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Short Communication

Analysis of UV Radiation and its Relationship with Solar Indices Using Statistical and Artificial Neural Network Method

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Abstract:

Study analyses hourly average of daily UV radiation measured at Chennai in relationship with solar indices by multi linear regression analysis and Artificial Neural Network to forecast performance parameter namely Mean Bias Error and Mean Average Percentage error (MAPE). Moreover, study compares predicted UV radiation against measured value. It is concluded that ANN model prediction or estimation is better than the multiple regression model.

Keywords: Daily UV radiation, Multi linear Regression Analysis and Artificial Neural Network, solar indices

1.0 Introduction:

Ultraviolet radiation is a specific part of the sun's total spectrum of wavelength. UV are generally classified into three wavelength regions namely Ultraviolet A (315-400nm), Ultraviolet B (280-315nm) and Ultraviolet C (100-280nm)[2]. UV A radiation is normally reflected back from atmosphere. Presence of ozone and oxygen in the stratosphere results in the absorption of nearly all UV-C radiation (200-280nm) and Solar UV-B radiation (280-315nm) significantly. Solar UV radiation that reaches the ground is after complicated scattering and absorption process in the atmosphere and at the earth surface.

Over the past few decades, the atmospheric science experts have found it beneficial to establish routine program to monitor various surface radiation quantities.[1] The observations raised serious concern in the Scientific Community of concomitant increase in Ultraviolet radiation reaching the earth's surface.(Frederick and Snell,1988,Grant 1988;;Blumthaler and Ambach,1990; Smith et al.,1992; Kerr and McElroy 1993;Jaque et.al 1994;Herman et.al.,1996) [2-7][and its detrimental effects on plants, animals, ecosystems and human health. This awareness led to the establishment of a network for monitoring solar radiation that was specifically focused on UV radiation reaching the

earth's surface. Given the important role of Ozone in blocking Ultraviolet radiation it is expected that any drop in stratospheric ozone will affect the levels of ultraviolet irradiance received at the earth's surface. The effects of UV radiation on plants, animals, ecosystem and human health are complex and inter related with each other stress factors (Kulandaivelu and Tevini 2003; cald well et al 2003)[8.9].

Solar indices used for analysis are sunspotnumber,10.7cm solarflux and aa index. Sunspots are tempory phenomena on the photosphere of the sun that appear visibily as dark spots compared to surrounding regions. The F 10.7 index is a measure of the solar radio flux per unit frequency at wavelength of 10,7cm, near the peak of the observed solar radio emission. The aa index is a measure of the disturbance level of the Earth's magnetic field based on magnetometer observations at two nearly antipodal stations.

2.0 Multiple Linear Regression (MLR):

MLR is used to represent the linear relationship between a dependent variable and one or more independent variables. The dependent variable are called predictand and the independent variables are predictors. MLR is based on least squares. The model measures the sum of squares of difference of observed and predicted value.

2.1 Model Equation:

The model equation expresses the value of predictand variable as a linear function of one or more predictor variables and an error term

$$Y_i = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + \dots + e_i$$

Models that involves more than two independent variables are more complex in straight but can still be analysed using multiple linear regression techniques

The variables $x_1, x_2, x_3, \dots, x_n$ are linearly independent. Here X_1 represents smoothed sunspot number, X_2 represents smoothed solar flux X_3 represents smoothed aaindex.

$$Y = A X$$

Then the inverse

$$X^{-1} X A = X^{-1} Y$$

$$A = X^{-1} Y \dots \dots \dots (1)$$

$$I = \text{inv}(X);$$

$$A = I^* Y \dots \dots \dots (2)$$

$$A = (a_0, a_1, a_2, a_3)$$

According to these variables the corresponding fitted regression is

$$Y_{\text{predicted}} = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + \dots$$

$$e_i = Y_{\text{pre}} - Y_{\text{meas}}$$

Y_{pre} = predicted value of UV radiation

Y_{meas} = measured value of UV radiation

The residuals measure the closeness of fit of the predicted values and actual predicted and in the calibration period.

3.0 Artificial Neural Network (ANN):

Artificial neural networks have been widely used for solving many forecasting and decision modeling problems.[10]. Artificial Neural Network usually called neural network is a mathematical model or computational model that is inspired by the structure and functional aspects of biological neural networks. A neural network consists of an interconnected group of artificial neurons and it imitate four basic functions of biological neurons(1) to receive input information from other neurons,(2) to combine these data,(3) to perform mathematical operations on the result and finally (4) to create adequate output data. ANN learn the relationship

between input and output parameters without knowing the exact physical interrelationship.

ANN normally consists of three layers which are interconnected by communication links that are associated with weights that determine the effect on the information passing through them(fig.1). These weights are determined by learning. Learning or training is called the process of modifying the connection weights using a suitable learning method . The objective of this study is to analysis UV data with solar indices and also compare the major errors produced in MLR and ANN.

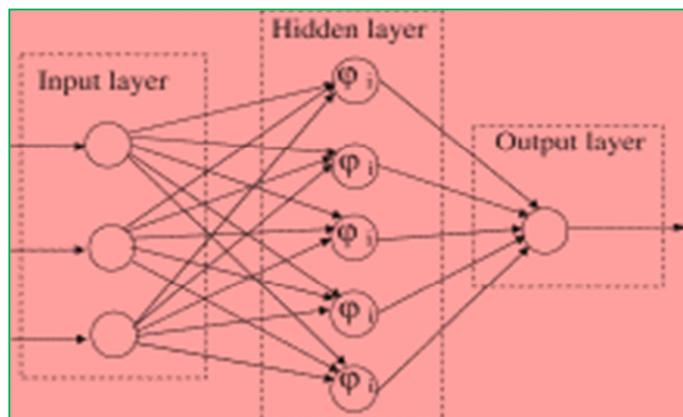


Fig.1: Structure of Artificial Neural Network

4.0 Data and methodology:

Hourly and daily UV radiation:

Hourly instantaneous values of UV radiation measured using UV Meter have been converted into hourly average daily values. Solar indices like smoothed sunspot number, 10.7cm smoothed solar flux and smoothed aa index were taken from the website <http://...>

Data measured and used are for the period August 2011 to December 2011. Using Multi linear regression analysis daily UV radiations were correlated with solar indices (smoothed sunspot number, smoothed solar flux and smoothed aa index). All the summation were done using MS excel and the values of multilinear coefficients were found using Matlab (version 7.0).

Using ANN based on free for ward back propagation, the learning rate was optimized at 0.0001, nearly 150 data were used for training and testing. We used 85% data for training to set up the model and 15% for testing. During the training period the network tested against the test set to determine accuracy and training is stopped when the mean average error remains unchanged, Finally the production set is used to test the network's result with unused data. The ANN model was implemented using MATLAB (version 7.0) code. Fig:2 and Fig:3 represent the predicted and measured values of UV radiation in Multilinear and Artificial Neural Network.

The study was conducted using 12 neurons with 6 iterations to get R value = 0.8088.

Formulae used are :

$$MBE = \frac{\sum_{i=1}^N (UV \text{ predicted} - UV \text{ measured})}{N}$$

$$MAPE = \frac{1}{N} \sum \frac{|UV \text{ predicted} - UV \text{ measured}|}{UV \text{ measured}} * 100$$

Results and conclusion:

For MLR analysis, Figures 2 show the comparison plot between predicted and measured values of UV radiation for Chennai for the period August 2011-December 2011 (hourly average daily values). For ANN, Figure 3 shows the comparison plots between predicted and measured values of UV radiation for Chennai during August 2011-December 2011 (hourly averaged daily values). Table 1 shows comparison of statistical measures of MLR and ANN such as Mean Bias Error (MBE) and Mean Average percentage Error (MAPE) as per calculation. In MLR, Mean Bias Error is **1.55882** and Mean Average Percentage Error is **9.443031** whereas in ANN Mean Bias Error is 0.87499 and Mean Average Percentage Error is 8.039362

Hence, analysis of UV radiation to compare predicted values with measured values using ANN Method gives minimum error. The same is suggested for analysis of UV radiation.

Table: 1

Error	solar indices	
	ANN	MLR
MBE	-0.87499	1.55882
MAPE	8.039362	9.443031

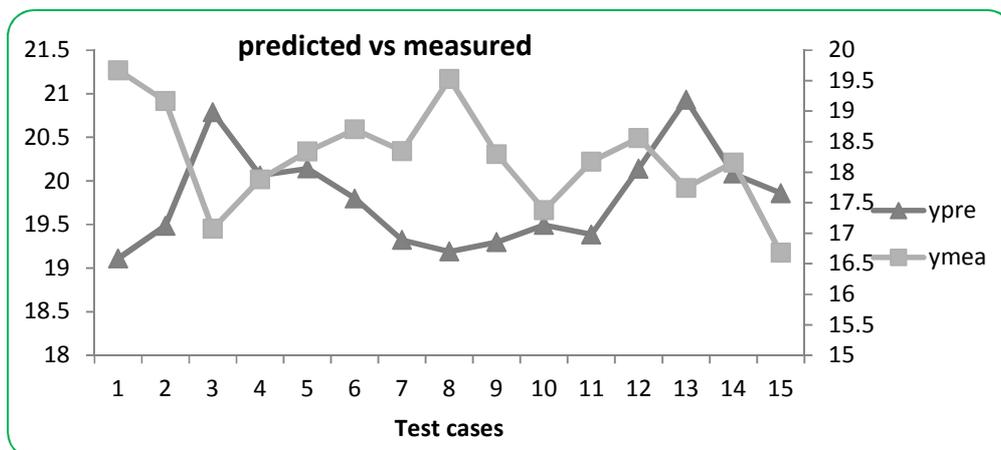


Fig. 2: Graph between observed and measured

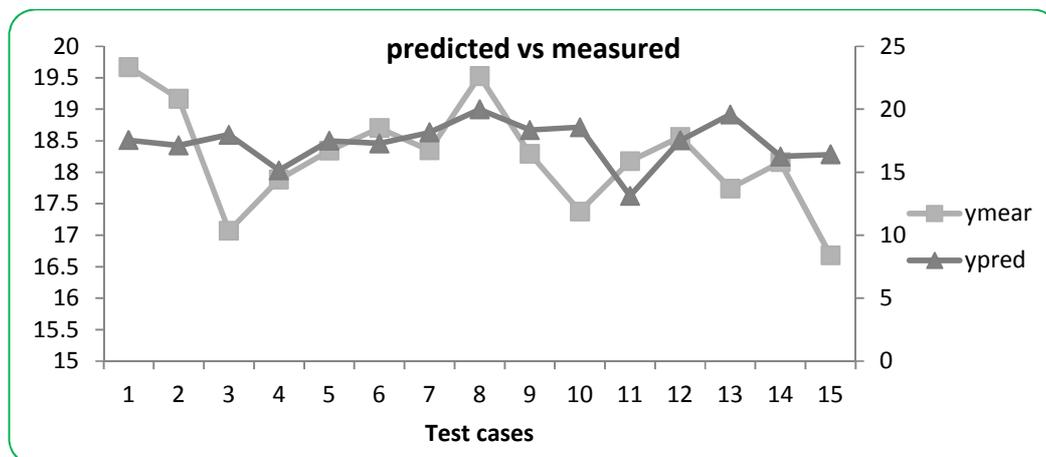


Fig.3: Graph between ANN predicted and measured values

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