RELATIONSHIPS BETWEEN PULSATING AURORAS AND FIELD-ALIGNED ELECTRIC CURRENTS

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Abstract: On the basis of ground-based all-sky TV images of auroras and simultaneous data of magnetic fluctuations observed by MAGSAT, the relationships between pulsating auroras and field-aligned currents are examined. It is found that pulsating auroras are embedded in the southernmost region of the upward field-aligned currents, and that E-W component fluctuations of magnetic field at MAGSAT are related well to fluctuations in auroral luminosities along a trajectory of the magnetic foot point of MAGSAT at the altitude of 100 km. The period of fluctuations is about 5 s and the spatial extent of the pulsation corresponds to 40 km in horizontal size in one of the examples. Although the separation of temporal variations from spatial structures is not yet made, the good relationships between auroral and magnetic fluctuations indicate that pulsating auroral patches are accompanied by field-aligned pair currents relevant to each pulsating auroral patch.

1. Introduction

Irregular magnetic pulsations observed on the ground below a pulsating aurora have long been understood in terms of either HM waves which propagate down from the magnetosphere or electric current modulation caused by conductivity fluctuations in the ionosphere produced by pulsating electron precipitation. Recent studies mostly in relation to the cosmic noise absorption (*e.g.*, REID, 1976; HEACOCK and HUNSUCKER, 1977; ARNOLDY *et al.*, 1982) showed that the magnetic pulsation below a pulsating aurora is very likely due to electric current fluctuations in the ionosphere, because the wave form of magnetic pulsation is similar to that of cosmic radio noise absorption.

Most recently, OGUTI *et al.* (1984) and OGUTI and HAYASHI (1984a, b) showed evidence that the magnetic pulsation below pulsating auroras is understood in terms of two electric currents, a field-aligned pair current and a twin-vortex current, which are theoretically expected to be induced in a pulsating auroral patch due to pulsating enhancement of conductivity in the auroral patch. Although their results appear to explain successfully the causalities between auroral pulsations and ground magnetic pulsations, the ground magnetic variations used in their studies do not include the direct magnetic effects of field-aligned currents except those of the equivalent currents, because the poloidal magnetic field due to the field-aligned pair currents, as well as due to the current carried by the electron precipitation, cannot be observed in principle below the ionosphere (FUKUSHIMA, 1969). Thus, it is understood that the magnetic data above the ionosphere are essential in order to directly confirm the existence of these field-aligned currents associated with a pulsating auroral patch.

In order to examine the field-aligned currents related to pulsating auroras, the relationships between auroral and magnetic fluctuations are examined in this paper on the basis of all-sky TV image of aurora and magnetic fluctuations at MAGSAT locations linked to the pulsating patches by magnetic field lines.

2. Data and Analysis

Auroral data used in this study were obtained at Steen River, Canada (corrected geomagnetic lat. 66.6°, long. 293.7°) on January 23, 1980 and at Kitdalen, Norway (corrected geomagnetic lat. 65.6°, long. 105.1°) on February 8, 1980 by low-light-level TV cameras. The auroral data were digitized (6-digit form) every one second for the time intervals when MAGSAT was in the all sky field of view. Any distortion of images was corrected using star field. The spatial resolution of auroras is about 20 km at auroral altitudes. The magnetic data used here to estimate local intensities and direction of the field-aligned currents are high time resolution (16 Hz) magnetic data from MAGSAT (LANGEL *et al.*, 1980). The spatial resolution of the magnetic data is about 0.5 km. The residual magnetic field vectors obtained by subtracting the MAGSAT model field 6/80 (LANGEL *et al.*, 1980) were first converted into the components parallel and perpendicular to the local main field direction. The perpendicular component is further divided into two components, parallel and perpendicular to the sun-earth line.

The altitude of pulsating auroras is usually in a range 90–100 km (BROWN *et al.*,

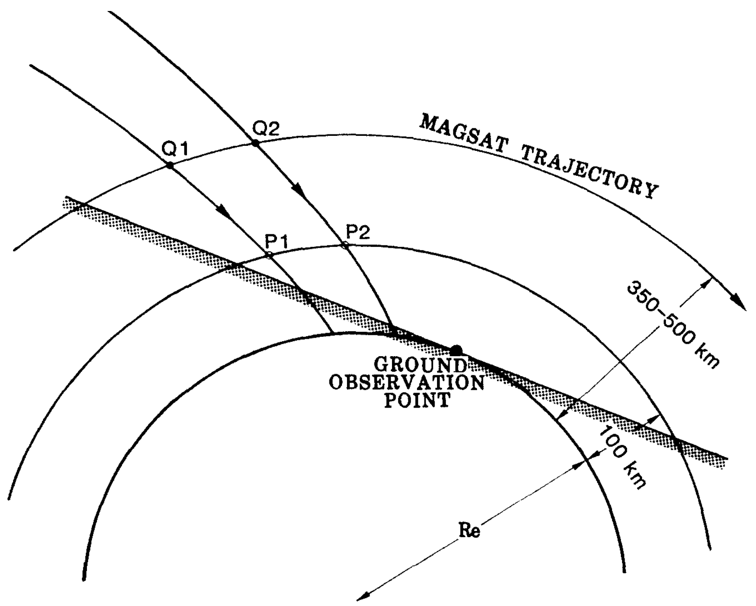

Fig. 1. Schematic illustration of the way to compare magnetic variation observed by MAGSAT with auroral luminosity. MAGSAT position (Pi) is traced along a magnetic field line to aurora altitude (Qi).

1976), whereas that of MAGSAT is 350–500 km (LANGEL *et al.*, 1980). Therefore, the MAGSAT position must be projected to the auroral level (100 km here) along magnetic field lines using the magnetic field model MGST 6/80 (LANGEL *et al.*, 1980) as seen in Fig. 1. The auroral luminosities at the magnetic foot point of MAGSAT are compared to the magnetic variations at the MAGSAT level.

3. Results

Figure 2 shows magnetic field variations along a MAGSAT path over Kitdalen for the time interval 0439 to 0443 UT on February 8, 1980. S and D in this figure denote the components parallel and perpendicular to the sun-earth line respectively, both being perpendicular to the local main field. Z denotes the component parallel to the local main field. Generally, S and D components represent the magnetic effects of the field-aligned currents, whereas Z component shows the magnetic effects of the ionospheric electric currents (IIJIMA *et al.*, 1982). S and D components in Fig. 2 indicate the existence of a pair of typical large-scale field-aligned currents. That is, the Region 1 downward current between 78° and 81° and the Region 2 upward current between 68° and 78°. Pulsating aurora region (66.7°–68.5°) is also displayed in Fig. 2. An example of auroral images taken during the interval is shown in Fig. 3 along with the trajectory of MAGSAT projected onto the auroral level (100 km). MAGSAT traversed near the eastern edge of the field of view. The pulsating aurora for the time shows a period of approximately 20 s, its low latitude boundary was well defined for

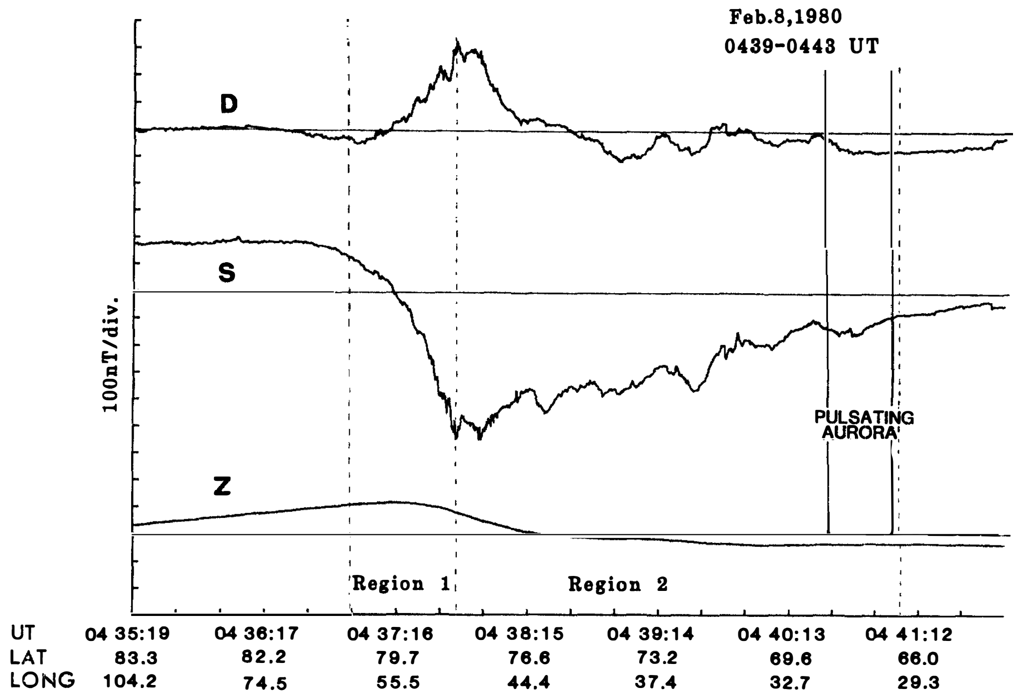

Fig. 2. MAGSAT data 0439–0443 UT on February 8, 1980 within the viewcone of TV camera set up at Kitdalen station in Norway. Typical paired field-aligned currents are observed. S(D) denotes the component parallel (perpendicular) to the sun-earth line and perpendicular to the local geomagnetic field.

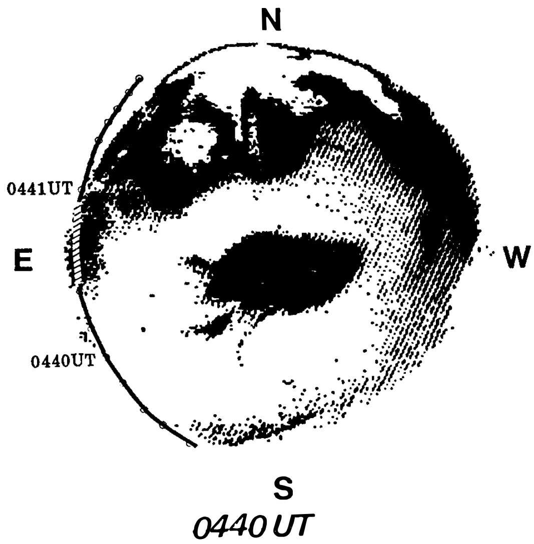

Fig. 3. Auroral image obtained by all-sky low light TV camera set up at Kitdalen in Norway. MAGSAT orbit is indicated.

that time. The shaded area of Fig. 3 indicates the region where auroral pulsation was seen along the MAGSAT path.

Comparing the MAGSAT path in Fig. 3 and magnetic variation in Fig. 2, the pulsating aurora (66.7°–68.5°) is found to be located within and at the southern-most part of the Region 2 current (66.0°–78.0°) where an upward field-aligned current exists. Note that the low latitude boundary of the Region 2 upward field-aligned current is almost coincident with that of the pulsating aurora. Unfortunately the MAGSAT path was far from the auroral station in the example and the period of pulsation was too long to examine the pulsation on board a moving satellite so that the correspondence between auroral and magnetic pulsations is not clear along the trajectory. The nearly simultaneous pulsations of aurora and magnetic field are shown in the next example.

Figure 4 shows an excellent example of magnetic variations at MAGSAT when MAGSAT traversed through the region of a pulsating aurora over Steen River as seen in Fig. 5. Here the aurora was a propagating-type pulsating aurora with period of 5 to 6 s occurring between 59° and 62°. The large-scale field-aligned current in this case was much more structured than the previous example. The Region 2 current, however, is still identified, and the pulsating aurora again appears to be embedded in the Region 2 current. The low latitude boundary of pulsating aurora, however, is a little south of that of the Region 2 in this example.

The most important features of the magnetic variations in Fig. 4 and auroral structure in Fig. 5 are that the pulsations, with a period of 5 to 6 s, are seen when MAGSAT traversed over the pulsating auroral region. These magnetic fluctuations indicate the periodic variations of field-aligned currents. The amplitude of the fluctuation amounts to 20 nT. Note that the fluctuation is largest in S component and only small fluctuation occurs in D component while no significant fluctuation is seen in Z component. The absence of the fluctuation in Z component indicates that the magnetic pulsation at MAGSAT is produced by field-aligned currents and that the contribution of the ionospheric currents is negligible. The relationships between magnetic fluctuations

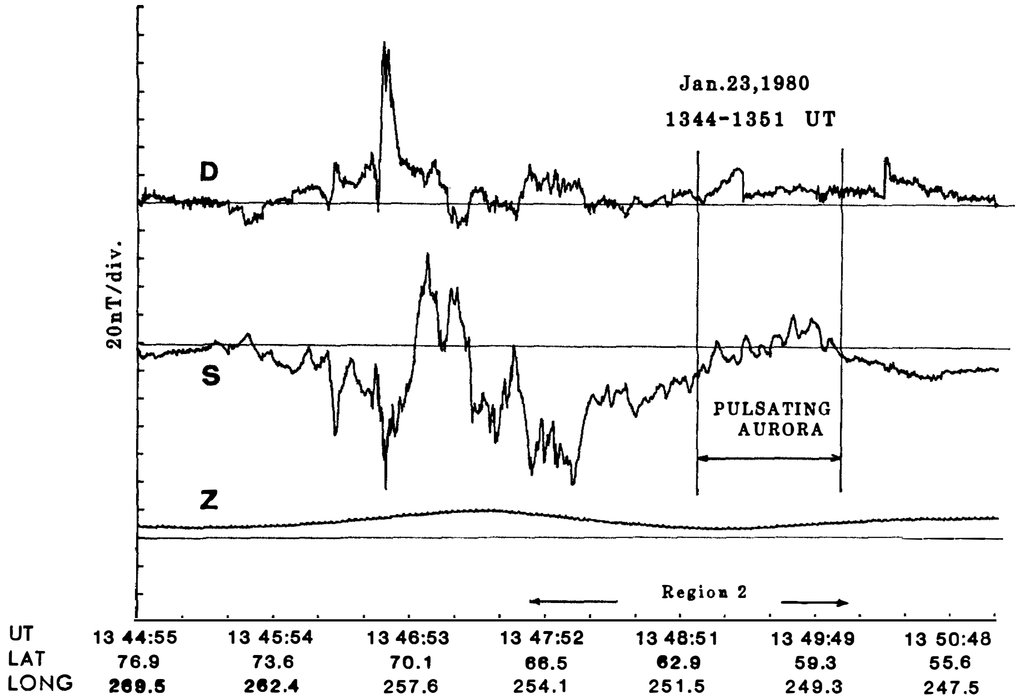

Fig. 4. Another example same as Fig. 2. Small scale quasiperiodic variation of field-aligned current overlapping the large scale variation. Small-scale variation is found mainly for S-component.

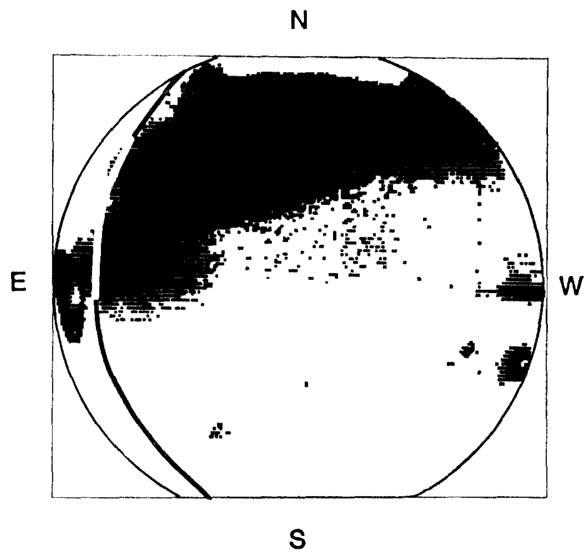

Fig. 5. Auroral image obtained by all-sky low light TV camera set up at Steen River in Canada at 1349: 50 UT on January 23, 1980. MAGSAT orbit is indicated.

at MAGSAT and auroral fluctuations at the magnetic foot point of MAGSAT are shown in Fig. 6. The peak-to-peak correspondence between magnetic and auroral fluctuations is evident in this figure. The peak in luminosity appears to correspond to the turning from westward to eastward deflection of the magnetic field. Figure 7 shows the power spectra of the magnetic and auroral fluctuations along with the relative phase between them. The peaks of power spectral densities of both magnetic and

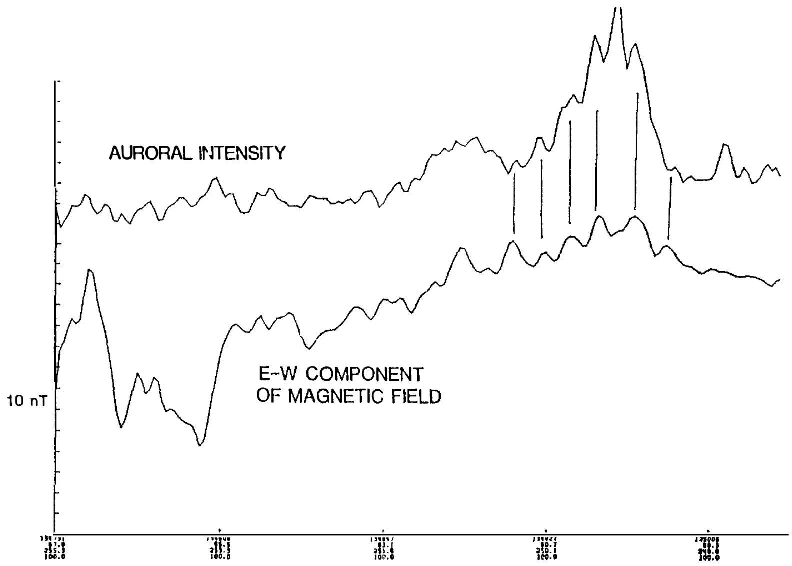

Fig. 6. Comparison between auroral luminosity and small-scale field-aligned current. The intensity of auroral luminosity is drawn in arbitrary scale.

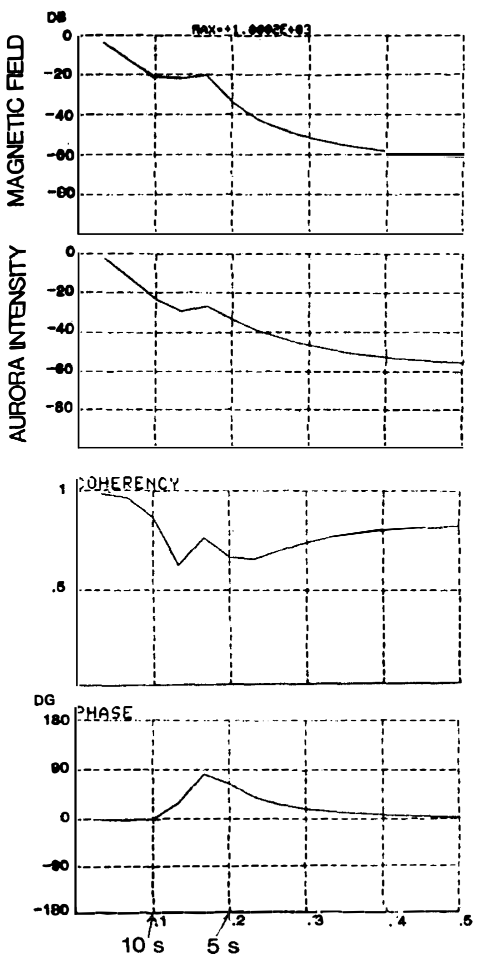

Fig. 7. Relationship between pulsating auroral variation and field-aligned current variation. Upper two panels show their spectra, the middle one shows the coherency between them, and the bottom shows the phase relation.

auroral pulsations are clearly seen at the same frequency. The relative phase in the bottom panel indicates that the magnetic eastward component follows behind auroral luminosity fluctuation about 90°.

4. Conclusion and Discussion

The result of this study shows the possibility that pulsating auroras in the morning sector appear at the low latitude part of the Region 2 current region where the upward field-aligned current exists. This is consistent with the result by ENGEBRETSON *et al.* (1984) that PiC pulsation is observed only when the Region 2 current exists overhead. The result also suggests that the inner boundary of injected energetic electrons leading to the pulsating precipitation is approximately equal to the low latitude boundary of upward field-aligned currents in the Region 2 current region. Although the species and energies of particles that carry an electric current and contribute to auroral emission could be different, this result may indicate the common source of the currents and auroral precipitations.

The close relationships between auroral and magnetic pulsations at MAGSAT level when compared on a common field line definitely indicate the existence of field-aligned currents relevant to each auroral patch. The dominance of *S* component indicates that the currents are in the form of a pair of sheets, and not in a filamental

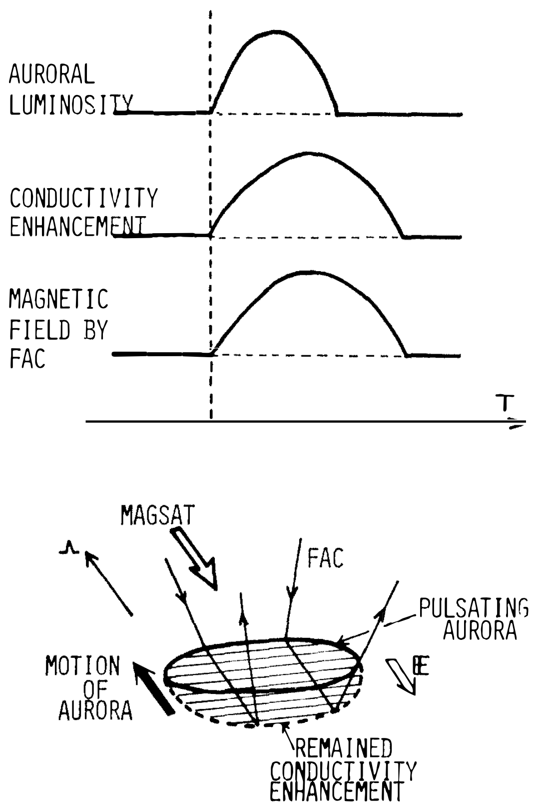

Fig. 8. Schematic illustration of 3-dimensional current system associated with the pulsating aurora.

structure. This is related to the fact that the pulsating auroral patch here is elongated in the east-west direction. As shown by OGUTI and HAYASHI (1984b), a migrating aurora produces an ionization tail in the ionosphere. The enhancement of the conductivity, when elongated in the east-west direction, naturally causes a pair of the field-aligned sheet currents also elongated in the east-west direction along the northern and the southern boundaries of the conductivity enhancement. The phase relation between auroral and magnetic pulsations is understood in terms of the relaxation time of the ionization in the ionosphere.

The relationships are schematically illustrated in Fig. 8. The top panel of Fig. 8 indicates the variation in auroral luminosity, conductivity change and related magnetic field variation due to field-aligned currents. The phase lag of the conductivity (field-aligned current) change behind the auroral luminosity variation is due to the relaxation time of the ionization. Note that the MAGSAT velocity is almost reverse to the auroral patch migration. The aurora here is a poleward propagating aurora with period of 5 to 6 s, which repeatedly appears in lower latitude and propagates poleward encountering the magnetic foot point of MAGSAT. Whenever the propagating patch encounters MAGSAT, the magnetic field fluctuation occurs at MAGSAT and lasts a little after the patch sweeps away. The magnetic deflection is well understood by the pair of sheet currents induced in and around the local enhancement of conductivity as schematically illustrated in the bottom panel of Fig. 8.

This study confirmed the validity of the field-aligned pair currents related to a pulsating auroral patch above the ionosphere proposed by OGUTI and HAYASHI (1984a, b). The precise comparison between calculation of expected magnetic field fluctuations at MAGSAT orbits and simultaneous temporal and spatial variations of auroral patches will be given in a separate paper.

Acknowledgments

The authors would like to thank K. UCHIDA for making the computer program used in this analysis. This work was done by using M-180 and Picture Analyzing System at the National Institute of Polar Research.

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(Received October 31, 1984; Revised manuscript received December 27, 1984)