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Effect of solar disturbance on the geomagnetic H,Y and Z fields in American electrojet station – II Sudden Commencement Storms.

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ABSTRACT
The paper describes the amplitudes of sudden storm commencements (SSC) in horizontal (H), vertical (Z) and eastward (Y) components of the geomagnetic field at the equatorial stations Hauncayo over the years 1958 to 1992. It is supplemented by similar study of the magnetograms at other equatorial stations Yauca, Chimbote, Chiclayo, Talara, Teoloyucan, San Juan and Fuquene for the year 1957-1959. The amplitudes of SSC (H) at Huancayo show a large enhancement near noon, a similar but flat maximum is observed in SSC (Y) but no signification daily variation in SSC (Z) can be seen. In contrast at Trivandrum SSC (H) and SSC (Z) show midday maxima but SSC (Y) amplitudes are insignificantly small. Even after normalization, the effect of magnetospheric compression is twice as large at American than at Indian sector. The nighttime SSC (H) shows a feeble enhancement over the equator in the American sector. The preliminary negative impulse sometimes observed before the main positive impulse at equatorial station occurs only when the strike of solar plasma with the magnetosphere is associated with the northward turning of the interplanetary magnetic field.

INTRODUCTION

The earlier paper (Rastogi 2003) discussed the effect of solar flares on the geomagnetic field components at the equatorial electrojet stations along 75°W meridional sector. The solar flare effect (sfe) comprises the sudden increase of solar ionising radiation in the dayside ionosphere. Sudden Storm Commencement (SSC) signifies the arrival of the plasma cloud consisting of charged particles from the sun following the solar flares or the solar coronal mass ejections. SSC is associated with current and electric field at various parts of the dayside as well as on the night side of the magnetosphere. The effects on the equatorial electrojet stations are the result of compression of the magnetosphere as well as due to the penetration of electric field from the magnetosphere via auroral regions in the equator (Rastogi 1976; Reddy, Somayajulu & Viswanathan 1981). Rastogi (1999) has described in detail the effects of the SSC at geomagnetic station Trivandrum, Kodaikanal, Annamalainagar and Alibag for the period 1958-1992 in India. It was felt useful to study the effect of SSC at electrojet station Huancayo (HUA), Yauca (YAU), Chimbote (CMB), Chiclayo (CCL) and Talara (TAL), which were in operation in Peru during the period 1957- 1959. This paper describes the result of such a study.

The amplitudes of SSC at Huancayo were published in Journal of Geophysical Year (1957-58) and for few years afterwards. The amplitudes of SSC for the rest of period at Huancayo and for other stations were scaled by the author himself from the micro film copies of the magnetograms for these stations supplied by the World Data Centre for Geophysics at Boulder Colo, USA from the Arthur Day Grant offered to the author jointly with Dr. A.H.Shapley.

SUDDEN STORM COMMENCEMENTS (SSC) IN H, Y & Z AT HUANCAYO

In Fig.1 are reproduced some of the magnetograms at Huancayo during SSC storms. It may be mentioned that the sensitivity of traces for Huancayo are comparatively smaller for the Y component than for H and Z components and therefore visual inspection of the traces suggest most prominent effect on the H component. A major storm at Huancayo commenced at 0917 hrs LT (75°W) on 8 March 1970 with the impulse of +182 nT in H, +50 nT in Y and only +15 nT in Z components, the total range of storm exceeded 800 nT. Very large and rapid oscillations were

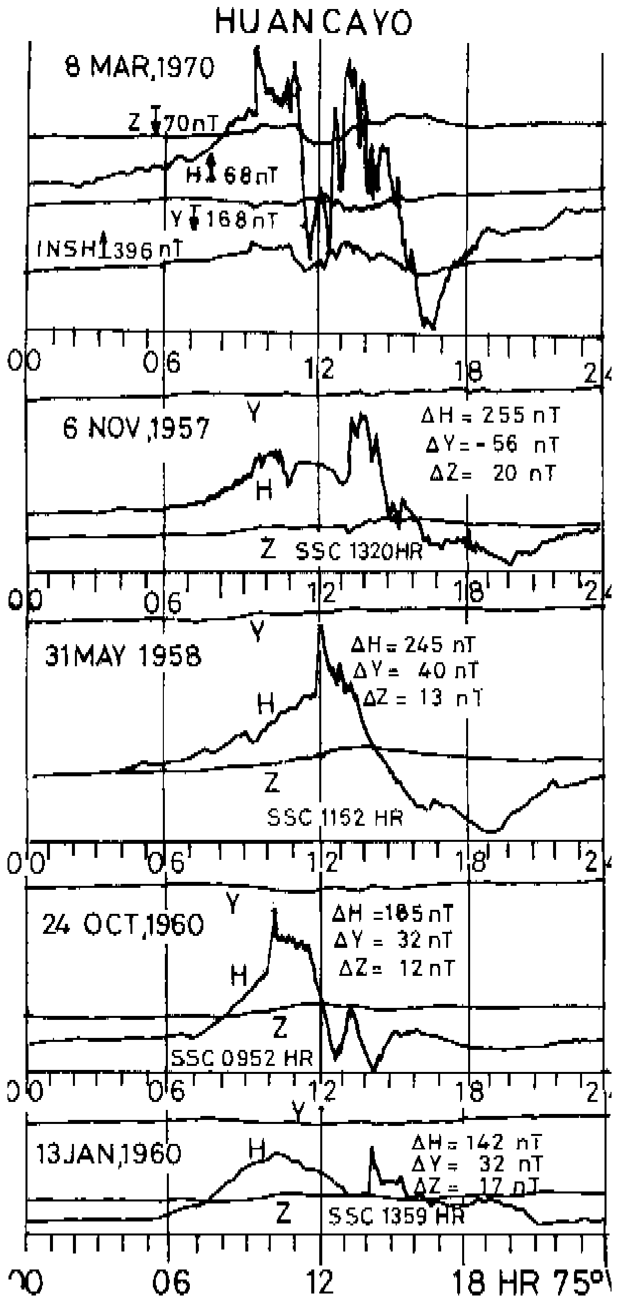

Figure 1. Copies of some magnetograms at Huancayo.

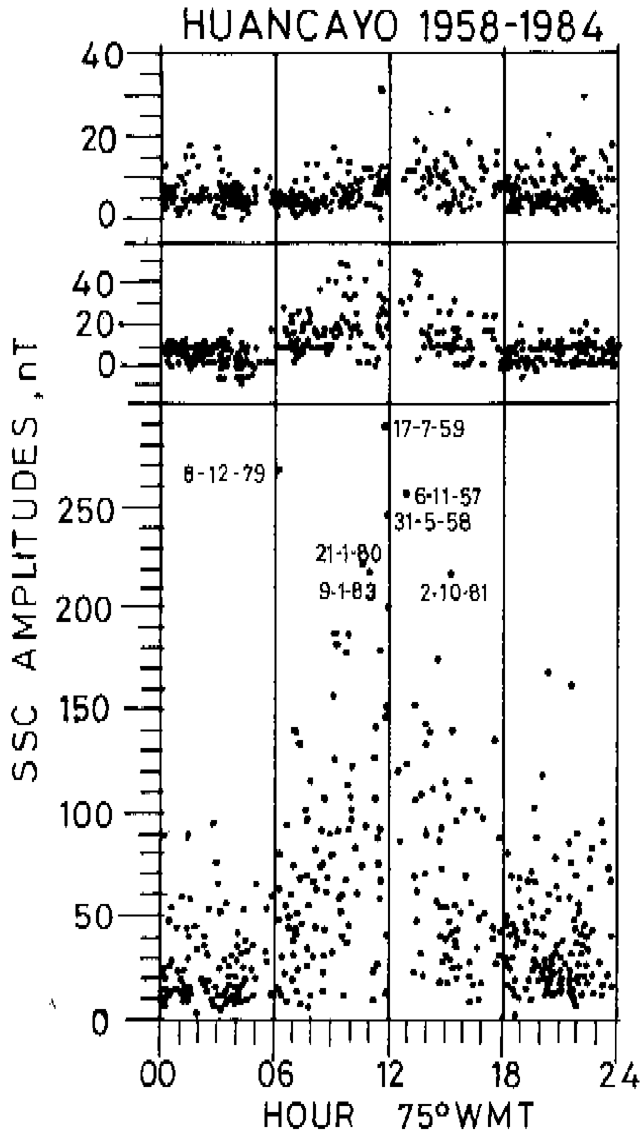

Figure 2. Massplot of individual SSC amplitudes in H, Y and Z fields against local time for Huancayo during the period 1958-1984.

observed during the initial and main phase of the storm. The storm with SSC at 1152 LT on 31 May 1958 again indicated large impulse of SSC of 245 nT in H, 40 nT in Y and only 13 nT in Z. The total range of storm was more than 600 nT but there were no significant fluctuations of the H , Z or Y field during the main phase of the storm. The SSC on 13 January 1960 at 1359 LT had ΔH of 142 nT, ΔY= 32 nT and ΔZ = 17nT. Thus, almost each of the storm had its own characteristic with varying of SSC amplitude, main phase and recovery phase.

In Fig.2 are shown the mass plot of individual values of SSC in H, Y and Z field at Huancayo during the period 1958 to 1984. There is large scatter of points for each of the components. Still an enhancement of SSC (H) can be easily seen for the midday hours. The largest SSC (H) was observed on 17 July 1959 amounting to 290 nT. There were eight SSC (H) during the period with the amplitude exceeding 200 nT. The mass plots of SSC (Y) also indicate a rather broader midday maximum. The largest SSC (Y) amplitude was observed on 18 March 1970, 6 January 1968 and 10 February 1968, none of these were largest SSC in (H). The distribution of points for SSC (Z) does not indicate any significant variation with the local time.

Next, we compared the overall average daily variation of SSC in H, Y and Z at Hauncayo and Trivandrum. In Fig.3 are shown the mean daily variations of SSC amplitudes at the two stations. SSC in H is maximum at both the stations at local noon hours but the maximum amplitudes of SSC (H) was about 140 nT at Huancayo and only 50 nT at Trivandrum. The amplitude of SSC (Z) was almost constant at 10 nT at Huancayo but it showed a large midday maximum of about 50 nT at Trivandrum. The amplitude of SSC in Y was very small at Trivandrum but it showed midday maximum of 20 nT at Huancayo.

Larger intensification of SSC amplitude in American than Indian sector can be seen by plotting the UT variation of the mean of individual ratio of SSC (H) at Trivandrum and SSC (H) at Huancayo. Such a curve is shown as Fig.4. The ratio was about 1.8 around 07 UT which is noon at Trivandrum but the minimum value was about 0.25 or ¼ around 16-17 UT when it is noon at American sector. Thus, it can be seen that the storm of same magnitude causes the SSC (H) to be about twice as large at Huancayo than at Trivandrum. Thus, the effect of magnetospheric compression due to impact of solar plasma is twice as large when the sun faces the American longitude than when it faces the Indian longitudes.

DIRECTION OF SSC DISTURBANCE VECTOR

Fukushima (1966) suggested that the disturbance vector due to SSC at middle and low latitudes should be parallel to the geomagnetic dipole axis and that the direction of the disturbance vector with respect to the geographic meridian can be estimated by ø = $\tan^{-1}$ (DY/DH). Rastogi (1998) showed that the magnetic meridian at Annamalainagar is 2.6°W while the dipole meridian is 6.2°W. Thus, the SSC disturbance vector should deviate by 2.6-6.2 = -3.6 or 3.6°W from the normal H vector before the SSC. The observed values were 10°W to 40°W. Studies of SSC at other equatorial

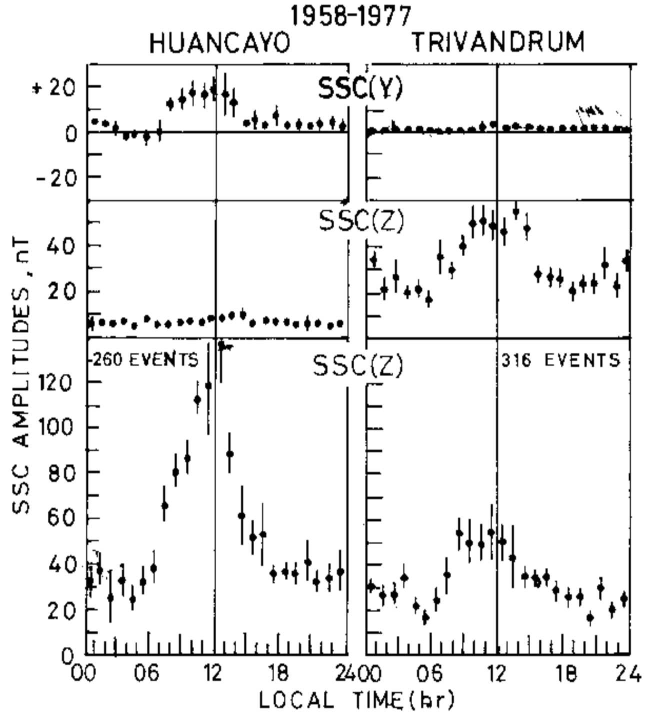

Figure 3. Local time variations of the hourly mean amplitudes of SSC in H, Y and Z fields at Huancayo and Trivandrum.

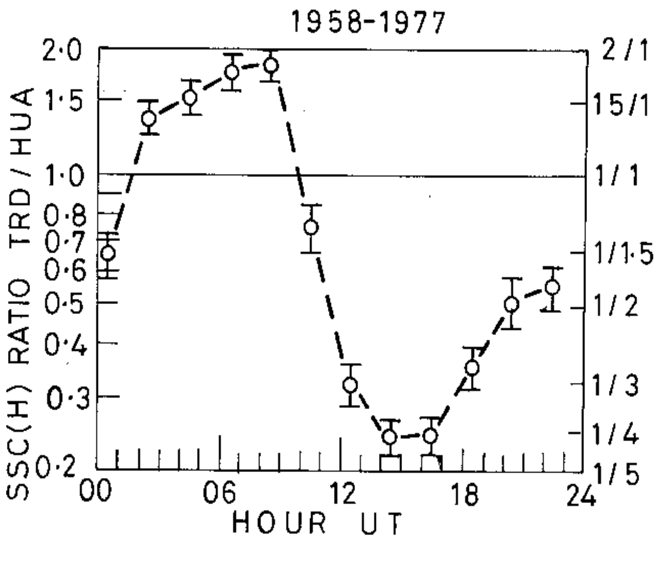

Figure 4. universal time variation of the hourly means of the ratio of SSCamplitude in H field at Trivandrum and Huancayo during the period 1958-1977.

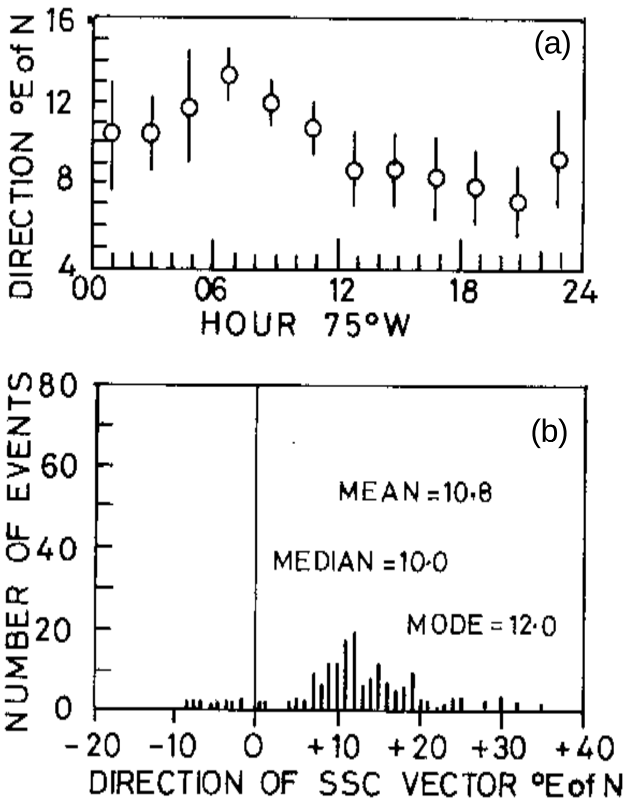

Figure 5. (a) Average hourly direction of SSC Disturbance vector at Huancayo. 5(b) Mean, mode and median values of the histogram of SSC Disturbance vector direction at Huancayo.

electrojet stations in India showed the disturbance vector to be about 10°-20°W of the geographic meridian but the shift of dipole meridian from the ground magnetic meridian at these stations were only 5°W (Rastogi 1998). Later, Rastogi, Winch & James (2001) showed that the equatorial ring current follows the dipole coordinate system and ΔH and ΔY during the during magnetic storms at low latitudes follow the relation ΔY/ΔH = sin (Y-D) where Y is the dipole and D the ground declination at the station. It was also shown that during the SSC and the initial phase of the storm the above relation is not followed by ΔY and ΔH, which are affected by sources other than the equatorial ring current.

In figs 5a and 5b are shown the local time variations of the SSC disturbance vector and the statistics of their angle at Huancayo over the period of study. It can be seen that the angle varies from the value of 7°E to 14°E, the maximum duration being around 07 LT minimums around 19 LT. This dawn maximum and dusk minimum indicates the possible effect of dusk-dawn magnetospheric electric field. The mean value of the angle was 10.8°E while the median the mode values were 10 and 12 respectively. The Y and D values at Huancayo during IGY were 0.7° and 5.0° respectively such that Y-D = -4.3°.

It may be concluded that whereas the disturbance ring current does follow the earth's dipole coordinate system but the SSC current vector deviates significantly from the geomagnetic dipole meridian due to other causes affecting it, like the magnetopause current, solar wind speed and density as well as interplanetary magnetic field direction.

LATITUDINAL VARIATION OF SSC AMPLITUDES

In Fig.6 are shown the magnetograms trace at HUA, YAU, CMB, CCL, TAL and FUQ during the SSC at 1330 LT on 14 June 1958. It can be seen that the SSC in H is positive at all stations. The SSC in Z is small negative at HUA and at all other northern dip stations CMB, CCL, TAL and FUQ. The amplitude of SSC in Z was positive at YAU and comparable in magnitude to the corresponding amplitude of SSC in H. A small positive impulse in Z at TAL is seen before the main negative impulse. The impulse of SSC in Y is small and negative at all station.

In Fig.7 are shown the mass plot of the amplitudes in SSC in H, Y and Z at all of the stations YAU to SJG.

The amplitudes of SSC in H were enhanced during noon hours at all equatorial station HUA, YAU, CMB, CCL and TAL but no significant daily variation was seen at other low latitude stations. The amplitude of SSC (H) was comparable at HUA and YAU and seems to describe from the equator.

The amplitude of SSC (Z) are extraordinary large at YAU with a maximum around noon. The amplitude of SSC (Z) at HUA were small and without any daily variation. Amplitude of SSC (Z) at CMB, CCL and TAL showed negative values during daytime and very small values during the nighttime hours. The SSC (Z) at FUQ was always negative but at TEO these were small positive. At SJG, SSC (Z) was mostly negative. These changes are in conformity with the increase of equatorial electrojet current causing positive impulse stations south and negative at station north of the equator.

The amplitudes of SSC (Y) did not show any definite pattern at any of the stations. The amplitudes were small and negative at electrojet stations in north of the equator and positive at HUA, YAU and FUQ. At TEO and SJG the individual SSC (Y) were equally positive or negative.

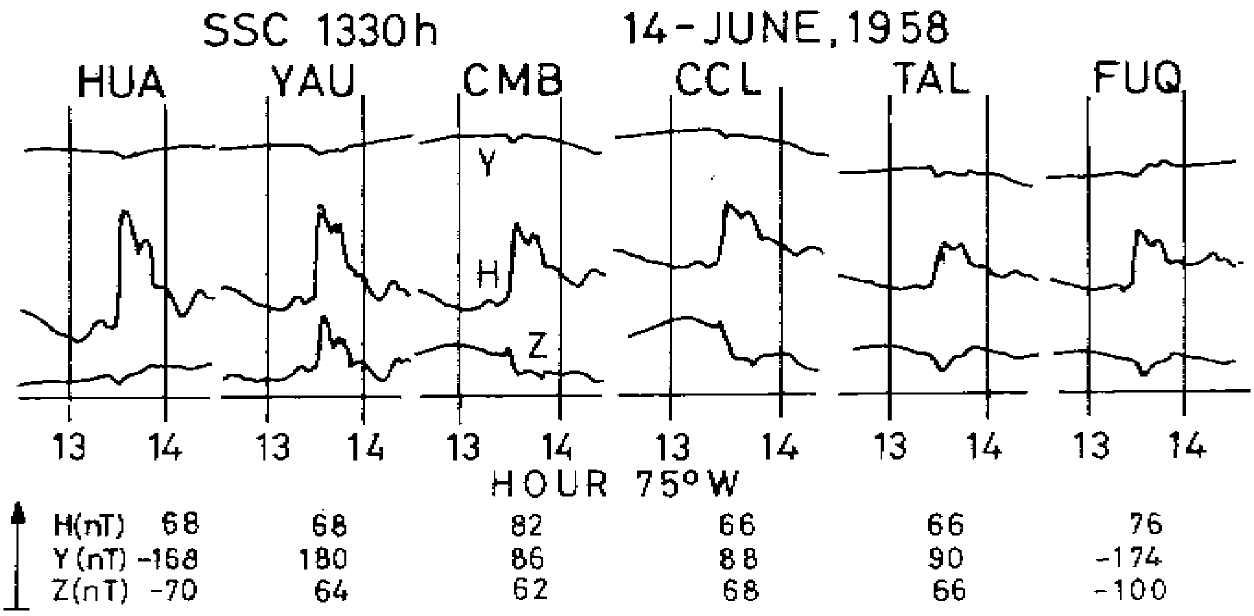

Figure 6. Signatures of SSC in H, Y and Z fields at Huancayo (HUA), Yauca(YAU) Chimbote(CMB), Chiclayo(CCL) Talara (TAL) and Fuquene (FUQ) starting at 1330 LT on 14 June 1958.

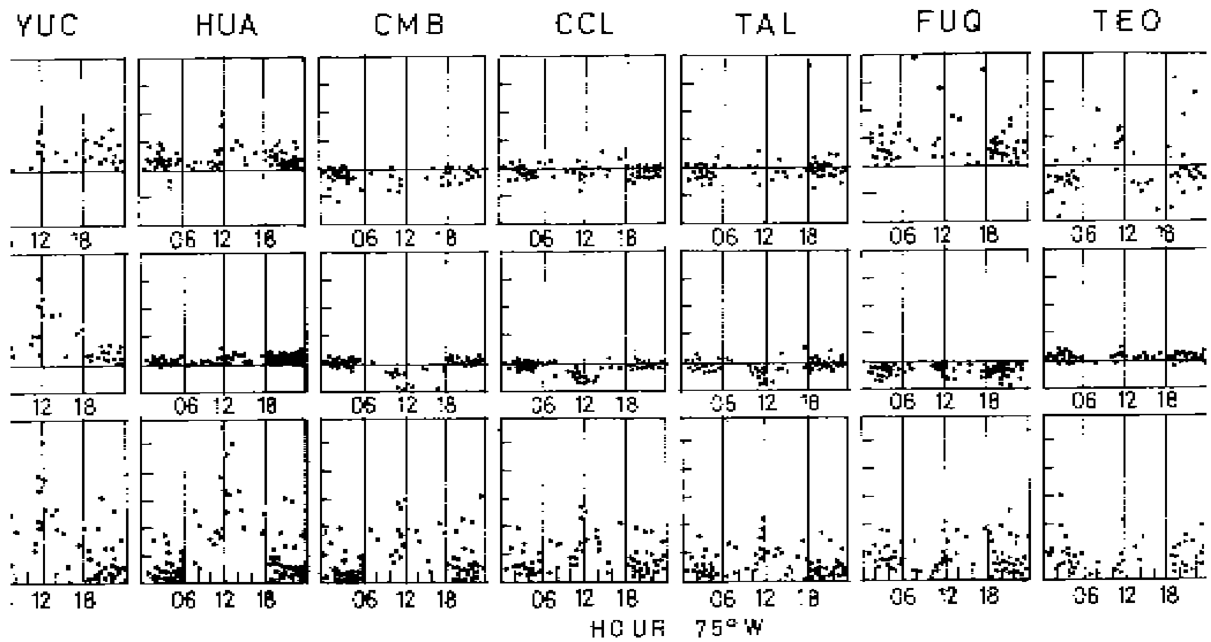

Figure 7. Mass plot of the amplitudes of SSC in H,Y and Z fields at low latitude stations in Peruvian sector during IGY- IGC period plotted against local time (75° W.)

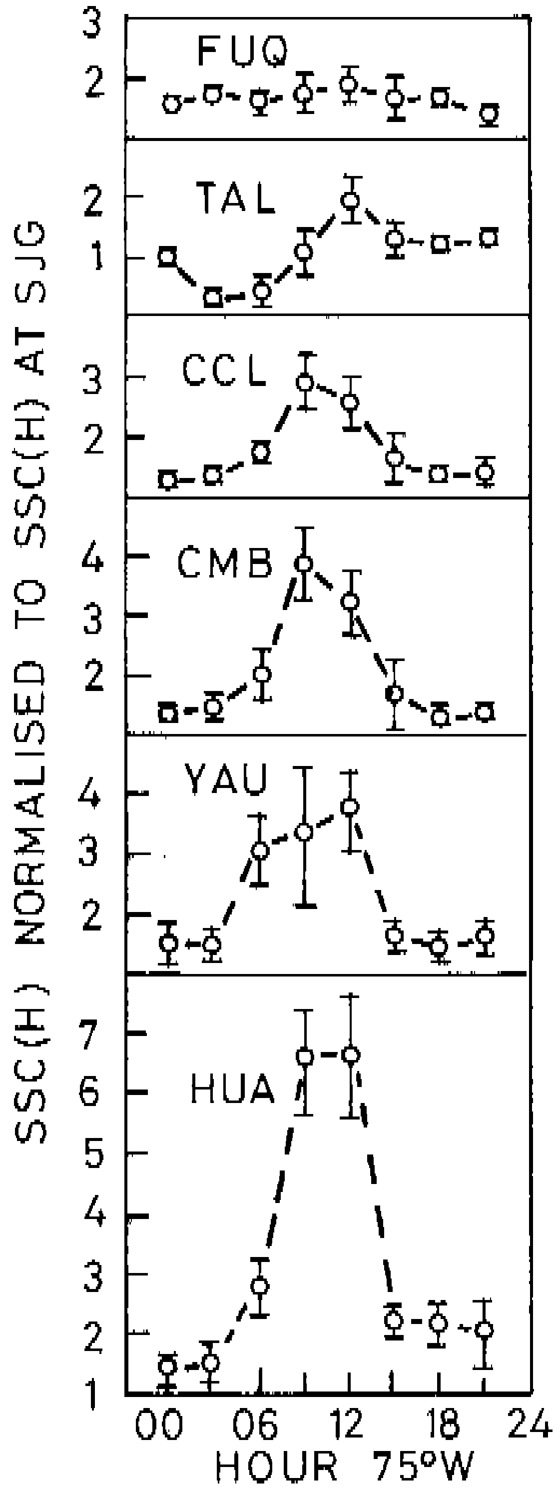

Figure 8. Daily variatio of the mean amplitudes of the SSC at different stations normalised to that at San Juan.

In Fig.8 are shown the average amplitudes of SSC (H) at different stations normalized to the amplitude of SSC (H) at middle latitude station Sun Juan. The enhancement of the amplitude at all electrojet stations at noon hours and the enhancement of midday values of SSC in H at equatorial stations are clearly seen. The amplitudes of ΔH during midday hours were about 6-7 times larger at Huancayo than at San Juan. It is interesting to note that the ratio of SSC (H) at HUA/SJG is greater than unity for any time of the night too. Rastogi, Kaushika & Trivedi (1966) had shown the amplitude of fluctuations in H at American station during the IGY-IGC period were enhanced over the magnetic equator even during the nighttime hours. To check this, in Fig.9 are shown the mass plot of the individual value of ΔH at Huancayo versus the corresponding value of ΔH at San Juan for the SSC accusing during the nighttime hours. A clear increase of ΔH at HUA with increase of ΔH at SJG is seen indicating the ratio of about 2.0 between ΔH HUA/ ΔH SJG.

In Fig.10 are shown the mean latitudinal variations of the amplitude of SSC in H at American and Indian longitudes sector for the SSC occurring during the daytime hours (09-15 LT) and during the nighttime hours (22-04 LT). At American sector there was an equatorial enhancement of about 6.0 during the daytime and about 1.6 during the nighttime. Along Indian sector the SSC (H) was enhanced at the equator by about 2.5 during the daytime hours, but during the nighttime hours a gradual decrease of the amplitude occurs around the magnetic equator. This seems to be the effect of large electromagnetic induction in Indian sector.

In order to check if the value of ΔZ during the SSC along the American sector follow the expectations from an equatorial electrojet current in Fig.11 are shown the individual values of SSC (Z) at northern station Chimbote and at southern stations Yauca against the corresponding SSC (H) at Huancayo, for the daytime as well as nighttime hours. During the daytime, as expected the ΔZ at northern station (CMB) decreases with increasing ΔH at HUA, while ΔZ at southern station (YAU) increase with increasing ΔH at HUA. During the nighttime the amplitudes of ΔZ at both the northern as well as southern station increase slightly with increasing ΔH at HUA. This suggests that there is a weak eastward current over the equatorial and low latitudes in American sector even during the nighttime hours.

In Fig.12 are shown some examples of SSC + observed at Huancayo. The preliminary negative impulse is mostly seen clearly in H trace. In contrast with Trivandrum where the reverse impulses are

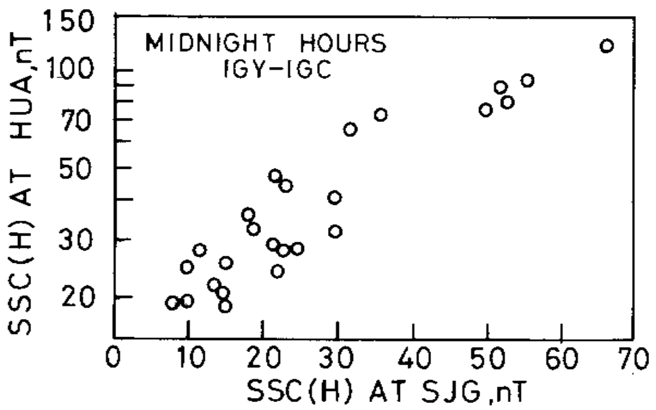

Figure 9. Relationship of the amplitudes of SSC in H during the night hours at Huancayo versus the same at San Juan.

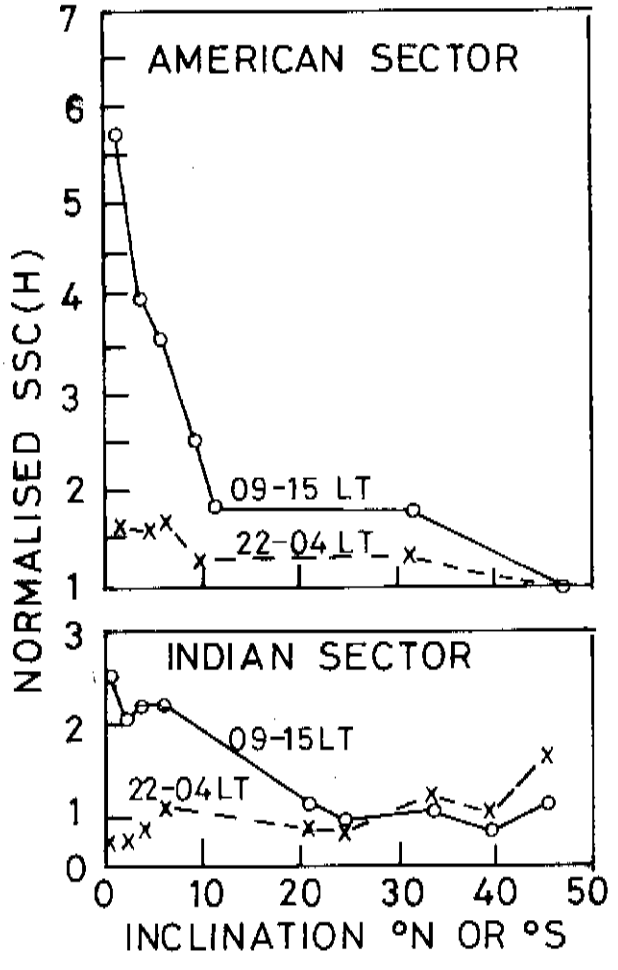

Figure 10. Normalised amplitude of SSC in H during the night time and daytime hours in American and Indian sector as the function of magnetic inclination at the station.

equally significant in H as well as in Z traces. No reverse impulse is seen in Y or Z traces at Huancayo due to its very small magnitude. Further, at Huancayo the ratio of negative impulse in H is much smaller compared than the corresponding main positive impulse.

In Fig.13 are shown the magnetograms of H, Y and Z components at the American stations during the SSC + at 1326 LT on 9 April 1951. At Huancayo the negative impulse was seen only on H traces but at Y area it was clearly recorded in both H and Z traces. At Chimbote the negative impulse in H is associated with a preliminary positive impulse in Z traces and no impression of preliminary trace is seen in Y trace. At Chiclayo and Talara the negative impulse in H is associated with a positive impulse in Z and a negative impulse in Y trace at Fuquene no preliminary impulse was seen in any of the traces.

Thus, it is concluded that the preliminary reverse impulse during SSC in observed at all equatorial electrojet stations and represents a reversed westward electrojet current before the eastward increase of the normal electrojet current due to the main part of the SSC.

In Fig.14 are shown two examples of SSC at Huancayo with pure positive impulse at 1612 UT on 13 July 1968 and a SSC with preliminary negative impulse followed by main positive impulse at 1225 UT on 18 November 1970. The corresponding variations of the latitude (θ) and scalar value (B) of the Interplanetary Magnetic Field (IMF) are also shown. It is seen that the pure SSC on 1612 LT was associated with a sudden increase of B and the southward turning of the latitude . The SSC + on 18 November 1970 was associated with the sudden increase of B and the northward turning of the latitude. It has been pointed out by Rastogi & Patel (1975) that the sudden impact of the solar plasma on the magnetopause of the earth is equivalent of the imposition of an electric field E = – V*Bz where V is the velocity of the solar wind and Bz = B sinθ is the component of Interplanetary Magnetic Field normal to the ecliptic.. This electric field is transferred to the auroral region and then to the equatorial latitudes through the ionosphere. The northward turning of the IMF produces a negative (westward) electric field in the ionosphere. There being an abnormally large electrical conductivity in the ionosphere E layer over the magnetic equator. This electric field causes a significant negative impulse in the current and hence, in the H field at equatorial station on the dayside of the earth. This is later followed by the compression of the magnetosphere causing the main positive impulse in H due to SSC. The imposition of an

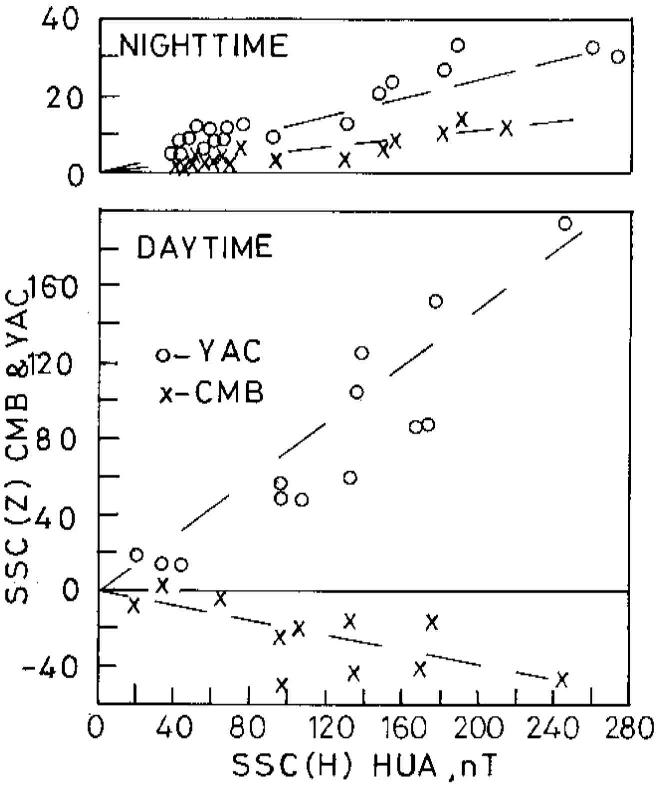

Figure 11. The amplitude of SSC in Z at Chimbote (CMB) and Yauca (YAU) during the daytime and nighttime hours as a function of SSC(H) amplitude at Huancayo.

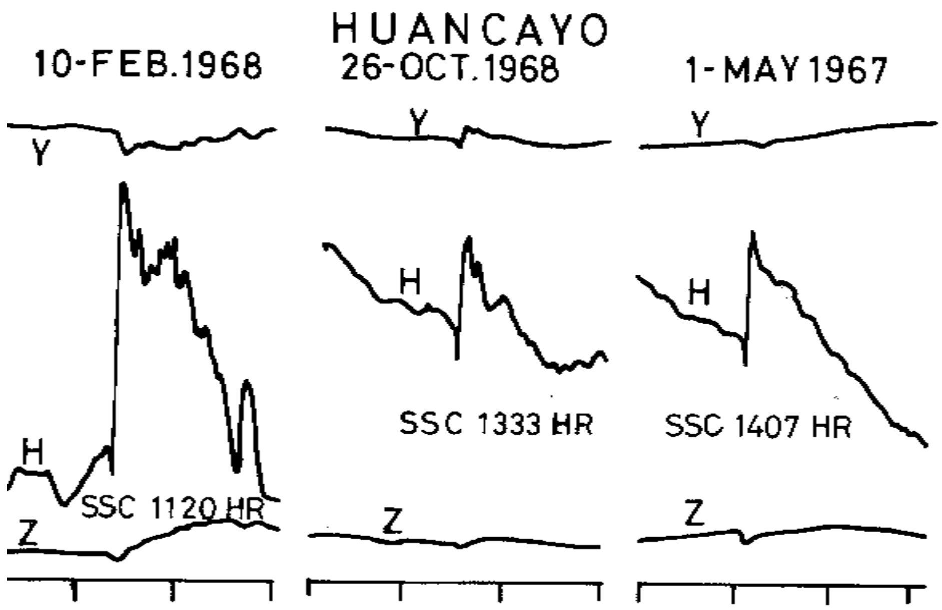

Figure 12. Three examples of SSC *type of disturbance at Huancayo in H , Y and Z magnetograms.

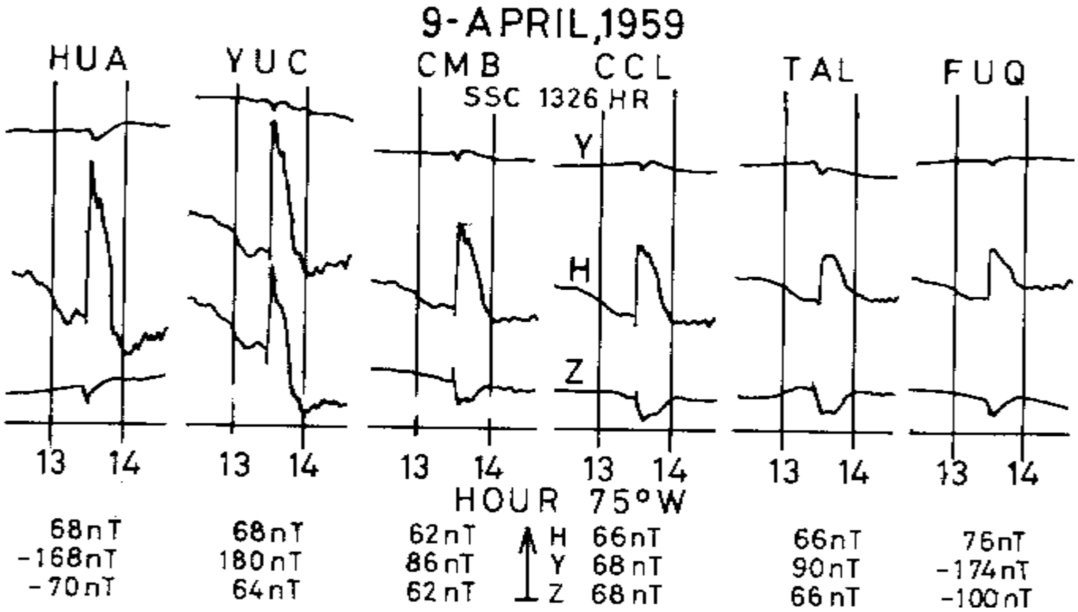

Figure 13. Signatures of sudden commencements in H, Y and Z fields at low latitude stations along 75^{O}W longitude sector during the disturbance of 9 April 1959.

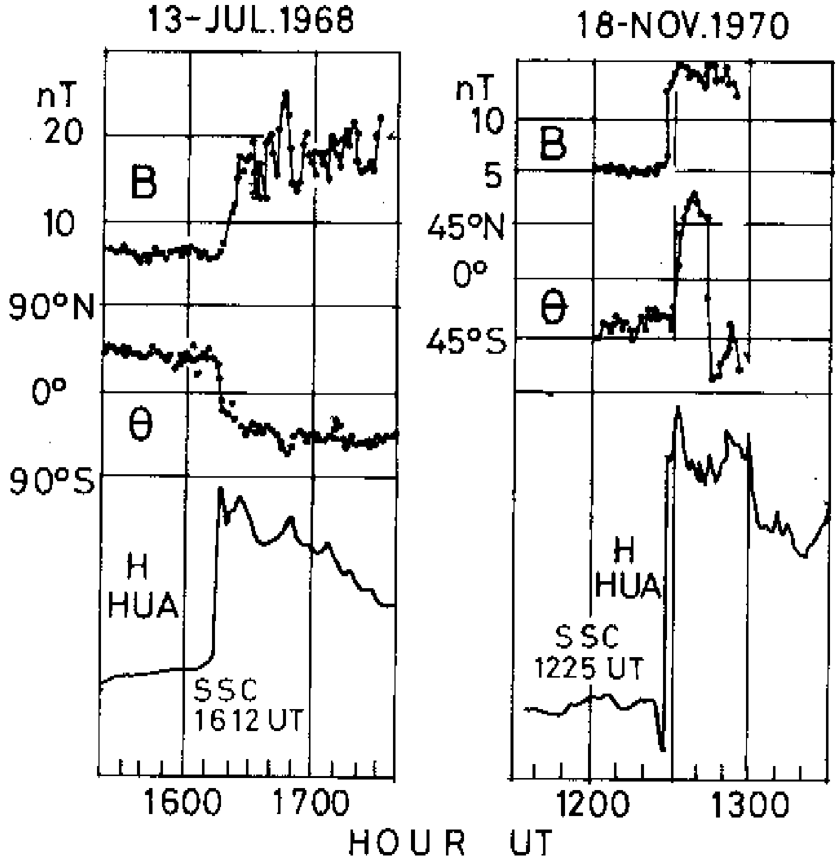

Figure 14. The two types of SSC in H ,one with pure positive impulse and the other with a preliminary negative impulse followed by the positive pulse compared with the variation of the Interplanetary Magnetic Field.

electric field on the equatorial ionosphere during a SSC has been experimentally verified (Rastogi 1976; Reddy, Somayajulu & Viswanathan 1981). Kikuchi, Araki & Masckawa (1978) have shown that the auroral electric field can be instantaneously transmitted to be equatorial region by the two mode of the transmission line between the ionosphere and the earth.

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