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First OI6300 and OI5577 Airglow Observation Results from 7.5^0 S

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Abstract

The Cariri Airglow Observatory has been started working since November, 1997. This observatory has a multi-filter photometer to measure the airglow emission intensities OI5577, OI6300, NaD, OH(6,2) band, O2 Atmospheric (0,1) band , and the OH and O2 rotational temperatures. The observatory is located at Sao Joao do Cariri, the driest region in the Northeast of Brazil at 7.4 S, 36.5 W. Continuous observation from day to day (13 days around the new moon period) make it possible to study nocturnal, day to day and seasonal variation of the airglow intensities. The nocturnal variations of OI6300 and OI5577 emissions show strong seasonal dependence, maxima during the equinox and minima in the solstices, and the phase of maxima shifting from month to month. It indicates that tidal oscillation is important factor in the equatorial mesosphere. The thermospheric OI 6300 emission also shows significant seasonal variation. Salient features of the seasonal dependency will be presented and discussed in terms of the atmospheric dynamical processes.

INTRODUCTION

The airglow intensity of the atomic oxygen OI 557.7 nm (green line) from the mesosphere and from the low thermosphere is due two distinct processes. The earlier comes from where the concentration of atomic oxygen is maximum, it is around 97 km of altitude. The excited $O(^1S_0)$ state decay to a lower state ($^1D_2$) emitting green line. The excited state, represented by " * ", is produced by a two-step process ($O + O + M$ (O_2 and N_2) $\rightarrow O_2^* + M$ then $O_2^* + O \rightarrow O(^1S_0)$). In the Thermosphere $O(^1S_0)$ is produced by dissociative recombination of ionised molecular oxygen with electrons ($O_2^+ + e \rightarrow O + O(^1S_0)$).
The other emission from atomic oxygen is the OI6300 (red line) and comes from the F-layer (250-300 km). It is produced also by dissociative recombination of ionised molecular oxygen with electrons but, in this case, the red line is due the decay from $O(^1D_2)$ to $O(^3P_2)$.
The observation of these two emissions is a powerful tools for study the chemistry and the dynamics from mesosphere and thermosphere region. The seasonal behavior of the airglow intensity amplitude and phase from equatorial region has not been extensively studied (Wiens and Weill, 1973, Takahashi et. al. 1998). Difficulty in carrying out airglow observation in the tropical zone is one of the reasons for the lack of the data.

THE SITE

The observation site was set up inside of area of meteorological station of the Federal University of Paraiba, UFPB, at São João do Cariri (7^{0}23' S, 36^{0}32' W), located in the Northeast of Brazil. It is relatively small city with population of around 4,000, providing less citylight effect for airglow observation. The city is located with a height of 500 m above sea level and the local climate is dry, around 20-35% of humidity at 3 o'clock p.m. during the summer season. This region is considered the driest place in Brazil. Because the region is dry the presence of clouds is not frequent, providing good observation condition. The biggest city (Campina Grande with about 300 thousands habitants) near the observatory is 80 km distance. The airglow observation instruments are installed inside a container (Figure 1), with a size of 2 x 3.5 m^2, with air conditioner working. There are two roof windows to look up the night sky.

Fig. 1 - Inside of container - The PC is used to operate the photometer (back).

INSTRUMENTATION

The Multi-3 has the purpose to observe the zenithal airglow emissions of OI5577, OI6300, NaD, OH(6,2) and O_2 besides the rotational temperatures of OH and O_2. The five tilting interference filters with 62.5 mm diameter are mounted in the filter wheel which has its temperature controlled. The Multi-3 has an aperture 50 mm diameter and a full of view of 2^0 full angle. The Table 1 shows the characteristics of two from 5 filters and their tilted positions. Others characteristics about the Multi-3 have been published elsewhere (Takahashi et. al., 1989). The temporal resolution for each observation is about 2 minutes. The Multi-3 was development in INPE and moved to Cariri in October 1997. A personal computer PC is used to operate the Multi-3. The values of airglow can be observed at the screen of the PC at local time.

Table 1 - Multi-3 Characteristics

Filter	Position	λ_0(Å)	$\Delta\lambda$(Å)*	Airglow
1	1	5577	10.65	OI5577
	2	5550	13.05	BG**
3	1	6300	11.7	OI6300
	2	6275	12.07	BG

* effective wavelength
** corresponding background continuum

OBSERVATION

Airglow observations were started on a routine basis at Cariri in November 1997. At Cariri it was only about 130 mm of rain precipitation in the whole year. Consequently many nights with good airglow observation condition were obtained. The observations were carried out for 13 days a month during the new moon period. Some of them with more than 9 hours with good clear sky conditions. A total of 142 nights of observation were chosen for the present work.

Monthly Average

The monthly average nocturnal variation was calculated considering every good data from each period of observation independently the temporal length of each night considered. The results are showing in the Figure 2. It is clear to see strong seasonal variation for all of the two parameters. They presented a minimum in winter of South Hemisphere. The fitted curve, obtained by least mean square, which represents the principal component of each parameter, was plotted superposed to respective parameter.

OI6300 The OI6300 presented a strong seasonal dependence. Its average presented maxima from February to April and from August to December. It presented also a small value in June. The difference between the maximum and the minimum from January to December was around 100R. The amplitude of variation was about 27 R.

OI5577 The behavior of OI5577 was similar to the last one but the variation between the minimum, in July, and the maximum, in November, was around 200R. It is about 10 times the minimum value. The reason was that the intensity of OI5577 presented values around 300 to 400 R from 19 to 24 hr in November. In order to eliminate the OI5577 from the F-layer, we subtracted the green line intensity from 20% of the OI6300 measured by the Multi-3 (Silverman, 1970; Takahashi et. al., 1989). The amplitude of variation was about 52 R. It is the double of OI6300.

Nocturnal Variation - Contour Map

The nocturnal variations of airglow and rotational temperatures are showed in the next two figures. Each tick at the abscissas means a specific night of each period of observation. The label below the abscissas means the beginning and the end day of each period. The ordinates represent local time; “25hr”, for example, means 1 a.m. and so on. The colour scale represents the intensity levels. The white blocks indicate no data, due to bad sky condition. The data were not applied any kind of smoothing process. These figures do not permit to study short period oscillation such as the gravity wave but it is possible to see day to day and seasonal behavior of the emissions.

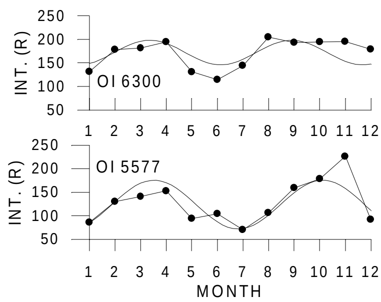

Fig. 2 – Seasonal variations of the monthly mean values of the airglow intensities observed at Cariri.

OI6300 The Figure 3a is a contour map of OI6300 from January to December of 1998. The contour map shows that the OI6300 has a maximum intensity during the night and it is progressively shifting from midnight in March/April to early evening in June/July. These maxima had a temporal width between 3 and 5 hours. In general, every night observed presented a large variation of the intensity. The OI6300 exceptionally had a large intensity between October 19 and 22.

OI5577: The behavior of the OI5577 intensity during the year is shown in the Figure 3b. According to Figure 2, the average is low in summer and winter solstices and high in the equinox. This feature is easily noted in the figure. Besides this seasonal variation, the OI5577 always presented high values in the begin of the night and quickly decreased to the end of the night. Some nights showed an increase after 2 a.m. In October and November, some nights presented a large intensity during whole the night.

DISCUSSION

The observed airglow intensities of red and green lines clearly show a semi-annual oscillation at the equatorial region. Cogger et. al., 1981 studied data observed from satellite and concluded that the amplitude of the semi-annual oscillation of OI5577 rises towards higher latitude. Garcia and Solomon (1985) predicted that the amplitude decrease towards the equatorial region. Takahashi et. al., (1995) observed strong seasonal variation of OI5577 from 4^0S and from 23^0S. They concluded that the semi-annual oscillations in 23^0S are smaller than 4^0S.

According to the fitting plotted in Figure 2, the OI5577 showed the biggest ratio between annual mean (A_0) and the amplitude of the semi-annual component (A_1). The analysis of the data showed that the variation is quasi-semi-annual. The last line of Table 1 shows the periods of the two observed parameters. It is important to comment that there is an error in the period. When we plot the average of each month, we did not make any mention to the begging day and to the end day of each period of observation. For example, the month #1 is relative to observation between January 21 and February 2 and the month #12 is relative to the period between December 12 and 24.

Table 2 - Annual Mean (A_0), Semi-annual Component Amplitude (A_1) and Period Oscillation (T_1) in Month.

	OI5577	OI6300
A_0	123.7	172
A_1	51.6	26.7
A_1/A_0	0.42	0.15
T_1	6.6	5.5

It is well know that the F-region OI6300 intensity long-term variation is related to ionospheric dynamics when the F-layer moves vertically downward and upward. The presence of plasma bubbles was detected but it will not treated here. Although the average of OI6300 has presented a variation of 5.5 months in 1998, the peak of intensity showed a different behavior of OI5577 (Figure 3b). The maxima values of OI6300 have stayed in the middle of the night, from 21 to 25 hr in January-March and in September-December. The other months, May-August, showed this peak towards dusk and come back to midnight.
The variation in OI5577 can be attributed mainly to the vertical movement of the atomic oxygen layer according to the seasonal period. Naturally this movement makes the concentration of atomic oxygen change and consequently the airglow, where the loss and the production of atomic oxygen are considered, are submitted to this long variation also. A singular increase towards dawn in OI5577 after a decrease from dusk to midnight can be seen in Figure 3b. Moreels et al. (1974) has explained this behavior as the result of less vertical mixing in equatorial regions resulting in no intensity increase in the OH intensity. It is easy to see it in March, May, September and October.

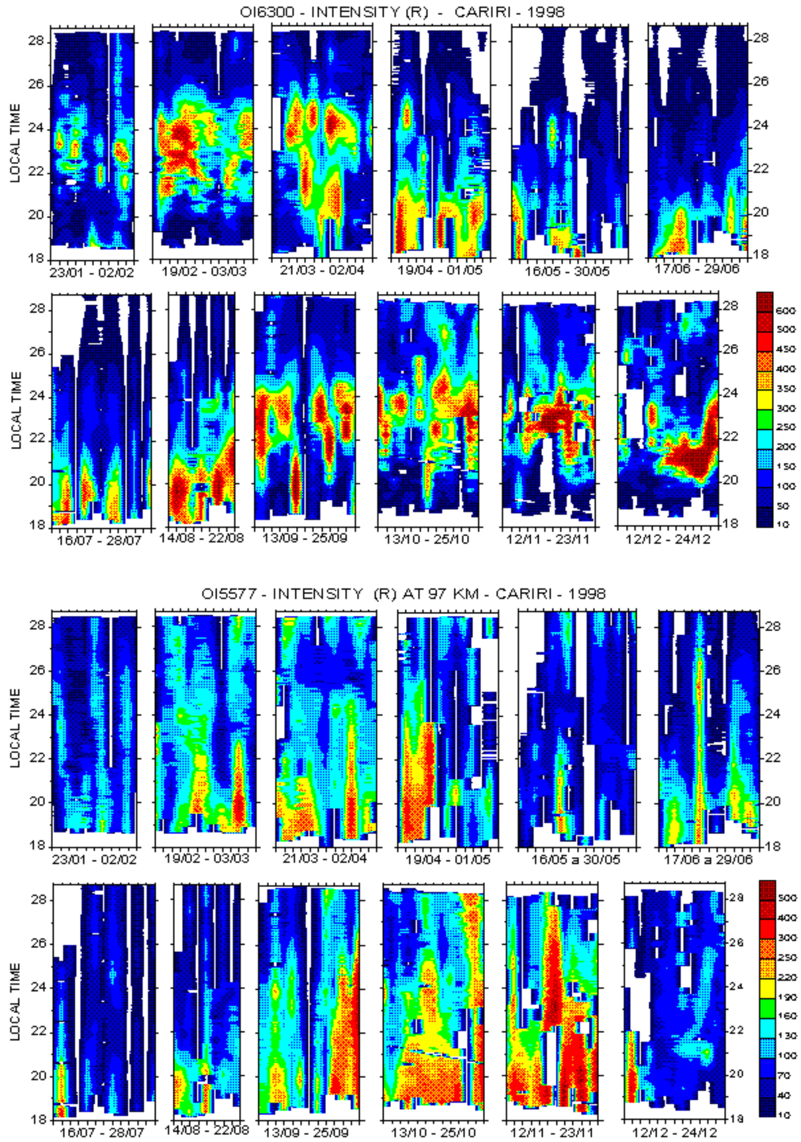

Fig. 3 - Contour map of airglow intensity of a) OI6300 (above) and b) OI5577 (below) observed at Cariri in 1998.

It is worthwhile to note that the intensity decrease from November (230 R) to December (80 R) is sudden and large.

Similar seasonal variation can be seen for the O2A band emission, although the amplitude of oscillation is smaller than OI5577. Such drastic change must be generated by sudden change of the atomic oxygen concentration and/or the emission height change suggested by Ward et al. (1997). Further investigation would be necessary in order to clarify the phenomenon.

CONCLUSION

The Cariri Airglow Observatory has showed an excellent site to study airglow by optical instruments on the ground. The geographical location and climate condition are favourable to observe the airglow. A total of more than 110 nights with more than 3 hours of continuous observation was obtained. The preliminary data analysis showed an evidence of strong semi-annual oscillation for the mesospheric airglow emission intensities. Periods of 5.5 months to OI6300 and 6.6 months to OI5577 were observed. The large number of data permitted to construct a contour map of the airglow of atomic oxygen, for every period of observation, which allows studying long term variation of airglow.

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