SPATIAL CORRELATIONS BETWEEN RADIO AURORA AND 4278 Å AURORA INTENSITY

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Abstract: In order to study the spatial relation between 50 MHz-radar echoes and visual auroral forms, a photometer observing auroral emissions at 4278 Å was installed at Mizuho Station during the period from July to October, 1978. Several examples of the measurements are shown to discuss qualitative differences between the radio aurora and the optical auroras. It is shown that the correlation between optical and radio aurora intensities becomes poor in highly active aurora but is generally good for quiet aurora. Phenomena are found that the radio auroral intensities become low within auroral arcs.

1. Introduction

Auroral radar echoes are known to be produced by the fluctuations in ionization density. Auroral scatterings come mostly from the *E*-layer between about 100 and 130 km. The radar can detect only one particular spatial Fourier-component of the electron density fluctuations, equal to a wavelength $\lambda/2$ in the medium, where λ is the radio wavelength (6 m in this experiment). Using this character, many observers of VHF radio aurora have attempted to relate the position of radar scattering region to visual auroral forms. While workers agree that there is a close statistical correlation between the occurrences of radio aurora and visual aurora, the correlation between the positions of echo region and visual aurora for individual cases is controversial and poorly understood (HULTQVIST and EGELAND, 1964). A more specific investigation was attempted at Saskatoon (LYON, 1960; FORSYTH, 1961). The radar observations were made by using a bistatic system. The optical observations were made with an auroral intensity recorder which can look continuously toward the reflection-point of radio path. The correlation coefficients for optical and radio signal intensities showed considerable variation. BALSLEY *et al.* (1973) reported an example that radar echoes are not exactly spatially coincident with the visual form but rather they occur near the equatorward edge.

From the "aspect-sensitivity" character of radio aurora, it follows usually that radar echoes return from large distances. Therefore, it is sometimes difficult for a radar station to obtain good data of distant visual auroras. Fortunately, Japan has Mizuho Station (70°42′S, 44°20′E; geomagnetic lat. 72.3°S, long. 80.62°E) which is about 270 km away from Syowa Station (69°00′S, 39°35′E; geomagnetic lat. 69.6°S, long. 77.1°E) to the direction of magnetic south. Since the echo regions of the Syowa Station auroral radar having a southward radar beam are located nearly over Mizuho Station, a photometer observing the spectral component of 4278 Å was installed at Mizuho Station in July 1978 in order to study closely the spatial correlations between radar and optical auroras. The observations were made during the period of July to October 1978.

2. Observation Method

The view angle of the photometer at Mizuho Station is 5°, and the diameter is 10 km at the height of 110 km from which radar echoes return. The radar transmits pulsed 50 MHz (pulse width = 100 μs, pulse repetition frequency = 50 Hz). The transmitting and receiving antenna is a Yagi-type, the beam of which directs toward magnetic south. The elevation angle of the radar beam is about 25°. The half-power width is about 40° in both vertical and horizontal planes. The radar equipment has been described by IGARASHI *et al.* (1981). Fig. 1 shows the antenna pattern projected on the ground, along with the contours of aspect-angle α and L value. It is noted in Fig. 1 that $\alpha = 89°$ over Mizuho Station. Experimental configuration in the meridian plane is illustrated in Fig. 2. Scattering regions of the radar wave are nearly over Mizuho Station where α is approximately 90°. Auroral echo intensity (time resolution ≃ one minute) does not necessarily represent the local intensity just

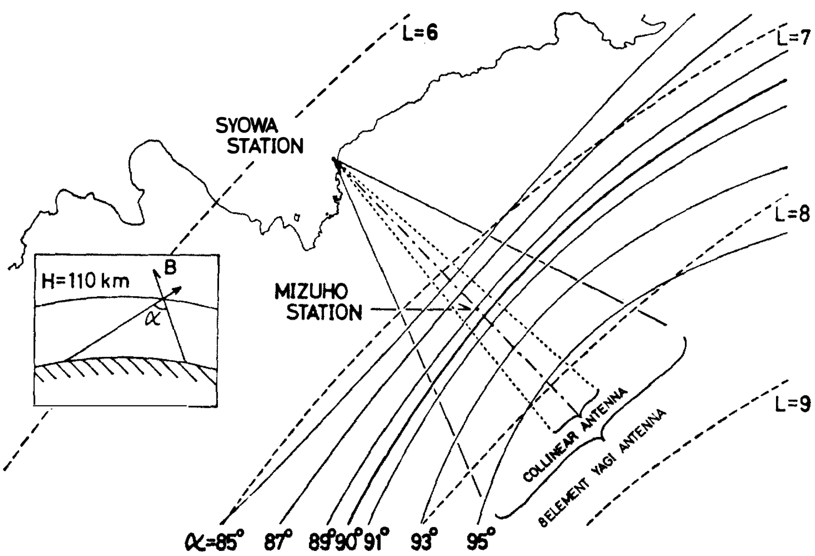

Fig. 1. Plan view of auroral radar antenna patterns along with contours of L value and aspect-angle for a height of 110 km. The inset defines the aspect angle α.

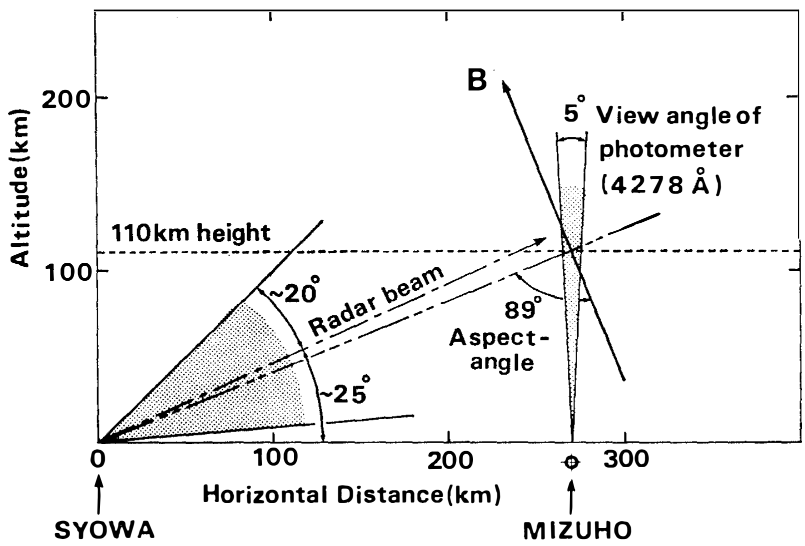

Fig. 2. Locations of the photometer and the region observed by the auroral radar. The elevation angle of the radar is 25°, the half-power beam width of the radar is about 40°, and the view angle of the photometer is 5°.

over Mizuho Station but is the peak value of the intensities detected in the large radar-beam volume. The radar-beam area centered over Mizuho Station is estimated to be roughly 100 km (N-S direction) × 200 km (E-W direction) which is far larger than that covered by the photometer. This indicates that we must be careful in comprehending the correlation of radar echoes with visual auroras. Time resolution of the optical aurora intensity is also one minute.

3. Experimental Results and Discussion

One example of the observations is shown in Fig. 3 which illustrates the time profiles of the optical aurora intensity, the magnetogram, and 30 MHz cosmic noise absorption (CNA) at Mizuho Station and the radio aurora intensity at Syowa Station from 2300 UT on August 3 to 0300 UT on August 4, 1978. From the figure, the following are found:

(1) Both the radio and optical auroras become strong at the onset time of substorms.

(2) The small-scale fluctuations of the geomagnetic H-component with periods below about 10 minutes exhibit a good correlation with those of the radio aurora intensity. When the radio aurora intensity increases, the H-component decreases.

(3) The radio aurora intensity is much more enhanced than the optical one during 0040–0100 UT, 0130–0145 UT and 0235–0250 UT. This may be due to the differences in the observing area between the radar and the photometer, as described

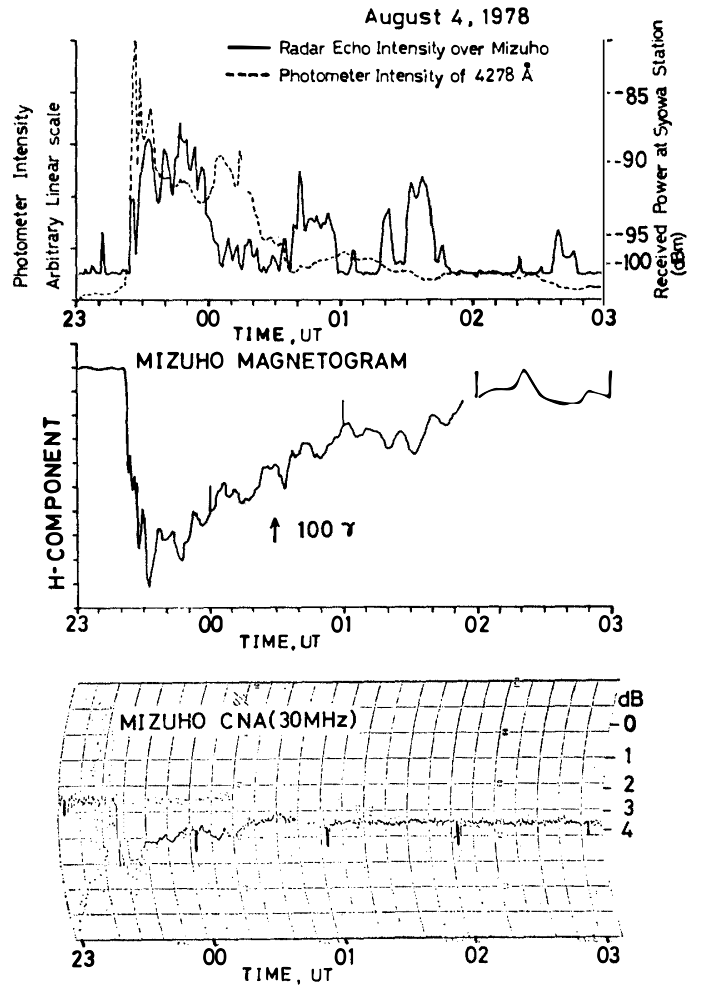

Fig. 3. Radio aurora intensity (50 MHz) and optical aurora intensity (4278 Å) [top], magnetic H-component at Mizuho Station [middle], and 30 MHz riometer record at Mizuho Station [bottom] on August 4, 1978.

in Section 2. The correlation becomes poor if irregularities appear outside the photometer view. Another possibility is that weak optical aurora and the irregularities produced by strong electric field coexist within the photometer view (see eq. (1)).

(4) On the contrary, the optical aurora intensity is more enhanced than the radio one during 0000–0030 UT. Radio aurora intensity depends on the amplitude of electron density irregularities. The following result is known from experimental and theoretical studies (Farley and Balsley, 1973; Sudan and Keskinen, 1979). The amplitude of density fluctuations is given by

$$<(\Delta N_e/N_e)^2> \propto V_d^2(\propto E_0^2), \quad (1)$$

where N_e is the electron density, ΔN_e is the density fluctuation of N_e, V_d is the drift velocity of irregularities, and E_0 is the electric field. Eq. (1) indicates that the fluctuation amplitude becomes small when E_0 is small. Then the received power also becomes small because the radar cross section is proportional to $<(\Delta N_e/N_e)^2>$. In this example it is inferred that the optical intensity was enhanced by the precipitation of auroral particles whereas the electric field was small resulting in a weak growth of irregularity.

The second example is shown in Fig. 4. From these data, the following results are found:

(5) In the explosive phase during 2310–2320 UT the radio aurora intensity has a good correlation with the optical aurora intensity.

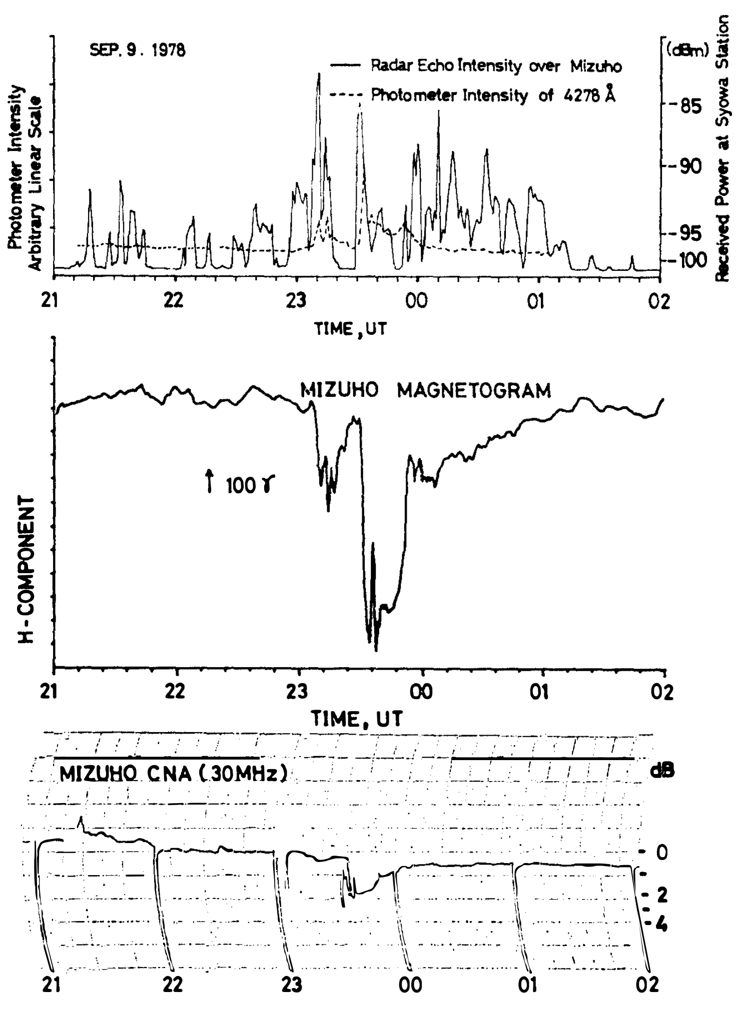

Fig. 4. Radio aurora intensity (50 MHz) and optical aurora intensity (4278 Å) [top], magnetic H-component at Mizuho Station [middle], and 30 MHz riometer record at Mizuho Station [bottom] on September 9, 1978.

(6) During 2330–0005 UT, the radio aurora intensity has also a good correlation with the fluctuations of about 10 minutes period of the *H*-component.

(7) It is difficult to interpret the fluctuations of the radio aurora intensity during 2100–2250 UT and 0005–0105 UT.

The third example is shown in Fig. 5. Fig. 6 shows the range-time-intensity (RTI) display during the time interval shown in Fig. 5. The records of all-sky camera are shown in Fig. 7. This is a typical example representating that quiet aurora arc elongating in the east-west direction moved toward magnetic south. Figs. 5, 6 and 7 indicate the following.

(8) The radio aurora intensity has a fairly good correlation with the optical aurora intensity when the aurora arcs were approaching Mizuho Station. However, the radio aurora intensity became small at about 1900 UT when the optical aurora intensity was maximum. After that a good correlation is sustained again. De La

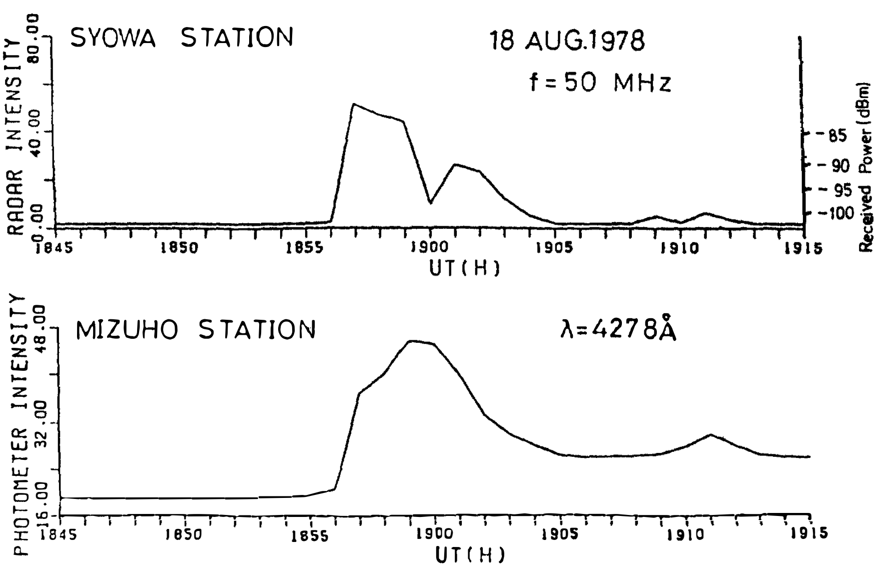

Fig. 5. Radio aurora intensity (50 MHz) and optical aurora intensity (4278 Å) measured when the auroral arcs passed over Mizuho Station. The time resolution of the record is one minute.

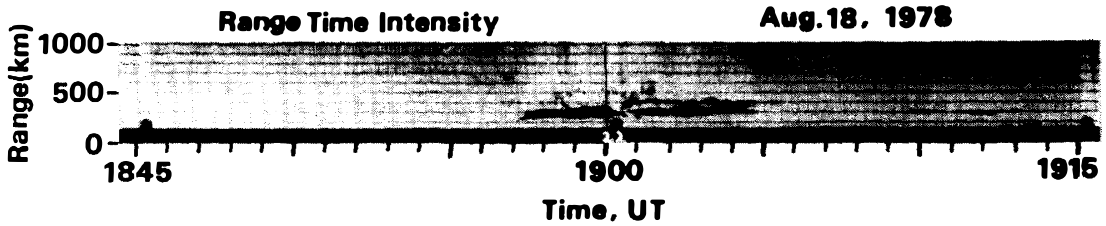

Fig. 6. Range-time-intensity of the radio aurora from 1845 to 1915 UT on August 18, 1978. The black stripes show the echo region.

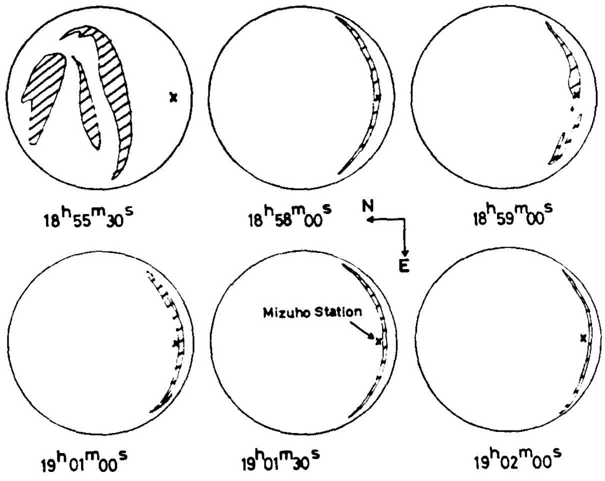

Fig. 7. Schematic all-sky photographs at Syowa Station from 1855:30 to 1902:00 UT on August 18, 1978. The hatched-area shows the region of visible aurora.

BEAUJARDIERE *et al.* (1977) showed by the radar observations of electric fields and currents associated with auroral arcs that the observed electric field decreased within the arcs in the early morning. This may be appropriate to the present case.

The third example shown in Fig. 5 is simpler in the auroral display than the other two examples examined earlier. The aurora belongs to a so-called quiet-arc type. For such a case it can be said that the optical and radar echo intensities have generally a good spatial correlation. Contrary to this, the auroras as presented in Fig. 3 were very active and highly variable in space and time. For such a case the correlation is often destroyed completely except at the initial phase of substorm.

4. Summary and Recommendation

By installing the photometer at Mizuho Station, Antarctica, the optical aurora intensity was compared directly with the radio aurora intensity. Both intensities are generally correlated in quiet auroral arc but the correlation becomes poor in highly active aurora except at the initial phase of substorm. The radio aurora intensities are largely enhanced when the magnetic H-component decreases, that is, when the electrojet-currents in the ionospheric E-region increase. An evidence that irregularity growth is suppressed in auroral arc was found.

If the spatial resolution of the radar is improved in future, the relation between particle precipitation and irregularity generation will be further clarified.

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