J. Indian Soc. Coastal Agric. Res. 35(2): 48-52 (2017)

Impact of El-Niño Event on Seasonal and Annual Rainfall over Odisha State

N. MANIKANDAN, G. KAR and S. ROY CHOWDHURY
Indian Institute of Water Management
Bhubaneswar - 751 023, Odisha

Received: 18.02.2017 Accepted: 14.08.2017

Above normal warming of sea surface temperature in the equatorial Pacific Ocean creates a phenomena called El Niño and causes change in sea level pressure pattern in the east and west Pacific Ocean which in turn affects normal pattern of wind movement across the globe. The present study attempted to analyze variations in the seasonal and annual rainfall of Odisha state during different El Niño years (strong, moderate and weak). For this purpose, monthly rainfall data for Odisha state, years of different intensity of El Niño events, different ENSO (El Niño – Southern Oscillation) indices were retrieved. Results revealed that El Niño events did not have much effect on southwest monsoon rainfall of Odisha (21% probability for below normal rainfall) but marked effect of El Niño was noticed on post monsoon rainfall and there are 71 and 53 per cent probability for below normal rainfall during post monsoon season over Odisha in strong El Niño and all El Niño years, respectively. Negative correlation was found between sea surface temperature anomaly (Niño 3.4 and Niño 3 region during February month) and southwest monsoon rainfall of Odisha.

(***Key words***: *El Niño, Rainfall variability, Sea surface temperature, Southwest monsoon*)

El Niño is a global climatic anomaly associated with rise in sea surface temperature over eastern equatorial Pacific Ocean around Christmas. This above normal increase in sea surface temperature brings change in atmospheric pressure at sea level between Tahiti (French Polynesia) and Darwin (Australia) which in turn affects planetary wind flow pattern. This phenomenon is known as Southern Oscillation. Both the events collectively known as ENSO (El Niño - Southern Oscillation) are believed to have significant effect on Indian monsoon rainfall. Rajeevan and Pai (2006) reported that studies on relationship between long term monsoon (June – Sept) rainfall data and El Niño events showed negative correlation and further informed that, most of severe droughts in India are experienced during El Niño years. There have been many studies on effect of El Niño events on inter annual variability of monsoon rainfall over India since 1980 (Kane, 2005; Pai, 2003; Krishnamurthy and Goswami, 2000; Krishna Kumar *et al.,* 1999; Rasmusson and Carpenter, 1983). However, few studies were carried out to find impact of El Niño events on regional/ state level (Patel *et.al.,* 2014; Rao *et al.,* 2011; Sudheesh *et.al.,* 2004; Victor *et al.,* 1995). The state of Odisha with 480 km coast line is highly vulnerable to natural disasters like drought, floods, cyclones, heat waves, etc. In Odisha, agriculture sector contributes about 16 per cent of Gross State Domestic Product (GSDP) and around 70 per cent of state population is directly or indirectly involved in agricultural activities (Anonymous, 2013). Proper distribution of rainfall during southwest monsoon is crucial since almost 60 per cent cultivable land is under rainfed situation. Hence, deficit/ scanty rainfall during monsoon affect food production, inland fish production and state's wealth in many ways. Indian total food grains production is reduced by 1-15 per cent in 12 out of 13 years in the El Niño years (Selvaraju, 2003). Gadgil and Gadgil (2006) indicated that severe drought impact country's GDP by 2 - 5%, albeit contribution of agriculture sector to GDP is dwindling substantially in recent years. In the light of above facts, the present investigation was attempted to understand the effect of El Niño events on seasonal and annual rainfall of Odisha state.

MATERIALS AND METHODS

Monthly rainfall data of Odisha state for the period 1951 to 2013 was collected from data archives of Indian Institute of Tropical Meteorology (IITM), Pune website (www.tropmet.res.in). Monthly rainfall data was converted into seasonal [Summer (Mar-May), Southwest monsoon (June-Sept) and Post monsoon (Oct-Dec)] and annual format. The percent deviations of seasonal and annual rainfall from their long-term average

**Corresponding Author :* E-mail: metsate@gmail.com

(1951-2013) were also computed. Simple probability was calculated based on number of below normal rainfall years and total number of El Niño years of different intensities. According to glossary of India Meteorological Department, if the seasonal rainfall deficiency is equal or more than 10 per cent when compared to long period average, it is considered as below normal rainfall years and *vice versa*. In the present study same criterion was followed for classifying below and above normal rainfall year. To understand the variation in seasonal and annual rainfall during different El Niño years, the years of different intensities of El Niño was obtained from the website (http://ggweather.com/enso/oni.htm) during 1951 to 2013 (Table 1). Data on different ENSO indices was retrieved from following websites.

Oceanic Niño Index - www.cpc.ncep.noaa.gov
Dipole Mode Index - www.jamstec.go.jp
Southern Oscillation Index – www.bom.au
Sea Surface Temperature Anomaly – http://www.esrl.noaa.gov

Oceanic Niño Index (ONI) is an indicator to recognize El Niño events (Null, 2011). According to him, events are defined as five consecutive months at or above +0.5°C anomaly for warm (El Niño) events. The threshold is further broken down into weak (with a 0.5°C to 0.9°C Sea Surface Temperature anomaly), moderate (1.0°C to 1.4°C) and strong (≥1.5°C) events.

Table 1. *Years of different intensities of El Niño during 1951 - 2013*

Intensity	Years
Weak	1951,1963,1968,1969,1976,1977,2004,2006
Moderate	1986,1987,1994,2002
Strong	1957,1965.1972,1982,1991,1997,2009

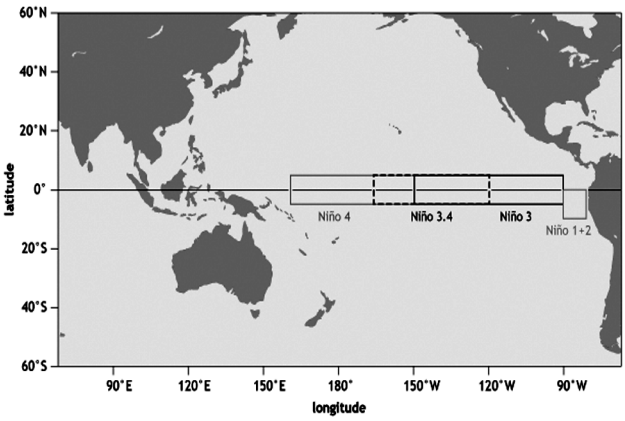

Fig. 1. *Location of the Niño regions for measuring sea surface temperature in the eastern and central tropical Pacific Ocean (Courtesy: NOAA Climate.gov image by Fiona Martin)*

Correlation analysis was carried out between different ENSO indices [Oceanic Niño Index (ONI-3-months running average values), Dipole Mode Index (DMI-monthly), Southern Oscillation Index (SOI-monthly) and monthly sea surface temperature anomaly (SSTA) of different Niño regions (Niño1+2, Niño3, Niño3.4 and Niño4) (Fig. 1)] and seasonal rainfall of Odisha, to find out the strength of relation.

RESULTS AND DISCUSSIONS

Seasonal rainfall variation during El Niño years

Actual rainfall received and percentage deviation from normal rainfall for summer, southwest monsoon, post monsoon and annual period during different El Niño years are presented in Table 2. The average annual rainfall of Odisha state is 1457 mm. Out of this southwest monsoon contributes 79 per cent, whereas post monsoon and summer season contributes 11 and 9 per cent, respectively. Only 2 per cent of annual rainfall is received through winter season. During the period (1951 – 2013), 19 El Niño years occurred over the globe. Out of which, 7, 4 and 8 years were classified as strong, moderate and weak El Niño years, respectively. From the table it can be inferred that there was only one below normal year observed in strong (1965) and weak (1976) El Niño year. But during four moderate El Niño years, deficit rainfall (-21%) was observed in two years and excess rainfall (9 and 35%) in another two years. Three excess rainfall years (1994, 2006 and 1997) were also observed during El Niño events. 16 per cent more rainfall was received during southwest monsoon 1997, the strongest ever recorded El Niño till now which had significant impact in many parts of the world but did not influence monsoon over Odisha state.

In the case of post monsoon season, pronounced effect of strong El Niño is seen when compared to moderate and weak El Niño years. Rainfall deviated to the tune of -22 to -79% during post monsoon season in five out of seven strong El Niño years except in 1991 and 2009 (Table 2). Out of four moderate El Niño years, two were below normal and two were above normal with regards to rainfall. Three drought and three excess rainfall years were noticed out of eight weak El Niño years. It indicates that the probability for deficit rainfall in post monsoon season over Odisha during strong El Niño years and all El Niño years (irrespective of intensity) is almost 71 and 53 percent, respectively. Average post monsoon season rainfall is more during the years with El Niño compared to normal rainfall in Tamil Nadu and coastal Andhra Pradesh (Rao *et al.,* 2011;

Geethalakshmi *et al.,* 2009). However, this positive impact of El Niño on post monsoon rainfall over south Peninsula was not observed over Odisha state. In Odisha, receipt of rainfall during post monsoon season (October-December) is mainly contributed through occurrence of cyclonic disturbances. It is inferred from Newsletter of Indo-US Science and Technology Forum (IUSSTF, 2012) that maximum number of tropical cyclones during post monsoon season (Mid-September to December) formed in Bay of Bengal crossed through Odisha coast and that brought heavy precipitation. However, study on inter annual variations of tropical cyclone activity in north Indian Ocean for the period 1983-2008 indicated that during El Niño year, conditions are less favourable for tropical cyclone genesis/ development and only fewer intense cyclones were observed during post monsoon season (Ng and Chan, 2012). Hence, it can be inferred that deficit rainfall in post monsoon season during El Niño years are due to occurrence of few intense tropical cyclone over north Indian Ocean. In the case of annual rainfall, deficit rainfall was noticed in 4 out of 7 strong El Niño years and 2 out of 4 moderate El Niño years. However, during eight weak El Niño years, only one below normal year was noticed (Table 2).

Correlation study between ENSO indices and southwest monsoon rainfall in Odisha

National Oceanic and Atmospheric Administration (NOAA), USA use Oceanic Niño Index (ONI) as ENSO indicator, which measures intensity of warm events (El Niño) and cold events (La Niña), calculated from sea surface temperature (SST) values recorded in the east-central tropical Pacific Ocean (Niño 1+2, Niño 3, Niño 3.4 and Niño 4) (Fig. 1). Nonetheless, there are other indices used as ENSO indicator based on atmospheric pressure at sea level (Southern Oscillation – SOI, Equatorial southern Oscillation), outgoing long wave radiation and wind/ movement of air flow over tropical Pacific Ocean (Barnston, 2015). There are indices like

Table 2. *Variability in seasonal and annual rainfall over Odisha state during different El Niño years*

Year		Summer (Mar-May)		Southwest monsoon (June-Sept)		Post-monsoon (Oct-Dec)		Annual	
		Rainfall (mm)	% deviation	Rainfall (mm)	% deviation	Rainfall (mm)	% deviation	Rainfall (mm)	% deviation
Strong	1957	59.1	-51	1049.7	-8	34.2	-79	1188.3	-18
	1965	143.6	19	987.8	-14	105.0	-35	1256.6	-14
	1972	39.9	-67	1129.1	-1	123.0	-24	1311.3	-10
	1982	141.3	17	1073.9	-6	50.7	-69	1302.9	-11
	1991	95.5	-21	1223.4	7	158.4	-2	1506.6	3
	1997	183.4	52	1330.5	16	125.8	-22	1662.4	14
	2009	84.7	-30	1174.0	3	155.4	-3	1414.1	-3
Moderate	1986	137.0	13	1252.1	9	301.5	87	1766.5	21
	1987	112.0	-7	908.7	-21	226.2	40	1270.1	-13
	1994	113.4	-6	1545.8	35	99.3	-38	1792.6	23
	2002	135.5	12	908.7	-21	92.4	-43	1153.4	-21
Weak	1951	176.6	46	1097.2	-4	214.4	33	1489.9	2
	1963	135.7	12	1195.8	4	191	19	1529.8	5
	1968	68.8	-43	1042.1	-9	271.6	69	1441.8	-1
	1969	97.7	-19	1147.8	0	108	-33	1353.9	-7
	1976	91.9	-24	970.6	-15	87.8	-45	1163.8	-20
	1977	176.3	46	1114.9	-3	160.2	0	1462.2	0
	2004	122	1	1054.8	-8	156.2	-3	1349.3	-7
	2006	185	53	1507.8	32	58.3	-64	1752.6	20
Normal Rainfall (mm)		121		1145		161		1457	

Table 3. *Correlation coefficient between different ENSO indices and monsoon rainfall over Odisha*

Index	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ	DJF
ONI(1951-2013)	-0.14	-0.16	-0.14	-0.08	0.01	0.04	0.04	0.06	0.07	0.07	0.08	0.08
Index	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SOI (1951-2013)	0.19	0.16	0.07	0.10	-0.16	-0.06	-0.09	-0.12	-0.17	-0.08	-0.00	-0.07
DMI (1958-2009)	-0.32*	-0.27	-0.12	-0.04	0.08	0.15	0.18	0.21	0.267	0.28	0.30	0.31
SSTA (1982-2013)												
Niño 1+2	-0.33	-0.24	-0.18	-0.24	-0.22	-0.11	0.04	0.09	0.11	0.07	0.12	0.11
Niño 3	-0.34	-0.39*	-0.38*	-0.28	-0.11	-0.01	0.04	0.09	0.09	0.16	0.15	0.15
Niño 4	-0.31	-0.35*	-0.28	-0.19	-0.14	-0.06	0.15	0.29	0.21	0.25	0.21	0.18
Niño 3.4	-0.36*	-0.39*	-0.36*	-0.27	-0.13	0.02	0.09	0.13	0.11	0.18	0.18	0.17

*significant at 5% level

Indian Ocean Dipole measured by an index called Dipole Mode Index (DMI) which is the difference between sea surface temperature (SST) anomalies in the western equatorial Indian Ocean (Saji *et al.,* 1999) and Equatorial Indian Ocean Oscillation (EQUINOO) (Gadgil, 2015) and plays an important role in the performance of Indian monsoon rainfall. Results of correlation analysis between different ENSO indices and monsoon rainfall of Odisha are furnished in Table 3. Except SOI, all other indices exhibited negative relation with monsoon rainfall. Though ONI and DMI (SOI) had negative (positive) relationship with monsoon season rainfall, the strength is feeble. However, DMI during January month was significantly (at 5% level) and negatively linked to monsoon rainfall. Among the SSTA of different Niño regions except Niño 1+2, other regions had significant (at 5% level) negative relation. Highest negative correlation was observed for SSTA of Niño 3.4 (r = -0.396) and Niño 3 (r = -0.393) region during February month.

CONCLUSIONS

The present investigation was carried out to find the effect of El Niño events in relation to seasonal and annual rainfall of Odisha state. It is understood that El Niño events did not have much effect on southwest monsoon rainfall over Odisha as only two below normal years (1965 and 1976) observed out of seven strong and eight weak El Niño years during the study period. But during four moderate El Niño years, deficit rainfall (-21%) was observed in two years and excess rainfall (9 and 35%) in another two years. Nevertheless, pronounced effect is seen on post monsoon rainfall due to El Niño events and it is understood that during strong El Niño years almost 71 per cent and during all El Niño years 53 per cent probability for deficit post monsoon season over Odisha. Correlation analysis between different ENSO indices and south west monsoon rainfall over Odisha state indicated that sea surface temperature anomaly during February month over Niño 3 and Niño 3.4 region in Pacific Ocean are having highest negative relationship.

ACKNOWLEDGEMENT

Authors are thankful to Indian Institute of Tropical Meteorology, Pune for providing monthly rainfall data for Odisha sub division. Authors are also thankful to Climate Prediction Centre of National Oceanic and Atmospheric Administration, Colorado, USA for providing sea surface temperature and Oceanic Niño Index data and Bureau of Meteorology, Australia for Southern Oscillation Index data and Japan Meteorological Society for Dipole Mode Index data.

REFERENCES

Anonymous, (2013). *State Agriculture Policy 2013*. Agriculture Department, Government of Odisha, Bhubaneswar, Odisha. 66 p.

Barnston, A. (2015). Why are there so many ENSO indexes, instead of just one? Available at: (https://www.climate.gov/news-features/blogs/enso/why-are-there-so-many-enso-indexes-instead-just-one)

Gadgil, S. (2015). Case study: El Niño of 2015 and the Indian summer monsoon, El Niño 2015 Conference on *Shared experiences: 20 years of climate services and framing the next steps in the research and development for climate resilience.* International Research Institute for Climate and Society, Earth Institute, Columbia University, USA, Nov 17-18, 2015. Available at: http://iri.columbia.edu/wp-content/uploads/2015/11/17nov15IRIgadgil.pdf.

Gadgil, S. and Gadgil, S. (2006). The Indian monsoon, GDP and agriculture. *Economic and Political Weekly* **41**(47): 4887-4895.

Geethalakshmi, V., Palanisamy, K., Yatagai, A. and Umetsu, C. (2009). Impact of ENSO and the Indian ocean dipole on the north-east monsoon rainfall of Tamil Nadu state in India. *Hydrological Processes* **25**(4): 633-647.

IUSSTF. (2012). *Modeling and Data Assimilation for Tropical Cyclone Predictions: Predicting landfalls*. Newsletter of Indo-US Science and Technology Forum **4**(2): 4-11

Kane, R. P. (2005). Unstable ENSO relationship with Indian regional rainfall. *International Journal of Climatology* **26**(6): 771-783.

Krishna Kumar, K., Rajagopalan, B. and Cane, M. (1999). On the weakening relationship between the Indian monsoon and ENSO. *Science* **284**: 2156-2159.

Krishnamurthy, V. and Goswami, B. N. (2000). Indian monsoon–ENSO relationship on interdecadal time scale. *Journal of Climate* **13**(3): 579-595.

Ng, E. K. W. and Chan, J.C.L. (2012). Interannual variations of tropical cyclone activity over the north Indian ocean. *International Journal of Climatology* **32**: 819-830.

Null, J. (2011). El Niño and La Niña intensities. http://ggweather.com/enso/oni.htm.

Pai, D. S. (2003). Teleconnections of Indian summer monsoon with global surface air temperature anomalies. *Mausam* **54**: 407-418.

Patel, H. R., Lungaria, M. M., Vyas Pandey., Sharma, P. K., Bapuji Rao, B. and Rao, V. U. M. (2014). *El Niño Episodes and Agricultural Productivity in Gujarat*. Technical Bulletin, Anand Agricultural University, Anand, Gujarat. 22 p.

Rajeevan, M. and Pai, D. S. (2006). *On El Niño-Indian Monsoon Predictive Relationships*. Research Report No: 4/2006, National Climate Centre, India Meteorological Department, Pune, India. 20 p.

Rao, V. U. M., Subba Rao, A. V. M., Bapuji Rao, B., Ramana Rao, B. V., Sravani, C. and Venkateswarlu, B. (2011). *El Niño Effect on Climatic Variability and Crop Production: A Case Study for Andhra Pradesh*. Research Bulletin No. 2/2011, Central Research Institute for Dryland Agriculture, Hyderabad. 36 p.

Rasmusson, E. M. and Carpenter, T. H. (1983). The relationship between eastern equatorial Pacific sea surface temperature and rainfall over India and Sri Lanka. *Monthly Weather Review* **111**: 517-528.

Saji, N. H., Goswami, B. N., Vinayachandran, P. N. and Yamagata, T. (1999). A dipole mode in the tropical Indian Ocean. *Nature* **401**: 360-363.

Selvaraju, R. (2003). Impact of El Niño–southern oscillation on Indian foodgrain production. *International Journal of Climatology* **23**: 187–206. doi:10.1002/joc.869

Sudheesh, M. V., Rao, G. S. L. H. V. P. and Manikandan, N. (2004). Effect of *El-Niño* on the rainfall pattern of Kerala. *Proceedings of the Indian Environmental Congress 2004*, December 16-18, 2004, Thriuvanathapuram, Kerala, India. pp 81-84.

Victor, U.S., Srivastava, N. N., Subba Rao, A.V.M. and Ramana Rao, B.V. (1995). El Niño's effect on southwest monsoon rainfall in Andhra Pradesh, India. *Drought News Network*. Available at: http://digitalcommons.unl.edu/droughtnetnews/89.