CHAPTER 2

WEATHER, CLIMATE, AND THE ENVIRONMENT

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What is Environmental History?

Environmental history is currently 'one of the most productive and innovative fields of historical research'.[1] A child of the ecological movement in the 1970s, it grew with the expansion of public awareness and practice of environmental issues. Whereas in 1985 an overview of the field could still have been obtained within a single summer, two decades later more than a hundred summers would have been needed.[2] Though the first attempt to establish a European Society for Environmental History (ESEH) on the model of the American Society for Environmental History (ASEH) in the United States failed in 1989, a second initiative in 2001 was successful. Other umbrella associations were created at a regional level during subsequent years, and in 2009, they were integrated into an International Consortium of Environmental History Organizations (ICEHO) to foster communication on a global level.

In general terms, environmental history investigates the interactions between man's natural environment and human societies on the basis of anthropogenic sources (those created by human activity). In this respect environmental historians need to take account of the work of natural scientists, who have the same objective but make use of different evidence. It is only since the 1970s that social scientists and historians have recognized that natural events could either cause or result from human actions. The fundamental change involved is evident from Wolfram Siemann's argument that, from a twenty-first century perspective, the environment needs to be regarded as a fourth fundamental category of human history, on an equal level with governance, economy, and culture. Indeed, every human action depends on biological preconditions, while control over crucial natural resources such as water, productive land, and energy is essential for the exercise of power. In a similar way, strong interconnections are recognized to exist between the environment, the economy, and culture.[3] There is hardly any subject that cannot be investigated from an environmental perspective, though the field still lacks a clear thematic and methodical profile.[4] Most studies explore the ways in which local people dealt with environmental problems over a small number of years. There are, however, important exceptions. Some surveys such as Joachim Radkau's *Nature and Power*[5] are global in scope. Others, such as Ian Simmon's *Environmental History of Great Britain*[6] stretch back in time over the last 10,000 years. John L. Brooke is the first environmental historian to draw a global picture of the material history of humankind in relationship with climate and earth history and even over the long geological period from the Palaeolithic to present. But, of course, he is not able to get close enough to grasp the meaning of events for historical agents.[7] The economic historian. Reinhold Reith has written the first environmental history of early modern central Europe.[8] A recent concise volume of essays edited by the same author provides a useful survey over the many facets of environmental history.[9]

This present chapter first examines current knowledge about environmental history. It then surveys how weather and climate have been and are being studied. Finally, the results of this research are assessed.

Agrarian Societies and their Environments

Most environments in early modern Europe—with the exception of remote forests, swamps, and high mountain areas—were modified in such a way that human labour had effectively eliminated the natural variety of habitats or areas of previously uniform environmental conditions (known as 'biotopes') in favour of a small number of crops, mainly cereals which were 'artificial bio-converters produced and reproduced by humans'.[10] Keeping and breeding livestock fed on grass, acorns, leaves, and so on, and then slaughtering them for meat, allowed humans to consume biomass (organic matter) that would otherwise be indigestible for them. On the other hand, domestic animals needed to be tended and fed, and often required human protection to survive.[11] This led Marina Fischer-Kowalski to coin the term 'colonization of natural systems' to describe the process underway. This colonization occurred in a multiplicity of ways, depending on local circumstances and available technical skills.[12] It also involved systematically persecuting, harrying, and destroying animals identified as harmful, such as birds of prey, otters, wolves, bears, lynxes, and foxes.[13]

The notion of social metabolism was employed by Rolf Peter Sieferle and his co-authors in order to establish systematic perspectives which would describe the interactions of agrarian societies with their environment. The concept of metabolism had first been developed from the 1860s in biology, where it stands for the totality of exchange processes between a cell and its environment. Over the last forty years its meaning has been expanded to encompass the exchange processes between society and its natural environment that are labelled social metabolism. They primarily entail production, consumption, technology, and population.[14] The organization of social–metabolic processes differs over time as well as according to the local environment and to the prevailing culture. Cultures are self-organizing communicative systems among humans. They follow their own internal momentum rather than being primarily tailored to adapt to external stimuli from the natural environment.[15]

The amount of energy available and its sources are essential both for conditions within societies and for their exchange with the environment.[16] Breaking down the economic–ecological history of the northern hemisphere according to the key energy source of society permits a distinction to be made between a period of hunter-gatherers, a period of agricultural society based on biomass production, a period of industrial society based on coal, and a period of consumer society based on petroleum and natural gas.[17]

From this perspective, traditional agriculture should be understood as an economic–ecological system powered through photosynthesis by the sun's energy. Photosynthesis is used by green plants to convert solar energy into biomass that may then be used to fuel living organisms. The sun's energy that falls on a given surface is relatively small and limited, albeit infinitely renewable.[18]

Fields, meadows, and woodlands produced the lion's share of the plant biomass on which early modern people depended for their existence. Fields and meadows provided food, fodder for the cattle, and raw materials, such as leather, horns, and wool, for the trades which dominated textile production. Working on the land, whether as a wealthy 'full time' farmer or as a poor cottager depending on additional sources of income, provided a livelihood for 80 to 90 per cent of households. Cultivated land was the focal point of social logic: it provided the most important means of production, the safest known investment, the most productive source of taxation, the only source of security for society. Land ownership evolved to become the index of social status and political power. Early modern farming was labour intensive and unproductive in monetary terms compared to the modern fossil-fuel based industrial agriculture. 'The most important crops were annual. After harvest they constituted an energy stock that was then largely consumed during the subsequent year. Other forms of solar energy such as wind and water power could not be stored. They had to be used in the moment when they became available'.[19]

Forests provided the largest source of energy available to agrarian societies. Wood provided most of the energy needed for cooking and heating. At the same time it was the fundamental material for building houses and ships, and making all kind of tools, vehicles, and machines. Woodlands were also employed for other purposes such as growing crops, grazing cattle, collecting litter, and producing potash and charcoal.[20] Charcoal became a fuel for iron-working. 'Earlier generations of scholars tended to suggest that iron-working produced deforestation and hence the move to coal as the major fuel. The British historical ecologist Oliver Rackham, on the other hand, has adopted the contrary argument that it was largely agriculture which fragmented the woods and that ironmasters were much in favour of the sustained production of charcoal, of which their chief source was the coppice'. [21] Typically, a coppiced woodland is harvested in sections on a rotation. Young tree stems are repeatedly cut down to near ground level. In subsequent years, new shoots will emerge, and, after a number of years, the coppiced tree is ready to be harvested, and the cycle begins again. This regulated, sustainable way of iron production is also found in the German Siegerland (North Rhine—Westphalia).[22] Glass- and salt-works being large consumers of firewood caused the depletion of forest resources. The deforestation of the area around the salt mine in Lüneburg (Lower Saxony) led to the growth of heathland. In the Salzkammergut (Austria) a system of ductworks stretching over dozens of kilometres guided the brine to forests which exist to the present day.[23]

To a limited extent, certain fossil fuels were exploited regionally. Peat was a cheap source of energy mainly exploited in the Netherlands. Coal extracted locally from deposits close to the surface by strip mining was utilized in England, in parts of Germany and the Southern Netherlands mainly for lime-burning, brick-making, glass manufacture, the production of salt, soap and alum, and in malting, brewing, and sugar refining. From the sixteenth century, coal was increasingly exported from the Tyne (North-East England) to London to meet the growing energy demands of the metropolis.[24]

One characteristic of pre-industrial societies was that materials were re-used rather than thrown away. Most metals were used over and over again, while in England there was a brisk market in second-hand garments and cloth. Paper was made from rags, initially of linen. All production depended on such re-use, with the result that the export of rags was forbidden in late seventeenth-century England.[25]

The amount of biomass that could be harvested was proportional to the surface of the cultivated area and required a correspondingly large workforce. Cultivation of plants usually provides more energy in the form of biomass than peasants needed for their subsistence. This surplus was appropriated by the ruling elites to support their own lives and to maintain the territorial administration.[26] If the agricultural workforce was inadequate or exiguous, it was augmented by forced labour as was common in the regions east of the river Elbe.

'The governmental apparatus, maintained by the surpluses of the peasant economy, was usually subdivided into three sectors: military, urban administration and public works sector, and the sphere of ritual and religion.' It was normally concentrated in towns. 'Foods and raw materials flowed into these centres to be processed and consumed there. A number of service professions, wage workers, artists, doctors and traders, who formed the mass of the urban population, settled there to sustain the territorial authorities.'[27] 'Urban centres depended both on the resource flows from the countryside and the loyalty of the rural population. Consolidation of rule was only possible through concentration of power, but in the end the exercise of authority was tied to a decentralisation of decision-making competence. In a sense a permanent flow of legitimacy from the centre to the provinces had to be organised, mirrored by a material return flow of resources in the form of taxes or tribute.'[28]

Plant biomass, as the most important energy source, was gathered from across a wide area. To be exploited by humans it needed to be accumulated, which required a significant expenditure in transportation energy, taking into account the constraint that the energy content of a cargo should always exceed the energy input required to transport it. Transportation costs varied greatly according to the method employed. Moving goods by sea was the cheapest. On canals, transport was three times more expensive, and over land—by carriage on bad roads—it was as much as nine times more expensive than by sea. These considerations placed regions situated close to the sea at an advantage, as people could import bulk articles such as grain and timber at much lower cost than communities in landlocked areas.[29] 'Big cities could emerge only in the heart of rich agricultural zones or on rivers and coasts well served by cheap transport. Cities in temperate climates also made heavy demands on their hinterlands for fuel. According to the calculations of Canadian geographer Vaclav Smil, in the temperate latitudes of Europe or China a city needed to have reliable access to woodlands for fuel amounting to fifty times its own area.'[30] For these reasons, the size of towns in landlocked areas was generally restricted. Rubbish in early modern towns was subject to laws and ordinances relating to the disposal of human and animal waste. Sewage went into private cesspits but before long, these compromised other dwellings. Animal refuse was another major problem: there was dung and straw from stables (especially of inns), the corpses of semi-feral pigs and dogs, and refuse from butchers.[31]

Agrarian societies were far from being unchanging. Although the inflow of the sun's energy flow was fixed, the efficiency with which it was utilized could usually be increased. On the one hand, this was a matter of improving irrigation methods and ploughing technology by using better methods of yoking horses together. On the other hand, parts of the cultivated land area within the cycle of the customary three-field system in central Europe were allowed to remain fallow every three years due to a lack of manure. Since the later Middle Ages, fallow land had served as a testing ground for innovations, initially for crops that naturally produced nitrogen such as legumes, then for new crops imported from the Americas from the sixteenth century onwards, that offered a higher nutritional return per unit of area, such as the potato in Europe north of the Alps and maize in the Mediterranean region. These innovations were connected to the new stage in globalization achieved though the discovery of the Americas. Early agricultural growth in England involved intensification through the introduction of forage crops such as the turnip (from around 1580) and clover (from around 1650), though the latter was only widely adopted after 1700. These provided food for the cattle which then contributed their dung to the fields. This meant among other things that there were fewer famines and so population growth was set to become constant. By 1700, crop yields had increased by about one-third upon their 1400 level.[32] In general, innovations expanded slowly and irregularly due to the shortcomings of the communications networks and the inherent constraints of the prevailing agrarian regime.

As additional labour was needed to increase yields or cultivate more land, agrarian societies were not capable of sustaining per capita economic growth. Marginal returns declined in the absence of more productive technologies and so every economic upturn choked itself off after a time.[33] This obstacle to growth was only removed through the access to abundant sources of fossil fuels from the late eighteenth century.

In addition, regional and supra-regional trade networks were improved, facilitating exchange between surplus and deficit areas, for example the growth of grain exports from the Baltic to Western Europe which began in the sixteenth century. Substantial parts of Europe, such as the Pannonian Basin (southeastern central Europe, with its centre in Hungary), Poland and Russia were much less densely populated, which paved the way for immigration into these regions.

Agricultural change was primarily a response to population increase. Marginal lands were cultivated during periods of population growth, low wages, and high grain prices and were then abandoned when these trends were reversed. Reliable overviews of population in early modern Europe prior to 1750 are scarce and fragmentary. More continuous information is available for England, France, and the territorial area of 'Germany'.[34] In the 1340s, on the eve of the Black Death, Europe's population may have been as high as 75 million, but it took until 1750 to almost double to 140 million. The four centuries from 1350 to 1750 can be divided into climate-friendly phases of relatively rapid demographic growth such as 1500 to 1570 and 1700 to 1740 which were interrupted by setbacks through repeated waves of plague (1340 to 1450) and the 'long seventeenth century' which was a phase of climate- and war-related decline followed by recovery.[35]

To a certain extent, early modern society was able to adapt the capacity of its agriculture to dynamic population growth. A proportion of the population came to be prevented from marrying at all, while a rise in the age of first marriage was evident and was important for the west European marriage pattern. By comparison with other cultures, women married relatively late, not until their mid-20s, and this reduced both the period of possible fertility and the likely number of children. This pattern of late marriage was brought about by the scarcity of landholdings which could be transferred from one generation to the next. Sons and daughters from a propertied household had to wait patiently for the point at which the property or at least the running of the farm was handed over, while the lower classes had to save the means necessary to establish a household through an extended period of employment as servants. A substantial proportion of Europe's population never married at all. [36]

> Urban populations generally were so unhealthy that they could not reproduce fast enough to offset their mortality; they were sustained only by constant influx from the surrounding countryside. Cities were black holes for population until improvements in sanitation and disease control were developed, only about 100 to 120 years ago. The natural decrease (surplus of deaths over births) in London in 1750 was so great, that it alone cancelled half the natural increase of all of England.[37]

Agrarian societies were not entirely sustainable in the long run even though their system was powered only by solar energy. In addition to forest depletion, soil degradation, exacerbated by frequent heavy rainfall, tended to undermine its fertility. Whether improvements in soil management could outweigh these problems, is open to debate.[38] Systemic analyses like that of Rolf Peter Sieferle and his co-authors all but ignore that life in agricultural societies was hard and highly uncertain. The inherent lack of stability is, on the one hand, related to the permanent threat of sudden death from epidemic disease. The experience of sudden death striking every age, every rank, men and women, infants and children through a handful of recurrent epidemics such as smallpox, typhus, dysentery, and plague was part of everyday life. On the other hand, the availability of plant biomass, fluvial transportation, wind and water power were highly volatile and unpredictable according to the character of the seasons. Harvest failures due to inclement weather were a high risk for early modern society, comparable to the threat of severe natural disasters for people today. They undermined the economic basis of the numerically preponderant lower social strata through a surge in food prices, plummeting real wages, unemployment, poverty, and hunger. The study of natural crises which over the past fifteen years has become an important dimension of environmental history, has convincingly demonstrated that nature, rather than being a benign mother, was often a source of disruption and disaster.[39] This also relates to recent experiences of natural disasters such as the devastating Elbe flood of 2003, the terrifying tsunami of 2004, and the disaster of hurricane Katrina in 2005.

The Historical Study of Weather and Climate: The Roles of the Scientist and the Historian

Robust evidence that weather and climate have changed significantly over the last millennium, has been assembled by palaeo-climatologists and historical climatologists. Palaeo-climatologists are scientists who analyse data stored in what may be styled the 'Archives of Nature', such as tree rings and ice cores. These data reveal changes in climate, usually temperatures, for periods extending over many centuries or even millennia. Climate stands for the statistical properties of climatic elements, usually temperature and precipitation in a given region over several decades. Historical climatologists are historians, geographers, and physicists interpreting documentary sources which survive in the 'Archives of Society' such as chronicles and weather diaries. Climate and climatic change cannot be experienced by our senses, in contrast to weather which is understood as atmospheric conditions over shorter time scales, ranging from days to seasons.[40] There is thus a gap between the scale on which palaeo-climatologists produce information and that on which humans perceive atmospheric changes and respond to them. Compared to data from Archives of Nature, documentary sources have the advantage of shedding light on the interplay of different weather elements, such as temperature, precipitation, snow-cover, cloud cover, and wind.

The objectives of palaeo-climatologists and historical climatologists are similar to the extent that both attempt to reconstruct climate for the period prior to the creation of national meteorological networks from the mid-nineteenth century. To that extent, data from Archives of Nature and Society to some extent complement each other. Where documentary data are fragmentary or lacking, longer term temperature or precipitation trends may be drawn from evidence contained in the Archive of Nature. In cases where it is important to establish the nature and severity of extreme conditions, documentary data are more differentiated and case-specific. Beyond reconstructions of climate, historical climatologists also study the history of rainfall and sunshine to investigate weather impact on time scales to which past societies were vulnerable, including short-term events such as killing frosts and devastating hailstorms. At the same time, extreme events and nature-induced disasters are foci for debates on, as well as social representations of, weather and climate. The article by Rudolf Brazdil and his co-authors provides an extended analysis and interpretation of documentary sources and their value and limitations.[41]

The study of the interaction of weather and society was central to historical climatology in the 1970s and early 1980s. This is related to the interests of its two founding fathers. Emmanuel Le Roy Ladurie is a historian with a passion for studying weather and climate. His *History of Climate since the Year 1000* was widely read and proved influential.[42] The late Hubert Lamb was a climatologist with a passion for human history.[43] In 1979 he convened an international 'Conference on Climate and History' in Norwich (United Kingdom). This gathering provided an umbrella organization which brought together more than 250 historians, geographers, climatologists, and archaeologists who had until then worked more or less in isolation. The public debate about the global food crisis taking place at that time made it an opportune moment to consider the impact of climate in the past. From the early 1980s, when the 'Green Revolution' gained momentum, famines disappeared from the headlines. At around the same time, the mainstream of historians turned away from investigating the facts of material life towards the more promising field of cultural history. Historical climatologists for their part became involved in research programmes which sought to reconstruct past temperatures in the context of the new debate on anthropogenic climate change. More recently, investigations into the consequences of weather and climate for human societies in the past are once more gaining ground. An International Society for Historical Climatology and Climate History was founded in 2012.

Weather History—A Composite Puzzle from Thousands of Parts

Humans are part of two different spheres of existence and causation: the natural and the cultural. With their bodies, they are part of the biological sphere of nature. With their minds, they are part of the symbolic sphere of culture.[44] Weather has a prominent place in both. Prior to the industrial age it was not only a significant component of man's biological life, but as a fundamental everyday experience it also held a prominent place in people's minds. Knowledge about and understanding of weather had been a central part of the culture of agrarian societies ever since the advent of writing. In order to make the memory of past events permanent, literate societies used to set down their experience of weather episodes together with their knowledge of climate, which was remarkable for the pre-meteorological era.

With regard to the content of sources, climate historians distinguish between three types of data: early instrumental measurements, direct narrative data and indirect proxy-data (Table 2.1).

The earliest meteorological instruments were developed by Galileo Galilei and his successors in Italy. In 1654 the Grand-Duke Ferdinand II of Tuscany sponsored the establishment of the first network of meteorological stations located mainly in the Italian peninsula.[45] In the eighteenth century, many individuals—priests, nobles, scholars, and wealthy landowners—acquired barometers and thermometers and began instrument observations. Early instrument measurements, prior to the period of national network

Table 2.1 Survey of Data on Weather and Climate from Archives of Society According to Data Category

Data Category	*Contents*
Direct Data	***(Early) Instrumental Measurements*** • Air pressure, air-temperature, precipitation, water gauges (Instrumental diaries) ***Direct or Narrative Data*:** • Measurements, from several times a day down to hourly (Weather diaries and ship's logbooks) • Reports of spells of weather, extreme weather anomalies, weather impacts and perceptions (Chronicles) • Dates of and reasons for Rogation Ceremonies and Days of Penitence (Ecclesiastical data)
Indirect or Proxy Data	***Biotic data*:** • Plant phenological observations • Timing of agricultural work ***Physical data*:** • Freezing and thawing of rivers and lakes, time of snowfalls and duration of snow cover (cryospheric data) • Reports on floods and low water; flood and low water marks (hydrological data) • Paintings of ancient glaciers; reports on advance and retreat of glaciers (glaciological data) ***Archaeological data:*** • Abandonment of settlements, changes in statistics of human height and in nutrition

observations from the late nineteenth century, are usually found in weather diaries alongside narrative accounts. Linking early instrument measurements to modern ones requires careful standardization, because early instruments were inadequate and guidelines as to where instruments should be located are often lacking, while metadata is seldom available.[46]

Direct data are weather narratives set down serially, ranging from scant mentions in weather diaries to extended descriptions found in chronicles. Chroniclers describe how people experienced and interpreted extreme weather events on the basis of their particular worldviews. Weather diaries began to be kept from the late fifteenth century, when the large-scale publication of astronomical calendars first provided a suitable medium for the daily recording of outline meteorological observations. On the high seas, daily changes in wind and weather were duly registered in ship's logbooks from the late seventeenth century. Every officer on board was required to keep data of this kind. Ecclesiastical data about the time and purpose of rogations, religious services conducted to mitigate climatic extremes such as droughts (*Pro Pluvia Rogations*) or endless rains (*Pro Serenitate Rogations*) are an important proxy for assessing the severity of extreme episodes of weather.[47]

Indirect data refers to biophysical evidence that is to some extent controlled by weather and climate. The word 'biophysical' is made up of the terms biological and physical. Biological data refers to the time of ripening of crops, and wild plants and the dates of agricultural activities such as the harvest. Physical data refers to indicators such as the duration of snow cover, the freezing and thawing of rivers, lakes, ponds, and streams as well as the incidence of floods and low tides. Many chroniclers were eager to include biophysical observations in their narratives, because those were known to be compatible with analogous occurrences in the past and future, and therefore suited to advance human knowledge concerning climatic risks. The relationship of biophysical proxies to climatic elements, temperature, and precipitation, must be established by the researcher employing statistical analysis. Pictorial representations of historic glaciers in the form of drawings and paintings allow reconstructions to be made of the previous extension and volume of the ice as far back as the seventeenth century.[48]

Another indirect source which is important is archaeological evidence. Archaeologists investigate climate and human activity in the past, primarily through the recovery and analysis of man-made relicts buried in Archives of Nature. Evidence about people's body height or about the establishment and abandonment of settlements is often assumed to result from the long-term effects of climate and/or climatic extremes, but such hypotheses need to be carefully validated.[49]

Another important distinction in the area of documentary evidence concerns the agents who generated or directed the production of sources. Knowing who produced the sources and why these were produced is essential in order to detect flaws and shortcomings (Table 2.2).

- **Personal Sources** were generated and shaped by individuals who were motivated to record weather observations. Such sources may contain both direct and indirect

Table 2.2 Survey of Data on Weather and Climate from Archives of Society According to Record Keeping Agents

Data category	*Personal sources*	*Institutional sources*
Instrumental:	• Instrumental diaries	• Protocols of a meteorological network stations
Direct or Narrative:	• Weather diaries	• Ship's logbooks
• Chronicles	• Mandatory reports about weather impacts	
	• Letters, Diaries	• Ecclesiastical evidence
	• Travellers' accounts	
	• Scientific papers	
Indirect or Proxy:	• all personal sources	• Administrative records on weather-related activities and sources of income

data. Most suffer from gaps of varying length for biographical reasons. Knowing the personal background of an author is helpful to assess which climatic elements he may have highlighted and which he may have disregarded. The date of an event can only be accepted if it falls within the lifetime of the author of the source which requires the date of his birth and death to be established.

- **Institutional sources** were generated and shaped within the framework of administrative structures, that is, organizations such as monasteries, hospitals, and town governments. These bodies did not primarily intend to document weather. Rather, they were concerned with the accounting of receipts and expenditures, some of which fluctuated according to the weather. Bureaucratic routines involved annual record keeping, also for years of 'average' climate, sometimes over several centuries. For example, the start of the sailing season each year in Stockholm, deduced from administrative sources on harbour activities, may serves as a proxy variable for January to April temperatures over the entire period from the early sixteenth century until at least the beginning of the 1870s, as Lotta Leijonhufvud and her co-authors demonstrated. Another example concerns the start of the winter grain harvest in Switzerland and southwest Germany which can be obtained from the accounts of the Basle Hospital and other administrative sources from 1444 to 1970 and acts as a proxy for March to July temperatures. Serial information concerning the beginning of the grape harvest in France and elsewhere goes back as far as the late fourteenth century. Bureaucratic routines may also include reporting to a higher authority. For example, Venetian governors in the Adriatic and Eastern Mediterranean had to report annually to their superiors in Venice, about events which affected income and expenditure in their territories, for instance storms damaging port installations or droughts destroying the harvest. In a similar way, authorities submitted reports about weather damage to crops or buildings when householders who had suffered applied for a reduction in their taxes, as case studies from today's Czech Republic demonstrate.[50]

There remains the problem of creating continuous quantitative time series from miscellaneous evidence contained in personal and institutional sources. Historical climatologists take on the challenge of fitting together thousands of individual pieces of evidence to create a detailed picture of past weather, which is then converted to continuous time series of proxy indicators of temperature and precipitation. The procedure is carried out as follows. Initially, it is essential to make sure that the picture obtained for a particular time span is 'meteoro-logical', that is, in accordance with atmospheric laws. Subsequently, an ordinal index is derived from the evidence for every month or season. It consists of seven grades encompassing values for temperature of -3 (extremely cold), -2 (very cold), -1 (cold), 0 ('average'), +1 (warm), +2 (very warm and +3 (extremely warm). Accordingly, the precipitation index employs the same methodology using grades of -3 (extremely dry), -2 (very dry), -1 (dry), 0 ('average'), +1 (wet), +2 (very wet) and +3 (extremely wet). Of course, assessing these so-called 'Pfister indices' is to some extent subjective, depending upon the quality of the evidence and the experience of the researcher. Yet there is a high degree of correlation for the indices obtained independently for separate countries. Nearly continuous monthly temperature indices are available for Germany, Switzerland and the Czech Republic from 1500 until the early nineteenth century. Petr Dobrovolny and coauthors succeeded to assess continuous temperature estimates from this evidence for every month of the year.[51] Another group under the same lead authors estimated monthly precipitation for the Czech lands from 1501 to 2010[52]. Sea-level pressure, temperature, and precipitation have been reconstructed statistically for the whole of Europe on a monthly (1659 onwards) and seasonal (1500 onwards) basis by Jürg Luterbacher together with his colleagues.[53]

Climatic Trends and Weather Extremes

The geographical range of documentary evidence and its availability over time in Europe are uneven. Data are still fragmentary for Northern Europe (except Iceland), the Balkans, and Russia, while it is almost continuous for western and central Europe from about 1170, at least for 'summer' and 'winter' seasons. This enabled Pierre Alexandre to produce a critical compilation of data from this core region for the period 1000 to 1425.[54] Records of seasonal temperature variations for Germany exist for the past millennium, extending back into the Middle Ages.[55] In the period after 1550 the quality and density of information greatly improves and near continuous indices are available for several countries. For England and France measured monthly temperatures are available from 1658/59.[56]

The final section of this chapter provides an outline of the main climatic trends. More detailed information may be found in regional syntheses of weather and climate which are available for Iceland, France, the British Isles, the Southern and Northern Netherlands, Germany, Switzerland, Italy, the Czech Republic, Hungary, Poland, and Russia.[57]

The principal change was that, within the last millennium, a warm medieval era gave way around 1300 to a cool 'Little Ice Age', which lasted until around 1900 when it, in turn, was replaced by a warmer trend mainly related to man-made global warming. The present warm period is now attributed to a higher incidence of solar radiation in the northern hemisphere, which results from orbital forcing brought about by variations in the path of the earth's orbit and of the angle and the spinning motion of its axis.[58] The concept of the 'Little Ice Age' describes a phase of renewed moderate glaciation after the disappearance of most mountain glaciers during the Climatic Optimum about 5,000 years ago.[59] The cooling of the Little Ice Age documented in the Alps through three major glacier advances is related to small fluctuations in solar activity and frequent volcanic eruptions in the tropics.[60] Rather than being uniformly cold, the climate during the Little Ice Age showed manifold, often contrasting, temperature and precipitation intervals including warm and dry extremes. There were also sharp contrasts between different parts of Europe due to the different effects of atmospheric shifts. These temperature and precipitation trends between 1350 and 1750 are described subsequently for Western and East-Central Europe as well as for the Mediterranean region.

Western Europe

In Western Europe (France, the British Isles, the Benelux countries, Switzerland, and Germany) the winter half-year (October through March) was colder and generally drier than in the twentieth century. This was particularly so from 1351 to 1370, 1418 to 1425, 1432 to 1443, 1477 to 1483, 1560 to 1573, 1680 to 1697, and in the 1740s. During the most severe winters, such as 1364, 1435, 1573, 1695, 1709, and 1740, cold and dry air masses flooded large parts of Europe for several months. The most extreme cold episode in January 1709 involved polar air which penetrated as far south as the Mediterranean Basin, killing most subtropical plants such as citrus and olive trees.[61] Winters were rather warmer from 1401 to 1417, in the 1470s, from 1520 to 1545, and again from 1617 to 1650. Temperatures from 1600 to 1615 frequently alternated between extremes of cold and warmth.

In a similar way, the data now available for the summer half-year (April through September) enable us to distinguish between colder periods (1452 to 1465, 1490s, 1510s, 1560 to 1598, and 1684 to 1705) and warmer intervals (1380s, 1412 to 1427, 1530 to 1565, and 1718 to 1730) as well as periods of more average, unspectacular weather. The transition from the 'Medieval Warm Period' to the 'Little Ice Age' involved a drop in April to July of average temperatures from 13°C to 12.4°C in England between the late thirteenth and the early fifteenth centuries. Superimposed on this long-term trend are alternating phases of colder and warmer growing seasons. The 1390s and the 1410s were slightly warmer. Cold periods were located around 1380, as well as in the early years of the fifteenth century.

The growing seasons (April to September) in the 1390s and the 1410s were rather dry. Increased rainfall occurred between 1355 and 1375, around 1380, in the early years of the fifteenth century and the early 1420s.[62] Record breaking heat-waves and multi-seasonal droughts were registered in much of Europe in 1473 and 1540.[63]

After 1560 a phase of cooling set in which lasted for many decades, gradually extending from winter to spring, summer, and autumn. By the 1580s the wide Denmark Strait between Iceland and Greenland was often found to be entirely blocked by pack-ice, even during summer.[64] Winters in Central Europe were 0.9°C colder from 1560 to 1600 compared to 1531 to 1560, while temperatures in spring declined 0.6°C, those in summer 1.0°C and those in autumn 0.5°C. The decade from 1591 to 1600 was the coldest.[65] Summer rainfall increased from northern Germany to the Alps with snow falling more frequently in higher altitudes. Alpine glaciers advanced rapidly—the Lower Grindelwald Glacier (in the Bernese Oberland) by one kilometre within as little as twenty years—and the number of severe floods in Switzerland increased fourfold. The agrarian economies located north of the Alps repeatedly suffered from 'years without a summer', such as 1585, 1628, 1675 and 1692, often triggered by large volcanic explosions in the tropics. In many countries, harsh weather occurred in the periods from 1618 to 1630, from 1640 to 1650, and from 1687 to 1695.[66]

Eastern Europe (Poland and Russia)

During the later fourteenth century, particularly in the 1360s, Russia experienced severe droughts resulting in dried out rivers, and forest and peat bog fires. In the country's central regions, the fifteenth century was the coldest since the High Middle Ages. Rainy summers (mainly in the 1450s), severe droughts (mainly in the early 1470s), and cold winters (mainly from 1440 to 1460) resulted in four decades when famines were frequent. The decades from 1480 to 1520 were very wet, while the first half of the sixteenth century was rather warm. In Poland, winters were rather mild, but highly variable during these decades. From 1550 winter temperatures dropped and remained low for two hundred years until 1750. In Poland, information about cool summers is lacking up to 1650, while in Russia both severe winters and cool summers were more often recorded, particularly between 1590 and 1620. Higher temperatures in the North during the first half of the seventeenth century allowed Russian vessels to pass through the Bering Straits and open the North-Eastern Route from the shores of the Kola Peninsula to the Pacific. Every second summer was dry between 1640 and 1659. Poland saw more warm summers during the first half of the seventeenth century than at other periods. In Russia, rainy summers, with recurring early season cold spells and late season frosts, became common during the second half of the seventeenth century. The eighteenth century was dominated by adverse conditions such as cold springs, summer cold spells, and late summer frosts. Likewise, cool summer seasons were recorded in Poland during the first half of the eighteenth century with the coldest in the period 1721 to 1740.[67]

The Mediterranean Basin

Average winter temperatures were, by comparison with twentieth-century figures, almost consistently colder, particularly in the Eastern Mediterranean.[68] In Catalonia (northeastern Spain) dry spells during the winter half-year were frequent in the mid-sixteenth century. Beginning around 1570, wetter and colder conditions became evident with increased precipitation and, at times, greater snowfall in higher altitudes. Rivers frequently flooded during the rainy season. The extent of marshlands increased due to greater fluvial discharge,[69] while the Eastern Mediterranean suffered from both coldness and drought. From 1590 to 1619 the climate was truly anomalous, especially due to the high frequency of catastrophic flooding in the western part of the Mediterranean, while the Ottoman lands experienced their longest drought during the past six hundred years.[70] The situation was similar in the mid-seventeenth century.[71]

The Importance of Weather and Climate for History

Viewpoints on the extent to which past variations in climate have affected societies are sharply divided. Physical scientists are unshakeable in their conviction that climate *must* have affected society in the past. Scientific reconstructions involving societal aspects are often presented in the form of monocausal arguments supported with smoothed curves on a high level of temporal and spatial aggregation. Nico Stehr and Hans von Storch argue that 'a large proportion of today's climate impact research is genuine climate determinism'.[72] Discussions about the social significance of climatic variations were and still are discredited by environmental determinism carried to an extreme by the geographer Ellsworth Huntington and his followers. This may be one reason why many historians tend to ignore altogether the possible importance of weather and climate on human development. Another reason may be the tendency of historians to avoid broad generalizations, because the differences from one case to another are fundamental in historical research.[73] Admittedly, controversial issues need to be discussed without ideological blinkers, albeit with good knowledge of the evidence and methods within both of the 'Two Cultures'. Rather than turning into a search for a deterministic explanation of the past, 'the inclusion of the climate factor in the study of history [as Jan de Vries has rightly argued] should be seen as an expansion of the context in which the workings of past societies are to be understood'.[74] In order to explore interactions between climate and human history, we need to bear in mind that many changes in the human realm such as the development of technology and trade, changes in institutional structure as well as wars and the rise of territorial states to a large extent follow their own internal momentum. To become more meaningful, the issue of 'climate' and 'history' needs to be broken down to lower levels of analysis, with a specific focus, for example, on food, health, or energy systems or on activities such as transportation, communications, military or naval operations (see Figure 2.1).

According to this model, weather and climate influence the availability of water with its many ramifications for irrigation, power generation, and river navigation. They also affect food production and demand for fuel as well as the health system. Most importantly of all, we need to remember that individuals are not simply passive victims of climatic variations. Rather, humans also developed adaptive strategies to buffer themselves, more or less effectively, against extreme weather and climatic change. The comprehensive volume edited by Robert W. Kates and his colleagues still provides the most elaborate and comprehensive framework with which to study climate–society interactions in the past. It results from cooperation between over a hundred authors and reviewers, and covers almost all important aspects such as agriculture, fisheries, water and energy resources, extreme event analysis, perception, and numerical modelling.[75]

A common sequence in climate impact study involves ordering impacts parallel to the major domains of science, beginning with the physical sciences, then moving to the social sciences, and finally to cultural responses and strategies of coping.[76] This approach assumes that the impacts of weather and climate triggered a chain of events that would otherwise not have occurred. The size of the top-down arrows indicates in Figure 2.2, how closely the effects are related to the climatic impact.

The most immediate consequences of extreme weather and induced extreme events are, of course, of a biophysical nature including primary (biomass) production, water availability, and micro-organisms. Fluctuations in food prices are among the most obvious consequences of a second-order impact, masked by the influence of other factors,

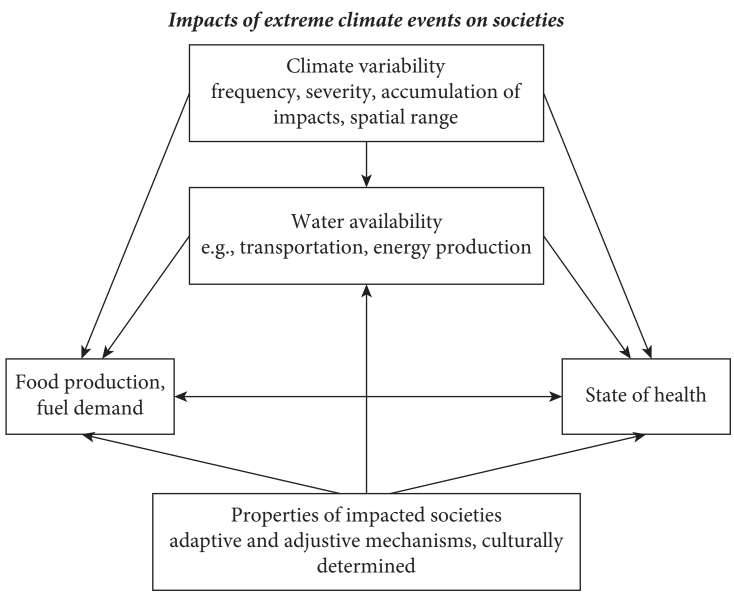

FIGURE 2.1 Impacts of extreme weather on society[86]

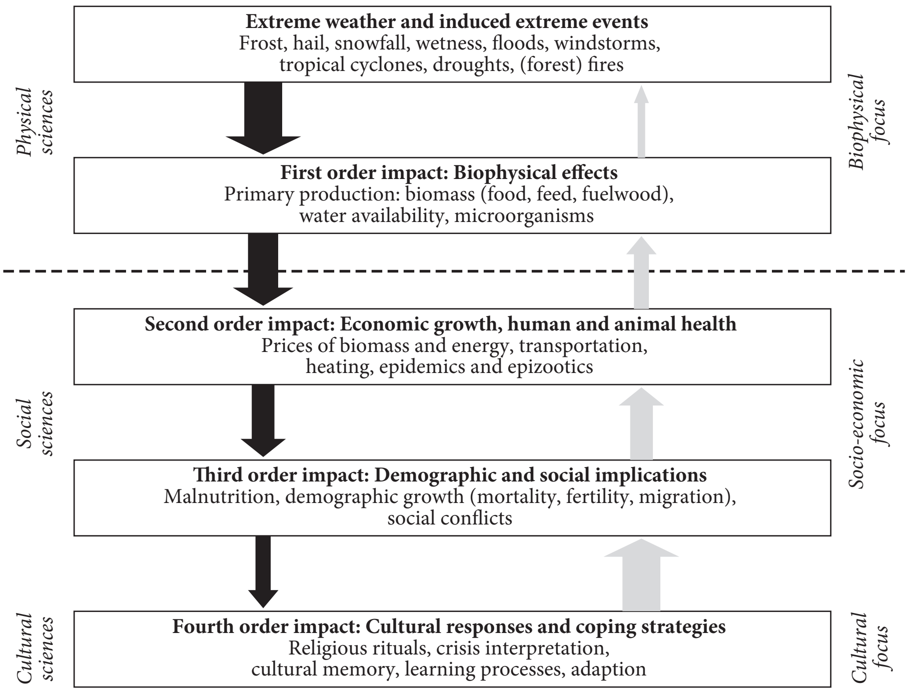

FIGURE 2.2 Simplified Climate-Society Interaction Model.
After Daniel Krämer, Menschen grasten nun mit dem Vieh. Eine Untersuchung der sozialen Verletzlichkeit der Gesellschaft in der letzten grossen Hungerkrise der Schweiz 1816/17, Basle, 2014 (in print) and Christian Pfister, 'Climatic Extremes, Recurrent Crises and Witch Hunts: Strategies of European Societies in Coping with Exogenous Shocks in the Late Sixteenth and Early Seventeenth Centuries', *The Medieval History Journal*, 10/1–2 (2007), 33–73, here 41.

such as supra-regional trade, public grain storage and speculation, together with epidemics and epizootics. A third-order impact makes itself felt mainly through demographic effects, such as a slump in the birth rate and excess mortality.[77] The fourth-order impact includes cultural responses, such as rogations, coping strategies to adapt to meteorological stress in terms of learning processes and social conflicts. Bottom-up arrows indicate how broad the options of individual or collective actors are to cope with direct or indirect effects of meteorological stress. The figure itself has merely a heuristic value. The model does not include the many other variables which, apart from climate, affect the various types of human activity; nor does it specify in detail which climate variables are critical for each activity.

Investigating the consequences of crop-failures necessitates examining the vulnerability of the main sources of food to variations in weather. In the words of Lucien Febvre: 'The action of climate on the natural environment in which man lives must be known before we can understand the action of climate on man.'[78] With regard to Western and Central Europe such a strategy mainly concerns food, grain, wine, and dairy production. It was shown that a given set of specific sequences of weather spells over the agricultural year named 'Little Ice Age Type Impacts' (LIATIMP), mainly involving sequences of chilly springs (April!) and extremely wet mid-summers, were likely to paralyse even sophisticated systems of risk avoidance.[79] Such weather sequences affected not only the output, but also the quality of grain and wine production. Harvesting during long wet spells made it much more difficult to store grain for food use, and a wet harvest compromised the following year's crop if damp seed prematurely sprouted or rotted in storage. Moreover, extreme weather in terms of severe droughts, cold or wet spells affected cattle and sheep through epizootics. By contrast with older views, it was shown that good and bad years do not necessarily follow each other randomly. Rather, they often appear bundled together in the form of longer runs of favourable and unfavourable years. The seven decades from 1560 to 1630 witnessed a significantly higher level of climatic stress when compared to preceding and subsequent periods. Simultaneously, grain prices in Southern Central Europe were far higher.[80]

Examinations of the vulnerability of society to climatic change need to be pursued by regional case-studies. The narrow framework which these provide best reveals the multifaceted political, social, and cultural settings influencing human perceptions of the world. 'In historic studies, the availability of data usually dictates the unit to be studied.'[81] In most cases, such evidence is produced in the regional context of communities, territories, or emerging nation states.

Periods of high climatic stress, particularly in synergy with war, had a disastrous impact on Europe's societies and economies, producing turmoil and rebellions, as Geoffrey Parker has recently demonstrated on a global level for the long seventeenth century.[82] The 1590s were a period of crisis and upheaval in many parts of Europe. Observers in France, England, Italy, and Spain referred to the 1590s as a time of great turbulence. From the mid-1580s to the late 1590s, France suffered from harvest failures, epidemics, and religious warfare. Sicily and Naples were shaken by a subsistence crisis in 1590 to 1592, while parts of Spain suffered from harvest failures during the same decade. In a similar way, England and Scotland saw a disastrous sequence of harvest failures (1593–97) with economic depression, widespread poverty, and high mortality from disease and starvation. In Austria there were large-scale peasant uprisings between 1594 and 1597 precipitated by higher food prices. Crops failed both in Finland (from 1595 to 1601) and Sweden (from 1596 to 1603) with great scarcity and consequent starvation. In Russia, a period of extreme winters, harvest failures, and famine in 1601 to 1603 turned a political succession crisis into the widespread outbreak of vagrancy, violence, and civil war over the following decade known as the 'Time of Troubles'.[83]

Yet, as Sam White argues, 'even when the fit between climatic and historical events seems too perfect to dismiss as mere coincidence, simply coupling the two fails to explain how and why one development led to another which constitutes the basic task of history'.[84] He provides a convincing and detailed line of reasoning why climate was a critical factor for the seventeenth-century crises of the Ottoman Empire: 'In the 1590s, the eastern Mediterranean underwent its longest drought in the past 600 years, causing widespread famine. At the same time, a disease of livestock wiped out most of the sheep and cattle in Anatolia, the Balkans, and the Crimea. Locked in a difficult war with the Habsburg Empire, the Ottoman state imposed high taxes and requisitions on the starving peasantry, fuelling a major uprising in Anatolia called the Celali Rebellion (1596–1610). Recurring Little Ice Age drought and cold contributed to the widespread violence, flight, and famine that followed, which left much of the Ottoman countryside depopulated by the early 1600s'.[85]

Needless to say, a universally applicable picture of social vulnerability to climate impacts is not to be expected from such studies. Quite the contrary: it would be worthwhile to illustrate the plurality of human responses and solutions in mitigating societal vulnerability to climate variability. Such cooperation would yield a picture of man's relation with climate which is tailored to the realities of the twenty-first century.

Notes

1. Uwe Lübken, 'Undiszipliniert: Ein Forschungsbericht zur Umweltgeschichte', in H. Soz and Kult (25 August 2010), <http://hsozkult.geschichte.hu-berlin.de/forum/2010-07-001> (accessed 7 September 2010).
2. John McNeill, 'Observations on the Nature and Culture of Environmental History', *History and Theory*, 42(4) (2003), 5–43, here 5.
3. Wolfram Siemann, 'Umwelt—eine geschichtswissenschaftliche Grundkategorie', in Wolfram Siemann, ed., *Umweltgeschichte. Themen und Perspektiven* (Munich, 2003), 7–20, here 13.
4. Frank Uekötter, *Umweltgeschichte im 19. und 20. Jahrhundert* (Munich, 2007), 3.
5. Joachim Radkau, *Nature and Power: A Global History of the Environment* (Cambridge, 2008).
6. Ian G. Simmons, *Environmental History of Great Britain* (Edinburgh, 2001).
7. John L. Brooke, Climate Change and the Course of Global History, Cambridge 2014.
8. Reinhold Reith, *Umweltgeschichte der Frühen Neuzeit* (Munich, 2011).
9. Martin Knoll/Reinhold Reith (Eds.), An Environmental History of the Early Modern Period: Experiments and Perspectives, Vienna/Münster/Berlin/Zurich 2014.
10. Rolf Peter Sieferle, *The Subterranean Forest. Energy Systems and the Industrial Revolution* (Cambridge, 2001), 15.
11. Sieferle, *The Subterranean Forest*, 17.
12. Marina Fischer-Kowalski, Helmut Haberl, et al., *Gesellschaftlicher Stoffwechsel und Kolonisierung von Natur. Ein Versuch in Sozialer Oekologie* (Amsterdam, 1997), 1–12, here 7.
13. Reith, *Umweltgeschichte*, 41.
14. Marina Fischer-Kowalski, 'Society's Metabolism. The Intellectual History of Materials Flow Analysis, Part I, 1860–1970', *Journal of Industrial Ecology* 2(1) (1998), 61–78.
15. Rolf Peter Sieferle, Fridolin Krausmann, et al., *Das Ende der Fläche. Zum gesellschaftlichen Stoffwechsel der Industrialisierung* (Cologne, 2006), 7–12.
16. Fridolin Krausmann and Marina Fischer-Kowalski, 'Gesellschaftliche Naturverhältnisse. Energiequellen und die globale Transformation des gesellschaftlichen Stoffwechsels', *Social Ecology Working Paper*, 117 (2010): 1
17. Christian Pfister, 'Das 1950er Syndrom. Die umweltgeschichtliche Epochenschwelle', in Christian Pfister, ed., *Das 1950er Syndrom. Der Weg in die Konsumgesellschaft* (Berne, 1995), 51–95; Simmons, *An Environmental History,* 13.

18. Sieferle, Krausmann et al., *Das Ende der Fläche*, 19.
19. Sieferle, *The Subterranean Forest*, 14.
20. Bernd-Stefan Grewe, 'Forest History', in F. Uekötter, ed., *The Turning Points of Environmental History* (Pittsburgh PA 2010), 44–54, here 51.
21. Simmons, *An Environmental History*, 106.
22. Simmons, *An Environmental History*, 94–95; Reith, *Umweltgeschichte*, 121.
23. Reith, *Umweltgeschichte*, 50–51.
24. Reith, *Umweltgeschichte*, 119–123.
25. Simmons, *An Environmental History*, 113–114. Simmons, *An Environmental History*, 109. For Central Europe, see Reith, *Umweltgeschichte*, 57.
26. Sieferle, Krausmann, et al., *Das Ende,* 26.
27. Sieferle, *The Subterranean Forest*, 30.
28. Sieferle, *The Subterranean Forest*, 30–31.
29. Sieferle, Krausmann, et al., *Das Ende*, 34.
30. John R. McNeill, 'The First Hundred Thousand Years', in F. Uekötter, ed. *The Turning Points of Environmental History* (Pittsburgh PA, 2010), 13–28, here 20.
31. Reith, *Umweltgeschichte*, 64–65.
32. Simmons, *An Environmental History*, 80.
33. Sieferle, Krausmann et al., *Das Ende*, 35.
34. For England: Anthony A. Wrigley and Roger S. Schofield, *The Population History of England, 1541–1871* (London, 1981). For France: Jacques Dupâquier, ed., *Histoire de la population française* (Paris, 1988). For Germany: Christian Pfister, *Bevölkerungsgeschichte und historische Demographie 1500–1800*, 2nd edn. (Munich, 2007).
35. Massimo Livi Bacci, *The Population of Europe* (Oxford, 1999).
36. Christian Pfister, 'The Population of Late Medieval and Early Modern Germany', in B. Scribner, ed. *Germany. A New Social and Economic History 1450–1630*, Vol. 1 (London, 1996), 33–62, here 41–43.
37. McNeill, 'The First Hundred Thousand Years', 20.
38. John R. McNeill and Verena Winiwarter, 'Soils and Societies: Perspectives from Environmental History: Introduction', in John R. McNeill and Verena Winiwarter, eds., *Soils and Societies: Perspectives from Environmental History* (Cambridge, 2010), 1–6.
39. For example, Christof Mauch and Christian Pfister, eds., *Natural Disasters, Cultural Responses: Case Studies Toward a Global Environmental History* (Lanham, 2009).
40. Mike Hulme, Suraje Dessai, et al., 'Unstable Climates: Exploring the Statistical and Social Constructions of "Normal" Climate', *Geoforum*, 40 (2009), 197–206.
41. Rudolf Brazdil, Christian Pfister, et al., 'Historical Climatology in Europe—the State of the Art', *Climatic Change*, 70 (2005), 363–430.
42. Emmanuel Le Roy Ladurie, *Times of Feast, Times of Famine. A History of Climate since the Year 1000* (London 1972); originally published as *L'histoire du Climat depuis l'An Mil* (Paris, 1967).
43. Hubert H. Lamb, *Climate, History and the Modern World,* 2nd edn. (London, 1995).
44. Rolf Peter Sieferle, 'Kulturelle Evolution des Natur-Kultur Verhältnisses', in M. Fischer-Kowalski and H. Haberl, eds., *Gesellschaftlicher Stoffwechsel und Kolonisierung von Natur* (Amsterdam, 1997), 37–53, here 39.
45. H. Howard Frisinger, *The History of Meteorology: to 1800* (New York, 1977), p. 000.
46. Dario Camuffo and P. Jones, eds., *Improved Understanding of Past Climate Variability from Early Daily European Instrumental Sources* (Dordrecht, 2002).

47. Weather diaries: Christian Pfister, Anita Bokwa, et al., 'Daily Weather Observations in Sixteenth-Century Europe', *Climatic Change*, 43 (1999), 111–150. Ship's logbooks: Dennis Wheeler, 'British Ships' Logbooks as a Source of Historical Climatic Information', in A. Kirchhofer, D. Krämer, et al., eds., *Nachhaltige Geschichte. Festschrift für Christian Pfister* (Zürich, 2009), 109–126. Ecclesiastical data: Mariano Barriendos, 'Climate and Culture in Spain. Religious Responses to Extreme Climatic Events in the Hispanic Kingdoms (16th–19th Centuries)', in W. Behringer, H. Lehmann, et al., eds. *Cultural Consequences of the Little Ice Age* (Göttingen, 2005), 379–414.
48. Samuel U. Nussbaumer, Heinz J. Zumbühl, et al., *Fluctuations of the 'Mer de Glace' (Mont Blanc area, France), AD 1500–2050: An Interdisciplinary Approach Using New Historical Data and Neural Network Simulations* (Innsbruck, 2007).
49. Colin Renfrew and Paul Bahn, *Archaeology: Theories, Methods and Practice*, 4th edn. (London, 2004), 13.
50. Stockholm: Lotta Leijonhufvud, Rob Wilson, et al., 'Five Centuries of Stockholm Winter/Spring Temperatures Reconstructed from Documentary Evidence and Instrumental Observations', *Climatic Change,* 101/1 (2010), 109–141. Switzerland and southwest Germany: Oliver Wetter and Christian Pfister, 'Spring-Summer Temperatures Reconstructed for Northern Switzerland and South-Western Germany from Winter Rye Harvest Dates, 1454–1970', *Climate of the Past*, 7 (2011), 1307–1326. France: Valerie Daux, Inaki Garcia de Cortazar-Atauri, et al., 'An Open-Database of Grape Harvest Dates for Climate Research: Data Description and Quality Assessment', *Climate of the Past*, 8 (2012), 577–588. Venice: Jean Grove and Annalisa Conterio, 'The Climate of Crete in the Sixteenth and Seventeenth Centuries', *Climatic Change*, 30/2 (1995), 223–247. Czech Republic: Brázdil, Rudolf, Chroma, Katarina, Valašek, Hubert, Dolak, N.N., Hydrometeorological extremes derived from taxation records for south-eastern Moravia, Czech Republic, 1751–1900AD, Climate of the Past, Clim. Past, 8, 467–481, 2012.
51. Dobrovolny, Petr, Moberg, Anders, Brazdil, Rudolf, Pfister, Christian, Glaser, Rüdiger., Wilson, Robert, van Engelen, Aryan, Limanowka, Danuta, Kiss, Andrea, Halickova, Monika, Mackova, Jarmila, Riemann, Dirk, Luterbacher, Jürg, and Böhm, Reinhard, Monthly, seasonal and annual temperature reconstructions for Central Europe derived from documentary evidence and instrumental records since AD 1500, Climatic Change, 101, 69–107, 2010.
52. Peter Dobrovolný, Rudolf Brázdil, Mirek Trnka, Oldrych Kotyza, Hubert Valášek: Precipitation reconstruction for the Czech Lands, AD 1501–2010, International Journal of Climatology wileyonlinelibrary.com) DOI: 10.1002/joc.3957
53. Jürg Luterbacher, Daniel Dietrich, et al., 'European Seasonal and Annual Temperature Variability, Trends, and Extremes Since 1500', *Science*, 303 (2004), 1499–1503; Andreas Pauling, Jürg Luterbacher, et al., 'Five Hundred Years of Gridded High-Resolution Precipitation Reconstructions Over Europe and the Connection to Large Scale Circulation', *Climate Dynamics*, 26 (2006), 387–405.
54. Pierre Alexandre, *Le Climat en Europe au Moyen Age—Contribution à l'histoire des variations climatiques de 1000 à 1425, d'après les sources narratives de l'Europe occidental* (Paris, 1987).
55. Rüdiger Glaser and Dirk Riemann, 'A Thousand-Year Record of Temperature Variations for Germany and Central Europe Based on Documentary Data', *Journal of Quaternary Science*, 24 (2009), 437–449.

56. Phil Jones and Mike Hulme, 'The Changing Temperature of Central England', in M. Hulme and E. Barrow, eds., *Climates of the British Isles: Past, Present and Future* (London, 1997), 173–196; Emmanuel Le Roy Ladurie, *Naissance de l'Histoire du Climat* (Paris, 2013).
57. Iceland: Astrid E. J. Ogilvie, 'Documentary Evidence for Changes in the Climate of Iceland, A.D. 1500 to 1800', in R. S. Bradley and P. D. Jones, eds., *Climate Since A. D. 1500* (London/New York 1992), 92–117. France: Emmanuel Le Roy Ladurie and Daniel Rousseau, *Les fluctuations du climat. De l'an mil à aujourd'hui* (Paris, 2011). UK: John Kington, *Climate and Weather* (London, 2010). Belgium and the Netherlands: Jan Buisman and Aryan F. V. van Engelen, *Duizend jaar weer, wind en water in de lage landen*. 4 vols. (1300–1750). Franeker, 1996–2006. Germany: Rüdiger Glaser, *Klimageschichte Mitteleuropas* (Darmstadt, 2008). Switzerland: Christian Pfister, *Wetternachhersage. 500 Jahre Klimavariationen und Naturkatastrophen 1496–1995* (Bern, 1999). Italy: Emanuela Guidoboni, Antonio Navarra, et al., *Nella spirale del clima. Culture e società mediterranee di fronte ai mutamenti climatici* (Bologna, 2010). The Czech Republic: Rudolf Brazdil, Petr Dobrovolny, et al., *History of Weather and Climate in the Czech lands*, 6 vols, Brno 1995–2004. Hungary: Lajos Racz, *The Steppe to Europe. An Environmental History of Hungary in the Traditional Age.* (Cambridge, 2013). Poland: Rajmund Przybylak, ed., *The Polish Climate in the European Context. An Historical Overview* (Dordrecht, 2010). Russia: Yevgenii P. Borisenkov, *Documentary Evidence from the U.S.S.R*, in Bradley, Jones, ed., *Climate Since A.D. 1500* (London, Routledge), London 1992, 171–183.
58. Heinz Wanner, Jürg Beer, et al. (2008). See the display in <http://en.wikipedia.org/wiki/Milankovitch_cycles> (accessed 9 June 2013).
59. François E. Matthes, 'Report of Committee on Glaciers', *Transactions of the American Geophysical Union*, 20 (1939), 518–529.
60. Heinz Wanner and Jürg Beer, 'Mid- to Late Holocene Climate Change: An Overview', *Quaternary Science Reviews*, 27 (2008) 1791–1828.
61. Marcel Lachiver. *Les années de misère. La famine au temps du Grand Roi 1680–1720* (Paris, 1991), 124.
62. Kathleen Pribyl, Richard Cornes, et al., 'Reconstructing Medieval April–July Mean Temperatures in East Anglia, 1256–1431', *Climatic Change*, 113 (2012), 393–412.
63. Oliver Wetter and Christian Pfister, 'An Underestimated Record Breaking Event. Why Summer 1540 was Likely Warmer than 2003', *Climate of the Past*, 9 (2013), 1–16, present a new series of grape harvests for Switzerland from 1444 to 2011. Oliver Wetter, Christian Pfister et al., 'The year-long unprecedented European heat and drought of 1540 – a worst case', *Climatic Change*, 125 (2014), 349–363, describe the worst nature induced disaster in Europe since 1500.
64. Lamb, *Climate,* 216.
65. Temperatures computed from the series of Dobrovolny et al. (2010).
66. Geoffrey Parker, *Global Crisis. War, Climate Change and Catastrophe in the Seventeenth Century* (New Haven, 2013).
67. Russia: Yevgenii P. Borisenkov, 'Documentary Evidence from the U.S.S.R', in R. S. Bradley and P. D. Jones, eds., *Climate Since A. D. 1500* (London/ New York, 1992), 171–183, here 173–174. Klimenko, Vladimir Solomina, Olga, Climatic Variations in the East European Plain During the Last Millennium: State of the Art, in Przybylak, *Polish Climate*, 71–102, here 81. Poland :Rajmund Przybylak, Piotr Oliúski, Waldemar Chorczewski, Wieslaw Nowosad, and Krzysztof Syta, Documentary evidence, in Rajmund Przybylak, ed., *The Polish Climate in the European Context. An Historical Overview* (Dordrecht, 2010),167–190,

68. Samuel White (2011), 134
69. Faruk Tabak, *The Waning of the Mediterranean, 1550–1870: A Geohistorical Approach* (Baltimore, 2008), 17.
70. Samuel White (2011), 136–137.
71. Parker, *Global Crisis*.
72. Nico Stehr and H. v. Storch, 'Von der Macht des Klimas. Ist der Klimadeterminismus nur noch Ideengeschichte oder relevanter Faktor gegenwärtiger Klimapolitik?', *Gaia*, 9(3) (2000), 187–195, here 187.
73. T. M. L. Wigley, N. J. Huckstep, et al., 'Historical Climate Impact Assessments', in Robert W. Kates, J. H. Ausubel, and Mimi Berberian, eds., *Climate Impact Assessment. Studies of the Interaction of Climate and Society,* SCOPE 27. (Chichester, 1985), 529–564, here 558.
74. Jan de Vries, 'Analysis of Historical Climate-Society Interaction', in Kates, Ausubel, and Berberian, eds., *Climate Impact Assessment. Studies of the Interaction of Climate and Society*, SCOPE 27, 273–292, here 274.
75. Robert W. Kates, Jesse H. Ausubel, and Mimi Berberian, eds., *Climate Impact Assessment. Studies of the Interaction of Climate and Society*, SCOPE 27 (Chichester, 1985).
76. Robert W. Kates, 'The Interaction of Climate and Society', in Kates, Ausubel, and Berberian, eds., *Climate Impact Assessment. Studies of the Interaction of Climate and Society*, SCOPE 27, 3–36.
77. Bruce M. S. Campbell and Cormac O'Grada, 'Harvest Shortfalls, Grain Prices and Famines in Pre-industrial England', *The Journal of Economic History*, 71(4) (2011), 859–886; Philipp Slavin, 'The Fifth Rider of the Apocalypse. The Great Cattle Plague in England and Wales and its Economic Consequences, 1319–1350', in S. Cavaciocchi, ed., *Economic and Biological Interactions, in Preindustrial Europe from the 13th to the 18th Century* (Florence, 2010), 165–179.
78. Lucien Febvre, *La terre et l'évolution humaine. Introduction géographique à l'histoire*, 2nd edn. (Paris, 1924), XXX. This reference is credited to Franz Mauelshagen.
79. Christian Pfister, 'Weeping in the Snow—The Second Period of Little Ice Age-type Crises, 1570 to 1630', in W. Behringer, H. Lehmann, et al., eds., *Cultural Consequences of the Little Ice Age* (Göttingen 2005), 31–85, here 62–68.
80. Christian Pfister, 'Little Ice Age-type Impacts and the Mitigation of Social Vulnerability to Climate in the Swiss Canton of Bern prior to 1800', in R. Costanza, Lisa J. Graumlich, et al., eds., *Sustainability or Collapse? An Integrated History and Future of People on Earth* (Cambridge MA 2007), 197–212, here 204–205.
81. See for both quotes Kates, 'Interaction' (1985), 10.
82. Parker, *Global Crisis*.
83. Austria: Peter Clark, 'Introduction', in P. Clark, ed., *The European Crisis of the 1590s. Essays in Comparative History* (London, 1985), 3–12. Finland: Timo Myllyntaus, 'Summer Frost: A Natural Hazard with Fatal Consequences in Preindustrial Finland', in C. Mauch and C. Pfister, eds., *Natural Disasters, Cultural Responses. Case Studies Toward a Global Environmental History* (Plymouth 2009), 77–102, here 83. Sweden: Clark, 'Introduction' (1985), 7. Russia: Chester S. L. Dunning, *Russia's First Civil War: The Time of Troubles and the Founding of the Romanov Dynasty* (University Park PA, 2001), quoted by Sam White, *Climate Change in Global Environmental History* (Oxford, 2012), 400.
84. Sam White, *The Climate of Rebellion in the Early Modern Ottoman Empire* (Cambridge, 2011), 13.
85. White, *Climate Change in Global Environmental History* (Oxford, 2012).

86. Christian Pfister, 'Climatic Extremes, Recurrent Crises and Witch Hunts: Strategies of European Societies in Coping with Exogenous Shocks in the Late Sixteenth and Early Seventeenth Centuries', *The Medieval History Journal*, 10(1–2) (2007), 33–73, here 40.

Bibliography

Behringer, Wolfgang, Hartmut Lehmann, and Christian Pfister, eds. *Cultural Consequences of the Little Ice Age* (Göttingen, 2005).

Behringer, Wolfgang. *A Cultural History of Climate* (Cambridge, 2010).

Bradley, Raymond S. and P. D. Jones, eds. *Climate since A.D. 1500* (London, 1992).

Le Roy Ladurie, Emmanuel. *Histoire humaine et comparée du climat*, Vol. 1. (Paris, 2004).

Mannion, Antoinette M. *Agriculture and Environmental Change* (Chichester, 1995).

Mauelshagen, Franz. *Klimageschichte der Neuzeit* (Darmstadt, 2010).

Parker, Geoffrey. *Global Crisis. War, Climate Change and Catastrophe in the Seventeenth Century* (New Haven, 2013).

Pfister, Christian, Rudolf Brazdil, and Rüdiger Glaser, eds. *Climatic Variability in Sixteenth Century Europe and its Social Dimension* (Dordrecht, 1999).

Radkau, Joachim. *Nature and Power: A Global History of the Environment* (Cambridge, 2008).

Reith, Reinhold. *Umweltgeschichte der Frühen Neuzeit* (München, 2011).

Uekötter, Frank, ed. *The Turning Points of Environmental History* (Pittsburgh PA, 2010).

White, Sam. *Climate Change in Global Environmental History* (Oxford: Blackwell, 2012).