Plate 1.4 Precipitation, Temperature and Runoff over the Past Few Centuries

Introduction

The present plate shows reconstructed data for precipitation and air temperature across the central Alpine arc from 1659 and documented or measured water-levels and runoff from 1500 for a number of selected catchments. The methods section indicates the particularities and importance of historical data sources for analysing climatic and runoff conditions in the past.

Data sources

The maps, time series and tables on the double-page spread are based on statistical climatic reconstructions obtained by analysis of the principal components and multiple regressions [8] that have been calibrated using 20th century instrument data (HISTALP and CRU TS 2.1 [4,9]). The reconstructions are based on a combination of long instrument data series, climatic information from written historical records and natural archives (tree-rings, ice conditions, ice drill cores, etc.), the data series for precipitation and temperature being independent of one another. From a spatial point of view, precipitation is extremely heterogeneous, which is why these reconstructions are less reliable than those concerning temperature (2 m above ground). In Switzerland temperature measurement series are available dating from 1752 (Geneva) and 1754 (Basle); precipitation has been systematically measured since 1863 (cf. plate 2.1[2]). The farther back one goes, the smaller the amount of data available for climate reconstruction, the lower their reliability and the smaller their variability. For this reason, reconstructions for the period prior to 1750 should be viewed with caution.

Owing to the fact that the initial data were gridded, the calculations of the time series refer to a slightly larger area than that shown in the maps (see fig. 3). The division into regions is based on the HISTALP project [4,9]; the analysis includes parts of the north-west and south-west regions defined in that project. For this plate they have been called “Alpennordseite” (northern side of the Alps) and “Alpensüdseite” (southern side of the Alps), and for the sake of simplicity, the whole area covered by the maps is referred to as the Alpine region.

The diagrams of historical floods and low water levels (fig. 1) have been drawn up using selected data and literature (including [1,5,7,10,12,15,17]) as well as the Euro-ClimHist electronic database [11]. The measurements were supplied by the Federal Office for the Environment (FOEN) [3]. The longest continuous measurement series for water-levels and runoff in Switzerland is for the R. Rhine in Basle (since 1808). The density of measuring stations in Swiss catchments has increased since the start of the 20th century (cf. plate 5.1[2]). All measurement series were used as obtained, so that any uncertainty or lack of homogeneity in the original series (for example conversion of water-levels to obtain flow rates, varying frequency of recordings, different types of measuring instruments, etc.) has been left unaltered.

Variation in temperature and precipitation

The top row of maps shows mean precipitation and temperature conditions from 1901 to 1950. The choice of this period as a reference period offers the advantage that it lies within the time when instruments were used and that there were virtually no significant trends in precipitation change during this 50-year period, although some trends in temperature change were evident. To produce the maps, data from the original grids (10′ • 10′ for precipitation and 0.5° • 0.5° for temperature) were interpolated using the nearest-neighbour method. The isolines and areas should be interpreted accordingly; they allow for supra-regional comparisons but not for the specific expression of local conditions.

The second row of maps indicates (for the whole year as well as for winter and summer separately) the mean spatial distribution of temperature and precipitation over periods of normally 50 years (with the exception of 1659–1700) in comparison with the reference period. Two 50-year periods were relatively dry (1751–1800 and 1851–1900) or wet (1801–1850 and 1951–2000), while the period 1659–1700 was similar to the reference period.

As the time series show, before 1800 summers tended to be wetter (compared with total precipitation for the whole year), while from 1950 on they tended to be drier. More recent winters have tended to be wetter than those in the reference period, however, especially on the northern side of the Alps. In the precipitation reconstructions in particular, the range of variation clearly decreases from around 1750 to 1659. Periods of extreme conditions during this time tend therefore to be underestimated.

The driest and wettest years, summers and winters in the Alps are shown in tables 1 and 2. Variations in precipitation and temperature compared with the reference period are shown individually for some of these years in the bottom row of maps.

It can be seen from the maps and the time series that it was predominantly colder up to 1900 than during the reference period. This phenomenon was more marked on the northern side of the Alps and in the annual and summer means, while comparatively higher temperatures were obtained in the reconstructions for the southern side of the Alps and the winter means. On the whole, the Alps experienced their coolest years around 1700 and 1880. A marked rise in temperature can be seen from around 1900 on. Apart from in winter, extremely warm periods were experienced around the middle of the 20th century and during the most recent decades.

Historical floods and low water-levels

The term "historical floods" can be defined in various ways. On the one hand, it can denote events that happened before runoff measurements were carried out systematically. On the other, it can be used for extremely unusual or rare occurrences with a return period of 100 years or more [5]. The first definition has been used for the present plate.

The historical and instrument data on which figure 1 is based provide a variety of information: measurements concern runoff or water-levels, while descriptions of events refer mostly to the damage caused. These two aspects are not necessarily directly related [14]. For this reason, a clear distinction has been made between the periods shown in the diagrams. Trends in frequency and intensity can be estimated and recent events can then be seen from a historical perspective. In figure 1, the intensity of the damage caused by historical floods is indicated at two levels: moderate or severe. The low water-levels for which data is available have been simply listed, with no attempt at distinguishing them by order of magnitude. Where measurement series are available, low water-levels are indicated only if the lowest 7-day mean for the corresponding year is less than the 5 % quantile of the series.

When such estimations are made, it is important to consider the increasing number of hydro-engineering works that affect watercourses, as well as the change in social attitudes. The example of Lake Zurich shows quite clearly how the water-level has been stabilised since measurements began through modification and regulation, as well as the construction of hydro-electric power stations; since 1950 there has been little change in the water-level. Flooding as seen in 1999 would have been considered normal for Lake Zurich 150 years ago. Furthermore, shifts in seasonal patterns should be interpreted with caution. The frequency of flooding of the rivers that are shown here appears to have decreased in autumn in particular, and increased in summer.

The information used as a basis for the diagrams was obtained from instrument measurements and a variety of historical sources. The extracts shown in figure 2 show such sources of information: early systematic measurement data were gathered by the Hydrometry Division of the forerunner of the FOEN. The diagrams show the lowest water-levels for Lake Maggiore from 1867 to 1896. Before the authorities started taking measurements, individual events were recorded using high and low water-level markers. One such marker that is well known is on the Oberer Rheinweg in Basle. Wolfgang Haller, a theologist from Zurich, kept a weather diary from 1545 to 1576. Such journals provide historical, qualitative information and they contain continual and often quantifiable climatic data [10]. The final image shows the Metzgerstein in Zurich. Before it was destroyed in 1823 it was visible when the water-level was low. Legend has it that in February 1585 it was the scene of a riotous drinking party.

A distinction can be made between various types of data, according to the source, the way they are processed and the quality of the results (table 3). The characterisation used here is based on that devised by other authors [2,5,6,10,12,16].

Atmospheric circulation, precipitation, flooding and low-water

For the various reasons given above, it is difficult to establish a direct correlation between the frequency of climatic events and climatic conditions, especially since there is a marked variation in climatic conditions within the Alpine region. On a multi-decade scale (e.g. for the maps of the 50-year periods) an approach involving changing circulation patterns is therefore adopted [8,13,14,16].

Extreme climatic conditions in a single year can indicate what has led up to a particular event, e.g. in connection with snow accumulation, soil saturation, groundwater levels and levels of lakes. Wet years do not always include flooding, however; high mean precipitation does not necessarily lead to extreme flood peaks: the wettest year during the entire period examined was probably 1977. Much damage was caused but it was not a year of extreme disasters. There are records of flooding on the R. Reuss and the R. Aare in 1720, the wettest year on the northern side of the Alps, while the wettest year on the southern side of the Alps was 1960, where no flooding occurred, however [12].

It is in fact unusual mean seasonal conditions that determine the likelihood of extreme events: for example, in autumn 1852, after an extremely wet summer, there was severe flooding of the Rhine, the Alpenrhein (upper reaches of the R. Rhine), the Aare and the Reuss rivers, and in autumn 1890 the Alpenrhein flooded and the Tessin also suffered widespread flooding.

The correlation between periods of little precipitation and low water-levels is more obvious. Low water-levels were recorded during all the dry years or seasons shown in the maps. For example, records reveal low water-levels for the R. Rhine in Basle in June 1949, for Lake Zurich in August 1706, for the R. Rhine in winter 1779 and for the R. Rhine and Lake Zurich in January 1858.

References

[1] **Ambrosetti, W. et al. (1994):** La piena del Lago Maggiore nell'autunno 1993: un evento di portata secolare. Istituto italiano di idrobiologia, Verbania Pallanza.

[2] **Brazdil, R. et al. (2005):** Historical climatology in Europe – The state of the art. In: Climatic Change 70(3):363–430, Dordrecht.

[3] **Bundesamt für Umwelt BAFU (2009):** Hydrologische Daten: www.hydrodaten.admin.ch

[4] **Efthymiadis, D. et al. (2006):** Construction of a 10-min-gridded precipitation data set for the Greater Alpine Region for 1800–2003. In: J. Geophys. Res. Vol. 111(D1), Washington.

[5] **Gees, A. (1997):** Analyse historischer und seltener Hochwasser in der Schweiz: Bedeutung für das Bemessungshochwasser. Diss. Geographisches Institut der Universität Bern.

[6] **Glaser, R. (2008):** Klimageschichte Mitteleuropas: 1200 Jahre Wetter, Klima, Katastrophen. Darmstadt.

[7] **Hügli, A. (2007):** Aarewasser: 500 Jahre Hochwasserschutz zwischen Thun und Bern. Bern.

[8] **Luterbacher, J. et al. (2004):** European Seasonal and Annual Temperature Variability, Trends, and Extremes Since 1500. In: Science 303(5663):1499–1503, Washington.

[9] **Mitchell, T.D., Jones, P.D. (2005):** An improved method of constructing a database of monthly climate observations and associated high-resolution grids. In: Int. J. Climatol. 25(6):693–712, Chichester.

[10] **Pfister, C. (1999):** Wetternachhersage: 500 Jahre Klimavariationen und Naturkatastrophen (1496–1995). Bern.

[11] **Pfister, C. et al. (2008):** Euro-Climhist. A Data-Base on past Weather and Climate in Europe and its Human Dimension. Historisches Institut der Universität Bern.

[12] **Röthlisberger, G. (1991):** Chronik der Unwetterschäden in der Schweiz. Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft Birmensdorf.

[13] **Schmocker-Fackel, P., Naef, F. (2010):** More frequent flooding? Changes in flood frequency in Switzerland since 1850. In: Journal of Hydrology, 3, Amsterdam.

[14] **Sturm, K. et al. (2001):** Floods in Central Europe since AD 1500 and their Relation to the Atmospheric Circulation. In: Petermanns Geographische Mitteilungen 148 (6):18–27, Gotha.

[15] **Vischer, D. (2003):** Die Geschichte des Hochwasserschutzes in der Schweiz: von den Anfängen bis ins 19. Jahrhundert. Bundesamt für Wasser und Geologie BWG, Bern.

[16] **Wanner, H. (2004):** Dynamic and socioeconomic aspects of historical floods in Central Europe. In: Erdkunde 58, no. 1:1–16, Bonn.

[17] **Weingartner, R., Pfister, C. (2007):** Wie ausserordentlich war das Niederwasser im Winter 2005/06? Eine hydrologisch-historische Betrachtung des Rheinabflusses in Basel. In: Hydrologie und Wasserbewirtschaftung 51, Heft 1:22–26, Koblenz.

[18] **Wetter, O., Pfister, C., Weingartner, R. (in Vorbereitung):** Hydrological floods over the last 740 years in the Upper Rhine basin.