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COMPARISON OF STORM-TIME CHANGES OF GEOMAGNETIC FIELD AT GROUND AND AT MAGSAT ALTITUDES

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1. INTRODUCTION

The purpose of this investigation is to compare the storm-time variations of geomagnetic field at ground and at MAGSAT altitudes.

2. TECHNIQUES

Most of the ground data are not yet available to us. We have asked for these from the WDC-A, Boulder, Colorado. However, we know that these will be for the H, D, Z components of geomagnetic field and, in particular, we wish to concentrate on the H component.

From the MAGSAT tapes, data are available for the X, Y, Z components. We converted these (by computer program) to yield the component $H = (X^2 + Y^2)^{1/2}$.

MAGSAT goes round the earth in a roughly polar orbit, needing about 1.6 hours. The plane of the orbit seems to be roughly perpendicular to the sun-earth line so that each pass has a south-north swing during local dusk hours and a subsequent north-south swing during local dawn hours. Thus, these two swings have equatorial crossings roughy 0.8 hours apart and at roughly diametrically opposite longitudes. After every complete pass, there is a longitude shift of

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about 24 degrees (westwards) and, in about 15 complete passes, 24 hours and all longitudes are covered.

Fig. 1 shows the $\overline{H}$ values for two successive halves of the same pass (379) for the low latitude region (equator to ± 30^{o}) geographically. During the pass, the satellite seems to change its altitude by a few tens of kilometers. We assumed that H is inversely proportional to R^3, where R = distance of the satellite from the center of the earth, and normalised all H values to a fixed R_o = 6800 km. What are shown in Fig. 1 are $\overline{H}$ values i.e. values of H normalised to a constant geocentric distance R_o = 6800 km. One can see that the latitudinal gradients of $\overline{H}$ are very large indeed (more than 150 gamma per degree) except near the $\overline{H}_{max}$. However $\overline{H}_{max}$ itself has a very large longitudinal variation. For example, it has values as high as 33000 gamma at longitudes of about + 100^{o}, dropping to as low as 23000 gamma at longitudes of about - 70^{o}, a drop of 10000 gamma in 170^{o} i.e. about 60 gamma per degree of longitude. In storm-time studies, the effects we expect are of the order of few tens of gamma. It is obvious therefore, that values of H or H_{max} cannot be used directly in such a study, lest even slight errors in latitudes or longitudes could give errors overwhelming the expected effect.

A reasonable alternative is to subtract out some base values which have already taken into account the gross features of the latitude and longitude variation of H. Such base values are obtained from the geomagnetic field model. The MAGSAT tapes we have contain model values of X, Y, Z viz. XMD, YMD, ZMD. We used these to obtain $HMD = (XMD^2 + YMD^2)^{1/2}$ and obtained $\overline{HMD}$ which is HMD normalized to a constant R_o = 6800 km as before. If the model is adequate, the difference $\Delta H = \overline{H} - \overline{HMD}$ should be zero. In Fig. 1, we show the latitude variation of ΔH for the two swings (N → S) and (S → N) of pass 379. In contrast to the sharp gradients in $\overline{H}$, the variation in ΔH is very small (few tens of gamma over a large latitude range). This is true for widely differing longitudes. Hence, the major gradients, both latitudinal as well as longitudinal, are taken care of by the model subtraction.

However, the fact remains that ΔH so obtained is not zero. We now examine the utility of ΔH for storm-time studies.

3. ACCOMPLISHMENTS

We obtained the latitudinal variation of ΔH (+ 30° to - 30° latitude) for the two swings of every pass, as shown in Fig. 1. To start with, we concentrated on ΔH_0 i.e. the values of ΔH at the equatorial crossing (geographical latitude zero). Table 1 shows a sample listing for passes Nos 154-169 on Nov. 12, 1979 (Julian day 44189). From the MAGSAT tape, values are available for Mean Local Time (MLT) as well as geographic longitude. The UT in Table 1 is calculated as:

$$UT = MLT - (\text{Longitude in degrees})/15.$$

for values at equatorial crossing only.

Fig. 2 is a plot of ΔH_0 at DAWN (dots) and DUSK (crosses) for six days Nov. 2-7 in the top row, Nov. 8-13 in the middle row and Nov. 14-19 in the botton row. Standard Dst (Sugiura and Poros, 1971 and similar furthur publications) is also plotted and K_p histograms are marked. For each day, there are about 15 dots of ΔH_0 (Dawn) and 15 crosses of ΔH_0 (Dusk). Judging from Dst, the period contains quiet as well as disturbed days. Thus, Nov. 5, 6, 15 were very quiet (highest 3 hourly K_p was 1^+). In contrast, Nov. 13-14 had a geomagnetic storm with K_p exceeding 5 and Dst reaching - 90. It is interesting to note that K_p does not always match Dst. Fig. 3 shows a plot of K_p versus Dst for Nov. 2-19, 1979. Whereas very high K_p are associated with high Dst, the scatter is very large, mainly because of the glaring mismatch on Nov. 15 when K_p was very low but Dst was still large (about - 30) in the storm recovery and on Nov. 11 when K_p was large while Dst was very small or positive. Dst is obviously a finer index of storm-time variations.

4. SIGNIFICANT RESULTS

The following is noteworthy in Fig. 2:

(i) Both the ΔH_o (Dawn) and ΔH_o (Dusk) seem to follow the Dst trend. Thus, these H residuals are representative of storm-time variations, at least qualitatively.

(ii) In general, ΔH_o is non-zero and is negative. The ΔH_o (Dusk) (crosses) are more negative. The non-zero values could be an indication of the inadequacy of the model. However, on Nov. 11 when Dst attained positive values, both the ΔH_o at Dusk and Dawn became almost zero. This leads us to believe that the non-zero values of ΔH_o are indicative mainly of storm-time activity, in smaller or larger degrees.

(iii) On Nov. 13-14, ΔH_o (Dusk) are numerically very much larger than ΔH_o (Dawn). Thus, the storm effect is seen more effectively in the Dusk sector. However, on Nov. 14 at about 0600 when the storm was still recovering (Dst about - 60), the Dawn and Dusk ΔH_o merge into each other, each having a value of about - 60.

(iv) Conventionally, the storm-time variation is considered to be composed of an isotropic component Dst and a LT dependent component DS. For the MAGSAT data, an average of ΔH_o (Dawn) and ΔH_o (Dusk) should be roughly equivalent to Dst while their difference should be equivalent to DS. However, as seen from Table 1, the ΔH_o at Dusk and Dawn are not recorded simultaneously (at the same UT) but are recorded about 0.8 hours apart. As a rough approximation, in-between values could be obtained as averages of the previous and succeeding values, separately for ΔH_o (Dawn) and ΔH_o (Dusk). For example in Table 1, ΔH_o (Dusk) at UT = 8.4 and UT = 10.0 are - 42 and - 40 respectively. Hence ΔH_o (Dusk), at UT = 9.2 could be assigned as - 41. Similarly, for UT = 2.4 and UT = 4.1, the ΔH_0 (Dawn) are - 18 and - 30 respectively. The in-between value for UT = 3.3 may be assigned as - 24. The complete set with manipulated values so obtained are given in Table 1. Also the average Dst' = [ΔH_0 (Dusk) + ΔH_0 (Dawn)]/2 and the difference DS' = [ΔH_0 (Dusk) - ΔH_0 (Dawn)] are given.

Fig. 4 shows a plot of Dst versus ΔH_0 (Dusk) in the upper half, for the four days Nov. 11-15, 1979. Values during the recovery of the storm (Nov. 14-15) are shown as triangles. Whereas the dots fall roughly on one straight line, the triangles seem to lie above this line, indicating lesser ΔH_0 (Dusk) when Dst is still high. In the lower half of Fig. 4, a similar plot is shown for Dst versus ΔH_0 (Dawn). The slope of the regression line is lesser, indicating smaller values of Dawn ΔH_0 compared to ΔH_0 (Dusk) for similar Dst.

Fig. 5 upper half shows a plot of Dst versus the average Dst' = [ΔH_0 (Dusk) + ΔH_0 (Dawn)]/2. The scatter about the regression line is much smaller as compared to that in Fig. 4 (upper half), indicating that Dst is more similar to this average Dst' than to either ΔH_0 (Dusk) or ΔH_0 (Dawn). The lower half of Fig. 5 shows a plot of Dst versus the difference DS' = [ΔH_0 (Dusk) - ΔH_0 (Dawn)]. Here, the scatter is very large. In particular, the DS' is very near zero for a large range of Dst, during the recovery phase (triangles) of the storm. This implies that the LT dependent DS' component vanishes much before the complete recovery of a storm.

(v) If the ΔH_0 (Dusk) and ΔH_0 (Dawn) plotted in Fig. 2 are genuine, the implication is that both Dst' and DS' are largely of magnetospheric origin and, Dst' lasts longer than DS'. Also, DS' is composed mainly of larger depressions from zero level of the Dusk values and the DS' values are not well correlated with Dst' values. Since the DS is attributed to partial ring currents associated with field-aligned currents passing through the auroral ionosphere, the lack of correlation probably indicates partially independent evolutions of the main equatorial ring currents and its leakages to the auroral regions.

(vi) If the ΔH_0 values have some non-physical origins, corrections for the same may be needed. If the model values HMD are wrong, one will have to await for better estimates. On the other hand, the model does not take care of local anomalies. Since the ΔH_0 shown in Fig. 2 are ΔH values at equatorial crossings, local anomalies at certain longitudes may affect the ΔH_0 values. For example, Regan et al (1975), indicate the Bangui or Central African anomaly at about + 15^0 longitude. Fig. 6 shows the latitude variation of ΔH for a few passes in this region. Whereas a clear depression (anomaly) is seen at about + 6^0 latitude, the value of ΔH_0 (at latitude 0^0) is - 16, - 30 and - 31 for the passes 264, 49, 380, all of which occurred at very low K_p and Dst. In Fig. 2, successive dots for several passes are consistently above the successive crosses, thus indicating that local anomalies are probably not playing any important role. Nevertheless, a quantitative estimate of ΔH_0 does need a proper correction for local anomalies, if any. To estimate the nature of these corrections, all passes at given longitudes (or at least longitude zones) will have to be examined for quiet periods and ΔH versus latitude patterns will have to be established for quiet periods, to be later subtracted from similar patterns for individual passes for disturbed days. Work in this direction is in progress.

In due course, ΔH_0 values so corrected will be compared with ground data, when these are available, and results will be reported in future reports. We are also keeping in mind the possibility that ΔH_0 (Dawn) and ΔH_0(Dusk) may differ because of Sq effects (Sugiura and Hagan, 1979).

5. DATA QUALITY

From about the first 400 passes that we have examined so far (Nov. 2-27, 1979), a majority shows a reasonable ΔH versus latitude variation as shown in Fig. 1. However, a few passes, notably passes Nos. 1-15 on Nov. 2, 1979 (Julian day 44179) show very odd patterns of ΔH versus latitude, with values ranging and oscillating from + 100 to - 100 or more. In Fig. 2, Nov. 2 shows very large ΔH_o (Dusk), unwarranted by the low values of Dst. A similar discrepancy occurs on Nov. 16. We believe that these passes are not reliable. This may kindly be reexamined and, if true, the MAGSAT investigators be informed corrections, if any.

The quality of the rest of the data seems to be very good.

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Sugiura M. and Poros D.J. Hourly values of equatorial Dst for the years 1957 to 1970. GSFC Publication X-645-71-278 (1971).

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TABLE 1. UT, Longitude and ΔH at equatorial crossing, as well as other parameters for passes 154-169 on Nov. 12, 1979 (Julian day 44189)

Pass Nº	UT	DUSK swing		DAWN swing		Dst	Complete set with Manipulated values				Average of DUSK ΔH₀ and DAWN ΔH₀	Difference DUSK ΔH₀ minus DAWN ΔH₀
							DUSK swing		DAWN swing			
		Long.	ΔH_0	Long.	ΔH_0		Long.	ΔH_0	Long.	ΔH_0		
154	0.0	- 96°	- 27	-	-	+ 1	- 96°	- 27				
154	0.8	-	-	+ 73°	- 15	+ 1	- 108°	- 29	+ 73°	- 15	- 22	- 14
155	1.6	- 119°	- 30	-	-	+ 1	- 119°	- 30	+ 61°	- 17	- 24	- 13
155	2.4	-	-	+ 49°	- 18	- 1	- 132°	- 29	+ 49°	- 18	- 24	- 11
156	3.3	- 143°	- 27	-	-	+ 2	- 143°	- 27	+ 38°	- 24	- 26	- 3
156	4.1	-	-	+ 26°	- 30	+ 7	- 155°	- 26	+ 26°	- 30	- 28	+ 4
157	5.0	- 166°	- 24	-	-	+ 9	- 166°	- 24	+ 15°	- 26	- 25	+ 2
157	5.9	-	-	+ 3°	- 21	0	- 178°	- 24	+ 3°	- 21	- 23	- 3
158	6.8	+ 171°	- 23	-	-	0	+ 171°	- 23	+ 9°	- 23	- 23	0
158	7.6	-	"	- 21°	- 24	+ 1	+ 159°	- 33	- 21°	- 24	- 29	- 9
159	8.4	+ 147°	- 42	-	-	0	+ 147°	- 42	- 33°	- 16	- 29	- 26
159	9.2	-	-	- 44°	- 8	0	+ 136°	- 41	- 44°	- 8	- 25	- 33
160	10.0	+ 124°	- 40	-	-	[illegible]	+ 124°	- 40	- 56°	- 17	- 29	- 23
160	10.7	-	-	- 68°	- 25	+ 13	+ 112°	- 39	- 68°	- 25	- 32	- 14
161	11.4	+ 100°	- 37	-	-	+ 5	+ 100°	- 37	- 80°	- 24	- 31	- 13
161	12.4	-	-	- 91°	- 23	+ 6	+ 89°	- 41	- 91°	- 23	- 32	- 18
162	12.9	+ 77°	- 44	-	-	+ 6	+ 77°	- 44	- 103°	- 25	- 35	- 19
162	13.9	-	-	- 115°	- 26	+ 1	+ 65°	- 41	- 115°	- 26	- 34	- 15
163	14.4	+ 53°	- 37	-	-	- 1	+ 53°	- 37	- 127°	- 25	- 31	- 12
163	15.2	-	-	- 138°	- 24	- 3	+ 42°	- 39	- 138°	- 24	- 32	- 15
164	15.9	+ 30°	- 40	-	-	- 3	+ 30°	- 40	- 150°	- 25	- 33	- 15
164	16.9	-	-	- 161°	- 25	- 3	+ 19°	- 46	- 161°	- 25	- 36	- 21
165	17.5	+ 7°	- 51	-		0	+ 7°	- 51	- 173°	- 28	- 40	- 23
165	18.2	-	-	+ 175°	- 31	+ 4	- 5°	- 39	+ 175°	- 31	- 35	- 8
166	19.0	+ 17°	- 26	-	-	+ 4	- 17°	- 26	+ 164°	- 26	- 26	0
166	19.7	-	-	+ 152°	- 21	+ 4	- 29°	- 24	+ 152°	- 21	- 23	- 3
167	20.5	- 40°	- 22	-	-	1	- 40°	- 22	+ 140°	- 25	- 24	+ 3
167	21.2	-	-	+ 128°	- 29	- 9	- 52°	- 25	+ 128°	- 29	- 27	+ 4
168	21.9	- 64°	- 27	-	-	- 9	- 64°	- 27	+ 117°	- 27	- 27	0
168	22.7	-	-	+ 105°	- 25	- 9	- 76°	- 28	+ 105°	- 25	- 27	- 3
169	23.4	- 87°	- 29	-	-	- 6	- 87°	- 29				

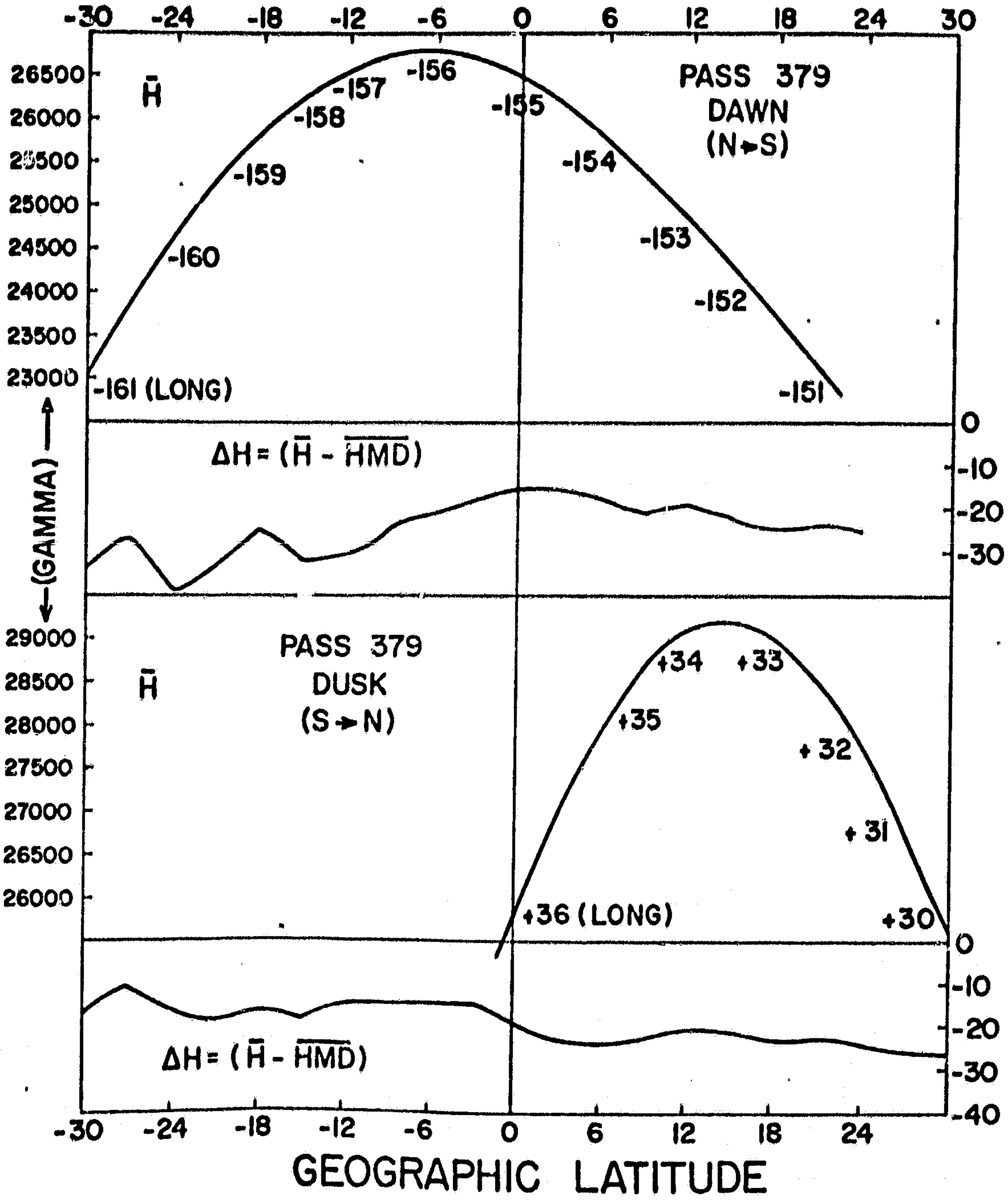

Fig. 1 - The latitude variation of $\overline{H}$ (the H component normalized to a geocentric distance of 6800 km) for the Dawn and Dusk swings of Pass 379 as also of $\Delta H = \overline{H} - \overline{HMD}$, where $\overline{HMD}$ is the normalised value, predicted by geomagnetic model.

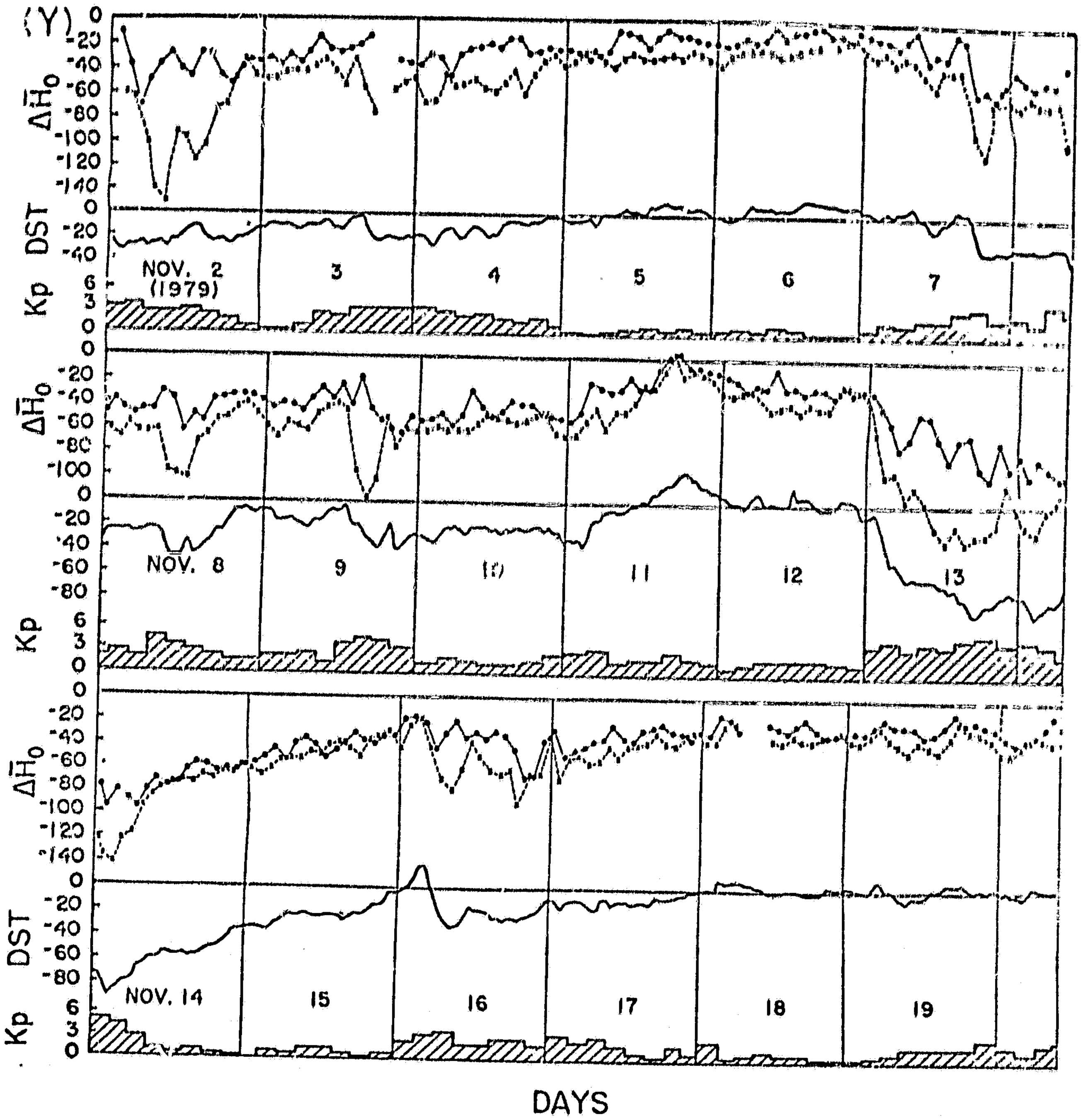

Fig. 2 - Plot of ΔH_0 (the ΔH values at equatorial crossings) for Dusk (crosses) and Dawn (dots) swings, as also of Dst for Nov. 2-7 (top), Nov. 8-13 (middle) and Nov. 14-19, 1979 (bottom). Kp is also indicated as histograms.

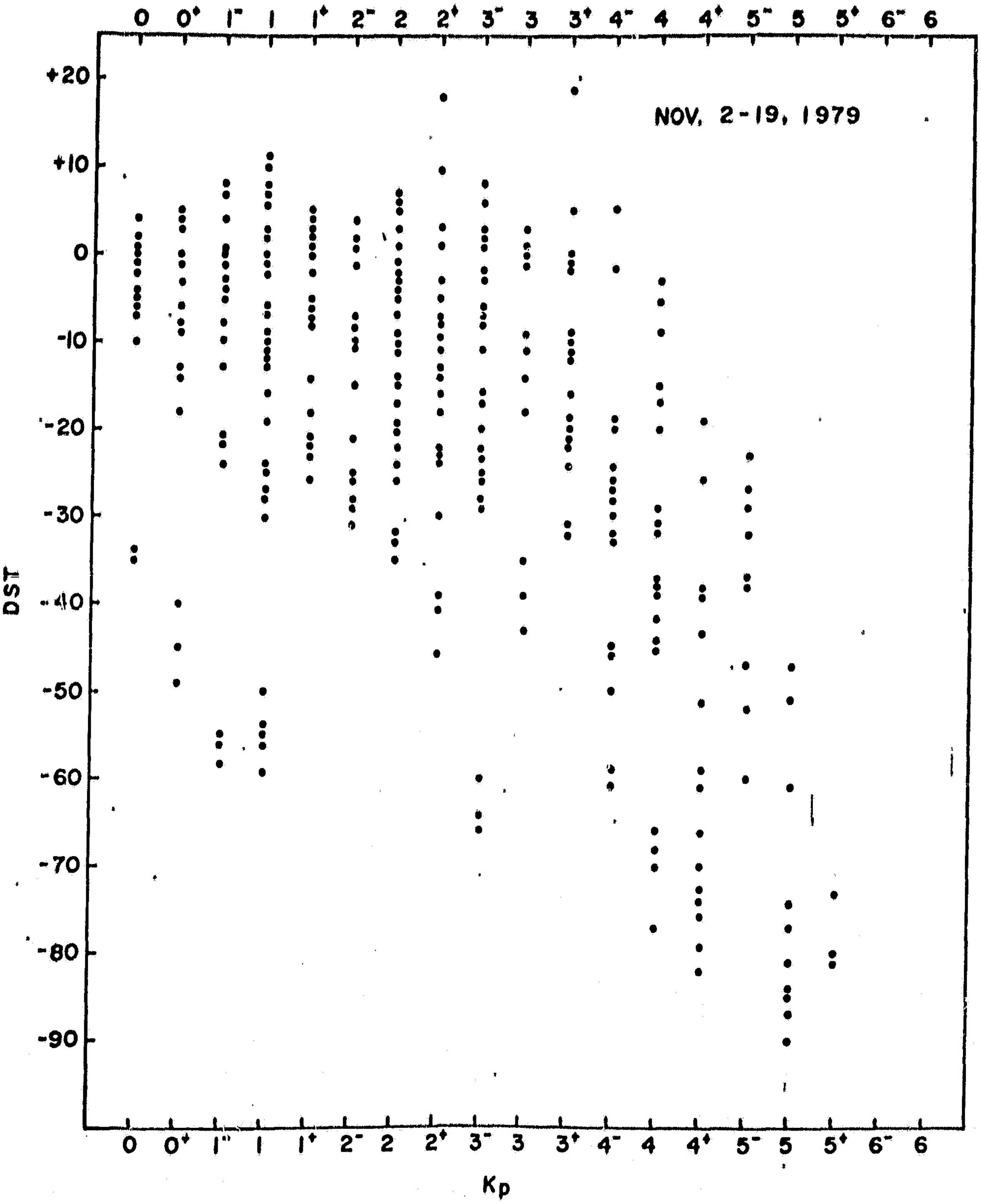

Fig. 3 - K_p versus Dst for Nov. 2-19, 1979.

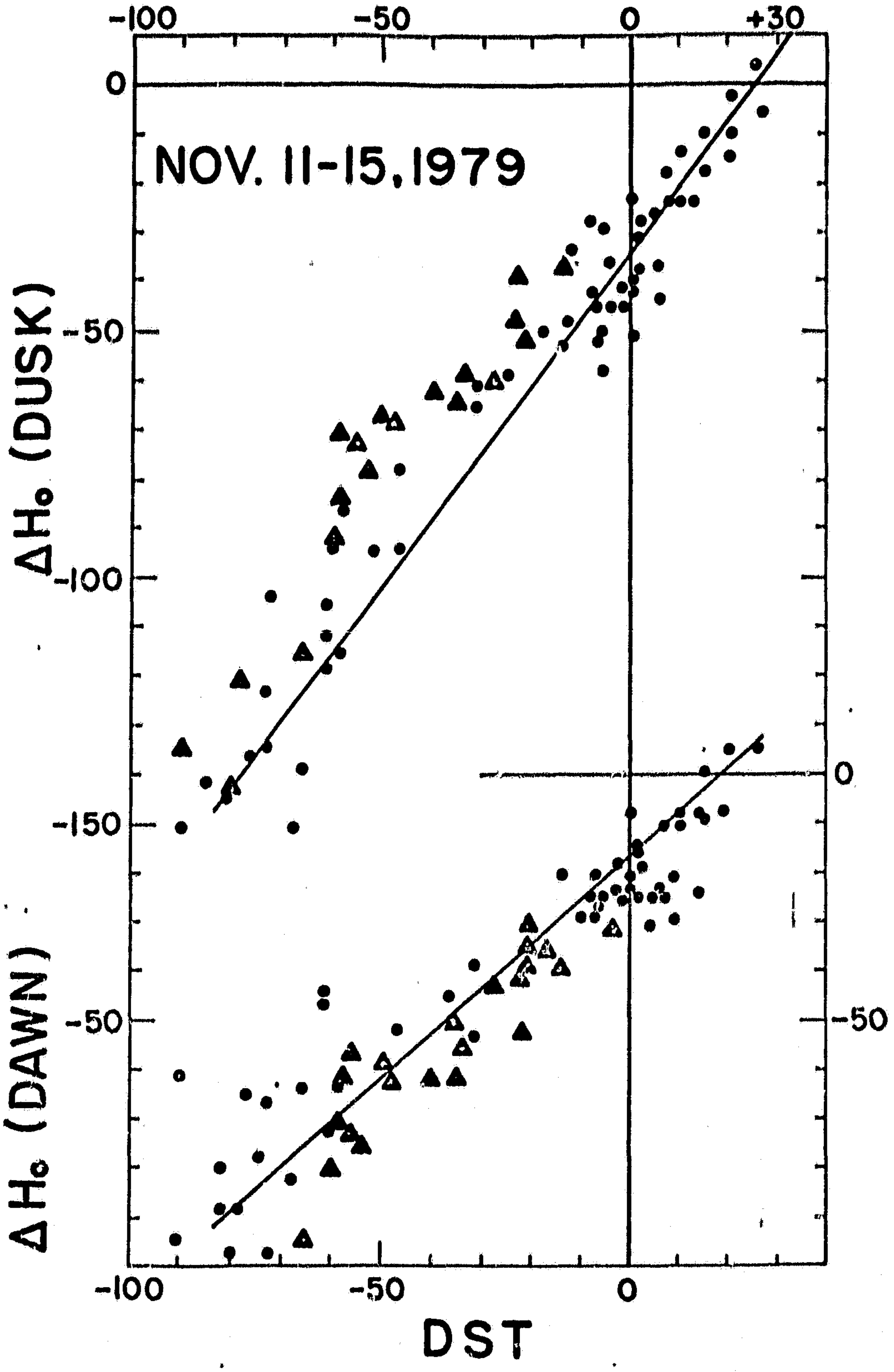

Fig. 4 - Dst versus ΔH_0 (Dusk) (upper half) and ΔH_0 (Dawn) (lower half) for the storm period Nov. 11-15, 1979. Triangles represent values in the recovery phase (Nov. 14-15).

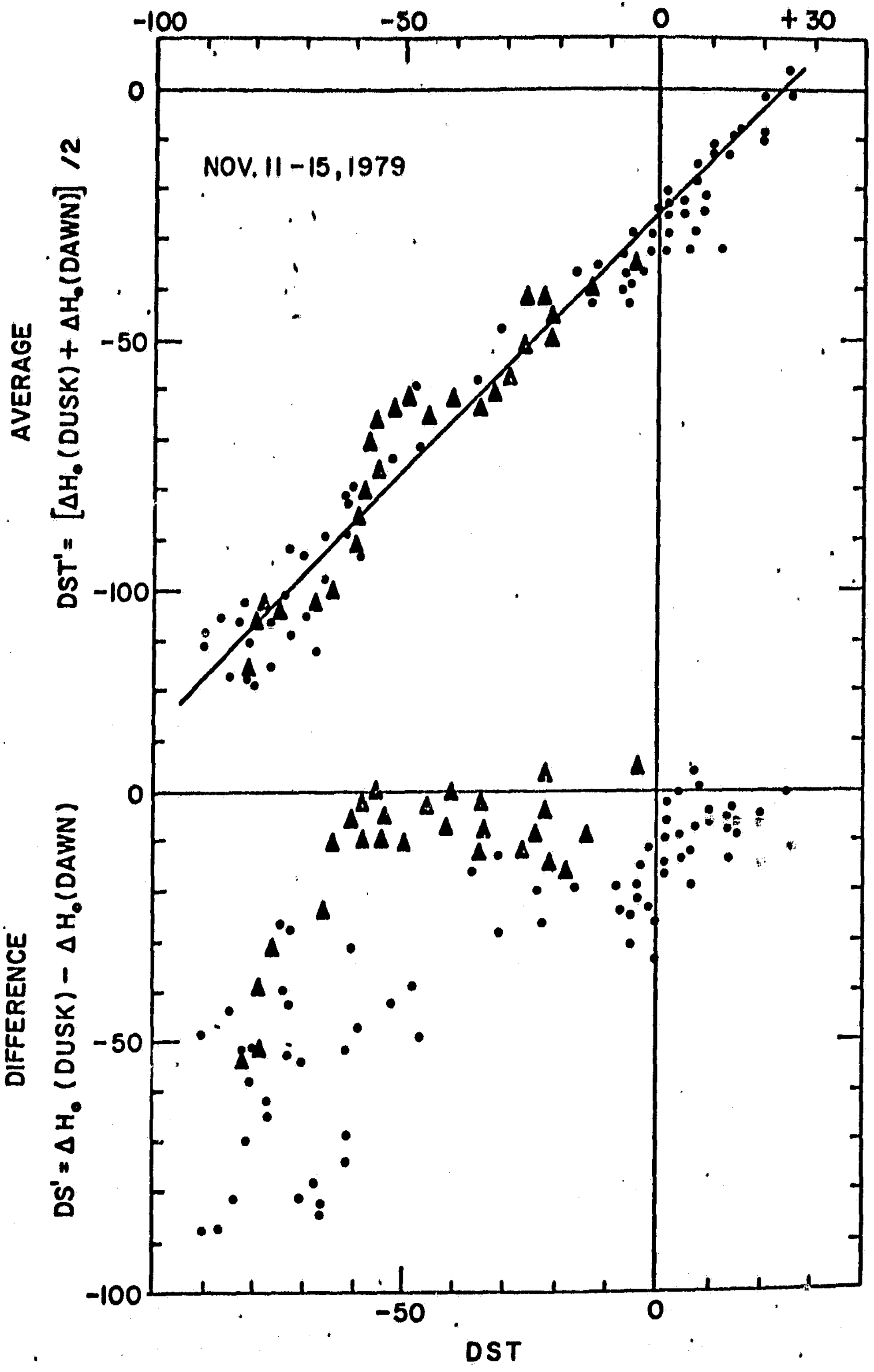

Fig. 5 - Dst versus Dst' = [ΔH_0 (Dusk) + ΔH_0 (Dawn)]/2 in the upper half and versus DS' = [ΔH_0 (Dusk) - ΔH_0 (Dawn)] in the lower half.

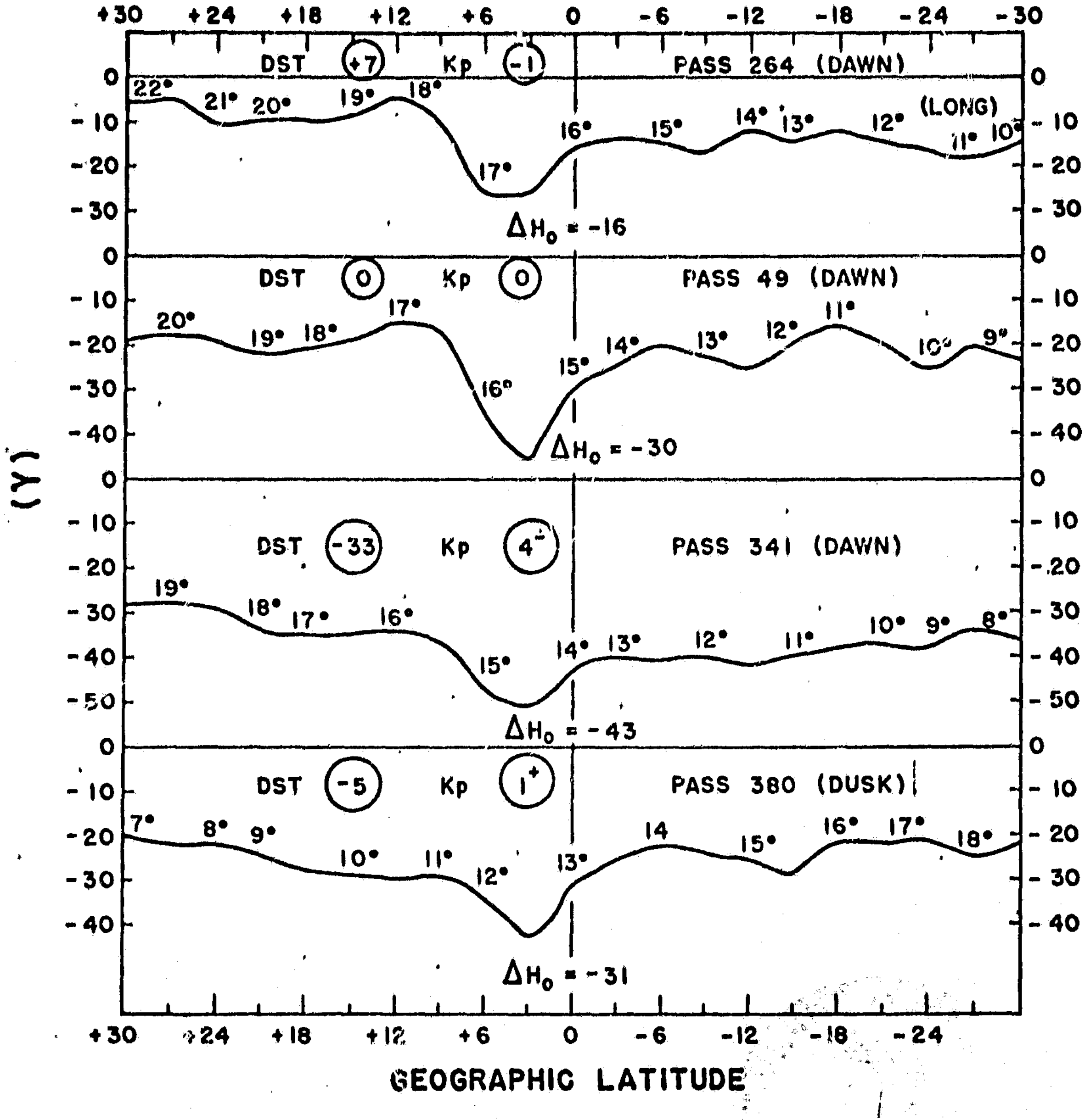

Fig. 6 - The latitude distribution of ΔH for a few passes at longitudes + 13° to + 16° in the Central African region. The Dst and K_p values are indicated and show quiet conditions for Passes 264, 49, 380 and disturbance for Pass 341.