Climatic change, culture, and civilization in North America

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Abstract:
Analysis of modern climatic data suggests a pattern of response to global cooling for precipitation in Mesoamerica and North America. Also research in palaeoclimatology has defined a series of globally warm and cold periods for the Holocene. This paper joins the study of modern and palaeoclimate into a time-series model which appears to explain some of the florescences and declines of civilizations in the region during the last 3,000 years. Economic buffering and local invulnerability to climatic change for specifiable reasons appear to cover those cases which defy climatic explanation.

Article:
The potential threat that climatic change poses to twentieth-century world civilization has fostered massive efforts by many palaeoclimatic researchers over the last decade and added a considerable amount of detail to our knowledge of the sequence of climatic events, particularly over the last 10,000 years (National Academy of Science 1975, *Quaternary Research* issue July 1979). In this paper the details of climatic chronology of the northern hemisphere are compared to the cultural chronologies of Mesoamerica and North America. When the beginnings and ends of outstanding periods of civilized activity are compared with climatic changes, these events in many instances appear to correspond. In the cases where they do not, alternative explanations are often satisfactory; that is, the effects of economic buffering and invulnerability to climatic change due to favourable local conditions. The detailed histories and prehistories of many North American civilizations offer interesting sequences of interaction in the give-and-take battle between urban man and the forces of nature.

We do not undertake the arduous task of proving in a concrete sense the cause-and-effect relationships between culture change and climatic change in North America. On the other hand, we do propose what we feel to be a reasonable array of relationships which can be tested by regional specialists.

The issue of environmental effects on people and social groups or cultures has been debated from time to time, so perhaps it is advisable to make explicit assumptions concerning culture change and environment. As is indicated in figure 1, we assumed that culture change is fostered by at least three forcing variables, of which environment is one. The amount of culture change

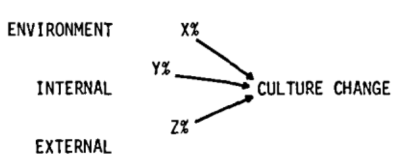

Figure 1 **Components of culture change**

observable over a given period in time may be attributable to any one or all, or any continuation of the forcing variables. Also, the proportion of contribution is variable, X per cent, Y per cent and Z per cent. Thus, when climate is changing radically, culture change may be accounted for almost wholly in terms of X per cent. On the other hand, during times of climatic stability, changes are attributable to internal forces such as powerful individuals in a proportion of Y per cent, or to external sources such as invasion by outsiders, Z per cent.

In many cases, the environmental impetus to cultural change is most easily recognized in the archaeological record. It is therefore logical to attempt a factoring out the environmental component of culture change before turning to the apparently more complex issues of external and internal forcing variables.

Recent climatic changes in North America

Sanchez and Kutzbach (1974) reasoned that, since the decade 1961 to 1970 was on the average much cooler than the period 1931-1960, they could study the distribution of temperature and precipitation between these two periods and determine the effects of cooling on the location of weather systems in North and South America.

Part of the results of their study are reproduced in figures 2 and 3. They show the percent of change in annual precipitation between the two periods for the year (figure 2) and for the month of January (figure 3). As might be expected, annual averages are generally downward, since

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cooler global temperatures discourage evaporation off the oceans and lower the capacity of the atmosphere to transport water landward. However, this does not mean drier conditions on the land. On the contrary, lower temperatures generally discourage evaporation and increase effective moisture. Brakenridge (1978) thinks that there was probably less rainfall in the American Southwest during the Ice Age but higher effective moisture accounts for the tremendous lakes and water-filled playas that are known to have characterized the area during the Pleistocene.

Examination of figure 3 shows as well that there is a seasonal shift in the amount of precipitation. In the face of annual drops in rainfall, many areas show substantial increases in rainfall

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during the month of January. Notable among these are the Texas area and parts of the heartland of Mesoamerican civilizations across southern Mexico and the lowland of the Yucatan Peninsula.

Examination of both maps will show that the increases and decreases in precipitation occur in east-west trending bands. The clearest example of such a band is across southern Mexico and Yucatan in the January map. Immediately to the north is a drier band across northern Mexico, a wetter band across southern U.S. east of the Rocky Mountains, and a drier band across mid- western U.S. east of the Rocky Mountains.

Sanchez and Kutzbach interpret the map to mean that there was a general southward movement of the bands of precipitation during the cooler years. In the 1930-1960 period the jet stream and its associated westerlies, cold fronts, etc., supported the agriculturally rich bread and corn baskets of the United States (Bryson and Murray 1977). Under the cooler conditions of the 1960s this belt shifted south, bringing with it its rains. The southerly shift of the jet and associated phenomena is in accordance with the findings of Angell and Korshover who discovered that the border between cold polar air and warm tropical air associated with the jet stream moves southward under colder conditions (Angell and Korshover 1977, 1978).

During the 1930-1960 period, southern U.S., particularly the Southwest, found itself under the influence of the drying winds of the subtropical high. The subtropical high is a zone of dry, high pressure air which is usually located at about 30° north latitude. It is the product of up- welling super-heated air at the equator which moves northward through the upper atmosphere, and, as is often said, what goes up must come down. This air comes down from the atmosphere at about 30° latitude. Since it lost its moisture in the upwelling process at the equator, where it comes down must be made dry by its undersaturated condition. This drying discourages the stabilizing balance between atmospheric moisture and surface temperatures. The great deserts of the northern hemisphere such as the Sahara, Arabian, Gobi, and Chihuahuan and Sonoran of the American southwest and northern Mexico are products of this process. The dry band across northern Mexico in figure 3 represents the southward movement of the subtropical high out of the southern U.S. and deeper into northern Mexico. These findings are in accord with analyses of the global energy balance and south Texas climate which show a lessening of the influence of the subtropical air mass after 1960 (Gunn 1979).

The next zone to the south is the much moistened strip across the south of Mexico. This zone of moist, tropical air is much more effective over southern Mexico because of the high mountains available to comb moisture out of the clouds coming off the Pacific. There are no high mountains in northern Mexico to trigger the precipitation. Observations by Hester (pers. comm.) in January 1979, during a field season in Belize, indicate that the increased precipitation in the Guatemalan lowlands is triggered by northern cold fronts which penetrate as far south as Yucatan in cold winters and produce rainfall from moisture carried in by the easterly trade winds.

In summary, then, precipitation in southern U.S., northern Mexico and southern Mexico is controlled by the coordinated north or south movements of bands of dry and wet air. This north and south movement is in response to changes in the annual average temperature of the atmosphere of the northern hemisphere. Colder times move the bands southward. Warmer times move them northward. These relationships are presented in a simplified graphic form in figure 4.

Climatic changes in North America during the last 8000 years

Many palaeoclimatic researchers have attempted to determine the alternating periods of glacial advance and retreat over the last 10,000 years, the post ice period. Perhaps the most widely accepted chronology is the one devised by Denton and Karlén. They studied the advance and retreat of tree lines in mountains in Alaska and Sweden. Trees overrun by glacial advances were dated using the radiocarbon or C14 technique. The results of their investigations are reproduced in figure 5 and transferred to figure 6 along the bottom.

COLD				WARM
Northern U.S.		Dry Polar Air		Canada
	35		45°	
Southern U.S.		Wet Westerlies		Northern U.S.
	30°		35°	
Northern Mexico		Dry Subtropical		Southwestern U.S.
	27°		30°	
Southern Mexico		Wet Tropical		Northern Mexico
	15°		27°	
Isthmus		Dry Tropical		Southern Mexico

Figure 4 Simplified graphic representation of the bands of wet and dry air which flow across North America, and simplified location estimates under Cold (left) and Warm (right) global climates.

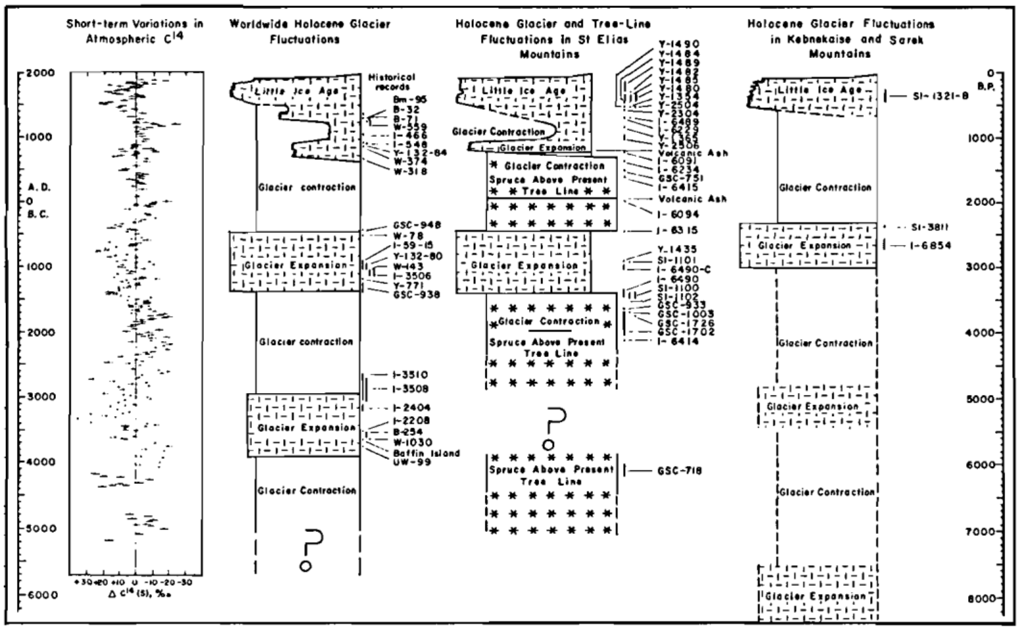

Figure 5 Holocene short-term C^{14} variations, glacier events, and tree-line fluctuations. Short-term C^{14} variations are from Suess (1970; figs 1 and 2) and represent deviations in C^{14} from a best-fit sine-wave curve drawn through the scatter of points representing long-term Holocene change in atmospheric C^{14}. Time scales are in calendar years. Therefore the C^{14} dates are corrected to calendrical years so that glacial and tree-line fluctuations can be compared directly with the absolute tree-ring chronology of short-term C^{14} variations.

A period of cold and glacial advance marks the interval from 1400 BC to 500 BC (all dates calendar or corrected C"); in some terminologies, the Sub-Boreal. The Earth was generally cooler, sea levels lower, and the bands of moist and dry air mentioned in the last section would have been shifted southward. Texas and southern Mexico would have been wetter, northern Mexico dry and northern U.S. drier.

From 500 BC to AD 600, referred to by Denton and Kadén as the Roman Empire Climatic Optimum, the bands would shift back to the north. The deserts of northern Mexico would be wetter, Texas and southern Mexico drier.

A second cycle of cold and warm temperatures followed, with AD 600-900 cold and AD 900-1250 warm. Of course, the exact boundaries drawn in both figures 5 and 6 must be taken to mean within a few decades. Also, the C14 dates are corrected to calendar years for reasons discussed in Denton and Karla's figure caption.

TABLE 1

Climatic conditions in the Upper Little Colorado[a]

Time period (A.D.)	*Rainfall intensity*	*Rainfall distribution*	*Cultural favourability*	*Global climate*	*Culture (AU site density)*
200–400	Decreased effective moisture	Biseasonal rainfall	Unfavourable	Warm	.20
400–600	Increased effective moisture	Biseasonal rainfall	Favourable	Cool	.41
600–900	Decreased effective moisture	Biseasonal rainfall	Unfavourable	Cold	1.08
900–1100	Increased effective moisture	Biseasonal at first, shifting to a heavy summer concentration	Favourable	Warm	2.61
1100–1300	Decreased effective moisture	Summer rainfall pattern	Most unfavourable	Cold	.58
1300–1500	Increased effective moisture	Biseasonal rainfall	Favourable	Cool	.10

[a]After Hevley 1964, adapted from Plog (1974:41–42).

Culture and civilization in North America

Culture change has at least three contributing components: environmental change, external cultural forces such as invasions by outsiders or heavy trade, and internal forces such as outstanding individuals and organizational breakdowns or elaborations due to population growth. Certainly the Mesoamerican cultural chronology is well embedded with examples of all of these. We will attempt in this section to sort out the respective contributions of these three forces.

The archaeological record shows that during the second and third millennia B.C. conditions in the Americas were ripe for the development of complex civilizations. Pottery and monumental architecture were grafted onto the existing agricultural complex from southern United States to Ecuador. From that time we can assume that there was a general upward momentum in population growth and cultural complexity which has continued with interruptions to the present day. Within that time range there were notable ups and downs in population and complexity in regional contexts. Some of these changes are attributable to expanding empires, perhaps beginning with Olmec domination of wide areas of Mesoamerica, certainly visible in the apparently omnipresent Teotihuacano manifestation, and also traceable historically in terms of Aztec and Spanish conquests.

The effects of outstanding individuals can only be traced through written records. However, it is known from hieroglyphic texts that centralized Maya regional states were established by dynamic individuals who were succeeded by less spectacular personages. As another example, the Aztec death-cult was exploited by a powerful government leader to control conquest and development of the Aztec state.

In the midst of this rich written and archaeological record, little attention has been given to the environmental component of cultural change (Hammond 1977:313). As we shall see, if one is willing to accept the temporal coincidence of marked climatic changes with cultural changes as being causally related, then the record allows at some points for the inference of climatic changes having substantial effects on the course of development in Mesoamerican civilization.

A very interesting aspect of this potential to gauge the effects of climatic change on high civilization resides in the fact that our culture was confronted with a similar climatic change about 1960 (Gunn 1979). Almost annual anxiety about food and fuel shortages and transportation interruptions bear witness to the fact that we are still in the process of adjusting to that change. We hope that examination of the effects climate had on past cultures will not only enhance our understanding of the progress of those civilizations, but perhaps suggest viable solutions of our own climatic dilemma.

In the following paragraphs we will examine the histories of fifteen ancient Mesoamerican cities and the cultural chronology of various areas of the U.S. in the light of the previously discussed information on the chronology and means of climatic change in North America (fig. 6). The sample from Mesoamerica (fig. 7) is simply the cities included in Jacquetta Hawkes' *Atlas of Archaeological Sites.* It is adequate for a broad area study for the following reasons. First, it is composed of the most spectacular and therefore most prominent and successful cities from various time periods. Second, the sample is spatially diverse enough to sample all areas of civilized North America.

A cursory examination of figure 6 shows that in some cases there are immediately observable correspondences between periods of active habitation in various cities and climatic intervals along the bottom. In other cases there do not appear to be correspondences. For instance, the relatively inactive Period II at Monte Alban is at the maximum of warmth during the Roman Empire Climatic Optimum between 100 B.C. and A.D. 200. Several cities terminate living habitation at around A.D. 900, the beginning of the Medieval Climatic Optimum. On the other hand, occupations at El Tajin and Chichen Itza run through the A.D. 900 date uninterrupted. If we are to find a complete explanation of the duration of habitation in Mesoamerican cities, then, the factors involved are more complex than a simple comparison between climatic and habitation chronologies will allow.

As we shall see, two qualifying concepts appear to cover most of the exceptions to climatic control of the duration of habitation. The first is VULNERABILITY to climatic change. Some

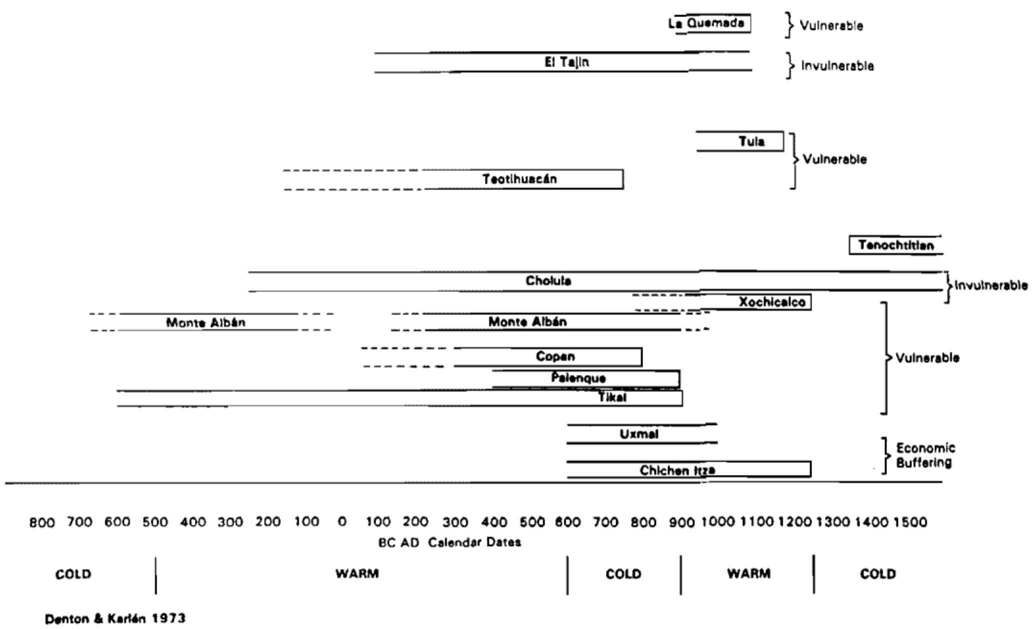

Figure 6 Duration of occupation of Mesoamerican cities utilized in the study

cities are so situated as to isolate them from the effects of climatic changes, others are quite vulnerable. The second concept, ECONOMIC BUFFERING, can also have significant moderating influences on the effect of climatic change either for better or worse.

Since the lowlands of eastern Mexico and Yucatan illustrate the possible effects of climate and the two moderating concepts, they are a good point of departure. It is worthy of note that all the humid, lowland florescences are during periods of cold climate. We define florescence as a period of initial or further rapid development of cultural complexity (or of civilization). The Olmec at San Lorenzo-La Venta established themselves in what is now an esturian swamp during the second millennium B.C. Occupation shifts from San

Lorenzo to La Venta about 900 B.C., apparently a product of a cultural event. However, occupation at San Lorenzo terminated at the same time as the end of that cold period (Coe 1977). Similarly, Hammond's work in Belize has shown that there were early developments in the Maya lowlands of Yucatan, an unlikely place to begin a civilization. However, as we have seen, colder periods bring more rainfall to the lowland areas. Increased precipitation, along with decreased evapotranspiration, would swell stagnant swamps into passable freshwater lakes with fish, enhance agricultural potential, etc. Also summers, in particular, tend to be cooler during periods of cold climate, so the temperatures may have been less formidable. Add to this the fact that sea levels fall during periods of glacial advance, which in the case of the ()lime would have drawn the salt marshes out of their homelands. Under such conditions the establishment of a civilization does not seem so unlikely.

Whether climate retarded the development of civilization in the lowlands during the warm Roman Empire Climatic Optimum should be a subject of study. Certainly the underlying momentum was maintained. However, it is interesting that Maya civilization attained its classical zenith during the cold period from A.D. 600-900. Puleston (1974) has found evidence for an urban implosion during the Late Classic about A.D. 770. In view of the extremely taxing effect of

Figure 7 Map of cities utilized in the study (adapted from Hawkes 1975)

population implosion on the environment, things must have been going very well at that point. Occupation at Tikal terminated coincidentally with the cold period. Notable is the demise not only of Tikal, but also Uxmal and Palenque from our sample of cities. Various studies have suggested that the collapse of Mayan civilization was a developmental overshoot which overtaxed the resources of the community (Culbert 1973). It seems possible, however, that overpopulation may only have provided the sufficient conditions for collapse. Rathje (1971) has pointed out that the Maya lowlands are devoid of many of the necessary resources which they used.

They were, therefore, heavily dependent on trade, and the spectacular development of Mayan civilization may, in part, be attributable to the necessity of trade (Rathje 1971). Also recent settlement pattern work by Adams (1977) shows that the Maya were apparently dependent on an exceptionally labour-intensive agricultural complex. In view of the fact that labour- intensive agriculture is a nearly infinitely expandable subsistence base, given adequate land and water (Geertz 1969:18), it does not seem likely that over-population in, and of, itself would supply the sufficient condition for a collapse of the magnitude of the Mayan event (see also Logan and Sanders 1976).

It does seem plausible, however, that if the amount of precipitation were substantially reduced, as it would have been at AD. 900, the effect would have been to undercut both the trade and agricultural efforts on which the Maya relied. Lakes used for transportation of trade and as a source of fish would have turned to impassable, humid, periodic swamps. Water would no longer have been available in sufficient quantities to feed the great canals and their subsidiary branches to maintain agricultural production. Ball has shown that extremely dry seasons can curtail even the production of the otherwise reliable ramon nut tree. Puleston theorizes that ramon provided a secondary, backup staple which made the maintenance of large populations possible in Mayan Yucatan. That is to say, ramon was a means of circumventing Liebig's Law of the Minimum. Since, as we have seen, warmer global climate would have had the effect of lengthening the dry season, reducing mid-winter precipitation, all the potential for catastrophe is inherent in the apparently rather delicate Mayan subsistence system.

Chichen Itza is the exception. Also Uxmal may have lasted 150 years longer than the central Maya lowland cities. In fact, at Chichen Itza the greatest development occurred during the warm Medieval Climatic Optimum. Here we invoke the moderating influence of economic buffering. Unlike the agriculturally oriented lowland Maya, Chichen Itza was established by Toltec colonialists to control exploitation of the salt beds of the northern coast of Yucatan (Eaton 1978). In this particular case the increased evapotranspiration of a warmer climatic interval would have enhanced rather than detracted from the city's economic orientation. The increased salinity of the sea, and increased rates of evaporation in the salt fields, would have served to increase production and strengthen the city as a centre of trade in the commodity of salt.

La Quemada provides interesting confirmation of the movement of the wet tropical air stream into northern Mexico during warmer times. The entire period of development of La Quemada was during the warm Medieval Climatic Optimum. Tula may also have fallen under the influence of this air stream. El Tajin is a peculiar case spanning two warm periods and one cold period. Because of its northerly location it is not surprising that it did well during the warmer periods, being subject to the wet, tropical air mass. Why it should have existed throughout the 600-900 minimum, with its dry, subtropical air, is still a question. It may be that El Tajin was not particularly vulnerable to climatic changes for some as yet unsurmised reason. Also, El Tajin had at least some irrigation systems and lay between two rivers, although the latter were not near by.

In like manner, Casas Grandes in Northern Mexico was occupied from A.D. 700 to 1684, with the major prehispanic florescence coming between A.D. 1060 and 1340. The florescence was based on the centre's importance as a loading point between Mesoamerica and the cultures of the Greater Southwest.
The great city of Teotihuacan was apparently in its heyday when the Roman Empire Climatic Optimum forced increased precipitation in Northern Mexico. A down-turn in the dominance of Teotihuacan has been noted at about A.D. 700 (Parsons 1974:89-90). The fact that occupation did not end suddenly with the end of the Roman Empire Climatic Optimum, but trailed off over a period of time, may be attributable to the buffering effect of climatically invulnerable resources such as obsidian, and also to the prestige of the city as a religious centre and a goal for pilgrimages.

The fortified city of Xochicalco was located near present-day Cuernavaca and to the southwest of Teotihuacan. It guarded the entrance to the Balsas River region (a jade source) and to Guerrero generally. Jaime Litvak-King (1970) has argued that Xochicalco only began really to reach its maximum florescence when Teotihuacan was on the wane. And Xochicalco may have deliberately blocked off the other city from access to Guerrero resources. Sanders (1965:184) suggests that Xochicalco may have been one of a combination of lesser city states that combined to bring down Teotihuacan. However, the evidence is that Xochicalco did not last very long, but was itself overthrown or had died on the vine by A.D. 1250. For our purposes, it is interesting to note that this period corresponds to the Medieval Climatic Optimum: the period of dominance by Xochicalco et al. may have been fostered by climatic factors.

The highlands of southern Mexico provide numerous insights into the progress of climatic and cultural change. Perhaps Monte Alban is the most interesting example. Monte Alban is located high on the top of a mountain. Until dried-up springs were discovered by James Neely during a survey (Neely and O'Brien 1973), it was thought that the city had to be supplied by water from the valley far below. It is significant that the springs are dry now, which indicates that during warm climatic intervals the springs of Monte Alban turn away their beneficence.

The occupation of Monte Alban had an up-and-down history. It was first inhabited in 600 B.C. From then till 100 B.C., monuments and architecture, along with some of the earliest writing in Mesoamerica, serve to mark the accomplishments of the city. Period H, from 100 B.C. to A.D. 200, was an interval of marginal habitation, few architectural achievements, etc. Then suddenly efforts were revived with demolition of old buildings and construction of massive new structures in Period III, A.D. 200-900. Since the break in habitation is at the apogee of the Roman Empire Climatic Optimum, it is tempting to think that the springs must have dried up during that time, forcing a down-turn in the occupation of the city, if not in its prestige.

Perhaps even more interesting is the termination of living occupation at Monte Alban at A.D. 900, but not the end of its use. In the subsequent warm period, Monte Alban was used as a mortuary city, suggesting that men in the waterless stage of their immortality still preferred the ancient and revered city. The fact that Mitla, a city of the Valley of Oaxaca below Monte Alban, continued the development of the local Zapotec culture, further substantiates the inference that Monte Alban was abandoned for reasons other than general population reduction. Flannery's studies in the Valley of Oaxaca have revealed a mature water-management system for agriculture. We might add, one tested by centuries of significant ups and downs in water supply.

Terminations of occupation at other highland cities, often by burning, as at Teotihuacan in the dry northern Basin of Mexico, indicate the vulnerability of highland cities to drier conditions, either directly through reduced agricultural productivity, or indirectly through population disruptions the probable cause of which is drying conditions. The sacking of Tula, for instance, may be attributable to drier conditions in northern Mexico, forcing resident populations southward. Likewise, the establishment of Tenochtitlan in the fourteenth century A.D. illustrates movement out of the north and the establishment of a city the success of which was favoured by adequate lake levels in the Valley of Mexico, the product of a cool interval known as the Little Ice Age.

Cholula is apparently an example of extreme invulnerability to climatic change. This condition may have been assisted by a location which suggests that it might have been in a zone of overlap between the warm and cold precipitation bands. In addition, Cholula, though located in a mountain valley, afforded easy access to the Vera Cruz coast which may have acted as an economic and/or climatic buffer. It is known, for instance, that the somewhat more distant Aztecs drew provisions from the coastal zone during a famine in 1454 (Kovar 1970:29-31).

In eastern North America the march of cultures has long been thought to have been a product of climatic changes. Griffin first proposed that the demise of Hopewell around AD. 600 was a product of a shift toward unfavourable climate. Subsequent research, reported by Streuver and Vickery, added the details to Griffin's surmise (Streuver and Vickery 1973). Finally, Baerreis, Bryson and Kutzbach (1976) placed the sequence of events in a firm palaeoclimatic perspective. Hopewell flourished during the Roman Empire Climatic Optimum. During this time Tropical Flint corn was grown, a variety not now adapted to high latitudes. After 600 A.D. corn was no longer grown in the Ohio Valley. Rather, a variety of lambs-quarter was cultivated, which was adapted to colder conditions. Northern flint corn was eventually developed and maize horticulture was reintroduced to the north. Even so, significant developments in the north-eastern U.S. awaited the coming of the Medieval Climatic Optimum. During that warm interval Cahokia, at the confluence of the Mississippi, Missouri and Ohio rivers, grew to the proportions of a city and was abandoned with the onset of the Little Ice Age. The city, of perhaps 50,000 people, was so completely abandoned by the sixteenth century that French priests failed to map it in their earliest visits to midwestern U.S. (Fowler 1974). By then, the centres of high culture had shifted to southern U.S. and taken form, such as Plaquemaine, Caddo, etc. In each case the areas of high civilization were located in the belt of wet westerlies, as it was shifted north and south by warming and cooling global climate.

The American Southwest offers an interesting perspective on our problem. The Southwest is one of the best studied areas of the world palaeoclimatically. In fact, the existing data on local climate and cultural interactions is more highly resolved than the global sequence we have been using from Denton and Karlén, figure 5. Table 1 shows the complex combinations of effective moisture and seasonal distributions of rainfall that can occur in the Upper Colorado River Valley along with Plog's (1974) discussion of cultural effects of climatic change. In the Southwest, neither very warm nor very cold global climates are favourable to domesticated or wild species of plants and animals. Rather, it is the mid-ranges of global climatic variation which foster favourable conditions. Site densities suggest that culture and population increased as long as rainfall occurred both in summer and winter (biseasonal), and that the densest populations were permitted by a combination of high effective moisture and biseasonal rainfall at the height of the Medieval Climatic Optimum. The intensive occupation of the Valley was terminated by the first cold interval of the Little Ice Age, which resulted in both decreased effective moisture and rainfall limited to summer.

Conclusion

In conclusion, then, we are prepared to argue that the growing array of palaeoclimatic evidence researched over the last decade should be considered as a part of the complex set of factors which govern the ups and downs of civilizations and cultures. The florescences of cultures in North America no doubt contain many instances of beginnings and endings which cannot be explained by coincident climatic events of similar magnitude. However, as we have pointed out, climatic change, coupled with the examination of climatic vulnerability and economic buffering, seems in many cases to offer potential explanations of the rise and demise of civilizations. Naturally, these observations are offered for consideration and testing by regional experts, not as proven facts.

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References

Adams, R. E. W. 1977. *Prehistoric Mesoamerica.* Boston: Little, Brown.

Angell, J. K. and Korshover, J. 1977. Variation in size and location of the 300 mb north circumpolar vortex between 1963 and 1975. *Monthly Weather Review.* 105(1):19-25.

Angell, J. K. and Korshover, J. 1978. The expanded north circumpolar vortex of 1976 and winter of 1976-1977, and attendant vortex displacement. *Monthly Weather Review.* 106(1): 137-142.

Baerreis, D. E., Bryson, R. A. and Kutzbach, J. E. 1976. Climate and culture in the Western Great Lakes region. *Midcontinental Journal of Archaeology. 1(1):*39-58.

Brakenridge, G. Robert. 1978. Evidence for a cold, dry full-glacial climate in the American Southwest. *Quaternary Research.* 9(1):22-40.

Bryson, Reid A. and Murray, Thomas, J. 1977. *Climates of Hunger: Mankind and the World's Changing Weather.* Madison: University of Wisconsin Press.

Coe, M. D. 1977. Olmec and Maya: a study in relationships. In *The Origins of Maya Civilization* (ed. R. E. W. Adams). Albuquerque: University of New Mexico Press.

Culbert, T. Patrick (ed.). 1973. *The Classic Maya Collapse.* Albuquerque: University of New Mexico Press.

Denton, George and Karlen, Wibjorn. 1973. Holocene climatic variations - their pattern and possible cause. *Quaternary Research.* 3(2):155-205.

Eaton, J. D. 1978. *Archaeological Survey of the Yucatan-Campeche Coast.* Middle American Institute, Tulane University. 46:1-67.

Fowler, Melvin L. 1974. *Cahokia - Ancient Capital of the Midwest.* Reading, Mass.: Addison-Wesley.

Geertz, Clifford. 1969. Two types of ecosystems. In *Environment and Cultural Behavior* (ed. A. Vayda). Garden City, New York: Natural History Press.

Griffin, James B. 1967. Eastern North American archaeology: a summary. *Science.* 156: 175-91.

Griffin, John W. 1974. *Investigations in Russell Cave.* National Park Service, Department of the Interior, Publications in Archaeology 13.

Gunn, Joel. 1979. Global Climate and Texas Moisture. In *The Impact of Climatic Change* (eds J. Gunn *et al.).* Center for Archaeological Research, University of Texas at San Antonio.

Hammond, Norman. 1977. The Earliest Maya. *Scientific American.* 236(3):116-133.

Hawkes, Jacquetta. 1975. *Atlas of Archaeological Sites* (second edition). New York: McGraw-Hill.

Hevley, R. H. 1964. *Pollen Analysis of Quaternary Archaeological and Lacustrine Sediments from the Colorado Plateau.* Unpublished Ph.D. dissertation. University of Arizona.

Kovar, Anton. 1970. The physical and biological environment of the basin of Mexico. In *The Natural Environment, Contemporary Occupation and 16th Century Population of the Valley* (eds W. Sanders, A. Kovar, T. Charleton, and R. Diehl). Department of Anthropology, Pennsylvania State University, Occasional Papers in Anthropology 3.

Litvak-King, J. 1970. Xochicalco en la caida del Clasico: una hipitesis. *Anales de Antropologia.* 7:131-144.

Logan, M. H. and Sanders, W. T. 1976. The model. In *The Valley of Mexico,* pp. 31-58 (ed. E. Wolf). University of New Mexico Press.

National Academy of Science. 1975. *Understanding Climatic Change: A Program for Action.* Washington, D.C.: National Academy of Science.

Neely, James A. and O'Brien, Michael J. 1973. *Irrigation and settlement nucleations at Monte Alban: A Test of Models.* Paper presented at the 38th Annual Meeting of the Society for American Archaeology, San Francisco.

Parsons, J. R. 1974. The development of a prehistoric complex society: a regional perspective from the Valley of Mexico. *Journal of Field Archaeology. 1:81-108.*

Plog, Fred T. 1974. *A Study of Prehistoric Change.* New York: Academic Press.

Puleston, Dennis E. 1974. Intersite areas in the vicinity of Tikal and Uazactun. In *Mesoamerican Archaeology: New Approaches* (ed. N. Hammond). Austin: University of Texas Press.

Rathje, William L. 1971. The origin and development of lowland Classic Maya Civilization. *American Antiquity*. 36(3):275-285.

Sanchez, W. A. and Kutzbach, J. E. 1974. Climate of the American tropics and subtropics in the 1960s and possible comparisons with climatic variations of the last millennium. *Quaternary Research.* 4(2): 128-135.

Sanders, W. T. 1965. *Cultural Ecology of the Teotihuacan Valley*. Department of Sociology and Anthropology, Pennsylvania State University.

Streuver, Stuart and Vickery, Kent D. 1973. The beginnings of cultivation in the Midwest-riverine area of the United States. *American Anthropologist.* 75(5):1197-1220.

Suess, H. E. 1970. Three causes of secular C^{14} fluctuations, their amplitudes and time constants. In *Radiocarbon Variations and Absolute Chronology,* pp. 595-604 (ed. I. V. Olsson). New York, Wiley Interscience.