2.6. Hail

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With extreme hail events, the individual storm cells are distributed along a line extending across the entire Central Lowlands and the Alpine foothills for several 100 km. Over five-hundred communes were affected by the five extreme hail events that occurred since 1920. These events are distributed evenly over the period of observation. However, the frequency of the four characteristic large-scale weather constellations responsible for extreme hail events has increased significantly since 1940. If the increase in frequency of these weather constellations continues, a rising number of extreme hail events must be expected in the future.

Definition of an extreme hail event

Hail events often occur over a very confined area. An individual hail cell generates a hail swathe that deposits several stripsof hail along the ground. In a large storm system, several hail cells can form producing numerous bands of hail in the whole of Switzerland. The hail, water and wind resulting from these can cause widespread damage to agriculture, forests, buildings and cars. In rare cases, several storm systems may arise covering the whole of Europe.

Extreme hail events can arise both from individual cells and from storm systems. In hail cells, extreme hailstone sizes of 5-10 cm, gusts of 144-180 km/h, rain intensities of 100 mm/h, precipitation of 30-50 mm/m^2 and several lightening strikes per km^2 may arise.[1] In an extreme storm system, the individual storm cells are situated along a line extending from west to east right across the Central Lowlands and the Alpine foothills, and cover a distance of several 100 km. Meteorologists term these systems mesoscale convective storm systems (MCS). In the wake of the linear formation, an extensive precipitation regime ensues in which rainfall may be intensive. In hail cells belonging to a formation, higher hail and rain intensities, rain quantities, windspeeds and lightening activity are observed than in isolated cells.[2]

In the following, we shall define these storm systems (MCS) in Switzerland to be extreme events. They impact over a large part of the country and cause widespread damage.

Meteorological conditions

Extreme MCS are known to occur in Switzerland under very specific meteorological conditions[3]:

(a) The large-scale weather constellation is characterised by a so-called trough system, with winds impinging on Switzerland from the south-west.

(b) A cold front with large temperature differences lies over France and extends well into Spain.

(c) Warm and humid tropical or subtropical air preceding the front is carried into Switzerland.

(d) The pressure differences over Switzerland are low and the stratification is unstable.

(e) Shortly before the arrival of the cold front from the west, solar radiation over the Central Lowlands is at a maximum. The lowest air strata heat up to over 30°C.

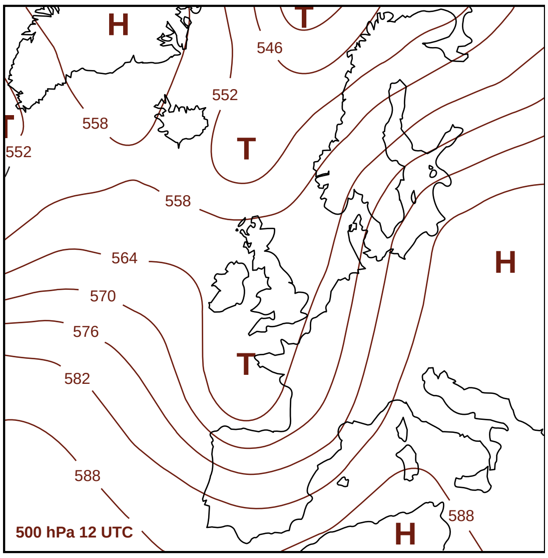

Fig. 33 Typical trough system over the Bay of Biscay with a south-westerly flow towards Central Europe (500 hPa niveau). The example refers to 5 July 1999.

(f) The cold front arrives in the late afternoon. In advance of, and within, the front, storm cells begin to form.

(g) The storm cells are positioned along one or more linear MCS.

Four characteristic large-scale weather constellations were responsible for the five extreme hail events occurring in the last 80 years. A common factor of all these is the south-west wind in advance of the front. A characteristic trough constellation over the Bay of Biscay that advanced on Central Europe from the south-west led to the extreme hail event on 5 July 1999 (Fig. 33).

Extreme event: frequency and trends

Areas of precipitation may be tracked, and large and intensive hail cells identified by means of weather radar. Individual hail cells may also be assigned to larger storm systems. However, systematic radar measurements did not begin in Switzerland until around 1980.

Thus no long-term measurements are available that could enable the frequency and trend of extreme events (MCS) to be analysed. However, the area affected by hail may be determined from hail insurance data. Also, the loss statistics permit scientific assessment of the effects of climate change on extreme hail events.

Statistics are available in the form of reliable and relatively homogenous measurement series beginning in 1920[4,5], showing the number of communes north of the Alps that reported hail damage in agriculture on each day of the year. These figures provide an indication of the extent of a storm system, assuming at least one farmer reported damage.

Fig. 34 shows how many communes reported hail damage in agriculture on how many days between 1920 and 1999. In total, 5690 days of hail were recorded. In five cases (0.1%), 500 or more communes (from among 2400) were affected. The fact that these five extreme hail days represent an MCS event is illustrated by the distribution of communes reporting damage during the hail event on 21 July 1992 (Fig. 35). This led to (insured) losses of approximately 100 million CHF. To these must be added the uninsured losses, including extensive losses to forest areas.

All days of hail between 1920 and 1999, for which over 100 communes reported damage, are shown in Fig. 36. The five extreme events are evenly distributed over the observation period.

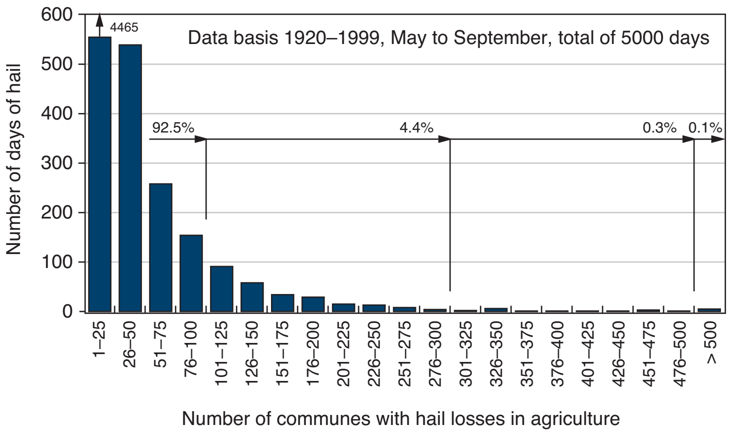

Fig. 34 Number of days of hail for a specified number of affected communes (from among 2400 Swiss communes to the north of the Alps) with hail losses in agriculture. On five (0.1%) of the 5690 days of hail between 1920 and 1999, over 500 communes were affected (last column). These cases are defined as extreme. Days with 100-200 affected communes are designated as heavy (3.9%, columns 5-8). The 4465 days of hail with only 1-25 affected communes occurred during the same period (79%, first column).

From 1980, the number of 'heavy' hail events causing losses in 100 to 200 communes increases. This trend is clearly shown in Fig. 37. Whilst prior to 1980 the frequency of hail events is approximately constant, it increases significantly between 1980 and 1994. Following the intensive year of hail in 1994, it decreases again, but remains above the average for the period before 1980.

Since 1940, the frequency of the four large-scale weather constellations responsible for extreme hail events has increased significantly in Central Europe in summer (Fig. 38).

Influence of climate change

Should the frequency of the four large-scale weather constellations continue to increase in the European region as a result of climate change, the conditions under which storm systems arise will become more frequent. In this case, more extreme hail events would be expected. Furthermore, the trend among the 'heavy' hail days could continue to increase.

Whether or not the events will become more intensive or not also depends on whether the stratification of the troposphere during the summer months becomes less stable as a result of climate change. Unstable stratification encourages the formation of storm cells during the progression of the front. Balloon measurements performed between 1954 and 1993 have shown that the temperature of the lower troposphere has risen more sharply than that of the upper troposphere, and that stratification stability has diminished.[1,5]

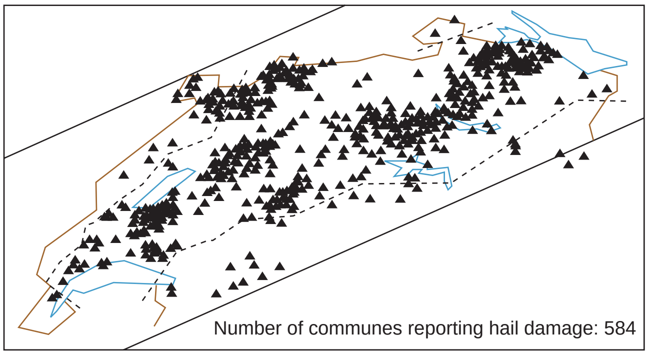

Fig. 35 Distribution of communes reporting hail damage on an extreme day (21.7.1992). The hail swathe accompanying the storm system (SW-NE direction) is clearly discernable from the distribution of the communes.

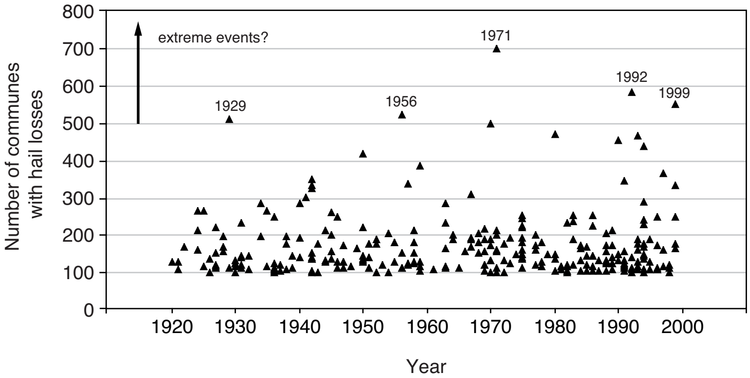

Fig. 36 Time series of days between 1920 and 1999 on which 100 and more communes north of the Alps reported hail damage in agriculture. The five extreme days are fairly evenly distributed over the observation period. For between 100 and 200 of the affected communes, somewhat more heavy bunching of hail days following 1980 may be seen.

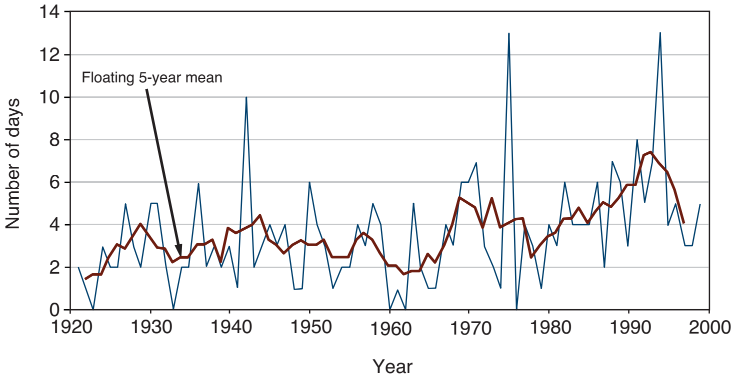

Fig. 37 Time series of the number of days with 100 and more affected communes between 1920 and 1999. The increasing trend of heavy hail days between 1980 and 1994 may be clearly seen.

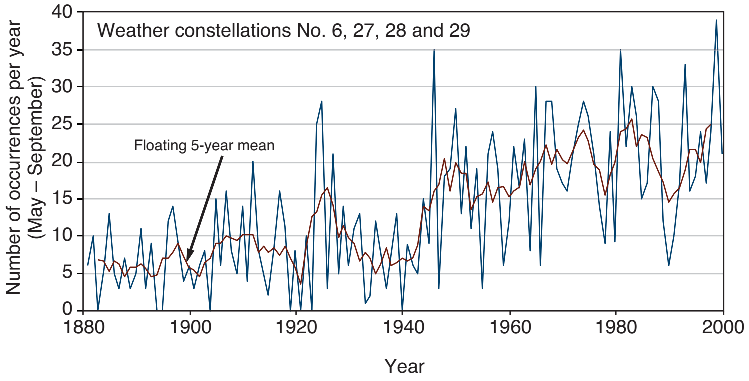

Fig. 38 Time series for 1881-2000 of the four weather constellations[6] responsible for extreme hail days. The south-westerly flow in advance of the front is common to all four constellations (Fig. 33). Since 1940, a marked increase in the frequency of the four weather constellations is observed.

The data series for hail days was processed up to 1999. New data for 2000 show a further 'extreme day' (3 July) on which 620 communes were affected. This means in affect that in the 10 years from 1992, 3 cases were recorded in comparison to only 3 cases in the 70 previous years. However, insufficient data are available to discern whether this represents a real trend or an incidental concentration (cf. Chapter 1.4).

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3 Huntrieser H., Zur Bildung, Verteilung und Vorhersage von Gewittern in der Schweiz, Diss. Nr. 11020, ETH Zürich, 246 S., 1995.

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5 Willemse S., A statistical analysis and climatological interpretation of hailstorms in Switzerland, Ph.D. Thesis No. 11137, ETH Zürich, 194 p., 1995.

6 Weather constellations according to Hess-Brezowsky: constellation 6 (south-westerly system, cyclonal, 5.7.1999, 3.7.2000), 27 (southerly system, cyclonal, 10.9.1956), possibly 28 (depression over the British Isles, probably 21.7.1992) and 29 (West European trough, 4.7.1929, 26.8.1971).