Sixteenth Indian Expendition to Antarctica, Scientific Report, 2000
Department of Ocean Development, Technical Publication No. 14 pp. 86 to 36

Velocity of small-scale auroral current systems over MAITRI, Antarctica in Jan 1997

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Abstract

In continuation of our earlier experiments operated at MAITRI, Antarctica, in Jan 1992, Jan 1995 and Jan 1996, to determine the velocity of disturbed-time overhead current systems, a similar experiment was conducted again in Jan 1997. Fluxgale magnetometers were operated at the three sites, MAITRI, DAKSHIN GANGOTRI, and FILCHNER FJELLA, recording daily variation (DV) and magnetic pulsations (MP) in the three orthogonal components X, Y and Z. the pulsations are recorded in the frequency band 33 mHz i.e. their time-periods range from 30 sec. to 3000 sec. The auroral current systems while drifting over the stations, leave signatures in the form of geomagnetic pulsations in the ground-based magnetometers, and the velocity of the current systems can be estimated from the time-lags in similar pulsations at the three stations using the inter-station distances. A velocity of 0.5 km/sec to 3 km/sec was obtained for conditions of moderate magnetic disturbance during the Jan. 1997 campaign at MAITRI and it tallies well with our earlier results.

1. Introduction

As part of India's ongoing Antarctic scientific program, India operates a permanent station MAITRI (MAT geog. Lat 70" 45'S, long 11° 45'E) in the Schirmacher Oasis, Antarctica. In addition, two summer camps were operated at DAKSHIN GANGOTRI (DG, with geog. Lat. 70 08'S, long. 12 E) and FILCHNER FJELLA (FF, with geog. Lat 71 57'S, 07 41E). The FF Camp station was set up in the mountains to the west of Wohlthat mountain range. The three stations form the vertices of a triangle with sides ranging from 76 km to 420 km. The problems related to operating such camps in the harsh climate and difficult terrain of Antarctica, especially in the hazardous mountain areas were reported earlier by DHAR et al. (1997). During sub-zero conditions, operating the instruments in such conditions becomes difficult, and recording at the two field camps gets disrupted owing to conditions such as a) rapid draining of batteries, and b) malfunctioning of analog and digital recorders. About 5 days of simultaneous recording was possible at the three sites, but the Earth's electromagnetic environment was not very magnetically disturbed. We present the results of velocities obtained from similar geomagnetic pulsation occurring at the two stations MAI and FF, during moderately disturbed conditions on Jan 18 and Jan 20. The recording at DG on both these days was not possible due to recorder problems and battery drainage.

The geomagnetic daily variations (DV) and the geomagnetic pulsation (MP) are being regularly monitored at MAI since 1992 by Indian Institute of Geomagnetism (IIG), Colaba,Bombay. Both DV and MP are recorded in analog and digital modes. The DV is recorded on charts at a speed of 3cm/hr, and digitally, at 1 min sampling interval, whereas MP is recorded at 12 cm/hr and 2 sec sampling interval. HANCHINAL et al.,(1996), and BANOLA AND RAJARAM (1997) have discussed in detail about the movement of MAI, normally a sub-auroral station into the auroral oval with increasing magnetic disturbance. At Disturbed times, when the normally closed geomagnetic field lines are opened up by the energy density of incoming solar wind plasma, MAI starts recording the magnetic signatures of auroral electrojet (AE) currents, field-aligned currents (lac), and other such auroral phenomena. The field - aligned currents (fac) are caused by the precipitation of energetic electrons from the magnetosphere into the auroral ionosphere, and the incoming electrons are subject to E X B drift in the east-west direction. Sharp variations in the X and Y components reorded by ground-based magnetometers are generally caused by fac (DHAR et al. 1999) in a companion paper in this issue. The velocities of the mobile, small- scale , auroral current systems can therefore be estimated from any area of magnetometers placed along east-west and north-south directions. KISABETH and ROSTOKER (1973), AKASOFU (1974) ANDRE and BAUMJOHANNA (1982) and OPGENOORTH et. al., (1983) have successfully operated such arrays in the northern auroral hemisphere and have estimated the velocities of such mobile small-scale auroral current systems.

Such closely- spaced arrays are easily operated for long duration in the more hospitable northern auroral regions, but operating such arrays in the difficult terrain and harsh climate of Antarctica is a very difficult proposition indeed, for various logistic reasons. DUNLOP et.al. (1994) used the widely spaced Australian stations in Antaractica for studying the characteristics of long-period geomagnetic pulsation, but such a widely spaced stations network can not be used to study the movement of small-scale auroral current systems. The most we were able to achieve in ice bound Antarctica was to set up three stations at the vertices of a triangle; to our knowledge there is only one other such report of triangulation of Antarctica (NEUDEGG et.al. 1996) Despite these problems and difficulties faced at Antarctica, IIG has been able to operate three magnetometers at the vertices of a triangular area four times so far i.e. in Jan. 1992, Jan 1995 and Jan 1996 and Jan 1997. The velocity auroral current systems estimated during the first three campaigns has been reported in earlier works (RAJARAM et, al., 1999, RAJESH KALRA et. al., 1996 and AJAY DHAR et.al., 1997). For a triangular array, keeping in mind the scale - size of these small - scale auroral current systems, the distances between the stations should ideally be 100-200 km. In practice this is difficult to follow because an Antarctic camp is set up to suit the needs of several fields of investigations; in this work, the distances range from 76 km to 420 km.

Detailed study of long period pulsation have been carried out by various investigators in the past. During magnetically quiet times (Q) these pulsations are believed to be caused by hydromagnetic waves generated in the upper atmosphere (LEHNERT 1956, KATO and WATANABE 1955, 1956, KATO and AKASOFU 1956, MATSUURA 1961). SATO (1962) considered pulsations during magnetically disturbed times to originate in localised small-scale ionospheric currents generated by charged particles precipitating along magnetic field lines from the outer magnetosphere. SATO observed these pulsations to appear more than during high magnetic activity as compared to low magnetic activity, but not necessarily to occur during times of severe magnetic activity; he also found the local time of occurrence of the pulstions to vary from place to place. The movement of auroral current systems with the help of closely-spaced magnetometer arrays was studied by different investigators for investigating different phenomena e.g. eastward drifting omega bands (ANDRE and BAUMJOHANN, 1982), westward travelling surges (AIKIO and KAILA, 1996) and pulsating arcs (BOSINGER et al, 1996).

2. Observations

Fig. 1(a) shows the triangular configuration of the three stations set up at Antarctica for this experiment. The sides of the triangle thus are:DG-MAI 76 km: MAI-FF, 360 km, and FF-DG, 420 km. When the coordinate system is rotated from the geographic frame to the geomagnetic frame, the corrected geomagnetic coordinates change as shown in Fig. 1(b). Note however that the scales are different for Fig. 1(a) and Fig. 1(b). This figure is shown to give the reader an idea of how the station aspect changes between geographic and geomagnetic coordinates. In this work since data from only two stations MAI and FF are available, no attempt is made to use trigonometrical methods, and hence only geographic coordinates are used for velocity estimates.

As mentioned above, magnetometer recording was possible on 5 days from the FF Camp station. Most of the days were magnetically quiet with very little geomagnetic pulsation activity observed on the records. We present the data for 2 days, 18 Jan 1997 and 20 Jan 1997. Jan 18 was a quiet day and Jan 20 a moderately disturbed day. No data were available for DG station during either of these days due to discharging of battery, and recorder problems. The drift speeds of these small-scale current systems could be estimated from the time-lags in similar pulsation's recorded at the two stations, but understandably the direction of the current systems could not be obtained.

2.1 18 Jan 1997

This was a magnetically quiet day with Kp=10°, but the period 02-03 UT recorded some pulsation activity al both FF and MAI sations (cf Fig.2). The 3 hourly Kp index for the intervals 00-03 UT and 03-06UT was 3° and 2° respectively. Seven clear sets of similar pulasations in the Y-component and 9 sets in the X-component (shown in Fig.2 and marked by arrows) were chosen.

The arrows are shown against the pulsation's selected, on the Y and X curves for Filchner Fjella station, and each of these has a counterpart on the Y and X curves for Maitri, with time-lags. The average drift speed was estimated to be 0.53 km/sec for the Y and X components respectively during these events; the Z component yielded a speed of 0.53 km/sec.The time-lags in the pulsation's reveal the current systems to be moving in the west to east direction. No clear pulsation's were seen in the Z variation.

2.2 20 Jan 1997

This was a moderately disturbed day with kp= 13- and is shown in Fig 3. A large number of pulsation's are observed in the time interval 21-00 UT, and the 3 hourly Kp index for this interval is 3-. The pulsation's are seen in all three components Y, X and Z. Simultaneous pulsation activity in Y and X-components suggests the presence of field-aligned currents overhead. 10 sets of pulsation's in the Y and X-components (marked by arrows for MAI) were chosen for this day. While these have clear counterparts in the Y component at the FF station there is considerable distortion in the X trace at MAI. From the time-lags in the pulsation's the average drift speeds for the overhead current systems are estimated as 3.34 km/sec. And 3.12 km/sec. In the Y and X components.

3. Conclusions

Estimating the distances between the stations and reading the time-lags in similar pulsation's at the two stations, the average drift speeds for the magnetically quiet day 18 Jan 1997 and the moderately Disturbed day 20 Jan. 1997 works out to between 0.5 to 3 km/sec. These values tally well with our previous results, and are within reasonable limits of the values obtained by other investigators for the northern auroral regions (1-3 km/sec). As mentioned earlier the authors are not aware of the existence of other such array experiments in the Antarctic auroral region for comparing results.

Acknowledgements

We are thankful to the Director, Indian Institute of Geomagnetism for constant encouragement and support towards studies of Antarctic geomagnetism. The members of the Expedition P. Elango, A.L Gudade S. Sankaran are also thankful to the Leader of the Sixteenth Antarctic Expedition, Dr. A.L. Koppar for his whole hearted support during the expedition our thanks also go to the Department of Ocean Development, Government of India, for providing all logistic support in the daunting task of going to Antarctica, carrying out experiments in that hostile terrain, and returning safe.

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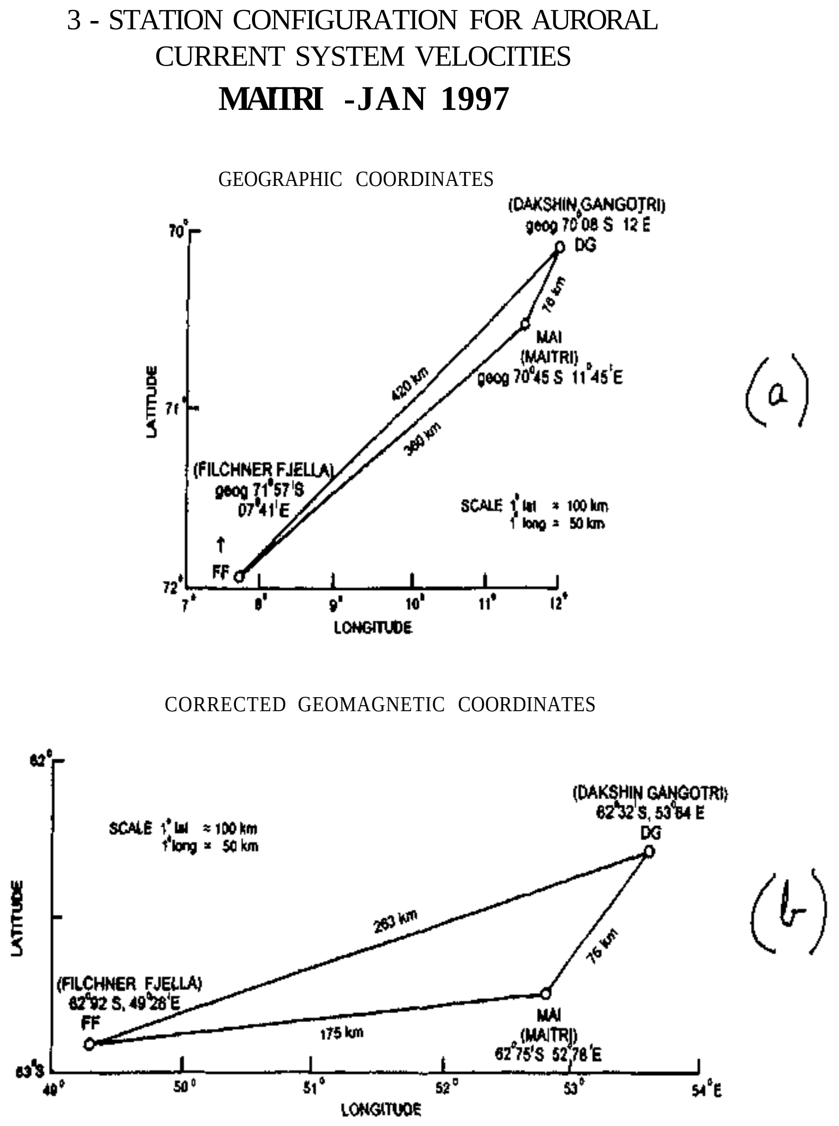


Fig. 1: Location and inter-station distances of the three Antarctic stations Dakshin Gangotri (DC) Maitri (MAI) and Filchner Fjella (FF), operated in Jan 1997 for the fluxgate magnetometer triangulation experiment. Fig. 1(a) depicts these in the geographic coordinate system. Fig. 1. (b) shows corrected geomagnetic coordinates for the same, as derived form 1GRF (1995) [ICRF is the International Geomagnetic Reference Field].

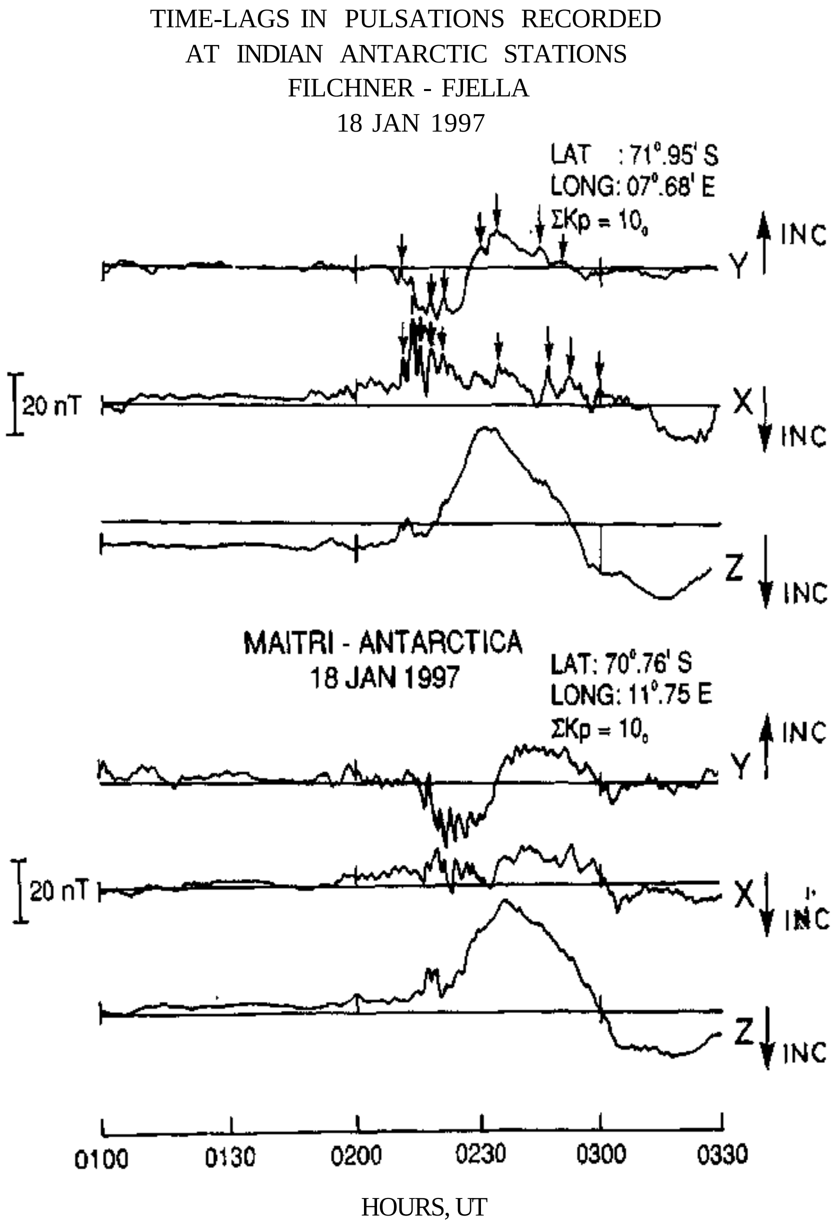
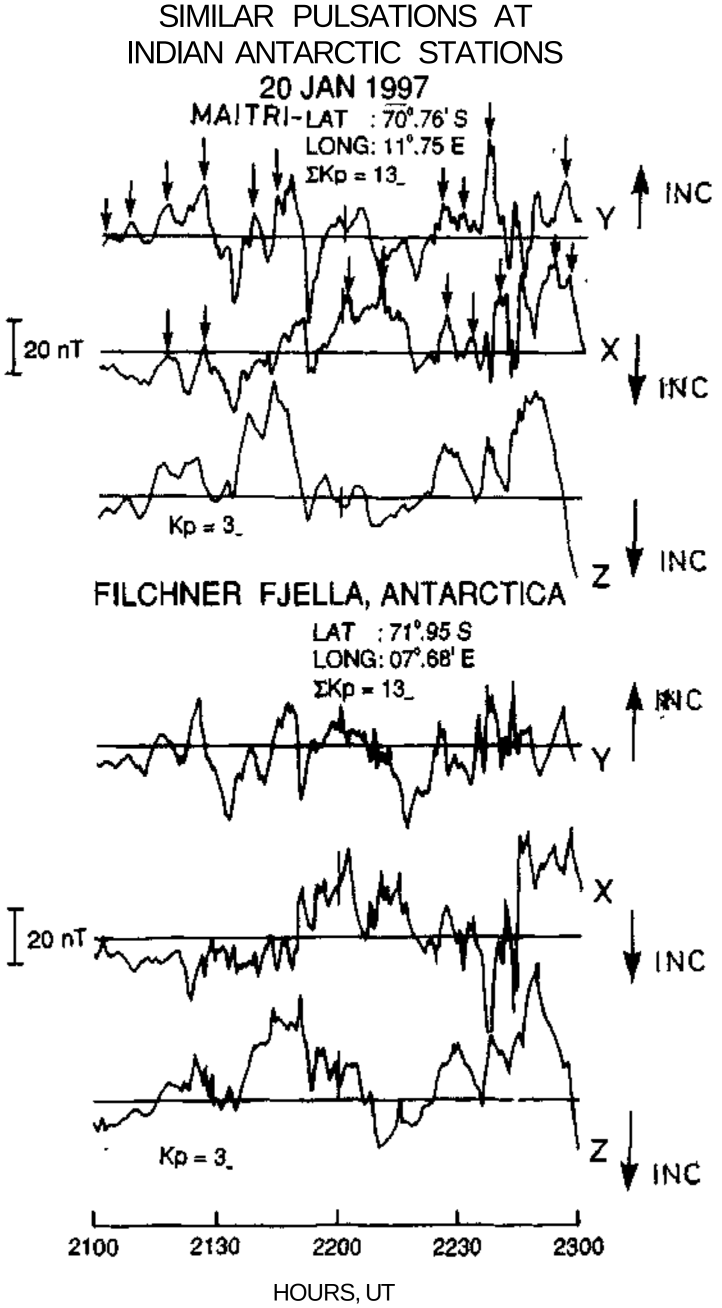


Fig. 2 : Pulsation recorded in the three orthogonal geomagnetic components Y (east-west), X (north-south) and Z (Vertical), recorded at the Camp station Filchner Fjella and at MAITR1 on 18 Jan 1997. This was a moderately Quiet day with sum Kp=10 and pulsation were seen only between 0200 - 03:30 UT. Pulsation for which time-lags were read are marked by arrows on the curves for Filchner Fjella.



Fig, 3 : Same as in Fig 2, but the day is 20 Jan 1997, a moderately disturbed day with sum Kp=13-. In this case pulsation occurred between 21-23 UT, and the ones for which time-lags were read are marked by arrows on the curves for MAITRI.