IJIRR

International Journal of Information Research and Review
Vol. 05, Issue, 11, pp.5826-5836, November, 2018

RESEARCH ARTICLE

INTER-ANNUAL VARIATIONS OF INDIAN OCEAN WARM POOL

[1,*]Dr. Lakshmana Rao, V. and [2]Prof. Sai Lakshmi, K.

[1]Assistant Professor, Dept., of Meteorology and Oceanography, Andhra University, Visakhapatnam
[2]Department of Basic Sciences, Sanketika Vidya Parishad College of Engineering, Visakhapatnam, India

ARTICLE INFO

Article History:

Received 27th August, 2018
Received in revised form
10th September, 2018
Accepted 19th October, 2018
Published online 30th November, 2018

Keywords:

Warm Pool, ElNiño,
LaNiña, ENSO,
Rain Fall And SST.

ABSTRACT

In this article we examine the relationship between the warm pool properties and the ElNiño, LaNiña, ENSO years for the period from 1870–2015. It is also the largest consistent contributor to the global Ocean warming trends. In this study we observed that a warm Indian Ocean can in turn modulate the pacific conditions including the ElNino events. So, basically such large warming over the Indian Ocean has implication on the global climate. In this article we focused on the causes for this warming and found that it was mainly due to ElNino events. The ElNino events weaken during the summer westerly winds over the Indian Ocean, but in the summer the effect of LaNino events the surface temperature increases around 2^0 C .The sea surface temperature over Arabian Sea, Bay of Bengal and equatorial Indian Ocean is favorable for the formation of warm pool in the years 1999, 2010. The year 2010, shows the sea surface temperature greater than 30^0c over equatorial Indian Ocean and south eastern Arabian Sea .This is a good condition for getting good amount of rain fall over India.

INTRODUCTION

Over tropical oceans, the regions with sea surface temperature (SST) above 28^0 c, referred as a "warm pool", has important implication to atmospheric process. It has been shown that the minimum SST required for active convection is 28^0 c (Gadgil *et al*., 1984; Graham and Barnet 1987). It has been found that regions with annual mean SST above 28^0 c are prone to tropical cyclones (Gray 1975). The most extensive and the best - known warm pool of world oceans is in the western pacific. Lukas and Webster (1989) have summarized its importance. It is a region of deep convection (Lau and Chan 1986; Ardanuy *et al*., 1987), convergence of surface winds (Rasmussen and Carpenter 1982), and high precipitation (Taylor 1973; Weare *et al*., ., 1981). The ascending branch of the walker circulation is located above this pool, and the latent heat released during the ascent supplies energy for the circulation. It has been found that during an El Nino event the warm pool and the region of deep convection migrates eastward (Gill and Rasmussen 1983; Donguy *et al*., 1984) by about 4000 km which is a fourth of the total length of the equatorial pacific. The western pacific warm pool (WPWP) may also have implication for the Indian summer monsoon. The SST over the area 120^0-160^0 E; 5^0-15^0 S was found to be positively correlated to the Indian summer monsoon rainfall (Nicholls 1983). A considerable area of the tropical Indian Ocean too has SST higher than 28^0 c.

Corresponding author: **Dr. Lakshmana Rao, V.,**
Assistant Professor, Dept., of Meteorology & Oceanography, Andhra University, Visakhapatnam.

The Indian Ocean warm pool (IOWP) can cover the equatorial region east of about 50^0 E, the Bay of Bengal and the eastern Arabian Sea. The importance of this pool for atmospheric processes over the Indian Ocean has been recognized. Joseph (1990) found that onset vortices of the Indian summer monsoon form over the warmest regions of the Indian Ocean.

A good part of the IOWP (Indian Ocean warm pool) has out going long wave radiation below 240wm^{-2} (Lukas 1988) indicating that it is a region of deep convection. IOWP is expected to play a role in the development of cyclones over the Bay of Bengal, some of which have been amongst the most destructive. The El Nino and associated atmospheric phenomena provides an impetus to study the WPWP. Significant progress has since been achieved (Donguy 1987). The data set used to describe IOWP and WPWP is the monthly-mean temperature at standard oceanic depths on a 1^0 x 1^0 horizontal grid covering the world oceanic, complied by (Sydney Levitus 1982). Only in the pacific and Indian ocean there exist regions with SST greater than 28^0 c throughout the year. In the pacific the area which satisfies this criterion is about 10 x 10^6 km^2, and in the Indian Ocean it is about 2.8 x 10^6 km^2. In the pacific, over an area of about 0.9 x 10^6 km^2, the monthly – mean SST throughout the year exceeds 29^0 c. though the contribution of the Indian Ocean to the total area of the world oceans where the SST exceeds 28^0 c throughout the year is only about a fourth, during a given month the Indian ocean's contribution is often much higher. The North Equatorial Current (between 8° and 20°N) and South Equatorial Current (between 10°S and 3°N) flow westward in the Pacific. The resulting convergence of mass leads to accumulation of warm water in the western Pacific which continues till an El Nino resets the cycle (Wyrtki 1985). In the Indian Ocean the surface currents near the equator are on an average towards the east (McPhaden 1982; Cutler and Swallow 1984). On the eastern boundary of IOWP, there is no wind- induced upwelling and there appears to be no pole ward transport of the heat accumulated due to surface heat fluxes. Though this explanation for the occurrence of IOWP on the eastern side of the ocean seems reasonable in view of the present meager evidence, additional studies are needed to ascertain its validity. Such an exercise could also bring out the role of through flow from the Pacific (Fine 1985) to maintain a warm eastern Indian Ocean.

The thermal structure of the upper 250 m a mixed layer, which on an average is 75 m, and a thermo cline which is best developed in the eastern equatorial Indian Ocean. Strong eastward equatorial surface jets occur in the Indian Ocean during the transition period between the monsoons (Wyrtki 1973). Their role in controlling IOWP is not known. Consequently, at present it is not possible to compare the roles of advection and air-sea fluxes in controlling the spread of IOWP along the equator. The apparent lack of correlation between the two curves in suggests that advection plays an important role. In the western equatorial Pacific, Donguy *et al*., (1984) have argued that horizontal advections as well as surface heat fluxes influence the heat budget. Complicating the issue further is the suggestion by Godfrey and Lindstrom (1989) that there are serious uncertainties with the estimates of air- sea fluxes over this region. In the immediate vicinity of the equator which is known to have strong jet-like eastward current (Wyrtki 1973), and in the region of the South Equatorial Current advection plays an important role. Elsewhere the air-sea fluxes appear to dominate most of the year. The warm pool is capable of influencing global climate via, for example, the Walker and Hadley circulations and serves as a major source of heat and water vapor (Sardeshmukh and Hoskins, 1988; Webster and Lukas, 1992).

The warm pool size was suggested to be a key factor regulating tropical mean SSTs by Pierre humbert (1995). The extension of the warm pool is positively correlated with the occurrence of westerly wind bursts in the western Pacific, which are known to be important for the onset of the El Niño events (Eisenman *et al*., 2005). Warm pool displacements and intensity variations are also known to affect the onset, intensity, and period of El Niño–Southern Oscillation (ENSO) (Picaut *et al*., 1996; Kessler, 2001; Sun, 2003; McPhaden, 2004). Williams and Funk (2011) showed that a large warming trend in the Indian Ocean over the past 60 years has expanded the Indian Ocean warm pool westward and argued that this expansion has been instrumental in a shift of the sinking branch of the Walker circulation westward to eastern Africa, causing rainfall deficit there. It has also been suggested that warm pool SSTs may affect tropical cyclone frequency and intensity. Webster *et al*. (2005) showed that an increasing trend in the tropical cyclone number and intensity over the past 35 years could be associated with a warming trend in the north Indian Ocean and western Pacific Ocean. Slow fluctuations in warm pool SSTs were suggested to be capable of regulating decadal variability in the Hadley and Walker circulations (Wang and Metha, 2008). The warming in the Indian Ocean, the mean strength of the Indian monsoon has weakened but it's inter annual variability has increased (Goswami, 2005). It was also noted that the typical negative correlation between ENSO and the Indian monsoon has weakened in recent decades (Kumar *et al*., 1999; Kinter *et al*., 2002). It has also been shown that the Indian Ocean warm pool is shallower than the Pacific warm pool (e.g., Meng and Wu, 2002).

METHODOLOGY

SST data can be taken from The National Oceanic and Atmospheric Administration (NOAA) from 1870 to2015 in March and April data can be taken to observe the difference between El Nino and La Nina years and the ENSO years. The data used for the months of March and April average during the period of 1870-2015 has been considered from NOAA'S website. Scientist of NCDC, America, prepared this data. It is the running two-month mean SST for the Niño i.e., 5^0S-25^0N and 60^0 E-110^oE. Using SST data for the period 1870–2015, the size, maximum and mean SSTs, and the longitudinal and latitudinal locations of the center of the warm pool are calculated in the region enclosed by the 28^0C isotherm within the region between 5^0S–25^0N and 60^0E–110^0E. We repeated our analyses with the warm pool defined by the 27.5^0C isotherm, which has been used in some studies to define warm pool, but found little difference. Only the results with the warm pool defined by the 28^0C isotherm are shown. In this study, the Indian Ocean warm pool is observed by using the dataset from NOAA's National Oceanographic Data Center.

RESULTS AND DISCUSSION

ElNiño +Ve IOD years: In the months of March and April, the Indian Ocean, the Arabian Sea, and Bay of Bengal have the same sea surface temperature values ranging from 28^0 to 30^0c. The head Bay of Bengal shows the values between 26^0 and 28^0c.over the Arabian Sea the region to the north of 12^0N shows low values when compared to the Indian Ocean.

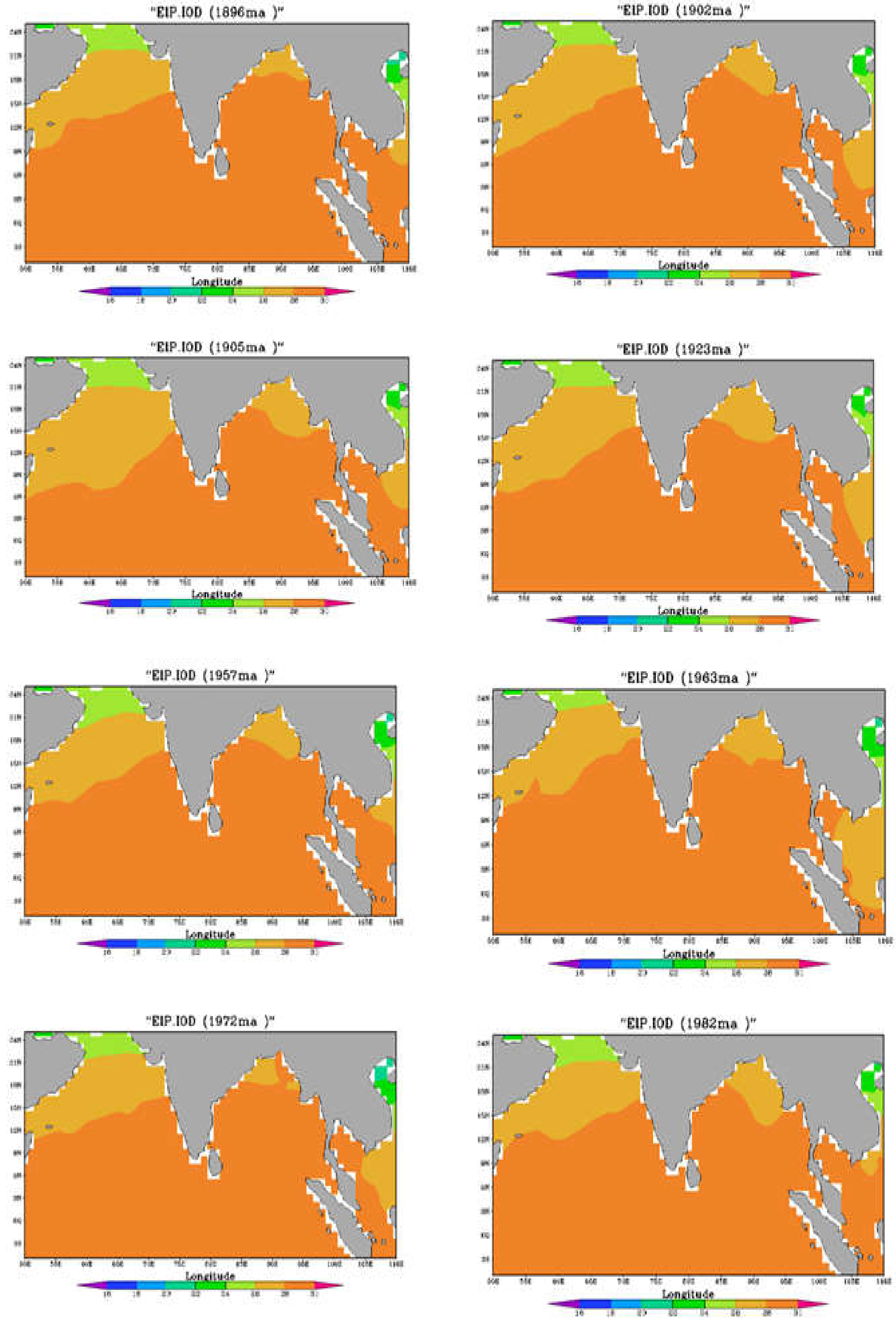
ElNiño -Ve IOD year: In the year 1930, in the months of March and April, only the East and south East Arabian Sea shows the sea surface temperature values 28 to 30^0c. The remaining parts of the Arabian Sea have the sea surface temperature values 28^0c. The Bay of Bengal shows the maximum values. This condition is not favorable for the monsoon over India.

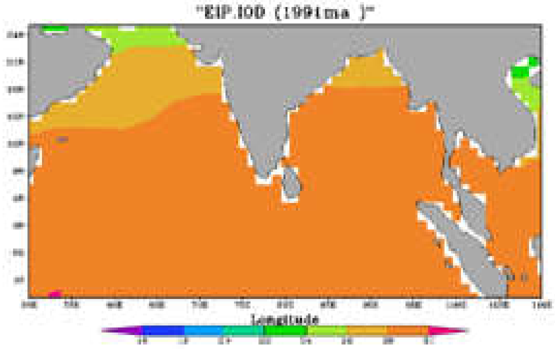
Strong ElNiño year: The mean pattern (March, April average) of sea surface temperature for the year 1997 the values of the sea surface temperature over most of the Arabian Sea and Bay of Bengal varies between 28 and 30^0c. It is a good condition for the formation of warm pool.

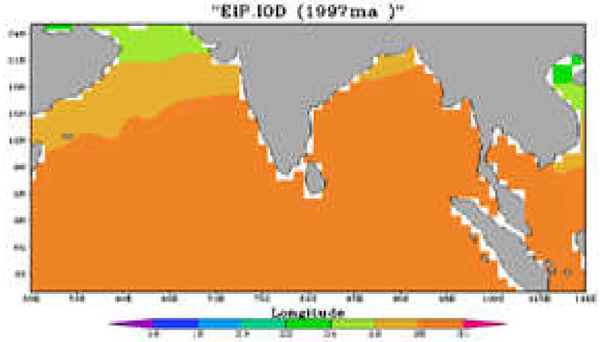
Weak ElNiño years: The mean pattern of sea surface temperature for the year 2004 is shown in the figure. The maximum value of sea surface temperature over the south eastern Arabian Sea indicates the favorable condition for the warm pool but the rain fall over India for the year 2004 is about 74cm.

LaNiña -Ve IOD years: The two months (March and April) mean SST pattern for the years 1906, 1909, 1910, 1916, 1917, 1928, 1933, 1942, 1950, 1975 and 1981 is observed. The region below 10^0 N shows the maximum SST (>28^0c) and the head Bay of Bengal and the North Arabian Sea shows the low

ElNino +Ve IOD years:

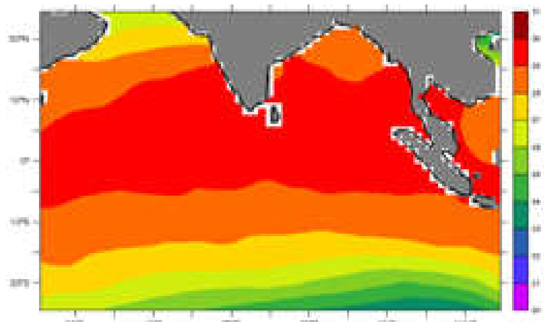


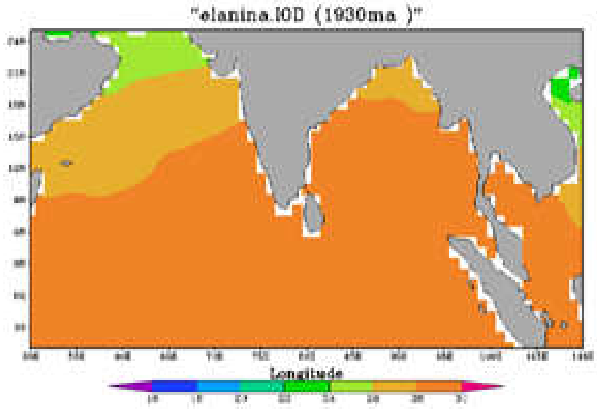




ElNino +Ve IOD mean:

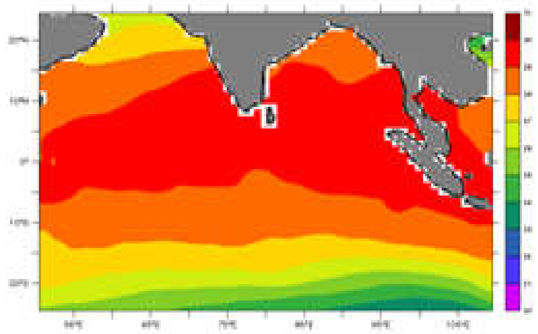
ElNino -Ve IOD year:

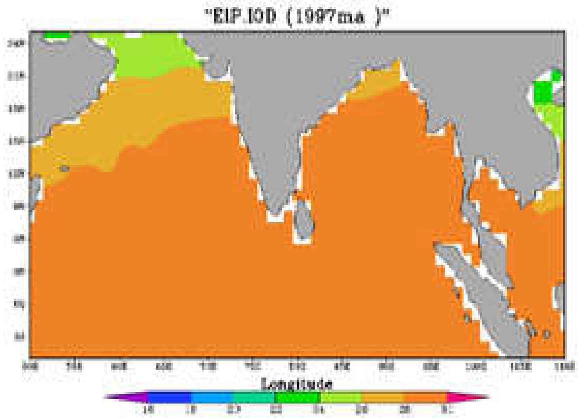




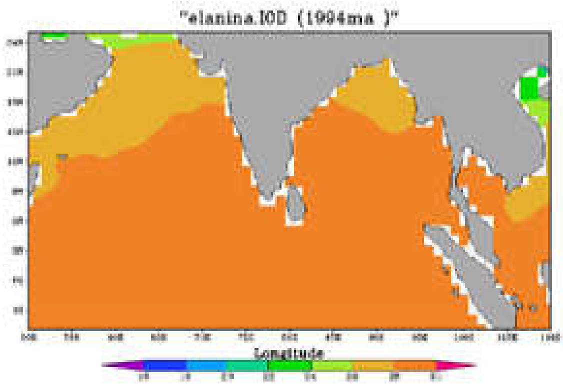
ElNino -Ve IOD mean:

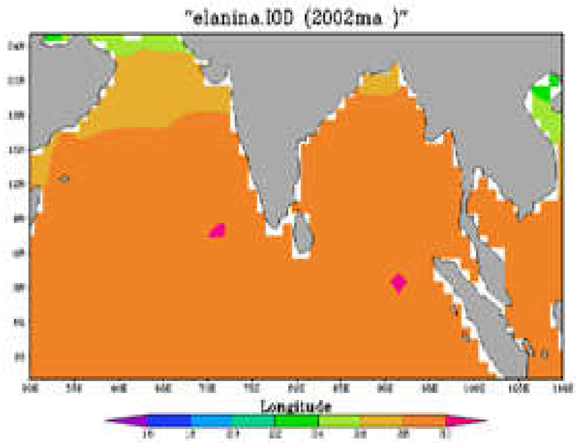
Strong ElNino year:



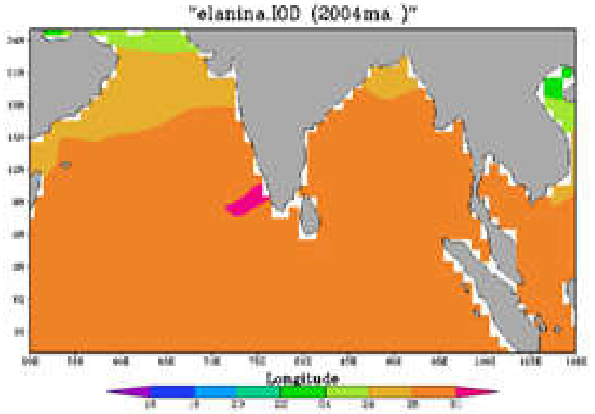


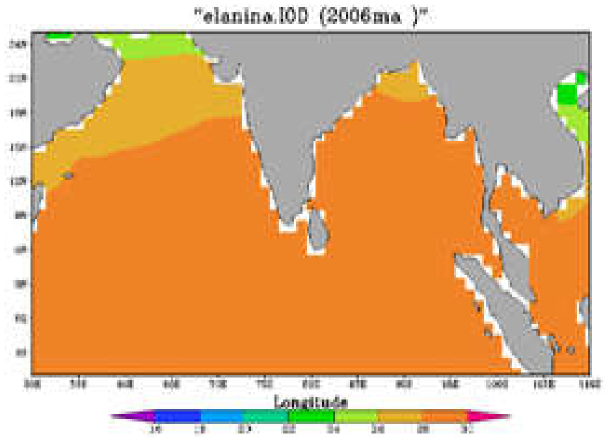
Moderate ElNino year:



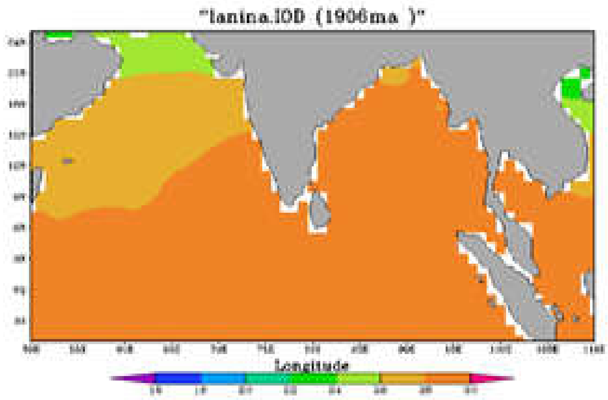


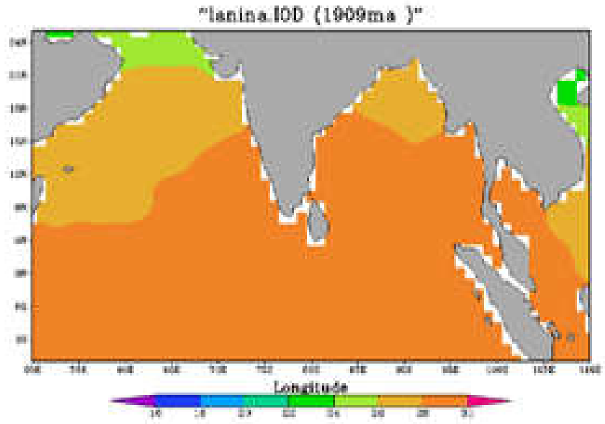
Weak ElNino year:

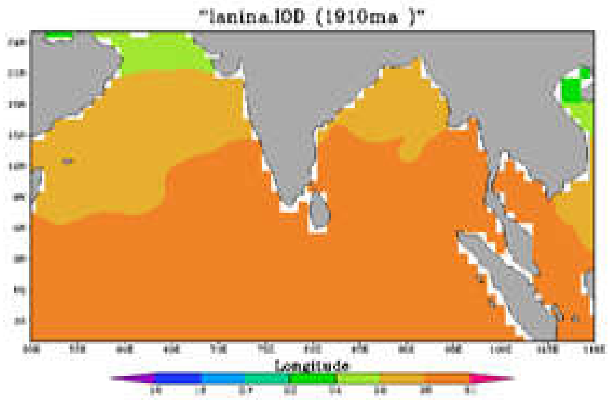


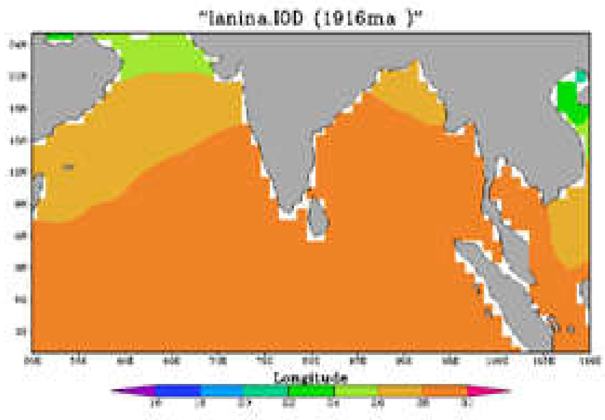


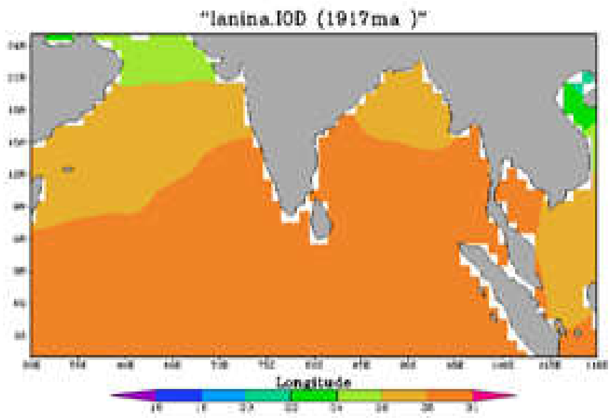
LaNiña –Ve IOD years:

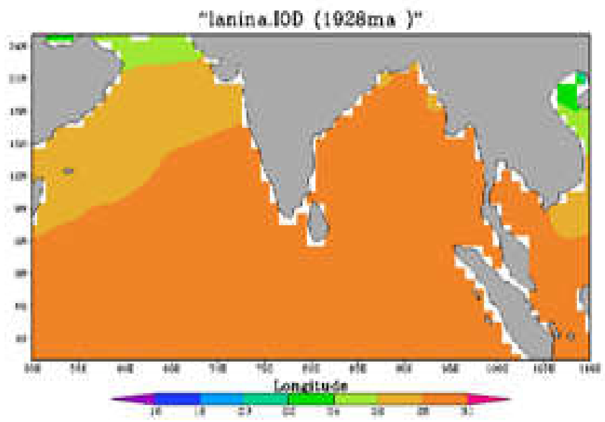


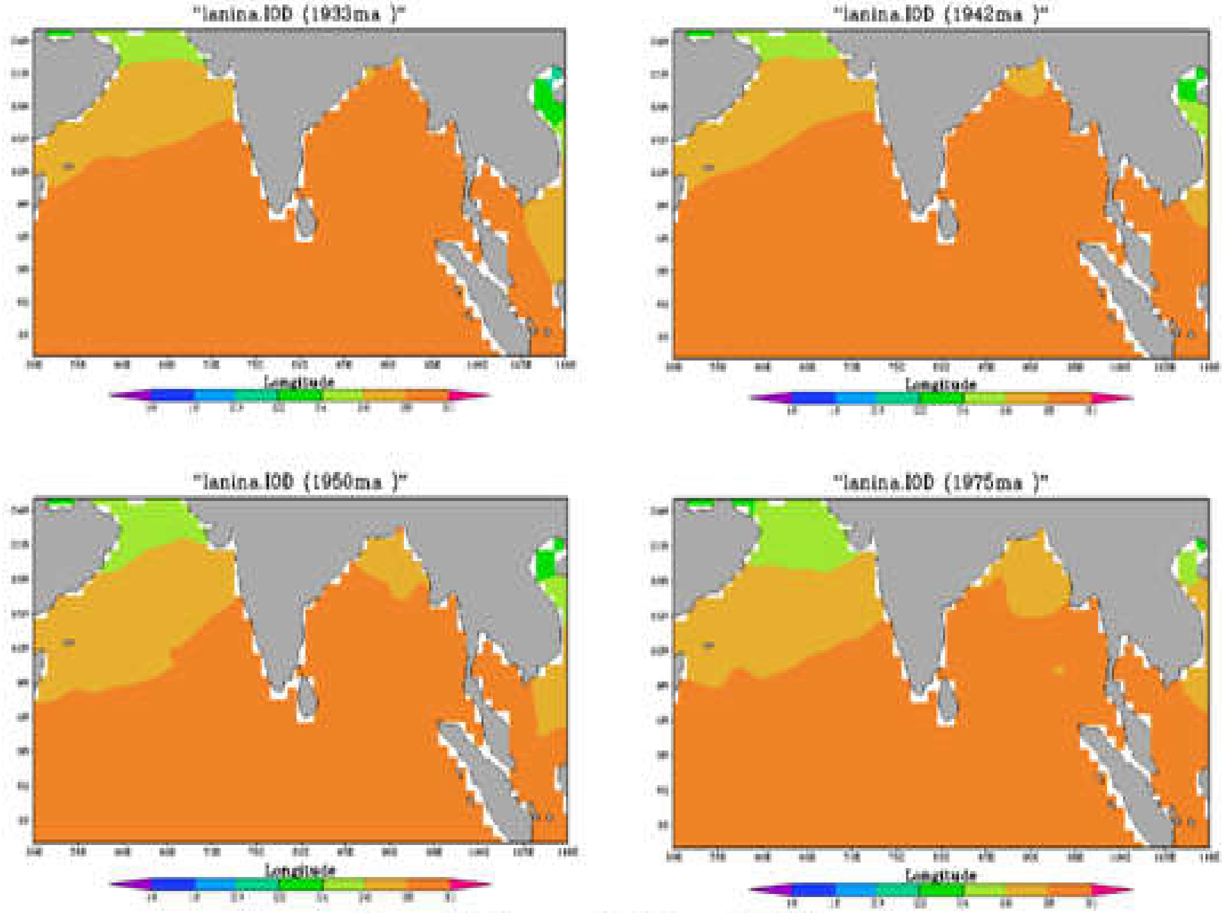




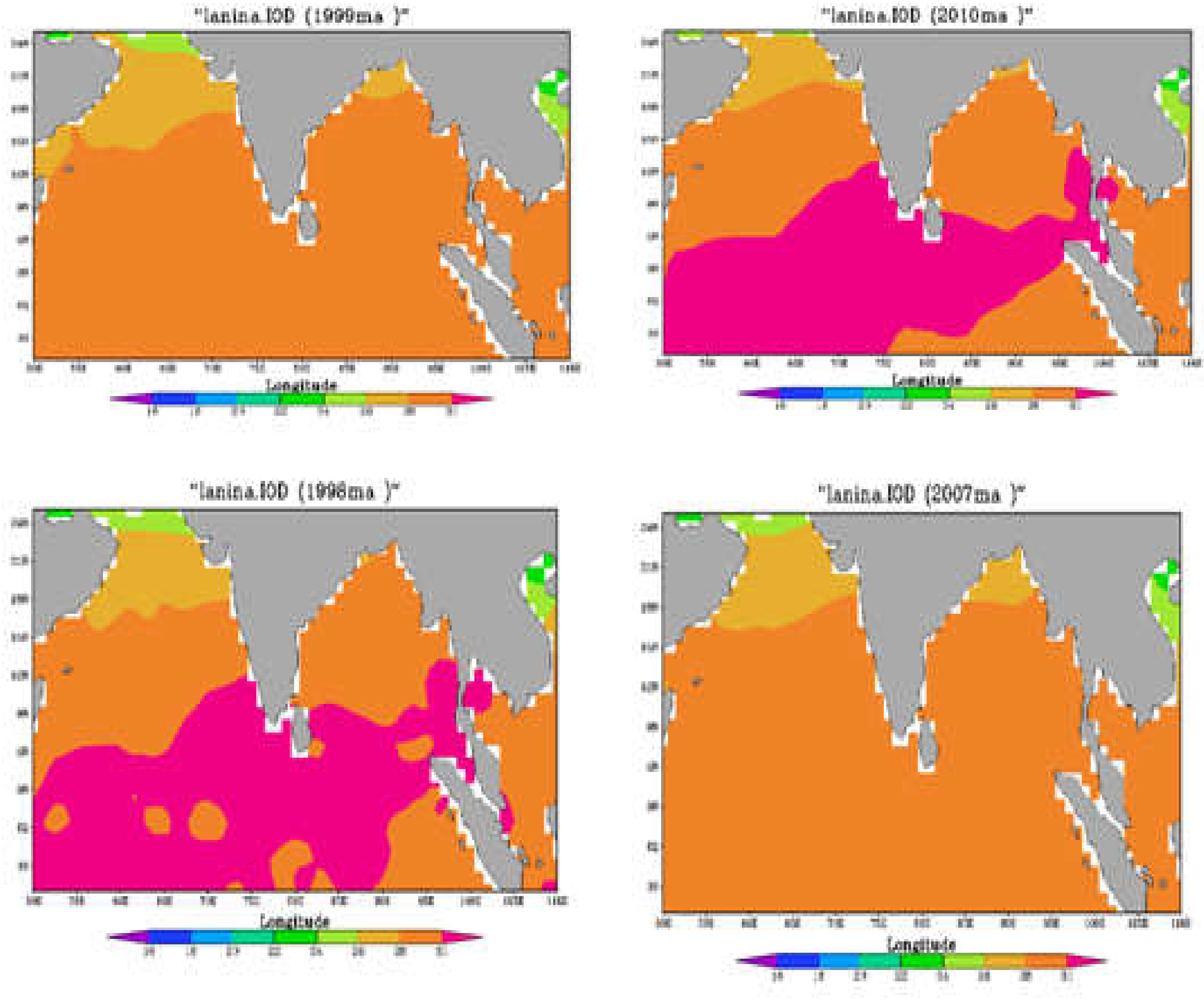




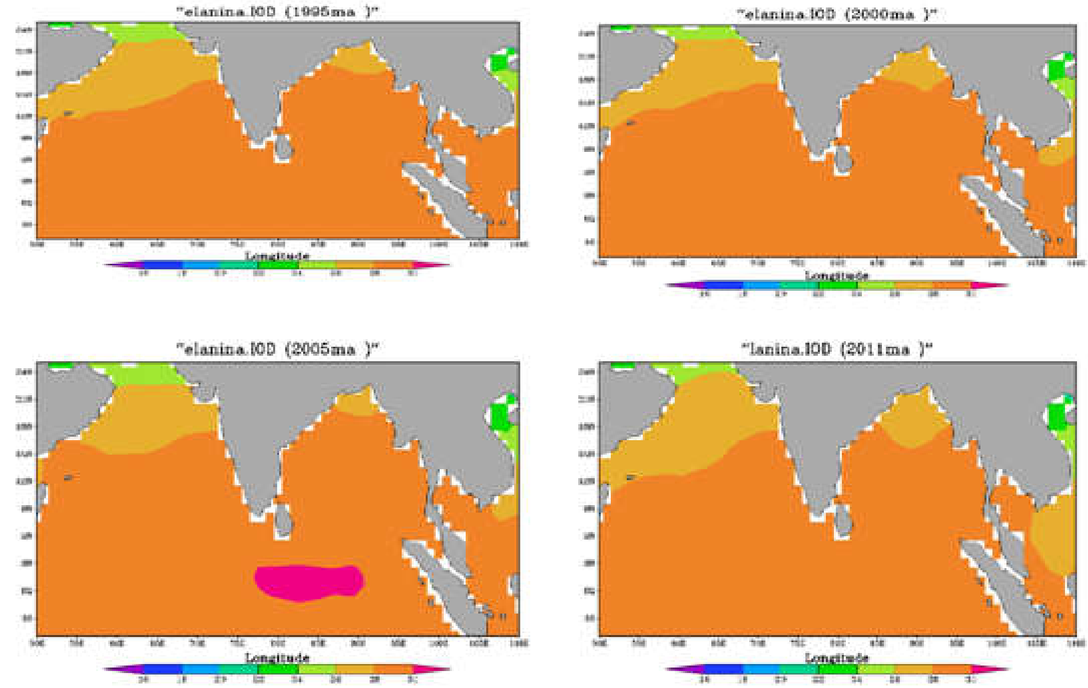




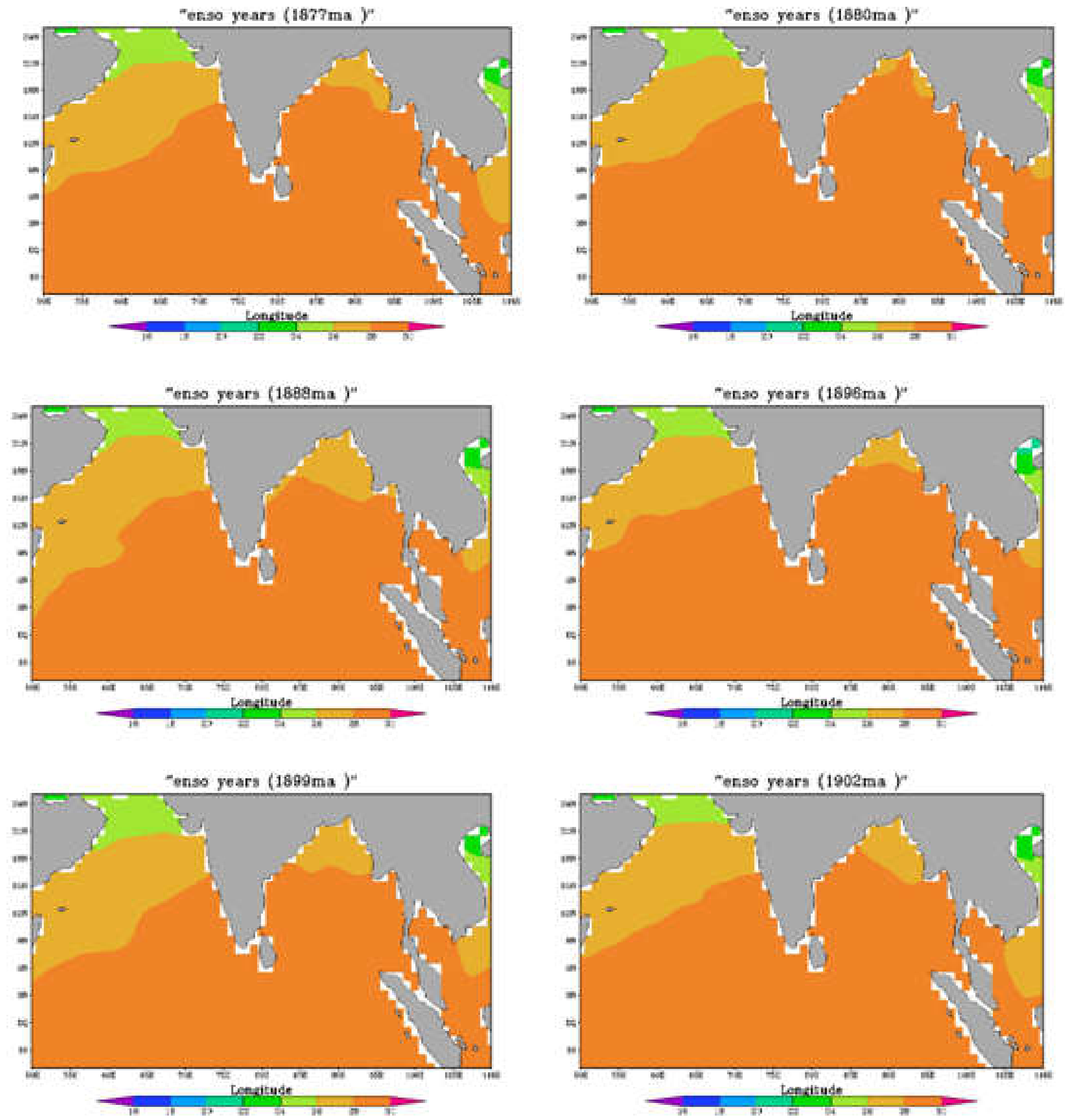
Strong LaNiña years & Moderate LaNiña years:

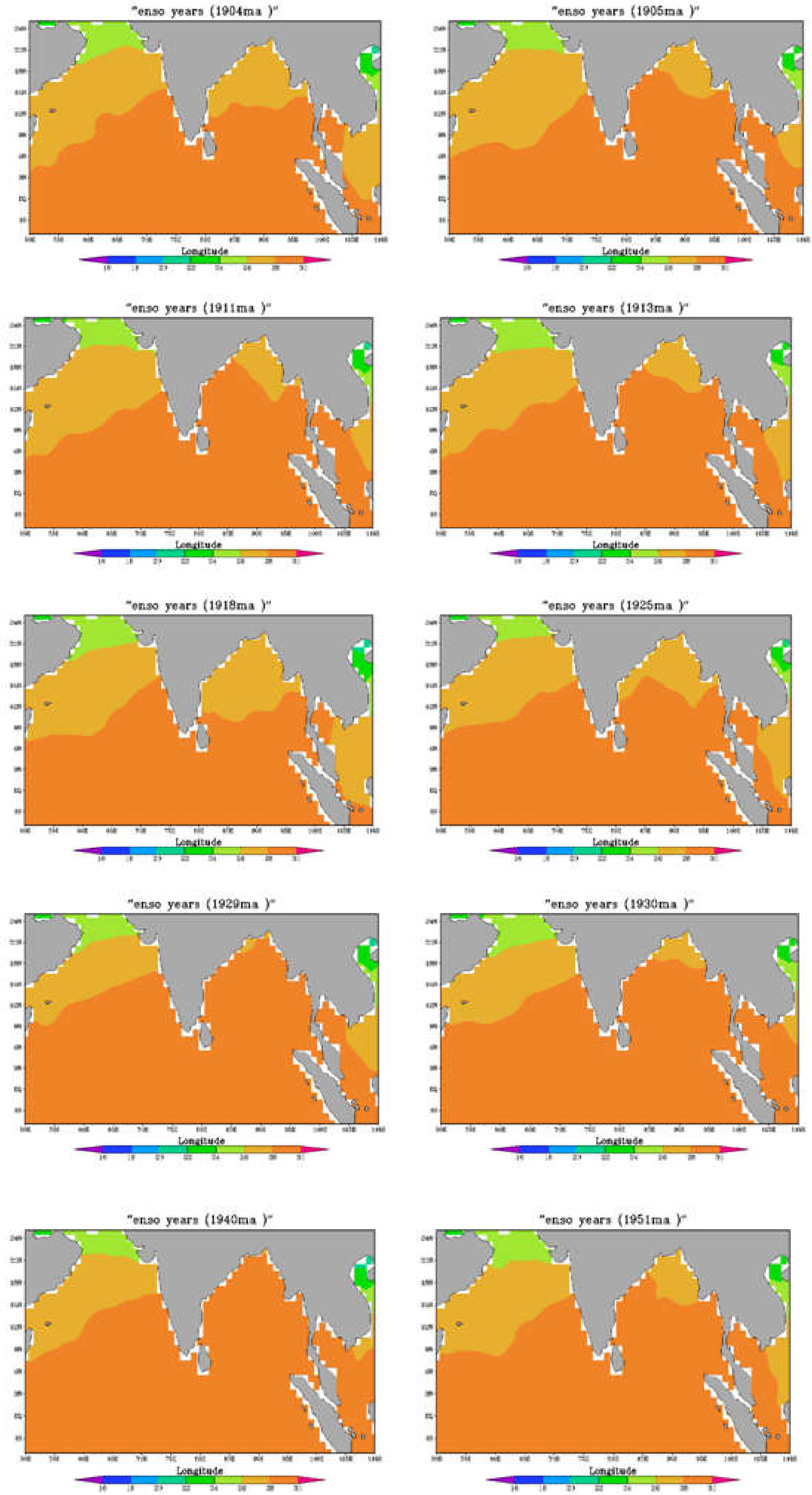


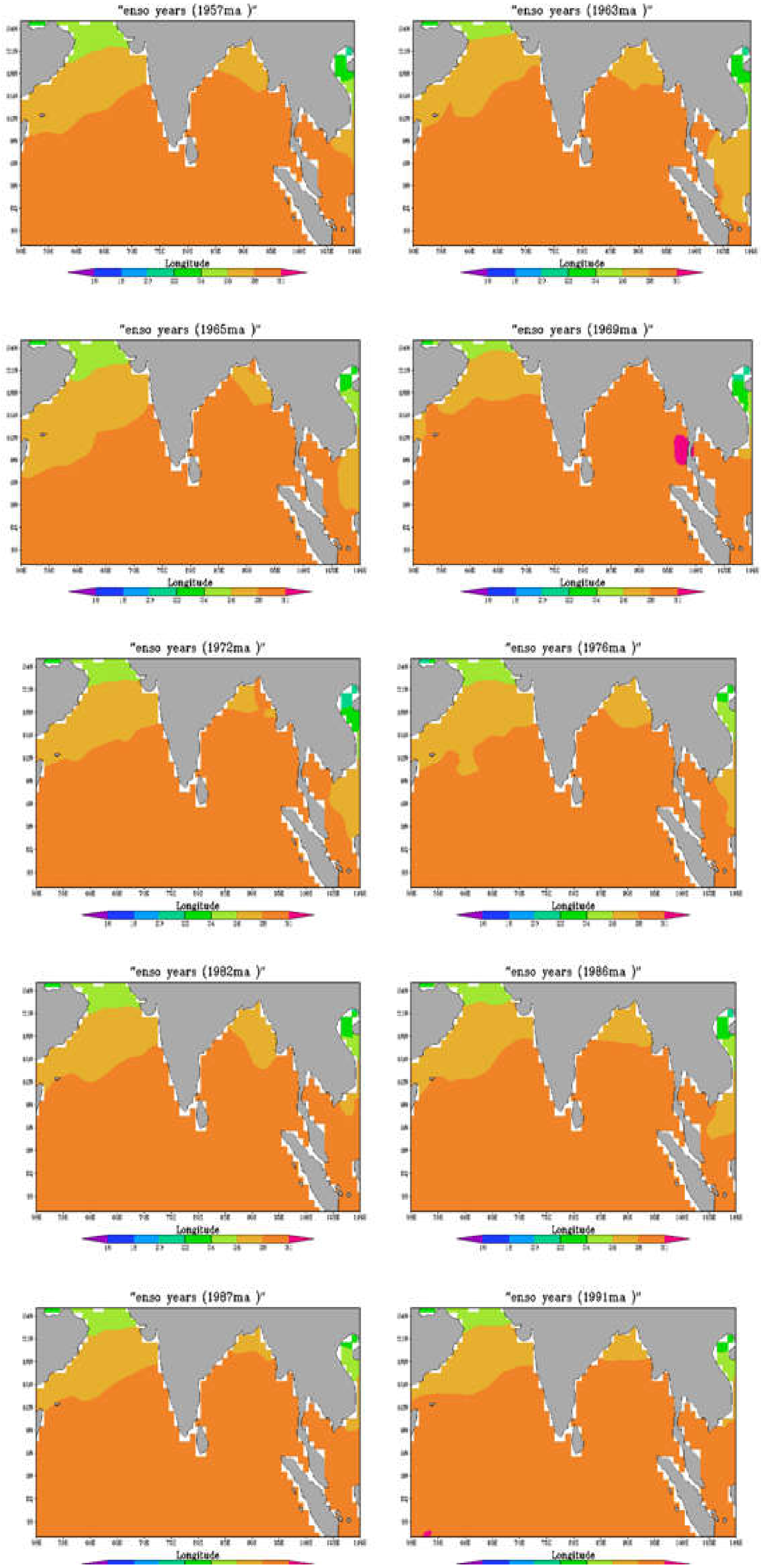
Weak LaNiña years:

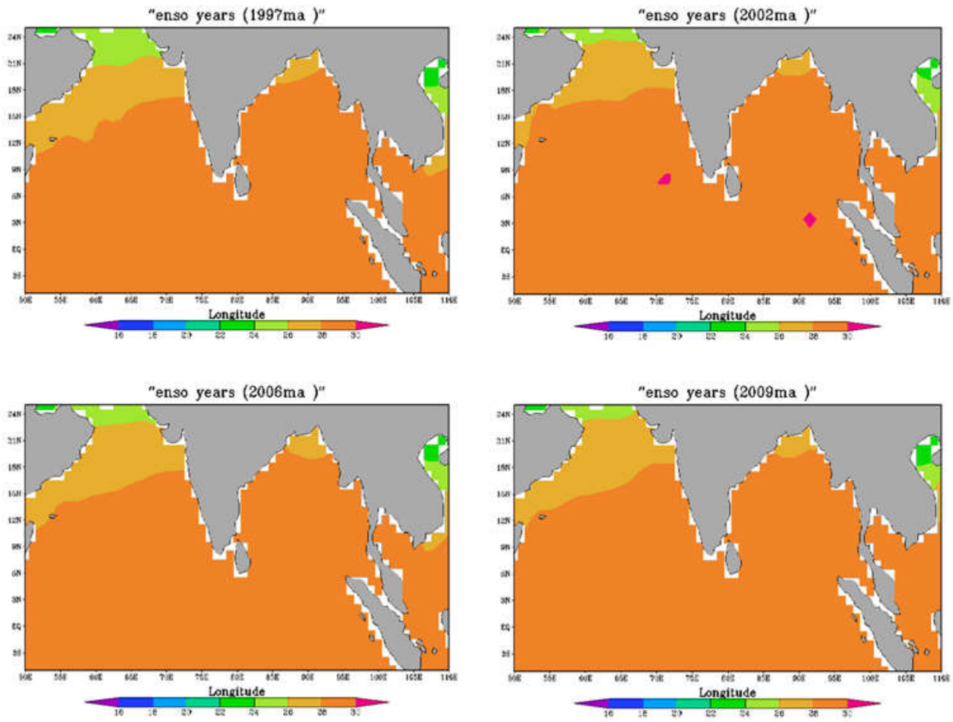


ENSO years:




"enso years (1904ma)"
"enso years (1905ma)"
"enso years (1911ma)"
"enso years (1913ma)"
"enso years (1918ma)"
"enso years (1925ma)"
"enso years (1929ma)"
"enso years (1930ma)"
"enso years (1940ma)"
"enso years (1951ma)"
Longitude


"enso years (1957ma)"
Longitude
"enso years (1963ma)"
Longitude
"enso years (1965ma)"
Longitude
"enso years (1969ma)"
Longitude
"enso years (1972ma)"
Longitude
"enso years (1976ma)"
Longitude
"enso years (1982ma)"
Longitude
"enso years (1986ma)"
Longitude
"enso years (1987ma)"
Longitude
"enso years (1991ma)"
Longitude



values of sea surface temperature. In the years 1906, 1928 and 1933 the entire Bay of Bengal shows same values. Over the Arabian Sea the sea surface temperature is low during the years 1906, 1909 and 1910. The SST over the South Eastern Arabian Sea is high, it may be the good condition for the warm pool formation and hence for the good amounts of rainfall over India. But during the year 1928 the India experiences less amounts of rainfall (below normal rainfall, 76 cm). There are other factors that affect the rainfall.

Strong LaNiña years: The sea surface temperature over Arabian Sea, Bay of Bengal and equatorial Indian Ocean is favorable for the formation of warm pool in the years 1999, 2010. The year 2010, shows the sea surface temperature greater than 30^0c over equatorial Indian Ocean and south eastern Arabian Sea .This is a good condition for getting good amount of rain fall over India.

Moderate LaNiña years: In the year 1998, the sea surface temperature over the equatorial Indian ocean and the south eastern Arabian sea shows the high values (>30^0c). The remaining parts of the Bay of Bengal and the Arabian Sea show the values 28 to 30^0c. The values of sea surface temperature over the most parts of Arabian Sea and Bay of Bengal and Indian Ocean ranges from 28 to 30^0c.

Weak LaNiña years: The two months mean SST pattern for the years 1995, 2000, 2005, and 2011 is observed. The SST over the Indian Ocean shows the same values for all the years. SST is low over the head Bay of Bengal and the North Arabian Sea. But in the year 2005, the SST is maximum (>30^0c) over the domain 2^0 S-3^0 N and 77^0 E-82^0 E.

ENSO years: The two months mean SST pattern for the years 1929, 1940, 1957, 1963, 1969, 1972, 1976, 1982, 1986, 1987, 1991, 1997, 2002, 2006 and 2009 shows that the most of area over the Arabian Sea high sea surface temperatures. The west coast of India and the south Eastern Arabian Sea shows the maximum temperatures.

During the years 1877, 1888, 1899, 1902, 1904, 1905, 1911, 1913, 1918, 1951 and 1965 the SST pattern shows that the SST is low in most of the area over the Arabian Sea. But the South Eastern Arabian Sea shows the high values when compared to the other parts of the Arabian Sea.

Conclusion

In the year 1998, the sea surface temperature in the months of March and April is about 30^0 c over the South East Arabian Sea. It is a good condition for the formation of the warm pool. In the year 1998, the SST's in the warm pool region are more. In 1998, All India Summer Monsoon Rainfall is 7.5% more than the average rainfall over All India Rainfall that is why we say that the year 1998 is good monsoon year. Hence we may conclude that the higher sea surface temperatures over warm pool area in the pre monsoon season because the good amounts of rainfall over India. And also the year 2010, shows similar temperatures and are responsible for the good monsoon. It is observed that during the LaNiña (strong, moderate and weak) years the sea surface temperatures are higher. This condition is favorable for the active monsoon over India. During the ElNiño (strong, moderate and weak) years the sea surface temperatures lie between 28^0 c and 30^0 c. And also during the ENSO years the South East Arabian Sea experiences higher sea surface temperature. This may be favorable for the formation of the warm pool. But there are other parameters that influence the monsoon over India.

REFERENCES

Clement, A. C., R. Seager, and R. Murtugudde 2005. Why are there tropical warm pools? *J. Clim*., 18, 52945331, doi:10.1175/JCLI3582.1.

Colborn J. 1975. the thermal structure of the Indian Ocean (Hawaii; The University press) 173pp.

Delcroix T., Dewitte B., duPenhoat Y. *et al*., . 2000. Equatorial waves and warm pool displacements during the 1992–1998

El Niño-Southern Oscillation events: Observation and modeling. *J. Geophys. Res.*, 105: 26 045–26 062.

Joseph P V. 1990. Warm pool in the Indian Ocean and monsoon on set; Trop. Ocean – atmos. Newsl. 53 1-5.

Mcphaden, J. 1982. Variability in the central equatorial Indian Ocean Part I: Ocean dynamics; *J. Mar. Res*. 40 157-176.

Meng, X., and D. Wu 2002. Contrast between the climatic states of the warm pool in the Indian Ocean and in the Pacific Ocean, *J. Ocean Univ. China*, 1, 119–124, doi:10.1007/s11802-002-0003-y.

Saji, N. H., and Yamagata, T.2003. Possible impacts of Indian Ocean dipole mode events on global climate, *Clim. Res*., 25, 151–169, doi: 10.3354/cr025151.

Saji, N. H., B. N. Goswami, P. N. Vinayachandran, and T. Yamagata 1999. A dipole mode in the tropical Indian Ocean, Nature, 401, 360–363,doi:10.1038/43854.

Shety SR. 1986. A model study of the seasonal cycle of the Arabian Sea surface temperature; *J .Mar. Res*.44 521-542.

Tourre, Y.M. and W.B. White, 1994. Does the Indian Ocean have El Niño of its own? *Eos*, 75, 585-6.

Vinayachandran PN. and S R Shetye1'national Institute of Oceanography, Dona Paula, Goa 403 004, India. Centre for Atmospheric Sciences, Indian Institute of Science, Bangalore 560012, India MS received 10 August 1990; revised 29 January 1991.

Webster, P. J., A. M. Moore, J. P. Loschnigg, and R. R. Leben 1999. Coupled oceanic-atmospheric dynamics in the Indian Ocean during1997–98, *Nature*, 401, 356–360, doi:10.1038/43848.

Williams, P., and C. Funk 2011. A westward extension of the warm pool leads to a westward extension of the Walker circulation, drying eastern Africa, *Clim. Dyn*., 37, 2417–2435, doi: 10.1007/s00382-0100984-y.

Wyrtki K 1973. An equatorial jet in the Indian Ocean science 181 262-264.

Xie, S.-P., H. Anamalai, F. A. Schott, and J. P. McCreary 2002. Structure and mechanisms of South Indian Ocean climate variability, *J. Clim*., 15,864–878, doi:10.1175/ 15200442 (2002)015<0864:SAMOSI>2.0.CO2

Zhang Qilong, Hou Yijun, QI Qinghua, BAI Xuezhi**.** 2009. Variations in the eastern Indian Ocean warm pool and its relation to the dipole in the tropical Indian Ocean. Chinese *Journal of Oceanology and Limnology* Vol. 27 No. 3, P. 640-649.

****