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Coronal mass ejection of 4 April 2000 and associated space weather effects

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Abstract

The effects of a Halo Coronal Mass Ejection (CME) erupted on 4 April 2000 are studied and reported here. The effect of such CME on the interplanetary medium (IPM) is sensed by the Interplanetary Scintillation (IPS) recorded at Rajkot. The Solar Observations of this CME and associated events, like Solar Energetic Particles (SEP) and flare, are presented. CME events with high speeds and negative magnetic field components have higher possibility of penetrating the earth's shield, viz. the magnetosphere. The 4 April 2000 CME with a high speed and southward component of IMF produced a big geomagnetic storm with D_{st} reaching -288 nT. Simultaneous ionospheric effects in F layer heights and auroral observations are reported. Such events are important in Space Weather Studies as these pose hazards to space operations including satellite communications and surveillance systems.

Keywords: Coronal mass ejection; Interplanetary medium; Interplanetary scintillation; Geomagnetic storm

1. Introduction

The effect of Coronal Mass Ejections (CME) and associated geomagnetic storms on space systems is called, in modern parlance, as Space Weather. A CME is a large outburst of coronal magnetic field and typically 10^9–10^{10} tons of plasma into the interplanetary space at speeds varying from 250 to 1000 km/s (Gosling, 1997). The scale and frequency of these events (several times a day to a few per week) (St. Cyr et al., 2000) make CMEs one of the most important contributors to space weather (McAllister et al., 1996; Richardson et al., 2000). 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.

During solar maximum phase, the number of such CMEs increases and many are capable of accelerating particles upto megaelectrovolts energies (see special issue of GRL 25 (14), 1998 for a detailed review). A well observed and thoroughly investigated CME occurred on 14 July 2000 on the Bastille day and hence called Bastille event (see special issue of Solar Physics, 204, 2001 for detailed analysis of various aspects of this event). The propagation of the associated IP shock in this event down to the location of Voyager-2 at 63 AU has been identified (Burlaga et al., 2001). Alongwith the vigorous development of space activities, increasing interest is directed towards Space Weather in order to mitigate or to avoid damage by space weather calamities to technological systems caused by intense solar events.

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In this paper, we discuss the space weather aspects of a large halo CME over the west limb which erupted at 1632 UT on 4 April 2000. This appears to be associated with 2F/C9.7 flare in AR8393. Observations of interplanetary medium (IM) using the IPS Array at Rajkot, India; data from the SOHO/LASCO coronagraph and EIT at 171 Å; magnetic field and plasma data from the ACE/WIND satellites; D_{st}, AE indices derived from ground-based magnetometer data; auroral images from the POLAR/UVI satellites and digisonde data are used to understand the complex solar–terrestrial relation during this event.

2. Observations and results

2.1. Solar phenomena

Fig. 1a shows the SOHO/LASCO/C3 image of the CME on 4 April 2000 and the modified SOHO/EIT heliogram at 171 Å is shown in Fig. 1b which are related to the source of the CME. The wide partial halo CME with a bright front seen by the coronagraph at 1632 UT was associated with a large filament disappearance in the NW sector and a 2F/C9 flare (N16,W66) in AR8393 (point 1 in Fig. 1b). Fig. 1b is a extreme ultraviolet imaging telescope (EIT)/SOHO X-ray image on which active regions are seen as dark spots indicated by numbers 1–5. The flare was simultaneously detected by GOES X-ray measurements at 1541 UT (Fig. 1c). The involvement of these global magnetic structures including north hemispheric regions (points 1 and 5 in Fig. 1b) and south hemispheric structures (points 2, 3 and 4 in Fig. 1b) is indicated by the CME form and span as well as by the EUV interconnecting large-scale structures in Fig. 1b. Subsequent phenomena seem to have in general, a post eruption character and were caused by a CME-related disturbance and the following reconnection of the magnetic field in an extensive region of the corona. CME's initial speed estimated from LASCO observations was 1188 km/s. It was deduced from coronagraph observations of height and time of CME material. The plot of CME's height and time is shown in Fig. 1d. The sequence of events related the present Halo CME is also shown in Fig. 1e.

Simultaneous with the solar flare which maximized at 1541 UT the filament disappearance was observed on the west of the flare. This flare was followed by a strong Solar Energetic Proton (SEP) event. Just after the flare, the increase of the solar relativistic electrons and protons was detected near the Earth by the Advanced Composition Explorer (ACE) satellite. Fig. 2 shows the SEP event, which starts at about the same time as the flare. Here the flux of protons in two energy ranges, >10 and >30 MeV are shown. It is to be noted that the flux of protons with energy >10 MeV attained a maximum value of 55 protons/cm^2 s sr at ~0930 UT on 5 April. The fluxes of solar energetic electrons associated with this flare for various energy ranges are plotted in Fig. 3. An abrupt increase in the flux for energy ranges 38–53 keV can be noticed (lower two panels). The increase is more gradual for the ions and protons (upper

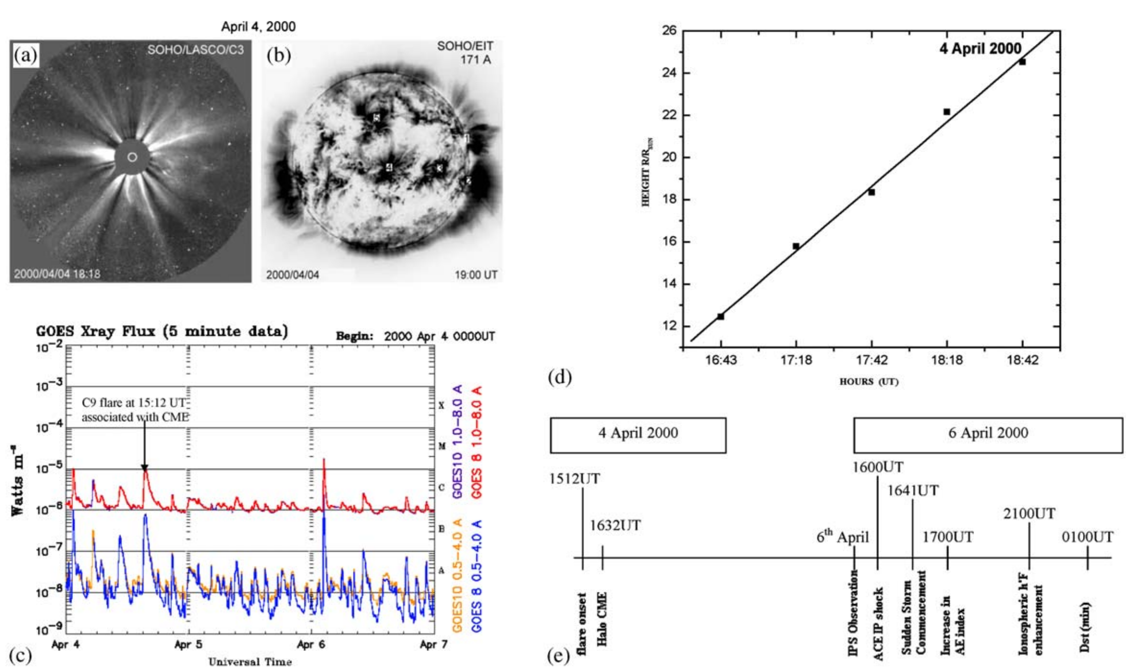

Fig. 1. (a) LASCO/SOHO image of Halo CME ejection, (b) EIT/SOHO X-ray image showing flaring active regions, (c) GOES X-ray flux showing C9 type flare which occurred from AR8933 (d) height–time plot of CME as seen by LASCO C2/C3 coronagraph, all associated with 4 April 2000 CME event and (e) time sequence of all events related to the CME.