A REVIEW OF AIRGLOW OBSERVATIONS AT EQUATORIAL AND LOW-LATITUDES IN THE BRAZILIAN SECTOR

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INTRODUCTION

Airglow observations provide a convenient technique for sensing remotely the properties of the upper atmosphere. Simultaneous ground-based observations of several airglow emissions make it possible to determine the propagation of disturbances in the upper atmosphere, to reveal mutual correlations between atmospheric layers and to investigate the spatial time distribution of the atmospheric composition. In 1970, airglow observations were started at INPE. However, observations of several airglow emissions on a routine basis started in 1975 at Cachoeira Paulista (22.7°S, 45.0°W), Brazil, which is situated inside, both the equatorial ionospheric anomaly and the South Atlantic magnetic anomaly. Also, in 1986, airglow observations of several emissions were started at Fortaleza (3.9°S, 38.4°W), Brazil, situated near both the geographic and geomagnetic equators. In this review, a summary of the present observational facilities and some recent results will be presented. The interest in airglow measurements in the region of the South Atlantic magnetic anomaly dated back to the discovery of the radiation belts. The aeronomic effects of charged particle precipitations in the anomaly region have attracted considerable attention (see e.g. Silverman, 1970; Gledhill, 1976). Some of the recent observations in the South Atlantic magnetic anomaly are also presented and discussed.

PRESENT AIRGLOW FACILITIES

The present observational facilities include measurements of the F-region (OI 630 nm and 777.4 nm) and mesospheric (OH(9,4) 775 nm, O_2 atm. (0-1) 864.5 nm, NaD 589 nm and OI 557.7 nm) nightglow emissions from both C. Paulista and

Fortaleza. Observations of the O_2 atm. and OH bands are also used to measure rotational temperatures. Also, a 15 cm OI 630 nm Fabry-Perot interferometer to measure the thermospheric winds and temperatures is in operation at São José dos Campos. In a cooperative bilateral project with the University of Texas at Dallas, a photometer is operated at C. Paulista to observe the N_2^+ 427.8 nm and H_β 486.1 nm nightglow emissions excited by energetic particle precipitation at low latitude during magnetic disturbances. In another bilateral project with Boston University a low light level imaging system is operated at C. Paulista. In its present configuration, the imaging can be used to study the OI 630 nm or 557.7 nm or NaD 589 nm nightglow emissions.

SOME RECENT RESULTS

a) Mesosphere and Lower Thermosphere

Simultaneous measurements in four nightglow emissions have been reported by Takahashi et al. (1985). It was observed that intensity enhancements appeared first in the OI 557.7 nm emission and thereafter in the sequence O_2 8645 nm, NaD 589 nm and OH (8-3), indicating a downward phase propagation (velocity ~6 km h^{-1}), implyng an upward transport of energy (gravity wave). Also, during 25 nights of simultaneous meridional scanning observations of the OH (8-3) and NaD emissions, wave effects were observed on two nights.

Takahashi et al. (1986) have observed that thé diurnal pattern of the O_2 atm. emission is similar to that of the OI 557.7 nm emission. The rotational temperature of O_2 atm. roughly covaries with that of OH but has a larger amplitude and occasionally leads that of OH. Takahashi et al. (1984) have reported that there is a semidiurnal oscillation in OH temperature.

b) F-region

In a series of papers, F-region equatorial irregularities, which are characterised by ionization depletions commonly known as equatorial plasma bubbles, have been investigated. Observations of depletions in the OI 630 nm emission have been reported by Sobral et al. (1980, 1981) and simultaneously in the OI 630 nm and 777.4 nm emissions by Sahai et al. (1981a, 1983). Remote sensing of ionosphere

(F-region peak electron densities and peak heights) by using simultaneous observations of the OI 630 nm and 777.4 nm emissions have been reported by Sahai et al. (1981b, 1983) and Bittencourt et al. (1983). Using a long series of observations during the period 1975-1982, Sahai et al. (1988a) have investigated solar cycle and seasonal variations of the low latitude OI 630 nm emission.

c) **Energetic Neutral Atom Precipitation**

Dessler et al. (1961) and Prolss (1973) have discussed the precipitation of ring current particles as energetic neutral atoms. A fraction of energetic neutral atoms impacts the thermosphere at low and middle latitudes. Enhancements in the N_2^+ 391.4 nm and H_β 486.1 nm emissions during strong magnetic disturbances have been reported from Cachoeira Paulista by Tinsley et al. (1982), Rohrbaugh et al. (1983) and Sahai et al. (1988b).

SOUTH ATLANTIC MAGNETIC ANOMALY

Earlier observations of particle precipitation and aeronomic effects in the South Atlantic magnetic anomaly have been reviewed by Gledhill (1976; see also Silverman, 1970). Voss and Smith (1980) have presented the global zones of energetic particle precipitation in the nighttime atmosphere during disturbed magnetic conditions. In the South Magnetic anomaly region, they have identified that the principal maximum in precipitation intensity occurs near $L = 1.4$ with a secondary maximum near $L = 2.6$ (south-east to the Brazilian Magnetic Anomaly region of low magnetic field intensity (0.25 Gauss contour)). Also, Datlowe (1985) reported observations of multiple peaks in energetic (100-1000 KeV) electron spectra at low altitudes (250 km) in the South Atlantic magnetic anomaly region, $1.2 \leq L \leq 2.0$, at all levels of geomagnetic activity. Gledhill and Hoffamann (1981) have reported observations of 0.2 to 26 KeV electrons in the South Atlantic magnetic anomaly region, but their observations surprisingly indicate that this energy flux decreases as Kp increases. Voss et al. (1985) have reported the development of a temporary equatorial zone ($\pm 20^\circ$ geomagnetic latitude) of ion radiation belt ($E > 45$ KeV at 240 km) during magnetic disturbances. These recent studies have identified global zones of precipitating energetic particles outside the auroral zone as well as pattern in the South Atlantic Anomaly region.

Kroll et al. (1977) observed an increased particle flux by the EUV spectrometer on board the satellite Aeros A and B, centered around 30°S, 320°E. However, electron density measurements from the same satellite did not show any well-defined disturbance area (Sheikh et al., 1979). Anomalous electron temperatures (more than 1000 K above normal) have been reported by Oyama and Schlegel (1984) from measurements by the satellite EXOS-A (Kyokko), centered more on the South American continent during all levels of geomagnetic activity. The dark current measurements from the spectrometer on board the satellite Bulgaria - 1300 to measure airglow emissions (OI 630 nm, 557.7 nm and N_2^+ 427.8 nm) showed high count rates during geomagnetic disturbances, centered at 23°S, 315°W, but no anomalous airglow emissions are reported (Gogoshev et al., 1985). Teskaya and Tulupov (1984) have reported Kilo Rayleighs of N_2^+ 391.4 nm emission from observations on board the satellite Cosmos - 900 in the South Atlantic magnetic anomaly. However, only a few Rayleighs of N_2^+ 427.8 nm emission (intensity ratio I391.4/I427.8 ~3) were obsrved in the same region by the satellite Bulgaria - 1300 (Gogoshev et al., 1985), putting some doubts on the levels of intensities reported by Tverskaya and Tulupov (1984). Abdu and Batista (1977) and Batista and Abdu (1977) have reported sporadic-E enhancements in the Brazilian magnetic anomaly region following magnetic storm events. Knudsen and Sharp (1968) have reported nighttime F2-layer electron density enhancements (~300 km) centered around 25°S, 320°W. However, from a comparison of ionosonde data obtained at São Paulo (24°S, 47°W), kane and Paula (1982) observe that F_0F2 at Tucuman is in general larger than that at São Paulo. Ciner and Smith (1973) have reported annual variation of the OI 630 nm emission from El Leoncito (32°S, 70°W) for 1967 (average 10.7 cm flux = 143). A comparison of the annual average of OI 630 nm emission observed at Cachoeira Paulista for 1978 (incidently for the same average 10.7 cm flux of 143) with that at El Leoncito (140 Rayleighs) shows that the intensities at C. Paulista (300 Rayleighs) are more than twice.

It is evident from the above discussions related to the observations in the South Atlantic magnetic anomaly that there is enough evidence related to energetic particle precipitation in this region. However, the studies related to the aeronomic effects of energetic particle precipitations are rather limited and need further investigations.

CONCLUSIONS

Recently, several Japanese scientific satellites (e.g. Taiyo, Hinotori and Ohzora) have obtained valuable aeronomic data in the South Atlantic Anomaly region. Also, another Japanese scientific satellite EXOS-D is expected to be launched in 1989 in a high-inclination orbit. A proposal is made to look into the possibilities of joint analysis of the existing ground-based airglow data in the Brazilian sector in conjunctions with satellite data and to plan coordinated ground-based and satellite measurements during EXOS-D passes in this region. Such work would lead to a better understanding of the equatorial and low-latitude upper atmospheric phenomena.

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