Mausam, (1994), **45**, 2, 161-164

551.553.21 : 551.577 : 556.12 "32"

Variations in precipitable water content in lower troposphere at Pune during summer monsoon

SURENDRA S. PARASNIS
Indian Institute of Tropical Meteorology, Pune
(Received 24 December 1992, Modified 30 August 1993)

सार—प्रस्तुत शोध पत्र में, 1980 और 1981 की ग्रीष्मकालीन मानसून ऋतुओं के दौरान, पुणे (18° 32′ उ०, 73° 51′ पू० समुद्रतल से 559 मी० ऊपर) में वर्षणीय जल की मात्रा में होने वाले परिवर्तनों का अध्ययन किया गया है। वायुमंडल में 900-650 हे० पा० तलों पर वर्षणीय जल की मात्रा के मानों से 2-3 और 7-8 दिनों की अवधि के चरममान दिखाई दिए हैं। अन्य मौसम प्राचलों में दिखाई देने वाली आवृत्तियां तुलनीय पाई गई।

ABSTRACT. Variations in Precipitable Water Content (PWC) at Pune (18°32'N, 73°51'E, 559 m asl) during summer monsoon seasons of 1980 and 1981, have been studied. Spectrum of PWC values in layers 900-650 hPa showed peaks at periods 2-3 and 7-8 days. The periodicities observed in PWC were comparable with those observed in other meteorological parameters.

Key words—Precipitable Water Content (PWC), Spectrum, Monsoon, Troposphere, Periodicity.

1. Introduction

Distribution of Precipitable Water Content (PWC) in atmosphere is a good indication of the dynamics of circulation systems. Larger amounts of PWC are associated with convection and lesser amounts are associated with subsidence (Hsu and Blanchard 1989). With intention to study variations in moisture contents in lower troposphere, PWC a parameter which depends upon moisture, has been chosen. PWC can be defined as the depth in cm of liquid water that would result by precipitation of entire water vapour present in the vertical column of one square cm cross-section. The seasonal and geographical variations in PWC values over some of the Indian stations have already been studied by Ananthakrishnan *et al.* (1965). In this study, the variations observed in PWC during two consecutive summer monsoon seasons over a tropical inland station have been compared with those observed in other meteorological parameters in earlier studies.

2. Observations and analytical procedure

Pune (18°32'N, 73°51'E, 559 m asl) is situated on leeside of the Western Ghats. Pune is not a routine aerological station. Special aerological observations were carried out during summer monsoons of 1980 and 1981 in connection with the artificial rainmaking experiment conducted by the Indian Institute of Tropical Meteorology, Pune.

2.1. *Method of computation*

The aerological data collected during summer monsoon seasons of 1980 and 1981 were used to obtain PWC values. From dry bulb and dew point temperatures, values of humidity mixing ratio (gm kg^{-1}) were evaluated for surface and isobaric levels 900, 850 ..... up to 500 hPa. PWC values were computed using following formula (Mukherjee and Ramana Murty 1978):

$$PWC = \frac{1}{g} \int_{\text{Surface}}^{500} r \, dp \qquad (1)$$

where, g is acceleration due to gravity (cm sec^{-2}) and r is humidity mixing ratio (gm kg^{-1}). Total PWC values for 156 days during 1980 and 1981 were thus obtained. Since PWC above 500 hPa level contributes to only 7% of total PWC of atmospheric column (Chowdhury 1983), PWC values obtained considering moisture up to 500 hPa level, in this study, actually represent 93% of total PWC. If surface pressure in hPa is P_1 then PWC in the layer from surface to 900 hPa is:

$$PWC = (r'/1000) \times (P_1 - 900) \qquad (2)$$

where r' is mean value of humidity mixing ratio for the layer. Since layers of 50 hPa thickness have been considered in this study, the PWC value for each layer above 900 hPa = $r'/20$. Values of PWC were

TABLE 1

Mean (cm), standard deviation (cm) and coefficient of variation (%) of PWC for different layers during 1980 and 1981

Layer	1980			1981		
	Mean (cm)	SD (cm)	CV (%)	Mean (cm)	SD (cm)	CV (%)
Surface-900	0.86	0.052	6	0.83	0.058	7
900-850	0.68	0.077	11	0.66	0.085	13
850-800	0.61	0.063	10	0.58	0.079	14
800-750	0.54	0.063	12	0.50	0.081	16
750-700	0.44	0.077	18	0.40	0.084	21
700-650	0.34	0.096	28	0.32	0.081	25
650-600	0.27	0.089	33	0.26	0.075	29
600-550	0.22	0.078	35	0.21	0.070	33
550-500	0.17	0.068	40	0.17	0.061	36

SD: Standard deviation (cm). CV: Coefficient of variation (%).

thus obtained for 9 layers, *viz.*, surface-900 hPa, 900-850 hPa, 850-800 hPa, ... 550-500 hPa.

2.2. *Spectrum analysis*

PWC values for each layer and total PWC were subjected to power spectrum analysis. The method followed here is mainly based on WMO Tech. Note No. 79 (1966). Length of the record is 78 observations (one observation daily) per year. Maximum lag used is 15 so that the frequency (n) refers to cycles in 30 days and the period is $30/n$ days. Before subjecting to power spectrum analysis the linear trend and long term variations have been removed by normalising the original data.

3. Results and discussion

3.1. *PWC and monsoon activity*

Daily values of total PWC are shown in Fig. 1 (solid lines). Pune is situated in the Madhya Maharashtra area of Maharashtra State and aerological observations over Pune are representative of the atmospheric conditions over the Madhya Maharashtra area. The index of monsoon activity was based on the rainfall activity over the Madhya Maharashtra area. The broken lines represent the index of monsoon activity. The different activities observed in summer monsoon season are described as Isolated (Iso), Scattered (Sc), Fairly Widespread (FW) and Widespread (W). Numerical values are assigned to these activities as 1-4 with increasing order of monsoon activity, *viz.*, Iso = 1, Sc = 2, FW = 3 and W = 4 same as in Parasnis (1990). Monsoon activity and PWC values are plotted with 2 days lag. The relationship between total PWC and

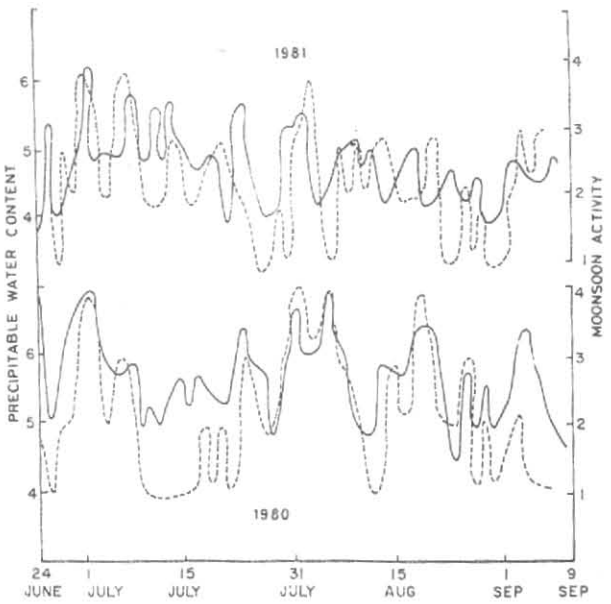

Fig. 1. Daily variation in total PWC (———) and monsoon activity (— — —) during 1980 and 1981 (24 June-9 September). The monsoon activity values are plotted against preceding 2 days values of PWC (*i.e.* 2 days lag)

monsoon activity is seen clearly in Fig. 1. Increase in monsoon activity is preceded by increase in total PWC. However, during some periods inverse relationship is observed as existing monsoon conditions over Pune may not be matching with monsoon activity over the Madhya Maharashtra area.

It may be noted that the lag of 2 days between PWC and monsoon activity matches well when we consider the significant changes in PWC and monsoon activity values. When the monsoon activity has changed from Iso/Sc to FW/W, this change has been associated in the PWC values. The non-matching or discripancies are seen only in cases where there are small variations (not significant variations in monsoon activity).

3.2. *Vertical variation in PWC values*

Table 1 gives mean values of PWC for different layers. Also, the Standard Deviation (SD) and Coefficient of Variation (CV) of PWC values are given in Table 1. The variations in PWC values in layer 750-500 hPa are more as compared to those in lower layers between surface-750 hPa. During summer monsoon, moisture content in lower troposphere (up to 850 hPa) remains more or less same (relative humidity 75%) irrespective of monsoon activity (Srinivasan and Sadasivan 1975). It is only during active monsoon spell that moisture in lower levels is pumped up to higher

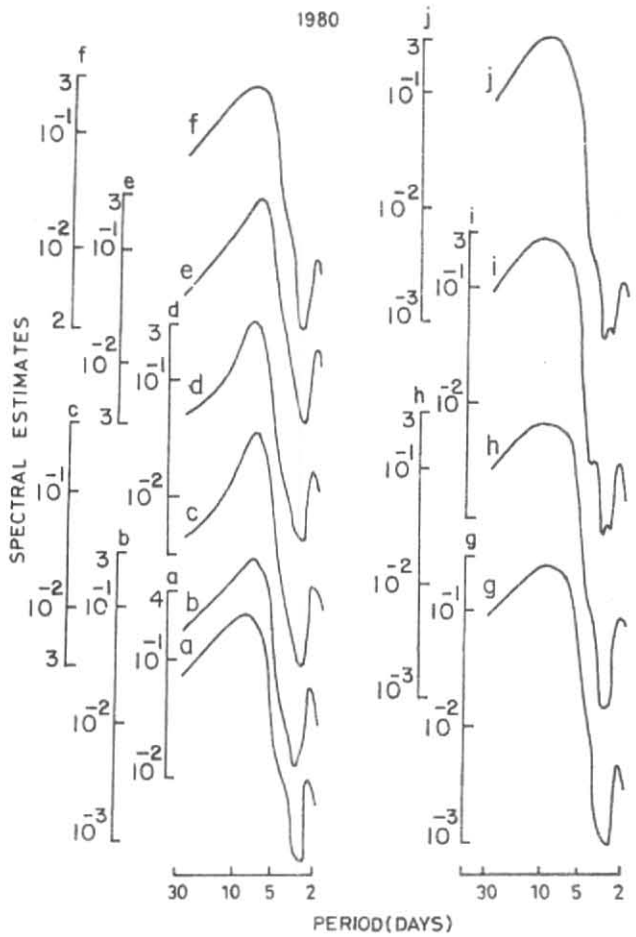

Fig. 2. Plots of spectral estimates for total PWC (a) and for different layers (b-j) for 1980. (b) : surface-900 hPa, (c) : 900-850 hPa ..... i : 600-550 hPa and j : 550-500 hPa

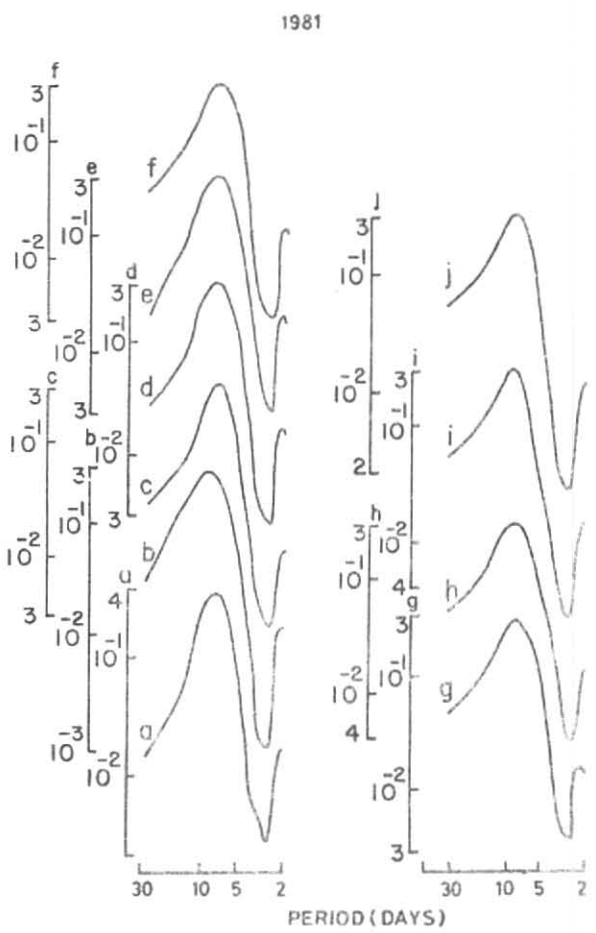

Fig. 3. Same as Fig. 2 for 1981

levels up to 500 hPa (Parasnis *et al.* 1985). Subsidence associated with weak monsoon conditions suppresses convection and growth of clouds. Higher values of CV observed in the layer 750-500 hPa reflect the variation in convective activity. The study of convective mixing in boundary layer during the summer monsoon has showed differences in sub-saturation in cloud layer (Parasnis and Morwal 1991).

3.3. *Spectral estimates*

Plots of spectral estimates against periods (frequency) are shown in Figs. 2 and 3 in respect of total PWC (up to 500 hPa) and PWC for each layer. From Figs. 2 and 3, it is seen that peaks in spectral density observed in different layers are between 2-3 and 7-8 days during both the years. However, only the peak observed at 7-8 days is significant (1% level). PWC represent moisture in atmosphere. Hence variations in PWC are due to variations in moisture during different phases of monsoon activity. The study of day-to-day variations in pressure gradients over India for the SW monsoon season by means of power spectrum analysis showed tendency for 5-6 days period (Bhalme and Parasnis 1975). This period was attributed to the pulsatory behaviour of the SW monsoon. Elements of monsoon systems showed periods of 2-6 days (Krishnamurty and Bhalme 1976). In an earlier study of wind characteristics during SW monsoon (Parasnis 1991), the spectral analysis of the u and v components revealed that the spectral energy was prominently shared by periods of 5-7 and 2-3 days. The 2-3 and 7-8 days periodicities observed in PWC are in agreement with the earlier studies.

4. Conclusions

The study of variation in PWC in ABL over a tropical inland station showed the following :

(*i*) The relationship between monsoon activity and total PWC showed that the monsoon activity is preceded by the increase in total PWC.

(*ii*) Peaks of the order of 2-3 and 7-8 days observed in the PWC values at different levels up to 500 hPa, perhaps, may be attributed to the periodicities of the same order observed in other meteorological parameters, such as, pressure gradients, wind etc during the summer monsoon in earlier studies.

Acknowledgements

The author is thankful to Dr. A.S.R. Murty for useful suggestions. Mrs. Savita B. Morwal helped in the preparation of the manuscript of this paper.

References

Ananthakrishnan, R., Selvam, A. M. and Chellappa, R., 1965, "Seasonal variations of precipitable water content in the atmosphere over India", *Indian J. Met. Geophys.*, **16**, 371-384.

Bhalme, H. N. and Parasnis, S. S., 1975, "5-6 days oscillation in the pressure gradients over India during SW monsoon", *Indian J. Met. Hydrol. Geophys.*, **26**, 71-76.

Chowdhury, A., 1983, "On the mass, heat and moisture balance in the field of monsoon depressions", *Mausam*, **34**, 383-394.

Hsu, S. A. and Blanchard, B. W., 1989, "The relationship between total precipitable water and surface level humidity over the sea surface : A further evaluation", *J. Geophys. Res.*, **94**, 14539-14545.

Krishnamurty, T. N. and Bhalme, H. N., 1976, "Oscillations of a monsoon system, Part I : Observational aspect", *J. Atmos. Sci.*, **33**, 1937-1945.

Mukherjee, B. K. and Ramana Murty, Bh. V., 1978, "Features of lower troposphere of contrasting rainfall at a tropical station", *Tellus*, **30**, 110-116.

Parasnis, S. S., Selvam, A. M. and Ramana Murty, Bh. V., 1985, "Variations of the thermodynamical parameters in the atmospheric boundary layer over the Deccan Plateau region, India", *Pure Appl. Geophys.*, **123**, 305-313.

Parasnis, S. S., 1990, "Stability of the sub-cloud layer during the summer monsoon", *Bound. Layer Meteorol.*, **52**, 69-74.

Parasnis, S. S., 1991, "Wind characteristics in the lowest 340 m of the Atmospheric Boundary Layer at Pune, India", *Bound. Layer Meteorol.*, **54**, 277-285.

Parasnis, S. S. and Morwal, S. B., 1991, "The convective boundary layer over the Deccan Plateau, India during the summer monsoon', *Bound. Layer Meteorol.*, **54**, 59-68.

Srinivasan, V. and Sadasivan, V., 1975, "Thermodynamical structure of the atmosphere over India during southwest monsoon season", *Indian J. Met. Hydrol. Geophys.*, **26**, 169-180.