Night time geomagnetic effects of solar flares

by

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RESUME. – *Une étude des données provenant des magnétogrammes normaux de deux stations équatoriales : Kodaikanal (Long. Géo. 77°28' E, Dip : 3,5°N) et Huancayo (Long. Géo. 75°20', O, Dip. 2,0°N) pendant une période de trois ans (1969-1971) a montré que les effets dus aux éruptions solaires sur la variation géomagnétique surviennent même côté nuit. Les effets géomagnétiques des éruptions solaires, observés à Kodaikanal, montrent une forme distincte et possèdent pendant la nuit une amplitude suffisante dans la composante H (4r. au maximum). Une étude comparative des caractéristiques des effets géomagnétiques de nuits dus aux éruptions solaires observés à Kodaikanal avec les effets de jour simultanés (SFE ou Crochet) observés à Huancayo, a permis de mettre en évidence un temps de croissance et de décroissance plus lent comparés à ceux du côté jour.*

ABSTRACT. – *A study of the normal run magnetogram data of two equatorial stations : Kodaikanal (Geo. Long. 77° 28' E, Dip 3.5°N) and Huancayo (Geo. Long. 75°20' W, Dip 2.0°N), for a three year period (1969-1971), showed that solar flare effects on geomagnetic variation do occur even in the dark hemisphere. The night time geomagnetic effects of solar flares as observed at Kodaikanal are noticed to exhibit a distinct shape and possess sufficient amplitude in the H-component (> 4 r at the maximum). A comparative study of the characteristics of the night time geomagnetic effects of solar flares observed at Kodaikanal in relation to the simultaneous day time effects (SFE or Crochet) observed at Huancayo, revealed that the night time effects are characterised by slower rise and decay compared to day time effects.*

I. Introduction

One of the transient variations in the geomagnetic field as monitored on the ground in the sunlit hemisphere is the effect of solar flares referred to as SFE (Geomagnetic Crochet). Earlier studies have shown that the occurrence of SFE is maximum around local noon and its amplitude has a local time variation similar to that of *Sq* field (McNish, 1937 : Nagata, 1952 : Subrahmanyam, 1964 : Pinter, 1967). Evaluation of ionospheric current systems during solar flare conditions revealed that SFE is not due to a mere augmentation of normal *Sq* field as thought of by Chapman (1937, 1961) and Champman and Bartels (1940) ; and the current flaring layer responsible for SFE is below the normal dynamo current carrying region (Volland Taubenheim, 1958 : Veldkamp and Van Sabben 1960 : Yasuhara and Maeda, 1961). A study using rapid run magnetogram data indicated that SFE could be due to enhanced electric conductivity due to solar XUV (1 - 1000 Å) flare radiation, as SFE's were often noticed to exhibit a composite structure consisting of a 'fast' component presumably due to EUV radiation (100 - 1000 Å) and a 'slow' component due to soft x-rays (1 - 100 Å) (Richmond and Venkateswaran, 1971).

Most of the earlier work on solar flare effect on geomagnetic variation is mainly confined to the sunlit hemisphere as it is generally considered that solar flare effect on geomagnetic variation occurs only in the sunlit hemisphere. However, observational evidence to the possibility that solar flare effect on geomagnetic variation does occur even in the dark hemisphere was presented a decade ago by Ohshio (1964). He reported the amplitude of the night time geomagnetic solar flare effects to be small and their shape not to be so distinct even at the maximum stage. Similar observations have been reported recently by Srivastava and Abbas (1974). An examination of normal run magnetogram data of Kodaikanal, a station in the electrojet, showed several instances during night time when there are conspicious short-lived perturbations in geomagnetic elements (usually in *H*-component). These perturbations are noticed to occur in concurrence with both solar x-ray flares (1-8 Å) (monitored by SOLRAD-9 and published in Solar - Geophysical Data) and sudden ionospheric disturbances in the sunlit hemisphere (Solar-Geophysical Data). This observation lends evidence to the possibility that geomagnetic effects do occur in the dark hemisphere in association with solar flares as first reported by Ohshio (1964). A preliminary study of the night time geomagnetic effects of solar flares as observed at Kodaikanal showed that they exhibit a well defined shape and possess sufficient amplitude in H-component ($> 4\gamma$ at the maximum) and are characterised by slower rise and slower decay compared to day time effects (SFE) observed at the same station (Sastri and Murthy 1975). Hereafter the night time geomagnetic effects of solar flares will be referred to as NTSFE while day time effects will be referred to as SFE through this paper.

In this communication are presented the salient results of a further study made using normal run magnetogram data of Kodaikanal (Geographic Longitude 77° 28′ E, dip 3.5° N) and Huancayo (Geographic Longitude 75°20′W, Dip 2.0°N), both the in the electrojet region, such that when Kodaikanal lies in the night hemisphere, Huancayo lies in the sunlit hemisphere and vice versa. The objective of this study is to see how far the earlier observation on the difference in the characteristics (rise time and decay period) of SFE's and NTSFE's is evident in the simultaneous effects observed at the two stations in the sunlit and dark hemispheres and to examine the validity of the interpretation of NTSFE by Ohshio (1964) as due to induction currents that are forced to flow in the ionosphere on the dark side of the earth due to the sudden increase in electrical conductivity in the sunlit hemisphere. The period covered in the present study is from January 1969 through December 1971 and a total of 15 well defined simultaneous effects observed (in H-component) at the two stations have been studied. It is to be mentioned that out of a total of 22 well defined night time effects noticed at Kodaikanal, simultaneous day time effects at Huancayo have been noticed for only 15 events.

II. Results

In figure 1 are presented two typical examples of simultaneous SFE and NTSFE observed at Huancayo and Kodaikanal respectively in the electrojet region. The close association in time between the occurrence of SFE and NTSFE may be noticed. Further, both the events are associated with solar x-ray flares (1-8 Å) and the consequent sudden ionospheric disturbances (SID) in the sunlit hemisphere as may be noted from the text of figure 1. Infact, all the 15 simultaneous events used in this investigation are associated with solar x-ray flares (1-8 Å) and consequent Sudden Ionospheric Disturbances (SID) in the sunlit hemisphere. In figure 2 is shown the time correlation of the occurrence of NTSFE's at Kodaikanal with the solar x-ray flares (1-8 Å). The convincing association in time between the occurrence of the two may be noticed. None of the 15 events studied in this investigation occurred during the course of a geomagnetic storm and hence could not be magnetic bays which occur usually during the main phase of the geomagnetic storm. The possibility that they could be sudden Impulses (SI) is also eliminated after checking with the data of Sudden Impulses (Solar-Geophysical Data).

Further, the Ap index for the days during which NTSFE's have been observed at Kodaikanal is usually less than 13 and in only 3 cases out of a total of 15, it exceeded the value 13. The above observations clearly indicate that the perturbations noticed and studied are genuine solar flare effects. It can now be seen from figure 1 that the NTSFE's observed at Kodaikanal exhibit a well defined shape and possess sufficient amplitude in the H-component ($> 4\gamma$ at the maximum) and can be identified visually with ease. These features differ from the earlier observations of Ohshio (1964) who reported the NTSFE's to be small in amplitude and do not exhibit a distinct shape even at the maximum stage. This could be due to the fact that in the present study the night time geomagnetic effects of solar flares are studied at only one station in the dark hemisphere : Kodaikanal, situated in the electrojet region, where relatively strong eastward electric current flows generaly even at night during geomagnetic solar flare effect, while in Ohshio's (1964) work the night time geomagnetic effects were studied at various stations scattered in the dark hemisphere where the electric current flow will be relatively weak.

To facilitate a comparative study of the characteristics of the simultaneous SFE and NTSFE events, the times of start, maximum and end of the same have been read from the original normal run magnetogram to an accuracy of ± 2 minutes. From this data the rise time and total duration of both SFE's and NTSFE's have been evaluated. The amplitude $(m)_r$ of both SFE's and NTSFE's has been evaluated following accepted procedure using the expression :

$$(m)_r = h_3 - (h_1 + h_2)/2 \qquad (1)$$

where h_1, h_2 and h_3 are the values of the horizontal component of the magnetic field at the start, end and maximum of the event. In figure 3 are shown the scatter plots of rise time and total duration of the 15 simultaneous events studied. It is evident that NTSFE's are characterised by slower rise and decay compared to SFE's, lending further support to this inference reached earlier (Sastri and Murthy, 1975)

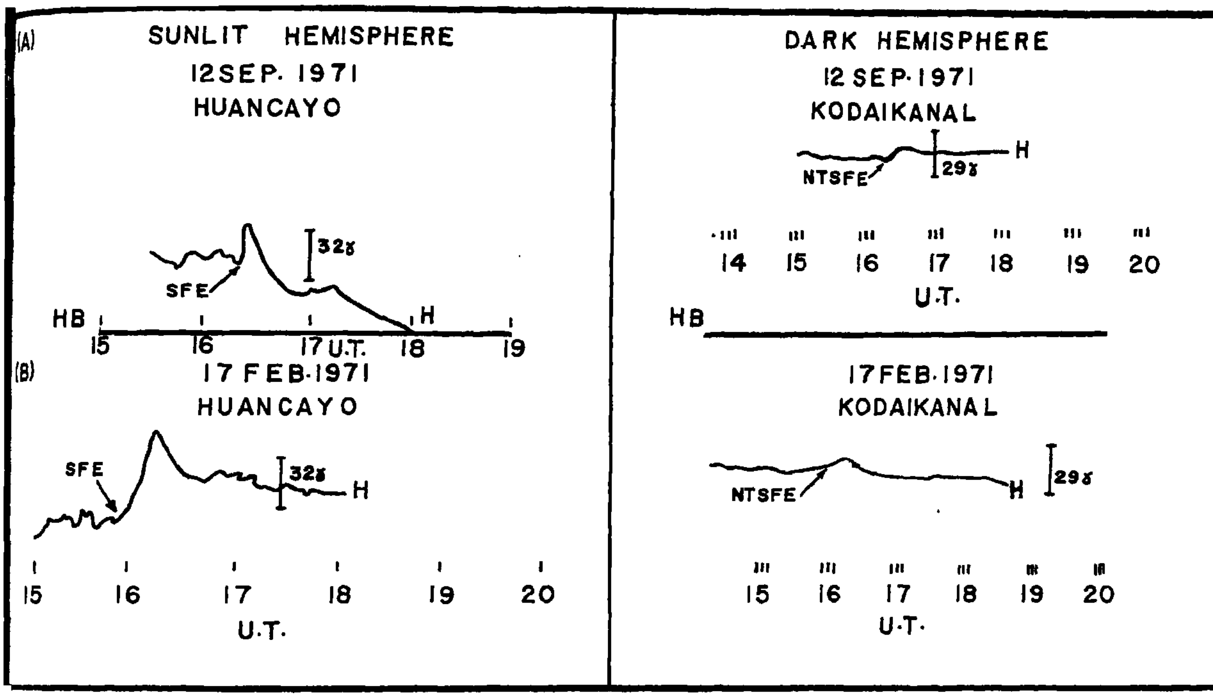

Fig. 1

Typical examples of simultaneous SFE and NTSFE observed at Huancayo and Kodaikanal respectively in the electrojet region.
a) 12 September 1971. Associated with both Solar x-ray flare (1-8Å) and SID's : Solar x-ray flare (1-8Å) – 1619-1624-1634 U.T. SID's – 1617-1627-1756 U.T., Ap = 8 (after Solar-Geophysical Data)
b) 17 February 1971. Associated with both Solar x-ray flare (1-8Å) and SID's : Solar x-ray flare (1-8Å) – 1558-1601-1634 U.T., SID's – 1558-1606-1815 U.T., Ap = 13 (after Solar-Geophysical Data).

from a comparative statistical study of the characteristics of SFE's and NTSFE's observed at Kodaikanal (obviously, not simultaneous).

In Figure 4 are shown the variations of the time difference between the maxima of NTSFE and the simultaneous SFE (figure 4a) and the ratio of amplitude of NTSFE to SFE (figure 4b) with the peak x-ray flux (1-8Å) of the corresponding solar flare for the 15 events. The following features may be noticed. Firstly, there is no definite trend in the variation of both the time difference in the maxima of NTSFE and SFE and the ratio of amplitudes of NTSFE and SFE, with the peak x-ray flux of the corresponding solar flare. Secondly, the occurence of maximum of NTSFE and SFE is not nearly simultaneous (within 1 minute) in a majority of the events studied even after allowing for the errors involved in scaling of the normal run magnetograms used in the analysis. Thirdly, the ratio of amplitude of NTSFE to SFE usually lies in the range 0.08 to 0.45 and in only 5 out of the 15 events studied it reached 0.5 and above.

III. Discussion

Ohshio (1964) interpreted the night time geomagnetic effect of solar flares (NTSFE) as due to electric currents induced into the dark hemisphere due to enhanced electrical conductivity in the sunlit hemisphere in order to make closed electric current in the ionosphere surrounding the earth. Following the earlier work of Rikitake and Yukutake (1962) who treated the geomagnetic solar flare effect as a world wide transient phenomenon, Ohshio calculated the time lag and intensity of geomagnetic solar flare effect due to electromagnetic induction. He found that a weak current flows in the dark hemisphere and that its intensity (near the midnight area) is about 20 % of that in the sunlit hemisphere (near the sub-solar area) and reaches a maximum over the globe in about 0.5 to 1.0 min. after the sudden increase in conductivity in the sunlit hemisphere.

A consideration of the observational results presented in the proceeding section in the light of those expected on Ohshio's (1964) work shows only partial agreement, as the time difference between the maximum of NTSFE and SFE is larger than expected in a majority of the cases, although the ratios of the amplitude of NTSFE to SFE usually lies in the range 0.08 to 0.45. This partial agreement could be due to the fact that Ohshio's calculations are mathematically idealised based on a model in which it is assumed that the electric conductivity increases suddenly without duration and also the ionospheric conductivity is considered to be isotropic.

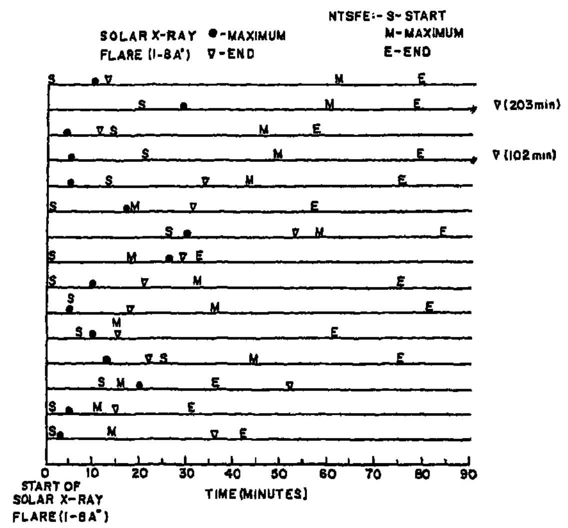

Fig. 2

← Time correlation of NTSFE's observed at Kodaikanal with solar x-ray flares (1-8Å).

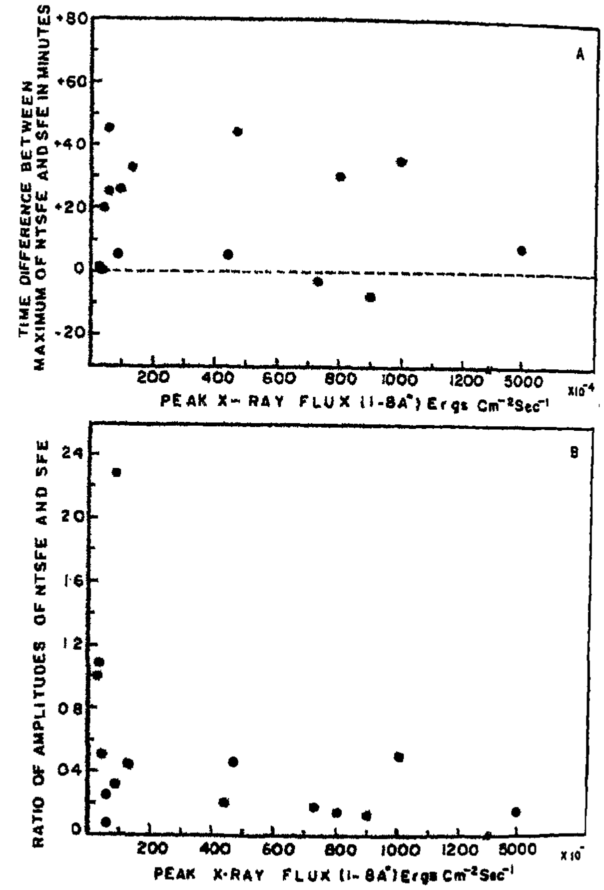

Fig. 4

Variation with peak x-ray flux (1-8Å) of solar flares of

a) Time difference between the maxima of NTSFE and SFE.

b) Ratio of amplitude of NTSFE to SFE.

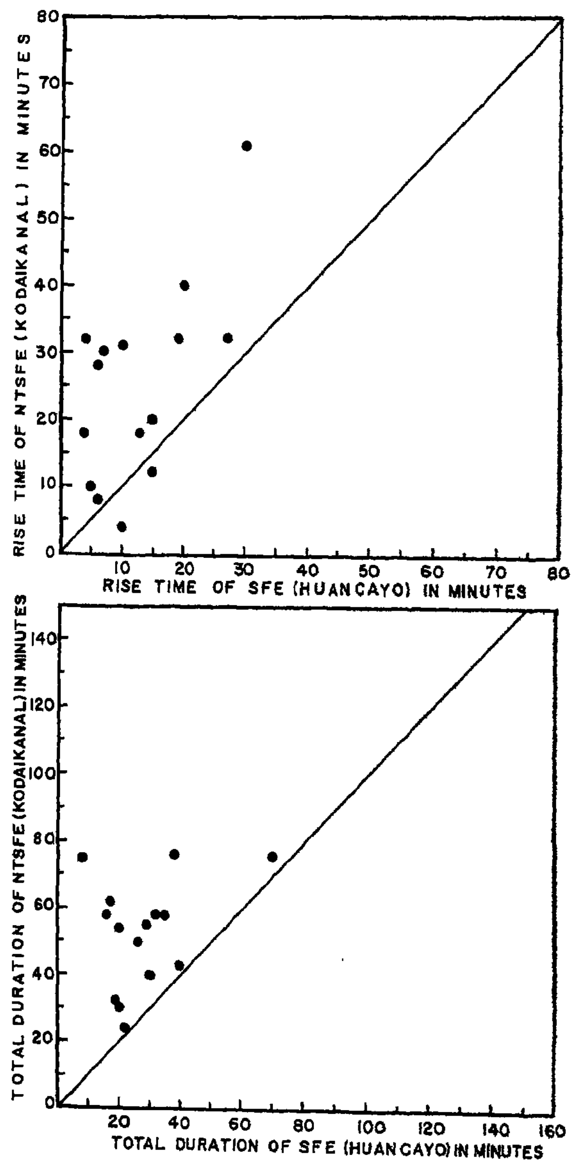

Fig. 3

← **Scatter plots of rise time and total duration of simultaneous SFE's and NTSFE's observed at Huancayo and Kodaikanal respectively.**

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Use is made of the following data, Solar-Geophysical Data ESSA/NOAA, Boulder, Colorado. U.S.A.