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El Nino: A Review

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Abstract: El Niño events are large climate disturbances which are originated in the equatorial Pacific Ocean, and occur in every 2 to 8 years. The developed phase of El Niño is characterized by unusual warm waters at the ocean surface, from the coasts of Peru and Ecuador to the center of the equatorial Pacific Ocean. This phenomenon is caused by strange weakening of the trade winds blowing westward, which allows warm surface waters to reverse their direction eastward. The climatic impacts of El Niño are amplifying throughout the world which can show several effects on regional weather. It is related with wide-ranging changes in the climate system and can lead to prominent socio-economic impacts affecting infrastructure, agriculture, health and energy sectors. Even though El Niño appears in the region of tropical Pacific; it has impact on the global climate and weather phenomena such as drought/flooding and tropical storms. The normal status in the equatorial Pacific is changed due to the raise in greenhouse gases which in turn results in El Niño Southern Oscillation (ENSO) changes. We can assure that ENSO variations will endure and influence the global climatic conditions in the coming decades and centuries. Hence, forecasting and interpreting ENSO conditions are essential to both the scientists and the public. In this paper, the occurrence of El Niño and its impact on global climate and socio-economic status has been studied and reviewed from literature.

Keywords: *ENSO, Trade winds, Drought, Climate*

1. Introduction

In literature, El Niño has been widely defined by various authors, which has no universal definition. Long ago, Peruvian fishermen called it El Niño, the Spanish phrase for the "Christ Child" (Dijkstra, 2006). Hurlburt et al. defined El Niño oceanographically as a massive influx of warm water into coastal region of Peru and Ecuador (Hurlburt et al., 1976). Philander defined El Niño phenomenon, as a combination of anomalously warm sea temperature, stronger than usual southward coastal current, high rainfall and floods in Ecuador as well as in northern Peru (Philander, 1990).

The Southern Oscillation is characterized by an inter annual see saw in tropical sea level pressure between the western and eastern Pacific, consisting of weakening and strengthening of the easterly trade winds over the tropical Pacific. El Niño and Southern Oscillation, is the most well-known coupled ocean–atmosphere phenomenon. Bjerknes postulated that ENSO involves positive ocean-atmosphere feedback. ENSO is recognized as the largest mode of inter annual variability of the global climate system; with a recurrence period around the 2–8 year band (Santos, 1999).

Sir Gilbert Walker described year-to year fluctuations in sea level pressure, surface air temperature, and precipitation which exhibited a distinctive global-scale teleconnection pattern extending over the Southern Hemisphere and a large part of the Northern Hemisphere (Walker 1923, 1924, 1928), Walker and Bliss (1932, 1937). Bjerknes (1966), Wooster and Guillen (1974), described El Niño conditions as a large-scale weakening of the Southern Hemisphere trade wind system beyond the normal seasonal weakening at that time, the termination of upwelling along the coasts of Peru and Ecuador, the sudden presence of anomalously warm surface waters with low salinity for nearly a 1000 km off the coast, and the southward extension of this water far beyond its usual summer limits.

During the phase of El Niño upwelling of the cold water along the coast of western South America is absent. The depth of thermocline is shallower in eastern pacific when compared to western pacific due to the process of upwelling. El Niño events have occurred in 1897, 1891, 1911, 1925, 1940 to 1941, 1957, 1965, 1972 to 1973, and 1976, 1982-83, 1986-87, 1991-92, and 1993, 1994 and 1997 (Messiner., 2000). It has been observed that the strongest El Niño events of the 20th century occurred in 1982-1983 and in 1997-1998.

2. ENSO Physics

The warm episodes which have occurred at irregular intervals and lasted typically from one to two years tend

to be characterized by the following atmospheric conditions:

1) Above-normal sea level pressure in the Australia-Indonesia trough region together with the weakening of the sub-tropical high in the Southeast Pacific. These conditions correspond to the negative phase of the Southern Oscillation as defined by Walker (Bjerknes, 1969; Quinn, 1974; Julian and Chervin, 1978, Wang and picaut, 2004).
2) Weakening or reversal of the easterly winds in the equatorial central Pacific, which constitutes an interruption of the climatological mean east-west circulation cell in this sector (Ichiye and Peterson, 1963; Wyrtki, 1975).
3) Sharply enhanced precipitation at equatorial stations to the east of 160ºE (Dobertiz, 1968; Quinn and Burt, 1972; Flohn and Fleer, 1975).
4) Enhancement of the Hadley circulation in the Pacific sector (Reiter, 1978a).
5) Teleconnections to extra tropical latitudes including a deepening and southward displacement of Aleutian low during the Northern Hemisphere winter season (Bjerknes, 1966, 1969, 1972; Rowntree, 1972; White and Walker, 1973; Namias, 1976).

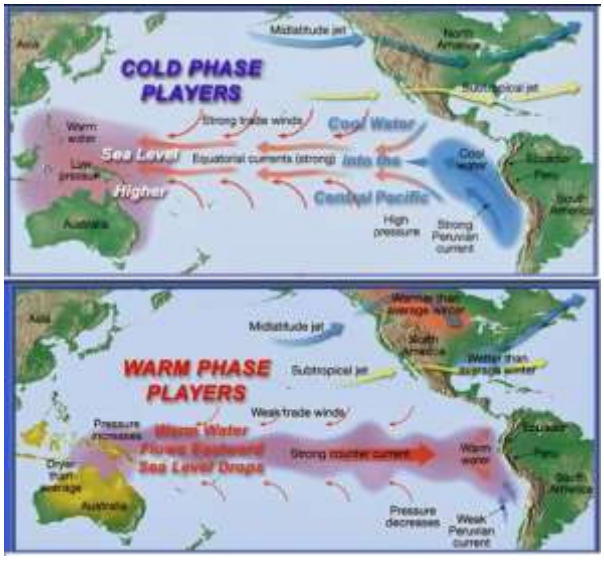

Figure 1: *Typical climate pattern of Pacific Ocean during normal and El Niño conditions.*

3. Causes

The oceanographic studies (Wyrtki, 1975; Hurlburt et al., 1976; McCreary, 1976; Philander, 1981) reveal that the weakening of trade winds during ENSO causes a horizontal redistribution of heat in the upper ocean and consequently causes the appearance of anomalously warm surface waters in the central and eastern tropical Pacific Ocean.

Generally, the trade winds blowing from east along the equator assemble the warm surface waters on the west side of the tropical Pacific. Meantime, nutrient rich cold deeper water are brought to the surface replacing the warm surface waters which are driven away from the coast of South America, a process called upwelling. This cold water is responsible for enhancing the primary productivity which supports fisheries. Thus heavy rainfall and low pressure is found over western tropical Pacific due to the carried warm surface waters whereas in the east the air above the cool water is relatively dry.

Relaxation of trade winds in the central and western Pacific is the early sign of El Niño progress. This allows the piled warmer water in the western Pacific to drift towards east. Thus the pressure level rises in the west Pacific and lowers in the east with maximum pressure fall over the central pacific. At the same time, thermocline becomes shallower in the eastern Pacific and elevates in the west. Thus the Bjerkenes hypothesis describing the commencement of El Niño is as follows: the weakening of low level atmospheric winds along the equator, relaxation of thermocline across the east-central equatorial Pacific, weakening of equatorial upwelling, the surface waters become warmer along the coast of South America, east-west sea surface temperature gradient will decline further and trade winds will weaken even more.

4. Impacts

Although, El Niño is originated in the tropical Pacific it has worldwide effects on seasonal weather and climate ecological, social, and environmental sectors. A trend of above-average precipitation between 30° and 35°S latitude in winter (June to August) is observed during El Niño events, while a trend of below-average precipitation is distinctive during La Nina events (Montecinos and Aceituno, 2003). El Niño events rises the sea surface temperatures which show serious effects on atmospheric wind and pressure patterns. These differences in wind, pressure temperature and precipitation patterns have impact on agriculture, forestry, transport infrastructure etc. Lisa Goddard et al., studied that ENSO events have unfairly generated socioeconomic calamities contributed to global economic losses of tens of billions of dollars (Lisa Goddard et al., 2005). This episode has also significant effects on health sector associated with intense hazard of certain vector-borne diseases such as malaria, dengue and Rift Valley fever.

4.1. On global weather

The tropical weather and climate undergoes several changes due to the differences in the oceanic and atmospheric circulation. Effects of ENSO can be directly observed in the climate of the tropics since

ENSO events are the most important sources of year to year variability in climate over the lower latitudes of the globe (Bartholy et al., 2006). Several teleconnections were described in the extra tropical regions (Glantz et al., 1991). Ropelewski et al., explained that the development of drought in many tropical land areas around the globe is one manifestation of the El Niño phenomenon studied from observationally-based analyses (Ropelewski and Halpert, 1987; Mason and Goddard, 2001). The human lives within the concerned region have to face drastic consequences of such droughts, sometimes may be severe (Lyon B., 2006). A major consequence of ENSO is to change the relative contributions of terrestrial vs. marine sources to insular food webs (Stapp et al., 1999).

4.1.1. South America

ENSO events, in South America are experienced in two ways: a) through its effects on both the ocean systems and atmosphere, and b) through its impacts on natural ecosystems (both marine and terrestrial) and on societal and economic sectors (like agriculture, fisheries, health) (Santos J. L., 2006). The El Niño phenomenon can have effect of precipitation over some regions of South America such as the Brazilian Northeast, Amazonia, South of Brazil and Uruguay (Cardoso A. O. et al., 2006). The amount of anomalous rainfall and river flooding in the southern coast of Ecuador and northern Peru remains the most reliable indicator of the strength of the El Niño events (Ortlieb, 2000). The effect of precipitation by ENSO in South America was less frequent in the Mid-Holocene when compared to the present climate and that the spatial distribution of the ENSO influence is considerably different in the two periods (Jorgetti., et al, 2006). The South American hydro-climatology is extremely affected by positive (El Niño) and negative (La Nina) events of the El Niño Southern Oscillation in various ways (Ropelewski and Halpert (1987), Aceituno (1988), Vuille (1999), Waylen and Poveda (2002)). Studies showed that there exist correlations between ENSO and the river discharge of the most important South American rivers; the Amazon and the Parana (Richey et al. (1989), Amarasekera et al. (1997). Increase in plant productivity during rainy El Niño years has been reported for coastal desert ecosystems in north-central Chile (Vidiella et al., 1999; Olivares and Squeo, 1999; Holmgren et al., 2006). In NE Brazil, El Niño has been popularly known to be causing severe droughts (Kane, 2006).

4.1.2. North America

El Niño offers the greatest chance to make clever long-range winter forecast for Canada. (Shabbar A., 2006). However, the impacts of El Niño over North America are weaker and more mutable (Zhuo Wang et al., 2007). The strongest El Niño events of the 20th century occurred in 1982-‘83 and in1997- ‘98. The effects of 1982-‘83 included significant storms throughout the southwest United States and one of Australia's worst drought of the century.

4.1.3. Asia, Europe and Australia

When El Niño event occurs, there is eastward shift of rainfall in the west Pacific region that tends to cause rainfall scarcities in western Pacific such as Australia, Philippines, Indonesia and India that may experience severe droughts while central Pacific islands experience surplus rainfall (Mike Davey et al., 2011). About half of the droughts over India have been related to this phenomenon (Kripalani and Ashwini Kulkarni 1998). One of the external factors responsible for the inter-annual variability of Indian summer monsoon rainfall (June through September) is the El Niño phenomenon. Although the climatological onset dates vary with regions, the inter annual variability of regional monsoon onset over most of Asia is partly affected by the ENSO (Joseph et al 1994, Lau and Yang 1997, Wu and Wang 2000, Zhang et al 2002, Mao and Wu 2007). The European continent is located far from the tropical Pacific Ocean; however, climatic teleconnections of ENSO can still be sensed (Wilby, 1993; Fraedrich, 1994; Van Oldenborgh et al., 2000). During a typical El Niño, the Asian monsoon usually weakens and is pushed towards equator, often bringing summer drought to north-west and central regions of India and heavy rainfall in the north-east.

4.1.4. India

Most of the severe droughts over India occurred in association with El Niño events (Rajeevan and Pai, 2006). Since 1950, there were 23 El Niño years and only 13 drought years and three of these droughts were in non-El Niño years. However, since 1980, all Indian droughts happened in the years of El Niño, but all El Niño years did not result in droughts (Shweta Saini and Ashok, 2003). Teleconnections associated with El Niño result in an overall warming of the Indian Ocean (Klein et al., 1999; Murtugudde and Busalacchi, 1999; Xie et al., 2009), due to changing cloud cover and wind patterns that relate to changes in ascending and descending branches of the Walker circulation (Du et al., 2009; Reason et al., 2000; Venzke et al.,2000). The intense 1997 positive IOD/El Niño event was characterised by a strong phytoplankton bloom in the eastern equatorial Indian Ocean; an area which is normally characterised by low productivity (Murtugudde et al.,1999; Susanto and Marra, 2005). Other documented impacts of the 1997 event included a decrease of surface chlorophyll in the Arabian Sea (Sarma, 2006) attributed to anomalous north easterly winds, as well as a bloom in the south eastern Bay of Bengal, owing to anomalous Ekman pumping in this

region (Vinayachandran and Mathew, 2003). Ashok et al., (2001) have shown that the IOD and ENSO have complementarily affected the Indian summer monsoon rainfall during the past four decades. Soman and Slingo (1997) showed that the tropical convective maximum over Indonesia and the western Pacific during the spring season (March to May) plays an important role in the monsoon onset over India.

4.2. On health

An increasing number of studies have shown that the El Niño cycle is related with changes in the risk of diseases transmitted by mosquitoes, such as malaria and dengue and other arboviruses (Sari Kovats et al., 2009). Diseases that spread from mosquitoes and rodents may strengthen after extreme events, especially flooding in association with ENSO events (Epstein et al., 1995); and in Ecuador and Peru epidemics of malaria appear related to flooding associated with El Niño occurrence (McMichael and Haines, 1997). A study done on the impact of drought in small villages in West Kalimantan, Indonesia, found that the health problems are increasing causing damage to the rural economy (Salafsky, 1994). Increases in the frequency of acute diarrhoeal diseases and severe respiratory diseases were noticed in Bolivia (Telleria, 1986) and in Peru (Gueri et al., 1986). Generalizations about the association between vector-borne disease transmission and El Niño are not easy, as local transmission depends on ecology of the local vector species, whose responses to timing and amount of rainfall may differ.

4.3. On marine life

The biological productivity is declined off the coast of western South America due to El Niño that reduces the upwelling of cold water. Regional studies were made by researchers on the effects of ENSO on the upwelling and oceanic currents, biology and fisheries, (Flores, 1989). Hales et al. found a relationship between the annual incidence of reported ciguatera fish poisoning and the SOI in some islands in the South Pacific where El Niño is associated with higher SSTs (Hales et al., 1999b). Some evidence is found that the existence and spreading of harmful coastal algal blooms is related to El Niño (Tester, 1994; Hallegraeff, 1993; Heed, 1998). The surprising increase in primary productivity associated with ENSO rainfall involves rapid increases in plant cover and seed production of herbaceous species (Hamman, 1985; Dillon and Rundel, 1990; Polis et al., 1997; Vidiella et al., 1999; Block and Richter, 2000; Gutierrez et al., 1999).El Niño's impact on Pacific ecosystems ranges from the open ocean to the west coasts of North and South America and involves benthic as well as pelagic communities (L. Levin et al., 2002). During El Niño, equatorial upwelling is suppressed in the eastern and central Pacific, thus reducing the supply of CO_2 to the surface (R. A. Feely et al., 2006). It was common to think before El Niño of 1982–1983 that ENSO events only had negative effects. Research, especially in marine shallow depths, has shown positive impacts as well (Tarazona et al., 2001).

4.4. On Tropical cyclones

El Niño events result changes in weather patterns around the world and influence the occurrence and intensity of tropical cyclone activity, including a decrease in Atlantic hurricane activity and an eastward shift of western Pacific cyclone activity. Thus, typhoons are 2.6 times more likely to occur near the Marshall Islands, Pacific Ocean, during an El Niño (Spennemann and Marschner, 1995) because El Niño events shift storm tracks to the West in the Pacific. It is fairly well understood how tropical cyclones are affected by ENSO (Landsea, 1999; Saunders et al., 1999).

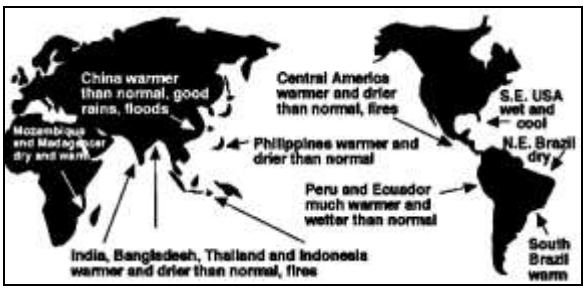

Figure 2: *Global impacts of El Niño 1997-98*

5. Discussion

- El Niño is a natural anomaly results from interaction between the ocean surface and the atmosphere with which we need to live with. Although, this phenomena occurs for every few years its impacts in the near future are critical.
- The effects of El Niño are felt throughout the world, where the interruption of normal weather conditions can have tragic socio-economic consequences. As warm water shifts eastward, increased heat and moisture rises into the atmosphere, modifies the atmospheric conditions which in turn can affect the weather system around the globe.
- It has wide spread impacts on global weather showing severe impacts on precipitation in South-East Asia and western Pacific. It causes abnormally low rainfall during monsoon season in South East Asia.
- El Niño episodes have severe effects on regional weather and crop yields which has economic consequences. In India, El Niño is generally feared to cause a drought. Floods in Peru and Chile are due to the impacts of this phenomenon.

- Development of droughts in many tropical areas is due to the effect of El Niño. During an El Niño event the eastward shift of rainfall in the west Pacific region tends to cause rainfall deficits in western Pacific that may experience severe droughts while central Pacific islands experience excess rainfall.
- It increases the risk of extreme weather but also has more subtle effects on human health. It is also related to the existence and spread of harmful coastal algal blooms.
- It also affects the biological productivity and fisheries in the eastern Pacific. During an El Niño episode, the appearance of warm water break off the process of upwelling therefore the production of phytoplankton is greatly diminished and the fish move to colder regions.

6. Conclusions

- El Niño events are large climate disturbances which are originated in the equatorial Pacific Ocean; typically recur every 2 to 8 years.
- El Niño episodes are related with the appearance of unusual warm waters across the central and eastern tropical Pacific which has severe impacts on large parts of the world.
- El Niño is thought to occur due to changes in the normal patterns of trade wind circulation**.**
- The dominant impacts of El Niño are temperature anomalies, changes in precipitation variability, floods and droughts throughout the world.
- It is associated with the increasing risks of vector-borne diseases.
- In most basins the frequency of tropical cyclones also depends on El Niño.

References

[1] Aceituno, P.: On the functioning of the Southern Oscillation in the South American sector, part I: surface climate, Mon. Wea. Rev., 116, 505–524, 1988.

[2] Amarasekera, K. N., Lee, R. F., Williams, E. R., and Eltahir, E. A.B.: ENSO and the natural variability in the flow of tropical rivers, J. Hydrol., 200, 24–39, 1997.

[3] Ashok, K., Guan Z, Yamagata T: Impact of the Indian Ocean Dipole on the relationship between the Indian monsoon rainfall and ENSO, Geophys. Res. Lett., 28, 4499–4502, doi: 10.1029/2001GL01329, 2001.

[4] Bartholy, J. and Pongracz, R.: Regional effects of ENSO in Central/Eastern Europe, Advances in Geosciences, 6, 133–137, 2006.

[5] Bjerknes, J.: A possible response of the atmospheric Hadley circulation to equatorial anomalies of ocean temperature. Tellus, 18, 820-829, 1966.

[6] Bjerknes, J.:Atmospheric teleconnections from the equatorial Pacific. Mon. Wea. Rev. 97, 163-172, 1969.

[7] Bjerknes, J.: Large-scale atmospheric response to the 1964-65 Pacific equatorial warming. J. Phys. Oceanography. 2, 212-217, 1972.

[8] Block, M. A. and Richter, M.: Impacts of heavy rainfall in El Niño 1997/98 on the vegetation of Sechura Desert in Northern Peru, Phytocoenologia, 30, 491–517, 2000.

[9] Cardoso, A. O., and Silva Dias P. L.: The relationship between ENSO and Paraná River flow. Advances in Geosciences, 6, 189–193, 2006.

[10] Dijkstra, H. A: The ENSO phenomenon: theory and mechanisms. Advances in Geosciences, 6, 3–15, 2006.

[11] Dillon, M. O. and Rundel, P.W.: The botanical response of the Atacama and Peruvian desert floras to the 1982–83 El Niño event, in Global Ecological Consequences of the 1982–83 El Niño Southern Oscillation, edited by: Glynn, P. W., Elsevier Oceanographic Series 52, p. 487–504, Amsterdam, 1990.

[12] Doberitz, R.: Cross-spectrum analysis of rainfall and sea temperature at the equatorial Pacific Ocean. Bonner Meteor. Abhand., 8, 61 pp, 1968.

[13] Du, Y., Xie, S.-P., Huang, G., and Hu, K.: Role of air–sea interaction in the long persistence of El Niño–induced north Indian Ocean warming, J. Climate, 22, 2023–2038, doi:10.1175/2008JCLI2590.1, 2009.

[14] Epstein, P., Penna, O., and Racedo, J.: Climate and disease in Colombia, Lancet, 346, 1243, 1995.

[15] Feely, R.A. et al., J. Geophys. Res. 111, C08S90, doi: 10.1029/2005JC003129, 2006

[16] Flohn, H., and Fleer, H.: Climate teleconnections with the equatorial Pacific and the role of ocean /atmosphere coupling .Atmosphere, 13, 96-107, 1975.

[17] Flores, M. J.: Incidencia de los Fenomenos “El Niño” en la Extracci´on de Recursos Pesqueros Marinos de la Pesquer´ıa Peruana en el Periodo 1950–1987, Memorias del Simposium Internacional de los Recursos Vivos en las Pesquer´ıas del Pacıfico Sudeste. Comisi´on Permanente del Pacıfico Sur., 467–476, 1989.

[18] Fraedrich, K.: An ENSO impact on Europe – A Review, Tellus, 46A, 541–552, 1994.

[19] Glantz, M. H., Katz, R. W., and Nicholls, N. (Eds.): Teleconnections Linking Worldwide Climate Anomalies , Cambridge University Press, New York, NJ, 1991.

[20] Gueri M, Gonzalez C and Morin V (1986): The effect of the floods caused by "El Niño" on health. Disasters, 10, 118–124, 1986.
[21] Gutierrez, J. R., Vidiella, P. E., Armesto, J. J.: Vegetation change and sequential flowering after rain in the southern Atacama Desert, J. Arid Environ., 43, 449–458, 1999.
[22] Hales S, Weinstein P and Woodward, A.: Ciguatera fish poisoning, El Niño and Pacific sea surface temperatures. Ecosystem Health, 5, 20–25, 1999b.
[23] Hallegraeff, G.M.: A review of harmful algal blooms and their apparent increase. Phycologica, 32, 79–99, 1993.
[24] Hamman, O.: The El Niño influence on the Galapagos vegetation,in: El Niño en las Islas Galápagos': el evento de 1982–1983,edited by: Robinson, G. and Del Pino, E. M., Fundaci´on Charles Darwin paralas Islas Gal´apagos, Quito, p. 299–330, 1985.
[25] Heed, Marine Ecosystems: Emerging Diseases as Indicators of Change. Year of the Ocean Special Report: Health of the Oceans from Labrador to Venezuela. Health and Ecological Dimensions of Global Change Program, 1998.
[26] Holmgren, M., Stapp P., Dickman, C. R., Gracia, C., Graham, S.,Guti´errez, J. R., Hice, C., Jaksic, F., Kelt, D. A., Letnic, M.,Lima, M., Lopez, B. C., Meserve, P. L., Milstead, W. B., Polis, G. A., Previtali, M. A., Richter, M., Sabat´e, S., and Squeo, F. A.: A synthesis of ENSO effects on drylands in Australia, North America and South America, Adv. Geosci., 6, 69–72, 2006.
[27] Hurlburt, H.E. John C.Kindle., and James J.O'Brien: A numerical simulation of the onset of El Niño. Journal of Physical Oceanography, Vol.6, NO.5. 1976.
[28] Ichiye, T., and Petersen. The anomalous rainfall of the 1957-58 winters in the equatorial central Pacific arid area .J. Meteor. Soc. Japan, 41, 172-182, 1975.
[29] Jorgetti, T., Silva Dias, P.L., and P. Braconnot, P.,: Review of: El Niño influence over South America during the mid-holocene. Advances in Geosciences, 6, 279–282, 2006.
[30] Joseph, P.V, Eischeid, J. K. and Pyle, R.J.: Interannual variability of the onset of the Indian monsoon and its association with atmospheric features El Niño, and sea surface temperature anomalies J. Clim. 7 81–105, 1994.
[31] Julian, P.R., and Chervin, R.M.: A study of the Southern Oscillation and Walker Circulation phenomena. Mon. Wea. Rev., 106, 1433-1451, 1978.
[32] Kane, R.P: El Ni no effects on rainfall in South America: comparison with rainfalls in India and other parts of the world. Advances in Geosciences, 6, 35–41, 2006.
[33] Klein, S. A., Soden, B. J., and Lau, N. C.: Remote sea surfacetemperature variations during ENSO: Evidence for a tropical atmospheric bridge, J. Climate,12,917932,doi:10.1175/15200442(1999)012<0917:RSSTVD>2.0.CO;2, 1999
[34] Kripalani, R.H. and Ashwini Kulkarni: No Droughts over India Following Very Strong El Niño Episodes Vol. 10, No. 2, June 1998.
[35] Levin L. et al., Prog. Oceanogr. 53, 1 (2002).
[36] Landsea CW: El Niño Southern Oscillation and the seasonal predictability of tropical cyclones. In: Diaz HF and Markgraf V (eds) El Niño and the Southern Oscillation: Multiscale Variability and Global and Regional Impacts. Cambridge, Cambridge University Press, 1999.
[37] Lau K. M and Yang, S.:Climatology and inter-annual variability of the Southeast Asian summer monsoon Adv. Atmos. Sci. 14 141–62, 1997.
[38] Lisa Goddard and Maxx Dilley: El Niño: Catastrophe or Opportunity. American Met. Society, .journal of climate, Vol 18, 2005.
[39] Lyon B**.** Robustness of the influence of El Ni˜no on the spatial extent of tropical drought. Advances in Geosciences, 6, 207–209, 2006.
[40] Mao, J. and Wu, G.: Interannual variability in the onset of the monsoon over the Eastern Bay of Bengal Theor. Appl.Climatol. 89 155–70, 2007.
[41] Mason, S. J. and Goddard, L.: Probabilistic precipitation anomalies associated with ENSO, Bull. Am. Meteor. Soc., 82, 619–638, 2001.
[42] McMichael, A. and Haines, A.: Global climate change: the potential effects on health, British Medical Journal, 315, 805–809, 1997.
[43] Messiner, R.: The impact of El Niño on water resources.Future challenges of providing high-quality water.Vol-II, 2000.
[44] Mike Davey, Dr.Matt Huddleston, Dr.Anca Brook Shaw, Global impact of El Niño and La Niña 3 Implications for financial markets, May 2011.
[45] Montecinos, A. and Aceituno, P.: Seasonality of the ENSO-Related Rainfall Variability in Central Chile and Associated Circulation Anomalies, J. Climate, 16, 281–296, 2003.
[46] Murtugudde, R. and Busalacchi, A. J.: Interannual variabilityof the dynamics and thermodynamics of the tropical IndianOcean, J. Climate,12,2300–2326,doi:10.1175/15200442,(1999)
[47] Namias, J., Some statistical and synoptic characteristics associated with El Niño .J. Phys. Oceanogr., 6, 130-138, 1976.
[48] Olivares, S. and Squeo, F. A.: Patrones fenologicos en especies arbustivas del desierto costero del norte-centro de Chile, Revista Chilena de Historia Natural, 72, 353–370, 1999.
[49] Ortlieb, L.: The Documented Historical Record of El Niño Events in Peru: An Update of the Quinn

Record (Sixteenth through Nineteenth Centuries), in: El Niño and the Southern Oscillation, Cambridge University, 2000.
[50] Philander S. G. H., Pacanowski, R. C. Tellus 33, 201-210 pp, 1981
[51] Philander, G.: El Niño, La Nina, and the Southern Oscillation, Academic Press, United States of America, 293p, 1990
[52] Polis, G. A., Hurd, S. D., Jackson, C. T., and Sanchez Pinero, F.: El Niño effects on the dynamics and control of an island ecosystem in the Gulf of California, Ecology, 78, 1884–1897, 1997.
[53] Quinn, and W. Burt,: Use of the Southern Oscillation in weather prediction. J. Appl. Meteor., **11**, 616-628, 1972.
[54] Quinn, W. N.: Monitoring and predicting El Niño invasions .J .Appl. Meteor., **13**, 825-830, 1974.
[55] Rajeevan, M. and Pai, D.S. 2006. On El Niño-Indian Summer Monsoon Predictive.Relationships. Res. Rep. No 4/2006. National Climate Centre, India Meteorological.Department, Pune – 411 005. Pp-20.
[56] Reason, C. J. C., Allan, R. J., Lindesay, J. A., and Ansell,T. J.: ENSO and climatic signals across the Indian Ocean Basin in the global context: Part I, interannual composite patterns, Int. J. Climatol., 20, 1285–1327, doi:10.1002/10970088(200009)20:11<1285::AID-JOC536>3.0.CO;2-R, 2000
[57] Reiter, E.A.,: Long-term wind variability in the tropical pacific; its possible causes and effects. Mon. Wea. Rev., 106, 324-330, 1978a.
[58] Richey, J. E., Nobre, C., and Deser, C.: Amazon River discharge and climate variability: 1903–1985, Science, 246, 101–103, 1989.
[59] Ropelewski, C. F. and Halpert, M. S.: Global and regional scale precipitation patterns associated with the El Niño/Southern Oscillation, Mon. Wea. Rev., 115, 1606–1612, 1987.
[60] Rowntree, P.R.,: The influence of tropical east Pacific Ocean temperature on the atmosphere. Quart. J. Roy. Meteor. Soc., 98, 290-321, 1972.
[61] Salafsky, N.,:Drought in the rain forest: effects of the 1991 El Niño/Southern Oscillation event on a rural economy in West Kalimantan, Indonesia. Climatic Change, 27, 373–396, 1994.
[62] Santos, J. L.: El Niño and La Nina: A Climate Oscillation, on: El Niño Event in Ecuador: From Disaster to Prevention, Comitato Internazionale per lo Sviluppo dei Popoli, 205 pp., 1999.
[63] Santos, J.L.: The Impact of El Niño – Southern Oscillation Events on South America. Advances in Geosciences, 6, 221–225, 2006.
[64] Sari Kovats, R., Menno J Bouma Andy Haines El Niño and Health. Protection of the Human Environment Task Force on Climate and Health Geneva 1999, WORLD HEALTH ORGANIZATION WHO/SDE/PHE/99.4, 2009.
[65] Sarma, V. V. S. S.: The influence of Indian Ocean Dipole(IOD) on biogeochemistry of carbon in the Arabian Seaduring 1997–1998, J. Earth Syst. Sci., 115, 433–450,doi:10.1007/BF02702872, 2006.
[66] Saunders, M.A., and Roberts, F. : El Niño's impact on landfalling intense tropical cyclones. In: Proceedings of the 23rd Conference on Hurricanes and Tropical Meteorology, 10–15 January 1999, Dallas, Texas, pp. 274–275, 1999.
[67] Shabbar, A., The impact of El Niño-Southern Oscillation on the Canadian climate. Advances in Geosciences, 6, 149–153, 2006.
[68] Shweta Saini and Ashok Gulati: El Niño and Indian Droughts- A Scoping Exercise. Indian Council for Research on International Economic Relations.
[69] Soman MK, Slingo J (1997) Sensitivity of the Asian summer monsoon to aspects of sea surface temperature anomalies in the tropical Pacific Ocean. Q J R.Meteorol.Soc. 123:309-336.
[70] Spennemann, D.H.R., and Marschner, I.C., : The association between El Niño/Southern Oscillation events and typhoons in the Marshall Islands. Disasters, 19, 194–197, 1995.
[71] Susanto, R. D. and Marra, J.: Effects of the 1997/98 El Niño on chlorophyll a variability along the southern coasts of Java and Sumatra, Oceanography, 18, 124–127, 2005.
[72] Stapp, P.,Polis, G. A., and Sanchez Pinero, F.: Stable isotopes reveal strong marine and El Niño effects on island food webs, Nature 401, 467–469, 1999.
[73] Tarazona, J., Arntz, W., and Castillo, E. (Eds.): El Niño in Latin America: Biological and Social Impacts, Alfred Wegener Institute, ISBN 9972-50-015-2, 423 pp., 2001.
[74] Telleria, A.V.,: Health consequences of floods in Bolivia in 1982. Disasters, 10, 88–106, 1986.
[75] Tester, P.A.,: Harmful marine phytoplankton and shellfish toxicity: potential consequences of climate change. Annals of New York Academy of Sciences, 740, 69–76, 1994.
[76] Van Oldenborgh, G. J., Burgers, G., and Klein Tank,A.: On the El Niño teleconnection to spring precipitation in Europe, Int. J. Climatol., 20, 565—574, 2000.
[77] Venzke, S., Latif, M., and Villwock, A.: Coupled GCM ECHO-2.Part II: Indian Ocean response to ENSO, J. Climate, 13, 1371–1383, 2000.
[78] Vinayachandran, P. N. and Mathew, S.: Phytoplankton bloom in the Bay of Bengal during the northeast monsoon and its intensification by cyclones, Geophys. Res. Lett., 30, 1572, doi: 10.1029/2002GL016717, 2003.

[79] Vuille, M.,: Atmospheric circulation anomalies over the Bolivian Altiplano during dry and wet periods and extreme phases of the Southern Oscillation, Int. J. Climatol., 19, 1579–1600, 1999.
[80] Walker, G.T., and Bliss, E.W.,:World Weather. IV.Mem.Roy.Meteor, Soc.,4,.119-139, 1932.
[81] Walker, G.T., and Bliss, E.W.,:World Weather.V.Mem.Roy.Meteor, Soc.,4,53-84, 1937.
[82] Walker, G.T., World Weather IX.Mem. Meteor.Dept 24, 275-332, 1924.
[83] Walker, G.T., World weather III, Mem Roy. Meteor, Soc., 17, 97-106, 1928.
[84] Walker, G.T.,Correlation in seasonal variations of weather VIII.Mem.I.Meteor.Dep, 24,75-131, 1923.
[85] Wang, and Picaut, J., Understanding ENSO Physics—A review. Earth's Climate: The Ocean–Atmosphere Interaction, C. Wang, S.-P. Xie, and J. A. Carton, Eds., Amer. Geophys. Union, 21–48, 2004.
[86] Waylen, P. and Poveda, G.: El Niño-Southern Oscillation and aspects of western South American hydro-climatology, Hydrol Process., 16, 1247–1260, 2002.
[87] White, W.B. and Walker, A.E.,: Meridional atmospheric teleconnections over the North Pacific from 1950 to 1972. Mon. Wea. Rev., 101, 817-822, 1973.
[88] Wilby, R.: Evidence of ENSO in the synoptic climate of the British Isles since 1880, Weather, 48, 234–239, 1993.
[89] Wooster, W.S., and O.Guillen,: Characteristics of El Niño in 1972.J.Marine Res.,32,387-404, 1974.
[90] Wu, R., and Wang B., Interannual variability of monsoon onset over the western North Pacific and the underlying processes J. Clim. 13 2483–501, 2000.
[91] Wyrtki, K., El Niño-the dynamic response of the equatorial Pacific Ocean to atmospheric forcing. J. Phys. Oceanogr., 5, 572-584, 1975.
[92] Xie, S. P., Hafner, J., Tokinaga, H., Du, Y., Sampe, T., and Hu KaiMing, H. G.: Indian Ocean capacitor effect on Indo-western Pacific climate during the summer following El Niño, J. Climate, 22,730–747, doi:10.1175/2008JCLI2544.1, 2009.
[93] Zhang, Y., Li, T., Wang, B., and Wu, G.: Onset of the monsoon over the Indochina Peninsula: Climatology and inter annual variations J. Clim. 15 3206–21, 2002.
[94] Zhuo Wang and C.-P. Chang Bin Wang: Impacts of El Niño and La Niña on the U.S. Climate during Northern Summer, Journal of Climate Volume 20, 2007.