netic line of force at night on quiet days, but the connection may be broken up occasionally in daytime or at the time of magnetic storms. On the other hand, the pair MI and CW(or Co) keeps good connection even on disturbed days. This will mean that the connection of these stations by geomagnetic line of force is hardly broken at any time. Although the connection by geomagnetic line of force is often disturbed for individual disturbance in high latitudes, the average disturbance field such as the *SD*-field is symmetric with respect to the geomagnetic equator as shown in Fig. 1, because irregular variations are smoothed out.

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JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-I, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part I

I-1-6. World Wide Changes in the Geomagnetic Field

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It is found that world wide changes in the geomagnetic field are not limited to ssc or si, and are frequently observed. Not only an increase, but also a decrease in the horizontal intensity occurs on a world wide scale. The morphology of this phenomenon is studied, and is found to show a pronounced similarity with that of ssc and si. This is consistent with the idea that there is a permanent interaction between the solar corpuscular stream and the geomagnetic field.

§1. Introduction

The continous existence of a solar corpuscular stream proposed by Biermann (1957) indicates the possibility that world wide changes of the geomagnetic field take place rather frequently, and are not limited to ssc or si. The earth's magnetic field is confined in a space of finite extent by the the impact pressure of the solar corpuscular stream and the geomagnetic field is changed on a world wide scale when the physical state of the stream changes, as shown by Parker (1958), Piddington (1960) and Dessler *et al.* (1960). Thus through the continuously flowing solar corpuscular stream world wide features of the geomagnetic field are always related, with some time lag, to the physical state of the sun. Since the physical state of the solar atmosphere is quite variable, it seems reasonable to expect world wide changes in the geomagnetic field to occur quite frequently. From this point of view, the number of occurrences of world wide changes of the types already known—ssc and si—seems to be too small.

Thus world wide changes of the geomagnetic field other than ssc or si were looked for, making use of magnetograms obtained from an extensive network of stations during a three-month period of the IGY. It was found, as was expected, that world wide changes, including both an increase and a decrease in the horizontal intensity, take place almost every day, at least around sunspot maximum. In this paper, examples and the morphology of this phenomenon are

briefly presented.

2. Data

By comparing magnetograms from several widely separated stations, Hartland, Fredericksburg, Tbilisi, Honolulu and Hermanus, changes were picked out which were recorded almost simultaneously at all of them. During the three month's interval from April to June, 1958, which is around sunspot maximum, at least twenty percent of all one hour periods contain at least one such change. Among these changes, twenty four of those of larger amplitude were randomly selected for analysis, and magnetograms were collected from twenty stations, most of which are uniformly distributed in middle and low latitudes in the northern hemisphere. (Data were also collected from high latitude stations, but could not be used for this analysis because the records were frequently obscured by local disturbances.) The data confirmed that these changes are really of world wide character. Examples are shown in Fig. 1. It can be seen that a decrease as well as an increase in the horizontal component occurs on a world wide scale. The former will be called a 'negative change' and the latter a 'positive change.' Among the examples selected, fourteen were positive changes and ten negative changes. According to the solar and geophysical data published in the Journal of Geophysical Research, none of the selected cases were registered as ssc or si by more than five stations, and only three of them occurred during the period of a magnetic storm which was reported from more than three stations. Most of them were found on magnetically quiet days. For the sake of comparison, records were obtained of four ssc's and two si's which were widely recognized during the same time interval.

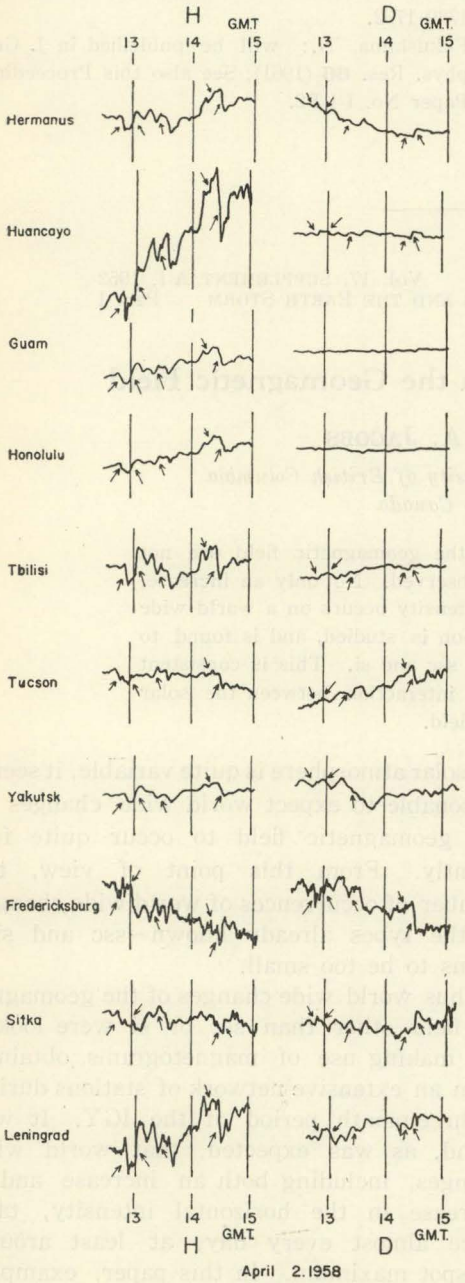

Fig. 1. Examples of world wide changes.

3. Form of the change

As can be seen from Fig. 1, the traces of the world wide changes in the horizontal intensity magnetograms are similar in most parts of the world. However, at latitudes higher than 40° at around 0800 LMT (represented by Fredericksburg and Sitka in the figure), the form of the change differs from that at other stations. Examination of rapid run magnetograms shows that in this region, the change is composed of two parts, as can be seen in Fig. 2. The horizontal intensity experiences a change of the same sign once in any part of the world, but later, while this change continues in most parts of the world, a second change, whose sign is opposite to that of the first, appears in a particular region of the world.

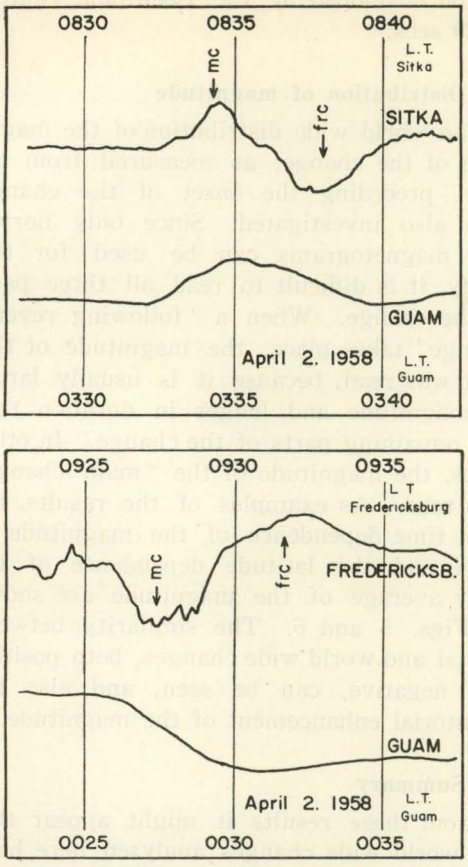

Fig. 2. Examples of 'following reverse change'. 'mc' and 'frc' stand for 'main change' and 'following reverse change' respectively. Upper half, positive change; lower half, negative change.

In the following description, these changes are called 'main changes' and 'following reverse changes' respectively. The fact that the horizontal intensity changes once with the same sign on a world wide scale distinguishes this phenomenon from other geomagnetic phenomena such as bays and solar flare effects. This type of reversal is known to occur in association with ssc (Oguti, 1956; Obayashi and Jacobs, 1957). For si's, Jackson (1952) gave some examples of reversed changes of this type. The regions of its occurrence obtained in our analysis for ssc's, si's and world-wide changes are in good agreement.

On the afternoon side of the earth, another type of reversed change is found to appear preceding the 'main change'. This is a decrease in the horizontal intensity for

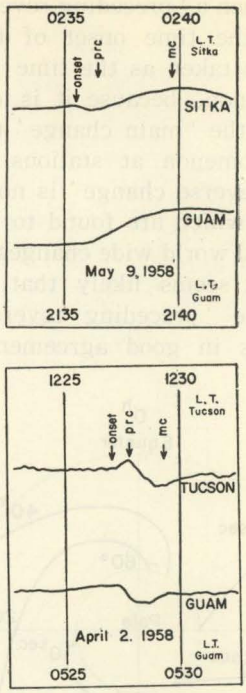

Fig. 3. Examples of 'preceding reverse change' abbreviated as 'prc' in the figure. Upper half, positive change; lower half, negative change.

'positive changes' and an increase in it for 'negative changes', as shown in Fig. 3. It can be distinguished from other small changes recorded just before the onset of the 'main change', firstly by the closeness of the time of its onset to the time when the 'main change' appears at stations where the reversed change is not observed, and secondly by the regularity of the region in which it is found. This reversed change will be called a 'preceding reverse change'.

A similar feature is sometimes associated with ssc and is called a 'preceding reverse kick', the whole phenomenon being designated ssc*. (Nagata, 1952; Abe, 1959). It is found also for some si's. The regions of occurrence of this 'preceding reverse change' for sudden commencements, si's and world wide changes are found to correspond closely.

4. Distribution of the time of onset

The time of onset is read on rapid run magnetograms of the horizontal intensity because the change in this component is usually more conspicuous than that in others. The error in reading is less than a few

seconds. When a 'preceding reverse change' is recorded, the time onset of this part of the change is taken as the time of onset of the phenomenon, because it is closer than the onset of the 'main change' to the onset of the phenomenon at stations where the 'preceding reverse change' is not observed. The results, which are found to be the same for ssc, si and world wide changes, are shown in Fig. 4. It seems likely that the region in which the 'preceding reverse change' takes place is in good agreement with the region enveloped by the isochronic contour of 20 secs.

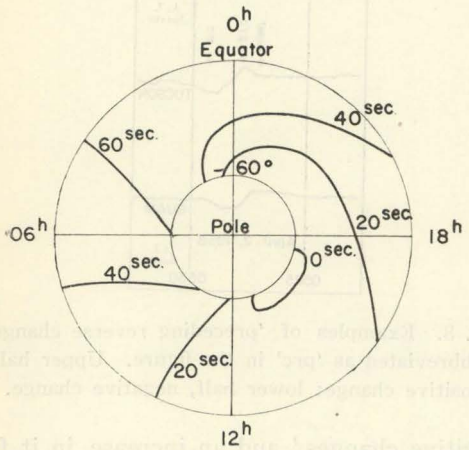

Fig. 4. Isochronic curve of the time of onset.

5. Distribution of magnitude

The world wide distribution of the magnitude of the change, as measured from the level preceding the onset of the change, was also investigated. Since only normal run magnetograms can be used for this study, it is difficult to read all three parts of the change. When a 'following reverse change' takes place, the magnitude of this part was read, because it is usually larger in magnitude and longer in duration than the remaining parts of the change. In other cases, the magnitude of the 'main change' was read. As examples of the results, the local time dependence of the magnitude at 50°N and the latitude dependence of the daily average of the magnitude are shown in Figs. 5 and 6. The similarity between ssc, si and world wide changes, both positive and negative, can be seen, and also the equatorial enhancement of the magnitude.

6. Summary

From these results it might appear that the world wide changes analyzed here have almost the same characteristics as ssc and si. The only differences are that they do

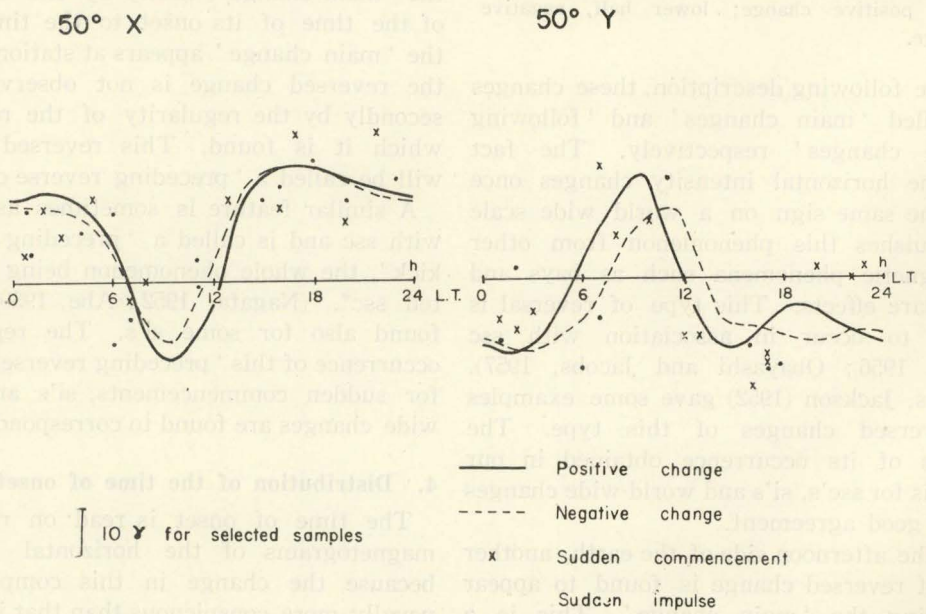

Fig. 5. Local time dependence of the magnitude of changes at 50°N.

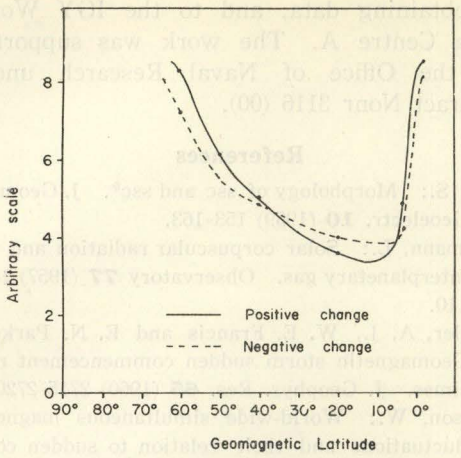

Fig. 6. Latitude dependence of the daily average magnitude of changes.

not precede a period of increased activity, that they are not always impulse shaped, and that sometimes there is a decrease in the horizontal intensity. Thus it seems that such world wide changes belong to a larger, more general class of changes in the geomagnetic field, which include ssc and si as special cases.

A schematic illustration of the distribution of the change in the horizontal component of the geomagnetic field from its level before the onset of a change is shown in Fig. 7, which is for a positive change, ssc and si. Diagrams for a negative change are obtained by reversing the direction of all the vectors. Fig. 7(a) represents the stage when only a 'preceding reverse change' is observed. Fig. 7(b) shows the distribution about one minute after the beginning of the stage shown in Fig. 7(a) and is that of the 'main change'. A few or several minutes later the 'following reverse change' appears, as shown in Fig. 7(c). In the blank region of Fig. 7(c) the vectors are but little changed from those shown in Fig. 7(b). If these changes are caused by electric currents flowing in the ionosphere, the equivalent overhead current systems are as drawn in Fig. 8 for a positive change, ssc and si. A negative change corresponds either to a decrease in the intensity of this current system, or to a current flowing in the direction opposite to that shown in the figure.

The remaining examples of changes, which

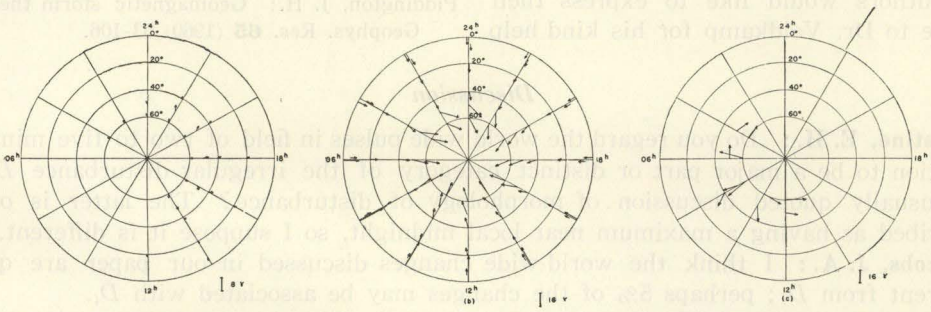

Fig. 7. Distribution of the horizontal component of world wide changes. (a) 'prc' stage; (b) 'mc' stage and (c) 'frc' stage. Scale corresponds to the average of those cases analysed.

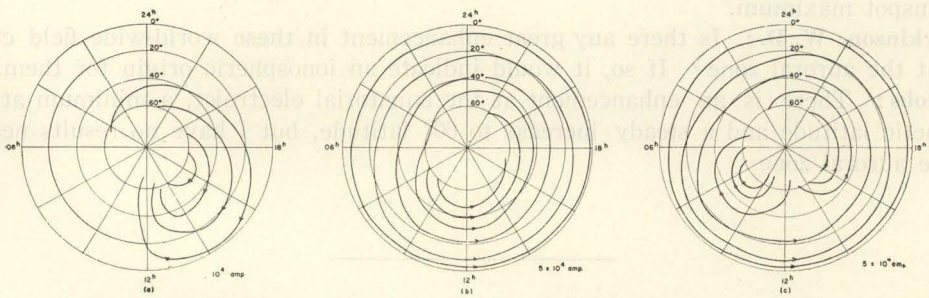

Fig. 8. Equivalent overhead current systems of world wide changes. (a) 'prc', (b) 'mc' and (c) 'frc'. The amount of electric current indicated in the figures flows between successive lines and corresponds to the average of those cases analysed. Assumed height 100 km.

were selected at the beginning of this study, but were not subject to detailed analysis, were found to be associated with a following reverse change. This fact, together with the wide extent of the area covered by the 5 stations used for finding cases of world wide changes seems to indicate that all these examples belong to the class of phenomena analysed here. It follows that world wide changes of the geomagnetic field with characteristics similar to those of ssc or si take place quite often—at least twenty percent of every one-hour period contains at least one of them. This is in agreement with the idea that the geomagnetic field is affected constantly by the physical state of the solar atmosphere through solar corpuscular emissions, although the connection between these changes and solar phenomena has not yet been determined. The existence of negative changes, the association with a 'preceding reverse change' and the 'following reverse change' are further problems which need explaining.

Acknowledgements

The authors would like to express their gratitude to Dr. Veldkamp for his kind help in obtaining data, and to the IGY World Data Centre A. The work was supported by the Office of Naval Research under contract Nonr 3116 (00).

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Discussion

Vestine, E. H.: Do you regard the world wide pulses in field of two to five minutes duration to be a major part or distinct category of the irregular disturbance D_i in the usually quoted discussion of morphology of disturbance? The latter is often described as having a maximum near local midnight, so I suppose it is different.

Jacobs, J. A.: I think the world-wide changes discussed in our paper are quite different from D_i; perhaps 5% of the changes may be associated with D_i.

Chernosky, E. J.: What does the 20% refer to? The full solar cycle or just some portion of it?

Jacobs: The 20% refers to the 3 months analysis which was covered at the time of sunspot maximum.

Parkinson, W. D.: Is there any great enhancement in these world-wide field changes at the auroral zone? If so, it would indicate an ionospheric origin for them.

Jacobs: There is an enhancement at the equatorial electrojet, a minimum at 20° magnetic latitude and a steady increase to 60° latitude, but I have no results nearer to the auroral zone.