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Solar Activity and Climatic Changes

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Abstract. Solar activities have had notable effect on palaeoclimatic changes. Contemporary solar activities are so weak and hence expected to cause global cooling. Prevalent global warming, caused by building-up of green-house gases in the troposphere, seems to exceed this solar effect. This paper discusses this issue.

Keywords: solar activity, global climatic change, global cooling and warming, green-house gases.

1 Introduction

The current episode of high solar activity since about the year 1940 is unique within the last 8000 years. This means that the Sun has produced more sunspots, but also more flares and eruptions, which eject huge gas clouds into space, than in the past, The Sun is More Active Now than Over the Last 8000 Years, (Solanki et. al., 2004). The United Nations Secretary General Ban –Ki moon at COP-14, in Pozna, (Dec.2008) stated that "Climate change has long since ceased to be a scientific curiosity, and is no longer just one of many environmental and regulatory concerns. It is the major, overriding environmental issue of our time, and the single greatest challenge facing decision makers at many level". Climate change has become a prominent item on the agenda of world concerns. It is a growing crisis with economic, health and safety, food production security, and other dimensions. There is alarming evidence that important tipping points, leading to irreversible change in major earth systems and ecosystems, may already have been reached or passed. The change of climate is pushing many earth systems towards critical thresholds that will alter regional and global environmental balances and threaten the world at multiple scales.

Questions are being asked, hypotheses are being proposed, trying to identify the real forces that drive the global climate change. Is it a geological issue or cosmological issue or an issue of social behavior? In this paper we try to discuss the solar activities and its effects on the climate changes.

2 Deep Solar Minimum of Cycle 23

Solar activity affects the climate but seems to plays only a minor role in the current global warming. For example the Earth's temperature has risen perceptibly in the last

30 years while the solar brightness has not appreciably increased in this time (Krivova and Solanki 2003, Krivova and Solanki 2004). The average solar activity has declined rapidly since 1985 and cosmogenic isotopes suggest a possible return to Maunder minimum conditions within the next 50 years.

The present part of this paper examines the deep minimum of solar cycle 23 and its likely impact on climate change. In addition, a source region of the solar winds at solar activity minimum, especially in the solar cycle 23, the deepest during the last 100 years, has been studied. Is this episode comparable to the Maunder Minimum or is it like the Dalton Minimum? Furthermore, the near future solar cycle 24 and prediction of its conditions are presented. The solar cycle 23 started in April 1996 and had its peak in early 2000, 2001. The decline phase of this period extended from 2002 until December 2009, which is the longest decline phase in the last 23 solar cycles. Solar cycle 24 started in 2009, it was a late starter, about three and a half years later than the average of the strong cycles in the late 20th century and almost three year later than the weak cycles of the late 19th century. For more details about solar cycle 23 activities and its statistics, see for example Hady (2002), Hady and Shaltout (2004), and Hady (2009). Figure (1) shows the length of the last 5 solar cycles 19, 20, 21, 22,23, in the left hand side part and the cycle 23 behavior and the cycle 24 prediction according to Marshall space flight center, NASA. We may observe the length of solar cycle 23 that extended for 13.5 years starting from April 1996, and it is a very weak cycle compared with solar cycle 19, Hathaway (2010).

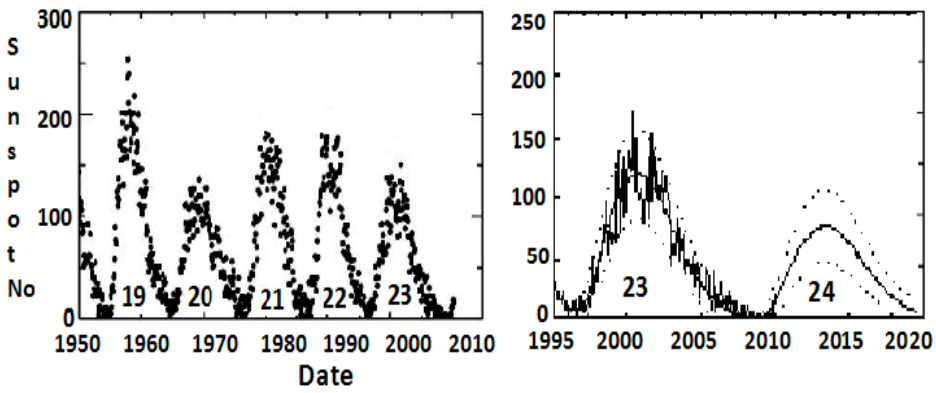

Fig. 1 – sunspot cycles, and cycle 24 prediction.

The monthly and yearly mean of sunspots during the solar cycle 23 and its decline phase until December 2009 are given in table (1). The data used to prepare table (1) and table (2) were obtained from Kandilli Observatory, Bogazici University, Turkey.

Table 1. Monthly and yearly means of sunspot numbers of solar cycle23.

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Year 2001 is the maximum solar activates of cycle 23:
 Monthly means: 95.6  80.6  113.5  107.7  96.6  134.0  81.8  106.4  150.7  125.5  106.5
132.2
Yearly Mean: 110.58
-----------------------------------------------------
Year 2003 is the year of starting decline phase of cycle23
Monthly means: 79.7  46.0  61.1  60.0  54.6  77.4  83.3  72.7  48.7  65.5  67.3
46.5
Yearly Mean: 63.57
-----------------------------------------------------
Year 2006 is the year of staring solar minimum of cycle23
Monthly means: 15.3  4.9  10.6  30.2  22.3  13.9  12.2  12.9  14.4  10.4  21.5  13.6
Yearly Mean: 15.16
-----------------------------------------------------
Year 2007 continuous of minimum of cycle 23:
Monthly means: 16.8  10.7  4.5  3.4  11.7  12.1  9.7  6.0  2.4  0.9  1.7  10.1
Yearly Mean: 7.5
Spotless Days 149 of 365 days ( 41% spotless days)
-----------------------------------------------------
Year 2008 continuous of minimum of cycle 23:
Monthly means:  3.3  2.1  9.3  2.9  3.2  3.4  0.8  0.5  1.1  2.9  4.1  0.8
Yearly Mean: 2.85
Spotless Days 266  of 366 days ( 73% spotless days)
-----------------------------------------------------
Year 2009 continuous of minimum of cycle 23
Monthly means: 1.5  1.4  0.7  0.8  2.9  2.9  3.2  0.0  4.3  4.6  4.2  10.6
Yearly Mean: 3.1
Spotless Days  274 of 365 days (75% spotless days)
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From Table 1 we note the spotless days during years 2007, 2008, 2009. During 2008 there were no sunspots observed on 266 days of the year's 366 days (73%), during 2009 the spotless days were 274 of 365 days (75% spotless days). These represent the deepest minimum compared with records of the 20th century. The sun is in a phase of unusually low activity, as indicated by sunspots numbers and spotless days; this depends on recorded observations to detect this change of the sunspot numbers for a long period during the 20th century. Figure (2) shows the spotless days in years of the 20th century.

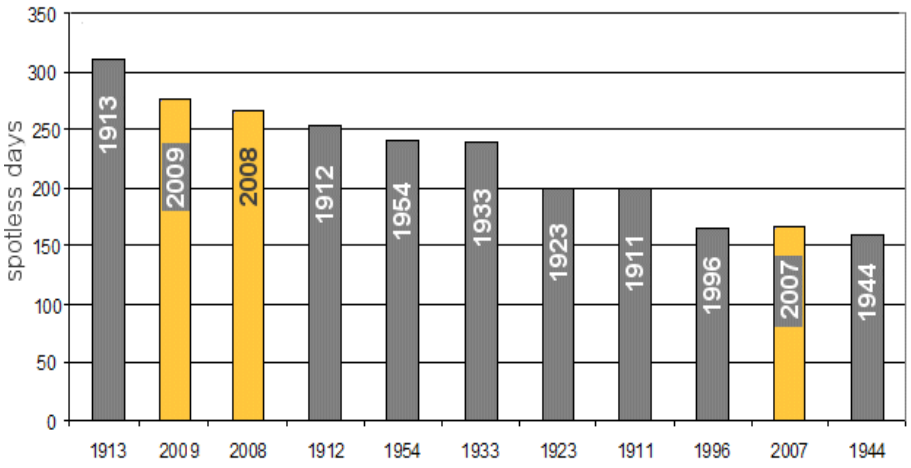

Fig. 2 – Sunspot counts for spotless years during the 20th century. The years 2007, 2008, 2009 are the years of minimum of solar cycle 23.

Monthly and yearly means for the flare index during the maximum activity of the solar cycle 23, and its decline phase until December 2009 are given in Table 2. Data in Table 2 show that the yearly means of flare index are less than 0.5 starting from year 2006, which means that reduced solar activity appears starting from year 2006.

Table 2. Monthly and yearly flare index of solar activity full disk of the solar cycle 23

Year 2001 is the maximum solar activates of cycle 23
Yearly Mean = 6.80
Monthly Means: 2.76 1.25 7.65 10.20 2.89 4.86 1.84 6.38 11.77 9.50 10.95 11.39
Year 2003 is the year of starting decline phase of cycle 23:
Yearly Mean = 3.46
Monthly means: 2.69 1.55 3.33 2.62 4.35 4.54 2.55 1.59 0.77 12.11 4.53 0.68
Year 2006 is the year of staring solar minimum of cycle 23
Yearly Mean = 0.54
Monthly means: 0.03 0.00 0.11 0.53 0.03 0.01 0.28 0.14 0.19 0.05 0. 4.89
Year 2007, continuous of minimum of cycle 23
Yearly Mean = 0.47
Monthly Mean: 0.49 0.01 0.01 0.02 0.24 1.53 1.16 0.21 0.00 0.00 0.01 1.88
Year 2008, continuation of minimum of cycle 23
Yearly Mean = 0.03
Monthly Means: 0.05 0.00 0.20 0.06 0.00 0.00 0.00 0.00 0.00 0.00 0.03 0.00
Year 2009, continuation of minimum of cycle 23
Yearly Mean= 0.027
Monthly Means: 0.04 0.00 0.03 0.06 0.00 0.00 0.00 0.00 0.00 0.00 **0.03** **0.20**

Prediction of the behavior of a sunspot cycle is fairly reliable once the cycle is well underway. A number of techniques are used to predict the amplitude of a cycle during the time near and before sunspot minimum. Relationships have been found between the size of the next cycle maximum and the length of the previous cycle, the level of activity at sunspot minimum, and the size of the previous cycle. The method used for solar cycle predictions depends on Feynman and Wilson methods see for example (Hathaway et al. 1994, 1999, and Wilson et. al. 2009). We shall show only the statistical results of our solar cycle predictions compared with all solar cycles as given in Table 3.

Table 3. Minimum and maximum of sunspot in the series of solar cycles.

Sunspot Cycle Number	Year of Min	Smallest Smoothed Monthly Mean	Year of Max	Largest Smoothed Monthly Mean	Rise to Max (Yrs)	Fall to Min (Yrs)	Cycle Length (Yrs)
1	1755.2	8.4	1761.5	86.5	6.3	5.0	11.3
2	1766.5	11.2	1769.7	115.8	3.2	5.8	9.0
3	1775.5	7.2	1778.4	158.5	2.9	6.3	9.2
4	1784.7	9.5	1788.1	141.2	3.4	10.2	13.6
5	1798.3	3.2	1805.2	49.2	6.9	5.4	12.3
6	1810.6	0.0	1816.4	48.7	5.8	6.9	12.7
7	1823.3	0.1	1829.9	71.7	6.6	4.0	10.6
8	1833.9	7.3	1837.2	146.9	3.3	6.3	9.6
9	1843.5	10.5	1848.1	131.6	4.6	7.9	12.5
10	1856.0	3.2	1860.1	97.9	4.1	7.1	11.2
11	1867.2	5.2	1870.6	140.5	3.4	8.3	11.7
12	1878.9	2.2	1883.9	74.6	5.0	5.7	10.7
13	1889.6	5.0	1894.1	87.9	4.5	7.6	12.1
14	1901.7	2.6	1907.0	64.2	5.3	6.6	11.9
15	1913.6	1.5	1917.6	105.4	4.0	6.0	10.0
16	1923.6	5.6	1928.4	78.1	4.**8**	**5.4**	**10.2**
17	**1933.8**	**3.4**	**1937.4**	**119.2**	**3.6**	**6.8**	**10.4**
18	**1944.2**	**7.7**	**1947.5**	**151.8**	**3.3**	**6.8**	**10.1**
19	**1954.3**	**3.4**	**1957.9**	**201.3**	**3.6**	**7.0**	**10.6**
20	**1964.9**	**9.6**	**1968.9**	**110.6**	**4.0**	**7.6**	**11.6**
21	**1976.5**	**12.2**	**1979.9**	**164.5**	**3.4**	**6.9**	**10.3**
22	**1986.8**	**12.3**	**1989.6**	**158.5**	**2.8**	**6.8**	**9.7**
23	**1996.4**	**8.0**	**2000.3**	**120.8**	**4.0**	**10.0**	**13.5**
Author's estimation of cycle 24							
24	**2009.96**	**9.0**	**2015.2**	**105.0**	**5.24**	**7.8**	**13.o4**
Mean Cycle Values:		**6.1**		**113.2**	**4.7**	**6.3**	**11.0**

From the tables and figures we can conclude that the solar activity are rapidly inclined downward from about 30 years ago and will continue for the next 50 years. Solar activities have had notable effect on palaeoclimatic changes. The surface warming and the solar cycle in times of high solar activity are on average 0.2°C warmer than times of low solar activity. Prevalent global warming, caused by building-up of green-house gases in the troposphere, seems to exceed this cooling solar effect. Fig. 3 compares the changes during last 150 year for solar cycle variations, earth surface temperature, and CO_2 variability. We notice that agreement for the parameters variation occurred until the year 1960. There is no agreement between solar cycle variations and Earth surface temperature after the CO_2 increasing dramatically from the year 1960.

The scientific consensus is that solar variations do not seem to play a major role in determining present-day observed climate change, but have played a major role in palaeoclimatic changes, for example, the climate cooling during the Maunder minimum (from year1645 until 1710), and Dalton minimum (from year 1797 until 1825) was due to the solar activities collapse.

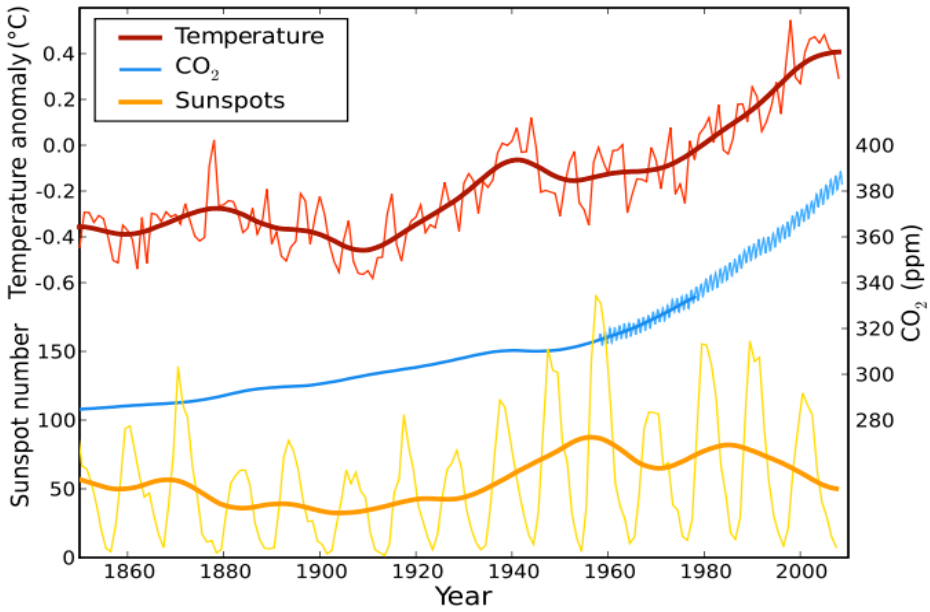

Fig. 3 – Temperature, Co_2 concentration in the troposphere, and sunspots variations starting year 1850 until 2010.

Due to the paucity of sunspots in the Maunder Minimum (1645 – 1710), ^{14}C data provides evidence for the presence of solar cycles and their length. According to Makarov and Tlatov (2007), solar cycles averaged 20 years long in the Maunder (See Callebaut, 2008). In Fig. 4, ^{14}C Count Variation in the bi-annual rings of the pine-trees from south Urals for 1600-1730 are shown, the solar minimum marked with vertical lines. The numbers along lower part of the figure are the length of the solar cycles from minimum to minimum measured in years.

To compare the start of the Maunder Minimum with current day minimum, Watts Anthony (2009) marked that the maximum of Solar Cycle 24 would be in 2015, that is, 15 years after the peak of the preceding cycle. There is also a parallel in the way that the ^{14}C is climbing above the peaks of previous minimum, as it is today with the Oulu neutron count. Neutron count tends to peak a year after solar maximum, so a neutron peak in 2010 is consistent with solar minimum in 2009. From Fig. 4, a repeat of the Maunder Minimum can be expected; the neutron flux will remain well above the levels reached in the minimum of the second half of the 20th century. Activity and timing of the current minimum, as well as the timing of the Solar Cycle 24 maximum in 2015 compares with the start of the Maunder Minimum. There is no data to date which diverge from the pattern of the start of the Maunder Minimum, Hathaway (2008).

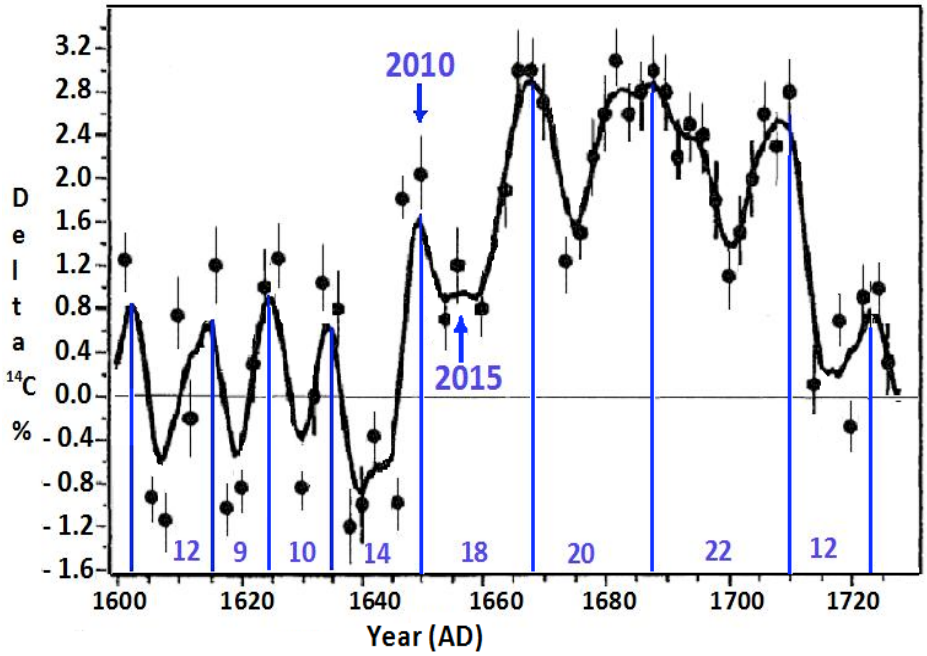

Fig. 4 – Solar cycles during the Maunder minimum, the solar minimum marked with vertical lines. The numbers along the lower part of the figure are the length of the solar cycles from minimum to minimum in years. The suggested comparison with years 2010, 2015 was marked by Watts A. (2009).

Is the Dalton minimum repeat possible? This question was asked after the deep solar minimum of cycle 23 and ending up at 13.5 years long. The Solar Cycle 24 was a late starter, about three and a half years later than the average of the strong cycles in the late 20th century and almost three year later than the weak cycles of the late 19th century. Fig. 5 shows the similarity of the solar cycles behavior during Dalton minimum years and the last two solar cycles 22 and 23, the prediction of solar cycles 24, 25, 26 agree with this supposition, Callebaut (2008), Watts (2010).

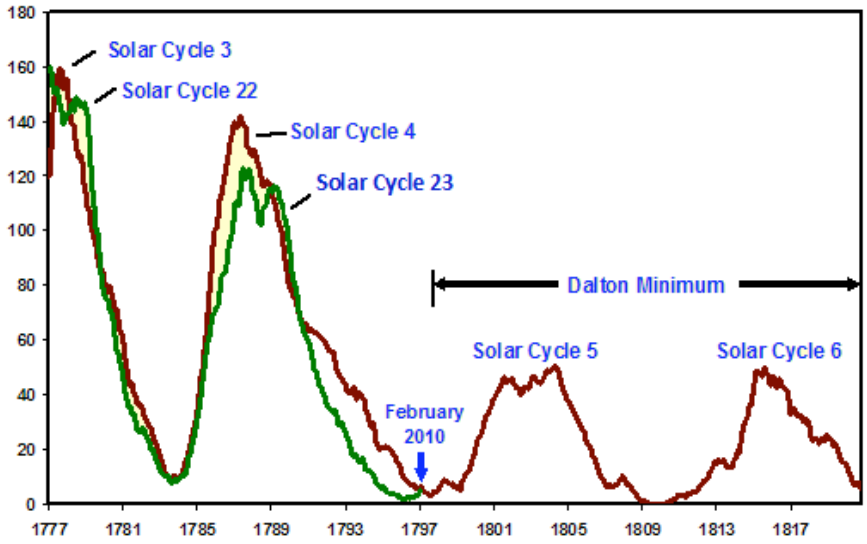

Fig. 5 – show the Dalton minimum era and the Solar Cycle 22 and 23 are overlaid on solar cycle 3 and 4 above to show similarity

We can conclude the following: Solar activities have had notable effect on palaeoclimatic changes. Contemporary solar activities are so weak and hence expected to cause global cooling. Prevalent global warming, caused by building-up of green-house gases in the atmosphere, seems to exceed this solar effect.

3 Conclusions

Although the solar activity during the last 30 years has a deep minimum there is a global warming. The solar variations of it activities do not seem to play a major role in determining present-day observed climate change, Prevalent global warming, caused by building-up of green-house gases in the atmosphere, seems to exceed and hence mask this solar effect, but it played a major role in palaeoclimatic changes, for example, the climate cooling during the Maunder minimum and Dalton minimum was due to the solar activities collapse.

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