

The Correlation Between Solar Energetic Particle Events & Coronal Mass Ejections

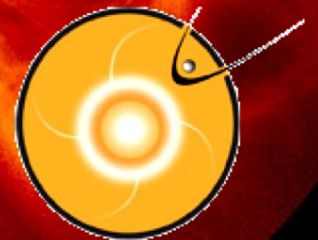
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I. Motivation

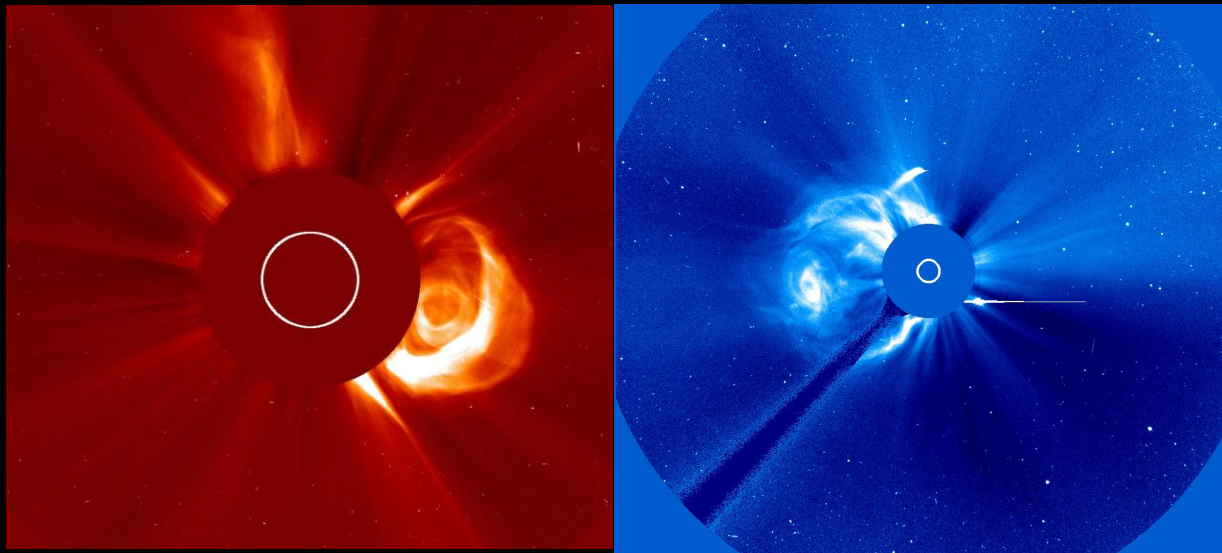
- ✓ Solar Energetic Particles (SEP) are harmful for NASA missions and the 2,000+ satellites in the sky
- ✓ Necessary to study the various parameters of SEP events and the coronal mass ejections that have a hand in accelerating the particles.
- ✓ By learning about the parameters, we can study the possible relationships between them
- ✓ Enable a forecasting system to predict the magnitude and duration of the SEP event from the CME

Past Work

- ✓ Some research conducted dealing with this specific correlation (2001, 2005)
- ✓ Many instrumental and forecasting improvements since
- ✓ Limitations of past studies
 - Solar radii view limited to 1.6-4.1 from MMS satellite
 - Plane of sky speed of CME due to limited view of sun
 - Specifications for CMEs not addressed
 - Magnetic connectivity not addressed

II. Background

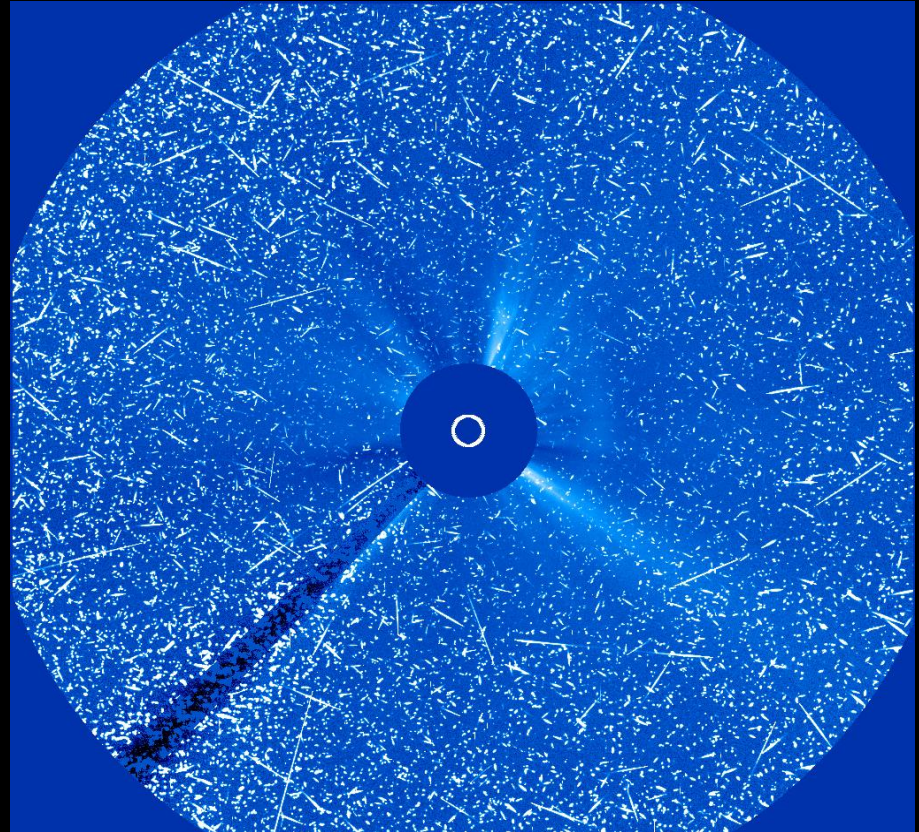
- ✓ Coronal Mass Ejections (CMEs): Consist of billions of tons of plasma, including solar material and magnetic field, which are hurled at several millions miles per hour, into the interplanetary medium. Not only are CMEs capable of causing SEP events also can cause geomagnetic storms on Earth.



January 23rd, 2012 CME — STEREO B January 8th, 2002 CME — SOHO

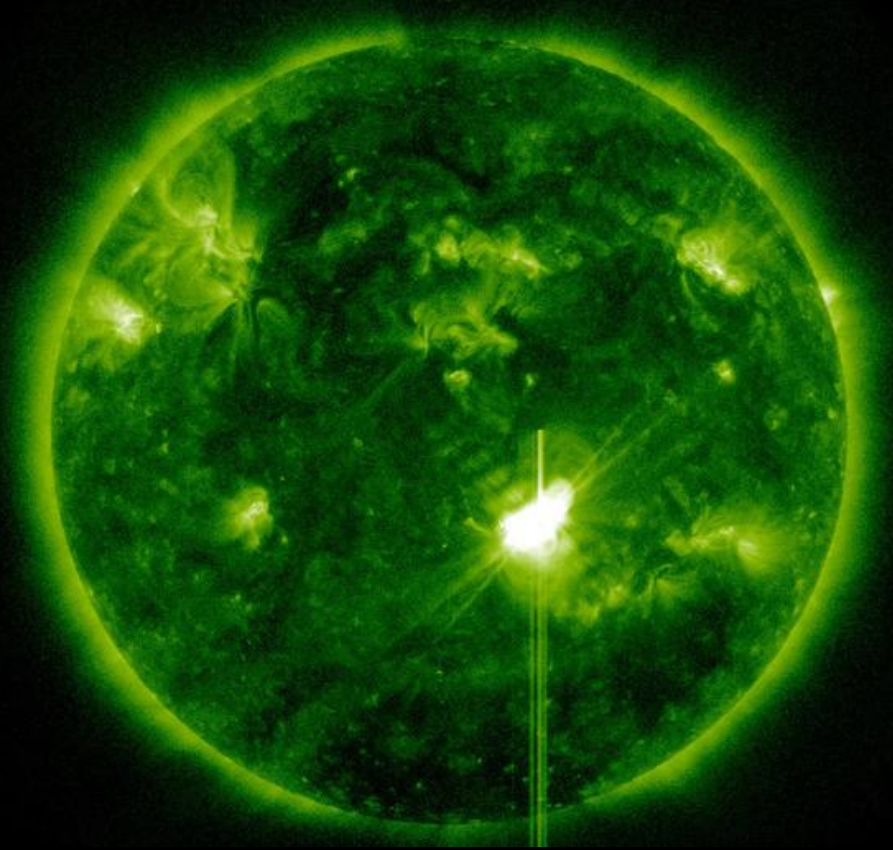
II. Background (cont)

✓ **Solar Energetic Particle (SEP) event:**
Occur when a CME or solar flare accelerates atomic particles by energizing them to very high energies into the heliosphere.



March 3rd, 2012 SEP effect —SOHO

II. Background (cont)

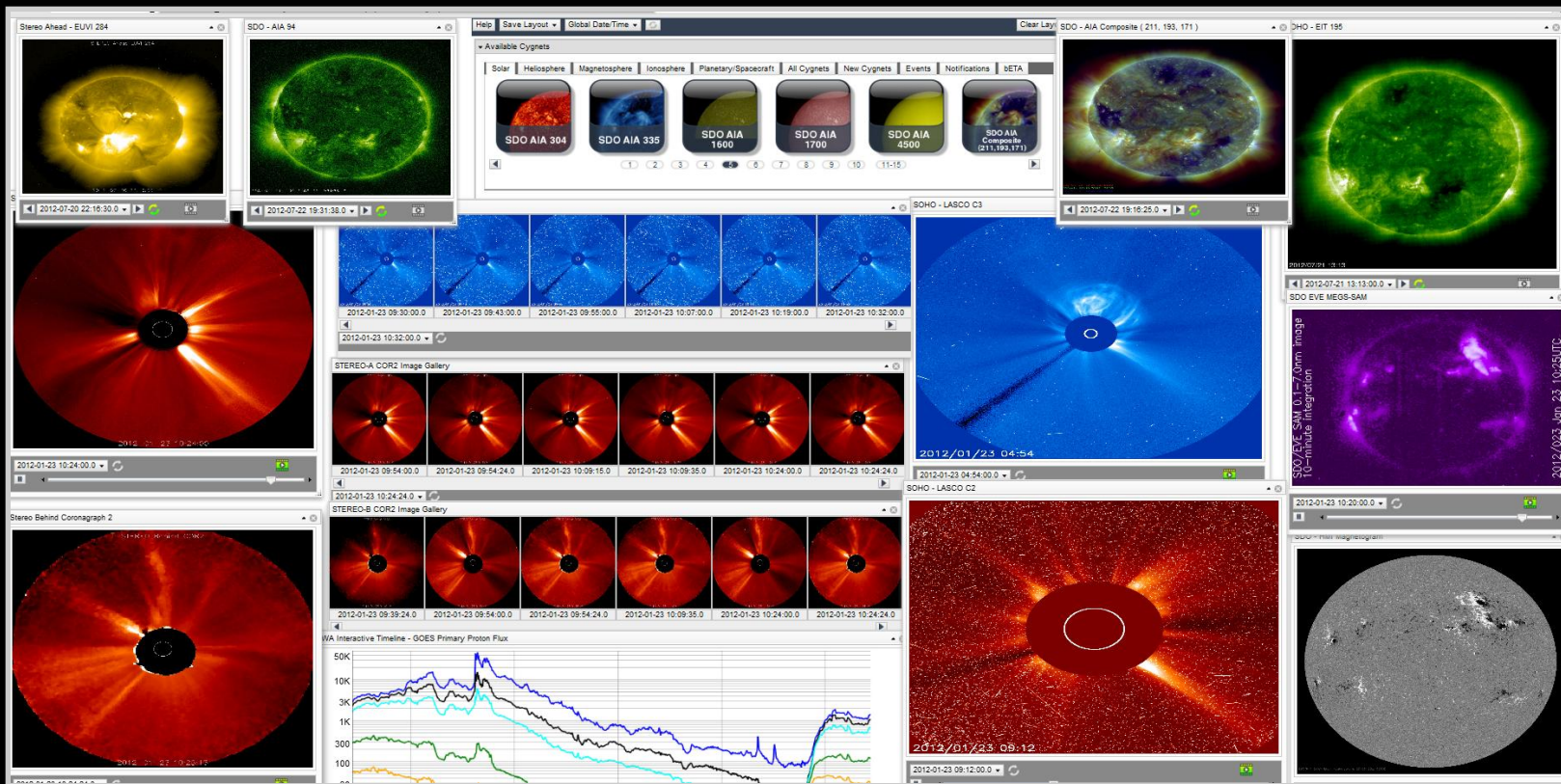


February 15th, 2011 Solar Flare — SDO

✓ **Solar Flare (SF):** An explosive release of magnetic energy in the form of electromagnetic radiation and fast atomic particles. SFs Occur in regions of concentrated magnetic fields i.e. sunspots and usually are the predecessor for CMEs and SEP events.

III. Method

- ✓ Used iNtegrated Space Weather Analysis System (iSWA) to analyze specific CMEs that influence the formation of SEPs.



III. Method (cont)

- ✓ Determined the associated SF and source region each of specific event
- ✓ Referenced NASA GSFC Space Weather Research Center (SWRC) notifications over the past 2+ years for CMEs and SEP events

```
## NASA Goddard Space Flight Center, Space Weather Laboratory ( SWL )
## Message Type: Space Weather Alert
##
## Message Issue Date: 2012-01-23T05:50:00Z
## Message ID: 20120123-AL-003

## Alert Summary:

Significant CME detected by STEREO-B COR2 / SOHO LASCO C3.

Start time of the event: 2012-01-23 04:00Z.

Estimated speed: ~2211 km/s.

Estimated opening half-angle: 62 deg.

Direction (lon./lat.): 26/41 in Heliocentric Earth Ecliptic coordinates.

Updates on this event will be provided when available.

## Notes:
This CME is associated with M8.7 flare peaked at 2012-01-23T03:59Z (see the alert 20120123-AL-001).
```

```
## NASA Goddard Space Flight Center, Space Weather Laboratory ( SWL )
## Message Type: Space Weather Alert
##
## Message Issue Date: 2012-01-23T06:00:00Z
## Message ID: 20120123-AL-004

## Alert Summary:

Solar energetic particle event detected by GOES. The flux of > 100 MeV protons exceeds 1 pfu starting at 2012-01-23T04:45Z and the flux of > 10 MeV protons exceeds 10 pfu starting at 2012-01-23T05:30Z.

Spacecraft between the Sun and Earth (including MEO, GEO and other high-altitude orbits and high-inclination LEO) can be impacted.

## Notes:
This SEP event is associated with the M8.7 flare peaked at 2012-01-23T03:59Z (see the alert 20120123-AL-001).

For questions, comments, requests etc. contact:
GSFC-Space-Weather-Desk <gsfc-spaceweatherdesk@mail.nasa.gov>
Y. Zheng, 301-286-0111 (office) 240-381-5237 (cell)
A. Pulkkinen, 301-286-0652 (office), 240-381-0968 (cell)
```


III. Method (cont)

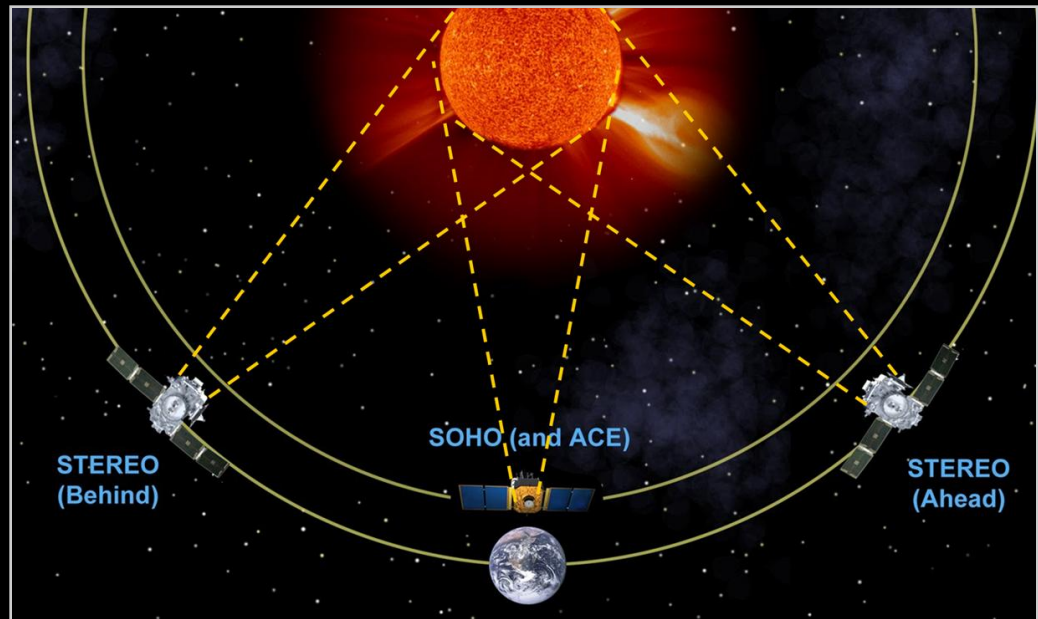
✓ Chose event if they met the following qualifications:

- Single CME event

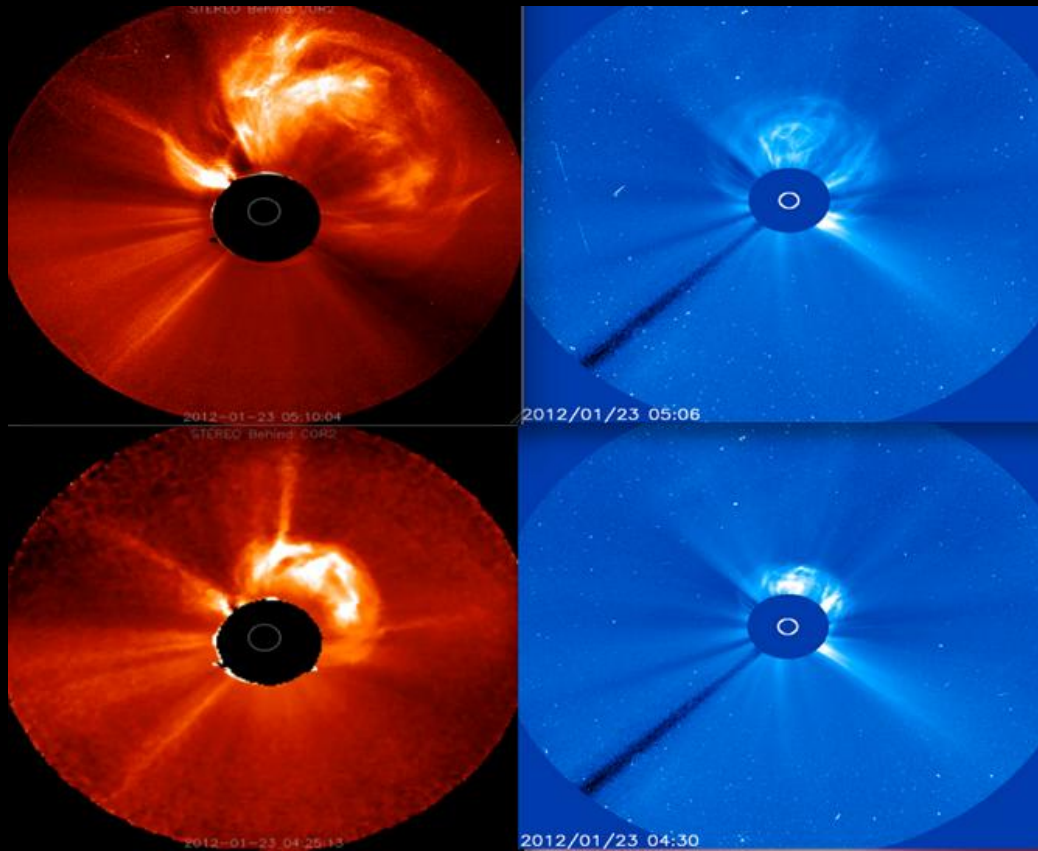
- Earth directed

- Clearly visible
on at least 2

- satellites



III. Method (cont)



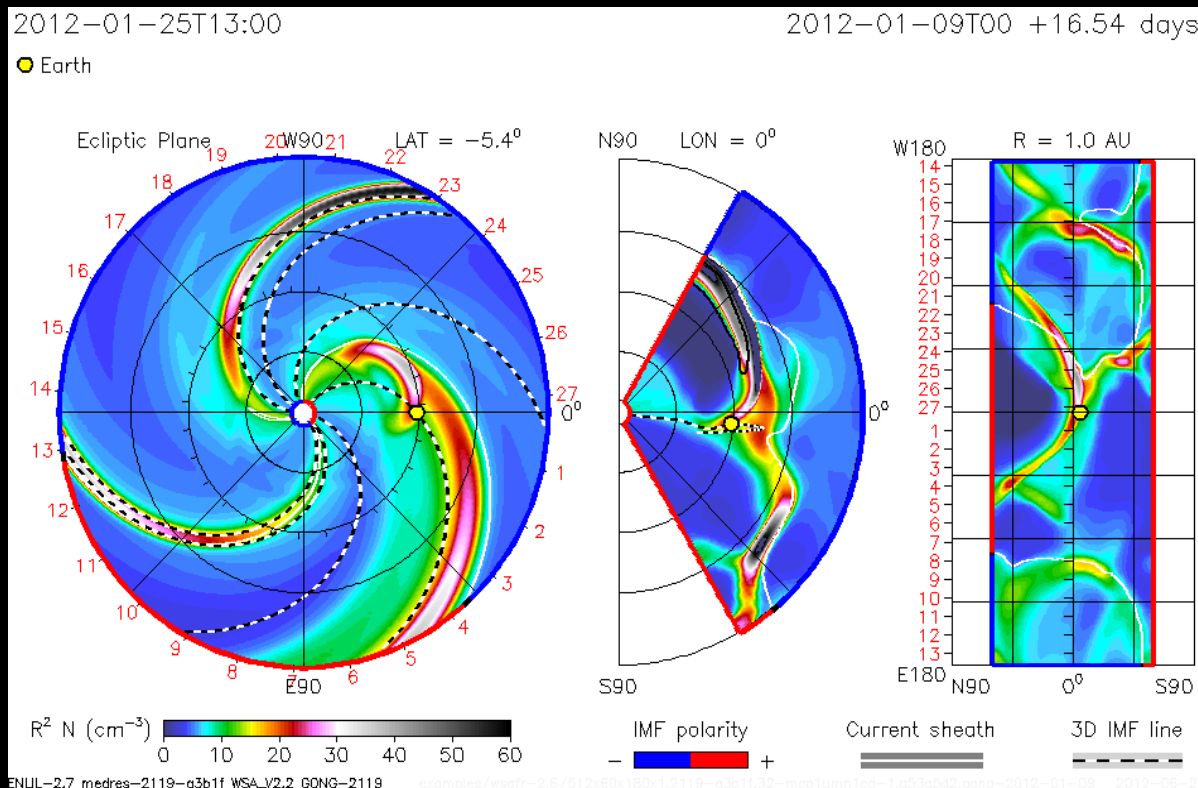
✓ Derived CME parameters via SWRC stereo analysis tool which was more accurate than forecasted model due to capability to backfill STEREO satellite data in addition to greater lapse time

- Latitude
- Longitude
- Velocity
- Time at 21.5 SR
- Omega

Thanks Marlo!

III. Method (cont)

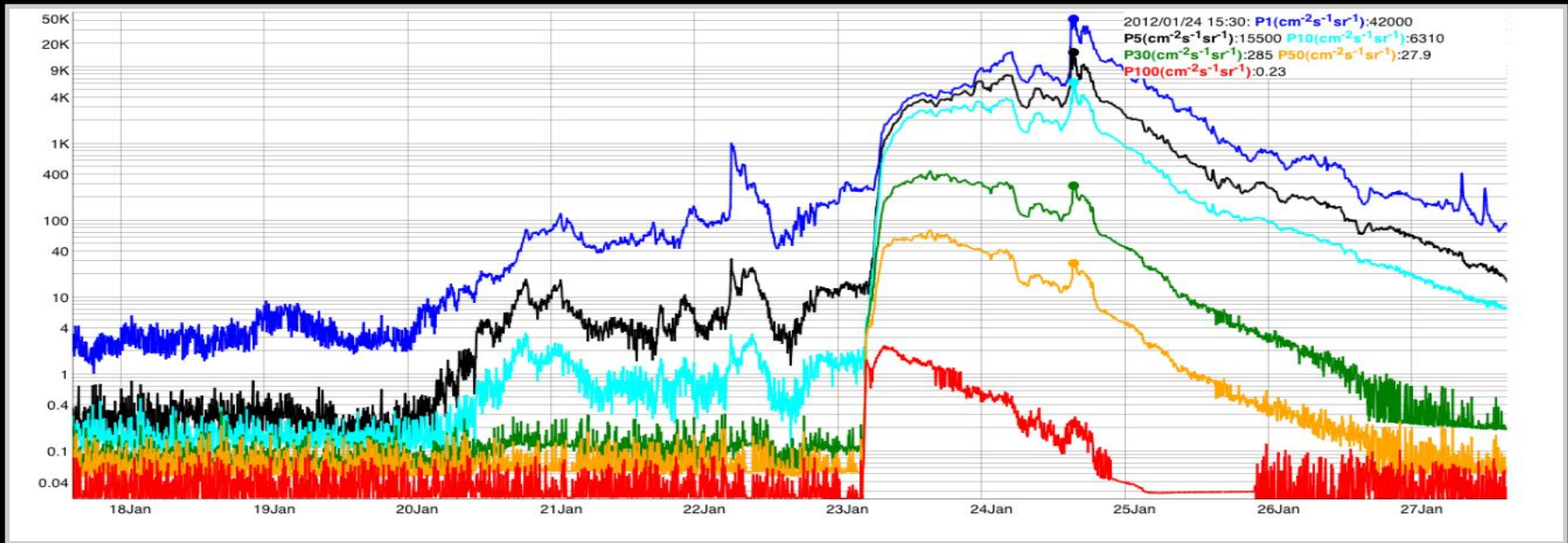
✓ Applied ENLIL Cone Model of CME to model event:



- Used average parameters of 15 runs
- Found rough magnetic connectivity

III. Method (cont)

✓ Found parameters of SEP event caused by CME using iSWA:

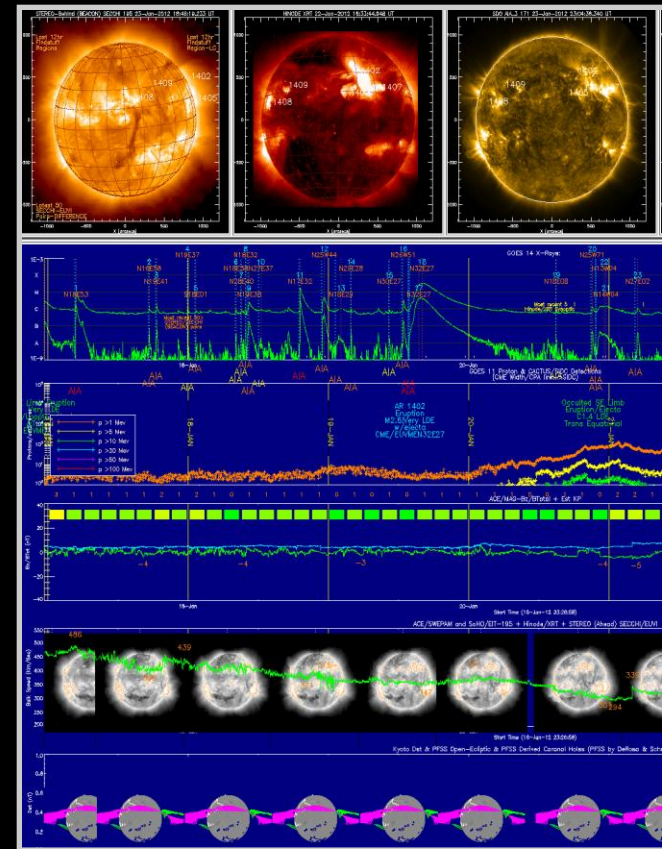


- Peak start time - Peak flux - Peak duration - Time to peak from evolution of CME

III. Method (cont)

✓ Used LMSAL to acquire SF parameters:

- Latitude
- Longitude
- Region (if available)
- Duration



III. Method (cont)

Utilized the parameters collected previous slides to conduct the following correlations:

- CME Speed vs Omega ^
- SF Duration vs SEP Duration ^
- SEP Duration vs CME Longitude ^
- SEP Duration vs Magnetic Connectivity ^
- SEP speed vs SEP Peak Intensity ●
- CME Speed vs SEP Duration *
- SF Latitude vs CME Latitude +
- SF Longitude vs CME Longitude +

Key:

● *Strong correlation visible*

* *Slight correlation visible*

^ *No visible correlation*

+ *Mostly positive correlation, as expected*

V. Limitations

- ✓ Few events because of strict qualifications.
- ✓ Some clear events had data gaps that could not be filled.
- ✓ Accurate data limited to when Stereo satellites were launched

VI. Results

- ✓ Solar Max
- ✓ Multiple CME
- ✓ Different Energy Bands
- ✓ Continuing research next semester at Penn State
 - Paper to be published
 - Present at AGU –just submitted abstract!!