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An analytical study of rainfall pattern over Chennai

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सार – चेन्नई में स्थित नुंगम्बाकम और मीनम्बाकम वेधशालाओं में रिकार्ड की गई दस वर्ष की अवधि की दैनिक वर्षा के दौर का इसमें विश्लेषण किया गया है । इस अध्ययन से वर्षा के दौर के तीन भिन्न पैटर्नों का पता चला है जिसके अनुसार फरवरी और मार्च में बहुत कम वर्षा हुई जबकि अप्रैल से सितम्बर तक 15 से 20 प्रतिशत और अक्तूबर से जनवरी तक बहुत अधिक वर्षा हुई । दक्षिण–पश्चिमी मानसून ऋतु के दौरान संध्या के समय, रात्रि और सुबह तड़के हुई वर्षा के दौर बहुत अधिक अविरुद्ध रहे जबकि उत्तर पूर्वी मानसून के दौरान दिन भर समान रुप से वर्षा हुई । जनवरी से सितम्बर के महीनों में प्रति दिन वर्षा के एक या दो दौर अधिक हुए । अक्तूबर से दिसम्बर के दौरान वर्षा के दो या उससे अधिक दौर तक की विशिष्ट वृद्धि हुई । जून से सितम्बर तक महीनों मे 65 प्रतिशत से अधिक वर्षा के दिनों में एक दिन में वर्षा की अवधि दो घंटे से कम रही जबकि अक्तूबर से दिसम्बर तक प्रतिशत का मान 50 से कम रहा। पूरे वर्ष में दो मि.मी. से कम वर्षा की मात्रा के वर्षा के दौर की संख्या लगभग 55 प्रतिशत रही । मार्च के महीने को छोड़कर पूरे वर्ष 7 मि.मी. प्रति घंटा से कम वर्षा के दौर की तीवता 60 से 70 प्रतिशत तक रही ।

ABSTRACT. The spells of daily rainfall received at Nungambakkam and Meenambakkam observatories located in Chennai for ten year period have been analysed. The study reveals that the spells have three distinct patterns with February and March having negligible spells while April to September being 15 to 20 percent and from October to January having very high values. The spells that occur during southwest monsoon season are having high consistency of occurrence during evening, night and early morning where as the spells during northeast monsoon are equally spread during the whole day. Frequency of one or two spells per day is more during the months January to September. There is significant increase in the value of two spells and more during October to December. In the months of June to September more than 65 percent of the rainy days, the duration of rainfall in a day is less than 2 hours while October to December the value of percentage is below fifty. The number of spells of rainfall with amount of rainfall less than two millimeters is about 55 percent throughout the year. The intensity of spells of rain of less than 7 millimeters per hour ranges from 60 to 70 percent for all the months except for the month of March.

Key words – Rainfall, Spells, Duration, Intensity, Standard deviation, Co-efficient of variation.

1. Introduction

Chennai located at 13° N, 80.2° E on the southeast coast of India, is an important metropolitan city. The study of rainfall over a populated city like Chennai assumes importance especially for the water managers for providing regular water supply to the city population. Since precipitation is the primary and major source of fresh water; a clear understanding of rainfall climate of a place is highly essential. Chennai has two Class-I Meteorological observatories *viz.* Nungambakkam and Meenambakkam (Fig. 1). Nungambakkam is representing Chennai city which is located nearly 4 kilometre west of Bay of Bengal. Meenambakkam is located southwest of Nungambakkam away from the coast nearly 10 kilometre close to the Airport and is generally taken to represent the suburban area of Chennai. Generally the city experiences warm to hot weather. In the annual total rainfall received during a year, major portion is received in the Northeast monsoon. Various studies have been done about the rainfall distribution of Chennai earlier. Krishnaswamy (1952) has done a detailed study, based on fifteen years data from the autographic charts of Madras (1932-42, 1944-47) showed that a single spell of rainfall of very short duration is also significant. Later Ramakrishnan (1953) has made a critical study of fifty years rainfall of Madras city for the period of 1891-1940. In his study he has observed three patterns (*i*) from middle January to

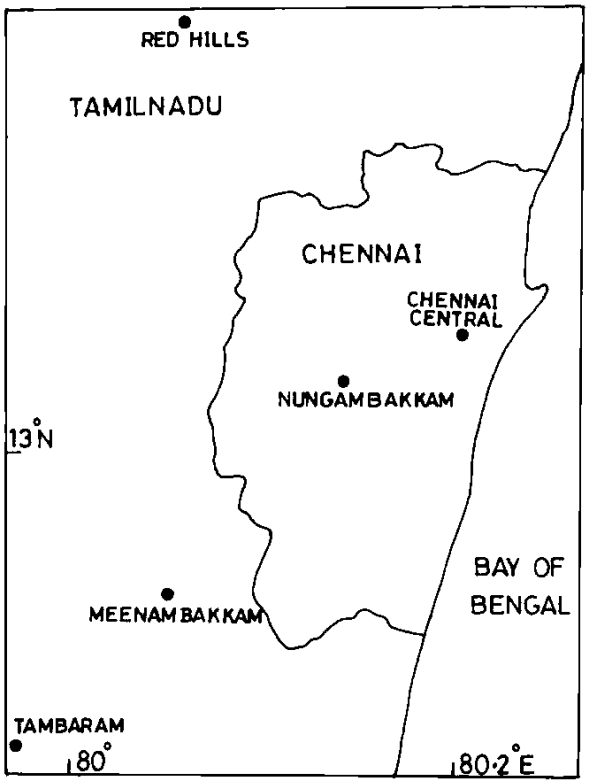

Fig. 1. Geographical location of Chennai and the Nungambakkam (city) and Meenambakkam (A.P.) observatories

middle April with negligible rainfall, (*ii*) middle April to 10th October and from 10th December to middle January fluctuating to 15 to 20 percent and (*iii*) 10th October to 10th December being the real rainy season. The rainfall can be studied from different aspects. An attempt is made in this paper to study in detail the daily rainfall spells of Chennai (both Nungambakkam and Meenambakkam) for the period of ten years (1992-2001).

2. Data and methodology

The rainfall data of Chennai, both Nungambakkam and Meenambakkam observatories were collected from the daily autographic rainfall charts for the period 1992 to 2001 from Regional Meteorological Centre, Chennai. The data has been analysed with the following norms. A spell of rain has been taken as one during which rain fell uninterruptedly. Duration of one spell is the time difference between beginning and ending of rainfall. The amount of rainfall of a spell is taken as the rainfall recorded during the whole duration of the spell. An amount of rainfall of a single spell of value as small as 0.1 millimeter is also taken into consideration. For defining the rainy day, the criteria used by India Meteorological Department *i.e.*, "The day in which the rainfall of 2.5 millimetre or more" is adopted. The spell is identified with the day and the time of beginning of the rainfall. Intensity of the spell is taken as amount of rainfall recorded divided by the time duration of the spell. The various aspects of rainfall spells such as month wise and season wise frequency, spells duration at intervals of four hours, amount of rainfall in a spell and their intensities have been analysed.

3. Result and discussion

3.1. *Frequency of rainfall spells*

Tables 1(a&b) gives the frequency of rainfall spells for each month for Nungambakkam and Meenambakkam respectively during the period of study *viz*. 1992 to 2001. It may be seen from the Table 1(a) pertaining to Nungambakkam that the average rainfall spell is about 4 in January and decreases to 2.4 in February and 0.4 in March. Raj (1998) studied the withdrawal of northeast monsoon rainfall over Tamilnadu and mentioned that the withdrawal of northeast monsoon in some years take place even after first week of January of next calendar year. Hence the average value is more in January than that of February and March. The value of average rainfall spell is generally very negligible during February and March with the single exception for February 2000. During the year 2000 because of an easterly wave, the clouding increased over southwest and adjoining west central Bay and entered into Tamilnadu coast during last week of February resulting in very good spells of rain [Figs. 2(a-c)] and that is why in Tables 1(a&b) value has increased in February 2000, otherwise during the rest of 9 years the values are very negligible. From the table it may be seen the average frequency value increases slowly from 4.2 in April to 22.9 in August, a dip to 18.6 in September then increases in October to 37.1 in November it is 54.3 and decreases to 27.3 in the month of December. Similarly in Table 1(b) pertaining to Meenambakkam the pattern of rainfall spells almost follows the similar trend with an average value of 4 during January with very much decrease in the month of February and March and the trend increases from April to August, a dip in September and increases in October and November to the high values of 33.2 and 46.8 and again falls in the month of December to 28.8. It may be seen from both the tables that in the month of September a slight fall in the average rainfall spells occurs. The lowest rainfall spells for both the places occurs in March 0.4 in Nungambakkam and 0.2 in Meenambakkam and the highest in the month of November with Nungambakkam 54.3 and Meenambakkam 46.8. The standard deviation and co-efficient of variation were calculated and tabulated for each month. It may be seen from the co-efficient of

TABLE 1(a)

Frequency of spells of rain, 1992 – 2001, Nungambakkam

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992	6	0	0	2	1	5	10	33	21	15	70	19	182
1993	0	0	1	0	2	16	25	25	14	48	61	31	223
1994	1	6	0	0	3	10	23	17	9	46	60	18	193
1995	17	0	1	0	15	8	12	21	16	38	24	2	154
1996	2	0	0	7	2	12	17	14	22	41	40	43	200
1997	8	0	0	6	2	11	21	27	25	33	84	49	266
1998	2	0	1	2	6	12	21	27	26	41	63	18	219
1999	2	0	0	2	6	9	13	16	12	57	35	32	184
2000	0	18	1	5	7	16	30	33	24	14	47	19	214
2001	2	0	0	18	8	17	28	16	17	38	59	42	245
Total	40	24	4	42	52	116	200	229	186	371	543	273	2080
AVE.	4	2.4	0.4	4.2	5.2	11.6	20	22.9	18.6	37.1	54.3	27.3	208
S.D.	5.228	5.797	0.516	5.473	4.237	3.864	6.848	7.109	5.854	13.6	17.8	14.61	32.61
C.V.	130.7	241.5	129.1	130.3	81.49	33.31	34.24	31.05	31.47	36.66	32.78	53.5	15.68

TABLE 1(b)

Frequency of spells of rain, 1992 – 2001, Meenambakkam

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1992	6	0	0	0	2	3	12	23	15	20	58	20	159
1993	0	1	1	0	3	15	19	21	10	49	51	37	207
1994	1	3	0	1	4	9	17	23	6	35	50	14	163
1995	13	0	1	1	9	6	12	20	22	37	26	7	154
1996	1	0	0	8	1	12	17	13	20	43	36	45	196
1997	10	0	0	7	2	13	13	23	22	30	60	47	227
1998	2	0	0	1	9	12	13	20	23	29	56	17	182
1999	4	0	0	4	6	13	11	19	14	30	31	26	158
2000	2	14	0	5	8	15	25	23	32	22	48	26	220
2001	1	0	0	17	11	15	26	12	21	37	52	49	241
Total	40	18	2	44	55	113	165	197	185	332	468	288	1907
AVE.	4	1.8	0.2	4.4	5.5	11.3	16.5	19.7	18.5	33.2	46.8	28.8	190.7
S.D.	4.37	4.39	0.42	5.30	3.57	4.08	5.42	4.08	7.43	8.92	11.74	14.89	32.08
C.V	109.29	244.00	210.82	120.36	64.85	36.14	32.86	20.73	40.15	26.86	25.08	51.70	16.82

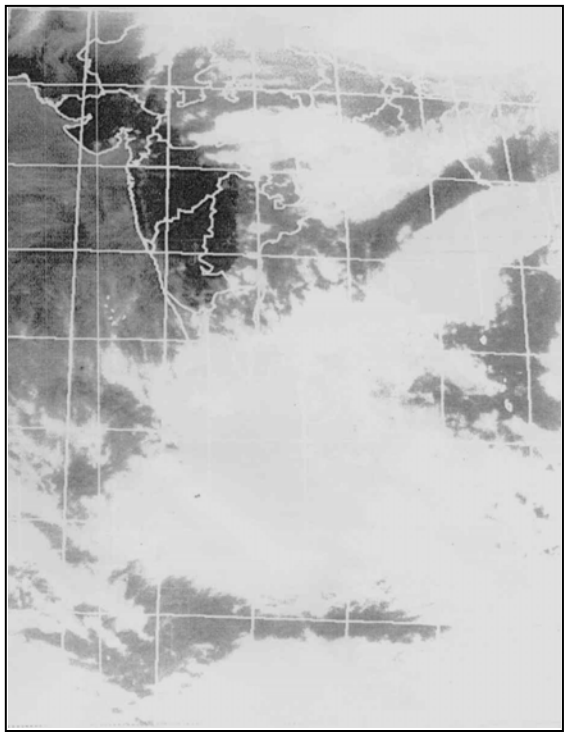

Fig. 2(a). INSAT imagery showing interaction between easterly wave and upper air westerly trough on 20th February 2000 at 0900 UTC

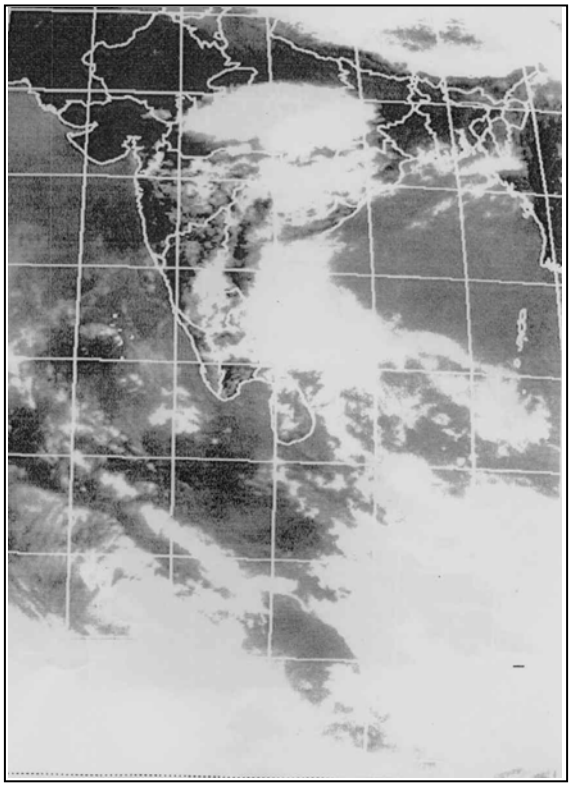

Fig. 2(b). INSAT imagery showing clouding over Andhra Pradesh and clouding from southwest Bay of Bengal entering into Tamilnadu and south coastal Andhra Pradesh on 23th February 2000 at 0900 UTC

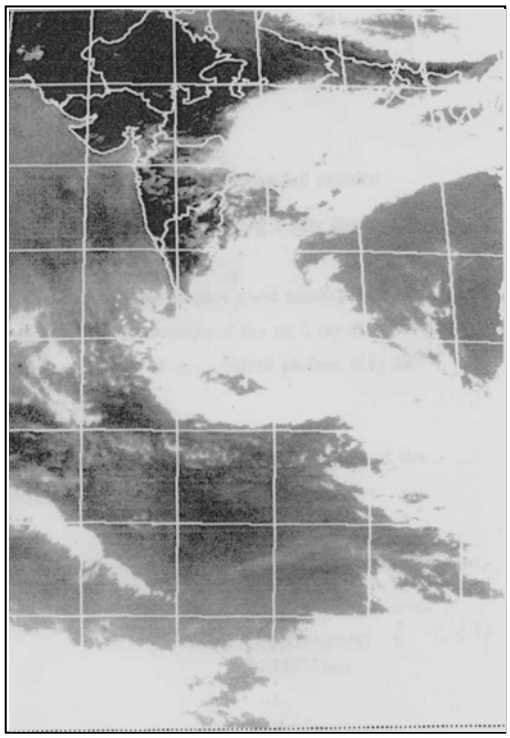

Fig. 2(c). INSAT imagery showing clouding over Peninsula on 24th February 2000 at 0900 UTC

variation that more consistency in number of rainfall spells is noticed in the month of August for both the places.

3.2. *Rainy days and spells of rain*

As mentioned earlier in the methodology number of rainy days, total number of spells and the average number of spells per rainy day for each month for Nungambakkam and Meenambakkam were calculated and the average number of spells per rainy day for each month is shown in Fig. 3. From the figure it may be seen that the value is 2.8 in January, maintain in February and dips to 1 in March and ranges between 1.5 & 2.7 upto September and value increase to 2.8 in October and then to about 3.5 during November and December with an exception of small increase in Nungambakkam in February. It agrees with the findings of Krishnaswamy (1952).

Tables 2(a&b) indicate the frequency of spells with 1, 2, etc upto 10 and above 10 spells of rain for each month for Nungambakkam and Meenambakkam. The figures indicated in the brackets represent the percentage frequency of spells. It may be seen from the tables that the number of rainfall spells upto 3 per day occupy about 75 percent of the total spells for the months beginning January to September. During October to December the

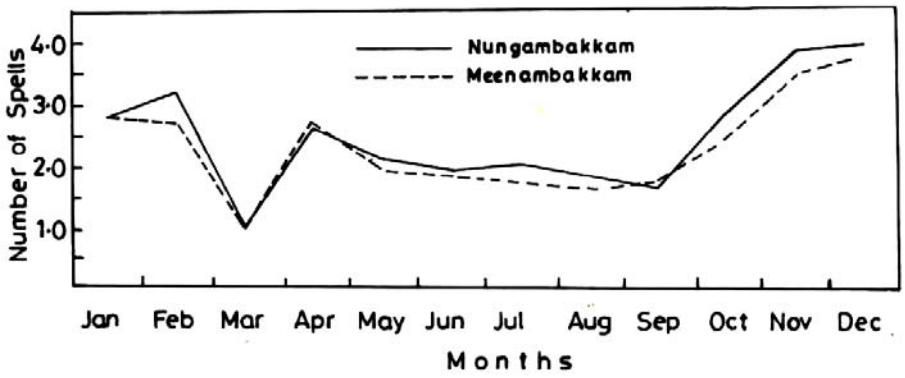

Fig. 3. Figure showing the average number of spells per rainy day

TABLE 2(a)

Number of days with different numbers of spells of rain, 1992-2001, Nungambakkam

Months	Number of spells										
	1	2	3	4	5	6	7	8	9	10	>10
Jan	10(48)	6(29)	4(19)	0	0	1(5)	0	0	0	0	0
Feb	4(44)	1(11)	2(22)	1(11)	0	0	0	1(11)	0	0	0
Mar	4(100)	0	0	0	0	0	0	0	0	0	0
Apr	9(47)	6(32)	0	1(5)	1(5)	2(11)	0	0	0	0	0
May	17(59)	7(24)	1(3)	3(10)	0	1(3)	0	0	0	0	0
Jun	56(70)	15(19)	6(8)	3(4)	0	0	0	0	0	0	0
Jul	66(56)	33(28)	12(10)	4(3)	2(2)	1(1)	0	0	0	0	0
Aug	94(64)	36(24)	11(7)	3(2)	0	3(2)	0	0	0	0	0
Sep	84(67)	27(22)	9(7)	4(3)	1(1)	0	0	0	0	0	0
Oct	61(40)	37(24)	23(15)	12(8)	7(5)	8(5)	4(3)	1(1)	0	0	0
Nov	45(28)	23(14)	26(16)	23(14)	18(11)	11(7)	8(5)	1(1)	1(1)	3(2)	2(1)
Dec	22(27)	16(19)	14(17)	12(14)	5(6)	5(6)	6(7)	0	1(1)	0	2(2)

TABLE 2(b)

Number of days with different numbers of spells of rain, 1992-2001, Meenambakkam

Months	Number of spells										
	1	2	3	4	5	6	7	8	9	10	>10
Jan	12(57)	4(19)	1(5)	3(14)	1(5)	0	0	0	0	0	0
Feb	4(50)	2(25)	1(13)	0	0	0	1(13)	0	0	0	0
Mar	2(100)	0	0	0	0	0	0	0	0	0	0
Apr	9(45)	6(30)	2(10)	1(5)	0	1(5)	1(5)	0	0	0	0
May	24(67)	8(22)	2(6)	1(3)	1(3)	0	0	0	0	0	0
Jun	53(68)	19(24)	3(4)	2(3)	1(1)	0	0	0	0	0	0
Jul	60(58)	31(30)	10(10)	2(2)	1(1)	0	0	0	0	0	0
Aug	93(68)	34(25)	6(4)	2(1)	2(1)	0	0	0	0	0	0
Sep	76(63)	33(27)	7(6)	4(3)	0	1(1)	0	0	0	0	0
Oct	69(44)	46(29)	17(11)	15(10)	4(3)	2(1)	4(3)	0	0	0	0
Nov	36(23)	42(27)	32(20)	18(11)	14(9)	7(4)	5(3)	3(2)	1(1)	0	0
Dec	25(26)	17(18)	25(26)	13(14)	5(5)	1(1)	4(4)	2(2)	3(3)	0	0

TABLES 3(a-d)

Number of spells of rain, occurred during various time intervals, Nungambakkam

Year	Time interval in hours						
	0-4	4 -8	8 –12	12 -16	16 -20	20 -24	Total
				(a) Winter season			
1992	1	3	0	1	0	1	6
1993	0	0	0	0	0	0	0
1994	1	1	4	0	1	0	7
1995	3	3	4	3	3	1	17
1996	0	2	0	0	0	0	2
1997	1	4	0	0	1	2	8
1998	1	1	0	0	0	0	2
1999	1	0	1	0	0	0	2
2000	4	3	2	2	2	5	18
2001	0	2	0	0	0	0	2
Total	12	19	11	6	7	9	64
AVE.	1.2	1.9	1.1	0.6	0.7	0.9	6.4
S.D.	1.317	1.37	1.663	1.075	1.059	1.595	6.398
C.V.	109.7	72.12	151.2	179.2	151.3	177.2	99.97
				(b) Pre-monsoon season			
1992	0	1	0	0	1	1	3
1993	0	1	2	0	0	0	3
1994	1	1	0	0	1	0	3
1995	1	2	2	3	3	5	16
1996	2	4	0	1	2	0	9
1997	0	3	2	0	1	2	8
1998	0	3	0	4	1	1	9
1999	0	0	1	1	2	4	8
2000	1	6	1	2	2	1	13
2001	5	4	1	4	4	8	26
Total	10	25	9	15	17	22	98
AVE.	1	2.5	0.9	1.5	1.7	2.2	9.8
S.D.	1.563	1.841	0.876	1.65	1.16	2.658	7.131
C.V.	156.3	73.64	97.29	110	68.21	120.8	72.76
				(c) Southwest monsoon season			
1992	15	6	4	5	19	20	69
1993	23	12	1	5	12	27	80
1994	15	3	0	0	25	16	59
1995	13	1	0	10	14	19	57
1996	10	6	8	8	8	25	65
1997	22	7	1	5	20	29	84
1998	13	15	8	8	25	17	86
1999	15	3	1	4	13	14	50
2000	22	11	6	12	30	22	103
2001	23	8	2	2	15	28	78
Total	171	72	31	59	181	217	731
AVE.	17.1	7.2	3.1	5.9	18.1	21.7	73.1
S.D.	4.886	4.417	3.178	3.635	6.935	5.334	16.07
C.V.	28.58	61.35	102.5	61.61	38.32	24.58	21.99
				(d) Northeast monsoon season			
1992	21	20	15	14	18	16	104
1993	27	25	23	15	23	27	140
1994	20	26	21	18	13	26	124
1995	22	11	11	10	6	4	64
1996	19	19	30	13	19	24	124
1997	37	25	29	23	22	30	166
1998	25	15	23	21	13	25	122
1999	29	28	15	18	13	21	124
2000	12	17	14	9	14	14	80
2001	27	29	20	29	18	16	139
Total	239	215	201	170	159	203	1187
AVE.	23.9	21.5	20.1	17	15.9	20.3	118.7
S.D.	6.757	6.005	6.385	6.146	5.087	7.818	29.64
C.V.	28.27	27.93	31.77	36.16	31.99	38.51	24.97

TABLES 3 (e-h)

Number of spells of rain, occurred during various time intervals, Meenambakkam

	Time interval in hours						
	0-4	4 -8	8 –12	12 -16	16 -20	20 -24	Total
				(e) Winter season			
1992	3	0	1	1	0	1	6
1993	1	0	0	0	0	0	1
1994	1	0	2	1	0	0	4
1995	3	1	5	2	1	1	13
1996	0	0	1	0	0	0	1
1997	2	2	3	0	1	2	10
1998	0	0	2	0	0	0	2
1999	2	1	1	0	0	0	4
2000	2	1	5	2	1	5	16
2001	0	1	0	0	0	0	1
Total	14	6	20	6	3	9	58
AVE.	1.4	0.6	2	0.6	0.3	0.9	5.8
S.D.	1.1738	0.6992	1.8257	0.8433	0.483	1.5951	5.4119
C.V.	83.842	116.53	91.287	140.55	161.02	177.24	93.309
				(f) Pre-monsoon season			
1992	0	0	1	1	0	0	2
1993	1	2	1	0	0	0	4
1994	0	2	1	0	2	0	5
1995	1	1	3	0	2	4	11
1996	3	1	1	2	2	0	9
1997	1	3	1	2	0	2	9
1998	2	1	1	4	1	1	10
1999	0	0	1	0	6	3	10
2000	2	3	1	2	3	2	13
2001	7	4	1	5	4	7	28
Total	17	17	12	16	20	19	101
AVE.	1.7	1.7	1.2	1.6	2	1.9	10.1
S.D.	2.1108	1.3375	0.6325	1.7764	1.9437	2.2828	7.1562
C.V.	124.17	78.676	52.705	111.02	97.183	120.15	70.853
				(g) Southwest monsoon season			
1992	12	2	2	3	20	14	53
1993	16	6	1	6	19	17	65
1994	11	0	1	0	23	20	55
1995	11	3	0	7	17	22	60
1996	18	5	4	8	5	22	62
1997	18	8	4	2	12	27	71
1998	12	9	6	11	17	13	68
1999	17	3	1	3	15	18	57
2000	21	12	5	10	24	23	95
2001	18	10	2	5	23	16	74
Total	154	58	26	55	175	192	660
AVE.	15.4	5.8	2.6	5.5	17.5	19.2	66
S.D.	3.5963	3.8816	2.0111	3.5668	5.8166	4.3919	12.284
C.V.	23.353	66.924	77.349	64.851	33.238	22.875	18.612
				(h) Northeast monsoon season			
1992	19	13	18	20	12	16	98
1993	24	21	28	21	21	22	137
1994	17	17	16	16	11	22	99
1995	17	15	8	11	11	8	70
1996	24	16	26	19	11	28	124
1997	32	14	22	22	20	27	137
1998	21	13	17	17	12	22	102
1999	22	18	19	9	11	8	87
2000	20	15	21	13	15	12	96
2001	25	29	22	20	24	18	138
Total	221	171	197	168	148	183	1088
AVE.	22.1	17.1	19.7	16.8	14.8	18.3	108.8
S.D.	4.4833	4.8408	5.5986	4.4672	4.9844	7.2119	23.752
C.V.	20.286	28.309	28.419	26.59	33.679	39.409	21.831

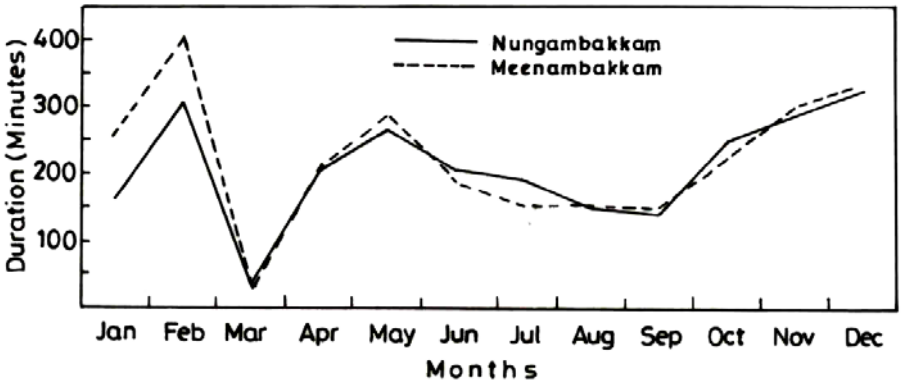

Fig. 4. Figure showing the average duration of rain (in minutes) on a rainy day

TABLE 4(a)

Number of days with different duration of rainfall, 1992 to 2001, Nungambakkam

Months	Duration in hours												
	<1	1 -2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12
Jan	13(62)	5(24)	0	1(5)	0	1(5)	0	1(5)	0	0	0	0	0
Feb	5(56)	0	0	2(22)	0	1(11)	0	0	0	0	0	0	1(11)
Mar	3(75)	1(25)	0	0	0	0	0	0	0	0	0	0	0
Apr	8(42)	2(11)	3(16)	1(5)	2(11)	1(5)	0	2(11)	0	0	0	0	0
May	9(31)	7(24)	2(7)	3(10)	2(7)	4(14)	0	0	1(3)	0	0	0	1(3)
Jun	45(56)	15(19)	6(8)	4(5)	4(5)	2(3)	3(4)	0	0	0	0	0	1(1)
Jul	61(52)	20(17)	16(14)	6(5)	2(2)	5(4)	2(2)	3(3)	0	0	0	0	3(3)
Aug	71(48)	28(19)	23(16)	12(8)	5(3)	1(1)	3(2)	1(1)	2(1)	0	0	1(1)	0
Sep	71(57)	22(18)	8(6)	9(7)	5(4)	2(2)	3(2)	2(2)	0	1(1)	2(2)	0	0
Oct	55(36)	28(18)	13(8)	13(8)	12(8)	8(5)	6(4)	1(1)	6(4)	3(2)	1(1)	3(2)	4(3)
Nov	50(31)	23(14)	15(9)	17(11)	10(6)	12(7)	4(2)	5(3)	1(1)	1(1)	5(3)	6(4)	12(7)
Dec	26(31)	12(14)	10(12)	5(6)	5(6)	5(6)	1(1)	1(1)	5(6)	2(2)	2(2)	1(1)	8(10)

TABLE 4(b)

Number of days with different duration of rainfall, 1992 to 2001, Meenambakkam

Months	Duration in hours												
	<1	1 -2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12
Jan	10(48)	4(19)	1(5)	3(14)	1(5)	1(5)	0	0	0	0	0	0	1(5)
Feb	3(38)	1(13)	0	0	0	0	0	2(25)	0	0	0	1(13)	1(13)
Mar	1(50)	0	1(50)	0	0	0	0	0	0	0	0	0	0
Apr	9(45)	3(15)	0	4(20)	1(5)	1(5)	0	1(5)	0	1(5)	0	0	0
May	21(58)	2(6)	3(8)	6(17)	1(3)	1(3)	0	1(3)	0	0	0	0	1(3)
Jun	41(53)	18(23)	5(6)	5(6)	5(6)	1(1)	0	1(1)	1(1)	0	0	0	1(1)
Jul	54(52)	18(17)	13(13)	4(4)	5(5)	1(1)	5(5)	1(1)	1(1)	0	0	0	2(2)
Aug	63(46)	24(18)	17(12)	15(11)	6(4)	5(4)	3(2)	2(1)	1(1)	1(1)	0	0	0
Sep	61(50)	22(18)	16(13)	6(5)	4(3)	7(6)	1(1)	1(1)	1(1)	0	0	0	2(2)
Oct	60(38)	25(16)	21(13)	16(10)	7(4)	6(4)	8(5)	1(1)	3(2)	3(2)	0	1	6(4)
Nov	44(28)	29(18)	23(15)	13(8)	6(4)	7(4)	5(3)	3(2)	4(3)	2(1)	4(3)	1(1)	17(11)
Dec	40(42)	11(12)	8(8)	4(4)	3(3)	5(5)	1(1)	2(2)	8(8)	3(3)	0	2(2)	8(8)

TABLE 5(a)

Number of spells with different amount of rainfall, 1992 to 2001, Nungambakkam

Months	Rainfall amount in mm									
	<0.5	0.5 - 2	2 - 5	5 - 10	10 -15	15 -25	25 -40	40 -55	55 -70	>70
Jan	12(30)	10(25)	8(20)	5(13)	1(3)	2(5)	0	2(5)	0	0
Feb	8(33)	9(38)	5(21)	0	0	0	1(4)	0	0	1(4)
Mar	0	1(25)	2(50)	0	0	1(25)	0	0	0	0
Apr	15(36)	10(24)	4(10)	3(7)	6(14)	1(2)	3(7)	0	0	0
May	10(19)	14(27)	8(15)	6(12)	5(10)	1(2)	0	4(8)	4(8)	0
Jun	28(24)	35(30)	27(23)	9(8)	10(9)	3(3)	2(2)	0	1(1)	1(1)
Jul	58(29)	65(33)	28(14)	24(12)	7(4)	6(3)	6(3)	2(1)	2(1)	2(1)
Aug	58(25)	73(32)	44(19)	26(11)	7(3)	9(4)	8(3)	2(1)	2(1)	0
Sep	42(23)	48(26)	29(16)	27(15)	9(5)	19(10)	8(4)	2(1)	0	2(1)
Oct	61(16)	128(35)	76(20)	45(12)	14(4)	23(6)	13(4)	4(1)	1(0)	6(2)
Nov	102(19)	176(32)	110(20)	63(12)	29(5)	24(4)	20(4)	5(1)	9(2)	5(1)
Dec	70(26)	83(30)	44(16)	29(11)	11(4)	14(5)	8(3)	8(3)	3(1)	3(1)

TABLE 5(b)

Number of spells with different amount of rainfall, 1992 to 2001, Meenambakkam

Months	Rainfall amount in mm									
	<0.5	0.5 - 2	2 - 5	5 - 10	10 -15	15 -25	25 -40	40 -55	55 -70	>70
Jan	10(25)	13(33)	10(25)	2(5)	3(8)	0	2(5)	0	0	0
Feb	1(6)	7(39)	3(17)	3(17)	2(11)	0	1(6)	0	0	1(6)
Mar	0	1(50)	0	0	1(50)	0	0	0	0	0
Apr	12(27)	14(32)	5(11)	3(7)	6(14)	2(5)	1(2)	1(2)	0	0
May	16(29)	14(25)	9(16)	5(9)	3(5)	4(7)	0	2(4)	0	2(4)
Jun	25(22)	39(35)	20(18)	9(8)	7(6)	6(5)	4(4)	1(1)	0	2(2)
Jul	40(24)	42(25)	33(20)	22(13)	10(6)	9(5)	5(3)	2(1)	1(1)	1(1)
Aug	31(16)	54(27)	42(21)	30(15)	17(9)	10(5)	6(3)	5(3)	2(1)	0
Sep	37(20)	54(29)	33(18)	23(12)	12(6)	14(8)	8(4)	2(1)	1(1)	1(1)
Oct	56(17)	108(33)	56(17)	51(15)	24(7)	18(5)	9(3)	5(2)	1(0)	4(1)
Nov	72(15)	160(34)	79(17)	63(13)	33(7)	29(6)	13(3)	7(1)	5(1)	7(1)
Dec	72(25)	82(28)	48(17)	32(11)	18(6)	8(3)	16(6)	4(1)	5(2)	3(1)

daily rainfall spells increase considerably and spells of rainfall of more than 8 are also seen in both places and spells with values above 10 are seen only at Nungambakkam.

3.3. *Time interval of occurrence of rainfall spells*

The spells of rainfall are classified in the interval of four hours duration and analysed season-wise and the

TABLE 6(a)

Number of spells of rainfall with different intensities, 1992 to 2001, Nungambakkam

Months	Intensity in mm/hr						
	0 - 4	4 - 7	7 - 12	12-20	20-40	40-60	>60
Jan	20(50)	7(18)	4(10)	4(10)	4(10)	0	1(3)
Feb	11(46)	6(25)	5(21)	0	1(4)	1(4)	0
Mar	2(50)	0	1(25)	0	1(25)	0	0
Apr	25(60)	5(12)	6(14)	2(5)	4(10)	0	0
May	23(44)	79(13)	11(21)	8(15)	3(6)	0	0
Jun	59(51)	21(18)	13(11)	15(13)	7(6)	1(1)	0
Jul	120(60)	23(12)	28(14)	20(10)	7(4)	0	2(1)
Aug	119(52)	47(21)	30(13)	20(9)	9(4)	3(1)	1(0)
Sep	80(43)	35(19)	27(15)	22(12)	16(9)	6(3)	0
Oct	148(40)	68(18)	70(19)	53(14)	25(7)	5(1)	2(1)
Nov	227(42)	117(22)	79(15)	67(12)	37(7)	8(1)	8(1)
Dec	124(45)	55(20)	39(14)	35(13)	16(6)	4(1)	0

TABLE 6(b)

Number of spells of rainfall with different intensities, 1992 to 2001, Meenambakkam

MonthS	Intensity in mm/hr						
	0 - 4	4 - 7	7 - 12	12-20	20-40	40-60	>60
Jan	16(40)	11(28)	7(18)	6(15)	0	0	0
Feb	7(39)	4(22)	3(17)	2(11)	1(6)	1(6)	0
Mar	1(50)	0	0	0	1(50)	0	0
Apr	24(55)	8(18)	4(9)	3(7)	1(2)	3(7)	1(2)
May	26(47)	15(27)	7(13)	5(9)	1(2)	0	1(2)
Jun	56(50)	16(14)	15(13)	15(13)	6(5)	2(2)	3(3)
Jul	66(40)	39(24)	23(14)	20(12)	14(8)	2(1)	1(1)
Aug	96(49)	34(17)	30(15)	17(9)	14(7)	2(1)	4(2)
Sep	90(49)	30(16)	33(18)	17(9)	11(6)	3(2)	1(1)
Oct	155(47)	53(16)	49(15)	43(13)	23(7)	7(2)	2(1)
Nov	186(40)	110(24)	79(17)	51(11)	31(7)	9(2)	2(0)
Dec	132(46)	58(20)	49(17)	29(10)	16(6)	4(1)	0

frequencies were taken from starting time of rainfall spells in that interval. Results are tabulated season-wise for both Nungambakkam and Meenambakkam and standard deviation and co-efficient of variation are also worked out. The results are shown in the Tables 3(a-d) for Nungambakkam and Tables 3(e-h) for Meenambakkam. From the co-efficient of variation it may be seen that the occurrence of spells do not show much significance for any particular time interval in winter and pre-monsoon seasons. It is noticed from the Tables 3(c&g) that more consistency is observed during the time interval of 1600 to 2400 hrs (late evening and night) and 0000 to 0400 hrs (early morning) *i.e.*, 78% of the spells occur in Nungambakkam and nearly 79% of the spells occur at

Meenambakkam during this time. The above result agrees with Hann's classification of the pattern of diurnal variation of precipitation for the maritime and coastal climate (Asnani, 1993), where most of the precipitation occurs at night or during early morning. It can also be seen from the Tables 3(d&h), that during northeast monsoon period the occurrence of the rainfall spells are equally spread at all the time intervals of the day.

3.4. *Total duration of rainfall*

The total number of rainy days, total duration of rainfall in each month (in minutes) and the average duration of rainfall (in minutes) on a rainy day for each month for Nungambakkam and Meenambakkam were calculated. The average duration of rainfall in minutes in a rainy day for each month is shown in Fig. 4. It may be seen from the figure that the average duration is less from January to March with the single exception for February due to the special synoptic situation in February 2000. The average values are increasing in April and May and decreases thereafter to reach the values around 150. It then increases to 240 in October and reaches around 300 in November and 330 in December.

3.5. *Daily duration of spells of rain*

Tables 4(a&b) show in greater detail the distribution of rainy days according to the following classification *viz*. days with duration of rainfall less than 1 hour, between 1 hour and 2 hour etc. and more than 12 hours for both Nungambakkam and Meenambakkam. The percentage values are indicated in the bracket. It is seen from the tables that in the months June to September, the period of southwest monsoon, on more than 65 percent of rainy days the duration of rainfall in a day is less than 2 hours. While in Northeast monsoon season the value of percentage of rainy days with less than 2 hours duration is below 55 percent. The other durations of classification lying between 2 hours and 7 hours occupies 30 percent. Also rainy days with spells of more than 7 hours duration are about 15 percent.

3.6. *Amount of rainfall*

The amount of rainfall of spells is classified into various intervals. Tables 5(a&b) give the amount of rainfall of the individual spells, with less than 0.5 millimeters, between 0.5 and 2 millimeters and so on to above 70 millimeters for Nungambakkam and Meenambakkam. The percentage values are indicated in the bracket. It may be seen from the tables that at both places, from January to September and December, the number of spells with amount less than 0.5 millimeters ranges from 20 - 35 percent and the value decreases from 15 - 20 percent during October and November. In fact the number of spells with rainfall amount of less than 2 millimeters is about 55 percent throughout the year. In general the spells of more than 2 millimeters and less than 40 millimeters occupy just around 40 percent where as the spells more than 40 millimeters is just 5 percent except during May where the value is 16 percent for Nungambakkam and 8 percent for Meenambakkam.

3.7. *Intensity of spell of rainfall*

As indicated earlier in the methodology the intensity of rainfall is taken as the amount of rainfall recorded divided by time duration of the spells. Tables 6(a&b) indicate the details of the various rainfall intensities, 0 to 4 millimeters per hour, 4 to 7 millimeters per hour, so on and upto 60 millimeters per hour and above 60 millimeters per hour for each month for both the places. It may be seen from the tables that the intensity of less than 7 millimeters per hour ranges from 60 to 70 percent for all the months except for March where the value is 50 percent. The percentage of intensities of rainfall spell in the interval of 7 millimeters to 20 millimeters per hour is about 25 percent. It is significant to note the spells of higher intensities with the amount of 20 millimeters per hour or more is less than 10 percent of the total value.

4. Conclusion

After a detailed study of rainfall data from the autographic charts of Nungambakkam and Meenambakkam, it is seen that the average frequency of rainfall spells monthwise is just around 4 in January decreases to negligible in March, steadily increases upto August, a dip in September and reaches the peak in November and decreases in December. Similar trend is noticed in the average number of spell per rainy day as well as in the average duration of rainfall for each month. Regarding number of spells per day, upto 3 spells per day occupy about 75 percent during January to September and spells of more than 8 are seen during October to December. It is also seen that the time interval of occurrence of rainfall spells for both Meenambakkam and Nungambakkan agrees with the Hann's classification pattern of diurnal variation of precipitation of coastal classification during southwest monsoon. During northeast monsoon season the frequency is evenly spread throughout the day. As far as the amount of rainfall of individual spells is concerned, rainfall amount of less than 2 millimeter is about 55 percentage throughout the year, more than 2 millimeter to 4 centimeter occupies just 40 percentage and more than 4 centimeter is just 5 percentage. Regarding the intensity, spell of rain less than 7 millimeter per hour ranges to 60 to 70 percentage for all months, between 7 millimeter to 20 millimeter per

hour is about 25 percentage and more than 20 millimeter per hour is less than 10 percentage. From the above study it is easy to understand the complete pattern of the rainfall over both for Chennai city and airport.

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