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Quantifying the seasonal variation in virtual height of ionosphere F2 layer at Pakistan atmospheric region

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ABSTRACT

The aim of this paper is to assess the seasonal variation in virtual height of ionosphere F_2 layer for Pakistan's atmospheric region (PAR). The sun is a main source of ionization in the extraterrestrial atmosphere, so that the variation depends upon the solar activity and geomagnetic conditions. The behavior of process has been represented by the descriptive techniques that comprise the simple regression and polynomial regression strategies. The relevance of these models has been illuminated using predicted values of different parameters under the seasonal variation of ionosphere F_2 layer in virtual height through the radio wave propagation. The information obtained from such analysis initiates a study towards formulating the phenomenon appeared due to interaction of radio zwave propagation with the ionosphere layer with special reference to the atmospheric region of Pakistan.

INSPEC Classification : A9420B, A9420D, A9420J

Keywords : autoregressive process, variation in virtual height, polynomial regression, simple regression

1. INTRODUCTION

The ionosphere is very important in radio wave communications, which absorbs large quantities of radiant energy from the sun, thus becoming heated and ionized (Wall, J. V. & C. R. Jenkins). It is earth's higher atmosphere and the F_2 layer is the superficial layer of the ionosphere. The virtual height of an ionosphere F_2 layer could be explained as the wave is refracted bent down gradually rather sharply. Incident and refracted rays below the ionized layer follow the same path as if the refection has taken place from the greater height. The mark is called virtual height of this layer, and in other words when the incidence and returned rays are extrapolated to a vertex they meet at a height h' is called virtual height. The F layer has a stable existence; even from side to side the height varies on a daily basis. This layer is the most important for radio communications in the frequency range of 3 to 40 MHz (Diebold, F. X, 1998).

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F_2 Layer

is the most important reflecting standard for high frequency radio waves and the height of F_2 layer varies from 250- 400 km. The electron density variation is higher in the day time than night.

A very important development for studying the higher atmosphere is the inspection of radio waves propagation by ionosphere stations taking vertical, oblique soundings. The electron concentration of the ionosphere has come to measure with-power radar systems which register the scattered radiation due to the electrons present in the ionosphere (Dolukhanov, M.1971).

The ionosphere's seasonal variation is related to a solar zenith angle change, while its solar cycle variation is linked to a change in the solar extreme Ultraviolet (EUV) and x-ray radiation. The important feature is that the maximum electron density of F_2 layer (N_mF_2) is larger in winter than in summer, in spite of the fact that the solar zenith angle is smaller in summer. This trend is called the seasonal anomaly, occurs because of the seasonal changes in the neutral atmosphere. Specifically, the summer-to-winter neutral circulation results an increase in the O/N_2 ratio in the winter hemisphere and a decrease in the summer hemisphere (Makridakis, S., S. C. Wheelwright & V. E. McGee., 1983). The day-time wavelengths are much shorter than the night-time ones. The point is that the day-time electron density of the F_2 layer is very high and it can reflect the higher frequencies. Conversely, the night-time electron density of F_2 layer goes down (Rishbeth, H, 1991).

Every part of the radio techniques were based on the fact that the refractive index, *m*, of a weakly ionized plasma is relative to the free electron number density. During the highly basic case that neglects collisions and magnetic field effects, the refractive index is simply.

$$m^2 = w^2_p / w^2 \qquad (1)$$

Wherever w_p is the plasma frequency and *w* is the frequency of the propagating wave. An ionosonde or ionosphere sounder is the oldest remote sensing apparatus and one of that is still widely used, transmits a radio pulse vertically and measures the time it takes for the signal to return. The reflection takes place, to a first order, where $w_p = w$. Thus, the time delay is used to determine the altitude of reflection and the frequency is an indicator of the electron density at that location. In actuality, the interpretation of an ionogram, the time delay against frequency characteristics, is more difficult. One difficulty is that the radio wave travels at the group velocity and not at constant velocity of light and this group velocity is itself purpose of the refractive index. The height calculated assuming that the waves travel with the velocity of light is called the virtual height. A further complication pertains to the effect of the geomagnetic field, which leads to multiple values of the refractive index (Prolss, G. W., 1995). While the solar cycle advances, the intensities of the three radiations change in different ways. Between solar minimum and maximum, the strength of lyman-alpha radiation increases by about 50% but that of X-radiation increases by a factor of about 10^3 (Ma, S., L. Xu & K.C. Yeh, 1995). The different geomagnetic storms can be significantly different and even for a given storm; the system's response can be very different latitudinal and longitudinal regions. How ever, it is educational to show the ionospheric response to the large magnetic storm that was triggered by a solar flare which appeared at 1229UT on October 19, 1989, and it was 22 maximum cycles Prolss, G. W., 1995), (Ma, S., L. Xu & K.C. Yeh, 1995). In response to the storm, there were long-lasting electron density depletions at high latitudes, as measured DGsonde S.U.P.A.R.C.O. Head Quarter, Karachi and worldwide ionosondes.

Correlation between h' and Ne of ionosphere F_2 layer

During the occurrence of ionosphere turbulence, the electron density of the F_2 layer takes a plunge and the virtual heights go up, so that the greatest usable frequencies are decreased.

The normal configuration of F_2 layer is disrupted and strata emerge in it. Through very strong ionosphere turbulence, the ionization of the F_2 layer can drop to a point where the layer will not reflect short waves any longer. The F_2 layer is damaged through ionosphere turbulence at elevated geomagnetic Latitudes.

METHODOLOGY

The results presented in this publication found that the auto regressive (AR) order one character of modeling, the seasonal variation in virtual height of ionosphere F_2 layer as a physical process is an appropriate position rather than using regression. The reported data suggest quantitatively the occurrence of the seasonal variation in virtual height of ionosphere F_2 layer is occurring. For this plan, we have modeled this phenomenon using the data recorded at the S.U.P.A.R.C.O Head Quarter, Karachi during the period of eleven months1989.

The Regression analysis describes the assessment of the unknown value of one variable from the known value of the other variable. Assume that we have data on two variables, y and x that we want to find the linear function of NeF_2 that gives the best forecast of seasonal variation of virtual height of ionosphere $h'F_2$ layer where best forecast is that the sum of squared forecast errors, for the sample of data (Ratcliffe, J.A, 1972). In particular, regression is the measure of the average relationship between two variables in terms of the original units of data. In other words, there must be a random component to the equation that relates the variables.

The aim of this section is to model the ionosphere layer reflection trend, in such a way that a close similarity can be established between the consequent predictions and the associated observed data. For this purpose to construct autoregressive model of order one, so that an appropriate model could be selected to determine that ionosphere layer reflection is a physical process. Figure 1 shows stationary but random variations of ionosphere virtual height that were recorded at the S.U.P.A.R.C.O. Head Quarter Karachi, Pakistan where D.G 256 Sonde has been installed under of S.U.P.A.R.C.O. Head Quarter.

Development of time series model to predict the seasonal variation in virtual height of ionosphere F_2 layer for Pakistan's atmospheric region. It has been known that an important aspect of scientific study is defined by the idea of a model. A model can identify the real position of a system. We have the data which consists on two variables. Time series is defined by a record of the values of any irregular capacity deliberate at diverse points of time. We may, for example, have a record of the virtual height of ionosphere F_2 layer data over a period of eleven months (1989) which is being used in this study.

Criteria for model choice of the seasonal variation in virtual height of ionosphere F_2 layer at Pakistan atmospheric region. The general characteristic of all the records which plunge within the area of "time series analysis" is that they prejudiced, at smallest amount in part of the casual variations in the seasonal deviation of virtual height of ionosphere $h' F_2$ layer and it is affected by definite atmospheric actions. Accordingly if we graph to explain particular sample of the seasonal variation in the virtual height of ionosphere F_2 layer in the atmospheric region of Pakistan, then we need to make a mathematical explanation of the ionosphere data obtained from a 256 D.G Sonding installation. Such a model explains both the deterministic and random features of the ionosphere. The creation of the model is one of the vital objectives of ionosphere $h'F_2$ layer analysis, if we can acquire a sufficient model for our series, it may give significant forthcoming the physical coordination generating the data and it can be used to forecast, for the future values of the series.

RESULTS AND DISCUSSION

To identify the idea, we can illustrate the case of autoregressive model which is normally used in time series model. The autoregressive model takes the form

$$X_t = a_o + JX_{t-1} + e_t \qquad (2)$$

Where X_t is expressed as a linear combination of its two immediately preceding values

$$X_t = JX_{t-1} + a_o \qquad (3)$$

Figure 1 is a daily original time plot of virtual height of F_2 layer data and Figure 2 is a scatter plot of h'F_2 against NeF_2 with the regression line superimposed. From this graph, it appears that to understanding the correlation between the electron concentration and the seasonal variation in virtual height of h'F_2 layer in the period (t-1) is useful in predicting the value of the total value of virtual height deliberation in period t. It seems that X_t can be explained as significance of X_{t-1}. Now estimate the regression coefficient of order one.

Figure 1.
The temporal variations of seasonal variation of virtual height of ionosphere F_2 layer versus time,

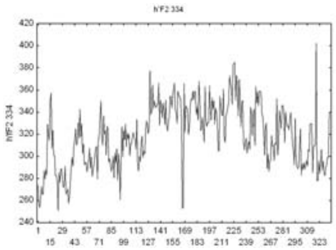
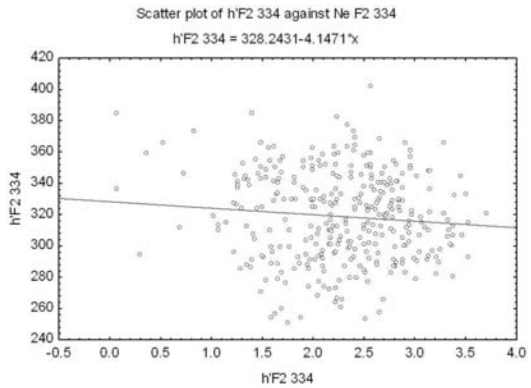


Figure 2.
This figure shows that a scatter plot of h'F_2 against NeF_2 with the regression line superimposed and negative trend is illustrated between the two variables during seasonal variation in the virtual height and electron concentration of ionosphere F_2 layer.



$X_t = JX_{t-1} + a_o$
$X = 293.893 + 0.997\,X_{t-1}$
t statistics: (5.866) (9.454) R^2 = 1.4 %
Where a_o = 293.893, J_1 = 0.997, and it shows that $J_1 < 1$

The t statistics for J_1 is 9.454 and the value of p is zero for, J_1. The t statistics in an autoregressive model does not exactly follow the t distribution because one of the necessary assumptions of the standard linear regression model has been violated From the analysis of variance (ANOVA), the coefficient of determination (R_2) can be calculated as

$$R^2 = \frac{ss}{Totalss} = \frac{6153}{377596} = 0.0134$$

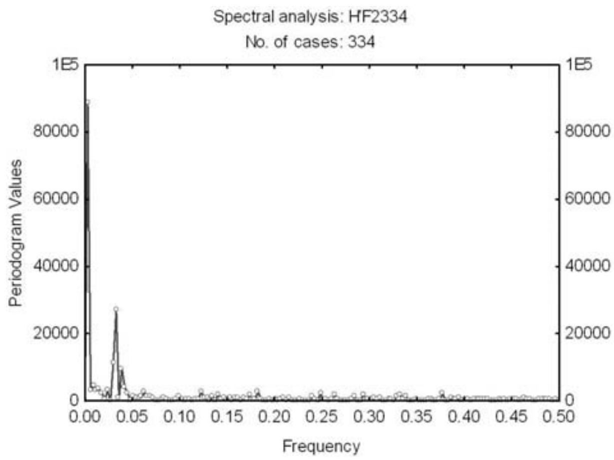
This indicates that 1.4 % of the difference is explained by the regression model. The remaining 98.6 % of the difference is itself unsolved. It shows that a good forecast of the value of x is potential when the earlier value of x is known. Using equation (3) to forecast the seasonal variation in virtual height of ionosphere F_2 layer for 335^{th} day by substituting

$X_t = JX_{t-1} + a_o$
$X_{366} = 293.893 + 0.997\ x_{344}$
$X_{365} = 293.287$ km, and obtain
$X_{366} = 293.893 + 0.997\ (293.287) = 295.095$km

Seasonal variation in virtual height of ionosphere F_2 layer is measured in km, consequently the forecast for the 335^{th} of the period specified for this communication is 295.095 km.

The periodogram illustrated in figure. 3, is used to categorize randomness in the data series. Also it helps in identifying seasonality in the given time series, and in recognizing the predominance of positive or negative autocorrelation (for positive autocorrelation low-frequency amplitudes should dominate, and for negative autocorrelation, high frequencies should lead Forecasting Methods and applications John Wiley and Sons).(Ghosh, S.N, 1998)

Figure 3.
Periodogram as shown is used to classify randomness in the seasonal variability in the virtual height of ionospheric F_2 layer.



1. Autoregressive processes may be established - pattern of autocorrelation, of partials, and within the line scale, will show a potential model.

2.The graph of the data set is a visual support to recognize the behavior of the pattern. The autocorrelations and the line scale are the review of the pattern presented in the data. They can expose a great agreement about the data and their characteristics.

3.The model can be used in the present case to state the dependence between X_t and X_{t-1} in the pair (X_t , X_{t-1}) , and to thus relate X_t with X_{t-1}, X_{t-1} with X_{t-} and so on. The plot of X_t and X_{t-1} for t = 2, 3. 334, is depicted in Figure 3. It can be examined that the points are scattered around a straight line.

$$X_t = JX_{t-1} + a_o$$

The above model expresses the dependence of the variable on itself at different times for model under consideration a_t at different t are independent, that a_t is independent of a_{t-1}, so that just like e_t the distribution of a_t is unspecified to be normal.

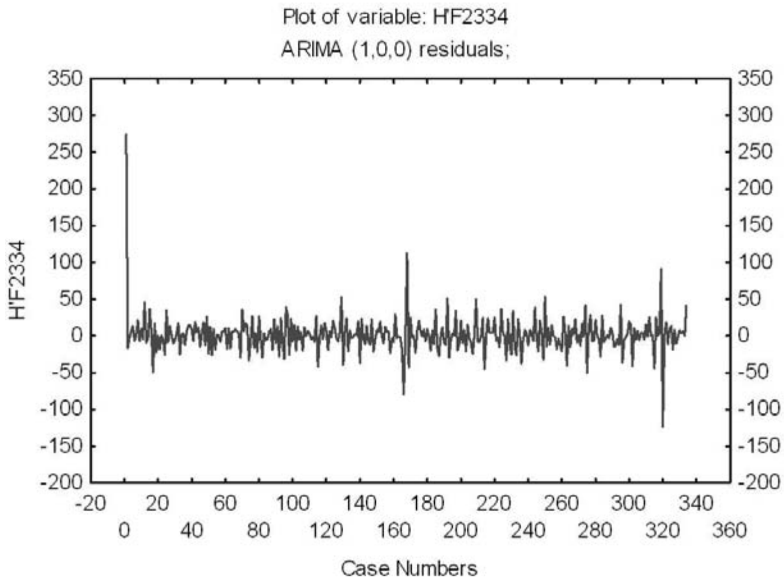
$$a_t \text{ - NID } (0, s^2_a) \qquad (4)$$

It has been distinguished that predictable model is entirely specified only when s^2_a is given in calculation to J_1, a_t is understood to be normal.

The value of X_t may increase or decrease without bound, because a_t have fixed finite variance and can not continually increase in magnitude to keep X_t within bound as depicted from Figure 4 that explains the residual analysis specified for this model and also confirms that this model is sufficient.

Figure 4.

Plot of residuals analyzed for Autoregressive model of order one after fitting to the seasonal variation in virtual height of ionosphere F_2 layer data for atmospheric region of Pakistan.



At the same time as a condition tells that if o J_1 > 1 or J_1 < -1, then the series will be non-stationary or unsteady time series. For a stationary stable time series, X_t remains surrounded in the motive it has finite variance, we would need J_1 <1. Figures 5 and 6 illustrate the estimated auto-correlation function and the Partial autocorrelation function from lag 1 to 15 respectively. Figure 5 depicts the estimated correlation between the y-axis vs the lag number on the x-axis and can be used to determine the pattern (AR) in the set of data. Similarly, figure 6 shows partial autocorrelation plot for the residuals of the seasonal variation of ionosphere F_2 layer. Partial autocorrelation is used to measure the degree of association between X_t and X_{t-1}, when the effects of other time lags 2,3,… up to X_{-1} are somehow partial led out. Their singular purpose in time series analysis is identifying an appropriate AR model for forecasting.

For the residuals of the virtual height of ionosphere F_2 layer, that showing an adequacy of the constructed model of seasonal variation in virtual height of F_2 for atmospheric region of Pakistan.

The serial arguments and the residual analysis in this figure demonstrate that the constructed model is reasonably adequate.

Figure 5.

Plot of Autoregressive function for seasonal variability in virtual height of ionosphere F_2 layer. estimates obtained from the estimating technique

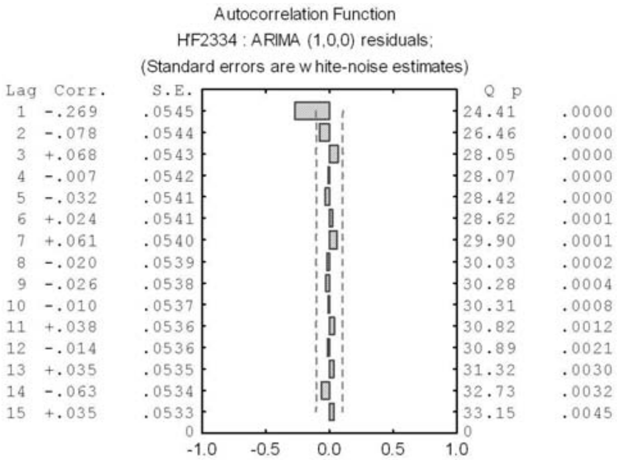
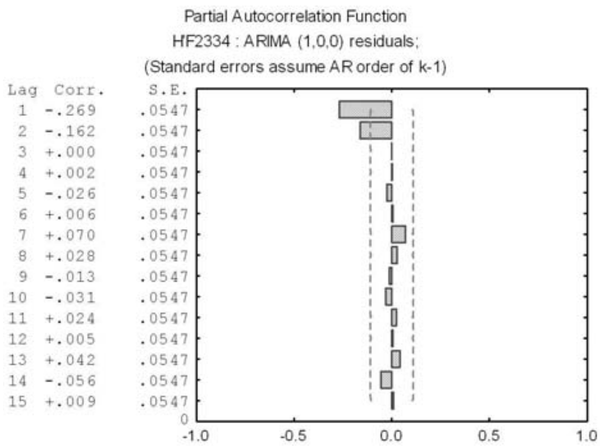


Figure 6.

Partial autoregressive for the residuals of seasonal variation in virtual height of ionosphere F_2 layer.



The dashed lines in the above mentioned figures demonstrate an approximate 95% confidence interval for an individual estimated partial autocorrelation. Thus, for independent observations, a particular confidence limits about 95% of the time. In these cases, the partial autocorrelation plots strongly recommend the presence of serial correlation in the ionosphere F_2 layer data and measure the degree of association; if the process is an autoregressive one then the partial autocorrelations can be examined to determine the order of the process. The order is equal to the number of significant partial autocorrelation. The constructed model can be inspected by separating the complete data set into two parts. First section which is regarded as the main part of the data set is operated to estimate or to compute the parameters. The values of the parameters estimated known as the predicted values. These values are compared with the data set which is regarded as the observed values as depicted in Table 1. Observed values are plotted against predicted values as depicted in the figure 7. These illustrations are verifying the results of.

Figure 7.
Plot of observed and predicted values verifying as a results of estimates obtained from the estimating techniques.

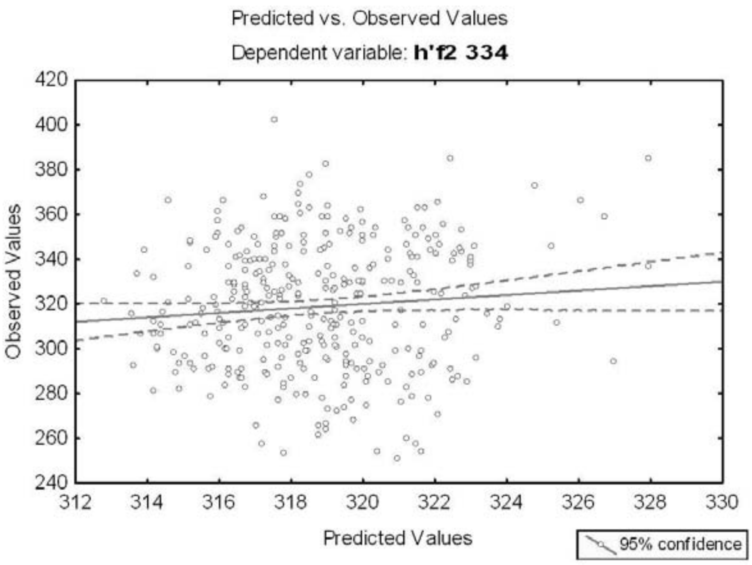


Table1
Comparison of observed and predicted values of virtual height of ionosphere F2 layer

S.No.	Observed	Predicted
1335	339.4452	296.4015
336	338.8913	278.0680
337	338.3383	263.9060
338	337.7863	251.9092
339	337.2351	241.2998
340	336.6848	231.6785
341	336.1354	222.8079
342	335.5869	214.5332
343	335.0393	206.7468
344	334.4926	199.3702

CONCLUSION

In this study, we have estimated the mean value of the seasonal variation of virtual height of h'F_2 layer and the deviation in virtual height of h'F_2 layer due to solar maximum and geomagnetic field. With the predication equation obtained from the time plot, the regression model may provide a very good fit to data.

The autoregressive (AR) order one model is clearer and easier to handle than the moving average from the virtual height data set which we have analyzed. In the case of finding the appropriate model for seasonal variation in virtual height of ionosphere layer h'F_2 layer, we have looked into the major parametric values of model. The sufficient model is justified for having insignificantly small residual autocorrelations. It can be seen that the AR (1) order one is suitable for making prediction and finding forecasts for the atmospheric region of Pakistan.

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