Geomagnetic Field Variations Near *Dakshin Gangotri,* Antarctica

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ABSTRACT

The geomagnetic field station was located at geographic latitude 69°59 S longitude 11 55 E (Dipole latitude 65 5°S longitude 54 5 E) The corrected geomagnetic co ordinates were 62 0 S 52 3°E Two intense magnetic disturbances were recorded on 10 January and 4 February with smaller scale disturbances in between Two substorms were lecorded 12 February substorm is characterised by a simple rise to peak value marked with a sharp sudden impulse followed by a steady fall and 13 February substorm is in effect a sequence of substorms with periodic waxing and wanning

By selected samples of magnetic records near *Dakshin Gangotri* and the corresponding magnetograms from the Indian equatorial region the interaction of solar wind and magnetosphere and the consequent geomagnetic field changes at auroral and equatorial latitudes have been studied

INTRODUCTION

The Second Indian Scientific Expedition to Antarctica reached the icy continent on 28 December, 1982 The initial days were spent in transferring material from ship to the land, erecting tent, setting up equipment and constructing a prefabricated structure for communication and recreation Scientific work began from January 8 1983

The geomagnetic field station was located at Geographic lat 69°59 S long 11°55 E (Dipole lat 65 5°S, long 54 5°E) The corrected geomagnetic co ordinates, as derived from geomagnetic main field model using MAGSAT data turns out to be 62 0°S, 52 3 E The conjugate location in northern hemisphere is in the vicinity of permanent geomagnetic observatories at Eskadalemuir and Rude Skov but there is no magnetic observatory in the precise conjugate location

The Indian field magnetic station consisted of (1) A proton precision magnetometer providing total field values (F) at a sampling interval of 10 sec with an accuracy of ± 1 nT The output was recorded on a strip chart recorder with sensitivity of 10 mv/cm The recorder has in bunt scale expanding device so that there was no loss of record for the entire duration (2) A 3 component fluxgate magnetometer with sensitivity of 1 volt/100 nT installed on a non magnetic pole fixed to a wooden stand The output was again fed to a strip chart recorder at 5 cm/hour speed but with no scale expander Due to this and due to the fact that the level of the fluxgate magnetometer kept changing by melting of the ice close to the legs of the steel there was considerable loss of record in the component recordings The discussions presented subsequently are, therefore, based entirely on the total field records (3) A fluxgate based vertical component magnetometer for providing spot values of Z at chosen location as part of a preliminary survey and a base line control for the variation station

The data availability spans the period 10 January to 17 February 1983 The scientific team experienced a stunning blizzard beginning on 19 February and ending on 21 February, 1983 Fortunately the records and equipment were safe and were retrieved with commendable alarcity

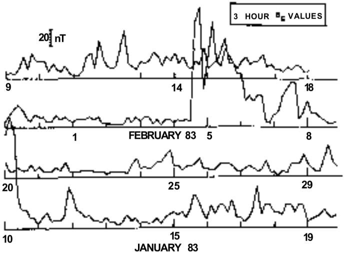

Fig 1 3 hourly a index indicative of geomagnetic activity in southern hemisphere (sub auroral latitudes) between Jan 10 and Feb 18 1983

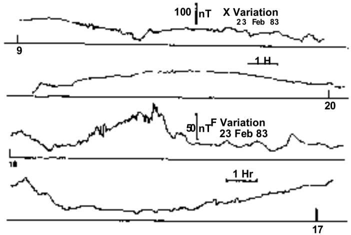

Fig 2 Quiet day daily variation of total field X component of 3 Feb 1983

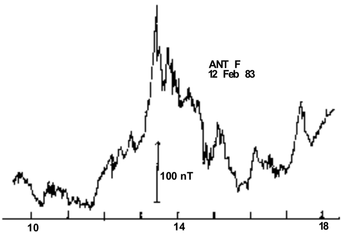

Fig 3 Example of a single substorm with onset growth and recovery

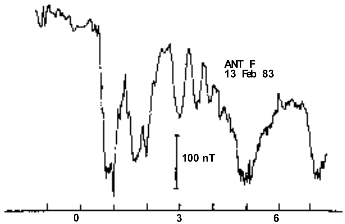

Fig 4 Example of a substorm with multiple expansion phases

DATA AND RESULTS

A gross idea of the magnetic condition prevalent in southern hemisphere during the expedition can be had from Fig 1 3-hourly a indices are derived from geomagnetic activity at several suitably located stations in the southern sub-auroral zone Values below about 20 nT can be considered 'quiet' periods

It is seen that the experiments began under condition of severe geomagnetic disturbance on 10 January and was periodically punctuated by similar scale disturbance till 4 February when again an intense magnetic disturbance was recorded all over the globe At low latitudes there was a storm sudden commencement whose amplitude in H at the equatorial observatory Trivandrum was 111 nT and the storm range was nearly 400 nT At Antarctica on both occasions the field agitation was so enormous and so rapid that the records could not be scaled sensibly due to severe overlap

X-component and F variation during one of the quiet intervals on 3 February, 1983 are shown in Fig 2 In this and in subsequent figures time indicated is in UT (Universal Time) The Magnetic Local Time (MLT), in which the field variation at high latitude are ordered is given approximately by (UT-1 hr) The local time at the base station near *Dakshin Gangotri* is ahead of UT by about 1 hour Even on quiet days fluctuations in F, both rapid and slow, are apparent indicating that calm intervals at Antarctica are rare indeed

In the next few diagrams we try to bring out some important features of the Antarctica geomagnetic field variations providing illustrative examples The complexity and individuality of these even at once make it apparent the need for continuous monitoring of the magnetic field on a long term basis

One of the most interesting aspects of solar wind magnetosphere interaction is the magnetosphenc substorms Several papers, reviews and books (Akasofu, 1977, Mc Pherron, 1979) are available but the precise mechanism involved in transfer of energy from solar wind, storing of the energy in the tail and subsequent release of the same causing surface magnetic field changes are yet to be understood clearly Highlighting this aspect are the Figs 3 and 4 which show two large substorms were recorded on successive days, one in the afternoon hours and another in the night hours While the first one of 12 February, 1983 is characterised by a simple rise to peak value marked with a sharp sudden impulse followed by a steady fall, the latter event of 13 February is in effect a sequence of substorms with periodic waxing and wanning

While in the previous two instances the duration were sufficiently large, Figs 5 and 6 depict two events where the substorm duration is small in comparison In Fig 5 one notices large longer-period pulsations both in the rising and recovery phase of the event Fig 6 is marked by a very rapid fall in the total field of nearly 600 nT with large amplitude pulsation and an equally dramatic recovery, after a short interval Similar features were reported from the records of the Indian Antarctica mission too In Fig 7 we show two trains of pulsation on 10 January and 17 February While the former falls in the recovery phase of a severe geomagnetic disturbance, the second one has been recorded during relatively calm intervals Two distinct categories of pulsations are immediately noticeable Later part of 10 February records is also characterised by longer-period oscillation with nearly 60 minutes periodicity The record for 10 January was digitized and subjected to power spectrum analysis through fast fourier transform As anticipated, the spectrum as shown in Fig 8 is dominated only by few discrete periodicities Prominent among the significant spectral peaks are those close to 450 sec (pc 5) and — 30 minutes (DP 2 fluctuations) known to be coherent from pole to the equator and related closely to the interplanetary magnetic field (IMF) fluctuations

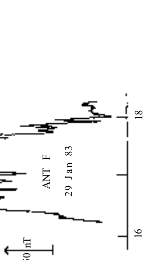

Fig 5 Substorm with large amplitude pulsations during the peak phase

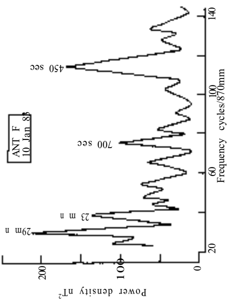

Fig 8 Power spectrum of the 10 Jan 1983 pulsations indicating dominant periods

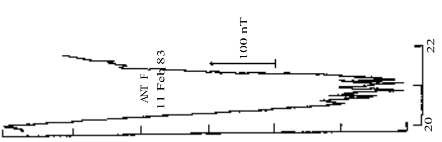

Fig 6 A large substorm with rapid onset and quick recovery with large amplitude pulsation during its peak

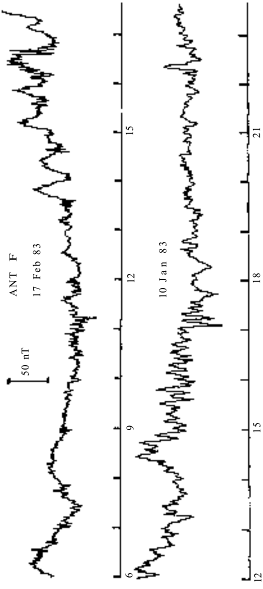

Fig 7 Pulsation at different frequencies observed on Antarctica records of F

Next we aim at establishing the link between equatorial geomagnetic field and the southern auroral zone records. For this purpose we utilize Trivandrum H records which are practically same as the total field records as the vertical component is almost zero at the station. The Izmnan variometer records, usually run on 20 mm/hr chart speed have been magnified three fold to nearly match the Antarctica F records. Again in all the diagrams the time marks are in UT which is ahead of Geomagnetic Local Time (MLT) by just one hour.

While there are plethora of events each having its peculiar signature at both locations, we have confined our attention to only three aspects (*i*) Sudden commencement (SSC) and sudden impulses (SI) at low latitudes and the sub storms at may trigger at auroral latitudes, *(ii)* low latitude positive bays and the corresponding field changes in Antarctica region and *(iii)* isolated structures seen on Indian chain of magnetometers and their counterpart at high latitudes.

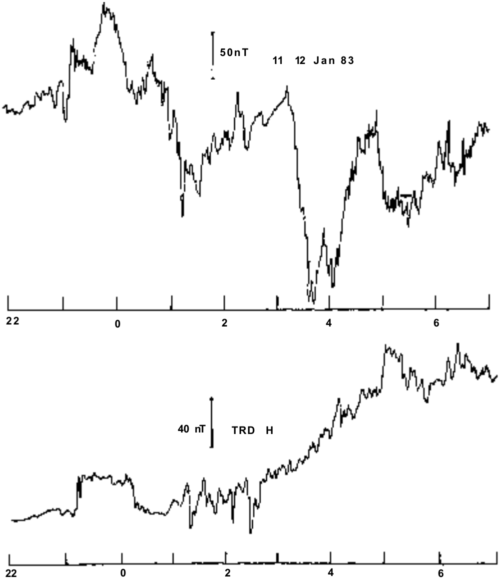

Fig 9 A rare SSC at Trivandrum (positive impulse followed by negative one) and corresponding Antarctica record

It is fairly well established that SSC of magnetic storms, and sudden impulses trigger magnetospheric substorms. Kokubun *et al* (1977) found that if IMF has been southward for sometime before the SSC, the probability is higher for triggering a substorm. Brown (1978) suggested that whenever SSC triggered a substorm the geomagnetic activity in the auroral zone was already in progress. Statistical analysis of SSC and substorms at Syowa Base—a Japanese Antarctic station-by Hirasawa (1982) suggested that substorms are preferentially excited by SSCs in the time interval 00 to 03 MLT.

On 11 January, a storm sudden commencement was recorded at 2309 UT at all low latitude stations. Contrary to the usual signature of magnetospheric compression by the interplanetary shock front as a sharp rise of the H field this SSC was followed by a negative impulse of nearly half the amplitude of the initial positive rise. Such events (SC + -) are very rare though the other type with a preliminary negative impulse followed by a sharp positive change (SC - +) has been quite well studied (Rastogi, 1978).

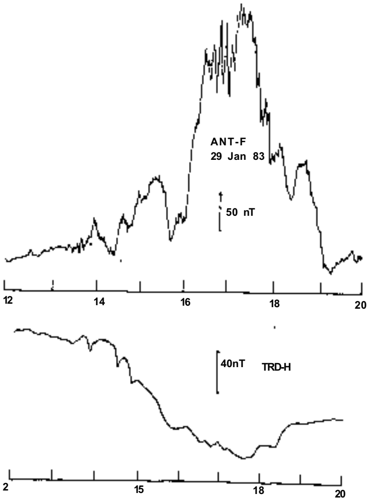

***Fig. 10.* Sequence of 3 negative sudden impulses at Trivandrum and corresponding Antarctica record**

The onset time of SSC is close to the favoured interval of 00-03 hrs MLT and therefore one should expect a triggered substorm following the commencement. Fig 9 presents Trivandrum and Antarctica F records for the event. It can be seen that the positive/negative impulse of the shock is also noticeable at Antarctica and that a moderate substorm was indeed initiated by the SSC .The initial phase of the storm at low latitude is characterised by high frequency oscillations which are also seen in Antarctica.

On 29 January, 1983, Trivandium magnetogram registered a sequence of three negative impulses at 1345 UT, 1427 UT and 1445 UT. If substorms were to be triggered only by compressed magnetosphere and are most often observed only in association with impulses in the early morning sector this sequence of negative impulses would not have any associated substorm Fig 10, however, clearly indicates that these negative impulses, indicative of expansion of the magnetosphere, have also been successful in triggering a major substorm during a period not considered "favourable". This event clearly demonstrates the complexity of the high latitude magnetic field change and the need, for comprehensive studies.

Geomagnetic positive bays are usually observed during local night hours at low latitudes Though initially considered to be manifestation of ionospheric return currents of polar magnetic substorms, they are now known to be related to distant currents of magnetospheric origin partially closing through night time ionosphere Bay activity exhibits several interesting correlation with IMF The low latitude bay signature has been suggested to be useful in precise determination of onset of moderate to large substorms (Burch, 1974) Thinning of the plasma sheet due to increased tail magnetic field leading to instability and consequent strengthening of westward auroral electroject is more or less an accepted concept. According to this simultaneous with the depression in the field at auroral station, equatorial station below the resistive sector in the tail should show an increase in the field caused by the absence of westward tail current there.

In the next set of figures (Fig 11 to 14) we show different manifestations of the evolution of the bay disturbance at Antarctica and Indian equatorial region. The bay activity and substorm field are nearly simultaneous in Fig 11 whereas the positive bay is preceded by a large substorm acvtivity in Fig 12 . In Fig 13 we find that despite the moderate activity at high latitudes, the H field at Trivandrum shows only a slow decrease of the field followed by a partial recovery. Fig 14 provides an example where the Antarctica field shows large substorm during night hours but at low latitudes there is no discernible bay activity. However, pulsatory fields are seen to be common features at both the locations .These examples-and there could be several others in the 40 days of data available-clearly reveal that the last word has not been said on the interrelationship between the auroral substorms and low latitude bays.

Apart from magnetic disturbances, substorm at high latitudes and bay activity at low latitudes, the records occasionally show some peculiar structure over short time intervals, apparently unrelated to any of the large scale processes of the magnetosphere .Some of these have been identified in magnetograms of the Indian chains Scrutiny shows that these events, in most cases are synchronous in Universal Time at Antarctica also, indicating that the cause is appaiently related to fluctuations in distant currents. Two examples of such isolated structures are shown in Fig 15 and 16 Except for the fact that the field variations are more rapid and more magnified at Antarctica regions, the coincidence is indeed remarkable.

By selected samples of magnetic records near *Dakshin Gangotri* and the corresponding magnetograms from the Indian equatorial region, we have attempted to show that there are several

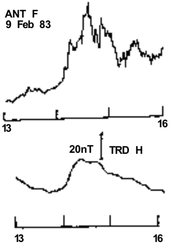

Fig 11 **Positive Bay (without pio) it Trivandrum and corresponding Antarctica record**

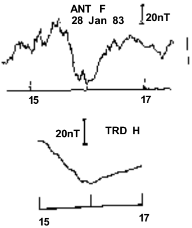

Fig 13 **Gradual decrease followed by recovery at Trivandrum and the corresponding activity at Antarctica**

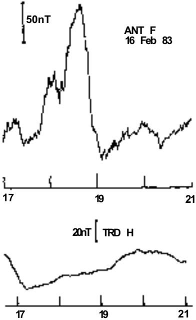

Fig 12 **Positive Bay at Trivandrum with pulsations preceded by substorms in Antarctica**

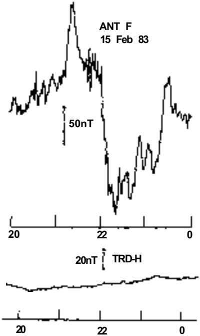

Fig 14 **Large substorm at Antarctica with no significant counterpart at Trivandrum except pulsatory fields**

interesting facets to be interaction of solar wind and magnetosphere and the consequent geomagnetic field changes at auroral and equatorial latitudes Much more needs to be done to unravel some of the mysteries of coupling between these two regions on some occasions and the absence at other times. The investigation could only be complete if we have records of all the three components at conjugate lacations and data of the interplanetary plasma and field parameters Also, with several semi-permanent magnetic stations already functioning in the Antarctica region, it will be useful if analysis is carried out on collated data for selected events. During the period of

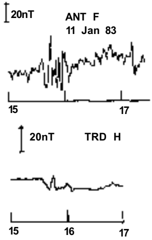

Fig 15 Simultaneous recording of solated structure at Trivandrum and Antarctica

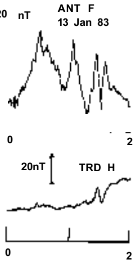

Fig 16 Another example of simultaneous recording of isolated structure at Trivandrum and Antarctica

International Magnetosphere Study (IMS) there have been several successful workshops on analysis of special events using all available data and similar studies with Antarctic data is essential.

There is definite need for a permanent station in the region of *Dakshin Gangotri.* Two stations geographically nearby at Syowa Base (Japan) and Novalaziravskaya (USSR) are actually located on different magnetic lines of force as is evident from their L values of 61 and 46 respectively and therefore the magnetic records are substantially different. Similarly if we consider a distribution of stations located on a given geographic latitude in the Antarctic region we notice that in reality some will be in auroral belt some equatorward of auroral zone and some even in the polar cap as located from their invarient latitude. For any effective study of the geomagnetic phenomena at Antarctica it will be essential to complement the permanent magnetic station with equipment such as digital lonosonde and nometer for measurement of D E and F region parameters so that a unified picture can emerge. In addition we should also explore possibilities of collaboration with institutions in northern hemisphere in Europe for studies related to conjugate phenomena.

As mentioned in the Introduction there was loss of data of the three component variations mainly due to periodic tilting of the variometer set up Efforts will be made to design a firm semi underground structure insulated from sunlight such that this problem does not too frequently occur. New records which have automatic zero effect will be utilised so that there is no loss of record.

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