The History of Rain and Fine Weather[1]

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In recent years, methods in climatic history have undergone some significant and highly interesting developments. Before saying something about them however, I should like to begin by recalling some of the best known of the various techniques employed in historical writings on climate, as applied to the last thousand years.

1. Concerning the latter part of this period—the last two centuries—the climate historian's task is, quite simply, to collate, verify, tabulate and publish basic series of meteorological observations. From the eighteenth century and the early years of the nineteenth onward, such records are in fact quite plentiful. As a model in this respect one may refer to the series of temperature readings for England and Holland for the last three centuries given by Gordon Manley and the Dutch researchers in this field.[2] The advantage of having thermometric series from neighbouring regions is that they can be checked for their mutual correlation: consequently, whenever any new records are discovered, they can be tested for correlations and their reliability can be established. Then, once one has an indication of the overall picture, the series enable the historian to detect on a regional, national, or even European scale, any intermittent fluctuations of temperature, tending towards warmer or colder weather which may have lasted chronologically a decade, a number of decades or even a century. And bearing in mind future research, we should not forget that in addition to such temperature records, there also exist early series of rainfall and barometric pressure records for the nineteenth century, and some even for the eighteenth century. Although often

less reliable than the records of temperature, they are nevertheless extremely valuable for defining the weather patterns and atmospheric conditions of the past. Huge numbers of valuable dossiers of this kind still lie buried away, even today, in the archives of observatories, medical and provincial academies, and learned societies.
2. For periods earlier than the eighteenth century, dendrochronology (the study of the growth-rings of trees) produces knowledge of the first importance on the subject of drought in arid or sub-tropical countries; on rainfall in temperate zones; and on cold conditions in northern lands. In the present article, we shall be concerned principally with the fluctuations of these three phenomena.
3. Phenology, the study of the annual dates of the flowering and fruiting of plants, has so far related exclusively to a series of documents almost unique of its kind: the wine-harvest dates (*vendanges*) registered in the archives. From these we may learn whether the March-September period in any given year was, on average, 'warm' or 'cool'.Whenever we have a series of such dates for an area or group of areas, they shed light on the temperature fluctuations from one year to the next, or one decade to the next—though not as yet from one century to the next.[3]
4. The '*événementiel*' (recorded events) method relies on the painstaking accumulation of empirical and qualitative observations of climatic conditions recorded at the time by contemporary witnesses in private correspondence, family diaries, parish registers, etc. John Titow gave us a model of the method in 1960, in his impressive article on the climate of England in the fourteenth century (*Economic History Review*) and we also have the 1949 publication by D.J. Schove[4] of a comprehensive study of the climatic fluctuations of sixteenth-century Europe and of the progressive cooling of the winters from 1540–1560 to 1600.
5. The glaciological method was recently demonstrated by J. Grove à propos of Norway in the seventeenth and eighteenth centuries (see his article in *Arctic and Alpine Research*, 1972). This method involves a combination of different types of research: analysis of documents (the Chamonix archives; the records of the sub-glacial farms of Norway; the Icelandic sagas); investigations calling on geomorphology (the study of moraines); palynology (the study of marshes and peat-bogs situated downstream of glaciers) and nuclear biology (the carbon 14 dating of the débris of trees left

behind in moraines or found rooted in rocky beds lately uncovered by retreating glaciers). These studies have made it possible to track the secular, sometimes multisecular ebb and flow of the glaciers and thanks to them we know the movements that have taken place in the ice-fields of Europe throughout the whole of the last thousand years; they offer an invaluable, if distorting, guide to weather pattern changes and in particular to changes of temperature.[5]

At this point however it seems to me essential to say a few words about the methodology, the fundamental aims even, that are associated with such techniques.

The *aim* of climatic history is not to explain human history, nor to offer simplistic accounts of this or that remarkable episode, (e.g., the crises of the fourteenth and the seventeenth centuries or the dramatic upturn of the eighteenth) not even when such episodes prompt us, with good reason, to reflect upon the great disasters of history. In the initial stages, its 'aim' is quite different. Essentially it is to produce a clear picture of the changing meteorological patterns of past ages, in the spirit of what Paul Veyne calls 'a cosmological history of nature'. True, this 'chronological cosmology', modestly limited to a study of regional climates, may serve as a discipline for future reference for a quite different and more ambitious project with human history as its object. The 'spin-off' of the history of the climate does indeed have a bearing on the chronology of famines and also, perhaps, of epidemics, but these are merely consequences derived from it. However important and even exciting they may be, they remain marginal. The historian of the climate should ignore the tactics of the moment. It seems to me that his strategy should be, first and foremost, to place himself in the front line, shoulder to shoulder in interdisciplinary collaboration with the natural scientists. And if, at the outset, they treat him as an intruder, a deserter from his own discipline with nothing of any value to impart, so much the worse for them. The historian should simply swallow the insult and carry on doing his best to get them to accept the specific contribution that he alone is able to make. Several years ago, Pierre Chaunu said that the first duty of the economic historian was in all modesty to supply the professional economist with his basic material. Similarly the climate historian's first duty is to supply the natural scientists—meteorologists, glaciologists, climatologists, geophysicists, etc., with archival material. The reasons for such a division of labour are obvious and unsensational: by his training (in palaeography, knowledge of Latin and above all mastery of the 'historian's craft') the professional historian alone has the key to certain types of data hidden away centuries ago in bundles of illegible old documents. Meteorologists have long ceased to be Latin scholars, let along—and who can blame them!—palaeographers or 'historiometricians'.

My second comment concerns the necessarily climatological background to all research conducted along these lines. Unless he is to confine himself to a bare recital of the variations of the climate of the past, the historian of rain and fine weather has a duty to work at his assignment primed with a complete understanding of the basic data relating to movements of air masses and atmospheric circulation. The general theories and syntheses relating to such data are well-known and are constantly under review. The latest and most uptodate account is by H.H. Lamb; (in 1970 I published a summary of this major work, but this should not be thought a substitute for consulting the original).[6]

These then are the essential presuppositions upon which, for the past fifteen years, my own investigations and those of several other researchers in the field of the recent history of the climate have been based. With these in mind I shall confine myself to pointing out the most recent developments, some of which are continuing along lines already referred to, others of which, on the contrary, are breaking entirely new ground. I shall also, in passing, note some of the most glaring gaps in our knowledge in the hope that one day new labourers in the field will come along and fill them.

1

With reference to the first method mentioned above—collecting, tabulating, constructing, putting into graphs and whenever necessary completing by informed extensions, some of the very early meteorological series—I have to say that recent results have not always reached the standard set by Gordon Manley in the 1950s with his series of British temperature readings for 1690 to 1955.[7] Since Manley the most impressive achievement remains that of von Rudloff (1967). In an important work almost unknown in France, the German meteorologist has, with the aid of dozens of previously published series, constructed a picture of the changing pattern of the climate of Europe from 1700 or 1750 up to the present day. The pattern has of course its characteristic phases: first, the little ice age; next, fluctuating, irregular rises of temperature after 1850 or 1900 of the order of one degree centigrade at the very most; lastly, the recent cooling down period since 1953–1955.[8] The merit of von Rudloff's book lies less, on the whole, in his definition of these broad phases, for that had been done before, than in his precise and subtly differentiated descriptions of them, with the seasonal changes clearly marked.

But we do not always see evidence, even when it is staring us in the face; even in the case when perspectives have been opened up for us elsewhere by Manley or Rudloff. As far as France is concerned. I shall therefore merely express a regret which at the same time shall be my own apology—*mea culpa*. Here in France, we are still waiting for someone to establish a reliable, annually numbered series of monthly temperatures running without interruption from the early eighteenth century up to the present day, an enterprise eminently possible thanks to the excellent archives of daily records preserved in the Paris Observatory and elsewhere. It would chiefly concern the northern half of the country, more precisely the Paris region and the north, where these series of old readings are the most plentiful. But our professional meteorologists are wholly engaged in the crushing task of providing a daily forecast of tomorrow's weather! They therefore have neither the opportunity nor the leisure to provide us with the information we need. Even M. Dettwiller[9] in his splendid book about the climate of Paris did not consider it appropriate to pursue his investigations further back than the nineteenth century. We can only hope therefore that one day a professional historian, or perhaps a team of experts drawn from various field, will undertake this truly long-range serial project.

While we wait for someone to produce these immensely long series of graphs, work has already begun on some vast documentary seams of meteorological data and is yielding interesting, if as yet incomplete, results. For instance, preserved in the Paris archives of the Academy of Medicine, are the findings of a weather survey—very topical and random as to method—which was the work of a team of observers, led by Vicq d'Azyr, covering the years from 1775 to 1790. It contains more than 150 series of daily meteorological observations drawn from the 'whole world' (of that time) but mostly from France.[10]

During the past few years, the use of the computer has made it possible to sift this enormous jumble of old papers and records, to

separate the wheat from the chaff, the good series from the bad. All those which are sufficiently long—covering more than four years—have been mutually correlated. Next, by means of a statistical test which is now normal practice in history and sociology, we were able to select, from the random heap, particular sets of series which produced a high correlation coefficient when matched regionally with their counterparts (above 0.80 and preferably above 0.90) over a great range of monthly data. The research team of the Sixth Section of the Ecole Pratique des Hautes Etudes, which has embarked on this investigation, has thus been able to eliminate or leave out of selection the series drawn from southern France: these are inadequate, poor in mutual correlation and appear to be the work of observers lacking in zeal, conscience or scruple. On the other hand, a certain number of local series emanating from the Paris region, from western France and especially from the extreme north of the country (Arras, Montdidier etc.) emerged triumphantly from the computer-statistical tests that we applied, with mutual correlation coefficients above 0.90. They were therefore retained for the 'follow-up studies' and thanks to them we have been able to lay the foundation for a thorough study of the climate of the last two decades of the Ancien Régime. By way of spin-off (cf. supra) this research has even produced a contribution which promises to add to our knowledge of the crises arising from crop surpluses that left their mark on the pre-revolutionary 'inter-cycle' previously described in the works of Ernest Labrousse. Our team has been able to show that, as far as their climatic aspect is concerned at least, the phenomena of over-production of wine and the correspondingly low prices revealed by Labrousse, were largely the result of a succession of warm years, and especially of hot springs and summers, around and after 1780. Similarly, study of the graphs makes abundantly clear the meteorological conditions which led up to the bad harvest of 1788, itself the cause of the '*Grande Peur*' and the social disorders of the spring and the critical summer of 1789. Notable among these conditions, of course, was the hailstorm of July 1788, which has long been common knowledge. But also—and this is a piece of information discovered by our team—the scorching of the grain just as it was on the point of ripening before the harvest of 1788; and earlier, in the autumn of 1787, rainstorms in the sowing season. All these items of evidence demonstrate the ineluctable element of chance which must be taken into account in any attempt to analyse the causes of the French Revolution.

2

Turning to the second discipline mentioned earlier—dendrochronology—it appears to me that the methodological advances that have quite recently become available to the historian, have taken two different directions. Firstly, the old formula or prescription of dendrologists of the past—as well-tried as it was unilateral—has now been superseded. It consisted, it will be remembered, of relating a dendrological series (taken for example from a particular variety of pinetree from some particular region of Arizona) to a climatic parameter, rainfall perhaps, or in certain circumstances aridity (the latter being associated both with precipitation—or rather the lack of it, and with evaporation caused by high temperature). Instead of this type of approach, which is both limited and subjective, present-day American dendrochronologists, Harold Fritts, for instance, prefer more universal and comprehensive methods. Currently and on into the future, their aim is to chart the annual or decennial growth of the conifers throughout an enormous continental area, such as the entire south-west of the United States. At the conclusion of this operation, they will have a chronological series of geographical charts—a film almost—each one of which will depict against a background of the territorial map, a network of isochronic forest-growth lines, strong or weak according to the region. By looking at this succession of maps one will be able to see, not only an 'episodic' but also a "spatialised" image of the successive changes of the climate and even of the ten-yearly movement of the air masses throughout the whole of the continental area under scrutiny. Harold Fritts has produced series of charts for vast regions, stretching from the present-day territory of San Francisco down to Los Angeles, that are extremely instructive in this respect. They reveal the succession of massive long-term waves of heat-drought or coolness-humidity which have by turns swept over the Pacific coast and the interior of the country, since the sixteenth century.

Secondly, Fritts no longer restricts his study to one single parameter (aridity in desert zones or perhaps summer temperature in Arctic forests); he is interested in the totality of weather patterns in any given year (with all their varied components of rainfall, temperature and seasonal changes); for this, total annual pattern is, in fact, statistically associated with 'an annual average tree-ring concomitant' thin, medium or thick. When it becomes possible to establish such a link between this or that 'weather pattern type' and this or that 'tree-ring type', the historian studies his graphs and can then compose a total history of the climate for any given region with all its complex fluctuations and temporal variations.[11]

This innovatorry dendrochronological methodology pioneered by the work of Harold Fritts, is specifically American. In Europe, we have not progressed so far—more is the pity, particularly when one thinks of the range of questions that might be raised, and solved, by research of this kind, questions that would be of interest not only in the abstract realms of diachronic cosmology, but also in matters of human history.

In the course of the last ten years or so however, European dendrochronology has turned up some new results which, in both subject matter and methodology, are not without interest. The most important studies in this field are those of Huber for the district of Hesse, and of Hollstein for the western areas of West Germany (the annual oak series, 820/1964 A.D.). Exemplary in its techniques of proof, the recent, final section of Hollstein's series is based on the study of some fifteen living trees, some a hundred years old, some older still. For his graphs of the earlier centuries ('modern', medieval or 'early-medieval') Hollstein has used dozens of timber samples taken from ancient beams, mainly from old buildings or historic monuments, some even from archaeological digs. After careful dating,[12] these samples have made it possible to extend far back chronologically into the past the German tree-ring series derived from living trees. Huber's researches, which were started more than thirty-five years ago, and subsequently Hollstein's, have drawn on hundreds of thousands of annual growth-rings and consequently, between them, the two authors have been able to reveal or to discover certain important episodes in the climatic history of western Europe. They have succeeded in brilliant style in confirming the existence of the *Sägesignatur* ('saw-tooth signature' or zigzag pattern) which had already been modestly hinted at in an earlier publication. During the eleven years from 1530 to 1541 in West Germany, in the Alps and in the Franco-Swiss Jura mountains, hot summer succeeded cool summer, and dry summer wet, in unvarying biennial sequence. This shows up both in the zigzag pattern of the graphs of old tree-rings and in the vintage dates in these parts of France and Switzerland, where the grape harvests between 1530 and 1541 alternated regularly between early and late. The biennial alternation that took place during these eleven very distinctive years also constitutes, when viewed over the long term, one of the very rare periods of, let us say, recurrence—one dare not call it rotation—which western meteorology has from time to time recorded, with approximate accuracy. But it is very seldom indeed that this 'biennial alternation' attains the clockwork regularity one finds on both sides of the Rhine throughout the 1530s.[13]

The 1530–1541 *Sägesignatur* thus provides a readily recognisable 'fingerprint' so the speak, making it possible (as a kind of bonus) to identify any timbers displaying it, whose age was previously unknown, as originating in the sixteenth century. Huber's and Hollstein's series have also made a great contribution in method and content to the historical study of both climate and agriculture. They have for example confirmed the very wet period in the years 1310–1320. During every season of most of the years in this decade, bad weather cast its shadow, with a number of incredibly heavy rainstorms. The excess of water rotted newly-sown seeds and ruined harvests; hence the great famines of 1315–1316. It also produced tree-rings that were unusually thick and luxuriant; (for of course trees indigenous to western Europe generally thrive on wet weather, differing in this respect from grains-crops, which are imports from the arid East and have never really become acclimatised to the leaden skies of the temperate continent). On all the German dendrochronological graphs the 1310 decade is therefore marked by a dome-shaped curve indicating thick rain-gorged tree-rings, thus providing a perfect example of the way in which wood and corn (or lack of corn) give proof of their complementary yet opposite histories.

Following the example of Huber and Hollstein, certain researchers on the other side of the Rhine are attempting to establish annual dendrological series in other regions of Germany to cover the last thousand years. (See for example the work in course of preparation by Mme. Siebenlist.) We must hope that on the model of the project initiated in Nancy by M. de Martin, the same will be done for France and in particular for our eastern provinces. Here it is always possible to make comparisons with the long German series which have the singular merit of existing and of being geographically extremely close; one might therefore expect some rapid progress and even the cutting of a few corners.

Finally, still on the subject of tree-rings, I must mention one last method, which it is important for the historian to know about, even if

he cannot employ it himself. It can provide him with a sensitive and precise image of the 'intraannual' climate of years and periods very remote in time. This latest method involves examination by microscope and X-rays of each growth-ring of a particular piece of wood with reference to a particular year. The growth and the dimensions of the cells which compose the tree-ring alter appreciably with the progress of the vegetative season, and also with the fluctuations, towards more wet, dry, hot or cold weather of the successive months and weeks of the year in question. It is therefore theoretically possible, thanks to the microscopic examination of the cells ranged in concentric 'beds', to obtain first-hand informaion on the climatic influences prevailing successively throughout the spring, summer and autumn of, say, the year 1284 or 1558, as it might be in Lorraine or in Würtemberg! It is only fair to say that studies along these lines (Fletcher's research in Oxford and Polge's in Nancy) have often reached the laboratory stage, but have seldom reached publication.[14]

One last word on dendrochronological methods. The compilation along the lines proposed by Huber and Hollstein of very long millennial or intermillennial series for Germany, France and Great Britain will render great service to the historians of the climate. But such series will be even more useful to archaeologists working on the medieval or early modern periods, who are interested in dating the timbers of old buildings, whether intact or in ruins. They will be able to date with absolute certainty oak beams forming part of any building they are examining. To do so, they will simply have to compare the growth-curves drawn from these beams with the outline of the master-diagram for the thousand-year history of all oak trees in the area under scrutiny, or in a neighbouring region. (Cf. on this point the study of houses in Lorraine which P. de Martin has proved, using this method, to date from the period of reconstruction following the Thirty Years War.)[15] The dendrochronological method thus appears to have a fundamental importance for chronological dating. On the other hand it is more marginal to the major preoccupations of historians of the climate.

3

However, the history of the wine-harvest dates remains central for our purpose. The perfecting of methods in this field, and the discovery by Madame Micheline Baulant of ad hoc archives in the Paris region have enabled us to extend further back in time the phenological series hitherto available to us. They could formerly be regarded as reliable from 1600 onwards. We now have reliable series dating from 1490–1500 onwards, throughout the sixteenth century. From a methodological point of view, it may be interesting to note how this 'reliability' was originally established. Mme. Baulant had discovered some fragmentary series of phenological documents, with many gaps and missing entries. These documents related to several series of wine-harvest dates from vineyards round Paris. Fortunately, as it happened, each of these series had its own specific gaps which could be filled in or estimated, thanks to data furnished by the other series in the Paris region. Companion series were also available for the sixteenth century in Burgundy, Franche-Comté and French Switzerland. They generally contained fewer gaps than the series mentioned above from the Ile-de-France. In the first phase of dealing with this 'hotch-potch', the most complete, or rather the least incomplete of the Paris region series (the records for Chartres, as it happens) was used as a standard of reference. The other Paris series were matched with it by making corrections where appropriate.[16] And now, from these various graphs, rectified or not, it became possible to construct an 'average' Parisian graph, more or less complete and without major gaps, a synthesis of all the basic series drawn from vineyards scattered around the capital. The next step was to compare this Paris graph with those for Burgundy, Franche-Comté and Switzerland, to see whether the curves matched. The result proved satisfactory—mutual compatibility of vintage date fluctuations: from year to year, within decades or over decades. On the basis of this satisfactory correlation it was considered legitimate to strike a balanced average of all the series mentioned above, from Lausanne to the Ile-de-France, with the result that we now have a unique comprehensive graph for the whole of the northern vineyards of France and Switzerland. Close study of the graph thus constructed proves that it has not been artificially distorted by any intrasecular tendency, towards either the advancing or the retarding of the wine harvest. Had any such tendency shown up, it would have been human in origin (we happen to know that in the seventeenth and eighteenth centuries, the Burgundy wine-growers—to give one example—put back their harvests, later and later, from one decade to the next and from one century to the next, in order to have grapes bursting with ripeness and yielding juice of very high sugar content which would convert in due course into a more alcoholic wine. This

retarding of the grape harvest to produce the 'noble rot' was practised increasingly from one century to another, so there can be no question of attaching any particular *climatic* significance to the lateness of the harvests as between centuries that appears on the Burgundy graphs from 1650 to 1780).

The new sixteenth-century graph, however, displays none of these 'human, all too human' symptoms. Interpreting the climate from it therefore becomes all the more exciting. Indeed it soon becomes apparent that it has much to tell us about the changes in the spring and summer temperatures *throughout the whole of the sixteenth century*, and not only about their short-term fluctuations; and , thank heaven, nothing at all about the personal idiosyncrasies of the wine-growers which in the circumstances, would be irrelevant to our purpose—the history of the climate. From this point of view, the most interesting conclusion to be drawn from this comprehensive document concerns the cooler nature of the spring-summer season during the second half of the century, especially from 1560 to 1600—a cooling process perfectly in accord with the substantial advance of the Alpine glaciers which were helped on their way by the absence of summer melting during this same period. Study of the vintage dates exhumed from the archives brings us to the same conclusion then as the documentary evidence from the Alps, long since gathered by the glaciologists—a genuine example to support the ideal of 'interdisciplinary research' so often praised in the abstract, so seldom realised in practice.

Meanwhile, back to our wines, in barrel and bottle. Bacchus, our patron deity in this respect, has an inexhaustible store of knowledge for us about the climate. Not only the wine-harvest dates, which historians from now on will have at their fingertips,[17] but also the quality of the wine, furnishes first-class documentary evidence of the weather patterns of past ages. Angot's statistical study of the subject suggests that in the case of our northern vineyards and also those of Germany, where the ration of sunshine is often insufficient for the grape the following maxim applies: good wine = hot summer, hot summer = good wine. The excellent post-war vintages (1947 for example) bear this out and meteorological series set against the wine connoisseurs' tables demonstrate it with remarkable accuracy. Conversely, in cold, cool or wet summers, for lack of sunshine the grapes wither or become watery before they have had time to ripen satisfactorily and to produce a sufficient quantity of sugar to yield a good degree of alcohol in due course; hence the very poor wines produced, for example, after the 1675 and 1968 grape harvests. Angot was a pioneer in this field, and drew attention to the remarkable possibilities that would be opened up by the systematic annual study of the quality of wines in recent centuries for the historiography of the summer climate. In 1895 he published an excellent annual series, covering several hundreds of years and relating to the changing qualities of Burgundy wines as far back as the seventeenth century. Unfortunately, after Angot, French historians missed a good opportunity. With their access to archives, they would have been well placed to take advantage of this method, but they have failed to pay any attention to the records of vintage qualities, good, bad or indifferent. In Germany, however, and in Luxemburg, Müller and Lahr respectively have established some remarkable series relating to the quality of the wine year by year, based on a number of vineyards situated near the Rhine, the Neckar, the Black Forest, etc. Von Rudloff has made use of these series to substantiate his history of the climate in the West from 1670 to the present. A few words on this topic might therefore not come amiss.

The various adjectives or epithets applied to the quality of German wines in this or that year ('acid', 'detestable', or 'delicious', 'extra-good', etc.) are more subjective and less precise, needless to say, than a wine-harvest date, which falls plumb on to a given point in a chronological table. It is nonetheless true that the Lahr-Müller method, however qualitative it might be, lends itself to the serial processing, dear to the *Annales* school of historians. Used in this way, it provides remarkable indications of climatic trends. Turning once again to the case of the sixteenth century (ever instructive and already several times referred to) I find that the *quality* of the wine can also, in its own fashion, tell us much about the secular trend. The years 1453–1552 taken en bloc, or decade by decade, were, on average, years of good German wines (which does not of course mean that certain individual years during this heaven-blessed century did not produce sour or tart wines). On the other hand (and here we have to make the opposite reservation) the five decades in Germany from 1553–1562 to 1593–1602 were, on average, characterised by bad vintages when the wine was sour.[18] The evidence of a century and more of series from the other side of the Rhine is all the more relevant in this connection since the German vineyards in question are typically marginal and northerly, and therefore extra sensitive, in

positive terms, to sunshine, which is rarely excessive and often deficient in this region. And it must be remembered that in those days there was no adding of sugar, or chemicals, to doctor failed wines or fake an acid wine into a *grand cru*. It appears quite clear then—and here we have corroboration from three different sources—that the evidence from the glaciers of the temporary cooling of the climate between 1500 and 1600 is borne out by the two available viticultural series—the wine-harvest dates and the quality of the wines (bad, in this case). The summers (and the springs) of the years 1553–1602 were decidedly less warm than those of the years 1452–1553. As a result the wine-harvests were late, the wine was bad and the glaciers increased in size, becoming dangerous even, so much so that in 1595–1605 they buried several villages in Chamonix and Grindelwald. Proof *a contrario* might be found for example in the frequently delicious wines of the 1860s and 1870s, and 1940–1953 in Germany and France, years when summer temperatures were at their highest for the nineteenth and twentieth centuries respectively.

We must hope, therefore, that the Müller-Lahr method will be tried out in France too, for France, according to a truism, useful to our purpose, has been the home of good wine ever since the Middle Ages. Our connoisseurs have kept faithful records, in note-books of every kind, of the good years and the bad, the delicious wines and the detestable. We must order these records into series better than Angot did almost a hundred years ago and then we must construct reliable, up-to-date graphs of the annual quality of the wines of Burgundy, Champagne and the Île-de-France since the sixteenth century. This will put into our hands a powerful research tool well able, in conjunction with other methods, to resolve many questions concerning the climate of the modern period.

4

I referred at the start of this article to the '*événementiel*' (recorded events) method historical study and its possibilities for regions such as ours where archives are plentiful. Recently, François Lebrun has greatly enlarged its scope in his book *La Mort et les hommes en Anjou aux XVIIe et XVIIIe siècles*. He has listed, for the province of Anjou, month by month and year by year, all the spells of hot and cold weather, wet and dry, with approximate indications of their intensity. His sources are parish registers, family diaries and other such documents. The final graphs and diagrams in the book, which present in visual form the results of Lebrun's research, consist of several strips of histograms in the lines of which one may read the illustrated history as it were of the climate of Anjou over a span of two centuries. Constructed as they are, these diagrams have made possible the formulation of a northern typology of events: famines in the seventeenth century and grain-crop deficiencies in the eighteenth, in which both of these phenomena—especially the first—are seen as expressions of the adverse meteorological conditions of the little ice age. Thanks to Lebrun, the climatic combinations most conducive to the onset of great famines are now known, and according to our author they are of two types:

a) *either*, the association (for one or several consecutive years) of *very cold winters and cool and wet springs and summers* (in other words, the most typical combination of the little ice age: cold winter + cool summer). This is apparently what happened in 1660 – 1661; 1692 – 1694; in 1709 to some extent; and lastly in 1740;
b) *or, a slightly more complex combination, consisting of a very wet and possibly mild winter, flooding the sowing season, and a wet and cold spring and summer.* In this case, only the spring and summer are typical of the little ice age pattern (a). As for the wet and possibly mild winter, it is more associated with another, somewhat different climatic pattern (b); in any case it has nothing icy about it. It was the association of (a) and (b) within this second combination that created (in 1630) and prolonged (in 1662) some of the great famines of the seventeenth century (and possibly the famines of the 1310 decade). This second type of association however, proves to be comparatively rare, as we can see from the infrequency, all things considered, of very great crises during the Classical Age.

In methodology, Lebrun's work is therefore doubly fruitful, serving both pure historical climatology and the history of catastrophes such as famines. But these Anjou-based studies and also the convergent studies in which De Martin has gathered together the meteorological data contained in the letters of Mme de Sévigné, will not take on their full significance[19] unless and until their results are eventually deposited in an 'archive bank' or a 'data bank'. In the vaults of such a bank, the series of information collected by this or that scholar could be combined with other series gathered by different authors, thus

constituting in the long run, a serial corpus of data relating to the climate. Such data would refer to a particular century, region, nation or continental area.

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To turn now to the glaciological method it is sometimes suggested that it may have served its turn. Certainly, many workable documents on the Alpine and Scandinavian glaciers have already been identified, published, tabulated, and serialised. Perhaps the time of diminishing returns has arrived. And yet, even in this area, splendid archival scoops are still possible; John Grove,[20] whose field of study is Scandinavia, has recently, thanks to the fiscal registers, brought to light fresh and precise knowledge of the destruction and impoverishment of the local farms caused by the looming glaciers in Norway, in the Jodestal range, between 1695 and 1750, and also, possibly, as long ago as 1340. In the Alps, any further discovery of new texts, by the standard methods of archive historians, would require a medievalist to delve into the municipal and ecclesiastical papers of Chamonix, so rich and, as yet, so little-known, as far as the fourteenth and fifteenth centuries, at least, are concerned. Again, in German-Switzerland, the absence of centralisation—in other respects beneficial—has meant that many deposits of archives remain intact and available, but scattered in the villages, cantons and bishoprics close to the great glacier systems (Grindelwald, Aletsch, Rhonegletscher, Allalin, etc.); genuine discoveries are therefore still possible in Switzerland even for the well-studied period of the 'little ice age' (1570–1850). Of course, the historian who undertakes this type of research would have to be not only a forager among old archives in the best Benedictine tradition, but also, to some extent, a geomorphologist capable of fieldwork on the spot. In any case, such a requirement should not daunt French historians, who have been academically trained from their apprentice days to meet the harsh demands of geography.

But the new breakthroughs of knowledge, in this particular territory of the history of the ice-fields, may come from two other methods based on techniques utterly different from those I have referred to or hinted at. Moreover, both methods will tear us away from our usual research haunts and transport us to that lost paradise of the history of the climate, situated somewhere in the approaches to the ice-fields of Greenland. The first of these two methods is specifically cartographical; it is also—to say the least—uncertain and debatable. We know that quite recently, thanks to the praiseworthy researches of the librarians of Yale University,[21] a new document, as controversial as it is unusual, has emerged to supplement the dossier of Scandinavian history—the sensational Vinland Map, compiled perhaps in the middle of the fifteenth century,[22] and thought to be possibly a representation in condensed form of the discoveries made by Scandinavian sailors in the course of their voyages during the tenth to the twelfth century. Contained in this map is a fairly accurate picture of the whole of the coastline of Greenland. As such (assuming of course that it is an authentic document) it might well be confirmation of Ivar Baardson's well-known chronology which subdivides into two periods:[23] in the first—from the late tenth to the end of the twelfth century—the southern half of the east coast of Greenland, to the latitude of the Gunnbjorn's Skerries[24] was relatively free of ice-floes, enabling navigators bound from Iceland to approach Greenland in a straight line from east to west; more generally, the Nordic settlers and sailors of this epoch—the 'mid-middle Ages'—are believed to have acquired an adequate knowledge—experimental and even quasi-cartographical—of the whole Greenland coastline, which is thought by some people to have found a distant echo in the Vinland Map.[25] Then, in the following phase (thirteenth to fourteenth century),[26] perhaps even as early as the twelfth century, the ice-floes drifted southward and blocked the former approach-routes to Greenland via the Gunbjorn's Skerries; they forced the Icelandic and Norwegian navigators making for Greenland to sail in a much more southerly line; consequently, circumnavigation of Greenland, if, that is, it had ever existed, ceased.

The attraction of such a periodisation is that it agrees with the recent discoveries of American and Danish researchers[27] in their studies of the medieval fluctuations in Greenland's climate as measured by the 'ice-cores'. But—is the Vinland Map genuine? G.R. Crone[28] contests it categorically: his scepticism should make us cautious and at the very least should prompt us to await new evidence. The very fact that the Vinland Map includes a drawing of the whole Greenland coastline constitutes an additional motive for Crone's mistrust! And on this point, he argues in an exactly contrary sense to Skelton, who was one of the 'discoverers' of the map. 'Another difficulty [of the Vinland Map]', writes G.R. Crone, 'is the apparent accuracy of the outline of Greenland, [which was] not circumnavigated until the nineteenth century. It is generally accepted that firstly, this great island could not have been circumnavigated at an early period despite a somewhat milder climate; secondly, that there seems to have been no motive for the Norsemen to have undertaken such a voyage; and thirdly, that the Norsemen did not use or make charts. It is possible that the map was reconstructed in or before 1448 from oral tradition and a study of the sagas, though even this hypothesis would not explain the Greenland outline.... For the present, it remains an enigma.'[29]

For the moment then, let us leave this enigma and, still on the subject of Greenland, turn to the certainties with which the practitioners of fossil-ice methodology have recently presented us. Their findings will furnish our second, most up-to-date approach in this field. What happened was that during the year 1966 an American research unit, the C.R.R.E.L. (Cold Region Research and Engineering Laboratory) succeeded in extracting an ice-core cut vertically through the entire thickness of the ice-field in a place called Camp Century (Greenland). The sample thus obtained measured 12 cm. in diameter... and 1,309 metres in length. The approximate age of the different sections from top to bottom of this thin column of ice was worked out by the C.R.R.E.L. scientists by means of a complex formula which takes into account the speed of accumulation of ice (35 cms. per annum) and the speed of its progressive compression under the weight of the upper layers. More than a thousand centuries of ice piled layer upon layer, right up to the present day, thus became available for systematic research. Dansgaard and others have undertaken the study of this immense ice-core sample.[30]

Evidence of this type is of obvious and essential interest for the history of the climate; in the oxygen isotope O 18, present in varying quantities in glacier ice, we have, in fact, a first-class indicator for the 'intra-glacial' exploration of the thermal conditions of past eras, since the concentration of O 18 in deposits of rain or snow (later to be 'deep frozen' in the polar ice-caps in the form of fossil-ice) is principally determined by the temperature at which the deposits in question were condensed: 'Decreasing temperature leads to decreasing content of O 18 in rain or snow; and vice versa.'

The Camp Century ice-sample indicates, firstly, at the very top of the slender column (in the most recently formed layers) high concentrations of O 18. They correspond to the well-marked climatic optimum of the years 1920–1930. Then, when we dig deeper into the ice bed at Camp Century, below the recent high temperature years

(1900–1950), we reach, and find characteristically poor in O 18, the levels of the 'little ice age'; broadly speaking this age extends from the thirteenth to the nineteenth century, during which time there were three main cold waves, the first occurring between 1160 and 1300. It was followed, not without interruptions, by a moderate remission, not too icy (1310–1480). Then the lowest depths of cold, of which there had been intimations as early as the sixteenth century, duly arrived in the seventeenth century, and again from 1820 to 1850. In contrast, the eighteenth century (1730–1800) appears as a well-defined if temporary period of rising temperatures.

Of course, this periodisation is neither definitive nor fixed once and for all. Other ice-cores from other ice-fields will be studied: they will correct or define this chronology more precisely. The important point is that through all the centuries-long fluctuations, corresponding to 'cycles' of very approximately one hundred and twenty years, the great cold periods marked in the Alps by the forward movements of the glaciers in the thirteenth, seventeenth and nineteenth centuries, are found once more, precisely located in time, in Greenland; and this despite the considerable differences resulting from the geographical distance between the European continent and the sub-continent of Greenland.

And then, penetrating still deeper into the layers of ice, the Camp Century diagram eventually arrives at the warm indices of the 'little optimum' of the Early Middle Ages! Abruptly, in the five centuries preceding 1125 A.D. (from, say, 610 to 1125 A.D.) the graph rises and levels out; throughout this period the O 18 concentration remains constantly greater than it will ever be during the icy centuries which mark the 'little ice age' (thirteenth to nineteenth centuries). This Early Middle Ages richness in O 18 clearly emphasizes the continuity of a phase of rising temperatures which persisted with sustained intensity for a period of some five hundred years (seventh to eleventh centuries). The Norsemen benefited,[31] there can be no doubt about it, from the opportunities offered them at this time by certain of the Arctic coasts which were freer of ice than usual. They vied with one another in making landfalls on the marginal lands of the kingdoms of Thule. The colonisation of Iceland in the ninth century, of Greenland in the tenth century—the former possibly, the latter certainly—benefited from this climatic bonus. In the 'favourable' period which extends from 610 to 1185 A.D., two thermal maxima stand out quite distinctly on the Camp Century graph, one during the last thirty

years of the tenth century, the other during the first quarter of the twelfth century. We meet with nothing equivalent until very much later, until the peaks of warmth in Greenland which occurred at the very end of the eighteenth century (1780–1800); and above all in the recent optimum (1920–1930). It will be apparent that the two Early Middle Ages high peaks of the 'little optimum' in Greenland coincide in an interesting manner with two critical episodes in the Arctic sub-continent. From 978 to 986, first Snaebjorn Galti, then Erik the Red, profited from the relatively ice-free seas to strike due west from Iceland to reach Greenland on the latitude of the Gunnbjorn's Skerries. From there Erik went towards the south of the great island where he created, at the same time as the *Eastern settlement*, his great Brattahlid farm.[32] Two and a half centuries later, at the height of the climatic and demographic fortune of this ultra-north settlement, a Greenland bishopric was founded at Gardar[33] in 1126.

The great Camp Century ice-core thus confirms the patient researches of the Danish archaeologists who had, as early as 1925, first suspected and subsequently demonstrated the existence of a medieval 'little optimum' in Greenland.

Furthermore, if we reach further back still into the past, the immense C.R.R.E.L. ice-core clarifies and confirms many other important episodes: thus the maximum of the Alpine glaciers, shown by the Fernau peat-bog to have occurred at an indeterminate data somewhere between 400 and 750 A.D., now has its probable equivalent in Greenland, with the cold episode registered by the Camp Century ice-core between 340 and 620 A.D. As with the 'little ice age' of 1580 to 1850, the probability is that this was an intercontinental phenomenon affecting at least Europe and America. Indeed, John Mercer in his important article, *Glacier variations in Patagonia* (1965),[34] notes that, according to carbon 14 dating, the glaciers of the American continent (Alaska and Patagonia) were showing signs of forward movement as early as 250 A.D. and reached their maximum about 450 A.D. If we go further back still[35] to the beginning of the first millennium A.D. (50 B.C.–200 A.D.), we see that the Camp Century graph strongly emphasises the extent of the sub-Atlantic fall in temperature which lasted throughout the last millennium B.C. (the coldest period occurring between 500 and 100 B.C.). Here again, Mercer's analysis generalises this conclusion; the entire complex of glaciers, not only in Greenland but also in the Alps, in Iceland, in Sweden, in New Zealand and in Patagonia—the latter magnificently dated—took a great leap forward between 500 B.C. and 300 B.C. to greet the coldest point of the sub-Atlantic temperature drop.[36]

Last but not least, the Camp Century ice-core definitively confirms the existence of the climatic optimum in prehistoric times. In Greenland, this reached its maximum temperatures between 5200 B.C. and 2200 B.C., and more precisely between 4000 B.C. and 2300 B.C.. So the fourth millennium before the Christian era (4000–3000 B.C.) in Europe as in Greenland, did indeed bring the 'thousands years of sunshine' that the pollen graphs of the northern countries had long been indicating.

The prodigious 'memory' of the polar ice-cap is thus able to preserve, thanks to O 18, a 'record of the fluctuations of the climate' from the great ice ages[37] to the very recent temperature rise.

Oxygen O 18 has helped us in other ways too: it has offered climatic history research an additional promising method. In 1967, Labeyrie and his colleagues[38] analysed the variations affecting the O 18 content of Calcium carbonate ($CaCO_3$) which is present in the different concentric rings of a white stalagmite of very pure calcite discovered in Aven d'Orgnac (Ardèche). The stalagmite is nearly seven thousand years old. The variations in O 18 content (v. supra) indicate changes in the ambient temperature of the cave. The results were as follows:

Tenth century A.D.	12.1 degress C
circa 1150 A.D.	11.5 degrees C
circa 1450	11.0 degrees C
circa 1750–1800	12.3 degrees C
circa 1940	11.7 degrees C

With the customary reservations as to the very limited and preliminary nature of these results, Aven d'Orgnac would appear therefore to testify to optima in the year 1000, and in the eighteenth and twentieth centuries; and to a Late Medieval drop in temperature around 1450. Unfortunately Labeyrie gives no figures for the seventeenth century which saw the culmination of the 'little ice-age'. But his pioneering work in this direction has opened up possibilities for further research which may well be taken up by historians.

To conclude this brief account of the recent and varied methods employed in the history of the climate with a general proposition, let

me say that, in view of these very varied techniques, some of which can be regarded as traditional historical methods interpreted along new lines, and others of which, initially at least, are foreign to the orthodox procedures of history, one guiding principle stand out: as far as the Christian era is concerned, the only road towards a convincing history of the climate is by way of interdisciplinary and comparative research. From the study of the ice-fields to the study of the wine-harvests, from Oxygen O 18 to tree-rings, from the medieval chronicles to accurate thermometric readings, diachronic meteorology testifies in many different voices to the profound unity (despite diversity in method) of the knowledge it imparts.

NOTES

For a more complete bibliography and further information the reader is advised to consult my book *Times of Feast, Times of Famine: A History of Climate Since the Year 1,000*, New York, 1971, and London, 1973. This book is the English edition of my work *Histoire du Climat depuis l'an mil*, Paris, 1967, much added to, corrected and brought up to date.

1. This article was first published in a collection of essays under the title *L'Histoire nouvelle et ses méthodes*, edited by Jacques Le Goff and Pierre Nora Paris, 1973.
2. See Manley and Labrijn (except where expressly indicated, the foot notes refer to the detailed bibliography to be found at the end of this article).
3. Angot, 1883, Le Roy Ladurie, 1967 and 1971.
4. Titow, 1960 and 1970.
   Schove, 1949.
5. Le Roy Ladurie op. cit.
6. Le Roy Ladurie., 1970; and especially H. Lamb, 1966.
7. G. Manley, article in *Quarterly Journal of the Roy. Met. Soc.*, 1946 and 1953. pp. 242–252 and p. 358, and in *Archiv fur Met Geophys. und Biokhmatol.*, 1959.
8. H. von Rudloff, *Die Schwankungen und Pendelungen des Klimas in Europa seit dem Beginn der regelmassigen Instrumenten Beobachtungen*. Brunswick (Vieweg, edn.), 1967. See also the long resume of this book I published in *Annales*, Sept. 1970.
9. J. Dettwiller, *Evolution séculaire du climat de Paris....* *Memorial de la Met nat.*, no. 52, Paris, 1970.
10. See the inquiry into these archives by the author and others in the collection of essays *Climat, médecins, épidémies*, Mouton, 1972.
11. H.C. Fritts, 'The Relation of Growth Rings in American Beech and White Oak to Variation in Climate', in *Tree-ring Bulletin*, 1961–62, vol. 25, 1–2; pp. 2–10. 'Tree-ring Evidence for Climatic Changes in Western North America', in *Monthly*