Daytime measurements of optical auroral emissions from Antarctica

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Optical methods have enabled us to detect auroral emissions during daytime conditions, and to identify a narrow latitudinal region of energetic particle precipitation from the Indian station Maitri (11°38'E; 70°45'S; 62.8°S I-lat.) in Antarctica. These observations are new. The energetic particles originate within the closed geomagnetic field lines close to the plasmapause region and maximize ~0830 h MLT (Magnetic Local Time) (~1200 UT). Enhanced proton precipitation activity could also be inferred during a moderate geomagnetic storm, suggesting the enhancement/activation of acceleration mechanisms during this event.

THE auroral phenomenon, which is caused by the interaction of high-energy charged particles with the atmospheric constituents is usually considered to be restricted to ±75° to ±80° magnetic latitudes in the dayside and ±65° to ±75° magnetic latitudes in the nightside of the earth. Due to the different locations of the geomagnetic and the geographic poles, the region of maximum occurrence probability of aurora is in the form of an oval and this is usually referred to as the auroral oval. In the dayside, where the solar wind kinetic pressure distorts the dipole-like configuration of the geomagnetic field, a narrow region around 80° south and north geomag. lat., referred to as the cusp, gets connected to the interplanetary space. The solar wind particles would then be directly guided into this region while the ionospheric particles would freely escape into the interplanetary medium. In the dayside, the polar cusp is the only region that maintains direct contact with the solar wind plasma. From magnetic topology point of view the cusp gets mapped into the dayside magnetopause region. From the available information in the literature, mostly based on rocket and satellite measurements, it is known that the dayside precipitation in the cusp region is less energetic compared to the nighttime conditions and as a consequence the emissions would preferably occur at higher heights (~150 km and above as compared to 110–120 km during nighttime). Significant amount of atomic emissions are known to occur due to lesser collisional deactivation at higher altitudes. There are no systematic ground-based observations on the variabilities of the optical signatures of aurora during daytime till now, mainly because of the inherent difficulty in the detection and measurement of these faint features in the presence of bright background continuum. The only attempt, a pioneering one, to detect daytime auroral emissions was made by Noxon[1] from the high-latitude regions in the northern hemisphere using a scanning polarimeter. Though successful detection of these emissions was made from the conventional auroral zone, no systematic intensity measurements could be made because of the inherent limitation in the technique.

In recent years, a new method has been used at PRL for the detection of faint emission features which constitute only 0.1% of the bright background continuum[2]. This new method has been used for the measurement of airglow emissions during daytime clear-sky conditions and several new results have already been obtained from equatorial and low-latitude regions[3–5].

The limitation of the dayglow photometer of being able to monitor only one wavelength at a time has been overcome by the use of innovative spiral masks[6]. These appropriate changes in the optics and introduction of electronic gate scanning techniques have enabled near simultaneous measurements of three emissions at different wavelengths. A specially coated (3900–8000 Å) Fabry–Perot etalon has been used as a narrow-band spatial filter. The details of the measurement techniques would be presented elsewhere.

The choice of the filters was made so as to represent the high- and low-energy electron-excited as well as proton-excited emissions. The multiwavelength daytime photometer was operated in a meridional scanning mode pointing towards magnetic south, the look angles ranging from 10° elevation to zenith in steps. The look angle, the choice of filters and appropriate gate delays were programmed to be automatically selected by a personal computer. The meridional scans, once in three minutes, were repeated round the clock. The information obtained represents the intensity variation of the chosen wavelengths with time. Observations were made at N_2^+ 1Neg. bands at 3914, 4278 and 4709 Å (high-energy electron-excited), OI 5577 Å (low-energy electron-excited) and 4861 Å H_β (proton-excited) emissions. Figure 1 depicts the surface plots of the variations in intensities with time and invariant geomagnetic latitude on two days, viz. 6 Feb. and 19 Feb. 1994. The various latitudes have been estimated based on the typical altitude of emission and the look angles, for three wavelengths.

The most striking observation is a steep rise in intensities at all the three wavelengths, namely 4709 Å, 4861 Å and 5577 Å at around noon hours (UT). The enhanced intensities are confined to a narrow latitudinal zone centred around 64°S mag. lat. and extend by ~2° in latitude. Large wave activities are seen to be centred around the peak emission and the associated particle precipitation. Unlike the other emissions, the 5577 Å emission is centred at 63°S. The background variation of 5577 Å emission is considerably lesser than its noontime peak. These observations indicate that the region of 5577 Å emission is narrower while the high-energy electron-excited and proton-excited emissions have a larger spatial spread. The present observations could be visualized as follows. The regions of particle precipitation and excited emissions are geomagnetically controlled and are expected to have a fixed orientation with respect to the sun. Due to the separation between the geographic and geomagnetic poles and the consequent precession of the magnetic pole with respect to the axis of rotation, the observational site cuts through the region of deposition around noon. This could result in the type of observed variations.

On 6 Feb., when the magnetic disturbance level was moderate, (ΣK_p = 43–), the overall intensity levels were found to be higher than that on 19 Feb. ($\Sigma K_p = 31$) and also on other days when the level of magnetic activity was considerably lower. Further, beyond 68°S mag. lat. no enhancement in the emissions is seen. The boundary at 68°S and the level of wave activity are depicted in Figure 2, wherein the two-dimensional ground projection of 4861 Å (proton-excited) intensities on 4 days during the month of February are shown along with the magnetic activity level (ΣK_p). The curves represent constant-intensity contours. As mentioned earlier, the latitudinal extent of the emission region is confined to 64° ± 1°S. Further, it is clearly seen that the wave activity associated with peak emission/deposition of energetic particles is quite prominent. During magnetically

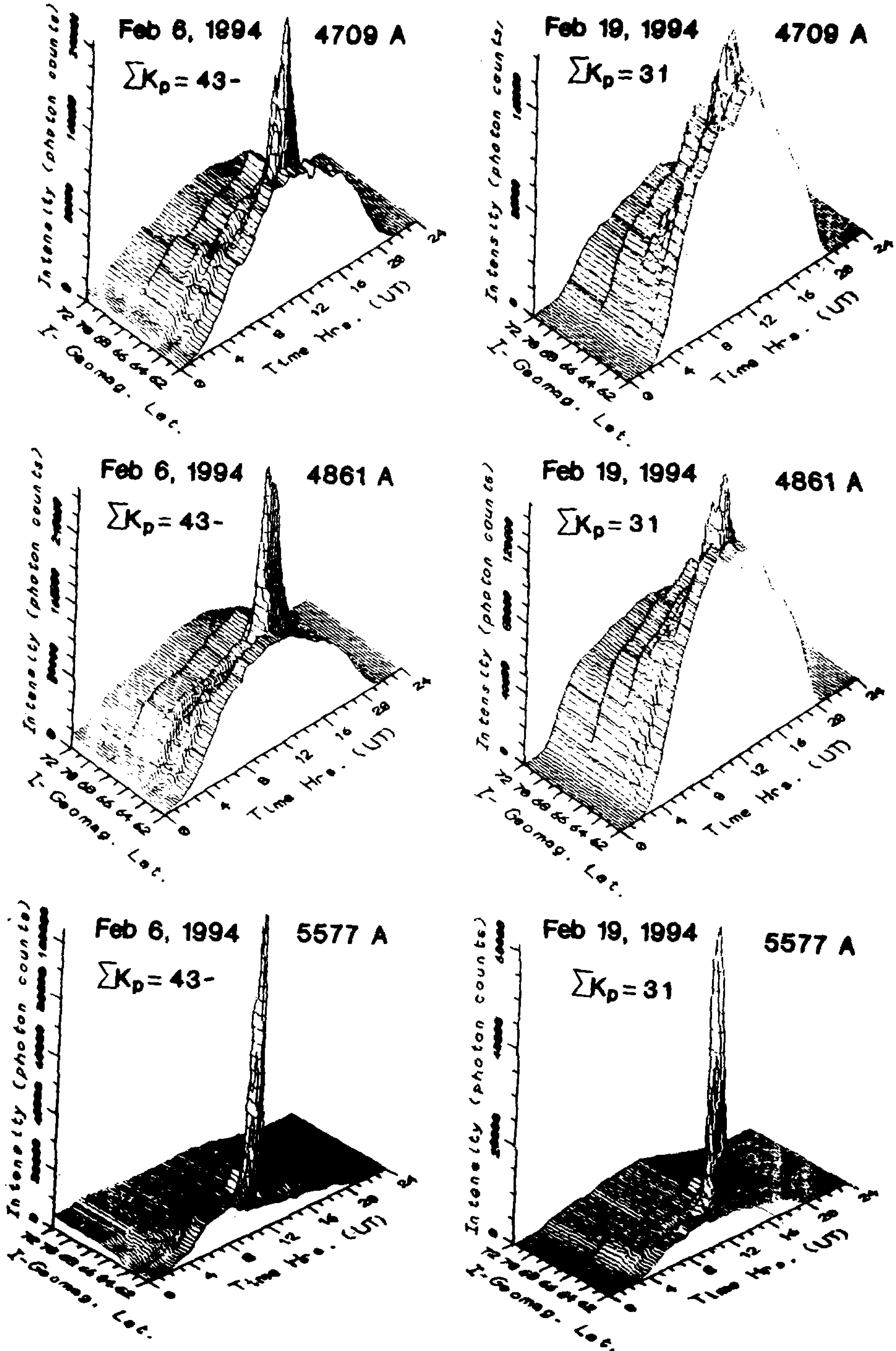

Figure 1. The temporal and latitudinal variabilities in the high-energy electron-excited (4709 Å), in proton-excited (4861 Å) and in low-energy electron-excited (5577 Å) daytime auroral emissions as recorded at Maitri – the Indian station at Antarctica – on 6 and 19 Feb 1994.

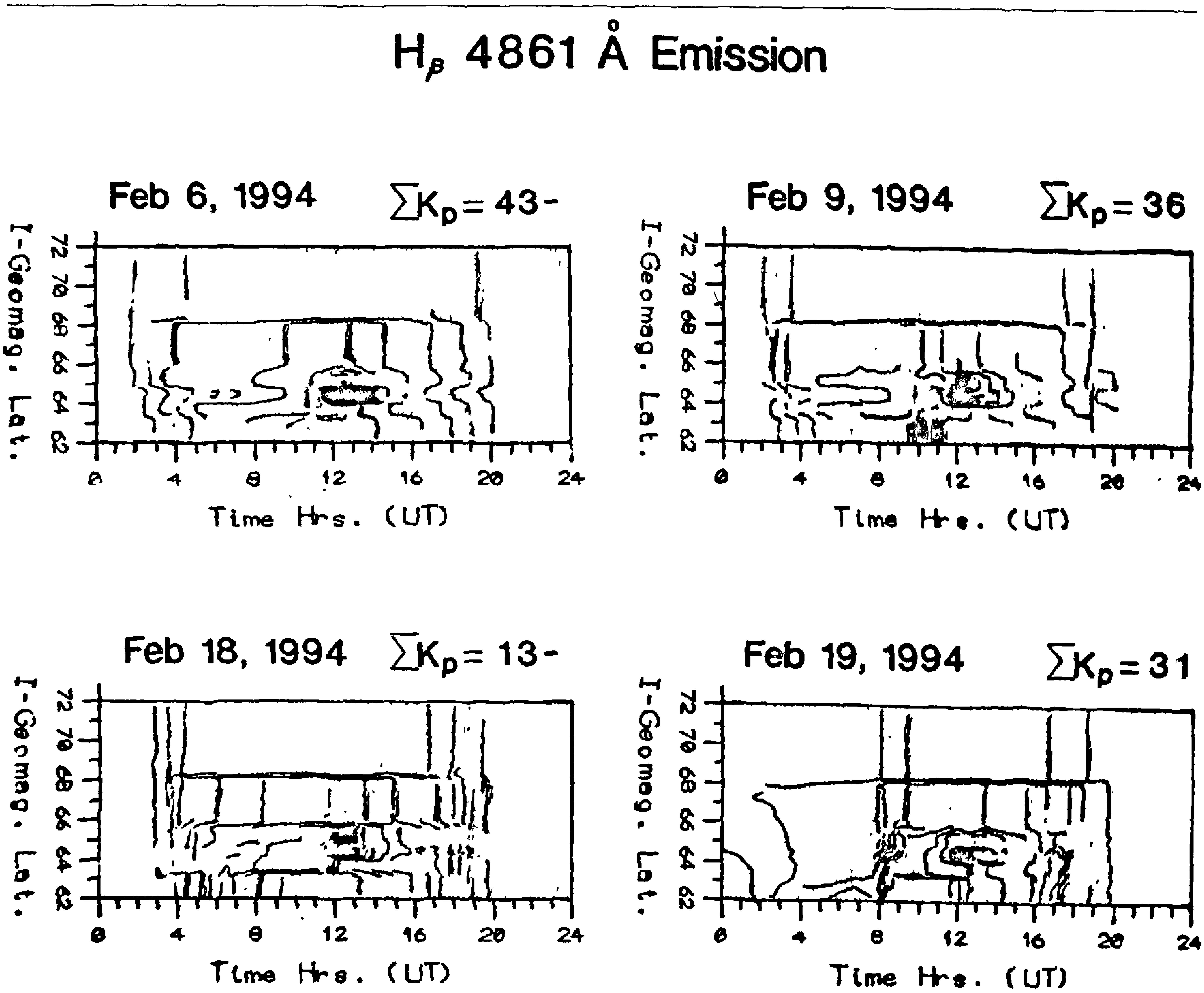

Figure 2. Ground projections of 4861 Å intensities during magnetically quiet and disturbed periods depicting the wave activity in the constant-intensity contours

quiet periods the wave activity is found to be low. Figure 2 shows the extent to which the activities are localized.

Though there have been no ground-based daytime optical measurements till now, it has been reported from the analysis of satellite data that there exists a region of particle precipitation in the ±60° to ±70° mag. lat., maximizing around 0630–1000 MLT[7]. Hartz[7] suggested that this rise in intensity in the forenoon hours could be due to the upper atmosphere acting as a sink for the particles in the outer Van-Allen belt region. Nighttime photometric measurements by Samson *et al.*[8] have also revealed narrow and sharply defined latitudinal zones of auroral emissions associated with electron and ion precipitations. Newell *et al.*[9] have attempted to classify regions of auroral activity based on satellite data and have mentioned the latitude zone of our interest to be possibly excited by particles originating from the central plasma sheet. VLF and ELF emissions have also been shown to maximize in this latitude zone around 0830–1030 MLT[10]. Through this communication, we are providing evidence, for the first time, from ground-based optical measurements for the presence of a narrow latitudinal zone of enhanced auroral activity in the daylit side of the earth. Incidentally, the L value of the Indian Antarctic station Maitri being 4.8, the geomagnetic field line passing through this station crosses the plasmapause – a critical transition region between the plasmasphere and the magnetosphere during the afternoon hours. The plasmapause is defined as the boundary between the magnetic flux tubes that corotate with the earth and those whose motion is dominated by the convective electric fields. Since the plasmapause is a sharply-defined region, elongated in the dusk sector[11], depending upon the solar wind ram pressure and the local time, the field lines over Maitri can be mapped either to the outer boundary of the plasmasphere or to the inner boundary of the magnetosphere. This makes it a unique location. Further, the enhanced intensities during a geomagnetic storm are a clear indication of a certain acceleration mechanism becoming more active during such events. A detailed investigation of the origin of the particles and their possible acceleration mechanism is in progress.

The present conclusions have been arrived at from the data collected on 13 clear days from Antarctica during January–February 1994 as a part of the XIIIth Indian Scientific Expedition. More extensive campaigns are being planned during the ensuing southern summer months.

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