SOLAR ACTIVITY AND THE CYCLONIC STORM/ HURRICANES DURING THE LAST FEW CENTURIES

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Abstract

The observed solar phenomena and its variability over a time-scale of the last few centuries particularly after the Maunder minimum, and along with our present knowledge of its long-term behaviour is briefly studied here particularly with reference to its influence on the cyclonic storm in the North Indian and the Atlantic Ocean. The notion of solar activity is revisited, considering the sunspot number as the true sequential indicator of various solar activity that have occurred over the ages. During the Mini Ice Age or the Maunder minimum, when the observed sunspots happenned to be very few inn number, the whole world experienced a much cooler temperature than before. This correlated the "Maunder Minimum" with the sunspot activity on the sun, an interval of few sunspots and aurora (geomagnetic storms). The information on solar activity with the cyclonic storm or Hurricanes are compared with regard to the last few centuries and turns out that, the cyclonic activity increases when there are more sunspot and vice versa giving an impression that solar activity influences our terrestrial climate.

Keywords: *Solar activity, Cyclonic storm, Solar dynamo*

Introduction

The variations in the solar activity and their effect on weather were revealed in few scattered references during the 17th century followed by a few more references in the 18th century and the scientific interest in the solar activity and its consequences gradually decreased. However, after William Herschel's remarks on sunspots and climate (Herschel 1796, 1801), the scientific interest in the solar activity has again increased and soon after, the field exploded (Smyth 1870). Meldrum, a British meteorologist in India, considered Indian cyclones (Meldrum 1872, 1885) and published, probably one of the earliest claims that a correspondence exists between the terrestrial weather pattern and the solar activity. The earlier data of the Tropical Cyclone of the North Indian Ocean (Arabian Sea and the Bay of Bengal) are available from 1648 and 1737 respectively but, it was highly underestimated as their average rate of recurrence was found to be even less than one per year. Since it is based on meteorological logs of vessels, it does not contain all storms and all the information for each storm. Later in 1875, the Indian Meteorological Department started an annual publication entitled 'Reports on the Meteorology of India' which was a systematic scientific study of tropical systems of the region.

To substantiate Meldrum claims, we compared the values of annual Sunspot number with that of the number of Cyclone occurred that annually in the North Indian Ocean from 1890 to 2018 and found that, it more or less corresponds to each other in the sense that, when the sunspot number increases, the frequency of the occurrences of the cyclone increases around that period and vice versa. This is illustrated in Figure (i) with regard to the North Indian Ocean. We also observed the similar pattern for the North Atlantic Hurricane from 1700 to 2018 from Fig (ii-iv) in 100 year scale each with a combined plot in Fig. (v). This gives us an impression that the changing terrestrial and atmospheric weather pattern is being influenced by the variable solar activity also.

The solar magnetic field (Hale 1908) is a dynamic process in the convection zone of the sun leading to the formation of phenomena like the sunspots, solar flares, coronal mass ejection (CME), solar cycles etc. The solar cycle is one way of manifestations in the periodic variations of the sun's activity and inactivity, over an 11-year period (Luby 1942). There are longer duration events such as the "Gleissberg cycle" with a time scale of approximately 100 years, followed by other even longer events. All these kinds of solar variations make the sun a unique contender in influencing our climate. Earth's natural phenomena and its variations may influence our climate for some time but may not steer the climatic system for long term duration. The currently accepted mean value of TSI (Total Solar Irradiance) according to the last solar cycle 23 (1996–2009) is around 1361 W/m2 (Willson 2014). This TSI value which was long considered as invariant is now observed to vary in time. Even for a minute alteration in solar-constant by 0.1% can have considerable change in the spectral irradiance. In high frequency regions like ultraviolet (UV) and extreme ultraviolet (EUV), the spectral irradiance varies by more than 10% throughout the solar cycle (Herschel 1801, Brown & Williams, 1969). These variations can notably affect the thinnest and most sensitive layers of the Earth's atmosphere; the ozone layer, and therefore will have vital implications for climate change.

The existence of all these solar phenomena poses a riddle in solar physics, leading to the growth of refined models from the convection zone till the solar corona and beyond. Over the decades a number of observations and experiments were being carried out from the ground to the space to find out more about the solar variability. Although the variations in the appearance of the sun are hardly visible to our naked eye, unless it is observed through some specific instruments, the variations or changes impacts us in a great way. Such events can mutate the earth's environment and ultimately affect our life like the strong geomagnetic storms in the earth's magnetosphere and ionosphere from the incoming solar winds thereby disrupting the satellite communication, power grid lines etc. (e.g., reviews by Haigh 2007; Gray et al. 2010; Mironova et al. 2015).

The variable solar activity of the past can be examined with respect to its heliosphere, to its affect on earth's atmosphere particularly the magnetosphere and so on, that runs over several decades, notably in terms of solar cycles. This is essential because it provides the average behaviour of the solar activity at regular intervals as in the case of a solar cycle, thereby making it possible to estimate how long the sun stays in states of very low and high state of activity called the solar minima and maxima respectively. This is directly due to the magnetic field from the sun that greatly influences it. One such extremely low activity called the grand minimum (spotless sun or no sunspots) was the Maunder minimum (from approximately 1645 - 1715). The cosmic rays and other high energetic particles from the outer space are constantly striking our earth thereby generating radioactive isotopes called the cosmogenic nuclides during such process in the Earth's atmosphere. Nevertheless, to propose such a model is tricky, because they are formed in complex atmospheric process which requires wide-ranging computations. It was during the period from 1960-80, that the first known model for cosmogenic nuclide production was developed [Lal & Peters, 1962; Lingenfelter, 1963; O'Brien, 1979]. However, there were shortcomings and was followed by improvements from many people over the years. Thus, it is presently a mixture of different yield functions calculated by different models with different assumptions and conditions.

Solar activity over many years back can be reconstructed from the knowledge about the concentrations of cosmogenic nuclides like 10Be (half-life ≈1.4·106 years), 14C (5730 years), 36Cl (3·105 years), etc. that originates from the cosmic rays (Abreu et al., 2010) and is recorded ready in nature in the form of terrestrial archives like in the ice cores, big or an old tree trunks, various sediments, etc. When the cosmic rays are very intense, the concentrations of the cosmogenic nuclides increase, thereby implying that, the sun was not as much active as before, because during that time, the solar magnetic field will protect the Earth from the galactic particle showers. This helps us to become aware of the chronological development of the solar magnetic activity, which forms the basis for the solar dynamo. In addition, it also provides a dependable way to learn solar activity of a long time scale (McCracken et al., 2004; Solanki et al., 2004; Vonmoos et al., 2006; Muscheler et al., 2007; Steinhil ber et al., 2012; Usoskin et al., 2014; Inceoglu et al., 2015;).

This paper tries to briefly mention about the solar physics with special reference to the sunspot number as an important index of solar activity. It is followed by a comment on the occurrence of the annual Hurricanes and tropical Cyclones of the North Atlantic and North Indian Ocean respectively along with their comparison to the corresponding sunspot number.

2. Solar Activities and their Index

Solar activity which depends on its magnetic field may be defined as the manifestation of continuous dynamic process in the Sun such as the Sunspot, Solar prominences and flares, CME, Solar storms and wind, etc. All these processes are complex, indirect, and forms a nonlinear dynamic system, and therefore, by observing such events, periodic patterns such as cyclicity will be exposed (Lychak, 2004, 2006). A number of solar quantifying indices for its activity have been projected with the intention to characterize and interpret various observables. Most of which are generally found to be concurrent to each when it comes to the solar cycle pattern. Also, indirect proxy data can also be used for quantifying solar activity for the purpose. Some of the solar activity index that is frequently used is reviewed here. Among the solar index, the sunspot number and/or sunspot groups which can be obtained by simple visual observations is considered as the most frequently used indices for solar activity.

2.1 Sunspot Number

In the 1850s Rudolf Wolf had designed an index called the sunspot number and now known as the Wolf or Zurich Sunspot Number (WSN) as his reconstruction and records of sunspot number been updated by his successors at the Zurich Observatory even after his death on December 6, 1893. This is the most frequently used solar indices to represent the solar activity. Sunspots seldom appear alone but generally cluster together in groups. Intense solar activity sometimes makes it difficult to distinguish one group from another nearby groups. Some ambiguity exists with the definition of groups, and some observers disagree about the actual number of groups, but a general agreement exists between most observers. The sunspot number, N is expressed using the formula:

$$N = c\,(10g + I),$$

(i). where is the number of individual spots, g is the number of cluster or group of sunspots, and *c* is a rectification that varies with the location and instrumentation by different observers. For more than a century, the sunspot number index has become an important tool in the study of the long-term behaviour of the sun's activity, especially in relations to the terrestrial climate (Eddy 1976; Li et al. 2005; Deng et al. 2011a,b; Xie et al. 2012). The WSN was fairly consistent and even. However, prior to 1849, there appears to have some reservations in several series of the data (Lockwood et al. 2014; Friedli 2016) leading to an interpolated pattern and so, have some possible errors and in-homogeneities. (Wilson 1998; Letfus 1999). As there were some reliability issues and uncertainties in the earlier WSN series particularly before 1750, the early sunspot data was reassessed extensively (Hoyt and Schatten 1996, 1998) and a new series called the Group Sunspot Numbers (GSN) was introduced by considering all the archival records available. The group sunspot number Rg is expressed as:

$$Rg = 12.08d \sum kn' \; Gn,$$

(ii) where Gi is the sunspot number in groups for the n th observer, k' is the observer's correction term, d is the number of investigators in a particular day, and 12.08 is a normalizing constant. However, the GSN also has some shortcomings. (Letfus 2000; Usoskin et al. 2003a; Vaquero et al. 2012). Rg is more vigorous than N in view of the fact that its sunspot groups can be easily identified because, it exclude the number of blurred individual spots in that instant of time thereby escaping the difficulty of identifying smaller groups of sunspots which are closer enough to appear as one big blurred spot for an observer with a low-quality observing instrument. Also, the way the individual sunspot are grouped together earlier and these days may need to be standardised (Clette et al. 2014).

Since the data for the GSN series is available from 1610 onwards, it also covers the Maunder minimum period (1645-1715) which is some 140 years earlier than the original WSN series, thus enabling a better study of the sunspot activity even during this period. And therefore, GSN can be measured as more consistent and standardized.

2.2 Indirect Solar indices

Sometimes the effect on various environments by the solar-variability which are not linked directly to the sun's activity may also be measured quantitatively which can also be considered as solar indices (indirect). They can be either terrestrial or geomagnetic and heliospheric or interplanetary. Geomagnetic indices can be the effects in the environment caused due to the variations in the properties of solar-wind and the magnetic field from the outer space such as low-latitude aurora (Silverman 2006) which are associated with high-speed solar-wind and are indirectly associated to the affect of the solar cycle and therefore can be considered as an indirect index of solar activity. A review of the geomagnetic effects of solar activity is found in Pulkkinen (2007). Heliospheric indices can be the quantities of the solar wind or the interplanetary magnetic field measured or estimated in the interplanetary space like the galactic cosmic-ray strength that is being recorded in natural archives over the ages, making it possible for the reconstruction of changes for the long timescale solar activity.

3. The Variable Sunspot Cycle

The key aspect of sunspot activity is the variable amplitude and duration of the sunspot activity cyclically, which originates from the solar-dynamo process having duration of 11 years commonly known as the Schwabe or solar cycle. This has the genesis from the Hale magnetic polarity cycle of 22-years, where that the polarity of sunspot magnetic fields flips every 11-year (Hale et al. 1919). A detailed review of solar cyclic variability is illustrated in (Hathaway 2015). But it was Christian Horrebow who in the 1770s first observed the possible variability in the sunspot numbers (Vitinsky 1965).

At times the usual interval of the normal solar activity almost disappears and practically no sunspot is observed and such periods are called the grand minima. The most recent grand minimum was the famous Maunder minimum from 1645-1715 (Eddy 1976, 1983) followed by the lesser known Dalton minimum (1790-1820) corresponding to the period of solar cycle 4 to 7; where the sunspot activity has not completely disappeared but still showed the Schwabe pattern of cyclicity. Other known previous grand minima were the Spörer minimum that happened around the period 1450-1550 and the Wolf minimum of the fourteenth century.

4. Hurricanes in the Atlantic

Tropical cyclones in the North Atlantic are called hurricanes, tropical storms, or tropical depressions. The maximum number of hurricanes occurs when the temperatures difference between far above the ground and sea surface is the maximum i.e., during the late summer. However, each basin has its own seasonal patterns. But on a global level, May and September are the least and most active month respectively for the occurrence of tropical storm. Table 1,encompasses all known Atlantic tropical cyclones from 1700 onwards. Most tropical cyclone formation occurs between June to November.

Table 1. Annual Hurricanes and corresponding Sunspot No. in the Atlantic Ocean

Year	No. of Hurricane	No. of Sunspot	Year	No. of Hurricane	No. of Sunspot	Year	No. of Hurricane	No. of Sunspot
1700	4	5	1727	2	122	1754	1	12.2
1701	0	11	1728	1	103	1755	0	9.6
1702	2	16	1729	2	73	1756	2	10.2
1703	4	23	1730	3	47	1757	1	32.4
1704	0	36	1731	2	35	1758	3	47.6
1705	2	58	1732	0	11	1759	1	54
1706	4	29	1733	2	5	1760	3	62.9
1707	2	20	1734	1	16	1761	2	85.9
1708	0	10	1735	0	34	1762	0	61.2
1709	0	8	1736	0	70	1763	0	45.1
1710	0	3	1737	1	81	1764	0	36.4
1711	0	0	1738	2	111	1765	2	20.9
1712	4	0	1739	0	101	1766	10	11.4
1713	4	2	1740	4	73	1767	3	37.8
1714	4	11	1741	0	40	1768	2	69.8
1715	2	27	1742	1	20	1769	3	106.1
1716	2	47	1743	3	16	1770	2	100.8
1717	1	63	1744	1	5	1771	2	81.6
1718	1	60	1745	0	11	1772	6	66.5
1719	0	39	1746	0	22	1773	3	34.8
1720	1	28	1747	5	40	1774	3	30.6
1721	0	26	1748	2	60	1775	4	7
1722	3	22	1749	2	80.9	1776	5	19.8
1723	0	11	1750	3	83.4	1777	4	92.5
1724	5	21	1751	3	47.7	1778	5	154.4
1725	0	40	1752	6	47.8	1779	4	125.9
1726	1	78	1753	0	30.7	1780	8	84.8
1781	3	68.1	1849	3	96.3	1917	2	103.9
1782	2	38.5	1850	7	66.6	1918	4	80.6
1783	3	22.8	1851	3	64.5	1919	2	63.6
1784	3	10.2	1852	5	54.1	1920	4	37.6
1785	4	24.1	1853	4	39	1921	5	26.1
1786	3	82.9	1854	3	20.6	1922	3	14.2
1787	4	132	1855	4	6.7	1923	4	5.8
1788	3	130.9	1856	4	4.3	1924	5	16.7
1789	1	118.1	1857	3	22.7	1925	2	44.3
1790	0	56.9	1858	6	54.8	1926	8	63.9
1791	3	121.5	1859	7	93.8	1927	4	69
1792	2	138.3	1860	6	95.8	1928	4	77.8
1793	2	103.2	1861	6	77.2	1929	3	64.9

1794	8	85.7	1862	3	59.1	1930	2	35.7
1795	3	64.6	1863	5	44	1931	3	21.2
1796	3	36.7	1864	3	47	1932	6	11.1
1797	2	24.2	1865	3	30.5	1933	11	5.7
1798	0	10.7	1866	6	16.3	1934	7	8.7
1799	2	15	1867	6	7.3	1935	5	36.1
1800	6	40.1	1868	3	37.6	1936	7	79.7
1801	2	61.5	1869	7	74	1937	4	114.4
1802	1	98.5	1870	10	139	1938	4	109.6
1803	4	124.7	1871	6	111.2	1939	3	88.8
1804	5	96.3	1872	4	101.6	1940	6	67.8
1805	2	66.6	1873	3	66.2	1941	4	47.5
1806	8	64.5	1874	4	44.7	1942	4	30.6
1807	4	54.1	1875	5	17	1943	5	16.3
1808	2	39	1876	4	11.3	1944	8	9.6
1809	2	20.6	1877	3	12.4	1945	5	33.2
1810	5	6.7	1878	10	3.4	1946	3	92.6
1811	4	4.3	1879	2	6	1947	5	151.6
1812	6	22.7	1880	9	32.3	1948	6	136.3
1813	6	54.8	1881	4	54.3	1949	7	134.7
1814	3	93.8	1882	5	59.7	1950	11	83.9
1815	8	95.8	1883	3	63.7	1951	8	69.4
1816	6	77.2	1884	4	63.5	1952	5	31.5
1817	2	59.1	1885	6	52.2	1953	7	13.9
1818	5	44	1886	10	25.4	1954	7	4.4
1819	5	47	1887	11	13.1	1955	9	38
1820	2	30.5	1888	6	6.8	1956	4	141.7
1821	3	16.3	1889	6	6.3	1957	3	190.2
1822	5	7.3	1890	2	7.1	1958	7	184.8
1823	3	37.6	1891	7	35.6	1959	7	159
1824	2	74	1892	5	73	1960	4	112.3
1825	5	139	1893	10	85.1	1961	8	53.9
1826	3	111.2	1894	5	78	1962	3	37.6
1827	5	101.6	1895	2	64	1963	7	27.9
1828	1	66.2	1896	6	41.8	1964	6	10.2
1829	4	44.7	1897	3	26.2	1965	4	15.1
1830	5	17	1898	5	26.7	1966	7	47
1831	5	11.3	1899	5	12.1	1967	6	93.8
1832	5	12.4	1900	3	9.5	1968	4	105.9
1833	3	3.4	1901	5	2.7	1969	12	105.5
1834	4	6	1902	3	5	1970	5	104.5
1835	3	56.9	1903	7	24.4	1971	6	66.6
1836	3	121.5	1904	3	42	1972	3	68.9

1837	10	138.3	1905	1	63.5	1973	4	38
1838	2	103.2	1906	6	53.8	1974	4	34.5
1839	4	85.7	1907	0	62	1975	6	15.5
1840	1	64.6	1908	6	48.5	1976	6	12.6
1841	5	36.7	1909	6	43.9	1977	5	27.5
1842	9	24.2	1910	3	18.6	1978	5	92.5
1843	3	10.7	1911	3	5.7	1979	5	155.4
1844	5	15	1912	4	3.6	1980	9	154.6
1845	1	40.1	1913	4	1.4	1981	7	140.4
1846	4	61.5	1914	0	9.6	1982	2	115.9
1847	2	98.5	1915	5	47.4	1983	3	66.6
1848	7	124.7	1916	10	57.1	1984	5	45.9
1985	7	17.9	1996	9	8.6	2007	6	7.6
1986	4	13.4	1997	3	21.6	2008	8	2.9
1987	3	29.4	1998	10	64.2	2009	3	3.1
1988	5	100.2	1999	8	93.4	2010	12	16.5
1989	7	157.6	2000	8	119.6	2011	7	55.7
1990	8	142.2	2001	9	110.9	2012	10	57.6
1991	4	145.8	2002	4	104.1	2013	2	64.7
1992	4	94.5	2003	7	63.6	2014	6	79.3
1993	4	54.7	2004	9	40.4	2015	4	69.8
1994	3	29.9	2005	15	29.8	2016	7	39.8
1995	11	17.5	2006	5	15.2	2017	10	21.7
						2018	8	7

The table above lists the Wolf or Zurich Sunspot Numbers (N) from 1700 to 2018 along with the number of Hurricanes in the Atlantic Ocean occurred in each corresponding year. These yearly means are the most commonly used solar index in sun/climate studies. For the

5. Tropical Cyclone in the North Indian Ocean

The historical Tropical Cyclone (TC) data are available from 1648 onwards over the Arabian Sea and 1737 onwards over the Bay of Bengal, both of which are in the North of Indian Ocean. But the frequency of TCs during those periods was highly underrated as the average interval of TC was even less than 1 (one) in both the Bay of Bengal and the Arabian Sea. Since it is based on meteorological logs of vessels, it doesn't have all the information for each storm. Hence, it is crucial to make another study of the available data based on current criteria, as it can help in evaluating long-term changes and can address the climate change-related issues. From 1875, the Indian Meteorological Department (IMD) has started an annual publication Journal entitled 'Reports on the Meteorology of India' to bring collectively in one single report, the meteorological data of the whole India and its adjacent areas. Table 2, encompasses all known tropical cyclones from 1890 onwards in the North Indian Ocean. The systematic scientific study of tropical systems in the Bay of Bengal and Arabian Sea was started during the 19th century by Henry Piddington.

6. Discussion

A comprehensive review with regard to the prediction, classification and results of the sunspot activity has been done (Hathaway 2009; Petrovay 2010; Pesnell 2012). Also, there's a method based on sophisticated dynamo numerical simulations (Choudhuri et al. 2007; Dikpati and Gilman 2006; Dikpati et al. 2008), but they also contradict with each other. So, there is no confirmation of any method or approaches that gives a reasonable way for the forecast of sunspot activity over a long time-scale. Only a series of successful predictions of several solar cycles can serve as a confirmation of the method's reliability and can shape a starting point of confidence; and that requires a number of decades to testify.

Here, the complex solar activity is briefly discussed along with their effects upon the terrestrial environment with a particular reference to the Cyclonic storm of the Atlantic and Indian Ocean respectively. It was also observed from the figures that, the sunspots and the cyclonic storm/hurricane correlate to each other in the sense that, when the sunspot number increases, the frequency of the occurrences of the cyclone increases and vice versa. This gives us an impression that the terrestrial weather pattern is being influenced by the variable solar activity.

7. Conclusion

While the solar indices portray the prevailing 11-year cyclic variability, the most common index of sunspot activity is the sunspot number, which is a synthetic index and is useful for the quantitative representation of overall solar activity outside the grand minimum. The amplitude of each solar cycle varies greatly from the almost clean Maunder minimum to the extremely high amplitude of cycle 19 (Lasted 10.5 years from April 1954 to October 1964). Since the sunspot number increases and decreases over a cycle of around every 11 years, its frequency is much wider when compared to the frequency of the number of Cyclone/Hurricane that occurs almost every year; as evident from all the figures. Also, sunspot number varies from 0-180 in both cases over the mention period of study; whereas the number of Cyclone/Hurricane occurs only between 0 to 10/15 times at the most per year. Hence, we see that their amplitude of each also varies from one another but behave correspondingly. We observed that the solar activity and terrestrial climate are related to each other.

Table 2. Annual Cyclonic storm and corresponding Sunspot No. in the North Indian Ocean

Year	No. of Cyclone	No. of Sunspot	Year	No. of Cyclone	No. of Sunspot	Year	No. of Cyclone	No. of Sunspot
1890	4	7.1	1933	8	5.7	1976	10	12.6
1891	4	35.6	1934	5	8.7	1977	5	27.5
1892	7	73	1935	6	36.1	1978	5	92.5
1893	10	85.1	1936	6	79.7	1979	5	155.4
1894	6	78	1937	6	114.4	1980	3	154.6

1895	5	64	1938	4	109.6	1981	6	140.4
1896	8	41.8	1939	7	88.8	1982	5	115.9
1897	6	26.2	1940	8	67.8	1983	3	66.6
1898	7	26.7	1941	8	47.5	1984	3	45.9
1899	3	12.1	1942	5	30.6	1985	7	17.9
1900	3	9.5	1943	7	16.3	1986	1	13.4
1901	3	2.7	1944	8	9.6	1987	5	29.4
1902	7	5	1945	3	33.2	1988	3	100.2
1903	8	24.4	1946	5	92.6	1989	3	157.6
1904	4	42	1947	4	151.6	1990	2	142.2
1905	6	63.5	1948	6	136.3	1991	3	145.8
1906	7	53.8	1949	1	134.7	1992	7	94.5
1907	8	62	1950	4	83.9	1993	2	54.7
1908	6	48.5	1951	4	69.4	1994	4	29.9
1909	8	43.9	1952	4	31.5	1995	3	17.5
1910	5	18.6	1953	1	13.9	1996	6	8.6
1911	5	5.7	1954	1	4.4	1997	3	21.6
1912	6	3.6	1955	6	38	1998	6	64.2
1913	6	1.4	1956	4	141.7	1999	5	93.4
1914	4	9.6	1957	4	190.2	2000	5	119.6
1915	6	47.4	1958	5	184.8	2001	4	110.9
1916	8	57.1	1959	6	159	2002	4	104.1
1917	3	103.9	1960	5	112.3	2003	3	63.6
1918	5	80.6	1961	5	53.9	2004	4	40.4
1919	6	63.6	1962	5	37.6	2005	3	29.8
1920	5	37.6	1963	6	27.9	2006	3	15.2
1921	4	26.1	1964	7	10.2	2007	4	7.6
1922	6	14.2	1965	6	15.1	2008	4	2.9
1923	4	5.8	1966	8	47	2009	4	3.1
1924	6	16.7	1967	6	93.8	2010	5	16.5
1925	7	44.3	1968	7	105.9	2011	2	55.7
1926	10	63.9	1969	6	105.5	2012	2	57.6
1927	7	69	1970	7	104.5	2013	5	64.7
1928	7	77.8	1971	7	66.6	2014	3	79.3
1929	6	64.9	1972	7	68.9	2015	4	69.8
1930	10	35.7	1973	6	38	2016	4	39.8
1931	5	21.2	1974	7	34.5	2017	3	21.7
1932	6	11.1	1975	7	15.5	2018	7	7

The table above lists the Wolf or Zurich Sunspot Numbers (N) for each year from 1890 to 2018 along with the number of Cyclonic storm occurred in each corresponding year. These yearly means are the most commonly used data's in sun/climate studies. For the years before 1890, data's on North Indian Ocean Cyclonic storm are not reliable.

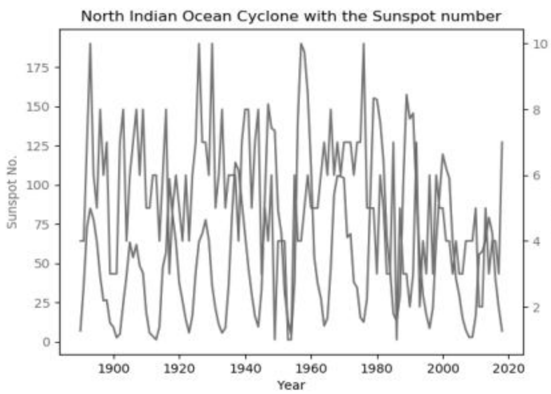

Fig. (i)

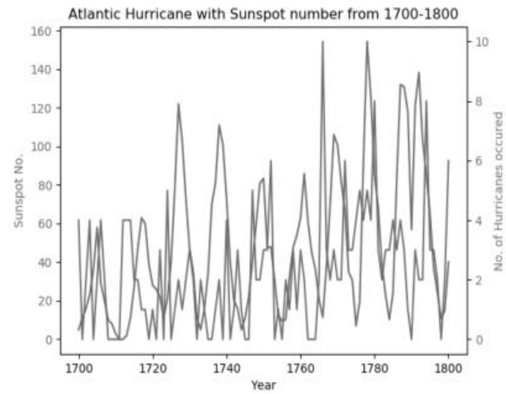

Fig. (ii)

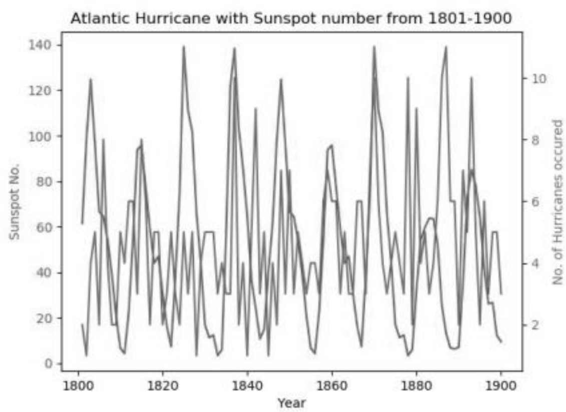

Fig. (iii)

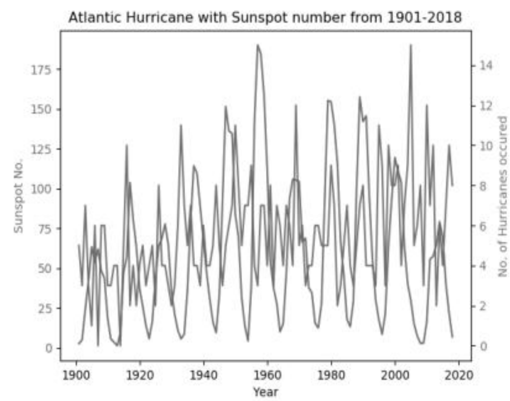

Fig. (iv)

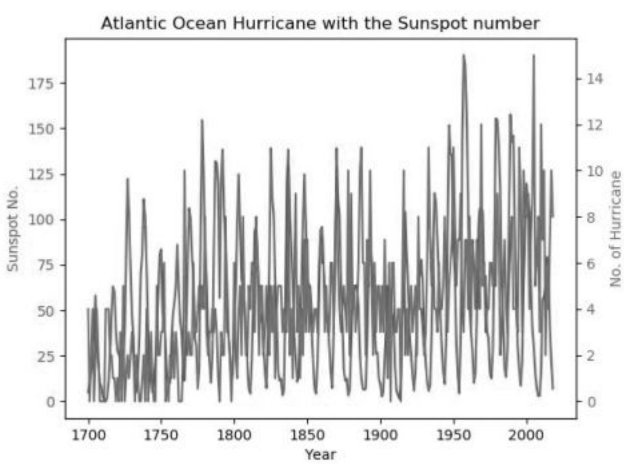

Fig.(v)

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