OI557.7 nm nightglow intensity from F-region observed at 7.4°S

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Abstract

At equatorial region, OI557.7nm airglow is produced at two distinct layers, one at ~97km (mesosphere) and the other at ~250km (F-region) of altitude. The OI557.7 nm from mesosphere is excited by a two-step mechanism (Barth mechanism) but, at F-region, OI557.7 nm and OI630 nm emissions are due to the dissociative recombination process ($O_2^+ + e^- \rightarrow O + O^*(^1D,\ ^1S)$). Airglow observations from ground stations measure the total OI557.7 nm intensity which is not interesting when mesospheric and/or F-region information are separately requested. The goal of this work is to determine the contribution of F-region to total OI557.7nm intensity. Strong intensity depletion of both emissions simultaneously occurs when a plasma bubbles is present at the emission layer. Because this, it was possible to determine that the ratio between OI557.7nm and OI630 nm intensity, in average, was 0.31±0.08. The data set correspond to a period of intensity observation by a multi-filter photometer from January 1998 to June 2001 installed at São João do Cariri (7.4°S, 36.5°W).

Introduction

The excitation mechanism of OI557.7nm (hereafter green line) was proposed at the first time by Chapman (1931). Barth (1961) proposed, for the green line from mesosphere, a two-step excitation mechanism represented by the reactions $O(^3P) + O(^3P) + M \rightarrow O_2^* + M$ and $O_2^* + O \rightarrow O_2 + O(^1S)$ where O_2^* is an excited state of O_2 formed directly in the recombination process. This mechanism is similar to the $O_2(0,1)$ atmospheric band excitation (McDade et al., 1986), because this, except to the phase, both temporal emissions intensities are nearly the same (Buriti et al., 2001). At F-region altitudes, where OI630 nm (hereafter red line) and green line also are emitted, the excitation mechanism consists of a dissociative recombination process $O_2^+ + e^- \rightarrow O + O^*(^1D,\ ^1S)$ (Peterson and Van Zandt, 1969). The green and the red lines come when the state ^1S and ^1D decay, respectively. It is known that the green line intensity is stronger at the mesosphere than at F-region (Takahashi et al., 1990; Sobral et al., 1992). Ground-based and rocket observations of green line and red line from F-region provide a latitudinal dependence of the ratio between OI557.7 and OI630 intensities, from 17 and 26% (Silverman, 1970; Takahashi et al., 1990; Fagundes et al., 1995).

Both emissions from atomic oxygen respond to a passage of a plasma bubbles. In this case, the intensities measured by the photometer, decay abruptly because the volume emission rate, of both emissions, is proportional to the electron density (Sobral et al., 1992). Simultaneous observation of red line, green line and $O_2(0,1)$ can inform the causer of the intensity variation.

Observation and Instrumentation

The data set used in this work corresponds a period of observation from January 1998 to June 2001 at equatorial region (7.4°S, 36.5°W). Simultaneous intensity emission of red line, green line and $O_2(0,1)$ was measured by an airglow spectrophotometer, Multi-3, which has been constructed at INPE with a purpose to measure airglow zenith intensities of OI5577, OI6300, NaD, OH(6,2) and $O_2(0,1)$, in addition to the rotational temperatures of OH and O2(0,1). The observations were carried out for 13 days a month during the new moon period. The photometer has an aperture of 50 mm diameter and the field of view of 2^0 full angle. Five interference filters with 62.5 mm diameter are mounted in a temperature controlled filter wheel. Wavelength scanning is carried out by tilting the filter against the photometer optical axis. The temporal resolution for each observation is about 2 minutes. The other characteristics about the Multi-3 have been published elsewhere (Takahashi et. al., 1989). A PC type personal computer is used to control the Multi-3, and to process the data, calculating intensity and temperature on real time. The equipment operates since November 1997 at the Observatory of Atmospheric Luminescence of Paraiba (OLAP).

The data set should satisfy two conditions: fast variation of red line and green line intensities at the same time due the presence of a plasma bubbles crossing the field of view of the photometer and slow variation of $O_2(0,1)$ intensity simultaneously. Because excitation mechanism of green line and $O_2(0,1)$ are similar, fast variation at both emissions is a strong evidence that the phenomenon occurred in the upper mesosphere, consequently this kind of data was rejected. The total of useful data during this period was 96 from 79 nights. January, February and December represented almost 82% of the data. September-November present only 17 data.

Figure 1 shows a good example of the presence of a plasma bubble cross the field of view of the photometer. The red and green line intensities decrease abruptly (~48.2%) from 2132LT to 2145LT while the $O_2(0,1)$ intensity varies slowly in this range of 13 minutes of observation. Figure 2 shows the image of the same plasma bubble detected by the photometer. This image, detected by a all-sky imager at 2142LT, shows the dark region at zenith position from North to South region.

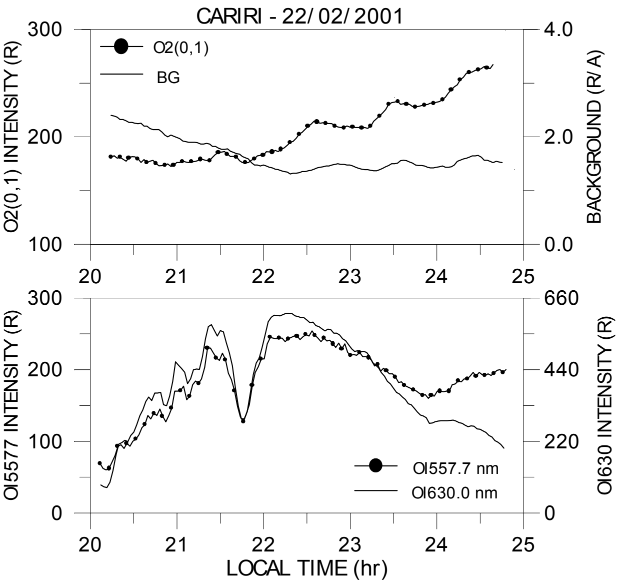

Fig. 1 – Nocturnal variation intensity of OI557.7 nm, OI630.0 nm and $O_2(0,1)$ band measured on 22/23 February 2001. Background variation intensity also is showed.

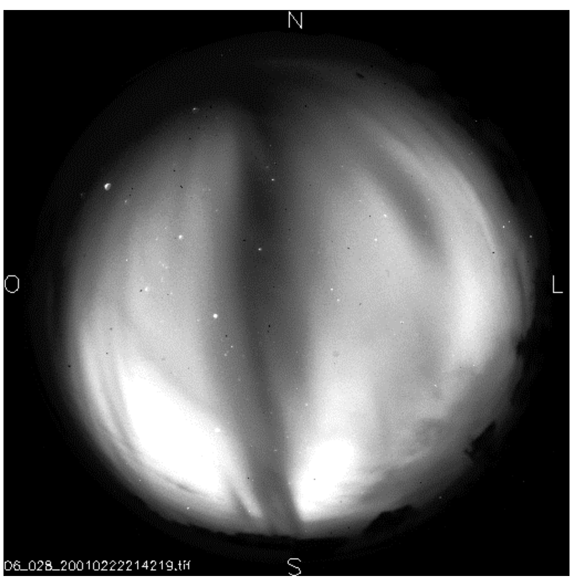

Fig. 2 – The plasma bubble detected by a all-sky imager on 22/02/2001 at 2142LT.

Results and Discuss

In order to obtain contribution of green line from F-region, it is necessary to measure the intensity of green and red lines just before and during the passage of a plasma bubble by the field of view of the photometer. The equation which relates the green and red lines intensities is given by (Fagundes et al., 1995):

$$r = \frac{\Delta I_{g(F)} + \Delta I_{g(M)}}{\Delta I_{r(F)}} \cong \frac{\Delta I_{g(F)}}{\Delta I_{r(F)}} \qquad (1)$$

where Δ is the difference between the intensity of the green line (*g*) (or red line (*r*)) intensity at F-region (or at upper mesosphere (M)) before and during the plasma bubbles occurrence. If the Equation (1) is open, then:

$$I^{B}_{g(F)} = I^{B}_{r(F)}\ r\ + I^{D}_{g(F)} - I^{D}_{r(F)}\ r \qquad (2)$$

where *B* and *D* means before and during the plasma phenomenon.
According to Equation (2), the green line intensity is proportional to red line intensity at F-region. The mean of *r* was 0.312 ± 0.082. According to Figure 3, values between 0.1 and 0.55 were observed. About 45% of data observed are between 0.25 and 0.35.

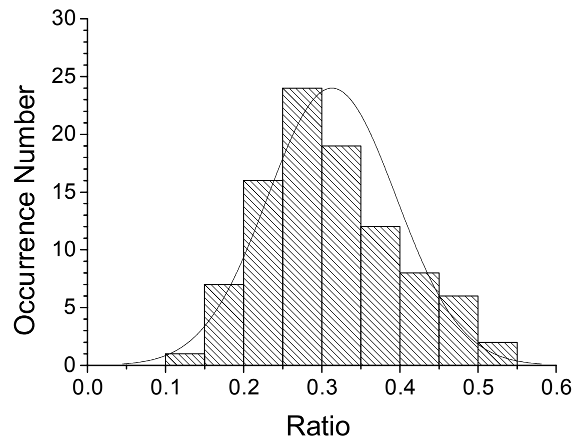

Fig. 3 – Number of occurrence of *r* observed in Cariri from 1998 to 2001.

The Figure 4 shows the result of every ratios *r* calculated by the Equation (1) from 24/01/1998 to 22/02/2001. It was possible to obtain more than one *r* values at the same night because some intensity depletions during the night satisfied the conditions to obtain the ratio. This figure shows a probably increase of *r* which is coincident with the maximum solar activity. There is not any information about ratio *r* between March and September. One of the reasons is that plasma bubbles are rare during these months and practically does not exist between June and August.
Some values of *r* have been obtained by different techniques since 1970. Simultaneous measurements of red line and green line by a photometer on board a rocket have presented different values of *r*. Observation at White Sands (32°N, 106°W) made by Gulledge et al. (1968), obtained *r* = 0.20. Sharp et al. (1975), at Wallops Island (38°N, 75°W) obtained *r* = 0.15. Takahashi et al. (1990), at Natal (6°S, 35°W) obtained a mean value of *r* = 0.17 but scattered between 0.25 at 200 km of altitude and 0.09 at 310 km. At emission peak (230km) the value observed was 0.21. Fagundes et al. (1995), made a study similar to ours but they had ionosonde data. They plotted values of

r as a function of F-2 peak height. The result was a no dependence of *r* with peak height between 200 and 240 km. Outside this range, the values of *r* decreased. Variation of *r* with height could be attributed to $O(^1D)$ quenching that makes the red line intensity increase when the quenching decrease (Takahashi et al. 1990).

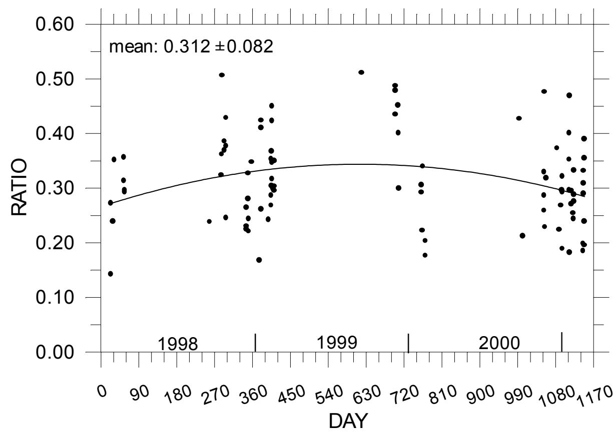

Fig. 4 – Ratio *r* during 3 years (dot). The line curve is a fitting in order to show a probably increase during maximum solar activity.

Conclusion

The contribution of F-region OI5577 to total intensity of green line airglow emission observed by a photometer at ground has been determined in this work. The analyses showed that green line intensity from F-region is about 31% of the red line intensity. Two results should be investigated deeply: the value of *r* depends on the latitude where the observation was done, because as near the equator, as larger the ratio and the ratio apparently depends on solar cycle.

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Reference

Barth, C. A. The 5577-angstrom airglow. *Science* 134, p. 1426, 1961;

Buriti, R. A.; Takahashi, H.; Gobbi, D. Temporal variation of the volume emission rates between OI5577 and $O_2(0,1)$. *Adv. Space Res*. 27, pp. 1159-1164, 2001;

Chapman, S. Some phenomena in the upper atmosphere. *Proc. Roy. Soc. Lond*. A132, p. 353, 1931;

Fagundes, P. R., Y. Sahai and Takahashi, H. Investigation of OI557.7nm and OI630 nm nightglow intensity ratios during the occurrence of equatorial F-region plasma bubbles. *J. Atmos. Terr. Phys*. 57, 8, pp. 929-932, 1995;

Gulledge I. S., Packer D. M. Tilford S. G. e Vanderslice J. T. Intensity profiles of the 6300Å and 5577Å OI lines in the night airglow. *J. Geophys. Res*. 73, 5535, 1968;

McDade I. C., D. P. Murtagh, R. G. H. Greer, P. H. G. Dickinson, G. Witt, J. Stegman, E. J. Llewellyn, L. Thomas, and D. B. Jenkins. ETON 2: Quenching Parameters for the Proposed Precursors of $O_2\left(b^1\Sigma_g^+\right)$ and $O(^1S)$ □557.7 nm in the Terrestrial Nightglow. *Planet. Space Sci.*, **34**, 9, pp. 789-800, 1986;

Peterson, V. L. and Van Zandt, T. E. $O(^1D)$ Quenching in Ionosphere F-region. *Planet. Space Sci.*, 17, p. 1725, 1969;

Sharp, W.E.; Rusch, D.W.; Hays, P.B. Dissociative Recombination Source for OI (^1D) Atoms. *J. Geophys. Res*. 80, 2876, 1975;

Silverman, S. M. Night airglow phenomenology. *Space Sci*., 11, p. 341, 1970;

Sobral, J. H. A.; Takahashi, H.; Abdu, M. A.; Muralikrishna, P.; Sahai, Y.; Zamlutti, C. J. $O(^1S)$ and $O(^1D)$ quantum yields from rocket measurements of electron densities and 557.7 and 630.0 nm emissions in the nocturnal F-region. *Planet. Space Sci.*, 40, No. 5, pp. 607-619, 1992;

Sobral, J.H.A .; Takahashi, H.; Abdu, M.A. ; Muralikrisma, P.; Sahai Y. ; Zamlutti, C.J. $O(^1S)$ and (D^1) Quantum Yelds from Rocket Measurements of Electron Densities and 557,7 and 630,0 nm Emissions in the Nocturnal F-Region. *Planet. Space Sci.,* 40 (5), 607-619, 1992;

Takahashi H.; Clemesha, B.R.; Batista, P.P.; Sahai,Y.; Abdu, M.A. ; Muralikrisma, P. Equatorial F-Region OI6300 Å and OI5577 Å Emission Profiles Observed by Rocket Borne Airglow Photometers. *Planet. Space Sci*., 38 (4), 547-554, 1990;

Takahashi, H., Y. Sahai, B.R. Clemesha, D.M. Simonich, N.R. Teixeira, R.M. Lobo, and A. Eras. Equatorial Mesospheric and F-region Airglow Emission Observed from Latitude 4 South. *Planet. Space Sci.* **37**(6), 649-655, 1989.