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Are Changes in the Earth's Rotation Rate Externally Driven and Do They Affect Climate?

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ABSTRACT

Evidence is presented to show that the phases of two of the Earth's major climate systems, the North Atlantic Oscillation (NAO) and the Pacific Decadal Oscillation (PDO), are related to changes in the Earth's rotation rate. We find that the winter NAO index depends upon the time rate of change of the Earth's length of day (LOD). In addition, we find that there is a remarkable correlation between the years where the phase of the PDO is most positive and the years where the deviation of the Earth's LOD from its long-term trend is greatest.

In order to prove that the variations in the NAO and PDO indices are caused by changes in the Earth's rotation rate, and not the other way around, we show that there is a strong correlation between the times of maximum deviation of the Earth's LOD from its long-term trend and the times where there are abrupt asymmetries in the motion of the Sun about the CM of the Solar System.

At first glance, there does not appear to be an obvious physical phenomenon that would link the Sun's motion about the Solar System's CM to the Earth's rotation rate. However, such a link could occur if the rate of precession of the line-of-nodes of the Moon's orbit were synchronized with orbital periods of Terrestrial planets and Jupiter, which in turn would have to be synchronized with the orbital periods of the three remaining Jovian planets. In this case, the orbital periods of the Jovian planets, which cause the asymmetries in the Sun's motion about the CM, would be synchronized with a phenomenon that is known to cause variations in the Earth's rotation rate, namely the long term lunar tides.

The periodicities seen in the asymmetry of the solar motion about the CM are all submultiples of the 179 year Jose cycle, with the dominant periods being 1/5 (= 35.87 yrs), 1/9 (= 19.86 yrs) and 1/14 (12.78 yrs). In addition, the realignment time for the orbits of Venus, Earth and Jupiter is a ¼ of the 179 year Jose cycle (= 44.77 yrs).

Through what appears to be a "Grand Cosmic Conspiracy" we find that:

6.393 yrs = (the 179 year repetition cycle of the Solar motion about the CM) / 28

6.396 yrs = (the 44.77 year realignment time for Venus, Earth, and Jupiter) / 7

which just happens to be realignment time for orbits of the planets Venus, Earth and Mars (= 6.40 yrs).

The significance of the 6.40 year repetition period is given added weight by the fact that if you use it to modulate the sidereal year of the Earth/Moon system, the side-lobe period that is produced, almost perfectly matches the 2nd harmonic time interval over which there are the greatest changes in the meridional and zonal tidal stresses acting upon the Earth (1 ¼ T_D = 433.2751 days = 1.18622 years, where T_D is the draconitic year).

We know that the strongest planetary tidal forces acting on the lunar orbit come from the planets Venus, Mars and Jupiter. In addition, we known that, over the last 4.6 billion years, the Moon has slowly receded from the Earth. During the course of this lunar recession, there have been times when the orbital periods of Venus, Mars and Jupiter have been in resonance(s) with the precession rate for the line-of-nodes the lunar orbit. When these resonances have occurred, they would have greatly amplified the effects of the planetary tidal forces upon the lunar orbit. Hence, the observed synchronization between the precession rate of the line-of-nodes of the lunar orbit and the orbital periods of Venus, Earth, Mars and Jupiter, could simply be a cumulative fossil record left behind by these historical resonances.

INTRODUCTION

Measurements of the variation in the Earth's length-of-day (LOD) since 700 BC show that the changes in this parameter have two main components:

The first is a steady increase in LOD by 2.3 milliseconds/century (ms/100y) caused by the combined gravitational force of the Sun and Moon acting upon the tidal bulge in the Earth's oceans (Stephenson 2003).

The second is a steady decrease in the LOD by 0.6 ms/100y caused by the post-glacial isostatic compensation of the Earth's crust (Stephenson 2003). The isostatic compensation is produced by the steady rebounding of the Earth's polar crust following the removal of the great northern ice-sheets.

The combined effects of these two components means that, on centennial to millennial timescales, the Earth's overall average LOD has been increasing by ~ 1.7 ms/100y.

Hence, if you exclude the long-term variations caused by the post-glacial isostatic compensation, as well as the external lunar and solar tidal forces, the Earth system (i.e. the atmosphere, oceans, solid Earth and liquid core) can be regarded as a closed, angular momentum conserving system. Thus, it is generally assumed that any change in the angular momentum of the liquid part of the Earth system (i.e. the atmosphere, oceans and liquid core) must be matched by equal and opposite changes in the angular momentum of the solid Earth.

This model receives strong support from observations of the Earth's LOD, that show that, on inter-annual time scales, the observed variations in the total angular momentum of the solid Earth are almost completely accounted for by equal and opposite changes in the total angular momentum of the atmosphere (Dikey 1995).

Indeed, it is believed that most of the observed variations in the Earth's rotation rate, on time scales up to about five years, are produced by significant global climate events such as the annual seasonal changes in atmospheric winds, the El Nino/La Nina oscillation (ENSO) and the Quasi-Biannual Oscillation (QBO) (Chao 1989 and Dikey 1995).

Mound and Buffet (2006) argue that it is unlikely that changes in atmospheric angular momentum could be responsible for variations in the Earth's rotation on time scales greater than about five years. They find a regular 5.8 ± 0.8 year variation in the Earth's rotation rate, which they claim is produced by a normal mode oscillation in the Earth's liquid core. They proposed that angular momentum is transferred back and forth between the Earth's liquid core and its mantle through a gravitational coupling.

Finally, on decadal time scales, changes in the Earth's LOD have been shown to correlate well with changes in the core angular momentum, as determined from core flow models constrained by variations of geo-magnetic field (Mound and Buffet 2006). It is believed that these decadal fluctuations are produced by standing waves in the fluid core known as torsional oscillations (Dikey 1995, Mound and Buffet 2006).

Of course, the implicit assumption that is being made in all of these claims is that there are no external torques acting on the Earth other than those caused by the **known** tidal forces of the Sun and Moon. But what if this assumption is wrong? What if there are additional external torques acting about the Earth's rotation axis, on decadal to centennial timescales, that have not been fully accounted for as yet? Could these variations in external torque be responsible for climatic changes seen here on Earth over similar timescales?

Evidence is present in this paper to show that changes in two major global climatic systems (i.e. the North Atlantic Oscillation and the Pacific Decadal Oscillation) are correlated with variations in the Earth's rotation rate. By themselves, these correlations do not prove that the changes in the Earth climate are driven by variations in the Earth's rotation rate. Indeed, it is just as likely that, it is the variations in the Earth's atmospheric and oceanic circulation patterns, associated with changes in these climate systems, which are responsible for producing the observed variations in the Earth's rotation rate.

However, further evidence is presented to show that the variations in the Earth's rotation rate that are correlated with changes in the climactic systems, also appear to be correlated with the times of maximum asymmetry in the motion of the Sun about the centre-of-mass of the Solar System (CM).

This begs the question, how do the climate systems here on the Earth "know" about the motion of the Sun about the centre-of-mass of the Solar System (CM)?

The logical answer to this question is that they don't. What must really be happening is that an, as yet, unknown phenomenon, synchronized with the motion of the Sun about the centre-of-mass of the Solar System (CM), must be responsible for the inter-decadal variations in the Earth's rotation rate. The implication being that it is these externally-drive inter-decadal changes in Earth's rotation rate that are causing the long-term variations seen` in the Earth's climatic systems, and not the other way around.

In section one, we present evidence to show that the phase of the North Atlantic Oscillation (NAO) is determined by the rate of change of the Earth's LOD. In section two, we present data to show that the phase changes of the Pacific Decadal Oscillation (PDO) over the last 300 years are synchronized with abrupt variations in the Earth's LOD.

In section three, we show that that the times of maximum deviation of the Earth's LOD from its long-tem trend, are closely correlated with the times of maximum asymmetry in the motion of the Sun about the centre-of-mass of the Solar System (CM).

Finally, in section four, we discuss the full implications of this finding, namely that it suggests that the changes in Earth's rotation rate must be externally driven, and it is these changes in the Earth's rotation rate that are responsible for the long-term variations seen in the Earth's climatic systems.

The central problem with this proof is that correlation is not causation. Just because we can show that the inter-decadal variations in the Earth's rotation rate are synchronized with the Sun's motion about the CM, does not prove that there a physically link between the two. Hence, we will extend the discussion in section four to include a brief description of a Cosmic Conspiracy model that can explain the link between the Sun's Barycentric motion and the inter-decadal changes in the Earth's rotation rate.

1. THE NORTH ATLANTIC OSCILLATION

One climate system that shows strong evidence that it is associated with changes in the Earth's rotation rate is the winter North Atlantic Oscillation (NAO). The phase of the winter NAO depends on the relative strengths of the high pressure systems centred on the islands of the Azores in the sub-tropical North Atlantic and the low pressure systems centred near Iceland and Greenland.

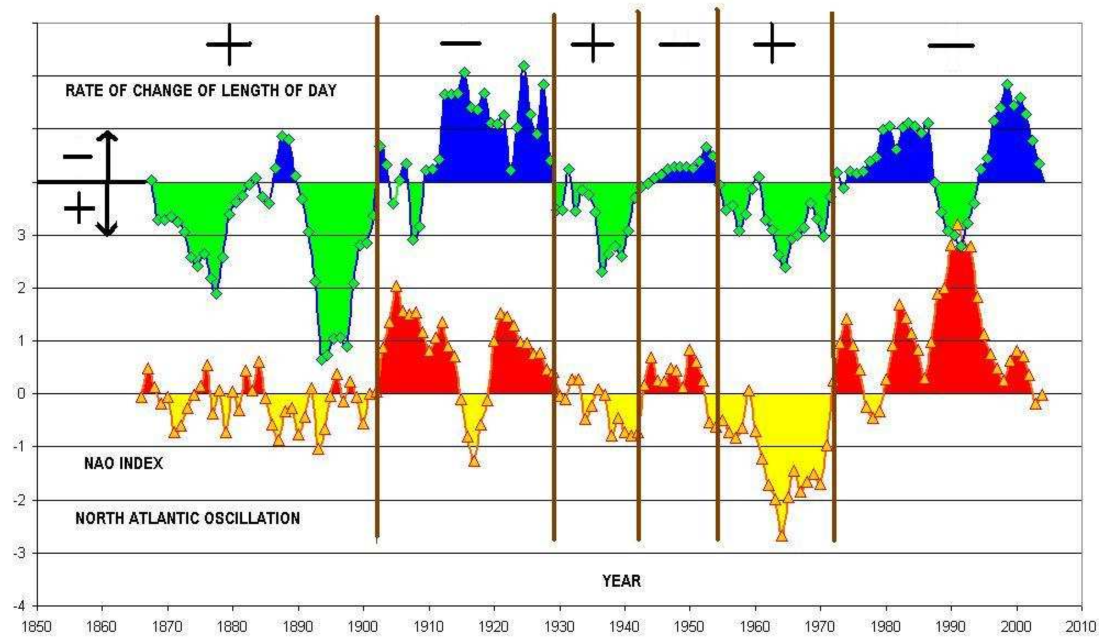


Figure 1: The top graph shows the time rate of change of the Earth's length of day (LOD) between 1865 and 2005. (Note: The LOD data has been transformed into arbitrary units so that it can be compared to the NAO index). Positive means that LOD of day is increasing compared to its standard value of 86400 seconds and that Earth is slowing down. The bottom graph shows the North Atlantic Oscillation Index between 1864 and 2006. The data points that are plotted in both graphs have been obtained by taking a five year running mean of the raw data.

The NAO is in a positive phase when the sub-tropical high pressure systems and the Icelandic low pressure systems are both stronger than normal. When the NAO is in this phase, the increased pressure gradient between the two systems leads to stronger and more frequent winter storms moving towards Europe on a more northerly track. This produces milder and wetter winters across much of northern Europe and colder and dryer winters across northern Canada and Greenland.

The NAO is in a negative phase when the sub-tropical high pressure systems and the Icelandic low pressure systems are both weaker than normal. When the NAO is in this phase, the decreased pressure gradient between the two systems leads to weaker and less frequent winter storms moving towards Europe on a more easterly track. This brings moist air into the Mediterranean regions and colder and drier air to northern Europe (UK Meteorological Office: http://www.metoffice.gov.uk/research/seasonal/regional/nao/index.html).

The top graph in figure 1 shows the time rate of change of the Earth's length of day (LOD) between 1865 and 2005. The time rate of change of the LOD is derived from LOD data that was kindly provided by Dr. N. Sidorenkov of the Hydrometcentre of the Russian Federation in Moscow. The data points that are plotted have been obtained by taking a five year running mean of the time rate of change data (Note: The LOD data has been transformed into arbitrary units so that it can be compared to the NAO index). Positive means that LOD of day is increasing compared to its standard value of 86,400 seconds and that Earth is slowing down.

The bottom graph in figure 1 shows the North Atlantic Oscillation Index between 1864 and 2006. The values for this winter NAO index are those published by: Dr. James Hurrell, NCAR/Climate and Global Dynamics Division (2007) at: http://www.cgd.ucar.edu/cas/jhurrell/Data/naodjfmindex.asc .

The data points that are plotted have been obtained by taking a five year running mean of the raw data.

Figure 1 clearly shows that the phase of the NAO index correlates with the time rate of change of the Earth's LOD. The figure highlights the point that whenever the rate of change of the LOD is negative (i.e. the Earth's rotation rate is increasing) the NAO is positive and whenever rate of change of the LOD is positive (i.e. the Earth's rotation rate is decreasing) the NAO is negative.

Hence, the winter NAO index is a good example of a climate subsystem that is directly associated with changes in the Earth's rotation rate. Unfortunately, there is no way of determining whether it is the fluctuations in the Earth's rotation rate that determine the phases of the NAO or the other way around. Nor does it tell us whether or not the observed changes in the Earth's rotation rate are caused by external torques. The only conclusion that can be drawn from this data is that long term changes in North Atlantic climate subsystem has an effect upon, or is affected by, changes in the Earth's rotation rate.

2. THE PACIFIC DECADAL OSCILLATION

The "Pacific Decadal Oscillation" (PDO) is a long-lived El Niño/La Niña-like pattern that is observed in the sea-surface temperatures (SST) of northern and central Pacific oceans. Positive (/negative) phases of the PDO are typified by warmer (/cooler) than normal temperatures in the north-eastern and tropical Pacific Ocean and cooler (/warmer) than normal temperatures in the region to the south-west of the Aleutian Islands.

The Pacific Decadal Oscillation (PDO) Index is defined as the leading principal component from an un-rotated EOF analysis of monthly residual North Pacific SST anomalies, poleward of 20^{o}N for the period 1900 – 1993 (Hare 1996, Zhang 1996, Mantua et al. 1997). The residuals are defined as the difference between the observed SST anomalies and the monthly mean global average SST anomaly (Zhang et al. 1997).

Unfortunately, instrumental SST data for the Pacific Ocean have only been recorded for a little over one century. This means that if we want to study the PDO index prior to 1900, we must use proxy data such as high resolution tree-ring widths (Biondi et al. 2001, D'Arrigo et al. 2001, Gedalof and Smith 2001, MacDonald and Case 2005) to reconstruct the annual PDO index.

Published PDO reconstructions differ depending upon whether they have been obtained using tree-ring data that is primarily sensitive to variations in precipitation (Biondi et al. 2001 and MacDonald and Case 2005) or from tree-ring data that is primarily sensitive to variations in air temperature (D'Arrigo et al. 2001). Both types of PDO reconstruction are calibrated using the available SST data obtained after 1900.

The tree-ring sites used by Biondi et al. (2001) are located in the mountains of southern California and Northern Baja California in Mexico, in a direction roughly parallel to the coastline. The tree-ring records used in their study come from Jeffrey pine (*Pinus jeffreys*) and big-cone Douglas fir (*Pseudotsuga macrocarpa*). Xylem growth rates of these species are mostly influence by cool-season precipitation variability (Biondi et al. 2001).

The tree ring sites used by MacDonald and Case (2005) were specifically chosen to be at opposite ends of the PDO precipitation dipole that exists between the SW United States and Rocky mountains of western Canada. The tree-ring records used in their study come from James pine (*Pinus flexilis*), a species that is known to be useful in producing dendroclimatological records of precipitation and stream flow (MacDonald and Case 2005).

Figure 2a compares the precipitation-sensitive PDO reconstruction of Biondi et al. (2001) with that of MacDonald and Case (2005). Overall, there is excellent agreement between the two PDO reconstructions. However, the agreement between reconstructed PDO indices breaks down when the precipitation-sensitive indices are compared with the temperature-sensitive indices.

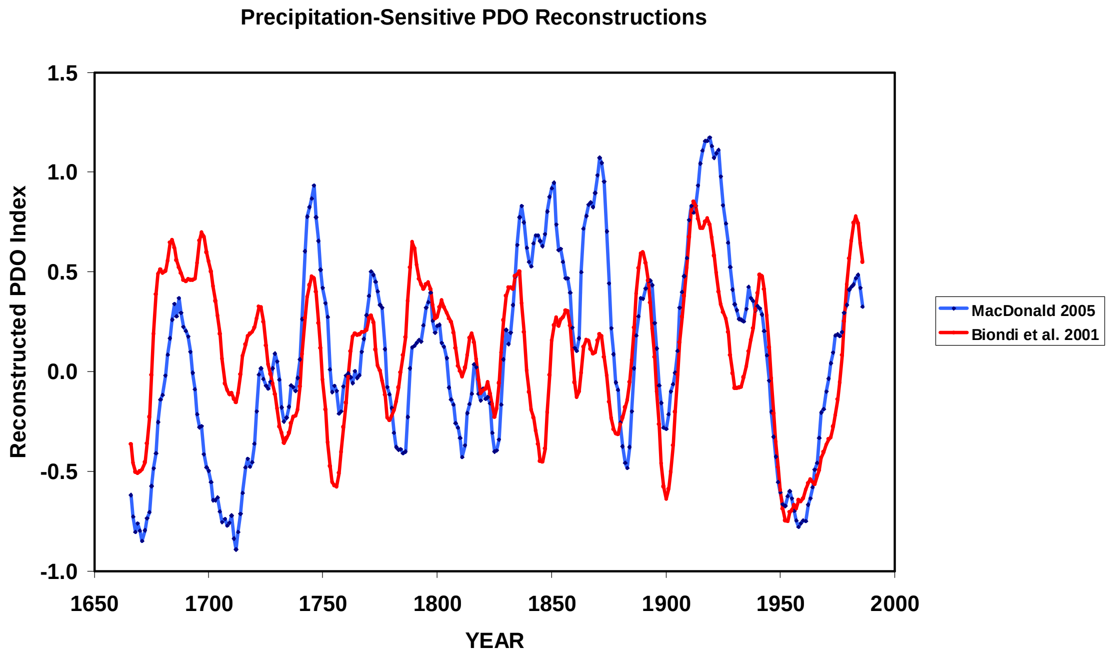


Figure 2a: compares the precipitation-sensitive PDO reconstruction of Biondi et al. (2001) with that of MacDonald and Case (2005).

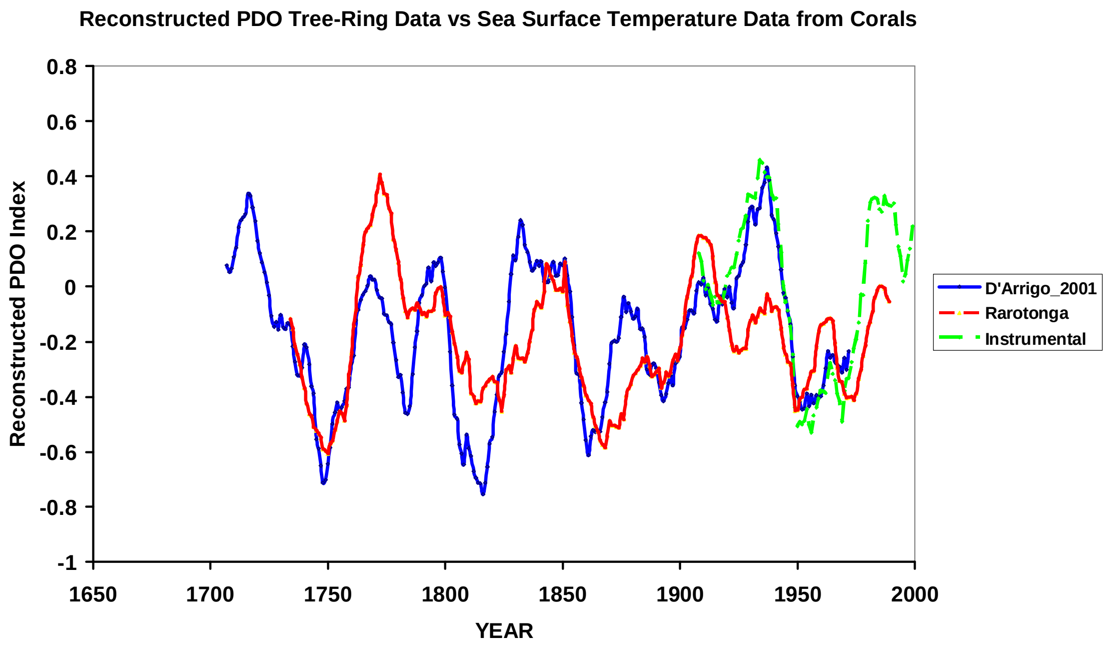


Figure 2b: shows the Rarotonga SST published by Lindsey et al. (2000) compared to the temperature-sensitive PDO reconstruction of D'Arrigo et al. (2001). The actual SST have been de-trended, inverted and scaled to allow them to be compared with the PDO index.

The tree ring sites used by D'Arrigo et al. (2001) are mostly located at coastal mountain sites along the Gulf of Alaska. The bulk of the tree ring data used in their study

come from mountain hemlock, a species whose tree ring widths are temperature-sensitive. However, their study also includes some precipitation-sensitive data obtained from Sitka Spruce that are found in Northern Mexico. Figure 2b shows the (predominantly) temperature-sensitive PDO reconstruction obtained by D'Arrigo et al. (2001).

A comparison between figures 2a and 2b shows that there are many peaks in the precipitation-sensitive PDO index in figure 2a that are also present in the temperature-sensitive PDO index in figure 2b. However, there are peaks in the precipitation-sensitive PDO reconstruction centred on the years: 1746, 1817, 1868, 1893 and 1920 that are definitely absent from the temperature-sensitive PDO reconstruction.

The difference between the two data sets should come as no surprise, given the implicit assumption that is made when these data sets are calibrated. The calibration methods assume that a proxy PDO index can be reconstructed by matching either the precipitation or temperature conditions at the study site with the instrumental North Pacific SST, at any given time. This allows the researcher to match the tree-ring growth rates with the measured instrumental PDO indices.

Unfortunately, the actual link between SST of the north-central Pacific Ocean and the corresponding temperatures and precipitation levels on the adjacent continents is not fully understood (Gedalof and Smith 2001). Combining this with the fact that the PDO has changed phase only three times throughout the instrumental period (Gedalof and Smith 2001), means that there is considerable uncertainty as to which PDO reconstruction serves as a better proxy of the actual PDO index.

In order to resolve this uncertainty, we have compared the two types of tree-ring PDO reconstructions with proxy SST that have been obtained by Linsley et al. (2000 & 2004). These SST have been derived using the Sr/Ca ratios measured in corals at Rarotonga in the South Pacific.

Figure 2b shows the Rarotonga SST published by Lindsey et al. (2000) compared to the temperature-sensitive PDO reconstruction of D'Arrigo et al. (2001). The actual SST have been de-trended, inverted and scaled to allow them to be compared with the PDO index. The inversion is necessary because whenever the SST in the Bay of Alaska are warmer than normal, the SST near Rarotonga are cooler than normal, and vice versa.

We can see from figure 2b that there is an excellent correlation between the temperature-sensitive PDO reconstruction of D'Arrigo et al. (2001) and the de-trended scaled and inverted Rarotonga SST. Indeed, it is clear that this correlation is a much better than that between the precipitation-sensitive reconstructions and the Rarotonga SST. Thus, we conclude that the temperature-sensitive PDO reconstruction is a better proxy for the actual PDO index than precipitation-sensitive PDO reconstructions.

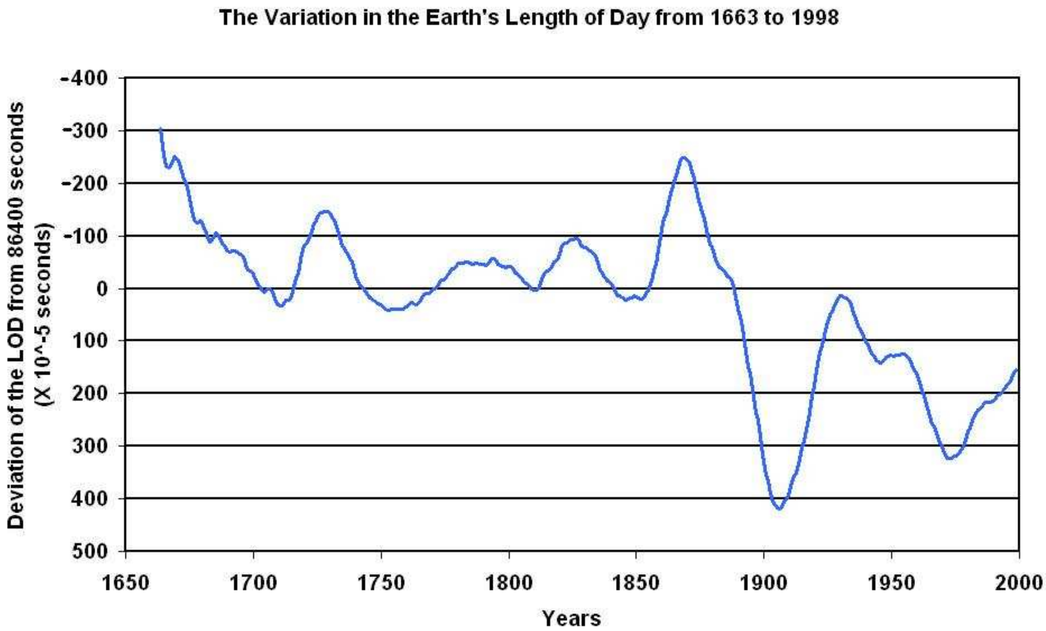


Figure 3: The difference between the actual LOD and the nominal LOD value of 86400 seconds, measured in milliseconds. The raw data has been smoothed using a 15 year running mean. In addition, the vertical scale has been inverted to so that up on the graph corresponds to an increase in the Earth's rotation rate.

Hence, from this point on, we will use the D'Arrigo et al. (2001) PDO reconstruction as our proxy PDO index.

In order to show that variations in the phases of the PDO are correlated with changes in the rotation rate of the Earth, we need to de-trend the Earth's LOD so that we can isolate the multi-decadal variations in the data.

DE-TRENDING THE EARTH'S LENGTH OF DAY

Figure 3 shows the variation of the Earth's length-of-day (LOD) from 1656 to 2005 (Sidorenkov 2005). The values shown in the graph are the difference between the actual LOD and the nominal LOD value of 86400 seconds, measured in milliseconds. The raw data has been smoothed using a 15 years running mean and the vertical scale has been inverted so that up on the graph corresponds to an increase in the Earth's rotation rate.

The general impression one gets about the long-term trend in the LOD variations in figure 3 are that it steadily decreases until 1700 A.D., levels out between 1700 and 1900 A.D., and then starts steadily decreasing again sometime immediately after 1900 A.D.

Unfortunately, any attempt to fit a long-term trend to the data in figure 3 is fraught with danger because the LOD is constantly varying. At best, the long-term trend that is adopted can only be an approximation to the actual trend in the data.

Given this uncertainty, we have decided to use three different methods to de-trend the data. As we use each de-trending method, we describe its limitations and highlight any assumptions that are being a made about the long-term trends. Finally, we compare the de-trended results from all three methods so that the reader can judge the robustness of the final result for themselves.

a. Low order polynomial fits to the whole data set

Figure 4 shows a first order polynomial fit to the LOD variations. The main advantage of a first order fit is that it makes the least assumptions about the general form of the long-term trends in the data.

We can see from this figure, that a linear fit can be used to successfully reproduce the gradual drop in the Earth's LOD over the 335 year time frame, however, this type of fit cannot reproduce the rapid changes in the LOD that are observed before 1700 A.D. and after 1900 A.D. In order to match these additional trends in the long-term data, a third order polynomial fit is required.

A third order polynomial fit to the LOD data is also shown in figure 4. It is evident from this figure that, unlike the linear fit, a third order fit can partially reproduce the observed decrease in LOD after 1900 A.D. However, it fails to significantly improve the quality of fit achieved by the first order polynomial prior to 1700 A.D.

Ideally, we should use a polynomial with order four or higher to better fit the decreases in LOD before 1700 A.D. and after 1900 A.D. However, we are limited from doing so

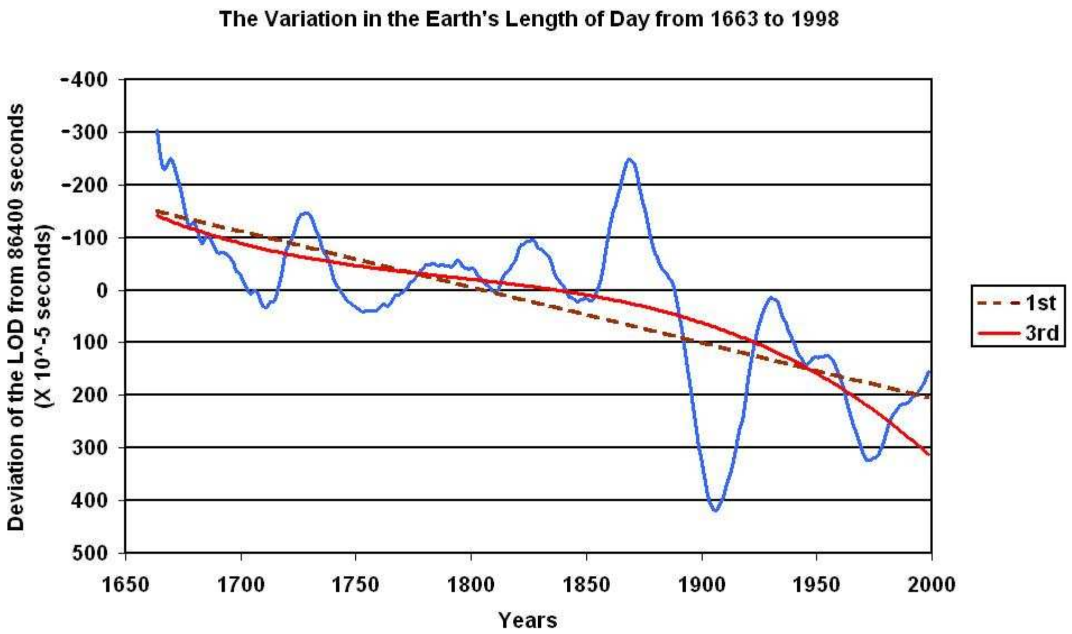


Figure 4: A first and a third order polynomial fitted to the LOD curve.

because polynomial fits with order greater than three are sensitive to short-term variations in the data.

b. Replacing a segment of the data set by its mean

The long-term trend in LOD data in figure 3 has two clear inflection points. The first is near 1700 A.D. where the LOD data stops steadily decreasing and abruptly levels off. After 1700 A.D., the long-term trend in the LOD appears to remain relatively constant until it reaches the second inflection point near 1900 A.D. After this date, the LOD starts to steadily decrease once more.

One way to obtain a better fit to the two ends of the LOD time series is to replace the segment of data between the two points of inflection by its mean value, and then fit a high order polynomial to the modified data. The problem is to identify the exact dates associated with the inflection points. Fortunately, the first inflection point is quiet abrupt, and so it must be close to 1700 A.D. However, the location of the second inflection point is not so clear cut. Figure 5 shows a set of three, sixth order polynomials, fitted to a modified LOD curve.

The LOD data used for each fit has been modified so that its data points have been replaced by the mean value for the LOD between 1700 A.D. and the date shown. All that we can say, is that it probably lies somewhere between 1900 and 1930 A.D.

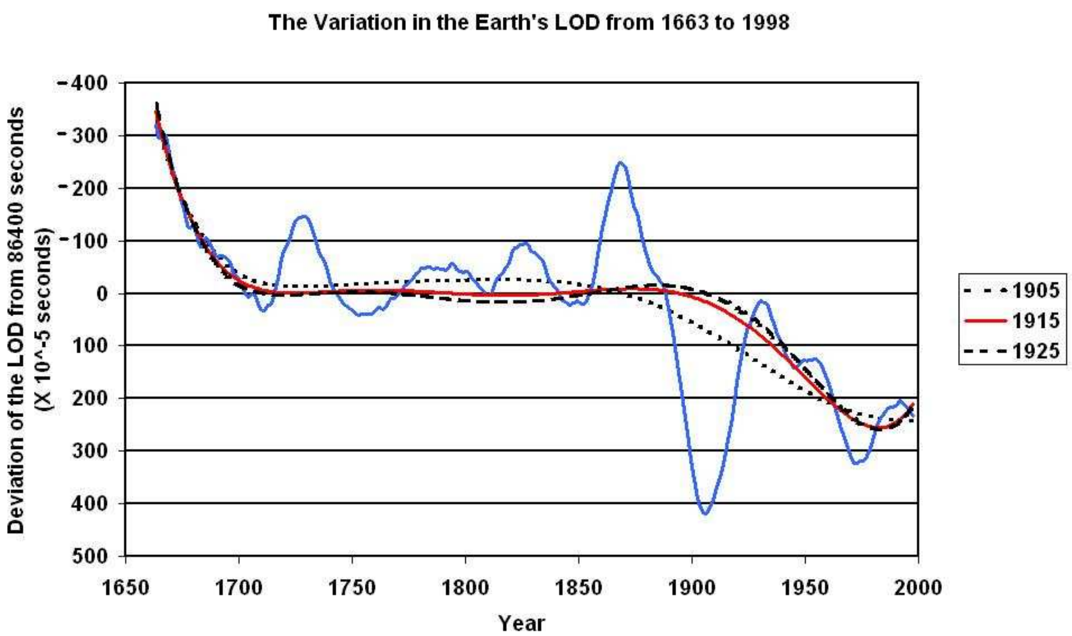


Figure 5: A set of three, sixth order polynomials, fitted to a modified LOD curve. The LOD data used for each fit has been modified so that its data points have been replaced by the mean value for the LOD between 1700 A.D. and the date shown.

It is clear that this fitting method does a much better job than the low order polynomial fits, when it comes to fitting the trends at either end of the LOD time series. However, it does so at the expense of making the assumption that the long-term trend in the LOD between 1700 and 1900 A.D. is flat.

c. Singular spectral analysis

Singular spectral analysis (SSA) is an excellent technique for extracting trends from time series data. The long term trend for the data series is given by the curve that is reconstructed from the first principal component of the SSA.

Normally, the SSA is done with a data window that is no more than 1/5th the length of the time series. Given that our LOD series spans 350 years, this means that we should use a data window with a length of 70 years. However, it is clear that LOD data series contains quiet strong variations with time scales of 50 – 70 years. In order to avoid this problem, we have use data windows whose lengths range from just under one third (i.e. 115 years), up to a maximum of one half of the full series length (i.e. 175 years).

Figure 6 shows SSA reconstruction from first principal component for a window length of 175 years. There is little discernable difference between the reconstructed curves if you vary the data window length from 115 to 175 years. However, the reconstructed curve begins to move upward if the data window length is made shorter than 115 years. This happens because the SAA fitting process starts to become sensitive to the short-term trends in the LOD data series.

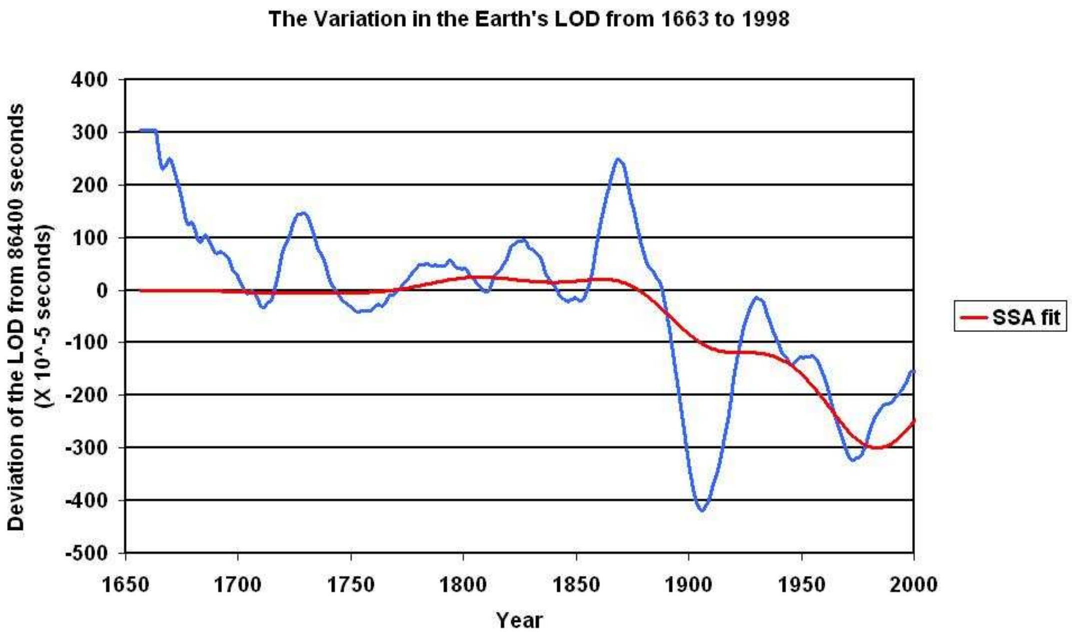
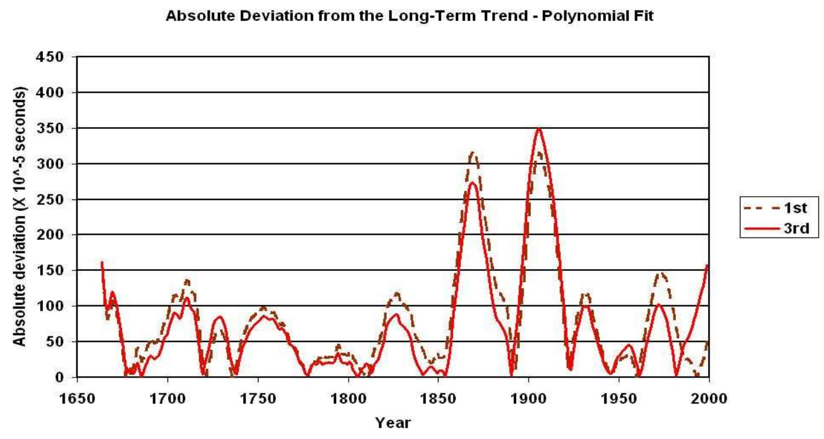
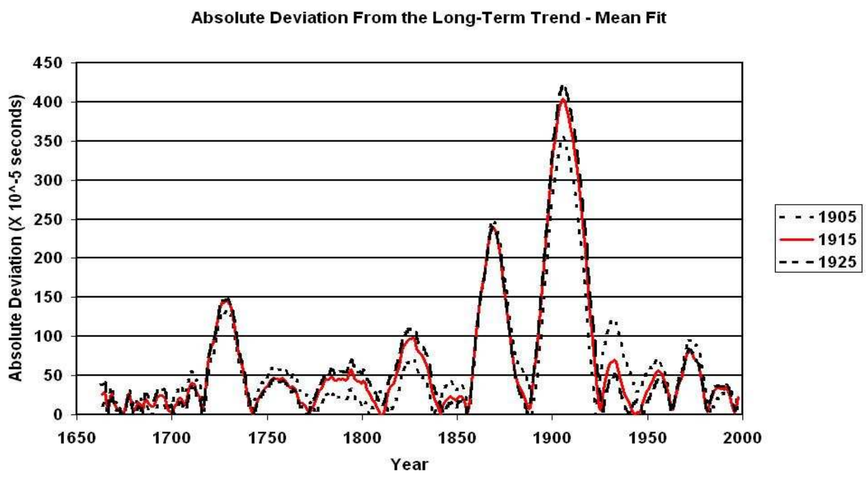


Figure 6: The reconstructed curve from the first principal component of the SSA of the LOD data for a data window length of 175 years. The first principal component accounts for 37.4 % of the total variance for a window length of 175 years and 37.7 % of the total variance for a window length of 115 years.

a)



b)



c)

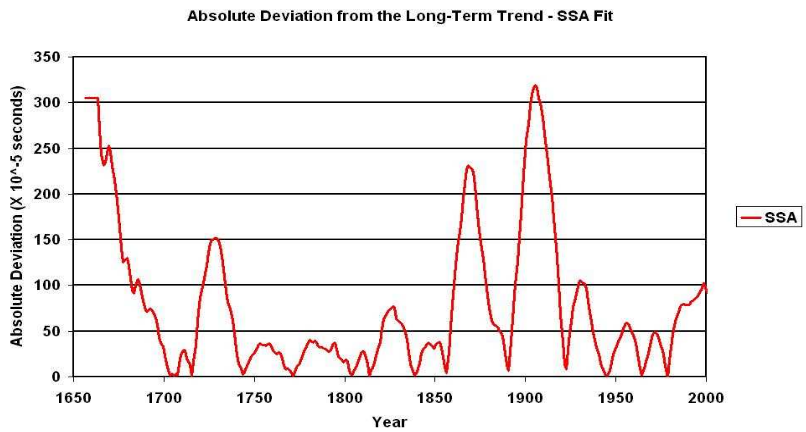


Figure 7: The absolute deviation of the LOD from the long term trend for the polynomial fitting method (7a), the mean fitting method (7b), and the SSA fitting method (7c).

d. A comparison of the three de-trending methods

Figures 7a, 7b and 7c show the absolute deviation of the LOD from the long term trend for the polynomial fit, the mean fit and the SSA fit, respectively. We have chosen to present the data in the form of absolute deviations from the long term mean as there is no certainty as to whether or not the sign of the deviation (i.e. whether it is positive or negative) is of physical importance.

Comparing these three graphs, we can identify nine significant peaks in the absolute deviation that are produced by all three fitting methods. These peaks are centered on the years 1729, 1757, 1792, 1827, 1869, 1906, 1932, 1956 and 1972.

COMPARING VARIATIONS IN THE PDO AND THE DE-TRENDED LOD

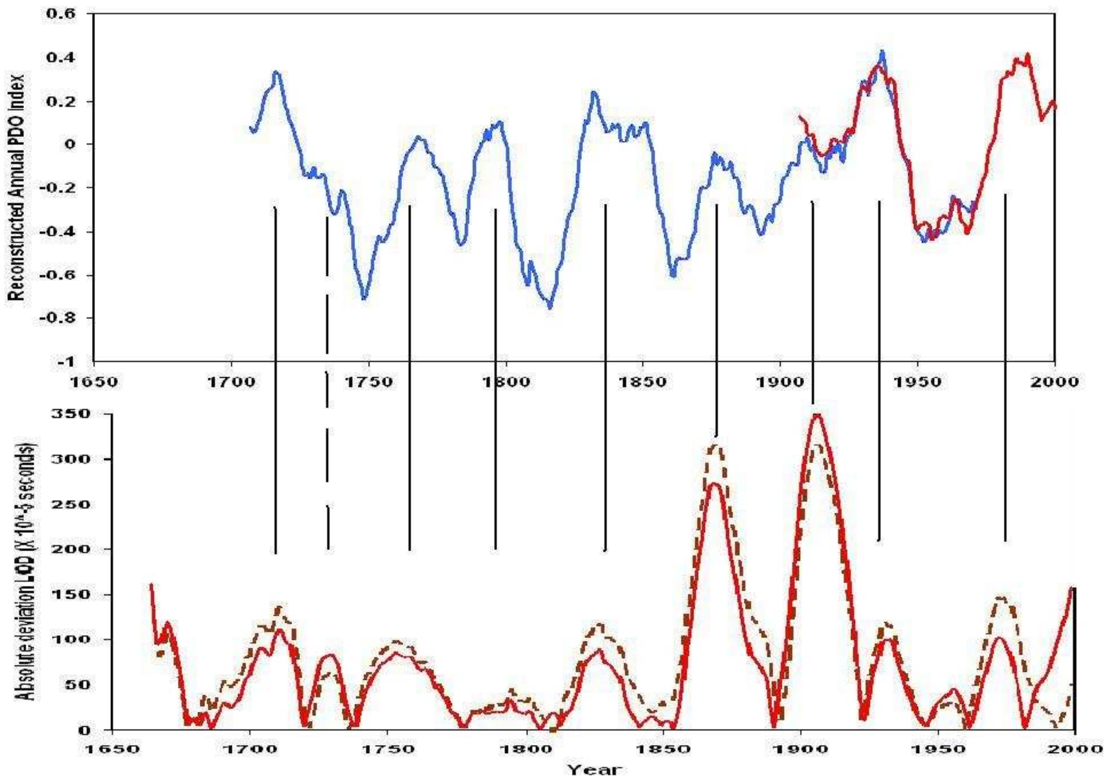


Figure 8: The upper graph shows the PDO reconstruction of D'Arrigo et al. (2001) between 1707 and 1972. The reconstruction has been smoothed with a 15-year running mean filter to eliminate short-term fluctuations. Superimposed on this PDO reconstruction is the instrumental mean annual PDO index (Mantua 2007) which extends the PDO series up to the year 2000. The lower graph shows the absolute deviation of the Earth's LOD from 1656 to 2005. The data in this figure has also been smoothed with a 15-year running mean filter.

A comparison between the upper and lower graph in figure 8 shows that, again, there is a remarkable agreement between the years of the peak (absolute) deviations of the LOD from the long-term trend and the years where the phase of the PDO reconstruction is most positive. While the correlation is not perfect, it is convincing enough to conclude the PDO index is another good example of a climate system that is directly associated with changes in the Earth's rotation rate.

Our result confirms the work of Minobe (2001), who found a statistically significant correlation between the PPO (Pacific Pentadecdal Oscillation), a climate index that is a close variant of the PDO, and the Earth's LOD.

Again, there is no way of determining whether it is the fluctuations in the Earth's rotation rate that determine the phases of the PDO or the other way around. Nor does it tell us whether or not the observed changes in the Earth's rotation rate are caused by external torques. The only conclusion that can be drawn from this data is that long term changes in PDO climate system has an affect upon, or is affected by, changes in the Earth's rotation rate.

In order to prove that it is the change in the Earth's rotation rate that is responsible for the variations seen in the PDO index, we need to show that the observed inter-decadal deviation in the Earth's LOD are synchronized with variations that are seen in a phenomenon that is external to the Earth.

3. THE SUN'S ASSYMETRIC MOTION ABOUT THE CENTRE OF MASS

Many people assume that the CM of the Solar System resides at the centre of the Sun. In fact, the Sun moves about the CM in a series of complex spirals, with the distance between the two varying from 0.01 and 2.19 solar radii (José 1965). This motion is the direct result of the gravitational forces of the Jovian planets tugging on the Sun.

If Jupiter was the only outer giant (Jovian) planet in the Solar System, the Sun would move about the CM of the Solar System in a slightly elliptical orbit (e = 0.048) with a semi-major axis of 1.08 solar radii, and a period of 11.86 years i.e. the Sun would revolve smoothly about a point located just above its surface.

However, the Solar System has three additional Jovian planets. Their presence means that the Sun's motion about the CM is subject to periodic asymmetries in its motion that can be very abrupt. In order to highlight the abrupt asymmetries in the Sun's motion, we need to remove the relatively smooth, almost circular motion of the Sun about the CM that results from gravitational tugging by Jupiter.

Figure 9 shows the Sun in a reference frame that is rotating with the planet Jupiter. The perspective is the one you would see if you were near the Sun's pole. A unit circle is drawn on the left side of figure 9 to represent the Sun, using an x and y scales marked in solar radii.

In the reference frame shown in figure 9, the smooth motion of the Sun that results from Jupiter's gravitational influence is removed. This means that the CM of the Sun/Jupiter system is a stationary point, located just above the Sun's right-hand surface on the x-axis at the co-ordinate (1.08, 0.00). We call this point the Sub-Jupiter point.

Also shown in figure 9, is the position of the CM of the Solar System for the years 1780 to 1820 A.D. (The Sky Level IV v5.00). The path starts in the year 1780, with each successive year being marked off on the curve, as you move in a clockwise direction.

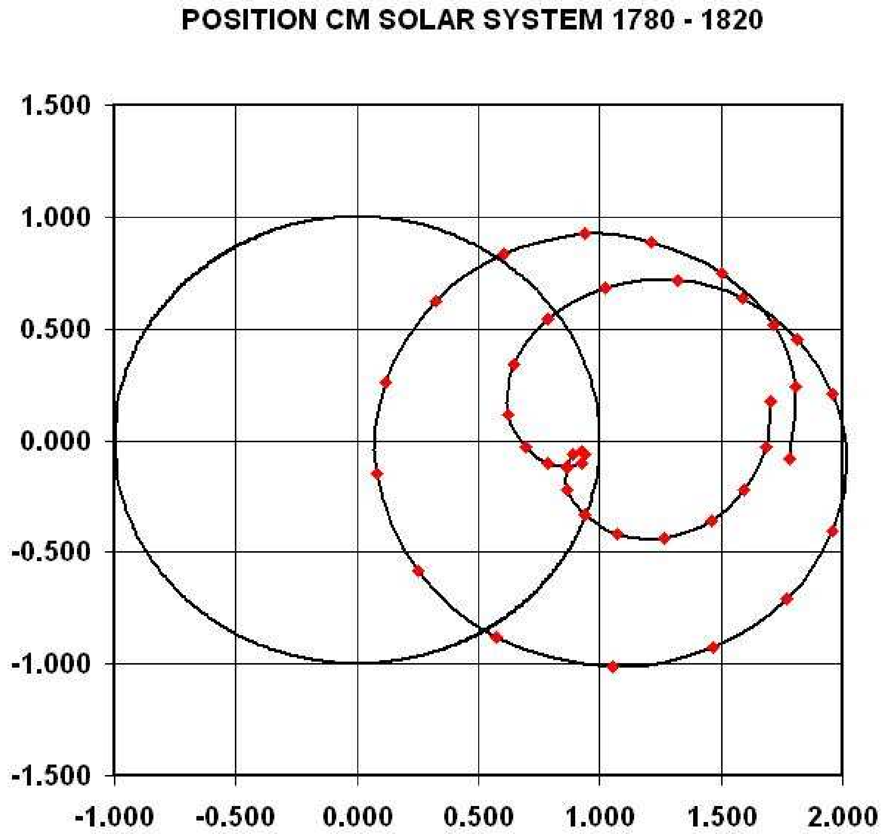


Figure 9: The Sun in a reference frame that is rotating with the planet Jupiter. The perspective is the one you would see if you were near the Sun's pole. A unit circle is drawn on the left side of this figure to represent the Sun, using an x and y scales marked in solar radii. The position of the CM of the Solar System is also shown for the years 1780 to 1820 A.D. The path starts in the year 1780, with each successive year being marked off on the curve, as you move in a clockwise direction. This shows that the maximum asymmetry in the Sun's motion occurred roughly around 1790-91.

The path of the CM of the Solar System about the Sun that is shown in figure 9 mirrors the typical motion of the Sun about the CM of the Solar System. This motion is caused by the combined gravitational influences of Saturn, Neptune, and to a lesser extent Uranus, tugging on the Sun.

The motion of the CM shown in figure 9 repeats itself roughly once every 40 years. The timing and level of asymmetry of Sun's motion is set, respectively, by when and how close the path approaches the point (0.95, 0.0), just to the left of the Sub-Jupiter point. Hence, we can quantify the magnitude and timing of the Sun's asymmetric motion by measuring the distance of the CM from the point (0.95, 0.0).

Figure 10 shows a plot of the distance of the CM of the Solar System (in solar radii) from the point (0.95, 0.00) between 1650 and 2000 A.D. The distance scale is inverted so that the top of the peaks correspond to the times when the Sun's motion about the CM is most asymmetric.

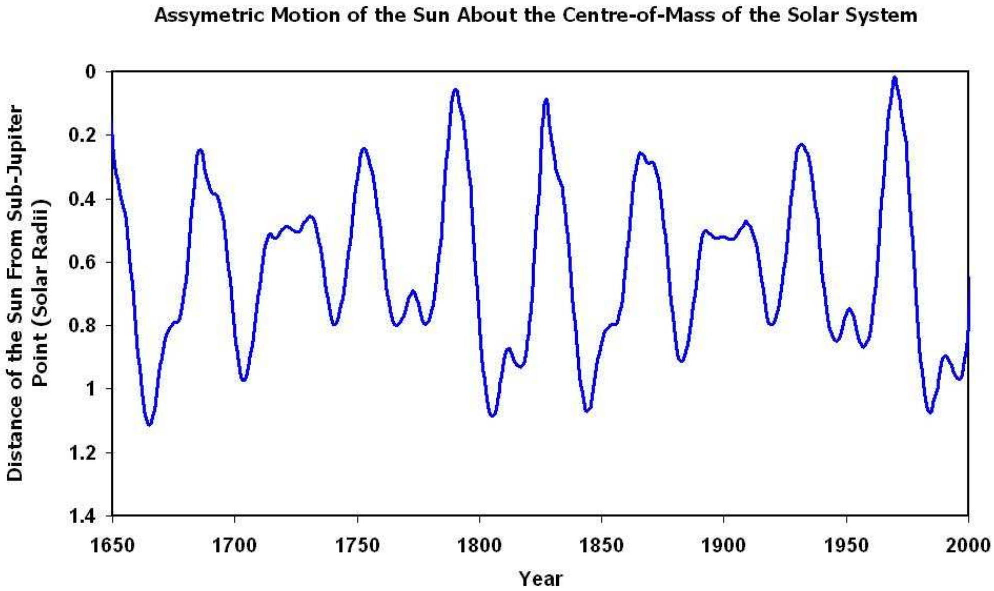


Figure 10: The distance of the CM of the Solar System (in solar radii) from the point (0.95, 0.00) between 1650 and 2000 A.D. The distance scale is inverted so that top of the peaks correspond to the times when the Sun's motion about the CM is most asymmetric.

An inspection of figure 10 shows that there are times between 1700 and 2000 A.D. where the CM of the Solar System approaches the point (0.095, 0.00). These are centred on the years, 1724, 1753, 1791, 1827, 1869, 1901, 1932, and 1970. Remarkably, these are almost exactly the same years in which the Earth's LOD experienced its maximum deviation from its long-term trend. This raised the possibility that the times of maximum deviation of the Earth's LOD might be correlated with the times of maximum asymmetry in the Sun's motion about the CM.

4. DISCUSSION: ARE THE INTER-DECADAL VARIATIONS IN THE EARTH'S LOD EXTERNALLY DRIVEN?

Figures 11a, 11b and 11c, show the absolute deviation of the Earth's LOD from its long-term trend for the polynomial, mean and SSA fits, respectively. Superimposed on each of these plots is a scaled version of the distance of the CM of the Solar System (in radii) from the point (0.95, 0.00). The reader can see for themselves that, from 1700 to 2000 A.D., on every occasion where the Sun has experienced a maximum in the asymmetry of its motion about the CM of the Solar System, the Earth has also experienced a significant deviation in its LOD from that expected from the long-term trends.

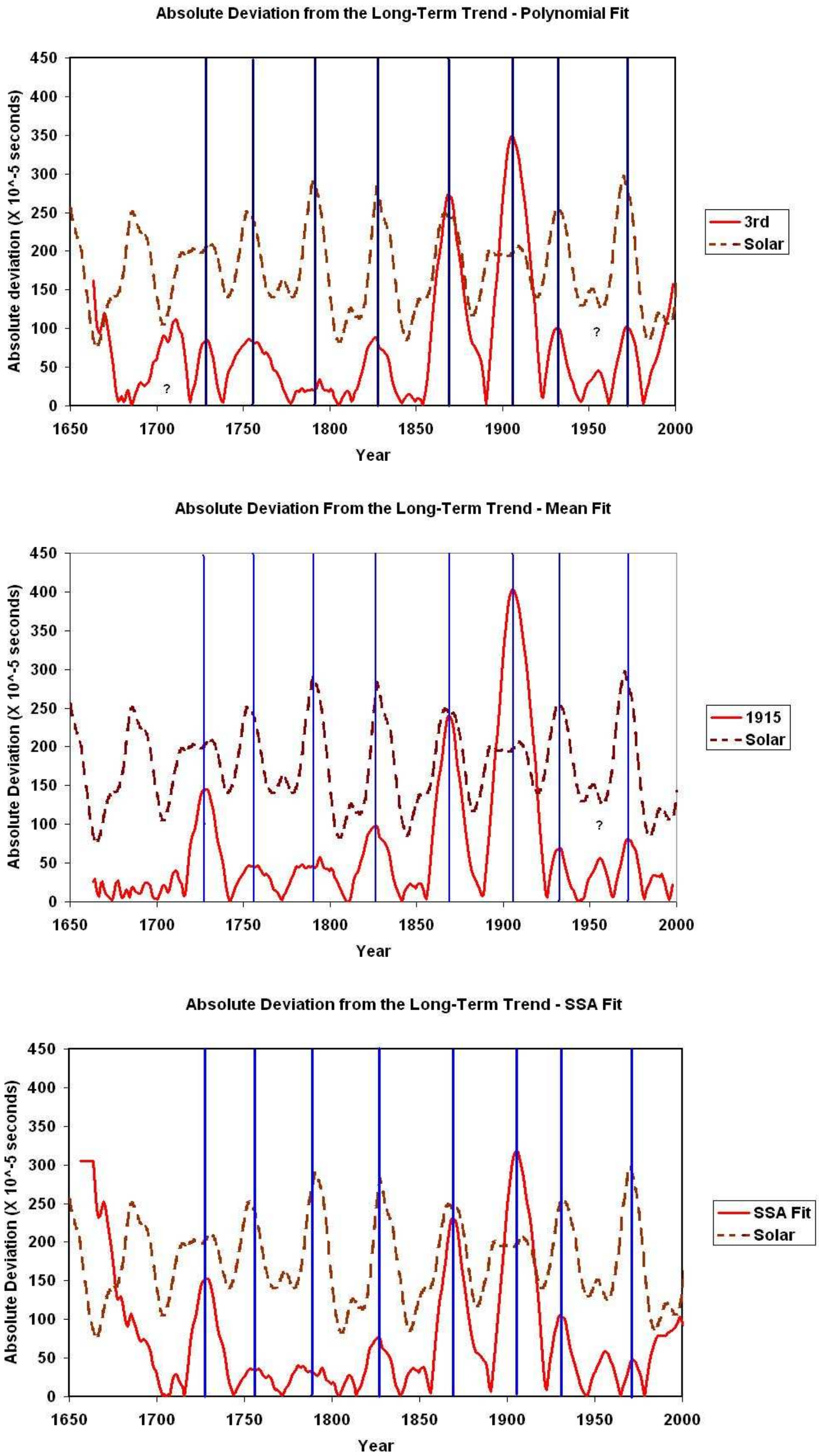


Figure 11: The absolute deviation of the Earth's LOD from its long-term trend for the polynomial fit (11a), the mean fit (11b), and SSA fit (11c). Superimposed on each of these plots is a scaled version of the distance of the CM of the Solar System (in solar radii) from the point (0.95, 0.00).

It is important to note, however, that we have not established a causal link between inter-decadal changes in the Earth's rotation rate and asymmetries in the Earth's motion about the Solar System's CM. All we have shown is that the timing of these two phenomena appears to be synchronized over a three hundred year period from 1700 to 2000 A.D. Therefore, the only way that we can completely rule out the possibility that the synchronization is simply a product of chance, is to come up with a plausible model that could physically link the variations in the Sun's motion about the CM to the inter-decadal changes in the Earth's rotation rate.

At this stage, all that we can offer is a limited outline of one possible model that could explain the underlying causal mechanism for the observed correlations. However, it will take much more research and investigation to see whether or not this model is correct.

THE "GRAND COSMIC CONSPIRACY" MODEL - LINKING THE ORBITAL PERIODS OF THE JOVIAN PLANETS TO LONG TERM VARIATIONS IN THE LUNAR TIDES

Our data supports the contention that when ever the Sun experiences a large asymmetry in its motion about the CM of the Solar System, the Earth also experiences a significant deviation in its rotation rate. A logical consequence of this is that when ever the Sun experiences as large asymmetry in its motion, so does the Earth. This raises the possibility that there might be a spin-orbit coupling mechanism operating between the Earth's motion about the CM of the Solar System and its rotation rate.

The biggest stumbling block to a spin-orbit coupling model is that no one has yet come up with a plausible mechanism to produce the required coupling.

There is a possibility that the synchronization between asymmetries in the solar motion and abrupt changes in the Earth's rotation rate are not physically linked. The reader will recall that no distinction was made between positive and negative deviations of the LOD from its long-term trend. However, logic tells us that positive deviations in the LOD (i.e. a slowing down of the Earth's rotation rate) involve angular momentum transfers between the liquid core/oceans/atmosphere and the solid Earth that are opposite in nature to those of the negative deviations in the LOD. This could indicate that the periodicities in the asymmetry of the solar motion are driven by a physical phenomenon whose timing just happens to match that of the underlying physical cause for the inter-decadal changes in the Earth's LOD.

Figure 12 shows the polar Fast Fourier Transform (FFT) of the asymmetry in the solar motion plotted in figure 10. The FFT indicates that the dominant periodicities evident in the asymmetry of the solar motion are at 45.37, 35.87, 19.86 and 12.78 years. These are just the synodic periods of Saturn/Uranus, Saturn/Neptune, Saturn/Jupiter and Jupiter/Neptune, respectively.

However, it is known that the positions of the four Jovian planets return to the same relative configuration roughly once every 179 years (Jose 1965). This is simply the result of the fact that the synodic periods of the Jovian planets are all whole number sub-multiples of the 179 year Jose Cycle:

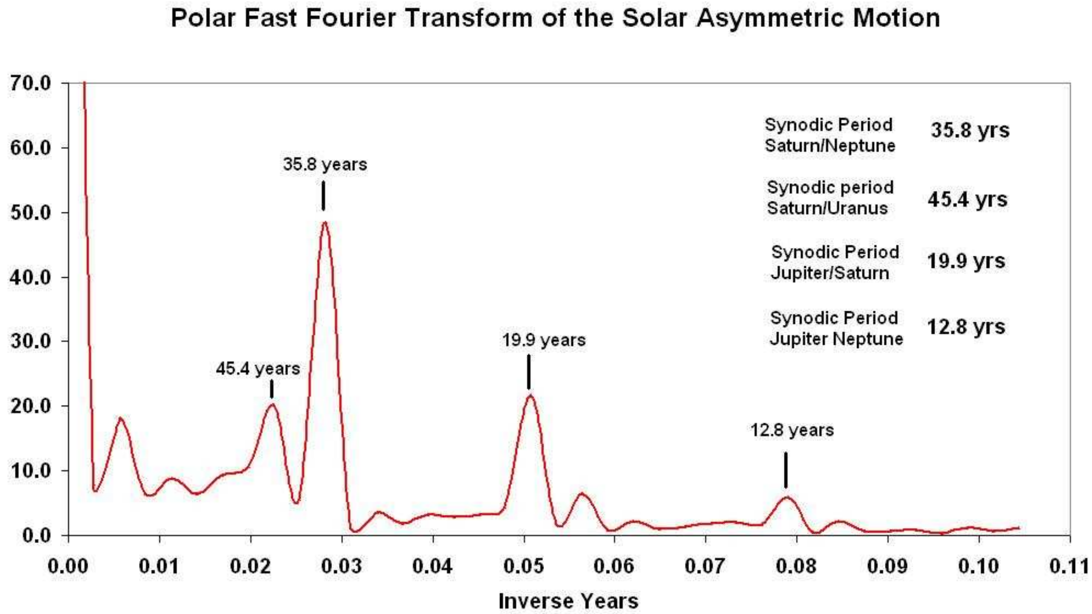


Figure 12: The polar Fast Fourier Transform (FFT) of the asymmetry in the solar motion that is plotted in figure 10. Care has been taken to remove the effects of aliasing from the data.

$9 \times S_{JS}$	$= 9 \times$ **19.858** yrs	= 178.72 yrs	S_{JS} = synodic period Jupiter & Saturn
$14 \times S_{JN}$	$= 14 \times$ **12.782** yrs	= 178.95 yrs	S_{JN} = synodic period Jupiter & Neptune
$13 \times S_{JU}$	$= 13 \times 13.812$ yrs	= 179.56 yrs	S_{JU} = synodic period Jupiter & Uranus
$5 \times S_{SN}$	$= 5 \times$ **35.871** yrs	= 179.36 yrs	S_{SN} = synodic period Saturn & Neptune
$4 \times S_{SU}$	$= 4 \times$ **45.368** yrs	= 181.47 yrs	S_{SU} = synodic period Saturn & Uranus

This means that the 179 year Jose cycle is the fundamental repetition period for the motion of the Jovian planets, and as a result, the motion of the Sun about the centre-of-mass of the Solar system. Hence, you would expect that if there is an extra-terrestrial phenomenon that is causing the inter-decadal changes in the Earth's rotation rate, it should vary with a period that is a sub-multiple of the Jose Cycle.

One way that the orbital motions of the Jovian planets could be linked to changes in the rotation rate of the Earth is if there were a "resonance" between the orbital periods of the Terrestrial planets and Jupiter and either the perigean (apsidal) or draconitic cycle of the Moon's orbit. In this case, it would be possible for the relative orientation of the Jovian planets to be synchronized with a phenomenon that is known to cause variations in the Earth's rotation rate, namely the long term lunar tides. If such a "grand cosmic conspiracy" exists, then it may help identify the actual long-term variations in the tidal influence of the lunar orbit that could be responsible for the inter-decadal variations in the Earth's rotation rate.

The Moon moves around the Earth in an elliptical orbit that is inclined to the plane of the ecliptic by ~ 5 degrees. This means that the Moon's orbit crosses the ecliptic at two points. The first point occurs at the place in the orbit where the Moon crosses the ecliptic from below. This point is known as the ascending node. The second point occurs at the place where the Moon crosses the ecliptic from above, and it is known as the descending node. The line joining these two places in the lunar orbit is known as the line-of-nodes. In addition, the Earth/Moon distance has a perigee of 363,000 km and an apogee of 406, 000 km. The line joining these two points in the lunar orbit is known as the line-of-apsides.

The orientation and shape of the lunar orbit is not fixed, however, but precesses slowly with respect to the stars. The line-of-apsides precesses in a prograde direction, taking 8.850(2) (sidereal) years to complete one revolution with respect to the stars, while the line-of-nodes precesses in a retrograde direction, taking 18.599(2) (sidereal) years to complete one revolution with respect to the stars. This means that every 5.996(7) (sidereal) years the line-of-nodes and the line-of-apsides of the lunar orbit move into alignment with each other. This alignment is the result of the fact that 79.5 anomalistic months (79.5 perigee to perigees = 2190.587 days) is almost exactly equal to 80.5 draconitic months (80.5 node to nodes = 2190.584 days).

The six year period between the alignments of the nodes plays an important role in determining the times at which the Earth experiences maximum tidal stress. The tidal forces acting on the Earth are at their strongest whenever the gravitational influences of the Moon are most strongly reinforced by the gravitational influences of the Sun. These times occur at either New or Full Moon, when the Earth, Moon and Sun are aligned. This means that the maximum variation in the large tidal stresses acting on the Earth will always occur whenever a Full or New Moon takes place while the Moon is located at one of the anti-nodes of its orbit and it is at either apogee or perigee.

In the month in which these alignments occur, the Moon's gravitational influence will go from experiencing its greatest (/least) to its least (/greatest) reinforcement from the Sun (i.e. when the Moon moves from New (/Full) to Full (/New) Moon), while it moves from a maximum point above (/below) to a maximum point below (/above) the ecliptic plane, in addition to moving from perigee (/apogee) to apogee (/perigee).

The problem is that even though the line-of-nodes and line-of-apsides coincide every six years, the points in the lunar orbit at which these coincidences occur are not necessarily aligned with the positions of the Full Moon and New Moon. In fact, the point of alignment slowly rotates with respect the New Moon/Full Moon line, only producing a grand alignment once every 66 years (i.e. 24096.6 days = 65.9(7) sidereal years). These grand alignments are produced because 816 synodic months (= 24096.96(0) days) almost exactly equals 885.5 draconitic months (= 24096.42(2) days) and 874.5 anomalistic months (= 24096.45(4) days).

Unfortunately, a 66 year cycle does not match any of the frequencies observed in the solar motion (see figure 12).One reason for the lack of a match between these frequencies is that we may be looking at the wrong aspect of the long-term tidal variations. When the Moon moves from perigee to apogee (or vice versa), it is mainly the magnitude of the tidal stress that varies. However, when the Moon moves from being five degrees above the ecliptic to five degrees below (or vice versa), it is mainly the meridional (North-South) and zonal (East-West) components of the

tidal stress that vary. One could argue that it is the size of the variations in the components of the tidal stresses that is more important in producing changes in the Earth's rotation rate. This is in fact the case for the equilibrium tides produced by the 18.6 year Draconitic cycle. These tides rhythmically compress and then expand large zonal bands of the world's oceans by up to several millimeters producing noticeable variations (~ 100 ms) in the Earth's rotation rate.

Thus, if we are interested in the timing of the maximum variations in the meridional and zonal components of the tidal stress, we need to find the times where the Moon moves from being five degrees above (/below) the ecliptic at New (/Full) Moon, to the time where the Moon is on the ecliptic at Full (/New) Moon.

There is three important points that we must address before we can investigate the time interval over which there are the greatest changes in the meridional and zonal tidal stresses acting upon the Earth.

Firstly, all of the time intervals and orbital periods that are quoted in the following discussion are means or averages. The fact that they are averages allows us to quote them to the stated level of precision. However, in many cases there can be significant variation of these time intervals and orbital periods about the quoted value of the mean. For example, half the sidereal orbital period of Jupiter is quoted as being 5.93118 sidereal years but the actual time it takes for Jupiter to complete half an orbit can vary from 5.6 to 6.2 years, depending upon where the planet is in its orbit at a particular time. Hence, the average values only become meaningful if we are considering time intervals that are very long compared to the orbital period.

Secondly, because the actual time intervals and orbital periods can vary about their respective means, it is possible for two time intervals or orbital periods to be in resonance even though they differ by a few hundredths of a year. The spread of an object's orbital period about a mean value ensures that that object may spend a significant proportion of its time at values immediately on either side of the mean. In this case, the two bodies involved will come into resonance with each other at irregular time intervals. For want of a better term, we will call this type of sporadic alignment between two bodies a "near resonance".

Finally, the Sun, Earth and Moon line up roughly once every 14.8 days, when the Moon's phase is either New or Full. This means that if we are trying to investigate any long term synchronization between the precession of the line-of-nodes and synodic period of the Moon, there will be an inherent variability in the synchronization of ~ ± 15 days simply because discrete nature of the lunar alignments. A good example of this is the fact that eclipses come in pairs separated by about 15 days. This phenomenon results from the fact that precession of the line-of-nodes is so slow that it allows the Moon to go from New (/Full) to Full (/New) Moon as the Moon passes near one of the nodes of its orbit.

The line of nodes of the lunar orbit appears to rotate around the Earth, with respect to the Sun, once every Draconitic Year (T_D = 346.620 075 883 days). This means that the Earth experiences a transition from a maximum to a minimum in the meridional and zonal components of the tidal stress (or vice versa), at times separated by:

	¼ T_D	=	86.65002 days	1st tidal harmonic
5 x ¼ T_D	= 1 ¼ T_D	=	433.275095 days = 1.18622 years	2nd tidal harmonic
5 x 1 ¼ T_D	= 6 ¼ T_D	=	2166.375474 days = 5.93111 years	3rd tidal harmonic

The first point that needs to be made about this is that there appears to be an almost perfect synchronization between the three tidal harmonic intervals and submultiples of the sidereal orbital period of Jupiter (T_J = 4332.82 days = 11.8624 sidereal years):

$$\frac{1}{50}T_J = 86.6564 \text{ days} \qquad \frac{1}{10}T_J = 433.282 \text{ days} \qquad \frac{1}{2}T_J = 5.93120 \text{ years}$$

The synchronization between the orbital period of Jupiter and the rate of precession of the lunar nodes is significant. However, this synchronization could be dismissed as just a coincidence, if it were not for one further piece of evidence that links the nodal precession of the lunar orbit with the orbital motion of the planets.

A remarkable near-resonance condition exists between the orbital motions of the three largest terrestrial planets with:

4 x S_{VE} = 6.3946 years where S_{VE} = synodic period of Venus and Earth
3 x S_{EM} = 6.4059 years S_{EM} = synodic period of Earth and Mars
7 x S_{VM} = 6.3995 years and S_{VM} = synodic period of Venus and Mars

This means that these three planets return to the same relative orbital configuration once every 6.40 years (see table 1 for the planet's orbital and synodic periods). Amazingly, the point in the Earth's orbit where the 2nd tidal harmonic occurs (i.e. 1 ¼ T_D), rotates around the Sun (with respect to the stars) once every 6.3699 years. This is just over three hundredths of year less than the time required for the realignment of the positions of the three largest terrestrial planets.

Thus, the realignment time for the positions of the three largest terrestrial planets also appears to be closely synchronized with the time period over which the Earth experiences a maximum change in the meridional and zonal components of the tidal stress.

TABLE 1

Sidereal Period	Venus	Earth	Mars	Jupiter
Days	224.70080	365.256363	686.9800	4332.820

Synodic Periods	Venus/Earth (S_{VE})	Earth/Mars (S_{EM})	Venus/Mars (S_{VM})
Days	583.9214	799.9359	333.9215
Sidereal Years	1.5987	2.1353	0.9142

Table 1: The synodic period is the time required for a faster inner planet to catch up to a slower outer planet. The Sidereal Period is the time for the planet to complete one orbit of the Sun with respect to the stars. Source: JPL ephemeris http://ssd.jpl.nasa.gov/horizons.cgi?s_body=1#top

Here lies the crux of the "Grand Cosmic Conspiracy" model:

a) The asymmetries in the motion of the Sun about the CM are dominated by periodicities that are submultiples of the 179 year Jose cycle. The 179 year Jose cycle is the fundamental repetition period for the motion of the Jovian planets, and as a result, the motion of the Sun about the centre-of-mass of the Solar system. Hence, you would expect that if there is an extra-terrestrial phenomenon that is causing the inter-decadal changes in the Earth's rotation rate, it should vary with a period that is a sub-multiple of the Jose Cycle.

b) The 179 year Jose cycle appears to be embedded within the relative sidereal orbital periods of Venus, Earth, Mars and Jupiter as well, with:

$28 \times S_{VE}$ = 7 x (6.3946 yrs) = 44.763 yrs
$69 \times S_{VJ}$ = 44.770 yrs = synodic period of Venus & Jupiter
$41 \times S_{EJ}$ = 44.774 yrs = synodic period of Earth & Jupiter
$20 \times S_{MJ}$ = 44.704 yrs = synodic period of Mars & Jupiter

This means that Venus, Earth and Jupiter, in particular, form alignments at submultiples of 179.08 years i.e.:

½ × 179.08 yrs = 89.54 yrs ¼ × 179.08 yrs = 44.77 yrs
and 1/8 × 179.08 yrs = 22.39 yrs 1/16 × 179.08 yrs = 11.20 yrs

These alignments only change slowly over hundreds of years and they closely match the well known Schwabe (~ 11.1 yrs), Hale (~ 22.2 yrs) and Gleissberg (~ 90 years) solar cycles.

d) A remarkable near-resonance condition exists between the orbital motions of the three largest terrestrial planets with:

4 x S_{VE} = 6.3946 years 3 x S_{EM} = 6.4059 years 7 x S_{VM} = 6.3995 years

e) Through what appears to be a "Grand Cosmic Conspiracy":

$6.393 \text{ yrs} = \frac{1}{28} \times$ the 179 year repetition cycle of the Solar motion

$6.396 \text{ yrs} = \frac{1}{7} \times$ the 44.77 year realignment time for Venus, Earth, and Jupiter

This firmly links the asymmetries in the motion of the Sun about the centre-of-mass of the Solar system to the realignment time period for the orbits of Venus, Earth, Mars and Jupiter.

f) The "Grand Cosmic Conspiracy" leads to a near resonance between the Jupiter's sidereal orbital period (T_J = 11.8624 yrs) and the harmonic time interval over which there are the greatest changes in the meridional and zonal tidal stresses acting upon the Earth (1/10 T_J = 433.282 days ≈ 1 ¼ T_D = 433.2751 days = 1.18622 years).

g) Not only that, the side-lobe period that is produced by the modulation of the Earth's sidereal year with a cycle that is only two or three hundredths of year shorter than the iconic 6.40 year period, almost perfectly matches the 2nd harmonic time interval over which there are the greatest changes in the meridional and zonal tidal stresses acting upon the Earth:

$$\frac{6.370 \text{ yrs} \times 1.00 \text{ yrs}}{6.370 \text{ yrs} - 1.00 \text{ yrs}} = 433.2743 \text{ days} = 1.18622 \text{ years}$$

h) We know that the strongest planetary tidal forces acting on the lunar orbit come from the planets Venus, Mars and Jupiter, in order of the size of their respective tidal influences. In addition, we known that, over the last 4.6 billion years, the Moon has slowly receded from the Earth. During the course of this lunar recession, there have been times when the orbital periods of Venus, Mars and Jupiter have been in resonance(s) with the precession rate for the line-of -nodes the lunar orbit (Ćuk 2007). When these resonances have occurred, they would have greatly amplified the effects of the planetary tidal forces upon the lunar orbit (Ćuk 2007). Hence, the observed synchronization between the precession rate of the line-of-nodes of the lunar orbit and the orbital periods of Venus, Earth, Mars and Jupiter, could simply be a cumulative fossil record left behind by these historical resonances.

Further support the "Grand Cosmic Conspiracy" comes from the motion of the Earth's pole.

The Earth has two distinct short-term wobbles. The first is the annual wobble which is a forced motion caused by the seasonal variations in the Earth's atmosphere, oceans and hydrosphere. The second is a periodic wobble of the Earth's polar axis with an average period of 433 days known as the Chandler Wobble (Gross 2000). This wobble is thought to be a free oscillation of the Earth's rotation axis caused by the fact that the Earth does not rotate about its figure axis.

Dissipation processes associated with wobble-induced deformations of the solid Earth should cause the Chandler wobble to freely decay on a timescale of about 30-100 years (Plag et. al. 2005), unless some force is acting to reinvigorate it. The fact that there has been no noticeable decay in the Chandler Wobble has raised questions about the source of excitation for the wobble. Gross (2000) proposed that the wobble was excited by a combination of atmospheric and oceanic processes, with the dominant excitation mechanism being ocean-bottom pressure fluctuations.

The Chandler Wobble also suffers from a sinusoidal variation in its amplitude that has a period of roughly 6.4 years (Kosek 2005). The amplitude modulation period of 6.4 years is most likely just a beat period produced by the interaction the annual oscillation and Chandler Wobble (Kosek 2005).

The "Grand Cosmic Conspiracy" model raises the possibility the source of excitation for the Chandler Wobble might have an extra-terrestrial origin. It is possible that the 6.40 year realignment period for the terrestrial planets has interacted with the sidereal orbital period of the Earth/Moon system over the eons, to produce a side-lobe modulation that it has slowly nudged the precession rate of the line-of-nodes of the lunar orbit towards its current value. Hence, we now have a precession rate that produces a 2^{nd} harmonic for the maximal changes in tidal stresses that varies on a time scale of 1 ¼ T_D = 433.2751 days = 1.18622 years.

The fact that 2^{nd} tidal harmonic is so close to the nominal 433 day period of the Chandler Wobble, suggests that the variations in lunar tides produced by the precession of the line-of-nodes of the lunar orbit could, in fact, be the source of the ocean-bottom pressure fluctuations that are thought to be responsible for the excitation of the Chandler Wobble.

Of course, all of these remarkable "cosmic coincidences" would actually make more sense if they were the result of fossilized synchronisations produced by past resonances between the precession rate of the line-of-nodes of the lunar orbit and the sidereal periods of Venus, Earth, Mars and Jupiter.

CONCLUSIONS

Evidence is presented to show that the phases of two of the Earth's major climate systems, the North Atlantic Oscillation (NAO) and the Pacific Decadal Oscillation (PDO), are related to changes in the Earth's rotation rate.

We find that the winter NAO index depends upon the time rate of change of the Earth's length of day (LOD), so that whenever the rate of change of the LOD is negative (i.e. the Earth's rotation rate is increasing) the NAO is positive and whenever rate of change of the LOD is positive (i.e. the Earth's rotation rate is decreasing) the NAO is negative.

In addition, we find that there is a remarkable correlation between the years where the phase of the PDO is most positive and the years where the deviation of the Earth's LOD from its long-term trend is greatest.

Unfortunately, the climate data does not allow us to decide whether it is the fluctuations in the Earth's rotation rate that determine the phases changes in the NAO and PDO or the other way around. Nor does climate data tell us whether the observed changes in the Earth's rotation rate are being driven by external forces. The only conclusion that can be drawn from the climate data is that long term changes in these two major climate systems has an effect upon, or is affected by, changes in the Earth's rotation rate.

In order to prove that it is the changes in the Earth's rotation rate that are responsible for the variations seen in the NAO and PDO indices, and not the other way around, we are required to show that the observed inter-decadal deviation in the Earth's LOD are synchronized with variations that are seen in a physical phenomenon that is external to the Earth.

We find that there is a strong correlation between the times of maximum deviation of the Earth's LOD from its long-term trend and the times where there are abrupt asymmetries in the motion of the Sun about the CM of the Solar System.

At first glance, there does not appear to be an obvious physical phenomenon that would link the Sun's motion about the Solar System's CM to the Earth's rotation rate. However, such a link could occur if the alignments of Terrestrial and Jovian planets were synchronized with the precession of the line-of-nodes of the Moon's orbit. In this case, it would be possible for the alignments of the planets to be synchronized with a phenomenon that is known to cause variations in the Earth's rotation rate, namely the long term lunar tides. We show that it is indeed possible that such a "grand cosmic conspiracy" does exist.

Through what appears to be a "Grand Cosmic Conspiracy" we find that:

6.393 yrs = (the 179 year repetition cycle of the Solar motion about the CM) / 28

6.396 yrs = (the 44.77 year realignment time for Venus, Earth, and Jupiter) / 7

In addition, a remarkable near-resonance condition exists between the orbital motions of the three largest terrestrial planets i.e.

$4 \times S_{VE} = 6.3946$ years $\quad 3 \times S_{EM} = 6.4059$ years $\quad 7 \times S_{VM} = 6.3995$ years,

suggesting that the 6.4 year period is a fundamental periodicity that links the alignments of Venus, Earth and Jupiter to the solar motion about the CM.

The significance of the 6.4 year periodicity is given added weight by the fact that if you use it to modulate the sidereal year of the Earth/Moon system, the side-lobe period that is produced, almost perfectly matches the 2nd harmonic time interval over which there are the greatest changes in the meridional and zonal tidal stresses acting upon the Earth i.e.

$$\frac{6.370 \text{ yrs} \times 1.00 \text{ yrs}}{6.370 \text{ yrs} - 1.00 \text{ yrs}} = 433.2743 \text{ days} = 1.18622 \text{ years}$$

The combination of all of these remarkable "coincidences" leads us to propose the following link between the orbital motions of Venus, Earth, Mars and Jupiter and the precession of the line-of-nodes of the Lunar orbit.

We know that the strongest planetary tidal forces acting on the lunar orbit come from the planets Venus, Mars and Jupiter, in order of the size of their respective tidal influences. In addition, we known that, over the last 4.6 billion years, the Moon has slowly receded from the Earth. During the course of this lunar recession, there have been times when the orbital periods of Venus, Mars and Jupiter have been in resonance(s) with the precession rate for the line-of-nodes the lunar orbit. When these resonances have occurred, they would have greatly amplified the effects of the planetary tidal forces upon the lunar orbit. Hence, the observed synchronization between the precession rate of the line-of-nodes of the lunar orbit and the orbital periods of Venus, Earth, Mars and Jupiter, could simply be a cumulative fossil record left behind by these historical resonances.

The "Grand Cosmic Conspiracy" model tries to explain why the asymmetries in the solar motion about the CM and changes in the rotation rate of the Earth are synchronized. In order for this apparent correlation to make any sense, there must be some underlying physical process that connects the relative motion of the four Jovian planets to a factor that can influence the rotation rate of the Earth. We conclude that the most likely candidate for the underlying physical process is the synchronization between the precession rate of the line-of-nodes of the lunar orbit and the relative sidereal orbital periods of Venus, Earth, Mars and Jupiter as a result of past resonances between these two phenomena.

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