

L E T T E R S

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IS SOUTHERLY LOWER LEVEL WIND AT AGARTALA AN INDICATOR OF WEATHER OVER NORTH-EAST REGION OF INDIA DURING SOUTHWEST MONSOON SEASON?

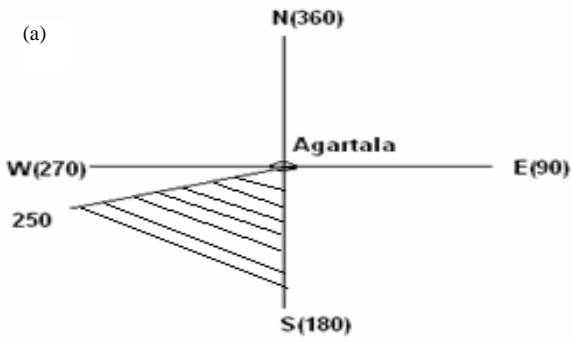
1. Occurrence of rainfall during Southwest monsoon season over N-E region is influenced by various systems like shifting of monsoon trough to foothills of the Himalayas, Low/Depression over North Bay of Bengal and its northward/northeastward movement, presence of low/depression over Gangetic West Bengal, Sub-Himalayan West Bengal, Bihar, cyclonic circulations over NE-Region in lower level and incursion of abundant moisture from Bay of Bengal due to its proximity supported by low level southerly wind flow etc. Forecasting of weather over this region due to its typical geographic location has always been a challenge. Several authors have studied wind as single parameter or in association with other parameters for its influence on weather over a particular region. Recently Dutta *et al.* (2006) studied the effect of Palghat gap on the rainfall pattern to north and south of its axis. Kar *et al.* (2003) utilized surface wind data along with moisture and studied its impact on weather in Indian Ocean region. Singh *et al.* (1996) had shown the importance of meridional winds in forecasting sub-regional monsoon rainfall. Sircar *et al.* (1969) studied wind distribution and associated wet or dry weather probability over Madras during monsoon and post-monsoon. Relationship between rainfall and lower and upper tropospheric winds and temperatures over Madras during monsoon have been studied by Srinivasan *et al.* (1967). Association with upper air wind flow and monsoon rainfall over Gangetic West Bengal have been studied by Srinivasan (1960). The present study focuses on the influence of southerly wind flow observed at Agartala (25° 53' N & 91° 15' E) at 850 hPa level during monsoon on the rainfall over the sub-divisions of Arunachal Pradesh, Assam & Meghalaya and Nagaland, Manipur, Mizoram and Tripura. An attempt has been made to establish a relation between the wind at Agartala at 850 hPa and distribution of rainfall over the above mentioned sub-divisions.

2. Daily wind data of Agartala at 850 hPa level of more than 3 knots recorded at 0000 UTC for monsoon season for period 1997 to 2006 has been used. The lower limit of 3 knots is fixed, as the basic purpose of the study is to explore the possibility of incursion of moisture from Bay of Bengal. More the wind speed means more

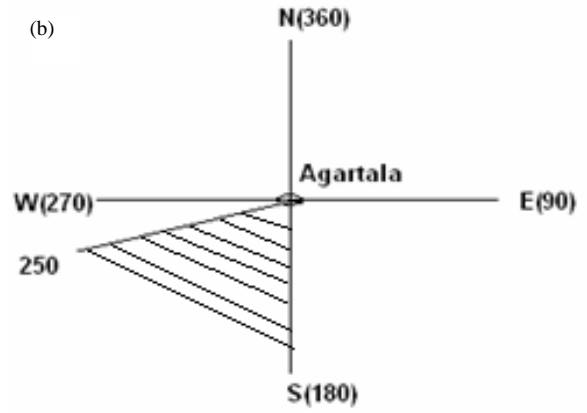
incursion of moisture. A total of 948 days have been identified for the study using RMC Guwahati weather bulletins. The directions of wind at 850 hPa at Agartala have been divided into six different categories for detailed analysis of 948 days Figs. 1(a-f). This figure depicts following categories.

- Category-1 : Zone of exposure between 180° and 250° with wind speed between 5-< 10 knots
No. of days/events = 108
- Category-2 : Zone of exposure between 180° and 250° with wind speed ≥ 10 knots
No. of days/events = 353
- Category-3 : Zone of exposure between 120° and 180° with wind speed between 5-< 10 knots
No. of days/events = 53
- Category-4 : Zone of exposure between 120° and 180° with wind speed ≥ 10 knots
No. of days/events = 214
- Category-5 : Zone of exposure between 120° and 250° with wind speed 3 – ≤5 knots and for zone 90° -120° & 250° - 270° with wind speed ≥ 3 knots
No. of days/events = 128
- Category -6 : Zone of exposure between 270° - 360° - 90° (full exposure)
No. of days/events = 92

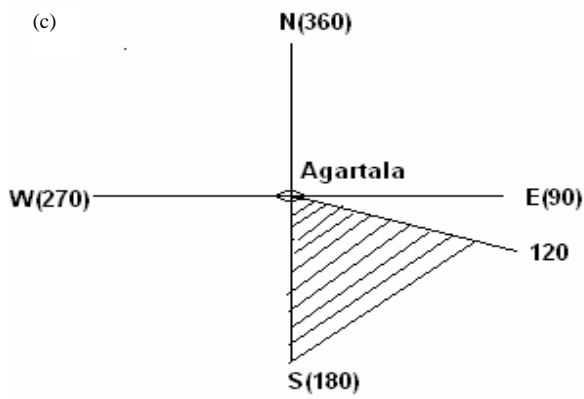
Probable occurrence of distribution of rainfall over all sub-divisions for each Category frequencies have been worked out on the basis of total number of occurrence of days. However, for comparison it has been presented in terms of percentage. Distribution of weather over these sub-divisions has been taken as Wide Spread (WD), Fairly Wide Spread (FWD), Scattered (SCT), Isolated (ISOL) and Mainly Dry (MD) as per the practice in IMD. Distribution such as WD and FWD being considered as occurrence of significant weather hence the combination of these two *i.e.*, WD+FWD is termed as 'Good Distribution'. Realization of the distribution of rainfall over all sub-divisions has been depicted in terms of percentage. Considering the direct exposure to southerly wind components attention is given to the most popular



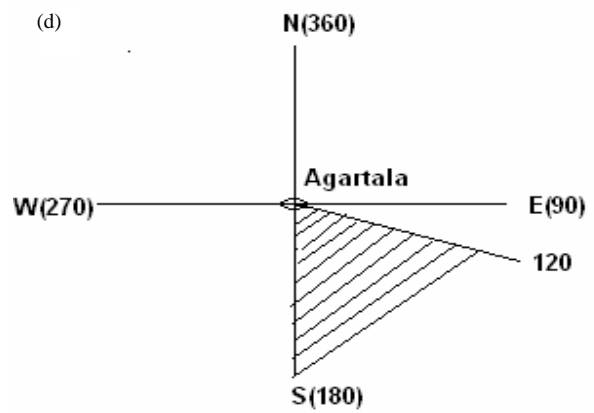
CAT-1: between 180° - 250° with wind speed 5 - < 10 knots



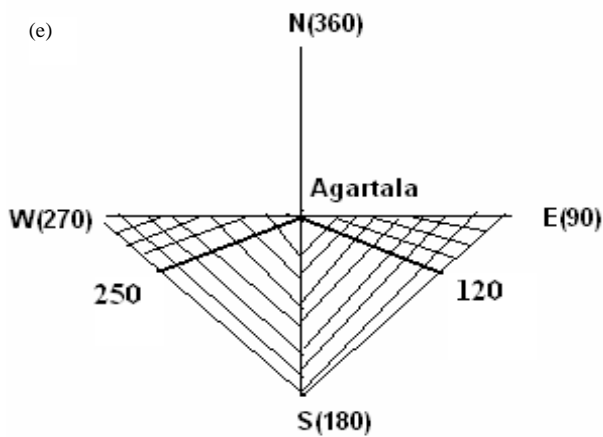
CAT-2: between 180° - 250° with wind speed ≥ 10 knots



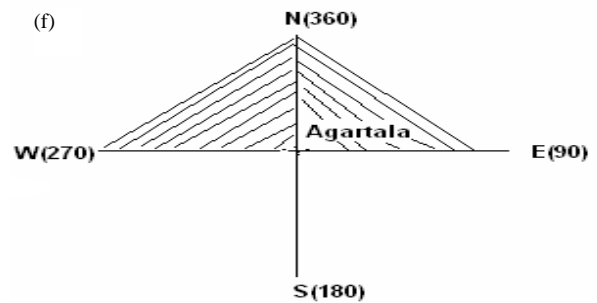
CAT-3: between 120° - 180° with wind speed 5 - < 10 knots



CAT-4: between 120° - 180° with wind speed ≥ 10 knots



CAT-5: between 120° - 250° with wind speed 3-5 knots and 90°-120° & 250°-270° with wind speed ≥ 3-5 knots



CAT-6: between 270° - 360° - 90° with wind speed ≥ 3-5 knots

Figs. 1(a-f). Wind direction and speed for different categories

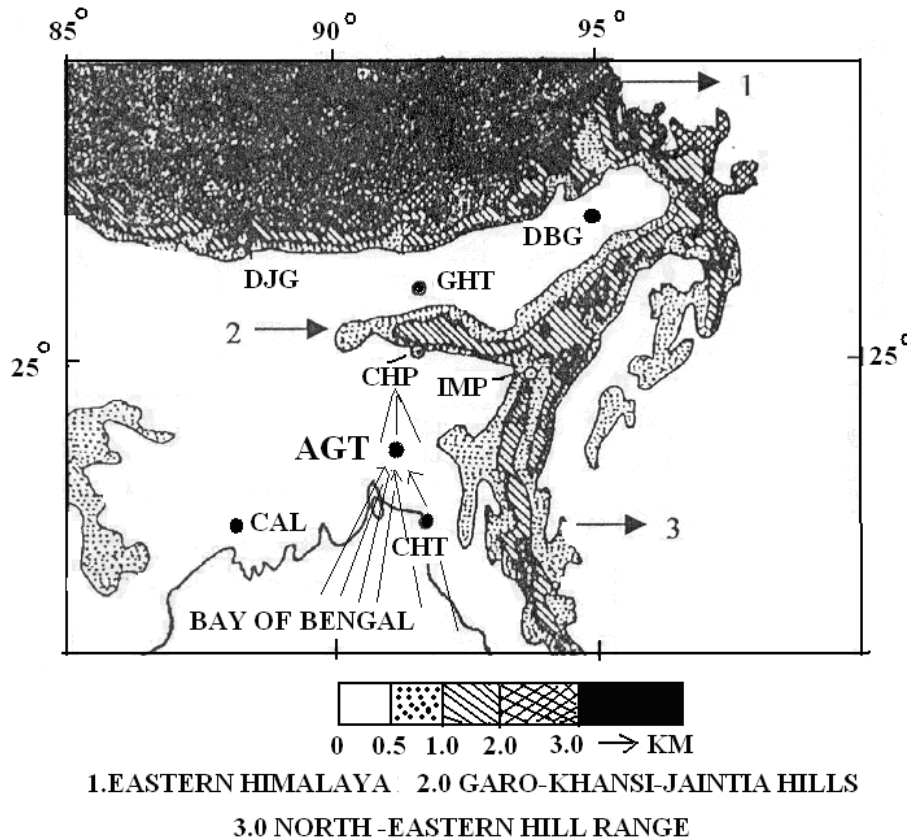


Fig. 2. TOPOMAP of N-E states

and well known station Cheerapunji located at Lat. 25° 15' N, Long. 91° 44' E and altitude 1313 meters above msl.in East Khasi hills. Thus the rainfall received at Cheerapunji during monsoon in terms of Heavy, Very Heavy and Extremely Heavy due to southerly wind components is also correlated with the distribution of rainfall over three sub-divisions.

3. Fig. 2 shows the geographical features of North East – Region consisting of topography, plain areas of Assam, part of Head Bay of Bengal and focus of study Agartala. This region is dominantly a hilly region due to its proximity of the Eastern Himalayas, presence of Northeastern hill ranges extending from north to south and the East-West oriented Garo-Khasi Jaintia hills across Meghalaya and adjoining Assam. The arrows pointing from Head Bay of Bengal to Agartala indicate the Southerly exposure without any obstruction for wind blowing from sea. Further the exposure is extended up to hills of Garo – Khasi – Jaintia which are having average height of about 1 km above m.s.l. thus obstructing the low level flow resulting in heavy down pour. Thus Cherrapunji located at East Khasi Hills has become popular as the

station receiving highest amount of annual rainfall in the world. The height above m.s.l. of hilly region of Meghalaya, Nagaland, Manipur and Mizoram and of sub-mountain region of Arunachal Pradesh have been depicted by shading. Assam State without any shading clearly indicates the plain land. The station Dibrugarh (DBG) located in upper Assam is having highest height of 112 metres above m.s.l. and Guwahati (GHT) in Lower Assam showing much less height as 56 metres only.

4. The first step of analysis of wind under consideration (Category No. 1 to 6) is involved of verification of its significant occurrence during monsoon season. As such out of total days of monsoon season total number of occurrence of wind under consideration for each year has been found out for Category. No. 1 to 5. Table 1 shows the average occurrence (%) of wind under consideration with 71% for last 10 years of period during monsoon. The highest and lowest observed values are 86% and 53% during year 2002 and 1999 respectively. Category-2 *i.e.*, between 180°-250° with speed ≥ 10 knots shows highest occurrence of events as 29% followed by category-4 *i.e.*, between 120°-180° with speed 10 ≥ knots

TABLE 1

Total events (%) of wind under consideration of different categories during monsoon season from 1997-2006

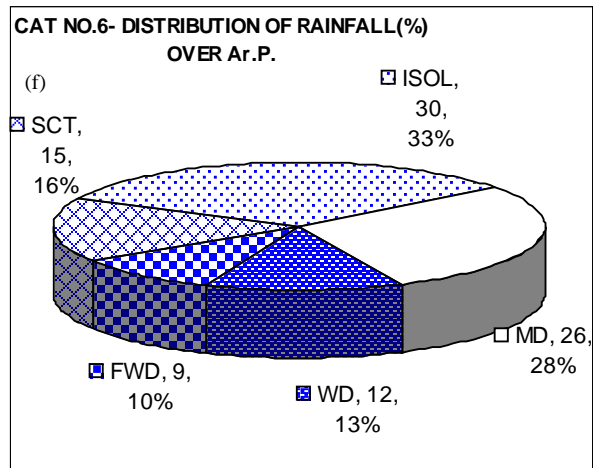
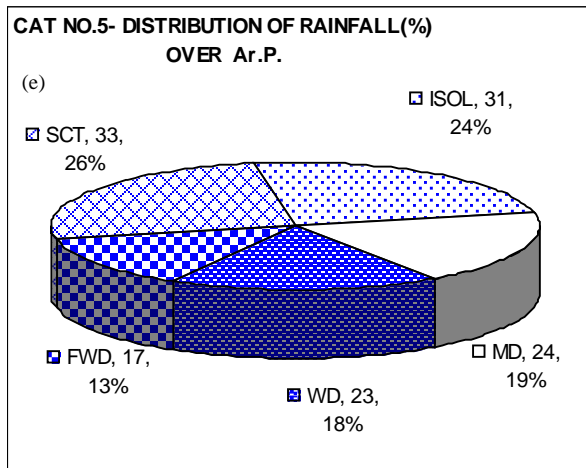
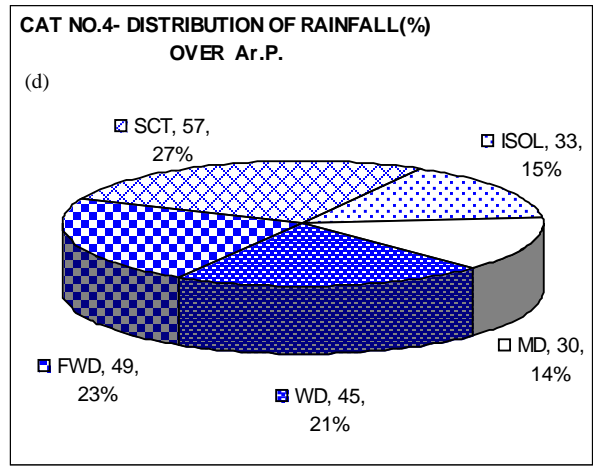
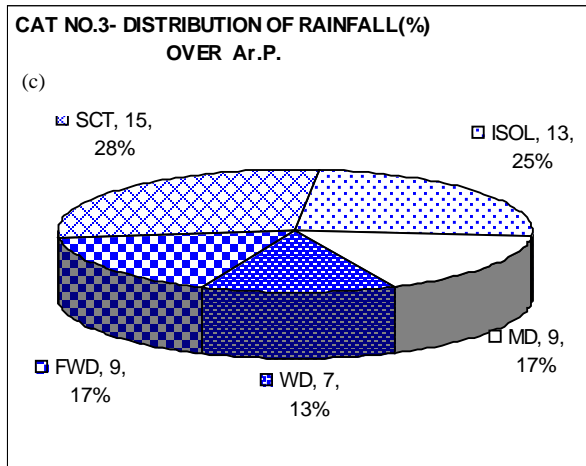
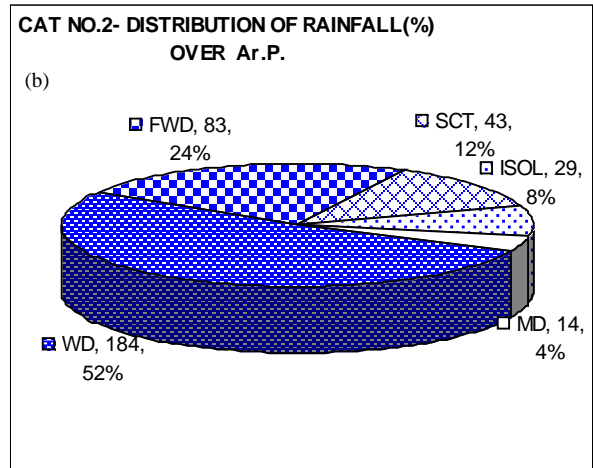
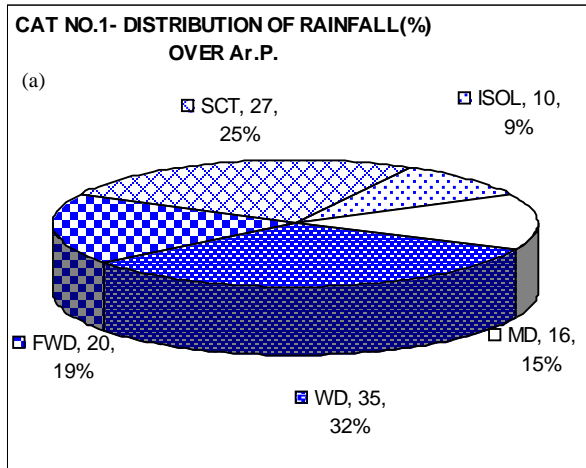
S. No.	Year	Total events (%) of southerly wind during monsoon period	Cat- 1	Cat - 2	Cat - 3	Cat - 4	Cat - 5
1.	1997	77%	9%	42%	3%	14%	9%
2.	1998	85%	6%	53%	1%	17%	8%
3.	1999	53%	5%	21%	2%	21%	4%
4.	2000	78%	3%	35%	4%	20%	15%
5.	2001	70%	7%	26%	5%	23%	9%
6.	2002	86%	14%	30%	3%	18%	21%
7.	2003	70%	11%	30%	11%	13%	5%
8.	2004	73%	14%	16%	5%	21%	18%
9.	2005	58%	10%	21%	6%	14%	8%
10.	2006	61%	11%	19%	4%	17%	10%
Average		71%	9%	29%	4%	18%	11%

showing 18% respectively out of 71% of total events. Whereas only 11% events have been noticed for Category-5 even after having wide exposure. This may be due to limitations put to wind speed. Similar results have been noticed for Category-1 and 3 in which due to narrow exposure for wind with speed (< 10 knots) is indicating only 9% and 4% chances of occurrence. Overall analysis clearly indicates that for zone $120^{\circ} - 180^{\circ}$ and $180^{\circ} - 250^{\circ}$ with wind speed ≥ 10 knots shows high chances (47%) of occurrence. In other words high wind speed between $120^{\circ} - 250^{\circ}$ during monsoon season enhances the chances of occurrence of weather.

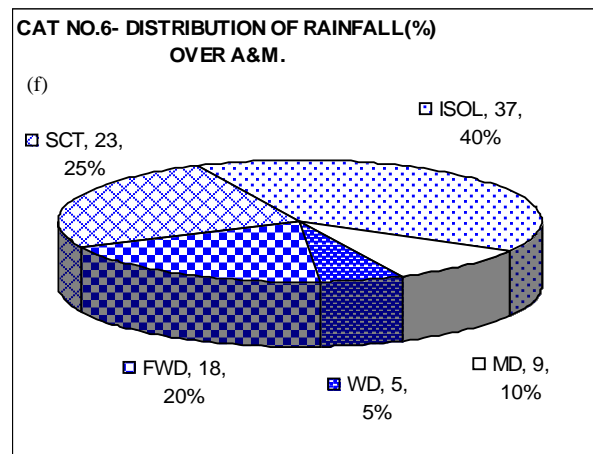
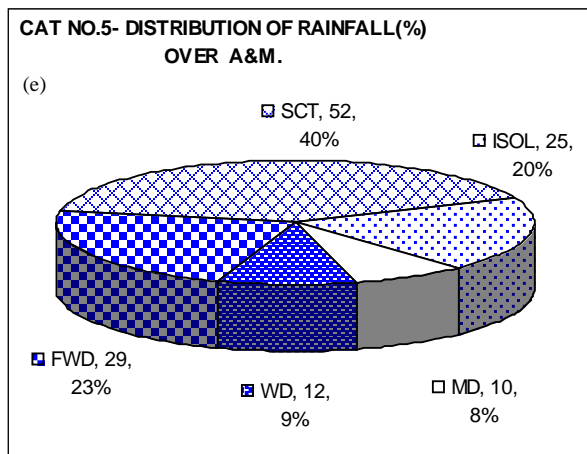
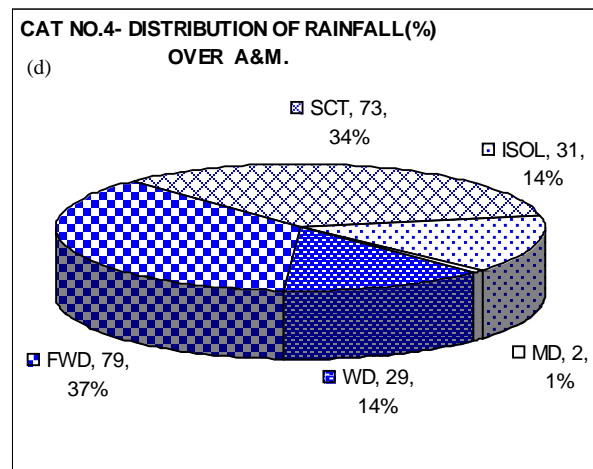
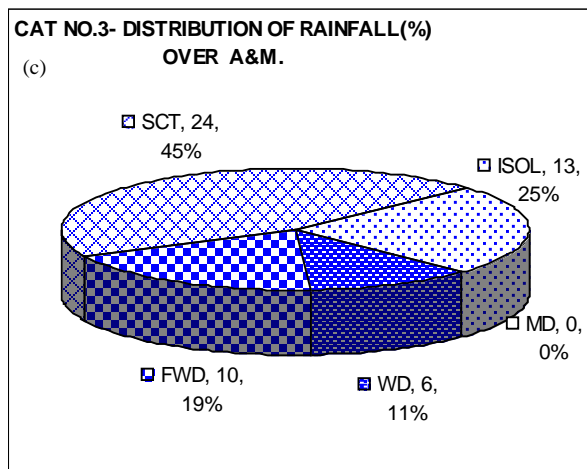
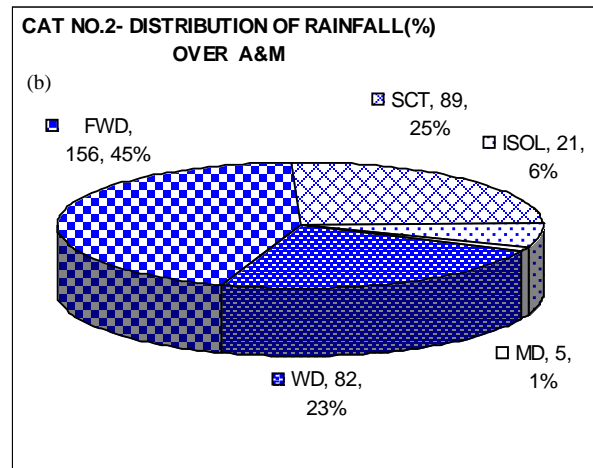
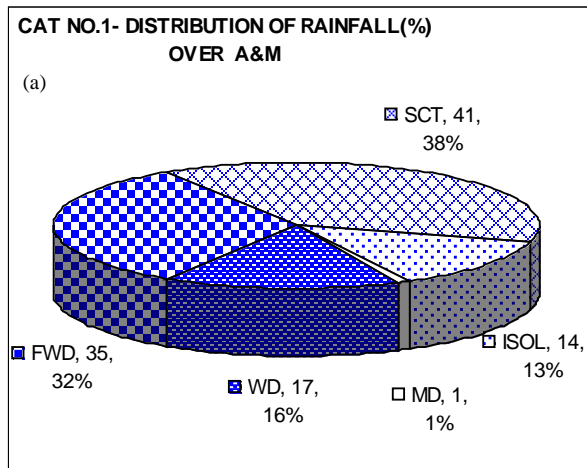
5. Analysis of occurrence of weather over Arunachal Pradesh [Figs. 3(a-f)] shows very high chances of 'Good Distribution' with 76% probability for Category-2 Fig. 3(b) followed by Category-1 Fig. 3(a) with 51% chances. Whereas for Category -6 (Northerly wind) the probability of 77% occurrence of SCT to MD support the earlier findings. Analysis of occurrence of weather over Assam and Meghalaya [Figs. 4(a-f)] shows 68% chances for 'Good Distribution' for Category-2 Fig. 4(b). This sub-division is dominated by SCT type with about average 34% chances for all Categories. The region may experience 50% weather distribution from SCT to WD even though the wind direction is Northerly. This may be due to sustained moisture over the plain areas of Assam and hills of Meghalaya. Analysis of occurrence of weather over NMMT [Figs. 5(a-f)] does not show much encouraging result. However under Category-3 Fig. 5(c) probability of 'Good Distribution' is found to be 53% followed by Category-4 Fig. 5(d) *i.e.*, 47%.

Comparatively this division seems to be less affected by Southerly/Southwesterly wind.

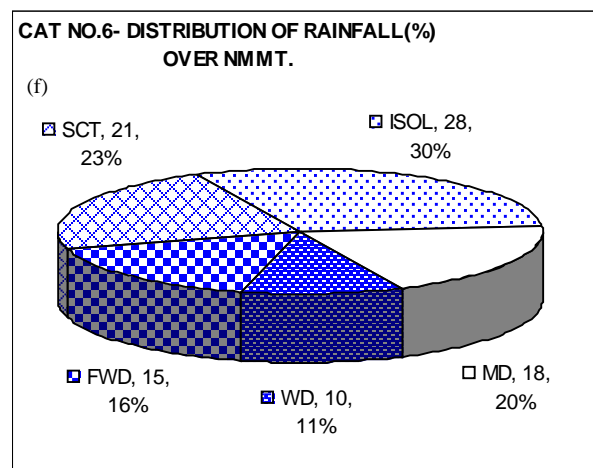
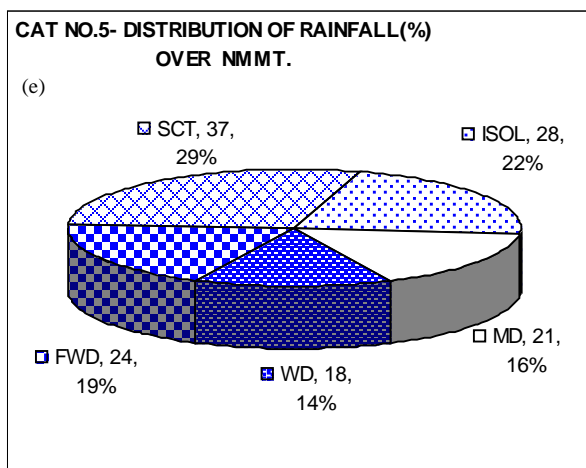
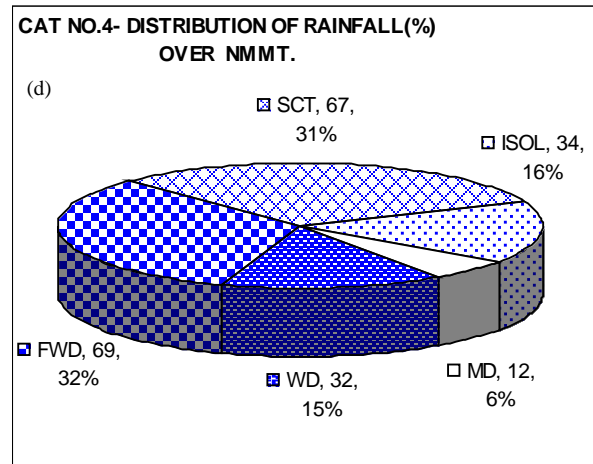
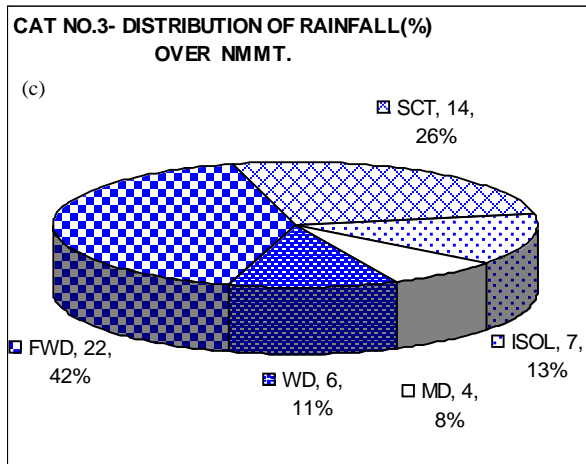
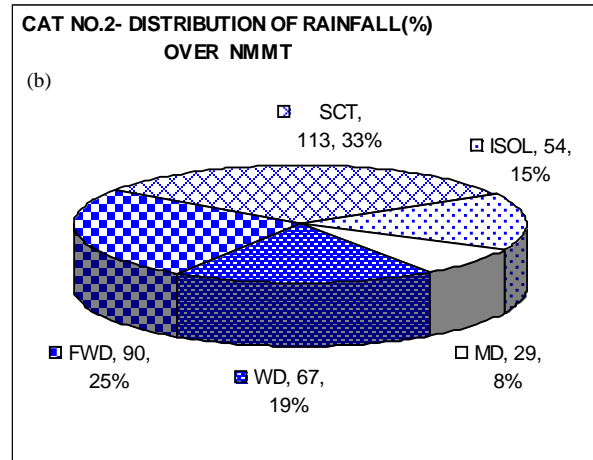
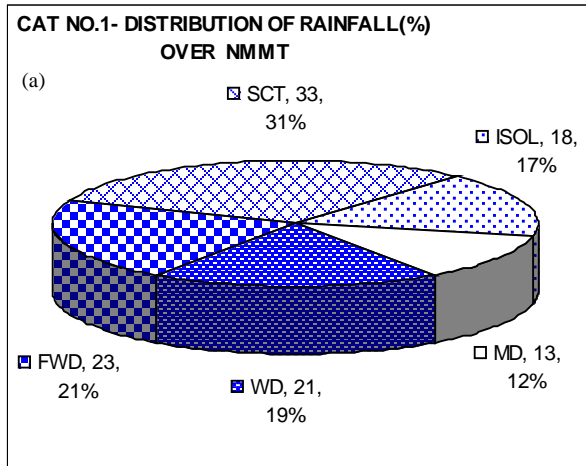
6. Figs. 6(a-i) shows the occurrence of Heavy to Extremely Heavy Rainfall at Cherrapunji and distribution of weather over all the three sub-divisions. Figs. 6(a-c) depict the distribution of weather over three sub - divisions and occurrence of Heavy rainfall over Cherrapunji. In case of Heavy rainfall over Cherrapunji the number of cases examined were 120 having mean wind direction and speed as 190° and 16 knots respectively at Agartala. The corresponding 'Good Distribution for Ar.P, A&M and for NMMT observed to be 75%, 73% and 59%. Figs. 6(d-f) show the relationship between occurrence of Very Heavy rainfall over Cherrapunji and distribution of weather over all the three Sub-divisions In this case the number of cases examined were 100 having mean wind direction and speed as 205° and 17 knots at Agartala. Occurrence of 'Good Distribution with a high probability of 90% and 87% respectively was noticed for Ar.P and A&M. NMMT however shows 63% chances. In case of Extremely Heavy rainfall over Cherrapunji the number of cases examined were 66 for the period under consideration having mean wind direction and speed as 215° and 21 knots at Agartala. Figs. 6(g-i) show still higher probability of 'Good Distribution' for Extreme Heavy rainfall events as 96% and 100% over Ar.P and A & M sub-divisions. In NMMT the probability was 69%. Thus there is a high correlation between occurrence of Heavy to Extremely Heavy rainfall over Cherrapunji and wind under



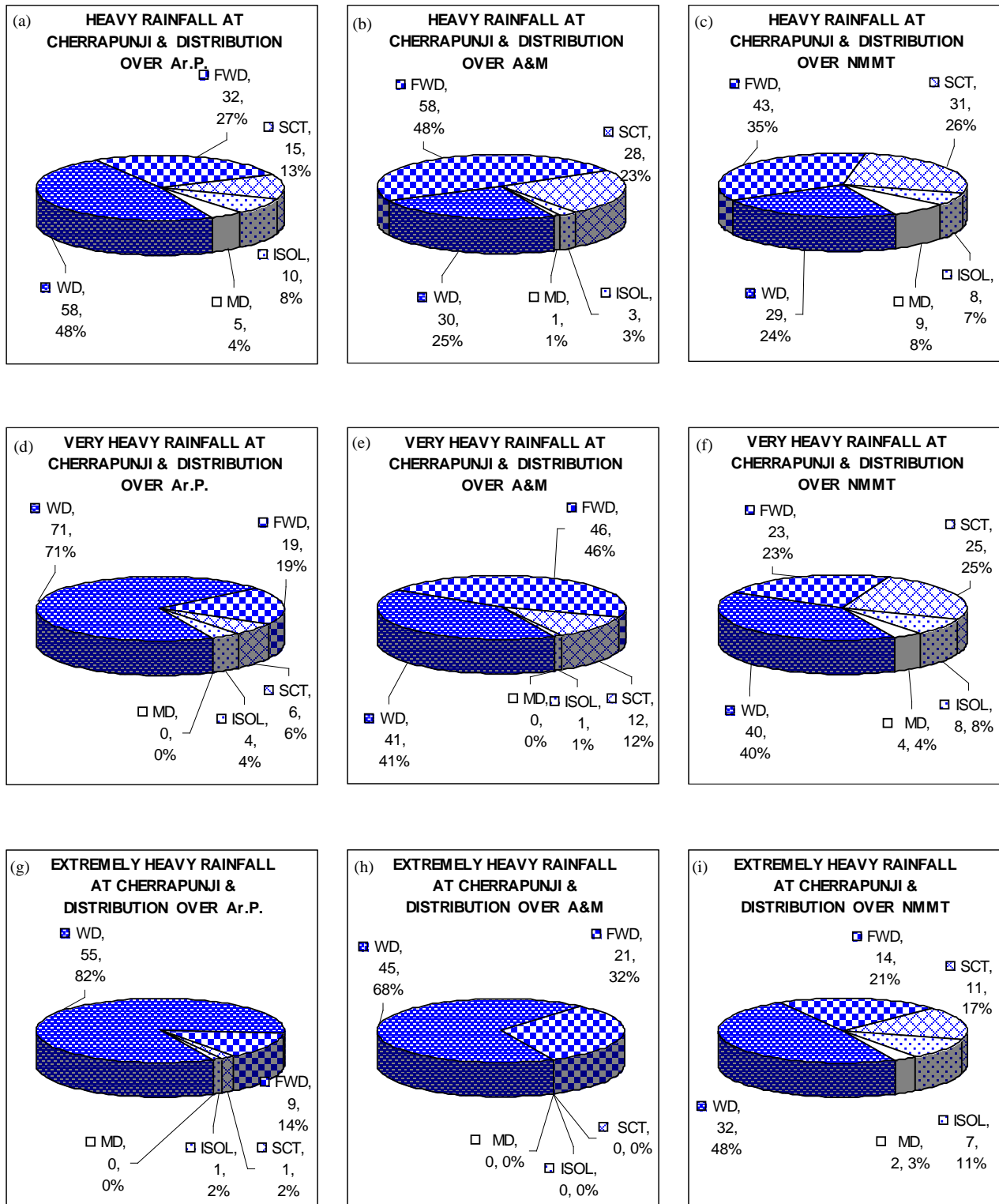
Figs. 3(a-f). Percentage distribution of rainfall categories over Arunachal Pradesh



Figs. 4(a-f). Percentage distribution of rainfall categories over Assam & Meghalaya



Figs. 5(a-f). Percentage distribution of rainfall categories over NMMT



Figs. 6(a-i). Heavy to extremely heavy rainfall at Cherrapunji and corresponding rainfall distribution over sub-divisions of Arunachal Pradesh, Assam & Meghalaya and Nagaland, Manipur, Mizoram & Tripura

consideration for Category-2. It is related to 'Good Distribution' over Arunachal Pradesh and Assam & Meghalaya.

7. The following conclusions could be drawn on the basis of the results presented above.

(i) Occurrence of wind under consideration shows significant result with 71% chances during monsoon period. Probability of occurrence of wind of Category-2 and Category-4 with speed ≥ 10 knots is 47%.

(ii) Occurrence of weather over Arunachal Pradesh shows very high chances of 'Good Distribution' with 76% probability for Category-2 followed by Category-1 with 51% chances. Assam and Meghalaya shows 68% chances for 'Good Distribution' for Category-2. Whereas NMMT shows 53 % chances for 'Good Distribution' for Category-2 followed by Category-4 with 47 % chances.

(iii) There is high correlation between occurrence of Heavy to Extremely Heavy rainfall over Cherrapunji and wind under consideration for Category No.2 which results in 'Good Distribution' over Arunachal Pradesh and Assam & Meghalaya. The relationship with Heavy rainfall shows 75%, 73% and 59% chances for 'Good Distribution' over Ar.P, A & M and NMMT respectively. With Very Heavy rainfall it shows 90%, 87% and 63% chances respectively. For Extremely Heavy rainfall it shows 96%, 100% and 69% chances respectively.

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