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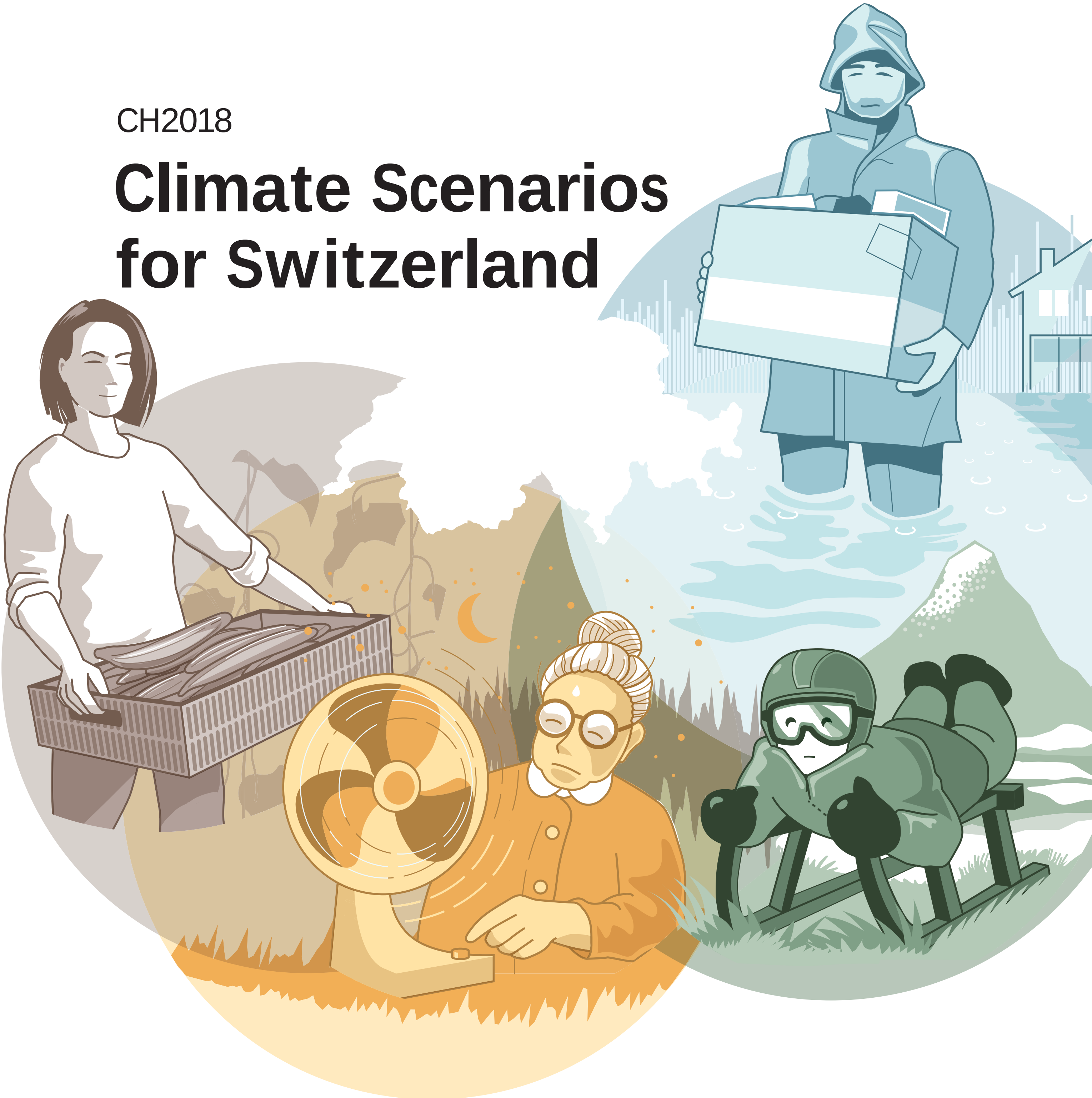
National Centre for Climate Services NCCS

CH2018

Climate Scenarios for Switzerland



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Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

MeteoSwiss

ETH zürich

C2SM Center for Climate Systems Modeling

UNIVERSITÄT BERN

sc | nat
Science and Policy
Platform of the Swiss Academy of Sciences
ProClim
Forum for Climate and Global Change

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A HARD LOOK AT OUR FUTURE CLIMATE

Right across the globe, temperatures are rising – and so is the danger that the climate will change dramatically. The countries which signed the Paris Agreement have committed to reducing their greenhouse gas emissions and averting a dangerous disruption of the climate system. Switzerland, too, has committed to halving its emissions by 2030 compared with 1990. The Federal Council wants to achieve even greater emissions reductions in the longer term.

We are on the right path, but in order to achieve our ambitious targets, we need everyone to be involved: from members of industry to politicians and individuals. Using tried and tested instruments in the transport, buildings, industrial and agricultural sectors, the Federal Council intends to take Switzerland into a low-emissions future. Switzerland can achieve significant reductions in greenhouse gases by means of renewable energy, carbon-neutral transport and greater levels of efficiency.

Even with the greatest of efforts, global warming can only be mitigated at best. The effects of climate change, already in evidence today, are only going to intensify. As an Alpine country, Switzerland will be particularly affected by these changes. We need to take steps to prepare for climate change, which is why the Federal Office of Meteorology and Climatology MeteoSwiss produces climate scenarios on a regular basis. This work brings together members of the scientific community and the public administration; the establishment of the National Centre for Climate Services NCCS has created a valuable network.

The CH2018 Climate Scenarios form an important working basis for the government's adaptation strategy, as they provide the clearest indications to date of where and how climate change may affect Switzerland. They therefore allow the government to make well-founded decisions while at the same time indicating the potential ways in which we can protect the climate effectively.

Alain Berset,
President of the Swiss Confederation and Head of the Federal Department of Home Affairs

In addition to this brochure, you will find further information on the website
www.climate-scenarios.ch:
→ Climate scenarios for the major regions of Switzerland
→ Technical Report on the Climate Scenarios CH2018
→ Web atlas with graphics and data series on local and regional climate change

OUR CLIMATE IN 40 YEARS’ TIME

The Climate Scenarios CH2018 describe how our climate could change up to the middle of this century and beyond. “Dry summers”, “Heavy precipitation”, “More hot days”, and “Snow-Scarce Winters” are some of the expected consequences of unchecked climate change for Switzerland. The potential impact of global efforts to mitigate climate change – and the extent to which climate change would still affect Switzerland – is shown by the scenario “When climate change mitigation takes hold”. The Climate Scenarios combine simulations that use the latest climate models with observations of the trends thus far, providing the most accurate picture to date of our country’s future climate.

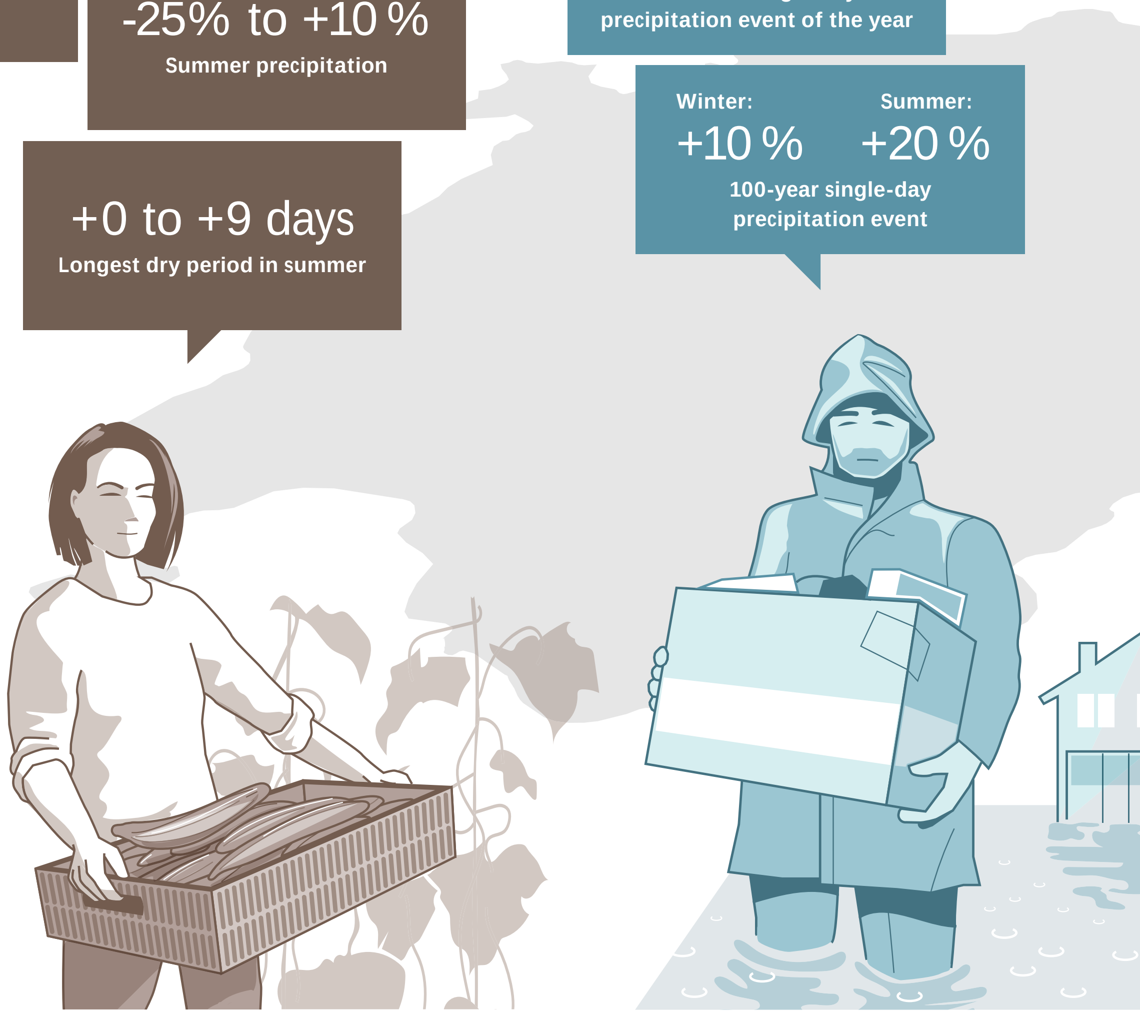
+2.5 °C to +4.5 °C
Summer temperature

-25% to +10 %
Summer precipitation

+0 to +9 days
Longest dry period in summer

Winter: +10 % **Summer:** +10 %
Heaviest single-day precipitation event of the year

Winter: +10 % **Summer:** +20 %
100-year single-day precipitation event



2060

This overview shows the range of possible changes by the year 2060 in comparison to the reference period 1981–2010. The figures are typical values for Switzerland as a whole. For regional values, please see → Page 16.

DRY SUMMERS

Vegetable grower Valérie is watering her cucumbers, as the soil is drier. Evaporation is increasing, and it is raining less often.

→ Page 6

HEAVY PRECIPITATION

Homeowner Urs is clearing out his cellar yet again, as extreme precipitation has become markedly more frequent and intense.

→ Page 8

WHEN CLIMATE CHANGE MITIGATION TAKES HOLD

Lowering the global emissions of greenhouse gases could curb future climate change. Approximately half of the potential changes in Switzerland's climate could be avoided by the middle of the 21st century, two-thirds by the end of the century.

→ Page 14

Switzerland in a changing climate → Page 18
How were the Climate Scenarios generated? → Page 20

+3 to +17
Very hot days
(currently one day per summer on average)

+2 °C to +5.5 °C
Hottest day of the year

+2 °C to +3.5 °C
Winter temperature

400 m to 650 m
Increase in elevation of the zero-degree line in winter

MORE HOT DAYS

Grandma Lucia can't sleep, as heat-waves and hot days and nights have become more common and more extreme.

→ Page 10

SNOW-SCARCE WINTERS

Gian is stuck on the grass, as winters are warmer and often bring rain instead of snow.

→ Page 12

DRY SUMMERS

In the long term, average amounts of precipitation in the summer months will shrink, and evaporation will increase. The ground will become drier, there will be fewer rainy days and the longest precipitation-free period will last longer.

A noticeable reduction in precipitation during the summer months is expected in the future. Although we are still experiencing a similar amount of rainfall on an average rainy day in summer as in the past, there are now more days without rain. The longest dry period in summer may last about a week longer on average by the middle of the century.

In general, areas in the west and the south will be more affected by a potential decrease in rainfall than eastern regions. Not only will there be less rain, but because of the high temperatures, more moisture will evaporate than it does at present. The ground will thus become drier, even if the amount of rainfall does not change.

The trend towards dryness will further increase with continued climate change. By the end of the century, dryness to an extent that has occurred only once or twice every ten years in the past could be occurring every two years.

Average temperatures can be simulated quite reliably with climate models. Precipitation is more difficult to predict, as it is subject to significant natural variations in terms of amount and distribution. This is due to the wide range of mechanisms that determine the atmospheric water balance. Despite such uncertainty, the climate simulations clearly indicate a long-term trend of reduced precipitation in summer.

The summers of 2003 and 2018 provide an idea of the potential effects of hot, dry summers. Apart from agriculture, the energy production and water management sectors are also affected by increasing dryness in summer.

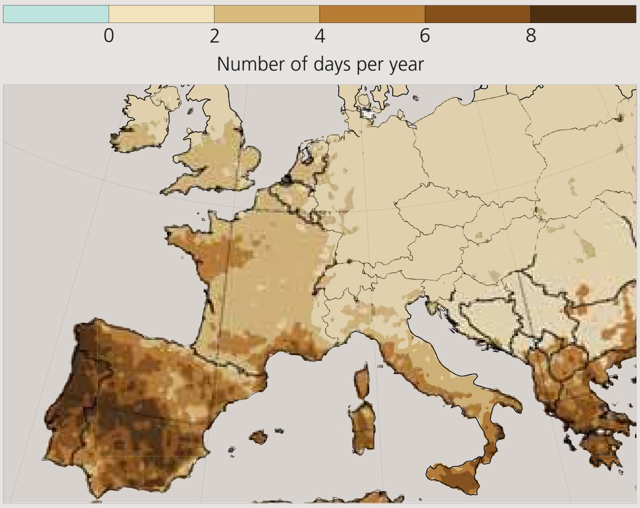
	Summer precipitation	Longest dry period in summer	Summer temperature
Possible around mid-century:	-25 % to +10 %	+0 to +9 days	+2.5 °C to +4.5 °C
Possible by the end of the century:	-40 % to 0 %	+1 to +9 days	+4 °C to +7 °C

Possible range of changes in comparison to 1981 to 2010 without climate change mitigation (simulation range).
Typical 30-year averages across Switzerland. Temperature changes are rounded to 0.5 °C, and precipitation changes to 5%.

Possible scenario in 2060: The average near-surface air temperature in Switzerland through June, July and August is about 4.5 °C warmer than today. At the same time, there is up to a quarter less rainfall, and the longest dry period without precipitation in summer lasts about 20 days instead of 11.

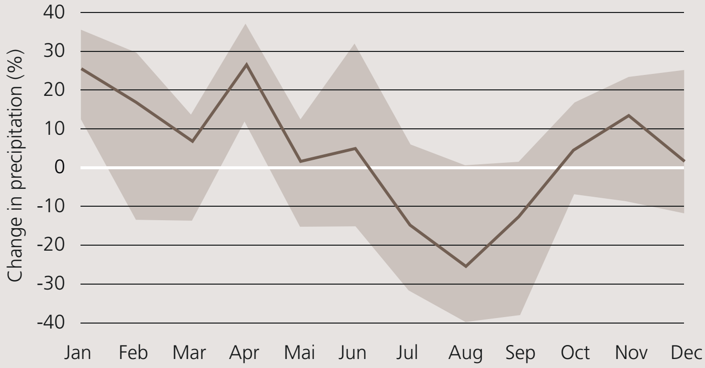
> "In extreme dryness, just one spark is enough to ignite a forest fire. The Climate Scenarios CH2018 help me to make more accurate assessments of the risk of forest fires as a result of climate change."
>
> **Dr. Marco Conedera,**
> **Head of Community Ecology Research Unit at WSL**

Change in the longest dry period in summer
Expected change around 2060 without climate change mitigation, in comparison to 1981–2010 (30-year averages).



Change in precipitation in La Chaux-de-Fonds
Change over the course of the year around 2060 without climate change mitigation, in comparison to 1981–2010 (30-year average).

Expected (median of all simulations)
Possible (range of the simulations)



Longer dry periods

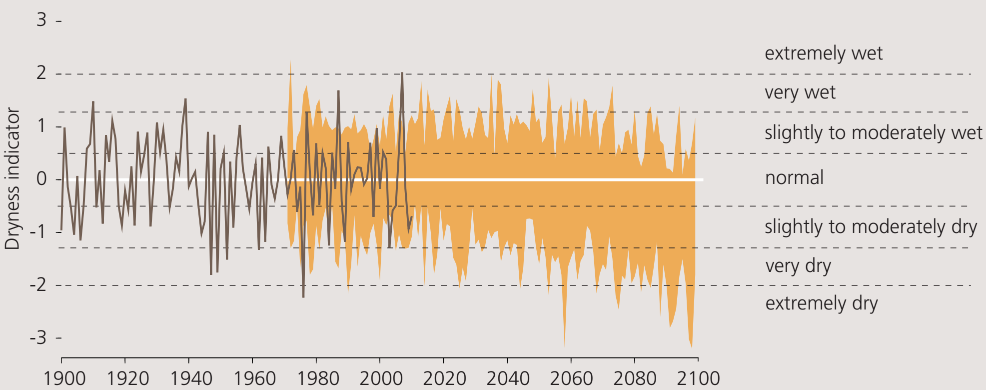
Our country is situated at the edge of a zone around the Mediterranean that is experiencing more extensive dry periods. By the middle of this century, the longest dry period in summer is expected to increase by about two days. However, depending on how far the dry belt extends, it could be up to nine days longer.

Shift in the annual cycle

Although precipitation is projected to increase in the winter, the summer months are becoming drier. This pattern is apparent in the example of La Chaux-de-Fonds in the Neuenburg Jura region.

Temporal development of summer dryness in the Jura region
Dryness indicator, standard deviation of summer precipitation amounts (June–August) from the norm for 1981–2010.

Measurement (average value from meteorological stations in Basel/Binningen, La Chaux-de-Fonds, Neuchâtel and Chaumont)
Possible without climate change mitigation (range of simulations)



Dryness becoming more common

Without climate change mitigation, dry conditions will occur more frequently in summer, as seen here in the example of Jura. This region is prone to dryness even though its rainfall is comparatively high, as water disappears quickly due to the karstic substratum.

HEAVY PRECIPITATION

Heavy precipitation events are likely to become significantly more frequent and intense in the future compared to today. This is the case for all seasons, but particularly for winter. Rare extreme events such as 100-year precipitation events will be markedly more intense.

Since 1901, the amount of precipitation falling in individual heavy precipitation events in Switzerland has risen by 12 percent. Because warmer air can hold about 6 to 7 percent more water per degree Celsius, the physics of the observed intensification of precipitation is well understood.

This trend is expected to continue in the future. In the case of unchecked climate change, the heaviest single-day precipitation events in winter would intensify by an additional 10 percent by the middle of this century; by the end of the century, the expected increase is 20 percent. In summer, the increase is about 10 percent. In the other seasons, the changes are between those for winter and summer.

The very rare precipitation events that occur once every 100 years will see increases as well. The change amounts to about 10 to 20 percent by mid-century, and about 20 percent by the end of the century. Thus, despite reductions in total amounts of precipitation in summer, the intensity of extreme events will increase.

However, the changes in heavy precipitation events vary over time and across regions and may deviate from the long-term trend over several decades.

The increased intensity of heavy precipitation events can have significant cost implications. For instance, heavy precipitation can cause landslides and flooding and thus result in widespread damage. Consequently, infrastructure such as flood protection and sewage networks must be properly designed to cope with these threats.

The potential for damage by precipitation extremes is expected to be higher in the future, and not only because of the higher amounts of precipitation. The increasing altitude of the snowline will increase the proportion of liquid precipitation in winter, thereby expediting runoff.

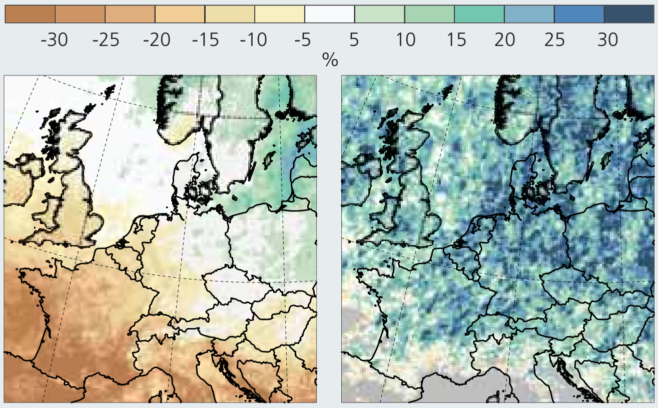
	Heaviest single-day precipitation event of the year		100-year single-day precipitation event	
	Winter	Summer	Winter	Summer
Expected around mid-century:	+10 %	+10 %	+10 %	+20 %
Expected by the end of the century:	+20 %	+10 %	+20 %	+20 %

Expected changes in comparison to 1981–2010 without climate change mitigation (simulation median, maximum across regions). The uncertainty range for heavy precipitation is not taken into account, as this is strongly influenced by natural fluctuations. Precipitation changes are rounded to 5%.

Possible scenario in 2060: The heaviest precipitation falling on a single day has increased by about 10 percent. A 100-year precipitation event in summer will bring about 20 percent more rain than today.

> "Building protection measures, flood defences and drainage systems must be better coordinated with one another in the future and have fit-for-purpose design and construction. In order to accomplish this, we need to not only rely on past data but also properly incorporate climate projections into the relevant standards."
>
> **Stefan Cadosch,**
> **President of the Swiss Association of Engineers and Architects sia**

Change in average and extreme precipitation in summer
Change around 2060 without climate change mitigation, in comparison to 1981–2010 (30-year averages).



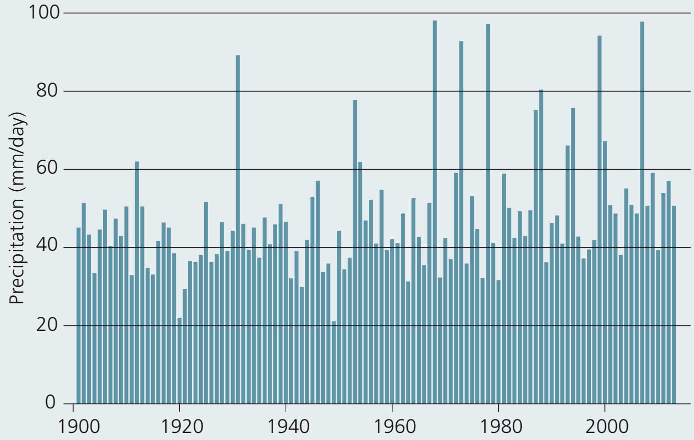
Average summer precipitation

100-year single-day precipitation event

Extremes intensify

Switzerland will be affected by the increasing summer dryness in the Mediterranean region (left-hand map). At the same time, it will be influenced by the increase in heavy and extreme precipitation events in northern Europe (right-hand map).

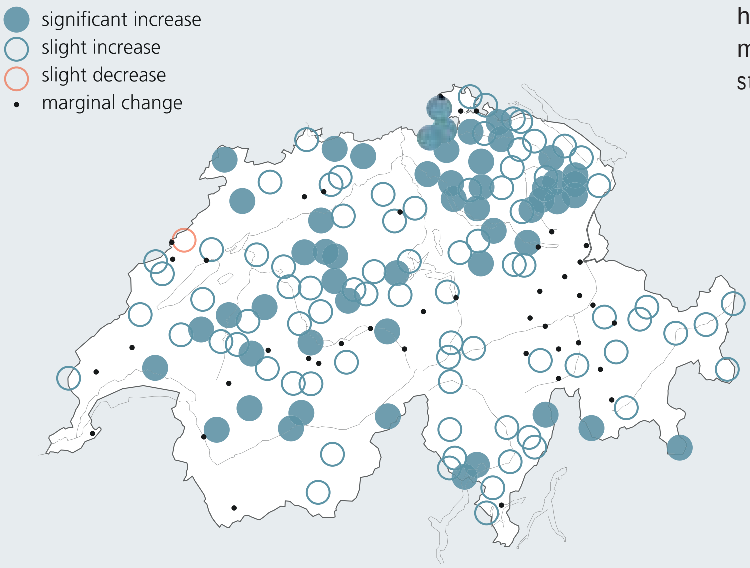
Heaviest single-day precipitation event of the year in Zurich



Variability of extremes obscures the trend

As the example of the data from Zurich shows, it is not easy to discern clustering of extreme precipitation events at one particular location. The figure shows the heaviest single-day precipitation measured in each year. The values vary widely, and the highest precipitation peaks are rare occurrences.

Trends in heaviest single-day precipitation event of the year
Observed trend in precipitation amounts from 1901 to 2014.



Clearer picture over Switzerland as a whole

It is only in the Switzerland-wide overview that the trend for heavy precipitation events clearly emerges. Of the 173 measurement stations, 158 show an increase in such events. None of the stations show a significant decrease.

MORE HOT DAYS

The increases in the highest temperatures are even more pronounced than for the average temperatures. Heatwaves and hot days and nights become more frequent and extreme. Heat stress is greatest in low-lying urban areas with high population densities.

Over the coming decades, average temperatures in Switzerland are projected to continue rising. The increases affect all four seasons but are most prominent in summer. If greenhouse gas emissions continue to increase, by the middle of this century, average summer temperatures may be up to 4.5 °C higher than now.

The increases in the highest temperatures are even more pronounced than for the average seasonal temperatures. By 2060, the hottest days in an average summer could be up to 5.5 °C higher than they are today. This is explained in part by the fact that less water will be evaporating and cooling the ground because there will be less moisture in the soil.

The regions of Europe that surround the Mediterranean Sea, including Switzerland, are affected by some of the most severe increases in temperature extremes worldwide. This trend has been apparent even over recent decades and is very likely to continue into the future.

With every additional degree Celsius increase in the average temperature in Switzerland, the number of very hot days approximately doubles. By definition, "Very hot" here refers to the 1% hottest days of all summers between 1981 and 2010. Currently, very hot days occur on average just under once per summer.* By the middle of this century, the number of these very hot days could rise to 18 in a typical summer. At the same time, heatwaves will become a much more common occurrence.

Particularly in low-lying regions, periods of heat stress for humans and animals will also increase. The combination of extreme heat and humidity means that the body is unable to cool down to a comfortable level.

The climate models do not take into account any urban heat-island effects. In heavily developed urban areas, temperatures (and especially temperatures at night) are a few degrees Celsius higher than in surrounding areas. The majority of the population in metropolitan areas is therefore affected to an even greater extent by the warming temperatures.

* In individual years, very hot days often occur clustered on consecutive days.

	Hottest day of the year	Number of very hot days**
Possible around mid-century:	+2 °C to +5.5 °C	+3 to +17 days
Possible by the end of the century:	+4 °C to +8.5 °C	+12 to +37 days

Possible range of changes in comparison to 1981 to 2010 without climate change mitigation (simulation range). Typical 30-year averages across Switzerland. Temperature changes are rounded to 0.5 °C.
**See explanation in main text.

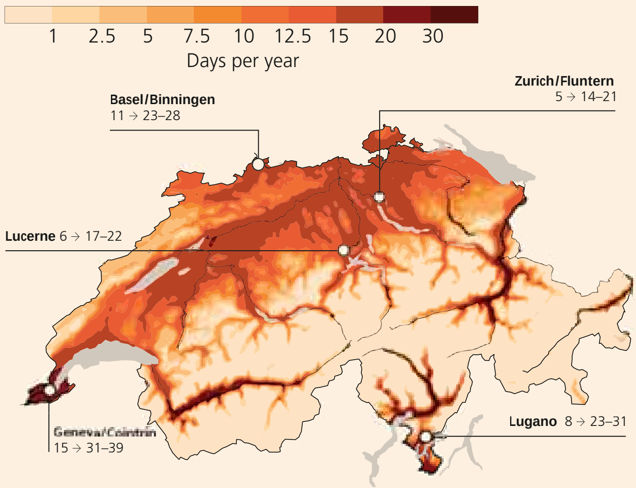
Possible scenario in 2060: On the hottest days in summer, temperatures shoot up 5.5 °C higher than we are accustomed to now. Hot summers such as in the record year of 2003 have become the norm. Very hot days – with temperatures that used to occur only once in a year – are now occurring on average 18 times per year.

"Cities are particularly vulnerable to heat. The city of Zurich is taking steps to prepare for climate change by developing a 'City Climate Master Plan'. It is important to have the best possible information at hand about increases in heat stress in order to be able to design appropriate adaptation measures."

Anna Schindler,
Director of Zurich City Development

Change in number of hot days

Changes in the number of days with temperatures above 30 °C around 2060 without climate change mitigation, in comparison to 1981–2010 (30-year averages). The values show the norm for the period of 1981–2010 and the possible range around 2060.

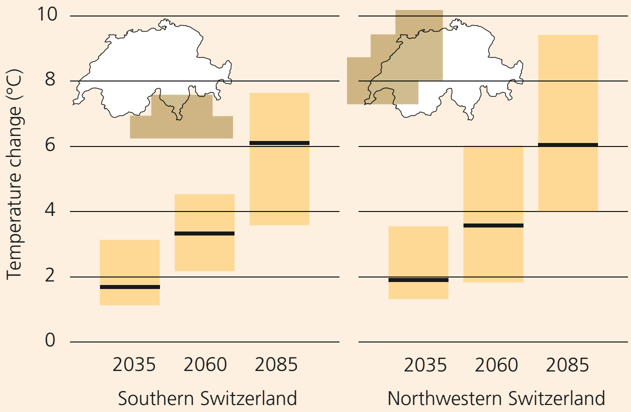


Change in annual maximum temperature

Average change around 2035, 2060 and 2085 without climate change mitigation, in comparison to the normal period of 1981–2010 (30-year average).

Expected (median of all simulations)

Possible (range of the simulations)



More hot days

Low-lying urban and residential areas are particularly affected by heat. On the Swiss Plateau and in the Alpine valleys, the thermometer is reading over the 30-degree mark more frequently – the temperature which denotes a "hot day". The greatest increases in hot days are expected in the regions of Geneva, Valais and southern Switzerland.

Highest temperatures increasing strongly

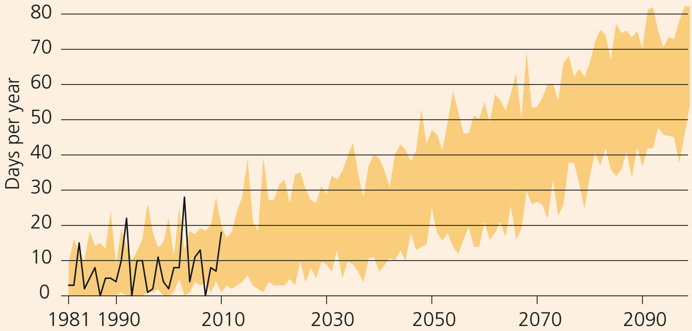
The hottest temperatures of the year are projected to increase significantly. By the middle of this century, the hottest day of the year south of the Alps may be up to 4.5 °C hotter than it is today, and north of the Alps even up to 6 °C hotter. This means that the hottest day in Geneva in an average year would have a temperature of about 40 °C.

Days with heat stress in Lugano

Days on which the human body is unable to cool down to a comfortable temperature because of the combined effects of heat and humidity.

Calculated from measurements

Possible without climate change mitigation (range of simulations)



Acute heat stress in Ticino

Ticino's climate is affected by the air currents from the Mediterranean and is generally a few degrees warmer than other regions of the country at similar altitudes. By the middle of this century, Lugano can expect about 30 days of heat stress every summer.

SNOW-SCARCE WINTERS

Winters will be significantly warmer by the middle of the century as well. Although there will be more precipitation, it will fall more frequently in the form of rain because of the higher temperatures. Particularly in lower-lying regions, it will snow less often and in smaller quantities. The snowy areas of Switzerland will therefore shrink considerably.

The climate warming experienced to date has already had a significant effect on the snow and ice conditions. The Alpine glaciers have lost about 60 percent of their volume since 1850. Moreover, at altitudes below 800 meters, the number of days with snowfall has halved since 1970.

Switzerland's average temperatures in winter will continue to rise in the future. By mid-century, the zero-degree line could increase in elevation from today's level at 850 metres to up to 1,500 meters above sea level. Snowfall will change as the result of two opposing effects: Increases in temperature will lead to a greater proportion of precipitation falling as rain, but the total amounts of precipitation in winter will also increase.

On balance, however, our country will experience a considerable reduction in both snowfall and snow cover. This will predominantly affect the low-lying areas, particularly in springtime. Below altitudes of 1,000 metres, snow cover will approximately halve by the middle of the century; by the end of the century, it will probably diminish by over 80 percent.

The higher altitudes will also be affected. The large majority of Alpine locations is expected to suffer reductions in snowfall, particularly in the spring. The decreased amounts of snow will also affect the glaciers: They will not be fed with enough snow, and they will also melt at a faster rate.

In winter, small-scale phenomena such as inversion layers and cold-air pools often dictate local weather patterns. Consequently, snowfall amounts fluctuate widely, and so it is difficult to simulate them in a climate model. This means that there could also occasionally be winters in the future with plenty of snow.

The changes in snowfall and snow cover not only have an effect on winter tourism but are also relevant for sectors such as hydropower and transportation.

	Winter temperature	**Elevation increase of the zero-degree line in winter**
Possible around mid-century:	+2 °C to +3.5 °C	400 m to 650 m
Possible by the end of the century:	+3 °C to +5.5 °C	700 m to 1050 m

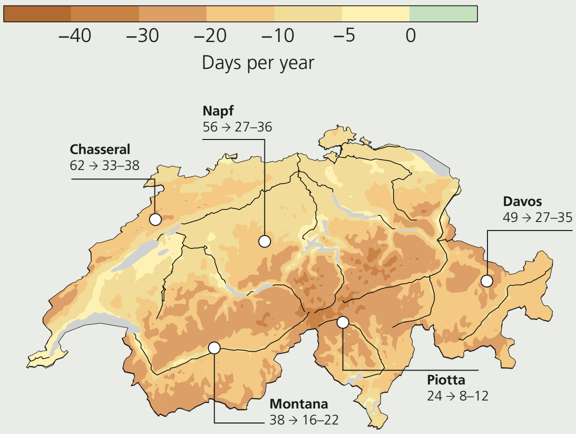
Possible range of changes in comparison to 1981 to 2010 without climate change mitigation (simulation range).
Typical 30-year averages across Switzerland. Temperature changes are rounded to 0.5 °C.

Possible scenario in 2060: In winter, it is on average 3.5 °C warmer than now. There is less snowfall in terms of both amount and frequency. Snowfall amounts in low-lying areas are reduced by half. The elevation of the zero-degree line has risen by 650 metres and is situated at about 1,500 metres above sea level in winter.

> “Winter tourism is an important attraction for our region as a destination. The new data will help us to arrive at clearer estimations of the challenges associated with the changing snow conditions.”
>
> **Carmelia Maissen,**
> **Mayor of Ilanz/Glion**

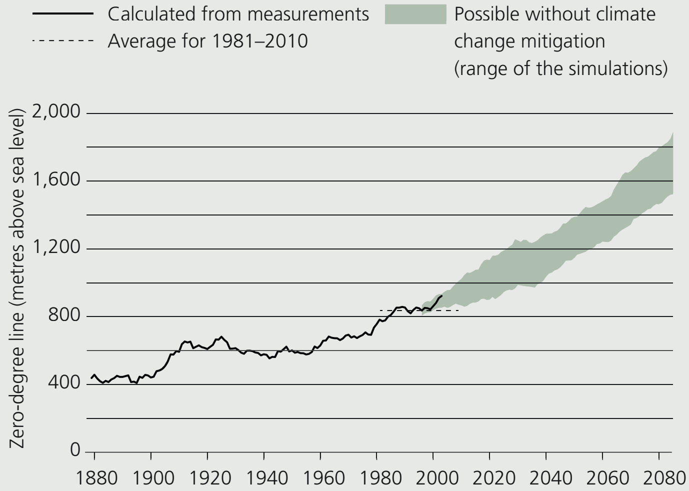
Change in number of days with snowfall

Expected changes around 2060 without climate change mitigation, in comparison to 1981–2010 (30-year averages). The values show the norms for the period of 1981–2010 and the possible range around 2060.



Zero-degree line

Zero-degree line in winter (Swiss average and 30-year running average).



Snow becomes a rarity

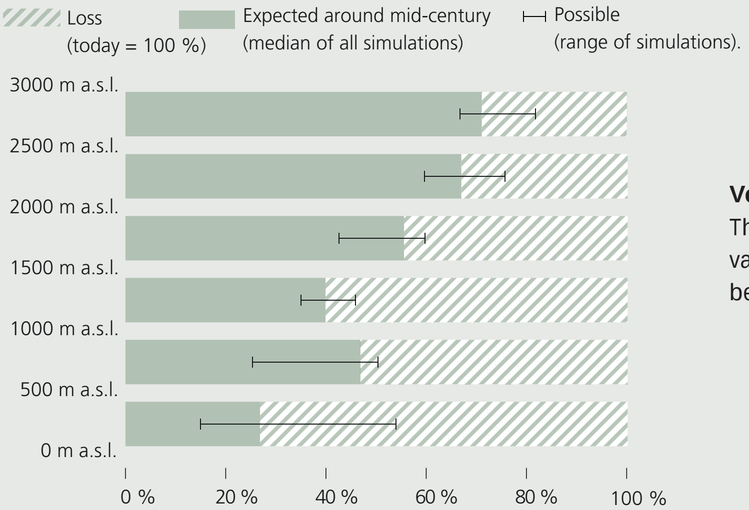
In higher-altitude, snow-rich locations, snow will fall on significantly fewer days; in the central Alps, 30 fewer days of snowfall per year are expected by the middle of this century. In the lower altitudes, and in particular on the Swiss Plateau, the number of snow days will not be reduced quite so dramatically, as it seldom snows in these areas already now.

Increase in elevation of zero-degree line

The elevation of the zero-degree line has already risen considerably, and this trend will continue even more markedly in the future. The areas with the right conditions for snow can be expected to shrink in size.

Snow cover

Snow cover around 2060 without climate change mitigation as a percentage of today’s norm, in terms of average snow water equivalent from September to May at different altitudes (30-year averages).



Very little snow at low elevations

The warming will cause snow cover to shrink significantly at all elevations. In lower-lying areas, snow-covered landscapes will largely be a thing of the past.

WHEN CLIMATE CHANGE MITIGATION TAKES HOLD

Lowering the emissions of greenhouse gases globally could effectively stem climate change. Approximately half of the potential changes in Switzerland's climate could be avoided by the middle of the 21st century, two-thirds by the end of the century. Although temperatures will still rise in Switzerland, the increases will be much smaller than if emissions are allowed to increase unchecked.

The aim of the 2015 Paris Climate Agreement is to limit the increase in the Earth's average surface temperature to well below 2 °C above pre-industrial levels. This global 2-degree target is likely to be achievable if the countries that have signed the agreement urgently reduce their hitherto steadily increasing emissions of greenhouse gases and practically halt them completely in the second half of this century.

Near-surface air temperatures will still increase further despite climate change mitigation – in Switzerland even more so than in the global average. A further increase of about 0.5 to 2.5 °C, depending on the season, is likely by the middle of this century. Added to the climate change already observed,* this results in warming by a total of 2 to 4 °C compared to pre-industrial temperatures.

Amounts of precipitation in summer in our country could decrease by up to 15 percent, and increase in winter by a similar percentage. These figures apply to the middle of the century but would change very little by the end of the century; this indicates that climate change mitigation measures would have a long-term stabilising effect on the climate.

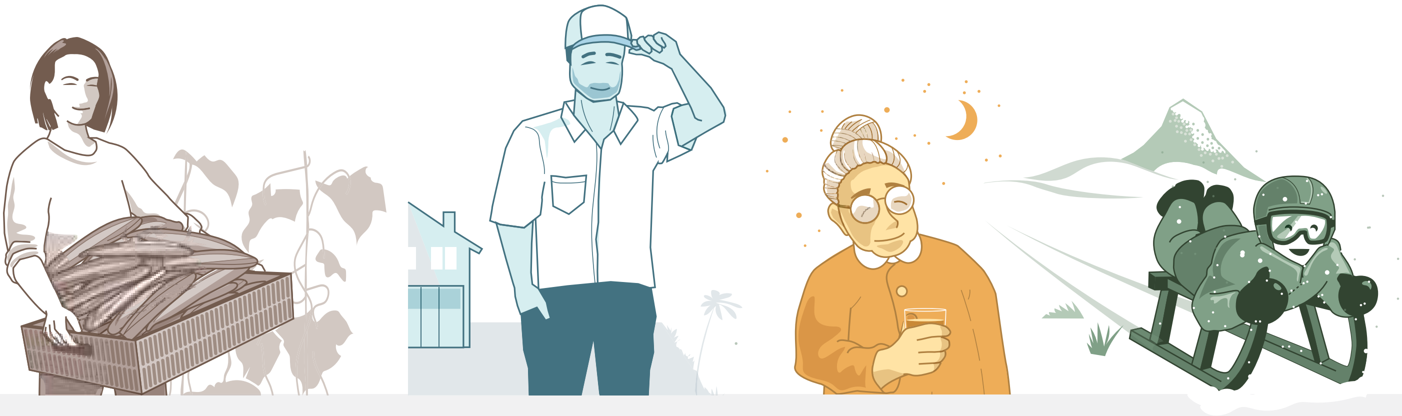
Climate change mitigation will also have an effect on other aspects of climate change in Switzerland: Increases in summer dryness, heat and heavy precipitation events and the lack of snow will be much less pronounced than if emissions were to continue unabated. We could therefore reckon with 10 very hot days per year – instead of over 30 without climate change mitigation (see page 10).

* The average temperature rose by 1.5 °C between the normal period of 1981–2010 and an early industrial period (1864–1900) (see graph of annual average temperature).

	Temperature Summer	Precipitation Summer	Number of very hot days	100-year single-day precipitation event in winter**	Temperature Winter
Possible around mid-century:	+1 to +2.5 °C	-15 % to +5 %	+0 to +8	+5 %	+0.5 to 2 °C
Possible by the end of the century:	+1 to +2.5 °C	-15 % to +10 %	+1 to +7	+5 %	+0.5 to 2 °C

Typical 30-year averages across Switzerland in comparison to 1981–2010. The figures for the end of the century are virtually identical. Temperature changes are rounded to 0.5 °C, and precipitation changes to 5%.
** For changes in heavy precipitation events, only the expected change is given.

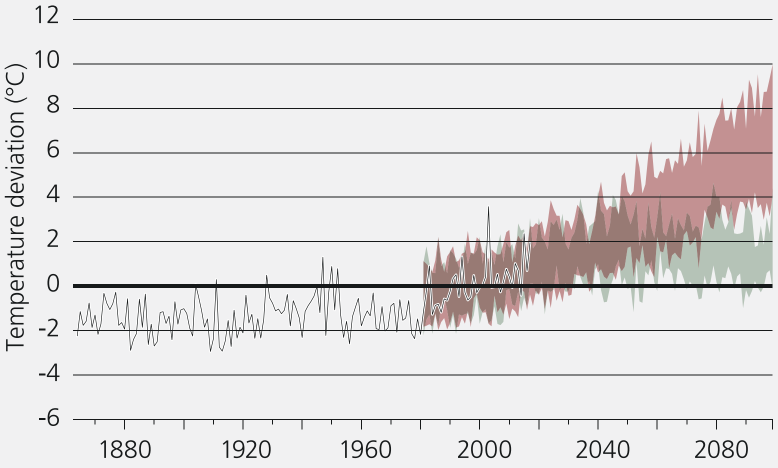
Possible scenario in 2060: Thanks to a concerted joint effort, the signatory countries have achieved the main target of the Paris Climate Agreement. This also has the effect of mitigating climate change in Switzerland: In summer, the temperatures here are about 1.5 °C warmer than before. However, without any effective mitigation measures, this increase would be between 2.5 °C and 4.5 °C.



Average summer temperature

Deviation of average Swiss summer temperature from the mean in the period from 1981 to 2010.

— Measurements
Possible **with** climate change mitigation (range of simulations)
Possible **without** climate change mitigation (range of simulations)



The potential of climate change mitigation

A comprehensive, worldwide reduction in greenhouse gas emissions would also curb warming in Switzerland considerably. Nevertheless, temperatures would still increase up to the middle of this century. In the case of an unabated growth of emissions, however, warming would continue well beyond this century.

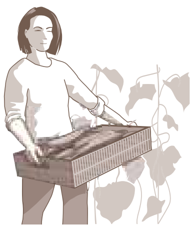
REGIONAL OVERVIEW

The Climate Scenarios CH2018 cannot be fully captured by a single outlook for the whole of Switzerland. Although the trends are similar for all parts of the country, there are considerable differences between the Swiss Plateau and the Alps, for example, and between northern and southern Switzerland. This overview complements the Switzerland-wide figures of the Climate Scenarios with regional variations.

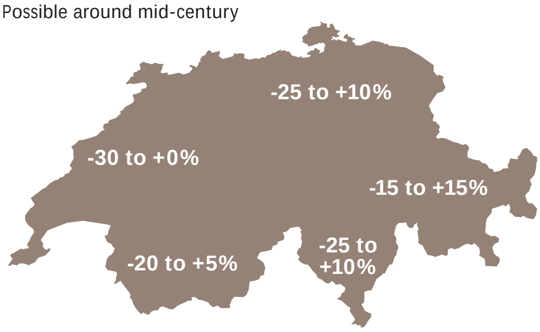
Temperature changes are rounded to 0.5 °C, and precipitation changes to 5 %.

2060 **without** climate change mitigation | 2085 **without** climate change mitigation

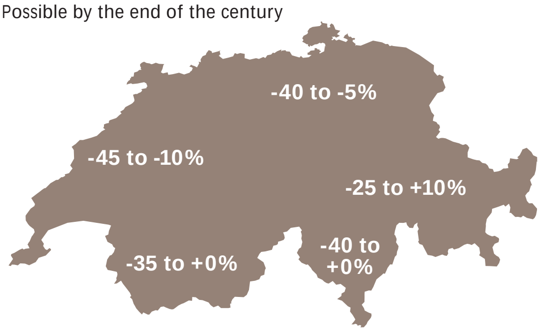
Summer precipitation



Possible around mid-century

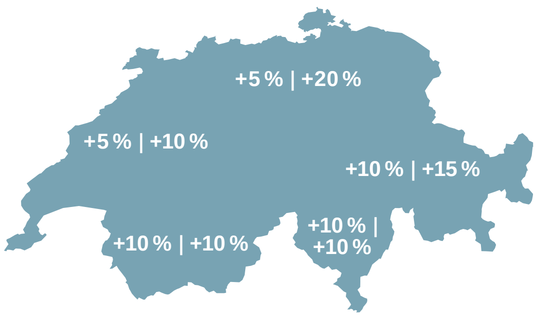


Possible by the end of the century

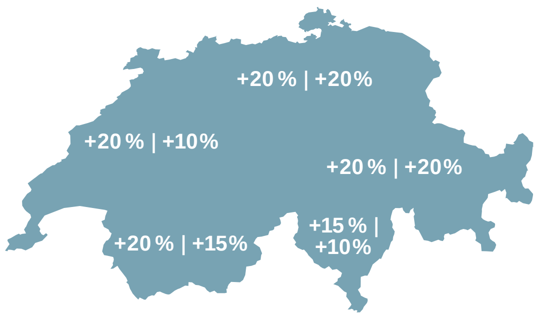


100-year single-day precipitation event (Winter | Summer)

Expected around mid-century

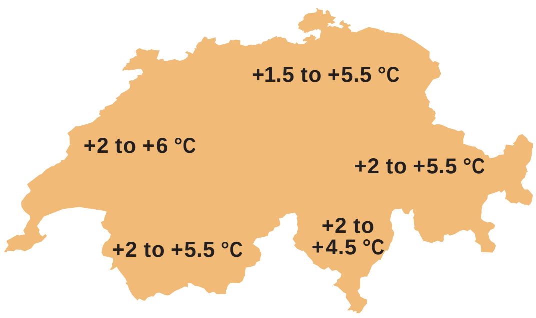


Expected towards the end of the century

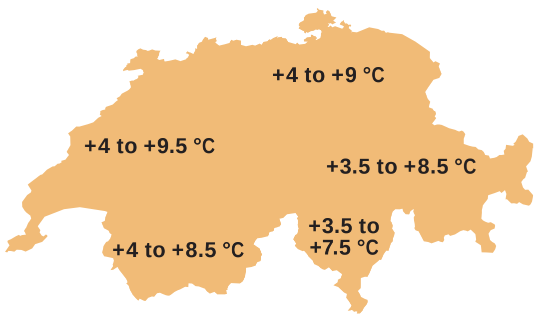


Hottest day of the year

Possible around mid-century

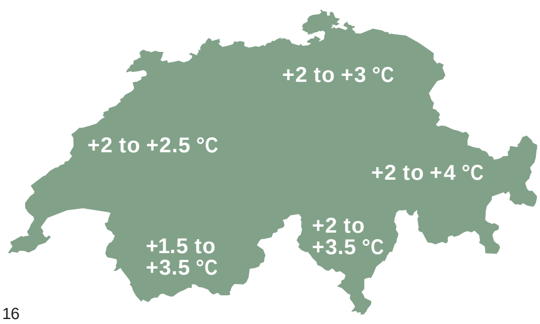


Possible by the end of the century

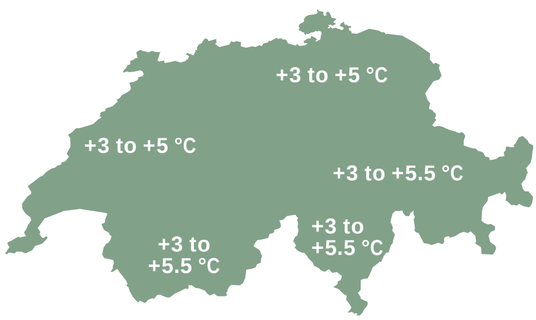


Winter temperature

Possible around mid-century



Possible by the end of the century

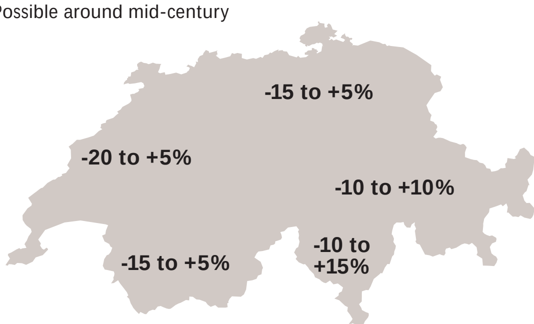


2060 with climate change mitigation

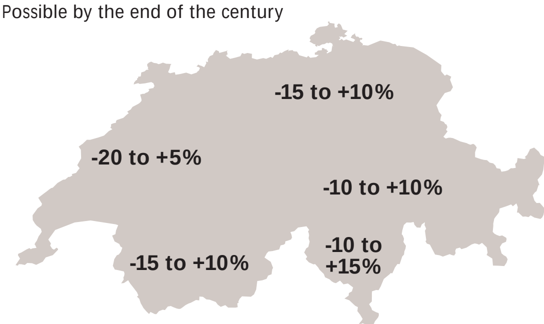
2085 with climate change mitigation

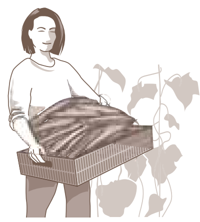
Summer precipitation

Possible around mid-century



Possible by the end of the century

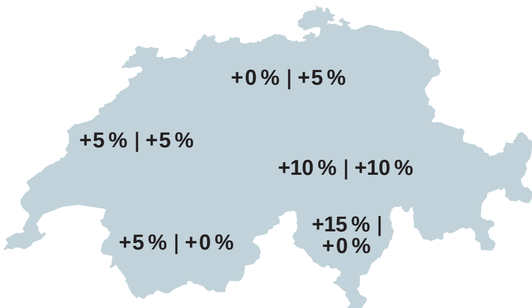




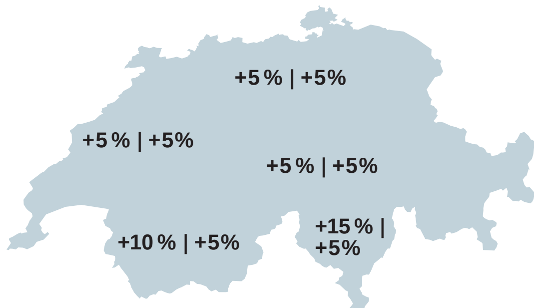
100-year single-day precipitation event

(Winter | Summer)

Expected around mid-century

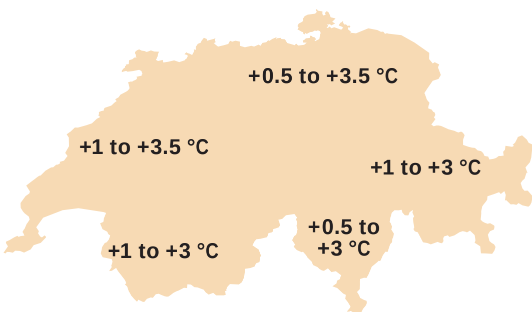


Expected by the end of the century

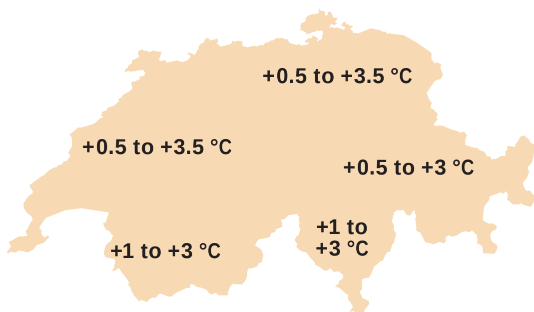


Hottest day of the year

Possible around mid-century

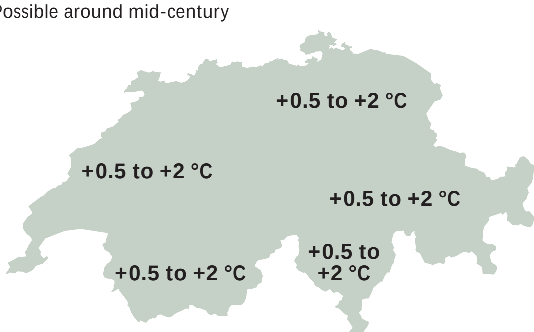


Possible by the end of the century

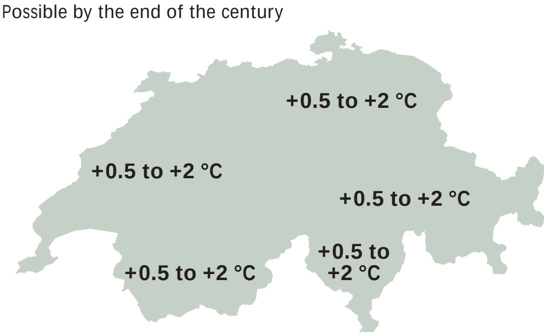


Winter temperature

Possible around mid-century



Possible by the end of the century



SWITZERLAND IN A CHANGING CLIMATE

All regions in Switzerland are considerably warmer than they used to be. The near-surface air temperature has risen over the last 150 years by about 2 °C – a considerably greater increase than the worldwide average. Nine out of the ten warmest years since records began have been in the 21st century. Heavy precipitation events have also become more intense and more frequent.

In Switzerland, there has been reliable long-term measurement of the climate since 1864. The data show clear evidence of climate change. For instance, the near-surface air temperature in Switzerland has increased over the last 150 years by about 2 °C.* This warming is considerably greater than the global average (0.9 °C). Since the 1980s, our climate has been experiencing its fastest recorded warming.

As a result of these temperature increases, we now have more frequent and warmer periods of hot weather than before. Moreover, the volume of the Alpine glaciers has shrunk by about 60 percent since the middle of the 19th century. Since 1970, the number of annual days of snowfall at 2,000 metres above sea level has diminished by 20 percent, and below 800 metres above sea level, it only snows half as often as it did then. The vegetation period is two to four weeks longer than in the 1960s.

Increases in heavy precipitation events can also be seen from the data series to date, and such events have become more intense and more frequent than they were at the beginning of the 20th century. Amounts of precipitation have also risen in wintertime.

Annual mean temperature 1864–2017

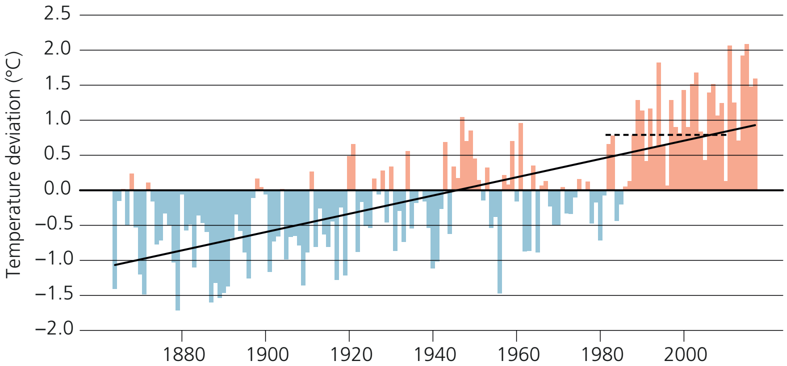
Deviation of average Swiss annual temperatures from the mean in the period from 1961 to1990

Years above 1961–1990 average

Years below 1961–1990 average

Linear trend 1864–2017

Average 1981–2010



Anthropogenic climate change

The human influence on climate has been clearly demonstrated. Global warming as the result of man-made greenhouse gases is likely the dominant cause of the observed climatic changes in Switzerland over the last 50 to 100 years. The observed warming is far too large to be explained by natural variability alone. Changes in other environmental systems such as the hydrological cycle and glacial conditions are also heavily influenced by the rise in temperatures, and thus these changes are also at least partially attributable to human activity.

The records do not give any clear indications of long-term trends in terms of the total precipitation in summer, nor of dry periods, low stratus or wind speeds. This may be attributable to the fact that these parameters are barely or not at all affected by climate change. It could also be the case that the influence of climate change has not yet become apparent for these parameters. The basis of observations is insufficient to determine changes in small-scale phenomena such as thunderstorms, tornadoes and hail.

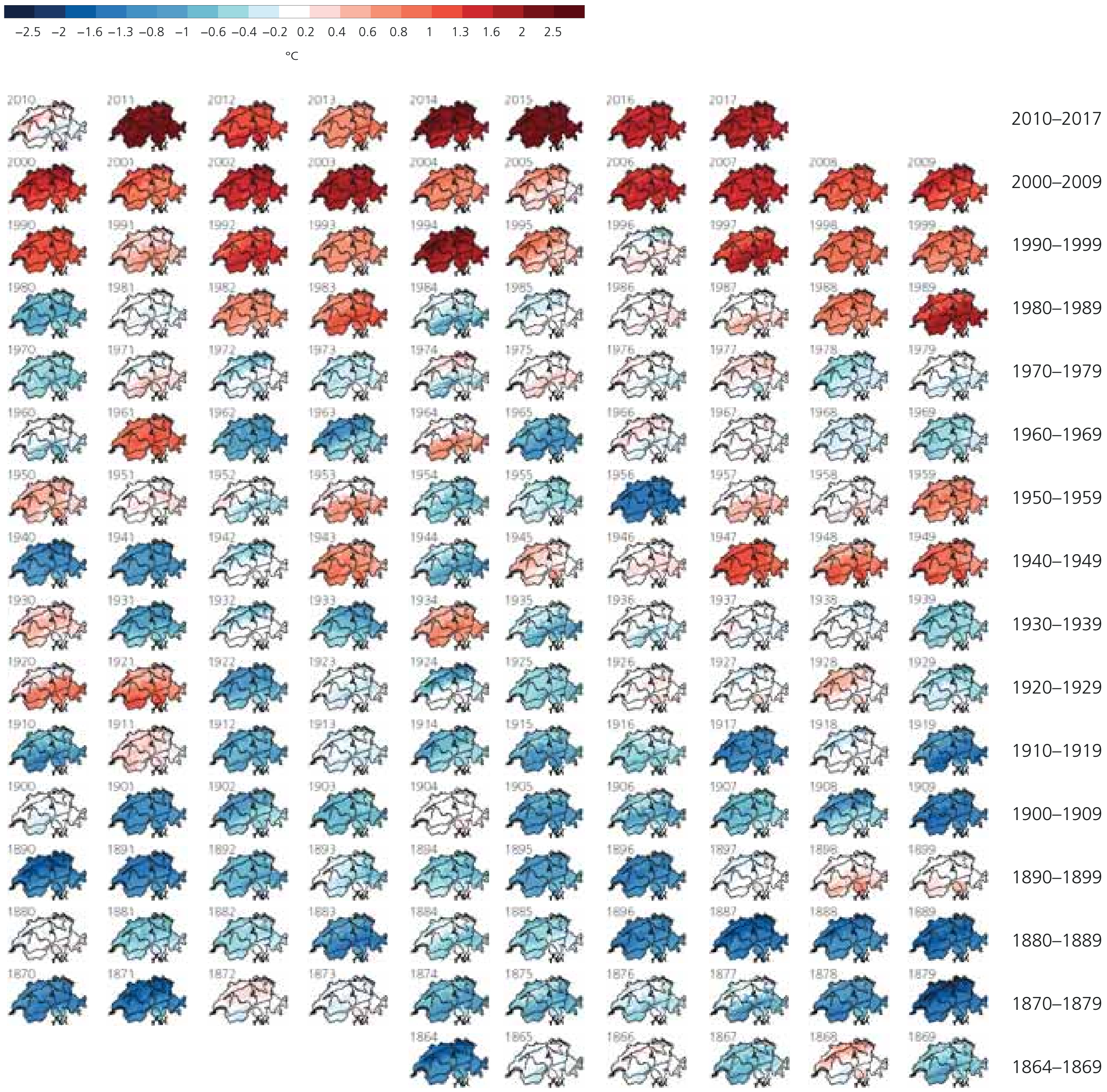
* The average temperature rose by 1.5 °C between the normal period of 1981–2010 and an early industrial period (1864–1900) (see graph of annual average temperature).

Clear trend

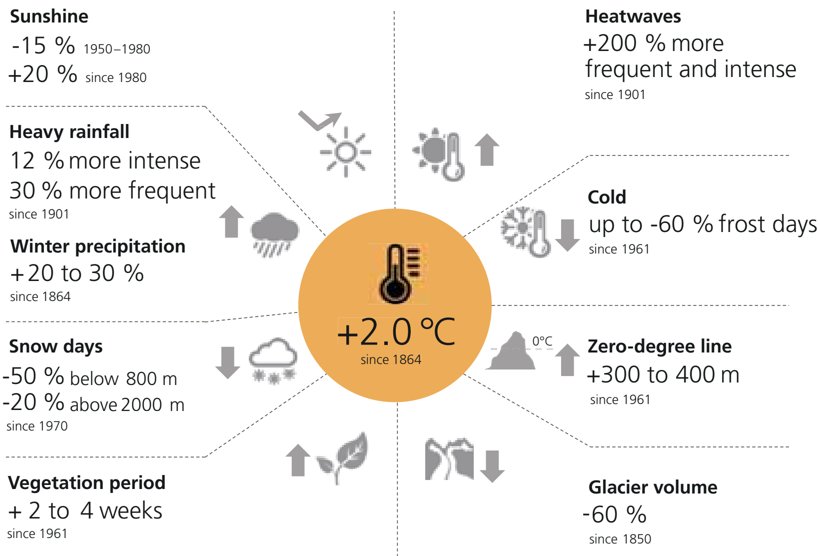
Although temperatures in Switzerland vary from year to year, the warming since the start of record-keeping is clearly identifiable. The trend line over the measurement period indicates a 2-degree warming from 1864 to 2017. The average over the normal period from 1981 to 2010 is shown by the dotted line.

Generally warmer: Annual mean temperature, 1864–2017

In every part of Switzerland, it is considerably warmer today than it used to be. Nine out of the ten warmest years ever recorded occurred in the 21st century. The figure shows the deviation from the average in the period from 1961 to 1990. Further information on Switzerland's climate can be found at www.meteoswiss.ch.



Observed changes



HOW WERE THE CLIMATE SCENARIOS GENERATED?

What are the consequences of a continued increase in greenhouse gas emissions, and how much success could comprehensive reductions in emissions have in terms of mitigating these consequences? These questions can only be answered with the help of computer simulations of climate models. The Climate Scenarios CH2018 translate the complex scientific results of such climate models into comprehensible outlooks.

Simulations using a total of 21 different computer models run at European research institutions form the basis of the Climate Scenarios CH2018. The comparative analysis of several simulations allows the uncertainties associated with the Climate Scenarios to be estimated.

With the help of statistical methods, the resolution of the results can be further enhanced. Where long-term, reliable measurements exist, it is possible to draw conclusions about certain meteorological measuring stations or to produce extensive maps with a horizontal grid box size of two kilometres, as for instance for temperature and precipitation.

With and without climate change mitigation

The primary cause of global climate change is the increase in greenhouse gas emissions by humans since industrialisation. The main agent is carbon dioxide (CO_2), which is mainly formed by the burning of fossil fuels, but also through deforestation. Other gases also contribute, particularly methane, which forms in the process of fermentation – in swamps, in the stomachs of cows and in rice paddies. These gases accumulate in the Earth's atmosphere and add to the natural greenhouse effect.

Whether and how quickly the concentration of greenhouse gases in the atmosphere will continue to rise depends on human behaviour. If all known climate change mitigation measures are fully exploited, it will be possible to reduce emissions of greenhouse gases quickly and sustainably. However, if no steps are taken, emissions will continue to rise unchecked.

* The Technical Report for CH2018 also investigates a middle-of-the-road scenario with limited climate change mitigation (RCP4.5).

The Climate Scenarios CH2018 illustrate the full range of possibilities in between these two extremes. In line with the work of the IPCC (Intergovernmental Panel on Climate Change), they take into consideration two* possible development scenarios for future greenhouse gas emissions:

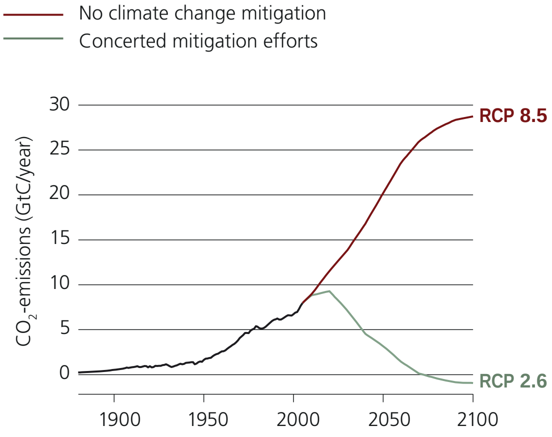
- *Concerted climate change mitigation efforts:* If efforts are initiated immediately to reduce emissions to virtually zero, the increase in greenhouse gases in the atmosphere can be halted within about 20 years. This will enable the goals of the 2015 Paris Agreement to be achieved, and global warming will be limited to 2 °C compared to pre-industrial levels (RCP 2.6**).

- *No climate change mitigation:* Mitigation measures are not implemented. Despite technological advances, climate-influencing emissions continually increase – and so does global warming. (RCP 8.5**).

** Representative Concentration Pathway

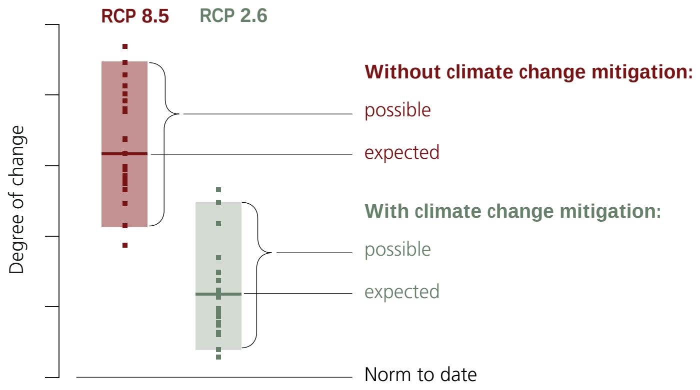
Emission scenarios

Global net fossil fuel and industrial CO_2 emissions.
(Source: adapted from IPCC 2013/WGI/Box 1.1/Figure 3b)



Spread of the results

Individual model simulations shown as points.



Reading the results

The Climate Scenarios CH2018 each describe an average level of climatic conditions over a period of three decades, grouped around the years 2035, 2060 and 2085. When the text refers to the "middle of this century" or 2060, this refers to the period from 2045 to 2074. Similarly, a reference to the "end of the century" means 2070 to 2099.

The current "normal" period for the Swiss climate is the period from 1981 to 2010. These thirty years serve as the starting point for the simulations and as the reference period for all data on future changes in comparison to today's climate. Notably, the climate has already changed since then, and the increase in temperature is happening more quickly than before 1980.

Of course, certain years in the future will deviate from the expected average values – as is the case now, where we see individual climate phenomena every year that measure lower or higher than the long-term average.

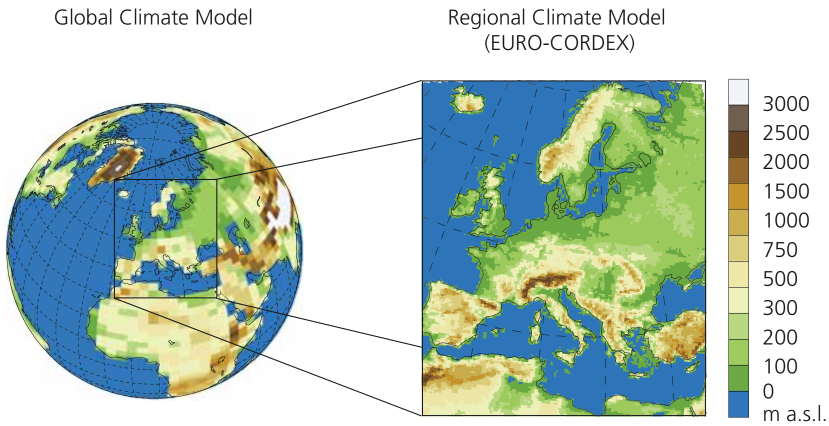
Simulations calculate how the climate would behave under the influence of rising or falling amounts of greenhouse gases. Because all models vary, they all produce slightly different results, even when the time period and influences being modelled are the same.

The projections of the climate models are always distributed within a certain range. Half the values sit above the so-called "median", and half below. The median is thus the most plausible value and is described as the "expected" outcome in the Climate Scenarios (dark line in the graph).

The second highest result of the climate models is shown by the upper limit of the displayed range, and the second lowest by the lower limit. Consequently, the result is not merely informed by the most extreme values. All values in between the upper and lower limits of the range are described in terms of the Climate Scenarios CH2018 as "possible" (coloured bars in the graph). The probability of actual values lying within the "possible" range is estimated to be two-thirds.

The simulated changes vary slightly from place to place. To arrive at a prediction of changes for Switzerland as a whole in each of the individual climate scenarios, the country was split into five regions, and the rounded median figures from these regions were analysed. Detailed information on the changes in these five CH2018 regions can be found in the Technical Report.

There is no simulation in which all aspects of climate change are strongly pronounced at the same time. For example, some of the simulations show severe summer dryness but moderate heavy precipitation events. It is therefore unlikely that the most extreme values for all climate parameters described would occur at the same time.



The models used for the Climate Scenarios CH2018 are part of the EURO-CORDEX (Coordinated Regional Climate Downscaling Experiment – European Domain). The aim of this initiative of the World Climate Research Programme is to refine the global climate simulations for Europe. Regional climate models are used for this purpose.

Climate models

A computer model is a system of physical and mathematical formulas and procedures that depict real-life conditions in simplified form. Climate models are constructed in a similar way to the models employed in weather forecasting. However, they are not restricted to the lower atmosphere where the weather plays out; they also simulate ocean currents and, to some extent, the interplay between snow, ice and vegetation.

Thanks to climate models and high-performance computers, our climate can be projected into the future. This allows us to identify the impacts of greenhouse gas emissions on the climate. Global models thus demonstrate how the climate could change on a global scale. However, their spatial resolution is too low to provide information on the regional climate of a small country such as Switzerland, and so regional climate models for various parts of the globe are also used. The results of these models are currently available at resolutions of between 12 and 50 kilometres.

Climate variability obscures the trends

Even though climate is a representation of the "average weather" in a location, it is still subject to natural fluctuations. Climate variables such as temperature and precipitation can vary widely over decades. The Climate Scenarios provide estimations of the future climate situation, including the long-term trend, on the basis of greenhouse gas emissions as well as natural fluctuations.

Fluctuations in climate variables can be greater over decades than the changes due to a long-term trend. One such example is the temporary attenuation of the global temperature rise between 1998 and 2012, widely known from controversial debates in the media as the «hiatus». By the same token, a temporary intensification of the long-term trend is also possible.

Theoretical considerations on climate change, climate models and previous measurement series largely agree with one another. It can therefore be assumed that the simulated trends will prevail in the long term. This also holds true even if measurements over the next few years take a different course in the short term because of natural fluctuations.

WHY NEW CLIMATE SCENARIOS?

The Climate Scenarios CH2018 confirm the previously known trends. However, they present a substantially more detailed picture of the future Swiss climate. On the website **www.climate-scenarios.ch**, users can find extensive additional information and datasets.

Work on the national Climate scenarios commenced at the beginning of this century. The first comprehensive estimates were presented in the report "Climate Change and Switzerland 2050" (CH2007). Four years later, the "Scenarios for Climate Change in Switzerland CH2011" followed. CH2018 – the new generation of Swiss climate scenarios – provides several innovations:

Expanded knowledge base

Another seven years' worth of data have been collected since the previous report. This has permitted a more precise determination of the measurement series trends. The latest scientific findings have also informed the CH2018 Scenarios. For example, the findings of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), published in 2013, were taken into consideration.

More and better models

Over the course of the last few years, a new generation of global and regional climate simulations has been developed, reflecting the current state of climate research and using the most up-to-date models. The new simulations have four times the spatial resolution of the simulations used in 2011 for the last report. Moreover, the statistical methods have been refined in order to facilitate improvements in localisation.

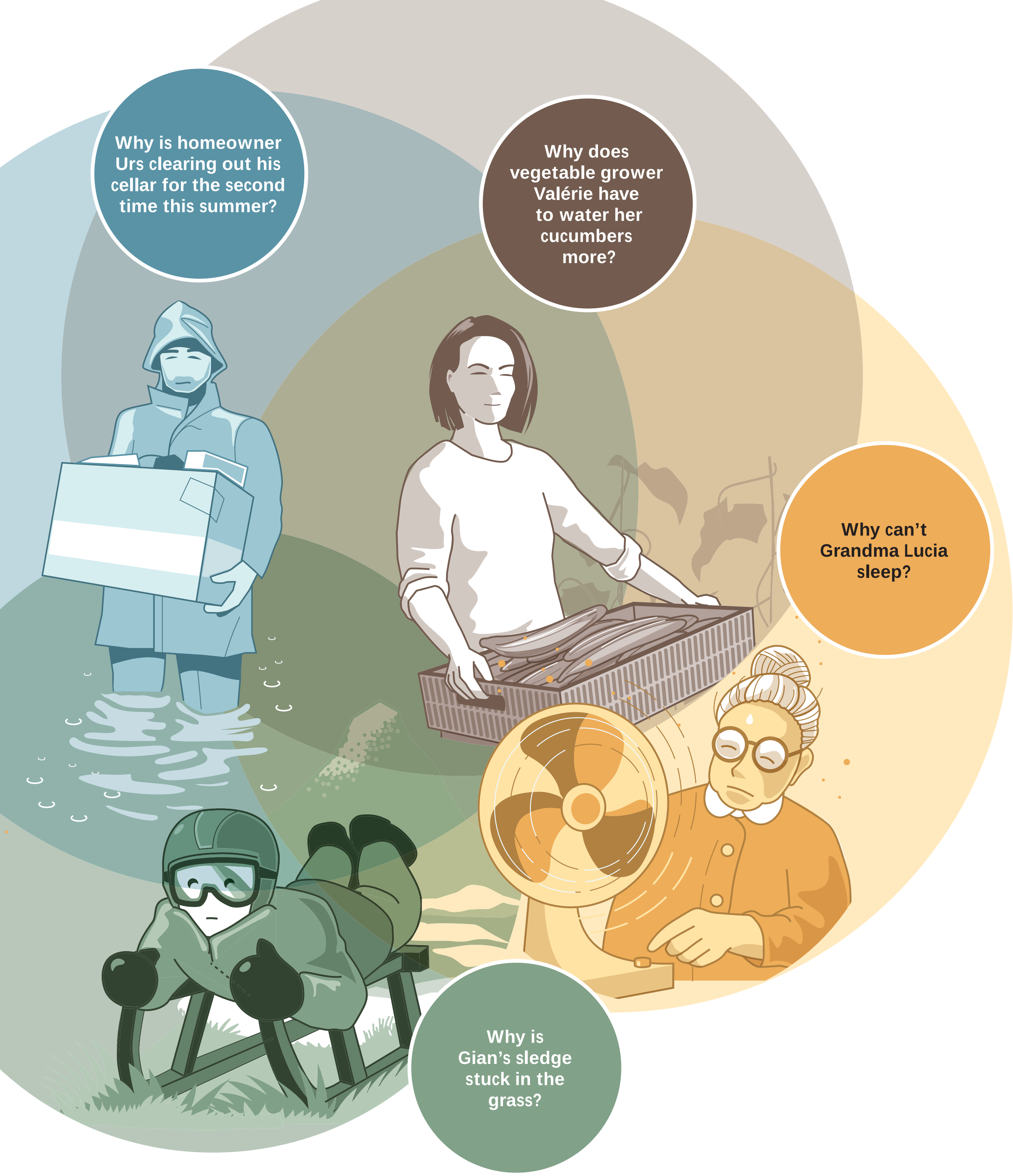
Closer ties to practice

The existing knowledge of the needs of users is continually growing. With these needs in mind, the current Climate Scenarios provide more concrete information on a range of key areas, including extreme events and local climate indicators.

The new Climate Scenarios confirm and expand the picture of future climate change in Switzerland that has been established in previous studies. In addition, there is now quantitative information for various trends which were previously only qualitative, such as precipitation extremes.

Since 2014, it has been an official mandate of the federal government to produce regular climate scenarios that will provide decision-makers with the most up-to-date knowledge foundation for planning adaptive measures to climate change. Important new developments are already taking place: For example, a new generation of global climate models forms the basis for the forthcoming sixth Assessment Report of the IPCC. At the same time, climate models are achieving ever-higher resolutions. At the moment, substantial effort is being invested in regional models that have a spatial resolution of two kilometres. For the first time ever, such models can simulate small-scale processes such as thunderstorms and Föhn.

Taking users' needs into consideration will be critical for the successful future development of new Swiss Climate Scenarios. Regular interactions between the producers and users of Climate Services will be a priority for the National Centre for Climate Services (NCCS) in the coming years.



Just how severely could climate change transform Switzerland, and to what extent might concerted mitigation measures prevent these changes? These questions are addressed by the new Climate Scenarios CH2018. Based on the latest computer simulations, these scenarios provide us with the most accurate insights into our future climate to date. **www.climate-scenarios.ch**