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Solar activity as a potential factor for foreshadowing drought in Indian summer monsoon regime

A. CHOWDHURY, V. P. ABHYANKAR and M. V. PHADKE

India Meteorolgical Department, Pune

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ABSTRACT. An attempt has been made to determine influence of solar activity on drought incidence in India. 100 year's rainfall (1875-1974) for northwest and peninsular India, have been analysed with respect to sunspot numbers and Baur's solar index and their distribution during drought years determined. Frequency of drought per cycle of solar activity have been obtained. Association between drought and maximum/minimum spottedness was tested by chi-square technique. Correlation have been computed between sunspots, Baur's index and rainfall during different phases of solar activity.

The results revealed that on an average drought occures once in a solar cycle. Occurrence of maxima or minima did not have any relationship with the drought, which was found to occur earlier as well as later than either of the epochs. Correlation analysis revealed that for the Peninsula, sunspots numbers and its values during middle of the waxing phase were significant. The Baur's index bears significant correlation with northwest Indian rainfall. It's value during the waxing phase as also during middle of waxing phase is also significantly correlated with northwest Indian rainfall. The index was significant for peninsula rainfall during middle of waxing phase.

1. Introduction

The sun being the ultimate source of energy in all meteorological processes, a possible association between the solar output and weather has long been investigated. Variations in the darkening of the photosphere has often been linked with long term climatic changes. The evidence presented concerning this relationship has been contradicting, complicating and rather confusing. By working out variations of excess or sub-normal daily rainfall, during post-monsoon season in Tamilnadu, Sengupta (1957) found significant correlations between sunspot activity and rainfall pattern. Jagannathan and Raghvendra (1966), related rainfall frequency parameters at selected stations in Rajasthan in the maximum and minimum epochs of the sunspot and found the variations in the parameters independent of solar activity. Recurrence of more frequent excess rainfall days over west Uttar Pradesh in January during sunspot minimum phase was observed by Deshpande (1970). Recently, King (1973) for example, found strong correlation between changes in solar radiation and climatic feature like drought, while Shapiro (1975) did not detect any apparent solar signal in the surface phenomenon.

The occurrence of drought and famine conditions in India, of late, has become a recurrent feature. Forecasting of drought from the past behaviour of rainfall series alone, has, however, met with little success (Raman *et al.* 1970, Rao *et al.* 1973, Chowdhury and Abhyankar 1979 etc). It was, therefore, thought worthwhile to explore the possibility of forecasting occurrence of weather phenomena like drought or sub-normal rainfall from the expected level of solar activity. In the present study, this extra terrestrial phenomena has been used as a parameter to determine its potentiality in forecasting drought. In the first work of its kind, anywhere in the world, and based on data from 1865 to 1912 for a few selected stations in India, Walker (1915) concluded that variations in solar activity affect the monsoon rainfall as a whole, but not the irregularity in its geographical distribution.

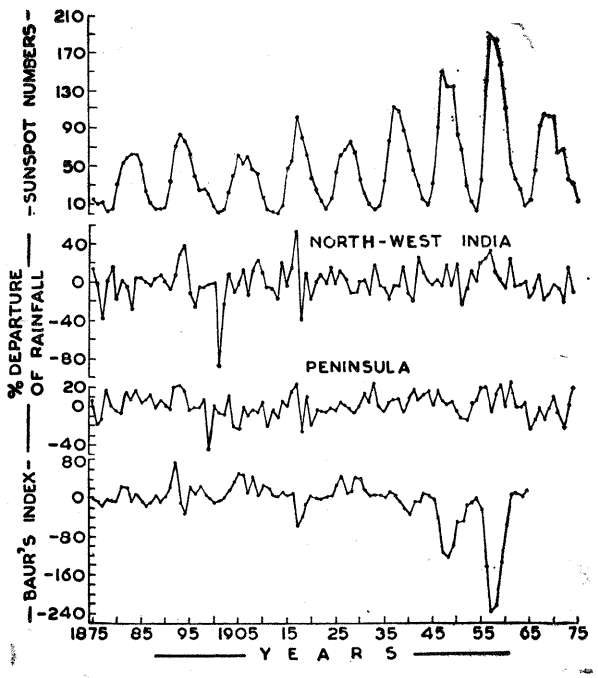

Fig. 1. Annual sunspot numbers, Baur(s) index and the rainfall departures (% for Peninsula and Northwest India)

2. Data material

From the rainfall point of view, the country is divided into two board forecast zones, *viz.*, northwest India and the peninsula, both being equally prone to frequent droughts. Annual rainfall for 100 years (1875 to 1974) are correlated with identical series of sunspot data. Pertinently, about 90 per cent of the annual rainfall in India, falls during the northern hemispheric summer between June to September. The mean annual sunspot numbers published by Wolf and Wolfer have been used, suplemented by those given by Lamb (1972). Correlations are obtained between rainfall and sunspots when alternatively it is at its extremes, during waxing and waning phases of the solar disturbances and during the middle of the rising or falling sunspot trends. Baur's index, which is a more reliable measure of variations in sun's photospheric activity are available for 90-year period (1875 to 1964) and are utilised in the study.

3. Rainfall classification

In India Meteorological Department, while considering spatial distribution of rainfall negative departure exceeding 19 per cent of the normal is termed as "deficient". In this study, also rainfall deficiency exceeding 19 per cent is designated as a drought situation. Similarly, rainfall exceeding 19 per cent of the normal in a year is termed as a wet year or an year of excess rainfall. Years not belonging to either of these categories are termed as years of normal rainfall. No attempt has been made to define degree of drought or wetness or to associate them with the solar eruptions.

4. Baur's index

Sunspots are normally accompained by other types of solar emissions, *viz.*, (*i*) occasional eruptions in which both ultraviolet and long wave radiations and particle emissions are produced; and (*ii*) bright faculae which are usually present around the spots. Sunspot numbers which measure only the dimmed portion of the sun, is perhaps not a very good indicator of variations in solar output. To overcome this deficiency, Baur (1949) proposed a solar index (S.I.) which gives a more reliable measure of solar fluctuations. Logically also better results should be expected from an index which measures the total area of faculae, *i.e.*, bright portions of the sun *minus* the total area of the spot (dimmed sun). The index is given by the following relationship :

$$\text{S.I.} = 10\,(F/\bar{F} - D/\bar{D})$$

where,

F = total area of sun's visible face;

D = total area of sunspots;

$\bar{F}$ & $\bar{D}$ = long term averages of F & D respectively.

5. Drought, wetness and the solar cycle

The period under study covers a little over 9 solar cycles. Over peninsula during the period, 6 cases each of drought and excess rainfall are noticed while northwest India experienced drought on 10 occasions and excess rainfall on 9 occasions. Thus on an average, one drought and one wet situation can be expected per cycle in the northwest India. Two instances of drought or wetness each may be expected in three oscillations of the solar cycle over the peninsula.

Strong fluctuations in the drought incidence or excess rainfall activity, occurred in different sunspot cycles though apparently without any regularities. The variation in the frequency is totally unrelated to that of the preceding or succeeding cycle so as to facilitate prediction. They are fairly frequent in some cycles occurring upto 3 times; in some cycle they are conspicuously absent.

6. Apparent climatic relationship and solar cycles

Fig. 1 shows a comparison between annual sunspot and the Baur's index together with the annual rainfall departures for both northwest India and the peninsula. This display the oscillations clearly in these elements and no regularity in successive peaks or trough is seen. The points are randomly scattered and do not indicate any relationship of the rainfall with either sunspot or the Baur's index. Any linear or functional relationship between these elements should have been reflected

TABLE 1

Correlation between the rainfall & sunspots, rainfall and Baur's index during different phases of the cycles

Sunspots & rainfall	Baur's index & rainfall	Phase of the cycle
	Peninsula	
0.20*	—0.16	All cycles
0.05	0.06	Maximum epoch
—0.04	—0.03	Minimum epoch
0.22	—0.21	Waxing phase
0.16	—0.18	Waning phase
0.61*	—0.72*	Middle of waxing phase
—0.15	0.27	Middle of waning phase
	Northwest India	
0.16	—0.22*	All cycles
0.43	—0.55	Maximum epoch
—0.01	0.02	Minimum epoch
0.29	—0.44*	Waxing phase
0.04	—0.19	Waning phase
0.58	—0.65*	Middle of waxing phase
0.03	0.18	Middle of waning phase

*Significant at 5% level

TABLE 2

Rainfall frequency during years in the vicinity of maximum and minimum epochs

Years	m—1 to m+2	M—1 to M+1	All other years	Total	Chi-square
		Peninsula			
Drought	2	1	6	9	3.92
Normal	26	24	35	85	(Not significant)
Wet	4	2	2	8	
Total	32	27	43	102	
		Northwest India			
Drought	2	3	4	9	1.34
Normal	27	20	44	91	(Not significant)
Wet	3	4	3	10	
Total	32	27	51	110	

m — Minimum epoch, M — Maximum epoch

in the alignment of the dots which, however, is lacking in this case. Dot diagrams (figures not presented) supported this postulations which has been confirmed by the correlation coefficient (shown in Table 1). The correlation coefficient between rainfall of northwest India and the Baurs' index and the peninsular rainfall and the sunspot, though small, are significant because of large available degrees of freedom and may perhaps not be interpreted as an indication of any linear relationship. It would also appear that there is no direct association between the solar activity and the rainfall, and the apparent solar-terrestrial relationship observed in isolated cases, the possibility that it is purely by chance, cannot also be entirely ruled out.

With a view to examining if there exists any relationship during some characteristic phases of the solar activity, such as rising/falling tendency of sunspots and particular type of rainfall departures, cycle is split-up in waxing and waning phases and correlations obtained. Correlations are also obtained between the rainfall with the sunspots and the Baur's index during the extreme epochs as well as the middle of the rising and falling tendencies of the solar activity. The results are illustrated in Table 1. The correlation coefficients are not found statistically significant, except in the following cases :

Peninsular rainfall

(*i*) With sunspot numbers in general,

(*ii*) Sunspots during the middle of waxing phase,

(*iii*) Baur's index during the middle of waxing phase.

Northwest India rainfall

(*i*) With Baur's index in general,

(*ii*) Baur's index during waxing phase,

(*iii*) Baur's index during the middle of waxing phase.

The high correlation observed in a few cases, may perhaps be the result of random coincidence of large departures of the same size in two elements and should not be interpreted as a consistent relationship. For their significance to be regarded as established, relationship of this kind needs to be observed for some more samples. This analysis thus confirms the conclusion drawn earlier that there is no direct relationship between the rainfall and the different stages of the solar cycle.

It may be stressed that cases where high correlations have been observed, not much variance could be explained. The maximum variance that these relationship explained was about 50 per cent. Thus, these high correlations are not of much predictive values.

7. Possible association with rainfall frequency

Relationship, if any, between the frequencies of rainfall departures and stages of sunspot cycles has also been examined. For this purpose, frequencies of wet, dry or normal years during the period from one year prior to the minima epoch to two years subsequent to it, and one year on either side of the maxima epoch are prepared. The resulting distribution is shown in Table 2,

and the statistical significance is tested by computing the chi-square. In neither peninsula nor northwest India is chi-square found significant. Thus, it appears that there is no apparent significant relationship between the frequences of occurrence of rainfall departures and the stages of the solar extremes.

8. Concluding remarks

The quest for understanding the interaction between the weather and the solar activity has proved extremely difficult. This is because the sunspot numbers are but one of the several types of solar disturbances for which largest records are available. The foregoing analysis clearly shows that the rainfall distribution in India does not reveal any characteristic fluctuations parallel to the anamolous variations of solar flares, and that there is no real cause-effect relationship between the solar activities and the monsoon rainfall. It is, thtrefore, not surprising to find that the apparent positive, but small, correlation found by Walker (1915) between Indian rainfall and the sunspots though maintained for few sunspot cycles, has nevertheless not yet become numerically large and statistically significant. The association between the sunspot activity and the rainfall is not consistent from cycle to cycle of sunsport variations as found earlier by Satakopan (1946). Hence it does not appear possible to forecast the nature of rainfall from the trend variations of solar out-burst.

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