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Study of rainfall features over Goa state during southwest monsoon season

S. M. METRI and KHUSHVIR SINGH

Meteorological Office, Panaji, Goa, India

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e mail : metrisunder@yahoo.com; singhkv2003@gmail.com

सार – इस शोध पत्र में गोवा के विभिन्न वर्षामापी केन्द्रों में 30 वर्षों की अवधि के वर्षा के लक्षणों का अध्ययन किया गया है। गोवा के प्रत्येक वर्षामापी केन्द्र के लिए औसत मासिक वर्षा, मानक विचलन और परिवर्तिता के गुणांक जैसे सांख्यिकीय प्राचलों का आकलन किया गया है। इस अवधि के दौरान हुई भारी वर्षा की कुछ घटनाओं का भी अध्ययन किया गया है। इस अध्ययन से गोवा के पूर्वी भागों की तरफ वर्षा में उल्लेखनीय वृद्धि की प्रवत्ति का पता चला है। गोवा में औसत वार्षिक वर्षा लगभग 330 सें. मी. होती है और दक्षिण पश्चिम मानसून ऋतु (जून से सितम्बर) के दौरान लगभग 90% वर्षा होती है। अध्ययनों से पता चला है कि भारी वर्षा की अधिकांश घटनाएँ दक्षिण पूर्व अरब सागर में सक्रिय अपतटीय द्रोणी और निम्न दाब तंत्रों के कारण हुई। इस अध्ययन से यह भी पता चला है कि गोवा के वर्षा के वितरण में पर्वतीय प्रभाव की महत्वपूर्ण भूमिका है। पर्वतीय प्रभाव के कारण वेलपोई में अधिकतम वर्षा होती है।

ABSTRACT. In this paper the rainfall features at different raingauge stations of Goa state have been studied for the period of 30 years. The statistical parameters such as mean monthly rainfall, Standard Deviation and Coefficient of Variation have been computed for each raingauge station of Goa. Some heavy rainfall events during the period have also been studied. The study shows the significant rising trend of rainfall towards the eastern parts of Goa. Goa experiences an average rainfall of about 330 cm annually and around 90% of annual rainfall occurs during southwest monsoon season i.e. (June to September). Studies revealed that most of heavy rainfall events caused due to active off-shore trough and low pressure systems formed over southeast Arabian Sea. It has also come out from the study that the orography of Goa plays an important role in rainfall distribution. Valpoi receives maximum rainfall due to its orographic effect.

Key words – Off-shore trough, Orography, Monsoon rainfall etc.

1. Introduction

Goa lies on the west coast of India and is well known for tourism, fisheries and Iron ore mining industries. Goa state is divided into two districts *i.e.*, North Goa and South Goa, with total 11 Talukas. Onset of southwest monsoon (hereafter referred as monsoon) over Goa state is awaited with great anxiety and demand. The onset of monsoon over Indian sub-continent is one of the important aspects in the evaluation of rainfall. The normal onset date of monsoon over Goa is around 5th June with a standard deviation of 8 days. The Monsoon over Goa is non linearly linked with many factors like surface winds, off-shore trough and orography etc. The monsoon first sets over Kerala and further advances to Goa state and rest of the country with variations, depending upon the strength of southwesterly winds and monsoon current. During the monsoon season, several semi-permanent weather systems are occurring, *i.e.*, off-shore trough and low pressure systems, which effect the distribution of rainfall in various parts of the west coast and other parts of the country. Coastal Karnataka, Kerala and Konkan & Goa are the regions of maximum precipitation over the west coast of India.

The orography plays an important role in distribution of rainfall over Goa. Roy Abraham *et al.*, (1996) have observed the simulation of monsoon circulation and cyclone with different type of orography. The study is aimed to know and gaining insight into analysis of variability and mean monthly rainfall amounts during the period.

A study about off-shore trough and very heavy rainfall events along the west cost of India during Armex-2002 was explained by Madan *et al.*, (2005). The off-shore trough plays an important role on the intensity and distribution of rainfall over Kerala, Karnataka and Goa state. It is also observed that when off-shore trough persists a day or two and becomes well marked, Goa receives heavy rainfalls. Estimating water resources in India as well as Goa state has been studied by Shankar *et al.*, (2004). A statistical analysis of rainfall distribution and trend of rainfall anomalies distractive during monsoon

period over West Bengal was described by Basu *et al*., (2004).

A study on the convective structure of atmosphere over the west coast of India during ARMEX-I was carried out by Mohanty *et al*. (2005). On some characteristic features of daily rainfall over mainly Maharastra is studied by Agashe and Padgalwar (2005). Prasad *et al*. (1991) studied the "Rainfall features in the districts of Bihar Plateau during southwest monsoon. A study on southwest monsoon rainfall characteristics in arid zone of Haryana was explained by Singh *et al.*, (2003).

Valpoi station receives maximum rainfall in Goa, due to its orography. The elevation of Sahyadris hills rising steeply just east of Valpoi is one of the reasons of high precipitation over Valpoi (Sattari Taluka). In this paper the trend of seasonal and annual rainfall over Goa has also been studied based upon 30 years data.

2. Data and methodology

Goa state is having two Departmental Observatories and eight out-post raingauge stations. The main observatory at Panaji lies on the west coast of India (Lat. 15° 29.3′ N and Long. 73° 49.4′ E). Neighbouring states of Goa are Karnataka and Maharastra which have wide network of hydrological observatories. Goa state has a good network of rain gauges under India Meteorological Department (IMD) to collect rainfall data from 10 stations at different locations. The daily rainfall data has been collected from the stations namely Valpoi, Ponda, Canacona, Margao, Sanguem, Quepem, Mapusa, Pernem, Panaji and Mormugao. The network of rainguage stations over Goa state is shown in Fig. 1. The data of 30 years monthly rainfall of different stations has been compiled and utilized in the present study.

Rainfall period of observation :

(*i*) Months : January to December

(*ii*) Years : 1971 to 2000 (*i.e*., 30 years)

The daily rainfall data of all 10 stations for a period of 30 years was collected from Goa observatory and analyzed. It may be noted that the data of some stations was not available for some period. This data is considered as missing and not utilized in the statistical analysis. The mean monthly rainfall amount computed is the key input for deriving frequency distribution of rainfall. The standard deviation is a measure of the scatter or dispersion of rainfall during monsoon season on mean monthly rainfall. The measure of variability of a distribution about

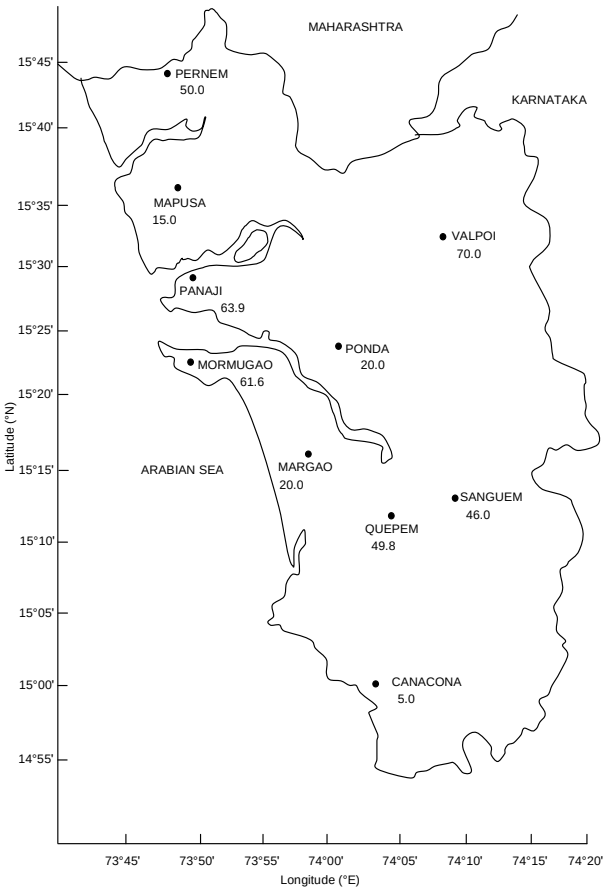


Fig. 1. Network of raingauge stations under IMD Goa with station height (m) above msl

the mean is expressed as coefficient of variation in percentage as:

$$\text{C.V.} = \frac{100 \times \sigma}{\text{Mean}}$$

Where "σ" is standard deviation

Mean is termed as mean monthly rainfall.

C.V. is used to determine coefficient of variation, the consistency or variability of rainfall at different stations of Goa during monsoon season.

3. Results and discussion

3.1. *Annual rainfall*

The rainfall over Goa is a crucial factor to meet the demands of industry, tourism, agriculture and other human activities in the state. Here efforts are made to show the different characteristics of monsoon rainfall over Goa, so

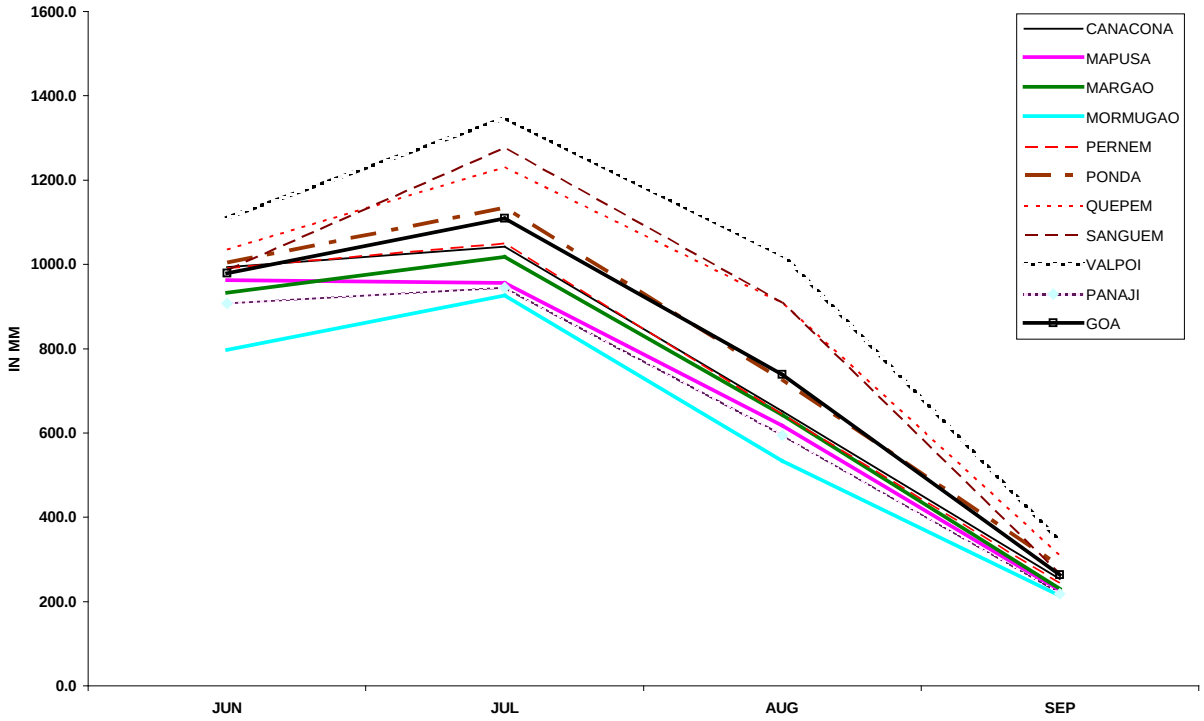
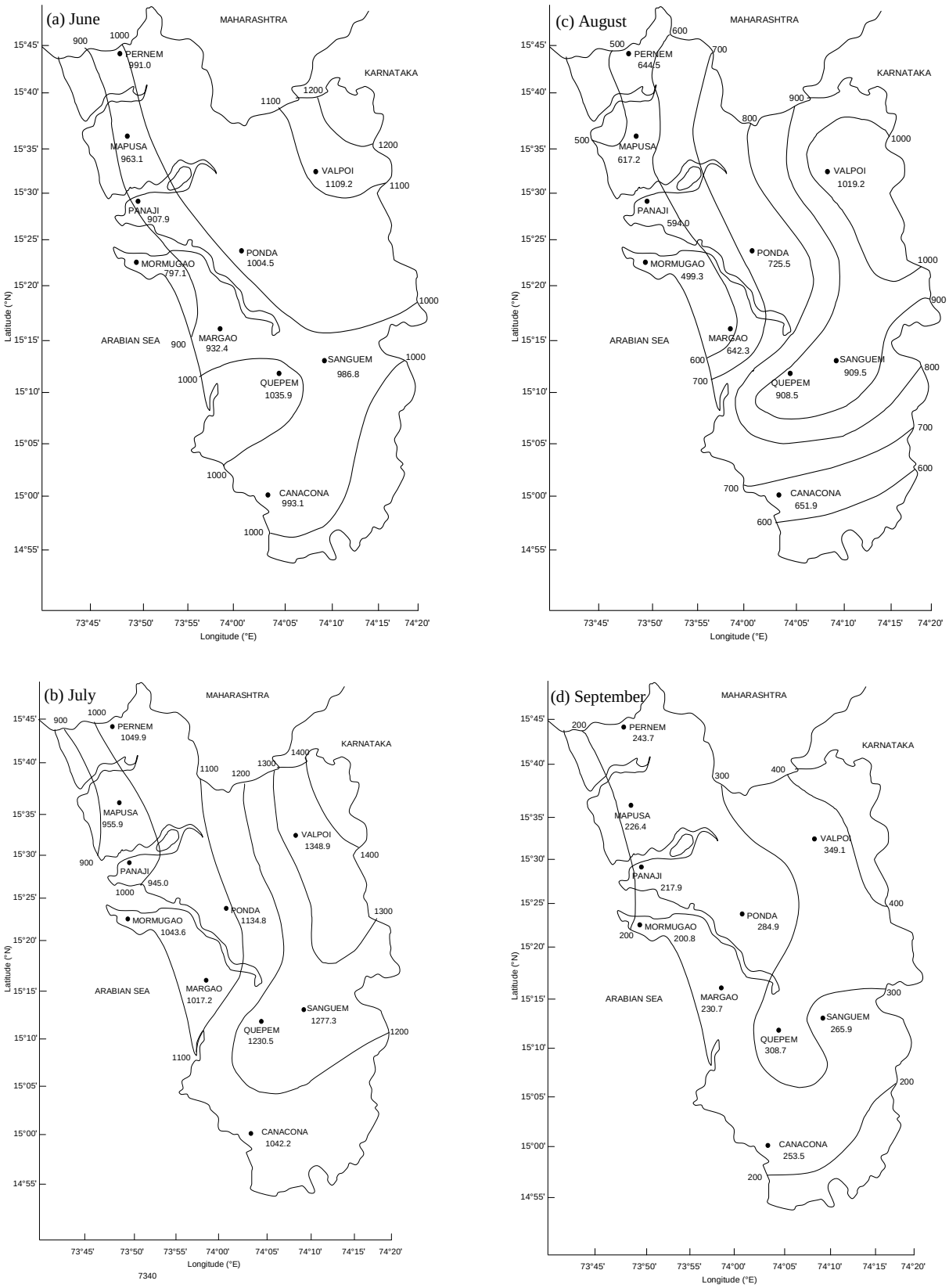


Fig. 2. Temporal variation of mean monthly rainfall during SW-monsoon (1971-2000)

TABLE 1

Mean monthly rainfall (mm) of ten raingauge stations in Goa State for the period 1971-2000

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Seasonal	Normals 1921-50
Canacona	1.1	0.0	1.5	3.8	63.7	993.1	1042.2	651.9	253.5	164.9	33.5	6.2	3215.3	2940.7	2934
Mapusa	0.3	0.0	0.1	6.5	58.6	963.1	955.9	617.2	226.4	114.2	20.7	3.4	2966.4	2762.6	2819
Margao	0.2	0.0	0.0	2.7	73.4	932.4	1017.2	642.3	230.7	121.0	24.0	5.5	3049.4	2822.6	2875
Mormugao	0.4	0.0	0.4	4.6	111.7	797.1	926.4	534.1	213.5	124.5	17.5	1.7	2732.0	2471.2	2464
Pernem	0.4	0.0	0.1	2.7	55.3	991.0	1049.9	644.5	243.7	130.0	18.8	5.9	3142.2	2929.0	3081
Ponda	0.0	0.0	0.0	6.1	69.2	1004.5	1134.8	725.5	284.9	131.1	39.5	5.0	3400.7	3149.6	3557
Quepem	0.0	0.0	0.3	3.9	85.3	1035.9	1230.5	908.5	308.7	172.3	38.8	6.0	3751.4	3483.6	3452
Sanguem	0.9	0.0	0.4	5.6	50.6	986.8	1277.3	909.5	265.9	164.5	36.0	3.2	3700.6	3439.5	3882
Valpoi	0.2	0.0	1.3	15.5	72.8	1109.2	1348.9	1019.2	349.1	167.2	63.6	4.0	4150.9	3826.3	3714
Panaji	0.6	0.1	0.6	4.1	67.2	907.9	945.0	594.0	217.9	124.4	27.3	3.6	2892.7	2664.8	2627
Avg	0.4	0	0.5	5.5	70.8	972.1	1092.8	724.7	259.4	141.4	32.0	4.4	3300.2	3045.4	3141



Figs. 3(a-d). Spatial variation of mean monthly rainfall during SW-monsoon for ten stations over Goa during June - September

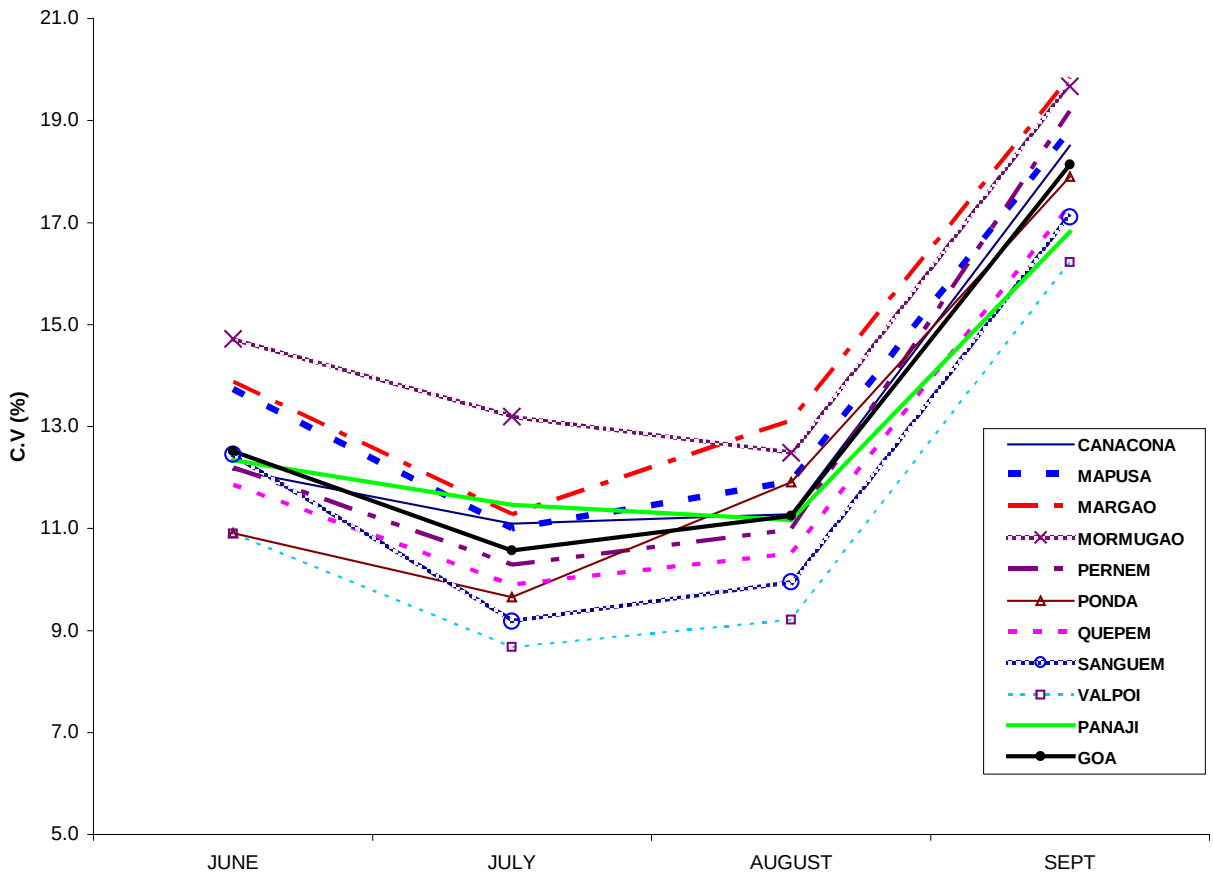


Fig. 4. Temporal variation of C.V. (%) of Mean monthly rainfall during SW-monsoon

that the planners, tourists, agriculturists and business community make a plan for betterment and welfare of the society. The mean monthly rainfall figures based on 30 years data at different stations, *i.e*., Valpoi, Quepem, Sanguem, Ponda, Margao, Mapusa, Panaji, Pernem, Mormugao and Canacona are shown in Table 1.

It is observed that more than 92 percent of annual rainfall is received during the monsoon period. The work-out mean annual rainfall of 10 stations based on 30 years available data are Canacona 3215 mm, Mapusa 2966 mm, Margao 3049 mm, Mormugao 2732 mm, Pernem 3142 mm, Ponda 3400 mm, Quepem 3751 mm, Sanguem 3700 mm Valpoi 4150 mm, and Panaji 2892 mm. This shows that the rainfall over Valpoi area is the highest 4150 mm, in the state. The study shows a trend of increase in annual rainfall over the years in all talukas except, Sanguem and Ponda which show decrease in comparison to present available normals, for the period 1921-50. The highest seasonal rainfall was received during month of June, July and August and lowest rainfall received during November and December months whereas January, February and March have hardly any rainfall at all the stations in Goa state. The overall mean annual rainfall received is about 3300 mm over the state. The average seasonal contribution of rainfall of 3045 mm to the annual rainfall of 3300 mm during 30 years of span is observed.

3.2. *Temporal and spatial variation of mean monthly rainfall*

3.2.1. *Temporal distribution of rainfall*

The mean monthly rainfalls of ten locations for 30 years have been computed for each of the monsoon period. The temporal variations of mean monthly rainfall over the station have been studied by Graphical method. The mean monthly rainfall trend has been increasing from the month of June to July and found decreasing from July to September.

From the Fig. 2, the highest mean monthly rainfall occurred at Valpoi station (1349 mm) during July,

TABLE 2

Mean monthly rainfall (mm), standard deviation and coefficient of variation (%)during SW-monsoon over Goa for the period 1971-2000

	June			July			August			September		
	Mean R/F (mm)	S.D	C.V %	Mean R/F (mm)	S.D	C.V %	Mean R/F (mm)	S.D	C.V %	Mean R/F (mm)	S.D	C.V %
Canacona	993.1	41.0	12.2	1042.2	35.8	11.1	651.9	22.2	11.3	253.5	13.9	18.5
Mapusa	963.1	43.0	13.7	955.9	33.8	11.0	617.2	22.2	11.9	226.4	11.6	18.8
Margao	932.4	42.8	13.9	1017.2	36.1	11.3	642.3	25.5	13.1	230.7	13	19.8
Mormugao	797.1	41.1	14.7	926.6	37.5	13.2	534.1	20.6	12.5	213.5	11.3	19.7
Pernem	991.0	39.4	12.2	1049.9	32.7	10.3	644.5	25.8	11	243.7	13.3	19.2
Ponda	1004.5	41.0	10.9	1134.8	36.8	9.7	725.5	25.7	11.9	284.9	16.4	17.9
Quepem	1035.9	85.5	11.9	1230.5	70.6	9.9	908.5	56	10.5	308.7	29.4	17.3
Sanguem	986.8	40.5	12.5	1277.3	37.0	9.2	909.5	28.8	9.9	265.9	13.9	17.1
Valpoi	1109.2	51.3	10.9	1348.9	46.3	8.7	1019.2	33.9	9.2	349.1	19.9	16.2
Panaji	907.9	42.2	12.3	945.0	39.2	11.5	594.0	24.5	11.2	217.9	12.7	16.8
Avg	972.1	46.8	12.5	1092.8	40.6	10.6	724.7	28.5	11.3	259.4	15.5	18.1

Sanguem 1277 mm and Quepem 1230 mm. During June, lowest rainfall is found at Mormugao (797 mm), Panaji (907 mm) and Margao (932 mm). The factors which influence the seasonal rainfall occurrence over Goa are orography, off-shore trough and other synoptic changes. The SW-winds generally blow over Goa during the active monsoon, due to the dual wind field; one is coming with a northerly component from north of system and other with the southerly component from southern system. Due to this dual wind field and favorable orography, the convergence and uplift of moist wind results into precipitation over Goa. The Goa state as a whole received about 3050 mm of rainfall during SW-monsoon season.

3.2.2. *Spatial variability*

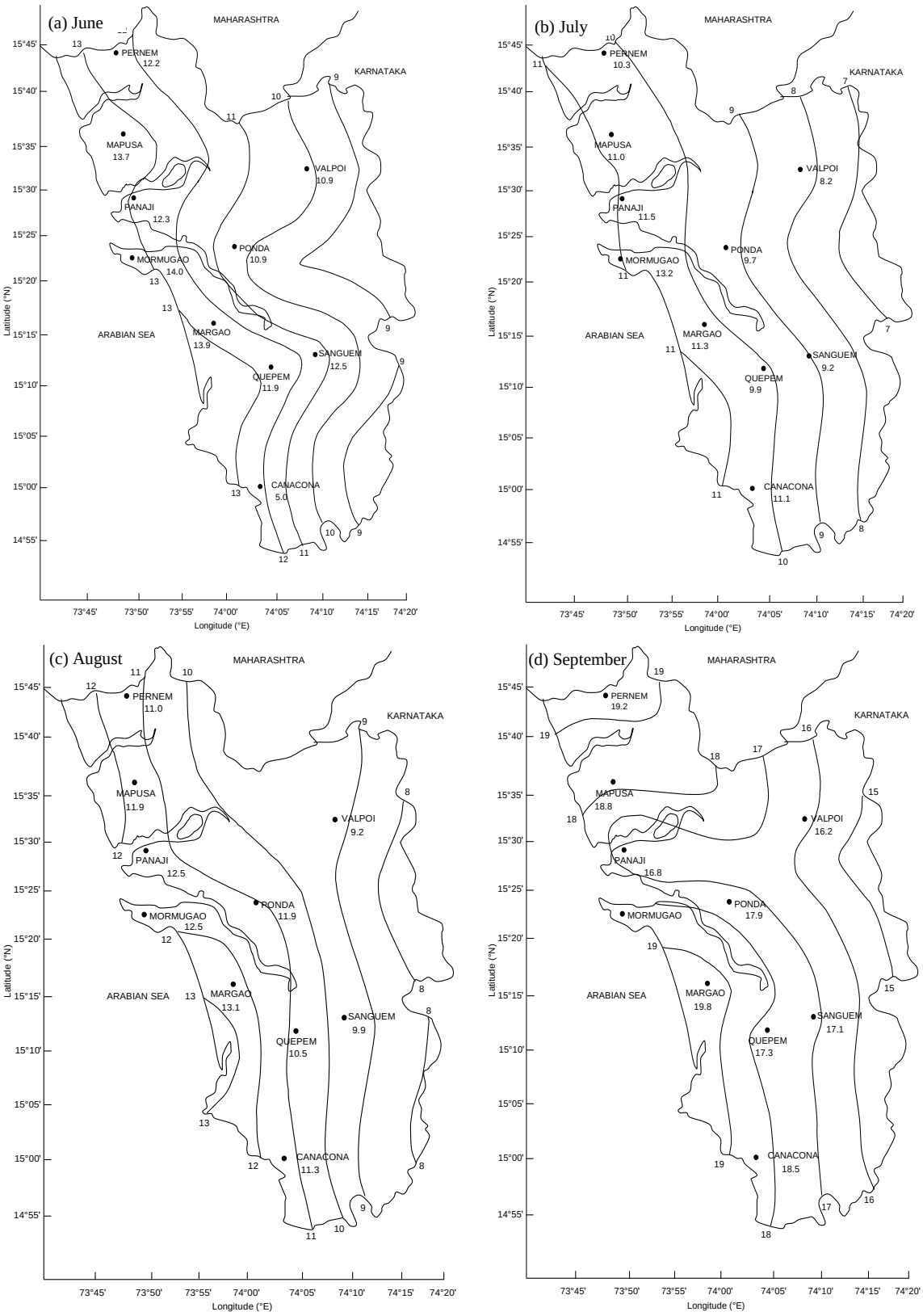
The spatial distributions of rainfall over Goa during monsoon have been studied. The spatial variation of mean monthly rainfall from June to September is shown in Figs. 3(a-d). The maximum mean rainfall in the month of July is found over northern and western parts of Goa with having the values of 1349 mm and 1277 mm at Valpoi and Sanguem respectively. In western part of Goa with minimum mean monthly rainfall of 213 mm at Mormugao and 217 mm at Panaji have been found in September. The mean minimum rainfall belt exists along the western and maximum mean rainfall over eastern parts of Goa. The distribution of mean monthly rainfall in the month of July differs from that in the month of June, August and September during the monsoon season.

3.3. *Variability of monthly rainfall*

3.3.1. *Temporal variability*

The coefficient of variation (C.V.) for monthly rainfall has been computed for the months of June to September and shown in Table 2. The temporal variation of C.V. for each station has been studied by graphical method. The results obtained are shown in Fig. 4.

It is observed that at 10 stations C.V. of monthly rainfall has decreased from June, attaining the minimum value in the wettest month of July and increasing trend in the subsequent months. Hence the rainfall consistency is more in the month of June. The C.V. of rainfall is maximum in the month of September at most of the places which is resulting less consistency of rainfall during the month. It is seen from the Fig. 4, that Valpoi has a minimum C.V. of 8.7 % in the month of July and maximum C.V. of 16.2 % in the month of September.



Figs. 5(a-d). Spatial coefficient variation of mean monthly rainfall during SW-monsoon for 10 stations over Goa during June - September

3.3.2. *Spatial variability*

The spatial distributions of C.V. of rainfall over Goa during monsoon period have been shown in Figs. 5(a-d). July has the highest rainfall of 1093 mm with minimum C.V. of 10.6% whereas September has the lowest rainfall of 259 mm with maximum C.V. of 18.1%.

The study shows that in the month of July, Valpoi has received highest mean rainfall of 1349 mm with minimum C.V. of 8.7% whereas Mormugao the lowest mean rainfall 926 mm with maximum C.V. of 13.2%. Similarly in the lowest rainfall month of September, Valpoi and Mormugao received highest and lowest mean rainfall of 349.1 mm and 213.5 mm with a C.V. of 16.2% and 19.7% respectively. The trend of C.V. shows increase from Eastern to Western parts with decreasing trend in rainfall over Goa state.

4. Conclusion

This study shows the following conclusions in respect of rainfall characteristics over Goa.

(*i*) Goa state as a whole receives mean annual rainfall of about 330 cms. Study revealed that SW monsoon contributes 90% of the annual rainfall of the state.

(*ii*) In general a decreasing pattern of rainfall is experienced in western parts and increasing pattern often over eastern part of Goa state. The Valpoi station, in Eastern parts recorded the highest seasonal rainfall of about 382 cms. The lowest seasonal rainfall of about 247 cms recorded at Mormugao in western parts during the period.

(*iii*) The highest mean monthly rainfall of about 135 cms is during the month of July at Valpoi station during the period.

(*iv*) The lowest mean monthly rainfall around 21 cms in September over Mormugao and Panaji during the 30 years period.

(*v*) The variability found decreasing with increase of rainfall to the month of July at many places in Goa, then found increasing upto September. The highest variability exists over western part of Goa during monsoon season. The variability of rainfall over eastern part and northern part is lower and rainfall is more reliable.

(*vi*) Valpoi station receives maximum rainfall during southwest monsoon season due to its orographic nature. The elevation of Sahyadris hills rising steeply just east of Valpoi, which exists at the foot hill of the range, is one of the main reasons of high precipitation over Valpoi.

(*vii*) The off-shore trough development plays a significant role in accelerating the south-west monsoon activity more. This leads contribution of seasonal rainfall during the period.

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References

Agashe, P. S. and Padgalwar, K. V., 2005, "On some characteristic features of daily rainfall over Madhya Maharashtra", *Mausam*, **56**, 3, p571.

Basu, G. C., Bhattacharjee, U. and Ghosh, R., 2004, "Statistical Analysis of rainfall distribution and trend of rainfall anomalies distractive during monsoon period over West Bengal", *Mausam*, **55**, 3, p409.

Lakshminarayanan, R. and Rajamohan, R., 2003, "A study of unusually heavy to very heavy rainfall over Kerala in October 1999", *Mausam*, **54**, 4, p861.

Madan, O. P., Mohanty, U. C., Gopal, Iyengar, Shivhare, R. P., Askav Prasad, Rao, Sam, N. V. and Bhatla, R. G., 2005, "Off-shore trough and very heavy rainfall events along the West coast of India during Armex-2002", *Mausam*, **56**, 1, p37.

Mohanty, U. C., Sam, N. V., Das, S. and Basu, S., 2005, "A study on the convective structure of the atmosphere over the west coast of India during ARMEX-1", *Mausam*, **56**, 1, p49.

Prasad, S. K., Prasad, B., Jaiswal, D. N., 1991, "Rainfall features in the districts of Bihar Plateau during South west monsoon", *Mausam*, **42**, 3, p298.

Roy Abraham, K., Dash, S. K. and Mohanty, U. C., 1996, "Simulation of monsoon circulation and cyclone with different types of orography", *Mausam*, **47**, 3, p237.

Shankar, D., Kotamaraju, V. and Shetye, S. R., 2004, "A quantitative framework for estimating water resources in India", *Current Science*, **86 F**, 543-552.

Singh, Mahendar, Singh, Ram, Niwas Ram and Sahrawat, K. D., 2003, "Study on southwest monsoon rainfall characteristics in arid zone of Haryana", *Mausam*, **54**, 4, p837.