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Three Station Fluxgate Magnetometer Experiment to Determine Auroral Current Velocities Over Indian Antarctic Stations

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Abstract

Close-spaced magnetometer arrays provide a powerful technique for monitoring mobile ionospheric current systems in the auroral regions. While several such arrays exist in the Arctic auroral regions (e.g. the Alberta array in Canada and the Scancdinavian array) there is no such array operating in Antarctica except for the Indian Summer Antarctic magnetometer array. During Jan. 1995 (as also during Jan. 1992 and now in Jan. 1996), the Indian Institute of Geomagnetism, Bombay operated 3- station arrays with separation distances of 100-200 km i.e. typical scale-size of the mobile auroral current systems. Velocities of these current systems as they drift eastwards or westwards in the auroral ionosphere is obtained by triangulation, from time-lags in the pulsations observed at the 3 locations. Velocities obtained are of the order 1 km/sec to 3 km/sec, and tally well with those observed at arrays in the northern hemisphere.

1. Introduction

The use of similar long-period pulsations on magnetograms at nearby Antarctic locations to understand the characteristics of the overhead auroral current systems, seems to have been first reported by Sato (1965). Pulsations on magnetometer arrays operated in Canada, were used by Wiens and Rostoker(1975) to understand the expansion phase of the magnetospheric substorm, by tracking the geomagnetic signature of the westward auroral electrojet i.e. the negative bay in the X-component. Pulsations on closely spaced magnetometer arrays in Alberta, Canada, have also been used by Kawasaki and Rostoker(1979) and Rostoker and Apps(1981) to estimate velocities of the eastward propagating auroral omega bands, and by Tighe and Rostoker (1981) to understand velocities of the auroral Westward Travelling Surge. The Scandinavian Magnetometer Array has been used to advantage in understanding the auroral current systems which are responsible for the eastward drifting omega bands (Andre and Baumjohann, 1982); for the Westward Travelling Surge

(Aikio and Kaila, 1996), and pulsating arcs (Bosinger *et al.,* 1996). However all these studies (except for Sato, 1965) are based in the auroral arctic region. A recent attempt to use an Antarctic array to understand the characteristics of Pc5 geomagnetic pulsations is by Dunlop *et al.* (1994). Here however, the array of Australian stations is widely spaced, ranging in geomagnetic latitude from -64°.5 S to -80°.8 S, and in geomagnetic longitude from 89°.5 to 329°.2. It is not possible to use such a widely distributed array to study small-scale current systems such as those associated with auroral substorm features.

The Indian Institute of Geomagnetism carries out unique experimentation in the Antarctica, in that it records geomagnetic pulsations at 3 locations separated by 100-200 km distance, which is the scale-size of the auroral current systems. This forms a Summer Antarctic Campaign, with 3 fluxgate magnetometers operating simultaneously, and through triangulation providing the velocity of the current systems.

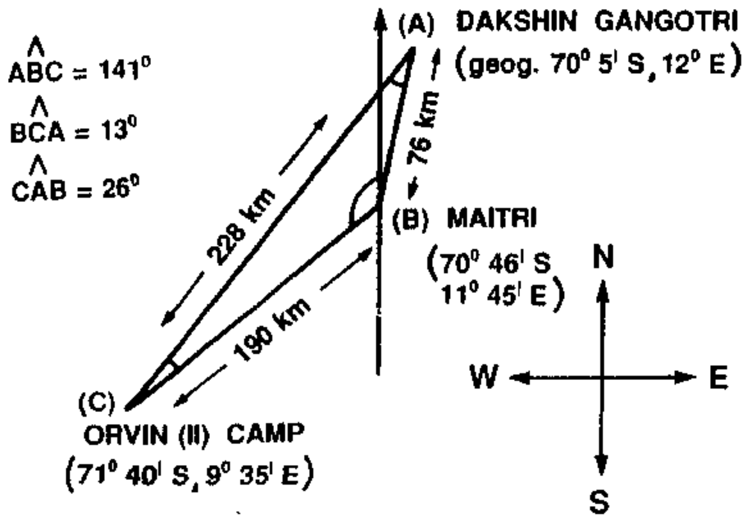
2.The Experiment

During the summer months of 14th Indian Antarctic Expedition (Jan-Feb 1995), IIG operated three fluxgate magnetometers at the vertices of a triangular area located in the Schirmacher region of Antarctica. Two of the vertices were at the Indian Antarctic bases Maitri (geographic latitude 70° 45 S, longitude 11° 45 E) and Dakshin Gangotri (geographic latitude 70° 05 S, longitude 12° 00 E); the third vertex at Orvin Camp (geographic latitude 71° 40 S, longitude 9° 35 E) was located in the Conrad mountains of Antarctica. The sides of the triangular set-up were roughly 75 km, 190 km and 228 km as shown in Fig. 1.

The objective of the experiment is to study the velocity of mobile current systems in the auroral region, which drift over the three locations and leave their geomagnetic signatures on the fluxgate magnetometers, as pulsations.

Three fluxgate magnetometers were oriented so as to respond to variations in the X (north-south), Y (east-west) and Z (vertical) components of the Earth's magnetic field variation. The output of the magnetometers was recorded in two modes. The daily variation (DV) was recorded on a chart speed of 3 cm/hr and the sensitivity of the instrument was varied from 10V Full Scale Deflection (FSD) to 40V FSD. Micropulsations (MP) in the DV with time-periods 30 sec to 3000 sec (i.e. frequencies 33 mHz to 0.33 mHz respectively, were separated out through electronic filters, and were recorded on analogue recorders running at a speed of 12 cm/hr. The DV (1 minute interval) and MP (2 sec interval) were also recorded in digital form on a solid state datalogger, and the data was periodically transferred to floppy diskettes for further computer processing. A

ANTARCTIC GEOMAGNETISM - JAN 1995
3 Station Fluxgate Magnetometer Experiment
(IIG)



First approximation result :-
Speed of mobile ionospheric current system over ORVIN MAITRI = 1.15 km/sec

block diagram of the experimental set-up used is given in Rajesh Kalra *et al.* (1995).

All three stations were made operational from 22nd Jan, 1995, but we were forced to have Orvin as an unmanned station and despite severe problems in running the station, three days data (30 Jan-1 Feb 1995 on the Y,X,Z geomagnetic components could be obtained.

Orvin had to run as an unmanned station because the Antarctic weather in Jan. 1995 was very bad, and frequent helicopter sorties for the purpose of setting up a camp could not be carried out. There was no tent or Portacabin, and the camp was essentially a big boulder behind which equipment worth a few lakhs


INDIAN INS
MULTI-FLUXGATE
CAMP
ANTARCTICA
MAGNETOMETER
CAMP

Fig. 2a & b

of rupees was left running unmanned (Figs 2a, 2b). The boulder served to stop the drift of snow on to the equipment, but there was no protection against the bitterly cold temperatures of -30° C. Needless to say the Riken-Denshi recorders balked and ran at very uneven speeds. It was just providential that no major blizzard occurred during the period, otherwise the equipment could have been blown about and buried and lost in snow. This scenario serves to illustrate the very difficult and formidable conditions for Antarctic experimentation.

3. Observations

Figure 3 shows stacked magnetograms (DV run at 3 cm/hr) for MAI, ORV and DG during 30 Jan 1995 17:00 UT and 31 Jan 1995 10:00 UT; some amount of data for DG is missing. The magnetograms have been arranged in a manner such that the major event, a substorm between 23:30 UT and 01:00 UT, characterised by positive Y and negative X, Z, lies in a stacked manner at the three locations. Time in UT and Recorder Sensitivity in Volts FSD is indicated on the figure.

Table 1 shows the time differences and time-lags between similar pulsations at MAI and ORV for events 1 to 9 (marked on magnetograms), occurring between 18:00 UT and 23:00 UT on 30 Jan. 1995. Time-lags vary between 1 minute to 4 minutes, corresponding to the causative current systems having speeds of 3.2 km/sec to 0.79 km/sec respectively. The average time-lag works out to be 2.44 minutes giving an average speed of 1.16 km/sec. The timings of the pulsations would suggest that for events 1 to 6, the causative system moved eastwards.i.e. from ORVIN to MAI. Events7,8,9 seem to have occurred earlier at MAI and later at ORVIN i.e. the localised current systems moved westwards, which is what would be expected when the midnight sector (00 UT at the three Indian stations) experiences a substorm (Wiens and Rostoker,1975). If one

Table 1: Time-lags for Pulsation Events between Maitri-Orvin 30 Jan. 1996

Events	Time in UT of Event	Difference in Spacings of Pulsations	Time-lag in Pulsations
1	1800	30.5-31.0 = 0.5mm	1 min
2	1807	33.5-34.5 = 1.0mm	2 min
3	1820	40.0-41.0 = 1.0mm	2 min
4	1930	75.0-77.0 = 2.0mm	4 min
5	2000	87.0-88.5 = 1.5mm	3 min
6	2015	97.5-99.5 = 2.0mm	4 min
7	2145	141.5-143.0 = 1.5mm	3 min
8	2325	190.5-191.0 = 0.5mm	1 min
9	2350	203.5-204.5 = 1.0mm	2 min

Average Time-Lag for 9 Events = 2.44 Minutes

INDIAN ANTARCTIC STATIONS
JAN 1995
TIME - LAGS IN VARIATIONS
RECORDED AT THREE LOCATIONS

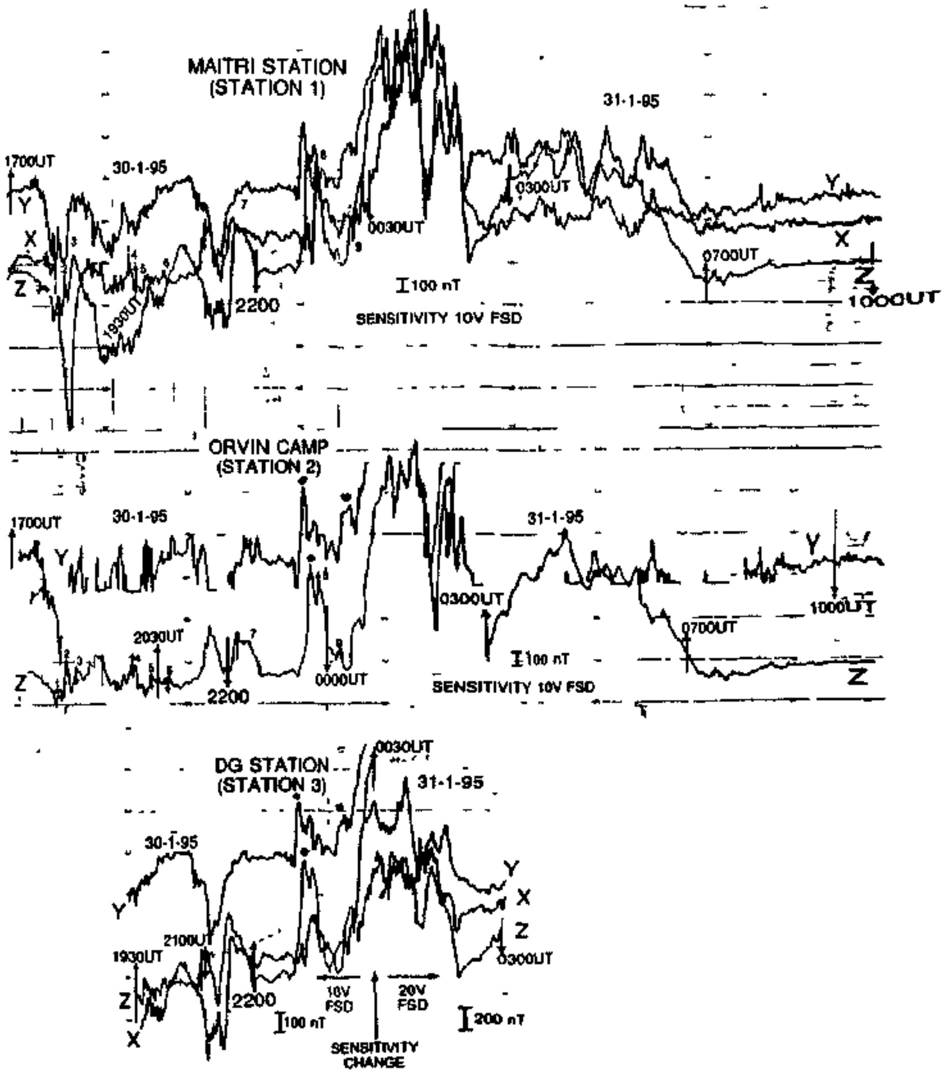


Fig. 3

separates out the pulsations on this basis, the average time-lag for events 1 to 6 (17:00UT-21:00UT) is 2.67 minutes and the average velocity of the causative current system is 1.02 km/sec in the eastward direction. Similarly the average time-lag for the events 7,8,9 is 2 minutes, and the velocity works out to 1.58 km/sec in the westward direction.

4. Conclusions and Discussion

The auroral regions of Earth play a special role in transfer of energy between the distant geomagnetosphere and the Earth's near- space environment i.e. the ionosphere. As the geomagnetic field lines preferentially channelise plasma emissions from the Sun towards high northern and southern latitudes of Earth this leads to strong, inhomogeneous localised current systems in the ionosphere and hence to severe magnetic fluctuations on ground- based magnetograms, notably at auroral latitudes. Monitoring of pulsations in the magnetic field variations at auroral locations separated by about 100-200 km (the scale-size of these current systems) can provide clues to the understanding of magnetosphere- ionosphere electrical coupling.

The values of ~1 km/sec to about 3.2 km/sec in the westward or eastward directions obtained on 30 Jan. 1995 for the velocity of localised current systems responsible for the pulsations seen at the Indian Antarctic stations fit in well with values observed by other workers at auroral locations [*cf.* 0.66 km/sec obtained by Andre and Baumjohann(1982); 1.9 km/sec to 2.3 km/sec by Tighe and Rostoker (1981); 0.8 km/sec to 2.0 km/sec by Kawasaki and Rostoker(1979); 0.6 km/sec to 1.6 km/sec by Rajaram *et al*.(1986)]. It may be mentioned that all these observations are for the Arctic auroral zone. The authors are not aware of any small-distance array studies in the Antarctic region, except for the Indian studies. The only study as mentioned earlier is that by Dunlop (1994), which is essentially a study of the magnetospheric origin of simultaneous pulsations at the distantly-spaced network of Australian stations and is not a velocity determination.

Our estimates of velocity have been carried out in a simple manner, taking the line-of-sight distance between Orvin-Maitri as 190 km as shown in Fig.1. We are reluctant to go in for any trigonometric or sophisticated estimates based on geomagnetic coordinates because the Recorder at Orvin Camp station reacted adversely to the cold temperatures of the open environment and it did not operate at a constant speed. This is a clear indication that for the third Indian Camp station in the Antarctic, an insulated Portacabin is a must, if our instruments are to work with reliability; open camps in Antarctica will not serve good scientific experimentation.

We are in possession of the digital micropulsation data recorded at the three stations on the same days 30 Jan, 1996 and 31 Jan, 1996, and are in the process of examining these. If the solid state digital datalogger has worked well at the outdoor Orvin Camp station, an accurate calculation can be made of the velocity of the causative current systems; studies in this direction are under way.

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