

# DROUGHT CYCLES IN ANASAZI LAND -- SUN, MOON, AND OCEAN OSCILLATIONS

presented at the PACLIM Conference, Asilomar, April 2009

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**The Southwest holds many mysteries in its ancient buildings, erected a thousand years ago, and long abandoned. Where did the ancient ones (“Anasazi”) go at the time? Why did they leave? Why did they never come back?**

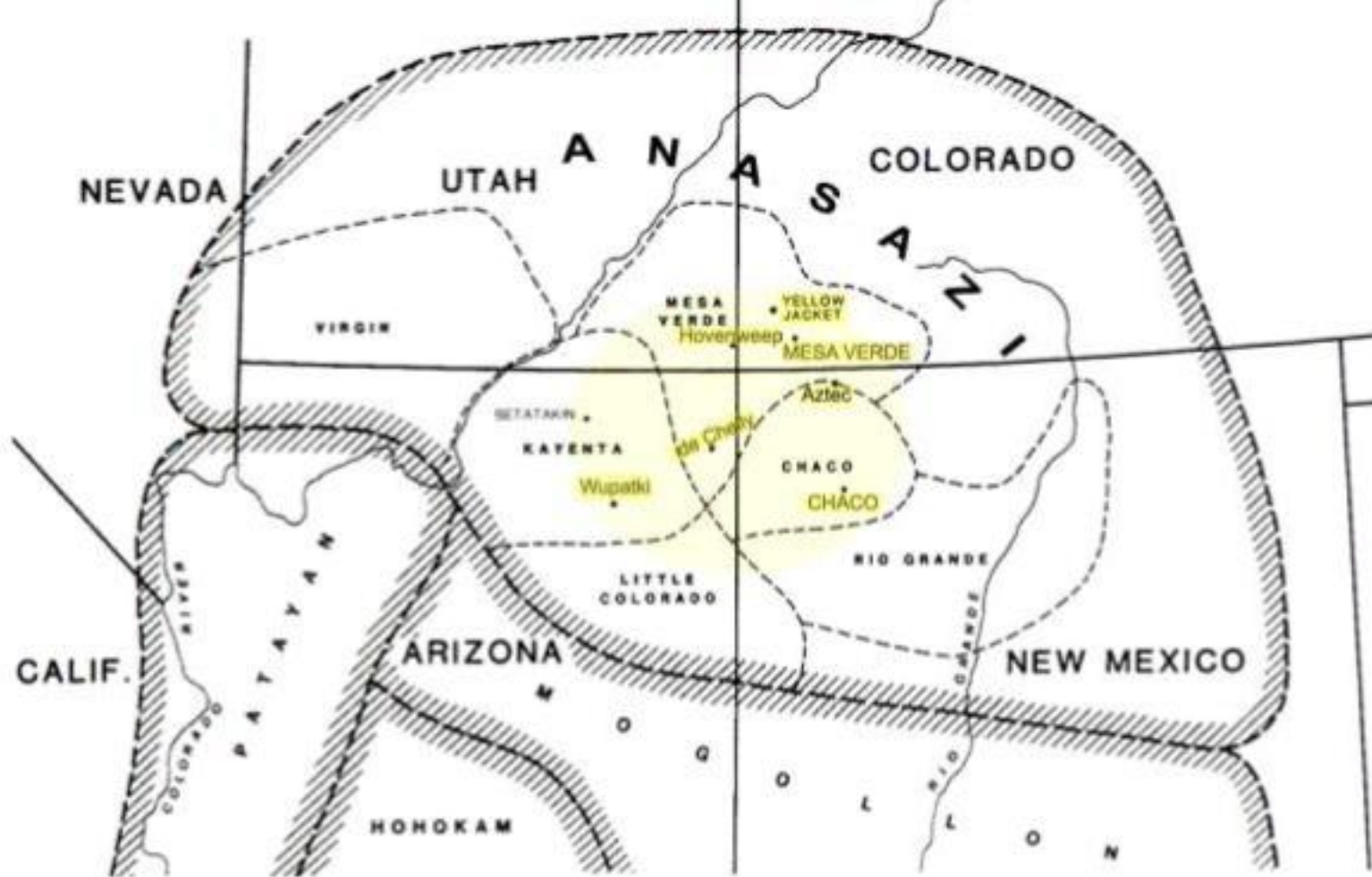


Fig. 8. Map of the Southwest, with major prehistoric culture area divisions. (Adapted from Ambler, *The Anasazi and Willey, Introduction to American Archaeology*, Vol. 1)

Lange et al. 1986

Famous sites includes the well-known tourist goals Mesa Verde, Aztec, Chaco Canyon, Wupatki and Canyon de Chelly -- all now protected parks.



**We know that drought history has greatly influenced the history of settlement and agriculture in the Southwest**

**(Chaco Canyon, Mesa Verde, Canyon de Chelly, etc.)**

**Abundance of ceremonial chambers suggests intense occupation with incantation, presumably rain and harvest magic**



The drought history of the Midwest and the West has much in common, on long time scales. Severe drought periods were common and widespread from the 8th to the 13th century. Note the spacing: 750, 950, 1150, 1280.

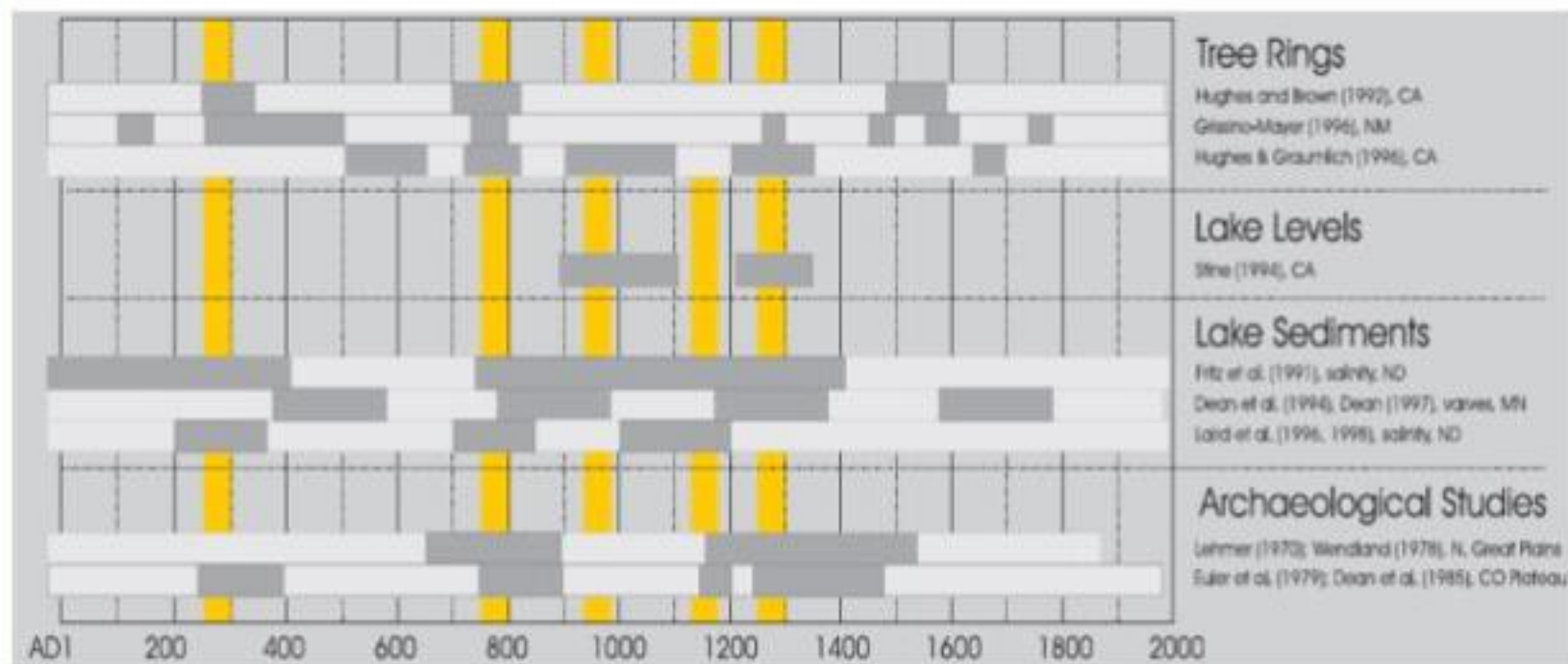
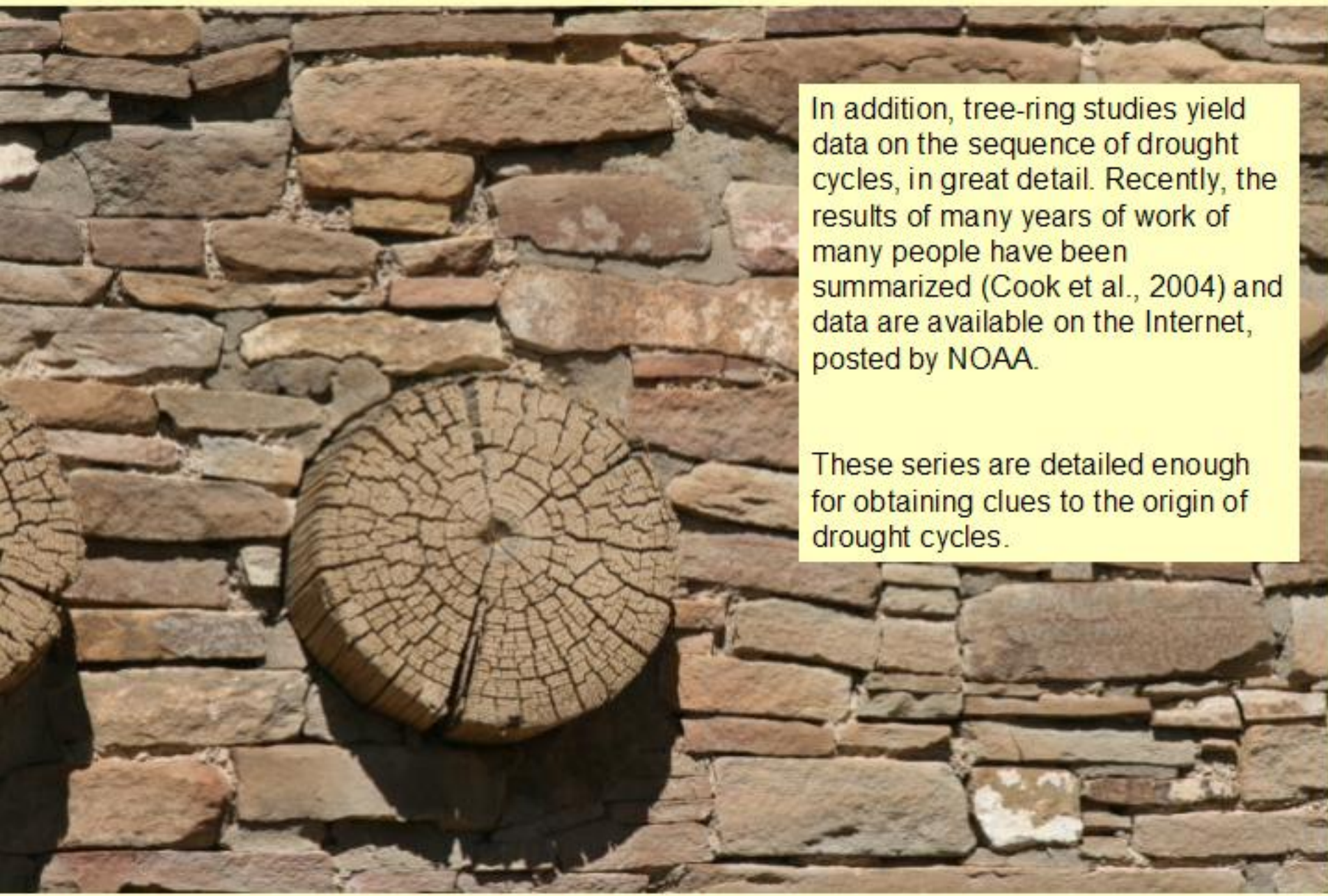


FIG. 10. Paleoclimatic records of Great Plains and western U.S. century-scale drought, A.D. 1–present, as recorded in a variety of paleoclimatic data. The pale gray horizontal bars reflect the length of the series, and the dark gray indicate periods of drought. Orange vertical bars represent multidecadal droughts that appear to have been widespread.

**Fotunately, the ruins have the information necessary to determine the time of building of these structures**



In addition, tree-ring studies yield data on the sequence of drought cycles, in great detail. Recently, the results of many years of work of many people have been summarized (Cook et al., 2004) and data are available on the Internet, posted by NOAA.

These series are detailed enough for obtaining clues to the origin of drought cycles.

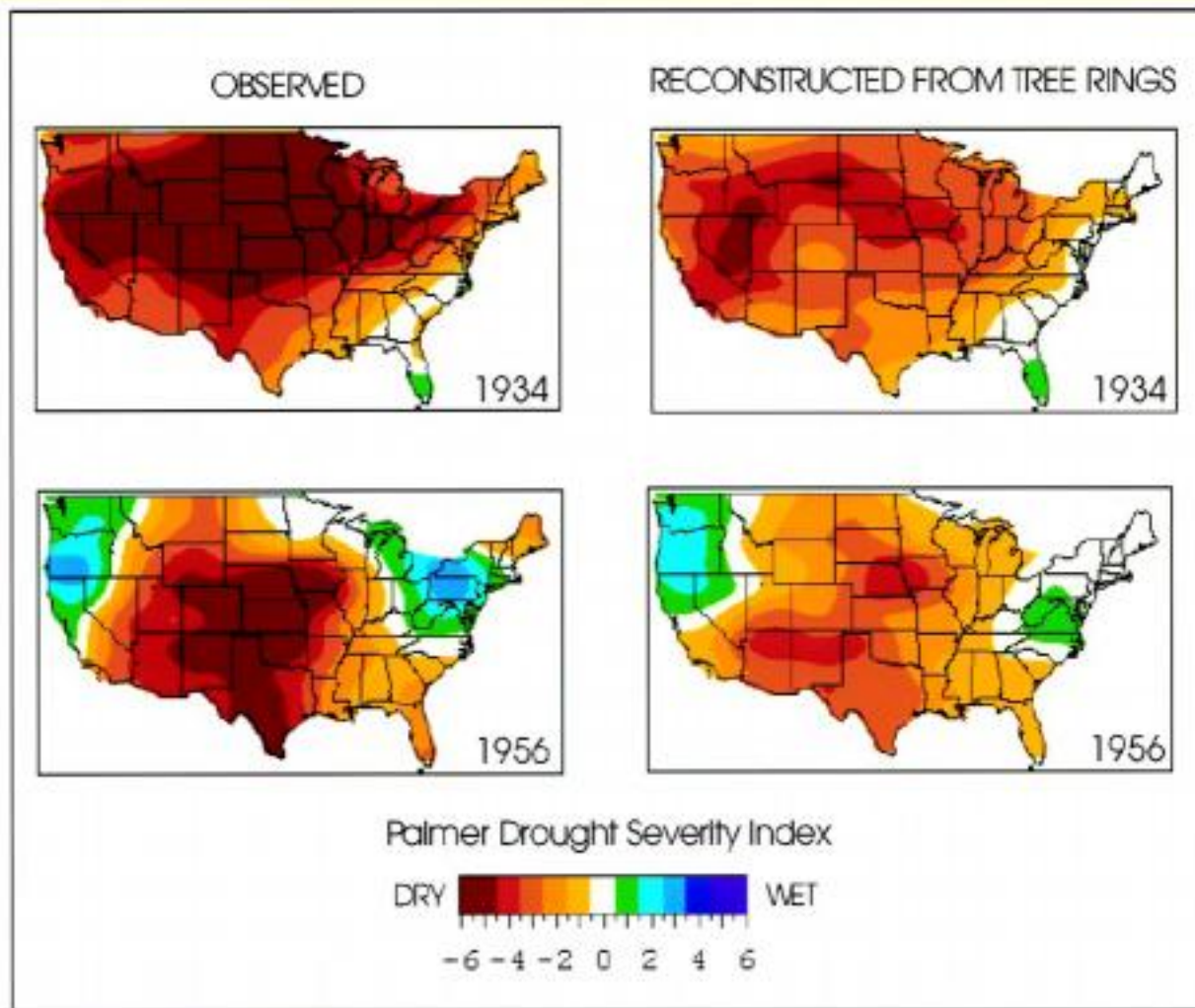
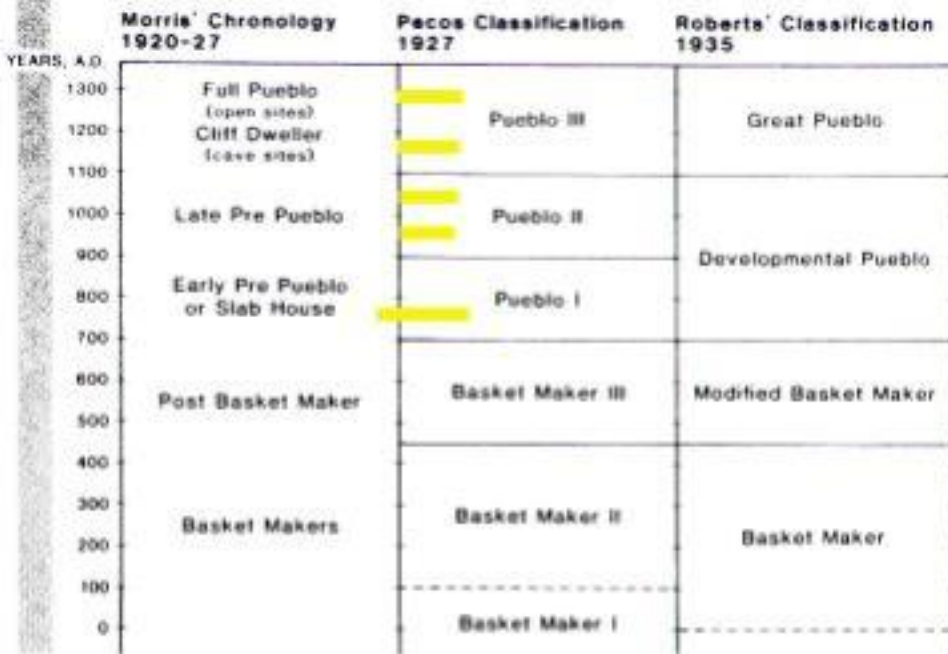


FIG. 5. Comparison of observed and tree-ring reconstructed PDSI values for two of the most extreme drought years in the twentieth century, 1934 and 1956. Although the severity of these droughts is not fully captured by the tree-ring reconstructions, the reconstructions duplicate the spatial extent and duration (see Fig. 6) of these droughts. Images are from the NOAA/NESDIS Web site (see text) (Karl et al. 1990; Guttman 1991; Cook et al. 1996).  
 Woodhouse and Overpeck 1998

**The evidence that tree-ring patterns yield drought patterns is excellent.**

# SAN JUAN DRAINAGE CHRONOLOGIES



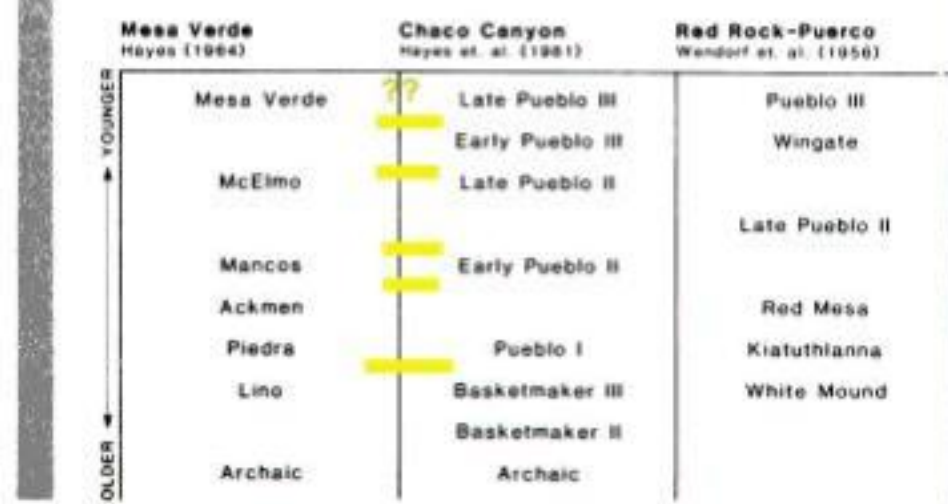
It is possible, indeed likely, that major drought events resulted in the cultural hiatuses and changes that are used to classify the progression of the making of tools, baskets and pots, and the changes in building styles that go along with that.

These are questions where climate science and archeology can meet and generate new insights.

Yellow bars: approximate chronological position of major drought periods.

Original drawing: see Lange and Leonard, 1985.

# SELECTED ANASAZI PHASE SEQUENCES



Earlier and more recent Southwestern chronology.

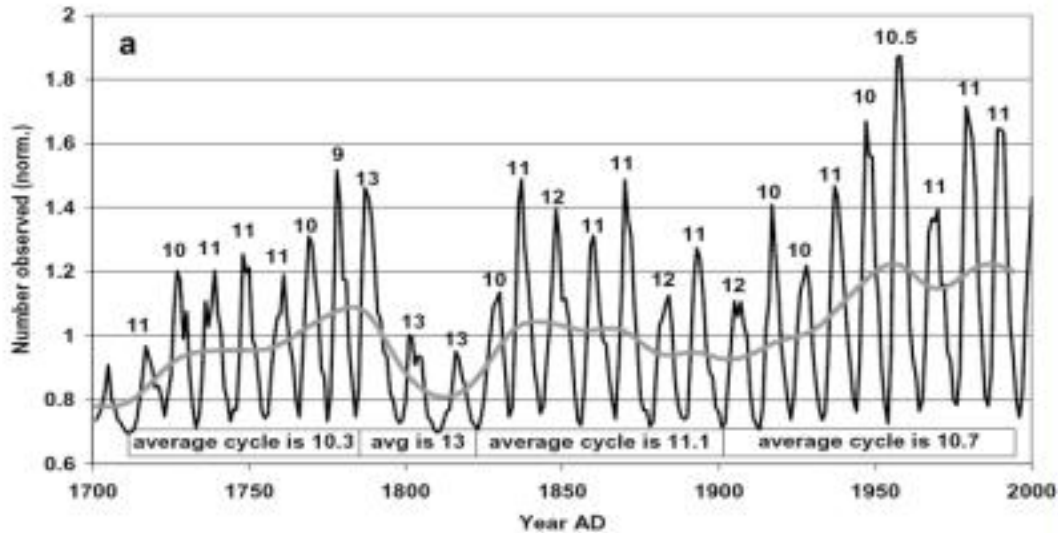
**The study of the abandoned ruins and cliff houses of the Southwest brought forth a new science: the reconstruction of climate change from tree-ring sequences.**



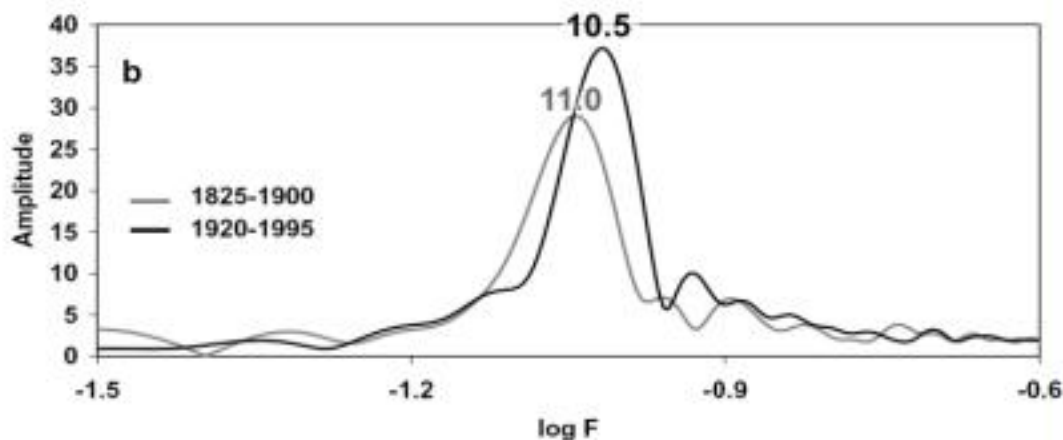
**A.E. Douglass,  
tree-ring pioneer**

**To get an idea about what drought history looked like in the West, through the last several centuries, we can turn to the tree-ring record.**

**The thickness of rings largely reflects rainfall.**

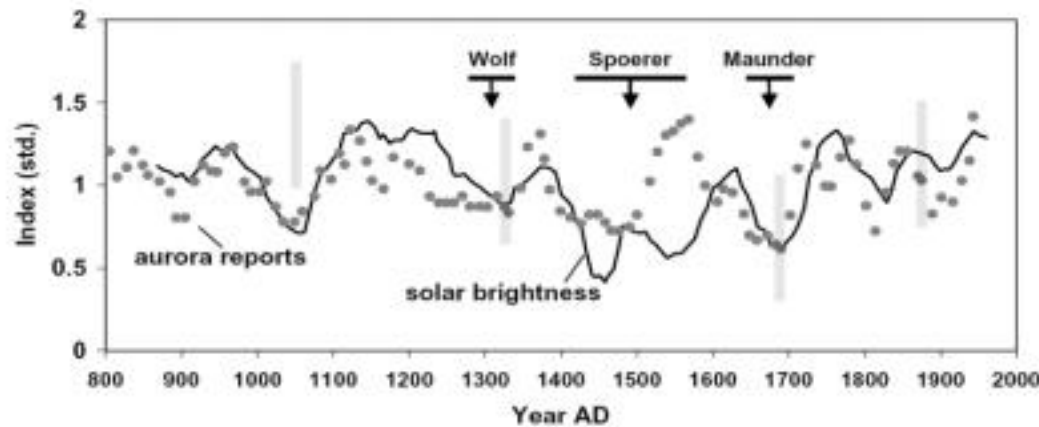


Data available from Royal Observatory, Belgium. Graph see Berger, 2008.

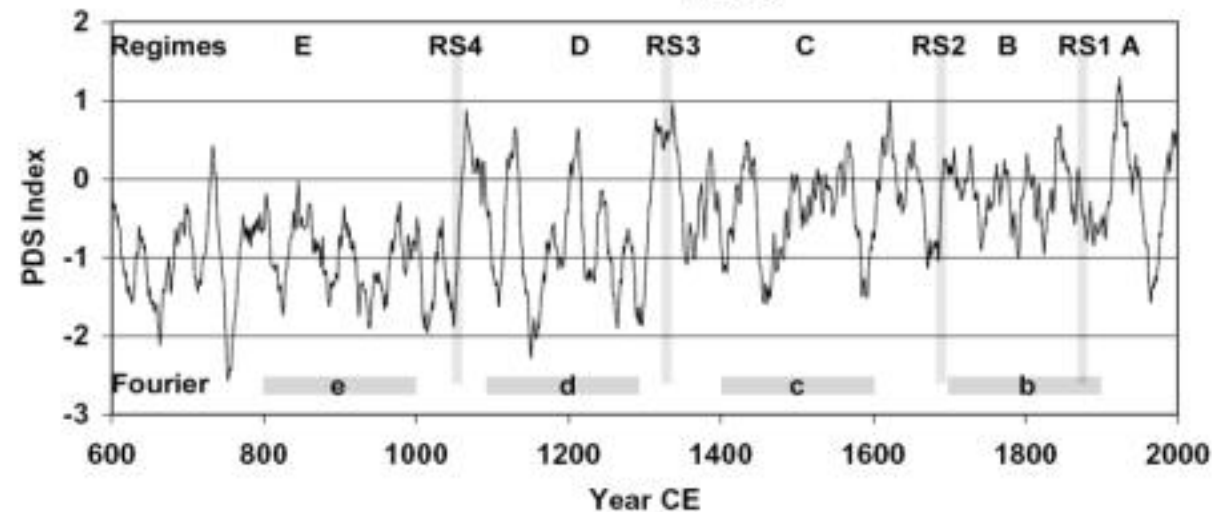


**Solar cycles change their period and amplitude through time (a). The 20th century had shorter and more energetic cycles than the 19th (b).**

**The sun is an obvious candidate for the forcing of the type of climate change represented by drought cycles. However, there are two problems: (1) Detailed information (sunspot cycles) are available only for the last 300 years, and (2) any match of reconstructed solar brightness with drought cycles is decidedly unimpressive.**

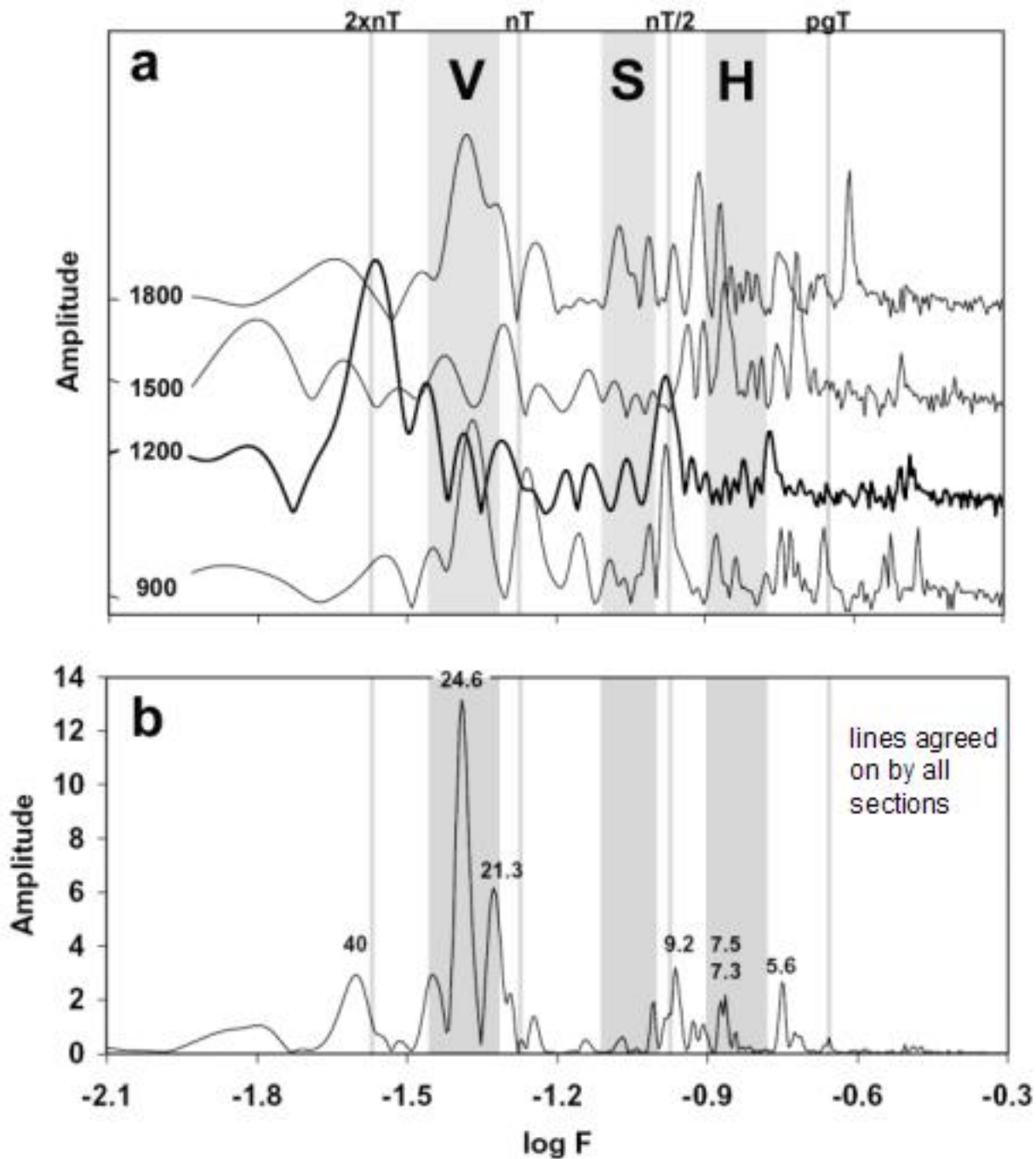


Solar activity based on cosmogenic nuclide production (Bard et al., 2000, 2003) and aurora reports (Schove, 1964).



PDS Index based on tree-ring data (Cook et al., 2004). RS1, RS2, etc.: regime shifts. A, B, etc.: climate regimes. Fourier sections: see next graph.

**Reconstruction of solar intensity is based on a number of proxies, such as radiocarbon and beryllium-10 abundance in ice cores, and aurora observations (upper graph). The labels “Wolf,” “Spoerer,” and “Maunder” refer to periods of minima in solar activity. There is some indication that climate regime shifts (RS4, RS3, RS2) coincide with solar activity minima. Other than that there is no indication of a match of (presumed) solar intensity history with drought cycles (as shown in lower graph).**



What needs explaining: power concentrated in V-band (twenties) and in H-band (sevens), but non-stationary, with occasional long cycles (here: 36) and lines at 9.2 and 5.6. (Clearly, these are not random patterns: note the background.)

Compare: twice the nodal tide is 37.2, one half the nodal tide is 9.3, and the interference between nodal and perigee tide is 5.8.

*The section centered on 1200 ("D" in previous graph) is totally dominated by tidal power!*

The section centered on 1800 ("B" in previous graph) has some power within the solar band (marked "S").

**Both solar and tidal lines have been reported as being present in tree-ring series, in western North America, *and they have been linked to drought:***

Currie, R. G., 1984. Periodic (18.6-year) and cyclic (11-year) induced drought and flood in western North America. *J. Geophys. Res.*, 89, 7215-7230.

Currie, R.G., 1984. Evidence for 18.6-year lunar nodal drought in western North America during the past millennium. *J. Geophys. Res.*, 89, 1295-1308.

Of these, solar cycles have become perfectly acceptable as topics of discussion when investigating the causes of climate change. In contrast, the discussion of tidal influence on climate (*even in the ocean!*) still raises eyebrows among the professionals. Such are the forces of convention.

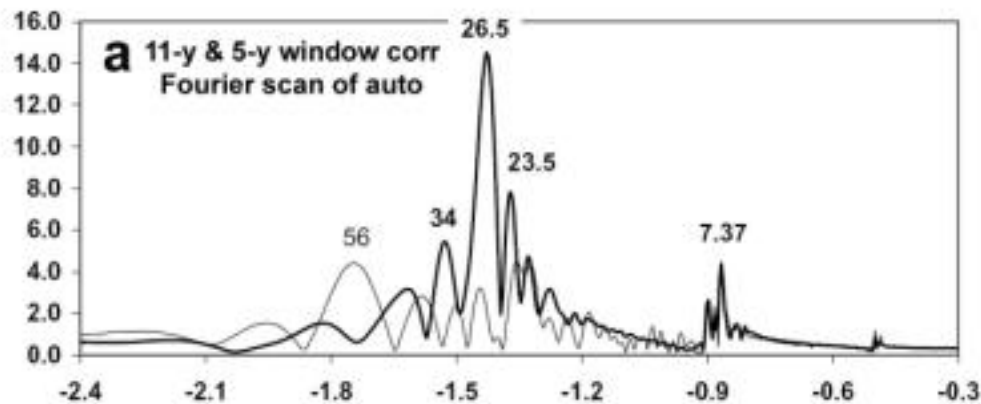
**Basically, attempts to match solar cycles (real and presumed) to drought cycles (as seen in tree rings) have not been successful, and statements linking the two types of cycles have been vague and of a general nature.**

**Hypothesis:**

**It is the interaction between solar and tidal forcing that matters.**

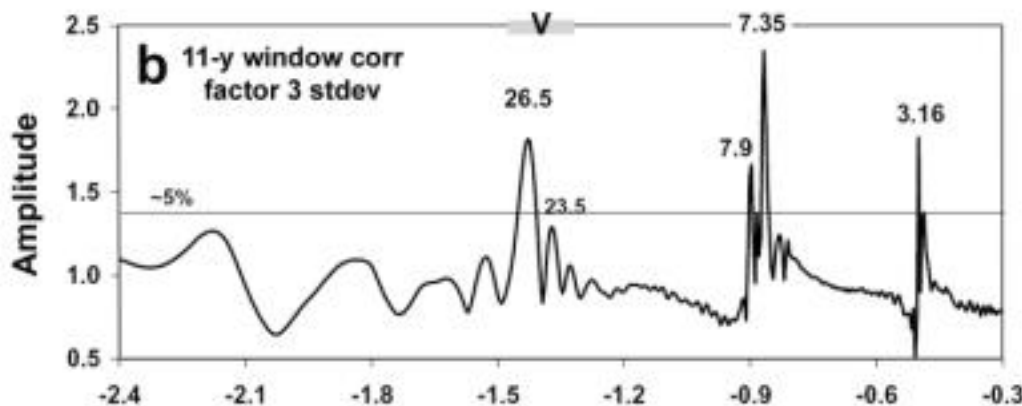
**This means that phase of both solar cycles and lunar cycles becomes very important, and this is the reason that cycles come and go. The forcing paces oscillations that pertain to ocean-atmosphere interaction in specific geographic settings (Berger, 2008).**

**What emerges are fluctuations reflecting the combination of oscillations (“stochastic”) with solunar interference patterns (quasi-deterministic).**

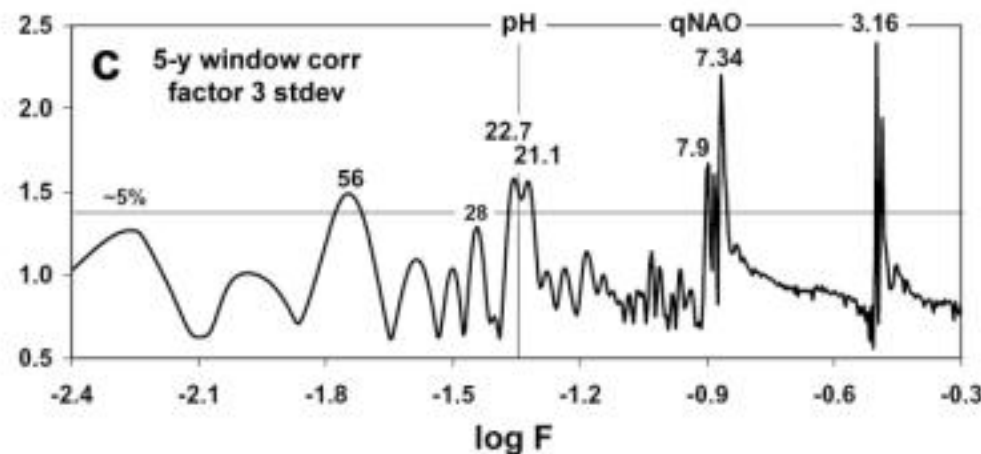


We can produce, artificially, the types of spectra expected for an interaction between solar activity and tides.

Windowed correlation of solar cycles and tidal cycles (last 300 years, windows of 5 or 11 years) yields series that contain the relevant cycles in the twenties (V-band) and sevens (H-band).



These artificially created series also provide for the commonly observed gaps in the spectrum (solar periods, tidal lines). The original input literally disappears, and only the interactive output remains.



The physical background would be that solar cycles and tidal cycles have the option to either re-enforce each other (positive correlation) or cancel each other (negative correlation). Apparently, that is what they do.

pH, pseudo-Hale; qNAO, quasi-NAO

The 5% confidence lines are based on comparing peaks with background, over a factor-of-3 window within the spectrum.

	tidal cycles		
	perigee 4.424	nodal 18.613	mixed 5.803
10.0	7.93	21.6	13.8
10.1	7.87	22.1	13.6
10.2	7.81	22.6	13.5
10.3	7.75	23.1	13.3 <small>prv</small>
10.4	7.70	23.6	13.1 <small>typ</small>
10.5	7.65	24.1	13.0
10.6	7.59	24.6	12.8
10.7	7.54	25.2	12.7 <small>mod</small>
10.8	7.49	25.7	12.5
10.9	7.45	26.3	12.4
11.0	7.40	26.9	12.3 <small>avg</small>
11.1	7.36	27.5	12.2 <small>aur</small>
11.2	7.31	28.1	12.0
11.3	7.27	28.8	11.9

While the various V- and H-band cycles can emerge from experiment, they can also be calculated as difference tones, from the equation

$$y = a * b / (a - b)$$

where a and b are the forcing cycles, and y is the interference cycle. For the common solar periods (as seen in sunspots and auroras), the expected interference cycles are listed in this table.

prv, privileged (interference with perigee is 1/3 of interference with nodal tide)

typ, typical sunspot cycle for the last 300 years

mod, dominant modern sunspot cycle for the 20th century

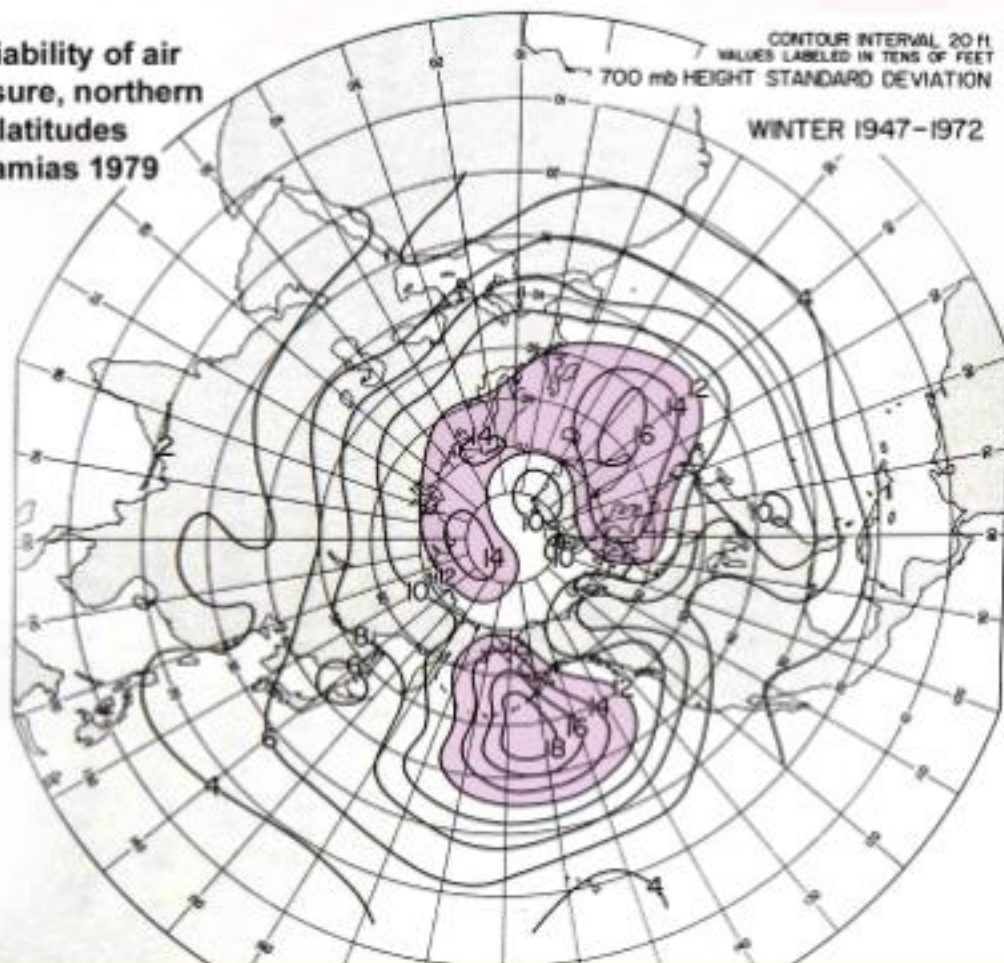
avg aur, average aurora cycle since 500 AD.

**How then do tides get into the trees and into the Palmer Drought Severity Index?**

**Presumably through the great oceanic oscillations that influence wind patterns and hence precipitation patterns in North America.**

**The pioneer in studying these systems was Jerome Namias (1910-1997) who linked air pressure patterns in northern latitudes to precipitation patterns in North America.**

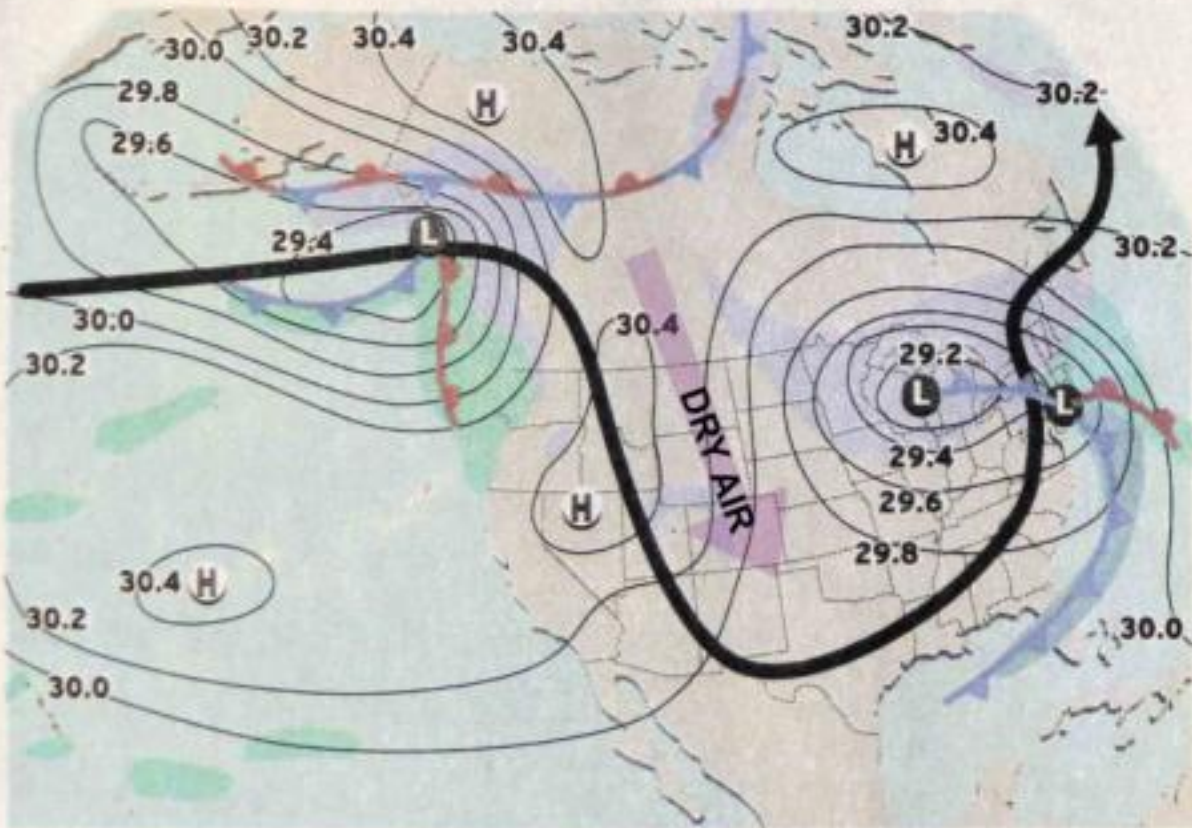
**Variability of air pressure, northern latitudes  
Namias 1979**




**In fact, the geographic sources of variability are not known. They could be in the tropics. Or they could be in high northern latitudes as originally proposed by Namias.**


**In either case, if tidal action is important, we should look to changing SST patterns in shelf seas and ensuing modulation of wind patterns.**

Heavy snow and coastal rain from the big storm will lift northward across New England today. Expect windswept snow showers to linger in the Midwest. Rain is on tap for the coastal Northwest.




**H** High: Center of fair weather air mass

 Cold front: Cooler air advancing in direction of barbs


 Stationary front: Where cold and warm fronts mix


**Precipitation**


 Rain

 Snow

**L** Low: Area of low pressure, often stormy

 Warm front: Warmer air advancing in direction of humps

 Jet stream: High-altitude, high-speed winds sculpt fronts

 T-storms

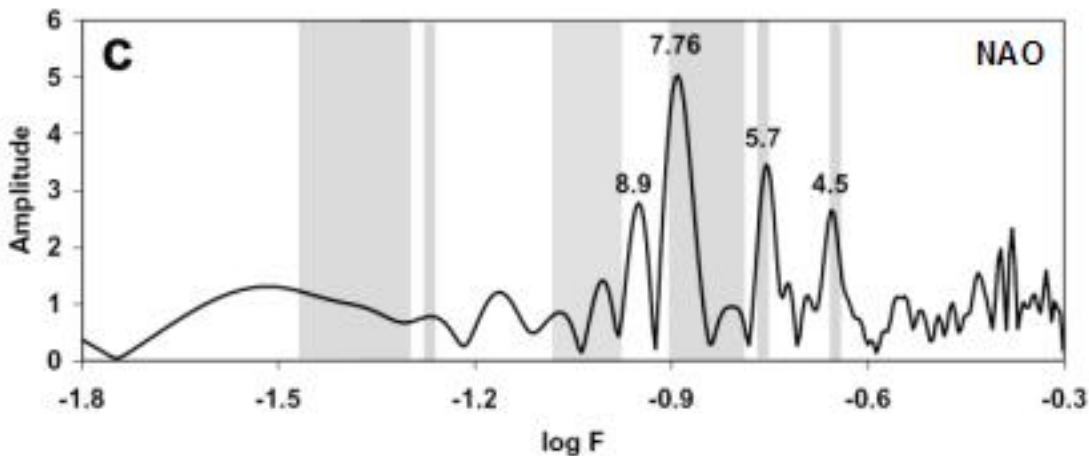
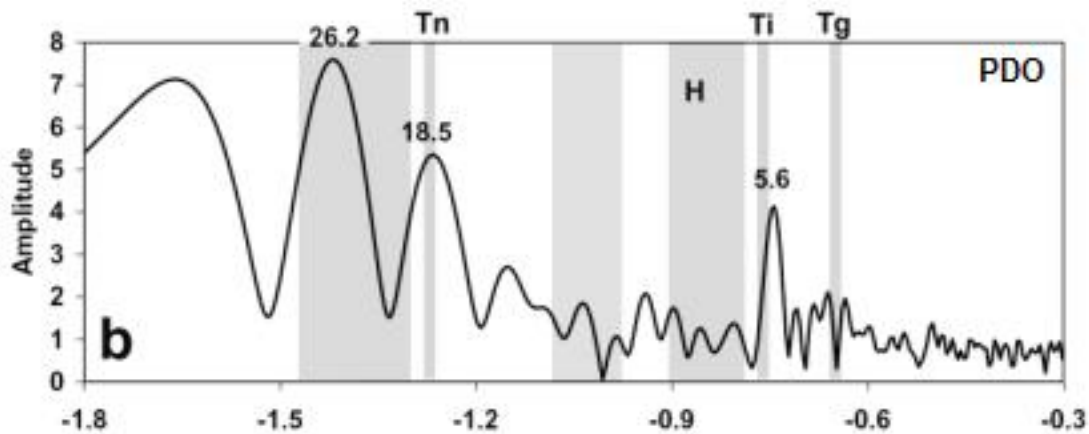
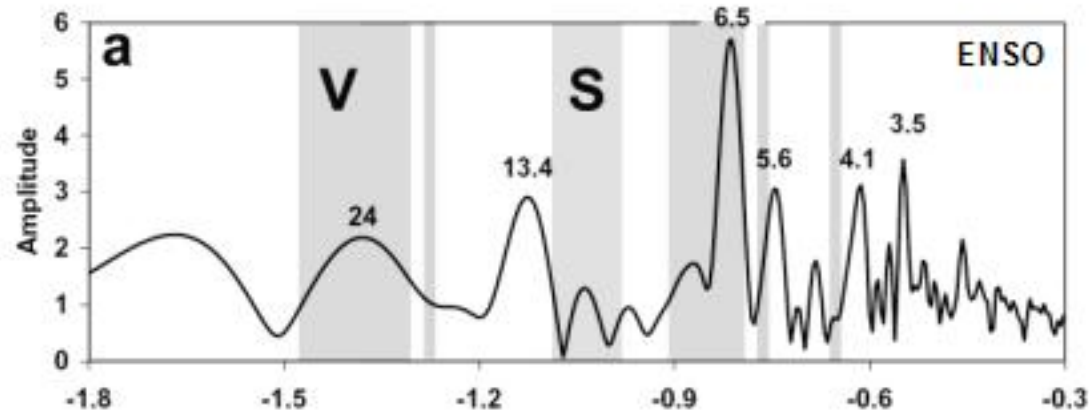
 Ice

**What we do know:**

**Intensity and position of the Aleutian Low and the North East Pacific High impact the path of the jet stream over North America, and hence the patterns of precipitation.**

**(ENSO is important, but clearly not the whole story.)**

For evidence of correlations between ocean oscillations and N. American precipitation, see Cayan et al., 1998; and much subsequent work on the subject (see background list).

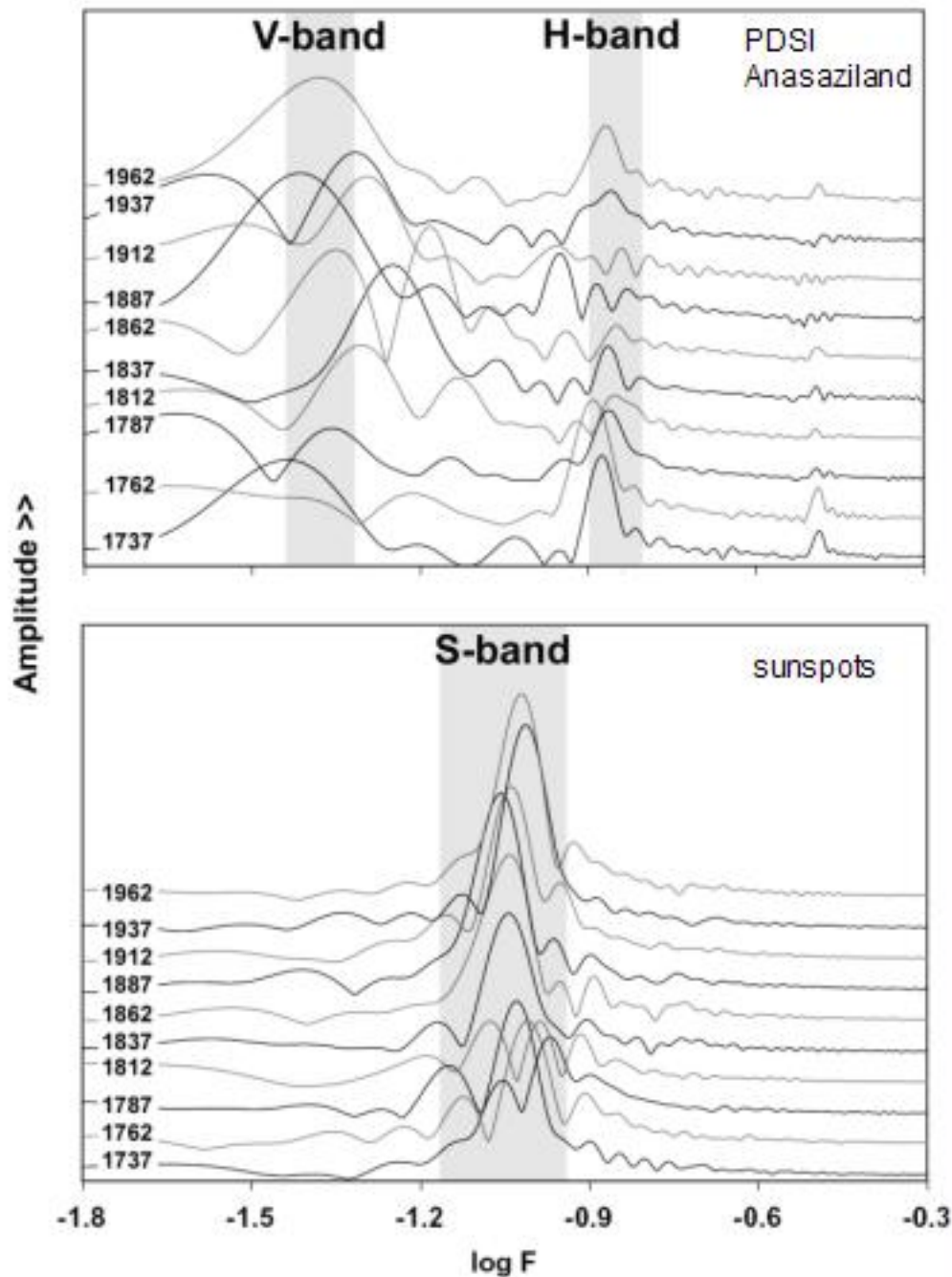


Do the ocean oscillations show the V-band and H-band power in their periodograms that are expected from the solar-tidal interaction hypothesis?

They do!

The ocean oscillations (which drive precip patterns) show the interference lines, and a hint of tidal lines (PDO, NAO) but no power at sunspot periods.

source for series: last 100 years only:  
Australia Met Bureau, Mantua (Washington),  
UK Met Office. b from Berger (2009).

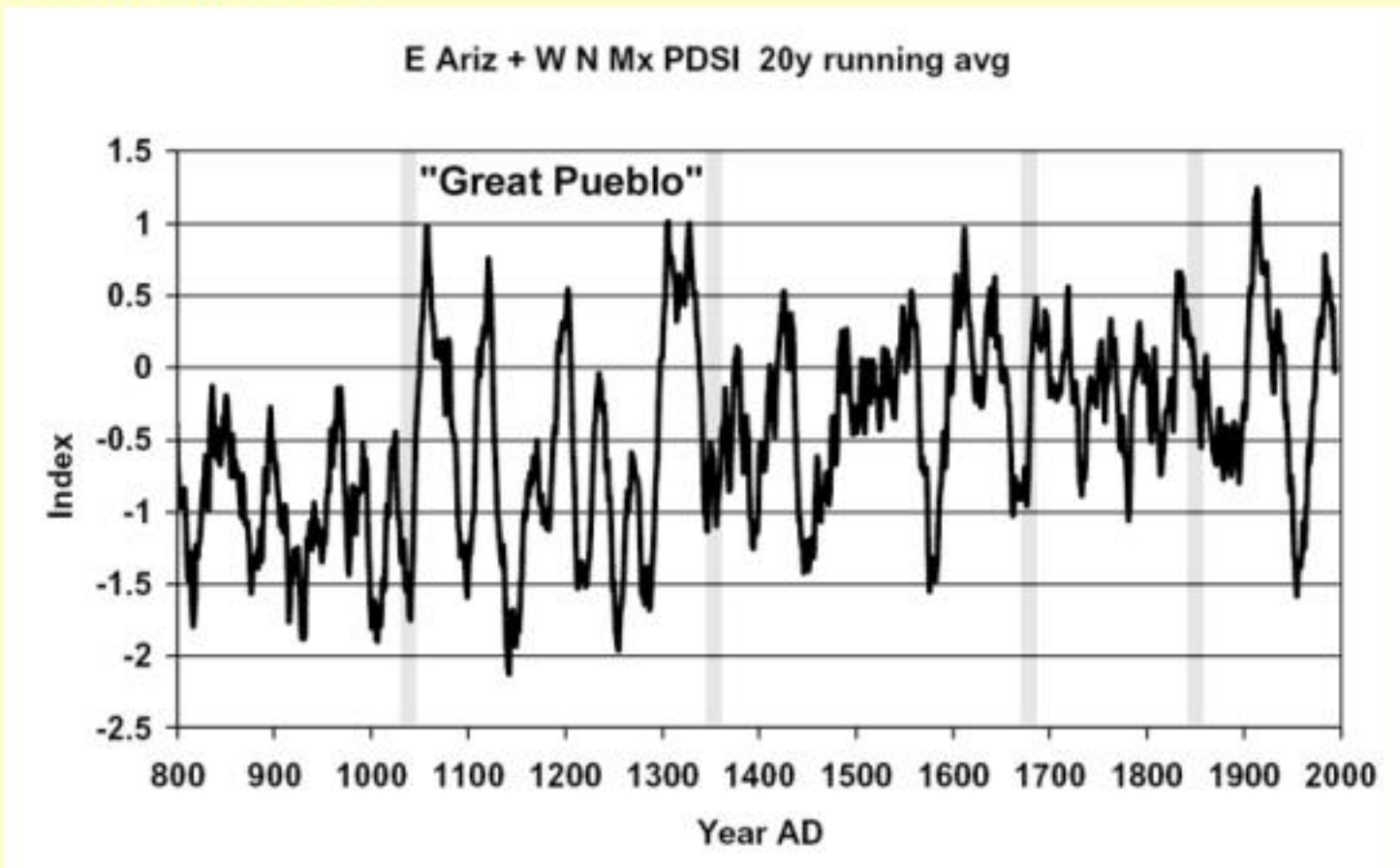


The presence of V-band and H-band power is not only intriguing, but opens up the possibility of reconstructing solar cycles for the past.

The non-stationarity in V- and H-bands must be related to the changing solar cycles, under the hypothesis (since tides don't change periods).

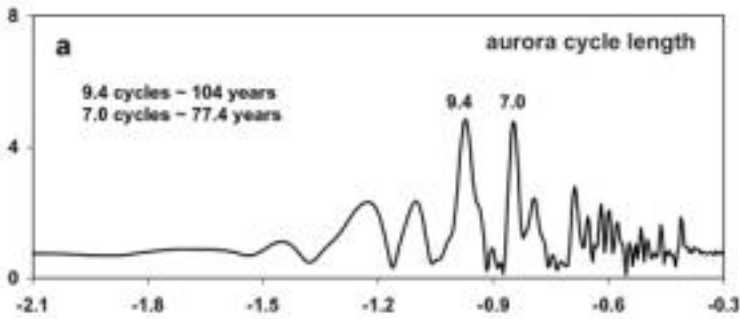
Thus, in principle, it should be possible to do the deconvolution of the output series, to get the non-stationary variable of the input series (that is, the solar cycles).

Assuming that the hypothesis of solar-tidal pacing of ocean oscillations has merit, what is the source of the long periods, and why do they come and go?



**A precise answer is possible:**

**No one knows.**



If the answer is to be found in solar cycles, spectra of solar activity and the drought narrative will have to show similar bands and lines in long waves.

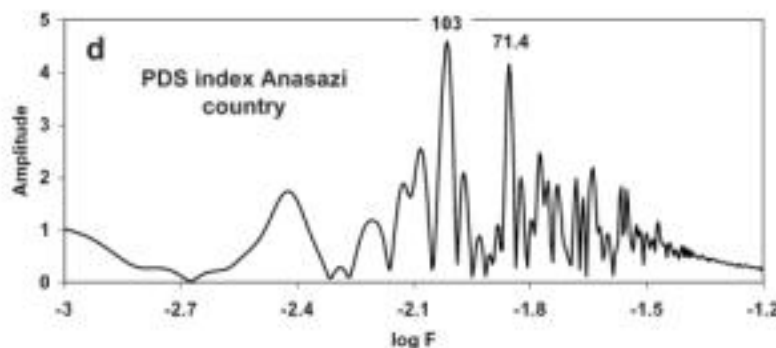
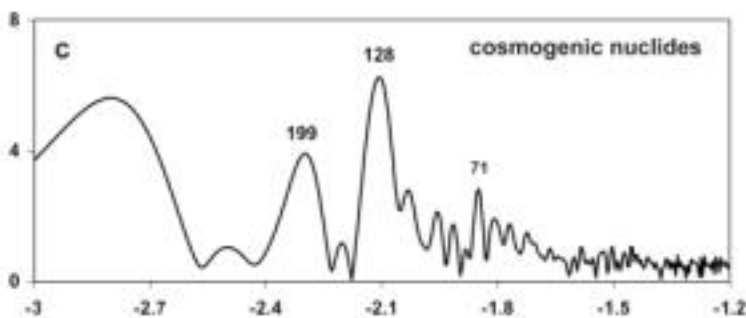
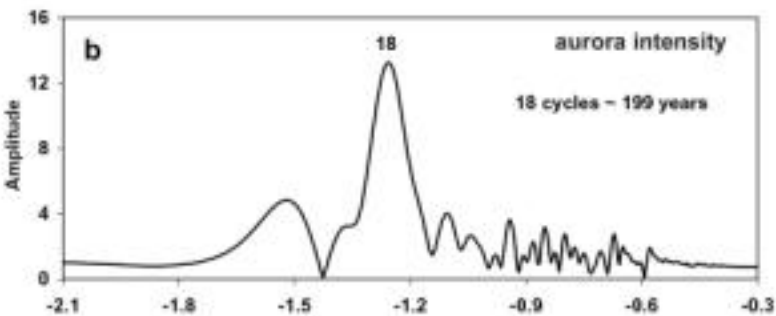
There is some indication that the cycle near 103 years and the one near 71 years is indeed present both in solar activity and in drought cycles, as shown in the graph to the left.

a, variations in the length of aurora cycles (which on average are 11.06 years long). Repeat periods are 104 years and 77.4 years, last 1500 years. Data from Schove, 1964.

b, variations in maxima of aurora events for each cycle. Repeat period is 199 years. Data from Schove, 1964.

c, abundance of cosmogenic nuclides in ice cores. Repeat periods are 128 years and 199 years. Data from Bard et al., 2000, 2003.

d, drought index variations in Anasazi country. Repeat periods are 103 years and 71.4 years. Data in Cook et al., 2004.



... but will it rain? And soon?



**THE END**

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