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NOTAS BREVES DE PESQUISA & DESENVOLVIMENTO TÉCNICO
SHORT RESEARCH & TECHNICAL DEVELOPMENT NOTES

foF2 FREQUENCY BANDS IN EL CERRILLO, MEXICO DURING MAGNETICALLY QUIET CONDITIONS.

E. A. Araujo-Pradere

This work describes the foF2 frequency bands (maximum-noon, minimum-midnight bands) and their main characteristics during magnetically quiet conditions and extreme conditions of solar activity. We have observed that there is a seasonal variation and parallel behavior between frequencies during High Solar Activity and Low Solar Activity. During High Solar Activity we can observe the seasonal anomaly and symmetry between both frequency bands.

Key words: Ionosphere; F2 layer.

BANDAS DE FRECUENCIAS foF2 EN EL CERRILLO, MEXICO, EN CONDICIONES MAGNETO TRANQUILAS -*Este trabajo describe las bandas de frecuencias de la capa F2 (conformadas por las bandas máximos-mediodía, mínimos-medianoche) y sus principales características en condiciones magneto tranquilas y bajo valores extremos de actividad solar. Obtuvimos que en Alta y Baja Actividad Solar se observa una variación estacional y un comportamiento paralelo entre los pares de frecuencias. En Alta Actividad Solar se observa además la anomalía estacional y simetría entre ambas bandas de frecuencias.*

Palabras claves: *Ionósfera; Capa F2.*

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INTRODUCTION

The F region has been intensively studied, mainly due to its influence on the propagation of radio waves. Determinations of the F2 frequency bands in magnetically quiet conditions and extreme conditions of solar activity give us, as a first approximation, the typical behavior of F2 layer critical frequency (foF2).

During disturbed geomagnetic conditions, these bands are very different and their changes can be a measurement of the ionospheric response to geomagnetic storms. This information is important in order to know the main factors that are affecting the ionosphere.

This work describes foF2 frequency bands in El Cerrillo, Mexico and their main characteristics.

DATA AND METHODS

Day-time hourly values of foF2 were selected for the radio sounding station "El Cerrillo" (ϕ = 19° 26' N, λ = 99° 42' W), Toluca, Mexico. The magnetic index Kp and the solar parameter Rz were used to define the level of geomagnetic perturbation and of solar activity, respectively.

We have assumed Rz $\cong$ 100 as High Solar Activity (HSA) and Rz $\cong$ 10 as Low Solar Activity (LSA) (which do not imply maximum or minimum values of Solar Activity). Finally, we have used Kp $\leq$ 3 in order to assure a quiet condition of the magnetosphere, thus we avoided geomagnetic field perturbations. For convenience, we chose the year 1964 (Rz = 10.2) as LSA and 1968 (Rz = 105.9) as HSA.

The data selection was conditioned by the quality of the information in the period of observation and we took into account the amount of data available in each period. These data were separated in four groups: maximum values, minimum values and noon and midnight values.The data were averaged for each month, in order to obtain the typical behavior during both years.

RESULTS

Fig. 1 shows foF2 frequency bands to a HSA year (1968). In this figure we can see a typical behavior of the ionospheric upper layer in these conditions. There is a symmetry between both bands of frequencies and different frequencies show a parallel behavior, i.e., the curve of maximum foF2 is parallel to the curve of noon foF2 as well as the curve of minimum foF2 is parallel to the curve of midnight foF2.

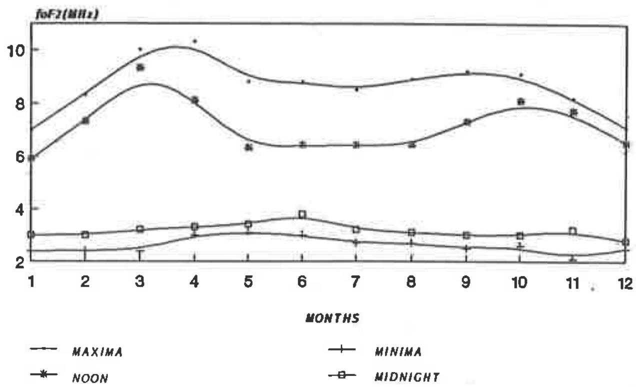

Figure 1 - foF2 frequency bands during High Solar Activity.

Figura 1 - *Bandas de frecuencias de foF2 durante Alta Actividad Solar.*

Remarkable features that we can see in the superior band are the seasonal variations (highest values of frequencies during equinoxes) and seasonal anomaly (winter values are greater than summer values). The first is the cause of the largest separation between frequency bands during these months and is equivalent to the maximum values observed in this period for several level of solar activity and several locations (Lois Menendez et al., 1992; Araujo-Pradere et al., 1996).

The most probable cause of these variations is the change in the atmospheric composition, but the mechanism has not been defined. Seasonal variations of atomic (O) and molecular (O_2, N_2) concentrations in the thermosphere (Rishbeth & Setty, 1961) have been supported by several studies. For mid and low latitudes and during equinoxes and winter, maximum ratios of [O]/[O_2] and [O]/[N_2] are higher than during summer, at least two times (Stubbe, 1975). Alcayde et al. (1974) found winter-summer rates of O_2 of 1.5 and 4.0, respectively. Such changes will affect the rates of production and loss which produce these anomalies.

Maeda et al. (1986) suggested that upward energy flux transferred by propagating internal gravity waves increases during the transition periods between the summer easterlies and winter westerlies in the lower atmosphere and this occurs twice a year (around the equinoxes) and could contribute to introduce a seasonal variation in turbulent mixing.

Fuller-Rowell (1997) proposed that the global scale interhemisphere-thermospheric circulation acts like a huge turbulent eddy. The effect of this "thermospheric spoon" is analogous to a conventional small scale turbulent eddy, mixing the lower atmosphere species below the turbopause. At equinox, the thermospheric prevailing circulation is weak since solar heating heats the atmosphere more uniformly. The combination of solar heating at low latitudes and Joule heating from magnetospheric sources at high latitudes leads to weak latitude pressure gradients and resultant light prevailing meridional winds. In this situation the species can be diffusively separated above the level of turbulent mixing (the turbopause). At solstice, the asymmetric heating of the globe produces a hot summer hemisphere and a pressure gradient that drives a strong interhemispheric prevailing meridional wind. This circulation is closed by upwelling in the summer hemisphere, down-welling in the winter hemisphere, and a weak return flow at lower altitudes to mantain continuity of mass flow.

Highest values are not at local noon. This can be explained by the strong transport process, which are very important in this altitude. Minimum values are just before sunrise, as we expected, due to loss by recombination. Other factor to take in account is the difference between the local time (90° W) and the real time (99°42' W) in El Cerrillo, which is about 35 minutes.

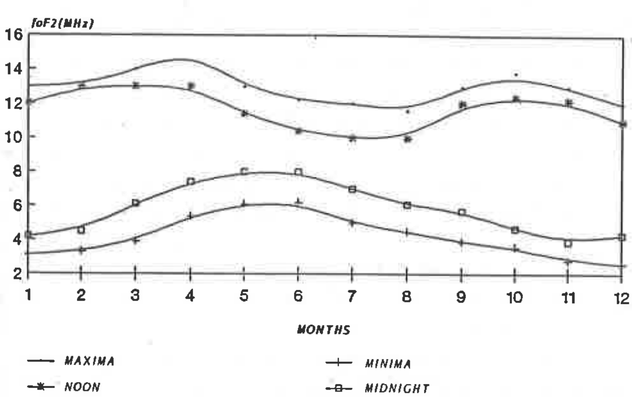

Figure 2 - foF2 frequency bands during Low Solar Activity.

Figura 2 *- Bandas de frecuencias de foF2 durante Baja Actividad Solar.*

Fig. 2 shows foF2 frequency bands to a LSA year (1964). In this figure we can see again the parallel behavior between different foF2 frequencies (maximum-noon, minimum-midnight), but there is no symmetry similar to that observed between both bands during HSA.

The superior band (maximum-noon) has similar behavior. We can see the seasonal variations but not the seasonal anomaly. The inferior band is now very flat, being without the variations observed during HSA.

All these features were observed in similar work made by Lazo & Palacio (1974) with data from Havana (ϕ = 22° 58' N, λ = 82° 09' W). The same parallel behavior between bands, the seasonal variations in both level of solar activity and the seasonal anomaly in HSA were obtained in their study. This similarity can be explained by the proximity location and similar conditions of both stations.

The absence of a seasonal anomaly during LSA may be due to the fact that the southern winds in winter are much stronger, almost twice during the day, than the winds in summer. The direction of the north-south component of the wind speed is towards the pole during the day; therefore the downward movement of the ionization is more intense and there is a greater accumulation of charged particles at lower heights in winter.

However, this is not consistent with the observational results. Numerical solutions of the continuity equation show that NmF2 should be reduced more intensely in winter than in the summer; the decay of the ionization in lower heights due to higher loss rate overcomes the increase due to the downward transport of plasma. This fact, plus the control that the ion drag exerts on the magnitude of the winds, allows us to understand why the seasonal anomaly does not exist during low solar activity.

The general behavior shown by the data from El Cerrillo is well in accordance with predictions from IRI/CCIR (International Reference Ionosphere / Comité Consultatif International des Radio Comunication). The noon values of foF2 from IRI/CCIR also shows the equinoxes maxima during HSA and the winter anomaly, although this effect is more marked in the data than in the predictions.

CONCLUSIONS

Bands of foF2 frequency have parallel behavior during both level of solar activity. There is a seasonal variation (maximum values of foF2 during equinoxes) and maximum values are not at noon. During HSA there is a seasonal anomaly (winter values are greater than summer values).

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BANDAS DE FRECUENCIAS foF2 EN EL CERRILLO, MEXICO, EN CONDICIONES MAGNETO TRANQUILAS

Utilizando los datos diarios de frecuencias críticas de la capa F2 ionosférica de la Estación de Radiosondeo de El Cerrillo (ϕ = 19° 26' N, λ = 99° 42' W), correspondientes al mediodía y medianoche, y conjuntamente con los valores mínimos y máximos de este parámetro; se construyen las bandas de frecuencias para años de alta y de baja actividad solar (asumiéndose respectivamente valores de Rz $\cong$ 100 y Rz $\cong$ 10). La banda superior queda así conformada por la frecuencia máxima más la frecuencia al mediodía, mientras que la inferior se compone de la frecuencia mínima más la obtenida a la medianoche.

Los años fueron seleccionados partiendo de la disponibilidad y calidad de los datos en los mismos y se impuso el criterio de Kp $\leq$ 3 en aras de garantizar un estado tranquilo de la magnetosfera. A partir de los datos de foF2 se obtuvo un promedio mensual representativo del comportamiento de estos valores en ambos años.

Los resultados obtenidos demuestran la existencia de un comportamiento típico para la ionosfera de latitudes medias. Para el periodo de Alta Actividad Solar se observa cierto paralelismo entre ambas bandas de frecuencias, es decir, a mayores valores de la frecuencia máxima corresponden mayores valores de la frecuencia al mediodía y viceversa. El mismo comportamiento se puede observar entre la frecuencia mínima y la frecuencia a la medianoche. Igualmente se destaca un comportamiento simétrico entre las bandas superior e inferior.

Las características más importantes que se obtienen en la banda superior son las variaciones estacionales (los mayores valores de frecuencias aparecen durante los equinoccios) y la anomalía estacional (los valores invernales son mayores que los de verano). La primera es la causa de las mayores desviaciones entre la banda superior y la inferior en esos meses y es equivalente a los valores máximos observados en ese periodo para diferentes niveles de actividad solar y diversas locaciones.

En periodos de Baja Actividad Solar también se puede observar el paralelismo entre las diferentes frecuencias de la capa F2, pero se pierde la simetría entre las bandas superior e inferior.

En la banda superior se destacan nuevamente las variaciones estacionales, pero no se observa la anomalía estacional, mientras que la banda inferior es ahora muy plana, sin las variaciones observadas durante Alta Actividad Solar.

El comportamiento general mostrado por los datos de El Cerrillo no difieren de las predicciones del IRI/CCIR (International Reference Ionosphere / Comité Consultatif International des Radio Comunication). Los valores al mediodía de foF2 también muestran los máximos equinocciales durante Alta Actividad Solar y la anomalía de invierno, aunque el efecto es más marcado en los datos que en las predicciones.

NOTAS SOBRE O AUTOR
NOTES ABOUT THE AUTHOR

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