Istituto Nazionale di Geofisica e Vulcanologia

Is global seismicity signed by the Markowitz wobble ?

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Abstract

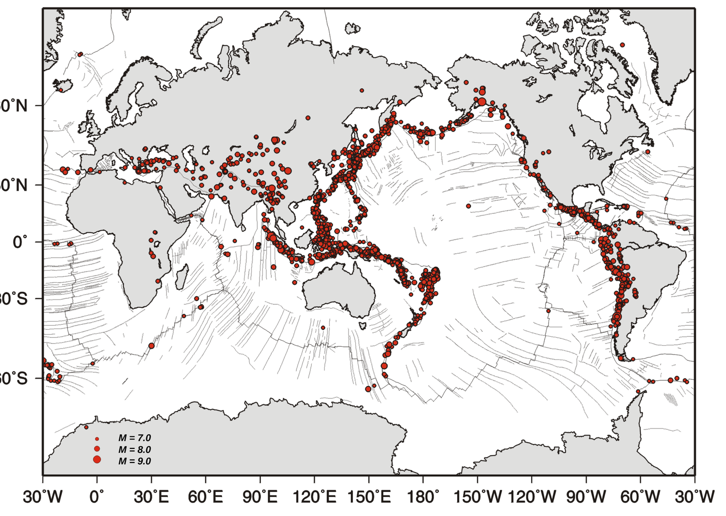
For the past 108 years the worldwide occurrence of large seismic events shows a significant cyclic temporal pattern of about 34 years. The spectral analysis of the irregular Earth's polar motion over the last 108 years filtered from the secular drifts shows that both LOD and polhody are affected by the same significant periodicity. The third amplitude of polar motion at decadal periodicity in the terrestrial reference frame, after the Chandler and annual, is known as Markowitz wobble.

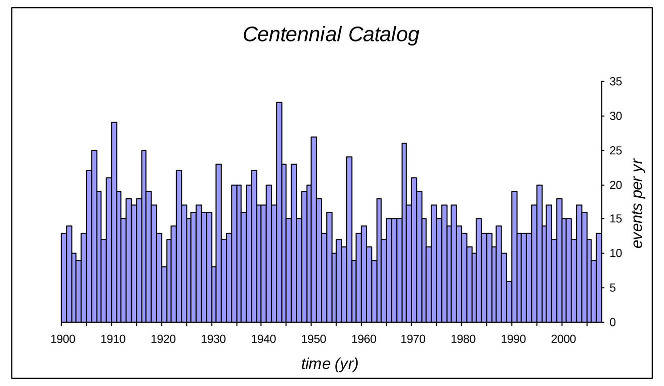
The spectral coherence between the seismicity and polar motion is high at long periods, reaching saturation value at about 20 years. No significant delay is shown by the cross-correlation analysis between LOD, polhody and seismicity.

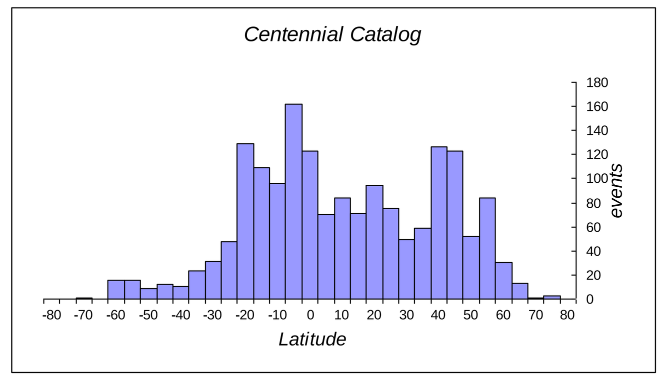
If we accept the idea that global seismicity and polar motion are both signed by the Markowitz wobble, we can infer that they could be modulated by the same cause.

Recent models hypothesize a gravitational and inertial coupling between the mantle and an inner core able to reproduce the Markowitz wobble on the polar motion. However, if the wobble signature on seismicity will be confirmed, this interpretation should probably be revised.

The Seismic Catalog

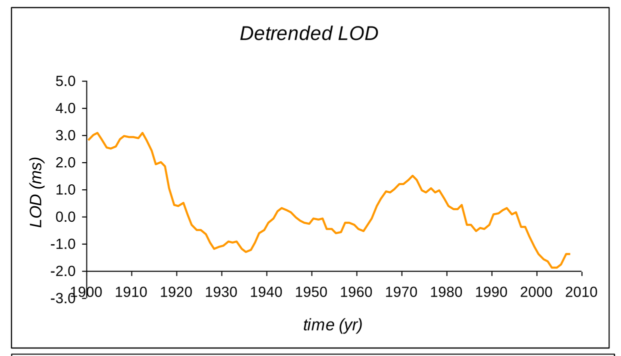


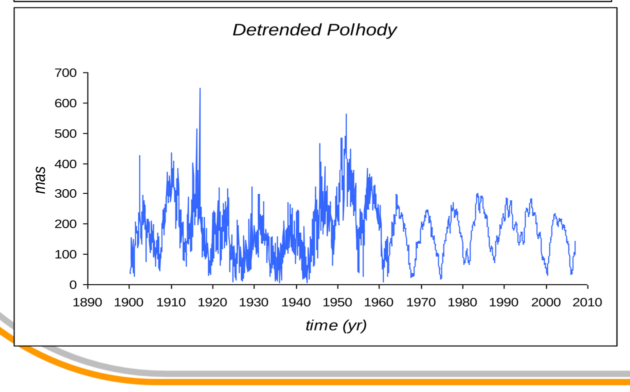




The recently revised global earthquake catalog is the Centennial (Engdahl and Villaseñor, 2002) extending from 1900 to April 2002, complete for magnitudes M≥7.0. To expand the time span, I added all the events with M≥7.0 from the USGS/NEIC global catalog. The updated dataset consists of 1720 events with M≥7.0, from 1900 to September 2007.

The Polar Motion





LOD

Detrended annual LOD values from JPL completed by yearly averaging the daily LOD values from C04

Polhody

Detrended values of $P(t) = \sqrt{X(t)^2 + Y(t)^2}$ where X and Y are the instantaneous coordinates of pole from EOP(IERS) C01 serie of the Earth Orientation Parameters given at 0.05 year over the interval 1890 to now.

All available at http://hpiers.obspm.fr/eop-pc

Series Analysis Flowchart

Raw Time series

Detrending, Filtering and Normalization

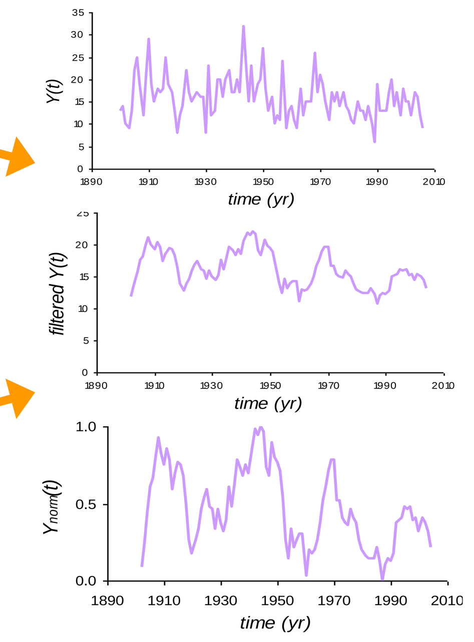
Detrending: linear secular trend removal

Filtering: low-pass 5yr moving average

Normalization: $y_{norm}(t)$ is defined as

$$y_{norm}(t) = \frac{y(t) - y_{min}}{y_{max} - y_{min}}$$

so that
$y_{norm}=0$ if $y(t) = y_{min}$ and
$y_{norm}=1$ if $y(t) = y_{max}$



Periodogram

Cross-correlation

Spectral coherence

Periodogram

Spectral analysis

If we have a discrete time serie of possibly unevenly sampled data, a useful method is based on the Lomb criterion. Although the periodogram can be evaluated for any frequency, it is traditionally evaluated only at a special set of evenly spaced frequencies (the Fourier frequencies).

It is well known that at the Fourier frequencies sinusoid components are orthogonal. However this property does not hold with missing data. To recovery the orthogonality, Lomb introduced a time delay τ, defined for each frequency ω by

$$\tau(\omega) = \frac{1}{2\omega} arctan \left\{ \frac{\sum_{n=1}^{N} sin\, 2\omega t_n}{\sum_{n=1}^{N} cos\, 2\omega t_n} \right\}$$

and defined the periodogram as

$$P(\omega) = \frac{1}{2\sigma^2} \left\{ \frac{\left[\sum_{n=1}^{N} x(t_n) cos\, \omega (t_n - \tau(\omega)) \right]^2}{\sum_{n=1}^{N} cos^2\, \omega (t_n - \tau(\omega))} + \frac{\left[\sum_{n=1}^{N} x(t_n) sin\, \omega (t_n - \tau(\omega)) \right]^2}{\sum_{n=1}^{N} sin^2\, \omega (t_n - \tau(\omega))} \right\}$$

where $x(t_n)$ is the zero-mean discrete serie of the available data and σ^2 the variance

Cross-correlation and spectral coherence

Cross-correlation

If we have two discrete series X(n) and Y(n), the general cross-correlation serie is defined as

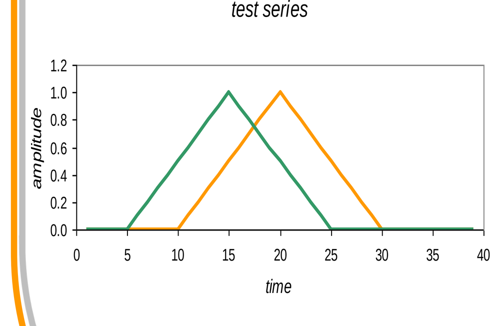
$$C(l)_{X,Y} = \begin{cases} \sum_{n=0}^{N-l-1} X_{n+l} \cdot Y_n^* & l \geq 0 \\ C(-l)_{Y,X}^* & l < 0 \end{cases}$$

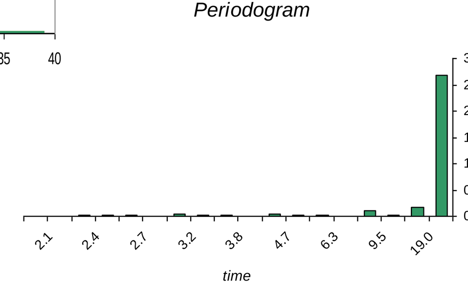
where l is the time lag and the superscript * indicates the complex conjugate. The estimation of cross-correlation between two sequences X(n), Y(n) evaluates the sum shown above with a FFT-based algorithm in the frequency domain. The procedure is equivalent to convolution with one of the two sequences reversed in time.

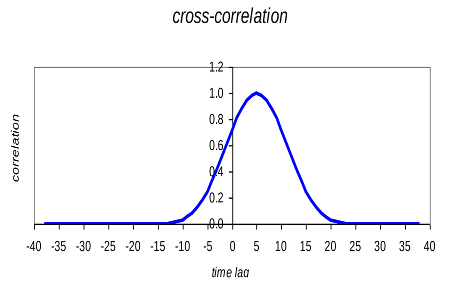
Spectral coherence

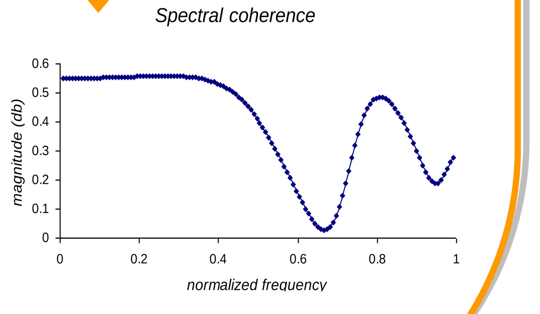
The magnitude squared coherence estimate is a function of frequency with values between 0 and 1 that indicates how well x corresponds to y at each frequency. The coherence is a function of the power spectral density (Pxx and Pyy) of x and y and the cross power spectral density (Pxy) of x and y. x and y must be the same length.

$$C_{xy}(f) = \frac{|P_{xy}(f)|^2}{P_{xx}(f) P_{yy}(f)}$$









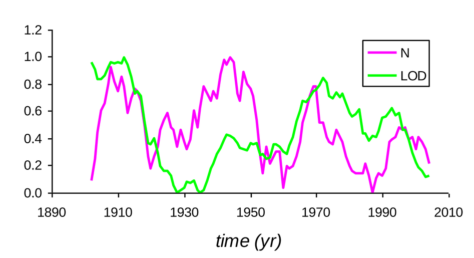
Markowitz wobble ?

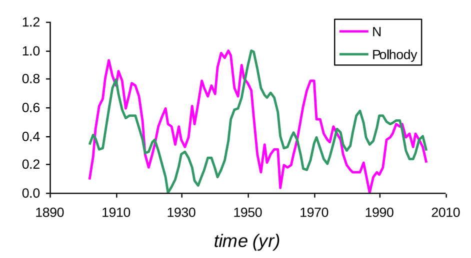
The motion of the Earth's rotation axis with a period of about 30 years was first reported by Markowitz in 1960 (24 years). The Markowitz wobble is the only stable retrograde polar motion with amplitude of about 25-30 mas corresponding to 0.5 m of motion on the Earth's surface, if compared with the Chandler it appears about 30 times smaller.

Recent models hypothesize a gravitational and inertial coupling between mantle and inner core, due to a time-dependent axial misalignment between the two density structures; another is based on oceanic and athmospheric circulation. All are able to explain the Markowitz periodicity, but are not able to account for its amplitude (Dunberry, 2008; Gross et al., 2005). At present, the modeling of the Markowitz wobble remains uncomplete.

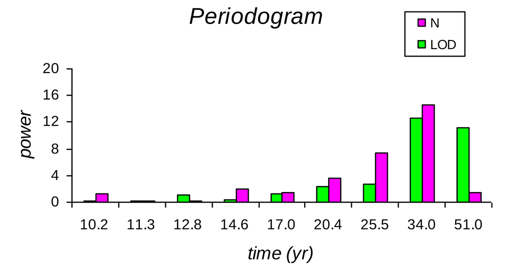
Here I analyze the time series of N (number of seismic events per year), LOD and Polhody

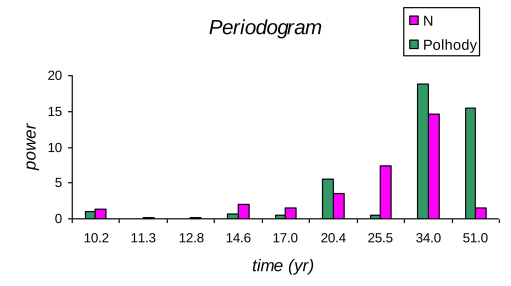
Detrended Normalized Time series N LOD Polhody



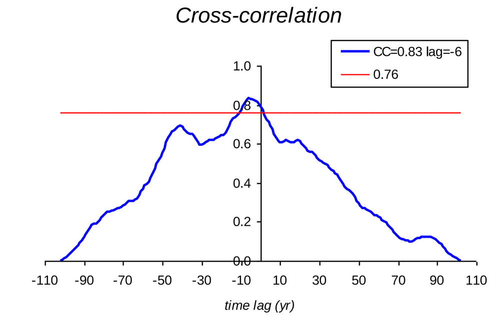


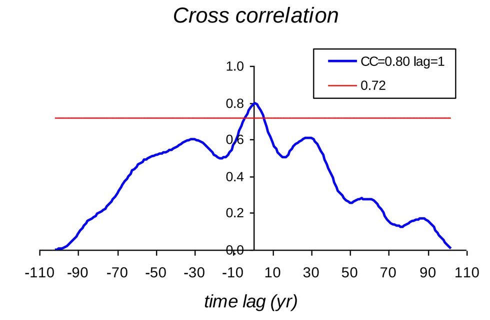
Time span
1900-2007



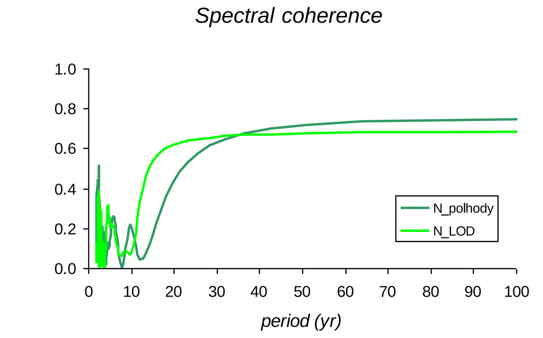


Significant periods
34, 51 yr
at 95% confidence level





Cross-correlations
0.83 c. i. 0.76-0.88
0.80 c. i. 0.72-0.86
at 95% confidence level
lag insignificant



Spectral coherence
high & stable for

N-LOD ≥15 yr
N-Polhody ≥25 yr

Thanks ! and References

A lot of thanks are due to:
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