environmental sciences proceedings

MDPI

Proceeding Paper

The Solar Influence on Tropical Cyclones Occures over Ban of Bengal and Arabian Sea Area †

Banerjee Dhruba*

Department of Physics, Swami Vivekananda Institute of Science and Technology,Dakshin Gobindapur, Kolkata, Pin -700145, India;dhrubabanerjee81@gmail.com

* Correspondence: dhrubabanerjee81@gmail.com;

† Presented at the title,Kolkata,

Abstract: During last few decades a prominent example of extreme weather event in Indian Ocean region is Cyclonic Storm. In this paper annual variation of different categories of tropical Cyclonic Storms like Tropical over Bay Of Bengal (BOB) and Arabian Sea (ARS) have been analyzed .The analysis revels that the total number of cyclone (TNC) has increased with high rate (gradient being +1.67 per year) and although C.S. is more over BOB than that over ARS. The rate of increase of C.S. over Arabian Sea is more than that over Bay of Bengal. Furthermore, two interesting features have been noted: (i) Monsoon tends to prohibit the formation of C.S (ii) Cyclonic Storm(C.S.) increases with the increase of Global Sea Surface Temperature (GSST) during said period. An attempt has also been made to find out the influence of solar activity on these extreme weather events. Keeping in mind that the Sun Spot Number (SSN) is an indicator of the strength of solar effects, it has been found that in most of the times the high value of SSN is associated with small number of total cyclone (C.S.). High SSN (> 90) and number of cyclones shows high Correlation coefficient (0.78) .Significance at 99.99% level while Correlation Coefficient (C.C.) of cyclones with time is 0.53 and with SSN < 60 it is0.095 . Thus it appears that although C.S. frequency is increasing with time, Sun's Spot's influence is such that it basically opposes the formation of cyclone provided SSN exceeds certain critical value (roughly 90).

Keywords: India Ocean; cyclone; solar influence; Critical Sun's Spot Number

Introduction:

The Indian Ocean is one of the most Tropical Cyclone(TC) generating region in the world, like hurricane in Northern Atlantic Ocean (NATL) and Eastern North Pacific Ocean(ENP) and a Typhoon occurs in the Western North Pacific Ocean (WNP), Western South Pacific (WSP) (Li et.al 2013) [1]. The Arabian Sea (ARS) and Bay of Bengal(BoB) are the main TC generating area. These two seas are surrounded by the extremely populated land area. Where the largest costal line of India around 7516 km(5400 km of mainland ,182 km in Lakshadweep and 1900 km of Andaman and Nicobar Island), 1980 km of Myanmar , 990 km of Pakistan , 710 km of Bangladesh is exposed to nearly 10% of the world tropical cyclones (NCRMP reports).

According to some previous work (Girishkumar& Ramachandran,2012)[2] there are two primary TC season, April to May(Pre monsoon) and October to November(Post monsoon) (Balaguru et.al,2012)[3], In post monsoon period at BoB the TC frequency (Singh et.al,2001)[4]. The TC formation of BoB and ARs is lower compared to the Atlantic and Pacific formation .But much higher populated area devastated due to the occurrence of landfall of those TCs in these Indian Ocean region(Webster 2008)[5],(Islam& Peterson 2009)[6],(McPhaden et.al 2009)[7].

Citation: To be added by editorial staff during production.

Academic Editor: Firstname Lastname

Published: date

Internal variability of Post monsoon TC activity in BoB focussing on climate phenomena such as Elnino southern oscillation(ENSO) (Girishkumar and Ravichandran 2012)[2],Indian Ocean Dipole(Singh 2008)[8],(Girishkumar and Ravichandran 2012)[2], Madden –Julian – Oscillation (Kichuki and Wang,2010)[9],CO_2 induced increases in TC intensity in coupled climate model (CCM) but considered only in Atlantic and Pacific basins(Knutson and Tuleya 2004)[10]. (Webster et.al,2005)[11] also studied in the above effects.

In India one of the extreme weather events is cyclone or Hurricanes/Typhoons /Willey Willey/ Baguiaes as it is known in other parts of World (Niyas et al,2009)[12] .The cyclones in India occur mainly either over Bay of Bengal (BOB) i.e. in eastern side or over Arabian Sea (ARS) i.e. the western side. There are different categories of cyclones according to wind speed e.g. cyclones, severe cyclones, super cyclone etc.(Table I). We shall discuss first the Genesis and Frequency distribution of Cyclonic Storms for the duration 1990 to 2009.

The solar influence on earth's climate is very well established things. There are several kinds of approaches has been done in last few decades. (Kim et.al,2017)[13].The solar cycles excite the earth's magnetic field as well as electric field system and the thermodynamic system (Kim & Chang,2014)[14]; (Lee & Yi ,2016)[15];(Na et.al,2016)[16].The various property of solar variability have been made in several important discussion.(Svenesmark & Friis-Christensen,1997)[17];(Reid,2000)[18],(Tinsley,2000)[19];(Roldugin& Tinsley,2004)[20];(Scafetta& West,2006)[21]

2. Materials and Methods

2.1. Data:

In this paper the best track data for tropical cyclone and the maximum wind speed of more than 20kt/hr have been obtained from the report of Cyclone Warning Division of Indian Meteorological Division (IMD), New Delhi and cyclone e-atlas published by IMD. The sunspot number (SSN) have obtained from the Sunspot Index and Long term solar observations (SILSO) i.e SILSO data/ image, Royal Observatory of Belgium, Brussels.The best track data consist of three hourly(00:00, 03:00, 06:00, 09:00,12:00,15:00,18:00,21:00 UTC) centre positions (Latitudes and Longitudes in degree), grade the maximum wind speed in knots (3 hourly average) ,and the central pressure in hPa for all TCs of Tc intensity or higher.

2.2. Genesis and Frequency Distribution of Cyclonic Storm:

With the available data from IMD (Indian Meteorological Department) we find that during1990-2009 maximum C.S. occur 88 in 1999 ,84 in 2004, and 80 in 2001.while minima occur 32 in1990, 30 in 1991 and 23 in 1993.

Aagain we obtain that the mean number of cyclone over BOB and ARS are respectively 843/20 =42 per yr. and 236/20 =12 per yr. (only18% of BOB's mean)

Therefore, the frequency of cyclone over BOB is more than 3 times that over ARS

When data are plotted against time 1990-2009, the Fig. 1 to Fig. 4 are obtained. We find from the fig. - 4 that the frequency of cyclone over ARS are irregular. For example, out of this of 20 years there are no C.S. in 7 years over ARS at all(but such a situation never occurs in BOB region.

Let us now analyze the Monthly variation of C.S as is given in Table-II for both the regions. From the Table-II we make the following observations:

There is no cyclone in both regions in the month of July- August. Also there is no cyclone in ARS in JAN to April

The frequency of C.S. is maximum in May and then in November for both over BOB and ARS. The ratio being 153:132=1.16 for BOB: ARS and then in the month of November it is 262:68=3.9.Thus Maximum no. of C.S occurs over ARS and it is in November, which is almost 4 times that over BOB but in May C.S. no. is almost same over BOB and ARS.

Let us now analyze the seasonal variation of C.S shows in Table-III.

From Table III it becomes evident that Monsoon time is not suitable for the formation of cyclonic storm over BOB and ARS. In other words, Monsoon appears to resist the formation of C.S . However, the resistance appears to be weaker over ARS.

Also we find the frequency of C .S during pre monsoon and post monsoon are more over BOB than it is over ARS. But during Monsoon the reverse thing happens namely the frequency is nearly 1.7 times over ARS than that over BOB region.

Thus it appears that C.S. over BOB (in Eastern India) and ARS (Western India) are interlinked inversely. Now, the rate of increase of C.S in ARS is more than that in BOB (vide ,Fig.-4) therefore in future western India may be more vulnerable for frequent cyclones and reverse is Eastern India implying thereby in the long run this may lead to change in climatic condition in Indian peninsula.

2.3. Annual Variation of Cyclone Frequency for Different Categories:

There are different categories of cyclone over Indian peninsula viz. Bay of Bengal and Arabian sea. When the no. of different types of cyclonic storm are plotted against time we obtain the Fig-1,1a-c. But the super cyclonic storm SuCS are mostly absent except in 1990, 1991,1999 2007 when the nos were 3, 4, 6 and 2 respectively. From the curves and the equations of the trend lines we find the rates and correlation coefficients including average values are as in the Table-III. From the above table we find all the rates are positive But the rate of increase of total cyclonic storm is highest1.67 per yr. and the average no. of total C.S is 59.25. It is, however, can be noted that intense tropical cyclone in the North Indian ocean during 1887 -1998 have also exhibited the similar trend(Singh, Ali Khan and Rahaman , 2008)[8] also see (Webster et al 2008)[5].

3. Result:

If we plot the 3 yrs. Moving average values of total C.S (T.C.S.) & only C.S we obtain the fig.-2 & Fig.-2.1.respectively. We can note that while the no. of C.S has increased step by step during 1990-96, 1997-2001, 2002-2010 like upward stairs,the maximum no. of C.S being (≈ 30,35,55) , the total no. of C.S increases suddenly after 1996 .Evidently the some other type of cyclone might be responsible for this sudden jump. If we look at the Fig.-2.2 & Fig.-2.3 we can note that the two categories namely, severe cyclones (SCS) & very severe cyclones (VSCS) are two events which have more frequent from & after mid nineties. In fact (Singh et al 2001) have pointed out that frequency of intense tropical cyclones has increased more than normal cyclone. In fact but our study reveals that during 1990-2009 while the rate of VSCS & SCS are less namely 0.42 & 0.22 respectively the rate of C.S. is 1.1 per yr.The 3 years moving average exhibit a declining tendency in recent year.

Often Sea Surface Temperature (SST) said to be influential agent for cyclone formation we shall not discuss this except that when SST and C.S. are plotted both are found to increase with time(SST has increasing rate 0.1 per year while TCS has increasing rate 1.67 per yr. Thus it appears at least SST does not give any resistance to cyclone formation (Sikka1977)[22].

We know Sun's Spot Number (SSN) is an indicator of Solar Activities.. If we take all SSN< 60 and the corresponding C.S. the Cor. Coef. comes out to be 0.095 but if we take SSN> 90 the C.C. becomes - 0.784 which clearly indicates inverse relationship exists provided SSN is greater than some critical value(say 90). The existence of such critical SSN has also been observed in many events. Now if we calculate the no. of C.S. in the years of Solar Max. and Min. we obtain the Table-V:

From the Table-V we find from solar maximum to solar minimum the average total C.S. increases from 39 to 60 i.e.by 53% although only C.S. remains almost same and SCS & VSCS increases nearly 5 times. These again supports the adverse effect of high SSN

on Cyclone formation when Solar activities increase. Fig 5 shows the comparative graph of SSN and the no of tropical cyclone.

Figures, Tables and Schemes

Table I. India Meteorological Department classifies the various low pressure systems Forming over the North Indian Ocean, as following:.

Sr.No.	Types of Disturbances	Associated wind speed	
1.	Low Pressure Area	< 17 knots	< 32 km/hr
2.	Depression	17-27 knots	32-50 km/hr
3.	Deep Depression	28-33 knots	51-59 km/hr
4.	Cyclonic Storm	34-47 knots	60-90 km/hr
5.	Severe Cyclonic Storm	48-63 knots	90-119 km/hr
6.	Very Severe Cyclonic Storm	64-119 knots	119-220 km/hr
7.	Super Cyclonic Storm	> 119 knots	> 220 km/hr

Table II. Monthly frequency distribution of Cyclonic Storm over BOB and ARS.

Months	BOB	ARS	Months	BOB	ARS
Jan	23	0	July	0	0
Feb	12	0	August	0	0
March	11	0	September	43	18
April	99	0	October	105	40
May	153	132	November	262	68
June	18	84	December	114	27

Table III. Analysis of seasonal variation of cyclonic storm.

Region	Season	No. per year
BOB-	Pre-Monsoon	15
	Monsoon	3
	Post monsoon	24
ARS-	Pre-Monsoon	6.6
	Monsoon	5
	Post monsoon	6.7

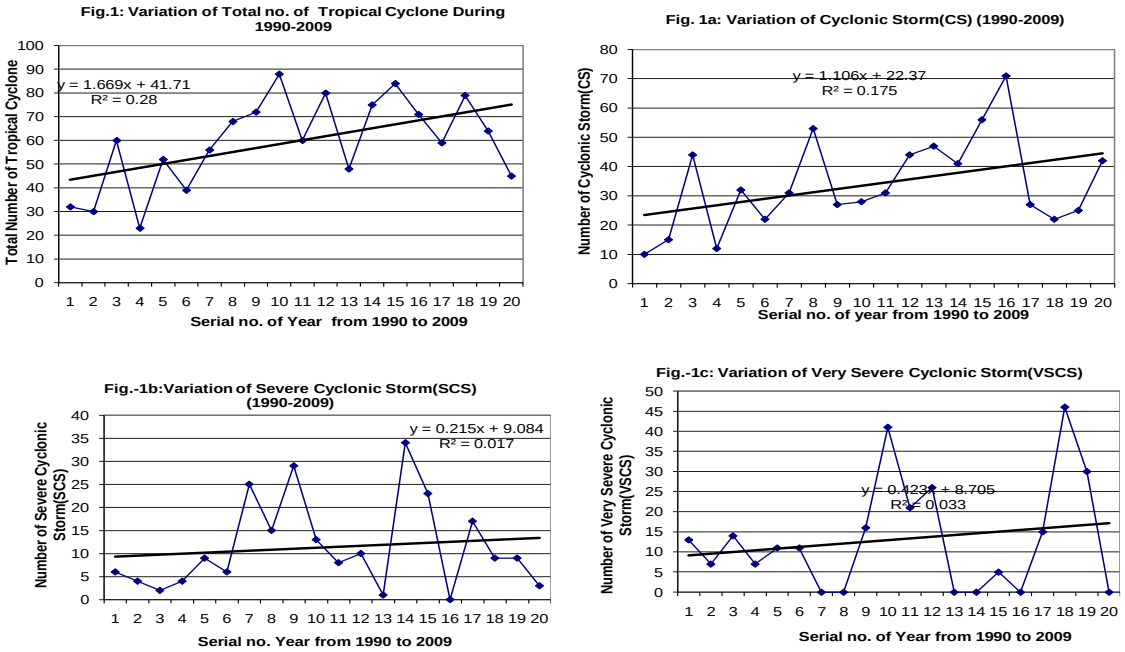
Table IV. Temporal trend of different categories of cyclonic storm.

Category	Average No.	Rate/Gradient	Cor.Coeff	Fig. no.
C.S	34	1.1	0.42	1a
SCS	11.35	0.22	0.13	1b
VSCS	13.15	0.42	0.18	1c
SuCS	0.75	----	----	---
Total CS	59.25	1.67	0.53	1

Table V. Cyclonic storm distribution insolar max and min.

		SSN	CS	SCS	VSCS	SuCS	Total
Solar	1991	146	15	4	7	4	30
maximum	2002	104	47	1	0	0	48

	Total	250	62	5	7	4	78
	Average	125	31	3	3.5	2	39
Solar minimum	1996	8.6	31	25	0	0	56
	2008	2.9	25	9	30	0	64
	Total	11.5	56	34	30	0	120
	Average	5.75	28	17	15	0	60



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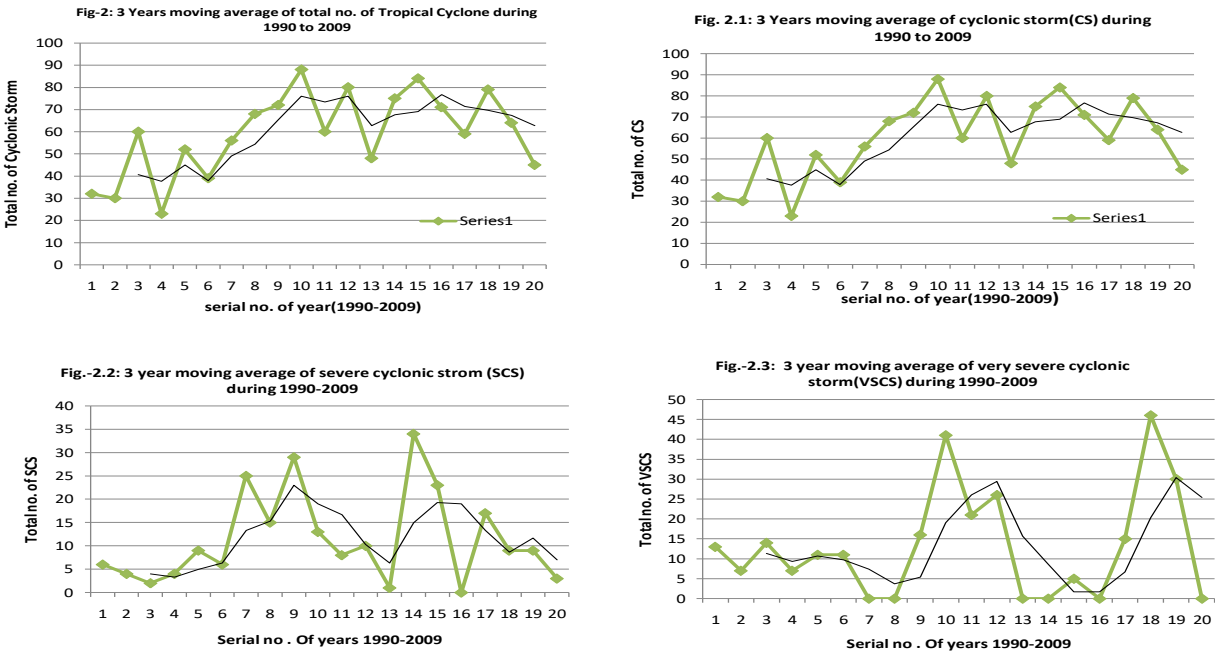
(a)Temporal variation of Different types of Cyclone no during 1990-2009. 155



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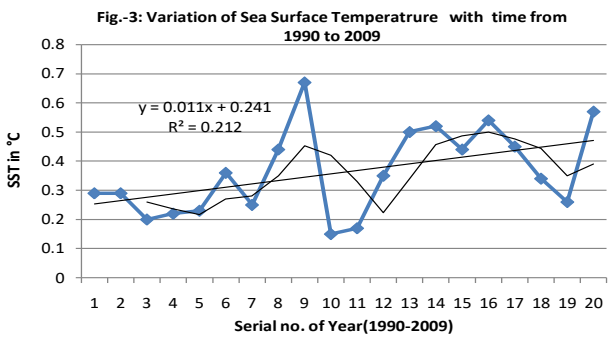
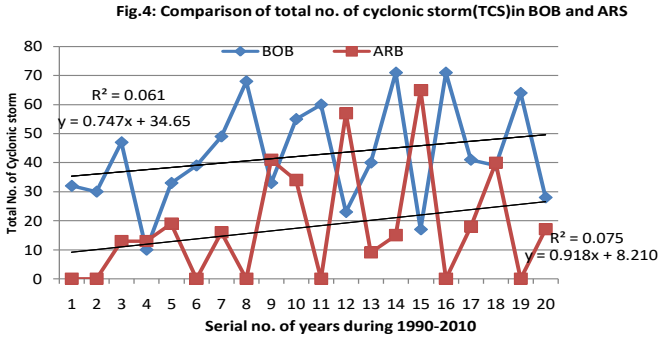
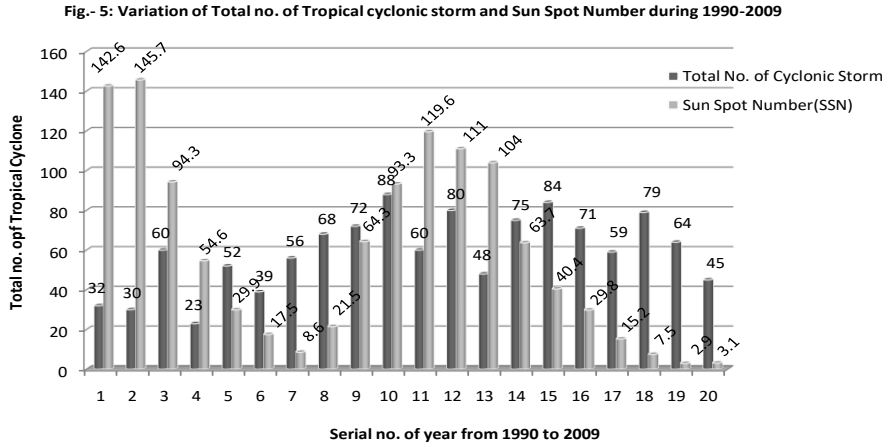
(b) Moving average of different cyclonic storm. 157







(c) Sea surface temperature(SST),Cyclonic storm in BOB and ARS and variation of TCs and Sun-spot number(SSN).

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