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Trends in equatorial Pacific sea surface temperatures

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सार – अलनीलों की परिघटना कम से कम 100 वर्षों से भी अधिक पुरानी है। बहुत से वैज्ञानिक और अन्वेषकों के अनुसार भूमध्यरेखीय प्रशांत महासागर में SST का भूमंडलीय मॉनसून परिचालन पर और इसके विपरीत भारतीय ग्रीष्मकालीन मॉनसून (ISM) पर प्रभाव रहा है। इस अध्ययन में SST के (ERSST) विस्तारित पुन: निर्मित आँकड़ों का उपयोग किया गया है। ये आँकड़े सांख्यिकीय पद्धतियों द्वारा किए गए विश्लेषण के अनुसार हैं। इसकी आवर्तिता को जानने के लिए फूरिये विश्लेषण किए गए। भूमध्यरेखीय प्रशांत महासागर के SST में जलवायु विज्ञान और उसकी प्रवृत्तियों का अध्ययन किया गया और प्राप्त परिणामों पर विचार किया गया।

ABSTRACT. The phenomenon of the “ElNino” is well known at least for more than 100 years. Many scientists and investigators showed that the equatorial pacific, especially the East Pacific SSTs, have an influence on the Global monsoon circulation and in turn on the Indian Summer Monsoon (ISM). The extended reconstruction of SSTs (ERSSTs) data has been used in this study. The data has been subject to analysis by statistical methods. Fourier analysis has been done to know periodicity. The climatology & trends in the Equatorial Pacific SSTs have been studied and results discussed.

Key words – Fourier analysis, Periodicity, Trend, Climatology, Indian summer monsoon, East pacific.

1. Introduction

“ElNino” is an oscillation of the ocean-atmospheric system with unusually warm ocean temperatures in the equatorial pacific. It is opposite of the phenomenon known as “LaNina” which is associated with cooler ocean temperatures. The “ElNino” is a warm episode whereas the “LaNina” is a cold episode in the Equatorial Pacific. In normal conditions, the trade winds blow towards the west across tropical pacific and the south east winds increase the warm water surface in the west pacific as a consequence of which the sea surface is 0.5 meters higher at Indonesia than at Ecuador. That makes the west pacific wet and the East pacific dry. However, during the “ElNino” phase the trade winds relax and the warm water starts flowing eastwards taking rainfall with it and pool up of warm water in the east pacific leads to increased rainfall along Peru-Ecuador coasts often leading to devastating floods (Wyrtki, 1985; Fedorov *et al.*, 2002; Wang *et al*., 2004; Clarke, 2008). The movement of the warm waters towards east alters the general circulation of the atmosphere that leads to weather changes worldwide.

To know the secrets of “ElNino” a Tropical Atmosphere Ocean (TAO) project was started. It consisted of seventy carefully placed buoys working together as an array, to collect vital data on sea surface temperatures of the Equatorial Pacific and the atmosphere above the Ocean. The project was completed in the year 1994 and scientists all over the world were able to watch for the signs of “ElNino” since then. Many countries participated in this project. The “ElNino” can be seen by the sea surface temperature measurements taken by TAO array. The TAO array (renamed as TAO/TRITON array on 1st January, 2000) consists of approximately 70 moorings in the Tropical Pacific Ocean, tele-metering oceanographic and meteorological data to shore in real-time via the Argos (Advanced Research and Global Observation system) satellite-based location and data collection system on board of the polar orbiting satellites of NOAA (National Oceanic and Atmospheric Administration) series which enables scientists to gather information as showing in Fig. 1. Global Tropical Moored Buoy Array (GTMBA) is a multi-national effort to provide data in real time for climate research and forecasting. Components of the global array include the Tropical Atmosphere Ocean/Triangle Trans-Ocean Buoy Network (TAO/ TRITON) in the Pacific, the Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) and the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) in the Indian Ocean. The main focus is on intra-seasonal-to-decadal and longer timescales, including “El Niño/Southern Oscillation” and its decadal modulation in the Pacific, the

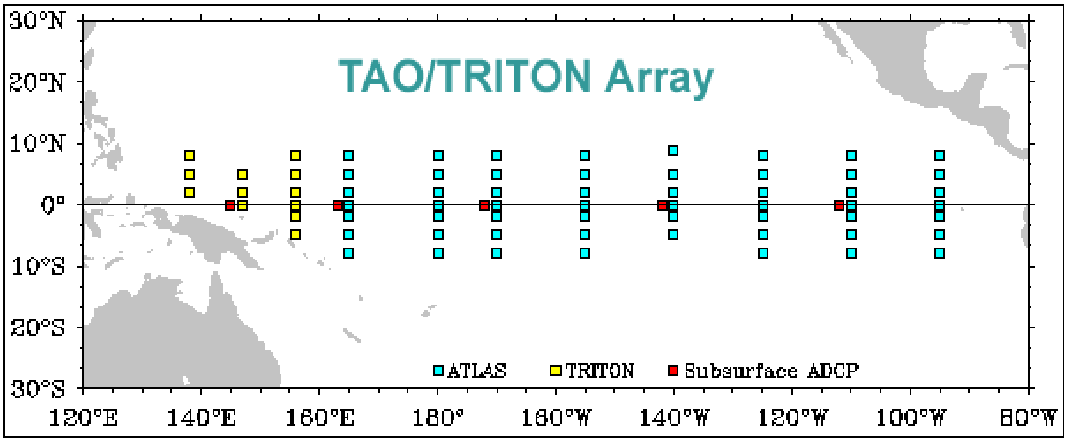

Fig. 1. Showing Tropical Moored Buoy Network (1999)

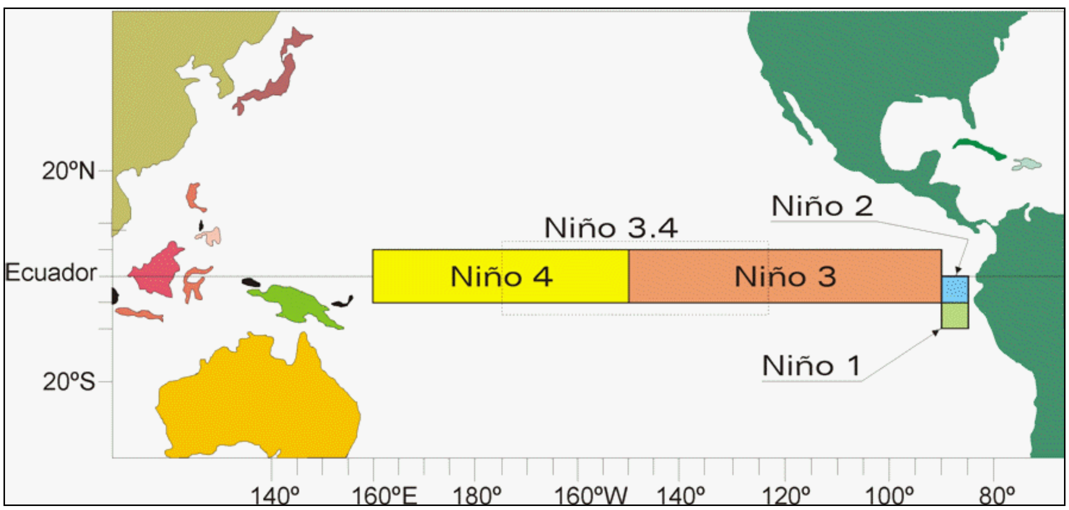

Fig. 2. Showing four NINO regions in Pacific Ocean

meridional gradient mode and equatorial warm events in the Atlantic and the Indian Ocean Dipole. The intra-seasonal Madden-Julian Oscillation which originates in the Indian Ocean but affects all three oceans. TAO/TRITON data have been used in over 600 refereed journal publications since its inception in 1985. Over half of these (341) have appeared since 2000. Recent scientific highlights include observational verification of the "Recharge Oscillator theory" for ENSO. The theory provided a formal mathematical framework for the hypothesis that a buildup of excess warm water in the equatorial band is a necessary precondition for the development of El Niño events. However, sustaining and enhancing the GTMBA is a high priority because of its unique and essential role in support of climate forecasting and research (Phaden *et al*., 2009 & 2010).

The analysis of ship, buoys and other platforms collected data under International Comprehensive Ocean Atmosphere Data (ICOADS) led to the extended reconstruction of SSTs (ERSSTs) with various versions and the latest being the ERSST v3. In this version satellite derived SST data has also been incorporated. This data set is generated using the *in situ* SSTs and improved statistical methods that allow the stable reconstruction using the sparse data. This data set is useful for long term global and basin wise studies. Both *in situ* and satellite (AVHRR) SST data were used as inputs. However, the addition of satellite SSTs introduced a small residual cold bias (in the order of .01 °C). The Advanced Very High Resolution Radiometer (AVHRR) is a broad-band, four or five channel (depending on the model) scanner, sensing in the visible, near-infrared, and thermal infrared portions of the electromagnetic spectrum. This sensor is carried on the National Oceanic and Atmospheric Administration's (NOAA's) Polar Orbiting Environmental Satellites (POES), beginning with TIROS-N in 1978. The data set included AVHRR IR channel measurements that can only be obtained in clear-sky conditions, and cloud contaminated data are often difficult to identify. This contamination leads to a cold SST bias in the retrievals. An attempt was made to correct for these biases as mentioned but the adjustment did not fully compensate for the cold bias or difficult to correct (Huang *et al.*, 2013). While this small difference did not strongly impact the long term trend, it was sufficient to change rankings of warmest month in the time series, etc. Therefore, the use of satellite SST data was discontinued and the resultant data set is v3b (Smith & Reynolds, 2003 & 2004; Smith *et al*., 2008). The improvements were justified with simulated data sets (Xue *et al.*, 2003)

2. Data and methodology

In order to study, the variations in the SSTs over the four NINO regions (NINO 4, NINO 3.4, NINO 3 & NINO 1.2) as shown in Fig. 2 the Extended Reconstructed Sea Surface Temperature (ERSST) monthly data sets for the period 1900-2011 (Smith *et al*., 2008), collected from the National Climate Data Centre (NCDC), US were used. The year-wise and month-wise SST data of four Nino regions is firstly averaged to get the climatology of the four Nino regions under consideration. The maximum, minimum SSTs recorded with month & year has been picked up. Then, the SST anomalies over the four Nino regions have been computed. Later, the data has been used to compute trends and periodicity using statistical methods and Fourier analysis respectively.

3. Results and discussion

Trenberth & Stepaniak, 2001 indicated that every "ElNino" event is somewhat different and distinct in character and warm phase episodes come in different flavors. The "ElNino" has been quantified in terms of SST anomalies in the Niño-3 region (5° N-5 °S, 150°-90° W) which exceed 0.5 °C or when SST anomalies in the Niño-3.4 region (5° N-5° S, 170°-120° W) exceed 0.4 °C. In addition to those noted above, use is made of SSTs averaged over the Niño-1+2 region (0°-10° S, 90°-80° W), which is the traditional Niño region along the South American coast, and Niño-4 (5° N-5° S, 160° E-150° W) region. However, the SSTs in all four Niño regions are highly correlated. Hence a simple description has not been easy to accomplish. To even approximately describe the character and evolution of ENSO events it is essential to have at least two indices and perhaps more, and a primary measure of success has been the magnitude of SST anomalies in Niño-3.4 region for example ONI (Oceanic NINO index). The 'Nino' areas of the equatorial Pacific Ocean were devised by the Climate Analysis Centre for real time climate monitoring. The identified key region in the eastern equatorial Pacific, centered near 2.5° S and 130° W, where the SST anomaly shows the highest correlation coefficient of 0.9 with average SST anomaly in the entire 20° N-20° S, 80°-180° W area, thus best represents the entire eastern Pacific Ocean. This key area is almost the centre of the Nino 3 region. Another index commonly used for monitoring the ENSO is the Multivariate ENSO Index (MEI) based on the six main observed variables over the tropical Pacific. These six variables are: sea-level pressure (P), zonal (U) and meridional (V) components of the surface wind, sea surface temperature (S), surface air temperature (A), and total cloudiness fraction of the sky (C). These observations have been collected and published in ICOADS for many years. The MEI is computed separately for each of twelve sliding bi-monthly seasons (Dec/Jan, Jan/Feb,..., Nov/Dec). After spatially filtering the individual fields into clusters, the MEI is calculated as the first un-rotated Principal Component (PC) of all six observed fields combined. This is accomplished by normalizing the total variance of each field first, and then performing the extraction of the first PC on the co-variance matrix of the combined fields. In order to keep the MEI comparable, all seasonal values are standardized with respect to each season and to the period 1950-93 as a reference period (Wolter and Timlin, 2011). The only special feature of MEI is that it takes more atmospheric parameters as where other well known indices are based on SSTs. The MEI is considered as the ENSO index where as ONI is considered as the Elnino index. Therefore, MEI has not much relevance in this study. El Niño and the Southern Oscillation (SO), also known as ENSO, is a periodic fluctuation in sea surface temperature (El Niño) and the air pressure of the overlying atmosphere between Tahiti and Darwin stations (Southern Oscillation) across the equatorial Pacific Ocean. "ElNino" is the warm phase of a dominant mode of coupled ocean-atmosphere. In the span of 112 years from 1900 to 2011 26 "ElNino" events occurred in which the "ElNino" event of 1997-1998 was a major event and was the strongest preceded by another major event 1982-1983 though not strong as the earlier one. The "ElNino" events are being closely monitored as such events have global impact and influence the rainfall patterns worldwide. The quasi periodic climatic southern oscillation (SO) coupled with sea surface temperature (SST) rise in the eastern pacific, a phenomenon known popularly as ENSO, is known to produce extreme weather all over the globe especially in those areas neighbouring the Pacific Ocean. "ElNino"/"Southern Oscillation" (ENSO) is the dominant mode of interannual climate variability, affecting tropical atmospheric variability such as the Walker circulation (Walker, 1923) and global climate through atmospheric teleconnections (Horel and Wallace, 1981). Long-term changes in ENSO characteristics have received much attention (Fedorov and Philander, 2001). Bjerknes (1969)

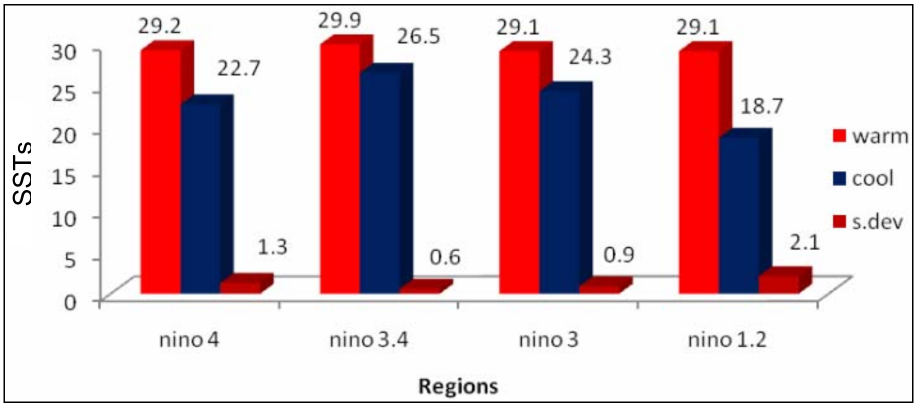

Fig. 3. Showing the Highest and Lowest SSTs over four NINO regions

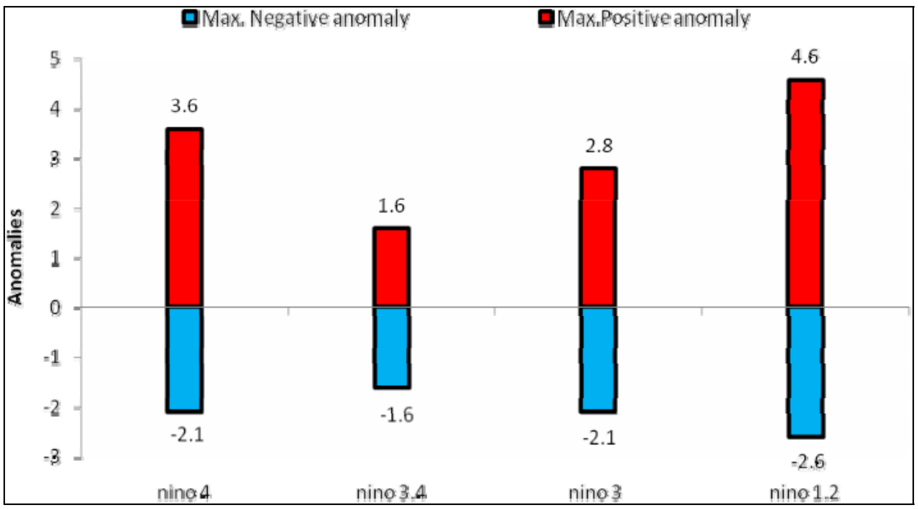

Fig. 4. Showing Highest & Lowest SST anomalies in Four NINO regions

recognized that there is a close connection between El Niño and the Southern Oscillation (ENSO) and they are two different aspects of the same phenomenon. Bjerknes hypothesized that a positive ocean-atmosphere feedback involving the Walker circulation is a cause of ENSO. An initial positive sea surface temperature (SST) anomaly in the equatorial eastern Pacific reduces the east-west SST gradient and hence the strength of the Walker circulation (Lindzen and Nigam, 1987), resulting in weaker trade winds around the equator. The weaker trade winds in turn drive the ocean circulation changes that further reinforce SST anomaly. This positive ocean-atmosphere feedback leads the equatorial Pacific to a warm state, *i.e.*, the warm phase of ENSO.

The study of variations of SSTs in the four "ElNino" regions of pacific is therefore of considerable importance and quite significant to understand the impact of the warming/cooling over these regions on the world weather and climate. In order to improve understanding of these aspects, the variation in the SSTs over the four NINO regions (NINO 4, NINO 3.4, NINO 3 & NINO 1.2) have been analyzed. The Nino 1.2 region is along Peru-Ecuador coast (0-10° S, 80-90° W). The other regions are Nino 3 (5° N-5° S, 90-150° W), Nino 3.4 (5° N-5° S, 120-170° W) & Nino 4 (5° N-5° S, 150° W-160° E). It is found from the data sets that the annual long period average (1900-2011) for the four regions are 25.70 °C, 28.28 °C, 26.82 °C and 23.01 °C respectively indicating that the region NINO 3.4 has so far been the warmest and the NINO 1.2 is the coolest region historically. As per the sea surface temperatures records the NINO 3.4, NINO 3, NINO 4 & NINO 1.2 regions are in the descending order in terms of warmth. The highest & lowest SST values are also indicated in Fig. 3. The NINO 4 region was so far warmest in the month of April 1998 (29.16 °C) and coolest in November 1955 (22.69 °C). Similarly, the warmest and coolest periods for other three regions NINO 3.4, NINO 3 & NINO 1.2 as observed, are November 2009 (29.91 °C) & January 1974 (26.52 °C), October

1997 (29.13 °C) & November 1955 (24.29 °C) and March 1998 (29.13 °C) & August 1916 (18.67 °C) respectively. The standard deviation of SSTs for the four regions NINO 4, NINO 3.4 and NINO 3 & NINO 1.2 are 1.25 °C, 0.63 °C, 0.94 °C & 2.11 °C respectively. The standard deviation is highest for NINO 1.2 region and lowest for NINO 3.4 region. The maximum negative anomaly of 2.58 °C is noticed over NINO 1.2 region in the month of November (1909) and the minimum negative anomaly of 1.05 °C is noticed in NINO 3 region in the month of August (1975). The maximum positive anomaly of 4.64 °C is noticed over NINO 1.2 region in the month of June (1983) and the minimum positive anomaly of 1.02 °C is noticed over NINO 3.4 region in the month of June (2002).The maximum & minimum negative anomalies for NINO 4 region are 2.08 °C (November, 1955) & 1.37 °C (May, 1955) for NINO 3.4 region 1.64 °C (July, 1917) & 1.05 °C (August, 1975), for NINO 3 region 2.08 °C (November, 1955) & 1.20 °C (January, 1988) and for NINO 1.2 region 2.58 °C (November, 1909) & 1.45 °C (January, 1909) respectively. The maximum & minimum positive anomalies for NINO 4 region are 3.63 °C (November, 1997) & 1.93 °C (April, 1998), for NINO 3.4 region 1.61 °C (November, 2009) & 1.02 °C (May, 1997), for NINO 3 region 2.75 °C (November, 1997) & 1.38 °C (May, 1992) and for NINO 1.2 region 4.64 °C (June, 1983) & 3.13 °C (February, 1998) respectively. The maximum & minimum anomalies are shown in Fig. 4. Thus, the data sets could pick up five major “LaNina” & “ElNino” events on board only to mention even though other “ElNino” events are also detected. The data sets are therefore reliable and are widely used in “ElNino” research. It is also seen that in NINO 4 region on 44 (39%) occasions warming greater than 0.5 °C is noticed in the month of December, on 33 (29%) occasions neutral conditions are observed and in the same region in April cooling of less than -0.5 °C is noticed on 17 (15%) occasions. Over NINO 3.4 region on 78 (70%) occasions neutral conditions are seen in the month of June and on 14 (13%) occasions warming greater than 0.5 °C is observed in the same month. In November on 37 (33%) occasions cooling conditions are noticed over NINO 3 region.

The month wise trend analysis using least squares method using intercept, slope and trend of the four data sets indicated negative long term trends in all the four regions and in NINO 4 the trend figures lie in between 0.33 (November) & 0.24 (January), in NINO 3.4 in between 0.37 (July) & 0.27 (January), in NINO 3 in between 0.36 (October) & 0.19 (February) and in NINO 1.2 in between 0.51 (February) & 0.27 (September). The results are statistically significant at 90% confidence level. Four different data sets were considered in the study made by Deser *et al.*, 2010. The data sets are Hadley Centre SST version 2 (HadSST2), Hadley Centre sea ice and SST version 1 (HadISST1) (Rayner *et al.*, 2003). The National Oceanic and Atmospheric Administration (NOAA) Extended Reconstructed SST version 3 (ERSSTv3b) (Smith *et al.*, 2008) and the Kaplan Extended SST version 2 (Kaplanv2) (Kaplan *et al.*, 1998). HadSST2 and Minobe & Maeda (2005) (both on a 2° × 2° latitude/longitude grid) are based on the International Comprehensive Atmosphere ‑ Ocean Data Set (ICOADS) and employ different quality control and bias correction procedures. Minobe & Maeda (2005) produce the SST data set with no “analysis” of the data is performed (e.g., no spatial or temporal smoothing or interpolation) and missing grid boxes are not filled in. HadISST1 (1° × 1°), ERSSTv3b (2° × 2°), and Kaplan v2 (5° × 5°) are analysis products which use different optimal statistical procedures to smooth the data and fill in missing values. Therefore, the SST data sets are of two types that are generally available to researchers. The first type is the one with little or no interpolation and the second type is the one with heavy interpolation. The Hadley Centre Sea Surface Temperature data set (HadSST) from the UKMO (United Kingdom Meteorological Office), Reynolds reconstructed SST data from NCEP (National Centre for Environmental Prediction and Kaplan SST data sets are heavily interpolated. The heavily interpolated SST datasets can have complete spatial and temporal coverage. However, the interpolation may include false gridded values. On the other hand the SST datasets without interpolation have large amount of missing data but without any artificial data.

Over the last century, sea surface temperature (SST) trends are generally positive across the global oceans, with the exception of negative trends in the far northern Atlantic Ocean (Deser *et al.*, 2010). SST trends in the equatorial Pacific Ocean are especially controversial due to the discrepancy in the sign of the trend in the central and eastern Pacific among various SST datasets (Karnauskas *et al.*, 2009).The study thus indicated that the “ElNino: conditions are on the receding side supporting the idea that the “ElNino” is dying away with neutral or “LaNina” conditions prevailing in four NINO regions of Pacific as the above figures indicate that over NINO 4 the maximum negative trend is in November and the maximum negative trend is in October over NINO 3. A study of the data sets of NINO 4 & 3.4 regions for the months of October & December using Fourier analysis suggested a periodicity of 2 & 3 years in NINO 4 and a periodicity of 5 years in NINO 3.4 region. Interannual sea surface temperature (SST) variability in the central equatorial Pacific consists of a component related to eastern Pacific SST variations (called Type-1 SST variability) and a component not related to them (called Type-2 SST variability). Type-1 variability is characterized by SST anomalies extending from the South

TABLE 1

Average, maximum, minimum and Standard Deviation of SSTs over four regions

Region	Nino 4	Nino 3.4	Nino 3	Nino 1.2
LPA	25.70	28.28	26.82	23.01
Max	29.16 (April,1998)	29.91 (November,2009)	29.13 (October,1997)	29.13 (March,1998)
Min	22.69 (November,1955)	26.52 (January,1974)	24.29 (November,1955)	18.67 (August,1916)
Std. dev.	1.25	0.63	0.94	2.11

Legend : LPA – Long Period Average (1900-2011); Max – Maximum; Min – Minimum; Std.dev. – Standard Deviation

TABLE 2

Intercept and slope for the trends in SST over four Nino regions

Region →	Nino 4		Nino 3.4		Nino 3		Nino 1.2	
Month ↓	Intercept	slope	Intercept	slope	Intercept	slope	Intercept	slope
Jan	16.905	0.004	18.484	0.005	19.444	0.004	8.108	0.008
Feb	17.165	0.005	18.418	0.005	19.912	0.003	7.578	0.009
Mar	17.127	0.005	17.863	0.005	18.802	0.004	8.680	0.009
Apr	17.063	0.005	17.648	0.005	17.889	0.005	8.374	0.009
May	17.830	0.005	17.403	0.006	19.160	0.004	6.213	0.009
Jun	14.885	0.006	16.555	0.006	17.198	0.005	5.992	0.009
Jul	15.644	0.005	15.545	0.007	16.627	0.005	8.081	0.007
Aug	15.368	0.005	15.671	0.006	16.196	0.005	10.837	0.005
Sep	14.326	0.005	16.075	0.006	15.485	0.006	11.081	0.005
Oct	12.924	0.006	15.283	0.007	13.702	0.006	10.739	0.005
Nov	13.180	0.006	15.313	0.007	13.886	0.006	9.475	0.006
Dec	13.852	0.006	17.070	0.006	15.573	0.006	5.331	0.009

American coast to the central Pacific and is associated with basin wise subsurface ocean variations. This type of variability is dominated by a major 4–5-yr periodicity and a minor biennial (2–2.5 yr) periodicity. In contrast, Type-2 variability is dominated by a biennial periodicity, is associated with local air–sea interactions, and lacks a basin wise anomaly structure. In addition, Type-2 SST variability exhibits a strong connection to the subtropics of both hemispheres, particularly the Northern Hemisphere. For this study both Hadley as well as ERSST v3b data sets were considered (Yu *et al.*, 2010). The study also revealed that the "ElNino" conditions first develop in the central pacific and then march east wards and then subsequently west wards. The long period averages, Maximum & Minimum observed values with standard deviation on annual scale are presented in Table 1. The month wise long period average SSTs (1900-2011) and their maximum & minimum values during the period of study are represented graphically for the four Nino regions in Figs. 5 to 8. The month wise and region wise regression equations for predicting the future state of the four regions considered for the purpose of study are presented in Table 2. Based on the statistical regression equation developed the predicted SSTs for the month of November for NINO 4 and for the month of October for NINO 3 region are presented graphically in Figs. 9 & 10 respectively. In Fig. 11, the month wise long period average values (1900-2011) of all the four Nino regions are presented. As of now it is understood that normally the west end of the Pacific Ocean is warmer and sea slightly higher level in comparison with the east end of the Pacific Ocean and due to slackening of Easterlies, the piling up of warm waters in West Pacific decrease and warm water move towards the eastern side of the Pacific. Here, Warm water in the coastal areas of Peru is considered as "ElNino" that occurs during Christmas month. Therefore, there is a time lag between these "ElNino" and normal conditions. Hence, if warm waters appear in the month of October in NINO 3 regions, the warm water move both ways to NINO 4 & NINO 1+2 regions. Therefore,

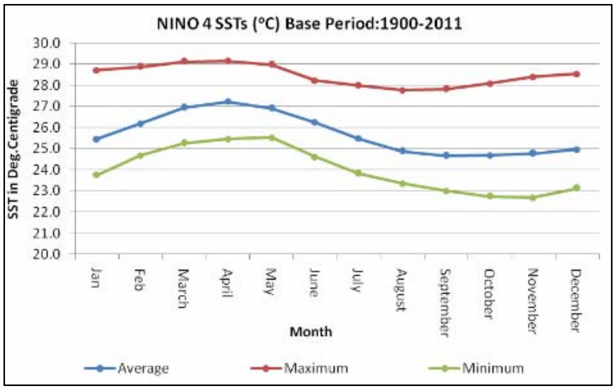

Fig. 5. Average, Maximum & Minimum SSTs over Nino 4 region (1900-2011)

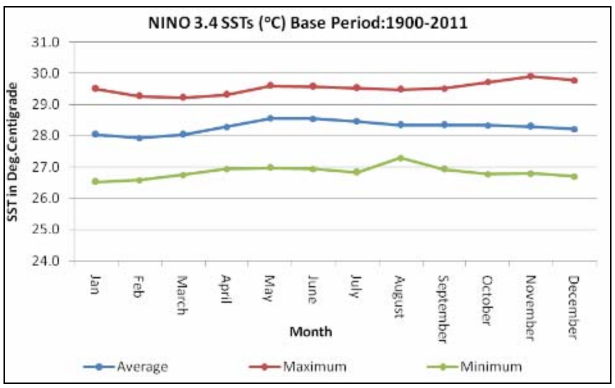

Fig. 6. Average, Maximum & Minimum SSTs over Nino 3.4 region (1900-2011)

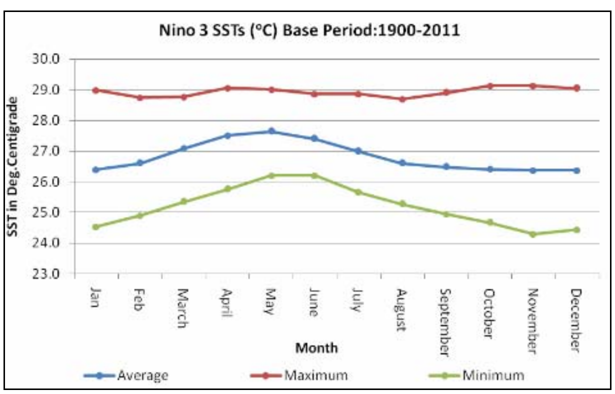

Fig. 7. Average, Maximum & Minimum SSTs over Nino 3 region (1900-2011)

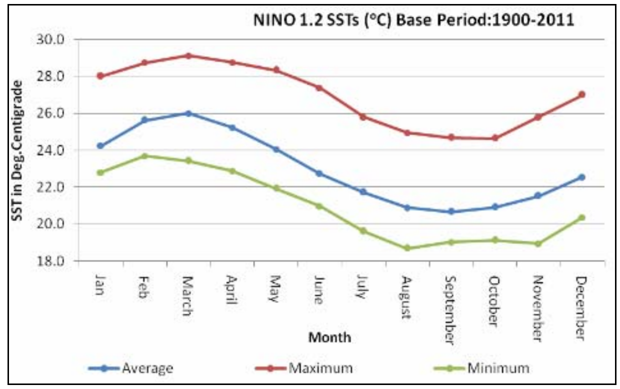

Fig. 8. Average, Maximum & Minimum SSTs over Nino 1.2 region (1900-2011)

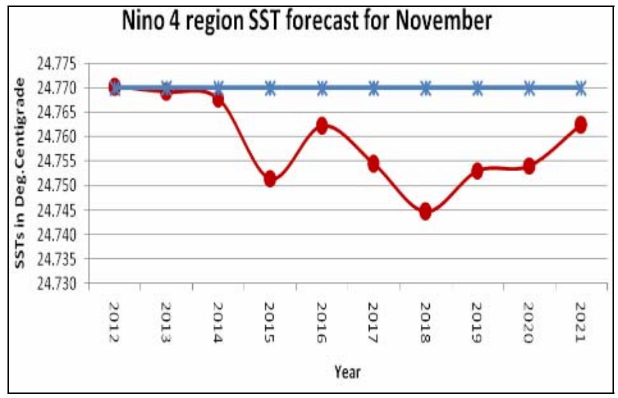

Fig. 9. SSTs forecast for Nino 4 region

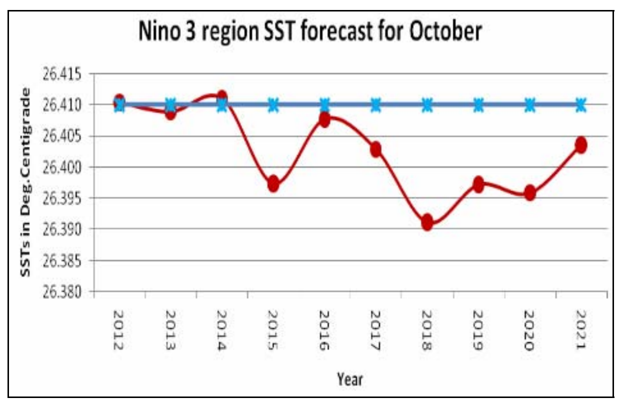

Fig. 10. SSTs forecast for Nino 3 region

"Elnino" would appear in the December month around Peru coast.

The study has been taken up as many scientists and investigators showed that the equatorial pacific especially the East Pacific SSTs have an influence on the monsoon circulation and in turn on the Indian Summer Monsoon (ISM). The warm episodes or "ElNino" events have been linked to the deficient summer monsoon over Indian sub continent and some studies have proved that "ElNino" event has a negative impact on the Indian Summer Monsoon one or two seasons later.

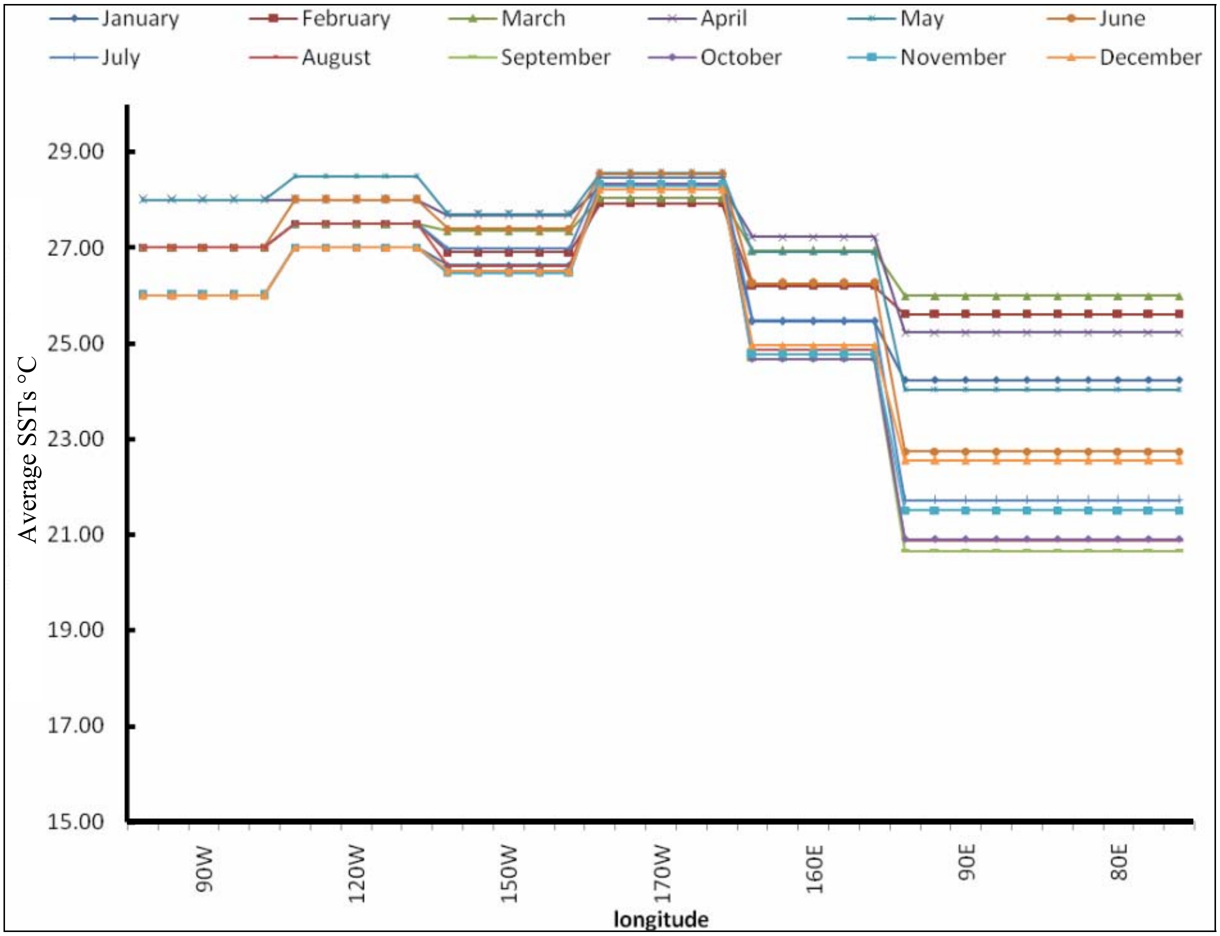

Fig. 11. Month-wise Long Period Average (LPA) SSTs

Rasmussion and Carpenter (1983) analyzed rainfall data of 1875-1979 pertaining to 31 Indian Meteorological Sub divisions to determine the relationship between Equatorial Pacific Warm Episodes and the inter-annual variability of Indian Summer Monsoon Rainfall. The analysis suggested a strong tendency for below normal rainfall during 25 moderate/strong warm events that occurred during the period. The area averaged rainfall (June to September) was below average in 21 out of 25 warm episodes. The studies to determine the relationship between warm episodes in Equatorial Pacific and Indian Summer Monsoon Rainfall are quite important because of the socio-economic impact of the ISMR. The weak monsoons are associated with drought, crop losses and strong monsoons are associated with devastating floods, loss of life & property and crop losses. Therefore, forecasting of Indian summer Monsoon rainfall based on the warm or cold episodes in the Equatorial pacific gained importance and momentum. However, to know the exact relationship, the circulation anomalies over Indian region during warm or cold episodes are to be investigated and understood. As per the earlier studies, warm episodes are associated with drought years. However the strong event of 1997-1998 didn't produce the expected results leading to the idea that the relationship between the warm episodes and the Indian summer monsoon is weakening. Kane (2006) indicated that in 133 year data only 60% of the "ElNino" or "LaNina" events are effective and the magnitude of anomalies are not in good relationship with these events. Krishna Kumar *et al.* (1999) after analyzing 140 years data suggested that the inverse relationship between warm episodes and the summer monsoon rainfall over India has broken down in recent years and he gave two possible reasons one, a South Eastward shift in the Walker circulation anomalies associated with ENSO events may Lead to a reduced subsidence over the Indian region, thus favoring normal monsoon conditions. Secondly, increased surface temperatures over Eurasia in winter and spring, may favor the enhanced land-ocean thermal gradient conducive to a strong monsoon. The results can be used for planning, policy making that suit to the evolution of the SST conditions in the Pacific Ocean as indicated in this study. The evolution of "LaNina" or neutral conditions may to certain extent offset the global warming and lead to cool summers in the coming decade.

4. Conclusions

Since "ElNino" events influence the world wide weather patterns due to changes in the Walker Circulation and also Hadley circulation, precise monitoring of these events is of utmost importance. These events have large socio-economic impact. The information on "ElNino" evolution and forecast necessary in near real-time in view of the above. Therefore, the study of climatology & History of "ElNino" events would help in predicting the future events. The correct prediction of "ElNino" events would help many countries worldwide as their economies dependent on the weather. In addition, the dynamical forecasts and the statistical forecasts are helpful in forecasting future Elnino events. Of the four NINO regions, NINO 3 & Nino 3.4 has highest average temperatures of around 28 °C & 27 °C respectively**.** The standard deviation of SSTs for the four regions NINO 4, NINO 3.4, NINO 3 & NINO 1.2 are 1.25 °C, 0.63 °C, 0.94 °C & 2.11 °C respectively. The surface wind driven warm waters of NINO 3 region move towards the NINO 3.4 & NINO 4 regions and away from the upwelling region of cool NINO 1+2 region. Once the surface winds become weak then the warm waters of NINO 3 region enter NINO 1+2 region causing "ElNino". These results confirm the earlier theories. Fourier analysis suggested a periodicity of 2 & 3 years in NINO 4 and a periodicity of 5 years in NINO 3.4 region. Nino 3 & Nino 4 regions have shown below normal SSTs during the months of October & November respectively over next ten years. Trend analysis using least squares method using intercept, slope and trend of the four data sets indicated negative long term trends in all the four regions. The results can be used after proper evaluation and validation, for planning, policy making that suit to the evolution of the SST conditions in the Pacific Ocean as indicated in this study and their possible impact on the monsoon rainfall based on the precise understanding of their relationships from other studies.

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