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THE RELAUNCH OF HISTORICAL CLIMATE IMPACT RESEARCH – A TIMELY CHALLENGE FOR HISTORICAL CLIMATOLOGY

"The nature of climate-society interaction is such that historical analysis is unavoidable. Most of the climate changes and fluctuations that interest us require the inclusion of duration, and hence of historical research."
Economic historian Jan De Vries[1]

1. Looking back

The vulnerability of past societies to climatic variation is not a recent emphasis of Historical Climatology. Rather, this topic was at the roots of Historical Climatology in its infancy between the early 1970's and the mid 1980's. Re-reading the largely ignored papers written at that time, masterly summarized in the comprehensive volume Robert W. Kates, Jesse H. Ausubel and Mimi Berberian,[2] turned out to provide a still valuable and stimulating basis for reconsidering this topic. In this context, it makes sense introducing this paper with a retrospective view on the beginnings of Historical Climatology in the 1970's and 1980's.

Le Roy Ladurie's "Histoire du climat depuis l'an mil",[3] particularly in the English translation,[4] was widely read and received beyond the French speaking world, considering books and articles by Florescano,[5] Brandon[6], Post,[7] Claxton and Hecht, [8] de Vries,[9] Pfister,[10]

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[1] De Vries, Jan: Analysis of Historical Climate-Society Interaction. In: Kates, Robert W.; Ausubel, Jesse H.; Berberian, Mimi (eds.): Climate Impact Assessment. Studies of the Interaction of Climate and Society, SCOPE 27. Chichester 1985, 273-292, here 278.
[2] Kates, Robert W.; Ausubel, Jesse H.; Berberian, Mimi (eds.): Climate Impact Assessment. Studies of the Interaction of Climate and Society, SCOPE 27. Chichester 1985.
[3] Le Roy Ladurie, Emmanuel: Histoire du climat depuis l'an mil. Paris 1967.
[4] Le Roy Ladurie, Emmanuel: Times of Feast, Times of Famine. A History of Climate since the Year 1000. London 1972.
[5] Florescano, Enrique: Precios del maíz y crisis agrícolas en México (1708-1810); ensayo sobre el movimiento de los precios y sus consecuencias económicas y sociales. Mexico City 1969.
[6] Brandon, P.F.: Late-medieval weather in Sussex and its agricultural significance. In: Transactions of the Institute of British Geographers, vol. 54, 1971, 1-17.

Parry,[11] Ingram and Underhill[12] and others. Motivated by environmental concerns, these scholars reaffirmed that "history is more than relationships among people; it involves human beings interacting with their environment".[13]

Most of them did not follow Le Roy Ladurie's advice of limiting their investigations to climate reconstruction. The French historian challenged the importance of a long-term climatic fluctuation of 1ºC describing it as "slight, almost intangible".[14] Geographer Martin Parry, being probably the most prominent pioneer in historical climate impact research, contradicted this view arguing that the range over which mean decadal temperatures fluctuated over the last centuries fluctuated was "large enough to have affected the long-term productivity of most types of agriculture and the ecological balance of many communities of plants and animals."[15] It needs to be stressed that Le Roy Ladurie used this curious argument for not being discredited as a determinist.[16] Cooperating with climatologists to reconstruct a history of weather and climate was already a taboo breaking in French historiography, where Historical Climatology was ill famed as a "fausse science".[17] The English climatologist Hubert H. Lamb, the most prominent pioneer of Historical Climatology together with Emmanuel Le Roy Ladurie, was less concerned about determinism. "Such labelling only tends to restrict freedom of thought", he wrote. "It will certainly be difficult, and may be dangerous, to generalize. […] In general, it seems helpful […] to think climate as a catalyst or

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[7] Post, John D.: Meteorological historiography. In: Journal of Interdisciplinary History, vol. 3, 1973, 721-732. Post, John D.: The Last Great Subsistence Crisis in the Western World. Baltimore 1977.
[8] Claxton, Robert H.; Hecht, Alan D.: Climatic and Human History in Europe and Latin America. An Opportunity for Comparitive Study. In: Climatic Change, vol. 1, 1978, 195-203.
[9] De Vries Jan (1976), XXXX. De Vries, Jan: Histoire du Climat et Economie - Des faits nouveaux, une interprétation différente. In: Annales E.S.C., vol. 32, 1977, 198-226.
[10] Pfister, Christian: Climate and Economy in Eighteenth-Century Switzerland. In: Journal of Interdisciplinary History, vol. 9/2, 1978, 223-243.
[11] Parry, Martin L.: Climatic Change, Agriculture and Settlement. Dawson 1978.
[12] Ingram, Martin J.; Underhill, David. J.: Historical Climatology. In: Nature, vol. 276, 1978, 329-334.
[13] Claxton, Hecht 1978: XX.
[14] Le Roy Ladurie 1972: 119.
[15] Parry 1978: 17.
[16] Pfister, Christian: Review of Emmanuel Garnier. Les dérangements du temps. 500 ans de chaud et du froid en Europe, Paris, 2010. In: Annales, vol. 66, 2011, 303-305, here 303.
[17] Le Roy Ladurie, Emmanuel: Abrégé d'Histoire du Climat du Moyen Âge à Nos Jours. Saint-Amand-Montrond 2007, here 14.

at least a trigger of change in the major breakdowns of societies and civilizations."[18] He considered climate and human history not being "wholly independent but partly interactive systems. It should be worth wile", he wrote, "to trace cause and effect in the linkages and certainly to look for any regularity."[19]

In July 1979, the Climatic Research Unit headed by Lamb convened the first international "Conference on Climate and History" to Norwich. This conference, sponsored jointly by prominent institutions such as the World Meteorological Organization WMO, the United Nations Environmental Programme UNEP, the Ford Foundation and the Rockefeller Foundation, was a milestone in the development of Historical Climatology. This denotation was coined by Martin Ingram and David Underhill in the renowned journal "Nature".[20] The conference provided an interdisciplinary umbrella for more than 250 historians, geographers, climatologists and archaeologists from over thirty countries who had so far more or less worked in isolation.[21] A great number of presented papers dealt with the significance of weather and climate for past subsistence crises, i.e. a genuine subject matter of historical climate change impact research. The most innovative of them were subsequently published in two volumes of essays.[22] At that time, Historical Climatology was accepted by famous climatologists such as Hermann Flohn, Gordon Manley and environmental physicists such as Hans Oeschger.

According to Benedetto Croce, historiography is always an interpretation of the past in the light of the present.[23] The issue of historical impact research was in line with the public discussion about the global food crisis lingering at that time. World market prices skyrocketed threefold for wheat and fivefold for rice between 1972 and 1974,[24] which parallels the jump in

[18] Lamb, Hubert H.: Climate, history and the modern world. London 1995, here 4.
[19] Lamb 1995: 6.
[20] Ingram, Underhill 1978: 329-334.
[21] Lamb, Hubert H.; Ingram Martin J.: Climate and history. In: Past and Present, No. 88, 1980, 136-141, here 137.
[22] Wigley, Tom M.L.; Ingram, Martin J.; Farmer, Graham (eds.): Climate and History. Studies in Past Climates and Their Impact on Man. Cambridge 1981. Rotberg, Robert I.; Rabb, Theodore K. (eds.): Climate and History. Studies in Interdisciplinary History. Princeton 1981.
[23] Croce, Benedetto: Zur Theorie und Geschichte der Historiographie. Tübingen 1915, XX.
[24] Gerlach, Christian: Die Welternährungskrise 1972-1975. In: Geschichte und Gesellschaft, vol. 31/4, 2005, 346-385.

grain prices during known subsistence crises in historical Europe. The “World Food Crisis”[25], taking humankind by surprise, was connected to a bundle of interrelated causes including among others the dissolution of U.S. grain reserves at the eve of the shock, the disintegration of the Bretton Woods monetary system, the effects of the so-called “oil price crisis”[26] and finally harvest failures in different regions of the globe, notably in the USSR, South Asia, North America, in the Sahel Zone and East Africa as well as the collapse of the anchovies fisheries at the Peruvian coast with its far-reaching consequences.[27] Most of those impacts turned to be related to the unusually strong El Nino of 1971-72. This event was instrumental for the understanding of climate as a global system of teleconnections.[28]

The World Climate Program (WCP) launched in February 1979 under the aegis of the World Meteorological Organization (WMO), already acknowledging that “a long-term global warming derived from the enrichment of the atmospheric content of the 'greenhouse' gases, is underway”.[29] Its ultimate objective was, anticipating the efforts of IPCC, “to insert climatic considerations into the formulation of rational policy alternatives”.[30] WCP was directed at four goals.

1. improving our understanding of the physical climate system;
2. improving the accuracy and availability of climate data;
3. expanding the application of current climate knowledge to human betterment;

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[25] Marx, Herbert (ed.), The World Food Crisis, New York 1975, quoted by Gerlach 2005: XX.
[26] Hohensee, Jens. Der erste Ölpreisschock 1973/74. Stuttgart, Franz Steiner, 1996; Venn, Fiona, The Oil Crisis. Harlow, Pearson Education limited, 2002. Pfister, Christian, The “1950s Syndrome” and the transition from a slow-going to a rapid loss of global sustainability, in: Frank Uekötter (ed.), Turning Points in Environmental History, University of Pittsburgh Press, 2010, 90-117
[27] Gerlach 2005: 349-356.
[28] Caviedes, César N.: El Niño in History. Gainesville 2001, here 96-103.
[29] Kates, Robert W.: Preface. In: Kates, Robert W.; Ausubel, Jesse H.; Berberian, Mimi (eds.): Climate Impact Assessment. Studies of the Interaction of Climate and Society, SCOPE 27. Chichester 1985, xiii-xix, here xiii.
[30] World Meteorological Organization, quoted by Kates, Preface, 1985: xiv.

4. advancing our understanding of the relation between climate and human activities (Impact Study Programme).[31]

In fact, Lamb's conference on "Climate and History" was conceived as a contribution to this objective. The Scientific Committee on Problems of the Environment (SCOPE) of the International Council of Scientific Unions (ICSU) then undertook to review the methods of climate impact assessment called for in the WCP.[32] The resulting volume edited by Robert W. Kates, Jesse H. Ausubel and Mimi Berberian (1985), the product of over 100 authors and reviewers, still provides the most elaborate and comprehensive framework to study climate and society interactions. It covers almost all important aspects such as agriculture, fisheries, water resources, energy resources, extreme event analysis, perception and numerical modelling. A specific chapter by Tom Wigley and co-authors deals with Historical Climate Impact Assessment including a review of 34 Historical Climate Impact Studies.[33]

Famines disappeared from the headlines from the late 1970s, when the Green Revolution gained momentum. Demographic concerns became displeasing, and in the early 1990s Nobel laureate William Fogel bluntly declared: "Famines were caused not by natural disasters but by dramatic redistributions of entitlements to grain."[34] The mainstream of historians moved away from dealing with the facts of material life to explore the new promising field of cultural history, even within fields such as demography (e.g. Livi Bacci),[35] where climate change was previously given at least some consideration (e.g. Post).[36] A browsing of 500 papers published in *Climatic Change* since 1990 yielded less than a dozen articles in which either the vulnerability of past societies prior to the Modern Instrumental

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[31] Kates, Preface, 1985: xiii-xiv.
[32] Kates, Preface, 1985: xv-xvi.
[33] Wigley, T.M.L; Huckstep, N.J.; Ogilvie, A.E.J. et al: Historical Climate Impact Assessments. In: Kates, Robert W.; Ausubel, Jesse H.; Berberian, Mimi (eds.): Climate Impact Assessment. Studies of the Interaction of Climate and Society, SCOPE 27. Chichester 1985, 529-563.
[34] Fogel, quoted by Landsteiner, Erich: (2005). Wenig Brot und saurer Wein. Kontinuität und Wandel in der zentraleuropäischen Ernährungskultur im letzten Drittel des 16. Jahrhunderts. In: Behringer, Wolfang; Lehmann, Hartmut; Pfister, Christian (eds.): Kulturelle Konsequenzen der "Kleinen Eiszeit" – Cultural consequences of the "Little Ice Age". Göttingen 2005, 87-147, here 98.
[35] Livi-Bacci, Massimo: The population of Europe. Oxford 1999.
[36] Post, John D.: Food shortage, climatic variability and epidemic disease in preindustrial Europe. The mortality peak in the early 1740s. Ithaca 1985.

Period or past social representations and memories of climate were addressed.[37] Historical climatologists, instead of further investigating socio-economic implications of past weather and climate, became involved in (international) research programmes directed at reconstructing past climate, primarily temperatures. Suffering from employing statistically limited method, they borrowed some basic statistical approaches from paleo-climatologists to be finally accepted by this community. [38]

For a long time, climatologists had attempted to construct the physical properties of climate by working with the statistics of measured weather over widely used climatic 30 year "normals", defined by the World Meteorological Organisation (WMO), at a given place.[39] Accordingly, climatic change was conceived as a shift in climatic averages. During the 1990s, when extreme events were felt to increase both in number and severity shifts in climatic variability became more important than averages, as the title of an influential paper by Richard Katz and Barbara Brown suggests.[40] Together with the rapid rise of historical disaster research from the late 1990's, this trend initiated a shift in the focus of Historical Climatology to increasingly considering short term events. [41]

2. Outline of a theoretical and methodical framework

Theoretical and methodical considerations about historical climate-society interactions are found both in the papers of economic historian Jan de Vries[42] as well as Tom Wigley and

[37] Pfister, Christian: The vulnerability of past societies to climatic variation: a new focus for historical climatology in the twenty-first century. In: Climatic Change, vol. 100, 2010, 25-31.
[38] Dobrovolný, Petr; Moberg Anders; Brázdil, Rudolf et al.: Monthly, seasonal and annual temperature reconstructions for Central Europe derived from documentary evidence and instrumental records since AD 1500. In: Climatic Change vol. 101/1-2, 2010, 69-107. Leijonhufvud, Lotta; Wilson, Rob; Moberg, Anders et al.: Five centuries of Stockholm winter/spring temperatures reconstructed from documentary evidence and instrumental observations. In: Climatic Change, vol. 101/1-2, 2010, 109-141.
[39] Hulme, Mike; Dessai, Suraje; Lorenzoni, Irene et al.: Unstable climates. Exploring the statistical and social constructions of "normal" climate. In: Geoforum, vol. 40, 2009, 197-206.
[40] Katz, Richard W.; Brown, Barbara G.: Extreme Events in a Changing Climate. Variability is more important than averages. In: Climatic Change, vol. 21, 1992, 289-302. The first author of this paper owes this reference to Franz Mauelshagen (2010).
[41] See the review paper by Schenk, Gerrit; Engels, Ivo J. (eds.): Historical Disaster Research. Concepts, Methods and Case-Studies. Historische Katastrophenforschung, Begriffe, Konzepte und Fallbeispiele. In: Historical Social Research/Historische Sozialforschung, vol. 32/3 (Special Issue), 2007.
[42] De Vries, Jan: Analysis of Historical Climate-Society Interaction. In: Kates, Robert W.; Ausubel, Jesse H.; Berberian, Mimi (eds.): Climate Impact Assessment. Studies of the Interaction of Climate and Society, SCOPE 27. Chichester 1985, 273-292.

co-authors. “Viewpoints on the extent, to which past variations in climate have affected societies are polarized”, according to Tom Wigley and co-authors. “Physical scientists are unshakeable in their belief that climate *must* have affected society in the past, and would be quick to quote examples such as the decline of the Roman empire, the influence of the Little Ice Age in Europe and so forth.” Closer examination shows, however “the 'demonstration' of climate's importance to be based often on deficient or inadequate data, oversimplified arguments, and/or a tendency to ignore non-climatic factors. Historians, on the other hand, tend to the opposite viewpoint. With notable exceptions, they have chosen to ignore the possible importance of climate on the development of society.”[43] De Vries stresses the point “that the inclusion of the climate factor in the study of history must not be regarded as a search for an alternative, and deterministic, explanation of the past, but as an expansion of the context in which the workings of past societies are to be understood.”[44]

Admittedly, effects of climate on history are difficult to demonstrate. It is frequently overlooked that both “climate” and “history” are blanket terms, situated on such a high level of abstraction that relationships between them cannot be investigated in a meaningful way in accordance with the rules of scientific methodology. On a very general level, it could be said that beneficial climatic effects tend to enlarge the scope of human action, whereas climatic shocks[45] tend to restrict it.[46]

To become more meaningful, “climate and history”, as a collective issue, needs be broken down to lower scales 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 (Figure 1).

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[43] Wigley, Huckstep, Ogilvie et al. 1985: 558.
[44] De Vries 1985: 274.
[45] Of course, the term “climatic shock” itself is ambiguous, as some of the people and groups involved always take advantage of situations of general distress, both economically and politically.
[46] Pfister, Christian: Weeping in the Snow – The Second Period of Little Ice Age-type Crises, 1570 to 1630. In: Behringer, Wolfgang; Lehmann, Hartmut; Pfister Christian (eds.): Kulturelle Konsequenzen der “Kleinen Eiszeit” – Cultural Consequences of the “Little Ice Age”. Göttingen 2005, 31-85, here 58-59.

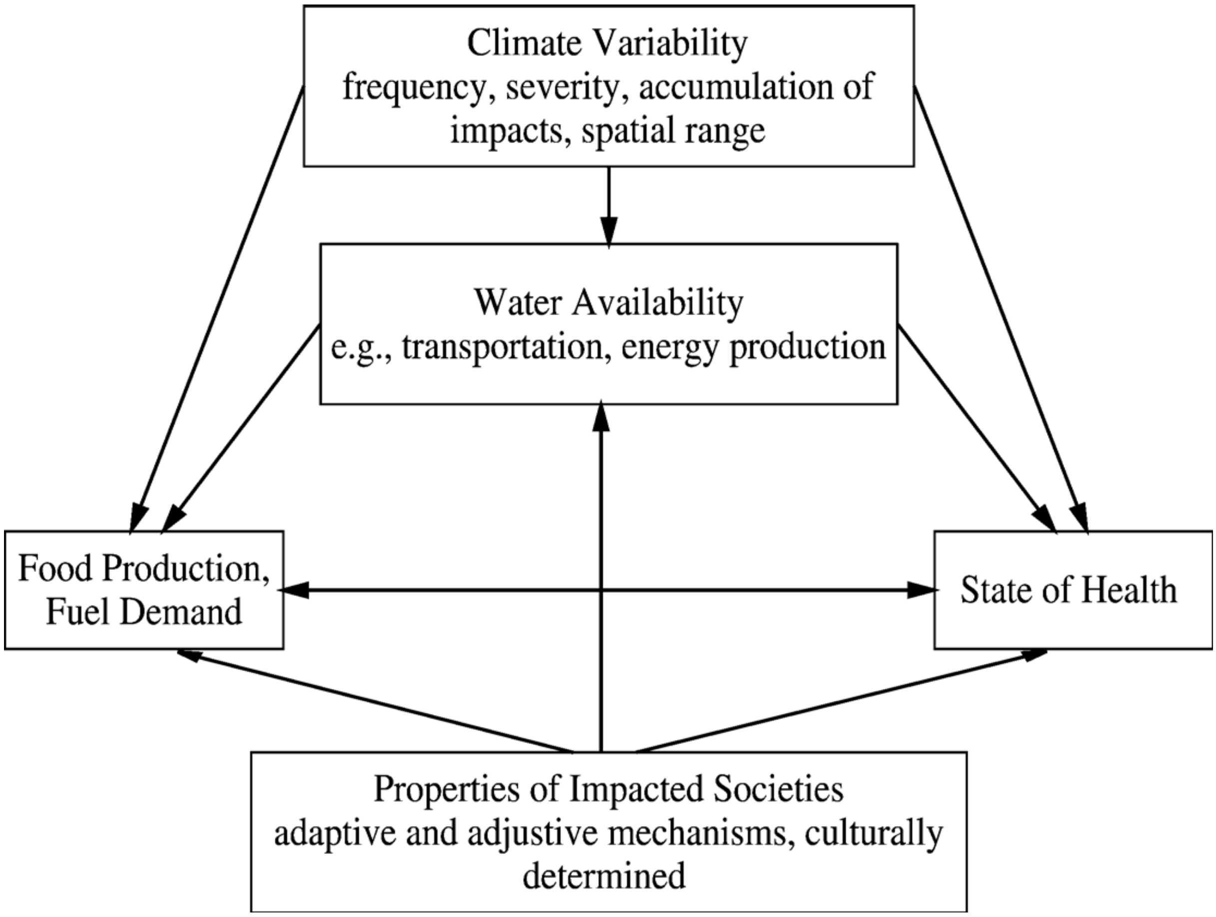

Figure 1: Impacts of Extreme Climate Events on Societies (Pfister 2007: 40).

According to this model, climate variability is determined by the frequency, the severity and the level of accumulation of impacts as well as by their spatial range. Climate affects among other things the availability of water with its many ramifications, e.g. on irrigation, power generation and river navigation. It also affects food production and fuel demand as well as the health system. The adaptive strategies commanded by he impacted societies are of fundamental importance for their vulnerability.

In order to investigate interactions between the history of human societies and the dynamics of their quasi-natural environment, we have to bear in mind that processes in these two spheres usually follow their internal drive and are independent of each other. In the human realm, population growth, economic development, the construction of networks of communication, the move toward globalization, changes in fundamental institutional structure as well as the rise or decline of empires need to be taken into account, just to mention some of the most obvious examples.

In the sphere of the natural environment, changes to which humans contribute – such as soil salinity, deforestation and drops in ground-water levels – should be distinguished from exogenous factors such as fluctuations in solar activity, orbital changes of the earth, changes in sea surface temperature, etc. It is particularly difficult to bring processes between the two spheres in line, because they often take place on different temporal and spatial scales.

A common sequence in climate impact study involves ordering impacts parallel to the major domains of science beginning with the physical sciences (climate, biophysical effects) moving then to social sciences (economy, demography, social conflicts),[47] finally to cultural responses[48] and coping strategies (Figure 2). This approach assumes that effects of weather and climate triggered a chain of events that would not have occurred without this effect. The size of the top-down arrows indicates, how closely the effects are related to the climatic impact. The most immediate effects of extreme weather and induced extreme events are of course of a biophysical nature including primary (biomass) production, water availability and microorganisms.

[47] Kates, Robert W.: The Interaction of Climate and Society. In: Kates, Robert W.; Ausubel, Jesse H.; Berberian, Mimi (eds.): Climate Impact Assessment. Studies of the Interaction of Climate and Society, SCOPE 27. Chichester 1985, 3-36.
[48] Behringer, Wolfgang. Kulturgeschichte des Klimas. München 2007, here 7.

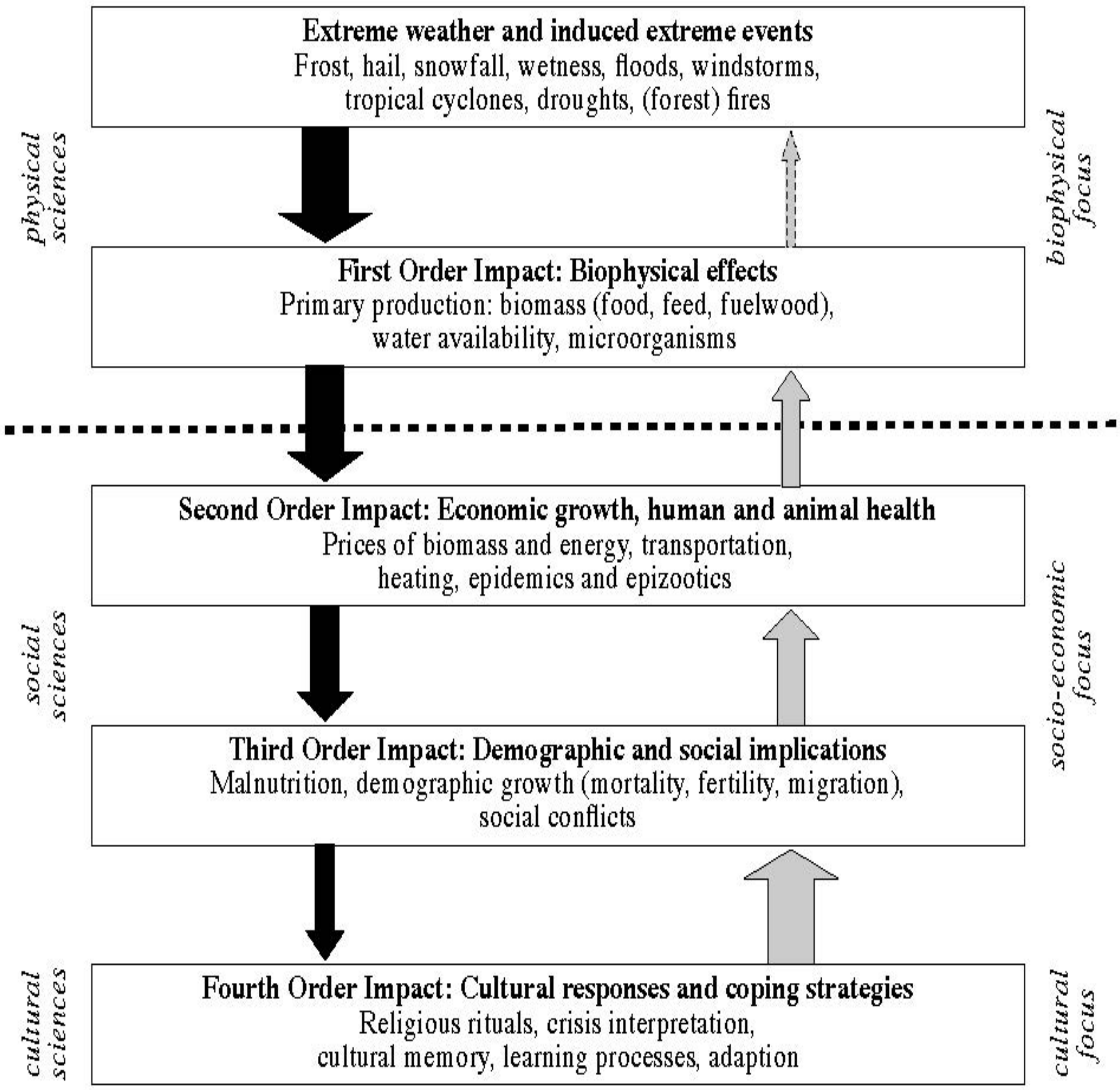

Figure 2: Simplified climate-society interaction model (conference paper by Daniel Krämer adapted and augmented based on Kates (Interaction, 1985: 12) and Pfister (2007: 41)).

Fluctuations in food prices are among the most obvious of consequences of a second order, masked by the working of other factors, such as supra-regional trade, public grain stocking, hoarding and speculation, besides epidemics and epizootics. The impact of a third order makes itself felt mainly through demographic effects, such as a slump in the birth rate and excess mortality. Malnutrition is known to be contingent on distributional systems, in turn dependent on power relations, factors of class and gender, and the supportive capacity of social networks (e.g. Sen).[49] Relationships between demography, weather and climate are intertwined with epidemiological and public health contexts in ways that are inextricable and at the same time highly controversial.[50] Those relating weather to epizootics are just beginning to be explored.[51] The fourth order impact includes cultural responses, such as rogations,[52] coping strategies to adapt to meteorological stress in terms of learning processes.[53] Bottom-up arrows indicate how broad the options of individual or collective actors are to cope with direct or indirect effects of meteorological stress. Presumably, measures directed at preventing famines (e.g. soup kitchens) and dampening price fluctuations (e.g. through improved transportation facilities and grain storage)[54] were possibly more effective than strategies of avoiding weather risks.[55]

The figure itself has mainly 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.[56] The order of impacts does not necessarily agree with the time sequence of events. Processes may as well pass off simultaneously or with different speed. Likewise, the many positive and negative feedback

[49] Sen, Amartya: Food Entitlement and Economic Chains. In: Newman, Lucile F. (ed.): Hunger in History. Food Shortage, Poverty and Deprivation. Oxford 1990, 374-386.
[50] Post 1985.
[51] Campbell, Bruce M.S.; O'Grada, Cormac: Harvest shortfalls, grain prices and famines in pre-industrial England. Working Paper, 2009. Slavin, Philip: The Fifth Rider of the Apocalypse. The Great Cattle Plague in England and Wales and its Economic Consequences, 1319-1350. In: Cavaciocchi, Simonetta (ed.): Economic and Biological Interactions, in Preindustrial Europe from the 13th to the 18th Century. Firenze 2010, 165-179.
[52] Barriendos, Mariano: Climate and Culture in Spain. Religious Responses to Extreme Climatic Events in the Hispanic Kingdoms (16th-19th Centuries). In: Behringer, Wolfgang; Lehmann, Hartmut; Pfister Christian (eds.): Kulturelle Konsequenzen der "Kleinen Eiszeit" – Cultural Consequences of the "Little Ice Age". Göttingen 2005, 379-414.
[53] Pfister, Christian: Learning from nature-induced disasters. Theoretical considerations and case studies from Western Europe. In: Mauch, Christof; Pfister, Christian (eds.): Natural disasters, cultural responses. Case studies toward a Global Environmental History. Lanham 2009, 17-40.
[54] Arnold, David: Famine. Social crisis and historical change. Oxford 1988. O'Grada, Cormac: Famine. A short history. Princeton 2009. Campbell, O'Grada 2009. Wisner, Ben; Blaikie, Piers; Cannon, Terry et al.: At risk. Natural hazards, people's vulnerability and disasters. Second edition. London 2004. Newman, Lucile F. (ed.): Hunger in history. Food shortage, poverty, and deprivation. Oxford 1990.
[55] Pfister, Christian: Das Klima der Schweiz von 1525 bis 1860 und seine Bedeutung in der Geschichte von Bevölkerung und Landwirtschaft. Bd. 2. Bern 1984, 49-60. Groh, Dieter: Strategien, Zeit und Ressourcen. Risikominimierung, Unterproduktivität und Mussepräferenz – die zentralen Kategorien von Subsistenzökonomien. in: Groh, Dieter (ed.): Anthropologische Dimensionen der Geschichte. Frankfurt 1992, 54-113. Further references in Parry 1978.
[56] Ingram, Martin J.; Underhill, David J.; Farmer, Greg: The use of documentary sources for the study of past climates. In: Wigley, Tom M.L.; Ingram Martin J.; Farmer, Greg (eds.): Climate and History. Studies in past climates and their impact on Man. Cambridge 1981, 180-213, here 22X.

loops contained in Bob Kates' seminal article are omitted in the different figures but described in the text.[57]

Linking these branches of knowledge from the two different "cultures", the natural sciences and the humanities,[58] is a difficult task, involving the integration of fundamentally different methodologies and models of explanation operating within different time-space frameworks. People committed to interdisciplinary approaches start from within their own discipline and then try to become familiar with other perspectives through reading relevant papers. For example, historians should become familiar with the various climatic factors to which different agricultural systems are sensitive.[59] What matters in people-climate interaction studies is the scale of time and space that is considered and also how time and space are conceptualised.[60]

Climate sciences starting from models of the physical world are directed at extending the climate record, mostly (annual) temperatures, as far back in time as possible on the basis of statistical procedures. Results of regional reconstructions are presented in the form of well-tuned smoothed curves on a high level of temporal and spatial aggregation highlighting the key point at a glance, which involves a quest for generalization. Such macro-approaches are not suited for demonstrating people-climate interactions. A recent example is the tree-ring based 2500 year long reconstruction of Central European summer precipitation and temperature by Ulf Büngten and co-authors, in which they claimed that "temperature minima in the early 17th and 19th centuries accompanied sustained settlement abandonment during the Thirty Years and the modern migrations from Europe to America".[61] Their paper mirrors the point made by Nico Stehr and Hans von Storch that "a large proportion of today's climate

[57] Kates, Interaction, 1985: 12-30.
[58] Snow, Percy C.: The Two Cultures and the Scientific Revolution. New York 1959.
[59] Parry 1978: 18.
[60] Kates, Interaction, 1985: 7-12.
[61] Büntgen, Ulf; Tegel, Willy; Nicolussi, Kurt et al.: 2500 Years of European Climate Variability and Human Susceptibility. In: Science Express, 13 January 2011, 1-4, here 3.

impact research is genuine climate determinism".[62] Martin Parry notes in this context, that an investigation of the synchronicity of climatic and economic events infers a space-time coincidence rather than causality.[63] According to Jan de Vries, such practices are "by no means confined to climatologists. Indeed, historians often encourage such inferences via their tendency to regard the establishment of a chronological narrative of events as, by itself, tantamount to explanation."[64] Historians, unlike scientists, "tend to eschew broad generalizations, partly because it is the detail, the differences from one case to another, which is central to historical research."[65]

Scientific investigations on people-climate interactions depend on written sources that are close to regional or local events. They should be primarily directed at investigating on how these societies worked in particular, which anomalous weather sequences involved the risk of widespread crop failures. Most environmental impacts described in historical sources happened within days, months or seasons, in some cases even within hours. Possible longer term consequences of environmental impacts are rarely addressed in the sources. On longer time scales, such micro-histories should look for changes in the frequency, severity and duration of adverse weather situations.[66]

Another major difference relates to the fact that natural sciences mainly depend on quantitative or quantified data, while human sciences mainly draw on narrative or qualitative evidence. "Linking these diverse methodologies […] is a major task for the emerging quasi-discipline of risk assessment. As yet, there has been no comprehensive study of the problems of integrating such scientific apples and oranges."[67] In some cases, however, despite the complex and often diffuse inherent interactions of temperature and precipitation, it may be

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[62] Stehr, Nico; Storch, Hans von: Von der Macht des Klimas. Ist der Klimadeterminismus nur noch Ideengeschichte oder relevanter Faktor gegenwärtiger Klimapolitik? In: Gaia, vol. 9/3, 2000, 187-195, here 187.
[63] Parry, Martin L.: Climatic change and the agricultural frontier. A research strategy. In: Wigley, Tom M.L.; Ingram Martin J.; Farmer, Greg (eds.): Climate and History. Studies in past climates and their impact on Man. Cambridge 1981, 319-336, here 321.
[64] De Vries 1985: 277.
[65] Wigley, Huckstep, Ogilvie et al. 1985: 558.
[66] Pfister 2005.
[67] Kates, Interaction, 1985: 5.

possible to modelling crop-weather relationships.[68] The links to societies, however, can hardly be quantified, one the one hand, because the needed data on agrarian production, demography etc. is hardly available. On the other hand, important factors such as human decision-making, the social environment or the political framework are not applicable for quantification. Even quantitative economic historian Jan de Vries suggested that in such cases "it is best to recognize frankly the limitations of current knowledge and build on it with careful observation leading to narrative reconstruction of the events at issue."[69] Often, the approach of "semi-descriptive case studies"[70] is used modelling biophysical climate impacts and completing the socio-economic impacts and responses with narrative evidence.[71]

In order to attempt this kind of modelling, an approach had to be developed to bring multi-monthly macro climate reconstructions and micro histories of weather and human affairs in line. The field of documentary data (see the review by Brázdil and coauthors[72]) not only includes all facets of evidence needed for reconstructing past weather and exploring anomalous weather induced impacts,[73] but also long series of continuous, quantitative and relatively homogeneous biophysical data which, like evidence from archives of nature, allow assessing multi-monthly estimates of temperature, and, less frequently, precipitation.[74]

In this view, expanding the index approach initiated by Charles E.P. Brooks and Hubert H. Lamb into a continuous monthly and seasonal ordinal temperature or precipitation index turned out to be a practicable solution. Such indices are a convenient way to converting weather narratives into quantitative data on climate and connecting them to available multi-monthly temperature estimates from biophysical data. Pfister Indices, as Franz Mauelshagen

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[68] Wigley, Huckstep, Ogilvie et al. 1985: 535.
[69] De Vries 1985: XXX.
[70] Ingram, Underhill, Framer 1981: XXX.
[71] Ingram, Underhill, Framer 1981: XXX.
[72] Brázdil, Rudolf; Dobrovolný, Petr; Luterbacher, Jürg et al.: European climate of the past 500 years. New challenges for historical climatology. In: Climatic Change, vol. 101, 2010, 7-40.
[73] Mauelshagen, Franz; Pfister, Christian: Vom Klima zur Gesellschaft. Klimageschichte im 21. Jahrhundert. In: Welzer, Harald; Soeffner, Hans-Georg; Giesecke, Dana (eds.): KlimaKulturen. Soziale Wirklichkeiten im Klimawandel. Frankfurt 2010, 241-269, here 243.
[74] Leijonhuvhud, Wilson, Moberg et al. 2010.

named them,[75] are synthetic variables on a seven-point scale ranging from -3 (very cold/very dry) to +3 (very warm/very wet) drawing on multifaceted fields of narrative and quantitative evidence.[76] In the absence of instrumental measurements Pfister Indices can be used for modelling relationships between climate and crops, prices or demographic variables (see 3.3.).

3. Case studies

3.1. Approaches to study people's vulnerability to climate in the past?

According to knowledge domain there are many different concepts of vulnerability that can hardly be brought in line. The growing body of literature on vulnerability contains a sometimes bewildering array of terms: vulnerability, sensitivity, resilience, risk, hazard etc.[77] Hans-Martin Füssel (2007) worked out a generally applicable vulnerability scheme distinguishing between four groups of related factors: (1) A focus of analysis such as the human-environment system, a population group, a geographical region or an economic sector; (2) an attribute of concern of the analysed system such as income, cultural identity or health; (3) a hazard which threatens attributes of the system; and (4) a temporal reference, because the risks to which a system is exposed, are expected to change significantly in the course of time. In his cross-tabulation (Table 1) he distinguishes an "internal" and an "external" sphere as well as a "socioeconomic" and a "biophysical knowledge" domain. What is "internal" or "external", depends, of course, on where the boundary between systems is drawn.

[75] Mauelshagen, Franz: Klimageschichte der Neuzeit 1500-1900. Darmstadt 2010, here 55.
[76] Pfister, Christian: Balancing between reconstructing past climate and human dimensions of destructive weather. The crux and challenge of Historical Climatology. In: RCC Perspectives, forthcoming.
[77] Kasperson, Jeanne X.; Kasperson, Roger E.; Turner II, B.L. et al.: Vulnerability to global environmental change. In: Kasperson, Jeanne X./Kasperson, Roger E. (eds.): The social contours of risk. Vol. 2: Risk analysis, corporations and the globalization of risk. London 2005, 245-318, here 249-252. Brooks, Nick: Vulnerability, risk and adaptation. A conceptual framework. Tyndall Centre for Climate Change Research, Working Paper 38. Norwich 2003.

		knowledge domain	
		socioeconomic	**biophysical**
sphere	**internal**	- household income - social networks - access to information	- topography - environmental conditions - land cover
	external	- national policies - international aid - economic globalization	- severe storms - earthquakes - sea-level change

Table 1: Examples for each of the four categories of vulnerability factors classified according to the dimensions sphere and knowledge domain. Source: Füssel, Vulnerability, p. 158.

Obviously, the keywords among the external socioeconomic factors, considering entries such as "international aid" and "economic globalization", are related to the present-day world rather than to the historical past. Entries such as "(over) taxation", "wars" and "embargoes" would be more adequate, as well as "climate extremes", "epidemics" and "epizootics" with regard to external biophysical factors.

"The interaction model [Figure 2] recognizes that impacts are joint products of the interaction of climate and society. Under such conditions, similar climatic impacts will have different socio-economic consequences under different sets of social conditions. These social conditions determine, whether a society is more or less vulnerable to a undesired variability in climate or more or less able to utilize the opportunity provided by a favourable variant."[78] The issue of exploring people's vulnerability to climatic shocks has thus two dimensions.[79] On the one hand, social vulnerability focuses on the ability of people to cope with occurring or anticipated external stress. It is well known that some communities are more susceptible to damage from external shocks than others, though the impact may be similar. Poverty and inequality, lack of food entitlement, insurance availability and housing quality undermines a group's ability to anticipate, cope with, resist and recover from external shocks.[80] Some of theses factor are related to a different organisation of material and human resources on a local

[78] Kates, Interaction, 1985: 6.
[79] Allen, quoted in Brooks 2003: 4.
[80] Cross, quoted in Brooks 2003: 4.

scale, whereas social, macro-economic, political and environmental shortcomings are often located on much larger scales. This cluster includes the level of socio-economic development (taking into account the degree of social stratification), demographic growth, the quality of infrastructure, the availability of technical equipment and the performance of governmental institutions. Social vulnerability exists within human systems independently of external hazards.

On the other hand, adaptive changes to reduce risk will only become effective in face of an external impact in the future.[81] The success of adaptation to climatic stress depends on both the rate of environmental change being faced and the rate of change possible in the adaptive response.[82] In any case, factors need to be identified that were contributing to increase or decrease vulnerability. Early enough, individuals, households, communities or territorial governments try to learn from external shocks to be better prepared to face future impacts. Learning not only involves individuals, but also organizations such as communities, governments and business firms, which have set boundaries for membership and established rules governing the delegation of competence and decision-making.[83] To what extent communities really adapted to crises and disasters, will only be revealed through another impact, which may occur decades later.[84]

An extreme event involves interacting human and environmental factors taking place on different temporal and spatial scales.[85] "Whatever the choice of events for which impacts are to be studied, an impacted group, activity or area exposed to those events must be selected." Vulnerability studies need to be addressed within a rather small framework of regional case-studies. This spatial concentration is connected to the multifaceted political, social and cultural settings affecting human perception of the world. "In historic studies, the

[81] Brooks, 2003: 5.
[82] Driver, Thackwray S.; Chapman, Graham P.: Time-Scales and Environmental Change. London 1996, here 259.
[83] Argyris, Chris; Schön, Donald A.: Organizational learning II. Theory, method, and practice. Reading 1996, here 16.
[84] Pfister, 2009: 17-40.
[85] Driver, Chapman 1996: 259.

availability of data usually dictates the unit to be studied".[86] In most cases, such evidence is produced in the regional context of communities, territories or nation-states.

Vulnerability was not static but dynamic and could vary from region to region within relatively small spaces. In Switzerland, the impacts of the last "year without a summer" 1816 resulted in an East-West- and a North-South-Pattern. At the beginning of the crisis, towns depending on the market, wine-growing areas on the shores of the lakes in the Swiss Plateau and crop-growing areas in the Swiss Plateau were more vulnerable than cattle-breeding regions, the inner alpine zones and the proto-industrialized regions of Eastern Switzerland and the Jura Mountains. Later on, vulnerability shifted to the densely populated, proto-industrialized and market integrated regions.[87]

Case studies in terms of absorbing narratives are closest to the experience of individuals and adequate to the preferences of a broad readership. However, they are not easily brought into a more general picture of climate variability, inasmuch as they should not only stand for themselves. This leads to an imbalance in how we actually understand past socio-environmental interactions: the emphasis as we go back in time from the present focuses increasingly on local and regional case-studies.[88]

Subsequently, some case studies on societal vulnerability to weather and climate are presented without, however, providing a full review on the abundant literature in this field. In dependence of Martin Ingram and co-authors[89] the studies are classified according to the time-scales of impacts distinguishing between (1) short term weather shocks, (2) multi-seasonal to multiannual anomalous weather conditions, (3) multidecadal variations, and (4) "Little Ages" such as the European Medieval Warm Period[90] and the Little Ice Age.

[86] See for both quotes Kates, Interaction, 1985: 10.
[87] Krämer, Conference Paper.
[88] Dearing et al., in press.
[89] Ingram, Underhill, Farmer 1981: XXX.
[90] The current term "Medieval Climate Anomaly" coined from an extra-European perspective suggests the existence of climate "normal". See Hulme, Dessai, Lorenzoni et al. 2009.

3.2. Short term weather shocks

Weather extremes on the daily or sub-daily level may sometimes produce longer term effects. Notably, the impact of a "silent killer", severe frost, is underestimated in this respect, particularly with regard to high altitudes or latitudes. One frosty night coming at a critical point in the agricultural cycle can destroy the entire harvest. The worst example is known from Finland.[91] On September 3, 1867, an early frost struck in the northern and eastern part of the country. Vegetation was so far delayed at that time that spikes of barley being covered with ice were still nearly green. As the country had already consumed its regular grain reserves after a sequence of several poor harvests, the train of events led to a severe famine, the last peacetime disaster of this kind in Europe. "As people migrated in search of food and work, they spread epidemics, and communities began to suffer not only from hunger and despair but also from disease. In spring of 1868 mortality rose steeply. The total population in Finland dropped by 6 percent, while the number of births, reflecting the seriousness of this famine, fell by almost a third."[92] Communications, prior to the advent of the railway, were still poor, and this was one reason why the central government in Helsinki was too slow for sending the needed quantities of emergency grain in time.[93]

For Southern Germany an exceptional case of crops destructed by severe night frost at the end of May is documented in the Little Ice Age: The astronomer Friedrich Rüttel reported from the Stuttgart area that he found cat-ice on the water in several places on the morning of 27 May, 1626. Overnight, grapevines, rye and barley were frost-burnt. Leaves of trees had turned black. This devastating event, together with subsequent crop failures, cattle diseases and price-surges shaped the witch-hunts in the following years.[94] Alone in the Duchy of

[91] Myllyntaus, Timo: Summer Frost. A Natural Hazard with Fatal Consequences in Preindustrial Finland. In: Mauch, Christof; Pfister, Christian (eds.): Natural disasters, cultural responses. Case studies toward a Global Environmental History. Lanham 2009, 77-102.
[92] Myllyntaus 2009: 85.
[93] Myllyntaus 2009: 85.
[94] Pfister, Christian: Climatic Extremes, Recurrent Crises and Witch Hunts. Strategies of European Societies in Coping with Exogenous Shocks in the Late Sixteenth and Early Seventeenth Centuries. In: The Medieval History Journal, vol. 10/1-2, 2007, 1-41, here 62.

Westphalia and in the Cologne archbishophric, archbishop Ferdinand of Bavaria had up to 2,000 persons burned as witches in the years after 1626.[95] Links to social and cultural history are obvious from this example. Likewise, extreme winter cold-waves repeatedly wiped out frost sensitive crops such as olives and citrus fruits in the Mediterranean region.[96] The best known example is the steamroller of arctic air advancing between January 5th and 6th , 1709 from northern France to the Mediterranean[97] leading in Provence to famine, vagrancy and riots.[98]

The impact of hailstorms in history is usually underestimated, even by disaster historians,[99] disregarding the far reaching hailstorm sweeping through France in June 1788 contributing to the grain price peak at the eve of the Bastille storm in July, 1789.[100] Since the Middle Ages narrative sources report extreme hailstorm almost annihilating crops within a broad area. In some regions, the traumatic experience of such events gave rise to annual "hail processions" in the early summer ending often near small stone cross memorials in the fields, where a high mass was celebrated.[101]

Severe winter storms, even really extreme ones, were less consistently inscribed in the cultural memory than devastating hailstorms, despite (or because of?) they involved long-standing destruction of strategically important timber resources and essential fruit-trees, as the

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95 Behringer, Wolfgang: Weather, Hunger and Fear. Origins of the European Witch-Hunts in Climate, Society and Mentality. In: German History, vol. 13/1, 1995, 1-27, here 3.

96 Salmelli, Daniele: L'alluvione e il freddo: il 1705 e il 1709. In: Finzi, Roberto (ed.): Le Meteore e il Frumento. Clima Agricoltura, Meteorologia a Bologna nel '700. Bologna 1986, 17-98, here 27.

97 Lachiver, Marcel: Les années de misère. La famine au temps du Grand Roi 1680-1720. Paris 1991, here XX.

98 Pallach, Ulrich-Christian: Hunger. Quellen zu einem Alltagsproblem seit dem Dreissigjährigen Krieg. Mit einem Ausblick auf die Dritte Welt. München 1986, here XX.

99 Exceptions are e.g. Brázdil, Rudolf; Valášek, Hubert; Svitak, Zbynek: Meteorological and Hydrological Extremes in the Dietrichstein Domains of Dolni Kounice and Mikulov between 1650 and 1849 according to Official Economic Records of Natural Disasters. In : Geografický časopis, vol. 55/4, 2003, 325-353. Mauelshagen, Franz: Sharing the risk of hail. Insurance, reinsurance, and the variability of hailstorms in Switzerland, 1880-1932. In: Environment and History, vol. 17/1, 2011, 171-191. Rohland, Eleonora: Sharing the Risk. Fire, Climate and Disaster. Swiss Re 1864-1906. Lancaster 2011.

100 Grove, Richard H.: The Great El Niño of 1789-93 and its Global Consequences. Reconstructing an Extreme Climate Event in World Environmental History. In: The Medieval History Journal, vol. 10/1-2, 2007, 75-98, here 92-93.

101 Pfister, Christian: "The Monster Swallows You". Disaster Memory and Risk Culture in Western Europe 1500-2000. In: RCC Perspectives, 2011, here 12. http://www.carsoncenter.uni-muenchen.de/publications/rcc_perspectives/index.html

case study about the sequence of violent winter-storms named “Hilaire-Prisca” in January, 1739, suggests for France and Switzerland.[102]

3.2. Multi-seasonal to multiannual anomalous weather conditions

Historical climate impact research was and still is mainly connected to studies about subsistence crisis at the regional level. Such crises grew often out of clusters of destructive weather conditions persisting for several seasons or years, often in combination with wars or internal disorder. Sequences of anomalous weather effects have a cumulative impact, often affecting the entirety of food resources including substitutes and exhausting stocks in function of their duration. Therefore, analyses of weather impacts should not be restricted to the basic staple food, usually some kind of grain, but include animal products, fruit and, in the case of Western Europe and the Mediterranean region, also wine. In addition, we have learnt from Bruce Campbell and Philip Slavin that such studies should look for side indirect impacts of adverse weather in the form of cattle plague, affecting drought power and thus grain production as well as protein supplies on the (multi-) decadal time-scale.[103]

The following discussion is focussed on western and central Europe disregarding the many valuable studies on subsistence crises attempted for other regions of the world.[104] In this context the first author of this paper developed a climate-impact model tailored to food production within the agrarian economies in the mixed economies of southern central Europe, where grain was the staple crop on the basis of the three-field system in combination with dairy and/or wine production. The climate sensitivity of the main sources of food, grain, wine and dairy products was investigated using both present and historical knowledge. It turned out that a given set of specific sequences of weather spells over the agricultural year, called

[102] Pfister, Christian; Garnier, Emmanuel; Alcoforado Maria, Joao et al.: The meteorological framework and the cultural memory of three severe winter-storms in early eighteenth-century Europe. In: Climatic Change, vol. 101/1, 2009, 281-310.
[103] Campbell, Bruce: Four famines and a pestilence. Harvest, price, and wage variations in England, 13th to 19th centuries. In: Liljewall, Britt; Flygare, Iréne A.; Lange, Ulrich et al. (eds.): Agrarhistoria på många sätt; 28 studier om manniskan och jorden. Festskrift till Janken Myrdal på hans 60-årsdag (Agrarian history many ways: 28 studies on humans and the land, Festschrift to Janke Myrdal 2009). Stockholm 2009, 23-56. Slavin 2010.
[104] Conference Paper Endfield and others.

"Little Ice Type Impacts" (LIATIMP), were likely to paralyze even sophisticated systems of risk avoidance (see Table 2).[105] "Years without a summer" affecting vine harvests, the nutrient content of hay harvests (and thus mild yields in the subsequent winter half-year) as well as the quality of harvested grain had the worst effects. It is frequently overlooked that harvesting during rain spells often involved sprouting of the ears and severe impinged on baking quality and stocking ability of grain.[106]

Critical Months	Agricultural Products Grain	Dairy Products	Vine
September-October	*Wet*	*Cold*	**Cold and Wet**
March-April	*Cold*	*Cold*	*(Late Frost)*
July-August	**Wet**	*Wet*	*Cold and Wet*

Italics: Weather Conditions Affecting the Volume of Harvests or Animal Production.
Bold: Weather Conditions Affecting the Quality (i.e., the Content in Nutrients or Sugar) of Crops.

Table 2: Weather Related Impacts Affecting the Agricultural Production of Traditional Temperate Climate Agriculture in Europe. Source: Pfister 2005: 65.

This model (Table 2) was used in a semi-descriptive case study comparing "Little Ice Age Type" impacts in Bohemia, which is part of today's Czech Republic and in the Swiss Canton Bern during the well known European subsistence crisis in the early 1770s. Comparisons of case-studies would, in a sense, entail that some common properties are found between the cases. In this case, however, differences largely prevailed. On the one hand, the duration of climatic stress was shorter in Switzerland, considering the lower impact factor and the lower variability of grain prices. While both countries experienced a more or less similar impact in 1769 and 1770, causing two successive harvest failures. Switzerland being closer to the Azores anticyclone escaped in 1771 whereas in Bohemia suffering from another wet

[105] Pfister 2005: 62-68.
[106] References

summer harvests failed for a third time. Differences in social vulnerability (magnitude of tax burden, existence of grain-stores, introduction of the potato, poor-relief efficiency) were even more pronounced between the two regions. Mortality in Bohemia related to skyrocketing grain prices, while people in the Canton Bern just suffered from a hunger crisis.[107]

3.3. Multidecadal variations in climate

Multidecadal and multiseasonal variations in climate, disregarding the recent period of anthropogenic Global Warming, are relatively rare within Europe in the last millennium,[108] and societal impacts can so far only be demonstrated for a few of them.[109]

The best documented example concerns the period 1570 to about 1630. The years around 1570 were the onset of a period of climatic deterioration which came to a climax during the 1590s and early 1600s. In order to highlight the outstanding character of this period, the average air pressure at sea-level was reconstructed by Professor Jürg Luterbacher, today in Giessen, for the period 1585 to 1597 (Figure 3).

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[107] Pfister, Christian; Brázdil, Rudolf: Social vulnerability to climate in the "Little Ice Age". An example from Central Europe in the early 1770s. In: Climate of the Past, vol. 2, 2006, 115-129.
[108] Examples
[109] See e.g. Pfister, Christian; Brázdil, Rudolf; Glaser, Rüdiger (eds.): Climatic Variability in Sixteenth-Century Europe and Its Social Dimension. Dordrecht 1999.

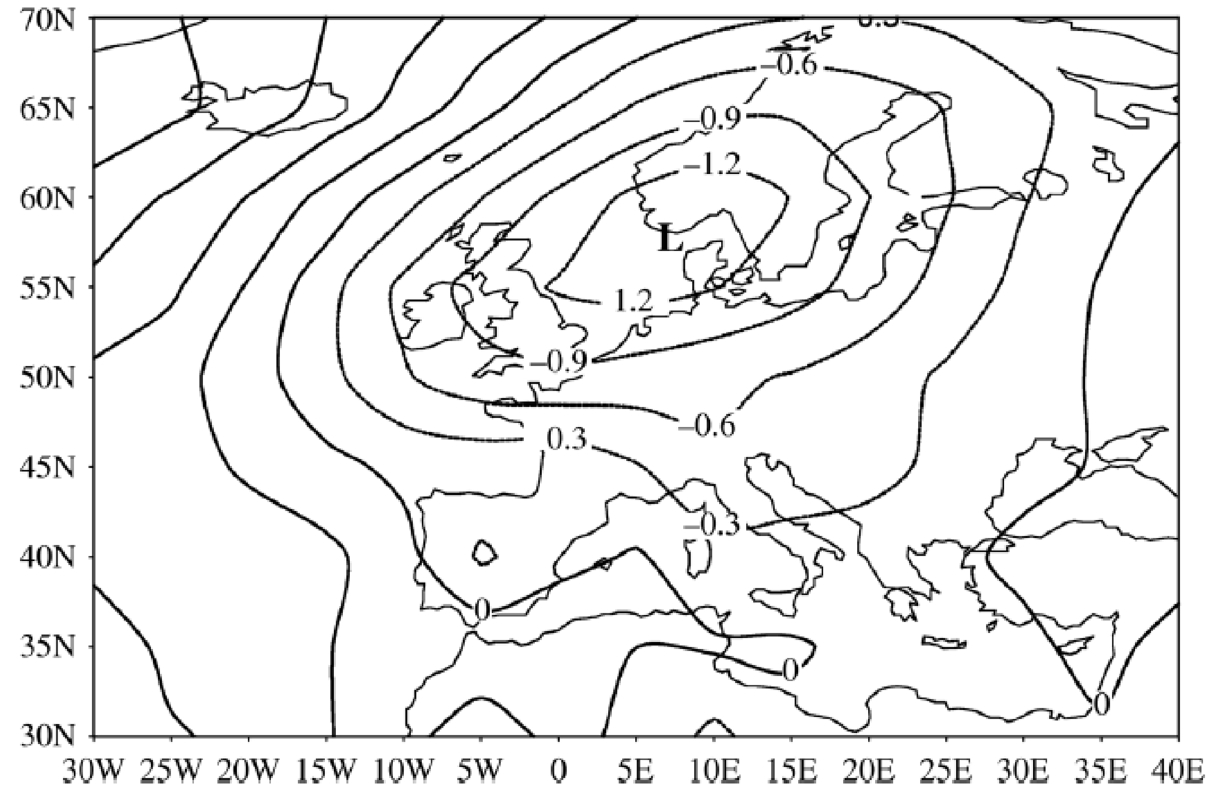

Figure 3: Average Air Pressure in Europe During the Summer, 1585 to 1597.(L = mean centre of the large troughs which frequently steered cool and humid air into mainland Europe). Source: Jürg Luterbacher in Pfister, 2007: 53.

Average weather during these 13 summers was dominated by subnormal pressure over large parts of Central Europe and by a weak and remote Azores anticyclone. Such synoptic situations lead to cool and rainy weather in relationship to the passage of frontal systems from the west and north-west. The somewhat higher pressure over Iceland points to occasional northerly flows, which may have moved polar air through the eastern Atlantic towards Central Europe. At present, such situations usually last for a week, in severe cases up to a month. In the late sixteenth century, summers were predominantly cool and rainy for no less than 13 years, including, however, a hot and dry summer in 1590. This pattern affected continental Europe north of the Alps from the Massif Central to Poland. Temperatures in Central Europe[110] from 1501/65 to 1566/1630 dropped in all seasons, by 0.9 ºC in winter, by 0.4 ºC in

[110] Comprising the territory of today's Germany, Czech Republic and Switzerland.

spring, by 0.7 ºC in summer and by 0.3 ºC in autumn.[111] The likely causes of this climatic shift are related to enhanced volcanic activity.[112]

Among the observers, who were aware of such fundamental changes in the nature of seasons, the Swiss politician and scientist Renward Cysat wrote in his collection of miscellaneous information known as the "Collectanea":

"[…] during recent years the weather and other things have taken such a peculiar and astounding course and undergone such extraordinary alterations [...] [that we had to record it] [...] as a warning to future generations. Unfortunately because of our sins, for already some time now the years have shown themselves to be more rigorous and severe than in the earlier past, and deterioration amongst creatures, not only among mankind and the world of animals but also of the earth's crops and produce, have been noticed, in addition to extraordinary alterations of the elements, stars and winds."[113]

The period 1560 to 1630 has, compared to preceding and subsequent periods, a significantly higher level of climatic stress, to conclude from the temperature and precipitation indices, the depressed level of vine production in Switzerland[114] and elsewhere,[115] and perhaps a substantial reduction in protein availability.[116] Reliable data on aggregate grain production are not available. At least, grain prices in southern central Europe were significantly higher during this period.[117] However, as economic historian Jan de Vries warns, we have to be very cautious to accept price fluctuations as a proxy for fluctuations in

[111] Calculated from Dobrovolný, Moberg, Brázdil et al. 2010.
[112] Palmer, Anne S.: High-precision Dating of Volcanic Events (A.D. 1301–1995) Using Ice Cores from Law Dome, Antarctica. In: Journal of Geophysical Research, vol. 106/D22, 2001, 28089-28096.
[113] Renward Cysat, translated by Pfister 2007: 54.
[114] Pfister 2005: 70.
[115] Landsteiner 2005: XX.
[116] Christian Pfister, Das Klima der Schweiz von 1525 bis 1860 und seine Bedeutung in der Geschichte von Bevölkerung und Landwirtschaft. 2 Bde. Bern, Paul Haupt, 1984, XXX.
[117] Pfister 2005: XXX.

the volume of output.[118] Walter Bauernfeind and Ulrich Woitek using both grain price data as well as temperature and precipitation indices for Germany, found that the impact of climate increased in the course of the sixteenth century.[119] Otherwise, the impact of wars should not be underestimated: In many parts of Europe, the 1590s were a period of crisis and turmoil.

In 1985, Peter Clark published a book of essays on this period that did not receive the attention it deserved.[120] Observers in France, England, Italy and Spain referred to the 1590s as a time of great upheaval.[121] From the mid-1580s to the late 1590s, France suffered from harvest failures, epidemics and religious warfare. Likewise, England and Scotland saw a disastrous sequence of harvest failures (1593-1597) with economic depression, widespread poverty and high mortality from plague and starvation. In Austria there were large-scale peasant uprisings between 1594 and 1597 precipitated by higher food prices. Turning to Scandinavia we hear of crop failures in Sweden (1596–1603) with great scarcity and starvation in the West and South,[122] as well as in Finland (1595-1601).[123] Sicily and Naples were shaken by a subsistence crisis in 1590-1592. Likewise, parts of Spain suffered from harvest failures in the 1590s.[124] Perceptions of and responses to such changes in central Europe, including mass burning of witches,[125] were described by cultural historians.[126] Probably, effects of climatic change were masked by the working of other factors mainly warfare, socio-economic and political inadequacies.

A period of multidecadal climatic shift occurred after the onset of the Little Ice Age in the fourteenth century, whereupon seasonal temperature patterns, not speaking about

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[118] De Vries 1980 and 1985.
[119] Bauernfeind, Walter; Woitek, Ulrich: The influence of Climatic Change on Price fluctuations in Germany during the 16hth Century Price Revolution. In: Climatic Change, vol. 43, 1999, 303-321.
[120] Clark, Peter (ed.): The European Crisis of the 1590's. Essays in Comparative History. London 1985.
[121] Clark, European Crisis, 1985.
[122] Clark, Peter: Introduction. In: Peter Clark (ed.): The European Crisis of the 1590's. Essays in Comparative History. London 1985, 3-22, here 7.
[123] Myllyntaus 2009: 83.
[124] Clark, Introduction, 1985: 4.
[125] Behringer 1995. Pfister 2007.
[126] E.g. Behringer 2007 as well as contributions in Behringer, Lehmann, Pfister (eds.) 2005.

precipitation patterns, prior to 1500 are not yet know in detail.[127] Temperatures considerably dropped between 1314 and 1330 in all seasons, disregarding autumn, for which information is scant.[128]. Crisis ridden were in particular the years the years between 1314 and 1325 both for clusters of wet and cold summers as well as intermediate droughts.[129] The wheat and rye harvests of 1315 were approximately 40 per cent below their normal level; in 1316 they stood at 60 per cent blow their average level; in 1321 they were as bad as in 1315.[130] The obvious result of this environmental shock was widespread famine, which seems to have killed about 10-15 percent of North-European population. Cattle plagues expanding from east to west, intensified through weather induced malnutrition of the animals, led to widespread cattle mortality. As a result, drought power, manure and milk were in short supply for more than a decade. In many areas the carrying capacity of cultural land and thus population density substantially declined prior to the Great Plague. Philip Slavin speaks about a "food crisis of the first half of the fourteenth century" created by an adverse combination of ecological and institutional factors.[131]

A widespread retreat of cultivation occurred in northern Europe under the combined influence of elevation and latitude, particularly along cold-marginal areas at the limit of cereal cultivation in Scotland, western Norway and Iceland.[132] Geographer Martin Parry investigated how significantly longer term changes in climate after the onset of the Ice Age promoted this shift assessing related changes in the frequency of crop failure. Altitudinal foreshortening of the growing season in cold maritime areas is particularly rapid resulting from a result of the exceptionally rapid fall in maximum temperatures.[133] The probability of harvest failure exhibits a quasi-exponential gradient with altitude. "For example, a rise of 25 m at the

[127] Pribyl, Cornes, Pfister 2011, Pfister, Christian / Kleinlogel, Gudrun / Schwarz-Zanetti, Gabriela / Wegmann, Milène: Winter severity in Europe. The fourteenth century, in: Climatic Change 34 / 1 (1996), S. 91–108, Glaser, weitere..
[128] Pfister et al., in preparation
[129] References
[130] Campbell 2009.
[131] Slavin 2010: 170-175.
[132] Parry 1978: 133-134.
[133] Parry 1978: 74-78.

cultivation limit in south-east Scotland led to a 50 percent increase in the frequency of failed harvests and to a doubling of the frequency of two consecutive failures."[134] Kathleen Pribyl assessed March-July temperatures in south-east England from grain harvest starting dates for the period 1256-1431 to be about 0.6ºC.[135] Under such conditions, even such seemingly small shifts in average temperatures being felt through short term variations in climate might have been the immediate stimuli to farm abandonment.[136] However, following Kathleen Pribyl's recent detailed analysis of weather and agrarian practices in Late Medieval Norfolk, the socio-economic impact of the Great Plague[137] leading to decreasing food prices and fundamental changes in the availability and the price of labour should also be considered besides the impact of climatic change. Under such conditions, migration to the lowlands became an opportunity for peasants in marginal areas.

The existence of vineyards in high medieval England is often used as an argument for a European Medieval Warm Period equalling or exceeding present-day temperatures.[138] Indeed, vine-growing is documented up to 55º of northern latitude prior to the fourteenth century.[139]. "This simplistic argumentation, however, neglects the fact that vine growing in England was not primarily directed by climatic in that region favoured the massive import of wine", as Kathleen Pribyl notices.[140]. Besides the warmer climate, demographic growth, leading to abundant cheap labour and to high wine prices, promoted the arrangement of vineyards, mostly by monasteries. However, rather than producing quality wine, English vineyards contributed to the supply of verjuice.[141]. Kathleen Pribyl demonstrated, that

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[134] Parry 1978: 92-93.
[135] Pribyl, Kathleen; Cornes, Richard C.; Pfister, Christian: Reconstructing medieval April-July mean temperatures in East Anglia, 1256-1431. In: Climatic Change, accepted.
[136] Parry 1978: 121.
[137] Pribyl, Kathleenm Weather in Late Medieval Norfolk. Agricultural Practices and their Climatological Significance. PhD Institute of History, University of Bern, 2011
[138] Pribyl, Kathleenm Weather in Late Medieval Norfolk. Agricultural Practices and their Climatological Significance. PhD Institute of History, University of Bern, 2011, 141
[139] Jäschke, Kurt-Ulrich: Englands Weinwirtschaft in Antike und Mittelalter. In: Schrenk, Christian; Weckbach, Hubert (eds.): Weinwirtschaft im Mittelalter. Zur Verbreitung, Regionalisierung und wirtschaftlicher Nutzung einer Sonderkultur aus der Römerzeit. Heilbronn 1997, 256-388.
[140] Pribvyl 2011: 141
[141] Jäschke, 1997. 286-89

"English summer temperatures dropped between 1300 and 1400 and wine quality must have been diminished in consequence. But what changed more and in a fundamental way in the wake of the Great Plague were population size and density as well as the availability and cost of labour. It is those changes, a shift in drinking habits and he still available large-scale import of Gascony wine that contributed largely to the end of most English vineyards during the fourteenth and fifteenth century.[142] "Some of them survived into the sixteenth century, as Kurt-Ulrich Jäschke has established in detail in his exhaustive study.

3.4. Little Ages

Human effects of Little Ages, considering their multi-centennial duration, can hardly be documented in a plausible way.

The Little Ice Age was named by U.S. glaciologist François E. Matthes. He concluded that of the world glaciers were on their highest level in the past millennium since the last Ice Age.[143] The LIA was a simultaneous, worldwide phenomenon that nonetheless allowed for considerable regional and local variation. According to the sophisticated reconstructions made by Hanspeter Holzhauser, it is known that the Aletsch Glacier and the Gorner Glacier, the largest in the Alps, were in an advanced position from the late fourteenth to the late nineteenth centuries.[144] The onset of the Little Ice Age seems to be far from clear considering the range of dates between 1250 and 1550 found in the literature. For western and central Europe, the dates of 1300 and 1860 are most often provided. This period made up of a manifold spectrum of monthly and seasonal temperature and precipitation patterns, including warm phases and extremes, is far from being climatically uniform.[145] There is no long term seasonal trend which agrees with the advanced position of glaciers during the Little Ice Age.

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[142] Pribvl 2011: 145

[143] Matthes, François E.: Report of committee on glaciers. In: Transactions of the American Geophysical Union, vol. 20, 1939, 518-523.

[144] Holzhauser, Hanspeter; Magny, Michel; Zumbühl, Heinz J.: Glacier and lake-level variations in west-central Europe over the last 3500 years. In: The Holocene, vol. 15/6, 2005, 789-801.

[145] References

The most adequate common climatic denominator for the LIA climate in central Europe are spells of cold advection in the winter half-year being more frequent, more persistent and more severe than in the preceding European "Medieval Warm Period" and the subsequent "warm twentieth century". These conditions, however, did not significantly affect the mass balance of glaciers. Superposed on this long-term trend of frequent severe cold spells during the winter half-year were incidental clusters of one to three extremely chilly and wet mid-summers and intermediate wet winters promoting far-reaching glaciers advances. Heinz Wanner and co-authors have coined the term "Little Ice Age-type Events" (LIATE).[146]

Considering both the discussion in the literature and first results of an ongoing research about seasonal temperature and precipitation trends for the European Medieval Warm Period, this multi-centennial time interval lasting from about 1000 to 1300 seems not to have been consistently warm, including multi-decadal cold periods and cold extremes.

4. Conclusions

The issue of people's vulnerability to climate was in line with the public discussion about the global food crisis of the 1970's. It was then eclipsed, when the Green Revolution gained momentum from the 1980's, and, consequently, historical climate impact research was largely abandoned. As high food prices and dearth are returning to the global agenda, today, historical climate impact studies might once more get some attention, albeit under different scientific circumstances. On the one hand, Historical Climatology substantially improved reconstructions of weather and climate over the last 25 years (standardization of temperature and precipitation indices, application of calibration/verification approach for continuous quantitative data from institutional sources as well as for temperature indices). Advances in historical climate impacts studies, on the other hand, remained comparatively small.

[146] References

To become meaningful, "climate and history," as a collective issue, needs be broken down to lower scales of analysis, with a specific focus, for example, on food, health, or energy systems or activities such as transportation, communications, military or naval operations. Such schemes involve dealing with the major domains of science beginning with the physical sciences (climate, biophysical effects) moving then to social sciences (economy, demography, social conflicts), finally to cultural responses and strategies to cope with direct or indirect effects of meteorological stress. Linking these branches of knowledge from the “two cultures”, the natural sciences and the humanities is an almost intractable task, involving the integration of fundamentally different objectives, methodologies and modes of explanation operating within different time-space frameworks:.

Different objectives, methodologies and modes of explanation

Natural sciences intend inferring general conclusions from their evidence, usually quantitative or quantified data. Climate sciences are directed at and improved understanding of the climate system. Starting from models of the physical world they are extending the climate record, mostly (annual) temperatures, as far back in time as possible on the basis of statistical procedures.

Fully describing and explaining individual cases is central to historical research. Case studies in terms of absorbing narratives are closest to the experience of groups and individuals and adequate to the preferences of a broad readership. Consequently broad generalizations are avoided.

Different time-space frameworks:

Results of climate reconstructions are presented in the form of well-tuned smoothed curves or graphs on a high level of temporal and spatial aggregation highlighting the key point at a glance.

Societies are sensitive and responsive to (extreme) weather anomalies, i.e. events taking place within daily to multi-seasonal time-windows. Historical vulnerability studies are addressed within a rather small framework of regional case-studies, depending on source availability. This spatial concentration is connected to the multifaceted political, social and cultural settings affecting human agency and perception of the world.

Approaches to integrating climatic variability into vulnerability studies take the form of involve semi-descriptive case studies, modelling relations between high resolution climate data with biophysical, possibly also with demographic and economic variables and completing the socio-economic impacts and responses with narrative reconstruction of the events at issue. In the absence of instrumental evidence, modelling hinges on the availability of monthly to seasonal ordinal synthetic variables called Pfister indices, converting weather narratives into quantitative data on climate and connecting them to available multi-monthly temperature estimates from biophysical data. Best data studies would be most conclusive, both in terms of diachronic analyses of a given region over time as well as in terms of synchronic vulnerability studies investigating regional responses to a major climatic impact such as Krämers' look at the consequences of the "year without a summer in Switzerland[147]. 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.

[147] See the paper by Daniel Krämer