

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



Annual Report of the KHR 2013

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Die 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 (KHR) works within the framework of the International Hydrology Programme (IHP) of UNESCO and the Hydrology and Water Resources Programme (HWRP) of WMO. It is a permanent, independent, international commission and has the status of the foundation as registered in the Netherlands. The members of the commission are the following scientific and operational hydrological institutions of the Rhine Basin:

- Federal Ministry of Agriculture, Forestry, Environment and Water Management, Division IV / 4 - Water Resources (Hydrographic central office), Vienna, Austria,
- Office of the State of Vorarlberg, Division VIIId – Water Policy, Bregenz, Austria,
- Federal Office for the Environment, Bern, Switzerland,
- IRSTEA, Antony, France
- Federal Institute of Hydrology, Koblenz, Germany,
- Office of the State of Hessen for the Environment and Geology, Wiesbaden, Germany,
- IHP/HWRP-Secretariat, Federal Institute for Hydrology, Koblenz, Germany
- Administration de la Gestion de l'Eau, Luxemburg
- Deltares, Delft, the Netherlands
- Rijkswaterstaat – Verkeer en Water Management, Lelystad, the Netherlands.

1. Hydrological Overview for the Rhine Drainage Basin

Meteorological characteristics

Austria, Source: Central Institute for Meteorology and Geodynamics (ZAMG)

For Austria, 2013 is the 11th warmest year in 246 years with a temperature deviation of plus 0.5 °C. The average temperature of the year is about 0.7 °C lower than the year 1994 which remains the warmest year. With this, the trend toward warmer than average years is set. Precipitation (+4% compared to long-term average) and sunshine (-3% compared to average) turned out to be average in the annual balance, but were characterised by extreme individual months: the strong rain at the end of May and the beginning of June brought the flood of the century and the wettest May since 1965. In January and February, Austria experienced one of the darkest beginning of the year in recorded history and in July a record sunshine.

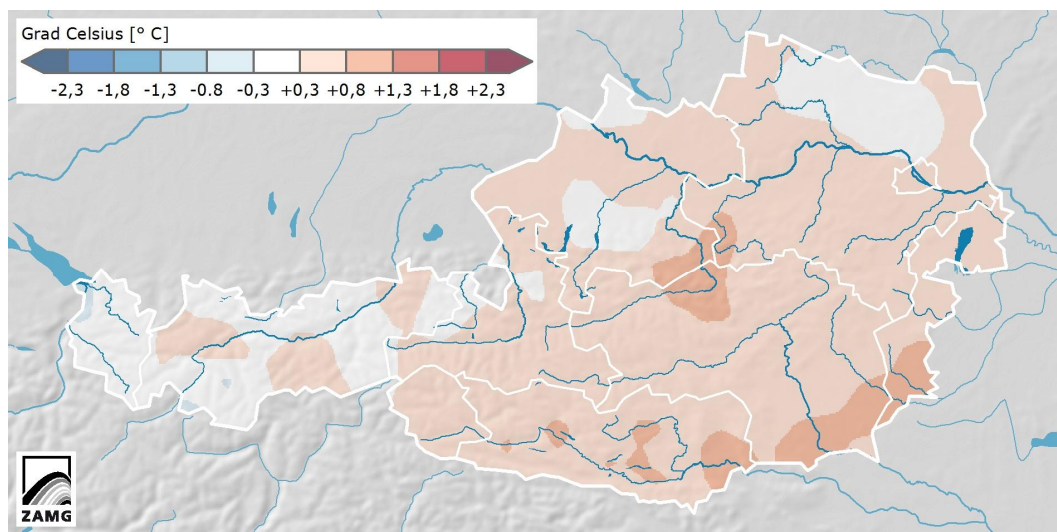


Figure 1: Temperature in Austria in year 2013: Difference in temperature from the long-term average of 1981-2010. Source ZAMG

Meteorological characteristics of the Rhine Basin in Austria

The total precipitation of the year in the Austrian part of the Rhine Basin lied between 96 and 114 % of the long-term average value. In the months January, February, May, June, and September, the monthly total precipitations were above average. In July there was exceptionally low precipitation. Therefore, despite the high total precipitations in May and June, the total precipitation of the year only exceeded the long-term average a little.

The intensive rainfalls at the end of May and until June 2nd led to partially rare flood events in smaller water bodies. At Innerlaterns, the measuring location, the highest total precipitation during the day was recorded at 156.2 mm.

The above-average precipitations in the months January and February were due to exceptional snow depth due to low temperature in the valleys. In Bregenz, a snow depth of 55 cm was recorded on February 9th.

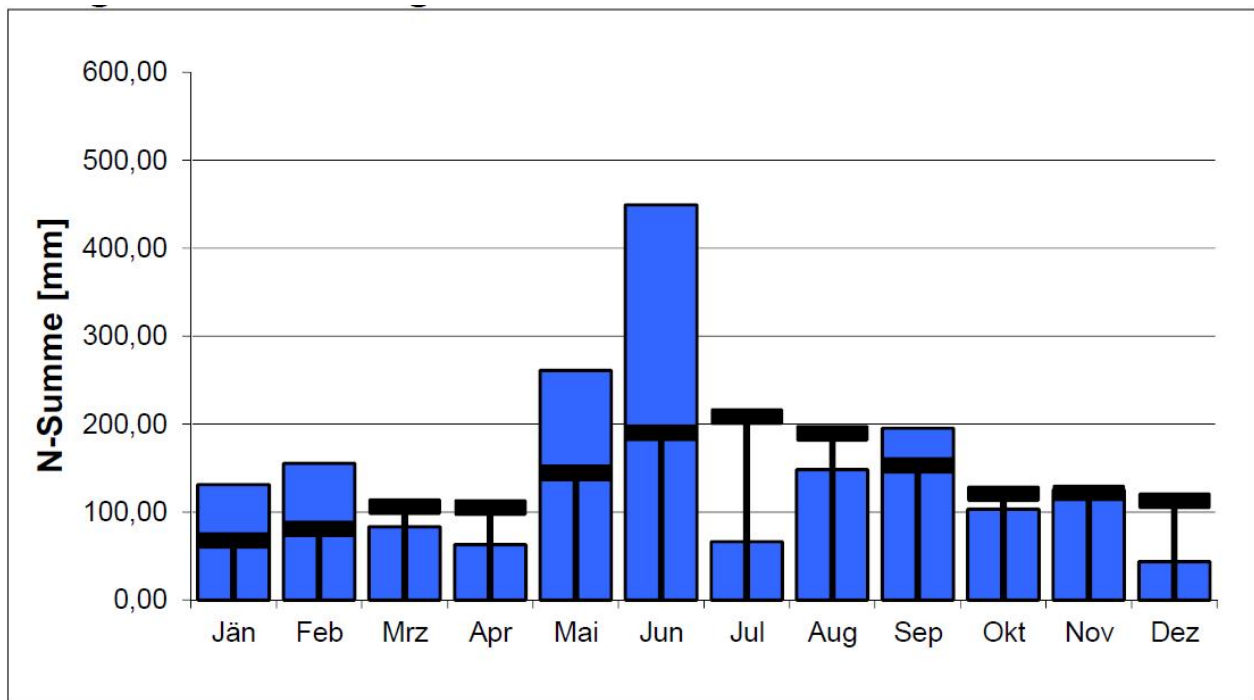


Figure 2: Monthly total precipitations in year 2013 (blue columns) in comparison with long-term monthly average at the measurement location Bregenz Altreuteweg

Switzerland, Source: MeteoSchweiz

The characteristics of 2013 were the winter conditions that went on until the end of April, the record lack of sun from January to May and an extremely sunny summer. In the whole of Switzerland, the air temperature of the year on average was exactly as the standard value of 1981–2010. The amounts of precipitation during the year reached an extended 90% to 110% of the standard. The northern Alps and Engadin were outliers in that this value was only 80 %.

In the first half of January, the prevailing mild winter weather continued from mid-December 2012. The second half of January delivered low temperatures. With the influx of mild, moist air, the first week of February initially brought abundant new snow to the mountains. There was an unusual amount of new snow by the end of the month in Südtessin. After a few mild days in the beginning of March, it became wintry again in mid-March.

With southwest winds, warm air arrived in mid-April in Switzerland. The temperatures were prevalently below 10 degrees already on April 20th. Heavy rainfall brought some new snow in the North up to the plain. High precipitations covered Tessin from 26th to 30th of April. The moist air flow from the south lasting from 14th to 21st of May brought heavy rainfalls again to the south side of the Alps. By the end of May, the moist Mediterranean flew over the Austrian part of the Alps to the northern Alps. From May 31st to the morning of June 2nd there was 80 to 150 mm of rainfall in the central and eastern parts of the Alps north slope, and 150 to 200 mm in a corridor from the Schwyz part of the Alps to the front part of Appenzell.

In the beginning of June, there was a phase of sunny weather that last multiple days for the first time since mid-April. Afterwards, the weather continued to be volatile until mid-June. It was hot like in summer from 16th to 19th of June. A heavy storm with hail and high wind

speeds in western Switzerland ended this summer phase on 20th June. In July and August, there was almost always sunny midsummer weather.

In the first days of September the temperatures in both sides of the Alps rose again to the midsummer values. In mid-September, cold polar air was recorded in Switzerland. Shortly before mid-October, a second strong polar air pushed the snowfall line on either side of the Alps up to 600 m downwards. It was followed by the lastingly mild second half of the month.

The first third of November brought wet and stormy weather due to the west wind, and the temperatures remained mild. From November 11th, calm high pressure zones were the dominant weather element well into December. The calm autumn weather was interrupted by a rainfall phase that lasted multiple days around November 20th, which brought the first new snow all the way from the north side of the Alps to the plain.

Due to the strong south current, which also brought the Christmas Föhn storm, an unusually large amount of snow fell on the south side of the Alps.

Table 1: Values of the year 2013 from selected MeteoSchweiz measurement stations in comparison to the standard 1981-2010

Station	Height above sea level	Temperature (°C)			Sunshine duration (h)			Precipitation (mm)		
		Mean	Standard	Diff.	Total	Standard	%	Total	Standard	%
Bern	553	8.7	8.8	-0.1	1709	1682	102	1113	1059	105
Zürich	556	9.1	9.4	-0.3	1540	1544	100	1094	1134	96
Genf	420	10.2	10.6	-0.4	1723	1828	94	1047	1005	104
Basel	316	10.3	10.5	-0.2	1521	1637	93	908	842	108
Engelberg	1036	6.2	6.4	-0.2	1268	1350	94	1478	1559	95
Sion	482	10.5	10.2	0.3	2067	2093	99	568	603	94
Lugano	273	12.9	12.5	0.4	1998	2069	97	1713	1559	110
Samedan	1709	2.1	2.0	0.1	1718	1733	99	640	713	90

Standard = Long-term average 1981-2010

Diff. = Difference of the temperature from the standard

% = Percent compared to the standard (standard = 100%)

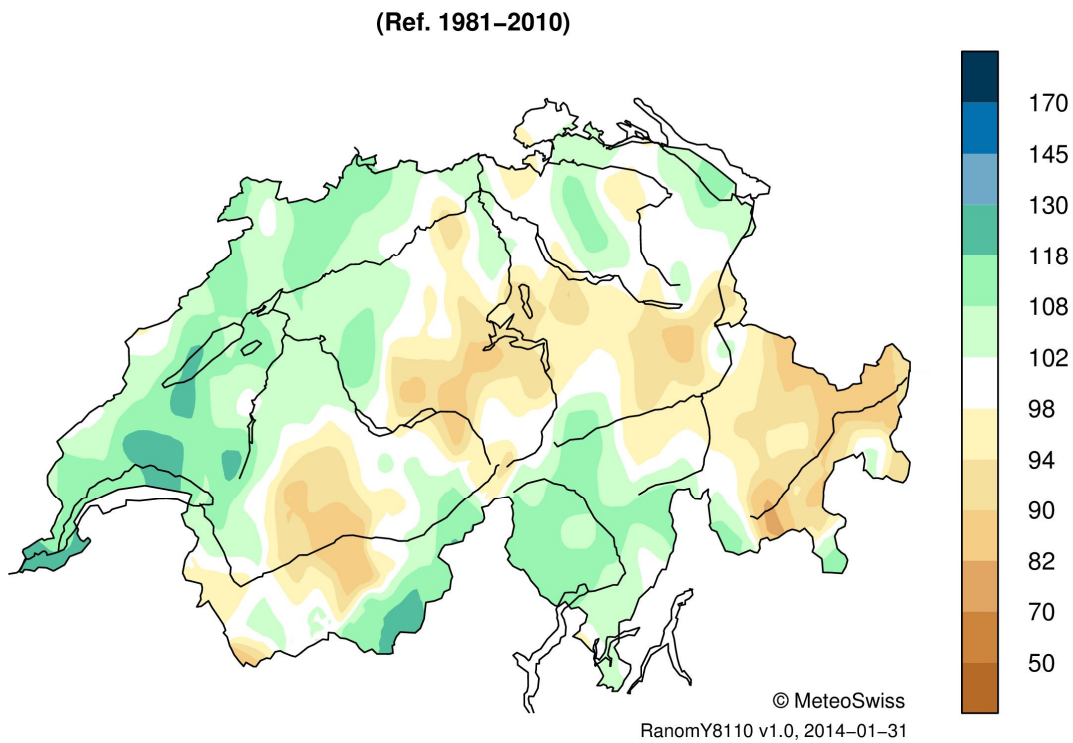


Figure 3: Total precipitation of the year Switzerland in percentage of the standard (1981-2010).

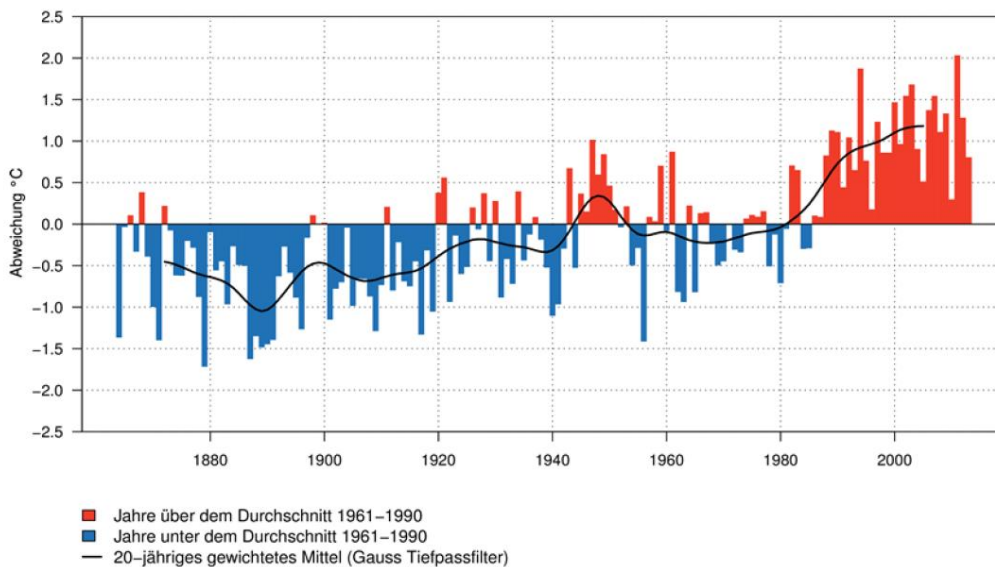


Figure 4: The annual temperature difference in Switzerland in 2013 compared to the long-term average (reference period 1961-1990). The too-warm years are in red, the too-cold years are given in blue. The black line shows the temperature profile averaged over 20 years.

Germany, Source German Meteorological Service (DWD)

From the outset, it should be noted that from the DWD a new reference timeframe for the comparison of data is in effect: in the future, the period from 1981 to 2010 will be used as a comparative series. In Figure 1 it is clear that the time series currently in use displays in the

course of the year about 0.7° K higher average temperature over the Rhine Basin in the Federal Republic of Germany compared to the reference series 1961-1990.

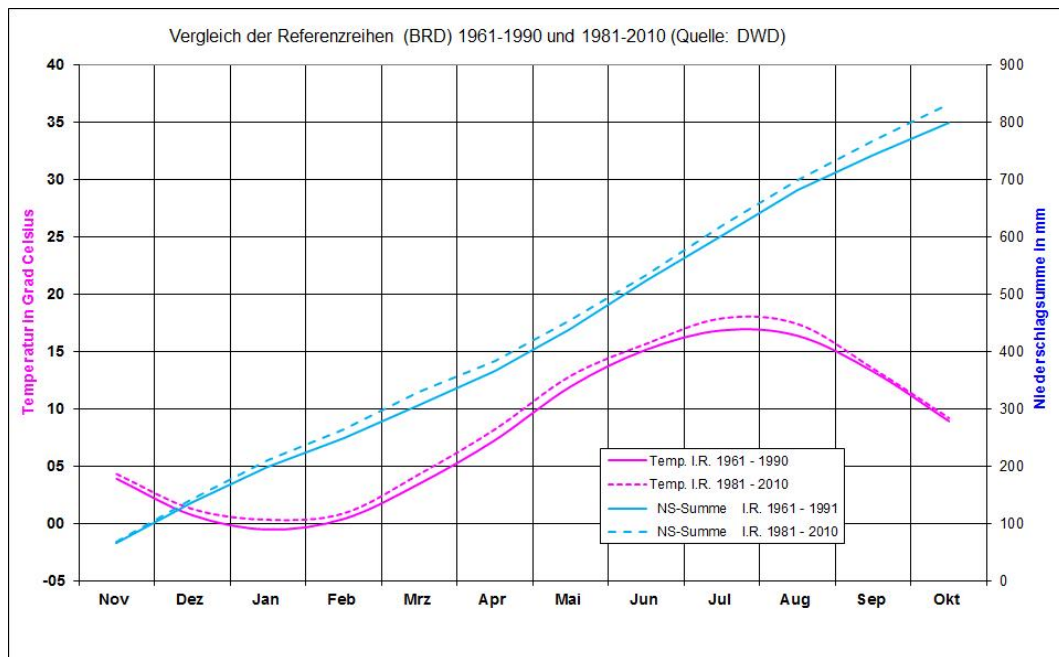


Figure 5: Monthly average precipitation and temperature (Source: BfG / Data: DWD – Average values 30-year periods)

The discharge year 2013 (Nov. 2012 to Oct. 2013) was in total a cool year. Contrary to the trend observed in the recent years, the recorded temperatures for the part in the Federal Republic of Germany were below the long-term observed average of the series 1981/2010 by 0.3 °K (1991/2010 +0.4 °K) with a calculated mean value of 8.6 °C.

Significant monthly differences from the average values used for comparison were recorded in February and March 2013 with -1.7 or -4.2 °K as well as in July with +1.5 °K (absolute values: cf. Fig. 6a). The fifth coldest monthly average of the temperature since the beginning of regular recordings in 1881 was recorded in March, and in July the sixth mildest. This basic characteristic which was observed in the entire Federal Republic is also recognisable in the Rhine Basin, here, for example at the measurement station Cologne (cf. Fig. 6b).

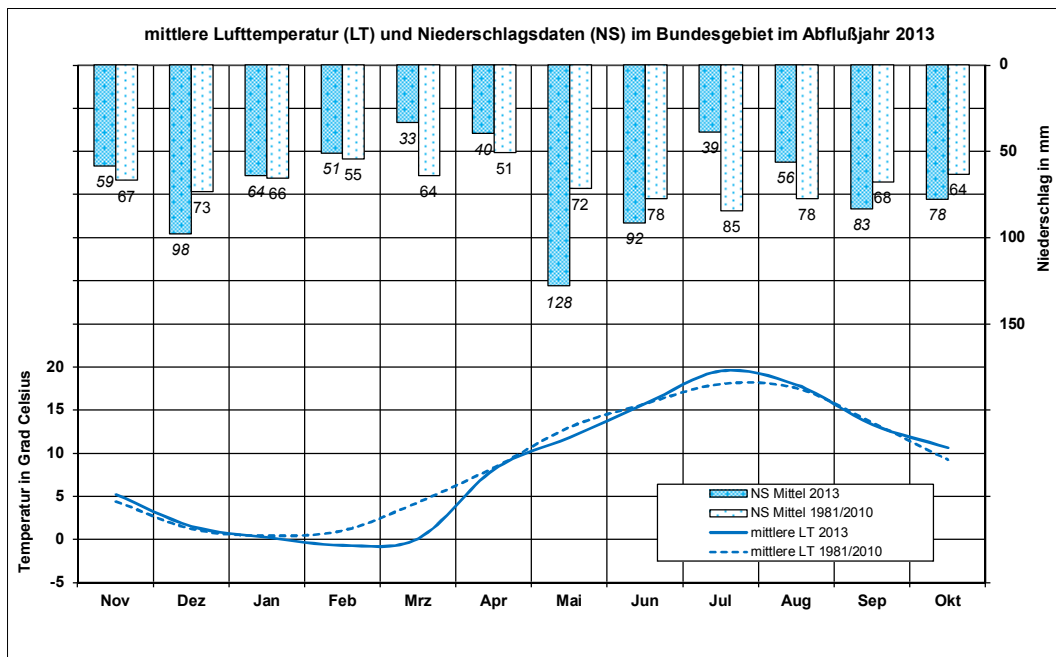


Fig 6a: Federal Republic of Germany: Comparison of the monthly temperature and precipitation data in discharge year 2013 compared to the long-term average 1981/2010 (Source: BfG / Data: DWD- monthly weather report 2013)

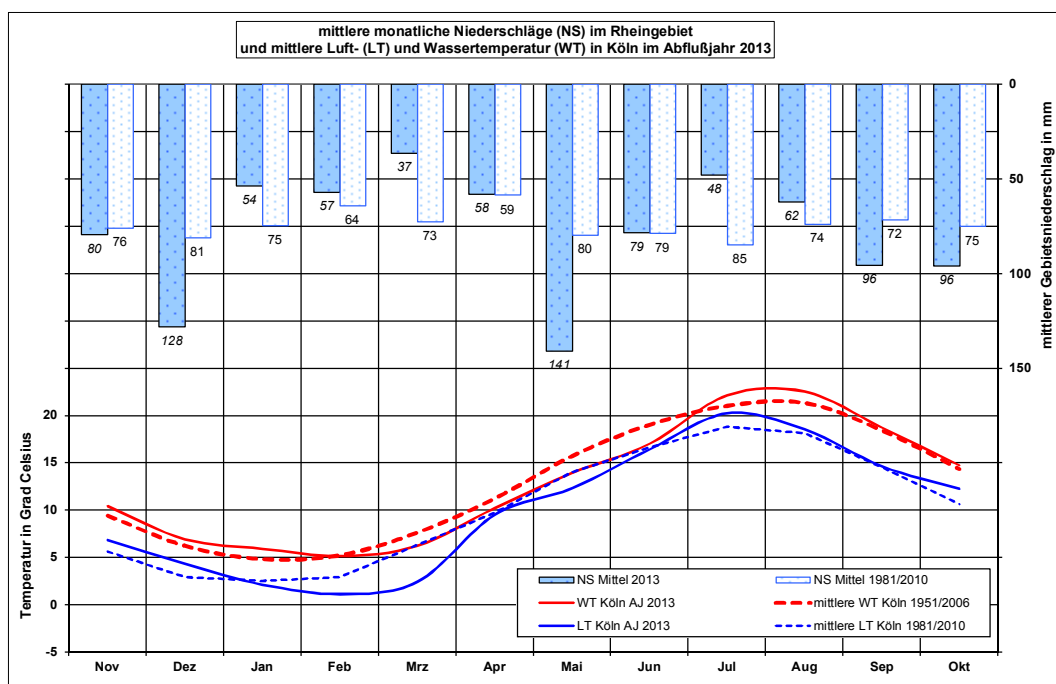


Figure 6b: Rhine drainage basin/Sample station Cologne: Comparison of the monthly temperature and precipitation data in the discharge year 2013 against the long-term average 1991/2010 (Source: BfG / Data T and NS: DWD, WT: WSV)

The average long-term total precipitations in the basin (reference period 1991/2010) were significantly exceeded in the entire Rhine Drainage Basin in May 2013 with the measured 176% of the reference value. In the drainage basin of Main, a registered regional average of 147mm, which is 208% of the long-term average, was recorded. For Germany, it was the

second wettest May since 1881. Only May 2007 had more rain. There were also dry months in 2013, such as the average precipitation in the Rhine basin of 33 mm recorded in March (50% of the long-term average) or the 39 mm registered in July (53% of the long-term average).

As in previous years, the rainfall distribution between the winter and summer halves of the year showed with 44% to 56%, a significant increase in the summer rainfall distribution compared to the long-term observed total precipitations of the series 1981/2010 (winter 47.9%, summer 52.1%). Also noticeable is the fact that in the Rhine Drainage Basin above the Main estuary (including the Main Basin) with an average of 110% over the entire year, below the Main estuary, however, only 91% of the annual total precipitation in the area was reached in comparison to the reference series.

For comparison, in the figures 6a and 6b, the areal averages for all of Germany and for the Rhine basin sampled by the Cologne gauge are illustrated. The areal precipitations are also remarkable alongside the 158% areal precipitation recorded in December 2012, also the 50% (33 mm) in March and the 53% (39 mm) in July recorded deficits.

Netherlands, Source: Koninklijk Nederlands Meteorologische Instituut (KNMI)

2013 was for the Netherlands a pretty cold year. The average temperature of the year at the station De Bilt was at 9.8 °C lower than the long-term average value of 10.1 °C. The first half of the year was especially cold. A frost period appeared in January, with seventeen consecutive frost days from 10th to 27th of January (minimum temperature under 0.0 °C) and twelve ice days (maximum temperature under 0,0 °C). The lowest temperature was observed on January 16th at the station Herwijnen at -18.0 °C. February was also relatively cold with sixteen frost days.

Spring had not been so cold since 1970. March and April had in total 28 frost days and an ice day. The first time after winter a temperature of 20.0 °C was observed was on April 14th at the station De Bilt.

The second half of the year was significantly warmer with average monthly temperatures around or higher than the long-term average value. July was quite warm and August really warm. From 21st to 27th of July, the main topic was a heat wave (minimum five consecutive days with the highest temperature of 25.0 °C or more and furthermore minimum three days with highest temperature of 30.0 °C). On August 2nd, the highest temperature of the year at 36.9 °C was observed at the station Arcen. September too had summer weather. This was followed by a very mild October and an average November. The temperature reached a value below null the first time at station De Bilt on November 11th. Finally, December ushered in an exceptionally mild beginning of winter.

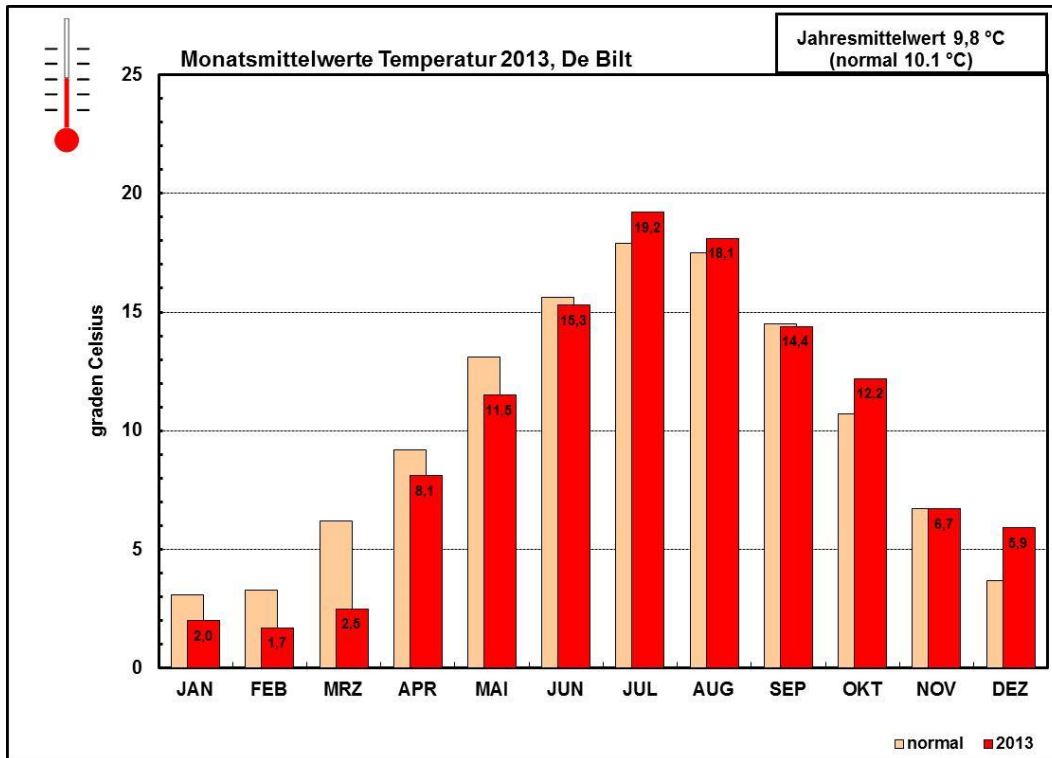


Figure 7: Monthly average values of the temperature at the station De Bilt / Netherlands 2013 in comparison with the long-term average (Source: KNMI)

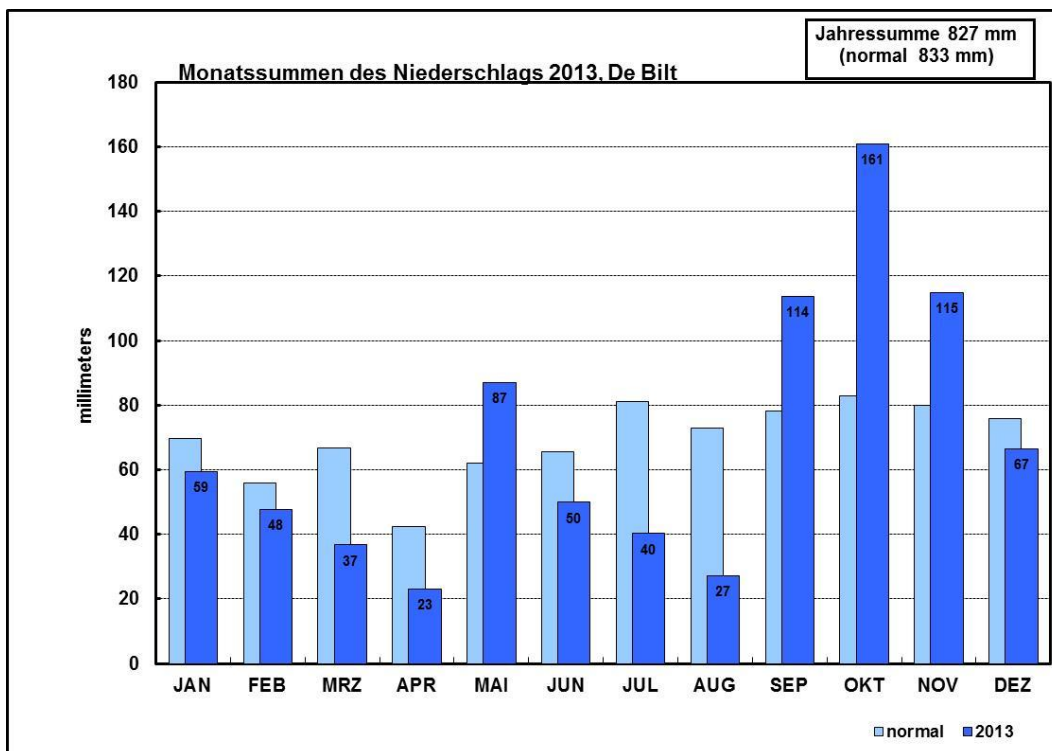


Figure 8: Total monthly precipitations at the station De Bilt / Netherlands 2013 in comparison with the long-term average value (Source: KNMI)

The amount of rainfall in 2013 at 827 mm was relatively close to the long-term average value of 833 mm. The first months of the year were dry. In January, February and March there was rainfall as regularly as snow. May was the first wet month of the year. The summer months June, July and August were again drier than normal. Autumn was in contrary, quite wet and was the third wettest autumn since 1906. All three autumn months have a higher total precipitation than the long-term average value. There was exceptionally high rainfall on the weekend from Friday 11th to Sunday 13th of October. Over 75 mm of precipitation was recorded within 24 hours at some stations.

The number of sunshine hours was 1628 hours in 2013, meaning 2013 can be registered as sunny on average. The long-term average value is 1602 sunshine hours. The months April, July, August, and December were above-average sunny. On the contrary, May, June, and November are to be recorded as dark.

Snow and glacier

Source: Schnee: WSL Institute for Snow and Avalanche Research SLF/ Glacier: Geographic Institute of University Fribourg and Research Institute for Hydraulics, Hydrology and Glaciology (VAW)

The snow depths were above-average over the entire winter in a large part of the Alps north side and Wallis, average in Nord and Mittelbünden as well as in Unterengadin, and below-average in Oberengadin and on the Alps south side. The glacier of the Swiss Alps showed a significantly lower mass loss compared to the long-term reference.

In winter 2012/2013 (November to April), the amounts of precipitation, especially in Mittelland, were higher than usual. The many new snow days caused Mittelland to be covered in 30 to 50 cm thick snow in mid-December. The snow depths of December 1998 ("Lawinenwinter 1999") were partly equalled. The snow depths were over the entire winter above-average in large parts of the Alps north side and Wallis, average in Nord- and Mittelbünden as well as in Unterengadin and below average in Oberengadin, and below-average on the Alps south side.

The winter already started in October with two snowfalls up to deeper places. From end of November to mid-December, it snowed again heavily, especially in the north and in the west. The snow depths in mid-December in the north and the west were already two to three times the long-term average value. The heavy snowfalls continued until mid-January. In the first half of February, it snowed regularly and heavily, especially in the north.

The first humidification of the snow blanket was in the beginning of March. In the first half of April, snow fell repeatedly. In mid-April, the moisture penetration of the snow blanket happened rapidly in high places. Another winter interruption followed a great warm period. In the west of Unterwallis, the snow depths were also above-average at the end of April. In large parts of the Alps north side and entire Wallis, they were average or below-average.

Normally, the snow depths decrease rapidly in May. In winter 2012/13 the snow depths however, increased prevalently between mid and end of May at the automatic measuring stations of the WSL – Institute for Snow and Avalanche Research SLF (IMIS stations), especially significant at the main Alpine ridge.

In the time between June and September, there were six periods where the snowfall and avalanche situations were of importance. Snow fell mostly only in the high mountains. In September, a new snow blanket began to build in the high mountains. High places with the exception of areas covered with glaciers were however for the most part snow-free.

In the hydrological year 2012/2013, measurements of the seasonal mass assessment were carried out at about 15 Swiss glaciers. Mid-April could be considered to have predominantly average or slightly above-average amounts of snow on the glaciers. The heavy rainfall between the end of April and the beginning of June was almost exclusively as snow due to the low temperatures. Therefore, the snow blanket in the high places of the glaciers reached its maximum quite late. The glaciers were thus still protected exceptionally well by the winter snow during the period of enduring hot and dry weather in July and August, and the melting began late. The glacier melting was largely stopped by new snowfalls already in mid-September.

On the glaciers of the Alps south side and the southern part of the Alps main ridge, balanced or even slightly positive mass balances could be measured. In contrast, the investigated glaciers north of the Alpine main ridge and the Alps north side as well as Engadin showed moderate mass loss. Nevertheless, it was significantly lower than in the previous years with -200 to -900 mm water equivalence. The regional difference in the changes of glacier capacities could be traced back to the distribution of the large amounts of snow in spring and early summer.

Despite the well above-average temperatures during the summer, the climate development in 2012/2013 for the glaciers was quite low. Since 2002 the ice of the Swiss Alps no longer showed similarly low mass losses. However, we should not yet speak of a trend reversal: Although the glacier melt happened less dramatically, the entire Switzerland continued to register a negative mass balance. Without the exceptionally strong snowfalls and the cold weather in May and June, the results would have been significantly worse for the glaciers.

Hydrological situation in the Rhine Basin in 2013

Water level of the great lakes in the drainage basin of the Rhine

Austria

At Lake Constance, the water level at the Bregenz gauge was above the equivalent long-term daily average values from the beginning of the year until April 6th. For the calendar days from 4th to 8th of February, new maxima of observed daily average values since 1864 were measured. In the time frame from 7th to 18th April, the daily average remained below average. Afterward, the snow melts in the Alps and the above-average precipitations caused the highest water level since 2001 at 488 cm, which was measured on 12th of June. Due to the below-average precipitations in July and August, there was below-average seasonal water level from July 12th to September 19th. Afterwards, the water level on average was again above the corresponding daily average values of the observation series 1864-2011 from mid-October to end of the year. (see Figure 9).

PEGELSTATION BREGENZ - BODENSEE
Wasserstandsbewegung von 1864 - 2011 (148 Jahre)
Pegelnulldpunkt: 392,14 m ü. Adria

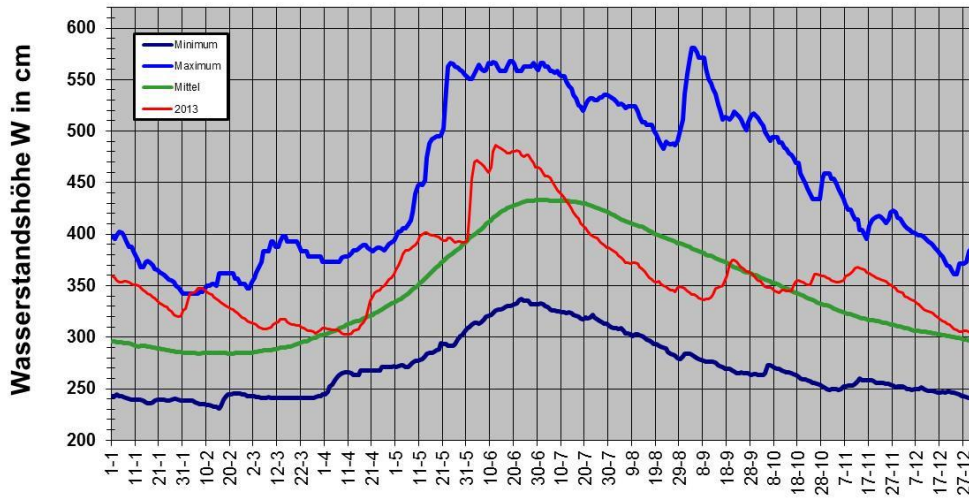


Figure 9: Gauge station Bregenz/Lake Constance. Water level movement of 2013 and main values of the period 1864 – 2011

Switzerland

The average water level in 2013 of the non-regulated Lake Constance was at around 25 cm above the average of the standard period 1981-2010. For the regulated lakes, this deviation from the standard was significantly smaller: Neuchâtel +0 cm, Lake Geneva +3 cm, Lago Maggiore +10 cm. Lake Constance and the Neuenburgersee started the year with relatively high gauge levels. While the Neuchâtel was reduced rapidly to the average January values, at Lake Constance it took until the end of March for the level normal for the season to be reached. The monthly average for January and February were at Lake Constance above 50 cm above the corresponding long-term water level.

The high gauge levels at Lake Constance in June were not extreme. However, because they lasted for so long, they led to a considerable monthly average with a deviation from the standard of +66 cm. The annual peak value on June 12th was 85 cm below the peak value of the entire measurement period, which was measured in 1999.

Lake Lucerne and Lake Zurich were in the area of "significant risk" a few days into June; for Lake Brienz, Lake Thun, Lake Biel and Lake Walen it was "moderate risk".

Water level and discharges of the rivers

Austria

The discharges of the most important feeds to Lake Constance were above the long-term average value in 2013.

- at Bregenzerach at 111 % (MQ 2013 = 51.6 m³/s, long-term MQ = 46.4 m³/s);
- at Alpine Rhine at 103 % (MQ 2013 = 238 m³/s, long-term MQ = 232 m³/s).

About flood event May 29th to June 2nd 2013

(Source: BMLFUW (2014) "The flood of June 2013– an hydrographical analysis")

In the time period May 30th until June 2nd, the total precipitations in almost the entire Austrian part of the Rhine Basin in Vorarlberg were significantly more than 100 mm, partly above 250 mm. It rained the strongest in the Drainage Basin of the Frutz (Innerlaterns: 266 mm), the Dornbirnerach (Station Ebnit: 268 mm), the Bregenzerach and the Leiblach in the north at the border with Bayern (Station Pfänder: 252 mm). In contrast to the Austrian Danube Drainage Basin, where the precipitations caused a century flood, flood peak with magnitude of HQ1-5 were in many cases reached in the waters of Vorarlberg. It could reach up to HQ10 at the Frutz, the Dornbirnerach and the Bregenzerach.

However, at the Leiblach, the drainage basin of which is located at the northern edge of the Alps in the direct influence area of the dam rainfall, another century flood event was registered only a short time after two HQ-100 events in June and July 2010 at gauge Unterhochsteg. The peak flow of 145 m³/s is the highest flow measured since 1976.

From Switzerland, the Rhine came with a water channel into a one-year high water (gauge Bangs/Rhine). Due to the Austrian Rhine feed, among others the Ill and Frutz rose to the level of HQ1 (gauge Lustenau/Rhein).

Switzerland

The discharge amounts of the large drainage basins were slightly above average over 2013. However, the late summer and December also witnessed periods with very low water levels and discharges in the rivers and lakes of Switzerland.

The annual averages of the large river basins in 2013 were at 5 to 15% above the standard period 1981 to 2010. With the decreasing drainage basin surfaces, the variability increased and there were also some medium-sized drainage basins with below-average discharges. However, the drainage basins with significantly above-average annual averages became prevalent in 2013.

Looking at the monthly discharges, six time periods can be roughly identified. The monthly average...

- ... was in January and February, mostly above the long-term average. Deviation from 20 to 40 % was often observed. The drainage basin of the Hinterrhein doesn't show this pattern: very low values were recorded in January as well as February.
- ... was at normal or below-average level, especially in March due to the low temperatures .
- ... was mostly above the long-term average from April to June. The flood in the beginning of June contributed to the fact that the June discharges were recorded as sharply above-average at the Reuss, the Limmat and the Aare.
- ... was mostly below-average in July, August and September. In a few drainage basins, only around 50% of the standard was recorded.
- ... was sharply above-average in October and especially in November. The Töss and the Mentue reached in November the double discharge amount compared to the standard.
- ... was in December sharply below-average in great parts of the river basins of the Aare, the Reuss, the Limmat and the Thur; they were sharply above-average on the Alps south side and in western Switzerland.

Observations with a finer temporal resolution show just how remarkably large dynamics can be hidden behind an annual average value: the Aare at Brugg for example, caused a flood eight times at more or less regular intervals, among which there were two events with considerable magnitude. The largest – end of May/beginning of June – had a return period of 5 to 10 years. However, the deep discharges also occurred in 2013: in August and September, for several days the measurement values were within the range of the lowest daily average for this month in the standard period. The Reuss and the Limmat also show a similar pattern to that of the Aare. The biggest flood event of the year occurred on the north side of the Alps in the beginning of June.

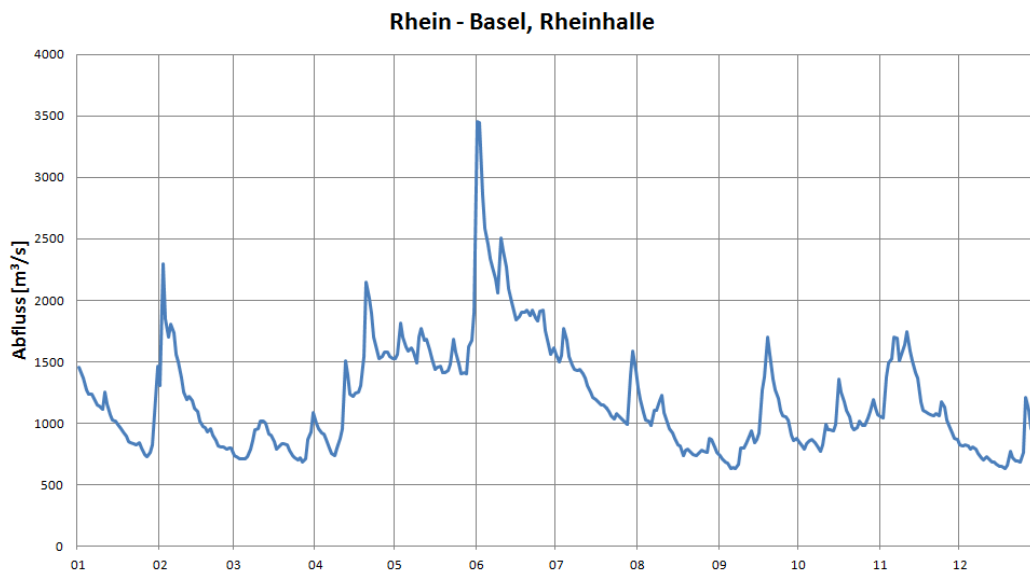


Figure 10: Hydrograph at gauge Basel, Rheinhalle / Rhine in 2013

A low pressure area over Eastern Europe caused a period of intense rain on the north side of the Alps from Friday, May 31st to Sunday, June 2nd 2013 in Switzerland. Exceptionally heavy precipitations occurred in central and eastern parts of the Alps north side according to Mete-oSchweiz. The highest total precipitations at those places were at 100 to 189 mm. Due to relatively low temperatures, the rains fell partly as snow in higher places.

The rivers and lakes on the north side of the Alps reacted to the rainfalls and the partial snow melt with strong water level rise. The rivers of the Central Plateau and Jura reached their peak discharge mainly on Saturday, June 1st. In eastern Switzerland, a second wave of flooding partly reached even higher discharge values on June 2nd. Afterwards, the discharges dropped in the rivers. The levels of Lake Zurich, Lake Lucerne as well as Lake Constance and Lake Walen continued to rise until Sunday night and partly until Monday. The discharge values of the lake outlets stayed correspondingly high. Due to more rains and the continuing snow melt, Lake Constance remained at high levels for weeks and first began to drop in July.

Discharges with return periods of 2 to 10 years were observed in many rivers on the north side of the Alps. The discharges were observed to be such that they only occur statistically on average every 10 or 30 years on the Reuss, the Thur and the Hochrhein between the estuary of the Thur and Basel.

New absolute records were not registered. The measurement values were, however partly close to the values of the storm in May 1999, August 2005 and August 2007. In certain plac-

es, new highest values were recorded in June. For example, the Rhine in Rheinfelden, the Reuss below Lake Lucerne and the Thur in Jonschwil and Halden. A 50-year flood was recorded at the Rheintaler Binnenkanal at St.Margrethen.

Germany

The run-off behaviour in discharge year 2013 (illustrated in the hydrographs in Figures 12 to 17 as well as the hydrological values listed in Table 2) was indeed significantly affected above the estuary of the Moselle River during the flood event as a result of the above-mentioned anomalies in May and June. Additionally, two more distinctive flood events can be recognised with all the measurement locations in the course of the year taken into account.

Table 2: Hydrological main values (discharge) for selected gauges in the Rhine Basin

Gauge	MQ		Rhine Basin: Flood events in discharge year 2013			MHQ 1931/2011
	2013	1931/2011	HQ 12.2012	HQ 02.2013	HQ 06.2013	
Maxau (Rhein)	1540	1250	3250	3270	4180	3150
Rockenau (Neckar) * 1951- 2011	183	137*	900	1180	1800	1170*
Raunheim (Main) * 1981- 2011	264	224*	929	731	1260	1110*
Kaub (Rhein)	2100	1650	4570	4370	5910	4250
Cochem (Mosel)	407	313	1810	1590	1650	2090
Cologne (Rhein)	2580	2110	6370	6030	6160	6430

Just in time for Christmas, the incipient thaw as well as heavy precipitations up to the high places caused a moderate December flood in the Rhine Basin. At the Rhine gauges that were consulted for evaluation, the discharges reached the magnitude of MHQ 1931/2011. After the water levels sunk to the area below the monthly average discharge, heavy precipitations in the beginning of February, especially in the Upper Rhine Basin, in turn caused the peak discharge values comparable to those in December.

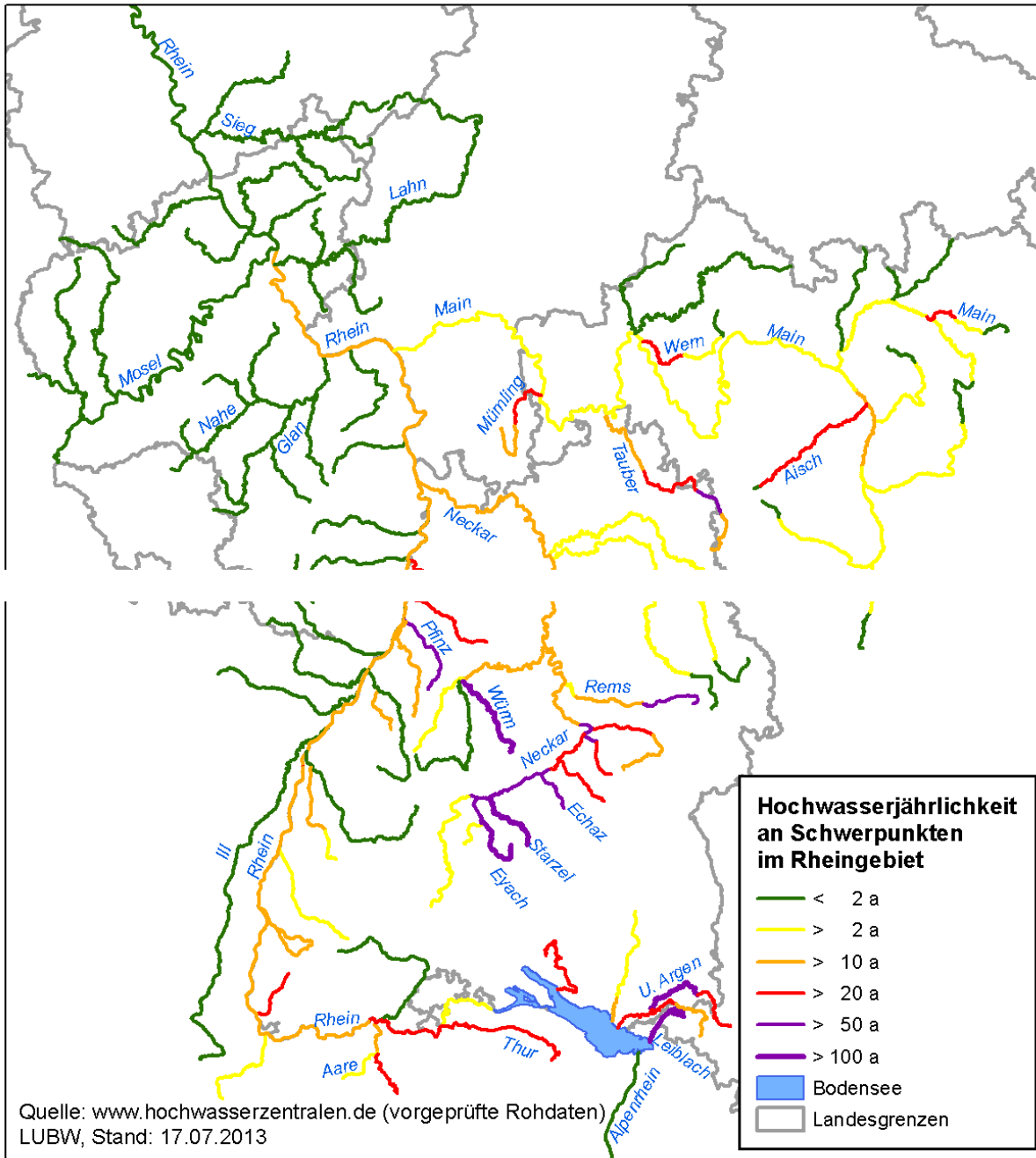


Figure 11: Highlights of the flood in June 2013 in the German Rhine Basin
(Source: LUBW/Flood warning centres, in BfG- Report 1797: Transnational Analysis of the June Flood 2013)

The last days of May and especially those of June brought exceptional flood, extreme to the German river basins. Compared to the water level record values of especially the Danube and the Elbe, the Rhine Basin escaped relatively lightly.

Corresponding to the large-scale distribution of precipitation, the greatest flood return periods in the Rhine Basin were reached in the Baden-Württemberg and the Bavarian parts of the drainage basin, especially at the tributaries of Lake Constance in Baden-Württemberg, at the

upper Neckar basin (partly above a century flood) as well as in the upper Main basin (crf. Fig. 11).

In the Rhine itself, the highest discharge return period with an about 30-year flood at the height of retention measure at Kehl-Straßburg was reached in the area of the Hochrhein downstream the Thur estuary to the upper Rhine. Along the upper Rhine, the highest levels of flood events in 1988 and 1995 were exceeded. At 869 cm, the marks of the flood in May 1999 (Maxau: 884 cm) was however not reached, which can also be attributed to the targeted use of flood mitigation measure; according to LUBW (2003) a water level reduction of up to 29cm occurred in the river stretch Maxau-Speyer.

The extent of the flood at the gauges Maxau and Worms could be limited by these retention measures to the peak values of around 10-year flood at Maxau or a 15-year flood at Worms.

In further current flow, overlapping with the flood waves of the Neckar and especially the Main caused a temporally lengthened flood peak at the gauge Mainz. As the tributaries downstream from Mainz contributed nothing to the hydrological behaviour of the sharpened discharges, the discharges below the estuary of the Moselle River were only within the area of the MHQ. In total, due to the use of the retention measures, the peak reducing effects in the further course of the Rhine in the magnitude of 5-20 cm (decreasing downstream) could be achieved.

Comparing the discharges which occurred in the annual average with the calculated MQ of the long-term defined ones, the observed Rhine gauges yield a plus of 24% on average, at the tributaries the Neckar and the Moselle reach the relative values around the area of 130%, the Main only 118% and a deficit of 10% was recorded at the Lahn. The distribution in the annual discharge in the winter and summer halves of the year yielded for the gauge Maxau a ratio of 45% to 55%, in Kaub a nearly similar MQ (51% to 49%), and in Cologne in winter period 46% to 54% was reached in summer. On average the ratio of winter to summer MQ at the tributary gauges were 2/3 to 1/3.

Shortfalls of the *annual* average lowest discharges (MNQ) on the Rhine and its tributaries were only recorded on the Moselle in seven days.

The *monthly* MNQ (mMNQ) were not reached especially in the summer half of the year (May-Oct) at the Rhine gauges, in which the number of the days with shortfall was on average 30 days. In the winter half of the year, the mMNQ was not reached only in 4 days on average.

At the tributary gauges, the values at the Main were not reached for only a day, at the Raunheim however 21 days, which nevertheless occurred only in the winter half of the year. At the gauge Kalkofen/Lahn, the shortfall frequency was by far the highest (winter 41 days with shortfall and summer 47), which the gauge Cochem with 18 days with a shortfall in winter and 51 in the summer hardly matched.

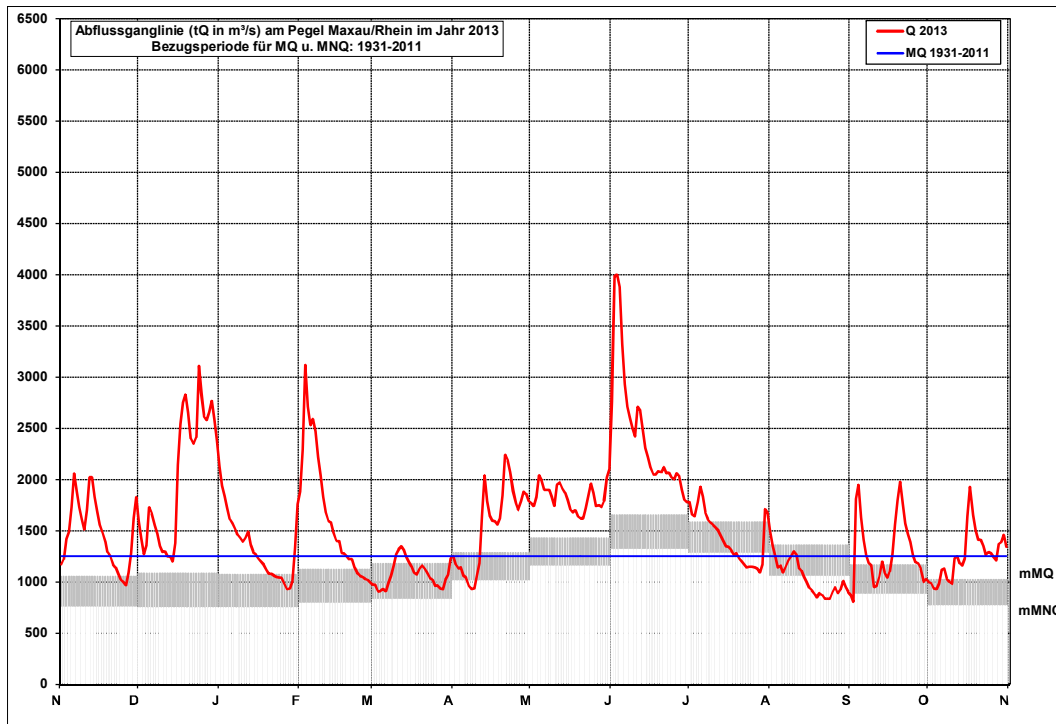


Figure 12: Hydrograph (tQ) at the gauge Maxau (Rhine) in 2013 in m^3/s (Reference period for MQ, mMQ und mMNQ: Period 1931-2011) (Source: BfG / Data WSV)

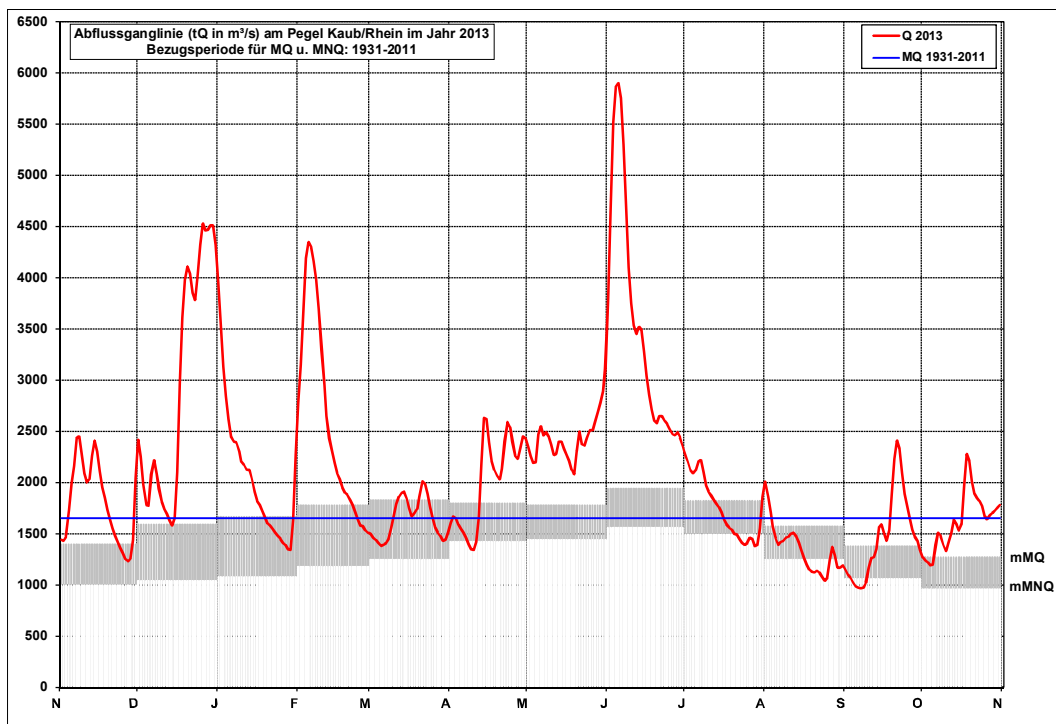
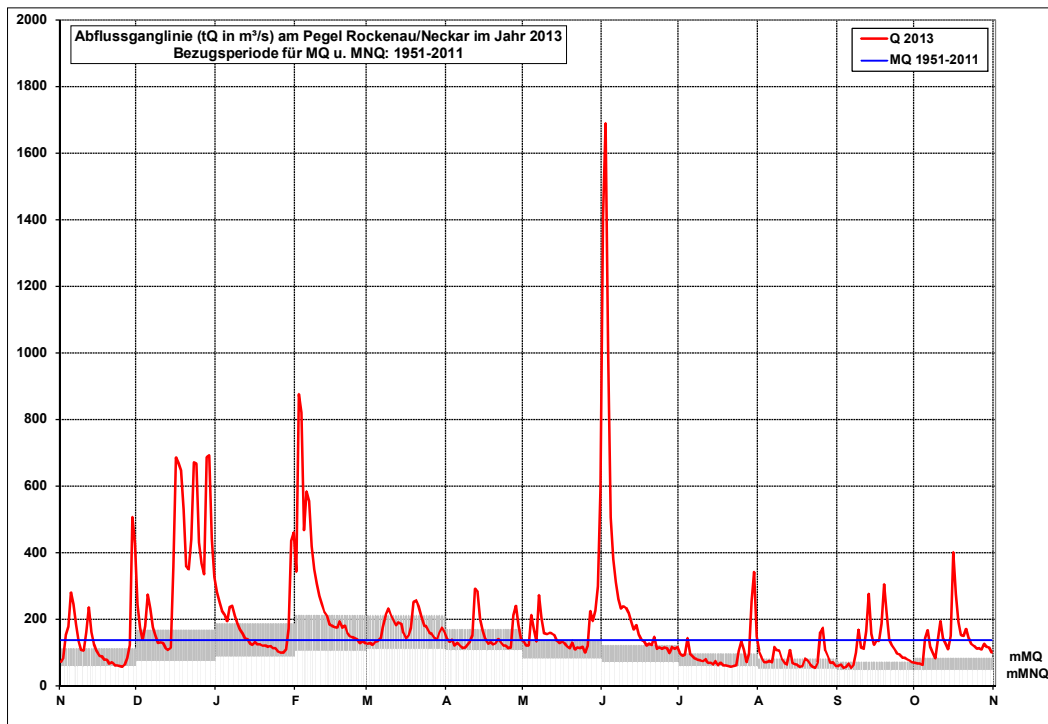


Figure 13: Hydrograph (tQ) at gauge Kaub (Rhine) in 2013 in m^3/s (Reference period for MQ, mMQ und mMNQ: Period 1931-2011) (Source: BfG / Data WSV)



Figure

Figure 14: Hydrograph (tQ) at the gauge Rockenau (Neckar) in discharge year 2013 in m^3/s (Reference period for MQ, mMQ and mMNQ: Period 1951-2011) (Source: BfG / Data WSV)

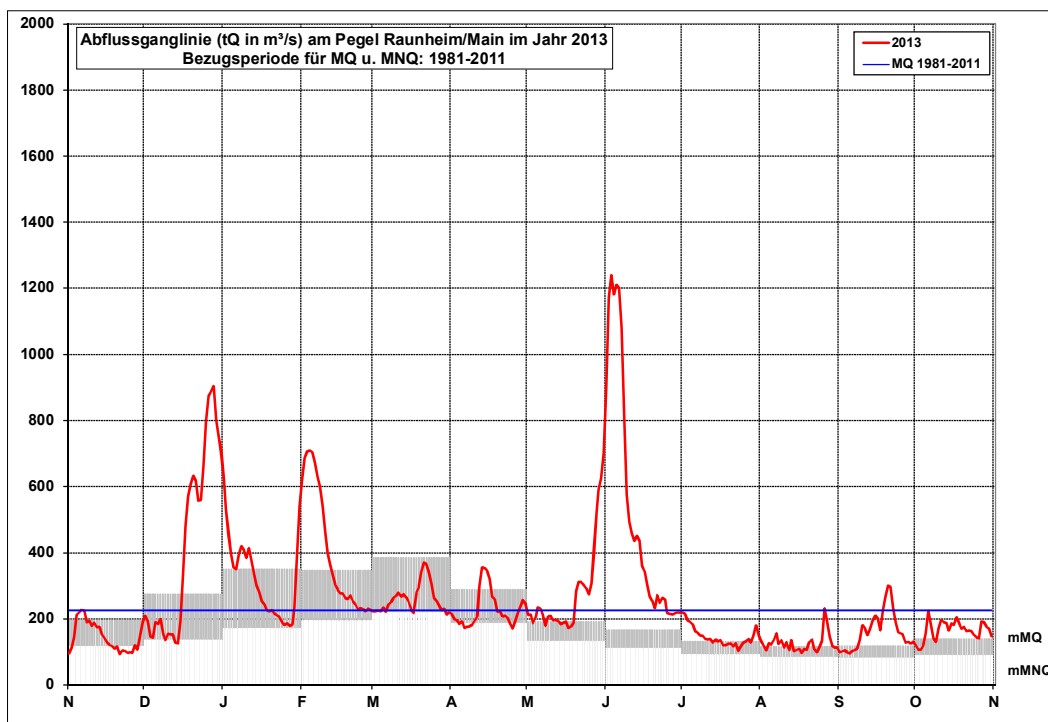


Figure 15: Hydrograph (tQ) at gauge Raunheim (Main) in discharge year 2013 in m^3/s (Reference period for MQ, mMQ and mMNQ: Period 1981-2011) (Source: BfG / Data WSV)

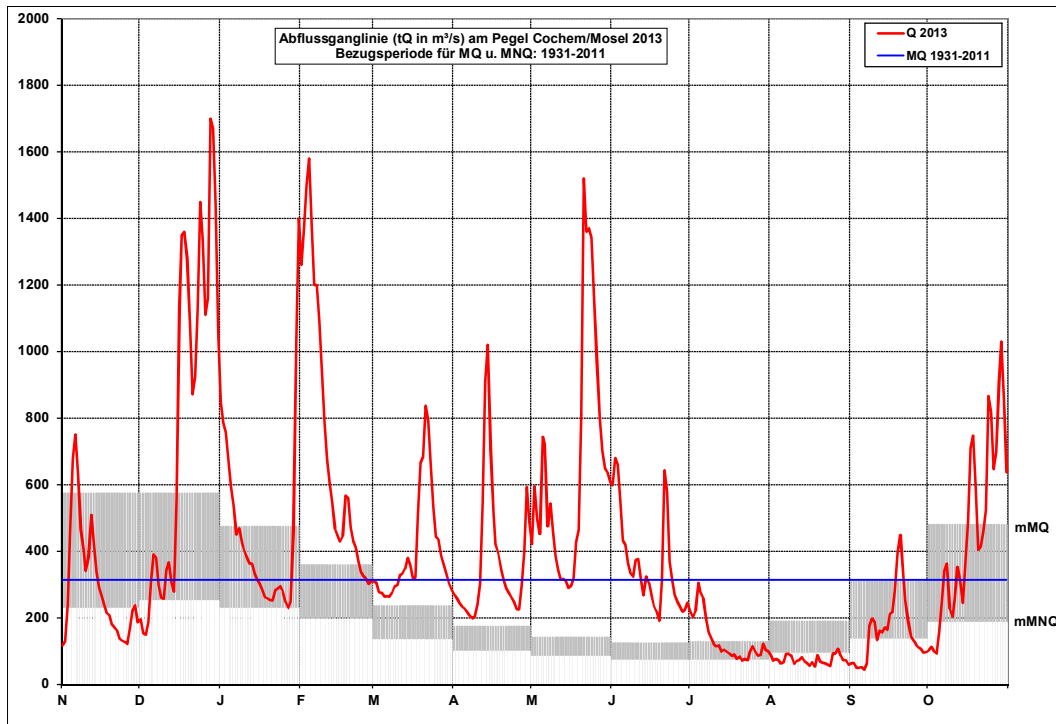


Figure 16: Hydrograph (tQ) at gauge Cochem (Moselle) in 2013 in m^3/s
 (Reference period for MQ, mMQ and mMNQ: Period1981-2011) (Source: BfG / Data WSV)

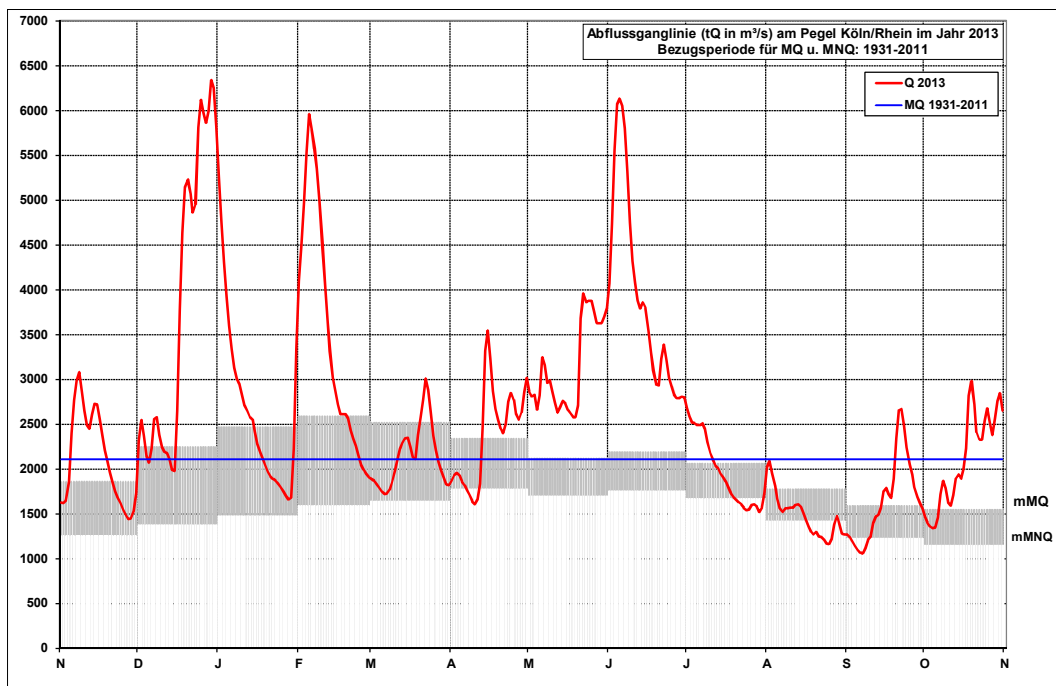


Figure 17: Hydrograph (tQ) at gauge Cologne (Rhine) in 2013 in m^3/s
 (Reference period for MQ, mMQ and mMNQ: Period1981-2011) (Source: BfG / Data WSV)

Water temperatures

Austria

The annual mean water temperature of Lake Constance at measurement location Bregenz Hafen at 12.2°C was 0.4°C over the long-term average value of 11,8 °C.

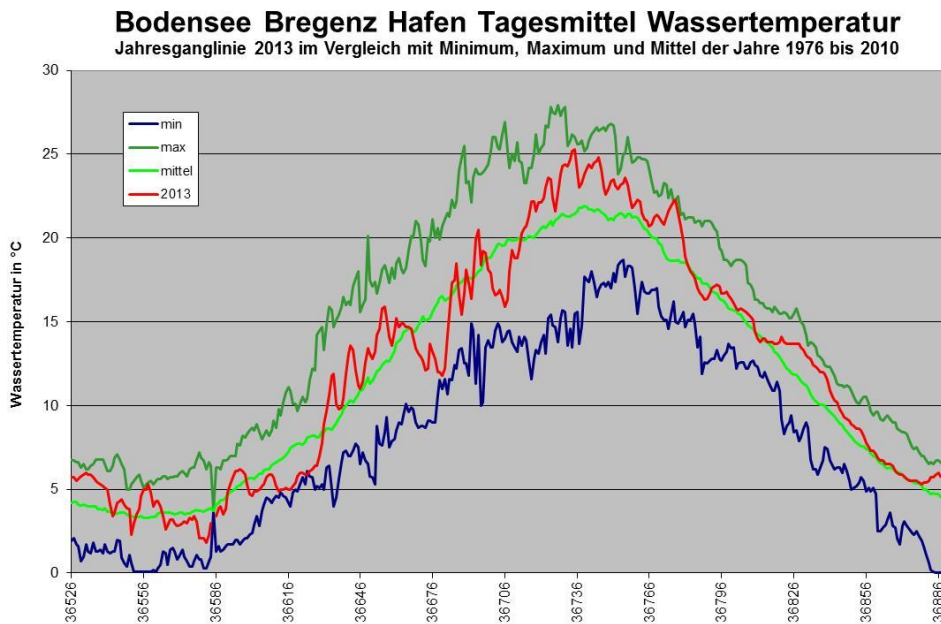


Figure 18: Annual hydrograph 2013 of the daily average value of the water temperature at Bregenz Hafen / Lake Constance

Switzerland

The cool first half of the year and the warm summer, mainly resulted in the average annual mean values of the water temperature. The deviations from the mean values of the standard period 1981-2010 were in the area of +/- 0.3 °C at the measurement stations, which have long enough measurement series to allow for a comparison. In the greater river basins, an about 1 °C lower water temperature was registered than in 2011, which, according to MeteoSchweiz the warmest year for Switzerland since measurement began in 1864.

In a few drainage basins, 2013 brought new monthly minima or monthly maxima. New minima were recorded especially for April and June. New monthly maxima occurred mainly in July, August, and September.

The Rhine in Rekingen experienced extreme fluctuations. In the beginning of June, there was a new monthly minimum in the 44 year measurement series at 9.4 °C. The monthly average value was at around 2 °C below the corresponding long-term average. The water temperatures in July and August were significantly higher than usual. The average values of both months were about 2 °C above the standard.

Germany

The average of water temperature (WT) recorded for the observation period of 12.6 °C at the measurement location Kaub are below the calculated long-term annual average by 1.4 °K, at gauge Cologne a shortfall of the average by 1.2 °K was recorded at 12.9 °C (crf. Fig. 19). The greatest deviations of the monthly average, each in the form of a shortfall from the average values, were recorded in June at measurement station Kaub at 3.8 °K and in Cologne 4,1 °K.

The maximum negative deviations from the daily values were in Kaub at 6.7 °K or 6.9 °K at the measuring station Cologne.

The course of the daily measured WT at the selected measurement location shows a three-part process. From the beginning of the observation time frame until the end of January, the WT in Cologne deviated on average by +0.1 °K , and in Kaub by -0.3°K only slightly from the calculated average values for the respective measurement locations. A similar process appears from July to the end of the discharge year, where the deviations at both measurement stations were below the long-term (1996-2010) calculated annual averages by 0.45 °K. A significant shortfall from the average was established for the period from February up to June. At the average water temperatures of 10.5 °C at both stations, the differences were on average about 2.7°K below the long-term average values.

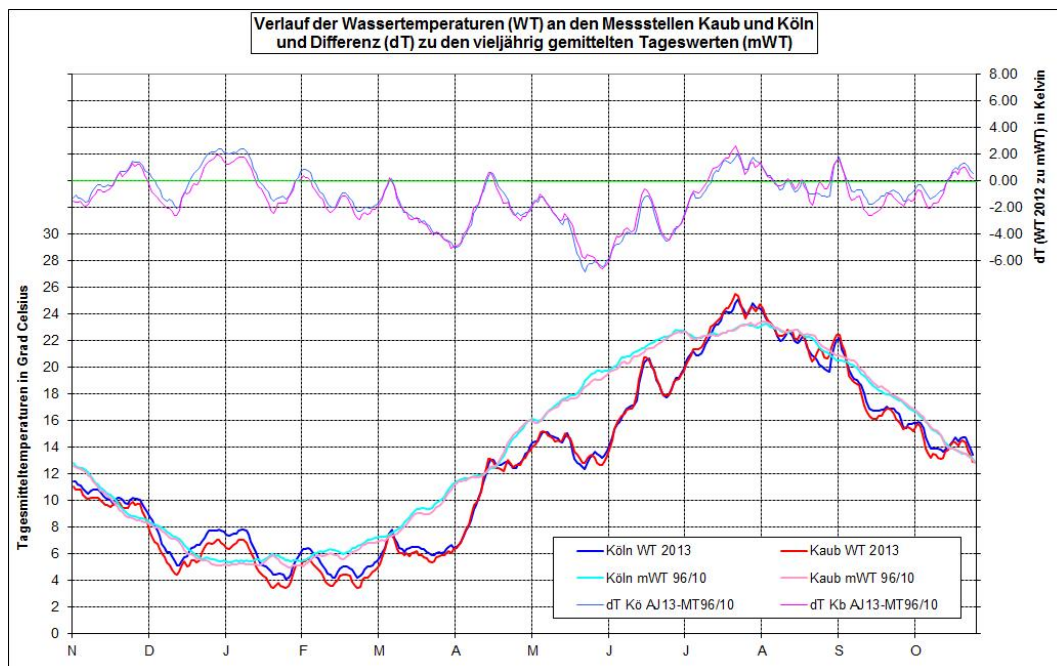


Fig. 19: Water temperatures in comparison to the long-term average values

Netherlands

At gauge Lobith the average value of the water temperature was at 13.6 °C about 0.6 °C above the long-term (1961-2012) calculated annual average value (see Figure 20).

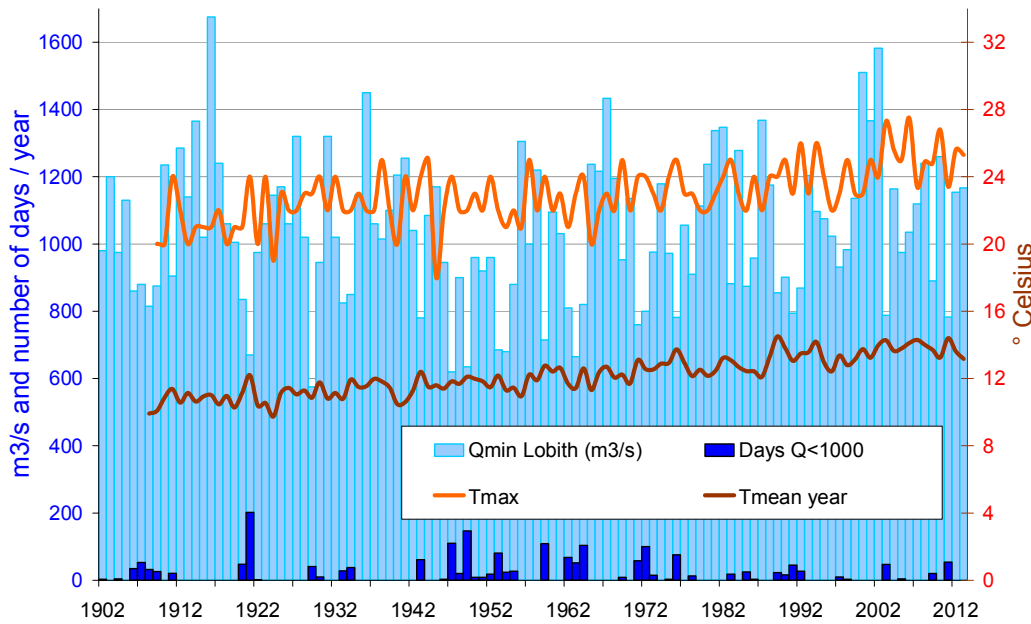


Figure 20: Average and maximum water temperatures at gauge Lobith/Rhine

Ground water

Austria

The above-average precipitation of May and June also caused above-average ground water levels in the first ten days of June in the Rhine Drainage Basin in Austria. The highest ground water levels since the beginning of measurement were recorded in June at several measurement locations.

Switzerland

In Switzerland, thanks to the constant observation of groundwater level and the spring discharge at about 100 representative measurement locations within the framework of NAQUA-Module QUANT, it is possible to map the status and development of groundwater quantity on country level. Furthermore, possible effects of climate change – predicted increased in the extreme events such as flood and drought periods – on the groundwater resources can be shown.

The long-term inspection of groundwater levels and spring discharges allows for the recognition of significant fluctuation with a certain periodicity. For groundwater in Switzerland, the low-level and high-level situations that last for several years take turns to occur. Between such situations, there is often a transition area, in which for a certain time average groundwater levels and spring discharges occur.

In Switzerland, predominantly normal, partly also high groundwater levels and spring discharges were observed in 2013. In the course of the year 2013 the groundwater levels and the spring discharges were as follows: the high groundwater levels and spring discharges in the Central Plateau at the beginning of 2013 normalised in the most parts in February and March 2013, meaning they were between the 10th and 90th percentile of the measurement periods 1993-2012 for these two months.

High amounts of rainfall in April and May 2013 as well as the strong rainfalls of 1st/2nd of June 2013 caused high groundwater levels and spring discharges on the north side of the Alps. Due to the strong precipitations of 1st/2nd of June, the river level in the Central Plateau and in

eastern Switzerland rose sharply, which caused a strengthened river water infiltration. As a consequence, a rapid rise in the groundwater levels occurred along the Aare, Limmat, Reuss and Hochrheins. A rapid rise of the discharge following the strong precipitations was observed also at the karst springs.

Due to the midsummer July and August 2013 with little rain, the groundwater levels and spring discharges were mostly normal. They were higher than in the heated summer of 2003 and the dry 2011, because in 2013 they were at a higher level at the beginning of summer.

The above-average rain quantity from September to November 2013 caused in western Switzerland partly new highest level of groundwater in November. At the end of December 2013, normal to high groundwater levels and spring discharges were observed in Switzerland.

History and properties of the suspended sediment in the German part of the Rhine in 2013

To get an overview of the suspended sediment, the data of the measurement locations Maxau (for the Upper Rhine) and Weißenthurm (for the area below the greatest tributaries) were evaluated. Concerning this cf. also Fig. 21a and 21b.

Extreme peak values at the daily loads are caused in summer by heavy rain events or in winter by the thaw period.

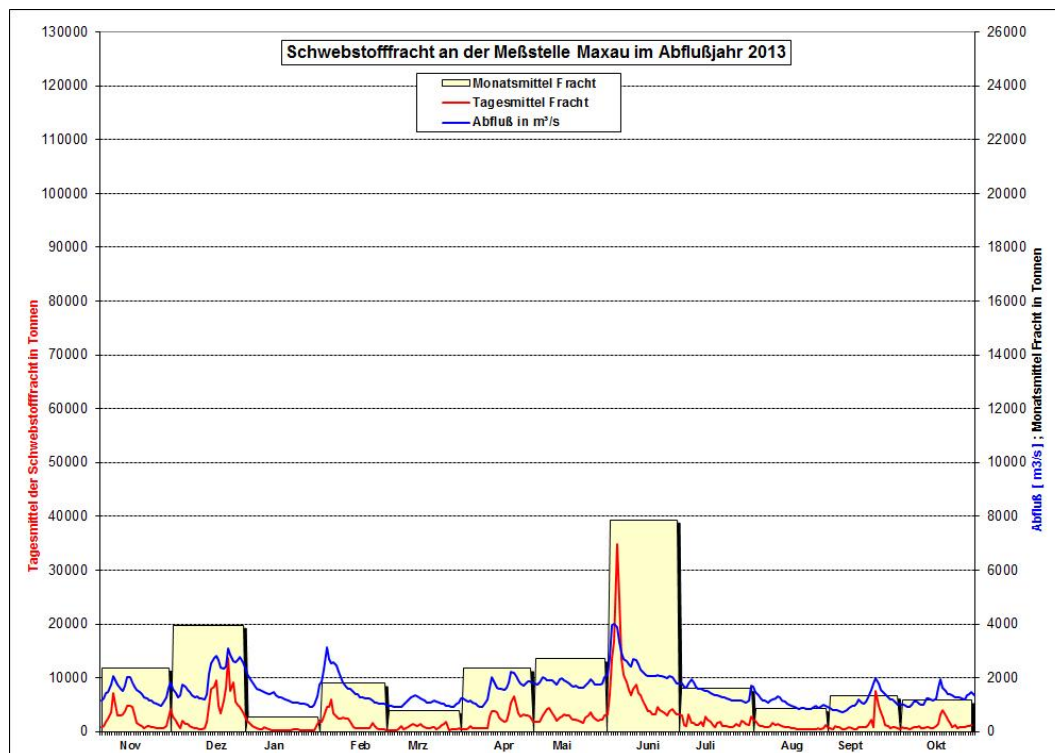


Figure 21a: Suspended sediment in 2013 at the measurement location Maxau, Rhine-km 362,3

In Maxau (Rhine-km 362,3), the annual suspended load was 827130 t, which corresponds to about 65 % of the long-term average of the reference period 1965/2007.

The highest monthly suspended sediment was recorded in the month of flood June 2013 at 236350 t, which corresponds to approximately 30% of the entire load of the year. The lowest monthly suspended sediment was observed in January 2013 with only 16664 t.

For daily load, the lowest was 160 t on January 27th at the measurement location Maxau with an average discharge of 926 m³/s, and the highest daily load was 34,864 t with an average daily discharge of 3880 m³/s on June 4th.

The gauge Maxau at Rhine-km 362.3 is used as the reference gauge for determining the discharges.

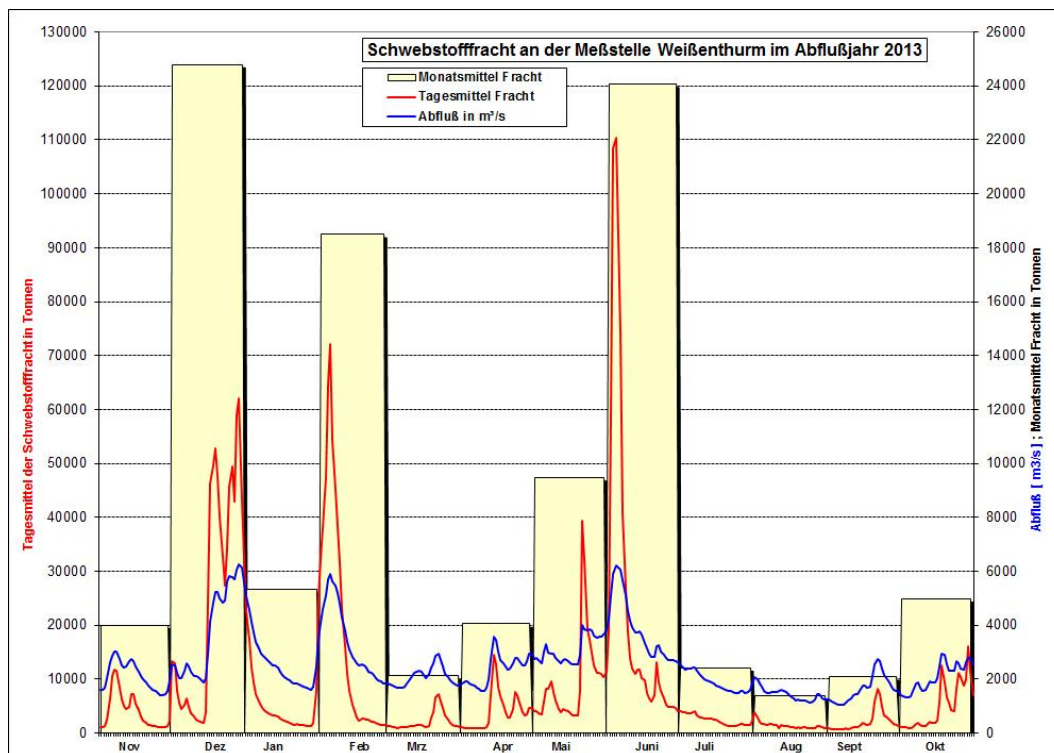


Abbildung 21b: Schwebstofffracht 2013 an der Messstelle Weißenthurm, Rhein-km 608,2

In Weißenthurm (Rhine-km 608,2) a yearly suspended sediment of 3114184 t was recorded¹; which corresponds to about 101 % of the long-term average of the reference period 1965/2007.

¹ Explanation for how the data for suspended sediment at the measurement location Weißenthurm was obtained: In the hydrological year 2013 due to a lack of staffs at the relevant WSA, the measurement of suspended sediment could only be conducted for a few days at the measurement location Weißenthurm. Therefore, the daily loads were calculated and added up from the data series of the measurement stations KAA Koblenz/Rheine (permanent measurement location obfuscation), Cochem/Moselle (permanent measurement location obfuscation) and Kalkofen/Lahn (daily bailed sample), and the concentration in Weißenthurm was calculated from the daily totals using the discharge series Andernach daily values.

The highest monthly suspended sediment was recorded at 769,111 t in January 2012 at the measurement location Weißenthurm, with a monthly average discharge (MQ) of 3780 m³/s, the lowest was only 43,153 t in August 2013 (MQ = 1440 m³/s).

The lowest daily load at the measurement location Weißenthurm was recorded at 655 t on September 06th 2013 with an average discharge of 1030 m³/s. In contrast, the highest daily load was 110,380 t on June 4th 2013 (with an average discharge of approximately 6230 m³/s).

The gauge Andernach at Rhine-km 613.8 is used as the reference gauge for determining the discharges.

2. Activities of the International Commission for the Hydrology of the Rhine (KHR) in 2013

The KHR has met twice in 2013, on 17th and 18th of April in Belval (Luxemburg) and on 18th and 19th of September in Wiesbaden (Germany).

Changes within the KHR

In the beginning of 2013 Ms. Ute Menke has taken over the position in the secretariat of Ms. Alberty Terlou.

The representative of France, Mr. Vazken Andréassian, has taken up a managerial role in the Directorate of Irstea. The future representation of France in the KHR should be decided in the near future.

Activities in the KHR projects

Climate changes

In the 71th session of the KHR, a possible continuation of RheinBlick2050 Project was discussed again. In the member states of the KHR, various projects in this area are planned. Die IKSR is mainly interested in the consequences of climate changes for the low discharges. For the time being, constructing a project plan is considered unrealistic.

ASG-Rhein: Contribution of snow and glacier melting to the Rhine discharges

In the 72th session of the KHR, the progress of the project was reported by Mr. Böhm (Company Hydron). The project was conducted by a consortium of University of Freiburg, University of Zürich and the engineering company Hydron. In September 2012, the project was started with a ‚Kick-off –Meeting‘. At the request of Switzerland, it was agreed to use a 1x1 Larsim model for the hydrological modelling of the Alpine drainage basin. Because this model belongs to the LUBW Baden-Württemberg, this Institute would be invited to the management group.

In the first phase of the project, mainly data would be collected. The meteorological data collection was successful. In the cooperation of BAFU with the Swiss Insititute for Snow and Avalanche Research, the snow data for the project will be processed.

Sediment

In the 72th session of the KHR, the preliminary results and the further planning for the project "From the source to the estuary" was presented by Ms. Gehres of BfG . The goal of the project is the construction of a sediment balance for the Rhine from the source in the Swiss Alps to the estuary in the North Sea for the time period from 1991 to 2010. The KHR participates in this project via a project advisory council. In this project, loads of clay, silt, sand, gravels and stone as well their sources and sinks are determined. The results lead to a better understanding of the process and possibly an optimisation of river management, e.g. via the use of calibrated models for river basin-wide analyses and analyses of the impacts of climate change.. The project ends in 2014 and is expected to conclude with a symposium in the beginning of 2015.

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

A project plan created by Deltares was discussed in the 71st session of the KHR. The KHR representatives found the proposal interesting but were not convinced that the specified budget for such an extensive study would be enough. It was agreed that a small colloquium as preparation for the first phase of the project would be organised. This event takes place in the beginning of 2014.

Deltares was commssioned to prepare the colloquium.

Study on the control potential of Lake Constance

Following the presentation by Mr. Belz, the topic was further discussed in the 70th session of the KHR. The KHR is of the opinion that it should be first made clear which studies have already been conducted in this area. The KHR would commission an evaluative-analytical literature study to the Technical University of Munich.

Future Activities

The KHR has established contact with the Mekong River Commission to plan a joint symposium on the topic of climate change.

The KHR celebrates its 50th anniversary in 2020. A new Rhine monograph should be published for this occasion.