1. Publication Nº	2. Version	3. Date	5. Distribution
INPE-2310-PRE/075		*January, 1982*	☐ Internal ☒ External ☐ Restricted
4. Origin *DGA*	Program *Ionosfera*		

6. Key words - selected by the author(s)

SPREAD F; RAYLEIGH-TAYLOR INSTABILITY; IONOGRAMS.

7. U.D.C.: *523.4-853*

8. Title *INPE-2310-PRE/075*

EQUATORIAL SPREAD F INSTABILITY CONDITIONS AS DETERMINED FROM IONOGRAMS

10. Nº of pages: *10*

11. Last page: *08*

12. Revised by

Yukitaka Nakamura

9. Authorship

M.A. Abdu,
R.T. de Medeiros,
J.H.A. Sobral.

Responsible author

13. Authorized by

Nelson de Jesus Parada
Director

14. Abstract/Notes

Conditions of plasma irregularity (or Spread F) generation under the Rayleigh-Taylor instability mechanism in the nighttime equatorial ionosphere are examined from ionogram data registered over Fortaleza (4°S, 38°W, mag. dip lat. - 1.7°) Brasil for a one year period. The results show that local ionospheric conditions such as the bottomside F-region electron density scale length and the ion-neutral collision frequency at the base of the layer, at sunset hours, determine the generation of the spread F irregularities over the equator in the post sunset hours.

15. Remarks *This work was partially supported by the "Fundo Nancional de Desenvolvimento Científico e Tecnológico (FNDCT)", Brasil, under contract FINEP-537/CT.*

EQUATORIAL SPREAD F INSTABILITY CONDITIONS AS DETERMINED FROM IONOGRAMS

M.A. Abdu, R.T. de Medeiros, J.H.A. Sobral

Instituto de Pesquisas Espaciais - INPE
Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq
12200 São José dos Campos, S.P., Brasil

ABSTRACT

Conditions of plasma irregularity (or Spread F) generation under the Rayleigh-Taylor instability mechanism in the nighttime equatorial ionosphere are examined from ionogram data registered over Fortaleza (4^{o}S, 38^{o}W, mag. dip lat. - 1.7^{o}) Brasil for a one year period. The results show that local ionospheric conditions such as the bottomside F-region electron density scale length and the ion-neutral collision frequency at the base of the layer, at sunset hours, determine the generation of the spread F irregularities over the equator in the post sunset hours.

INTRODUCTION

One of the leading problems in the area of equatorial ionospheric irregularities concerns that of the ambient ionospheric conditions and the instability mechanisms that operate under these conditions, leading to the generation of the irregularities. In recent years, experimental results from VHF radars and from satellite and rocket instrumentations (Woodman and La Hoz, 1976; McClure et al., 1977; Kelley et al., 1976) have provided evidence that these irregularities are actually associated with rising plasma depleted regions, or "bubbles", in the equatorial ionosphere. The irregularities giving rise to Spread F echoes in ionograms and "plumes" in the backscatter echoes are known to occur within and at the steep edges,or the "walls",of the bubbles. (Tsunoda et al., 1979; Morse et al., 1977; McClure et al., 1977), having been produced there by secondary plasma instability processes. The primary process that is responsible for the generation of the plasma bubble, in the first place, is generally believed to be the well known Rayleigh-Taylor (R-T) fluid instability mechanism whose applicability to the case of equatorial ionosphere was first suggested by Dungey (1956). Theoretical investigations on the generation of the plasma bubble by the Rayleigh-Taylor mechanism have been carried out by several authors (Haerendel, 1973; Chaturvedi and Kaw, 1975; Hudson and Kennel, 1975; Ott, 1978) and experimental evidence to this effect has been suggested from rocket and radar observations campaign carried out over Natal, Brasil (Kelley et al., 1976; see also Woodman and La Hoz, 1976). Numerical simulation of the bubble dynamics under the condition of collisional Rayleigh-Taylor regime has been carried out by Scannapieco and Ossakow (1976) and Ossakow et al. (1979), using local ionospheric models. Recently Anderson and Haerendel (1979) have investigated the plasma bubble vertical motions using field line integrated ionospheric properties, such as electron densities and Pedersen conductivity, and have presented results that show that ambient ionospheric electric field could be significant, compared to the gravity driven electric field in determining the vertical velocity of the plasma bubble in the earlier phase of its development.

Thus, experimental results having implications on the generation mechanism of spread F irregularities should be helpful at the present stage of our investigation into this area. In the present note we have carried out a statistical study on the spread F irregularity developments at sunset hours over Fortaleza to examine whether the occurrence (or otherwise) of these irregularities are dependent on the presence (or absense) of the instability condition according to the theory of R-T instability mechanism, as determined from the local ionograms.

DETERMINATION OF THE R-T INSTABILITY CONDITIONS FROM IONOGRAMS

According to the linear theory, under collisional regime, of the R-T mechanism, an initial perturbation in the ionization will grow (or not) in amplitude to become unstable, depending upon whether the factor γ is positive (or negative), where

$$\gamma = (1/n_0)(dn_0/dh)(g/\nu_{in}) - \nu_R,$$ (Ossakow et al., 1979).

Here, ν_{in} is the ion neutral collision frequency, $\nu_R = K_1[O_2] + K_2[N_2]$ is the recombination rate and $n_0/(dn_0/dh)$ is the scale lenth (L) of the ambient local electron density distribution. According to this expression, the instability growth rate gets positive only at the bottom side of the F-layer. In order to determine the scale length of the bottom side electron density distribution from the ionograms, we used the expression:

$$L = (f_0/2)/(\Delta f_0/\Delta h'),$$

since n_0 is proportional to the square of the plasma frequency (f_0). The use of the virtual height h' instead of the real height h in this expression will introduce only negligible effect in the final result, since the low-lying ionization at hours following the F-region sunset is negligibly small and, further, the difference between h and h' will remain nearly the same for small changes in f_0 so that $\Delta h' \simeq \Delta h$. The Δf_0 was taken as 1 MHz centered around 2.5 MHz and $\Delta h'$ was determined for the corresponding frequencies. In many cases, the results obtained in this frequency range was compared with that obtained with an adjascent frequency interval of 1 MHz for verifying consistency of the results. The ionograms used were mostly between 1800 and 1830 LT, since the spread F onset over Fortaleza occurs in this local time interval (Abdu et al., 1981). A total number of 119 events (or ionograms) were analysed, taken arbitrarily at a rate of approximately 10 ionograms in each month of the year 1978. The temperature dependent quantities K_1, K_2, ν_R and ν_{in} were calculated with the help of the US Standard Atmosphere Model (1976) for exospheric temperatures representative for each of the ionograms.

RESULTS AND DISCUSSION

The four possibilities of the γ and Range type spread F (RSF) occurrence statistics considered are as follows:

(a) $\gamma > 0$, with RSF occurrence;
(b) $\gamma > 0$, without RSF occurrence;
(c) $\gamma < 0$, without RSF occurrence;
(d) $\gamma < 0$, with RSF occurrence.

The percentage occurrences of each of these possibilities are presented as a histogram in Figure (1). The dashed lines on the histogram represent the results corresponding to a possible error in the values of the γ's that could be introduced by an uncertainty of 5 km in reading the virtual heights from the ionograms. The figure shows that the range type spread F occurred in about 95 percent of all the cases of positive instability growth rate, and only 5 percent of these cases occurred without spread F. Further, spread F was completely absent for all cases of the negative values of γ. It seems clear from the figure that the spread F irregularities occur only when γ is positive. This result seems to be very interesting, since they show that the conditions for the occurrence of the spread F irregularities over a station depends upon the existence of R-T instability condition as per local ionospheric parameters. In other works, the generation of plasma bubble seems to be possible under local ionospheric conditions. Whether the instability conditions as determined from the local ionospheric parameters would be modified if field line integrated quantities are considered is difficult to verify experimentally (at least from the existing experimental results available). It may be that once the development of the plasma bubble (or the growth of an initial perturbation amplitude into instability) is initiated under local ionospheric conditions, the subsequent growth and vertical ascension of the field aligned plasma bubble could be determined by the field line integrated electron densities and Pederson conductivities, and by the ambient ionospheric east-west electric field, in the way discussed by Anderson and Haerendel, 1979 (see also Balsley et al., 1972).

CONCLUSIONS

In summary, the results of analysis of spread F data during one year over Fortaleza show clearly that the spread F irregularities in the evening ionosphere occur only when local conditions of R-T instability mechanism is present. Whether the presence of such local instability conditions does necessarily imply simultaneous occurrence of the necessary conditions in the field line integrated properties remains to be verified. Such a verifications, however, is not simple and would involve coordinated measurements of plasma bubble and ambient ionosphere properties by means of backscatter radar measurement over the equator and satellite and ionosonde measurements over equatorial and low latitude stations, simultaneously.

FIGURE CAPTIONS

Figure 1 - Histogram showing the percentages of range type spread F (RSF) occurrences and non occurrences, for two cases of the R-T instability growth rate γ, namely $\gamma > 0$ and $\gamma < 0$.

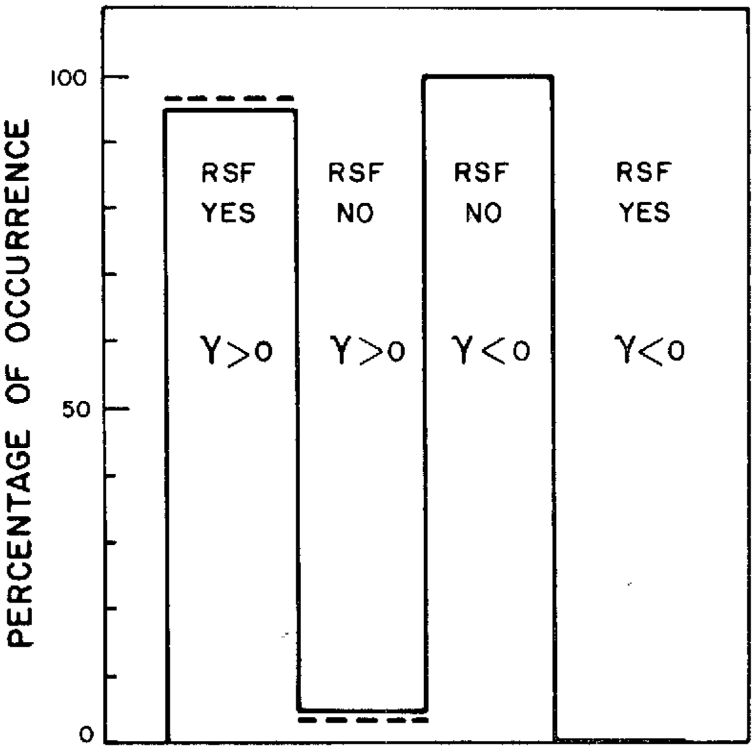
100
50
0
PERCENTAGE OF OCCURRENCE
RSF
YES
RSF
NO
RSF
NO
RSF
YES
γ>o
γ>o
γ<o
γ<o

Fig. 1

REFERENCES

Abdu, M.A., I.S. Batista, and J.A. Bittencourt.Some characteristics of spread F at the magnetic equatorial station Fortaleza, J. Geophys. Res., 86, 6836-6842, 1981.

Anderson, D.N., and G. Haerendel, The motion of depleted plasma regions in the equatorial ionosphere, J. Geophys. Res., 84, 4251-4256, 1979.

Balsley, B.B., G. Haerendel, and R.A. Greenwald, Equatorial spread F: Recent observations and a new interpretation, J. Geophys. Res., 77, 5625-5628, 1972.

Chaturvedi, P.K., and P. Kaw, Steady-state finite amplitude Rayleigh-Taylor modes in spread F, Geophys. Res. Lett., 2, 381-383, 1975.

Dungey, J.W., Convective diffusion in the equatorial F-region, J. Atmos. Terr. Phys., 9, 304-310, 1956.

Haerendel, G., Theory of equatorial spread F, preprint, Max-Planck Institut, Garching, West Germany, 1973.

Hudson, M.K., and C.F. Kennel, Linear theory of equatorial spread F, J. Geophys. Res., 80, 4581-4590, 1975.

Kelley, M.C., G. Haerendel, H. Kappler, A. Valenzuela, B.B. Balsley, D.A. Carter, W.L. Ecklund, C.W. Carlson, B. Hausler, and R. Torbert, Evidence for a Rayleigh-Taylor instability and upwelling of depleted density regions during equatorial spread-F, Geophys.Res. Lett, 3, 448-450, 1976.

McClure, J.P., W.B. Hanson, and J.H. Hoffman, Plasma bubbles and irregularities in the equatorial ionosphere, J. Geophys. Res., 82, 2650-2656, 1977.

Morse, F.A., B.C. Edgar, H.C. Koons, C.J. Pice, W.J. Heikkila, J.H. Hoffman, B.A. Tinsley, J.D. Winningham, A.B. Christensen, R.F. Woodman, J. Pomalaza, and N.R. Teixeira, Equion, an equatorial ionospheric irregularity experiment, J. Geophys. Res., 82, 578-592, 1977.

Ossakow, S.L., S.T. Zalesak, B.E. McDonald, and P.K. Chatuverdi, Nonlinear equatorial spread F: Dependence on altitude at the F peak and bottomside background electron density gradient scale length, J. Geophys. Res. 84, 17-29, 1979.

Ott, E., Theory of Rayleigh-Taylor bubbles in the equatorial ionosphere, J. Geophys. Res., 83, 2066-2070, 1978.

Scannapieco, A.J., and S.L. Ossakow, Nonlinear equatorial spread F, Geophys. Res. Lett., 3, 451-454, 1976.

Tsunoda, R.T., M.J. Barons, J. Owen, and D.M. Torole, Altair: An incoherent scatter radar for equatorial spread F studies, Radio Sci., 14, 1111-1119, 1979.

US Standard Atmosphere, National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, United States Air Force, Washington, D.C. 1976.

Woodman, R.F., and C. La Hoz, Radar observations of F region equatorial irregularities, J. Geophys. Res., 81, 5447-5466, 1976.