Solar Wind-Magnetosphere Coupling Effect on Radio Refractivity in 2008 for Minna

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Abstract

Solar wind-magnetosphere coupling effect on radio refractivity is investigated from hourly measurement of meteorological parameters and interplanetary parameters for dry and rainy season in Minna (Latitude 9° 36' 50" N and Longitude 6° 33' 24" E) North central, Nigeria for the year 2008. Data used for the work is made up of hourly interval record of meteorological parameters and interplanetary parameters calculated from the data obtained from the Center for Basic Space Science (CBSS) measured with Vantage PRO II Automatic Weather station and through Omini web for each day in all the months of the year in 2008 for both dry and rainy seasons. The result showed that variations of solar wind and radio refractivity time increases almost in an hourly cycle between the 1st hours to the 14th hour during dry season while during rainy season, they exhibit linear decrease with time between 1st hour to the 19th hour. Also the correlation between solar wind energy with radio refractivity is negligible. It was showed as well that solar wind changes with a positive gradient in dry season while solar wind decreases with negative gradient in rainy season.

Key words: Solar wind, magnetosphere coupling, radio refractivity

1. Introduction

Solar-Wind Magnetosphere Coupling investigations have been gathering valuable in situ records of magnetospheric plasma, solar wind plasma, and their electromagnetic fields for several decades. These data have been the primary means for studying the complex plasma interactions that occur in critical boundary regions such as the bow shock, the magnetopause (Russell, 1995), the central plasma sheet (Baker *et al.*, 1996), and the auroral zone. These data also are the basis of statistical models of the magnetosphere.

There are, however, many open questions on the global nature of magnetospheric processes which cannot be answered with current data. Reconnection, for example, is a key process in solar wind-magnetospheric coupling, but little is known about its spatial character, its temporal properties, or associated plasma entry (Paschmann *et al.*, 1979). The central plasma sheet is the focus of the substorm process, yet little is known about the location, size, and evolution of neither the dipolarization region nor its relationship with a near-earth neutral line (Baker *et al.*, 1996). The cusp region is critical to the origin of magnetospheric plasmas but little is known about the relationship between plasma entry and the state of the subsolar recconnection region (Fuselier *et al*., 1997). The role of solar wind energy input at the lower-latitude boundary layer is not understood (Phan *et al.*, 1997). These open questions call for the need for multi-point measurements of plasma and electromagnetic fields. An experimental investigation that provides concurrent measurements of plasma parameters over an extended region of the magnetosphere would have many advantages.

According to some researchers, magnetospheric boundaries are in constant motion during solar wind magnetosphere coupling processes, thus, making single-point observations technique hard to interpret. Employing multi-point observations would help to resolve the ambiguity of space and time and the interdependence of small-scale plasma phenomena and large-scale magnetospheric processes could be investigated. Magnetospheric structures and boundaries are ever changing with solar wind conditions, the interplanetary magnetic field (IMF), and substorm activity. In order to understand and quantify magnetospheric processes, one must understand the electromagnetic field and plasma topology which, in spite of many years of in situ observations, has not been mapped on a global scale (Fuselier *et al.*, 1991).

This work is, therefore, aimed at investigating the effect of solar wind earth magnetosphere coupling on radio refractivity in dry and rainy seasons at Minna for the year 2008 using meteorological parameters and solar wind parameters.

2. Solar wind

Solar wind is a stream of charged particles ejected from the upper atmosphere of the Sun and, is flowing outward from the Sun. It was first suggested by British astronomer Richard C. Carrington. It is mostly made up of electrons and protons with energies ranging from 10-100 keV. The stream of particles varies in temperature and speed over time. These particles can escape the Sun's gravity because of their high kinetic energy and the high temperature of the corona.

The solar wind creates the heliosphere, a vast bubble in the interstellar medium that surrounds the solar system. Other phenomena include geomagnetic storms that can knock out power grids on Earth, the aurorae (northern and southern lights), and the plasma tails of comets that always point away from the Sun (Meyer-Vernet, Nicole, 2007).

The solar wind is responsible for the overall shape of Earth's magnetosphere, and fluctuations in its speed, density, direction, and entrained magnetic field strongly affect Earth's local space environment.

2.1. Magnetosphere

Magnetosphere is formed when a stream of charged particles, such as the solar wind, interacts with and is deflected by the intrinsic magnetic field of the planets or other similar body. Earth is surrounded by a magnetosphere, as are the other planets such as Mercury, Jupiter, Saturn, Uranus, and Neptune with intrinsic magnetic fields.

The strongest coupling between the solar wind and the Earths'magnetosphere occurs when their magnetic fields reconnect in regions of nearly opposite directions. The physics underlying reconnection occurs on the sub-gyroscale where the ions and eventually the electrons encounter magnetic structure that demagnetizes the charged particles so that they are no longer tied to the magnetic field holding them and drift across it. This process allows field lines from different plasma regimes to connect. This process is referred to reconnection. Dayside reconnection is largely believed to control solar-wind magnetosphere coupling effect observed in the atmosphere (Dungey, 1961; Hones, 1984; Kamide and Slavin, 1986; Goertz et al., 1993; Russell, 2000; Cowley et al., 2003).
The main result of solar-wind magnetosphere coupling effect on radio refractivity is the large scale magnetospheric electric filed that drives plasma convention and this make the solar wind pressure pulse to affect magnetospheric cavity.

3. Data acquisition method

The data used for this work covered the period of one year starting from January to December, 2008. The data are in two forms. First one is meteorological parameters which are raw recorded 5minutes data of temperature, humidity and pressure. These data were provided by the Centre for Basic Space Science (CBSS).

The second type of data is the interplanetary magnetic data obtained from omini website (www.ominiweb.com). This data consists of 5munites data value of solar wind velocity and interplanetary magnetic field components of Bz(nT), Bx(nT), By(nT) and solar wind pressure.

From the data, hourly averages of solar wind interplanetary magnetic field parameters for each day of the month were calculated using excel package. Solar wind energy (ε) of the magnetosphere will be

calculated using:

$$\varepsilon = V_{sv} B^2 sin^4\left(\frac{\theta}{2}\right) l_o^2 \quad (1)$$

where V_{sv} = *solar wind velocity*

$|B|$ = *magnitude of the interplanetary magnetic field*

$\theta = \arctan(B_y/B_z)\ for\ B_z > 0\ and\ 180^0 - \arctan(B_y/B_z)\ for\ B_z \leq 0$

l_o = *dayside magnetopause scale length which is equal to* $7R_E$

Bz = z-component of *interplanetary magnetic field*

By = y-component of *interplanetary magnetic field*

Also, the hourly averages of meteorological parameters for each day of the month were calculated using excel package. From the values obtained, partial pressure of water (e) was determined from the following equation:

$$e = e_s \cdot \frac{H}{100} \quad (2)$$

where H is the relative humidity, and e_s is the saturation vapour pressure determined by Clausius-Clapeyron equation given as:

$$e_s = 6.11 exp[17.5(T - 273.16)/(T - 35.87)] \quad (3)$$

Employing the values of meteorological parameters (temperature, pressure and relative humidity) computed, radio refractivity was calculated using;

$$N = 77.6\frac{P}{T} + 3.37 \, x \, 10^5 \, e/T^2 \quad (4)$$

where

P = atmospheric pressure (hPa)

e = water vapour pressure (hPa)

t = absolute temperature (K)

Equation (4) may be employed for the propagation of radio frequencies up to 100GHz (Willoughby, *et al,* 2002).

The two results (solar wind coupling and radio refractivity) were compared to actually deduce solar-wind magnetosphere coupling effect on radio refractivity at Minna in the year 2008.

4. Results and Discussion

The meteorological parameters and the solar wind parameters data are an hourly record of solar wind and meteorological event observed for both dry and rainy season in Minna for the year 2008 on each day within the Months. Although the research was carried out in all the days and months of the year, the Months of February and August respectively were chosen to represent dry and rainy season for the rest of the months in year 2008.

Fig 1 and 2 are the plots of variations of solar wind and radio refractivity with time for dry season in 2008 for Minna

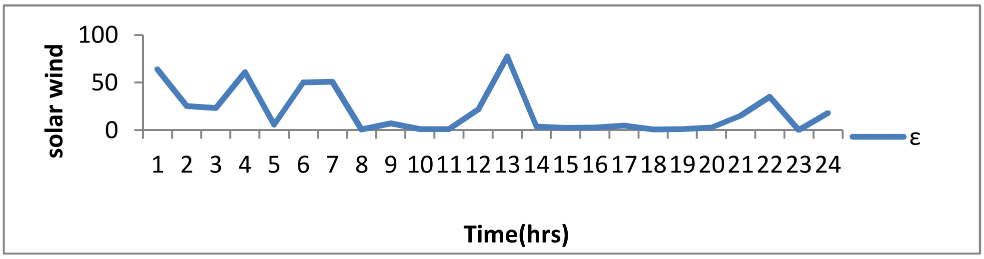

Fig 1: Variations of solar wind with time during dry season

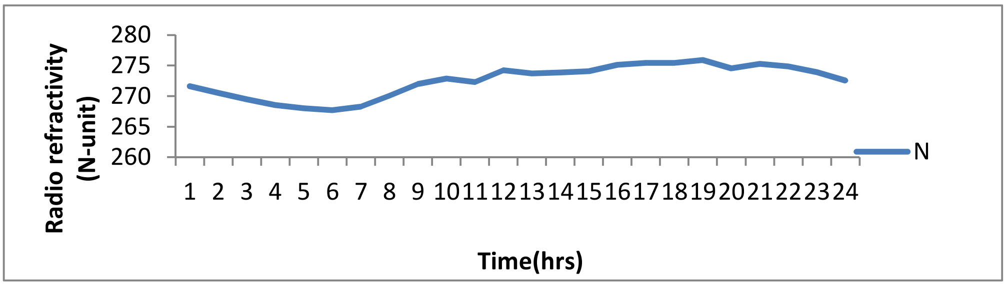

Fig 2: variations of radio refractivity with time during dry season

From figure 1, variations of solar wind with time is almost an hourly cycle with the maximum peak occurring at the 12th hour (1200hr) on average at quiet days during dry season. In figure 2, it equally appeared that the variations of radio refractivity followed the same trend as the solar wind with the maximum peak occurring at 19th hour and 20th hour (1900hr and 2000hr) in day 1 for dry season. From the plots, it is observed that the dependence of solar wind and radio refractivity with time is high due to the high solar activities within the solar system during dry season.

Fig 3 and 4 show the plots variations of solar wind and radio refractivity with time for rainy season in 2008 for Minna

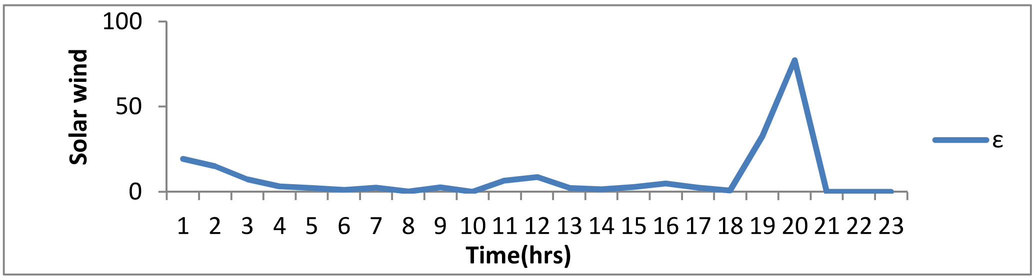

Fig 3: Variations of solar wind with time during rainy season

In figure 3 and figure 4, variations of solar wind with time and variations of radio refractivity with time decreased almost linearly within the hours of the day in rainy season with the minimum decrease between the 1st hours to 18th hour within the period of the day. This is the period when there is slow out flow of solar wind with less energy into the Earth's magnetosphere during solar wind magnetosphere coupling. But from 19thhour-21sthour, when there is no dayside reconnection between solar wind and the Earth magnetosphere, there is a sudden increase in the variations of solar wind and radio refractivity with time.

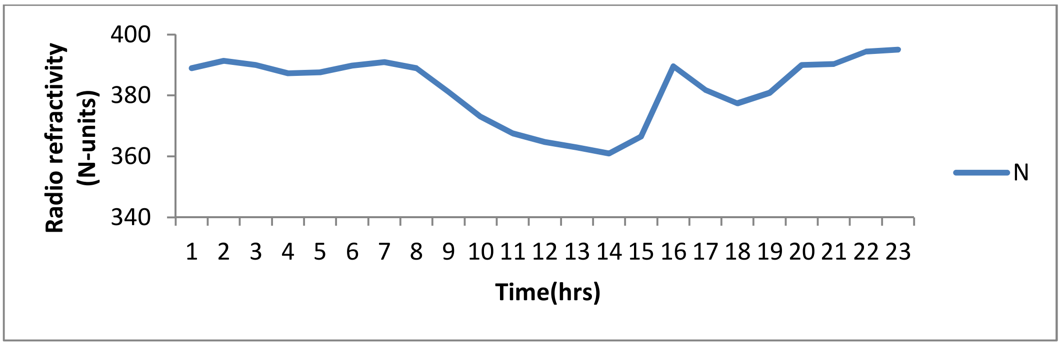

Fig 4: variations of radio refractivity with time during rainy season

Correlation analysis of solar wind as a function of radio refractivity in dry and rainy season (fig 5 and fig 6) were done to investigate the level at which solar wind correlates with radio refractivity within the two seasons in 2008 for Minna during solar wind magnetosphere coupling. The solar wind correlation coefficients (0.118 and 0.003) for dry and rainy season indicate the level at which radio refractivity depends on solar wind, and from the result, it is shown that solar wind does has a weak correlation with radio refractivity for both dry and rainy seasons.

Fig 5 and 6 show the plots of correlation of solar wind with radio refractivity during dry and rainy season in 2008 for Minna

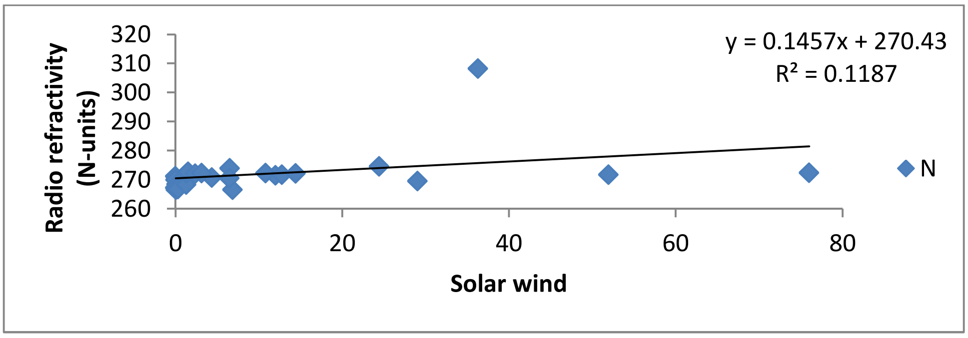

Figure 5: Correlation of solar wind with radio refractivity during dry season

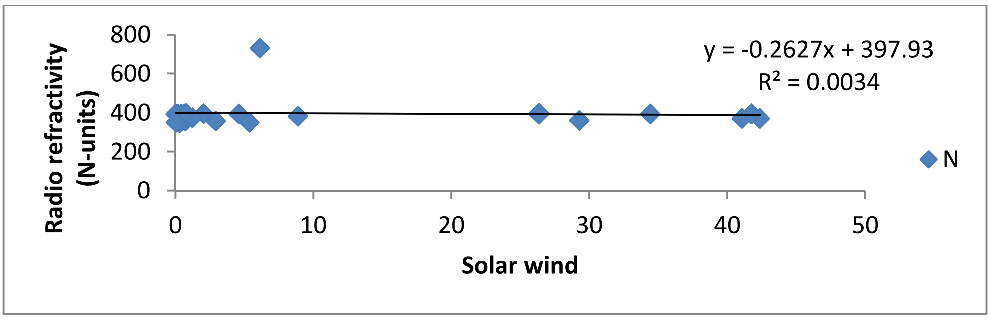

Fig 6: Correlation of solar wind with radio refractivity during rainy season

The analysis equally showed that solar wind has positive slope during dry season (i.e. $\frac{dN}{d\epsilon}$ = 0.145) while during rainy season solar wind has negative slope (i.e. $\frac{dN}{d\epsilon}$ = -0.262). Therefore, from the analysis, the rate at which solar wind changes with radio refractivity is mostly noticed during rainy season when compared with the dry season in 2008 for Minna. The ratio of the rainy season value to the dry season value is about 2 times.

Conclusion

From the analysis of the result of the work, it is observed that solar wind magnetosphere coupling has no much effect on radio refractivity during dry season and rainy season in Minna in 2008, but as solar wind changes with time during solar wind magnetosphere coupling, radio refractivity also changes with time. The change resulting from the solar wind energy is random, owing to the random events from the sun. This effect is caused by the changes in meteorological parameters such as temperature which directly affect radio refractivity. The correlation coefficient between radio refractivity and solar wind energy at both dry and rainy showed no significant values. Hence, the cause of change in radio refractivity is not the same cause of change in solar wind energy. Therefore, it can be said that solar wind magnetosphere has more significant effect on radio refractivity during rainy season than the dry season. Thus this work was focused on the effect of solar wind magnetosphere (Earth magnetosphere) coupling on radio refractivity, and we therefore suggest that research should be carried out on the other planetary magnetosphere to see their effect on radio refractivity within the seasons of the year.

Acknowledgement

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