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Verification of operational rainfall forecast over eastern India during southwest monsoon season

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सार – देश की अर्थव्यवस्था के साथ-साथ सार्वजनिक हित के विभिन्न क्षेत्रों में भारतीय ग्रीष्म मॉनसून वर्षा के पूर्वानुमान और उसके सत्यापन का प्रत्यक्ष प्रभाव पड़ता है। इस अध्ययन में छह मौसम उपखंडों, जिनमें पूर्वी भारत के पाँच राज्यों नामतः पश्चिम बंगाल, सिक्किम, बिहार, झारखंड और ओडिशा शामिल हैं, के लिए प्रतिदिन जारी सिनॉप्टिक पद्धति के वितरण पूर्वानुमान के सत्यापन पर प्रकाश डाला गया है। इस अध्ययन के लिए 2011 से 2013 तक के तीन वर्षों के मॉनसून ऋतु के आँकड़ों का उपयोग किया गया है। सिनॉप्टिक पद्धति की उपयोगिता को समझने के लिए वर्षा की विभिन्न श्रेणियों जैसे शुष्क, इक्का दुक्का, छिट पुट, अनेक स्थानों पर और दूर दूर तक, के लिए वर्षा के वितरण से संबंधित सत्यापन किया गया। इसमें मौसम उपखंडवार पूर्वानुमान पर्सेंटेज करेक्ट (पी सी) और हेडके स्किलस्कोर (एच एस एस) की संयुक्त श्रेणियों तथा पृथक श्रेणियों के लिए पी सी, पी ओ डी एवं सी एस आई, दानों के लिए आँकड़े प्रस्तुत किए गए हैं। यह देखा गया है कि मौसम उपखंडों में उप हिमालयी पश्चिम बंगाल (एस एच डब्ल्यू बी) और सिक्किम में इस पद्धति की दक्षता सबसे अधिक रही और इसके बाद गांगेय पश्चिम बंगाल (जी डब्ल्यू बी), ओडिशा, झारखंड और बिहार रहे।

ABSTRACT. The Indian summer monsoon rainfall forecast and its verification has a direct impact on various sectors of public interest besides economy of the country. The present study highlights the verification of distribution forecast of synoptic method issued daily for six met subdivisions, comprising of five states of eastern India namely West Bengal, Sikkim, Bihar, Jharkhand and Odisha. Three years monsoon season rainfall data from 2011 through 2013 are used for the study area. The distribution-oriented verification is done for different rainfall classes like dry, isolated, scattered, fairly widespread and widespread to understand the usefulness of the synoptic method. Statistics are presented for both combined classes of Percentage Correct (PC) and Heidke Skill Score (HSS) of the met subdivision wise forecast and PC, POD and CSI for individual classes. It has been observed that among the met subdivision the efficiency of the method is highest in Sub Himalayan West Bengal (SHWB) & Sikkim followed by Gangetic West Bengal (GWB), Odisha, Jharkhand and Bihar.

Key words – Monsoon rainfall, Eastern India, Synoptic method and forecast verification.

1. Introduction

Murphy and Winkler (1987) and Doswell (1996) stated that forecast verification is an essential, necessary component of a forecasting system, since it provides a "measure" of the quality and value of a numerical forecast. Forecast verification is how the quality, skill and value of a forecast is assessed. The purpose of forecast verification is to check for consistency, quality and value of a forecast. A forecast has high quality, if it predicts the observed conditions well according to some objective or subjective criteria. It has value if it helps the user to make a better decision. The process of forecast verification compares the forecast against a corresponding observation of what actually occurred or an estimate of what occurred. For the public to trust a forecast, it needs to be both accurate and consistent (Murphy, 1993). Brier and Allen (1951) identified economic, administrative, and scientific reasons for verification. Different verification approaches can provide information about different statistical and physical aspects of the forecast-observations agreement/ disagreement. Mohapatra *et al.* (2009) used various skill score for forecasting of heavy rainfall over Bihar and Uttar Pradesh for 5 year of data (2001-2005) and compare the result with data of early 1970 epoch. They have observed that the skill of heavy rainfall forecast increased in 2001-2005 compare to 1970 epoch. The choice of the verification method is therefore mainly related to the kind

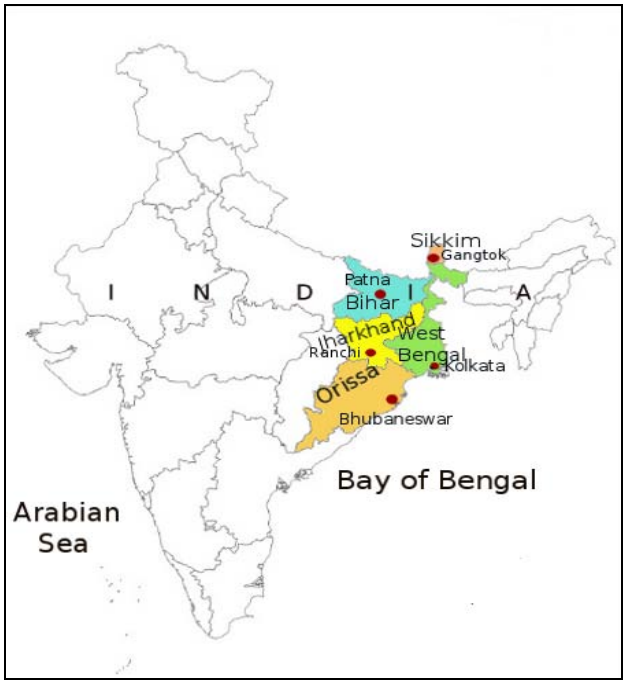


Fig. 1. Forecast states of eastern India under RMC, Kolkata

TABLE 1

Rainfall category for forecast and verification

S. No.	Rainfall class	No of places	Distribution
1.	Dry	-	No station reported rainfall
2.	Isolated	One or two Places	25% of area or less gets rainfall
3.	Scattered	At a few Places	(26-50)% of area gets rainfall
4.	Fairly Widespread	At many Places	(51-75)% of area gets rainfall
5.	Widespread	At Most place	(76-100)% of area gets rainfall

of information that the final user wishes to gain from the verification However, some verification approaches are more suitable than others for verifying spatial precipitation forecasts since they deal better with the precipitation field cha racteristics and its non-normal distribution. Hence, it is easy to understand that verification is a multi-faceted process, since it depends not only on the type of forecast, but also on the reason for which the verification is done.

Southwest monsoon rainfall forecast and its verification are always of great interest because of their socioeconomic impact on the country. Therefore, the study focuses on verification of spatial rainfall forecast of eastern India issued on operational basis with a view for improvement in the forecasting techniques and an increase in value to the users.

2. Data and methodology

2.1. *Forecast region and background*

Regional Meteorological Centre, Kolkata (RMC Kolkata) provides weather forecasts to different users for five states of eastern India, *i.e*., West Bengal, Sikkim, Bihar, Jharkhand and Orissa (Fig. 1). Each of these states consists of one Meteorological (Met) subdivision except West Bengal which comprises of two sub divisions namely - Sub Himalayan West Bengal & Sikkim (SHWB) and Gangetic West Bengal (GWB). SHWB & SKM is dominated by orography mainly associated with Eastern Himalayas. The main synoptic situation for monsoon rain over GWB and Odisha is Low Pressure Area /Cyclonic Circulation over North Bay of Bengal/GWB and monsoon trough through this area.JRKD and BIH is land locked and dominated by Chotta Nagpur plateau area.

Thus, for a total of six met subdivision short range forecasts (1 to 3 days) of rainfall in each successive 24 hr intervals is predicted upto 3 days for five different categories like dry (DRY) isolated (ISOL), scattered (SCT), fairly widespread (FWD) and widespread (WD), as spatial distribution criteria following the forecasting norms of India meteorological department (IMD) . Details criteria of the classes are given in Table 1. The distribution of realized rainfall was calculated as weighted mean of the respective met sub division. The no of rain gauges considered for different met sub divisions for the purpose are 60-62,105-106, 84-85, 20-24 and 60-62 for SHWB & Sikkim, GWB, Odisha, Jharkhand and Bihar respectively. Daily rainfall data have been collected from these stations at 0830 hrs IST. Besides IMD, raingauge stations maintained by respective state government are also considered. Stations showing consistency in data period are selected for the study.

2.2. *Forecast method*

Currently the forecast issued by IMD is a consensus forecast mainly based on numerical guidance from a set of global and regional numerical Weather Prediction (NWP) models blended with synoptic guidance through latest observational tools and technique. While for 24 hours forecast, the synoptic guidance contributes largely to consensus forecast, the numerical guidance dominates for lead period beyond 24 hours.

TABLE 2 (a)

Contingency table for verification of spatial distribution rainfall forecast

Observed Range	Forecast range					
	D	ISOL	SCT	FWD	WD	TOTAL
D	a	b	c	d	e	J
ISOL	f	g	h	i	j	K
SCT	k	l	m	n	o	L
FWD	p	q	r	s	t	M
WD	u	v	w	x	y	N
Total	O	P	Q	R	S	T

PC = [(a+g+m+s+y)/T]*100

HSS = [a+g+m+s+y - (JO+KP+LQ+MR+NS)/T]/ [T-(JO+KP+LQ+M R+NS)/T]

TABLE 2 (b)

2 × 2 contingency table for verification of rainfall forecast based on yes/no forecast

Observed	Forecast	
	Yes	No
Yes	A	B
No	C	D

PC = (A+D)/(A+B+C+D)*100 = HIT RATE * 100

POD = A/(A+B)

CSI = THREAT SCORE = A/(A+B+C)

2.3. *Forecast and verification period*

In the present study, rainfall forecast issued for 122 days of monsoon season from 1st June to 30th September for each of the met subdivision during 2011-2013 has been verified.

The rainfall forecast issued for different met sub-division is verified by computing a number of categorical statistical skill measures from the elements of the contingency table on monthly basis. They include Percentage Correct (PC), Heidke Skill Score (HSS) from 6 × 6 Contingency table (Table-2(a)) to consider the performance of the forecast. The Percentage correct (PC), Probability of Detection (POD) and Critical Success Index (CSI) for each of the categories calculated by reducing the above 6 × 6 Contingency into 2 × 2 Contingency table (Table-2(b)) for yes/no forecast. The detailed procedure of this forecast verification is mentioned in Table 2 (a &b).

For 2 × 2 contingency table the percent correct is the percent of forecasts that are correct. PC ranges from zero (0) for no correct forecasts to one (1) when all forecasts are correct. It is used as the standard score for the forecasts verification. Probability of detection (hit rate) signifies what fraction of the observed "yes" events. It is sensitive to hits, but ignores false alarms. It is very sensitive to the climatological frequency of the event and good for rare events. It ranges from 0 to 1 and the perfect score is 1.

Critical success index (also denoted CSI) signifies how well the forecast "yes" events corresponded to the observed "yes" events. It measures the fraction of observed and/or forecast events that were correctly predicted. The range varies from 0 to 1, 0 indicates no skill and a perfect score is 1. The problem with this score is that it does not take into account the correct forecast of null events. The Heidke Skill Score (HSS) measures the fractional improvement of the forecast over the standard forecast. Like most skill scores, it is normalized by the total range of possible improvement over the standard, which means Heidke Skill scores can safely be compared on different datasets. The range of the HSS is -∞ to 1. Negative values indicate that the chance forecast is better, 0 means no skill, and a perfect forecast obtains a HSS of 1

For individual category of forecast, average value of PC, POD and CSI during 2011-2013 has been analyzed and discussed. Whereas for combined forecast verification, monthly value of HSS and PC has been analyzed and discussed

3. Results and discussion

3.1. *Analysis of skill score of individual category forecast*

3.1.1. *Analysis of PC for individual category of forecast*

The percentage Correct (PC) associated with different spatial distribution for all the five subdivisions has been shown in Fig. 2. It has been observed that PC for all type of forecast for these five divisions has been very high during monsoon period ranging from 62% to 99%. For SHWB & Sikkim; it varies from 99% for DRY category to lowest 76% for FWD. For GWB lowest PC is for SCT and FWD distribution at 76% only. Again, for Odisha, Jharkhand and Bihar, the lowest PCs are for SCT distribution with 70%, 62% and 64% respectively.

3.1.2. *Analysis of POD for individual category of forecast*

Probability of Detection (POD) for spatial distribution for all the five subdivisions is shown in Fig. 3.

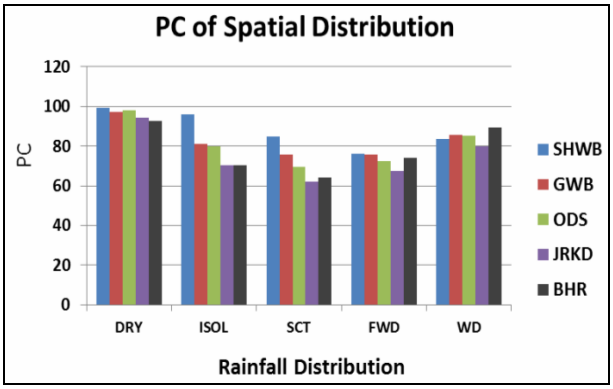


Fig. 2. Analysis of PC for individual category forecast

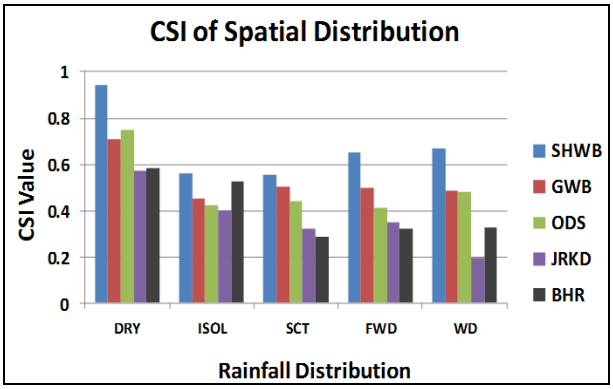


Fig. 4. Analysis of CSI for individual category forecast

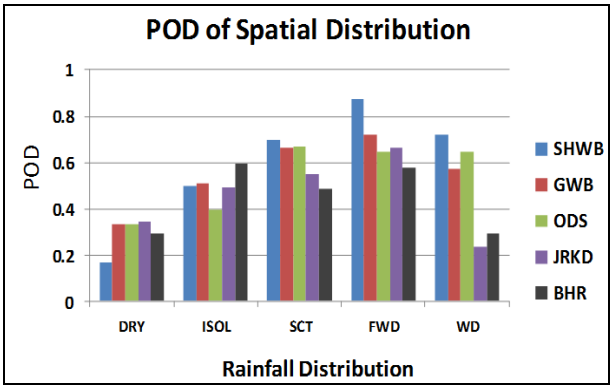


Fig. 3. Analysis of POD for individual category forecast

It has been observed that the POD of DRY distribution is very low for all the subdivisions. For SHWB & Sikkim, POD has been highest for FWD followed by WD, SCT and ISOL. For GWB; POD is highest for FWD followed by SCT, WD and ISOL. Odisha has highest POD (0.67) for SCT followed by FWD, WD and ISOL. Jharkhand and Bihar have moderate POD for ISOL, SCT, FWD and low for WD and DRY.

3.1.3. *Analysis of CSI for individual category of forecast*

CSI for all the five subdivisions have been shown in |Fig. 4. It has been observed that CSI for DRY is highest for all the five subdivision. For ISOL distribution it is highest for SHWB & Sikkim followed by BHR, ODS, GWB and JRKD. For SCT and FWD distribution, highest CSI has been for SHWB & SKM followed by GWB, ODS, JRKD and BHR.Whereas for WD distribution, it has been highest for SHWB & SKM followed by GWB, ODS, BHR and JRKD.

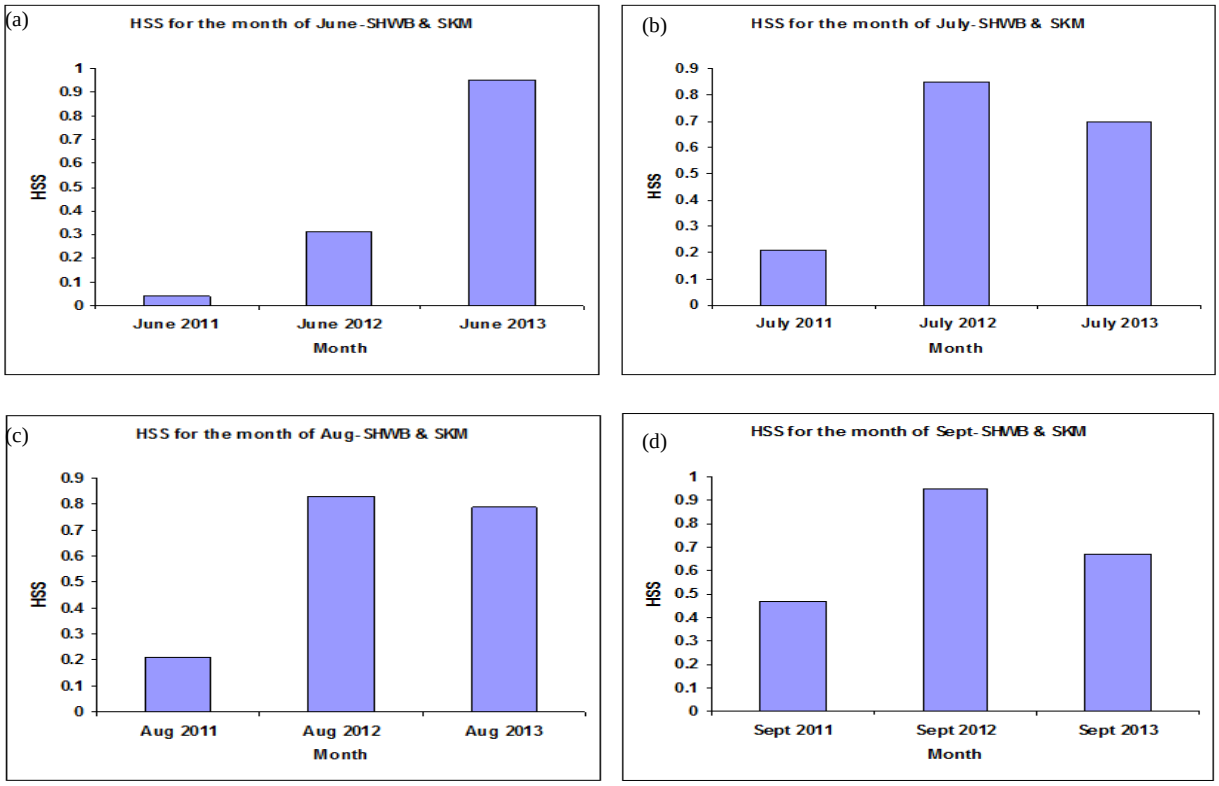
3.2. *Analysis of HSS for combined forecast*

Figs. 5(a-d) indicate the HSS score of SHWB & SKM during the monsoon month (June-September). The HSS scores of this subdivision has shown a sharp improvement from 2011 to 2013 for all the monsoon month and the score reached upto the index > 0.7 in 2013 which is very high from forecasting point of view. For forecasting of this subdivision, the knowledge of the nature of orography along with monitoring of moisture incursion from Bay of Bengal is very important. This part of India got maximum rainfall during the break monsoon condition.

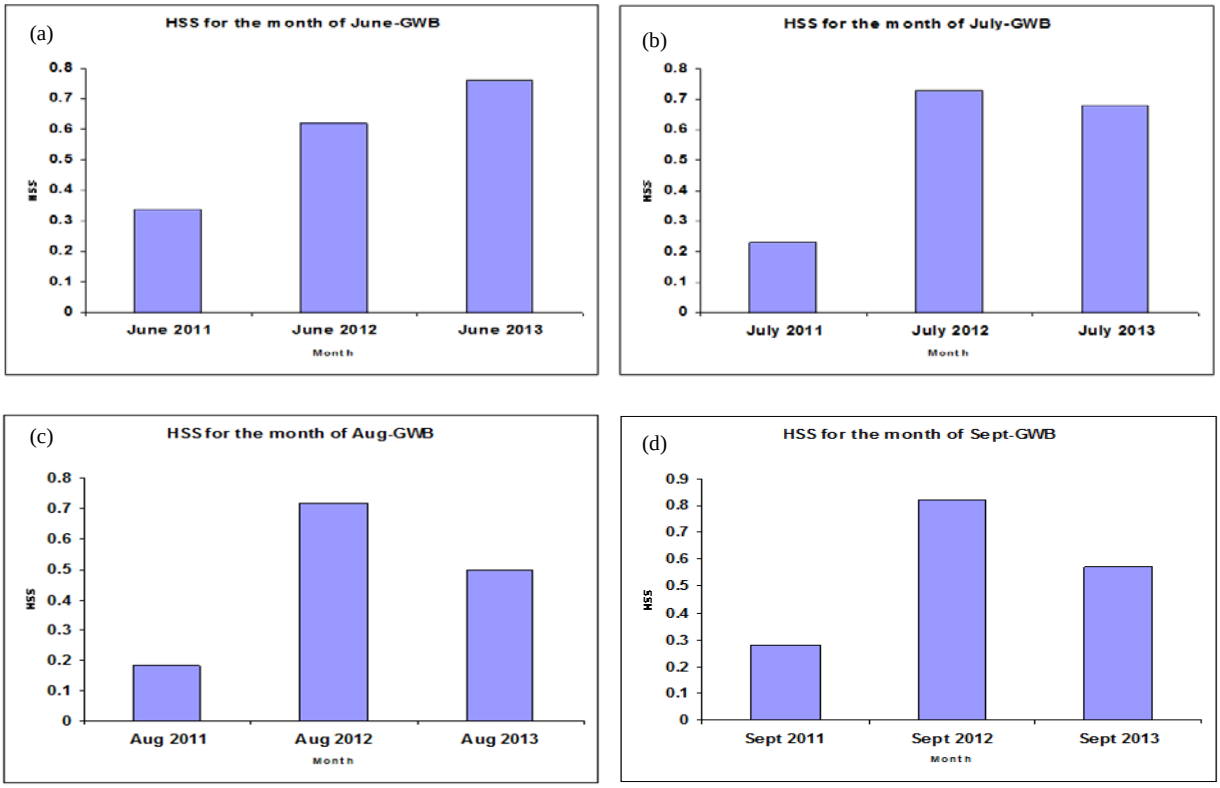
HSS for GWB is shown in Figs. 6(a-d) for the month of June, July, August and September respectively. The HSS index for June is showing that the forecasting efficiency has been increasing with time during this period. Again, the HSS score for other months also has very high value in 2012 and 2013 in comparison with 2011.

The HSS score for ODS is also showing significant increase in the efficiency of weather forecasting in June and August month [Figs. 7(a-d)]. The other two months of the monsoon season also showing variable success and with minimum score in July 2012.

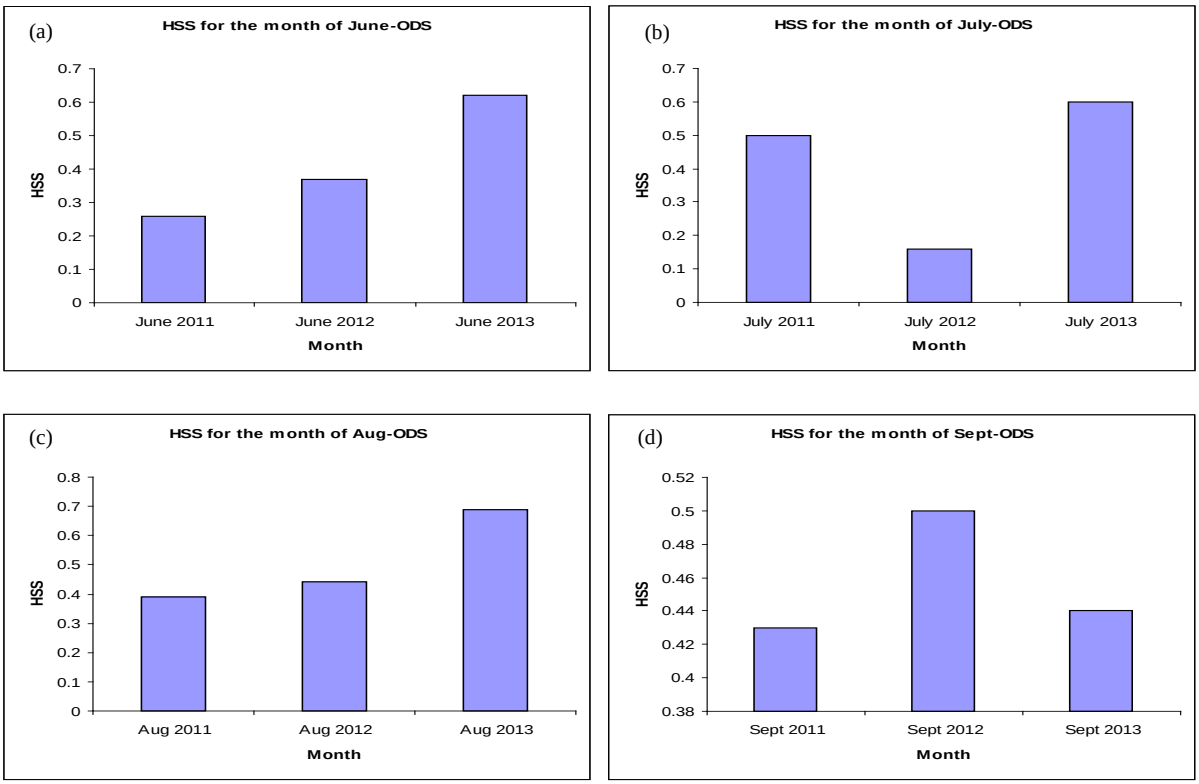
The HSS scores for the subdivision of JRKD and BIHAR is shown in Figs. 8(a-d) and 9(a-d) respectively. The score is not very encouraging particularly in the month of June and July. The other two months namely August and September is showing consistency but overall score is lower than 0.5. The reason may be that last two year the monsoon rainfall activity in these two subdivisions was below normal to deficient and mainly weak monsoon activity prevailed in this regions. During weak monsoon season rainfall occurred due to convective



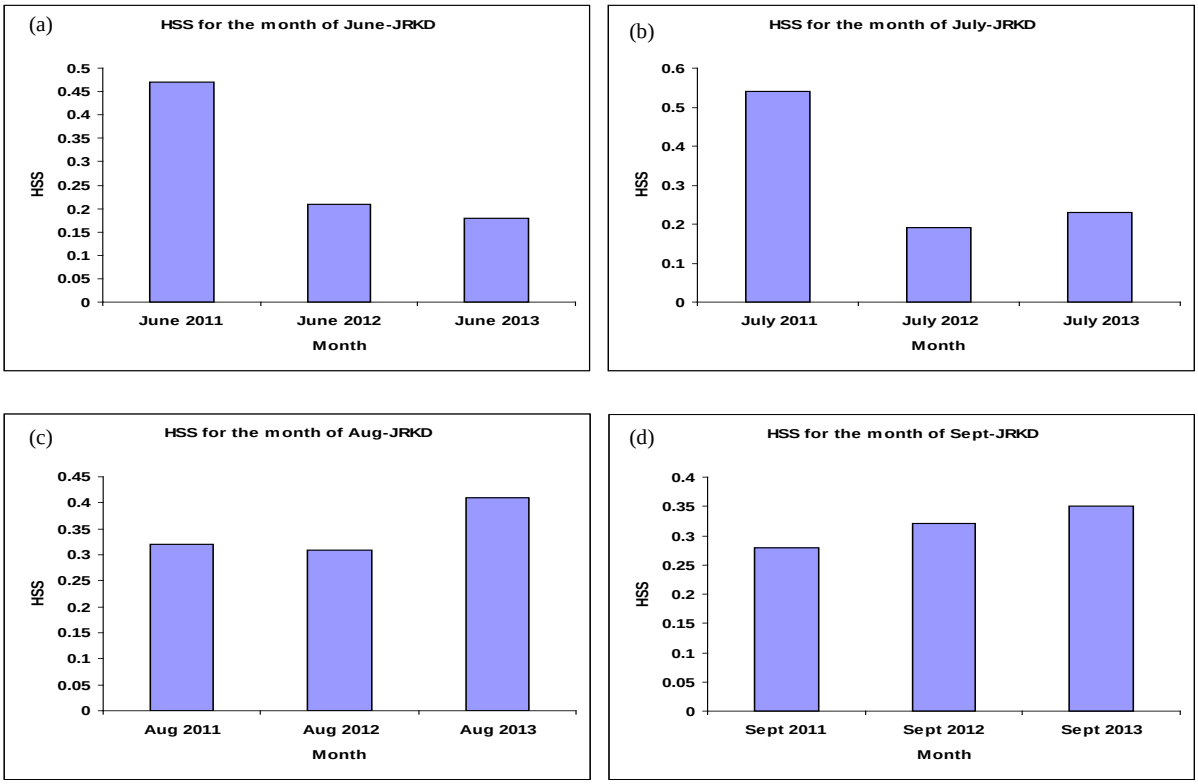
Figs. 5(a-d). HSS score of SHWB & SKM



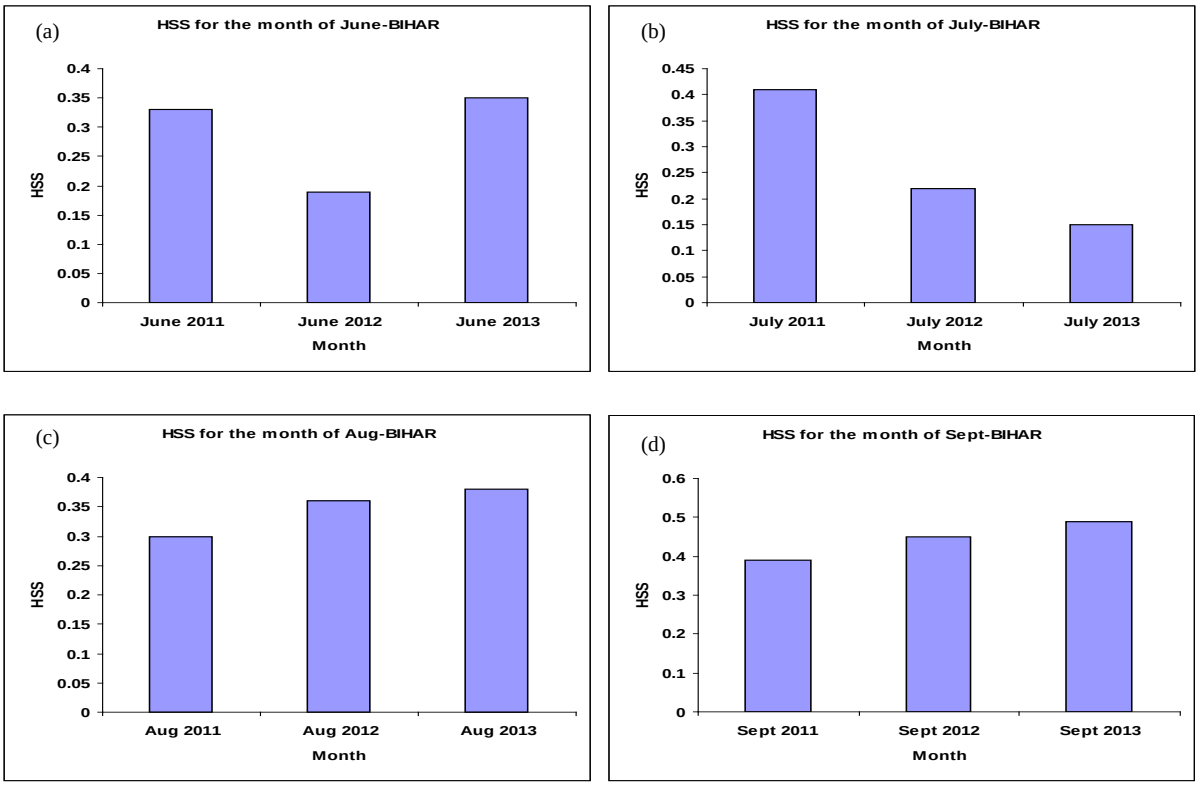
Figs. 6(a-d). HSS score of GWB



Figs. 7(a-d). HSS score of ODISHA



Figs. 8(a-d). HSS score of JRKD



Figs. 9(a-d). HSS score of Bihar

TABLE 3

The percentage correct (%) occurrence of subdivision wise rainfall

Met. sub division	SHWB & Sikkim			GWB			Odisha			Jharkhand			Bihar		
Month/Year	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013
June	43	60	97	50	80	83	47	57	73	60	53	43	50	57	53
July	42	90	81	42	84	77	66	45	71	71	45	48	58	45	42
August	42	90	87	39	84	61	58	61	77	48	48	58	48	61	61
September	61	97	77	43	87	70	57	63	60	40	47	57	57	60	70

activity which is very localized and difficult to predict with synoptic scale forecasting.

3.3. *Combined PC analysis of all classes*

PC analysis of forecast verification of these five subdivisions is given in Table 3. Form the table it has been observed that SHWB & SKM has showing a moderate PC in 2011 and very good PC for the all the month of 2012 and 2013. GWB has also shown moderate PC in all the month of 2011 and very high score in 2012 and high score in 2013.ODS has shown moderate to high score during this 3 years with a range from 45% to 77%. JRKD and BIHAR has shown the PC value from 40% to 71% of range.

4. Conclusions

(*i*) There is gradual increase in performance from 2011 through 2013 over all the met sub division of eastern India. HSS for SHWB & SKM has shown a sharp

improvement from 2011 to 2013 for all the monsoon month. For GWB and ODS, HSS for June has showing increasing efficiency and other months are also showing high value in 2012 and 2013 compare to 2011. For JRKD and BHR, HSS has been increasing from 2011 to 2013 but overall score is lower than 0.5. Combined PC analysis shows that SHWB & SKM has showing a moderate PC in 2011 and very good PC for the all the month of 2012 and 2013. GWB has also shown moderate PC in all the month of 2011 and very high score in 2012 and high score in 2013. ODS has shown moderate to high score during these 3 years with a range from 45% to 77%. JRKD and BIHAR has shown the PC value from 40% to 71% of range.

(*ii*) PC for individual category distribution for SHWB & Sikkim varies from 99% for DRY category to lowest 76% for FWD. For GWB lowest PC is for SCT and FWD distribution at 76% only. Again, for Odisha, Jharkhand and Bihar, the lowest PCs are for SCT distribution with 70%, 62% and 64% respectively.

(*iii*) POD value for the individual forecast category for all the subdivisions have been moderate for the category of FWD, SCT and ISOL. For WD category, it is moderate for SHWB & SKM, GWB and ODS and low for JRKD and BHR. For ISOL category, it is low for all the five subdivision.

(*iv*) CSI for individual category of forecast has been moderate to high (ranging between 0.55 and 0.94) for SHWB & SKM followed by GWB, ODS, BHR and JRKD

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