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

Annual CHR Report 2020

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Cover photo: Floods at the Waal near Nijmegen on 09.02.2020.
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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 Management Programme (HWRP) of the World Meteorological Organization (WMO). It is a permanent, independent, international commission and has the status of a foundation, registered in the Netherlands. Members of the commission include following scientific and operational hydrological institutions of the Rhine basin:

- Federal Ministry of Agriculture, Regions and Tourism, Section I — Water Management — Division I/3 Water Management (HZB), Vienna, Austria,
- Office of the Vorarlberg State Government, Department VIID — Water Management, Bregenz, Austria,
- Federal Office for the Environment, Bern, Switzerland,
- INRAE, Antony, France
- Université Gustave Eiffel, Nantes, France
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- Water Management Specialist Administration, Luxembourg,
- Deltares (an independent institute for applied research), Delft, Netherlands,
- Rijkswaterstaat — Transport and Water Management, Lelystad, Netherlands.

1. Hydrological Overview for The Rhine Catchment Area

Meteorological Characteristics

Austria, Source: Central Institute for Meteorology and Geodynamics (CIMG)
2020 was significantly warmer in Austria than many years within the 18th, 19th and 20th centuries. In summary, 2020 was 1.2 °C warmer than the 1981-2010 climatological average and 2.0 °C warmer than the 1961-1990 climatological average, which was not yet as strongly influenced by global warming. Overall, 2020 was the fifth warmest year in the Austrian lowlands since records began (the first complete year was 1768). This means that a total of 15 of the warmest years are in the 21st century.

In the high Alpine peak regions, 2020 was actually the warmest year in the 170-year history of Alpine measurement, with a deviation of +1.5 ° C from the 1981 - 2010 average. It is thus on a par with the year 2015. The measurement series of the Sonnblick observatory recorded a new station record with an annual average of -3.5 ° C (deviation +1.6 ° C, 1981-2010). The measurements series of complete years has existed there since 1887.

In Upper Austria, Lower Austria, Vienna and Burgenland, the year was 1.2 to 1.6 ° C warmer than the 1981-2010 mean. In the valleys of Tyrol, Salzburg, Styria and Carinthia, the temperature deviations were between +0.7 and +1.3 ° C. Above 1000 m above sea level, the year was between 0.7 and 1.9 ° C warmer than the 1981-2010 mean.

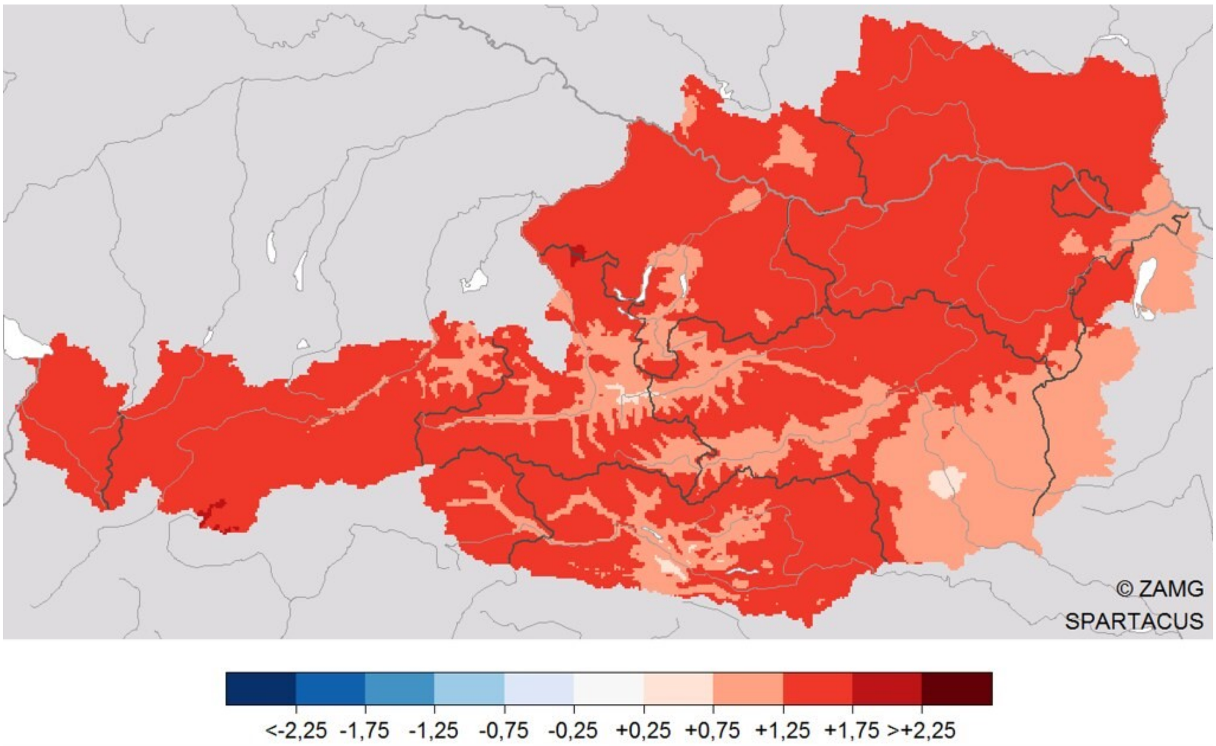

Figure 1: Temperature in Austria in 2019: Deviation of temperature from the multi-annual average/s of 1981-2010. Source: ZAMG

After three years in which precipitation was largely too low, especially in the summer months, precipitation in 2020 was balanced to well-above-average in almost all parts of the country.

The very important precipitation in summer months of June to August contributed significantly to the positive balance with an increase of 26 percent compared to the 1981-2010 average. However, February (+27%), September (+20%), October (+60%) and December (projected +100%) also had significantly more precipitation than the average for these months.

The annual balance recorded an area average of 10 per cent more precipitation over Austria. This makes 2020 one of the 25 wettest years since 1858.

Precipitation quantities were well-balanced in Vorarlberg, in Tyrol north of the Inn, in Salzburg north of the Salzach, in Upper Austria, in parts of Styria as well as in Central Burgenland and in the south-eastern part of Lower Austria. 2020 was 10 to 20 per cent wetter in large parts of Lower Austria, in Seewinkel, in southern Burgenland, in Eastern Styria, along, as well as south, of the main Alpine ridge from North Tyrol to Lower Tauern and in Lower Carinthia. In East Tyrol and Upper Carinthia, 20 to 40 per cent more precipitation than average occurred, in some places up to 60 per cent more.

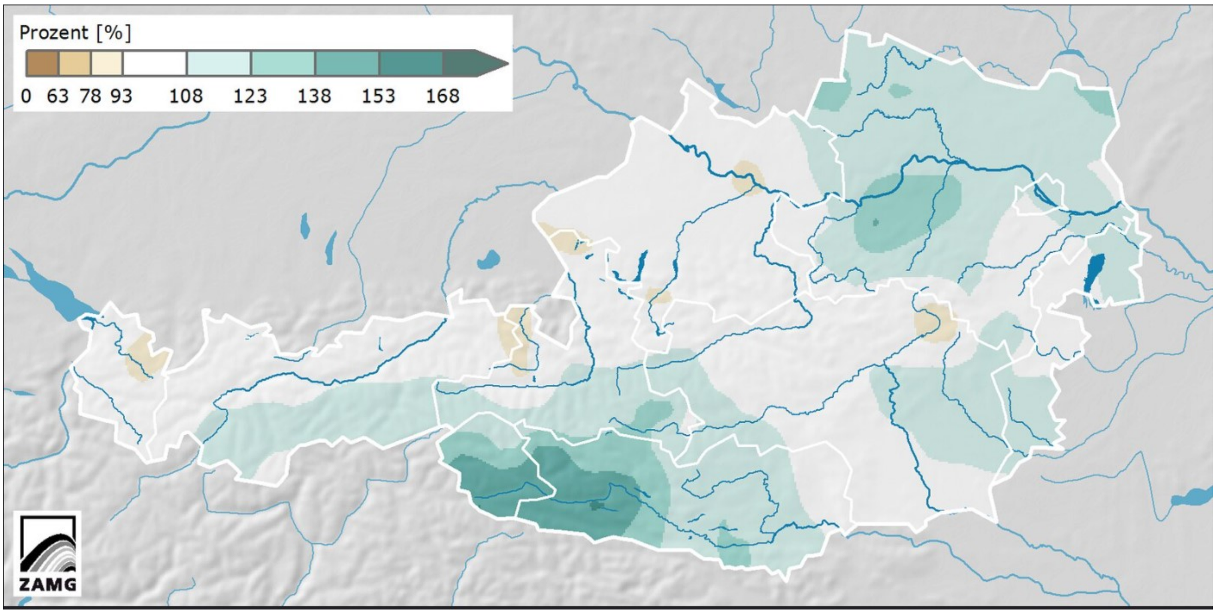

Figure 2: Precipitation in Austria in 2020: Deviation of precipitation from the multi-year average: 1981-2010. Source: ZAMG

2020 was a very sunny year. On average, the sun shone 9 percent longer in Austria compared to the 1981-2010 average. The year 2020 was one of the ten sunniest years since 1925. Balanced sunshine conditions prevailed (deviation +/- 5%) from the Arlberg to the Ausseerland and Upper Carinthia. In Upper Austria, Lower Austria, Vienna, Burgenland, Lower Carinthia and large parts of Styria, the sun shone 5 to 15 per cent longer than in an average year. With a +17 percent increase on the 1981-2010 average, the Rhine Valley was the sunniest region in Germany.

Meteorological characteristics for the Austrian Rhine region. Source: Hydrographic Service of the Vorarlberg

In 2020, the monthly precipitation totals of February, June, August and October were above the average for the respective month. December recorded average quantities of precipitation, while the other months, in some cases, recorded significantly below-average precipitation totals (Figure 3). The total annual precipitation in the Austrian part of the Rhine catchment area was 97% of the long-term average.

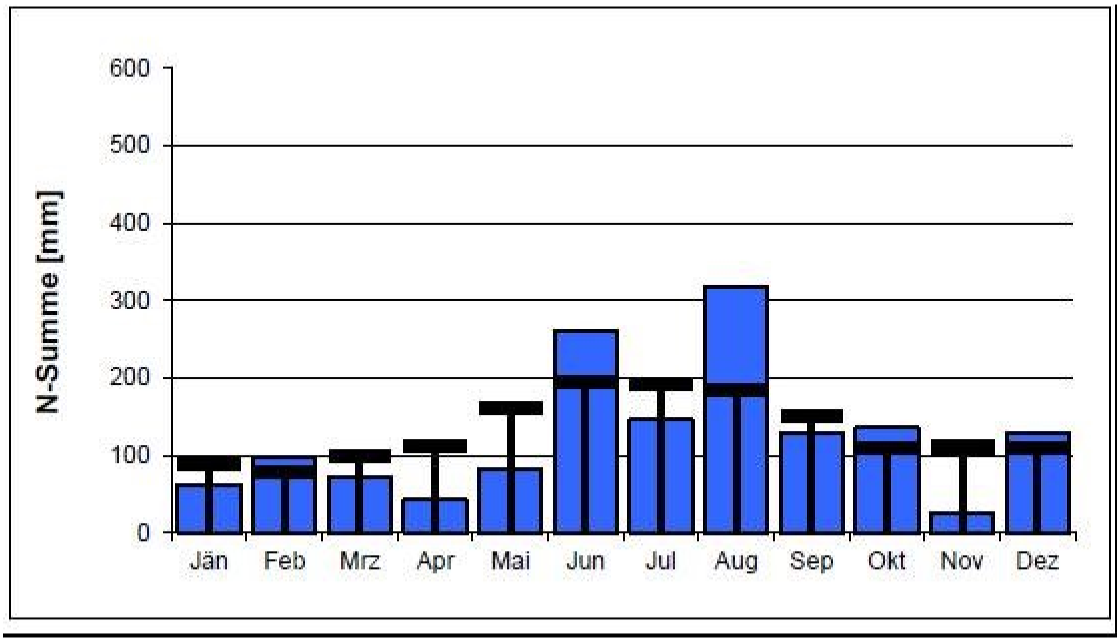

Figure 3: Monthly precipitation sums in 2020 (blue columns) compared to the long-term monthly average (1981 — 2010) at the Bregenz Altreuteweg measuring station

In the Austrian Rhine catchment area, the average annual air temperature was 1.5 ° C higher than the long-term average.

Switzerland, Source: Federal Office of Meteorology and Climatology (MeteoSchweiz)
Switzerland recorded the mildest winter since measurements began in 1864. February weather was particularly mild across the country. Most areas of Switzerland received sufficient precipitation over the entire winter with totals between 100 and 120% of the 1981-2010 norm. The southern side of the Alps recorded very little precipitation in January and February. In the rest of the country, 150 to 200% of the average precipitation occurred in February, thanks to frequent, mildly humid west and north-west currents. February 2020 was unusually stormy. In the first half of February, three winter storms hit Switzerland.

After the mildest winter ever recorded, Switzerland recorded the third warmest spring since measurements began. As a result of the frequent good weather, the precipitation totals in spring, in large areas of Switzerland, were only 50 to 70% of the norm. The reason for this was the persistent dry period from mid-March to the end of April. In April, precipitation was generally only 40 to 60% of the norm. In north-western Switzerland, on the eastern Swiss plateau, and on the central northern slope of the Alps, the April quantities were even lower in many places.
After a summer start with average temperatures, hot temperatures developed towards the end of July and in the first half of August. The first heatwave took place in the western part of Switzerland, on July 27th. In the south, the heat set in on July 28th. The second heatwave took place on the southern side of the Alps on August 6th and on the northern side of the Alps on August 7th. This period, with daily highs of 30°C plus, lasted six to seven days, depending

on the region. A sustained south-westerly current was responsible for warm, humid Mediterranean air flowing to the southern side of the Alps from the 28th- 30th August, 2020. On August 28 and 29, 2020, very heavy precipitation took place in Ticino and the neighbouring areas of the canton of Graubünden. On 29 and 30 August, the heavy precipitation also extended to the eastern northern slopes of the Alps.

The weather was mostly mild in the autumn months of September and November. In November precipitation was extremely low. October, on the other hand, was cool and rainy with massive heavy precipitation at the beginning of the month. Triggered by a strong south-westerly current, with some hurricane-like southerly winds, the heavy precipitation mainly hit the southern side of the Alps; however, it also reached the Valais, the Bernese Oberland, Central Switzerland and Graubünden.

At the exact start of the meteorological winter, some snow fell in the north, reaching down to low lying areas. Two days later, heavy snowfall began on the southern side of the Alps and extended northwards across the Alps. Further snowfall brought a lot of fresh snow to the mountains of Ticino and Graubünden.

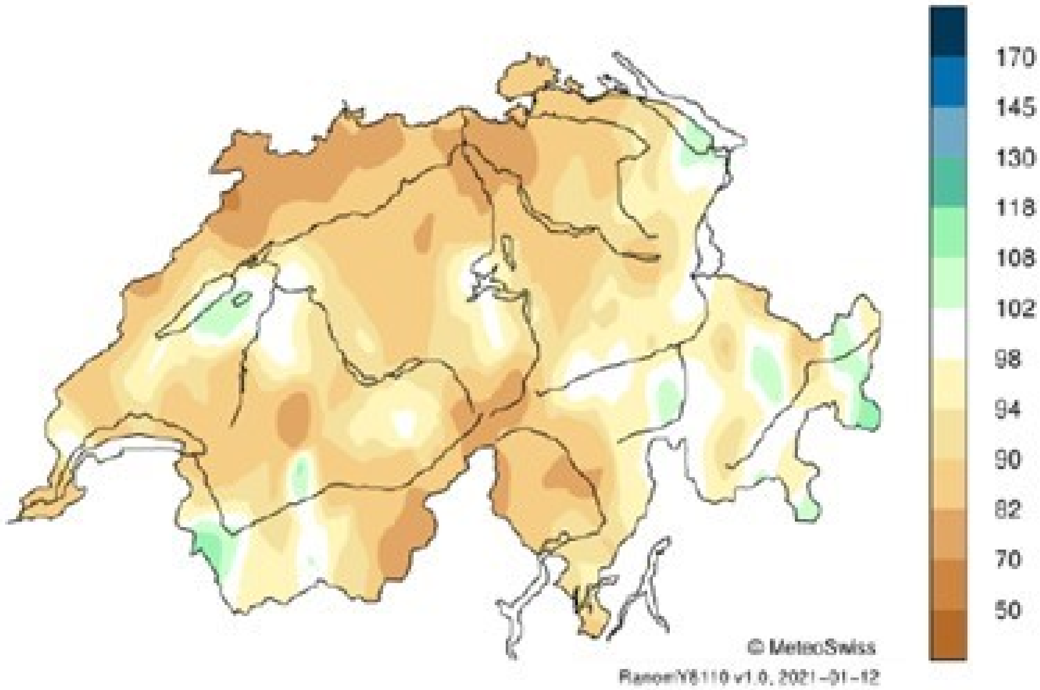

Figure 4: Annual precipitation Switzerland 2020 in percentages of the norm (1981-2010).

The annual rainfall in 2020 reached a widespread 80 to 100% of the 1981-2010 average. On the southern side of the Alps and in the Engadine, the values were mostly between 90 and 110%.

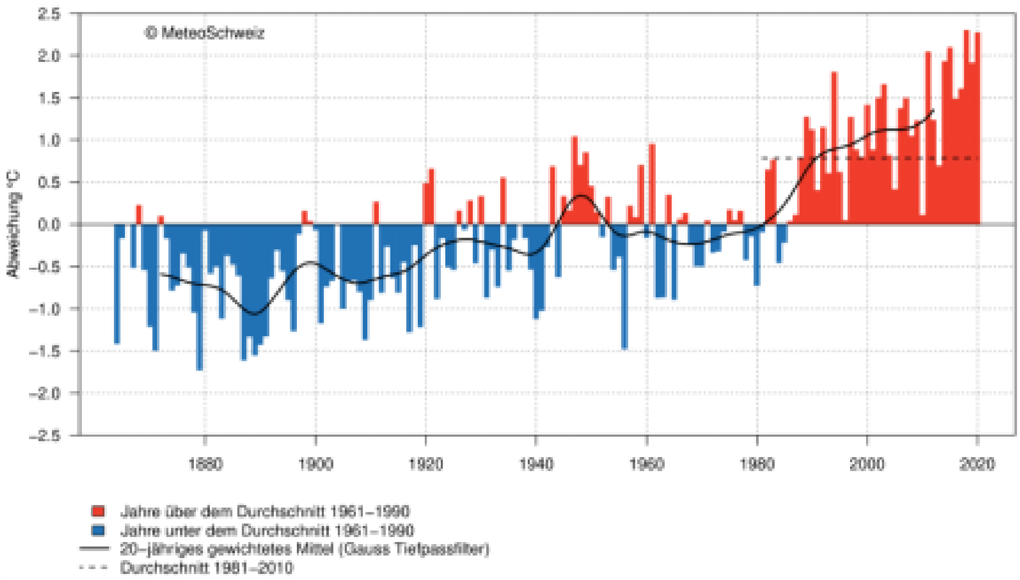

Figure 5: Deviation of the annual temperature in Switzerland in 2020, compared to the long-term average (reference period 1961-1990). The years that are too warm are shown in red, the years that are too cold in blue. The black line shows the temperature trend averaged over 20 years.

Table 1: Annual values in 2020 at selected MeteoSwiss measuring stations, compared to the 1981-2010 standard norm

Station	Height	Temperature (°C)			Duration of sunshine (h)			Precipitation (mm)		
	m.ü.M	Mean	Norm	Dev.	Total	Norm	%	Total	Norm	%
Bern	553	10.3	8.8	1.5	2155	1683	128	1037	1059	98
Zurich	556	10.9	9.3	1.6	2056	1590	129	860	1134	76
Geneva	420	12.2	10.5	1.7	2113	1768	120	794	1005	79
Basel	316	12.1	10.5	1.6	2057	1590	129	676	842	80
Engelberg	1036	7.9	6.4	1.5	1517	1350	112	1557	1559	100
Sion	482	11.6	10.1	1.5	2279	2093	109	545	603	90
Lugano	273	13.7	12.4	1.3	2340	2067	113	1542	1559	99
Samedan	1709	3.0	2.0	1.0	1931	1733	111	734	713	103

Norm = Long-term/multi-year average 1981-2010
Dev. = Deviation of temperature compared to the norm
% = Percent in relation to norm (norm = 100%)

Germany, Source: Deutscher Wetterdienst (DWD)
After 2018 and 2019, the two consecutive years with low precipitation, the trend continued into the hydrological year 2020 (i.e., from November 2019 to October 2020) in the two sub-basins of the Rhine catchment considered (Basel gauge to Mainz gauge, 72000 km² and Mainz gauge to Lobith gauge, 68500 km²). Thus, in the annual total, 90.6% (previous year 84%) and 94.7% (previous year 82%) of the average multi-year precipitation values of the years 1981 to 2010, were achieved. However, there was a wide range of variation in the individual months. The month with the highest precipitation in both sub basins was February, where around 2.5 times the long-term average was reached (see Figure 6). In relation to that specific area of Germany, it was the second wettest February since records began in 1881.

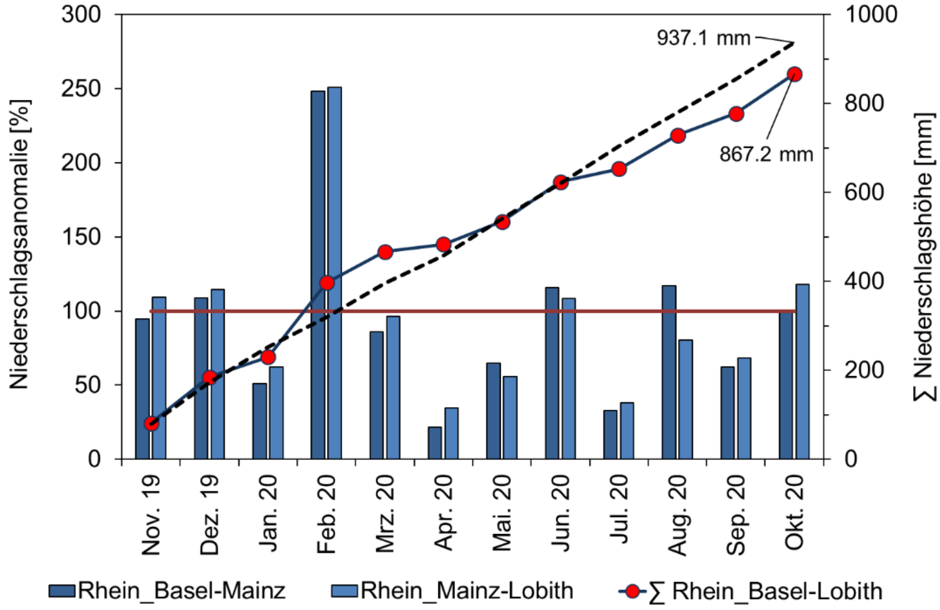

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Figure 6: Relative monthly anomalies (blue bars) of the area's precipitation for the hydrological year 2020 in the Rhine basin, for sub-basins Upper Rhine (Basel to Mainz including Main) and Middle and Lower Rhine (Mainz to Lobith), against the background of the multi-year averages for the reference years: 1981 to 2010 (purple horizontal line). Plotted in black, the summed-up monthly precipitation levels for the Rhine area from Basel to Lobith (∑) for the hydrological year 2020, in comparison to the cumulative line for the years 1981 to 2010 (dashed line) (data source: DWD and weather services of neighbouring countries)

In contrast to February 2020, which was dominated by wet westerly weather conditions, the months of January, April, May, July and, to a lesser extent, September, proved to have very little precipitation and plenty of sunshine due to the prevailing high-pressure zones. The remaining months were only slightly above, or below, the long-term average values. In the winter, spring and autumn months of the two sub-catchment areas, the southern area was somewhat drier, while dry conditions prevailed in the summer months of June and July in the northern sub-area. If one looks at both areas together, despite the extremely humid February, a precipitation deficit of 70 mm for the hydrological year 2020 is revealed; this is 7.5% less than the long-term average. In the course of 2020, the cumulative line of the accumulated monthly volumes of precipitation, from July to October, was below that of the long-term monthly average (see Figure 7).

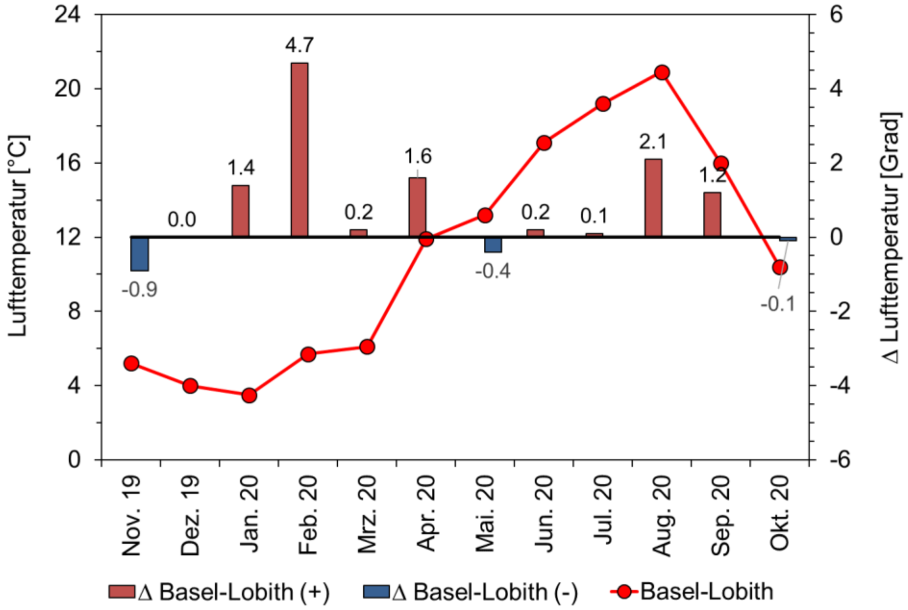

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Figure 7: Monthly averages and monthly anomalies in the air temperature for the Rhine sub-catchment area from Basel to Lobith, for the hydrological year 2020. The anomalies (Δ air temperature, right ordinate) relate to the multi-year period 1981 to 2010 (data source: DWD and neighbouring countries' weather services)

The average temperature across Germany in February 2020 was 4.4 degrees above the long-term average. It was the second warmest February since records began in 188. Also for the area average of the Rhine basin, for the sub-catchment between Basel and Lobith (see Figure 7), the temperature deviation of 5.7 ° C was 4.7 degrees, considerably higher than the average for the period 1981 to 2020. Only November, May and October were slightly cooler than the long-term, multi-year average. While December 2019 was still of average temperature, the remaining months were 0.1 degrees (July) to 2.1 degrees (August) warmer. August 2020 was the second warmest in Germany, after 2003. April 2020 should also be highlighted at this point; it was not only 1.6 degrees warmer than the long-term reference value but was also the sunniest April since records began in Germany in 1951. This was the third driest April in Germany, after 1893 and 2007. Overall, the hydrological year 2020 at 10.3 ° C, was 0.8 degrees warmer than the long-term average.

The Netherlands, Source: Koninklijk Nederlands Meteorologisch Instituut (KNMI) (Royal Dutch Meteorological Institute)
Together with 2014, 2020 was the warmest year since measurements began in 1901. The average annual temperature at De Bilt station was 11.7 ◦C. 2020 was the seventh warm year in a row. The picture that emerges fits with the trend of an overall warming climate.
The 37.0 ◦C, recorded at the Arcen station in the south of the country, was the highest temperature of the year and was recorded on August 8th. Only July was cool, which is remarkable, as it was a very warm summer. May was normal, but in all other months, the average temperature was (significantly) above the long-term average (Fig. 8).

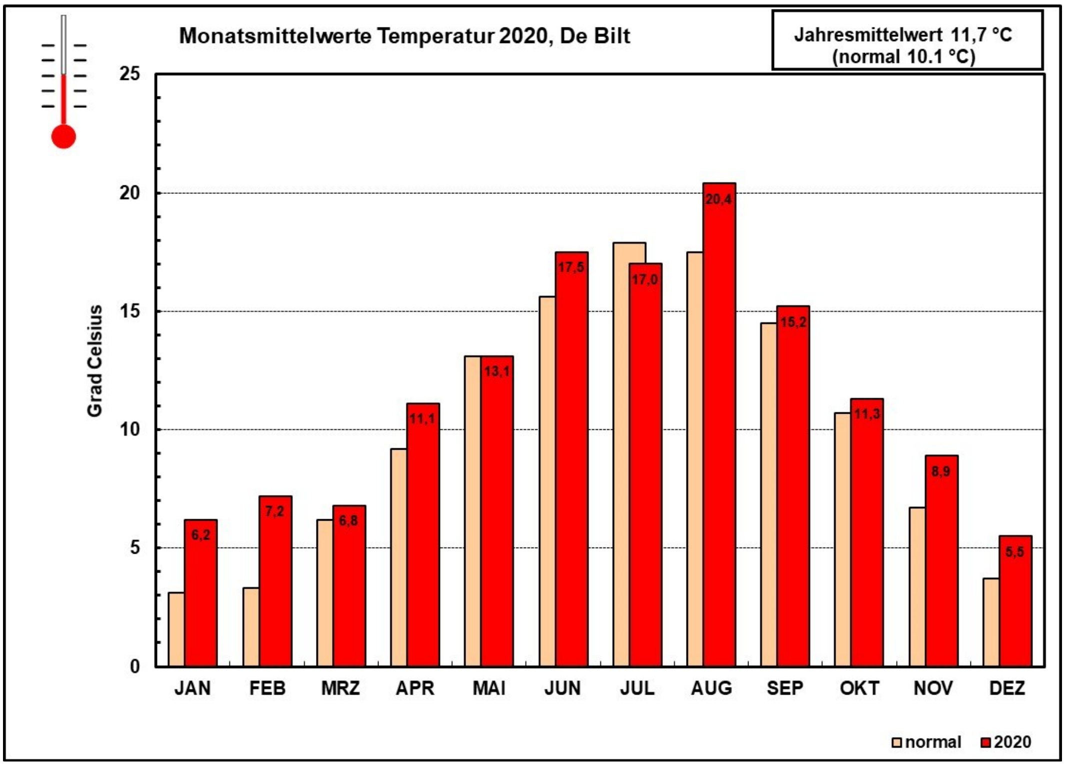


Figure 8: Monthly average temperature values at the De Bilt station in 2020, compared to the multi-year (1981-2010) average value (source: KNMI)

With 2026 hours of sunshine, 2020 was very sunny once again. The long-term average is 1639 hours; 2020 was the third sunniest year since observations began. The winter months had too little sun and October was very dark. July and December had almost the normal amount of sunshine. The other months were very sunny.

With an average of 856mm of precipitation at De Bilt station, 2020 was drier than normal. The long-term average is 887 millimeters. 2020 was again very dry in many places in the east and south-east, following the abnormally dry years of 2018 and 2019. 2020 was pretty wet on the west coast. In the east and south, the drought had not ended in all locales by the end of September. At the end of September there was a precipitation deficit (evaporation minus precipitation in the period April to September) of more than 300 mm in many locales in the south and south-east. In summer, showers (thunderstorms) sometimes caused problems.

There was practically no snow to be seen in 2020. Wet snow fell in West Brabant on February 26th and 27th. On December 29th, wet snow fell in the northeast, which remained on the ground for a while.

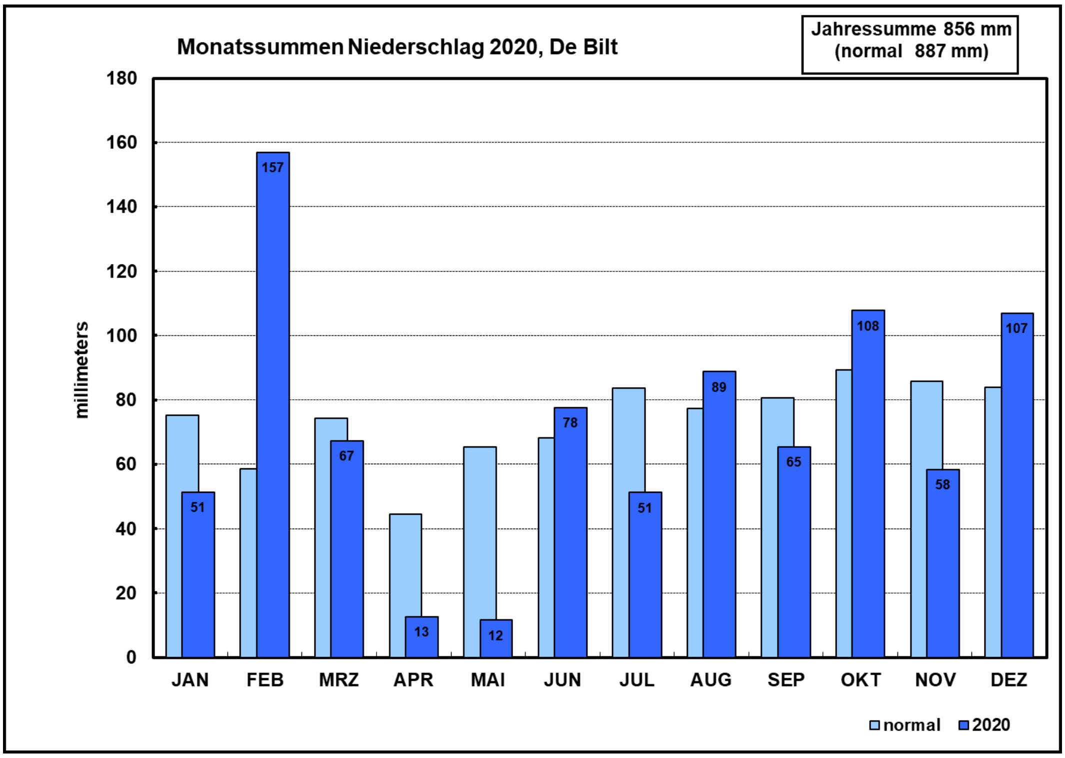


Figure 9: Monthly sums of precipitation at the De Bilt station in 2020 compared to the multi-year (1981-2010) average value (source: KNMI)

Snow and Glaciers

Snow

Source: WSL Institute for Snow and Avalanche Research SLF

October 2019 was very warm and brought abundant precipitation. The high snowfall line meant that snow fell only in the high-altitude mountains. November was very overcast in the south. With high quantities of precipitation and the falling snow line, a record-high amount of new snow fell on the southern slopes of the Alps in November. December was warm and humid. There was abundant precipitation in western Switzerland in the Alps, especially on the southern slopes of the Alps. At the end of the year, 80 to 120 cm of snow was widespread in the Alps at an altitude of 2000 meters. In the south and in some areas in the west there was up to 200 cm of snow.

January 2020 was very low in precipitation and warm throughout Switzerland. At the end of the month, the weather in Switzerland was determined by low pressure. Within two days, 40 to 70 cm of snow fell, above a height of 1400 m, in Lower Valais, in the Gotthard region, and on the eastern side of the Alpine Northern slope, up to 100 cm of snow.

February also remained dry on the southern slopes of the Alps. For several weeks the weather was determined by south-westerly circulation. Cold air thrusts, on the other hand, were almost non-existent. At the end of February, it snowed repeatedly, and at times intensely. in a period of three days, more than 50 cm of snow fell in the west and in the north. Over the whole month, the snow depths were only above average in Valais compared to the long-term average.

Snowfalls, some intense, at the beginning of March were accompanied by storm-level winds. Along the southern slopes of the Alps, it snowed right down to low altitudes. In Ticino, this ended a dry period of 70 consecutive days. From March 21st, the temperature dropped significantly on both sides of the Alps. At the end of March, widespread snowfall occurred once again. Most of the snow fell at 20 to 40 cm on the central part of the southern Alpine slopes, in the Rhine Forest area, and in Bergell.

April brought a lot of sunny days and early summer warmth. At the end of the month, extensive precipitation occurred again for the first time, at times it showed up to moderate levels. When taking the entire month into account, a large precipitation deficit was measured. Due to the warmth, snow melted rapidly. At the end of April, many measuring stations were maxed out, up to 2000 meters. Even at high altitudes, the snow depths were significantly lower than usual for this time of the year.

May was mild. Nevertheless, repeated snowfalls in the higher-altitude mountains occasionally created winter conditions. At the beginning of the month, there was widespread snowfall, mainly in the north and the west. The second half of May started off with precipitation. Most of the snow fell in the Bergell and Bernina regions. Following this period, it warmed up to summer conditions for several days and the zero-degree limit rose to over 4000 m.

Glaciers

Source: Department of Geosciences at the University of Freiburg and Research Institute for Hydraulic Engineering, Hydrology and Glaciology (VAW) at ETH Zurich

In the past decade, glacier melt has been stronger than ever since observations began. The loss continued relentlessly in 2020, but thanks to a slightly milder summer it was not equally dramatic in the whole of Switzerland. At the beginning of May, the snow on the glaciers corresponded to the average of the last ten years. However, the melting of the glacier tongues began early on and reached very high levels. In September 2020, the lowest snow depth since measurements began 100 years ago, was measured in the Nähr area of the Great Aletsch Glacier near the Jungfraujoch. Compared to the years 2017 to 2019, however, the state of most glaciers was a little less serious. Nevertheless, in the hydrological year 2019/20 almost 2% of the total glacier volume was lost across Switzerland. This negative trend continues.

Clear differences in losses were measured in the volumes of winter snow and melt across 20+ glaciers in all parts of the country. While low-lying, flat glaciers (e.g. Glacier de Tsanfleuron (VS)) recorded an average reduction in ice thickness of 2 meters, glaciers in the high elevations of southern Valais, as well as in Ticino and Engadin (e.g. Findel Glacier or Ghiacciaio del Basòdino) only lost around 0.5 Meters in thickness. This is due to a large volume of snowfall in early winter, as well as the positive effect of summer snowfalls. Since 1960, Swiss glaciers have lost so much water, that Lake Constance could be filled with the melt-water. This has changed the landscape in the Alps significantly: Glacier aprons are expanding and new mountain lakes are forming. Small, individual glaciers (e.g. Vadret dal Corvatsch (GR)) had to be removed from the monitoring network due to their complete disintegration. Glacier retreat also creates dangers, which has been effectively demonstrated with events such as the ice break on the Turtmann Glacier (VS) and the emptying of the glacial lake on the Plaine Morte (BE).

Hydrological Status of the Rhine Region in 2020

Water levels in the Large Lakes in The Rhine's Catchment Area.

Austria

From the beginning of the year until 8 April, the water level of Lake Constance was above the long-term average for the years 1864 - 2018 for the respective calendar days. Subsequently, the below-average precipitation in the first half of the year resulted in below-average water levels until the end of August. The highest annual water level was 404 cm and was measured on 3 July. Floods at the end of August on the Alpine Rhine led to above-average water levels from the 1st to the 13th of September. After a period with below-average water levels up until September 28, a subsequent period with above-average water levels followed and lasted up until the end of the year (see Figure 10). The annual average for the Bregenz water level is 347 cm, which was almost exactly the same as the long-term annual average (345 cm).

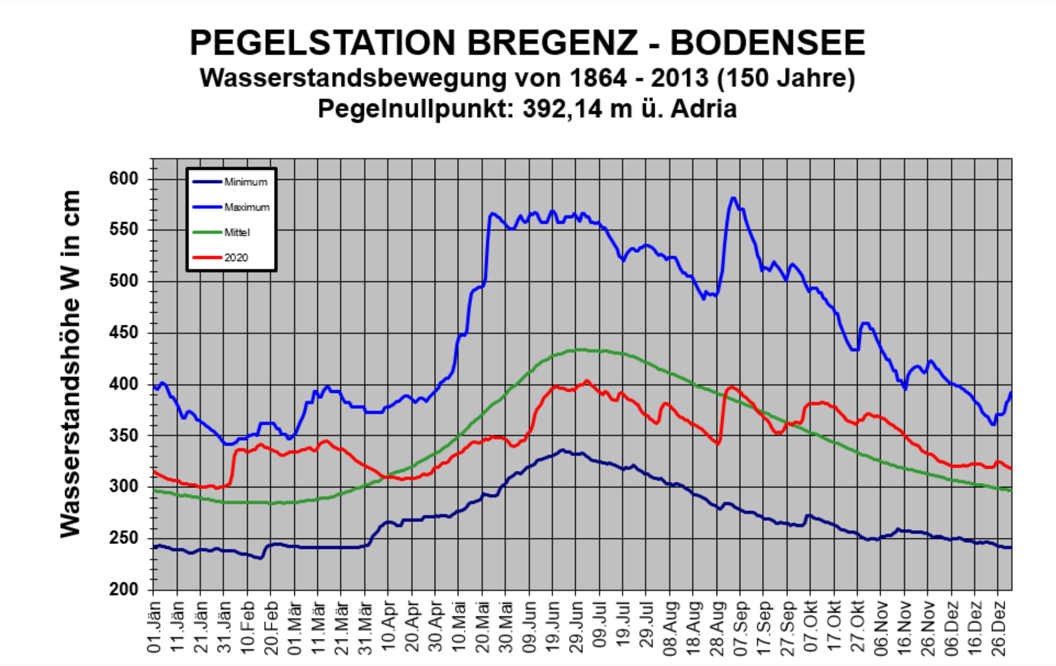


Figure 10: Hydrograph of the water level of Lake Constance at the Bregenz gauge in 2020 (red curve) in comparison with long-term (multi-year) minima, maxima and average values

Switzerland

Most of the average annual water level values in the Great Lakes in 2020 correspond to the respective long-term average values, or merely a few centimetres lower. There are exceptions, however: the largest negative deviations from the norm were recorded at Walensee, with a -8 cm level, and the Zugersee and Thunersee with -5 cm level. The Lake Constance (Obersee) level was once again well above the norm, at +12 cm. The reasons for the low average annual value at Lake Thun are discussed later in this paragraph.

Measured water levels in monthly and daily resolution shows a very different picture compared to annual data. The unregulated Lake Constance clearly shows the consequences of the mild winter, the warm but stormy February, the spring with low precipitation, and the hot summer: in February and March the level was well above the long-term average, from May to August it was clearly below that. With the heavy precipitation at the end of August, a phase with above-average water levels commenced, which lasted until the end of the year. At Lake Neuchâtel, levels fluctuated within the usual narrow range. The difference between minimum and maximum water levels in 2020 is less than half a meter. The corresponding difference for Lake Constance is around twice as much, and at Lake Maggiore more than six times as much. In addition to the water level fluctuation for Lake Maggiore, the dynamism of these levels is also noteworthy. Rapid increases in water levels are not uncommon for this lake. During the floods in October, Danger Level 2 was recorded on seven separate days. At Lake Lugano, two periods saw the water levels at Danger Level 2: this was the case on six days at the beginning of June, and on five days at the beginning of October.

The water levels of Lake Geneva continued to show a characteristic flow pattern in 2020 with a continuous, steep drop in the water levels up until March, flattening out in March and April, a steep rise up until the beginning of June, with a constant level until the end of the year. Compared with the long-term averages, however, the low during March and April 2020 was significantly lower, and the level increase in the second half of the year occurred somewhat later. A pair of ducks was partly responsible for the delayed ascent (see below).

With the exception of Lake Constance and Lake Walen, all of the Great Lakes of Switzerland are regulated. In addition to the flow regime of the lakes' inflows and short-term weather conditions, other factors also influence the regulation of the lakes. Here are two examples from 2020:

1. The water level in Lake Thun was particularly low between the 20th of January and the 20th of February. The reason for this was that regulation services for the Office for Water and Waste, Canton of Bern, had made an agenda decision for an extraordinary lowering of the water. In favourable weather conditions, a very low lake level of 557.00 m.ü.M is maintained every four years at this time of year. This makes it possible to carry out construction projects along the banks. The lowering of the levels takes place alternately at the two large Upper Bernese lakes. The Lake Brienz level will be lowered again in 2022.
2. The irregularity of the water level on Lake Geneva had a completely different cause: Bulletin 293 of the Ornithological Information Service of the Swiss Ornithological Observatory in Sempach reported an breeding record of eider ducks on Lake Geneva. A breeding duck was discovered in mid-May and the chicks appeared on the 5th of June. In collaboration with the Office for Aquatic Ecology of the Canton of Geneva, regulation of the lake level was adjusted so that the level did not rise in the usual way for this time of the year. This prevented the nest from being flooded.

Water levels and discharges

Austria

The discharge of the Alpine Rhine in 2020 was 3% above the long-term average. The two largest Lake Constance feeders from Austria, Bregenzerach and Dornbirnerach, recorded an annual discharge that was slightly below average. The average annual discharge as compared to the long-term average:

- on the Bregenzerach: 91% (MQ 2020 = 42.5 m^3 / s, long-term MQ = 46.6 m^3 / s, for the years 1951-2019);
- on the Dornbirnerach: 94% (MQ 2020 = 6.64 m^3 / s, long-term MQ = 7.05 m^3 / s, for the years 1984-2019);
- 103% on the Alpine Rhine (MQ 2020 = 238 m^3 / s, long-term MQ = 231 m^3 / s, for the years 1951-2019).

Switzerland

The average annual discharges of the large river basins in 2020 - compared to the norm: 1981-2010 - was in a similar range as in 2019. The range in 2020 was -40% to +5%, however, much lower than in the previous year (-25% to + 20%). Significantly below-average discharges were observed in the north and north-west of Switzerland. On the Birs the discharge was only 61% and on the Doubs, it was 66%. Annual discharges between 80% and 90% were recorded at the Aare near Brugg, the Limmat, the Thur and the Maggia. Discharges between 90% and 105% were measured at the Reuss, at the Rhine near Diepoldsau, at the Inn, at the Ticino and at the Rhone. The Aare, near Brugg, was once again well below the long-term average. No other river basin showed such a marked long-term downward trend in annual discharge over the past 30 to 40 years.

Three medium-sized catchment areas show significantly more runoff than in the norm period. They are located in the Valais and the Engadine. The areas with normal (90% to 110%) or slightly lower discharge (85% to 90%), are located south of a line that extends from Lake Geneva, over the Pre-Alps, to eastern Switzerland. To the northwest of this line, the annual discharge does not go over 90% of the norm. Most of the medium-sized areas in the Central Plateau actually remain below 80%. The greatest discharges, with values below 70% of the norm, were observed in the central plateau and northern Switzerland, between the Suhre and Ergolz rivers. The Allaine recorded the lowest annual average at Boncourt, a new record.

A pattern that can be seen in many catchment areas on the north side of the Alps shows values that were well above average for February, relatively low values for April to July, and again well above average for October. The high discharge in February is the result of the mildly humid west and north-west air currents, that brought widespread above-average rainfalls. The heavy precipitation at the beginning of October was so high, that the effects can be clearly seen, even in the monthly values. Many medium-sized catchments have seen discharges that are 30% to 60% above normal. On the Vorderrhein and Hinterrhein, they even exceeded the long-term average monthly values by 80 to 90%.

In contrast to the north side of the Alps, February showed above-average discharge rates in the Rhone basin; however, so did January, March and April, which were markedly too wet. This also applies to the Poschiavo and the Münstertal. The discharge of the Rhone at Porte du Scex in January was a good 50% above the norm; in April it was almost 30% (above the norm). Since January and February were already markedly low in precipitation in southern Switzerland, the monthly values in many places remained below the long-term average from the beginning of the year up until July. On the Maggia near Locarno, discharges never reached more than 65% of the norm from March to July; in April and July, they were only at around 30%. In August and October - the two months with the largest flood events in 2020 - the monthly averages were more than twice as high as in the reference period.

In the southeast of Switzerland, in the Münstertal, all monthly values - with the exception of June and July - were above the corresponding long-term average values. In addition to the major supra-regional flood events in August and October, there was a notable event in Ticino at the beginning of June. The catchment areas around Lake Lugano were particularly affected. The reasons for the high levels were explained in the MeteoSwiss Climate Bulletin: “A first cold front from the west brought precipitation across Switzerland on June 4th. The cold front remained almost stationary over Switzerland in between, which means that 80 mm of rain accumulated over the day in some places in Ticino. Another cold front brought abundant rainfall on the northern side of the Alps on June 7th. On the southern side of the Alps, thunderstorms caused daily precipitation of well over 100 mm at several measuring stations. At the Ponte Tresa measuring station, 172 mm was measured. Due to this rainfall, Tresa, near Ponte Tresa, recorded around 50% more discharge than normal in June, and in the Magliasina near Magliaso, more than double the usual montly discharge for June occurred. The Magliasina and the Cassarate near Pregassona measured a new June maximum during the flood event in early June. The annuality of the peak discharge of the Magliasina was 30 to 50 years.

During the year new highs or lows for individual months in other catchment areas were recorded: February maxima at just under 10 stations in the Alps; April minima at around 10 stations in northwestern Switzerland, the central midlands and the Thur region; June minima at the Aare (Bernese Oberland), Limmat and Murg near Frauenfeld; October maxima at around 20 stations, mainly in Ticino, the Upper Valais, the Reuss and Graubünden.

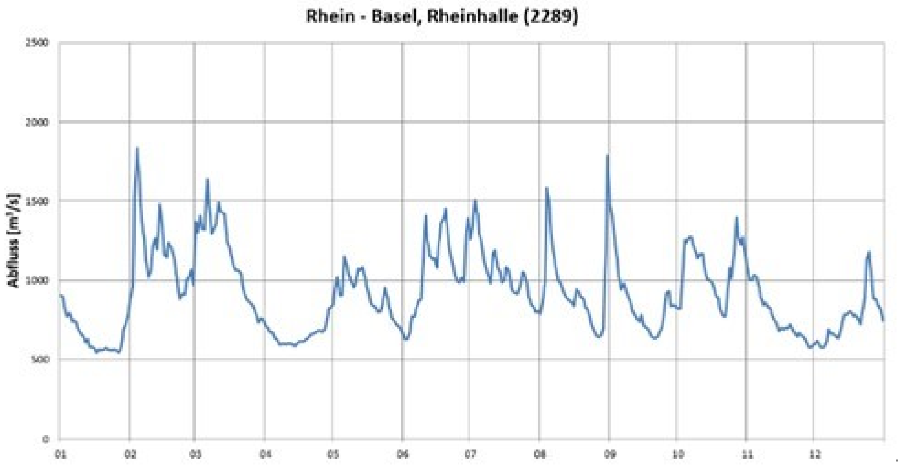


Figure 11: Discharge hydrograph at the Rhine gauge - Basel, Rheinhalle in 2020

Germany

In view of the general weather conditions, the water supply of the Rhine remained below average in the hydrological year 2020. This was mainly due to the low-discharge summer half-year, whereas the winter half-year average to slightly above-average discharges were recorded, mainly due to the high discharge months of February and March. Table 2 shows this in numbers based on the representative gauges Maxau, Kaub and Duisburg-Ruhrort.

Table 2: Year-round and average seasonal discharge values for the hydrological year 2020 compared to the long-term reference values for the period: 1961 to 2020, at the Maxau / Upper Rhine, Kaub / Middle Rhine and Duisburg-Ruhrort / Lower Rhine gauges (data: WSV)

hydrologische Jahre	MQ(1961/2020)	MQ(2020)		SoMQ(1961/2020)	SoMQ(2020)		WiMQ(1961/2020)	WiMQ(2020)	
	[m³/s]	[m³/s]	Verhältnis zum MQ(1961/2020 [%]	[m³/s]	[m³/s]	SoMQ(1961/2020 [%]	[m³/s]	[m³/s]	WiMQ(1961/2020 [%]
Maxau	1260	1100	87	1350	1030	76	1170	1180	101
Kaub	1690	1470	87	1640	1210	74	1740	1720	99
Duisburg-Ruhrort	2260	2010	89	1970	1390	71	2550	2640	104

As can be seen from Figures 12, 13 and 14, the multi-year daily and annual comparative values were mostly undershot throughout the discharge course of the hydrological year 2020. This was already the case in the winter months (with exceptions, especially in February) and then almost universally in the warm season from the second half of March onwards. What is striking here is a south-north gradient, i.e. the flow of the Upper Rhine (Maxau gauge) with its catchment area characterized by hills and high mountains, repeatedly benefited from precipitation events in the summer. These were less significant towards the Middle and Lower Rhine, or were completely absent; this caused more pronounced low-water conditions, which developed in the downstream part below the mouth of the river Main (cf. especially Figure 5 with the hydrographical analysis of the Lower Rhine level at the Duisburg-Ruhrort gauge).

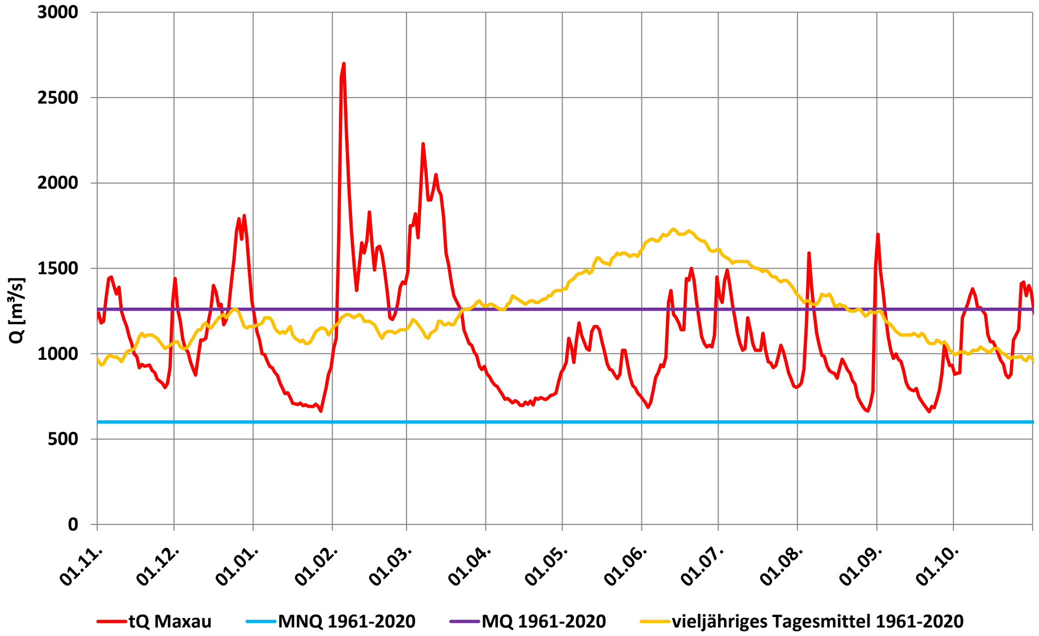


Figure 12: Daily discharges (tQ) at the Upper Rhine, Maxau gauge, in the hydrological year 2020 against the background of the multi-year daily averages as well as the MNQ and MQ values of the reference period 1961 to 2020

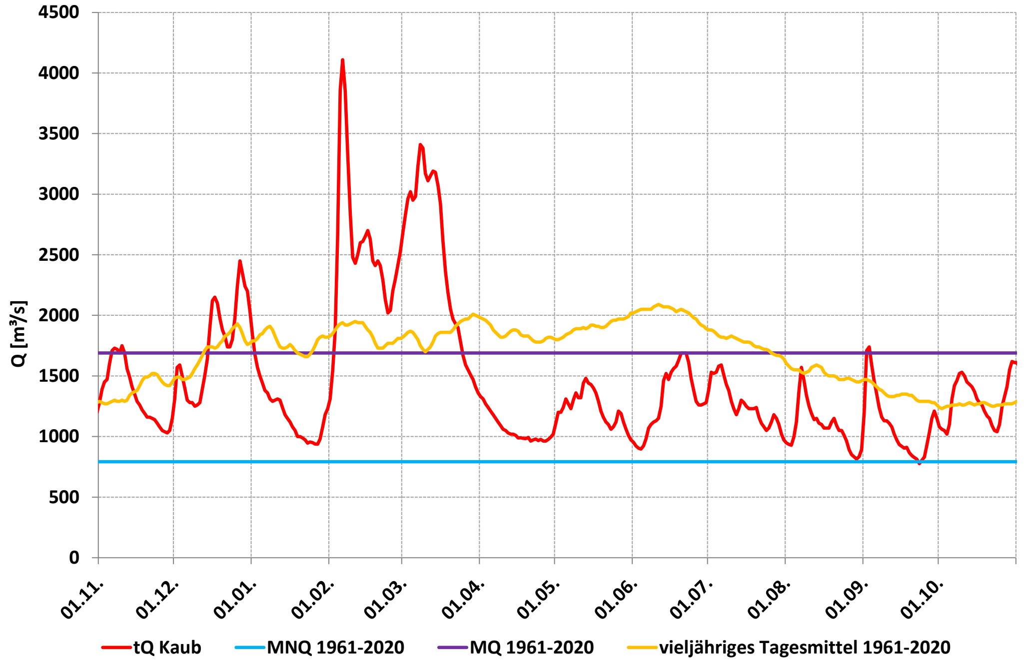


Figure 13: Daily discharges (tQ) at the Middle Rhine, Kaub gauge, in the hydrological year 2020 against the background of the multi-year daily averages as well as the MNQ and MQ values of the reference period 1961 to 2020

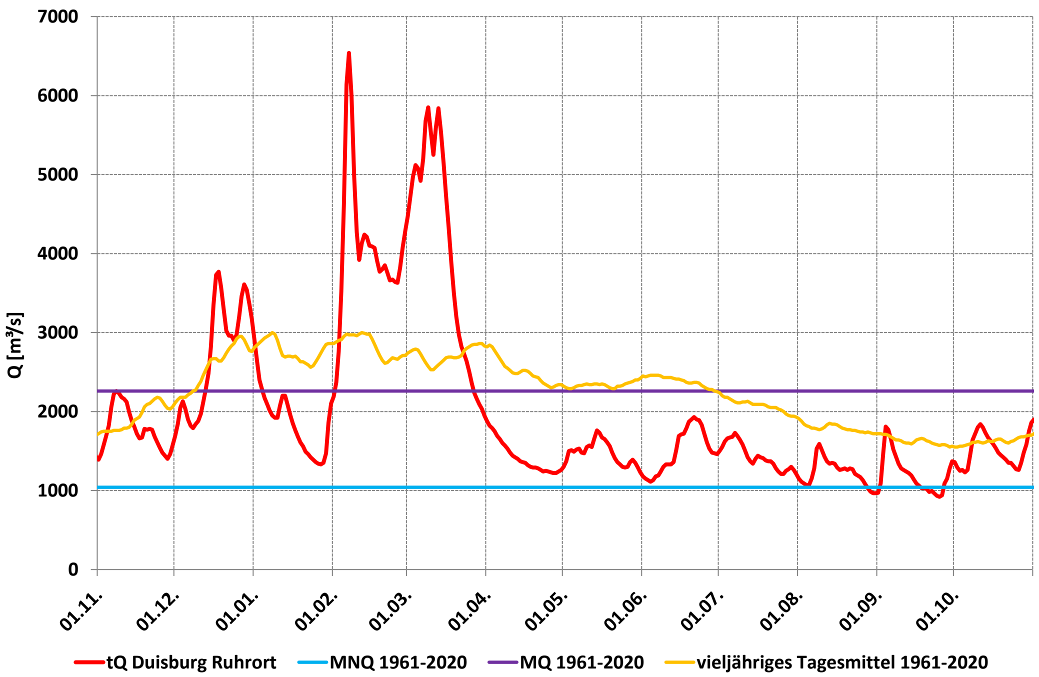


Figure 14: Daily discharges (tQ) at the Lower Rhine, Duisburg-Ruhrort gauge, in the hydrological year 2020 against the background of the multi-year daily averages as well as the MNQ and MQ values of the reference period 1961 to 2020

Table 3, with an overview of the main and extreme hydrological values recorded along the Rhine in 2020, shows that the peak discharges that occurred in the first week of February in the Upper and Middle Rhine, remained below the long-term HQ average. Only in the Lower Rhine (Duisburg-Ruhrort gauge) the MHQ level was pretty much achieved. The discharge peaks in 2020 represent insignificant flood events in a long-term comparison.

Table 3: Average and extreme values for the discharge of the hydrological year 2020 compared to the long-term reference values for the period 1961 to 2020 at the gauges Maxau / Upper Rhine, Kaub / Middle Rhine and Duisburg-Ruhrort / Lower Rhine (data: WSV)

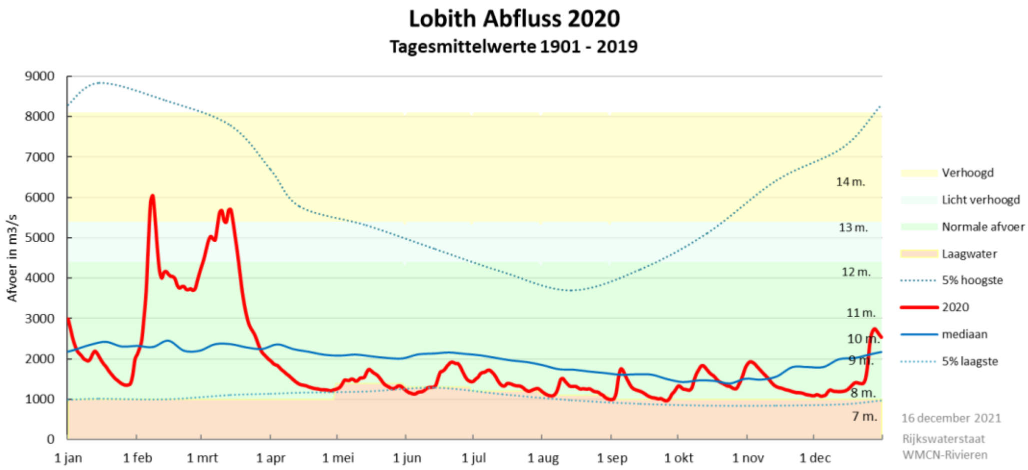
hydrologische Jahre	MQ(1961/2020) [m³/s]	MQ(2020) [m³/s]	MNQ(1961/2020) [m³/s]	NQ(2020) [m³/s]	Datum	NM7Q(2020) [m³/s]	Datum	MHQ(1961/2020) [m³/s]	HQ(2020) [m³/s]	Datum
Maxau	1260	1100	600	660	21.09.2020	691	21.01.2020	3240	2800	04.02.2020
Kaub	1690	1470	792	777	23.09.2020	823	19.09.2020	4330	4140	06.02.2020
Duisburg-Ruhrort	2260	2010	1040	920	25.09.2020	965	20.09.2020	6640	6670	07.02.2020

In relation to low water levels, the lowest flow rates occurred in the Upper Rhine in January and September; between the mouth of the Main and the German-Dutch border, this was uniformly the case in September. In principle, this corresponds to the normal annual discharge pattern of the Rhine in its various sections. The MNQ1961 / 2020 in the Upper Rhine, in contrast to the Middle and Lower Rhine, was not undercut. NM7Q recorded in 2020 uniformly reached levels in the German course of the Rhine, which are anticipated approximately every two years over a multi-year average.

The Netherlands

In 2020, the Rhine water levels and discharges were characterized by two short high water periods. The first high water period took place between February 6th and 10th. This so called runoff peak developed very quickly. In January, the water levels continued to fall, and towards the end of January water levels of 8.00 m + NAP were measured at the Lobith gauge. Water levels of 8.00 m + NAP fall into the 10% lowest levels for this period compared to other years. From this low starting point, the water level rose rapidly, and on February 7th exceeded 13.00 m at the Lobith gauge and reached a high of 13.63 m on February 8th.

The second high water period followed a short time later. From March 9, the water level of 13.00 m + NAP was exceeded again in Lobith, reaching a high of 13.24 m + NAP on March 14. From March 14, the water level sank sharply to below 9.00 m + NAP and did not exceed this value again until mid-December.



Hydrograph of the daily average discharge at Lobith gauging station in 2020 (red curve) compared with the long-term, multi-year minima, maxima and average values for the years 1901-2019.

Water Temperatures

Austria

The average annual water temperature of Lake Constance at the Bregenz Harbour gauge was 13.4 ° C, 1.3 ° C above the long-term average of 12.1 ° C. With a few exceptions, which were caused by the snowmelt in the high mountains and phases of cold weather, the daily averages for 2020 were above the daily averages for the long-term measurements: 1976-2019. (see Figure 16).

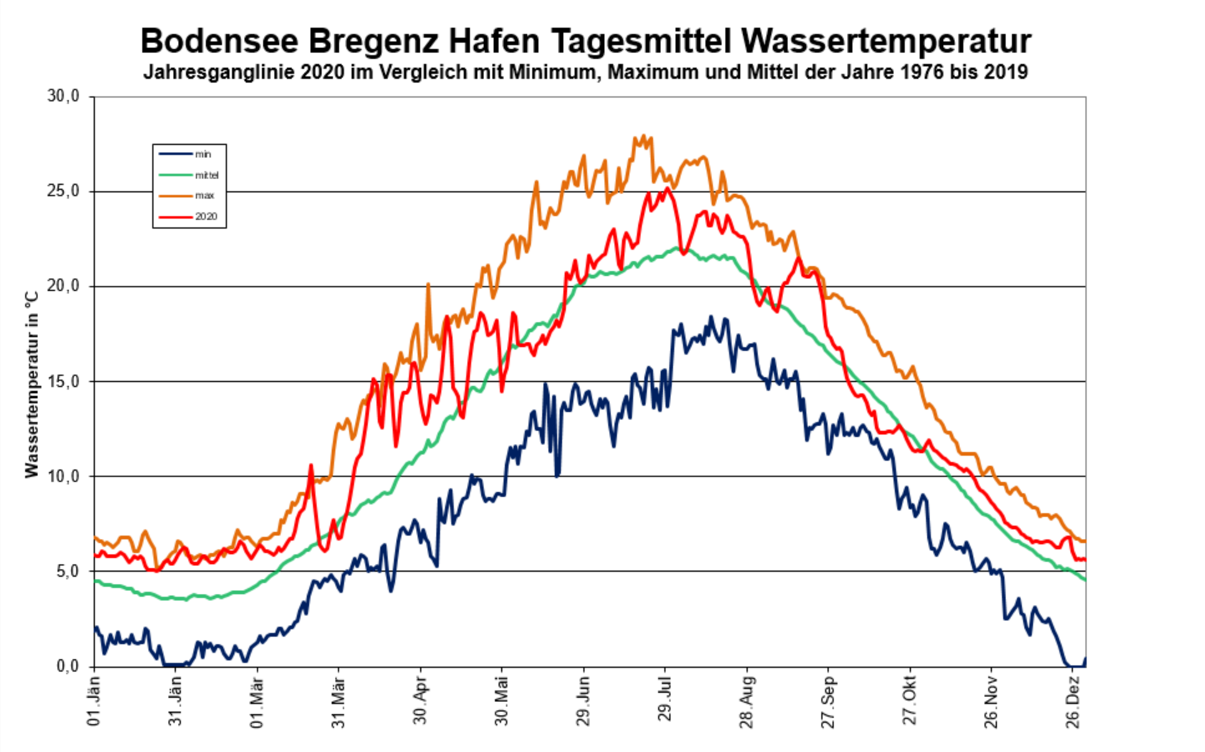


Figure 16: Water temperature of Lake Constance at the Bregenz gauge in 2020 (red curve) in comparison with long-term, multi-year minima, maxima and average values for the years 1976-2019.

Switzerland

In terms of air temperatures, 2020 was as warm as the last record year 2018. High air temperatures were measured mainly in the Alps and the Jura mountains. This was also evident in the average annual values of the water temperatures in the rivers: occasionally new maxima were recorded, especially along the Jura Arc and in the Alpine region. In contrast to 2019, when no new highs occurred anywhere, the trend of warming rivers continued somewhat more slowly in 2020 than in 2018.

In terms of seasonal trends, 2020 was characterized by the mildest winter to date, with high air temperatures and a great deal of winter sun. While new monthly lows for water temperatures were recorded in some places in January, from the Alpine region to Lake Constance, an unusually high number of new highs for the month of February at the FOEN's (Federal Office for the Environment) measuring stations, towards the end of winter, were recorded. New monthly minima and maxima were also measured in the same month at a few stations in the Alpine region. This was due to the strong fluctuations in water temperature.

Although spring 2020 was the third warmest spring since measurements began, and it was extremely sunny in the region, with persistent drought conditions, especially in April, this did not have any excessive effects on the extreme values of the water temperatures. Likewise, the moderate heat waves in summer did not have a significant impact on the monthly values across Switzerland. There were only a few new monthly maxima in the three summer months - especially in the Alps.

Due to the unstable autumn weather, with mild and sunny conditions at the outset, new monthly water temperature highs and lows were recorded at individual measuring stations in

September. In October, during which high levels of precipitation were recorded, the water temperature did not exceed the previous monthly maximums at any locations, nor did it fall below any previous minimum values. It was not until November that new monthly highs were recorded, with the water temperatures in the Alpine and Lake Constance regions.

In December, at the beginning of winter, the snowfall throughout Switzerland did not have a significant effect on water temperatures. The only location where the previous monthly lows were not reached was in the east of the country, in a few isolated cases.

The Netherlands

At the Lobith gauge, the average water temperature of 14.2 ° C was around 1 ° C above the annual average, calculated over many years (1961-2020) (see Figure 17). In terms of the highest average water temperatures, 2020 was in 7th place (measurement years: 1908-2020).

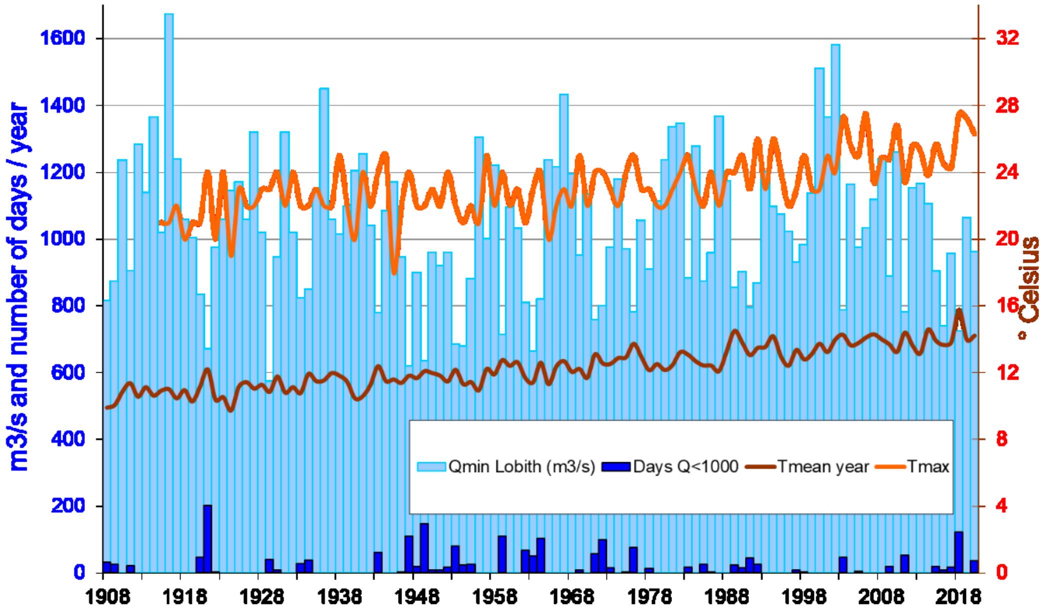


Figure 17: Average and maximum water temperatures 1908-2020 at the Lobith/Rhine gauge

Groundwater

Austria

At the beginning of 2020, the groundwater levels were above average. With the melting of the snow, the highest groundwater levels of the year were reached in some areas in March. Other areas reached the highest groundwater levels in September, as a result of the heavy rainfalls in August.

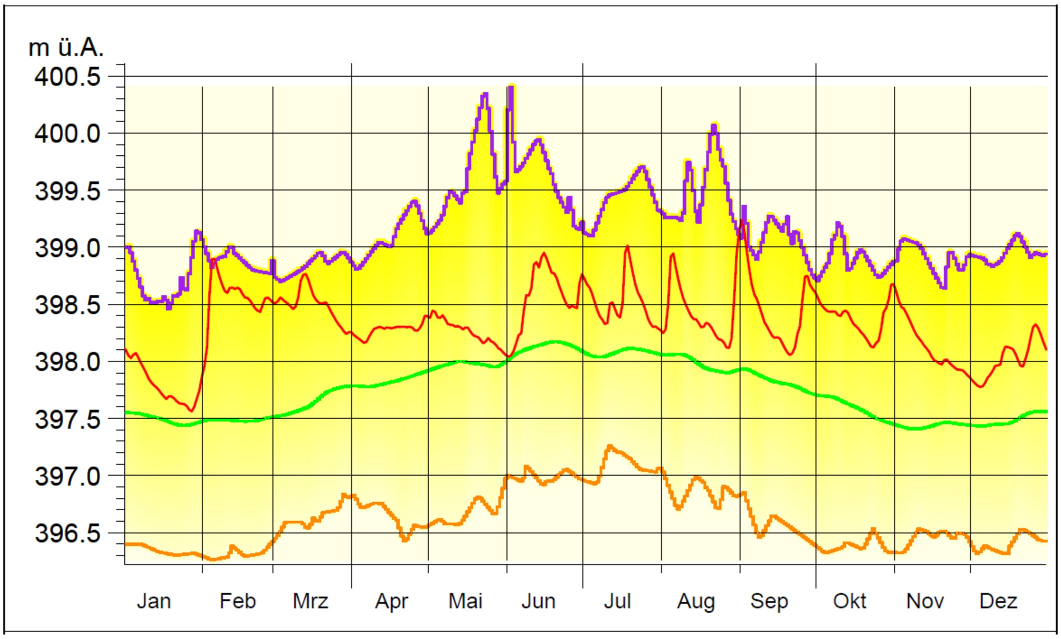


Figure 18: Hydrographs of the groundwater level in 2020 compared with long-term minimum, maximum and average values (1964 - 2019) Bregenz monitoring station Bl 50.1.09B

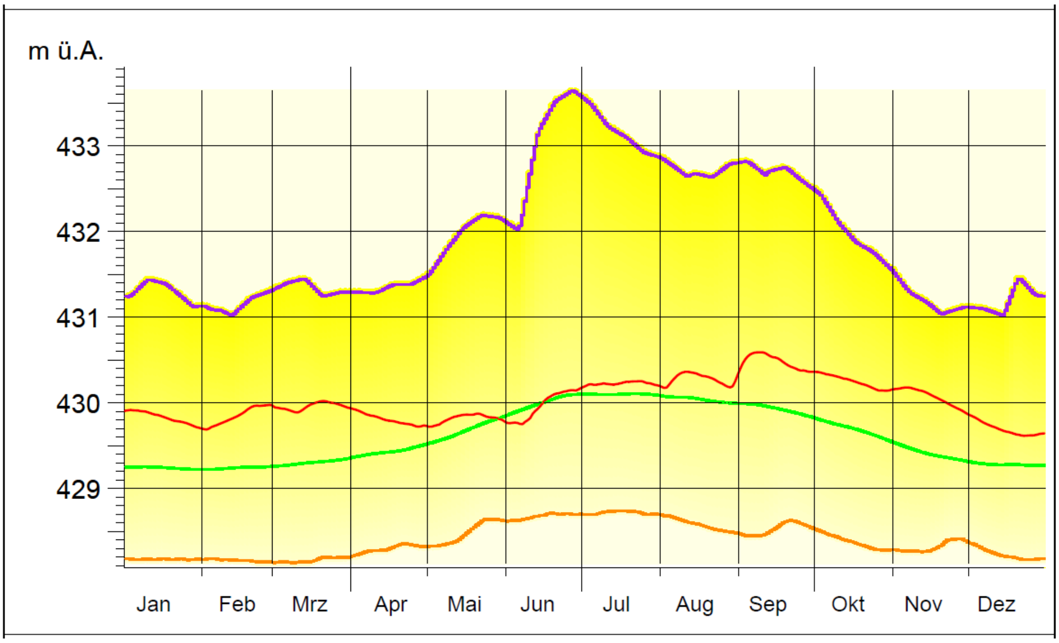


Figure 19: Hydrographs of the groundwater level in 2020 compared with long-term minimum, maximum and average values (1962 - 2019) Feldkirch-Altenstadt measuring station, Bl 01.32.01 A.

Switzerland
Corresponding to the multi-year weather pattern (temperature and precipitation), longer periods with a rather low or rather high quantitative condition of the groundwater conditions can often be identified in the groundwater in Switzerland. In this regard, 2019 falls within a period that has lasted since 2015, which provides a multi-year comparison for low groundwater levels and spring discharges. As a result of heavy precipitation, high levels were recorded, during this limited period, at around every second measuring point in October.

At the beginning of 2020, normal groundwater levels and spring discharges were widely evident. The above-average precipitation in February resulted in high groundwater levels and spring discharges at around every third measuring point at the beginning of March. Below-average precipitation in April and May led to normal, and in some cases low, groundwater levels and spring discharges on the northern side of the Alps at the end of May. In the course of the continued below-average rainfall in June and July, low groundwater levels and spring discharges were widely recorded in the central and eastern plateau during this period. In the valleys and river plains of the Alps, on the other hand, groundwater levels remained in the usual (normal) range as a result of increased river water filtration caused by the melting snow and glaciers. From 28th to 30th August and from 2nd to 5th October there was intense precipitation on the southern side of the Alps and in the central Alps. As a result, the groundwater levels along the rivers and the spring discharges rose in particular. In October, for example, high groundwater levels and spring discharges were temporarily recorded at every second measuring point. November was exceptionally low in precipitation, so that by the end of the year normal groundwater levels and spring discharges were again widely recorded.

Suspended Solids

Austria
The annual load of suspended solids on the Alpine Rhine at the Lustenau measuring point in 2020 was around 2.2 million tonnes, within the average range of for the years: 2010 - 2019 (around 2.3 million tonnes). The highest monthly load was recorded for August at approx. 1.1 million t. This corresponds to 51% of the total annual load.

The lowest daily loads were recorded on 10 February, at around 60 t, the highest daily load was recorded on August 30 with a load of 532 580 t (24.4% of the annual load).

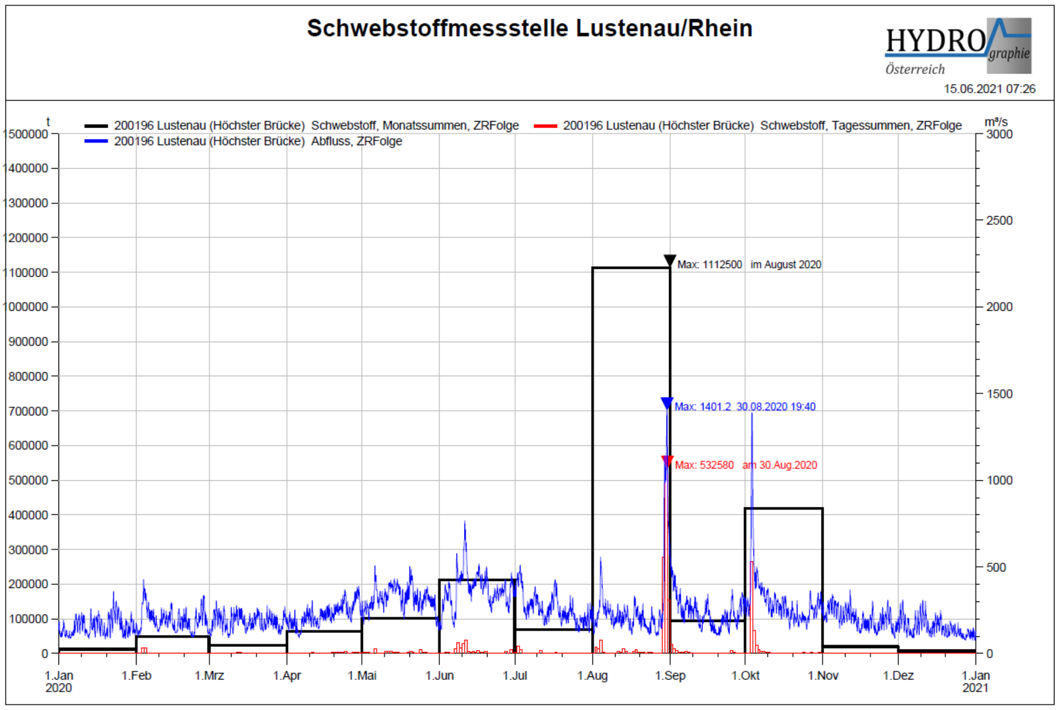


Figure 21: Monthly suspended sediment loads for the Alpine Rhine at the Lustenau gauge in 2020, with daily loads (red curve) and discharge hydrograph (blue curve).

2. The Activities of the International Commission for the Hydrology of the Rhine Basin (CHR) in 2020

The CHR met once in 2020. The spring meeting, which should have been held in Switzerland, was cancelled due to COVID-19 restrictions. The autumn meeting (No. 86) was organized online on September 24, 2020.

Personnel Changes within the CHR.
The position of Secretary of the CHR was transferred from Mr. Eric Sprokkereef to Mr. Roel Burgers (also Rijkswaterstaat) in spring 2020. Mr. Sprokkereef will continue to support and guide Mr. Burgers in the coming period. Mr. Carlo Scapozza has been Head of the Hydrology Department at FOEN since October 2019 and participated in a CHR meeting in September for the first time. On January 1, 2020, Mr. Marc Daniel Heintz took over the position of Managing Director of the ICPR from Ms. Anne Schulte-Wüllwer-Leidig. It was also the forst time that Mr. Heintz participated in a CHR meeting in September.

Current and Future Activities Within the Framework of CHR Projects
ASG-Rhein: the snow and glacier melt components of the streamflow of the River Rhine
The second phase of the ASG project started in 2018. The questions to be examined are:

- How will the total discharge in the Rhine and the contributions of rain, ice and snow melt change under climate change?
- What will happens when all the glaciers have melted?
- Are compensatory effects to be expected?
- Which discharge component is most sensitive to climate change?

Initial Results:
Averaged over 195 Swiss sub-catchment areas, 7% of discharge originates from glacier melts, 35% from snow melts and 57% from rain. By the end of the century, an overall decrease of about 9% in discharge is projected. The greatest decrease is within the ice volumes (ice component of precipitation). A 7.5% decrease in annual discharge has been calculated for the Rhine. Future changes in total discharge is still marginal, but large spatial and temporal changes for ice, snow and rain, in terms of discharge volumes, are to be expected. Spatial differences are linked to ice coverage and altitude. The shift in discharge proportions, when seen in the total discharge volumes, will lead to higher discharges in winter and lower ones in summer and autumn. The amount of snow in the total discharge shows the greatest spatial differences, and this aspect is certainly highly significant for the total discharge at high altitudes. In the glaciated areas, glacier melt has already reached its maximum rate, or will reach it in the next 20 years.

Socio-economic Influences on The Low-Water Regime of the Rhine
In an online meeting of the Steering Committee in September 2020, the upcoming project phases were discussed and some amendments were made to the project. The project will now focus on the development of a calculation tool that will be able to forecast, or compute, scenarios. A water balance must be created, taking the sub-catchment areas into account.
The project will try to collect new, as well as additional data, via communication with CHR members. An agreement was reached to form a working group with representatives from all member states.

Hydrological Memory of the Rhine
During the autumn 2018 session, the CHR expressed its interest in a project in which historical data is collected and made available. It was agreed that a preliminary study be carried out first. A concept plan was presented at the spring session of 2019. The BfG will award a contract to the University of Bonn for a 2-year project, which includes a post-doctoral study.

The preparation of the contract, on the part of the BfG, is delayed due to specification of services. It is expected that the awarding of the contract to the Geographical Institute (University of Bonn), under the direction of Prof. Herget, is to take place in January 2021.

Sediment
After the 84th meeting of the CHR in 2019, the CHR secretariat took the initiative, after approval from CHR members, and requested a quote/offer for the creation of a status report for the entire Rhine area, from the University of Natural Resources and Life Sciences (BOKU) in Vienna. BOKU will perform this work together with the Dutch consultant Blueland. The study is divided into 4 work stages. First of all, the relevant contact persons in the states bordering the Rhine should be identified with the help of a questionnaire. Then the data should be requested from the organizations via these contact persons. A literature review should also be carried out, where the results from previous studies will, of course, be utilized.

Climate Change
In the autumn meeting of the CHR, the project MOSARH21, https://webgr.inrae.fr/en/mosarh21/ was presented by Mr. Thirel (Inrae, France). The main aim of the project is to create future discharge forecasts for the French tributaries of the Rhine. The most important secondary goals were to create a robust protocol for hydrological models, quantification of uncertainties within the entire model chain, and comparison of the future predictions compiled by MOSARH 21, with the previous project results
.
The result of the study is that flood discharges will increase slightly to moderately in the near future. More extreme changes and effects are to be expected between 2071-2100. The expectations for low water development are forecast as low to moderate in the near future. In the more distant future results will again be contradictory; a significant decrease is forecast in the mostly pessimistic scenarios.

Mr. Thirel's presentation again highlighted an important task for the CHR, i.e. to continue to address the impacts of climate change on the hydrology of the Rhine, as well as to continue with the drafting of "Rhine View 2050", with respect to the management of extremes The three Rhine Commissions are open to intensified collaboration. Queries pertaining to any gaps in knowledge in the neighbouring countries should therefore be made in writing.

The CHR members consider further discussions on this topic necessary. Preparation of an overview document was agreed, to be discussed at the spring 2021 meeting, outlining this issue and including all data up to the current state of information.

Community of Practice Young River Professionals
The project management of the project “Youth for the Rhine” is now with UNESCO-IHE. A contract for the pilot project was signed and agreed upon between RWS and IHE. The CHR can make contributions.

CHR's Strategic Orientation
In 2020, work on the strategy document for the next ten years continued. The definitive strategy of the CHR is to be presented at the CHR conference. This is also the date for publication.

CHR Anniversary 2050
The work on creating the commemorative publication was stopped at the end of 2020 and will start again in 2021.
The CHR Secretariat will revise the conference program at the beginning of 2021.
The declarations of intent for collaboration between the member states and between the CHR and ICPR, CHR and CCNR, CHR and WMO, as well as CHR and UNESCO, are available and have been agreed.

Public Relations
A contract was awarded to redesign the CHR website. The redesign should be completed before the conference in 2021.

CHR Publications
The CHR published the Rhine Region's Hydrological Annual Report for 2019 in two languages.