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Solar Variation and Climate Change - in reference to Indian Rainfall Pattern

Review Article

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Abstract: Life on the Earth depends on energy received from the sun. Any factor that alters the radiation received from the sun or lost to space will affect climate. The Earth's climate has always being changing. This is documented in historical as well as geological records. There is some indication that solar cycles have an effect on climate. The cloud formation may be influenced by galacitc cosmic rays through ionization change that cause microphysical changes in the atmosphere, affected the growth and nucleation of ice particles. the local decrease in the amount of cloud cover related to short term changes in the cosmic rays due to increased solar activity. Through this paper, we carried out a comprehensive analysis on solar variation and its impact on earth climate from last century. We also analysis the impact of solar variation on Indian Monsoon patter and concluded that Solar variation has directly impact on earth climate as well as causes of flood and drought in India.

Keywords: Solar irradiance, Climate Change, Sunspots, Sunspot cycle, Total Solar Irradiance, rainfall pattern.

1. Introduction

The Sun is the source of the energy that causes the motion of the atmosphere and hydrosphere thereby controls weather and climate. Any change in the energy from the Sun received at the Earths surface will therefore affect climate. During stable conditions there has to be a balance between the energy received from the Sun and the energy that the Earth radiates back into Space. This energy is mainly radiated in the form of long wave radiation corresponding to the mean temperature of the Earth. From historical and geological records we know that the Earths climate has always been changing. Since it is the Sun's energy that drives the weather system, scientists naturally wondered whether they might connect climate changes with solar variations (fig 1 & 2).

The sunspots were observed in the far East over 2000 years, but examined more intensely in Europe after the invention of telescopes in the 17th century. In 1647 Johannes Hevelius in Danzig made drawings of the movements of sunspots eastwards and gradually towards the solar equator. In 1801 William Herschel attempted to correlate the annual number of sunspots[2]. The 11-year cycle of the number of sunspots was first demonstrated by Heinrich Schwabe[3] in 1843.

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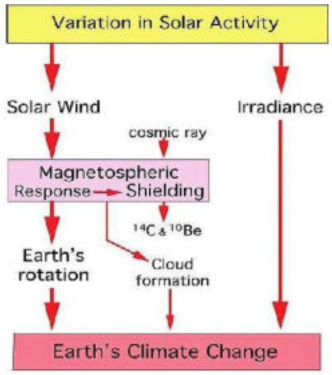

Figure 1. Effect of Solar variation on Earths Climate [1]

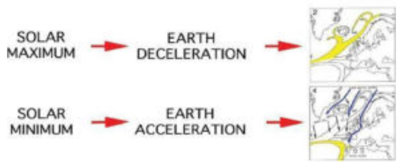

Figure 2. Relations among solar cycles. Earths rate of rotation and the observed changes in the ocean circulation in the North Atlantic [1]

Eddy[4] (1976) provided the first thorough study of long-term (century scale) variations in solar activity and climate. This study indicated a very strong link which he hypothesized and accounted for by small changes in the solar total irradiance. Subsequently studies of palaeoclimate and historical solar activity inferred by its modulation of 14C in tree rings and 10Be in ice cores provided evidence that long-term minima in solar activity seems to be associated with climate on Earth that is colder than average. Accordingly, Hingane et al[5], 1985; Ramanathan et al. [6], 2001; Reddy MS & Venkatraman C[7], 2002; Rastogi N & Sarin MM[8], 2005; Lau KM & Kim KM[9], 2006; Tinsley AB & Fangqun Yu[10], 2007; Sajani et al[11], 2012; Sarkar B[12], 2013; Davies et al[13], 2013 etc had studied the effect of solar variation on Atmospheric ionization & clouds, Asian rainfall pattern.

Sunspots are actually a side effect of the suns magnetic field during solar flares can get caught in the earth's magnetic field, display the Northern Lights in polar regions. The average sunspots have a diameter of about 37,000 km and appear as dark spots within the photosphere, the outermost layer of the Sun. The photosphere is about 400 km deep, and provides most of our solar radiation. The layer is about 6,000 degrees Kelvin at the inner boundary and 4,200 K on the outside. The temperature within sunspots is about 4,600 K. The number of sunspots peaks every 11.1 years[14].

The idea of a relationship between long-term changes in solar activity and climate published and re-examined[4],[15] the record of the globally averaged Sea Surface Temperature (SST) and noticed a striking similarity between this and the long-term variation of solar activity represented by the 11 year running mean Zrich sunspot number (fig. 3). Among the particular features he pointed out, was the prominent minimum in the early decades of this century, the steep rise to a maximum in the 1950s, a brief drop during the 1960s and early 1970s followed by a final rise. Based on the model calculations Reid suggested that the solar irradiance may have varied by approximately 0.6% from 1910 to 1960 in phase with the 80-90 year cycle (the Gleissberg period) of solar activity represented by the envelope of the 11 year solar activity cycle. This interpretation tells that the SST was highly influenced by the thermal inertia of the oceans which may imply a considerable delay in the temperature response. The case was demonstrated that the smoothed land surface temperature of the Northern Hemisphere preceded by both the smoothed sunspot number and the smoothed SST curve by nearly twenty years[16].

Satellite measurements pinned down precisely how solar brightness varied with the number of sunspots. Over a sunspot cycle the energy radiated varied by barely one part in a thousand; measuring such tiny wiggles was a triumph of instrumentation[18]. Single decade of data was too short to support any definite conclusions about long-term climate change, but it was hard to see how such a slight variation could matter much[19]. Since the 1970s, rough calculations on general grounds had indicated that it should take a bigger variation, perhaps half a percent, to make a serious direct impact on global temperature.

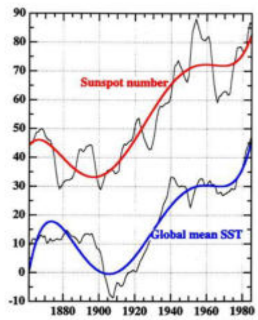

Figure 3. **Relationship between Sunspot and Global mean sea surface temperature[17].**

2. Objective and Methodology

2.1. Objective

Variation of sun light and radiation is the base of classification of climatic zones, rainfall and ecosystems. As sun always changes its radiation may affect earth and its climate. To find out the effect of sun variation on earth following objective has been chosen:

(i) Discuss the solar variation and its effect on Earths climate.

(ii) Variation of Climate in last century.

(iii) Effect of Sun spot on India rainfall pattern.

2.2. Methodology

To best understand the effect of sun variation on earth's climate, first we discuss types of solar activities and its affect on earth, measurement of sun variation in present and past time (before satellite era) and reconstruction of past solar variation. Effect of sun spot on Indian rainfall pattern we have taken rainfall data from year 1901 to 2003 and show the rainfall below normal (drought condition) or above normal (flood condition). On the basis of above study, we could find out the best inferences.

3. Types of Solar activities and its affect on earth

3.1. Types of Solar activities

The sun is always be an active source of energy. It has its own weather and storms, its storms can affect Earths weather. The sunspots, solar flares, coronal mass ejections (CMEs), solar wind storm are the main solar activities happens in Sun. The sunspots are magnetic storms on the surface of the sun. Solar flares are intense blooms of radiations that come from the release of the magnetic energy associated with sunspots. Coronal mass ejections (CMEs) are burst of solar material (clouds of plasma and magnetic fields) that shoot off the suns surface. The other solar events include solar wind streams that come from the coronal holes on the sun and solar energetic particles that are primarily released by CMEs.

3.2. Affects of Solar activities on Earth

The solar activities affect the earth in many ways, in following manner:

(i) Damage to human satellites and other high tech systems in space caused by an active Sun which generates geomagnetic storms.

(ii) Radiation hazards for astronauts and satellites caused by a quiet sun. The weak solar wind allows more galactic cosmic rays into the inner solar system.

(iii) Weather on earth can also be affected.

(iv) Global climate change including long term periods of global cooling, rainfall, drought and other weather shifts may also be influenced by solar cycle activity documented in historical records and scientific investigations.

4. Measurement of Solar Variation

The idea that the sunspots may affect the weather or climate here on Earth had been nurtured for several centuries. Galileo has been given the credit for establishing the existence of sunspots after the invention of the telescope in 1611. The hypothesis of links between sunspots (solar activity) and temperature, pressure and rainfall on Earth were popular during the 19th century and a number of claims were made, based on empirical and statistical studies. None of these, however, have withstood with the test of time. The support for sunspots and weather/climate waned after the 1950s, probably as a result in meteorological advances through the frontal theory and numerical modeling.

There is no single instrument measuring climate change. Instead there are thousands of measuring devices spread across the globe, on land, under the sea and in the air. The climates of remote epochs had been obtained by the analysis of natural conditions in the past[20]. Some of these natural conditions examined are sediment formation, rock weathering, formation of water reservoirs, the existence of living organisms, ocean sediments, analysis of ice cores, tree rings, lake sediments and glaciers. These natural conditions depend upon atmospheric factors and are appropriate for researching the our past climate.

The palaeographic data and information on paleotemparatures obtained by isotropic analysis of organic remains appears to be very helpful in the study of ancient climates.

The direct measurements of Total Solar Irradiance (TSI) are only available over the past two decades it is necessary to use other proxy measures of solar output to deduce variations at earlier dates. The simplest form of reconstruction of a proxy measure, such as sunspot number[21] or solar diameter[22], was calibrated against recent TSI measurements and extrapolated backwards using a linear relationship. The various proxies vary marked as indicators of solar activity (fig 4). The other terrestrially based indicators of solar activity recorded by cosmogenic isotopes in tree-rings and ice-cores also show longer term modulations. The 14C/12C ratio was high when sunspot number was low and an active sun results in a strong solar wind; deflects cosmic rays and decrease 14C production: positive 14C anomaly= cold climate[23].

The evidences were suggesting that the Sun truly change at least superficially from one century to another. Already in 1961 Stuiver M[24], was concerned about peculiar variations in the amount of radioactive carbon-14 found in ancient tree rings. The Carbon-14 is generated when cosmic rays from the far reaches of the universe strike the atmosphere. Stuiver noted how changes in the magnetic field of the Sun would change the flux of cosmic rays reaching the Earth[24] . Suess (1968) [25] noticed that the same centuries showed a low count of sunspots, fewer sunspots apparently made for colder winters. The yearly global average temperature is subjected to variations without any immediate cause in terms of a change in the radiative forcing because the existence of internal oscillations in the atmosphere and the complex coupling to the oceans. Similarly, Solar activity cannot be characterized by a simple number, up till now we have not identified the exact physical mechanism that is involved. Satellite observations indicate that during 11 year cycle sunspot minimum, solar irradiance is lower (0.1%), interplanetary magnetic field is also weaker[23], [26], [27].

5. Reconstructions of past variations of total solar irradiance

The fundamental approach recognizes that solar radiative output is determined by a balance between increases due to the development of faculae and decreases due to the presence of sunspots. The Long-term changes are also speculated to be occurring in the quiet Sun against which these variable when active regions are set. The sunspot darkening depends on the area of the solar disc covered by the sunspots while the facular brightening has been related to a variety of indices. These include sunspot number[28] emission of singly ionised calcium (Ca II at 393.4 nm) [29], solar cycle length, solar cycle decay rate, solar rotation rate and various empirical combinations of all of these[19], [30].

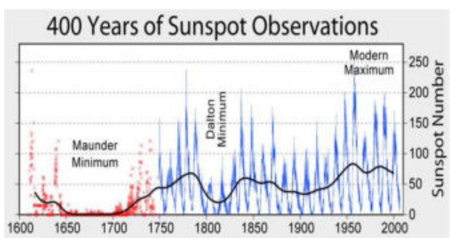

Figure 4. **The yearly averaged sunspot number for a period of 400 years (1610-2010) [31].**

In addition to estimates the impact of active regions on TSI potential contributions due to the variation in brightness of the quiet Sun have been estimated[29], [32]. These were largely based on observations of the behaviour of Sun-like stars[33] and the assumption was that during the Maunder Minimum (an extended period during the late 17th century during which no sunspots were observed) the Sun was in a non-cycling state. The various reconstructions vary widely in the values deduced for TSI during the Maunder Minimum relative to the present.

Mendoza[34] (1997) has pointed out that uncertainties in the assumptions made about the state of the Sun during that period could imply a range between 1 and 15 Wm-2 reduction in TSI less than present mean values although the estimates lie in the range of 3 to 5.5 Wm-2. The figure 5 shows group sunspot numbers from 1610 to 1996[35] together with five TSI reconstructions. The sunspot numbers (grey curve, scaled to correspond to Nimbus-7 TSI observations for 1979 to 1993) show little long-term trend. Lean et al. [28] (1995, solid red curve) determine long-term variability from sunspot cycle amplitude; Hoyt and Schatten[19] (1993, black solid curve) use mainly the length of the sunspot cycle; the Solanki and Fligge[30] (1998) blue curves (dotted) are similar in derivation to the Lean et al. and Hoyt and Schatten methods. The Lockwood and Stamper[36] (1999, heavy dash-dot green curve) use an entirely different approach, based not on sunspot numbers but on the geomagnetic index, and predicted somewhat larger variation over individual cycles but less on the longer term change Clearly, even disregarding the shifts due to absolute scaling, there are large differences between the TSI reconstructions. Thus the knowledge of solar radiative forcing is uncertain, even over the 20th century and certainly over longer periods

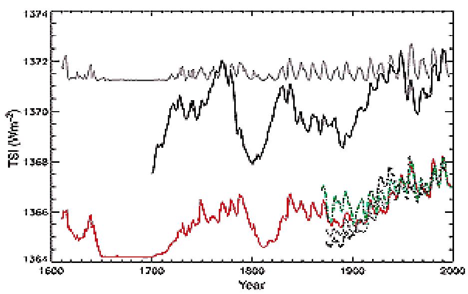

Figure 5. **Reconstructions of total solar irradiance (TSI) scaled to Nimbus-7 observations for 1979 to 1993[37].**

5.1. Solar ultraviolet variation

The variations in stratospheric composition and thermal structure resulting from ultraviolet irradiance changes may have an impact on tropospheric climate. The first mechanism whereby this might happen is through changes in radiative forcing[38]. Thus, in addition to a direct increase in downward short-wave irradiance at the tropopause, higher solar activity can cause an increase in downward infrared flux by heating the stratosphere and also radiative forcing due to Ozone (O_3) changes. When O_3 increases, reduced the solar radiative forcing by about 0.1 Wm^{-2} at solar maximum[38], Wuebbles et al[39] (1998) computed a value of -0.13 Watt per m^2 due to O_3 increases since the Maunder Minimum and about -0.02 Wm^{-2} from minimum to maximum of the solar cycle[40]. Hansen et al[41]. (1997a) showed an additional forcing of about +0.05 Wm^{-2} from minimum to maximum of a solar cycle due to O_3 increases and lower strato-spheric warming. The O_3 response using two-dimensional chemical-transport models in which temperature changes are estimated using the fixed dynamic heating approximation[38], [39], [40]. During change in solar irradiance and O_3, the stratospheric temperature response in Global Circulation Models (GCMs) [42], [43].

The negative radiative forcing values probably correspond to O_3 change profiles which peak at higher altitudes, and thus have less impact on lower stratospheric temperature and long-wave radiative forcing, although the different methods for calculating temperature change may also be important. Rind and Balachandran[44] (1995) investigated the impact of large increases in solar ultra-violet on the troposphere with a GCM and confirmed that altered refraction characteristics affect wave propagation in winter high latitudes. During study the effects of thermospheric heating of three-dimensional model of the atmosphere between 10 and 140 km, found that non-linear interactions in the winter hemisphere resulted in changes to the stratospheric circulation[45].

6. Discussions

The Milankovich cycles (Milutin Milankovic,1930s) also described the relationship between temperature and solar irradiance at 65° N latitude, on the basis of data got from the Vostok Ice-core. The changes near the north polar area, about 65° North, are considered to be important due to the large amount of land area. The land masses respond to temperature change more quickly than oceans, which have a higher effective heat capacity and concluded that solar irradiance is directly related to temperature variation (figure 6). Although the solar cycles statistically have not been proven to have a direct effect on weather, but there is some indication that solar cycles have an effect on climate. Some researchers claim that there is a connection between the 22 year solar cycle and the roughly 20 year drought cycle in the Great Plains. There have been several periods during which sunspots were rare or absent, most notably the Maunder minimum (1645-1715) the peak of little ice age, and less marked in the Dalton minimum (1795-1820). During the Maunder minimum the proportional concentration of radio-carbon (^{14}C) in the Earths atmosphere was slightly higher than normal, causing an underestimate of the radio-carbon date of objects from those periods.

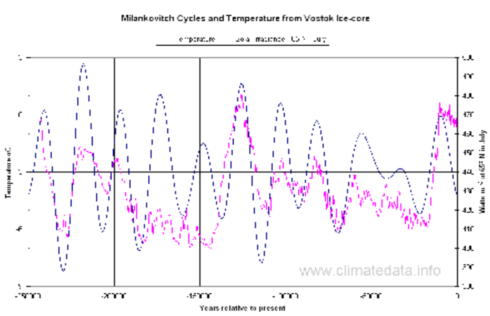

Figure 6. **Milankovitch Cycles (Solar irradiance) and Temperature received at 65° N in July [46].**

The premise of excess 14C concentrations in independently dated material (such as tree rings), the other minima have been found at times prior to direct sunspot observations, for instance the Sporer minimum from 1450 to1540. The data from 8,000 year-old bristle-cone pine trees indicate 18 periods of sunspot minima in the last 7,800 years[47] . This and other studies have shown that the Sun (as well as other stars) spends about a quarter of its time with very few sunspots. There is another well-known, super-imposed variation of annual sunspot numbers, of about 85 years. This irregular variation affects the length of the sunspot cycle, ranging from 9.8 to 12.0 years. The maxima of sunspot-cycle length occurred in 1770, 1845 and 1940. The Old Farmers Almanac actually use solar cycles in their long term forecasts. This is thought to affect the tropical Hadley cell circulation and the tracks of mid-latitude cyclones. Incidentally, the Sporer, Maunder, and Dalton minima coincide with the colder periods of the Little Ice Age, which lasted about 1450 to 1820. It was discovered recently that the sunspot number during 1861-1989 shows a remarkable parallelism with the simultaneous variation in northern hemisphere mean temperatures. There is an even better correlation with the length of the solar cycle, between years of the highest numbers of sunspots. For example, the temperature anomaly was - 0.4 K in 1890 when the cycle was 11.7 years, but +0.25 K in 1989 when the cycle was 9.8 years [16].

The satellite data documented a decrease of 3% in global cloud cover from the solar minimum around 1987 to the solar maximum around 1990. The effect of a decrease of cloud cover would be dependent on the type of clouds that are affected. A decrease of high clouds would result in lower temperatures while a decrease in the low-altitude clouds would mean an increase in temperature[48]. On the average a decrease in the various cloud types will mean a warming. The effect of a 3% decrease in cloud cover is believed to represent a global warming corresponding to 1-1.5 Wm^{-2} [49]. Compared to the 0.1% change in solar irradiance during the same interval which corresponds to 0.25 Wm^{-2} when taking into account the effect of the albedo of the Earth. With this amount the solar forcing of long-term variations in global temperature seems plausible and a number of the reported correlations between solar activity variations and climate may then be immediately explainable. The figure 7 shows the solar cycles in global temperatures, the vertical grid lines are 11 year solar cycle intervals and the solid thin line is the annual mean global surface temperature as published by the Australian Bureau of Meteorology. The mean temperature for each 11 year solar cycle interval is shown by the dashed horizontal lines and that values is written in each interval. The mean temperature for each 11-year solar cycle interval is shown by the dashed horizontal lines and that value is written in each interval. For example, the last solar cycle from 1999 to 2010 averaged 14.39 degrees C, the hottest 11-year solar cycle since the end of the mini cold phase in 1850 [51] .

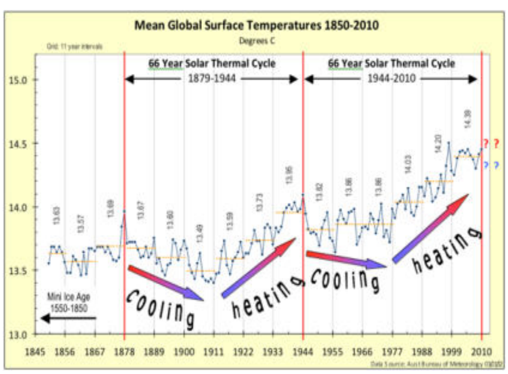

Figure 7. **Mean Global Surface Temperature from 1850 to 2010[50].**

It was estimated that in 1878, the Earth was exceptionally warm but the next 33 years (being 3 solar cycles) were cooler years followed by another 33 years of steadily increasing temperature up until 1944-66 years. This pattern was repeated in 1944-2010; another 66 year temperature maximum was recorded in 1944, immediately followed by 33 years of cooler temperatures followed by another 33 year of steadily increasing temperatures up until 2010- 66 years after the 1944 peak the warm year. The twentieth century was almost as warm as the centuries of the Mediaeval Warm Period (1450-1300 BC), an era of great achievement in European civilization. The recent warm period, from 1976-2000, appears to have come to an end and astro-physicists who study Sunspot behaviour predict that the next 25-50 years could be a cool period similar to the Dalton Minimum of the 1790s-1820s [52]. The figure no 7 also indicates that 2010 year, will be followed by 33 years of relative cooler or non-warming years as the Sun moves through its 66 years seasonal thermal cycle. There is a prominent cycle near 205 years in many paleoclimate indictors and also in solar activity. Correlations between solar activity and climate, often arising from this common cycle, are ubiquitous in the past 10,000 years, especially in drought and rainfall[53], [54], [55], [56].

6.1. Effect of Sun spot on Indian rainfall pattern

Variation in Solar activity lead to changes in the Solar wind and in Solar irradiance (fig 8), both of which may affect Earths climate. The variations in irradiance are known to be small or even minute. The variations in Solar Wind are large and strong, via the interaction with the Earths magnetosphere, it affects Earth rate of rotation, by that forcing several different terrestrial variables like the Gulf Stream beat in the North Atlantic. Simultaneously, the shielding capacity affects the concentration of cosmogenic nuclides[57]. At any rate, there are two different ways for changes in Solar activity may affect Earths climate; via irradiance or via the Solar Wind. The cloud formation may be influenced by galacitc cosmic rays through ionization change that cause microphysical changes in the atmosphere, affected the growth and nucleation of ice particles[58]. The local decrease in the amount of cloud cover related to short term changes in the cosmic rays due to increased solar activity[59], [60]. Total sun spot number and Year from 1995 to 2013 given in the table 1.

Table 1. **Sun spot number from year 1995 to 2013[61].**

Year	Total sunspot
1995	210
1996	103.5
1997	257.8
1998	770.5
1999	1118.1
2000	1435
2001	1331.1
2002	1249.4
2003	766.1
2004	485.7
2005	357.7
2006	182.6
2007	91
2008	33.6
2009	37.4
2010	197.8
2011	667.8
2012	690.9
2013	775.8

Guhathakurta P. and Rajeevan M[62]. (2006) prepared a table for Indian rainfall pattern from year 1901 to 2003; shown as

Table 2 & 3 (frequency of drought and flood years) and noticed that alternating sequence of multi-decadal periods having frequent droughts and floods years i.e. (i) 1901-30 Dry period (ii) 1931-60 Wet period (iii) 1961-90 Dry period (iv) 1991-2020 (possibly) Wet period. The earlier studies also found the similar results of 30 alternate sequence of dry and wet period. These studies indicat that the rainfall pattern also following the 66 year solar thermal cycle of cooling and heating; when solar thermal cycle passes heating phase, India received low rainfall (dry periods) and when solar thermal cycle passes cooling phase, India hasd received high rainfall[63], [64].

Table 2. **Decadal Mean (% departure from normal), frequency of drought and flood years[62].**

Decade	Decadal mean (% departure from normal)	Frequency of deficient year	Frequency of Excess year
1901-10	-2.2	3	0
1911-20	-2.5	4	3
1921-30	-0.4	1	0
1931-40	1.7	1	1
1941-50	3.3	1	1
1951-60	2.5	1	3
1961-70	-0.1	2	1
1971-80	-0.8	3	1
1981-90	-0.3	2	2
1991-2000	0.6	0	1
2001-2003	-5.9	1	0

Table 3. **Decadal Mean (% departure from normal), frequency of drought and flood years[62].**

Flood year i.e. anomaly exceeding 10%	Drought year i.e. anomaly below 10%
1916, 1917, 1933, 1942, 1947, 1956, 1959, 1961, 1975, 1983, 1988, 1994	1901, 1904, 1905, 1911, 1918, 1920, 1928, 1941, 1951, 1965, 1966, 1968, 1972, 1974, 1979, 1982, 1985, 1986, 1987, 2002

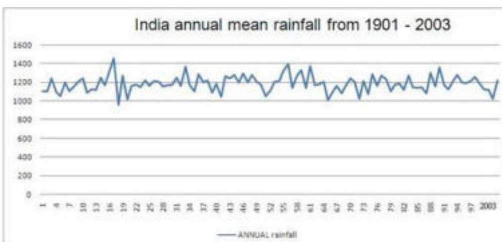

Figure 8. **India Rainfall pattern from year 1901 to 2003 (Source: After [62].)**

In comparison with figure 8, the Indian rainfall pattern to Sunsopt from the fig 4 and table 1, we could infer that during high sun spot number, India received below normal rainfall (drought) and when low sun spot number, India received high rainfall (flood). The clouds have a very strong impact on the radiation balance and little energy is needed to change the cloud formation process.

7. Conclusions

The solar related fluctuations are apparent on the earths surface including the oceans and atmosphere. The evidences from the empirical Sun-climate linkage and recent studies suggest that the climate responses to radiative forcing are complex and holistic, engaging the troposphere, stratosphere, surface and the ocean in multiple dynamic and radiative adjustments that alter the existing circulation patterns in different ways as yet only poorly parameterized numerically. There are strong evidences that the past solar output has changed and this change has been responsible for changes in the climate over decades. If the sun is cyclic in nature, it may be possible to forecast future solar irradiance changes. The Indian Monsoon are indirectly proprosanl to the sun spot numbers when high sun spot number India received below normal rainfall pattern(drought) and when low sun spot number, India received high rainfall pattern (flood). Rainfall pattern in India also changes as solar thermal cycle change and it was preducted that next few years India will receive above normal rainfall.

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