International Journal of Agriculture and Crop Sciences.
Available online at www.ijagcs.com
IJACS/2012/4-17/1291-1299
ISSN 2227-670X ©2012 IJACS Journal

Investigation the Southern Oscillation Index Effect on Dry/Wet Periods in North of Iran

Miromid Hadiani, Saeid Jahanbakhsh Asl, Majid Rezaei Banafsheh, Yaqub Dinpajouh, Esmaeil Yasari

Ph.D. Student Tabriz University. Physical Geographic Department
Professor, Tabriz University Physical Geographic Department
Assistant Professor, Tabriz University Physical Geographic Department
Assistant Professor, Tabriz University, Water Engineering Department
Assistant professor, Department of Agricultural Science, Payame Noor University, I.R.of IRAN

Corresponding author email :m.omidhadiani@gmail.com

ABSTRACT: Most of researchers in synoptic studies believe, there is a relationship between climatic and hydrological phenomena in different corners of the world with EL-Nino and southern oscillations index. therefore in this research, seven synoptic stations containing long-term data selected and analyzed the rainfall data in a regional study and investigated the correlation between Southern Oscillations index and incidence of dry/wet periods in north of Iran. The results in 95% level of significance showed that, there is a significant relation between mean annual rainfall in north of Iran and Southern Oscillation index. It should be considered that the correlation index between these two parameters was not equal in different spots and it decreased considerably from west to east. Mean while, there was a negative Pearson correlation between this index and monthly/annual rainfall in north of Iran which occurs with a few months delay. Whereas changes of Southern Oscillation index in summer and autumn, mainly showed more correlation with its influence on the rainfall in March and such changes, during the winter and spring was effecting on the rainfall in January until August in north of Iran.

Key words: El Nino, Southern Oscillation, Dry/wet Period, Rainfall, Correlation, North of Iran

INTRODUCTION

In synoptic point of view, climatic changes are mainly affected by condition and features of troposphere layer. Features of this layer themselves are also influenced by solar activities, the layer above it (Stratosphere), and the lower layer including lithosphere and hydrosphere. Among these, the effect of hydrosphere layer is remarkable for minor changes in temperature of oceans and seas cause considerable changes in hemisphere's general circulation and hence in climatic condition of earth. Climatologists believe that the inner energy of Pacific Ocean which is the largest and mean while involves the fewest islands, is a driving motor of atmospheric systems.

Therefore, occurrence the El-Nino phenomenon in Pacific Ocean, changes most of the atmospheric patterns. In this case, rainfalls in Iran also changes in general pattern. El-Nino does not effect on the rainfalls of Iran directly. In other words, El-Nino phenomenon has directly affected on changes of Jet stream and Indian Ocean streams and such changes would be indirectly effective on the rainfall pattern of Iran. Regarding damages resulted from the occurrence of flood and drought in Iran, it is important to study the relationship between the outbreak of Southern Oscillation Index (SOI) and rainfall in dry/ wet periods. There are plenty of studies in the matter of the relationship between rainfall deficit and the phenomenon of Southern Oscillation or El-Nino, which generally used statistical methods to estimate and analyze the correlation coefficient between annual/monthly rainfalls and Southern Oscillation index (SOI).

Walker (1923,1924,1928), analyzed the correlation between El-Nino and seasonal Monson rainfall forecasting in India which showed in the positive phase of Southern Oscillation (SO), the rainfall in Indonesia (including north of Australia) and India was lower than normal level.

Dennett and et al. (1978), were predicting seasonal rainfall in Fiji by Southern Oscillation index. Meanwhile Bhalmc and et al. (1983), Rasmussen and Carpenter (1983), also realized that the extensive droughts of India appeared at the time of warm trend of Southern Oscillation. By observing monthly rainfall of 1700 stations in all over the world, Ropelewski and Halpert studied the relationship between rainfall pattern and Southern Oscillation and El Nino in regional and global form and declared a significant relationship between the rainfalls in different areas of the world specially in the Pacific Ocean, Australia, Indian subcontinent, central and south of Africa and North/South /Latin America.

Suppiah (1988), showed the annual semi-warm rainfalls in Sri lanka (seasonal south-west Monsoon), have a positive correlation and annual semi-cold rainfalls (seasonal north-east Monsoon), have a negative correlation with Southern Oscillation index. Quinn (1992), Whetton and Rutherford (1994), used the data of Nile historical flood and studied incorporating Nile flood in relation to Southern Oscillation in a 400-year period. On the other hand, Cane and et al. (1994), also realized there is a strong relationship between Southern Oscillations Pacific ocean surface temperature and corn crops in Zimbabwe. Adiku and et al. (1995), and Chiew and et al. (1998), emphasized on the possible use of Southern Oscillation index for prediction of rainfall, stream flows and regional drought and discussed its positive effect on improving agricultural water management in under-studied areas. In addition Chiew and et al (1998), explained that Southern Oscillation caused disorder in climatic condition and there was a time-delay between the occurrence of this phenomenon with rainfall changes and stream flows in Australia significantly. Considering the relationship, it is suggested to use the Southern Oscillation index for predicting spring rainfall in eastern areas and summer rainfall in northeast of Australia for water resources and lands management.

Lucero Omar Abel (1998), in addition to studying the effects of the Southern Oscillation on the probability for climatic categories of monthly rainfall in a semi-arid region and its effect on agricultural water management, divided the Southern Oscillation index (SOI), trends classified as weak, normal and strong. In this division on weak position, the 5-years moving average standard deviation of Southern Oscillation index in five successive months is less than -0.5 and during at least one month is less or equal to -1. In strong trend these quantities in a five-month period are more than +0.5 and during at least one month are more or equal to +1 which are generally accompanied by La-Nina occurrence. Normal class is often the stage of transition between limit quantities and oscillation are effective on distribution of monthly rainfall probabilities just in four months.

Ranatunge and et al. (2003), studied changes in the southwest monsoon mean daily rainfall intensity in Sri lanka. El-Askary and et al. (2004), with an analysis of rain gauge derived from precipitation variability over Virginia and its relation with the El-Nino and Southern Oscillation reached a significant relation with the significance level of 95% and Pearson correlation coefficient evaluated 68%. Paeth and et al. (2008), believed in uncertainties in climate change prediction and climatic parameters by El-Nino, Southern Oscillation and monsoons. In Iran also Modarres pour (1996), analyzed the effect of ENSO event on rainfall and temperature of Iran from May to August, September to November (autumn), December to February (winter), March to August (spring). The results during the years of ENSO event (Years of 1986, 1990, 1993, 1997 and 2007) and also during the years after this event shows in different seasons do not have the same condition at the time of El-Nino occurrence and kind or intensify of effectiveness is also different seasonally and has local differences as well. Meanwhile in the years after El-Nino, the rainfalls in all over Iran were lower and temperature was higher than the mean.

Khosh Akhlagh (1998), in the study of extensive droughts in Iran by use of synoptic analyses and their synchronization with El-Nino occurrence proved that there is a correlation (-0.236) between Iran's monthly rainfalls and El-Nino. The results showed a negative relation between incorporating rainfall of 84% of selected station over Iran and ENSO phenomenon occurrence. During El-Nino, rainfall in these spots of Iran was higher than the mean. Nazem Al Sadat (1999), studied the effect of Southern Oscillation and El-Nino on autumn rainfalls of Iran and found a negative correlation coefficient between autumn rainfall and SOI in most of under- studied station expressed that El-Nino increases the autumn rainfall in Iran. Moreover the intensify of autumn rainfall in some areas such as Eastern and Western Azarbaijan , Kordestan, Zanjan, Ardabil, Markazi, Semnan and Tehran was more than other areas in Iran as a result of ENSO effectiveness and in the mentioned areas correlation coefficient have adequate time consistency.

Ghayour and Asarkerch (2001), compared Oscillation component and showed that its fluctuation index of North Atlantic Ocean (NAO), and Southern Oscillation index (SOI), was highly effective on temperature of Jask and as a whole it justifies up to 40% of fluctuation component variability. Nazem Al Sadat and Ghasemi (2003), assessed the amount of effect of Southern Oscillation and El-Nino on six-cold-months rainfalls of some provinces including Isfahan, Fars, Khozestan, Char Mahal Bakhtiari, Bousher and Kohkilouye and Boyer Ahmad. The results showed that La-Nina occurrence caused 20 to 50% decrease in rainfall in Boshehr, Kohkilouye and Boyer Ahmad, and south of Fars. In other provinces, this occurrence didn't cause any considerable changes in six-cold- months rainfall and on the contrary to La-Nina, El-Nino caused 20 to 70% increase of such rainfall in most station which depended on the geographic location of the station.While most intensive wet-yearly-periods was during El-Nino condition. Nazem Al Sadat and et al. (2005), studied the climatic changes and variability in south and southwest of Iran from the perspective of rainfall and coactions with Southern Oscillation and El-Nino. Observation concluded that Southern Oscillation and El-Nino are effective on Iran's climatic changes and variability. In other words increasing the El-Nino intensity and frequency (warm period), affects on the increasing process of cold-seasons rainfall in south and southwest areas of Iran.

Nazem Al Sadat and et al. (2006.a) studied rainfall data as a climatic condition marker in order to reveal climatic changes and measured the amount of this changes in two areas of southwest (dry area) and north (wet area) of Iran and also studied the probable effect of El-Nino and Southern Oscillation (ENSO) on creating climatic changes. The results showed that in 1975 was the most probable year for changes in time series of Southern Oscillation index (SOI). The intensity of El-Nino (warm trend) during 1975-1999 was determined more and higher than the similar amounts during 1951–1975. According to this finding for both under-studied areas, specially for southwest areas, the year of changes in rainfall time series was generally in agreement with mid 1970s. In most under-studied station, especially in southwest areas the average rainfall in the period after 1975 showed a remarkable increase as compared with similar amounts in the period before this year. While in southwest areas the average rainfall of autumn and winter showed a considerable increase in the period after 1975. Spring rainfall in such areas decreased in this period. In contrast for northern areas, an increase of summer and autumn rainfall and a decrease of spring and winter rainfall was observed in recent period. In monthly comparison the increase of rainfall activities in southwest and northern areas related to March and May in order. Nazem Al Sadat and et al. (2006.b studied the effect of Southern Oscillation and El-Nino on discharges of Fars province rivers and showed that the possibility of hydrological drought/wet period, occurrence in El-Nino period was less/more and in La-Nina period was more /less than base period. Hagh Negahdar and et al.(2007), studied the effect of El-Nino and Southern Oscillation on the occurrence of annual maximum flood (AMF), in southwest of Iran (Dez and Karoon dams watershed areas), in March to April period as the most important period for AMF occurrence. The results showed, there is a possibility of AMF quantity occurring more than the neutral average in months of March and April in the domains of Dez and Karoon with El-Nino occurrence. It is vices versa in La-Nina. Besides the intensity of AMF changes in El-Nino is more than in La-Nina; because in north of Iran rainfalls in different seasons happen and affect by synoptic condition under different convection, orographic or frontal system. So it is necessary to study the amount of influence of current synoptic condition on rainfall changes. As mentioned before most researchers believe Southern Oscillation changes of Pacific Ocean is effective on synoptic condition of different areas directly or indirectly. Thus in this research selected seven synoptic stations in the north of Iran with more than 36–years data including Gilan, Mazandaran and Golestan provinces and regional analysis of rainfall quantities and modeling prevailing relations with rainfall quantity and Southern Oscillation index was studied. The results showed there is a nonlinear relationship between these two parameters with a time delay of 2 to 8 months in proportion to different months and seasons.

MATERIALS AND METHODOLOGY

In this study, monthly and annual rainfall data of seven synoptic station involving Bandar Anzali, Rasht, Ramsar, Noshahr, Babolsar,Gharakhil and Gorgan (from 1971 to 2005) as well as corresponding amounts of Southern Oscillation index were used. The statistical period and studied stations were selected in a way with the least lack data and extending the period for achieving better statistical results and have a good covering over the domain of north of Iran including Gilan, Mazandaran and Golestan provinces. Applied monthly data were statistically analyzed by SPSS, Quatro pro. and Statplus software. To determine dry and wet periods of selected stations during the base period it is applied percentage difference method showed as formula (1) in which P_1 is monthly rainfall quantities and $\overline{P}$ is average monthly rainfall by millimeter during the base period. ΔP is also the amount of percentage difference in which position amounts show wet period and negative amounts indicate drought.

$$\Delta P = \frac{P_1 - \overline{P}}{\overline{P}} \times 100 \qquad (1)$$

Pearson correlation coefficient and analysis of nonlinear regression variance were used to evaluate the relations between occurred phenomena. Correlation between rainfall data and Southern Oscillation index at the same time and also with the hypothesis that due to the distance between Iran's domain and the local position of these Oscillations simultaneous effect might not be observed caused the analysis be computed with a **1–12** months delay; Moreover total annual rainfall of Iran was examined by means of correlation with annual ENSO index and prevailing relations were modeled. On the other hand, deviation from average of annual rainfall in the years of El-Nino occurrence (1993, 1991, 1987, 1986, 1982, 1976 and 1969), was studied with graphic procedure and besides determining dry and wet years their correspondence with El-Nino duration was identified. Statistical index of percentage difference and deviation from mean were applied to determine wet and dry years. In this way the average annual rainfall in each station during statistic period was considered as zero and the amounts higher than mean with position mark and the amounts lower than mean with negative mark in the graphs represent wet and dry periods.

RESULTS

By monthly study and seasonal assess on changes of Southern Oscillation index and percentage of rainfall differential mean in the north of Iran, it was identified that the effect of Southern Oscillations on rainfalls in this area occurs with a time delay which is changeable in different months. Furthermore in 75% of cases based on Pearson correlation coefficient there was a negative relationship between this index and percentage of rainfall differential mean. The equations models in this relationship are generally nonlinear. Regional analysis and modeling obtained different models based on the climatic zones and the most effectiveness was observed in wet and extreme wet climate areas (table 1 and 2). Regional models between Southern Oscillation index and the quantities of rainfall differential percentage based on different climates discussed in table 3 which despite low regression coefficient with 95% significant level, regard to equations analysis of variance and P value quantities (between 0/0001 to 0/0003).

Table 1. Regional monthly models of Southern Oscillation index (SOI), and differential mean percentage (D.M.Pre.)

Month (SOI Index)	Month (D.M. Pre.)	Equation
Jan.	Jun. – Aug.	$D.M.P. = 17.6 + 42.9Cos(0.15SOI_{Index} + 2.21)$
Feb.	Jun. – Aug.	$D.M.P. = 0.99 - 20.4Cos(-0.25SOI_{Index} - 11.4)$
Mar.	Aug.	$D.M.P. = \frac{-10.98 - 0.79SOI_{Index}}{1 + 0.11SOI_{Index} + 0.003SOI_{Index}^2}$
Apr.	Jun. – Aug.	$D.M.P. = 0.05SOI_{Index} - 0.02SOI_{Index}^2 - 0.003SOI_{Index}^3 - 0.44$
May	Feb. – Apr.	$D.M.P. = 2.46 + 18.3Cos(0.44SOI_{Index} + 1.3)$
Jun.	March	$D.M.P. = \frac{-4.67 - 0.47SOI_{Index}}{1 + 0.04SOI_{Index} + 0.0003SOI_{Index}^2}$
Jul.	March	$D.M.P. = -1.21 + 17.7Cos(0.66SOI_{Index} + 0.13)$
Aug.	March	$D.M.P. = -2.1 - 0.92SOI_{Index}$
Sep.	March	$D.M.P. = 1 + 13Cos(0.29SOI_{Index} + 1.5)$
Oct.	May	$D.M.P. = -1.5 - 1.64SOI_{Index}$
Nov.	Feb – Mar.	$D.M.P. = -14.2(1 - e^{-0.045SOI_{Index}})$
Dec.	March	$D.M.P. = \frac{3.6 - 0.38SOI_{Index}}{1 - 0.17SOI_{Index} + 0.007SOI_{Index}^2}$

Table 2.Statistical analysis of regional monthly models of Southern Oscillation index (SOI), and differential mean percentage (D.M.Pre.)

Month SOI Index	Month D.M. Pre.	Pearson Correlation Coe.	Estimated t value	t value	Sig. level 1%	Model	Regression Coe.	Result's Standard Dev.
Jan.	Jun. – Aug.	0.2	-0.07	1.645	√	Sinusoidal	0.222	96.01
Feb.	Jun. – Aug.	0.2	-0.27	1.645	√	Sinusoidal	0.146	97.43
Mar.	Aug.	-0.19	-0.51	1.645	√	Rational	0.349	75.01
Apr.	Jun. – Aug.	-0.3	-1.03	1.645	√	Polynomial	0.166	97.1
May	Feb. – Apr.	0.21	-0.79	1.645	√	Sinusoidal	0.199	56.45
Jun.	March	-0.2	-1.12	1.645	√	Rational	0.263	38.85
Jul.	March	-0.23	-0.55	1.645	√	Sinusoidal	0.285	38.6
Aug.	March	-0.24	-0.86	1.645	√	Linear	0.24	38.9
Sep.	March	-0.21	-0.08	1.645	√	Sinusoidal	0.144	59.47
Oct.	May	-0.27	-0.22	1.645	√	Linear	0.268	60.16
Nov.	Feb – Mar.	-0.22	-0.04	1.645	√	Exponential	0.202	45.67
Dec.	March	-0.19	-0.55	1.645	√	Rational	0.297	38.45

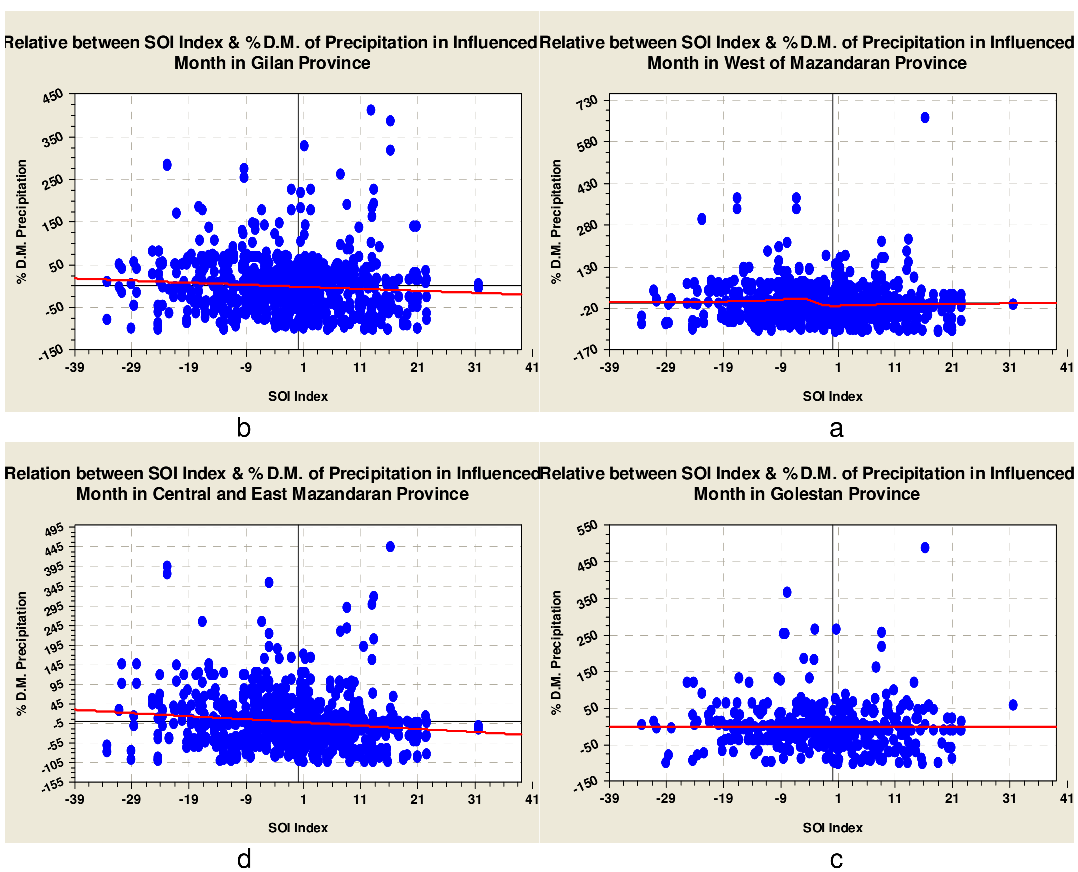


Figure 1. Trend of regional models of southern oscillation index (SOI) and differential mean percentage separated to climatic areas a. Gilan b. West Mazandaran province c. Central and east Mazandaran province d. Golestan

Table 3.Regional Models of Southern Oscillation index (SOI) and differential mean percentage in separation of climatic areas.

Result's Standard Dev.	Regression Coe.	Equation	Clima	Region
66.26	0.08	$D.M.P. = -0.74 - 0.5SOI_{Index}$	Very Extreme Wet	Gilan
64.77	0.14	$D.M.P. = \frac{-10.5 - 3.6SOI_{Index}}{1 + 0.33SOI_{Index} + 0.05SOI_{Index}^{2}}$	Extreme Wet	West of Mazandaran
65.6	0.135	$D.M.P. = -1.26 - 0.81SOI_{Index}$	Wet	Centeral and east of Mazandaran
65.17	0.057	$D.M.P. = \frac{-0.04SOI_{Index}}{SOI_{Index} - 0.2}$	Semi-Wet	Golestan

On the other hands, it is compared the quantities of Southern Oscillation index with the deviation from mean rainfall index in synoptic stations in order to express the relationship between Southern Oscillation index and dry/wet periods in north of Iran. The results are represented in figures 2 and 3.

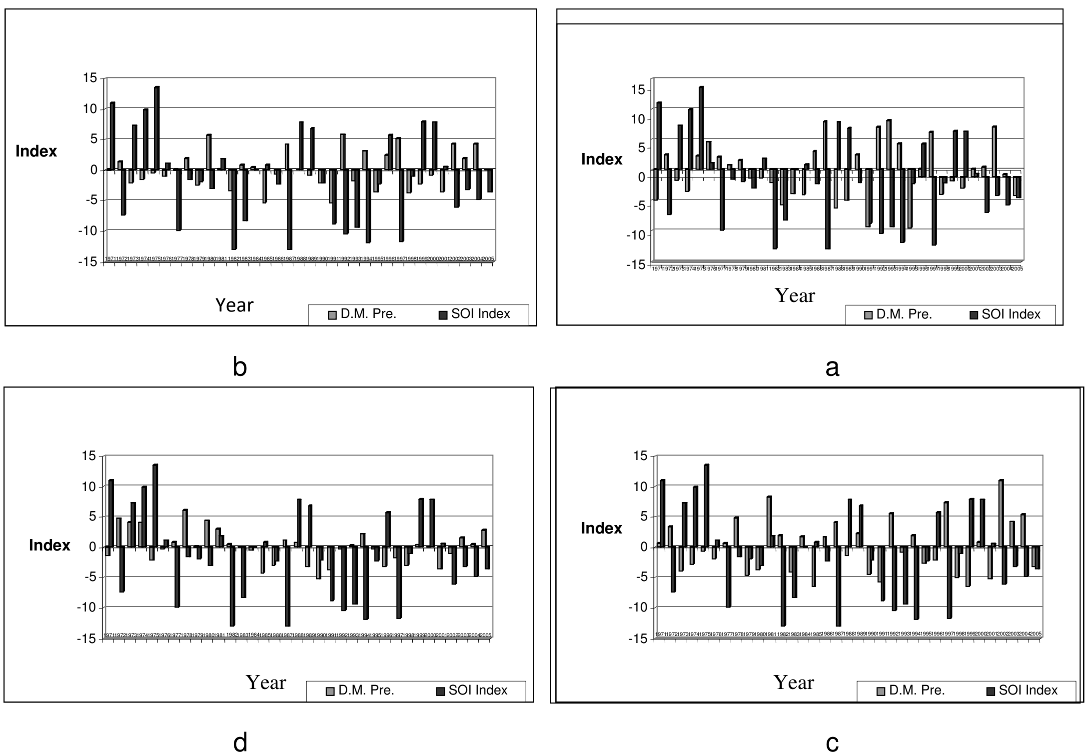
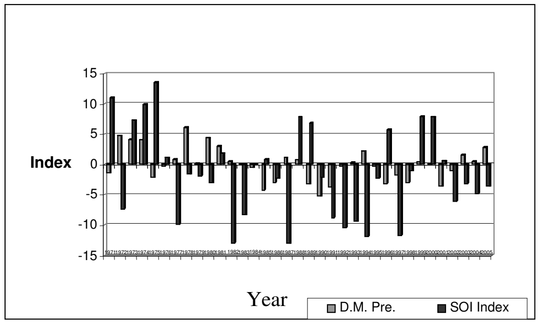
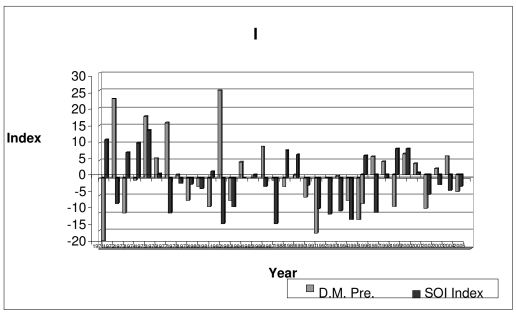
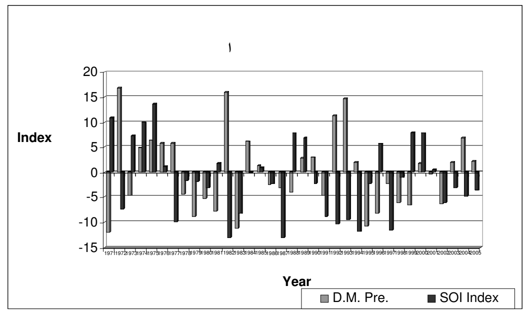


Figure 2.The comparison of Southern Oscillation index (SOI) and differential mean percentage in dry/wet periods in stations of Mazandaran province a.Noshahr, b.Gharakhil, c.Babolsar, d.Ramsar



a





c b

Figure 3.The comparison of southern oscillation index (SOI) and differential mean percentage in dry/wet periods in stations of Gilan and Golestan provinces a.Gorgan, b.Rasht, c.Bandar Anzali

DISCUSSION AND CONCLUSION

Investigation of rainfall in 7 synoptic stations in north of Iran with 36-years data, considered as a reliable long–term statistics, realized the mean rainfall in these stations as an average rainfall in this area has a significant relationship with Southern Oscillation index. In other words, the study of rainfalls in north of Iran during 8 years corresponding with El-Nino occurrence showed that in 7 years of this period rainfall was higher than 30–years mean which indicates wet period during these years and just in the year 1987 the average rainfall was a bit lower than mean. Azizi (2000), studied the El-Nino and dry/wet periods in Iran and estimated the Pearson correlation coefficient between Iran's rainfall index and Southern Oscillation index about -0.37 in significant level of 5%. It shows that during El-Nino occurrence, rainfalls in Iran were more than normal level and higher than mean.

By monthly observation and seasonal assessment of Southern Oscillation index and rainfall differential mean percentage in north of Iran, it is found out the effect of Southern Oscillations on rainfalls in this area occurs with a time delay which is changeable in different months. The changes of winter Southern Oscillation index usually effect with 5-7 months delay on the rainfall of north of Iran and have a negative relationship and the most effectiveness was observed in the months of August. The changes of this index was effective in the under-studied area in the beginning of spring (April) with 1-2 months delay, from June to August. In other words we can conclude that Southern Oscillation index from winter until the beginning of spring in the area of Pacific Ocean was effective on rainfalls of late spring and beginning of winter (June to August) in north of Iran.

This is while the oscillations of mentioned index during middle to late spring (June to May) 9-10 months later, summer Oscillations 6-8 months later and autumn Oscillations about 3-4 months later in north of Iran showed their effectiveness on the rainfalls by a negative relationship. That is to say Southern Oscillation index from mid-spring to late autumn in Pacific Ocean was effective on the rainfalls of late winter to early spring (February to April) in north of Iran and the most changes of rainfall in north of Iran during this period was in the month of March. Investigation of Pearson correlation coefficient between Southern Oscillation index and rainfalls in the case-study area showed, just in early winter in southern hemisphere (January and February), the correlation coefficient was positive (about 0.2), and in the other times of year the relation was quite inversely, approximately – 0.23 estimation. It is important to mention that this coefficient is changeable in different months and even from west to east of studied domain.

In regional analysis it is found that in eastern semi–humid regions (Golestan province), and also in highly humid regions in northwest of Iran (Gilan province), which have a little rainfall, Oscillations compared to long–term rainfall mean during a year. There is the least correlation between Southern Oscillation index and regional rainfalls. On the other hand the most correlation and effectiveness are observed in highly humid regions of Mazandaran province, one of whose reasons might be climatic factors like special topography of the area and close distance between Caspian sea and Alborz mountains and too many rainfall changes in this region compared to annual long-term mean during prolonged years.

Except for the months of August and October, in other months the regional relations over these changes in north of Iran are nonlinear models and generally follow Sinusoidal and Rational models. Altogether it seems Southern Oscillations of Pacific Ocean are indirectly effective on the climate of north of Iran by affecting atmospheric circulation elements as movement of equatorial hot core of Pacific Ocean causes a particular movement in spatial atmospheric circulation and caused to form a new spatial atmospheric systems which eventually has a positive effect on rainfall of the area in most years and associated with El-Nino. Because the rainfalls in north of Iran generally occur in cold period of year and normally in this period, the hot and convergency belt of earth is in southern hemisphere and besides the El-Nino occurrence benefits from hot water resource on its own. It can reinforce the regional convergency and atmospheric circulation movement toward southern latitudes. On the other hand the movement of hot water sources is followed by movement in Walker circulation components which can be effective on side-tropical high pressure in northern hemisphere. Of course the movement of side-tropical high pressure center has an inevitable impact on meteorological systems effective on Iran. Yet the effectiveness quantity of Southern Oscillation index in north of Iran is not great enough to cause climatic changes or any major and remarkable changes from year to year.

REFERENCES

Adiku S G K, Stone RC. 1995.Using the Southern Oscillation Index for improving rainfall prediction and agricultural water management in Ghana,Agricultural Water Management, Volume 29, Issue 1, 85-100.

Azizi Q. 2000. El-Nino and Dry/Wet periods of Iran, J. of Geographic Research, No. 38, pp. 71-84.

Bhalmc HP, Mooley DA, Jabhav SK. 1983. fluctuation in the Deought/flood areas over land and relationships with the Southern Oscillation. Mon. Wea. Rev., 111, 86-94.

Cane MA, Eshel G, Buckland RW. 1994. Forecasting Zimbabwean marine yield using eastern Pacific sea surface temperature, Nature, 30, 204-205.

Chiew FH S, Piechota T C, Dracup J A, McMahon TA. 1998. El Nino/Southern Oscillation and Australian rainfall, streamflow and drought: Links and potential for forecasting Journal of Hydrology, Volume 204, Issues 1-4, 30, 138-149.

Dennett MD, Elston J, Prasad PC. 1978. Seasonal rainfall forecasting in Fiji and the Southern Oscillation, Agricultural Meteorology, Volume 19, Issue 1, 11-22.

EL-Askary H, Sarkar S, Chiu L, Kafatos M, El-Ghazawi T. 2004. Rain gauge derived precipitation variability over Virginia and its relation with the El Nino southern oscillation, Advances in Space Research, Volume 33, Issue 3, 338-342.

Haqshenas A, Akhtari R, Saqafian B. 2007. Investigating the effect of El-Nino and SOI on Floods of West south of Iran, Water and Waste water J., No. 18, pp. 66-78.

John J, Oliver J E. 1993. Climatology an atmospheric science, New York, Macmillan Company, 169-178.

Khoshakhlaq F. 1998. ENSO and its effect on Precipitation regime of Iran, Geographic Research J., No. 51, pp. 78-89.

Linacre ET, Geerts B. 1997. Climates and weather explained, London, Routledge, 432 pp.

Lucero O A. 1998. Effects of the southern oscillation on the probability for climatic categories of monthly rainfall, in a semi-arid region in the southern mid-latitudes, Atmospheric Research, Volume 49, 337-348.

Modarres poor A. 1996. ENSO and Abnormality in Clima of Iran, Msc. thesis, Islamic Azad University, P. 189.

Nazem Al Sadat SM, Qasemi AR. 2003. ENSO and Precipitation of cold 6-months of Centeral and West South of Iran, Agricultural and Natural Resources Technology, No. 7, pp.1-13.

Nazem Al Sadat SM, Rahimi M, Keshavarzi A. 2006.b. Assessment of ENSO effective on Hydrological condition of rivers in Fars Province in Dry/Wet Periods, J. of Iranian Agricultural Science, No.37, pp. 361-369.

Nazem Al Sadat SM, Samani N, Yari A, Molaei Nikoo M. 2005. ENSO and Climate change and Precipitation Variations in South and West South of Iran, Scientific J. of Agriculture, No. 28, pp. 81-100.

Nazem Al Sadat SM, Samani N, Yari A, Molaei Nikoo M. 2006.a. Effective Force of ENSO on Climatic Changes in Iran, J. of Science and Technology, No. 85, pp. 555-565.

Nazem Al Sadat SM. 1999. Investigation on El-Nino and Southern Oscillations effective on Fall Precipitation of Iran, Second Regional Conference of Climate Change, Meteorological Organization of Iran.

Paeth H, Anja S, Petra F, Andreas H. 2008. Uncertainties in climate change prediction: El Niño-Southern Oscillation and monsoons, Global and Planetary Change, Volume 60, Issues 3-4, 265-288.

Qayour A, Asakere H. 2001. Study of Remote Sensing effects on Iran Climatology, Geographic Research J., No. 64, pp. 93-113.

Quinn WH. 1992. A study of the Southern Oscillation- related climatic activity for A.D. 622-1900 incorporating Nile flood data in El Nino: Historical and paleoclimatic aspects of the southern oscillation, edited by M.H. Glantz, New York, Cambridge Uni. Press., pp.119-648.

Quinn WN, Zopf DO, Short KS, Kuo Ynag RT. 1978. Historical trends and statistics of the southern Oscillation, El NiNo and Indomesian droghts, Fish. Bull., 76, 663-678.

Ranatunge E, Malmgren BA, Hayashi Y, Mikami T, Morishima W, Yokozawa M, Nishimori M. 2003. Changes in the Southwest Monsoon mean daily rainfall intensity in Sri Lanka: relationship to the El Niño–Southern Oscillation, Palaeogeography, Palaeoclimatology, Palaeoecology, Volume 197, Issues *1-2*, *1-14*.
Rasmusscn EM, Carpenter TH. 1983. The relationship between eastern equatorial Pacific Sea surface temperatures and rainfall over Indian and Srilanka, Mon. Wea. Rev., 111, 517-528.
Rasmusson EM, Wallace JM. 1983. Meteorological aspects of the El Nino / southern oscillation, Scince, 222, 1195-1202.
Ropelewski C, Halpert M. 1987. Global and regional scale precipitation patterns associated with El Nino / Southern oscillation, Mon. Wea. Rev., 115, 2352-2362.
Streten NA. 1983. Southern hemisphere circulation contrastsin the winter 1972 and 1973. Preprint first international conference on the southern hemisphere meteorology, Sao Joase das Capos, Brazil, 108-111.
Suppiah R. 1988. Atmospheric circulation variations and the rainfall of Serilanka, Sci. Rept., Inst. Geosci., Uni. Tsukuba, Sec. A. Vol. 9, 75-142.
Tyson PD. 1987. Climatic change and variability in Southern Africa, Cape Town, Oxford University Press.
Walker GT. 1923. Correlation in seasonal variations of weather, VIII: A preliminary study of world weather, Mem. Indian Meteor. Dept., 24, 75-131.
Walker GT. 1924. Correlation in seasonal variations of weather, IX: A further study of world weather, Mem. Roy. Meteor. Soc., 3, 81-95.
Walker GT. 1928. World weather III: Mem. Roy. Meteor. Soc., 2, 97-104.
Whetton P, Rutherford I. 1994. Historical ENSO tele connections in the Eastern Hemisphere, Climate changes, 28, 221-253.