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Long range forecast and development of a weak southwest monsoon during 2017- Pt. I: Long range forecast

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ABSTRACT

India received below normal rainfall during 2017 southwest monsoon. Formulation of Long Range Forecast (LRF), based on South Indian Ocean Convergence Zone (SIOCZ) model and the results of verification of the forecasts at district and subdivision levels and for India as a whole have been discussed in this part of the study. For the sake of comparison, the forecast from the operational models have also been reproduced. The results of verification have shown that SIOCZ model's district level forecast was in 'Excellent' category in the states of Tamilnadu, Andhra Pradesh, Himachal Pradesh, Maharashtra and Goa and in 'Very Good' category in Telangana. At the subdivision level forecast was in 'Excellent' category in the months of June, July and August and in 'Very Good' category in September. The forecast for bi-monthly rainfall was in 'Excellent' category for all the three bi-monthly periods of Jun+ Jul, Jul+ Aug and Aug+ Sep and also for the season as a whole (Jun-Sep). For India as a whole, forecast was in 'Useful' category in August and September and during the bi-monthly periods of Jul+ Aug and Aug+ Sep. An Update had been issued in August for improvement of rainfall during the second half of the season. However, the improvement in rainfall did not take place over Central and Northwest India. Instead it remained confined to south Peninsula only.

Key words: Southwest monsoon, South Indian Ocean Convergence Zone model, Long range forecast, Update, Forecast verification.

INTRODUCTION

Long range forecasting of monsoon rainfall has continued to remain an important aspect of weather forecasting in India, ever since the first Long Range Forecast (LRF) of monsoon rainfall was issued by IMD in 1886 (Blanford,1884). With changes, from time to time, in number of parameters used for preparing the forecast, its format and content, issuing of operational LRF of monsoon rainfall using parametric models has continued till date. But, the operational models often fail to foreshadow the extreme seasons (Drought/ Excess monsoons), e.g., the deficiency in rainfall, for India as a whole, during four consecutive years, 1984 (-4%), 1985(-8%), 1986 (-13%) and 1987 (-18%) could not be forecast. Failure of the operational models in foreshadowing the deficiency, in any of these four years, became a cause of concern. An urgent need was felt to improve long range forecasting of monsoon rainfall. Department of Science and Technology (DST), IMD and the Indian Institute of Tropical Meteorology (IITM) jointly proposed Parametric and Power Regression Models (Gowariker et al., 1989) as an improvement to the existing models. Real time forecast from the models became available from 1989 onwards. After the failure of the improved models in foreshadowing the drought in 2002, efforts were made by IMD to further improve the Parametric and Power regression models in 2003.Issuing forecast for four geographical regions of India, viz., Northwest India, Central India, East and Northeast India and south Peninsula, in addition to the forecast for India as a whole, also began from that year. However, the improved version of the model also could not foreshadow the drought in 2004. The efforts of Gupta and Onkari Prasad (1992), both from IMD, resulted in proposing Southern Hemispheric Equatorial Trough (SHET) model. Real time forecast from this model became available from 1990.The improved version of the model is now known as South Indian Ocean Convergence Zone (SIOCZ) model (Prasad, Singh and Prasad, 2014). The model has since produced reasonably good forecast of rainfall for India as a whole and its subdivisions (35 till 2002 and 36 thereafter) for the past 28 years including 2017. It may be mentioned here that SIOCZ model alone could foreshadow the deficiency in rainfall in drought years of 2002, 2004, 2009 and severe drought like conditions during the first half of the season in 1992 and 2012. Results of verification of the forecasts, in some of the years, have been reported by Onkari Prasad (1993, 2000, 2001). The verification of the forecasts for the year 2016 has been reported by Onkari Prasad et al., (2018).

SIOCZ model differs from other models because of its ability to identify the precursors, as features in the activity of SIOCZ, as seen in cloud/OLR data from the Indian Ocean region. The precursors are distinctly different for Excess, Normal and Deficient monsoons. Several

Table 1. Long range forecast of rainfall during 2017 southwest monsoon issued by IMD and realized rainfall

Region	Period	Forecast as % of Long Period Average (LPA)		Five category probability forecast				Realized rainfall (%) of LPA
				Category	Rainfall range as % % of LPA	Probability (%)		
		18 April	6 June			Forecast	Climate	
All India	Jun-Sep	96 ± 5	98 ± 4	Deficient	≤ 90	7	16	95
Northwest India	Jun-Sep	96 ± 8		Below normal	90-96	28	17	90
Central India	Jun-Sep	100 ± 8						94
Northeast India	Jun-Sep	96 ± 8		Normal	96-104	50	33	96
South Peninsula	Jun-Sep	99 ± 8						100
All India	July	96 ± 9		Above normal	104-110	13	16	102
		8 August						
All India	August	99 ± 9		Excess	> 110	2	17	87
All India	Aug-Sep	100± 8						87
All India	Jun-Sep	100± 4		Excess	> 110	2	17	95

Source: Press releases on 18th April, 6th June and 8th August and 'End of season report' on 2017 southwest monsoon issued by IMD.

improvements have been made in the model (Prasad, Singh and Prasad, 2014), since the first forecast was prepared in 1990. The improved version of the model has enabled to prepare forecast of seasonal rainfall in the districts of Tamilnadu for the past 13 years (2005-2017) (Prasad, Singh and Subramanian, 2010), Himachal Pradesh for 10 years (2008-2017) (Prasad and Singh, 2007), Andhra Pradesh and Telangana for 4 years (Prasad, Singh and Prasad, 2016b,c) and Maharashtra and Goa for 2 Years (2016-17) (Prasad, Singh and Prasad, 2016d). Identification of precursors, formulation of LRF of rainfall during 2017 southwest monsoon and its verification is discussed in this part of the study.

LONG RANGE FORECAST

Long Range Forecast (LRF) of 2017 monsoon was available from the following models:

i. Operational Statistical Ensemble Forecasting System (OSEFS)
ii. Monsoon Mission Coupled Forecasting System (MMCFS)
iii. South Indian Ocean Convergence Zone (SIOCZ) model

Forecast from OSEFS

The operational LRF of rainfall for 2017 monsoon had been issued by IMD in 3 stages, i.e., on 18th April, 6th June and 8th August. The 18th April forecast was for India as a whole and for the season as a whole. The 6th June forecast was an update on the forecast of 18th April. In addition to forecast for India as a whole, forecast for seasonal rainfall for four broad regions of India, namely, Northwest India (NW India), East and Northeast India (E&NE India), Central India, South Peninsula and rainfall for the country as a whole for the months of July were also included. The forecast of 8th August consisted of the rainfall for the month of August and for the second half of the season, both for India as a whole. The forecast, probability forecast and the realized rainfall are reproduced in Table 1.

Forecast from MMCFS model

Atmospheric and oceanic initial conditions for the month of March 2017 had been used to generate the forecast. Forecast had been computed as an average of 44 ensemble members. The model had suggested that the rainfall averaged for the country as a whole and for the season (Jun-Sep) was likely to be 96% ±5% of LPA. The forecast had been upgraded to 100% ±5% on 6th June.

Forecast from SIOCZ model

It had been shown earlier by the authors that assigning SAI could be done by using either cloud or OLR data (Onkari Prasad, Singh and Prasad, 2014). This had been done by using both Cloud and OLR data for two excess monsoons (1988 & 1994), two normal monsoons (1993&1997) and two droughts (2002&2009). Beginning from 2017, SIOCZ model forecasts are being issued using OLR data from INSAT-3D as provided by IMD and OLR Total and OLR anomaly maps as made available by NOAA/ESRL/PSD on their website (http://www.esrl.noaa.gov/psd/map/clim/sst.shtml), on real time basis. OLR anomaly data were not available from INSAT satellites. NOAA OLR anomaly charts for the period February-July 2017 are reproduced

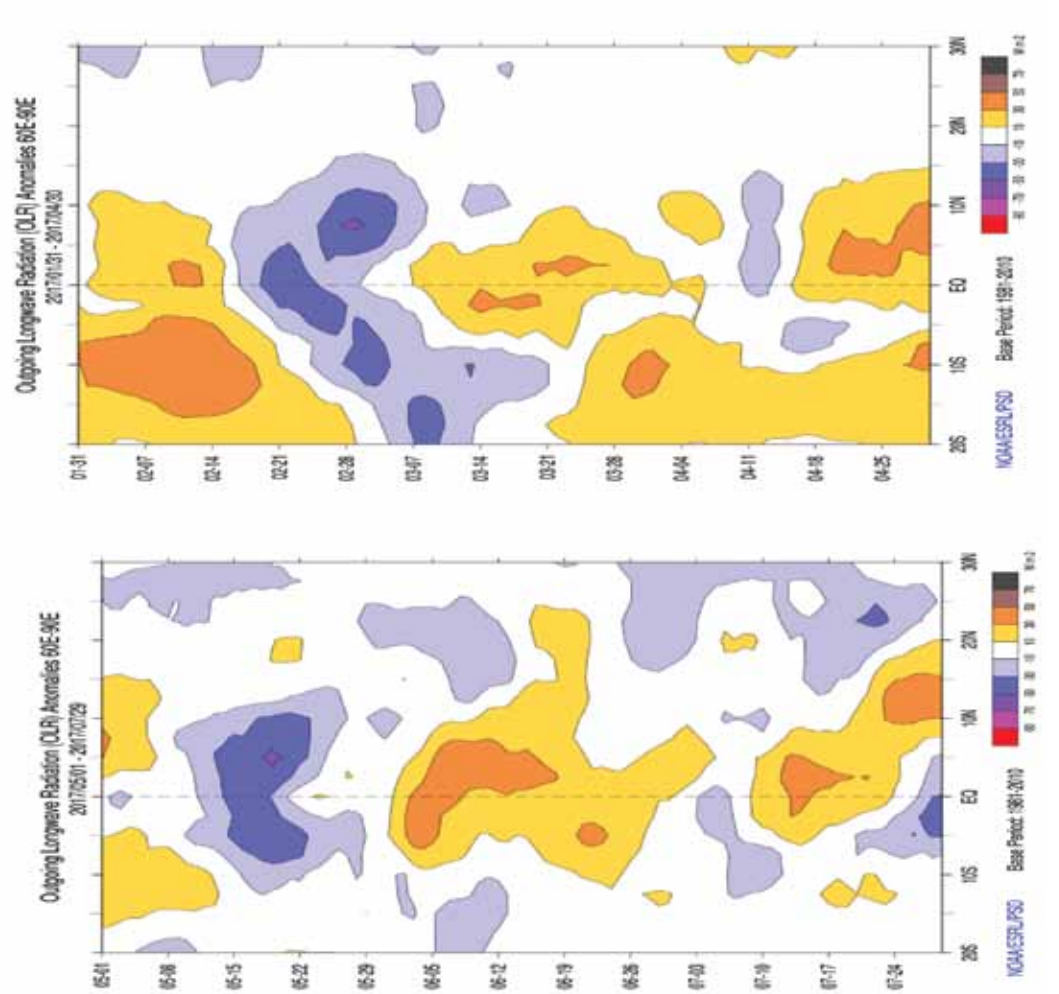

Figure 1. Upper panel: Weekly mean OLR anomaly over the region bounded by 30°N-20°S and 60°E-90°E during February-April 2017. **Lower panel**: Same as upper panel but for the period May-July 2017.

in Figure 1. SIOCZ model forecasts were issued in 3 stages: (i) on 30th March, (ii) 5th June and (iii) 10th August (Update) (Onkari Prasad, Singh and Prasad, 2017).The features in the activity of SIOCZ till the first half of February 2017 had indicated development of a 'Normal' monsoon. However, there was a change in the feature in the activity of SIOCZ during the second half of February-March, when weak convection (negative OLR anomaly, shaded in blue in Figure 1) developed over equatorial areas of Indian Ocean (IO). The convection moved northward as well as southward during the next 3 weeks and 4 weeks, respectively. While the convection moved north of equator up to 15°N, it moved to the south of equator up to 20°S. Convection persisting for 3-4 weeks, in continuation, to the south of equator during February-March and its movement as far south as 20°S, was an early signal for development of a 'Weak' monsoon. During March of 'Normal'/'Active' monsoon years, convection either moves northward or it remains confined to the areas close to the equator. Thus, an early signal indicating likely development of a 'Weak' monsoon appeared during Feb-Mar 2017. In order to foreshadow 2017 summer monsoon as a 'Weak' monsoon, repeat of this feature during the pre-monsoons of April-May was awaited. Accordingly, the first stage forecast issued on 30th March was "***2017 southwest monsoon is likely to develop as a 'Normal' monsoon with Indian summer Monsoon Rainfall on the lower side of its Normal (100%).***

As two monsoons can never be exactly similar, the features in the activity of SIOCZ are also not the same in any two years. However, there were years in the past when the important feature in the activity of SIOCZ was comparable. Available cloud data show that the feature, as seen in the activity of SIOCZ during Mar-May 2017, i.e., development of SIOCZ for 3-4 weeks in continuation, had occurred in 1982, 2002, 2004 and 2009. ISMR in these years was deficient: 1982 (Jun: -17%, Jul:-23 %, Aug: 9 %, Sep:-32%, and Jun-Sep: -15%), 2002 (9%, -54%, -2%, -13%, and -19%), 2004 (-1%, -20%, -4%, -30% and -14%) and 2009 (-47%, -4%,-26%,-20% and -22%),respectively. However, two changes, suggesting likely improvement in rainfall scenario, were taking place at the time of issuing the forecast: (i) The spell of convection, which developed

Table 2. Forecast, Update, realized rainfall as % departure from normal (100%) and Model Error (ME).
Forecast, update and realized rainfall have been shown in bold italics in the subdivisions where CC between SAI and rainfall is significant at 95% level or more.

Subd. S. No.	Jun(10*)			Jul(20*)			Aug(12*)				Sep(16*)			
	FC	RR	ME	FC	RR	ME	FC	UD	RR	ME	FC	UD	RR	ME
1	-23D	-20D		-12N	-4N		-6N	-5N	3N		-16N	-9N	-14N	
2	-19N	-25D		6 N	-3N		-14N	0N	22E		22E	15N	-18N	
3	-15N	-18N		5N	-25D		-12N	-7N	6N		2N	2N	4N	
4	***-26D***	***24E***	3	-2N	22E		-11N	-8N	48E		5N	-1N	20E	
5	-17N	-18N		11N	-22D		-8N	-2N	56E		-3N	-2N	-7N	
6	-9N	-21D		12N	47E		2N	2N	-15N		-1N	9N	-34D	
7	***-4N***	***-2N***	7	-5N	4N		0N	6N	-17N		***-13N***	***3N***	***-19N***	5
8	-4N	-39D		***-10N***	***47E***	4	-11N	-9N	-22D		3N	14N	-49D	
9	-3N	-50D		13N	11N		-9N	-6N	18N		-9N	-6N	-42D	
10	***-3N***	***-53D***	9	***-14N***	***10N***	5	***-24D***	***-14N***	***-37D***	4	-2N	3N	-57D	
11	***-6N***	***13N***	11	***-20D***	***-30D***	6	-15N	-10N	-55D		***-27D***	***-7N***	***-5N***	8
12	-10N	5N		-13N	8N		-15N	-11N	-18N		***-18N***	***-1N***	***3N***	7
13	***28E***	***162LE***	15	***-12N***	***-58D***	12	-10N	4N	-58D		***-41D***	***-13N***	***2N***	12
14	39E	148LE		***-11N***	***-49D***	11	***-11N***	***7N***	***-30D***	7	***-47D***	***-19N***	***-33D***	10
15	***3N***	***30E***	7	***-26D***	***-29D***	5	-26D	-17N	-3N		***-34D***	***-14N***	***-25D***	7
16	23E	144LE		***-12N***	***-6N***	11	**-9N**	**22E**	***-13N***	11	-34D	-19N	-53D	
17	***15N***	***174LE***	19	***-22D***	***114LE***	9	**-32D**	**0N**	***-53D***	9	-27D	-4N	-49D	
18	***-8N***	***42E***	17	***-16N***	***30E***	9	-11N	-6N	-54D		***-53D***	***17N***	***-53D***	26
19	***-14N***	***14N***	9	-17N	1N		9N	7N	-44D		***-43D***	***-20D***	***-11N***	14
20	***-22E***	***-12N***	12	***-27D***	***2N***	4	-6N	6N	-52D		-13N	-4N	-28D	
21	4N	5N		***-26D***	***9N***	10	***-3N***	***22E***	**-37D**	8	***-33D***	***3N***	***-58D***	16
22	17N	-5N		***-34D***	***16N***	12	5N	12N	22E		-45D	7N	-45D	
23	2N	20E		-13N	-2N		6N	14N	-35D		***-26D***	***11N***	***58E***	13
24	14N	31E		***-19N***	***16N***	5	5N	14N	-20D		***-9N***	***14N***	***24E***	9
25	-6N	27E		***-17N***	***-57D***	7	***-7N***	***19N***	***40E***	11	***-28D***	***5N***	***-11N***	12
26	-1N	-12N		***-21D***	***-19N***	5	2N	7N	-8N		***-41D***	***-9N***	***-21D***	11
27	-9N	-1N		-19N	0N		-52D	-10N	66LE		***-32D***	***-8N***	***-18N***	9
28	-7N	44E		**-19N**	**-6N**	7	***-4N***	***11N***	**82LE**	6	-10N	1N	-12N	
29	-8N	49E		***-16N***	***-41D***	6	***-6N***	***13N***	***-17N***	7	***-23D***	***-6N***	***-30D***	6
30	15N	34E		***-15N***	***-45D***	8	***-5N***	***26E***	***-10N***	12	3N	6N	45E	
31	-11N	4N		-13N	-39D		***-13N***	***1N***	***-14N***	9	24E	11N	42E	
32	-3N	-4N		-12N	-29D		8N	18N	10N		***-21D***	***11N***	***6N***	12
33	17N	25E		-20D	-43D		***-2N***	***12N***	***-5N***	6	0N	3N	43E	
34	15N	-23D		***-25D***	***-41D***	6	***-11N***	***11N***	***14N***	5	21E	16N	81LE	
35	-8N	-11N		-16N	-48D		***-7N***	-2N	10N		-9N	10N	78LE	
36	6N	58E		***-6N***	***-43D***	6	***0N***	10N	-5N		-2N	7N	32E	
%*	**80**			**85**			**83**	**66**			**75**	**81**		
India	-6BN	4N	5	-13D	**2N**	**5**	-9BN	1N	**-13D**	**5**	**-17D**	**0N**	**-12D**	**5**

Name of subdivisions: 1. Bay Is. 2. Ar. Pradesh 3.Assam & Megha, 4.NMMT, 5.SHWB & Sikkim, 6.GWB 7.Orissa, 8.Jharkhannd, 9.Bihar, 10.EUP, 11.WUP, 12. Uttarakhand, 13.Dlh,Har,Cha, 14. Punjab, 15. H.P., 16. J&K, 17. W. Raj, 18. E. Raj, 19. WMP, 20.EMP, 21. Guj Reg, 22.Sau. & Kutch, 23. Konkan Goa, 24. Madhya Maharashtra, 25. Marathwada, 26.Vidarbha, 27.Chhattisgarh, 28.CAP, 29.Talangana, 30.Rayala, 31.Tamilnadu & Puducherry, 32. Coastal karnataka, 33.North Interior Karnataka, 34.South Interior Karnataka, 35.Kerala and 36. Lakshadweep. (x*)- x is the No. of subdivisions where CC between SAI and rainfall was significant at 95% level or more, %*: % of sub- divisions (out of the number of subdivisions where CC is significant in the month or bimonthly period/season) where forecast was in 'Useful' category.

Categorization of rainfall (as followed in IMD) (i) for rainfall in districts and sub-divisions: Large Excess (LE):60% or more, Excess (E):59% to 20%, Normal (N):±19%, Deficient (D): -20% to -59% and Large Deficiency (LD): -60% or less.
(ii) for India as a whole: Excess(E): > 10%, Above Normal (AN): 10% to 5%, Normal (N): ±4%, Below Normal (BN): -5% to -10%, Deficient(D): < -10%.

Table 3. Same as Table 2 but for the season as a whole.

Jun- Sep (26*)														
Subd. S.No.	FC	UD	RR	ME	Subd. S.No.	FC	UD	RR	ME	Subd. S.No.	FC	UD	RR	ME
1	*-15N*	***-8N***	-9N		14	***-14 N***	***9N***	-22D	9	27	***-20D***	***-9N***	-10N	6
2	-3N	1N	-11N		15	***-25 D***	***-13N***	-13N	5	28	***-11 N***	***5N***	14N	6
3	-5 N	-2 N	-10N		16	***-11N***	***9N***	2N	8	29	***-14N***	***2N***	-13N	6
4	-10N	-8 N	25E		17	***-31 D***	***11 N***	39E	12	30	***-1N***	***16N***	27E	6
5	-3 N	-1 N	2N		18	***-21 D***	***-2N***	-8N	7	31	***-21 D***	***9N***	31E	10
6	4 N	10 N	-3N		19	***-15N***	***-1 N***	-16N	5	32	***-6 N***	***4N***	-16N	4
7	*-5N*	***1N***	-9N		20	***-16 N***	***-4N***	-10N	10	33	***-6 N***	***5N***	3N	3
8	***-6 N***	***2N***	-10N	3	21	***-25N***	***11N***	9N	10	34	-3 N	8 N	2N	
9	-2 N	2N	-9N		22	***-17N***	***6N***	35E	3	35	***-9 N***	***-3N***	-9N	3
10	***-13 N***	***-2 N***	-28D	4	23	***-5N***	***3 N***	10N	6	36	-1 N	6 N	11N	
11	***-21D***	***-10N***	-31D	5	24	***-5N***	***9 N***	17N	8	%*	***96***	***80***		
12	***-15 N***	***-6N***	-2N	3	25	***-16N***	***2N***	-6N	5	India	***-12D***	***0 N***	***-5BN***	5
13	***-14N***	***9N***	-26D	10	26	***-17N***	***-3 N***	-23D	3					

from the week ending on 15th May for the next 2 weeks was weak in the region south of equator and (ii) positive SST anomaly over the Equatorial Indo-Pacific region had started decreasing beginning from the first week of May. Considering that both the developments were in phase for likely improvement in rainfall, the assigned value of SAI had been moderated from 16 to 14. SAI=14 corresponds to 12% below normal ISMR with model error of ±5%. SIOCZ model had, therefore, foreshadowed 2017 southwest monsoon as a 'Weak' one with ISMR expected to be 12% below normal, i.e., in 'Deficient' category. The value assigned to SAI for the subdivision of Tamilnadu and Puducherry was 15. Monthly, bi-monthly and seasonal rainfall forecast as well as realized rainfall in the subdivisions and for India as a whole and forecast of seasonal rainfall in the districts of Tamilnadu, Andhra Pradesh, Telangana, Himachal Pradesh and Maharashtra & Goa and realized rainfall are included in Tables 2-4.

Update

In the past, Update/Updates had been issued in 2010 (Onkari Prasad and Singh, 2013b), in 2013 (Onkari Prasad, Singh and Prasad, 2016a) and 2016 (Onkari Prasad,Singh and Prasad,2018).In 2017, an intra-seasonal change in the activity of SIOCZ, suggesting improvement in rainfall took place during July: As a recurrence of the main feature in the activity of SIOCZ, an active spell of SIOCZ developed during the week ending on 10th July. But it turned out to be very weak (**Lower panel** of Figure 1). Thereafter, another active spell of SIOCZ developed during the week ending on 24th July. These developments in the activity of SIOCZ were a departure from the main feature, i.e., SIOCZ remaining active for 3-4 weeks in continuation. This was an indication of likely improvement in rainfall scenario and, therefore, it formed the basis for the issue of an Update. In addition, decrease in SST anomaly in Nino 3.4 region from 0.48°C in May to 0.35°C in July also favoured probable return of normal monsoon conditions over India during the second half of the season. A value of 9, which corresponds to normal rainfall over India, was assigned to SAI for computing rainfall during August & September and for the season as a whole in the subdivisions, India as a whole and in the districts of Andhra Pradesh, Telangana and Himachal Pradesh. The value assigned to SAI for Tamilnadu and Maharashtra and Goa was 11. The updated forecast rainfall figures are included in Tables 2-4.

Verification of Forecasts

For verification at district and subdivision level, forecast as well as realized rainfall figures have been considered in two broad categories only, i.e., 'Large Excess (LE)/Excess(E)/ Normal(N)' and 'Deficient(D)/Large Deficiency (LD)'. Verification of forecasts is discussed below, in brief, for those districts and subdivisions only where CC between SAI and rainfall is significant at 95% level or more. The district level forecast/Update has been categorized as 'Average', 'Good', 'Very Good' and 'Excellent', if the forecast/Update was in 'Useful' category between 50% and 59% districts of a state where CC was significant, 60% districts, 61-80% districts and 81-100% districts, respectively. This categorization has been used for differentiating subdivision-wise forecasts for monthly, bi-monthly and seasonal forecasts.

Table 4a. Same as Table 2 but for the districts in the states

Tamilnadu (30*/32)					Andhra Pradesh(12*/13)				
District	FC	UD	RR	ME	District	FC	UD	RR	ME
Ariyalur	***-26D***	***-13N***	**40 E**	8	Srikakulam	-2N	2 N	20E	
Chennai	***-7 N***	***5N***	**2 N**	9	Vizianagram	***-10N***	***-4N***	***6N***	2
Coimbatore	***19 N***	***26E***	**169LE**	18	Visakhapatnam	***2 N***	***11N***	***8N***	3
Cuddalore	***-15N***	***-5N***	**22 E**	8	East Godavary	***-8 N***	***6N***	***14N***	6
Dharmapuri	***-12N***	***0N***	**2 N**	8	West Godavary	***-12N***	***2 N***	***3N***	5
Dindigul	***-10N***	***7N***	**39 E**	6	Krishna	***-13N***	***3N***	***-1N***	6
Erode	***16 N***	***30E***	**35 E**	18	Guntur	***-9N***	***8N***	***18N***	7
Kanchipuram	***-17N***	***-1***	**0 N**	9	Prakasham	***-7N***	***7N***	***18N***	5
Kanyakumari	8N	5N	-16 N		Nellore	***-1N***	***12N***	***50E***	5
Karur	***-19N***	***-1N***	***57 E***	8	Kurnool	***-11N***	***2N***	***13N***	5
Krishnagiri	***-12N***	***0N***	***32 E***	8	Anantpur	***-13N***	***5N***	***18N***	7
Madurai	***7N***	***12N***	***21 E***	6	Cuddapah	***-12N***	***5N***	***34E***	7
Nagapattinam	***-22D***	***-1N***	***5 N***	8	Chittor	***-1N***	***16N***	***47E***	7
Namakkal	***-11N***	***5N***	***12 N***	8	% of districts where FC/Update was in 'Useful' category	100%	100%		
Nilgiri Hills	-17N	-11N	-4 N		Telangana(10*/10)				
					District	FC	UD	RR	ME
Perambalur	***-46D***	***-26D***	***90LE***	8	Adilabad	***-6N***	***12N***	-28D	9
Puddukotai	***-24D***	***-9N***	***16 N***	8	Nizamabad	***-14N***	***-2N***	-25D	9
Ramanathpurm	***-32D***	***-10N***	***41 E***	9	Karimnagar	***-1N***	***12N***	-25D	5
Salem	***-16N***	***-6N***	***10 N***	8	Medak	***-14N***	***1N***	-15N	7
Sivganga	***-13N***	***-3N***	***75LE***	6	Warangal	***-8N***	***7N***	3N	6
Thanjavur	***-30D***	***-8N***	***51 E***	8	Khammam	***-6 N***	***5N***	2N	6
Theni	***17N***	***25E***	***131LE***	6	Rangareddy	***-20D***	***-1N***	-15N	7
Thiruvallur	***-12N***	***4N***	***10 N***	9	Hyderabad	***-6N***	***5N***	9N	5
Thiruvarur	***-26D***	***0N***	***32 E***	18	Nalgonda	***-20D***	***2N***	-6N	6
Thoothukudi	***-6 N***	***-4N***	***41 E***	9	Mahbubnagr	***-26 D***	***-9N***	-9 N	6
Trichirapally	***-22D***	***6N***	***14 N***	8	% of districts where FC/Update was in 'Useful' category	70%	70%		
Tirunelveli	***0N***	***4N***	***49 E***	8					
Tirupur	*-12N*	***-4N***	***100LE***	8	Himachal Pradesh (6*/12)				
					District	FC	UD	RR	ME
Tiruvannamlai	*-20D*	***-7N***	***33 E***	9	Bilaspur	-7N	-1N	9 N	
Vellore	*-17N*	***1N***	***23 E***	8	Chamba	-33 D	-26D	-50 D	
Villupuram	*-25D*	***-9N***	***8 N***	8	Hamirpur	***-3N***	***14N***	0 N	7
Virudhunagar	***-9 N***	***9N***	***49 E***	6	Kangra	***-15N***	***-5N***	3 N	4
% of districts where F/C / Update were in useful category	90%	100%			Kinnaur	***-29 D***	***-15N***	-32 D	6
					Kullu	***-1N***	***-9 N***	14 N	4
					Mandi	-19 N	-11N	9 N	
					Simla	***-21D***	***-10N***	1 N	4
					Sirmur	-37 D	-29D	-8 N	
					Solon	***-27D***	***-15N***	-16 N	5
					Una	11N	23E	18 N	
					Lahol-Spiti	NA	NA	-70 D	
					% of districts where FC/Update was in 'Useful' category	83%		100%	

Table 4b. Same as Table 4a but for the districts in Maharashtra & Goa

Maharashtra & Goa (32*/36)									
District	FC	UD	RR	ME	District	FC	UD	RR	ME
Thane	***-5N***	***3N***	32 E	4	Jalna	***-14N***	***7N***	-2 N	7
Mumbai City	***4N***	***4N***	10 N	4	Beed	***-13N***	***8N***	12 N	8
Raigarh	***-6 N***	***4N***	17 N	4	Parbhani	***-26D***	***8N***	-21 D	8
Ratnagiri	***-4N***	***3N***	5 N	4	Hingoli	***-20D***	***7N***	-28 D	7
Sindhudurga	***0N***	***4N***	-4 N	3	Osmanabad	***-21D***	***6N***	24 E	6
North Goa	***1N***	***3N***	-13 N	3	Latur	***-21D***	***8N***	2 N	8
South Goa	***-2N***	***3N***	-14 N	3	Nanded	***-18N***	***9N***	-22 D	9
Nandurbar	***-1N***	***7N***	-11 N	7	Buldhana	***-10N***	***5N***	2 N	5
Dhule	***-3N***	***5N***	-2 N	5	Akola	***-6N***	***5N***	-22 D	5
Jalgaon	***-10N***	***6N***	-15 N	6	Wasim	***-8N***	***5N***	-28 D	5
Nasik	*-1N*	*3N*	31 E		Amraoti	***-7N***	***4N***	-30 D	4
Ahmednagar	***-8N***	***7N***	55 E	7	Yeotmal	***-15N***	***7N***	-34 D	7
Pune	-3N	3N	50 E		Wardha	***-13N***	***4N***	-14 N	4
Satara	***25E***	***3N***	17 N		Nagpur	***-12N***	***5N***	-4 N	5
Solapur	***-9N***	***6N***	25 E	6	Bhandara	***-15N***	***4N***	-27 D	4
Sangli	-4N	3N	-11 N		Gondia	***-11N***	***4N***	-37 D	4
Kolhapur	***14N***	***3N***	-14 N	3	Chandrapur	***-16N***	***5N***	-32 D	5
Aurangabad	***-16N***	***6N***	-7 N	6	Gadchiroli	***-7***	***4N***	-22 D	4
% of districts where FC/Update was in 'Useful' category						81%	62%		

In the districts

At district level, a forecast is considered 'Useful', if both the forecast as well as the realised rainfall were in the same broad departure category, as mentioned above, or they became so when model error was taken into account. The forecast, realised rainfall and Model Error (ME) in the districts of Tamilnadu, Andhra Pradesh, Telangana, Himachal Pradesh and Maharashtra & Goa are included in Table 4. In Tamilnadu, forecast was in 'Useful' category in 90% of districts and the Update in 100% of districts. In Andhra Pradesh, the % of 'Useful' forecast as well as for the Update was 100%. The updated forecast was closer to the realised one. However, the realised rainfall was, in general, higher than the updated values. In Telangana, the forecast as well as the Update was in 'Useful' category in 70% districts. In Himachal Pradesh, forecast was in 'Useful' category in 83% districts and the updated forecast in all the 6 districts, where CC is significant. In Maharashtra & Goa, forecast was in 'Useful' category in 91% of districts and the Update in all the 32 districts, where CC is significant. Thus the district level forecast was in 'Excellent' category in Tamilnadu, Andhra Pradesh, Himachal Pradesh and Maharashtra & Goa. The forecast as well as the Update was in 'Very Good' category in Telangana.

In subdivisions

At sub-divisional level also, a forecast is considered 'Useful', if both, the forecast as well as the realised rainfall, are in the same broad departure category or they become so after ME is taken into account. The ME is different for different subdivisions and the same is included in Tables 2&3.The forecast rainfall was in 'Useful' category in 80%, 85%, 83% and 75% subdivisions in the months of June, July, August and September, respectively. The Update was in 'Useful' category in 67% and 81% of subdivisions for the months of August and September, respectively. Thus the forecast was in 'Excellent' category in Jun, Jul and Aug and in 'Very Good' category in Sep. The Update was in 'Very Good' category in Sep and in 'Good' category in Aug. The table containing the data on forecast, Update and realized rainfall for the bi-monthly periods could not be included here due to lack of space. However, the same could be obtained as an average of monthly forecast/Update/realized rainfall for two consecutive months. The ME for bimonthly periods is available in one of the earlier publications by Onkari Prasad and Singh (2013a). The number of subdivisions, where CC between SAI and bi-monthly rainfall during Jun+ Jul, Jul+ Aug and Aug+ Sep, was 24, 24 and 20 respectively. The forecast was in 'Useful' category in 92%, 83%, and 95% of

subdivisions. The Update was in 'Useful' category in 71% of subdivisions during Jul+ Aug and 60% during Aug+ Sep, respectively. Thus the Update was in 'Very Good' category during the bi-monthly period of July+ Aug and in 'Good' category during Aug+ Sep.

For India as a whole

The forecast, Update and the realised rainfall for country as a whole are included at the bottom of Tables 2&3. For India as a whole, a forecast is categorized to be in 'Useful' category, if the forecast as well as the realized rainfall were in the same departure category, or the forecast came in the departure category of realized rainfall after the ME (±5%) was taken into account. Otherwise the forecast was considered as not in useful category. The monthly forecast was in useful category in June, August and September. The bi-monthly forecast was in useful category for the bi-monthly periods of Jul+ Aug and Aug+ Sep. The forecast for the seasonal rainfall, i.e., 12% below normal as compared to 5% below normal of realized rainfall, was slightly below the useful category mark. The Update issued in August was not in useful category for the bi-monthly period of Aug+ Sep and also for the season as a whole.

CONCLUSIONS

1) The main feature in the activity of SIOCZ, i.e., development of an active spell of SIOCZ for 3-4 weeks in continuation, first appeared during February-March and continued up to October. An intra-seasonal change got superimposed over the main feature in July and continued up to October.

2) Though 2017 southwest monsoon, with 5% below normal Indian Summer Monsoon Rainfall (ISMR), has been entered in the records as a 'Below normal' monsoon, monthly rainfall in the subdivisions during Jul-Sep was similar to that for a 'Deficient' monsoon.

3) SIOCZ model's forecasts for a normal monsoon with rainfall on the lower side of 'Normal' (100%) issued on 30th March, for a weak monsoon on 5th June and the Update issued on 10th August for likely improvement in rainfall during the second half of the season, were able to capture most of the features of rainfall distribution during 2017 southwest monsoon season. However, the improvement in rainfall during the second half of the season, as indicated in the Update, remained confined to southern Peninsula only.

4) The performance of SIOCZ model forecast was better in the districts of the states, compared to that in the subdivisions and for the country as a whole.

5) Intra-seasonal change in the activity of SIOCZ during the second half of 2017 southwest monsoon was more closely related to the distribution of rainfall over India than the mid-season transition from El Nino to ENSO Neutral conditions in equatorial East Pacific.

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Compliance with Ethical Standards:

The authors declare that they have no conflict of interest and adhere to copyright norms.

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