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THE NAO INDEX LUNAR VARIABILITY

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1 INTRODUCTION

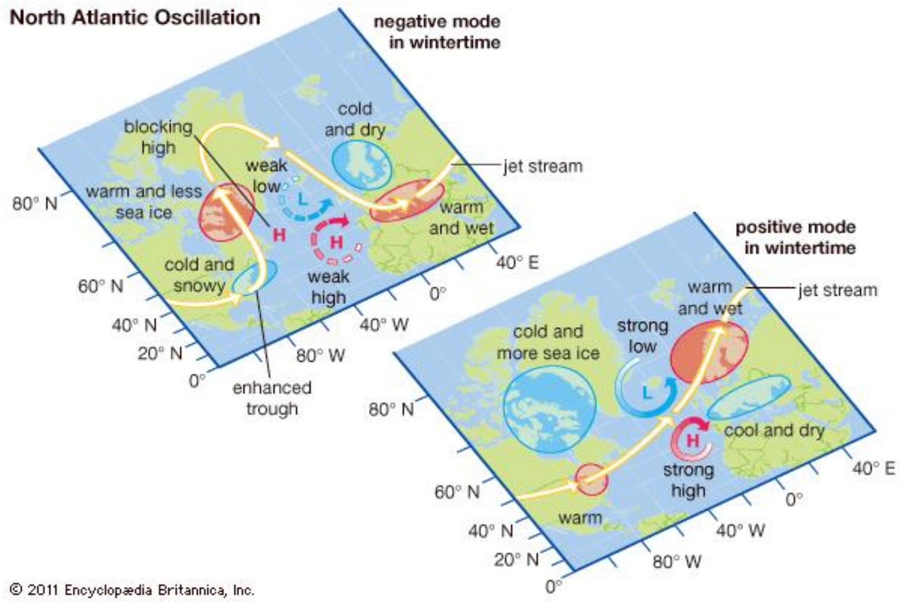

Figure 1. The North Atlantic Oscillation

The North Atlantic Oscillation (NAO) is a weather phenomenon in the North Atlantic Ocean of fluctuations in the difference of atmospheric pressure at sea level (SLP) between the Icelandic low and the Azores high. Through fluctuations in the strength of the Icelandic low and the Azores high, it controls the strength and direction of westerly winds and location of storm tracks across the North Atlantic. [1]. The NAO winter index is based on the (December thru March) station-based difference of the normalized sea level pressure.

The NAO index as a weather indicator

The NAO index value is a weather indicator for Northern Europa and Scandinavia. In Scandinavia:

1. Positive values of the NAO index are associated with low atmospheric pressure difference between Iceland and Azores. In Scandinavia it causes warm winds from west, mild winters and rain-full summers.
2. Negative values of the NAO index are associated with high atmospheric pressure difference between Iceland and Azores. In Scandinavia it causes cold winds from north, cold winters and less rain-full summers.

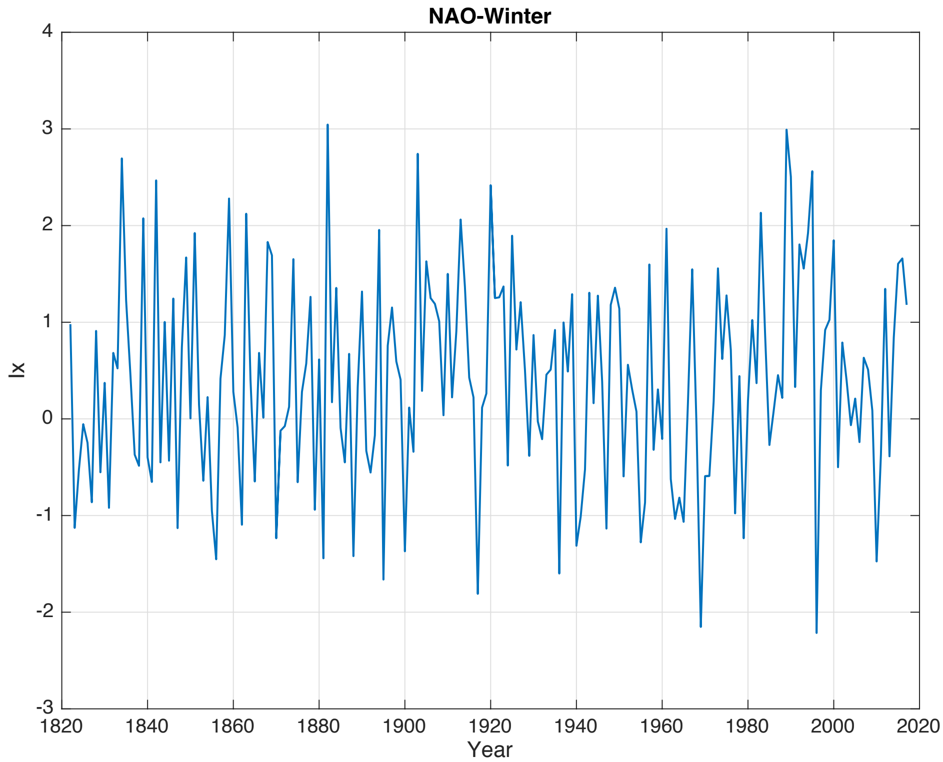

Figure 2. The NAO-winter index data series from 1822 to 2017.

Figure 2 shows the annual NAO winter index from 1822 to 2016 [4]. The NAO winter index is computed by (December (n-1)+January (n)+February (n) + Mars (n))/4. The NAO winter index looks random and has large fluctuation from one year to another. A wavelet spectrum analysis of the data series shows periods trends in the NAO index data series.

The cause of NAO oscillation is not well understood. The Russian oceanographer Izhevskii introduced a system view of interacting processes between the hydrosphere, the atmosphere, and the biosphere. He argued that the heat in the ocean is a non-homogenous flow from a warm equator to the cold pole. This flow of heat in the ocean influences atmospheric processes. Atmospheric processes are reflected in the North Atlantic Oscillation (NAO), and the NAO influences weather and climate variations in and around the Atlantic. A strongly positive NAO winter index will lead to stronger winds and warmer air in winter. A positive trend from 1960 increased winter temperature in the North Eastern Atlantic and the North Sea, a trend shift that has led to speculation about more fundamental climate change, connected to an Arctic oscillation.

2. THE NAO INDEX VARIABILITY

2.1 THE WAVELET AUTOCORRELATION SPECTRUM

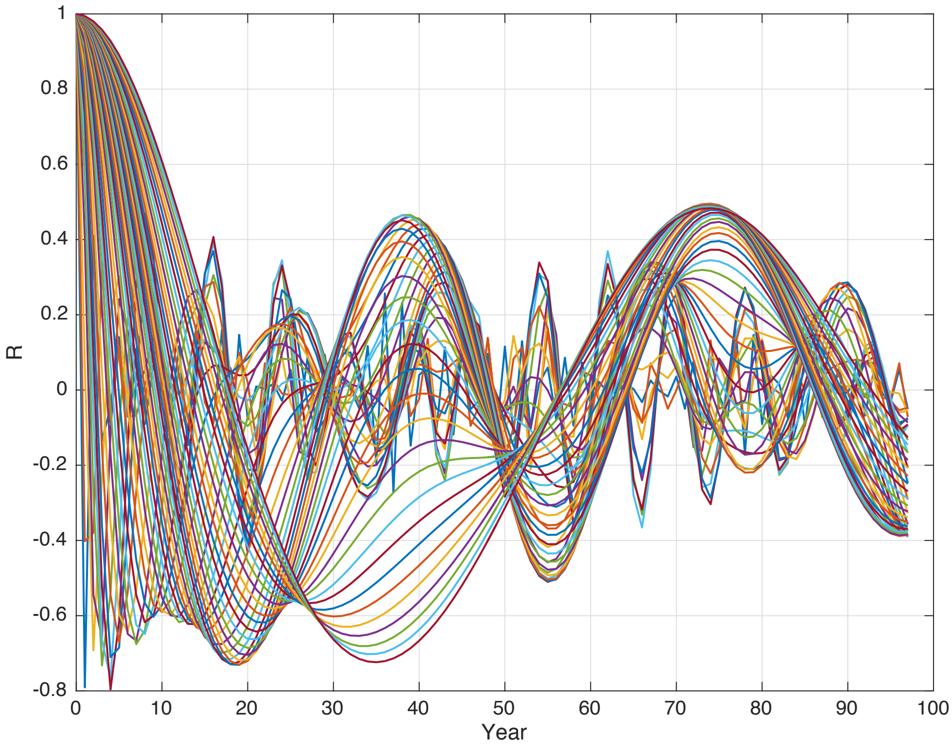

Figure 3. Autocorrelation spectrum RW(nao, s, m) of the Kola wavelet spectrum W(nao, s, t) for s=1 to 0.6N and m=0 to 58.

Stationary periods in the wavelet spectrum W(nao, s, t) are identified by a correlation to periods in the autocorrelations of the wavelet spectrum [3]. Figure 3 shows a set of computed autocorrelations WR(nao, s, m) of the NAO Index wavelet spectrum W(nao, s, t). The wavelet autocorrelation wavelet spectrum show (Figure 3) a correlation the first stationary periods: WR(nao, r, T) =[(0.48, 8), (0.36, 39)]. The first and sub-harmonic periods are: WR(nao, r, T) =[(0.48, 8), (0.40, 16), (0.24, 24), (0.13, 32), (0.31, 42), (0.33, 54), (0.34, 62)]. The period of moons perigee has a spectrum of P(mp, 8.847)=[8.847, 2*8.847=17.7, 26.5, 35.4, 44,2, 53.1, 61.9,…115.0). The period difference to the stationary moon perigee period is only [1, 2, 2, 3, 2, 1, 1] years. Long period has the first and the sub-harmonic periods: WR(nao, r, T) = [(0.36, 39), (0,48, 74), (0.40, 112), (0.22, 150), (1.8, 180)].

Relation to lunar periods

The stationary 18.6-year lunar period has the harmonic spectrum: P(ln, 2*18.61) = 37.22) = [37.22, 2*37.22 = 74.44, 3*37.44 = 111.66, 4*37.22 =148.88]. The difference between the identified stationary periods of WR(nao, r, T) and the stationary lunar period P(ln, 2*18.6) is only [1, 0, 0] years. The lunar nodal period and moon perigee period have a coincidence period of 3*37.44 = 111.66 yr and 13*8.847 = 115.0 yr, a difference of only 3.3 years. This mean that the NAO winter index variability is controlled by a spectrum of 8.847-year and 18.6-year lunar periods.

2.2 THE WAVELET SPECTRUM

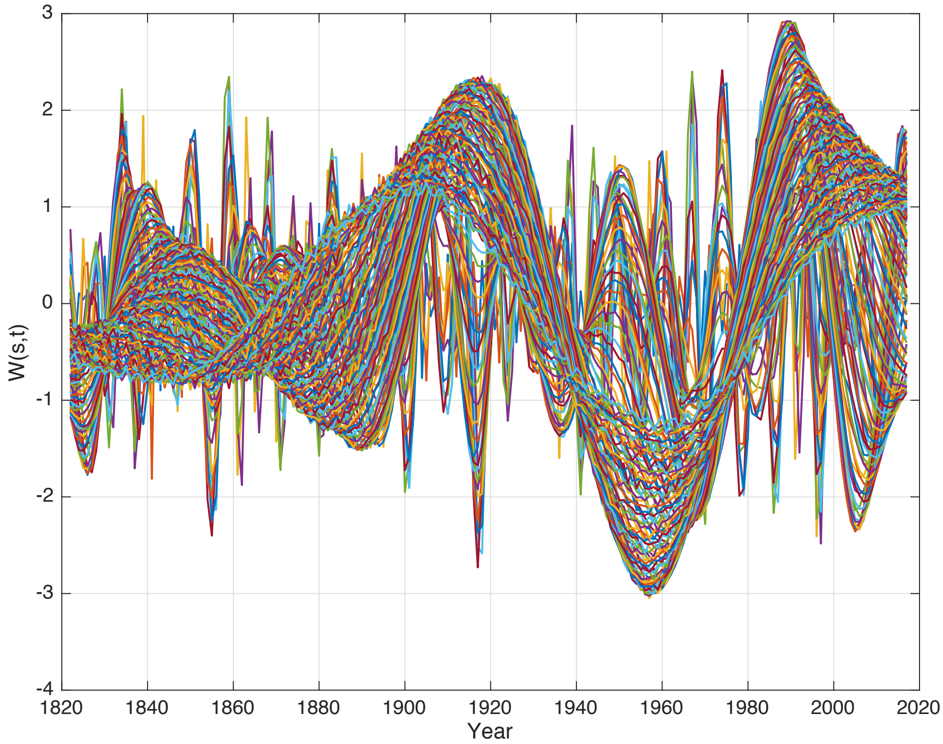

Figure 4. Wavelet spectrum W(nao, s, t) of the NAO winter index data series, for s = 1...0.6N and t=1822 to 2017.

Dominant periods and phase-relations

The computed wavelet spectrum W(nao, s, t) of the NAO-index series is shown on Figure 4. The wavelet spectrum W(nao, s, t) represents a time period from 1822 to 2017 and a wavelet scaling range is s = 1…0.6N, and the data series contains N = (2017-1822) = 195 data points. The wavelet spectrum W(nao, s, t) on Figure 3 shows phase shifts at:

P(nao, min, yr) = [(-1.5, 1888),(-2.9, 1957)]
P(nao, -0, yr) = [(0,1832), (0, 1899), (0, 1977)]
P(nao, max, yr) = [(0.49, 1852), (2.19, 1919),(2.9, 1990)]
P(nao, +0, yr) = [1862, 1937, 2015]

The period distance between min, -0, max, and +0 is [69, 73, 69, 77] years, or a mean period of 72 years, which is close to the lunar nodal period 4*18.61 = 74.4 years.

Upcoming next phase events

The upcoming next phase events are: P(nao, min, yr,) = [1957+72=2029], P(nao, -0, yr) = [1977+72 = 2049]. P(nao, max, yr) = [1990+72=2062] and P(nao, +0, yr) = [2015+72=2087].

The identified dominant 74-year period and the period phase information may be confirmed by computing the wavelet power spectrum, the wavelet phase spectrum and the wavelet power spectrum.

Dominant periods in NAO variability

The identified dominant periods [9, 37, 74, 112] (yr) in the wavelet spectrum W(nao, s(t)), has a min/max and -0/+0 phase shifts at:

1. P(nao, s(112)) = [(-0.8, 1856), (-0, 1875), (1.6, 1908), (+0, 1931), (-1.8, 1960), (-0, 1985), (1.3, 2010)].
2. P(nao, s(74)) = [(-0, 1836), (0.4, 1850), (+0, 1862), (-1.2, 1880), (-0, 1897), (2.1, 1919), (+0, 1937), (-2.9, 1959), (-0, 1977), (2.3, 1995), (+0, 2017)].
3. P(nao, s(74/2),max) = [(0.8, 1842), (0.5, 1871), (0.3, 1949), (2.9, 1990)].
4. P(nao, s(74/2),min) = [(-1.3, 1857), (-1.5, 1891), (1.7, 1914), (-0.5, 1936), (-2.2, 1968), (-1.2, 2011)].
5. P(nao,s(9),max) = [1967, 1974, 1983, 1992, 2000, 2007, 2015...2024]. P(nao, s(9),min) = [1970, 1979, 1986, 1992, 1997,2002, 2011.....2020].

2.3 THE WAVELET PHASE SPECTRUM

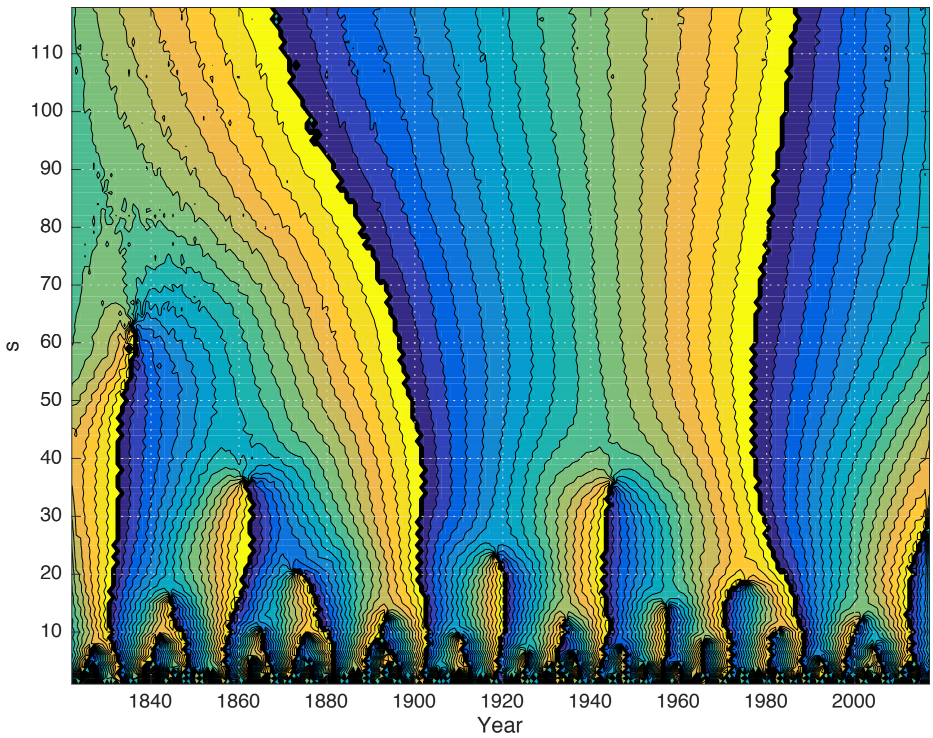

Figure 5. Wavelet phase spectrum WF(nao, s, t) of the NAO wavelet spectrum W(nao, s, t), for s=1...0.6N.

A wavelet phase spectrum identifies long and short climate shifts periods. Figure 5 shows the wavelet phase spectrum from the NAO winter index. The wavelet phase spectrum WF(nao, s,t) is identified by computing a Hilbert transform of the wavelet spectrum and shown on Figure 4. The wavelet phase spectrum WF(nao, s,t) has (-/+) phase shifts in the years: WF(nao, -0, long) = [1833, 1902, 1978], WF(nao, -0, short) = [1833, 1862, 1902, 1943, 1978],

The long period has phase shift in a distance of w = [69, 76] years, or a mean period of 73 years. The short phase spectrum has a distance of: [29, 40, 41, 35] years, or a period of w = 39 years, which are close to lunar period 74/2 = 37 years. The next -0 phase shift is estimated to the year. 1978 + 73=2051.

Upcoming next phase shift
Identified and estimated upcoming next phase shifts are: WF(nao, -0, 73) =[1833, 1902, 1978, 1978+73=2051] and WF(nao, -0, 39) =[1833, 1862, 1902, 1943, 1978, 1978+73=2017].

2.5 THE WAVELET POWER SPECTRUM

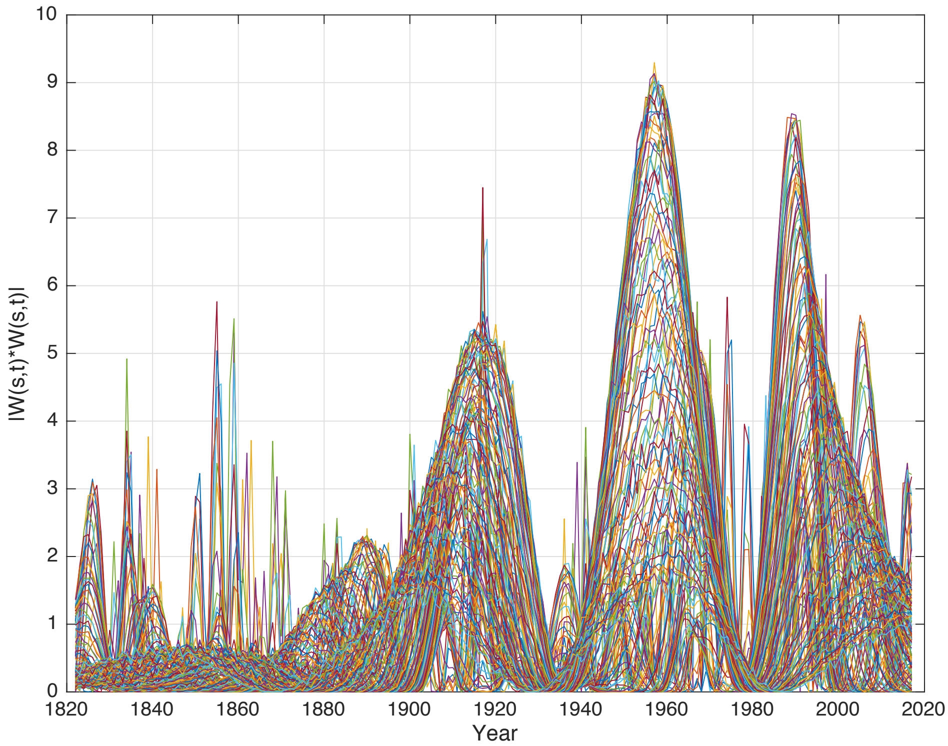

Figure 6. Wavelet power spectrum P(nao, s, t) of the NAO wavelet spectrum W(nao, s, t), for s=1...0.6N.

Figure 6 shows the power spectrum of the NAO winter index wavelet spectrum. The wavelet power spectrum is computed by WP(nao, s, t)=W(nao, s, t)*W(nao, s,t), and identifies the power of the most dominant periods in the wavelet spectrum. The power spectrum has an amplitude phase information:

WP(nao, max, yr) = [(2.2,1888), (5.2,1917), (9.0, 1957), (8.9, 1991)].
WP(nao, 0, yr) = [(0,1900), (0,1935), (0,1980)].

The mean distance between max and 0 states are: [40, 40, 34, 35,45], a mean distance of 38 years and a mean period of w = 76 years.

Period coincidences
The high wavelet maximum at WP(nao, max, yr)= (9.0, 1957), is caused by the wavelet period coincidence of W(nao, s(115) = (-1, 1960) and W(nao, s(74)) =(-2.9, 1959). This period coincidence explain the cold period close the 1960.

The high wavelet maximum at WP(nao, max, yr) = (8.9, 1991), is caused by the wavelet period coincidence of W(nao, s(74) = (2.3, 1995) and W(nao, s(74/2)) = (2.9, 1990). At the same time the long period W(nao, s(112)) has a maximum the year 2017. The warming period from 1960 to 2017 may then be explained by a positive coincidence between the lunar periods: [W(nao, s(37), W(nao, s(74), W(nao, s(112)]. The stationary lunar periods: [8.847, 18.613] have a coincidence period of [74, 112] (yr), which have coincidences of [149, 224, 336, 447, 560…] (yr).

3 GENERAL NAO INDEX MODEL

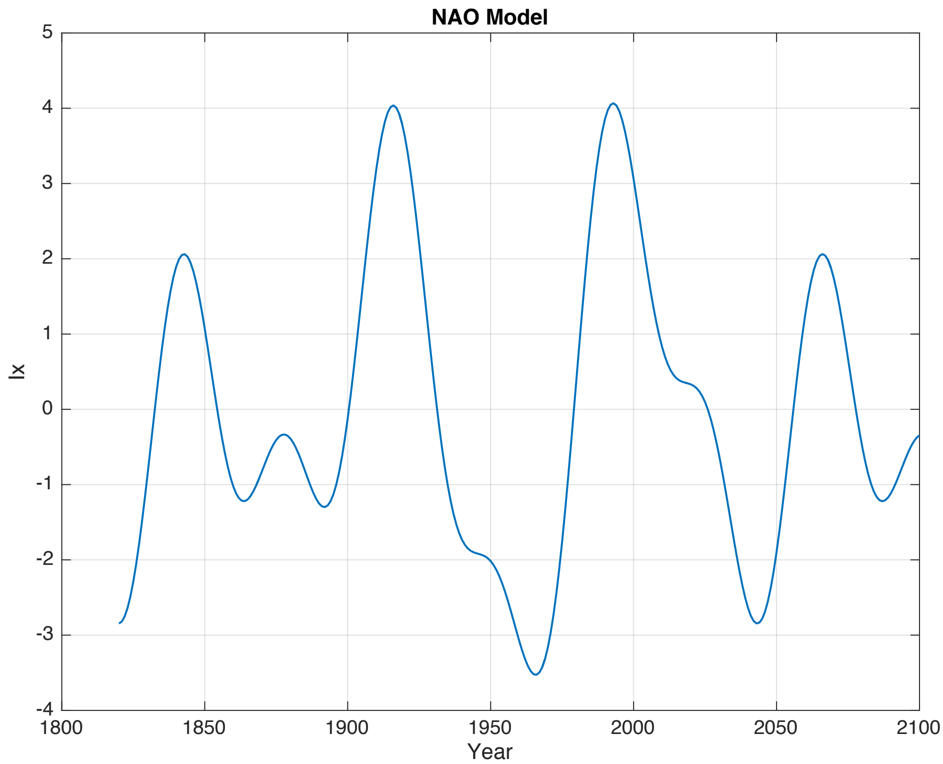

Figure 8. Computed NAO index P(nao, t) = Ix for t = 1820…2100

The autocorrelations of the wavelet spectrum W(nao, s, t) shows that all dominant periods in the NAO data series variability, are related to a spectrum of stationary 8.85-year and 2*18.61-year Lunar nodal periods. The identified stationary wavelet periods may be transformed into a set of deterministic periods by the simple model

P(nam, 112, t) = A(nam, 112)cos(2pi(t-1931)/6(18.613))
(nam, 74, t) = A(nam, 74)cos(2pi(t-1995)/4*18.613)
P(nam, 39, t) = A(nam, 39)cos(2pi(t-1990)/2*18.613)
P(nam, 9, t) = A(nam, 9)cos(2pi(t-2015)/8.847)
P(nam, t) = P(nam, 112, t)+P(nam, 74, t)+P(nam, 39, t)+ P(nam, 9,t)

From the identified dominant periods in the wavelet spectrum, the estimated period amplitude vector is: A(nam, 9…112) = [0.12, 0.30, 0.58, 0.33].

Figure 7 show the computed NAO index trend from 1820 to 2100 when the A(nam, 9, t) = 0. The computed deterministic NAO index Ix has a set of phase-shifts at the year: P(nam, Ix(phase shift), T) = [(-0, 1833), (0.50, 1843), (+0, 1854), (-0.30, 1863), (-0, 1900), (+0, 1931), (-0.88, 1966), (-0, 1979), (1.0, 1993), (+0, 2026), (-0.71, 2043), (+0, 2056), (0.51, 2067), (+0, 2078), (-0.32, 2116), (-0, 2124), (1.0, 2140), (+0, 2155), (-0.88, 2182)].

Upcoming events

The model show that the NAO index has a maximum at the year 1993, an upcoming negative trend from 2026, a deep minimum at the year 2043, temporary maximum at 2067, a temporary minimum at 2116, a global maximum at 2140 and a deep minimum at 2182. The distance between global maximum and between global minimum are 2140-1993 = 147 year and 2180-1967=213 years.

Deep NAO-index minimum and global maximum from 1000 A.D.

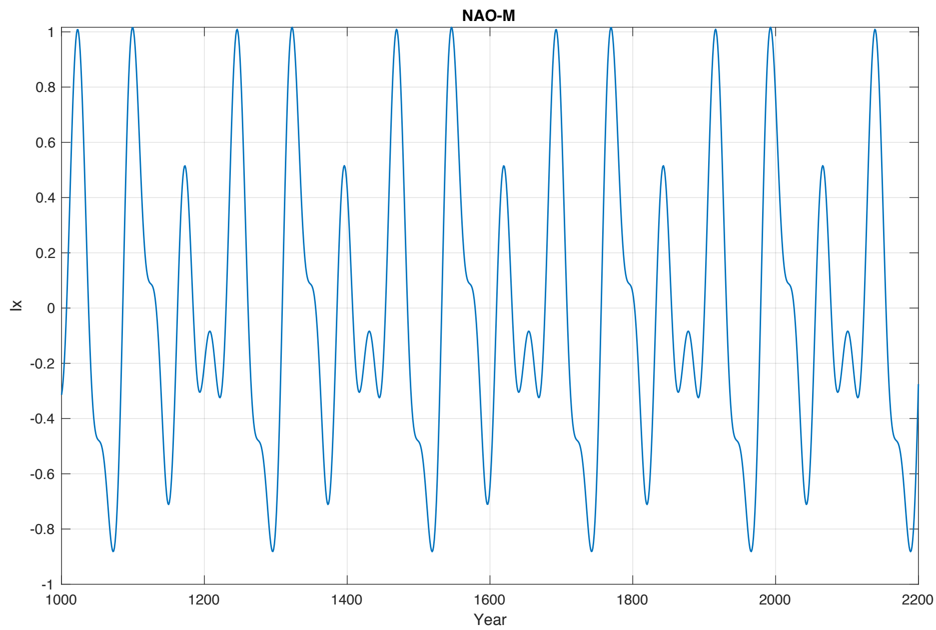

Figure 8. Computed NAO index P(nao, t) = Ix for t = 1000…2200

From 1000 A.D to 2200 the computed deterministic NAO index Ix has a deep minima of P(nam, Ix(min), T) = [(-0.88, 1073), (-0.88, 1295), (-0.88, 1519), (-0.88, 1742), (-0.88, 1966), (-0.88, 2191)] (Figure 8). Known solar minimum (Usoskin,) are the years P(tsi(min), T)= [Oort (1010-1070), Wolf (1270-1340), Spörer (1390-1550), Maunder (1640-1720), Dalton (1790-1820)]. The distances between P(tsi(min), T) and P(nam, Ix(min), T) are only [3, 0, 0, 20] years.

From 1000 AD to 2200 the computed NAO index has a global maximum, after a deep minimum at: P(nam, Ix(max), T) = [(1.0, 1101), (1.0, 1321), (1.0, 1546), (1.0, 1768), (1.0, 1993)], which an event period of 220 years.

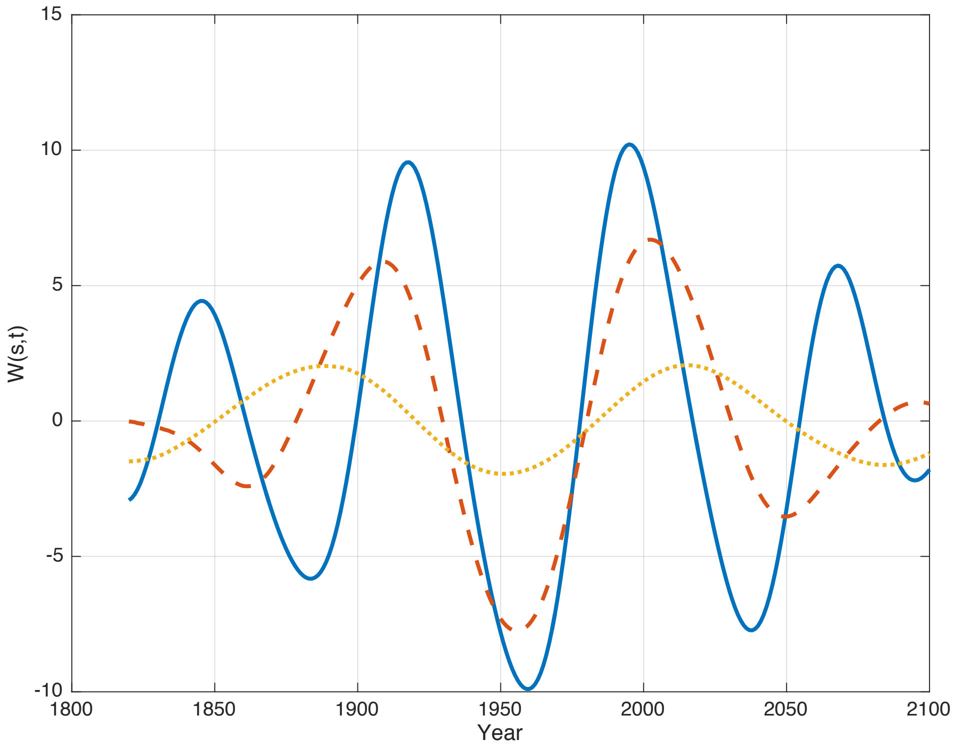

Figure 9. Identified dominant wavelet periods in the computed NAO index P(nam, t) = Ix for t = 1820…2100. Blue, red, yellow are W(nam, s(37), t), W(nam, s(74), t), W(nam, s(112), t).

Figure 9. shows the identified dominant periods in the wavelet spectrum W(nam, s, t), where blue, red, yellow are W(nam, s(37), t), W(nam, s(74), t), W(nam, s(112), t). The figure show there is a phase coincidence between the stationary lunar periods from 1900 to 2020, that explain the large NAO index variation in this period.

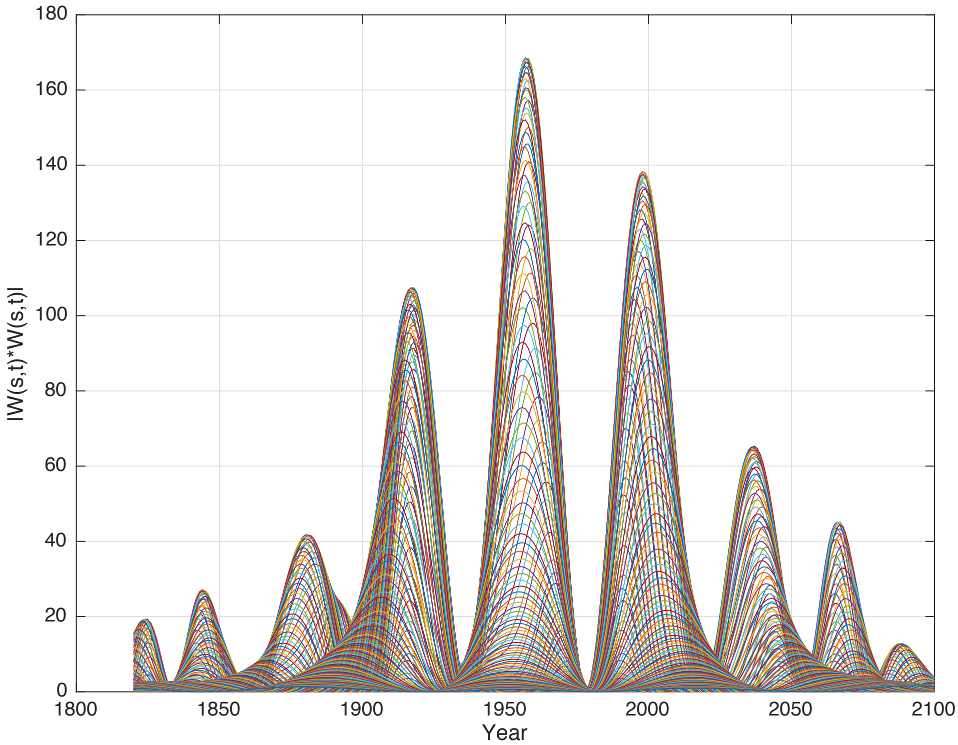

Figure 10. Wavelet power spectrum WP(nam, s, t) of the deterministic model of the NAO data series, for s=1...0.6N and t=1820 to 2100.

Figure 10 show the wavelet power spectrum WP(nam, s, t) of the deterministic model of the NAO data series, for s = 1...0.6N, (N=2017-1820) and t =1820 to 2100. The wavelet power maximum at: WP(nam, s, t) = [(18.3, 1824), (26.9, 1845), (40.0, 1881), (106.7, 1918), (167.3, 1957), (138.4, 1998), (64.7, 2037), (44.0, 2067), (11.23, 2090)], where there is a maximum coincidence between the periods. The maximum coincidence has the time distances of [36, 37, 39, 41, 39] (yr), a mean distance of 38.4 years and a full period of 76.8 years.

3 DISCUSSION

Arctic Ocean Resonance

This investigation confirm that the NAO winter index is controlled by a spectrum of lunar periods. A possible explanation is Arctic resonance. Lunar periods are identified in North Atlantic Temperature variability, in Arctic ice extent, Arctic Ocean water circulation and Earth axis rotation [3]. This relation indicates a possible Arctic coincidence resonance, like a water flow resonance in a rotating wineglass. The "Wineglass" hypothesis is based on the idea of there is a resonance in Arctic Ocean, caused by e Earth Axis nutation oscillation. The stationary Earth Axis oscillation may cause an Arctic ocean water circulation, like a wobbling wineglass [3]. A possible chain of events may be:

1. The gravity force between the Earth, Moon and Sun, moves the Earth around a Earth-Moon Barycenter.
2. Periods in the Earth-Moon Barycenter causes a spectrum of lunar periods in the wobbling Earth axis.
3. The dominant lunar period wobbling Earth Axis has a dominant period of 18.6 years. The lunar perigee rotates in a period of 8.847 years and introduces an amplitude modulation in the 18.6-year axis rotation.
4. The force of the 18.6-year wobbling polar position, forces circulating water in the Arctic Ocean, in a spectrum of n*18.6-year periods.
5. A continuous supply of forced movement energy is distributed throughout circulating water in the Atlantic Ocean. Circulation water in the Arctic Ocean causes an 18.6-year spectrum of inflow of warm Atlantic water to Atlantic Ocean and a spectrum of cold-water outflow to the Greenland Sea.
6. The inflow of warm Atlantic water the Atlantic Ocean has a coincidence the 18.6-year lunar nodal and the 8.85-year lunar perigee tide in North Atlantic Water.
7. The inflow of warm Atlantic Water to the Arctic Ocean, influences Arctic ice extent.
8. Arctic ice extent represents an isolator between warm Atlantic water and cold air and thus influences the Arctic air temperature.
9. The Arctic air temperature influences the NAO winter index.

4 SUMMARIES

The identified NAO winter index model has a variability show that:

1. The NAO index variability is controlled by a spectrum of 18.6-year lunar nodal periods and a spectrum of 8.85-year lunar perigee periods, which are controlled by the Moon.
2. Maximum and minimum trends in the NAO-index, weather and temperature variability, are controlled by period- and phase coincidences.
3. The dominant periods have a computed maximum at the year 1993, a negative index state from 2026, and a deep minimum index at the year 2047.
4. Computed NAO index model minimum has a coincidence to known solar minimum from 1000 A.D.
5. The deep computed NAO minimum at 1966 and a NAO maximum at 1993, is a rare event in a period of 220 years.

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