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Letters to the Editor

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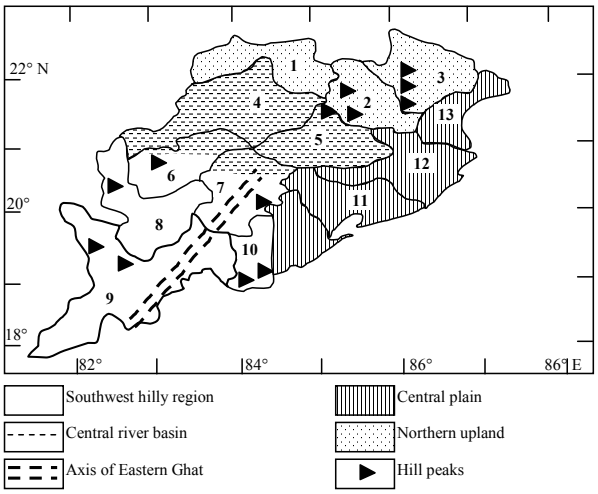
SOME CHARACTERISTICS OF MONSOON RAINFALL VARIABILITY OVER ORISSA

1. Indian monsoon rainfall largely depends on the westward moving low pressure systems (LPS) developing over Bay of Bengal and their life time, as LPS like low, depression, deep depression and cyclonic storm etc. are the major rain bearing systems (Mooley and Shukla, 1989). Orissa, a meteorological sub-division of India is more dependent on the activity of the monsoon trough and the LPS forming over Bay of Bengal along the monsoon trough, as it lies close to but south of the eastern end of the monsoon trough over Indian main land. The monsoon rainfall over Orissa largely depends on frequency of formation, region of formation, intensity and movement etc. of LPS (Mohapatra and Mohanty, 2001). It shows variations with respect to the variation in characteristic features of LPS. Mohapatra and Gupta (2001) have found from climatological data that mean monthly rainfall during monsoon season over different zones of Orissa depends mainly on interaction between orography and LPS developing over Bay of Bengal. Here in this study, the spatial variability of the monsoon rainfall over Orissa and its relation with physiography and large scale synoptic systems like LPS developing over Bay of Bengal have been analysed based on 15 years data (1985-99) of monthly monsoon rainfall over different zones of Orissa. Orissa has been divided into 13 rainfall zones (Fig. 1) for the above purpose.

2. Orissa consists of broadly four physiographical regions (Govt. of India, 1971), *viz*. (*i*) coastal plain (*ii*) southwest hilly region (*iii*) central river basin and (*iv*) northern upland (Fig. 1). The coastal plain comprises of Balasore (BLS), Cuttack (CTK), Puri (PRI) and coastal areas of Ganjam (GNJ) zones. The southwest hilly region comprises of interior Ganjam (GNJ), Koraput (KRP), Kalahandi (KLH) and two thirds of Bolangir (BLR) and Phulbani (PLB) zones. Also there are a good number of hill peaks in this Eastern Ghat region. GNJ and eastern part of KRP zone lie on the eastern side of Eastern Ghat. The Eastern Ghat hill ranges extend from Tamilnadu State in the southwest to Orissa in the northeast being almost parallel to the east coast of India. The northern upland is a high land with a few hill peaks. It consists of Sundargarh (SNG), Keonjhar (KNJ) and Mayurbhanj (MBJ) zones and northern most part of Dhenkanal (DNK) zone. The central river basin consists of Sambalpur (SBP) zone and remaining areas of BLR, PLB and DNK zones. The zones of CTK and BLS constitute north coastal Orissa. The zones of PRI and GNJ constitute south coastal Orissa. The zones of SBP, DNK, SNG, KNJ and MBJ constitute north interior Orissa. The zones of KLH, BLR, PLB and KRP constitute south interior Orissa.



1. Sundargarh (SNG) 2. Keonjhar (KNJ) 3. Mayurbhanj (MBJ) 4. Sambalpur (SBP) 5. Dhenkanal (DNK) 6. Bolangir (BLR) 7. Phulbani (PLB) 8. Kalahandi (KLH) 9. Koraput (KRP) 10. Ganjam (GNJ) 11. Puri (PRI) 12. Cuttack (CTK) 13. Balasore (BLS)

Fig. 1. Physiographical map of Orissa

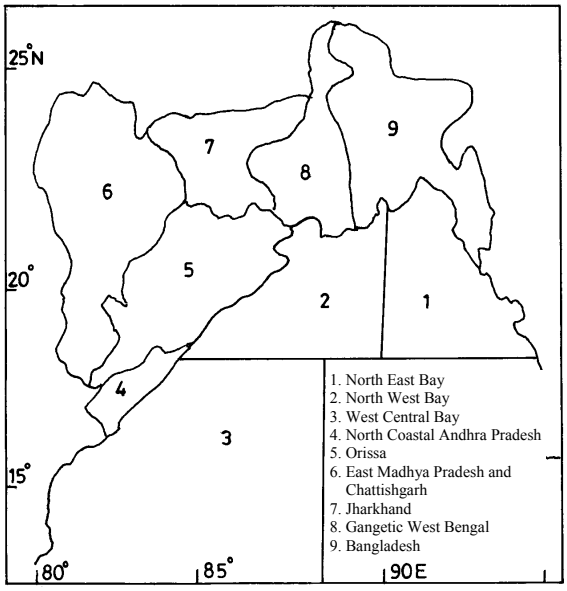
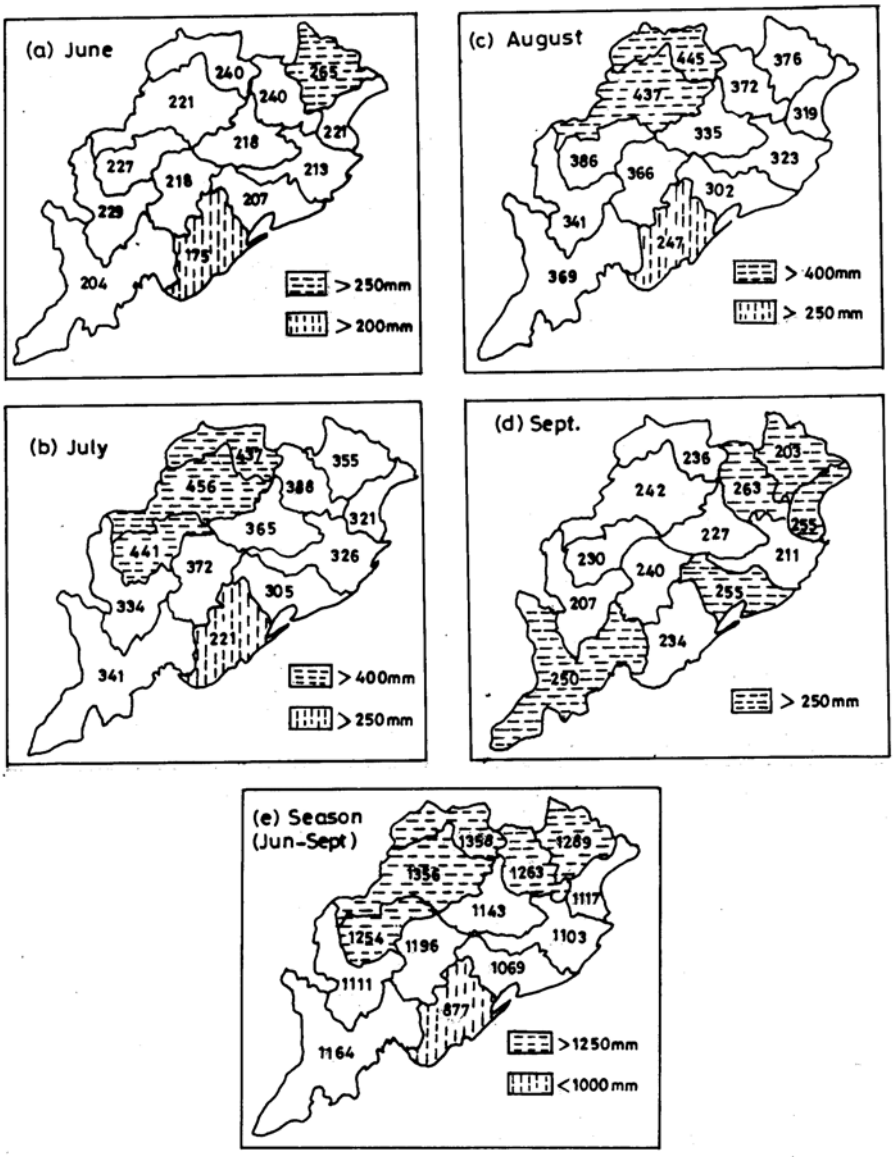


Fig. 2. The regions of low pressure systems under consideration in the present study

3. The rainfall departure from the long period average during different monsoon months and the season



Figs. 3(a-e). Normal rainfall (mm) distribution over different zones of Orissa during monsoon months and season

for the period of 15 years (1985-99) have been collected from Meteorological Centre, Bhubaneswar. The data on LPS have been collected from various publications of India Meteorological Department and from the journal, "Mausam". The frequencies of LPS days over different regions affecting rainfall over Orissa have been found out. The different regions of LPS under consideration are northwest (NW) Bay of Bengal, northeast (NE) Bay, west central (WC) Bay, north coastal Andhra Pradesh (NCAP), Orissa, Gangetic West Bengal (GWB), east Madhya Pradesh and Chattishgarh (EMPC), Jharkhand (JKD) and Bangladesh (BDS) as shown in Fig. 2. The seasonal monsoon rainfall affinity regions have been found out by calculating the inter-district correlation coefficients (CC). The role of synoptic scale monsoon circulations like LPS on monsoon rainfall over Orissa has been found out by analysing the correlation between frequency of LPS days over different regions and rainfall over different zones in Orissa for the monsoon season.

4. The normal rainfall distributions over different zones of Orissa during different monsoon months and the season are given in Fig. 3. Interior Orissa gets higher rainfall than coastal Orissa during monsoon season. The western side of Eastern Ghat and adjoining areas get more rainfall than eastern side of Eastern Ghat. It may be due to

TABLE 1

The correlation between frequency of LPS days over different regions and seasonal rainfall over different zones of Orissa during 1985-99

Zone	1	2	3	4	5	6	7	8	9	10	11	12
BLS	0.02	-0.24	0.11	0.36*	0.54	0.67	-0.15	0.25	0.52	0.01	-0.33	-0.09
CTK	-0.32	-0.07	0.02	0.32	0.34	0.49	-0.27	0.19	0.49	0.01	-0.19	0.12
KNJ	-0.05	-0.42*	0.04	0.48	0.36*	0.65	-0.19	0.15	0.37*	-0.03	-0.17	-0.02
DNK	-0.11	-0.33	-0.13	0.57	0.28	0.63	-0.18	0	0.61	-0.38*	-0.39*	-0.09
SNG	-0.21	-0.4*	0.03	0.56	0.21	0.63	-0.17	0.3	0.54	-0.07	-0.21	0.05
MBJ	-0.22	-0.67	-0.01	0.52	0.31	0.64	-0.4*	-0.05	0.2	-0.25	-0.41*	-0.3
SBP	-0.11	-0.42*	-0.02	0.61	0.18	0.64	-0.2	0.03	0.62	-0.42*	-0.42*	-0.15
GNJ	0.18	-0.03	-0.12	0.45	0.38*	0.59	-0.3	-0.3	0.36*	-0.38*	-0.35	-0.25
PRI	-0.14	-0.08	-0.16	0.41*	0.23	0.45	-0.36*	-0.32	0.46	-0.39*	-0.31	-0.14
KLH	0.1	-0.52	-0.1	0.55	0.08	0.5	-0.01	0.12	0.51	-0.49	-0.49	-0.07
BLR	0.01	-0.45	-0.01	0.41*	0.11	0.43*	-0.14	-0.05	0.53	-0.44	-0.4*	-0.12
PLB	0.17	-0.29	-0.17	0.51	0.23	0.53	-0.15	0.09	0.65	-0.33	-0.32	0.05
KRP	0.26	-0.27	-0.19	0.55	0.15	0.52	-0.07	-0.15	0.47	-0.42*	-0.36*	-0.06

1: NCAP, 2 : WC and adjoining NW Bay, 3 : NW and adjoining WC Bay, 4 : NW Bay, 5 : NW and adjoining NE Bay, 6 : 3+4+5, 7 : NE and adjoining NW Bay, 8 : Gangetic West Bengal (GWB), 9 : Orissa, 10 : Bangladesh (BDS), 11 : Jharkhand (JKD), 12 : East Madhya Pradesh and Chhatishgarh (EMPC)
Underlined figures represent: Significant at 0.95 level of confidence * Significant at 0.90 level of confidence

the interaction of basic monsoon flow with LPS over NW Bay etc and the orography due to Eastern Ghat. As the basic monsoon flow is generally westerly with the LPS over NW Bay, western side of Eastern Ghat becomes windward side and gets more rainfall. It may be mentioned that most of the LPS develop over NW Bay and the frequency of LPS days is maximum over NW Bay among different regions under consideration (Mohapatra and Mohanty, 2001). The seasonal rainfall over GNJ zone, which lies on eastern side of Eastern Ghat, is lowest among different zones of Orissa, as GNJ zone lies on the lee side of Eastern Ghat with generally westerly basic monsoon flow over the region. The KLH zone gets lowest rainfall among the zones in western side of Eastern Ghat during the season.

5. The comparison of the CC between seasonal rainfall over different zones indicates that the rainfall over different zones are directly correlated with each other. The seasonal rainfall over DNK, SBP and PLB zones are significantly and directly correlated with all the remaining zones. Considering CC > 0.75, it is found that the coherence among the seasonal rainfall over different zones decreases gradually and gives rise to different homogeneous regions. According to distribution of CC > 0.75, the most coherent region extends from southeast to northwest and consists of PRI, DNK, PLB and SBP zones. Other coherent regions are (*i*) south coastal Orissa and (*ii*) north coastal Orissa. The zones of KLH and BLR also show the CC > 0.75 with SBP zone. The zones in the northern upland and KRP zone do not show CC > 0.75 with any other zone. The orientation in spatially coherent region with CC > 0.75 from PRI zone in the southeast towards SBP zone in the northwest may be attributed to the fact that (*i*) most of the LPS develop over northwest Bay with the monsoon trough from the system extending west-northwestwards (*ii*) these zones lie parallel to but a little south of the monsoon trough (*iii*) the region a little south of monsoon trough gets most intense rainfall (Raghavan, 1973; Pathan, 1993) and (*iv*) these LPS move west-northwestwards along the monsoon trough.

6. The CCs between the frequencies of LPS days over different regions and the rainfall over different zones have been calculated for the monsoon season and results are given in Table 1.

The seasonal rainfall over any zone of Orissa is directly correlated with LPS days over NW Bay, Orissa and NW & adjoining NE Bay. While, the CC is significant for most of the zones with LPS days over NW Bay and Orissa, it is significant for some zones in coastal and north

TABLE 2

The correlation coefficients (CC) between frequency of non-LPS days and seasonal monsoon rainfall over different zones in Orissa

Zone	BLS	CTK	KNJ	DNK	SNG	MBJ	SBP	GNJ	PRI	KLH	BLR	PLB	KRP
CC	-0.33	-0.31	-0.35	-0.21	-0.37	0.04	-0.16	-0.10	0.0	-0.11	-0.06	-0.21	-0.12

interior Orissa with LPS days over NW and adjoining NE Bay. The positive CC is more significant for the zones on western side of Eastern Ghat and adjoining central river basin with the LPS days over Orissa. It indicates that the southwest sector of the LPS over NW Bay, Orissa and NW & adjoining NE Bay gets more rainfall due to interaction of basic monsoon flow, orography and the LPS. It has been earlier proved that the left forward sector or the southwest sector of a depression gets most intense rainfall due to maximum low level convergence (Rao and Rajamani, 1970, 1975, Rajamani and Rao, 1981). Considering total LPS days over NW Bay, NW and adjoining WC Bay and NW and adjoining NE Bay, the CC is significantly positive for all zones.

While the LPS days over WC and adjoining NW Bay, NE and adjoining NW Bay, JKD and EMPC show negative correlation with seasonal rainfall over all the zones, that over BDS shows negative CC with seasonal rainfall over all the zones in Orissa except north coastal Orissa. The seasonal rainfall over most parts of western side of Eastern Ghat and adjoining zones of SBP and SNG significantly decreases with increase in frequency of LPS days over WC and adjoining NW Bay, as with the LPS over WC and adjoining NW Bay, the eastern and western sides of Eastern Ghat become windward and lee side respectively leading to more rainfall on eastern side and adjoining coastal Orissa and less rainfall on western side of Eastern Ghat. The LPS days over BDS shows significantly negative CC with rainfall over south Orissa and adjoining zones of SBP and DNK, as these zones do not lie in the left forward sector of LPS over BDS. The seasonal rainfall over KLH is worst affected among different zones due to increase in LPS days over JKD.

The seasonal rainfall over any zone is not significantly correlated with LPS days over NW and adjoining WC Bay, GWB, EMPC and NCAP.

The correlation between frequency of days without any LPS (henceforth non-LPS days) and the seasonal rainfall indicates that the rainfall over all the zones except MBJ and PRI decreases with increase in non-LPS days (Table 2). It changes little for MBJ and PRI. The rate of decrease, though insignificant is higher over north Orissa except MBJ. The rate of decrease is higher over the zones on western side of Eastern Ghat than over the zones on the eastern side of Eastern Ghat and adjoining south coastal Orissa. For Orissa as a whole, the seasonal rainfall decreases insignificantly with increase in non-LPS days.

7. The zonal rainfall considered in this study is a derived parameter as the rainfall in a zone is the average of the rainfall recorded over different rain gauge stations in that zone. So the zonal rainfall may come close to the reality only if the network density of rain gauge stations is adequate and rain gauge stations are uniformly distributed. Similarly, the network density of rain gauge stations changes from time to time depends upon the availability of data. These are a few limitations of this study as the study is based on the average rainfall of different zones and not on the actual rainfall recorded at different rain gauge stations.

8. The following broad conclusions can be drawn from the above analysis.

(*i*) The seasonal monsoon rainfall is higher over interior Orissa than over coastal Orissa. The western side of Eastern Ghat gets more rainfall than the eastern side.

(*ii*) According to inter-district CC > 0.75 in the seasonal monsoon rainfall, there are three spatially coherent regions in Orissa, *viz*. (a) central Orissa extending from southeast to northwest (PRI, DNK, PLB and SBP), (b) north coastal Orissa and (c) south coastal Orissa.

(*iii*) The seasonal rainfall significantly increases over most of the zones with increase in LPS days over NW Bay and Orissa and over some zones in coastal and north interior Orissa with increase in LPS days over NW and adjoining NE Bay.

(*iv*) The seasonal rainfall significantly decreases over western side of Eastern Ghat and adjoining SBP and SNG zones with increase in LPS days over WC and adjoining NW Bay and over south Orissa and adjoining SBP and DNK zones with increase in LPS days over BDS. The seasonal rainfall over KLH zone is worst affected among different zones with increase in LPS days over JKD.

(*v*) The LPS days over NW and adjoining WC Bay, GWB, EMPC and NCAP do not show significant correlation with seasonal rainfall over any zone in Orissa.

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References

Govt. of India (Ministry of Planning), 1971, Census of India (Orissa),1971.

Mohapatra, M. and Gupta, D. C., 2001, "Meteorology of Eastern Ghat region of Orissa", Proceedings of national conference on "Eastern Ghat region of Orissa", held at Regional Research Laboratory, Bhubaneswar.

Mohapatra, M. and Mohanty, U. C., 2001, "Low pressure systems and southwest monsoon rainfall over Orissa", Abstract of the Proceedings of national symposium, "TROPMET-2001" held at Mumbai during February 2001.

Mooley, D. A. and Shukla, J., 1989, "Main features of the westward moving low pressure systems which form over Indian region during the summer monsoon season and their relation to monsoon rainfall", *Mausam*, **40**, 137-152.

Pathan, J. M., 1993, "Latitudinal variation of rainfall during the month of July in relation to the axis of monsoon trough over India", *Mausam*, **44**, 384-386.

Raghavan, K., 1973, "Break monsoon over India", *Mon. Wea. Rev*., **101**, 33-44.

Rajamani, S. and Rao, K. V., 1981, "On the occurrence of rainfall over southwest sector of monsoon depression", *Mausam*, **35**, 215-220.

Rao, K. V. and Rajamani, S., 1970, "Diagnostic study of monsoon depression by geostrophic baroclinic model", *Indian J. Met. Geophys*., **21**, 184-194.

Rao, K. V. and Rajamani, S. 1975, "Computation of vertical velocity in comparing release of latent heat of condensation", *Indian J. Met. Geophys*., **26**, 369-374.

M. MOHAPATRA
Meteorological Centre, Bhubaneswar, India
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