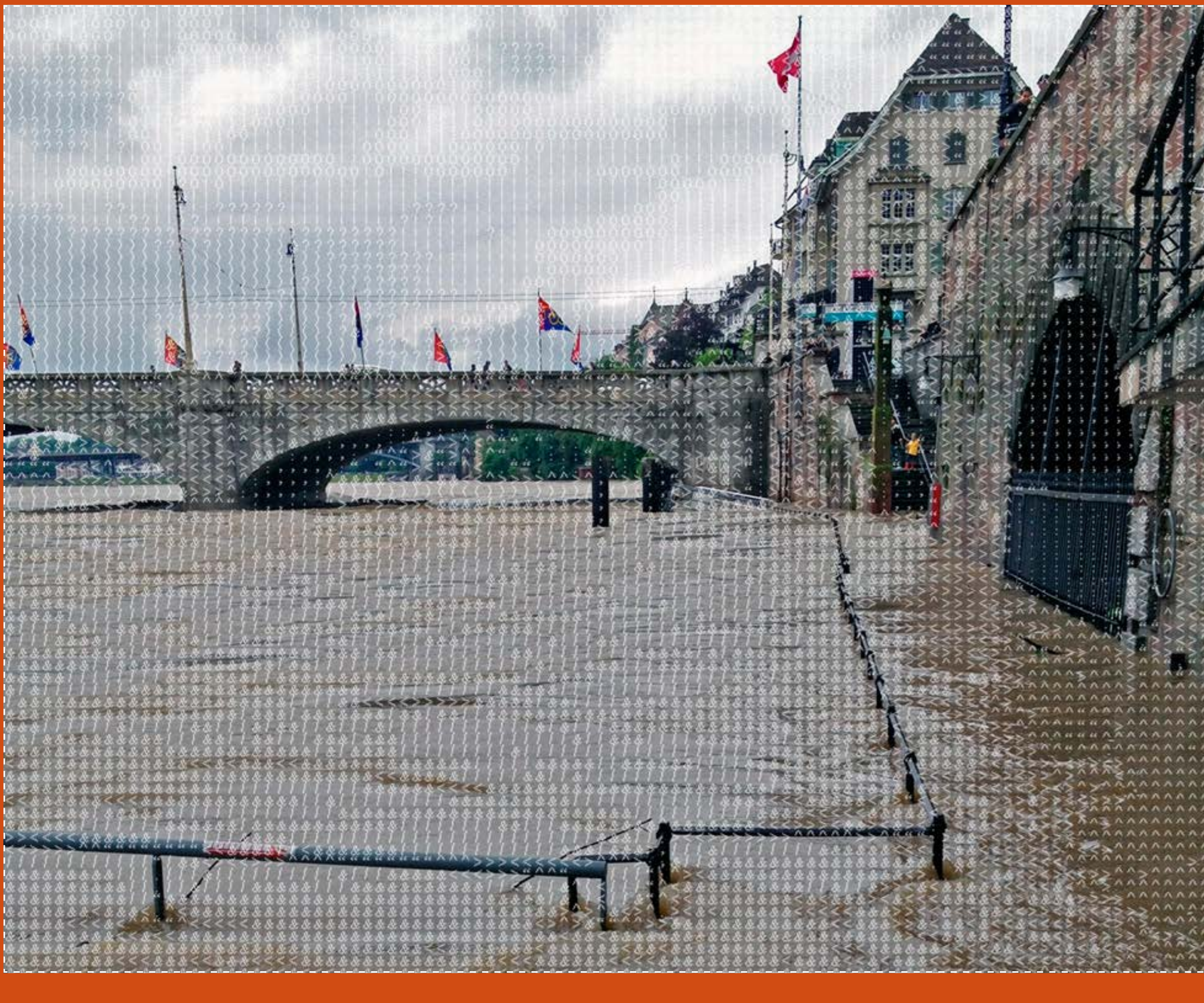
> Hydrological Yearbook of Switzerland 2013

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



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Office for the Environment FOEN

> Contents

Impressum

Issued by
Federal Office for the Environment (FOEN)
The FOEN is an office of the Federal Department of the
Environment, Transport, Energy and Communications (DETEC).

Authors
FOEN, Hydrology Department
Weather: 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)

Editing
Jacqueline Dougoud, Zurich

Suggested form of citation
FOEN (ed.) 2014: Hydrological Yearbook of Switzerland 2013.
Federal Office for the Environment, Bern. Environmental Status
No 1411: 32 p.

Design
upart, Bern

Cover picture
The River Rhine in Basel on 1 June 2013
Photo: Christophe Hug, FOEN

Photo credits
Page 8: David Volken, FOEN
Page 12: Matthias Huss, Department of Geosciences, University of Fribourg

Database
The hydrological analyses are based on provisional data for 2013.

To obtain printed version and PDF download
BBL, Federal publications distribution, CH-3003 Bern
Tel. +41 58 465 50 50
verkauf.zivil@bbl.admin.ch
Order number: 810.200.014e
www.bafu.admin.ch/uz-1411-e

This publication is also available in French, German and Italian.

Further information and data at www.bafu.admin.ch/hydrology

> Foreword

In 2013 the Federal Office for the Environment (FOEN) celebrated “150 years of hydrometry in Switzerland”. A conference was held at which experts looked back over the long history of water measurements in Switzerland and discussed the challenges of monitoring the hydrological cycle now and in the future. During the summer, interested parties in different regions of Switzerland had the opportunity to visit the Swiss hydrometric stations and to learn more about the work of the hydrologists. It proved a valuable exchange for everyone involved.

A readiness to adapt to current and future needs whilst retaining the tried and tested is also the aim of this publication. After almost 100 editions of the “Hydrological Yearbook of Switzerland” the FOEN is maintaining the tradition of annual publication. And the Yearbook will continue to provide an overview of water management in Switzerland, but in a slightly different form; reports on the weather, snow and changes in the glaciers are now included, the main focus being on interpreting the measured data for the year under review. The review of the year gone by is supplemented by information on selected notable phenomena – for 2013, these were two flood events.

The content of the previous Hydrological Yearbooks remains the same, but in a more up-to-date form; readers interested in data series and actual numbers can find them on the FOEN website. All the hydrological information needed to answer questions about water management, water protection and flood protection or for hydraulic and engineering projects, research and many other applications continues to be available.

Dominique Bérod
Head of the Hydrology Division
Federal Office for the Environment (FOEN)

> Abstracts

The “Hydrological Yearbook” 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 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», 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

The year 2013 was marked by the persistence of wintry conditions until the end of April, the record low sunlight levels from January to May and an extremely sunny summer. Across Switzerland as a whole, the mean air temperature for the year exactly equalled the 1981–2010 average. Annual precipitation was 90 to 110 % of normal over wide areas but only 80 % in isolated parts of the Northern Alps and the Engadine.

Snow and glaciers

Snow depth was above average throughout the winter of 2012/2013 (November to April) in large parts of the Northern Alps and Valais, was average in Northern and Central Graubünden and the Lower Engadine and was below average in the Upper Engadine and the Southern Alps.

The mass losses from glaciers in the Swiss Alps were much lower in the hydrological year 2012/2013 than during the past decade. In the Southern Alps the glaciers even recorded a slight growth.

Discharge conditions

The annual discharges in the large catchments were 5 to 15 % above the 1981–2010 long-term average.

In January and February monthly discharges were widely above average. In March they were at normal or below-average levels, mainly due to the low temperatures, and from April to June they were generally above the long-term average. In July, August and September, below-average discharges were recorded over wide areas. Some catchment areas recorded only approximately 50 % of normal. In October and particularly in November the monthly discharges were well above normal. December saw discharges well below average in large areas of the basins of the Rivers Aare, Reuss, Limmat and Thur and well above average in the Southern Alps and Western Switzerland.

Torrential rain led to very high discharges and water levels in the lakes and rivers of the Northern Alps during the weekend of 1 and 2 June 2013. Many of the FOEN monitoring stations in the regions affected recorded two- to ten-year flood levels.

In June 2013 an intensive snow melt caused the discharge on the Rhone to rise markedly. From Brig to Lake Geneva, discharges that only occur statistically every two years on average were measured.

Lake levels

Water levels in the lakes in the Southern Alps rose to high levels in late April/early May and again in the second half of May. After an autumn with quite low water levels, they again reached a high level by the end of December. The highest levels in the lakes of the Northern Alps were reached in June and July. They were not extreme but still met the criteria for warnings to be issued.

Water temperatures

The combination of a cold spring and hot summer resulted in the annual average surface water temperatures being very close to the long-term average.

Stable isotopes

The stable water isotopes (deuterium and oxygen-18) in the precipitation had lower than average δ values in January and February 2013 due to the cold weather. By contrast, high δ values were widely observed in the precipitation in summer 2013.

Groundwater

During the year the groundwater levels and spring discharges recorded were normal overall, but high in some areas.

1 > Notable phenomena in 2013

Torrential rain at the beginning of June 2013 led to very high discharges and water levels in the lakes and rivers north of the Alps. But the snow melt event on the Rhone – also in June 2013 – showed that floods can also occur without rainfall.

1.1 Floods north of the Alps from 1 to 3 June 2013

Low pressure over Eastern Europe led to continuous heavy rainfall in Switzerland north of the Alps from Friday 31 May to Sunday 2 June 2013. According to MeteoSwiss, the rain was extremely torrential over the central and eastern part of the north of the Alps, where the highest precipitation totals were 100 to 180 mm. Due to the relatively low temperatures, some of the precipitation fell as snow at higher altitudes.

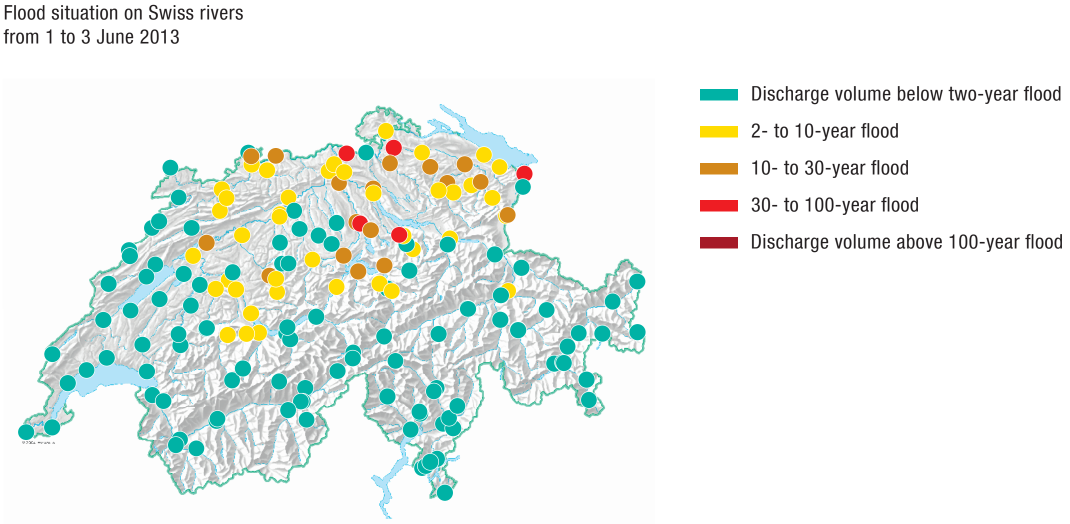
High discharges and lake levels …

In some areas north of the Alps the precipitation and snow melt led to marked rises in water levels in the rivers and lakes. The peak discharges on most of the watercourses on the Central Plateau and in the Jura Mountains were reached on Saturday 1 June. In Eastern Switzerland a second flood peak on Sunday 2 June caused even higher discharges. The flows in the rivers then subsided. The levels in Lakes Zurich, Lucerne, Constance and Walen continued to rise until Sunday night or Monday. The discharges at the lake outflows also remained at this high level. Due to further precipitation and the continuing snow melt, Lake Constance maintained a high level for weeks and only began to fall slowly in July.

… but hardly any records

Discharges with return periods of 2 to 10 years were recorded on many rivers north of the Alps. The Rivers Reuss and Thur and the Upper Rhine between the confluence of the Thur and Basel experienced discharges that statistically only occur every 10 to 30 years on average.

No absolute records were broken, but some data came close to the figures for the storms of May 1999, August 2005 and August 2007. New maximums for the month of June were measured in some locations, such as on the Rhine at Rhein-



Flood situation on Swiss rivers
from 1 to 3 June 2013

Figure 1.1 *A comparison of the maximum discharges measured with the flood statistics shows that levels that only occur once every two to ten years on average, or even less frequently, were recorded in some locations.*

felden, on the Reuss below Lake Lucerne and on the Thur near Jonschwil and Halden. There was even a 50-year flood level recorded on the Rheintaler Binnenkanal near St. Margrethen.

Water levels were even higher in 1999

The continuous rain and resultant high water levels were reminiscent of the images from spring 1999 and the storms of August 2005 and 2007. According to MeteoSwiss, the precipitation event did in fact resemble the storms of 2005 and 2007 in origin and development.

Hydrologically, the storm can also be compared with that of 1999, which had a similar genesis. In that year precipitation had already been high in the spring and deep snow lay north of the Alps, with the ground already well saturated before the event. However, in 1999 precipitation had been even more intense and the lake levels were already higher before the event than in 2013. In the spring of 2013 the agencies responsible had focussed their attention on regulating the lakes and lowering their levels in advance, which prevented even higher water levels occurring.

Compared with previous events, therefore, the damage was relatively minor. The strenuous efforts of the agencies and relief teams certainly contributed to this. And Switzerland was spared the worst on this occasion; in Germany and Austria the precipitation was much higher. The same event hit those countries much harder.

1.2 Snow melt floods in June 2013

In June 2013 an intensive snow melt caused the discharge on the Rhone to rise markedly. From Brig to Lake Geneva discharges that only occur every two years on average were measured.

How did it happen?

From 14 June 2013 an area of high pressure over Central Europe caused significant warming in the mountains. The zero degree isotherm was over 4000 m above mean sea level (AMSL) in some areas on 18 June. To compound matters, the Föhn wind set in on 17 June, which meant that the snow cover did not freeze overnight, even at high elevations. At that time the snow line in Valais was still at 2200 m AMSL on north-facing slopes and an average of 2500 m AMSL on south-facing slopes. 40 % of the Rhone basin still had snow cover.

So much snow had not been seen in mid-June for at least 40 years; there was even more than in the June following the avalanche winter of 1999.

The heatwave combined with the Föhn and the wide extent and great depth of the snow cover caused an exceptional snow melt such as had not been experienced for decades. During this period the only precipitation to fall in the catchment area of the Rhone was a small amount in the Southern Valais Alps – the rest of the basin was dry.

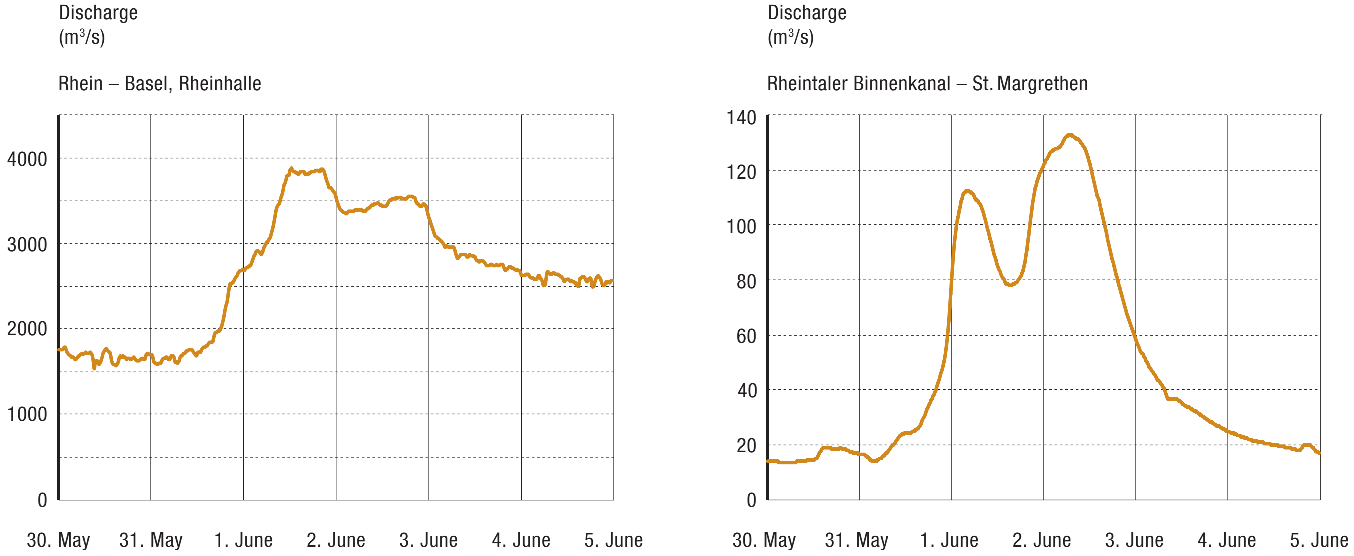


Figure 1.2 *The discharge hydrographs for 30 May to 5 June 2013 from the FOEN monitoring stations Rhein – Basel, Rheinhalle (left) and Rheintaler Binnenkanal – St. Margrethen (provisional data for both stations).*

Pronounced rise in discharge

The unusually high snow melt caused the tributaries of the Rhone to swell considerably from 16 June. These large inflows led to a marked increase in the flow rate on the Rhone from below Brig to where it enters Lake Geneva. On several days from 19 June the Rhone-Brig, Rhone-Sion, Rhone-Branson and Rhone-Porte du Scex FOEN monitoring stations recorded discharges that only occur statistically once every two years on average. Over five days in total, the FOEN Hydrological Forecasts Section issued flood hazard level 2 (medium hazard) warnings for the Rhone.

Hydropower plants as reservoirs

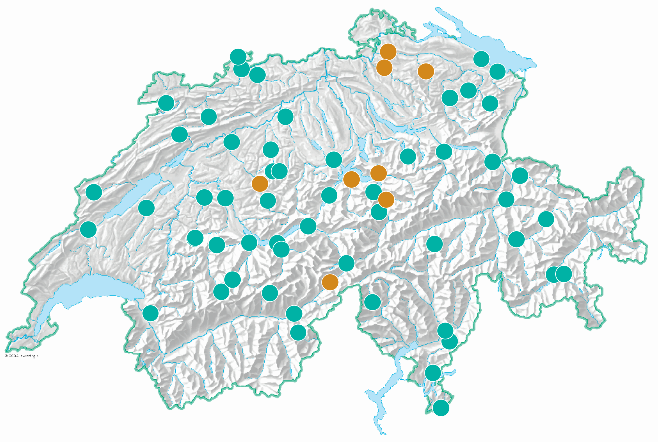
If the precipitation forecast at the time (30 to 50 mm on 19 June) had fallen as rain up to 3500 m AMSL, considerably higher discharges would have been recorded in the Rhone. Another undoubted advantage was the fact that the reservoirs in Valais were only 10 to 15 % full on average in mid-June 2013 and were able to retain much of the melt water.

The following comparison shows the importance of the hydropower plants. The area of the Rhone basin down to Brig is 913 km^2 and that of the Vispa down to Visp is 778 km^2. The peak discharge observed on the Rhone in Brig during this event was 314 m^3/s. Despite only a small difference in catchment size and similar snow cover, the peak discharge on the Vispa at Visp was nearly three times lower at 110 m^3/s. The large hydropower plants of Grande Dixcence (Mattertal) and Mattmark (Saastal) retained large volumes of water, unlike the Rhone down to Brig, which is a less engineered river system.

Melt flooding over wide areas is possible

It was previously known that catchment areas with pronounced glacial features, particularly smaller ones, can generate a discharge of the magnitude of a two-year flood without any precipitation events in conditions of high snow and glacier melt in spring and summer. This snow melt event showed that this is also possible in catchments with an area of several thousand square kilometres.

Figure 1.3 *The Rhone near Brig during the snow melt of mid-June 2013.*



🟧 Indicator station with a flood event in 2013

🟩 Indicator station with no flood event in 2013

Figure 1.4 *The 64 discharge monitoring stations that are analysed for the flood indicator. In orange: stations that recorded at least one HQ$_{10}$ in 2013.*

1.3 Flood events indicator

The annual peak discharges (highest discharge in a given year) are determined every year at 64 long-term FOEN discharge monitoring stations. An annual peak discharge is defined as a flood event if its flow rate is greater than the HQ_{10} flow calculated for the station (HQ_{10} flow = discharge that is exceeded statistically every 10 years). The indicator shows the total of all flood events per annum at the 64 stations.

Flood events occurred at eight indicator stations in 2013. With the exception of one location, the peak discharges were caused by the floods in the area north of the Alps from 1 to 3 June 2013. As the graphic of the flood situation at that time shows (see section 1.1), the HQ_{10} flow was also exceeded at other stations, but these are not included in the indicator calculation. The indicator stations were selected in order to obtain uniform spatial distribution across Switzerland, featuring similar catchment areas and minimal anthropogenic impact. The indicator can then provide reliable information on longer-term changes in the frequency of flood events in Switzerland.

An evaluation of the annual peak discharge data from 1930 to 2013 shows that the frequency of flooding has been rising since the mid-1970s, with an above-average number of flood events observed during the past 15 years. By contrast, there were only very few flood events between 1960 and 1975. Over the past 500 years, climatic changes (such as fluctuations in atmospheric circulation) have caused repeated alternation between phases with many and few flood events.

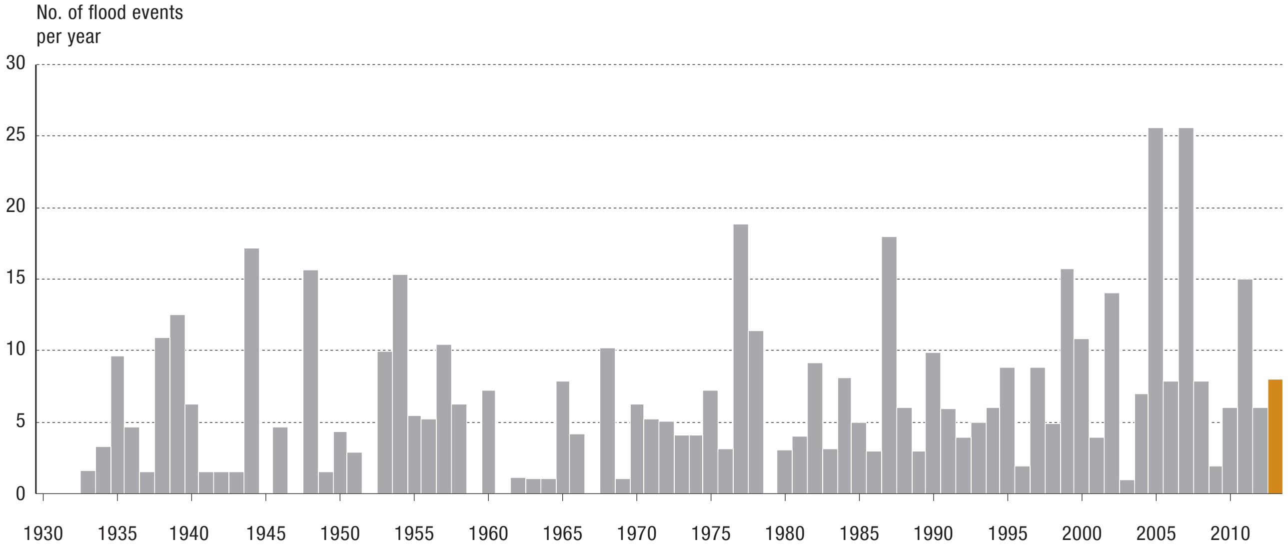


Figure 1.5 *The total number of all flood events at the 64 stations per year. In orange, the 2013 indicator value.*

2 > Weather conditions

The year 2013 was marked by the persistence of wintry conditions until the end of April, the record low sunlight levels from January to May and an extremely sunny summer. Across Switzerland as a whole, the mean air temperature for the year exactly equalled the 1981–2010 average. Annual precipitation was 90 to 110 % of normal over wide areas but only 80 % in isolated parts of the Northern Alps and the Engadine.

The first half of January 2013 saw a continuation of the mild winter weather prevailing since mid-December 2012. The second half of January brought low temperatures. An influx of mild, moist air in the first week of February led initially to abundant fresh snow in the mountains. The snowfall was unusually heavy in Southern Ticino towards the end of the month. After a few milder days in early March, wintry conditions returned around mid-month.

South-westerly winds brought warm air to Switzerland in mid-April, but by the 20th temperatures were again widely below 10 °C. In the north, high precipitation brought fresh snow down to lowland levels. As a consequence of air masses being blocked in the south there was again heavy rain south of the Alps from 14 to 21 May. In late May moist Mediterranean air moved across the Austrian Alps to the Northern Alps. Between 31 May and the morning of 2 June, precipitation of 80 to 150 mm was recorded in the central and eastern parts of the Northern Alps and reached levels of 150 to over 200 mm in a corridor from the Schwyz Alps to Lower Appenzell.

At the beginning of June a period of a few days of sunny weather occurred for the first time since mid-April. The weather then continued changeable until mid-June. Hot summer conditions arrived from 16 to 19 June. In Western Switzerland a violent storm front with hail and high winds brought this fine spell to an end on 20 June. July and August saw almost continuous sunny summer weather.

In early September temperatures again rose to midsummer levels on both sides of the Alps, but by mid-month Switzerland was in the grip of cold polar air. Shortly before the middle of October, a second powerful blast of polar air lowered the snow line to 600 m on both sides of the Alps. Mild conditions persisted in the second half of the month.

The first ten days of November brought wet and windy westerly conditions with temperatures remaining very mild. Calm conditions prevailed from 11 November until well into December due to high pressure. The dry autumn weather was broken by a phase of precipitation lasting for several days around 20 November which brought the first snowfall to the lowlands north of the Alps.

During the phase of strong southerly flow, which also brought the Föhn winds at Christmas, there was extremely heavy snowfall in the Southern Alps.

Source: MeteoSwiss

Annual precipitation totals as a percentage of normal

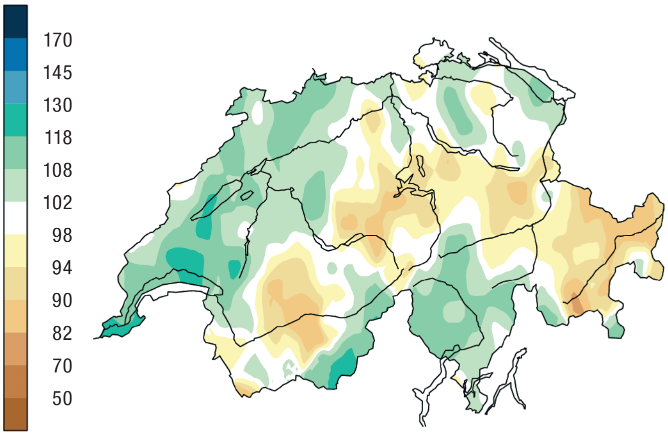


Figure 2.1 *Annual precipitation was 90 to 110 % of normal over wide areas but only 80 % in isolated parts of the Northern Alps and the Engadine.*

3 > Snow and glaciers

Snow depth was above average throughout the winter in large areas of the Northern Alps and Valais, average in Northern and Central Graubünden and the Lower Engadine and below average in the Upper Engadine and the Southern Alps. The mass losses from glaciers in the Swiss Alps were much lower than the long-term average.

3.1 Snow

Precipitation was higher than normal in the winter of 2012/2013 (November to April), particularly on the Central Plateau. The many days of fresh snowfall led to widespread snow cover 30 to 50 cm deep on the Central Plateau by mid-December. The depths experienced in December 1998 ("avalanche winter of 1999") were equalled in some cases. Over the winter as a whole, snow depth was above average in large parts of the Northern Alps and Valais, average in Northern and Central Graubünden and the Lower Engadine and below average in the Upper Engadine and the Southern Alps.

Winter set in as early as October with two snowfalls down to low levels. It continued to snow heavily from the end of November to mid-December, especially in the north and west. By mid-December, snow depth in the north and west was already twice to three times the long-term average. Heavy snowfalls continued until mid-January. It snowed frequently and heavily in the first half of February, particularly in the north.

The first slight thaw in the snow cover occurred in early March, but it again snowed repeatedly in the first half of April. In mid-April a rapid thaw began at high altitudes, but the warm spell was followed by a further return to wintry conditions. Snow cover was still above average in the west of Lower Valais at the end of April. It was average in large areas of the Northern Alps and the rest of Valais and below average elsewhere.

Snow cover is normally greatly reduced in May. In the winter of 2012/13, however, it increased widely between the middle and end of May at the automatic monitoring stations operated by the WSL Institute for Snow and Avalanche Research (SLF), particularly on the main Alpine ridge.

Between June and September there were six periods of significance in terms of snowfall and avalanche situations. Snow mainly fell only on the high peaks. In September fresh snow cover began forming on the high peaks, but high elevations were generally unaffected, apart from glaciated regions, due to the mild weather.

Source: WSL Institute for Snow and Avalanche Research SLF

Snow depth (% of normal)

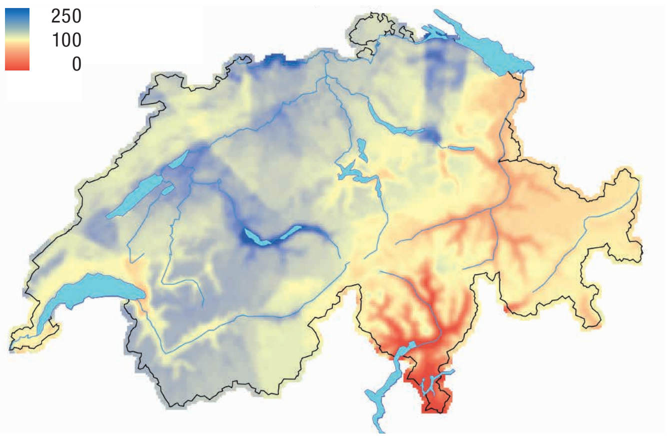


Figure 3.1 *Snow depths 2012/2013 compared with the 1971–2000 period during the winter months of November to April.*

3.2 Glaciers

In the hydrological year 2012/2013 measurements of the seasonal mass balance were made on approximately 15 Swiss glaciers. In mid-April the snow volumes recorded on the glaciers were generally average or slightly above average. The high precipitation between late April and early June fell almost entirely as snow due to the low temperatures. Consequently the snow cover at high glacier elevations only reached a maximum very late in the season. During the lengthy spell of hot and dry weather in July and August, the glaciers were still extremely well protected by winter snow, which did not start melting until very late. As early as mid-September the glacier melt was generally halted by fresh snowfalls.

Glaciers in the Southern Alps and the southern slopes of the main Alpine ridge (e.g. Ghiacciaio del Basòdino, Findelen glacier) recorded neutral or even slightly positive mass balances (an increase of around 100 mm water equivalent). By contrast, the glaciers studied on the northern ridge and in the Northern Alps and in the Engadine had moderate mass losses, but at –200 to –900 mm water equivalent the decrease was much less than in recent years. The regional differences in glacier storage changes can be explained by the distribution of the large volumes of snow in the spring and early summer.

Despite temperatures being well above average during the summer, the 2012/2013 climatic trends were very positive for the glaciers. The ice fields in the Swiss Alps had not experienced such low mass losses since 2002. However, a reversal of the trend cannot be assumed; although the glacier melt was less dramatic, a negative mass balance is evident across Switzerland as a whole. Without the unusually heavy snowfalls and the cold weather in May and June, the outcome would have been far worse for the glaciers.

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

Figure 3.2 *Discharge from the Findelen glacier in September 2013.*

4 > Rivers and lakes

The discharges in the large catchments throughout 2013 were slightly above average. In the late summer and the month of December there were periods with very low discharges and water levels in the rivers and lakes of Switzerland. Water temperatures were within the long-term average range.

4.1 Discharge conditions and lake levels

Discharge conditions

In 2013 the annual averages for the large catchments were 5 to 15 % above the mean for the 1981–2010 period. As the area of a catchment decreases, the variability increases, and there were a few medium-sized catchments with below-average discharges, but in 2013 catchments with an annual mean well above average were more prevalent. The results for the rivers Töss at Neftenbach, Venoge at Ecublens and Mentue at Yvonand were 20 to 40 % above normal. Ticino – Piotta, with approximately 90 % deviation, tops the stations with discharges well above average (see figure 4.2 Annual mean 2013).

An evaluation of the monthly discharges indicates that they can be divided very roughly into six time spans. The monthly mean …

> … in January and February was widely above the long-term average. Deviations of 20 to 40 % were frequently observed. The catchments of the Hinterrhein and Maggia did not follow this pattern; very low levels were recorded in both January and February.
> … in March varied between a normal and below-average level, largely due to the low temperatures.
> … from April to June were mainly above the long-term average. The high April and May discharges on the Maggia can be seen very clearly in the graphic of daily discharges (see figure 4.8). The flood in early June was a contributory factor to the well above-average June discharges on the Reuss, Limmat and Aare.
> … in July, August and September were widely below average. Some catchments recorded only approximately 50 % of normal (e.g. Emme and Maggia in July; Emme, Gürbe, Hinterrhein, Landquart, Thur and Töss in August).

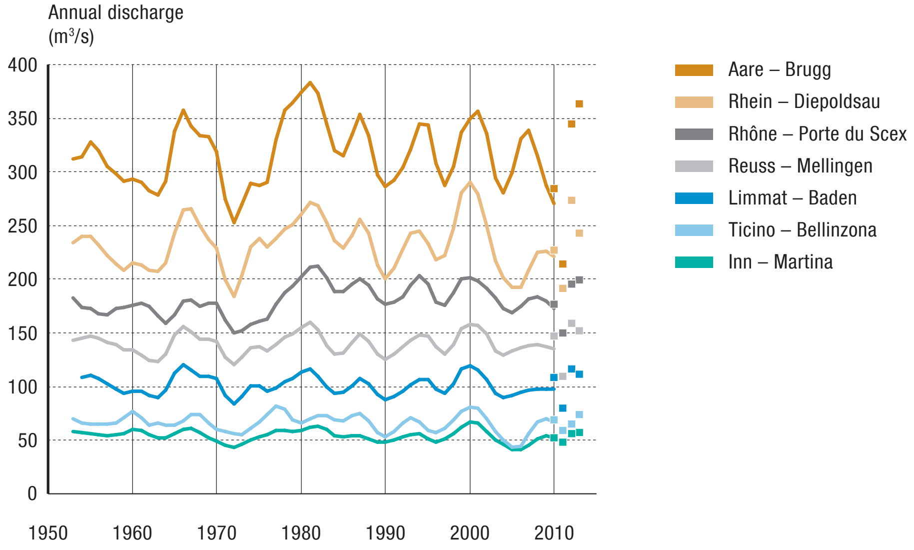


Figure 4.1 *Changes in the annual discharges for selected large catchments from 1950. Moving averages (over seven years) are shown as lines and the last four annual discharges as points.*

> … in October and particularly in November were well above average. The Töss, Mentue and Venoge reached twice the normal discharge in November. In this rough evaluation the Maggia is once again the exception. Its November discharge was only approximately 40 % of the mean over the long-term period.
> … in December were well below average in large parts of the Aare, Reuss, Limmat and Thur basins, although they proved to be well above average in the Southern Alps and in Western Switzerland.

Graphics with more precise temporal resolution (figures 4.5–4.8) demonstrate effectively the wide fluctuations that can be concealed behind an annual mean; for example, the Aare at Brugg discharged flood levels eight times at more or less regular intervals, two events being of considerable magnitude. The biggest – end May/early June – had a return period of five to ten years. Yet low discharges also occurred in 2013; over several days in August and September discharges were within the lowest daily average range for the same months in the reference period. The Reuss and Limmat exhibited similar patterns to the Aare.

The flood event described in section 1.1 was not limited the hydrographs for the large catchments north of the Alps. The event is even more striking in medium-sized catchments such as those of the rivers Emme, Thur and Muota, because the remaining discharges stayed at a comparatively low level.

A very wide variation can also be seen in the hydrographs for the Rhone, Inn and Ticino. Here the regulation of discharge by the power plants is very pronounced. The typical weekly cycles caused by the differences in electricity consumption on working days and at weekends are clearly visible (see figure 4.6).

Discharge conditions in selected medium-sized catchments

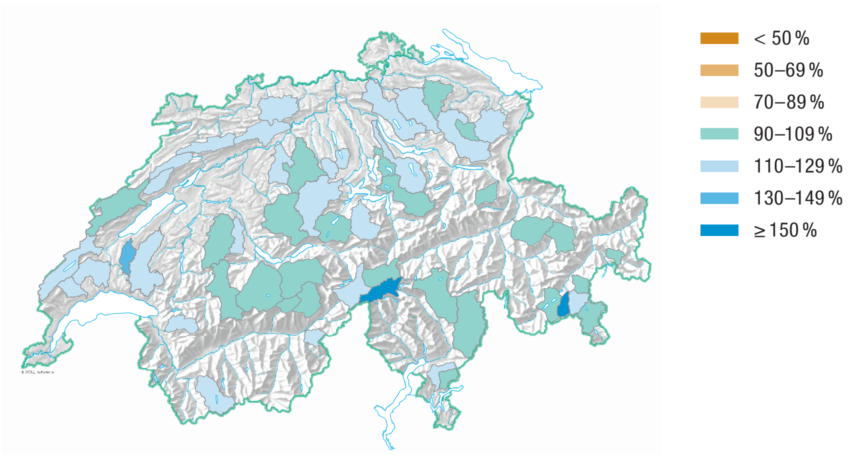


Figure 4.2 *Annual mean 2013 compared with the mean discharge for the long-term average period 1981–2010 [%] in selected medium-sized catchments.*

Monthly mean discharges in selected large catchments

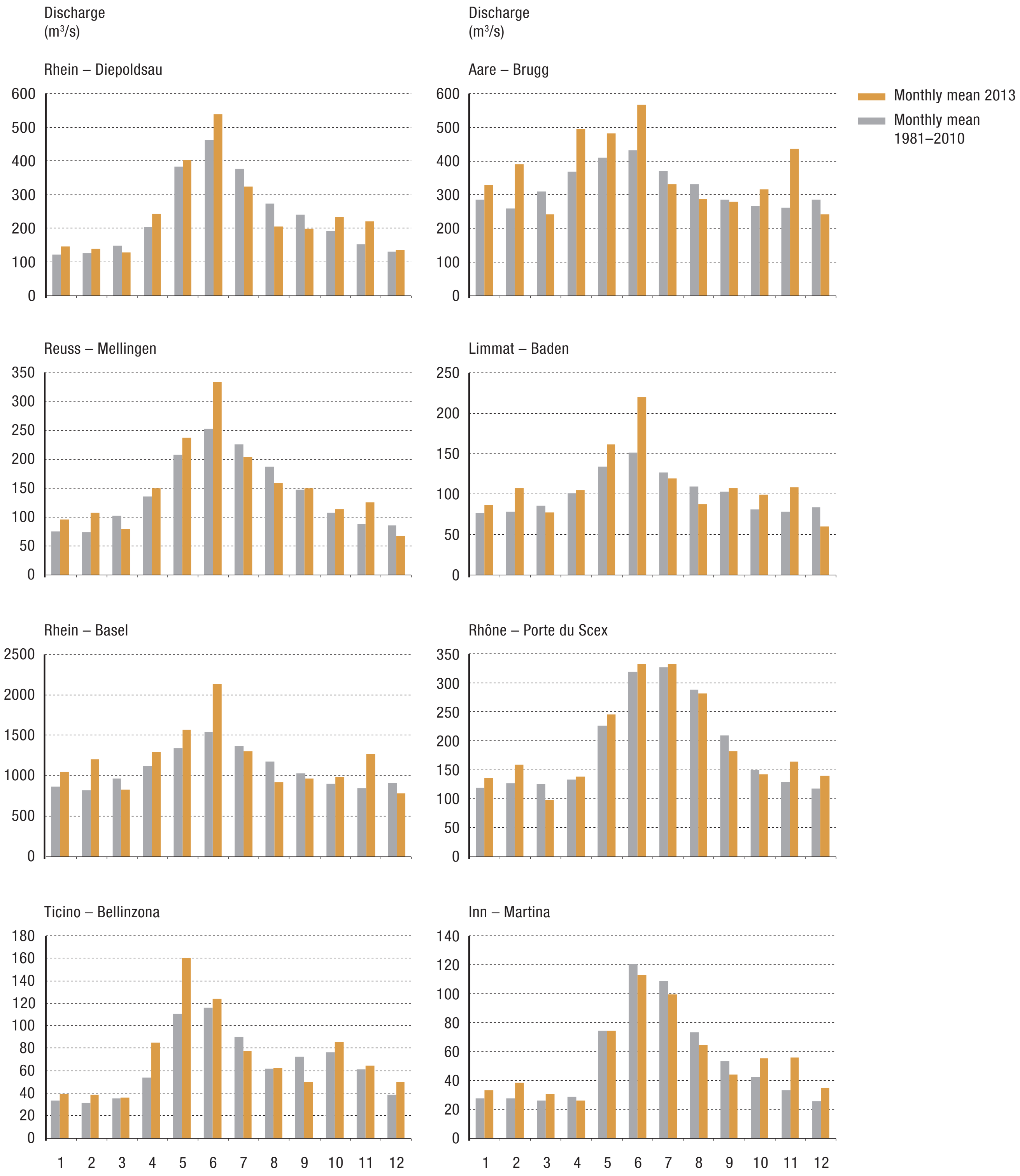


Figure 4.3 *Monthly mean discharges 2013 (orange) compared with the monthly mean for the long-term average period 1981–2010 (grey).*

Monthly mean discharges in selected medium-sized catchments

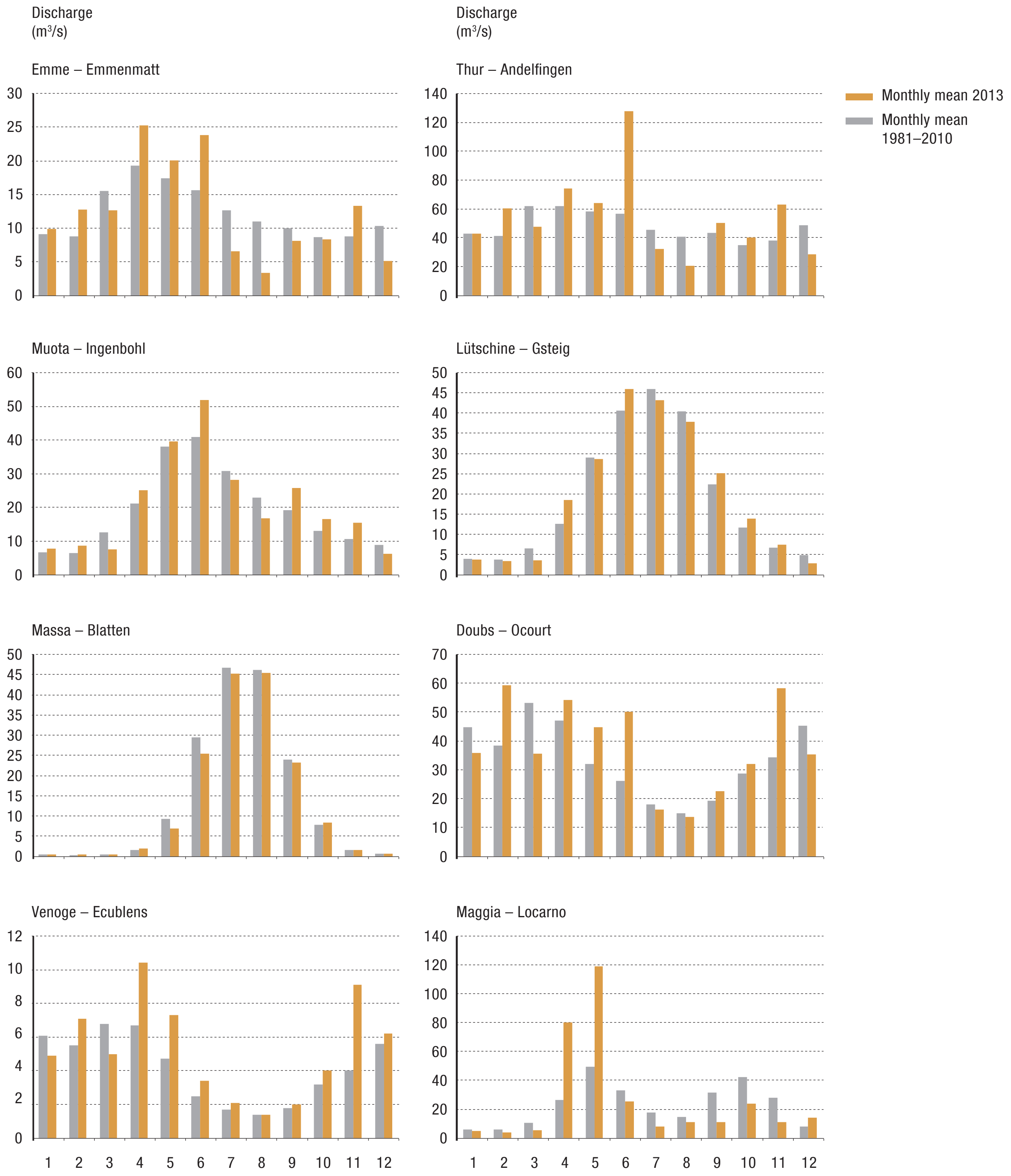
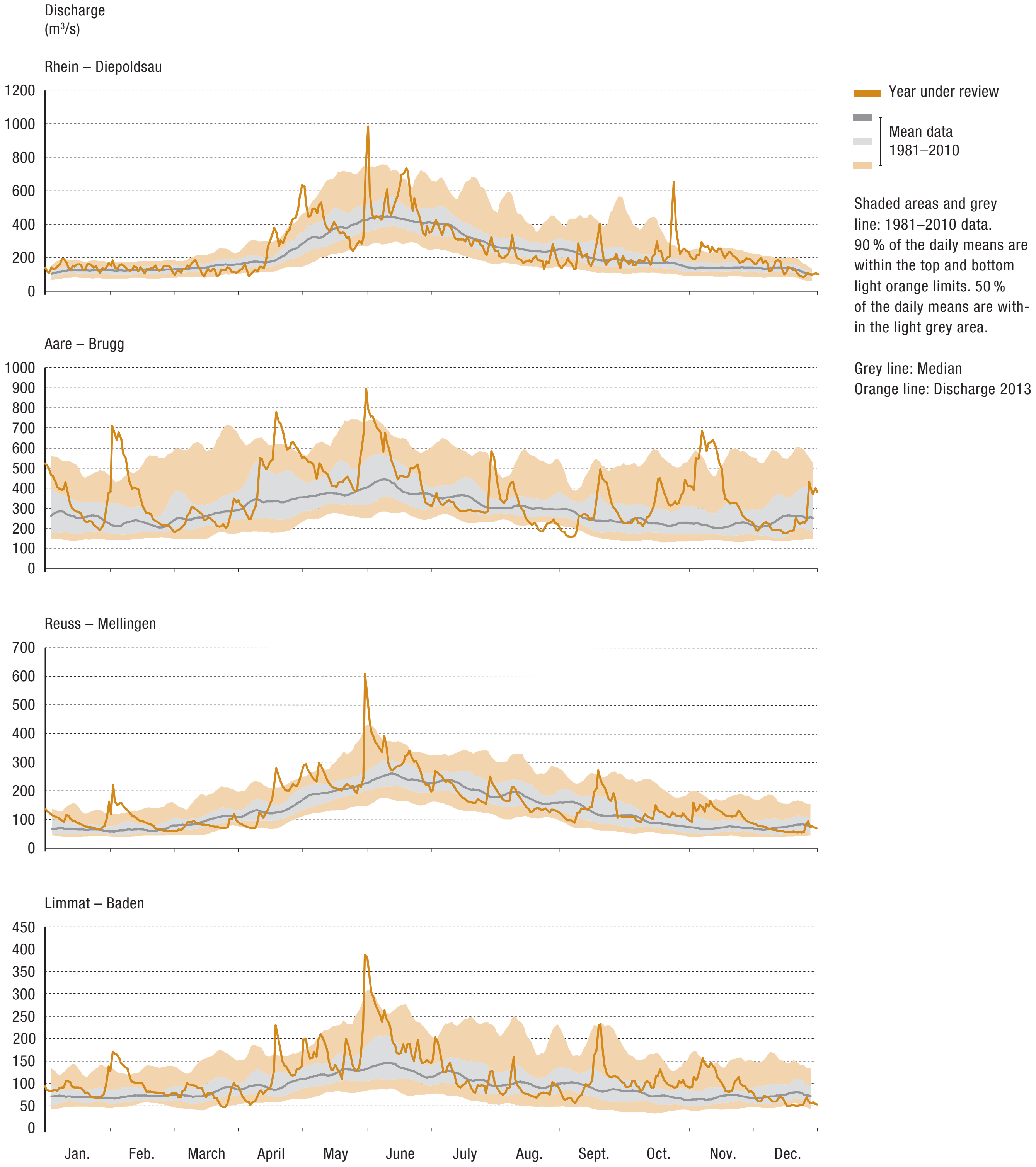


Figure 4.4 *Monthly mean discharges 2013 (orange) compared with the monthly mean for the long-term average period 1981–2010 (grey).*

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



Rhein – Diepoldsau

Aare – Brugg

Reuss – Mellingen

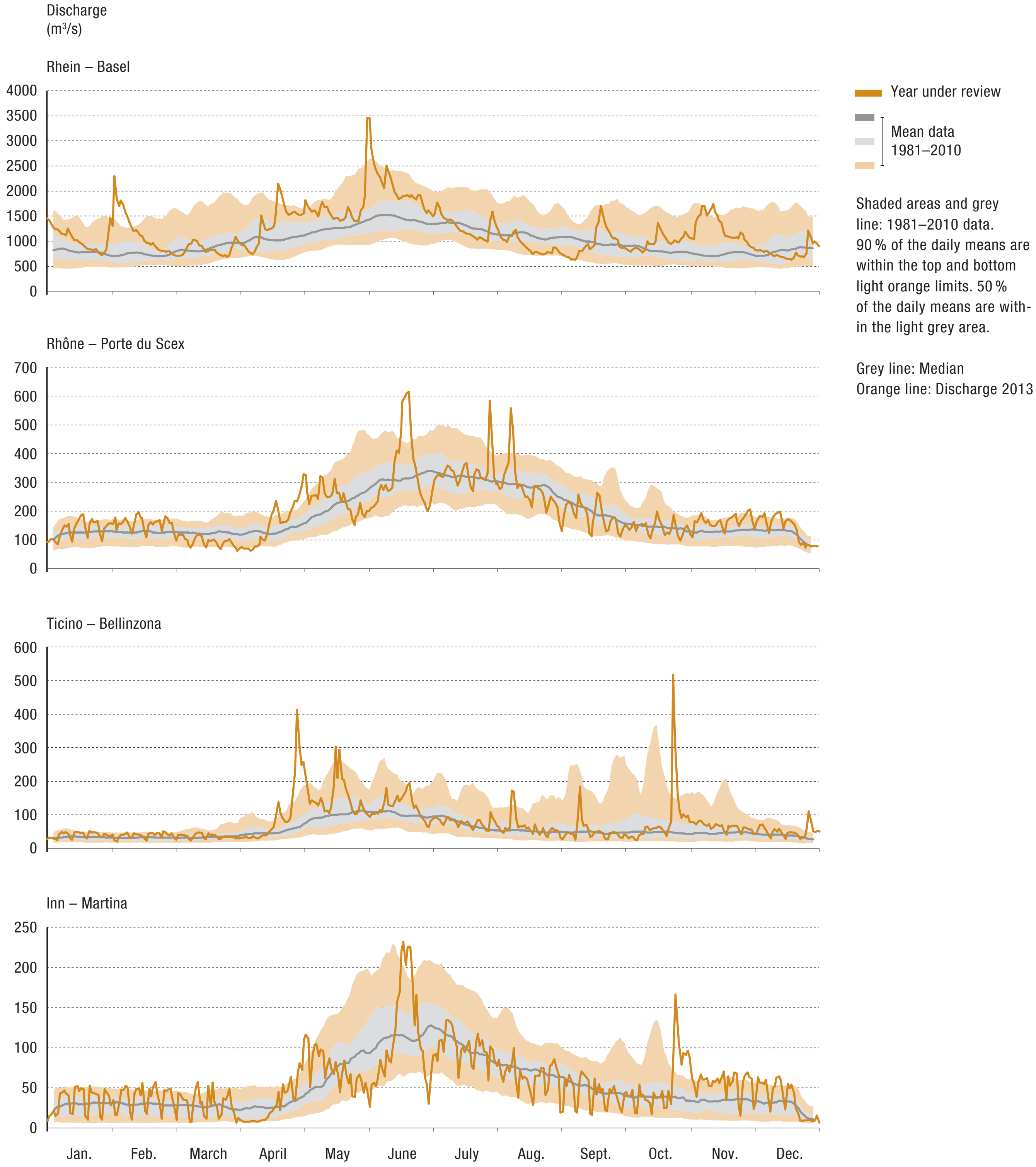
Limmat – Baden

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

Grey line: Median
Orange line: Discharge 2013

Figure 4.5 *Daily mean discharges 2013 (orange line) compared with the daily mean for the long-term average period 1981–2010.*

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

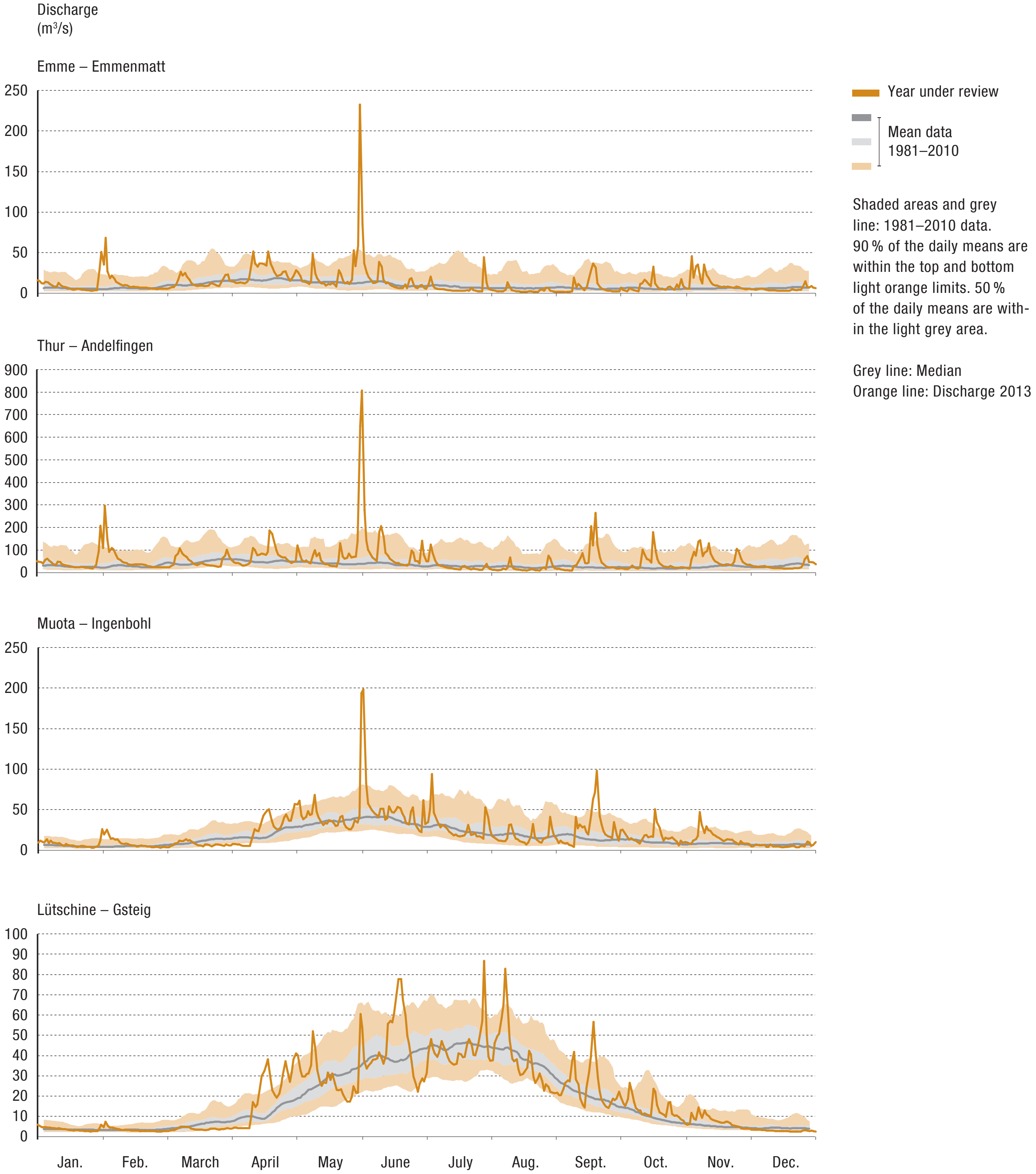


Shaded areas and grey line: 1981–2010 data. 90 % of the daily means are within the top and bottom light orange limits. 50 % of the daily means are within the light grey area.

Grey line: Median
Orange line: Discharge 2013

Figure 4.6 *Daily mean discharges 2013 (orange line) compared with the daily mean for the long-term average period 1981–2010.*

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

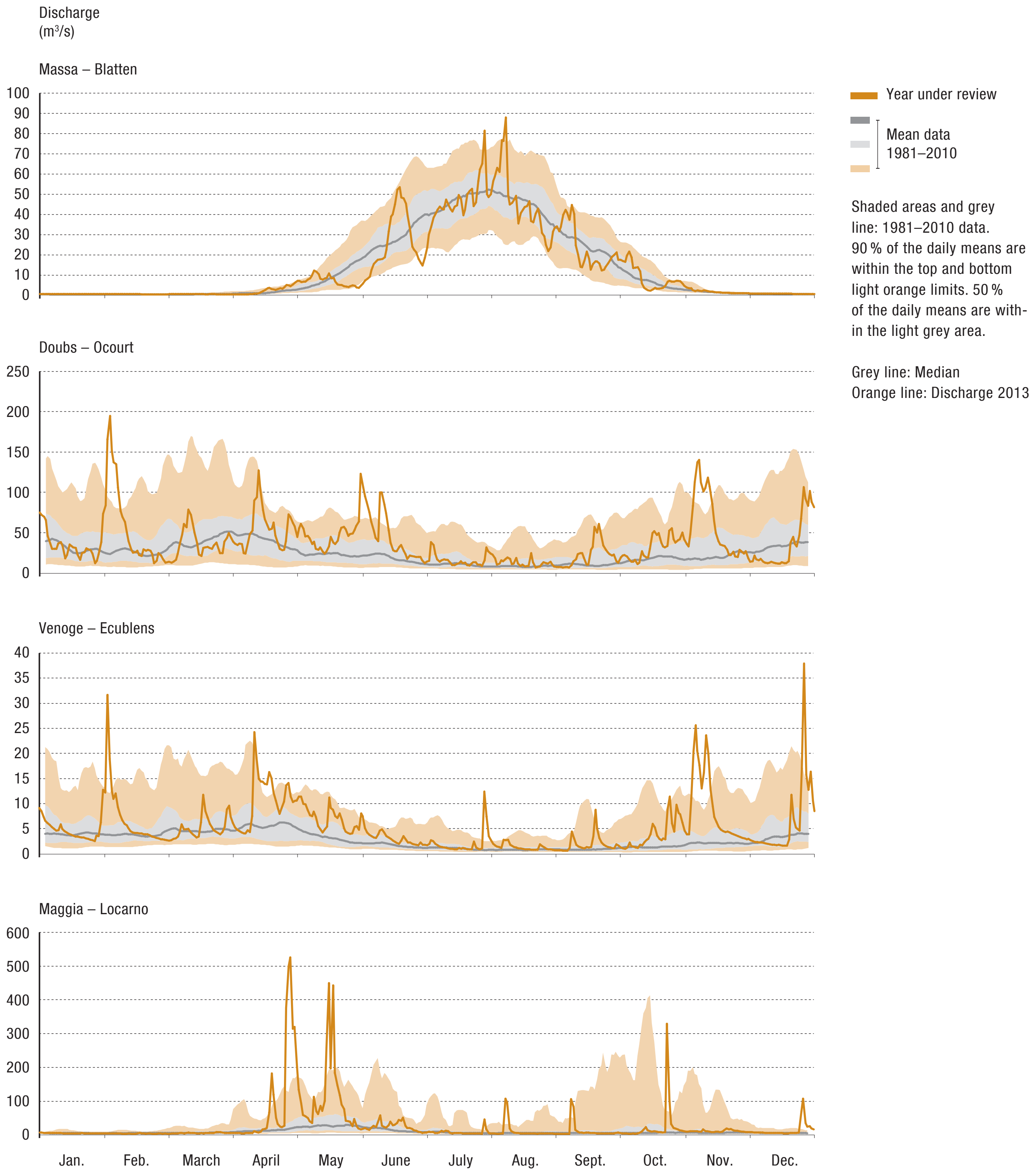


Shaded areas and grey line: 1981–2010 data. 90 % of the daily means are within the top and bottom light orange limits. 50 % of the daily means are within the light grey area.

Grey line: Median
Orange line: Discharge 2013

Figure 4.7 *Daily mean discharges 2013 (orange line) compared with the daily mean for the long-term average period 1981–2010.*

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



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

Grey line: Median
Orange line: Discharge 2013

Figure 4.8 *Daily mean discharges 2013 (orange line) compared with the daily mean for the long-term average period 1981–2010.*

Lake levels

The 2013 mean water level in Lake Constance (unregulated) was around 25 cm above the mean for the long-term average period 1981–2010. In the regulated lakes this deviation from the norm was significantly lower: Lake Neuchâtel +0 cm, Lake Geneva +3 cm and Lake Maggiore +10 cm. Lakes Constance and Neuchâtel began the year with relatively high water levels. Lake Neuchâtel fell quickly to average January levels, but it took until the end of March for the seasonal norm to be reached in Lake Constance. On that lake the monthly averages for January and February were more than 50 cm above the equivalent long-term water levels.

The water level in Lake Maggiore rose rapidly in late April/early May and then again in the second half of May. On 2 May it reached 195.16 m, the highest level of the year. This meant that it exceeded the threshold for the "significant hazard" range by over 30 cm, but it remained 34 cm below the flood limit.

The high water levels in Lake Constance in June were not extreme, but because they continued for such a long time they resulted in a unusually high monthly mean, which deviated from the long-term average by +66 cm. The highest level of the year on 12 June was 85 cm below the maximum for the entire period of monitoring records, which occurred in 1999.

Lakes Lucerne and Zurich fluctuated within the "significant hazard" range for just a few days at the beginning of June; "medium hazard" was experienced on Lakes Brienz, Thun, Biel and Walen. In the second half of June, high water levels were recorded for a few days on Lake Geneva.

After that no further unusually high levels occurred on the larger lakes for the rest of the year until the end of December, when Lakes Maggiore and Lugano rose to a high level for one last time, following an autumn with quite low water levels. In September and October the average water level in Lake Maggiore was more than 50 cm below normal but by late December it had reached nearly 50 cm above normal.

Monthly mean water levels in selected lakes

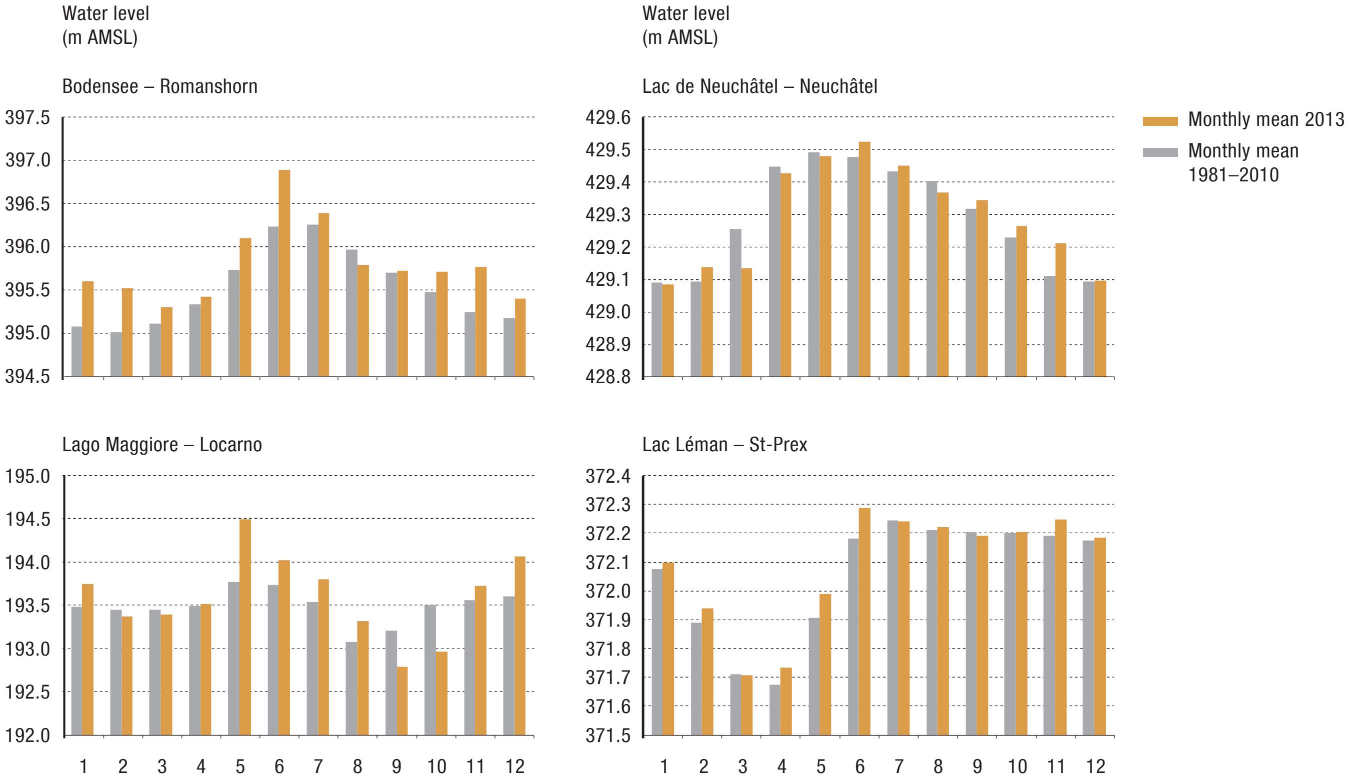
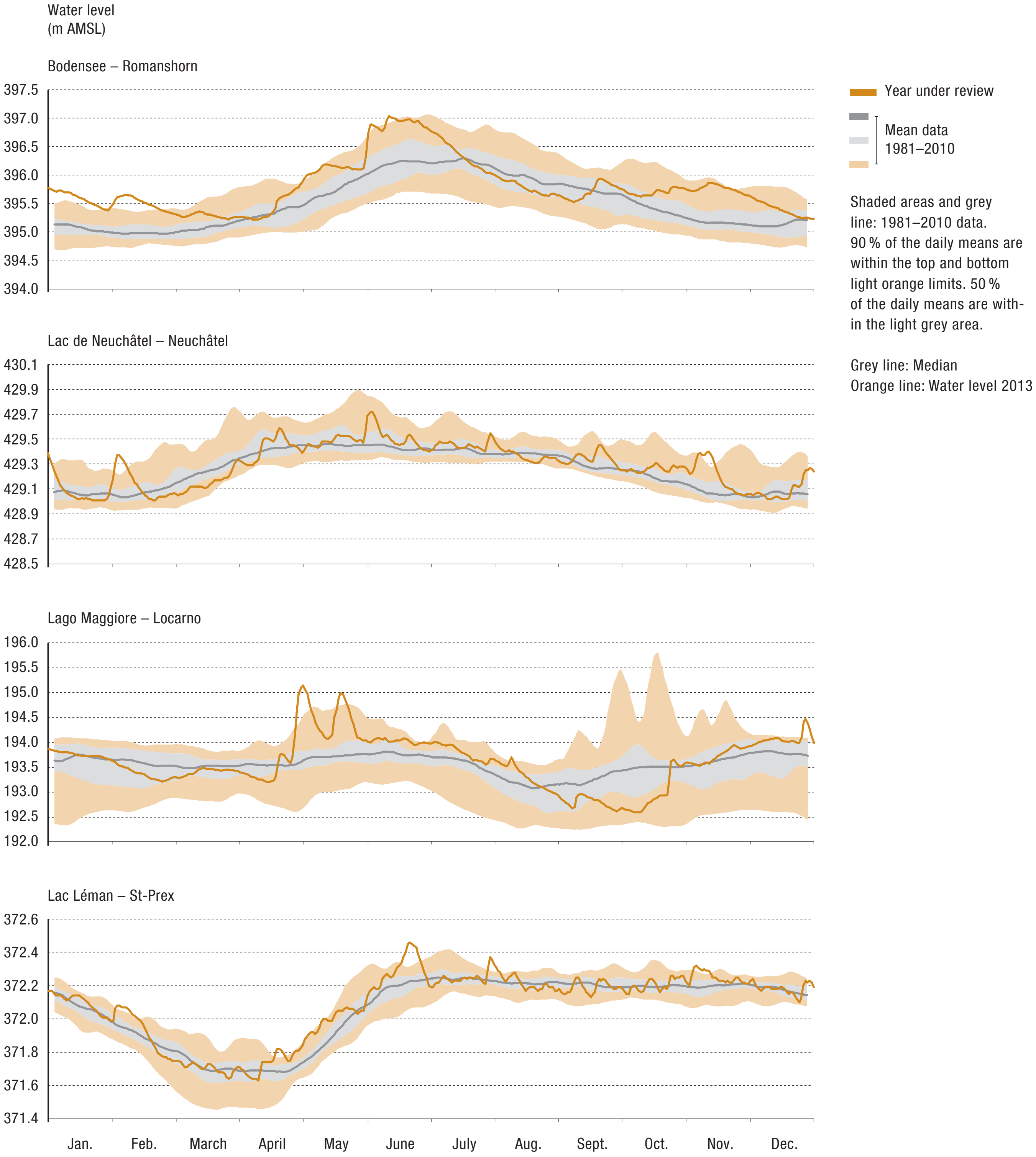


Figure 4.9 *Monthly mean water levels 2013 (orange) compared with the monthly means for the long-term average period 1981–2010 (grey).*

Daily water levels in selected lakes



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

Grey line: Median
Orange line: Water level 2013

Figure 4.10 *Daily mean water levels 2013 (orange line) compared with the daily mean for the long-term average period 1981–2010.*

4.3 Water temperatures

The cold first half of the year and hot summer resulted in widespread average annual mean water temperatures. The deviations from the long-term average for the period 1981–2010 – at the monitoring stations which have measurement data dating back far enough to allow a comparison to be made – were within the range +/–0.3 °C. In the larger catchments (see figure 4.11), the water temperature recorded was around 1 °C lower than in 2011, the warmest year in Switzerland overall since records began in 1864 according to MeteoSwiss. The temperature difference in the Rhone at Porte du Scex was only 0.4 °C from the 2011 mean. Due to the high glaciation of the Rhone basin, temperatures in that river generally vary within a much smaller range than, e.g., the Rhine at Rekingen (see figure 4.12).

A chilly year on the Doubs

2013 was the coldest year yet for two rivers with relatively short data records of only 12 years. These are the Doubs at Ocourt and the Venoge at Ecublens, which has already been mentioned in section 4.1 as a catchment with an above-average annual discharge.

2013 brought new monthly minimum or maximum records in some catchments. New minimums were mainly measured in the months of April and June. New monthly maximums occurred predominantly in July, August and September and in November.

Extreme fluctuations on the Rhine

The mild winter weather at the start of the year was common to all the four catchments in figure 4.12. Only in the Ticino at Riazzino was a new monthly maximum recorded for January.

Extreme fluctuations were experienced by the Rhine at Rekingen. At the beginning of June there was a new monthly minimum record for the 44-year data series of 9.4 °C. The mean for the month was approximately 2 °C below the long-term average. The water temperatures in July and August were then much warmer than usual; the averages for the two months were some 2 °C above normal.

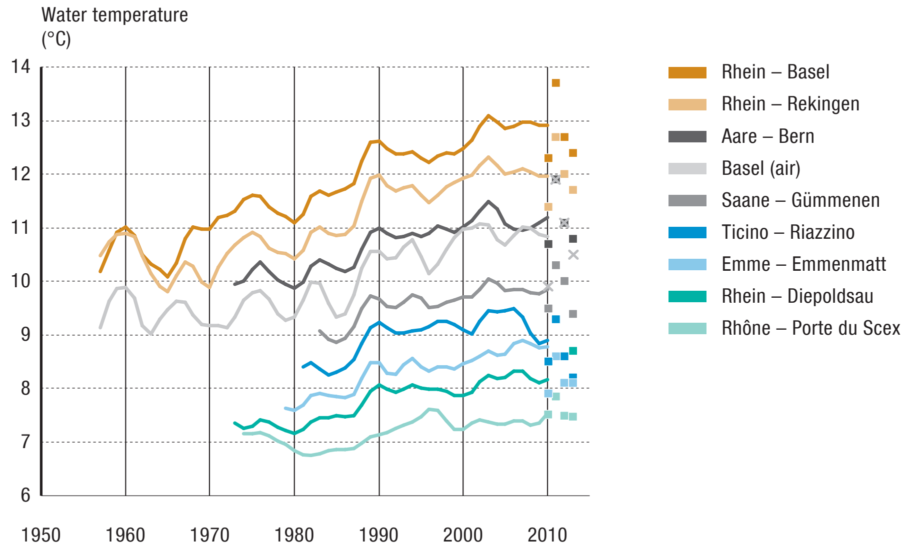
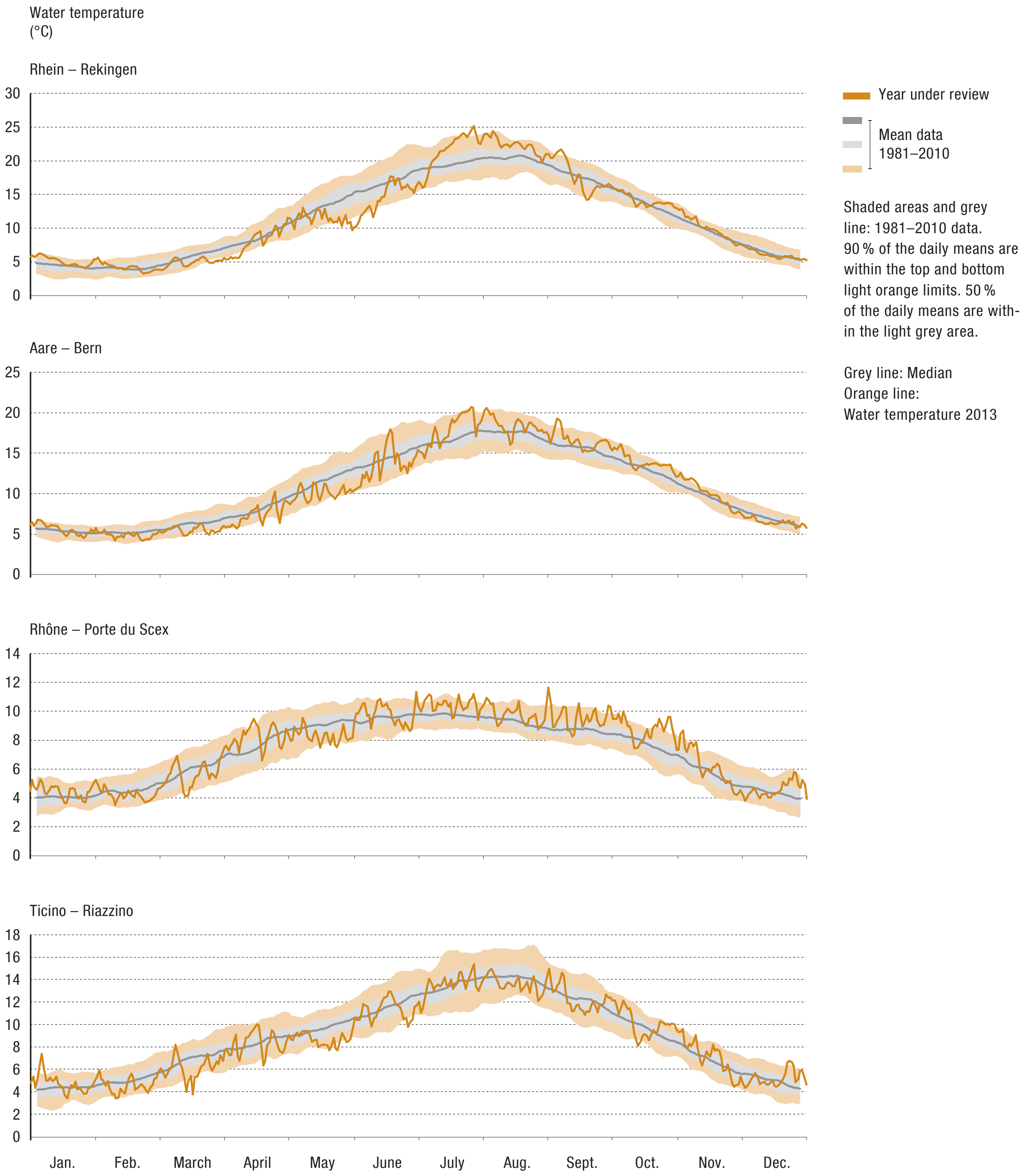


Figure 4.11 *The evolution of water temperature from 1954 to 2013 in selected Swiss rivers. Moving averages (over seven years) are shown as lines and the last four mean annual temperatures as points.*

Mean daily temperature at selected stations



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

Grey line: Median
Orange line:
Water temperature 2013

Figure 4.12 *Daily mean temperature 2013 (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 stations and nine stations on rivers (figure 4.13) to provide reference data for these analyses.

The annual cycle of stable isotopes in the precipitation in 2013 shows below-average δ values in January and February due to the cold weather. High δ values were observed widely in the precipitation in summer 2013, however. In Northern Switzerland unusually low δ values were measured in the precipitation in December 2013 due to the cool conditions. The δ^{2}H and δ^{18}O values in the precipitation rose generally between 1980 and 2005 at all the monitoring stations, though since 2005 no clear trend in δ values has been observed.

A general increase in δ^{2}H and δ^{18}O values can be seen in the rivers (e.g. in the Aare, Rhine and Rhone) from 1994 to 2008, but once again a trend has not been apparent since 2008. During the hot and dry months of July and August 2013, the discharge in the rivers consisted mainly of groundwater and glacier melt water due to the low precipitation. During this period the discharge from the rivers with catchments in the Alps (Aare, Rhine, Rhone) was composed largely of glacier melt water, which was reflected in their low isotope values (e.g. Aare – Brienzwiler monitoring station). Along the Alpine rivers on the Central Plateau the percentage of discharge from glacier melt water fell, whereas the percentage from groundwater increased. This caused the isotope values in the months of July and August 2013 to be higher on the Central Plateau than in the Alps (e.g. at the Aare – Brugg monitoring station).

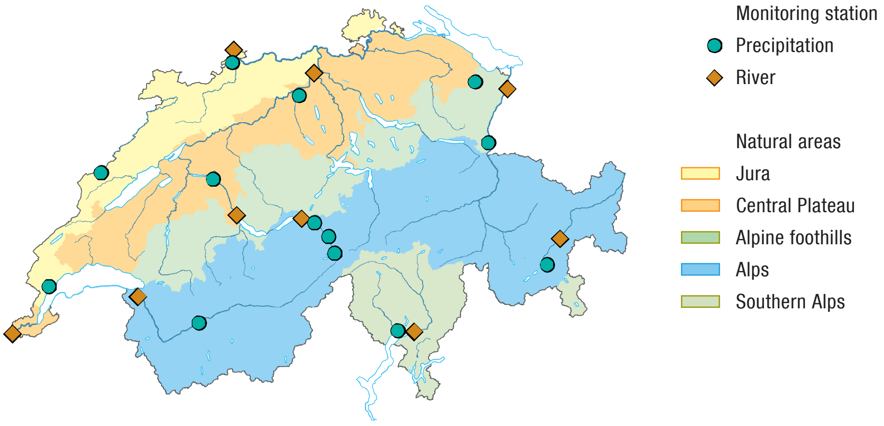


Figure 4.13 *Monitoring stations in the NAQUA ISOT module to monitor the isotopes in precipitation and in rivers in Switzerland, 2013 status.*

4.5 Water quality / Physical and chemical characteristics

The quality of the 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 current status and trend of water quality in the Swiss rivers are surveyed by the FOEN under the National River Monitoring and Survey programme (NADUF) and jointly with the cantons under the National Surface Waters Quality Monitoring programme (NAWA) at 111 monitoring stations. In addition to monitoring the 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 published in the Hydrological Yearbook on a regular basis. Further information and data can be found on the website (see p. 31).

National River Monitoring and Survey
(NADUF) monitoring stations

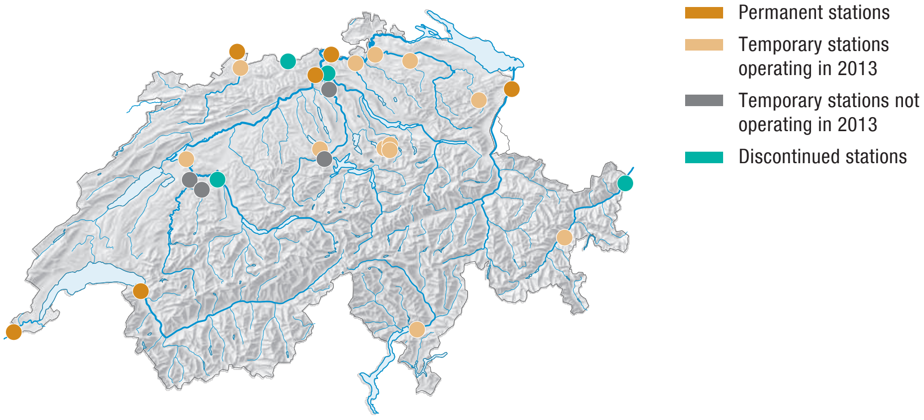


Figure 4.14 *National River Monitoring and Survey programme (NADUF) monitoring stations to monitor water quality in Switzerland, status 2013.*

5 > Groundwater

In 2013 the groundwater levels and spring discharges recorded were mainly normal but also high in some places. The quality of groundwater in Switzerland is generally good.

5.1 Groundwater quantity

By continuously monitoring groundwater levels and spring discharges at around 100 monitoring stations 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 – given the predicted increase in extreme events such as floods and drought – can also be identified.

Through longer-term observation of groundwater levels and spring discharges, significant fluctuations with a specific periodicity can be identified. For example, Swiss groundwater levels alternate regularly between periods of low and high levels lasting for a number of years. These situations are generally linked by a transition range when average groundwater levels and spring discharges occur for a period of time.

In 2013 the Swiss groundwater levels and spring discharges recorded were largely normal but sometimes high. Their changes over 2013 were as follows:

The high groundwater levels and spring discharges on the Central Plateau at the beginning of 2013 (figure 5.1, Groundwater situation on 14 January 2013) returned to approximately normal in February and March, being then between the 10th

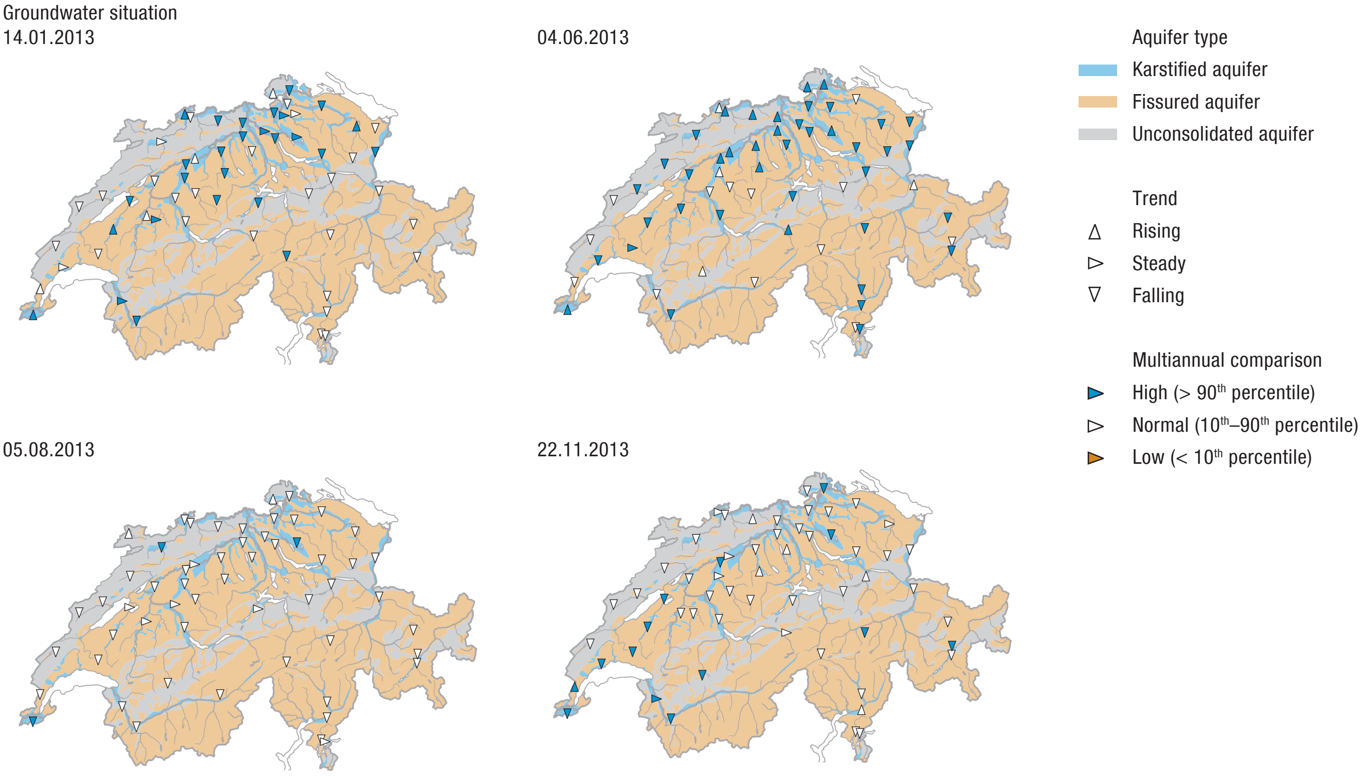


Figure 5.1 *Groundwater levels and spring discharges and their trends on four reference dates in 2013 and compared with the 1993–2012 monitoring period.*

and 90th percentile of the 1993–2012 monitoring period for those two months.

Sharp rise after rainfall in early June

High precipitation in April and May 2013 and the heavy rainfall on 1/2 June led to high groundwater levels and spring discharges in the Northern Alps (figure 5.1, Groundwater situation on 4 June 2013). River levels on the Central Plateau and in Eastern Switzerland rose significantly during the high precipitation of 1/2 June (section 1.1), causing increased river water infiltration. Consequently there was a rapid rise in groundwater levels along the rivers Aare, Limmat, Reuss and Upper Rhine. The high precipitation also caused a rapid increase in discharges from karstified springs.

During the low-precipitation summer months of July and August 2013, groundwater levels and spring discharges largely reverted to normal (figure 5.1, groundwater situation on 5 August 2013). They were higher than in the heatwave summer of 2003 and the low precipitation year 2011 because they began from a higher initial level at the start of the summer of 2013.

The above-average precipitation amounts in the months of September to November 2013 generated some new record high groundwater levels for the month of November in Western Switzerland. At end December 2013 normal to high groundwater levels and spring discharges were observed in Switzerland (figure 5.1, Groundwater situation on 22 November 2013).

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 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 measures to protect groundwater also play an important role, which is why groundwater quality analyses focus on 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 (see p. 31).

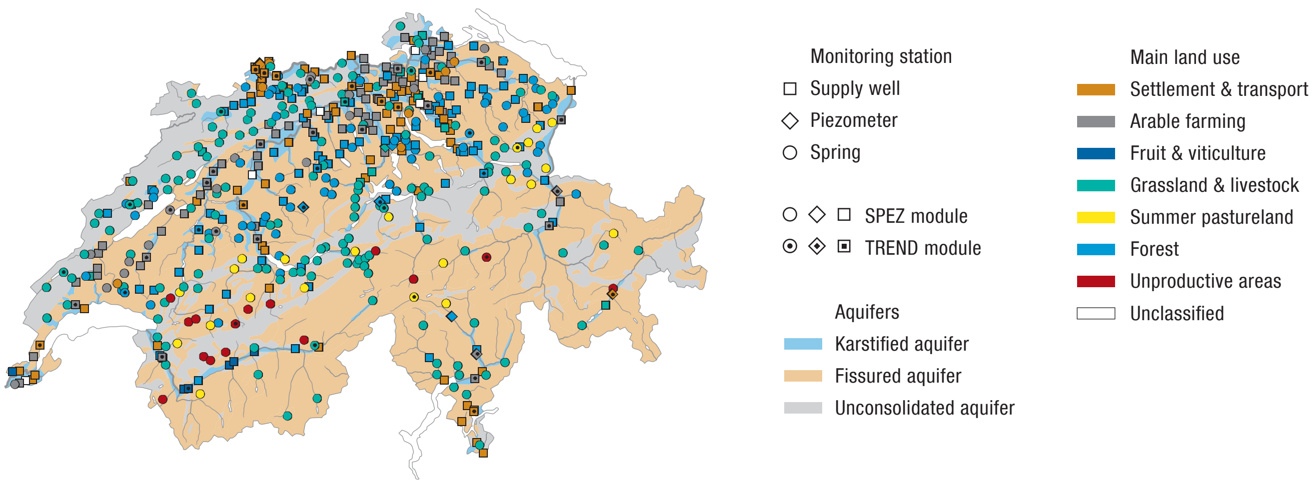


Figure 5.2 *Monitoring sites of the NAQUA SPEZ and TREND modules to monitor groundwater quality, with main land use in the catchment and type of aquifer, status 2013*

> Annex

Glossary

Hazard level

In accordance with the provisions of the Alarm Ordinance, the FOEN uses a five-step hazard scale to warn of floods. The hazard steps provide information on the intensity of the event and its potential impact and make recommendations for action. The flood limit for lakes denotes the transition from the “significant hazard” to the “high hazard” stage. Flooding is likely to occur at this water level. Buildings and infrastructure may be affected.

HQ_x

Discharge exceeded statistically every x years.

National Surface Waters Quality Monitoring (NAWA)

In collaboration with the cantons, the FOEN creates the database to document and analyse the status and trend of Swiss water bodies at the national level.

National River Monitoring and Survey Programme (NADUF)

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

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 precipitation and river water.

Normal value

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

^{2}H, ^{18}O

Deuterium (^{2}H) is a natural stable isotope of hydrogen, oxygen18 (^{18}O) a natural stable isotope of oxygen. Isotopes are atoms of an element with the same proton count but a different neutron count.

δ 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/warnungenvorhersagen/en
  > Hydrologic bulletin
- FOEN Groundwater Bulletin:
  www.bafu.admin.ch/grundwasserbulletin
- Results of the NAQUA National Groundwater Monitoring:
  www.bafu.admin.ch/naqua
- Results of the NADUF National River Monitoring and Survey:
  www.bafu.admin.ch/naduf
- Water indicators:
  www.bafu.admin.ch/water_indicators