Behavior of the scale height at the F2 layer peak derived from Digisonde measurements at two European stations

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Abstract

A new technique is presented to estimate the electron density topside profile from information derived from ground-based ionograms. The electron density above the F2 peak is approximated by an α-Chapman function with constant scale height (H_m). The scale height is derived from the shape of the bottomside profile near the F2 peak. Digisonde data obtained at two European stations: Ebro (40.4°N, 0.3°E) and El Arenosillo (37.1°N; 353.2°E) for different times of day, seasons, and periods of the solar cycle to study the variations of H_m. The results of the analysis are in good agreement with those reported by other authors. A table of values is presented for typical hours of the day and different seasons and solar activity conditions. This study, once extended to a larger database, will support modeling H_m as a function of time, season, latitude, solar activity and magnetic activity, and contribute to the formulation of the topside electron density in the IRI model.

Keywords: Middle latitude ionosphere; Topside electron density profile; Scale height

1. Introduction

Electron density profiles derived from ground-based ionograms provide information up to the F2 layer peak, hmF2. Different true-height inversion programs are available that calculate the bottomside profiles from the ionogram echo traces (e.g., Huang and Reinisch, 1996; Titheridge, 1985). The information on the topside electron density distribution, usually derived from topside sounder and incoherent scatter radar (ISR) measurements, is scarce, compared with the bottomside.

Reinisch and Huang (2001) introduced a new technique of estimating the topside profile from ground-based ionograms, assuming an α-Chapman function with a constant scale height H_m. The scale height is derived from the shape of the bottomside profile near the F2 peak and provides a good estimate for the electron density profile up to around 700 km. Recently Reinisch et al. (2004) have shown that the H_m values, produced routinely by Digisondes, can be helpful in improving the formulation of the IRI topside electron density profile (Bilitza, 2001).

The objective of the present paper is to analyze the behavior of the scale heights using the F2 layer Digisonde data at two European stations: Ebro (40.4°N, 0.3°E) and

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El Arenosillo (37.1°N; 353.2°E) during different times of day, seasons. and periods of the solar cycle.

2. Data used

The analysis presented in this paper uses ionograms (manually scaled) recorded by two DGS 256 from the European stations: Ebro (40.4°N, 0.3°E) and El Arenosillo (37.1°N; 353.2°E). The database covers the four seasons: summer (July), winter (January), fall (October), and spring (April), and two levels of solar activity: low solar activity, LSA (1995, Rz12 = 17.2) and high solar activity, HSA (1999, Rz12 = 95.3, and 2000, Rz12 = 116.8). The individual electron density profiles with their corresponding scale heights H_m at the F2 layer were obtained from the ionograms using the ARTIST program (Huang and Reinisch, 1996; Reinisch and Huang, 2001). The monthly median values of H_m ($n = 25$–30 days) were calculated for a given month and a given hour for the 3 years (1995, 1999, and 2000) and the two ionospheric stations.

3. Results

3.1. Behavior of the scale height at El Arenosillo

Figs. 1a and b illustrate the variations of the median values of H_m at El Arenosillo for the four seasons and two years of different solar activity: 1995 (Rz12 = 17.2) and 1999 (Rz12 = 95.3). The figures show the following characteristics: (1) H_m does not exhibit a clear diurnal variation in winter (January) and fall (October). The values of H_m for these two seasons vary from 30 to 42 km at LSA and from 30 to 59 km at HSA. However, in the year 1999, H_m presents a slight trend. A peak occurred at sunrise during the two seasons with a value of 52 km in winter and 59 km during fall. (2) For July (summer) and April (spring) a more defined diurnal variation is observed: the parameter H_m is greater during the daytime period (06 to 18 UT) than during the night time period (19 to 05 UT), reaching maximum values generally around noon. This behavior is better observed during low solar activity. The nighttime values range from 29 to 46 km at LSA, and from 36 to 50 km at HSA. The daytime values of H_m vary between 29 and 68 km at LSA and between 43 and 76 km at HSA. (3) During daytime, H_m is generally greater in summer (43–76 km) and spring (37–66 km) than in winter (29–52 km) and fall (29–59 km). This seasonal behavior is clearer at LSA. The seasonal differences are less evident during night time at both levels of solar activity. (4) Although some exceptions have been found, in general, H_m increase with solar activity, ranging between 28 and 68 km at LSA and between 36 and 76 km at HSA.

3.2. Behavior of the scale height at Ebro

Figs. 2a and b depict the diurnal variations of H_m for Ebro for the four seasons and two different levels of solar activity: 1995 (Rz12 = 17.2) and 2000 (Rz12 = 116.8). It shows that, in general, the variations of H_m with time day, season, and level of the solar activity are similar to those observed at El Arenosillo.

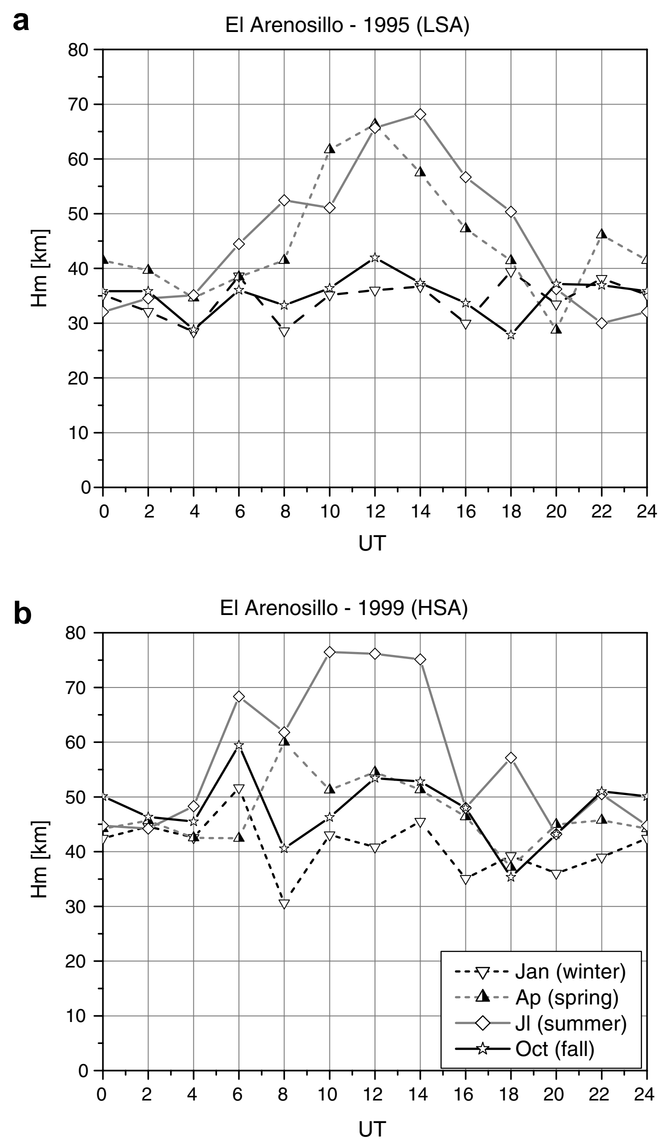

Fig. 1. Average variation of the scale height H_m in km, at El arenosillo (37.1°N; 353.2°E) for the four seasons (winter, summer, fall, and spring) and two years of different level of solar activity: (a) 1995 (Rz12 = 17.2) and (b) 1999 (Rz12 = 95.3) as indicated in the top of each plot.

In order to summarize the results for both stations, we present in Table 1 the values of H_m over El Arenosillo and Ebro for four typical hours of the day (00, 06, 12, and 18 UT), the four seasons of the year (summer, winter, fall, and spring) and two levels of solar activity: LSA and HSA. The analysis of the table confirms the main features mentioned above, that is: H_m exhibits a clear diurnal variation in summer and spring (with maximum values at noon); the seasonal differences are more evident during daytime than during nighttime, and H_m increases with solar activity.

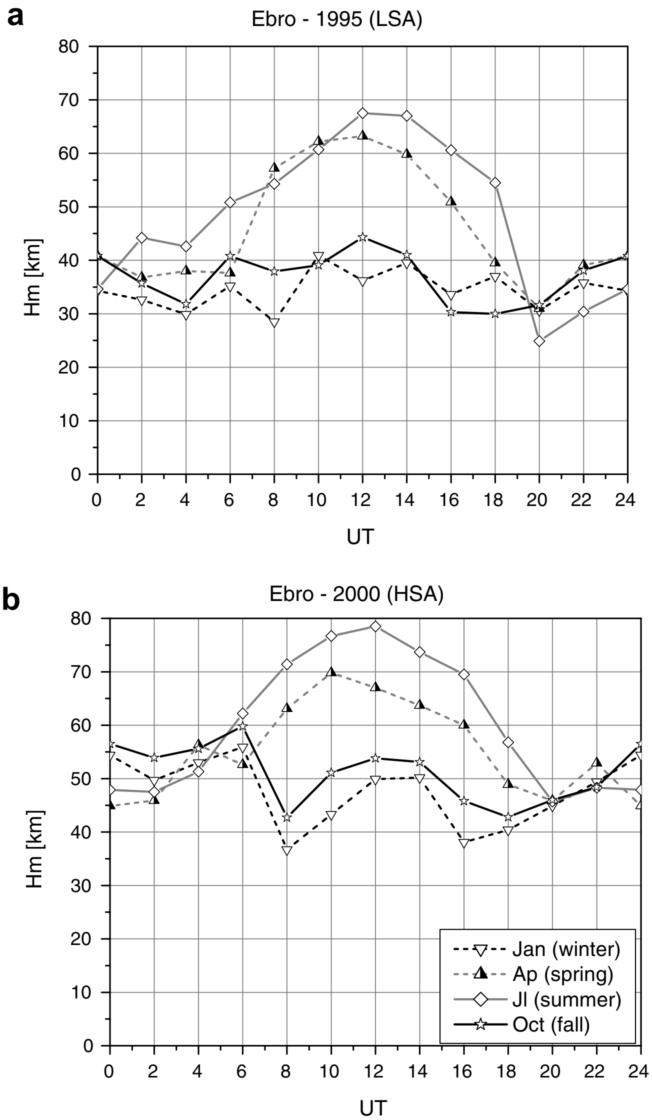

Fig. 2. Average variation of the scale height H_m in km, at Ebro (40.4°N; 0.3°E) for the four seasons (winter, summer, fall and spring), and two years of different level of solar activity: (a) 1995 (Rz12 = 17.2) and (b) 2000 (Rz12 = 116.8) as indicated in the top of each plot.

It is important to point out that the diurnal and seasonal variations of the scale heights observed at Ebro and El Arenosillo are similar to those reported by Reinisch et al. (2004) using data from Hainan Island (19.4N; 109.0E) and Millstone Hill (42.0N; 288.5E) during the years 2002 (Rz12 = 101.7) and 2003 (Rz12 = 65.6).

4. Conclusion

Many efforts have been made in the last decades to improve the International Reference Ionosphere, IRI (Bilitza, 1990, 2001) using measurements obtained by different techniques. The ground-based ionosonde data recorded at different locations have been widely used to test the IRI predictions of different ionospheric characteristics such as the critical frequencies of the E, F1, and F2 layers (foE, foF1, foF2), the corresponding peak heights (hmE, hmF1, hmF2) and parameters derived from electron density profiles (B0, B1, D1).

The introduction of a new technique of estimating the topside electron density profile from the information contained in the ground-based ionograms (Reinisch and Huang, 2001) offers a new tool for the study of the topside electron density profiles and a new data resource to improve the IRI topside profiles. Parameters such as total electron content and scale heights can be derived from the ionograms using the mentioned technique.

This paper analyzes the variations of the scale heights obtained from ionosonde data recorded at El Arenosillo (37.1°N; 353.2°E) and Ebro (40.4°N; 0.3°E) during different seasonal and solar activity conditions. The main results of our study are: (1) H_m exhibits a clear diurnal variation in summer and spring with maximum values around noon at both levels of solar activity, while the diurnal variations in winter and fall are small; (2) during daytime H_m presents higher values during summer and spring than during winter and fall, and the nighttime values exhibit no clear seasonal dependence; (3) in general, the scale heights increase with increasing solar activity; (4) a table (Table 1) of preliminary H_m values is presented for the four seasons, four typical hours of the day and two levels of solar activity (LSA and HSA) capturing the variations of the scale height at the two locations for which the analysis was done.

The results of this study are similar to those reported by Reinisch et al. (2004) using data from Hainan Island (19.4N; 109.0E) and Millstone Hill (42.0N; 288.5E) for the years 2002 (Rz12 = 101.7) and 2003 (Rz12 = 65.6). While the analysis presented here is only valid for two locations, it can be combined with results from other stations to

Table 1
Monthly median values of the scale heights H_m at (a) El Arenosillo and (b) Ebro during the four seasons (winter, spring, summer, and fall) at four typical hours of the day (00, 06, 12, and 18 UT) for two levels of solar activity: low solar activity (LSA) and high solar activity (HSA)

Season	Solar Act.	00 UT	06 UT	12 UT	18 UT
(a) El Arenosillo					
Winter	LSA	35	39	36	40
	HSA	42	52	41	39
Spring	LSA	41	38	66	41
	HSA	44	42	55	37
Summer	LSA	32	45	66	50
	HSA	45	68	76	57
Fall	LSA	36	36	42	28
	HSA	50	59	53	35
(b) Ebro					
Winter	LSA	34	35	36	37
	HSA	54	56	50	40
Spring	LSA	41	38	63	40
	HSA	45	53	67	49
Summer	LSA	35	51	68	54
	HSA	48	62	78	57
Fall	LSA	41	41	44	30
	HSA	56	60	54	43

arrive at a global model for H_m as a function time of day, season, latitude, and solar and magnetic activities. Such a model would support the development of a better IRI Ne topside model.

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