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11 Analysis of Historical Climate–Society Interaction

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11.1 INTRODUCTION

In this discussion of the techniques of analysis appropriate to the study of climate-society interactions in the past, it is desirable to begin by considering briefly those developments of modern historical research that have brought many historians to regard climate and environmental phenomena in general as appropriate objects of historical study. In so doing the reader will better understand

1. the position of historical research *vis-à-vis* the physical, biological and social sciences,
2. the type of role that the climate factor can hope to find in the explanation of historical change, and
3. the justification for the methodological recommendations to be made later in this chapter.

11.2 HISTORY AND SOCIAL SCIENCE

Historical research has always been rich in its variety, for the historian immodestly asserts his terrain to

embrace all of past human experience. And yet, it cannot be denied that historians have long tended to restrict their interests and limit themselves methodologically by adhering, often implicitly, to the view that history consists of an accumulation of discrete human events. The historian's task appeared to be, first and foremost, to catalogue chronologically and describe as fully as possible these events, and, second, if possible, to establish connections among them that could hope to `explain' how and why one thing led to another.

Since the historian felt compelled to work through the events step-by-step, ever aware that each was of potentially great significance, it is not hard to understand that the bewildering variety he encountered encouraged modesty about what the historian could hope to explain in a `scientific' way. The historian was more inclined to see his task as the infusion of meaning into the past, much as a novelist infuses meaning into modern life. History could evoke and exhort, but it could not really do to the past what social scientists profess to be able to do to contemporary society.

This standpoint, reduced to a caricature by the brevity of my treatment here, has by no means disappeared. But it is now challenged by historians who argue for the systematic application of social scientific methodology, and by those (not always the same) who argue that the rigorous focus on [human] events is not only overly restrictive but positively misleading. The first stream strips away the historical profession's false modesty at the same time as it abandons literary pretensions by making history nothing more nor less than social science applied to past events. The second stream, often referred to as the `Annales school' after the French historical journal that acted as the mouthpiece of its exponents, has more profound and interesting implications. In place of history as a profusion of `mere' events, this school argues for the use of a tripartite concept of time, or duration: the event, the conjuncture and the structure. It is important to note that these progressively longer durations are not simply combinations of events into ever greater aggregations. On the contrary, it is the structures—very slow-to-change features of life such as institutions, ideologies, psychological dispositions, geographical features and ecology —that are basic to these `structuralist' historians. Structures that channel and confine history until they give way, whether gradually or suddenly, are more important than the mere, often fleeting, event, which captures the newspaper headlines and briefly captures our attention, but is generally of no significance in actually changing things of importance. Between these two durations, one measured in days or a year, the other in centuries, is the conjuncture. Conjunctures are combinations of processes that join to bring about change in the medium term, usually in some patterned way. Demography, technological development, and price-forming markets are examples of forces that give rise to these cyclical processes.

With the acceptance of this framework of durations it is a logical next step to expand the range of phenomena studied by the historian to those that are not, strictly speaking, human events. History could become less anthropocentric with the recognition that 'non-human histories' play a role in the maintenance and demolition of structures, and join in the generation of conjuncual processes. An example will help make my point. `Traditional' historians have often noted the outbreak of epidemic diseases—think of that celebrated, infamous event, the Black Death. These diseases could be explained by the knowledge of how rodents, bacilla, fleas, and the like carry and spread them. But beyond this, such events are exogenous to history. They are `Acts of God' in the sense that insurance contracts use that term. Historians have also, of course, been concerned with how change in human society—in social

organization, scientific progress, income inequalites—could render these medical facts of life more or less potent. Here the epidemiological variable is endogenized. What is new to the structural approach is the recognition that there could be an epidemiological history that is autonomous from human history but is capable of impinging on it at times.

In the same way, we can distinguish among three modes of historical treatment of the climate variable. The historian of the event has long recognized the role of climate, or perhaps more correctly of weather, as a random variable—an exogenous fact of life—that has influenced harvests and human health, and occasionally has wrought great destruction via floods, hailstorms, and other natural disasters.

Changes in human society that enable the forces of nature to be tamed (through technological changes reducing societal vulnerability to specific weather events) and human activities that themselves bring about climate change (for example, through deforestation or the release of CO_2 represent climate as an endogenized variable.

Finally, we come to a climate history that is exogenous and non-random (in the sense of exhibiting climate change as Hare defined it in Chapter 2). This non-human history, with its various and still imperfectly understood effects on human society, is this volume's chief object of interest, and it has come to attract the attention of historians who work in the structural tradition described above. The French historian Fernand Braudel expressed over 10 years ago his fascination with `the possibility of a certain physical and biological history common to all mankind [which] would give the globe its first unity well before the great discoveries, the industrial revolution, or the interpenetration of economies' (Braudel, 1973, 19). What he had in mind was the contemporaneous occurrence of comparable events such as the collapse of empires, demographic change, and massive civil unrest in zones of the world not in intense contact with each other. These events, he speculated, might be explained by a world-embracing non-human history of climate and epidemiology.

The point deserving emphasis here is that through the deployment of various notions of duration, history is in a position to embrace new phenomena, including 'non-human histories' that expand the role of historical research. If social scientific history, strictly defined, seeks to merge the study of the past with the social sciences, the practitioners of the tradition described above have sought something different —to make history a meeting ground for various disciplines in the physical, biological and social sciences.

Historical research is sometimes said to be characterized by a careful scrutiny of sources (source criticism) and a devotion to chronology. Both are, of course, important to research in *any* discipline. It is more useful to emphasize history as a discipline of context. It is the historian's aim to explain events and processes by situating them in their full context. The contribution of recent historical research has been to enlarge our understanding of context to embrace differing durations and what I have called non-human histories.

For the benefit of the non-historian it is important to emphasize 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. It follows that we must not nurture extravagant expectations about the single-handed influence that climate change has had on society, nor can we expect the isolation and measurement of these effects to be easy or straightforward.

The research of historians and climatologists plus the example of recent events have prepared the ground for the acceptance of climate change as a vehicle of long-term historical explanation (for historians' views, see Davis, 1973; Parker and Smith, 1978). At the same time, scholars interested in contemporary policy feel the need for a better grasp of the types of historical experience with climate change. It is now recognized that the study of climate and society organized on the basis of impact models (see Kates, Figures 1.1 and 1.2 in this volume) are, by themselves, of limited value. They should serve as building blocks in the development of interaction models, ideally those embracing feedback processes (see Kates, Figure 1.5). Impact models are essentially ahistorical to the extent that they focus on an event and its direct consequences. Interaction models, on the other hand, merge with historical studies the more they seek to integrate climate events into the larger social and natural complex in which those events occur.

The great challenge for historical research is to find methodologies that do not ignore the requirement of treating society as an interacting complex—that is, to honor history as a discipline of *context*—while at the same time simplifying the task sufficiently to render it manageable. Historical research cannot make use of laboratory experiments that isolate the effect of variables one at a time; likewise, the time duration of historical research is almost always too great to permit the use of the *ceteris paribus* assumptions favored by the social sciences. On the other hand, the inclusion of all potentially relevant factors in an historical model is clearly beyond human capacities.

The dilemma as it applies to historical climate studies was presented by Anderson (1981) as an identification problem in which climate change is one of numerous changes working upon a society. These together produce numerous effects. No simple assessment of causation is possible in this situation, and it is particularly suspect to *infer* a climatic cause from an observed effect. The illegitimacy of this practice is sufficiently obvious to obviate the need for elaboration. Also objectionable is the common practice of treating contemporaneity of events as tantamount to causation. Parry (1981) offers a clear-headed discussion of this problem, and notes that:

> [Climate historians], despairing of the viability of a more rigorous approach ... have sometimes resorted merely to an investigation of the synchroneity of climatic and economic events ... Yet all that can be established by this argument is a space–time coincidence. (p. 321)

This practice is 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.

Whether only two discrete events are linked or two time-series are found to correlate well with each

other, all that has been demonstrated in either case is association. To go further requires that a model of causation be established and that the hypotheses flowing from it be tested.

Here we come to a point where the objection will be raised, particularly by historians, that this—model building and hypothesis testing—is precisely what cannot or should not be done in historical research. After all, does it not do violence to the need to comprehend the multitude of factors and the unfathomable complexity of historical change emphasized above? Is it not better to rely on the inspired intuition and the insights of the historian, based on his laboriously acquired general knowledge of a particular time and place, than to seek a specious scientific accuracy?

The answer to these questions must be that the acknowledged difficulties of reconstructing past climate–society interaction offer no reason to adopt other scholarly standards than those for contemporary research in the social and physical sciences. There is no philosophical reason to distinguish historical explanation from [social] scientific explanation. Indeed, the nature of the phenomenon being discussed in this volume 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.

The specific techniques that may be useful in the study of climate–society interaction cannot be listed briefly. However, a survey of the historical studies now available (see Wigley *et al.*, Chapter 21) makes clear that it is important to begin with a sufficient base of knowledge about both the relevant physical and/or social processes *and* the historical context (institutional, economic and cultural) to specify the elements of a testable causal model. The further exploration of the model can proceed in different ways, depending on the character of the model and of the available data. The predicted consequences of a specific climatic phenomenon (in Parry's parlance, `postdicted', since the predictions apply to events that have already occurred) can be specified through simulation (Parry, 1978), or can be confronted with the historical record via statistical techniques such as regression (de Vries, 1980; Lee, 1981), contingency tables (Ogilvie, 1981), or cross-spectral analysis (Lee, 1981).

The quantitative societal data that are most commonly used for the historical study of climate impact are, in order of general availability, commodity prices, demographic events (births, deaths, marriages), tax revenues, trade volumes, and production measurements.* Quantitative data for western countries after about 1650 are by no means scarce, but indicators appropriate for the testing of hypotheses about the impact of climate on the society often are. These hypotheses frequently require knowledge of production levels, which is among the least abundant types of quantitative information. Investigators often substitute for the unavailable production data the much more abundant price data. A great deal of confusion and erroneous inference has resulted from the uncritical use of this substitute. In order to accept price fluctuations as a proxy for fluctuations in the volume of output, very strong assumptions must be made (about the extent of markets, the volume of trade, the existence of substitutes, the elasticities of supply and demand), assumptions which are rarely sustainable in practice (see de Vries, 1980).

Where quantitative techniques are not applicable, or practicable, as is often the case, or when not enough is known even to specify plausible hypotheses, 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. Anthropological field research has popularized the term `thick description' for this systematic assembly of detail uncontaminated by *a priori* interpretive biases. By developing a better understanding of sequential events and by expanding the context in which the events can be situated, `thick description' can give rise to fruitful hypotheses at the same time that it helps supply the data with which they can be tested.

* The sources for these types of quantitative data are numerous, and no effort can here be made to offer a comprehensive bibliography. For the study of Europe, however, references to many of the relevant document collections can be found in Braudel and Spooner (1967), Mitchell (1975), Wilson and Parker (1977), Abel (1980), Flinn (1981), Wrigley and Schofield (1981), Le Roy Ladurie and Goy (1982).

In general, there is little to distinguish the range of techniques available to historical research from contemporary studies in the social sciences. A more specific historical contribution is located in the selection of the issues chosen for study and the time-scales selected for the examination of climatic effects. It is to these issues that we shall now turn.

11.3 HISTORICAL ANALYSIS

11.3.1 Climate Chronology

This discussion of historical interaction between climate and society must pass over in silence the role of historical research in constructing the record of climate variability and change. For this issue see Hare, Chapter 2, as well as Ingram *et al.* (1981), and Pfister (1980). It must be recognized that the selection of time-scale and the choice of research methodology is sensitively affected by the available climate record. It is important to continue the work of extending back in time climate data that are, in the words of the French historian Le Roy Ladurie, `continuous, quantitative, and homogeneous' (1959, 138). Evidence of a less refined sort, evidence that indicates the direction of change between decades or 50-year periods, for example, or that identifies only extreme events, is not without its uses but limits severely the types of issues that can be addressed, as will become apparent below.

11.3.2 Perception

Fundamental to any modeling or formulation of hypotheses about societal adaptations to climate change is knowledge about how people perceived climate change before the establishment of meteorological offices and the broad dissemination of their data-collecting activities. This is important because `adaptation' as opposed to `impact' implies human choice, and this requires individual perception. Even when the object of study is very long-term climate change, the unit of perception must remain the individual and his interpretation of discrete events of relatively short duration.

Traditional historical research techniques would appear to be well suited to the study of perception. The source materials are generally descriptive (letters, diaries, log books, treatises, agricultural almanacs) and

their interpretation depends very much on one's knowledge of contemporary customs, habits and beliefs.

Thus far, studies have focused primarily on the perception of climate in newly settled territories. The interest of historians in the American West has long been directed to how explorers and settlers interpreted the climate of the Great Plains. The climate itself exhibited cycles of drought, and it appears that settlers alternately overestimated and underestimated the region's agricultural possibilities. Eventually the accumulated knowledge and experience of the inhabitants narrowed the range of uncertainty, and institutions were established to deal with that. The settlement history of the Great Plains extends over less than 150 years. The settlement of Greenland and Iceland extends over a much longer period, although the documentation, particularly for the former, is much less complete. Here the studies of Ogilvie (1981) and McGovern (1981) use narrative description to identify the signals that reached the inhabitants and to determine how they were interpreted.

An interesting study that emphasizes the role of ideology (or presumed scientific knowledge) in limiting the ability of explorers and settlers to interpret correctly the climate with which they came in contact is Kupperman's (1982) study of early English experience in Massachusetts. Her study is of particular interest because of the comparisons made by the early settlers between their new habitat and the old England in which they had acquired their attitudes and expectations.

In non-marginal, long-settled areas with well-established material cultures the perception of climatic change will almost certainly be found to consist of incremental, subtle alterations in customary procedures and rules-of-thumb. It is possible that careful analysis of literary evidence can expose such decisions, but it appears likely that the historian will generally have to infer such perceptions from behavior and rely on a model of individual decision-making rather than on direct evidence.

The last word has by no means been spoken about this subject, but recent work points in the direction of seeing individual responses involving decision-making under conditions of uncertainty where the decision-maker tries to estimate the probability of certain events (usually, exposure to extremes of climate). The relevant information to the decision-maker—and hence, the information that the historical researcher needs—is not long-term averages of temperature or rainfall, but rather evidence of variability. One might say that it is the variability of the variability that is likely to be the bearer of signals to the individual decision-maker, the medium through which climate change works on society.

It was just such a problem of decision-making under uncertainty that the eighteenth-century Virginia tobacco planter Landon Carter pondered when, in 1770, he wrote in his diary:

> I cannot help observing as I have before done that this climate is so changing [that] unless it return to its former state Virginia will be no Tobacco Colony soon. (Quoted in T. H. Breen, 1983, 276-277.)

Carter was not yet ready to accept that the experience of the recent past (cold growing seasons) should be used to establish a new norm, governing future expectations. And we now know that the Virginia tidewater did not, in fact, cease to be a center of tobacco production. Carter remained committed to the

crop but many of his fellow planters took steps to diversify and to reduce their dependence on tobacco in the 1760s and 1770s. In those years George Washington stopped the cultivation of tobacco and converted Mount Vernon to a grain-growing enterprise.

In view of the many other factors that could have influenced the production decisions made by Washington and his fellow planters, it would be rash to conclude on the basis of the contemporaneity of events alone that climatic variability induced the observed behavior. But any study of this episode must establish a model featuring decision-making under conditions of uncertainty.

At this point a word must be said in defence of the concept of 'decision-making' in preindustrial society. Eighteenth-century planters may have been rational businessmen, but did peasants process data, estimate probabilities, and perform cost/benefit calculations? The social scientist's custom of labeling all preindustrial societies as `traditional' implies that peasants did none of these things. But this traditional view of the social scientist is certainly in error. By modern standards, the decision-maker in earlier centuries worked with insufficient information (for example, there were no weather bureaus), he operated under peculiar constraints (in particular, those imposed by the absence or imperfection of markets for such things as seed and insurance), and he may have been influenced by some considerations dismissed today as irrational. Indeed, as the `Annales school' historians emphasize, significant changes in behavior may have occurred only when new dangers or new opportunities persisted for a long time. In other words, it took a particularly strong signal to evoke a response. But so long as these adaptive responses existed, and the preponderance of historical inquiry into the economic and demographic life of ordinary people deep into the European past insists that they did, investigations of the long-term relationship of climate to society cannot realistically take the form of impact models, i.e., where the human agent is assumed to be passive, or imprisoned in routine.

A useful analogy can be made to demographic history, where the ruling model linking society to demographic behavior is that bearing the name of T. R. Malthus. Malthus argued that the growth of a population could be stopped in two ways. Either the `preventive check'—human decisions to restrain the `passion between the sexes' and voluntarily restrain fertility—would operate to slow the growth of numbers, or, in the absence of decision-making, the `positive check', the inexorable, inevitable rise of mortality as population outstripped food supply, would do so. The `positive check', an impact model, is imposed by nature, and most historians used to believe that it was the dominant mechanism regulating population before the demographic transition of the nineteenth century. Peasants, it was argued, did not make fine calculations about their fertility behavior.

The impressive advances in historical demography of the past two decades (Flinn, 1981; Wrigley and Schofield, 1981) have amply demonstrated that the preventive check *did* function, that a decision-making model is necessary to account for the historical interaction of population and economy. Fertility control was, by modern standards, imperfect, and it was achieved differently than today (primarily through controls on marriage). But no one can now make the easy assumption that birth rates in the past were `natural', that is, uncontrolled.

The model of perception and decision-making that I here urge upon the reader has important implications for the further design of historical studies of climate–society interactions. It asks us to identify the specific vulnerabilities of a society, given its institutional and technological characteristics, and to inquire into how the society accommodated to the risks to which it became exposed.

Further, for historical analysis it is obviously relevant to inquire how a society's vulnerability and its capacity to distribute risk changes over time. That is, in the interaction of climate and society over long periods of time both climate and society can change. Figure 11.1 offers a schematic presentation of some of the possibilities.

In these examples the narrowing or widening of the `band of tolerance' characteristic of a society's technological and institutional endowments can be regarded as an autonomous structural change. That is, it may occur not in response to climatic change, but independently of it, in response to social phenomena. Scenario D can place a society under climatic stress just as much as alterations in climate (Scenario B) or climatic variability (Scenario C).

11.3.3 Climate Impact

Most studies of climate history have focused attention on the impact of climatic events—the events usually extreme and the impacts usually some form of damage, whether to crop production, human health, or life itself. This simplest form of climate-society study needs to be transcended, as I have argued above, both for the sake of policy relevance and of historical accuracy. But impact studies can nonetheless serve as building blocks for the more complex sorts of analysis. This is especially true of time-series studies of annual events as opposed to the study of isolated events.

Careful statistical studies, such as Lee's regression and cross-spectral analyses of the effects of rainfall and temperature on variation in mortality and fertility in preindustrial England (Lee, 1981) can help place the year-to-year influence of climate in a broader context in which its relative importance (compared, for example, to the incidence of warfare, price changes, or real wage changes) can be assessed. I tried to do the same with regression and difference-of-means techniques in identifying the impact of climatic variance on several types of agricultural production in preindustrial Holland (de Vries, 1980).

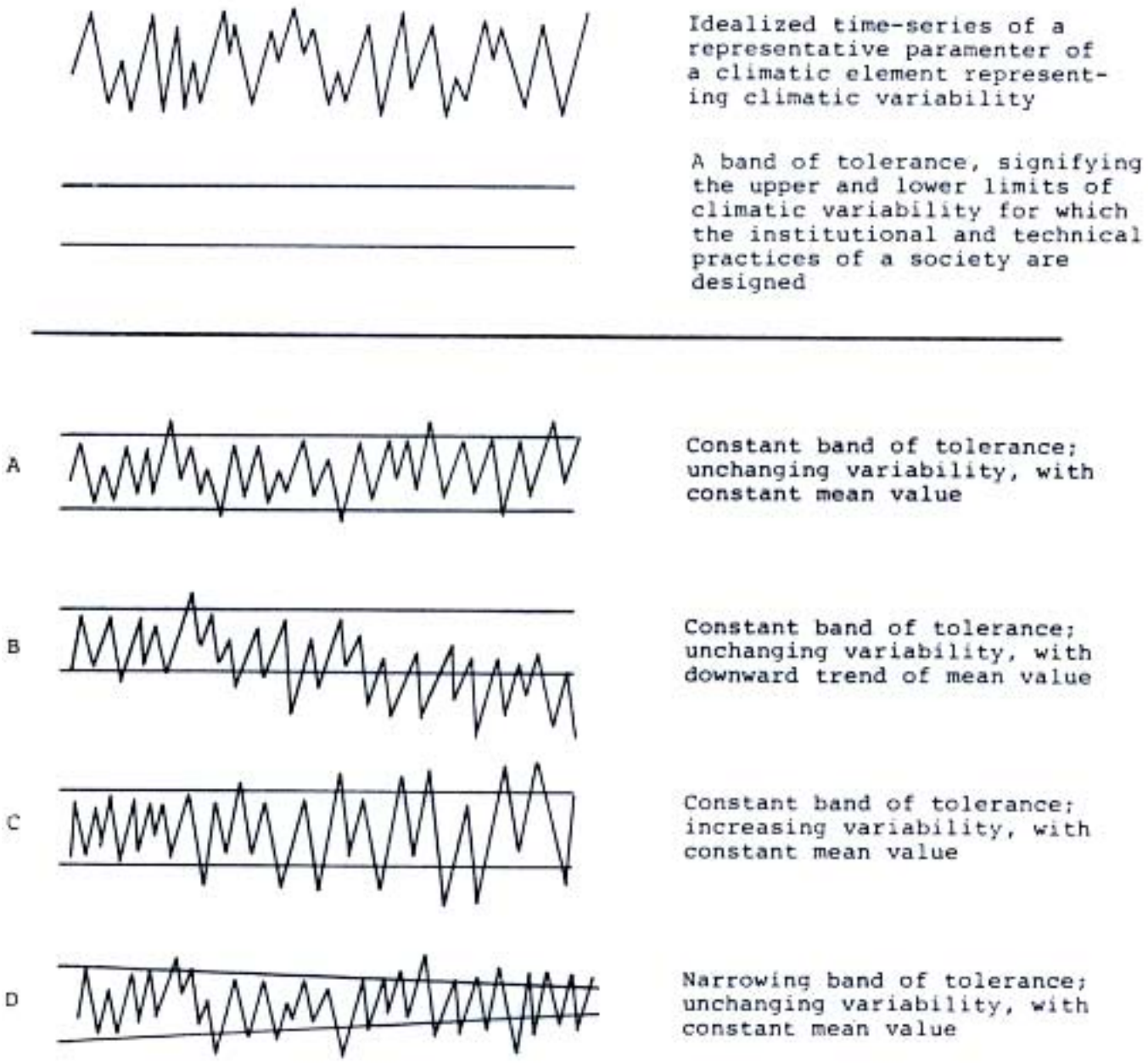

Figure 11.1 Idealized time-series of climate variability and societal `band of tolerance' designed to portray scenarios of climate change and societal change that can give rise to climatic stress

The results to date of such studies have been to assign to annual climatic variation a modest, but tangible, role in accounting for annual variation in demographic and economic phenomena. The preindustrial European societies that have been the object of study were certainly not perpetually held in thrall by the tyranny of mother nature. Yet there were undeniably periods of particular stress, usually produced by a succession of years, of abnormal weather. The two most thorough monographic studies of climate history yet produced each focuses on such multiyear periods of climatic stress: Pfister's (1975) study of the Bern region in 1755–97 (with particular emphasis placed on the stress years, the `katastrophenketten' 1768-71), and Post's (1977) study of the climatic effects of the volcanic eruption of 1816. Both studies augment quantitative data with `thick description' of social, cultural, political and economic events in and

around the periods of stress in order to come to a better understanding of the misfortunes experienced.

The investigation of `climatic stress' periods might yield richer fruits if it were integrated into the *crise de subsistence* literature developed over the past two decades by historians of preindustrial Europe. *Fames, pestis et bellum* periodically disrupted economic and demographic life. A long list of historians, including the Frenchmen J. Meuvret (1971), P. Goubert (1960), and J. Jacquart (1974) and the Americans A. Appleby (1978) and M. Gutmann (1980) have sought to trace systematically the consequences of these three traditional scourges of mankind. Their work nicely complements that of climate historians in this specific way: the latter are ordinarily most interested in the immediate impact of a climatic event, usually a biosphere impact. The later second- and third-order impacts on the economy, society and political life are assumed to exist but rarely are followed in any detail. The historians of subsistence crises, on the other hand, ordinarily are content simply to assume that climate plays some unspecified role in bringing about crop failure, and perhaps, higher morbidity, but they have attained greater specificity in tracing these biosphere factors in demographic, economic and social life. This has been achieved by focusing on geographically restricted areas, such as a village, or cluster of villages, and by compiling detailed quantitative evidence on local socioeconomic life.

In general, these crises are seen as the product of interaction between external forces (war, epidemic disease, and high food prices—the latter itself the product of weather and/or external market forces) and internal structures, most notably the local economy, the demographic structure and the social organization. The nature of crop specialization and the transportation system, the function of church and local government in regulating distribution, the inheritance customs, and the compensatory demographic behavior of the population are among the factors woven into the historian's accounts of societal responses to periods of stress.

The consensus of these studies of subsistence crises is to reject the notion that catastrophe follows unavoidably upon the appearance of one of the external stress factors. Goubert (1973) states:

> The true demographic crisis, as studied principally in northern, eastern, and central France, where the population is densest and grain is the standard crop, stems from a series of climatic accidents (usually high summer rainfall) *in a given socio-economic context.* (p. 38) [Emphasis added]

Gutmann observed that the great catastrophes of early modern Europe took place when warfare, harvest failure, and epidemic disease occurred in combination. For the rural villages around the Belgian city of Liège, which he studied in detail, Gutmann (1980) concluded that:

> Bad weather [by itself] might produce a year or two of difficulties, and a few years of recovery, but [it] could not turn around the region's generally favorable economic and demographic climate. The dynamic mixed economy of the region ... probably explains this phenomenon. A bad harvest caused by bad weather might tip the balance in a locale with a poor or single-product economy; it could not do so in the Basse-Meuse [the region of Gutmann's study]. (p.199)

These historical studies of stress periods agree on two things. First, the really lethal crises combined bad

weather with war or epidemics; second, the severity of the crisis depended to a large extent on the socioeconomic characteristics of the locale. Goubert found the severe weather conditions of the 1690s to hasten the destruction of the small farmers in the monocultural villages of northern France; Gutmann found no lasting negative effects in the mixed-farming villages near Liège.

11.3.4 Cycles

Even when periods of climatic stress, studied in isolation, are found to impose problems that are well within the capacity of the social and economic institutions to absorb, it remains possible that their recurrence in a more-or-less patterned way can impose a rhythm, or cyclical process, on a society. Interest in such climate impact goes back at least to the late nineteenth century when the British economist W. Stanley Jevons (1884) sought to link business cycles to the 11-year sunspot cycle. More recently both Pfister and Post have maintained that the climatic fluctuations they have studied in such detail possessed an added importance as generators of economic and demographic cycles (Pfister, 1975, 190; Post, 1977, 267). Goubert, too, was stuck by the recurrence of subsistence crises about once every generation in seventeenth- and eighteenth-century France. But he attributed this more to the rhythm of demographic recovery and renewed population pressure than to any pattern of climatic fluctuation (that is, to scenario D rather than B or C in Figure 11.1). This reminds us of the need to place climatic variables in their historical context, preferably in well-specified models. It is also worth bearing in mind that in a society where `normal' climate variability produces an average of one failure in every four harvests, chance alone will generate *katastrophenketten* of two harvest failures in succession on average once every 16 years, and of three successive failures every 64 years.

In our current state of knowledge, it seems prudent to recommend that investigations of the part played by climatic variation in feeding conjunctional patterns should emphasize their random and exogenous character. Indeed, a widely held view among economists is that cyclical processes are essentially statistical artifacts generated by the cumulative effects of random shocks to the economy (de Vries, 1980).

11.3.5 Climate Change

The study of the short- and medium-term consequences of extreme climate events is by no means a new interest of the historian. Rather, it is a traditional theme that is now being pursued with greater analytical sophistication. When we turn to the issue of the historical consequences of long-term climate change, we enter an area that was long *terra incognita* and is now just beginning to be explored. Elsewhere (de Vries, 1980) I surveyed the historical research and speculation in this field, concluding that:

> Historians are psychologically ready, even eager, for the rise of climate change as a vehicle of long-term historical explanation, but do not possess the means of distinguishing its impact from among the many other variables at work on human society. (p. 624)

This statement suggests that the key obstacle to progress is methodological. Indeed, the challenge of

isolating the climate factor from the many at work on a society is daunting. But the prospects for progress in this difficult area depend at least as much on asking the right questions. Once this is achieved, a rigorous and ingenious use of existing social theory and statistical techniques can serve to advance our understanding of climate–society interaction.

Here, once again, we must begin with the question of perception. The response, if any, of a society to climate change must be predicated on some system of gathering, storing and assessing information about the environment. Only when such activities are entirely absent can one realistically utilize climate impact models. In all other cases long-term climate change involves a population in the process of decision-making under conditions of uncertainty. Specifically, decision-makers must calculate changes in the underlying probability of an adverse event (such as crop failure) on the basis of incomplete evidence.

The historian's *ex post* knowledge of changes in the frequency of extreme events may be superior to that of the decision-maker, but he must go further to relate that knowledge to the society with which the climate comes in contact. Questions need to be asked about the vulnerability, or sensitivity, of social and economic arrangements to climatic variation. The analyst of climate–society interaction cannot assume `society' to be a constant any more than he can assume constancy in climate. In the long run, technological and institutional changes can alter the society's sensitivity to climate events even in the absence of real climate change. Among the factors that play a major role in altering vulnerability are transportation, storage and distribution systems, the crop-mix of agriculture, the degree of market integration, and the availability of insurance or cooperative practices. Both of the last two features influence the way the risk of loss due to climate is distributed among social classes and over larger or smaller populations of producers.

Examples of technical changes in the past that broadened or narrowed the band of tolerance are numerous: the replacement of oxen by horses as draught animals improved the chances for a good harvest by reducing the time required for plowing and planting (White, 1962). On the other hand, the replacement of bread grains by potatoes in the European diet increased the caloric output per unit of land but exposed society to crisis in the event of even a single year of crop failure because potatoes could not be stored from one harvest year to another (Mokyr, 1983). A systematic assembly of such information can lay the foundation for a long-term `history of risk' that could shed light on many aspects of economic and political, as well as climate, history.

This brings us to the third type of question that can shed light on the process of long-term climate change. Besides *perception* of change, and *vulnerability* to climatic variation, we need to ask questions about societal *adaptation* to change. Here the main issue is likely to be how exposure to risk is minimized or diffused. The social unit that bears risk can vary from the individual producer to society at large. Similarly, the individual's response to an increased risk exposure can vary along three dimensions: *production changes* that alter the catastrophe threshold (for example, safety-first farming strategies), *political initiatives* that shift or spread risk to others, and *abandonment* of the risky activity, perhaps accompanied by migration. On the first type of response, see Jodha and Mascarenhas, Chapter 17 of this volume, and de Vries (1980, 626–629); on the second, see Warrick and Bowden (1979) and Bowden *et*

al. (1981, 494-508); on the third, see Parry, Chapter 14 of this volume, and Parry (1978). Here it should be noted that the analysis of marginal areas, where the adaptation choices of the decision-maker are restricted to a `yes or no' decision, is but the exposed tip of the iceberg of adaptations to climate change. Just as the pursuit of physical events through their biological, economic and political consequences involves the researcher in a `cascade of uncertainty' (see Kates, Chapter 1), so the pursuit of adaptations to climate change from marginal, to recently settled, to non-marginal, to long-settled areas involves the researcher in a `cascade of subtlety'. This difficulty can be avoided only by focusing on cases where a limiting factor enforces a yes–no decision in place of the more general situation where marginal adjustments are possible. Besides the geographical limitations exploited in the study of arable farming at high elevations or at the northern margin of cultivation, other such limiting factors can be identified in sectoral studies of specific economic activities such as fishing and rainfall-sensitive crop production.

In the analysis of all three types of questions discussed above it is important to bear in mind the dynamic character of long-run adjustment processes. Changes in perception and vulnerability and efforts at adaptation almost always occur incrementally. Their cumulative result in the long run can be unexpected and even unintended. The drilling of deeper wells to alleviate drought can intensify aridity in the long run; the assumption by a state of the risk of producing in a marginal area can expose the entire society to loss if the chance of crop failure rises permanently to a higher level. The narrowing of the genetic base of crop seed can reduce vulnerability to *present* climate while increasing the vulnerability to climate *change*.

Historical studies can advise contemporary policy-making in a tangible way by calling attention to the typically dynamic process of climate-society interaction. Society adapts to long-term natural processes via a succession of short-term responses, some of whose ultimate consequences are either unforeseen or incorrectly assessed. Part of the resulting policy failure is simply the product of incomplete information; another part flows from the discrepancy in the durations required for perception of change, for implementing various types of adaptation, and for feeling the effects of the changed practices.

In view of the insight of `Annales school' historians that society is always waist-deep in routine and semi-immobilized by a combination of external, `objective' constraints and internal, self-imposed limitations (Le Roy Ladurie, 1977; Braudel,1977), we can expect the duration required to perceive a need for adaptation to be substantial, giving rise to discontinuous, `jerky' responses. These might be triggered by multiyear stress periods that are themselves only incidental to a long-term climate change. In other words, societal responses might be to something other than a long-term natural process, giving rise to a chain of discrete, possibly contradictory, adjustments.

11.4 CONCLUSION

The techniques of analyzing historical climate–society interaction are numerous, drawn as they are from existing social theory and statistics. Their fruitful use depends on the formulation of strategic questions that capture the dynamic quality of historical change. I argue here that these questions should focus primarily on the process of decision-making in a probabilistic framework, in particular on decisions

concerning the control and distribution of risk. It is not the spectacle of catastrophe that should be the primary object of interest.

The success of historical investigation also requires the acquisition of sufficient knowledge of the time and place being studied to enable specification of causal models of climate–society interaction. In the absence of such initial groundwork, statistical measures of association and narrative identifications of space/time contemporaneity cannot safely be interpreted. It follows that the larger the scope of the investigation, the more difficult it is to achieve a sufficient level of specificity in the causal models as well as in the record of climate variation itself. The prospects for success in historical research are far greater when the scope is restricted to small areas and/or individual sectors of socioeconomic life, such as Lee's analysis of fertility and mortality (1981), Parry's study of the Lammermuir Hills of Scotland (1978), or my investigation of dairy production in Holland (de Vries,1977). Hope exists for an advance in understanding via an aggregation of such studies; this cannot be said for a frontal attack on the question `what was the impact of the Little Ice Age in Europe?'

Finally, it bears repetition that the pursuit of the `climate element' should be integrated into the larger historical context. Climate change should not be treated as an *alternative* explanation of history, but as an *additional* explanatory factor. Indeed, the numerous ways that societies have dealt with—or failed to deal with—climatic stress requires that the climatic factor be placed in the fullest possible historical context.

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