J. Ind. Geophys. Union (January 2012)
Vol.16, No.1, pp.1-10

South Indian Convergence Zone Model: A new approach to seasonal forecasting of summer monsoon rainfall in India Part II: Forecast for India as a whole

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ABSTRACT
Evolution of South Indian Convergence Zone (SICZ) and its close relationship with the activity of southwest monsoon over Indian subcontinent had been discussed in Pt I of this paper by Prasad, Singh and Prasad (2010). This part of the paper aims at developing a technique to use this relationship in seasonal forecasting of summer monsoon rainfall. The method of assigning South Indian Convergence Zone (SICZ) Activity Index (SAI) using mean cloudiness and mean cloud anomalies has been discussed. SAI, ranked from 1 to 20, is inversely related to Indian Summer Monsoon rainfall (ISMR) and it is highly correlated (CC > .9) with it. Linear regression equations between SAI and ISMR, rainfall for India as a whole during monsoon months of June, July, August and September and bi-monthly periods of June+ July, July+ August and August+ September have been developed using data for a period of 25 years (1972-1997, except 1978 when cloud data were not available after 16th March). Data for a period of 13 years (1998-2010) have been used for verification of forecasts. Forecast verification has shown that the model is capable of producing reasonably good forecast of ISMR, rainfall in individual months and bi-monthly periods during southwest monsoon season.

INTRODUCTION

The proposed model is based on the premise that southwest monsoon, which could be categorized based on various ranges of % departure of Indian Summer Monsoon Rainfall (ISMR), has a typical rainfall distribution, in space and time, over Indian subcontinent associated with each monsoon category. Once the category for the coming monsoon has been estimated based on the characteristic features of cloudiness over equatorial regions of Indian Ocean during the period January-May, the rainfall distribution pertaining to that category becomes the forecast. Had the cloud data been available for a large number of years, say 100 years or so, then there was every likelihood of a previous year cloudiness pattern being available which could be used as an analogue and the rainfall of that year be the forecast rainfall for the given year. Satellite observed cloudiness data are available for a limited temporal extent, as compared to rainfall data. This does not allow us to find years with matching characteristics of equatorial cloud features. It is, therefore, necessary to assign an index to cloud features, so that correlation between the index and the rainfall could be worked out and used to compute forecast rainfall.

METHODOOGY

The first step in this method consists of assigning SAI values. This is the most important aspect of the new approach to seasonal forecasting of rainfall in India. A limited period of cloudiness data (16 years between 1972-1989 except 1978, 1981) were available when the idea of quantifying the activity of SICZ, by assigning an index to equatorial cloud features, was first attempted (Gupta and Prasad, 1992). Earlier to that an attempt to use the activity of SICZ, was made by Prasad et al (1988) in the medium range forecasting of rainfall in India. Cloud data are now available for about 4 decades beginning from 1972. In a recent study relating to improvement of seasonal forecast of rainfall in meteorological subdivision of Tamilnadu and Pondicherry using SICZ model (Prasad et al, 2010a), it was found that preparing mean cloudiness and mean cloud anomalies pertaining to various ranges of % departure of rainfall proved helpful in assigning values of SAI. It was further shown in Pt I of this study (Prasad et al., 2010b) that there exists a pattern in the development of circulation features, as seen in cloudiness data, over the equatorial regions of Indian Ocean during the period January-May. These patterns are distinctly different and identifiable for ‘Excess’, 'Normal' and 'Deficient' monsoons. Development of cloud patterns was also found to be different for different monsoon categories. As shown in Pt. I, 12 values of SAI could have been sufficient to cover the entire range of ISMR from an 'Excess' monsoon of category-M1 to a 'Deficient' monsoon of category-M12, had it been possible to assign SAI with an accuracy of ±1. Year to year variations in cloud features belonging to the same category of monsoon and availability of satellite cloud data for a relatively shorter period of time (38 years between 1972 and 2010 except 1978) compared to rainfall data (136 years between 1875 and 2010) put a limitation on assigning SAI index with an accuracy of ±1. Consequently, it is appropriate to cover the range of ISMR by assigning SAI ranked from 1 to 20 (Prasad et al., 2011a). Accordingly, we have categorized ISMR into 20 categories. Table 1 gives the Monsoon Categories (MC), corresponding values of SAI and range of ISMR, number. of Years (Y1) when rainfall was in the given range during the period 1875-2010 / number of years (Y2) when satellite observed cloud data were available during the period January-May 1972-2010. Cloud data were not available for monsoon categories M1, M2, M11, M19 and M20.

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Mean cloudiness and mean cloud anomalies have been worked out for those monsoon categories where cloud data were available for 2 years or more. For monsoon categories M3-M6 and M16-18 cloud data were available for 1 year only. Cloud data were not available for monsoon categories M1, M2, M11, M19 and M20. For all other categories figures showing mean cloudiness and mean cloud anomalies (Fig.1 and Fig. 2 respectively) have been used in assigning SAI. As summarized in Pt I of the study, cloud features pertaining to each year during the period of study (1972-2010) have been identified and used in assigning SAI. Since cloud data were not available for SAI values of 1, 2, 11, 19 and 20, cloud features pertaining to these categories are not available in Table 2. After having assigned SAI in each year, cloud features pertaining to an year with their % departure of ISMR have been arranged in the increasing order of the value of SAI. There is close correspondence between SAI and % departure of ISMR for different monsoon categories as given in Table 1. However, in some years the % departure of ISMR has gone slightly out of the range pertaining to the assigned value of SAI. This has resulted while finding the best fit values of SAI and ISMR for the model development period of 1972-1997, discussed below. In some of the years (during the model development as well as model verification period), ISMR was different than that expected as per the assigned value of SAI. SAI, cloud features and % departure of ISMR pertaining to those years have been shown separately, in Table 2a. Large differences between realized and forecast rainfall had resulted due to large intra-seasonal changes in those years. This is further discussed below.

Table 1. Monsoon Category (MC), SICZ Activity Index (SAI), corresponding range of % departure of ISMR, No. of Years (Y1) when rainfall was in the given range during 136 years period of 1875-2010/ No. of years (Y2) when satellite observed cloud data were available during 38 years period of January-May 1972-2010 (except from 16th March to 31st May1978)

MC/SAI	1	2	3	4	5	6	7	8	9	10
% departure of ISMR	⩾ 23	22–20	19–17	16–14	13–11	10–8	7–5	4–2	1–-1	-2 –-4
(Y1/Y2)	(1/-)	(1/-)	(2/1)	(7/1)	(5/1)	(11/1)	(19/5)	(19/4)	(14/7)	(17/3)
MC/SAI	11	12	13	14	15	16	17	18	19	20
% departure of ISMR	-5–-7	-8–-10	-11–-13	-14–-16	-17–-19	-20–-22	-23–-25	-26–-28	-29–-31	⩽32
(Y1/Y2)	(4/-)	(13/5)	(6/2)	(4/2)	(5/2)	(2/1)	(2/1)	(2/1)	(-/-)	(1/-)

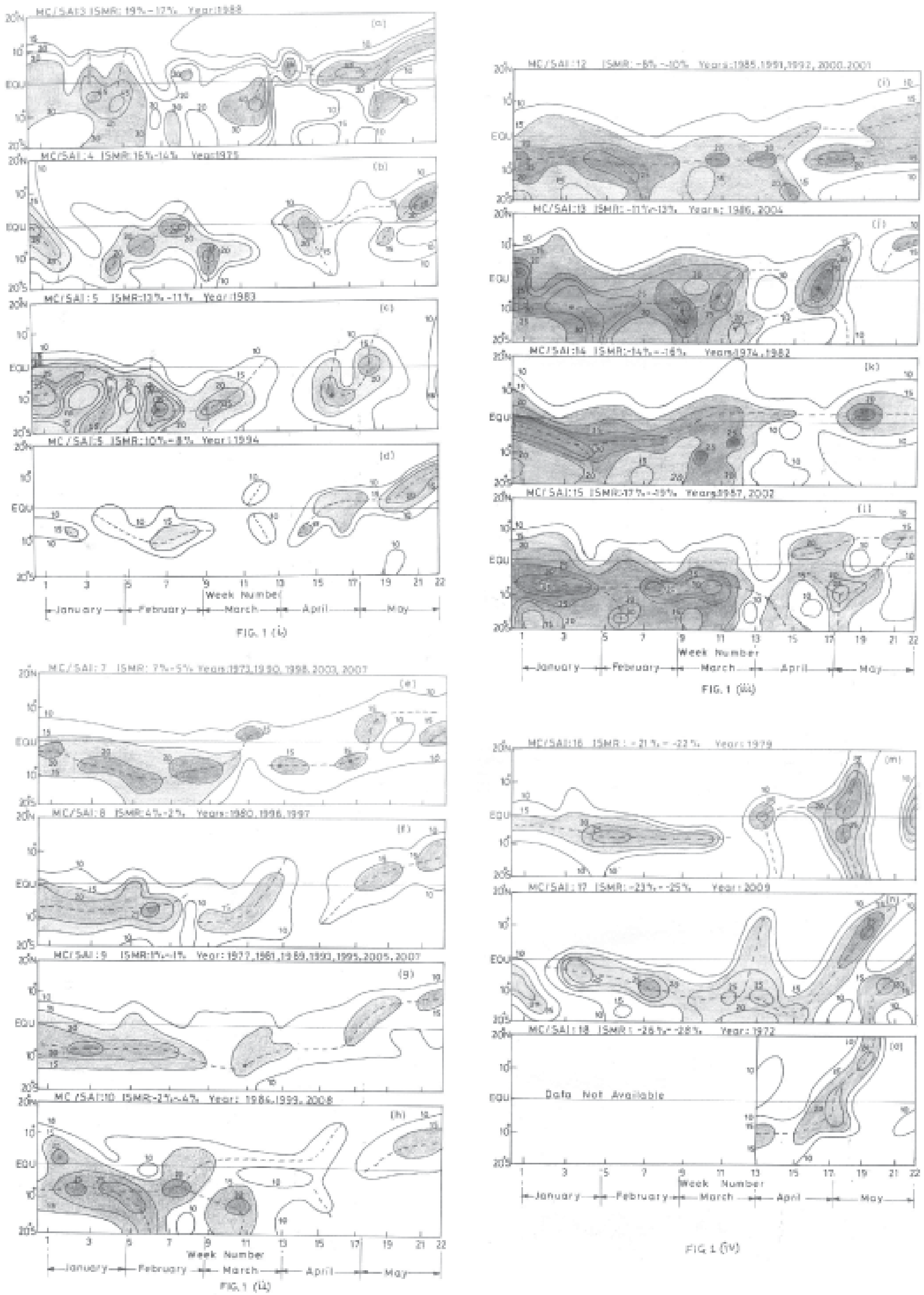

Fig.1 (a)-(o): Zonal weekly mean cloudiness over the area bounded by latitudes 20 deg. S to 30 deg. N., longitudes 40 deg. E to 100 deg. E.

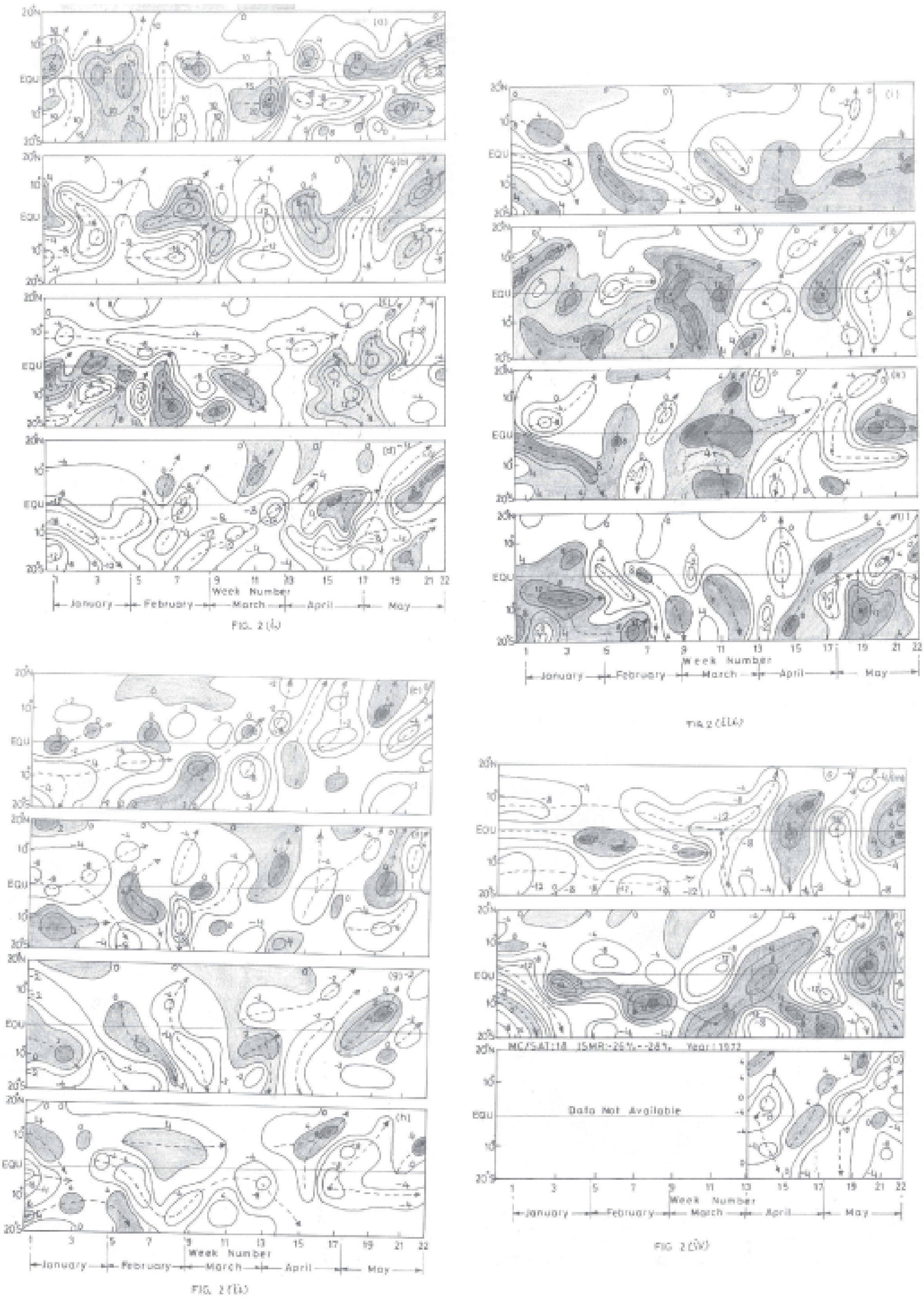

Fig. 2(a)-(o): Anomalies of zonal weekly mean cloudiness. Anomalies have been obtained by subtracting the mean of zonal weekly mean cloudiness for the period 1973-2008.

Table 2. South Indian Convergence Zone (SICZ) Activity Index (SAI), main features of cloudiness during the period Jan-May of the year (% departure of ISMR)

SAI	Main cloud features	Year (ISMR)
3	Development of 2 very prominent spells of active SICZ, with a weak spell in between, during Jan - Mar. Thereafter, equatorial trough developed to the north of equator and moved progressively northwards up to 20° N lat. by the end of May.	1988 (19%)
4	Considerable reduction in cloud amounts and development of alternate spells of active and weak SICZ during Jan-May. Anomalies associated with active SICZ during Feb, Apr and May moved northward of equator and reached up to 20° N lat. by the end of May.	1975 (15%)
5	Reduction in cloud amounts during Jan-May. 5 spells of active and weak SICZ developed during Jan-May. Jan, Apr- May spells of active SICZ had a tendency to move towards north of equator. Apr Spell of Positive Cloud Anomalies (SPCAs) was very prominent to the north of equator.	1983 (12%)
6	SICZ remained weak with considerable reduction in cloud amounts during Jan -Mar. 2 very prominent spells of active SICZ with a weak spell in between developed during Apr -May. Anomalies associated with both moved up to 20°N by the end of May .	1994 (10 %)
	SICZ remained active during Jan-Feb. Spells of active and weak SICZ developed during Mar-May. Anomalies associated with active and weak spells reached up to 10° N during Mar and 20° N during Apr-May.	1973 (7 %)
	Reduction in cloudiness. SICZ remained weak during Jan -May. 2 MCZ developed north of equator during Apr - May, moved northward and reached up to 20 °N lat. by May end.	2007 (6 %)
	Development of alternate spells of active and weak SICZ during Jan-May. PCAs associated with a spell of active SICZ during Apr started moving northward and reached up to 20° N lat. by the middle of May.	2003 (5 %)
7	Development of alternate spells of active and weak SICZ during Jan -May. Weak spells were prominent during Jan-Mar and active spells during Apr-May. Anomalies associated with both spells reached up to 20° N lat..	1990 (6 %)
	SICZ remained active during Jan-Feb. Alternate spells of active and weak SICZ developed during the 2nd half of Mar-May. Anomalies associated with both had a tendency to move towards north of equator.	1980 (4 %)
	SICZ was weak during Jan -Mar. 3 spells of active and 2 spells of weak SICZ developed during Apr -May. Associated anomalies moved northward and reached up to 20° N lat. by the end of May .	1996 (4%)
	SICZ was weak. Alternate spells of active and weak SICZ developed during Jan -May. Associated anomalies moved northward and reached up to 20° N lat by the end of May.	1998 (4%)
	Reduction in cloud amounts. Development of spells of active and weak SICZ. 2 MCZ developed during Apr - May, moved northward and reached up to 20° N lat. by May end.	2006 (-1 %)
	SICZ was active during Feb and generally weak during Jan and Mar -May. 2 spells of active SICZ developed close to equator during Apr-May and reached up to 20° N lat.	2008 (-2 %)
8	SICZ was active during Jan -Feb. Spells of active and weak SICZ developed during Mar -May. Active spell during May moved northward and reached up to 20° N lat..	1977 (1 %)
	Development of alternate spells of active and weak SICZ during Jan-May. Associated anomalies moved towards north and south of equator during Jan-Apr and towards north only in May.	1989 (1 %)
9	SICZ was active during Jan -Feb. Alternate spells of weak and active SICZ developed during Mar -May. Both spells moved northward and reached up to 20° N lat. by May end.	1997 (2%)
	SICZ was weak during Jan -Mar. Alternate spells of active and weak SICZ developed during Apr -May. Anomalies associated with active and weak spells moved towards north of equator. During Apr –end and May they reached up to 20° N lat..	1976 (0 %)
	Development of alternate spells of active and weak SICZ during Jan-May. Anomalies associated with them moved towards north and south of equator till Apr. May anomalies moved towards north only.	1993 (0 %)
10	Development of alternate spells of active and weak SICZ during Jan-May. During April -May anomalies became weak, moved northwards and reached up to 10° N lat. only.	1995 (1%)
	SICZ was active during Jan-Feb. Alternate spells of active and weak SICZ developed during Mar-May. Mar-Apr spell of active SICZ was very prominent and lasted for 6 weeks, in continuation. It was confined to areas south of lat. 5° N. PCAs associated with May spell of active SICZ reached up to 15°N lat..	1981 (0 %)

Contd...

13	SICZ remained active during Jan -Mar. 2 alternate spells of active and weak SICZ developed during the Mar - May, moved northward and reached up to 20° N lat. by the end of May.	1985 (-8 %)
	SICZ remained active during Jan -Mar. A spell each of active and weak SICZ developed during Apr. Both anomalies moved towards north and south of equator. SICZ became active in May for 4 weeks, in continuation.	1991 (-9 %)
	SICZ remained active during Jan -Mar. Alternate spells of active and weak SICZ develop ed during Apr -May, associated anomalies moved towards north as well as south of equator and reached up to 20°N/ 20°S lat. respectively by the end of May.	2001 (-9%)
14	Reduction in cloud amounts. SICZ was active during Jan-Apr. MCZ associated with the last spell of active SICZ moved northward and reached up to 20° N lat. by May end.	2004 (-14%)
15	SICZ remained active during Jan -Apr. A spell of active SICZ developed in May close to equator and moved up to 15° N lat. by the end of the month.	1974 (-15%)
16	SICZ remained active during Jan -Mar. Alternate spells of active and weak SICZ, lasting for 3 -4 weeks in continuation, developed during Mar -May and moved towards north as well as towards south of equator. May spell of active SICZ remained confined to areas between 10° S- 10° N only.	1982 (-15%)
	SICZ remained active for 4 week, in continuation, in Jan, Mar and during Apr - May. The PCAs associated with the spell during Apr -May was followed by a weak spell for 3 weeks, in continuation, till the last week of May. While PCAs associated with active spell moved towards north as well as towards south of equator, the NCAs associated with weak spell remained confined to the areas between 10°N-10° S only.	2002 (-19 %)
	SICZ remained active during Jan -Mar. An equatorial trough developed between equator and 5°N for 6 weeks in continuation (1st week of April - 2nd week of May). It intensified during the last 3 weeks when cloudiness also increased south of equator up to 10°S lat.. The MCZ moved during the last week and reached 20°N/20°S respectively. Movement towards north was rather fast (15° lat in 7 days against average speed of 1° lat/day).	1979 (-21%)
17	SICZ remained active during Jan -May. There was slight weakening in April when a weak equatorial trough developed to the north of equator. An active SICZ developed for 4 weeks in continuation in May.	1987 (-19%)
	SICZ remained active from middle of Jan to Apr (in a more southerly latitudes (10°S -20°S during Apr -May). It became active again during the 2nd half of May. 2 spells of PCAs and NCAs developed during Apr -May. PCAs originated in active SICZ , lasted for 2 weeks only and reached up to 15° N lat.. In contrast, NCAs were more marked, lasted for 4 weeks in continuation and moved from equator to 20° N lat..	2009 (-23%)
18	Cloud data were not available during Jan -Mar. SICZ developed at an interval of 7 weeks during Apr -May. Positive anomalies associated with Maximum Cloud Zone (MCZ) moved northward and reached up to 20° N lat..	1972 (-26%)

Note: Cloud data pertaining to SAI =1, 2, 11, 12, 19 and 20 were not available.

Table 2a. Same as Table 2 but for the years with large differences between realized and forecast rainfall

SAI	Main cloud features	Year (ISMR)
5	Spell of active SICZ developed in Jan, Feb and Mar. A prominent active spell developed during Apr-May to the north of equator and reached up to 20°N lat. by the end of May.	1999 (-4%)
	Development of spells of active and weak SICZ during Jan -May. May spel l lasted for 2 weeks, started moving northward and its MCZ reached up to 20° N lat. by the end of May.	2010 (2%)
13	SICZ remained active during Jan -Feb. Spells of active and weak SICZ developed during Mar-May. Last spell of SICZ remained active for 4 weeks in continuation in May.	2005 (-1 %)
14	SICZ remained active during Jan -first half of May. In addition 2 spells of active and weak SICZ developed during Apr-May. Their anomalies reached up to 20° N lat.	1984 *(-4 %)*
	SICZ remained generally activ e during Jan -May. In addition, an equatorial trough developed to the north of equator during the first week of May, moved northwards up to 10° N lat. during the next 2 weeks and weakened.	1992 (-8 %)
	SICZ remained active from the middle of Jan till the last but one week of May. PCAs associated with active SICZ started moving northward during the second half of May and reached up to 15° N lat. by the end of May.	2000 (-8%)
16	SICZ remained active during Jan -Mar with increased cloud amounts. SICZ again developed for 3 weeks, in continuation, beginning from the 3rd week of Apr.	*1986 (-13%)*

CORRELATION BETWEEN SAI AND RAINFALL

ISMR and SAI values for the period of 25 years (1972-199 except 1978) have been used to compute CCs and to develop linear regression equation between SAI and rainfall. The CCs between best fit set of SAI values (Table 2) and ISMR during the model development period as mentioned above and linear regression coefficients are given in Table 3. Table 3 also includes the CCs and regression constants for monthly and bi-monthly periods during the season for India as a whole. The CCs are significant at 99% level (.50) for monthly and bimonthly rainfall. CC is high (e ≥ .9) between SAI and ISMR. This satisfies one of the requirements of the model, i.e., the value of SAI assigned to cloud features with respect to ISMR should be high so that the same value could be used for developing regression constants in meteorological sub-divisions of India (36) also (to be discussed in Pt III).

VERIFICATION OF FORECASTS

The Standard Deviation (S.D.) criteria has been used to verify the results. The values of S.D. of % departure of monthly, bimonthly and seasonal rainfall for India as a whole for the period under study (38 years) are given in Table 3. The values of S.D. pertaining to a much longer period of rainfall data [110 year: 1901-2010] have also been included in Table 3. A comparison of both values shows that S.D. pertaining to the period of study are comparable to those belonging to a longer period of data except for the months of June and July. For the purpose of verification, both realized and forecast rainfall have been grouped into 3 categories, namely, 'Excess'- rainfall more than 1 S.D., 'Normal' - rainfall within (+/-) 1 S.D. and 'Deficient'- rainfall less than -1 S.D.. Realized as well as forecast rainfall has been further grouped into two broad categories, i.e., 'Excess/ Normal' and 'Deficient/Scanty'. The expected error in assigning SAI is ±2. Accordingly, the error in forecast rainfall for individual months and bi-monthly periods becomes twice the value of regression constant 'a' (Table 3). The error varies from one month to another and so also from one bi-monthly period to another. The average error for ISMR comes out to be about ±5 %. A forecast is considered 'Useful' if both the realized as well as forecast rainfall categories are the same or they become same after taking into account the Model Error (M.E.).

Realized (R) and Forecast (F) rainfall for the period of model development (1972-1997 except 1978) are shown in Table 4. Both R and F have been put in italics and underlined if the forecast did not satisfy the 'Useful' criteria. The forecast in respect of ISMR satisfies the 'Useful' criteria in all the years. This shows that the best fit values of SAI have satisfied one of the basic requirements of the model that they should give a reasonably good forecast of ISMR. It also confirms the improvement in the method of assigning SAI which has used mean cloudiness and mean cloud anomalies data for assigning SAI. Percentage of 'Useful' forecast ranges from 88% for the month of June to 100% in the months of July and September. It is 92% in August. The monsoon sets in over various regions

Table 3. Standard Deviations of rainfall, Correlation coefficients between SAI and rainfall and regression constants relating SAI and rainfall

Month/Period	Standard Deviation of % departure of rainfall		Correlation Coefficients and linear regression coefficients		
			CC	a	b
	Period: 110 yrs [1901-2010]	Period: 38 yrs [1972-2010 except 1978]	Period:25 years [1972-1997 except 1978]		
June	21.8	17.1	-.55	-2.2	122.3
July	15.2	13.4	-.80	-2.5	121.6
August	15.0	14.8	-.66	-2.3	125.7
September	23.3	21.6	-.68	-3.4	129.3
Jun+July	12.1	13.5	-.74	-2.3	122.0
July+August	11.6	11.6	-.89	-2.4	123.7
August+September	14.7	15.1	-.81	-2.8	127.5
June-September	10.5	10.8	-.96	-2.4	122.3

Table 4. Realized and forecast rainfall with their departure categories during 25 years' period of model development [1972-1997,except 1978] for India as a whole

Year	Jun R F	Jul R F	Aug R F	Sep R F	Jun+Jul R F	Jul+Aug R F	Aug+Sep R F	Jun-Sep R F
1972	73D 83N	69D 77D	86N 85N	76D 68D	71D 80D	77D 81D	81D 76D	74D 79D
1973	92 N 109N	97N 107N	128E 112N	111N 109N	95N 108N	112N 109N	119E 110N	104N 108N
1974	74D 90N	96N 85D	95N 92N	78N 78N	85D 97N	95N 88N	86N 85N	85D 86D
1975	105N 114N	106N 112N	121E 117E	132E 116N	105N 113N	114E 114E	127E 116N	112E 113E
1976	90N 103N	99N 99N	128E 105N	82N 99N	95N 101N	114E 102N	105N 102N	100N 101N
1977	114N 105N	113N 102N	99N 108N	87N 102N	114E 103N	106N 105N	93N 105N	100N 103N
1979	85N 88N	84D 82D	82D 89N	72D 75D	84D 85D	83D 86D	77D 82D	79D 84D
1980	138E 107N	101N 104N	102N 110N	81N 105N	119E 106N	101N107 N	91N 108N	100N 105N
1981	96N 101N	107N 97N	91N 103N	104N 95N	101N 99N	99N 100N	98N 99N	104N 98N
1982	83N 92N	77D 87N	109N 94N	68D 82N	80D 89N	93N 90N	88N 88N	86D 88D
1983	93N 111N	96N 109N	124E 114N	144E 112N	94N 110N	110N 112N	134E 113N	112E 110N
1984	113N 92N	92N 87N	96N 94N	85N 82N	103N 89N	94N 90N	90N 88N	92N 88D
1985	94N 94N	94N 90N	95N 96N	87N 85N	94N 92N	95N 93N	91N 91N	90N 91N
1986	111N 88N	86D 82D	87N 89N	69D 75D	98N 85D	87D 86D	78D 82D	86D 84D
1987	78D 85N	71D 80D	96N 87N	75D 71D	75D 83D	84D 83D	86N 79D	82D 81D
1988	107N 116N	127E 114E	115N 119E	125E 119N	117E 115E	121E 117E	120E 119E	118E 115E
1989	119E 105N	105N 102N	93N 108N	90N 102N	112N 103N	99N 105N	91N 105N	101N 103N
1990	112N 107N	96N 104N	112N 110N	109N 105N	104N 106N	104N 107N	111N 108N	106N 105N
1991	109N 92N	91N 87N	81D 94N	66D 82N	100N 89N	86D 90N	73D 88N	91N 88D
1992	78D 90N	81D 85D	98N 92N	97N 78N	79D 87N	90N 88N	98N 85N	92N 86D
1993	104N 103N	96N 99N	75D 105N	137E 99N	100N 101N	85D 102N	106N 102N	100N 101N
1994	129E 109N	121E 107N	113N 112N	83N 109N	125E 108N	117E 109N	98N 110N	110N 108N
1995	76D 101N	104N 97N	100N 103N	106N 95N	90N 99N	102N 100N	103N 99N	100N 98N
1996	115N 107N	93N 104N	119E 119E	88N 105N	104N 106N	106N 107N	104N 108N	103N 105N
1997	106N 103N	98N 99N	109N 105N	94N 99N	102N 101N	104N 102N	102N 102N	102N 101N
% of 'Useful' Forecast	88	100	92	100	96	96	96	100

of India during the month of June and its progress is not continuous every year. This is also reflected in S.D. of rainfall for the month of June and the forecast rainfall. It is interesting that the figures are highest (100%) for the month of July as well as the bi-monthly period of June+ July. These two months happen to be important from the point of view of performance of the monsoon and its forecast. A good forecast of monsoon rainfall during these two months is of great practical utility.

Monthly performance of the model during the model verification period is given in Table 5. Percentage of 'Useful' forecast ranges from 77% in August to 100% in June and 85% in July and September. Performance of the model in the month of August is not as good as in other months. This has resulted due to large differences between forecast and realized rainfall in the years 1999, 2001, and 2005. There were large intra-seasonal changes in monsoon circulation from its first half (June-July) to the second half (August-September) during these years. These changes started in the month of August. As a result the

Table 5. Same as Table 4 but for 13 years' period of forecast verification [1998-2010]

Year	Jun R F	Jul R F	Aug R F	Sep R F	Jun+Jul R F	Jul+Aug R F	Aug+Sep R F	Jun-Sep R F
1998	96N 107N	98N 104N	101N 110N	127E 105N	97N 106N	99N 107N	114N 108N	106N 105N
1999	105N 111N	91N 109N	*84D 114N*	111N 112N	98N 110N	88N 112N	98N 113N	96N 110N
2000	115N 92N	92N 87N	87N 94N	78N 82N	104N 89N	90N 90N	83D 88N	92N 88D
2001	136E 94N	95N 90N	*81D 96N*	*64D 85N*	116N 92N	88N 93N	*72D 91N*	91N 91N
2002	109N 88N	46D 82D	98N 89N	87N 75D	78D 85D	72D 86D	93N 82D	81D 84D
2003	110N 109N	107N 107N	96N 112N	99N 109N	108N 10N	101N 109N	97N 110N	105N 108N
2004	99N 92N	80D 87N	96N 94N	70D 82N	90N 89N	88N 90N	*83D 88N*	87D 88D
2005	91N 94N	115E 90N	*72D 96N*	120N 85N	103N 9N	93N 93N	96N 91N	99N 91N
2006	87N 107N	98N 104N	107N 110N	102N 105N	93N 106N	103N 107N	105N 108N	99N 105N
2007	119E 109N	98N 107N	98N 112N	118N 109N	108N 108N	98N 109N	108N 110N	105N 108N
2008	124E 107N	*84D 104N*	101N 110N	95N 105N	104N 106N	92N 107N	98N 108N	98N 105N
2009	53D 85N	*96N 80D*	74D 87N	*80N 71D*	74D 83D	85D 83D	77D 79D	77D 81D
2010	84N 111N	103N 109N	106N 114N	113N 112N	93N 110N	104N 112N	109N 113N	102N 110N
% of 'Useful' Forecast	100	85	77	85	100	100	92	100

rainfall in August was most affected. It is proposed to discuss these aspects in detail in the concluding part of the study (Part IV).

Performance of the model was quite satisfactory (100%) during the bimonthly periods of June+ July and July+ August. There was slight reduction in the percentage during the bimonthly period of August+ September (92%). Seasonal forecast of rainfall, i.e., forecast of ISMR was again quite satisfactory during the period of verification, as was the case during the period of model development. However, there are 3 years during the forecast verification period when the difference between forecast and realized rainfall were large: 1999- 14%, 2005- 8% and 2010- 8%. Otherwise, the performance of the model is very similar to that during the period of model development. As mentioned above, large differences between realized and forecast rainfall occurred due to large intra-seasonal changes in summer monsoon circulation system. The intra-seasonal changes during southwest monsoon-2010 in relation to rainfall forecast based on SICZ model have been examined by Prasad and Singh (2011). It is proposed to discuss the intra-seasonal changes which affected the performance of southwest monsoon in other years also, in the concluding part of the study.

CONCLUSIONS

The use of mean cloudiness and mean cloud anomalies pertaining to different categories of southwest monsoon have proved helpful in assigning South Indian Convergence Zone Activity Index. The verification results have shown that the forecasts of ISMR and rainfall during individual months as well as bi-monthly periods of the season, i.e., June+ July, July+ August and August+ September, for India as a whole are reasonably good. The study has demonstrated that assigning South Indian Convergence Zone Activity Index, the most important aspect of this new approach to seasonal forecasting, is expected to become simpler in future, when satellite observed cloud data become available for some more years.

ACKNOWLEDGEMENTS

The authors express their sincere thanks to Dr. Ajit Tyagi, Director General of Meteorology for his keen interest in the development of models for seasonal forecasting of rainfall in India. Data used in the study are also gratefully acknowledged. One of the authors (OP) would also like to record his sincere gratitude to his Ph.D. supervisor, Prof. P. N. Belov and his colleagues at the Department of Meteorology and Climatology, Moscow State University, Moscow (Russia).

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