# Historical Climatology and the Study of Climate Fluctuations During the Past Millennium

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*ABSTRACT. Historical climatology as a branch of science is defined. Basic groups of data sets divided into man-made and natural sources as well as the general method of the historical-climatological analysis are described. Climate paradigms for the last millennium are discussed. Prospects of historical-climatological research are presented.*

*KEY WORDS: historical climatology, documentary evidence, climate reconstruction, climate fluctuation, past millennium.*

## Historical climatology

Historical climatology can be defined as a branch of climatology dealing, on the basis of man-made and natural documentary evidence, with the reconstruction of climate and weather extremes, their causal clarification and their impacts on man and nature in the period before the beginning of continuous instrumental observations. Thus it contributes to the knowledge of the state and behaviour of the climate system in the period of the prevailing effect of natural climate forcing at the time, when the activity of man on the climate reached only local to regional scale. Historical climatology is delimited by the earliest man-made documentary evidence with respect to palaeoclimatology and by the beginning of systematic meteorological observations with respect to climatology of the instrumental period. The time delimitation of historical climatology is thus geographically much heterogeneous (for more details see Brázdil, 2000).

## Data base of historical climatology

Data for climatic reconstruction of the pre-instrumental period can be either man-made or based on natural proxy evidence. Man-made evidence includes early instrumental records, descriptive documentary evidence and archaeological data. Early instrumental records, made before the beginning of systematic meteorological observations, cover in most cases only short periods or they have sporadic character. Descriptive documentary evidence includes both direct information about weather and about phenomena and events dependent on weather (for instance freezing of rivers, harvest or vintage). This is an exceptionally rich source, including written reports from annals and chronicles, daily weather reports, personal and official correspondence, travel diaries, economic records, pictures, leaflet newspapers, early journalism, epigraphic records etc. Archaeological data have to be taken as resulting from the long-term effects of climate and/or climatic extremes, the connection with climate sometimes being ambiguous. As for natural records, the climate signal must be extracted from different proxy series. The most frequently used proxies for the last millennium are those relating to glaciers, tree rings, palaeobotany, sediments and borehole measurements.

Descriptive documentary evidence provides the database for most historical-climatological studies. Compared with natural proxy data, it has following advantages (Pfister et al., 1999):

- good dating control and high time resolution
- disentanglement of meteorological elements (temperature, precipitation, wind etc.)
- focus on anomalies and weather disasters
- sensitivity to events throughout the year (no seasonal restriction)

Its drawbacks include (Pfister et al., 1999):

- discontinuous and heterogeneous structure
- bias by the selective perceptions of observers
- restriction of analysis to simple and robust techniques of mathematical elaboration and interpretation

## Methods of historical-climatological analysis

Historical-climatological analysis includes the following steps:

a) compilation of the proxy chronology

Compilation of the continuous proxy chronology, which must reach the period of instrumental measurements, depends on the density and quality of the basic information, and is to some extent affected by the subjectivism of researchers. A critical approach to the basic material, methods of processing and standardisation employed should guarantee elimination of inhomogeneities in the series.

b) calibration

It is identification of the relation (response or transfer function) between the proxy characteristic and the meteorological element available in the calibration period.

c) verification

The relationship obtained is applied to the verification period, for which the values of the meteorological element are calculated. These are then compared with the measured values, using various statistical techniques.

d) reconstruction

If the response function obtained expresses the variability of the series of the meteorological element under consideration with satisfactory precision, the proxy chronology can be used for climate reconstruction. This procedure is based on the assumption that the response function is valid over the whole period of the reconstruction.

## Climate of the last millennium

The climate of the last millennium has commonly been seen as including a Medieval Warm Epoch (MWE), a period of climatic deterioration, the Little Ice Age (LIA) and the current warming trend. For example, Lamb (1977) placed the MWE in the period 950–1200 (but in 1150–1300 in the greater part of Europe), and the LIA in 1550–1850, with the most pronounced phase in the period 1550–1700. The concept of the LIA was first introduced by Matthes (1939) and relates to the behaviour of glaciers, not directly to climate. It means that the LIA was the most recent period during which glaciers extended globally, their fronts oscillating about advanced positions (Grove, 1999). Several combinations of meteorological factors control an advance phase or a retreat one. Consequently, the MWE (see also Lamb, 1965) can be defined as the period between the glacial

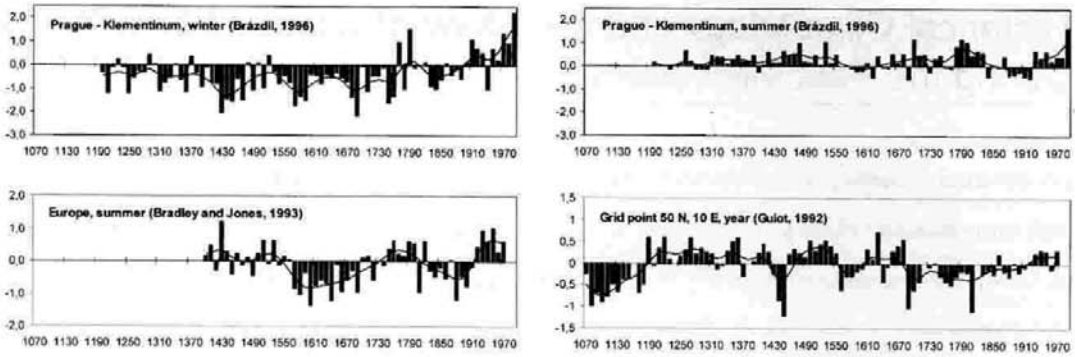


**Fig. 1.** Fluctuations of decadal temperature anomalies (°C; Europe - sigma units). Smoothed by the Gauss filter for 10 items. Reference periods: 1851–1950 (Prague), 1860–1959 (Europe), 1851–1979 (grid points). Years on the x-axis always mean the first year of the respective decade.

advances of the LIA and the preceding phase of glacial expansion late in the penultimate millennium (Grove and Switsur, 1994). Also in this period fronts of glaciers fluctuated as they have been observed to do during the warming of the 20th century. It means that the MWE and LIA were not periods of unbroken warmth and cold, respectively, but rather periods of different temperature variations in time and space. Some areas were warm at times when others were cold and vice versa, and some seasons may have been relatively warm while other seasons in the same region were anomalously cold (Bradley, 2000). Mean annual temperature of Northern Hemisphere for the last 1000 years (Mann et al., 1999) shows a gradual decline up to the beginning of the 20th century followed by a sharp increase up to the present. The 1990s are probably the warmest decade in at least a millennium. Some examples from Europe (Fig. 1) document the complexity of temperature fluctuations of the last millennium in this region.

## Prospects of future investigations

Further historical-climatological research should be directed to:

a) Complementation of the existing data base, compilation of series of temperature and precipitation indices for individual countries and regions and their cross-control.
b) Reinforcement of the new mathematical-statistical methods used in the reconstruction of temperature and precipitation series on the basis of descriptive documentary evidence.
c) Compilation of series of weather extremes and their evaluation in terms of intensity, causes, seasonality, impacts and long-term trends.
d) Reconstruction of circulation patterns as a basis for understanding climate fluctuations and the clarification of regional differences.
e) Closer engagement with climate modellers and use of GCM outputs in the study of climatic forcing and for overcoming drawbacks in documentary evidence.
f) Use of high-resolution data on temperature, precipitation and weather extremes as inputs in impact studies intended to illuminate the effects of climate on history and society.

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