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PRECIPITABLE WATER VAPOUR AND RAINFALL OVER VISAKHAPATNAM

1. Precipitable water vapour in the atmosphere may be defined as the depth of water that would result should all water vapour in a vertical column of the atmosphere over a unit area be condensed. Since the density of water is unity, the depth in cm of the condensed water vapour is numerically equal to its mass in gram. It is a measure of the total moisture content of the atmosphere.

Ananthakrishnan *et al.* (1965) studied the precipitable water vapour content in the atmosphere to bring out a relationship between Precipitable Water Vapour Content (PWVC) and rainfall over a station. Mokashi (1968) studied the mean precipitable water vapour in the atmosphere over India in different months. Similar studies on the usefulness of PWVC in forecasting heavy rainfall over Lucknow was carried out by Lal (1992).

In the present study the radiosonde data of Visakhapatnam (Lat. 17° 43 N, Long. 83° 14′ E), situated on the east coast of India, has been examined with a view to see whether PWVC has any bearing in forecasting rainfall over Visakhapatnam. Single radiosonde data of Cyclone Warning Centre (CWC), Visakhapatnam has been used in addition to rainfall data over CWC, Visakhapatnam and Visakhapatnam Airport separated by a distance of about 16 km.

PWVC, in a layer of thickness $(p - p_0)$, is calculated by using the formula (Mokashi 1968) :

$$w = r \frac{(p - p_0)}{1000}$$

where, r — Humidity mixing ratio in gm/kg of dry air,

p — Pressure of bottom layer,

p_0 — Pressure of top layer.

The entire column of atmosphere is divided into layers of 100 hPa thickness $(p - p_0) = 100$ with mixing ratios $r_1, r_2, r_3, \ldots$., then the total precipitable water in the column is :

$$w = \frac{(r_1 + r_2 + r_3 + \ldots\ldots)}{10}$$

The mean of the values of 'r' of the bottom and top of an isobaric layer can be taken as the mean mixing ratio for the layer. Contributions from layer up to 500 hPa level only are taken into account.

2. 0000 and 1200 UTC radiosonde ascents of Visakhapatnam, during June to October for the five-year period 1987 to 1991, have been utilised and PWVC values for morning and evening ascents were calculated. Average PWVC for the day has been arrived at by averaging the 0000 UTC and 1200 UTC PWVC. The PWVC so arrived at is compared with the next day (24-hr) rainfall. A longer period (5 years) radiosonde and rainfall data have been used to increase the usefulness of this method in forecasting precipitation.

The study is confined to June-October as Visakhapatnam receives above 80% of its annual rainfall during this period. October month is also included in the study because October is the rainiest month which accounts for nearly 26% of the annual rainfall over Visakhapatnam.

TABLE 1

Frequency distribution of rainfall in different ranges of PWVC (CWC Visakhapatnam)

Precipitable water vapour content (PWVC) (gm/cm^2)	Total No. of occasions	No rain	< 2.5 mm	2.5-20 mm	20.1-34.9 mm	35-64.9 mm	> 65 mm	Rainfall occasions (%)
< 4.0	66	60 (91%)	3 (5%)	2 (3%)	1 (1%)	—	—	9
4.0-5.0	151	75 (50%)	45 (30%)	21 (14%)	4 (3%)	2 (1%)	4 (3%)	50
5.1-6.0	304	116 (38%)	121 (40%)	49 (16%)	9 (3%)	4 (1%)	5 (2%)	62
6.1-7.0	195	53 (27%)	70 (36%)	51 (26%)	12 (6%)	5 (3%)	4 (2%)	73
7.1-8.0	22	1 (5%)	8 (36%)	9 (41%)	3 (14%)	—	1 (5%)	95
8.1-9.0	3	—	1 (33%)	—	—	2 (67%)	—	100

TABLE 2

PWVC for heavy rainfall and associated synoptic situation (CWC Visakhapatnam)

S. No.	Date	Rainfall (mm)	Previous day PWVC (gm/cm^2)			Synoptic situation
			0000 UTC	1200 UTC	Average	
1	5 Aug '87	122.0	5.6	5.8	5.7	A trough of low from northwest Bay to southwest Bay across westcentral Bay along and off Andhra coast on 4th.
2	20 Aug '87	73.7	5.9	3.3	4.6	A trough of low over westcentral Bay on 19th.
3	20 Sep '87	89.2	5.7	5.0	5.3	A trough of low along eastcoast on 19th.
4	16 Oct '87	177.8	4.5	—	4.5	Cyclonic storm in Bay 350 km southeast of Machilipatnam on 15th.
5	18 Jul '88	73.0	5.9	6.5	6.2	Depression in Bay 200 km east southeast of Kalingapatnam on 17th.
6	10 Aug '88	67.4	5.5	7.1	6.3	A low pressure area over north Bay on 9th.
7	19 Sep '88	125.2	6.5	7.7	7.1	A well marked low pressure area over northwest and adjoining westcentral Bay on 18th evening.
8	25 Sep '88	74.6	5.9	3.8	4.9	A feeble low pressure area over westcentral Bay off Andhra coast on 24th.
9	1 Oct '88	70.8	5.2	6.0	5.6	Depression over Bay 120 km east of Visakhapatnam on 1st morning.
10	23 Jul '89	91.7	6.3	6.6	6.5	Deep depression 300 km east northeast of Visakhapatnam on 22nd.
11	17 Aug '89	84.2	5.9	5.6	5.7	Depression 200 km east of Visakhapatnam in the evening of 16th.
12	7 Sep '89	74.4	3.2	6.5	4.9	Cyclonic circulation in lower levels over northwest and adjoining westcentral Bay off north Andhra coast on 7th morning.
13	28 Sep '89	75.7	5.5	5.9	5.7	A low pressure area over Gangetic West Bengal on 27th.
14	12 Jul '91	78.2	6.8	—	6.8	A low pressure area over westcentral Bay on 11th.

TABLE 3

Frequency distribution of rainfall in different ranges of PWVC (Airport Visakhapatnam)

Precipitable water vapour content (PWVC) (gm/cm^2)	Total No. of occasions	No rain	< 2.5 mm	2.5-20 mm	20.1-34.9 mm	35-64.9 mm	⩾ 65 mm	Rainfall occasions (%)
< 4.0	66	57 (86%)	7 (11%)	1 (1%)	1 (1%)	—	—	14
4.0-5.0	151	85 (56%)	35 (23%)	26 (17%)	1 (1%)	3 (2%)	1 (1%)	44
5.1-6.0	304	121 (40%)	98 (32%)	57 (19%)	14 (5%)	11 (4%)	3 (1%)	60
6.1-7.0	195	46 (23%)	75 (38%)	54 (28%)	2 (1%)	13 (7%)	5 (3%)	77
7.1-8.0	22	3 (14%)	5 (23%)	10 (45%)	1 (5%)	2 (9%)	1 (5%)	86
8.1-9.0	3	—	1 (33%)	—	2 (67%)	—	—	100

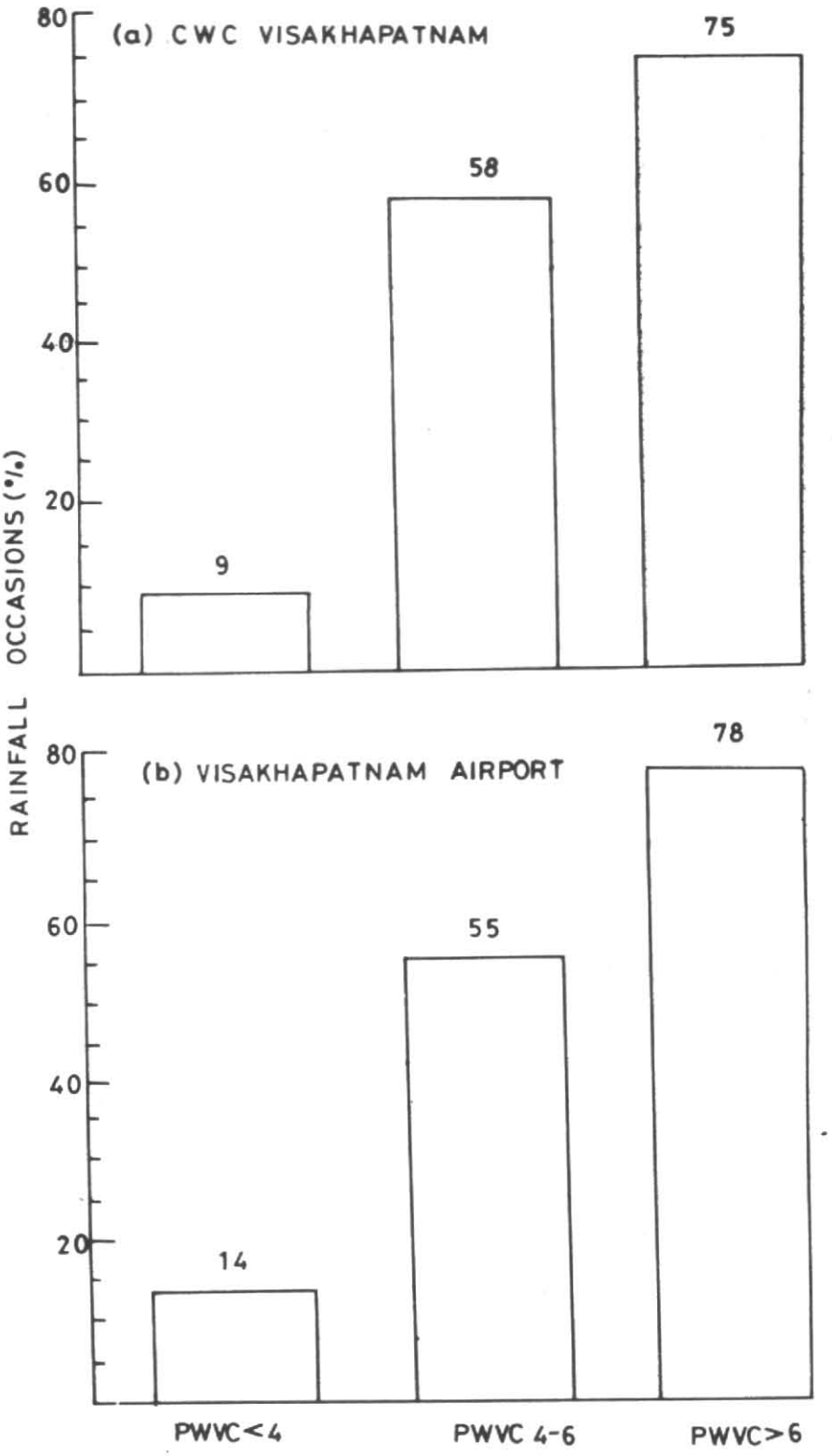

Fig. 1 (a & b). Percentage occasions of rainfall in different ranges of PWVC

Present paper is divided into two sections dealing with the analysis of PWVC and rainfall for CWC Visakhapatnam and Visakhapatnam Airport.

3. *CWC Visakhapatnam* — Frequency distribution and percentage occurrence of rainfall corresponding to different ranges of PWVC with respect to next day

TABLE 4

PWVC for heavy rainfall and associated synoptic situation (Airport Visakhapatnam)

S. No.	Date	Rainfall (mm)	Previous day PWVC (gm/cm^2)			Synoptic situation
			0000 UTC	1200 UTC	Average	
1	16 Oct '87	124.6	4.5	—	4.5	Cyclonic storm in Bay 350 km southeast of Machilipatnam on 15th.
2	18 Jul '88	75.5	5.9	6.5	6.2	Depression in Bay 200 km eastsoutheast of Kalingapatnam on 17th.
3	10 Aug '88	65.2	5.5	7.1	6.3	A low pressure area over north Bay on 9th.
4	19 Sep '88	129.5	6.5	7.7	7 1	A well marked low pressure area over northwest and adjoining westcentral Bay on 18th evening.
5	1 Oct '88	86.0	5.2	6.0	5.6	Depression over Bay 120 km east of Visakhapatnam on 1st morning.
6	23 Jul '89	80.4	6.3	6.6	6.5	Deep depression 300 km eastnortheast of Visakhapatnam on 22nd.
7	13 Aug '90	67.6	6.5	6.7	6.6	A low pressure area over westcentral Bay off north Andhra coast on 13th.
8	6 Jun '91	67.3	5.7	6.1	5.9	A low pressure area over Rayalaseema, Telangana and neighbourhood on 6th morning.
9	25 Sep '91	91.6	5.0	6.2	5.6	A low pressure area over southeast Madhya Pradesh on 24th.
10	6 Oct '91	109.1	6.3	6.3	6.3	A cyclonic circulation over southwest Bay off south Andhra coast up to 5.8 km asl on 5th.

rainfall amounts are tabulated in Table 1. During the period under study there were 741 days for which PWVC values could be evaluated. The PWVC values evaluated ranged from 1.9 to 9.2 gm/cm^2.

From the table it is seen that when the PWVC was less than 4 gm/cm^2. there are only 6 occasions of rainfall out of 66. As the PWVC amount increased from 4, the percentage of occurrence of rainfall also increased. When the PWVC was more than 7 gm/cm^2 in almost all cases there was rainfall.

It is also evident from the same table that there is no significant relationship between the intensity of precipitation (rainfall amounts) and the magnitude of PWVC.

PWVC for heavy rainfall occasions during June-October (1987-1991) and associated synoptic situations are shown in Table 2. Heavy rainfall here refers to rainfall of 65 mm or more in 24 hours ending at 0830 IST of date.

From the table it is seen that there are 14 occasions of heavy rainfall and in each case the synoptic situation is favourable. The table is also self explanatory of the fact that magnitude of PWVC has no bearing on intensity of precipitation.

The different ranges of the PWVC and the associated frequency of rainfall in percentage are shown in Fig. 1 (a).

4. *Visakhapatnam Airport* — Tables 3 & 4 show the frequency distribution and percentage occurrence of rainfall corresponding to different ranges of PWVC and heavy rainfall and associated synoptic situation respectively.

The results show similar trends of relationship between PWVC and subsequent rainfall amounts as in the case of CWC Visakhapatnam.

The different ranges of the PWVC values and the associated frequency of rainfall in percentage are shown in Fig. 1 (b).

From the above analysis it may be concluded that the critical value of PWVC of '7 gm/cm^2' appears to be suitable to indicate high probability of occurrence of rainfall (about 85% of occasions or more) next day both for CWC Visakhapatnam and Visakhapatnam Airport.

It is always advantageous to use PWVC in conjunction with the synoptic situation in forecasting local rainfall, especially the heavy rainfall.

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