Journal of Geography, Environment and Earth Science International
2(2): 77-94, 2015; Article no.JGEESI.2015.008

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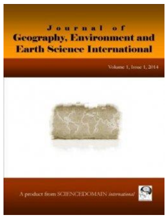

Is there a Quasi-60 years' Oscillation of the Arctic Sea Ice Extent?

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Authors' contributions

This work was carried out in collaboration between the authors who equally contributed to the data collection and their analysis. Both the authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2015/16694
Editor(s):
(1) Wen-Cheng Liu, Department of Civil and Disaster Prevention Engineering, National United University, Taiwan and Taiwan Typhoon and Flood Research Institute, National United University, Taipei, Taiwan.
Reviewers:
(1) Anonymous, USA.
(2) Anonymous, Brazil.
(3) Mazzarella Adriano, Department of Earth, Environment and Resources, University of Naples Federico II, Italy.
(4) Anonymous, India.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=1002&id=42&aid=8837

Original Research Article

Received 11th February 2015
Accepted 25th March 2015
Published 15th April 2015

ABSTRACT

A better understanding of the future climate pattern developments in the Arctic may only follow a better reconstruction of the past patterns of natural oscillations and the determination of the forcing and the resulting oscillations occurred in the climate parameters over different time scales. The proposed information for the past demonstrates the Walsh & Chapman reconstruction [1] claiming a flat sea ice 1870 to 1950 is too simple. The Arctic sea ice experienced a drastic reduction that was phased with warming temperatures 1923 to 1940. This reduction was followed by a sharp cooling and sea ice recovery. This permits us to also conclude that very likely the Arctic sea ice extent also has a quasi-60 years' oscillation. The recognition of a quasi-60 year's oscillation in the sea ice extent of the Arctic similar to the oscillation of the temperatures and the other climate indices may permit us to separate the natural from the anthropogenic forcing of the Arctic sea ice. The heliosphere and the Earth's magnetosphere may have much stronger influence on the climate patterns on Earth including the Arctic sea ices than has been thought.

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Keywords: Arctic; sea ice; climate oscillations; measurements; computations.

1. INTRODUCTION

The recent article [2] suggests a link between the Greenland climate and solar activity on a millennial scale. Changes in solar activity have caused decadal- to millennial-scale fluctuations in both the modern and Holocene climates. While direct observational records of solar activity, such as sunspot numbers, exist for only the past few hundred years, solar variability for earlier periods is reconstructed from measurements of cosmogenic radio nuclides such as ^{10}Be and ^{14}C from ice cores and tree rings. Their high-resolution ^{10}Be record from the ice core collected from central Greenland spans the time from 22,500 to 10,000 years ago. Using ^{14}C records to control climate-related influences on ^{10}Be deposition, [2] reconstruct centennial changes in solar activity to find that during the Last Glacial Maximum, solar minima correlate with more negative δ^{18}O values of ice and are accompanied by increased snow accumulation and sea-salt input over central Greenland. Solar minima could have induced changes in the stratosphere that favour the development of high-pressure blocking systems located to the south of Greenland. The interesting conclusion of [2] is that the mechanism behind solar forcing of regional climate change may have been similar under both modern and Last Glacial Maximum climate conditions. It is therefore of paramount importance to understand to what extent the present sea ice evolution in the Arctic is at least partially a natural movement.

Here we present all the available observations and computational information:

- recent (since 1979) satellite measurements of South and North pole sea ice extent and Global, South and North Pole surface air temperatures;
- -reconstructions (computations) of the Global, South and North pole temperatures and North Pole sea ice extent since the end of the 1800s/beginning of the 1900s;
- -scattered but consistent empirical information showing a shrinking of the Arctic sea ice in the first half of the 1900s followed by a sharp recovery.

In the discussion section, this information is then shown to support a coupling between Arctic sea ice extent and Arctic surface air temperature, and the existence of a quasi-60 years' oscillation of all the climate parameters for the Arctic as also evidenced in many pieces of literature. The work then shows the contradictions of the Arctic sea ice reconstruction [1] that like other reconstructions of temperatures and sea levels supporting the IPCC narrative, are not supported by observational evidence. The actual information for the past is mostly missed in the reconstructions, but what is available contradicts the parable of warming temperatures, rising seas and shrinking sea ice following the anthropogenic carbon dioxide emission since the end of the 1800s. Specifically the presented data are shown to be directly (measured sea ice extents) or indirectly (measured temperatures) inconsistent with the reconstruction [1].

2. AVAILABLE EXPERIMENTAL AND COMPUTATIONAL DATA

The climate-related parameters including temperatures, sea levels and sea ice are characterized by numerous oscillations with various periodicities. In addition to a longer term movement initiated about 1910, the temperature reconstructions since the 1800s show that the worldwide temperatures have oscillated with up to a quasi-60 year's multi-decadal periodicity [3,4]. The existence of the quasi-60 years' climate periodicity is confirmed by several authors [3-15]. The recent (since 1979) satellite air temperatures and sea ice extent measurements show consistency between ice shrinking or expanding and warming or cooling of the North or South Pole. The reduced sea ice extension for the Arctic is associated to a warming surface air temperature, as the increased sea ice extension for the Antarctic is associated with a cooling of the surface air temperatures. It is therefore likely that also the sea ice pattern in the Arctic could have experienced similar oscillation.

2.1 Global Temperature Reconstruction

Fig. 1 presents the global surface air temperatures reconstructed by the National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies (GISS) [16]. The reconstructed GISS global temperature data since 1880, Figs. 1 a, b, are accompanied by the fitting of the data with a line and sines. The data are shown as monthly values plus the values de-trended vs. the linear fitting. The warming trend is 0.0065°C/year. The GISS product is biased towards much larger than actual warming [3,4]. Despite the many adjustments of the GISS product to comply with climate model descriptions, the longer term warming phase started in 1910 with superimposed quasi-60 year's oscillations. There is about the same warming between 1910 and 1940 as the warming between 1970 and 2000 and the flat temperature (or '*pause*') between 1940 and 1970 is like the pause since 1998 [3,4]. The data are downloaded from [16] and the analysis is provided here.

2.2 Arctic & Antarctic Temperature Reconstructions

Fig. 2 presents the reconstructed HadCRUT4 temperatures for the Arctic and Antarctic as proposed by [17]. HadCRUT consists of monthly sea temperature records compiled by the Hadley Centre of the UK Met Office and land temperature records compiled by the Climate Research Unit (CRU) of the University of East Anglia, hence the acronym HadCRUT. Figs. 2 a, b present the mean annual surface air

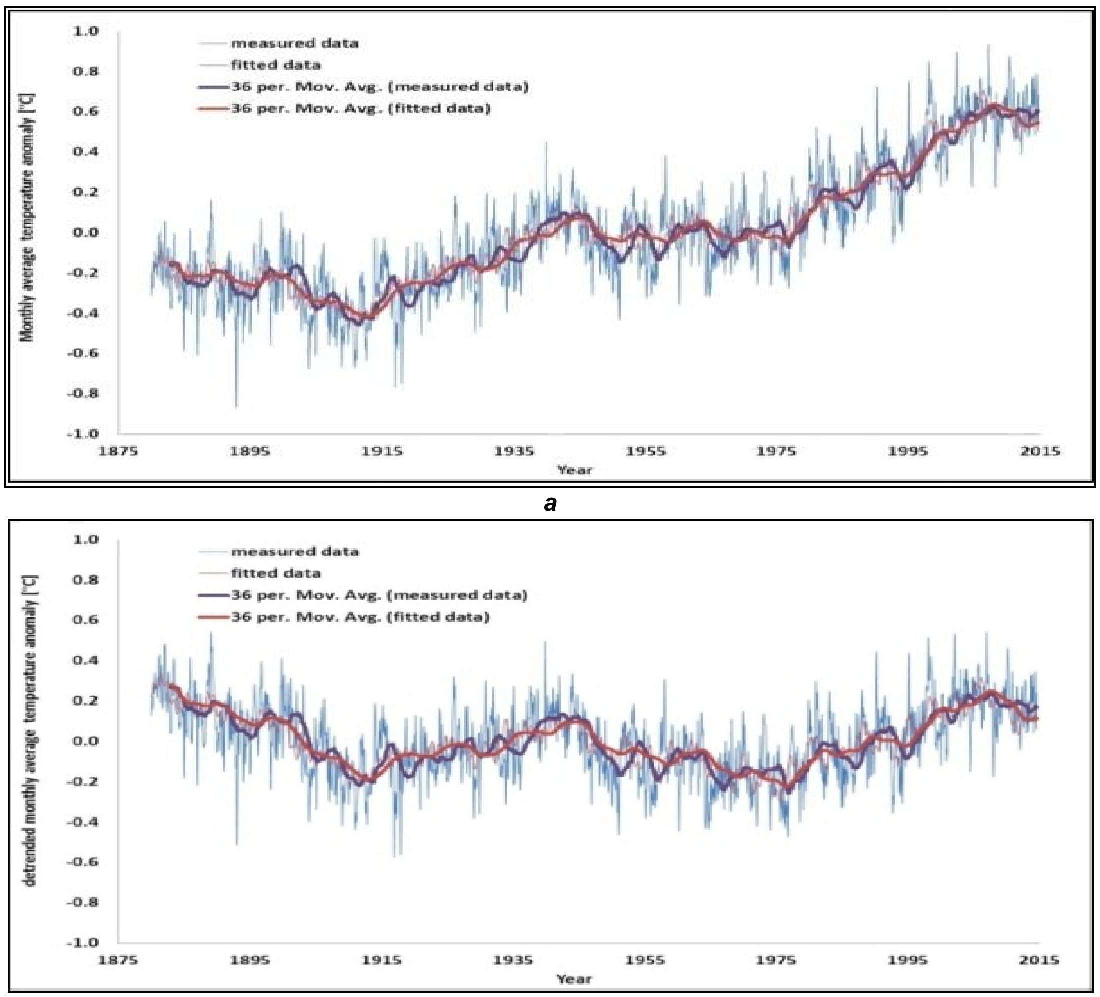


Fig.1. Reconstructed global surface air temperatures since 1880.a) are the temperature anomalies, whileb) are the values de-trended to the linear fitting line. Data are from [16]. The 36 months moving averages are superimposed. While the accuracy of the reconstruction especially for what concerns the warming trend is questionable, as this pattern is the result of continuous adjustments of the computational procedure and of the supporting temperature records with often drastic changes of past temperatures suddenly introduced (see comparison of 2014 v3 with 2011 v2 as an example), noteespecially the quasi-60 years' distance between peaks and valleys

temperature anomaly 70-90 ºN (Arctic) and 70-90°S (Antarctic) compared to the WMO normal period 1961-1990. The data for the Arctic cover a longer time span (since the 1900s) even if the older measurements are very scattered, while the data for the Antarctic are more recent. The Antarctic temperature oscillations are much smaller than the Arctic ones. The specific amplification mechanisms for the Arctic region [18] are responsible for the warming and cooling oscillation rates above the global oscillation rates. The Arctic temperatures were reducing until 1917, then they warmed considerably up to 1921 and peak about 1939. Then there is a cooling until about 1965 and then a warming 1980 to present (2013). The Arctic temperatures seem to suffer a quasi-60 year's oscillation with double peaks about 1937 and 1944 and then 2005 and 2011, with much warmer temperatures experienced since the early 1920s.Considering the quality of the information prior to 1920 is very scattered, the only conclusion that may be drawn from Fig. 2a is that the Arctic temperatures warmed from 1920 to 1940, reaching peak values 1940 – 1945, then the Arctic temperatures reduced to about 1970, and warmed up to about same peak values 2005-2010. Unlike the Arctic, the Antarctic has no trend over the shorter time window. The images are reproduced from [17].

2.3 Global, Arctic & Antarctic Short Term Satellite Temperatures

The latest (1979 to present) satellite Arctic, Antarctic and global temperatures are presented in Figs. 3 to 5. The data are downloaded from the University of Alabama Huntsville (UAH) National Space Science & Technology Center (NSSTC), [19] and analyzed here. The trends are computed by linear fittings. Over the short time window 1979 to present, the satellite temperatures show a warming for the globe of 0.0138 °C/year, a much larger warming for the North Pole of 0.0441°C/year, and a cooling for the South Pole of -0.00014°C/year.

2.4 Arctic & Antarctic Short Term Satellite Sea Ice Extents

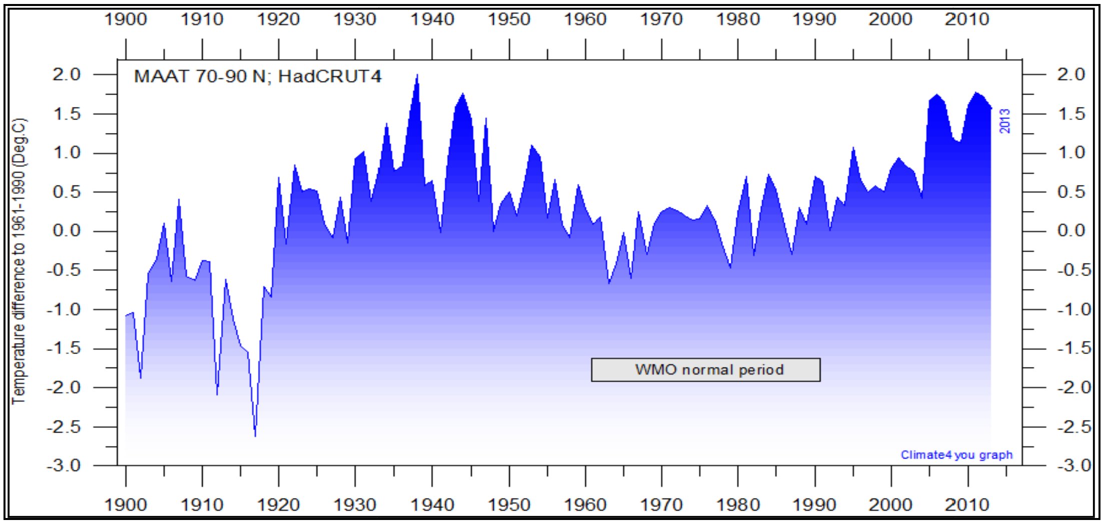
The National Snow and Ice Data Center (NSIDC) sea ice extent by satellite [20], Figs. 6 and 7 respectively for the North and the South pole, show over the same period a reduction of the North Pole sea ice at a rate of $-0.06016\cdot10^6$ sq. km/year, and an increase for the South pole sea ice of$0.02737\cdot10^6$ sq. km/year. The trends are computed by linear fittings. While the North Pole sea ice is shrinking over the short time period, the South Pole sea ice is increasing. Consistently, there is a warming for the North Pole and a cooling for the South Pole. The short term temperature result, Figs. 3 & 4, correlates well with the sea ice extent result, Figs. 6 & 7. The data are downloaded from [20] and analyzed here.

2.5 Arctic Sea Ice Extent Reconstruction

The historical sea ice extension for the Northern Hemisphere is proposed in Fig. 8. The data are downloaded from [21] and analyzed here. The historical sea ice extent for the North Pole by [1] further updated to the year 2008, does not present any quasi-60 year's periodicity, and does not seem to follow the temperature of Fig. 2a. The sea ice cover is reducing since 1950, while it is increasing earlier. If the ice melting is proportional to the warming temperature, Fig. 2a and Fig. 8a cannot both be correct. In particular, the start of the ice melting is phased with cooling or not warming temperatures until 1980, and the previous warming period that produced the hot temperatures 1937 to 1943 very close to the present temperatures had no effect on the ice melting. It is unclear where [1] gathered the information needed to define the seasonal and yearly sea ice pattern for the time window 1870 to 1950, as surveys were very difficult to perform except during the summer months. This historical sea ice extension for the North Pole is generally accepted as the ice pattern for the Arctic [22]. The reconstruction [1] does not exhibit any quasi-60 years' oscillation while the temperatures have a strong quasi-60 years' signature.

2.6 Other Information Available for the Past Arctic Sea Ice

There is scattered but consistent information available for the Arctic sea ice that seems to confirm that a reduction and recovery of North Polar ice have occurred before, suggesting the latest Arctic pattern is at least partially a naturally recurring event. The Arctic climate variations are amplified by the specific mechanisms, the Arctic amplification [18], that make the Arctic, a sea surrounded by land, much more unstable than the Antarctic, a land surrounded by sea. This factor has to be properly accounted together with natural and possible anthropogenic for cings to understand the future Arctic climate evolutions.



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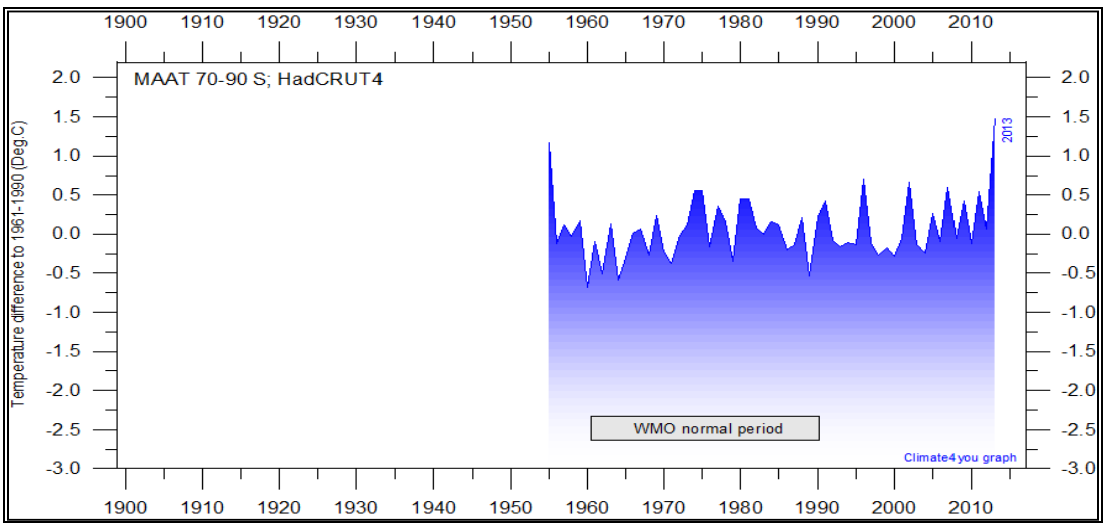

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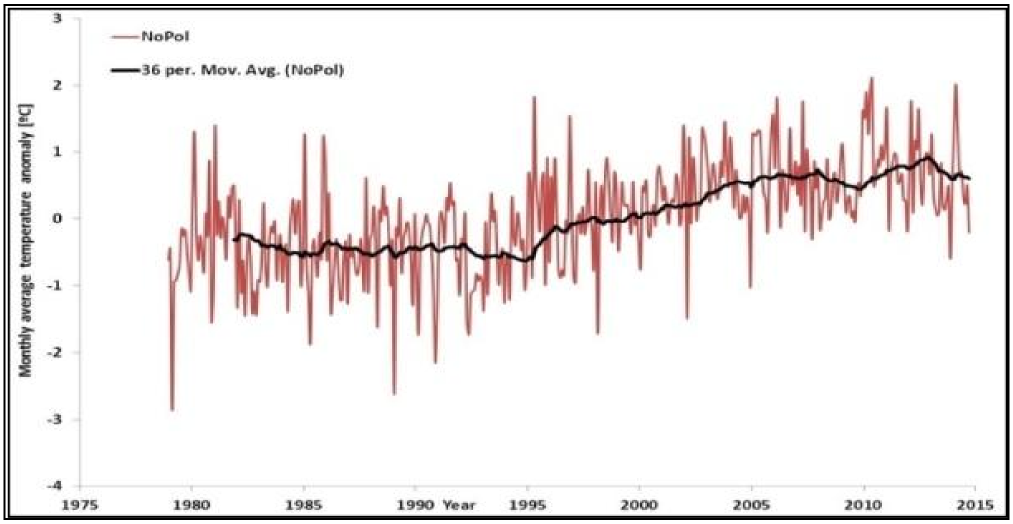
Fig. 2. Reconstructed Arctic and Antarctic surface air temperatures since 1900 (Arctic) and 1957 (Antarctic respectively). a) are the Arctic and b) the Antarctic temperature anomalies. The images are from [17]. **The peak Arctic temperatures of 1940-1945 are close to the values of 2005-2010, suggesting a quasi-60 years' oscillation may also be present in this pattern. The measurements prior to 1920 are particularly unreliable**

In the article of 1922 THE CHANGING ARCTIC by Ifft [23] the effect of global warming on the Arctic climate was already evident. "*The Arctic seems to be warming up. Reports from fishermen, seal hunters, and explorers who sail the seas about Spitzbergen and the eastern Arctic, all point to a radical change in climatic conditions, and hitherto un-heard-of high temperatures in that part of the earth's surface.*"

The reduction of sea ice extent 1922 to the end of the 1930s (during the second world war there was no measurement) is confirmed by the Dänische Meteorologische Institut (DMI) maps of the Arctic ices recently brought to the attention of the scientific community by [24].

Brunnur [25] presented a number of maps showing Arctic ice extend from 1893 to 1961 collected by DMI in "*Nautisk Meteorologisk Aarbog*". Each year DMI have collected information on sea ice extend so that normally each of the months April, May, June, July and August ice extend was published. Lansner [25]



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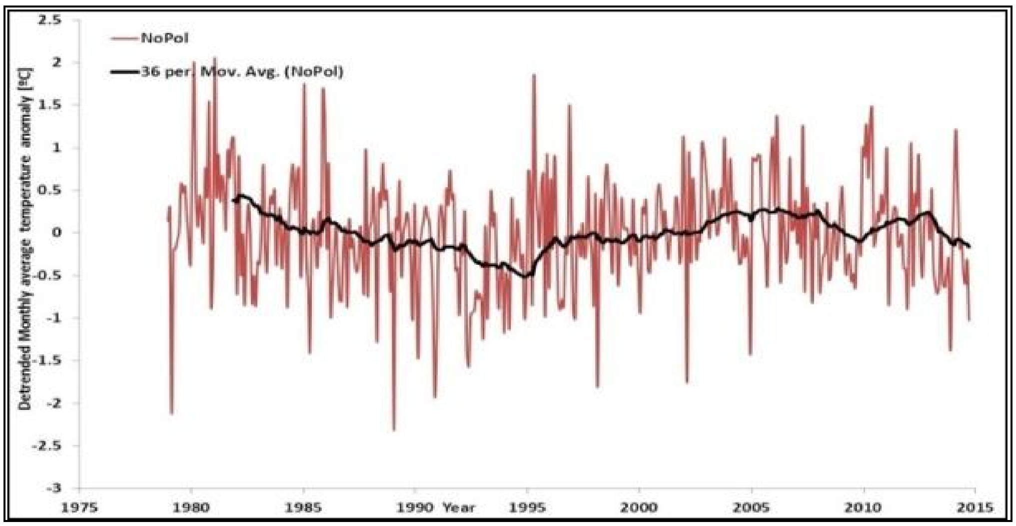


b

Fig. 3. Satellite temperatures of the North Pole since 1979.a) are the temperature anomalies, while b) are the values de-trended to the linear fitting line. Data are from [19]**. The 36 months moving averages are superimposed.**

analyzed the August data, where the ice coverage is not the minimum, because the September data were unavailable. Some of these maps (images from [25]) are reproduced in Fig. 9, and compared with the latest satellite images (from [21]) in Fig. 10 for years that Fig. 2a tells us experienced similar annual temperatures.

August data in the beginning of the twentieth century resemble that of satellite-described ice coverage for recent years. In the period 1901-1920 the differences are minimal. In 1923 some changes appear. The ice east of Svalbard and east of Novaja Zemlja is on retreat. In 1930, the retreat has gone even further and Svalbard is ice free, as ice free waters are observed Far East of Novaja Zemlja. Baffin Bay is now almost ice free. The ice extent on the Pacific side of the Arctic remains rather constant in all these years.

In 1932 in August there was open ice almost all along the Russian shore. In 1935 open waters are observed not that far from the North Pole. In 1937, more open waters are observed in the Pacific and East Siberian areas. In 1938 there are unprecedented areas of open waters, but the year after, 1939, the ice extent resembles the pre-1923 extent. A decline in Arctic ice area from around 1921 ended possibly in 1938. There are no images for the years 1940-45, but in 1952, the August sea ice area was similar to the 1900-1920 extend.

The DMI maps show a sea ice decline from 1923 to 1938 followed by a possible sharp recovery in the mid-1940s (but the years of the Second World War are missing) and certainly similar to the 1900s sea ice extent in the 1950s.

A comparison of past DMI maps and present satellite images (these latter also from [21]) shows the August ice areas for 1935 and 1997 were roughly similar, just as the ice areas for 1938 and 2000 are similar. Warm Arctic years in the 1930's images from DMI compare quite well to recent satellite inferred Cryosphere Today August graphics [21]. The ice areas for 1935 and 1996 were roughly similar to the ice areas for 1938 and 2000.

The extended reconstruction of [1] does not show in 1935 an ice area similar to 1996, but something roughly $1.9 \cdot 10^6$ sq. kmsmaller (Greenland is $2.1 \cdot 10^6$ sq.km). The extended reconstruction [1] of the Arctic ice area data also suggests more ice in 1937 than 1921, while DMI

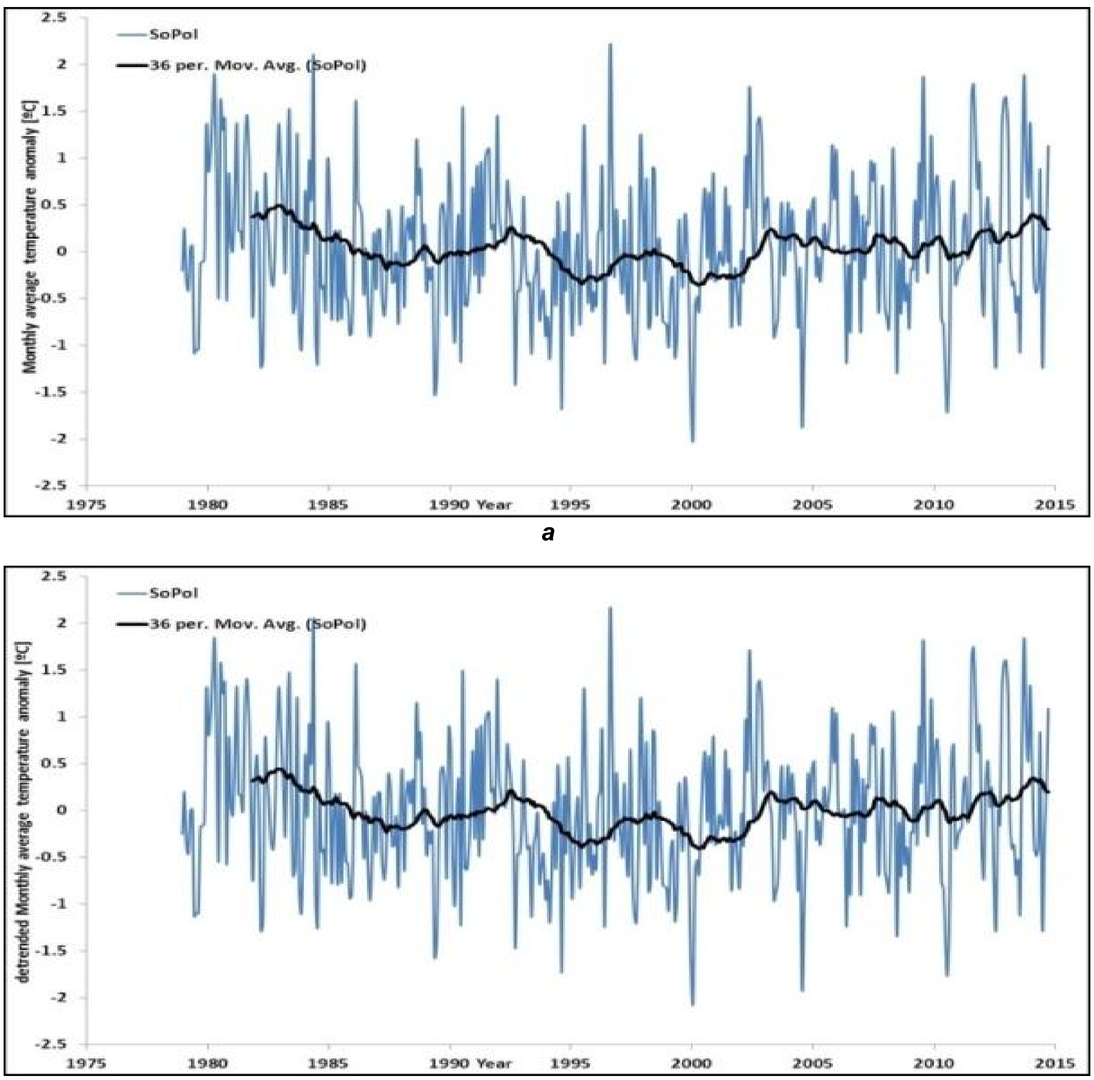
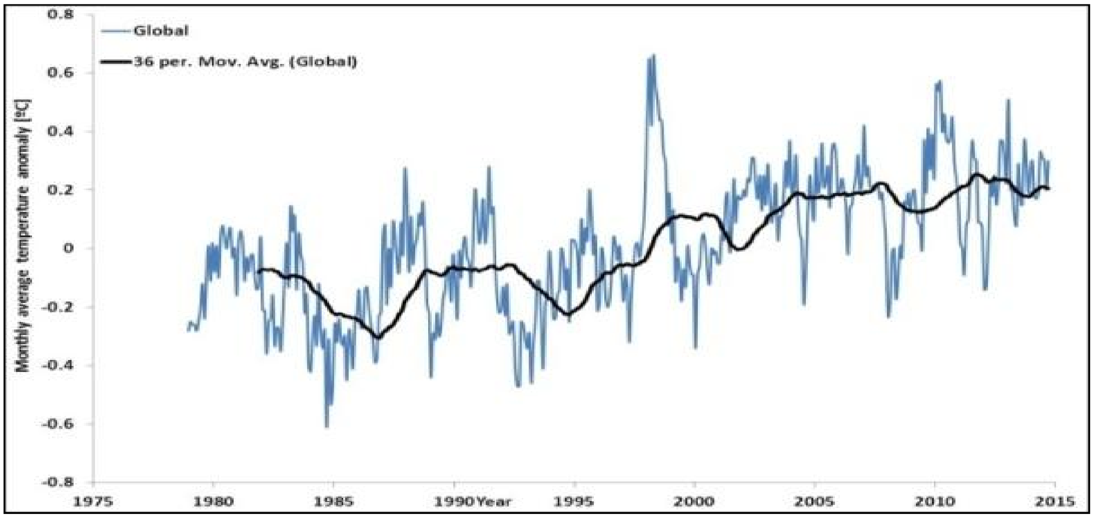


Fig. 4. Satellite temperatures of the South Pole since 1979.a) are the temperature anomalies, while b) are the values de-trended to the linear fitting line. Data are from [19]**. The 36 months moving averages are superimposed**



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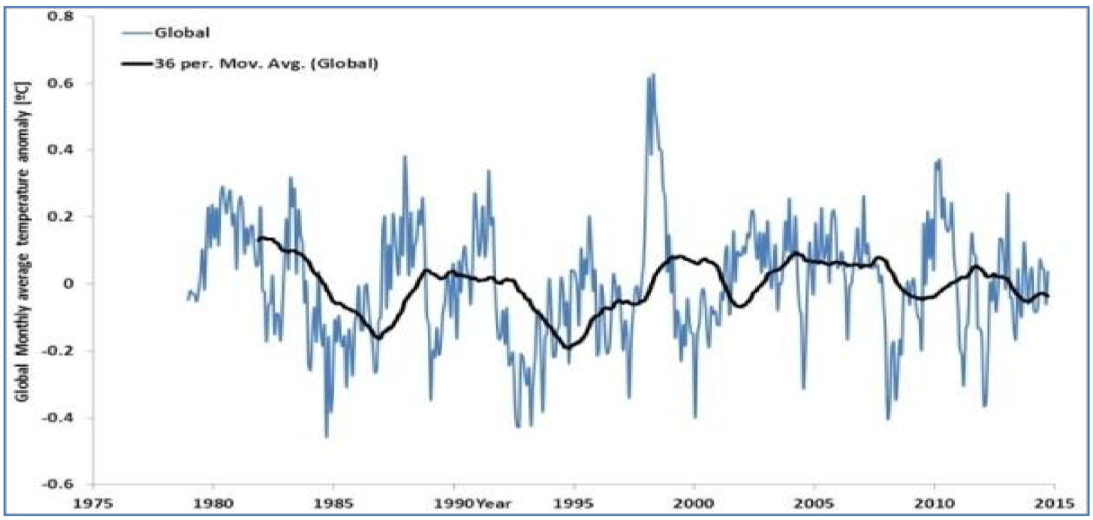


b

Fig. 5. Satellite temperatures of the Globe since 1979. a) are the temperature anomalies, while b) are the values de-trended to the linear fitting line. Data are from [19]**. The 36 months moving averages are superimposed.**

suggests a strong decline after 1921. The DMI maps are perfectly consistent with the temperatures of Fig. 2a, which casts serious doubt about the time series of the extended reconstruction [1] of the Arctic sea ices shown on Fig. 8a.

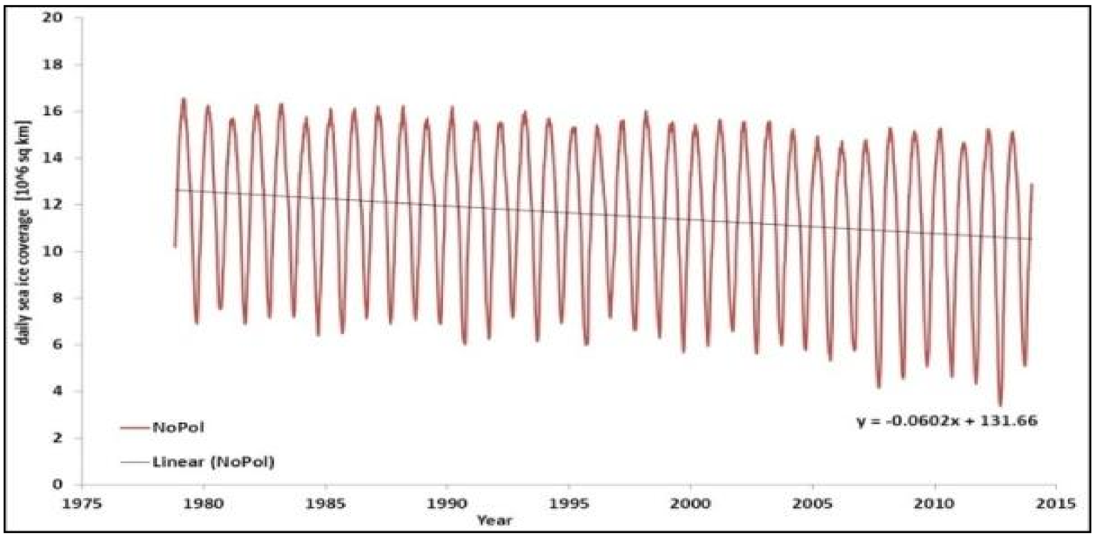
The sea ice extents of August 1910 and August 1950 are close, Figs. 9a and 9b. In August 1923, the sea ice extent is slightly reduced vs. the 1910 values, Fig.9.c, and in August 1936 the sea ice extension is significantly reduced, Fig. 9d. In August 1937 and August 1938, Figs. 9e and 9f, the sea ice extension is further reduced. This indicates the possibility of a more gradual sea ice reduction followed by a sharp recovery of the sea ice in the first half of the 1900s.

The recent satellite maps of Figs.10a,b,c show a sea ice coverage 1997-2000 close to the one of 1935-1938 of Figs. 9d,e,f.

3. DISCUSSION OF A QUASI-60 YEARS' PERIODICITY IN THE ARCTIC SEA ICE

The data proposed in the previous paragraph suggest that there may be an oscillation of Arctic ice coverage but presently the reference work for the Arctic ice does not show this and indicates continuously decreasing ice coverage. Temperatures and sea ices are certainly coupled as shown by the satellite results, and if the Arctic temperatures oscillate, the Arctic sea ice should logically do the same, as confirmed by the scattered information for the first half of the 1900 from the Ifft's narrative [23] to the DMI maps.

The information available for the Arctic sea ice coverage is scattered and it is difficult to reconstruct a reliable pattern spanning even only the last 100 years. The reconstruction [1] proposes a sea ice extension about constant from 1870 to 1950s and then sharply decreasing, in the yearly values as well as the values in every season. Other information, such as the DMI maps, shows that during the summer months the sea ice reduced 1920 to 1940 consistently with a contemporary warming phase clear in temperature measurements, and during the years 1900 to 1920 the summer sea ice extent w as close to the 1950s values. Furthermore, the end of the 1930s DMI summer sea ice maps obtained with a different technique are close to the satellite sea ice maps of the latest 1990s.



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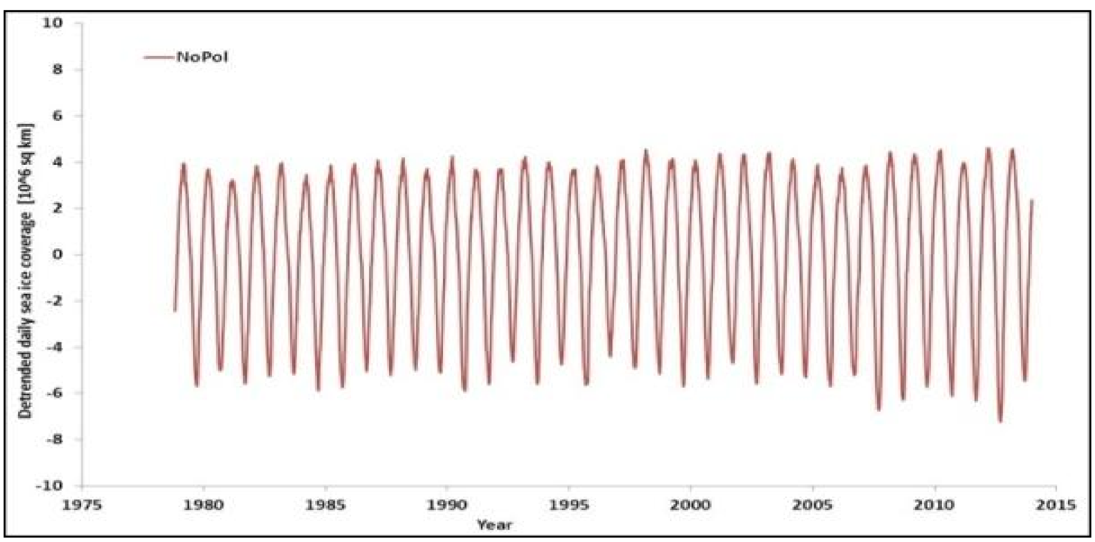

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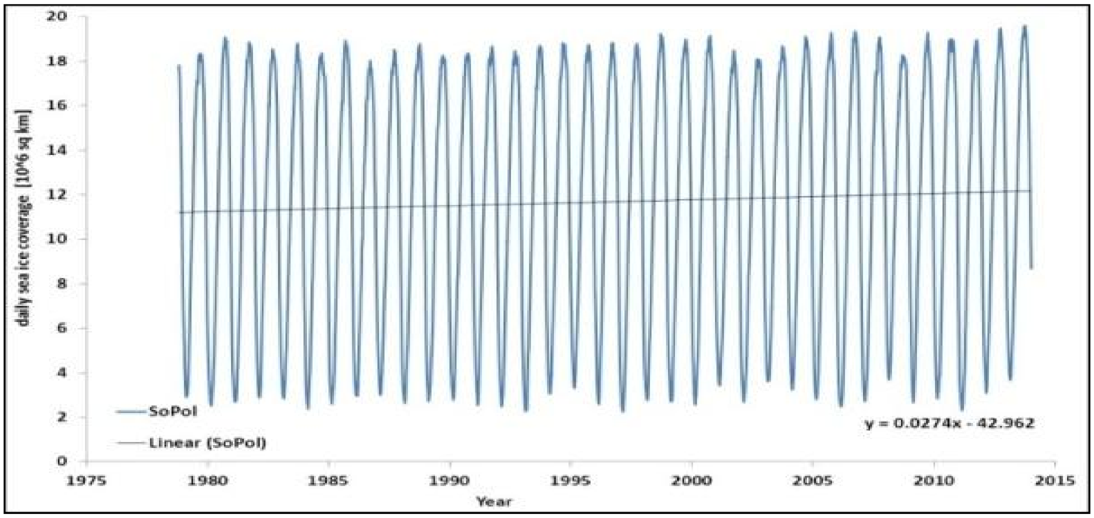
Fig. 6. Satellite sea ice extent North Pole since 1979. a) are the sea ice coverage anomalies, while b) are the values de-trended to the linear fitting line. Data are from [20]. **The shrinking of ice is consistent with the warming temperature of Fig. 3**



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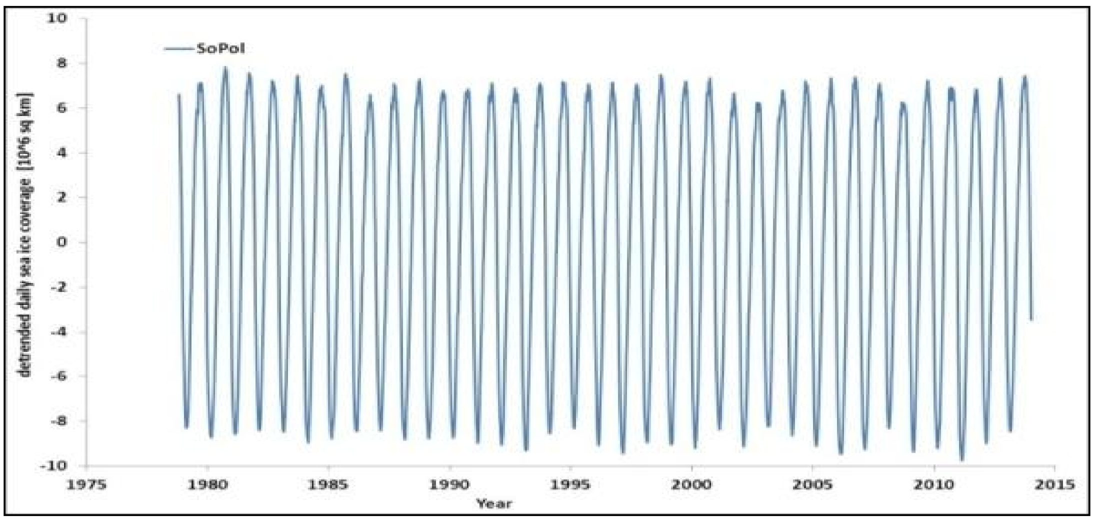

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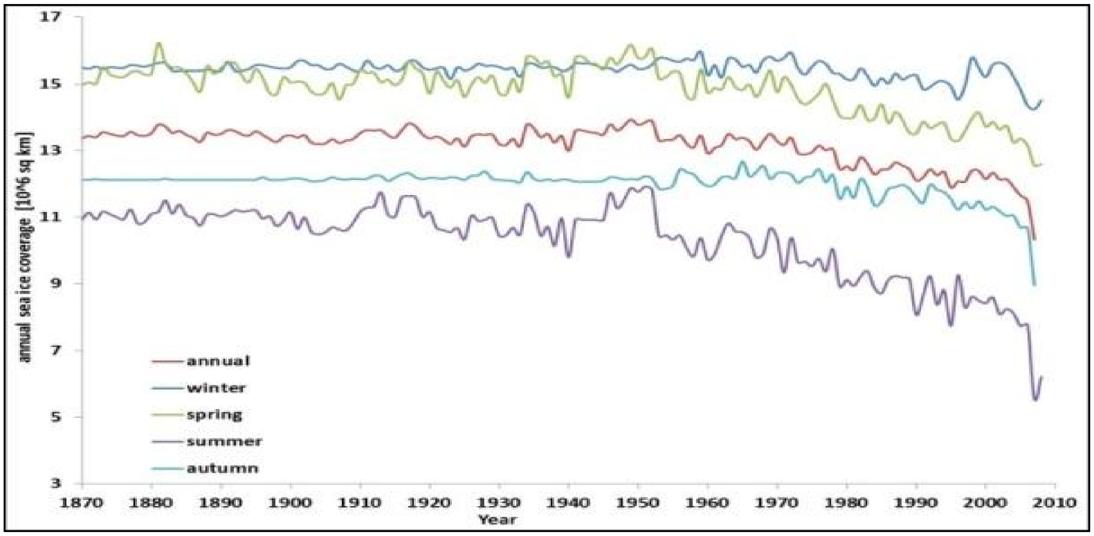
Fig. 7. Satellite sea ice extent South Pole since 1979. A) are the sea ice coverage anomalies, while b) are the values de-trended to the linear fitting line. Data are from [20]**. The expansion of sea ice is consistent with the cooling temperature of Fig. 4**

The recent satellite measurements of sea ice and temperatures show consistency for the Arctic as well as the Antarctic. The DMI maps are consistent with the temperature trend. The reconstruction [1] is not consistent with this temperature trend. While the reconstruction [1] has no quasi-60 years' periodicity, the temperature reconstruction has a clear quasi-60 year periodicity, as the top temperatures of the 1940 and 2000 are very close. The DMI sea ice maps in the end of the 1930s are also very similar to the satellite sea ice maps end of the 1990s and suggest a similar quasi-60 year periodicity in the sea ice extent.

The DMI maps show sea ice extension 1900-1920 similar to 1950, and a decreasing sea ice 1920 to 1940. The years of the Second World War are missing. These maps indicate a shrinking and recovery process occurred in the first half of the 1900s apparently coupled to the Arctic temperatures. The recovery seems also complete, within the limits of the uncertainty of the sea ice extent, with the DMI techniques. The DMI sea ice maps are not consistent with the reconstruction [1] but are consistent with the temperature trend. The August sea ice extent of 1950 is about the same as the sea ice extent 1900 to 1920. The August sea ice extent of the end of the 1930s is significantly reduced and not far from the satellite results obtained at the end of the 1930s.

It is very unlikely that the sea ice extent had no oscillation over the time window 1870 to 1950. The Arctic sea ice is probably subject to a quasi-60 years' oscillation. There may be other relationships movements, as it is clear for example in the temperatures, where a quasi-60 years' oscillation is superimposed on a warming trend started about 1910.



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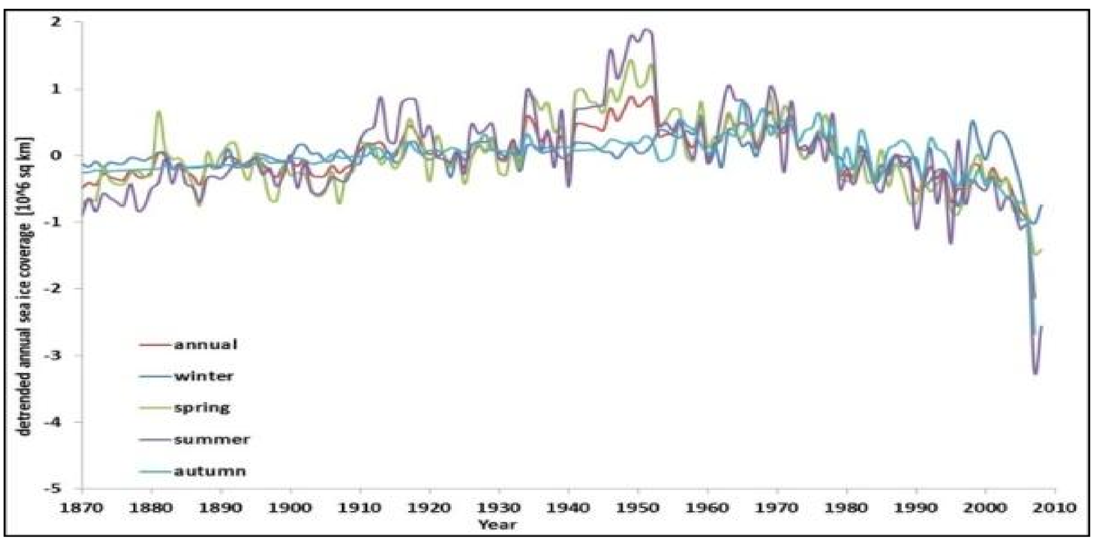

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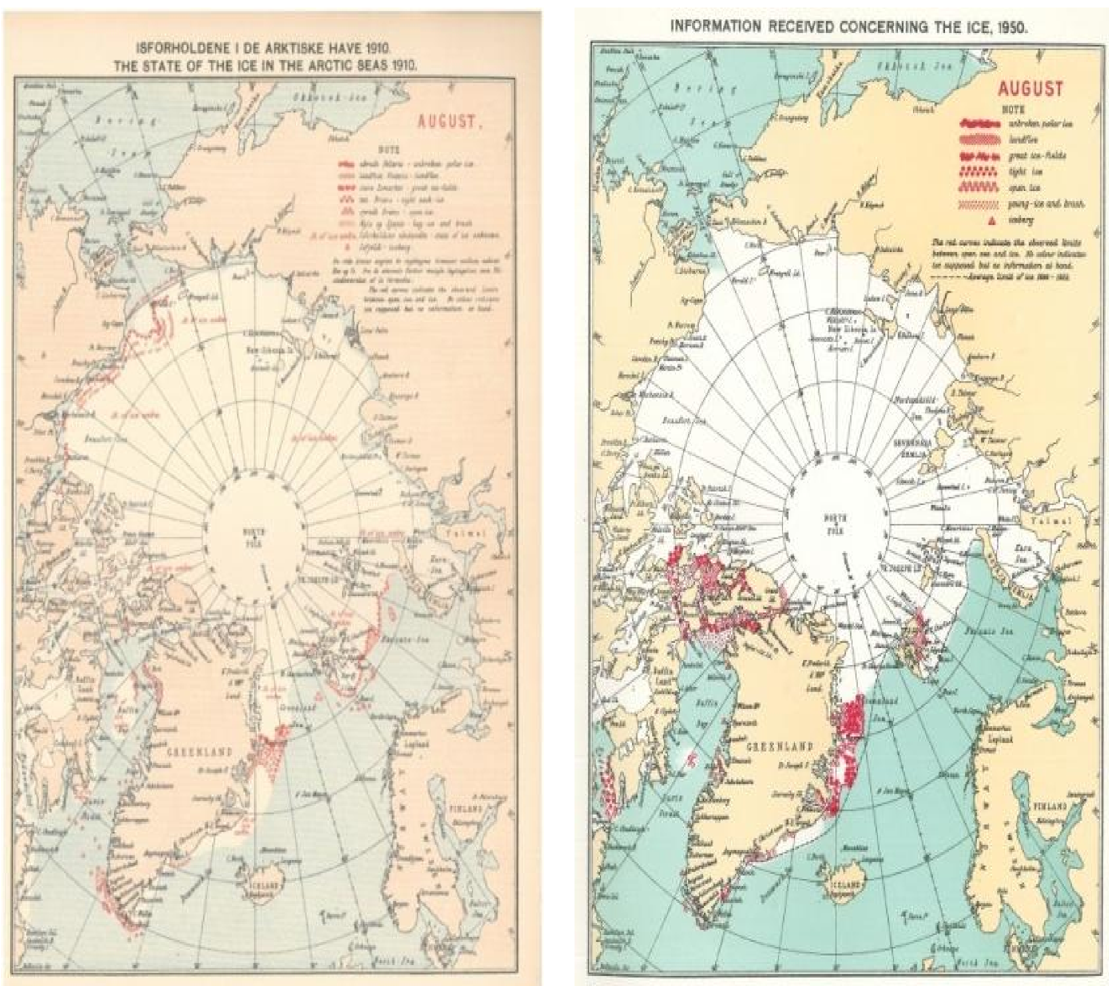
Fig. 8. Extended Walsh & Chapman [1] **North Pole sea ice extent, for every season and yearly.a) are the sea ice coverages, whileb) are the values de-trended vs. the linear fitting line. Data are downloaded from** [21]**. This pattern of sea ice extent is inconsistent with the temperature pattern of Fig. 2.a. In particular, the very hot Arctic period 1940-1945 is claimed to have the largest sea ice coverages. The pattern is also inconsistent with the actual measurements of sea ice performed by the Dänische Meteorologische Institut (DMI), as shown in Fig. 9**

A significant literature supports the existence of a quasi-60 years' oscillation in the Arctic sea ice similarly to the Arctic temperature further supporting the claim that the extended reconstruction [1] may be inaccurate, at least over the period 1880 to 1950.

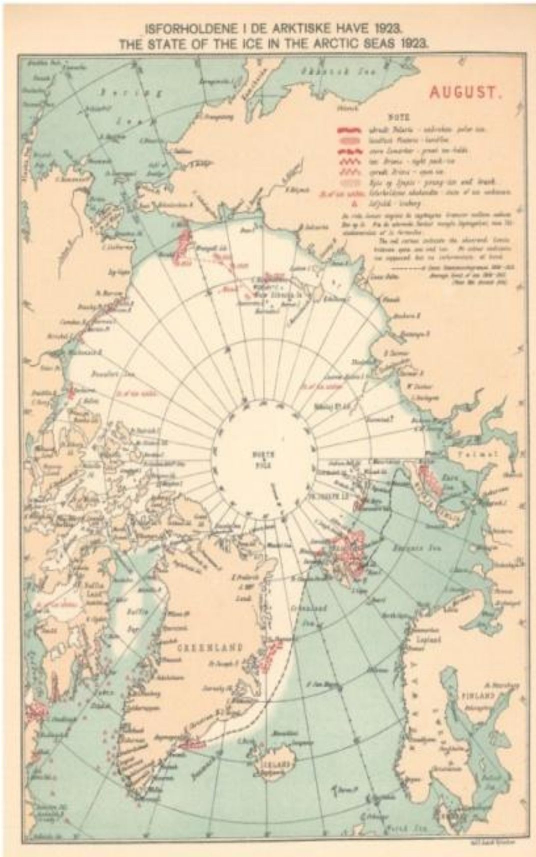
Klyashtorin and Lyubushin [26] analysed the climate indexes fluctuations and populations of major commercial fish species for the last 1500 years to characterize the 50-70 year climate fluctuations and fish production dynamics. The comparative dynamics of de-trended global temperature anomaly, the temperature anomaly of the Arctic circumpolar zone and global and local Atmospheric Circulation Indexes (ACI) since the end of the 1800s show very close similarities and the presence of a quasi-60 year's oscillation.

The time series for temperature over the last 1500 years, reconstructed by the analysis of Greenland ice core samples and annual growth rings of the long-living trees (Arctic pine (*Pinus silvestris*) tree from Scandinavian Peninsula and North-California bristlecone pine tree, (*Pinus aristata*) show the presence of a quasi-60 years' fluctuation [26]. The spectrum of periodical temperature fluctuations for 1423 years by Greenland ice core samples shows a 54 years and a longer 157 years fluctuation. The spectrum of periodical temperature fluctuations for 1400 years by the Arctic pine tree growth rings shows a 60 year and a longer 108 years fluctuation.



a *b*

Fig. 9. a,b. Past DMI maps (from [24]**) for August 1910 and August 1950. The sea ice extent is similar**



c

d

Fig. 9. c,d. Past DMI maps (from [24]) for August 1923 and August 1936. The sea ice extent is shrinking over this time window

The Spectrum of periodical moisture fluctuations for 1500 years according to California bristlecone pine tree growth rings shows a 76 year and a longer 158 years fluctuation. This indicates the predominant periodicity of climatic fluctuations during the last 1000 years equal about 60 years with variation from 55 to 76 years.

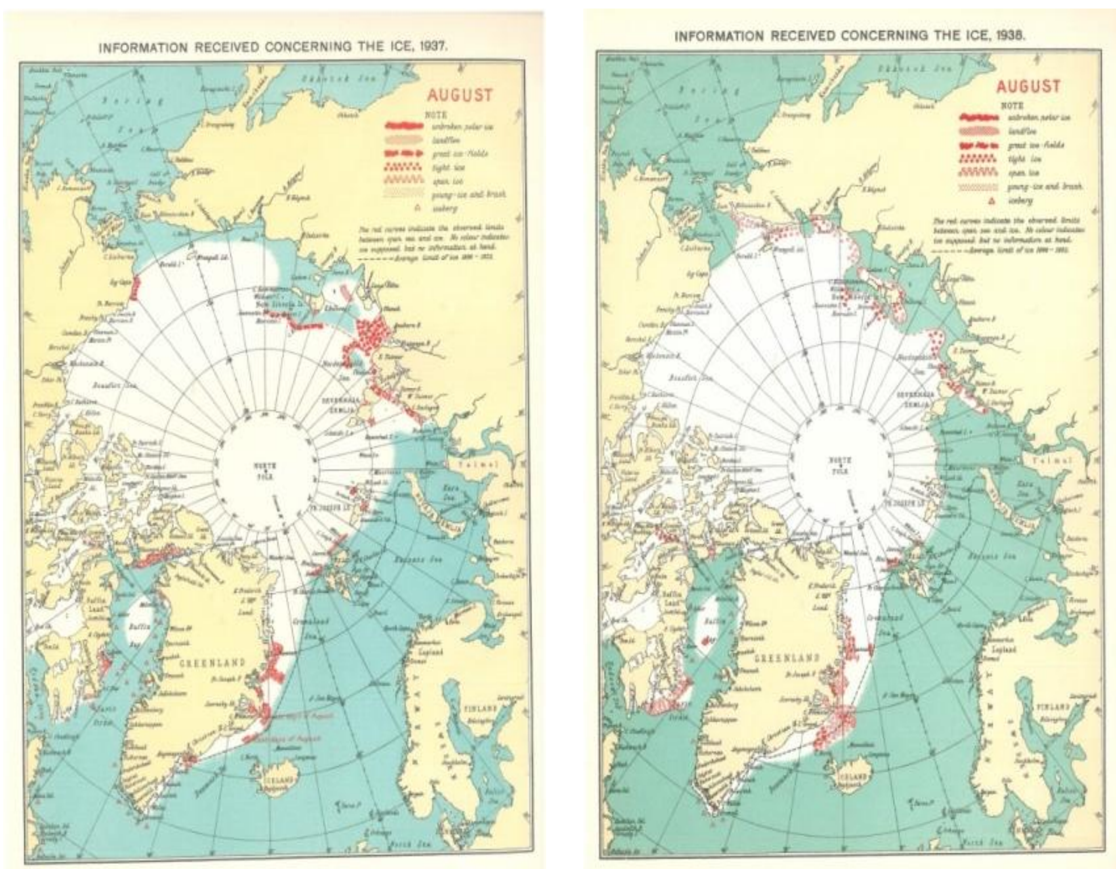
According to [27] the warming event in the first part of the 20th century was a long lasting event commencing in the early 1920s and reaching its maximum some 20 years later. The following decades were much colder, although not as cold as in the early years of the last century, until the latest warming phase shifted of quasi-60 years. As noted by [28] and [29] the ongoing warming has reached in the 2000s the peak values of the 1940s.

Polyakov [30] used April through August ice observations in the Nordic Seas, Iceland, Greenland, Norwegian and Barents Seas, to construct time series of ice-edge position anomalies spanning the period 1750-2002. They found evidence of oscillations in ice cover with periods of about 60 to 80 years and 20 to 30 years, superimposed on a continuous negative trend. The persistent ice retreat started in the mid-1900s.

Venegas and Mysak [31] analyzed century-long records of sea ice concentration and sea level pressure pole ward of 40°N latitude. They evidenced many quasi-decadal and inter-decadal timescale fluctuations accounting for a large fraction (60-70%) of the natural climate variability in the Arctic. They identified climate signals with periods of 6-7 years, 9-10 years, 16-20 years, and 30-50 years. According to [27] a computational analysis of the spatial characteristics of the observed early century surface air temperature anomaly reveals the temperature variation was associated with similar sea ice variations.

Mörner [32] discusses how solar variability affects Earth climate not only through solar irradiance as generally considered, but predominantly through the interaction of the Solar Wind with the Earth's magnetosphere. The 60-years cycle recorded in solar activity and earth rotation affect the oceanic circulation, the temperatures, the sea level changes and the Arctic sea ice. As also evidenced by [33] the solar-planetary beat has a 60-years cycle. The Earth's rate of rotation has a 60-years Length of Day (the standard method to measure the Earth's rate of rotation) cycle. The Global temperature has a 60 years cycle. The North Atlantic circulation has 60 years as well as 120 and 240 cycles. The North Atlantic cycle has an inflow to the Arctic of warm Atlantic waters. Global temperature and inflow to the Arctic cycles affect the regional Arctic temperature having the 60 years cycle, the Barents Sea water temperature has the 60 years cycle, the sea ice cover in the Barents seas has the 60 years cycle, and the herring and cods stocks in the Barents seas also have the 60 years cycle.

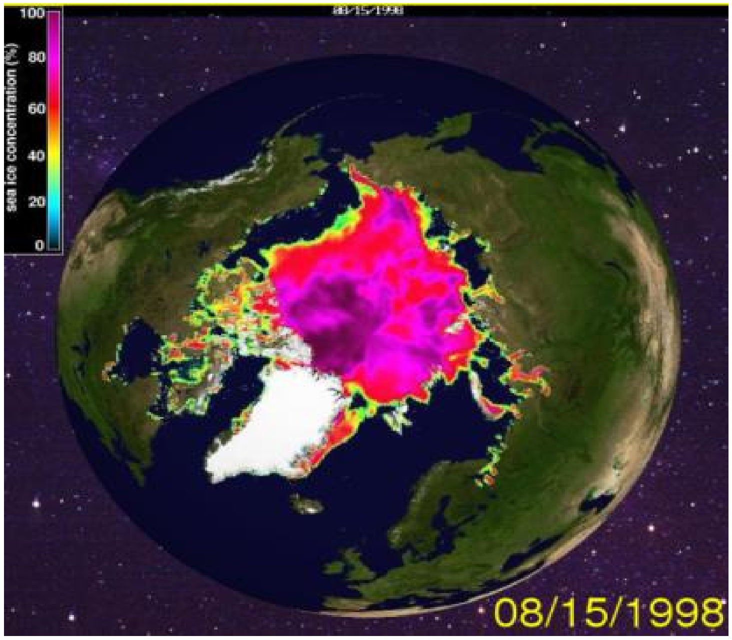
The North Pole sea ice extent [1] is therefore inconsistent with the very large amount of information in the literature showing the Arctic sea ice have a very different pattern, mostly oscillatory. The latest images of sea ice for the Arctic (and the Antarctic) are provided by [34].



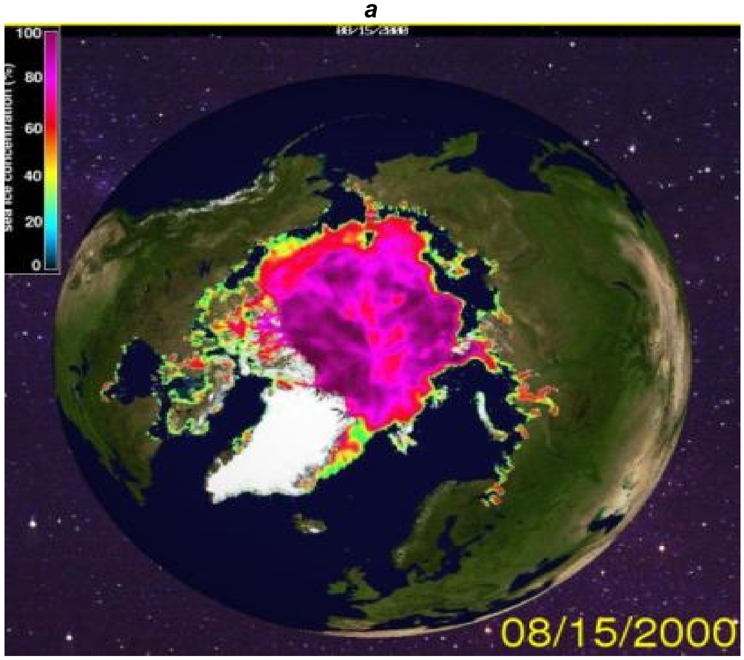
e *f*

Fig. 9. e,f: past DMI maps (from [24]) for August 1937 and August 1938. The sea ice has further considerably reduced. The sea ice was stable 1910 to 1923, then drastically reducing 1923 to 1940. During the Second World War there are unfortunately no measurements, but after the war the 1950 extension is similar to the 1910 values. Note that the DMI maps are only available during the summer months, as it was practically impossible to perform surveys during the winter months over most of the last century. These maps e, fclosely resemble the latest satellite maps for recent years, as shown in Fig. 10

This Global Sea Ice Reference Page has all the Arctic and Antarctic current graphs and imagery from multiple sources. All images are automatically updated immediately upon update at their source. The 2014 results show a sea ice extent recovering to values that, according to some of the providers of information, are the largest of the last decade and within the average 1981-2010±2 standard deviations. The sea ice of the Arctic seems far from full recovery, but the ice free conditions claimed by many seem far from the truth.

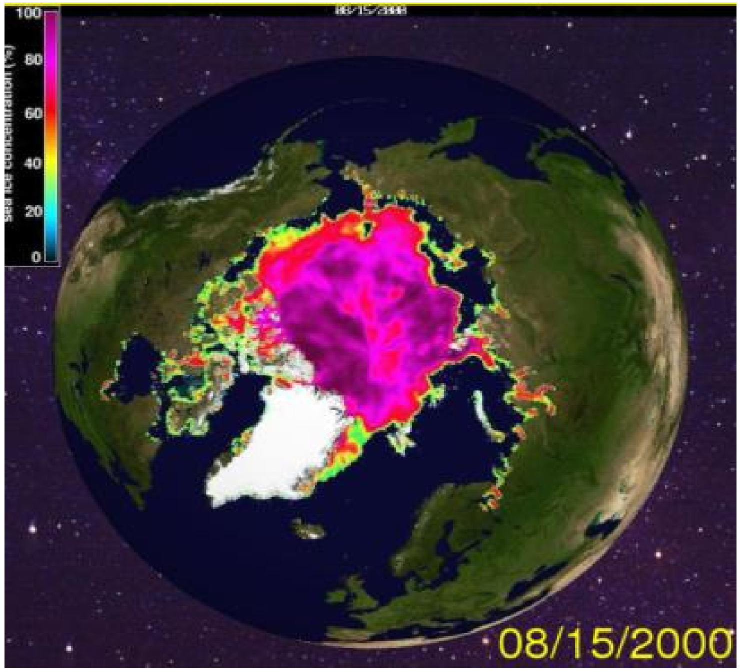


a



b

Fig. 10. a,b Present satellite maps (from [21]**) showing a sea ice coverage 1997-2000 close to the one of 1935-1938**



c

Fig. 10. C Present satellite maps (from [21]) showing a sea ice coverage 1997-2000 close to the one of 1935-1938

4. CONCLUSION

It is shown that the Walsh & Chapman reconstruction of the Arctic sea ice extent [1] is not based on actually measured data. The flat arctic sea ice 1870 to 1950 conflicts with the historical sea ice information of the DMI maps that demonstrate a drastic reduction of arctic sea ice 1923 to 1939 and about same Arctic sea ice prior of 1923 and about 1950.

The flat trend is also inconsistent with the Arctic temperature reconstructions which show a warming since the 1920s and a cooling phase before the latest prolonged warming phase. It is not plausible that the strong warming 1923 to 1945, not very different from the more recent warming phase should have had no effect on the Arctic sea ice extent.

As the Arctic temperature oscillates with a quasi-60 years' periodicity, then the Arctic sea ice should do the same, and as the Arctic sea ice has declined strongly in the recent past but it has also strongly recovered, some recovery will surely occur again in the future.

ACKNOWLEDGEMENTS

The authors have no financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=1002&id=42&aid=8837