Geofísica Internacional (2004), Vol. 43, Num. 2, pp. 143-151

Time variation of total electron content over Tucumán, Argentina

M.Mosert[1], R.Ezquer[2,3], C. Jadur[4] and R. del V. Oviedo[2]

[1] *Complejo Astronómico El Leoncito, CONICET, San Juan, Argentina*

[2] *Laboratorio de Ionosfera, Depto. de Física, CONICET, San Miguel de Tucumán, Argentina*

[3] *Fac. Regional Tucuman, Universidad Tecnológica Nacional, San Miguel de Tucumán, Argentina*

[4] *Departamento Matemáticas, Fac. de C. Exactas UNSa, Salta, Argentina*

Received: March 31, 2002; accepted: June 4, 2002

RESUMEN

Este trabajo presenta un análisis de la variabilidad del contenido electrónico total, TEC, sobre Tucumán (26.9S; 294.6E; Dip: -21.1) usando mediciones obtenidas por medio de la técnica Faraday durante el período de alta actividad solar comprendido entre abril de 1982 (R_{12}=114) y marzo de 1983 (R_{12}= 75). Los parámetros de variabilidad seleccionados para el estudio han sido la desviación standard del valor promedio **s** y el índice de variabilidad **v** = (desviación estándar / promedio) x 100. Las variaciones diurnas y estacionales de ambos parámetros de variabilidad han sido analizadas. Un estudio comparativo con la variabilidad día a día de la frecuencia crítica de la región F2, **foF2**, ha sido también llevado a cabo. Una tabla de valores de la variabilidad relativa **v** es presentada. Estudios adicionales se recomiendan con el objeto de extender este tipo de análisis a datos de TEC obtenidos en distintas condiciones geográficas y geofísicas.

PALABRAS CLAVE: TEC Faraday, anomalía ecuatorial.

ABSTRACT

The day-to-day variability of total electron content, TEC**,** at Tucumán (26.9S; 294.6E; Dip: -21.1) has been studied. The database includes **TEC** measurements by Faraday rotation during the high solar activity period from April 1982 (R_{12}= 114) to March 1983 (R_{12}= 75). Two variability parameters have been used in the analysis: the standard deviation from the mean values **s** and the variability index **v** = (standard deviation/mean value) x100. The diurnal and seasonal variations of both variability parameters have been analyzed. A comparative analysis with the day-to-day variability of critical frequency in the F2 region, **foF2**, is presented. A table of values of the relative variability **v** is presented in terms of seasons and typical hours. Additional studies are suggested in order to extend the results to other geographical and geophysical conditions.

KEY WORDS: Faraday TEC, equatorial anomaly.

INTRODUCTION

One of the best known and widely used ionospheric empirical model is the International Ionosphere Reference, IRI, (Bilitza 1990,1997). This model is the result of an international common project of the Committee On Space Research (COSPAR) and the International Union of Radio Science (URSI). IRI provides monthly averages of electron density, electron and ion temperatures and the composition of positive ions in the non-auroral ionosphere for magnetically quiet conditions.

For many applications the need of a better description of the variability of ionospheric parameters has been pointed out in the framework of the IRI Task Force Activities at the International Centre of Theoretical Physics (ICTP), Trieste, Italy and IRI Workshops (Bilitza,2001). This description should include the average of the ionospheric parameters with indication of some measurement of the spread from the average since the users of the model need this information.

One of the ionospheric parameters of interest is the total electron content TEC, parameter responsible for most of the effects that radiowaves undergo when they are passing through the ionosphere.

As it is known the highest values of TEC occur in the equatorial anomaly regions located at approximately ± 15 degrees from the magnetic equator. Most of data available of TEC are from the mid-latitude regions particularly from the Northern hemisphere. In Argentina measurements of TEC using the Faraday rotation Technique (Davies, 1980) have been obtained at Tucumán (26.9S; 294.6E; Dip: -21.1), a place located near the southern peak of the equatorial anomaly, during the high solar activity period from April 1982 to March 1983. Using this database Ezquer and Adler (1989) presented the first morphological study of TEC over Tucumán.

The objective of the present paper is to analyze the day to day variability of the TEC measurements over Tucumán using the same high solar activity period mentioned above. Our intention is to estimate quantitatively the variability in terms of daytime and nighttime conditions and seasons.

DATA USED IN THE STUDY

The TEC measurements were obtained at Tucumán (26.9S; 294.6E; Dip: -21.1) using radio signals transmitted from the geostationary satellites ATS 3 (0; 255E) and GOES 3 (0; 296E) during the period from April 1982 (R_{12}= 114) to March 1983 (R_{12}= 75) near the maximum of the second highest solar cycle. Data were available for all the hours and days of the months analyzed except April 1982 where only 15 days were available. The hourly means of each month were calculated together with the corresponding standard deviations **s**. Taking account that for many applications is helpful to know the variability **s** as a fraction of the mean value the variability index **v** = (standard deviation/mean value) x100 has been also calculated. The two parameters **s** (absolute variability) and **v** (relative variability) have been used in the study as variability parameters.

In order to investigate the relations between the variability of the Faraday TEC measurements and the variability of the F2 region density peak from where comes most of the contribution to TEC, the critical frequency of the F2 region **foF2** has been scaled from the ionograms recorded at Tucumán during the period studied. The representative months of summer (January 1983), fall (April 1982), winter (July 1982) and spring (October 1982) have been chosen for the comparisons. The hourly monthly means of foF2 and the two corresponding variability parameters **s** and **v** have been also calculated for all the set of data.

ANALYSIS OF THE RESULTS

Tables 1, 2 and 3 show the hourly mean values of TEC in TEC units of 10^{16} m^{-2} for each one of 4 summer months (January 1983, February 1983, November 1982 and December 1982), the 4 winter months (May 1982, June 1982, July 1982 and August 1982) and the 4 equinoctial months (March 1983, April 1982, September 1982 and October 1982) respectively with indication of the corresponding values of **s** and **v**.

Diurnal variations of the variability parameters

The values of **s** are generally lower during the morning hours from 02 – 03 LT to 10 LT than at others times of the day. It can be seen that the parameter **s** decreases from 00 LT presenting a minimum at hours around the minimum TEC (between 05 and 08 LT). This minimum ranges from 3.5 and 6.0 TEC units during the summer time, from 1.8 to 2.4 TEC units during winter time and from 3.0 and 7.1 TEC units during the equinoctial months. After this minimum the absolute variability increases reaching maximum values at noon or post noon hours. The exceptions are for March 1983 and April 1982 where the maximum values are reached at 22 LT and 00 LT respectively. The maximum values range between 13.8 and 18.8 TEC units during summer, between 10.3 and 21.8 TEC units during winter and between 13.7 and 24.5 TEC units during the equinoxes.

The variability index **v** presents maximum values at hours around the minimum TEC (05-06 LT) after an increase starting from 00.00 LT. This increase is more remarkable during the months of January 1983, March 1983 and April 1982 than at other months. The maximum values of **v** range from 47% to76% during the summer months, from 63% to 100% during the winter time and from 40% to 78% during the equinoctial months. After the maximum the relative variability shows a decrease starting from about sunrise to noon or post noon hours.

Seasonal variations of the variability parameters

Table 4 presents the averages of the 4 hourly mean values of TEC corresponding to: the 4 summer months, to the 4 equinoctial months and to the 4 winter months with the corresponding values of **s** and **v**. It can be seen that the values of **s** during the wintertime are lower than those observed during summer or equinoctial months for hours between 00 LT and 10 LT. After this behavior is inverted: the lower values of **s** are observed during the summer or equinoctial months.

The relative variability is greater during the winter months than during the summer and equinoctial months most of the time. The values of **v** range from 15.7% to 59.7% during summer, from 18.7% to 76.7% during winter and between 12% and 48.8% during the equinoctial months.

The results indicated before allow to present a preliminary table of values of the relative variability **v** centered around 4 typical hours of the day: 00 LT, 06 LT, 12 LT and 18 LT for different seasons: winter, summer and equinox (Table 5).

This table illustrates once more the diurnal and seasonal behavior of the variability parameter **v**:

(i) Greater values of **v** are observed around midnight than around midday, with maximum variability at sunrise.
(ii) The variability is in general lower in summer and equinox than in winter.

Table 1

Hourly monthly averages of TEC in TEC units of 10^{16} m^{-2}, standard deviations **s** (unit: 10^{16} m^{-2}) and variability indexes **v** (%) from measurements obtained at Tucumán during each summer month of the period from April 1982 (R_{12}= 114) to March 1983 (R_{12}= 75): January 1983, February 1983, November 1982 and December 1982.

	January 1983			**February 1983**			**November 1982**			**December 1982**		
L.T	**TEC**	**s**	**v%**	**TEC**	**s**	**v%**	**TEC**	**s**	**v%**	**TEC**	**s**	**v%**
0	16.9	5.4	32	32.4	9.7	30	42.3	13.4	32	26.5	10.6	40
1	18.4	11.2	61	31.6	10.6	34	39.3	16.8	43	23.1	10.2	44
2	15.5	9.7	62	27.7	10.0	36	33.7	15.9	47	19.8	9.3	47
3	11.8	7.2	61	20.7	9.4	45	25.6	9.2	36	17.8	9.1	51
4	9.6	6.4	66	15.8	8.3	53	17.5	6.2	35	16.5	11.4	62
5	6.5	4.9	76	11.8	6.2	52	15.2	7.1	47	16.1	10.4	64
6	8.8	5.4	61	10.8	5.9	55	18.9	5.4	29	22.0	8.2	37
7	17.3	5.8	34	17.9	5.7	32	28.6	3.5	12	33.5	7.3	22
8	24.9	5.7	23	26.6	5.7	22	37.5	4.2	11	42.3	6	14
9	31.5	5.7	18	32.2	6.6	20	46.1	4.7	10	47.7	7.2	15
10	37.6	5.8	15	38.3	9.5	25	51.9	5.7	11	55.0	8.5	15
11	44.4	7.2	16	46.1	11.9	26	62.2	5.6	9	62.3	10.6	17
12	50.6	8.7	17	54.6	14.9	27	71.9	7.7	11	66.8	15.6	23
13	55.0	10.4	19	61.8	16.6	27	79.4	8.5	11	73.9	12.5	17
14	59.6	11.9	20	65.6	18.2	28	85.7	12.2	14	76.4	14.0	18
15	60.8	11.4	19	67.9	18.8	28	87.4	13.8	16	74.5	15.4	21
16	59.9	11.8	20	68.0	17.5	26	87.9	13.3	15	73.6	14.0	19
17	55.8	13.9	25	65.1	16.4	25	86.3	12.8	15	70.5	14.7	21
18	49.5	13.9	28	59.7	15.7	26	82.2	11.4	14	65.0	13.8	21
19	44.2	12.4	28	52.7	18.0	34	74.8	6.7	9	60.0	13.5	22
20	34.7	9.1	26	49.9	10.8	26	57.9	9.7	17	48.8	11.6	24
21	25.8	7.6	29	46.3	12.1	26	54.2	6.4	12	37.7	11.7	31
22	21.7	8.1	37	41.1	12.4	30	48.1	8.6	18	32.5	11.5	35
23	18.6	6.2	34	34.4	11.0	32	45.3	11.1	25	28.7	10.1	35

TEC and **s** units: 10^{16} m^{-2} (TEC unit)

Table 2

Hourly monthly averages of TEC in TEC units of 10^{16} m^{-2}, standard deviations **s** (unit: 10^{16} m^{-2} and variability indexes **v** (%) from measurements obtained at Tucumán during each winter month of the period from April 1982 (R_{12}= 114) to March 1983 (R_{12}= 75): May 1982, June 1982, July 1982 and August 1982.

	May1982			**June 1982**			**July1982**			**August 1982**		
L.T.	**TEC**	**s**	**v%**	**TEC**	**s**	**v%**	**TEC**	**s**	**v%**	**TEC**	**s**	**v%**
0	38.6	13.6	35	17.6	7.1	40	14.2	10.3	72	16.5	6.5	40
1	27.4	10.6	39	12.2	6.5	54	9.8	8.5	87	12.2	5.2	42
2	17.5	6.4	36	8.8	4.5	51	7.4	6.4	87	8.9	3.8	43
3	11.6	4.9	42	6.8	3.5	52	5.5	5.1	92	7.3	3	41
4	7.9	3.9	49	5.4	3.3	62	4.2	4.1	96	5	2.3	46
5	4.9	2.7	54	3.6	2.4	68	2.8	2.7	96	3.7	1.8	50
6	3.7	2.6	70	2.7	2.0	74	2.4	2.4	100	3.4	2.1	63
7	5.6	2.2	39	4.6	2.6	56	3.6	3.1	86	7.1	3.0	43
8	13.9	3.4	24	12.2	3.6	30	12.3	6	49	18.2	4.6	25
9	20.6	4.6	22	19.0	4.8	26	19.4	6.7	33	29.6	61	20
10	27.5	7.7	28	25.5	5.7	22	25.3	7.9	31	43.1	10.1	23
11	35.3	10.5	30	31.9	7.0	22	35.1	10.3	29	58.9	13.6	23
12	44.8	12.7	28	41.5	8.9	21	45.7	12.9	28	71.5	14.5	20
13	58.3	14.2	24	53.0	9.3	18	58.9	15.6	26	81.2	15.5	19
14	68.8	15.7	23	62.5	8.7	14	66.3	17.2	26	88.0	14.4	16
15	79.2	14.1	18	70.1	8.2	12	68.4	19.4	28	86.2	14.3	17
16	85.5	13.9	16	72.3	9.4	13	68.3	21.8	32	83.0	12.1	14
17	88.0	15.6	18	71.9	10.3	14	62.2	19.1	31	76.6	11.4	15
18	85.6	16.7	20	66.7	9.4	14	53.0	19.5	37	67.0	11.8	18
19	78.0	15.9	20	58.3	9.2	16	48.1	18.6	39	57.1	12.2	21
20	78.0	16.2	21	51.3	9.3	18	37.6	19.0	51	47.2	11.8	25
21	71.3	15.2	21	42.0	9	21	32.6	17.2	53	37.6	12.2	32
22	63.0	15.3	24	34.8	9.5	28	26.2	16.3	62	29.3	10.9	37
23	51.7	14.4	28	25.6	8,8	34	18.2	12.2	67	22.1	7.9	36

TEC and **s** units: 10^{16} m^{-2} (TEC unit)

Table 3

Hourly monthly averages of TEC in TEC units of 10^{16} m^{-2}, standard deviations **s** (unit: 10^{16} m^{-2}) and variability indexes **v** (%) from measurements obtained at Tucumán during each equinoctial month of the period from April 1982 (R_{12}= 114) to March 1983 (R_{12}= 75): March 1983, April 1982, September 1982 and October 1982.

	March 1983			**April 1982**			**September 1982**			**October 1982**		
L.T	**TEC**	**s**	**v%**	**TEC**	**s**	**v%**	**TEC**	**s**	**v%**	**TEC**	**s**	**v%**
0	49.0	11.5	23	72.2	22.3	31	39.7	13.0	33	57.8	13.3	23
1	43.8	9.7	22	51.1	16.4	32	33.6	12.2	36	43.9	11.7	27
2	36.8	8.4	23	37.3	17.4	47	28.7	9.2	32	44.0	11.7	27
3	28.5	9.5	33	23.7	12.6	53	21.8	6.1	28	28.5	7.5	26
4	18.5	9.2	50	13.1	7.4	58	15.2	5.7	37	19.1	6.2	33
5	14.0	8.9	64	8.3	6.5	78	12.5	5.7	46	15.7	6.2	40
6	12.3	7.4	60	5.8	3.4	57	11.1	5.3	48	17.7	5.3	30
7	18.6	7.1	38	9.0	3.3	37	23.0	6.9	30	32.7	7.3	22
8	25.6	7.2	28	19.9	3.0	15	37.2	10.2	27	44.3	8.2	19
9	31.3	8.0	26	27.1	6.1	22	50.1	12.2	24	57.0	10.7	19
10	39.0	8.3	21	35.3	5.9	17	63.5	11.6	18	72.0	14.5	20
11	48.0	9.0	19	47.0	8.0	17	76.0	15.5	20	87.9	18.3	21
12	58.0	9.9	17	58.1	10.0	17	89.8	20.1	22	98.3	15.5	16
13	67.0	10.5	16	70.3	11.7	17	103	24.3	23	109	14.3	13
14	71.5	12.1	17	82.9	15.9	14	106	24.5	23	117	11.6	10
15	80.5	10.4	13	95.2	12.7	13	107	23.5	22	116	13.3	11
16	84.2	11.4	13	102.7	13.0	13	105	21.7	21	116	10.1	9
17	86.3	10.1	12	111	13.9	13	99.4	20.2	20	109	6.6	6
18	83.4	8.7	10	117	13.6	12	90.7	16.8	19	102	6.8	7
19	76.1	9.5	12	113	12.0	11	75.0	13.9	19	85.9	10.4	12
20	68.9	11.9	17	110	15.9	14	64.9	12.9	20	73.2	9.5	13
21	69.4	11.9	17	109	15.6	14	58.5	13.0	22	72.2	11.3	16
22	64.9	13.7	22	104	18.0	17	53.7	13.0	24	67.0	10.5	16
23	54.7	11.8	22	87.2	19.7	23	47.1	11.7	25	63.7	12.5	20

TEC and **s** units: 10^{16} m^{-2} (TEC unit)

Table 4

Hourly monthly averages of TEC in TEC units of 10^{16} m^{-2} for the 4 summer months, winter months and equinoctial months obtained at Tucumán during the corresponding standard deviations **s** (unit: 10^{16} m^{-2}) and variability indexes **v** % are also indicated during the period from April 1982 (R_{12}= 114) to March 1983 (R_{12}= 75).

	Summer			Winter			Equinox		
L.T	**TEC**	**s**	**v%**	**TEC**	**s**	**v%**	**TEC**	**s**	**v%**
0	29.5	9.77	33.5	21.7	9.4	46.7	54.6	15	27.5
1	28	12.2	45.5	15.4	7.7	55.5	43.1	12.5	29.3
2	24	11.2	48	10.6	5.3	54.2	36.7	11.6	32.3
3	19	8.7	48.2	7.8	4.1	56.7	25.6	8.9	35
4	15	8.0	54	5.6	3.4	63.2	16.5	7.1	44.5
5	12.4	7.2	59.7	3.7	2.4	67	12.6	6.8	57
6	15.1	6.2	45.5	3.05	2.3	76.7	11.7	5.4	48.8
7	24.3	5.6	25	5.2	2.7	56	20.8	6.1	31.8
8	32.8	5.4	17.5	14.1	4.4	32	31.7	7.1	22.3
9	39.4	6.0	15.7	22.1	5.55	25.2	4	9.3	22.8
10	45.7	7.4	16.7	30.3	7.8	26	52.4	10	19
11	53.7	8.8	17	40.3	10.4	26	64.7	12.7	19.3
12	60.9	11.7	19.5	50.8	12.3	24.2	76	13.8	18
13	67.5	12.0	18.5	62.8	13.6	21.7	87	15.2	17.3
14	71.8	14.0	20	71.4	13.5	19.7	94.3	16	16
15	72.6	12.0	21	75.9	14.0	18.7	99.6	14.9	14.8
16	72.3	14.1	20	55.9	14.3	18.7	101.9	14	14
17	69.4	14.4	21.5	52.6	14.1	19.5	101.4	12.7	12.8
18	64.1	13.7	22.2	68	14.4	22.2	98.3	11.5	12
19	57.9	12.6	23.2	40.9	13.9	24	87.5	11.5	13.5
20	47.8	10.3	23.2	34	14.0	28.7	79.2	12.6	16
21	41	9.5	24.5	45.8	13.4	31.7	77.2	12.9	17.3
22	35.8	10.1	30	38.3	13.0	37.7	72.4	13.8	19.8
23	31.8	9.6	31.5	29.4	10.8	41.2	63.2	13.9	22.5

TEC and **s** units: 10^{16} m^{-2} (TEC unit)

Table 5

Values of **v** (%) for Tucumán during the period from April 1982 to March 1983 for winter, equinox and summer months and for 4 typical hours: 00 LT, 06 LT, 12 LT and 18 LT.

Local Time	v% Winter	v% Equinox	v% Summer
00.00	47.8	26.4	36.8
06.00	66.5	45.9	43.4
12.00	23.9	18.2	18.3
18.00	21.9	12.8	22.3

Relations between TEC and the critical frequency foF2

As it is known most of the contribution to TEC comes from the near the F2 region density where models and routine data are available. As ionosonde data of the critical frequency of the F2 region, **foF2**, were available at Tucumán for the period under study, the relations between the variability of the two ionospheric parameters: TEC and **foF2** has been investigated. The months chosen have been the representative months of summer (January 1883), fall (April 1982), winter (July 1982) and spring (October 1982) and the comparisons have been done using the relative variability parameter **v**.

Table 6 shows for each month the values of the relative index **v** for the two parameters: TEC (**v** TEC) and **foF2** (**vfoF2**). It can be observed that in all the cases the variability of **foF2** is lower than the variability of TEC. The trends of the diurnal and seasonal variations of the relative variability **vfoF2** are in general in agreement with those observed for the **v**TEC values. These results indicate that there are other related parameters to the variability of TEC that must be investigated such as the slab thickness parameter.

It is important to point out that these results are in agreement with those presented by Mosert *et al*. (2002) where they analyzed the day to day variability of TEC provided by a new technique (Huang and Reinisch, 2001) using ionosonde data from two Argentine stations; Tucumán (26.9S; 294.6E; Dip: -21.1) and San Juan (31.5S; 290.4, Dip: -28.1) during different seasonal and solar activity conditions. The behavior of the variability presented in this analysis is in general the same than that indicated by Adeniyi and Radicella (2001) when they analyzed the variability of Faraday TEC from an equatorial station.

This work is only a preliminary step in the study of the day to day variability of TEC. Our results are limited to a period of high solar activity and a location near the southern peak of the equatorial anomaly: Tucumán. Further analysis will be done using data obtained by different techniques and for different geographical an geophysical conditions.

CONCLUSIONS

The main results of the study of the day to day variability of TEC over Tucumán are given below.

Absolute variability

(1) The values of **s** are in general lower during the morning hours than at other hours of the day.

(2) After a decrease from 00LT the absolute variability presents a minimum at hours of minimum TEC (05LT – 08LT)

(3) The parameter **s** during the winter months is generally lower than those observed during the summer and equinoctial months for hours between 00LT and 10LT. After this behavior is generally inverted.

Relative variability

(1) The parameter **v** presents maximum values at hours of minimum TEC (05LT – 06LT).

(2) The relative variability is greater during winter time than during summer and equinoctial months most of the time.

(3) The relative variability of **foF2** is lower than that observed in the TEC values indicating that there are other parameters related to the variability of TEC that must be investigated.

The obtained results can be helpful for modeling the ionosphere in particular the TEC behavior.

The Table 5 presented in this paper is limited to one station (Tucumán) during a high solar activity period. However it can be helpful as an orientation for future studies that should include a larger database obtained by different techniques during different geographical and geophysical conditions.

Our results can contribute to the formulation of a quantitative model of TEC, that should not only provide the mean values of the parameter under different conditions but also some measure of the spread from a monthly mean such as the standard deviations. For some applications can be helpful to indicate the relative variability using parameters such as the variability index used in this study.

Table 6

Variability indexes **v** (%) for the parameters TEC (**v** TEC) and **foF2** (**v foF2**) over Tucumán during the representative months of summer (January, 1983), winter (July, 1982), fall (April, 1982) and spring (October, 1982) for the period April 1982 (R_{12}= 114) to March 1983 (R_{12}= 75).

January 1983			**April 1982**			**July 1982**			**October1982**		
LT	**v TEC %**	**v foF2 %**	**LT**	**v TEC %**	**v foF2 %**	**LT**	**vTEC %**	**v foF2 %**	**LT**	**v TEC %**	**v foF2 %**
00	32	9	00	31	22	00	72	27	00	23	18
01	61	13	01	32	13	01	87	26	01	27	17
02	62	15	02	47	16	02	87	23	02	27	12
03	61	16	03	53	16	03	92	26	03	26	23
04	66	19	04	58	33	04	96	23	04	33	16
05	76	17	05	78	33	05	96	24	05	40	17
06	61	14	06	57	28	06	100	31	06	30	12
07	34	10	07	37	12	07	86	22	07	22	6
08	23	7	08	15	13	08	49	21	08	19	8
09	18	5	09	22	13	09	33	20	09	19	8
10	15	9	10	17	10	10	31	17	10	20	7
11	16	8	11	17	5	11	29	15	11	21	3
12	17	1	12	17	5	12	28	12	12	16	7
13	19	5	13	17	3	13	26	15	13	13	2
14	20	24	14	14	3	14	26	14	14	10	2
15	19	22	15	13	3	15	28	13	15	11	2
16	20	21	16	13	3	16	32	16	16	9	1
17	25	17	17	13	4	17	31	16	17	6	2
18	28	6	18	12	4	18	37	16	18	7	5
19	28	7	19	11	3	19	39	20	19	12	2
20	26	11	20	14	4	20	51	21	20	13	5
21	29	12	21	14	5	21	53	17	21	16	10
22	37	9	22	17	38	22	62	20	22	16	10
23	34	8	23	23	24	23	67	22	23	20	20

BIBLIOGRAPHY

ADENIYI, J. and S. M. RADICELLA, 2001. Variability of TEC over an Equatorial Station, Proceedings IRITFA 2000, IC/IR/2001/7, ISNB, 92-95003-06-3, 75-82, Trieste, Italy.

EZQUER, R. G. and O. N. ADLER, 1989. Electron Content over Tucumán. *J. Geophys. Res., 94, A7,* 9029-9032.

BILITZA, D., 1990. International Reference Ionosphere 1990, NSSDC 90-92, World Data Center A R&S, Greenbelt, U.S.A.

BILITZA, D., 1997. International Reference Ionosphere – Status 1995/1996. *Adv. Space Res., 20, 9,* 1751-1754.

BILITZA, D., 2001. International Reference Ionosphere 2000. *Radio Science, 36, 2,* 261-275.

DAVIES, K., 1980. Recent Progress in Satellite Radio Beacon Studies with Particular Emphasis on the ATS 6 Radio Beacon Experiment. *Space Sci. Rev. 25,* 357.

HUANG, X. and B. W. REINISCH, 2001. Vertical Electron Content from Ionograms in Real Time. *Radio Science, 36, 2,* 335-342.

MOSERT, M., R. EZQUER, R. DEL V. OVIEDO, C. JADUR and S. M. RADICELLA, 2002. Temporal Variability of TEC using Groud-Based Ionosonde Data from two Argentine Stations. Adv. Space Res. (*In press*).

M.Mosert[1], R.Ezquer[2,3], C. Jadur[4] and R. del V. Oviedo[2]

[1] Complejo Astronómico El Leoncito, CONICET,
Av. España 1512 (sur), Casilla de Correo 467,
San Juan, C. P. 5400, Argentina.
Email: mmosert@casleo.gov.ar
mmosert@hotmail.com
[2] Laboratorio de Ionosfera, Depto. de Física, CONICET,
Av. Independencia 1800, San Miguel de Tucumán, C. P. 4000, Argentina.
Email: rezquer@herrera.unt.edu.ar
[3] Fac. Regional Tucumán, Universidad Tecnológica Nacional,
Rivadavia 1050, San Miguel de Tucumán, C. P. 4000, Argentina.
Email: scytec@frt.unt.edu.ar
[4] Departamento Matemáticas, Fac. de C. Exactas UNSa,
Av. Bolivia 5150, C. P. 4.400, Salta, Argentina.
Email: cjadur@ciunsa.edu.ar