Available online at www.sciencedirect.com
SCIENCE DIRECT®
Advances in Space Research 36 (2005) 1835–1839
ADVANCES IN SPACE RESEARCH
(a COSPAR publication)
www.elsevier.com/locate/asr

Energetic particle acceleration during a major magnetic storm

R. Kerttula [a], K. Mursula [a], T. Asikainen [a,*], R. Friedel [b], D. Baker [c], F. Søraas [d], J.F. Fennell [e], J.B. Blake [e], M. Grande [f]

[a] Department of Physical Sciences, P.O. Box 3000, FIN-90014, University of Oulu, Finland
[b] LANL, NIS-2, MS 426, Los Alamos, NM 87544, USA
[c] Laboratory for Atmospheric & Space Physics, University of Colorado, Boulder 1234 Innovation Drive Boulder CO 80303, USA
[d] University of Bergen, Department of Physics, Allegates 55, N-5007 Bergen, Norway
[e] Mail Stop M2-259, The Aerospace Corp., P.O. Box 92957, Los Angeles, CA 90009, USA
[f] Space Physics Division, Space Science and Technology Department, CCLRC Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX, UK

Received 21 December 2002; received in revised form 25 March 2004; accepted 26 March 2004

Abstract

We study the global properties of energetic (>30 keV) particles during the main and early recovery phase of a major magnetic storm of March 31, 2001, using data of the NOAA 15 and 16 and the CLUSTER satellites. During the storm main phase the ring current energetic electron and ion fluxes were increased by nearly two orders of magnitude, and the flux maxima were shifted to below $L = 3$. The maximum ion fluxes were observed at about 07 UT, coinciding with the minimum Dst. However, the highest fluxes of energetic electrons were observed only at about 16–18 UT, indicating significant differences in the acceleration of energetic electrons and ions during the storm. We suggest that the ion maximum at about 07 UT was due to field-aligned acceleration of ions from the ionosphere whereas the electron maximum at 16–18 UT was due to a large injection from the nightside.

Keywords: Magnetic storm; Energetic particle injections; Energetic particle boundaries

1. Introduction

Geomagnetic storms are known to enhance the ring current (RC) strength, which is mostly due to new ions appearing at $L < 4$ (Smith and Hoffman, 1973; Hamilton et al., 1988; Korth and Friedel, 1997). Particularly during major magnetic storms the RC intensification is mostly provided by O^+ ions of ionospheric origin (Hamilton et al., 1988; Daglis, 1997), and oxygen ions can be the main ion species during the main phase of intense storms. In this paper we will analyse both electron and ion dynamics during a great storm of March 31, 2001, and show that they depicted a surprisingly different behaviour during this storm.

2. Instrumentation

In this study, we use energetic particle data from the Medium Energy Proton and Electron Detector (MEPED) instrument onboard the NOAA 15 and 16 satellites. Ions (no mass separation is provided) and electrons are measured separately at roughly vertical (0°) and horizontal (90°) directions with 30° field of view. Note that at high (low) latitudes the 0° detector measures mostly precipitating (trapped) particles and vice versa for the 90° detector. The MEPED instrument has six energy channels for ions (from 30–80 to >7000 keV) and three for electrons (from >30 to >300 keV). The NOAA 15 and 16 orbits are circular at an altitude of about 850 km. The orbital plane is 20–08 MLT for NOAA 15 and 14–02 MLT for NOAA 16 (see Evans and Greer, 2000, for more details of the MEPED instrument).

* Corresponding author.
E-mail address: timo.asikainen@oulu.fi (T. Asikainen).

0273-1177/$30
doi:10.1016/j.asr.2004.03.023

The Research with Adaptive Particle Imaging Detectors (RAPID) spectrometer for the Cluster mission analyzes suprathermal plasma distributions in the energy range from 20 to 400 keV for electrons, 40–1500 keV for protons and 10–1500 keV/nuc for heavier ion species The RAPID instrument uses two different and independent detector systems for the detection of nuclei and electrons: Imaging Ion Mass Spectrometer (IIMS) and Imaging Electron Spectrometer (IES) (see Wilken et al., 1997, for a more detailed description of the RAPID instrument).

3. Observations

3.1. Storm overview

On March 31, 2001, the Advanced Composition Explorer (ACE) satellite was measuring interplanetary conditions at about (223, −23. −12) R_E. As shown in Fig. 1, IMF Bz component was fluctuating between large positive and negative values until about 04 UT when the direction changed southwards for about three hours. Strongest negative values (<−40 nT) were observed around 06 UT. The solar wind (SW) velocity increased between 00 and 02 UT in two steps from about 400 to above 750 km/s. Solar wind dynamic pressure, which mainly followed the changes in SW density, showed dramatic variations during the first six hours of the day. At about 0020 UT, it had a very sharp peak which lasted only about half an hour. Another, longer pressure increase occurred roughly from 02 to 06 UT. These interplanetary conditions led to the generation of a major (Dst = −360 nT) magnetic storm with a rapid main phase starting at 04 UT and ending at 08 UT. The extreme geomagnetic conditions can also be verified by the LANL geostationary satellite data (not shown here), which indicate that the magnetopause was pushed inside the geosynchronous orbit in the dayside roughly at about 03–08 UT and even in the morning and evening sectors at about 06 UT. After a period of positive values, the IMF Bz experienced another long interval of negative values at about 14–21 UT which caused a secondary minimum in Dst (−285 nT).

3.2. NOAA observations

The two NOAA satellites verify that both ion and electron fluxes were increased by nearly two orders of magnitude from the average level on March 30 to their storm time maxima. The maximum ion flux was at 05–07 UT while that of electrons occurred only at about 16–18 UT.

Fig. 2 plots the NOAA 16 90° ion fluxes versus L value for March 31, 2001. Each plot contains data from half a satellite orbit around the equator (negative L corresponding to the southern hemisphere). Data from each L shell width of 0.5 is averaged, leading to a changing time resolution along the orbit. The first and third (second and fourth) columns of plots present data from the postnoon (postmidnight) sector. Ion fluxes were systematically higher in the nightside than dayside until the end of the day. Fig. 2 shows that the flux maxima shifted

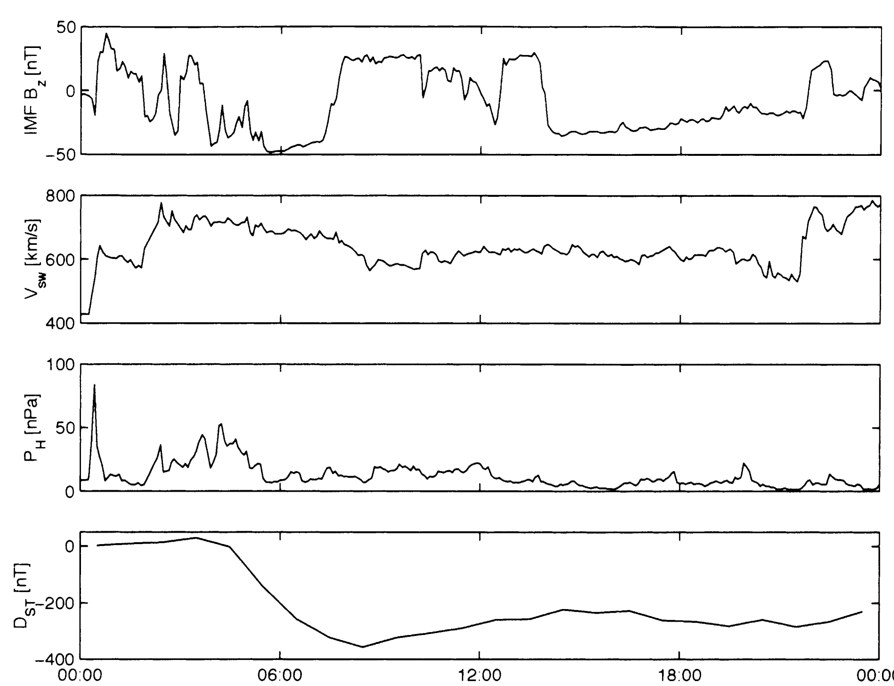

Fig. 1. ACE observations on March 31, 2001, of IMF Bz component, solar wind velocity, and solar wind pressure together with the Dst index.