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ScienceDirect
Advances in Space Research 43 (2009) 1821–1824
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

Study of maximum electron density N_mF_2 at Karachi and Islamabad during solar minimum (1996) and solar maximum (2000) and its comparison with IRI

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Received 27 November 2007; received in revised form 26 September 2008; accepted 26 September 2008

Abstract

The monthly hourly medians of maximum electron density, N_mF_2, at two Pakistani ionospheric stations, Karachi and Islamabad, have been determined for solar minimum (1996) and solar maximum (2000) and compared with IRI predictions using the URSI coefficients. At night and pre-noon period the N_mF_2 values at both stations are almost equal during the 2 years. However, at post-noon the values at Karachi are considerably larger than those at Islamabad due to the equatorial or geomagnetic anomaly. Karachi (geomag. coord. 16.44°N, 139.08°E) lies near the region of the equatorial anomaly (+20 and −20 geomagnetic latitude), so most of the N_mF_2 values at Karachi are larger than those at Islamabad (geomag. coord. 24.46°N, 145.67°E). The maximum monthly values of N_mF_2 show a semi-annual variation at Karachi and Islamabad both during 1996 and 2000 as predicted by IRI.

Keywords: Maximum electron density; Equatorial anomaly; Evening anomaly; Geomagnetic anomaly; Bite-out Phenomenon; IRI

1. Introduction

The ionospheric F region plays an important role for ground-to-ground and satellite-to-ground high frequency communications and has been extensively studied with ionosondes. The worldwide research of the ionosphere resulted in huge amounts of data on the temporal, seasonal, and geographic variations of the ionosphere (e.g., Rajaram and Rastogi, 1977; Pavlov and Pavlova, 2005, 2007; Rishbeth, 2001; Lee and Reinisch, 2006). The variations in the F_2 layer critical frequency f_oF_2, which are much altered during magnetically disturbed days, cannot be explained on the basis of simple theory (Wright et al., 1957; Watts, 1958), and require more advanced explanations (Prölss, 1993). The behavior of the F region is in general fairly irregular and is often classified into a number of anomalies such as equatorial anomaly, seasonal anomaly, evening anomaly, etc. (Olatunji, 1967; Davies, 1969; Anderson, 1973; Huang and Jeng, 1978). During the period of minimum solar activity in 1996, the smoothed sunspot number (SSN) was 8.6 whereas during the period of maximum solar activity in 2000 it was 119.6 (ftp.ngde.noaa.gov). The objective of the present paper is to compare the monthly hourly medians of the F_2 peak densities N_mF_2 at Karachi and Islamabad and study the associated ionospheric phenomena.

2. Experimental technique

The ionospheric data of Karachi (geog. coord. 24.95°N, 67.14°E) and Islamabad (geog. coord. 33.75°N, 72.87°E) employed in the present study have been acquired with Digisondes 256 (Reinisch, 1996). These Digisondes operate at peak power output of 10 kW nominal. Each ionogram is acquired within 30 s.

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doi:10.1016/j.asr.2008.09.034

3. Method of data analysis

The critical frequency of the ordinary component for the F_2 layer, f_oF_2, at hourly intervals, was manually scaled from the ionograms, and monthly hourly medians of f_oF_2 were determined both for Karachi and Islamabad, from which the median peak densities N_mF_2 were derived using $N_mF_2\ (m^{-3}) = 1.24\times10^4\ [f_oF_2\ (MHz)]^2$ (*see for example*, Davies, 1969). The monthly hourly medians of N_mF_2 at Karachi and Islamabad for 1996 and 2000 have been plotted for comparison for comparison with the IRI predictions.

4. Results and discussions

4.1. Comparing N_mF_2 at Karachi and Islamabad

4.1.1. Solar minimum (1996)

Comparison of the N_mF_2 values at Karachi and Islamabad for 1996 shows that from March to October the monthly hourly medians of N_mF_2 at Karachi are considerably greater from about noon to sunset than those at Islamabad, whereas in the remaining months this difference is small. However, at night until ~10 LT, the hourly medians of N_mF_2 at both the stations are almost equal throughout the year. Fig. 1 shows the diurnal variations during August 1996 as an example. The IRI N_mF_2 predictions using the URSI coefficients for August are in general agreement for Islamabad, but overshoot during the daytime for Karachi. As predicted by IRI, the daytime median N_mF_2 values for Karachi are greater than those for Islamabad. It is noticed that the IRI N_mF_2 predictions for both stations deviate less from the measurements during nighttime than during daytime.

4.1.2. Solar maximum (2000)

During all months in the year 2000 the monthly hourly medians of N_mF_2 at Karachi in the afternoon are greater than those at Islamabad. During the night and from sunrise to noon, however, the N_mF_2 medians at both stations are almost equal throughout the year. The N_mF_2 variations for May 2000 (Fig. 2) illustrate the typical behavior, showing similar features as the solar minimum data in Fig. 1 with different scales on the vertical axes. The IRI monthly N_mF_2 values for both stations are greater than the observed monthly median values. The model significantly overestimates N_mF_2 for Karachi.

The larger N_mF_2 values observed at Karachi, compared to those at Islamabad, can be explained by Karachi's location (16.4°N geomagnetic) which is within the equatorial anomaly region (Anderson, 1973). The IRI predictions also show larger N_mF_2 median within the equatorial anomaly region (i.e., at Karachi) than those outside (i.e., at Islamabad). Rajaram and Rastogi (1977) examined a band of strong East–West equatorial electrojet current which interacts with the horizontal magnetic field to cause an $E \times B$ drift of ionization vertically upward; the uplifted ionization subsequently diffuses along the field lines to sub-tropical latitudes (±20° geomagnetic latitude). While Karachi (16.44°N geomagnetic latitude) lies in the region of the equatorial anomaly, Islamabad (24.5°N geomagnetic) is outside the anomaly, explaining the larger N_mF_2 median values at Karachi.

4.2. Seasonal variation of N_mF_2 at Karachi and Islamabad

The seasons in increasing order of maximum N_mF_2 values in 1996 and 2000 both for Karachi and Islamabad are – Summer (June–August), Winter (December–February), Fall (September–November), and Spring (March–May). This seasonal classification of the months follows the suggestions made by Davies (1969) for ionospheric studies. Table 1 lists the maximum N_mF_2 values for each season in 1996 and 2000 at both stations. Fig. 3 presents the maximum monthly N_mF_2 values for Karachi, clearly showing semi-annual variations for both 1996 and 2000. For Karachi, for both high and low solar activity, the crests

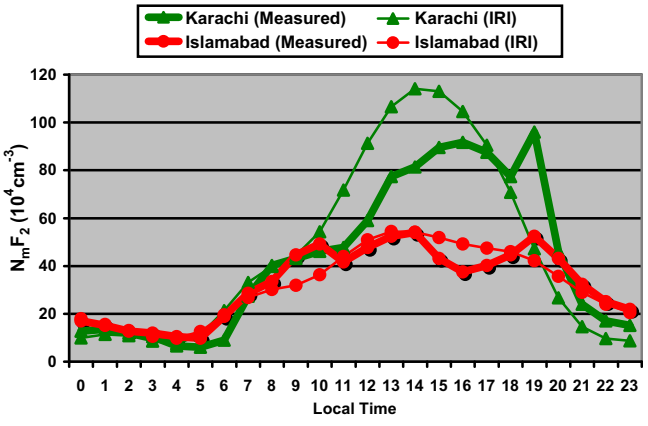

Fig. 1. N_mF_2 hourly medians during solar minimum measured with the Karachi and Islamabad ionosondes and predicted by IRI using the URSI coefficients, August 1996.

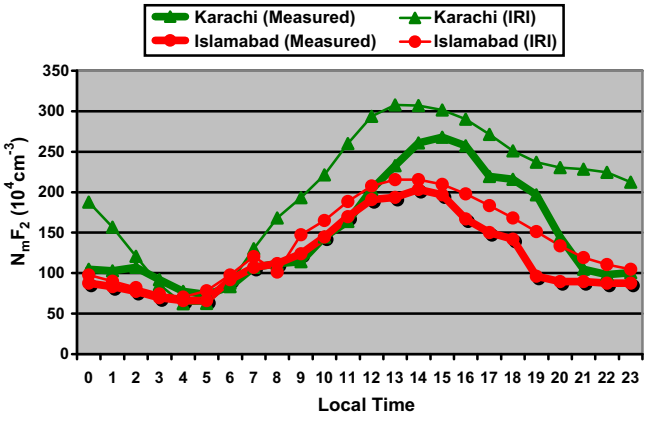

Fig. 2. N_mF_2 hourly medians during solar maximum measured with the Karachi and Islamabad ionosondes and predicted by IRI using the URSI coefficients, May 2000.