www.ijrls.pharmascope.org

ISSN 2231-2935
Research Article

Evaluation of Predictability of Mean Minimum and Maximum Monthly Temperature Using ANFIS

Behrouz Sobhani[1*], Akbar Goldust[2]

[1]Faculty member of University of Mohaghegh Ardabili
[2]PhD in Climatology, University of Mohaghegh Ardabili

ABSTRACT

As temperature is one of the main elements of formation of weather, changes in temperature can change climate of every region. Hence, temperature prediction can have scientific and applied importance. At the present study, ability of Adaptive Neuro-Fuzzy Inference Systems (ANFIS) in predicting mean minimum and maximum monthly temperature has been evaluated. Temperature data have been obtained monthly for 288 months (from 1988 to 2010) from stations of Pars Abad, Ardabil and Khalkhal in Ardabil Province. 70% of the data have been specified to training and 30% have been devoted for testing the model. The model has predicted, based on desired trainings, predictable elements from Jun 2004 to Dec 2010. For purpose of evaluating model efficiency, predicted data by the model have been compared with real data based on test period. According to obtained results, in most cases, ANFIS model has desirable efficiency for predicting mean minimum and maximum monthly temperature in stations of Ardabil Province.

Keywords Monthly Temperature; ANFIS; Prediction; Ardabil Province; Climate.

INTRODUCTION

Climate is one of the most important factors in evolution and deformation of living things. One of the main elements of the climate is temperature. Researchers apply temperature data for implementing scientific, economic and industrial purposes. Accordingly, investigating temperature is so important. According to importance of temperature in social-economic plans, investigating temperature variability and predicting it n different time and space ranges has been considered by scholars, which have determined specific dimensions of this issue. Some examples of these studies include studies of Zekai (1998); Turkes (1996) and Leite et al (1996). Moreover, Khorshid Dust et al (2009) have also predicted absolute minimum and maximum temperature of Isfahan using time series methods and have indicated that among applied methods, Halt-Winters method has more ability for the desired prediction. Adaptive Neuro-Fuzzy Inference System is one of the main models applied for different predictions. Kumar (2012) has applied ANFIS model for predicting weekly minimum temperature in India and has confirmed efficiency of the model for prediction. Moreover, Aliyari et al (2008) have applied the model for predicting air pollution in Arak; Safavi (2008) for predicting qualitative situation of Zayanderood River; Fallah Ghaheri et al (2010) for predicting spring rainfall of Khorasan Razavi; and Honar et al (2010) have applied the model for predicting side weir discharge and have confirmed desirable accuracy of the model for prediction.

Studying research literature indicates that ANFIS model has desirable efficiency for different kinds of prediction. Scholars have applied in their predictions mostly those elements correlated with predicted element. At the present study, possibility of predicting mean monthly maximum and minimum temperature using ANFIS model has been evaluated. This has been conducted without interference of any correlated element and would be possible just based on previous pattern of data.

MATERIALS AND METHODS

Adaptive Neuro-Fuzzy Inference Systems (ANFIS)

ANFIS has been presented by Jang in 1993. Combination of fuzzy system, which is based on logical rules of "if-then", and artificial network method, which is able to extract knowledge from numerical information, have led to presentation of ANFIS system. In figure 1, Sogno Fuzzy System with two inputs, 1 output, 2 rules and ANFIS as its equivalent has been presented (Jang, 1993). The system includes 2 inputs of X and Y and an output of "f" with two rules as follow:

$$\text{Rule 1: If } x \text{ is } A_1 \text{ and } y \text{ is } B_1, \text{then } f_1 = p_1 x + q_1 y + r_1$$

$$\text{Rule 1: If } x \text{ is } A_2 \text{ and } y \text{ is } B_2, \text{then } f_2 = p_2 x + q_2 y + r_2$$

* Corresponding Author
Behrouz Sobhani
Bsobhani152@gmail.com

Where; *x* and *y* are the inputs, A_i and B_i are the fuzzy sets, f_i are the outputs within the fuzzy region specified by the fuzzy rule, p_i, q_i and r_i are the design parameters that are determined during the training process.

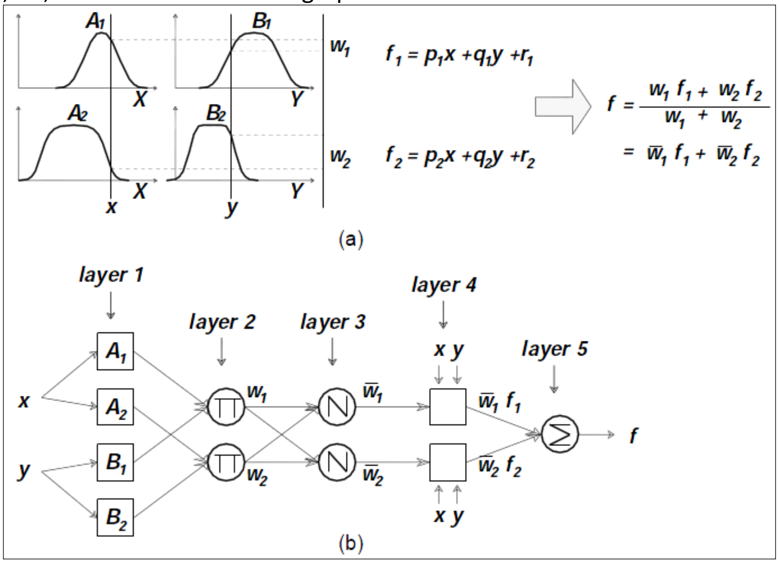

Figure 1: (a) fuzzy reasoning; (b) equivalent ANFIS

According to figure 2, ANFIS structure has been formed of 5 layers as follows:

Firth layer, input nodes: in this layer, membership degree of input nodes to different fuzzy ranges has been determined using membership function.

$$O_i^1 = \mu_{A_i}(x) \qquad i = 1,2$$

Or (1)

$$O_i^1 = \mu_{A_{i-2}}(x) \qquad i = 3,4$$

Parameters in every node can be a determinant for form of membership function of fussy set in same node. Membership function of fuzzy sets can be usually presented by bell-shaped functions as follows:

$$\mu_A = \frac{1}{1+\left(\frac{x-c_i}{a_i}\right)^{2b_i}} \qquad (2)$$

The blood was drawn from the orbital venous plexus by puncturing with tip of pasture pipette under light ether anesthesia and the blood was allowed to fall drop by drop ether anesthesia and the blood was arrested by gently pressing the eye ball with the help of dry cottoWhere; X input value to node "i" and set $S_1 = \{a_i, b_i, c_i\}$ are known as consequent parameters.

Second layer, basal nodes: every node on this layer calculates activity degree of a rule:

$$O_i^2 = w_i = \mu_{A_i}(x) \times \mu_{B_i}(y) \qquad i = 1,2 \qquad (3)$$

Where; $\mu_{A_1}(x)$ refers to membership degree of X in A_i set; $\mu_{B_i}(y)$ refers to membership degree of y in B_i set.

Third layer, mean nodes: in this layer, node i has normalized activity degree of i rule against total activity degree of rules as follows:

$$O_i^3 = \bar{w}_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad i = 1,2 \qquad (4)$$

Where; $\bar{w}_i$ refers to degree of normalized activity of rule i.

Fourth layer, result nodes: in this layer, output of every node is equal to:

$$O_i^4 = \bar{w}_i \int i = \bar{w}_i (p_i x_1 + q_i x_2 + r_i) \qquad i = 1,2 \qquad (5)$$

Where; $S_2 = \{p_i, q_i, r_i\}$ set is known as consequent parameters.

Fifth layer, output nodes: in this layer, each node calculates final output as follows (number of nodes is equal to number of outputs):

$$O_i^5 = \sum_{i=1}^{n} \bar{w}_i \int i \qquad (6)$$

After implementing the model, root mean square error has been applied in order to evaluate accuracy of the model.

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(o_i - e_i)^2}{n}} \quad (7)$$

Where; o_i and e_i are respectively observed and predicted values in time i; and n is number of observations.

STUDY AREA AND MODEL APPLICATION

Study Area

Studied area in this study has been Ardabil Province Iran. The province has been located in northwest of Iran as it is illustrated in figure 2. In Ardabil, data gained from synoptic stations in Pras Abad, Ardabil and Khalkhal have been applied for this purpose as it is obvious in table 1. The data include mean minimum and maximum monthly temperature during statistical period of 24-year with 288 months since Jan 1987 to Dec 2010.

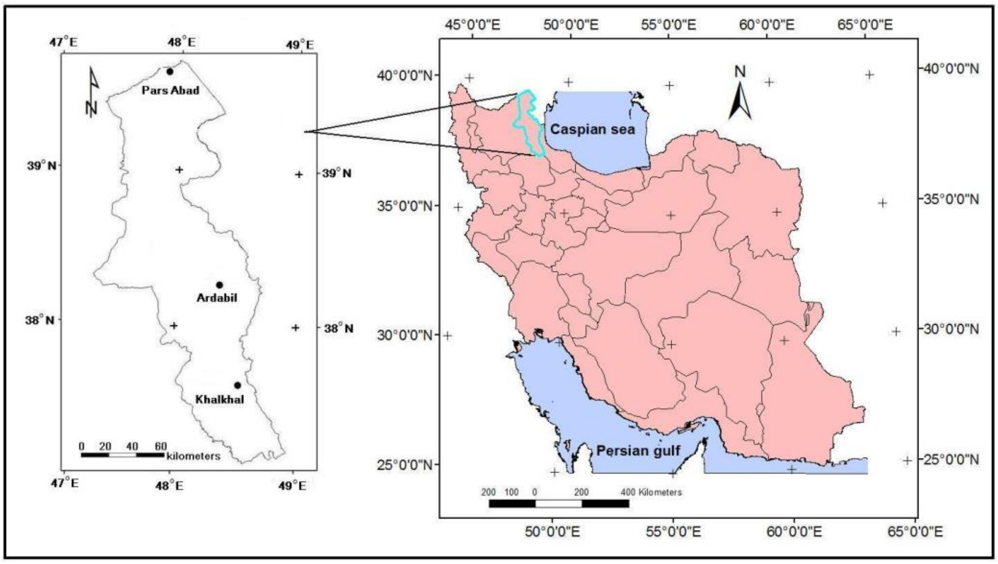

Figure 2: location of studied area

Model Application

At the present study, ANFIS model has been trained based on 70% of data (since Jan 1987 to May 2004 for 209 months) and has been tested based on other remained 30% (since Jun 2004 to Dec 2020 for 79 months). In order to determine structure of ANFIS, using grid partitioning method has been applied for selecting 4 membership functions in gauss form. Hybrid model has been applied for purpose of training the model. In regard with training the model, number of epochs was 150 and value of error tolerance was considered 0.

After training and implementing the model, data were predicted during examination and predicted and observed data were the compared using graphs and root mean square error (RMSE). Figures 3-5 have illustrated comparison of observed and predicted data. According to the diagrams, it could be found that the model has been able to predict total procedure of data properly. In most cases, high error can be observed in peaks and perigees of data series. Particularly, prediction error is more in minimums rates.

In most cases, temperature variations have been more in cold seasons than others over the different years. The model has made error in predicting these cases. In other words, in most cases, the model has predicted temperatures of warm seasons that have less variation.

Based on figures 3-5, in late months of the year 2007, temperature has been lower than it at same time by other years. The model has more errors in these cases, since recorded temperatures in these months have been repeated less than others in epochs.

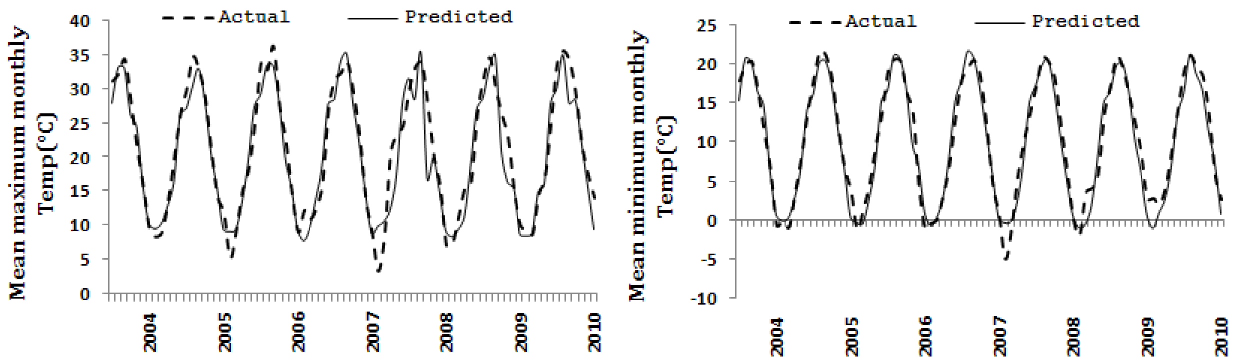

Figure 3: Observed and predicted monthly temperature in Pars Abad Station

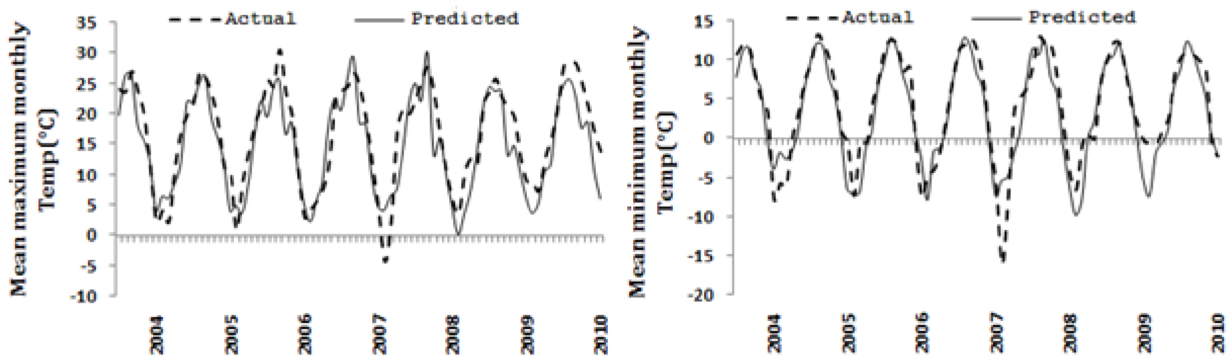

Figure 4: Observed and predicted monthly temperature in Ardabil Station

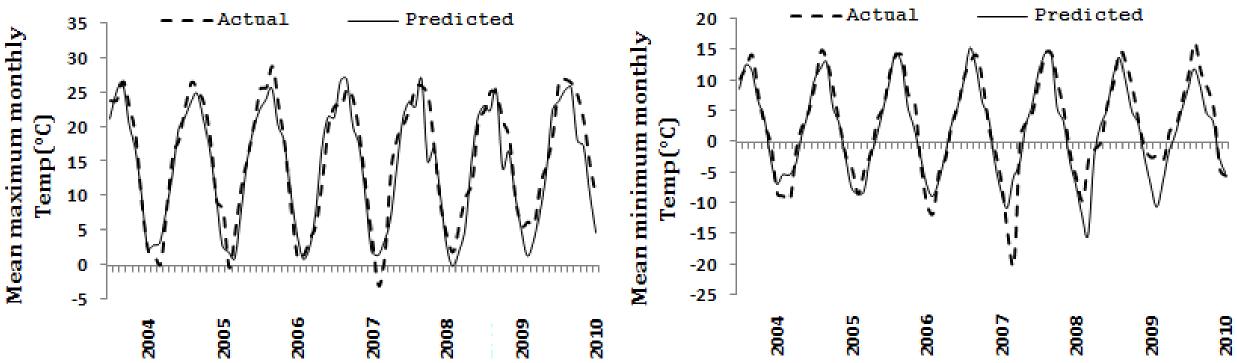

Figure 5: Observed and predicted monthly temperature in Khalkhal Station

RESULT AND DISCUSSIONS

In tables 2 and 3, error values of epoch and test periods have been presented based on root mean square error. Most error value in Ardabil station has been in mean maximum monthly temperature and lowest error in Pars Abad station has been in mean minimum monthly temperature.

According to investigation of several cases of statistical features of data, a significant relationship could be observed between statistical features and observed prediction error. Most existing error has been related to Ardabil station in mean maximum monthly temperature. In this case, data included most changes and lowest variance and SD than other data. Instead, the lowest error level has been related to Pars Abad station in mean minimum monthly temperature with lowest changes and highest variance and SD. Therefore, the less the range of changes and the more the range of variance and SD are, the more accurate prediction would be.

CONCLUSIONS

At the present study, probability of predicting mean maximum and minimum monthly temperature in Ardabil stations has been evaluated using ANFIS model. Using graphic models and root mean square error (RMSE), predicted and observed data in epoch have been compared with each other. Obtained results indicate that in most cases, ANFIS model has desirable efficiency for predicting mean minimum and maximum monthly temperature in stations of Ardabil Province (in Ardabil station, error value is undesirable for mean maximum monthly temperature).

Table 1: information of studied stations

Station Name	Latitude	Longitude	Elevation (m)
Pars Abad	39° 39′ N	47° 55′ E	31.9
Ardabil	38° 15′ N	48° 17′ E	1332
Khalkhal	37° 38′ N	48° 31′ E	1796

Table 2: error level of epoch

	Pars Abad	Ardabil	Khalkhal
Mean minimum monthly Temp (˚C)	0.35	0.93	0.83
Mean maximum monthly Temp (˚C)	0.57	1.02	0.80

Table 3: error level of epoch

	Pars Abad	Ardabil	Khalkhal
Mean minimum monthly Temp (˚C)	0.79	1.82	2.18
Mean maximum monthly Temp (˚C)	1.85	3.04	1.95

REFERENCES

[1] Kumar, P. 2012. Minimum Weekly Temperature Forecasting using ANFIS, ISSN Computer Engineering and Intelligent Systems, 3:1719-2222.

[2] Jang, J.S.R. 1993. ANFIS: adaptive network-based fuzzy inference systems. IEEE Trans. Syst., Man Cybern, 23:665-685.

[3] Khorshdoost, A.M, Sanii,R and Ghvidel Rahimi, M. 2009. predicting maximum and minimum temperatures in Isfahan using time series methods, geographical area, 26:31-48

[4] Fallah Ghaheri, G.A., Moosavi, M and Nokhandan, M 2008. predicting seasonal rainfall based on synoptic patterns using ANFIS model, Studies of Natural Geography, 66:121-139

[5] Honar,T,. Tarazkar, M.H and M. Tarazkar,M .2010. estimating side weir discharges using ANFIS, Soil and Water Protection, 2:169-177

[6] Aliyari,M,. Teshnelab, M and Khakisedg, M.H. 2007. short-term prediction of air pollution using multilayer perceptron neural networks, delay memorized line, gamma, and ANFIS using hybrid methods based on POS, Journal of Control, 1:1-19

[7] Safawi, H.R. 2007. predicting quality of rivers using ANFIS, third conference of managing water resources of Iran, Tabriz University, college of Civil Engineering, 2-9

[8] Leite, H.R., Mand, J .1996. The autoregressive model of climatological time series an application to the longest time series in Portugal, International Journal of Climatology, 16-:1165-1173.

[9] Zekai, S. 1998. Small sample estimation of the variance of time averages in climate time series. International Journal of Climatology, 18:1725-1732.

[10] Turkes, M. 1996. Observed change temperature in Turkey, International Journal of Climatology.