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A Study on the Latitudinal Features of the Ionospheric Absorption Excursion

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This paper is concerned with a study of the range of absoption variation termed here as "Ionospheric Absorption Excursion", making use of the average differences between the upper and the lower deciles of absoption. The behavior of this parameter is discussed for low and middle latitude ionospheric conditions. The relative importance of this parameter in the F-region and the lower ionosphere is then considered using the latitudinal variation in the F-region absorption expected from the observed latitudinal variation in the critical frequency of the F_2 layer.

Trata-se de um estudo da faixa de variação da abosorção, aqui denominada "Excursão da Absorção Ionosférica", utilizando a média das diferenças entre os decis superiores e os decís inferiores da absorção. Discute-se o comportamento dêste parâmetro para condições ionosféricas de baixa e média latitude e considera-se então a importância relativa do parâmetro na região F e na baixa ionosfera por meio da variação latitudinal da absorção na região F conforme a observação dessa variação na frequência crítica da camada F,.

1. Introduction

Ionospheric absorption measurements at low and middle latitude stations using riometers have been carried out in the past at several locations. It is now known that the total absorption observed occurs in two main absorbing regions of the ionosphere, namely, the D and the F-regions (see for example Mitra and Sarada[1], Bhonsle and Ramanathan[2], Abdu et *al.*[3], Lusignan[4]). The relative magnitude of the F-region absorption has been observed to be strongly dependent on the critical frequency of the F_2 layer (f, F,). It has also been observed to vary with the latitude of the

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observations. However, no work on the behavior of the excursion of the absorption values in these two ionospheric regions has been reported before. Nor has there been any systematic study made on the latitudinal variation in the average absorption values and their excursions. In this paper, we report an attempt to study these features making use of the 30 MHz riometer data collected at ***São José dos Campos*** during 1963, 1964 and 1965[5,6] and the published data for the Stanford and the Pullman stations (Lusignan[7]).

2. Method of Analysis and the Results

Using the hourly values of the ionospheric absorption A (db) of every day, of each month, the upper (A_U) and the lower (A_L) deciles were taken to define the quantity

$$\Delta A = A_U - A_L \qquad (1)$$

and, by plotting this quantity as a function of time, we obtain the curves of Figure 1. The main characteristic shown by the monthly curves is a tendency to repeat itself during each month with maxima occurring mostly between late afternoon and sunset hours.

A more compact representation of this could be provided by taking an average as

$$\overline{\Delta A} = \frac{1}{12} \sum_{i=1}^{12} \Delta A_i . \qquad (2)$$

This parameter, which is plotted in Figure 2, is then used for studying certain features of the ionoespheric absorption[8].

Let us consider some aspects of the curve in Figure 2, where we show the mean absorption excursion of 1963, 64 and 65. During the 14 hours between 20 and 10 LT, i.e., roughly from just after local sunset, the ionizing processes depending on solar influence are totally extinguished (night period from 20 to 6 LT) or they are just incipient (4 hours of sunlight, from 6 to 10 LT). At these times the ionospheric absorption, in both highest and lowest peaks, has very limited values so that the excursion between the extremes is at its daily narrowest and it holds an almost constant value (within the allowance of the riometer measurements). This value was .8 db for 1963, .3 db for 1964 and .4 db for 1965 (Figure 2).

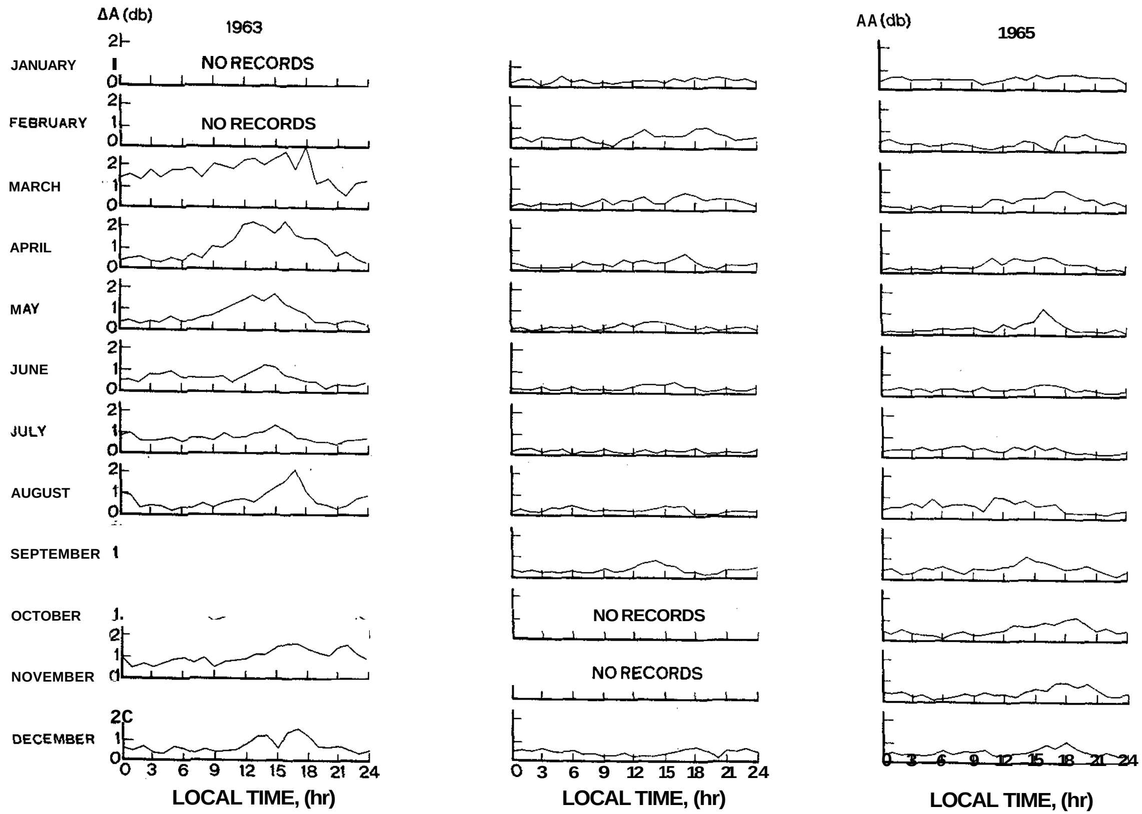

Figure 1. Ionospheric absorption excursion at *São José dos Campos* riometer (30 MHZ).

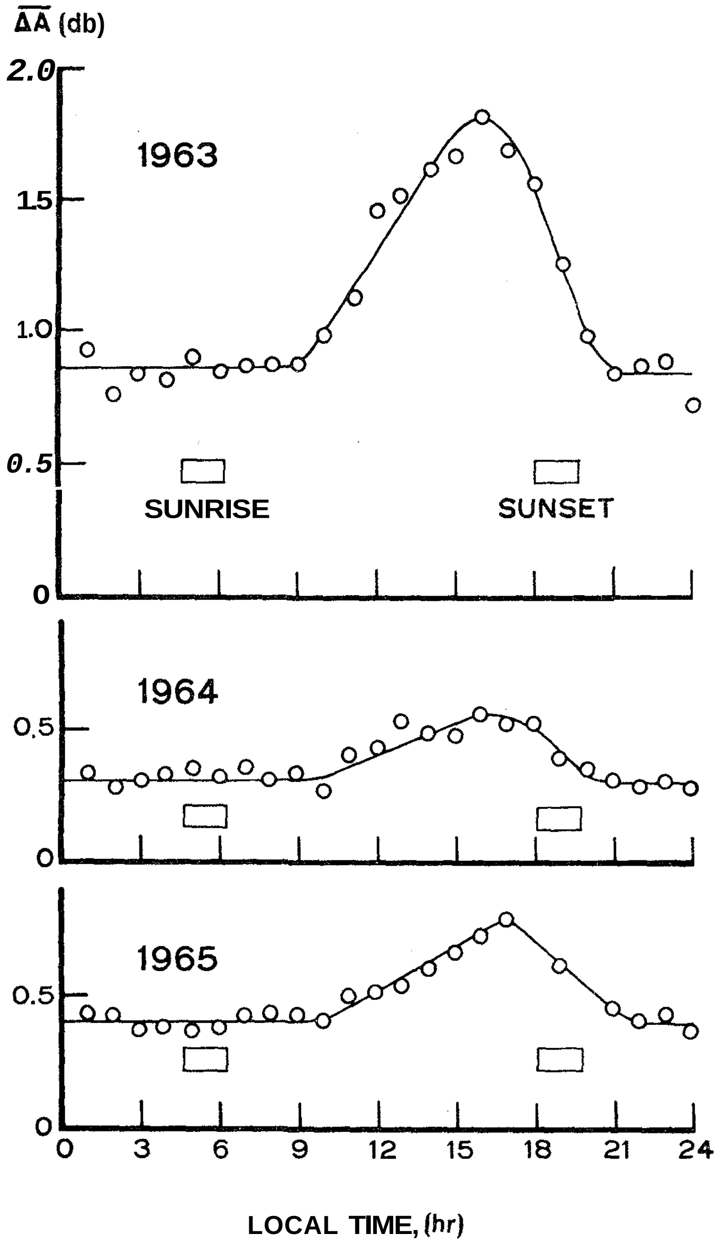

Figure 2. Mean yearly absorption excursion at *São José dos Campos SP*.

An identical computation made for the Stanford and the Pullman stations on the available 1958 and 1959 data gave (Figure 3):

STANFORD	1958	.8 db
STANFORD	1959	.9 db
PULLMAN	1958	.5 db
PULLMAN	1959	.5 db

Now, considering the data and curves of the SJC station (Figure 2), we find the peak at 17 LT. In other words, this is a time of strongest maxima and minima, and the excursion is at its maximum during the 24-hour period. This means that, at 17 LT, we have statistically the greatest amplitude of fluctuation in ionization compatible with the calmest ionosphere. Before and after that, we have, respectively, ever-increasing and ever-decreasing values limited, of course, by the ten hours of constant excursion At the SJC station, in 1963, the rate of increase was almost equal to that of decrease (.1 db per hour), while for 1964 and 1965 it was .05 db per hour and .07 db, respectively; but taking into account instrumental sensitivity, this rate can be rounded up to .1 db per hour. The global balance between the time in which it changes could depend on the latitude of the station (absolute value), as per the following table:

STATZON	DZP (approx.)	LATZTUDE	EXCURSION (hrs)	
			constant,	variable
SJC	22.5'' S	23°12'43'' S	14	10
Stanford	63.0° N	37°26' N	11	13
Pullman	72.0'' N	46'43' N	9	15

It is known that at SJC the main peak of the ionospheric absorption is not in proximity to the zenith (local noon), but around two and half hours later (14.30 LT). It is interesting also to observe (Figure 2) that the interval between the latest sunrise at SJC and the start of excursion growth is almost three and a half hours, while the decrease phase begins an hour and a half before the earliest sunset of the year[g].

Merely qualitative considerations suggest that the curve of the annual average excursion variation should indicate the cumulative effects of successively overlapping solar flare ionizations on some components of the D-region (upper deciles). It could also be enhanced by possible changes in the recombination coefficient in the D-region (lower deciles). These

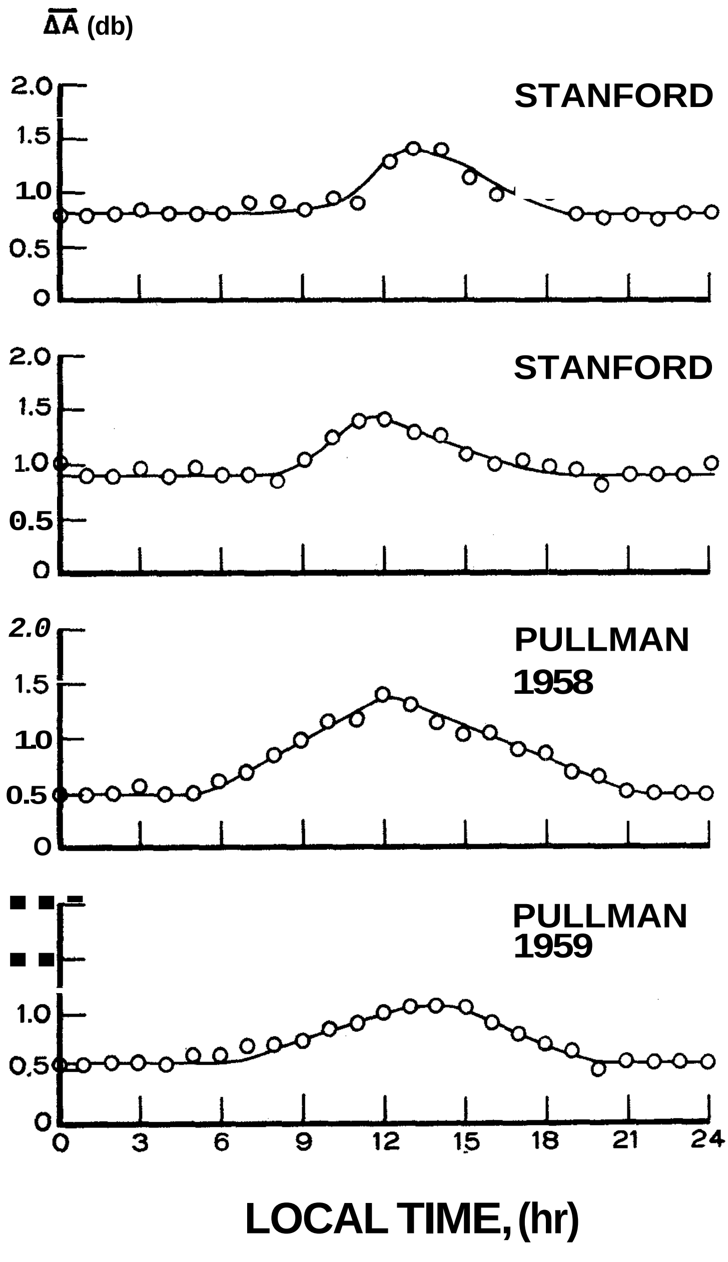

Figure 3. Mean yearly absorption excursion.

effects must be related to the spectral region of 2-20 Å X-rays which, together with Lyman a of 1215.7 Å, and EUV radiation is known to be the main source of free electrons in the equatorial " D region.

3. Discussion

It was mentioned above that the absorption excursion for ***São José dos Campos*** did not maximize at the same time as the average diurnal variation of absorption. It is therefore useful to know the overall diurnal features of the absorption excursion in relation to the corresponding average absorption for all three stations discussed here. These are plotted in Figure 4: the open circles show the average yearly absorption ($\tilde{A}$) during 1965 for SJC and during **1959** for Stanford and Pullman; the triangles represent the corresponding absorption excursion ($\overline{\Delta A}$). It should be noted here that the latter two stations are located at a higher latitude (middle latitude), in the northern hemisphere, than ***São José dos Campos,*** in the southern hemisphere. In Figure 4, the time difference between the maximum in $\overline{\Delta A}$ and $\tilde{A}$ is larger and more pronounced at SJC than at the other two stations. Furthermore, the average absorption at the middle latitude stations maximize around local noon and therefore appears to be controlled by the solar zenith angle during the day. On the other hand, the average absorption for ***São José dos Campos*** maximizes in the afternoon hours (around 14.30 hr LT) suggesting thereby the presence of absorption from sources apparently not under direct solar control.

It is known that the total absorption measured by a riometer at a low latitude station consists of a significant contribution (20-50 percent) from the F-region of the ionosphere even during solar minimum conditions (see, for example, Abdu et *al.*[3], 1967). The diurnal maximum of this component occurs between 14-16 hr LT. It seems possible, therefore, that the occurrence of the maximum at **14.30** hr LT at SJC is due to the presence of a significant contribution from the F-region at this low latitude station. A possible illustration of the significance of the F-region component of absorption on the magnetic dip is presented in Figure 5, in which curve (a) represents a typical variation with magnetic dip of the noon f_0F_2 (taken from Ostrow and Stuart[10]). The proportional F-region absorption (taken as proportional to $f_0F_2^4$, Abdu et *al.*[3], 1967) is represented by curve (b). The approximate location of these stations are marked on this Figure from which it appears evident that the contribution from the F-region, namely, that which is not directly under solar control should be insignificant at Stanford and Pullman. The noon peak in $\tilde{A}$ observed at these stations is, therefore, almost entirely due to the lower ionospheric absorp-

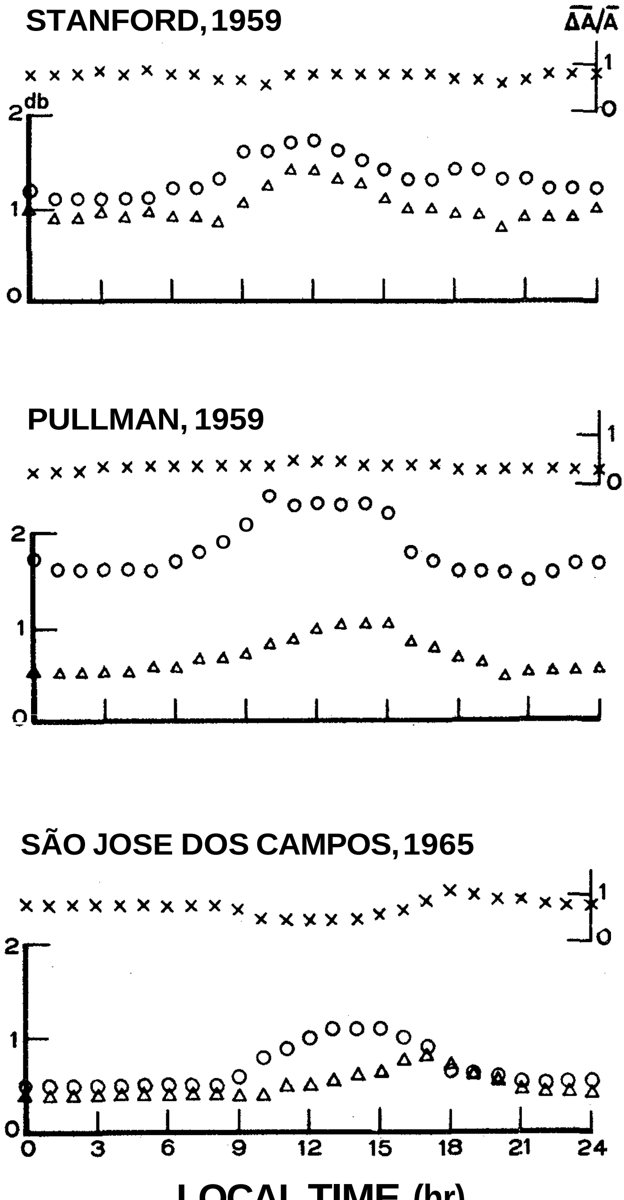

Figure 4. Median monthly absorption (houly aver. $\bar{A}$) : o. Mean yearly absorption excursion ($\overline{\Delta A}$) : Δ Ratio $\overline{\Delta A}/\bar{A}$: x.

tion. However, it may be noted in Fig. 4 that the actual values of *A* are larger at these stations than at SJC. This could be due to the fact that the middle latitude observations were made during the maximum of solar activity while the low latitude observations are relevant to solar minimum conditions. Furthermore, in the middle latitude records there is a tendency for a secondary maximum, though of small amplitude, to occur in the hours following sunset. The causes of this are not well understood. However, it may be noted that a certain amount of nocturnal attenuation of cosmic radio noise and some of its time varying features, which could not be explained by collisional losses alone, have been qualitatively interpreted by workers in the past (see, for example, Ramanathan and Bhonsle[11], Mitra and Shain[12], Abdu et *al.*[3]) as due to possible scattering by the irregularities present in the upper ionosphere. (It should also be pointed out that a possible uncertainty in the determination of the "quiet day curve" for cosmic noise could also cause some shift in the absorption values).

In light of the above discussion, we can now consider the aspects of the yearly average diurna1 features in the fractional absorption excursion which are plotted as crosses in Fig. 4. This shows a significant decrease at SJC in the afternoon hours approximately at the time of the maximum of the average absorption ($\bar{A}$). This is in contrast to the middle latitude stations where the fractional variation remains nearly constant throughout the day. Although there is some fluctuation in these values for the Stanford results, that does not appear to be significant nor systematic wmpared to the behavior observed for SJC.

This observation thus leads to the important wnclusion that the percentage yearly average-absorption fluctuation is less significant in the F-region of the ionosphere than in the lower part of the ionosphere which is known to be under direct solar control. The possible reason for this could be the fact that the sources of ionization such as those due to solar flares which could cause or enhance the average excursion in the yearly absorption values in the lower ionosphere are expected to be less significant in the F-region of the ionosphere. This does not explain, however, the behavior during the night. In view of the lack of agreement in the literature, on the possible sources of night time ionization, this aspect is not being considered here at present.

4. Conclusion

An absorption range parameter termed as "absorption excursion" has been used in this paper to infer a certain behavior of the lower and upper

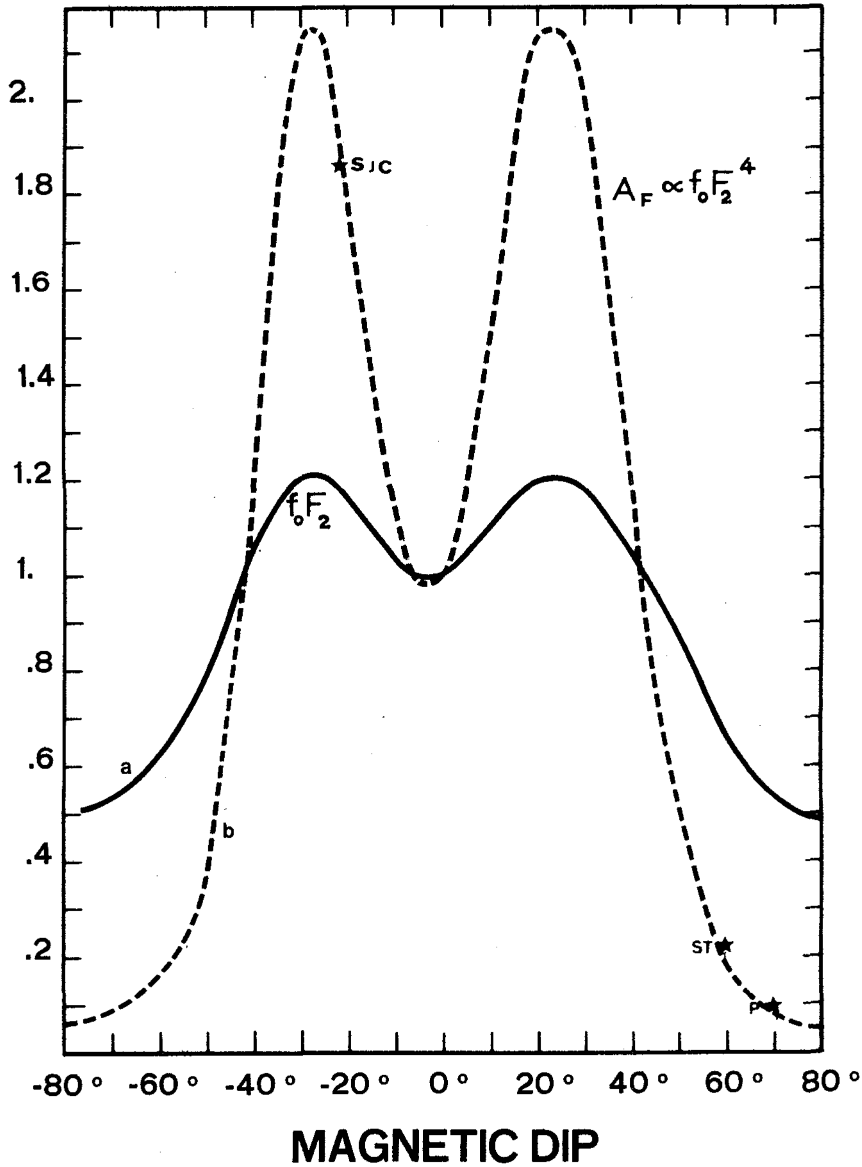

Figure 5. The vanation of the noon critical frequency of the F_2 – layer (f_0 F,) with magnetic dip, curve (a), and the corresponding expected' F^2 region absorption calculated as proportional to $f_0 F_2^4$, curve (b). These values are normalized with respect to the magnetic equator.

ionosphere. The magnitude of this parameter and its diurna1 variation are observed to vary with latitude. It is also shown that the contribution from the F-region to the total ionospheric absorption observed by a riometer is more significant at low latitudes while it is very small at middle latitudes even during sun spot maximum period.

The percentage fluctuation in the absorption excursion appears to be smaller in the F-region as compared to the lower ionosphere, which is directly under solar control.

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