A 139-Year Dendroclimatic Cycle, Cultural/Environmental History, Sunspots, and Longer-Term Cycles

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Introduction

Higher resolution time-stratigraphic records suggest correlation of lower frequency paleoclimatic events with Milankovitch obliquity/precessional cycles and of higher frequency events with the evidently resonance-related Pettersson maximum tidal force (MTF) model (Karlstrom 1961). Subsequently published records, mainly pollen (Hevly and Karlstrom 1974), seemingly confirm that atmospheric resonances may have modulated past climatic changes in phase with average MTF cycles of 1668, 1112, and 556 years, as calculated in anomalistic years from planetary movements by Stacey (1963, 1967). Stacey accepts Pettersson's (1914) dating of AD 1433 (517 YBP) for the last major perihelian spring tide based solely on calculations of moon- and earth-orbital relations to the sun. Use of AD 1433 as an origin for the tidal resonance model seemingly continues to provide a best fit for the timing of cyclical patterns in the presented paleoclimate time series.

Dating basal contacts (point boundaries) in Southwest alluvium produces temporal clustering seemingly in phase with the doubling of the 556-year Phase Cycle or its 2/1 (278-year) resonance (Hevly and Karlstrom 1974; Karlstrom 1988). This result, however, is unconfirmed by spectral analyses of Colorado Plateau dendroclimatic records that clearly define only 1- to 2-year cycles (Dean 1988). This could result either from tree-ring standardization procedures that eliminate longer-term trends or from difficulties in applying spectral analyses to detrended composite records characterized by:

- Relatively short cross-dated segments that further limit lower-frequency analysis.
- Interrupted high-frequency cyclical patterns that episodically change sign through a transition point, suggesting nonlinear response to an external forcing function (chaos theory).
- Varying amounts of distorting noise (nonclimatic effects on tree growth).

Moreover, spectral analytical results statistically define dominant cycle lengths (not their timing) and are sensitive to differing levels of smoothing

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and positioning that can mask real cycles and generate spurious ones (aliasing). Use of half-cycle smoothing positioned on cycle turning points thus should provide a more direct and critical test of the resonance model, since the model imposes severe constraints on both timing and cycle length and permits concurrent testing of longer- and shorter-term harmonics.

Half-Cycle Analysis of Southwest Dendroclimatic Records

As shown in Figures 1-10, preliminary half-cycle analyses of Southwest dendroclimatic records from California to New Mexico and Coloradoproduce common intervals of generally warmer/drier climate alternating with intervals of cooler/wetter climate that are most strongly in phase with the doubling of the 278-year subphase cycle, or the 4/1 (139-year) resonance of the 556-year phase cycle. Higher frequency resonance patterns vary from record to record, evidently reflecting differing response functions, variable timing of nonlinear phase reversals, and differing amounts and distribution of distorting noise.

Trend correlation coefficients of the 139-year cycle range from 0.75 to 1.0, or within the upper part of the correlation range (<0.6->0.9) of tree-ring/climate calibrations. This suggests that the cycle is real, regionally robust, and evidently related to changing atmospheric patterns and dynamics. Continued half-cycle analysis of other dendroclimatic records may define diagnostic regional patterns as well as differing local responses, thus advancing understanding of climatic/biologic processes.

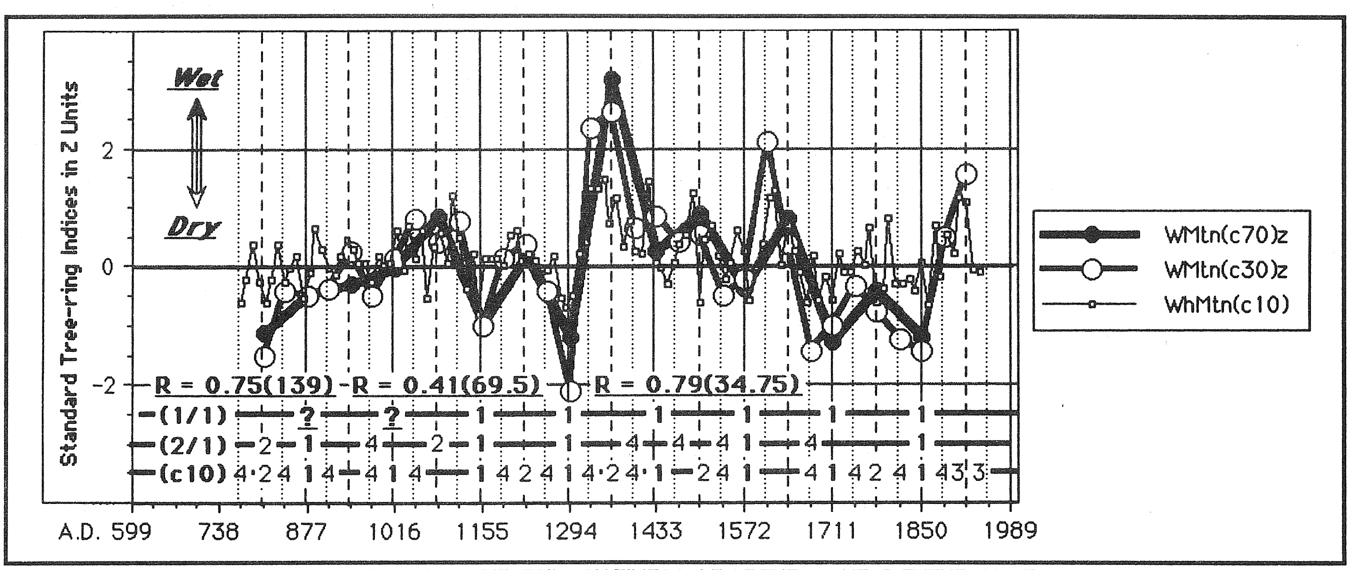

Figure 1. HYDROGRAPH OF WHITE MOUNTAINS, CALIFORNIA, ON TIMESCALE OF THE 139-YEAR EVENT CYCLE AND ITS 2/1 (69.5-YEAR) AND 4/1 (34.75-YEAR) RESONANCES

Half-cycle and near-half-cycle smoothing positioned on cycle turning points; conversion to Z units after smoothing. Decadal indices from Station 12 (Fritts 1967). Trend correlations suggest a fairly strong precipitation response to the 139-year event cycle and a stronger response to its 4/1 (34.75-year) resonance (Bruckner cycle).

Refined analysis requires use of annual indices that permit the most precise half-cycle smoothing (Figures 6-9). Near half-cycle smoothing using 10-year and 20-year smoothed indices (Figures 1-5) does not appear to significantly affect analytical results of the longer-term trends, but it does limit analyses to those cycles with wave lengths of more than 20 and 40 years, respectively.

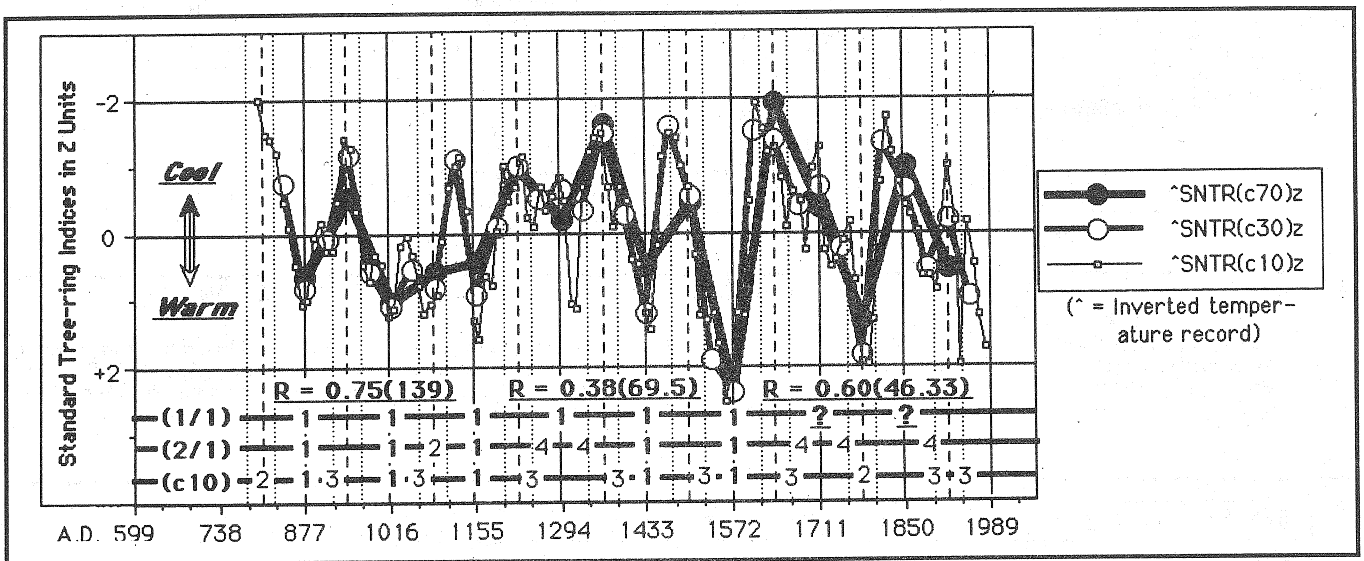

Figure 2. THERMOGRAPH OF THE SIERRA NEVADA, CALIFORNIA, ON TIMESCALE OF THE 139-YEAR EVENT CYCLE AND ITS 2/1 (69.5-YEAR) AND 3/1 (46.33-YEAR) RESONANCES

Half-cycle and near-half-cycle smoothing positioned on cycle turning points; conversion to Z units after smoothing. Upper timberline tree-ring 10-year indices from Scuderi (1987). Trend correlations suggest a fairly strong temperature response to the 139-year event cycle. In higher frequencies there is a stronger tendency to respond to the 3/1 than to the 2/1 resonance. Contrast with Figure 1.

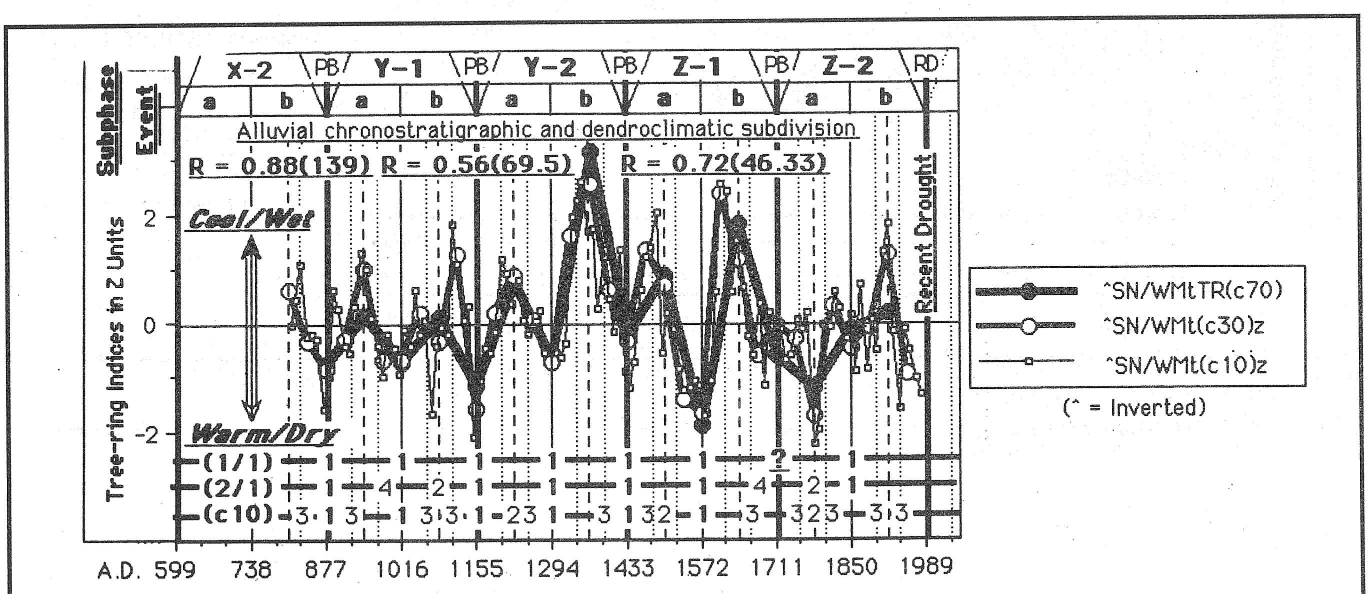

Figure 3. HYDROTHERMOGRAPH OF CENTRAL CALIFORNIA ON TIMESCALE OF THE 139-YEAR EVENT CYCLE AND ITS 2/1 (69.5-YEAR) AND 3/1 (46.33-YEAR) RESONANCES

Constructed by combining hydrograph of White Mountains (Figure 1) with inverted thermograph of the Sierra Nevada (Figure 2). The combined precipitation/temperature record improves correlation with the 139-year event cycle and emphasizes higher frequency response to the 3/1 resonance. The sign inversion in Z-2a evidently results from an unusually deep temperature trough at the half-cycle position centered AD 1780. The chronostratigraphic subdivision is after Karlstrom (1988). PB = Point Boundary (clustering of alluvial basal-contact dates).

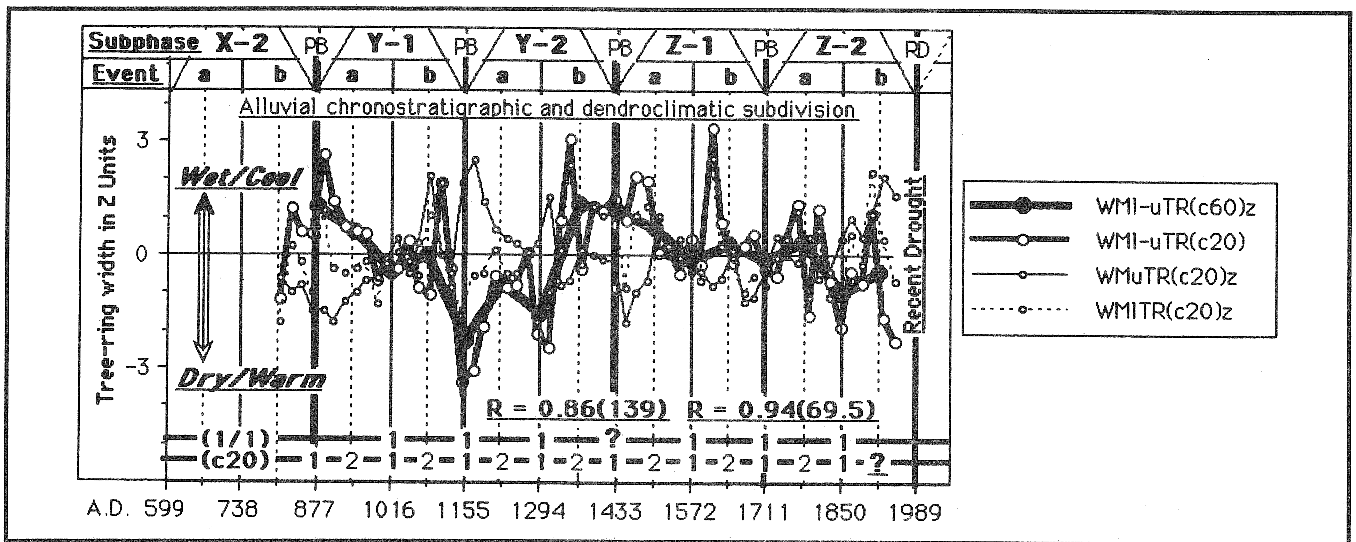

Figure 4. HYDROTHERMOGRAPH OF WHITE MOUNTAINS, CALIFORNIA, ON TIMESCALE OF THE 139-YEAR EVENT CYCLE AND ITS 2/1 (69.5-YEAR) RESONANCE

Curve constructed by combining the lower timberline (precipitation) record with the upper timberline (temperature) record, which is inverted to satisfy parallelism with the paleoclimatic equation. The 20-year tree-ring indices are from LaMarche (1974). The chronostratigraphic subdivisions are from Karlstrom (1988). PB = Point Boundary (clustering of basal-contact dates). As in Figure 3, combination of precipitation and inverted temperature curves improves correlation with the 139-year event cycle but, in contrast, also suggests a strong in-phase relationship with the 2/1 (69.5-year) resonance rather than with the 3/1 (46.33-year) resonance.

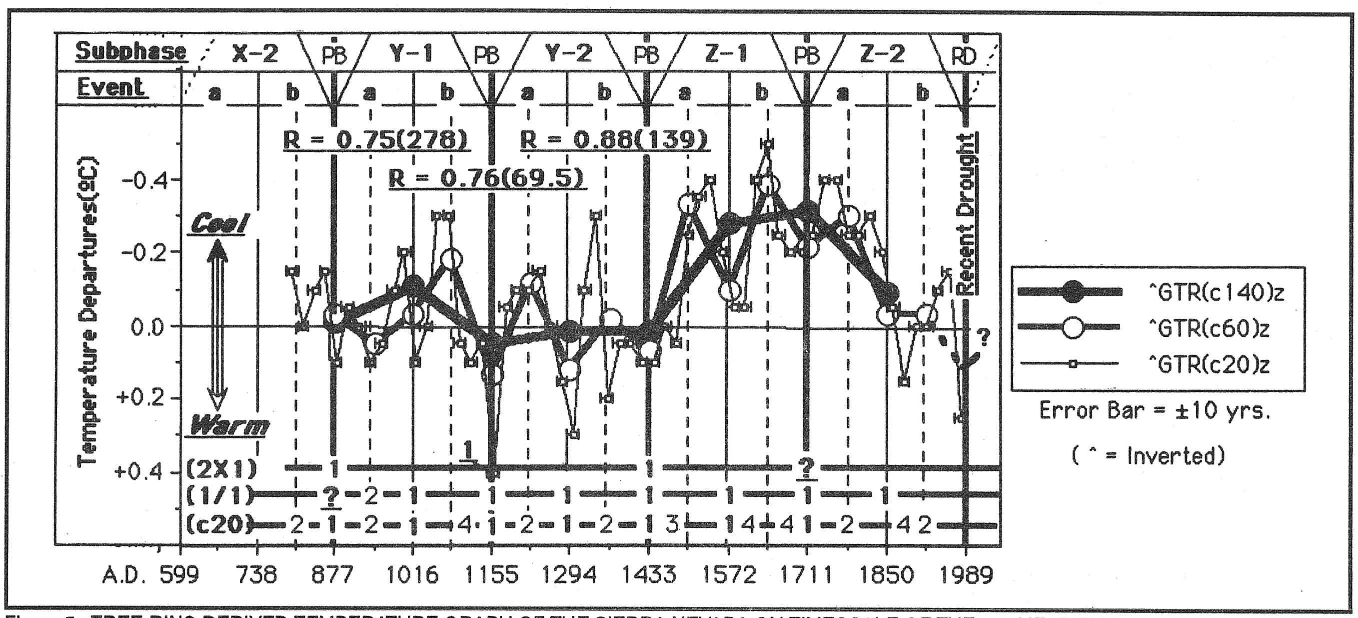

Figure 5. TREE-RING-DERIVED TEMPERATURE GRAPH OF THE SIERRA NEVADA ON TIMESCALE OF THE 139-YEAR EVENT CYCLE AND ITS 2/1 (69.5-YEAR) RESONANCE

Half-cycle smoothing and chronostratigraphic subdivision as before. Curve replotted at 20-year intervals from Graumlich (1992). Strongest correlations are with the 139-year event cycle and its 2/1 (69.5-year) resonance. Compare with Figures 1, 2, and 4.

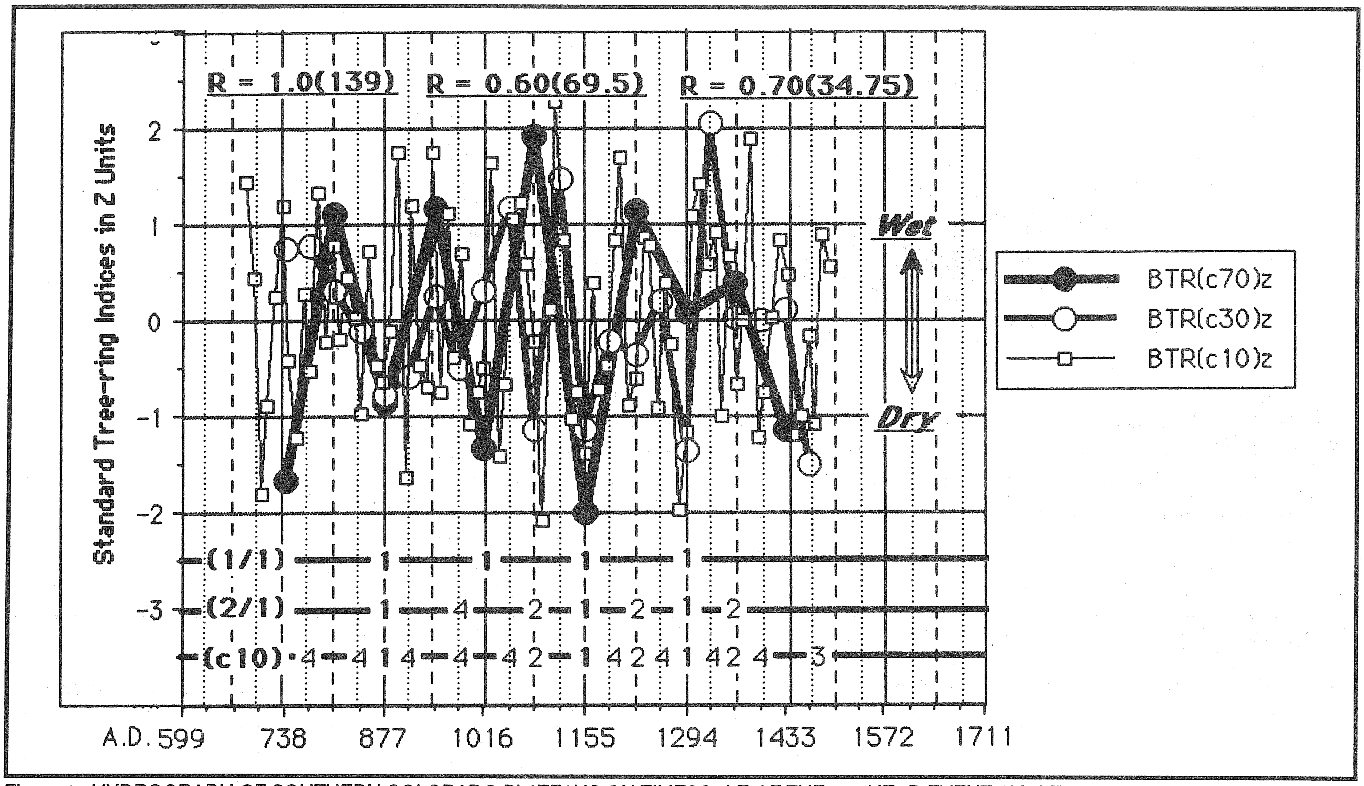

Figure 6. HYDROGRAPH OF SOUTHERN COLORADO PLATEAUS ON TIMESCALE OF THE 139-YEAR EVENT CYCLE AND ITS 2/1 (69.5-YEAR) AND 4/1 (34.75-YEAR) RESONANCES

Half-cycle smoothing as before. Seventeen station 10-year indices from Berry (1982). Very strong precipitation response to the event cycle; lesser but significant response to the 4/1 (34.75-year) resonance (Bruckner cycle).

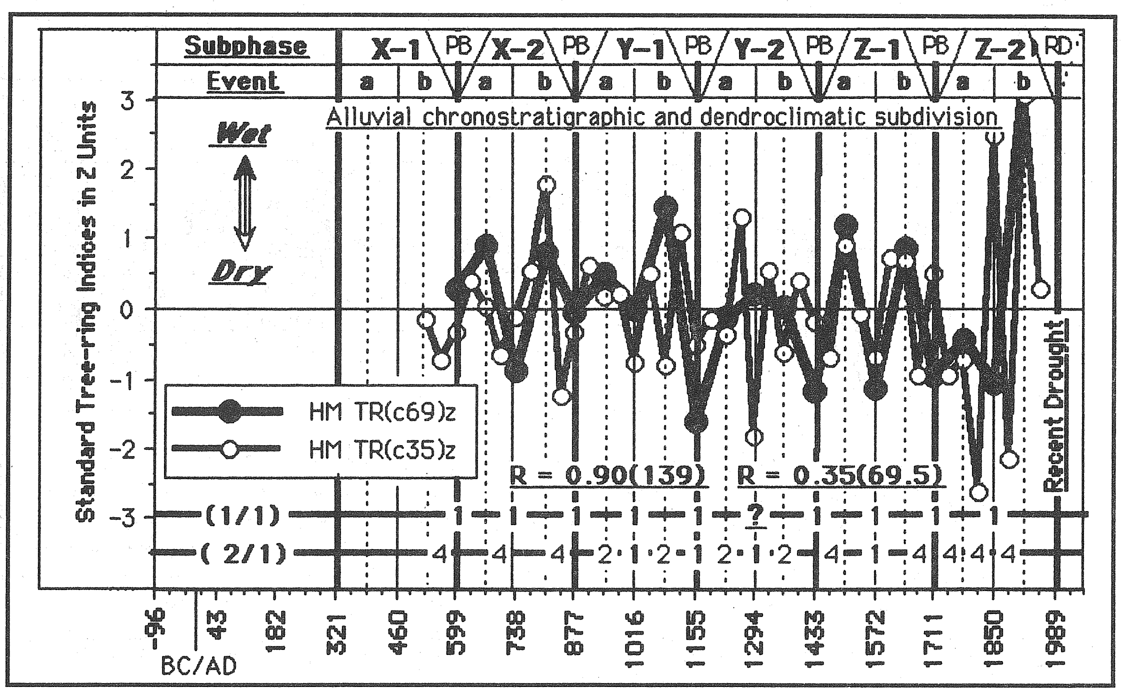

Figure 7. HYDROGRAPH OF HOPI MESAS, ARIZONA, ON TIMESCALE OF THE 139-YEAR EVENT CYCLE AND ITS 2/1 (69.5-YEAR) RESONANCE

Half-cycle smoothing and chronostratigraphic subdivision as before. Annual tree-ring indices from Dean and Robinson (1978). Very strong response to the event cycle; weak or insignificant response to the 2/1 resonance.

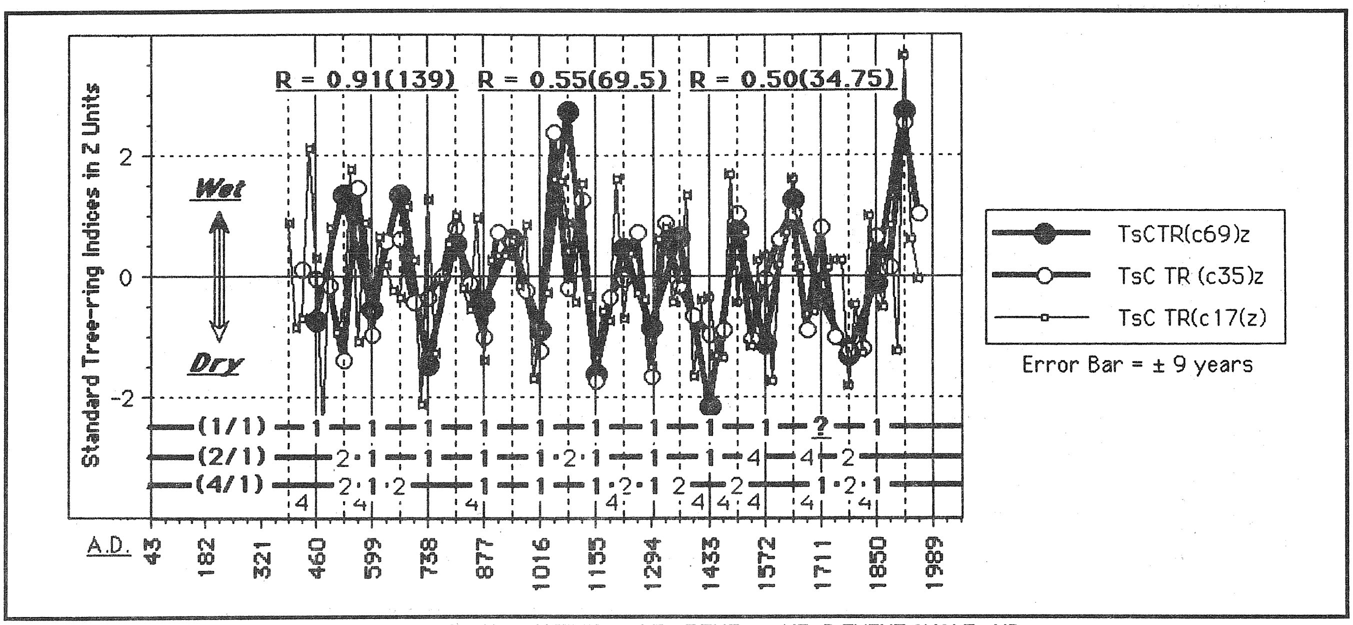

Figure 8. HYDROGRAPH OF TSEGI CANYON, ARIZONA, ON TIMESCALE OF THE 139-YEAR EVENT CYCLE AND ITS 2/1 (69.5-YEAR) AND 4/1 (34.75-YEAR) RESONANCES

Half-cycle smoothing same as before. Annual tree-ring indices from Dean and Robinson (1978). Very strong response to the event cycle; weak or insignificant response to the higher frequency half-resonances. The sign inversion between AD 1711 and 1850 appears to result from an unusually deep dry interval at the half-cycle position (AD 1780) or contemporaneous with the deep temperature high in one of the Sierra Nevada records (Figure 2), but not evident in the other (Figure 5)..

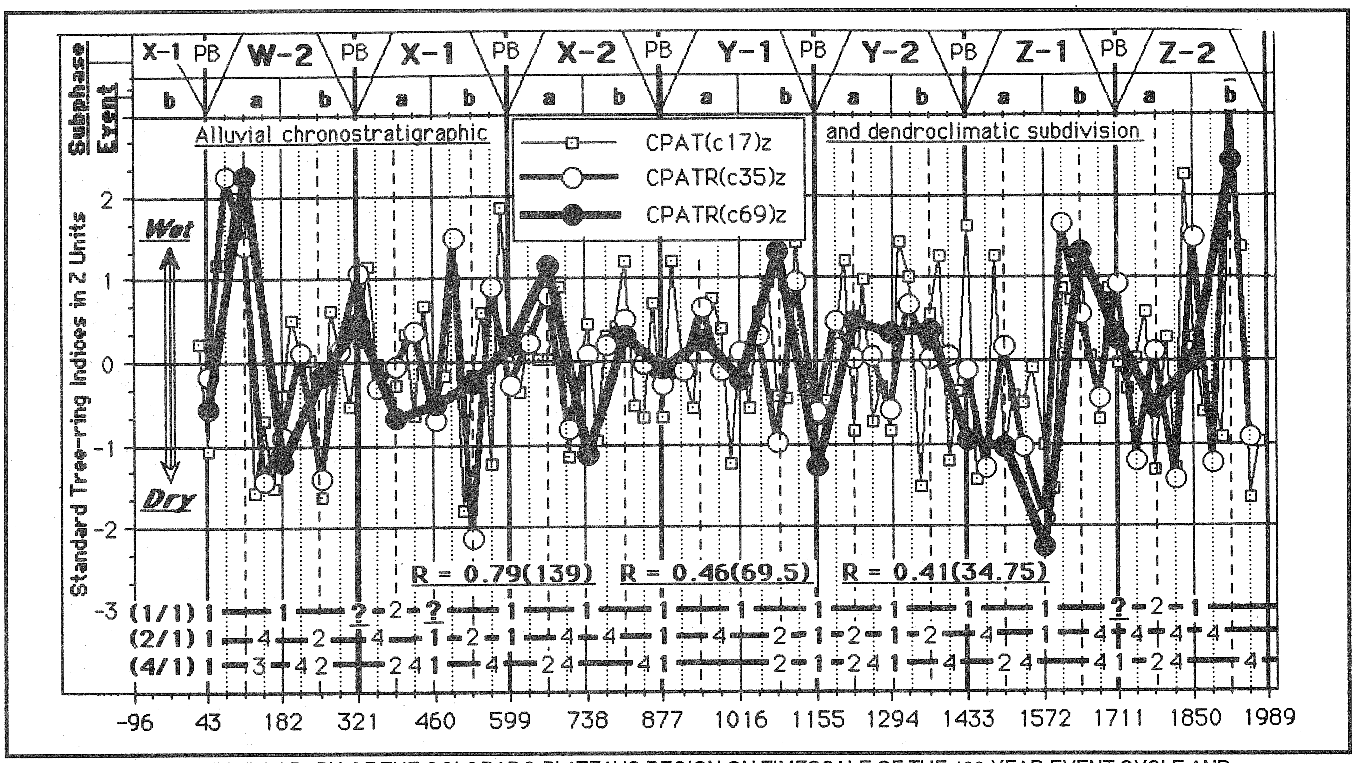

Figure 9. 25-STATION HYDROGRAPH OF THE COLORADO PLATEAUS REGION ON TIMESCALE OF THE 139-YEAR EVENT CYCLE AND ITS 2/1 (69.5-YEAR) AND 4/1 (34.75-YEAR) RESONANCES

Half-cycle smoothing and chronostratigraphic subdivision same as before. Annual indices from Dean and Robinson (1978). Though including many incomplete records, the regional composite retains a fairly strong response to the event cycle but weak or insignificant response to the higher frequency resonances.

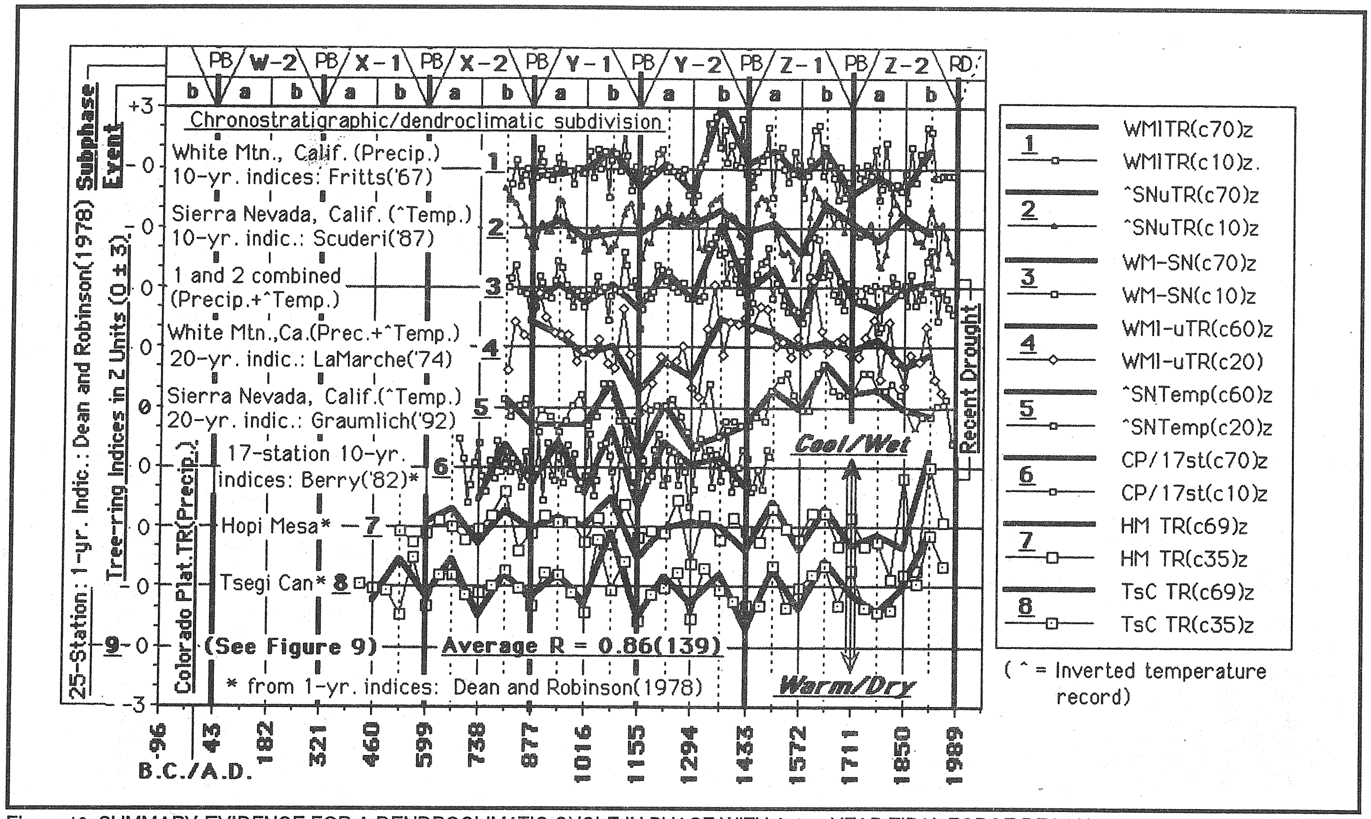

Figure 10. SUMMARY EVIDENCE FOR A DENDROCLIMATIC CYCLE IN PHASE WITH A 139-YEAR TIDAL FORCE RESONANCE
Trend correlations for local temperature and precipitation range from 0.75 to >0.90, or within the correlation range of tree-ring/climate calibrations. This suggests that the cycle is real and evidently related to changing atmospheric dynamics and patterns. Similar half-cycle analyses of other records may define differing regional patterns and responses, advancing understanding of climatic/biologic process.

Additional High-Resolution Records Suggesting Various Components of the Solar Insolation/Tidal Resonance Model

The 139-year resonance, herein called the *event cycle*, is but a higher-frequency component of the resonance model, as characterized by a series of longer- and shorter-term cycles ranging from years to thousands of years. Figures 11 to 29 provide additional examples of high-resolution records, many previously not analyzed for the presence of secondary cycles, which appear to record various harmonic components of the solar insolation/tidal resonance model.

Egyptian Cultural/Environmental Events

Egypt provides one of the longest historically chronicled records of political and environmental change (Hoffman 1979; James 1979). Economic and, by implication, political fortunes were intimately tied to the annual flooding of the Nile River. Series of extremely low and extremely high floods could have seriously affected the economic base and, thus, political stability. Resonance analysis of the Egyptian record suggests the strongest correlation between dynastic subdivision and the 139-year event cycle (Figure 11). Most dynastic changes took place during the dry epicycles (presumably during intervals of falling and generally low flood levels), suggesting that environmental stress may have played a contributing role in dynastic succession. The three intermediate periods mark short intervals of extreme political unrest, with complete loss of central administrative control and (including in the last two periods) split local control shared with foreign invaders. Reasons for these intervals of rapidly changing political fortunes remain enigmatic and speculative, but they probably reflect a mix of internal and external social factors combined with the possibility of occasional higher destabilizing floods, since all of the intermediate periods are centered on wet epicycles and essentially begin and end in dry epicycles of the 139-year event cycle.

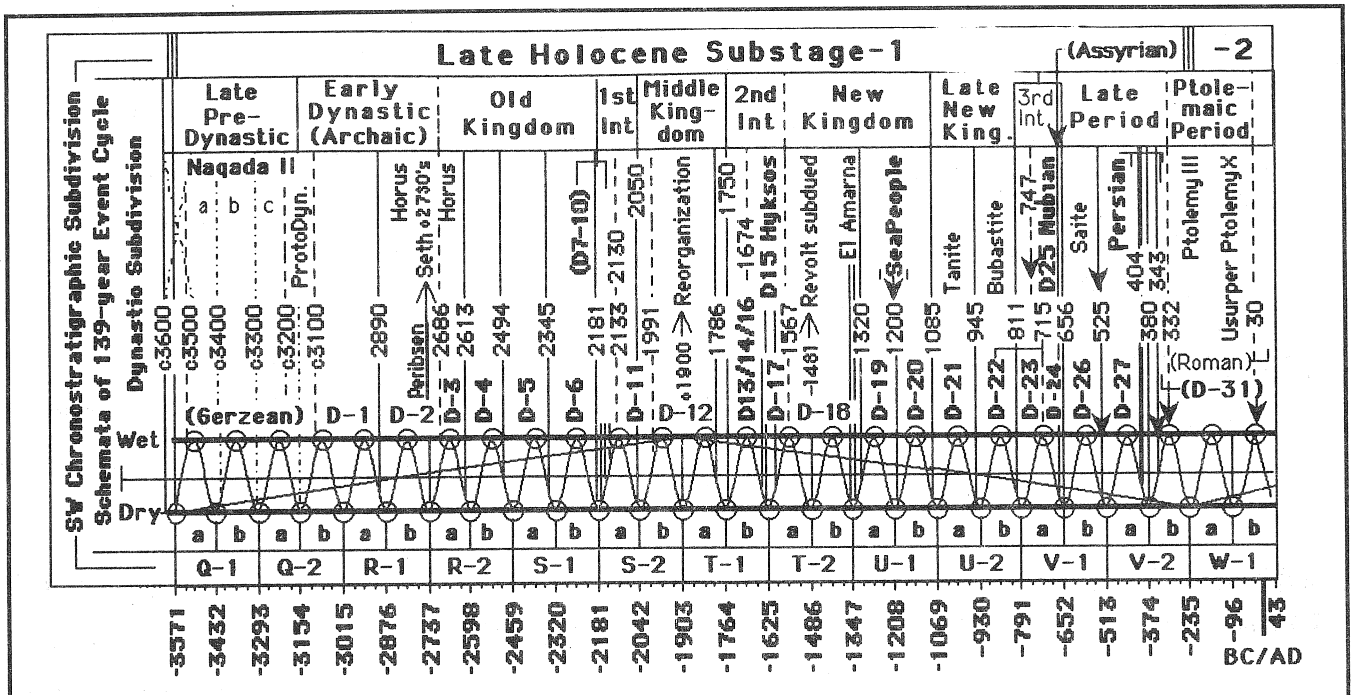

Figure 11. CORRELATION OF EGYPTIAN DYNASTIC HISTORY WITH SCHEMATA OF THE 139-YEAR EVENT CYCLE

Reconstruction of dynastic record primarily after James (1979), who notes that dating is approximate and increasingly so toward the beginning of the record. Most dated boundaries (solid lines) fall within the dry epicycles and the remaining few (dashed lines) fall within the wet epicycles, indicating that environmental stress (lower Nile levels?) may have contributed to dynastic succession. See Figure 27 for extended correlation of the Egyptian/Nubian record with longer-term climatic trends.

Sunspot/Climate Correlations

Intense climatic research has focused on correlation of climate with solar change as indirectly indexed by the sunspot cycle of about 11.1 years and by its double Hale magnetic cycle of about 22.2 years. Correlation has been attempted both with sunspot number and sunspot cycle-length.

One of the strongest correlations suggesting cause-and-effect relationships between solar activity and climate is provided by Friss-Christiansen and Lassen (1992), who correlate sunspot cycle-length with Northern Hemisphere average temperature and with the Iceland temperature curve of Bergthorsen (1969). In Figure 12, I extend the Iceland temperature

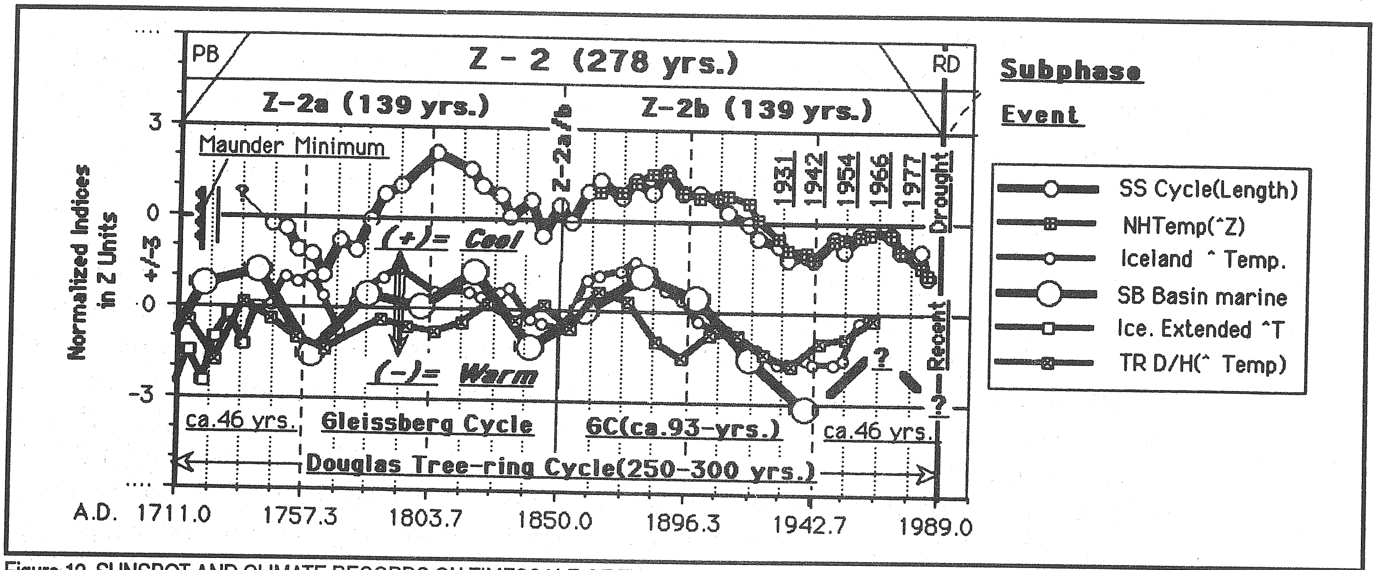

Figure 12. SUNSPOT AND CLIMATE RECORDS ON TIMESCALE OF THE 139-YEAR EVENT CYCLE AND ITS 3/1 (46.3-YEAR) AND 12/1 (11.5-YEAR) RESONANCES

Sunspot, hemispheric temperature, and Iceland indices to 1745 from Friis-Christiansen and Lassan (1991); extension of Iceland temperature record by indices from Bergthorssen (1969). Santa Barbara marine indices from Pandolfi *et al* (1980); tree-ring-dated isotope indices from Epstein and Yapp (1976). Sunspots and collated climatic records appear to be related to the tidal resonance model through in-phase relationships with the about 46-year resonance and its double Gleissberg sunspot cycle (see Figures 14 and 15). Some tendency for sunspot length and higher-resolution climate records to oscillate in phase with the 11.5-year resonance.

curve to AD 1700 and add two proxy climate records (Figures 14 and 15) that also parallel the sunspot cycle-length curve as well as or better than the proxy Iceland temperature record. The sunspot-length and collated climatic records appear to be related to the tidal resonance model primarily through in-phase relationships with the about 46-year resonance and its double Gleissberg sunspot cycle. This, in turn, suggests some sort of relationship between solar activity and tidal resonances as dominated by lunar and solar perturbations of Earth's atmosphere. Researchers have estimated the Gleissberg cycle variously between 80 and 100 years in duration. Correlation with the tidal resonance model suggests its average length lies nearer 90 years.

Other researchers have sought correlation between climate and the sunspot cycle itself. Figure 13 is a graph of the solar-tide and sunspot curves used by Gribbin (1976) in support of his failed prediction of a 1982 major earthquake in the Los Angeles area. The prediction (Gribbin and Plagemann 1975) is based on the following linkages:

- Solar tides (due to perturbations of tidal planets Venus, Earth, and Jupiter) modulate the sunspot cycle,
- In turn affecting Earth's climate,
- In turn perturbing Earth's spin,
- In turn triggering earthquakes through resulting structural adjustment in Earth's crust.

Most scientists (Anderson and Okai 1975; Meeus 1975; and others) anticipated the failure of Gribbin and Plagemann's dire prediction. Among other criticisms, Anderson and Okai (1975) believe the sun/tide calculation is in error and that the planetary alignment of 1982 is not as tight as predictable for 1990 and, in either case, is insufficient to produce earthquakes.

The apparent failure of the solar tide/sunspot correlation does not necessarily impact traditional sunspot/climate correlation. I have added two tree-ring records to Figure 13, one from the Midwest (Michell *et al* 1979) and one from the Colorado Plateaus (this paper). Both records correlate well with the Hale double (magnetic) sunspot cycle. In his seminal analysis of weather cycles, Burroughs (1992) considers that the cyclical analysis by Michell *et al* (1979) of Midwest tree-ring records provides one of the best cases for a possible cause-and-effect relationship between solar activity and climate. Half-cycle analyses of annual indices of these tree-ring records (as well as of the sun/tide and sunspot curves) use turning points of a fundamental fifth harmonic of the tidal model that closely matches the timing and average length of the Hale double sunspot cycle. The strong cyclical pattern obtained by half-cycle smoothing of the Midwest record essentially replicates the results of Michell *et al* (1979), who used different analytical procedures.

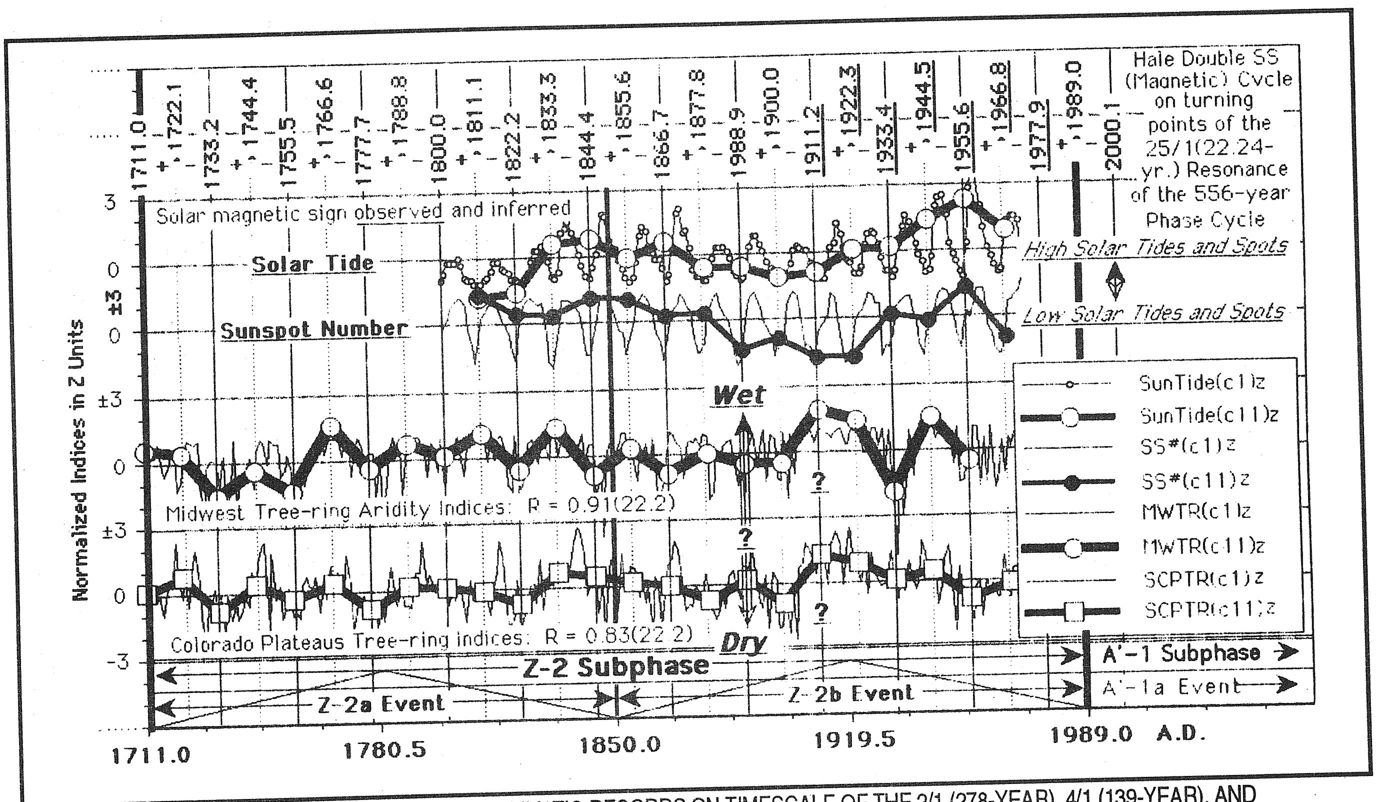

Figure 13. SOLAR TIDES, SUNSPOTS, AND DENDROCLIMATIC RECORDS ON TIMESCALE OF THE 2/1 (278-YEAR), 4/1 (139-YEAR), AND 25/1 (22.24-YEAR) RESONANCES OF THE 556-YEAR PHASE CYCLE

Annual indices of sunspots and solar tides from Wood in Gribbin (1976); Midwest tree-ring indices from Michell *et al* (1979) in Burroughs (1992); Colorado Plateaus tree-ring indices from Dean and Robinson (1978). Half-cycle smoothing on turning points of the 25/1 (22.24-year) resonance that is in phase with the average Hale double sunspot (magnetic) cycle. This, in turn, seemingly integrates solar/earth tidal phases with terrestrial climate through solar magnetic change (+ solar magnetism = generally increased Earth rainfall).

Though more complacent, the smoothed Colorado Plateaus tree-ring curve shows similarities, including the short interval of phase reversals near the beginning of the century. The comparably smoothed sunspot curve does not show the same pattern of secondary trends, but it does suggest correlation with the 139-year event cycle in that lower sunspot numbers occur in the middle and higher sunspot numbers occur near the beginning and end of the cycle. These higher- and lower-frequency correlations seemingly integrate solar/tidal phases with terrestrial climate through solar magnetic change (with positive solar magnetism equating with generally increased Earth precipitation).

Uncertainties remain concerning the physical linkages between solar magnetism, tidal resonances, and climate. Equally critical, the Hale cycle has been observed only since the beginning of this century, and projection of the same magnetic alternation between successive sunspot cycles into the past or the future remains speculative.

Lower Frequency Components of the Solar Insolation/Tidal Resonance Model

In Figures 14-29, I provide additional high-resolution climate records that are seemingly in phase with longer-term components of the solar insolation/tidal resonance model. Procedures for analyzing time stratigraphy and pollen time series remain the same as discussed in Karlstrom (1961), Ray and Karlstrom (1968), Karlstrom (1969), Hevly and Karlstrom (1974), and Euler *et al* (1979).

Figures 14-16 include a California tree-ring isotope, a California marine, and a Swedish pollen time series that seem to be primarily in phase with the 278-year subphase cycle.

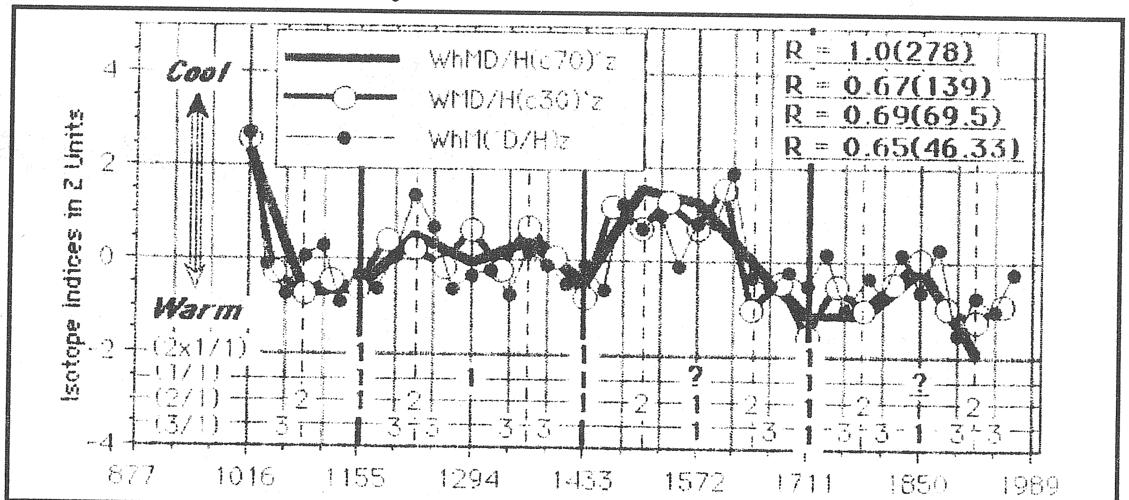

Figure 14. TREE-RING-DATED ISOTOPE RECORD OF THE WHITE MOUNTAINS, CALIFORNIA, ON TIMESCALE OF THE 139-YEAR EVENT CYCLE AND ITS 2/1 (69.5-YEAR) AND 3/1 (46.33-YEAR) RESONANCES

Centered 10-year isotope (D/H) temperature indices from Epstein and Yapp (1976).Taken as a whole, the record shows a strong tendency to oscillate in phase with the 278-year subphase cycle but weak or insignificant tendencies with the event cycle and its 2/1 (69.5-year) and 3/1 (46.33-year) resonances. Note, however, some apparent systematics in the complex resonance pattern. Between AD 1150 and 1433 (subphase Y-2), the secondary trends are apparently dominated by the event cycle, between AD 1433 and 1711 (subphase Z-1) by its 2/1 resonance, and between AD 1711 and the present (subphase Z-2) by its 3/1 resonance (see Figure 12). It remains unclear how much of the complexity results from distorting noise, from nonlinear response, or from selective local tree response to in- and out-phasing of superposed atmospheric resonances. Note similarities with the California marine record (Figure 15).

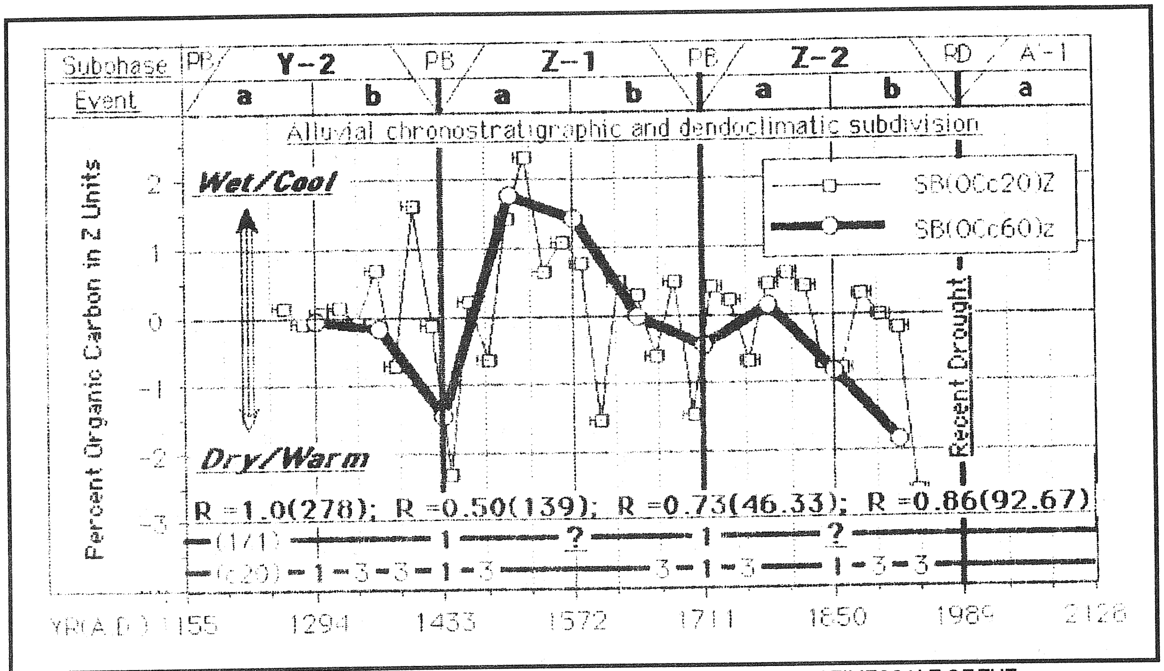

Figure 15. VARVE-DATED MARINE RECORD OF SANTA BARBARA BASIN, CALIFORNIA, ON TIMESCALE OF THE 139-YEAR EVENT CYCLE AND ITS 3/1 (46.33-YEAR) RESONANCE

Indices from Pandolfi *et al* (1980), replotted at 20-year intervals. Original indices collated with a Japanese tree-ring record that includes a cycle of 273 20 years (18/0) and 271 11 years (D/H). As shown, a similar-length marine cycle is in phase with the 278-year subphase cycle, suggesting that greater amounts of organic carbon were supplied during major Southwest wet (depositional) intervals. Record shows a tendency to oscillate in phase with the about 46-year resonance and a stronger tendency with its double (about 93-year) Gleissberg cycle (Figure 12).

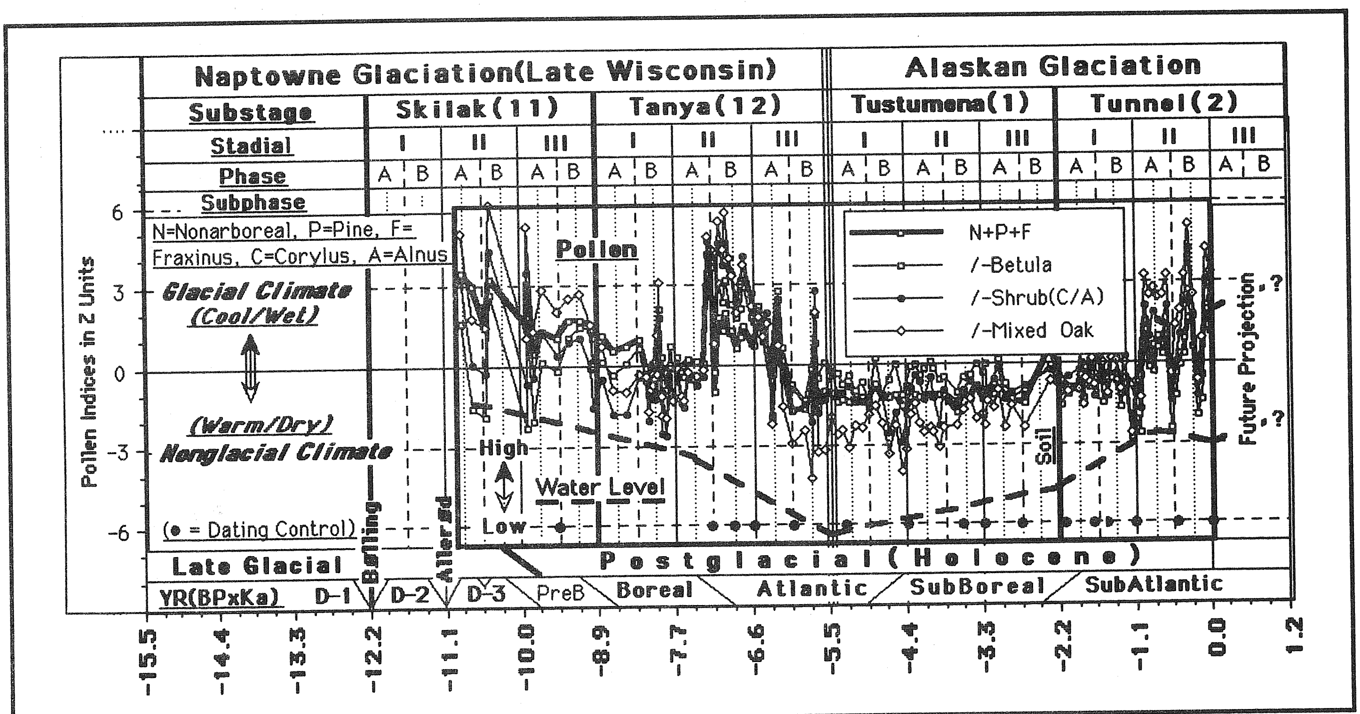

Figure 16. STANDARD POLLEN AND HYDROLOGIC RECORD OF AGERÖDS MOSSE, SWEDEN, ON TIMESCALE OF THE 1112-YEAR STADIAL CYCLE AND ITS 2/1 (556-YEAR) PHASE AND 4/1 (278-YEAR) SUBPHASE RESONANCES

Pollen and relative hydrologic indices after Nilsson (1964a,b). The Alaska glacial (point boundary) classification and its cyclical subdivisions (Karlstrom 1961; upper 5 rows) are correlated with the transition-boundary classification of Europe (lower 2 rows). Strong tendency to oscillate in phase with the 278-year subphase resonance. The record suggests that the late-Atlantic marks a drier and the warmest interval in Postglacial time (Karlstrom 1956; Figures 18, 21, 23, 24). Nilsson's chronology is based on a minor conversion (x1.03) of conventional 14/C dates (half life of 5568 years). For comparability with other 14/C-dated records, the above Agaröds Mosse chronology is also derived by using conventional 14/C results.

Figures 17 and 18 include a California and an Alaska pollen time series that seem to be primarily in phase with the 556-year phase cycle.

Figures 19-22 include two marine time series (from Equatorial Pacific and the Antarctic), a dated hydrologic/pollen record from Utah, and an Arizona pollen time series that seem to be primarily in phase with the 1112-year stadial cycle.

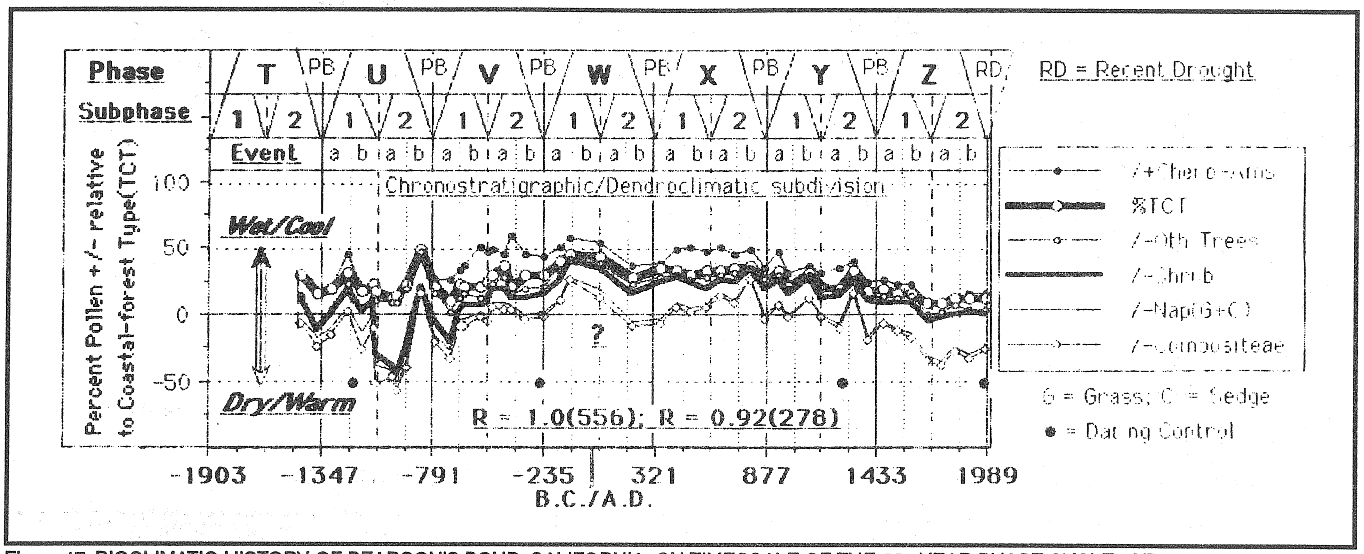

Figure 17. BIOCLIMATIC HISTORY OF PEARSON'S POND, CALIFORNIA, ON TIMESCALE OF THE 556-YEAR PHASE CYCLE AND ITS 2/1 (278-YEAR) SUBPHASE AND 4/1 (139-YEAR) EVENT RESONANCES

Dated pollen indices from Adam (1975). Chronostratigraphic subdivision after Hevly and Karlstrom (1974), Karlstrom (1988). PB = point boundary (clustering of basal-contact dates). Strongest tendency to oscillate in phase with the phase cycle and its 2/1 subphase resonance; weaker tendency with the event cycle.

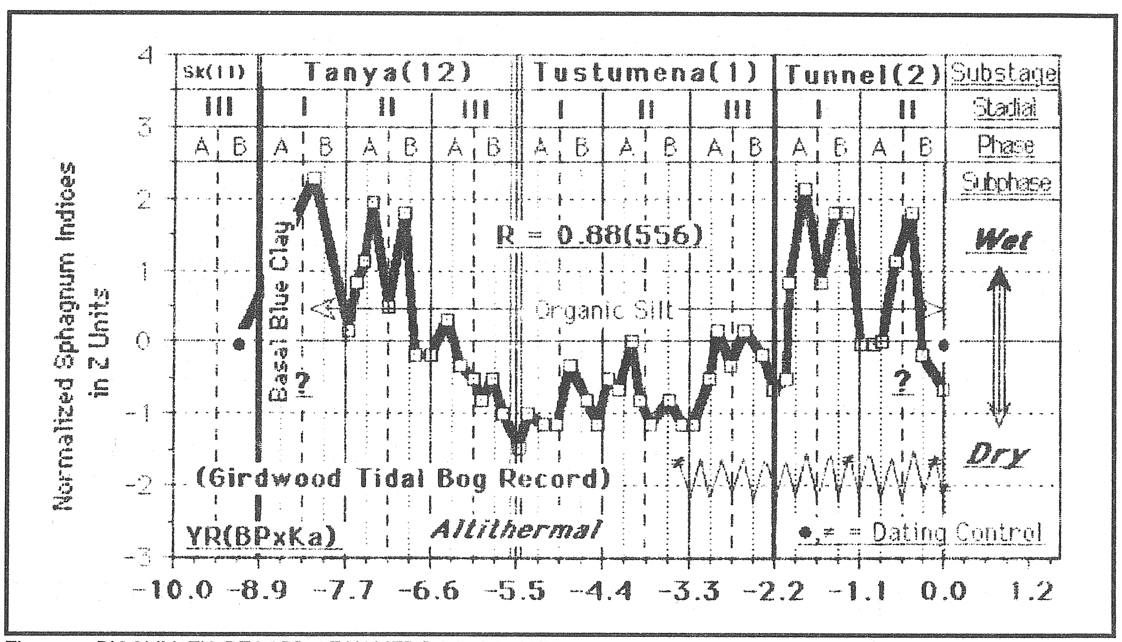

Figure 18. BIOCLIMATIC RECORD OF HOMER BOG, COOK INLET, ALASKA, ON TIMESCALE OF THE 1112-YEAR STADIAL CYCLE AND ITS 2/1 (556-YEAR) PHASE CYCLE AND 4/1 (278-YEAR) SUBPHASE RESONANCE

Pollen indices of Huesser (1965) time-calibrated by basal date listed in Karlstrom (1964). The higher-frequency Girdwood Bog record is schematically plotted as interpreted climatically in Karlstrom (1961). Because of lesser sensitivity, Homer Bog shows the strongest tendency to oscillate in phase with the 556-year phase cycle and positions the driest Postglacial interval contemporaneous with that in the late-Atlantic of northern Europe (Figure 16).

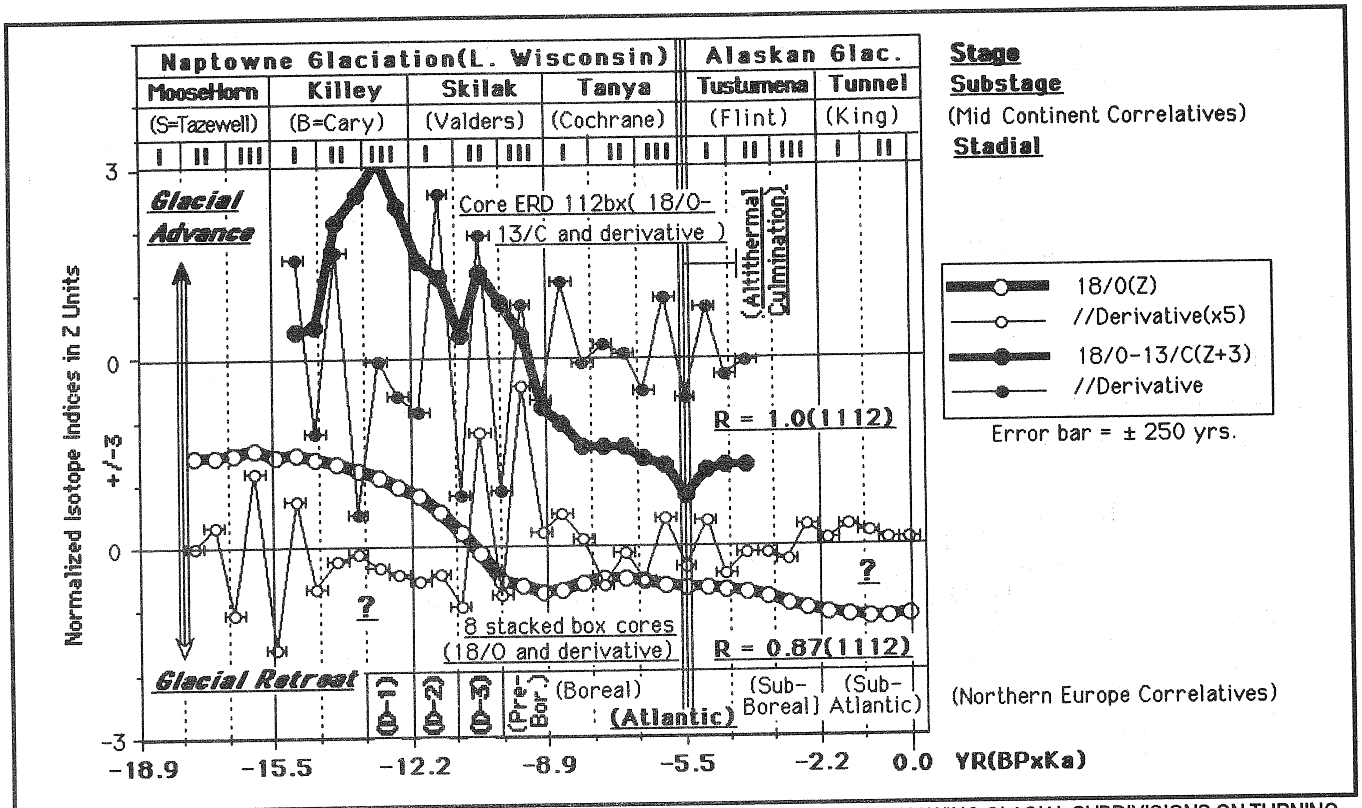

Figure 19. EQUATORIAL PACIFIC OCEAN-CORE RECORDS (AND DERIVATIVES) ON TIMESCALE SHOWING GLACIAL SUBDIVISIONS ON TURNING POINTS OF THE 3336-YEAR SUBSTAGE CYCLE AND ITS 3/1 (1112-YEAR) STADIAL RESONANCE

Centered 500-year-interval isotope indices from Berger *et al* (1987). Alaska glacial chronology and correlations after Karlstrom (1961, 1976b). Lower row = classic Scandinavian bioclimatic (pollen) subdivision of Late Glacial and Postglacial time (Figure 16). The derivatives suggest that secondary trends of glacial melting (18/0) and surface water temperature (13/C) were strongly in phase with the stadial cycle during the last 18000 years. D-1 to 3 = Dryas glacial advances.

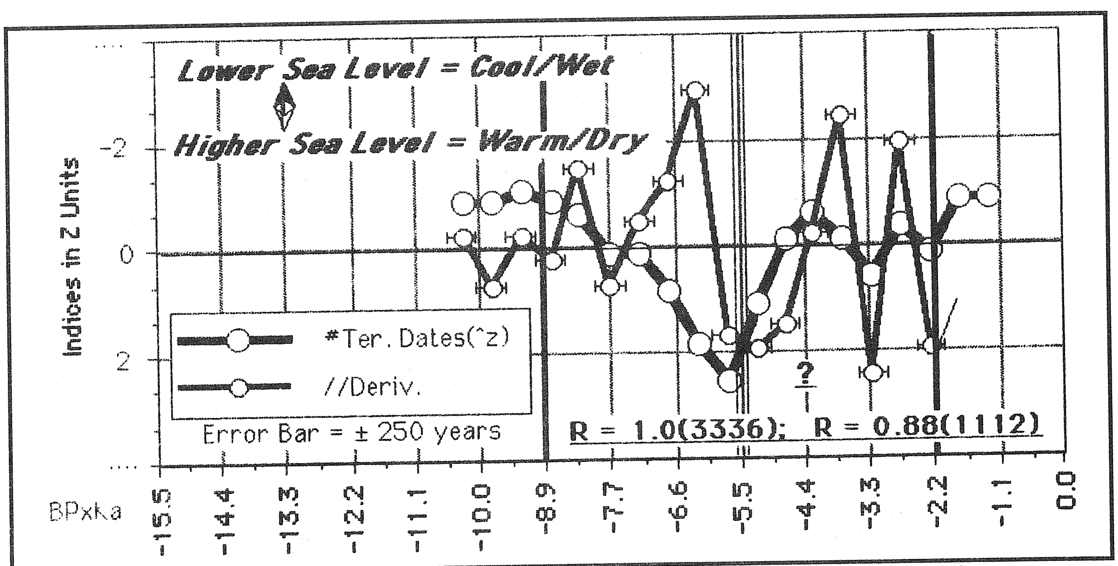

Figure 20. TIME-FREQUENCY DIAGRAM OF DATED MARINE TERRACES IN THE ANTARCTIC ON TIMESCALE OF THE 1112-YEAR STADIAL CYCLE

Centered 500-year indices from Berkman (1992). N=88. Clustering of dates suggests a high sea level stand during the culmination of the Northern Hemisphere Altithermal. Derivative amplification suggests a strong tendency for secondary sea levels to oscillate in phase with the 1112-year stadial cycle. Correlations with terrestrial records suggest glacioeustatic controls.

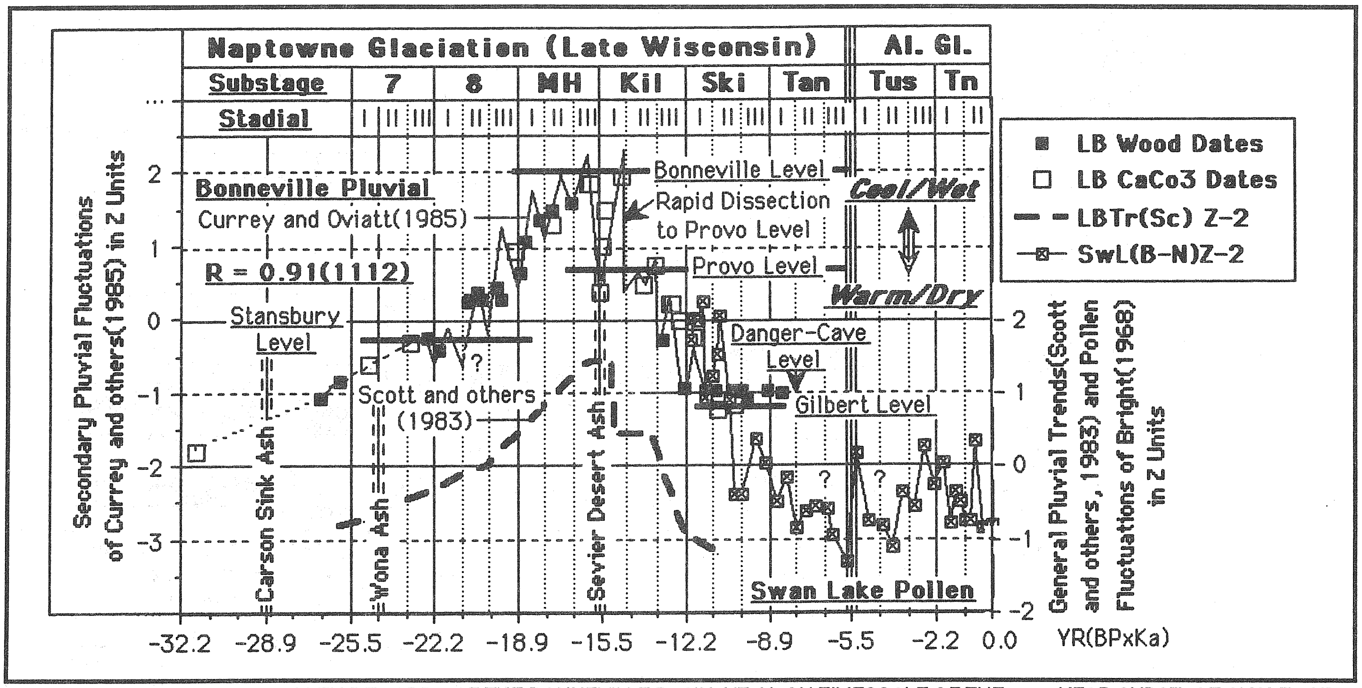

Figure 21. LAKE-LEVEL AND POLLEN RECORDS OF THE BONNEVILLE BASIN, UTAH, ON TIMESCALE OF THE 3336-YEAR SUBSTAGE CYCLE AND ITS 3/1 (1112-YEAR) STADIAL RESONANCE

Clustering of dated littoral- and shallow-water samples strongly suggests secondary lake-level changes between 22000 and 11000 YBP in phase with the 1112-year stadial cycle. The pollen record evidently extends the same resonance pattern to the present (Hevly and Karlstrom 1974). Recorded volcanic eruptions apparently occurred during interstadial (lower water/drought) epochs.

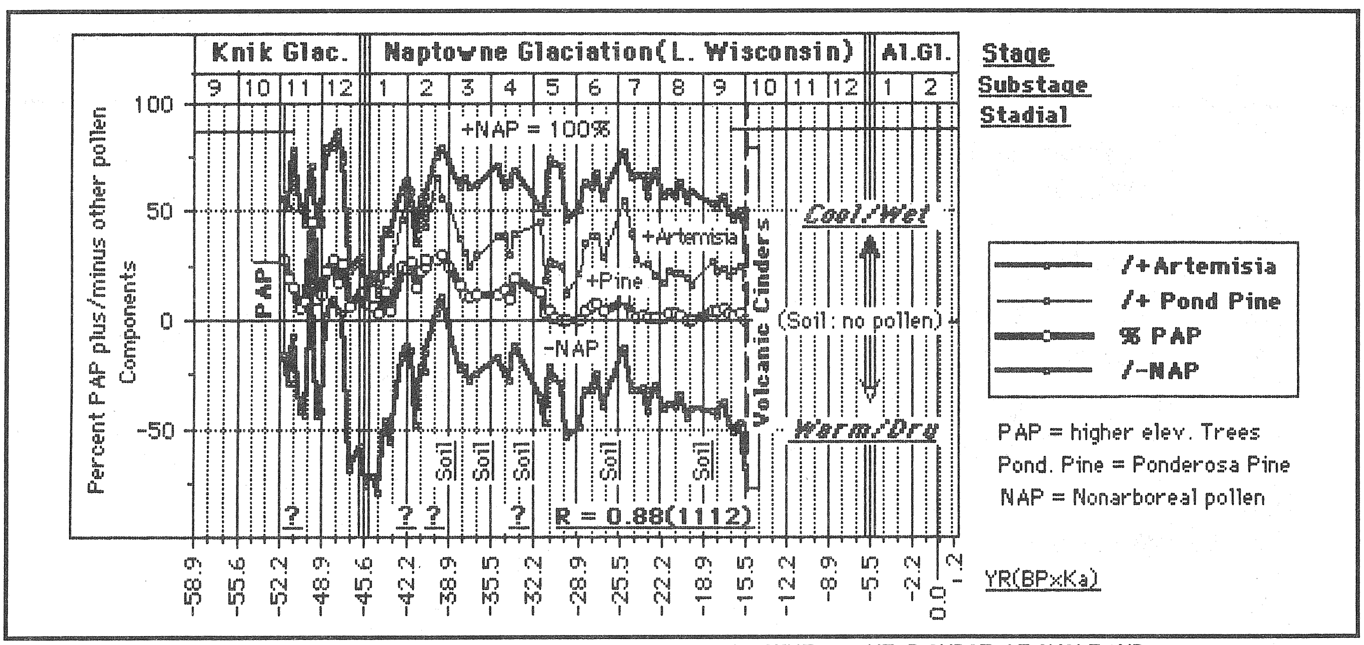

Figure 22. BIOCLIMATIC RECORD OF WALKER LAKE, ARIZONA, ON TIMESCALE OF THE 3336-YEAR SUBSTAGE CYCLE AND ITS 3/1 (1112-YEAR) STADIAL RESONANCE

Pollen indices from Berry as time-calibrated in Karlstrom (1976b). Strong tendency for the record to oscillate in phase with the stadial cycle. Several of the inter-substage epochs are marked by soils (oxidized zones with no pollen) suggesting lower water levels and subaerial exposure. The covering volcanic cinders date contemporaneous with the Sevier Desert Ash of the Lake Bonneville Basin to the north (Figure 21).

Figures 23-26 include three pollen time series (from Canada and Spain) and a Tunisian ground water time series that seem to be primarily in phase with the 3336-year substage cycle.

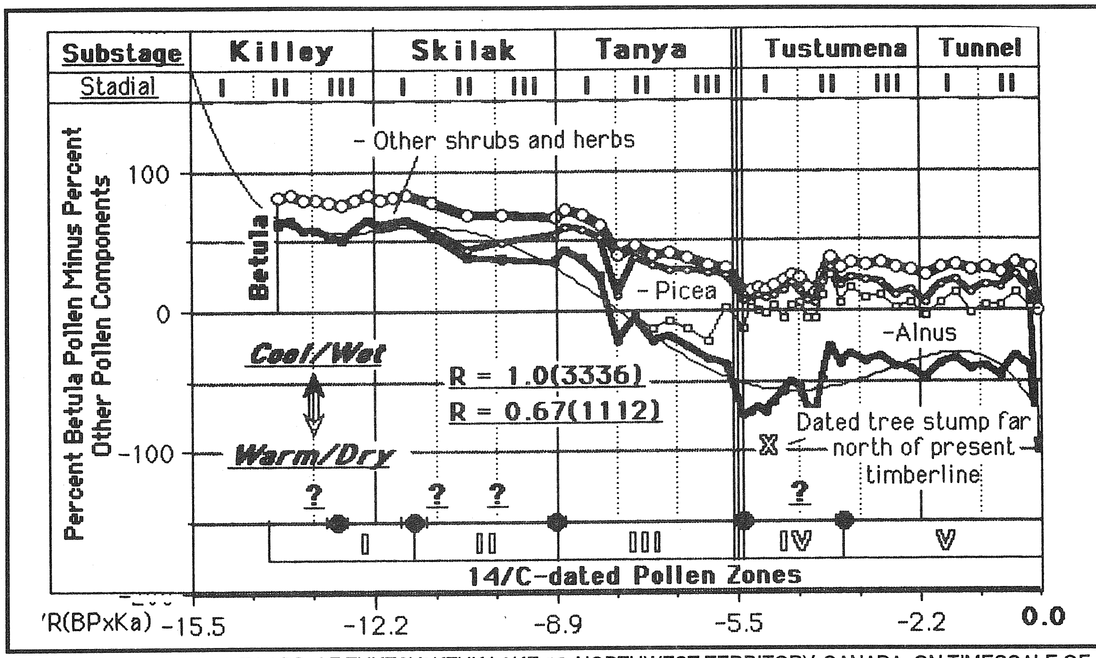

Figure 23. BIOCLIMATIC RECORD OF TUKTOYAKTUK LAKE #5, NORTHWEST TERRITORY, CANADA, ON TIMESCALE OF THE 3336-YEAR SUBSTAGE CYCLE AND ITS 3/1 (1112-YEAR) STADIAL RESONANCE
Pollen indices from Richie and Hare (1971). This high-latitude record (N70°) suggests warmest/driest climate and most northerly expansion of timberline between 5000 and 6000 years ago, or contemporaneous with Altithermal culmination, as dated in the Southwest and elsewhere (Figures 16, 18, 19, 20, 21). Strong tendency to oscillate in phase with the substage cycle; weaker tendency with the stadial cycle.

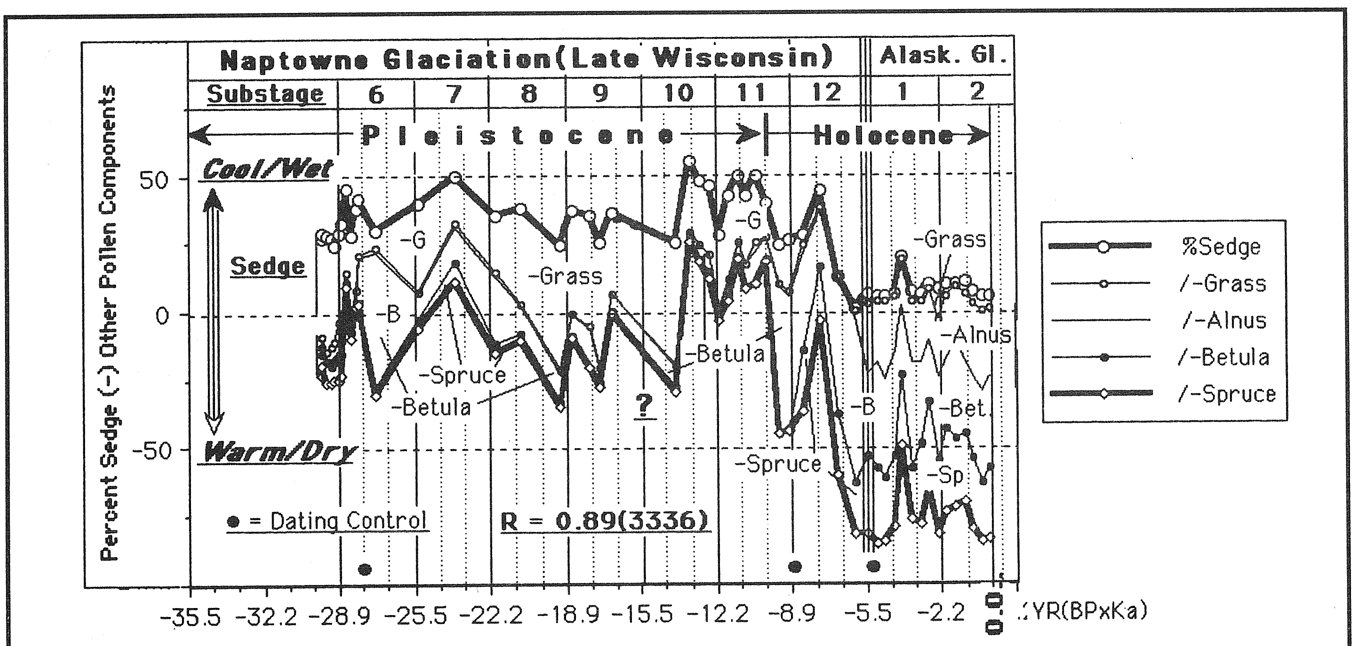

Figure 24. BIOCLIMATIC RECORD OF ANTIFREEZE POND, YUKON TERRITORY, CANADA, ON TIMESCALE OF THE 3336-YEAR SUBSTAGE CYCLE AND ITS 3/1 (1112-YEAR) STADIAL RESONANCE
Pollen indices from Rampton (1970). Alaska glacial classification and cyclical subdivision from Karlstrom (1961). Trend analysis suggests a strong response to the substage cycle and, where the sampling interval is sufficiently close, to the stadial cycle.

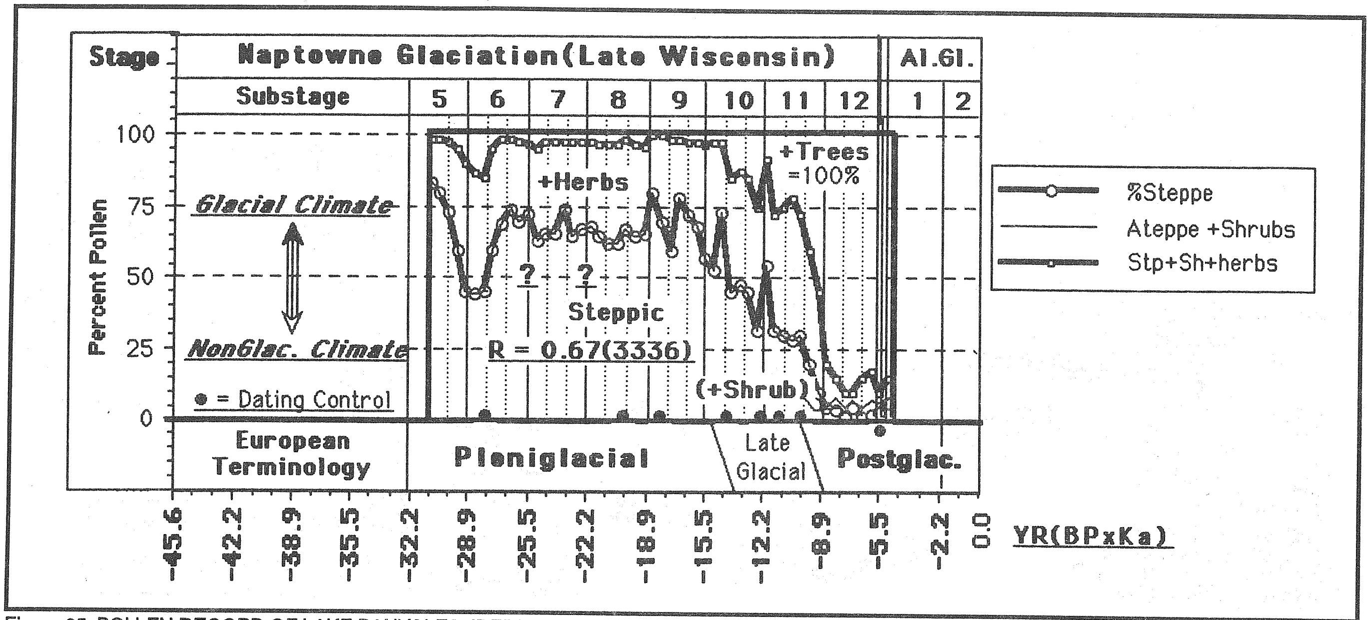

Figure 25. POLLEN RECORD OF LAKE BANYOLES, IBERIAN PENINSULA, ON TIMESCALE OF THE 3336-YEAR SUBSTAGE CYCLE AND ITS 3/1 (1112-YEAR) STADIAL RESONANCE

Pollen indices replotted at 500-year intervals from Figure 4B in Perez-Obriol and Juliá (1994). Dating control by U/Th and radiocarbon. Alaska glacial classification and point-boundary cyclical subdivision (Karlstrom 1961; upper two rows) correlated with transition-boundary European classification (lower row). Fairly strong tendency for in-phase relationships with the substage cycle.

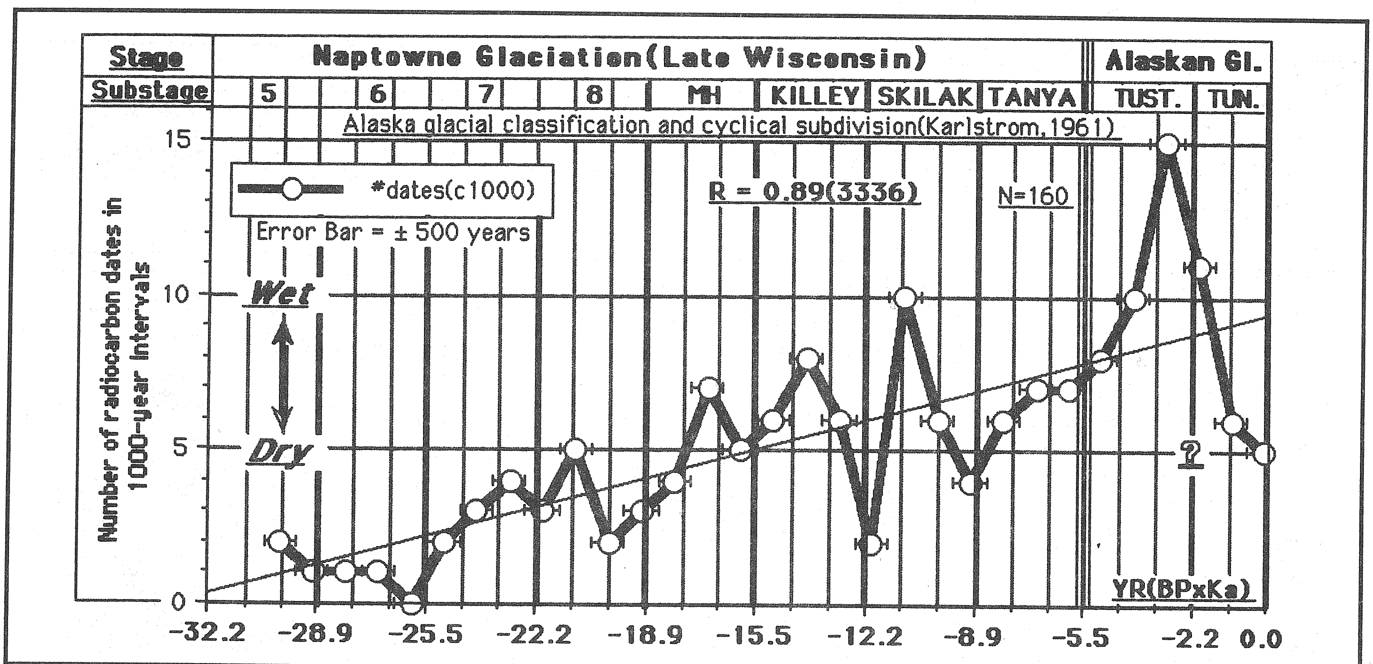

Figure 26. TIME-FREQUENCY DIAGRAM OF DATED GROUND WATER IN TUNISIA ON TIMESCALE OF THE 3336-YEAR SUBSTAGE CYCLE AND ITS 3/1 (1112-YEAR) STADIAL RESONANCE

Indices from Scharpenseel *et al* (1980). Wetter climate apparently reoccurred substantially in phase with the 3336-year substage cycle (Figure 27). Note the typical progressive decrease in number of dates with age.

Figure 27 includes dated Egyptian and Nubian cultural and environmental events, partly in phase with lower north latitude processional cycles and partly with the 3336-year substage cycle.

Figure 28 includes two marine isotope chronologies (from the Equatorial Pacific and Equatorial Atlantic oceans) that are fine-tuned to the 65°N latitude insolation curve and considered to provide standard global records of the Ice Ages.

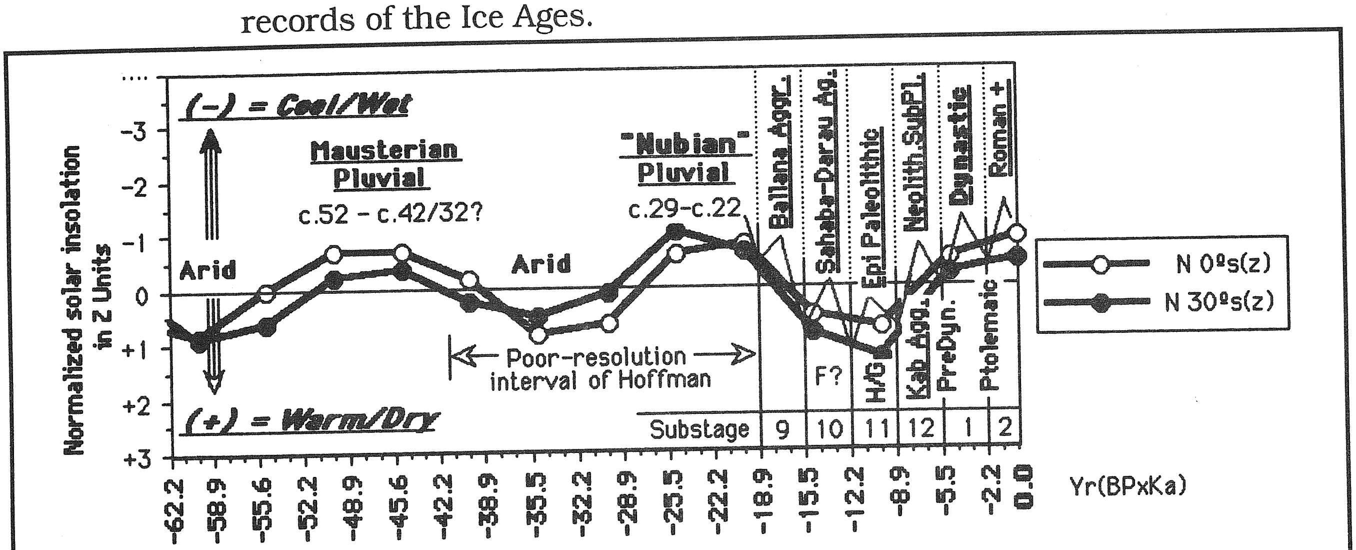

Figure 27. SOLAR INSOLATION CURVES OF NORTHERN SUMMER HALF-YEARS FROM THE EQUATOR TO N30° LATITUDE
The 3336-year substage cycle is schematically superposed on the insolation trends. Dated Nubian and Egyptian cultural/environmental events are positioned as summarized in Hoffman (1979). More recent dating of Nubian pluvials c29-22 and c9-6/3 (Neolithic subpluvial and Dynastic in age) is after Pachur and Hoelzman (1991), and appears to confirm the correlation between generally wetter climate and precessional solar-insolation minima north of the Equator. Secondary hydrologic and cultural events apparently are in phase with the 3336-year substage cycle. F? = possible earliest farming during the Sahaba Darau Aggradation interval (substage 10). H/G = temporary return to hunting and gathering strategies during the ensuing drier Epi Paleolithic interval (substage 11). See Figure 11 for historical subdivision of Dynastic time.

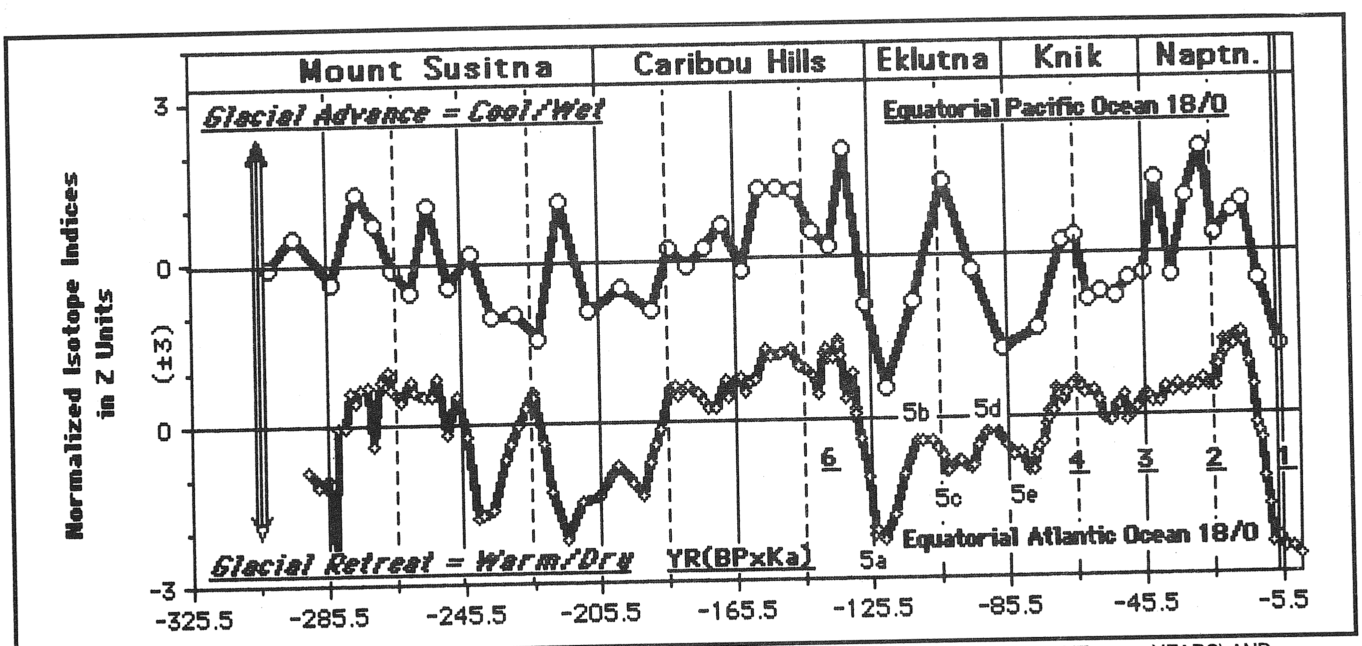

Figure 28. TWO "STANDARD" MARINE ICE AGE CHRONOLOGIES ON TIMESCALE OF THE INSOLATION CYCLE (ABOUT 40000 YEARS) AND ITS 2/1 (ABOUT 20000 YEARS) RESONANCE ASSUMING A RESPONSE LAG OF ABOUT 4500 YEARS (Karlstrom 1961)
Equatorial Pacific record from Chuey *et al* (1987); the Equatorial Atlantic record from Martinson *et al* (1987). Both are fine-tuned to the Milankovitch climatic model assuming corresponding response lags. The curves differ mainly in (1) out-of-phase relationships about 225000 YBP, and (2) relative glacial amplitudes of the last 125000 years, suggesting either heterogeneities in the global record or difficulties with dating procedures and sample mixing. Note the tendency for near in-phase oscillations with the obliquity 2/1 (about 20000-year) resonance.

Figure 29 shows the latitudinal insolation curves that progressively change from the dominant obliquity cycle at the poles to the dominant precessional cycle at the Equator. Since the isolation curves are based on summer half-years, precessional trends north of the Equator are 180 degrees out of phase with those south of the Equator. Six selected high-resolution terrestrial-climate time series are referenced as to type and source and in the figure are positioned according to latitude. These dated records seem to parallel the local latitudinal insolation trends more closely than the records at other latitudes, suggesting direct latitudinal insolation control of climate. Particularly significant is the apparent 180-degree phase reversal across the Equator, as represented by the Afar and Egyptian/Nubian records to the north and the East Africa records immediately south of the Equator, just those relations expected from local Precessional-insolation control. The Antarctic (Vostock) ice-core record of temperature and CO_2 strikingly parallels Obliquity/Precessional cycle trends in the South 60°-90° Latitude belt, the precessional elements of which are also 180 degrees out of phase with those in the Northern Hemisphere and with the associated K/Ar-dated North American glacial record of Richmond (1976). TheNorth 37°Latitude Devils Hole isotope/ temperature record of Winograd *et al* (1992) also parallels Richmond's glacial chronology (glaciations 6-8) and the corresponding insolation

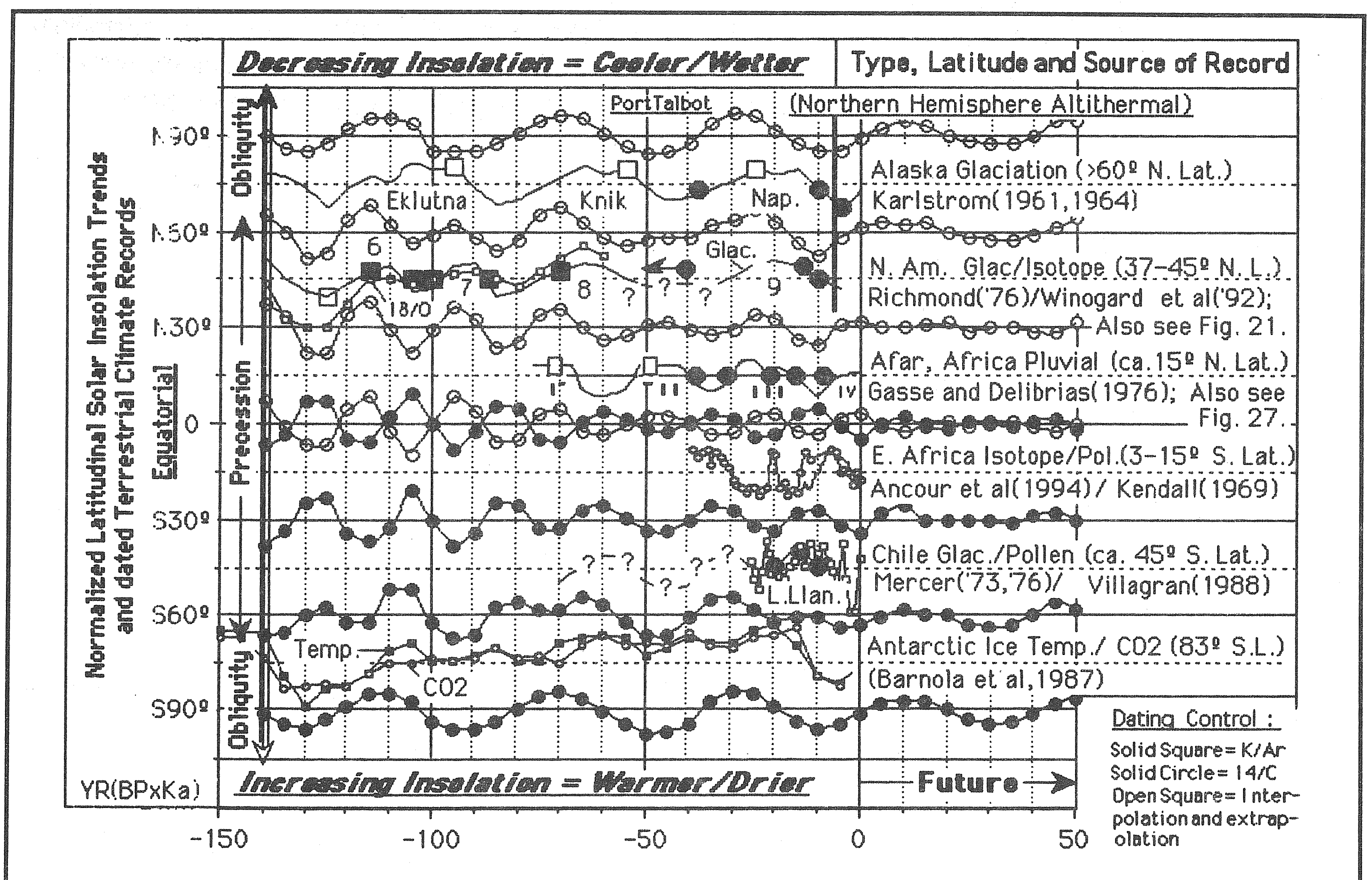

Figure 29. LATITUDINAL INSOLATION CONTROL OF TERRESTRIAL CLIMATIC RECORDS

These dated records seemingly 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 inter-hemispheric climatic synchrony must be reassessed as a basis for Ice Age correlations and resulting global paleoclimatic reconstructions (Karlstrom 1961). See also Crowley and Kim (1994).

trends in the North 30°-60° Latitude belt. Cause-and-effect relationships are apparently satisfied by a consistent response lag (0-5000 years) between the modulating latitudinal insolation trends and the independently dated climate changes. Precessional elements of the Milankovitch model are also invoked by Crowley and Kim (1994) to accommodate the recent coral dating of about 130,000 years ago for a major high-sea-level stand and for the contemporaneous high-temperature interval in the Devils Hole isotope record. Additional long, high-resolution terrestrial records (particularly in the upper north latitudes and the middle south latitudes) are required for more critical testing of the Obliquity/Precessional insolation model and for direct assessment of the latitudinal representativeness of the selected time series.

Natural Fluctuations of Atmospheric Greenhouse Gases

The striking correlation in the Antarctic ice-core record between isotope temperature and CO2 contributes to the current greenhouse gas controversy by providing direct evidence of large, natural, temperature-related fluctuations in atmospheric CO2. Coupled with recent evidence of declining greenhouse gas components in the atmosphere following culmination of a drought (warmer/drier) interval about 1990, as predicted by the resonance model (Figures 1-10; Karlstrom 1976a), this strongly suggests that current climate modeling requires modification to accommodate higher as well as lower frequency, natural (nonanthropogenic) climate fluctuations in future projections of atmospheric greenhouse gases.

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