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Day-to-day variability of ionospheric characteristics in the American sector

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Abstract

This paper presents an analysis of the variability of ionospheric characteristics (f_oF2, M(3000)F2) measured at American latitudes (latitudinal range: −65.2, 18.5). The database includes ionograms recorded during different seasonal and solar activity conditions. The parameters used are: median, lower and upper quartiles. Two parameters are considered: **Cup** = upper quartile/median, and **Clo** = lower quartile/median. The diurnal, seasonal and latitudinal behaviour of the variability is analysed for low and high solar activity. The variability parameters for four typical time periods of the day (22-02LT; 05-07LT; 10-14LT; 18-20LT) are presented for different seasons and the two levels of solar activity. The results indicate that the variability of f_oF2 is high in low solar activity and larger at night than during the day. Most of the considered cases have shown that the variability of f_oF2 has a latitudinal dependence. For some cases the variability was maximum at modip ≅ ±30. The fact that the quartiles are not equidistant from the median value suggests that it would be convenient to develop a model on **Cup** and **Clo** in order to predict the variability range of f_oF2. Moreover, low variability was observed for M(3000)F2 and it does not vary with modip.

Keywords: Ionosphere; Critical frequency; Variability

1. Introduction

In the framework of the IRI Task Force Activities and IRI Workshops the need for a good description of the variability of ionospheric magnitudes has been pointed out (Bilitza, 2000). A model of ionospheric variability would be useful for the user of the ionospheric model. An operator or satellite designer needs to know the monthly median value of the magnitude and the expected deviations from it. Many efforts have been devoted to obtaining knowledge on the variability of different ionospheric characteristics (Mosert and Radicella, 1995; Bradley, 2000; Kouris and Fotiadis, 2002; Mosert et al., 2002; Ezquer et al., 2002a,b; among others).

Some characteristics of F2 peak variability reported in the literature (Aravindan and Iyer, 1990; Jayachandran et al., 1995; Rishbeth and Mendillo, 2001; Kouris and Fotiadis, 2002; Mosert et al., 2003, among others), are: (a) the variability is greater at night than during the day; (b) the variability is higher in winter than in summer; (c) the variability is higher at periods of low solar activity; (d) the variability is somewhat greater at

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subauroral and equatorial latitudes than at midlatitudes; (e) the variability of the propagation parameter M3000F2 is lower than that observed for the critical frequency of F2 region (f_oF2). Rawer et al. (2003) found a maximum of variability at modip 30. Most of the mentioned authors used standard deviation and mean to study variability. In this paper we study the variability of f_oF2 and M3000F2 over the American sector.

Median, lower and upper quartiles are used to specify variability, because they have the advantage of being less affected by large deviations in the value of the ionospheric characteristic that can occur during magnetic storms.

2. Data and results

The data used for this study were obtained at 14 American stations, which are shown in Table 1. These data correspond to three years of high solar activity (1957, 1958 and 1959) and three years of low solar activity (1964, 1965 and 1966).

Following the recommendation given in the IRI Task Force Activity (Bilitza, 2001) the data from each station were grouped according to:

Seasons: equinox, summer and winter; Solar activity: Low solar activity (LSA), High solar activity (HSA) and LT period: (22–2), (5–7), (10–14) and (18–20).

Median, upper quartile (Qup) and lower quartile (Qlo) were obtained for each group. The following parameters were calculated:

$$\mathbf{Cup} = \mathrm{Qup/median},$$

$$\mathbf{Clo} = \mathrm{Qlo/median}.$$

The following parameter is used to study the variability:

$$\mathbf{Cup} - \mathbf{Clo} = (\mathrm{Qup} - \mathrm{Qlo})/\mathrm{median} = (\mathrm{Inter\ quartiles\ range})/\mathrm{median}.$$

For example, **Cup** = 1.20 means that Qup is 20% greater than median and, **Clo** = 0.80 means that Qlo is 20% lower than median.

Fig. 1 shows the results for f_oF2, equinox, LSA. For 22–2 LT, all the curves vary with modip. It can be seen that in general **Cup** and **Clo** are not equidistant from the value 1, which means that the quartiles are not equidistant from the median value. The parameter **(Cup−Clo)** reaches a minimum near modip = 0. For (5–7) LT the parameter **(Cup−Clo)** shows a maximum around modip = 0. For (10–14) LT, **Clo** is almost constant, low variation with modip is observed, **(Cup−Clo)** shows a maximum at modip = −30. Similar behaviour of **(Cup−Clo)** is observed for (18–20) LT. This figure shows that, in general, the lowest variability (lowest **(Cup−Clo)** values) are observed around modip = 0. Moreover, the variability is greater by night (22–2 LT) than by day (10–14 LT).

The results for f_oF2, equinox HSA are shown in Fig. 2. In general, the parameter **(Cup−Clo)** shows a low variation with modip. The lowest variability is observed for the period (10–14) LT. A comparison with Fig. 1 shows that the variability is higher in LSA than in HSA. In some cases a maximum of variability is observed near modip 30.

Fig. 3 shows the results for summer LSA. In general, the variability at night is greater than during the day. For (18–20 LT) an almost constant value of **(Cup−Clo)** is observed. In some cases a maximum of variability is observed near modip = 30.

The results for f_oF2, summer, HSA are shown in Fig. 4. A low variability and almost a constant value of the **(Cup−Clo)** parameter can be seen during the daylight hours. The comparison with Fig. 3 shows that the variability in HSA is lower than in LSA. The maximum at modip = 30 is not observed.

Figs. 5 and 6 shows the results for winter LSA and HSA, respectively. The results are similar to that mentioned previously.

Table 1
List of stations used in this study

Station	Modip	Dip	La. Geog.	Lo. Geog.	La. Geom.	Lo. Geom.
Puerto rico	41.81	49.90	18.50	292.90	29.20	3.00
Panama	33.81	38.11	9.40	280.10	20.60	349.30
Bogota	29.20	31.97	4.50	285.80	15.90	355.40
Talara	14.53	14.82	−4.60	278.70	6.60	348.50
Chiclayo	11.27	11.38	−6.80	280.20	4.40	350.00
Huancayo	3.27	3.24	−12.00	284.70	−0.70	354.60
Lapaz	−3.77	−3.70	−16.50	291.90	−5.10	1.60
Natal	−7.42	−7.44	−5.70	324.80	3.70	34.50
Tucuman	−21.30	−21.10	−26.90	294.60	−15.50	4.10
San pablo	−23.15	−23.47	−23.50	313.50	−13.00	21.90
Buenos aires	−31.57	−31.96	−34.50	301.50	−23.30	10.10
Concepcion	−34.28	−35.00	−36.60	287.00	−25.20	357.20
Pt. stanley	−46.81	−48.04	−51.70	302.20	−40.50	9.80
Argentine is.	−57.73	−58.71	−65.25	295.73	−53.90	3.90

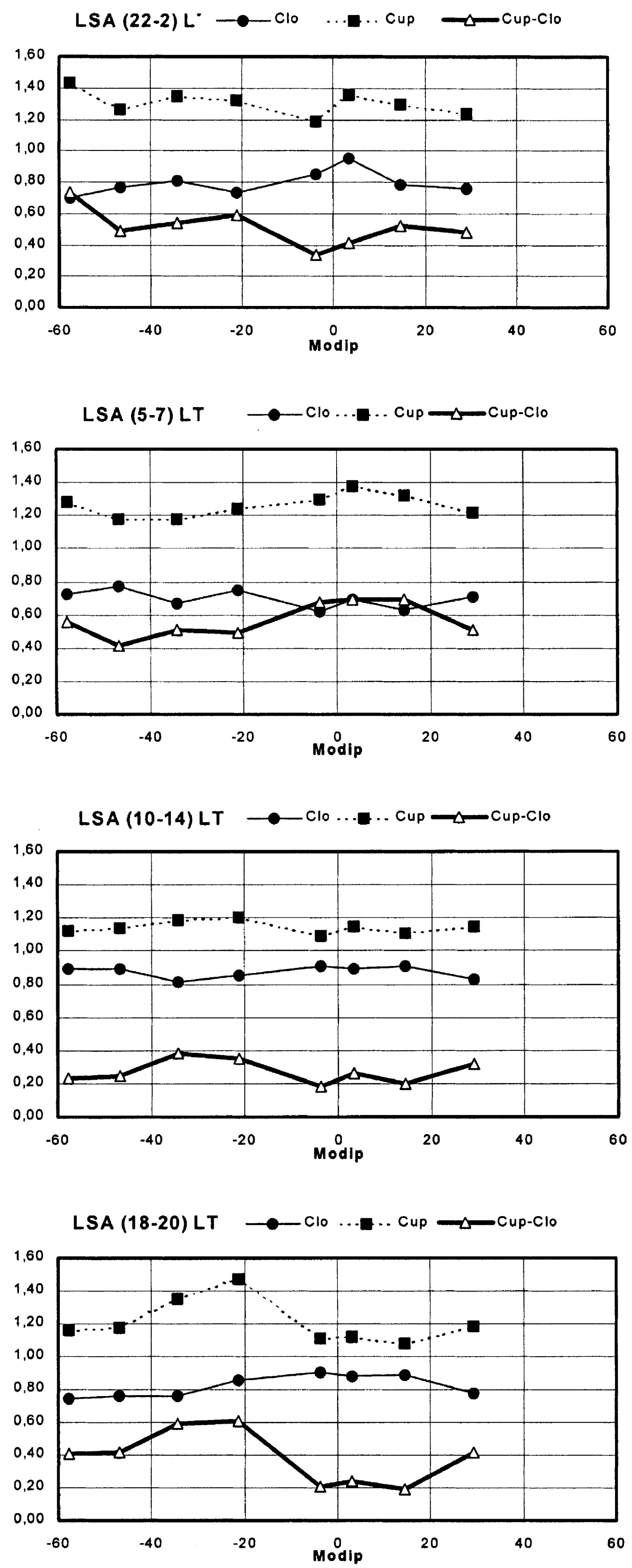

Fig. 1. Latitude dependence of variability parameters Cup, Clo and Cup−Clo for f_oF2 at low solar activity at the equinoxes for the different LT hour blocks as indicated.

In general, **Cup** and **Clo** shows an opposite behaviour. When **Cup** increases **Clo** decreases and vice versa. But they are not symmetric with respect to the value 1.

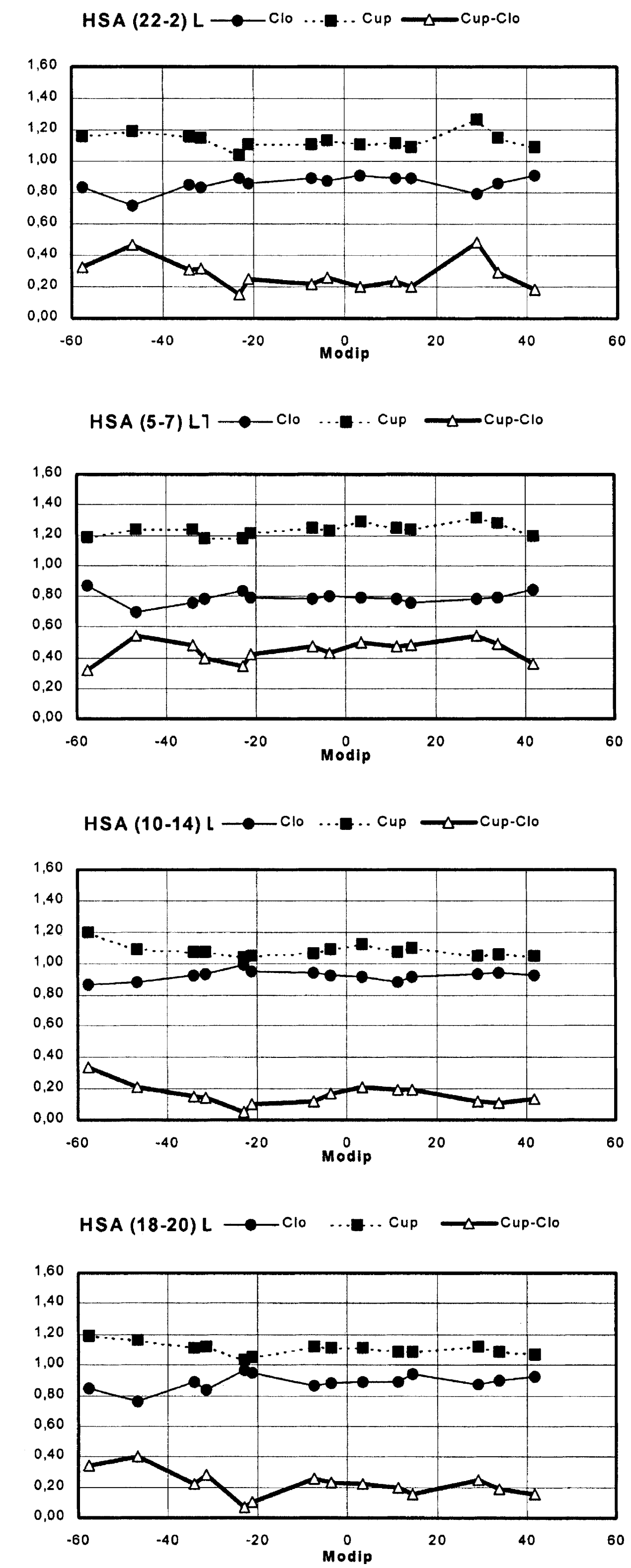

Fig. 2. Latitude dependence of variability parameters Cup, Clo and Cup−Clo for f_oF2 at high solar activity at the equinoxes for the different LT hour blocks as indicated.

This means that the quartiles are not equidistant from the median value, which suggests that it is not convenient to give the variability range of f_oF2 as:

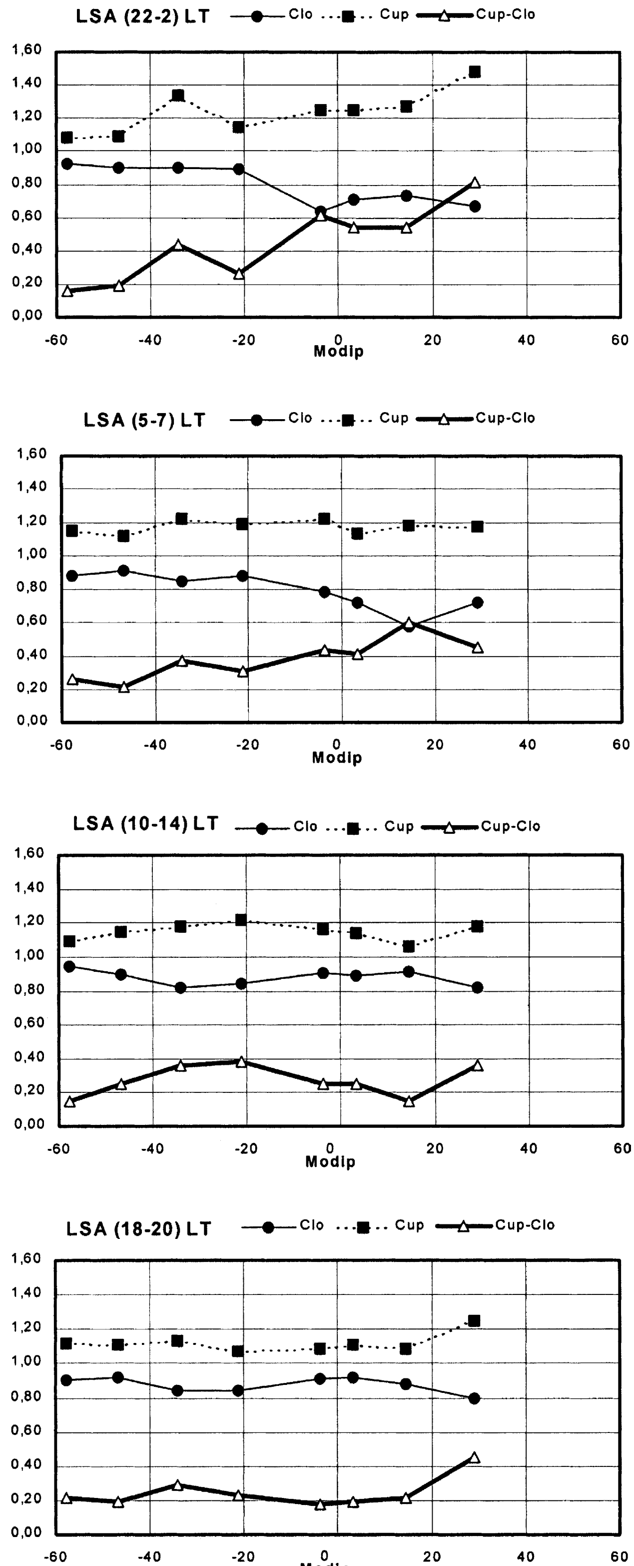

Fig. 3. Latitude dependence of variability parameters Cup, Clo and Cup−Clo for f_oF2 at low solar activity in the summer for the different LT hour blocks as indicated.

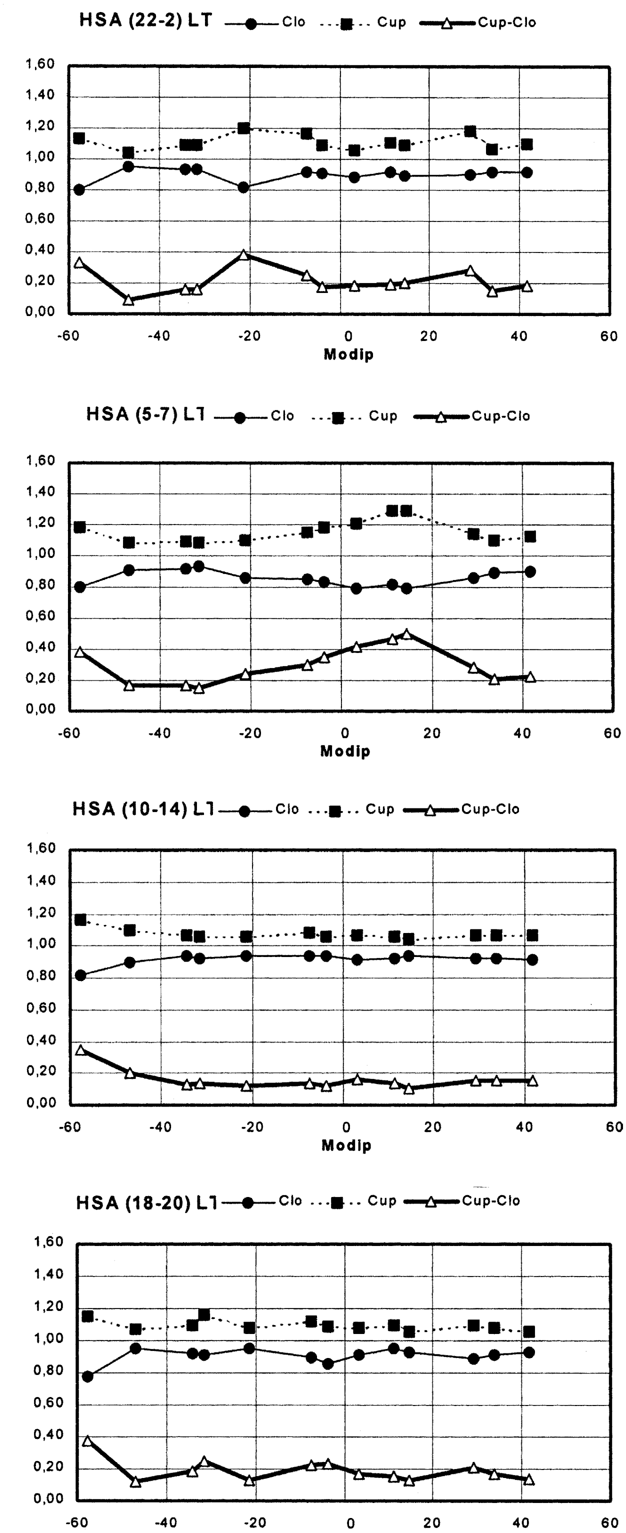

Fig. 4. Latitude dependence of variability parameters Cup, Clo and Cup−Clo for f_oF2 at high solar activity in the summer for the different LT hour blocks as indicated.

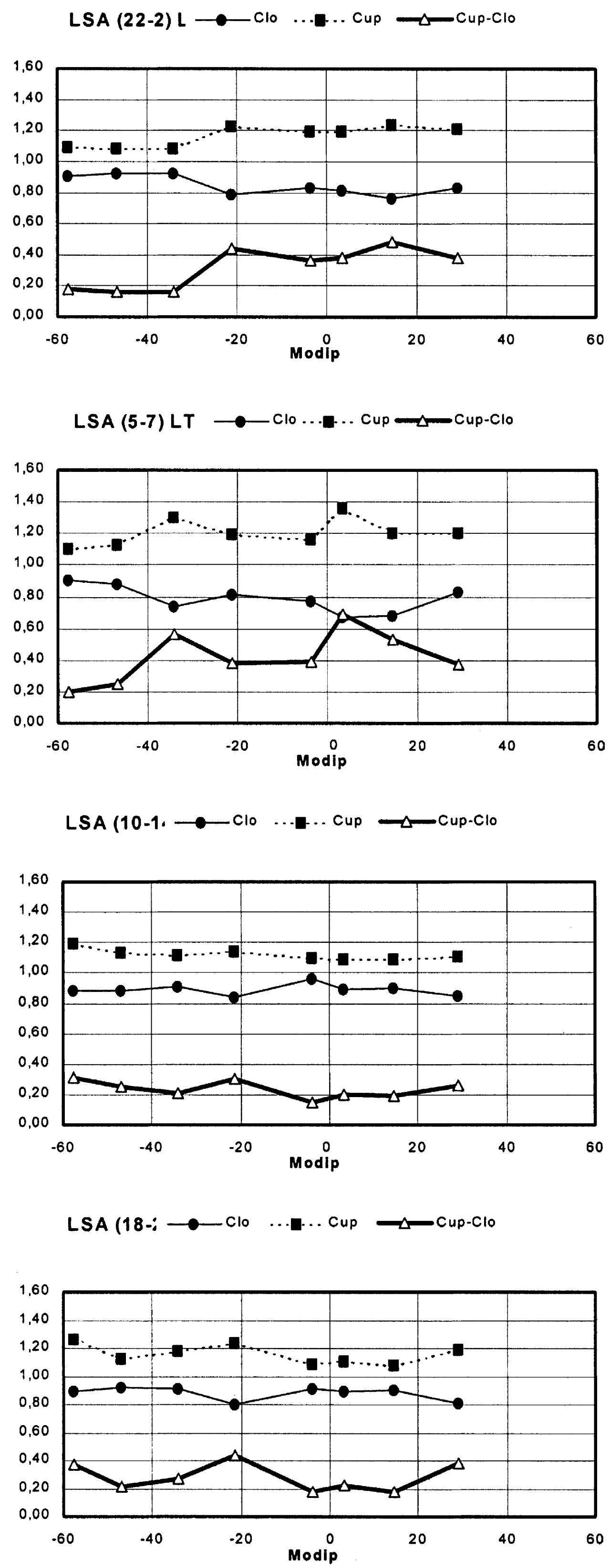

Fig. 5. Latitude dependence of variability parameters Cup, Clo and Cup−Clo for f_oF2 at low solar activity in the winter for the different LT hour blocks as indicated.

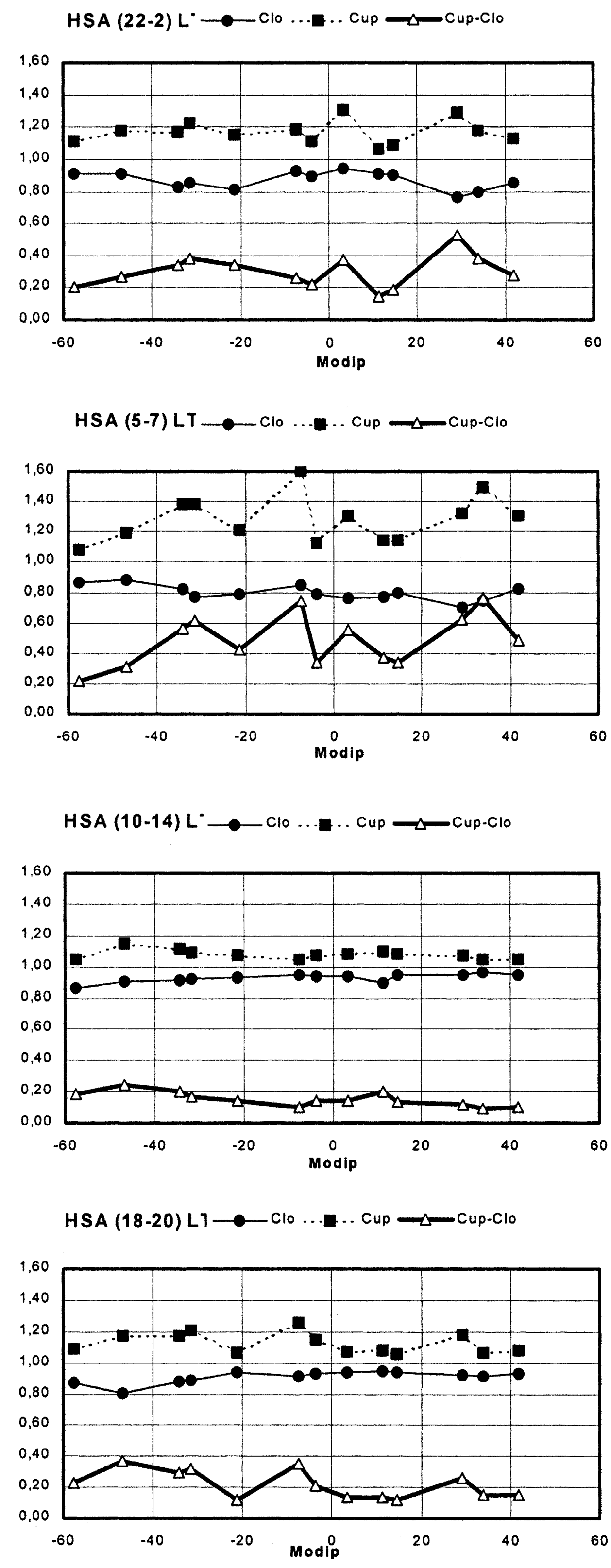

Fig. 6. Latitude dependence of variability parameters Cup, Clo and Cup−Clo for f_oF2 at high solar activity in the winter for the different LT hour blocks as indicated.

$$\text{median} \pm (\text{Qup} - \text{Qlo})/2$$

and that it seems more convenient to express that range as:

$$[\text{median} \times \mathbf{Clo}, \text{median} \times \mathbf{Cup}].$$

Fig. 7 shows the results obtained for M3000 F2, equinox, LSA. It can be seen that the **(Cup−Clo)** values do not vary with modip and that the variability is low. Similar results were obtained for all considered cases.

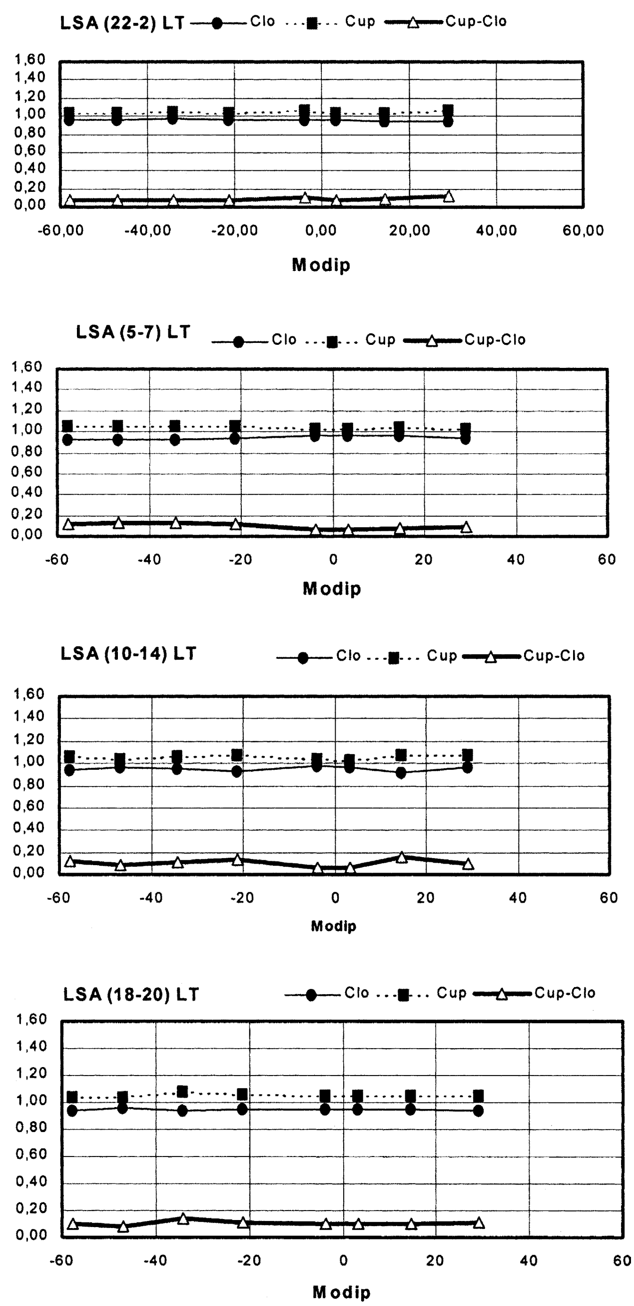

Fig. 7. Latitude dependence of variability parameters Cup, Clo and Cup−Clo for M3000F2 at low solar activity at the equinoxes for the different LT hour blocks as indicated.

3. Conclusions

A study of f_oF2 and M3000F2 variability in the American sector has been done. Data from 14 stations corresponding to six years have been used.

With reference to the variability of f_oF2 the results show that:

- The variability is higher at LSA.
- The variability is larger at night than during the day.
- For some cases the variability was maximum at modip ≅±30.
- There is no clear seasonal dependence. However, for high latitude stations the variability is larger at times of equinox than at times of solstice.
- Most of the considered cases have shown that **(Cup−-Clo)** values vary with modip (Latitudinal variation of **(Cup−Clo)** values). But it is not the same for all cases. For Summer-LSA- (22–2) LT the **(Cup−Clo) latitudinal** behaviour is opposite to that observed for Equinox-LSA- (22–2) LT.
- High values of bf (Cup−Clo) near the magnetic equator and low **(Cup−Clo)** values at high latitudes have been observed for the first case, and vice versa for the second one.
- For some cases corresponding to daylight hours, the above-mentioned latitudinal variation is not observed.
- The highest **(Cup−Clo)** value (≅0.80) was observed at high latitude, summer, LSA, (22–2) LT, among other cases. The lowest **(Cup−Clo)** value (≅0.05) was observed at low latitude, Equinox, HSA, (10–14) LT, among other cases.
- The fact that the quartiles are not equidistant from the median value suggests that is not convenient to give the variability range as:

  $$\text{median} + (\text{Qup} - \text{Qlo})/2.)$$

- It seems convenient to develop a model for **Cup** and **Clo** in order to predict the variability range of f_oF2.
- With reference to the variability of M3000F2: Low variability was observed for the M3000F2 parameter. The results show that the variability parameter does not vary with modip, almost the same value was obtained for all stations.
- Additional studies considering other solar activities and ionospheric variables will be done in order to contribute to the development of a variability model.

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