NASA/CR- 97- 206794

FINAL

7N-46-CR

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Final Technical Report

Project Title:	**Global MHD Simulation of Mesoscale Structures at the Magnetospheric Boundary**
Principal Investigator:	**Jean Berchem**
Period of Award:	**5/01/96 - 9/30/97**
Grant Number:	**NAGW-4541**

Progress Summary

Steady solar wind conditions

We have continued our modeling of the solar wind/magnetosphere interaction for steady solar wind conditions by carrying out a series of 3 D global magneto-hydrodynamics (MHD) simulations using a set of predetermined solar wind parameters as input to the code. These runs cover three regimes of constant dynamic pressure:

regime	density (cm-3)	velocity (km/s)	thermal pressure (pPa)
low:	5	300	3.45
medium:	7.3	420	5.04
high:	10	650	13.81

For each of these three regimes we simulated three periods of 40 minutes each, using different directions of the interplanetary magnetic field (IMF):

south :	B_x=0 nT	B_y=0 nT	B_z=-5 nT
dusk:	B_x=0 nT	B_y=5 nT	B_z=0 nT
north:	B_x=0 nT	B_y=0 nT	B_z=5nT

In addition, the nine sets of steady solar wind conditions defined above were run for two different values of the Earth's tilt angle to obtain magnetospheric configurations for the 1/17/97 at 10:00 (Sun -22.90°, Dusk -00.43°) and 5/21/97 at 12:00 (Sun 23.61°, Dusk 00.68°). With the results from the simulations that we ran last year for two other dipole tilts (0° and 35°), we have 36 data sets to study the dynamics of mesoscale structures at the magnetospheric boundary.

We have started the analysis of these runs to investigate geometrical properties and the topology of the magnetic and electric fields for the different solar wind regimes and orientations considered. Preliminary results indicate that merging sites are consistent with patterns proposed for antiparallel merging at the dayside magnetopause. Another goal of this investigation is to establish the displacement of the cusp region as a function of the solar wind dynamic pressure, IMF direction and magnetic field dipole tilt. One of the difficulties of that study is to locate precisely the cusp in the simulation results. We have used several case studies to establish a series of criteria in to permit a routine identification of that location. We need now to process the rest of the simulation results using these criteria to obtain statistical results.

Multispacecraft-simulation intercomparisons

During the past year we worked on correlative studies using the Geotail, IMP8, and Wind spacecraft. The principle of these studies is to use solar wind plasma and magnetic field measurements as input parameters to drive the three-dimensional global MHD simulations and then to compare their results with observations. Our approach in carrying out these comparisons has been to produce time series from the simulations and compare them with those measured by instruments onboard equatorial spacecraft located at a downstream location. The two case studies we worked on stem from our participation at the Wind/Geotail Correlative Studies Workshop held May 16-18, 1995 in Honolulu and December 16-17, 1995, in Berkeley, and at the Polar meeting at Goddard Space Flight Center, January 6-9, 1996.

The first case study we address illustrates the complexity of the magnetic field topology and convection patterns that can occur at the dayside magnetospheric boundary for periods of northward IMF with strong B_X and B_Y components and large plasma density fluctuations. This study is based on events observed on December 27, 1994, while Geotail was skimming the dayside magnetopause and the Wind spacecraft was monitoring the solar wind. Contour plots of the plasma density obtained at different times in the simulation show the tailward convection of the gusts of plasma in the magnetosheath, which appears as a large amplitude wave propagating on the surface of the magnetospheric boundary. The simulation also shows that the draping of the magnetosheath field over the afternoon and dusk sectors accounts for the negative X component of the magnetic field observed by Geotail. Something less expected though, is the warping of the field lines in the dusk magnetosheath because of the X component of the IMF. An immediate consequence of the large reversal of the field is to create a region of low magnetic field and high density, i.e. high beta plasma, in the dusk flank of the magnetosheath. Considering that those field lines are open, such a configuration can explain the presence of a relatively steady boundary layer populated by a mixture of magnetospheric and solar wind plasmas. The results also show that a field line that is reconnected on the dawnside, convects over the entire dayside boundary because of the field tension and the tailward motion of its open end in the dusk flank of the magnetosheath. An interesting consequence of this convective transport of plasma from dawn to dusk, is that it implies sunward flows in the dawn and prenoon regions of the boundary layer.

The second comparison we worked on combines dynamic and topological aspects associated with mesoscale structures at the magnetospheric boundary. This study was based on an investigation of the evolution of the distant tail boundary at 200 R_E from the Earth. The events used in that study were observed on July 7, 1993, when the direction of the IMF was predominantly northward and marked by a slow rotation of its clock angle component. Results from the simulation show that the asymmetric stresses imposed by the draping of magnetosheath field lines and the unbending of the newly reconnected IMF considerably alter the shape of the distant tail as the solar wind discontinuities convect downstream of the Earth. As a result, the cross section of the distant tail is considerably flattened in the direction perpendicular to the IMF clock angle, the direction of the neutral sheet following that of the IMF. The simulation also reveals that the combined action of magnetic reconnection and the slow rotation of the clock angle component of the IMF lead to a braiding of the distant tail magnetic field lines along the axis of the tail with the plane of the braid lying in the direction of the IMF. Such a twisted configuration explains the mesoscale structure observed at the boundary and the rapid traversal of the tail lobes. Another important feature also revealed by the simulation is that unconnected field lines resulting from the reconnection of lobe field lines with solar wind field lines at the high-latitude magnetopause cross the 200 R_E plane in a region that one might expect to be filled by open field lines from the lobes. Such a configuration seems to be the counterpart of the magnetospheric asymmetries associated with the Y-component of a southward directed IMF. When this occurs, flux is added preferentially to the dusk side of the northern lobe and to the dawn side of the southern lobe for IMF $B_Y < 0$. Results from the simulation suggest that for a northward IMF with $B_Y < 0$, flux is removed preferentially from the dawn side of the northern lobe and from the dusk side of the southern lobe.

Presentations and articles

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Administrative Matters

Due to NASA reorganization, the second year funding of this research was processed through Goddard Space Flight Center under the new grant NAG5-4685.

Patents or Inventions Resulting

None