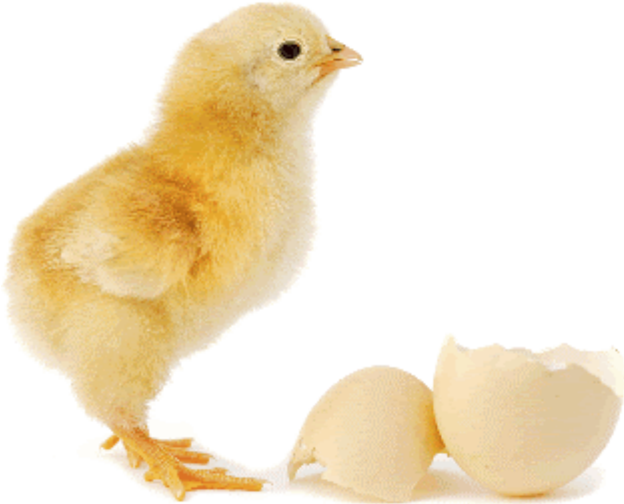
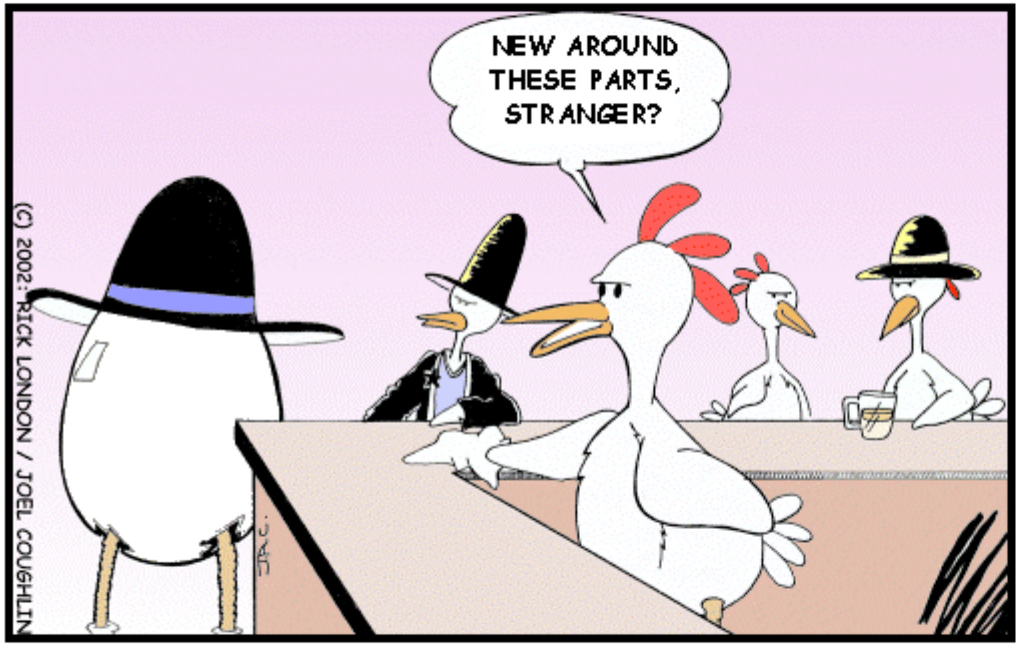
http://www.barnsley.towntalk.co.uk/eventsimg/barnsley22124.gif



WHICH CAME FIRST ?

http://www.londonstimes.us/toons/cartoons/joel_chicken_or_egg.gif



AND YET THE QUESTION REMAINED: "WHO CAME FIRST?"

The Chicken or the Egg?

DO LONG-TERM VARIATIONS OF THE SUN DRIVE CLIMATE CHANGE?

- Some scientists claim that variations in the Sun's energy output, over periods of tens to hundreds of years, play a crucial role in causing changes in the Earth's climate. They base their claim on the undeniable fact that the Sun provides almost all of the energy that drives the climate system. They argue that if this is the case then surely small variations in the Sun's energy output should cause significant changes in the Earth's climate.

- Other scientists have disputed this claim, pointing out that the observed variation in the amount of electromagnetic (e.g. light) radiation received at the top of the Earth's atmosphere only amounts to ~ 0.1 %. They firmly believe that variations in the solar radiation of this size are far too small to produce any significant change in the Earth's climate.

- Those proposing that the Sun is the main driver of climate change shoot back and claim that these other scientists are being naive in believing that the Earth's climate can only be affected by variations in the Sun's output of electromagnetic radiation. They point out that the Sun has many properties that vary considerably on time scales of decades to centuries, such as variations in strength of the interplanetary solar magnetic field,.. →

- ❖ Continued.

  changes in the amount of cosmic rays entering the Earth's atmosphere, variations in the amount of solar UV flux being absorbed in the Earth's stratosphere, and changes in the level of solar wind particles striking the Earth's polar regions. They claim that anyone of these phenomena could cause changes in the Earth's climate on decadal to centennial time scales.

- ❖ The scientists who deny that the Sun is a major player in climate change point out that there are no valid scientific models linking variations in these other properties of the Sun to climate change, and so on and on the argument goes.

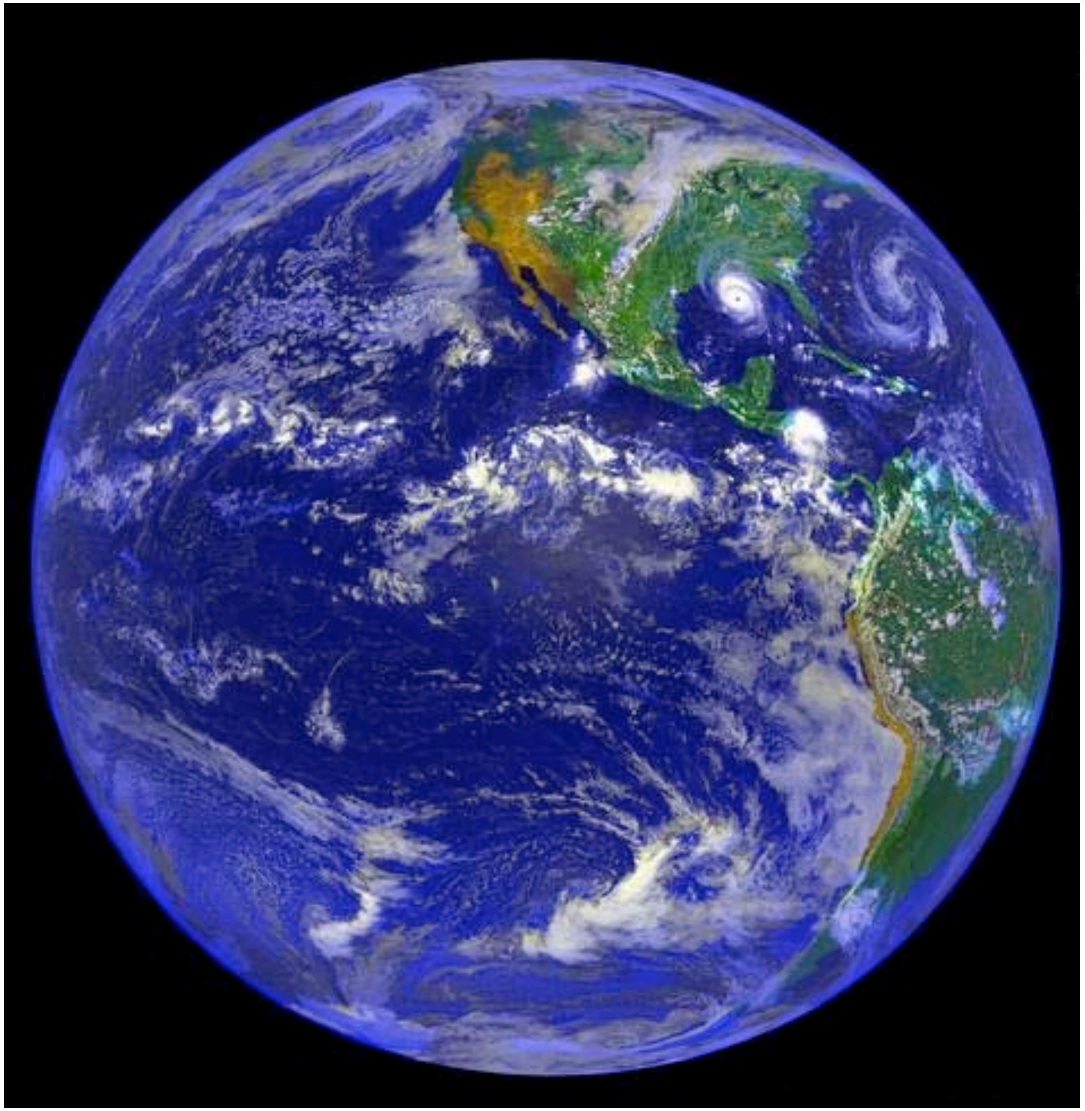
- ❖ But what if, there is a third factor that no one has yet considered that not only drives the variations in solar activity that we see on the Sun but also drives the changes that we see in climate here on the Earth?

- ❖ In order to find this "third factor" we must first ask ourselves the question,

Which came first, the chicken or the egg?

What I want you to do is consider three very important players.

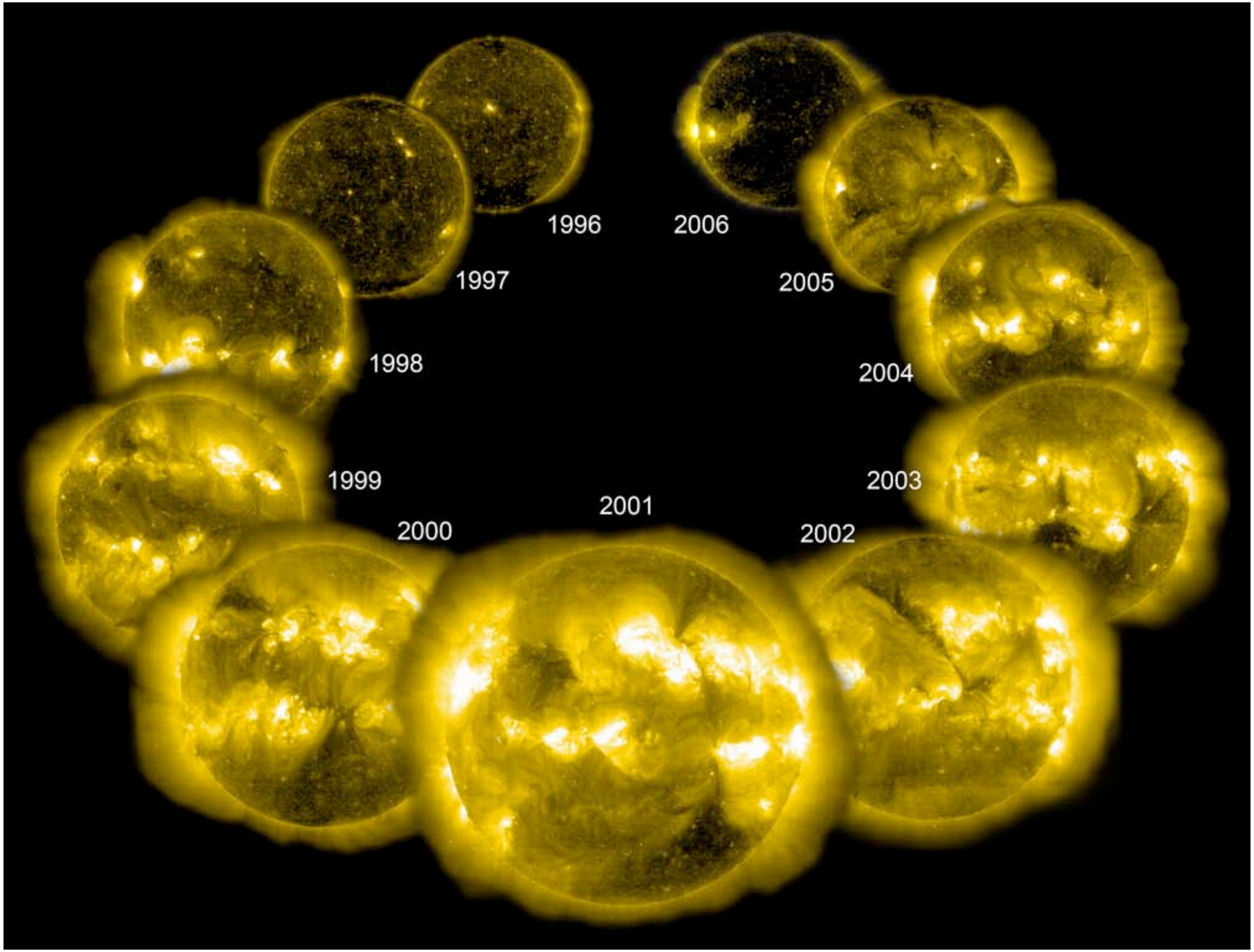
The first player is the Earth's climate system.



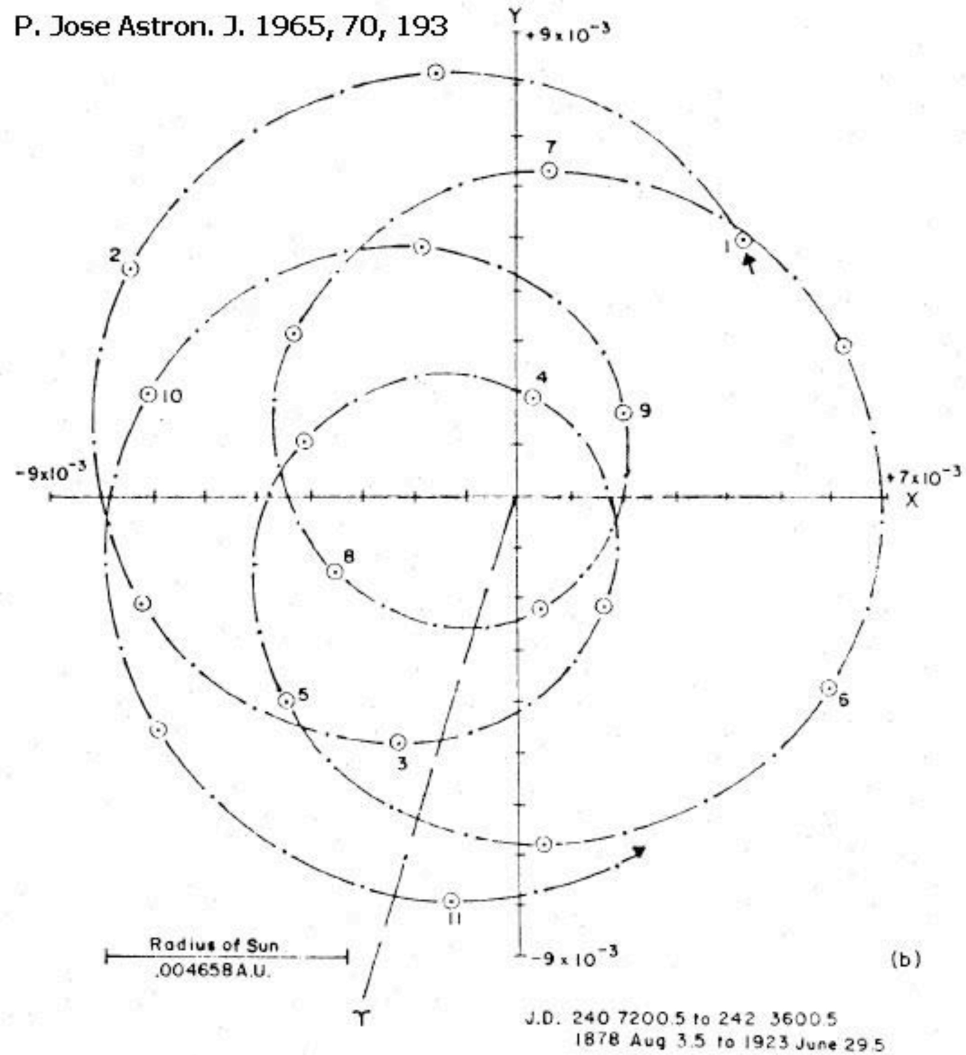
http://space.about.com/od/pictures/ig/Earth-Pictures-Gallery/The-Americas-and-Hurricane-And.--0O.htm

The second player is the Earth's Rotation.

The third player is the general level of solar activity on the Sun,..



which some believe is caused by the motion of the Sun about the centre-of-mass of the Solar System.



Shown here is the position of the centre of the Sun (circles with dots) with respect to the centre-of-mass of the Solar System between 1878 and 1923.

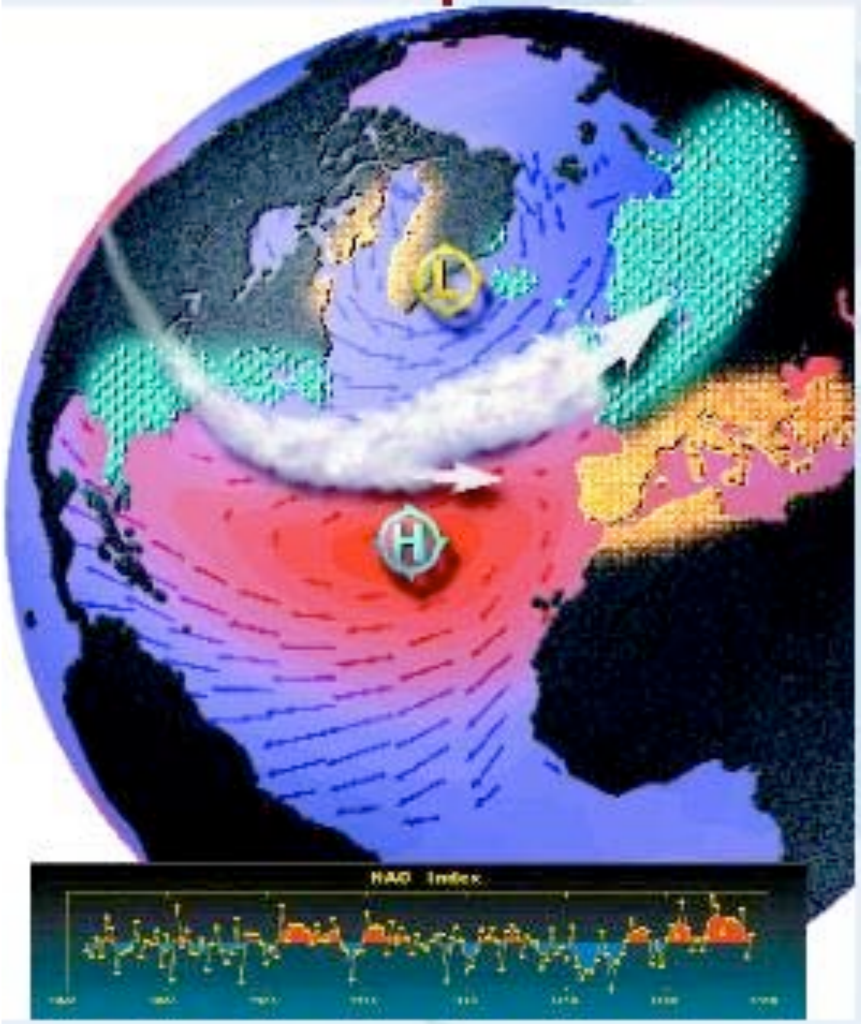
Our initial task is to see if there is any link between two of our major players, the Earth’s climate system and changes in the Earth’s rotation rate, on time scales ranging from decades to centuries. In order to establish this link, we need to look at two major climate systems:

The North Atlantic Oscillation (NAO)

The Pacific Decadal Oscillation (PDO)

The first climate system that we will look at is the NAO. This system is based on the pressure differential between Icelandic Lows and Sub-tropical Highs that are located in the North Atlantic Ocean. The next slide shows that the NAO can be in either a positive of negative phase.

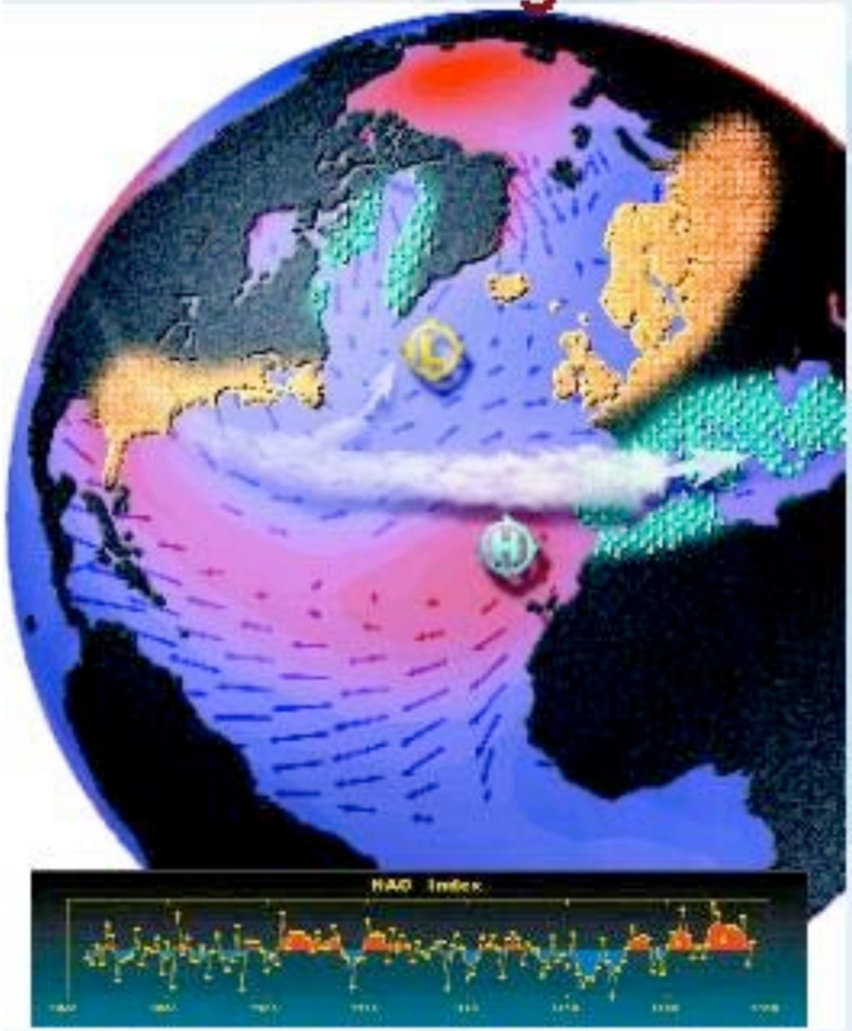
The positive NAO index phase



- The positive NAO index phase shows a stronger than usual subtropical high pressure center and a deep than normal Icelandic low.
- The increased pressure difference results in more and stronger winter storms crossing the Atlantic Ocean on a more northerly track.
- This results in warm and wet winters in Europe and in cold and dry winters in northern Canada and Greenland.
- The eastern US experiences mild and wet winter conditions.

Martin Visbeck Feb04, 2000

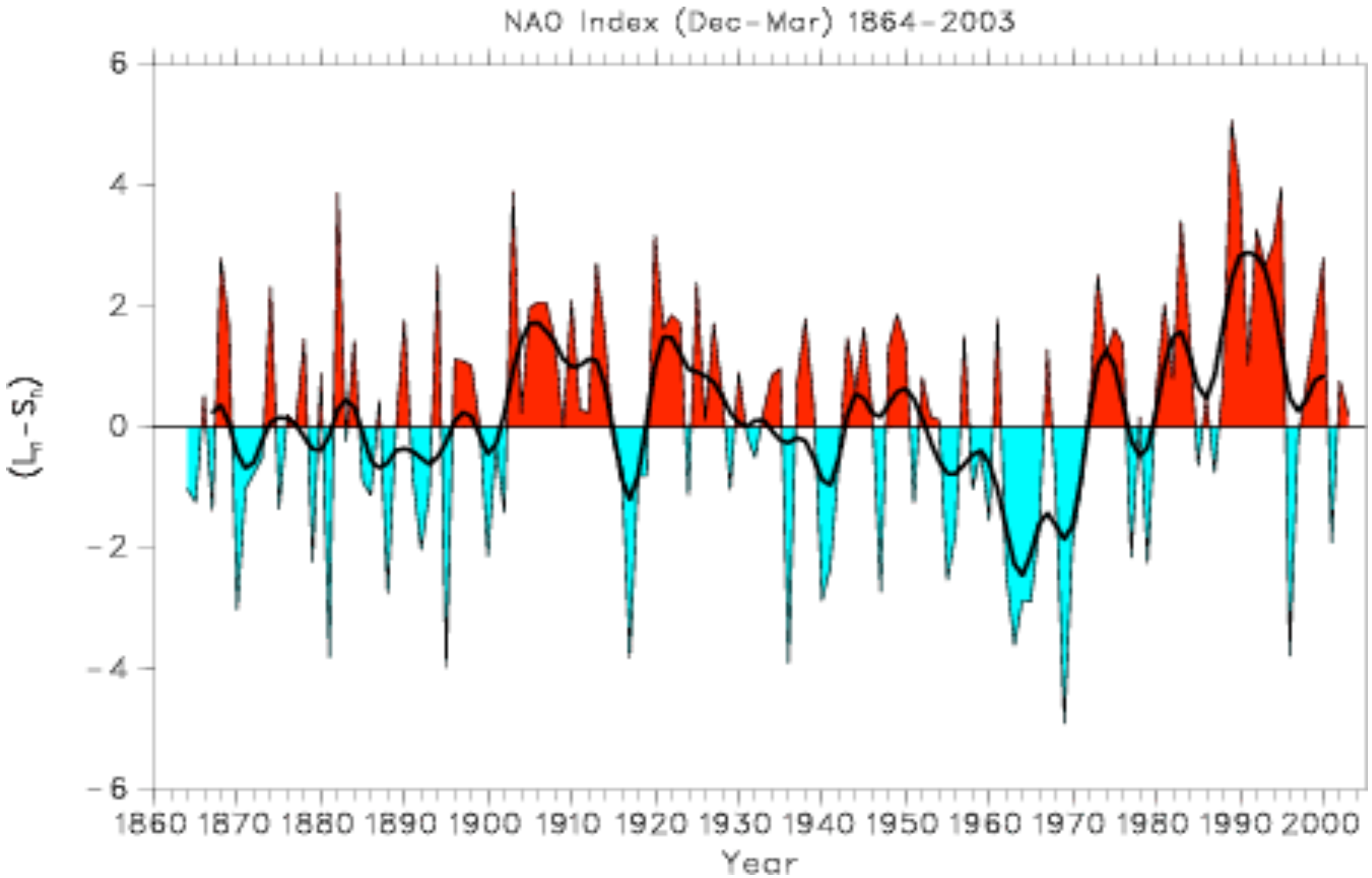
The negative NAO index phase



- The negative NAO index phase shows a weak subtropical high and weak Icelandic low.
- The reduced pressure gradient results in fewer and weaker winter storms crossing on a more west- east pathway.
- They bring moist air into the Mediterranean and cold weather to northern Europe.
- The US east cost experiences more cold air outbreaks and hence snowy winter conditions.
- Greenland, however, will have milder winter temperatures.

Martin Visbeck Feb04, 2000

http://www.cgd.ucar.edu/cas/jhurrell/nao.stat.winter.html



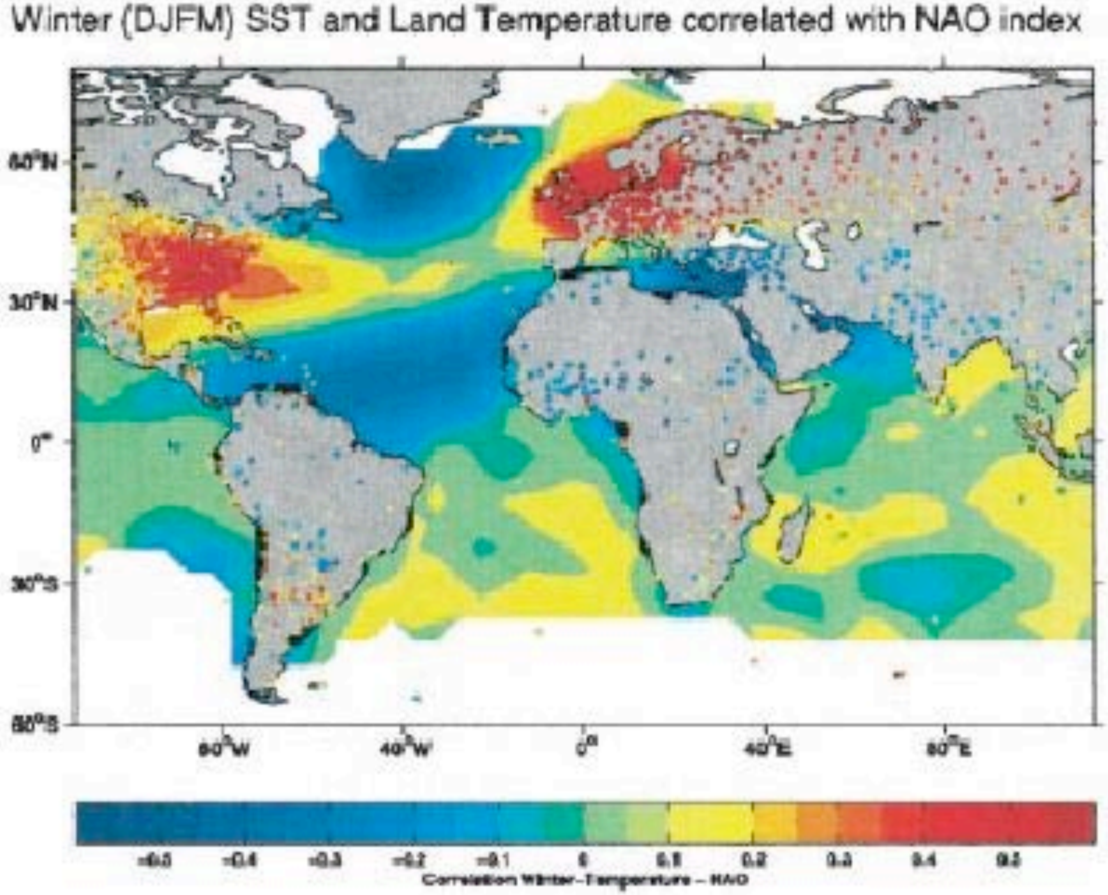
The graph above shows the Winter (December through March) index of the NAO based on the difference of normalized sea level pressure (SLP) between Lisbon, Portugal and Stykkisholmur / Reykjavik, Iceland since 1864. The SLP anomalies at each station were normalized by division of each seasonal mean pressure by the long-term mean (1864-1983) standard deviation. Normalization is used to avoid the series being dominated by the greater variability of the northern station. Positive values of the index indicate stronger-than-average westerlies over the middle latitudes. Red regions indicate times of positive NAO, while blue indicate times of negative NAO.

- The following slide shows how sea and land temperatures correlate with the NAO index. Areas where there is a high correlation are shown in red, while the areas with a low correlation are shown in blue.

- It is immediately apparent from this slide that the NAO affects much of Western Europe as well as the eastern half of the populated areas of North America.

- This mean that the NAO plays a role in affecting the temperatures of close to a billion people, making it one of the worlds largest and most important climate systems.

- Not only does it have a major role in setting temperatures in Western Europe but it also significantly affects the levels of rainfall experienced in both Northern and Southern Europe.



| PNAS | November 6, 2001 | vol. 98 | no. 23

Martin H. Visbeck*†, James W. Hurrell‡, Lorenzo Polvani§, and Heidi M. Cullen¶

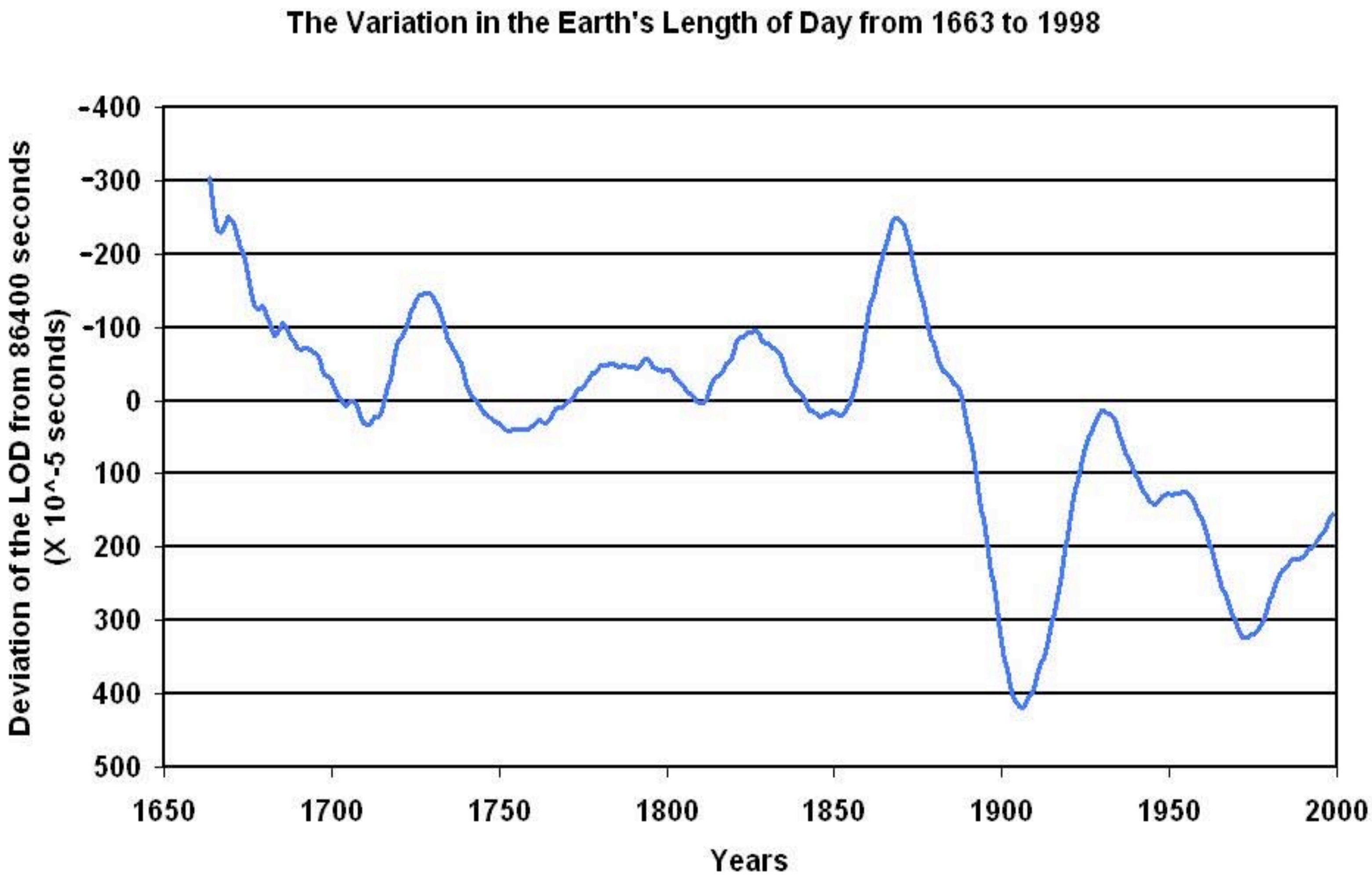
- The nominal time for the Earth to make one rotation is known as the length of day or LOD and it has a value of 86400 seconds.

- 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.



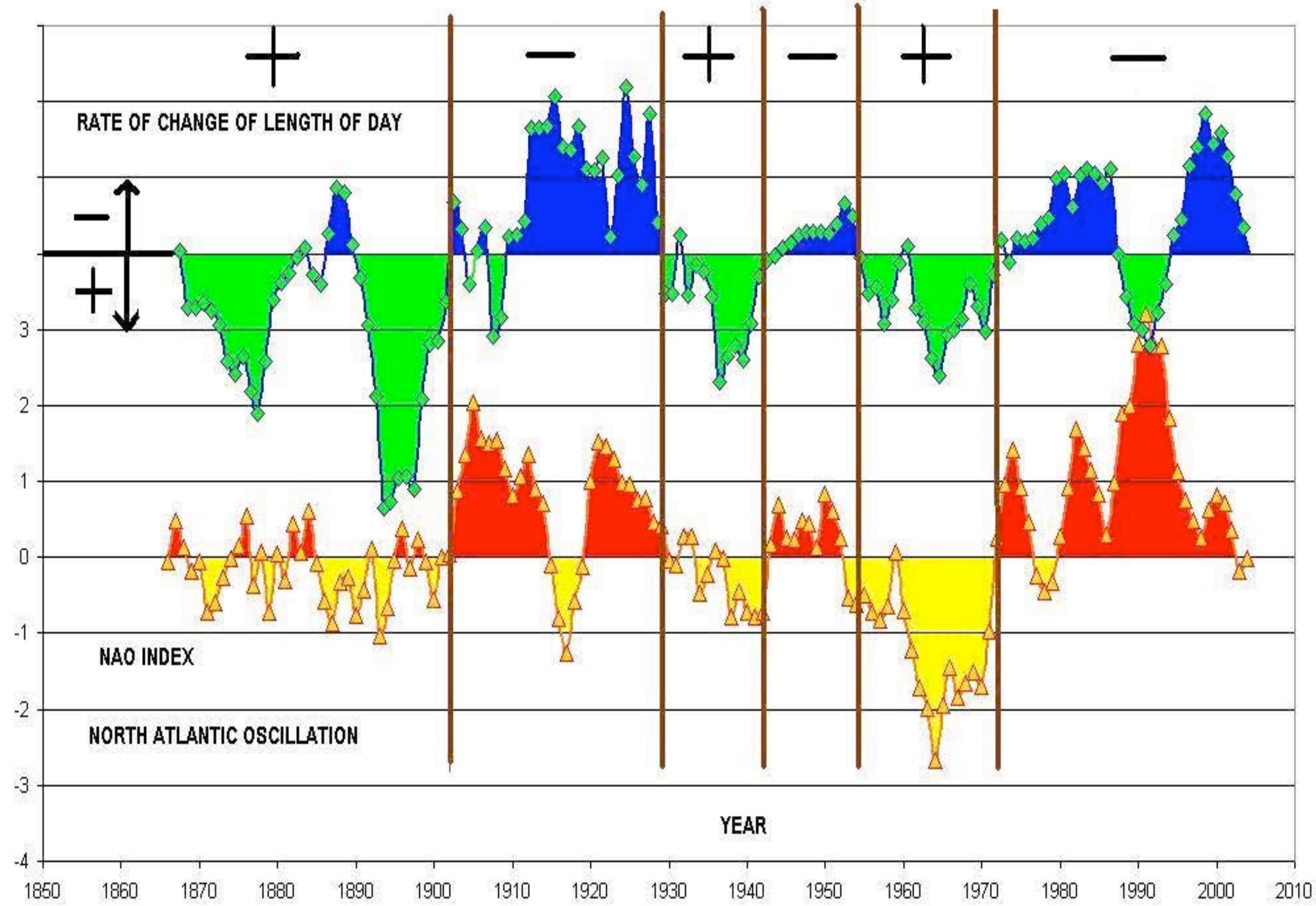
The graph above shows the difference between the actual LOD and the nominal LOD value of 86400 seconds, measured in milliseconds, from 1656 to 2005 (Sidorenkov 2005). The raw data has been smoothed using a 15 year running mean. In addition, the vertical scale has been inverted so that up on the graph corresponds to an increase in the Earth's rotation rate. One thing that is immediately apparent is that LOD can vary by ~ few milliseconds over decadal timescales.

The question now becomes:

Is there any connection between the observed changes NAO index and variations seen in the Earth's LOD?

The winter NAO index is published by Dr. James Hurrell, NCAR/Climate and Global Dynamics Division (2007) at: http://www.cgd.ucar.edu/cas/jhurrell/Data/naodjfmindex.asc

The LOD data was kindly provided by Dr. N. Sidorenkov of the Hydrometcentre of the Russian Federation in Moscow.



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 DJFM 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 graph on the previous slide clearly shows that 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 system 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. The only conclusion that can be drawn from this data is that long term changes in the North Atlantic climate system has an effect upon, or is affected by, changes in the Earth's rotation rate.

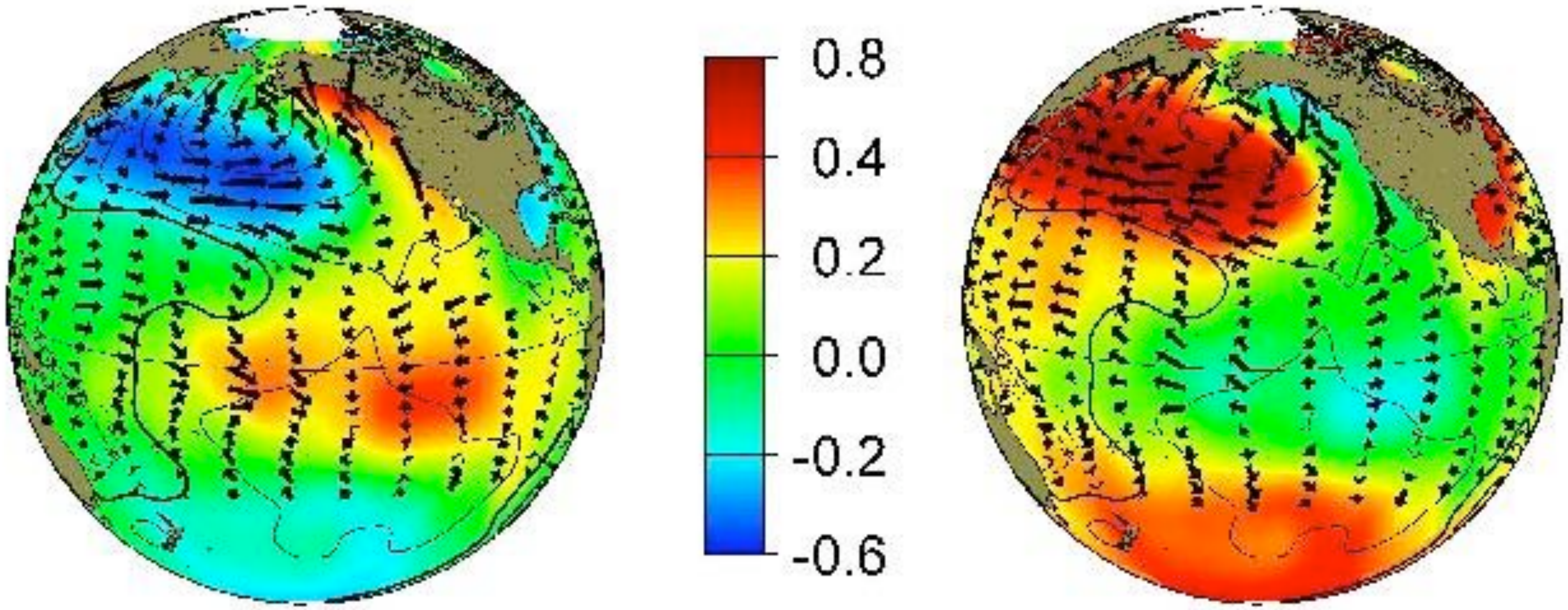
- Thus, we can say that the NAO correlates with the rate of change of the Earth’s rotation, however, we do not know which one affects the other.

- **In other words, we are left with the quandary, which comes first, the chicken or the Egg?**

The second climate system that we need to look at is the PDO

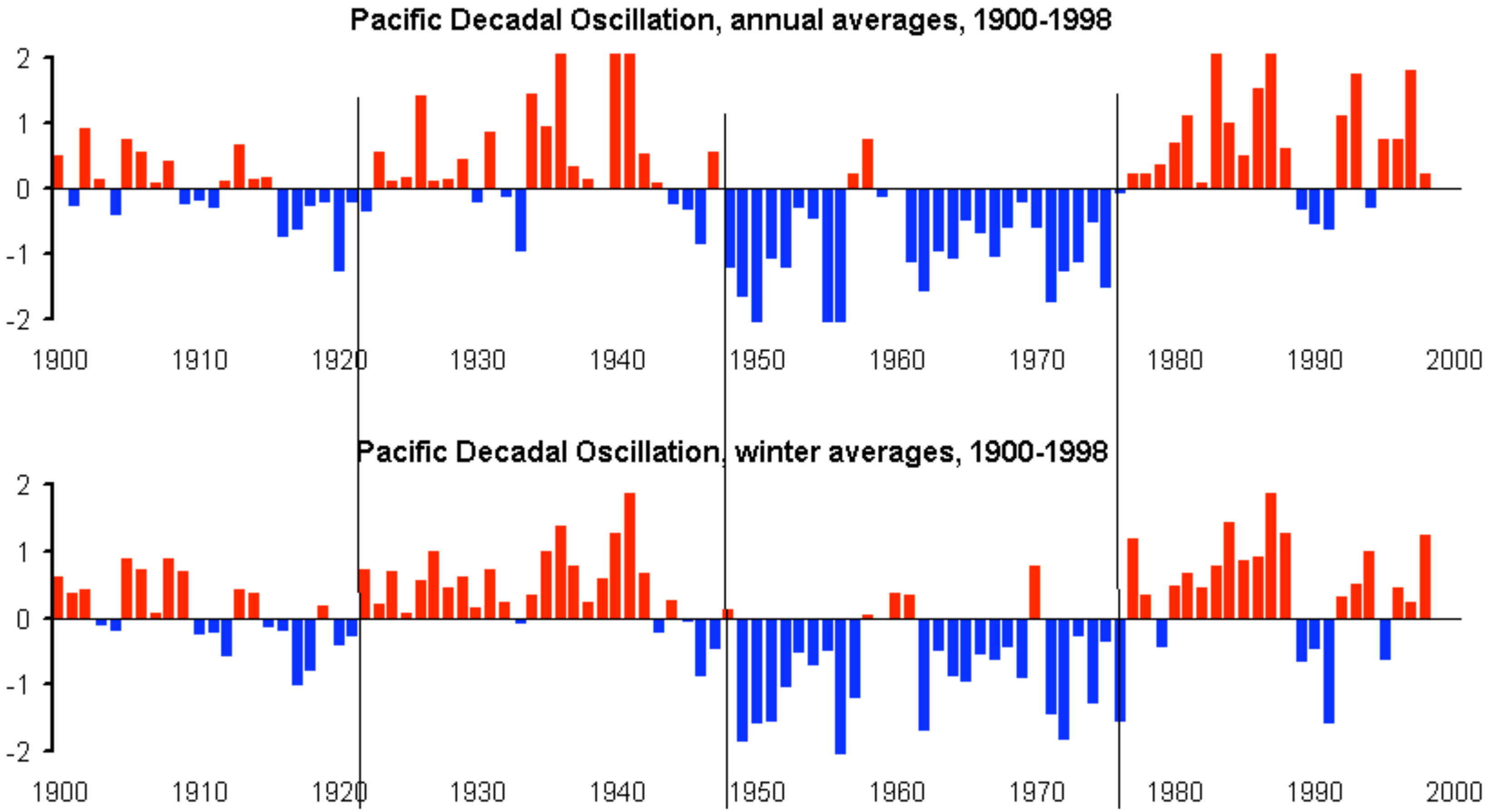
PACIFIC DECADAL OSCILLATION

PDO POSITIVE PDO NEGATIVE

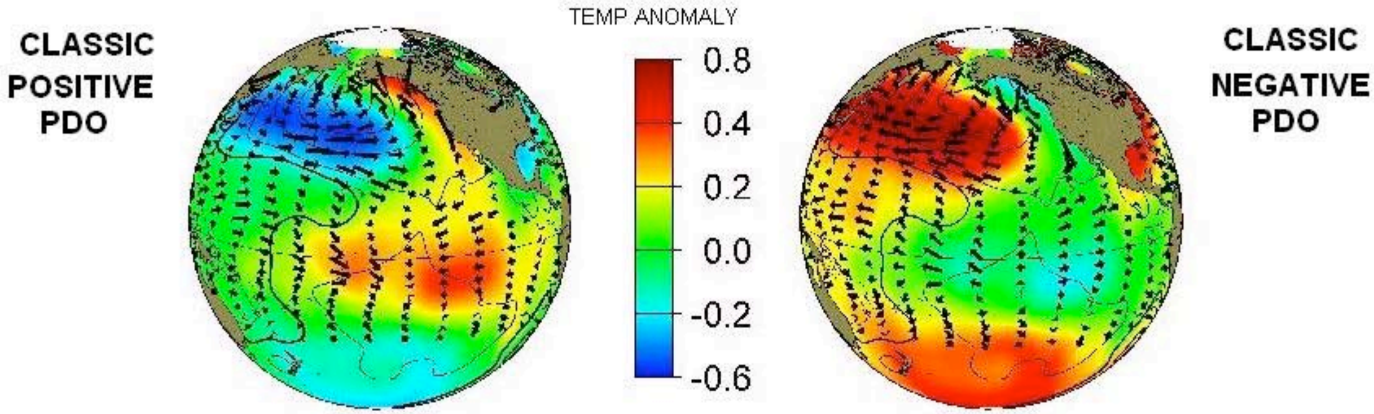


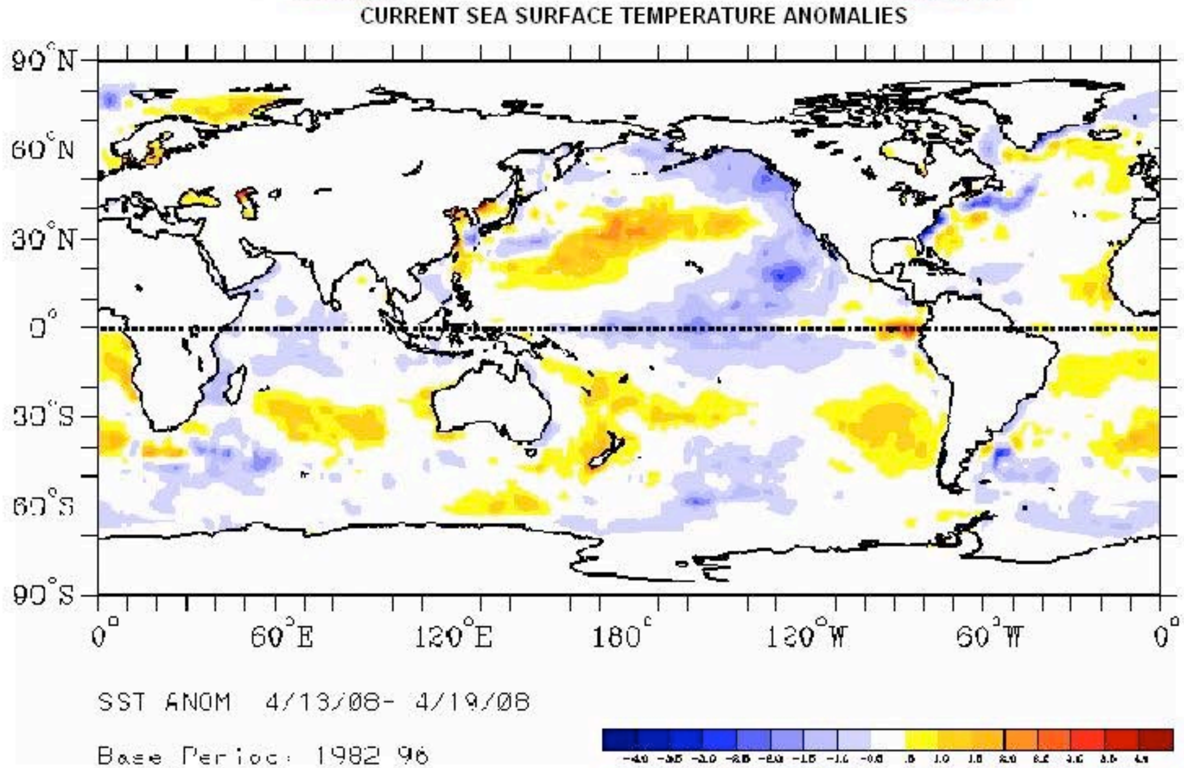
The "Pacific Decadal Oscillation" (PDO) is a long-lived El Niño/La Niña-like pattern that is observed in the sea-surface temperatures (SST) of northern and central Pacific oceans. Positive (/negative) phases of the PDO are typified by warmer (/cooler) than normal temperatures in the north-eastern and tropical Pacific Ocean and cooler (/warmer) than normal temperatures in the region to the south-west of the Aleutian Islands. It is important to note that while the El Niño/La Niña oscillation varies on a time scale of 4 – 5 years, the PDO variations are governed by a time scale that is believed to be a combination of a 20 year and 60 -70 year pattern.

How has the PDO varied over the last 100 years?



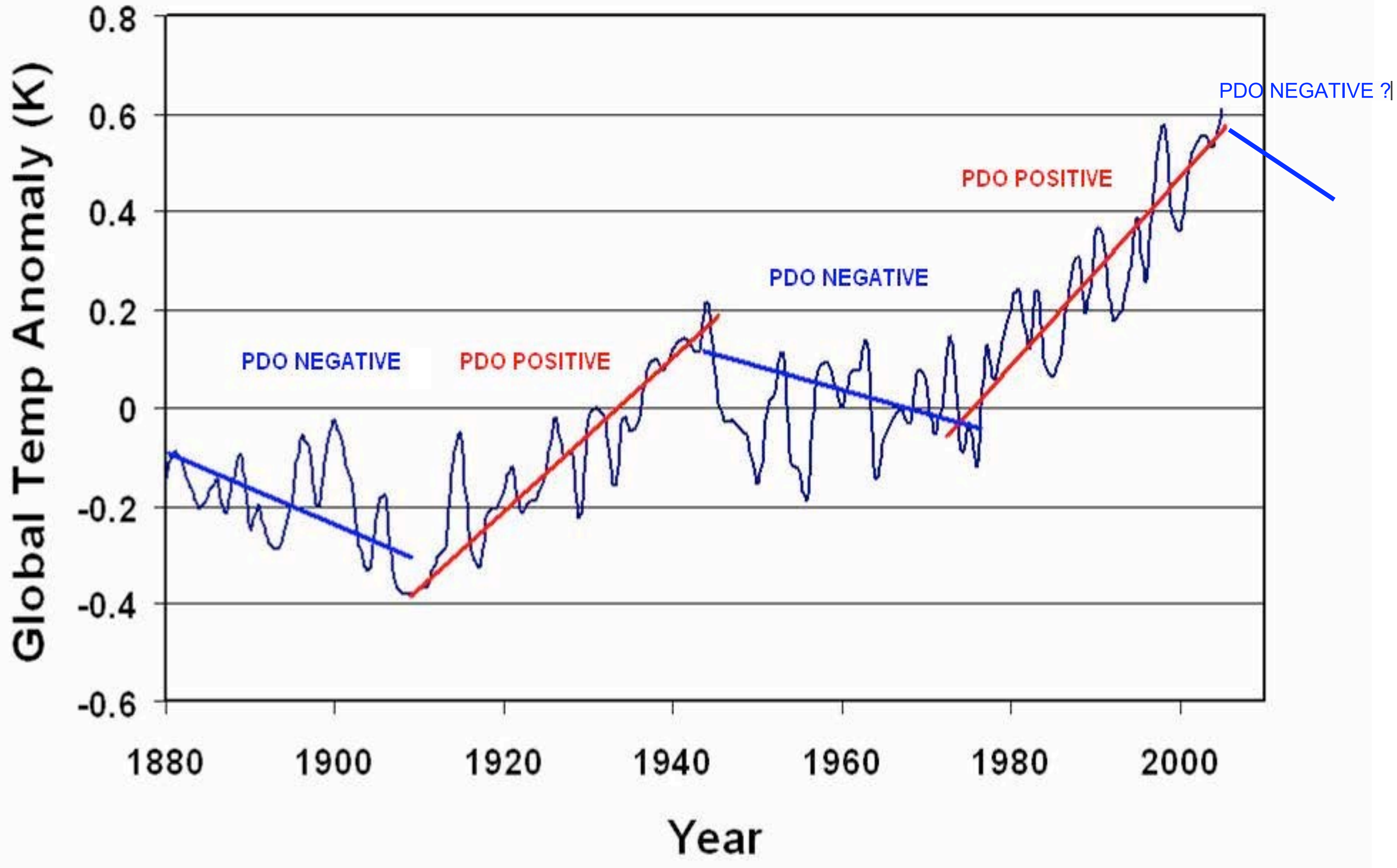
And what is its phase in 2008? – See the next slide



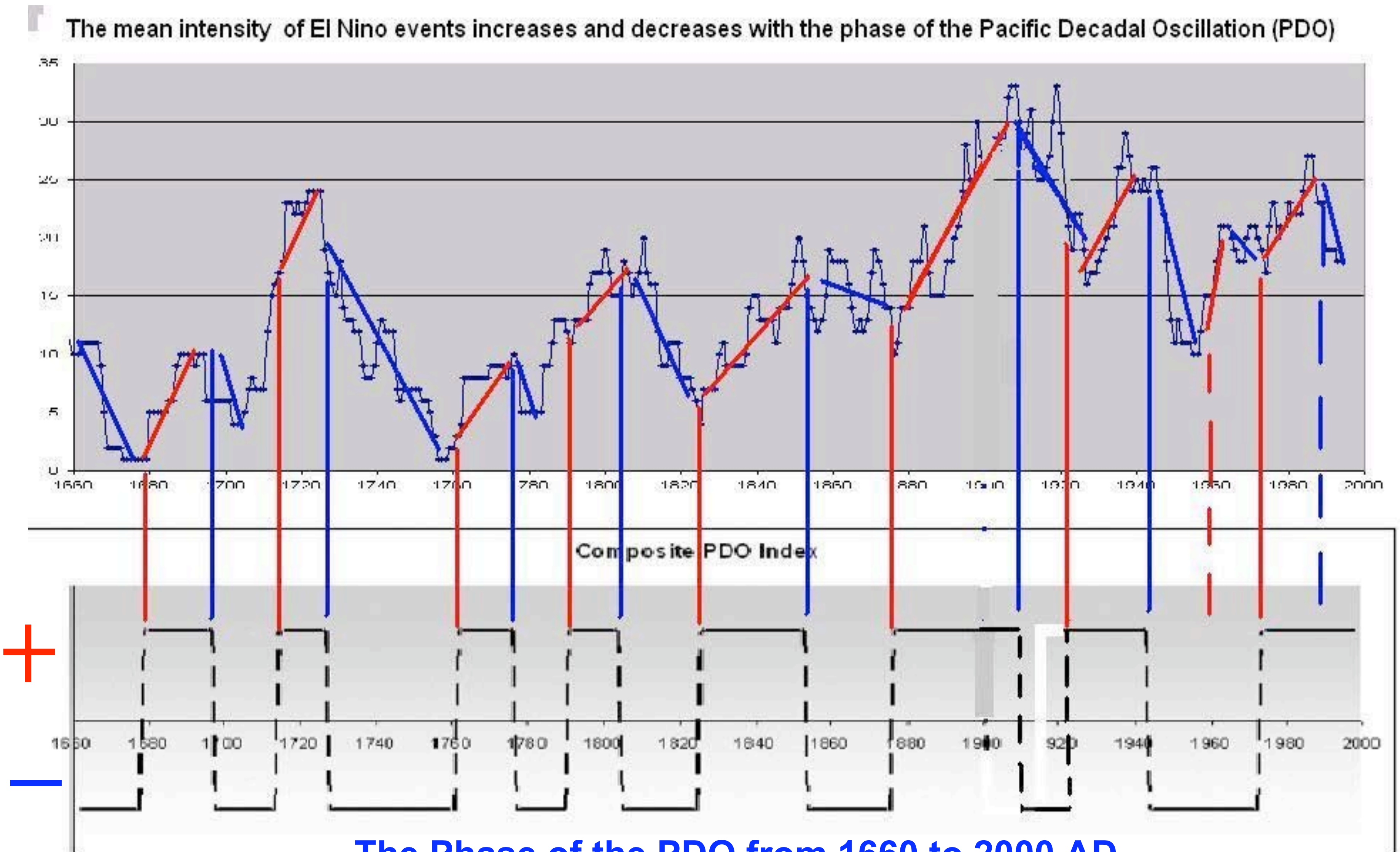


The PDO has just flipped into a negative phase !

What could this mean for the World's mean temperature?



AND HOW DOES THE PHASE OF THE PDO AFFECT THE INTENSITY OF EL NINOS?



The Phase of the PDO from 1660 to 2000 AD

Verdon and Franks (2006)

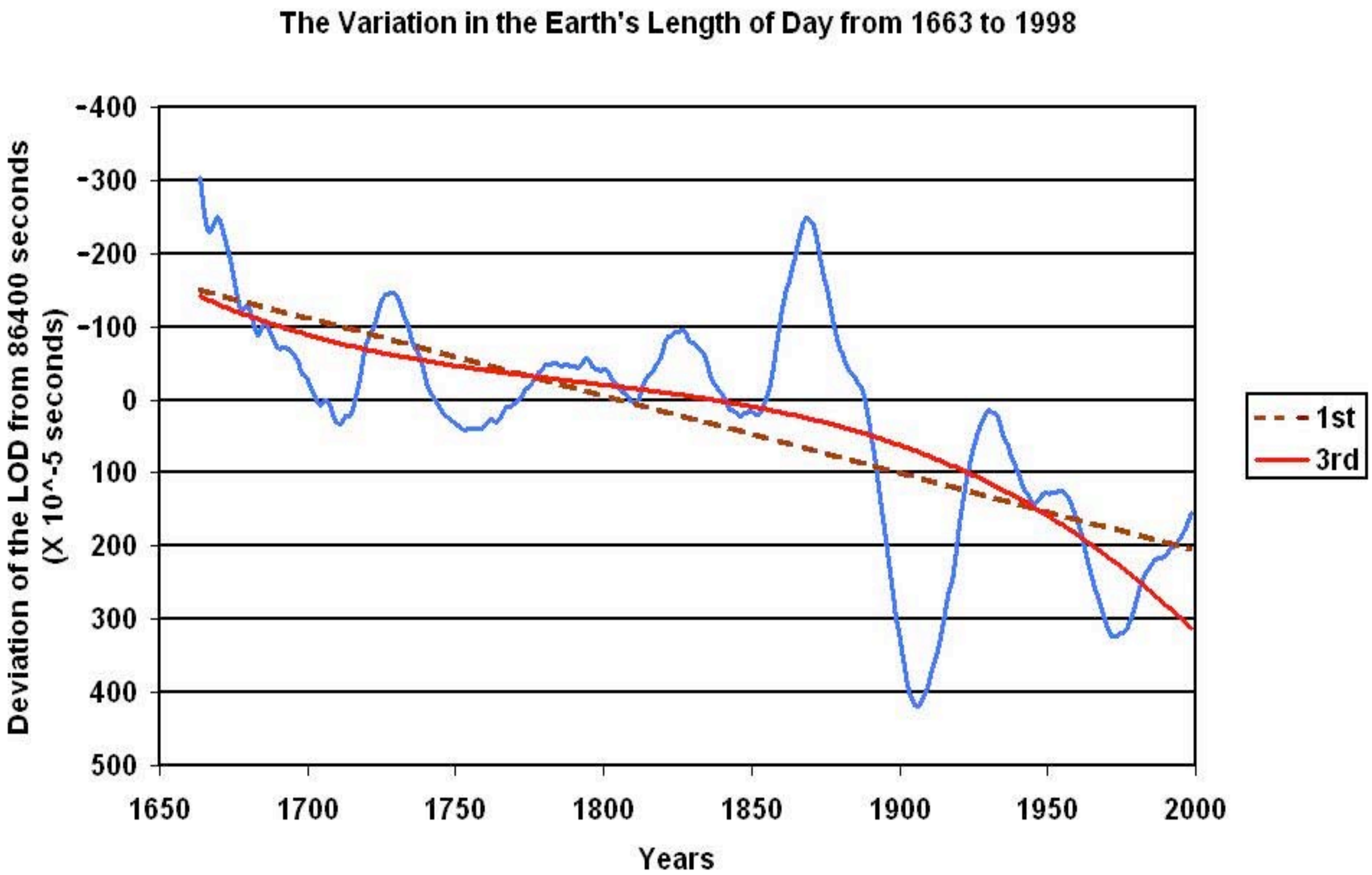
GEOPHYSICAL RESEARCH LETTERS, VOL. 33, L06712, doi:10.1029/2005GL025052, 2006

Hence, the PDO is a climate system that:

- ❖ Has the potential of possibility influencing the rate of warming and cooling of the world over the coming decades

- ❖ Appears to modulate the relative intensity of El Nino/La-Nina events – a climate system that play a pivotal role in producing periods of droughts and floods here in Australia.

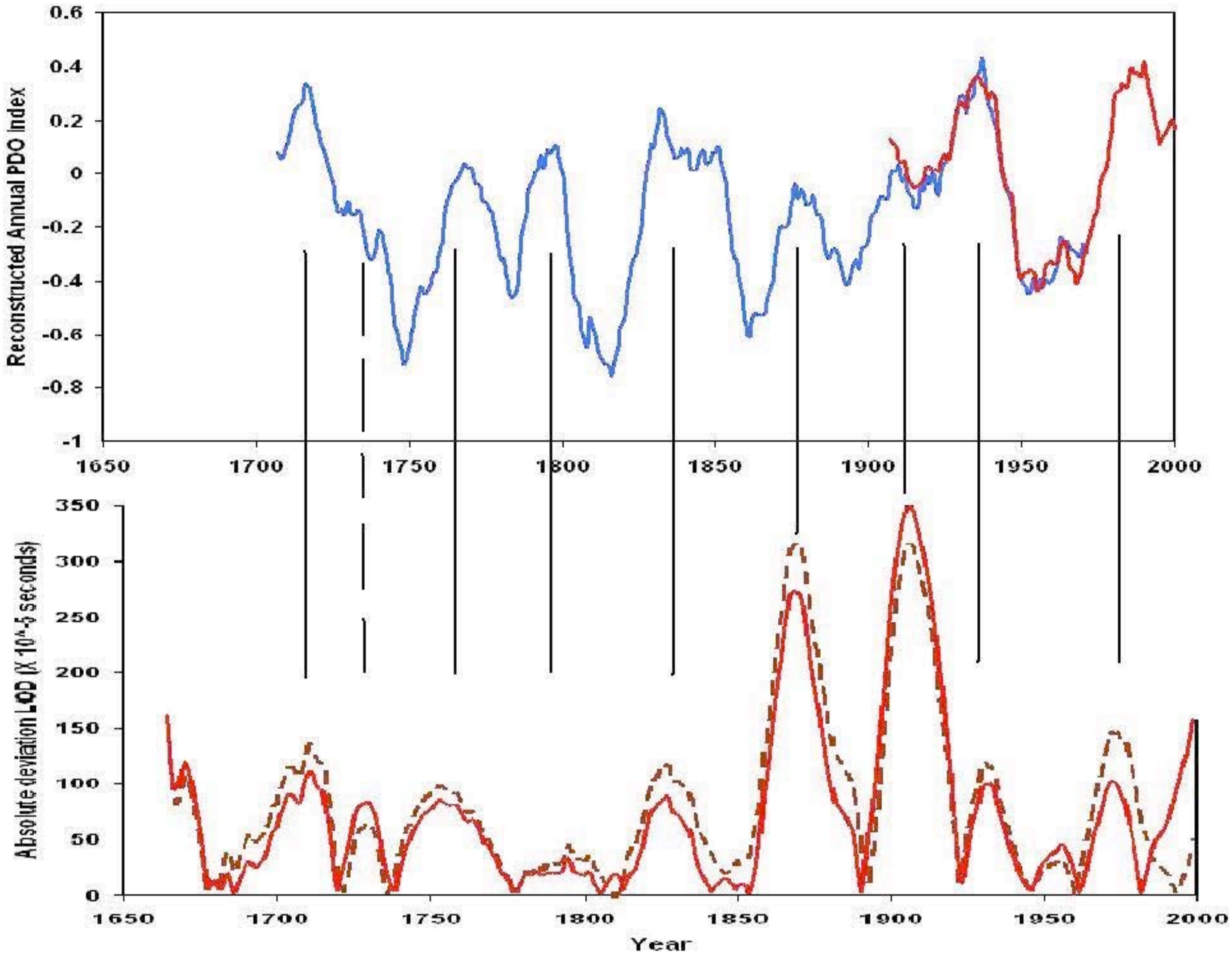
So is the PDO correlated with changes in the Earth's rotation rate?



A first and a third order polynomial is fitted to the LOD curve to find the long term deviations in the Earth's rotation rate.

And the answer is an emphatic YES if you compare the long term deviations in the Earth's rotation rate with long term variations in the PDO (D'Arrigo et al. 2001)

See the next slide!



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 the previous slide shows that 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.

What is most important, however, is that the peaks in the absolute deviation of the Earth's rotation precede those of the PDO by an average of 6 – 8 years!!

(look carefully at the two lower time scales in the previous graph)

This means that it must be long-term variations in the Earth's rotation rate that are effecting the phase of the PDO, possibly through its influence upon the up welling of cold water in the North Pacific ocean.

SO IT APPEARS THAT WE HAVE DETERMINED WHICH CAME FIRST WHEN IT COMES TO THE PDO AND CHANGES IN THE EARTH'S ROTATION RATE

But what cause the long-term changes in the Earth's rotation rate?

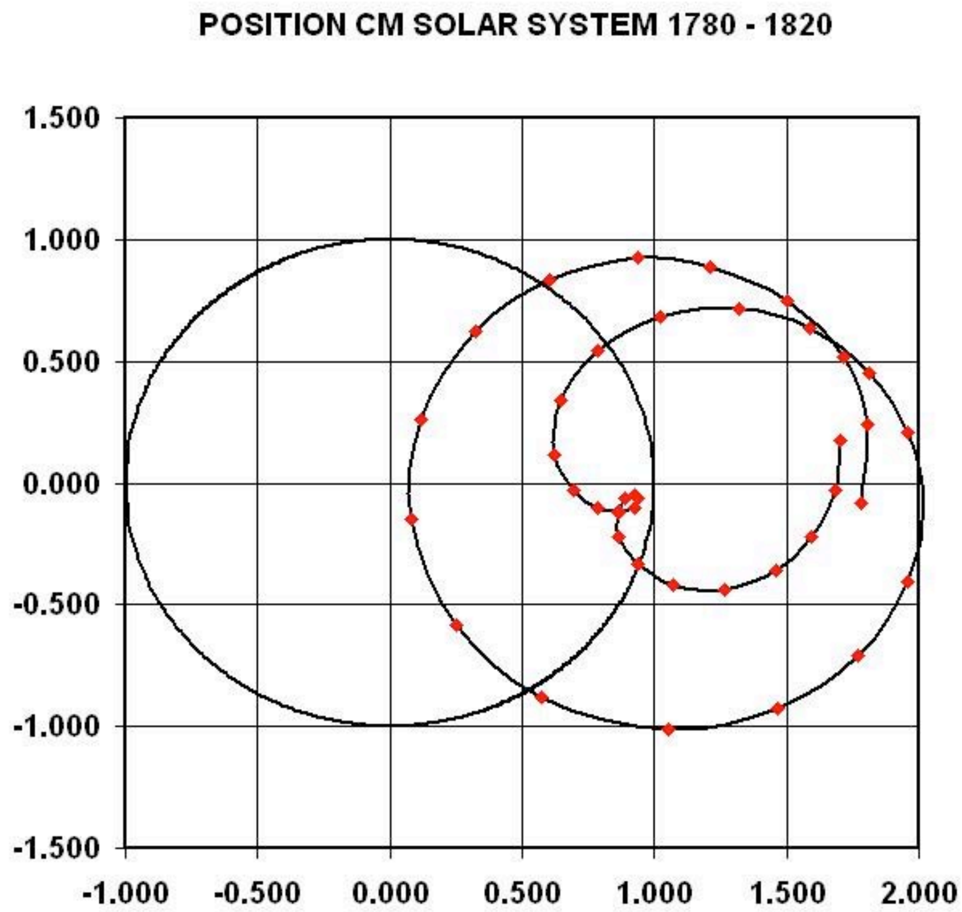
This is where we bring in our third player:

The motion of the Sun about the centre-of-mass of the Solar System and its affect upon the level of solar activity.

- 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.



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 previous slide 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 the figure to represent the Sun, using an x and y scales marked in solar radii.

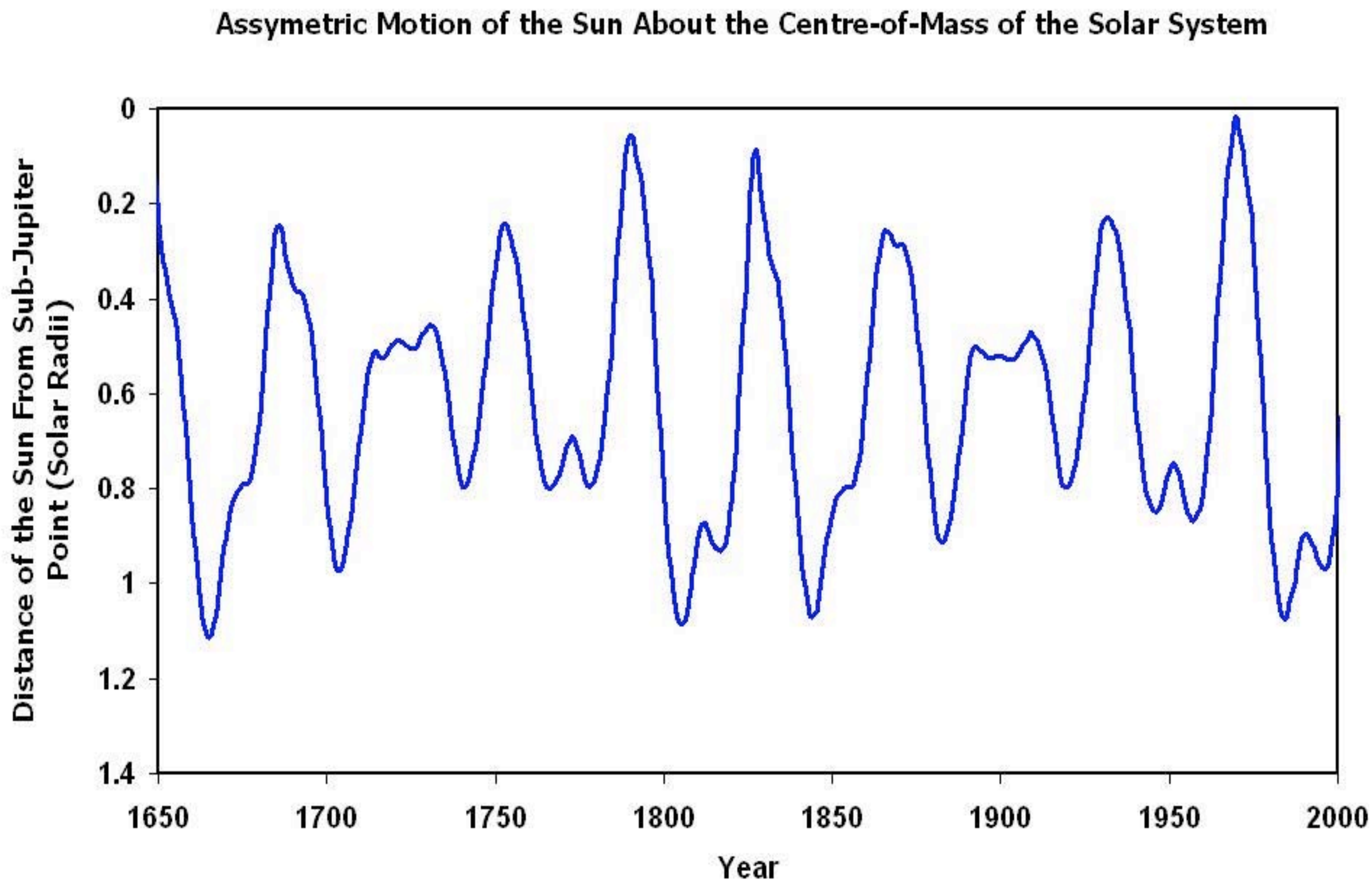
- In this reference frame, the smooth motion of the Sun that results from Jupiter's gravitational influence is removed. This means that the centre-of-mass of the Sun/Jupiter system is a stationary point, located just above the Sun's right-hand surface on the x-axis at the co-ordinate (1.08, 0.00). We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

- Also shown in this figure, is the position of the centre-of-mass of the Solar System 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.

- The path of the CM of the Solar System about the Sun that is shown in this figure 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 this figure 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.

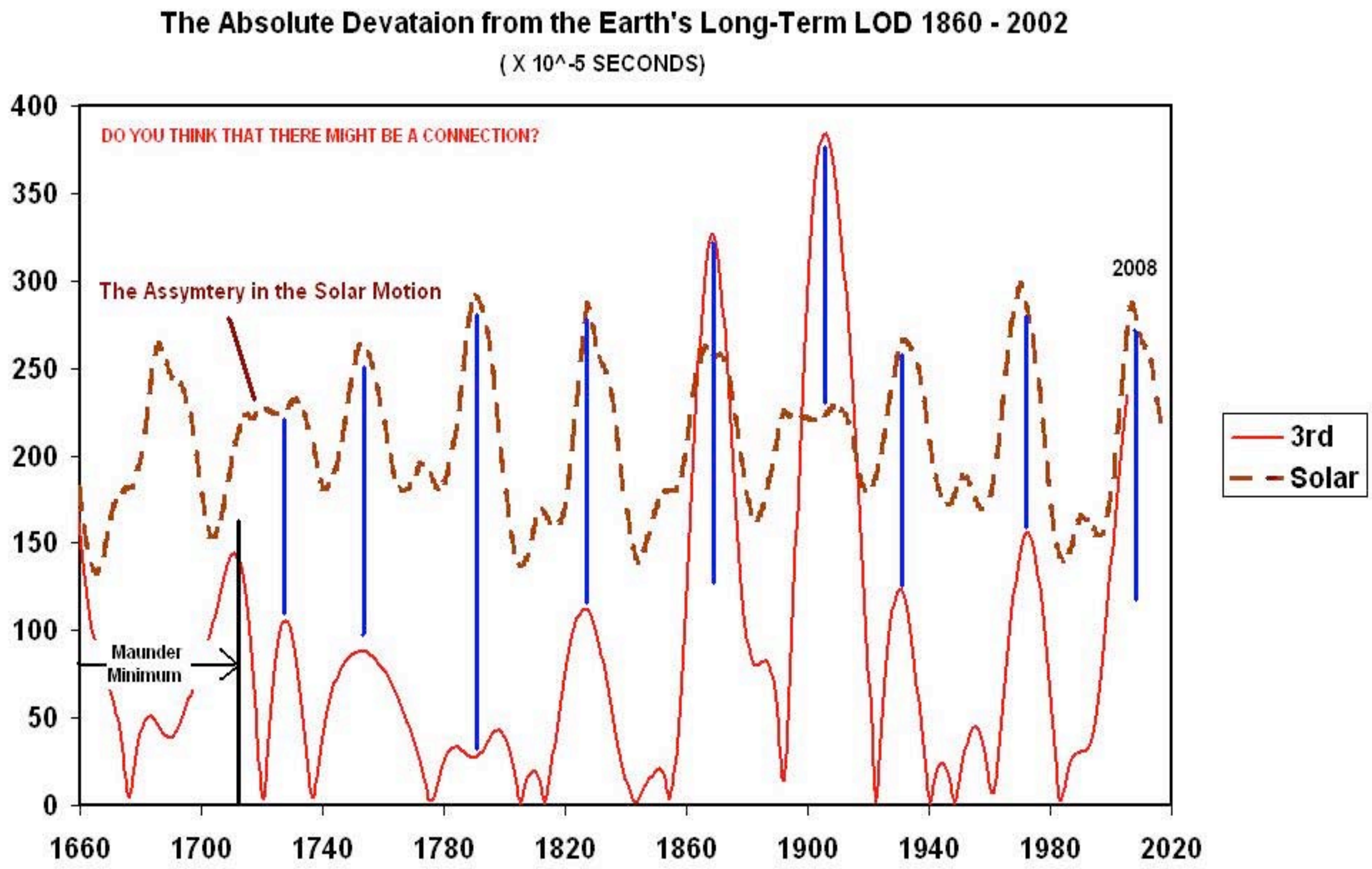
- Hence, we can quantify the magnitude and timing of the Sun's asymmetric motion by measuring the distance of the CM from the point (0.95, 0.0).



This figure shows a plot of the distance of the centre-of-mass 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.

So how do the asymmetries in the Sun's motion about the centre-of-mass of the Solar system compare to long-term deviations in the Earth's rotation rate?

Hold onto your seat!



The Absolute Devataion from the Earth's Long-Term LOD 1860 - 2002
(X 10^-5 SECONDS)
DO YOU THINK THAT THERE MIGHT BE A CONNECTION?
The Assymtery in the Solar Motion
2008
Maunder Minimum
400
350
300
250
200
150
100
50
0
1660
1700
1740
1780
1820
1860
1900
1940
1980
2020
3rd
Solar

- 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 centre-of-mass of the Solar System, the Earth has also experienced a significant deviation in its rotation rate (i.e. LOD) from that expected from the long-term trends.

- This implies that changes in the Earth's rotation rate are being driven by a phenomenon that is external to the Earth that is somehow synchronized with the Sun's motion about the centre-of-mass of the Solar System.

- And, given that the peaks in the deviation of the long-term rotation rate of the Earth precede positive peaks in the PDO by ~ 6 – 8 years, it also saying that at least one major climate system here on Earth (i.e. the PDO) is also being driven externally.

  (Note: This means that the PDO, which is currently negative, should flip back to being positive in about 2016 – 2018, 6 to 8 years after maximum asymmetry in the solar motion in 2008)

So we have established that:

A phenomenon external to the Earth that is synchronized with Sun's motion about the centre-of-mass of the Solar System

↓

Produces long-term deviations in the Earth's rotation rate

↓

That synchronizes the changes in phase of the PDO (and possibly the NAO)

↓

Which modulates the intensity of El Nino/La Nina phenomenon and possibly plays a major role in regulating the World's mean temperature

- And what is this external phenomenon that that is driving the deviation in the Earth's rotation rate on decadal to centennial time scales?

- And why is it synchronized with the Sun's motion about the centre-of-mass of the Solar system?

To get answers to this and more you will have to read my paper that will be published in Russian in early 2009.

However, if you can't wait, the next four slides could provide important clues about the answers to these important questions.

One very important conclusion that follows from all of this is that if you believe the results of our paper:

Does a Spin–Orbit Coupling Between the Sun and the Jovian Planets Govern the Solar Cycle?

I. R. G. Wilson[A,C], *B. D. Carter*[B], *and I. A. Waite*[B]

Publications of the Astronomical Society of Australia, 2008, 25, 85–93

This paper claims that the level of solar activity on the Sun is governed by a spin orbit coupling mechanism between the rotation rate of the Sun and the orbital motion of the Jovian planets.

If this is the case, then it is possible that the reason why the Earth's climate appears to affected by the level of solar activity may just be an illusion!

WHAT DO YOU MEAN AN ILLUSION?

What my work implies is that there is NOT a strong direct link between variation in the level solar activity and the earth's mean temperature on decadal to centennial time scales.

However, they both appear to go up and down together for the simple reason that they are both linked to same underlying cause:

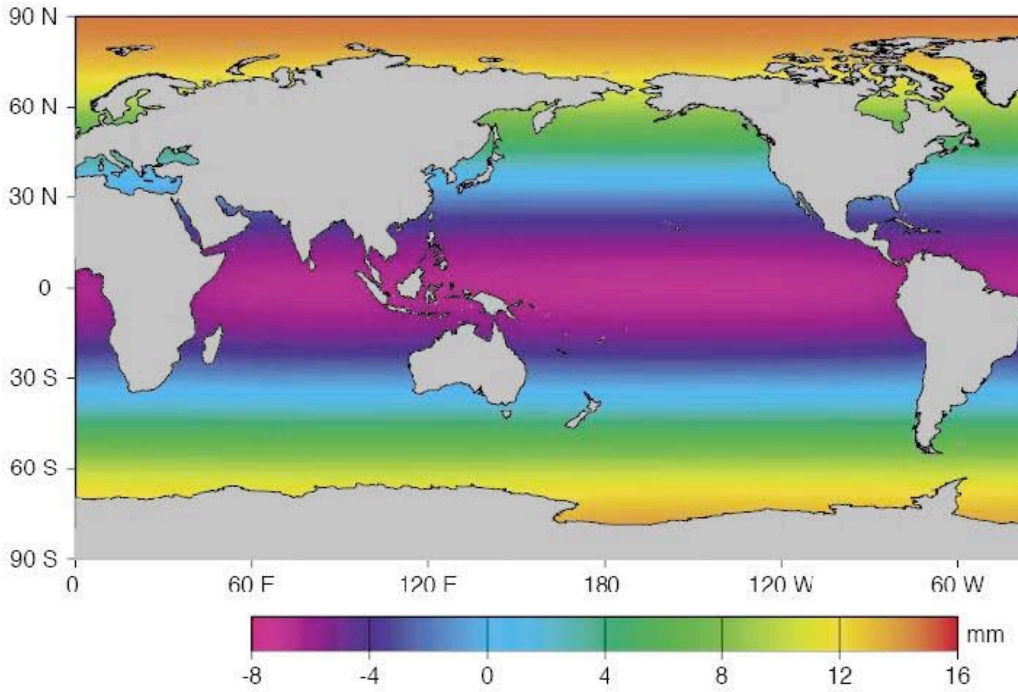
Orbital motion - Jovian planets ➔ Spin-orbit Coupling ➔ Solar rotation ➔ The level of solar activity

Orbital motion - Jovian planets ➔ External phenomenon ➔ Earth's Rotation ➔ PDO ➔ Earth's mean temp.

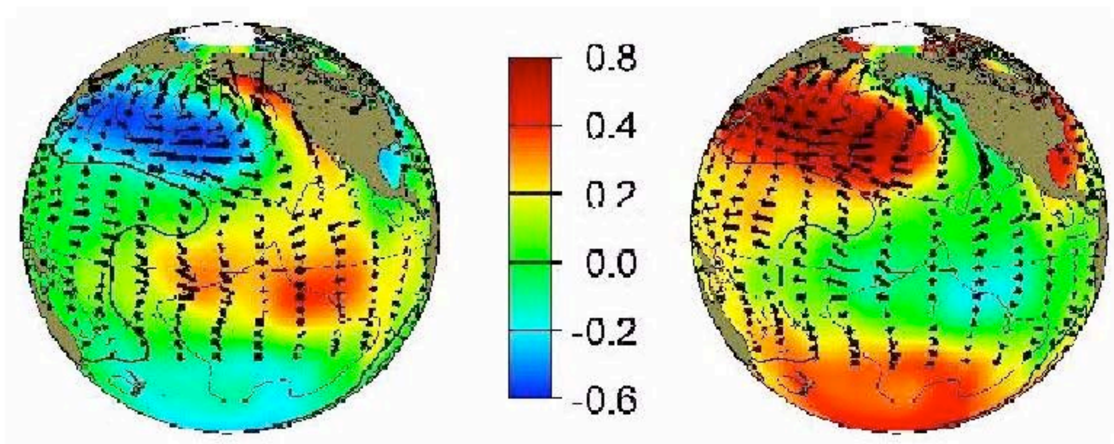
Such a model might explain why small changes in the energy output on the Sun appear to produce mysteriously amplified effects upon the World's mean temperature!

18.6-y Node Tide (Self-consistent equilibrium)

Elevation (mm) when nodal longitude N = 0



Note: N = 0 during years ..., 1969, 1987, 2006, ...



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