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Measurement of Ground surface temperature with Schumann resonance relation at Agra

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ABSTRACT*:* The relation between Schumann resonance (SR) intensity and ground surface temperature (GST) is studied at Agra region. For this purpose, SR intensity data observed at Agra (geographic lat.27.2°N, long.78°E) and GST data for the low latitude region from website: http://www.tutiempo.net/ are taken. The variations of average intensity and GST data over a period of one year from 01 April, 2007 to 31 March, 2008 are studied. It is seen that the variation curves for the two sets of data match satisfactorily and a cross-correlation coefficient of 0.4 is found which is consistent with earlier result for low latitude region. A linear regression analysis is carried out to find a link between the two and regression coefficients calculated. The regression equation is utilized to verify the calculated and measured GST which are found to match satisfactorily also. Here, we use this equation to calculate GST by substituting measured values of SR intensity and compute the unknown average ground surface temperature of Agra for the month of May, 2007 is found of 31.3 °C.

Keywords: **Schumann resonance, ground surface temperature, correlation coefficient, regression analysis.**

I. INTRODUCTION

The extremely low frequency (ELF) waves radiated from lightning discharges travel around the world in the earth-ionosphere space on account of long wavelengths involved and very low attenuation. The resonance between direct and round-the–world waves generates standing waves at the frequencies of 8, 14, 21….Hz which are known as Schumann resonance (SR) bands as they were first predicted by Schumann [1]. The importance of Schumann resonance phenomena has been identified rather recently as they found wide ranging applications in the studies of global thunderstorm activities, lower ionosphere, and effects of various geophysical events like solar flares, solar cycle, and earthquake etc [2].

The connection between Schumann resonance intensity and the planetary tropical temperature anomaly was first demonstrated by Williams [3]. The inherent concept is that the heated ground surface causes the air convector, which transports the worm humid air upward and triggers the cloud formation. The convection increases with temperature and liftsgreater amount of vapor, so that immense clouds are developed. Any vertical motion of particles in a cloud causes its electrification; hence, the lightning activity ought to be proportional to the ground temperature [4]. Though, the earlier work by Williams correlated the SR intensity with temperature anomaly, the recent works have exploited the temperature itself rather than temperature anomaly. For example, works by Satori [5] and Satori *et al.*[6] have inferred the seasonal migration of tropical thunderstorms along the meridian triggered by tropical temperature changes, Sekiguchi *et al.*[7],[8] have studied SR intensity data obtained in Japan for the period of 1999-2002 and compared with ground surface temperature (GST) data for different latitude intervals. Hayakawa *et al.*[4] have made a quantitative comparison of temperature and electromagnetic data for 43 months long and used cross-correlation coefficient to evaluate their linear connection. Nickolaenko and Hayakawa [9] have provided an overview of results of SR studies done in the interval from 27th (Maastricht) to 28th (New Delhi) URSI general assemblies including the ELF intensity and global land temperature and Schumann resonance on other planets.

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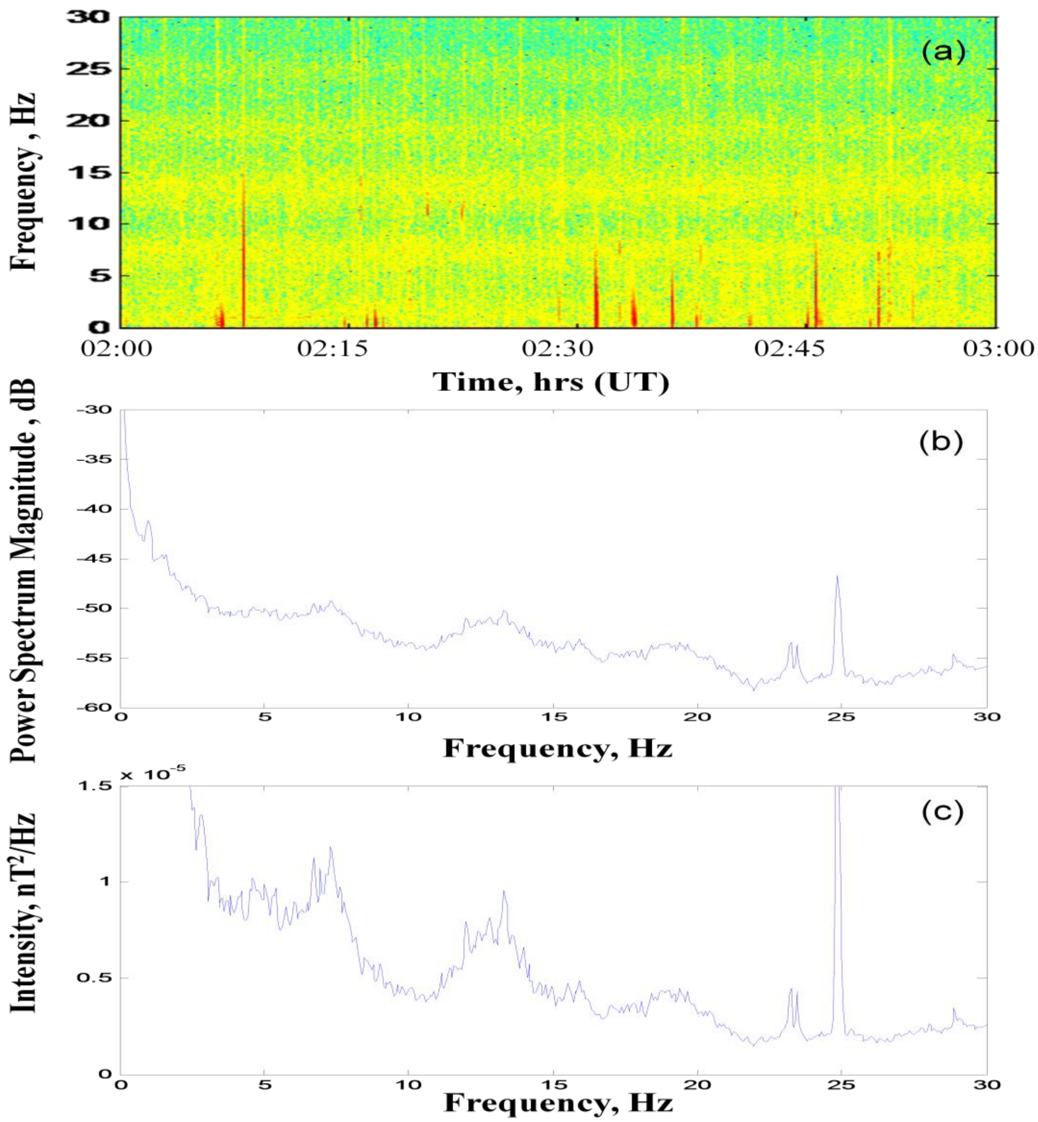

Fig.1 (a) Frequency-time spectrogram of the ULF/ELF magnetic field emissions recorded at Agra showing four Schumann resonance lines (b) Static spectra (PSD) of the data shown in Fig. 1a and, (c) Corresponding intensity-frequency variation.

In the present paper we make an attempt to compare the Schumann resonance intensity data obtained at Agra (geographic lat.27.2^{o}N, long.78^{o}E) with the ground surface temperature data for the low latitude region and carry out cross-correlation analysis to find out a linear regression relationship between the two. The results show that the cross-correlation coefficients are positive and the variations of calculated and observed temperature match satisfactorily.

II. EXPERIMENTAL SETUP

A set of modified 3-component search coil magnetometer (LEMI-30), imported from Lviv centre of Institute of Space Research, Ukraine, was installed on Bichpuri campus of our college (R. B. S. College, Agra) and routine observations for ULF/ELF magnetic field emissions started. The three sensors of the magnetometer are buried one meter underground in North-South (X-component), East-West (Y-component), and vertical (Z-component) directions separated from each other. The complete set up is similar to the one used by us earlier [10], [11] but with some modification in CAM (communication) unit and software. Also the locations of the sensor and recording system are changed after extensive surveys for better result. The location of the sensors is chosen in the agriculture fields of the campus in rural area about 12

Km West of Agra city, to avoid intense electric and electromagnetic disturbances. The data from the sensors are brought to the CAM unit placed in an observation room about 150 m away through specified cables, and digitized at a sampling rate of 64 Hz to be recorded on the hard disc of the computer. Round the clock observations are taken where time synchronization is obtained through a GPS system.

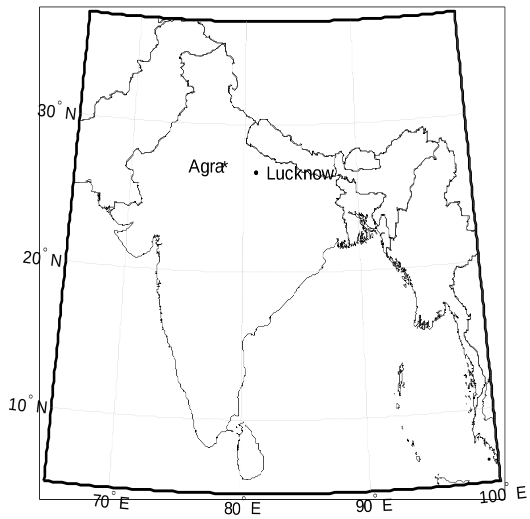

Fig.2. Map of India showing two different stations in the latitude range ±30° N and 3° wide longitude.

III.ANALYSIS PROCEDURE FOR SCHUMANN RESONANCE DATA

Offline analysis of the ULF/ELF data is carried out for a period of one year from 01 April, 2007 to 31 March, 2008 using FFT available in MATLAB software with 1024 words of data length at a time. The dynamic spectra (Frequency-time spectrograms) for each day are examined for good quality Schumann resonance bands. It may be mentioned here that, although we have taken all possible precautions to minimize electric and electromagnetic disturbances from spurious sources, the data are not perfectly free from the disturbances of powerful electric equipments, acoustic noise, movements of trains (about 300 m away), and other man-made noises. However, for the present analysis purpose we have selected best quality data. In doing so, some data gaps are found which are filled by taking 3days running averages so that a continuity of data may be maintained. The dynamic spectra are converted in to static spectra (PSD) which are then converted into intensity-frequency graphs for better reproduction of intensity peaks. A running average of 3 points is used for smoothing the intensity data at all frequencies. An example of dynamic and static spectra of SR recorded at Agra station is shown in Fig.1. Here, Fig. (1a) shows the dynamic spectra in which four SR lines are clearly seen. The time is shown in UT which is related to local time (LT) by the relation LT=UT+5.5hrs, Figs (1b), and (1c) show the corresponding static spectra.

IV.GROUND SURFACE TEMPERATURE (GST) DATA

The ground surface temperature (GST) data are taken from the website http://www.tutiempo.net/en/climate/Agra/07-2012/422.htm. Since SR is a global phenomenon, the regional temperature variation may have profound influence on its characteristics. Keeping this in view, we consider temperature variation for different stations lying in the low latitude region between ± 30° latitude. The stations are so chosen that they may lie on different latitudes but within 3° of longitude. These stations are Agra (geographiclat. 27.15°N, long.77.96°E) and Lucknow (geographiclat. 26.75°N, long.80.8°E) Fig.2 shows the locations of these stations in India. Hence an average monthly variation of temperature over the above stations may well represent the GST at Agra. From an examination of the temperature variations over Agra and that over other stations, we find that the two do not differ much in summer but differ significantly in winter months (see Fig.3).

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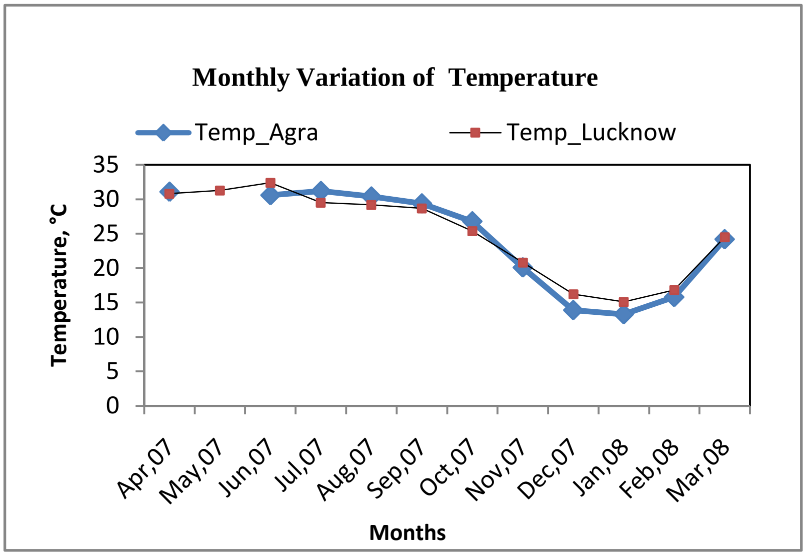

Fig.3. A comparison of measured global surface temperature variation at low latitudes with ±30°
with those at Agra during April, 2007 and March, 2008.

III. RESULTS AND DISCUSSION

In order to examine the connection between SR intensity and GST in the low latitude region we consider the first mode SR only as done by Williams[3] keeping in view the fact that the maximum intensity is concentrated in the first mode normally. For this purpose, we process the data through a digital band pass filter for frequency range between 6 and 9 Hz and select only those filtered data which contain clear first mode resonance peaks. Then we determine the peak frequencies and corresponding intensities. In this way a time series of the data is formed for 24 hours each day for the period of 12 months from 01 April, 2007 to 31 March, 2008. The intensity data are then averaged for each day, and then for 30 days to find average intensity for a month.

The variation of SR intensity (daily averages) over the period of one winter season from November, 2007 to February, 2008 is shown in Fig.4 by thick dark line curve. Also shown in the figure is the variation of GST at Agra by thin curve. In order to represent the same ordinate for both the data, the intensity is multiplied by 12×10^4. From Fig.4 it may be seen that average pattern of variation of these two sets of data are almost similar.

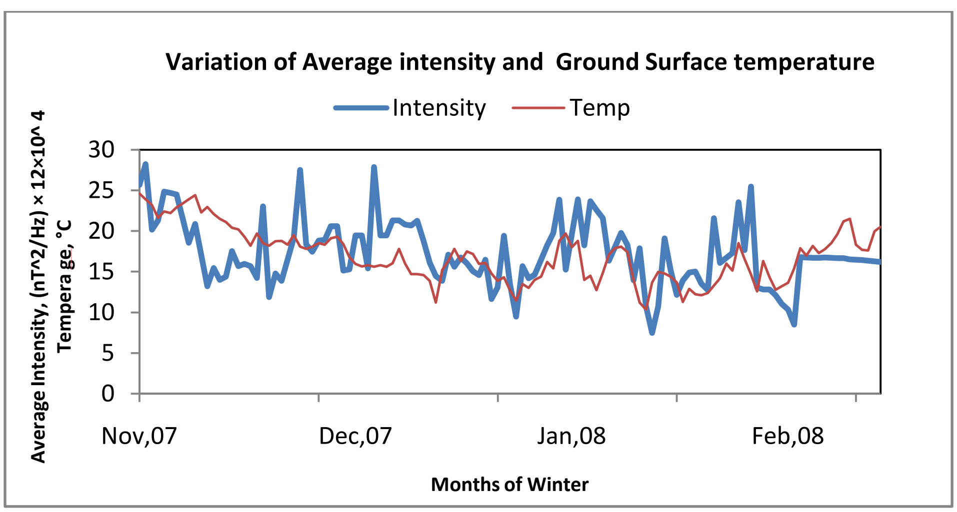

Fig.4. Average SR first mode intensity variation over the period November, 2007- February, 2008 (thick dark line curve). The superimposed curve (thin line curve) shows the average measured GST variation over the period.

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To ascertain the level of correlation between the two sets of data, we compute the correlation coefficients. It is seen that the cross-correlation coefficient for the whole year is 0.34 and the best for the three seasons is 0.4 for winter months. The result of cross-correlation coefficient of 0.4 for the two sets of data is consistent with Hayakawa et al. who have found similar result for low latitude but higher values for middle and higher latitudes.

We now find the link of the annual variation of the SR intensity (dB) with the GST by using the linear regression. The procedure may be illustrated for the low latitude region by computing the coefficients of regression A and B in the relation[4]

I[dB] = A + B * T. . . . .(i)

Where I[dB] is the SR intensity and T is the monthly average GST measured for low latitude. The regression coefficients are computed from the formulas;

A = { ∑I [dB] – B * ∑ T }/ N . . . . (ii)

B = { N*(∑T*I [dB]) - ∑I [dB] * ∑T} / { N*[∑(T^2)] – [∑T]^2} . . . .(iii)

In our case N=12 months. The calculated values for the coefficients are

A = -39.5632

B = 0.0572

So that the final linear regression relation is given as

I[dB] = -39.5632 + 0.0572 * T . . . . (iv)

The linear equation (iv) can be used to deduce SR intensity or GST in low latitude region if one of them is known. Here, we use this equation to calculate GST by substituting measured values of SR intensity and compare the results with the measured GST. The result is shown in Fig. 5. The unknown average ground surface temperature of Agra for the month of May, 2007 is found of 31.3 ⁰C. It may be seen here that the calculated and measured values of GST match satisfactory with minor deviations in few months.

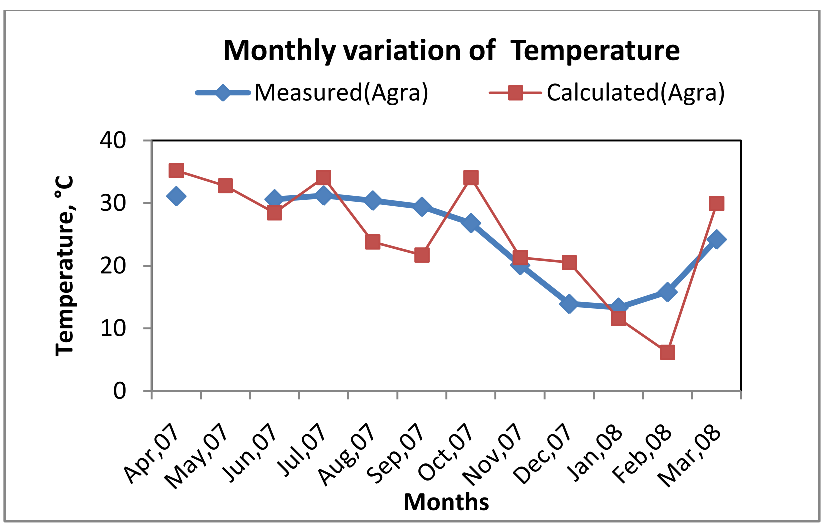

Fig.5. Variation of measured and calculated GST over the period.

From the results presented in Figs (4-5) it is seen that cross-correlation coefficients between the SR intensity and GST are positive but small compared to those at middle and high latitudes obtained by Hayakawa *et al*. [4] further, the calculated temperature deviates from the actual observed temperature in few months. Although, the exact reasons for these problems are still not known, we expect that the result may be improved by making an extensive study invoking the following modifications;

(i) Consideration of long data set for at least 4-5 years as have been done by Williams[3] and Sekiguchi *et al*. [7], [8].

(ii) The intensity of an individual SR mode is a function of source – observer distance. The role of diurnal motion of thunderstorms should be reduced by incorporating cumulative intensity of SR modes in the analysis [12]-[14].

(iii) Simultaneous SR intensity data should be taken at least at two antipodal observing stations to eliminate the distance factor. The motion of thunderstorm activity will be of opposite signwith respect to these observing points, and the distance factor will be eliminated in the sum of resonance intensities because the source motion will increase the intensity at one point and decrease at the other by the same amount so that the sum becomes independent of the source position.

(iv) We propose to carry out an extensive study of SR intensity relation with GST in our future work by taking care of these modifications.

IV. CONCLUSION

It is seen that cross-correlation coefficients between the SR intensity and GST are positive but small compared to those at middle and high latitudes obtained by Hayakawa *et al*. [4] further, the calculated temperature deviates from the actual observed temperature in few months. Although, the exact reasons for these problems are still not known, we expect that the result may be improved by making an extensive study invoking the above modifications. The unknown average ground surface temperature of Agra for the month of May, 2007 is found of 31.3 ºC. It may be seen here that the calculated and measured values of GST match satisfactory with minor deviations in few months.

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