Historical records as evidence in the climate change debate

The forces of nature remain unnoticed by the general public until they disrupt its daily routines. The scientific world is then expected to integrate extreme events into a larger system and give its interpretation of them. Historical records have a very important role to play in this context.

Christian Pfister

The oldest British weather hut in Antarctica (Port Lockeroy).

The climate of the past has left its traces all over the globe, and these are researched by many scientific disciplines. Historical climatology mainly assesses data from anthropogenic archives, which contain two types of information:

– Direct data, including qualitative descriptions of the weather and, from the late 17th century, early measurements using instruments
– Indirect data, also referred to as proxy data, i.e. quantifiable descriptions of biological or physical occurrences that act as climate indicators

In Western Europe, climate observations from historical documents date back to Carolingian times (approx. 800). Thanks to the scope, completeness, and temporal resolution of this material, the 1,200 years down to the present day can be divided into five periods:

1 Before 1300: mainly descriptions of anomalies and natural disasters. The more extreme an event, the more frequent and detailed the accounts we have.
2 1300–1500: nearly continuous description of weather conditions in summer and winter, sometimes in spring, rarely in autumn.
3 1500–1800: virtually complete description of the weather month by month, and day by day in places.
4 1680–1860: measurements using instruments on an individual basis; the first short-lived meteorological networks.
5 Since 1860: instrument measurements within the scope of national and international meteorological networks.

The older data types were overlaid by more recent ones, though not entirely supplanted. The following is a brief introduction to the evidence.

Records of daily weather were given a boost from the close of the 15th century on thanks to the rise of astronomy, which became the leading branch of science, and to the invention of the letterpress. Astronomical calendars looked forward one to two decades and presented calendar data and the pre-calculated positions of the planets for each day. Each month was given a double page, the right-hand page having one line left empty for each day. In these empty lines, personal notes were made, including brief weather observations. From the 16th century, 33 such weather diaries are known for central Europe. Starting with the 17th century, the weather descriptions became more detailed (cf. p. 29). Weather diaries can be analysed by counting and averaging phenomena like rain, snow, and frost and comparing them with the corresponding average values of nearby meteorological stations. A few years ago, within the scope of the EU project CLIWOC, work started on a methodical evaluation of shipping logbooks, which usually contain systematic observations of wind direction and weather. Thousands of these exist. The CLIWOC database mainly covers the region of the North Atlantic for the period between 1750 and 1850.

Most authors of chronicles and weather diaries were aware that their description had a subjective tinge. In order to improve the inter-subjective and inter-temporal comparability of their data, they wove into their descriptions observations of natural phenomena which were known climate indicators.

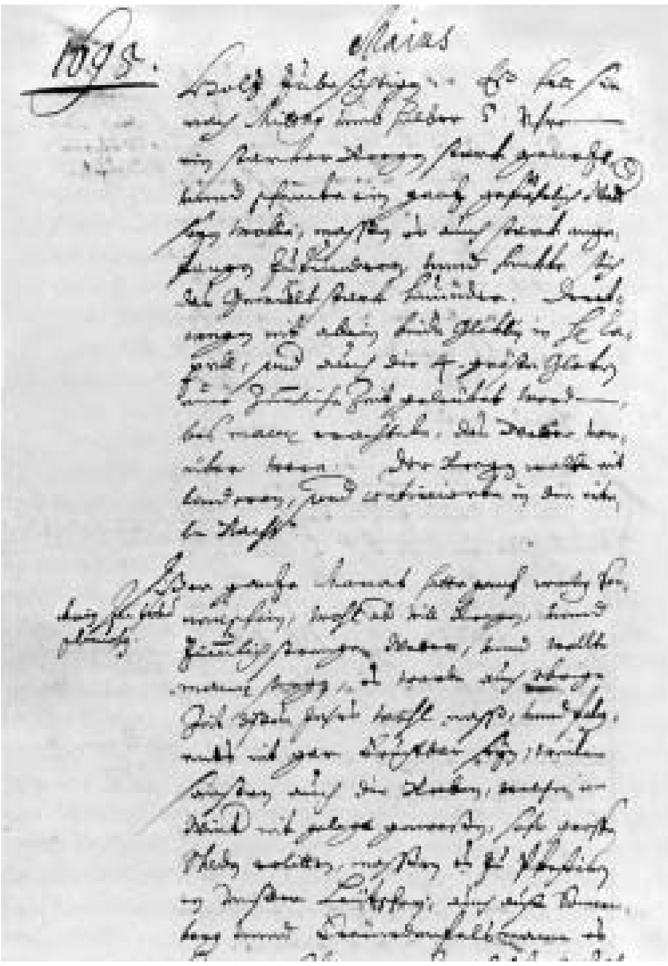
In the warmer half of the year, these included particulars on the quantity and the sugar content of must and observations on the flowering and harvest times of (cultivated) plants. Placidus Brunschwiler, the abbot of Fischingen Monastery (Canton Thurgau), for example, describes the summer of 1639 as follows: "In the month considered here [May], until the 17th day of August, there was hardly ever a really warm day, but more rain and cold winds, so that we did not harvest hay and corn until the 17th day of August, which is usually done around St James' Day [25 July]." A grain harvest delayed by three-and-a-half weeks was shown for the instrumental measurement period only in the "year without summer" (1816) **> Smolka, p. 50**, so that this points to a temperature anomaly on the same scale for 1639.

Mercury thermometer according to Réaumur, 1780: The oldest instrumental measurement series commence in the second half of the 17th century. From the second half of the 18th century on, meteorological instruments spread quickly. This thermometer, made in Mannheim in 1780, has a scale based on that of the French physicist René-Antoine Réaumur: water freezes at 0°C and boils at 80°C. Today's Celsius scale has been used in Germany since 1924.

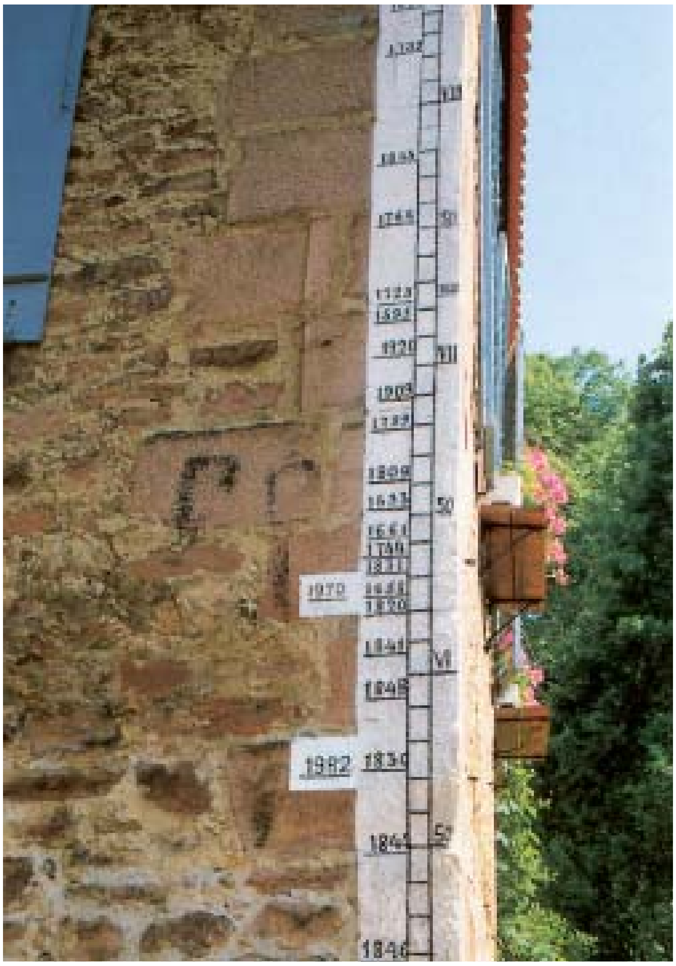
In the winter months, the common climate indicators were snowfall frequency, the duration of snow cover, the time and duration of ice cover on bodies of water, the occurrence of frost, and – in warm winters – the activity of flora and fauna. Recordings of annually recurring events in the winter months were less frequently systematic: since the late 15th century, the books of the city of Tallinn, Estonia, have recorded the day on which the first ship entered its port after the ice cover thawed in spring. Using a whole host of documents, Gerhard Koslowski and Rüdiger Glaser have established the extent to which the western part of the Baltic Sea was frozen after 1501. To record the level of flooding on an inter-subjective basis, high-water marks were mounted on bridges and buildings.

In 1597, Galileo Galilei built the first known instrument to determine air temperature and started to take instrumental measurements. Among the pioneers of observations using instruments, the Parisian physician Louis Morin deserves special mention: between 1665 and 1713, Morin took thermometer and barometer readings three times a day and was the first observer to systematically record the direction of cloud movement. In the 18th century, meteorological instruments spread more rapidly. With a view to finding a common denominator for these meteorological activities, Karl Theodor, Elector of Palatinate, established the Societas Meteorologica Palatina in 1780. This international scientific society provided its members with uniform instruments, issued guidelines for carrying out measurements and published the results. The society's meteorological network extended from Greenland to Rome, from La Rochelle to Moscow. It was broken up by the armies of the French Revolution.

Large databases like Euro-Climhist, HISKLID and CLIWOC already store hundreds of thousands of descriptive and early instrument-based data. Millions of other documents are awaiting discovery in archives. When evaluating documented data, a check is first made as to the spatial consistency of all the direct and indirect data available for a given period of time, using meteorological criteria. In accordance with the informational robustness of the various data types, the seasonal or monthly data fields are analysed to derive numerical indices for temperature and precipitation. These indices have seven tiers, ranging from –3 (extremely dry or extremely cold) via zero ("normal") to +3 (extremely wet or extremely warm). Any interpretation must be adapted to a continuously changing data environment and take account of source-specific, ecological, and individual aspects. It cannot be formalised in mathematical terms, but the results can undergo statistical vetting.



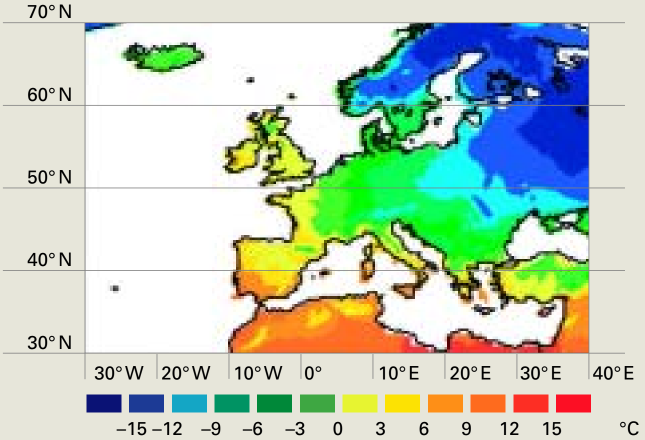
Weather description by Father Josef Dietrich (1645–1704) at Einsiedeln Monastery (Switzerland). Father Josef kept the monastery journal from 1672 until 1695. Not infrequently, the weather description for a single day extends over several lines and is surprising in its wealth of meticulously detailed observations. Dietrich already distinguished between four types of cloud and classified precipitation by duration and intensity. The movement of a cold front on 29/30 May 1695, for example, is described as follows: "We found a very wet morning because it had rained incessantly all night and was still raining in the morning. Higher up, there was a little snow. Toward midday, the rainy weather stopped again, and it looked much brighter; by 3 o'clock, there was even a bit of sunshine."



To document the level of severe floods for posterity, high-water marks on buildings were used to indicate maximum levels.

On this house in Wertheim at the confluence of the rivers Tauber and Rhine, 24 high-water levels are documented. Tens of thousand of high-water marks were destroyed in the 20th century.

Fig. 1a Temperatures in the record winter of 1709 in Europe



For the record winter of 1709, statistical methods were used to estimate seasonal and monthly temperatures, with the support of early instrument-based measurements and temperature indices, for 5,000 grid points in Europe. In eastern central Europe, this most extreme winter of the last 500 years was as much as 6°C too cold. In the night from 5 to 6 January 1709, France was reeling under a cold-air front advancing at a speed of 40 km/h, bringing a temperature drop of some 20°C. On the morning of 6 January, the cold air had reached the Mediterranean and caused untold damage to frost-sensitive plants.

Fig. 1b Deviations from the mean, 1901–1998

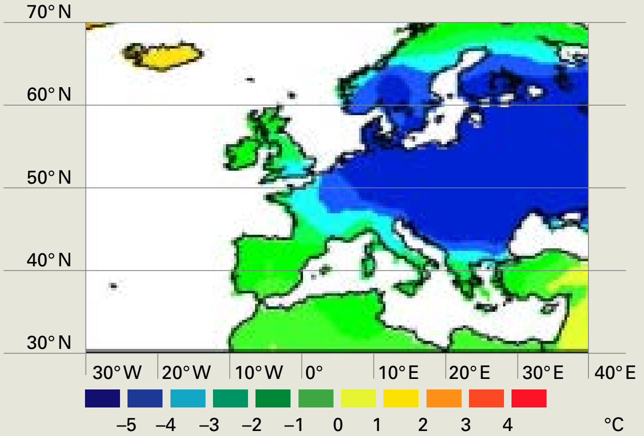
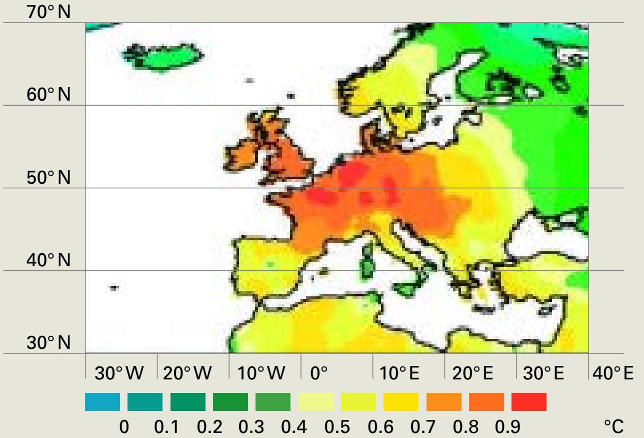


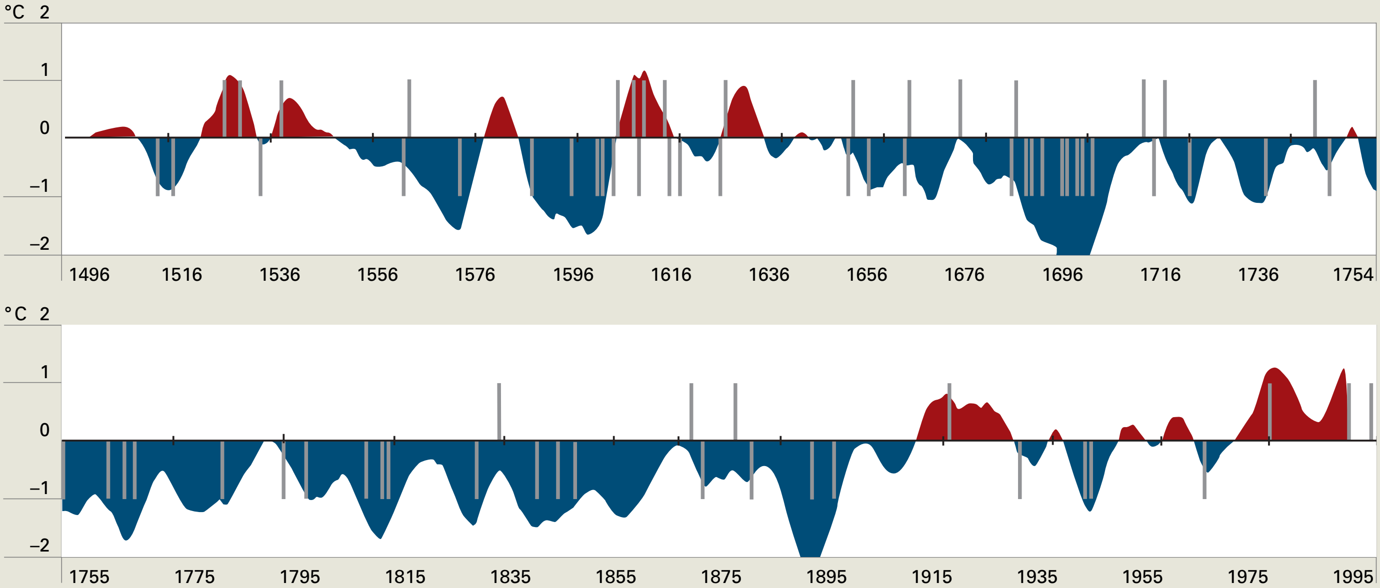
Fig. 1c RE temperature



The RE (reduction of error) values are a statistical measure of the quality of the reconstructions. The higher the RE value, the higher the confidence in the quality of the reconstruction.

Source: Luterbacher et al., 2004

Fig. 2 Fluctuations in winter temperatures in Switzerland's Mittelland region (1496–1995)



Source: Pfister, Wetternachhersage, 1999

For the period before 1755, figures have been estimated using temperature indices. Thereafter, they are based on measurements: the winters of the "Little Ice Age" (until 1895) were 0.5°C colder in the long term than those of the 20th century, and as much as 2°C between 1675 and 1700.

How can index series be further evaluated? To start with, a statistical comparison of index series and measurement series can yield regression equations which, in turn, can be used to estimate temperature and precipitation. Also, using these indices as starting material, it is possible to model the impact of climate on climate-sensitive sectors, such as pre-industrial agriculture, but also the effect of climate fluctuations on eco-systems in the past. Finally, studies have shown that a few geographically well-distributed series of measurements for temperature, precipitation, and air pressure suffice to estimate the sea-level air pressure field and the spatial patterns of temperature and precipitation for the whole of Europe.

On the basis of such considerations, Jürg Luterbacher, Heinz Wanner, et al. (University of Berne) have reconstructed spatial changes in air pressure, temperature, and precipitation for more than 5,000 grid points throughout Europe using statistical models. Until 1658, seasonal and, subsequently, also monthly reconstructions were made (Fig. 2). On this extensive spatial basis, the significance of climatic influences for the price of grain, the business cycle, and the outbreak of epidemics in recent centuries is currently being investigated systematically for the first time.

Presented below are some of the results of historical climate research which have become important in recent discussions about anthropogenic climate change. The outstanding climatic anomaly in recent years was undisputedly in the summer of 2003. Across Europe, the summer was the warmest in the last 500 years. In southern central Europe, it put all record temperatures observed since the start of instrument-based measurements (1755) well into the shade. The only analogous case from the last 700 years was possibly the summer of 1540, when grain and vine ripened at the same time as in 2003, which points to similar temperature conditions. Still, the drought of 1540 was much more serious. From mid-March to the end of September, large areas of (central) Europe were under almost continuous high pressure. In these six months, a little rain fell on only a few days. Numerous wells dried up, and the smaller rivers between the Rhine and the Carpathian Mountains ran dry. At some points along the Rhine, it was possible to wade across the river. Many people had to travel long distances at night to fetch their water in wine kegs, which were carried by pack animals. Forests went up in flames, and the fires were so numerous that a veil of smoke settled over wide areas of the continent. Can this severe analogous case of 1540 be cited as a fact which invalidates the significance of the summer of 2003 as evidence of the greenhouse effect?

An answer to this is provided by the chart below: for each decade in the period 1501 to 2000, it shows the number of extremely warm and extremely cold months (anomalies). The measurement series (since 1755) were converted to index data. The colour scale shows the nature of the precipitation in the various, thermally extreme months (very wet, "average", very dry). Three phenomena stand out:

1 Extremely cold and dry months (with dominating winds from north to east) occurred more frequently between 1570 and 1890 than since then. Such anomalies are regarded as indicating the "Little Ice Age", which started in central Europe around 1300 and ended in the late 19th century.

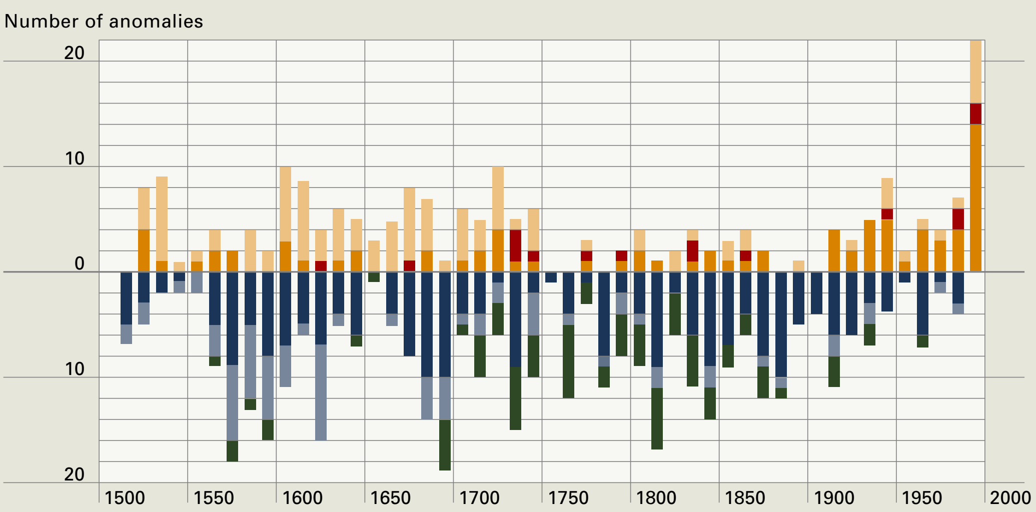
2 In the years 1901 to 1990, an average of five cold and four warm anomalies were measured. In the 1990s, cold extremes did not occur at all, while the number of much too warm months has risen five-fold compared with the average values in the period 1901–1990. The maximum value of 22 warm anomalies (1991–2000) is more than twice as high as the maxima in the period 1501–1990.

3 The analogous case of 1540 must be assigned to a different environment in climate history than the extreme summer of 2003. The Mediterranean summer of 1540 was followed two years later by a cold and wet summer, during which the much-battered glaciers were able to recuperate. The summer of 1947, also cited occasionally as a case similar to that of 2003, was preceded by a cold winter in which the Rhine froze in Germany.

The greenhouse-effect scenarios assume that, as average values rise, the spectrum of extremes will shift. Cold extremes will vanish: what was deemed normal in the past, will now become "cold", and what used to be "warm" will become normal. And, beyond the record heat figures measured hitherto, so the thinking goes, we will have to face what are literally unprecedented extremes. The developments in the last 15 years in central Europe are largely in line with this scenario. The very cold extremes, which were a firm component of our climate for centuries, have disappeared entirely since 1988. Instead, the warm extremes in the 1990s occurred five times more often than in the entire "warm" 20th century. And, with the summer of 2003, we have been given a taste what might lie ahead.

It is the remit of scientists (and science historians) to fit present-day events and developments into a larger context. This is true not only of political events but, in an age of global warming, also – and increasingly so – of climate anomalies and natural disasters. Historical climatology is able to provide arguments for discussion in this area.

Fig. 3 Sum of the extremely warm and extremely cold months (anomalies) per decade (1501–2000), classified by precipitation conditions



Source: Christian Pfister, HLS, Atelier Marc Zaugg, Berne

The "Little Ice Age" stands out owing to an accumulation of cold anomalies, and the present-day greenhouse climate owing to the 22 extremely warm months in the 1990s, a number unprecedented since 1500.

- warm-dry
- warm-moist
- warm

- cold
- cold-moist
- cold-dry

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Christian Pfister (born in 1944) studied history and geography at the University of Berne. After obtaining his doctorate in 1974, he continued his studies at the Universities of Rochester (NY) and East Anglia in Norwich (UK) (1976/77). From 1990 to 1996 he was a member of the Swiss National Fund for Research into Environmental History. Since 1997 he has been Professor for Economic, Social, and Environmental History at the Historical Institute, University of Berne. Pfister has 200 publications to his name on demographic, climatic, agricultural, and environmental history, changes in cultural landscapes, and the history of natural catastrophes. In 2000, he was awarded the Eduard Brückner Prize "for outstanding interdisciplinary services to climate research".