Archives and the Environmental Scientist

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> Visionary power
> Attends the motions of the viewless winds,
> Embodied in the mystery of words. . . .
> (William Wordsworth, *The Prelude*)

Archives have long ceased being the nearly exclusive domain of historians and genealogists. For several decades archival resources have attracted an increasing number and variety of social scientists and, more recently, those concerned with reconstructing past physical environments. This interest of environmental scientists in archival evidence has been prompted by advances in scientific methodology and by such recent concerns as the Malthusian threat of global overpopulation, rapid resource depletion, and the spectre of environmental deterioration. The implications of these conditions have added urgency to the need to elucidate further the nature of environmental change and, ultimately, to predict its course.

In the environmental sciences, prediction is empirical rather than theoretical, largely conducted by projecting past trends and relationships into the future. Since the scientific record of past environments is meagre, however, alternative sources of evidence are essential and, among them, various archival resources offer significant potential for probing the historical past. Nowhere is this more apparent than in climatology in which for several decades there has been imaginative use of historical evidence for studying past climates. Documents have played a useful role in reconstructing past biological and hydrological environments, and changes in these environments have in turn been used as valid indicators of climatic change. For example, various fauna and flora, as well as hydrological features and events, are sensitive as phenological indicators; historical descriptions of their changing characteristics can provide important evidence of climatic change over time.

Scholars in the humanities and social sciences, like their colleagues in the environmental sciences, are displaying an increased interest in the environmental past and for many of the same reasons. Although long concerned with the impact of environmental forces upon man, they have increasingly come to study man as an active, and often destructive, agent of environmental change. Some recent scholarly literature shows that these two interests have fostered a desire

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to re-examine the full spectrum of man's changing interrelations with his biophysical milieu. For example, Nash has advocated an environmental history involving not only descriptions of past environments, but also studies of the environment "as evidence of man's values, ideals, ambitions and fears."[1] More specifically, Post has called for the development of a meteorological historiography,[2] while Tuan has sought new insights into the man/land relationship in his study of the affective bonds between peoples and places, or topophilia.[3] Rather more ambitiously, Le Roy Ladurie has proposed an environmental methodology for historians that would lead ultimately to an ecological history concerned not only with the impact of environment upon man, but also with man's role as an active agent in the environment.[4]

Whatever their intent, all historical studies that share a common interest in the environment depend in varying degree upon the availability of accurate information about the nature of the environmental past. This paper examines broadly the kinds of research that have been done by climatologists employing archival sources and outlines a case study of the freezing and breaking of river estuaries on Hudson Bay based upon historical descriptions of these events. It demonstrates how scientific information can be derived from documentary evidence and, by implication, indicates the kinds of historical records that are most valuable for scientific investigation and therefore worthy of preservation in archives. The paper also deals with certain problems of interpreting different types of documentary sources, thereby illustrating the strengths and limitations of this evidence for climatologists, historians and other scholars concerned with the environmental past.

For the most part, the evidence employed by the environmental scientist is composed of standardized observations whose accuracy and sensitivity have been judged by the scientific community as sufficient to measure changes in the processes or phenomena under investigation. Records of this nature can be readily analyzed, but most research into the historical period does not have scientific measures of this sort available. Climatology is no exception, for the records of weather stations from which standardized observations derive span a time period which is extremely brief when compared to the time intervals over which major environmental changes occur. Before turning to the different types of written evidence which may be consulted in archives, it is useful to consider first the circumstances that have caused the climatologist to resort to sources which initially appear to be unscientific and far removed from more familiar types of evidence.

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1 Roderick Nash, "American Environmental History: A New Teaching Frontier," *Pacific Historical Review* 41 (1972): 363.

2 John D. Post, "Meteorological Historiography," *Journal of Interdisciplinary History* 3 (1973): 721-32.

3 Yi-Fu Tuan, *Topophilia: A Study of Environmental Perception, Attitudes, and Values* (Englewood Cliffs, 1974).

4 Emmanuel Le Roy Ladurie, *Times of Feast, Times of Famine: A History of Climate Since the Year 1000*, trans. Barbara Bray (London, 1972), pp. 7-22.

THE PLACE OF HISTORICAL EVIDENCE

Although the earliest instrumental weather observations were made in the medieval period and continuous records can be established for regions of Europe since the late seventeenth century,[5] standardized observations commenced sporadically in Europe only in the mid-nineteenth century. In fact, the development of a global network of scientifically reliable observations awaited the advent of aviation, and for large parts of the earth's surface acceptable weather observations span but several decades save in the most favoured areas where they might extend through a century (figure 1). The study of climatic and related environmental changes is often concerned with events which have occurred through intervals vastly greater than the period of instrumental record.[6] Therefore, indirect evidence of these changes must be used, the diversity of which is suggested in the simple classification represented in figure 2.

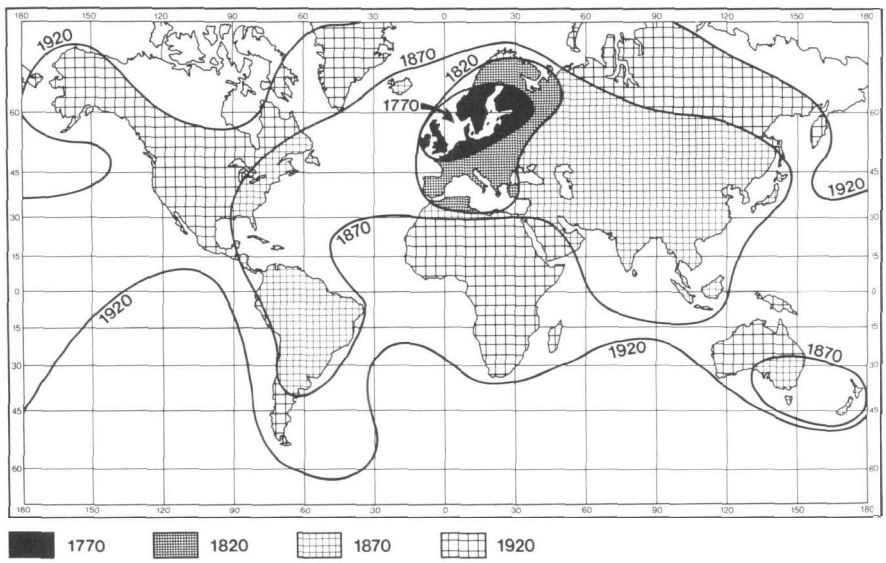

Fig. 1. *Global distributions of instrumental weather observations at fifty-year intervals since 1770. This is based upon the distribution of barometers, but the patterns of temperature and rainfall measurements do not differ fundamentally from those of pressure (based on data contained in: H.H. Lamb and A.I. Johnson "Secular Variations of the Atmospheric Circulation Since 1750,"* Geophysical Memoirs *14, no. 110 [1965].)*

5 H.H. Lamb, "Reconstructing the Climatic Patterns of the Historical Past," *Endeavour* 33, no. 118 (1974): 40-47.

6 For instance, the scientist seeking to describe and explain the major episodes of glaciation may extend his climatic studies over the whole 4.5 billion years of the earth's history, or he may focus upon the 3 million years of the present glacial period. Even if the study were confined to the last period of major climatic change in Canada—the millenia from the most recent maximum ice development to the present—the time frame will cover eighteen thousand years. Within this period, moreover, there was a general amelioration of climate punctuated by many singular episodes lasting centuries and millenia that must be described and explained. The last of the major post-glacial episodes of climatic change, the so-called Little Ice Age of relative cold and wetness, commenced in the sixteenth century, reached its most severe state in the eigh-

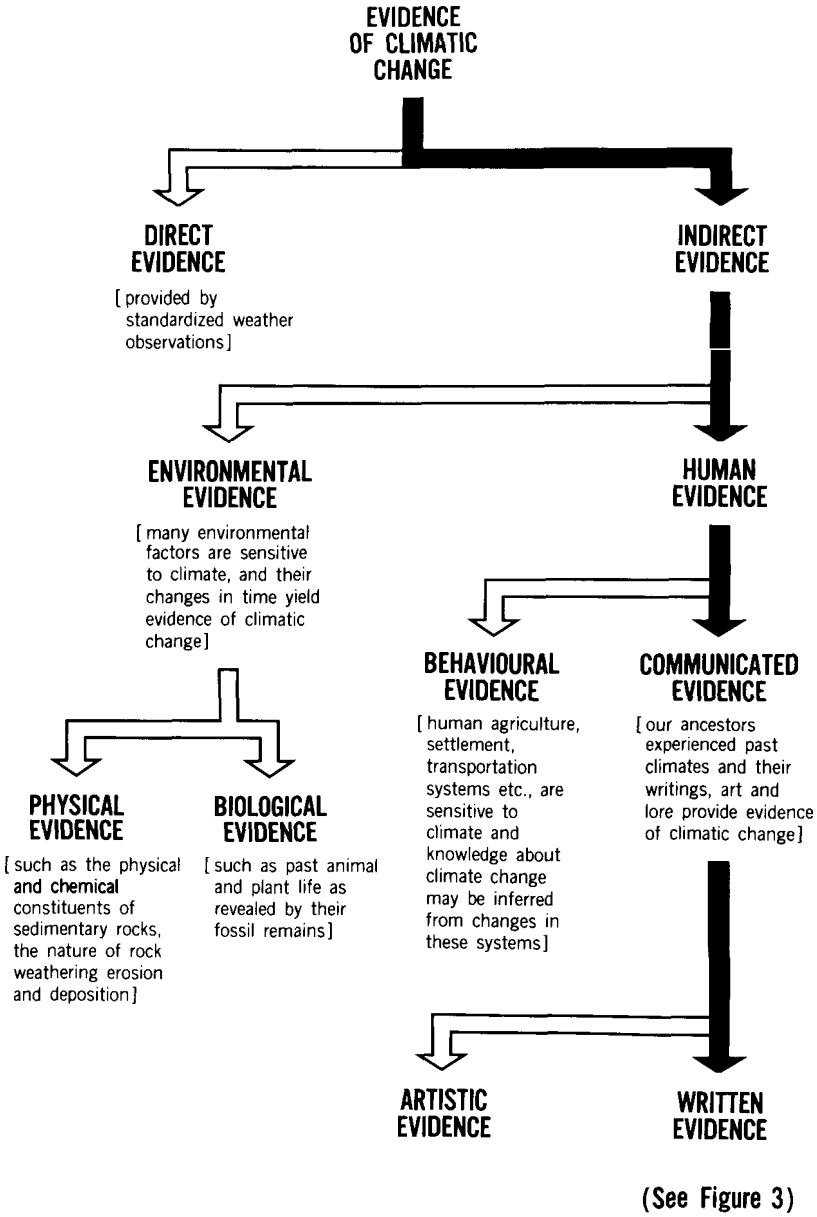

Fig. 2. *General classification of types of evidence of climatic change.*

Just as instrumental observations are very limited in temporal duration, so also human evidence spans a relatively small part of the time period that con-

teenth century and terminated by the middle of the nineteenth. Obviously non-instrumental evidence must be explored to extend our knowledge of climatic change throughout most of the globe prior to the late nineteenth century.

cerns the climatologist. Communicated evidence is particularly restricted since it becomes available only after the development of man's ability to describe his observations in art and in writing. At the extreme limit, communicated evidence is available during the six thousand years following the development of writing in Mesopotamia, or through tens of thousands of years if the information contained in cave paintings is included. But in much of the Old World this evidence is confined to the last one or two millenia and, in the New World, its availability is measured in centuries.

The temporal limits of communicated human evidence raise the serious question whether the information in archives can add to that which will be known from the instrumental (direct) evidence, and from the physical and biological environmental (indirect) evidence. However, it should be stressed that the utility of a type of evidence depends not only on its distribution in time and space, but also upon its sensitivity. Many types of environmental evidence can give only a rough idea of climatic differences between millenia, centuries or decades. The written record, by contrast, can discriminate between years, months, and even days giving a very detailed picture of climatic change. In short, such documentary records as journals and diaries kept at daily intervals, can yield information as sensitive as instrumental weather observations, and their accuracy may be comparable to that of modern scientific records.

The importance of communicated human evidence is further established by the prevailing concern with present climatic trends and those of the immediate future. During the period of instrumental measurement, there have occurred global variations of temperature and widespread changes in the distribution and intensity of aridity. These trends have occurred in a period of unprecedented population growth and world economic interdependency, with the result that many scholars fear that even small deteriorations in temperature or raininess may have disastrous effects. The present decade has witnessed an unprecedented demand from politicians, conservationists, economists, farmers, and the public for improved long-term climatic forecasting. Given today's state of development of meteorological science, it is not possible to forecast climatic changes over periods of years. Since long-term forecasts must be performed empirically by projecting past trends into the future, the key to improving short-term forecasts lies in a fuller understanding of the past. In this context, the period of greatest value is that spanned by instrumental evidence, but the historical past immediately preceding the instrumental period is also of vital concern.

Although written sources compose by far the greater part of the communicated evidence of scientific value, other types of media may convey significant information bearing upon past climate. Climatological research employing media other than the written word has been confined largely to analyses of artistic evidence.

ARTISTIC EVIDENCE

In Egypt, a minor humid period is believed to have existed from about 5000 BC to about 2350 BC, and Butzer considers that some of the most convincing

proof of this is the artistic evidence found in caves.[7] Rock-drawings of landscapes made by early hunters and nomadic livestock-raising cultures depict fauna such as gazelle, antelope and ostrich, as well as species now limited to tropical Africa including elephant, rhinoceros, hippopotamus and giraffe. Between the First and Fourth Egyptian Dynasties (approximately from 2800 BC to 2600 BC), the exotic savanna fauna disappeared permanently from the rock-drawings. While this is not conclusive proof of climatic change, for there may have been biological or cultural causes, it does support results derived from physical environmental evidence.

The use of such evidence, especially as a means of verifying trends, is not confined to the pre-literate past. The following quotation illustrates the manner in which sixteenth-century Dutch landscape painting has been employed in studying Europe's climate:

> The period of cold climate in recent centuries left its mark upon the art of the time in ways that are really quite familiar. Pieter Bruegel the Elder's famous picture "Hunters in the Snow" started the fashion of the Dutch winter landscape scenes. This picture, painted in February 1565, records the winter of 1565, the longest and severest winter that anyone then living had experienced; but it was also symptomatic of the sharp deterioration of the general winter climate going on in that decade, when the frequency of snow at Zurich in Switzerland doubled as compared with the preceding 20 years. The experience apparently so impressed Bruegel that he recast many of his religious pictures in the setting of the bitter northern winter, thus dramatizing the exposure to poverty in the circumstances of Christ's birth. A particular example is afforded by his 1563 and 1567 versions of the visit of the three kings to the Holy Family in an open shed, the former without any weather indicated in the scene or implied by the clothes worn by the people in it and the later version with the shed on the outskirts of a village beside a frozen river and snow falling. There were many more Dutch winter pictures painted later in the same tradition. These included some in which Bruegel's sons Pieter the Younger and Ian used the same landscape as their father with only minor changes such as substituting frosty sunshine for falling snow. A sufficient number of similar winters followed in the later sixteenth, seventeenth and eighteenth centuries to supply the inspiration.[8]

WRITTEN EVIDENCE

In their search for evidence of past climates, scientists have analyzed the written record with enthusiasm and imagination. In most cases, this research has drawn upon written records that bear directly upon climatic phenomena; however, other sources with perhaps less concrete links to the physical world have also been usefully exploited. Fictional accounts, like graphic art, can provide certain insights into past climates. Although products of the imagination, works of fiction are usually set in the real world. Factual accounts, on the other hand, aim at faithfully reflecting the real world, but remain subjective inasmuch as they are modified by the perceptions and predilections of the author. In short, works of fiction are not wholly imaginative, and factual ac-

7 K.W. Butzer, "Climatic Change in Arid Regions Since the Pliocene," *Arid Zone Research* (UNESCO) 17 (1961): 41-42.

8 H.H. Lamb, "Britain's Changing Climate," *Geographical Journal* 133 (1967): 461-62.

counts are not purely objective descriptions of the world. Nevertheless, information about past climates can be gleaned from both sources though the level of subjectivity severely degrades the scientific utility of fiction, especially in the absence of corroborating evidence.

FICTIONAL ACCOUNTS

Fragments of environmental information contained in novels, plays and poetry have, despite their inherent subjectivity, been considered of sufficient scientific value to warrant climatological investigation. For example, significance has been attached to the descriptions of cold, snowy Christmasses in Victorian England contained in Charles Dickens' novels. The British climatologist H.H. Lamb considers Dickens' accounts of the Thames freezing in midwinter and of long spells of snow cover as being indicative of winter conditions significantly more severe than those of the present.[9] Similarly, another scholar has identified a useful reference to a cool, wet summer in 1594 in Shakespeare's *A Midsummer Night's Dream*:[10]

> Through this distemperature we see
> The seasons alter: hoary-headed frosts
> Fall in the fresh lap of the crimson rose,
> . . . The spring, the summer,
> The childing autumn, angry winter, change
> Their wonted liveries, and the mazed world,
> By their increase, now knows not which is which.
> (II, i, 106-14)

It bears emphasis that this climatologist's purpose was not to use established knowledge about the weather of the late sixteenth century to interpret Shakespeare's work, but rather to derive information about the weather of the time.

Some of the most interesting examples of poetry which may be used as climatic evidence are found in Chinese sources dating as far back as approximately 3000 BC. The climatologist Chu K'o-chen has interpreted poetry from the period 1100 BC to 1400 AD by isolating poetic allusions to natural phenomena whose distributions are indicative of climate. Chu K'o-chen's use of literary works, especially poetry, has been described in the following terms:

> The poets and men of letters in particular have left descriptions of birds and flowers from which climatic change can be deduced. Plum trees, much loved by the Chinese and producing a fruit used as a condiment, were often mentioned in poetry and essays of the Yellow River valley region. After the T'ang and Sung Dynasties, there appear to have been no plum trees to write about in north China, which could be explained by lower temperatures. This literature also contains frequent references to bamboo and lacquer trees, both growing beyond their northern climatic limits of today. During the Eastern (or Later) Han Dynasty the astronomer-poet, Chang Heng (78-139 AD), wrote an ode in which he referred to the plentiful orange groves near the "South Capital" in today's southern Honan. But in the Three Kingdoms period, Ch'ao Ts'o

9 Ibid., pp. 448-49.

10 R. Gregory, "British Climate in Historic Times," *Geographical Teacher* 12 (1924): 254.

(155-220 AD) planted orange trees there which would flower but not fruit. Ch'ao's son planned to review his war fleet (255 AD) at the Kuanling, but the event had to be suspended because the Huai River froze for the first time on record.

Lychee, another favourite fruit of the Chinese, is a sensitive tree which succumbs at temperatures below −4°C. Today lychees are limited to the south of Nanling, that is to the subtropics. However, according to the poets, Chang Shih (765-830 AD), Lu Lu (1125-1210 AD), and Fan Ch'eng-ta (1226-93 AD), the lychee was an economic crop in the Szechuan basin in western China. The fruit appears to have been absent from that area since the twelfth century.[11]

FACTUAL ACCOUNTS

Two broad categories of factual accounts differing in degree rather than kind are distinguished in figure 3. Factual accounts written sporadically are fundamentally deficient for climatological investigations for they lack the temporal regularity that is the *sine qua non* of studies of climatic change. Like artistic evidence and fictional accounts, their most useful role lies in supplying fragments of otherwise unavailable information, or in verifying or validating data derived from other sources. Included in this category of evidence are private letters, memoranda, accounts of journeys and expeditions, occasional reports and, depending upon the degree of regularity, even diaries and journal accounts.

Probably the earliest records of this nature exploited by climatologists are Chinese oracle bones. They provide the only written records available in China prior to 1100 BC and contain carved descriptions of farm crops and agricultural methods as well as predictions of rain or snow. For example, the climatologist Chiao-min Hsieh reports that oracle bones of the Yin Hsu period (1400-1100 BC) record cultivation of rice in the Anyang region of northern Honan in March, one month earlier than is the case today.[12]

How sporadic accounts can supplement data derived from chronicle accounts was shown in a recent study by the Canadian Atmospheric Environment Service. In attempting to reconstruct rainfall patterns in the Red River Settlement during the pre-instrumental period, T.R. Allsop used individual letters and the isolated comments of travellers to complete a synthesis of wet and dry years constructed mainly from chronicle accounts.[13] The Louis Riel Papers in the Provincial Archives of Manitoba illustrate the sporadic distribution of environmental commentary typical in accounts of this nature. Table 1 presents references to weather phenomena in this correspondence relating to the Red River Settlement and other locations in the Canadian Northwest. The following excerpts from the Alexander Ross Family Papers in the Manitoba archives indicate the kinds of environmental information that can be gleaned from private correspondence:

11 Chiao-min Hsieh, "Chu K'o-chen and China's Climatic Changes," *Geographical Journal* 142 (1976): 252-53.

12 Ibid., pp. 248-56.

13 T.R. Allsopp, *Agricultural Weather in the Red River Basin of Southern Manitoba over the Period 1800 to 1975*, Canada, Atmospheric Environment Service, CL1-3-77 (Downsview, 1977).

February 6, 1854: Have never had such a cold winter—55° below zero, 8° below we have ever seen it.

April 14, 1854: The ice has just started; we were looking at it at the old ice house.

March 31, 1858: Spring has set in earlier than usual . . . snow mostly gone, creeks all running . . . ice started here today . . . never known to do so before. . . .[14]

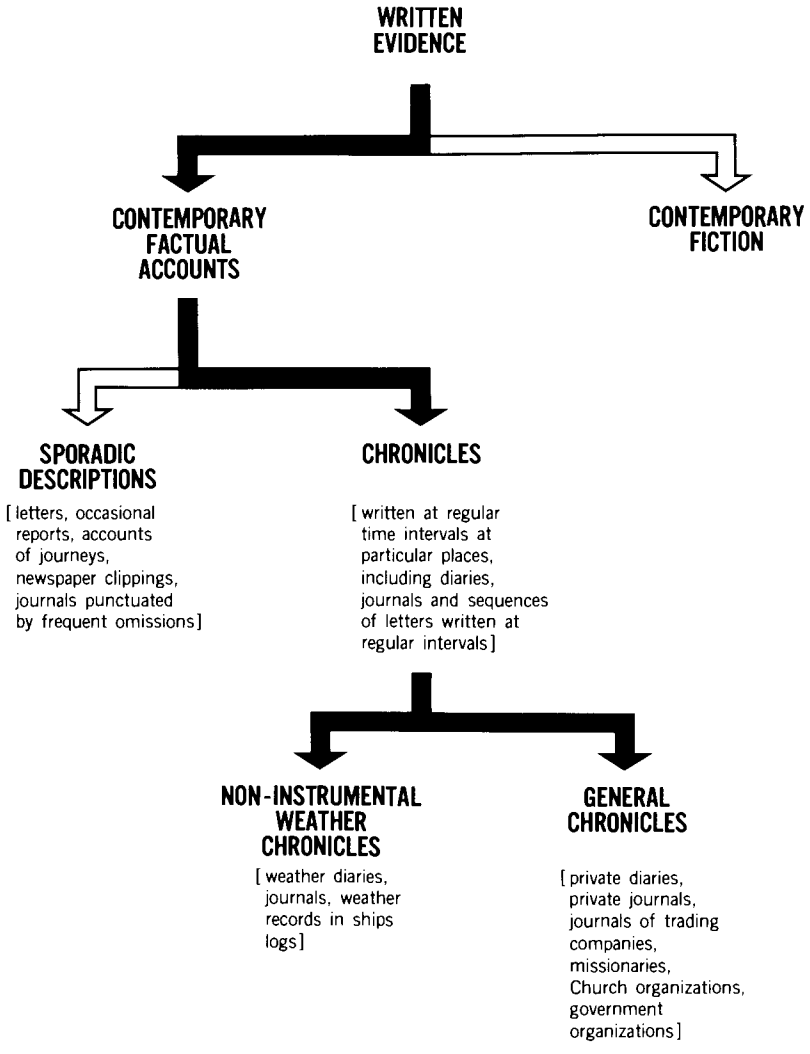

Fig. 3. *General classification of types of written evidence of climatic change.*

14 Provincial Archives of Manitoba, MG 2 C14, Alexander Ross Family Collection (1810-1903).

Such descriptions can generally play only a secondary research role; chronicle accounts are the principal written source upon which historical climatological investigations rest. The latter include non-instrumental weather chronicles on the one hand, and chronicles of a more general nature on the other (figure 3). Although the difference is again one of degree rather than kind, the weather chronicles are distinguished by their objectives and content. Written with the intention of recording specific weather phenomena at regular time intervals, their content is restricted largely to descriptions of matters such as windspeed and direction, cloudiness, raininess, warmth, cold, frosts, fog and snow. The more common general chronicles are the diaries and journals kept for purposes other than recording weather, but which nonetheless often contain numerous references to the environment.

	Assiniboine River	Ile à la Cross	Red River Settlement	Saskatchewan	Winnipeg
1868			Snow (8)		
1870					Weather (189)
1871	Rain (101)		Floods (87, 89)	Rain (107)	
1872			Ice (147, 154)		
1873		Rain (209)			
1875		Floods (312)			
1876		Floods (319, 320)			
1877		Snow (330)			
1880		Floods (388, 389)			

Table 1. *References to weather phenomena contained in Louis Riel Papers, Provincial Archives of Manitoba. (The catalogue numbers of particular items in the papers are given in parentheses.)*

Whereas the information contained in the weather journal is more or less systematic and comprehensive, that in the general chronicle is not only incidental to the main purpose of the record, but is also impressionistic, focussing on occurrences which have attracted the attention of the author. This bias constrains the research possibilities since the phenomena most often described are extreme and rare episodes. This means that references to exceptional hot spells, floods, thunderstorms, blizzards, droughts, and so forth are relatively common, and that phenological indicators are prominently mentioned. The first snowfall in autumn, the break-up of rivers in spring, the first appearance of blossom on fruit trees, the date of ripening of fruit, the first migration of birds, the breaking of the monsoon in subtropical climates, are all occurrences noteworthy to even the casual observer. As a consequence, general chronicles have yielded measures of the passage of the seasons and of the incidence of ex-

ceptional weather conditions. Following an extensive study of the documentary sources from medieval Europe, Lamb concluded that the most reliable weather indicators in sources of this nature are:

1. Severity or mildness of the weather prevailing in the main winter months of December, January and February. The effects upon landscape, transport and the agricultural economy are likely to have been reported in all important cases. It should be possible to identify confidently the persistent spells: mild winters by rains, flooding and thunderstorms even in continental regions, also by early or out-of-season flowering of plants; severe winters by frozen rivers, lakes and seaways, and by many sorts of privation and damage.
2. Raininess or drought in summer. Again the effects upon the landscape and upon agriculture are reasonably sure to have achieved mention in all outstanding cases. Wet summers produce flooding and ruined crops, though highly coloured accounts of individual thunderstorms may occur in otherwise good summers. Dry summers are known by parched ground and dwindling rivers, whilst the grain crops are usually good; forest fires are also particularly liable to occur. The rain character of a summer is surer of faithful recording than the temperature, since an oppressive heat wave might well be the only recorded reference to temperature in an otherwise poor summer.[15]

While the distinction between weather journals and general chronicles is important for analytical applications in climatology, both are examined here in the context of the kinds of evidence available, with examples drawn from Japan, Britain and Canada.

Like China, Japan has a rich legacy of historical sources from which climatic information has been gleaned. Outstanding among chronicles exploited by Japanese scientists are those that relate to phenological events extending through several centuries. Until 1868, the Emperor held an annual celebration to mark the blooming of the cherry tree at Kyoto. This event was described so consistently through time that a record of blooming dates derived from the written descriptions extends back to the ninth century.[16] A second example refers to Lake Suwa, which freezes annually, prompting local inhabitants to forecast the weather of the following summer from the manner of its freezing. Descriptions of the freezing of the lake were kept in the records of the nearby temple of Suwa and the Jaturugi shrine and, from these, annual dates of freezing are available from 1444.[17] A third study was based on the first snow covering at Tokyo, an event commonly described in the historical sources because of the custom of feudal lords extending season's greetings and making presentations to the feudal government at this time. At Tokyo this event is recorded an-

15 H.H. Lamb, "On the Nature of Certain Climatic Epochs Which Differed from the Modern (1900-39) Normal," *Arid Zone Research* (UNESCO) 20 (1963): 125-50.

16 H. Arakawa, "Climatic Change as Revealed by the Data from the Far East," *Weather* 12 (1957): 46-47.

17 H. Arakawa, "Fujiwhara on Five Centuries of Freezing Dates of Lake Suwa in . . . Central Japan," *Archive für Meteorologie, Geophysik und Bioklimatologie,* Ser. B., vol. 6 (1954): 152-66; T. Yazawa, "Climatic Fluctuations in Central Japan Since the Mid-Fifteenth Century," in *Climatology, Hydrology, Glaciology, 1976,* XXIII International Geographic Congress (Moscow, 1976), vol. 2, pp. 138-40.

nually back to 1632-33, and dates are sporadically available for Kyoto as far back as 792-93.[18]

In Britain as in most countries, the chronicles are available in both primary and secondary sources. A remarkable meteorological chronology of weather descriptions taken mainly from early documentary sources was prepared by C.E. Britton.[19] This work runs from 2668 BC to 1450 AD, a date significant because it coincides roughly with the development of printing and the consequent expansion of the textual record. More than fourteen hundred references are presented ranging from terse phrases to lengthy descriptive passages. Derived from more than two hundred sources, the majority are drawn from only ten sources, both primary and secondary.[20]

H.H. Lamb's interesting work on European climatic changes[21] during the last millenium was based on Britton's chronology and several other published works as well as original documentary evidence.[22] Lamb chose to study the region in Europe bounded by 45° and 55°N, and Iceland and Russia because of the wealth of documentary evidence available and because of the area's sensitivity to atmospheric circulation changes. His study of this evidence produced analyses of the temporal and spatial distributions of summer wetness and winter severity from 1100 to 1960.

In comparison with Japan and Britain, the documentary evidence from Canada spans a brief period, but it is nonetheless important and is exceptionally rich in some of its characteristics. The record predates the development of instrumental observations and encompasses a period of exploration and settlement by essentially literate people over a vast area of largely untouched wilderness. There was in the early historical period a preoccupation in Canada with environmental problems that is reflected in the documentary legacy. This con-

18 H. Arakawa, "Dates of First or Earliest Snow Covering for Tokyo Since 1632," *Quarterly Journal of the Royal Meteorological Society* 82 (1956): 222-26.

19 C.E. Britton, "A Meteorological Chronology to A.D. 1450," *Geophysical Memoirs* 8, no. 70 (1936): 2-177.

20 In order of frequency of use, Britton's ten principal sources are: Thomas Short, *A General Chronological History of the Air, Weather, Seasons, Meteors, Etc.*, 2 vols. (London, 1749); *Matthaei Parisiensis Monachi Sancti Albani Chronica Majora*, (Journal of Matthew Paris), 7 vols., Rolls Series, 1872-84; *Annales Ultonienses*, (Annals of Ulster, to A.D. 1131 only). (Irish with Latin trans.) In *Rerum Hibernicarum Scriptores Veteres*, by Dr. O'Conor, (Buckingham, 1826); *Anglo-Saxon Chronicle* (Saxon text and English trans.), 2 vols., Rolls Series, 1861; *Annals of Connacht* (Irish with Eng. trans.), Rolls Series, 1871; *Chronicon Scotorum* (Irish with Eng. trans.), Rolls Series, 1866; *Annales Prioratus de Wigornia,* (Annals of Worcester), Rolls Series, 1869; *Rogeri de Wendover Chronica, liber qui dicitur Flores Historiarum,* (Chronicle of Roger of Wendover), 3 vols., Rolls Series, 1886-89; T.H. Baker, *Records of the Seasons, Prices of Agricultural Produce Etc.* (London, 1884); *Annales Monasterii de Waverleia,* (Annals of Waverley), Rolls Series, 1865.

21 H.H. Lamb, "On the Nature of Certain Climatic Epochs," pp. 125-50.

22 Various other sources used by Lamb were: I.E. Buchinsky, *The Past Climate of the Russian Plain*, 2nd ed. (Leningrad, 1957); R. Hennig, *Katalog Bemerkenswerter Witterungsereigvisse von den ältesten Zeiten bis zum Jahre 1800.* Abh. Preuss. Met. Inst., vol. 2, no. 4 (Berlin, 1904); C. Easton, *Les hivers dans l'Europe occidentale* (Leyden, 1928); E. Vanderlinden, *Chronique des événements météorologiques en Belgique jusqu'en 1834*, Mém. Acad. R. Belg, 2nd series, vol. 5 (1924).

cern generated an abundance of environmental comment which has survived in Canadian archives and also in those of the two principal competitors for empire in early North America, France and Britain. Sources of climatological significance originated with individuals and a variety of organizations including government, religious institutions and corporate enterprises. In terms of length, scope and quality, the records of the Hudson's Bay Company provide a corpus of chronicles unrivalled in North America, yet the potential for environmental research into these records remains largely untapped.

Founded in 1670, the Hudson's Bay Company (HBC) is the longest lived of the great chartered joint stock companies, its records spanning more than three centuries of Canadian history. During its first two hundred years, the Company ruled over Rupert's Land and adjacent territories. By the middle of the nineteenth century, at the height of its territorial extent, the Company's trading area encompassed almost all of mainland Canada and, in the west, stretched from the Arctic Circle south to San Francisco Bay. Throughout this period, the London headquarters of the HBC required its servants to maintain meticulous records of business operations in North America, including environmental phenomena impinging upon the execution of trade in this vast wilderness domain. The policies of the Governor and Committee in London ensured not only the keeping of detailed records in North America, but also their preservation in London, leaving for posterity a unique corporate archives.

The Company's archives house records as varied as explorers' journals, Indian trade accounts, ships' logs, letter books and even daily temperature records from instrumental observations.[23] Among them, the records most important for environmental reconstructions are the post journals and ships' logs, the value of which, like many other series in the Company's archives, lies in their fullness and regularity, and in their wealth of environmental information.

As early as 1683, the officers in Rupert's Land were instructed to keep "Journalls of what hath been done in the respective factories & of all ocurances."[24] Although some journals have been lost, or destroyed in fires or in shipping accidents, they are among the most complete of the Company's records, spanning the years from 1705 to 1940. At times, however, the board of directors in London did not consider the journal-keeping adequate, and deficiencies in this regard prompted the following directive in 1814:

> These Journals are to contain nothing but a plain & simple memorandum of facts. . . . They must however be distinct & full, containing all the particulars that may contribute to the better understanding of the transactions that are mentioned. . . . Among the circumstances, which are always to be noticed in the Journals, is the weather & progress of the Season:—the date of the freezing in of the lakes & rivers; the chief falls of snow & their depth; the greatest thickness of the Ice; the commencement of Thaw: the breaking up and clearing away of the Ice, the commencement of vegetation; the opening of the leaf of the most remarkable trees; the flowering of any remarkable plant . . . the

23 See D.W. Moodie, "The Hudson's Bay Company's Archives: A Resource for Historical Geography," *Canadian Geographer* 21 (1977): 268-74.

24 Joan Craig, "Three Hundred Years of Record," *Beaver*, Outfit 301 (1970): 67.

> ripening of any kind of native fruit, or of any species of cultivated produce; the commencement of frost in the Autumn & the fall of the Leaf. . . . The observations are not to be considered as a matter of idle curiosity; but may be of very essential use.[25]

Figure 4, which shows the number of post journals available in the Company's archives for each year in the period 1700-1870, also reflects major patterns in

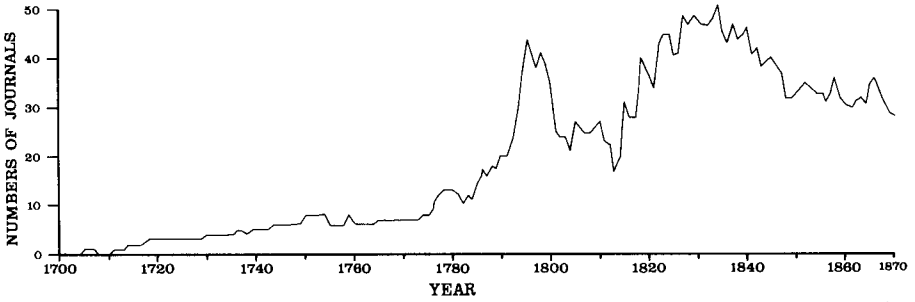

Fig. 4. *Numbers of Hudson's Bay Company post journals available in the Company's archives for each year between 1700 and 1870.*

the Company's history. For example, it illustrates that few journals were kept prior to 1774, a period during which Company settlement was confined to the shores of Hudson Bay and when its overseas establishments were few in number but that following 1774, when the Company built settlements inland, both the number of journals and their distribution in space rapidly expanded. More than two hundred different post journals have survived, although most are of only a few years' duration. Those with periods of record in excess of thirty years are shown in figure 5.

Although only limited environmental research has been completed using these journals, they embrace long periods and vast areas for which both instrumental observations and descriptive accounts of environment are otherwise lacking. These records therefore afford a unique opportunity for reconstructing distributions of fauna and flora, migrations of birds and ungulates, incidences of forest and prairie fires, dates of germination, budding, leafing and blossoming of vegetation, dates of ripening of fruit, changes in the morphology of river estuaries, distribution of sea ice and fogs, freezing and breaking of rivers and lakes, flooding, and the occurrences of snow, rain, frost, and thunder. Insofar as nearly all these journals describe wind direction on a daily basis, they acquire some of the characteristics of weather chronicles. The journals also contain isolated comments on rare astronomical events, such as unusual displays of the aurora, and even geological episodes such as earthquakes on the shores of Hudson Bay.

The utility of the HBC post journals for climatological reconstruction was first demonstrated by MacKay and Mackay in a study of historical dates of freeze-up and break-up on the Churchill and Hayes Rivers.[26] Minn later used

25 Hudson's Bay Company, Letter from the Governor and Committee to Thomas Thomas, London, 9 April 1814, Hudson's Bay Company Archives, Provincial Archives of Manitoba, A 6/18, pp. 211-13.

26 D.K. MacKay and J.R. Mackay, "Historical Records of Freeze-up and Break-up on the Churchill and Hayes Rivers," *Geographical Bulletin* 7 (1965): 7-16.

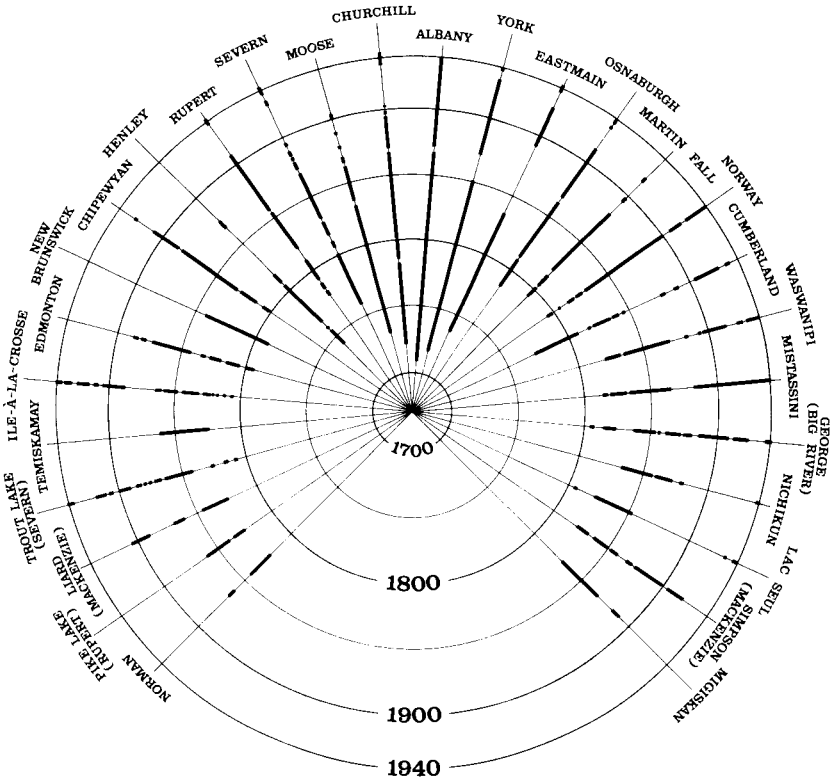

Fig. 5. *Temporal distributions of selected Hudson's Bay Company post journals, from 1670 to 1940. These are the journals having the longest durations prior to 1870; all span at least thirty years in that period.*

the post journals to elucidate the air mass climatology of western Canada during the early nineteenth century.[27] In a more recent study of historical dates of freeze-up and break-up, Moodie and Catchpole have demonstrated that information derived from these journals compares in accuracy with that obtained from the present network of Canadian stations observing freeze-up and break-up.[28] As part of a broader, computer-based investigation into environmental observations in the York Factory and Fort Churchill post journals, Ball has produced tables of both meteorological and faunal data. The latter include tables of migration into the Hayes River estuary of the Snow Goose and the Canada Goose during the eighteenth and nineteenth centuries.[29]

Unlike the post journals, HBC ships' logs have only recently been exploited

27 R. Minns, "An Air Mass Climatology of Canada During the Early Nineteenth Century: An Analysis of the Weather Records of Certain Hudson's Bay Company Forts," (Master's thesis, University of British Columbia, 1970).

28 D.W. Moodie and A.J.W. Catchpole, "Valid Climatological Data from Historical Sources by Content Analysis," *Science* 193, no. 4247 (1976): 51-53.

29 Personal communication with Prof. T. Ball, Department of Geography, University of Winnipeg.

for environmental research.[30] As a type of evidence, ships' logs have been employed effectively in a variety of contexts.[31] For example, Oliver and Kington have developed daily weather maps of part of the North Atlantic Ocean and Western Europe for the late eighteenth century using ships' logs to supplement land-based observations.[32] Several characteristics of the HBC ships' logs make them a particularly valuable source of data on the marine environment. The Company's ships sailed annually between England and Hudson Bay through seas where ice posed a serious threat to navigation. Yet these voyages became an annual routine of almost clockwork precision. The fleet followed essentially the same route each year using latitude sailing from the Orkneys to Cape Farewell, Greenland, and thence through the narrow, ice-congested bottleneck of Hudson Strait where ships hugged the north shore to avoid the worst drift ice. Consequently, landmarks important to the ships' safety were frequently observed and noted, providing modern researchers with good opportunities for fixing the positions of the ships. Once through the strait, the ships broke convoy at Mansfield Island and proceeded either southward to James Bay or westward to Churchill and York Factory (figure 6). The fleet was almost always composed of two or more ships and was occa-

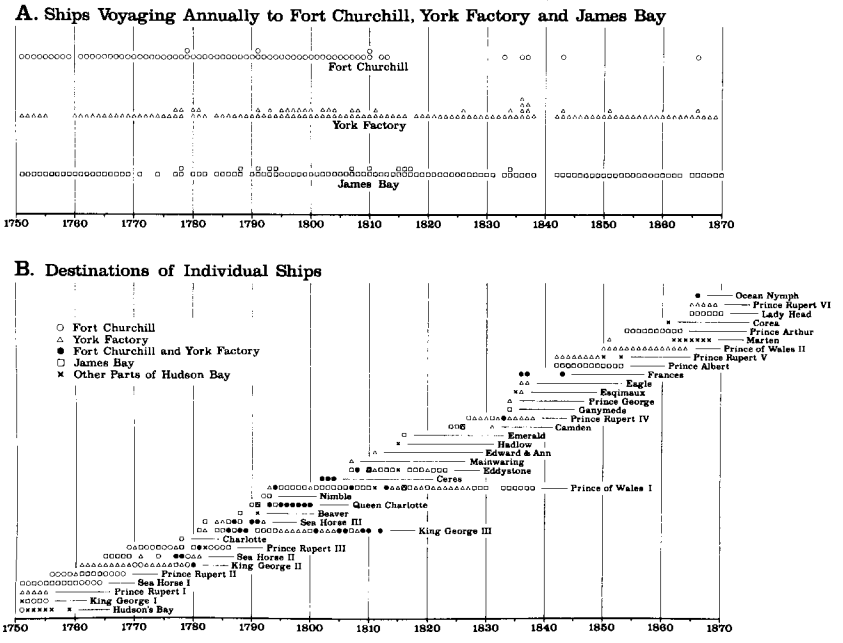

Fig. 6. *Hudson's Bay Company ships voyaging from England to the Bay, 1750 to 1870. The diagram includes only voyages for which logs are preserved in the Company's archives.*

30 In the Department of Geography, University of Manitoba, the Hudson's Bay Company logs are currently being researched to obtain sea ice data as well as weather data related to the problem of navigating in Arctic waters.

31 J. Oliver and J.A. Kington, "The Usefulness of Ships' Log-books in the Synoptic Analysis of Past Climates," *Weather* 25 (1970): 520-28.

32 Ibid., pp. 526-27.

sionally accompanied by a Royal Navy escort. Furthermore, the Company required that more than one log be kept on each ship—by the captain and the mates. Therefore, several logs may exist for any given year (table 2) and, with the exception of 1839-41, logs from the Company's ships are available and catalogued for the period 1751 to 1900.

Number of ships per year, yielding logs	Number of years
0	3
1	4
2	46
3	54
4	12
5	2

Table 2. *Frequency distribution of annual numbers of Hudson's Bay Company ships voyaging from England to the Bay, 1751 to 1870.*

It is difficult to imagine circumstances more conducive to the study of climatic change using ships' logs than those bearing upon the voyages of the Company's ships in the eighteenth and nineteenth centuries. These trips, which began in the North Atlantic and extended into the essentially unknown eastern margins of the arctic seas, were made over a time span that probes deeply into the Little Ice Age. Significant changes in sea ice conditions which may well have been encountered and recorded may extend the findings of Danish scientists on ice distribution along the Greenland coast and of current American research using ships' logs to reconstruct ice conditions in Bering Strait and within the Chukchi and Beaufort Seas.[33] Research of this nature is of value, not simply for its physical investigations, but also for the indispensable information it generates bearing upon the applied problems of oil and gas exploration, pollution and transportation in high latitude marine environments.

While the post journals and ships' logs have been singled out for examination here, the variety of other HBC documents should not be overlooked as sources for the study of past environments. The account books of the Company, for example, are as well distributed in space and time as the post journals, and afford exceptional opportunities for investigating the changing faunal resources which supported commerce.[34]

In addition to the records of the Hudson's Bay Company, Canadian archives contain a wide array of sources for historical environmental investiga-

33 Personal communication with Prof. W.R. Hunt, Department of History, University of Alaska. This historical research is being conducted at the University of Alaska as part of the Outer Continental Shelf research programme, sponsored by the National Oceanic and Atmospheric Administration of the United States.

34 For a discussion of the account books see: Arthur J. Ray, "The Early Hudson's Bay Company Account Books as Sources for Historical Research: An Analysis and Assessment," *Archivaria* 1 (Winter 1975-76): 3-38.

tion, in particular, general chronicles extending over lengthy segments of the pre-instrumental period. In Western Canada, for example, instrumental observations commenced only in the last decades of the nineteenth century. Among the research materials available for this region before this time are the daily journals, and the weekly and monthly divisional reports of the North West Mounted Police (NWMP). The unique record kept by the police during the early phase of pioneer settlement in Western Canada includes the Prairie Fire Reports which commenced with the enactment in 1889 of the Prairie Fire Ordinance empowering the NWMP to appoint fire guardians to compel settlers to assist in fire control. Reporting of prairie fires was sporadic before 1889; however, after this date, each NWMP division was required to submit to the Commissioner a monthly fire report indicating the location of each fire, the action taken by the police in combating it, and the results of investigations into its causes. Although the fire and routine divisional reports of the NWMP span only a brief period, they do contain detailed environmental commentary about the prairie landscape immediately before the drastic changes imposed by man during the rapid settlement of the West.

Covering an even briefer period, but nonetheless of value for the reconstruction of the pre-settlement physical landscapes of Canada, are the records generated by the early land surveys. The comprehensive field notes of the Dominion Land Survey and surveyors' diaries recording weather phenomena and other environmental conditions afford unrivalled sources for reconstructing vegetation on the eve of settlement. Watts, for example, used these sources to reconstruct broad-scale vegetation patterns prior to the influx of settlers to the Canadian prairies.[35] Even so, this invaluable resource remains largely untapped in most regions of Canada.

Servants of the church as well as agents of government and trade left a rich documentary legacy now in Canadian archives. The record varies greatly from region to region, beginning in Western Canada in the early decades of the nineteenth century. Most prominent among the religious archives for this region are those of the Church Missionary Society, the Oblates of Mary Immaculate and the Sisters of Charity. The extensive holdings of the Oblates, for example, have been centrally organized and contain an almost complete collection of missionary journals kept throughout northern and western Canada. Although the Oblate *codex historicus* spans briefer periods than many of the Hudson's Bay Company post journals, it exhibits many of their attributes as a source of historical environmental information.

In addition to institutional chronicles, personal diaries are clearly a significant resource, providing abundant environmental commentary. Although traditionally employed by European environmental scientists, this category of evidence has not been widely exploited in Canada despite its obvious potential arising from the exposure of the early Canadian diarists to extreme environmental hazards. The private diaries of settlers in the Red River valley, a selection of which are illustrated in figure 7, are replete with references to spring break-up, thunderstorms, inundations of their river lot farms, grasshopper

35 F.B. Watts, "The Natural Vegetation of the Southern Great Plains of Canada," *Geographical Bulletin* 14 (1960): 25-43.

and caterpillar plagues, crop diseases, prairie fires, crippling frosts, blizzards and droughts.

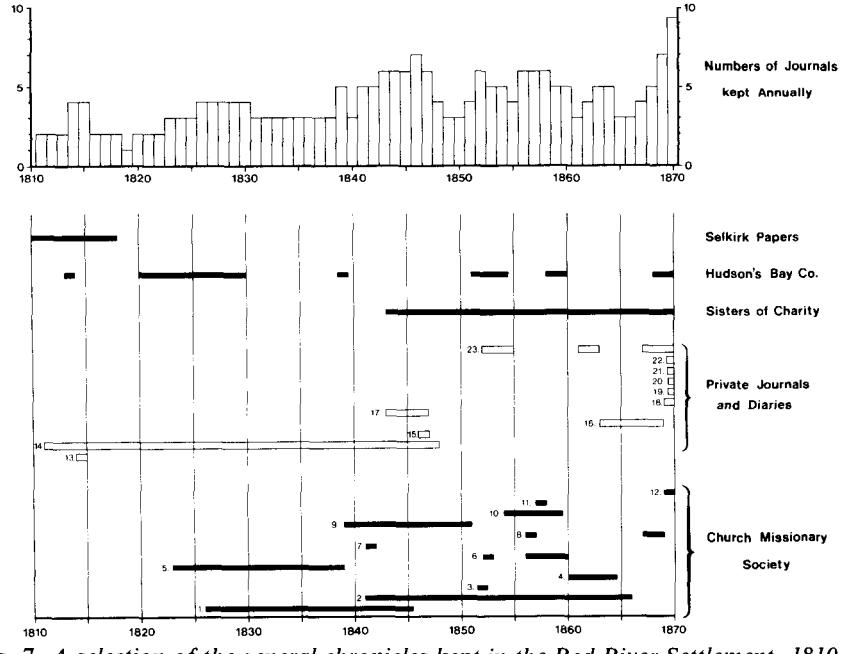

Fig. 7. *A selection of the general chronicles kept in the Red River Settlement, 1810 to 1870. This is based on the chronicles catalogued in the inventory of the Provincial Archives of Manitoba, the Church Missionary Society finding aid, and the Hudson's Bay Company's archival catalogues.*

ANALYSIS OF THE WRITTEN EVIDENCE

While colleagues in the social sciences and history put complex questions to documentary sources, the environmental scientist might appear to be a brusque investigator wanting direct answers to simple questions. Has temperature or growing season increased or decreased? When were the major peaks and troughs and what were the rates of change between these intervals? These would all appear to be more tangible questions than any which might be asked about foreign policies or economic systems. Yet annual or decadal changes in foreign policy or economic conditions were often catastrophic and therefore much more prominent in the historical record than slight environmental fluctuations which might have been noted incidentally.

In discerning shifts of natural phenomena, however, the fundamental problem does not reside in any inherent characteristics of environmental change. Rather, it lies in the nature of the evidence or of the measurements available to describe change. Essentially, the detectability of any change is as much a function of the accuracy and sensitivity of the measuring instrument as it is of the processes that produce it. Since standardized measurements of sufficient accuracy and sensitivity are not available for most of the historical period, the scientist must resort to entirely different and unfamiliar kinds of evidence of change. In so doing, he like the historian must pose his questions with as

much regard for the limitations of the evidence as for the problem under investigation. In resorting to descriptive accounts, the scientist is attempting to extract scientific information from ostensibly unscientific sources. In short, the researcher must rely upon the observations of predecessors whose perceptions and descriptions of physical phenomena cannot easily be verified. Unless these historical observations can be measured and tested, the nature of the documentary evidence in relation to modern scientific counterparts cannot be assessed, making their value in ascertaining past environmental conditions speculative at best.

Observational problems of this nature are, of course, endemic to all forms of historical enquiry. They are also endemic to the environmental sciences where they are negotiated by standardized procedures of observation. Today's standards, however, cannot be imposed upon the historical record. At best, the standards of past observers can be interpreted with as little distortion as possible, and compared with those of today to establish a valid basis for the measurement of historical change.

METHODS OF ANALYSIS

The classical method of historical analysis has long been employed in investigations of past environments. In this approach, the eminent scholar reads with meticulous care the documents pertaining to a problem and then makes his own judgements about that problem. The acceptability and quality of these judgements may be conditioned as much by the mind of the reader as by the documents read. Although much useful information bearing upon the environmental past has been obtained in this manner, there is an increasing awareness among scientists that more systematic and objective methods of analysis are required if the information contained in documents is to be exploited most advantageously for rigorous scientific purposes.[36]

The general procedure of content analysis has been developed in the social sciences to meet these fundamental requirements. It consists essentially of applying standardized scientific procedures to documentary interpretation, and its success in this context has identified it as one of the basic innovations of the social sciences in this century.[37] Details of these methods as they have been adapted to environmental research are fully elaborated elsewhere.[38] Although shrouded in jargon, they involve routine procedures of sampling, classification, enumeration and testing designed to eliminate subjectivity by ensuring that the quality of the inferences is set by accepted standards and not by the intellectual powers of individual scholars.

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36 One of the main centres for the study of historical documentary sources is the Climatic Research Unit at the University of East Anglia, in the United Kingdom. Its Director, H.H. Lamb, reports in a private communication (September 1977) that "one of the most important conclusions of our historical [work] is that most of the main collections of historical weather references that have been published . . . are unreliable, because the compilers used second-hand sources and we have found it necessary to re-check everything . . . back to the original source."

37 K.W. Deutsch, J. Platt and D. Senghaas, "Conditions Favouring Major Advances in the Social Sciences," *Science* 171 (1971): 450-59.

38 D.W. Moodie and A.J.W. Catchpole, *Environmental Data from Historical Documents by*

Content analysis aims to achieve such a high degree of objectivity that different readers will arrive at the same judgements about a problem when provided with the same evidence, rules and procedures. Indeed, the only test for reliability or objectivity is the extent to which similar results are reached by different readers from the same source. If the rules and procedures governing the operation of the analysis can be made sufficiently explicit, the analysis can be computerized and the problem of subjectivity completely eliminated. Finally, content analysis requires that the validity as well as the reliability of the analysis be tested by comparing the data yielded by the analysis with independent data, a procedure which can be accomplished in a formal, mathematical manner by virtue of the quantification procedures of the methodology.

One of the principal strengths of content analysis is that it involves the conversion of lexical and other qualitative information into numerical form. On the one hand, this permits gauging the perceptions of past observers with much more precision than classical methods of historical analysis allow. And on the other hand, the conversion of the historical observations into numbers facilitates reliability and validity testing.

The most widespread technique whereby textual material is given quantitative expression is the frequency count. In this procedure, inferences are derived strictly from the frequency with which specified words and themes appear within text. Associated with simple frequency counts are multivariate analyses which ask not merely how often given words or themes appear in a text, but how often they appear in conjunction with other specified words or themes. These and other numerical procedures permit the application of mathematics and statistics to virtually the entire range of source materials that might be employed in historical environmental reconstructions.

If only informally, these aspects of content analysis have long been used by environmental scientists. For instance, Butzer in his study of cave drawings applied numerical procedures of content analysis to the symbols which appeared. These procedures have also been used by climatologists in analyses of written communications. Chu K'o-chen evaluated the frequencies of descriptions of floods and droughts in two Chinese chronicles to derive numerical indices of raininess in China since 0 AD.[39] Numerical methods were used experimentally by Lamb in his extraction of indices of summer wetness and winter severity from European documentary sources written after 100 AD.[40] To illustrate some of the research techniques, a formal application of content analysis employing Hudson's Bay Company post journals follows.

A Content Analysis of Hudson's Bay Company Post Journals

The objective of this analysis was to obtain annual dates of freeze-up and break-up of rivers from descriptions of these events in the post journals. The

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Content Analysis: Freeze-up and Break-up of Estuaries on Hudson Bay, 1714-1871, Manitoba Geographical Studies 5 (Department of Geography, University of Manitoba, 1975).

39 Chiao-min Hsieh, "Chu K'o-chen and China's Climatic Changes," p. 251.

40 H.H. Lamb, "On the Nature of Certain Climatic Epochs," pp. 125-50.

journals analyzed, selected on the basis of duration and continuity of record, were therefore those maintained at the oldest continuously settled establishments of the Company on Hudson Bay,[41] namely Fort Albany, Moose Factory, York Factory and Churchill. From these journals there was ultimately derived a record of dates of freeze-up and break-up of the estuaries of the Moose, Albany, Churchill and Hayes Rivers spanning the period 1714-1870.

The journals do not contain numerical tabulations or systematically organized environmental descriptions The contents vary according to the predispositions and literary skills of their authors, although there is a common focus upon matters of importance to the economy and routine of the trading posts. The journals frequently refer to general environmental conditions at the posts, and notes on ice and water surfaces are particularly common in spring and fall when thawing and freezing set the tempo of the water-borne traffic that was the life-blood of the fur trade. Although the journals provide numerous descriptions of these conditions, they do not contain dates of freezing and breaking in any direct form. Furthermore, the processes of freezing and breaking are so complex that the Canadian Atmospheric Environment Service has difficulty in identifying criteria for observing them objectively.[42] Great variations in the timing of these processes can occur over short distances on the same water body, while the duration of the processes themselves as, for example, between the first appearance of ice and the development of a complete and permanent ice cover, may exceed one month.

At the outset, the research was directed toward acquiring data analagous to those observed in the modern Canadian meteorological network. At this juncture there was no assurance that the journals contained sufficient information to derive these data. Thus, the content analysis was initially intended to ascertain how freezing and breaking were perceived and recorded by the journal keepers. Three questions in particular were investigated: 1. What stages in the freezing and breaking process were most frequently and consistently described? 2. Which word roots or phrases were used to describe freezing and breaking and how consistently were they applied? 3. To what degree did the observations pertain to the location of the fort or to other known points or zones within the river estuaries? Answers to each of the questions were obtained by subjecting the entire journal or relevant comment to frequency analyses.

The first of these analyses demonstrated that interest focussed upon the earliest manifestations of both freezing and breaking, and that sufficient information was also available in most years to date the termination of the freezing process but not that of breaking. The second analysis dealt with the terminology employed by journal authors in describing these points in the two processes. It was found, for example, that 149 different root words and phrases were used to describe spring break-up. Despite wide semantic variation, it was

41 Earlier this analysis had been applied to the journals of three inland posts and the results were published in: A.J.W. Catchpole, D.W. Moodie and B. Kaye, "Content Analysis: A Method for the Identification of Dates of First Freezing and First Breaking from Descriptive Accounts," *Professional Geographer* 22, no. 5 (1970): 252-57.

42 An outline of several revisions in the Canadian definitions of freeze-up and break-up is given in: A.J.W. Catchpole and D.W. Moodie, "Changes in the Canadian Definitions of Break-up and Freeze-up," *Atmosphere* 12 (1974): 133-38.

also determined that the fourteen most common root words accounted for more than 90 percent of all relevant commentary in spring. From the character of these words, moreover, it was established that dates of freeze-up and break-up consistent with certain of the dates observed in the current network could be retrieved from the journals. The results of the third frequency analysis confirmed that lengthy sequences of the dates so defined could be derived for several different locations within each estuary. This analysis involved counting the frequency of references to place names associated with the freeze-up and break-up descriptions, and locating each place on maps insofar as this was possible.

Having identified the different biases in the perception and description of freezing and breaking, categories delimiting moments in these processes were established to expedite the dating procedure. Rules for logging the journal commentaries into these categories were devised, and reliability tests were performed to assess the objectivity with which different coders or analysts could obtain identical dates by applying the same procedures to the same documents. These tests isolated flaws in the initial research design which required more precise elaboration of the coding rules. The categories of freezing and breaking finally selected were chosen on the basis of reliability of interpretation, length of record in the post journals, and comparability with modern categories of freezing and breaking.

The final step in the content analysis was to obtain a measure of the validity of the dates retrieved, that is, to demonstrate that the analysis had in fact measured what was intended to be measured. This testing revealed that the dates derived from the accounts of the Hudson's Bay Company post journals afforded measures comparable to those observed in the present meteorological network. Just as the historian endeavours to verify his findings, or the meteorologist seeks to test the quality of his instruments, so too the environmental scientist must establish the validity of factual accounts if the data yielded are to be of scientific value. In short, this type of content analysis satisfies the major criteria established by the eminent French historian, Emmanuel Le Roy Ladurie, for historical environmental research.

> There are plenty of unpublished texts describing the winters, summers, inclemencies, droughts, floods, and so on, for this or that year of the fourteenth or fifteenth century. Such evidence abounds in all the manorial, legal, ecclesiastical, and administrative archives. System is what is needed. These texts should be used to establish valid series, by region, year, season, or even month, by kind of climatic phenomenon (cold, heat, drought, humidity, etc.), and by intensity of climatic phenomenon. All this should be done with the aid of the most up-to-date classifying techniques, including computers.[43]

As these and other techniques of studying the historical environment are developed, it seems likely that increasing pressure will be placed upon archives to support this kind of research with suitable documentation, finding aids and expertise. Knowledge of some of the techniques and applications of this research would seem to be a useful beginning. Apparently mundane comments and observations on the environment made in the past have a value beyond

43 Emmanuel Le Roy Ladurie, *Times of Feast, Times of Famine*, p. 268.

simply providing some background colour for a description of a political situation or a social condition. Such information, especially if extensively distributed through time and space, can provide valuable clues to the evolution and possible future directions of our environment. While climatologists in Canada have begun to penetrate the record surviving in our archives, this should not be regarded as an indication that acquisition policies should ignore records suitable for studies into our historical environment. In fact quite the contrary is true, particularly in view of the continuing degradation by man of our natural environment and its wildlife.