Research Paper

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Solar Events on 18 November 2003 and Its Consequences

Physics

KEYWORDS : Coronal Mass Ejection, Interplanetary Medium, Radio Telescope

Ravindra M. Jadav Gujarat Arts and Science College, Ahmedabad – 380006.

ABSTRACT

The paper describes the effects of space weather event on the interplanetary medium (IPM) sensed by Ooty Radio Telescope. The solar observations by LASCO coronagraph onboard SOHO, GOES X-ray measurements, satellite measurements of the interplanetary parameters and the geomagnetic storm index Dst are used in the study to understand the space weather effects in the different regions of the solar-terrestrial environment. Attempt had been made to correlate events occurred at various place and time to understand the sequence of events that starts from our closest star.

1. Introduction

The effect of Coronal Mass Ejections and associated geomagnetic storms on space systems is called Space Weather. A Coronal Mass Ejection (CME) is a large outburst of coronal magnetic field and typically 10^9 to 10^{10} tons of plasma into the interplanetary space at speeds varying from 250 to 1000 km/s (Gosling, 1997). CMEs often drive interplanetary shocks, which upon arrival on the Earth, cause geomagnetic storm. The geomagnetic storms that signal the arrival of CMEs in the near earth space pose hazards to space operations, major effects being release of trapped particles from the magnetosphere to auroral zones causing increased spacecraft charging, interference with satellite communication and surveillance systems, atmospheric heating by charged particles resulting in increased satellite drag, deterioration of magnetic torque attitude control system of satellites etc. Recently Jadav et al., (2005) have presented the space weather aspects of a large halo CME on 4 April 2000, which appeared to be associated with 2F/C9.7 flare in AR8393.

2. Experimental data:

Observations of Interplanetary medium using the **g-values** obtained from the IPS observations **with the** radio telescope at Ooty and plasma data from the ACE/WIND satellites; D_{st} indices derived from ground based magnetometer data and ionospheric observations using the GPS receivers are used to understand the complex solar-terrestrial relation events of 18 November 2003 are used.

3. Observations and Results of the event of 18 November 2003

The period of October - November 2003 witnessed extra ordinary solar storms. During the period 44 M-class and 11 X-class solar flares were reported. (Woods et al., 2004)). This unusual activity was mainly from two large sunspot groups (10484 and 10486). As pointed out by Gopalswamy et al., (2005) the largest geomagnetic storm of solar cycle 23 occurred on 20 November 2003. This was caused by a CME from the sunspot 10501 that erupted near the centre of the Sun on 18 November 2003.

3.1 Solar observations:

LASCO and EIT observed a full halo CME on 18 November 2003. A wide faint loop front was seen in C2 at 0806 UT in SE quadrant but brightest in the S (Figure 1) at 0826 UT this front had faint extensions up to the N pole. At 0850 UT a second, much brighter front appeared spanning 160 degrees from the SE to NW and with fainter extensions to the N pole. These developed into a full halo CME by 0918 UT.

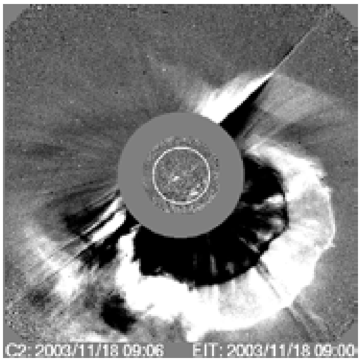

Figure 1: CME observed by LASCO onboard SOHO on 18 November 2003 event.

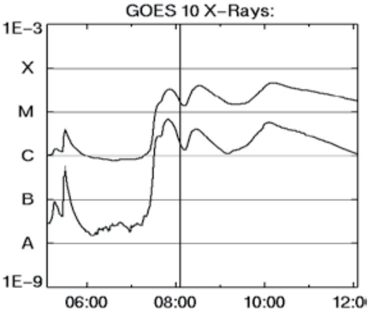

Figure 2: GOES X-ray flux data showing an M-class flare at 0740 UT on 18 November 2003.

The CME was associated with a complex activity around AR 0501 between 0736 and 0900 UT as seen by EIT. GOES observations (Figure 2) show rather extended and structured M class flares between 0716 and 0900 UT. Both an EIT wave and dimming were observed in association with this event. From the height-time plot (not shown here) of the sequence of coronagraphs, the initial velocity V_{CME} is found to be 1659.6 km/s. The mean plane of sky speed was 1175 km/s measured at PA 177 with possible evidence for slight acceleration.

3.2 Interplanetary Observations:

The Ooty Radio Telescope (ORT) observes several radio sources every day and generates the g-maps which represent the excess plasma turbulence in a given direction along the line of sight to the source over the mean value. When CME material crosses the line of sight it will show up as larger value of g in excess of unity. The ORT observations during this event show significant enhancement in g-values for at least three radio sources on 19 November 2003 (Figure 3). For sources 2012+234, 2018+295 and 1802+110 g-values quadrupled to 3.9, 3.78 and 2.272 respectively. The high rise in the g -values suggest the presence of interplanetary signature of the coronal mass ejection.

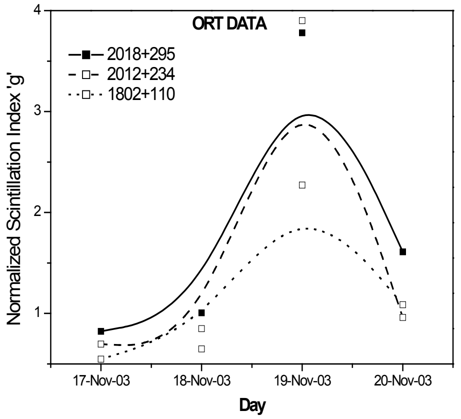

Figure 3: Enhancement in g-value of radio sources observed by Ooty Radio Telescope during 8 November 2003 event (elongation angles: 1802+110 = 47.3, 2018+295 = 85.2, 2012+234 = 79.9)

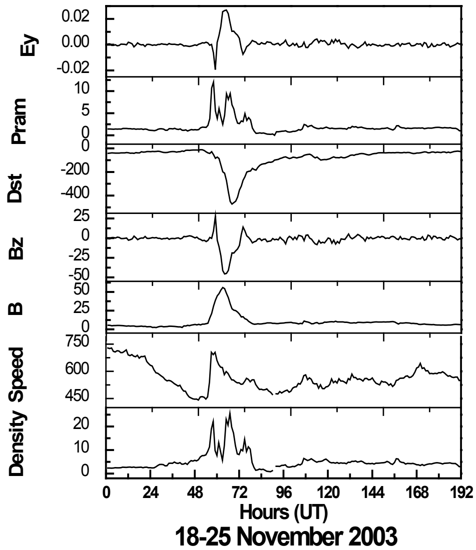

Figure 4: Interplanetary parameters at 1 AU observed by ACE satellite during 18-25 Nov 2003.

Other interplanetary parameters observed by ACE satellite indicating the interplanetary effects of the coronal mass ejection are shown in Figure 4. The solar wind speed (second panel from bottom) increased abruptly from 450 km/s to 704 km/s on 20 November 2003 at 0900 UT. This was indicative of the presence of shock associated with the arrival of CME material. The density (bottom panel) also increased simultaneously with speed and remained high for about 24 hrs, indicating the passage of ICME. The second panel from top in Figure 4 describes ram pressure which intermittently remained high. The product of V_x^2 and density (nm) of the solar wind is defined as the ram pressure. The magnetic field B and temperature increased as shown in figure 4a. B_z started its negative excursion from a positive value of 28 nT at 1100 UT reaching a value of – 45 nT at 1600 UT on 20 November 2003. This negative excursion of B_z is considered to be an important driver of geomagnetic storm.

3.3 Ionospheric Effects

It is well known that CMEs triggered geomagnetic storms due to the interaction of the CME plasma and magnetic field associated with it with the Earth's magnetosphere. Coupled with a very sharp decrease in southward magnetic field B_z upto -45 nT on 20 November 2003 (Figure 4), the CME produced the largest geomagnetic storm of solar cycle 23, characterized by a D_{st} value reaching at – 472 nT on 20 November 2003 at 2000 UT. The CME evolved into a magnetic cloud, which was highly tilted so that the axial magnetic field had strong south ward component that reconnected with earth's magnetic field triggering the magnetic storm (Gopalswamy et al., 2005). The eastward component (E_y) (Figure 4, uppermost panel) of magnetospheric electric field ($=V_x$ x B_z) was positive after a sharp decline during the storm time.

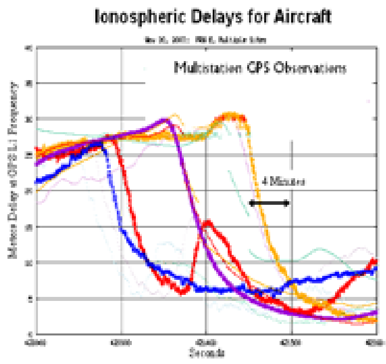

Figure 5: Multistation GPS observations showing ionospheric delay in meters during storm phase.

During storm time, ionospheric Total Electron Content (TEC) varies from its usual behavior hence Global Positioning Satellite (GPS) signals received at ground level undergo group delay depending upon the variation in the TEC. The ionospheric delays calculated from the GPS TEC measurements during this event are shown in Figure 5. Drastic decrease in the delay by 20-25 meters is observed within a short duration of 4 minutes in some longitude sectors. At the same time increase in the delay by about 10 meters (arrow) and then subsequent recovery are seen in other longitude sectors. This indicates the large plasma redistribution, causing ionospheric plasma enhancements during the daytime and depletions during the nighttime. This is probably a consequence of the positive values of E_y shown in Figure 4a.

5.0 Discussion and conclusion:

Largest geomagnetic storm of current solar cycle (D_{st} ~ - 472 nT) occurred on 20 November, 2003 due to the CME eruption on 18 November near Sun Centre. This CME evolved into a magnetic cloud, which was highly tilted so that the axial magnetic field had strong southward component which reconnected with earth field and produced the storm (Gopalswamy et al 2005). It is pertinent to note that the X28 class flare on 4 November 2003 was not at all geoeffective as it was erupted from the western limb of the Sun, hence directed away from the earth into interstellar space.

To mention the other space weather effects during Oct- Nov., 2003, CME events, 11 major satellite operations were disrupted including MARS Express spacecraft. Barrage of solar protons forced the crew of the International space Station to take shelter in an internal module. HF radio blackouts were experienced in northern Canada as a result of the major solar proton event on 28 October 2003.

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