



THE SOLAR WOLF-GLEISSBERG CYCLE AND ITS INFLUENCE ON THE EARTH

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ABSTRACT- The only continuous solar observations that extend over the important climatic time scale of decades to centuries are those of sunspots, yielding a measure of magnetic activity. There are evidences for the modulation of the amplitude of the 11 year solar cycle in a period of about 80 years known as Wolf-Gleissberg cycle. The Cycle seems to be fairly clear in the sunspot record and in its proxy measurements by cosmogenic isotopes. The cycle appears to show up in many meteorological parameters, suggesting that there may be an important sun/climate connection over long periods of time(Hoyt and Schatten 1997).

The Solar Wolf-Gleissberg cycle stimulate solar forcing on terrestrial phenomena's as evident from the pattern of Global temperature (both air and ocean temperatures). Solar Wolf- Gleissberg periodicity is marked in a wide range of terrestrial evidences since millions of years and is still at work. It is found that climatic fluctuations are induced at the turning points of such cycles.

In order to solve this problem, it is found that there are three types of solar cycles occurring on the sun namely, those occurring during Maunder minimum anomalies that caused the very cold weather in the little ice age (1645-1715), normal sunspots and low amplitude (weak sunspots of longer duration) occurring in the shallow dip in between successive Wolf- Gleissberg cycles. The later ones also induce cooling of the air and sea surface temperatures.

The key in understanding the cause and effect of those types of solar cycles lies in the fact that those low amplitude intermediate cycles rotate faster than the normal ones thus . Hoyt and Schatten (1997) argue that any change in solar rotation rate is a very persuasive indicator that the deeper levels of convection are varying, and hence there is a corresponding variation in solar luminosity and irradiance. Also there has been evidence of change of the daily equatorial rates and cycle length at the maximum of the last Solar Wolf-Gleissberg cycle around cycle 19.

Climate fluctuations are known from, sharp rises or falls of lakes levels, temperature anomalies, change in the general wind circulation and droughts and flood- Hazards.

Yousef(1995a) predicted the downturn of solar activity in 1997 with the start of weak low amplitude fast rotation and longer duration sunspot cycle 23. This is evidently confirmed by the sharp rise of lake Victoria level in 1997-98. Lean (2001) is also seeing a drop in the solar irradiance which might be the start of a longer term drop.

Since that is the case, then 1997 is a year of climate fluctuation and a drop of global earth air and sea temperature is predicted soon similar to that happened during similar circumstances around 1800 and 1900, with increased El Nino and La Nina frequencies leading to wide spread flood -drought hazards and God knows best.

1-INTRODUCTION

“A growing mass of evidence suggests that transient events on the sun affect our weather and long term variations of the sun’s energy output affect our climate. Solar terrestrial exploration can help establishes the physical cause and effect relationships between solar stimuli and terrestrial responses. When these relationships are understood, science will have an essential tool for weather and climate prediction“. This paragraph was written by Robert D. Chapman as part of a proposal for a five-year plan for Solar Terrestrial Programs in the National Aeronautics and Space Administration(Herman and Goldberg 1978).

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The subject of Sun-weather relationships is built on correlations between changes in solar activity and changes in terrestrial weather and climate. Several books and conferences have been devoted to Solar

influences on the Earth, e.g.: Herman and Goldberg (1978) in their book *Sun Weather and Climate*, "The Solar Engine And Its Influence On The Earth's Atmosphere" edited by Nesme Ribes (1994), "Solar Out Put And Climate During The Holocene", Edited by Frenzel (1995), "The Role of The Sun In Climate Change" by (Hoyt and Schatten (1997) and recently, "Solar Variability And Climate " edited by Friis -Christensen et al. (2000).

Solar variations can be of the order of 11-yr. sunspot cycle, the 22-yr. oscillations in the solar polar magnetic field. A longer variation of roughly 80-yr. (Krivsky 1995, Hoyt and Schatten 1997), referred to as the Wolf-Gleissberg cycle. As far as long periodicities are concerned, proxy data help build up a rather stronger case for the 80 to 90 year and 180 to 200 year cycles (Burroughs 1992). Carbon-14, which responds to solar variations, has reported cycle of around 200 years. This same cycle also shows up in such other climate proxies as the oxygen-18/oxygen-16 ratio used to measure oceanic temperatures, and tree-rings, which respond to precipitation and temperature. These results suggests sun/climate connection (Hoyt and Schatten 1997). In addition, on the long time scale, historical accounts for the absence of sunspots and coincident drop in aurora reports mark a period of solar inactivity known as Maunder Minimum (1645-1715), Eddy (1978). It is now generally believed that ^{14}C anomalies in tree rings of known ages mark times in the past when other weaker solar activity episodes have occurred. Episodes of anomalously strong activity are indicated as well. The interval between anomalies varies, but is perhaps characteristically around 400 yr. Stuiver Braziunas (1992) reported oscillations with a period of 416 year.

It is the purpose of the present work, first to review and establish strong connections between Solar (80-100) yr. Wolf-Gleissberg cycles, and various climatic criteria, as manifested both in contemporary time series as well as periodicities. Secondly to review known climatic fluctuations and to show that they are coincident with Wolf-Gleissberg cycles turning points and thus are stimulated by Solar forcing possibly arising from magnetic changes in and in-between those cycles with the capacity of backward and foreword forecast of various climatic fluctuations as manifested by droughts, abrupt rise or fall of lakes or closed sea levels as well as global cooling or warming ; God's permit.

2-THE IMPORTANCE OF SUCH STUDY

The Earth's weather machine is an exquisitely complex affair, in which many processes are simultaneously at work. . Clearly however the weather system is principally driven by the sun (Roberts 1976).

Solar radiation is an unfailing source of energy for the Earth. Without visible and infrared (IR) radiation from the sun, Earth's surface temperature would be too cold to support life. Nor would there be energy to fuel photosynthesis or power the circulation of the lower atmosphere and oceans that profoundly influence living organisms. Lack in solar ultraviolet (UV) radiative inputs, Earth's middle atmosphere would be devoid of ozone and its upper atmosphere cold and unionized. Living things would be exposed to damaging high -energy solar photons. Society would lack the many benefits of Earth-orbiting space craft and global communication (Lean 1997).

All of those solar radiative outputs in addition to the corpuscular radiation are Wolf- Gleissberg cycle dependant variables.

For these reasons monitoring ,understanding and predicting the sun's radiation variability and its terrestrial impacts is a component of the US Global change research program, the National space weather program, NASA's Mission to Planet Earth, Space Environment Effects and Sun-Earth Connections Programs and one of the five key current topics in space physics research (Lean 1997). The subject of sun- earth connection has great impact on world economy and military effects and have entered the American Congress (Wentzel 1994).

Climatic fluctuations ,which are related to the Wolf-Gleissberg cycles, are very crucial to life on earth. In the 1970s, the CIA encouraged research in this field because of its implication on food production and political instabilities. It was found that optimum climatic conditions between 1930-60 was ideal for green revolution in world food production and that there is a likelihood to return to the 19th century climate characterized by marked drop in global temperature and wide spread drought-flood hazards that led to many revolutions and political instabilities. It is estimated that a one degree drop in European temperature will lead to a drop of the number of people sustained by one hectare from three individuals to two and to the possibilities that one fifth of the world population will be subjected to hunger (extracted from Abu El Ezz (1980) short translation of CIA book " The weather Conspiracy : the coming of the new ice age:").

Since there are indications that changes in the solar energy output influence the Earth's climate ,on time scales ranging from the Wolf-Gleissberg cycle up to the Maunder type of climate anomalies, and since persistent variations in total solar irradiance over a century could have explained a wide range of climatic changes that occurred in the past (Pap and White 1994), therefore studying the effect of the Wolf-Gleissberg cycle on terrestrial phenomena can improve our understanding to sun-earth connections which can lead to long range forecast of various terrestrial responses and climatic fluctuations.

Since the first curiosity-driven discoveries of solar-terrestrial linkage, a more urgent imperative has emerged to quantify the relevance for earth of the Sun' variable radiation(Lean 2000 quoting the American National Research Council 1994).

3-SOLAR ACTIVITY CYCLES

According to Nesme-Ribes et al (1994) three types of solar cycles can be defined from the analysis of modern and historical cycles:

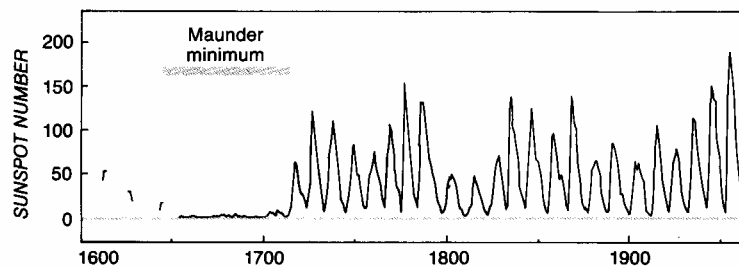


Fig 1: Time series of annual mean sunspot number (Noyes 1990). Note three types of Solar activity

1) *Normal solar cycles* in which

- * the length is approximately 10 to 11 years.
- * the sunspot number is large, and roughly symmetrical about the equator. A slight time asymmetry is observed, but this is essential due to the fact that each hemisphere is active at different times.
- * sunspot rotation is fairly rigid, especially near the sunspot maximum.
- * auroral activity is observed, due to the presence of flaring active regions and also due to the dipole field structure.

2) *GM cycles(Maunder minimum type)* in which

- * the length is approximately 9-10 years.
- * the sunspot number is small, largely asymmetric.
- * auroral activity is reduced

3) *Weak cycles*, in which

- * the length is possibly greater than 11-yr.
- * the sunspot number is small (compared with normal cycles), but shows little north-south asymmetry.
- *auroral activity is intermediate between that of the normal and GM cycles.

4-WOLF-GLEISSBERG SOLAR CYCLES

Naked eye sunspots were observed in antiquity. The Arabic astronomer Abu Alfadhl Giaafar followed a sunspot for 91 days in A.D. 807 (Hoyt and Schatten 1997).

When Rudolf Wolf reconstructed solar activity based on historical observations of sunspots, he found an 11-year cycle going back to at least 1700. In 1853 , Wolf also claimed that there is a 83-year sunspot cycle. This longer term variation becomes evident simply by smoothing the data. Wolf's original discovery of an 83-year cycle was forgotten, but the long cycle was rediscovered by H.H. Tuner , W. Schmidt, H.H. Clayton and probably others. After W. Gleissberg also discovered this 80 to 90 year cycle around 1938, he published so much material on the subject that ever since ,it was called Gleissberg cycle(Hoyt and Schatten 1997).

The only continuous solar observations that extend over the important climatic time scale of decades to centuries are those of sunspots, yielding a measure of magnetic activity (Reid 1995). There is evidence for a modulation of the amplitude of the 11 year solar cycle in a period of about 80 year. Although sunspot numbers may be traced back with confidence only about two and half centuries, auroral records have been used to trace the level of activity back more than 2 millennia. Other long periods that have been reported are 200,400 and 600 years (Howard 1977).

The Gleissberg cycle manifest itself in total activity, cycle lengths, sunspot structure and probably other parameters for which we do not have sufficiently long time series (Hoyt and Schatten 1997).

Eighteen years simple moving average smoothing of the mean annual sunspot numbers (R_z), including prediction, is shown in Fig 2a (revised from Yousef 1995). This figure shows three solar episodes superimposed on them, are the 11-year cycles. Downturn of solar episodes occurred during cycles 5 and 6 in the first minimum (the Dalton minimum) and 12 to 14 in the second minimum. Further 18 years filtering of the smoothed data almost annihilates the superimposed 11 years cycles and thus the solar Wolf-Gleissberg cycles stand up clearly in Fig 2b. The two minima occurred during the years (1810-1811) and 1901, with 90 years separating interval. Figure 2b is quite similar in part to the secularly smoothed values of auroras frequency numbers for each decade, (Gleissberg, 1971) and to the smoothed solar constant (Schatten, and Orosz 1990). From the above results, we must expect a third minimum early in the 21st century (Yousef 1995).

Table I reproduced from Yousef (1995) shows the characteristics of the last three Wolf-Gleissberg cycles as well as the coming one. It indicates that the maxima of the previous three cycles are double humped. The interval between the start of the minimum duration of the cycles 2 and 3 is 80 years. It is also important to note that the interval between the secondary maximum of cycle 1 and that of cycle 2 is 80 yr.

The 80 year periodicity is also found in Nile water (Yousef & El Rae 1995).

The duration between the start of minimums of cycles 3 and 4 is 120 yr. and the interval between the two maximums of cycles 2 and 3 is 119 years, while the duration between the secondary maximums of cycles 2 and 3 is 121 years. This explains the 121 year periodicity found in Equatorial Nile water for the period (1129-1351 AD).

Hoyt and Schatten (1997) reported 23 year cycle found by several authors in several parameters and 46-year cycle reported in climate. Those two cycles could be higher harmonics of the 80- to 90- year Gleissberg cycle.

TABLE 1
CHARACTERISTICS OF SOME RECENT SOLAR-WOLF-GLEISSBERG CYCLES
SHOWING THEIR TURNING POINTS

CYCLE	1	2	3	4
DURATION OF MIN		1797-1823	1877-1913	1997-2032
SMOOTHED MIN		1810-1811	1901	2009
SMOOTHED MAX	1727-28*	1838-1840	1957-1958	
SECONDARY MAX	1778-1780	1860	1981	
Allen 1973	1776	1854		

- First maximum of the cycle was added to the table after checking the list of Wolf sunspot number listed in Hoyt and Schatten (1997). It is lower than the secondary maximum contrary to the situation for cycles 2 and 3.

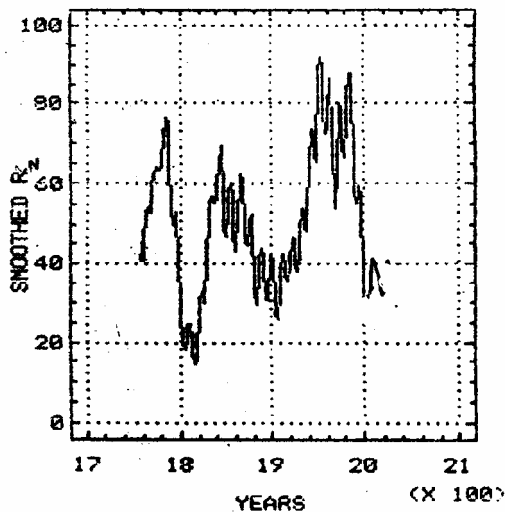


Fig 2 a: 18 years smoothed Wolf Sunspot Number showing the Wolf- Gleissberg cycles, superimposed on them are the sunspot cycles. Note the present downturn of solar activity.

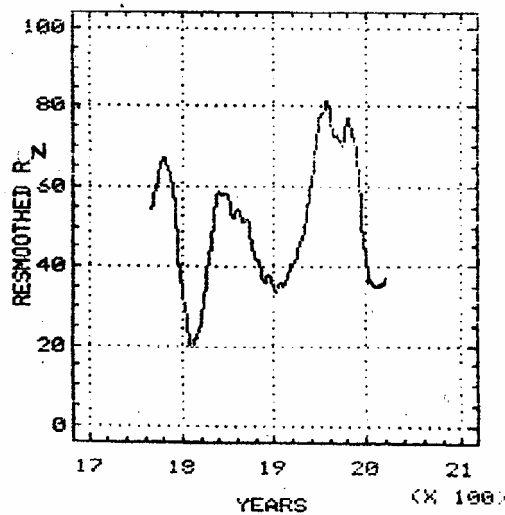


Fig 2b: Further 18 years smoothing of Fig 2a showing the Wolf-Gleissberg cycles.

5-EVIDENCES OF SOLAR WOLF-GLEISSBERG CYCLES IN SOLAR AND SOLAR INDUCED TERRESTRIAL RESPONSES

1- COHERENCE WITH THE PATTERN OF WOLF-GLEISSBERG CYCLES

a- Solar Irradiance, UV and IR

The first real breakthrough in solar total irradiance measurements came with the advent in radiometers on spacecraft launched in late 1978. Variation with the 11 year cycle in the case of cycles 21 and 22 is of the order 0.1 percent(Reid 2000 and references therein). Bigger change can be expected on a long term scale (Roederer 1995 and references therein).

The problem of solar irradiance long term variation has been discussed by several authors, e.g. White et al. (1997), Lean (1997,2000a) and Friis-Christensen et al.(2000).

Simulation of long-term irradiance variability consistent with trends inferred from Sun-like stars and cosmogenic isotopes requires the adoption of an index of long-term variability, IL

Model estimates of long-term variability in total solar irradiance and in the two spectral bands in the UV and IR produced in figure (3) adapted from Lean (2000 b) show Wolf- Gleissberg cycles inferred from sunspot cyclic variations.

When computing their solar- irradiance model , Hoyt and Shatten (1997) only used two parametrs

- (1) the amplitude of the solar cycle variation and
- (2) the amplitude of the Gleissberg cycle variation.

The first parameter based on the Nimbus-7 observations . The second parameter is chosen so that the Maunder Minimum will be about 0.25% less bright than the modern sun.

b- The Pattern of cosmogenic isotopes.

From the extant historical sunspot records, only three Wolf-Gleissberg cycles can be discerned. Recent techniques using cosmogenic isotopes have constructed solar activity on longer time scales. Two isotopes are commonly used --carbon-14 and Be-10, both produced by cosmic rays. Galactic cosmic rays are modulated by changes in the strength in interplanetary magnetic field arising from changes in solar activity. Hence measurements of the isotope concentration as a function of time provide proxy measures about the history of solar activity. Fig 4, show the resemblance of the Be-10 long term variation to the solar Wolf Gleissberg cycle.

C- The Pattern of Global temperature

The annual mean global air temperature track the sunspot cycle length as shown in fig 5 implying that the solar cycle length represents the climatic relevant part of the solar variation (Roederer1995). Those patterns are also Wolf-Gleissberg patterns.

The global average sea surface temperature (SST) shown in fig 6 (adapted from Roederer1995) and his reference also remarkably show the Wolf- Gleissberg pattern.

The global air and SST will be discussed further in due time.

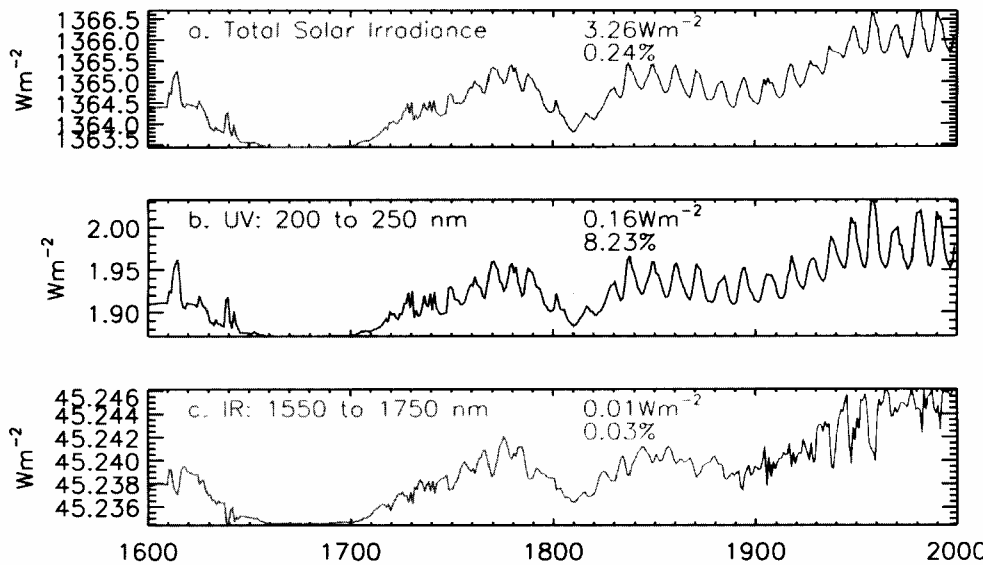


Fig 3 : Model estimate of long-term variability in total solar irradiance and in two spectral bands in the UV and IR showing the Wolf-Gleissberg cycles (after Lean 2000)

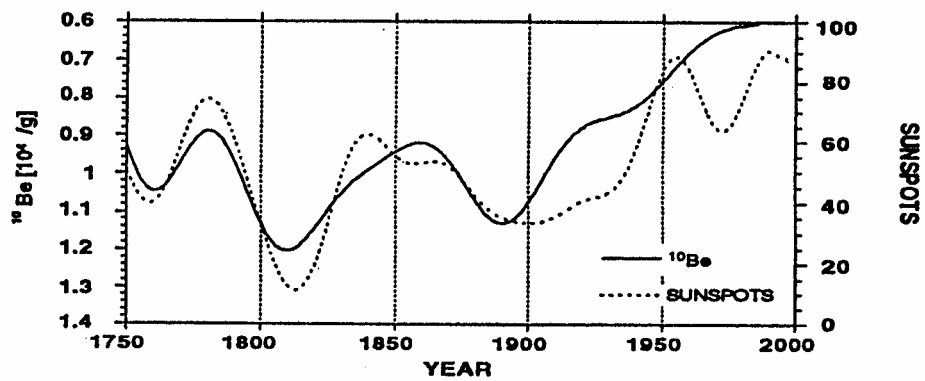


Fig 4: Coherence between long-term variation of Be isotope (solid curve) and Solar Wolf Gleissberg cycles (dotted curve) showing the Dalton minimum around 1800 and a lesser solar activity minimum around 1900 (after Hoyt and Schatten 1997 and his reference).

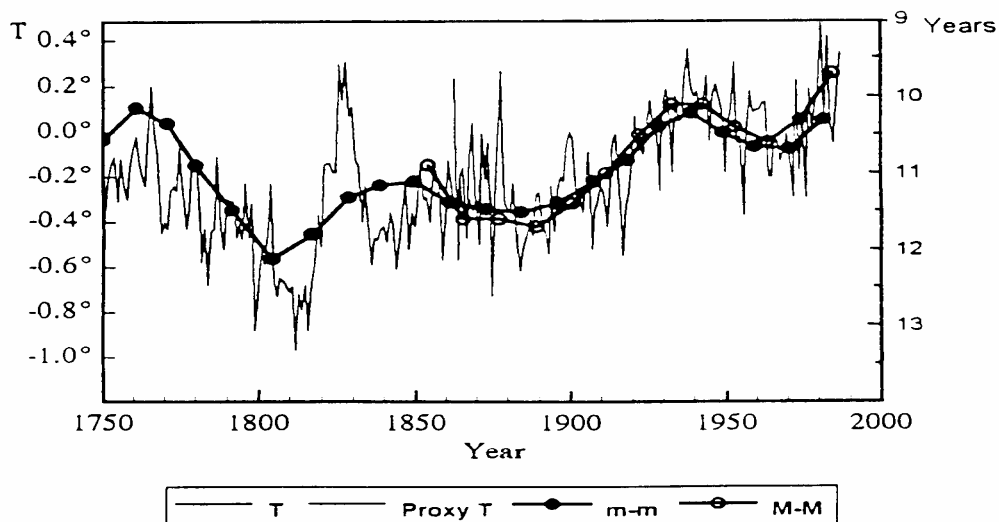


Fig 5 : Annual average of the northern hemisphere air temperature (thin curve) and appropriately filtered values of the sunspot cycle length (solid curve) determined independently by means of sunspot minima (m-m) and maxima (M-M), note reverse scale, all showing Wolf-Gleissberg cycles (adapted from Roederer 1995 and references therein).

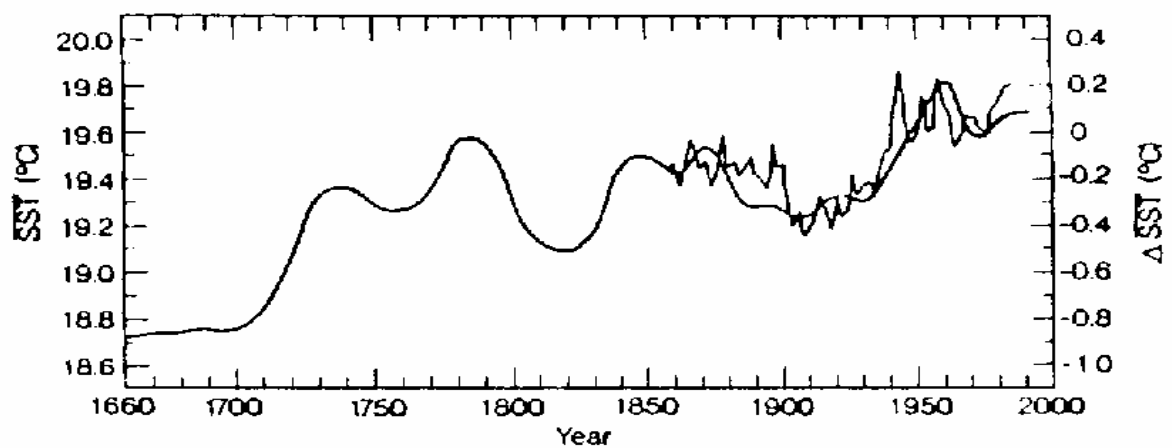


Fig 6: The sea surface pattern seem to resemble the Wolf - Gleissberg cycles with temperature drop during the time of intermediate weak solar cycles around 1800 and 1900. Similar drop occurred during the little ice age.

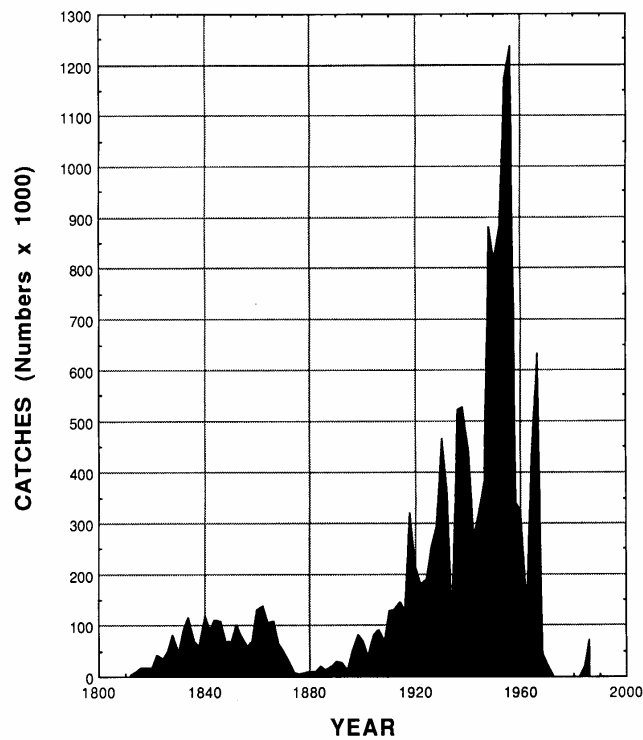


Fig 7: The Solar Wolf-Gleissberg cycle evident in the catches of winter herring off western Norway with the superimposed spikes resembling individual sunspot cycles. Note the peak coincidence with the maximum of the Wolf-Gleissberg cycle (1957-59), with climate fluctuation happening soon after. The herring normally inhabit waters with temperatures between 3 and 13°C, thus this fascinating diagram represents biological winter time series of the North sea temperature.

d-Biological Effects

Fisheries: The Atlanto -Scandian herring fishery

The Baltic and North Sea herring fisheries underwent sharp changes alternating with each other in a way that had obvious climatic significance (Lamb 1982).

The Atlanto-Scandian herring fishery began about one thousand years ago. Traditionally the main fishery of adult herring had been a winter fishery along the Norwegian west coast. Figure (7) shows the catches of winter herring off the western Norway. It is evident that the number of catches follow two Wolf- Gleissberg cycles closely.

The number of catches was very low around 1800 and 1900, i.e. during the weak solar intermediate cycles. The number of catches rose from several hundred metric tons in 1810 to 70,000 metric tons in 1830 and reaches a maximum of 100,000 metric tons during the 1860 secondary maximum of Wolf- Gleissberg cycle and then declined in 1870s. In 1880s and 1890s, the annual catches totaled only 13,000 metric tons. The number of catches rose again with the development of the following Wolf- Gleissberg cycle reaching a peak of 10 million metric tons in 1957 (maximum of Wolf- Gleissberg cycle) and then declined sharply to 3 million metric tons in 1963. The decline of herring fishery extended also to USSR and Iceland ending with the collapse of the Scandian herring stock. (Krovinn and Rodionov 1992).

During the 1960s, the intensification of fishing pressure coincided with pronounced change in the regional climate. Analysis of about a thousand years of herring fishery indicated that there had been analogous situations in the past, when fishery disappeared. Before its disappearance toward the end of the previous century, the fishery tended to shift northward. A similar situation was observed in the 1950s and 1960s.

Since the herring normally inhabit waters with temperatures between 3 and 13°C (Lamb 1982), then the Wolf-Gleissberg pattern evident in fig 7 actually is a biological temperature time series off western Norway. The increased abundance of herring should also reflect abundance of food necessary to sustain the fish. It is found that for example that the density of sea weeds off the shore of Scotland follow exactly sunspot cycles for the years 1946 to 1955 (Hoyt and Schatten 1997 and references therein).

No economical measures can be done to increase the declining herring catches in the area, but they have to wait for the start of the next Wolf-Gleissberg cycle possibly around 2020 or 2032.

6-WOLF-GLEISSBERG CYCLE PERIODICITY INDUCED IN SOME TERRESTRIAL RESPONSES

a- Cosmogenic Isotopes

By monitoring the variable production rate of cosmogenic isotopes such as ^{14}C in our atmosphere, a time history of solar changes can be obtained over a long period of time. Stuiver and Braziunas (1992), from power spectrum of 9600 yr long ^{14}C record reported periodicities at 88,85, 82,75,63 and 57 years.

b-Solar Signal In Ocean And In Mediterranean Sea Sediments

Analysis 1600 year record of sea sediment of carbonate mud core on the continental shelf in the gulf of Tarnato Italy suggests that the following periodicities are found in the Mediterranean sea sediment 43.6, 59.0, **82.6** and 137.7 yr in good agreement with radio carbon (138.9, **83.3**, 59.5 and 46.1 yr) This agreement seem to indicate that different terrestrial reservoirs resonate at the same frequencies and suggest common solar and or climate origins for the two records considered.

The analysis of a core from the Ionian Sea showed well defined regular oscillations corresponding to periods of 137,59, 12.1 and 10.8 years (Burroughs 1992). The 12.1 yr. periodicity represents that of weak intermediate weak cycles, while the 10.8 yr. period corresponds to ordinary sunspot cycles during the bulk of the Wolf-Gleissberg cycles. For comment on 137 and 59 yr periodicities consult section g on Nile water.

c-Glacial Varves

Cycles conspicuous in late Precambrian (from about 680 Myr) glacial varves in Australia reveal strong climatic periods of about 11,22,145 and 290 yr and a weaker period near **90** yr. The 11, 22 and 90 years cycles equate with sunspot periods and the longer cycles with solar and climatic periods as indicated by tree-ring studies (Williams 1981). The presence of such periods in rocks hundreds of millions of years old have important implications in solar physics and solar terrestrial relations.

d- Central England Temperature

A series of monthly temperatures for lowland central England is the longest in the World, extending back to 1659. Fig 8 is the power spectrum for the period 1700 to 1950 (Burroughs 1992 and references therein). A strong 76 yr. periodicity is evident in central England temperature.

e- Dendroclimatology

Dendroclimatology is the study of tree rings to obtain climatic information. Figure 9 shows the power spectra of a Lapland tree series for the period 1463 to 1960. The most marked periodicity during this period is of the order of Wolf-Gleissberg periodicity at 90 yr(Burroughs 1992 and references therein) .

f-Nile Water

The 80 year cycle is evident in historical Nile records(Yousef and El Rae 1995) which are ENSO related. Fig (10) shows cross correlation between Equatorial and Ethiopian Water for the period 622-1467 AD. with 300 years lag. The following remarks are deduced :

- a) The two variables are negatively correlated. At zero lag, the correlation coefficient is -0.8.
- b) It changes from negative to positive correlation gradually over a cycle of 131 years(average) reaching zero lag at about **80** years average delay.

i.e $131 \text{ yr} = 80 + 51 \text{ yr}$, both are strong periodicities in Nile water and the sun..

- c) A fundamental cycle of $266 \pm 1 \text{ yr}$ exists between two successive maximums.

The power spectra of Atlantic tropical cyclones (upper curve in Fig 11 cited in Hoyt and Scatten1997) Which shows strong 133 and 51.3 periodicity in agreement with the above mentioned relation. In addition ocean sediments show nearby periodicities(see table II) . It seems that the three periodicities 131-33, 80 and 51 yr are interrelated and that Nile water, Atlantic cyclones and ocean sediments are interrelated.

g-El Sahel droughts

Major Famines and droughts during the past 300 years have been correlated by Nicholson (cited in Faure and Gac 1981) who found they are repeated at intervals of **$72 \pm 16 \text{ yr}$** . This period is of the order of Wolf- Gleissberg cycle .

h-Cyclones

Hoyt and Schatten (1997) and references therein report fascinating follow of the number of Indian cyclones to the 11 year cycles for the period about 1845-1910 . By 1910 the positive solar activity correlation has become negative.

The Atlantic hurricanes frequencies are comparable to solar periodicities. The Number of Atlantic tropical cyclones show 51.3 and 133 yr. (Wolf- Gleissberg cyclicity = $133-51.3$) as shown in figure 11 .

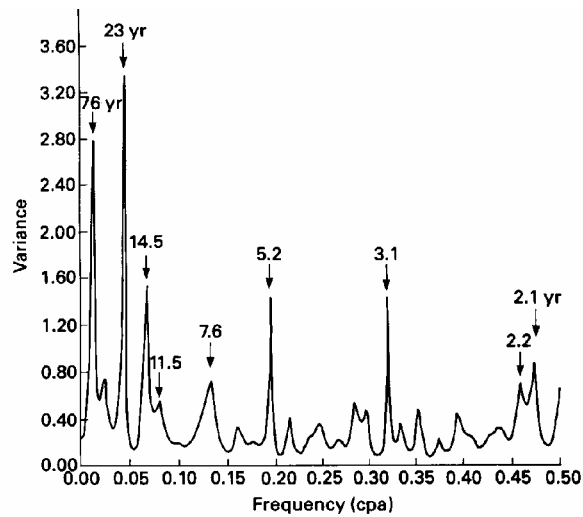


Fig 8 : The power spectrum of central England temperature record for the period 1700-1950 showing notable 76 year periodicity related to Wolf-Gleissberg cycle among other periodicities. (Figure extracted from Burroughs 1992 after Mason 1976)

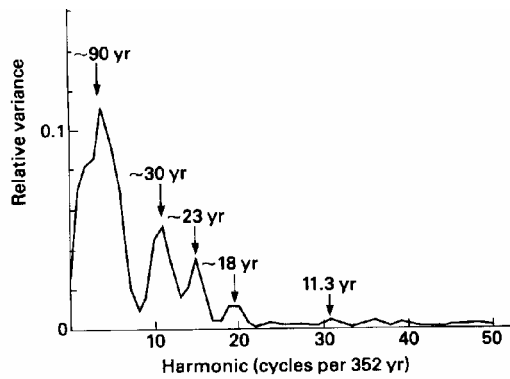


Fig 9 : The power spectrum of a Lapland tree-ring series for the period 1463 to 1960. This series , which is considered to provide an indication to temperatures during the high summer in northern Finland, shows the most marked periodicities at 90,30 and 23 years(From Lamb 1972 cited in Burroughs 1992)

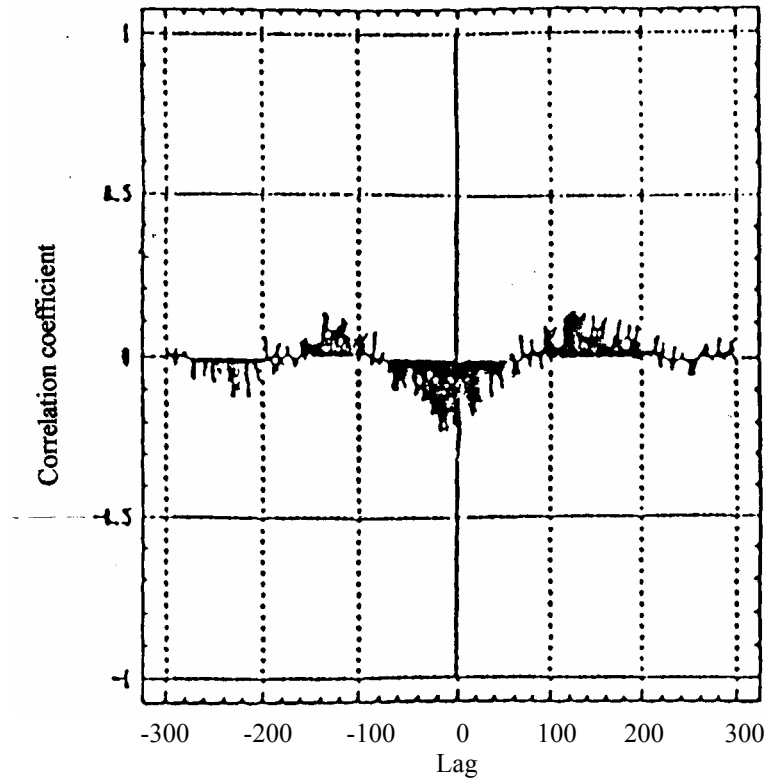


Fig 10: Cross correlation between the Equatorial and Ethiopian water during the period (622- 1467) with 300 years time lag (extracted from Yousef and El Rae 1994). Maximum correlation coefficient at zero lag is -0.8, The two variables are negatively correlated for a period of 80 years wolf-Gleissberg cycle, then they switch to positive correlation for the next 51 years making a 131(80+ 51) yr cyclicity. Note the corresponding periodicity in the next upper figure.

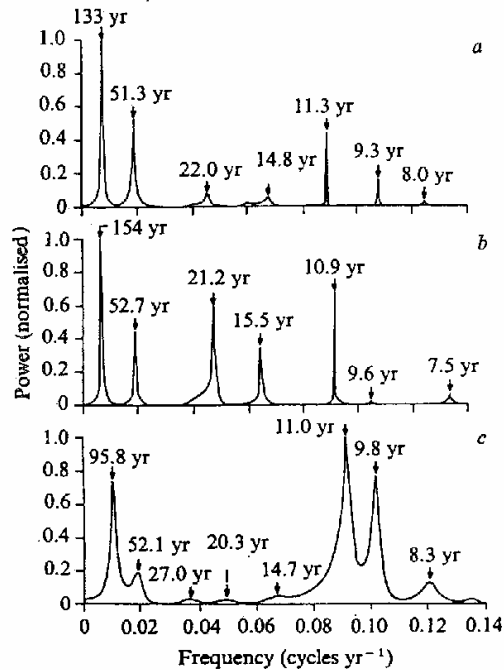


Fig 11 : The power spectra for a number of Atlantic tropical cyclones (upper curve), the length of the tropical cyclone season, and the Wolf-Sunspot Numbers (cited in Hoyt and Schatten 1997), suggesting that solar activity plays a role in the generation of Atlantic hurricanes.

Table II
Wolf-Gleissberg cycle forcing on different terrestrial responses

Terrestrial response	Duration yr	Ref
ENSO related time series		Michaelson (1989) cited in Arrigo and Jacoby (1991)
1000 yr precipitation in New Mexico 985-1970	80-100	Arrigo and Jacoby (1991)
Nile water Ethiopian 887-1128 AD, the strongest periodicity Ethiopian 1229-1467 AD Ethiopian +equatorial 622-1467 Ethiopia 622-1467 Equatorial 622-886 Equatorial 1229-1467 Max-Min 1738 -1914	80.6 80.6 79.8 88.7 88 121 80	Yousef, and El Raey (1995) Shaltoot and Tadros (1989)
El Sahel Major Famines and droughts during past 300 years .	72± 16 (56-88)	Nicholson (cited in Faure and Gac 1981)
Aurora 450-1450	88	Feynman and Fougere (1994)
Radiocarbon Go back 9600 1570BC-1830AD only evident at this period	85,67,143& 218 85 and 67 127	Burroughs (1992) and references therein
Geological Sediments Various	90&200	Burroughs (1992) and references therein.
Ocean sediments	59 138	Burroughs (1992) and references therein.
Atlantic Tropical Cyclones Number	51.3 133	Hoyt and Schatten (1997) and references therein
Glacial varves from ~680 Myr- Australia	90	Williams (1981)
Ice core Green land (Oxygen isotopes)	78& 181	Burroughs (1992) and references therein.

After compiling the above table , I came across a similar table compiled by Hoyt and Schatten (1997) which is reproduced here as Table III

Table III
Some meteorological and proxy time series showing cyclic variation close to the 80-90year Gleissberg cycle

<i>Parameter</i>	<i>Cycle length</i>	<i>Author(s)</i>
Temperature related		
Central England temperature	76 years	Burroughs, 1992
Interdiurnal temperature variability in Budapest	80 years	Berkes, 1955
Prague climate	89 years	Thraen, 1949
Winter severity (Europe)	83 years	Clough, 1933
Winter severity (Europe)	80 years	Maksimov, 1952
Icelandic ice concentration	80 years	Maksimov, 1952
Oxygen isotopes (Greenland)	78 years	Dansgaard et al., 1973
Deuterium isotopes (tree rings)	95 years	Libby, 1983
Precipitation related		
Beijing rainfall	84 years	Burroughs, 1992
Low stage of Nile	83 years	Clough, 1933
Nile floods	77 years	Hameed, 1984
Caspian Sea level	80 years	Maksimov, 1952
Midwestern U.S. droughts	90 years	Moseley, 1944
U.S. drought index from tree rings	90 years	Burroughs, 1992
Tree rings		
Lapland tree rings	90 years	Lamb, 1972
Sequoia growth per decade	83 years	Clough, 1933
California tree rings	80 years	Maksimov, 1952
Tree rings	90 years	Moseley, 1940

7-SOME ASPECTS OF CLIMATE FLUCTUATIONS

1-TEMPERATURE FLUCTUATIONS

a-Land- Air Temperature

Figure (12) Shows the drop of air -surface temperature for three sites in Great Britain. It is evident that temperature drop occur in between Wolf-Gleissberg cycles when intermediate weak small amplitude sunspot start to occur in 1878. The temperature drop indicate climate fluctuation marking the end of a Wolf-Gleissberg cycle. The sudden rise of temperature points to another climate fluctuation indicating the development of a new Wolf-Gleissberg cycle and end of small amplitude solar cycles.

Temperature appear to be out of phase with solar activity from 1880 to 1930 but in phase earlier than 1880 and later than 1930 in Great Britain (Hoyt and Schatten 1997). However, in the case of Lake Victoria, during those low amplitude cycles from 1902 to 1922, the lake level was in phase with solar activity with +.88 correlation coefficient (see fig 19).

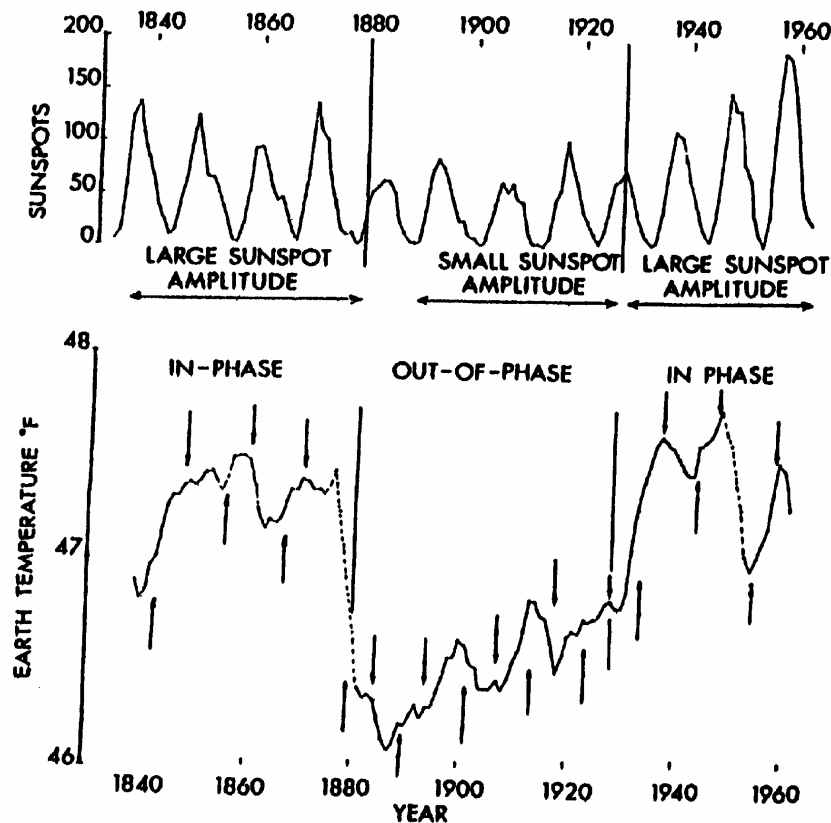


Fig 12 : Air surface temperatures from Edinburgh, Wakefield ,and Greenwich in Great Britain shown with Wolf sunspot Numbers. Temperature appear to be out of phase with solar activity from 1880 to 1930, but in phase for other years. (Adapted from Hoyt and Schatten 1997 and references therein)

b-Evidence from Sea Surface Temperature Variation

Figure 13, after Reid (2000) shows an example of the kind of correlative evidence used to support claims of the relationship between solar activity and global climate. In this case , the solar parameter is the 11- running mean of the annual sunspot number , and the departure of the globally averaged sea-surface temperature from the long-term average. Sea-surface temperatures (SSTs) have been measured on a routine basis by ocean going ships since the middle of the 19th century.

Figure 13 b shows the 11-year running mean SST data averaged over each of the three main ocean basins, and the overall similarity of the least square polynomials is a strong indication that the temperature variation is truly global in nature. The cooling around the turn of the century appears every

where , and is coincident with weak solar cycles, and is followed by a warming from 1920 through about 1950s(Reid 2000), i.e. warming goes with the development of the Wolf-Gleissberg cycle through its maximum as is evident from figure 13 a. These arguments compel us to consider a forcing mechanism in the sun itself , being the source of terrestrial climate change.

8-EL NIOS

Combining the estimates of El Nino frequency and sunspot numbers (relative numbers (showing the Wolf-Gleissberg cycles), Anderson (1990) cited in Sharp (1992) showed that the records for the last 300 or so years are strongly negatively correlated as seen in Fig (14) , from which he concludes that solar energy may modulate ENSO frequencies. My comment on this diagram is as follows:

- a) El Nino events were more frequent during the little ice age.
- b) Positive correlation between sunspot number and El Nino frequency occurred with the maximum of the first Wolf- Gleissberg cycle around 1780. Correlation reversal occurred with strong negative correlation around 1800 and 1900, i.e during the intermediate weak solar cycles. there is increased frequency of El Nino On the other hand, the sea surface temperature dropped considerably during the little ice age, the Dalton's minimum around 1800 and around 1900 (fig 13).
- c) Since El Ninos are hot water currents in the Pacific while La Ninas are colder ones, then we must conclude that strong La Nina events were also more frequent during times of reduced solar activity mentioned in d. Since both of those Nios cause drought-flood hazards in certain locations in opposition to each other, then the Maunder minimum and the periods of drop of solar activity in between Wolf-Gleissberg cycles are characterized by enhanced frequencies of El Nino and La Nina events leading to wide spread flood-drought hazards.

Since we have entered a similar weak solar cycles era, it is to be expected that both El Nino and La Ninas frequencies will be increasingly high . Owing to the presence of the 200 years solar and terrestrial periodicity, and from evidences accumulated during the past few years, it seems extremely likely that the terrestrial events that is and will be happening during the present drop of solar activity will be similar to those that occurred during the Dalton's minimum of 1800. As seen in fig 14 El Nino frequency will be increasingly high particularly till the mid of the weak cycles duration causing prolonged droughts in regions that are usually dry during El Nino e.g. Ethiopia and El Sahel zone and excessive rain in some other locations. During the second half of the weak solar cycles duration, it seems that La Ninas will be more frequent causing enhanced strong successive Nile flooding as was the case during the Dalton's minimum. Reverse situation was observed in Nile floods during the drop of activity around 1900, i.e the first half of the drop was characterized by high floods while the second half was dominated by low floods (Yousef 1996,1998).

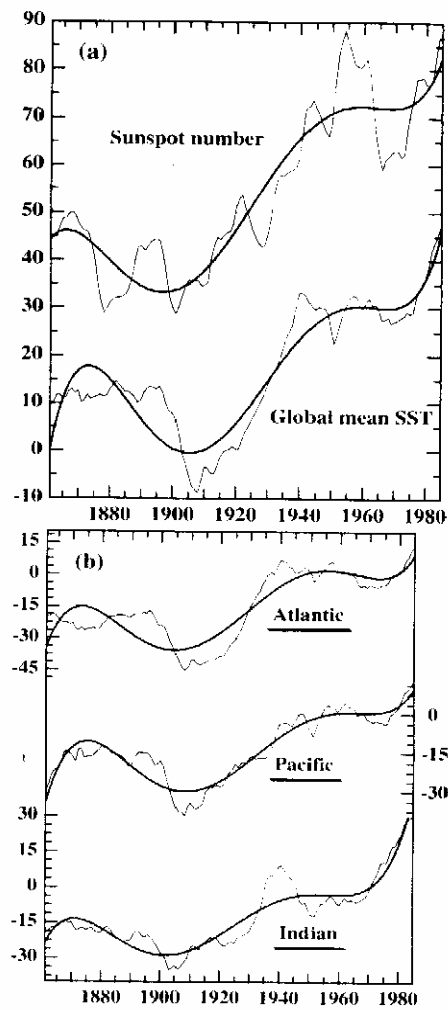


Fig 13: a) Eleven yr. running means of the annual sunspot number (i.e Wolf-Gleissberg cycle) and mean global mean sea surface temperature shown as departures from the 1951-80) average in units of 0.01k (lower light curve). Heavy curves are least squares 7th degree polynomial fits to the data.

b) Same as (a) for the three major basins (after Reid 2000).

Note the striking control of the solar Wolf- Gleissberg cycle on SST of major oceans as well as global mean SST.

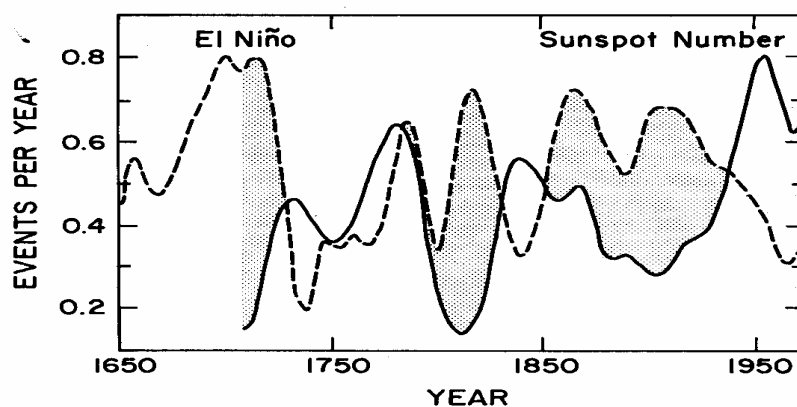


Fig 14 : The effect of Wolf- Gleissberg cycle (continuous line)on the modulation of El Nino frequency(broken line) for more than 300 years.

9-CROSS CORRELATION BETWEEN ENGLISH WELSH PRECIPITATION AND SUNSPOT NUMBER AND CORRELATION REVERSAL AT WOLF-GLEISSBERG CYCLES TURNING POINTS

Smoothed precipitation cycles for England and Wales are shown in Fig. 15. The time series has been divided at the 9 turning points leading to 10 files. Cross correlation between the smoothed annual precipitation and sunspot number has been carried out for each of the ten files and the results are shown in Fig. 16. Table IV gives the sign of the cross-correlation and the lag in years for each of the intervals studied (Yousef 2000b).

Table IV
Cross Correlation between Annual Precipitation in England-Wales and Sunspot Number for the Interval 1787-1970

TIME SPAN Yr		SIGN OF CROSS CORRELATION	LAG IN YEARS
1787-1796	10	- ve	Zero
1797-1805	9	+ ve	Zero
1806-1829	24	+ ve	-1
1830-1854*	25	- ve	+4-5
1855-1875	21	- ve	-1 to zero
1876-1896	21	+ ve	Zero
1897-1924	28	+ ve	Zero
1925-1944	20	- ve	Zero
1945-1958*	14	+ ve	Zero
1959-1970	11	- ve	Zero

Bold years coincide with the solar weak activity intervals in between Wolf-Gleissberg cycles.

- denotes maximum of Wolf-Gleissberg cycles.

It is obvious that the annual precipitation in England- Wales is highly correlated with the sunspot number during the period 1787-1970, yet the cross- correlation keeps on changing sign. The lag between the two variables is essentially zero, however during the period 1830-1854 (maximum of Wolf-Gleissberg cycle 1838-40), the lag was +4—5 years. This lag reduced the correlation coefficient to a rather low value.

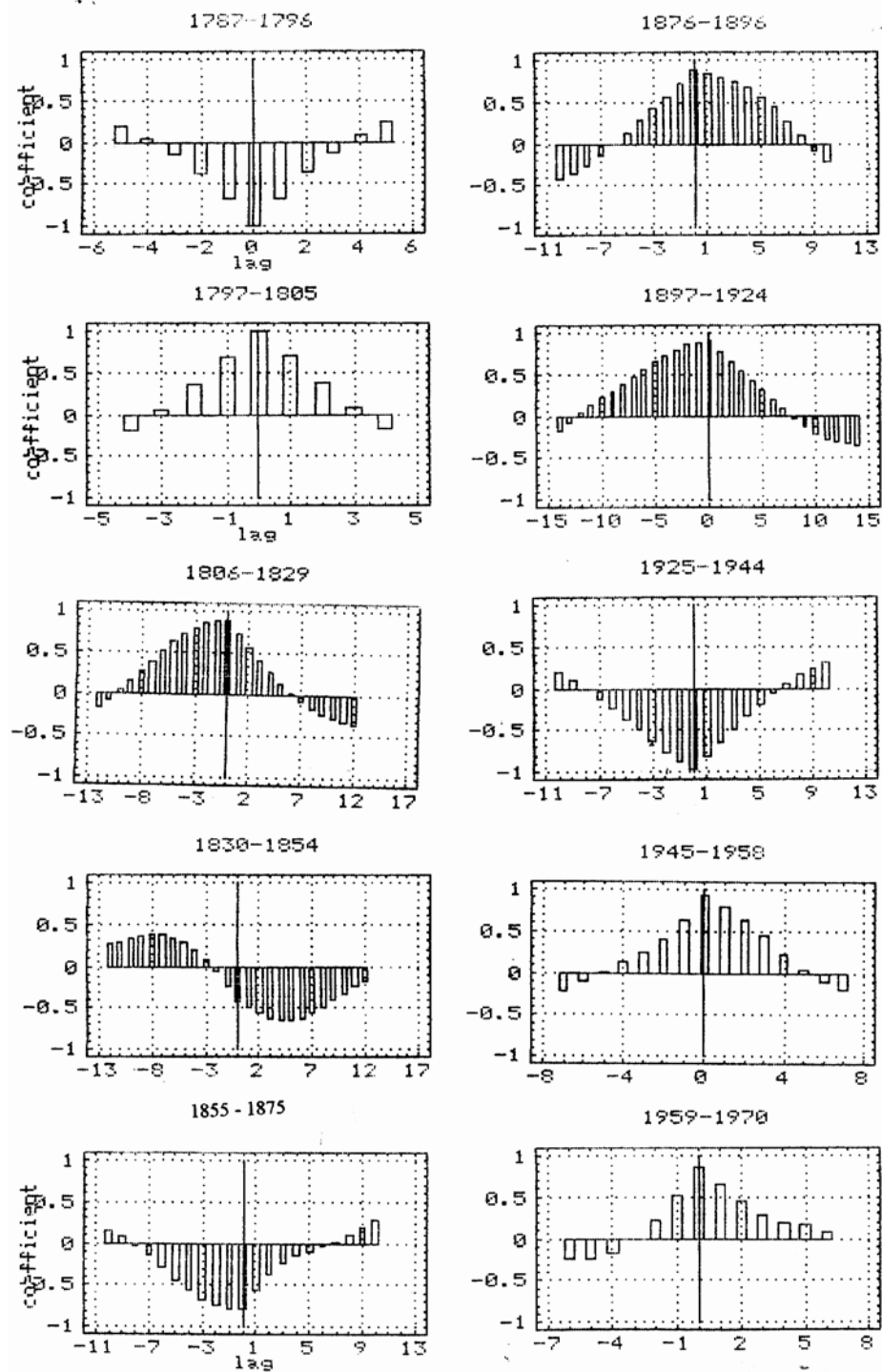


Fig 16: Cross correlation between sunspot number and precipitation in England -Wales for 10 successive time spans determined by the turning points in the corresponding smoothed precipitation cycle shown in fig 15. Note the alternate reversal of the sign of sun-precipitation strong correlation. Correlation reversals occur at the Wolf-Gleissberg turning points.

10-THE OCCURENCE OF CLIMATE FLUCTUATIONS AT THE TURNING POINTS OF WOLF -GLEISSBERG CYCLES

It is noticed that climatic fluctuations do occur at the dates of turning points shown in Table I and Fig 16. reproduced from Yousef (2000 a). Review of climatic fluctuations is given

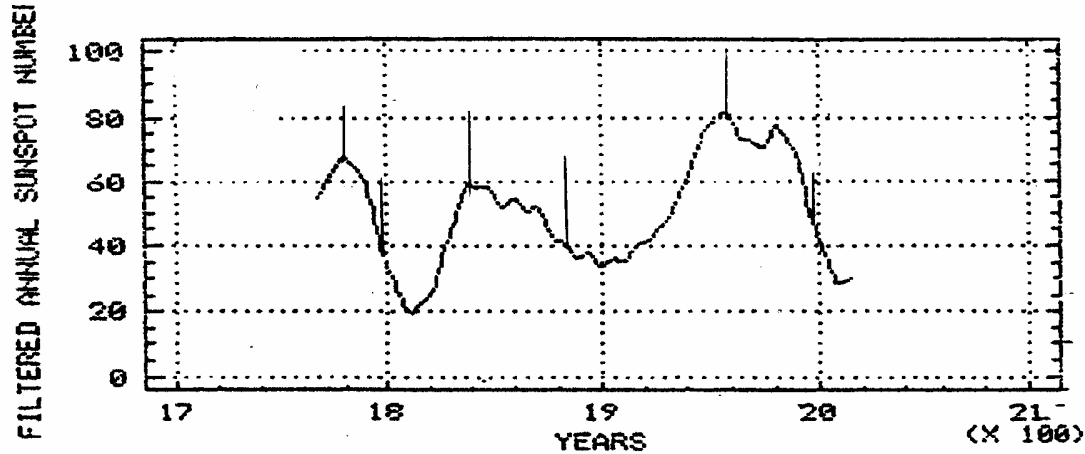


Fig 16: Re-smoothed sunspot numbers showing three Wolf- Gleissberg cycles. The vertical lines indicate the dates of turning points at which sudden rise (or fall) of Lakes occur indicating the onset of climate fluctuations. Note that climate fluctuation(change) occurred in the early sixties just following the maximum of the previous Wolf-Gleissberg-cycle, and consequently must have occurred at pervious maximums around 1780 and 1838-40. At the termination point of Wolf-Gleissberg cycle and the beginning of weak intermediate solar cycles in 1878, Lake Victoria rose sharply indicating the onset of climate fluctuations and the beginning of an era or severe El Ninos and La Ninas causing several decades of drought- flood hazards. Earlier climate fluctuation must have occurred around 1797. Recently, in 1997-98 another sharp rise of Lake Victoria occurred marking the end of the last Wolf-Gleissberg cycle and the start of solar cycle No 23 which has proved to be considerably weaker than its previous cycles. 1997-98 is the onset of climate fluctuation which would be similar to that of 1797. The coming era is believed to be a recurrent of the frequent natural hazards that happened around 1800. Other climate fluctuations occur at the build up of new Wolf-Gleissberg cycles e.g. as happened in 1922. Another similar climate change must have occurred at the end of Maunder minimum (1645-1715)- which coincided with the maximum of little ice age- and beginning of Wolf-Gleissberg cycles

1-Maximum OF WOLF-GLEISSBERG CYCLE

a-1838-40 Maximum

Correlation reversal in the July temperature in central England was reported by King et al. (1974) and King (1975) (cited in Herman and Goldberg 1985). In temperature data over the period 1750-1880, it was noted that the July values varied in phase with the double (22-yr) sunspot cycle up to about 1830, after which the decrease in temperature lagged the sunspot number decrease to such an extent that by 1840 (maximum of Wolf-Gleissberg cycle) it was out of phase by one half of an 11 year cycle. Cross-correlation between solar activity and precipitation for England-Wales shown in fig 15 and table IV show exactly similar results. By 1860 (secondary maximum of Wolf-Gleissberg cycle), the temperature was again in phase with the 22-yr cycle, but around 1880 (end of Wolf-Gleissberg cycle) the correlation broke down again. According to King (1975), the central England July temperature have exhibited an 11-yr periodicity since 1880.

b-1957 And Early 1960s

1-The rise or fall of Lakes levels (for details consult Yousef et al.2000, The Sharp Rise of Lake Victoria, a Positive Indicator to Solar Wolf- Gleissberg Cycles Turning Points, Paper 1, this volume

2-Termination of Wolf Gleissberg cycles and beginning of intermediate weak solar cycles

a-The 1878 Rise Of Lake Victoria (for details see Yousef et al. 2000 , this volume)

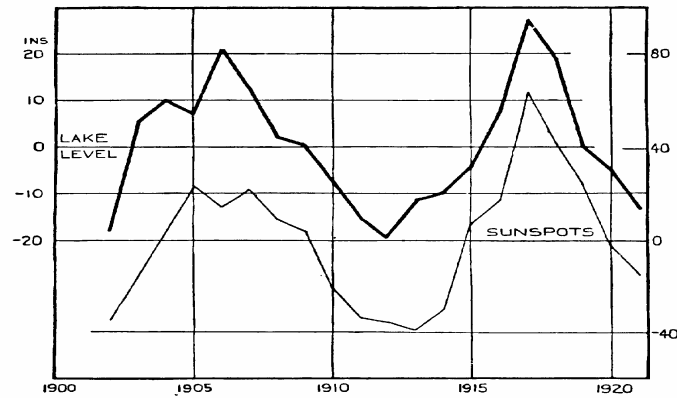


Fig 17: The cyclic rise and fall of Lake Victoria levels in response to solar forcing over two intermediate weak solar cycles (after Show 1933). The correlation coefficient is $+0.88$ (cited in Herman and Goldberg 1978). Note that similar cyclic pattern of Lake Victoria level (from 1890 to 1902, with maximum at 1895) preceded the two cycles shown here. In other words, the Lake level sympathized with all of the weak solar cycles Nos 13, 14 and 15. However, solar cycle No 12 which is the first of the intermediate weak series of cycles forced the Lake level to rise sharply in 1878-9 and then to fall between 1880 to 1890.

B-1878 drop of temperature

Five degrees drop of temperature for the small town of Soria in Spain (Donaire 2000) starting 1878 indicating climate fluctuation as seen in figure (18) in coincidence with the termination of Wolf-Gleissberg cycles and start of another type of low amplitude solar cycles. It is very important to note that there has been considerable warming prior to that drop.

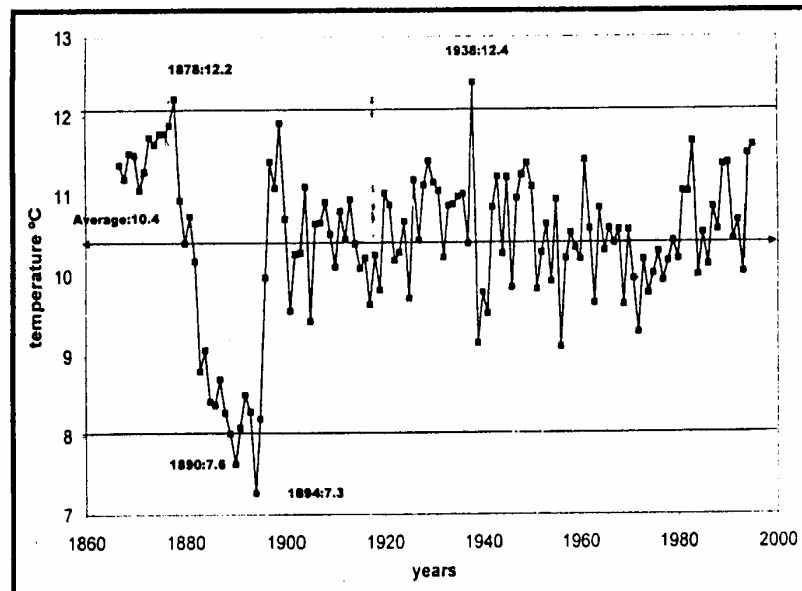


Fig 18: Temperature anomalies in Soria, a small town in Spain. Adapted from Donaire (2000). Notice the 1887 drop of temperature indicating climate fluctuation. Prior to this drop there has been more than a half a degree rise in temperature.

3-Start of New Wolf-Gleissberg cycles

1922 reversal with solar correlation

Herman and Goldberg (1978) and Hoyt and Schatten (1997) listed many events that showed sign reversals in many locations in the world and to all kinds of meteorological variables around 1922, including rainfall, lakes levels, Greek etesian winds, location of Icelandic lows and the number of Indian monsoons.

In a number of cases, it has been noted that correlations between meteorological parameters and sunspots have broken down or even reversed after the elapse of several solar cycles. . According to Herman and Goldberg (1978), it might be that the failures contain vital key to an identification to a real link. For the entire tropical zone, the correlation coefficient for annual temperature and sunspot number(11-yr cycle was -0.38 up to 1920, but for the period 1921-1950, the correlation coefficients had reversed and the coefficient was +0.23.

In the 50°-60° N band , rainfall was strongly negatively correlated with sunspot number with a coefficient of -0.67 in the years 1890-1913, and then the trend abruptly reversed. From 1914 to 1960 when the analysis ended, the correlation coefficient is 0.74(cited in Herman and Goldberg 1985 after Xanthakis(1973)).

Adams et al...(2001) and references therein, report that a warming of 4 deg.C per decade was observed in an ice core from northern Greenland for the 1920's , but this corresponded to a global shift of 0.5 deg.C or less. There is some evidence that this event may have been widespread.

In 1924 flash floods flooded the Holy Kaaba in response to the turning start point of the last Wolf-Gleissberg cycle as seen below

**Fig 19: El KAABA El MUSHARA 1924
embedded in flash floods**

11- 1997-98 CLIMATE FLUCTUATIONS IN RESPONSE TO TERMINATIONS OF WOLF-GLEISSBERG CYCLE AND START OF WEAK SOLAR CYCLES

The 1997 Sharp Rise of Lake Victoria

1997 was a unique year as the lake level dropped steadily from June to October to 11.32 m then rose abruptly up to 12.87 m in May 1998. Around this time was the end of the previous solar cycle and the beginning of a new one. 1997-1988 was also a strong El Nino year.

Comparison of the 1997-98 sharp rise with sunspot number for the present solar cycle and solar irradiance indicates that the sharp rise of Lake Victoria is coincident with the start of new weak sunspot cycle with some delay. Solar irradiance increase of about 0.11% in the above period is well associated with an increase of about 1.6 meters in Lake level . The mechanism of this relationship is not currently well defined (Yousef et al. 2000 , this volume).

This sudden rise must have been similar to the rise which was reported earlier at 1877-78 at the end of a Wolf-Gleissberg cycle. 1997-98 marked the end of the last Wolf-Gleissberg cycle which started in 1913.

12-Discussion

It was found that climate fluctuations occur in response to turning points on Wolf-Gleissberg cycles. Lets look closer at the different types of solar cycles .

Figure (20) after Hoyt (1990) cited in Hoyt and Schatten (1997) shows the solar equatorial rotation rate in degrees per day plotted for the last century. It is shown that the equatorial solar rotation was high in the late 1800s (i.e. in the case of weak intermediate solar cycle , type) , and decreased to a minimum in the second quarter, i.e. around 1922-24 when reversal of solar-climate correlation occurred. During the maximum phase of Wolf-Gleissberg cycle , the rotation rate increased again coinciding with the late 1950s 1960s climate fluctuation. Cycle 23 is a weak cycle that marked the end of the Wolf-Gleissberg

cycle, thus it is expected that faster equatorial (and possibly at higher latitudes) daily rotation rates would result. Hoyt and others are invited to update their earlier work in order to verify this conclusion. Hoyt and Schatten (1997) argue that any change in solar rotation rate is a very persuasive

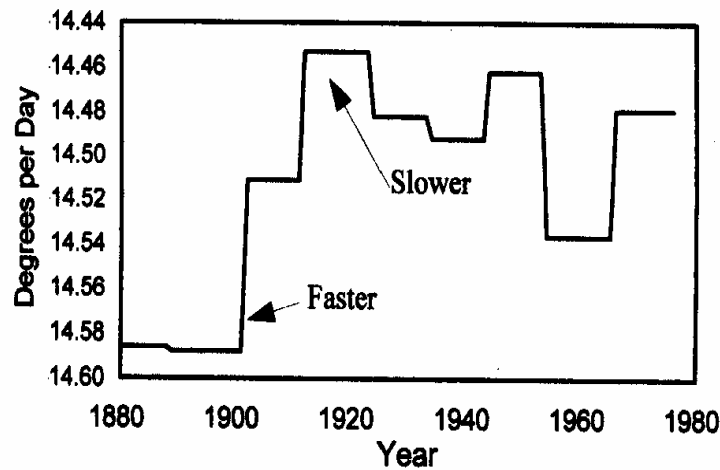


Fig 20: The solar equatorial rotation rate in degrees per day for the last century.

indicator that the deeper levels of convection are varying, and hence there is a corresponding variation in solar luminosity and irradiance. Slowing equatorial rotation is expected for a brighter sun.

Another line of thought is related to the variation in solar cycle length which is in excellent coherence with the Northern Hemisphere temperature anomalies after (Hoyt and Schatten 1997). Again the intermediate weak solar cycles in the late 1800s are longer in length than those during the Wolf-Gleissberg cycles. Around the Maximum of this cycle in the late 1950s-early sixties an increase in cycle length occurred coincident with climate fluctuation..

Again an increase in solar cycle length is to be expected for the weak solar cycle number 23 , perhaps similar to those of cycles 5 and 6 around 1800s.

13-CONCLUSION

Evidences indicating that important climatic features, such as droughts and unusually growing seasons, are dependent on the solar cycle to such an extent that significant progress could be made in forecasting the occurrence of such features if some account were taken of the expected levels of solar activity in the future (King 1973).

When thinking about climate change on time scale of decades to centuries, it is important to recognize the dominant effect of the oceans, which cover over 70% of the planet's surface , and are largely responsible for the transport of heat from low to middle and high latitudes, particularly during the winter season. For a mechanism to be viable as Sun-climate link, it should be capable of explaining the SST variation of the kind illustrated in Fig 13 , occurring with the same magnitude and direction in all of the Earth's ocean basins.

In a press release (2000) on " The sun's influence is an important factor in global climate change "drawn by scientists from around the world in July 1999 in Bern; realizing that the variability of the solar radiation is an important factor affecting the climate of the earth. Several proposed mechanisms have been discussed extensively:

- Total irradiance; larger irradiance changes are expected on time scales larger than 11 years cycle.
- Solar magnetic fields: During periods of high solar activity, the increased solar magnetic fields enhances the shielding of cosmic rays. It is postulated , based on empirical correlations, that less cosmic rays reduce the global cloud cover and therefore increases the temperature.
- UV flux: The changes in UV flux are much higher (more than 10 times) than the changes of the total solar irradiance in the upper atmosphere. Both absorption and enhanced

production of ozone lead to a temperature change of the stratosphere and therefore also to its dynamics. The coupling to the stratosphere and troposphere dynamics could lead to changes in tropospheric wind regimes and thus lead to temperature changes at the Earth's temperature .

Since the solar magnetic fields, solar cosmic rays UV , x-rays and definitely solar irradiance all show Wolf- Gleissberg cycles, then all of these solar parameters work collectively ,each in a different part and heights of the earth's atmosphere with the net result of solar forcing inducing variable long term terrestrial responses of the order of the Wolf-Gleissberg cycles.

One positive conclusion of this review is discovering that climate fluctuations manifested by sharp rises or falls of lakes or closed sea levels, reversals of the sign of solar terrestrial responses, sharp anomalies of temperature, whether on air or sea surface temperatures, droughts and flood hazards, changes in the general wind circulation etc do coincide with the turning points of Wolf- Gleissberg cycles . Those long-term solar cycles can be described by polynomials of the tenth order(Yousef 1998).

From the solar physics point of view, what happens at those turning points? The answer is related to the acceleration or retardation in the daily rotation rates of the solar photosphere during the time of the turning points, start, maximum and termination. Variation in a solar rotation rate may be indicators of changes in solar luminosity due to the coupling between convection and rotation (Hoyt and Schatten 1997). Acceleration of the rotation rate occur during the intermediate interval in between successive Wolf-Gleissberg cycles occupied by low amplitude long duration solar cycles. Some how, this acceleration lead to drop in solar irradiance. One point of argument ,is that cyclic solar forcing to terrestrial precipitation particularly near the equator do occur with the second and the following weak solar cycles which persist till sharp retardation of the photospheric rotation rates occur leading to another climate fluctuation indicated by reversal or cease of correlation . At the maximum of the Solar Wolf- Gleissberg cycle, acceleration of the photosphere do occur. Thus it seems very important that the acceleration or deceleration of the convection zone plays a major role in modulating the magnetic activity of the sun. It is logical to assume that similar acceleration and deceleration extend to the other layers of the solar atmosphere, e.g. modulating the magnetic energy and the temperature in the corona resulting in X ray and UV following the same pattern of the Wolf-Gleissberg cycles.

Solar terrestrial stimuli is very important in weather and climate forecasting. It may well be , in another decade or so that extended forecasting will be unthinkable without consideration of solar activity(Roberts 1976).

It seems that the time has come for this extending forecast based on prediction of solar activity. Yousef(1995a) predicted a low amplitude level of cycle 23 and the following cycles This will lead to drops in solar irradiance, UV, X-ray, Solar cosmic rays, weakening of interplanetary magnetic fields etc similar to the Dalton's drop of solar activity around 1800 and the following drop around 1900 AD. . As a consequence, global temperature drop during the next few decades are to be expected. Indeed , a climate fluctuation did occur in 1997 as manifested by the sudden rise of lake Victoria

. It is forecasted that by the decline of cycle 23 , reduction of precipitation will result in African Equatorial region with a considerable drop in the Lakes levels , while a considerable rise in precipitation will occur in the middle east ending the drought conditions that prevailed for several years in the area. Thus it is expected that considerable rise in the dead sea level is to be expected. There is thus no need to join the dead sea with the Mediterranean sea according to the Israeli plan or to the Red sea according to the Jordanian plan. In the case of the American Great lakes which at present induce considerable concern about its falling down, it is anticipated that drought condition will continue till the end of solar cycle 23 around 2009.

Since El Nino frequency is solar Wolf-Gleissberg cycle modulated ,and since on one hand during weak cycles ,enhancement of El Nino frequency do ,while on the other hand., sea surface temperature drop, then we must postulate increment is La Ninas strength and frequency in order to compensate El Nino heating effects. Since both the pair of the Nios cause drought-flood hazards, then worldwide drought-flood hazards are to be expected.

Due to the 200 years solar and terrestrial cyclicity, then the present drop of activity will induce El Nino- frequencies similar to those around 1800. In that case , from fig 14, the frequency of El Nino will be increasing during the first half of the weak solar cycles duration causing frequent low Nile floods and Sahelian droughts, while during the second half of the period , La Nina events will be more frequent causing more destructive Nile floods as was the case for Nile floods around the 1800 AD drop of solar activity. Alert is renewed to the Egyptian governments and other Sahelian governments and God knows best.

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