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Study of thunderstorm and rainfall activity over the Indian region

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RESUMEN

Se utilizaron las medias mensuales de días de tormenta (TS) y cantidad de lluvia (RF) correspondientes a treinta años (1951-1980), obtenidas de 260 observatorios distribuidos de manera uniforme en el país, para obtener los porcentajes de ocurrencia mensuales, estacionales y zonales a partir de los totales de la India. Los resultados indican que hay un lapso de tiempo de un mes entre la presentación de los picos de actividad de TS y RF. El análisis estacional de estos dos parámetros sugiere que la precipitación asociada con la temporada de TS postmonzón parece ser mayor que la de la temporada premonzón. El análisis de TS y RF en seis zonas indica que hay un gran rango de variación en los dos parámetros mes tras mes en estas zonas, pero que la media de treinta años del porcentaje de ocurrencia es más o menos de la misma magnitud en cada zona.

ABSTRACT

Thirty years (1951-1980) of mean monthly thunderstorms days (TS) and rainfall (RF) amounts for 260 Indian observatories spread uniformly over the country were used to obtain their monthly, seasonal and zonal percentage of occurrence from all India totals. The study has revealed that there is a time lag of one month in the occurrence of peak activity of TS and RF. Seasonal analysis of these two parameters suggest that rainfall yield associated with postmonsoon season TS seems to be higher than the premonsoon season. Six zone analysis of TS and RF has suggested that there exists a wide range of variation in both parameters month after month in that zones, but the 30 year mean percentage of occurrence seems to be more or less equal in magnitude in each zone.

Key words: Thunderstorms, rainfall, convection, thunderstorm climatology, Indian summer monsoon.

1. Introduction

In India, the interest in thunderstorms and the related rainfall has been evinced for a long time. It is an important weather phenomenon particularly during premonsoon and postmonsoon seasons over the Indian region. There exists hardly a month without the occurrence of thunderstorms in some or other part of the country.

Thunderstorm phenomenon is important to meteorologists and it is an important hazard to aviation (Awadesh, 1992). A knowledge, therefore, of thunderstorm climatology is essential for meteorologists.

Considerable amount of literature is available on thunderstorm studies over the Indian region as well as abroad (Sohoni, 1931; Rao and Raman, 1961; Raman and Raghavan, 1961; Williams, 1961; Chaudhury, 1961; Rao *et al*., 1971; Balogun, 1981; Oladipo and Mornu, 1985; Prasad and Pawar, 1985; Sivaramkrishnan, 1990; Awadesh, 1992; Moid, 1995, 2001) during the last three decades in which many successful investigations have been made to understand the climatology, frequency, diurnal variation, monthwise and seasonwise distribution of thunderstorms.

Among the studies referred above, most of them has been restricted to a particular station or small area, or more restricted to definition of thunderstorms, except some studies made by Raman and Raghavan (1961) and the recent study of Manohar *et al.* (1999). This couple of studies have dealt with many stations in India and investigated the TS activity.

However, the present study pertains to a large number of stations (260) which cover the whole Indian region. The purpose of this study is to focus attention on the general distribution of thunderstorm and rainfall on an annual, seasonal, monthly and zonal basis. This study also emphasis the need for more studies in this direction.

2. Data and methodology

The mean monthly values of thunderstorms days (TS) and rainfall amounts (RF) for the 30 year period (1951-1980) were used in the present study. These data have been obtained from climatological tables published by the India Meteorological Department (IMD, 1999), Pune, for 300 meteorological observatories. These tables give 30 year monthly average values of thunderstorm and rainfall along with their annual sums. In the present study TS and RF data for only 260 stations were used which are well distributed all over the country. The criterion adopted for selection of the stations and hence for data was: mean value of TS and RF should be available for the entire 30 year period. The location of these stations are shown in Figure 1. Using the above data of TS and RF for all 260 station, the following mean values have been computed:

(i) Annual totals

(ii) Monthly mean percentage of occurrence of TS and RF

(iii) Seasonal percentage of occurrence of TS and RF. The seasons are premonsoon (March-May); monsoon (June-September); postmonsoon (October-November); Winter (December-February)

(iv) India has been divided into six homogeneous regions based on RF as suggested by Singh and Sontakke (1999). These regions are depicted in Figure 4. The zonal monthly mean percentage of occurrence of TS and RF have been prepared. The above monthly, seasonal and zonal mean percentages are useful to understand the distribution of the above two parameters across the country.

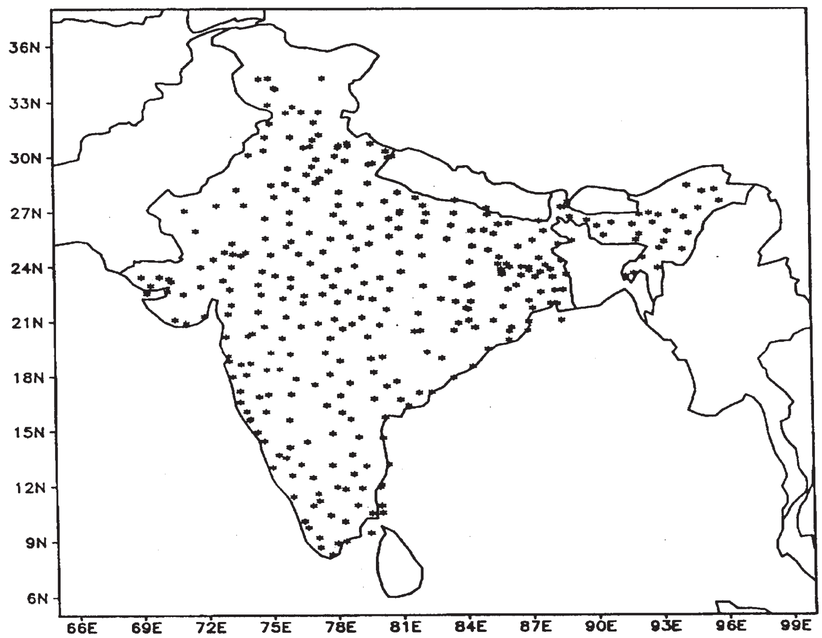

Fig. 1. Map of India showing 260 observatory stations.

3. Results and discussion

3.1 Monthly percentage of occurrence of TS and RF over the Indian region

Figure 2 shows the histogram of all India annual mean percentage of occurrence of TS and RF (average of all 260 stations). From this figure it is seen that the TS activity increases consistently from the month of January and attains a first peak in the month of June. It then decreases till the end of July and then again picked up in the month of August, and attains a second lower peak in the month of September. After September the activity has diminished systematically. The RF activity also shows similar increase as TS during the first half of the year, but, in this case the increase has started from the month of March consistently and giving rise to a single peak in the month of July. From July onwards the activity shows a systematic diminution. A careful examination of this figure suggests that there is a time lag of one month in the occurrence of peak activity for TS and RF. This lag may be due to the prime period of the onset phase of summer monsoon rainfall over the Indian region. The pre-onset period is mostly associated with an increase in the TS activity (Manohar *et* al., 1999). Reduced TS activity corresponding to a peak increase in the RF activity is again related with the setting up of summer monsoon over the Indian region. These results clearly suggest that during the period of active monsoon season the occurrence of TS is relatively diminished. The present result of low percentage of TS occurrence which corresponds to a peak period of the monsoon season is in partial agreement with the result of Zipser (1994). Also, it is seen that TS and RF activity is observed to be minimum in winter months. The correlation coefficient (CC = 0.7835) obtained between these two parameters is significant at 0.1% level.

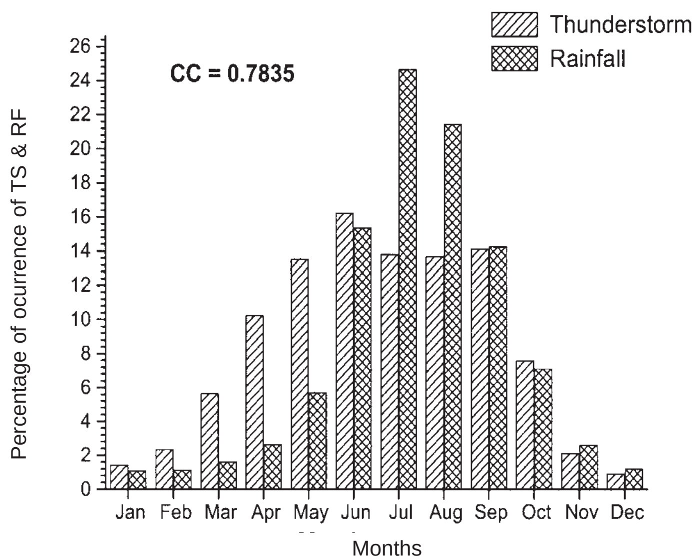

Fig. 2. Annual percentage of thunderstorms (TS) and rainfall (RF) during 1951-1980 over the Indian region.

3.2 Seasonal percentage of occurrence of TS and RF

Figure 3 is a bar diagram of the seasonal percentage of occurrence of TS and RF over the Indian region. It is seen from this figure that the percentage of occurrence of TS activity appears to be higher than that of RF activity in the premonsoon seasons whereas it is nearly equal in post monsoon and winter seasons. In the monsoon season the RF activity is higher than the TS by 18%. The percentage of occurrence of RF in premonsoon, monsoon, postmonsoon, and winter seasons is 10, 61.5, 21.4 and 6%, whereas the corresponding TS percentage is 29.5, 43.5, 21.7 and 6.9% respectively. From these percentages it appears that both RF and TS activity are observed to be maximum in the monsoon season (i.e. 61.5 and 43.5%) as compared to the other three seasons (Landsberg, 1971; Freier, 1978; Zipser, 1994; Manohar *et al*., 1999). Seasonal CC value is computed and it is 0.82. The observed higher value of CC may be an outcome of the maximum TS and RF activity during the monsoon season. This result appears to be consistent with the studies made by Manohar *et al*. (1999). These studies suggested that in the monsoon season the onset, withdrawal and revival of monsoon after the break are associated with merging of thunderstorm activity. Further, it is also seen that in the premonsoon season the percentage of occurrence of TS is 29.5% and that of RF is 10%. These higher and lower values of TS and RF for this season can be explained as the RF associated with certain TS is mainly due to convection. Hence the RF yield confined to certain TS depends upon the availability of moisture and in some cases RF yield may not be available due to lack of moisture (Koteswaram and Srinivasan, 1958).

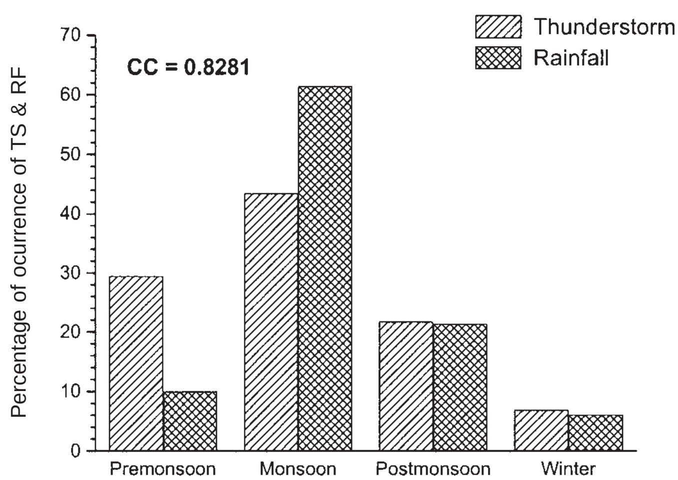

Fig. 3. Seasonal percentage occurrence of TS and RF over the Indian region during 1951-1980.

During the post monsoon season, the percentage of occurrence of TS and RF activity is observed to be nearly the same (i.e. 21.7 and 21.4%, respectively). Percentage comparison of TS and RF between pre- (29.5 and 10%) and post- monsoon seasons suggests that TS in post monsoon seasons produces more rainfall. Possibly the more RF activity is mainly due to the western disturbances and the formation of tropical cyclones in the Bay of Bengal (Paul, 2001).

The correlation coefficient between TS and RF is computed for all seasons together as well as for individual seasons. For all seasons the value of CC, 0.8140, is significant at 0.1% level, and for individual seasons the values for premonsoon, monsoon, postmonsoon, and winter seasons are 0.92, -0.90, 1.0 and 0.37, respectively. Here, it is interesting to note that the correlation coefficient between TS and RF during the monsoon season is -0.90. The plausible cause for a negative correlation coefficient between the above variables is an increase in RF by warm monsoon clouds. Manohar *et al*. (1999) have observed that TS activity over India increases from south to north following the onset and the advance of the southwest monsoon from Kerala to Kashmir. Thus, this may be the plausible reason for the reducing of TS activity following the heavy rainfall from south to north. The reason for high TS activity in the north (Manohar *et al*., 1999) is the collision of warm moist air from the south and cold dry air from the north near the northern latitude (18-23°N) in this season.

3.3 Monthly percentage of occurrence of TS and RF for six different zones

Figure 4 shows the six different zones of the Indian region and the corresponding stations. Figure 5(a-f) gives the monthly percentage of occurrence of TS and RF in six different zones, North-West India (NWI) (Fig. 5a), North-Central India (NCI) (Fig. 5b), North East India (NEI) (Fig. 5c), West-Peninsular India (WPI) (Fig. 5d), South-Peninsular India (SPI) (Fig. 5e), and East Peninsular India (EPI) (Fig. 5f). In these figures the open bar represents TS and the dark shaded bars represent RF. The characteristics of TS and RF noticed from Figures 5(a-f) are described in Table 1.

From this table it is seen that extending from west to eastwards, and east of longitude 77°, during the monsoon months (June-September), a spatial increase is noticed in TS and RF but their magnitude shows consistent decrease in all zones except NCI and EPI. A probable cause for this increase for NCI and EPI is that these zones come directly under the monsoon trough region (Rajkumar and

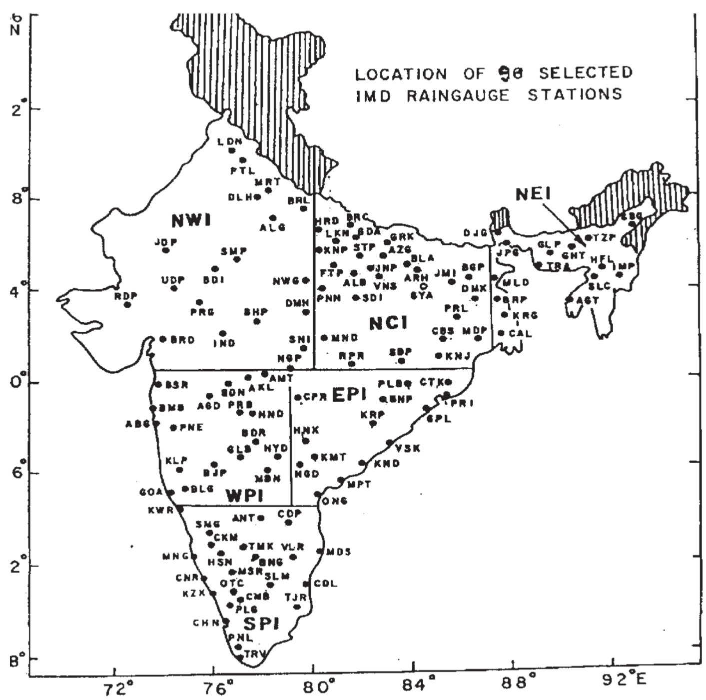

Fig. 4. Map of India showing six homogeneous zones of the Indian region.

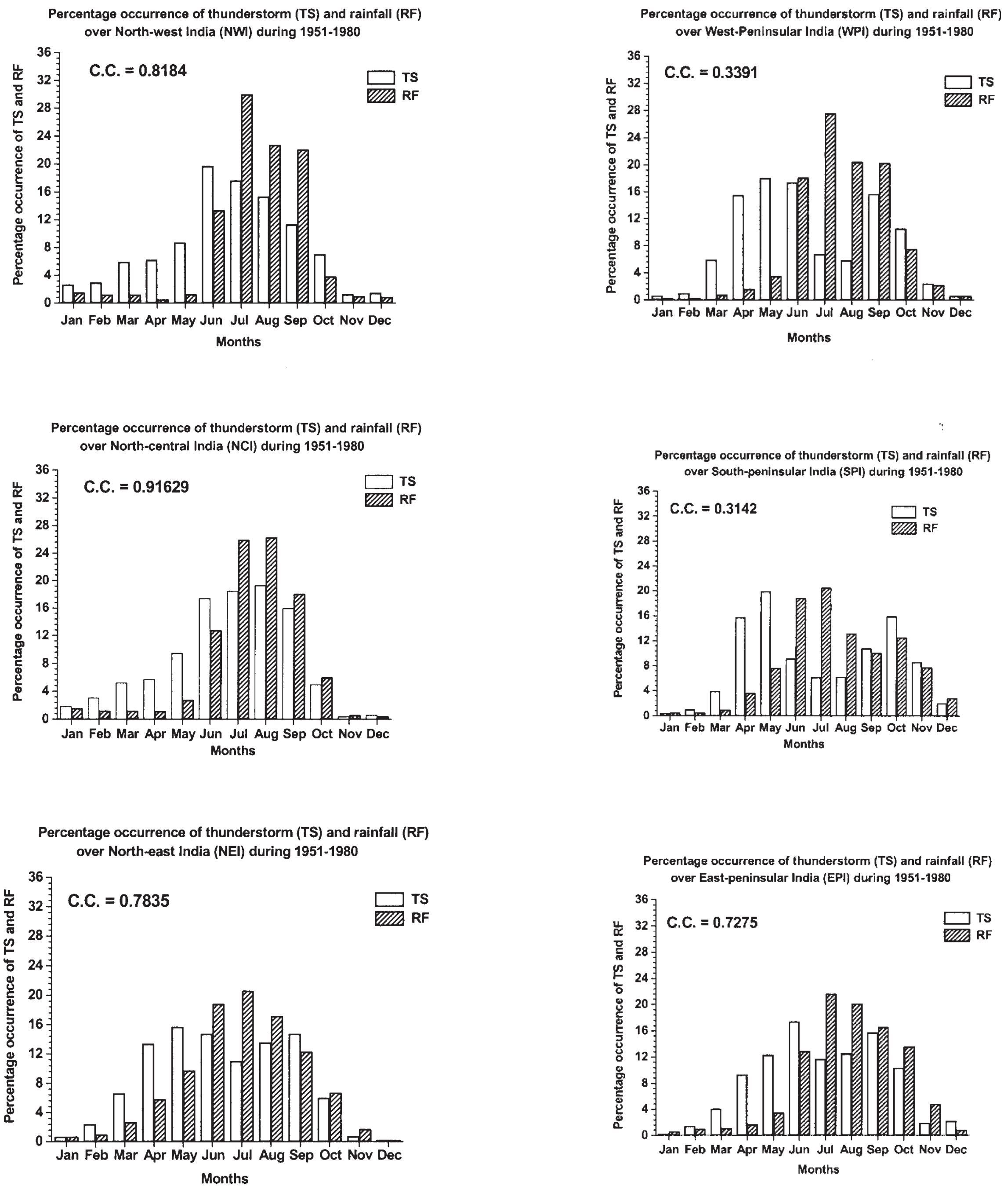

Fig. 5. Percentage occurrence of TS and RF for six different zones

Table 1. Characteristics of percentage of occurrence of TS and RF for six zones during 1951-1980.

Zones	% Range TS	% Range RF	TS maxima	RF maxima	% of TS/RF occurred between June and Sep.	CC values
NWI	1-20	0.3-30	June	July	64 / 86	0.82*
NCI	0.5-19.5	1-26	August	August	71 / 83	0.92*
NEI	0.2-18.5	0.9-21	May and Sep	July	54 / 69	0.78*
WPI	0.5-18	0.5-28	May and Sep	July	46 / 86	0.34
SPI	0.2-20	0.3-20	May and Oct	July and Oct	57 / 71	0.31
EPI	0.2-18	0.2-22	June and Sep	July	32 / 63	0.73*

* Significant at 0.1% level.

Narishima, 1996). In addition, this frequent occurrence of cyclonic storms and the depression over the Bay of Bengal may be one of the reasons for the increase noticed in TS and RF in EPI. For NCI the increase in TS and RF activity may be the effect of more land mass area and hence maximum convective activity. The last column of Table 1 gives the CC value of each zone. From these values it is seen that, except WPI and SPI, the CC values are significant at 0.1% level. The lower CC value at SPI and WPI may be due to the minimum land mass area of the zone affecting the convection. The slightly higher value of CC at WPI may be due to the occasionally development of a low pressure system in the Arabian sea.

Figure 6 shows the pie diagrams for TS and RF for six different zones as discussed in Table 1. These pie diagrams represent the 30 years mean percentage of occurrence of TS and RF in

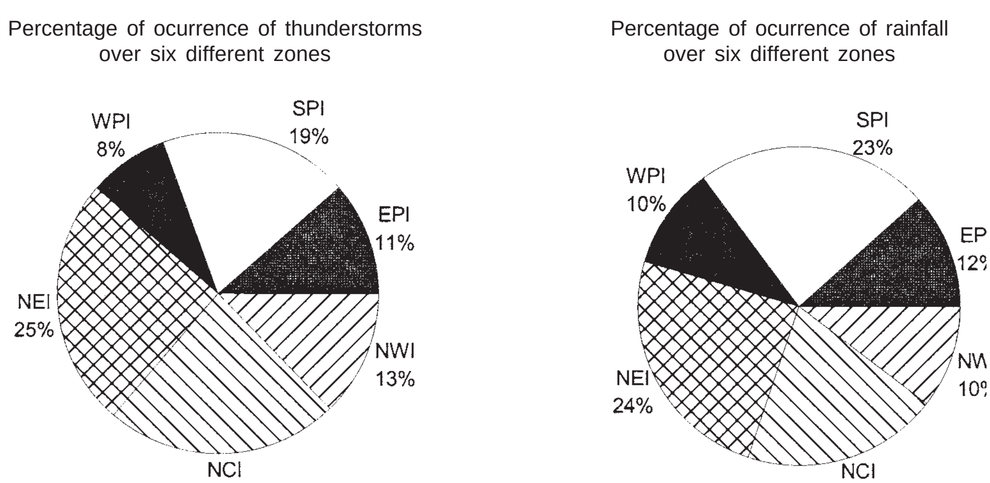

Fig. 6. Pie diagram showing the percentage of occurrence of TS and RF (percentages obtained from all India TS and RF activity)

different zones. From this figure it is seen that the highest (25%) percentage of occurrence of TS is noticed in NEI and the lowest (8%) in WPI, whereas the percentage of occurrence of TS in the other four zones is 24% in NCI, 13% in NWI, 11% in EPI and 19% in SPI. Similarly for RF the highest (24%) mean percentage of occurrence is observed in NEI, the lowest (10%) in WPI and NWI. In the other zones the percentages are 23% in SPI, 20% in NCI and 12% in EPI. This figure also suggests that although both parameters (TS and RF) show a wide range of variation month after month, as discussed in Figure 5(a-f), their 30 years mean percentage of occurrence seems to be more or less equal in each zone, i.e. 25 and 24% respectively in NEI; 24 and 20% in NCI, 13 and 10% in NWI; 11 and 12% in EPI; 19 and 23% in SPI and 8 and 10% in WPI.

4. Conclusions

After analizing 30 years (1951-1980) of mean TS and RF data for 260 stations well distributed all over the country we can suggest the following:

(i) The monthly mean percentage of occurrence of TS and RF suggests that there is a time lag of one month in the peak occurrence of TS and RF which may due to prime period of onset of the SW monsoon over the Indian region.

(ii) Seasonal percentage of occurrence of TS and RF shows that (a) in the monsoon season both parameters show higher percentage of occurrence. The negative correlation coefficient obtained in this season may be due to the mixed mode of continental and monsoon regimes of the convective rainfall; (b) rainfall activity associated with TS in the post-monsoon season is higher than that of the premonsoon season; this may be due to the occurrence of tropical cyclones in the Bay of Bengal.

(iii) Monthly percentage of occurrence of TS and RF at six different zones shows that, except for WPI and SPI, both parameters are highly correlated.

(iv) Six zone analysis of TS and RF has suggested that there exists a wide range of variation in both parameters month after month in respective zones, but the 30 year mean percentage of occurrence of TS and RF seems to be more or less equal in magnitude for each zone.

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