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Assessment the Effect of ENSO on Weather Temperature Changes Using Fuzzy Analysis (Case Study: Chabahar)

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Abstract

The effects of El Niño and La Niña have been considered as the major variables in weather changes in the Middle East. This issue has been shown by regression indexes in a number of papers. The presented study has proven that the El Niño and La Niña should be added to the weather forecast variables because of their major effects. Weather forecasts could be influenced by some variables that have uncertainty, so the deterministic approaches may lead to incorrect predictions. The proposed algorithm can be used when some variables have uncertainty. In this study, a probabilistic approach has been chosen to show the effect of El Niño and La Niña on the monthly maximum temperature. Different ENSO Indices have been proposed for El Niño or La Niña occurrences but each of them has some deficiencies. In order to overcome the drawback of using one of the ENSO Indices, the fuzzy based analysis approach has been chosen in this paper. Data from Chabahar, one of the stations in the south of Iran, has been chosen for the algorithm to be applied on. MATLAB has been used to run the algorithm on the data. The results show that El Niño and La Niña lead to major effect on the amount of monthly maximum temperature in the south of Iran.

Keywords: El Niño; ENSO; La Niña; Precipitation.

1. Introduction

The fluctuations in both sea surface temperatures (SSTs) in the eastern equatorial Pacific and in sea level pressures in the southern Pacific at time scales of two to seven years is referred to the El Niño/Southern Oscillation (ENSO).

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This phenomenon that occurs every few years around Christmas time, was first named by Peruvian fishermen centuries ago, and was taken into consideration by scientists in the last few decades because of its large global influence. Following the very strong, very well observed and very heavily reported event in 1997–98, El Niño started to be considered as main reason for anything unusual that happened anywhere in the world. This is implicated in drought in the Altiplano of Peru and Bolivia and catastrophic flooding in coastal Peru and Ecuador. Resulting huge forest fires in Kalimantan spread a thick cloud of smoke over Southeast Asia and crippled air travel by shutting down airports in Singapore, Malaysia and Indonesia [1]. The 1997–98 El Niño also triggered an explosion in research interest of marine and geophysics scientists [2]. Although the perception of public El Niño's influences are somewhat complicated, the climate impacts that listed above have been shown to be strongly correlated with El Niño events at least in the past century. There is also plenty of evidences prove that El Niño has been a prominent feature of the Earth's climate for at least the past 130,000 years [3,4]. The impact of El Niño is shown by the many of these proxy data, such as tree rings and oxygen isotope in fossil corals; actually reveals the variations in rainfall rather than temperature. The long-term climate records also indicate that El Niño behavior is quite sensitive to climatological conditions, so it is possible that El Niño would behave differently in future. Unfortunately, the long-range projections given by the present climatological models are far from conclusive [5,6]. Moreover, El Niño events also exhibit irregularities in the timing of onset, in the amplitude of SST anomalies and in the duration of events [7] that make it difficult to forecast the next El Niño onset, severity and its duration. Understanding of El Niño's dynamics is started when it was recognized that it is part of a coupled instability of the tropical Pacific ocean–atmosphere system [8]. El Niño atmospheric counterpart, the Southern Oscillation, is a seesawing of atmospheric mass, and hence of the sea level pressure, between the eastern and western Pacific. The ENSO cycles have two basic elements. First, there is a positive feedback between the zonal winds that are the result of the pressure gradient, and the equatorial SST gradient which is itself influenced by the wind-driven upwelling and thermo cline fluctuation; Second, the equatorial ocean dynamics, particularly the non-dispersive equatorial Kelvin and Rossby waves, provide the out-of-phase element that makes the system oscillate between cold and warm phases, namely El Niño and La Niña states [9-12]. This dynamic coupling is the essence in many of ENSO models. Many statistical connections between the ENSO and some changes in climate variables around the world have been studied [1,2] but it is not yet clearly understood how changes in the sea level of the Pacific Ocean affect the weather pattern at great distances. It has been shown that ENSO has a great effect on weather changes in some places [2-5, 13]. El Niño and La Niña states may also be effective in Iran's weather changes and therefore, this teleconnection has been studied in this paper. Initially, by using statistical methods, it has been shown that the ENSO should be mentioned in weather analyses and forecasting. Then a probabilistic approach has been presented to determine the dependency level of this phenomenon to the weather in certain places. One of the climatology parameter, monthly maximum temperature, is considered in this paper. Chabahar synoptic weather station is chosen to show the effect of El Niño and La Niña on this weather parameter. In contrast with the mentioned papers that study the El Niño effects on climates changes by using the regression approaches, the probabilistic approach is applied, in this paper, which is more useful when data has uncertainty. Moreover, the results derived by using this approach are better making sense.

There are many attempts to monitor the ENSO by the atmospheric or oceanic variables. It should be mentioned that ENSO is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales and one of the best indices is obtained when we attempt to monitor ENSO by basing the Multivariate ENSO Index (MEI) on the six main observed variables over the tropical Pacific. These six variables are: sea-level pressure, zonal and meridional components of the surface wind, sea surface temperature, surface air temperature, and total cloudiness fraction of the sky [14-15]. In this paper, the MEI is gathered for each of twelve month. The normalized version of the ENSO Index is used in this paper.

In order to keep the MEI comparable, all seasonal values are standardized with respect to each season.

As stated before, different ENSO Indices have been proposed for El Niño or La Niña occurrences but each of them has some deficiencies [16-19]. In order to overcome the drawback of using one of the ENSO Indices, the fuzzy based analysis approach has been chosen in this paper that moderates the drawbacks and advantages of one of the ENSO Indices. Moreover, because of the ENSO irregularity the effect of the El Niño on the climatological variables cannot be investigated using traditional methods so in this paper fuzzy-based data analysis approach has been chosen to show the effect of El Niño and La Niña on the monthly maximum temperature.

2. Material and Methodology

The data for this study was obtained from the monthly Local Climatological Data (LCD) publications produced by the Iran Meteorological organization. This study covers the 43-year period from 1963 through 2005. The monthly maximum of temperature data was collected for all of the months. This study has been applied to the data collected from Chabahar synoptic weather stations in coastal area in the south of Iran. The information of the location of the synoptic station has been collected in table 1.

Table 1. Chabahar synoptic weather stations information

Station Name	Zone Code	Latitude	Longitude	Elevation (m)
Chabahar	40898	25 17' N	60 37' E	8.0

The temperature data are gathered from 1963 to 2005 in every month. The Enso Index (EI) values are also gathered in this duration. The goal of this paper is to plot the Cumulative Distribution Function (CDF) of the monthly maximum of temperature probability considering the measured data in the Chabahar Station. In order to show the effect of El Niño and La Niña on the monthly maximum of temperature, the fuzzy based stochastic analysis approach is chosen in this paper. The algorithm steps are described, as follows:

Step1: The variable under study (value of temperature) is showed in the following form:

$$X=\{X^{(k)}_i \mid 1\le i\le N^{(k)}, 1\le k\le 12\}; \quad (1)$$

where k is the month number and $N^{(k)}$ is the number of data in the month k that shows the years number with available data. At this step, all of data is arranged in matrix form. So the element (i,j) in X, is the temperature in the month j and in the year i. Similar procedure is done for Enso Index that is formed into a matrix with the same size of the temperature matrix.

Step2: dividing data to smaller ranges

$$\delta X^{(k)}=[\max(X^{(k)})-\min(X^{(k)})]/100 \ (1\le k\le 12) \quad (2)$$

$$x^{(k)}_j=\min(X^{(k)})+j*\delta X^{(k)}; \ (1\le j\le 100, 1\le k\le 12) \quad (3)$$

where, $\delta X^{(k)}$ is called accuracy level. So the next calculations are applied on the 100 points among the data.

$x^{(k)}_j$ is the value of the temperature that we want to calculate that what percent of all of the data is higher than this level.

Step3-a: in years with EI>0 (El Niño occurrence):

$$A^{(k)}_j=\{f(EI^{(k)}_i) \mid X^{(k)}_i \ge x^{(k)}_j, 1\le i\le N^{(k)}, 1\le k\le 12, 1\le j\le 100\}; \quad (4)$$

$$B^{(k)}j=\{1-f(EI^{(k)}_i) \mid X^{(k)}_i \ge x^{(k)}_j, 1\le i\le N^{(k)}, 1\le k\le 12, 1\le j\le 100\}; \quad (5)$$

Step3-b: in years with EI<0 (La Niña occurrence):

$$C^{(k)}{}_j=\{f(EI^{(k)}{}_i)|\ X_{(k)i} \geq x^{(k)}{}_j\ ,1\leq i\leq N^{(k)},1\leq k\leq 12,\ 1\leq j\leq 100\}; \quad (6)$$

$$B^{(k)}{}_j=\{1\text{-}f(EI^{(k)}{}_i)|\ X^{(k)}{}_i \geq x^{(k)}{}_j\ ,1\leq i\leq N^{(k)},1\leq k\leq 12,\ 1\leq j\leq 100\}; \quad (7)$$

where, f is the function that the fuzzification process is done based on it. (Fig. 1)

It should be mentioned that the EIs are mapped by a membership function (as shown in Fig 1), to the "fuzzy values". The process of converting the input values to the fuzzy values is called "fuzzification".

Step4: calculating probabilities for El Niño/La Niña years, as follows:

$$P(A^{(k)}{}_j)=N(\Sigma A^{(k)}{}_j); \quad (8)$$

Step 5: plot the CDF of variable X for different values.

In the Fig. 1, a is the values that 10% of all of the EI data is greater than that and b is the value that 10% of all of the EI data is less than that.

3. Results

The result of applying the proposed algorithm on data has been shown in the fig. 2. The program has been developed and run in MATLAB Software. The results show that the proposed algorithm can distinguish the maximum temperature in the years with El Niño, with La Niña or on the normal years without El Niño or La Niña occurrences. Using this probabilistic result, a system planner (all of systems that are influenced by the weather temperature changes) can investigate the effect of El Niño or La Niña on the weather temperature changes.

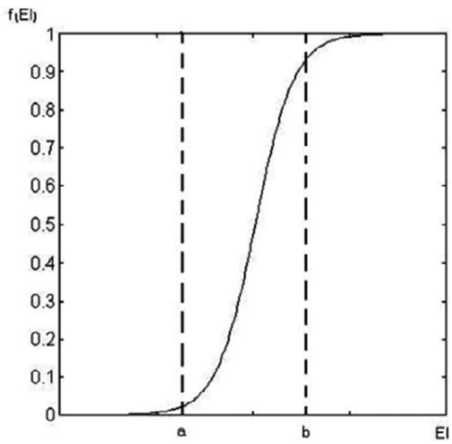

Fig. 1. Sigmoid membership function used in this paper

4. Discussion and Conclusion

Data recorded at Chabahar synoptic weather station are chosen to show the results of proposed algorithm in order to study the effects of El Niño and La Niña on a weather parameter like maximum and minimum of temperature. The results in this paper show that in the normal years without ENSO occurrences, the maximum of temperature is greater than that in years with El Niño occurrence. In the years with La Nina occurrences, it is expected that the minimum and maximum temperatures are greater in comparison with the years without any events. As shown in fig 2, it is clear that the maximum and minimum of temperature is reduced more in years with El Niño occurrence with comparison to the years with La Niña occurrence. This phenomenon is the result of dominance of the high pressure front in the El Niño years while in La Niña years the existence of the low pressure front leads to warmer weather. The probabilistic approach has been chosen in this paper to demonstrate the effects of El Niño and La- Niña in the south of Iran. This approach is better than regression approaches for using in the forecasting processes.

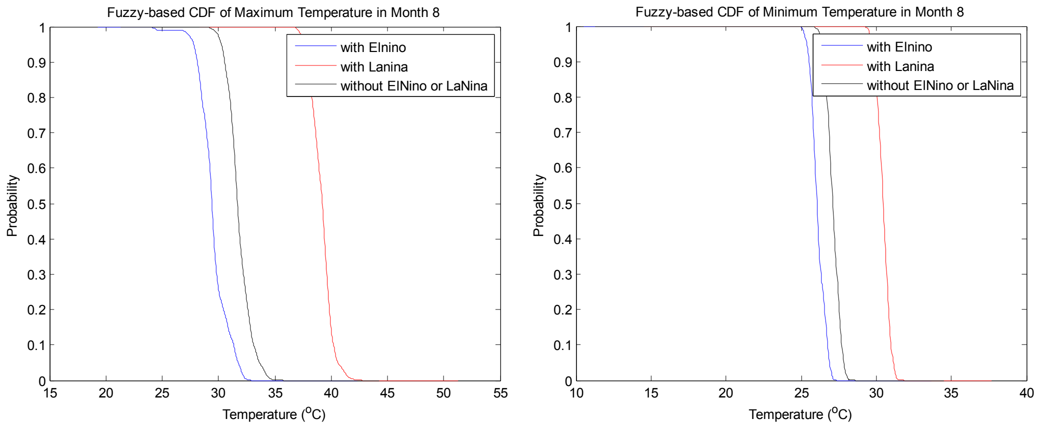

Fig. 2. Result of applying the proposed algorithm on maximum and minimum temperature data in August

References

[1] Cane MA. 2004. The evolution of El Niño, past and future. *Earth and Planetary Science. Letters* **164** : 1–10.

[2] McPhaden MJ, Zebiak SE, Glantz MH. 2006. ENSO as an integrating concept in Earth science. *Science* **314** : 1740–1745.

[3] Hughen KA, Schrag DP, Jacobsen SB, Hantoro W. 1999. El Niño during the last interglacial period recorded by a fossil coral from Indonesia. *Geophysical Research Letters* **26** : 3129.

[4] Tudhope AW, Cilcott CP, McCulloch MT, Cook ER, Chappell J, Ellam RM, Lea DW, Lough JM, Shimmield GB. 2001. Variability in the El Nin˜o-Southern Oscillation through a glacial-interglacial cycle. *Science* **291** : 1511–1517.

[5] Collins M. 2000. Understanding uncertainties in the response of ENSO to greenhouse warming. *Geophysical Research Letters* **27** : 3509–3513.

[6] Doherty R, Hulme M. 2002. The relationship between the SOI and the extended tropical precipitation in simulations of future climate Change. *Geophysical Research Letters* **29** : 1475.

[7] Neelin JD, Jin FF, Syu HH. 2000. Variations in ENSO phase locking. *Journal of Climate* **13** : 2570–2590

[8] Bjerknes J. 1969. Atmospheric teleconnections from the equatorial Pacific. *Monthly Weather Review* **97** : 163–172.

[9] Zebiak SE, Cane MA. 1987. A model El Nin˜o-Southern oscillation. *Monthly Weather Review* **115** : 2262–2278.

[10] Battisti DS, Hirst AC. 1989. Interannual variability in a tropical atmosphere–ocean model: influence of the basic state, ocean geometry, and nonlinearity. *Journal of the Atmospheric Sciences* **46** : 1687–1712.

[11] Cane MA, Munnich M, Zebiak SE. 1990. A study of self-excited oscillations of the tropical ocean–atmosphere system Part 1: linear analysis. *Journal of the Atmospheric Sciences* **47** : 1562–1577.

[12] Jin FF. 1997. An equatorial ocean recharge paradigm for ENSO Part I: conceptual model. *Journal of the Atmospheric Sciences* **54** : 811–829.

[13] Braesicke P, Morgenstern O, Pyle J. 2011. Might dimming the sun change atmospheric ENSO teleconnections as we know them?. *Atmospheric Science Letters* **12** : 184–188.

[14] Wolter K. 1987. The Southern Oscillation in surface circulation and climate over the tropical Atlantic, Eastern Pacific, and Indian Oceans as captured by cluster analysis. *Journal of Applied Meteorology* **26** : 540-558.

[15] Wolter, K., and M.S. Timlin, 1993: Monitoring ENSO in COADS with a seasonally adjusted principal component index. *Proc. of the 17th Climate Diagnostics Workshop*, Norman, OK, NOAA/NMC/CAC, NSSL, Oklahoma Climate Survey, CIMMS and the School of Meteorology, University of Oklahoma, 52-57.

[16] Allan RJ, Ansell T. 2006. A new globally complete monthly historical gridded mean sea level pressure dataset (HadSLP2): 1850-2004. *Journal of Climate* 19, 5816-5842.

[17] Quinn WH, Neal VT. 1992. The historical record of El Niño events. *Climate since A.D. 1500* : 623-648.

[18] Rayner NA, Brohan P, Parker DE, Folland CK, Kennedy JJ, Vanicek M, Ansell TJ, Tett SFB. 2006. Improved analyses of changes and uncertainties in sea surface temperature measured in situ since the mid-nineteenth century. *Journal of Climate* **19** : 446-469.

[19] Wolter K, Timlin MS. 2011. El Niño/Southern Oscillation behavior since 1871 as diagnosed in an extended