DRAFT -

Combined Oscillations of Terrestrial Polar Motion, Solar System Dynamics, & the Lunar Nodal Cycle

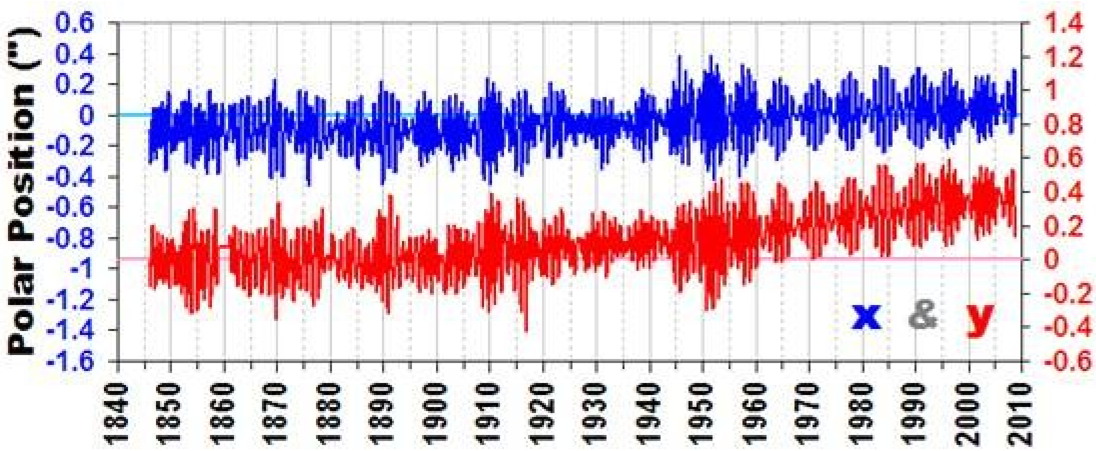
Paul L. Vaughan, 11Oct09

The Schwabe (?9.9 low - 11.1 avg - 14 hi? year) and Hale (?22.2 year?) sunspot cycles are well-related on average to the Jaupiter-Neptune conjuction at half the JN conjunction period.

The phase reversal of the Chandler wobble (0-5 year movements of the Earth's axis – involving small precessional and obliquity shifts) provides a distinctive signal at the time of the Dirty Thirties.

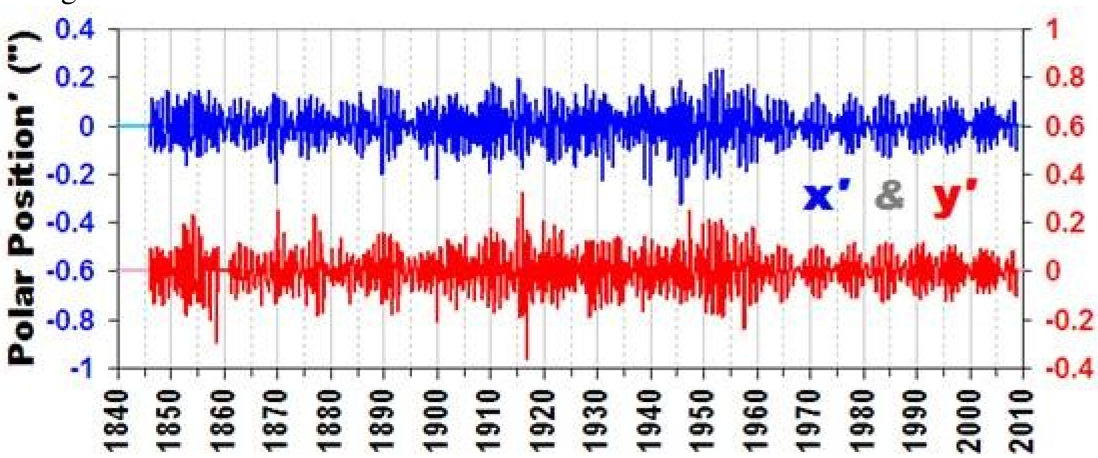
endpage

Terrestrial Polar Motion:

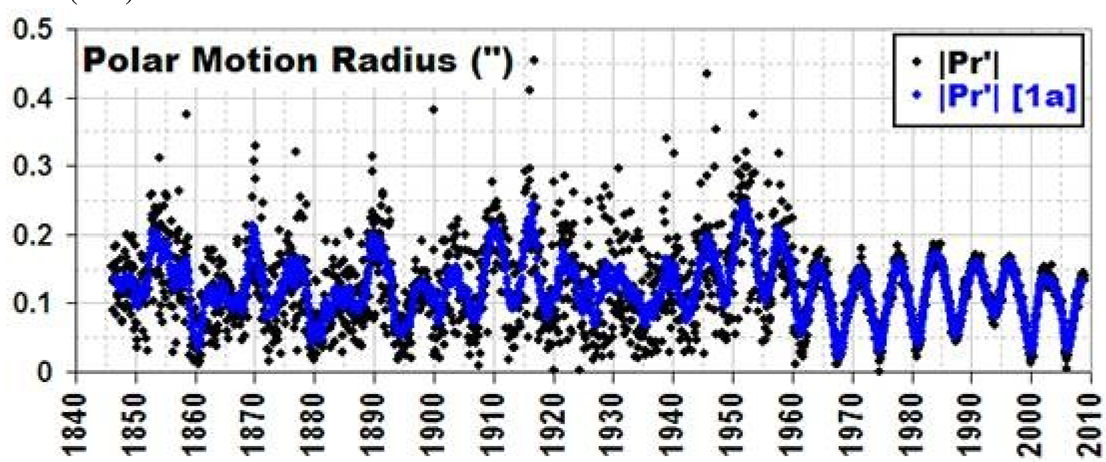


Note that y-direction data are missing for 1859-1861.]

Differencing:

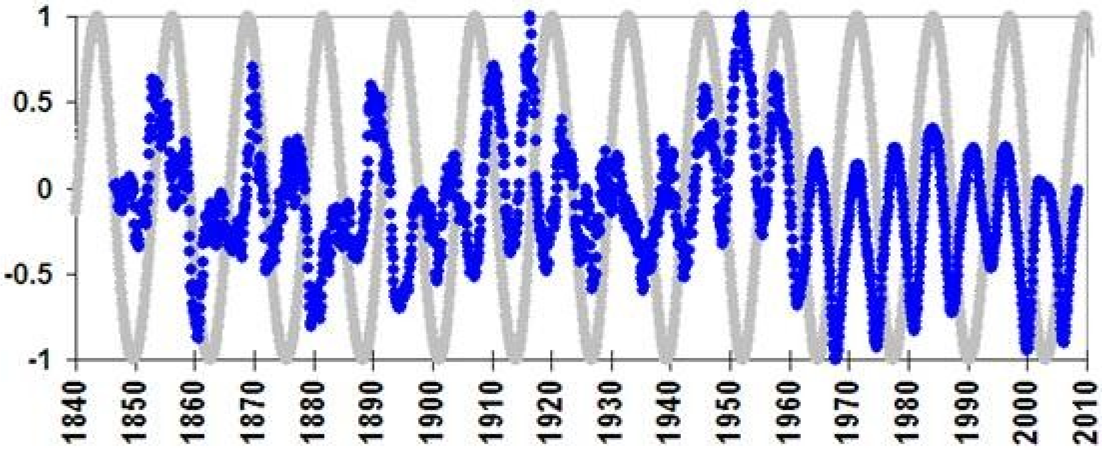


The radius (|Pr'|):

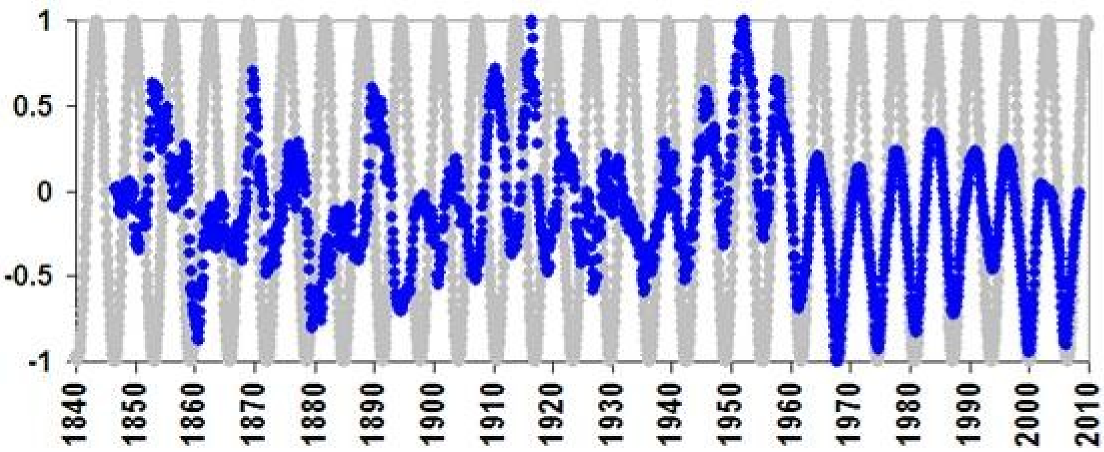


Note: [1a] denotes 1 year smoothing.

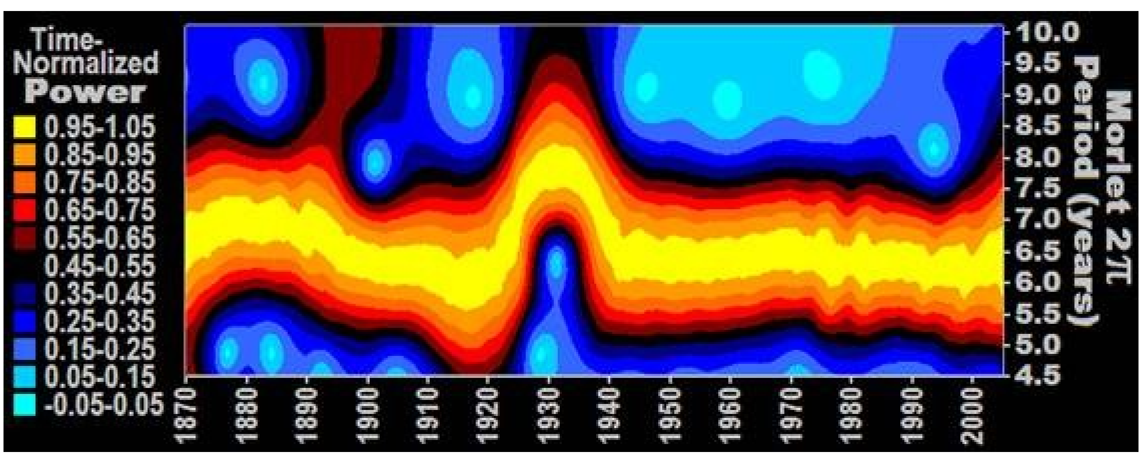
Comparing with Jupiter-Neptune (JN) synods



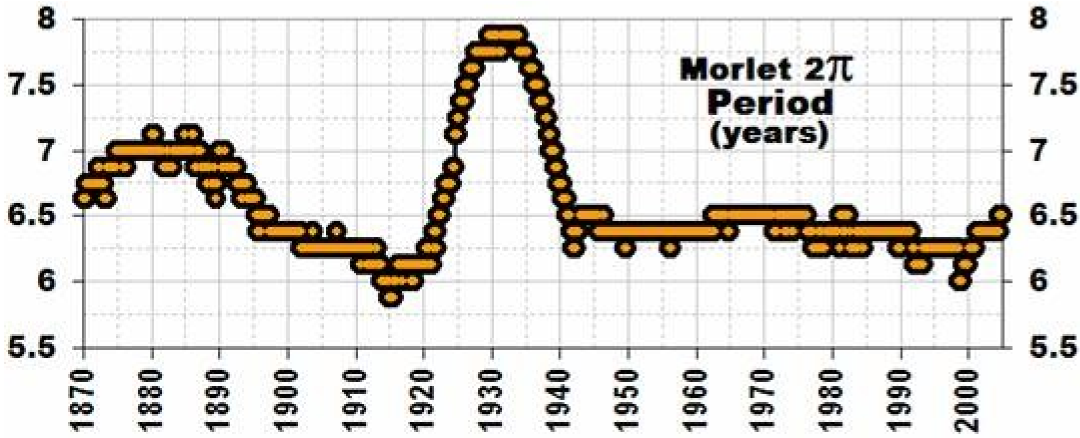
JN conjunctions



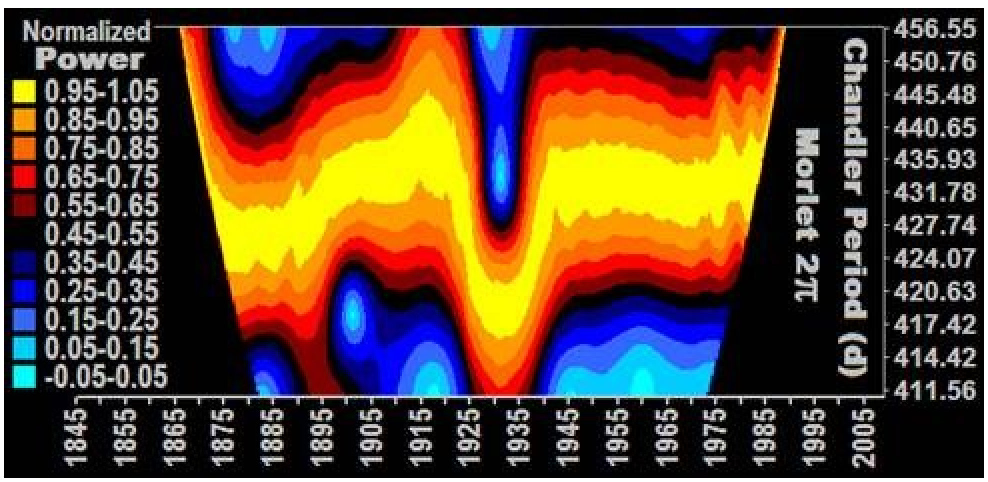
The agreement *after* the Chandler Wobble phase reversal (late 1910s to 1940) is striking. The Chandler Wobble phase reversal is evident in the time-normalized wavelet-transform power of | Pr'|:



The wavelet-estimated period of |Pr'|:



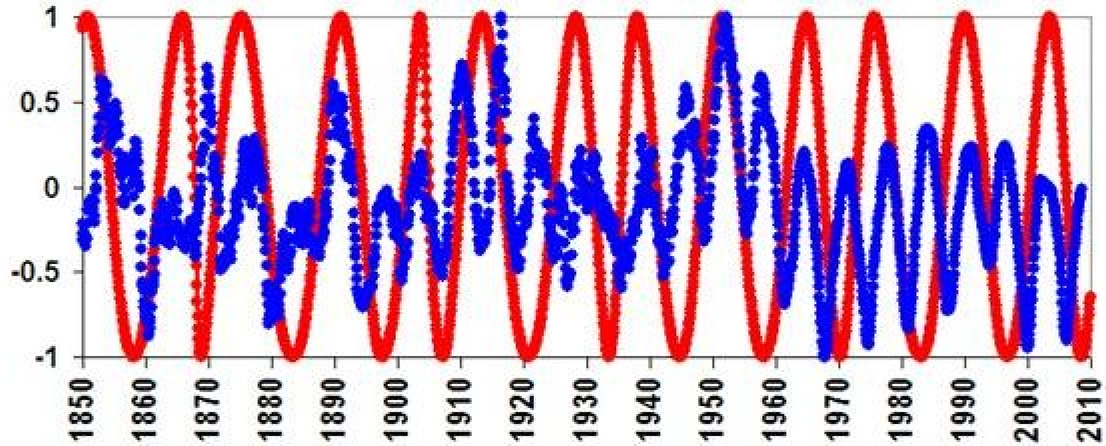
The Helmholtz acoustic equation facilitates conversion from group-wave period to Chandler-wave period:



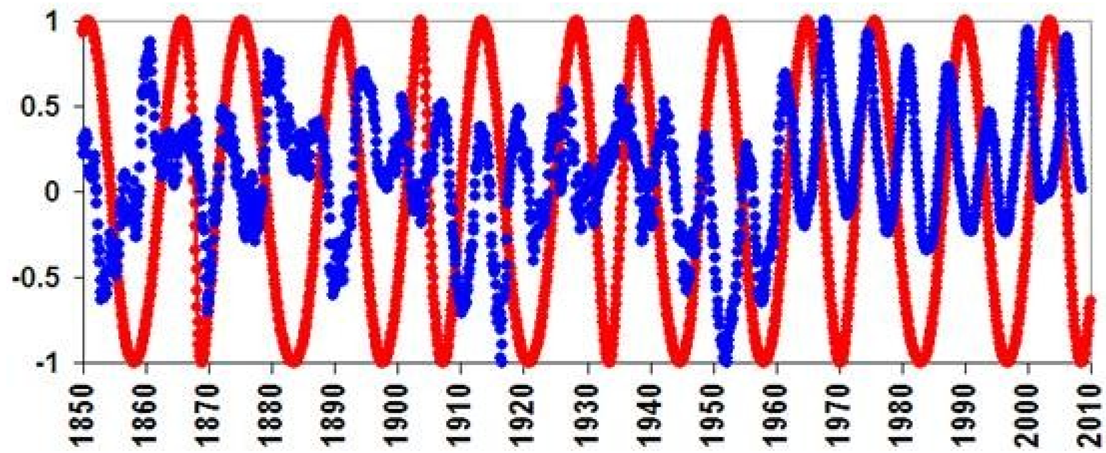
The question that remains:

Can any sense be made of phase-relations *before* the Chandler reversal?

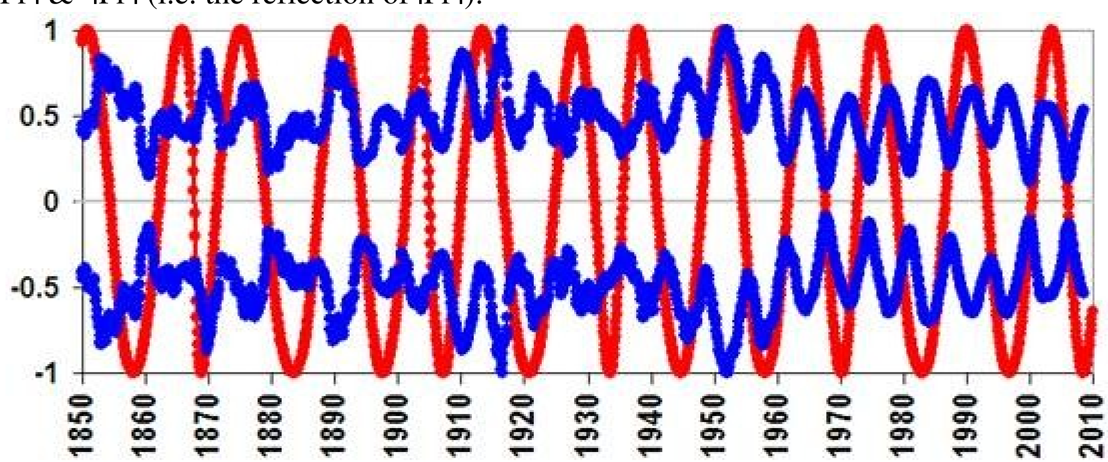
The radial acceleration (**r''**) of the sun relative to the solar system barycentre (centre of mass) is an index of solar system dynamics with a *nonstationary* period that is *equal on average* to the period of JN:



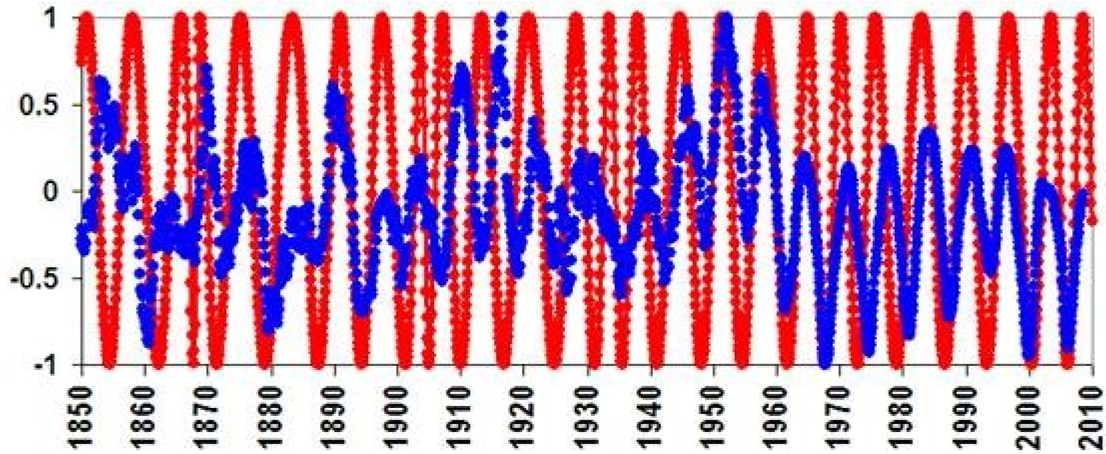
Flipping **|Pr'|**:

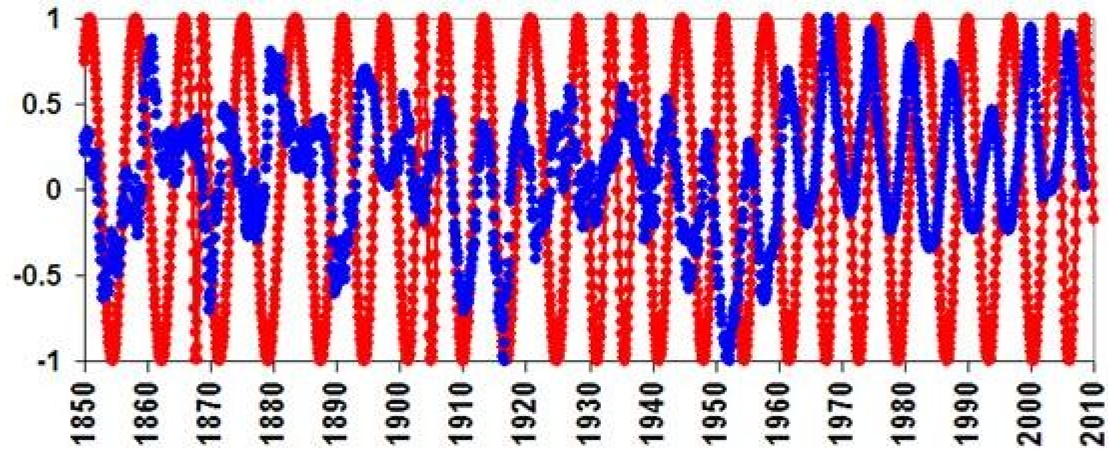


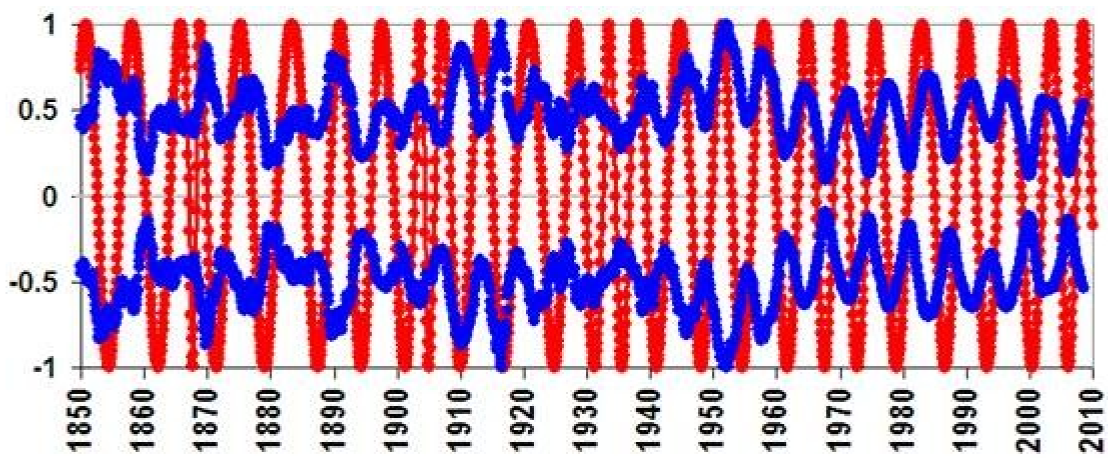
Both |Pr'| & -|Pr'| (i.e. the reflection of |Pr'|):



Introducing the harmonic r''/2 and taking analogous views:

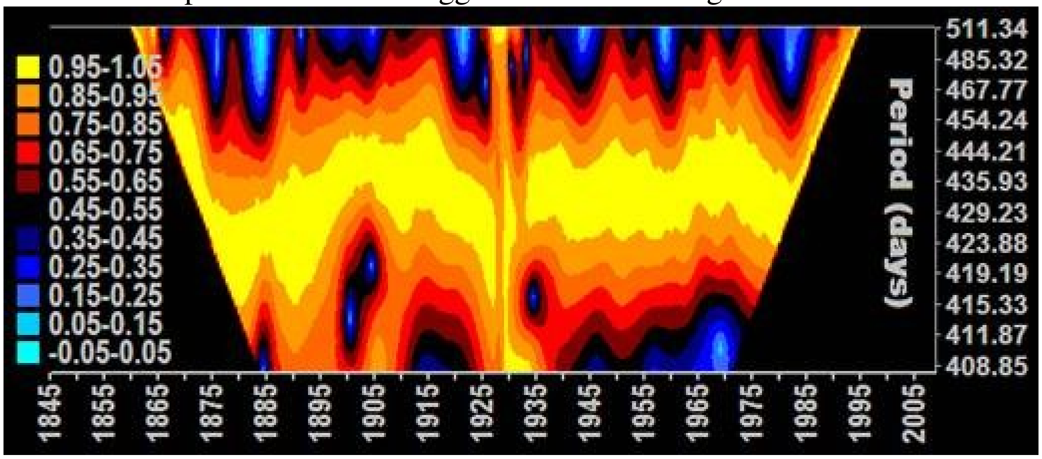




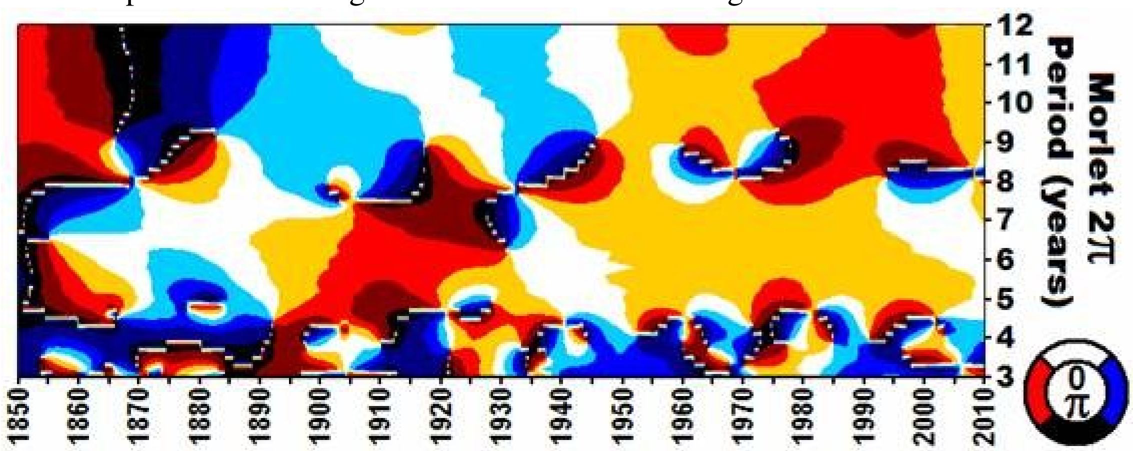


There appears to be loose resonance, with (roughly) a decade including anti-phase episodes during the Chandler Wobble phase reversal. [Reminder: Polar motion y-direction data are missing for 1859-1861.]

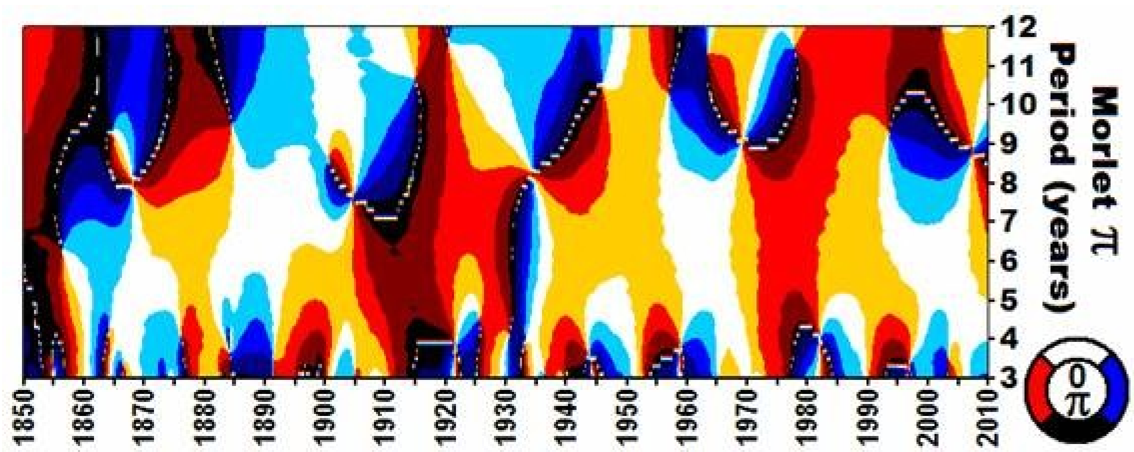
Cross-wavelet relative-power coherence suggests further investigation is warranted:



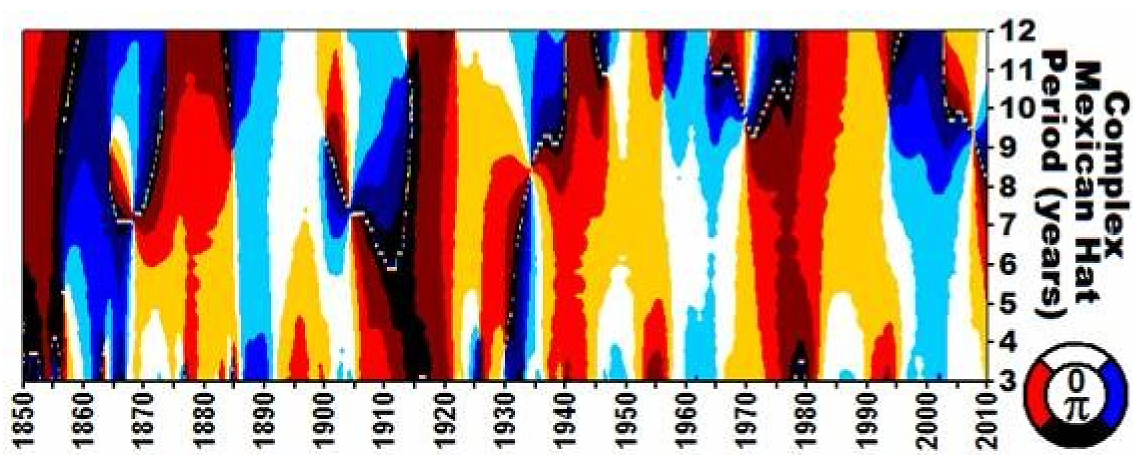
Cross-wavelet phase-differencing can be used to assess the angular fit:



Morlet 2**pi** wavelet (heavy angular smoothing):



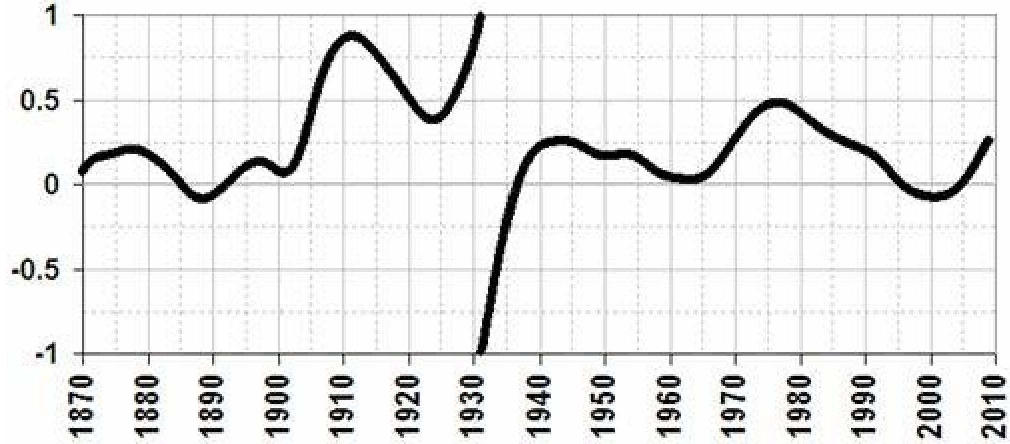
Morlet **pi** wavelet (intermediate angular smoothing):



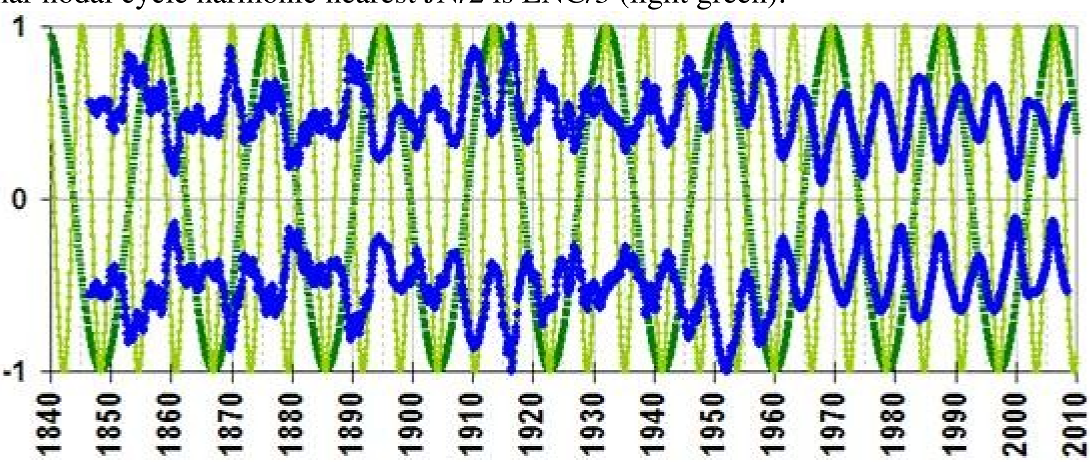
Complex Mexican Hat wavelet (minimal angular smoothing):

The phase-agreement at the timescale of JN/2 (~6.4a) is good, with deviations in the 1910s, ~1931, and in the late 1970s *corresponding with well-known excursions of Earth orientation parameters (EOP) and extrema of the LNC*.

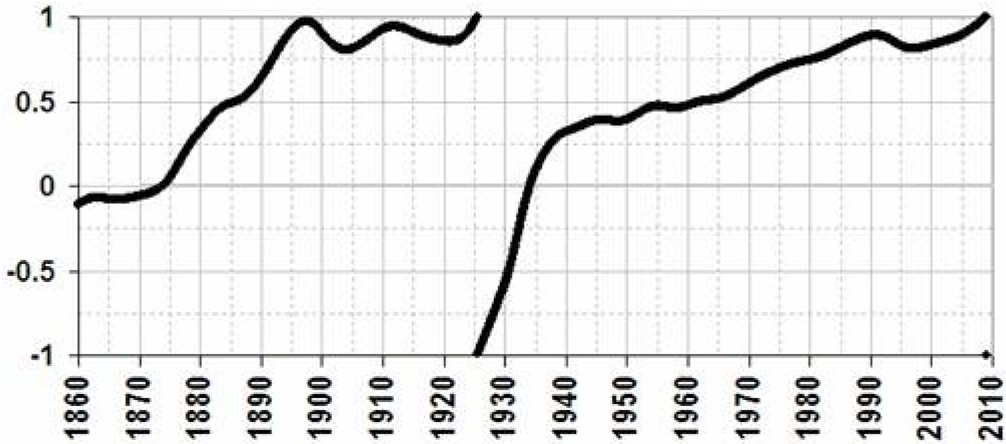
JN/2-timescale |Pr'| & r''/2 phase-difference (in units of **pi** radians) based on Morlet **pi** wavelet transforms:



The lunar nodal cycle harmonic nearest JN/2 is LNC/3 (light green):

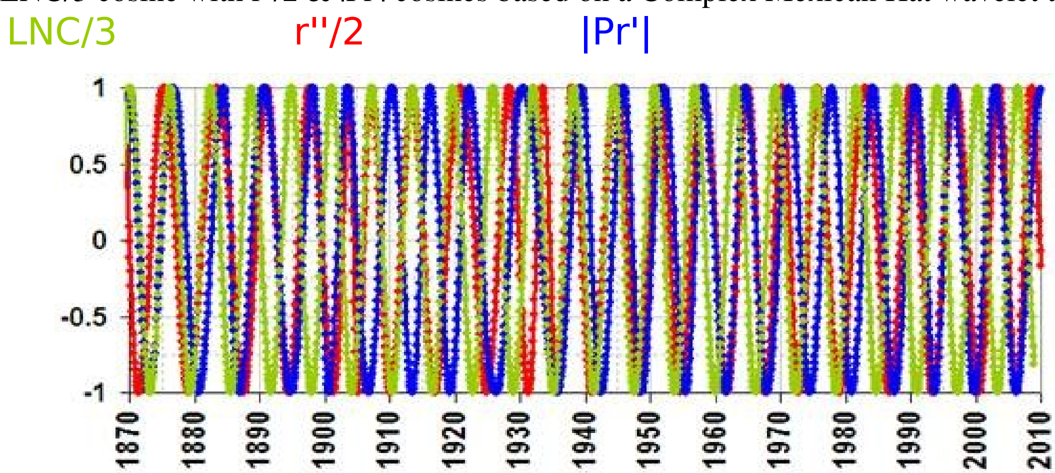


The JN/2-timescale |Pr'| & LNC/3 phase-difference, based on a Morlet **pi** wavelet transform of |Pr'|:

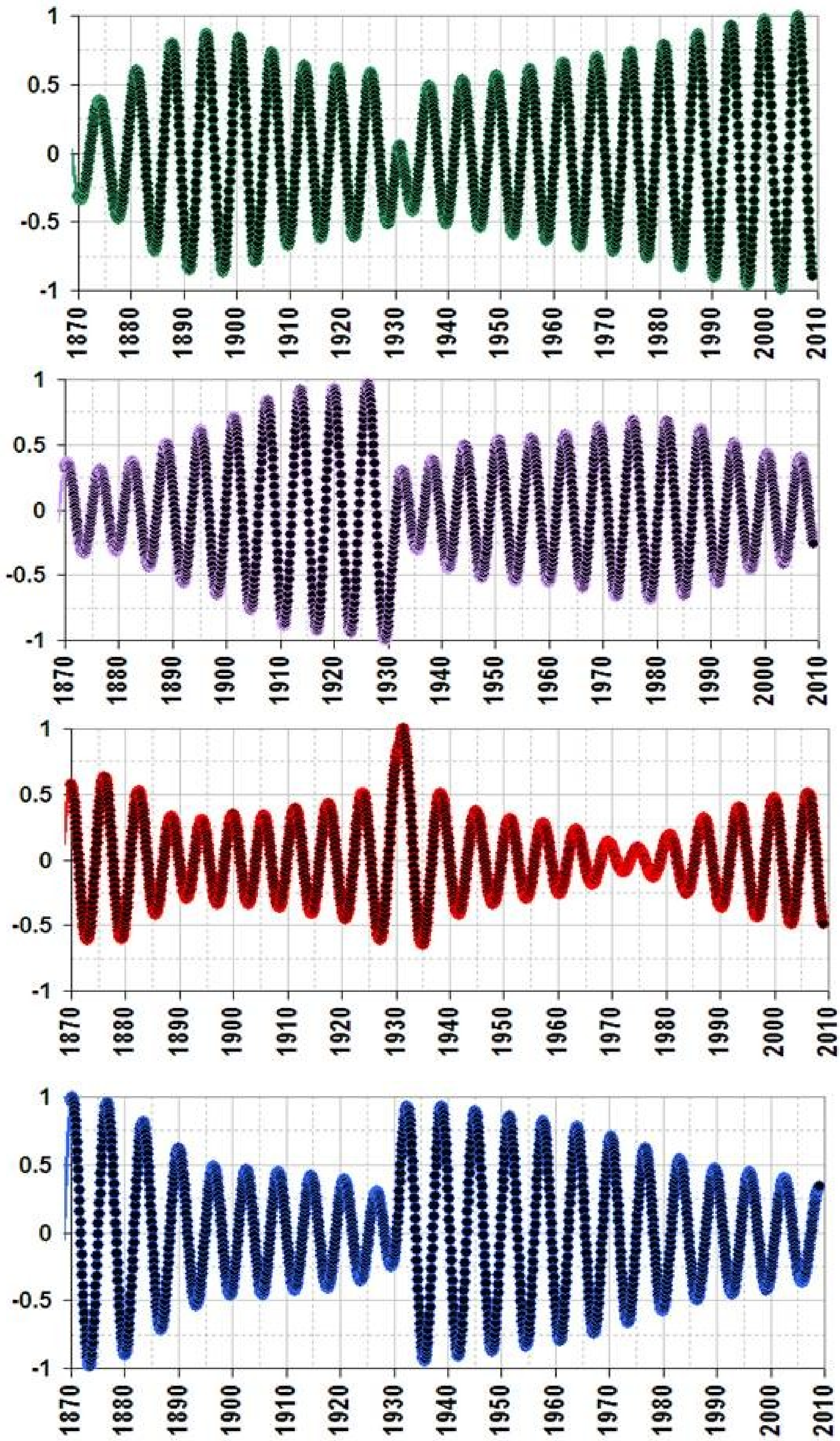


Note that there is more phase-difference drift between |Pr'| & LNC/3 than there is between |Pr'| & r''/2.

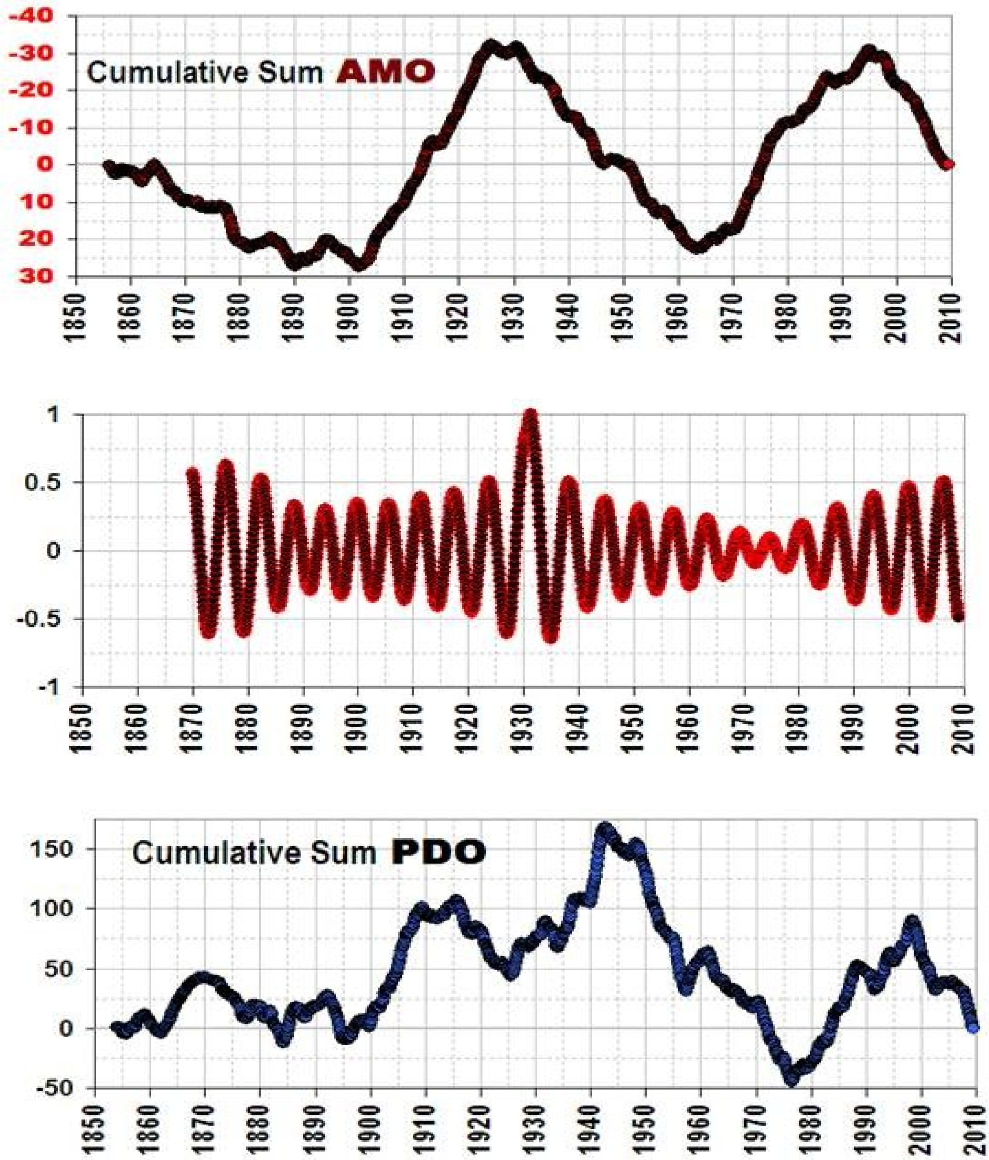
The LNC/3 cosine with r''/2 & |Pr'| cosines based on a Complex Mexican Hat wavelet transform:



The 4 interference-combinations of the 3 waves, based on Morlet 2**pi** wavelet transforms, are:

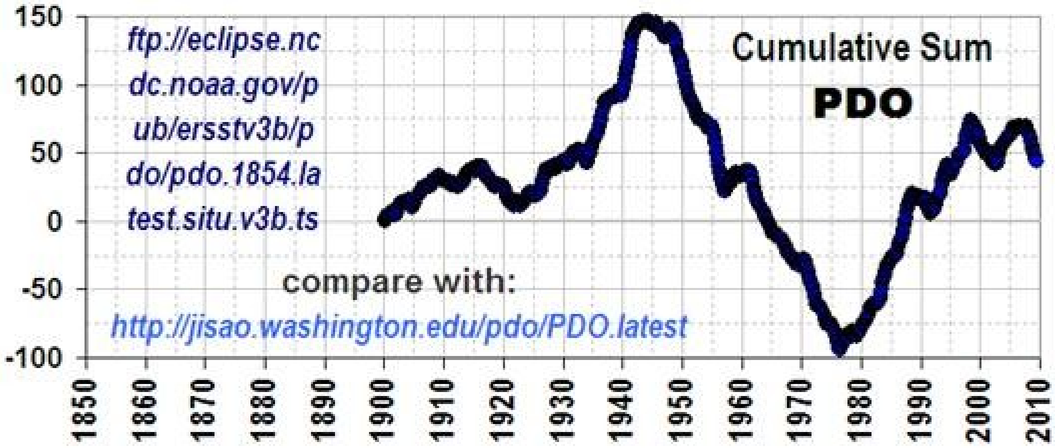


Compare the third pattern (red) with the Atlantic Multidecadal Oscillation (AMO) and the Pacific Decadal Oscillation (PDO):



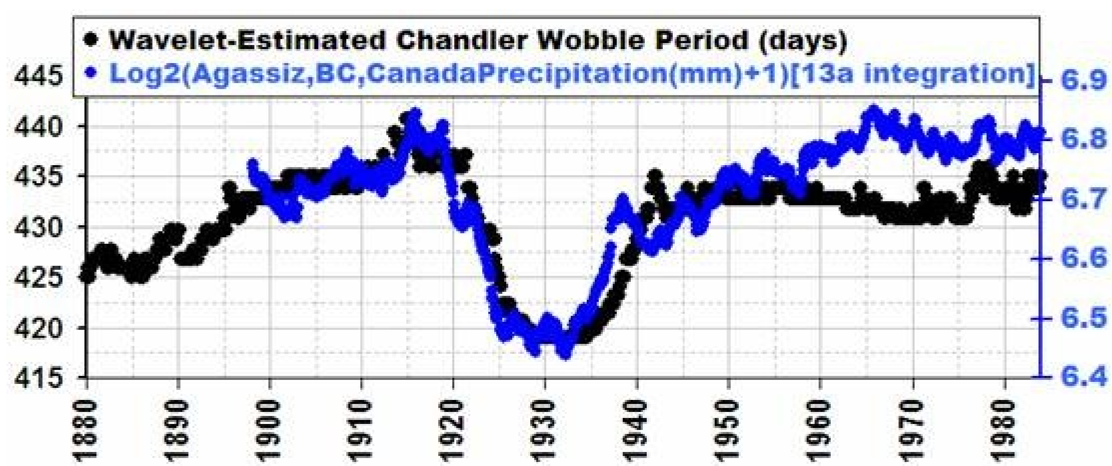
The agreement is good. The spike corresponds with:
1) the termination of a steep rise in Arctic temperatures,
2) a deep minimum in Southern Ocean SSTs (sea surface temperatures),
3) a maximum in the specific mass of Antarctic ice (N.S. Sidorenkov), and
4) the early part of the major North American "Dirty 30s" "Dust Bowl" drought.

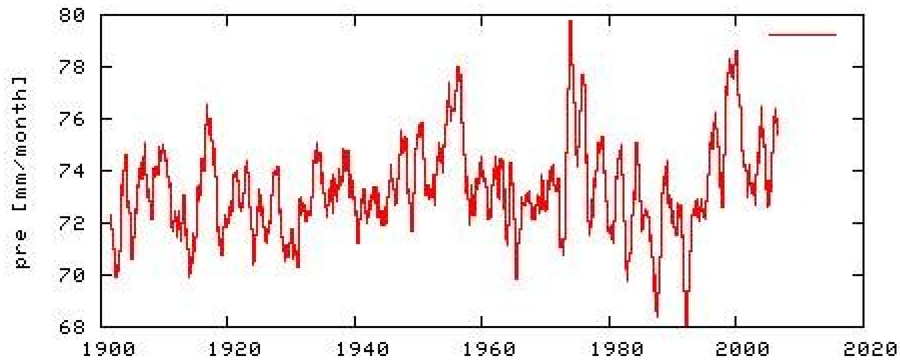
(Neither (1) nor (4) are presently well understood, but the works of Yu.V. Barkin & N.S. Sidorenkov provide promising clues about terrestrial oscillations.)



More generally, the change-points in EOP correspond with interannual & decadal dips & spikes in regional precipitation (which are interrelated via global-scale spatial-modes, partly due to ENSO). One regional example:

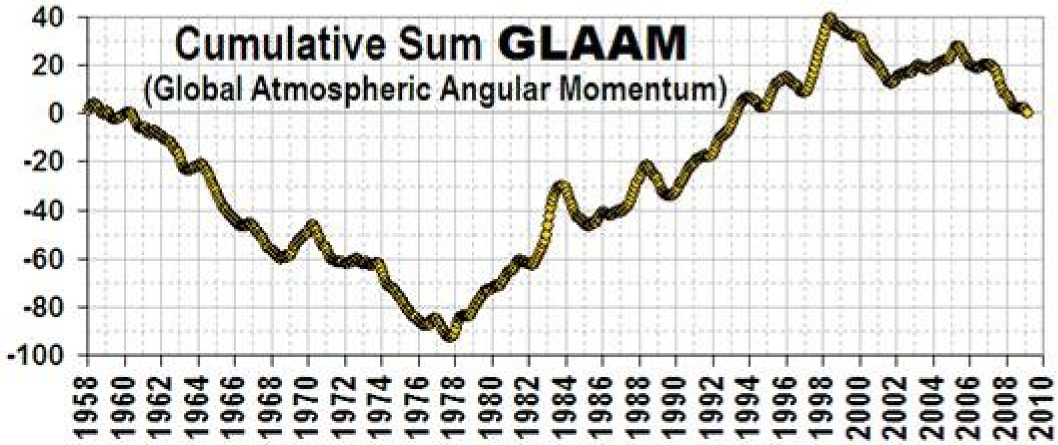
The 1976 change-point corresponds with a spike in global precipitation south of 55N (i.e. 55N-90S (very-loosely representing non-Arctic drainage/ocean regions)).





Source: KNMI Climate Explorer. http://climexp.knmi.nl/start.cgi?someone@somewhere

One more example of a ~1976 change-point (from the countless examples available) is global atmospheric angular momentum (GLAAM), which is known to be strongly related to EOP:

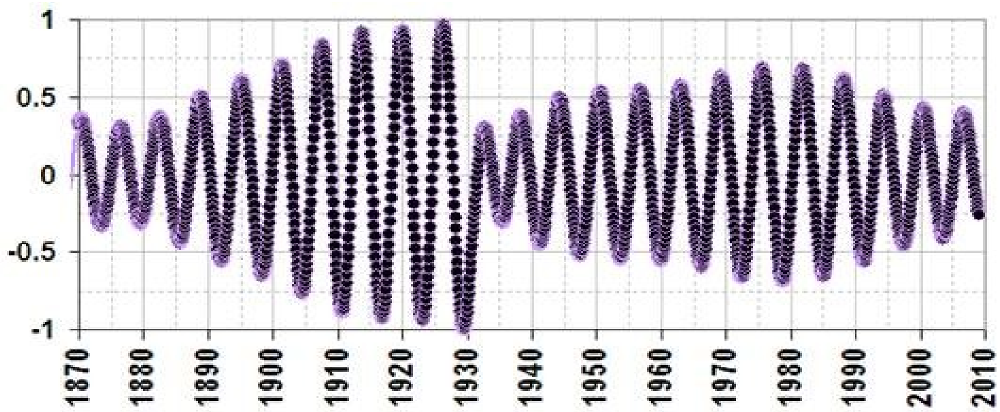


Heavy angular smoothing is useful for establishing dominant periods, such as 6.4a (JN/2) & 7.8a (possibly a Saturn-Neptune modulation of JN/2), which are evident in the wavelet-power plots above.

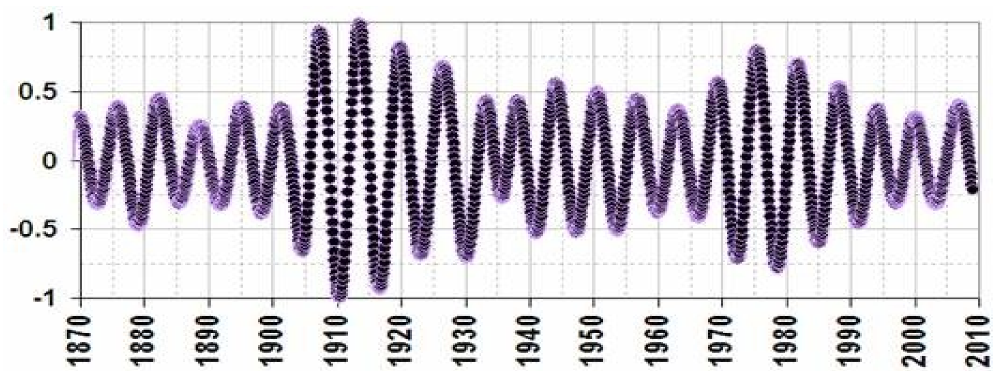
The wave-interference combinations depicted above were based on the heavy angular smoothing of the Morlet 2**pi** wavelet.

Wavelets lighter on smoothing show the same *major* features *plus more details*.

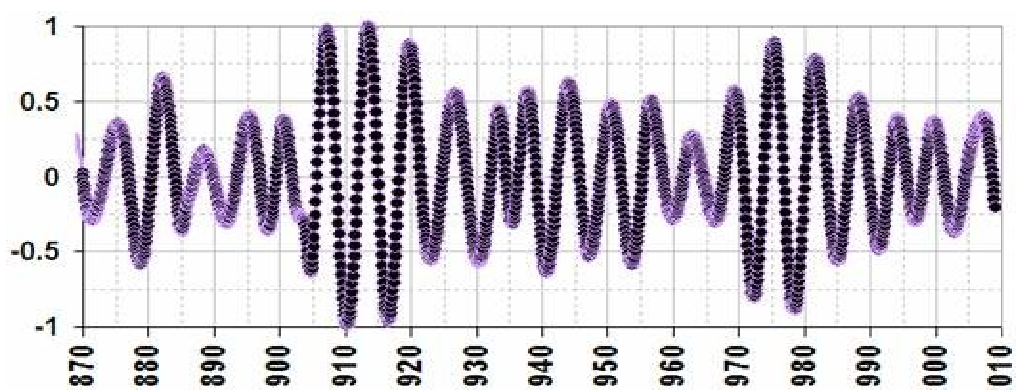
Morlet 2**pi** wavelet (*heavy* angular smoothing):



Morlet **pi** wavelet (*lighter* angular smoothing):

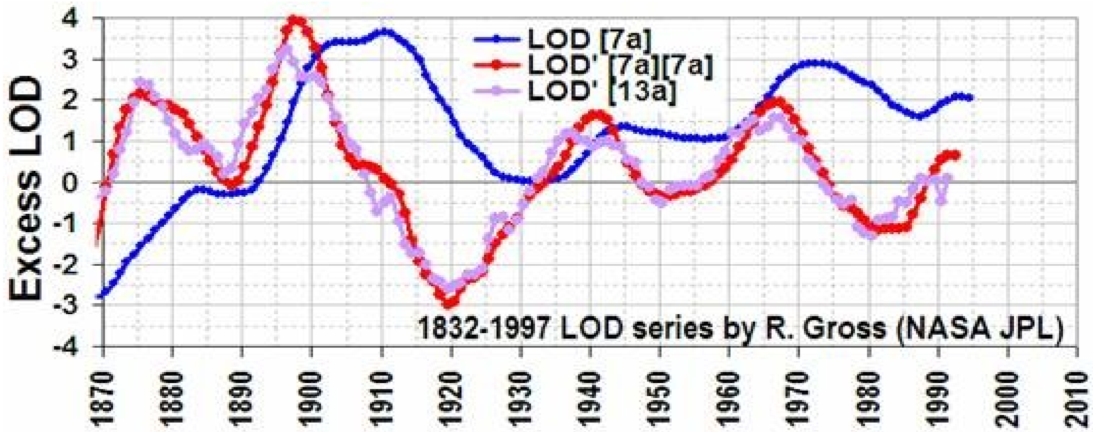


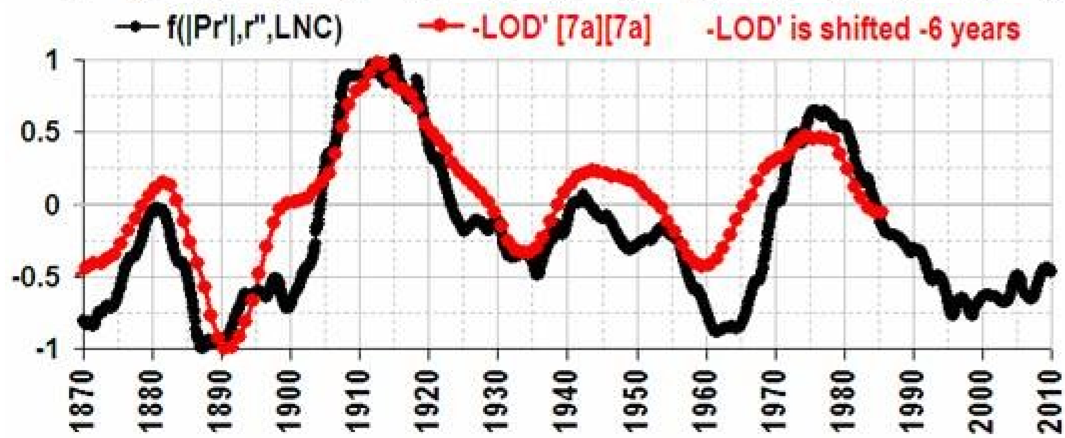
Complex Mexican Hat wavelet (*light* angular smoothing):



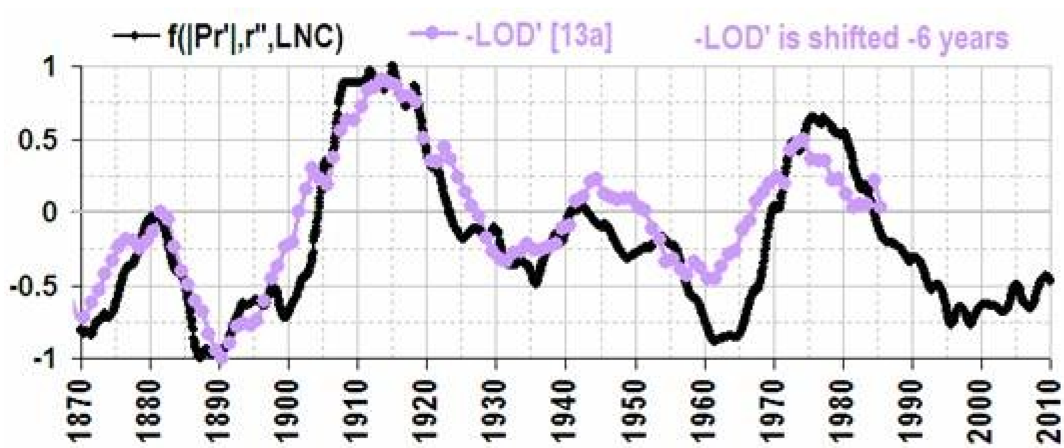
LOD (length of day) is related to the envelope of the higher-frequency content conveyed for this combination by the Morlet **pi** & Complex Mexican Hat wavelets (which will be denoted f(|Pr'|,r'',LNC) in what follows).

First, LOD & its rate of change:





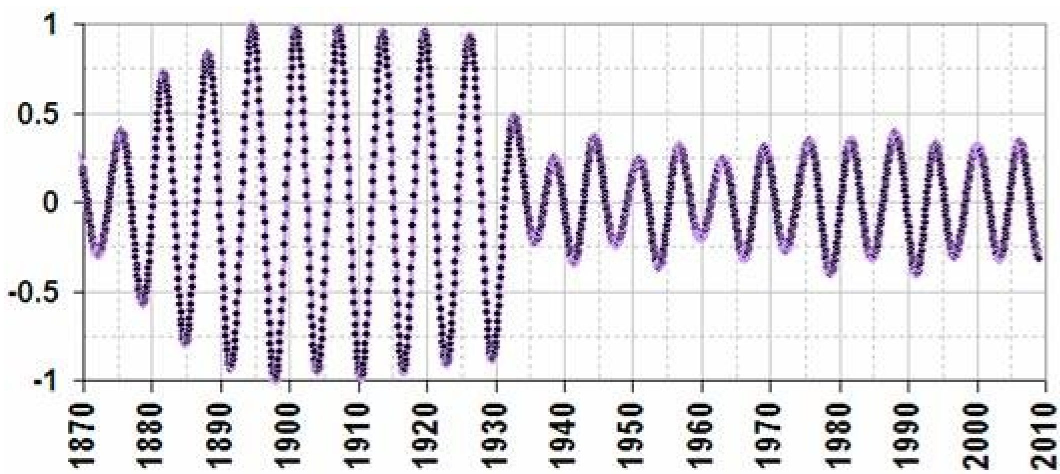
The negative of the rate of change of LOD (-LOD'), which corresponds with the acceleration of Earth rotation, shows a relationship with f(|Pr'|,r'',LNC):



The results for the Morlet **pi** wavelet are similar.

An investigator relying only on the Morlet 2**pi** wavelet or the popular Morlet 6 wavelet, both ofIn addition to t which sacrifice time-localization to achieve longer-term frequency-resolution, might miss the relationship with LOD.

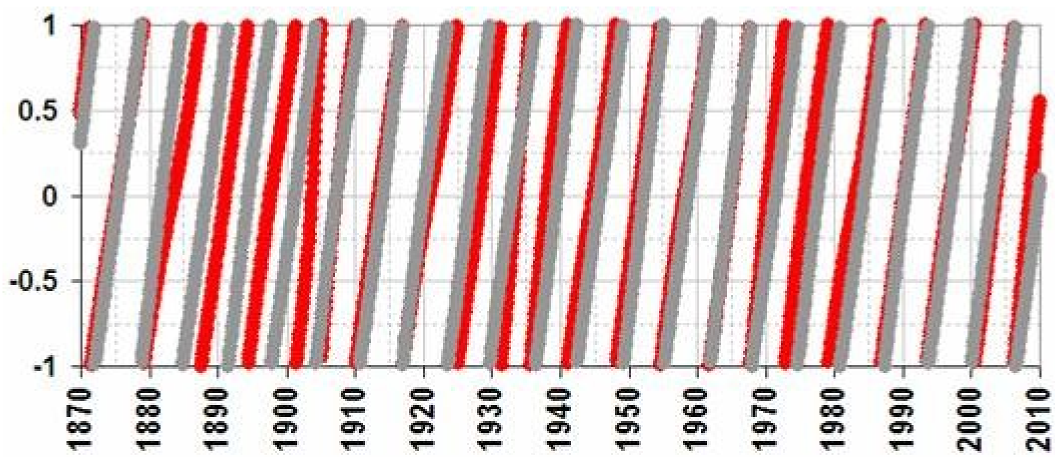
It is also worth noting that an investigator focusing on JN/2, rather than r"/2, would find the following:



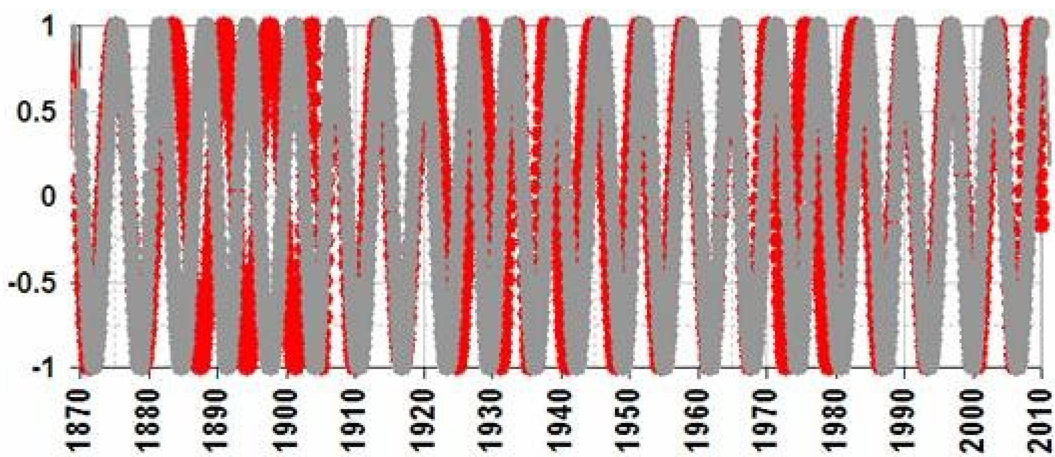
The details of the relationship with LOD are only striking when the highest-frequency Jovian-conjunction component (JN/2) is included in an index of the *whole* solar system (r''/2 in this study). The key is that JN/2 & r''/2 have the same frequency content *only* *on* *average*. Aberrations in r''/2, which are *not* present in JN/2 *alone*, interfere with |Pr'| & LNC/3 in a manner that relates to -LOD'.

Illustration of the aberrations in r''/2 (red) relative to the more stationary (i.e. regularly-spaced) JN/2 (grey):

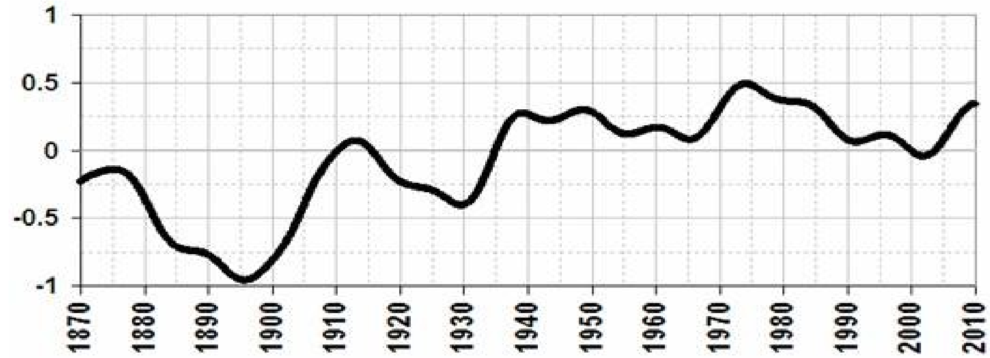
Angles (in units of **pi**):



Cosines:In addition to t

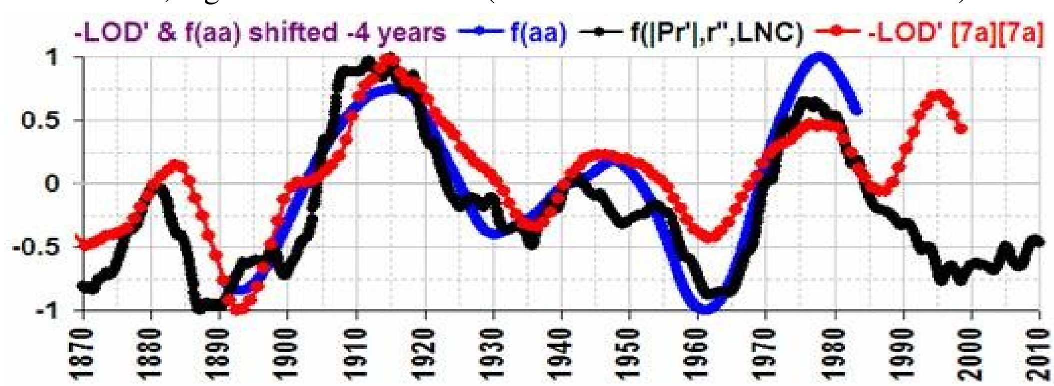


Phase-difference (based on Morlet **pi** wavelet):



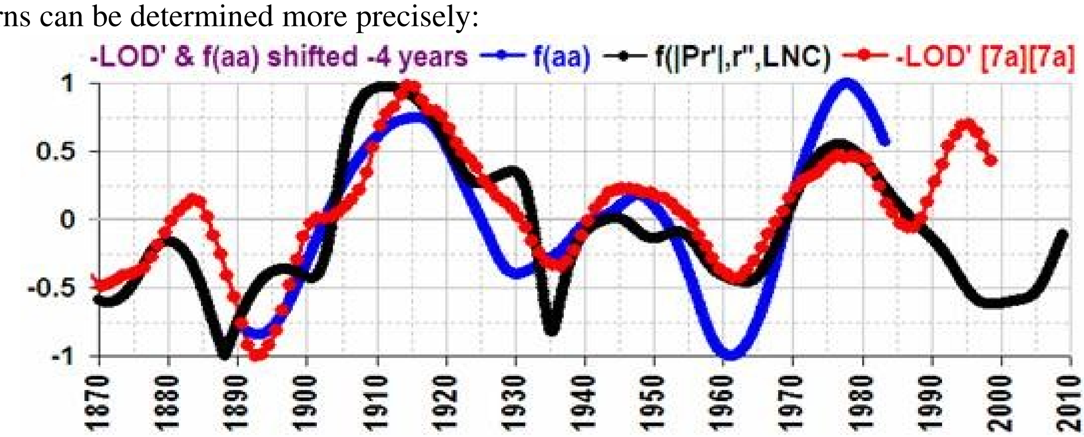
Interestingly, the rate of change of the absolute value of the year-over-year difference of geomagnetic aa index, smoothed over Hale cycles, shows the same decadal-timescale pattern:

Here the 1832-1997 LOD series of R. Gross has been extended beyond 1997 using annual summaries of newer, higher-resolution IERS (International Earth Rotation Service) data. The



reversal of the phase relationship between -LOD' & f(|Pr'|,r'',LNC) around 1990, which is consistent with Earth nutation patterns, requires further investigation.

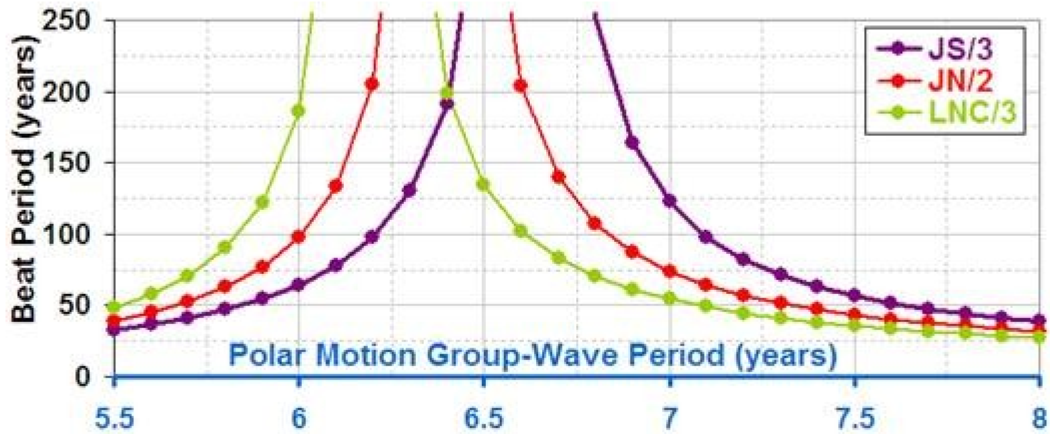
The following is a repeat of the above plot to demonstrate that envelopes of wave-interference patterns can be determined more precisely:



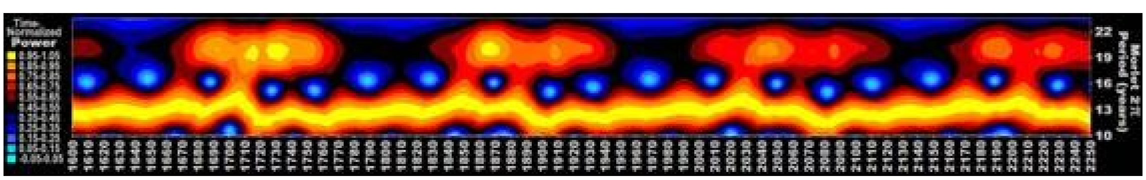
(This envelope is based on Morlet **pi** wavelet transforms.)

Conclusions

1) LOD, aa index, PDO, AMO, & terrestrial oscillations more generally appear related to combinations of |Pr'|, LNC/3, & r''/2. Other celestial harmonics near the period of |Pr'| might be strategic candidates for further study.



2) There is a systematic phase-relationship between polar motion (|Pr'|) and solar system dynamics (r''/2, which relates to JN/2 *on average*). Thus, the following wavelet transform of r'', which summarizes the acceleration & deceleration of r'' cycling, is suggestive of the timing of terrestrial-oscillation regime-shifts:



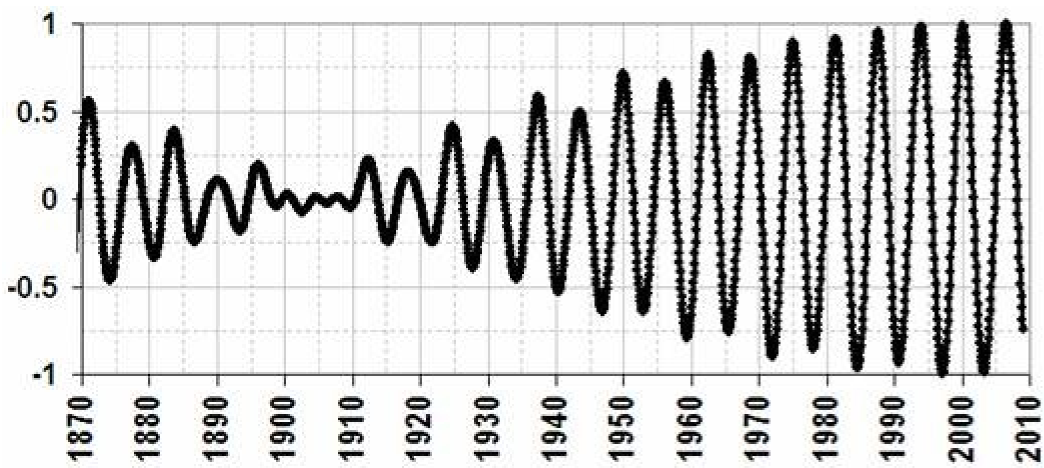
http://www.sfu.ca/~plv/RegimeChangePoints.PNG

3) Further investigation is necessary.

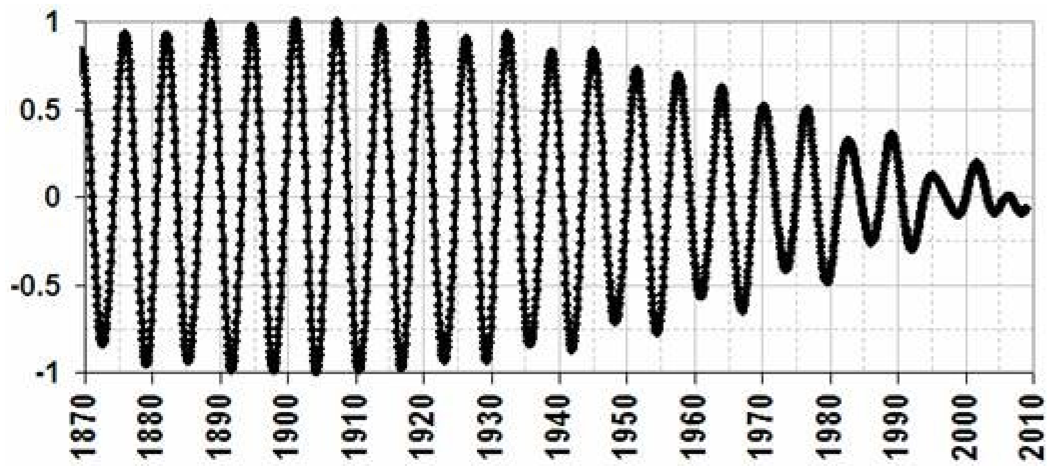
Further Discussion

It is worth noting that JN/2 & LNC/3 have a 205 year beat period. Note that we are (roughly) reaching an extremum now (2009):

Contrast of JN/2 & LNC/3:

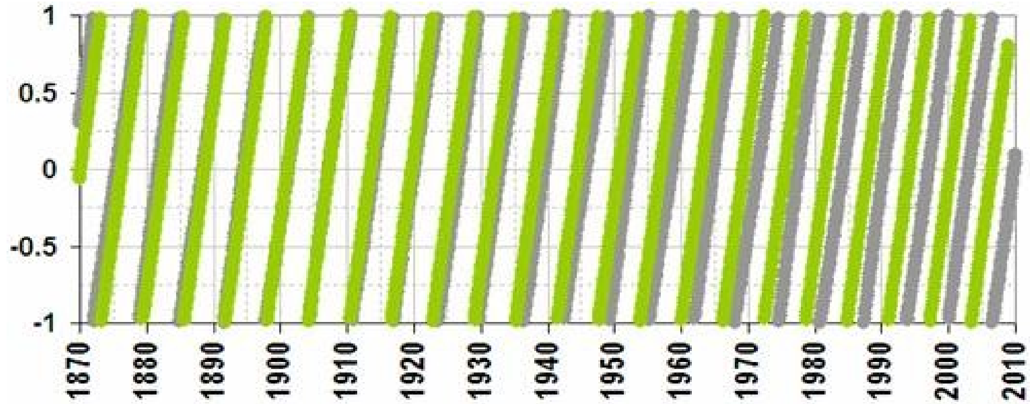


Blend of JN/2 & LNC/3:



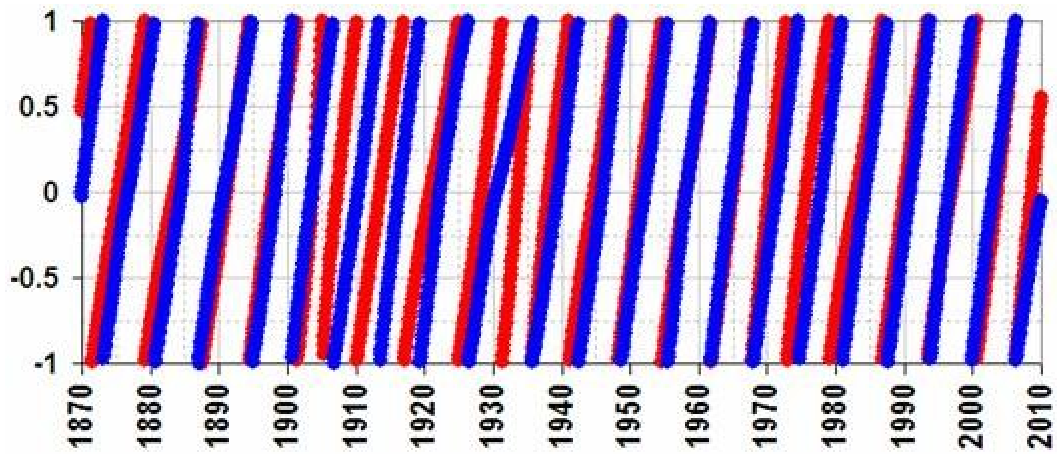
It is worth considering some details.

Phase **JN/2** & **LNC/3**:

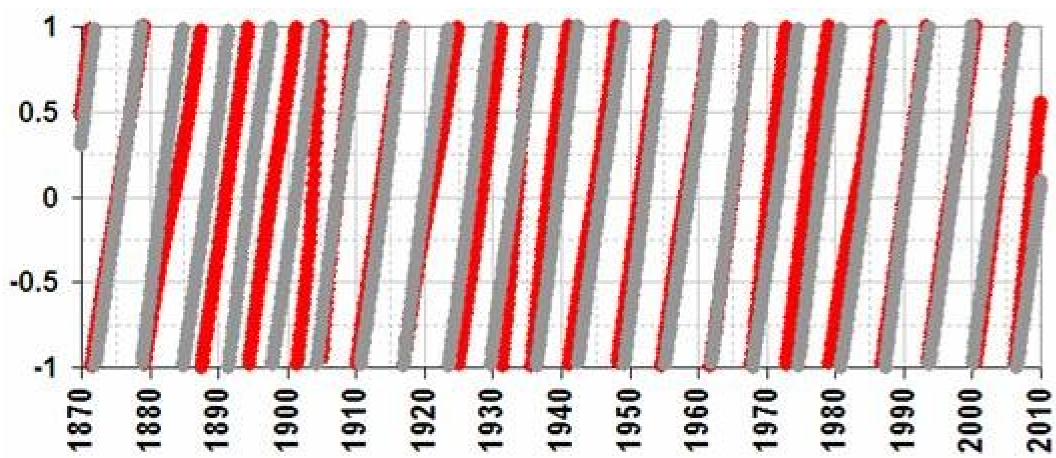


Conditioning on the previous plot ("mostly-together" or "mostly-apart"), note how the following 2 patterns either agree or disagree systematically:

Phase **r''/2** & **|Pr'|**:

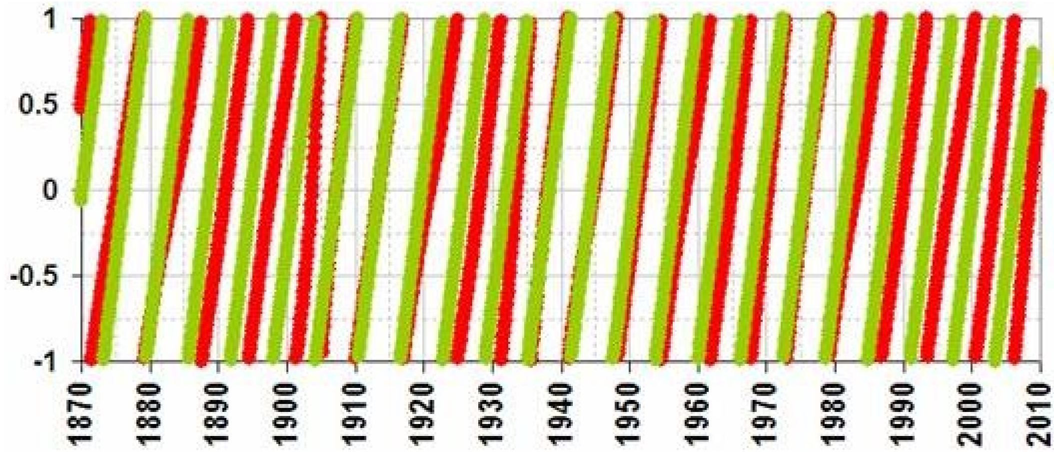


Phase **r''/2** & **JN/2**:

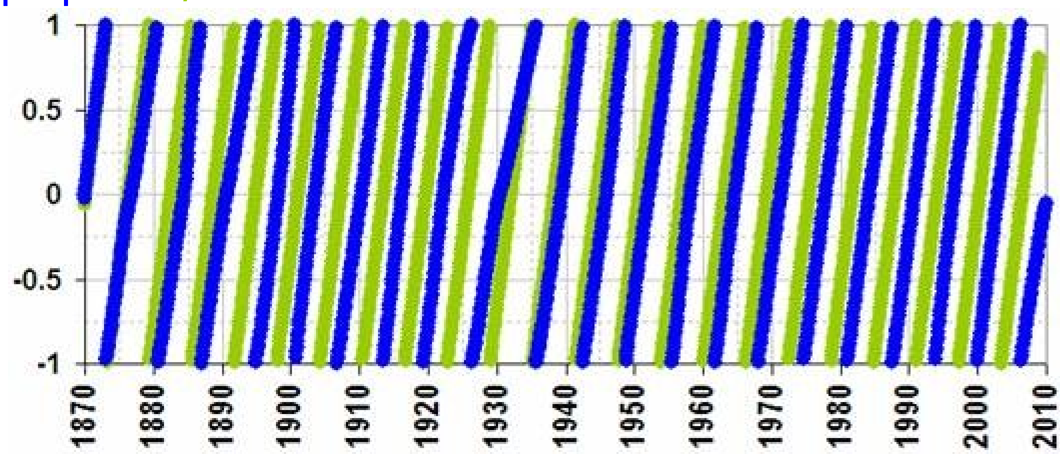


They "mostly *dis*agree" on the *left* & "mostly agree" on the right.

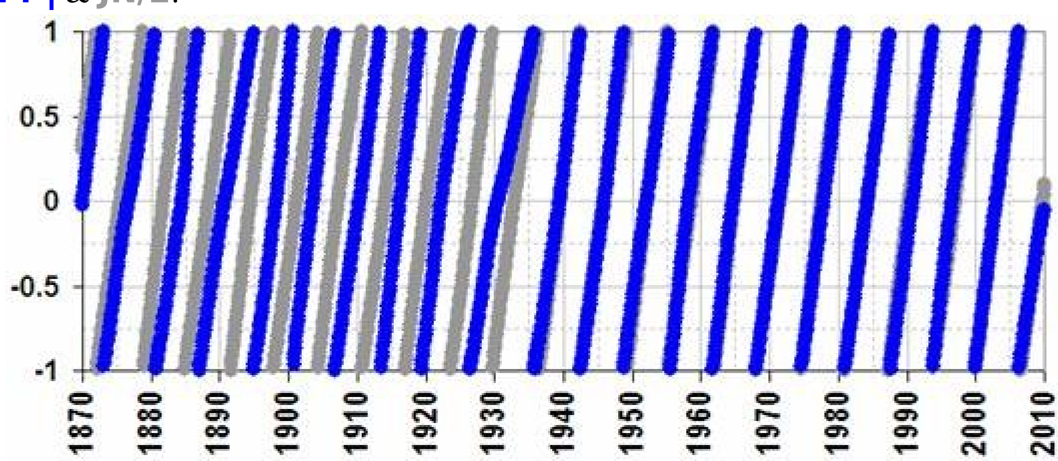
This message is reinforced by the following (compare with previous two plots):
Phase **r''/2** & **LNC/3**:



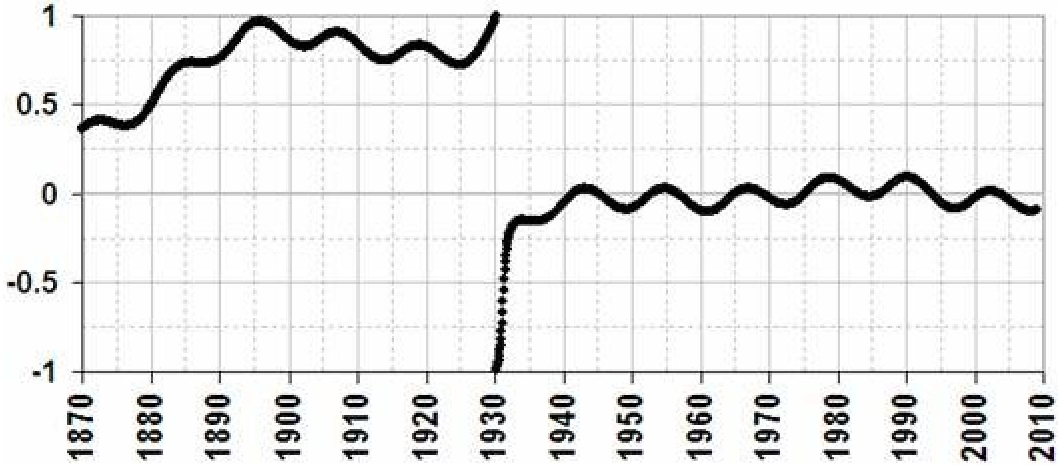
Note where there is agreement here:
Phase **|Pr'|** & **LNC/3**:



Compare with the following:
Phase **|Pr'|** & **JN/2**:

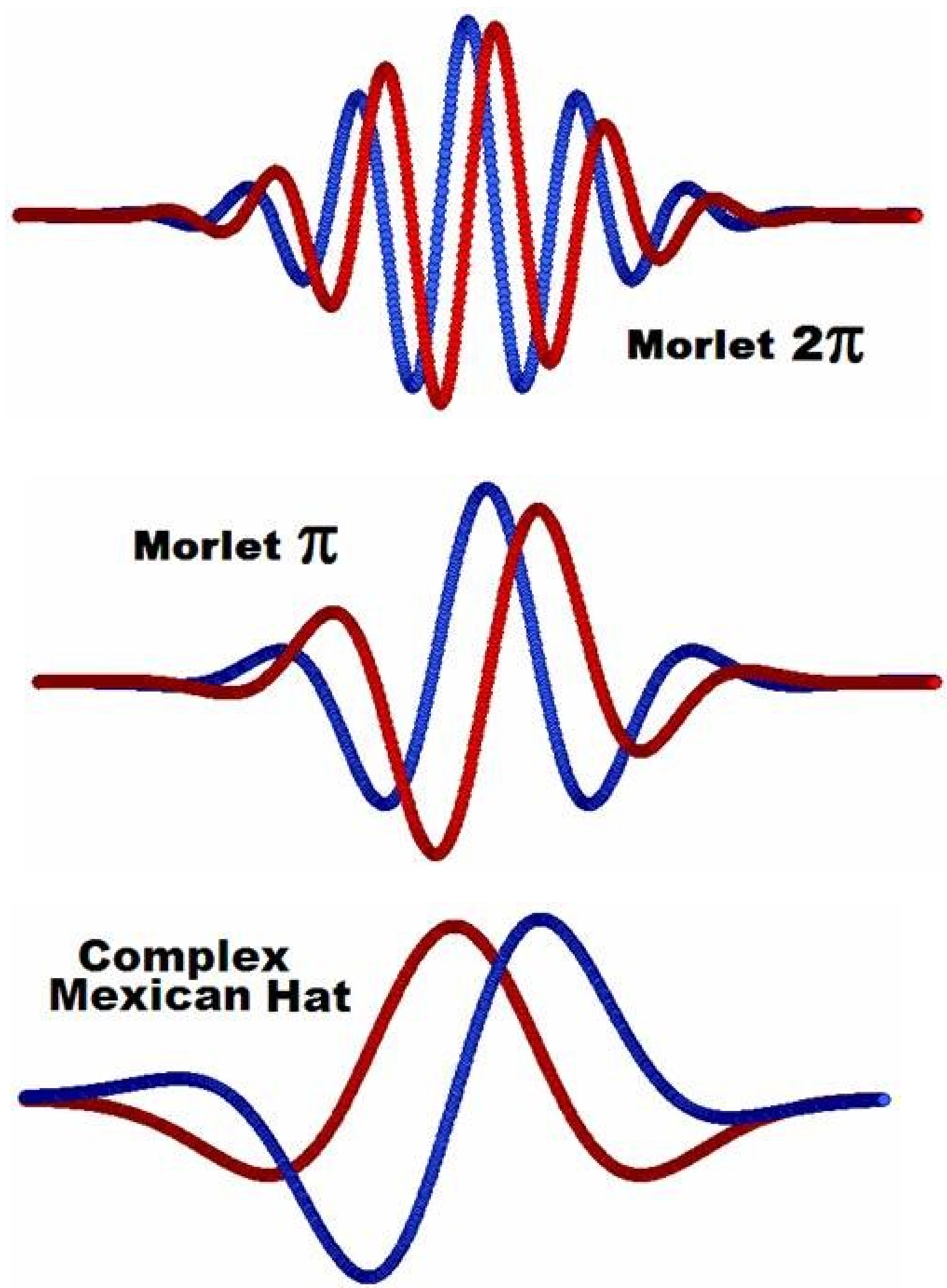


Phase-difference (Morlet 2**pi**) between JN & |Pr'|

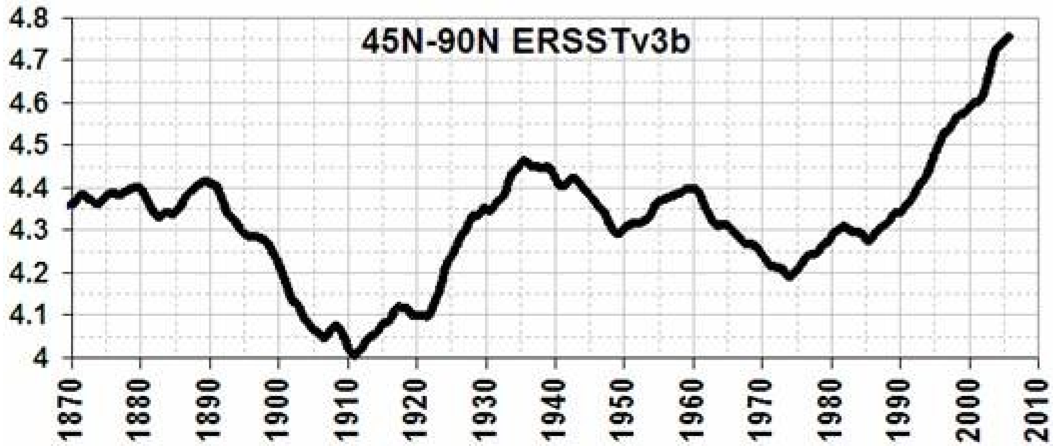

1
0.5
0
-0.5
-1
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

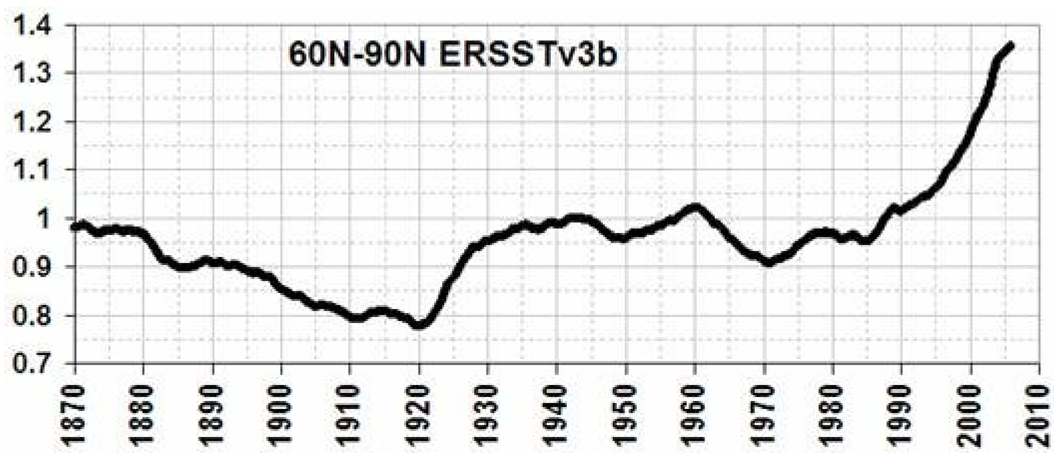
Appendix

The wavelets:

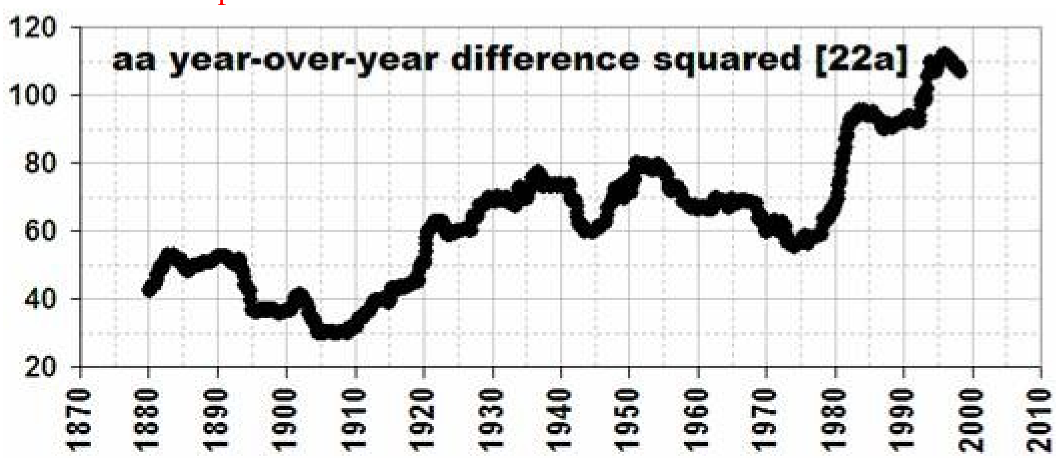


Additional **draft**-plots, which have influenced the line of research presented above and which will be the subject of further research:

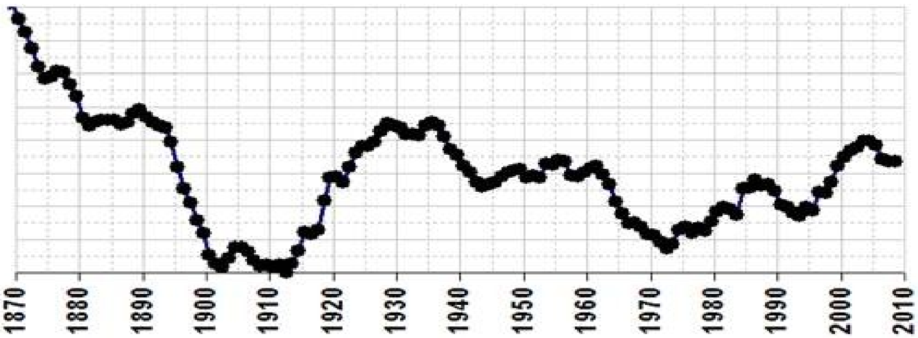




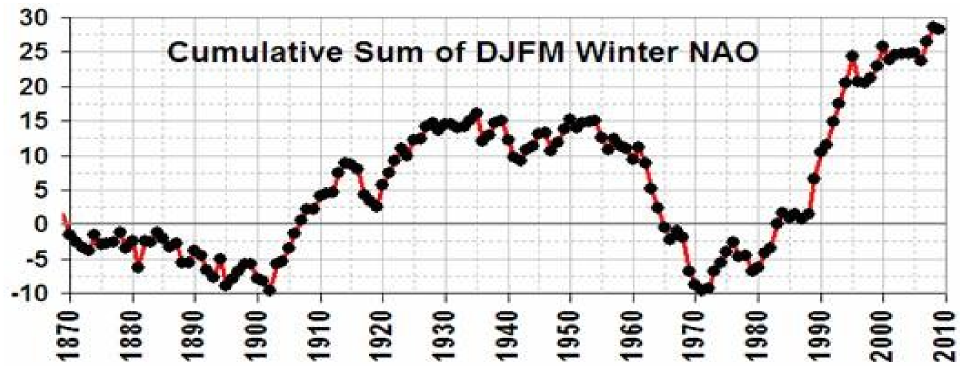
add: 70N-90N T&PPT plots



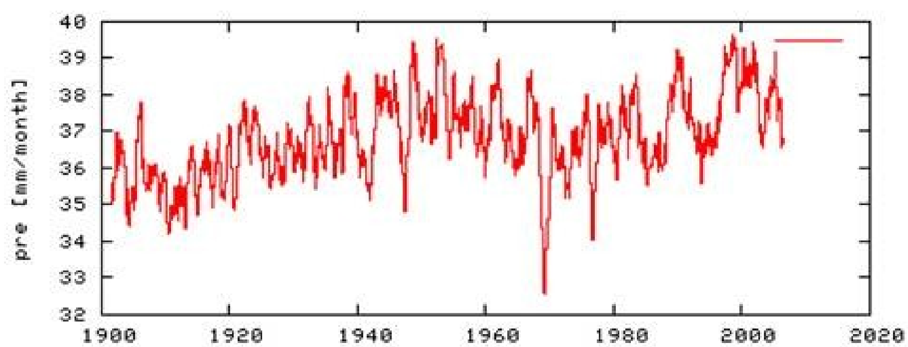
-LOD:



55N-90N Precipitation:



Source: KNMI Climate Explorer. http://climexp.knmi.nl/start.cgi?someone@somewhere



Source: Sidorenkov, N.S. (2005). Physics of the Earth's rotation instabilities. Astronomical and Astrophysical Transactions 24(5), 425-439.
http://images.astronet.ru/pubd/2008/09/28/0001230882/425-439.pdf

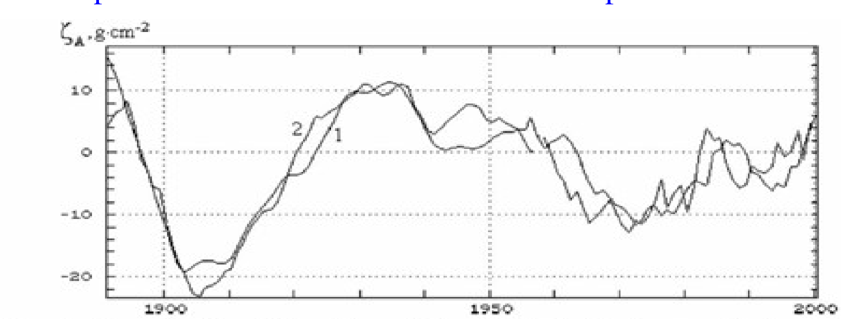
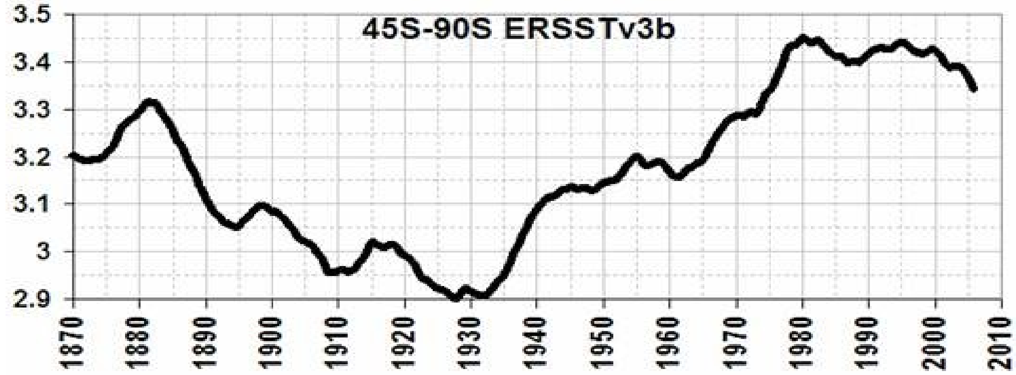
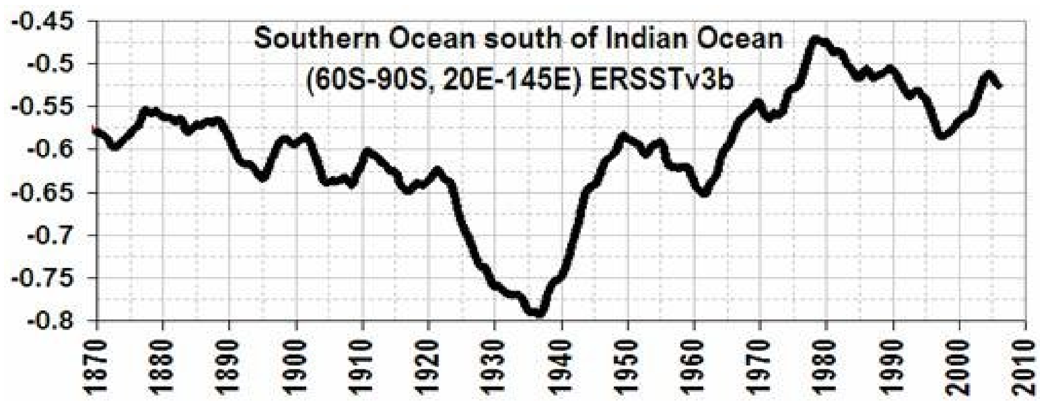
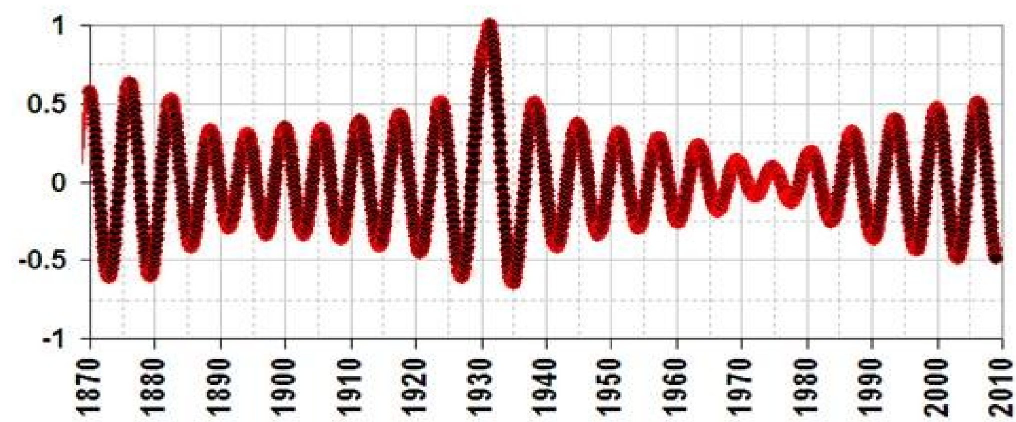
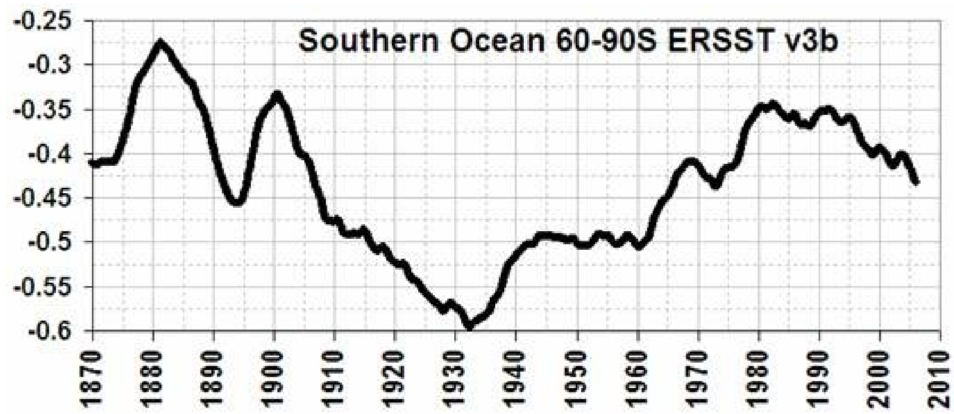


Figure 7. Temporal variations in the specific mass ζ_A (g cm^{-2}) of ice in Antarctica: curve 1, the theoretical value of ζ_A; curve 2, the empirical value of ζ_A [7].

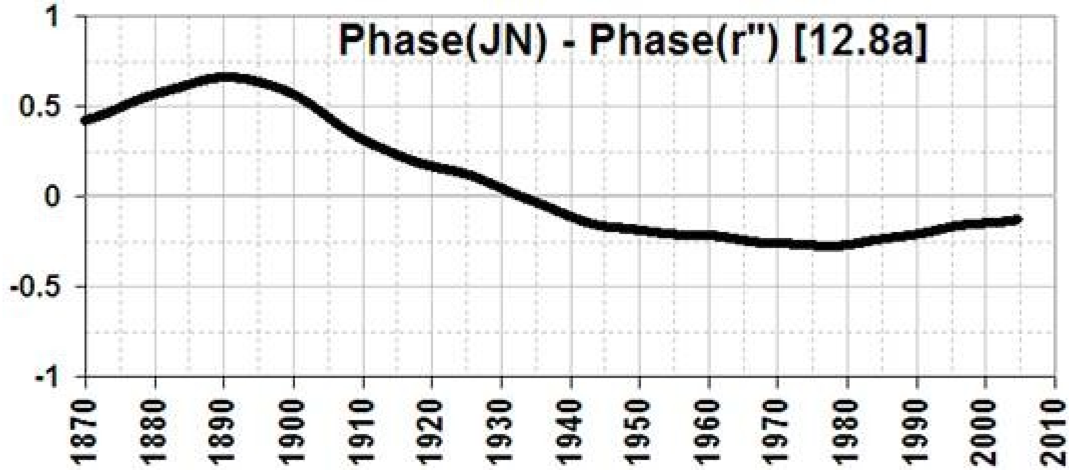

45S-90S ERSSTv3b
3.5
3.4
3.3
3.2
3.1
3
2.9
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

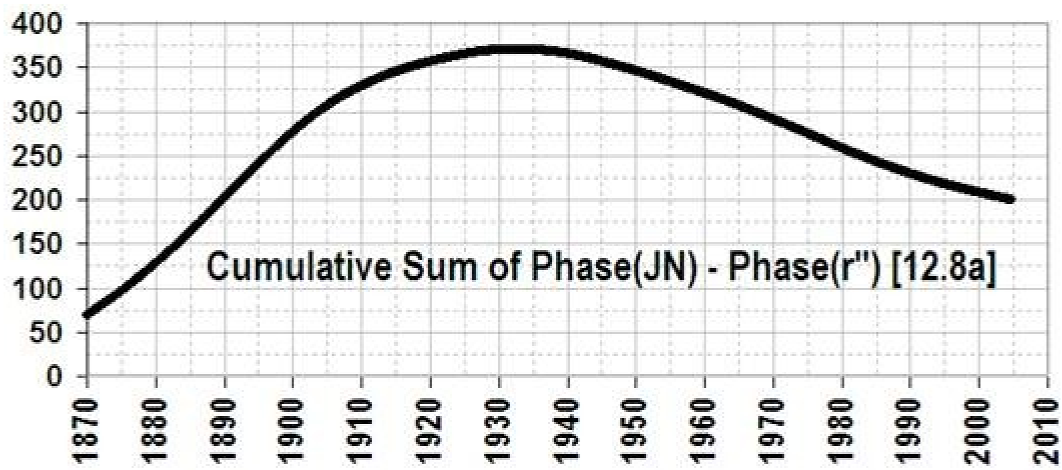

Southern Ocean south of Indian Ocean
(60S-90S, 20E-145E) ERSSTv3b
-0.45
-0.5
-0.55
-0.6
-0.65
-0.7
-0.75
-0.8
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

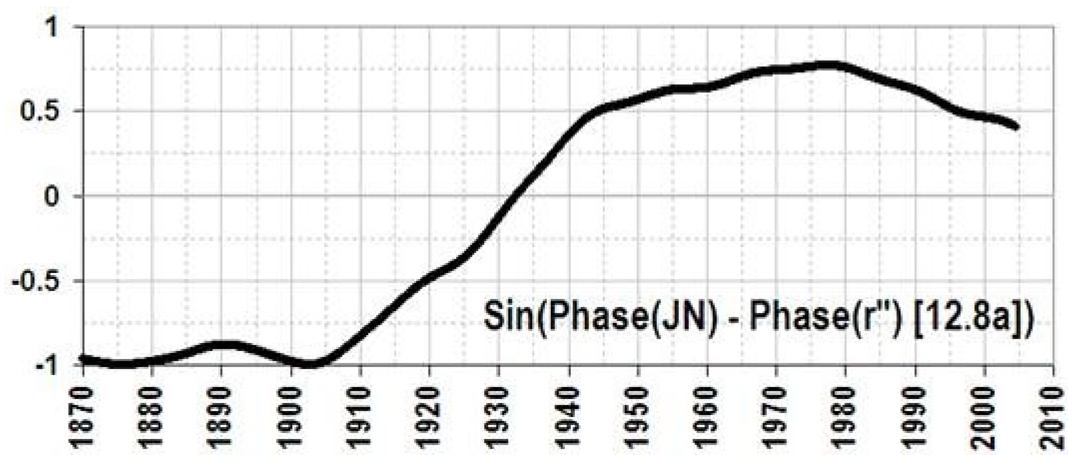

1
0.5
0
-0.5
-1
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

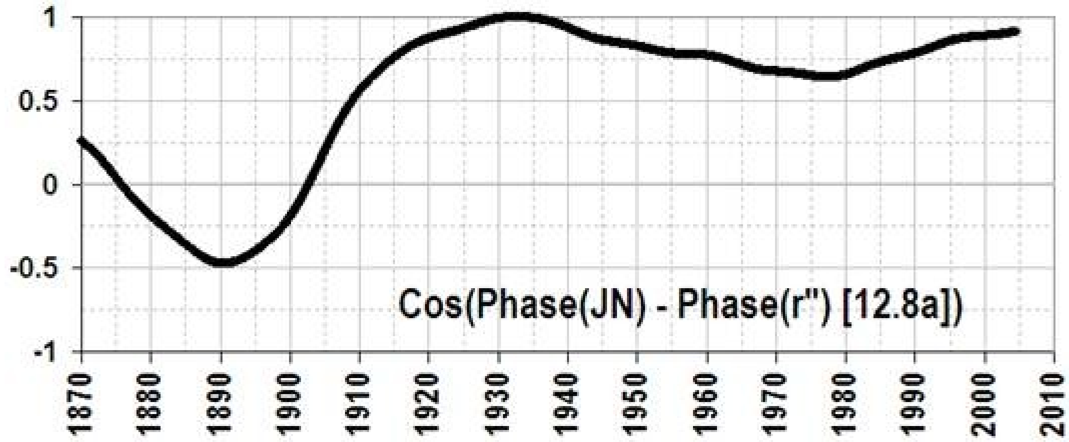

Southern Ocean 60-90S ERSST v3b
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5
-0.55
-0.6
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Morlet 2**pi**:

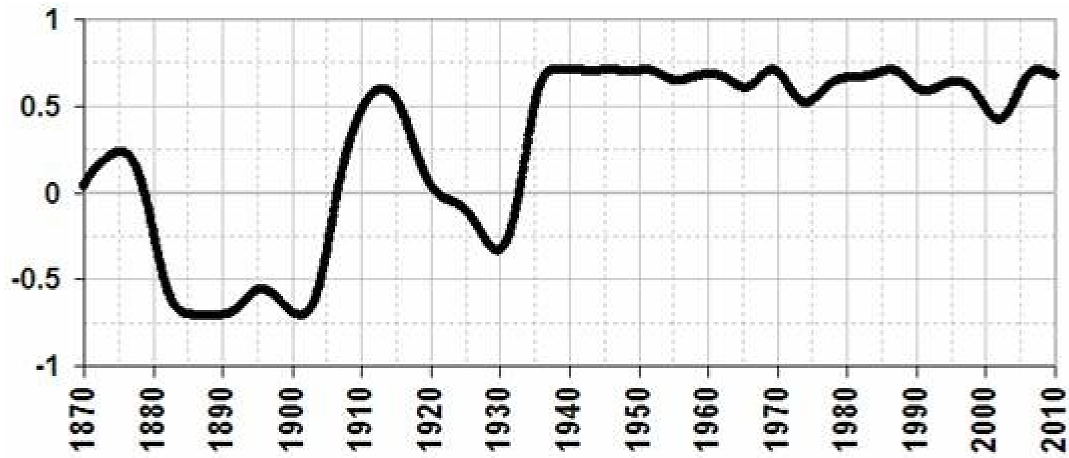

Phase(JN) - Phase(r") [12.8a]
1
0.5
0
-0.5
-1
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010


Cumulative Sum of Phase(JN) - Phase(r") [12.8a]
400
350
300
250
200
150
100
50
0
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

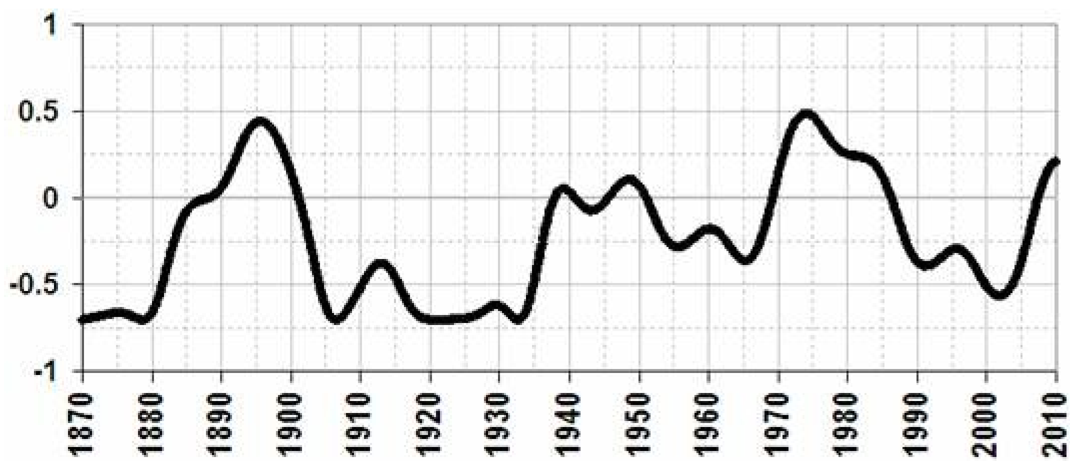

Sin(Phase(JN) - Phase(r") [12.8a])
1
0.5
0
-0.5
-1
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010



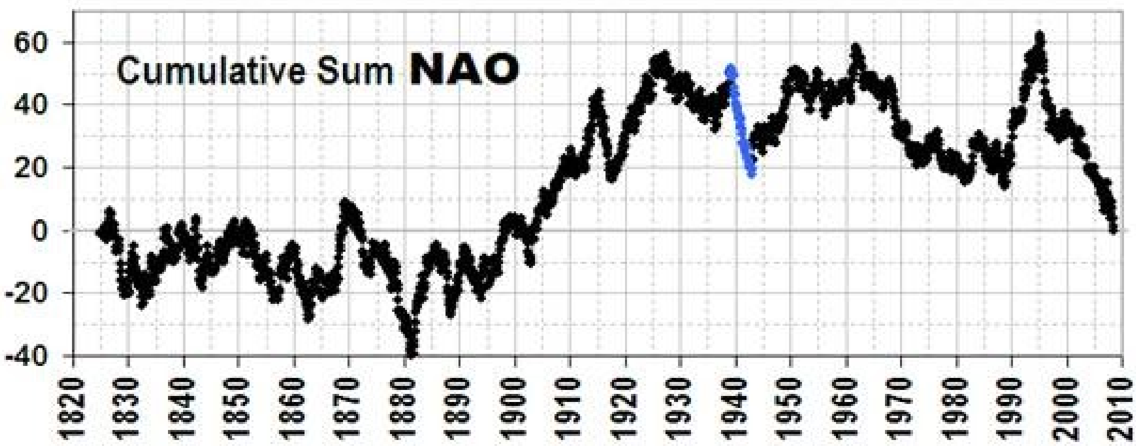
Average of the sine & cosine of the phase-difference (Morlet **pi**) between JN & r":

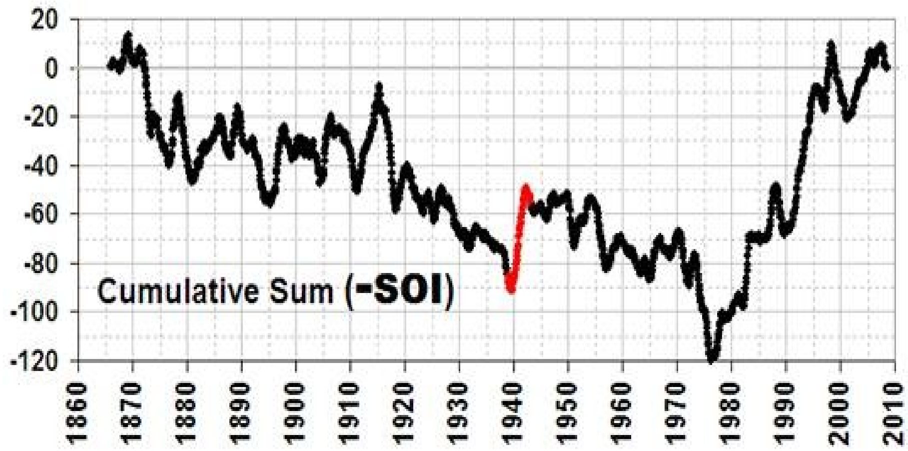


Average of the sine & -cosine of the phase-difference (Morlet **pi**) between JN & r":

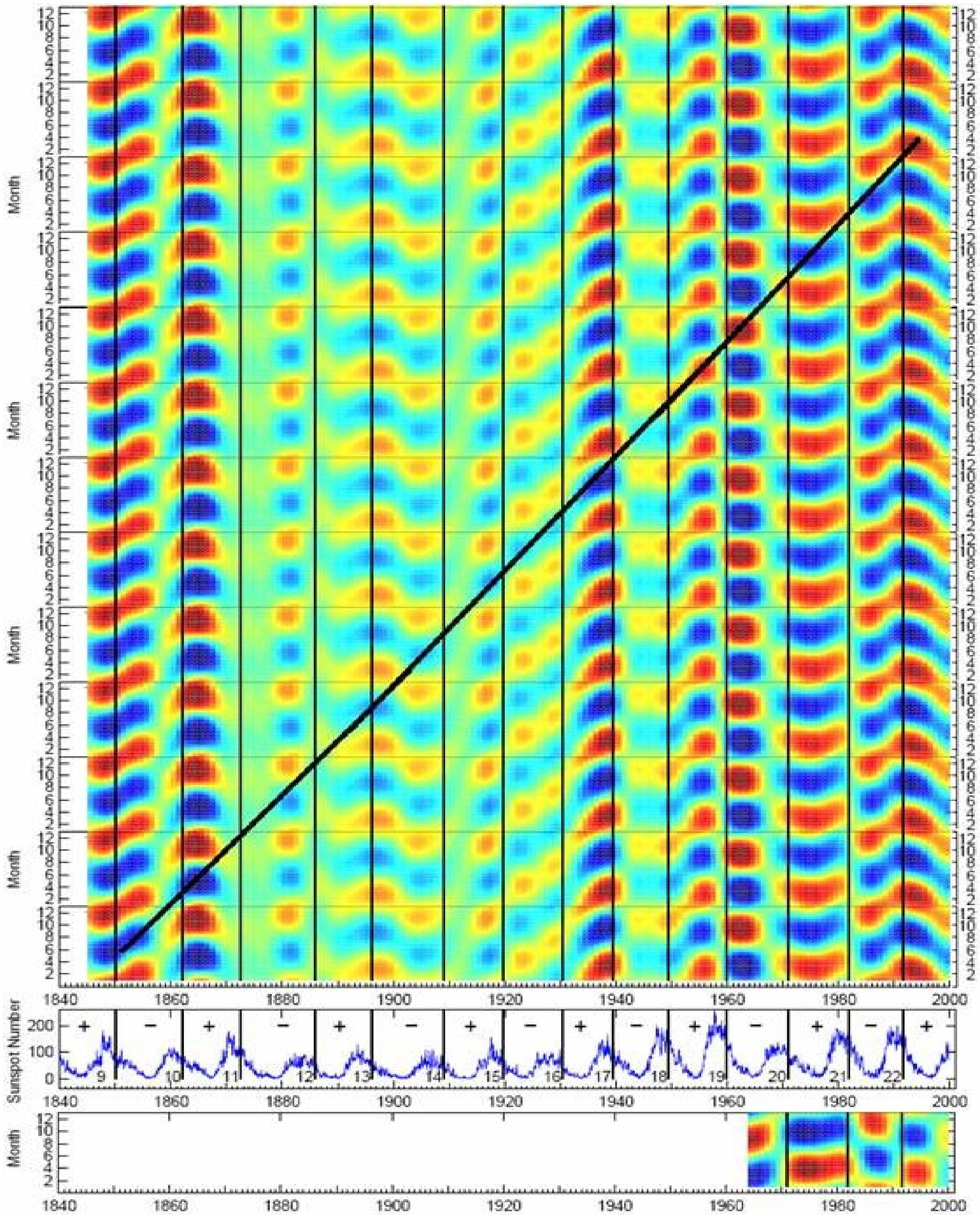


An item that warrants further investigation:
Note the bounce (highlighted below) in NAO & SOI when polar motion stabilized in the late 1930s:





There are connections involving interannual-annual aa index contrasts (or something confounded), SOI, & precipitation.



Filtered annual **variation of**:

- *Top*: extended **aa index** (1845-1999) -3.5 nT to +3.5 nT
- *Bottom*: solar wind (**SW**) **speed** (1964-1999) -25 km/s to +25 km/s

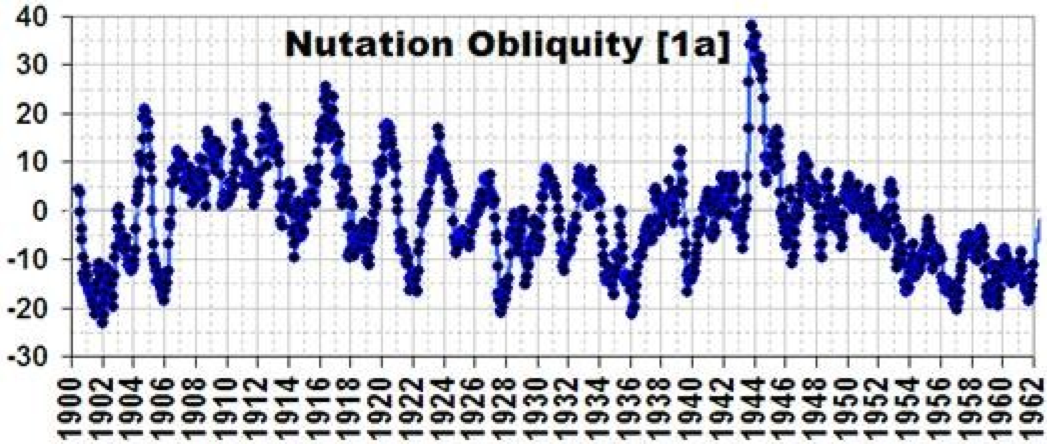
Middle Panel: Monthly **sunspot numbers**, with **magnetic helicities** (**+** & **-**).

Vertical lines denote *approximate* time of sun's polarity reversal (2 years after official sunspot maximum).

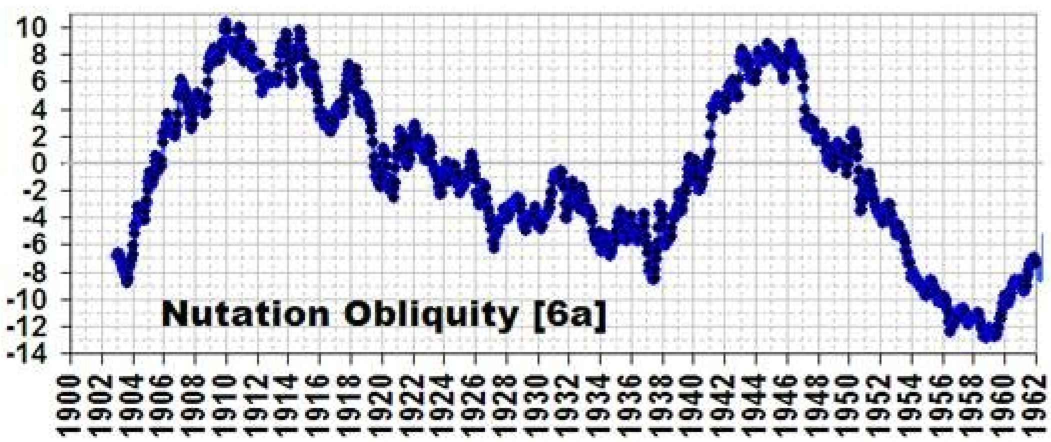
Adapted from:

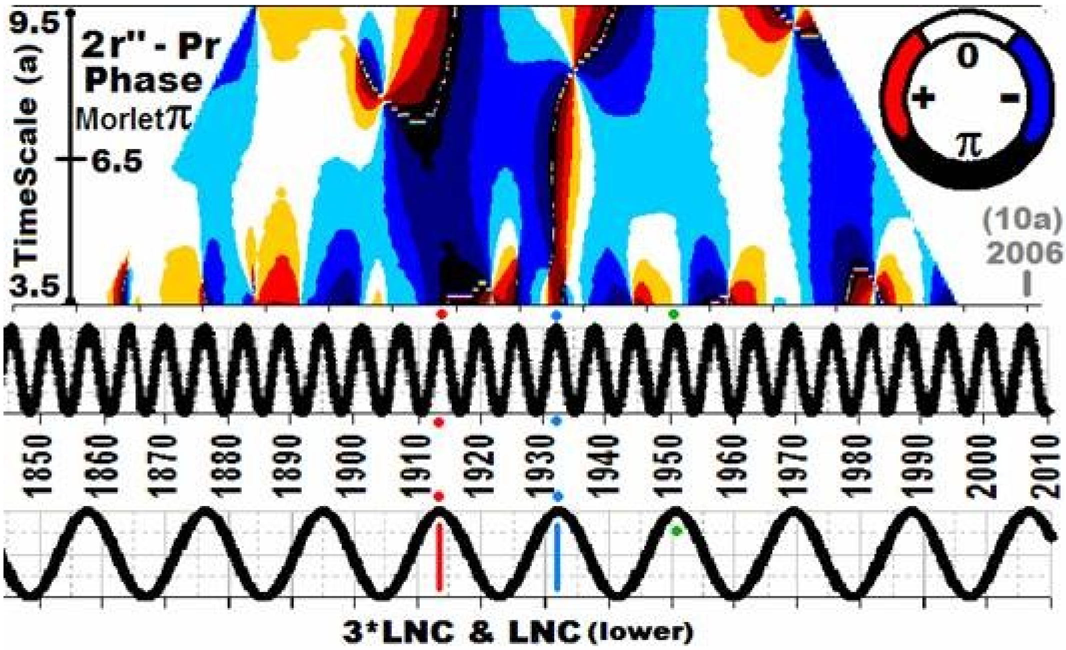
K. Mursula & B. Zieger (2001). Long-term north-south asymmetry in solar wind speed inferred from geomagnetic activity: A new type of century-scale solar oscillation? Geophysical Research Letters 28(1), 95-98.
http://spaceweb.oulu.fi/~kalevi/publications/MursulaAndZieger2001.pdf

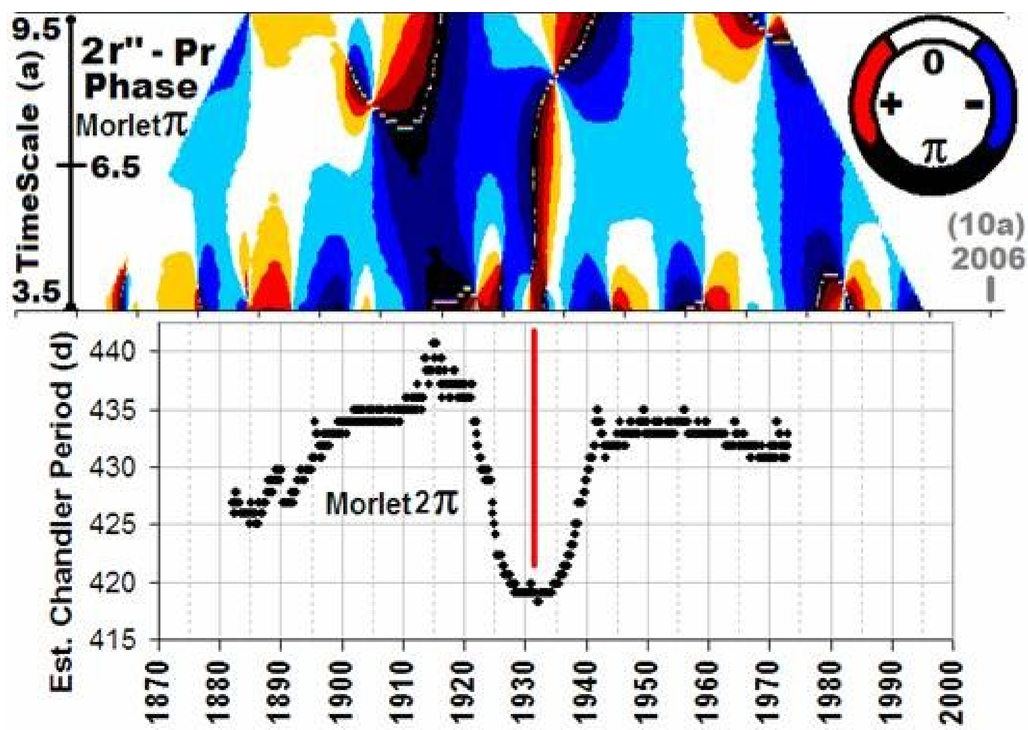
The ENSO period plunged immediately afterward (determined by wavelet power spectrum), coincident with a spike in Nutation Obliquity:



Note the broader-scale phase-concordance with the cumulative PDO, the Chandler Wobble period, and the 1905-1942 run in aa index:




9.5
2r" - Pr
Phase
Morletπ
6.5
TimeScale (a)
3.5
0
+
-
π
(10a)
2006
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
3*LNC & LNC (lower)


9.5
2r" - Pr
Phase
Morletπ
6.5
TimeScale (a)
3.5
0
+
-
π
(10a)
2006
Est. Chandler Period (d)
440
435
430
425
420
415
Morlet2π
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000

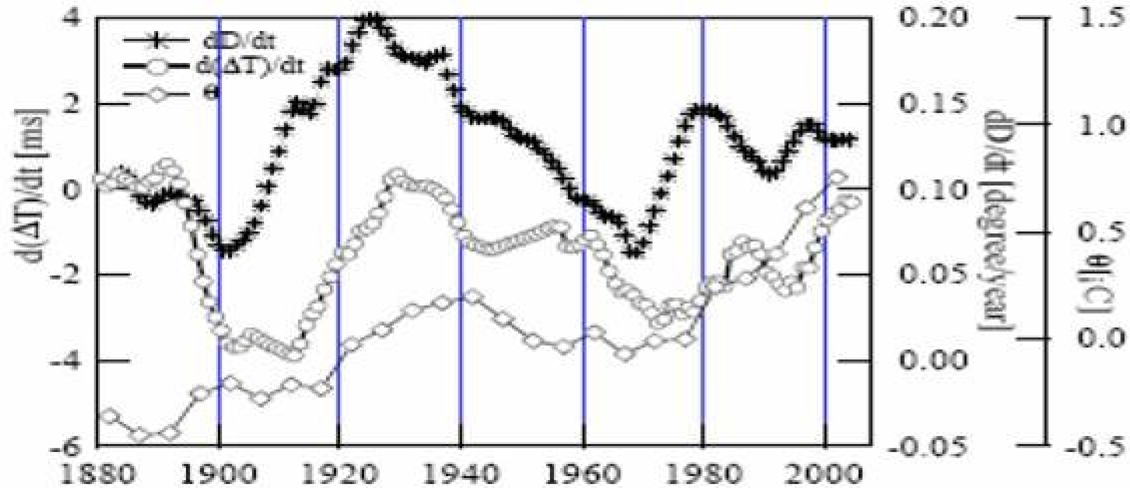


Figure 15 Secular variation of the geomagnetic declination for CLF observatory (*); excess length of the day (o); global temperature (◊).

Adapted from: Johnston, D.P. (2008). An alternative view of global warming. http://www.appinsys.com/GlobalWarming/Johnston_MagneticGW.pdf

Suggested:

Compare the patterns in the above figures with related figures from the literature

1) All figures here:
Ponyavin, D.I.; & Zolotova, N.V. (2004). Nonlinear analysis of climatic time series with cross recurrence plots.
http://geo.phys.spbu.ru/~ned/Ponyavin_and_Zolotova_2004.pdf

2) Figures 2 & 4:
Ponyavin, D.I.; Barliaeva, T.V.; & Zolotova, N.V. (2005). Hypersensitivity of climate response to solar activity output during the last 60 years. Memorie della Societa Astronomica Italiana 76, 1026-1029.
http://geo.phys.spbu.ru/~ned/P_B_Z_2005MmSAI..76.1026I.pdf

3) Figures 16-25:
Zolotova N.V.; & Ponyavin D.I. (2005). Recurrence and cross recurrence plot analysis of natural time series, Educational and methodical materials. St. Petersburg University Press. (in Russian)
http://geo.phys.spbu.ru/~ned/ZP_methodology.pdf

4) Figure 4:
Ponyavin, D.I. (2004). Solar cycle signal in geomagnetic activity and climate. Solar Physics 224, 465-471.

5) Figures 3, 5, 9b, & 11b:
Xue, Y.; Smith, T.M.; & Reynolds, R.W. (2003). Interdecadal Changes of 30-Yr SST Normals during 1871-2000. Journal of Climate 16, 1601-1612.
http://www.ncdc.noaa.gov/oa/climate/research/sst/papers/xue-etal.pdf

6) Figures 9, 10, & 11:
Carvalho, L.M.V.; Tsonis, A.A.; Jones, C.; Rocha, H.R.; & Polito, P.S. (2007). Anti-persistence in the global temperature anomaly field. Nonlinear Processes in Geophysics 14, 723-733.
http://www.uwm.edu/~aatsonis/npg-14-723-2007.pdf
http://www.icess.ucsb.edu/gem/papers/npg-14-723-2007.pdf

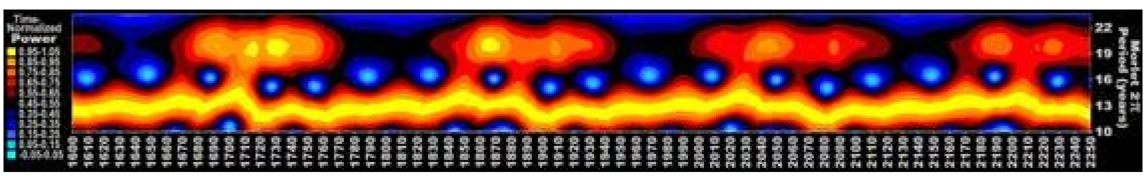
7) Figure 7:
Sidorenkov, N.S. (2005). Physics of the Earth’s rotation instabilities. Astronomical and Astrophysical Transactions 24(5), 425-439.
http://images.astronet.ru/pubd/2008/09/28/0001230882/425-439.pdf

8) Figure 1:
Sidorenkov, N.S. (2003). Changes in the Antarctic ice sheet mass and the instability of the Earth's rotation over the last 110 years. International Association of Geodesy Symposia 127, 339-346.

9) Figures 2 & 3:
Sidorenkov, N.S. (2005). The decade fluctuations of the Earth rotation velocity and of the secular polar motion. In: Journees 2004 - systemes de reference spatio-temporels. Fundamental astronomy: new concepts and models for high accuracy observations, Paris, 20-22 September 2004, edited by N. Capitaine, Paris: Observatoire de Paris, ISBN 2-901057-51-9, 2005, p.153-154.
http://syrte.obspm.fr/journees2004/PDF/Sidorenkov.pdf
"The initial cause of the decade oscillations of the atmospheric and oceanic circulations are, probably, the gravitational interaction between the Earth's non-spherical and eccentrical envelopes and the Moon, Sun, and planets (J.V.Barkin, 2002)."

10) Figure 3:
Keeling, C. D. & Whorf, T. P. (1997). Possible forcing of global temperature by the oceanic tides. Proceedings of the National Academy of Sciences of the USA 94(16), 8321-8328.
http://www.pnas.org/content/94/16/8321.full.pdf?ijkey=YjbRA3bMQaGic

11) Figures 7 & 8:
Abarca del Rio, R.; Gambis, D.; Salstein, D.; Nelson, P.; & Dai, A. (2003). Solar activity and earth rotation variability. Journal of Geodynamics 36, 423-443.
http://www.cgd.ucar.edu/cas/adai/papers/Abarca_delRio_etal_JGeodyn03.pdf
Compare with JS-timescale (19.86a) pattern here:



http://www.sfu.ca/~plv/RegimeChangePoints.PNG

12) Figure 2:
Trenberth, K.E. & Stepaniak, D.P. (2001). Indices of El Nino Evolution. Journal of Climate 14, 1697-1701.
http://www.cgd.ucar.edu/cas/Trenberth/trenberth.papers/tniJC.pdf

13) Tsonis, A.A.; Swanson, K.; & Kravtsov, S. (2007). A new dynamical mechanism for major climate shifts. Geophysical Research Letters 34, L13705.
http://www.uwm.edu/~aatsonis/2007GL030288.pdf

14) Klyashtorin, L.B.; & Lyubushin, A.A. (2007). Cyclic Climate Changes and Fish Productivity. Government of The Russian Federation, State Committee For Fisheries of The Russian Federation, Federal State Unitary Enterprise (FSUE), Russian Federal Research Institute of Fisheries and Oceanography (VNIRO). Moscow, VNIRO Publishing.
http://alexeylyubushin.narod.ru/Climate_Changes_and_Fish_Productivity.pdf

15) Klyashtorin, L.B. (2001). Climate change and long term fluctuations of commercial catches: the possibility of forecasting. FAO Fisheries Technical Paper No. 410,

98p., FAO (Food Agriculture Organization) of the United Nations, Rome.

html - main index:

http://www.fao.org/docrep/005/Y2787E/Y2787E00.HTM

pdf - directory of chapter-pdf-files:

ftp://ftp.fao.org/docrep/fao/005/y2787e/

Of particular interest:

Chapter 2. Dynamics of Climatic and Geophysical Indices

html:

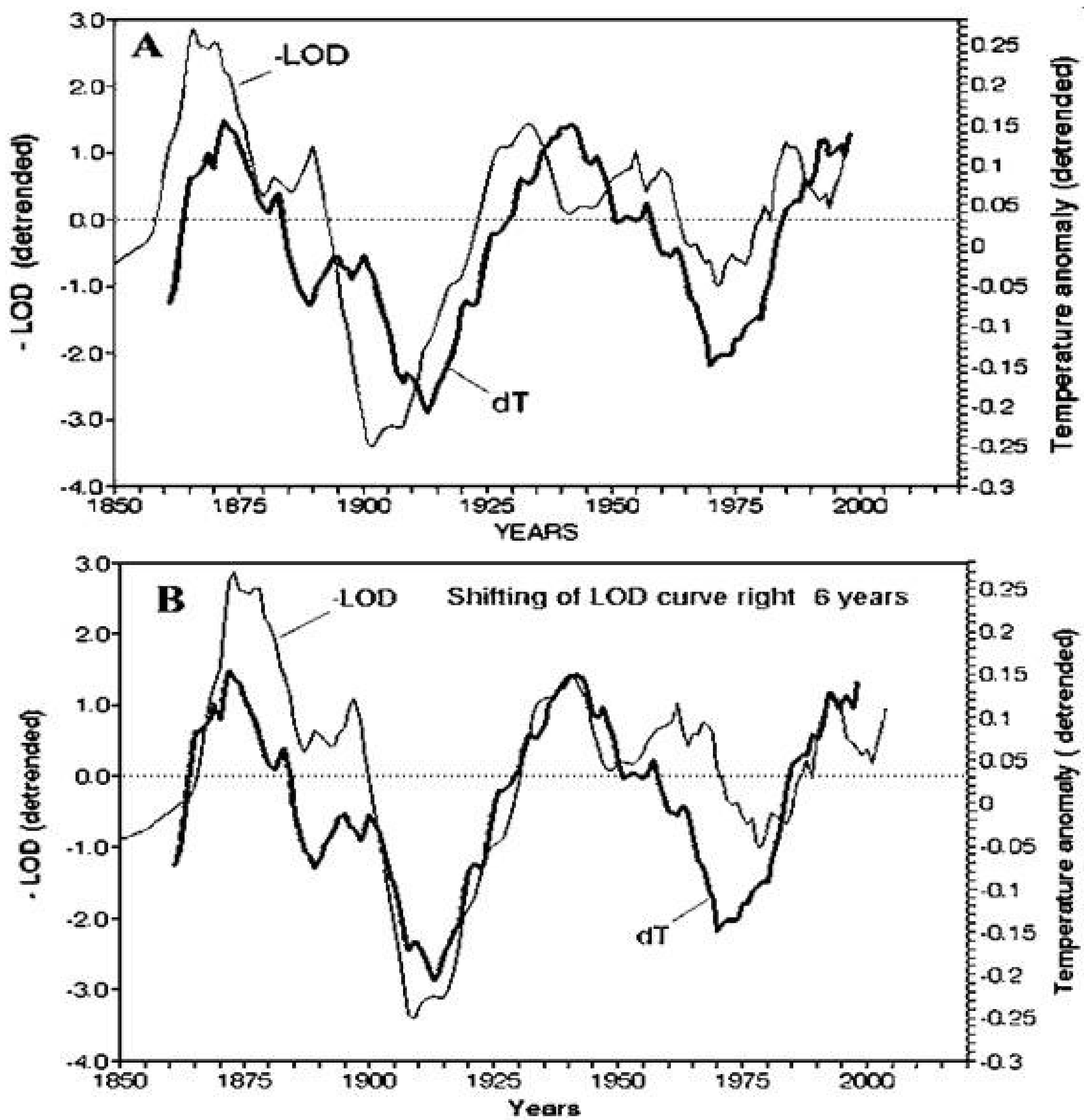
http://www.fao.org/docrep/005/Y2787E/Y2787E03.HTM

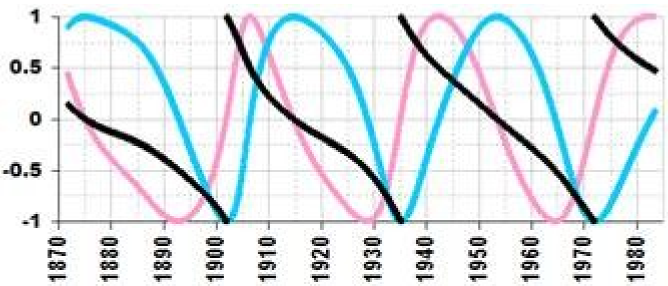
pdf:

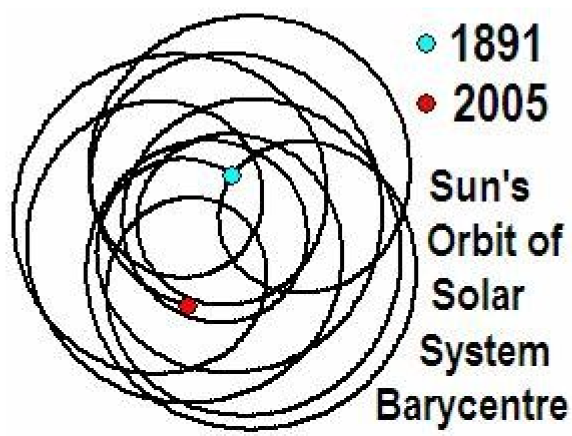
ftp://ftp.fao.org/docrep/fao/005/y2787e/y2787e01.pdf

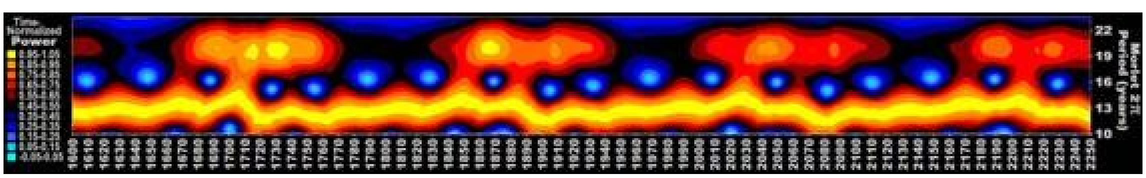
3 major climate indices:

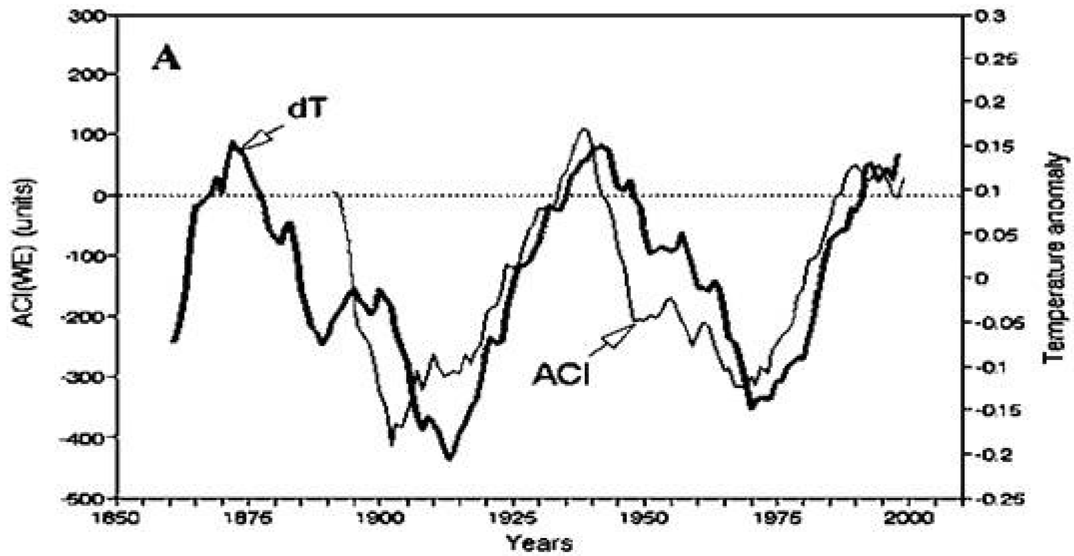
1) dT (global temperature anomaly)
2) Atmospheric Circulation Index (ACI)
3) LOD

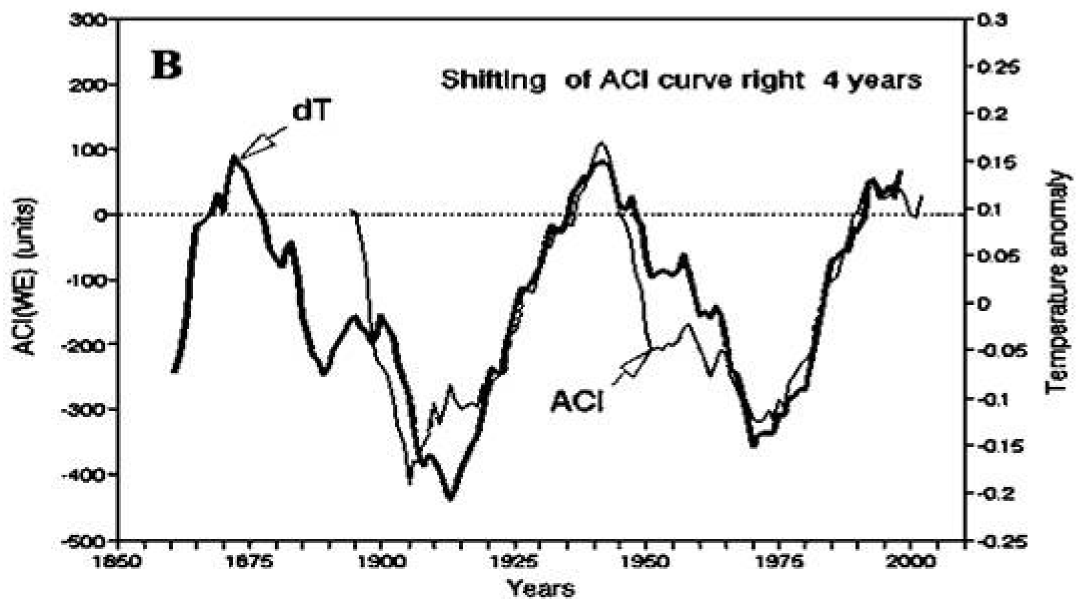


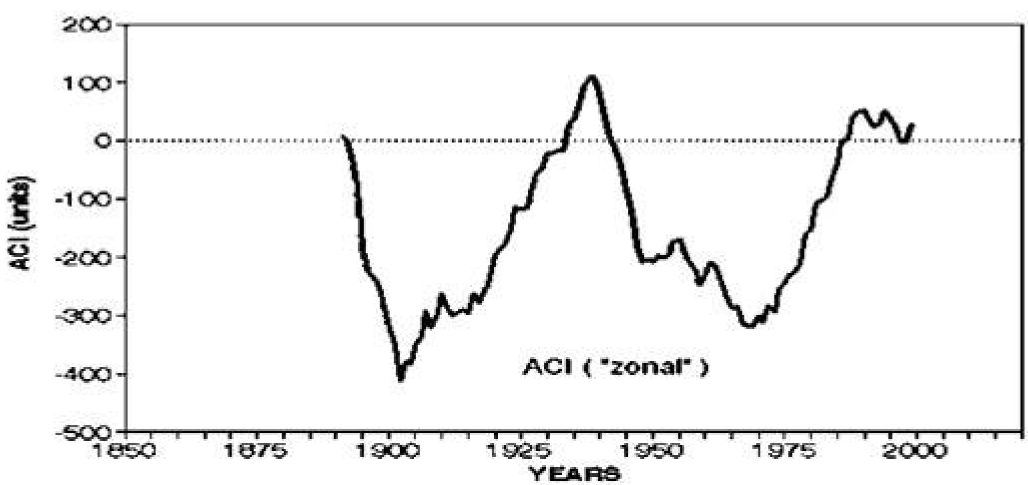

1
0.5
0
-0.5
-1
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980


1891
2005
Sun's Orbit of Solar System Barycentre




A
dT
ACI
ACI(WE) (units)
Temperature anomaly
300
200
100
0
-100
-200
-300
-400
-500
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1850
1875
1900
1925
1950
1975
2000
Years


B
Shifting of ACI curve right 4 years
dT
ACI
ACI(WE) (units)
Temperature anomaly
300
200
100
0
-100
-200
-300
-400
-500
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1850
1875
1900
1925
1950
1975
2000
Years


ACI ("zonal")
ACI (units)
200
100
0
-100
-200
-300
-400
-500
1850
1875
1900
1925
1950
1975
2000
YEARS

Earth moves with the sun, but what is happening instantaneously? The terrestrial polar motion empirical record suggests that Earth's heterogeneous shells respond differentially to celestial influences. As Barkin suggests, traditional assumptions (for example, concentricity & uniformity) are limiting factors in our conceptualization.

http://www.sfu.ca/~plv/RegimeChangePoints.PNG