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Role of Indian ocean temperatures on droughts over Andhra Pradesh

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सार – छोटे अनुपात के क्षेत्रों के लिए सूखे का विश्लेषण करना, अनेक उपयोगकर्ताओं, खास तौर पर योजनाकारों के लिए आवश्यक होता है। इस शोध पत्र में 1950 - 2000 की अवधि में आंध्र प्रदेश में सूखे से प्रभावित क्षेत्रों और अलग-अलग महीनों में बंगाल की खाड़ी में समुद्र सतह तापमान (एस एस टी) की विसंगतियों के बीच पाए गए सहसंबंध पर विचार करते हुए आंध्र प्रदेश राज्य में सूखे पर हिंद महासागरीय तापमानों के प्रभाव का विवेचन करने का प्रयास किया गया है। विभिन्न ग्रिडों पर बंगाल की खाड़ी में समुद्र सतह तापमानों पर नज़र रखते हुए आंध्र प्रदेश में सूखे की पूर्व चेतावनी देने में यह अध्ययन अत्यंत उपयोगी सिद्ध होगा और यह योजनाकारों के लिए लाभकारी होगा।

ABSTRACT. Analysis of drought over a smaller scale region is requirement of many users, mainly planners. In the present study an attempt has been made to see the impact of Indian Ocean temperatures on the droughts over Andhra Pradesh state by considering correlation between sea surface temperature (SST) anomalies over Bay of Bengal during different months and area affected by drought over Andhra Pradesh state during the period 1950 - 2000. The study would be useful in the early warning of drought over Andhra Pradesh by monitoring of sea surface temperatures over Bay of Bengal in different grids and would be beneficial for planners.

Key words – Drought, SST over Bay of Bengal, Andhra Pradesh.

1. Introduction

A study of sea surface temperature and other parameters over Indian Ocean region in some years of contrasting southwest monsoon rainfall in India was made by Singh (1983). Joseph and Pillai (1984) examined inter annual variation of sea surface temperature and Indian monsoon rainfall. Rao and Goswami (1988) have worked on Inter annual variation of SST over the Arabian Sea and Indian Ocean. Study of initial state of North Indian Ocean and subsequent summer monsoon was made by Singh (1996, 1999). Soman and Slingo (1997) have studied on sensitivity of Asia Summer monsoon to aspects of sea surface temperatures in tropical Pacific and Indian Oceans. Clarke *et al*. (2000) have worked on Indian Ocean SST and Indian summer rainfall for predictive relationships and decadal variability. Bachiochi *et al*. (2001) studied the effect of Indian Ocean warming on the Indian monsoon. Rajeevan (2001) examined interaction among deep convection, sea surface temperature and radiation in the Asian monsoon region where as Rajeevan *et al*. (2002) studied predictive relationships between Indian Ocean sea surface temperatures and the Indian summer monsoon rainfall. Variability of the Indian Ocean in relation to monsoon and ENSO was studied by Krishnamurthy and Kirtman (2003). Pai (2003) worked on inter annual variation in the sea surface temperature threshold for the deep convection over north Indian Ocean. Wu and Kirtman (2004) studied impacts of the Indian Ocean on the Indian summer monsoon and ENSO relationship. Khole and De (2004) have examined the association between the monsoon onset over Kerala (MOK) and Sea Surface Temperature (SST) over north Indian Ocean. South west Indian Ocean SST variability, its local effect and remote influence on Asian monsoon has been studied by Annamalai *et al*. (2005). The results indicated that Indian Ocean SST anomalies during December through May that develop in response to both atmospheric and oceanic processes, El-Nino need to be considered for a complete understanding of regional climate variability, particularly around the Indian Ocean.

Earlier studies cited above were for whole of India. Some of the studies on drought, dry and wet spells etc. are made on regional scale. In IMD publication "Climate of Andhra Pradesh" (1973), various meteorological parameters and other derived parameters including drought have been studied. Study of dry and wet spells over Meteorological sub-divisions of India were studied by Gore (2000), droughts over Andhra Pradesh were studied by Gore (2002). However impact of SST on droughts over Andhra Pradesh are not studied on regional scale. In the present paper we intend to study the regional droughts over Andhra Pradesh in association with SST over Bay of Bengal for the period 1950-2000.

TABLE 1

Districts, area, mean, standard deviation and coefficient of variation of summer monsoon rainfall (Period : 1950-2000) for Andhra Pradesh

S. No.	Districts	Abbreviations of the districts	Area in 000' sq km	Mean rainfall (mm)	Standard deviation (mm)	Coefficient of variation (C.V. %)
1.	Adilabad	ADL	16.1	940.7	249.7	27
2.	Ananthapur	ANT	19.1	307.6	101.0	33
3.	Chittoor	CHT	15.2	397.7	113.1	28
4.	Cudappah	CDP	15.4	393.9	110.1	27
5.	East Godavari	EGD	10.8	729.7	177.7	24
6.	Guntur	GNT	11.4	559.5	150.9	27
7.	Hyderabad	HYD	0.2	624.8	168.0	27
8.	Karimnagar	KRM	11.8	792.8	211.2	27
9.	Khammam	KMM	16.0	856.0	197.4	24
10.	Krishna	KSN	8.7	685.7	196.1	29
11.	Kurnool	KRN	17.7	454.2	122.3	27
12.	Mahaboobnagar	MBN	18.4	549.7	159.4	29
13.	Medak	MDK	9.7	754.2	215.1	29
14.	Nalgonda	NLG	14.2	529.3	131.0	25
15.	Nellore	NLR	13.1	329.0	104.7	32
16.	Prakasam	PKS	17.6	375.6	119.2	32
17.	Nizamabad	NZB	8.0	918.9	278.7	30
18.	Ranga Reddy	RGR	7.5	660.6	177.3	27
19.	Srikakulam	SKK	5.8	748.6	139.8	19
20.	Visakhapatnam	VSK	11.2	667.7	134.9	20
21.	Vizianagaram	VZG	6.5	709.0	119.8	17
22.	Warangal	WRG	12.9	840.6	205.7	24
23.	West Godavari	WGD	7.7	753.6	188.4	25
	Average		**11.9**	**633.9**	**164.0**	**26**

2. Data and methodology

Monthly sea surface temperatures (at grid points 2.5° × 2.5°) over Bay of Bengal from 1950 to 2000 have been collected from NCRP / NCAR, USA. Daily rainfall data for Andhra Pradesh state for 348 stations of 21 districts for the period 1950 to 2000 was collected from National Data Centre.

2.1. *Criteria for meteorological drought*

As per India Meteorological Department a meteorological drought over an area is defined as a situation when rainfall over that area is less than 75% of the climate normal. Ramdas (1950) suggested to define monsoon drought based on deficient rainfall by 25% or more of normal during the monsoon season. Koteswaram (1976) applied the same method. A very simple method is followed by several investigators to classify the performance of monsoon rains based on the departure of seasonal rainfall from its mean in comparison to the standard deviation (Sikka (1999). The monsoon is considered to have failed if the deficiency of rainfall is equal to or above 1.0. This definition could also be used on all India basis, a homogeneous region of India basis and a sub-divisional basis or on a district/block/station basis provided an appropriate standard deviation for each area is used.

TABLE 2

Districts affected by drought over Andhra Pradesh

Year	Districts and area affected by drought (000 sq km)	Total area affected (000 sq km)
1950	ADL CDP SKK	37.3
	16.1 15.4 5.8	
1951	CHT CDP	30.6
	15.2 15.4	
1952	ADL ANT CHT CDP EGD GNT HYD KRM KMM KSN KRN MBN NLG NZB PKS RGR VSK WGD	227.0
	16.1 19.1 15.2 15.4 10.8 11.4 0.2 11.8 16.0 8.7 17.7 18.4 14.2 8.0 17.6 7.5 11.2 7.7	
1953		
1954	No drought	
1955		
1956		
1957	CHT	15.2
	15.2	
1958		
1959	No drought	
1960		
1961	ANT	19.1
	19.1	
1962	No drought	
1963	PKS SKK	23.4
	17.6 5.8	
1964		
1965	No drought	
1966		
1967		
1968	ADL CHT CDP EGD GNT KRM KMM KSN MDK NZB PKS RGR NSK WRG WGD	188.7
	16.1 15.2 15.4 10.8 11.4 11.8 16.0 8.7 18.4 8.0 17.6 7.5 11.2 12.9 7.7	
1969	EGD	10.8
	10.8	
1970	No drought	
1971	ADL CDP HYD KRM KMM KSN KRN MBN MDK NLR NZB RGR WRG	155.8
	16.1 15.4 0.2 11.8 16.0 8.7 17.7 18.7 9.7 13.1 8.0 7.5 12.9	
1972	ADL ANT GNT HYD KMM KSN KRN MBN MDK NLG NLR NZB PKS RGR WRG WGD	198.3
	16.1 19.1 11.4 0.2 16.0 8.7 17.7 18.4 9.7 14.2 13.1 8.0 17.6 7.5 12.9 7.7	
1973	VSK	11.2
	11.2	
1974	ADL KRM NLG SKK WRG	60.8
	16.1 11.8 14.2 5.8 12.9	
1975	No drought	
1976	VSK	11.2
	11.2	

TABLE 2 (*Contd.*)

Year	Districts and area affected by drought (000 sq km)	Total area affected (000 sq km)
1977	HYD KMM NLR PKS RGR WRG WGD	75.0
	0.2 16.0 13.1 17.6 7.5 12.9 7.7	
1978	No drought	
1979	EGD GNT KMM KSN WRG WGD	67.5
	10.8 11.4 16.0 8.7 12.9 7.7	
1980	CHT CDP	30.6
	15.2 15.4	
1981	No drought	
1982	CDP	15.4
	15.4	
1983	No drought	
1984	ADL ANT EGD KMM KSN PKS WRG	101.2
	16.1 19.1 10.8 16.0 8.7 17.6 12.9	
1985	ANT CDP HYD KRM KRN MBN NLR WRG	108.6
	19.1 15.4 0.2 11.8 17.7 18.4 13.1 12.9	
1986	CDP KRN MBN NLR	64.6
	15.4 17.7 18.4 13.1	
1987	ADL EGD GNT KSN NLG SKK VSK VZG WGD	92.4
	16.1 10.8 11.4 8.7 14.2 5.8 11.2 6.5 7.7	
1988		
1989	No drought	
1990	ANT NLG	33.3
	19.1 14.2	
1991	No drought	
1992	CHT CDP MBN	49.2
	15.4 15.4 18.4	
1993	GNT KSN WGD	27.8
	11.4 8.7 7.7	
1994	ANT CDP GNT HYD KRN MBN MDK NLG NLR PKS RGR	144.3
	19.1 15.4 11.4 0.2 17.7 18.4 9.7 14.2 13.1 17.6 7.5	
1995	KRM	11.8
	11.8	
1996	No drought	
1997	ADL HYD KRM MBN MDK NZB RGR WRG	84.6
	16.1 0.2 11.8 18.4 9.7 8.0 7.5 12.9	
1998	No drought	
1999	CHT CDP HYD MBN MDK NLR	72.0
	15.2 15.4 0.2 18.4 9.7 13.1	
2000	No drought	

State drought - 1952, 1968, 1971, 1972, 1977, 1984, 1985, 1987, 1994, 1997, 1999
(11 Drought Years from 1950 to 2000)

TABLE 3

Classification of years based on number of districts – affected by drought and area (000 sq. km)

No. of Districts	Classification of years					
> 15	Years	1952	1972			
	No.	18	16			
	Area	227.0	198.3			
10-15	Years	1968	1971	1994		
	No.	15	13	11		
	Area	188.7	155.8	144.3		
5-10	Years	1974	1977	1979	1984	1985
	No.	5	7	6	7	8
	Area	60.8	75.0	67.5	101.2	108.6
	Years	1987	1997	1999		
	No.	9	8	6		
	Area	92.4	84.6	72.0		
1-4	Years	1950	1951	1957	1961	1963
	No.	4	2	1	1	2
	Area	87.3	30.6	15.2	19.1	23.4
	Years	1969	1973	1976	1980	1982
	No.	1	1	1	2	1
	Area	10.8	11.2	11.2	30.6	15.4
	Years	1986	1990	1992	1993	1995
	No.	4	2	3	3	1
	Area	64.6	33.3	49.2	27.8	11.8

TABLE 4

Years with no drought over Andhra Pradesh

1950-1960	1953, 1954, 1955, 1956, 1958, 1959, 1960
1961-1970	1962, 1964,1965, 1966, 1967, 1970
1971-1980	1975, 1978
1981-1990	1981, 1983, 1988, 1989
1991-2000	1991, 1996, 1998, 2000

District wise meteorological droughts satisfying with above two criteria were identified for all districts in Andhra Pradesh for the period 1950-2000. Total area affected for state Andhra Pradesh in each year during the period 1950-2000 has also been computed. The state drought has been identified for 25% or more of the state area is affected by drought.

TABLE 5

Classification of years based on total area of state affected by drought

Years	< 10%	10-25%	26-50%	\>50%
1950-1960	1957	1950, 1951	-	1952
1961-1970	1961, 1963, 1969	-	-	1968
1971-1980	1973, 1976	1974, 1979, 1980	1977,	1971, 1972
1981-1990	1982	1986, 1990	1984, 1985, 1987	-
1991-2000	1995	1992, 1993,	1997, 1999	1994

All India drought year is defined when the rainfall deficiency of the country is more than 10% of the seasonal rainfall and when 20-40% of the country is under drought conditions. When spatial coverage of drought is more than 40% it is called as all India severe drought year. Before 2007 only spatial coverage was considered and after that both rainfall deficiency of the country and spatial coverage are considered for drought studies.

SST anomalies in different months for the period 1950-2000 in 6 different grid boxes over the Bay of Bengal, *viz.*, Southwest grid (5-13° N, 80-86° E), South east grid (5-13° N, 86-93° E), East Central (13-18° N, 87.5-95° E), West Central (13-18° N, 80-87.5° E), North West (18-22° N, 84-90° E), North East (18-22° N, 90-95° E) have been computed. The correlation of SST anomalies over particular grid box of Bay of Bengal and month with area affected by drought over Andhra Pradesh during the period 1950-2000 has been computed. The correlations are computed corresponding to different grids and different months.

3. Results and discussion

Table 1 shows districts, area (sq km), mean rainfall, its standard deviation and Coefficient of Variation (C.V.) during 1950-2000 for Andhra Pradesh state. The rainfall among the districts is highly variable ranging from 307.6 to 940.7 mm. Also C.V is ranging from 17% to 33%. Table 2 depicts various districts along with area affected by drought in each year from 1950-2000. Table 3 shows classification of years based on number of districts affected by drought and area. During years 1952 and 1972, 18 and 16 number of districts respectively were affected by drought. In the years 1968, 1971 and 1994, more than 10 districts were affected by drought. Table 4 shows 23 years with no drought over Andhra Pradesh. Table 5 shows classification of years based on total area

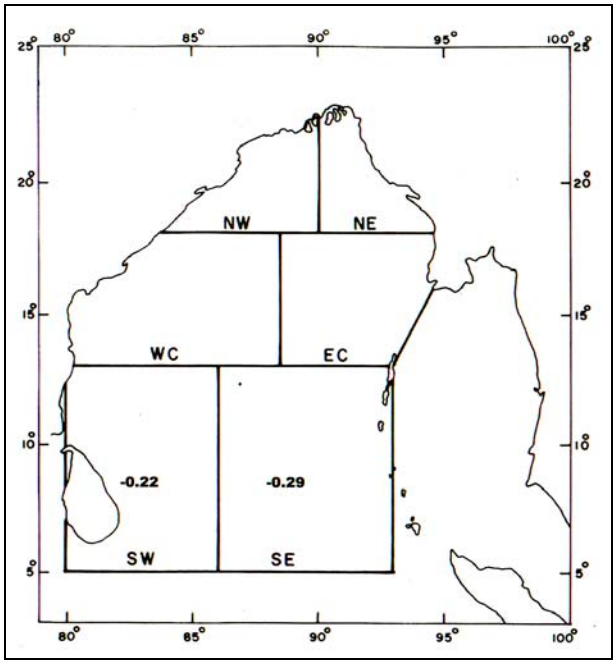

Fig. 1. Significant correlation of SST anomalies over six grids of Bay of Bengal and area affected by drought over Andhra Pradesh during March

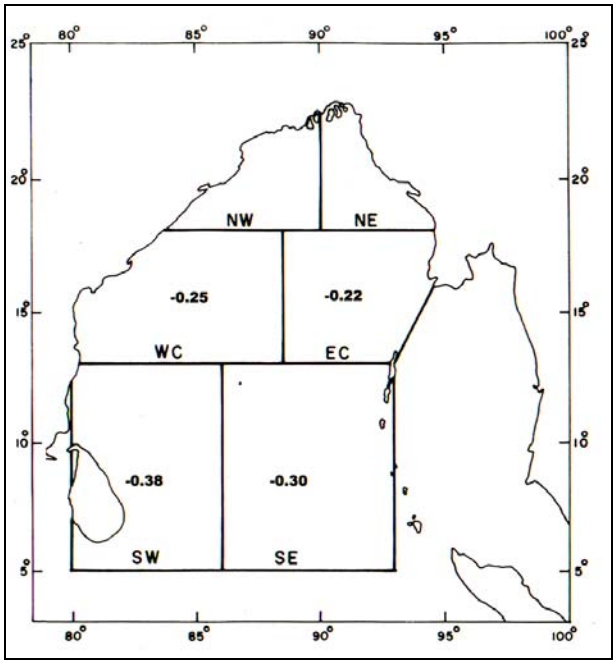

Fig. 2. Significant correlation of SST anomalies over six grids of Bay of Bengal and area affected by drought over Andhra Pradesh during April

of state affected by drought. Area of Andhra Pradesh state is 2,75,069 sq km. The 11 years of state drought identified with above criteria are: 1952, 1968, 1971, 1972, 1977, 1984, 1985, 1987, 1994, 1997 and 1999.

The 5 years 1952, 1968, 1971, 1972 and 1994 were worst state drought years where more than 50% of the state area was affected by drought. The years 1952 and 1972 were the first and second worst drought years when 82% and 72 % area of state was under drought.

The drought core area has been identified by considering those districts affected by drought, when more than 10 districts were under drought in some of the years under consideration. These districts in drought core area are Adilabad, Anantapur, Cudappah (Kadapa), Guntur, Hyderabad, Karimnagar, Khammam, Krishnanagar, Kurnool, Mahaboobnagar, Nalgonda, Nizamabad, Prakasam, Ranga Reddy, West Godavari, Nellore and Medak.

The all India drought years during 1950-2000 are 1951, 1965, 1966, 1968, 1972, 1974, 1979, 1982, 1985, 1987. The 4 common monsoon drought years for Andhra Pradesh state as a whole and India as a whole during 1950-2000 period are 1968, 1972, 1985, 1987.

Table 6 shows correlation matrix of SST anomalies over 6 grids of Bay of Bengal in different months and area affected by drought over Andhra Pradesh. Fig. 1 depicts significant correlation of SST anomalies over southwest and southeast grids of Bay of Bengal and area affected by drought over Andhra Pradesh during March. Fig. 2 depicts significant correlation of SST anomalies over 4 grids, *viz*., west central, east central, southwest and southeast grids respectively during April.

The correlation of SST anomalies over various grids of Bay of Bengal and area affected by drought over the state of Andhra Pradesh shows significant negative correlation in April for southwest, southeast, east central and west central grids. The correlation as above in March shows significant negative correlation for southwest and southeast grids. In south west grid the correlation in April was significant at 0.01 level of significance, (which is 0.3830). In southeast grid for both March and April the correlation of SST and drought over Andhra Pradesh is significant at 0.05 level of significance. In March for southwest grid and in April for east central and west central grids the correlation of SST and drought over Andhra Pradesh is significant at 0.1 level of significance. As such in southwest and southeast grids both March and April correlation coefficients are significant. Therefore, monitoring of SSTs in southeast and southwest grids from

TABLE 6

Correlation of SST anomalies over 6 grid boxes of the Bay of Bengal and area affected by drought over Andhra Pradesh (Underlined values are statistically significant at 0.01 or 0.05 or 0.1 level)

Month	SW	SE	EC	WC	NW	NE
Jan	0.06	0.03	-0.02	-0.03	-0.12	-0.15
Feb	-0.13	-0.09	-0.07	-0.08	0.07	0.05
Mar	-0.22	-0.29	-0.21	-0.16	0.04	0.00
Apr	-0.38	-0.30	-0.22	-0.25	-0.10	-0.15
May	-0.14	-0.18	-0.21	-0.17	-0.03	-0.07
Jun	-0.16	-0.10	-0.04	0.00	0.19	0.07
Jul	-0.01	0.02	0.08	0.00	-0.03	-0.09
Aug	-0.09	-0.09	-0.08	0.00	-0.08	-0.16
Sep	-0.17	-0.13	-0.14	-0.15	-0.01	-0.05
Oct	0.00	-0.07	-0.10	-0.05	-0.08	-0.17
Nov	0.09	0.05	0.04	0.05	-0.04	-0.06
Dec	0.00	0.00	0.00	0.00	0.00	0.00

March to April can be done. In March southeast grid is more important for monitoring of SSTs because of higher correlation coefficient than southwest grid. During April more emphasis can be made in monitoring of SSTs in southwest grid. Also following to it monitoring of SSTs in southeast, east central, west central grids also can be made for supportive inferences. Thus SST data for the Bay of Bengal in March and April can provide useful forewarning for the occurrence of drought over Andhra Pradesh for the monsoon season.

4. Conclusion

(*i*) There are 11 state drought years for Andhra Pradesh, *viz*., 1952, 1968, 1971, 1972, 1977, 1984, 1985, 1987, 1994, 1997 and 1999. The 5 years 1952, 1968, 1971, 1972 and 1994 are worst state drought years.

(*ii*) The common drought years for Andhra Pradesh state as a whole and India as a whole are only four, *viz*., 1968, 1972, 1985 and 1987.

(*iii*) The temperatures in southwest and southeast grids of Bay of Bengal from March to April can provide useful information for early warning of monsoon seasonal drought over Andhra Pradesh.

(*iv*) Southeast grid SST monitoring in Bay of Bengal during March is important as correlation of SST and drought over Andhra Pradesh was significant at 0.05 level of significance.

(*v*) During April, SSTs over southwest grid box of the Bay of Bengal are important indicators of drought over Andhra Pradesh because of highly significant correlation coefficient of SST and drought over Andhra Pradesh at 0.01 level of significance.

(*vi*) Also, the SSTs over southeast, east central and west central grid boxes of Bay of Bengal can be monitored in April, for supportive inferences of drought over Andhra Pradesh following to indication in southwest grid.

(*vii*) No significant correlation of SST and drought over Andhra Pradesh is seen in northwest and northeast grids.

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