Linear Rayleigh-Taylor instability and Spread-F time behaviour in Tucumán, Argentina

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RESUMEN

Se estudia el rol del viento neutro zonal (U) y de la longitud de escala de gradiente (L) como contribuciones a la tasa de crecimiento de la inestabilidad lineal de Rayleigh-Taylor, a los fines de dar cuenta del comportamiento temporal de las irregularidades de la capa F, tal como fueron detectadas en Tucumán (26° 49'S, 65° 13'0), desde enero de 1978 hasta diciembre de 1988.

Palabras clave: Irregularidades, inestabilidad, tasa de crecimiento, viento neutro, longitud de escala de gradiente, actividad solar.

ABSTRACT

The role of the zonal neutral wind (U) and the gradient scale length (L) is studied as contributions to the linear Rayleigh-Taylor instability growth rate, in order to account for the temporal behaviour of F layer irregularities as detected in Tucumán (26°49'S, 65°13'W) from January 1978 to December 1988.

Key words: Irregularities, instability, growth rate, neutral wind, gradient scale length, solar activity.

OBSERVATIONS

Several instabilities and mechanisms have been invoked to explain the conditions for the onset, development and time-dependent evolution of electron density irregularities in the F layer (Abdu et al., 1981; Chaturvedi and Ossakow, 1977; Fejer et al., 1979; Kelley, 1989; Kloster-meyer, 1978; Sudan, 1977; Zalesak et al., 1982)

These irregularities can be detected on ionograms as range Spread-F (Kelley, 1989). Statistical analysis of ionograms recorded at Tucum‡n (26°49'S, 65°13'W) from January 1978 to December 1988 (solar cycles 21 and 22) show an usual range Spread-F time behaviour in mid-latitudes. It is a nighttime phenomenon with a marked seasonal periodicity modulated by the solar cycle, although this modulation is not so sharp. Seasonal maxima occur in local summer (December-January) and the peak is centered about midnight (Figure 1a and 1b). The zonal neutral wind velocity (U) and the gradient scale length (L) can account for the main features of this temporal behaviour considering their contributions to the Rayleigh-Taylor instability in its linear form, and disregarding triggering and enhancing processes.

DISCUSSION AND CONCLUSIONS

According to Kelley (1989), R-T instability growth rate, gRT, is given by eq (1)

$$\gamma_{RT} = \frac{E_{oz}'}{LB}\cos\alpha + \frac{g}{\nu_{in} L}\cos\alpha + \frac{E_{ox}' + UB}{LB}\sin\alpha \qquad (1)$$

where x is directed eastward and z upward, a is the layer tilt angle measured from the east through zenith, and the dip angle is neglected. The electric field contribution, given by the polarization electric field (Eo) and the wind dependent term (UB), is assumed to exceed the gravitational contribution. We center our discussion on the wind-dependent term because the E x B drift is important primarily during the postsunset hours, when our data do not show any exceptional occurrence. There is no difference between seasons concerning the onset times for the phenomenon, as there should be if the polarization field played at decisive role.

Figure 2 (Louro and Duhau, 1988) represents the zonal wind velocity U vs. local time at two heights: 250 and 450 km. From the sign of U in eq. (1), the effect will be destabilizing during nighttime as observed. Figure 3 depicts Up and Ud, the pressure and ion drag components of zonal wind, vs local time at 250 km high. It is apparent that the Up component, which depends strongly on neutral temperature, is the main contributor to the sign of U. In summer, when radiation flux and temperature are high, Spread-F development is favoured by a rising Up and a dropping electron concentration (Nmax a T-1/2), which means lower values for L and ν_{in}.

Figures 4, 5 and 6 show the mean values of L in May, September and December respectively. Three years with different sunspot numbers have been considered: 1980 -198.5 average sunspot number, 1983 - 119.6 a.s.n., 1986 - 74.1 a.s.n.; and four hours: 12:30 h local time, at which Spread-F has never been observed at this latitude, 19:39 h in the evening, at which generation conditions are set;

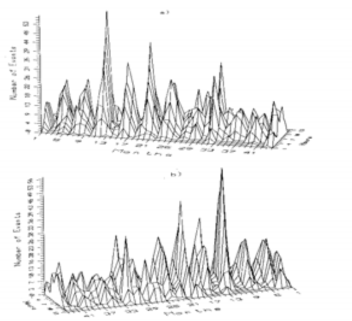

Fig. 1. Occurrence rate of range Spread-F vs time and months. (Y axis: figures represent hours from 07:00 pm. X axis: figures are counted once every three months).

23:39 h at night, when Spread-F usually presents a high occurrence, and 5:39 h close to dawn and related with secondary processes. In the same figures we note the height at which L has been measured (never further than 40 km from the height of maximum electron concentration (km), as well as the corresponding electron concentration cm-3á10-3. Except for September 1980, which presents a slightly higher value of L at 23:39 h than that corresponding to 12:39 h, the L maximum values are reached at the latter time, whatever the season and the sunspot number. On the other hand, electron concentration peaks at noon, and in most cases, it rises strongly with sunspot number. The exception is in September, in the evening.

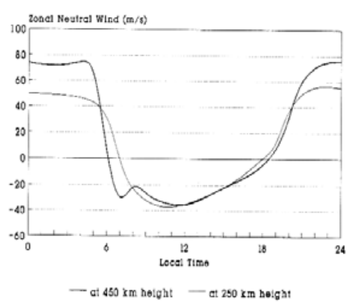

Fig. 2. Zonal wind velocity vs local time at 250 and 450 km altitude.

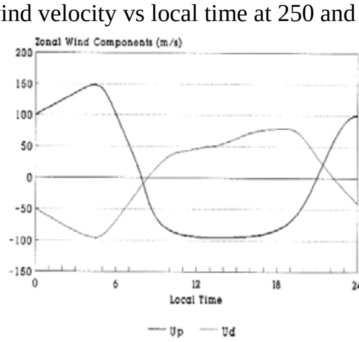

Fig. 3. Up and Ud (pressure and ion drag components of zonal wind, respectively) vs local time at 250 km altitude.

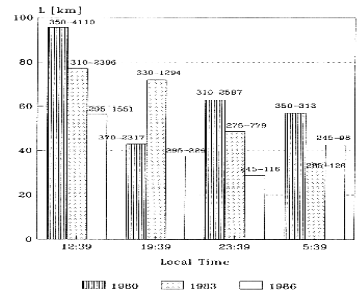

Fig. 4. Average May values of the gradient scale length (L) for different solar activity years and local times. (Height of maximum electron concentration is noted in km, and electron concentration, in cm-3 10-3).

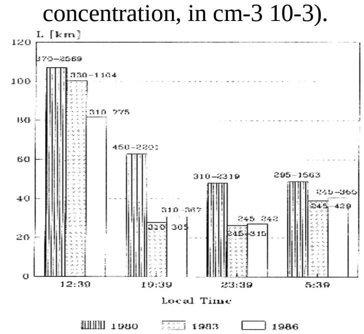

Fig. 5. Same as Fig. 4, except for September.

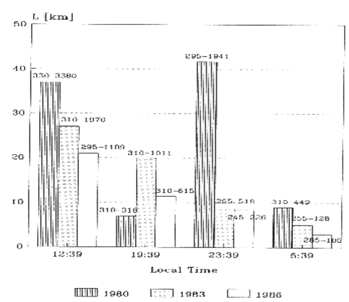

Fig. 6. Same as Fig. 4, except for December.

Since the high value of L lowers the growth rate of the instability, and so does the high electron concentration through uin in the gravitational term, both effects could explain the Spread-F diurnal behaviour even when polarization fields existed. The values of L also depend on time, season and sunspot number. Roughly, they are maximum in December, average in May and minimum in September. Minimum time also changes with season and sunspot number except for December, when the minimum occurs at 23:39 h in the three different sunspot numbers years. We conclude that L affects the growth rate by different amounts depending on the season. Summer maxima should be associated with other variables, mainly with the wind velocity. It should be borne in mind that the L contribution is regular in December, concerning the time, and its dependence on season in stronger than its dependence on sunspot numbers.

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