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Teleconnections Between El Niño/Southern Oscillation and Rainfall and Temperature in Iran

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Abstract: El Niño/Southern Oscillation (ENSO) has been linked to climate anomalies around the world. This study investigates the relationship between ENSO events and rainfall and temperature in Iran. Six sites with contrasting climates were selected and statistical analyses were performed to determine the impact of ENSO on winter, spring, summer and autumn precipitation and temperature. Significant correlations were found between average July-August SOI (Southern Oscillation Index) and precipitation and temperature of the following autumn and winter. In other cases, significant correlations were rare. In 2 of the 6 selected locations, autumns were significantly ($p<0.01$) wetter and cooler in El Niño (based on July-August average SOI) years than neutral or La Niña years. Warm phase of ENSO (El Niño years) correlated with significantly drier winters in 2 of the 6 selected locations. Negative July-August average SOI (El Niño) conditions was associated with warmer winter in all 6 selected locations. It was concluded that this teleconnection could be used in forecast application.

Key words: ENSO, precipitation, temperature, seasonal prediction, forecast

Introduction

Some of year-to-year variations in climate are associated with patterns that are coherent on a large scale and this has provided a scientific basis for skillful prediction (Hammer *et al*., 2001). El Niño/Southern Oscillation (ENSO) has major effects on climate around the world and one indicator of the state of ENSO, the Southern Oscillation Index (SOI) has been used to forecast global rainfall probabilities (Stone *et al*., 1996). The effect of an ENSO event is generally strongest in the tropical pacific genesis region and contiguous continents (Hammer *et al*., 2001). However, ENSO also has influence in extra tropical latitudes and it is not negligible. A number of studies have confirmed that ENSO has a significant impact on variability of rainfall (Chiew *et al*., 1998; Mason, 2001; Rocha, 1999; Van Oldenborgh *et al*., 2000) and temperature (Jones and Trewin, 2000; Müller *et al*., 2000) over different parts of the globe.

For Iran, Nazemosadat (1999) has reported that autumn rainfall is negatively correlated with autumn average SOI. In another study he (Nazemosadat, 2001) found that for the main parts of Iran, winter average SOI positively related with winter rainfall, but for a few stations cold events (La Niña) generally were coincided with low rainfall (drought). This study not mentioned the possible relation between ENSO and temperature. In this preliminary study, therefore, we evaluate lag-correlation between ENSO and rainfall and temperature in some selected Iranian stations with contrasting climates.

Materials and Methods

This study was conducted at Gorgon University of Agricultural Sciences, Gorgan, Iran during year 2002-2003. Iran has an area of 1,648,000 km^2 and includes two major mountain systems, named

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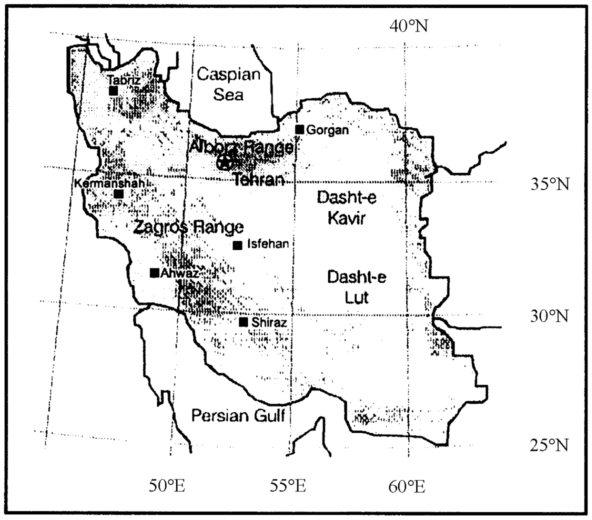

Fig. 1: Map of Iran showing main mountain systems and selected stations for this study

Alborz and Zagros (Fig. 1). These mountain ridges which run east and southeast from the northwest corner of the country, surround two uninhabited deserts, Dasht-e Lut and Dasht-e Kavir. Six climate stations with long-term and reliable daily weather data were selected for the study to represent a large geographical area and several climatic zones in Iran. The selected sites included Tabriz (38.13°N, 46.28°E and 1364 m asl), Gorgan (36.85°N, 54.27°E and 13 m asl), Kermanshah (34.32°N, 47.12°E and 1322 m asl), Isfahan (32.67°N, 51.87°E and 1600 m asl), Ahwaz (31.33°N, 48.67°E and 22 m asl) and Shiraz (29.55°N, 52.60°E and 1488 m asl) (Fig. 1). The climatic characteristics of the locations represent temperate sub-humid, cold sub-humid (boundary between sub-humid and semiarid), cold arid, warm desert and cold (boundary between cold and temperate) semiarid climates. Mean annual temperature is 12.2°C for Tabriz, 17.6°C for Gorgan, 14.0°C for Kermanshah, 16.2°C for Isfahan, 25.1°C for Ahwaz and 17.5°C for Shiraz. Total average annual rainfall is 294 mm for Tabriz, 607 mm for Gorgan, 487 mm for Kermanshah, 125 mm for Isfahan, 240 mm for Ahwaz and 334 mm for Shiraz that occur during 84 wet days for Tabriz, 99 for Gorgan, 77 for Kermanshah, 35 for Isfahan, 34 for Ahwaz and 42 for Shiraz. For each location, 30 years (1966-95) of daily data for rainfall and maximum and minimum temperatures were available. The SOI data (one of the ENSO indicator) were obtained from www.longpaddock.qld.gov.au.

In evaluation of the association between ENSO and autumnal and winter rainfall in Iran, Nazemosadat (1999; 2001) found that the best results are obtained by defining autumn as October to December and winter as January to March. Therefore, in this study winter was defined as January-March, spring as April-June, summer as July-September and autumn as October-December. In order to explore the lag-correlation between ENSO and rainfall and temperature, following procedure was used. For winter, average SOI were calculated for January-February, February-March and January-March. Then correlation coefficients were calculated between these SOIs and rainfall amount and temperature of its following spring, summer and autumn. The same procedure was used for other seasons.

To categorize warm and cold phases of ENSO, those years in which SOIs were less than -5 and above+5 were considered El Niño and La Niña, respectively. Then, an analysis of variance was conducted with three treatments, El Niño, La Niña and neutral. Mean comparison was carried out using Least Significant Difference (LSD) test with 0.1 level of probability (0.9 level of confidence).

Results and Discussion

Significant correlations were found between average summer SOIs (July-August, August-September and July-September averages) and rainfall and temperature of the following autumn and winter. In the other cases, significant correlations were rare and excluded from this study. The number of significant correlations was slightly greater for average July-August SOI than August-September and July-September. Therefore, only results relating to July-August were included in this study.

Years between 1966 and 1995 were divided into each of two ENSO phases, El Niño, La Niña and neutral years according to July-August SOI as described in methods section. By this classification, warm phase or El Niño years occurred in 69, 72, 76, 77, 82, 87, 93 and 94 (8 events). Cold events or La Niña occurred in 71, 73, 74, 75, 81 and 88 (6 events). The remaining 15 years between 1966 and 1995 were classified as neutral ENSO events.

Significant correlations were found between July-August average SOI and precipitation of the following autumn and winter in 2 of the 6 selected locations (Table 1). For Tabriz and Kermanshah, in the northwest of the country, July-August El Niño events correlate with above-average precipitation of the following autumn. As an example, Fig. 2a shows the July-August average SOI versus precipitation of the following autumn in Tabriz; El Niño years (negative SOI values) are associated with higher autumn precipitation, while La Niña conditions (positive SOIs) are likely to produce drier than average autumn precipitation. In Kermanshah, El Nino years had a 23% greater autumn precipitation, but differences between the ENSO phases were not statistically significant (Table 2). In Tabriz and Kermanshah, autumn precipitation contributes 28 and 35% of the annual precipitation (data not shown). In Kermanshah and Ahwaz, in the West Side of the country, significant correlations were observed between July-August average SOI and winter precipitation (Table 1). Mean comparison showed that La Niña years have had 33% greater precipitation in Kermanshah and 23% in Ahwaz. Winter precipitation contributes 45 and 50% of the annual precipitation in Kermanshah and Ahwaz, respectively (data not shown).

The association between ENSO phases and precipitation found here is in agreement with many other reports. For Northwest USA, Redmond and Koch (1991) showed that the SOI could be used as a predictor for climate, especially during winter. Greatest correlations between SOI and winter climate patterns occurred with about a 4-month time lag, with summer SOI correlating well with conditions in the Northwest during the following winter. For the Canadian Prairies, Bonsol and Lawford (1999) reported that the average number of summer extended dry spells are associated with El Niño events. The number of these spells is significantly lower for non-El Nino periods. Kahya and Karab (2001) found that streamflows in Turkey is responsible to the extreme phases of SO. Rocha (1999) found that ENSO is related to above-average autumn precipitation over the Iberian Peninsula (IP) as a whole and below-average spring rainfall over the southeastern IP. In a statistical analysis of more than a century of data, Van Oldenborgh *et al*. (2000) found a strong connection between strong El Niño winter events

Table 1: Simple correlation coefficients between average July-August SOI and following autumn and winter rainfall amount and temperature at selected sites

	Following autumn		Following winter	
SOI	Rainfall	Temperature	Rainfall	Temperature
Tabriz	-0.48***	0.30	0.08	-0.36*
Gorgan	0.21	0.49***	0.14	-0.36*
Kermanshah	-0.33*	0.05	0.39**	-0.48***
Isfahan	-0.24	-0.07	0.17	-0.31*
Ahwaz	-0.24	-0.18	0.34*	-0.53***
Shiraz	-0.07	-0.10	-0.04	-0.33*

*, **, ***, Significant at 0.90, 0.95 and 0.99 level of confidence, respectively

Table 2: Total rainfall and mean temperature of autumn and winter and their standard deviations by ENSO phases (1966-1995). ENSO phases are defined based on July-August average SOI

		Autumn		Winter	
		Rainfall	Temperature	Rainfall	Temperature
Tabriz					
	La Niña	57±15b	7.1±1.2ab	76±34a	-1.5±2.2b
	El Niño	112±42a	6.5±1.6b	77±28a	1.7±2.4a
	Neutral	78±37b	7.8±0.9a	87±30a	0.8±1.5a
	Total	83±40	7.3±1.3	82±30	0.6±2.1
Gorgan					
	La Niña	216±28a	15.0±1.2a	188±37a	7.4±1.5b
	El Niño	198±65a	13.4±0.8b	194±36a	9.2±0.8a
	Neutral	191±71a	14.6±0.9a	196±42a	8.6±1.5a
	Total	198±62	14.3±1.1	194±38	8.5±1.5
Kermanshah					
	La Niña	153±54a	9.5±0.7a	289±115a	1.7±1.4b
	El Niño	211±103a	9.6±0.9a	180±67b	5.0±1.4a
	Neutral	160±61a	9.9±0.7a	210±70b	4.3±1.4a
	Total	172±75	9.7±0.7	218±87	3.9±1.8
Isfahan					
	La Niña	30±24a	10.5±1.2a	64± 23a	4.8±1.0b
	El Niño	47±27a	10.8±0.9a	50±36a	6.6±1.1a
	Neutral	36±21a	11.1±0.7a	61±32a	6.7±1.1a
	Total	38±23	10.9±0.9	59±31	6.3±1.3
Ahwaz					
	La Niña	90±46a	19.6±0.9a	149±57a	13.5±0.6b
	El Niño	111±49a	20.1±1.1a	99±37b	15.6±0.9a
	Neutral	101±47a	20.0±0.7a	121±49ab	14.8±1.0a
	Total	102±46	19.9±0.9	121±49	14.8±1.2
Shiraz					
	La Niña	80±46a	12.6±0.9a	207±125a	7.5±0.6b
	El Niño	93±58a	13.0±1.1a	195±73a	8.6±0.7a
	Neutral	112±86a	12.9±0.6a	199±84a	8.4±1.2a
	Total	100±71	12.9±0.8	199±88	8.3±1.0

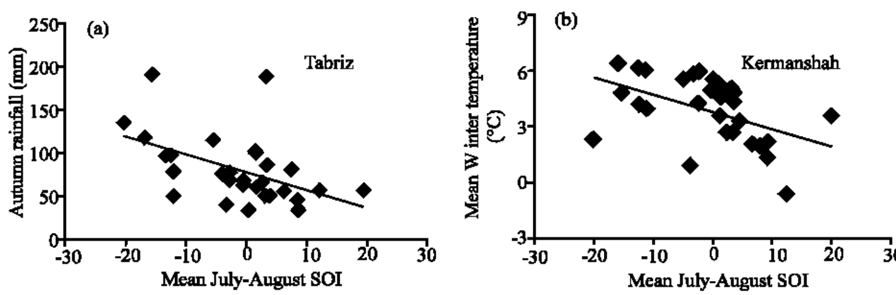

Fig. 2: Relationships between mean July-August SOI and autumn rainfall at Tabriz (a) and mean winter temperature at Kermanshah (b)

and high spring precipitation in a band from southern England eastwards into Asia. Lloyd-Hughes and Saunders (2002) reported a connection between ENSO and European and North African precipitation, especially across the central Europe region.

For autumn temperature, only one significant correlation was found between July-August average SOI and Gorgan autumn temperature (Table 1). In this location near the Caspian Sea, autumn temperatures were 1°C cooler in El Niño years compared to long-term average (Table 2). For Tabriz, autumn temperature in El Niño years were cooler compared to long-term average (11%) (Table 2). Winter temperatures correlate well with SOI values and significant correlation coefficients were observed in all 6 selected locations (Table 1). In general, negative July-August average SOI (El Niño) conditions are associated with mild winter temperatures, while positive SOIs (La Niña) have greater likelihood of colder than average winter temperatures (Table 2). In La Niña years winter temperatures were 1.9°C lower than long-term average in Tabriz, 1.1°C in Gorgan, 2.2°C in Kermanshah, 1.5°C in Isfahan, 1.3°C in Ahwaz and 0.8°C in Shiraz. As an example, Fig. 2b shows mean winter temperatures at Kermanshah compared with the previous July-August average SOI. El Niño years generally results in mild conditions during winter, while La Niñas are associated with colder temperatures. This significant connection between ENSO phases and temperature is in agreement with other reports. Jones and Trewin (2000) reported that the SO plays a major role in variability of seasonal maximum, minimum and mean temperature and diurnal temperature range. The observed relationships were strongest over eastern Australia year round and over northern Australia during the summer half year. The SO-temperature correlations were comparable in magnitude with those described previously for Australian rainfall, but with a strong geographical and seasonal variation. Müller *et al*. (2000) showed that part of the frost frequency variability within the central region of Argentina is explained by the ENSO cycle. The low phase of SOI correlate with those years for which the number of frost events remained below the total annual mean.

Results of this study indicate that autumn and winter precipitation and temperature values vary by July-August average ENSO phases in some selected sites in Iran. The impact of ENSO is less certain for autumn and winter precipitation and autumn temperature, but it is consistent and stronger for winter temperature. This teleconnection may enhance initiation of other studies, investigating association between ENSO and natural disasters, such as floods and droughts, streamflows, extreme precipitation and temperature events and agricultural productions. Also, this teleconnection could be used in forecast applications, but the degree of variation within phases may limit the usefulness of simple approach used in this study. Therefore, more precise definition of ENSO phases, or the use of climate forecasts specific to each individual year based on numerical models may be required (Phillips *et al*., 1998).

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