Addendum I: Paleoclimate and the Solar-Insolation / Tidal-Resonance Climate Model

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In climate research, instrumental observations of the past 100 or so years drive speculation on climatic process and global changes in atmospheric circulation. Likewise in paleoclimate research, generally less precise but much longer time series provide the basis for speculation on ultimate cause(s) and the resulting temporal and spatial patterns of longer term climate change. Recent papers (Karlstrom 1995, 1996) provide detailed analyses of more than 40 high-resolution time series culled from the extensive paleoclimate literature that appear to define cyclical elements of the Solar-Insolation/Tidal-Resonance Climate Model. This model was earlier referred to as the Milankovitch/Pettersson Climatic Theory (Karlstrom 1961 cf).

This paper provides comparable analyses of an additional 20 or so, evidently supportive, climate and volcanic time series. The tree-ring, historical, pollen, cultural, time-frequency, and hydrologic records range in length from 400 to 90,000 years and spatially from Alaska to Tierra del Fuego. Included are records from both Old World and New World sites. The temporally defined cycles range in wavelength from decades to 10s of thousands of years.

Procedures of analysis and presentation are discussed in previous papers. These differ from those of most paleoclimatic researchers:

- By placing subdivision boundaries at chronostratigraphic Point Boundaries marking inferred warm/dry culminations rather than at conventional (approximate) transitional positions to increase precision in temporal definition and correlation of both longer- and shorter-term events (Karlstrom 196l; Ray and Karlstrom 1968).
- By procedures in presentation of percent-frequency pollen and other types of similar records that contrast the inferred warmer/drier indices from inferred cooler/wetter indices by subtracting the former from the latter components (Hevly and Karlstrom 1974).
- By plotting, at various levels of smoothing, the selected paleoclimatic records on common time scales to graphically judge degree and sign of correlation and to facilitate cyclical analyses of both primary and secondary trends.

In: C.M. Isaacs and V.L. Tharp, Editors. 1997. *Proceedings of the Thirteenth Annual Pacific Climate (PACLIM) Workshop, April 15-18, 1996*. Interagency Ecological Program, Technical Report 53. California Department of Water Resources.

- By half-cycle smoothing and differencing (derivatives) of those records based on equal-interval sampling as a direct test of correlation with the theoretically dated Solar Insolation/Tidal Resonance Model (Karlstrom 1995).

The coefficient of correlation (R) shown on most of the figures is simply the percent of apparent match between paleoclimatic trends and turning points of the theoretical cycle or resonance indicated by wavelength in years within the accompanying parentheses.

Paleoclimate Time Series

Figure 1 summarizes the highest resolution data available relating to climate, hydrology, and cultural history of the Anasazi on the Colorado Plateaus. The striking correlation between longer-term climatic change (from tree-rings), inferred hydrology (from Point Boundary analysis of Southwest alluvial chronostratigraphy), and the number and distribution of tree-ring dated surface sites (crude proxy for population size and movement) suggests strong influence on prehistoric cultural evolution in the region. These results are generally in keeping with both previously and subsequently published interpretations (Karlstrom *et al* 1976; Euler *et al* 1979; Berry 1982; Breternitz 1988; Gumerman 1988; Hevly 1988; Karlstrom 1988; Petersen 1988, Plog *et al* 1988; Orcutt 1991; Dean and Funkhouser 1994). As noted by J.S. Dean (personal communication, 1996) two papers now in press[1] provide tree-ring and alluvial reconstructions that bear an uncanny resemblance to my climatohydrologic model. Alternative nonclimatic or behavioral interpretations of cultural adaptation are also addressed in Gumerman (1988) and most recently elaborated by Dean (1996) in the form of a conceptual model interrelating low- and high-frequency changes in environment with demographic and behavioral adaptations of the prehistoric Anasazi over the past 2000 years. A similar pattern of cyclical change (the 139-year Event Cycle) may be reflected historically in Egyptian dynastic changes back to mid-Holocene time (see Figure 22, below).

Figures 2-5 are European historical and tree-ring proxy records of climate that when analyzed by half-cycle smoothing predominantly record in-phase relations with the 139-year Event Cycle (Figure 2) and with the 278-year Subphase Cycle (Figures 4 and 5). Figure 3 suggests that the irregular higher frequency trends of some bioclimatic records may be largely reproduced by plotting the fractional subharmonics to the differing seasons of recurrence.

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[1] One on tree-ring data from New Mexico by Grissino-Mayer and the other on dated alluvium in Colorado by Force and Howell.

Figure 6 contains time-frequency diagrams of historical floods and frosts in China that suggest strong in-phase relations of floods with the 278-year Subphase Cycle and of frosts with its 2/1 (139-year) and 6/1 (34.33-year) resonances. The nearly one-to-one phasing of frosts with the 6/1 resonance (Brückner Cycle) is particularly impressive.

Figures 7-10 are pollen and isotope records from the Midwest (Figures 7 and 8), Alaska (Figure 9) and the Southwest (Figure 10) that show common Late Glacial and Postglacial trends and a moderate to strong tendency to oscillate in phase with the secondary 3336-year Substage Cycle.

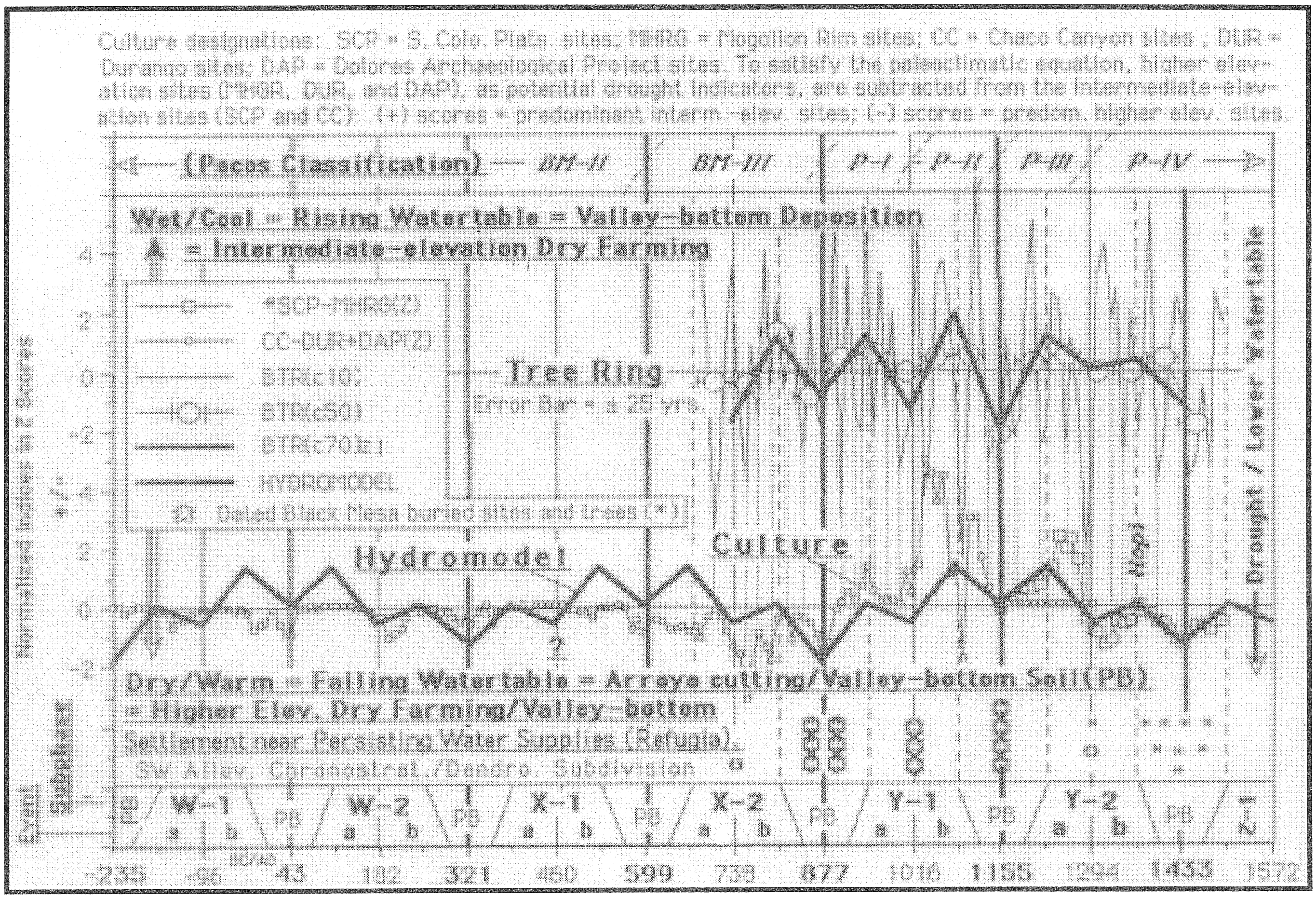

Figure 1 Colorado Plateaus dendroclimate, hydrology, and culture on timescale of the 139-year Event Cycle and its 2/1 (69.5-year) resonance.

Decadal tree-ring indices from Berry (1982); 50-year and half-cycle smoothing. Tree-ring and radiocarbon-dated buried sites and trees and chronostratigraphic subdivision from Karlstrom (1976a, 1988); PB = clustering of basal contact dates. Tree-ring-dated surface sites from Euler *et al* (1979), Berry (1982), and Breternitz *et al* (1986). Note striking parallelisms between longer-term tree-ring trends, inferred hydrology and number of dated sites (population proxy).

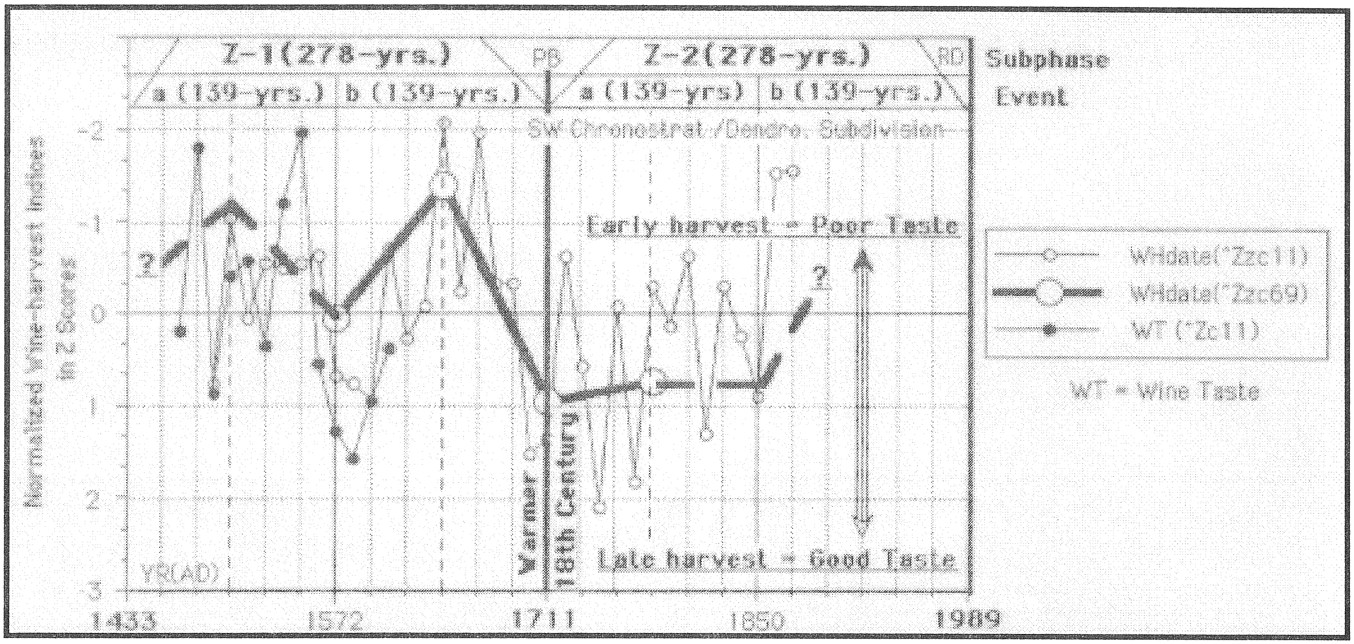

Figure 2 Northern European historical wine-harvest dates and quality on timescale of the 278-year Substage Cycle and its 2/1 (139-year) and 6/1 (23.166-year) resonances.

Annual wine indices from Ladurie (1971). Strong tendency for oscillations in phase with the 139-year Event Cycle. Note, however, the irregularities in the higher frequency trends that apparently are largely reproducible by plotting the seasonality of the fractional subharmonics, as shown in Figure 3.

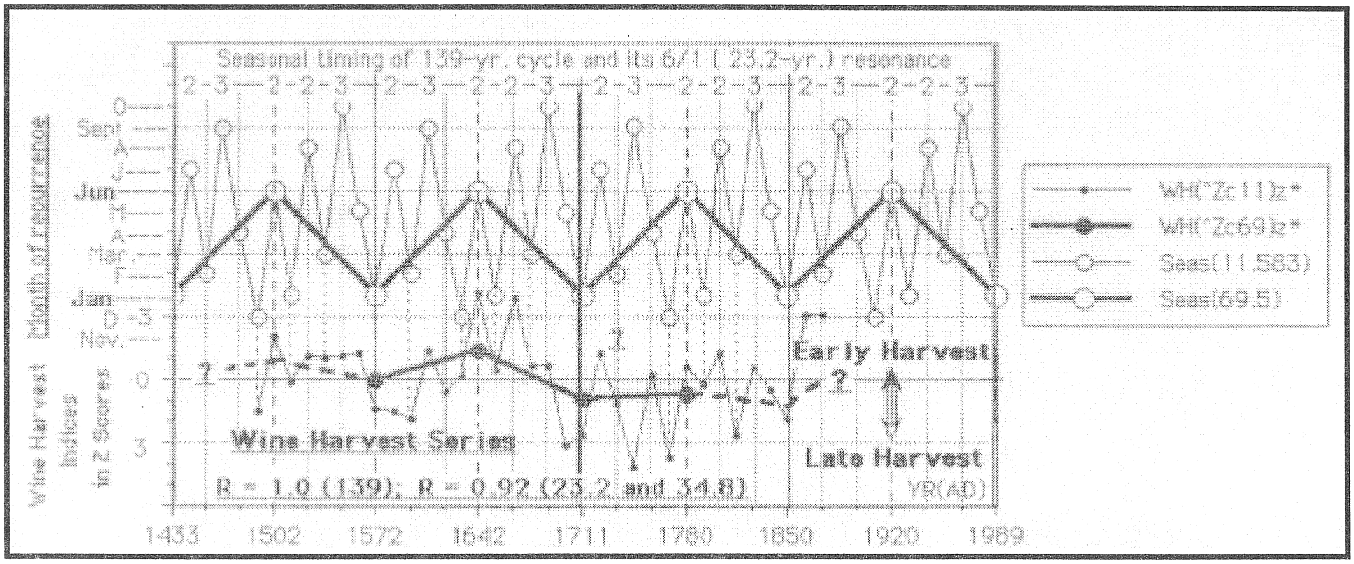

Figure 3 Correlation of Laderie's (1971) wine-harvest series with seasonal timing of the 139-year Cycle and its 2/1 (69.5-year) and 6/1 (23.166-year) resonances.

Smoothing as before centered on cycle turning points. Two-point cycle = 23.2 years; three-point cycle = 34.8 years. The resulting seasonal higher frequency series of 2/3/2/2/3-point cycles repeat in all Event Cycles and appear to have a strong expression in the higher frequency components of the wine-harvest record. The climatic dynamics involved remain obscure, but the largely replicated pattern does suggest that resonance forcing at differing seasons may explain part of the irregularities in some higher frequency bioclimate records.

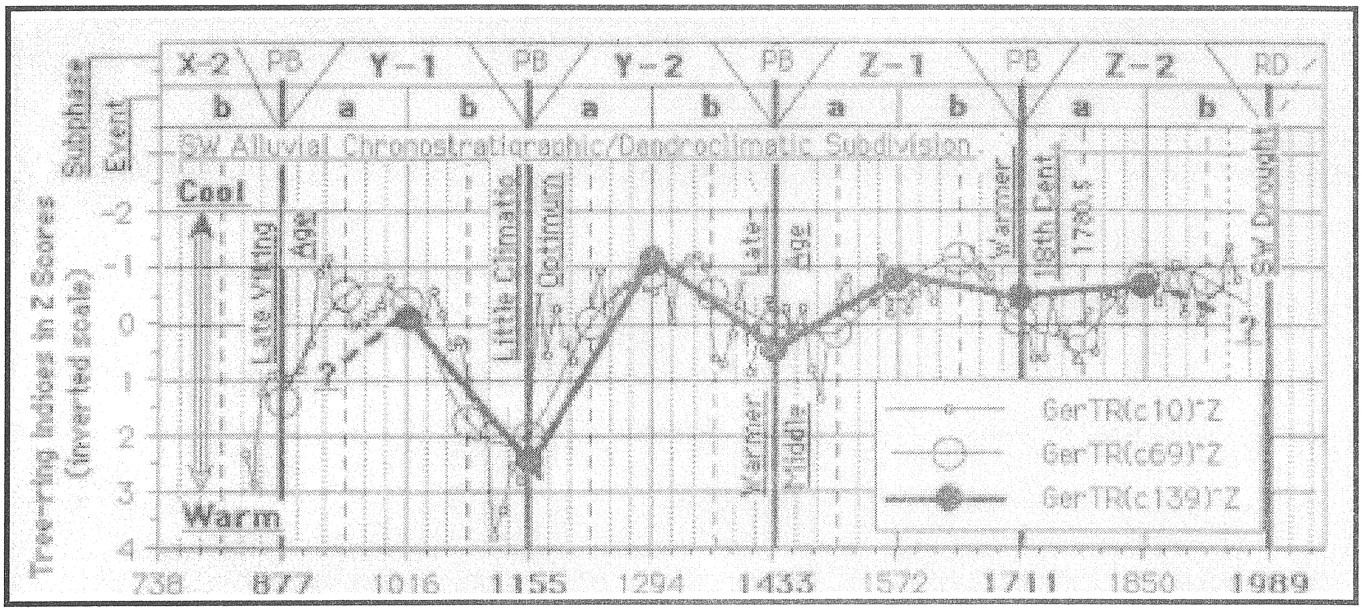

Figure 4 German tree-ring record on timescale of the 139-year Event Cycle and its 2/1 (69.5-year) and 6/1 (23.17-year) resonances.

Annual tree-ring indices from Ladurie (1971). Half-cycle smoothing as before. In contrast to the comparably smoothed North American Southwest dendroclimatic records that reveal the regionally robust 139-year Event Cycle (Figure 23), this German record shows the strongest tendency to oscillate in phase with the longer-term 278-year Subphase Cycle, suggesting differing response functions and/or regional atmospheric dynamics. Of the higher frequency components, the 6/1 (23.17-year) resonance apparently provides the best fit for the decadal fluctuations. That temperature may have been the limiting factor on tree growth in Germany is suggested by its northerly location as well as by other European evidence that centers the warmer "Little Climatic Optimum" in the 12th century and the warmer "Late Middle Age" in the 15th century. The tree record further suggests a warmer interval in the 18th century, or again compatible with that of the Southwest, including the short anomalously warm interval around AD 1780 present in some of the Southwest dendroclimatic records (Figure 23-2, -3, and -8). PB= Point Boundary.

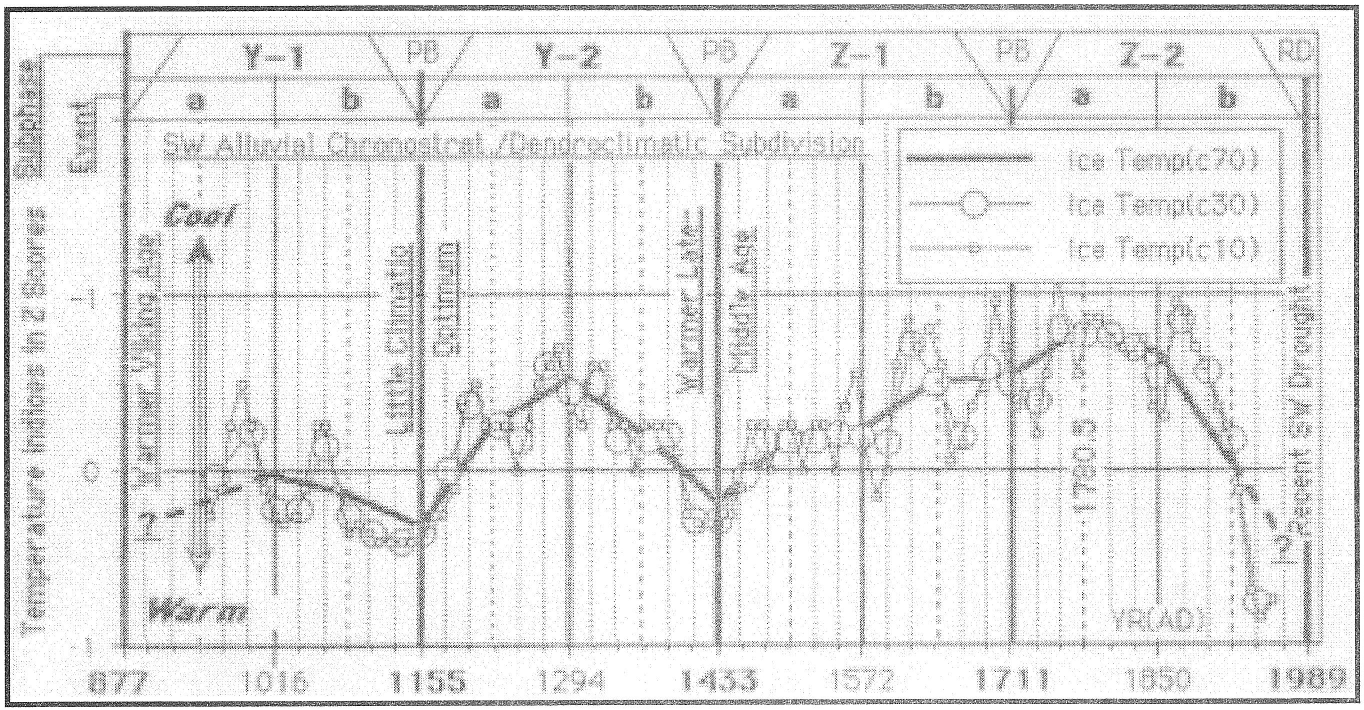

Figure 5 Iceland temperature record on timescale of the 139-year Event Cycle and its 2/1 (69.5-year) and 6/1 (23.166-year) resonances.

Ten-year temperature indices from Bergthorsen (1969). Half-cycle smoothing as before. Note the strong tendency to oscillate in phase with the 278-year Subphase Cycle, and the lesser tendencies with the 139-year Event Cycle and its 2/1 (69.5-year) and 6/1 (23.17-year) resonances. Compare with the shorter wine harvest record (Figure 2) and with the German tree-ring record (Figure 4), both of which appear to share common cyclical timings though with differing amplitudes. These differences may, in part, reflect differing regional climates, differing response functions and lags, or imperfections (nonclimatic noise) in these differing types of proxy records. The Medieval Warm period (MWP) placed from about AD 900 to 1300 by Lamb (1977) appears to combine several separate warmer intervals as recorded in higher resolution records from Europe, the Southwest, and elsewhere. For apparent post-AD 1700 correlation with Sunspot indices, see Figure 12 in Karlstrom (1995).

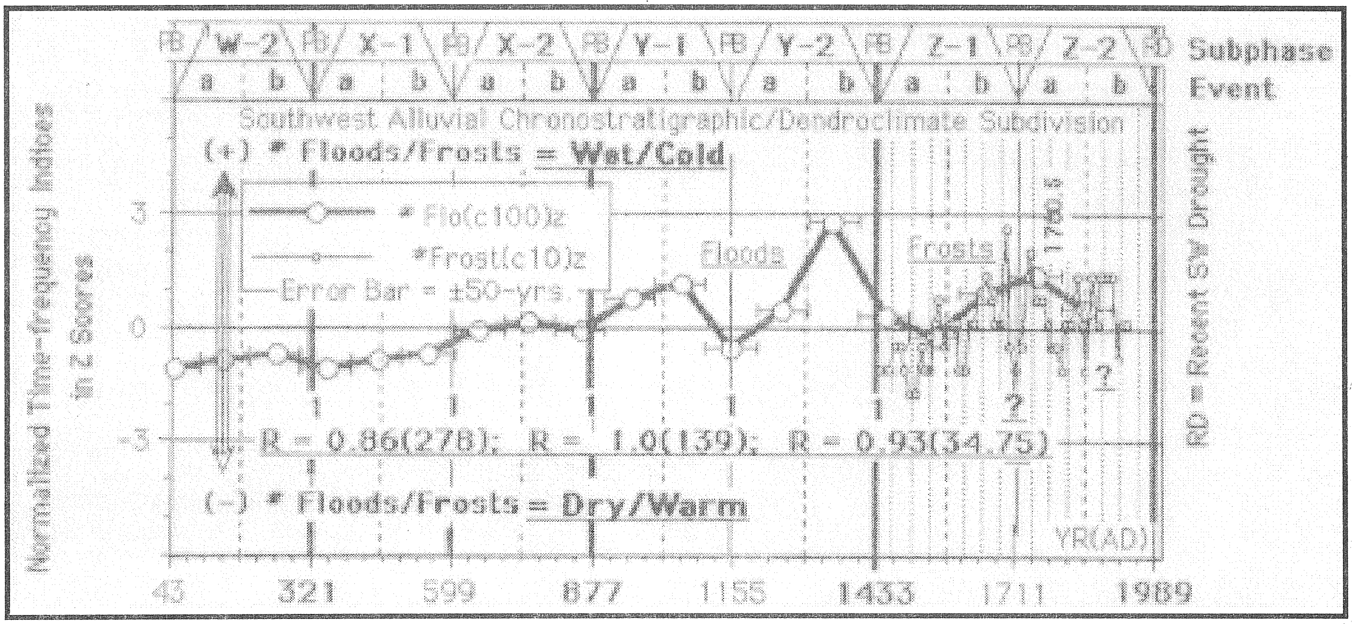

Figure 6 Chinese historical records of the frequency of floods (centered in 100-year intervals) and of frosts (centered in 10-year intervals) on timescale of the 278-year Subphase Cycle and its 2/1 (139-year) and 8/1 (34.75-year) resonances.

Indices from Bradley (1985: Floods p. 393; Frosts p. 383). Strong tendency for the century-smoothed flood record of northern China to oscillate in phase with the 278-year Subphase Cycle; equally strong tendency for the decadal frost record of central and southern China to oscillate in phase with its 2/1 (139-year) and 8/1 (34.75-year = Brückner Cycle) resonances. Note also the anomalously warm interval around AD 1780, which also appears in the German tree-ring record (Figure 4) and in some of the Southwest tree-ring records (Figure 23). The apparent strong correlation with the Brückner Cycle is particularly impressive. A similar cycle appears to be more mildly expressed back to AD 700 in a decadal tree-ring record of the southern Colorado Plateaus (Figure 24).

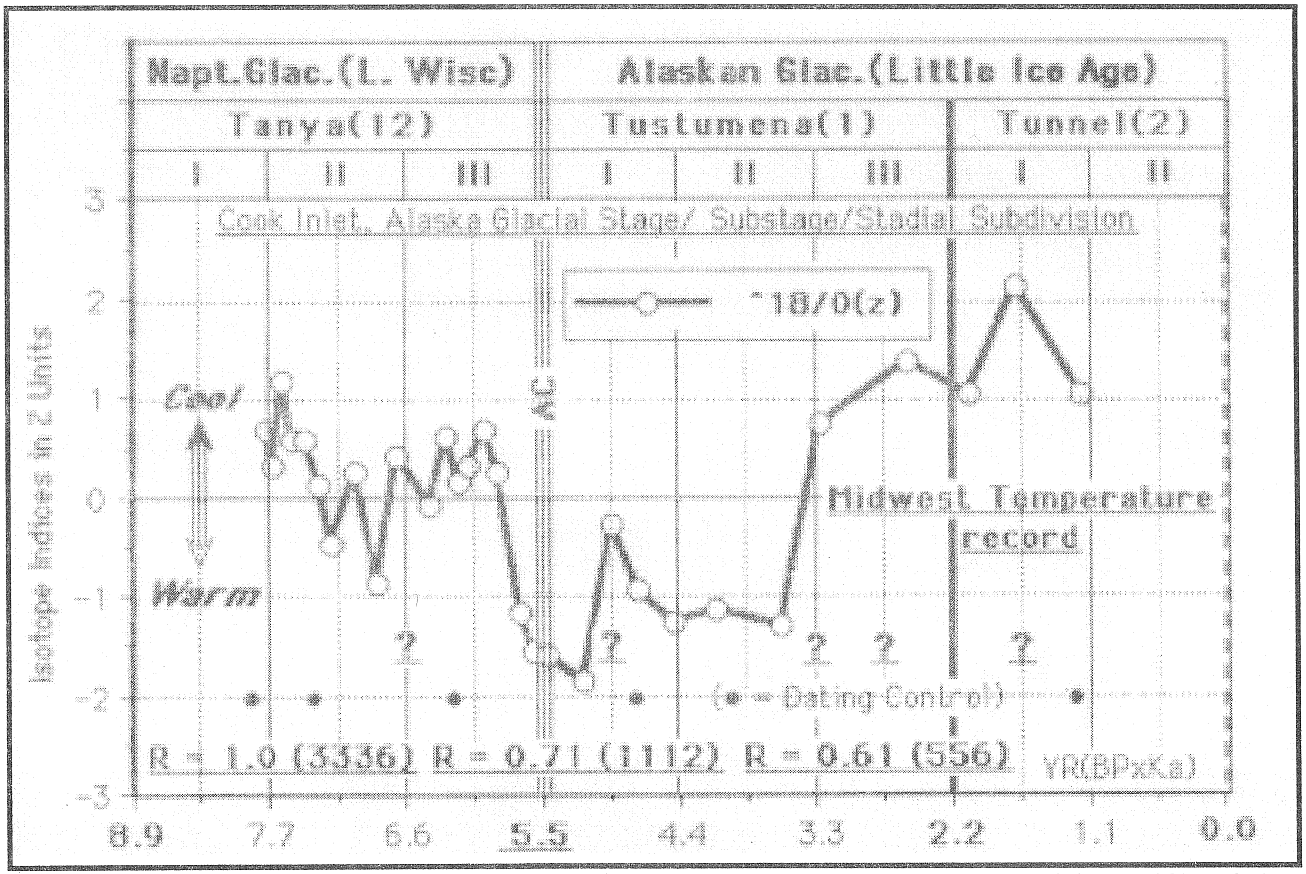

Figure 7 Midwest isotope record of the Holocene (speliothem calcite) on timescale of the 1112-year Stadial Cycle and its 2/1 (556-year) Phase Cycle.

U/Th-dated oxygen-isotope (temperature) indices from Dorale *et al* (1992). The record clearly places the warmest postglacial interval in the Midwest between 5000 and 6000 years ago, or contemporaneous with that in Europe (late Atlantic) and the western United States (Altithermal culmination = AC). The speliothem record also suggests a strong tendency to oscillate in phase with the Substage Cycle, a weaker tendency with the Stadial Cycle, and a very weak, or insignificant, tendency with the Phase Cycle due partly to sample spacing being too wide.

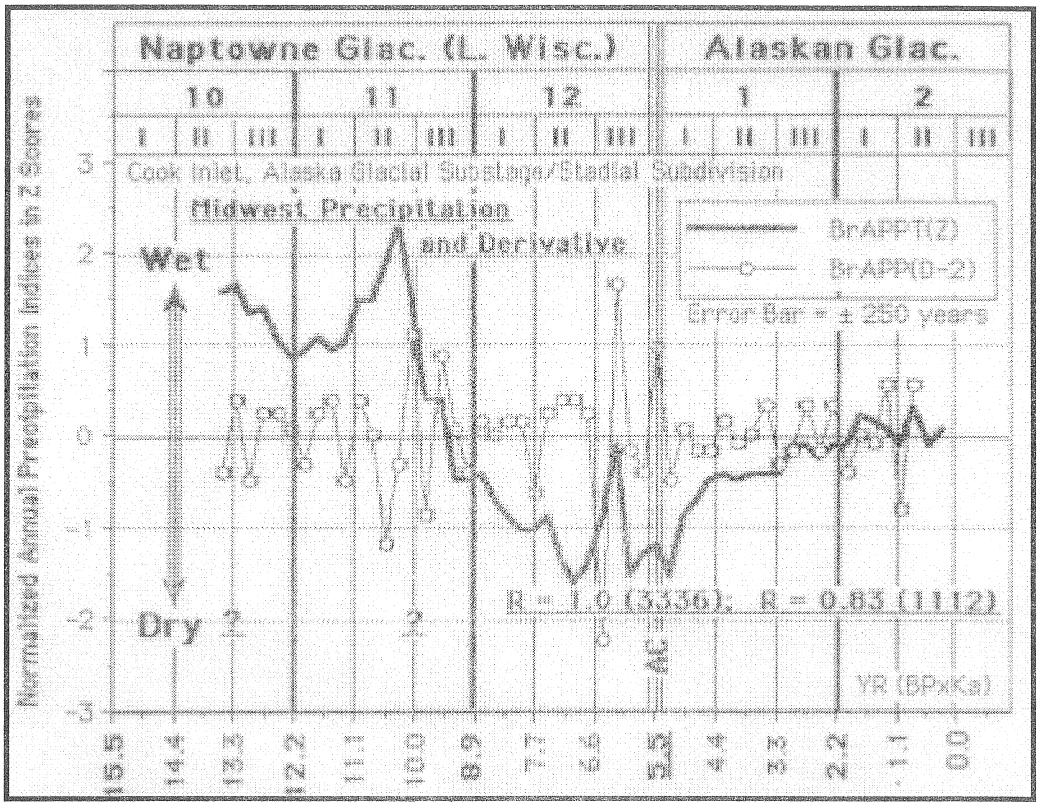

Figure 8 Pollen-derived precipitation record from the Midwest on timescale of the 3336-year Substage Cycle and its 3/1 (1112-year) Stadial resonance.

Annual precipitation indices from Webb and Bryson (1972) replotted in 500-year intervals. Strong tendencies to oscillate in phase with the Substage and Stadial cycles. This precipitation record, combined with the speliothem temperature record (Figure 7) strongly suggests that at least in part of the Midwest, the Altithermal marks the driest and the warmest interval in postglacial time, similar to that in the western United States.

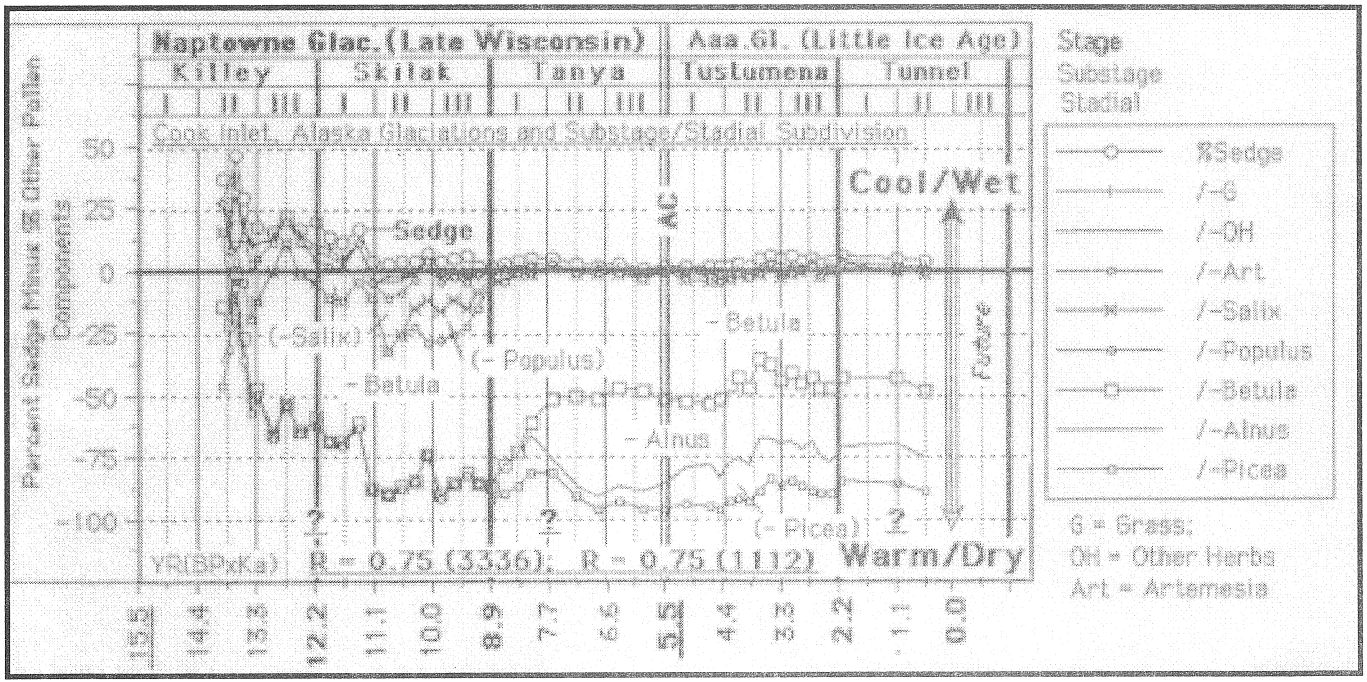

Figure 9 Bioclimatic record of Sithylemenkat Lake, northern Alaska (N66°) on timescale of the 1112-year Stadial Cycle and its 2/1 Phase (556-year) resonance.

Dated pollen indices from Anderson *et al* (1990). This high-latitude record, though somewhat complacent, seems to replicate middle latitudes Northern Hemisphere records in placing the warmest/driest postglacial interval between 5000 and 6000 years ago. This result, however, does not agree with the general palynological consensus that the warmest postglacial interval in Alaska is marked by the Populus maximum about 10,000 years ago. The Lake record also suggests a fairly strong tendency to oscillate in phase with the Substage and Stadial cycles..

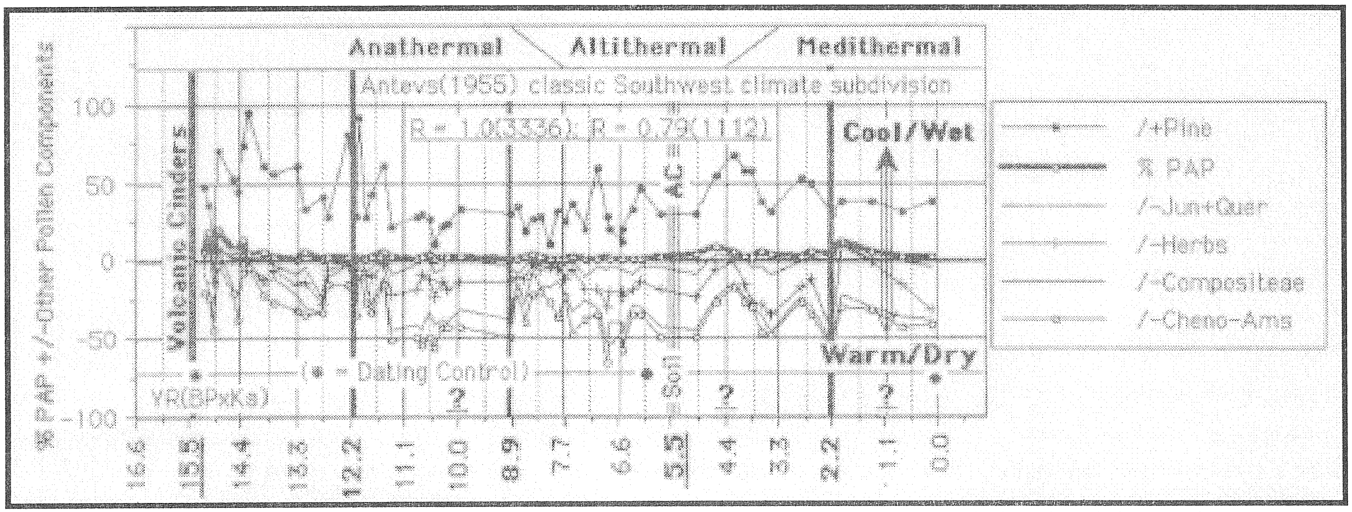

Figure 10 Bioclimatic record (15,500 YBP-present) of Walker Lake, Arizona, on timescale of the 1112-year Stadial Cycle and its 2/1 (556-year) resonance.

Pollen indices after Hevly (1989). Strong tendency for oscillations in phase with the Substage Cycle and a fairly strong tendency with its 3/1 Stadial Cycle. Although the Altithermal Culmination is seemingly well defined by pollen plus an associated soil suggesting lowest postglacial lake levels, an earlier, equally warmer and drier interval is suggested by pollen between 11,000 and 9,000 years ago, or near the end of the early Holocene (Southwest Anathermal and European Late Glacial) and essentially coincident with the local Precessional Solar Maximum 9/10 (Figure 26).

Figures 11-14 are Southern Hemisphere pollen and glacial records that suggest generally in-phase relations with Southern Hemisphere precessional insolation trends (which trends are 180 degrees out-of-phase with counterpart trends in the Northern Hemisphere), but also a moderate-to-strong tendency for secondary oscillations to phase with their Northern Hemisphere counterparts.

Figures 15-17 are Pluvial records that again appear to record out-of-phase primary climatic trends across the Equator but also again suggest moderate to strong in-phase relations of the superposed secondary oscillations in both hemispheres with the global tidal-resonance model.

Figures 18-20 are the longest pollen records from the Northwest (Figure 18), Southwest (Figure 19) and Midwest (Figure 20) that show some regional variability in generally similar primary trends but also moderate to strong tendencies of secondary trends to oscillate in phase with the Substage Cycle and tidal-resonance model.

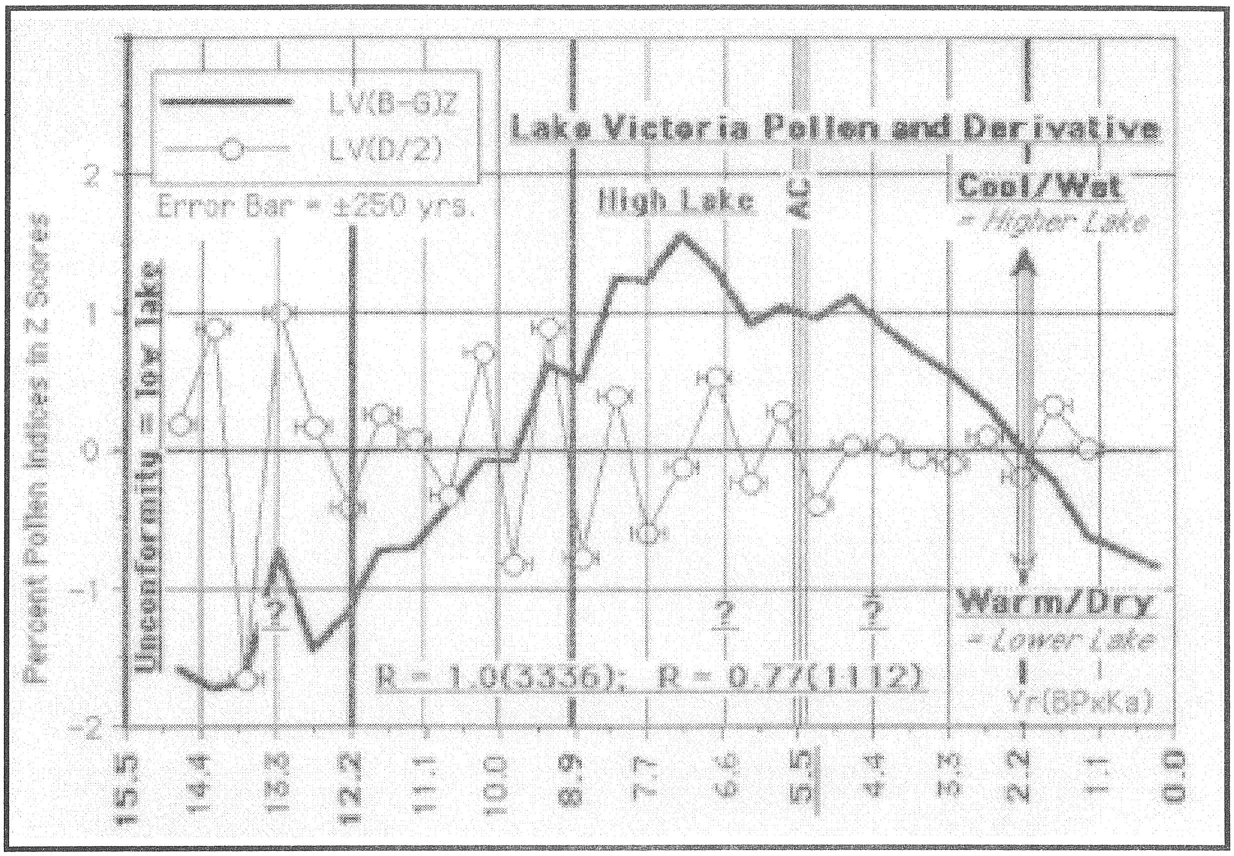

Figure 11 Lake Victoria pollen record on timescale of the 1112-year Stadial Cycle.

Pollen indices from Kendall (1969) replotted in centered 500-year intervals. Very strong tendency to oscillate in phase with the Substage Cycle; lesser but significant tendency with the Stadial Cycle. Note that the Altithermal Culmination (AC = maximum postglacial warm/dry) of the middle to upper latitudes of the Northern Hemisphere occurs here south of the Equator near the apex of a primary wetter/cooler maximum coincident with Precessional Minimum 10, which is displaced about 10,000 years from its Northern Hemisphere counterpart (Figure 26).

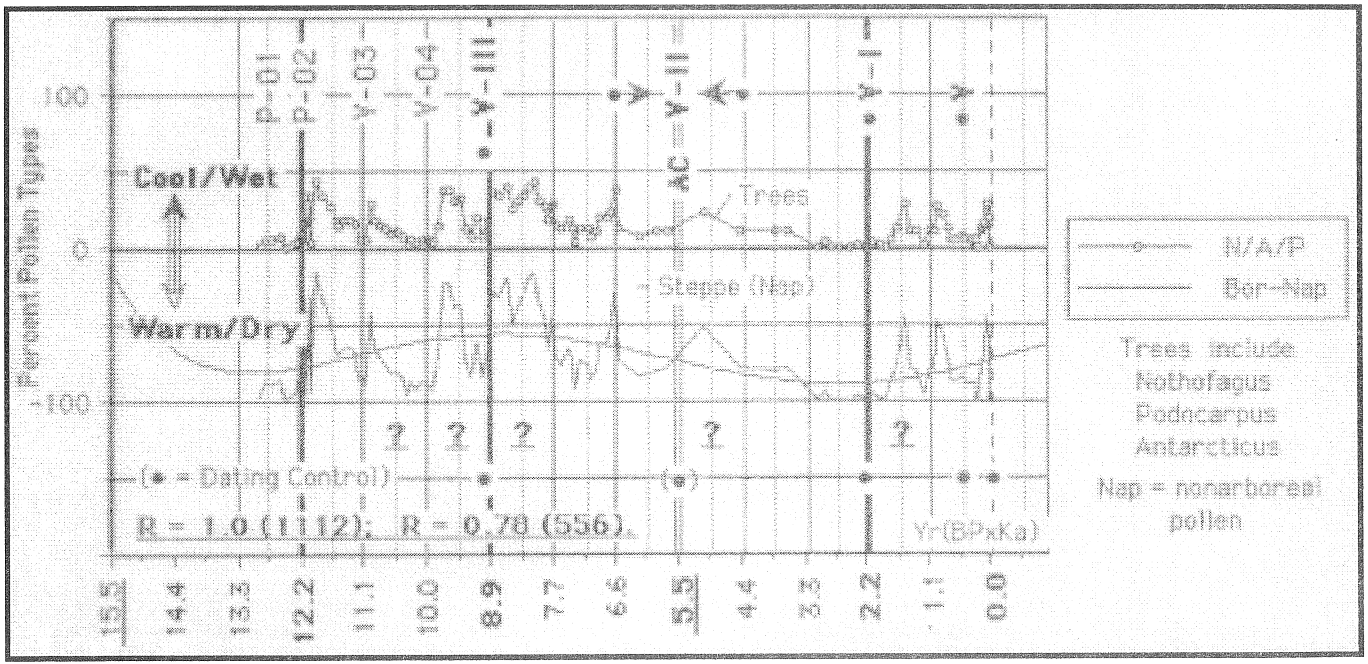

Figure 12 Bioclimatic record of La Mission Bog, Argentina, on timescale of the 1112-year Stadial Cycle and its 2/1 (556-year) Phase resonance.

Pollen indices and correlation with dated volcanic ash from Auer (1968) (Karlstrom 1968). As dated, strong tendency to oscillate in phase with the Stadial Cycle; lesser but significant tendency with the Phase Cycle. Primary trends seem to parallel that of the S60° Latitude insolation curve, including the post-2000-YBP slight upward trend that apparently reflects increased influence of Obliquity insolation at these higher latitudes (S55° L). Compare with Figures 11 and 26. V=volcanic ash; P=pumice. Also see Figure 27.

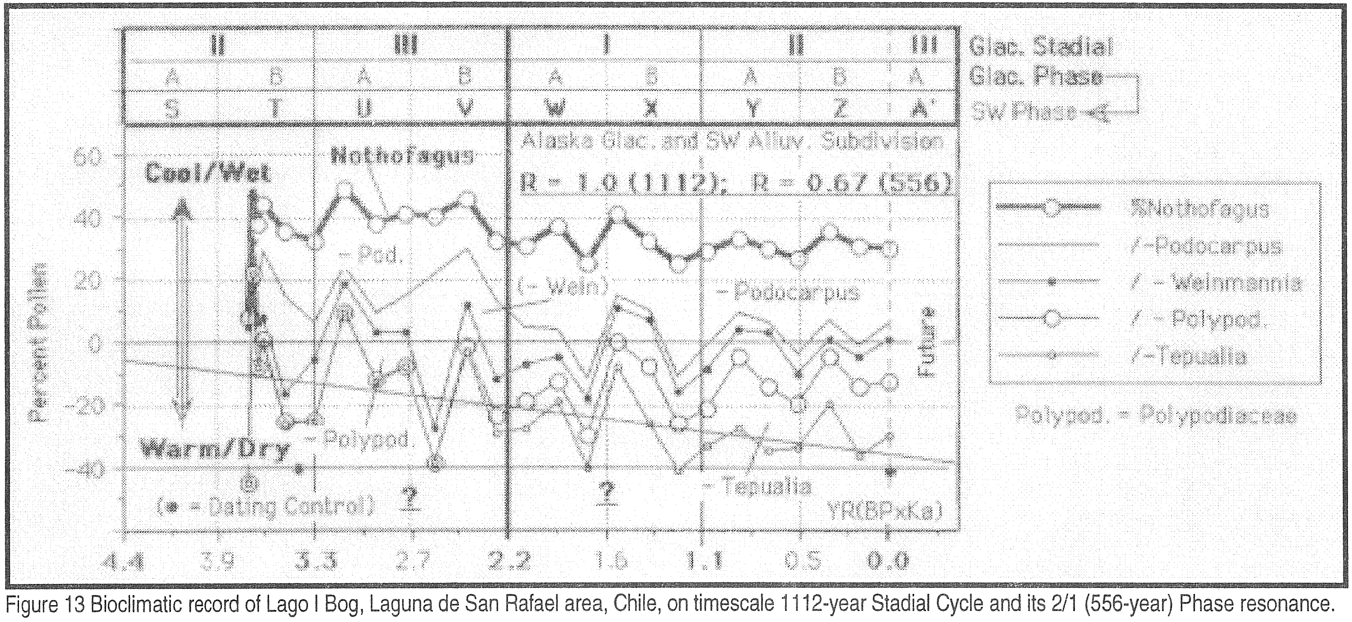

Figure 13 Bioclimatic record of Lago I Bog, Laguna de San Rafael area, Chile, on timescale 1112-year Stadial Cycle and its 2/1 (556-year) Phase resonance.

Pollen indices from Heusser (1960). Very strong tendency to oscillate in phase with the Stadial Cycle; a lesser, perhaps insignificant, tendency with the Phase Cycle. Note the primary warming/drying trend to the present, which parallels the local Precessional insolation trends near S45° latitude. These in turn are opposed to those in the counterpart Northern Hemisphere latitudes and with the correlative Little Ice Age (Figures 18, 19, 21, 26).

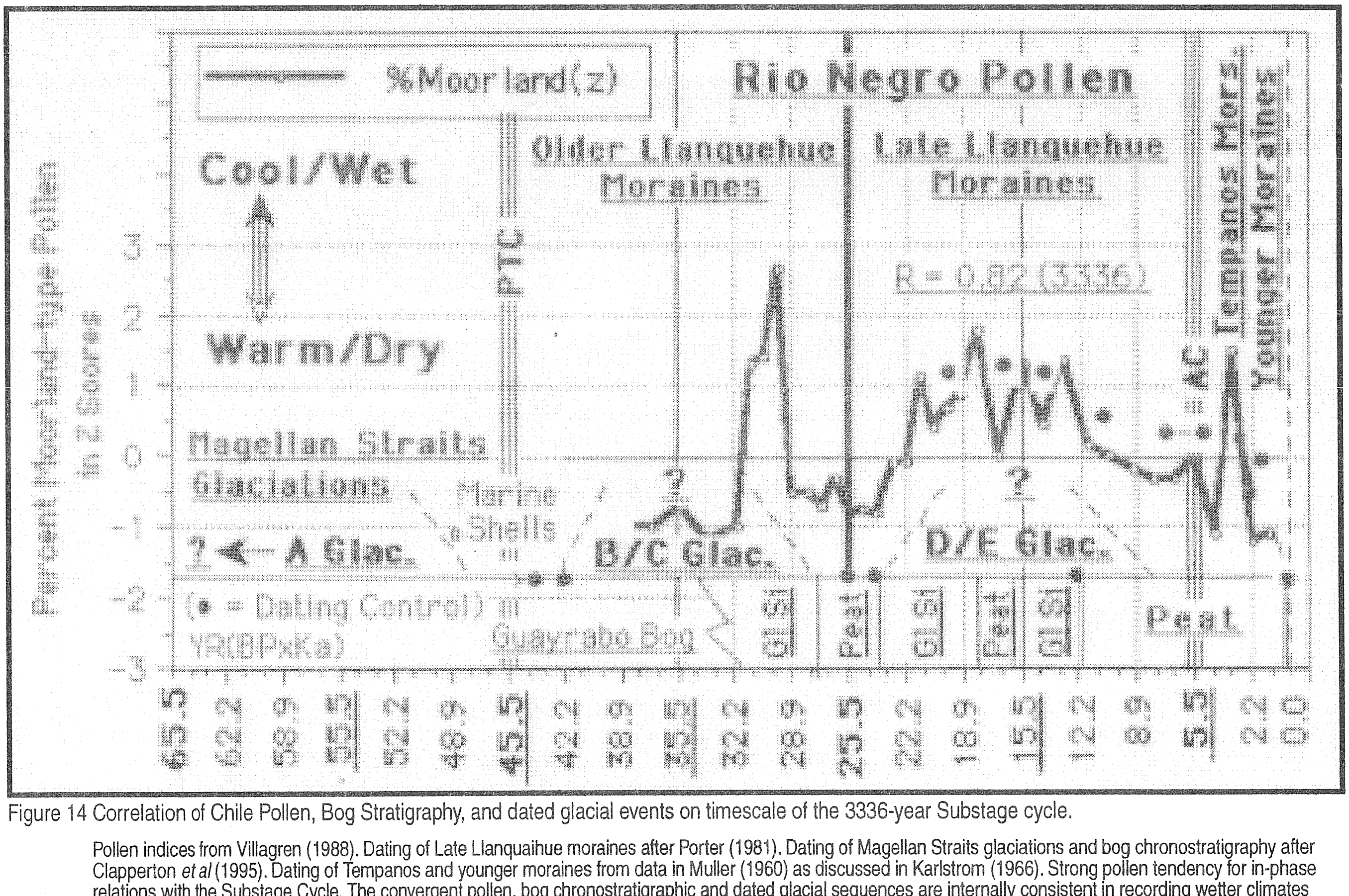

Figure 14 Correlation of Chile Pollen, Bog Stratigraphy, and dated glacial events on timescale of the 3336-year Substage cycle.

Pollen indices from Villagren (1988). Dating of Late Llanquaihue moraines after Porter (1981). Dating of Magellan Straits glaciations and bog chronostratigraphy after Clapperton *et al* (1995). Dating of Tempanos and younger moraines from data in Muller (1960) as discussed in Karlstrom (1966). Strong pollen tendency for in-phase relations with the Substage Cycle. The convergent pollen, bog chronostratigraphic and dated glacial sequences are internally consistent in recording wetter climates and glaciations between 45,000, 25,000, and 12,000 years ago, or compatible with direct correlation with the precession-dominated insolation trends of the Southern Hemisphere. These are offset about 10,000 years from counterpart precessional and glacial trends in the Northern Hemisphere (Figures 21 and 26).
Gl Si=Glaciolacustrine silt = glaciation. Peat = nonglacial interval.

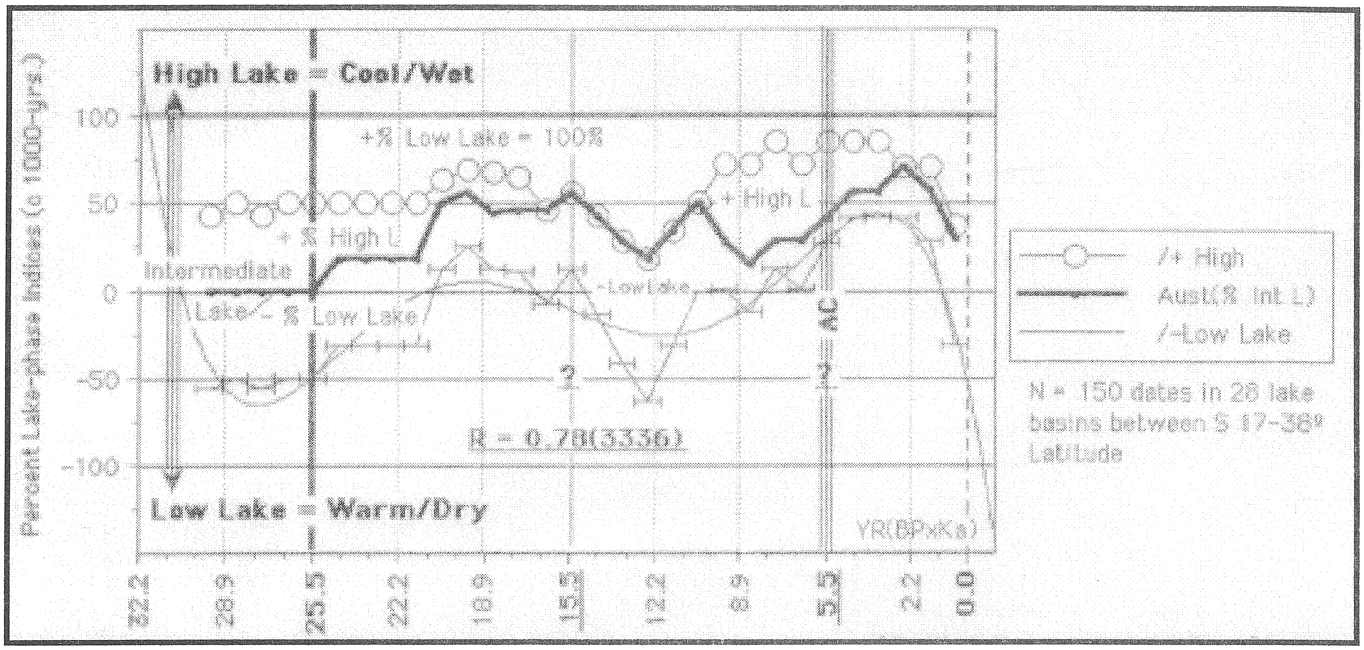

Figure 15 Time-frequency diagram of Australian lake phases (% high/intermediate/low) on timescale of the 3336-year Substage Cycle.

Lake-phase indices from Street and Grove (1979). Fairly strong tendency to oscillate in phase with the 3336-year Substage Cycle. This record seems to provide an additional example of a Southern Hemisphere climatic record suggesting precessional controls 180 degrees out of phase with Northern Hemisphere counterparts, as exemplified by the Southwest Lake record (Figure 16). For other records suggesting opposing primary climatic trends in the two hemispheres, see Figure 26. In the Northern Hemisphere, the Altithermal Culmination (AC) marks the turning point between postglacial warming/drying and trends toward cooler/wetter climate; in the Southern Hemisphere, it is seemingly closely associated with a cool/wet maximum with warming/drying trends to the present. Note the secondary cool/wet peak at about 20,000 years ago that appears to correlate with comparable secondary trends in other Southern Hemisphere records and with opposing secondary trends in Northern Hemisphere records as shown in Figure 26.

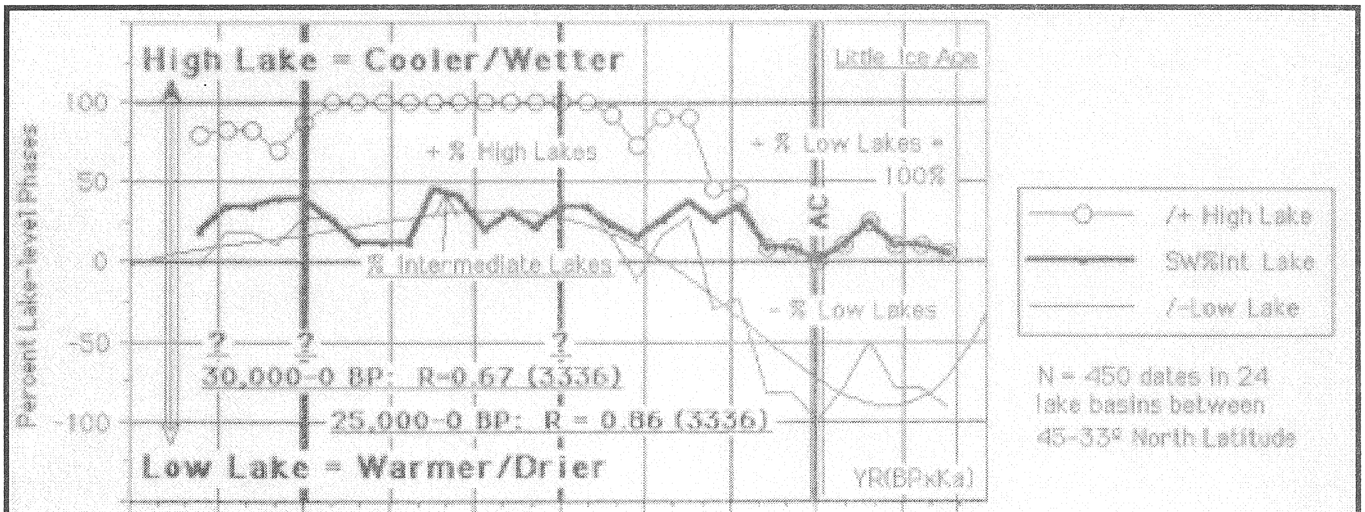

Figure 16 Time-frequency diagram of North American Southwest dated lake-level phases (% high/intermediate/low) on timescale of the 3336-year Substage Cycle.

Lake-level indices from Street and Groves (1979). Weak or insignificant tendency to oscillate in phase with the Substage Cycle, but a much stronger tendency in the post-25,000-YBP part of the curve controlled by a larger number of dates. More notable is the general trend of the dataset that suggests wetter/cooler climate around 20,000 years ago and warmest/driest climate around 5500 years ago, or generally consistent with regional pollen records (Hevly and Karlstrom 1974; Karlstrom 1995; this paper).

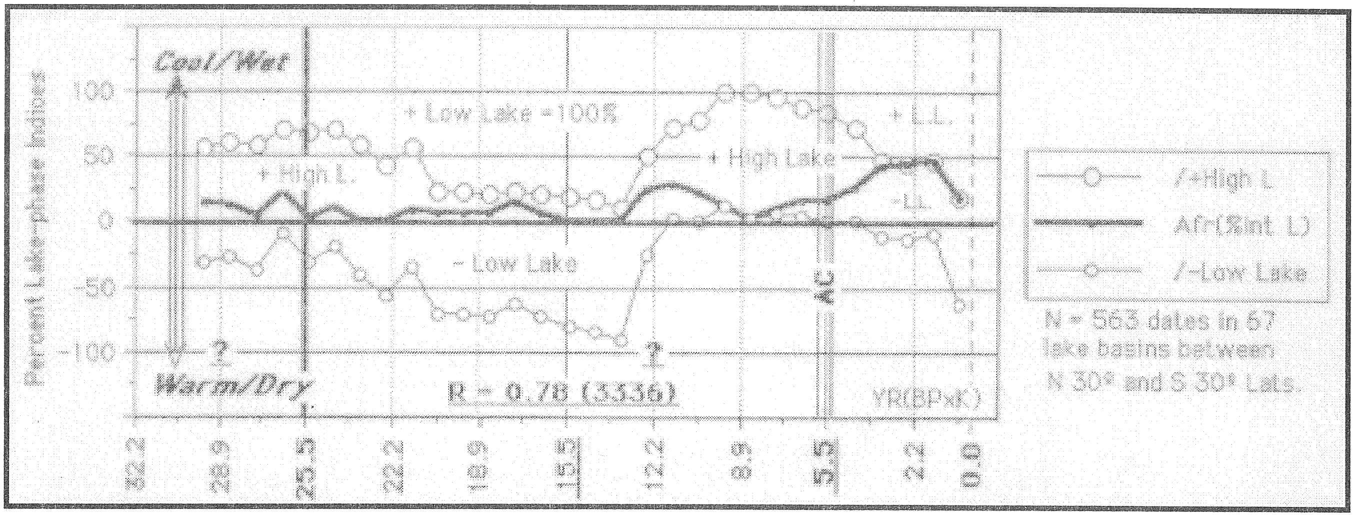

Figure 17 Time-frequency diagram of African lake phases (% high/intermediate/low) on timescale of the 3336-year Substage Cycle.

Lake-phase indices from Street and Grove (1979). Diagram is unsuitable as a test of the Precessional-insolation control model in that it mixes dates from lake basins both north and south of the Equator. As earlier suggested (Karlstrom 1966) and further supported by evidence presented in this paper, whereas longer-term climatic trends (presumably determined by Precessional insolation) were in opposition across the Equator, higher frequency climatic components (presumably modulated by tidal resonances) were globally synchronous. Therefore, it seems significant that the Equator-straddling African dataset shows a fairly strong tendency to oscillate in phase with the Substage Cycle while showing a mixture of both Southern and Northern Hemisphere primary trends, suggesting a predominance of Northern Hemisphere dates in the early part and a predominance of Southern Hemisphere dates in the later part of the record.

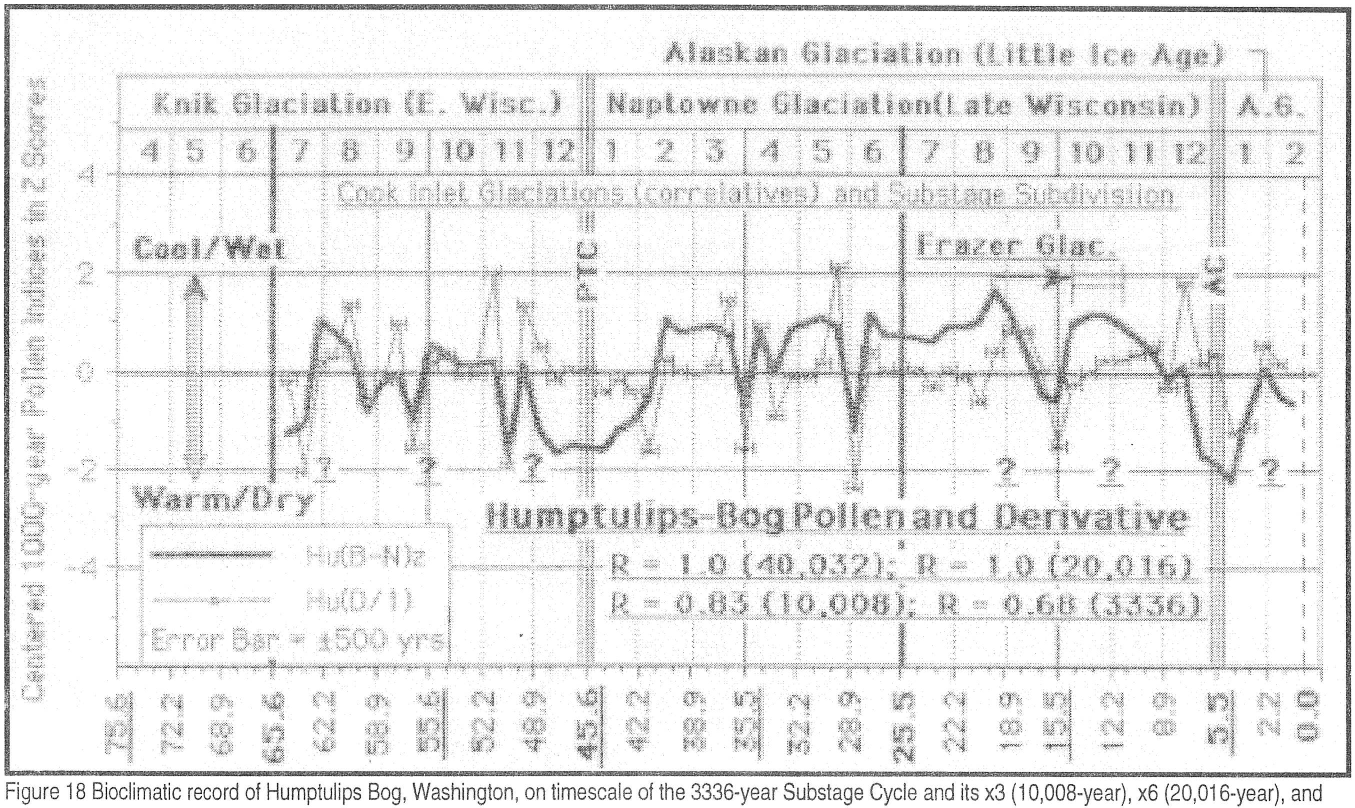

Figure 18 Bioclimatic record of Humptulips Bog, Washington, on timescale of the 3336-year Substage Cycle and its x3 (10,008-year), x6 (20,016-year), and x12 (40,032-year) super harmonics.

Pollen indices from Heusser (1965) replotted in 1000-year intervals. Strong tendency for oscillations in phase with the 3x, 6x, and 12x superharmonics; weak, or insignificant, tendency with the base Substage Cycle, but a stronger tendency (0.79) in the post-45,000-year (more firmly dated) part of the record. B=Boreal, N=Nonarboreal components. PTC=Port Talbot Culmination. AC= Altithermal Culmination. Note that the apparent coolest/wettest interval (about 20,000 years ago) occurred several thousand years before maximum extension of ice lobes of the Frazer Glaciation in the nearby Juan de Fuca Straits and Puget Sound trough.

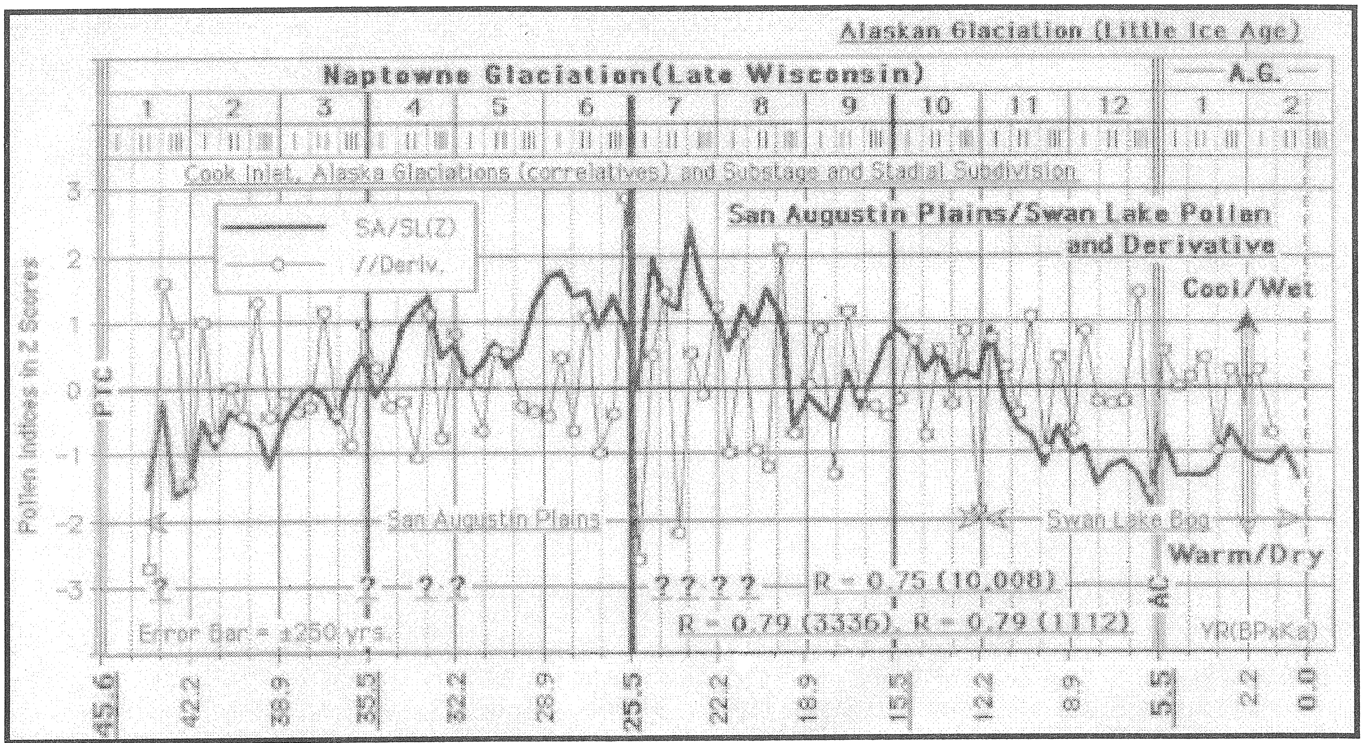

Figure 19 Southwest bioclimatic record on timescale of the 3336-year Substage Cycle and its 3/1 (1112-year) Stadial Resonance.

Pollen indices (Boreal-Nonarboreal) replotted in 500-year intervals from data of the San Augustin region (Clisby *et al* 1964) and of the Swan Lake Bog, southern Idaho (Bright 1968). Fairly strong tendencies for oscillations in phase with the Substage and Stadial cycles. The combined record suggests cooler/wetter climate in the Southwest about 23,000 years ago, or thousands of years before maximum extensions of continental ice during the Last Glacial Maximum (LGM=late Wisconsin). However, the outermost belts of transecting moraines of this age date oldest in Ohio (about 21,000 YBP) and progressively younger in Illinois (about 28,000 YBP), in Iowa (about 14,000 YBP), and in North Dakota (about 12,000 YBP), presumably because of westward-shifting ice centers. Which is the LGM?

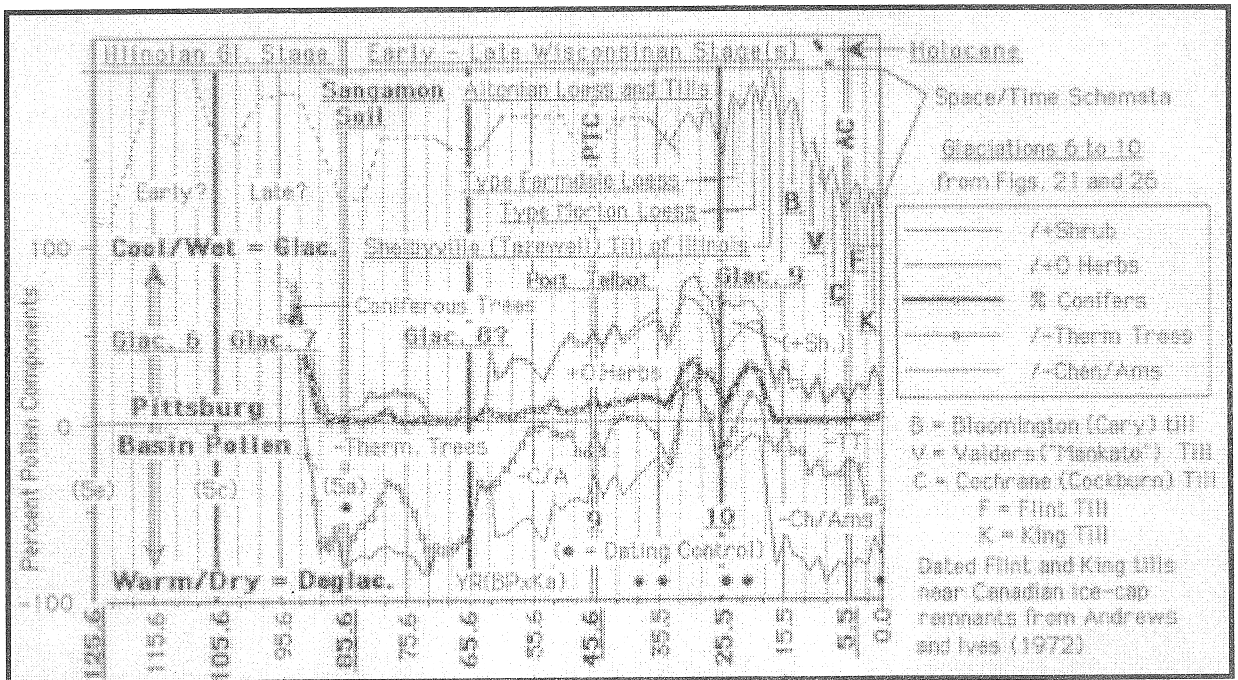

Figure 20 Bioclimatic record of the Pittsburg Basin, Illinois, on timescale of the 10,008-year Cycle and its 3/1 (3336-year) Substage Resonance.

Pollen indices from Grüger (1972). Beyond the radiocarbon-controlled part, the record is fine-tuned to the "standard" marine record of the Equatorial Pacific (Figure 25a), which places the thermophylous-tree maximum and the Sangamon Soil as correlatives of 5a (85,000 YBP) rather than of 5e (125,000 YBP) in the "standard" Equatorial Atlantic marine record (Figure 25b), as generally assumed. This alternative correlation seems more consistent with uniform depositional rates and obviates the presumption of a major unconformity in the pollen record for which there is no direct evidence. Dating of the classic morphostratigraphic substages in designated type localities suggests correlation with the ±3300-year cycle (Karlstrom 1961, 1976b) and also, as shown above, with secondary oscillations in the pollen record. Note that the PTC coincides with a minor thermophylous-tree maximum at the apex of Precessional Minimum 9 and correlative glaciations (Figure 21).

Figure 21 shows correlation of opposing high-resolution glacial records of the Northern and Southern Hemispheres with marine chronostratigraphy, precessional trends, and latitudinal displacement of the Caloric Equator and associated Intertropical Convergence Zone (ITCZ)

Figures 22-26 are previously published figures (Karlstrom 1995) slightly modified for ready comparison with the additional paleoclimatic time series presented in this Addendum.

Figures 27 and 28 are time-frequency diagrams of global and North American volcanic activity and correlation with the tidal resonance model.

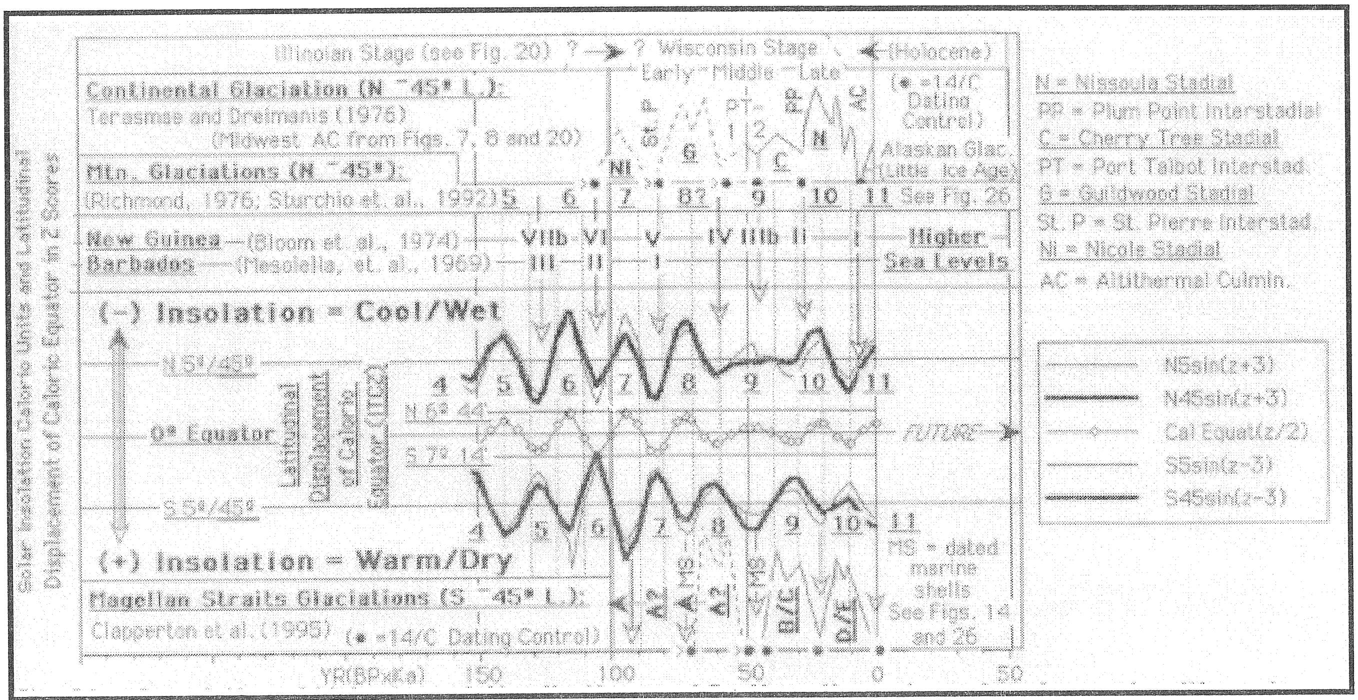

Figure 21 Correlation of highest resolution Northern and Southern Hemisphere glacial records with marine chronostratigraphy (glaceoeustatic sea levels) and, in turn, with opposing hemispheric processional trends and latitudinal displacements (in degrees) of the Caloric Equator and associated Intertropical Convergence Zone (ITCZ).

Richmond (1976) and Terasmae and Dreimanis (1976) see a remarkable coincidence between their glacial chronostratigraphies and that of the dated sea level records. This supports the concept of glaceoeustasy but not necessarily that of inter-hemispheric climatic synchrony. This is because the much greater volume of glacial ice in the Northern Hemisphere can mask opposing meltwater trends in the interconnected oceans of the Southern Hemisphere (Karlstrom 1966). Clapperton *et al* (1995) see no clear-cut correlation of their Southern Hemisphere glacial record with that of the Northern Hemisphere. However, their B/C and D/E glacial complexes, as broadly dated between 45,000 years, 25,000 years, and the present, most closely correlate with the local Southern Hemisphere precessional trends, which in turn are displaced 10,000 years from their Northern Hemispheric counterparts and correlative continental glacial events. Insolation curves after Milankovitch (1941). Alternate N-S displacement of the Caloric Equator and reversing insolation gradients may serve to force or facilitate modulation of changing summer circulation patterns in the two hemispheres. Note the apparent absence in lower Southern Hemisphere of the Northern Hemisphere Alaskan Glaciation due to opposing precessional trends. (Also Figure 13).

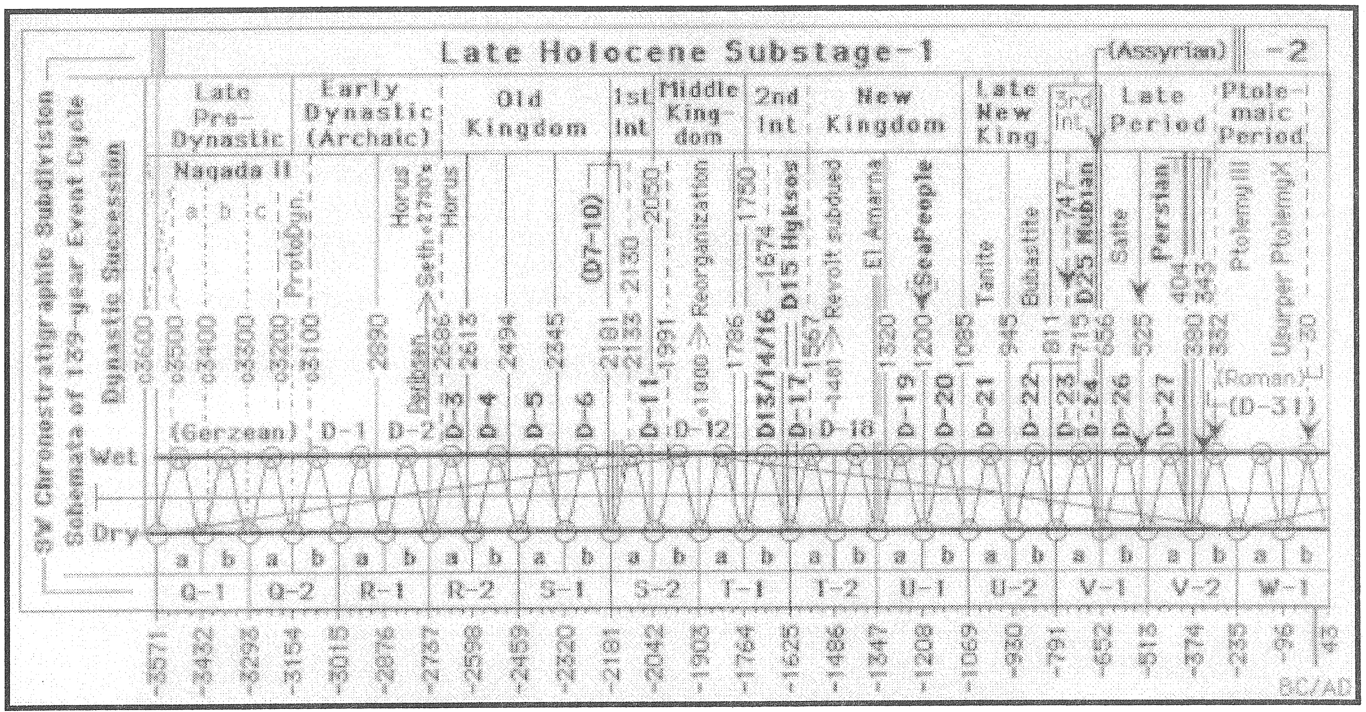

Figure 22 Correlation of Egyptian Dynastic History with schemata of the 139-year Event Cycle.

Reconstruction of dynastic record from James (1979), who notes that the dating is approximate and increasingly so toward the beginning of the record. Most dated boundaries (solid lines) fall within the dry epicycles; the remaining few (dashed lines) fall within the wet epicycles, suggesting that environmental stress (lower Nile levels) played a contributory role in dynastic succession. If so, empirical evidence for the Event Cycle is extended back to the mid-Holocene. Similarly, instrumental temperature evidence of its about-70-year half cycle is projected back to the mid-Holocene through correlation with dated beach ridges of Lake Michigan (Delcourt *et al* 1996). Modified from Figure 11 in Karlstrom (1995).

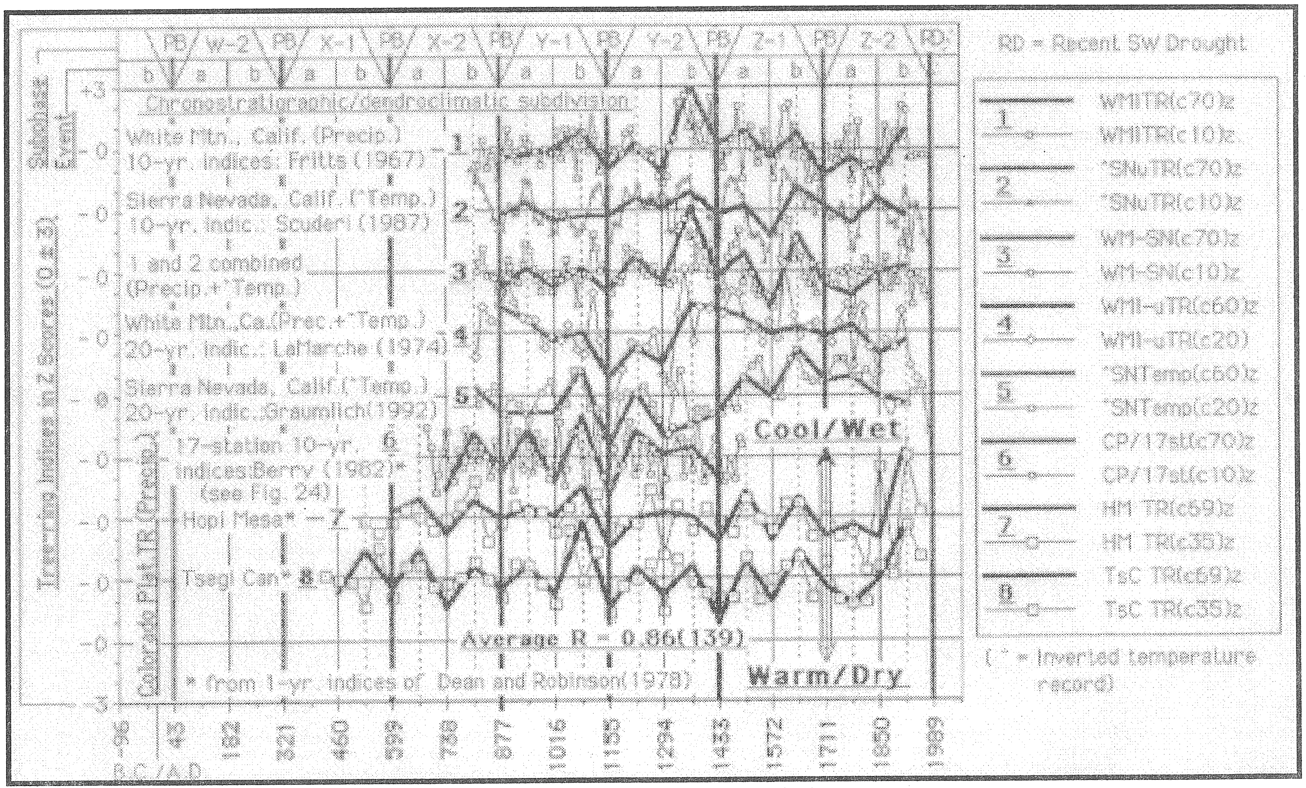

Figure 23 Summary evidence for a dendroclimatic cycle in phase with the 139-year Event Cycle.

Half-cycle smoothing positioned on cycle turning points. Trend correlations, temperature and precipitation, range from 0.75 to >0.90, or within the upper range of tree-ring/climate calibrations. This suggests that the cycle is real, regionally robust, and related to changing atmospheric dynamics and patterns. Similar half-cycle analyses of other records may define different regional patterns and responses, advancing understanding of climatic/biologic process. Modified from Figure 10 in Karlstrom (1995). PB=Point Boundary (clustering of Southwest basal alluvial dates) from Karlstrom (1988).

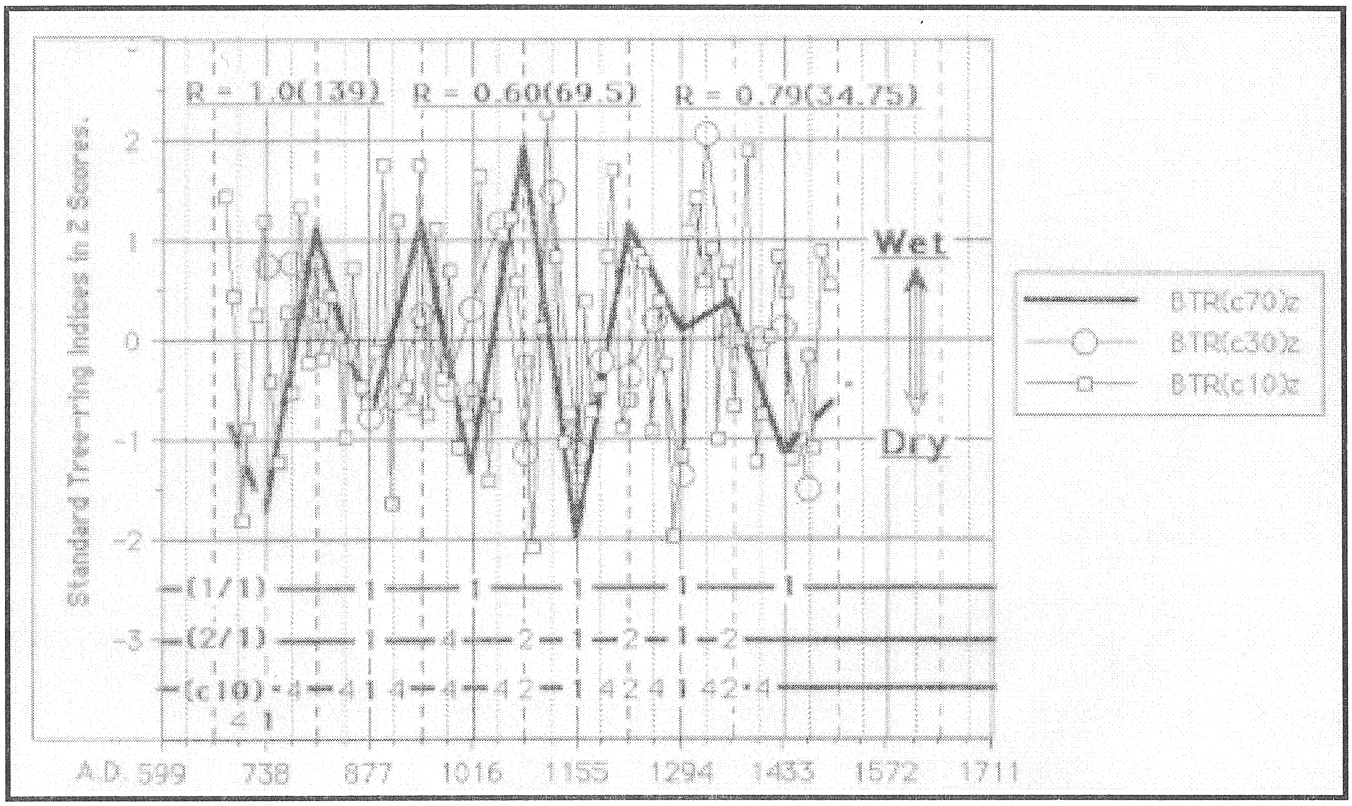

Figure 24 Dendroclimate record of the southern Colorado Plateaus on timescale of the 139-year Event Cycle and its 2/1 (69.5-year) and 4/1 (35-year) Resonances.

Seventeen-station decadal tree-ring indices from Berry (1982). Half-cycle smoothing as before. Very strong precipitation response to the Event Cycle; lesser but significant response to the 4/1 (34.75-year = Brückner Cycle) resonance. Figure same as Figure 6 in Karlstrom (1995).

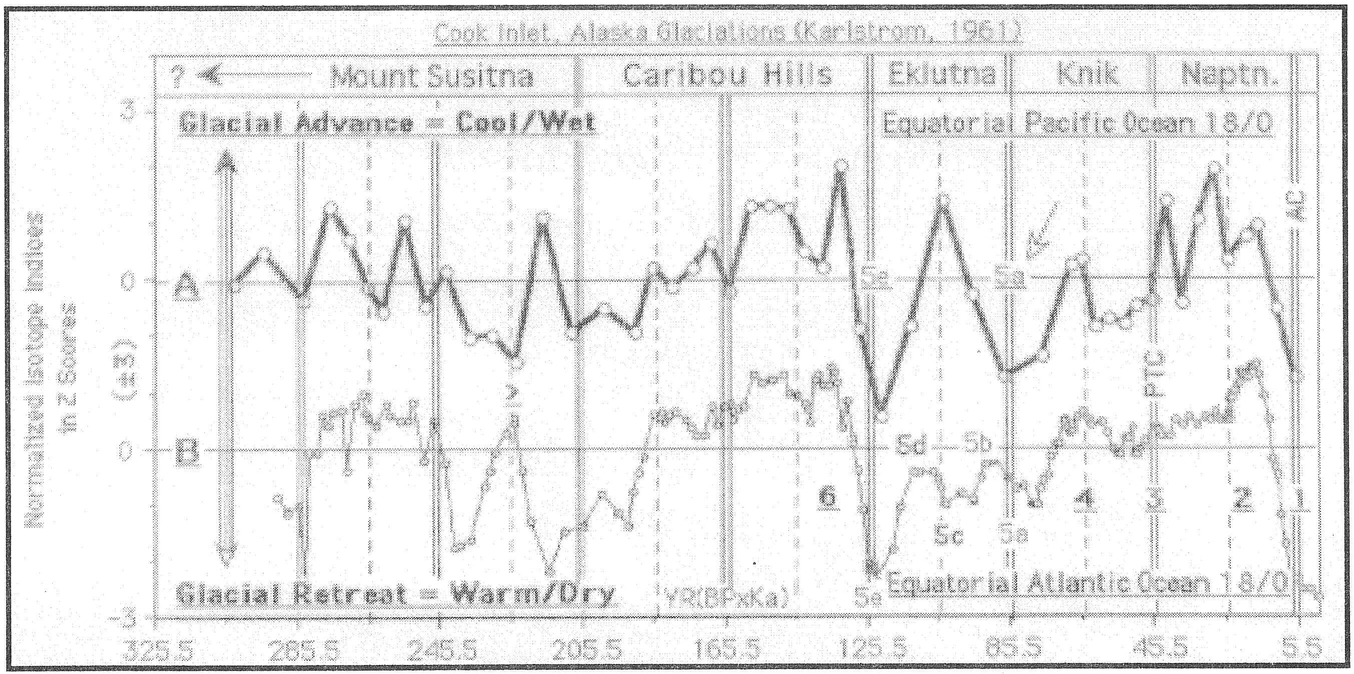

Figure 25 Two "standard" Marine Ice Age chronologies on timescale of the Obliquity Insolation Cycle (about 40,000 years) and its 2/1 about 20,000 years) Resonance assuming a response lag of about 4500 years (Karlstrom 1961).

Equatorial Pacific record from Chuey *et al* (1987); the Equatorial Atlantic record from Martinson *et al* (1987). Both are fine-tuned to the Milankovitch Climate Model assuming corresponding response lags. The curves differ mainly in (1) out-of-phase relations about 225,000 years ago and (2) relative glacial amplitudes in the past 125,000 years, suggesting either heterogeneities in the marine record or remaining difficulties with dating procedures and sample mixing. Note the tendency for in-phase oscillations with the Obliquity 2/1 (about 20,000 year) Resonance. Modified from Figure 28 in Karlstrom (1995).

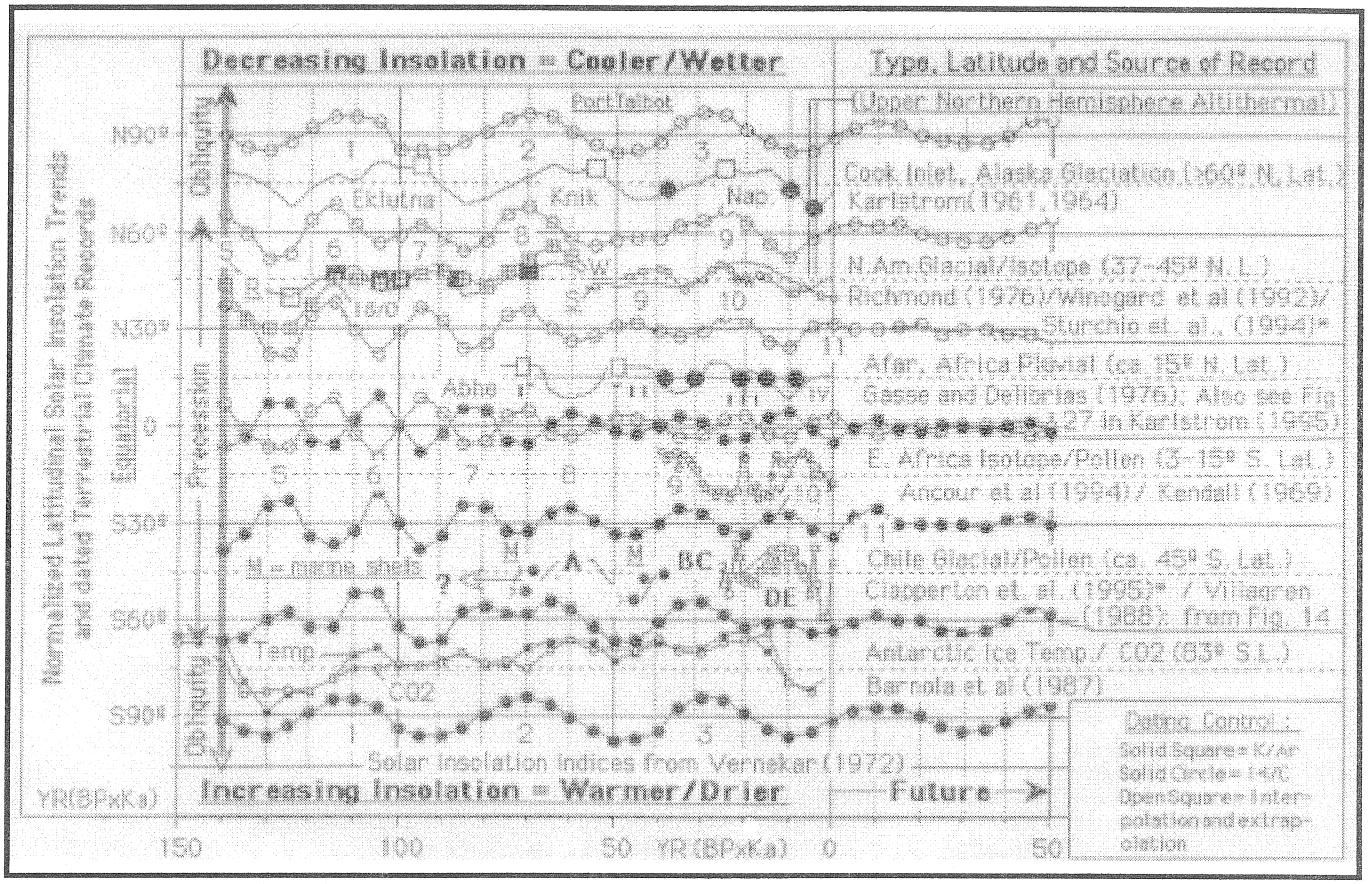

Figure 26 Latitudinal control of terrestrial climate records.

These dated records seem to parallel more closely the local latitudinal insolation trends than the records at other latitudes. If these climate records are representative of their respective latitudinal belts, the conventional concept of interhemispheric climatic synchrony must be reassessed as a basis for Ice Age correlations and resulting global paleoclimatic reconstructions (Karlstrom 1961). Modified from Figure 29 of Karlstrom (1995): *=added record.

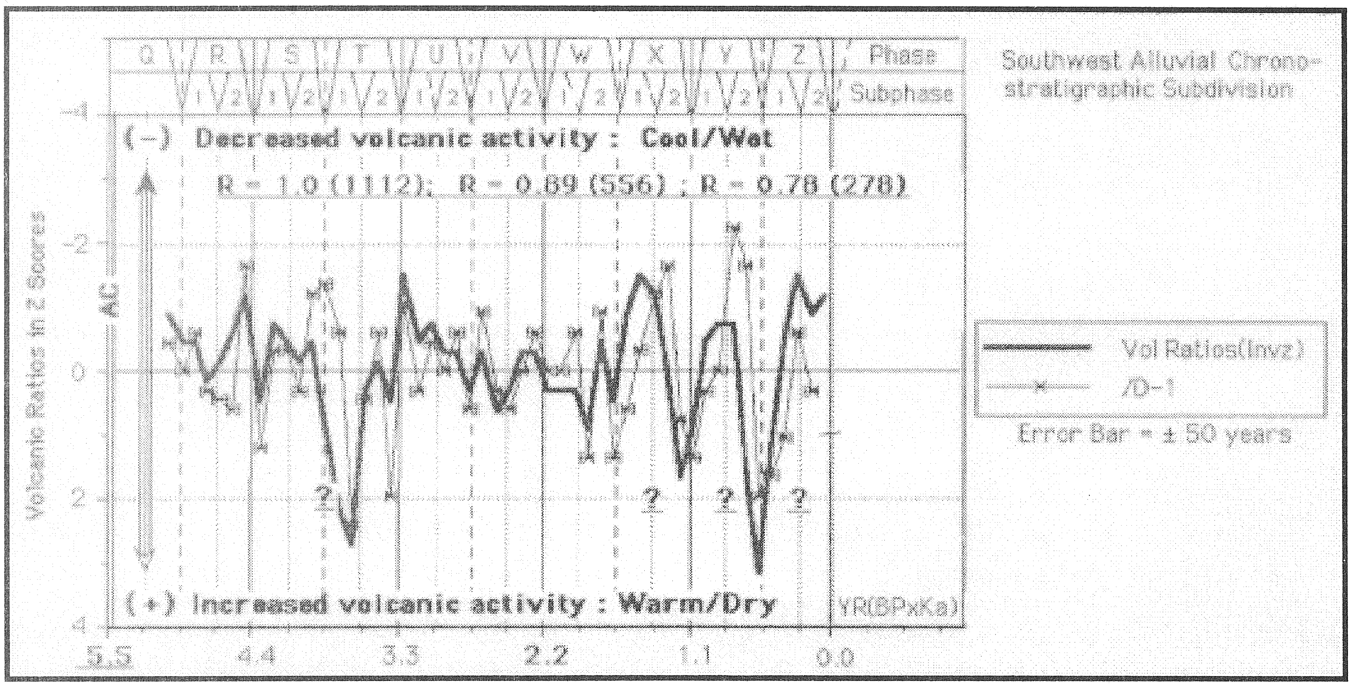

Figure 27 Time-frequency diagram and derivative of dated volcanic events on timescale of the 1112-year Stadial Cycle and its 2/1 (556-year) and 4/1 (278-year) resonances.

Volcanic-ratio indices from Bryson and Goodman (1980) converted to Z Scores. Strong tendency for intervals of increased volcanism to phase with drought (warm/dry) intervals of the Subphase (278-year) Cycle and stronger tendencies with its x2 (556-year) and x4 (1112-year) superharmonics. These correlations strongly suggest that tidal resonances and associated increased rate of Earth's spin play a role in triggering volcanic activity and minimize the importance of transitory cooling (and warming) of the atmosphere by volcanic ejecta as a causal factor in longer-term climate change. From his pioneer work on South American pollen, Veni Auer (1966) early suggested the correlation between volcanism and warmer climate. Time-frequency analyses of dated volcanic events culled from the radiocarbon literature through 1972 suggest similar statistical relationships between volcanism and warm climate in North America and globally through common correlation with the tidal model (Figure 28). Bryson and Goodman's selected global dataset thus apparently provides independent support for these correlations. To predict local volcanic events solely by tidal intensity, however, is highly uncertain because of the statistical nature of the correlation and because of the triggering mechanism that requires endogenetic processes near threshold conditions.

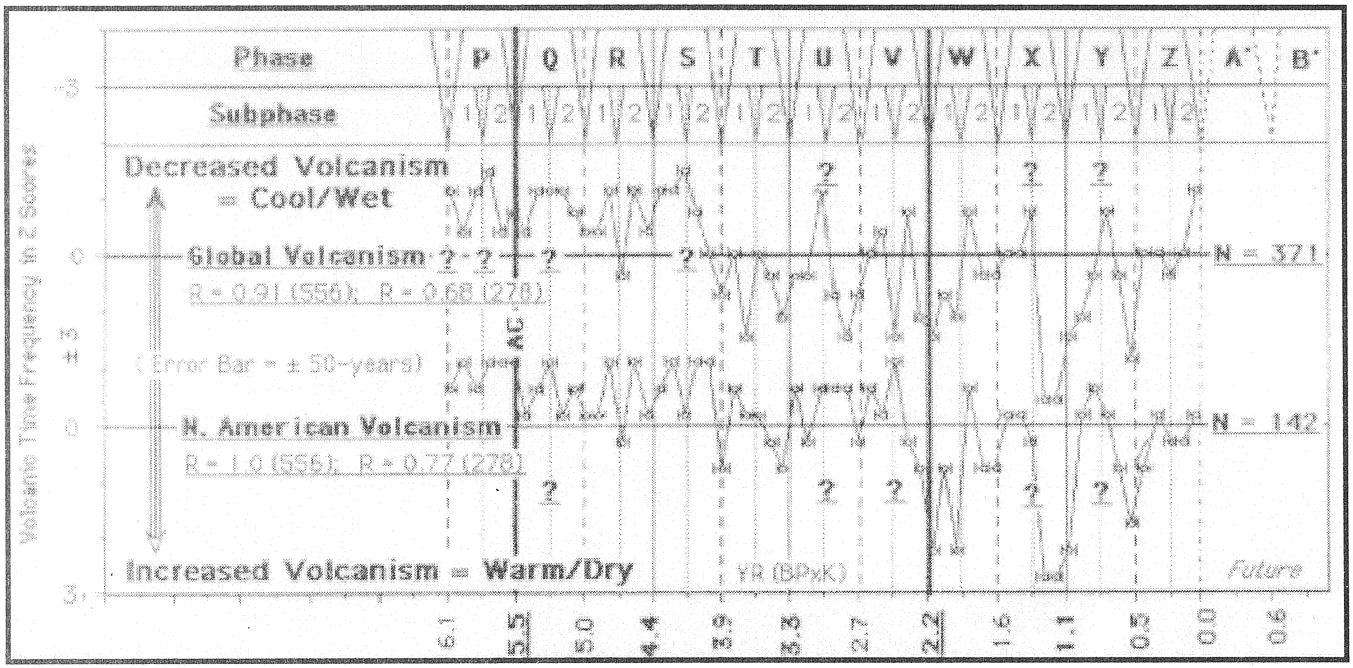

Figure 28 Time-frequency diagrams of global and North American volcanic activity on timescale of the 556-year Phase Cycle and its 2/1 (278-year) Resonance.

Volcanic indices from Figure 7 in Karlstrom (1975); 100-year class intervals centered in centuries. Note strong tendency for increased volcanic activity during the warm/dry epicycles of the Phase Cycle and the lesser tendencies during those of the Subphase Cycle.

Summary

Detailed cyclical analyses of the additional Northern and Southern Hemisphere terrestrial time series presented in this paper provide an expanded database that substantially fortifies and extends previous interpretations and correlations with the Solar-Insolation/Tidal-Resonance Model. However, in the absence of an accepted climatic theory and a fuller understanding of the climatic dynamics and atmospheric circulation patterns involved, it is necessary to assume that the presented empirical correlations represent in some fashion direct cause-and-effect relationships and, further, that the expanded database is sufficient to generally satisfy the fundamental requirement of latitudinal representativeness. With these caveats in mind, I conclude the following:

- Longer-term "Ice Age" changes were out of phase across the Equator and evidently modulated by Precessional-insolation trends, which in the Northern Hemisphere are 180 degrees out of phase with those in the Southern Hemisphere. The supporting data run counter to the conventional assumption of interhemispheric synchrony and parallel glacial records and suggest that major revisions are required in the derived concepts of global atmospheric circulation dynamics and patterns. Theoretically, there appears to be no apparent reason why, if the Northern Hemisphere glaciers responded directly to summer half-year insolation (the Milankovitch mechanism), the glaciers and associated hydrologic processes in the Southern Hemisphere were not similarly controlled by the opposing local summer-insolation trends. Interconnected ocean bodies explain why the greater volumes of continental ice in the Northern Hemisphere generally dominated the marine meltwater and glacioeustatic records of both hemispheres. In contrast, the terrestrial climatic records suggest that the current (nominal) atmospheric circulation barrier between hemispheric air masses created by the oscillating Intertropical Confluence Zone persisted throughout the time of record.
- In contrast to the above longer-term climatic trends, superposed secondary oscillations (those less than several thousands of years in duration) were synchronous across the Equator and evidently were modulated by tidal resonances generated essentially simultaneously throughout the global atmosphere.
- Detailed analysis of a bioclimatic record (Figure 3) suggests that differing seasonal timings of fractional higher frequency atmospheric resonances contribute to fluctuational variability present in some bioclimatic time series.
- The longest pollen records (Figures 18-20) suggest a terrestrial cycle of about 10,000 years, comparable in length to that recently noted in higher resolution marine records.

- The correlation of increased global volcanic activity with warmer/drier epicycles of the Tidal-Resonance Model strongly suggests that tidal stressing of the lithosphere played a triggering role in volcanic frequency and minimizes the importance of transitory cooling (and local warming) by volcanic ejecta as a causal factor in longer-term climate changes. To predict local volcanic events solely by tidal intensity, however, is highly uncertain because of the statistical nature of the correlation and because of the presumed triggering mechanism that requires endogenetic processes near threshold conditions.
- The Solar-Insolation/Tidal-Resonance Model appears to satisfy temporal and spatial similarities and differences in paleoclimatic records not explained by other climate models. It is a viable scientific hypothesis in that it remains empirically testable by continued cyclical analyses of scores of other high-resolution records available in the extensive international paleoclimatic literature. Further testing should concentrate on the distribution of records improving uniformity of global coverage — particularly in upper latitudes to satisfy dominant Obliquity controls and along the Equator to satisfy past displacements of the Caloric Equator and associated Intertropical Convergence Zone. These longer-term Equatorial displacements along with changing insolation gradients (Figure 21) are potentially important mechanisms for driving or modulating seasonal atmospheric circulations patterns in the two hemispheres.
- When sufficient supporting data are accumulated, it will be possible to significantly improve (within limits of sampling interval and dating resolution) the dating and correlation of secondary cycles by fine-tuning to the theoretical tidal-resonance model. This model is primarily built on the celestial-mechanics calculations of Pettersson (1914) as cyclically extended by Stacey (1963, 1967) and continues to provide a best fit for the paleoclimatic records presented in this and previous papers. Additional celestial-mechanics analyses of tidal-force changes are required to assess the general validity of the Pettersson-Stacey calculations and to define the higher-frequency components of planetary perturbations.

Acknowledgments

The results of my research on paleoclimate have been tempered in the crucible of vigorous discussions with numerous colleagues over the course of many years. Early on, I am particularly indebted to my U.S. Geological Survey colleagues, the late L.L. Ray, W. Bradley, H.W. Coulter, John Hack, Al Chidester, and Robert R. Sutton; to many others, including the late J Harlen Bretz, Kritiof Fryxel, Rudy Edmond, Ernst Antevs, V. Auer, Carl Lindroth, Eric Hultén, Alexis Dreimanis, and David Bloomenstock; to George Ball, Robert Rausch, and W.C. Mahany; and also to Rhodes Fairbridge for his insightful, eclectic, and extensive contributions to paleoclimatic research. Later on, special acknowledgment is due my colleagues (Jeffrey S. Dean, Robert C. Euler, George J. Gumerman, and Richard H. Hevly) in the "Gang of Five" for provocative ideas and comradeship during our 15 years of joint field research on environment and prehistoric culture of the Colorado Plateaus. I also thank Jeff Dean, Dick Hevly, and Eric Karlstrom for reading and commenting on an earlier version of this paper. Any errors in data selection, analysis, and interpretation remain my own. Finally, I acknowledge the professionalism and assistance of Caroline Isaacs and Vera Tharp, editors of the PACLIM Workshop, who have greatly facilitated the publication of my most recent research results.

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