INDIVIDUAL AND COUPLED EFFECTS OF THE ENSO AND PDO ON THE INCIDENCE OF AUTUMNAL DRY AND WET PERIODS IN IRAN

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ABSTRACT. – Individual and coupled effects of the ENSO and PDO on the incidence of autumnal dry and wet periods in Iran. The El Niño-Southern Oscillation (ENSO) is strongly connected to the inter-annual to intra-seasonal variations of Sea Surface Temperature (SST) over the Pacific Ocean equators. On the other hand, the Decadal Pacific Oscillation (PDO) is related to quasi-decadal fluctuations of the Pacific SSTs in the north-eastern parts of the ocean. The present study has made an effort to analyse the individual and the coupled effects of the ENSO and PDO on autumn precipitation in Iran for the period 1951-2005. Total precipitation data was collected for 41 rain-gauge stations spread in various parts of the country. Moreover, concurrent SST anomalies over the Niño 3.4 region were used as the ENSO indicator. Years related to the rank 1 to 18and 37 to 55 (18 years each) were categorized as the ENSO negative (El Niño) and positive (La Niña) phases, respectively. After obtaining the PDO data, similar procedure was also used to detect 18 years of the high or low phase of the PDO (PPDO or NPDO, respectively). The events that El Niño or La Niña years were coincided with the positive or negative phase of the PDO were then investigated. The results indicated that, precipitation has significantly suppressed or enhanced during the La Niña or El Niño event, respectively. Although the above or below normal precipitation was generally coincided with the PDO positive or negative phase, the effects of this Oscillation on precipitation variability were generally found to be significant for south-east rather than south-west of the country. While precipitation variability in south-west parts of the country was more sensitive to ENSO, the PDO was more influential on precipitation variability in southeast districts. The more dry or wet event was recognized as the periods that La Niña or El Niño is, respectively, coincided with the negative or positive phase of the PDO (La-LPDO and El-HPDO.

Keywords: ENSO, PDO, precipitation, interaction, southern Iran

1. INTRODUCTION

The El Niño-Southern Oscillation (ENSO) is strongly connected to the inter-annual to inter-seasonal variations of Sea surface Temperature (SST) over the Pacific Ocean equators. Several works addressing the effects of ENSO on Iran's climate have been made in recent years (Nazemosadat and Cordery 2000, Nazemosadat and Ghasemi 2004, Nazemosadat et al 2006, Soltani and Golipour, 2006) The Decadal

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Pacific Oscillation (PDO) is, however, related to multi-decadal fluctuations of the Pacific Ocean SSTs in the northeast of the Ocean between 20^{o} N and 65^{o}N. A strong positive (or negative) PDO index indicates that the SST anomalies of the eastern extra-tropical North Pacific are warmer (or colder) than the western and central portions, which is similar to the El Niño-created (or La Niña-created) pattern. Newman, et al. (2003) reported that both inter-annual and decadal variability in PDO, are the sum of direct ENSO forcing. Verdon and Franks (2006) reported that phase changes in the PDO have a propensity to coincide with changes in the relative frequency of ENSO events, where the positive phase of the PDO is associated with an enhanced frequency of El Niño events, while the negative phase is shown to be more favourable for the development of La Niña events.

The influence of these Oscillations on global climate is generally more obvious when the ENSO or PDO is in its extreme condition. For such circumstances, the SST anomalies over a per-defined Ocean waters are highly positive or negative.In spite of close inter-relationships between ENSO and PDO, a number of investigators assessed the couple and separate effects of these two inter-related phenomena on climate variability in various parts of the world ((Newman, et al. 2003; Edgar et al 2006; Praskievicz and Chang 2009; Biabanaki et al. 2014). As will be shown here, such assessment is vital for comprehensive understanding the role of the Pacific surface climate on precipitation variability in Iran.

The present study has made an effort to investigate individual and couple effects of the ENSO and PDO on the occurrence of seasonal dryness or wetness in Iran. The areas whose rainfall variability is sensitive to either ENSO or PDO were then distinguished.

2. DATA AND METHODS

2.1. Precipitation

Total monthly October-December precipitation data covering the 1951-2010period were used for 41 rain gauge stations spread in various parts of Iran. These three monthly data were averaged to produce seasonal time series. In Iran, the water-year calendar approximately starts from October and these three months commonly consider as autumn. Fall precipitation is essential for successful sowing, seed germination, planttillering and subsequent production yield. Spatial distribution of the percentage that autumn precipitation accounts for total annual precipitation is depicted on Fig 1. As indicated, this precipitation is more critical for southwest and north of Iran; where the percentage varies from 36% to 44%. The contribution, however, drops to maximum 26% for the eastern half of the country.

2.2. ENSO and PDO series

Monthly October-December time series of the Niño 3.4 and the PDO index were gratefully extracted from the webpage of NOAA for the period 1951-

2005.These monthly data were then transformed into seasonal series and used as the ENSO or PDO indicator. Each of these series was then ranked in descending order to categorize positive or negative phase of the index. For the Niño 3.4 series, epochs which were related to the rank 1 to 18 or 37 to 55 (18 years each) were, respectively, assigned as the El Niño or La Niña events (abbreviated as El and La in Table 1). The selected warm and cold episodes were mostly identical to the list of these events obtained in Climate Prediction Centre of NOAA webpage. Similarly, the positive (warm) or negative (cold) phase of the PDO was then categorized (HPDO or LPDO in Table 1, respectively). Two important alternatives including the episodes that El Niño was coincided with the HPDO or La Niña years accorded with LPDO were then selected for further investigation (El-HPDO with 8 years and La-LPDO with 10 years in Table 1).

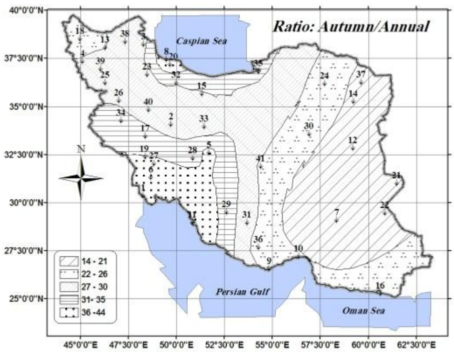

Fig. 1. ***Percentage that autumnal precipitation accounts for total annual precipitation. Geographical location of the stations is indicated by numbers 1 to 41***

Table 2. ***The years coincided with El Niño, La Niña, HPDO, LPDO, El-HPDO and La-LPDO***

Phenomena	**ENSO**	
Phase	**El**	**La**
Years	1951,1963,1957,1963,1965,1968, 1969,1972,1976,1977,1982,1986, 1987,1991,1994,1997,2002,2003, 2004	1954,1955,1956,1962,1964,1967,1970,197 1,1973,1974,1975,1983,1984,1988,1995,1 998,1999,2000
Total	**18**	**18**
Phenomena	**PDO**	
Phase	**HPDO**	**LPDO**
Years	1954,1958,1959,1969,1976,1979, 1980,1981,1983,1984,1986,1987, 1991,1992,1993,1997,2002,2003	1951,1955,1956,1961,1962,1963,1964,196 6,1970,1971,1973,1975,1990,1994,1998,1 999,2001,2005
Total	**18**	**18**
Phenomena	**ENSO-PDO**	
Phase	**El-HPDO**	**La-LPDO**
Years	1969,1976,1986,1987,1991,1997, 2002,2003	1955,1956,1962,1964,1970,1971,1973,197 5,1998,1999
Total	**8**	**10**

2.3. Constructing precipitation composites

For each of the considered stations, precipitation composites constructed for El, La, HPDO, LPDO, El-HPDO and La-LPDO. Mean precipitation was then computed for each of these composites as well as for the whole study period of each station. These statistics were then used to define the following indices:

A: $(\overline{R}_{El}/\overline{R}_{La})$as well as$(\overline{R}_{HPDO}/\overline{R}_{LPDO})$ where $\overline{R}_{El}$, $\overline{R}_{La}$, $\overline{R}_{HPDO}$ and $\overline{R}_{LPDO}$ signifies mean seasonal precipitation for the El Niño, La Niña, positive and negative phase of the PDO, respectively.

B: (N_{Wet-El}/N_{El}) as well as (N_{Dry-La}/N_{La}) where N_{Wet-El}, N_{El}, N_{Dry-La} and N_{La} represents the frequency of the El Nino years which were coincided with above normal precipitation, total number of the El Niño events, frequency of the La Niña years which were coincided with below normal precipitation and total number of the La Niña events (18 years), respectively.

C: $(\overline{R}_{El-HPDO}/\overline{R}_{La-LPDO})$, where $\overline{R}_{El-HPDO}$ or $\overline{R}_{La-LPDO}$ represent the mean precipitation during the El-HPDO and La-LPDO, respectively.

The Non-parametric Mann-Whitney test was applied to examine the difference between median precipitation during the opposite phases of the ENSO or PDO as well as between El-HPDO and La-LPDO conditions. These tests are appropriate for non-normally distributed datasets, which are frequently encountered in precipitation time series (Yue et al., 2002). Due to small sample size, the Fisher Exact tests (Agresti, 1992) were also used to examine if the frequency of above or below normal precipitation is significantly associated to the occurrence of opposite phases of the ENSO or PDO.

3. RESULTS

3.1. ENSO - precipitation composites

As delineated in Fig. 2, the ratio of R_{El} / R_{la} is greater than unity for all parts of the country suggesting that for the considered stations, mean precipitation during El Niño is consistently greater than corresponding value during the La Niña events. The ratio is remarkably greater for northwest, west and north of the country implicating that below or above normal rainfall in these areas is strongly related to the cold or warm phase of ENSO, respectively. Compare to La Niña years, occurrence of the El Niño increased precipitation from about 20% to 180% in various parts of the country. According to the applied Mann-Whitney test, precipitation difference between these two phases is significant for the shaded areas.

Fig. 3 delineates the probability of having wet period during El Niño events and symbols denote stations with significant results. As indicated, the probability is below 50% for almost southern half of the country and above 70%

for northwest districts emphasizing the influential role of ENSO on precipitation variability in the later areas.

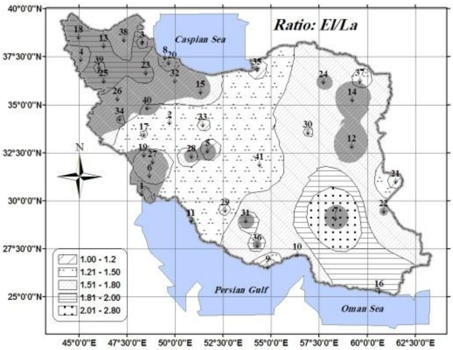

Fig. 2. ***Spatial distribution of the ratio of ($\overline{R}_{El}/\overline{R}_{La}$) for Iran. Difference in precipitation amount is significant for the shaded areas***

Fig. 4 is similar to Fig. 3 but for having drought during La Niña episodes. According to this Fig, meteorological drought is pervasive during La Niña and the probability of below normal precipitation exceeds than 61% for almost all parts of Iran. For only a few stations in southeast of the Caspian Sea and the Persian Gulf coastlines drought probability is less than 50%. Although the incidence of ENSO warm phase increases the probability of above normal precipitation in the south coast of the Caspian Sea, La Niña does not substantially induce drought in these areas. While alternation of the ENSO phases significantly modulates the frequency of wet or dry event in the west coasts of the Sea, this modulation consistently reduces eastward. In general, the effect of La Niña in triggering drought in Iran was found more remarkable than the role of El Niño for motivation of wetness.

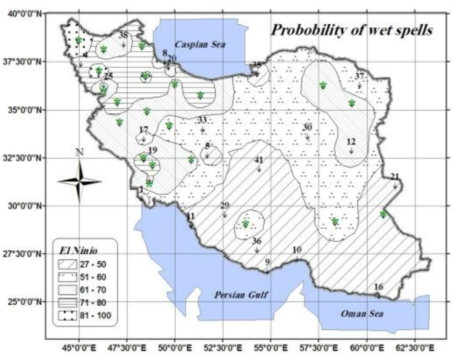

Fig. 3. ***Probabilities that El Niño events harmonize with the above normal precipitation. Symbols denote the stations for which the Fishes Exact test is significant***

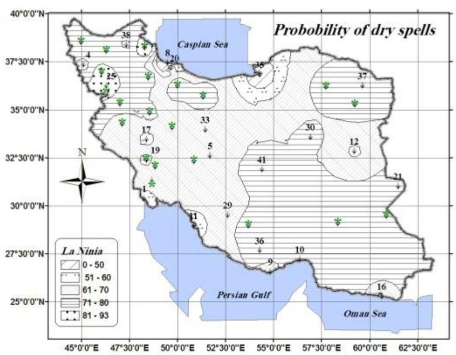

Fig. 4. ***Like Fig. 3 but for La Niña events and occurrence of drought events***

3.2. PDO phases

Fig. 5 likes Fig. 2 but for the ratio of R_{HPDO}/ R_{LPDO}. With the exception of a few sporadic stations, the ratio is consistently greater than unity for all parts of the country indicating that the occurrence of the positive or negative phase of the PDO harmonizes with a widespread increase or decrease in Iran's autumn precipitation, respectively. The measure of the ratio increases in the northwest-southeast orientation. This implicates that the incidence of positive or negative PDO phase, enhances or suppresses precipitation in the south-eastern parts of Iran, respectively. While the ratio generally varies from 1.0 to 1.5 in northern areas, it exceeds 2.5 in south-eastern districts. The shaded area exhibits the regions for which the Mann-Whitney test is significant.

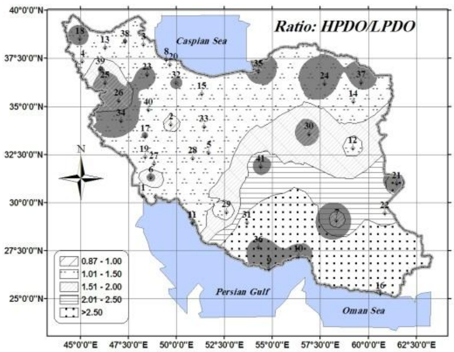

Fig. 5. ***Like Fig.2 but for (*** $\overline{R}_{HPDO}/\overline{R}_{LPDO}$ ***)***

For elaborating the areas that are more sensitive to either ENSO or PDO, differential values of the (REl / Rla) and (RHPDO / RLPDO) computed (Fig 6). Based on this Fig, while north-western parts of the country are highly sensitive to the change in ENSO phase, PDO is more influential over the south-eastern districts.

Since the effects of ENSO and PDO are in-phase, extreme wet or dry events are expected when warm or cold phases of these two phenomena are coincided. The ratio of $\overline{R}_{El-HPDO}/\overline{R}_{La-LPDO}$ (where R is the precipitation amount during either El-HPDO or la-LPDO) is therefore computed and mapped in Fig 7. As indicated, the ratio is mostly about 1.0 for northern half of the country but reaches to about 4.0 in the south and southeast districts. Our close examination revealed that precipitation amount during the El-HPDO episodes is generally greater than long-term mean by about 10% in the northwest to 150% in the southeast of Iran. Surprisingly, for some stations in the east of the country, near the Iran-Afghanistan border, these statistics were either near or less than 1.0.

Prevalence severe drought in most parts of Iran and particularly in south-eastern districts is the main feature of the La-LPDO episodes. For such circumstances, precipitation deficiency over these areas generally deviates from 35% to 87% of the long-term mean. The most sever precipitation deficiency (13%

to 40% of mean) is evident in the coastal areas near the Hormoz strait between the Persian Gulf and Oman Sea.

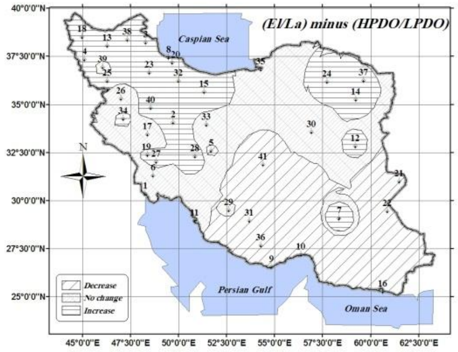

Fig. 6.*Spatial distribution of the difference between* ***(*** $\overline{R}_{El}/\overline{R}_{La}$ ***) and (*** $\overline{R}_{HPDO}/\overline{R}_{LPDO}$ ***)***

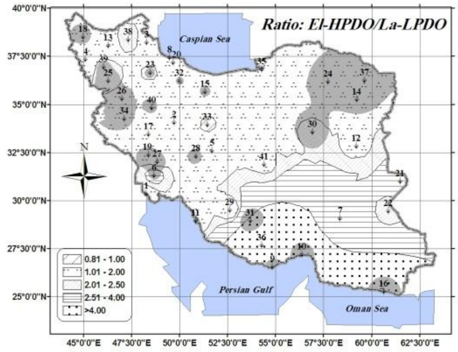

Fig 7. ***Like Figs. 2 and 5 but for (*** $\overline{R}_{El-HPDO}/\overline{R}_{La-LPDO}$ ***)***

4. CONCLUSIONS

The study concluded that, for northwest, north and west of Iran, precipitation significantly suppresses or enhances during the La Niña or El Niño event, respectively. This suppression or enhancement, however, was insignificant for south-eastern districts. Contrary to ENSO, the PDO-precipitation relationships were found significant for these districts. Severe dry or highly wet condition occurred when La Niña or El Niño was coincided with the negative or positive phase of the PDO (La-LPDO and El-HPDO, respectively). Precipitation has enhanced during the El-HPDO by about 10% in the northwest to 150% in the southeast of Iran. Widespread severe drought in most parts of Iran and particularly in southeastern districts was, however, the main feature of the La-LPDO episodes. For such circumstances, precipitation deficiency over these areas generally deviated from 35% to 87% of the long-term mean.

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