Data and methods of climatological evaluation in historical climatology

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Data and Methods of Climatological Evaluation in Historical Climatology

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Abstract: The article summarizes which types of data and procedures are employed in historical climatology in order to arrive at climatic information. With respect to data handling descriptive data of a sporadic nature have to be distinguished from systematically recorded data. Instrument readings are also in a class of their own, as are the many types of proxy data. A climatic interpretation can only be done by means of a whole range of at times complex procedures. Historical climatology is situated between traditional historical science and the natural sciences. Critical source analysis and hermeneutics are part of their tools just as simple tests, multiple statistical methods or the reference to fundamental physical processes. Critical evaluation of sources, semantic profiles, derivation of indices, calibrations by means of regression analysis, comparisons with present-day standard data sets, regionalization, synoptic reconstruction and comparisons based on descriptive statistical evaluations are some of the terms that give an idea of the complexity, of the approaches and of the results that may be obtained. Two fundamental problems are related to the empirical determination of the reliability of the data and to data management. Both of them could be coped with successfully by establishing a special data bank. Since it is possible to derive quantitative time series and especially synoptic weather maps out of the historic data sets a link to modern computer simulated modelling is in progress.

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1. Introduction

In the context of the discussion about the possible global warming and of human impact on climate historical climatology has increasingly received attention over the last decades (LAMB 1977, WIGLEY, INGRAM & FARMER 1981, BARON 1982, LE ROY LADURIE 1983a,b; PFISTER 1985, ALEXANDRE 1987, GLASER 1991, BRADLEY & JONES 1992, BRAZDIL & KOTYZA 1995). The importance of historical climatology is its considerable contribution to our understanding of the climatic processes and to the interaction of humans and the environment. Various types of data lend themselves to the deciphering of the climate of the past Three major groups should be distinguished: descriptive data, historical instrument readings, and proxy data. Rather sporadic descriptive information is supplemented by that laid down in the form of diaries written in a systematic way with a high temporal resolution. Early instrument readings are complicated by the penchant of the observers for experiments and by technical difficulties. Proxy data, which give indirect access to climatic information comprise a wide field of suitable data types (Figure 1).

In order to make use of these data a similar wide array of methods has to be employed, frequently combining elements of natural science with historical elements. It is this hybrid approach that makes this kind of research so attractive. Whereas the compilation of data is subject to the historical principle of critical source evaluation, most of the analysis being based on the hermeneutical approach, the application of numerical methods to the results thus obtained can lead to a level of objectivity which corresponds to a natural science approach. The object proper of this type of research, namely weather and climate, calls for a natural science approach, which in turn can help verify procedures and results of the historical approach. Mainly in the field of proxy data numerical information exists that lends itself to quite a number of methodological approaches. Its a vast area of research that is open to all kinds of linkages.

Our group is working currently on a transect through central Europe from southern Germany to the coastal region in the north. The physical structure of this region is well-suited for a climatic regionalization.

2. Sources and their application

From the complex field of suitable data the three types already referred to were chosen:

1. descriptive weather information
2. instrument readings, and
3. proxy data.

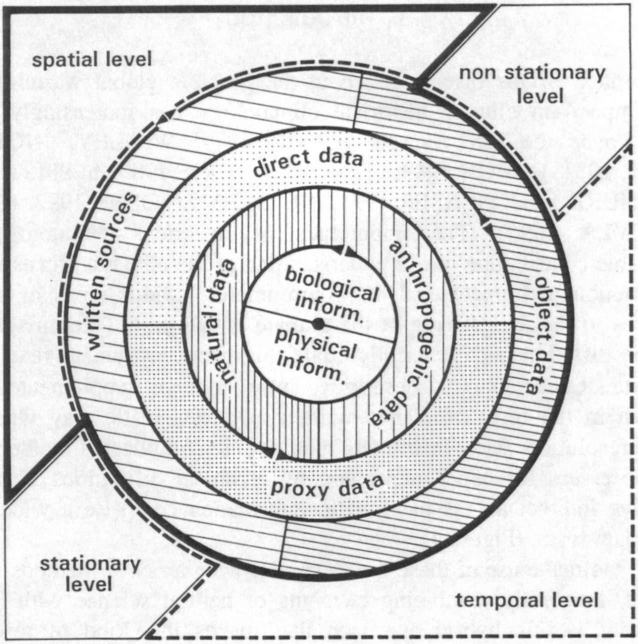


Fig. 1: Data types.

The suitability and relative merits of each type of sources have been discussed by INGRAM, UNDERHILL & FARMER (1981), PFISTER (1985), and GLASER (1991) and therefore need not be repeated here in detail. The main steps of a critical source analysis are given in Figure 2.

2.1. The descriptive source information

Descriptive source information must be separated for systematic reasons as

1. irregularly spread data which occur mostly in a more or less sporadic way, related to seasons, months or single weather events like thunderstorms, and
2. systematically organized weather journals with daily information. For the more recent past these can be calibrated by comparing them to already existing instrument readings. Their evaluation is done by means of the descriptive statistical method described in chapter 2.2.

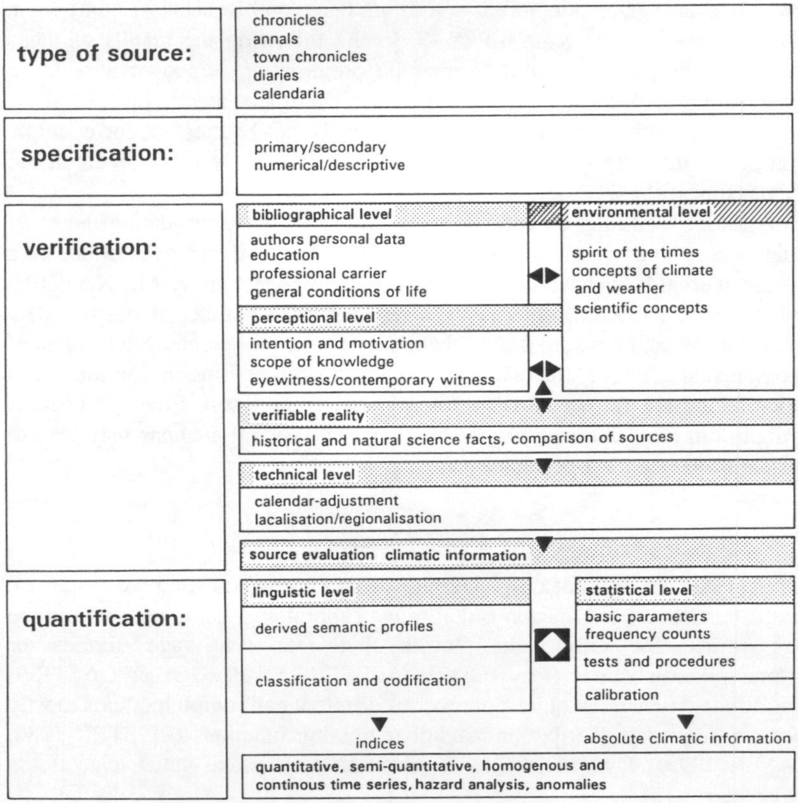


Fig. 2: Main steps of a critical source analysis.

Descriptive sources with a seasonal temporal resolution continually cover all of central Europe back to about the year 1500, and for much of this time even monthly information is available. As has been shown already in a number of papers, meaningful results can be obtained from semiquantitative time series analysis using simple classification schemes such as indices.

The text sources have to be subjected to a semantic analysis leading to a hierarchical system of the terms used, taking into considerations changes of meaning in the course of time (Table 1). In a following step these data have to be classified, beginning with a simple ranking procedure. Positive and negative expressions are given the index -/+ 1 on the monthly scale, leading to a seasonal index ranging from +3 to -3. In the following the results of these ratings are compiled in tables. A graphic presentation is shown here for a source from Bad Windsheim (Figure 3). Whenever the semantic profiles allow more linguistic differentiation, more index levels can be created; for example seven at the monthly level which lead to correspondingly more levels at the seasonal timescale.

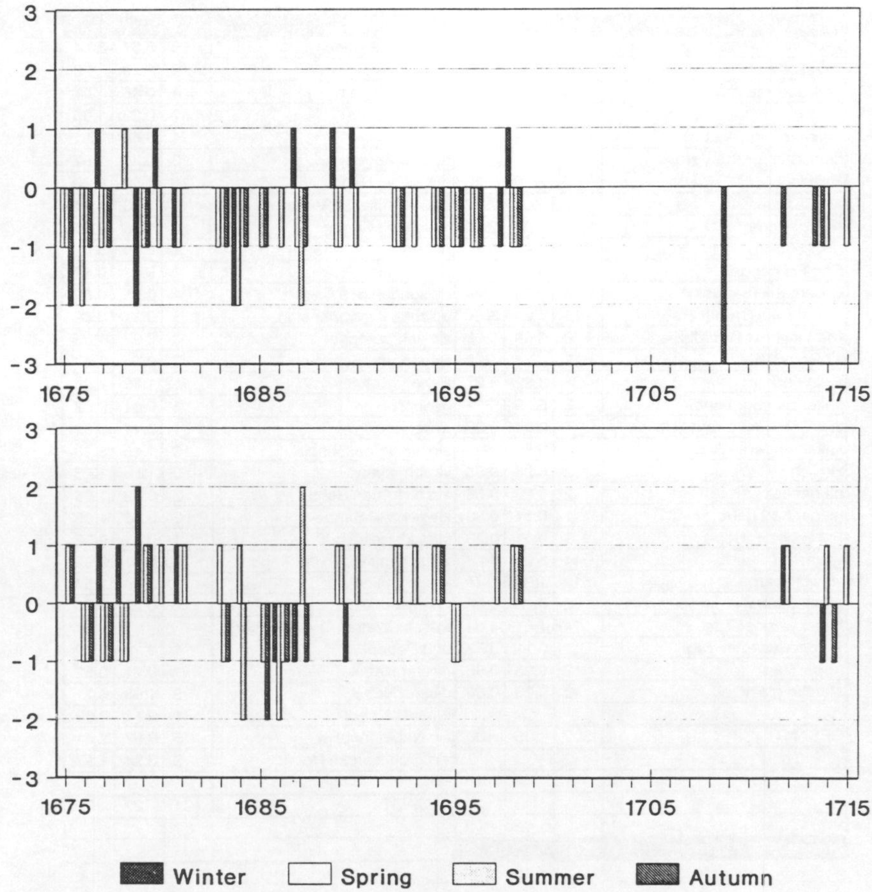
For studies focussing on earlier times, especially those pre-dating the early modem era, where continuous records are no longer available, evaluations on a ten-year interval basis have proved to be suitable (LAMB 1977, ALEXANDRE 1987, GLASER 1995). At this level of resolution the number of positive data may, for instance, be juxtaposed to the number of negative ones. Such series of indices reveal climatic fluctuations at a reasonable resolution for the times studied. They are further suitable for regional comparison. Filter procedures highlight longterm changes; further treatment by spectral analysis may lead to information concerning periodicity.

2.1.1. Calibration

Historical climatology not only attempts to obtain semi-quantitative results on climatic conditions, but to carry out absolute calibrations, i.e. to derive from the index series not only value levels, but real centigrade figures or mm-precipitation values (f.e. RODRIGO, ESTEBAN-PARRA & CASTRO-DIEZ 1994). There exist quite a number of different calibration methods mostly based on frequency distributions and/or regression functions (PFISTER 1985, GLASER 1995). Their reliablility is given as a statistical value, e.g. as the standard error.

To improve the understanding of the use of indices modern instrumental time series have been transformed into indices (Figure 4). The first column represents a very simple transformation calculated at the seasonal scale and based on the mean plus/minus a standard deviation criteria for positive and negative indices of the standard period 1951-1980. The second column has been calculated from monthly values using the same criteria. The seasonal index has then been calculated as the sum of the monthly indices ranking from +3 to -3. For the third column an index from -3 to +3 has been employed at the monthly scale, leading to a seasonal index ranging from -12 to +12. It is quite interesting to see that the structure of each time series and its fluctuations are rather similar. Even with this very simple unweighted index the ups and downs contained in the original instrument data are well represented. This procedure is sufficient for a meaningful identification of major climatic phases.

Fig. 3: Thermal and hygric indices for Bad Windsheim during the Maunders phase.



Tab. 1: Semantic profile of the Leonhard Treuttwein III weather diary, Fürstenfeld, 1587.

Temperatur	1	2	3	Niederschläge	1	2	3
(gar) kalt (Wetter)	87	10	28.8	Regen (geregnet)	58	6.67	30.4
ziemlich kalt	12	1.38	4	starckh geregnet	12	1.38	6.3
überauß kalt	3	0.34	1	schwer Regen	4	0.46	2.1
khiel	2	0.23	0.66	groser Regen	2	0.23	1.05
raucher Tag (Wetter)	8	0.92	2.65	vil Regen	4	0.46	2.1
starckhen/groben/grossen				etliche Regen	3	0.31	1.57
Reiffen	7	0.8	2.32	ein wenig Regen	10	1.15	5.23
ain Reiffen	7	0.8	2.32	cleines (clains) Regle	8	1.03	4.71
hart gefroren	8	0.92	2.65	weich mit Regen	2	0.23	1.05
Eis/gefroren	8	0.92	2.65	offt geregnet	1	0.11	0.52
Rog Eis gangen	3	0.35	1	Platzregen	1	0.11	0.52
Grundt Eis (gangen)	9	1.03	2.98	nit sunderliche Regen	1	0.11	0.52
kalt mit viel Grundt Eis	11	1.26	3.64	etlich mal gerechnet	1	0.11	0.52
(gar) kalt mit Grundt Eis	6	0.69	0.69	zimlich geregnet	2	0.23	1.05
vil Grundt Eis	7	0.8	0.8	Regen und Schneien	2	0.34	1.57
kalt Wind(en)	28	3.22	9.27	Schne (Schneyen)	15	1.72	7.85
kalter raucher Windt	6	0.69	2	geschnie	1	0.11	0.52
ziemlich windig und kalt	1	0.11	0.33	geschnip	1	0.11	0.52
kalten undern Windt	6	0.69	2	ein wenig geschneit	10	1.15	5.23
zimlich kalt Windt	2	0.23	0.66	vil schneyen	20	2.3	10.5
nit gar kalt	2	0.23	0.66	ain dick(h)en Schne	2	0.23	1.05
nit gar hart gefroren	1	0.11	0.33	ziemlich vil Schne	2	0.23	1.05
kalter waser Nebel	1	0.11	0.33	starckh gestaindt	1	0.11	0.52
warm	44	5.06	14.6	weisch mit Kisel und Regen	1	0.11	0.52
zimlich warm	12	1.39	4	kleine Staindle	3	0.34	1.57
glindt (glend)	2	0.23	0.66	Windtstaineln	2	0.23	1.05
feiner warmer Tag	14	1.61	4.64	starckh Wetter, Dunder, Plitz			
weicher warmer Tag	1	0.11	0.33	und Regen	1	0.11	0.52
haiser Tag	2	0.23	0.66	nasser Nebel	1	0.11	0.52
starckh glonit	2	0.23	0.66	dickhe Nebel	8	1.03	4.71
				Wasser Nebel	1	0.11	0.52
GESAMT	302	35	100	ain Nebel (nüblig)	5	0.57	2.61
				ain groß starckh Nebel	3	0.34	1.57
				GESAMT	191	22	100
Summe aller Aussagen	870						

Temperature (Temperatur) and precipitation (Niederschläge)
1 = number of entries,
2 = precentage of entries in relation to all entries,
3 = precentage of entries in relation to specified weather element..

Tab. 2: Classification of descriptive weather data of the Bad Windsheim data.

after GLASER, MILITZER & BUSCHE (1994)

Winter (thermal information=19 years; hygric information=8 years):

T+ : 1677, 1680, 1687, 1689, 1690 (5) [26] {12}
T- : 1679, 1681, 1684, 1703, 1712, 1714 (6) [32] {15}
H+ : 1677, 1678, 1679, 1681 (4) [50] {10}
H- : 1686, 1687 (2) [25] {5}
T±0: 1676, 1678, 1683, 1685, 1686, 1693, 1695, 1698 (8) [42]
H±0: 1676, 1693 (2) [25]

Spring (thermal information=10 years; hygric information=13 years):

T+ : (0) [0] {0}
T- : 1675, 1676, 1677, 1680, 1681, 1683, 1684, 1687, 1714, 1715
(10) [100] {24}
H+ : 1680, 1681, 1683, 1684, 1714, 1715 (6)[46] {15}
H- : 1676, 1677, 1678, 1686 (4) [31] {10}
T±0: (0) [0]
H±0: 1675, 1678, 1687 (3) [23]

Tab. 2 continued.

Summer (thermal information=18 years; hygric information=18 years):

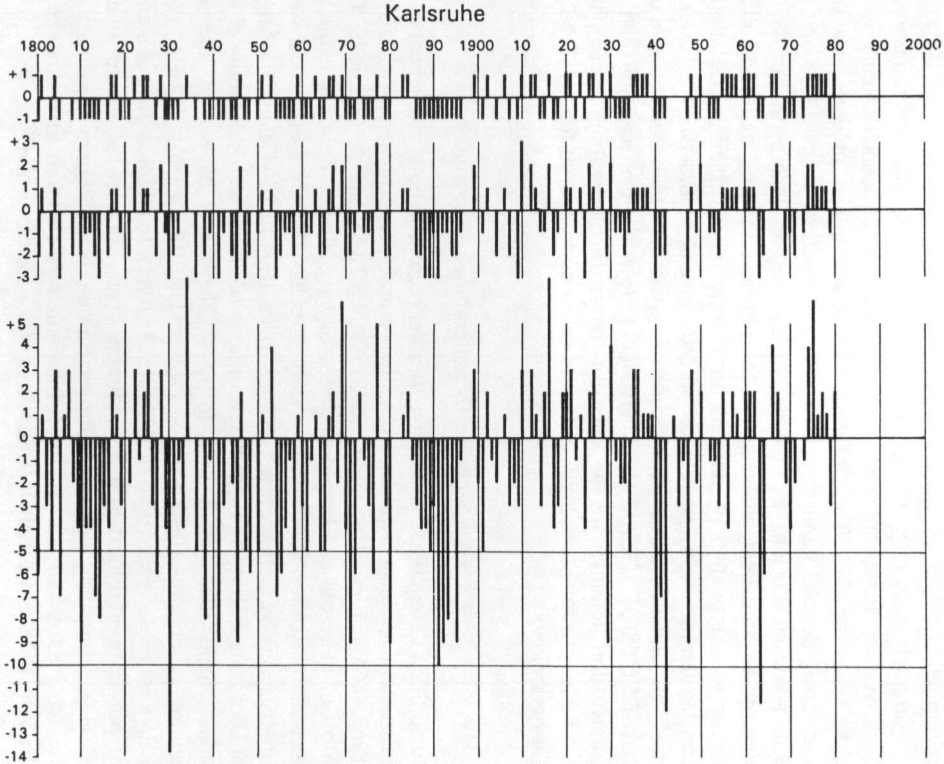
T+ : 1678 (1) [6] {2}
T- : 1675, 1679, 1685, 1686, 1687, 1689, 1692, 1695, 1696, 1698
(10) [56] {24}
H+ : 1675, 1679, 1681, 1687, 1689, 1692, 1694, 1698 (8) [44] {20}
H- : 1676, 1678, 1683, 1684, 1685, 1686, 1695, 1697 (8) [44] {20}
T±0: 1676, 1677, 1681, 1683, 1684, 1693, 1694 (7) [39]
H±0: 1677, 1693 (2) [11]

Autumn (thermal information=18 years; hygric information=12 years):

T+ : (0) [0] {0}
T- : 1675, 1676, 1677, 1679, 1683, 1684, 1685, 1687, 1692, 1694,
1695, 1696, 1697, 1698, 1713 (15) [83] {37}
H+ : 1675, 1679, 1694 (3) [25] {7}
H- : 1676, 1677, 1683, 1685, 1686, 1687, 1689 (7) [58] {17}
T±0: 1681, 1689, 1693 (3) [17]
H±0: 1681, 1693 (2) [17]

() = *number of documented years*
[] = percentage of documented years
{} = percentage of documented years based on the assumtion of their thermal and moisture "normality" where no information is available (including "0" = average years)

Fig. 4: Different winter temperature indices from modern instrumental readings at Karlsruhe.



2.2. Weather diaries

As earlier mentioned, for systematic reasons weather diaries have to be treated as a type of sources of its own (CHERNAVSKAYA 1994, MUNZAR 1995). As a rule they cover a few years only, with some exceptions, such as the diary by Hermann IV Landgraf of Hessen which comprises 30 years of systematic observations. The weather records in general refer to selected climatic elements or weather phenomena, such as the aspect of the sky, temperature or precipitation .

Although there may be inaccuraries for which the observer is responsible, such weather diaries are reliable enough to permit frequency counts, as to the days with snowfall. This information compared with modern data of the previously defined standard periods, so that deviations are easily recognizable, will allow conclusions as to their climatic nature. This procedure is called descriptive statistical analysis. As for physical reasons individual climatic elements and weather phenomena are closely related, their interrelationships can be determined by correlation procedures and be described by regression analysis. Under certain conditions even the synoptic conclusions may be drawn (cf. DEUTSCH, GLASER & GUDD 1996). As the methods and their information potential are the same for the visual observations accompanying the early instrument readings, examples referring to both of them will be given further below.

2.3. Data recorded by meteorological instruments

In addition to numerous descriptive weather records there is also a host of early instrument readings available from the central European region (RUDLOFF 1967, MANLEY 1974, DEMARRE, VAN ENGELEN & GEURTS 1994). Most of these old and long-period records have already been studied, e.g. the records by Reyxer, Kiel, of which only parts have been preserved; the weather observations by Camerarius, Tubingen, from 1691 to 1694, those by Allgöwer at Ulm from 1710 to 1714, or the recordings taken by the Kirch family at Berlin and Leipzig/Guben from 1683 to 1774. These data have been interpreted, among others, by HELLMANN (1893), GREBE (1936), FLOHN (1949), LENKE (1961, 1962, 1964) or BRUMME (1981). In addition there is a number of publications related to a few extreme years, such as the severe winter of 1708/09, compiling data from all over Europe. In addition to these data series we have translated and interpreted Leibniz's diary taken at Hannover from 1677 to 1678 as well at Hoffmann's at Halle for the year 1700.

The problems related to the interpretation of these data are well-known. There is the problem of uncalibrated instruments, of irregular recording hours or of mistakes in positioning the instruments. Awareness of these possible sources of error is a prerequisite for any attempt at absolute calibration, but frequently the necessary information is sadly lacking.

In spite of these drawbacks the data, often including several entries per day, are most valuable. They are directly available as numbers and thereby lend themselves to advanced statistical analysis. Necessarily there is a multitude of possible approaches, due to the fact that only few of these diaries can be compared to each other, so that specific solutions must be found for each case. These major traits of the climatic interpretation of this type of data taken together make evident some general principles:

In each of the studies frequency counts of selected meteorological and climatological elements have been found useful. Comparing the tabular data arrived at to the modern data from the official standard periods will lead to tentative meaningful interpretations. In order to stay within the framework of this paper, again only a few examples from the Allgöwer weather recordings will be presented.

They permitted frequency analysis of a number of elements listed in Table 2. It is the advantage of this procedure that it is applicable to almost any data of this type, and that they allow the comparison with modern data. Of course other procedures, such as the frequency distribution by LENKE (1961) or the approach used by FLOHN (1949) or BRUMME (1981) of establishing regressions between winter means and days with snowfall as the percentage of total precipitation days are equally suitable for absolute calibration.

To serve as an example, the parameters „days with precipitation" and „days with snowfall" taken from the Camerarius (Tübingen) and Hoffmann (Halle) data were compared to the data of the official recording period 1889-1930 (Table 3). The resulting figures denote the deviation of each year from this longterm average. This compilation gives a first numerical indication of the year by year variation of precipitation. Especially the drier seasons show well when the data are regarded together with the descriptive records for those years. The comparison of days with snowfall to the numbers contained in the longterm average adds an estimate of winter severity to the hygric component. Again the data can be improved by incorporating the descriptive records. In addition to hygric and thermal parameters the weather diaries frequently also contain information on wind direction. The following example is a compilation from the Allgöwer manuscript.

The compilation of wind direction data - easy to be determined even by rather untrained observers - is of much use, especially with respect to the analysis of weather dynamics. The methods outlined here can practically be applied to all diaries, thereby yielding valuable information on major climatic elements. LENKE, working with the Allgöwer data, arrived at an absolute calibration by means of frequency analysis. The presentation given in Figure 5 has been filtered for easier visualization. These few examples may suffice to indicate the potential contained in these weather records for climatic interpretation. Assuming a linear snowfall/temperature relationship for winter and a linear temperature/precipitation days relationship for summer,

Tab. 3: Devitation of the number of days with precipitation from the longterm avarage of days with rainfall > 1 mm (1889 -1930).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Leibniz at Hannover												
	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1677								(1)	(-4,9)		(-6)	(-3,8)
1678			(-7)	3,6	1,2	-3						
Kirch at Leipzig												
	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1682												-5,1
1683	(-5,6	-0,5)	-5,7	7	-3,1	0,6	4,6	8,8	0,6	3,6	3,2	-0,1
1684	0,4	3,5	10,3	-2	-1,1	-3,4	-3,4	-2,2	4,6	-1,4	3,2	0,9
1685	3,4	-2,5	5,3	0	-0,1	2,6	9,6	3,8	1,6	-4,4	0,2	-1,1
1686	-0,6	-0,5	-2,7	0	5,9	2,6	2,6	2,8	1,6	-0,4	-0,8	-0,1
1687	0,4	2,5	10,3	10	-2,1	1,6	2,6	0,8	5,6	0,6	3,2	7,9
Arnold at Sommerfeld nearby Leipzig												
	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1688	-3,6	-4,5	1,3	3	4,9	1,6	1,6	-3,2	0,6	6,6	1,2	-4,1
1689	-2,6	5,5	10,3	2	4,9	1,6	-2,4	-2,2	0,6	4,6	5,2	-3,1
1690	2,4	-2,5	-4,7	2	2,9	-4,4	2,6	4,8	4,6	10,6	-1,8	3,9
1691	-5,6	2,5	-2,7	-8	1,9	8,6	-2,4	0,8	-0,4	-1,4	-3,8	-3,1
1692	-0,6	3,5	1,3	4	-0,1	6,6	6,6	4,8	1,6	5,6	4,2	-0,1
1693	7,4	3,5	10,3	6	6,9	2,6	0,6	0,8	11,6	8,6	6,2	4,9

Tab. 3: continued.

Camerarius at Tübingen

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1691	-	-	-	-	-	-	-3,4	-7,7	-3,5	-5,5	0	-4,9
1692	1,9	8,3	6,6	3	0,6	3,5	4,6	0,3	3,5	-2,5	0	-0,9
1693	3,9	1,3	11,6	5	4,6	3,5	1,6	-5,7	3,5	3,5	10	7,1
1694	3,9	0,3	6,6	-2	-1,4	1,5	-	-	-	-	-	-

Kirch at Guben (Station Cottbus)

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1697	-3,6	-3,1	-1,5	0,6	-1,0	-3,2						

Hoffmann at Halle

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1700	10	-1,8	-2,8	5,4	-1,4	-1,9	-4,1	2,4	-1,8	4,2	5,8	4,3

Allgöwer at Ulm

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1710	-	-	-	-	-	-	-	-	-	3,8	-3,3	-2,9
1711	3,3	6,6	8,3	5,4	4,9	-5	3,2	8,3	1,4	5,8	6,7	0,1
1712	-1,7	7,6	3,3	9,4	2,9	-2	4,2	1,3	1,4	3,8	8,7	4,1
1713	-0,7	4,6	3,3	6,4	2,9	2	7,2	2,3	2,6	7,8	3,7	-2,9
1714	-7,7	1,6	-	-	-	-	-	-	-	-	-	-
1715	-	-	-	-0,6	-2,1	0	2,2	3,3	-0,6	0,8	-1,3	-0,9

()= Data uncomplete or insecure

Tab. 4: Devitation of the number of days with snowfall from the longterm avarage of total days with snowfall (1889 -1930).

Kirch at Leipzig

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1682	-	-	-	-	-	-	-	-	-	-	-	-1,7
1683	-4,7	-0,8	-3,9	-0,9	-0,3	0	0	0	0	-0,3	-1,5	1,3
1684	2,3	2,2	7,1	0,1	-0,3	0	0	0	0	-0,3	2,5	2,3
1685	3,3	-4,8	3,1	0,1	-0,3	0	0	0	0	-0,3	2,5	-3,7
1686	-7,7	-1,8	-1,9	0,1	-0,3	0	0	0	0	-0,3	2,5	-3,7
1687	2,3	-0,8	3,1	7,1	-0,3	0	0	0	0	-0,3	-2,5	2,3

Arnold at Sommerfeld nearby Leipzig

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1688	-1,7	-4,8	-1,9	0	0	0	0	0	0	2,7	2,5	-1,7
1689	-0,7	-3,8	4,1	-0,9	0	0	0	0	0	0,7	2,5	-0,7
1690	-1,7	-4,8	-1,9	0,1	0	0	0	0	0	0	-1,5	4,3
1691	-3,7	-3,8	-3,9	0,1	0	0	0	0	0	0	-1,5	-1,7
1692	0,3	3,2	-0,9	-0,9	0	0	0	0	0	1,7	2,5	-4,7
1693	0,3	0,2	8,1	0	0,7	0	0	0	0	3,7	4,5	3,3

Tab. 4: continued.

Camerarius at Tübingen

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1691	-	-	-	-	-	-	0	0	0	0,8	3,3	-0,4
1692	4,1	6,8	1,4	-1,4	-0,1	0	0	0	0	2,8	3,3	-1,4
1693	1,1	-1,2	6,4	-1,4	0,9	0	0	0	0	3,8	10,3	9,6
1694	6,1	-0,2	0,4	-0,4	-0,1	0	-	-	-	-	-	-

Kirch at Guben

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1697	-3,5	-2,3	-2,7	3,2	-0,2	-	-	-	-	-	-	-

Hoffmann at Halle

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1700	1,6	-1,6	-2	-2,4	-0,3	0	0	0	0	-0,4	0,9	-0,2

Allgöwer at Ulm

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
1710	-	-	-	-	-	-	-	-	-	0,6	-1,6	-4,6
1711	1,3	3	2,3	-1,6	-0,3	0	0	0	0	-0,4	-0,6	-0,6
1712	-2,7	4	4,3	0,4	-0,3	0	0	0	0	-0,4	2,4	-0,6
1713	0,7	-3	-1,7	5,4	-0,3	0	1	0	0	-0,4	6,4	-2,6
1714	-6,7	-2	-	-	-	-	-	-	-	-	-	-

Tab. 5: Percnet frequency of wind directions at Ulm 1712.

	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	C
Jan																	
Feb																	
Mar	-	-	7	-	12	6	44	-	6	-	7	12	-	6	-	-	-
Apr	3	3	12	11	15	7	23	-	5	-	6	11	-	3	-	1	-
Mai	-	4	2	15	8	6	18	4	-	8	25	6	-	2	-	2	-
Jun	2	2	-	25	14	19	-	2	4	8	9	8	7	-	-	-	-
Jul	-	-	5	23	38	13	11	-	4	2	1	1	2	-	-	1	-
Aug	2	-	5	13	43	11	12	-	-	2	5	2	2	2	-	-	2
Sep	-	6	3	14	41	14	-	-	-	-	11	5	-	-	3	-	3
Okt	6	3	13	13	31	8	7	-	2	2	8	-	5	-	-	-	2
Nov	-	2	6	23	39	6	-	-	-	-	18	4	-	-	-	2	-
Dec	-	2	2	30	18	14	12	-	8	2	6	4	-	-	-	-	2
Year	***2***	***2***	***6***	***17***	***26***	***11***	***11***	***1***	***2***	***2***	***10***	***5***	***2***	***1***	***1***	***1***	***1***

Tab. 6: Monthly and annual means of temperature (degrees Celsius) for Berlin 1700 - 1710.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1700	-	-	-	-	-	-	-	(14,9)	-	-	-	0,6
1701	-4,2	-1,5	1,6	-	-	(15,4)	(18,9)	(15,8)	-	-	-	-0,5
1702	2,0	-0,5	0,6	2,6	(10,9)	16,0	16,0	15,8	(10,1)	(7,5)	(0,2)	0,6
1703	-2,8	-0,9	0,6	7,7	14,1	16,1	15,4	16,3	11,4	6,1	2,2	2,5
1704	-4,9	-0,5	3,9	9,4	11,8	14,1	17,1	-	-	-	-	(-0,9)
1705	(-7,1)	-	(1,0)	-	-	(16,0)	(18,3)	17,8	(8,7)	7,5	0,7	1,8
1706	-3,4	-2,8	0,4	6,3	(11,6)	17,4	16,5	14,9	11,2	8,2	1,4	1,8
1707	-2,3	1,0	0,6	4,6	10,9	17,2	17,2	15,0	11,4	4,4	1,6	0,6
1708	1,4	-0,7	3,9	(6,1)	10,7	13,9	12,1	17,1	12,8	1,4	0,0	-4,6
1709	-13,2	-6,9	0,2	9,7	10,2	18,0	15,8	15,4	10,7	6,7	2,9	0,6
1710	-3,0	-1,7	3,1	-	(12,9)	-	-	-	-	-	-	-

()= data uncomplete or insecure

Source: BRUMME (1981)

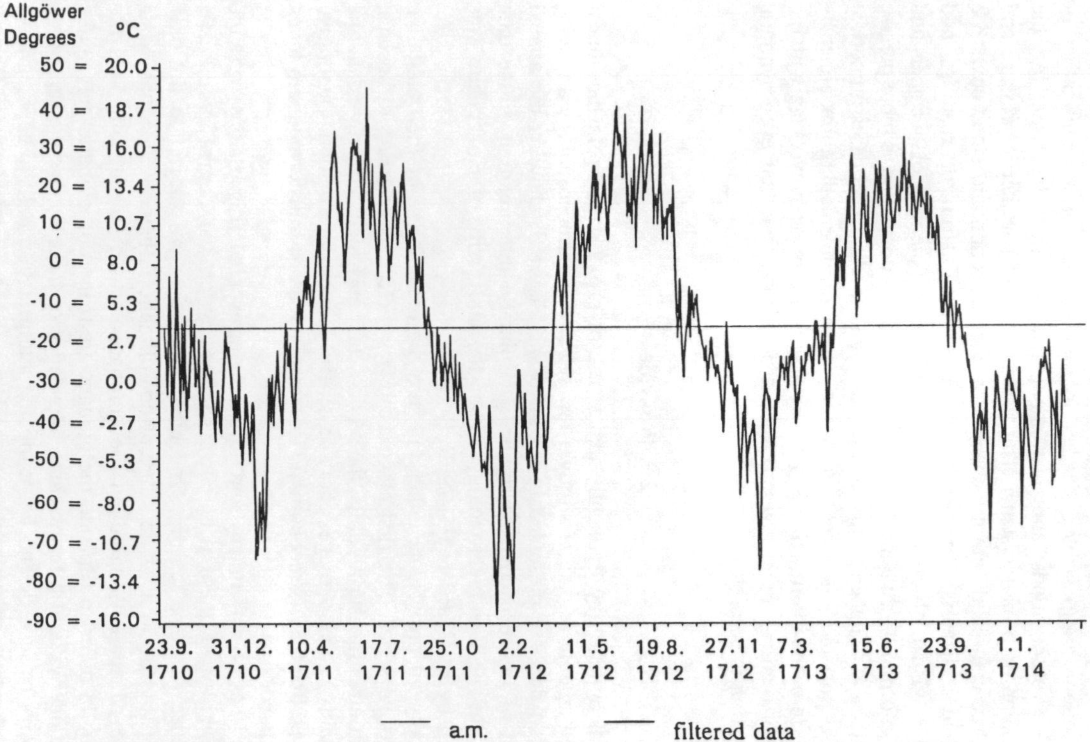


Fig. 5: Temperature variations at Ulm 1710 - 1714. Source: LENKE (1964).

BRUMME, by making use of the Kirch data, arrived at the following temperature data for Berlin (Table 6):

In this way, although still subject to unavoidable uncertainties, absolute quantifications are possible. Weather journals containing a combination of descriptive observations and instrument readings may be used for the identification of frontal systems. The rise and fall of barometric pressure and temperature combined with the changes in wind direction and cloud cover are very good indicators. To sum it up, historical instrument readings and systematic visual observations possess a higher potential of weather and climate information than the first class of data. The information is more precise and is given at a higher temporal resolution, and in almost all cases numerical analysis is possible. There are two approaches to absolute calibration, either by making use of the interrelationship of climatic elements, or by working with the instrument readings themselves. It should be emphasized that even synoptic interpretation is possible.

2.3. Proxy data

Historical climatology frequently makes use of proxy data. From the almost unlimited amount of data sets only a few selected dendrochronology and wine production data are presented in Figure 6 and Figure 7, showing the annual variation of the respective parameters. A climatic interpretation of the data obtained at the dendrochronology lab of the University of Hohenheim was published by BECKER & GLASER 1991.

Basically all proxy data either fall into the quantitative or the qualitative class of time series. The first class comprises yield lists referring to bushels, barrels or other measuring units, the second class may include relative data like wine quality (good, average, poor) or general harvest information. Qualitative sequences, like the indirect climatic information, can be transformed into index series.

There has been much and often controversial discussions on the interpretability of these data, always centering on the degree of climatic dependence of these sensors. Undoubtedly the data are subject to not only climatic, but also to a whole range of non-climatic influences. For many data elaborate calculations based on the comparison with current situations are necessary in order to separate the climatic from the non-climatic part of the information. Without a far-reaching knowledge of these factors the separation will always be insufficient. For a reliable interpretation holistic or integrative approaches must be undertaken involving a lot of historical study. Harvest yields, for instance, have to be rated in the context of soil and landform conditions, of techniques employed for planting, fertilizing or harvesting. The present-time models necessary for interpretation range from simple correlations to multiple procedures such as factorial analysis (cf. LAUER &

Fig. 6: **Variations of wine prices (A), quality (B) and quantity (C) at Kitzingen, Franconia, 1500- 1650.**

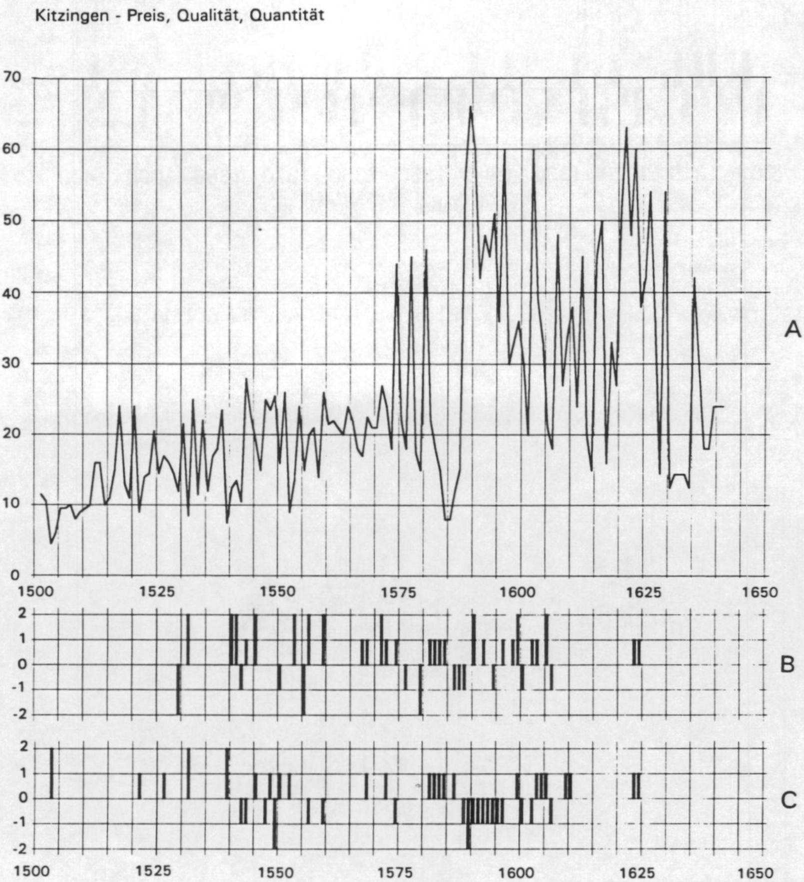
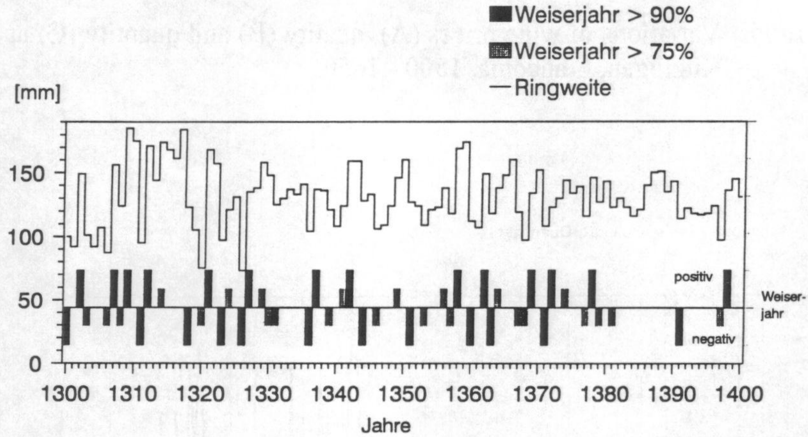
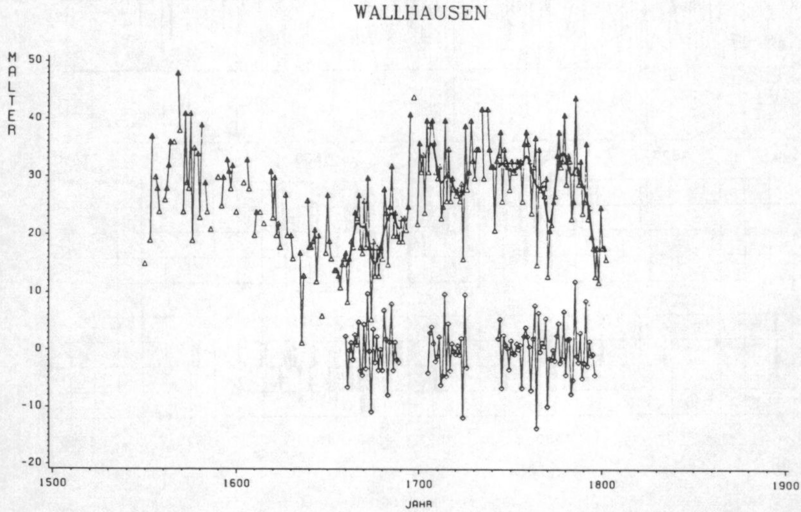


Fig. 7: Variations of oak tree-ring width in Franconia 1300 - 1400.



line = ring width in mm,
long black columns = pointer years on the 95% level,
short gray columns = pointer years on the 75% level.
Source: Dendrolabor, University of Hohenheim, pers. com. B. BECKER & J. HOFMANN.

Fig. 8: The development of taxed rye yields at Wallhausen (near Miltenberg).



The original data (triangles) have been passed through a Gaussian low-pass filter (upper curve) in order to emphasize the long-term non-climatic part of the information. The lower curve (rhombs) represents the corresponding high-pass filtered values regarded as the part primarily influenced by the climatic course of the year.

FRANKENBERG 1986), yet the results of which are difficult to interpret. Similarly complicated is the use of response functions, when climatic information is to be extracted from tree ring data or phenological time series (BIRRONG & SCHÖNWIESE 1987).

These approaches work well in simply structured climatic regions, but they are likely to fail in the complicated temperate climate regions. A model set up for the interpretation of tree ring width in the Würzburg area, for instance, revealed that there are five different seasonal climate constellations that mainly affect tree-ring development in different ways. This result is typical for all tree-ring series of central Europe, with the exception of extreme growth conditions such as those close to the tree-line.

The treatment of yield information is similarly complex. To that end filtering techniques were developed that separate the yield curves into a high and a low frequency part, thereby approximately allowing to separate the socio-cultural and other non-climatic influences from the short-term weather-dependent yield variations (Figure 8)[1].

The physical proxy data too are not free of noise. Flood marks to be used for hydrological interpretation, for instance, have to be scrutinized in various ways: were they engraved in the correct position in the first place, or have they been dislocated in later times? It also should be asked wether and to what extent the surroundings have been changed in ways affecting the water-retention capacity of the landscape. Only if these questions are answered the long historical records can be made use of for applied purposes such as flood probability. Flood marks are probably the most impressive and most easily understood indicators of former environmental catastrophies, especially those recording the events of summer 1342, January 1682 or February 1784 that affected abnost all large central European drainage basins (GLASER & HAGEDORN 1990).

These remarks can only hint at the wide range of suitable proxy data. Similarly there is also a wide range of methods to be applied to extract the climatic information. In spite of the limitations inherent in this type of data there are a number of points that speak in favour of their use: there is an almost complete areal coverage, the data are relatively easy to collect, and they are available in measurable units convertible to modern units such as days, metres, kilograms or Oechsle degrees. Therefore they also lend themselves to a complex statistical treatment. Experience has shown that they also allow the extraction of information at the seasonal scale. Spruce-tree growth signatures, for instance, allow conclusions as to summer precipitation, whereas the freezing of rivers and lakes most obviously reflects winter temperature conditions. Another important point that should not be underestimated is that

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[1] **The original data (triangles) have been passed through a Gaussian low-pass filter (upper curve) in order to emphasize the long-term non-climatic part of the information. The lower curve (rhombs) represents the corresponding high-pass filtered values regarded as the part primarily influenced by the climatic course of the year.**

these data can be verified by viewing them together with the descriptive information. The independently established time series can mutually help improve the interpretation of each of them.

In addition to the written sources pictorial presentations may also yield climatic information, such as pictures of glaciers at a specific stage of advance or retreat or the freezing of rivers and lakes depicted in the Dutch paintings of the „Little Ice Age".

3. Development and structure of the Historical Climatic Data Bank „HISKLID"

At a certain size the data sets used for quantitative and regional historical climatological analysis can only meaningfully be handled by means of electronic data processing. To that end a large amount of sources has been compiled in a data bank developed for this purpose. It has been designed for a clear structuring of the source information collected, for a high degree of differentiation, and for comprehensive coding. In order to facilitate the communication with other working groups the data bank was set up using widely-spread PC software components and the Statistical Analysis System SAS (SAS Institute Corp.) available at the University of Würzburg computing center. Part of the texts compiled in this data bank have also been made accessible in print as vol. 2 of „Materialien zur Erforschung früher Umwelten" (MEFU 2; GLASER & MILITZER 1993). The data bank is by now fully operational, so that two working groups at Halle and Leipzig could be incorporated in the system.

All the numerical and descriptive data sets on historical climatology collected so far have been processed and compiled in this data bank which is still growing. Extensive use of it was made for the writing of this paper. The data are verified using standardized procedures of critical source analysis and then encoded. In order to make the data accessible and useful for a large user community access is not only given to the standardized and encoded data, but also to the original text quotes used. This procedure has the advantage that the generalization inherent in the encoding can be traced back in each case, and that the phobia against „number crunching" often keeping people from working with data bases made up of nothing but columns of letters and numbers is avoided in the first place (see Excerpt from HISKLID).

3.1. The transformation of source information into data points

The complex structure and variability of the sources and data used calls for a wide range of methods of bringing them into a useful form. The linking of different data types has been proved to be very effective. In the ideal case

Excerpt from HISKLID

1513	02	19 21		18500-79			160807	
1513	02	23		18500-79		00	00	

* Am 19. Februar fiel wegen ... eine große Menge Schnee bei stürmischen Westsüdwestwind, was bis zum 21 Februar dauerte.
Am 23. Februar hat, weil ..., die Kälte nachgelassen und es gab eine große und enorme Stille der Luft an diesem Tag. *

1513	03	01		18500-79			0603	
1513	03	03		18500-79		+1	15	
1513	03	04		18500-79		-130	230503	

* Am 1. März wehte ein starker Ostwind wegen der Vereinigung von Sonne und Mercur. Denn der Mercur reißt den Osten an sich.
Am 3. März fiel mittelmäßig Schnee, die Luft war durch eine milde Wärme genügend temperiert, ich glaube nämlich, daß ...
Am 4. März gab es kalte Luft peristasis unter Ostwind und Eis und Schnee wurden flüssig; ... *

1513	03	07 15		18500-79			00 02	
1513	03	15 18		18500-79			00 04	

* Am 7. März gab es heiteres und ruhiges Wetter, ... Das dauerte bis zum 15. März. Daraufhin bis zum 18. März war es bewölkt, trotzdem ruhig, und es fiel kein Regen. *

1513	03	18 21		18500-79			02	
1513	03	21 23		18500-79		-2		
1513	03	23 28		18500-79		-2	050102	

* Am 18. März ... fing es an, heiter zu sein, was bis zum 21. März dauerte, an dem eine halbe Stunde nach Mittag Vollmond war; die aeris peristasis dauerte die folgenden zwei Tage, und darauf war es fünf Tage heiter, wenngleich ein eisiger Nordwind wehte und es daher sehr kaltes aere peristasis war. *

1513	03	27		18500-79		-140	00	
1513	03	27	30	18500-79			05	
1513	03	28	25 27	18500-79			050606	
1513	03	28	27 29	18500-79			02	
1513	03	29		18500-79		-208	040102	
1513	03	29	25	18500-79		40	15	

* Am 27. März war ..., da gab es eine leichte Kälte (Frost?) und ruhiges Wetter, aber in der Nacht folgte ein Regenguß (Unwetter?).
Am 28. März erzeugte ... einen heftigen Westsüdwestwind, und es gab einen Regenguß, von Mittag aber bis zum Abend oder Sonnenuntergang war es heiter.
Am 29. März wegen ... gab es eine große Kälte und am Morgen fiel eiskalter Schnee und es gab Eis und die Gewässer waren zugefroren. ... diese Kälte dauerte beinahe den ganzen Tag bei einem mäßig wehenden Nordwind. *

1513	04			DR-12-69	DR-12-71	42	15	01

* Schneefall und Spätfrost im April, Reben erfroren. *

1513	04	01		18500-79		-1	030102	
1513	04	03		18500-79		-1	030102	
1513	04	05		18500-79		-1	030102	
1513	04	16		18500-79		00	070705	
1513	04	16	29	18500-79			05	

* Am 1. April ..., am 3. April ..., am 5. April ... An keinem dieser Tage ist jedoch eine erwähnenswerte Wetterveränderung eingetreten, es blieb durchgehend heiter und manchmal wehte ein leichter, kalter Nordwind, der eine aeris peristasim erzeugte.

descriptive source information that is hardly suitable for quantification can be combined with numerical information for the same period. In order to come to understand the complex path from data acquisition to treatment and encoding, all the steps are to be presented in this chapter as a case study from the source to the final deposition of the data in the data bank (cf. GLASER & MILITZER 1993).

As already mentioned, only original sources and quotations are to be included. In the course of lengthy archive work it appeared, however, that document loss in archives is very high. Therefore recourse had to be taken to secondary sources, if their contents were confirmed by original data found at a later date. One test for the reliability of secondary sources is their structure, such as a word-by-word transscription from the original sources including their characteristic stylistic and semantic irregularities which suggest a high degree of authenticity. In order to reduce the degree of uncertainty or to avoid overinterpretation, the value of each source is rated with an index next to the bibliographical description. In the course of further data acquisition secondary sources like that may then be upgraded or excluded from further analysis. The text sources are recorded in the main data file in the following way:

Structure of a source file:

|1. Source code |
|2. Bibliographical description |
|3. [Index or indices of source quality; 4. Dating system used] |

The descriptive data are written into a word processing file in their original language and spelling, following the general rules of source editing. Their encoding is done in a header line comprising 19 information segments as presented in the data mask below. The information segments can be separated from each other and can thus be transferred without any problem to other, also to less powerful databank systems. The verbal information in data field 20 remains with the text file: They can be called up at any time by using the respective code. Layout of a data file.

```
1    ¦2    ¦3  ¦4  ¦5  ¦6  ¦7  ¦8  ¦9        ¦10       ¦
xxxxx¦xxxxx¦xxx¦xxx¦xxx¦xxx¦xxx¦xxx¦xxxxx-xxx¦xxxxx-xxx¦

11  ¦12  ¦13  ¦14  ¦15¦16    ¦17   ¦18¦19   ¦20
xxxx¦xxxx¦xxxx¦xxxx¦xx¦xxxxxx¦xxxxx¦xx¦xxxxx¦*text*
```

1-20 data field number
x = maximum available digits per field
| = limit of a data field (not entered during encoding)
data in the given field are insecure
* starts and finishes source text in the word processing mode
<> includes additional information in the word processing mode

[] Expalantions, comments, datations
- mandatory entry in the code column

Quicklook of the data field numbers and their content

Field 1: year (number of years) = 1-5
Field 2: until year (entry for periods only) = 6-10
Field 3:month or season (number of months) = 11-13
Field 4: until month (entry for periods only) = 14-16
Field 5: day, decade or pentade (number of days) = 17-19
Field 6: until day, decade or pentade (entry for periods only) = 20 -22
Field 7: hour (number of hours) = 23-25
Field 8: until hour (entry for periods only) = 26-28
Field 9: source code = 29-31
Field 10: place of observation (entry only when not identical with source code) = 38-46
Field 11: temperature
11.1 = general information: 47-48
11.2 = special information: 49-.50
Field 12: precipitation
12.1 = general information: 51-52
12.2 = special information: 53-54
Field 13: Wind by force and direction
13.1 = force of wind: 55-56
13.2 = direction of wind: 57-58
Field 14: state of the sky
14.1. = could cover : 59-60
14.2 = sky phenomena: 61-62
Field 15: natural events = 63-64
Field 16: empty
Field 17: phenology
17.1 = object 71-72
17.2 = phase/event: 73-75
Field 18: effect on people = 76-77
Field 19: prices = 78-82

Field 20: text quotation, started and finished with * .

Field entries

Field 1: year (for periods: from year): 1-5
Field 2: until year (entry for periods only) 6-10
Field 3: month (01-12) or season of the year referred to in the preceding fields (for periods: from month resp. season): 11-13
winter = 13 (December to February; Winter 1500 = December 1499 to February 1500!)
spring =1 4 (March to May)

summer = 15 (June to August)
autumn = 16 (September to November)

In cases different contemporary views of seasonality are taken down.
Field 4: until months (entry for periods only): 14-16
Field 5: day, decade or pentade or undetermined monthly datum of the month listed in the preceding field (for
periods: from day or decade or pentade): 17-19

1. pentade = 32	1. decade = 38
2. pentade = 33	2. deacde = 39
3. pentade = 34	3. decade = 40
4. pentade = 35	beginning = 41
5. pentade = 36	middle = 42
6. pentade = 37	end = 43

Field 6: until day, decade or pentade (entry for periods only): 20-22
Field 7: hour or undetermined part of a day (for periods: from hour): 23-25
Field 8: until hour (for periods only) 26-28
.... morning = 25
.... before noon = 26
.... noon = 27
.... afternoon = 28
.... evening = 29
.... night = 30

Field 9: source code variant 1 (= place of observation): 29-37
Field 10: Code for place of observation; entry only when not identical with source code: 38-46

For the German territories the working group created an alphanumerical system based on the former postal code system, by which the climatic information can be grouped and called up in clearly defined spatial segments with a variable resolution. Both the present and the historical names of states, regions, landscapes and places are considered. Historical territories are encoded in relation to the position of the territories within the present states of Germany.

Examples for the encoding of place-names at various levels of resolution:

1st level:	DR-00-00	Deutschland - D
2nd level:	DR-xx-00	present federal states without city states
Example:	DR-07-00	Hessen (German federal state)
3rd level:	DR-07-xx	any region or territory in Hessen
Ex.:	DR-07-01	Rheingau (a region in Hessen)
4th level:	0xxxx-xx	places former East Germany
	lxxxx-xx	places former West Germany
Ex.:	16000-00	Frankfurt/Main (city in Hessen)
Ex.:	05300-00	Weimar (town in former East Germany)

For the other European countries at present only a low resolution raster is available (AR/AO). Future adaptation as needed.

Ex.:		
1st level:	Ar-OO-00	Europe, EU (excl. Germany)
2nd level:	AR-xx-00	European states
Ex.:	AR-01-00	Poland - PL
3rd level:	AR-02-xx	regions, territories within the respective country
Ex.:	AR-02-01	Bohemia
4th level:	AO-02-xx	places within the respective country
Ex.:	A=-02-01	Prague

DR = Germany, German territories, regions and landscapes
AR = Europe excluding Germany, European countries, territories, regions and landscapes
AO = places of the respective country
xx = fields with numerical entries
Field 11: temperature
Field 11.1: General information: 47-48

+3 Summer : hot, self-combustion of forests, emergency slaughtering, sanitary restrictions, entries such as „such a hot summer as nobody had experienced before", „eggs could be boiled in the sand", exceptionally hot summer".

Winter: unusually mild (perhaps supported by phenological observations such as flowering of trees in January, extremely early tilling etc.), entries such as „such a warm winter, no frost or snow, so that all the animals could graze in the pastures all the time".

+2 Summer : hot, very warm, very mild, excellent weather, very good weather winter season: mostly mild to very mild; warm winter in relation to early vegetation growth

In summer clear evidence of dryness, scarcity of rain, crops negatively affected by heat; perhaps indicators as in +3, but of shorter duration: „it has been very hot", „very good time".

+1 warm, sultry, mild air, good weather, warm water, good weather
Winter : partly mild, no frost
Summer : the very best summer, warm summer

0 = normal; not especially referred to in homogenous data sources; Winter tendency towards frost, barely cold, somewhat cold

-1 Summer cool, unpleasant, frequent rains, poor wine harvest, reduced harvest, poor weather, unfruitful year, strong frost

Winter clearly cold, average frost, some frost, rather frosty, hoarfrost, cold, frequent snowfalls, wells partly frozen over, watermills partly blocked by frost, drift ice at the coast

-2 Summer (and spring): cold, unusually long rainy periods in summer, cold northerly winds, poor wine harvest (sour wine), generally poor harvest, cold, unfruitful, as cold as in winter

Winter very cold, hard winter, biting frost, long-lasting frost, seam of ice along the coast, very constant winter

Spring very cold, cattle could not be put in the pastures before Mayday, late vegetation growth

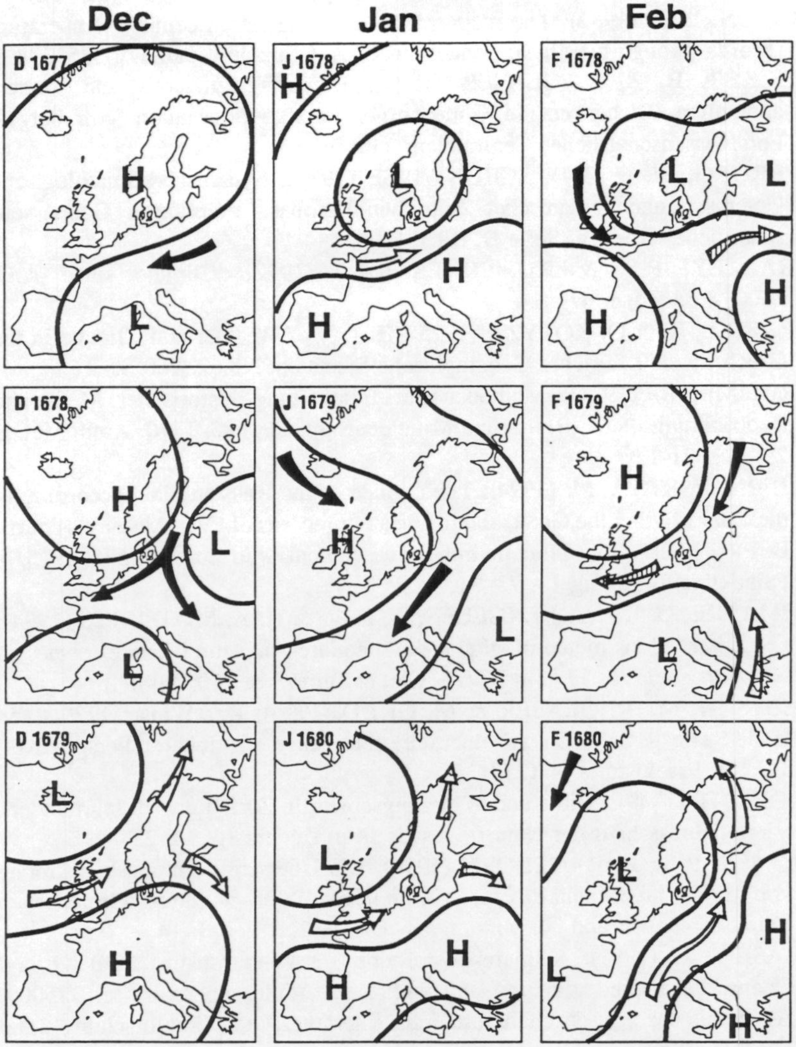
-3 unusually cold, very sharp frost in winter, very cold, people and cattle frozen to death, lasting ice-cover of lakes and rivers, coast covered with ice all over, trees show frost-cracking, food supply crisis, administrative measures to combat crisis, mill operations stopped, wild animals in the settlements.
In winter too cold a winter, bitter cold, long-lasting winter as nobody can remember, birds freeze in the air.
In summer no wine harvest, rotting hay, crops ripening too late with food crisis, extremely long-lasting cloud cover.

4. Final Remarks

The article summarizes the different data and methods in historical climatology in order to arrive at climatic information. Varying procedures are presented and discussed as critical evaluation of sources, semantic profiles, derivation of indices, calibrations by means of regression analysis, comparisons with present-day standard data sets, quantification, regionalization and data pooling.

In recent years - due to an intensified international cooperation - progress has been made in the field of synoptic interpretation (Figure 9). It was possible to derive from the complex data sets monthly - or for specific periods - daily weather maps. Another approach succeeded with the definition of modern analogues for historic weather situations (GLASER & GUDD 1996). With such results it is now possible to connect historical climatology with modern computer based complex models and dynamic interpretation (f.e. JACOBEIT 1993, 1994). Questions concerning global warming and/or dynamic changes are expected to be discussed in another time-window and within another climatological frame. First efforts are in progress within international projects like ADVICE. For the next few years we can expect a new dimension in climatology. In the field of social science we can offer detailed climatic information, which could be used for better interpretation of climatic effects and their impact on human society and economy.

Fig. 9: Synoptic interpretation of monthly weather maps for the wintertime 1677 - 1679.



White arrows: Warm air advection. Hatched arrows: Moderate air advection. Black arrows: Cold air advection

Source: WANNER et al. 1994.

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