Mesosphere-Ionosphere coupling processes observed by ionosonde and airglow photometer in the equatorial region

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This paper was prepared for presentation at the 9th International Congress of the Brazilian Geophysical Society held in Salvador, Brazil, 11-14 September 2005.

Abstract

Equatorial ionosphere sounding at São Luís (2.6 S, 44.2 W) and Fortaleza (3.9 S, 38.4 W), and mesospheric airglow OI5577, O_2b(0,1) and OH(6,2) emissions and OH rotational temperature observation at Cariri (7.4 S, 36.5 W) have been carried out since 1999. Spectral analyses of the ionospheric F-layer bottom height (h'F) and mesospheric airglow emission intensities reveal that there are quasi 2 and 4 day period oscillations in their temporal variations. Simultaneously observed meteor wind at 90 km of altitude at Cariri also showed similar periodic oscillations. It might indicate that planetary scale oscillations, Rossby-gravity waves and Ultra Fast Kelvin waves, are present in the ionosphere, passing through the mesosphere.

Introduction

The earth's ionosphere is strongly influenced by several physical processes, such as solar flux, magnetic activity from above and dynamical processes from the mesosphere-lower thermosphere (MLT) region. Attention has been called to the dynamical processes, so called "meteorological influence" after Chen [1992] observed 2 day oscillation in amplitude of the equatorial ionization anomaly (EIA) and suggested a presence of planetary wave in the equatorial region. Forbes et al. [1997] also reported quasi 2-day oscillation in f_oF_2, which could be connected with the quasi 2-day oscillation in the MLT winds. Statistical survey on the periodic oscillation of the ionosphere was presented by Forbes et al.[2000]. Pancheva et al.[2002] studied variation of the maximum height of the ionospheric F_2-layer, hmF_2, with 27 day, 16 day and quasi 2 day periods. They reported that the 16 day period must be related to 16-day modulation of the semidiurnal tide in the MLT region, and the quasi 2 day oscillation activity increased during the geomagnetic disturbances. They further mentioned that the 2 day oscillation could also be generated by the quasi-2 day wave in the neutral wind in the MLT region. These works demonstrate presence of a long period (longer than 2 days) oscillation in the ionosphere. However the wave excitation and propagation mechanism (contribution of wave dynamics from the lower atmosphere and influence of magnetic disturbances, etc.) are still open question.

Ionospheric F-layer base virtual height, h'F, is sensitive to the local electric field. Particularly in the magnetic equator region, where the magnetic field is horizontal, the ExB effect is mainly responsible for the vertical movement of h'F. The rapid rise of the F layer around sunset (18:00 Local Time (LT)) is caused by the enhanced zonal (eastward) electric field. This E-field is produced by the F layer wind dynamo in the evening side [Rishbeth, 1971]. Therefore if there is a day to day variability in h'F, it must be related to the day to day variability of the F region wind dynamo. During a magnetically quiet condition, the F-region dynamo is mainly controlled by thermospheric zonal wind. During the magnetically disturbed conditions, however this assumption can not be applied. Penetration of auroral E-field into the equatorial region and modulation of the thermospheric wind system caused by Joule heating in the auroral region could induce the h'F variability. But a periodic oscillation should not be expected in this case. Therefore the day to day variability of h'F could be a good indicator of the F-region dynamics related to the thermospheric wind system.

The purpose of the present work is to find out whether h'F in the equatorial region has any periodic oscillation. If there is, what is this oscillation related to ? Is there any influence from the MLT region or from some other factor ? In order to investigate these points, we chose two data sets, h'F and mesospheric airglow emissions observed in a same latitudinal zone, to find out any common feature between them. The MLT region winds observed at Jakarta were also compared with h'F.

Instrumentation

São Luís Ionosonde: Ionospheric data are measured by a Digisonde DGS256 that works as a pulse radar system with a wideband 10 kW peak power transmitter and precise fast-switching frequency synthesis, covering the frequency range from 0.5 to 30 MHz [Reinisch et al., 1989], installed at São Luís, Brazil (2.6° S, 44.2° W). The operation frequency is one ionogram each 15 min. The ionospheric parameter used in this work is the minimum virtual height of the F layer (h'F).

Cariri airglow photometer: A multi-channel filter photometer (MULTI-3) measures zenith intensity of the airglow emissions, OI 557.7 nm (hereafter OI5577), O_2b(0,1) band at 865 nm (hereafter O2) and OH(6,2) band at 847 nm (hereafter OH). The photometer characteristics has been reported elsewhere [Takahashi et al., 1989]. The photometer sensitivity was calibrated using a laboratory standard light source (Eppley ES-8315). Estimated errors in the absolute intensity for OI5577 is approximately 5 %, and for OH and O2 the errors are around 10 % owing to the increased systematic error in calibration.

Observation and Results

Airglow observation was started on a routine basis at São João do Cariri (7.4° S, 36.5° W) in January 1998. The observation site is located in a dry weather region in Brazil, permitting continuous observations. An Ionosonde (Digisonde) has been installed at São Luís (2.6° S, 44.2°W) in 1994, working on a continuous basis. The two sites are separated by approximately 1000 km. In the present analysis a data set of one year from March 1999 to February 2000 was used.

Nocturnal and day to day variations of the ionospheric F-layer bottom height (h'F) are investigated. In order to find out periodic oscillation, the Morlet wavelet spectral analysis was applied for the h'F time series, and the results are shown in **Figure 1**. The h'F time series used are for 20:00 and 21:00 LT from March 1, 1999 to February 28, 2000. The circled areas indicate where the oscillation was identified with a significance level higher than 90 % and the gray scale shows spectral density. The power spectrum of 21:00 LT shows much clear evidence of oscillation. The 2 day and 4 day oscillations are clearly identified, although the 4 day oscillation is rather wide band, between 3 to 5 days.

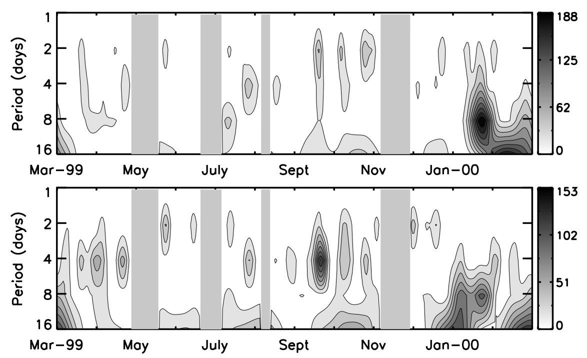

Figure 1. Wavelet power spectrum of the h'F time series, a fixed local time at 20:00 LT (top) and 21:00 LT (bottom), from March 1, 1999 to February 28, 2000. The rectangular gray areas indicate no data during the period.

For the airglow data time series, it is difficult to apply the wavelet analysis, because the series are not continuous but discrete. To find out periodicity of them, therefore, we used Lomb Scargle (LS) spectral analysis for each monthly group. The LS spectral analysis was applied for all of the airglow time series grouped in each moon period and the periodic oscillation features are compared with the h'F power spectrum. Due to some lack of the data between the two time series, not all of the data could be compared with each other. Except these months, most of the months showed a good coincidence in their oscillation period. In **Figure 2** the LS periodogram of the OI5577 and OH-T are compared with the h'F power spectrum for three groups those showed a good coincidence. From March 9 to 26, 3 to 4 day oscillation of the OI5577 and OH-T can be seen. During this period, the h'F spectrum showed a 3-5 day oscillation. For the interval of June 5 to 20, the airglow emissions showed strong 2-3 day oscillations as mentioned in the Figure 3. In the same period, the h'F series showed a quasi 2 day oscillation. In the period of September 3 to 14, the airglow showed a strong 4-5 day oscillation and h'F also showing a 4-6 day oscillation. Only one group of data (April 7-21) had no coincidence of oscillation between the airglow and h'F.

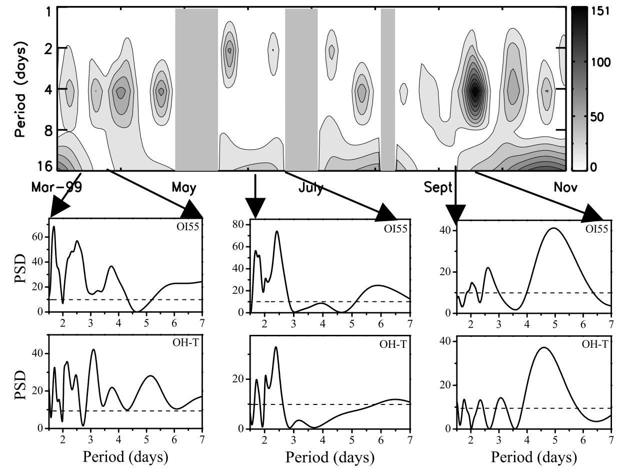

Figure 2. Comparison between the wavelet power spectrum of the h'F time series (top) and the Lomb Scargle power spectrum of the mesospheric airglow OI5577 and OH temperature time series (bottom). The arrows show the period of airglow observation along the h'F time series.

Discussion and Summary

There are several factors to be considered for the day to day variability of h'F during the evening period in the equatorial region. Electric field penetration from the polar ionosphere during the magnetically disturbed condition is one of them. Modulation of the global scale thermospheric wind system due to Joule heating in the polar region should be another one. These are, however, sporadic phenomena related to the magnetic disturbance. Another factor to be considered should be variation of the thermospheric wind system. It is well known that the thermospheric wind has a strong diurnal oscillation migrating with the sun. In addition to the migrating wind system, some planetary scale wave propagations are also present as mentioned previously. The present results of the common feature between the airglow and ionospheric h'F day to day variability strongly suggest a possibility of that they have common sources in the equatorial region. It could be related to the dynamics in the MLT region, Rossby –gravity waves and Ultra Fast Kelvin waves (Vincent [1993] and Takahashi et al. [2002]). Generation of the oscillation by the other sources, geomagnetic activity for example, would also be possible and to be further investigated.

Acknowledgments:

São Luís ionosonde (Digisonde) is in operation under responsibility of INPE. The authors thank Goreti Aquino who reduced the ionogram and F. C. Bertoni for useful discussions. Airglow photometer (Multi-3) is in operation under collaboration with Federal University at Campina Grande.

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