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Discussion Hour 4:

Reconnection Near Earth Versus in the Distant Tail

Moderator: *T.A. Potemra*

AZIMUTHAL EXPANSION OF THE SUBSTORM CURRENT WEDGE

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ABSTRACT

In this work we present observations from two geostationary satellites GOES-5 and GOES-6,located at 282°E and 265°E respectively during an isolated substorm occurred on May 7,1986.We also present magnetic field data from six ground based Observatories which are within 202°E and 294°E geographic longitudes for the same event.The spatial distribution of our observation points allow us the detailed study of the azimuthal expansion of the substorm current wedge.Our data analysis shows evidence that the substorm initiation and development mechanism includes the cross-tail current diversion/disruption,the substorm current wedge formation and the azimuthal expansion of the plasma sheet.The triggering mechanism is initially confined in a longitudinaly narrow sector,which was estimated to be less than 2h in MLT near local midnight.Then it expands both eastward and westward with the same order velocities although the westward one seems to be larger than the eastward one.

1.INTRODUCTION

Quiet time magnetospheric models suggest that the magnetic field configuration near the geostationary orbit (6.6 R_E) should be nearly that of a dipole.However,the dipolarlike configuration is changed during the periods of enchanced geomagnetic activity.During substorm growth phase the magnetic field near geostationary orbit is greatly distored into a much more taillike configuration.The substorm expansion phase onset is marked by a reconfiguration of the magnetic field to a more dipolar configuration (Sauvaud and Winckler,1980).

This process is called dipolarization and it is due to the diversion of a portion of the cross-tail current (Lui,1978;Kaufmann,1987).On the other hand,from the viewpoint of the energy transfer from the magnetosphere to the ionosphere the substorm expansion phase onset is marked by the explosive release of the energy stored in the magnetosphere.The cross-tail current diversion/disruption could result in the release of the magnetic energy and therefore the two viewpoints coincide.The diversion of the cross-tail current has been attributed to the formation of a substorm current wedge (McPherron et al.,1973).In this wedge model, earthward field-aligned currents flow from the magnetotail to the ionosphere on the eastern side of the wedge,they continue in the ionosphere formating a westward electrojet and finally return back to the magnetotail by tailward field-aligned currents on the western side of the wedge.The current wedge initially develops within a restricted local time sector near local midnight.Previous studies on this subject have concluded that the substorm current wedge is not stationary with time.The study of the magnetic field data provided by the synchronous satellites GOES-2 and GOES-3 has revealed a longitudinal expansion with time both eastward and westward (Nagai,1982). Magnetic field and energetic particles data from two geostationary satellites GOES-5 and GOES-6 relative to the AMPTE/CCE (at 8R_E) and AMPTE/IRM (at 11.6R_E) satellites data provided significant evidence that the region of substorm initiation is also radially limited.The region subtended by the current wedge expands radially down the tail as well as azimuthally (Lopez and Lui,1990; Lopez et al.,1990;Ohtani et al.,1991).

One of the most characteristic signature of a substorm in the near geosynchronous region is a variation in the flux of energetic particles (Sauvaud and Winckler,1980; Lopez et al.,1988).During the substorm growth phase the energetic particle flux decreases while the substorm onset is associated with an injection of energetic particles.The major cause of this is due to the thinning and subsequent expansion of the plasma sheet (Lopez et al.,1989).The geosynchronous energetic particle flux variations are also due to an earthward displacement of trapped energetic particles as they follow contours of constant B (Sauvaud and Winckler,1980).

To summarise,the substorm initiation and development mechanism includes the cross-tail current diversion,the substorm current wedge formation and the expansion of the plasma sheet.These phenomena do not occur uniformly

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throughout the magnetotail.They begin in a longitudinaly narrow sector and spread to other regions as the current wedge expands. The purpose of this contribution is to determine the time sequence of the events that compose a magnetospheric substorm phenomenon according to the cross-tail current disruption model and to study the azimuthal expansion of the substorm current wedge.

2.OBSERVATIONS

In this work magnetic field data from April to May 1986 period from the two geostationary satellites GOES-5 and GOES-6 located at 282°E and 265°E respectively,has been used.The magnetic latitude is approximetely 11° for GOES-5 and 9° for GOES-6 during this period.Therefore, the satellite distances from the magnetic equator plane are $1.3R_E$ (north) for GOES-5 and $1R_E$ (north) for GOES-6.The neutral sheet deviation from the magnetic equator plane is negligible according to the expression established by Lopez (Lopez,1990), so the above values also give the satellites possitions with respect to the neutral sheet.Quiet time geomagnetic field values have been substracted from the GOES magnetic field values,according to Rufenach model (Rufenach et al., 1992).The magnetic field data are presented in dipole VDH coordinate system.We have also used magnetic field data from six ground Observatories which are located within 202°E and 294°E geographic longitude.They are mostly middle and low latitude stations.The GOES-5 satellite is located between the Fredericksburg and San Juan meridians, while GOES-6 is between Tucson and Boulder meridians.This spatial distribution of our observation points allowed us the detailed study of the azimuthal expansion of the substorm current wedge.

We have choosen five events during the period April to May 1986 and in this paper we present the event occurred on May 7,1986 between 0500-0900 UT.The 1-minute values of H-,V- and D-component of the disturbed magnetic field,the energy density and the 0.6-4.2MeV energetic protons flux for GOES-5 and GOES-6 are presented in Fig.1 and 2 respectively.The local substorm onset is marked with a vertical line.We define local substorm onset to be the time when a particular satellite observes a dipolarization to the magnetic field.From both the V- and H-component magnetograms it is clearly showed the change in the magnetic field geometry to a more taillike configuration prior to the local onset. This phase is referred as the "growth phase" of the substorm.The D-component disturbances are due to the substorm associated field-alinged currents (FACs).The first indication of them is at 0612 UT in GOES-6 sector with a westward perturbation of D-component while in GOES-5 sector is at 0615 UT with an eastward perturbation.This implies first that GOES-6 was closer to the disturbance region and that the two satellites were initially on different sides of it.Knowing that both satellites are north of the neutral sheet we conclude that GOES-5 was eastward of the disturbance region,which is referred as onset sector, while GOES-6 was westward of it.The center of the disturbance is then suggested to be within 252°E and 268°E, or better in 2300-2400 MLT sector.The width of the onset sector is estimated to be less than 2h in MLT.Both of them are equatorward of the center of the FAC,although GOES-5 seems to be closer to it (GOES- 5 recorded a larger disturbance).This gives a location for the center of the disturbance region tailward of geosynchronous orbit.Dipolarization was first recorded by GOES-6 at 0641UT while at the same time the change into a taillike configuration was still in progress at GOES- 5. Eventually, GOES-5 recorded the dipolarization at 0653 UT. According to the fourth panel of Fig.1 and 2 the local onset time coincides with a reduction in the energy densities,which can interpreted as the release of magnetic energy stored in the magnetotail during the growth phase.The energy release could be attributed to the disruption/diversion of the cross-tail current. Therefore,the classic substorm onset definition is in agreement with the substorm current wedge model .

The bottom panels of Fig.1 and 2 show the variations of 0.6-4.2 MeV energetic protons flux during this event.At GOES-6 sector a decrease in particle flux is recorded during the growth phase while the substorm local onset is associated with a particle injection.Because GOES spacecraft travel in a geostationary orbit, this energy channel is responding primarily to trapped outer-zone particles.Therefore,the decrease in particles flux is probably due to an earthward motion of the trapped outer-zone particles.The rapid increase in the flux is partially due to the recovery of the inner plasma sheet and to earthward plasma injection.On the other hand GOES-5 was out of the trapped zone during this event and this has been inferred by the low flux level of energy protons recorded by GOES-5.

The D- and H-component magnetograms from the ground Observatories for the same event are presented in Fig.3 and 4 respectively.The D-component disturbances are due to the downward or upward FACs while the H-component disturbances are due to the intergrated effects of the substorm current wedge.Positive bay at H-component associated by a westward deflection of the field (negative D-perturbation) indicates that the station is eastward of the center of the substorm current wedge.On the other hand, positive bay at H-component associated by a positive D-perturbation indicates that the station is westward of the substorm current wedge (Lopez et Lui, 1990).According to the above scenario Tucson and Boulder are westward of the

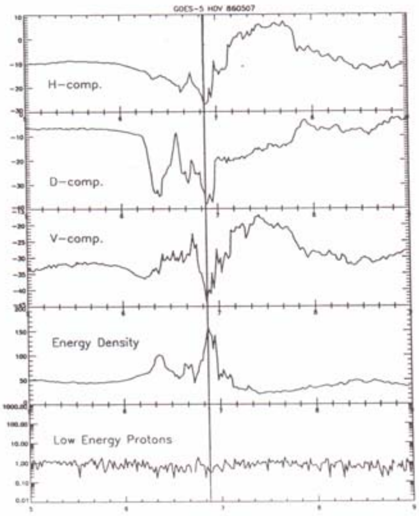

Fig.1:The H ,D and V component of the magnetic field ,the energy density and the flux of energetic protons with energies 0.6-4..2 MeV from GOES-5.

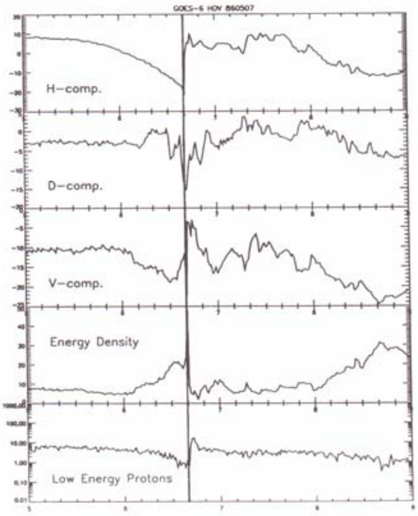

Fig.2:The H ,D and V component of the magnetic field ,the energy density and the flux of energetic protons with energies 0.6-4..2 MeV from GOES-6.

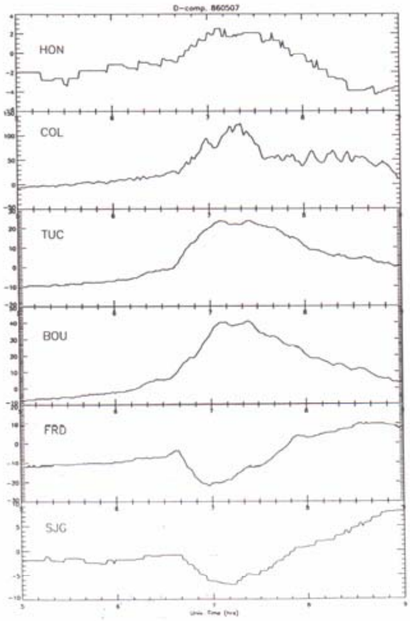

Fig.3:The D-component magnetograms from six ground Observatories.

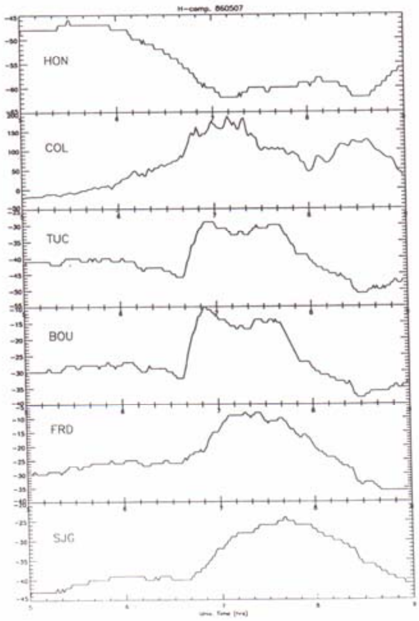

Fig.4:The H-component magnetograms from six ground Observatories.

current wedge center,while Fredericksburg and San Juan are eastward of it.Then the center is located somewhere between Fredericksburg and Boulder in geographic longitude,and rather closer to Boulder.This results in a location of it between 255°E-269°E which is in agreement with the result from the geosynchronous magnetic field data analysis.The onset sector expands both westward and eastward.From the H-component magnetograms the estimation of the westward and eastward propagation velocities is possible.The estimated velocities are 0.48°/min and 0.93°/min respectively.A faster westward propagation is noted,although the propagation velocities are of the same order.

3.DISCUSSION AND CONCLUSION

In this study we present the magnetic signatures of the substorm event of May 7,1986 in the geosynchronous region.The same signatures are obtained from the study of other four events,namely April 1,April 23,May 5 and May 12,1986.These signatures are in conformity with the cross-tail current disruption model. Prior to the substorm onset and during a phase referred as growth phase the near-earth magnetotail geometry change to a more taillike configuration.At the same time magnetic energy is stored into the magnetotail,the plasma sheet is thinning and the trapped outer-zone seems to move earthward.These signatures may be correlated to an intesification and an earthward motion of the inner edge of the cross-tail current.At the substorm onset the magnetic field is relaxed to a dipolar geometry. This process is called dipolarization and it coincides with the release of the energy which means that it may be attributed to the diversion/disruption of the cross-tail current. The dipolarization of the field is also accompanied by the formation of the substorm current wedge. The current wedge initially develops within a restricted local time sector.The center of this sector is located between 2300-2400 in MLT and in a radial distance tailward of the geosynchronous orbit.We estimated that the width of the current wedge is less than 2h in MLT.It is noteworthy that the substorm current wedge is not a state-stable formation but it expands with a propagation velocity greater to the west.

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