Investigation of Major Solar Eruptions of Solar Cycle 23 & 24 and their geoeffectiveness

Megha Pandya, R Selvakumaran, Sandeep Kumar, B. Veenadhari
Indian Institute of Geomagnetism, New Panvel, Navi Mumbai-410218, India

Abstract

The fiery Sun goes through some markedly different cycles and causes change in the geospace environment. The Coronal Mass Ejections (CME) is the major cause of geomagnetic storms, when its direction is towards the Earth. These CMEs erupt from the outer atmosphere of the sun (corona) in the form of closed loops having magnetised plasma inside. The intensity of the geomagnetic storm depends on the product of the solar wind speed and the value of Bz, which intensify the ring current when the time duration Bz remains negative. Owing to the weak polar magnetic field, the solar cycle 23 went into a prolonged minimum characterized by unusually large number of days without sunspots. This was marked by the reduced number of geomagnetic intense events during solar cycle 24 compared to solar cycle 23, even though the number of CMEs is same. To investigate this, the average values of CME speed and Dst index for the moderate and intense events of solar cycle 23 and 24 is compared. An interplanetary magnetic flux rope is the major cause of large geomagnetic storms. To examine the effect of the type of ICME (i.e. Magnetic cloud, Ejecta or Sheath) giving moderate or intense geomagnetic storm, the ascending phase of the solar cycle 23 and 24 will be investigated. However, the excess CME expansion contributes to the diminished effectiveness of CMEs in producing magnetic storms during cycle 24, due to the fact that the magnetic content of the CMEs is diluted and ambient fields has weakened (Gopalswamy 2014). Some of the results regarding the intense and moderate events for solar cycle 23 and 24 and the geoeffctiveness will be discussed in the meeting.

Introduction

1. The Sun-Earth relation:

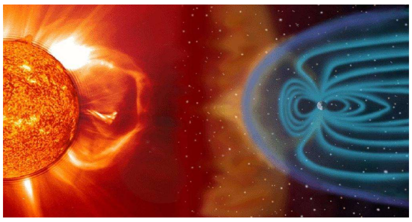


Figure 1: The Sun-Earth relation. [www.nasa.gov]

- Dynamics of solar magnetic field gives rise to IP structures and geomagnetic activities on the Earth. [Hathway, 2010]
- The supersonic solar wind is obstructed by the earth's magnetosphere, protecting the Earth from the energetic particles and its atmosphere to blow away
- The activity of the Sun depends on the number of dark spot on the surface of the Sun known as sunspots, that has a periodicity of nearly 11 years.

2. The solar activity:

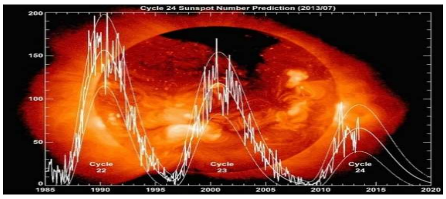


Figure 2: The Sunspot Cycle [www.nasa.gov]

3. CME and its structure:

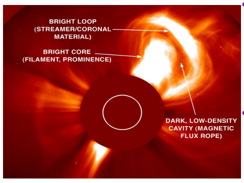
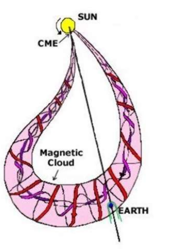


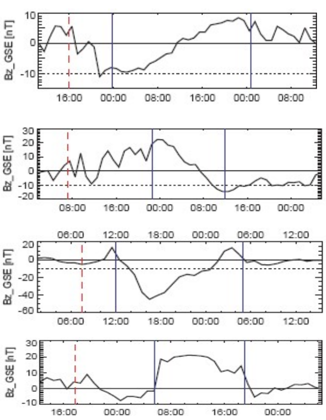
Figure 3: Three Part Structure of CME. [www.nasa.gov]

- An ICME with a fluxed tube structure accelerates into the medium due to excess total pressure (particle plus magnetic) [Forbes et al., 2006]
- The plasma clouds occurring in interplanetary space has twists in the magnetic field called "magnetic flux ropes".

- Bright outer rim
- Dark cavity behind rim
- Bright inner core of erupted prominence material

4. Identification of ICME:





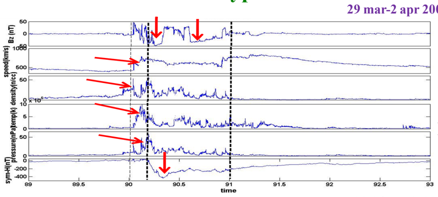
- High B ~ 10-25nT
- Smooth Bz rotation
- Low proton T and β values

Data

- ❑ Dst index (SC 23 and SC 24): World Data Centre (WDC), Kyoto
- ❑ CME origin and CME speeds: SOlar Heliospheric Observatory (SOHO)
- ❑ Monthly average Sun spot number : www.ips.gov.au
- ❑ IP Parameters: ACE and WIND satellites [cdaweb.gsfc.nasa.gov]
- ❑ H-component data: Alibag Observatory
- ➢ Duration of study: 1996-2015

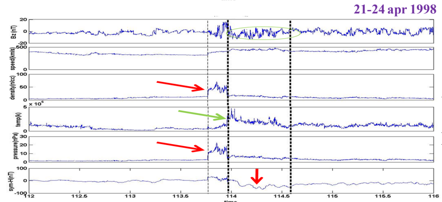
Identification of type of ICME structure

29 mar-2 apr 2001



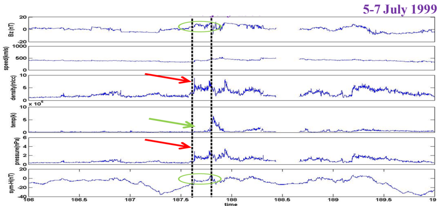
-MC (FS)
Dst=-387nT

21-24 apr 1998



- Sheath
Dst=-67nT

5-7 July 1999



- Ejecta
No storm

Analysis

-The storm events are classified based on the intensities as: Moderate (Dst ≤ -50 nT) and Intense (Dst ≤ -100 nT)

-The type of ICME (MC, EJ, S) and its effect on the geomagnetic storms with moderate to intense geomagnetic activity are observed.

-The combination of IP parameters which contributes the most for the intense activities are also calculated.

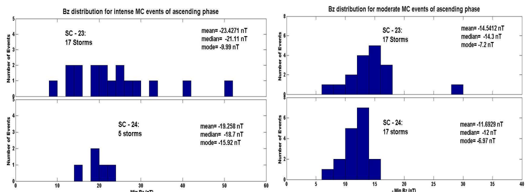
-Intense geomagnetic storms are associated with the fast CMEs and strong IP shock and the complex fluxed rope structure.

-The solar sources responsible for the moderate geomagnetic storms are identified during the both the cycles

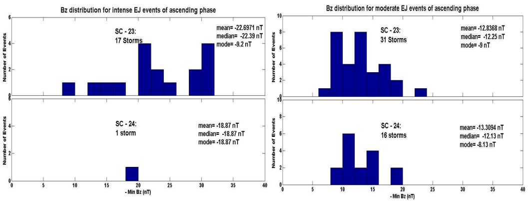
-The solar and interplanetary characteristics of the moderate storms driven by CME are compared for both the solar cycle

Results

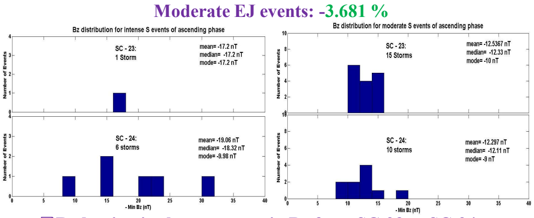
1. Bz distribution for moderate and intense events:



❑ Reduction in the average min Bz from SC-23 to SC-24:
Intense MC events: 17.7915 %
Moderate MC events: 19.58 %



❑ Reduction in the average min Bz from SC-23 to SC-24:
Intense EJ events: 16.86 %
Moderate EJ events: -3.681 %



❑ Reduction in the average min Bz from SC-23 to SC-24:
Intense Sheath events: 28.505 %
Moderate Sheath events: 35.48 %

2. CME & CIR driven geomagnetic storms:

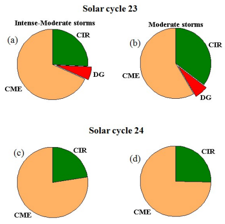


Figure 4: Distribution of CME and CIR driven intense-moderate and moderate storms during solar cycle 23 (a,b) and solar cycle 24 (c,d)

- ➢ Geomagnetic storm classification based on source origin:
  - CME driven
  - CIR driven

	Source Origin	Intense Moderate	Moderate
Solar cycle 23	CME	110 (66.6%)	63 (56.7%)
	CIR	43 (26%)	40 (36 %)
	Total	165	111
Solar cycle 24	CME	54 (78.2%)	43 (75.4)
	CIR	15 (21.7%)	14 (24.5%)
	Total	69	57

3. Occurrence rate of CME & CIR driven storms:

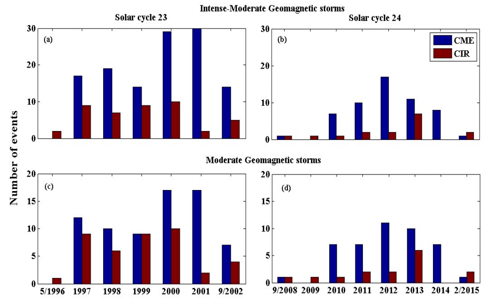


Figure 5: Yearly occurrence of CME and CIR driven storms Intense-moderate and moderate storms for solar cycle 23 (a,b) and solar cycle 24 (c,d)

CME as a source:

❑ Intense storms occurrence rate:
- **➢ For solar cycle 23: peaks around 2001**
- **➢ For solar cycle 24: peaks around 2012**

❑ Moderate storms occurrence rate:
- **➢ For solar cycle 23: peaks at 2000-2001**
- **➢ For solar cycle 24: peaks around 2012**

4. Distribution of Dst value:

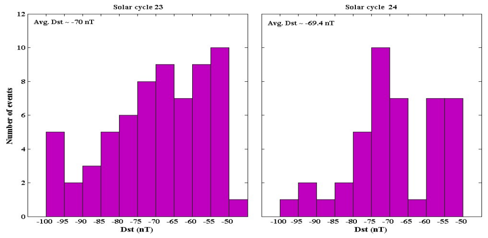


Figure 6: Distribution of Dst value for moderate storm occurred during solar cycle 23 and 24

❑ The average Dst values for both the cycles: nearly -70 nT
➢ No reduced geoeffectiveness in terms of Dst

Summary of Results

➢ The minimum Bz values showed a wider distribution in cycle 23 when compared to cycle 24.

➢ Nearly 1/4 of the intense storms for cycle 24 has been reduced when compared to cycle 23.

➢ The CME driven moderate storm follows the SSN and its occurrence rate is nearly same for both the cycles.

➢ Nearly equal Dst strength for CME driven moderate storms indicating no change in geoeffectivness.

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