The Sun-Earth Connection of Major Geomagnetic Storms

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Event chain from Sun to Earth

CME
Flare
Coronal Dimming
Filament Eruption

Lack of Observations

ICME
CIR

Storms In Geo. Space

LASCO
EIT
MDI
MDI (SOHO)

ACE
WIND

Dst
.....
Major Geomagnetic Storms

• Dst ≤ -100

Dst index in 2000
Distribution of Major Storms (1996-2004)

• 79 major events (Dst <= -100)
• 16 severe events (Dst <= -200)
How to Find Solar Sources

• Step 1: set the 120-hr backward search window
• Step 2: find all halo CMEs in the window (AW >= 120)
• Step 3: find out front-side halo CMEs, and locate their source region
• Step 4: find a reduced adaptive search window using solar wind velocity jump (Zhang et al. 2003)
Three Types of Solar Drivers

1. S Type: driven by a single CME
2. M Type: driven by multiple CMEs interacting in IP
3. C Type: driven by CIR from Coronal Hole
S Type Driver (example)

Dst peak at 2001/04/12 00:00 UT, driven by CME at 04/10 05:30 UT
M Type Driver

- Complex Dst plot, multiple CMEs (and flares)
- Complex solar wind flow
- Consecutive CMEs from same active region
C Type Driver

- CIR (Corotation Interaction Region)
- Coronal Hole
Solar Drivers of Major Storms

70 Major Storms (excluding 9 in data gap)

15 Severe Storms (excluding 1 in data gap)
Source Regions of Major Storms

- **Active Region**
- **Quiet Sun Region**
- **Coronal Hole**
- **Unknown!!!**

70 Major Storms
Source Region Distribution

Dst >= -200
Dst <= -200
Intra-Solar Cycle Variation of Source Regions

Before Polar Reversal (Nov. 2001)

After Polar Reversal (Nov. 2001)
Velocity of CME and ICME & Transit Time

CME Transit Time from Sun to Earth (hr)
CME Transit Time from the Sun to Earth

Ave. time = 57 hr
Delay Time Betw. ICME Arrival and Dst Peak

Ave. time = 16 hr
Discussion and Conclusion

• Three Types of Solar Drivers
  – S Type: 56%
  – M Type: 26%
  – C Type: 17%

• Hemispheric Dependence on Solar Cycle
  – Western Hemisphere preferred for all phases
    – Explanation: west hemisphere connection due to spiral IP field
  – Northern Hemisphere preferred before polar field reversal
    – Southern Hemisphere preferred after polar field reversal
    – Explanation: Participation of global field in geo-effective Bz component
  – North-Eastern quadrant is un-favored for all phases in solar cycle 23

• Inner Heliospheric Observations are needed to identify the Sun-Earth-connection chain and predict the arrival time