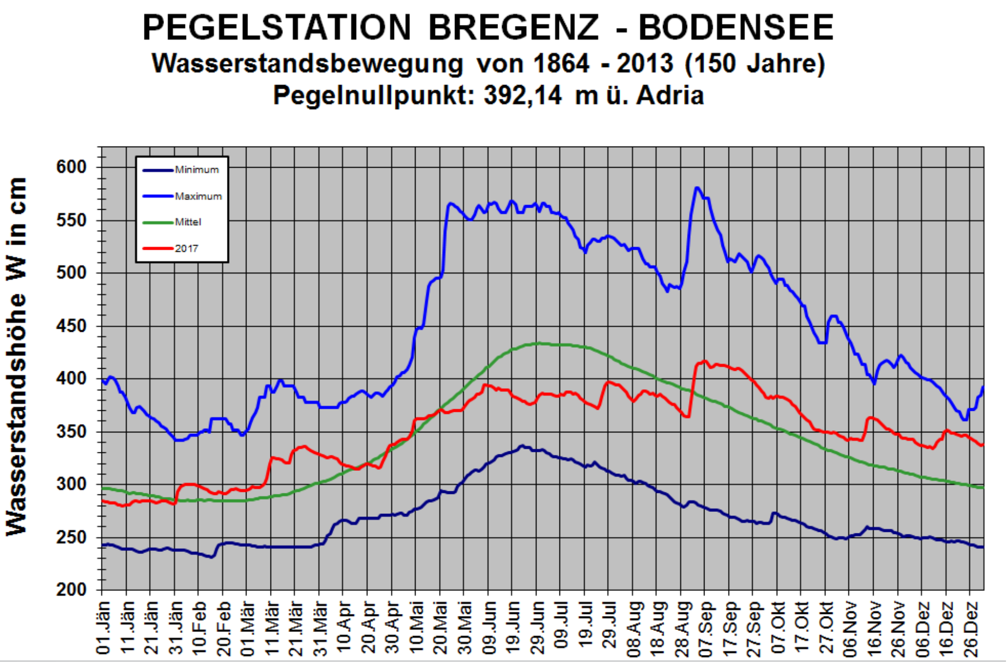


Figure 10: Hydrograph of the water level in Lake Constance at the Bregenz gauge in 2017 (red curve) compared to long-term lows, highs and average values

Switzerland
Once again, with the large lakes of Switzerland, the annual average water level values of Lake Maggiore and Lake Constance (Obersee) deviate most significantly from the long-term average level values. In 2017, at the Lake Maggiore-Locarno station they are -29 cm, at Lake Constance--Romanshorn +15 cm. The other large lakes recorded average level values close to or just a few centimetres below the values of the reference period 1981-2010. That Lake Constance is a bit out of line, is not surprising: In the last 10 years the water level difference between Obersee and Untersee has increased continuously. It was around 35 cm in 2017 and therefore the largest ever since measurements began.

The water levels of large lakes have developed differently during the year. Lake Constance, Lake Maggiore and Lake Geneva started at a level usual for the season. By contrast, Lake Neuchâtel was 31 cm below the long-term monthly average in January. The water levels from the beginning of the year are the lowest recorded at Lake Neuchâtel during the 35-year measurement period. The new lowest level was registered on the January 30 at 428.75 m a.s.l.. From February to the end of the year, the deviations of the monthly average from the standard were not more than 9 cm. Lake Neuchâtel. Lake Biel and Lake Murten are connected by the Zihl Canal and the Canal de la Broye. As a result, low water levels at Lake Neuchâtel also mean low water levels at the other two lakes. Therefore, there were new lowest January and February levels there too. Apart from what was already mentioned, of the larger lakes of Switzerland, new lowest January levels were also recorded for Lake Zug (measurements since 1930) and Lake Sarnen (measurements since 1974); Lake Zurich remained only 2 cm above the previous lowest level in January.

At Lake Geneva, only March is worth mentioning. The water level was on average 13 cm above the long-term value. In the remaining months, the deviation was never greater than 5 cm.

The Bodensee and the Lago Maggiore showed opposite developments. During February and March as well as September (resp. October) onwards to the end of the year there were relatively high water levels at Lake Constance and low water levels at Lake Maggiore. The deviations from the long-term monthly average values were significantly greater than those at the lakes on the southern end of the Jura. The positive deviations on Lake Constance were between 37 and 54 cm from September to the end of the year. The precipitation deficits in Ticino in the fourth quarter did not lead to new records (5 cm above the December minimum) but led to water levels, which were about 120 cm below the usual values.

None of for alert relevant thresholds were exceeded at any of the four lakes. At Lake Constance, the highest water level in 2017 was 32 cm below the limit of danger level 2, which is that way almost exactly one meter below the highest water level of the previous year.

Water levels and discharges of river water

Austria
The discharge of the Alpine Rhine in 2017 was below the long-term average. At the other tributaries to Lake Constance from Austria the discharges were also above average in accordance with the above average precipitation. The annual load compared to the long-term average was:

- at the Bregenzerach 116 % (MQ 2017 = 53.8 m³/s, long-term MQ = 46.5 m³/s);
- at the Dornbirnerach 118 % (MQ 2017 = 8.30 m³/s, long-term MQ = 7.06 m³/s);
- at the Alpine Rhine 92 % (MQ 2017 = 213 m³/s, long-term MQ = 231 m³/s).

Switzerland

The annual average of the discharges of the large river basins were all below the values of the reference period 1981-2010. The annual average of the discharges from Doubs, Birs and Maggia were more than a third below the long-term average values. In the river basins of the Aare, the Rhone, the Ticino, the Thur and the Inn 75% to 90% of the normal amount of water was discharged. At Reuss Limmat and Alpine Rhine it was over 90%.

Only a few mid-sized basins achieved above-average annual discharges; one of them is the Massa. Especially the summer with the substantial melts of the glacier has contributed to the above-average value. June was more than 60% and August just 20% above the corresponding long-term monthly average values. Basins with discharges below 70% of the standard are predominantly located in western and north-western Switzerland as well as in North Tessin. New smallest annual discharges were measured at the Areuse near Boudry (records since 1983) and at the Sorne near Delémont (records since 1983). The basins in central and north-eastern Switzerland recorded largely normal values.

In many mid-sized basin areas in western and north-western Switzerland average or above-average levels during March and December, below-average discharges during the months before and in between were measured; this was also the case at the Doubs near Ocourt. With only about 15% of the normal monthly discharge, the values in January were well below the standard. January was not just a month of extremes at the Doubs: At almost 30 stations on the northern side of the Alps, there were new lowest January levels. Following a temporary recovery during February and March, the water levels of many basin areas remained at a low level from April to November. Only the above-average precipitation in November in large parts of the northern side of the Alps brought a relaxation of the low water situation. The monthly average of many rivers significantly exceeded the norm values in December. In the basin areas of central and eastern Switzerland during April and May no low water levels were registered, since during April the precipitation totals there were significantly above the standard. In these regions, the water levels were mainly very low in the summer. In autumn, the situation normalised in many places. The rivers Linth, Limmat, Thur and Alpine Rhine were already increasing discharges during September.

Huge discharge events did not occur in 2017. However, worth mentioning is the flood of late August/early September, that was announced in the Federal Natural Hazards Bulletin of August 31: „A strong upper air flow from the southwest will carry along warm and humid air from the western Mediterranean to the Alps. In the bottom area, a depression forms over northern Italy, which causes a north-easterly current in the lower air layers of the northern side of the Alps. With both currents a counter current layer develops, which leads to heavy precipitation in the central and eastern parts of the country". The Rheintaler Binnenkanal at St. Margrethen and the Goldach at Goldach, each recorded every 30 years, the sitter at St. Gallen, a 10-year flood. In contrast to a stormy precipitation, this precipitation event had supra-regional dimensions and brought therefore remarkable water level increases even in large rivers. In the Rhine at Diepoldsau, during those days the highest point of the year was recorded. It was still lying 200 m^3/s below a biennial flood.

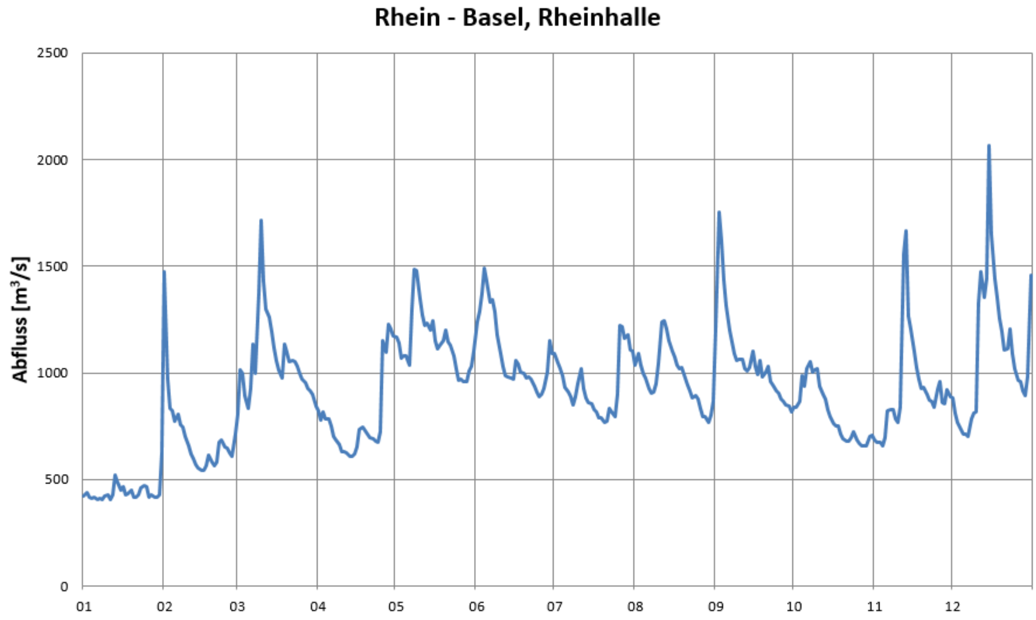


Figure 11: Discharge hydrograph at the Rhine - Basel gauge, Rheinhalle in 2017

Germany
The water supply in the discharge year 2017 was initially characterised by the significant precipitation deficit (illustrated in the graphs in Figures 12 to 17). At the end of the low water phase, which has been ongoing since the late summer of 2016 *(see BfG-Report)* At the beginning of March, several storm lows became discharge active, where their significant precipitation led to regionally limited flooding. The annual maximum level values relevant for the year of discharge were measured at all considered water levels. The water supply in the following months remained mostly below average; short-term increases in discharges were never sustainable.

In 2017 the annual MQ at the measuring stations in the Rhine were significantly below the long-term annual average (see Table 2). On the Neckar the MQ were 40% lower, on the Main, the deficit was 32%, on the Moselle, the MQ2014 are only 48% in contrast to the measured long period (1931-2011), Furthermore, 68% of the total annual discharge was already discharged at the Cochem measuring station just in the first five months.

The ratio of winter MQ to summer-MQ for the Rhine corresponds to the long-term observations at the Maxau gauge, while for Kaub and Cologne the MQ exceed in the summer months those of the winter months. In the canalized tributaries Neckar and Main, the ratio was almost stable, although here in the long-term comparison (period 1931-2011) the winter discharge accounts for two thirds of the total discharge. By contrast, in the case of the Mosel, the winter months discharge totals were, at 74%, significantly overweight (see Tab.2).

Table 2: Comparison of average discharges (MQ) in the discharge year for selected gauges in the Rhine basin and in relation to the long-term reference period (1931/2011), except Rockenau, Raunheim.

	MQ			*MQ 2017*		
Water level	*2017*	*1931-2011*	*MQ 2017 in % of MQ of the long-term comparative period*	*Winter*	*Summer*	*% Wi/Su (long-term reference period)*
Maxau (Rhine)	986	1250	79%	879	1090	45/55 (45/55)
Rockenau (Neckar) * 1951-2011	82.1	137	60%	82.9	81.3	51/49 (64/36)
Raunheim (Main) * 1981-2011	150	221	68%	140	160	47/53 (68/32)
Kaub (Rhine)	1250	1650	76%	1150	1354	46/54 (51/49)
Cochem (Moselle)	150	314	48%	223	78.2	74/26 (64/36)
Cologne (Rhine)	1510	2110	72%	1490	1530	49/51 (55/45)

The annual discharges at the Maxau (Rhine) gauge fell short of the long-term average on 310 days, in the winter months on 158 days, in the summer months on 152 days. In Kaub they were recorded falling short on 319 days (winter 158 to summer 161) as well as in Cologne on 332 days (152 to 180). On the tributaries they fell short against the average values for the observation period on the Neckar and Main on 329 and 316 days, respectively, on the Moselle on 313 days, where the ratio winter/summer was determined on the Neckar (163/166) and Main (152/164) as well as on the Moselle (130/183).

With the MNQ, which have been measured long-term, the water levels of the Rhine fell short on average for 40 days, in Rockenau am Neckar for 5 days, in Raunheim/Main for 6 days and the front-runner was the Cochem/Mose gauge with 59 days.

Shortfalls with long-term measured monthly discharges (mMQ) were observed in the whole Rhine basin area in the summer months, in Maxau on 306 days (Winter 144; Summer 162), in Kaub on 309 (161/148) and Cologne on 315 (163/152) days. On the Neckar 309 (171/138), Main 241 (176/65) as well as the Moselle 323 (144/179) days of shortfall were observed.

Significant shortfalls of the average monthly low-level discharges (mMNQ) were observed on the Rhine gauges on average on 185 days (Wi 109 Su 76), on the Neckar it was on 175 days (Wi 119 Su 56), on the Main 156 days (Wi 136 Su 20) and on the Moselle (Cochem) the mMNQ had shortfalls on 235 days (Wi 101 Su 134).

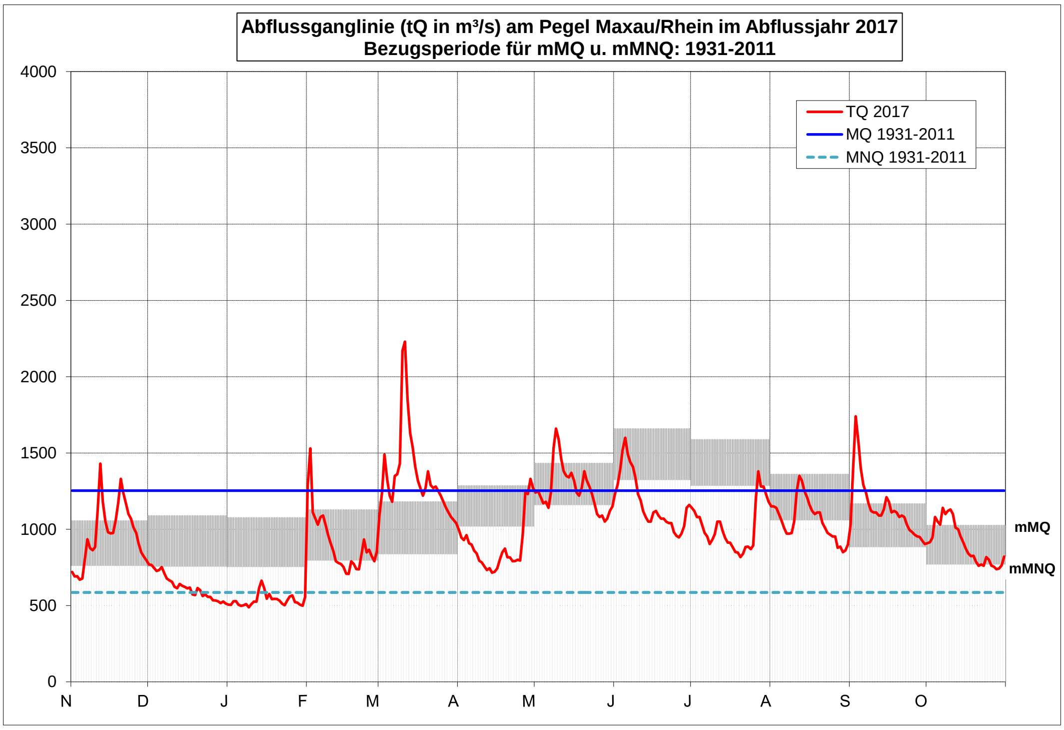


Figure 12: Daily discharges (tQ) at the Maxau (Rhine) gauge in 2017 compared to long-term averages in m³/s (reference period for MQ, mMQ and mMNQ: period 1931-2011)

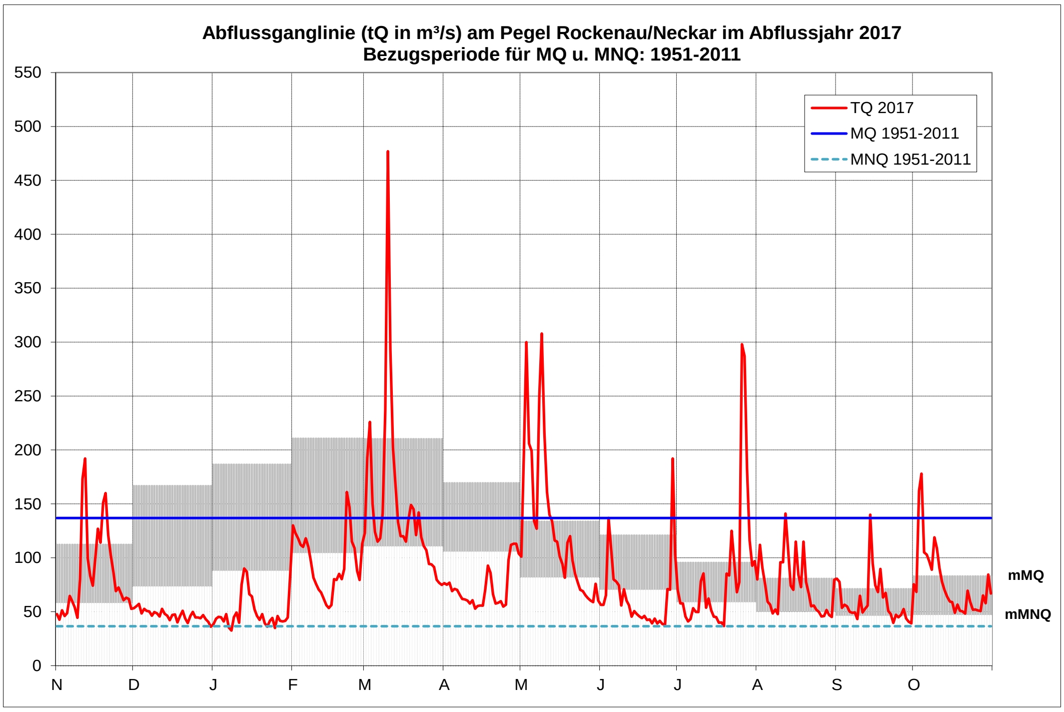


Figure 13: Daily discharges (tQ) at the Rockenau (Neckar) gauge in 2017 compared to long-term averages in m³/s (reference period for MQ, mMQ and mMNQ: period 1951-2011)

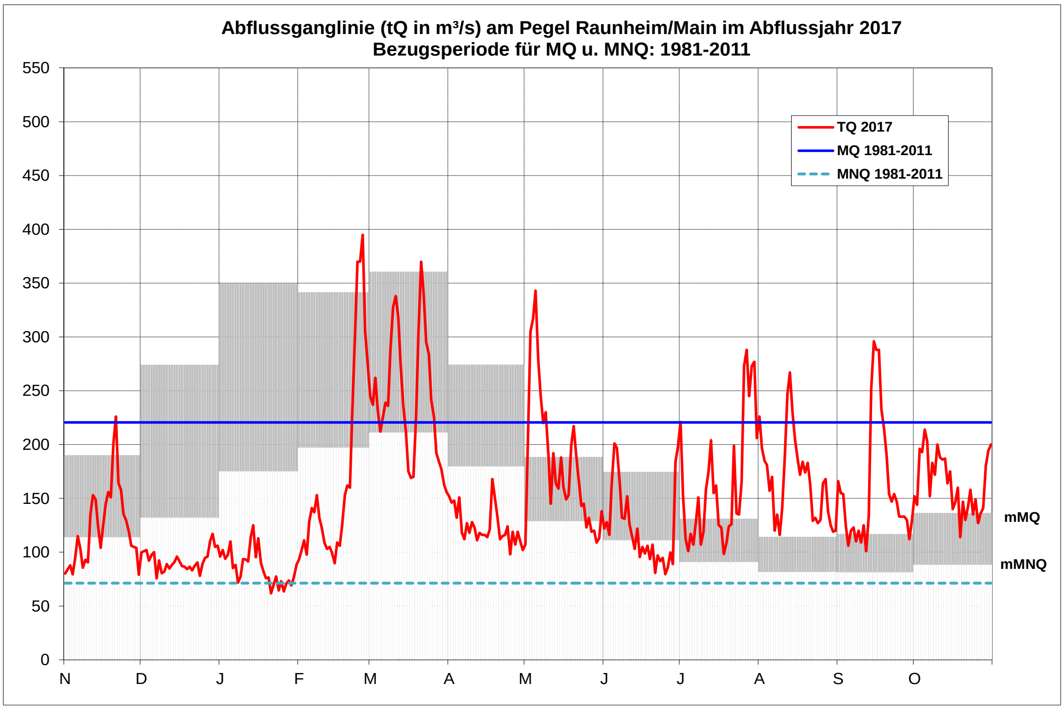


Figure 14: Daily discharges (tQ) at the Raunheim (Main) gauge in 2017 compared to long-term averages in m³/s (reference period for MQ, mMQ and mMNQ: period 1981-2011)

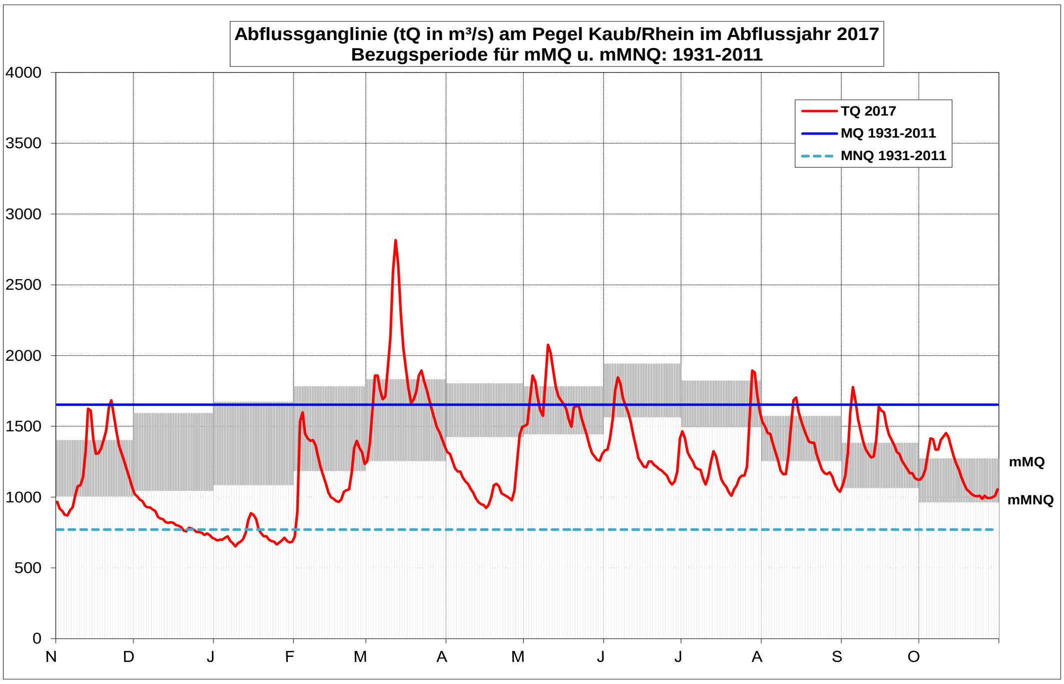


Figure 15: Daily discharges (tQ) at the Kaub (Rhine) gauge in 2017 compared to long-term averages in m³/s (reference period for MQ, mMQ and mMNQ: period 1931-2011)

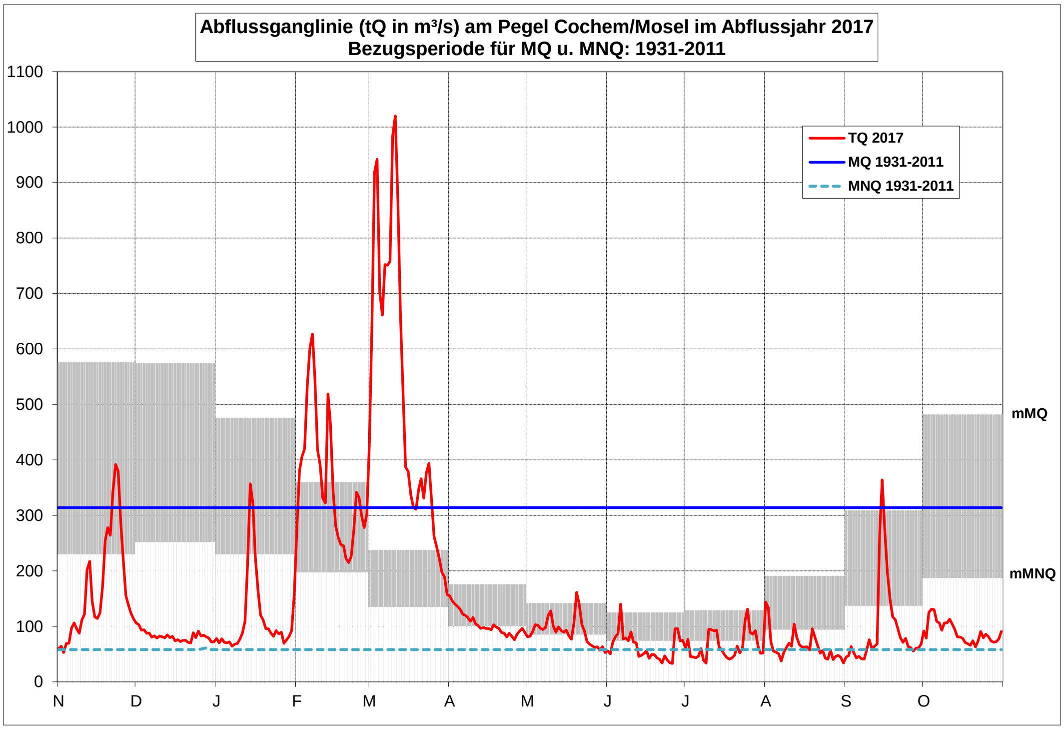


Figure 16: Daily discharges (tQ) at the Cochem (Mosel) gauge in 2017 compared to long-term averages in m³/s (reference period for MQ, mMQ and mMNQ: period 1931-2011)

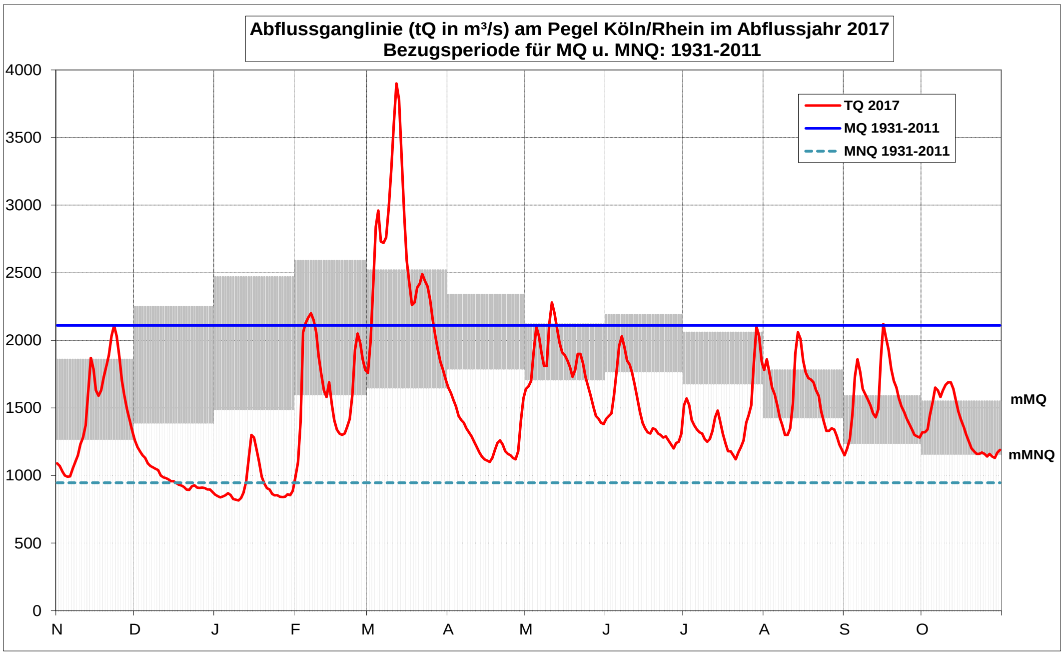


Figure 17: Daily discharges (tQ) at the Cologne (Rhine) gauge in 2017 compared to long-term averages in m³/s (reference period for MQ, mMQ and mMNQ: period 1931-2011)

Netherlands

The hydrological situation of the Rhine in the Netherlands in the previous year was especially characterised by a relatively long period of low discharges (from May until about mid-November). There was hardly any flood in the first half of the year. In the last months of 2017, the water levels and discharges were already above the long-term average for a long time. The highest measured discharge occurred at the Lobith gauge on December 18 with approximately 5,100 m^3/s. In addition to this small flood wave at the end of the year, there was still a small peak on March 15. The discharge at the Lobith gauge reached that day a value of about 3,800 m^3/s (see Figure 18).

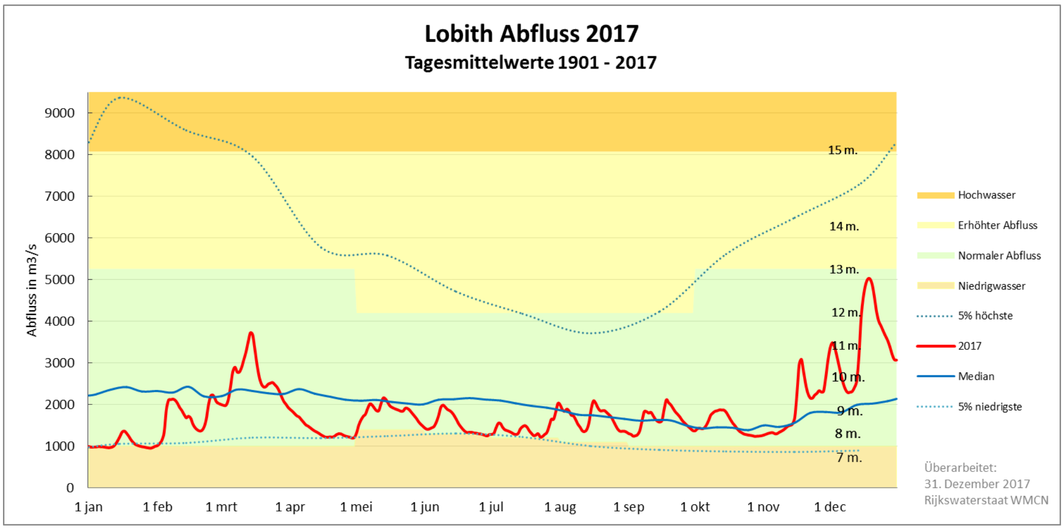


Figure 18: Hydrograph of the daily averages of the discharge at the Lobith gauge in 2017 (red curve) compared to the long-term lows, highs and averages of the period 1901-2017

Water temperatures

Austria

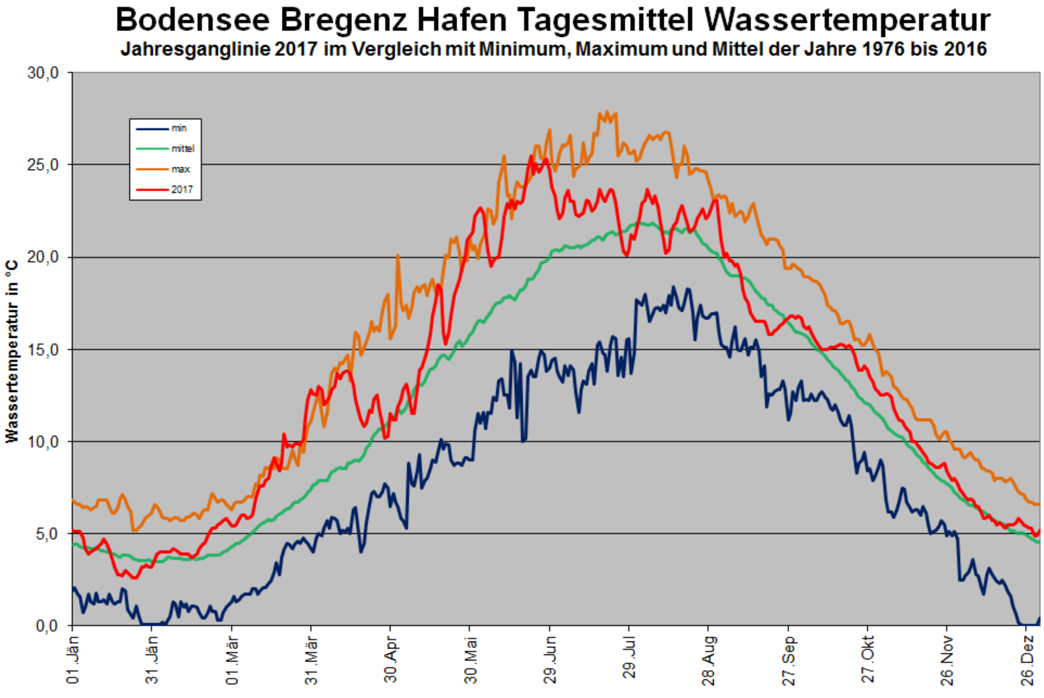


Figure 19: Hydrograph of the water temperature of Lake Constance at the Bregenz gauge in 2017 (red curve) compared to long-term lows, highs and averages of the period 1976-2016

With 13.4°C, the annual average water temperature of Lake Constance at the Bregenz Hafen gauge was 1.5°C above the long-term average of 11.9°C (see Figure 19).

Switzerland
The year 2017 was, in Winter and in Summer, characterised by very high air temperatures. Some regions of Switzerland, especially on the southern side of the Alps, recorded an above-average number of sunny days. This resulted in a significant increase of the annual maximum water temperatures of Swiss river water, being exceeded as compared with the previous year. Nevertheless, in relation to the extreme year of 2015, the maximum values in 2017 were exceeded less frequently, namely at approximately ten percent of the measuring stations in the northern Alps and occasionally in the area of Lake Constance and in the eastern central Alps. A shortfall from the previous year's minimum values, as in the previous year, has not been observed at the federal measuring stations.

The first quarter of 2017 was characterised by two opposite temperature profiles: in January, an unusually cool monthly air temperature was measured. Accordingly, spread over the whole of Switzerland, shortfalls of the previously lowest measured values were observed at more than one third of the stations.

In contrast, very warm periods from February 22 onwards also led to a significant warming of the river water. This led occasionally to exceeding the previous highs in February. This trend continued in March 2017 in a strengthening manner. The water temperature continued to rise and another quarter of the stations recorded new highs for the month. During these winter months, however, no maximum values were exceeded at the stations in the area of the Jura Arc.

After the warm end of the winter and the following rather cool weeks, in May there followed again significantly warmer days.

After the warm spring followed a very warm Summer. In June, the further warming and a five-day heat wave significantly affected the temperature of the waters. More than one third of the FOEN measuring stations recorded new highest June values. Only in turn, the stations in the Jura Arc showed no new highs for the month of June.

After July had been only slightly warmer than the standard, it came in August again to warmer summer weather. However, this did not affect the water temperature as strongly as the heat period in June. This is why the maximum values in August were only sporadically exceeded in the midlands, in the eastern central Alps and on the southern slope of the Alps.

A very cool September and an October with plenty of autumn sun did not affect the water temperature significantly. It came only sporadically to the previous minimum and maximum values of the measuring periods being exceeded or fallen below. In December, however, the water temperature at barely under a quarter of the stations was below the previously measured minimum values.

Germany
The average water temperatures (WT) measured for the observation period were 13.4°C at the measuring station Kaub and are below the annual long-term average by 0.5°K. At the gauge in Cologne, temperatures were 13.9°C and below average by 0.1°K.The largest deviation of the monthly averages (below averages) were measured in January at the Kaub measuring station by -2.8 K and the Cologne measuring station by on average -2.1 K. The largest positive deviations from the monthly averages were measured in June at Kaub as +1.7 K and in Cologne as +1.2 K and in October by +1.3 K. The maximum negative deviations with the daily values in Kaub in January were -4.6 K or -3.9 K in May, at the Cologne measuring station respectively -3.5 K. The largest positive deviations at the beginning of June were +3.9 K in Kaub and +2.9 K in Cologne.

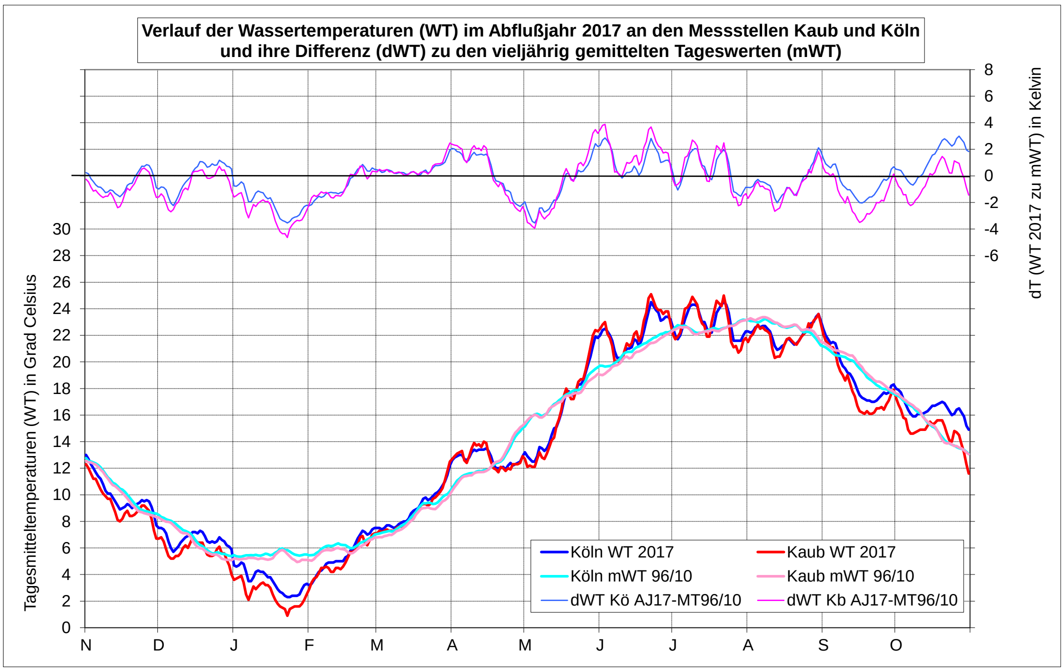


Figure 20: Water temperatures compared to the long-term averages (AJ = discharge year; Source: WSV)

Netherlands

With 13.8°C, the average water temperature at the Lobith gauge was about 0.7°C above the long-term (1961-2017) calculated average annual value (see Figure 21).

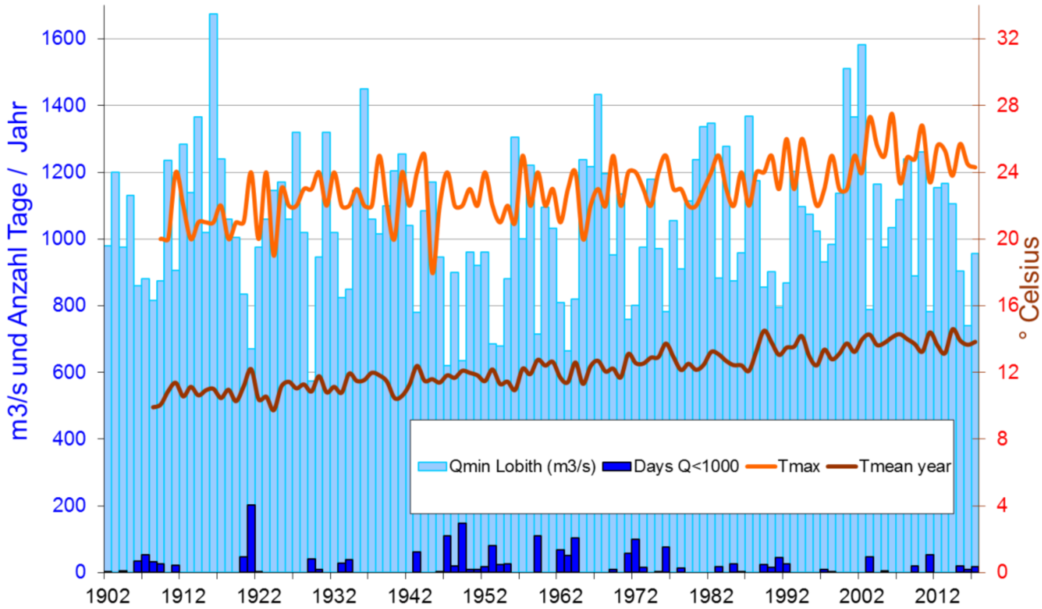


Figure 21: Average and maximum water temperatures in 2017 at Lobith/Rhein gauge

In the ranks of highest average water temperatures, 2017 came in 11th place (records 1908-2017)

Groundwater

Austria

At the beginning of the year, the groundwater levels were below average and increased, due to snowmelt and precipitation until May, to above-average levels. After that, they fluctuated around the average until the end of August. The substantial precipitation at the end of August led in part to new measurements of highest levels for the period of early September. Until the end of the year, groundwater levels remained mainly above average.

Switzerland

The annual development of the groundwater levels and spring discharges in 2017 in Switzerland can be summarised as follows:

As a result of the low precipitation in December 2016, the groundwater levels and spring discharges in January 2017 were low at about every second measuring station. In February, groundwater levels and spring discharges increased in western Switzerland and Ticino as a result of above-average precipitation and the onset of snowmelt due to the warm weather.

From March to May, groundwater levels and spring discharges due to average rainfall remained for the most part within the normal range. However, in areas with below-average precipitation, temporary low groundwater levels and spring discharges were recorded. Overall, widespread normal groundwater levels and spring discharges with declining tendencies were observed in mid-June.

From June to August, there was consistently below average precipitation in western Switzerland, while in Central and Eastern Switzerland heavy rainfall led to above-average precipitation. Near-surface and groundwater aquifers that were dependent on rivers were able to benefit from these in particular. In mid-September, for example, widespread normal groundwater levels and spring discharges with an uneven trend were observed.

October was generally warm and dry. November continued to see small amounts of precipitation on the southern side of the Alps and in western Switzerland, which partly led to low groundwater levels and spring discharges in these areas. By contrast, in November heavy precipitation in Central and Eastern Switzerland caused an increase in groundwater levels and spring discharges. At the beginning of December, groundwater levels and spring discharges on the northern side of the Alps were widely in the normal range, partly already above it. On the southern side of the Alps normal to low groundwater levels were observed.

During December high precipitation fell countrywide - sometimes as snow in the midlands. At the end of December, groundwater levels and discharges were within the normal range in the whole country.

Suspended sediments

Austria

At 1.8 million tonnes, the annual suspended sediment load on the Alpine Rhine at the Lutenau measuring station in 2017 was slightly more than 10% lower than the average of the years 2009 – 2016 (approx. 2.05 million tonnes). Due to the flooding in early September, in September the largest monthly load of 2017 (about 645 thousand tonnes) and for September 1 the highest daily load (about 345 thousand tonnes) were measured. The monthly load in September represents a little over one-third of total annual load.

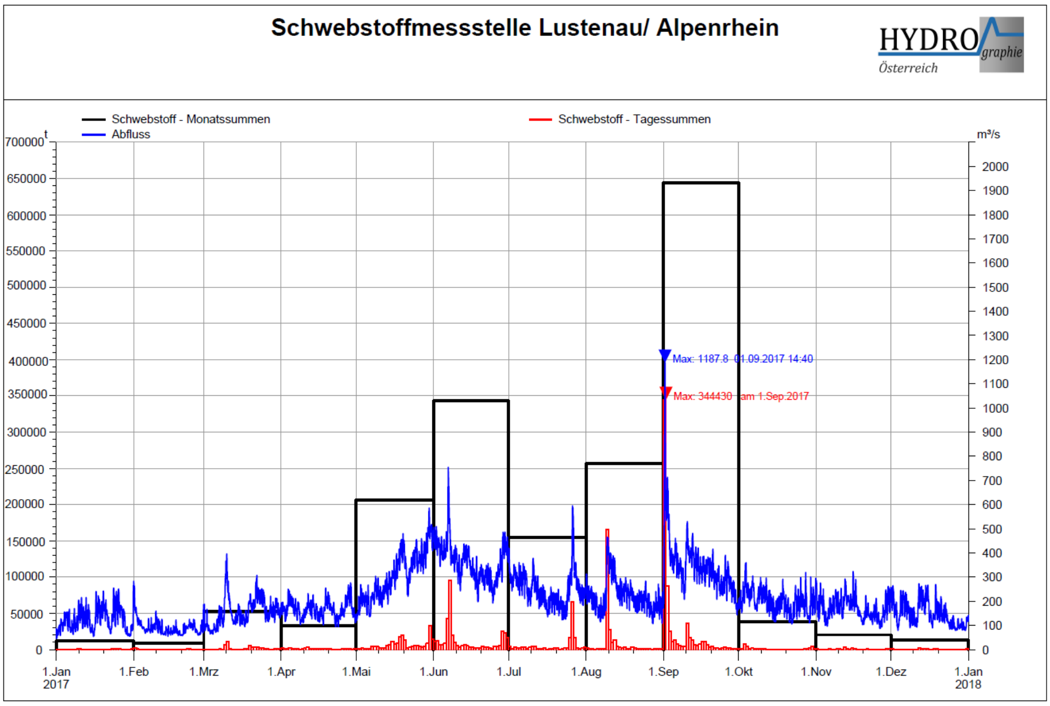


Figure 22: Monthly loads of suspended sediments of the Alpine Rhine at the Lustenau gauge in 2017 with daily loads (red curve)

Germany

To obtain an overview of the suspended sediment loads, data from the measuring stations Maxau (Rhine-km 362.3) was analysed for the upper Rhine (see also Figure 23). For the regions of the middle Rhine/lower Rhine (below the large tributaries), no data could made available in sufficient form at the measuring station Weißenthurm (Rhine-km 608.2) due a change in the measuring methodology of data for the observation period.

In general, extreme peak values for daily loads are a result of heavy rainfall events in summer and the start of the snow melt in winter.

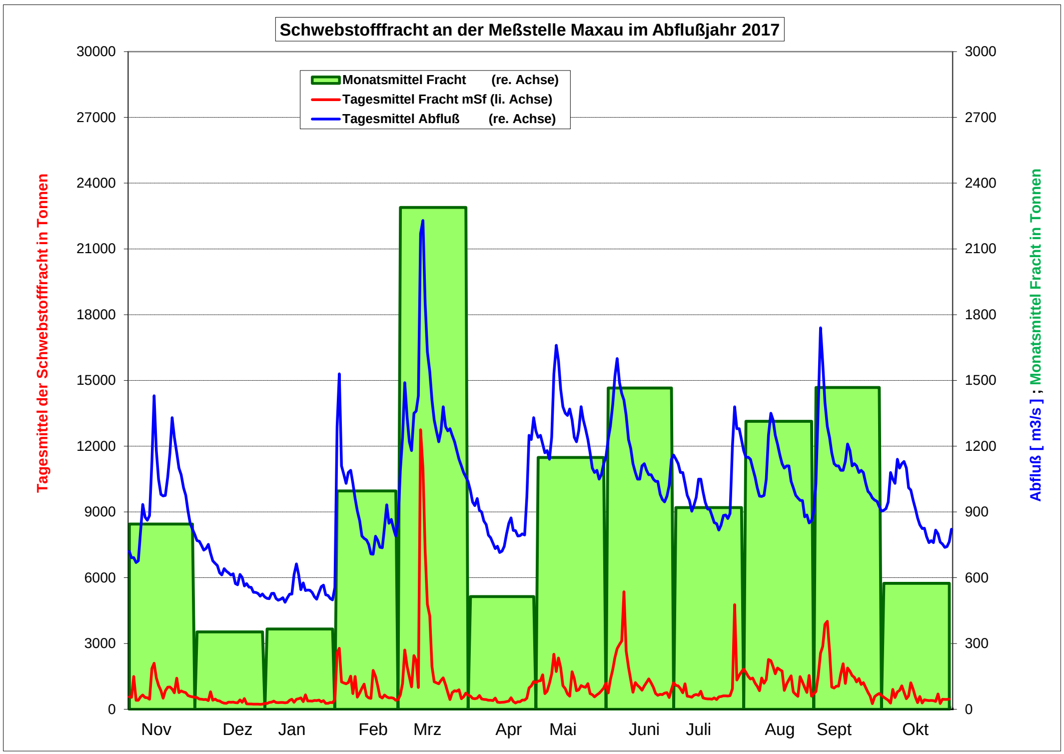


Figure 23: Maxau suspended sediment measuring station, Rhine-km 362.3

The annual suspended sediment load in Maxau was 372 569 t in total, which corresponds to about 29% of the long-term average of the reference period 1965/2007.

The highest monthly suspended load transport was measured at the measuring station Maxau in March 2017 with 70 976 t (monthly average: 2 290 t) measured, which corresponds to approx. 19% of the total annual load. The lowest monthly suspended sediment load was measured in December 2016 with only 10 933 t (monthly average: 353 t).

The daily loads at the measuring station Maxau were at a minimum on 29.12.2016 with 223 t compared to an average discharge of 516 m³/s, and at a maximum on 14.03.2017 with 12 749 t compared to an average daily discharge of 2 170 m³/s.

2. Activities of the International Commission for the Hydrology of the Rhine Basin (CHR) in 2017

The CHR met twice in 2017, on April 4 and 5 in Esch-sur-Alzette (Luxemburg) and on the September 21 and 22 in Basel (Switzerland).

Personnel changes within the CHR
In 2017, there were no personnel changes within the CHR.
There were extensive discussions about the succession of Mr. Moser as President of the CHR. Mr Moser's term expires in autumn 2018. In spring 2018, a new chairman should be elected.

Activities in CHR projects
Sediment
The CHR has supported the project 'From the Source to the Estuary - A Sediment Balance of the Rhine', carried out by the BfG and the University of Aachen, with a steering group. The project was completed at the end of 2014 and the project results were presented in a seminar in March 2015. The project report draft was completed at the end of 2016 and was published in German mid-2017 as CHR Report II-22. The publication of an executive summary in English is planned.

ASG-Rhine: Contribution of snow and glacier melts to the Rhine discharges
The first phase of the project was completed in 2015. The results were presented in a workshop in November in 2015.
The final report (in two languages: German and English) was completed in 2016. Furthermore, a synthesis report (extended abstract) was prepared for the project in 2016. The synthesis report (CHR publication I-25) presents the results of the project in a structured and comprehensive way, which makes them accessible to a wide readership.
Different specialist articles were published about the project and the results were presented at several (inter)national conferences.
A preparatory group has created the requirements for the second phase of the project in autumn 2016. At the end of 2017 there an offer will be made by the Consortium of the Universities of Freiburg and Zurich together with the engineering firm Hydron GmbH for the implementation of the second phase. The further development of content relates primarily to the aspects:

- Further development of hydrological models (HBV/Larsim)
- Improvement of snow melting practices
- Design models 2006 – 2100

The project management of the second phase will be placed under the Federal Office for the Environment in the Switzerland. A steering group has been formed with participants from the CHR member states and external experts.

Lake Constance as water reservoir - a literature review
The CHR has commissioned the Technical University Munich to conduct an evaluative-analytical literature review. The concept report of this study was distributed in the internal CHR circle in 2015. In 2016 a revised version of the study was sent to the CHR representative of the countries with request for comments. Subsequently, the report was sent to all federal states and cantons of the Rhine basin with the request for comments. The comments received were incorporated into the report in 2017. The revised document was submitted to the CHR members for approval for the last time in autumn 2017. A publication in the 'blue' CHR publication series is planned for 2018.

Climate change
At the 79th meeting in April, Mr. Hattermann from the Potsdam Institute for Climate Impact Research gave a lecture on the topic of climate change. Mr. Hattermann showed, that different hydrological models will quite accurately predict the change of the discharge regime on the Rhine. In the latest climate scenarios, the range of temperature increase by 10% has not increased in comparison to the results from the RheinBlick 2050 study.

At the 80th meeting in September, it was noted that there are new national climate scenarios, but that the 2007 IPCC report continues to serve as the foundation for science. As a result, there is no need now, to calculate the new national scenarios hydrologically

Socio-economic influences on the low water regime of the Rhine
On the occasion of the symposium organised in March 2014, the topic was also discussed at the CHR meetings in 2017.
At the spring meeting, Mr. Ruijgh (Deltares) presented the project progress. A first workshop took place at the end of March in Koblenz. In this workshop, basic information was collected from the different sectors or from the stakeholders.
In autumn 2017, another workshop took place with a smaller group of participants. Subsequently, it will be investigated, which socio-economic influences have the greatest impact on the discharge.

Hydrological memory of the Rhine
The CHR intends, to start a new project for the collection, optimisation and homogenisation of long-term hydro-meteorological histories. The preparation of such a database is absolutely essential for future projects and especially for a long-term security of the data. Also, such a com- mon database could lead to an improvement of the scientific work at universities and colleges and can men or enable at all the comparability of the results of different studies.
Mid-2017, CHR contacted Prof. Herget of the University of Bonn with the question, whether the University of Bonn would be interested in conducting a preliminary study. In so doing, Prof. Herget expressed his interest in principle to participate in the project. Since he is involved in other projects until the end of the year, the talks will continue at the start of 2018.

Collaboration with other organisations
Coordination took place with the working group Low Water of the ICPR. The leadership of this working group was assumed by Mr Brahmer.

In the CHR meetings conferences and events of IHP and HWRP were pointed out.

At the Mekong River Commission, the anchoring of work in a regional and political context has not finished yet. Therefore, there is no symposium with representatives of European river commissions to be expected for the time being.

The Huaihe River Commission (Huaihe) invited the CHR to a Huaihe-Rhein workshop in China. The workshop took place in February 2017. The workshop staff participating of FOEN, BfG, Rijkswaterstaat and Deltares. At the end of the workshop, topics for possible collaboration were defined. The Huaihe Commission has proposed, to conclude an agreement of cooperation with the CHR. The agreement was approved by the CHR representatives in the form of "Letter of Intent". A return visit of the Huaihe Commission to the Rhine area will take place in 2018.

Publications of CHR
The project report,"From the source to the estuary" was published in German as CHR Report II-22

The report on the CHR symposium 'Water levels rise - humanity is facing catastrophe', in German: 'Land unter - Der Mensch vor der Katastrophe', (Halle, March 2016), was published as CHR Report II-23 in the Green Series.

The CHR has published the Hydrological Annual Report 2016.

Events organized by CHR
On September 21 was the CHR colloquium on the topic of low water was organised with the subtitle "Science meets practice". Three Rhine commissions, ICPR, ZKR and CHR had sent out invitations for this colloquium.
The event proceeded satisfactorily. Representatives from all key sectors were present and attempts were made in advance, to also receive contributions from all countries around the Rhine. In the discussion at the end of the first day all problem points were summarised. The involvement from the shipping industry was relatively high. This industry is concerned about the future problems of more frequent periods of low water. The colloquium has encouraged the three Rhine commissions to maintain a good exchange of information and has shown the importance of the observer status.
The colloquium report can be downloaded from the CHR website.
All lectures can be downloaded here.