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Time/altitude electron density variability above Ebro, Spain

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Abstract

The time series of electron density profiles $N(h)$ obtained at midlatitude station Ebro (40.5°N, 0.5°E) since 1995 up to now have been evaluated in order to obtain the typical time/altitude electron density variability. The standard deviation $\sigma(h)$ of the individual profiles from Monthly Averaged Representative Profile (MARP) is used for such purpose. The percentage of $\sigma(h)$ vs. MARP shows a distinct daily, seasonal and altitude pattern of variability. As expected, the larger variability occurs during night-time, there being however much better expressed at the base of the F region. Typical values of percentage of variability at altitudes of the electron density maximum are 10–20%, whereas they can be as large as 50% during night-time at the base of the F region. The systematic daily, seasonal and long-term behaviors of $\sigma(h)$ are discussed in terms of potential modeling purposes. The potential physical causes driving systematic behavior of $\sigma(h)$ are discussed also.

Keywords: Ionosphere variability; IRI model; Electron density profiles; B parameters; Variability-quartile-median-IRI

1. Introduction

Among the ionospheric community exists an interest to develop models of ionospheric variability (Bilitza, 2000). Many research works have been conducted on that matter, one to obtain knowledge of the variability of ionospheric characteristics (e.g., Ezquer et al., 2004; Rishbeth and Mendillo, 2001; Forbes et al., 2000) and others to model the ionospheric variability (e.g., Araujo-Pradere et al., 2005, 2004; Mendillo et al., 2002). The ionospheric variability quantified at the midlatitude F region electron density peak reveals the following main pattern: it is larger by night, about 33%, than by day, about 20% (Rishbeth and Mendillo, 2001); it increases from typical values of 10–15% in summer to maximum values of 15–40% in winter (Araujo-Pradere et al., 2005); and the variability tends to increase with geomagnetic activity in winter and equinox but remained fairly constant in summer (Araujo-Pradere et al., 2005).

There is a recent increasing interest into the framework of International Reference Ionosphere model (IRI) on the variability of the electron density profile $N(h)$. Related to that and among others, Bradley et al. (2004) shows that variability of $N(h)$ depends on height for a single bottomside F_2-layer subject to changes in both height and peak density. Mosert et al. (2004) have found that day-to-day variability of the E and F_1 regions is generally less than that of the F_2 region. Also, Amarante et al. (2004) reached the following results on the relative variability of $N(h)$ based on records from mid to mid-low latitude stations: f_0F_2 is the dominant factor that determines the variability of $N(h)$, the highest variability is located about 100 km below h_mF_2 and it increases with solar activity, the diurnal course of variability minimizes around noon and maximizes around midnight and dawn, and the seasonal course of variability presents maxima at autumn and winter for 00 and 18 LT.

There is a clear interest for ionospheric model users to know the typical behavior of the ionosphere, what one would expect for specific ionospheric conditions; but also the expected deviations from that typical behavior, the

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range within measurements are likely to be (Ezquer et al., 2004). The interest of physicists is to deepen into the knowledge of the ionospheric variability and their causes, and the main reason for this interest is the role played by the ionosphere in the Earth's environment due to the coupling processes from above and below (Rishbeth and Mendillo, 2001). They recognize the geomagnetic activity as the main cause of the ionospheric variability but meteorological causes transmitted from below may contribute comparatively. The quiet time ionospheric disturbances (QD) contribute to the ionospheric variability also (Mikhailov et al., 2004 and references there in), which may be attributed to the impact from below. The degree of the observed ionospheric variability that may be attributed to different sources of solar origin and of dynamical phenomena transmitted from the lower atmosphere have been evaluated by Forbes et al. (2000). They found the variability of N_mF_2 about the mean under quiet geomagnetic conditions and at all latitudes to be of ±25–35% at periods from few hours to 1–2 days and of ±15–20% at periods of 2–30 days, there being small contribution due to solar flux variations, and assumed these results to be a reasonable estimate of the ionospheric variability due to 'meteorological influences'. Model results evaluated that disturbances originated from the lower atmosphere may cause variations of 10–30% in the N_mF_2 (Mendillo et al., 2002), and that the day-to-day variability of the F_2-layer is better related to wind variations than to variations of the thermospheric composition.

The aim of this paper is to obtain the typical time/altitude variability of the ionosphere from the typical daily pattern of the $N(h)$ profiles at mid-latitude station over Europe. Results of daily, seasonal, and long-term pattern of $N(h)$ variability are discussed in terms of potential causes as solar and geomagnetic activity, 'meteorological influences' from below and in terms of potential modeling results. For this purpose, we use the retrospective database of the Ebro observatory (40.8°N, 0.5°E) electron density $N(h)$ profiles, covering the years from 1995 to 2005.

2. Data and analysis

We use the continuous database of vertical incidence ionograms from the Ebro Observatory (40.8°N, 0.5°E) recorded by a DGS 256, covering the time interval from January 1995 to December 2005. Note that at the Ebro longitude the local time practically matches the universal time used for regular measurements. All together we analyzed about 11 years of $N(h)$ profiles, except some data gaps occurred by sounder failure. The ionogram's traces have been carefully revised by operator in order to avoid any mistake of the Automatic Real Time Ionogram Scaler with True Height (ARTIST) (Huang and Reinisch, 1996a) and recalculated with NHPC algorithm. The individual profiles corresponding to a given month and a given hour have been used to obtain the Monthly Averaged Representative Profile (MARP). See Huang and Reinisch (1996b) for details. The MARPs were computed excluding the individual profiles having deviations larger than 25% in order to avoid extreme profiles probably linked with most disturbed ionospheric conditions. Therefore, for a given month and a given hour we obtain the typical profile expected for quiet ionospheric conditions in the same way as in Blanch et al. (2007). However, instead of analysis on the $N(h)$ profiles, we will analyze the plasma frequency profiles, $f_p(h)$ that are related by the following well known expression:

$$N(h) = 1/80.6 f_p^2(h), \quad (1)$$

where, f_p is expressed in Hz and N in m^{-3}.

The $f_p(h)$ profiles obtained from the MARPs are considered as the 'mean' profiles for a given month and a given hour under quiet ionospheric conditions. A 'pseudo standard deviation' $\sigma(h)$ is computed from the MARP and the individual profiles according typical standard deviation expression:

$$\sigma \approx \sqrt{\sum (x_i - \bar{x})^2 / n - 1}, \quad (2)$$

where, x_i refers to the individual profiles, $\bar{x}$ refers to MARP and n are the number of individual profiles for a given month and a given hour.

This way we obtain the expected variability $\sigma(h)$, or better said the typical deviation from the typical profile expected for a given month and a given hour. In order to avoid the strong modeling effects at the E region and at the E–F valley region of the NHPC algorithm during nighttime, we consider for this study the lowest height that for which f_p to be equal to 2 MHz, and the upper height to be 45 km above h_mF_2. Fig. 1 depicts two examples of the $f_p(h)$ profiles obtained from the MARPs compared with the individual $f_p(h)$ profiles recorded during these months and the expected variability $\sigma(h)$ obtained from them. From this figure, we observe that $\sigma(h)$ decreases with increasing height for nighttime $f_p(h)$ profiles, the opposite being true for daytime profiles.

We assume the above mentioned $\sigma(h)$ as proxy of altitude variability for a given local time and month. $\sigma(h)$

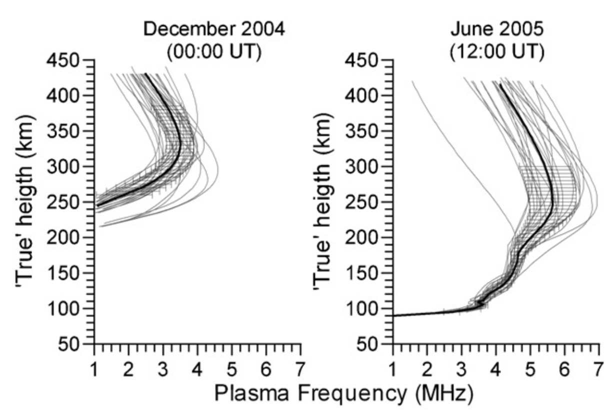

Fig. 1. Two example of the MARP (thick black line) obtained for December 2004 at midnight (left) and for June 2005 at midday (right) over Ebro station. The individual profiles of both times are depicted as grey thin lines. Error bars indicate the 'standard deviation' $\sigma(h)$.