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FULL LENGTH ARTICLE

Modeling minimum temperature using adaptive neuro-fuzzy inference system based on spectral analysis of climate indices: A case study in Iran

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Abstract Nowadays, a lot of attention is paid to the application of intelligent systems in predicting natural phenomena. Artificial neural network systems, fuzzy logic, and adaptive neuro-fuzzy inference are used in this field. Daily minimum temperature of the meteorology station of the city of Mashhad, in northeast of Iran, in a 42-year statistical period, 1966-2008, has been received from the Iranian meteorological organization. Adaptive neuro-fuzzy inference system is used for modeling and forecasting the monthly minimum temperature. To find appropriate inputs, three approaches, i.e. spectral analysis, correlation coefficient, and the knowledge of experts,are used. By applying fast Fourier transform to the parameter of monthly minimum temperature and climate indices, and by using correlation coefficient and the knowledge of experts, 3 indices, Nino 1 + 2, NP, and PNA, are selected as model inputs. A hybrid training algorithm is used to train the system. According to simulation results, a correlation coefficient of 0.987 between the observed values and the predicted values, as well as amean absolute percentage deviations of 27.6% indicate an acceptable estimation of the model.
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1. Introduction

human beings have invariably been closely in touch with weather events. Owing to this fact, identification of the factors affecting long-term and short-term weather changes and also climate fluctuations is of particular importance. Since temperature is one of the most fundamental elements of climate formation and its changes may transform the weather patterns in any region, a large segment of climatology researches has been earmarked to the investigation of the temperature behavior in different time and location scales (Rosenberg et al., 1983; Smith et al., 2006; Majnooni-Heris et al., 2011). Temperature

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is one of the essential parameters of the weather and one of the few measurable thermodynamic variables. Modeling and prediction of temperature and particularly minimum temperature are of special importance in the fields of agricultural climatology, glaciation and frost management, water resources planning and management, irrigation networks, tourism and everyday life issues. Weather transformations are extremely volatile. These changes lead to the emergence of weather patterns and forms of weather flows which occur in different time scales. Large-scale transformations and synoptic factors have a great effect on temperature and the minimum temperature event is more related to transformation factors. Teleconnection patterns may be used in order to study and identify minimum temperature variations in short-term and long-term periods. The reason is the fact that teleconnection patterns can be in a way indicative of these large-scale transformations. Understanding the causes and the identity of climate changes is one of the most significant purposes of gathering climatology data and monitoring climatological phenomena. In this regard, climatological fluctuations caused by teleconnection patterns have taken on tremendous importance. Teleconnection is one of the climatic characteristics in the global scale. By means of this mechanism, the changes that occurred in the temperature or pressure pattern in a region of the Earth are transferred to other regions using large-scale systems and they affect weather conditions in different ways (Osborn, 2006, 2011). Teleconnection patterns typically possess fluctuating low-frequency behavior and they are used in order to forecast the average weather conditions during several-month or annual time periods. Figures indicating teleconnection patterns are called climate indices. Hence, it is crucial to study minimum temperatures according to these indices which represent the interaction of weather and environmental patterns and can play an important role in identifying short-term and long-term behaviors of monthly minimum temperature and the modeling thereof.

One of the important aspects of the analysis of time series is spectral analysis which deals with the analysis and decomposition of time series to components with different frequencies. Alternation and hidden cycles in the behavior of the climatic parameters are revealed in this method. Taghavi et al. (2011) presented a climatological regionalization for 65 synoptic stations of the Iranian Meteorological Organization using the spectral analysis method and clusterization. The spectral analysis method was used to investigate average temperature in northwestern Iran. According to the research findings, the temperature of the region contained a two-and-a-half-year period (Asakereh, 2010). The entire physical processes of the soil are directly or indirectly dependent on temperature. The daily and annual estimations of the soil temperature were carried out in different depths in six stations located in western Iran using the Fourier series analysis. In this research, the air temperature (2 m high) was merely used.

A review of different references indicates the existence of numerous models for the prediction of minimum air temperature which are used in order to investigate the solutions to combat the threat of frost and glaciation (Allen, 1957). Prediction of average daily temperature was carried out in Turkey using artificial neural networks (Dombayci and Gölcü, 2009). The adaptive neuro-fuzzy inference system is used as a new method for prediction (Jang, 1993). Air temperature forecast in northwestern Iran was carried out using a neuro-fuzzy inference system (Darbandi and Arvanaghi, 2009). Nayak et al. (2004, 2005) used intelligent systems in order to model precipitation-runoff. The results demonstrated that the non-linear model of precipitation-runoff is much more efficient in the adaptive neural-network-based fuzzy inference system, compared to independent neural and fuzzy systems. Rojas et al. (2008), Zounemat-Kermani and Teshnelab (2008), Wang et al. (2009), and Firat et al. (2009) separately compared the capability of ANFIS in predicting time series with that of other intelligent systems. The results indicated much better efficiency of this system compared to other intelligent systems. The adaptive neuro-fuzzy inference system was used to estimate daily evaporation in eastern Iran (Moghaddamnia et al., 2009a,b). In another research, meteorological parameters effective in the solar radiation level were determined using gamma test. The forecast of solar radiation level was then carried out using artificial neural networks and the adaptive neuro-fuzzy inference system (Moghaddamnia et al., 2009a,b). Ustaoglu et al. (2008) used three different intelligent system methods in order to predict minimum, maximum and daily average temperature. Kisi and Ozturk (2007) estimated the water requirement of the reference plant using the ANFIS system. Forecasting autumn droughts in eastern Iran was carried out using different input variables. Climatic indices, precipitation and the drought index were used as the input variables of the ANFIS system. The input variables were introduced to the model with zero-, one-, two-, and three-month delays. The results showed that appropriate inputs are different for different delays and using a certain input will not lead to optimum modeling (Hosseinpour Niknam et al., 2011). Among other researches in this context, the studies by Coulibaly et al. (2005) and Drake (2000) may be pointed out. Since temperature is one of the fundamental factors in climate formation and its changes can transform the weather patterns in any region, researchers have always paid attention to its prediction and estimation. To this end, numerous methods including intelligent systems such as the ANFIS system have been developed. This research aims at predicting the monthly minimum temperature of the region under study in order to combat frost and glaciation and the incidents caused by this environmental hazard. The appropriate inputs for the model were initially selected and then, the ANFIS system was used to forecast the monthly minimum temperature.

2. Material and methods

In this research, the statistical data pertaining to the monthly minimum temperature of the meteorology station of the region under study was used for modeling. The daily minimum temperature of the station was received from the Iranian Meteorology Organization for the 42-year statistical period since 1966–2008. Afterward, the monthly minimum temperature was extracted (1). The monthly values for 13 teleconnection indices were also extracted from the website of the National Oceanic and Atmospheric Administration in the same statistical period. The specifications of the station of the region under study are demonstrated in Table 1. In the subsequent step, the

Table 1 Specifications of the station under study.

Latitude	Longitude	Elevation
36 16 N	59 38 E	999.2 M

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