2003 ICES Annual Science Conference. Tallinn. ICES CM 2003/T:02
Theme Session T. On the State Stability of the northern North Atlantic: Patterns and Trends.



# A Lunar nodal spectrum in Arctic time series

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## Abstract

The paper presents a wavelet spectrum analysis of the time series from the Polar movement, the Arctic ice extent, the Kola temperature, and the NAO winter index. The results show that all time series have dominant harmonic and sub-harmonic cycles which are correlated to the 18.6 yr lunar nodal spectrum. The lunar spectrum is explained by an Arctic oscillation caused by gravity from the 18.6 yr lunar nodal cycle. The oscillating gravity force from the Moon is distributed on the Earth as a lunar nodal spectrum and observed as an oscillating climate disturbance. The spectrum has stationary cycle periods and time variant phases. The time variant phase is controlled by a dominant sub-harmonic cycle of 74 years which modulates a phase-reversal in higher frequent periods. The identified lunar nodal spectrum in all time series are explained by a mutual related Arctic Oscillation system.

Key words: Arctic oscillation system, Climate oscillation, Lunar nodal tide, NAO winter index, Polar position, 18.6 yr lunar nodal spectrum, Wavelet analysis.

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# Introduction

The Swedish oceanographer Dr. Otto Pettersson (1848-1941) is one of the founders of the ICES organization. In 1909 Pettersson studied the relation between herring catches and tides in Gullmarfjord on the West cost of Sweden. The studies showed that the lunar perigee variation was related to the freshwater and the arrival of schools of herring. As the ocean water presses in toward that inland sea it dips down and lets the fresh surface water roll out above it; and at that deep level where salt and fresh water come into contact there is a sharp layer of discontinuity, like the surface film between water and air. This salt layer had a vertical fluctuation in long time series. He found that the fluctuation was correlated to the Moon phases, long period tides and long periods herring catch. He explained these fluctuations by a long period vertical tide that influenced the layers of different density in the ocean. Fluctuations in the layers then influenced the sea surface temperature, the climate and the recruitment of herring. He concluded that the long period tide cycles of 18.09 and 111 years were the cause of herring biomass fluctuations at Bohuslen (Petterson O., 1912, 1914a, 1914b, 1915, 1930).

Petterson argued there is two types of tides. The *diurnal and the semi-diurnal tide* caused by the rotation of the Earth under the gravitational field of the Sun and the Moon. The second type of tide he called *the parallactic tide*. This tide depends upon the varying distance of the Sun and the Moon and their position relation to the Earth. Analyzing the distance he found oscillating periods of 9, 18, 93, 111, 222… 1433 and 1850 years. The most important cycle was the 18.09 yr Saros cycle and the 111 yr cycle which he called “The Greater Saros” (Petterson; 1915, 1930). Ljungman had presented the theory that long-term biomass fluctuation of herring was related to a 111 year sunspot cycle. Now Pettersson found a 111 yr cycle which matched the 111 year cycle in the herring records from Ljungman. Petterson saw there was a relation between the long-term waves and extreme climate events and biomass fluctuations. He found a close relation between the winter temperature at the Ona light house at the Norwegian west coast and the air climate in Sweden (Pettersson, 1914a; Helland-Hansen and Nansen, 1909). From these estimates he argued that hydrographic changes effected the air climate in Scandinavia (Sanders, 1995).

The parallactic tide theory from Otto Pettersson was not accepted by other scientists. The theories of tides were based on the work from Laplace. The work from Laplace showed that this tide is too small to have any noticeable influence on the sea. When Petterson draw the conclusion that the cycles of herring was an astronomical coincidence of lunar periods, he presented his results to Krümmel. Krümmel did accepted the reality of the phenomenon, but he declared that such considerable oscillations in the intermediate layer of the sea could not possibly be a tide phenomenon (Petterson, 1930). Krümmel wrote in his comment that: “anyone who has the slightest knowledge of the theory of tides must perceive that it cannot be a tide phenomenon”. The famous meteorologists Waldemar Köppen said “this is to give our planet’s satellite in space the blame for catastrophes of which she is absolutely guitness”. The leading authority in astronomy in America professor Young said, “The multitude of current beliefs as to the controlling influence of the moon’s phases and changes over the weather and various conditions of life are mostly unfounded and in the strict sense of the word superstitious”.

Petterson did not accept the result from Laplace and the comments from the others. He continued to argue that the model from Laplace was based on an homogenous sea. To him they overlooked the fact that the sea consists of layers of different density, whish can glide one over the other. A long-term vertical tide could introduce a vertical fluctuation in the layers. A vertical fluctuation in the layers then could explain fluctuations of herring recruitment in Bohuslen, fluctuation on the surface temperature, and fluctuations in climate (Pettersson, 1915, 1930).

**The 18.6 yr standing wave.**

Russian scientists continued the ”Lunar-wave” theory from Pettersson. In 1930’s the ideas of long-period tides that influenced the water circulation in the Atlantic was investigated by A L Chizhevsky, V B Shostakovich, M S Eygenson, B M Rubashev, T V Pokrovskaya, Lisitzin, Rossiter and others. Maksimov and Smirnov (1964, 1965, 1967, 1967) estimated a standing 19-year tide in the Atlantic Ocean. They found that this long period wave influences the velocity and circulation of water masses and the sea temperature. The estimated changes in the temperature were about +/- 0.2 degree Celsius in the Atlantic and the Kola section. Maksimov and Smirnov (1970) summarized the investigations by a Standing wave theory.

1. A Standing wave: There is a global standing 19-years wave in the oceans. In a time series from 1922 to 1960 it is identified a 19-year tidal wave that covers the Atlantic Ocean. This wave has the same cycle time in St. Andrew Sound, Faroes-Shetland Channel, Nordøyane, Skomvær, and Kola median.
2. A standing node: The standing wave has a maximum at the Arctic pole, a 50% maximum at the equator and a zero node at the 35 degree Latitude.
3. A standing “astronomical” current: There is a corresponding long-term “astronomical“ current that fluctuates between the pole and the equator. The current has a maximum at the node.

The 18.6 yr tidal water temperature in the North Atlantic was expressed by the equation $T_{18.6}(t)=0.24°C \sin(19.35°t+80°)$. Where $T_{18.6}(t)$ has a maximum in 1950 and a minimum in 1959. The climate theory from Maksimov and Smirnov was based on the conclusions

1. A 19-years sea-current oscillation: Small 19-year fluctuations in the Atlantic currents was sufficient to change the vertical temperature distribution and the surface temperature.
2. A 19-years atmospheric tide: Interaction between 19-years surface of the surface temperature fluctuation introduced a 19-years tidal fluctuation in the atmosphere.
3. A 19-years weather fluctuation: A 19-years tidal fluctuation in the atmosphere introduces a 19-years fluctuation in the weather.

Maksimov and Smirnov concluded, “The tidal phenomena in the atmosphere are not a consequence of the existence of pressure wave in the atmosphere of high latitudes, but the develop in nature soley as a result of the development in the seas and oceans (especially in high latitude) of a long-period lunar tide which causes modifications in the transport and distribution of the heat in the hydrosphere.” Maksimov and Smirnov (1965) has the following comment in this paper. “Krümmel once commented that any idea that the Moon affected weather was pure superstition. In our opinion, this judgment, which has had a great effect on science, was over hasty.” The results supported the ideas from Pettersson. At the same time it showed that Pettersson had mixed the 18.6 yr lunar nodal tide and the 18.09 yr Saros tide.

This paper presents the result of a wavelet time series analysis of Arctic climate indicators. These time series are the Polar position movement, Barents Sea ices extent, the Kola section temperature series and the sea level at Hammerfest. The results shows there is a dominant 18.6 yr lunar nodal spectrum in all time series. This investigation supports the results from Pettersson and Maksimov and Smirnov. The identified spectrum from en 18.6 yr lunar nodal cycle is explained by an Arctic oscillation system.

# Materials and methods

The Polar position data series (y-direction) is based on the official data from The International Earth Rotation Service (IERS) and covers the year 1846 until 2002. The time series is provided from the Internet address http://hpiers.obspm.fr/eoppc/eop/eopc01/. The time series has 10 samples per year from 1846 to 1900 and 20 samples per year from 1900 to 2002 and represents the celestial pole offset in arc degrees. This time series are used to identify the Chandler wave. The 6, 18 and 74 years cycles are identified by the annual mean value of this time series.

The referred area of Barents Sea ice extent covers the Norwegian Sea, the Barents Sea and the Kara Sea bounded by 10°E, 80°N and 70°E. The data are based on April values from 1864 until 1998 (Vinje, 2001).

Russian scientists at the PINRO institute in Murmansk have provided monthly temperature values from the upper 200 m in the Kola section along the 33°30'E medial from 70°30'N to 72°30'N in the Barents Sea (Bochkov, 1982). The data series from 1900 until 2001 has quarterly values from the period 1906-1920 and monthly values from 1921, partly measured and partly interpolated. In this presentation the annual mean temperature is analyzed.

The North Atlantic Oscillation (NAO) is defined as the normalized pressure difference between a station on the Azores and one on Iceland. The NAO index analysis is based on the official data from Climate Research Unit and covers the years 1822 until 2001. The data series is obtained from the Internet address http://www.cru.uea.ac.uk/cru/data/nao.htm. In this presentation the NAO winter index is computed as the annual mean temperature from December to March.

The time series of sea level at Hammefest is provided by Statens Kartverk in Norway. The time series has the mean monthly values from 1957 to 2002.

*The wavelet transformation*

The analysis problem is to identify a possible lunar nodal cycles in the time series. Stationary cycles are expected to introduce cycles of a time variant amplitude and phase in systems when there are time variant external relations. In a long time series this will introduce a time variant amplitude and phase in the estimated cycles. This property makes it difficult to identify stationary cycles by straight forward statistical methods. A second problem is that in these short time series, it is difficult to identify low frequent cycles and to separate the high frequent cycles from noise. Wavelet transformation is an appropriate method to analyze time variant data series. A continuous wavelet spectrum is computed by the wavelet transform

$$W(a,b) = \frac{1}{\sqrt{a}} \int_R x(t) \Psi\left(\frac{t-b}{a}\right) dt \qquad (1)$$

where x(t) is the analyzed time series, $\Psi(\ )$ is a wavelet impulse function, W(a,b) is the computed wavelet cycles, b is a translation in time and a is a time scaling parameter in the wavelet filter function. The computed wavelets W(a,b) represents a set of filtered time series from the time series x(t) and the impulse functions $\Psi(\ )$. In the following analysis, a Coiflet3 wavelet transform is chosen from many trials on tested data (Matlab, 1997; Daubechies, 1992). This wavelet transformation represents a linear phase filter which is able to separate additive cycles in a time series. A wavelet transformation W(k,t) represents a set of cycles in the time series x(t). The time series x(t) thus may be represented by a sum of dominant wavelets that has most of the energy in the time series x(t). Then we have

$$x(t) = \sum_k \mathrm{W(k,t)} + \mathrm{v(t)} = W(t) + v(t) \qquad (2)$$

where k is a cycle period, W(k,t) represents a dominant wavelet cycle where the cycle period is k years, W(t) is the sum of wavelet cycles, and v(t) is error. A wavelets cycle W(k,t) represents a moving correlation to an impulse period k. A dominant cycle period thus represents the best correlation to a cycle period k.

*Cycle period verification*

The lunar nodal spectrum U(j?$_0$) is identified in the wavelet spectrum by computing the cross-correlation quotient

$$R(k) = E[u(jw_k)W(k,t)] \quad (3)$$

where u(j?$_k$) is the cycle k in the lunar nodal spectrum U(j?$_0$) and W(k,t) is the cycle k in the computed wavelet spectrum. The wavelet cycle time k is tested by computing the correlation coefficient R(k) between the dominant wavelet cycle W(k,t) and a potential known cycle u(j?$_k$).

*The correlation quality verification*

The correlation value of quality is computed by Q(k)=R(k)*sqrt[(N-2)/(1-R(k)*R(k)] where N is the number of samples in the time series.

*Cycle dominance verification*

The cycle amplitude dominance is identified by the Signal/Noise-relation. The Signal/Noise-relation between the dominant wavelets and the error is computed by

$$S/N = \mathrm{var}(W(t)) / \mathrm{var}(x(t) - W(t)) \quad (4)$$

where var(e(t)) = var(x(t)-W(t)) represents the estimated error in the time series.

# Results

Table 1 shows the results of the wavelet spectrum analysis. The table shows it is identified a lunar nodal spectrum in all analyzed Arctic time series. In this table the angle frequency ?$_0$=2p/T$_0$=2p/18.6134 (rad/yr). T$_0$=18.6134 is the lunar nodal cycle. The lunar nodal spectrum is identified in all analyzed time series. The time series of the Polar position, the Barents Sea ice extent, the Kola section temperature, the Hammerfest sea level and the NAO winter index has an harmonic spectrum from the T$_0$=18.6 yr cycle.

Table 1 shows that the identified cycles has a good correlation to a nodal reference cycles and a good Signal/Noise-relation between the identified cycles and noise. These estimates shows that the cycles from the lunar nodal spectrum has a major influence on the dominant fluctuations in the time series. The close relation between the cycle phase in the different time series demonstrates that the wavelet analysis method is of good quality.

| ***Climate Indicator*** | ***Nodal spectrum*** w$_0$ **(rad/yr)** | ***Cycle phase*** **f (rad)** | ***Phase delay to Polar*** D**f (rad)** | ***Nodal cycle correlation*** **R** | ***Signal noise relation*** **S/N** |
|---|---|---|---|---|---|
| Lunar nodal cycle | $\omega_0$ | 1.00p | 0.00p | | |
| Polar position | $\omega_0/4$<br>$\omega_0$<br>$3\omega_0$<br>$15\omega_0$ | 1.29p<br>1.00p<br>-1.09p<br>-1.09p | | 0.86<br>0.70<br>0.44<br>0.96 | 2.6 |
| Arctic Ocean *) | $\omega_0/4$<br>$3\omega_0/4$<br>$9\omega_0/4$ | | | | |
| Barents ice ext. | $\omega_0/4$<br>$\omega_0/$<br>$3\omega_0$ | 0.25p<br>1.50/0.50p<br>-1.09/-0.09p | 1.07p<br>0.50p<br>1.00p | 0.73<br>0.74<br>0.64 | 2.0 |
| Kola section temp. | $\omega_0/4$<br>$\omega_0/3$<br>$\omega_0$<br>$3\omega_0$ | 0.29p<br>0.90p<br>1.55/0.55p<br>-1.09/0.09p | 1.00p<br><br>0.45p<br>0.00p | 0.95<br>0.89<br>0.90<br>0.37 | 3.2 |
| Hammerfest Sealevel. | $\omega_0$<br>$3\omega_0/$ | 1.00p<br>-0.09p | 0.0p<br>1.0p | 0.73<br>0.37 | 1.6 |
| NAO winter index | $\omega_0/4$<br>$\omega_0$<br>$3\omega_0$ | -0.99p<br>1.48/0.48p<br>-1.29/-0.29p | 0.28p<br>0.52p<br>-0.8p | 0.90<br>0.48<br>0.2 | 3.0 |

Table 1 Identified lunar nodal cycles in Arctic climate indicators.

*) Estimated by Bønisch and Schlosser (1995).

*Lunar nodal cycle phase-reversal*

The lunar nodal spectrum has a stationary cycle time but not stationary amplitude and phase. In most time series the amplitude of the $4T_0$=74.4 yr cycle introduces a p (rad) phase-reversal in the harmonic cycles of $T_0$=18.6 and $T_0/3$=6.2 years. The phase-reversal property introduces a new type of uncertainty in forecasting. The lunar nodal cycles may still be deterministic, but to make long-term forecasting we have to know more about when we may expect the next phase-reversal. This phase-reversal explains why the lunar nodal cycles has been difficult to estimate by standard spectrum analysis methods.

The physical processes behind this phase-reversal are still unclear. The analysis indicates there is a multiplicative modulation between the 74 yr cycle and the cycles from the lunar nodal tide. When the 74 yr cycle meets a physical limitation in negative direction, it will lead to a phase-reversal of the modulated carrier cycle.

# Discussion

The 18.6 yr lunar nodal cycle introduces a 18.6 yr oscillating gravity force on the Earth. The oscillating force is distributed on the Earth as a lunar nodal spectrum and observed as an oscillating climate disturbance. In this investigation a 18.613 yr lunar nodal spectrum is identified in all analyzed time series. The identified spectrum has stationary cycle periods and time variant phase. The time variant phase is controlled by the dominant 74 yr cycle which introduces a phase-reversal in higher frequent periods.

### The materials and methods

The spectrum analysis has some potential sources of errors. Possible errors in data samples are unknown. In this investigation long trends in the data are analyzed. Single data errors are not then supposed to be a problem.

The time series are analyzed by a wavelet transformation to identify dominant cycle periods and phase relations between all time series. The Coiflet3 wavelet transformation (Matlab, 1997) is chosen from many trials on tested data. This wavelet transformation is useful to identify cycles in the time series. The cycle identification has two fundamental problems. One problem is identifying periodic cycles when the phase has a reversal in the time series. The phase reversal property of the stationary cycles excludes traditional spectrum estimate methods. The problem is solved by first identifying the dominant cycles and then correlate the cycles to known reference cycles. The second problem is identifying the long period cycles of 55 and 74 years. This problem is solved by the same method. First, identify the dominant long wavelet periods, then correlate the periods to a known cycle reference. The cross-correlation method shows that the dominant cycles have a close correlation to the lunar spectrum. The Signal/Noise-relation shows the identified cycles represents most of the energy in the time series. There is coherence between the estimated cycle time and the cycle phase in all time series. This confirms the good quality of wavelet analysis method.

### The Arctic Oscillation System

The identified lunar nodal spectrum in the time series may be explained by an Arctic Oscillation system. A possible explanations of the identified lunar nodal cycles are:

- The First Cause theory: The correlation to the 18.6 cycle, identifies the 18.6 gravity force cycle from Moon as the first cause.
- The parallel movement theory: The close phase-relation between the lunar nodal tide and the Polar position movements, indicates that there is parallel movement of the lunar nodal tide and the Polar position.
- The lunar nodal spectrum theory: The identified harmonic spectrum, indicates the energy from the 18.6 yr lunar nodal cycles gravity force is distributed as a spectrum of harmonic and sub-harmonic cycles in the ocean tide and in the Polar position movements.
- The mantle-tide theory: The lunar nodal spectrum in the Polar position, indicates that the 18.6 yr cycle introduces a 18.6 yr vertical and the horizontal tide in the liquid mantle of the Earth. The energy from this tide is distributed as the lunar nodal spectrum, which is identified in the time series of the Polar position.
- The “wine-glass” theory: The cycle time of circulating Arctic water, indicates that the Arctic Ocean behaves as a rotating wine-glass. A 74 yr rotating Polar motion introduces a 74 yr water movement cycle in the Arctic Ocean by resonance. Harmonic cycles of water movement are distributed at different water densities and at different water layers.
- Phase-reversal theory: The phase-reversal in the time series, indicates that there is a multiplicative modulation between the 74 yr cycle in the Arctic Ocean and the 18.6 yr lunar nodal tide. When a 74 yr cycle has limitations in negative direction, it will introduce a 180 degree phase-reversal in the stationary 18.6 yr lunar nodal cycle.

- The Barents Sea push-pull theory: The phase-relation between the Kola cycles and the Polar position cycles, indicates the inflow of Atlantic water to the Barents Sea is a result of a push-pull effect between Polar position movements of water in the Arctic Ocean and the lunar nodal tide spectrum in the Atlantic Ocean.
- The Barents Sea ice oscillation theory: The Barents ice Oscillation reflects interaction between the Atlantic horizontal tidal spectrum and rotation water in the Arctic Ocean.
- The Kola cycle oscillation theory: The phase-relation between the lunar nodal tide and the Kola temperature cycles, indicates the Kola cycle oscillation is an indicator of the horizontal Atlantic lunar nodal tide.
- The NAO winter oscillation theory: The phase-relation between the lunar nodal spectrum in the NAO winter index an Arctic ice extent, indicates lunar spectrum in the NAO winter index represents a disturbance from lunar nodal spectrum in the Arctic ice extent oscillation.

The relation to the deterministic gravity cycle from the Moon opens a new possibility for better understanding the Arctic climate fluctuations and a possibility of forecasting climate cycles in periods of 6 to 75 years or more.

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