Name of research institute or organization:

MeteoSchweiz, Zürich

Project description:

The weather in 2005

The most important climatologic event in 2005 was certainly the devastating storm on August 21 and 22. The extremely heavy rainfall, which lasted in part more than 36 hours, caused flooding, landslides, and mudflow, and did enormous damage in large areas of Switzerland. The Berner Oberland region was especially hard hit by the unusually heavy rainfall, a subject which will be discussed in detail in reviewing the weather in summer 2005.

Table 1 illustrates that compared to the long-range means from 1961-1990 in both the plains of the northern side of the Alps as well as in the high mountainous areas, the year 2005 was too warm. In Bern it was +0.7° C and at Jungfraujoch +0.9° C warmer than the average. The duration of sunshine was also above the long-range mean (=100%) in the region of Bern (115%) and in the Jungfraujoch region (108%). Precipitation in the Jungfrau region corresponded to the long-term mean, while the amounts in the plains were clearly below average.

Table 1: Comparisons of three parameters with the long-range mean 1961-1990 at the stations Jungfraujoch and Bern. For temperature the deviation from the long-range mean is shown. Duration of sunshine and precipitation are expressed relative to the average amounts. Because precipitation is not measured at Jungfraujoch, values from Kleine Scheidegg have been used.

	Jungfraujoch	Bern
Mean temperature	+0.9° C	+0.7° C
Duration of sunshine	108%	115%
Precipitation	101%	83%

Significant incursion of cold air at the beginning of the year

2005 started where 2004 left off: a stable high pressure system over southwest Europe produced sunny weather until mid-January. In the higher areas of the Swiss Alps it was almost as warm as in springtime, and on January 7, 2005, the thermometer at the weather station Jungfraujoch at 3580 meters above sea level briefly climbed above freezing. The stable high pressure weather came to an end at the end of the month with a massive cold front, bringing partly heavy snowfall even into the lowlands. There was a marked drop in temperature in the mountains, illustrated by the maximum daily temperature of -26.3° C on January 25, 2005, at Jungfraujoch. During the following night, -29.5° C was measured at Jungfraujoch, the record low temperature there for 2005.

There was a further heavy thrust of polar air on February 13, 2005, which started an unusually long period of cold weather. Repeated surges of artic air with varying amounts of humidity hit the Alps. By the end of February the northern side of the Alps registered 12 to 17 days of mostly light snow fall, and in Zürich snow fell on 19 days. The last time there were similar numbers of days with snowfall was in 1996

and 1986. However, because the snowfall was only light, no extremely great amounts of snow were registered. Temperatures remained frosty even during the daytime.

The situation was different on the protected southern side of the Alps with practically no precipitation. Together with the very dry January, it had been 20 years since Tessin had had such a dry period at the beginning of a year.

Records in spring time

The exceptionally cold weather continued on to the beginning of the meteorological spring. After the arrival of a cold front of Siberian air at the end of February, the nights of March 1 and 2, 2005, were clear, allowing the air to cool out over the freshly fallen snow. The result was that many stations, especially those in the flatlands on the northern side of the Alps, reported their lowest local temperatures in 2005. Several stations, such as in Bern, measured the lowest March temperatures since measurements have been recorded. The frosty weather with occasional snowfall continued throughout the following days.

Mid-March the weather changed drastically, due to a warm high pressure system over Italy. This occurred in the lowlands as well as in the mountains. For example, on March 5, 2005, the temperature at Jungfraujoch reached a daytime high of only -20° C, and in Bern the temperature stayed below freezing with a daytime high of -4° C. About a week later, on March 16, 2005, it was -0.6° C at Jungfraujoch and +18.0° C in Bern – almost 20 degrees warmer. And at the same time in Tessin it was +27-28° C, a new record for March.

The month of April also had phases of exceptional weather. The month began calmly due to a high over eastern Europe, but then several low pressure systems activated weather conditions. Starting April 7, 2005, a low pressure system caused long periods of precipitation south of the Alps and then snowfall down into the lowlands north of the Alps. This was followed by a low pressure system that moved from southern France to Upper Italy, bringing considerable precipitation as rain and snow into the midlands. This heavy precipitation was triggered by the collision of humid, warm air masses from the southwest with cold air masses from the north. This caused the snowfall mentioned above. Bern registered 5 cm of new snow on the morning of April 17, 2005, and Geneva had 3 cm of new snow, something that hadn't occurred there so late in April since 1931. The main load of snow fell in the region of Lausanne and Lauvaux as well as the in southern arm of the Jura in Waadt. Parts of the city of Lausanne had more than 30 cm of snow on the morning of April 17, 2005.

As is usually the case with spring snow, it didn't stay long. The longer hours of sunshine made the temperatures climb rapidly, and by the end of April the +24-28° C temperatures reached early summer levels. The last time temperatures this warm were measured in April was in 1993. And it was also warmer at Jungfraujoch. On April 30, 2005, the daytime maximum reached +3.0° C, which is usually only measured in the summer months.

The warm weather dominated through to the beginning of May. On May 3, 2005, a storm front from the west brought a period of unsettled and cool weather. It rained more or less constantly in light or moderate intensity. This kind of "April" weather lasted until May 23, 2005, after which an extensive high pressure system brought in summer weather untypical for the end of May. Many stations reported the first sweltering temperatures in 2005 of 30° C and higher. For many stations this was the first time such high May temperatures had been registered since 1969, and for some

stations even since 1953. With +8.9° C Jungfraujoch registered the highest May temperatures since 1961. However, it is advisable to be cautious when making comparisons with the past, especially with regard to record values. Measurement conditions often change with time. Weather stations are moved, or new meteorological instruments are put in operation. This means that great caution should be exercised in comparing old measurements with modern measurements. And this is the case with the measurements at the Jungfraujoch station. One method that is used to make historical measurements comparable with modern ones is the so-called homogenization of data series, which tries to adjust old measurements to modern measurement conditions based on statistical methods. A complete homogenized data series for Jungfrauoch is not available at present.

Heat at the beginning and severe rainfall at the end of summer 2005

As can be expected in June, the first heavy summer thunderstorms came in. On June 3, 2005, there was hail and stormy weather that mainly affected the Berner Oberland. This would not be the last time that this region would be struck by severe weather in 2005.

After the passage of these thunderstorms the entire region of the northern side of the Alps experienced a period of unsettled, cool weather. The nights from June 7-11 were especially cold for this time of year. Bern had ground frost every night in this period, which hadn't occurred in June since the beginning of ground temperature measurements in 1981.

Starting in mid-June a subtropical high pressure system drove temperatures up to summer levels. In many places temperatures during the second half of July were above 30° C. In the Basel area they even reached 34° C. Nevertheless, record temperatures, which were set in the scorching June of 2003, and in June 2002, 1950, and 1947, were reached or broken at only a very few stations.

An active system with heavy thunderstorms cooled temperatures off starting July 4, 2005. At Jungfraujoch the temperature sank to -7.9° C and in parts of Canton Graubünden the snow line sank to 1700 meters above sea level. This highly unstable layered air mass produced thunderstorms with tornado funnels over Lake Geneva and in the Zürcher Oberland on July 5, 2005. The subsequent weather was unsettled but relatively warm. A stable phase of beautiful summer vacation weather didn't arrive as people were hoping for. It didn't occur until the last days of July, and then only for a few days. Air masses coming from Africa caused the hottest and most humid days of the year on July 27 and 28, 2005. The record high temperature at Jungfraujoch in 2005 was measured at 12.7° C, and the year's highest temperature in Switzerland was measured in Geneva at 36.2° C. Two heavy thunderstorms in July caused severe local damage. The first storm on July 18, 2005, devastated a large part of the upper Lake Geneva area. Gusts of up to 160 km/h and hail caused enormous damage to the vineyards. Another thunderstorm accompanied by hazelnut sized hailstones and gale-force winds rampaged the western shore of Lake Geneva.

In the first half of August, cool and rainy weather prevailed. Snow fell in the higher mountain passes of the Alps. During occasionally clear nights, the temperatures sank notably. Several stations in the plains of the northern side of the Alps registered almost the record low for the beginning of August. And in the mountains it was cool and unpleasant. At Jungfraujoch for example the daytime maximum temperature reached only -3.2° C on August 8, 2005.

The devastating storms in August 2005

On August 18 and 19, 2005, a low pressure system was located over France. This low pressure system crossed over to the Gulf of Genova and then by August 23, 2005, moved over the eastern Alps going north. In the process, warm and humid air masses from the Mediterranean were carried along over the Alps and jammed back onto the northern slope of the Alps by north easterly winds. Meteorologists call this a "Vb-condition", and it is known to have repeatedly caused devastating amounts of precipitation in the past. This is exactly what occurred on August 21 and 22, 2005. In the ensuing heavy rainfall, six people lost their lives and the material damage amounted to approximately two billion Swiss francs. The Berner Oberland and central Switzerland were severely affected. Almost every valley from the lower Simmental through to Canton Uri experienced landslides and mudflows. Streams torrentially flooded over their banks, devastating villages, farmland, bridges, railway lines, and roads. Entire valleys were cut off for days. Even some higher areas of the Alp foothills were affected, especially from Emmental to Lake Zug, and the town of Weesen on Walensee. It flooded in parts of the midlands as well. In the city of Bern the river Aare flooded over its banks into the Matte. The river Reuss flooded houses in the area Wasseramt. The Lake of Thun, the Lake of Lucerne, and the Lake of Biel also flooded over their banks. And even farther away, the areas of upper Prättigau and Lower Engadin also experienced damage.

An exceptionally rare phenomenon

Unprecedented was the fact that within 48 hours the large northern slope of the Alps was inundated with more than 100 liters of rain pro m2 (= 100mm). (See figure 2.) Several stations measured record amounts (see table 2 and figure 3). For some of these stations the statistical recurrence rate for such an event is much greater than 100 years.

Table 2: Accumulated precipitation during 48 hours. Measurement period August 21 (Sunday 05:40 h UTC) to August 23, 2005 (Tuesday, 05:40 h UTC).

Measurement station	Amount of precipitation	Previous maximum amount	Measured on	Data available since
Meiringen	205 mm	159 mm	07.03.1896	1889
Brienz	181 mm	129 mm	13.02.1990	1961
Wimmis	141 mm	120 mm	07.05.1985	1961
Engelberg	190 mm	153 mm	21.12.1991	1901
Einsiedeln	152 mm	142 mm	07.08.1978	1900
Marbach/LU	181 mm	165.mm	02.06.2004	1961
Napf	178 mm	158 mm	13.02.1990	1978

Events preceding the flooding

There are other ominous circumstances that preceded the flooding. Even before the devastating precipitation began, a great deal of rain had already fallen during the month of August in the affected areas. This had already equaled the usual amounts

for the entire month of August. In addition, the snow line had risen to 3000 meters above sea level and even higher, meaning that the precipitation in the mountains up to that level was not bound in the form of snow and ran off immediately.

Even during the days immediately preceding the flooding, several regions experienced large amounts of precipitation. There was heavy rain on the northern slopes of the Alps during a thunderstorm on the evening of August 18, 2005, and thunderstorm activity continued on August 19 and 20, especially in the foot hills of Fribourg, the Napf area, in Entlebuch through to central Switzerland. The ground was saturated with water and unable to absorb the huge amounts that followed: streams and rivers flooded over in no time.

What could the future bring?

The results of regional model analyses for Europe for the second half of the 21st century show an increasing tendency in the mean precipitation intensity and the frequency of days with intensive precipitation. For Europe this could mean that the rate of extreme events occurring every 50 years could shrink to 25 years. This increase in heavy precipitation can also be interpreted as a result of the intensified hydrological cycle due to the greenhouse effect. Today an intensified hydrological cycle during the winter months and for the entire European continent is considered to be very probable. In the Alps it could especially cause an increase in precipitation of long duration.

Dry autumn

At the end of August and the beginning of September 2005 a high pressure system covered middle Europe and brought many sunny late summer days. The warm and dry weather brought relief to the flooded areas, the level of the lakes and rivers sank, and the saturated ground dried again. Some stations once again registered temperatures of +30° C, and there were a few typical local summer thunderstorms. Mid-September a cold front came into Switzerland from the northwest, sinking temperatures drastically and causing heavy rainfall. On the morning of September 17, 2005, it snowed partly down to 1700 m above sea level on the northern side of the Alps. The night of September 21, 2005, was clear and cold, thus cooling off the air masses. This led to the first local frosts in autumn 2005.

At the start of the month of October 2005 it rained heavily again in large areas of Switzerland. For the northern slopes of the Alps, Wallis, and large areas of Graubünden and Tessin, these were the last notable amounts of precipitation during the month of October, which later led to a considerable deficit. Tessin, for example, only received 20% of the usual amount of precipitation for October. During the last ten days of the month a high pressure system over the Mediterranean brought very warm weather for the time of the year. In higher regions the temperatures nearly reached historical records. Several stations in Wallis and in Graubünden measured new record high temperatures. In general, the temperatures in the mountains made one think more of summer than of the approaching winter.

The relatively mild and dry weather continued through the first days of November 2005. It wasn't until November 17 that a low pressure system over Ukraine brought in a disturbance to the Alps. This disturbance was followed by cold polar air, and in the eastern plains snow fell partly into the lowlands and with it the first covering of snow of the winter 2005/2006. Temperatures stayed below 0° C for the first time the

entire day on November 24, 2005. Climatologists call this an “ice day”. Another low pressure system brought snow to the entire country on November 26, 2005, which was earlier than southern Switzerland has on the average, but which could be expected in the north. It was only a light layer of snow, however, and the month of November was generally very dry. Combined with the very dry month of October, this led to an extremely dry situation from the eastern Berner Oberland through to Appenzell and the Rhine valley, as well as in the Upper Rhine valley, the Gotthard area, and northern Tessin. Looking at all the meteorological autumn months September to November, the last similarly dry autumn was in 1962 and 1961. The water level in rivers and lakes sank continually, and the fish in small rivers were endangered for the lack of water. Lake Constance reached a level almost as low as had ever been measured since the beginning of measurements in 1864, and Swiss reservoirs were almost at an historically low level as well.

The first day of December was cold. It rained shortly thereafter up to 1300 m above sea level in the north and snowed 15 to 30 cm in the south. From December 6 to 9, 2005, it snowed in the north down into the lowlands, and the south was sunny again. Then dry and relatively cold air moved in from the north, with a short interlude on December 16 and 17 when it snowed heavily in the northern slopes of the Alps and made a thin covering of snow in the east. There was only snow for a white Christmas above 600 m above sea level in the midlands. On December 26, 2005, another blast of arctic air moved in, and temperatures sank even lower. In the midlands it was between -10° and -15° C on December 30, 2005. The temperature in Samedan was -31° C and in La Brévine -35.9° C, which was the coldest temperature measured in Switzerland in 2005.

In Tessin it snowed 15-30 cm, and on the night of December 30, 2005, it also snowed heavily in the north. On the last day of the year, temperatures rose above freezing.

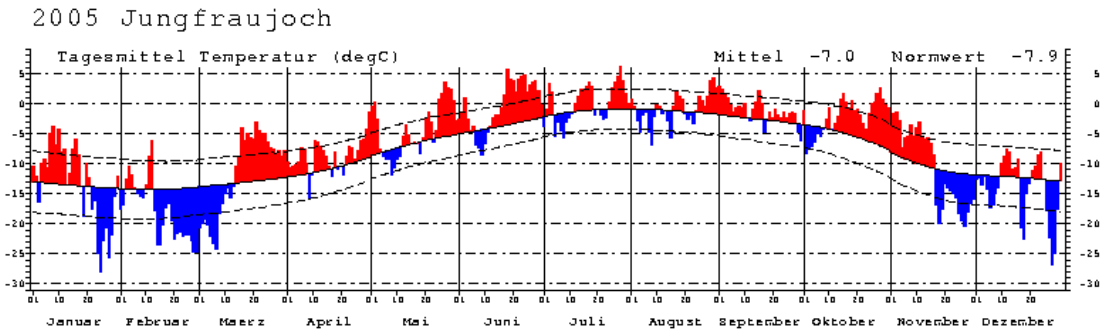

Figure 1: Mean temperature in 2005 measured at the station Jungfraujoch compared to the long-term mean 1961-1990 (solid line) and to the long-term mean variation (broken lines = standard deviation).

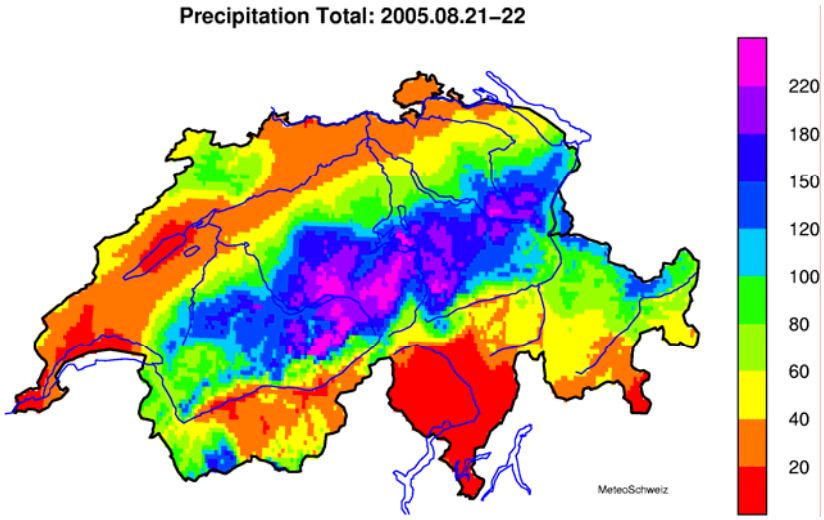

Figure 2: 48 hour sum of rainfall on August 21 and 22, 2005 (07:00 until 07:00 on the following day). Analysis of the measurements from 372 MeteoSwiss stations and 42 mountain stations of the Swiss Federal Institute for Snow and Avalanche Research, Davos. This precipitation map was prepared by C. Frei, MeteoSwiss.

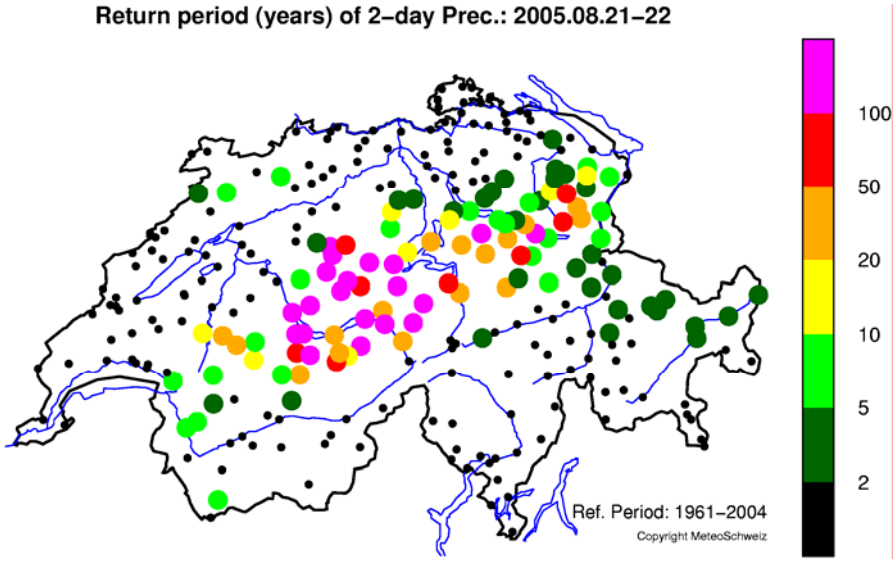

Figure 3: Estimated periods (in years) of the recurrence of the sum of precipitation measured on August 21 and 22, 2005. The recurrence period indicates how frequently on a long-term average the observed amount of precipitation can be expected at the same station, assuming the climate is stationary. The periods were estimated by using extreme value statistics for the long measurement series of MeteoSwiss. This precipitation map was prepared by C. Frei, MeteoSwiss.

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