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THE BARENTS SEA TEMPERATURE VARIABILITY 1900-2100

The winter is coming

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ABSTRACT

North Atlantic Water controls the climate of the northern part of Europe. The water current passes the Faroe-Shetland Channel and into the Norwegian Sea and continues north with a minor inflow to the Barents Sea. In the Barents Sea Kola section the water temperature has been monitored since 1900 and now represents an indicator of Arctic climate, expected Barents Sea biomass growth and expected economy growth along the Norwegian coastline.

The Barents Sea temperature has grown the last 30 years to a level, far above historical records. The purpose of this study is to investigate new trends in the Barents Sea temperature variability. Will the Barents Sea temperature continue to grow, or will the temperature turn into a new cold period. The results show that the temperature in the Barents Sea most likely has reached a turning point and we may expect a temperature reduction period for the next 30 years.

A possible 30-year long temperature reduction in the Barents Sea will introduce a colder climate in North-Europe and influence the marine ecosystem in the Norwegian Sea and the Barents Sea. This will have a dramatic effect on the marine industry, the maritime industry, the fish farm industry and the economy on the Norwegian coastline.

1 INTRODUCTION

"In August 1895, at the VI International Geographical Congress in London, Professor Otto Pettersson (Sweden) suggested a project of international cooperation in the field of investigation of the sea. The necessity of pooling the scientific efforts from European fishing countries was caused by a fear for the fortune of fisheries in connection with overfishing in the North Sea. This idea found support at the Geographical Congress and there was expressed a will to broaden a cooperation between different states in studying the biological resources of the Baltic and North Seas, as well as of the North Atlantic. To meet the challenges of scientific cooperation, the International Council for the Exploration of the Sea (ICES) was founded in June 1899 at the Conference taking place in Stockholm (Sweden), the major tasks of which were the study of marine fisheries and the protection of biological resources from injurious exploitation." (PINRO Murmansk, 2016).

A first start in 1900 was to monitor two important oceanographic data series. One was the inflow of North Atlantic water to the Norwegian Sea in the Scotland Faeroe channel. The other was the inflow of North Atlantic water from the Norwegian Sea to the Barents Sea, in the Kola section. These two data series now represents the longest oceanographic data series in the world. For decades they have been of most importance as an indicator for expected biomass growth in the Norwegian Sea and the Barents Sea.

If you can predict the future, you can control the future. The Kola section temperature in the Barents Sea represents an indicator of current recruitment of cod, herring and capelin in the Barents Sea. If you know the annual temperature, you have an indicator of expected biomass growth for the next 3-5 years. If you can estimate the future Kola temperature, you can estimate the biomass growth for a longer future period. A predicted future is dependent on there is deterministic information in the data series. If there is not something deterministic in the data, we can only explain the past.

In 1909 Otto Pettersson, who started the data series monitor program, studied the relationship between herring catches and tides in Gullmarfjord on the west coast of Sweden. The study showed that the variation in the lunar perigee was related to fresh water movements and the arrival of schools of herring. He concluded that the long-period tide cycles of 18 and 111 years were the cause of herring biomass fluctuations at Bohuslen (Petterson O., 1905, 1914a, 1915, 1930; Lindquist, 2002). Other scientists did not accept the tide theory from Otto Pettersson in his time. Tides were related to the Moon, and the Moon was still associated with astrology. The work from Otto Pettersson was, however, continued by Russian scientists up to 1960´s when Maksimov and Smirnov (1964, 1965, 1967) introduced a standing wave theory. A standing 19-year sea wave that covers the Arctic Ocean, a standing node that has a maximum at the Arctic pole and a standing 19-year current between the Pole and the equator.

A deterministic 18.6-year lunar nodal cycle in the Kola section data series was presented for the first time at the ICES annual meeting in 1966 (Yndestad, 1966a,b). At the same time it was discovered the existence of sub-harmonic periods of 3*18.6=55.6 and 4*18.6=74.4 years. The Lunar nodal period spectrum in the Kola data series was later confirmed by a wavelet spectrum analysis that identified the phase information. The lunar nodal periods now explained the biomass variability in the Barents Sea and predicted the coming growth of cod, haring and capelin in 2009-2010 (Yndestad, 1999), (Yndestad, 2004b), (Yndestad, Turrell, & Ozhigin, 2008), (Yndestad & Stene, 2002), (Yndestad, 2003), (Yndestad, 2004a), (Yndestad, 2009).

In 2015 we have longer data series to estimate longer periods. At the same time the Barents Sea temperature has reached a level, far above historical records. The purpose of this study is to investigate the new trends in the Barents Sea temperature variability. Will the Barents Sea temperature continue to grow, or will it turn into a new cold period.

2 THE KOLA SECTION DATA SERIES

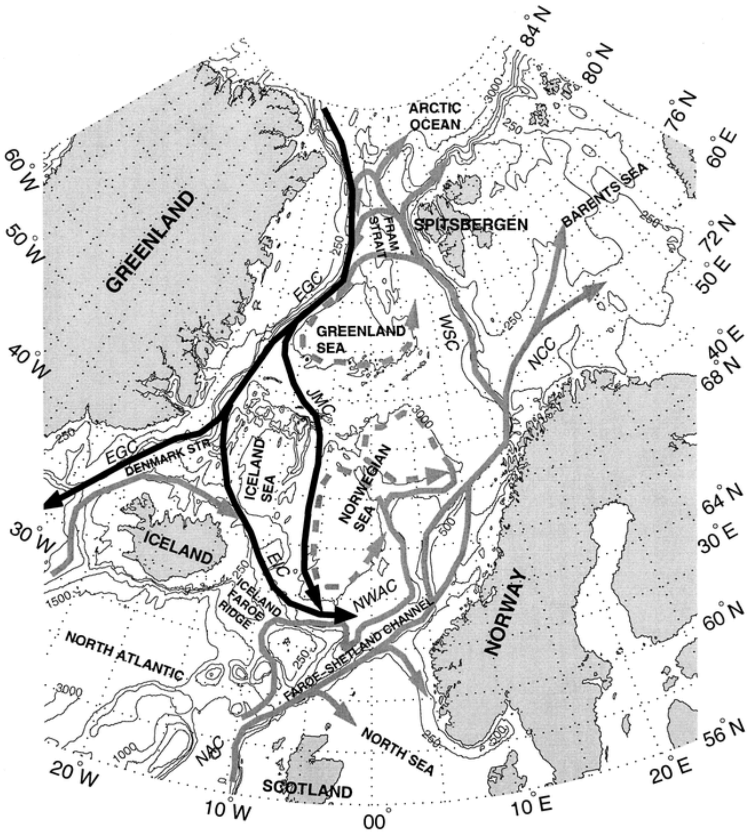

Figure 1. Inflow of North Atlantic Water to the Barents Sea.

Inflow of North Atlantic Water (NAW) passes from the North Atlantic through the Faroe-Shetland Channel and into the Norwegian Sea. The current continues north with a minor inflow to the Barents Sea. One part returns to the Greenland

Sea, and one part has an inflow to the Arctic Ocean through the Fram Strait. From the Fram Strait, the current circulates in the Arctic Ocean and returns to the Greenland Sea return current (Figure 1). It has been well known for decades that this current has a major influence on the climate in northern Europe. To contribute to the study of regional climate variability, the temperature in the Faroe-Shetland Channel and the Kola section in the Barents Sea have been monitored for more than a 100 years; this represents two of the longest oceanographic time-series in the world. The North Atlantic Water temperature and the Kola section water temperature represent long-term regional climate indicators. Better understanding of the causes of fluctuations of these indicators may lead to a better understanding of climate variability and forecast climate change.

In this analysis, the variability in the climate indicators was characterized by the time-series spectrum properties. This spectrum may have information about the source of the deterministic properties that cause water mass characteristic fluctuations, including temperature. If these time-series have temporary deterministic properties, there is a possibility of forecasting dynamic change in the North Atlantic Water temperature, the Barents Sea water temperature and regional climate.

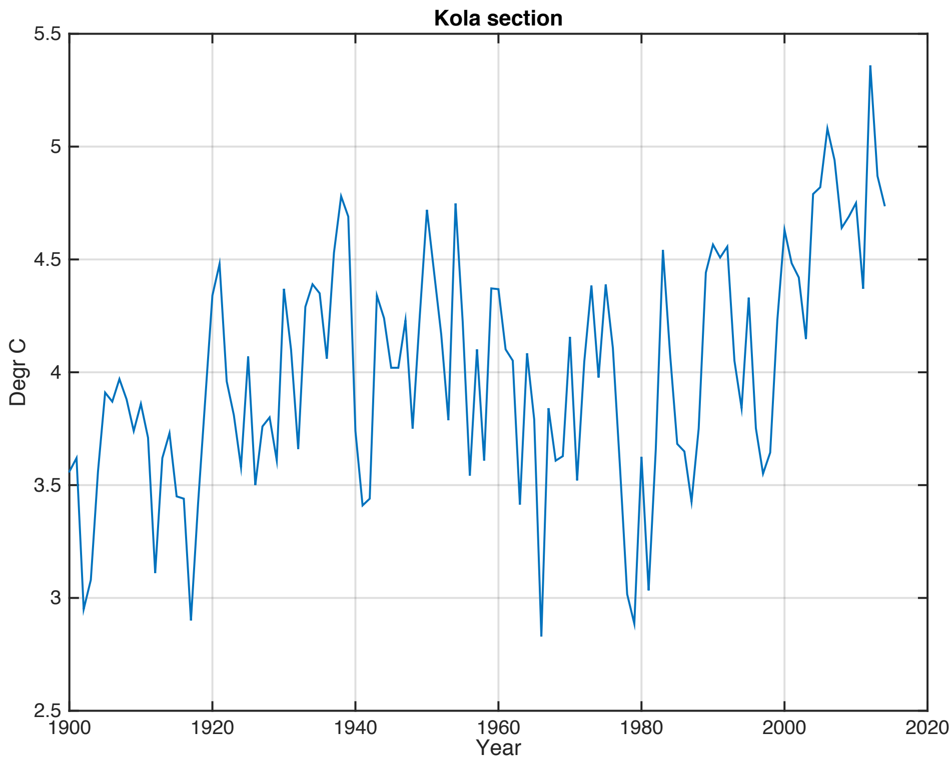

Figure 2. The Kola section data series from 1900 to 2014.

The Kola data series is measure in the Barents Sea in the period from 1900 to 2014 and represents the longest continue oceanographic data series in the world. The data used here were monthly temperature values from the upper 200m in the Kola section along the 33130^{0} E medial from 70130^{0} N to 72130^{0} N in the Barents Sea. The Kola data series is monitored by PINRO in Murmansk, Russia and supported by PINRO, Murmansk (Vladimir Ozhigin, personal communication 2015).

The Figure 2 shows that the data Barents Sea temperature increased from about 3.5 to 4.75 degrees in this period. At the same time the data series has large fluctuations that looks random. Is this a random or a natural variability? To answer this question, we may first transform the data series into a wavelet spectrum.

2.1 STATIONARY PERIODS

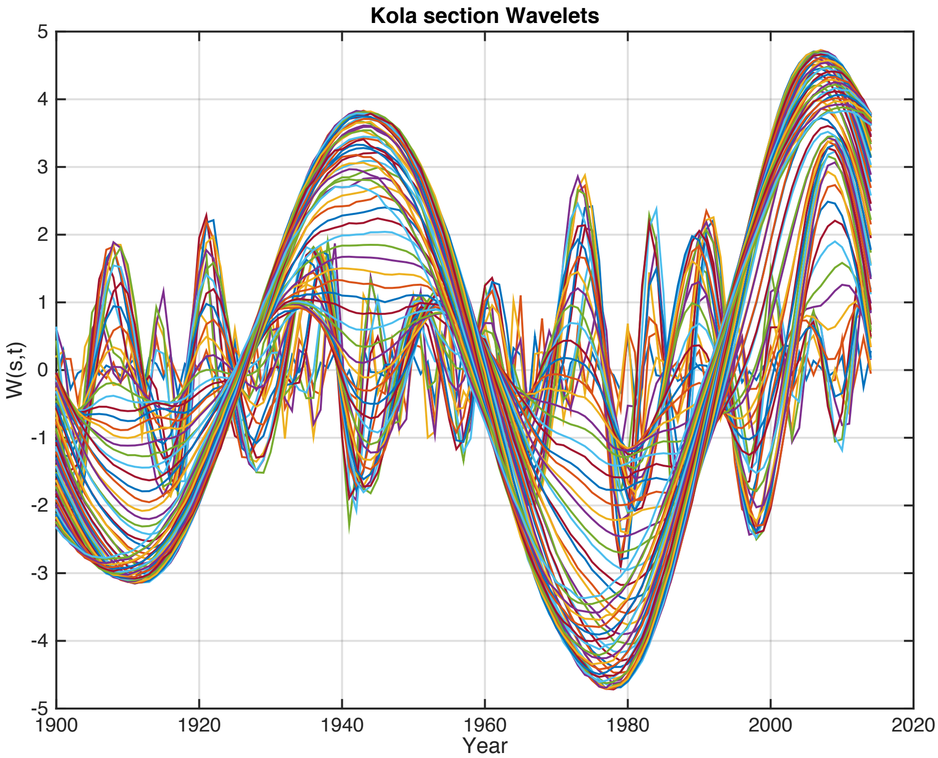

Figure 3. Wavelet spectrum Wko(s, t) of the Kola data series, for s=1...0.6N and t=1900 to 2014.

The computed wavelet spectrum Wko(s,t) of the Kola data series is shown on Figure 3. The wavelet spectrum Wko(s,t) represents a time period from 1900 to 2013 and a wavelet scaling range is s=1...0.6N, and the data series contains N=(2014-1900)=114 data points.

The identified wavelet spectrum Wko(s,t) has a maximum at: [(3.7, 1943), (4.7,2007)], a mean period 64 years. Wko(s,t) has minima at [(-3.1, 1911), (-4.1,1978)], or in a period of 67 years. If this is a stationary period, we may expect a new minimum at approximately the year 1978+60=2048.

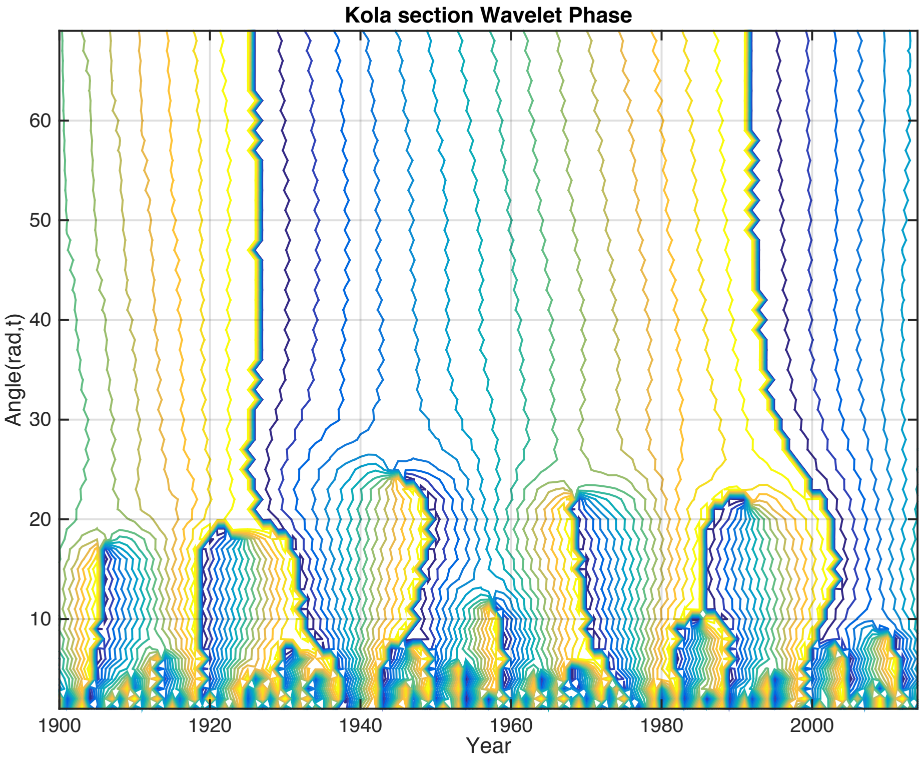

Figure 4. Wavelet phase spectrum WPko(s, t) of the Kola wavelet spectrum Wko(s,t), for s=1...0.6N.

The wavelet phase spectrum WPko(s,t) is identified by computing a Hilbert transform of the wavelet spectrum and shown on Figure 4. The long period in WP(s,t) has -/+ phase shifts in the years [1926, 1992], or in periods of [66] years. If this is a stationary period, we will have a new -/+ phase shift in 2058. The shorter periods has a -/+ phase shift at the years [1906, 1919, 1931 , 1948, 1970, 1986, 2003]. The mean periods, sub-harmonic and coincidence periods are identified by estimating the autocorrelations of the wavelet spectrum Wko(s,t).

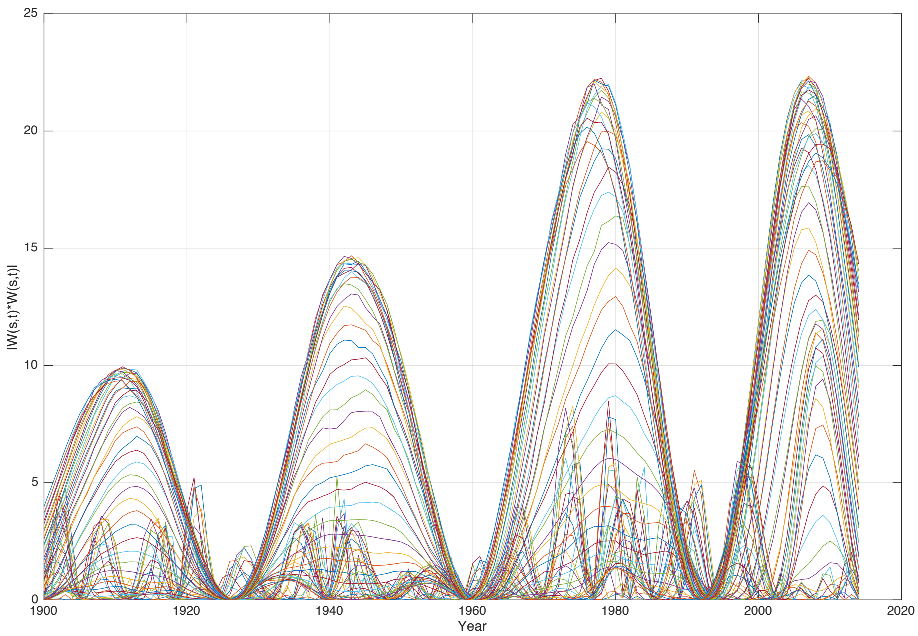

Figure 5. Wavelet power spectrum Pko(s, t) of the Kola wavelet spectrum Wko(s,t), for s=1...0.6N.

The wavelet power spectrum on is computed by Pko(s,t)=Wko(s,t)*Wko(s,t). The wavelet power has maximum amplitude at [(10,1911), (14.5,1943), (22,1978), (22,2007)]. The distance between the periods are [32, 35, 29] years. The last period is influenced by the short data series. If the real period time is between 32 and 35, we may expect the real maximum in 2007+4=2011. The wavelet power spectrum shows that the fluctuation power has increased from 10 to 22 in 1980. If this is a stationary period, the Kola section temperature will turn into a colder period that has a new minimum approximately in 1978+66=2044.

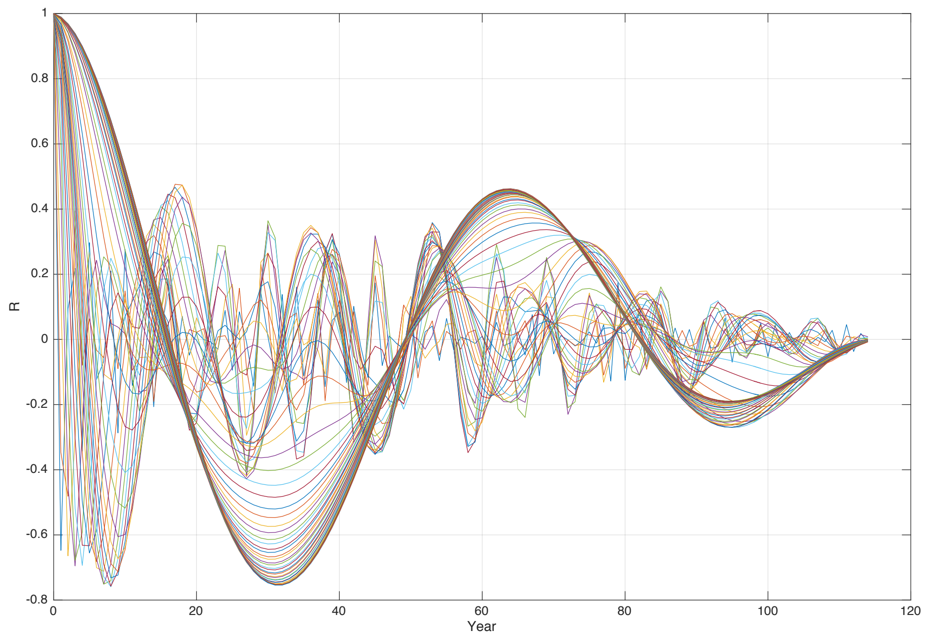

Figure 6. Autocorrelation spectrum RWko(s, m) of the Kola wavelet spectrum Wko(s, t) for s=1 to 0.6N and m=0 to 58 .

Stationary periods in the wavelet spectrum Wko(s,t) are identified by computing the autocorrelations of the wavelet spectrum. Figure 6 shows a sett of computed autocorrelations RWh4(s,m) of the Kola wavelet spectrum Wko(s,t). Dominant periods in RWko(s,m) show the first stationary periods, the sub-harmonic period and the coincidence periods in the wavelet spectrum Wko(s,t).

The first stationary periods in RWko(s,m) has a maximum correlation R at a period distance of m years for R(r,m) at [(0.2,9yr), R(0.5,18yr), R(0.42, 64yr)]. Each first stationary period produces a set of sub-harmonic periods. The first period R(0,37,9yr) produces [R(0.3, n*9yr), R(0.5, n*18yr), for n=2,3,4,,,. The period R(0.42, 64yr)] represent a mean period of (3*18+4*18)/2 = 64 years. 64 years is too short for a good period identification in a time series of 114 years. This means the may be a dominant 3*18 and a 4*18 year period in the data series.

The identified 9-yr period in RWh4(s,m) is known from the 18.6 year Lunar nodal cycle that produces a Lunar nodal tide period of 18.6/2=9.3 years. A possible source of the 64 year period is (3*18.6=55.6+4*18.6=74.4)/2 = 65 years.

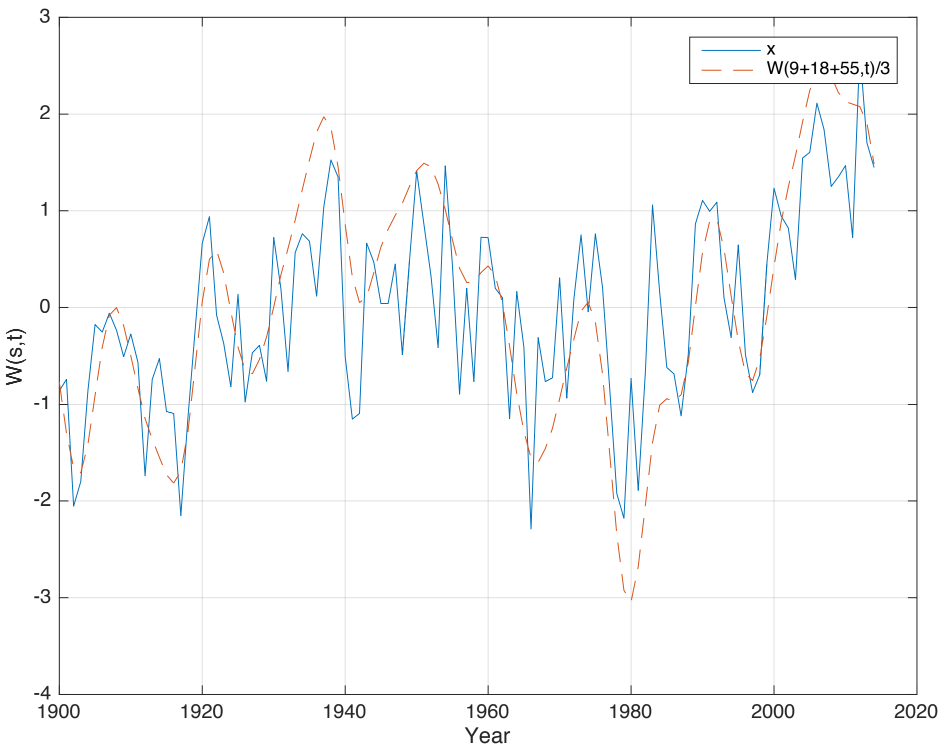

Figure 7. The Kola data series (x) and a mean of the dominant periods Wko(9, t), Wko(18, t), Wko(55, t).

Figure 7 shows the Kola data series and a mean of the dominant periods Wko(9, t), Wko(18, t), Wko(55, t). The cross correlation between the Kola data series and the mean of [Wko(9,t)+Wko(18,t)+Wko(55,t)]/3 is estimated to Rko(9,18,55)=0.78, a Person quality Q=13.3 for N=113 samples. This high correlation indicates a close relation between the identified dominant periods and the Kola section variability.

2.2 DETERMINISTIC MODEL

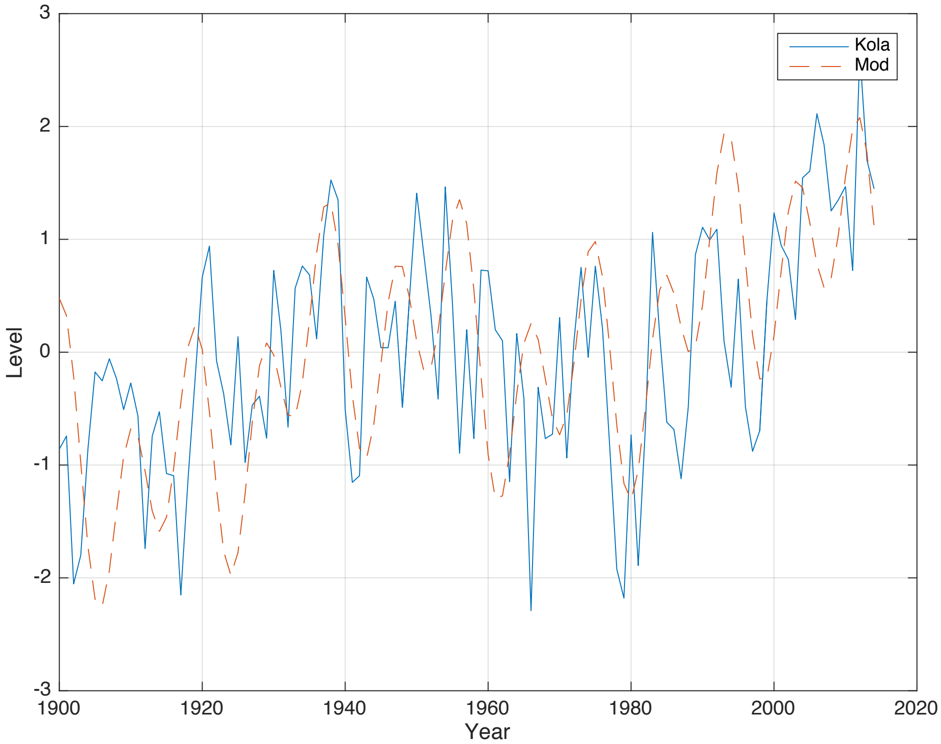

Figure 8. The Kola data series (Kola) and a the computed deterministic data series P(ko,t) from the deterministic model (Mod).

The autocorrelations of the wavelet spectrum Wko(s,t) shows that all dominant periods in the Kola data series variability, are related to the stationary 18.6 year Lunar nodal tide period. The identified stationary wavelet periods may be transformed into a set of deterministic periods by the simple model

P(ko,9,t) = Ako(9)cos(2pi(t-1975)/18.6/2)
P(ko,18,t) = Ako(18)cos(2pi(t-1954)/18.6) (5)
P(ko,55,t) = Ako(55)cos(2pi(t-1943)/3*18.6)
P(ko,74,t) = Ako(74)cos(2pi(t-1947)/4*18.6)
P(ko,167,t) = Ako(167)cos(2pi(t-2000)/3(3*18.6))
P(ko, t) = P(ko,9,t) + P(ko,18,t)+P(hsc,55,t)+P(ko,74,t)+P(hsc,167,t)

where the period amplitude are: Ako(9)=0.6, Ako(18)=0.4, Ako(74)=0.5, Ako(167)=0.4. Selecting the same wavelet period in the wavelet spectrum identifies the period amplitude and phase.

A cross correlation between the Kola data series and P(ko,t) is estimated to: R=0.6 and a Pearson quality Q=9 for N=113 samples. The coherence between the both wavelet spectrum estimated to 0.8-0.95 for periods > 18. In this model the correlation is reduced from 0.78 to 0.6, caused by phase disturbance in the periods. At the same time the deterministic model demonstrates the deterministic periods in the Kola data series variability.

2.3 THE NEXT MINIMUM

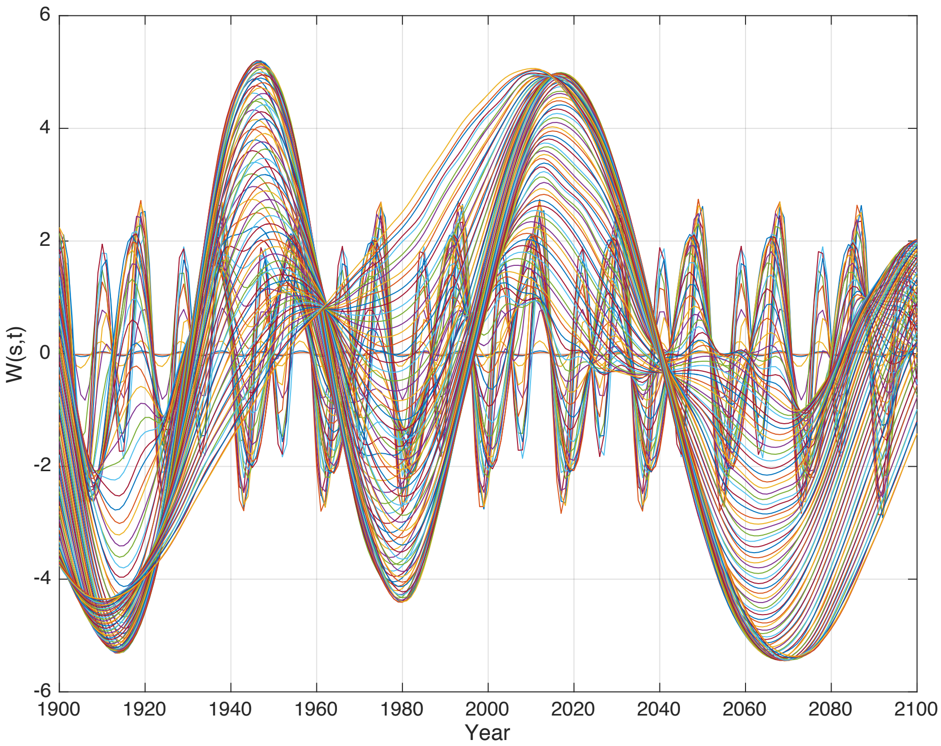

Figure 9. Wavelet spectrum Wkom(s, t) of the deterministic model of the Kola data series, for s=1...0.6N and t=1900 to 2100.

From this deterministic model, we can compute a future estimate of the Kola temperature variability. Figure 9 shows the wavelet spectrum from the deterministic model in the period 1900 to 2100. The wavelet spectrum shows that we may expect a maximum at in 2017 and a new minimum at approximately in 2050, and a mean level like the period from 1900 to 1920.

3 DISCUSSION

The estimated mixing energy required to maintain the large-scale thermohaline circulation is about 2TW. One-half of this energy is provided by tides. The 3-body relation between the Earth, Moon and the Sun introduces a spectrum of tides, from a period of hours to hundreds of years. Long tides have small amplitudes, but much power over a long time period.

The results from this study confirm that the Kola section data series variability is correlated to a period spectrum from the 18.6-year lunar nodal tide. The 18.6-

year lunar nodal tide is a stationary first period. The energy from the tide is distributed in a new set of sub-harmonic tides in the circulating ocean system. The amplitude of some sub-harmonic lunar nodal tides are amplified by resonance in ocean currents. The sea temperature fluctuations are caused by vertical mixing of ocean currents and by coincidence to long solar irradiation periods.

Figure 2 shows that the Kola section temperature has grown from 1920 to 1940 and from 1980 to 2014. This study shows that this period is caused by the phase-relations between sub-harmonic periods. The Barents Sea temperature increased up to 2014, when the sub-harmonic periods have a maximum state. The simulation model shows a turning point at approximately 2017. Then they are turning at the same time, and contribute to a new long cooling period.

It is unclear how deep this possible temperature reduction will be. The model from this investigation indicates a reduction down to a 1920-level. The global sea temperature data series (HadSST3) from 1850 to 2015 is expected to have a maximum at the same time and a new minimum at 2040-2050 (to be published). Long tides, caused by the Earth, Moon and Sun, have global influence the sea temperature. A possible turning of the Kola temperature is supported by other investigations. North Atlantic Current temperature (along 59N, 30-0W, 0-800m deep) is reduced 1 degree from 2007 to 2016 (Climate4you, May 2016). The cold water is coming.

A possible 30-year long temperature reduction in the Barents Sea is caused by less inflow of warm North Atlantic Water to the Norwegian Sea. Less inflow will introduce a colder climate in North-Europe, a colder Barents Sea, a colder Arctic climate and more Arctic ice extent. A colder Norwegian Sea and Barents Sea will cause a dramatic biomass reduction and have a dramatic effect on the marine industry, the maritime industry, fish farm industry and the whole economy on the Norwegian coastline.

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