Theory for preliminary negative impulse in storm sudden commencement in H at equatorial stations

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Abstract. It is shown that the storm sudden commencement (SSC) in H field at low latitude station consists of only a positive excursion when the interplanetary shock due to the solar plasma impinging on the magnetosphere is associated with a southward excursion of the interplanetary magnetic field (IMF). When the signature of SSC at low latitude station consists of a preliminary negative excursion preceding the main positive excursion of the H field, the solar plasma causing the compression is associated with a northward excursion of the IMF. It is suggested that the signature of SSC(H) at equatorial stations is the result of combined effect of the compression of magnetosphere by the solar plasma as well as due to the electric field effects associated with the velocity of the solar plasma (v) interacting with the northward component (B_z) of the interplanetary field (i.e., $E = -v_x B_z$).

Keywords. SSC in H ; interplanetary magnetic field; equatorial H field.

1. Introduction

The sudden commencement of geomagnetic storms is characterised by a sudden change in all the three components of the geomagnetic field at low latitudes, the most important one being the sudden increase of the horizontal component (H). Ferraro *et al* (1951) found that on some occasions the signature of sudden storm commencement (SSC) was complex and the positive impulse in H was sometimes preceded by a preliminary negative impulse. They designated such events as SC*. Matsushita (1960) analysing the geomagnetic data from a number of stations during IGY showed that SC* events are observed within electrojet region during daytime hours; these are inhibited at low and middle latitudes and are again seen at high latitudes during most of the hours of the day. Rastogi (1971) examining the extensive series of magnetograms at Kodaikanal confirmed that these events designated by him as SSC—+ are seen only during daylight hours and that about 50% of SSCs at Kodaikanal during the daylight hours are complex with preliminary negative impulse preceding the main positive impulse. Later, examining the magnetograms of other Indian stations, Rastogi and Sastri (1974) showed that these events are not completely absent but are very rare at non-equatorial electrojet region. The amplitude of negative impulse was shown to decrease with latitude much more rapidly than that of positive impulse. It was felt necessary to investigate if the complex structure of SSC in H at equatorial stations is associated with the B_z component of IMF during the impact of solar plasma with the magnetosphere. This paper is the result of such an enquiry.

2. Results

In figure 1 are shown two examples of H magnetograms at Huancayo (dip 2°N) showing pure SSC with clear positive excursions on 13 July 1968 and 26 July 1969. In the diagram are also shown the 82 sec average values of the magnitude B , and the latitude θ of the interplanetary magnetic field as measured on board the Explorer 33 or 35. The values of $\theta = +90^\circ$ and -90° correspond to southward and northward directions of interplanetary magnetic field respectively. The positions of the satellite with respect to the earth and its magnetosphere are also shown in the diagram.

Referring to the event on 13 July 1968, the magnetogram at Huancayo showed a sudden increase of H by $+98\gamma$ at 1612 UT. The magnitude (B) of IMF showed a sudden increase at 1617 UT. There is a delay in IMF changes with respect to geomagnetic change by about 5 min. In this particular case the satellite was about 30 earth radii behind the earth, and the delay was associated with the transit time of the solar plasma. Before the SSC, the value of latitude θ of IMF was about $+40^\circ$, at SSC it changed suddenly southward and remained about -45° afterwards. A sudden transition of the B_z component to southward direction corresponds to an eastward electric field on the sunward hemisphere. Thus both the compression of

Figure 1. Examples of two pure SSC+ at Huancayo and the corresponding changes in the interplanetary magnetic field magnitude (B) and the latitude (θ) as well as the orbit showing position of the satellite at the time of SSC. Note that the interplanetary shock is accompanied by a southward excursion of the latitude.

the earth's magnetic field and the sudden change of B_z field would increase the magnetic field at ground giving rise to a SSC signature which is purely positive.

Referring to the second example of 26 July 1969 a pure SSC was seen at Huancayo magnetogram at 1153 UT. The sudden increase of the B field at the Explorer 35 was felt at 1202 UT about 9 min later as the satellite was on the back side of the earth at a distance of about 40 earth radii. The sudden increase of B was accompanied by a sudden decrease of θ from about 0° to about -80° . Thus again both the changes of B and θ had an effect which would cause an increase of the geomagnetic field at ground causing a pure SSC in H .

Now we show two examples of SSC—+ at Huancayo in figure 2 together with the data of interplanetary magnetic field magnitude (B) and latitude (θ) as well as the orbit of the satellite indicating the position of the satellite with respect to the earth at the time of SSC. Referring to the event on 18 November 1970 a negative excursion was immediately followed by a large positive excursion of H field at 1225 UT. A sudden increase of IMF occurred at 1228 UT. The first change in the latitude was a large positive change of θ from about -35° (southward) to $+76^\circ$ (northward). The second example refers to 10 February 1968 when the sudden change in IMF was felt at 1608 UT and the SSC at Huancayo occurred at 1621 UT. The satellite was about 60 earth radii in the sunward side of the earth. In this case too the sudden increase of B was accompanied with increase of the latitude θ i.e. northward

Figure 2. Examples of two SSC—+ at Huancayo and the corresponding changes in the interplanetary magnetic field magnitude (B) and the latitude (θ) as well as the orbit showing the position of the satellite at the time of SSC. Note that the interplanetary shock is accompanied by a large change of latitude (θ) towards the northward direction.

excursion. In these events the increase of B suggesting the compression of magnetopause would cause the increase of the H field at ground while the increase of the latitude θ northward would cause a westward electric field on the sunlit side of the earth, this would cause a decrease of the magnetic field.

3. Discussion

It is suggested that the dynamo region first experiences the change of the electric field due to the interaction of the solar wind with B_z , the decrease of the ground geomagnetic field is later superseded by the increase of H caused by the compression of the magnetosphere. In cases, when the change of latitude is northward one gets the preliminary negative excursion preceding the main positive excursion of sudden commencement. The preliminary negative excursion changes to positive excursion when the shock is accompanied with the southward change of the latitude and merges with large enhancement of H due to compression of the magnetosphere.

During night hours any change of the electric field over the equatorial region would have insignificant effect on H due to very low electron density in the dynamo region. This explains the absence of SSC—+ even at the equator during the nighttime hours. This also would explain the absence of the negative pulse of SSC at middle latitude. Because of the special configuration of the geomagnetic field with respect to the ionosphere over the dip equator, the equatorial electrojet region is very sensitive to the changes of the electric field and hence the amplitude of negative impulse is extremely pronounced over the dip equator. The positive excursion being primarily originated due to compression and is seen at most of the latitudes.

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