551.515.2 :551.553.21

INTER-RELATIONSHIP BETWEEN NW PACIFIC TYPHOON ACTIVITY AND INDIAN SUMMER MONSOON ON INTER-ANNUAL AND INTRA-SEASONAL TIME-SCALES

1. The various aspects of the inter-relationship between Indian summer monsoon and NW Pacific typhoon activity were studied by many researchers. Raman (1955) associated breaks in monsoon spells with typhoons in the west Pacific moving north of Lat. 30°N. Saha *et al.* (1981), Sadler and Kilonsky (1977) and Ramanna (1969) addressed westward propagating remnants of NW Pacific typhoons and monsoon depressions. Recently Joseph (1990) examined the association between monsoon activity and cyclogenesis over NW Pacific on intraseasonal time-scale of 30-50 day cycle. In this study the relationship between the Indian summer monsoon and NW Pacific on interannual and intraseasonal time-scales is empirically examined.

2. *Data* — The number of typhoons monthwise during the period 1959-1989 and six hourly tracks of typhoons (1970-1988) were obtained from Joint Typhoon Warning Centre, U.S.A.

All India summer monsoon rainfall time series was obtained from Parthasarathy *et al.* (1987), and the details of monsoon depressions and other data relevant to monsoon activity were taken from *Indian Daily Weather Report* and weather summaries in *Mausam*, published by India Meteorological Department.

3. *Results and discussion*

3.1. In order to examine whether monsoon rainfall is related to typhoon activity prior to, and during the monsoon season the time series NT1, NT2, NTD1, NTD2 were constructed and correlation coefficients were computed. The number of typhoons formed and the number of typhoon days observed during the period March to May and June to September are denoted as NT1, NT2, NTD1 and NTD2 respectively. The low pressure systems with maximum wind speed exceeding 33 kt are termed as typhoons.

A typhoon day is counted as the day in which a typhoon was observed at 0000 UTC over NW Pacific. If there were more than one typhoon on that day it was counted as one only. The latitudinal belt in which typhoon days have been worked out is between equator and 35° N.

Correlation coefficients were computed with monsoon rainfall time series (MRF) and are given below as NT1 (—0.01), NT2 (—0.16) for the period 1950-1989 and NTD1 (—0.13), NTD2 (—0.653) for 1970-1988. The value of NTD2 is significant at 1% level.

The time series of number of typhoon days during the monsoon months June to September is correlated with monsoon rainfall significantly. The time series NTD2 and MRF during the period 1970-1988 are shown in Fig. 1. During the years with deficient monsoon rainfall typhoon days were more than normal and *vice versa.*

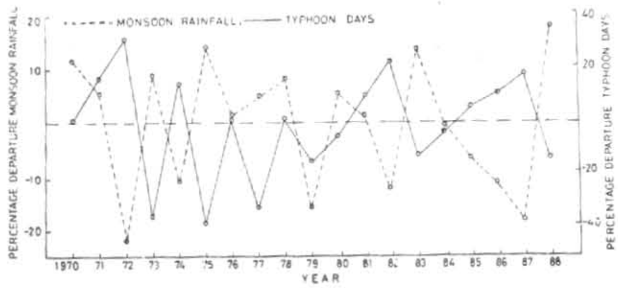

Fig. 1. Time series of all India monsoon rainfall and typhoon days during the months June to September (Period : 1970-1988)

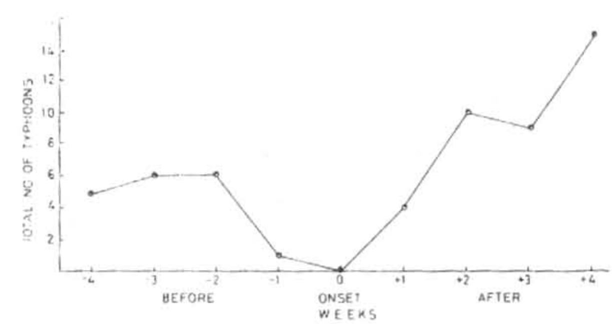

Fig. 2. Superposed epoch diagram with zero week containing monsoon onset over Kerala during the period 1970-1988 showing number of typhoons formed 4 weeks before and after monsoon onset

Kanamitsu and Krishnamurti (1978) pointed out that excess typhoon days was one of the reasons for deficient rainfall during 1972. When west Pacific becomes active with excess typhoon days intense atmospheric heating causes Tibetan anticyclone to shift southeastwards and lead to weak monsoon.

3.2. Fig. 2 shows the superposed epoch diagram with zero week containing monsoon onset over Kerala during the period 1970-1988 showing number of typhoons formed 4 weeks after monsoon onset and 4 weeks before monsoon onset. It can be noticed that typhoon genesis suddenly drops during the onset phase of monsoon over Kerala. In fact not a single typhoon has formed on the week containing monsoon onset during 19-year period considered in this study. This means during onset phase of monsoon over Kerala the ITCZ over Pacific becomes inactive. Typhoon genesis is associated with the activity of ITCZ as most of the typhoons originate in or just poleward side of the ITCZ (Gray 1968).

To see whether more/less typhoon days before onset date cause delay in monsoon onset, the correlation was computed between time series NTD1 and time series of onset dates. The correlation was found to be —0.162 which is very poor and not significant and thus it can be concluded that typhoon activity does not affect monsoon onset date.

TABLE 1

Number of typhoons formed over NW Pacific during active and weak spells of monsoon yearwise 1985-1988

Year	Active spells	Weak spells
1985	2	6
1986	2	5
1987	0	7
1988	1	4
Total	5	22

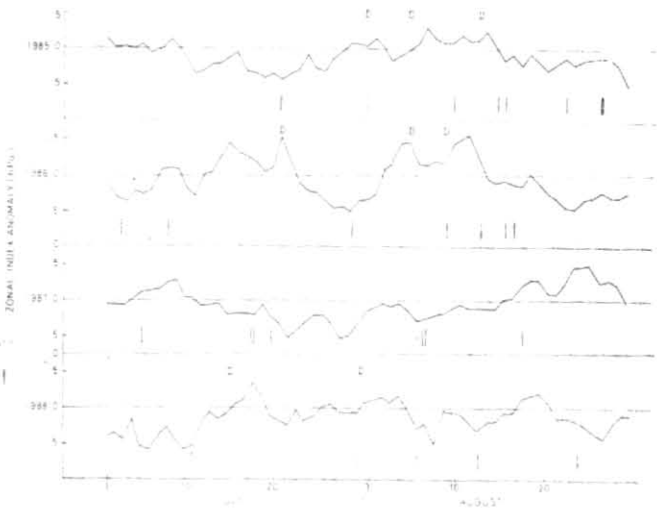

Fig. 3. Daily values of zonal index (m.s.l. pressure difference between Thiruvananthapuram and Nagpur) from 1 July to 31 August (Period : 1985-1988, D : Denotes the day at which a depression formed over Bay of Bengal and vertical bars on the x-axis denotes the date at which a typhoon had formed over NW Pacific)

3.3. Joseph (1990) discussed about the sea-saw oscillation in convective activity over north Indian and west Pacific Oceans in the time-scale of 30-50 days.

The daily monsoon activity can be determined with regional parameters like zonal index, *i.e.*, pressure gradient over peninsular India (Paul *et al.* 1990). In this study meridional pressure gradient over peninsular India (zonal index) was used to determine the strength of monsoon activity. Mean sea level pressure difference between Thiruvananthapuram and Nagpur is considered to give a measure of the pressure gradient south of monsoon trough. This parameter gives an indication of strength of the low level westerly flow over peninsular India. Strong westerly winds are noticed when the monsoon trough is well marked and is positioned in its normal position (Paul *et al.* 1990).

Fig. 3 shows the daily values of anomaly of msl pressure gradient between Thiruvananthapuram and Nagpur from 1 July to 31 August during 1985-1988. The daily weather charts of these days were referred and it was found that generally when zonal index was positive monsoon trough was either on normal or south of normal position on sea level charts, which indicates active phase of monsoon. On the other hand zonal index was negative, the monsoon trough was north of normal position on sea level charts.

It can be seen that typhoon genesis is more prominent during the weak spells of monsoon, just before and after the active spell. The frequency of typhoon formation during active phase of monsoon is, however, very small.

Table 1 shows the number of typhoons formed during active and weak spells yearwise. On an average the number of typhoons formed during weak spells were more than four times the number of typhoons formed during active spells.

3.4. Saha *et al.* (1981) examined maps of 24 hrs change of sea level pressure during July and August and found that 87% of the 52 lows and depressions that formed in the Bay of Bengal were associated with predecessor disturbance coming from the east. In 64% of instances the predecessor was associated, however, with weaker systems originating over a broad region of land and sea.

Ramanna (1969) compared the number of cyclonic systems of the south China sea crossing the coast between latitudes 15° and 25° N with number of cyclonic systems formed in the Bay of Bengal in comparable latitudes during a period of 60 years. He concluded that not more than 20% of the system could have formed in this manner during July and August.

Sadler and Kilonsky (1977) concluded that none of the monsoon depressions that formed in the Bay in July and August period had any connection with previous storms in the south China sea.

Using a larger data set (1973-1987) it was found that out of sixty monsoon depressions formed during the period June to September, nine depressions were the remnants of typhoons which crossed Burma coast either as low pressure area or as a cyclonic circulation, emerged into Bay of Bengal and subsequently reintensified.

On an average 15% of monsoon depressions forming during the period June to September are the remnants of typhoons over NW Pacific which cross Burma and emerge into Bay of Bengal. Saha *et al.* (1981) also reported similar result using a smaller data set (1969-1978).

4. *Conclusions*

(*i*) All India monsoon rainfall and number of typhoon days over NW Pacific during the period June to September is significantly and negatively correlated.

(*ii*) During the onset phase of monsoon over Kerala the typhoon genesis over NW Pacific is reduced. Typhoon activity prior to onset of monsoon, however, do not affect the onset date.

(*iii*) On the intraseasonal time-scale it has been observed that typhoon genesis is more (less) pronounced during the period when monsoon is weak (active).

(*iv*) On an average 15% of monsoon depressions forming during the period June to September are the remnants of typhoons moving westwards and emerging into Bay of Bengal.

The intraseasonal relationship addressed in the study is needed to be documented with better data set and obvious choice is to use outgoing longwave radiation (OLR) data.

5. The author is grateful to Dr. Frank H. Wells, Technical advisor, Joint Typhoon Warning Centre, U.S.A. for providing the tracks of typhoons used in the study and Shri S. E. James of Gujarat University for providing the computer facility and helping in retrieving the data. The author is also thankful to Shri. S. P. Saxena, Director for his encouragements and the anonymous referee for his valuable comments.

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M. RAJEEVAN

Meteorological Centre, Ahmedabad

1 November 1991, Modified 19 June 1992