Artificial Neural Network Based Prediction of

Maximum and Minimum Temperature

in the Summer Monsoon Months over India

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Abstract

In the present paper, Artificial Neural Network has been adopted to forecast the maximum and minimum temperature monsoon months. The temperature of June, July, August has been predicted with the help of January to May temperature. In both the cases, maximum and minimum temperature is greatly predicted in the month of August. In the largest part of the cases, prediction error lies below 5%.

In formulating the ANN-based predictive model, three-layer network has been constructed. The data published by Indian Institute of Tropical Meteorology (http://www.tropmet.res.in) are explored to develop the predictive model. The analysis is found to produce a forecast with small prediction error.

Keywords: Temperature prediction, Monsoon months, Artificial Neural Network, Prediction error

1. Introduction

Meteorological Parameter forecast is one of the most significant tasks all over the world (Holton, 1972; Gadgil et al., 2005). Weather condition is a very much complex system and nonlinear. Soft computing techniques have opened up new avenues to the complex system researches. It has three basic components, e.g., Artificial Neural Network (ANN), Fuzzy Logic, and Genetic Algorithm. Here ANN has been adapted for predicting the proposed purpose.

Artificial Neural Network (ANN), a component of Soft Computing, is highly suitable for the situations where the underlying processes exhibit chaotic features (Nagendra and Khare, 2006). The concept of ANN is originated from the attempt to develop a mathematical model capable of recognizing complex patterns on the same line as biological neuron work (Hornik, 1991; Maqsood et al., 2002). It is useful in the situations where underlying processes / relationships display chaotic properties. ANN does not require any prior knowledge of the system under consideration and are well suited to model dynamical systems on a real-time basis. It is, therefore, possible to set up systems so that they would adapt to the events which are observed and for this, it is useful in real time analyses, e.g., weather forecasting, different fields of predictions, etc.

The problem of generating predictions of meteorological events is more complex than that of generating predictions of planetary orbits. This is because the atmosphere is unstable and the systems responsible for the events are the culmination of the instabilities and involve nonlinear interaction between different spatial scales from kilometres to hundreds of kilometres (Holton, 1972; Gardner and Dorling, 1998). Sahai et al. (2000, 2003) showed that the variability in the Indian monsoon rainfall depends heavily upon the sea surface temperature anomaly over the Indian Ocean. As the extra tropical circulation anomalies display energy dispersion away from the region of anomalous tropical convection,

they have been interpreted as a Rossby wave response to latent heat release is associated with the tropical convection. In regions of anomalous tropical heating, there is a dynamical response with anomalous large-scale ascent and upper tropospheric divergence, which acts as a Rossby wave source for extratropical waves. Conversely, in regions of reduced convection and anomalous cooling, the tropical response is one of anomalous descent and upper-tropospheric convergent inflow. Thus, it is obvious that surface temperature influences the monsoon rainfall to a large extent (Gardner and Dorling, 1998; Sahai et al., 2000, 2003). The present paper aims to look into the patterns of temperature over India during the monsoon months using Artificial Neural Network (ANN). The surface temperature is extremely related to the monsoon rainfall. So, the prediction of surface temperature in the monsoon months is essential for developing any predictive model for the summer monsoon rainfall that influences the agro-based Indian economy to a large extent (Gardner and Dorling, 1998; Hsieh and Tang, 1998). Here January to May maximum and minimum temperature is used as input parameter to predict the temperature of the monsoon months.

2. Data used in the present paper

In India, the months June, July and August are identified as the summer-monsoon months. The present study explores the data of these three months for the period 1901-2003. This paper develops ANN model step-by-step to predict the maximum and minimum temperature over India during summer-monsoon by exploring the data available at the website http://www.tropmet.res.in, published by Indian Institute of Tropical Meteorology.

3. ANN based prediction of summer-monsoon temperature in India

The model building process consists of four sequential steps:

(i) Selection of the input and output for the supervised Backpropagation learning

(ii) Selection of the activation function

(iii) Training and testing of the model

(iv) Testing the goodness of fit of the model

The Backpropagation Algorithm (BP) and the method of steepest descent, opened up application of Multilayered ANN for many problems of practical interest (Sahai et al., 2000, 2003; Kamarthi and Pittner, 1999; Sejnowski and Rosenberg, 1987; Widrow and Lehr, 1990). A multilayered ANN contains three basic type of layers: input layer, hidden layer and output layer. Basically, the Backpropagation learning involves propagation of error backwards from the output layers to the hidden layers in order to determine the update for the weights leading to the units in the hidden layer.

Kartalopoulos (1996) and Perez (2000) showed that the generalized delta rule is one of the most commonly used learning rules for feed forward Multilayered ANN. For a given input vector, the output vector is compared to the correct result. If the difference is zero, no learning takes place; otherwise, the weights are adjusted to reduce this difference. The learning is done by least-square-error minimization. The least-square-error (E) between the target output (T) and actual output (O) can be given by (Yegnanarayana, 2000)

$$O_i^{l+1}(k) = f(\sum_{j=1}^{N_l} w_{ji}^l O_j^l(k) - \theta_i^{\ l+1}) \tag{1}$$

where, w_{ji}^l = weight between node i of layer $l - 1$ and node j of layer l.

$O_j^l(k)$ = actual output (for pattern k of the jth node in layer l (after nonlinearity)).

$\theta_i^{\ l+1}$ = bias of neuron i, that can be considered as weight of an input having value 1. The bias is also called the 'free parameter'.

The total error E for the network and for all patterns k is defined as the sum of squared differences between the actual network output and the target output at the output layer L. It is given by

$$E = \sum_{k=1}^{k} E_k = \sum_{k=1}^{k} \left(\frac{1}{2} \sum_{i=1}^{N_L} \left[T_i(k) - O_i^l(k) \right]^2 \right) \tag{2}$$

The goal is to evaluate a set of weights in all layers of the network that minimizes E. The ultimate weight update equation for the mth step would be

$$w_{ji}^h(m+1) = w_{ji}^h(m) + \Delta w_{ji}^h(m) \tag{3}$$

The purpose of the present paper is to forecast the mean monthly surface temperature in the monsoon months (June, July and August) over India. An ANN model has been developed using the supervised training procedure to predict the

said weather parameter over the study period. Since three months are the target months, the model is generated in a supervised manner with three desired outputs. From the whole dataset, the input and the desired output matrices are generated. The input data are separated into training and test set. The training set consists of 75% of the whole data and the remaining 25% constitutes the test set. The input matrix contains six columns that correspond to the average monthly temperature over the study period and pertains to the months of December, January, February, March, April and May. The ANN model generated here is a single-hidden-layer model, and the hidden layer contains 2 nodes. After running the model up to 500 epochs, the results are validated for the test set. The outcomes of the validation phase are presented in the next section.

4. Results and discussion

The learning rate η is taken to be 0.9. A three-layered feed forward neural net is now designed. Three models are generated for both maximum and minimum temperature. There are three outputs in both the three models. The first model is for June maximum and minimum temperature prediction, second for July and third for August. In both models, the initial weights are chosen randomly from −0.5 to +0.5. After training iterations, the network is tested for its performance on validation data set. The training process is stopped when the performance reached the maximum on validation data set. After training and testing, the prediction error values are computed for each model. The results are schematically presented in Figs. 1-3 and 5-7. In the month of August the PE is very low (Figs. 4 & 8), and the actual and predicted graphs of temperature are significantly associated (Figs. 3 & 7) in both maximum and minimum temperature. Also in the month of August, the percentage of prediction error is below 5% in both maximum and minimum temperature (Figs. 9 & 10). The results show that the third model produces the lowest prediction error among the three possible predictive models.

5. Conclusion

In the present paper, Artificial Network with Backpropagation learning has been implemented to predict average summer monsoon temperature over India. Six predictors have been explored to generate the input matrix for the Neural Net. After 500 epochs, the Artificial Neural Network has been found to produce a forecast with small prediction error. The study, therefore, establishes that the third model is the best predictive model over the other two models.

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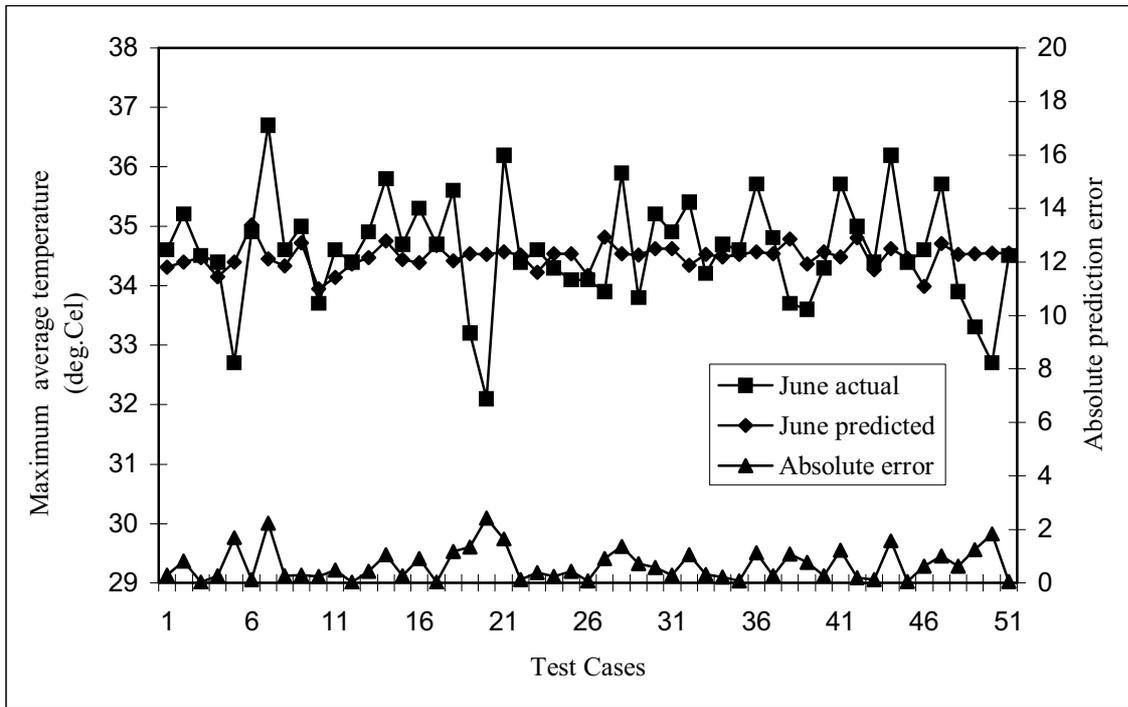
Figure 1. The figure shows that the actual and predicted maximum temperature and the absolute prediction error graph for the month of June.
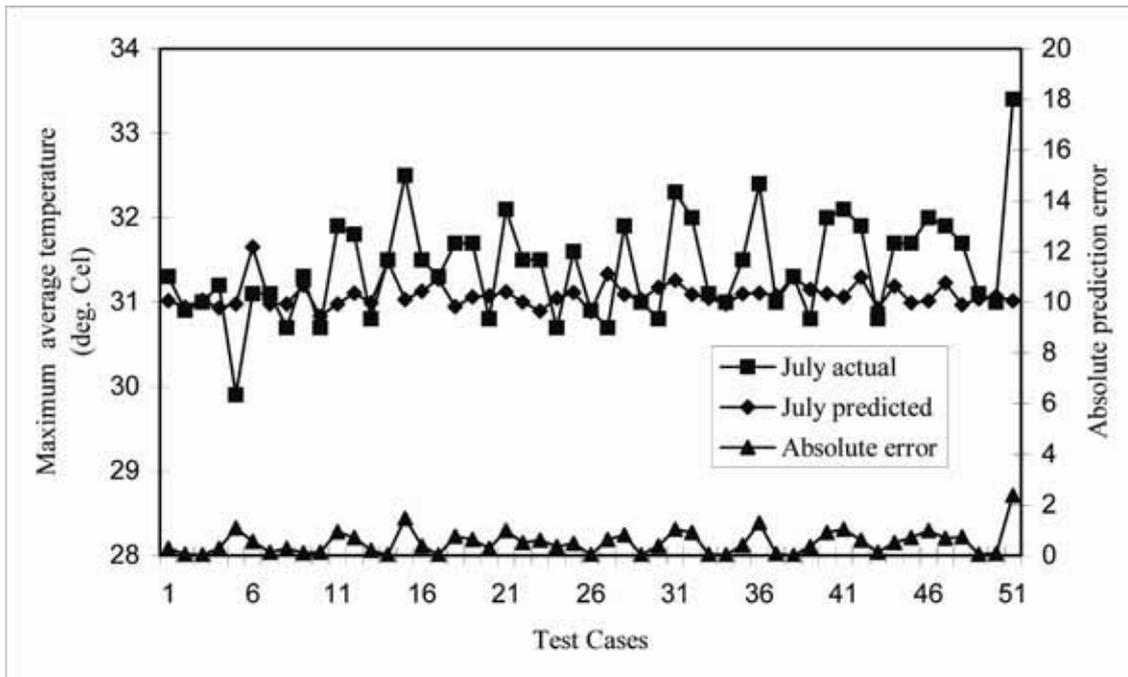
Figure 2. It depicts the actual and predicted maximum temperature and the absolute prediction error graph for the month of July.
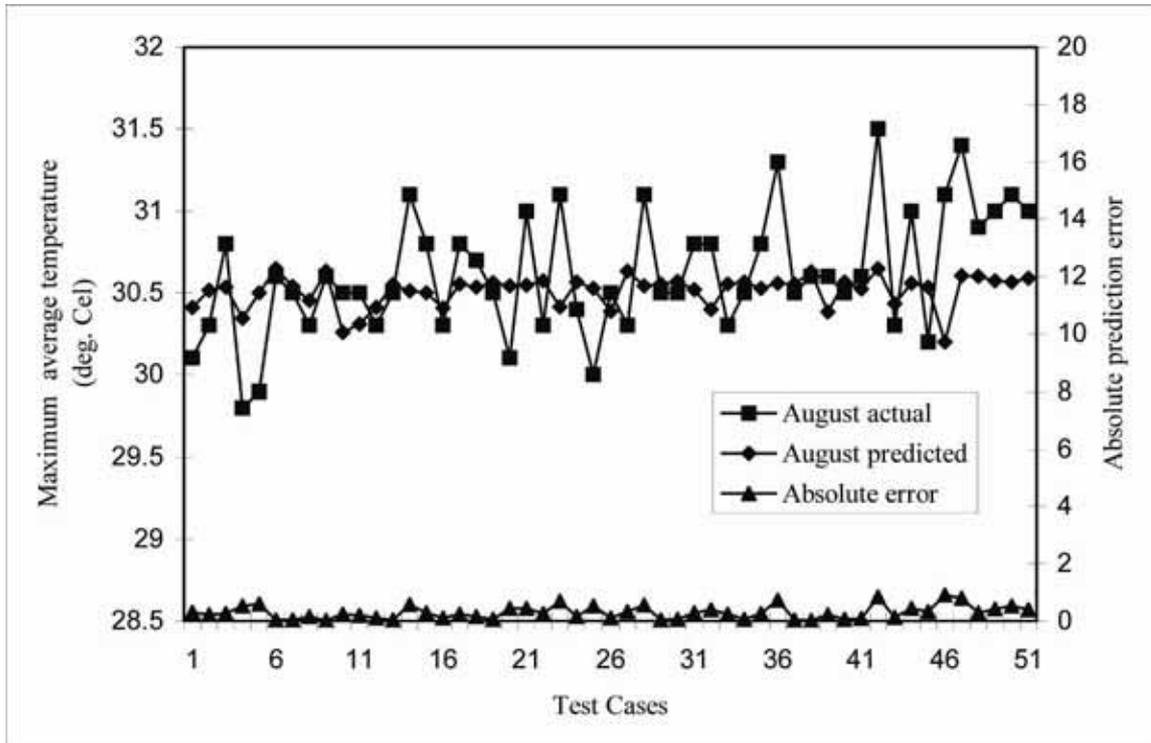
Figure 3. The actual and predicted maximum temperature and the absolute prediction error graph for the month of August are shown.
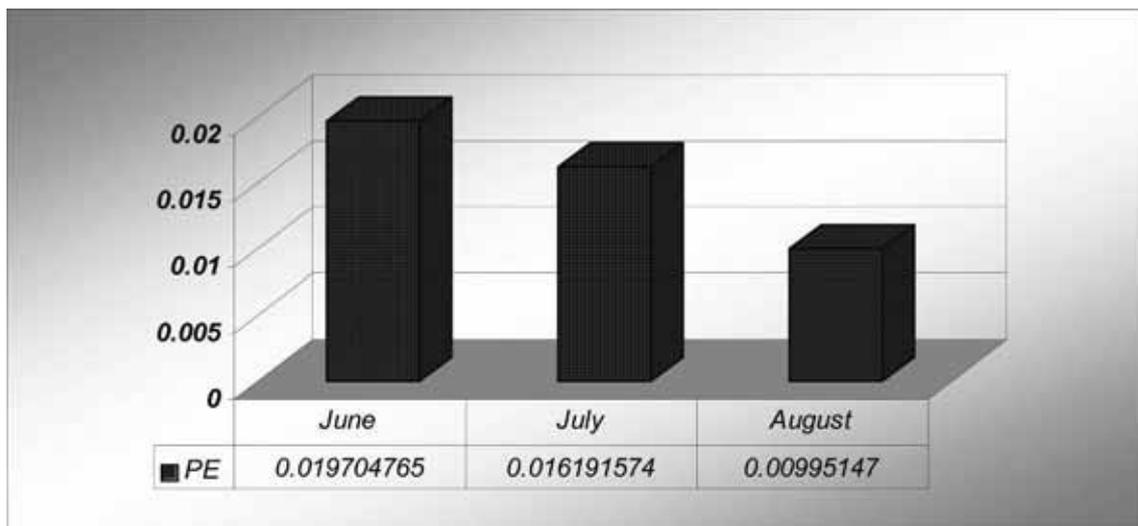
Figure 4. Relative comparison of the prediction errors (PE) produced by the three output models in predicting maximum temperature over India. The computation is made over the test cases.
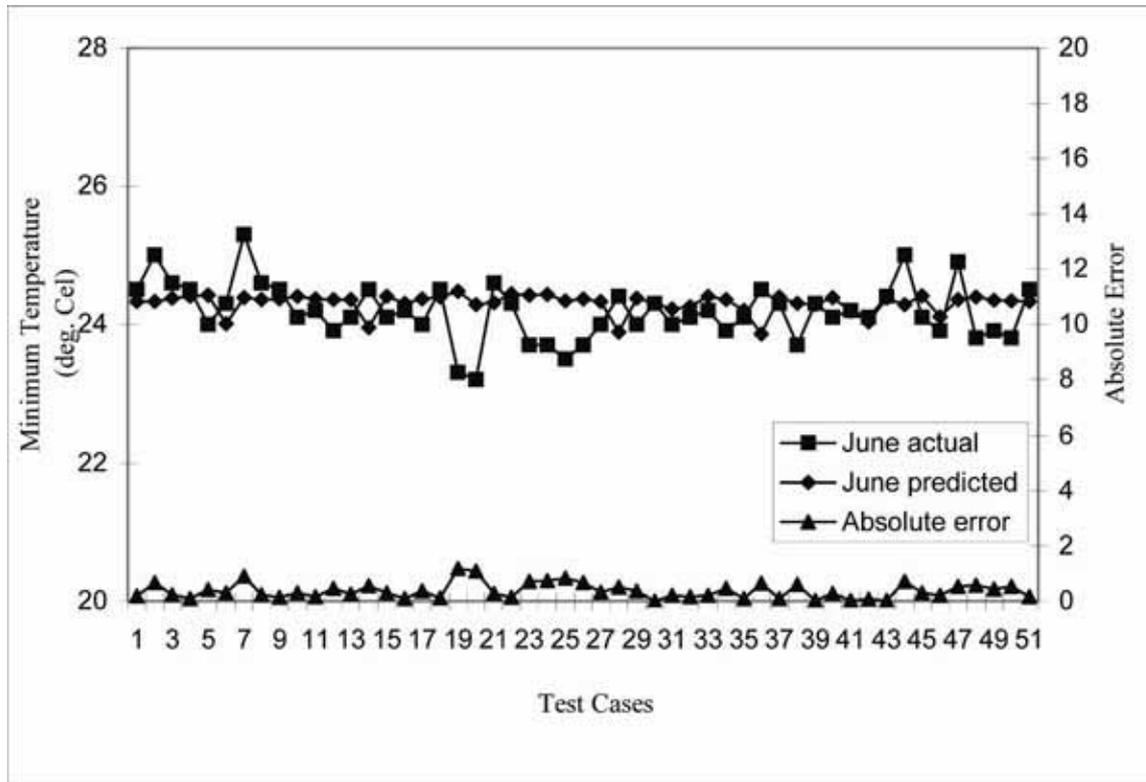
Figure 5. The figure represents the actual and predicted minimum temperature and the absolute prediction error graph for the month of June.
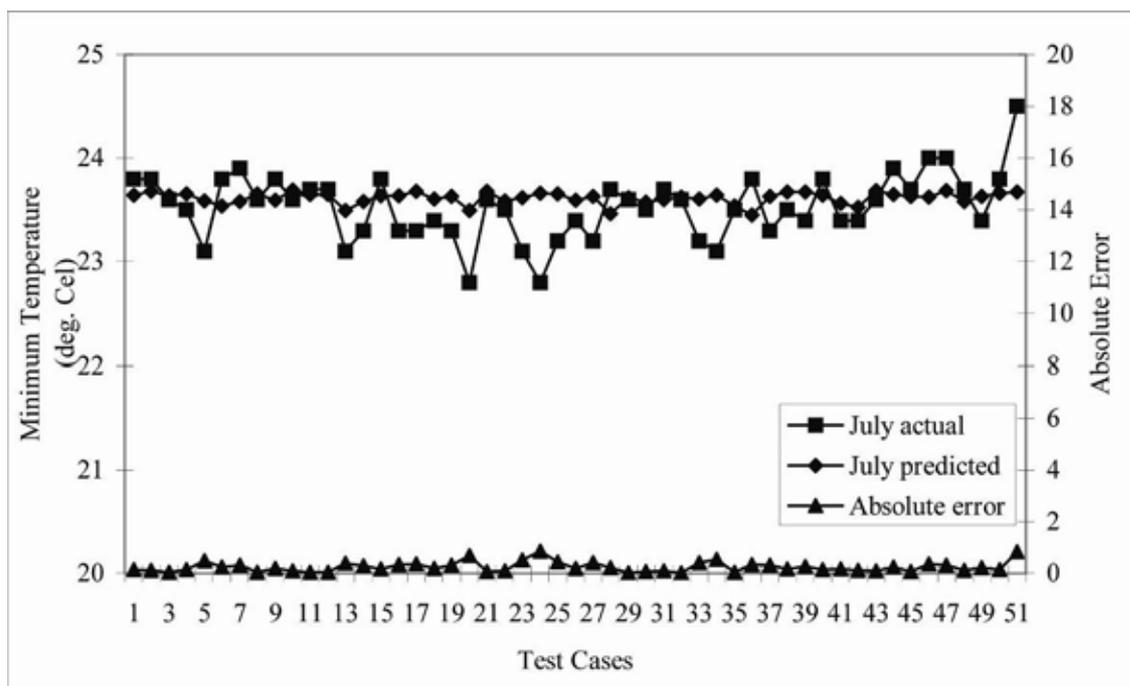
Figure 6. The actual and predicted minimum temperature and the absolute prediction error graph for the month of July.
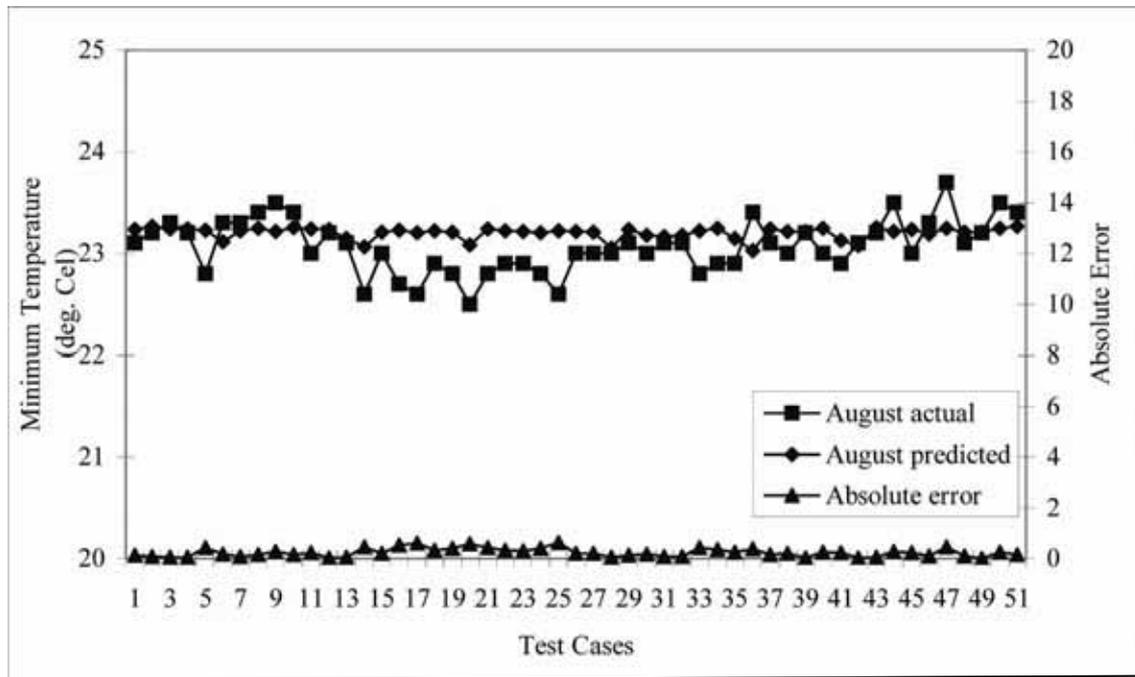
Figure 7. The figure depicts the actual and predicted minimum temperature and the absolute prediction error graph for the month of August.
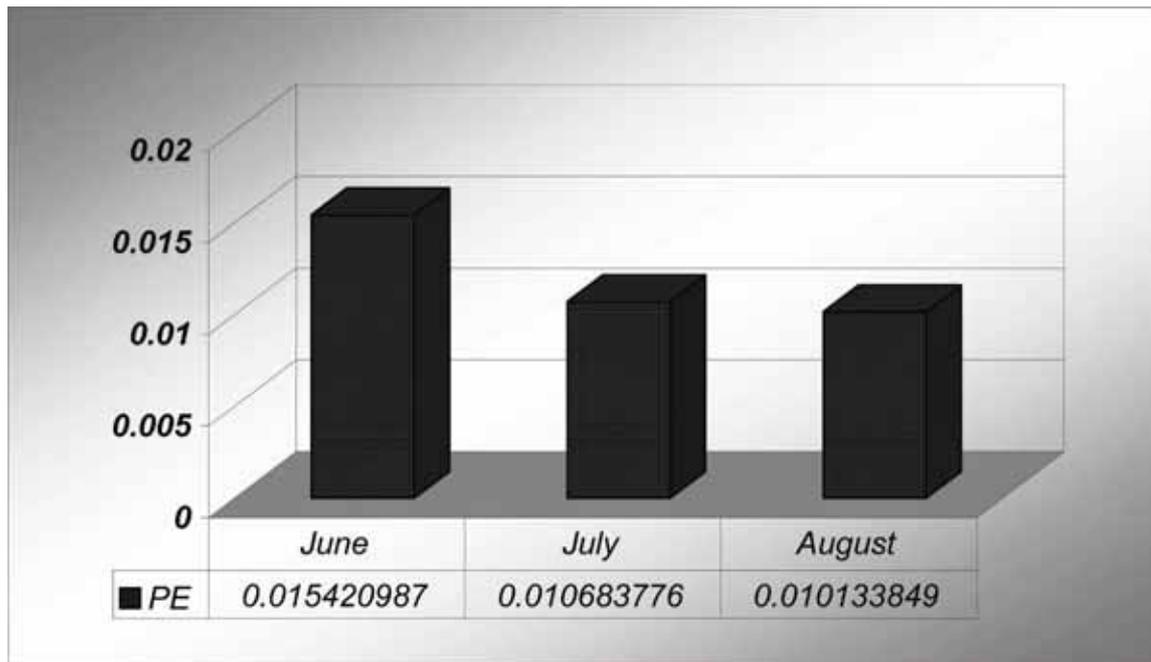
Figure 8. Relative comparison of the prediction errors (PE) produced by the three output models in predicting minimum temperature over India. The computation is made over the test cases.
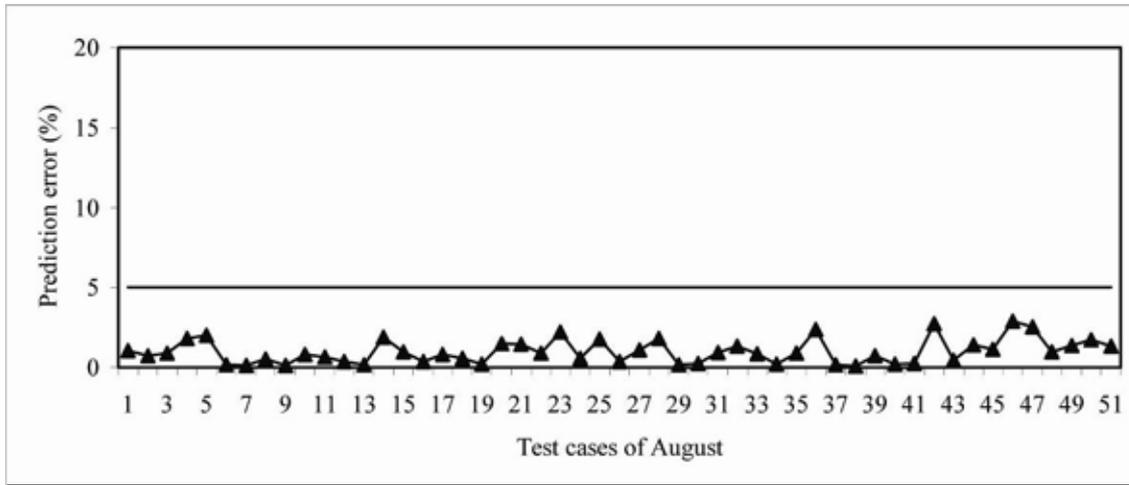
Figure 9. This figure shows the percentage of prediction error is below 5% in the month of August maximum temperature.
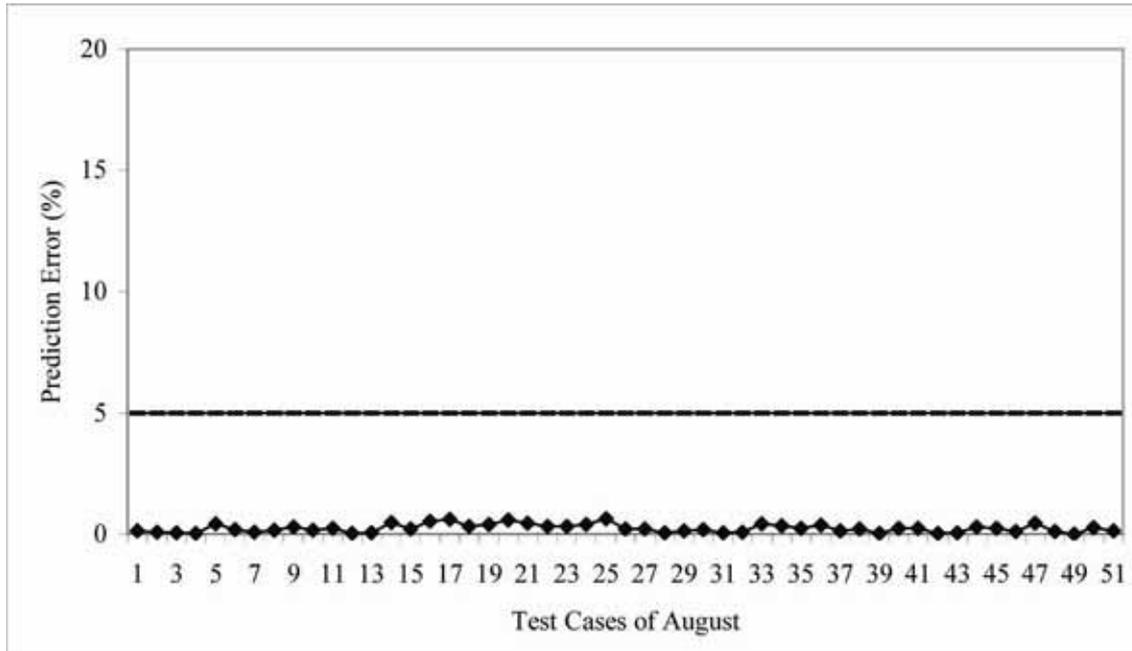
Figure 10. The percentage of prediction error is below 5% in the month of August minimum temperature.