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Evolution of ENSO Related Rainfall Anomalies for Lower Tapi River, India

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Abstract

The present study is an attempt to detect anomalies in rainfall for lower Tapi basin due to ENSO events. Daily rainfall data have been used for the present analysis. The data have been collected from state water data centre from 1961 to 2001. With the availability of suitable data 1982, 1986, 1987, 1991, 1997, 2002 and 2009 are the El Nino years and 1988, 1998, 1999, 2007 and 2010 are the La Nina years analysed for the present study. The yearly extreme precipitation indices have been computed for frequency, intensity and duration for the base period 1981 to 2010. For the El Nino years 1997 and 2009 positive anomalies have been observed in the frequency based indices. In the years 1982, 1987, 1991, 1997, 2002 and 2009, positive anomalies have been observed for the intensity based indices. Positive anomalies results into better rainfall during El Nino events. Negative anomalies have been observed in the years 1998 and 1999 of the La Nina events for the frequency based indices and for the years 1988, 1998, 1999, 1007 and 2010 negative anomalies have been observed in the intensity based indices. The analysis of La Nina events results in a decrease in rainfall. The precipitation duration based indices have not indicated clear trend. The overall analysis showed that ENSO is not directly affecting the rainfall of the study region.

Keywords- ENSO; El Nino; La Nina; Extreme climate indices; Anomalies; Lower Tapi basin

1 Introduction

According to International research institute for climate and society, Gilbert Walker found out in the late 1800's, the presence of dry spell in India is associated with movements in El Nino Southern Oscillation (ENSO). Most significant dry seasons are appeared to happen amid El Niño occasions and better than expected precipitation is appearing to happen amid La Nina occasions in India. The climatic change is observed by the El Nino Southern Oscillation phenomenon. Many researchers have studied the association between ENSO anomalies and their impact on climate all through the globe (Andreoli et al., 2005; Arblaster et al., 2012; Donat et al. 2014, Bothale et al., 2015). El Nino event is a warm phase and La Nina event is a cool phase of ENSO. Bothale et al. (2014), study identified that rainfall shows positive anomaly for the period of La Nina events and negative anomaly observed all through the periods of El Nino events in the Upper Wardha watershed of Maharashtra, India. Positive anomaly for the period of La Nina events, results better rainfall while multimodal rainfall observed for El Nino periods in the study region. According to Bothale et al. (2015), El Nino and La Nina impact may vary with respect to the size of the geographical area. The relation among ENSO and yearly climate indices for precipitation were observed prominent. The multimodal nature of precipitation was observed for the El Nino period and heavy rainfall was observed for the La Nina period. The Oceanic Nino Index (ONI) and the precipitation anomalies were prominent during El Nino phase of ENSO. The aim of the present study is to find out the anomalies of yearly extreme climate indices with respect to long term normal years during ENSO events.

2 Study Area

Tapi basin is located in the Northern part of the Deccan plateau. The Tapi basin lies between East longitudes of 72˚ 38′ to 78˚ 17′ and North latitudes of 20˚ 5′ to 22˚ 3′. Its area is about 65,145 km2. The basin is divided into upper, middle and lower sub basins. The Lower Tapi basin is the study area for the present analysis. The annual rainfall of the lower Tapi basins is about 1,042 mm.

3 Data Collection and Methodology

Daily rainfall data were collected from state water data centre (SWDC), Gandhinagar for the period 1961 to 2012 for fifteen rain gauge stations.

In the present analysis nine extreme climate indices on the basis of precipitation suggested by the joint World Meteorological Organization(WMO) Commission for the Climatology(CCI)/World Climate Research Programme (WCRP) project on Climate Variability and Predictability(CLIVAR)/Joint WMO- Intergovernmental Oceanographic Commission (IOC) Technical Commission on Oceanography and Marine Meteorology(JCOMM) Expert Team on Climate Change Detection and Indices(ETCCDI) (Peterson et al. 2001; Alexander et al. 2006) have been analysed. The climate indices for precipitation suggested by ETCCDI are as per table 1. These indices have been calculated first and then attempt has been made to find out anomalies with respect to the base period. The Extreme climate indices are classified in three groups viz precipitation frequency based indices (TOTPRCP, RR10 and RR20), precipitation intensity based indices (RX1 day, RX5 day, SDII and R95T) and precipitation duration based indices (CDD and CWD)(Donate et al., 2014). The El Nino and La Nina periods identified based on a threshold of +/(-) 0.5˚ C for the Oceanic Nino Index(ONI). It is the average of running 3- month SST anomaly for the Nino 3.4 region. This region lies between 0.5˚ N - 0.5˚ S, 120˚–170˚W. When five consecutive overlapping 3-month SST is at or above the 0.5˚ anomaly it is identified as El Nino event. When five consecutive overlapping 3- month SST is at or below the 0.5˚ anomaly the event is identified as La Nina. The threshold is further broken down and moderate (1.0 to 1.4), strong (1.5 to 1.9) and very strong (≥ 2.0) SST anomaly events are selected for the present study. Accordingly for the study period 1982, 1986, 1987, 1991, 1997, 2002 and 2009 are the El Nino years while 1988, 1998, 1999, 2007 and 2010 are the La Nina years for the present study region. Anomalies in the yearly extreme indices are found for the year 1981 – 2010, which is considered as a base period for the present analysis.

4 Analysis and Result

4.1 Frequency Based Precipitation Indices

Anomalies for the yearly extreme climate indices of rainfall for the identified ENSO years have been computed. Anomalies for frequency based indices are as shown in table 2. It is observed from the analysis that almost all the rain gauge stations show positive anomalies for frequency based indices for some years of El Nino events. The negative anomalies have been observed for some years of La Nina events in the present study almost for all the thirteen rain gauge stations. Positive anomalies results an increase in rainfall both in frequency and intensity for the El Nino occasions. Whereas negative anomalies results, decrease in rainfall for the La Nina occasions.

For the El Nino year 1997 positive anomalies have been observed for PRCPTOT for 4 rain gauge stations. While positive anomalies for RR10 have been observed for 6 rain gauge stations and positive anomalies for RR20 have been observed for 5 rain gauge stations. Similarly for the El Nino year 2009 positive anomalies have been observed for PRCPTOT for 7 rain gauge stations, positive anomalies for RR10 have been observed for 6 rain gauge stations and positive anomalies for RR20 have been observed for 11 rain gauge stations. For the La Nina year 1998 negative anomalies have been observed for PRCPTOT for 8 rain gauge stations. Whereas negative anomalies for RR10 have been observed for 4 rain gauge stations and negative anomalies for RR20 have been observed for 6 rain gauge stations. Likewise, for the La Nina year 1999 negative anomalies have been observed for PRCPTOT and RR10 for all the 13 rain gauge stations. While negative anomalies for RR20 has been observed for 12 rain gauge stations. La Nina years 2007 and 2010 also show negative anomalies.

4.2 Intensity Based Precipitation Indices

Anomalies for intensity based indices are as shown in table 3. It is observed from the analysis that almost all the rain gauge stations show positive anomalies for intensity based indices for some years of El Nino events. The negative anomalies have been observed for some years of La Nina events in the present study almost for all the thirteen rain gauge stations.

As per Table 3 the El Nino year 2009 shows positive anomalies for Rx1 for 3 rain gauge stations and positive anomalies for Rx5 have been observed for 7 rain gauge stations. Whereas positive anomalies for SDII have been observed for 9 rain gauge stations and positive anomalies for R95T have been observed for 2 rain gauge stations. Similarly for the El Nino year 1982 positive anomalies have been observed for Rx1 for 6 rain gauge stations and positive anomalies for Rx5 have been observed for 2 rain gauge stations. For the El Nino year 2002 positive anomalies for SDII have been observed for 4 rain gauge stations. The El Nino events 1987, 1997 and 1991 also show positive anomalies for the yearly indices. The La Nina year 1999 show negative anomalies for Rx1 for 11 rain gauge stations and negative anomalies for Rx5 have been observed for 13 rain gauge stations. Whereas negative anomalies for SDII have been observed for 12 rain gauge stations and negative anomalies for R95T have been observed for 12 rain gauge stations. Similarly for the La Nina year 2010 negative anomalies have been observed for Rx1 for 11 rain gauge stations, negative anomalies for Rx5 have been observed for 13 rain gauge stations. While negative anomalies for SDII have been observed for 8 rain gauge stations and negative anomalies for R95T have been observed for 7 rain gauge stations. The La Nina year 1998 show negative anomalies for Rx1 for 6 rain gauge stations and negative anomalies for Rx5 have been observed for 8 rain gauge stations. Whereas negative anomalies for SDII have been observed for 8 rain gauge stations and negative anomalies for R95T have been observed for 6 rain gauge stations. The La Nina year 2007 show negative anomalies for Rx1 for 8 rain gauge stations and negative anomalies for Rx5 have been observed for 2 rain gauge stations. While negative anomalies for SDII have been observed for 4 rain gauge stations and negative anomalies for R95T have been observed for 7 rain gauge stations. The La Nina year 1988 also shows negative anomalies.

4.3 Duration Based Precipitation Indices

Anomalies for precipitation duration based indices are not showing a clear trend of ENSO events. Figure 1, 2 and 3 depict anomalies for the Surat rain gauge station.

Rain gauge station	Year	Anomalies (%)			Rain gauge station	Year	Anomalies (%)		
		PRCPT OT	*RR10*	*RR20*			*PRCPT OT*	*RR10*	*RR20*
Bodhana	1997	+40.58	+54	+46.76	Songadh	1991	-	+12.40	-
	1998	***-7.13***	-	-		2002	+13.32	-	-
	1999	-81.22	-49.50	-139.58		1998	-34	-1.80	-30.18
Chalthan	2009	+47.58	+22.07	+40.32		1999	-108.46	-21.51	-76.67
	1999	-16.13	-10.90	-2.78		2007	-14.46	-14.14	-12.42
Kadod	2009	-	-	+18.61		2010	-15.63	-	-
	1999	-61.81	-23.60	-22.08	Surat	1982	-	-	+7.59
	2007	-13.15	-	-		1997	-	+5.48	-
	2010	-30.43	-	-		2009	+12.07	-	+2.16
Kakrapar	2009	-	+3.76	+20.29		1998	-10.23	-5.87	-18.81
	1998	-55.33	-42.56	-83.33		1999	-34.70	-15	-27.95
	1999	-39.83	-35.61	-41	Ukai	1997	+5.53	-	+4.67
	2010	-18.53	-	-		2009	+10	+17	+26.67
Kamrej	2009	+29.97	+17.96	+36.44		1999	-18.67	-1.72	-
	1998	-17.77	-1.84	-5.93	Uteva	1997	-	+17.30	+12.73
	1999	-40.81	-32.24	-46.67		2009	-	-	+23.20
Kholvad	2009	+30.48	+15.05	+41.28		1998	-2.68	-	-28
	1998	-3.50	-	-		1999	-52.59	-45.71	-47.69
	1999	-49.67	-46.30	-69.63		2007	-	-	-1.05
Mandvi	1997	-	+9.81	-	Valthan	1997	+45.85	+56.27	+52.31
	2009	-	+12.25	+11.16		2009	+5.09	-	+19.13
	1999	-3.99	-11.95	-2.17		1998	-10	-	-
	2007		-1.46	-		1999	-60.66	-62.78	-24
	2010	-9.91	-	-					
Orna	1997	+8	+23.70	+9.82					
	2009	+14.58	-	+22.12					
	1999	-63.47	-83.11	-114.17					

[a] Note: Numbers with red colour (bold) indicate El Nino events and numbers with blue colour (bold and Italic) indicate La Nina events.

Table 2: Anomalies for frequency based precipitation indices

Rain Gauge station	Year	Intensity based indices				Rain Gauge station	Year	Intensity based indices			
		Rx1 day	Rx5d ay	SDII	R95T			Rx1 day	Rx5d ay	SDII	R95T
Bodhana	1997	13.2	-	-	-	Songadh	2002	9.7	17.3	19.8	20.4
	2002	-	-	30.0	-		1998	-	-10.7	-51.5	-20.7
	1998	-	-6.6	-12.0	-		1999	-192	-85.0	-65.2	-239.4
	1999	-20.2	-15.8	-78.3	-		2007	-17.1	-	-7.5	-11.8
	2010	-68.3	-43.7	-10.2	-7.9		2010	-97.4	-64.7	-17.1	-77.1
Chalthan	2009	37.0	46.0	59.9	-	Surat	1982	4.3	-	-	-
	1988	-	-	4.5	-		1991	5.9	-	-	-
	1999	-	-2.8	-5.3	-2.8		2009	31.8	9.0	23.2	10.8
	2007	-50.0	-	-	-38.7		1998	-	-	-11.6	-

Rain Gauge station	Year	Intensity based indices				Rain Gauge station	Year	Intensity based indices			
		Rx1 day	Rx5d ay	SDII	R95T			Rx1 day	Rx5d ay	SDII	R95T
	2010	-39.8	-5.0	-	-		1999	-	-	-	-62.5
Kadod	1999	-19.2	-14.2	-61.8	-8.0		2007	-6.9	-16.3	-	-2.2
	2007	-8.4	-17.7	-13.2	-		2010	-21.4	-42.2	-	-21.2
	2010	-80.6	-44.1	-30.4	-	Ukai	1982	39.2	7.4	-	-
Kakrapar	1982	25.4	-	-	-		1987	11.8	-	-	-
	2009	-	-	7.3	-		1997	-	-	-	13.4
	1998	-44.9	-6.4	-15.3	-73.6		2009	-	8.3	17.8	-
	1999	-29.0	-45.2	-30.3	-62.8		1988	-	-4.1	-	-
	2007	-41.6	-	-	-9.0		1999	-7.6	-54.2	-17.7	-23.5
	2010	-36.7	-50.1	-29.2	-32.1		2010	-37.1	-98.0	-	-11.8
Kamrej	2009	-	26.2	44.7	-	Uteva	1986	18.0	24.8	20.7	-
	1998	-	-19.0	-28.5	-21.4		1997	-	-	-	10.6
	1999	-6.8	-21.9	-58.9	-		2009	-	-	19.9	-
	2010	-	-9.3	-15.1	-		1998	-	-	-3.7	-
Kholvad	2002	-	-	20.3	-		1999	-9.6	-20.6	-19.9	-75.7
	2009	-	20.0	41.6	5.6		2007	-39.2	-	-20.9	-27.0
	1998	-6.0	-15.9	-25.2	-12.6		2010	-33.4	-44.7	-37.2	-
	1999	-15.3	-14.8	-41.2	-9.3	Valthan	1982	39.1	14.9	-	24.2
	2010	-6.9	-7.6	-	-		2009	-	11.4	32.0	-
Mandvi	1982	23.7	-	-	-		1998	-17.4	-10.1	-14.1	-
	1999	-	-22.0	-	-9.0		1999	-20.0	-15.2	-15.1	-93.2
	2007	-14.7	-	-	-11.1		2007	-42.1	-18.9	-	-26.6
	2010	-45.9	-54.7	-	-61.0						
Orna	1982	12.8	-	-	-						
	2002	-	-	11.4	-						
	2009	12.8	5.8	35.2	-						
	1998	-	-32.9	-8.8	-9.0						
	1999	-	-	-24.0	-27.0						
	2007	-111.9	-56.0	-	-79.9						

[b] Note: Numbers with red colour(bold) indicate El Nino events and numbers with blue colour(bold and italic) indicate La Nina events.

Table 3: Anomalies for intensity based precipitation indices

5 Conclusion

From the present study, following findings can be summarized:

1. For the base period, El Nino years are 1982, 1986, 1987, 1991, 1997, 2002, 2009 and La Nina years 1988, 1998, 1999, 2007, 2010 are identified.
2. The El Nino years 1997 and 2009 show positive anomalies for precipitation frequency based indices.
3. The La Nina years 1998 and 1999 show negative anomalies for precipitation frequency based indices.
4. The El Nino years 1982, 1987, 1991, 1997, 2002 and 2009 show positive anomalies for precipitation intensity based indices.
5. The La Nina years 1988, 1998, 1999, 2007 and 2010 show negative anomalies for precipitation frequency based indices.
6. The trend of the duration based precipitation index is not clear for ENSO events.

7. The positive anomalies of yearly climate indices results into better rainfall in the study region during El Nino events.

8. The negative anomalies of yearly climate indices results in a decrease in rainfall in the study region during La Nina events.

9. It is concluded that ENSO is not directly affecting the rainfall of the study region.

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Index based on	Index	Parameter	Description	Unit	Equation
Based on precipitation intensity based index	Rx1day	Monthly maximum 1-day precipitation	RRij be the daily precipitation amount on day i in period j.	mm	$Rx1day_j = \max(RR_{ij})$
	Rx5day	Monthly maximum consecutive 5-day precipitation	RRkj be the precipitation amount for the 5-day interval ending k, period j	mm	$Rx5day_j = \max(RR_{kj})$
	SDII	Simple precipitation intensity index	RRwj be the daily precipitation amount on wet days, w (RR ≥ 1mm) in period j	mm/day	$SDII_j = \frac{\sum_{w=1}^{W} RR_{wj}}{W}$
	R95pTOT	Annual total PRCP when RR > 95p	RRwj be the daily precipitation amount on a wet day w (RR ≥ 1.0mm) in period i and RRwn95 be the 95th percentile of precipitation on wet days in the 1961-1990 period.	mm	$R95_{j}=\sum_{w=1}^{W} RR_{wj}$ 95 where RRwj > RRwn 95
Based on precipitation duration based index	CDD	Maximum length of dry spell	maximum number of consecutive days with RR ≥ 1mm. RRij be the daily precipitation amount on day i in period j.	days	Count the largest number of consecutive days where, $RR_{ij} < 1mm$
	CWD	Maximum length of wet spell	maximum number of consecutive days with RR ≥ 1mm (CWD) RRij be the daily precipitation amount on day i in period j.	days	Count the largest number of consecutive days where, RRij ≥ 1mm
Based on precipitation frequency based index	RR10	Annual count of days when Precipitation ≥ 10mm	RRij be the daily precipitation amount on day i in period j.	days	Count the number of days where, RRij ≥ 10mm
	RR20	Annual count of days when Precipitation ≥ 20mm	RRij be the daily precipitation amount on day i in period j.	days	Count the number of days where, RRij ≥ 20mm
	PRCPTOT	Annual total precipitation in wet days	RRij be the daily precipitation amount on day i in period j.	mm	If I represents the number of days in j, then $PRCPTOT_j = \Sigma\Sigma RR_{ij}$

Table 1: List of Extreme climate indices

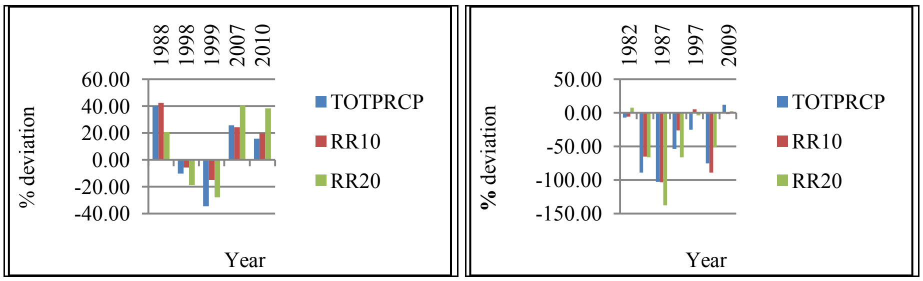

Figure 1: Precipitation frequency based index for Surat rain gauge station

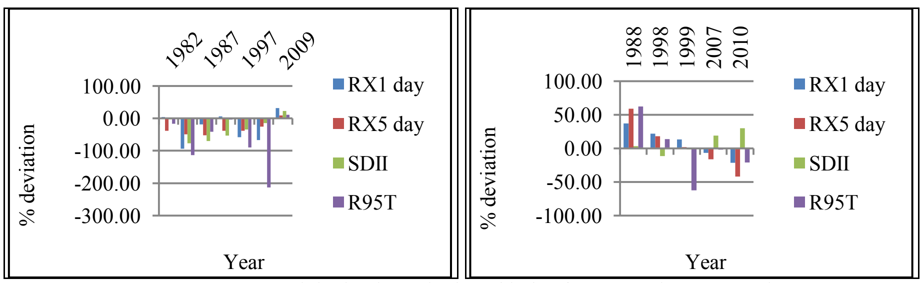

Figure 2: Precipitation intensity based index for Surat rain gauge station