COMPLEX STRUCTURE OF EQUATORIAL ELECTROJET CURRENT

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ABSTRACT

The value of ΔH (with reference to midnight value) at the equatorial electrojet station minus ΔH at the low latitude stations (outside the equatorial electrojet) on the same longitude shows excellent correlation with the doppler shift of VHF echoes during quiet as well as severe geomagnetically disturbed days. The equatorial sporadic *E* irregularities and hence the equatorial electrojet fields at 100 km seem to start about 10 min later than the start of the Sq current in the morning hours. This confirms the earlier suggestion that equatorial electrojet current is not a single current but has significant contributions from non-Sq current system.

INTRODUCTION

The abnormally large daily variation of the horizontal geomagnetic field (*H*) in the vicinity of the magnetic dip equator, has been successfully interpreted as due to abnormally large eastward current called equatorial electrojet over the dip equator during the daytime hours[1]. The large currents are consequent to the augmented electric conductivities in the *E* region of the ionosphere over the dip equator generated by the Hall polarization field perpendicular to the magnetic lines of force[2]. One of the most important consequences of the equatorial electrojet fields has been the occurrence of equatorial sporadic *E* (ES-q) configuration on the ionograms[3]. Consequent to the generation of cross-field (gradient) plasma instabilities are created at the base of the *E* region due to the interaction of Hall polarization field with the gradient of plasma density[4]. Another evidence of equatorial electrojet currents has been the measurements of the ionospheric drifts[5] or the measurements of *E* region electron drifts by the doppler shift of VHF backscatter echoes from the Es irregularities[6]. Occasional daytime depressions of the *H* field at the equator, a phenomenon known as counter-electrojet, was accompanied by the disappearance of Es-q reflections from the ionograms and the reversal of ionospheric drifts from westward to eastward direction[7].

The depressions in *H* at equatorial stations even when ΔH was not negative (partial counter electrojet) were also associated with the absence of Es-q on the ionograms and of VHF forward scatter signals[8,9]. It was shown that the sudden disappearance of Es-q occurred when the latitudinal profile of ΔH and ΔZ was reversed and not necessarily when ΔH at an equatorial station decreases below the nighttime level[10]. Using the height versus power profile data of VHF backscatter echoes at Jicamarca it was shown that the electrojet irregularities appeared or disappeared precisely when ΔH (Huancayo minus Fuquene) crossed the zero level with the accuracy of a couple of minutes[11].

Although the simultaneity of the counter-electrojet index (ΔH equatorial minus ΔH non-equatorial) and the reversal of the electric field at 100 km has been well established, no quantitative relation has been shown between the counter-electrojet index and the strength of the electric field. A VHF backscatter radar has been operating at Thumba on 54.95 MHz since 1972. Here we have used the published data[12-14] of the doppler shift of the backscatter signals which is proportional to the phase velocity of the irregularities, which, in turn, is proportional to the electric field in the ionosphere to study the relation between electron drifts in the *E* region and the magnetic field at ground.

EXPERIMENTAL OBSERVATIONS AND RESULTS

In figure 1 are reproduced the doppler shift data on magnetically quiet days of 23 February 1978, 13 May 1975 and 14 August 1974, together with the daily ΔH at Trivandrum (TRD), Alibag (ABG) and (TRD-ABG).

On 23 February 1978, both ΔH (TRD) and ΔH(ABG) show smooth daily variations with the maxima of Alibag occurring few hours later than at Trivandrum. The depression in doppler shift in the afternoon hours is not reflected in ΔH(TRD) curve but clearly seen in ΔH(TRD-ABG) curve.

Referring to the data for 13 May 1975, the daily peak of ΔH(ABG) occurred a couple of hours later than the time of daily peak of ΔH(TRD). The ΔH(TRD) did show a minimum in the evening hours, but the values were never negative. ΔH(TRD-ABG) on the other

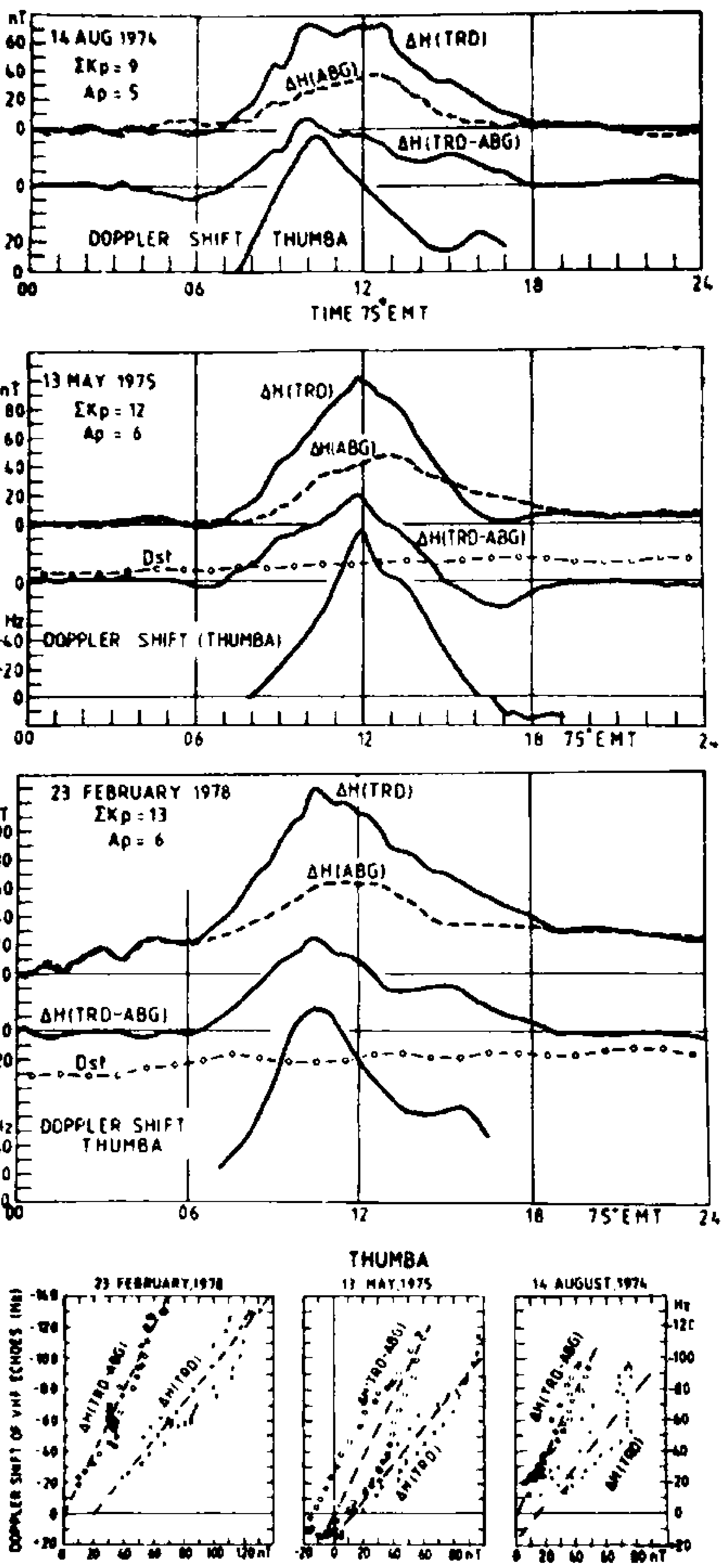


Figure 1(a). Comparisons of the daily variations of doppler shift of VHF backscatter echoes at Thumba with ΔH at Trivandrum (TRD), at Alibag (ABG), and with ΔH(TRD-ABG) on 23 February 1978, on 13 May 1975 **(b)** Mass plot of f_D vs ΔH(TRD) and f_D vs ΔH(TRD-ABG) on 23 February 1978, 13 May 1975 and 14 August 1975.

hand, showed negative value in the afternoon hours beginning 1500 LT. The doppler shift data also showed reversal of the electric field after 1600 LT.

On 14 August 1974 the variation ΔH at Trivandrum had a flat maximum from 1000–1400 LT, whereas ΔH at Alibag had a distant maximum at 1300 LT. The doppler shift had a single peak at 1045 LT which corresponded well with the single peak of ΔH(TRD-ABG) at 1030 LT.

Table 1 ΔH values corresponding to $f_D = 0$

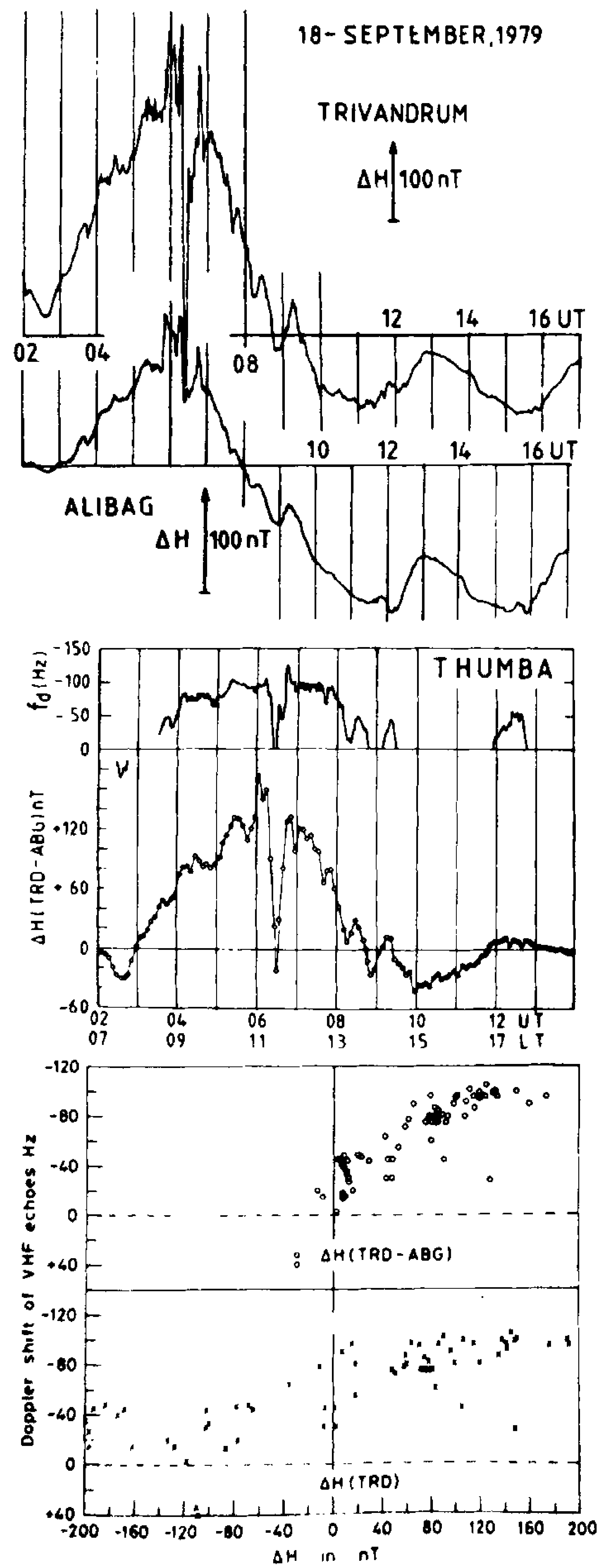
	f_D H(TRD)	f_D H(TRD-ABG)
23 February 1978	20 nT	0 nT
13 May 1975	15 nT	0 nT
14 August 1975	13 nT	0 nT

In figure 1(c) are plotted the scatter points of the doppler shift frequencies f_D against corresponding values of ΔH(TRD) and ΔH(TRD-ABG) separately for the three days. The least square lines are also indicated in the diagrams and table 1 gives the value of ΔH corresponding to $f_D = 0$.

The straight line relating f_D with ΔH(TRD) crosses the X axis at some positive value of ΔH indicating a threshold value of ΔH(TRD) for the starting of the VHF echo doppler shift; this being about 15–20 nT. The line relating f_D to ΔH(TRD-ABG) crosses the axes at the origin indicating the absence of threshold value for the irregularities backscattering the VHF echoes if ΔH(TRD-ABG) is used.

Similar analyses were done for the data obtained during the geomagnetic storm periods of 15 February 1978 and 18 September 1979 as shown in figures 2 and 3. A storm sudden commencement had occurred at 2147 UT on 14 February 1978 or at 0247 LT (75°E MT) on 15 February 1978. It is seen from the magnetograms (figure 2a) that every short period fluctuations in H was greatly magnified in Trivandrum than at Alibag while the slowly varying components were similar at the two places. It is to be noticed from figure 2(b) that the positive values of ΔH(TRD-ABG) have coincided remarkably well in time with the negative values of f_D corresponding to the westward drifts or to the eastward electric field. The negative values of ΔH(TRD-ABG) correspond with either the

Figure 2(a). Magnetograms at Trivandrum and Alibag on 18 September showing geomagnetic storm following SSC at 0549 UT on 18 September 1979 **(b)** Temporal variations of ΔH(TRD-ABG) and the doppler shift of VHF backscatter echoes at Thumba on 18 September 1979. (c) Mass plot of f_D vs ΔH(TRD) and f_D vs ΔH(TRD-ABG) on 18 September 1979.



(**Figure 2.** See p. 434 for caption).

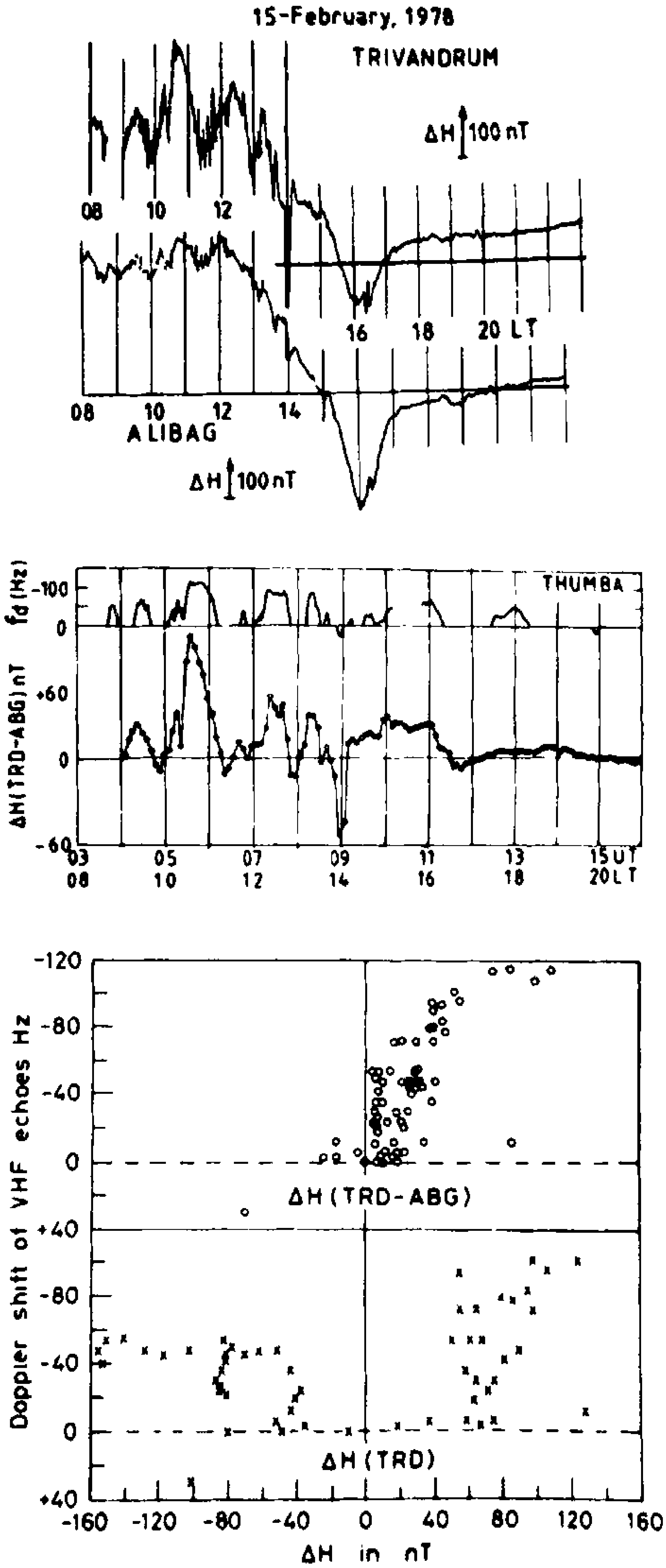


Figure 3(a) Magnetograms at Trivandrum and Alibag on 15 February showing geomagnetic storm following SSC at 2147 UT on 14 February 1978. (**b**) Temporal variations of ΔH(TRD-ABG) and the doppler shift of VHF backscatter echoes at Thumba on 15 February 1978. (c) Massplot of f_D vs ΔH(TRD) and f_D vs ΔH(TRD-ABG) on 15 February 1978.

absence of VHF echoes or with positive value of f_D. From figure 2(c) it can be seen that, when the individual values of f_D are plotted against ΔH(TRD), no definite relations can be obtained, but the same f_D data plotted against ΔH(TRD-ABG) show an excellent relation, the average curve passing through the origin. Thus even during disturbed conditions ΔH(TRD-ABG) indicates an excellent parameter for the eastward electric field in the ionosphere without any assumptions made.

On 18 September 1978 SSC had occurred at 0549 UT or 1049 LT (75°E MT). The storm range of H at Kodaikanal was reported to be 506 nT.

Referring to figure 3(a) the SSC at 0549 UT was followed by large fluctuations of H with a very large depression of ΔH at 0630 UT = 1130 LT exceeding 200 nT. After 0700 UT the geomagnetic field had continually decreased due to ring current effects, but there were no rapid fluctuations of the field. Referring to figure 3(b), the value of ΔH(TRD-ABG) had decreased below zero in the forenoon, for a very brief period around 0630 UT (1130 LT) and in the afternoon. It is interesting to find the excellent time corresponding between the positive values of ΔH(TRD-ABG) and the negative values of f_D. From figure 3(c) again the mass plot of f_D shows smooth relationship with ΔH(TRD-ABG) with the mean curve passing through origin.

It is concluded that ΔH(TRD-ABG) is shown to be an excellent parameter for the equatorial electrojet for defining the direction of the ionospheric electric field, and indicates a good quantitative estimate of the equatorial electrojet current strength responsible for E region irregularities.

DISCUSSION

Rastogi[15] suggested that the equatorial electrojet current consists of one associated with general Sq current system flowing eastward at about 107 km and another associated with high latitude auroral electrojet currents flowing over the equator at 100 km either eastward or westward depending upon the solar magnetospheric conditions existing at that time.

The results shown here that the equatorial electrojet irregularities start developing only when ΔH at equator exceeds ΔH at non-equatorial station suggests that with sunrise first the Sq currents starts building up and later the electrojet part responsible for Es irregularities. Here it has been shown quantitatively that the electric fields associated with Es irregularities have a significant contribution from the non-Sq source and ΔH at equatorial minus ΔH at non equatorial station is definitely a very exact index of defining the equatorial electrojet properties.

ACKNOWLEDGEMENTS

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