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Forecasting El Nino events for the region Nino 3.4

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ABSTRACT
Meteorologists have observed that northern hemisphere (NH) is warmer than southern hemisphere (SH). It is well known that extra tropical low pressure system tends to move equator ward and eastward. Cold air coming from 40°S or from South of 40°S is restricted by persistent lows (negative anomalies of geo potential height at 850 hPa: extra tropical lows) located between 140°E - 080°W/30°S- 40°S during El Nino years. Coverage area of lows may be found to be more in the northern latitudes. Prominent low features may be observed from January-February onwards when three months average value of the Ocean Nino Index (ONI) starts increasing from lower to higher value during certain years. Presence of low is also reflected by associated circulation/trough observed at 850 hPa vector wind between 140°E - 080°W/30°S-40°S. Westerly component of wind can be observed prominently between 160°E - 080°W and 40°S - equator depending upon the position of lows. Subtropical highs (positive anomalies of geo potential height at 850 hPa) at 850 hPa, located between 140°E - 080°W/ 30°S - 40°S weaken and shift southwards, and extra tropical low pressure systems, located south of 40°S shift northwards from their position during El Nino years. The contrast feature is observed during La Nina years and many non El Nino years in the form of prominent highs, which are observed between 140°E-080°W/30°S-40°S and the coverage area may be found to be more in the northern latitudes. Similar feature can be observed in the form of anti cyclone or ridge at 850 vector winds. Easterly component of wind can be observed prominently between 160°E - 080°W and 40°S - equator depending upon the position of highs.

Nino 3.4 is 5°N-5°S/170°W-120°W

Key words: Geo potential height anomalies at 850 hPa, low, high, ONI, El-Nino and La Nina years.

INTRODUCTION

Rise in ONI values (ONI is based on SST departures from average in the Nino 3.4 region) for Nov-Dec-Jan from previous three months average Oct-Nov-Dec sets the panic alarm among the meteorologists all over the globe from January-February onwards. It was widely reported in Indian News Media in the last week of January 2017 (as quoted by private weather forecaster "Skymet"), "El Nino could resurface this year, affecting rainfall in the country. The current prediction indicates a rise in SST and if the trend sustains it could lead to a weak monsoon this year". As per ENSO bulletin issued by NOAA dated 6th February 2017, ONI value for Nov-Dec-Jan (NDJ) 2017 has increased to -0.7 from -0.8 from previous months (OND 2016) ONI value. A weaker than normal Indian monsoon has profound impacts on food production, energy supply and the economy of India. As has been widely reported recently, a weak monsoon could push up food prices and with it inflation testing the present Government's ability to promote economic growth (Slingo et al., 2014). A close observation of monsoon rainfall during El Nino and non El Nino years exhibits a rather unpredictable monsoon rainfall pattern, detailed below: 1) The available recorded information indicates that normal monsoon rainfall occurred over India during El- Nino years: 1953, 1957, 1958, 1963, 1969, 1976, 1977, 1994, 1997 and 2006 (1958 and 1994 have been considered as El Nino years as ONI value reached ≥ 0.5°C from SON). 2) In comparison deficient rainfall occurred over India during non-El-Nino years 1966 and 1974. 3) In contrast deficient rainfall occurred during El-Nino years: 1951, 1965, 1972, 1979, 1982, 1986, 1987, 1991, 2002, 2004, 2009 and 2015 (1979 has been considered as El Nino year because ONI value reached ≥0.5°C from SON). {P.S: El Nino years, in which ONI value reached ≥0.5 from OND (1968, 2014) and started decreasing from DJF and onwards (1983, 1992 and 1998), have not been included in El-Nino years}.

As the details given above clearly exhibit a quixotic monsoon rainfall pattern during El Nino and non El Nino years an attempt has been made, in the present study, to examine the possibility of forecasting EL-Nino events a few months before the onset of Indian summer monsoon in June or at least in the first week of June.

Shortly after Christmas each year a warm ocean current flows south along the coasts of Ecuador and Peru. Not every year, but occasionally, that current is stronger; it flows further south and is very warm. The result is extra heavy rain, which the coastal inhabitants of those countries have always welcomed for abundance of crops that it brings, and hence the name El Nino (the Christ child), for gifts of plenty that it bestows. Normally there is a large area of high pressure sitting over the eastern edge of the Pacific Ocean, just off the South American coast. From this high pressure zone the southern trade winds blow towards a large area of low pressure that is settled over Indonesia, on the other side of the ocean. These steady winds are strong and they drag the cool water that lies off South America westwards with them, so that it warms by contact with the atmosphere and by the heat of the Sun while travelling vast distances. The result is thick layer of warm water over the Western Pacific (around 40 cm higher than next to South American coast), and a mild deeper current that flows towards the east, known as counter current, which gently brings the warm water back, to cool, rise up off South America and start again. In the sky above, meanwhile, this body of warm water evaporates and moist air rises, adding to rains such as the monsoon. Further aloft and now drier, the air is carried by the fast moving upper-level winds to the east, where it cools and descends, adding to high pressure zone off South America where the cycle began. This, in essence, is the Walker circulation, and this is 'normality' (Lynch 2002). El Nino is a band of warm Ocean water temperatures that periodically develops off the Pacific coast of South America. El Nino is defined by prolonged warming in the Pacific Ocean sea surface temperatures when compared with the average value. The accepted definition is a warming of at least 0.5°C (0.9°F) averaged over the east central tropical Pacific Ocean. Typically, this anomaly happens at irregular intervals of two to seven years and lasts nine months to two years. The average period length is five years. When the warming occurs for only seven to nine months it is classified as El Nino conditions; when it occurs for more than that period it is called El Nino "episodes". Similarly La Nina conditions and episodes are defined for cooling. There is a phase of 'El Nino-Southern Oscillation' (ENSO), which refers to variations in the temperature of the surface of the tropical eastern Pacific Ocean and in air surface pressure in the tropical western Pacific. The two variations are coupled: warm oceanic phase, El Nino, accompanies high air surface pressure in the western Pacific, while the cold phase 'La-Nina' accompanies low air surface pressure in the western Pacific. The Southern Oscillation is the atmospheric component of El Nino. This component is an oscillation in surface air pressure between the tropical eastern and the western Pacific Ocean waters. The strength of the Southern Oscillation is measured by the Southern Oscillation Index (SOI). The SOI is computed from fluctuations in the surface air pressure difference between Tahiti and Darwin, Australia. El Nino episodes are associated with negative values of SOI, meaning there is below normal pressure over Tahiti and above normal pressure off Darwin. Low atmospheric pressure tends to occur over warm water and high pressure over cold water in part because of deep convection over the warm water (Reddy and Reddy 2014). The El Nino–Southern Oscillation is a single climate phenomenon that periodically fluctuates between 3 phases: Neutral, La Nina or El Nino. If the temperature variation from climatology is within 0.5°C (0.9°F), ENSO conditions are described as neutral. Neutral conditions are the transition between warm and cold phases of ENSO. Ocean temperatures (by definition), tropical precipitation, and wind patterns are near average conditions during this phase. Close to half of all years are within neutral periods. During El Nino years the cold water weakens or disappears completely as the water in the Central and Eastern Pacific becomes as warm as the Western Pacific (Wikipedia).

The onset of El Nino takes place during the northern hemispheric winter. At the time of onset of El Nino, weakening of the Southeast Pacific surface anticyclone and associated southeast trade winds, appearance of positive SST anomalies between 10°S and 30°S extending across much of the Southeast Pacific have been observed (Asnani, 2005). It has been observed that SST-anomalies in Eastern Pacific are directly and visibly connected to anomalies in the position and intensity of low-level subtropical anticyclones. It is also known that these low-level subtropical anticyclones in the eastern pacific form a chain of low-level subtropical anticyclones throughout the global subtropics; if one anticyclone has anomalous position or intensity, the whole global chain of low-level subtropical anticyclones manifests anomalies in position and intensity (Asnani and Verma 2007). Two types of El Nino episodes have been identified over Nino 3.4 area: (i) Spring (SP) type in which SST anomaly (SSTA) first increased to > 0.5°C in April or May and (ii) Summer (SU) type in which SSTA became >0.5°C in July-August. Composites of SSTA'S for these two types showed the following characteristics: (a) SP type generally shows stronger warm episode and also longer period episode than SU type event in terms of SSTA'S>0.5°C. (b) For the SP type events, equatorial westerly wind anomaly extends to International Date Line by January of EL Nino year; for SU type events, the westerly wind anomaly extends to International Date Line by May of the El Nino year, (Xu and Chan 2001). The inverse relationship between El Nino and ISMR is statistically significant only during and at the end of the monsoon season (Rajeevan and McPhaden, 2004). Most of the severe droughts over India are associated with El Nino. However, only less than half of El Nino events are associated with deficient rainfall over India. In other El Nino years, ISMR was either normal or excess. A recent study suggested that El Nino with warmest SST anomalies in the Central Pacific are more effective in focusing drought producing subsidence over India than events with the warmest SST

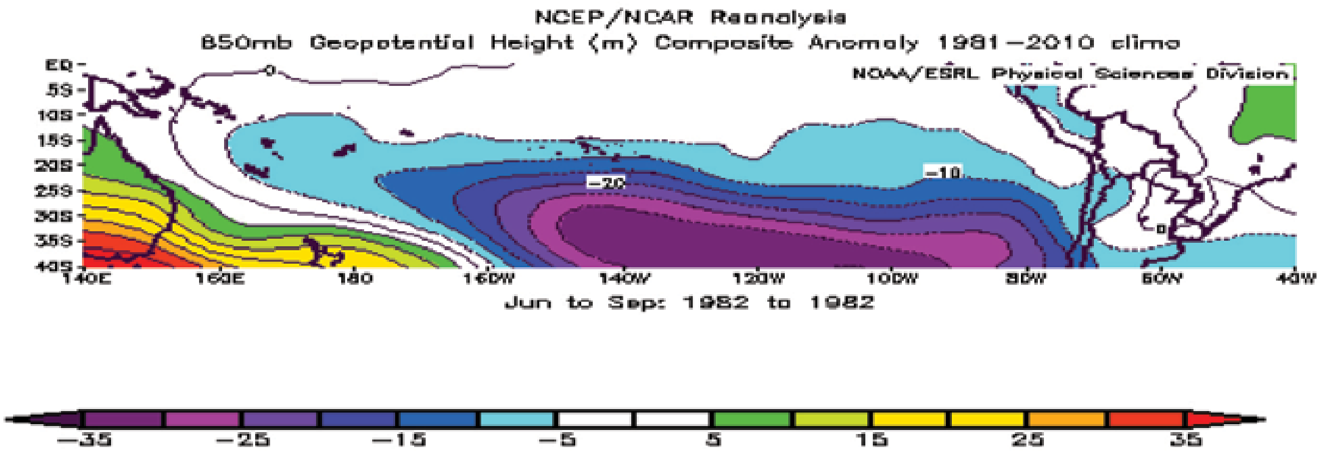

Figure 1. Anomaly of 850 hPa geo potential height for Jun-Sep 1982.

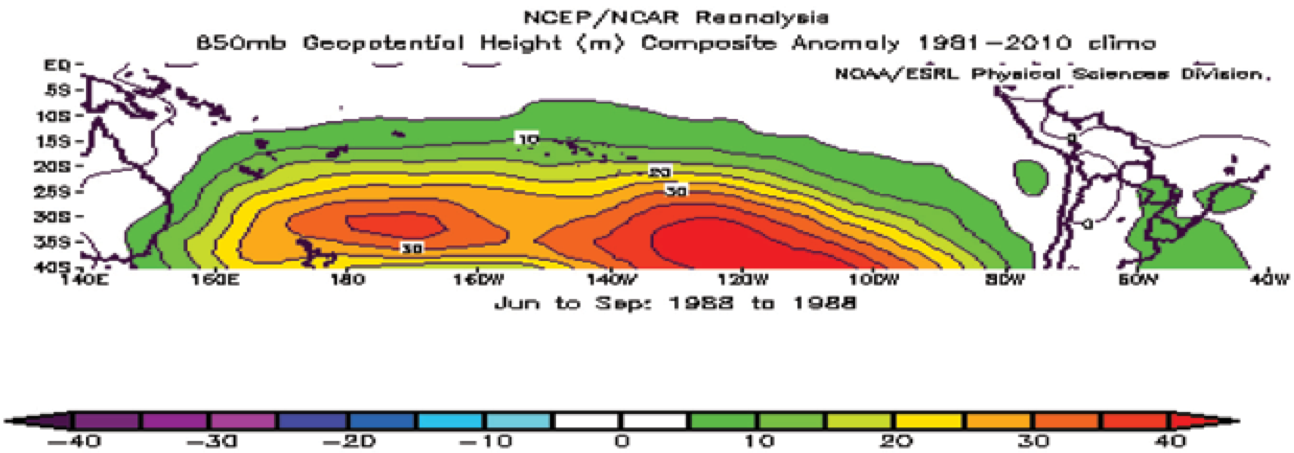

Figure 2. Anomaly of 850 hpa geo potential height for Jun-Sept 1988.

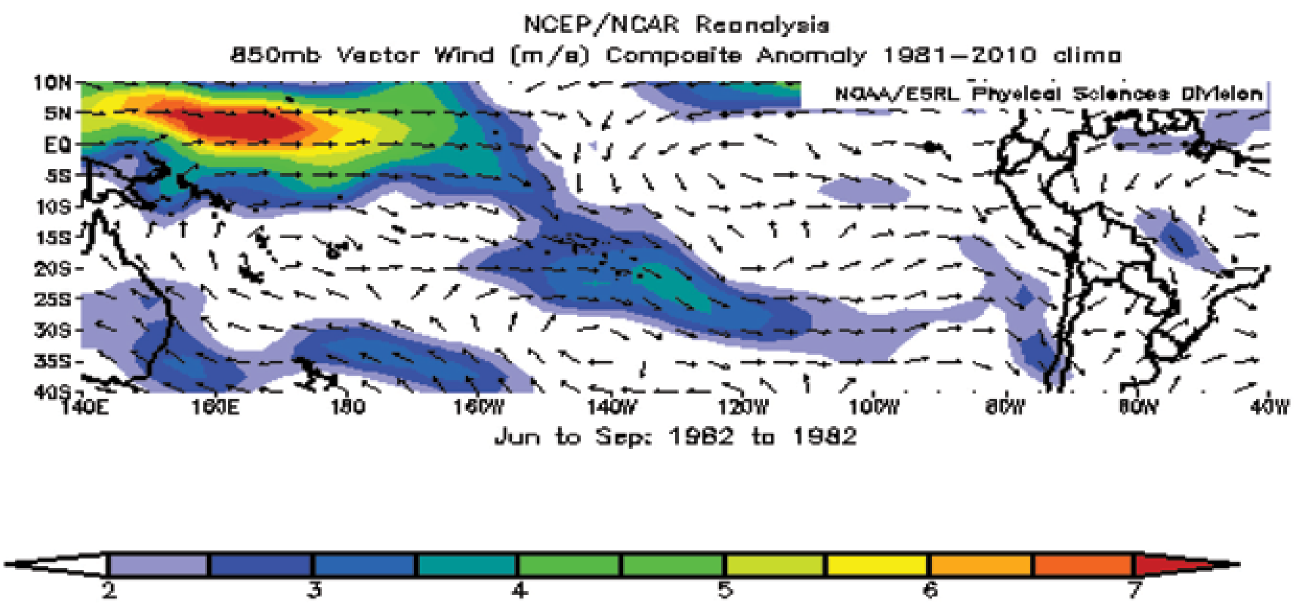

Figure 3. Anomaly of 850 hPa vector wind for June-September 1982.

anomalies in the eastern equatorial Pacific (Rajeevan and Pai, 2007). In the year 2014 Australian Weather Bureau declared an El Nino alert, saying there was at least a 70% chance of occurrence of the weather pattern that is also linked to weak monsoons in India, but some climatic models predicted that it could set in as early as July 2014. The alert was later withdrawn by the end of July. There was consensus among international weather agencies that an El Nino would occur in 2014 but its timing and intensity remained uncertain, as per the then existing scenario as on 30th July (Reddy and Reddy, 2014). For 2014, going by forecasts of IMD and Skymet, it appeared that El-Nino may hit Indian monsoon in the second half of monsoon period. At the time of prediction it was not clear and certain whether it would cause a drought or not. NOAA pegged the probability of El Nino developments intensifying by summer at 70%. Both the Indian weather agencies were forecasting a sub-normal rainfall (IMD forecast at 93% of LPA and Skymet at 94% of LPA but not a drought yet: Saini and Gulati 2014). The forecasts from the Met office (UK) seasonal prediction system from June for July, August and September showed substantial changes in the tropics-wide rainfall with notable decreases in the Indian monsoon. The risk of a poor monsoon was 2-3 times greater in 2014 than normal (Slingo et al., 2014). In reality; the intra monsoon rainfall pattern was rather fluctuating and unclear from region to region leading to considerable hardship to farming community. From this experience it has become clear that weather experts cannot come to any conclusion based on a limited data of local to regional nature, covering a narrow window of time. Keeping this in view we have made use of a large set of data covering a large span of time and viewed closely intricate variations from time to time to have a better synoptic view of weather pattern during El Nino and La Nina years.

At least one pair of high (+ anomaly) and low (- anomaly) combination (high- low or high- low- high or high- low- low or low- high- low- high etc.) is required at 850 hPa, for normal monsoon rainfall over India (% of long period average; rainfall range: 96-104), 97% with an error of ± 6%, during summer monsoon season, north of 40°S/30°S between 040°W -120°E. Deficient rainfall (% of long period average; rainfall range: < 90), 88% with an error of ±6%, can be forecast if only low, as was the case in 1968 and 2002, or high (as in 2012) or low-high combination (as in 1982, 1987 and 2009) is observed (Kumar et al., 2016). The fact that the NH is warmer than the SH is potentially linked to the fact that the ITCZ is in the NH (Kang et al., 2008).

DATA

Anomalies of 850 hPa level geo potential height, vector wind, air temperature and SST from 1982 from January onwards for (i) El Nino years: 1951, 1953, 1957, 1958, 1963, 1965, 1969, 1972, 1976, 1977, 1979, 1982, 1986, 1987, 1991, 1994, 1997, 2002, 2004, 2006, 2009 and 2015: 22years, (ii) La Nina years: 1950, 1954, 1955, 1964, 1970, 1973, 1975, 1988, 1995, 1998, 1999, 2007, 2010 and 2011: 14 years and (iii) other significant Indian summer monsoon years: 1956, 1966, 1974, 1983, 1990, 2003, 2014 and 2016: 8 years have been prepared by using NOAA Earth System Laboratory (U.S.A) website. El Nino and La Nina episodes table, based on ONI (NOAA), from 1950 to 2016 has been used. All India monsoon rainfall data for all these years have been used from IMD website.

Analysis and Forecast

The features in anomaly of 850 hPa geo potential height and vector winds for El Nino and La Nina Years from June-September have been studied in relation to El Nino and La Nina events. It has been observed in excess of 80% cases that low/lows (negative anomaly) occupy maximum area in terms of horizontal width between 140°E-080°W/30°S-40°S (Figure 1) during El Nino years and during La Nina years high/highs (positive anomaly) occupy maximum area between the considered longitudinal and latitudinal width (Figure 2). Low/high at 850 hPa geo potential height remains associated with circulation/trough or anticyclone/ridge respectively at 850 hPa vector winds with minor changes in their cover region, Figure 3 and Figure 4. In 1982 (Figure 3), westerly component of wind has been dominating between 170°W-080°W from 35°S-05°S.

Prominent ridge can be seen in Figure 4 between 140°E - 080°W/35°S. Easterly component of wind is seen from 30°S to north of equator between 160°E-080°W. It has been observed that when ONI value starts increasing from lower to higher value, e.g. -0.8°C (NDJ) to -0.6°C (DJF) or 0.3°C (DJF) to 0.4°C (FMA), prominent low (larger area) with circulation/trough can be observed from January-February onwards. Year wise observation of dominant negative anomalies in different months between Jan to May has been given for the following El Nino years: 1951: Mar (JFM: -0.6), Apr and May, 1953: **Jan** (NDJ: 0.3) and May, 1957: Jan (NDJ: -0.4), Apr and May, 1963: Apr (FMA: 0.1) and May, 1965: Feb (DJF: -0.5), Mar, Apr and May, 1969: Apr (ONI value started decreasing from FMA: 0.9 to JJA: 0.4 and started increasing from JAS: 0.5) and May, 1972: Jan (NDJ: -0.8), Feb, Apr and May, 1979: Apr (FMA: 0.2) and May, 1982: Apr (FMA: 0.2) and May, 1986: Apr (FMA: -0.3) and May, 1997: **Mar** (JFM: -0.4), Apr, and May, 2002: Feb (DJF: -0.2), Mar and May, 2006: Apr (FMA: -0.4) and May, 2009: Apr (FMA: -0.4) and May, 2015: **Mar** (JFM: 0.5), Apr and May. In all the months between Jan and May low may not be found dominating in a month or two. But the reliable synoptic feature can be considered for forecasting El Nino events for the area Nino

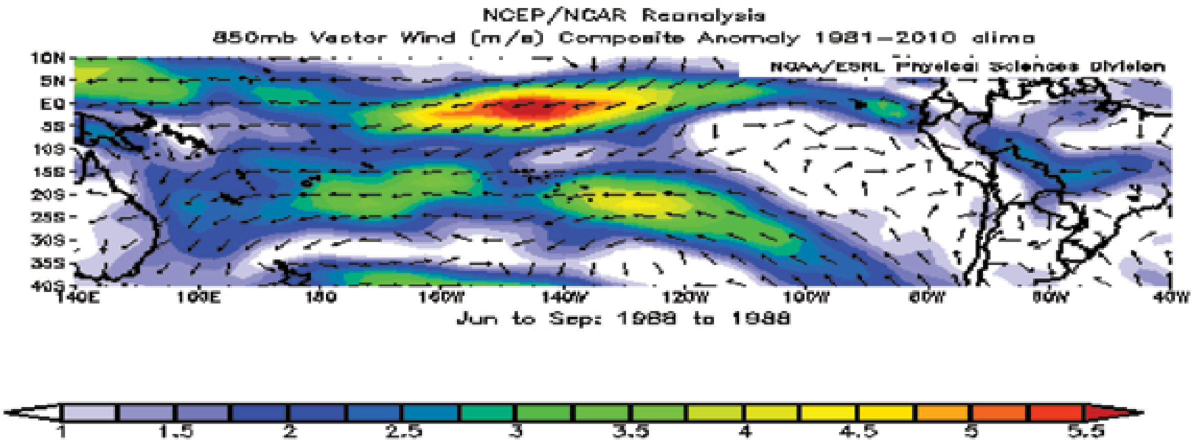

Figure 4. Anomaly of 850 hPa vector wind for Jun-Sep 1988.

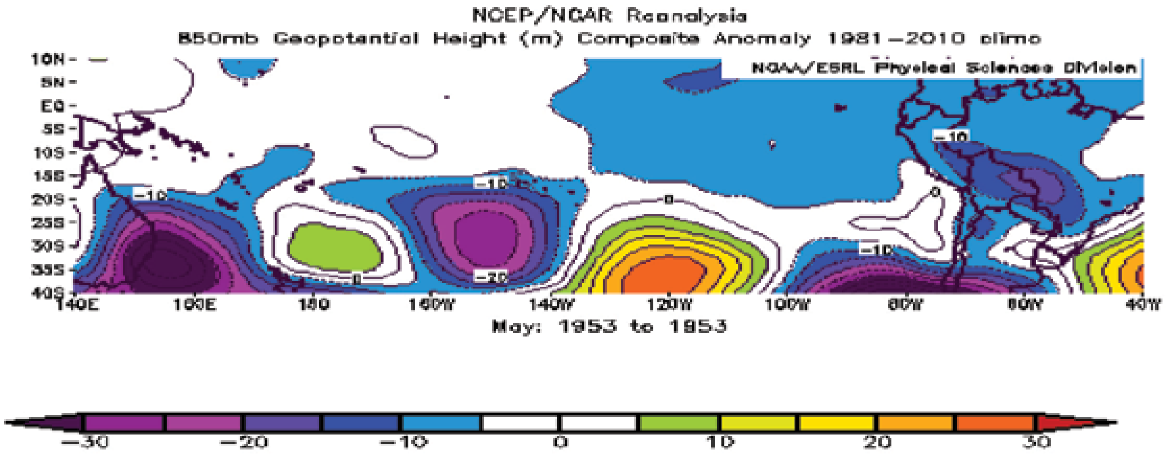

Figure 5. Anomaly of 850 hPa geo potential height for May 1953.

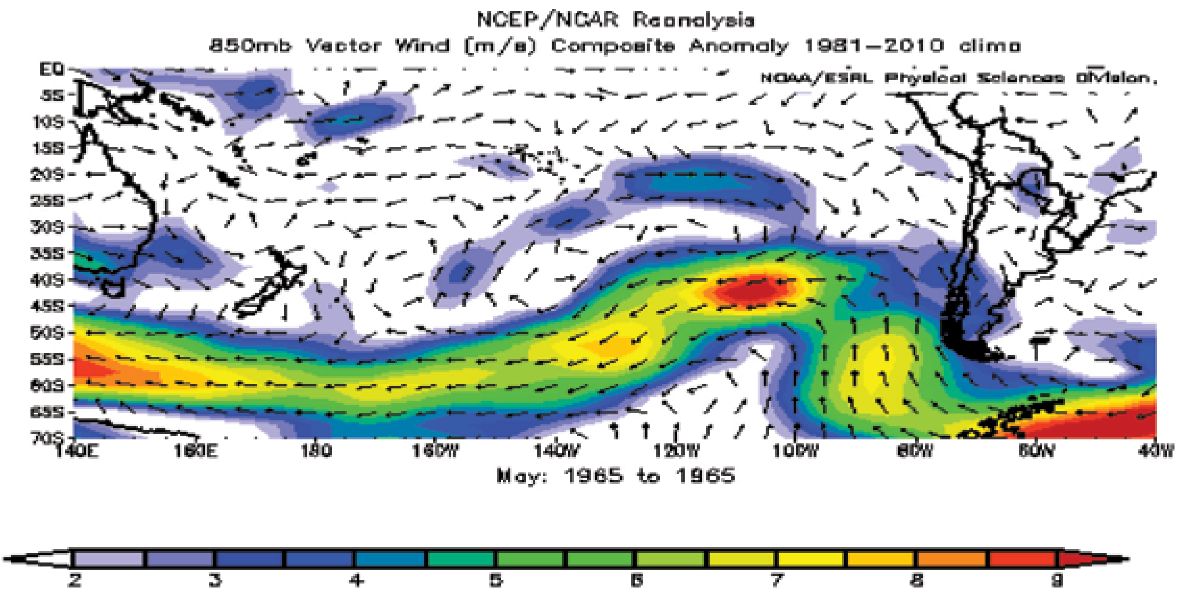

Figure 6. Anomaly of 850 hPa vector wind for May 1965.

3.4 (5°N-5°S/170°W-120°W) in almost all cases (21 years) in the first week of June when global data become available for May during the onset period of Indian Summer Monsoon. ONI value has reached ≥0.5°C for three months average during 1958: SON (0.5), 1976: ASO (0.5), 1977: (ASO: 0.5), 1991: (MJJ: 0.6), 1994: (SON: 0.6) and 2004: (JJA: 0.5) and El Nino events during these years can be forecast only from May data. When three months average ONI values were observed as -0.6, -0.5, **-0**.4, -0.3, 0.1, 0.2 and 0.3 El Nino features have been also observed in different years. Prominent low with circulation, covering maximum longitudinal width between 140°E-080°W/30°S-40°S, have been observed for the month of May for forecasting El Nino events for the following years when anomaly of geo potential height and vector wind were considered: 1951, 1953, 1957, 1958, 1963, 1965, 1969, 1972, 1976, 1977, 1979, 1982, 1986, 1991, 1994, 1997, 2002, 2004, 2006, 2009 and 2015 (21 years). In 1953, low-high-low-high-low composition has been observed with maximum coverage area by lows and last low was located along west coast of South America (Figure 5). Dominant circulation area was also observed at 850 hPa of vector winds.

In other years (except 2004) continuous low can be easily identified. In May 1965, dominant trough at 850 hPa can be seen south of 40°S with dominant circulations along the trough (Figure 6). Westerly component of wind can be seen from 40°S to 15°S between 160°W - 080°W (Figure 6). ISMR during 1965 from Jun-Sep has been observed as -18.2% from normal value, however there is no one to one relationship with El Nino and ISMR.

In May 1972, continuous low is seen from 170°E - 080°W along 40°S and centre of anti cyclone has shifted south of 60°S. However, dominant trough and circulation can be seen above it and north of 40°S (Figure 7) Westerly component of wind can be seen north of 40°S to 20°S between 160°W - 080°W. In 1972, ISMR from Jun-Sep have been found as -23.9% from normal value, which has been observed as the worst till date.

Anomaly of 850 geo potential height for May 2002 shows one low is located from 150°E-125°W and another low near west coast of South America along 080°W/40°S and a feeble high between 120°W-100°W slightly above 40°S. Westerly component of wind can be seen much prominent over the areas of low (Figure 8).

In 2009, ISMR from Jun-Sep has been found as -21.8% from normal value. Dominant low at 850 hPa can be seen along 40°S and has shifted northwards and high has shifted southwards during May 2009 (Figure 9). Anomaly of vector wind at 850 hPa for June shows strong circulations south of 10°S between 140°E-080°W. Feature of a partly occluded extra tropical low pressure system can be seen centred just south of 30°S and 100°W connected with a circulation west of 160°E (Figure 10). Westerly component of wind can be seen dominating from 30°S. All India monsoon rainfall during June 2009 has been observed as -47.2% from normal value.

Dominant low has been found for February and March 1987 between 140°E-080°W along 40°S which confirms that El Nino conditions are getting stronger. But when ONI value started decreasing from Feb-Mar-Apr (1.1 from 1.2) to Apr-May-Jun (0.9), the synoptic features for continuation of strong El Nino events have weakened. A small low is seen from 120°W-140°W between two highs (160°E-150°W and 110°W-080°W) north of 40°S in anomaly of 850 hPa geo potential height for May 1987 (Figure 11). But in the extended chart up to 60°S, a strong low is seen centred south of 40°S between two highs. A circulation is seen prominently in the anomaly at 850 hPa vector wind in association with the low in the extended chart. Another circulation is seen between 30°S-20°S along the west coast of South America. It appears from the climatological studies that the extra tropical low may move equator ward. The picture becomes clear as anomaly of 850 geo potential height from 22 Jun-28 Jun shows strong low from 140°E - 100°W along 40°S. ONI value started increasing from May-Jun-Jul (1.1). So the forecast may be modified in the beginning of July 1987. In 2004, ONI value remained constant as 0.3 up to Jan-Feb-Mar and anomaly of 850 geo potential height showed dominant low for February and March 2004 along 40°S. But when ONI value decreased during Feb-Mar-Apr and Mar-April-May high dominated feature had been observed for April 2004.

In May coverage area for low has been found around 070° (140°E-170°W and 125°W-105°W) and high is restricted to 045° (165°W-135°W and 95°W-80°W) along 40°S. So El Nino is expected during 2004. During 1958 when ONI value started decreasing from Jan-Feb-March (1.5 from 1.7) and the trend continued till Aug-Sep-Oct (0.4), low dominated feature has been observed for May 1958 and ONI value again increased (0.5 to 0.6) from Sep-Oct-Nov onwards. In 1966 and 1974 low dominated features have been observed during May between 140°E-080°W. So, synoptic features had not been found favourable in Nino 3.4 region for good summer rainfall over India during these two years. Warning for deficient rainfall over India has been issued by UK, USA and Australia weather offices from July onwards during 2014 but high dominated features have been observed for April and May 2014 (Figure 12). For the country as a whole, rainfall for the season (June-September) was 88% of its long period average (2014 South West monsoon, End of Season Report, IMD). However, actual rainfall during July (90%), August (90%) and September (108%), has not been observed as deficient. Below normal rainfall occurred in July and August and above normal in September. Anomaly of geo potential height for May 2016 shows dominant low along 40°S but anomaly from 1st - 5th June 2016 shows dominant high from 150°E-080°W.

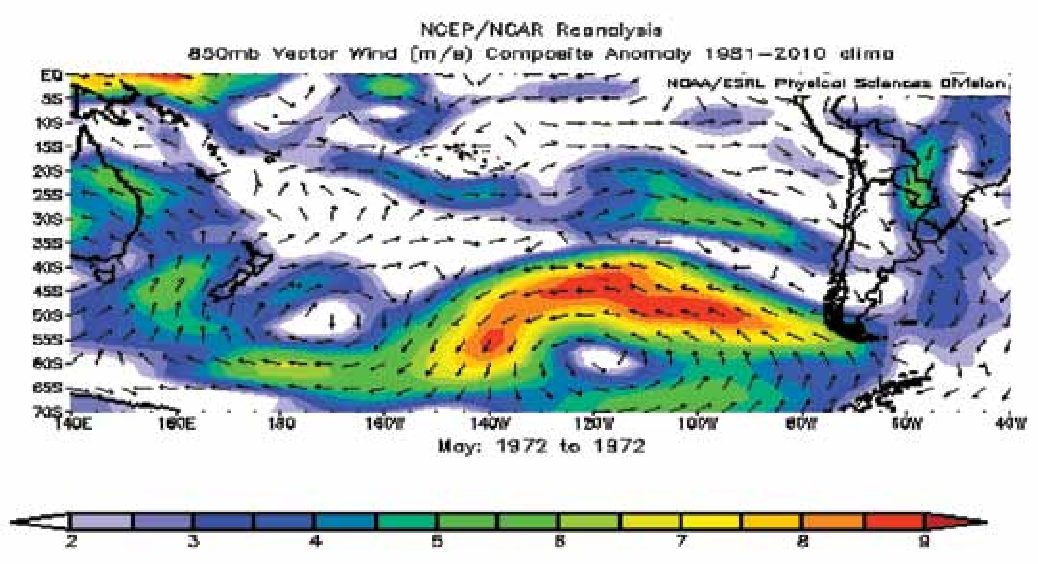

Figure 7. Anomaly of 850 hPa vector wind for May 1972.

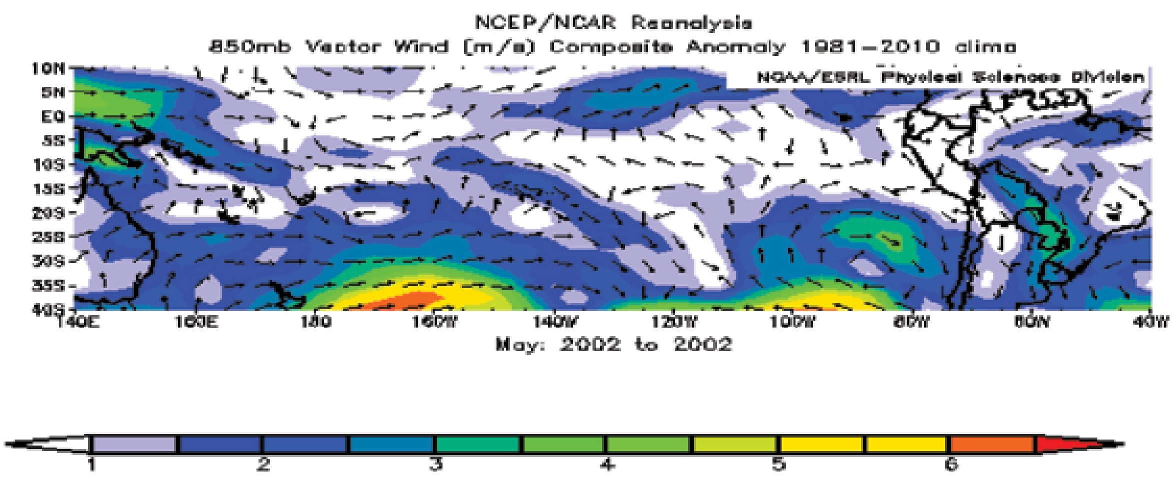

Figure 8. Anomaly of 850 hpa vector wind for May 2002.

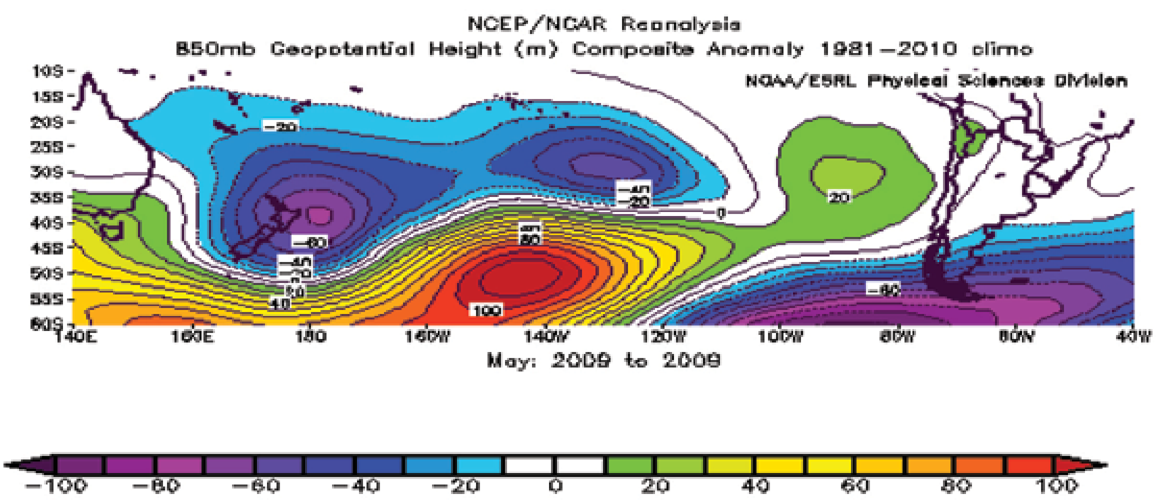

Figure 9. Anomaly of 850 hPa geo potential height of May 2009.

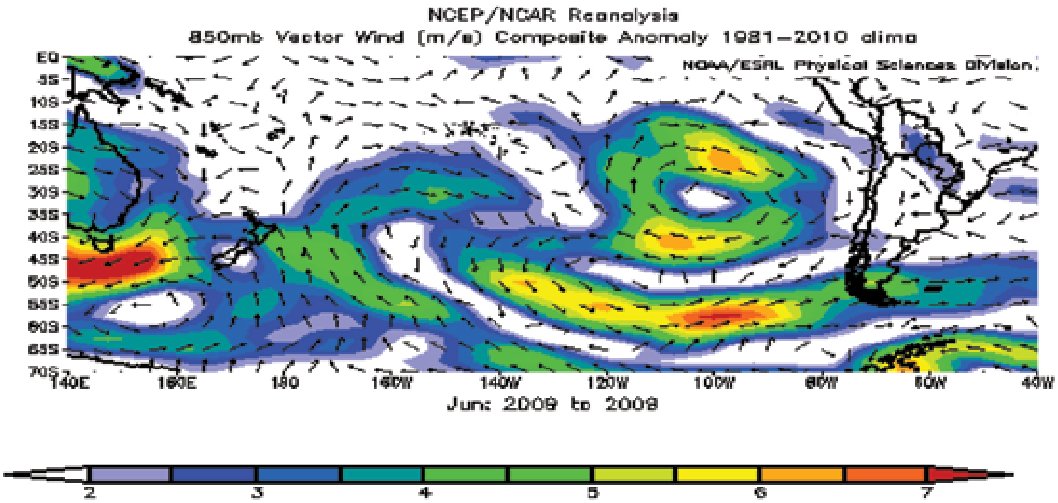

Figure 10. Anomaly of 850 hPa vector wind for Jun 2009.

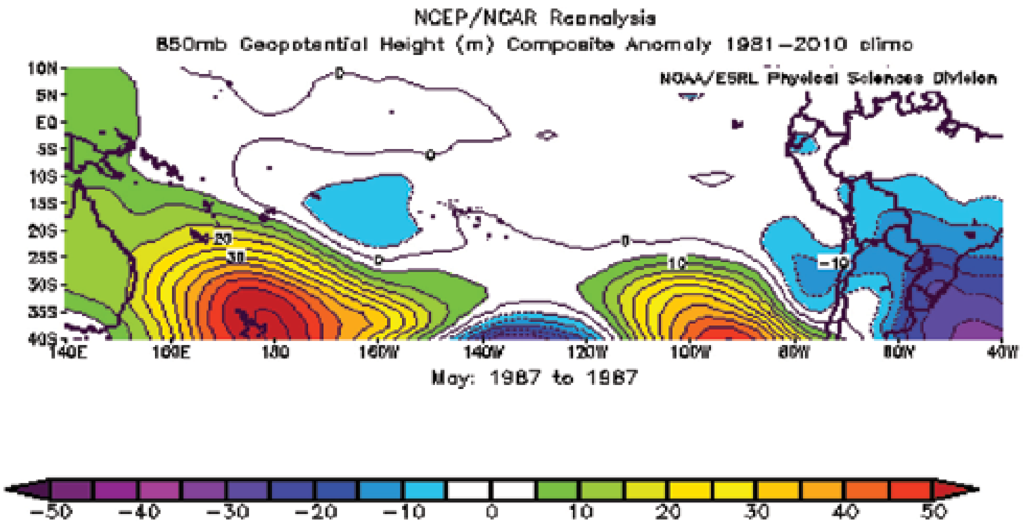

Figure 11. Anomaly of 850 hPa geo potential height for May. 1987.

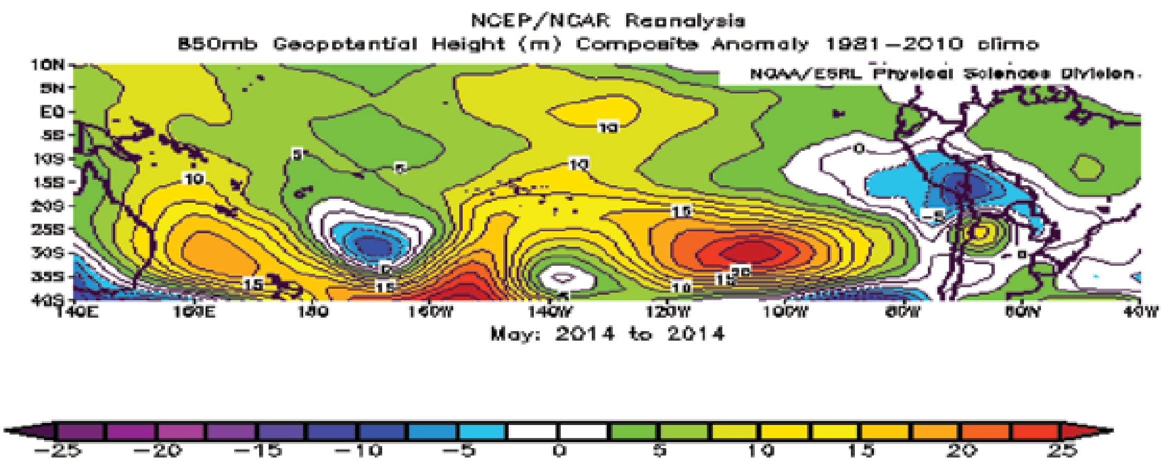

Figure 12. Anomaly of 850 geo potential height for May 2014.

High dominated features have been observed during different months of the following La Nina years (within bracket: months): 1950 (Feb, Mar and May), 1954 (Mar and May), 1955 (Feb, Mar and Apr) 1964(Mar and May), 1970 (Feb and May), 1973 (Feb, Mar and Jun), 1975 (May: vector wind dominant), 1988 (Jan, Mar, Apr and May) 1995 (May), 1998 (Feb, Apr and Jun), 1999 (May), 2007 (Feb, Mar, Apr and May) 2010 (Mar, Apr and May) and 2011 (May). Three months average ONI values have been found ≥ 0.5°C during the following years: 1964 (JFM: 0.6), 1970 (DJF: 0.6), 1973 (DJF: 1.7), 1988 (NDJ: 1.1), 1998 (DJF: 2.1), 2007 (DJF: 0.7) and 2010 (JFM: 1.2), even then La Nina features have been observed during Mar 1964, Feb 1970, Feb 1973, Jan 1988, Feb 1998, Feb 2007 and Mar 2010 respectively. In addition to these years high dominated features have been observed during 1956 (113.6%), 1983 (113%), 1990 (106.2%) and 2003 (102.3%) when above 100% rainfall have been observed over India during summer monsoon season. Study of anomalies of 850 geo potential air temperature and SST did not give any significant result for forecasting EL-Nino events.

CONCLUSIONS

i. Dominant feature of negative anomaly of 850 hPa geo potential height (low) has been observed between 140°E-080°W/30°S-40°S during El Nino years. Associated cyclonic circulation/trough can be observed in anomaly of 850 hPa vector wind. As a result westerly component of wind is found dominant north of 40°S. Dominant negative anomalies have been also observed when three months average ONI values have been reported between -0.8° to 0.3°C.
ii. Dominant contrast feature of positive anomaly of 850 geo potential height (high) has been observed between 140°E-080°W/30°S-40°S during La Nina years. Associated anti cyclone/ ridge can be observed in anomaly of 850 hPa vector wind. As a result easterly component of wind is found dominant north of 40°S. The contrast feature in the month of May has been found correct in 11 years out of 14 La Nina years (78.57%). Dominant positive anomalies have been also observed when three months average ONI values have been reported between 0.4°C and 2.1°C.
iii. Out of 22 years, El Nino events have been forecast correctly for 21 years (95.45%), except 1987, on the basis of May synoptic features. For 1987, modified forecast can be issued in the first July of 1987 as dominant low feature was observed in the last week of July. In 2016, changes have been reflected in 1st - 5th June data. Checking of first week data is needed to rectify El Nino events forecast during certain years.
iv. In 15 years out of 21 years El Nino events have been forecast on the synoptic features of May, when ONI values have been observed <0.5°C.
v. From synoptic features of May, El Nino events have been forecast, when ONI values reached ≥0.5°C during JJA (1951, 1963, 2004 and 2009), ASO (1976, 1977 and 2006) and SON (1979 and 1994).
vi. Persistence of extra tropical lows/circulations/troughs restricts the movement of cold air from 40°S or from south of 40°S to northern latitudes during El Nino years.
vii. Subtropical highs located between 140°E-080°W/30°S-40°S weaken and shift southwards (south of 40°S/45°S/50°S) and extra tropical lows located south of 40°S shift northwards from their position during El Nino years.
viii. Longitudinal width from 140°E-080°W/30°S-40°S has been found significant for forecasting El Nino events.
ix. In 1966 and 1974 conditions were not favourable for ISMR between 140°E-080°W/40°S.
x. Anomaly of 850 hPa air temperatures and SST did not suggest any significant feature for forecasting El Nino events.

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Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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*The impact of environmental warming on ice drainage basins of Antarctica

The environment of Antarctica is unique in many ways, one being that the continent is covered almost entirely by a vast sheet of ice, stretching from the towering plateau of East Antarctica to the chain of mountainous islands (interconnected by ice) that form West Antarctica. If Earth's oceans and atmosphere continue to warm at the rates projected by most climate models, over the next few hundred years, the Antarctic ice sheets could melt enough to cause a sea level rise of several meters. Most likely, the severity of ice loss will vary geographically because of physical differences across the continent, such as ice thickness and bedrock topography. The eastern side of the ice sheet is much larger and has slow-flowing glaciers, and its bedrock is a rocky terrain of deep basins and high mountain ranges buried beneath the ice. Recent studies have already shown warm ocean water flowing southward from areas of the East Antarctic Ice Sheet, suggesting that the region could be affected by further warming. To find out more, Golledge et al. used an ice sheet model to simulate the flow of water from melting ice sheets, ice shelves, and ice streams over thousands of years. They also examined data on the average long-term rates of ice loss for each ice drainage basin, or catchment, to determine which catchments are most sensitive to various conditions associated with climate change.Comparing the results of their models to other simulations and observations and given a projected ocean temperature rise of about 36°F, the researchers found that the majority of East Antarctica's future ice loss will most likely come from a catchment in the eastern Weddell Sea called Recovery.The researchers predict that how soon and how much the ice sheet in this region melts will determine the degree to which East Antarctica will contribute to future sea level rise. In turn, this could amplify surface temperatures, producing an even greater global impact. (**Source**: Golledge et al, 2017,Geophysical Research Letters, https://doi.org/10.1002/2016GL072422, 2017).