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Possible influences of North Atlantic Oscillation on winter reference evapotranspiration in Iran

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A B S T R A C T

The North Atlantic Oscillation (NAO) is known to be responsible for most of inter-annual atmospheric variability over the Northern Hemisphere, particularly in Europe and the Mediterranean basin. Owing to the importance of reference evapotranspiration (ET_o) in irrigation planning, water resource monitoring and management, we assessed the impact of the NAO on the ET_o variability during the winter months from December to March in Iran. The Penman–Monteith FAO 56 method was applied to estimate ET_o based on meteorological data from 41 synoptic stations during a period of 40 years (1966–2005). The correlation between the monthly NAO index and the ET_o time series was computed using the Spearman's rho test for time lags from 0 to 6 months. The simultaneous and lag correlation analyses demonstrated that the winter ET_o series over Iran had negative correlations with the NAO index at almost all the stations. The highest negative correlation of 0.53 was observed between the January ET_o series and the August NAO at Tabriz station located in the northwest of Iran, whereas the highest positive correlation of 0.55 was found between the January ET_o series and the simultaneous NAO at Bandar-Lengeh station which is situated on the northern coast of the Persian Gulf. Averaged over the 41 stations, the winter ET_o values during the negative phase of the NAO were about 3% higher than those during the positive phase.

1. Introduction

Reference evapotranspiration (ET_o) rate is an agroclimatic parameter worldwide used as a necessary component in every project of regional scale concerning irrigation planning, water resources monitoring and management, or land use development, since it is considered as a sufficient estimator of the climatic impact on crop water requirements (Dalezios et al., 2002). Therefore, monitoring the temporal variations of ET_o offers valuable information for regional hydrology and agricultural water requirements (Tabari et al., 2012).

Iran is located in the southwest of the Middle East and is characterized by large inter-annual variability of climatic parameters (Ghahraman, 2006; Modarres and da Silva, 2007; Modarres and Sarhadi, 2009; Tabari and Hosseinzadeh Talaee, 2011a, 2011b, 2011c). The country mainly as an agrarian society is seriously vulnerable to the climate variability as most of the geographical area falls under the arid and semi-arid types of climate. It seems very likely that any change in the availability of water will play a key role in the sustainable development of agriculture and environment in the country (Dinpashoh et al., 2011). In addition, there has been much discussion recently about virtual water trade and the links between hydrology and food security. Iran is considered a highly food insecure nation, largely due to the poor water resources available. Thus, understanding evapotranspiration dynamics will be critical for managing local water resources and food security issues (Tabari et al., 2012).

Several studies have shown that Iran's evaporation and evapotranspiration had a high variability during the last decades. Tabari and Marofi (2011) studied the temporal variations of pan evaporation at 12 stations located in western Iran for the period 1982–2003. They found a significant increasing trend at 67% of the stations at the average rate of (+) 160 mm/month per decade. Dinpashoh et al. (2011) examined the trends in ET_o over the 16 weather stations and found that the increasing trends in ET_o were more pronounced than the decreasing trends. Tabari et al. (2011, 2012) also showed that ET_o significantly increased at the majority of the Iranian stations, but the trends were found to be significant at about 30% of the stations.

Large-scale atmospheric circulation patterns explain much of the variability and trends in climatic parameters at the regional scale (e.g., Nazemosadat and Cordery, 2000; Buermann et al., 2003; Nazemosadat and Ghasemi, 2004; Ryoo et al., 2004; Ghasemi and Khalili, 2006, 2008; Gu et al., 2009; Bannayan et al., 2011; López-Moreno et al., 2011). Among them, the North Atlantic Oscillation (NAO) has been recognized for more than 70 years as a

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dominant mode of climate variability in the Northern Hemisphere (Walker, 1924). However, it has only received more attention in recent years (e.g., Hurrell, 1995, 1996; Hurrell and van Loon, 1997; Hoerling et al., 2001; Hurrell et al., 2001; Turkes and Erlat, 2003; Şarlak et al., 2009; Lee and Zhang, 2011). Some researches have reported that the winter surface climate of the Northern Hemisphere is related to the NAO (e.g., Zorita et al., 1992; Eshel et al., 2000; Pozo-Vazquez et al., 2000, 2001; Cullen et al., 2002; Trigo et al., 2002, 2004; Aravena et al., 2009). The Middle East region is commonly neglected in North Atlantic studies because of its proximity to the monsoonal region and the relative scarceness of hydrological data. A relationship between the Eastern Mediterranean and the Atlantic sector is expected since the NAO controls the Atlantic heat and moisture fluxes into the Mediterranean region (Kahya, 2011). As a result of the NAO, cooler and drier winter conditions occur in the Mediterranean extending into the Middle East during the positive phase of NAO, and the warmer and wetter winters during the negative phase (Cullen et al., 2002). Strong linkages of NAO with temperature in the Middle East were also reported by Mann (2002). Moradi (2004) showed that precipitation and temperature of Iran are influenced by the NAO, while the NAO index was weekly correlated with the precipitation and temperature of the Zagros Mountain (Masih et al., 2011) and aridity index of the northeastern Iran (Bannayan et al., 2010).

Although the study of the relationship between the large-scale atmospheric circulation modes and evapotranspiration variability is very attractive, there is little work in this field. Sabziparvar et al. (2011) investigated the impacts of ENSO on ET_o variability in some warm climates of Iran. They found that about 74% of the correlations between the Southern Oscillation Index (SOI) and ET_o were statistically significant in spring and summer months. In addition, they showed that the time lag between El-Nino events and the observed maximum impacts on ET_o was about 5 months at the warm sites of Iran.

Unfortunately, unlike ENSO, there has been no study addressing the possible influence of the NAO on ET_o variability. Thus, the current study was performed to investigate the NAO impacts on the variability of winter ET_o at 41 synoptic stations of Iran. During a period of 40 years (1966–2005), the correlations between the NAO index and the estimated ET_o values for two scenarios (with and without time lag) were constructed using the Spearman's rho test.

2. Data

The weather data were obtained from 41 Iranian synoptic stations for a period of 40 years (1966–2005). The geographical position of the selected stations is presented in Fig. 1 and Table 1. Eleven climatic variables were recorded including: (1) mean air temperature; (2) maximum air temperature; (3) minimum air temperature; (4) dew point temperature; (5) relative humidity; (6) water vapor pressure; (7) wind speed; (8) atmospheric pressure; (9) precipitation; (10) solar radiation; and (11) sunshine hours. The 24-h wind speed was recorded in km/h at a 10 m height, and the necessary corrections were applied to convert it to m/s at a 2 m height to confirm to its application in the Penman–Montieth FAO 56 formula. Data were provided by the Islamic Republic of Iran Meteorological Organization.

First of all weather data were quality-controlled with the double-mass curve analysis (Kohler, 1949). A double-mass curve analysis is a graphical method for identifying or adjusting inconsistencies in a station record by comparing its time trend with those of other relatively stable records of a station, or an average of several nearby surrounding stations. The results of the correlation analysis and the double-mass curve analysis were checked in order to contrast both series and to use them alternatively when a segment of each series was missing.

The weather data were missing for some stations for certain months and/or years. The stations with more than 5% of missing data were omitted from the study to minimize errors or biases in our analysis. The missing weather data were estimated using other available data according to Allen et al. (1998). The recommended procedures for estimating weather missing values have been applied by numerous researchers (e.g., Annandale et al., 2002; Popova et al., 2006; Cai et al., 2007; Gocic and Trajkovic, 2010).

The North Atlantic Oscillation is a dominant mode of multi-annual variability in the atmosphere, most pronounced in winter (Bannayan

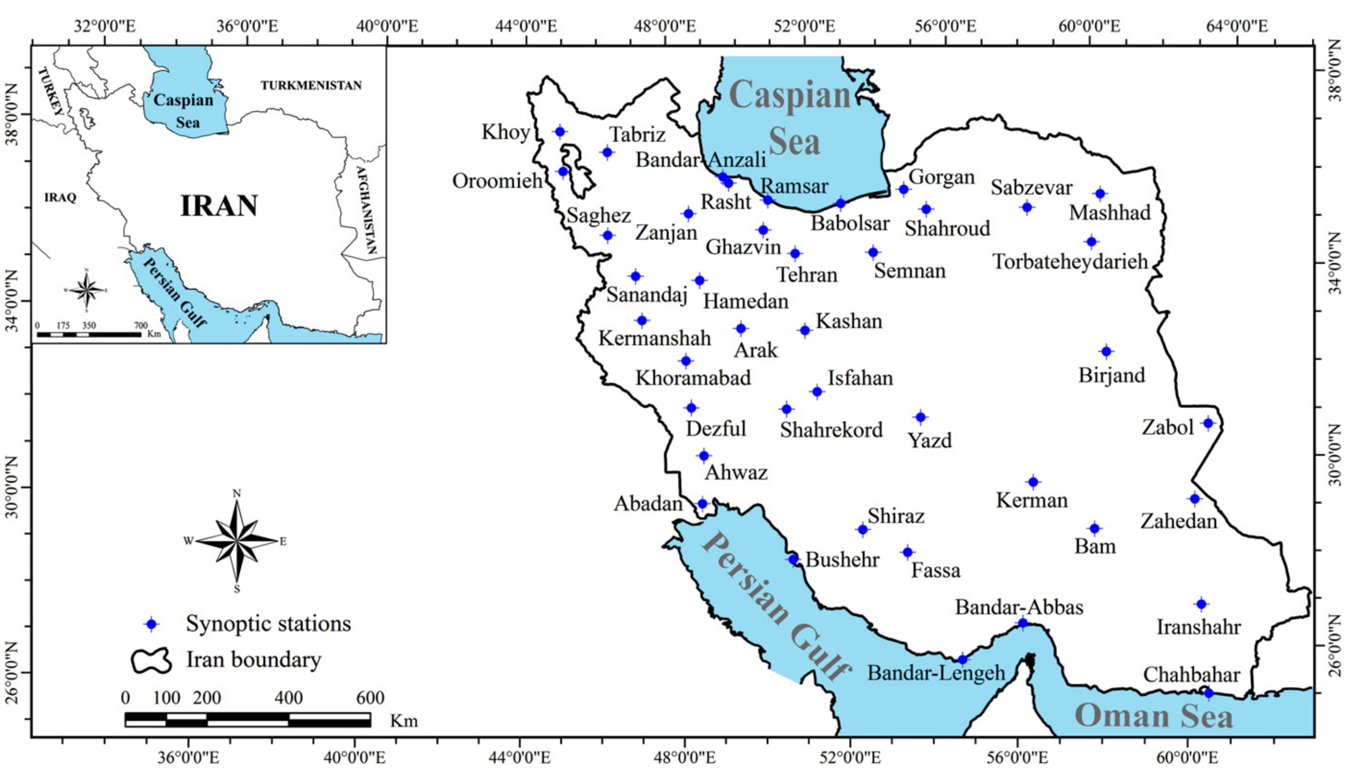

Fig. 1. Distribution of the synoptic stations used in the study.