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Effect of interplanetary magnetic field on ionosphere over the magnetic equator

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ABSTRACT

Large and quick changes of the latitude of the interplanetary magnetic field from its southward to northward direction is shown to be associated with the disappearance of the *q* type of sporadic *E* layer at the equatorial ionosphere during the daytime or with the reversal of *E* region horizontal and *F* region vertical electron drifts during the hours of daytime as well as nighttime.

This phenomenon is suggested as the imposition of an electric field in the ionosphere from the evening to the morning sector of the earth and is thus in a direction opposite to that of the Sq electric field. The resultant electrostatic field on the equatorial ionosphere would be decreased or even reversed from its normal direction. This would result in the reduction of electron drift velocity. On some occasions when the normal Sq field is over-compensated by the magnetospheric electric field, the electron drifts are reversed and the irregularities in the *E* region due to the cross-field instabilities are inhibited resulting in the sudden disappearance of the *q* type of *Es* layers.

INTRODUCTION

IT has been discovered through extensive studies of interplanetary and surface observations that the electric field in the polar ionosphere is considerably affected by the interplanetary magnetic field. Several research papers and review articles have summarised these results (Willis 1971, Heppner 1972, Mozer *et al.* 1974). However, very little attention has been given to the possible effects of the interplanetary magnetic fields on the equatorial ionosphere which has the special advantage of being free from

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violent and fast changes that one would observe at the polar ionosphere. The highly variable state of the polar ionosphere is due to easy access of the particles from the interplanetary space and the tail region of the magnetosphere. The equatorial ionosphere has relatively slow and distinctive variations because the charged particles do not have ready and uncontrollable access to the low latitudes. Due to greatly enhanced conductivity in the equatorial electrojet region, the ionosphere in this region is very sensitive to the changes of electric field imposed on it. Any change in the electric field at the *E* region over the magnetic equator has its immediate effect on the electron drift velocity. One of the sensitive methods of measuring *E* region electron drift velocity is through the doppler shift of VHF backscatter echoes from the *E* region irregularities. One such powerful station has been operating at Jicamarca, Peru (dip 2° N). One of the simpler methods of estimating the *E* region electric field is through the ionospheric drift by spaced receiver technique. Ionospheric drift was measured at Thumba during 1964–69 and it has been shown that the drift speed during midday or the midnight hours decreases with increasing magnitude of the southward component of the interplanetary magnetic field (Rastogi and Chandra, 1974). The horizontal *E* region ionospheric or electron drift is shown to be normally westward during daytime and eastward during nighttime, the reversals occurring at about 0700 hr and 2000 hr (Balsley 1973). Similarly the vertical electron drift in the *F* region is closely linked with the horizontal *E* region electron velocity, eastward *E* region electric drifts correspond to downward *F* region electron drifts and westward *E* region drifts correspond to upward *F* region drift.

The other very important feature of the equatorial ionosphere associated with the electric field is the sporadic *E* reflections observed in the ionograms. A particular type of *Es* layer which is transparent to upper ionospheric layers and which does not produce multiple reflections in the ionograms is designated as *Es–q* (Knecht 1959). This type of *Es–q* was shown to occur over a width of 700 km centred over the magnetic equator (Knecht and McDuffie 1962) and this agreed very well with the position of the equatorial electrojet as deduced from geomagnetic field variations (Forbush and Casaverde 1961). This special type of sporadic *Es–q* has been suggested by Rastogi (1972 *a*) to be due to gradient (or cross-field) instabilities at the base of the *E* region due to interaction of horizontal magnetic field on the vertically upward plasma gradient and the Hall polarization electric field. Many other types of *Es* configurations indirectly related with equatorial electrojet are also observed in the equatorial ionograms, *e.g.*, during periods of weak electrojet or of counter electrojet sometimes multiple layers of *Es* are observed near the dip equator (Rastogi 1974). This type of *Es* layer near the equator has been explained by Chandra and Rastogi (1975) as due to the transportation of long lasting metallic ions along the magnetic lines of force towards the equator by the meridional component of the neutral wind.

The *Es–q* layer has been shown to disappear when the ionospheric drift or the electron drift reverses towards eastward direction from its normal westward direction during daytime hours (Rastogi *et al.* 1971, Rastogi 1973). This is interpreted as due to the reversal of E–W electrostatic field at 100 km level which in turn reverses the direction of Hall polarization field downward which then being opposite to the direction of plasma gradient causes the inhibition of the cross-field instability and thereby the disappearance of *Es–q* reflections in the ionograms. The most confident criterion for the reversal of electric field and so of the electric current at 100 km has been shown by Rastogi (1975) to be the value of the geomagnetic field at an equatorial station minus the same at a station outside the electrojet region at any time of the day becoming less than the corresponding value during the nighttime.

In the present paper we have studied the possible coupling between the equatorial ionosphere and the interplanetary magnetic field (*IMF*). We have sought only the features of the equatorial ionosphere associated with horizontal east–west electrostatic field. There are mainly two features; first, the sudden disappearance of the *Es–q* layer at the equatorial station Huancayo ($\lambda = 12°$ S, $\phi = 75°$ W, dip lat. = 1° N) during local daytime hours. The second parameter studied is the electron velocity computed from the doppler shift of VHF echoes from the *E* or the *F* region at Jicamarca, Peru. during the hours of daytime as well as nighttime.

The interplanetary magnetic field data are taken from the observations from Explorer 33, 34 and 35 satellites. The parameters of the IMF are the magnitude of the field (B), the latitude (θ) which is the angle between the direction of the field and the ecliptic plane, $-90°$ meaning southward and $+90°$ meaning northward field; longitude (ϕ) which is the angle between the Sun–Earth line and the direction of the field component in the ecliptic plane and lastly $B_z = B \sin \theta$ is the vertical component of the field. In this paper, we have concentrated our study to the changes of θ or of Bz. For some of the events studied, the density and the velocity of the solar wind values near the satellite were also available and are used.

The geomagnetic field at the following observatories are studied to assess the changes in the ionospheric currents: (1) Huancayo (dip 1° N) a station close to the dip equator, (2) Fuquene (dip 33° N), a northern station outside the equatorial electrojet region, (3) San Juan (dip 51° N), a station near the northern Sq focus and (4) Thule (dip 86° N), a northern polar station, all roughly in the same longitude zone. The value of $\triangle H$ at Huancayo minus $\triangle H$ at Fuquene is also plotted in the diagrams, the reference value being taken for 0000 hr. A negative value of $\triangle H$ (HUN–FUQ) is considered as indicative of counter-electrojet current at the *Es–q* level.

Events were noted showing sudden reversals of the equatorial electric field as evidenced by the sudden disappearance of *Es–q* at Huancayo or the sudden reversal of the electron drift velocity at Jicamarca. Simultaneous *IMF* data were sought for these events and it was checked if any of these satellites were situated outside the magnetosphere so that field parameters measured by the satellite instruments are not affected by the geomagnetic field of the earth. Only those events are discussed here when the simultaneous data of the equatorial ionosphere and the interplanetary magnetic

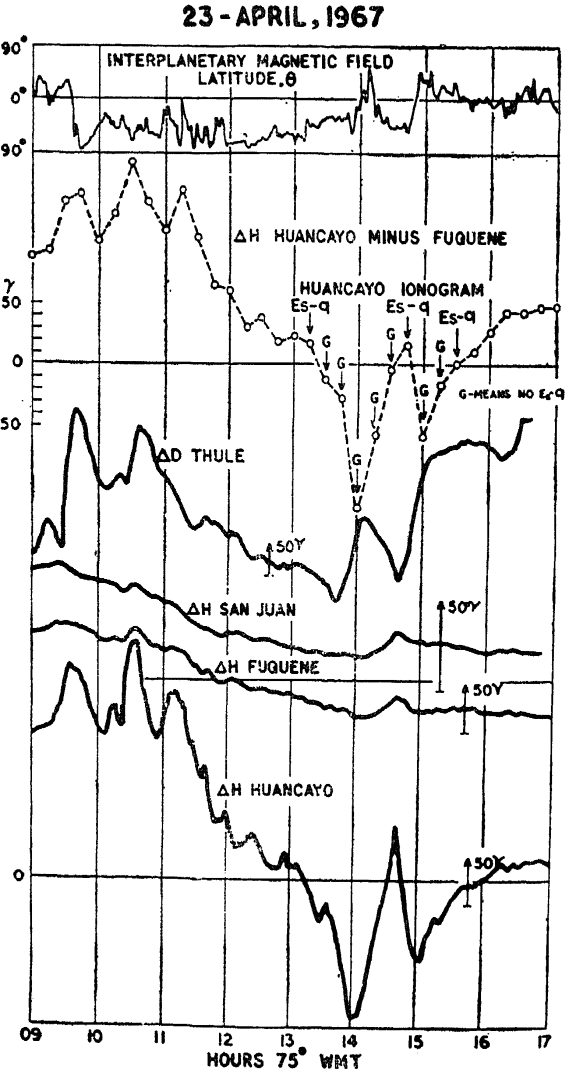

Figure 1 (*a*). The variations of geomagnetic field at ground observatories and the latitude of interplanetary magnetic field on 23 April 1967 associated with the disappearance of *Es–q* between 1330–1430 and 1500–1515 hr.

field are available. Time standard used is 75° WMT for American stations and 75° *EMT* for Indian stations.

(A) *Interplanetary magnetic field and* q *type of equatorial sporadic* E *layer*

Rastogi (1972 *b*) has described the disappearance of *Es–q* at Huancayo on 23 April 1967. In figure 1 (*a*) are shown the variations of the magnetic field at the ground stations and the latitude θ of *IMF* as measured at satellite Explorer 33, while figure 1 (*b*) shows the position of satellite with respect to the magnetosphere. The satellite on 23 April 1967 was within the magnetosheath at about 0200 hr position at a distance of about 55 earth radii.

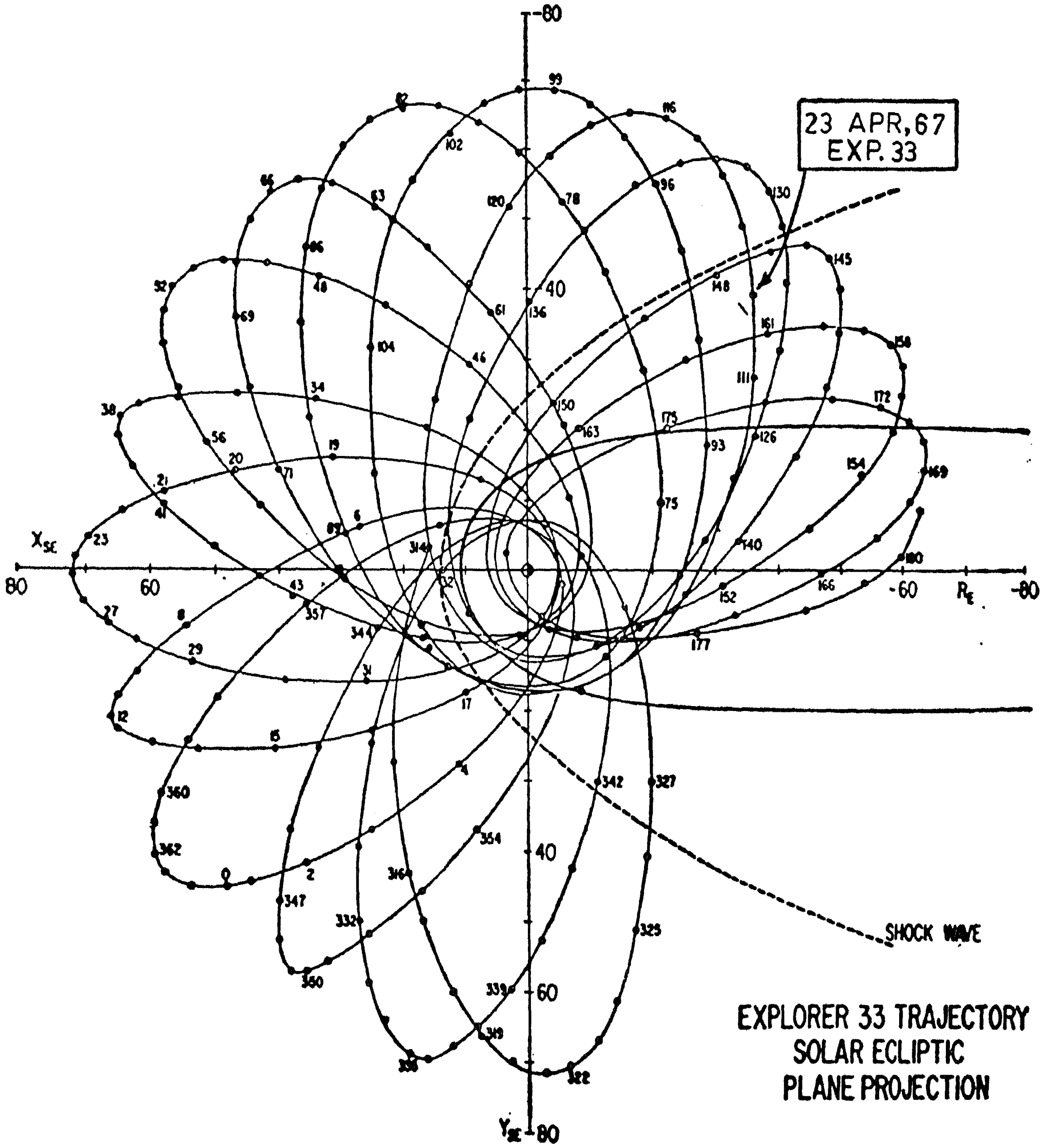

Figure 1 (*b*). The trajectories of satellite Explorer 33 projected on the solar ecliptic plane indicating the positions of the satellite on 16 January 1967 and on 23 April 1967.

The ionograms at Huancayo on 23 April 1967 showed sudden disappearance of *Es–q* at 1330 hr. The *Es–q* remained absent on all ionograms till 1430 hr and reappeared at 1445 hr. The *Es–q* echoes were again absent at 1500 and 1515 hr. These periods of no *Es–q* condition tally remarkably well with the periods of negative value of $\triangle H$ (*HUN–FUQ*). There are seen two minima in $\triangle H$ (*HUN*) at 1405 and 1500 hr. The latitude, θ, of *IMF* showed sudden changes from its negative value to large positive values around 1400 and 1445 hr. The *Bz* component of *IMF* abruptly changed from $-$ 15ν at 1352 hr to a value of + 15ν at 1409 hr and from $-$ 7ν at

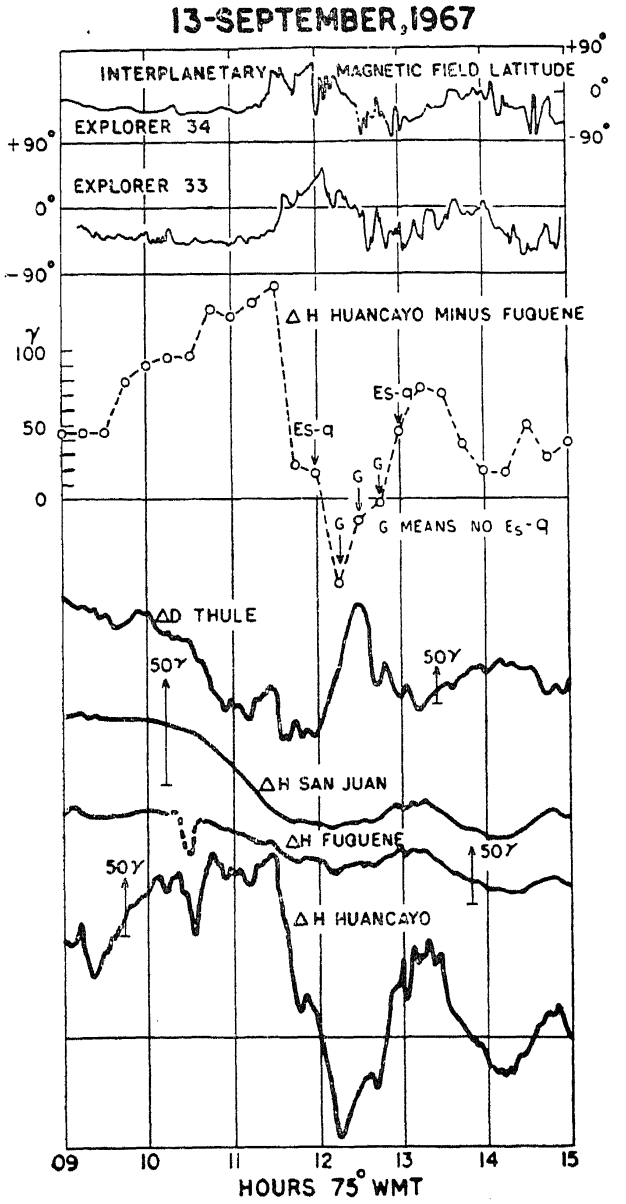

Figure 2 (*a*). The variation of the magnetic field at ground observatories and at explorer satellite outside the magnetosphere and the associated disappearance of *Es–q* layer at Huancayo on 23 April 1967.

1445 hr to $+ 9v$ at 1455 hr. The satellite position at 1400 hr was $X = - 34 \cdot 8$, $Y = - 46 \cdot 9$ and $Z = - 19 \cdot 8$ earth radii in solar ecliptic coordinates. The first disappearance of *Es–q* occurred about 20 minutes before the sudden change of Bz as seen by the Explorer 33.

The reversal of Bz component from negative to positive value corresponds to reversal of the electric field from east to west direction. For example, the induced electric field $E = - V \times B$ has Ey component (*E–W* electric field) equal to $- V_x B_z$ where $V_x \approx V$ radial in $- X$ direction. If we take solar wind plasma velocity as 500 km/sec (actual measurements of plasma were not available on this day) and $Bz = - 15\nu$ then $Ey = V_x B_z = 7 \cdot 5$ mV/m eastward at 1352 hr. This eastward electric field then abruptly changes to westward electric field when Bz component is $+ 15\nu$, *i.e.*, Ey changes to $- 7 \cdot 5$ mV/m. Similar calculations when Bz changes from $- 7\nu$ to 9ν give a resultant change of westward field of about 8 mV/m imposed on the magnetosphere. We suggest that such westward electric fields

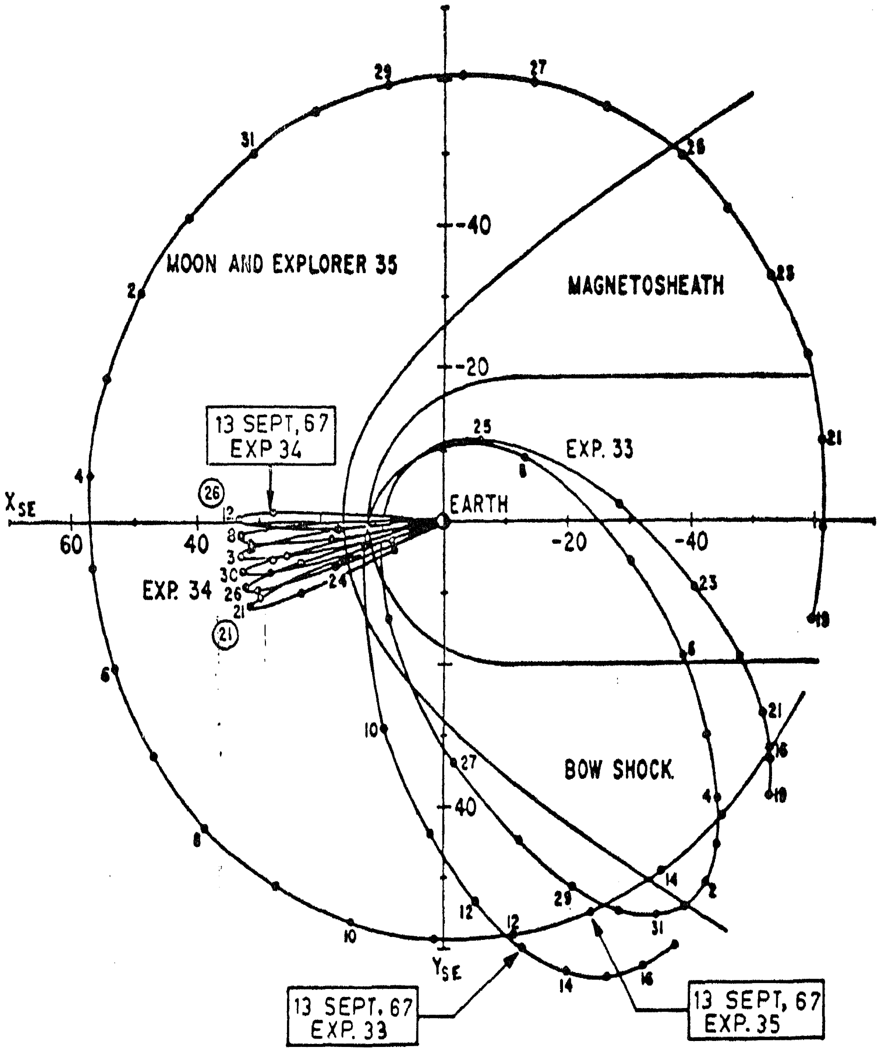

Figure 2 (*b*). The trajectories of the satellite Explorer 33, 34 and 35 projected on the solar ecliptic plane indicating the position of the satellites on 13 September 1967.

are responsible for the sudden *Es–q* disappearance and for the reduction of the *H* component of the geomagnetic field primarily at the equatorial latitudes where the electric field is primarily in *E–W* direction.

Another example of sudden disappearance of *Es–q* at Huancayo associated with sudden changes in *IMF* occurred on 13 September 1967. The changes in the geomagnetic field at ground observatories and the *IMF* latitude at Explorer 33 and 34 satellites are shown in figure 2 (*a*) while the trajectories of the satellites are shown in figure 2 (*b*). In figure 3 are reproduced the ionograms during the day showing the disappearance of the *Es–q* layer. From the ionograms one can see very strong *Es–q* echoes above 100 km at 1130, 1145 and 1200 hr. The occurrence of slant *Es* echoes, the virtual height increasing with frequency suggests the presence of strong irregularities around 100 km. These *Es* echoes had suddenly disappeared in the ionograms for 1215, 1230 and 1245 hr. Strong *Es–q* echoes were again seen after 1300 hr. The *H* field at Huancayo showed a large decrease at 1130 hr with a minimum around 1215 hr. Similar changes are also seen at Thule in *D* component. The value of $\triangle H$ (*HUN–FUQ*) showed a sudden drop at 1130 hr but it decreased to negative value only after 1215 hr and became positive again at 1330 hr. The *Es–q* did not disappear when $\triangle H$ (*HUN–FUQ*) dropped suddenly but only when it decreased below zero. The

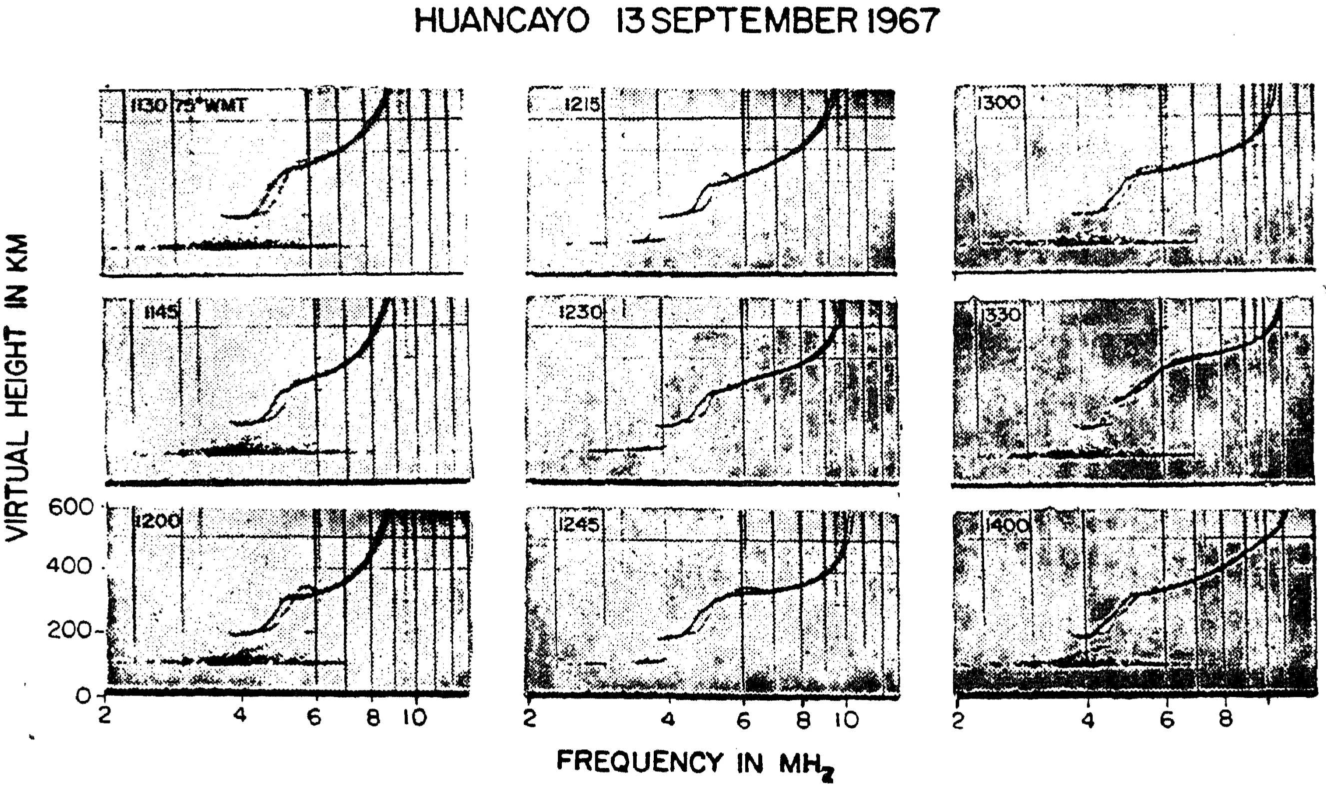

Figure 3. Ionograms taken at Huancayo on 13 September 1967 showing sudden disappearance of *Es–q* between 1215 and 1245 hr.

Explorer 34 was almost on the noon side of the earth at about 30 earth radii while Explorer 33 was at the evening side about 20 earth radii behind the earth. The latitude θ of *IMF* at Explorer 33 showed excursion in positive direction, rather slowly from about 1130 hr to 1200 hr while the Explorer 34 felt the changes about 10–15 minutes earlier. The positive excursion of the latitude corresponds fairly well with the large decrease of $\triangle H$ (*HUN–FUQ*) between 1130 and 1300 hr.

In figure 4 are shown the interplanetary magnetic field components B_x, B_y, B_z, and associated electric field components E_y and E_z derived from $E = -V \times B$. Also shown are plasma velocity V and plasma density N observed by Explorer 33 and 35. All the data points are 10 min averages. Consequent to the change of B_z from negative to positive value, the electric field component E_y started decreasing from 1125 hr and reached a minimum value around 1215 hr. This westward component of E_y did decrease the

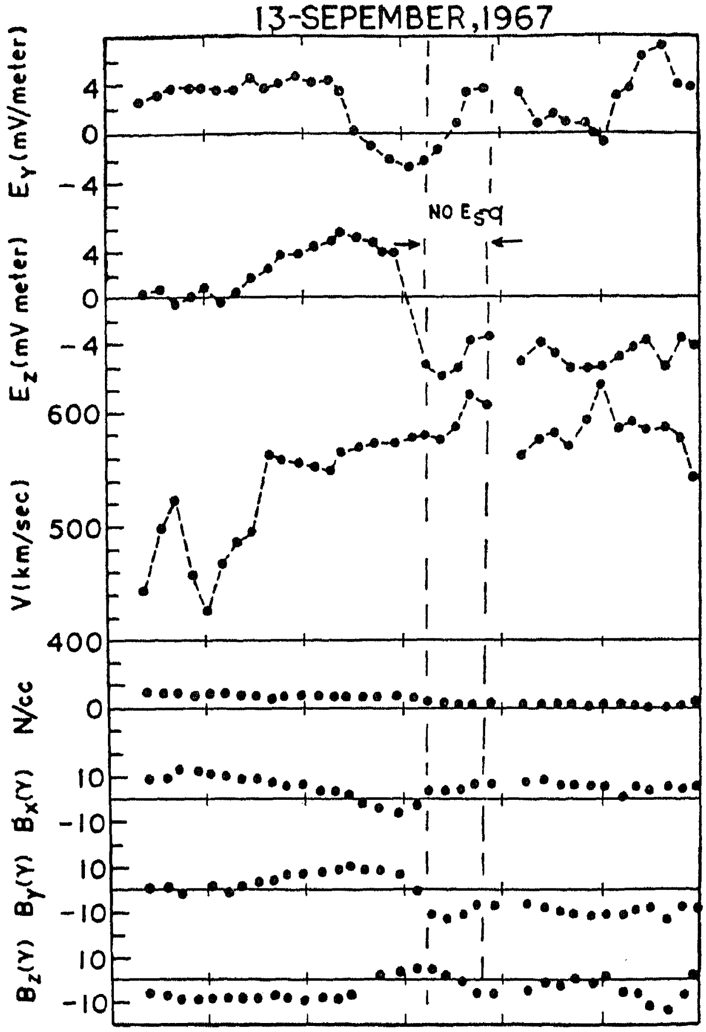

Figure 4. The variations of interplanetary magnetic field components B_x, B_y and B_z, the solar wind speed V and number density N and the associated electric fields $E_y = V B_z$ and $E_z = V B_y$, and the associated disappearance of Es–q at Huancayo.

geomagnetic *H* component at Huancayo but it failed to cancel the usual daytime eastward electric field to cause the disappearance of *Es–q*. Only when E_y attained maximum negative value at about 1215 hr, then the *Es–q* disappeared at Huancayo.

Several examples of the disappearance of *Es–q* were observed at Huancayo on 28 February 1968. This was a magnetically disturbed day. Sudden disappearance of *Es–q* were observed between 0845–0915, 0945–1145 and 1245–1315 hr. Complete plasma and magnetic field data were available on this day and 15 min averages of solar ecliptic B_x, B_y, B_z, E_y and E_z with plasma velocity *V* and the density *N* are shown in figure 5 (*a*) while the trajectories of the satellites are shown in figure 5 (*b*). Explorer 34 was well inside the magnetosphere close to the neutral sheet region and hence the data were not suitable for *IMF* studies. Explorer 35 was ideally located at

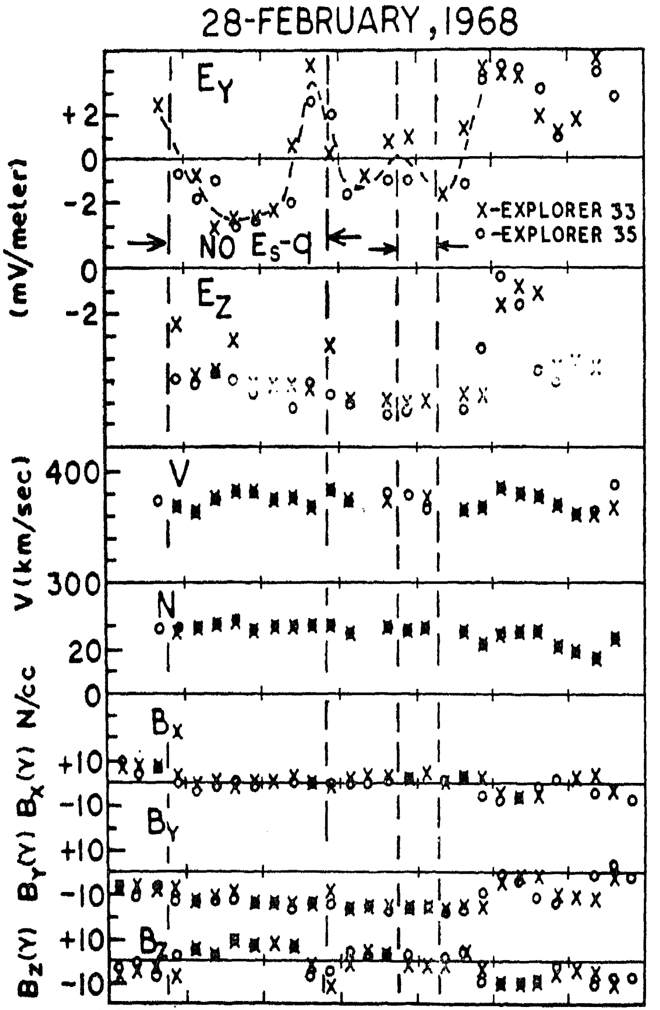

Figure 5 (*a*). The variations of the interplanetary magnetic field components B_x, B_y and B_z, the solar wind plasma density *N* and the velocity *V* and the associated electric fields E_y and E_z on 28 February 1968. The *Es–q* had disappeared at Huancayo between 0945–1115 and 1245–1315 hr 75° WMT.

about 60 earth radii approximately on Sun–Earth line in the interplanetary space. Explorer 33 had an approximate position of $X = 40$, $Y = -55$ earth radii in X–Y plane. When both plasma and field data are combined the Explorer 33 data were represented by cross and Explorer 35 data represented by dots. There was a few minutes time delay in perturbations observed by two satellites and therefore 15 minutes averages were considered for all of the quantities. Note that both Explorer 33 and 35 are registering interplanetary fluctuations 15–20 minutes earlier than the changes in *Es–q* because they are at $X = 40$ and 60 earth radii respectively. If the satellite data are

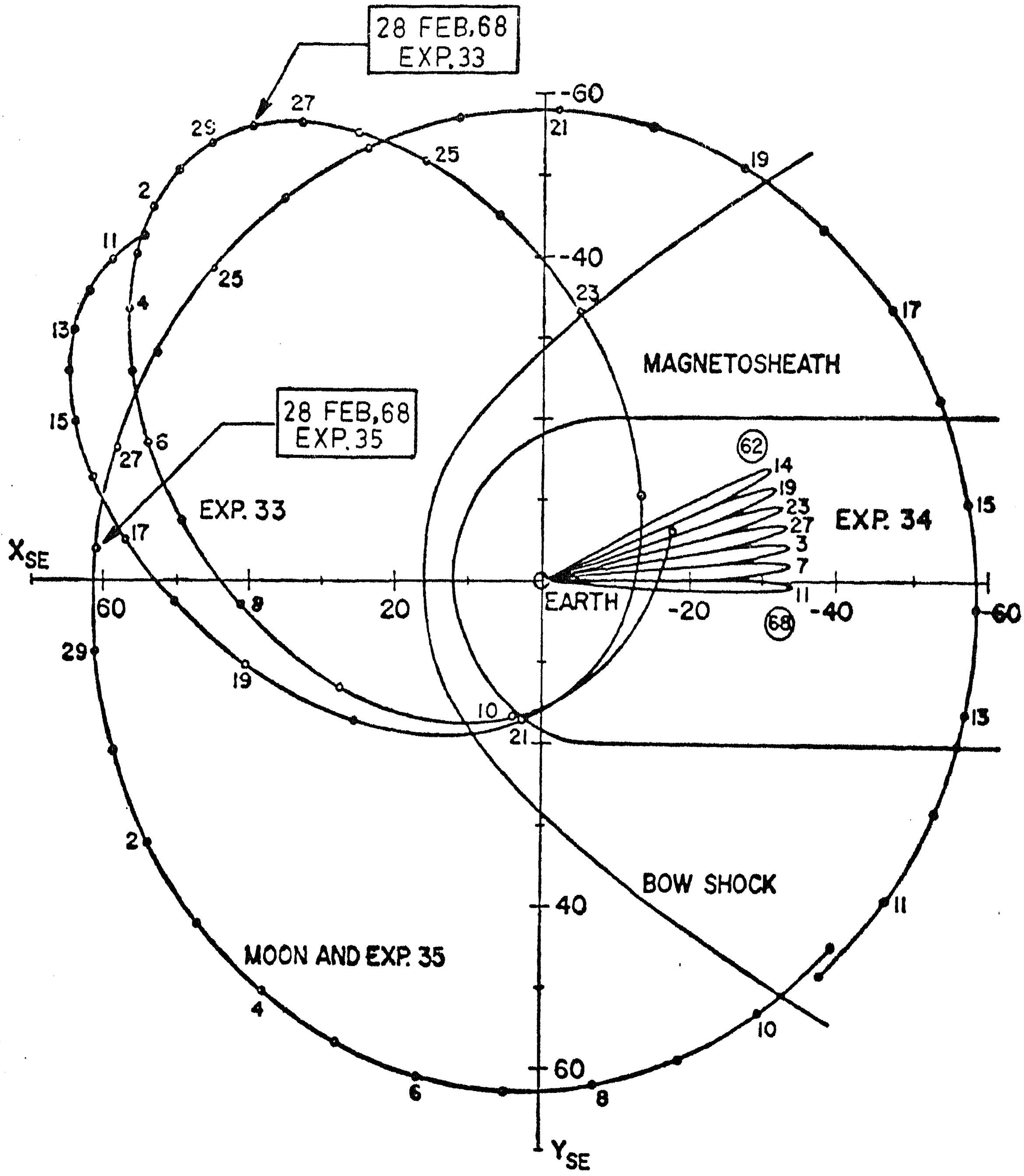

Figure 5 (*b*). The trajectories of the satellites Explorer 33, 34 and 35 projected on the solar ecliptic plane indicating the positions of the satellite on 28 February 1968.

moved back in time by this time delay of 15–20 minutes, the *Es–q* disappearance would become coincident with the westward E_y (negative) field and the B_z component changing from negative to positive value.

(B) *Interplanetary magnetic field and the electron drifts in equatorial ionosphere*

Balsley and Woodman (1971) have shown that for the Jicamarca location the average east–west electric field in the *E* region (E_y) and the east-west electron drift velocity V_y are related as

$$E_y = -6 \times 10^{-6} V_y$$

where the electric field is expressed in v/m and the drift velocity is given in m/s. Similarly the east–west *F* region electric field is related to vertical plasma drift velocity by relation given by Woodman (1970) by

$$E_y = 2{\cdot}5 \times 10^{-5} V_z$$

where E_y and V_z are expressed in *v/m* and *m/s* respectively. Thus the horizontal *E* region drifts or the vertical *F* region drifts can be utilized to estimate the horizontal electric fields in the ionosphere.

In figure 6 (*a*) are shown the electron drift velocities in the *E* and *F* regions of the ionosphere at Jicamarca on 2 November 1968 together with the changes of the magnetic field at ground observatories and at Explorer 33 and 35 satellites. The position of these satellites with respect to the magnetosphere is shown in figure 6 (*b*). The Explorer 33 was about 50 earth radii at noon meridian while Explorer 35 was about 60 earth radii on the evening meridian with respect to the earth. Both the satellites were thus suitably located to study the interplanetary magnetic fields. The Explorer 34 was well inside the magnetosphere. Large changes in the latitude of *IMF* are seen on the records of both the satellites. It is to be noted that these variations occur about half an hour earlier at Explorer 33 than at Explorer 35 because Explorer 35 is more than 60 earth radii away on the Sun–Earth line. A large change in the latitude occurred between 1300 and 1400 hr. At Explorer 33 the value of θ changed from a value of about $-90°$ at 1315 hr to a value close to $+90°$ at 1345 hr. The geomagnetic *H* field at Huancayo showed a sharp decrease of about 100 ν between 1320 and 1350 hr. The changes of H field at Fuquene were similar to that at Huancayo but of much less magnitude. The *E–W* electron drift in the *E* region at Jicamarca showed sharp decrease from its value of about 350 m/sec around 1330 hr to almost zero by 1400 hr. These sudden drops in electron drift velocities are undoubtedly the consequence of the decrease of *E–W*

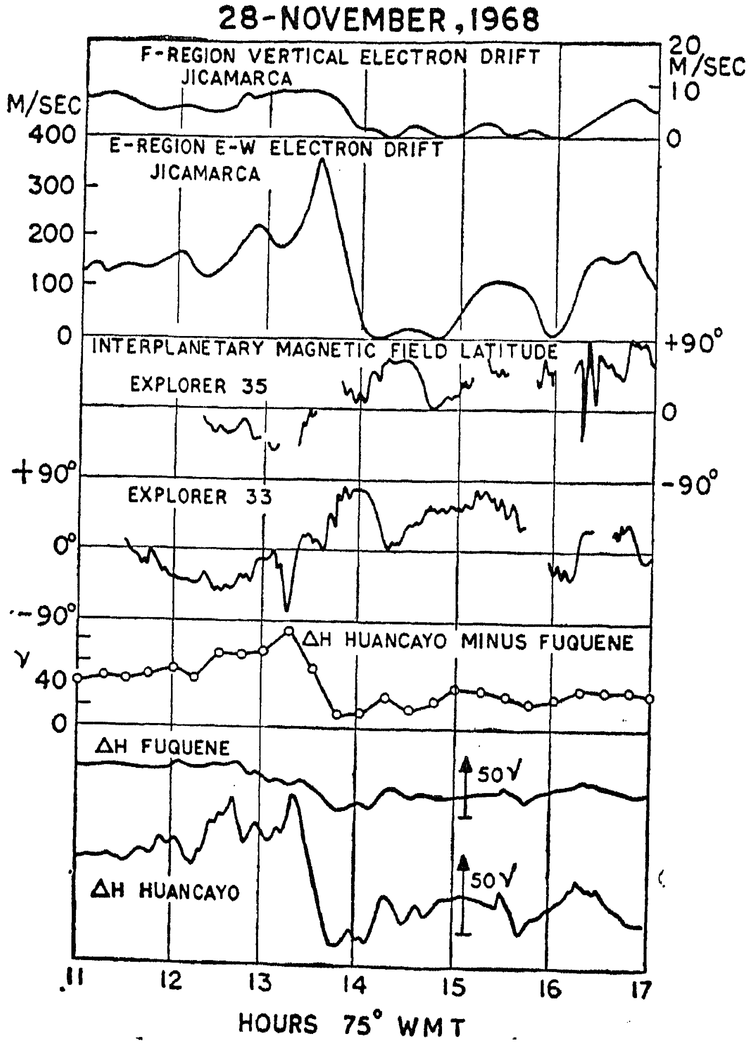

Figure 6 (*a*). The horizontal E region electron drifts and vertical F region plasma drifts at Jicamarca on 28 November 1968 compared with the changes in the latitude of interplanetary magnetic field at satellites Explorer 33 and 35. The geomagnetic fields at ground observatories Huancayo and Fuquene are also shown for comparison.

electric field at the ionospheric level which are suggested to be due to imposition of a westward electric field originated at the magnetosphere levels due to the reversal of interplanetary magnetic field from southward to northward direction.

Another example of the association between *IMF* and the daytime E region electron drifts is shown in figure 7 (*a*) for 6 March 1969. The trajectories of the satellites are shown in figure 7 (*b*). As seen from the diagram, the satellite Explorer 34 was within the magnetosphere, the trajectory was in the midnight sector, Explorer 33 was very close to the bow shock region, Explorer 35 was in the magnetosheath region at a distance of about 60 earth radii. Thus, while the positions of Explorer 33 and 34 were not suitable for the study of *IMF*, the data from the Explorer 35 were good enough for estimating the latitude (θ) or the Z component of *IMF*. The latitude θ of

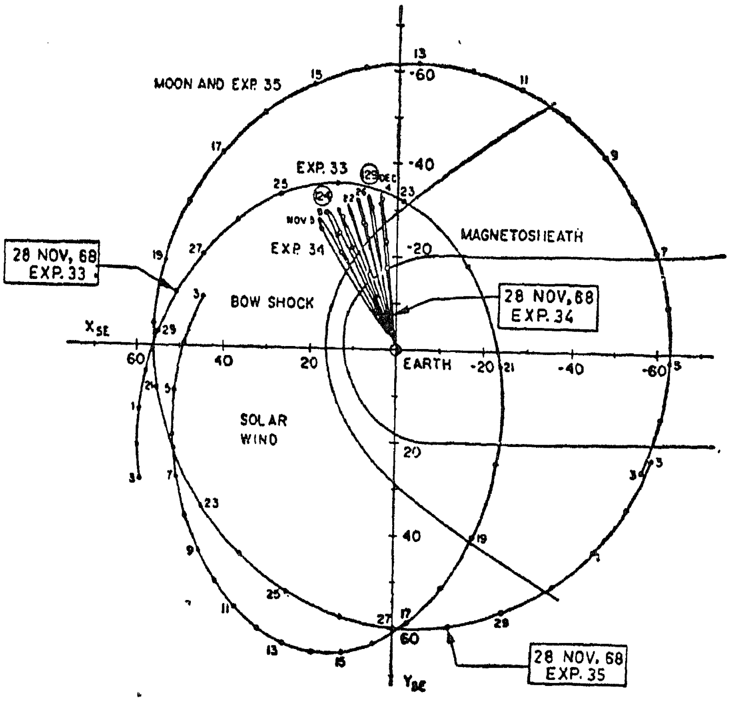

Figure 6 (*b*). The trajectories of the satellites Explorer 33, 34 and 35 projected on the solar ecliptic plane indicating the positions of the satellites on 28 November 1968.

IMF shows a complete reversal from $-90°$ to $+90°$ at about 1300 hr. The geomagnetic *H* field at Huancayo showed a sudden decrease of more than 100 γ at 1230 hr. The *E* region drift velocity showed a sudden drop after 1230 hr from a value of about 400 m/sec to less than 50 m/sec. There is a delay of about half an hour in the changes of *IMF* with respect to ionospheric changes and is consistent as the satellite was about 60 earth radii behind the earth.

We now present an example of the changes in ionospheric drift velocities during nighttime hours associated with the changes of *IMF* direction for 3 July 1968. Figure 8 (*a*) shows the variations of the geomagnetic *H* field at ground, *IMF* latitude and plasma parameters at satellite level and the ionospheric *E* and *F* region drift velocities over Jicamarca. Figure 8 (*b*) shows the trajectories of the satellites on 3 July 1968. The Explorer 33 was in midnight sector within the magnetosphere while both Explorer 34 and 35 were in the evening sector in the interplanetary space.

During the nighttime hours, the *E* region drifts are eastward (negative) while the *F* region drifts are downward. The reversal of these directions occurs generally about an hour after the sunrise. On 3 July 1968, a sudden reversal of both the *E* as well as *F* region drift was noticed around 0340 hr. The *H* field had a comparatively small increase due to very low ionization in the *E* region during nighttime hours. The Explorer 35 as well as 34

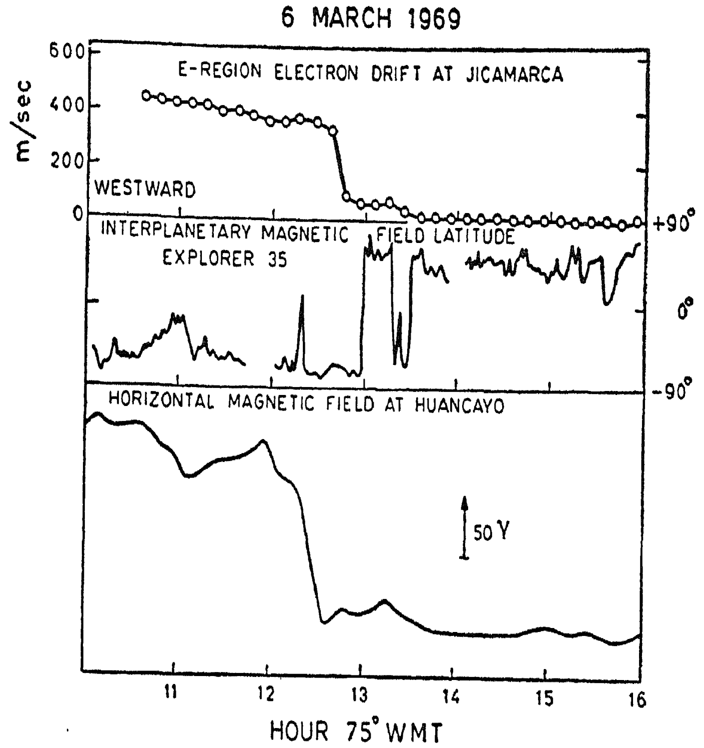

Figure 7 (*a*). The horizontal electron drifts at *E* region at Jicamarca on 6 March 1969 compared with the geomagnetic *H* field at ground observatory Huancayo and the latitude of interplanetary magnetic field at Explorer 35 satellite.

experienced a sudden reversal of the latitude of *IMF* at about 0330 hr. Thus, it is concluded that the abnormal reversal of ionospheric drift at Jicamarca during nighttime hours and hence of the electric field at ionospheric heights were due to the superimposition of magnetospheric electric field generated by the reversal of the *Z* component of the interplanetary magnetic field.

In figure 9 are shown two cases of *Es–q* disappearance and of the fluctuations in the latitude of *IMF*. Considering the case on 16 January 1967, when the satellite Explorer 33 was well in the interplanetary space (refer figure 1 *b*), there was large positive excursion of θ around 1030 hr 75° *EMT*, which produced a decrease in *H* at Kodaikanal as well as at Alibag but no effect was seen in *Es–q*. This decrease in *H* at Kodaikanal occurred near noon and was not enough to cancel the normally large positive ΔH at that time. On the same day, there occurred a counter-electrojet event accompanied by the disappearance of *Es–q* at 1445 hr but there was no significant change in the latitude of *IMF*. This shows that every large change of *IMF* need not result in the reversal of electric field at the equator, nor is every disappearance of *Es–q* to be associated with *IMF*.

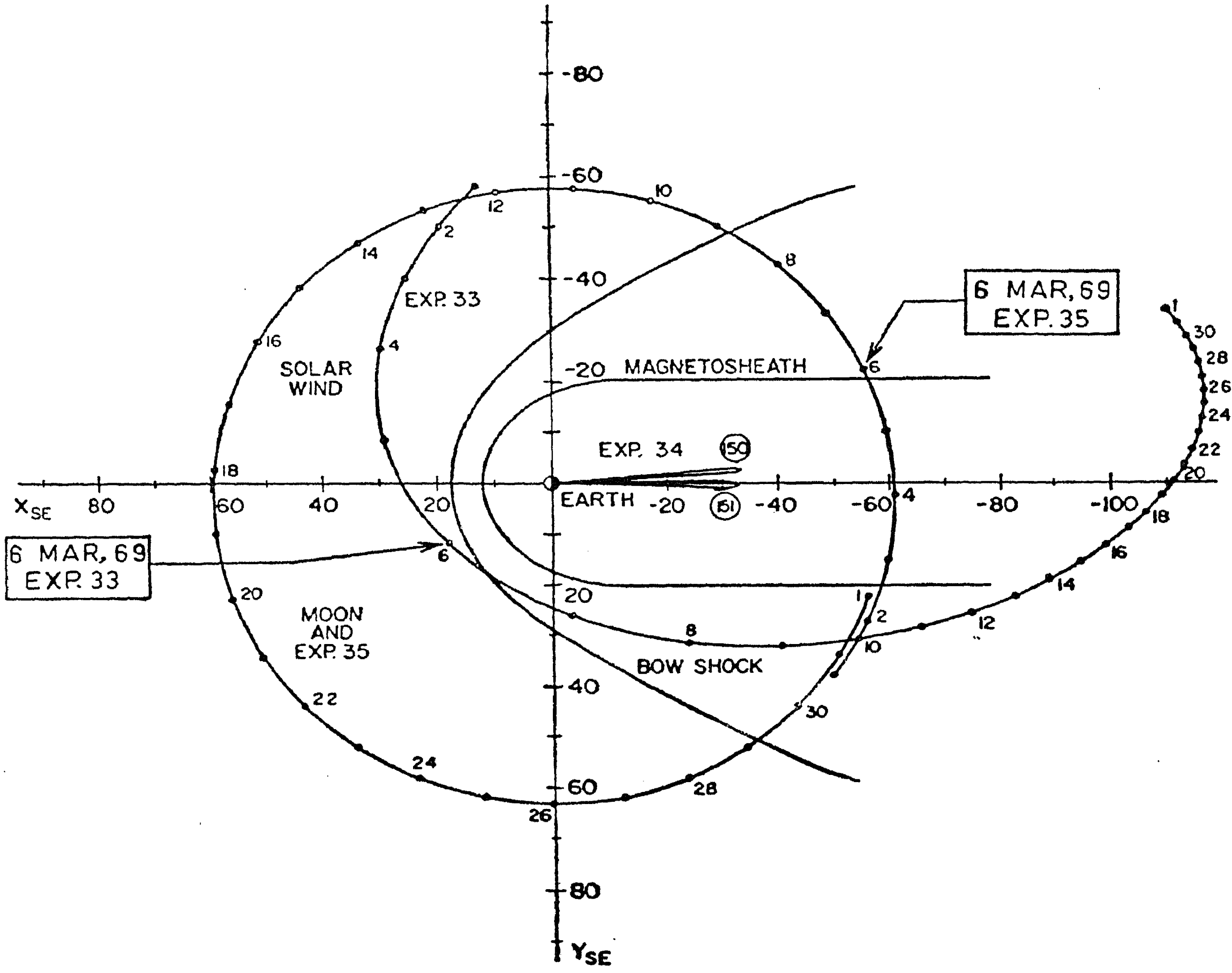

Figure 7 (*b*). The trajectories of the satellites Explorer 33, 34 and 35 projected on the solar ecliptic plane showing the positions of the satellites on 6 March 1969.

Now consider the changes of magnetic field at Trivandrum and at satellites Explorer 33 and 35 on 13 September 1967. Both these satellites were in the interplanetary space and were close to each other. One notices large fluctuations in θ at both the satellites around 0930, 1100 and 1330 hr 75° *EMT*. These large positive excursions in θ are associated with large depressions of H field at Trivandrum; however, $\triangle H$ (Trivandrum-Alibag) remained positive for first two events because these occurred at times close to noon. The positive excursion at 1330 hr caused $\triangle H$ (*TRV–ALB*) to decrease below zero and was associated with the disappearance of *Es–q* at Thumba (a station close to Trivandrum).

DISCUSSION

The concept of cross-field instability originally proposed by Simon (1963) has been applied to ionospheric plasma in order to explain small

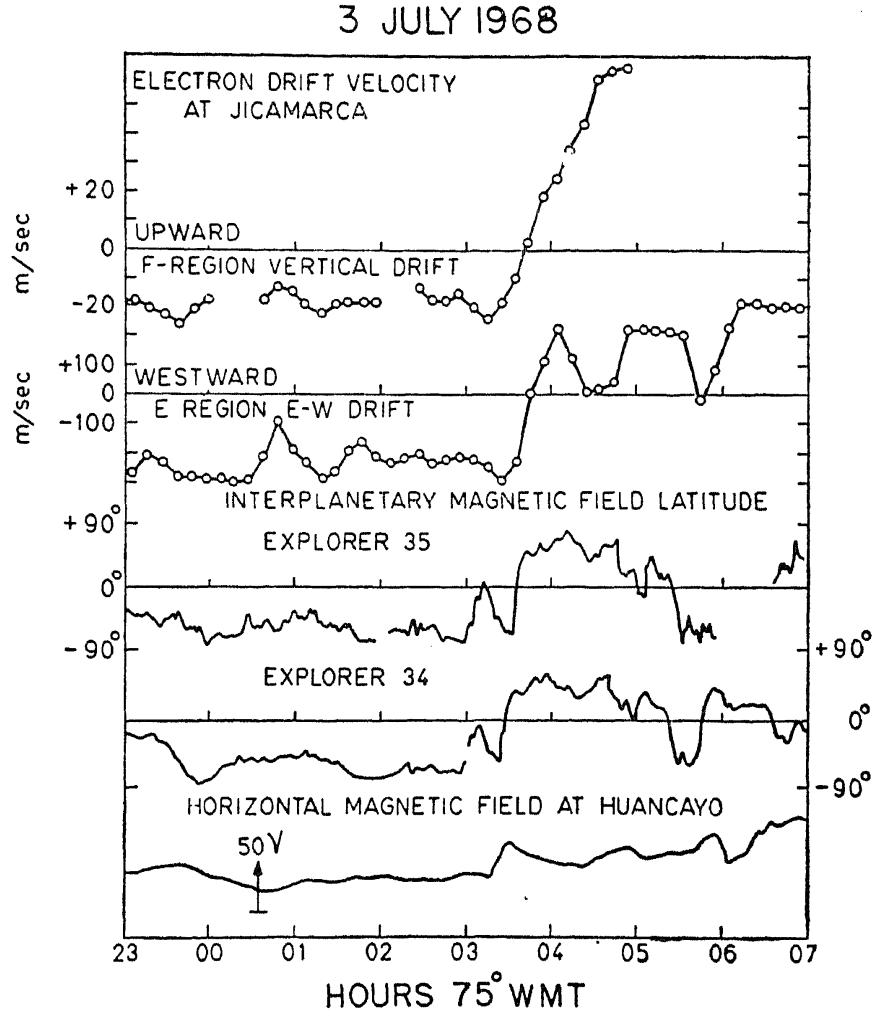

Figure 8 (*a*). The *E* region horizontal drifts and *F* region vertical drifts at Jicamarca during the nighttime on 3 July 1968 compared with the interplanetary magnetic field latitude at Explorer 34 and 35 satellites as well as the geomagnetic *H* field at ground observatory, Huancayo.

scale irregularities in the electron density in the ionosphere (Reid 1968). Extensive arguments have been presented by Rastogi (1972*a*) for the explanation of *Es–q* phenomenon, one of the special type of equatorial *Es* layers in terms of cross-field instability. In brief one needs mutually perpendicular *E* and *B* fields in plasma with a density gradient in the same direction as that of the *E* field. For our purpose, the equatorial ionosphere usually has 1 or 2 mV/m east–west electric field in the *E* region of the dayside ionosphere (Balsley 1973). This eastward electric field causes the Hall polarization field which is directed upward. The *Es–q* appears around 100 km where upward gradient of the plasma gradient and the upward Hall field are both maximum and are perpendicular to the northward geomagnetic field. In order to inhibit this instability evidenced by the disappearance of the *Es–q*, one needs the eastward *E* field at 100 km to become zero or be westward. This would make the Hall polarization field to be zero or downward, *i.e.*, in

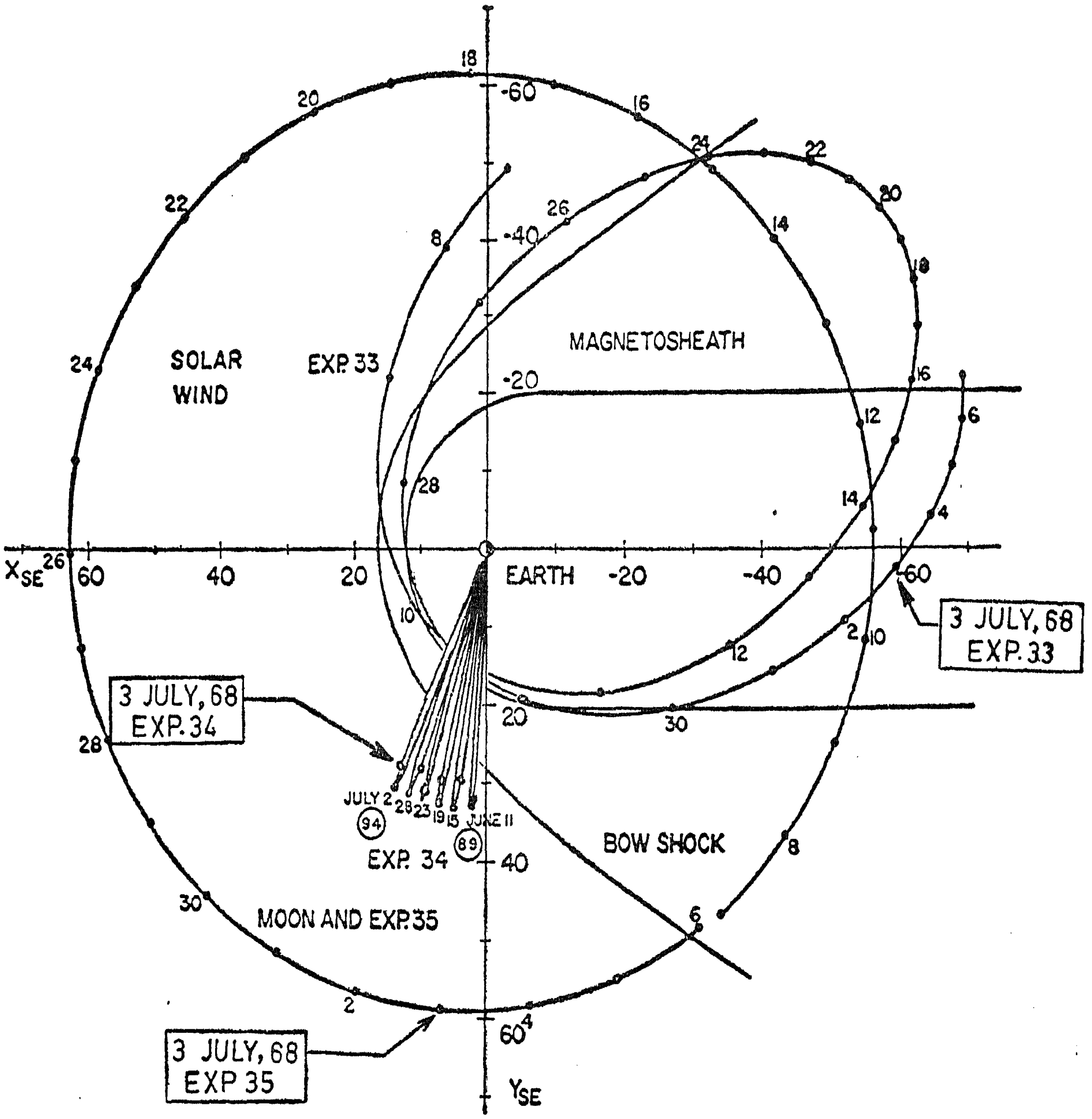

Figure 8 (*b*). The trajectories of the satellites Explorer 33, 34 and 35 projected on the solar ecliptic plane indicating the positions of the satellites on 3 July 1968.

opposite direction of the density gradient, thereby the conditions for the generation of the cross-field instabilities are not fulfilled.

The sudden change of the interplanetary B_z component from negative to positive value would give induced electric field component E_y to change from eastward (positive) to westward (negative). This westward electric field has been computed from the interplanetary data to be of the magnitude of 2 to 4 mV/m. Reid (1968) has shown that the field of order of 1 mV/m can be very effective in small scale irregularities. How does the interplanetary induced electric field affect the low latitude equatorial ionosphere? This is still an unsettled problem. Mozer *et al* (1974) have studied the relationship between the interplanetary magnetic field and the electric field observed by balloons at high latitudes. Considerable research work on

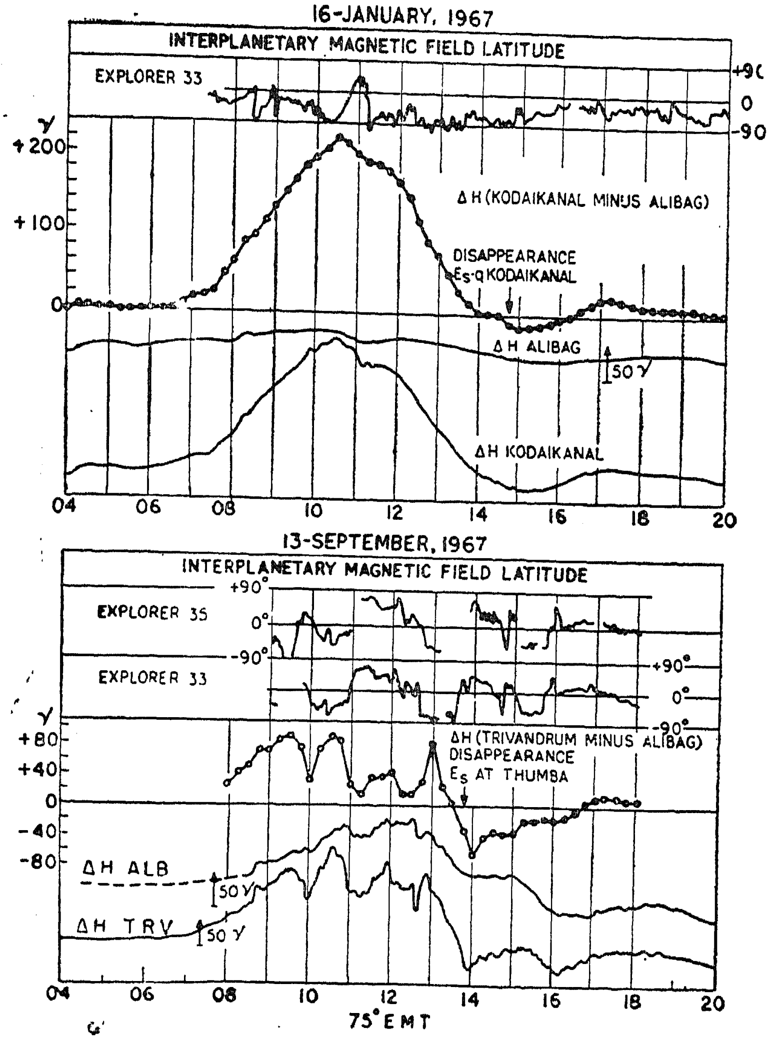

Figure 9. Variations of the ground geomagnetic *H* field and the interplanetary magnetic field latitude during some events of the disappearance of *Es–q* at the equatorial station. Note every change of *IMF* latitude need not cause disappearance of *Es–q* nor every disappearance of *Es–q* layer has to be associated with the reversal of the *IMF* latitude.

magnetopause structure and the coupled high latitude electric field has been described by Willis (1971). The quantitative results on the electric field generated in the ionosphere through outer magnetosphere has been calculated by Reid (1965). We suggest that this high latitude electric field may give effective 1 or 2 mV/m westward field at the low-latitudes and then sufficient field changes are available to inhibit *Es–q*.

CONCLUSION

Large and quick changes in the latitude of the interplanetary magnetic field from its southward to northward direction are associated with an imposition of an electric field in the ionosphere from the evening to the morning sector of the earth. This electrostatic field is westward in the daylight hemisphere and eastward in the night hemisphere and thus is in a direction opposite to that of the *Sq* produced electric field in the equatorial zones for the daytime as well as nighttime hours. Depending upon the magnitude of the magnetospheric electric field and of the *Sq* field at that time, the resultant electrostatic field on the equatorial ionosphere is decreased or even reversed from its normal direction.

If the magnetospheric field is smaller than the *Sq* field, then there would be a reduction of the ionospheric drift velocities. During daytime hours the reduction of velocity would cause a decrease of electrojet currents and in the reduction of the geomagnetic *H* field near the dip equator. A partial counter-electrojet may occur accompanied by the sudden disappearance of *Es–q*. During the nighttime effects may be too small to be detected due to very small electrical conductivities in the ionosphere.

If the magnetospheric field is larger than the *Sq* field, a reversal of the ionospheric electron drift would result. If the event occurs during the daylight hours it would result in the occurrence of a clear counter-electrojet current and in the sudden disappearance of the *Es–q* layer in the equatorial ionograms.

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