

### I-1-3. Changes in the Geomagnetic Field Associated with Magnetic Disturbance

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A decrease in the magnetic horizontal component intensity ( $H$ ) lasting for several hours to a day or more is usually associated with the existence of a magnetic disturbance. In this paper a study is made of the longer term changes in  $H$  and  $Z$  and occurrences of Quiet Days, Disturbed Days, Storm Sudden Commencements, Sudden Impulses, Small Changes, etc., for several days before as well as during the disturbance. It is found that  $H$  rises, and  $Z$  generally falls, for three or four days before the disturbance as if in anticipation of it. The rise in  $H$  is lowest at middle latitudes and greatest near the auroral zone. The behavior of  $H$  and the other parameters studied suggest that the pre-disturbance variations may be linked to the disturbance mechanism.

#### Introduction

In studies made of geomagnetic storms and disturbances, the greatest amount of attention has been directed toward the period of the actual disturbance. That is, the period ordinarily studied begins with the hour or so in which the storm sudden commencement (SSC) occurs, or in which other marked changes appear in the character of the trace. In non-polar latitudes, the SSC onset of the storm is usually followed by a short duration increase in the horizontal magnetic component ( $H$ ), then by a much longer and larger  $H$  decrease. This decrease is generally considered to be the major manifestation of a storm and thus receives most attention. In this paper, a study is made of the daily changes in  $H$  and other phenomena before the storm onset, as well as after, to determine what may precede the disturbance.

A simple criterion is used here as the basis for the selection of events indicating disturbance, and is based upon abrupt change from a day that is quiet or moderate in activity to a day that is disturbed. A Greenwich day is selected as a zero day (initial day of pair) in this analysis if the International magnetic character figure  $C_i$  for the day following is at 1.0  $C_i$  greater than the initial day of the pair. These dates were noted along with the dates of 5 or more days before and after each selected zero day. Initial dates were

obtained from IUGG/IAGA Bulletin 12 e and 12 f (Bartels and Veldkamp 1950-1951). For each such date, corresponding daily  $H$  and  $Z$  values for each of several stations, were entered into tables evaluated in the phased and standard superposed epoch manner. (Chernosky, 1953), (Chree, 1913).

The choice of an increase in  $C_i$  as the criterion for the analysis was made for the following reasons: (1) An increase of  $C_i \geq 1.0$  from one day to the next provides a simple selection method that minimizes any statistical maneuvering. (2) An increase of 1.0 or more in  $C_i$  occurs infrequently enough to be an unusual event but frequently enough to have statistical body. (3) It indicates the onset of a disturbed period of about a day or more in duration that contrasts with the quiet or moderate day or days preceding. (4) The usual non-sequential occurrence of such events ( $\Delta C$  equal to or greater than 1.0) eliminates the smoothing of peaks and valleys that consecutive selected events can develop in the superposed epoch type analysis. (5) This increase in  $C_i$ , the abrupt onset, can include disturbances which begin with or without SC or other such phenomena.

To differentiate this selection basis from SSC selections, and because of the abrupt change from a quiet or moderate day to a disturbed day, this day to day increase in  $C_i$  of 1.0 or greater is called an abrupt onset (AO).

**Results**

Examination of other events occurring on these abrupt onset dates show the following: (1) None of the initial days but twenty (75 %) of the second days of the abrupt onset pairs coincides with the internationally selected five most-disturbed days of each month (5D). (2) Fourteen of the zero days and none of the plus one days coincide with the five most quiet days of each month (5Q). (3) Two of the initial days and eleven of the plus one days have SSC's occurring on them. Data on SSC's Sudden Impulses (SI), Small Changes (SmC), Solar Flare Effects (SFE),

etc. were obtained from IUGG/IAGA Bulletins 12 e and 12 f. There are, however, no SSC's on the three days preceding the zero day of the pairs and only one each on five of the six days following the second or disturbed day of the pair. However, days which occur five, six, and seven days before the initial day of the pairs have either two or four SSC's. These occurrences are shown in Figs. 1 and 2.

With reference to the 5Q and 5D days it is of interest to note that these days both together, occur least (4 times of 15%) on the fourth day before the zero day, and only five

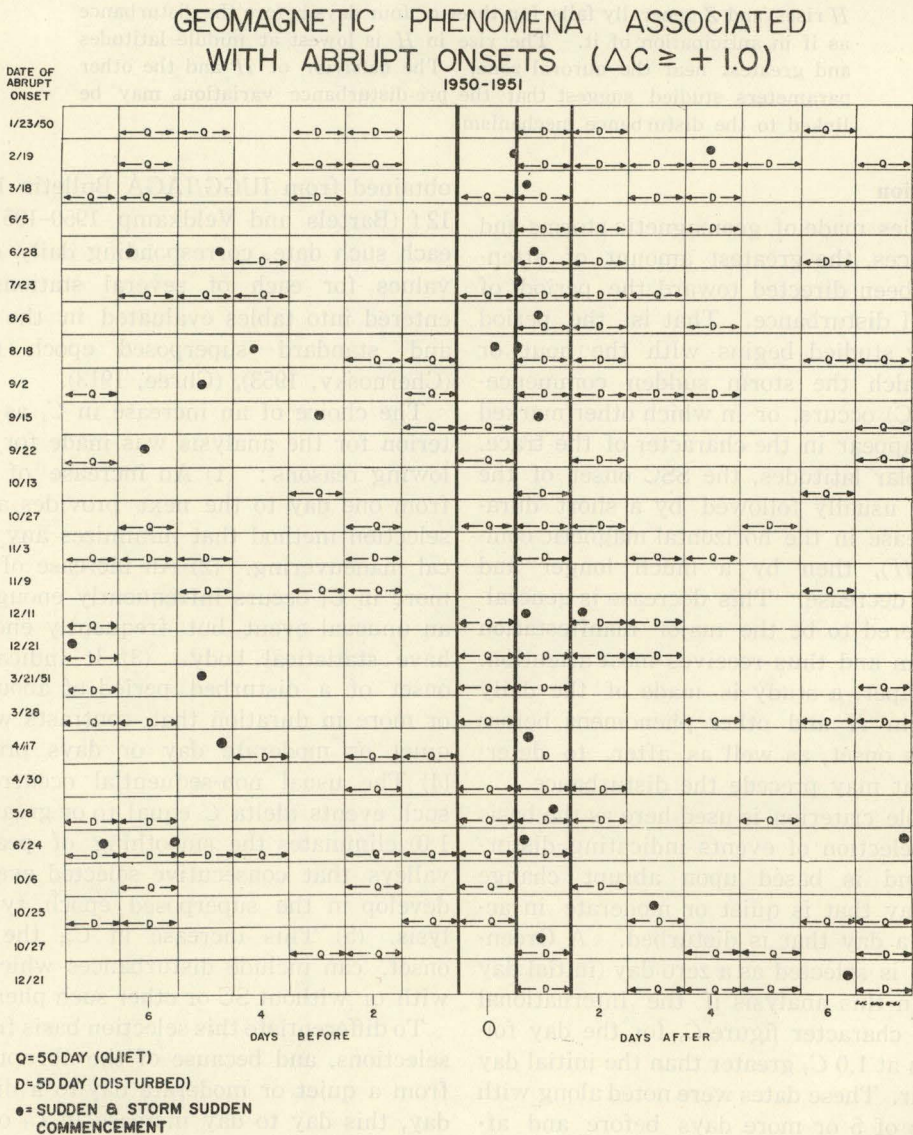


Fig. 1.

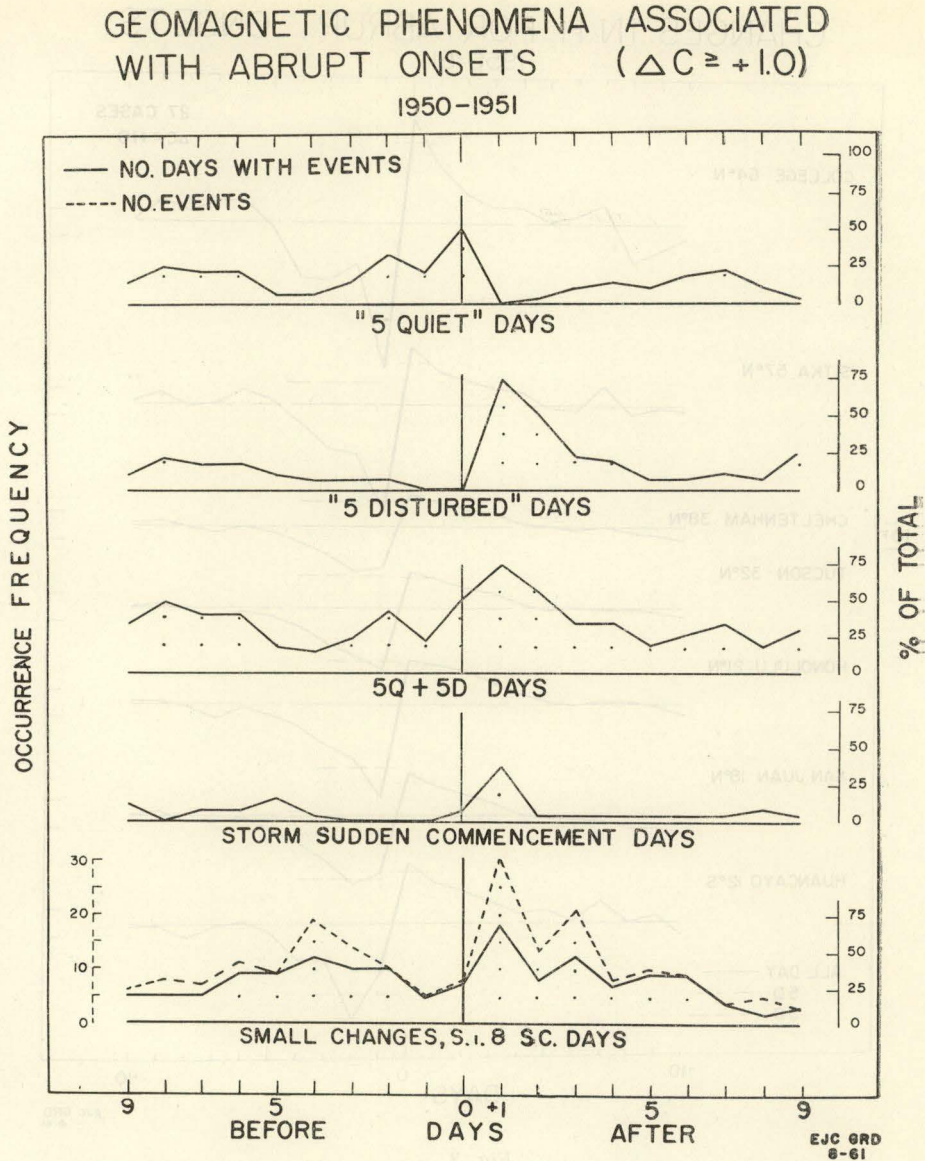


Fig. 2.

times the fourth day after the plus one day of the AO pair. The observation that this fourth day is markedly average because of the very few 5Q or 5D days is also aided by the almost equal occurrence frequency of those few 5Q and 5D days noted then.

The  $H$  values for the 21-day series associated with the abrupt onsets show  $H$  to increase, from near the average of all-days value, to a maximum value on zero day (Fig. 3). On plus one or plus two day, which is disturbed,  $H$  decreases, as is expected on a disturbed day, to a value as much and

more below the all-days mean as the increase was above the all-days mean. At the more easterly stations of the group shown, the minimum is attained on plus 2 day. Subsequent to the disturbance decrease,  $H$  increases and reaches the all-days average about 5 or 6 days after zero day. The excursion of  $H$  above and below the all-days mean is greatest in gamma value near the auroral zone, and least at middle latitudes. See Fig. 3.

The  $Z$  values, in general, act oppositely to  $H$  and show a small decrease in  $Z$  prior to

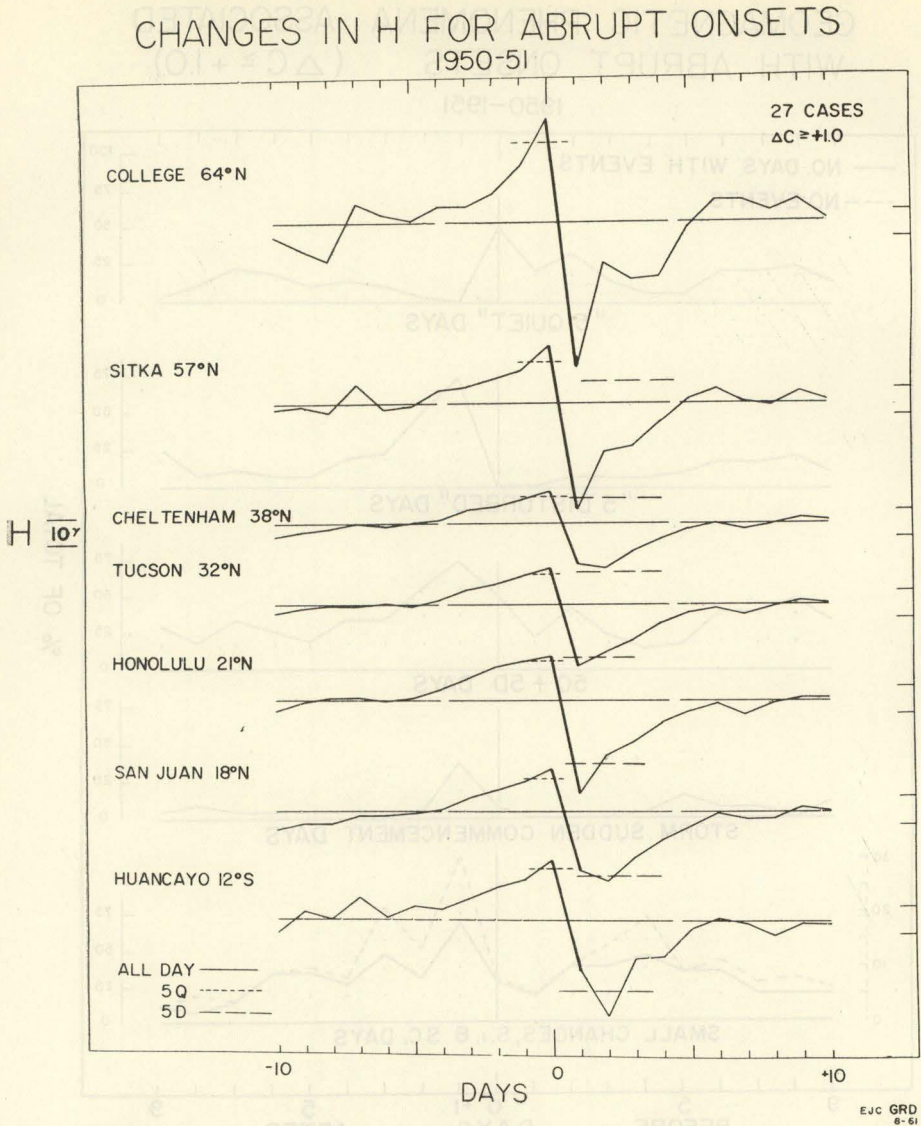


Fig. 3.

the abrupt onset, particularly at the lower latitude stations. See Fig. 4. At College, the abrupt onset increase in  $Z$  is not preceded by the 3 to 5 day progressive change as in the lower latitude stations. Sitka is an exception in that  $Z$  increases, as does  $H$ , during the abrupt onset.

The  $H$  and  $Z$  values when graphed together for almost any one of the stations show the trends previously mentioned in a very interesting fashion. See Fig. 5. The average values for each day from at least 10 or more days before to 10 days after each abrupt onset during 1950-51 was computed from

Tucson and Cheltenham data. With  $H$  plotted against  $Z$ , the points are, in general, clustered somewhat randomly about the all day average from 10 days until about 3 or 4 days before the abrupt onset. After this time a generally direct progression of the points away from the all day average occurs until day zero is reached. This progressive change is reversed in direction at the time of the abrupt onset. After the abrupt onset shift, the points or values return to the all day average in about 5 days. San Juan and Honolulu data graphs are similar to Tucson and Cheltenham.

As the values of  $H$  and  $Z$  show a marked

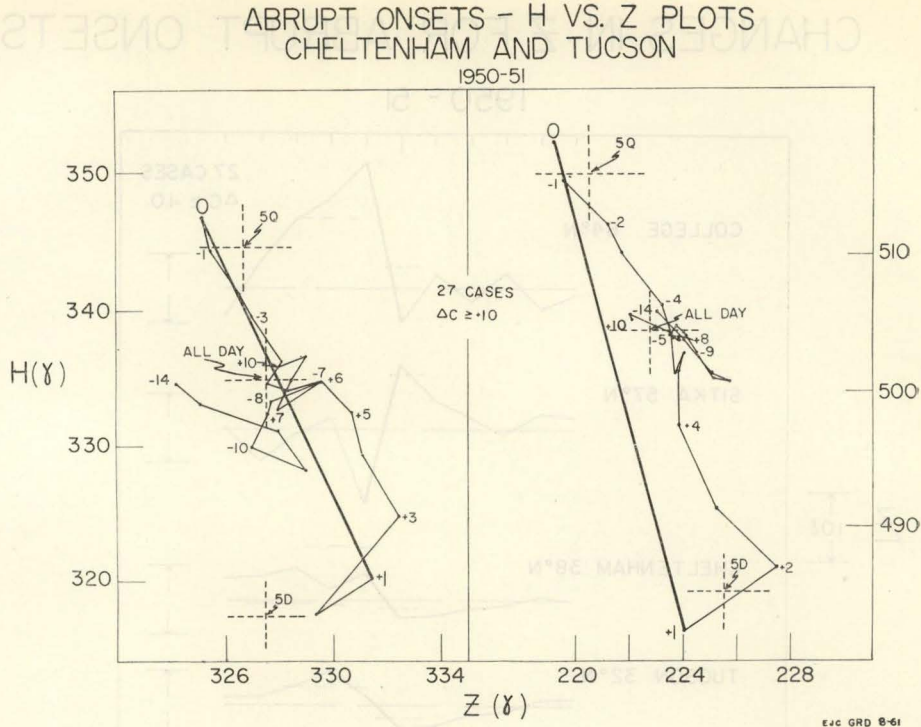


Fig. 4.

departure from the all-days average, it is desirable to make comparisons with other appropriate selected values. One such check is made against the  $H$  (and  $Z$ ) values for the internationally selected five quiet and the five most disturbed days of each month as follows: An average  $H$  (and  $Z$ ) value for the 5Q days and for the 5D days of each month was obtained. A weighted average of these monthly values for the period 1950-1951 was derived and compared with the  $H$  (and  $Z$ ) values of the abrupt onset pair of days. The weighting was accomplished by using each monthly five quiet or disturbed day average as many times as the abrupt onsets were found in that month.

A second comparison was made with the average value of  $H$  (and  $Z$ ) for all days of the type from which they were selected. Average values of  $H$  (and  $Z$ ) were obtained for all days where  $C_i$  was 1.0 or less and where  $C_i$  was 1.0 or more, for checking against the initial day and the plus one or plus two days of the abrupt onset.

The result of the first comparison were as follows: In general the values of  $H$  and  $Z$  were more extreme for the abrupt onset pair

of days than were the corresponding 5Q and 5D day average, although not all the days involved were classified as 5Q or 5D. (See Fig. 3) The comparison with the  $H$  values for all days having the same  $C_i$  range as shown gave the same results. Here the AO date values were higher and lower than were the values for the whole group from which they were selected which might be expected.

It can be observed during these two years that Storm Sudden Commencements did not occur in the three days preceding an abrupt onset. In the one case where successive abrupt onsets occurred within two days of each other there was no SSC noted during the first abrupt onset. The two SC-like changes, which were not followed by storms, (recorded separately in 1950 only), were noted on -6 and -3 days, days which preceded the abrupt onsets.

The Sudden Impulses (SI), or Small Changes (SmC), and Sudden Commencements (SC) type phenomena display a maximum on the second or disturbed day of the abrupt onset. They are found on 23 of the plus one days and Pulsational Sudden Commencements are found on three of the remaining four plus

# CHANGES IN Z FOR ABRUPT ONSETS

1950 - 51

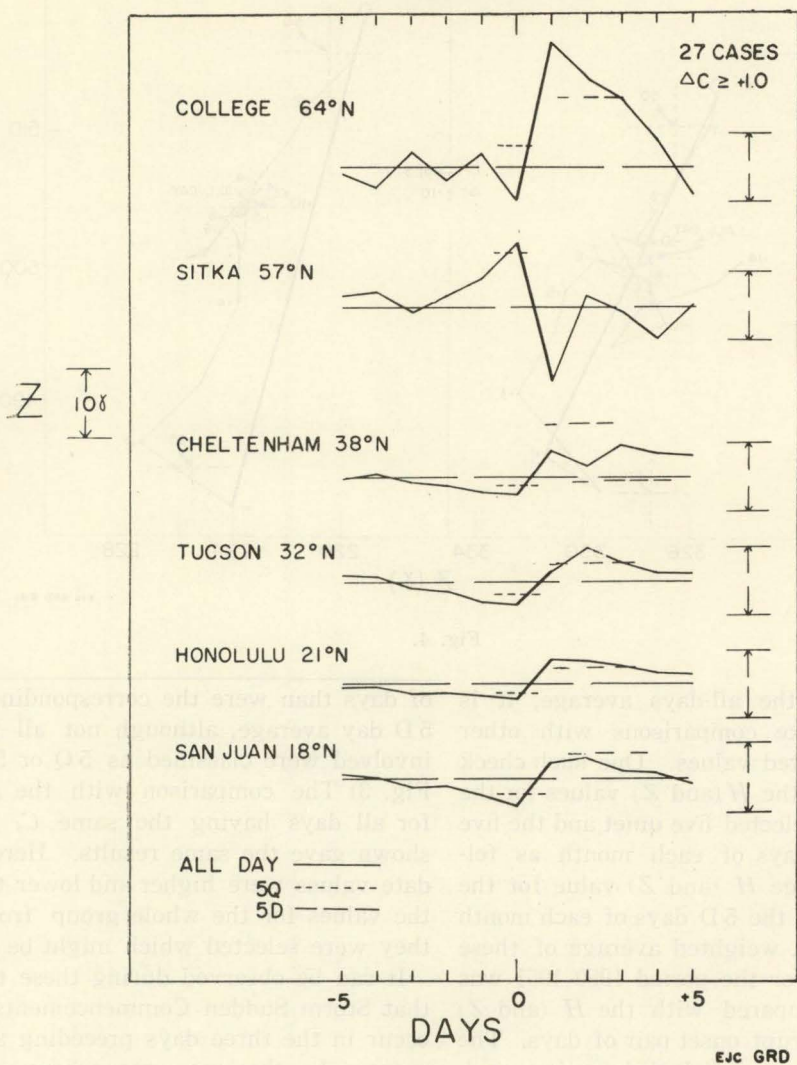


Fig. 5.

one days. Secondary maxima occur on plus three and minus four days. A regression is noted from the high number of events on minus four day to a low minimum value on the plus one day.

### Discussion

Disturbances do not, of course, necessarily start at Greenwich midnight, the disturbances might begin late in the initial day, or late in the plus one day of the AO pair. In any case the results that are obtained do not at-

tain the extremes that might be associated with selections based more closely on the time of onset of disturbance.

The rise to a maximum value of  $H$  just before the onset of a disturbance occurs in all latitudes and is not the anomalous behavior of an isolated station. Normally the higher values of  $H$  (and possibly the lower values of  $Z$ ) are generally associated with the magnetically quieter times. This association comes about because (1) the  $H$  values tend to increase on quiet days (non-cyclic change)

and (2) the opposite effect, a decrease, occurs during disturbance. In the comparison made here it is found that the initial day  $H$  value for abrupt onsets is almost always somewhat higher than the value obtained in the five quietest days per month although only about half of the days included are classified as 5Q days and a few are moderately active. The abrupt onset plus one (or sometimes plus two) day has an  $H$  value that is generally less than the 5D day value although here only about 75% of the included days are 5D days.

A second comparison of the selected AO days against the group from which they were selected shows the same relationship, where in the AO selection has the more extreme values. In this comparison the lower values occur in somewhat greater proportion in the AO initial day selection than in the normal population. For the plus one AO day selection there is a larger proportion of the middle and higher values. These distributions would be partially expected because of the basic nature of the abrupt onset. The average change in  $C_i$  corresponding to the abrupt onset is a change of +1.2 from 0.3 on zero day to 1.5 on plus one.

It is of interest to note that no SSC occurred on the three days prior to the AO initial day but occurred four times on the minus five day. In order to have a following storm, without interfering with the AO, an SSC would have to occur early on minus one day or before then. Actually the SI and SmC events are at a minimum of the day before the AO. The trend for the several days previous to the AO suggests these phenomena tend to avoid this interval or else are suppressed to some extent. It is interesting to speculate that the SI's and SmC's originate in much the same basic way as do the SSC's but are modified by conditions to become what might be termed "frustrated SSC's." Some credence is accorded by the fact that SI's and SmC's, like SSC's, are most frequently associated with the onset of disturbance as is indicated by the maximum on plus one day shown in Fig. 2.

### Conclusion

The gradual rise in  $H$  prior to the AO may be partially explained by the increasing number of quiet days and decreasing number of

disturbed days during that period. The question remains however, as to why the antecedent quiet days and disturbed days should anticipate the AO events that follow them. This question is also valid for the behavior of the SI's and SmC's. If the events noted were unrelated to the disturbance following them there should be a random occurrence of all events up until the first day of the abrupt onset pair.

There is a certain positive conservation factor in geomagnetic activity from which it is expected that like days tend to follow after each other. (Chapman and Bartels, 1951). In this case, however, it is to be noted that since it is the last day which may be quiet these days tend to precede it. A problem that requires further attention is one of determining a *normal* level of  $H$  (and other components). If the predisturbance change is considered a return to normal, then the all-days average is naturally lower than normal because of the inclusion of storm-time decreases. If the change prior to the AO is an actual increase, then the all-days average of  $H$  is more representative of a combination of above-normal pre-disturbance levels and below-normal disturbance levels.

On the basis of this analysis (and others unreported here) it is recommended that studies of magnetic storms include the period preceding them as well, since the quiet period preceding has phenomena which suggest its existence as an integral part of the disturbance following.

### Acknowledgment

The detailed computations were made by M.P. Hagan and Joan Collins at the Physics Research group of Emmanuel College and by A. Shickman. Some of the graphs were prepared by N.E. Collingwood. Thanks are also due to Elwood Maple for editorial comments.

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### Discussion

**Singer, S. F.:** To what extent is the "build-up" in  $H$  preceding the main phase a function of your particular selection criterion, *i.e.*, "abrupt onsets"? In other words, would you observe this effect if you took, say, all magnetic storms, or all SC storms?

**Chernosky, E. J.:** I believed that the build-up will appear in other similar groupings. I have found the same trends with selections of the five quiet and disturbed days and with ten day sequences of non-disturbed days. Since about half the events included in the abrupt onset table shown are associated with sudden commencement and sudden commencement storms, I expect a similar table of sudden commencement storms will show the same results.

**Parkinson, W. D.:** Have you tried a super-imposed epoch analysis using days of high  $H$  as zero days? If so, do you find a definite increase in disturbance in days immediately following days of high  $H$ ?

**Chernosky:** A study of change in  $H$  was made and it was found that an increase in  $C$  value occurred at time of  $H$  decrease. It was preceded by a decrease in  $C$  value showing more quiet before an  $H$  decrease. Studies of high  $H$  values are being considered and some tentative ones have been made but the study is incomplete.

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## I-1-4. Characteristics of Telluric Current at Land and Sea Based Stations

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Telluric current activity as observed at land based stations tend to display a pronounced principal direction effect. At stations located near the coast the direction tends to be perpendicular to the shoreline, suggesting a pronounced geological control of the directional aspects of the activity.

The writer has operated telluric current recording systems at many sites in the Tanana Valley of Alaska. This valley lies generally parallel to the auroral zone and a degree or two to the south. Hodograms of the disturbance activity in this region as recorded over periods of say 24 hours by continuously operating X-Y plotters are completely filled in ellipses with axis ratios of 5 or 10 to 1. Only during period of major disturbances does the recording pen trace excursions ex-

terior to this well formed ellipse. The direction of the major axis in the Tanana Valley ranges from geographic north-south to about 35° counterclockwise from this orientation. Of seventeen sites occupied near College only one displayed a principal direction to the northeast. There seems no obvious explanation of this principal direction either in terms of geomagnetic phenomena or geological structure.

Correlation of telluric current and magnetic amplitude activity is very high. Monthly correlation coefficients between the daily average of the magnetic  $A$  figures and the daily average of the 3-hourly scalings of the telluric current amplitude for several months are all above 0.9. This statistical result is also substantiated by day to day subjective