

Reconstructing Past Climate and Natural Disasters in Europe Using Documentary Evidence

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Historical climatology

Extending continuous, semi-quantitative monthly and seasonal temperature and precipitation data back into the pre-instrumental period on the basis of documentary data is the primary aim of historical climatology. This branch of science, situated at the interface between climatology and history, has developed methods for interpreting and quantifying documentary data on weather and climate. An additional focus includes the interpretation of current natural disasters within an historical context. Historical climatology also includes investigations into the vulnerability of past economies and societies and explores past discourses on, and social representations of, climate.

Documentary weather and climate data

A climate historical source is a unit of evidence that contains one of several types of documentary data on weather and climate.

Documentary data are classified according to several criteria (see Table 1)

Direct observations: Documentary data are the only kind of palaeoclimatic data that provide direct observations of meteorological parameters. Most importantly they provide the only evidence that directly relates to socio-economic

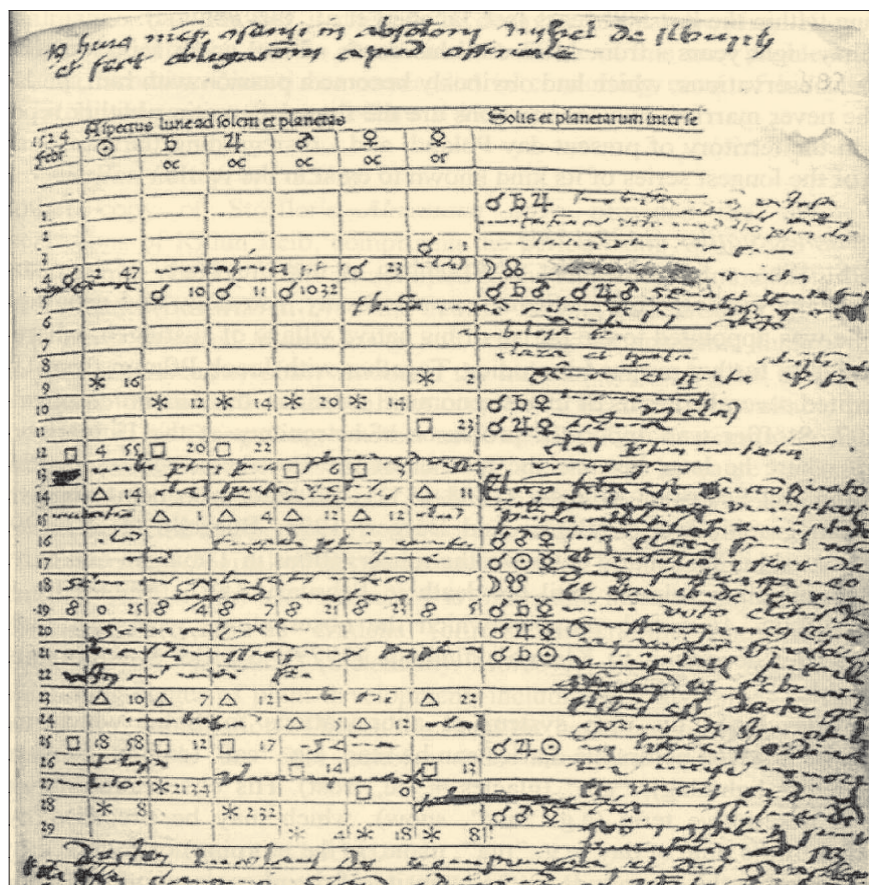


Fig. 1: A page of the weather diary kept by the theologian Marcin Biem at the Jagiellonian University of Cracow (Poland), February 1524. Professor Biem wrote in Latin and he frequently used abbreviations. Entries in weather diaries lend themselves to various forms of frequency analysis. For synoptic analyses it has become commonplace to arrange the entries in tables and represent them using the appropriate symbols of the WMO.

climate impacts, in particular with regard to rare but socio-economically significant disasters prior to the period of instrumental measurement. Direct observations may

cover all months and seasons of the year. Depending on the type of data (Fig.1), they may have a time resolution ranging from hours to seasons. An example taken from the earliest known weather diary kept on the European continent, dated 1399, reads: "Sept 1st: day rainy and cloudy, night cloudy and air cold". The author, identity unknown, lived in the surroundings of Basel, Switzerland (Thorndike L., 1966: A daily weather record from the years 1399 to 1406, ISIS 57, 90-91).

Indirect or proxy observations: Many observers were themselves well aware that their narratives included a subjective bias. Thus, they referred to physical and biological

Table 1: A classification of documentary evidence (adapted from Pfister et al., 1999)

Perception of Weather and Climate	Kind of Evidence	
Direct	Observed	Measured
	Weather anomalies Natural hazards Weather spells Daily weather Pictorial	Barometric pressure Temperature Precipitation Water-gauge etc.
Indirect (Proxy Data)	Organic	Inorganic
	Phenology Crop yields Time of crop harvests Cultural Rogation ceremonies	Water levels Duration of snow, frost and ice Epigraphical archaeological remains

proxy indicators that were known to be more objective yardsticks and that could be compared over time. The group of proxy data is made up of a broad variety of indicators that are as different among themselves as those obtained from natural archives. Each data type needs to be presented for itself in the same way as is done with natural proxy data. An example: "The summer of this year [1347] was so cold and rainy that all crops were extremely slow in growth. All of them had to be harvested unripe" (Chronicle of Zwettl, Austria). Indeed, a long series of tree-ring density data from Lauenen (Switzerland) independently confirms that this particular summer was the coldest of the last millennium.

Continuous and discontinuous observations

Discontinuous observations:

Narrative and/or instrumental observations that were made by individuals for their own sake are discontinuous. Chroniclers often tried to obtain more continuity by copying the observations of their predecessors. Individual perceptions of the environmental are known to be affected by their cultural, social, professional and personal background. For example, professionals, such as wine-growers or farmers, perceive weather in the way it affects their daily affairs whereas intellectuals such as clergymen, early scientists and "amateurs" made systematic attempts to unravel the working of climate in order to derive reliable weather predictions.

Continuous observations: Continuous indirect data are the product of routine administrative processes. They were recorded for socio-economic reasons in an institutional framework. For example, the beginning of wine and grain harvest was regulated by many communities in order to prevent tax evasion. Another example is the regular record of wages paid on Saturdays for community work (e.g. cutting ice at the mills, harvest work) in the town of Louny (NW Bohemia). These were scrupulously recorded in a book of



Fig. 2: Saint Narcisus was the first bishop of Girona (NE Spain). His relics were displayed in rogations both for rain and during long periods of rain - for warm weather in summer.

accounts from 1450-1632 and can be used as proxies for temperature reconstruction (Brázdil and Kotyza 2000).

Rogations are standardized liturgical actions meant to cope with situations resulting from climatic stress. In the Spanish world they were called forth by guilds and municipal authorities when crops were jeopardized. According to the nature and severity of the climatic stress a specific religious action, such as a prayer at church, the exhibition of relics, a procession or pilgrimage to a shrine was mandated (Fig. 2). The rules for rogation ceremonies were set by the pope. Their costs are laid down both in the account-books of the municipalities, as payments, and in those of the church as receipts (Barriendos, 1997).

Spatio-temporal distribution of documentary data in Europe

The oldest reports on climate anomalies and natural disasters are contained in chronicles from the eighth century AD. Most of these were written in the nascent reign of Charlemagne which included contemporary Germany and France, the Benelux countries, Switzerland and Northern Italy. Some were also written in Ireland and England. From about 1050 the tradition of keeping chronicles spread to the territories of contemporary Catalo-

nia, Czech Republic, Denmark, Hungary, Iceland, Poland and Slovakia and somewhat later to the Baltic, Russia and Finland. Records from south-eastern Europe are scanty until the eighteenth century.

The characteristic nature of reports from Western and Central Europe, including Northern Italy, are listed below.

- **Prior to 1300:** Reports of socio-economically significant anomalies and natural disasters.

- **1300 to 1500:** More or less continuous reports on the characteristics of summers and winters (to some extent also on those of spring and autumn) including reference to "normal" conditions.

- **1500 to 1800:** Almost complete description of monthly weather patterns, to some extent also of daily weather and a growing number and diversity of continuous proxy records related to the rise early local, regional and state bureaucracies.

- **1680 to 1860:** Instrumental measurements made by isolated individuals and the first short-lived international network observations (Breslau-Network 1717-1726 and Palatina-Network 1780-1792).

- **1860 onwards:** Instrumental observations in the framework of national and international networks.

The list needs to be understood in a cumulative way. Older climate observations are not replaced by, but rather superposed on, more recent ones. In sum, over time the quality of the data improves and their density, spatial coverage and time resolution increase.

Methods for reconstructing temperature and precipitation

The usual method for reconstructing climate from documentary evidence involves the following steps:

(i) Critical review of sources and calibration of indirect data

Documentary evidence needs to be critically reviewed according to the rules of historical source interpretation. In particular it must be determined whether the author of the document really witnessed the events he describes or whether

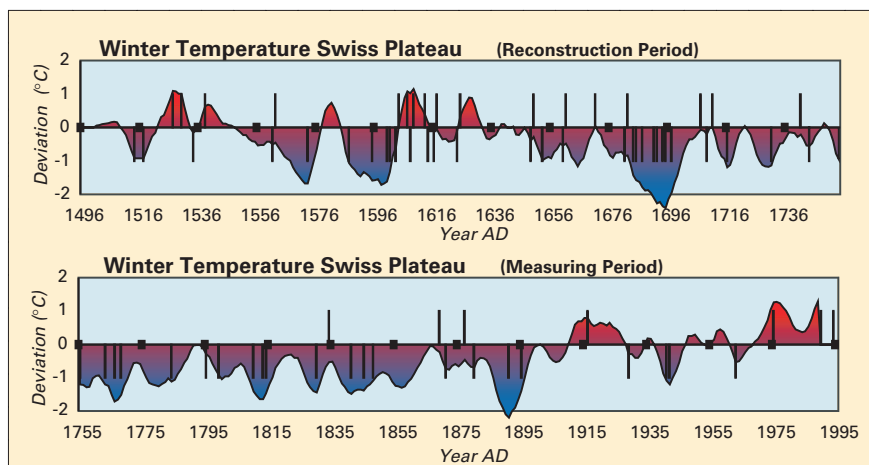


Fig. 3: 11 year running average winter (DJF) temperature in Switzerland 1496-1995. The data for 1496 to 1754 are estimated from documentary evidence. The standard error is $\pm 0.2^\circ\text{C}$. The data from 1755 are based on the instrumental series from Basel (Pfister 1999).

he copied the observations from another source. Copying is a major source of misdating. An unreflected use of non-contemporary observations may lead to spurious duplication of extreme events. Reports of climate-dependent physical or biological processes such as the freezing of bodies of water or the times of flowering of plants need to be calibrated against series of instrumental measurements.

(ii) Construction of temperature and precipitation indices

The construction of indices for the pre-instrumental period requires cross-checking all types of data available for a specific month to ensure an unequivocal climatic reconstruction. This involves methodological, source-dependent and interpretative assessments. The result is expressed in terms of an ordinal intensity index for temperature and precipitation, which may include either three or seven classes, according to the time resolution of the evidence. Unweighted index values are: -1 for unmistakably cold or dry months, 0 for "average" months, +1 for unmistakably warm or wet months, whereas the weighted index allows seven classes to be distinguished: +3 extremely warm or wet, +2 very warm or wet, +1 warm or wet, 0 normal, -1 cold or dry, -2 very cold or dry, -3 extremely cold or dry. Seasonal or annual indices are obtained by averaging monthly values which involves calibration and verification.

(iii) Calibration

Calibration establishes a transfer function between a series of index values and a corresponding series of instrumental temperature or precipitation measurements. During the calibration period both the proxy and measured values must be available.

(iii) Verification

The relationship obtained by calibration is applied to an independent verification period, for which the values of temperature and precipitation are obtained from the transfer function. These are then compared with the measured values. Various statistical techniques may be used to compare the measured and reconstructed values. It is also necessary to indicate what portion of the variability of the instrumental series is captured by the proxy.

(iv) Assessment of temperature and precipitation

If the response function obtained captures the variability of temperatures and precipitation with satisfactory precision, the chronology of the index values can be used to provide a reconstruction. As with all proxy records, this procedure assumes that the response function is constant over the entire period of the reconstruction.

This approach has been applied to produce temperature and precipitation reconstructions over the past millennium in Germany,

Switzerland (Fig. 3) and the Czech Republic as well as for deriving a Central European series for the sixteenth century (Pfister et al. 1999).

An alternative method of climate reconstruction using several series of indices for spatial reconstruction of climate parameters is described in the article of Luterbacher et al. (this volume).

Conclusion

Documentary evidence includes a broad variety of data types, which allow high resolution reconstruction of weather and climate in Europe over the last millennium. These data cover all seasons and months of the year and allow us to distinguish between temperature and precipitation. Significantly, documentary evidence is the only kind available that can lead to the analysis of natural disasters (e.g. severe floods, windstorms, frosts, hailstorms) and their impact upon past societies. The more extreme an event, the more numerous and detailed are its descriptions in historical sources. Thus, analysis of documentary data enables an investigation of the relationship between variations in climate and the frequency and severity of extreme events - a major source of societal concern in light of global warming.

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