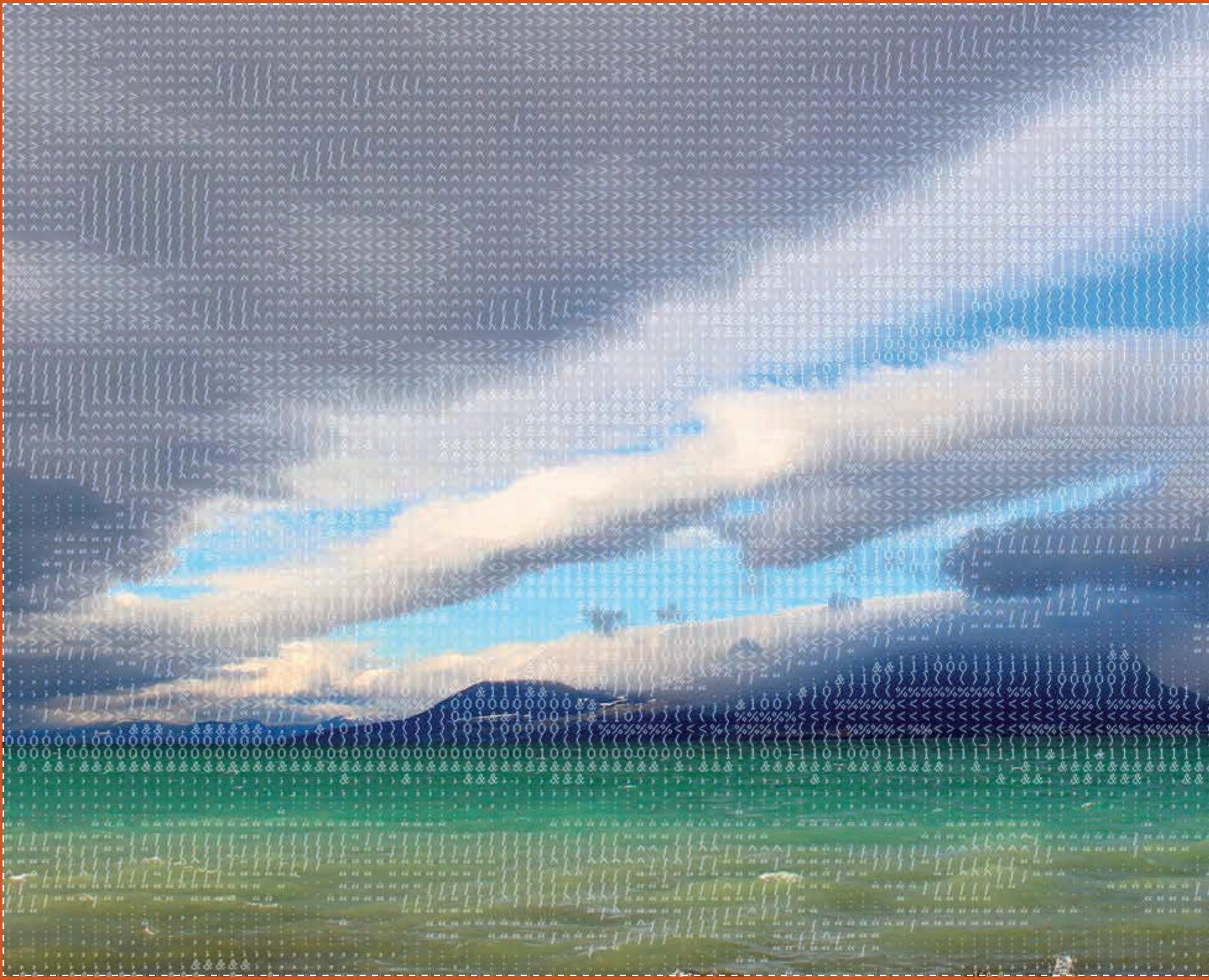
> Hydrological Yearbook of Switzerland 2012

Discharge, water level and water quality of the Swiss water bodies



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> Contents

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Authors
FOEN Hydrology Department
Weather: Federal Office for Climatology and Meteorology (MeteoSwiss)
Snow: WSL Institute for Snow and Avalanche Research (SLF)
Glaciers: Department of Geosciences, University of Fribourg, and Laboratory of Hydraulics, Hydrology and Glaciology (VAW)

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Jacqueline Dougoud, Zurich

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> Foreword

2012 – A year without notable phenomena? The major river discharges, water temperatures and groundwater levels all varied by and large within a normal range. Short-term or local anomalies occurred: the cold February, which caused water temperatures to fall and produced magical ice formations on the Swiss lakes; the impressive flood wave which moved down the rivers Zulg and Aare in Canton Bern after a violent thunderstorm at the beginning of July 2012; the heatwave in August which brought high water temperatures to delight swimmers in the rivers. These moments will be remembered by many.

Viewed as a whole though, 2012 was a normal year: for once there are no descriptions of floods or droughts in the first chapter of this Hydrological Yearbook of Switzerland. Various examples and analyses are used to show how the hydrological data for 2012 dovetail with the average for the long-term series of measurements. They also show that the year generated almost no new extremes.

However, it was a notable year for the project "Climate Change and Hydrology in Switzerland" (CCHydro), which was concluded in the spring of 2012 with a conference and a publication. Since 2009, researchers led and funded by the FOEN had studied the impact of climate change on the Swiss water regime up to the year 2100. They came to the conclusion that there will be little change to the available water supply, but that the stored volumes of snow and ice will decline as a result of the higher air temperatures. Summers are likely to be drier and winters wetter. Discharges will be seasonally redistributed and floods and low water events will probably occur more often. The consequences of this and other scenarios are being studied under the National Research Programme 61 "Sustainable Water Management". The results should be available in 2014.

However, we hope and assume that there will still be the occasional year when the Hydrological Yearbook has no notable phenomena to report.

Karine Siegwart
Vice Director
Federal Office for the Environment (FOEN)

> Abstracts

The “Hydrological Yearbook of Switzerland” is published by the Federal Office for the Environment (FOEN) and gives an overview of the hydrological situation in Switzerland. It shows the changes in water levels and discharge rates from lakes, rivers and groundwater and provides information on water temperatures and the physical and chemical properties of the principal rivers in Switzerland. Most of the data is derived from FOEN surveys.

Keywords:
hydrology, rivers, lakes, groundwater, water level, discharge, water temperature, water quality

Das «Hydrologische Jahrbuch der Schweiz» wird vom Bundesamt für Umwelt (BAFU) herausgegeben und liefert einen Überblick über das hydrologische Geschehen auf nationaler Ebene. Es zeigt die Entwicklung der Wasserstände und Abflussmengen von Seen, Fliessgewässern und Grundwasser auf und enthält Angaben zu Wassertemperaturen sowie zu physikalischen und chemischen Eigenschaften der wichtigsten Fliessgewässer der Schweiz. Die meisten Daten stammen aus Erhebungen des BAFU.

Stichwörter:
Hydrologie, Fliessgewässer, Seen, Grundwasser, Wasserstand, Abfluss, Wassertemperatur, Wasserqualität

Publié par l’Office fédéral de l’environnement (OFEV), «l’Annuaire hydrologique de la Suisse» donne une vue d’ensemble des événements hydrologiques de l’année en Suisse. Il présente l’évolution des niveaux et des débits des lacs, des cours d’eau et des eaux souterraines. Des informations sur les températures de l’eau ainsi que sur les propriétés physiques et chimiques des principaux cours d’eau suisses y figurent également. La plupart des données proviennent des relevés de l’OFEV.

Mots-clés:
hydrologie, cours d’eau, lacs, eaux souterraines, niveaux d’eau, débits, température de l’eau, qualité de l’eau

L’«Annuario idrologico della Svizzera», edito dall’Ufficio federale dell’ambiente (UFAM), fornisce una visione d’insieme degli eventi idrologici in Svizzera. Illustra l’andamento dei livelli idrometrici e delle portate dei laghi, dei corsi d’acqua e delle acque sotterranee e contiene informazioni sulle temperature e sulle proprietà fisiche e chimiche dei principali corsi d’acqua in Svizzera. I dati in esso pubblicati provengono in gran parte da rilevazioni effettuate dall’UFAM.

Parole chiave:
idrologia, corsi d’acqua, laghi, acque sotterranee, livelli delle acque, portate, temperatura dell’acqua, qualità dell’acqua

> Summary

Weather conditions

Averaged over Switzerland as a whole, the annual temperature in 2012 was 0.5 °C above the 1981–2010 average. In Northern Switzerland and some eastern parts of the northern slopes of the Alps, precipitation was 110 to 125 % of the 1981–2010 average. On the south side of the Alps and in Northern and Central Graubünden it was 110 to 120 % of the average in some parts. Elsewhere, precipitation was generally 95 to 110 % of average.

Snow and glaciers

The winter of 2011/12 was a snowy one at medium and high altitudes, particularly in December and January. Relatively little snow lay at low levels and in the south. As little snow fell in February and March and almost none in November, the total new snow throughout the winter was slightly below average. The 2011/12 hydrological year was marked by high glacier mass losses.

Discharge conditions

2012 was generally an average year. Mean annual discharges in the large catchments to the north of the Alps were between 10 and 20 % above the average for the 1981–2010 reference period. Discharges in the Rhone and Inn were just above average at about 5 %, and were just below in the Maggia and Ticino.

Monthly discharges in the large river catchments to the north of the Alps were above average, principally in January and from September to December. Low discharges were recorded from February to April and in July and August. June was well above normal in the Rhine, Reuss and Limmat and just below in the Aare. There were no significant variations from the long-term monthly averages in the major Rhone and Ticino river catchments. On the Inn, discharges were well above normal in June but below average in July.

Lake levels

The 2012 annual mean levels for Lakes Neuchâtel, Geneva and Maggiore were just a few centimetres below average. Among the larger Swiss lakes, the water level in both Lake Constance and Lake Walen (also unregulated) was well above the long-term average.

Water temperatures

The 2012 annual mean temperatures were only a few tenths of a degree above the long-term average for the 1981 to 2010 period, making them considerably lower overall than in 2011 but higher than in 2010. In 2012 the greatest positive variations from the average values occurred on the lower sections of the large Aare and Rhine river basins, where they were around 0.5 °C.

Stable isotopes

The stable water isotopes in the precipitation had low δ values at the beginning and end of the year as the result of above-average snowfalls. In August the δ values were above average because of the hot weather.

Groundwater

Groundwater levels and spring discharges were generally normal in 2012. Nevertheless, low groundwater levels occurred locally in the hot, dry summer months of July and August, and high levels occurred from September to November as a result of above-average precipitation.

1 > Notable phenomena in 2012

The year 2012 had few notable hydrological phenomena. The discharges from the major river catchments, water temperatures and also groundwater levels varied generally within the normal range.

1.1 2012 – an unremarkable year

2012 brought a cold spell in February, limited local floods in late June/early July and in October and a heatwave at the end of August. In general this year of little damage will be remembered as normal and unspectacular. This is illustrated by four examples.

Annual precipitation and annual discharge

Figure 1.1 shows precipitation since 1901 compared with discharge (mean for Switzerland as a whole). The orange point represents 2012. Its position shows that the year lies in the middle range for both annual precipitation and annual average discharge.

Duration curves compared

The 2012 duration curve for the Rhone at Porte du Scex is compared in Figure 1.2 with the curves for a very wet year (1999) and an extremely dry year (1976) and with the curve for the 1981–2010 reference period. In the high and medium discharge range, the values for the year under review are very close to those for the reference period. The duration curves for the low discharges lie within a narrow band. This is due to the great influence exerted by hydropower use, which has the effect of evening out the low water discharges.

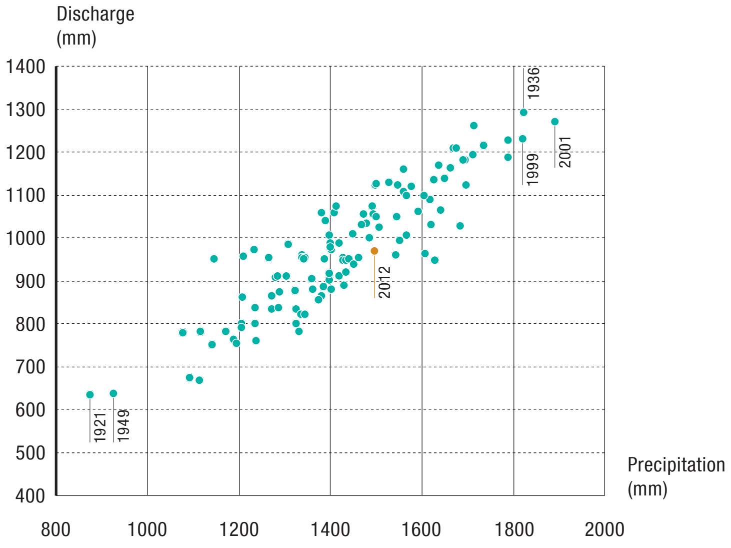


Figure 1.1 *Annual precipitation and annual mean discharge from 1901 to 2012 for Switzerland as a whole. 2012 in orange.*

Average lake levels

To gain a profile of the lake levels, the number of days on which the water level in Lake Constance was above a specific threshold was determined. The threshold used was the summer height, which is the highest of the twelve long-term monthly averages. The summer height in Lake Constance in July was 396.41 m AMSL. Figure 1.3 shows the number of days on which the summer height has been exceeded since 1930. At 42 days, 2012 was just above the long-term average of 39.5 days.

Average water temperatures

The monthly average water temperatures in 2010, 2011 and 2012 at the Aare monitoring station at Bern are compared in Figure 1.4. Here the 2012 annual average temperature was much lower than in the dry and warm year of 2011, but higher than in 2010.

At the Aare monitoring station at Bern the water temperature in February was 0.7 °C below the long-term monthly average. However, it did not reach a new monthly minimum – unlike at a number of stations on the lower sections of the large Aare and Rhine rivers and the Rhone below Lake Geneva. The heatwave in August resulted in a monthly average which was 2 °C above the long-term average but still 1.4 °C below the August 2003 record.

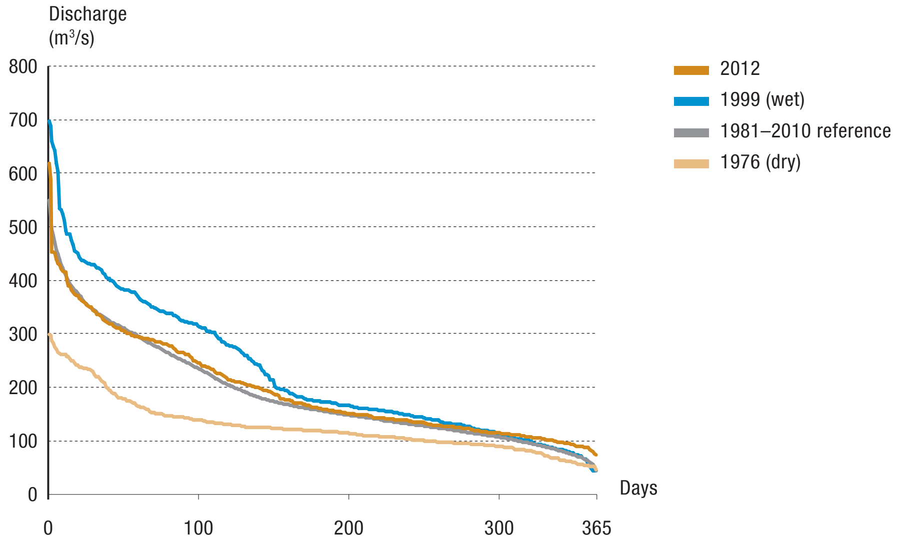


Figure 1.2 *Discharge duration curves for the Rhône – Porte du Scex station. Comparison between the year under review and a wet and a dry year and with the 1981–2010 reference period.*

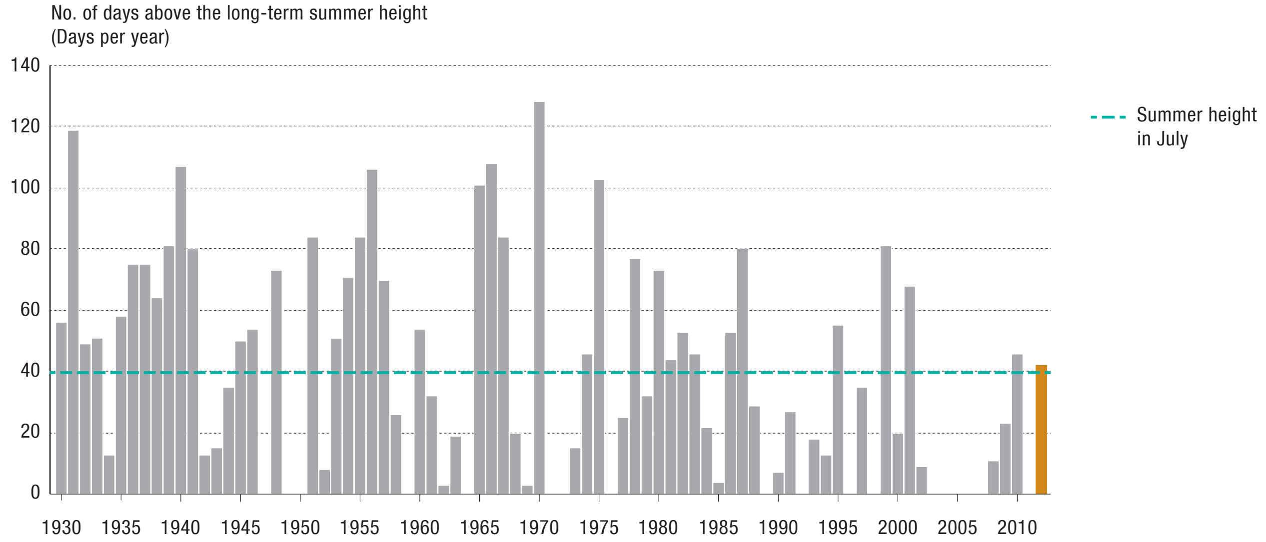


Figure 1.3 *Number of days on which the water level in Lake Constance was above the summer height. 2012 in orange.*

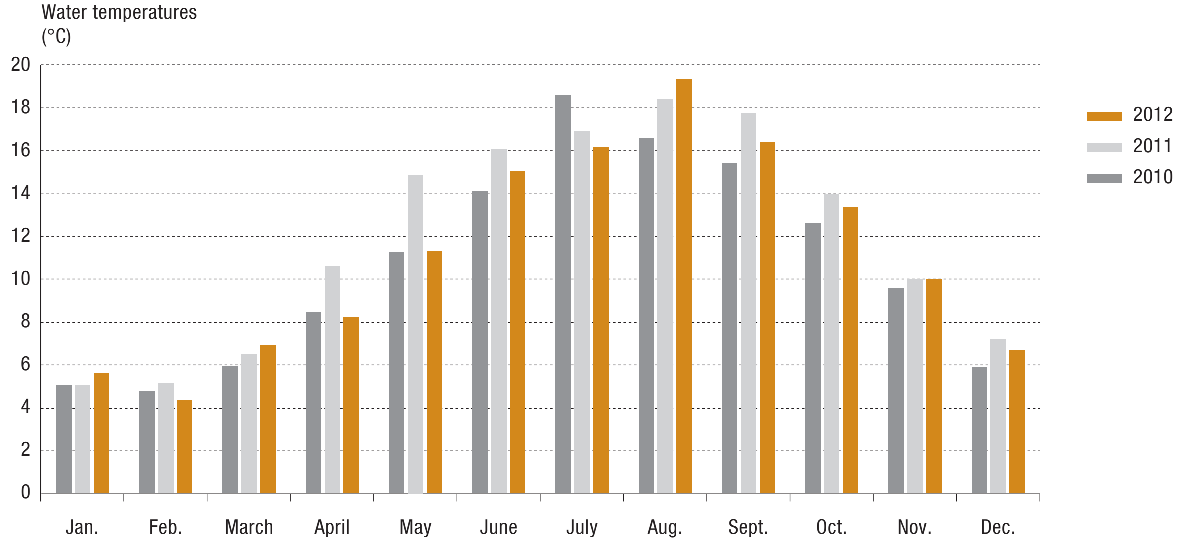


Figure 1.4 *Monthly average water temperatures in 2010, 2011 and 2012 at the Aare – Bern station.*

1.2 "Mean discharge" indicator

The amount of water discharged on average during a year or a season is called mean discharge. Naturally, it depends on the precipitation falling in the region and how much of that does not become discharge through evaporation or long-term storage (e.g. in glaciers). It can also be affected by human activity, for example by water management intervention (e.g. irrigation, water diversion, water retention in reservoirs or lake regulation). Discharge and its distribution over the seasons are important parameters for water ecology and management (hydropower, drinking water use, irrigation, navigation).

Long discharge time series reveal how the water regime changes as a result of the above-mentioned influences. Discharge reacts sensitively to changes in climate: the rise in air temperature observed since the 19th century boosts glacier melt and increases evaporation. A simultaneous increase in precipitation has also been observed over the past hundred years. In contrast to the summer and winter discharges, no trend is apparent in the mean discharge over the year. The individual annual discharges are subject to very wide fluctuations. Looking at the 20th century overall, no clear trends can be seen in either the Rhine at Basel or the Rhone at Porte du Scex. But a breakdown into winter and summer half years does indicate that mean discharge is tending to increase slightly in winter and to fall in the summer season.

Winter discharges are increasing because in an increasingly warm climate, more precipitation falls as rain in the winter and less is stored temporarily as snow or ice. Then at the time of the snow and glacier melt in summer part of the storage effect is lost and summer discharges tend to decrease. The effects of this on nature, water quality and water management can be both positive (e.g. higher hydropower production in winter) and negative (e.g. drought and water shortage in summer).

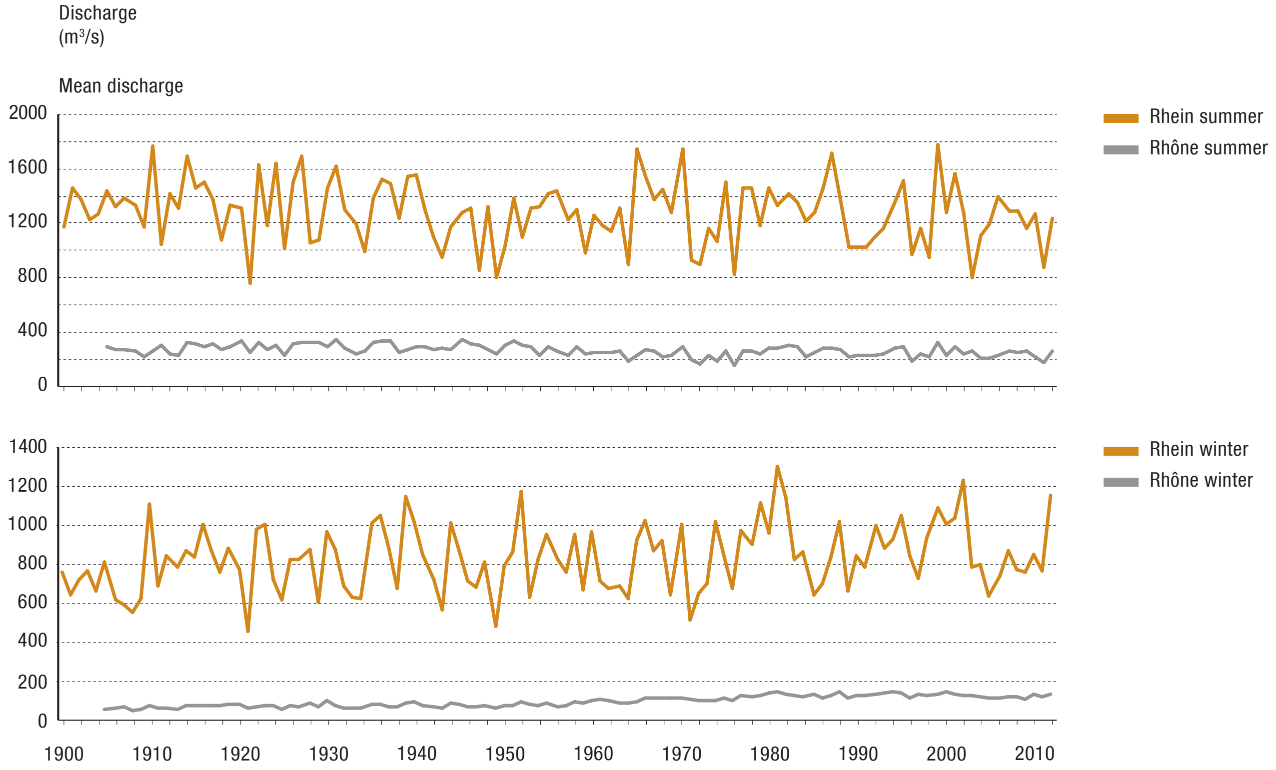


Figure 1.5 *Mean summer and winter discharges at the Rhein – Basel and Rhône – Porte du Scex stations since 1900 and 1905.*

2 > Weather conditions

Averaged across Switzerland as a whole, the 2012 annual temperature was 0.5 °C above the 1981 to 2010 average. In Northern Switzerland and some eastern parts of the northern slopes of the Alps, precipitation was 110 to 125 % of the 1981–2010 average. In some places on the south side of the Alps and in Northern and Central Graubünden it was 110 to 120 % of normal and elsewhere it was widely 95 to 110 %.

By the end of 2011, snow depth was already widely above average in the Swiss Alps. A strong north-westerly flow in the first few days of 2012 again brought large snowfalls at higher altitudes. From the beginning of February, Switzerland was in the grip of the worst cold spell for 27 years. In the second week of February smaller lakes on the Central Plateau froze. It then turned unusually mild. In the second half of February, exceptionally mild weather affected the south side of the Alps, before spreading across the whole of Switzerland, continuing into the first few days of April. It was the second warmest March on record nationally, and was the warmest on the southern side of the Alps since records began in 1864.

After the record warm spell, the weather until late April was changeable and cool. On 11 May temperatures were 27 to 29 °C in many places, and over 30 °C was recorded at others.

Just one day after the summer heat, Switzerland was again firmly in the grip of cold polar air. With heavy rain, temperatures in the lowlands only reached just above 10 °C. Further heavy precipitation followed in the last third of May. The first half of June was cloudy and wet countrywide. Changeable periods of weather with repeated incursions of cool air masses were also predominant in the first three weeks of July.

A sustained longer period of summery conditions for the whole of Switzerland did not arrive until August. After mid-month Switzerland actually experienced a real heatwave.

A strong polar air stream in late August brought the high summer of 2012 to an end. Large amounts of precipitation fell in the northern Alps. In the last few days of September strong Föhn wind conditions set in, with heavy relief precipitation regionally on the south side of the Alps. Afterwards the weather alternated rapidly between sunny and mild and wet and grey days, followed in mid-October by another powerful blast of cold air with heavy precipitation. There was then a beautiful Indian summer from 17 to 25 October

A huge blast of polar air in the final days of October laid a blanket of snow over a large part of Switzerland. On 12 November a sustained autumnal high pressure system was established, with mild and sunny weather. In the final days of November heavy precipitation set in in the west and particularly on the south side of the Alps. After heavy snowfall, most of Switzerland was white on 8 December. The snow cover remained for around a week in the lowlands north of the Alps before disappearing during the third weekend of December in the rain and mild temperatures. Yet on the south side of the Alps it snowed heavily up to that weekend.

Source: Federal Office for Meteorology and Climatology (MeteoSwiss)

Total annual precipitation (% of average)

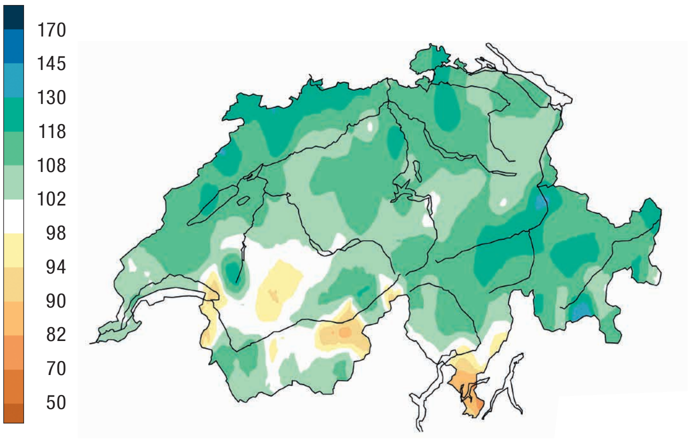


Figure 2.1 *Annual precipitation amounts widely reached 95 to 110 % of normal. Even higher precipitation fell in regions of Northern and Eastern Switzerland.*

3 > Snow and glaciers

The winter of 2011/12 was a snowy one at medium and high altitudes, particularly in December and January. There was relatively little snow at low levels and in the south. As little snow fell in February and March and almost none in November, the total new snow over the whole winter was slightly below average. The hydrological year 2011/12 was marked by high glacier mass losses.

3.1 Snow

Snow depth over the whole winter was

> above average in the Valais (apart from the Goms region), in the northern Alps, in Northern and Central Graubünden and in the Lower Engadine,
> average in the Goms, the Gotthard area and Val Müstair,
> below average in the southern Alps and in the Upper Engadine.

The autumn of 2011 saw little snow and was very warm, with snow in the south only at high altitude. Except for southern regions, it did not begin to snow until December. In December and January exceptionally high snowfalls occurred in the Valais, on the northern alpine slopes and in Graubünden, resulting in record snow depths, frequent high avalanche risks and accidents and property damage in some regions.

Although the snow cover was generally well consolidated, very compact and thick, serious snow slides began shortly after the snow cover was established; high snow slide avalanche activity followed from December.

During the cold spell in February 2012, weak layers formed near the surface. The snow cover began to loosen at the end of February. Many wet snow and snow slide avalanches were triggered in two phases, some of which caused property damage. The snow melt then began. By March the avalanche situation was generally good. Wintry conditions returned in some parts in April and the snow melt declined. In the north, there was still above-average snow cover in the spring. Medium altitudes lost snow cover in May and as early as April in the south. High altitudes became snow free in June and July.

During the June to September period there were eight spells of cold air. At the height of summer snow fell mainly on the high peaks, but in June and September it snowed down to medium altitudes. Due to the heat and frequent rainfall, there was barely any snow on the high peaks in August. In September a blanket of snow formed again in the high mountains.

Source: WSL Institute for Snow and Avalanche Research (SLF)

Snow depth (% of average)

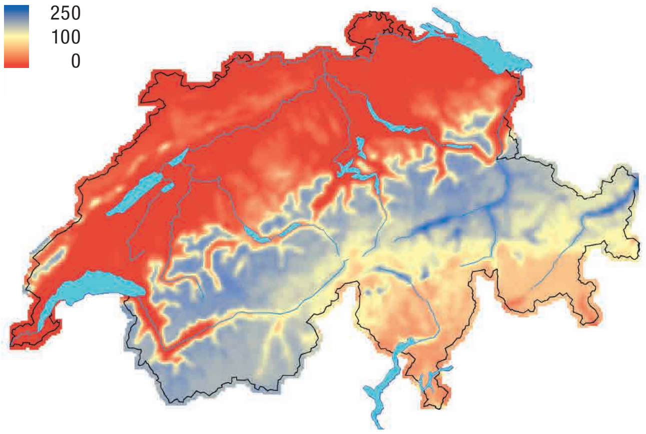


Figure 3.1 *Snow depths in winter 2011/12 compared with the 1971 to 2000 period during the winter months of November to April.*

3.2 Glaciers

Glaciers in Switzerland again recorded high mass losses in the hydrological year 2011/12. These were not quite as high as in the hydrological year 2010/11, but were nonetheless considerable. Although the winter was a relatively snowy one on the glaciers and the snow disappeared later than in the previous year, the melt was intensive at the end of June and particularly in August 2012.

On the glaciers studied, mass balances were measured of between –510 mm water equivalent (Adler glacier) and –2100 mm water equivalent (Gries glacier). The Blau Schnee glacier in the Säntis area actually recorded a clear positive mass balance, although an exact measurement could not be taken. This situation was probably the result of a local effect. Most glaciers had mass balances equivalent to the loss of one metre ice thickness, slightly below the average for previous years. However, the past decade has been marked by extreme glacier melt rates, the hydrological year 2011/12 therefore did not relate to an easing of the situation.

The data indicate a slight north-south gradient: the two measurement series between Ticino and the Valais (Basodino and Gries) are conspicuous for their very negative mass balances. However, this effect seems to be limited predominantly to the regions south of the main Alpine ridge.

The mass losses from the glaciers in the Valais approximate to the average for the past 10 years. Though the glaciers in the northern Alps lost much greater mass in the hydrological year 2010/11 than those further south, the situation was balanced in the period under review.

Source: Department of Geosciences, University of Fribourg and Laboratory for Hydraulics, Hydrology and Glaciology (VAW)

Figure 3.2 *View of the Vorabfirn (GL, GR) in July 2012.*

4 > Rivers and lakes

2012 was generally an average year for discharge and water temperature. In the large river catchments to the north of the Alps, the annual mean discharge was between 10 and 20 % above the average for the reference period. Discharge in the Maggia and Ticino was just below average.

4.1 Discharge conditions

In the large river catchments to the north of the Alps, the annual mean discharge was between 10 and 20 % above the average for the 1981–2010 reference period (Figure 4.1). The Rhone and Inn were slightly above average at about 5 % and the Maggia and Ticino were just below.

The spread of variations in the 2012 annual mean from the long-term averages was greater for the medium-sized catchments (Figure 4.2). The river with the greatest positive deviation from normal was the Ergolz at +40 %. The catchments with the greatest negative difference were in the Ticino (those with the monitoring stations Cassarate – Pregassona at –28 % deviation or 72 % of the reference value, Ticino – Piotta at 87 % and Moesa – Lumino at 88 % of normal discharge). Half of the fifty or so other selected catchments were in the neutral range (90 to 110 % of average) and half were in the slightly above-average range (110 to 130 % of average). The catchments with above-average discharges were mainly located in the Jura and the eastern part of the area north of the Alps; most of the catchments with normal discharges were in Western Switzerland, the Valais and the Engadine.

Looking at the monthly discharges, some similarities can be seen in the large river catchments on the northern side of the Alps (Figure 4.3). Monthly discharges were mainly above average in January and from September to December. Low discharges were recorded from February to April and in July and August. June was significantly above average in the Rhine, Reuss and Limmat and just below in the Aare. We can also see similar patterns in the medium-sized catchments of the Thur at Andelfingen and Emme at Emmenmatt (Figure 4.4). In the major river catchments of the Rhone and

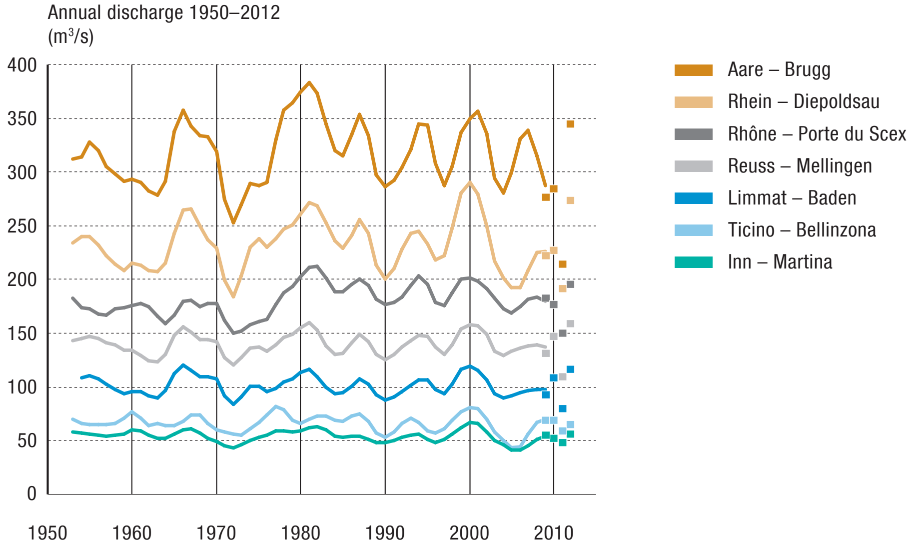


Figure 4.1 *Variation in the annual discharge for selected large catchments since 1950. Moving averages (over seven years) are shown as lines and the last four annual discharges are shown as points.*

Ticino there were no significant deviations from the long-term monthly average. On the Inn, June was well above normal but July was below.

Some of the daily mean hydrographs fluctuate widely. Particularly noteworthy were the rapid sharp changes from flood to low water at the beginning of July on the Aare, Reuss and Limmat and the series of smaller floods on the Aare and Rhine from October to year end (Figure 4.5). Particularly evident was a distinctive event in October which occurred in all the river catchments on the northern side of the Alps.

Two events deserve closer attention: on Monday 2 July 2012 a strong southerly wind drove moist, unstable air towards the southern flank of the Alps and brought heavy showers and thunderstorms, some of which reached the area north of the Alps. The precipitation, combined with the snow and glacier melt, led to high water levels and discharges in the rivers and lakes in the Valais and the Grimsel and Gotthard region. Many FOEN monitoring stations in these areas recorded floods which statistically only occur every two to ten years. A discharge volume within the range of a 30-year flood was measured on the Rhone at Reckingen, and on the Goneri at Oberwald even a 100-year flood was recorded – although it should be noted that the measurement series at that station is still relatively short (monitoring began in 1991). New maximums for the month of July were recorded at these two stations and on the Massa at Blatten (Figure 4.8), the Rhone at Brig and the Vispa at Visp.

On 8 October Switzerland was under a warm front which remained stationary for several days. A moderate north-westerly wind brought bursts of moist, mild air which built up along the Alps. This resulted widely in discharges with a return period of about two years. Ten-year floods were recorded on the Ergolz and Lorze. Lake Lucerne reached danger level 2 (moderate danger) and Lake Zurich danger level 3 (considerable danger).

In a large monitoring network there are always stations where records are set, even in a generally average year. *Regionally*, maximum monthly discharge peaks occurred in January, June, July (Valais), September (Kleine Emme and Sarner Aa) and November (North-West Switzerland). *Transregionally*, there were new maximum monthly discharge peaks in April (Central Switzerland) and October (Emme, Reuss, Limmat and Thur). *Isolated* new minimum daily means occurred in February, May and August. In 2012 there were no months in which drought was widely observed.

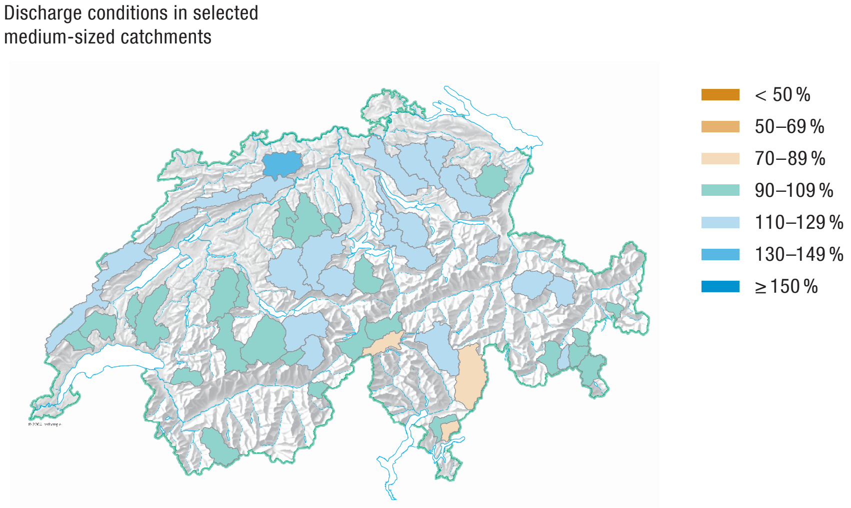


Figure 4.2 *Annual mean 2012 compared with the mean discharge for the long-term reference period 1981–2010 in selected medium-sized catchments [%].*

Monthly mean discharges in selected large catchments

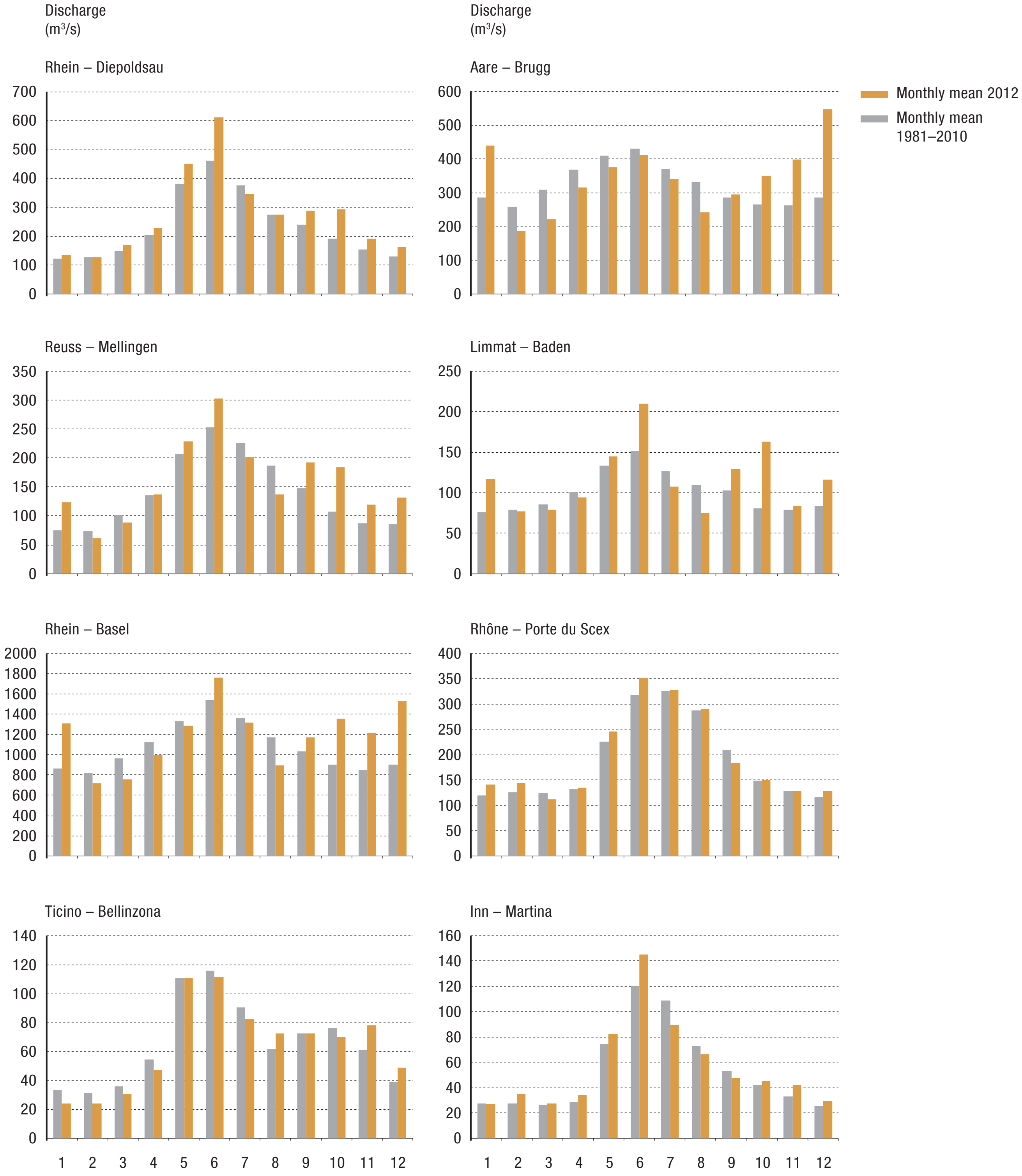


Figure 4.3 *Monthly mean discharges 2012 (orange) compared with the monthly mean for the long-term average period 1981–2010 (grey).*

Monthly mean discharges in selected medium-sized catchments

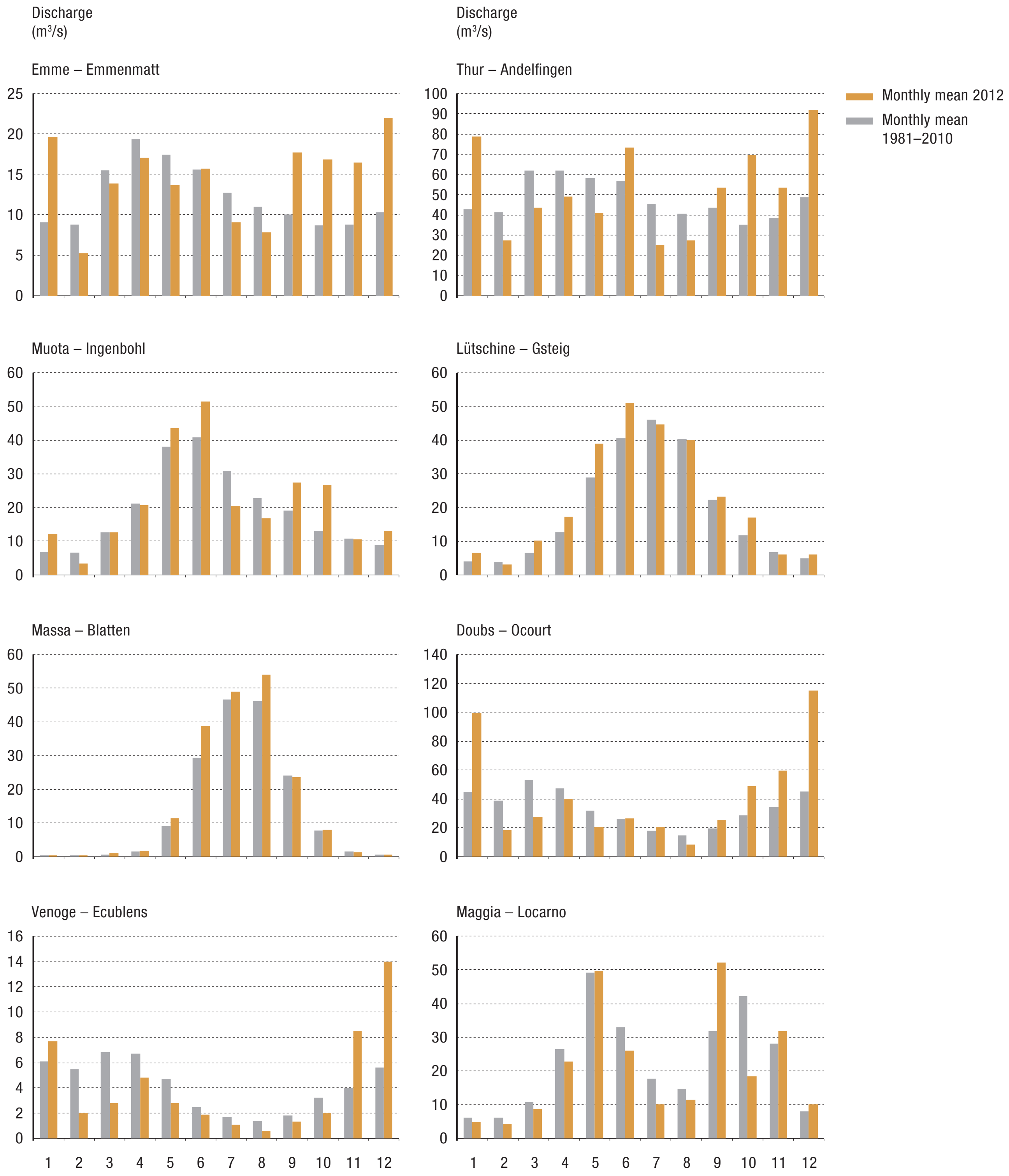
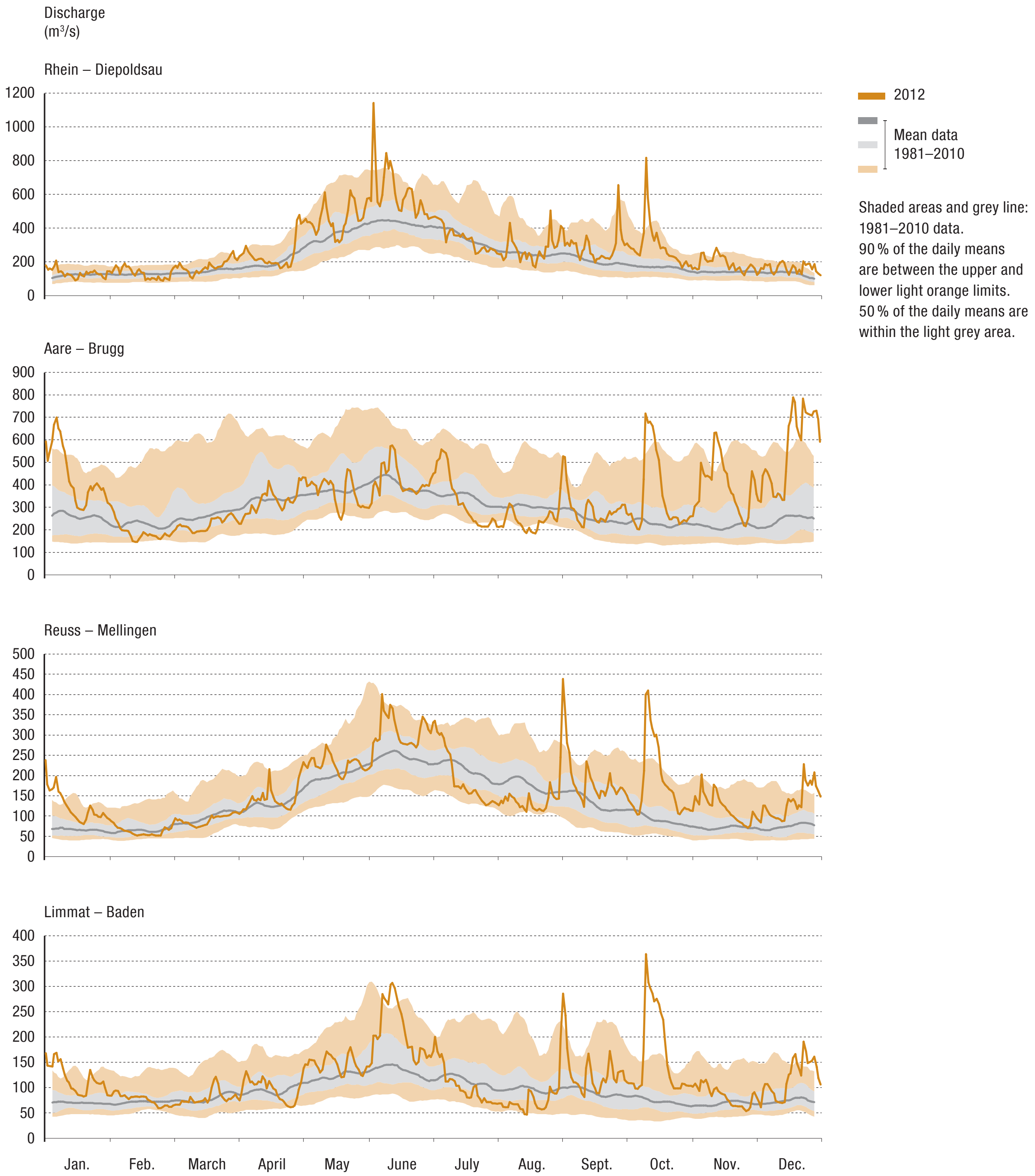


Figure 4.4 *Monthly mean discharges 2012 (orange) compared with the monthly mean for the long-term average period 1981–2010 (grey).*

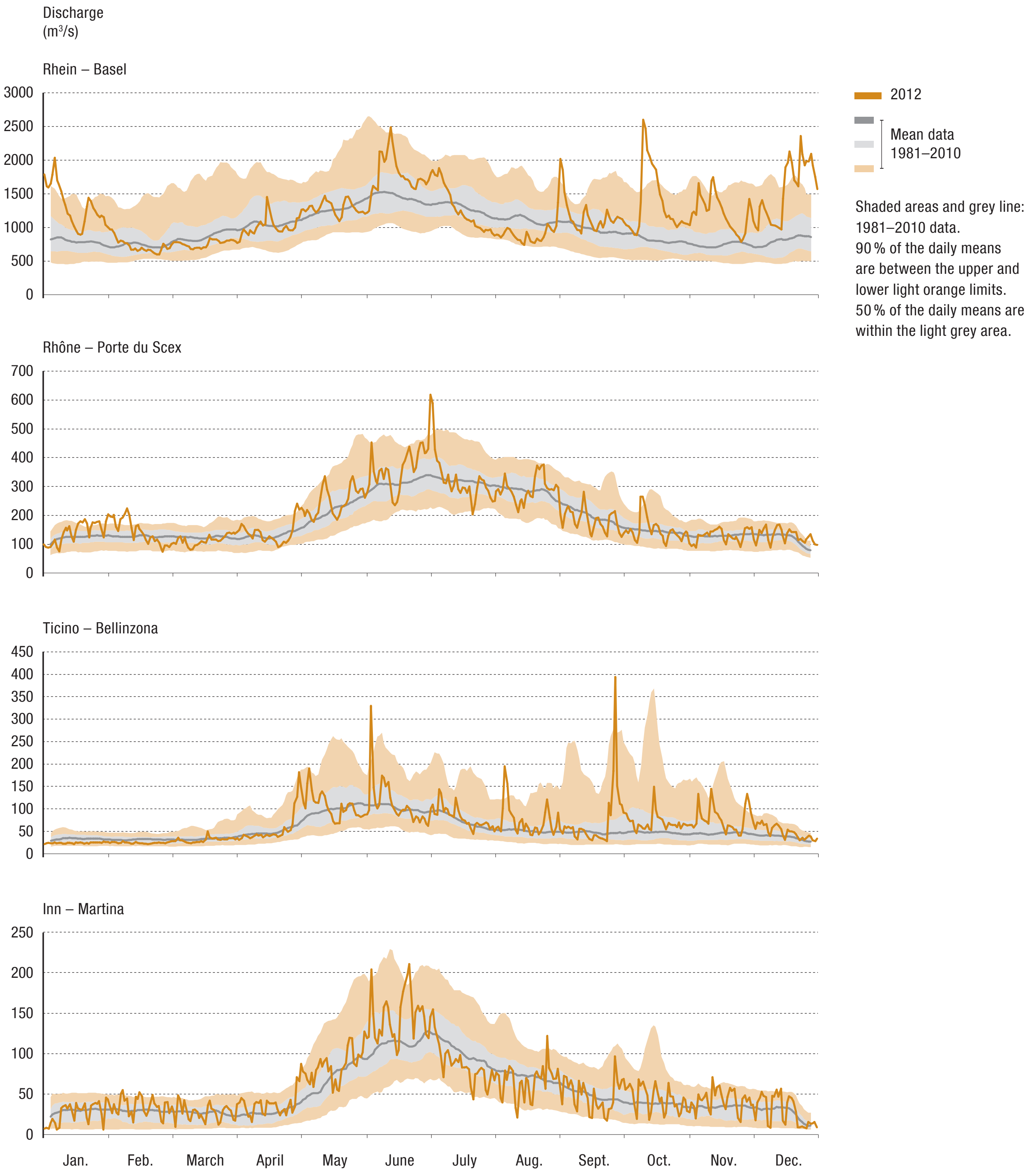
Daily mean discharges in selected large catchments (1/2)



Shaded areas and grey line: 1981–2010 data. 90 % of the daily means are between the upper and lower light orange limits. 50 % of the daily means are within the light grey area.

Figure 4.5 *Daily mean discharges 2012 (orange line) compared with the daily mean for the long-term average period 1981–2010 (grey).*

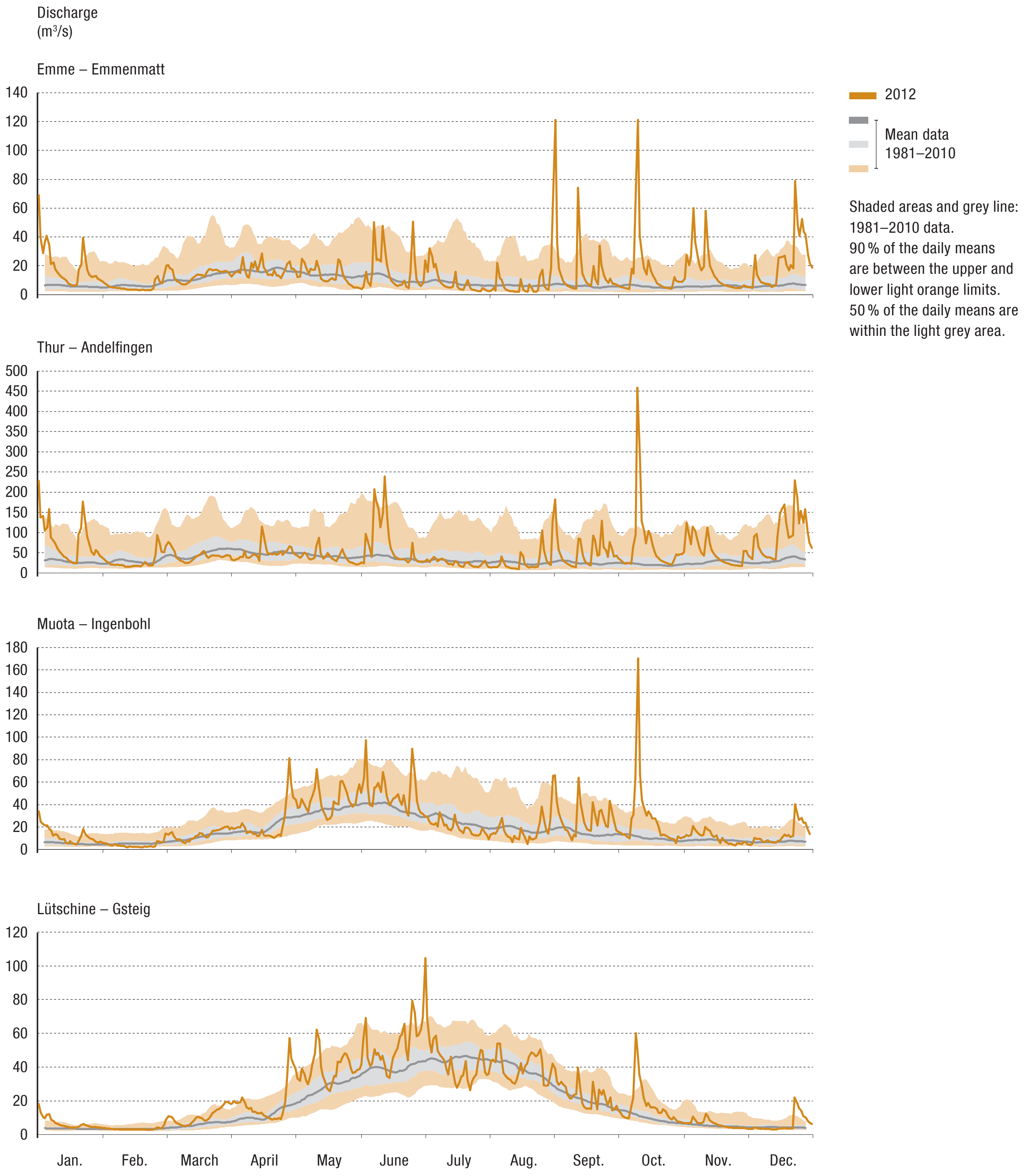
Daily mean discharges in selected large catchments (2/2)



Shaded areas and grey line: 1981–2010 data. 90 % of the daily means are between the upper and lower light orange limits. 50 % of the daily means are within the light grey area.

Figure 4.6 *Daily mean discharges 2012 (orange line) compared with the daily mean for the long-term average period 1981–2010 (grey).*

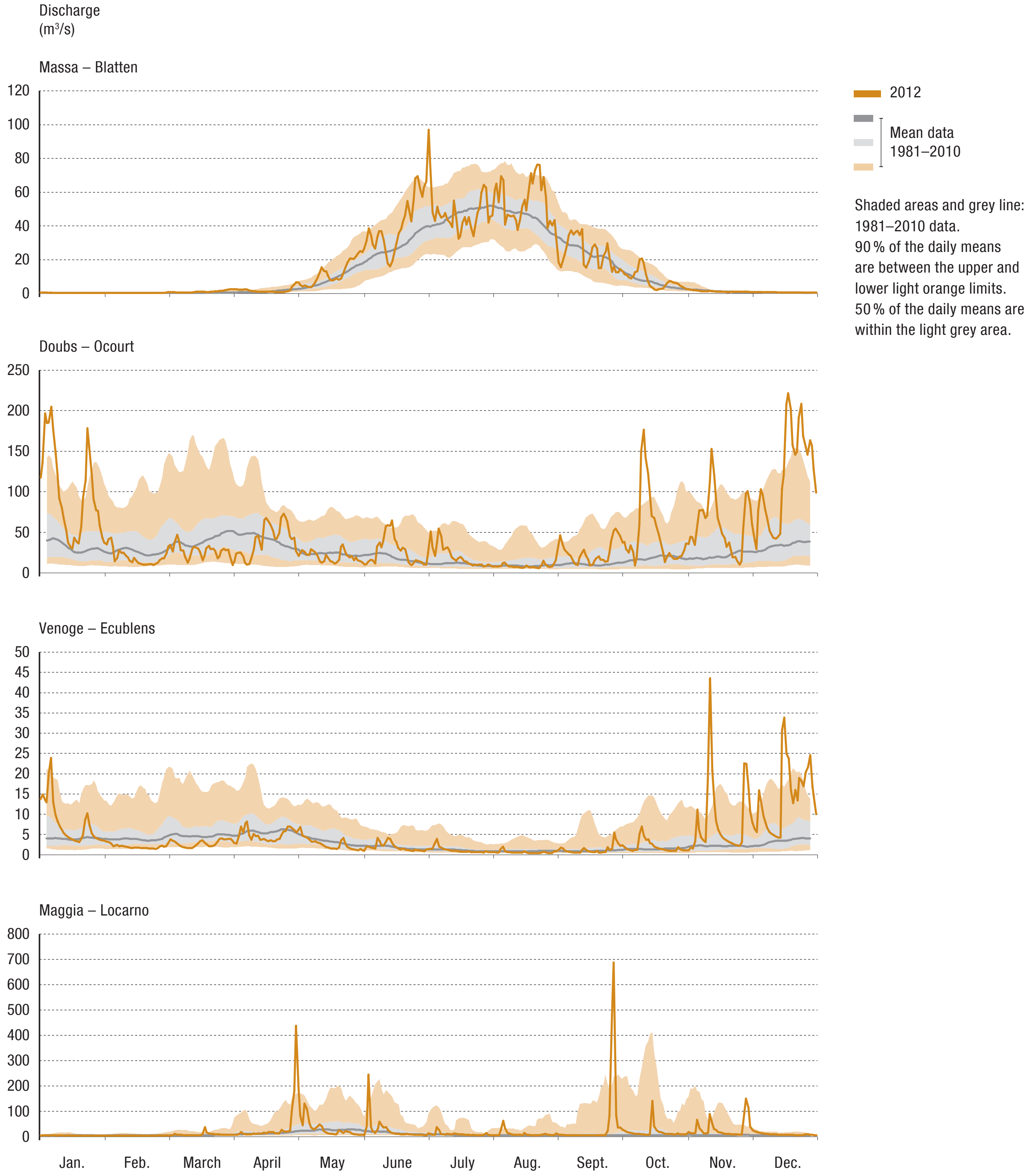
Daily mean discharges in selected medium-sized catchments (1/2)



Shaded areas and grey line: 1981–2010 data. 90 % of the daily means are between the upper and lower light orange limits. 50 % of the daily means are within the light grey area.

Figure 4.7 *Daily mean discharges 2012 (orange line) compared with the daily mean for the long-term average period 1981–2010 (grey).*

Daily mean discharges in selected medium-sized catchments (2/2)



Shaded areas and grey line: 1981–2010 data. 90 % of the daily means are between the upper and lower light orange limits. 50 % of the daily means are within the light grey area.

Figure 4.8 *Daily mean discharges 2012 (orange line) compared with the daily mean for the long-term average period 1981–2010 (grey).*

4.2 Lake levels

On Lake Constance (unregulated), the 2012 annual mean varied from the long-term average water level by +28 cm. As expected, the deviations on the regulated lakes were low, given that regulation is used to try to maintain the water at a specific level according to the season. Lakes Neuchâtel, Geneva and Maggiore were just a few centimetres below average values in 2012. Among the larger Swiss lakes, apart from Lake Constance, the water level in Lake Walen (also unregulated) was well above the long-term average (Figure 4.9).

There were wide deviations from the annual average on Lake Constance because water levels were hardly ever below average during the year. The early part of the year saw water levels above average, followed by a normal phase from the end of February to the beginning of June, above-average monthly values in June (+45 cm) and July, a quiet period in August, then water levels well above average from September to year end. The deviations from average were considerable in June and October, but the peaks were far from extreme. The highest June peak was 97 cm below the June maximum of 1999, and although the highest recorded level in October was far above the long-term October average, it was still 19 cm below the October maximum for the whole monitoring period.

It is not always easy to regulate the water level of a lake, and deviations from an ideal value cannot be prevented in every case. In Lake Neuchâtel the stable annual balance was only achieved because the significant negative deviations from the mean values for February to July were balanced by positive deviations from October to year end.

In Lake Geneva, the low levels in March and April were notable, as was the rise in water level in June – delayed by about a month compared with an average regime. The monthly mean in May was therefore 18 cm below the long-term May average. This made the late seasonal rise even steeper, and the water level exceeded the 95th quantile in June. Water levels in the second half of the year were very close to average.

In Lake Maggiore the 2012 variation was very pronounced: the water level was some 50 cm below the long-term average in February and March, around 30 cm above average from May to July, 50 cm below average in September and then more than 30 cm above average once again in November and December.

Monthly mean water levels in selected lakes

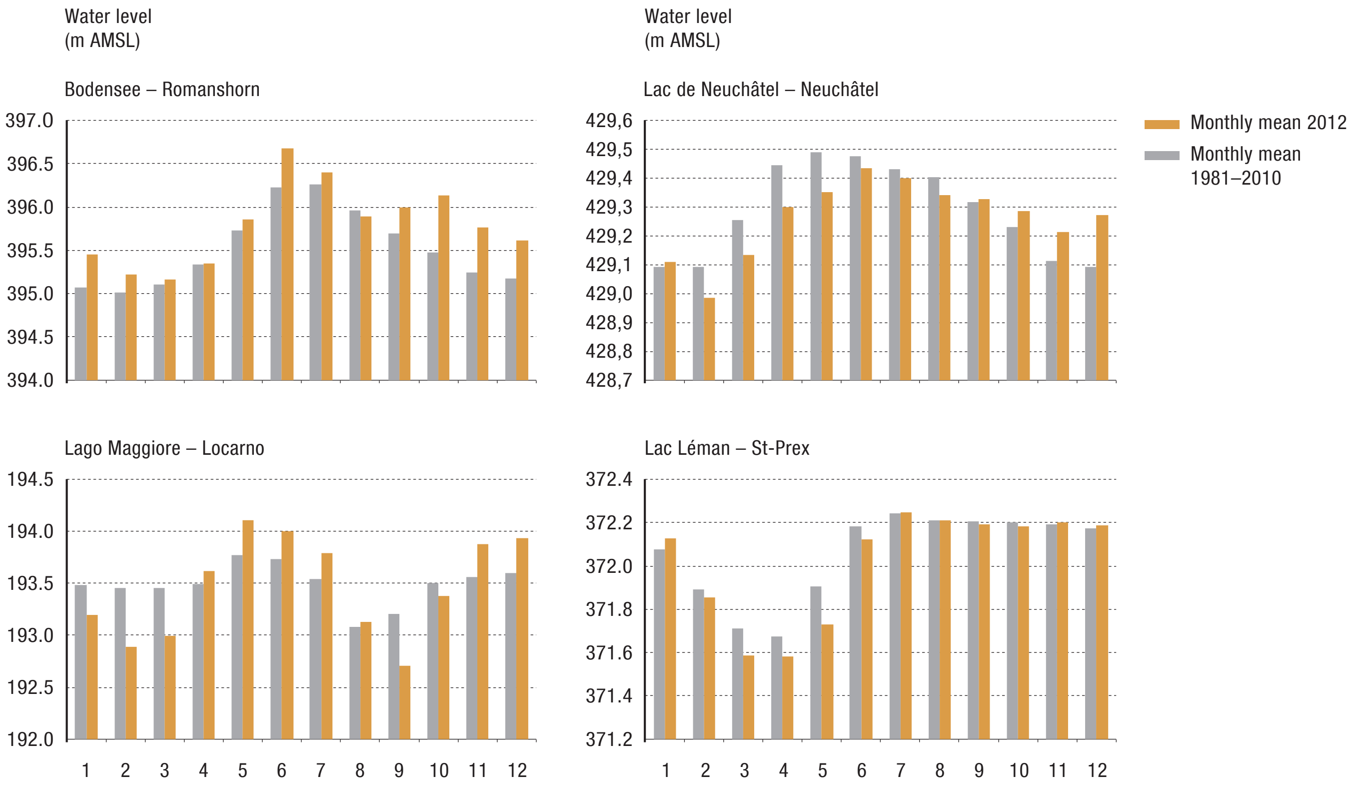


Figure 4.9 *Monthly mean water levels 2012 (orange) compared with the monthly mean for the long-term average period 1981–2010 (grey).*

Daily water levels in selected lakes

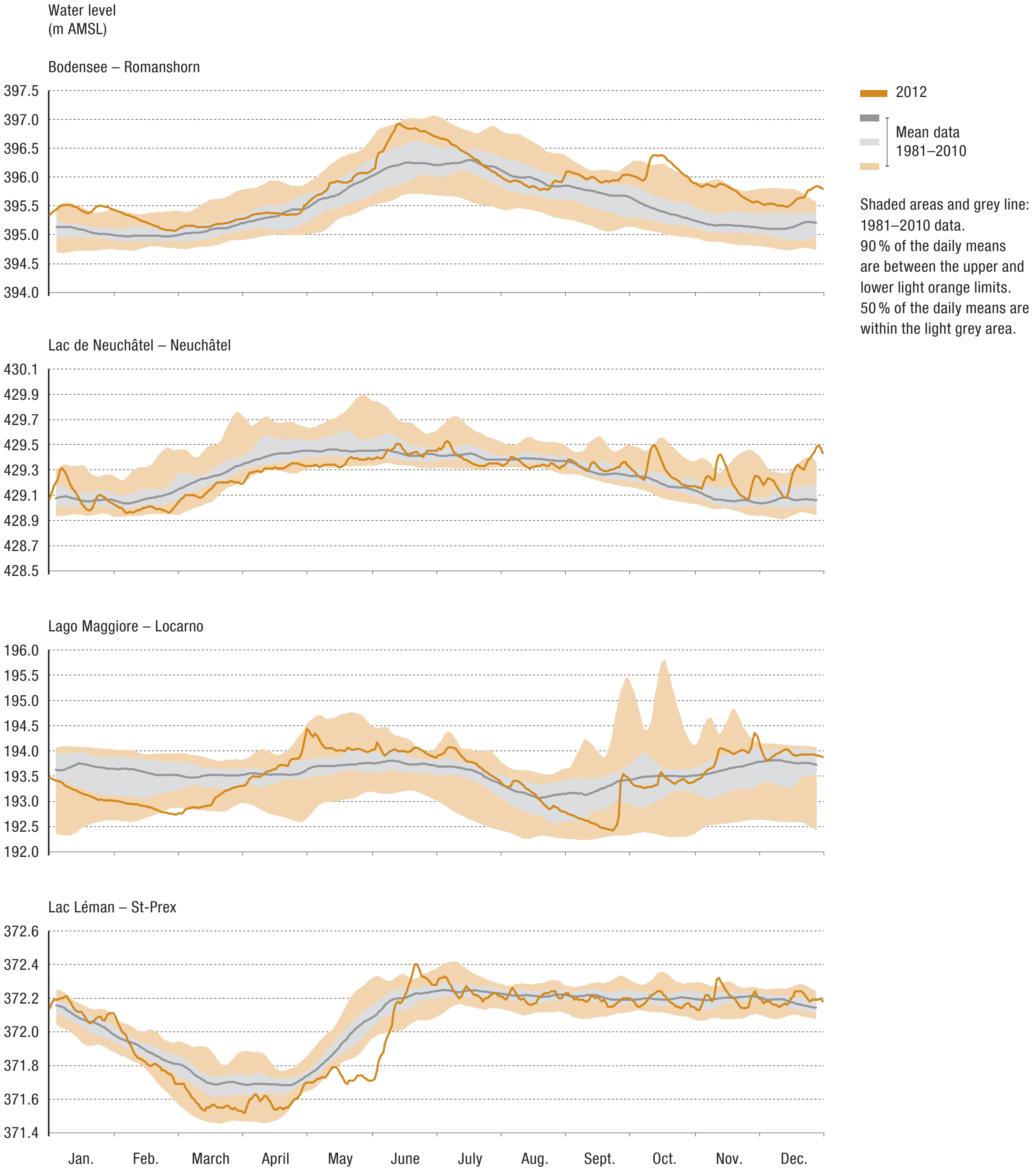


Figure 4.10 *Daily mean water levels 2012 (orange line) compared with the daily mean for the long-term average period 1981–2010.*

4.3 Water temperatures

The 2012 annual mean water temperatures were only a few tenths of a degree above the long-term average for the 1981–2010 period and were therefore generally much lower than in 2011 but higher than in 2010. Figure 4.11 shows that the variability differs in the various river catchments. The annual means for the last three years were within 0.4 °C on the Rhone at Porte du Scex, within 1.3 °C on the Rhine at Rekingen and within 1.4 °C on the Rhine at Basel. In 2012 the largest positive deviations from the average values occurred on the lower sections of the large Aare and Rhine river catchments; they were around 0.5 °C. The highest positive difference from the long-term annual average was recorded on the Broye at Payerne, namely +0.8 °C; only a few stations were below the long-term average. Two of these were the Rhone at Sion (–0.1 °C) and the Muota at Ingenbohl (–0.2 °C). No station in the temperature monitoring network reached a temperature that exceeded the previous highest annual average or was below the lowest annual average.

During the year, there were few significant deviations from the reference period median in the daily mean temperatures in the four large catchments shown in Figure 4.12. The February figure was well below the 5 % quantile boundary. This was observed in all the river catchments. In the Aare and Rhine, temperatures rose well above the average during the second half of August. In the Rhone, temperatures in the autumn fluctuated at an above-average level, and at the end of December temperatures in the Rhone and Ticino again rose briefly to the 95 % quantile boundary.

In terms of monthly maximums or minimums, only February was noteworthy in 2012. In this generally unspectacular year, new monthly minimums were recorded in February to the north of the Alps in the lower sections of the major rivers (Aare, Rhine, and Rhone below Lake Geneva). An exception to the temperature situation was the Aare – Brienzwiler station, where the highest February value of the 44-year measurement series, 7.9 °C, was recorded on 28 February. The above-average August temperatures mentioned above were not very significant and did not result in new monthly maximums.

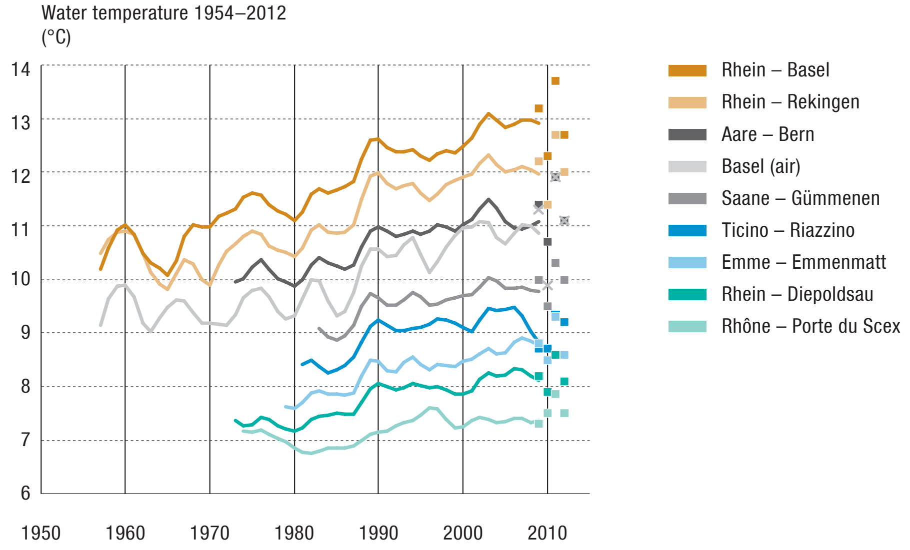
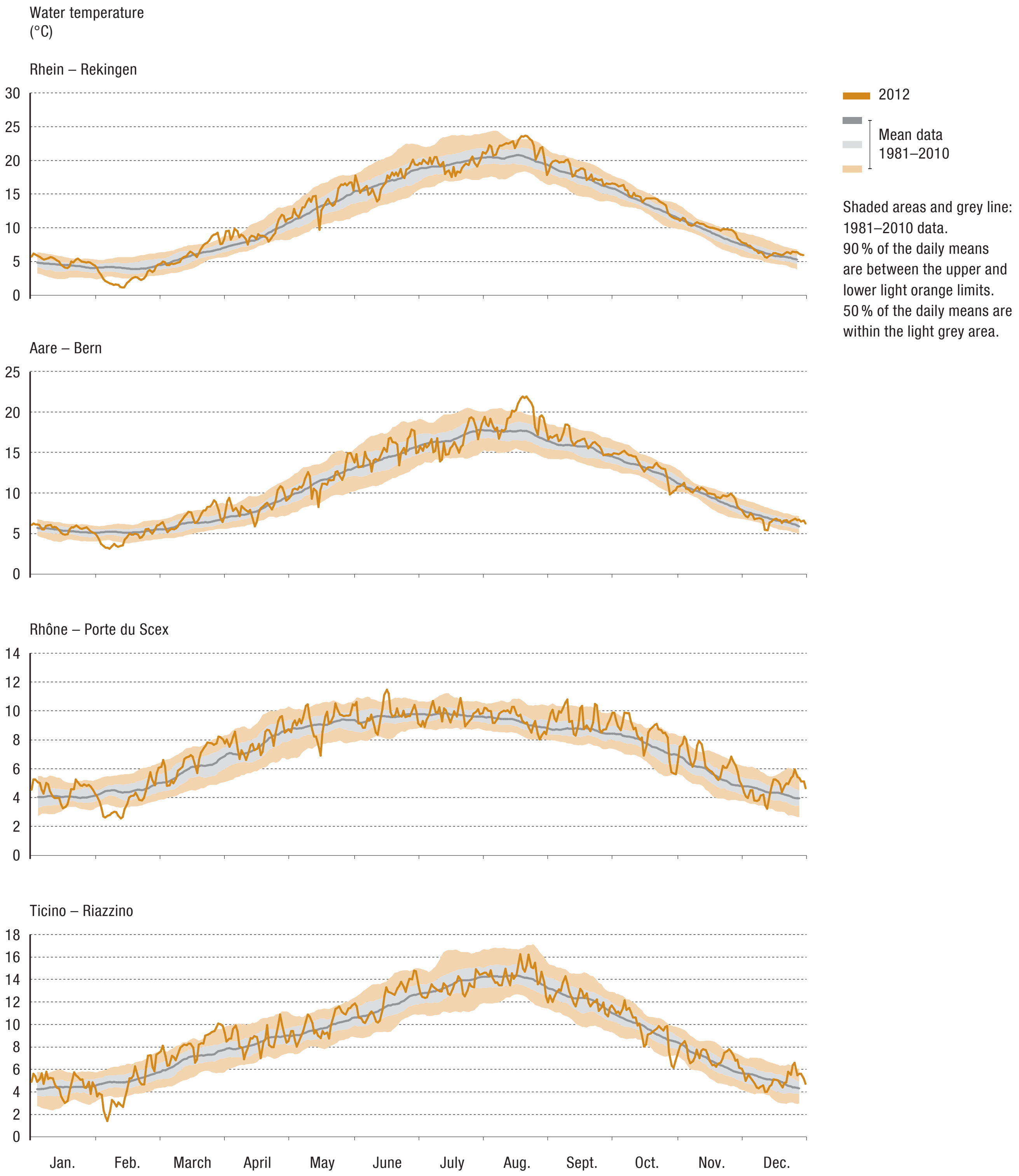


Figure 4.11 *Changes in water temperatures from 1954 to 2012 in selected Swiss rivers. Moving averages (over seven years) are shown as lines and the last four annual means are shown as points or crosses (air).*

Mean daily water temperature at selected stations



Shaded areas and grey line: 1981–2010 data. 90 % of the daily means are between the upper and lower light orange limits. 50 % of the daily means are within the light grey area.

Figure 4.12 *Daily mean water temperature 2012 (orange line) compared with the daily mean for the long-term average period 1981–2010.*

4.4 Stable isotopes

Stable water isotopes are suitable for determining the origin of water components in regional climatic, environmental and water body studies. As part of the NAQUA ISOT module, long-term regional changes in deuterium (^{2}H) and oxygen-18 (^{18}O) are recorded at 13 representative precipitation monitoring sites and seven monitoring sites on rivers (Figure 4.13), to provide reference data for these analyses.

In relation to precipitation, an increase in δ^{2}H and δ^{18}O values between 1980 and 2005 can be observed at all the monitoring sites, but no such trend has been apparent for the δ-values since 2005. The annual picture for stable isotopes in the precipitation in 2012 was marked by low δ-values at the beginning of the year resulting from the above-average snowfalls in the mountains and a long cold spell in February. The δ-values were above average in August as a result of the hot weather. Because of heavy snowfalls, low δ-values were again recorded in the precipitation at the end of the year.

From 1994 to 2008 a general increase can be seen in the δ^{2}H and δ^{18}O-values in the rivers (e.g. Aare, Rhine and Rhone), but here again the trend is not seen after 2008. In 2012 the stable isotopes in the Rhine above Lake Constance, the Rhone above Lake Geneva and the Ticino recorded their lowest δ-values in the spring during the snow melt and their highest δ-values in the summer as a result of the hot weather. In the Aare at Brienzwiler the lowest δ-values were in the spring during the snow melt and the highest δ-values were in the autumn due to the warm weather. Downriver on the Aare at Brugg – the highest δ-values, however, occurred in January and February.

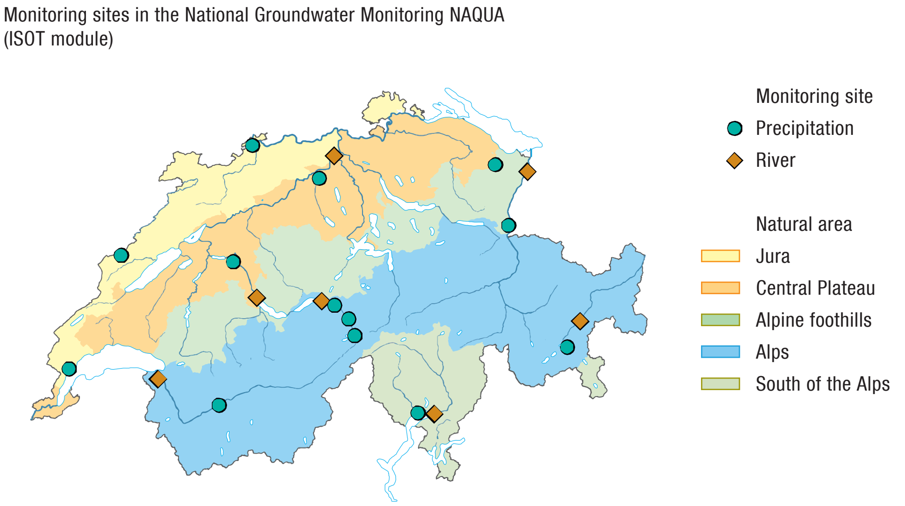


Figure 4.13 *Monitoring sites in the NAQUA ISOT module to monitor the isotopes in precipitation and in rivers in Switzerland, 2012 status.*

4.5 Water quality / Physical and chemical characteristics

The quality of water in Swiss rivers is generally good. Nutrient levels have fallen significantly over recent decades. However, the input of micropollutants continues to pose a challenge. Peak levels of pollution from plant protection products and biocides have also been detected in smaller watercourses during rainfall.

The status and trend of water quality in Swiss rivers is surveyed by the FOEN under the National River Monitoring and Survey programme (NADUF) at 17 monitoring sites and jointly with the cantons under the National Surface Waters Quality Monitoring programme (NAWA) at 111 monitoring sites. In addition to monitoring changes in water constituents, the surveys are intended to evaluate the effectiveness of water protection measures. The water quality analyses therefore focus on longer-term changes rather than seasonal fluctuations and for this reason they are not routinely published in the Hydrological Yearbook. Further information and data can be found on the FOEN website (p. 31).

National River Monitoring and Survey (NADUF) monitoring sites

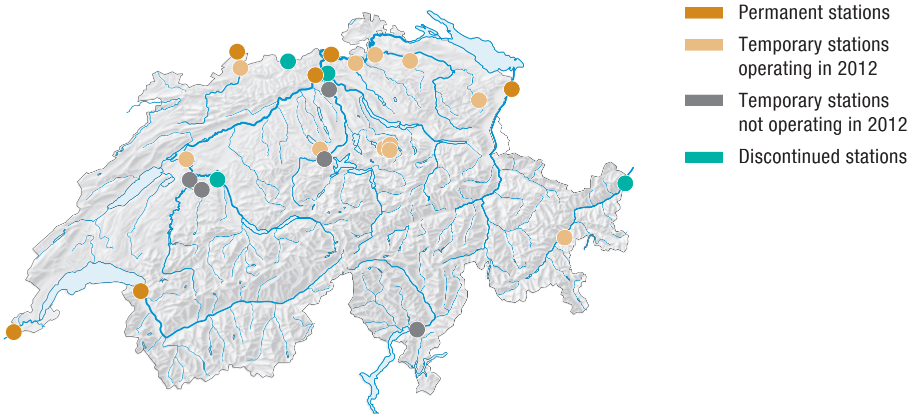


Figure 4.14 *National River Monitoring and Survey programme (NADUF) monitoring sites to monitor water quality in Switzerland, 2012 status.*

5 > Groundwater

The groundwater levels and spring discharges recorded in 2012 were normal by and large. Swiss groundwater is generally of good quality

5.1 Groundwater quantity

By continuously monitoring groundwater levels and spring discharges at around 100 monitoring sites under the NAQUA QUANT module, a nationally representative overview of the status and trend of groundwater quantity can be created. The potential impact of climate change on groundwater resources, for example the predicted increase in extreme events such as floods and drought, can also be identified.

By observing groundwater levels and spring discharges over the longer term, significant fluctuations with a specific periodicity can be identified. For example, Swiss groundwater levels alternate regularly between periods of high and low levels lasting for a number of years. These situations are generally linked by a transition phase during which groundwater levels and spring discharges are average for a period of time.

In 2012 the groundwater levels and spring discharges recorded in Switzerland were widely normal. The changes in those levels and discharges over 2012 were as follows:

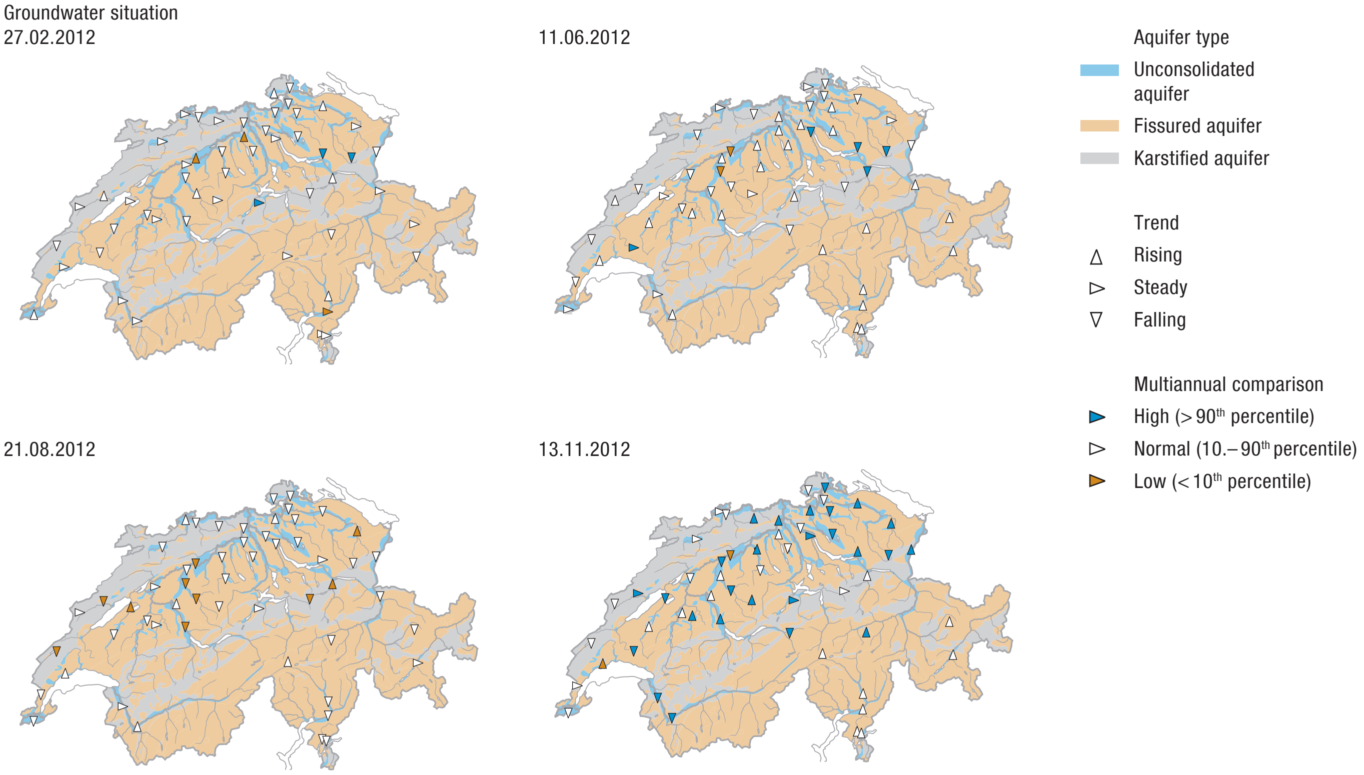


Figure 5.1 *Groundwater levels and spring discharges and their trends on four reference dates in 2012 and compared with the 1992–2011 monitoring period.*

The nationwide low groundwater levels and spring discharges in 2011 reverted largely to normal at the beginning of 2012 thanks to the above-average precipitation in December 2011 and January 2012 (Figure 5.1, Groundwater situation on 27.02.2012).

Following above-average precipitation in April and June 2012, normal groundwater levels and spring discharges were maintained throughout Switzerland (Figure 5.1, Groundwater situation on 11.06.2012).

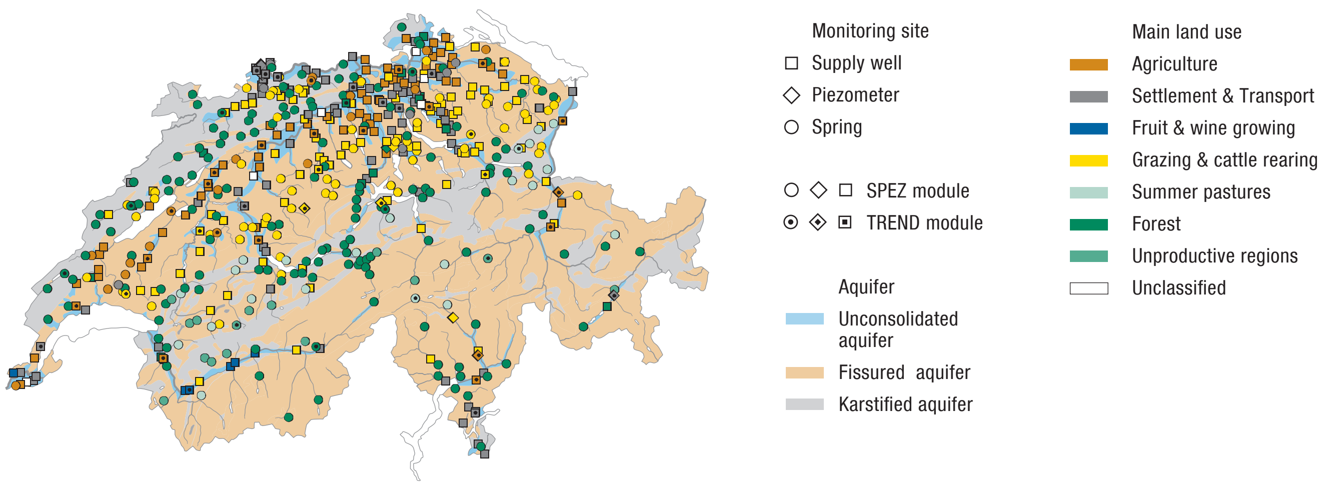
During the summer months of July and August 2012 with low precipitation, groundwater levels and spring discharges were generally normal but low in some places and tending to fall (Figure 5.1, Groundwater situation on 21.08.2012).

The above-average precipitation in the months of September to November 2012 led to high groundwater levels and spring discharges nationwide (Figure 5.1, Groundwater situation on 13.11.2012). New high groundwater levels were reached locally for the month of December 2012 (e.g. at the Brittnau AG, Dietikon ZH, Düdingen FR, Luterbach SO, Märstetten TG, Trub BE monitoring sites).

5.2 Groundwater quality

The quality of groundwater in Switzerland is generally good to very good. In large urban areas and in regions with intensive agriculture, however, it can contain traces of undesirable artificial substances.

Under the NAQUA National Groundwater Quality Monitoring programme, the status and trend of groundwater quality are recorded at 550 nationally representative monitoring sites. In addition to early detection of problematic substances and undesirable developments, checks on the effectiveness of groundwater protection measures also play an important role, which is why groundwater quality analyses focus on statistically significant longer-term changes rather than seasonal fluctuations. These analyses are therefore not published in the Hydrological Yearbook. Further information and data can be found on the FOEN website (p. 31).



Monitoring sites of the NAQUA National Groundwater Monitoring programme (TREND and SPEZ modules)

Figure 5.2 *Monitoring sites of the NAQUA TREND and SPEZ modules to monitor groundwater quality with main land use in the catchment and type of aquifer, 2012 status.*

> Annex

Glossary

Danger level

In accordance with the provisions of the Alarm Ordinance (SR 520.12), the FOEN uses a five-step danger scale to warn of floods. The danger levels give information on the intensity of the event and its potential impact and make recommendations on how to respond. The flood limit for lakes is the point at which the level classed as "considerable danger" becomes "high danger". Floods are likely to occur at this water level. Buildings and infrastructure may be affected.

HQ_x

Discharge that is statistically exceeded every x years.

National Groundwater Monitoring (NAQUA)

The NAQUA National Groundwater Monitoring programme consists of the four modules QUANT, TREND, SPEZ and ISOT. Groundwater quantity is monitored in the QUANT module and quality is monitored in the two modules TREND and SPEZ. The ISOT module observes the water isotopes in the water cycle, i.e. in precipitation water, river water and groundwater.

National River Monitoring and Survey Programme (NADUF)

The monitoring programme follows the development of water constituents in selected Swiss rivers.

National Surface Waters Quality Monitoring (NAWA)

In collaboration with the cantons, the FOEN creates the data basis used to document and analyse the status and trend of Swiss surface waters at national level.

Quantile

A quantile is a measure of position in statistics. A quantile defines the percentage of data in a distribution which is above or below a specific limit. For example, the 95 % quantile is the threshold showing that 95 % of a mass of data is lower and 5 % is higher. The best known quantile is the median (or 50 % quantile). It divides the data in a distribution into two equal parts.

Reference value

Average values (reference values) for different parameters from a long-term monitoring period are needed to describe the average climatological or hydrological conditions at a station. The reference period 1981–2010 is used in this Yearbook whenever possible.

^{2}H, ^{18}O

Deuterium (^{2}H) is a natural stabile isotope of hydrogen. Oxygen-18 (^{18}O) is a natural stable isotope of oxygen. Isotopes are atoms of an element with the same proton number but a different neutron number.

δ-values (delta values) are ratios of the corresponding isotopes $\delta(^{2}H/^{1}H)$, abbreviated to $\delta^{2}H$, and $\delta(^{18}O/^{16}O)$, abbreviated to $\delta^{18}O$.

Further information on the website

Detailed information on the FOEN hydrometric monitoring networks and current and historical data can be found on the website at:
www.bafu.admin.ch/hydrologicalyearbook

- Current and historical data:
  www.hydrodaten.admin.ch
- FOEN Hydrological Bulletin:
  www.hydrodaten.admin.ch/en/hydro_bulletin.html
  > Hydrologisches Bulletin
- FOEN Groundwater Bulletin:
  www.bafu.admin.ch/en/groundwaterbulletin.html
- Results of the NAQUA National Groundwater Monitoring:
  www.bafu.admin.ch/naqua
- Results of the National River Monitoring and Survey Programme (NADUF):
  www.bafu.admin.ch/naduf
- Water indicators:
  www.bafu.admin.ch/water_indicators
- Climate Change and Hydrology in Switzerland (CCHydro):
  www.bafu.admin.ch/projekt-cchydro