551.515.11

## CLIMATOLOGY OF CYCLONIC DISTURBANCES OVER LAKSHADWEEP

1. Tropical cyclones are synoptic systems disastrous to human life, cattle and property due to strong winds, high tides and heavy rains they bring with them. Tropical cyclones have long-term impact on the economy of the countries struck by them. Studies of cyclonic disturbances that hit various coastal states of India have been undertaken and results were published. The cyclonic disturbances that affect two main islands of India namely Lakshadweep and Bay Islands are also very useful for studies of cyclonic disturbances over India. Sridharan *et al.* (2000) have studied in detail the effect of cyclonic disturbances that affect Bay Islands. Lakshadweep is another group of Islands and is one of the Meteorological Subdivisions of India out of 36 Sub-divisions and lies in Arabian Sea approximately between 8 - 12° N and 71 - 74° E covering the land area and comprising of 36 Islands out of which 10 are only inhabited. The Islands are scattered in the Arabian Sea, 200 to 400 kms. from Malabar coast and 10 - 400 km from each other. Islands of Lakshadweep cover an area of 32 sq. km. Fig. 1 gives the Geographical position of the Island. Out of the ten inhabited Islands, Agati, Amini and Minicoy are the three main Islands. These Islands receive more than 60% of rainfall during the southwest monsoon.

2. *Study of the cyclonic disturbances over Lakshadweep Islands* - Few authors has carried out detailed study of storms in the Arabian Sea. Jayaraman (1964) examined the combined series of storms and depressions for the period 1901 to 1955 for trend and suitability of Poisson distribution. Thiruvengadathan (1976) has made a detailed study on the climatological behavior of the storms and disturbances in the Arabian Sea during the period 1891 – 1974 dividing the period into six equal parts of 14 years each. Mooley and Mohile (1984), after studying the cyclonic storms in the Arabian Sea for the period 1870-1980, remarked that there is an increase in the trend of frequency of cyclonic storms and also of the opinion that the storm striking different coast around the Arabian Sea follows the Poisson probability of distribution. A detailed study of cyclonic disturbances in the Arabian Sea for the period 1891-1997 was taken by Sridharan *et al.* (2000) for all the coasts including Pakistan, Oman, Yeman and Africa. In this paper an attempt has been made to study the cyclonic disturbances crossing the Lakshadweep Island for the period of 110 years.

3. *Data & Methodology* - The cyclonic disturbances over Lakshadweep Islands for the period considered in this study is 1891-2000. The data for the period 1891-1990 has been collected from IMD's publication (1979, 1996) "Tracks of Storms and depressions in the Bay of Bengal and Arabian Sea" and the data for the remaining period 1991-2000 were collected from the reports of Annual Cyclone Review Meetings and the report on cyclonic disturbances over North Indian Ocean published by Regional Specialised Meteorological Centre, New Delhi. For the studies an area bounded by 71° E to 74° E and 8° N to 12° N has been considered and the nature/behavior of cyclonic disturbances which affected this area is studied. The rainfall studies is confined to the period of 1951-2000. The rainfall data for the period 1951 to 1980 was collected from MAUSAM and for the period 1981 to 2000 was collected during the period *i.e.*, the week in which the storm affected the Island from Indian daily weather report.

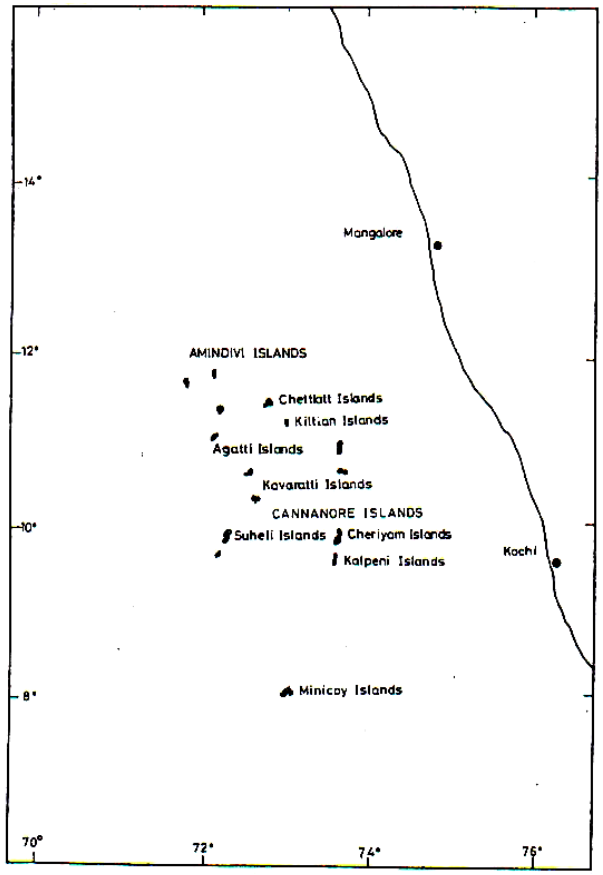


**Fig. 1.** Location of Lakshadweep Islands

4.1. *Cyclonic disturbances* - During the period 1891-2000 all the disturbances *viz*. depressions, cyclonic storms and severe cyclonic storms that crossed the Lakshadweep Islands were taken into account. From the

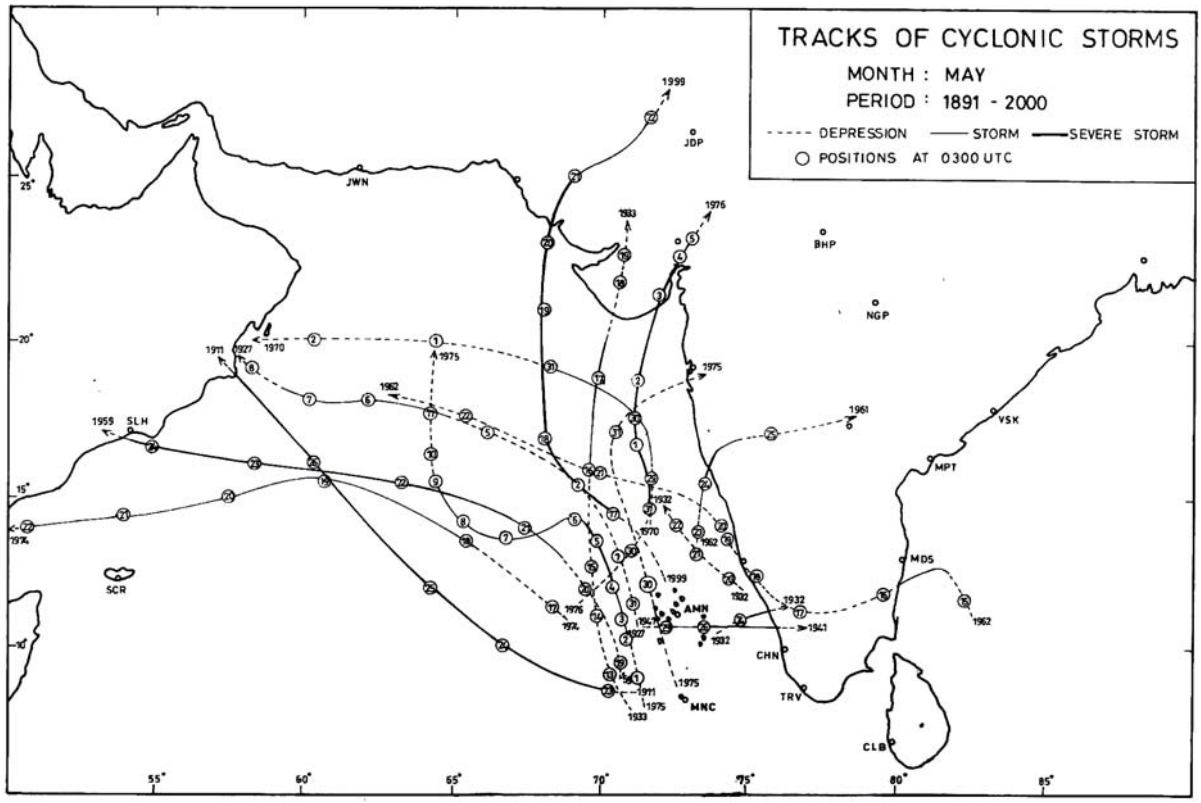


**Fig. 2(a).** Tracks of cyclonic systems affecting Lakshadweep

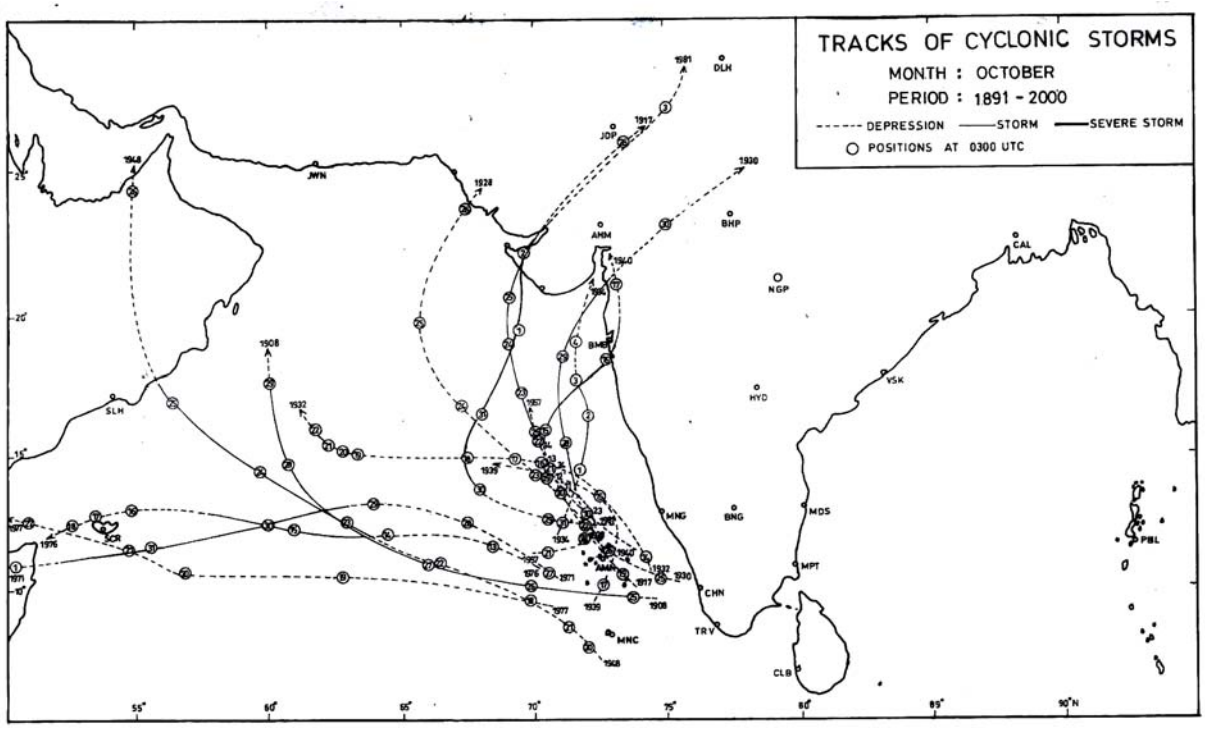


**Fig. 2(b).** Tracks of cyclonic systems affecting Lakshadweep

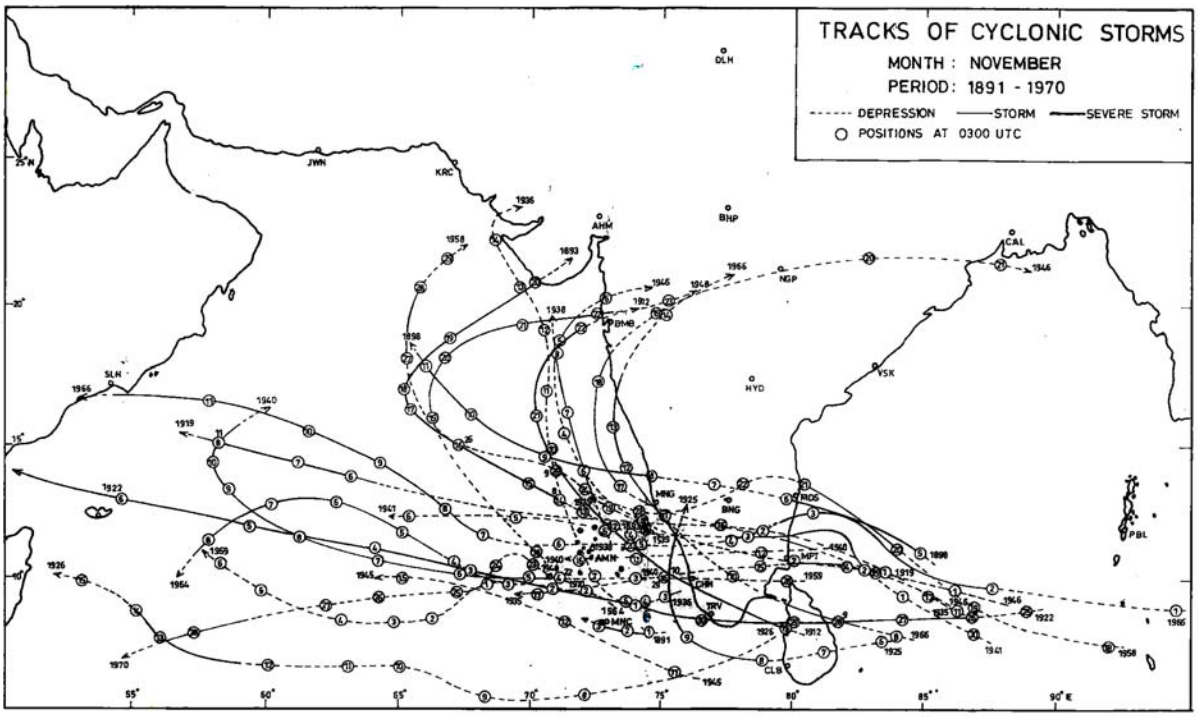


**Fig. 2(c).** Tracks of cyclonic systems affecting Lakshadweep

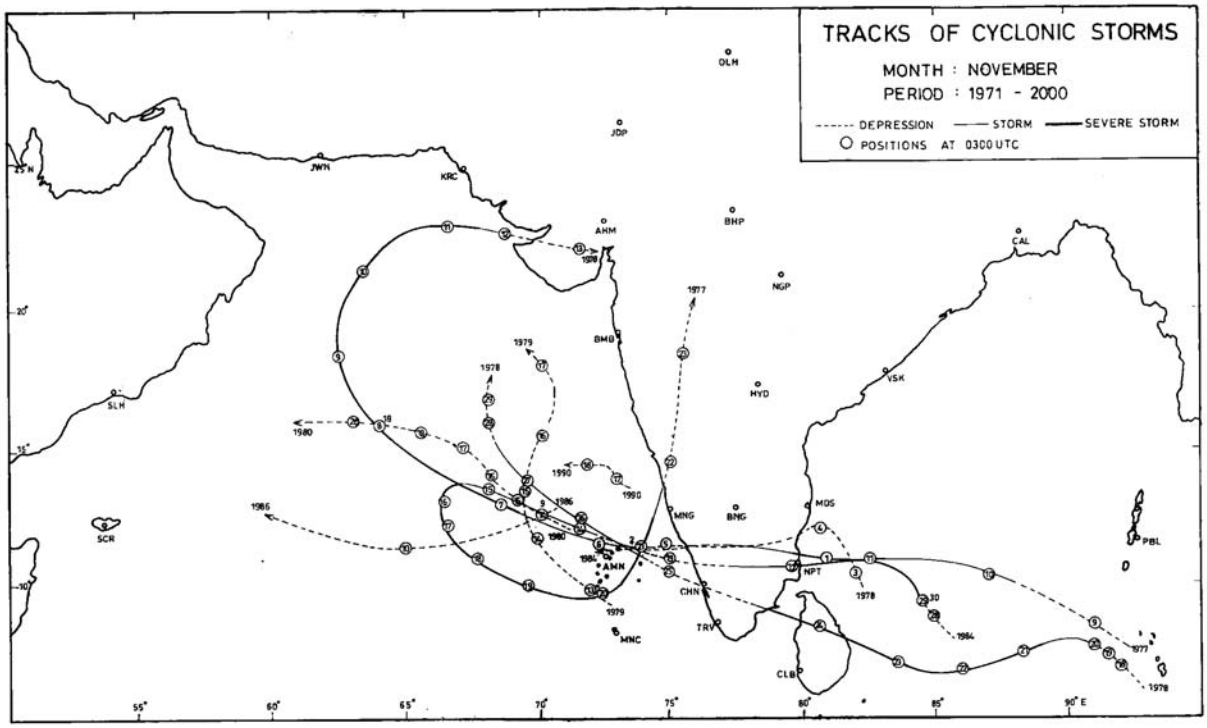


**Fig. 2(d).** Tracks of cyclonic systems affecting Lakshadweep

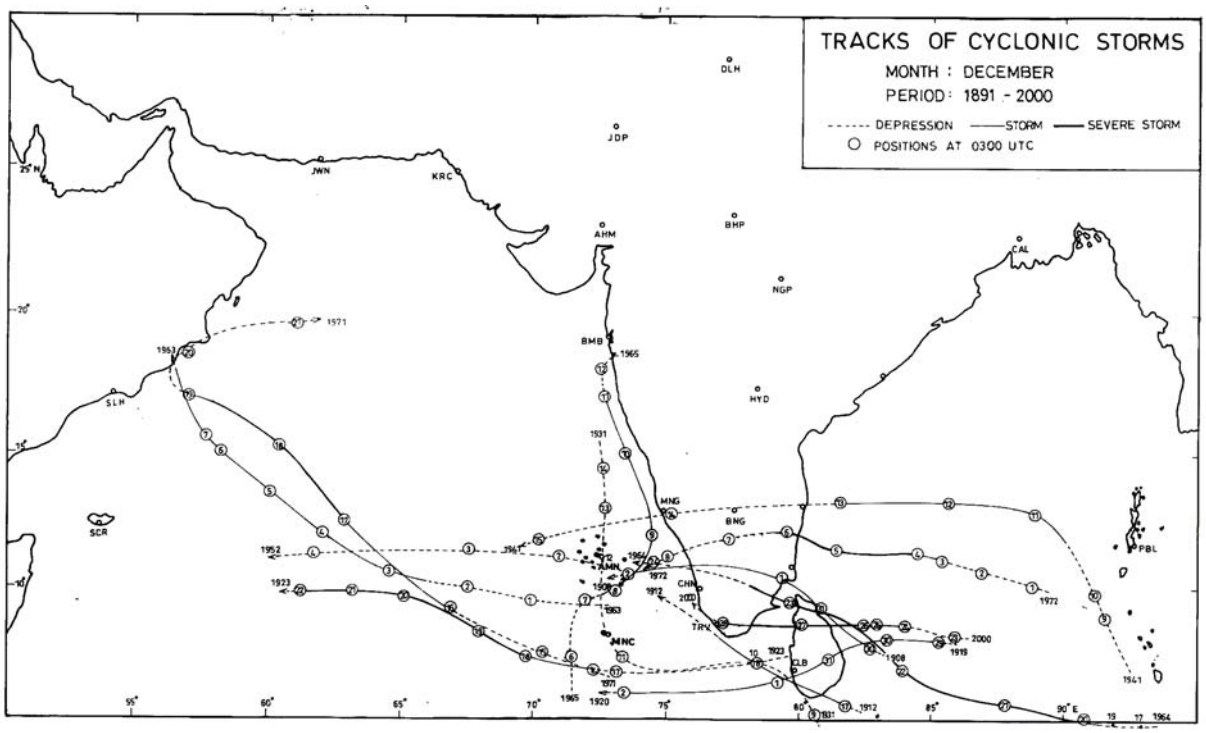


**Fig. 2(e).** Tracks of cyclonic systems affecting Lakshadweep

**TABLE 1**

**Monthly frequency of cyclonic disturbances which crossed Lakshadweep islands during the period 1891-2000**

| Month | No. of cyclonic disturbances | No. of cyclonic storms | No. of severe cyclonic storms |
|---|---|---|---|
| Jan | 2 | 1 | 0 |
| Feb | 0 | 0 | 0 |
| Mar | 0 | 0 | 0 |
| Apr | 4 | 0 | 0 |
| May | 12 | 1 | 0 |
| Jun | 3 | 0 | 0 |
| Jul | 0 | 0 | 0 |
| Aug | 0 | 0 | 0 |
| Sep | 2 | 1 | 0 |
| Oct | 16 | 1 | 0 |
| Nov | 27 | 2 | 5 |
| Dec | 9 | 0 | 0 |
| Total | 75 | 6 | 5 |

data, it is seen that there were altogether 75 cyclonic disturbances affected the Lakshadweep Islands. Out of which there were 5 severe cyclonic storms, 6 cyclonic storms and rest were depressions. Figs. 2(a-e) gives the tracks of cyclonic disturbances during May, October, November and December that crossed the area in and around Lakshadweep Islands.

4.2. *Frequency of cyclonic disturbances* - Table 1 gives monthly frequency of cyclonic disturbances that affected Lakshadweep Islands. It is seen that disturbances affect the Islands mostly in premonsoon and postmonsoon seasons. During the monsoon season, the frequency of disturbances affecting Lakshadweep Islands is very less. It is further seen that the highest number of systems that

**TABLE 2**

**Statistics of cyclonic disturbances which affected Lakshadweep Islands during the period 1891-2000**

| Month | No. of system crossing Lakshadweep | | | | | No. of system which strike | | No. of systems weakened |
|---|---|---|---|---|---|---|---|---|
| | From east | From west | From north | North of 10° N | South of 10° N | Indian coast | Other than Indian coast | |
| Jan | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 2 |
| Feb | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Apr | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 |
| May | 6 | 5 | 1 | 10 | 2 | 7 | 2 | 3 |
| Jun | 2 | 0 | 1 | 3 | 0 | 1 | 2 | 0 |
| Jul | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aug | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sep | 2 | 0 | 0 | 2 | 0 | 0 | 1 | 1 |
| Oct | 11 | 2 | 3 | 12 | 4 | 5 | 4 | 7 |
| Nov | 18 | 2 | 7 | 16 | 11 | 6 | 3 | 18 |
| Dec | 7 | 1 | 1 | 4 | 5 | 1 | 2 | 6 |
| Total | 50 | 11 | 14 | 50 | 25 | 21 | 15 | 39 |

**TABLE 3**

**Trend analysis of the cyclonic disturbances that crossed over Lakshadweep Islands during the period 1891-2000**

| Period | Premonsoon (April-May) | | | Monsoon (June-September) | | | Postmonsoon (October-December) | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total CD | CS | SCS | Total CD | CS | SCS | Total CD | CS | SCS | |
| 1891 – 1925 | 2 | 0 | 0 | 1 | 0 | 0 | 11 | 1 | 4 | 14 |
| 1926 – 1980 | 13 | 1 | 0 | 3 | 1 | 0 | 39 | 2 | 1 | 55 |
| 1981 – 2000 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 4 |

CD – Cyclonic Disturbances; CS – Cyclonic Storms; SCS – Severe Cyclonic Storms

formed/crossed over Lakshadweep Islands in the month of November (36%), and least in January and September (3%). During February, March, July and August the Lakshadweep Islands are free from disturbances.

4.3. *Percentage of probability* - While computing, Sridharan *et al.* (2000) has found out that maximum number of disturbances formed in Arabian Sea during the post-monsoon season accounting to 48%, in monsoon months 33% and in pre-monsoon season 18%. In the case of the disturbances affecting Lakshadweep Islands, it may be noted that maximum number of disturbances formed during the post-monsoon season accounting to 69%, in monsoon month 7%, in pre-monsoon season 21% and in winter season 3%.

4.4. *Probability of cyclonic disturbances* - Since the occurrence of the cyclonic disturbances over the Islands in any given month is small, Poisson distribution holds good for the analysis of data. It is seen that the probability of the Islands being affected by a system in any given year is negligible in February, March, July and August. The probability of the Islands being affected by a system in any given year is 0.018 in January, 0.036 in April, 0.095 in May, 0.027 in June, 0.018 in September, 0.123 in October, 0.225 in November and 0.087 in December. Frequency of depressions and cyclonic storms including severe cyclonic storms (CS/SCS) that affected Lakshadweep Islands in different months is shown in Table 1. The disturbances which intensified into cyclonic storm or severe cyclonic storm month wise is 50% in January, 8% in May, 50% in September, 6% in October, 26% in November and nil in rest of the months. If we take post-monsoon season as a whole, 15% of the systems attained cyclonic storm/severe cyclonic storm intensity, the contribution of severe cyclonic storm being 9%. In November 19% of the disturbances attained the severe cyclonic storm intensity whereas no disturbance attained

**TABLE 4**

**Significant rainfall recorded at the time of system crossing Lakshadweep Islands**

| Year | Date of crossing | Place | Date | Amount of rainfall (cm) |
|---|---|---|---|---|
| 1971 | 14 Dec 1971 | Minicoy | 14 Dec 1971 | 16 |
| 1975 | 01 May 1975 | Agati | 02 May 1975 | 16 |
| | | Amini | 03 May 1975 | 14 |
| 1976 | 30 May 1976 | Lakshadweep Islands | | Heavy rainfall |
| 1976 | 13 Oct 1976 | | | Very heavy rainfall |
| 1977 | 27 Nov 1977 | Amini | 21 Nov 1977 | 25 |
| 1978 | 06 Nov 1978 | Agati | 06 Nov 1978 | 31 |
| | | Amini | 06 Nov 1978 | 18 |
| | | Minicoy | 06 Nov 1978 | 12 |
| 1979 | 18 Sep 1979 | Amini | 18 Sep 1979 | 14 |
| 1981 | 29 Oct 1981 | Minicoy | 26 Oct 1981 | 11 |
| | | Minicoy | 27 Oct 1981 | 32 |
| | | Minicoy | 28 Oct 1981 | 19 |
| | | Minicoy | 29 Oct 1981 | 10 |
| | | Minicoy | 30 Oct 1981 | 65 |
| | | Minicoy | 31 Oct 1981 | 21 |
| | | Minicoy | 01 Nov 1981 | 31 |
| | | Minicoy | 02 Nov 1981 | 19 |
| | | Amini | 28 Oct 1981 | 41 |
| | | Amini | 29 Oct 1981 | 30 |
| | | Amini | 30 Oct 1981 | 15 |
| | | Amini | 31 Oct 1981 | 23 |

the SCS intensity in October and in December months. Table 2 gives the direction from which the disturbances approach the Lakshadweep Islands. It is seen that the majority of the disturbances approach the Islands from the east. While examining the individual months, it is seen that during April, two systems approached from east and one from west. In May, six systems approached from east and five from west and in June two from east and no system approached from west. In September all the systems approach from East. In 11 October (73%), in 18 November (67%) and in 7 December (70%) of the total systems approach from the east and 2 (13%) in 2 October, (7%) in 1 November, and (10%) in December approach from the west. Further it is noticed that 50 (67%) of the systems originated from nearby area of the Lakshadweep Islands only. The disturbances which originate in the Bay of Bengal crossed east coast of India and re-emerged into the Arabian sea and affecting the Lakshadweep area is maximum in November.

4.5. *Cyclonic storms/severe cyclonic storm* - Six cyclonic disturbances attained the intensity of cyclonic storms (CS), three of them (50%) intensified during postmonsoon season, 1(17%) each in monsoon, pre-monsoon and in winter seasons. Five cyclonic disturbances intensified into severe cyclonic storm (SCS) and all of them accounting during post-monsoon season only. No disturbance intensified into severe cyclonic storm intensity during pre-monsoon and monsoon season. The study has further indicated that the maximum number of cyclonic storm/severe cyclonic storm formed in the month of November.

4.6. *Trend analysis* - From trend analysis performed on the number of disturbances in the area of Lakshadweep Islands during the period 1891–2000, it is seen that an increasing trend is noticed in the formation of disturbances. It is in agreement with the conclusion made by Mooley and Mohile (1984) based on their study on cyclonic storms in the Arabian Sea. To substantiate the above argument the study period 1891-2000 has been divided in to three sub periods namely, 1891-1925, 1926-1980 and 1981-2000 and the frequency of disturbances in each period is given in Table 3. On examining it is seen

that the mean formation in the second sub-period is significantly higher than the other two sub-periods. It is also observed that during the second sub-period, the mean annual number of formation is double the mean annual number in other two sub-periods taken together. It may also be seen from the Table 3 that the trend which showed an upward tendency upto the year 1980, has started showing a decreasing trend both in formation and intensification during the third sub-period.

4.7. *Weakening of the cyclonic disturbances* - While studying the climatology of the disturbances affecting the Lakshadweep Islands, weakening of the cyclonic disturbances was also considered. Thiruvengadathan (1976) has observed that there is a peculiar feature of the behavior of disturbances/formed over Arabian Sea during his study period 1891-1974, and found that many of the systems weaken over the sea itself. The present study indicates that over all 39 systems weakened in the sea itself which is in agreement with the earlier study of Thiruvengadathan. It is found that the month wise percentage of disturbances that weakened is minimum in the month of May and maximum during January and in the month of June no disturbance weakened. Seasonwise percentage distribution indicates that during post monsoon season, the percentage of weakening of the disturbances to the total disturbances of respective season is 60% monsoon it is 20 % and pre-monsoon season it is 31%.

4.8. *Significant amount of rainfall* - In Table 4, the significant rainfall amount received in the stations of Lakshadweep Islands at the time of storm affecting Islands is given. The amount of rainfall received in the individual Island stations at the time of storm crossing is studied from the period of 1951 onwards. The significant amount of rainfall (more than 10 cm) has been taken into consideration and presented in the Table 4. It is seen from the table that sometimes all the island stations received rainfall whenever a system crossed. During 1978 on 6th November, Minicoy, Amini and Agati received 12 cm, 18 cm and 31 cm of rainfall respectively when a system crossed the Islands. It may also be seen that rainfall continued to be received on many days by the Island stations during a system crossing. During 26th October to 2nd November 1981, Minicoy received rainfall amount of 11 cm on 26th, 32 cm on 27th 19 cm on 28th, 10 cm on 29th, 65 cm on 30th, 21 cm on 31st, 31 cm on 1st November, 19 cm on 2nd, whereas Amini received 41 cm on 28th, 30 cm on 29th, 15cm on 30th and 23cm on 31st. Further significant point is that the system which intensified into severe cyclonic storm with a core of hurricane winds has given total rainfall of 208 cm at Minicoy in 8 days and 109 cm at Amini in 4 days. It may be concluded that the rainfall distribution over Lakshadweep Island stations during the storm situation is not uniform and there is a significant variation in the rainfall amount.

5. The authors are thankful to the Deputy Director General of Meteorology, Regional Meteorological Centre, Chennai for the encouragement and facilities provided for this study. The authors are also thankful to S/Shri RM. A. N. Ramanathan for helping in the project and M. Bharathiar and N. Selvam for the diagrams in this paper.

**References**

India Meteorological Department, 1979 & 1996, "Tracks of storms and depressions in the Bay of Bengal and the Arabian Sea".

India Meteorological Department Publications, 1991 to 2000, "Reports of the Annual Cyclone Review Meeting".

Jayaraman, S., 1964, "On the distribution of storms and depressions in the Arabian Sea", *Indian J. Met. & Geophys.*, **15**, 2, 287-288.

Mooley, D. A. and Mohile, C. M., 1984, "Cyclonic storms of the Arabian Sea, 1877-1980", *Mausam*, **35**, 2, 127-134.

Sridharan, S., Muthuchami, A. and Ramakrishnan, B., 2000, "Climatology of cyclonic disturbances over Andaman and Nicobar Islands", *Mausam*, **51**, 1, 96-100.

Sridharan, S., Muthuchami, A. and Ramakrishnan, B., 2000, "Climatology of cyclonic disturbances in the Arabian Sea", *Mausam*, **51**, 2, 179-184.

Thiruvengadathan, A., 1976, "Climatological behavior of storms and depressions in the Arabian Sea", *Indian J. Met. Hydrol. & Geophys*., **27**, 2, 205-206.

S. NATARAJAN
B. RAMAKRISHNAN
SANTOSH ARORA
P. A. SUBADRA

*Regional Meteorological Centre, Chennai, India*
(*3 September 2003, Modified 4 February 2004*)