Space Weather Forecasting Chains of Events

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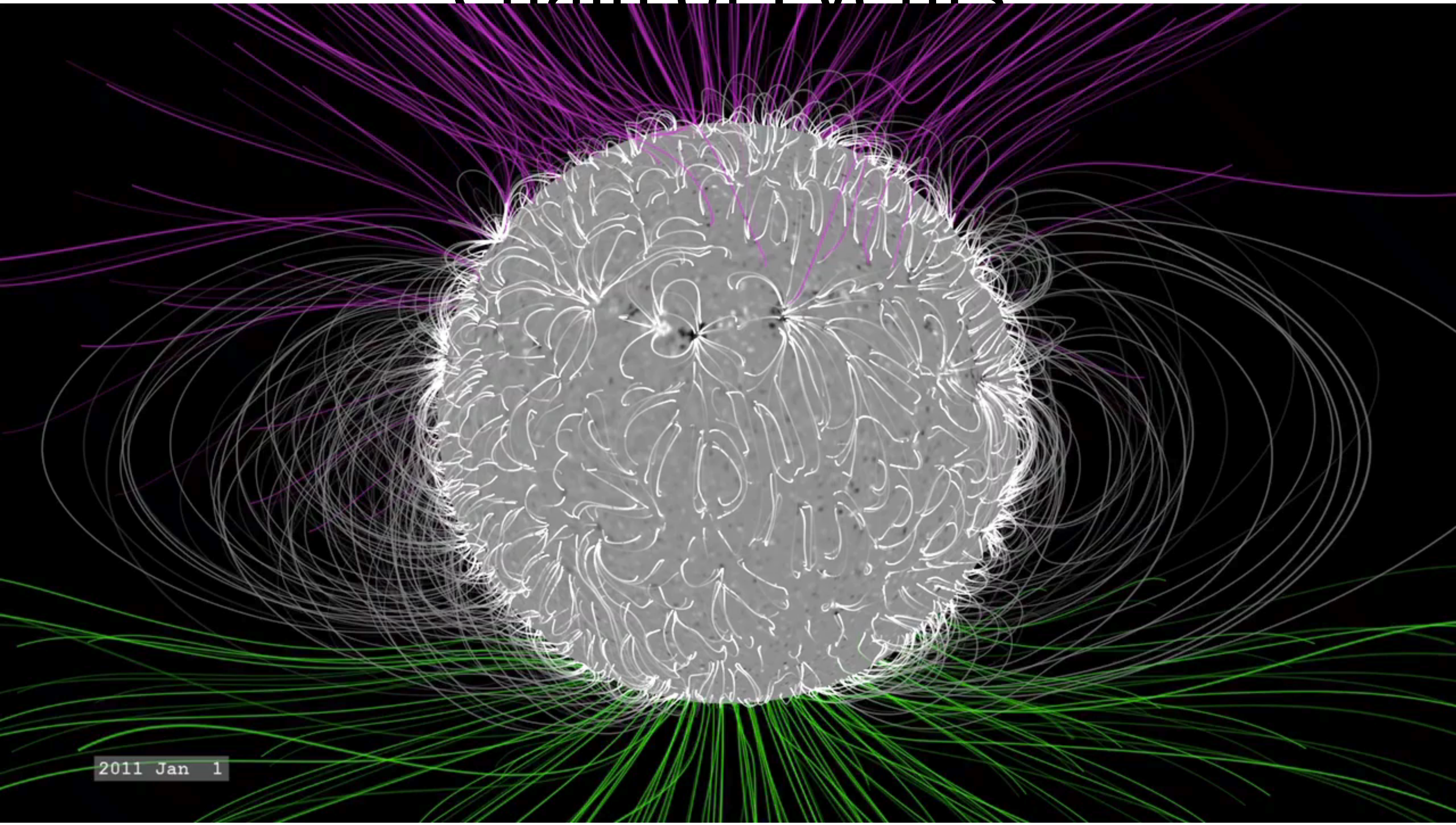
Chain of Events



“4 years of solar magnetic field” by Bridgman, DeRosa & Schrijver https://svs.gsfc.nasa.gov/4391

Chain of Events
(from the standpoint of physics)

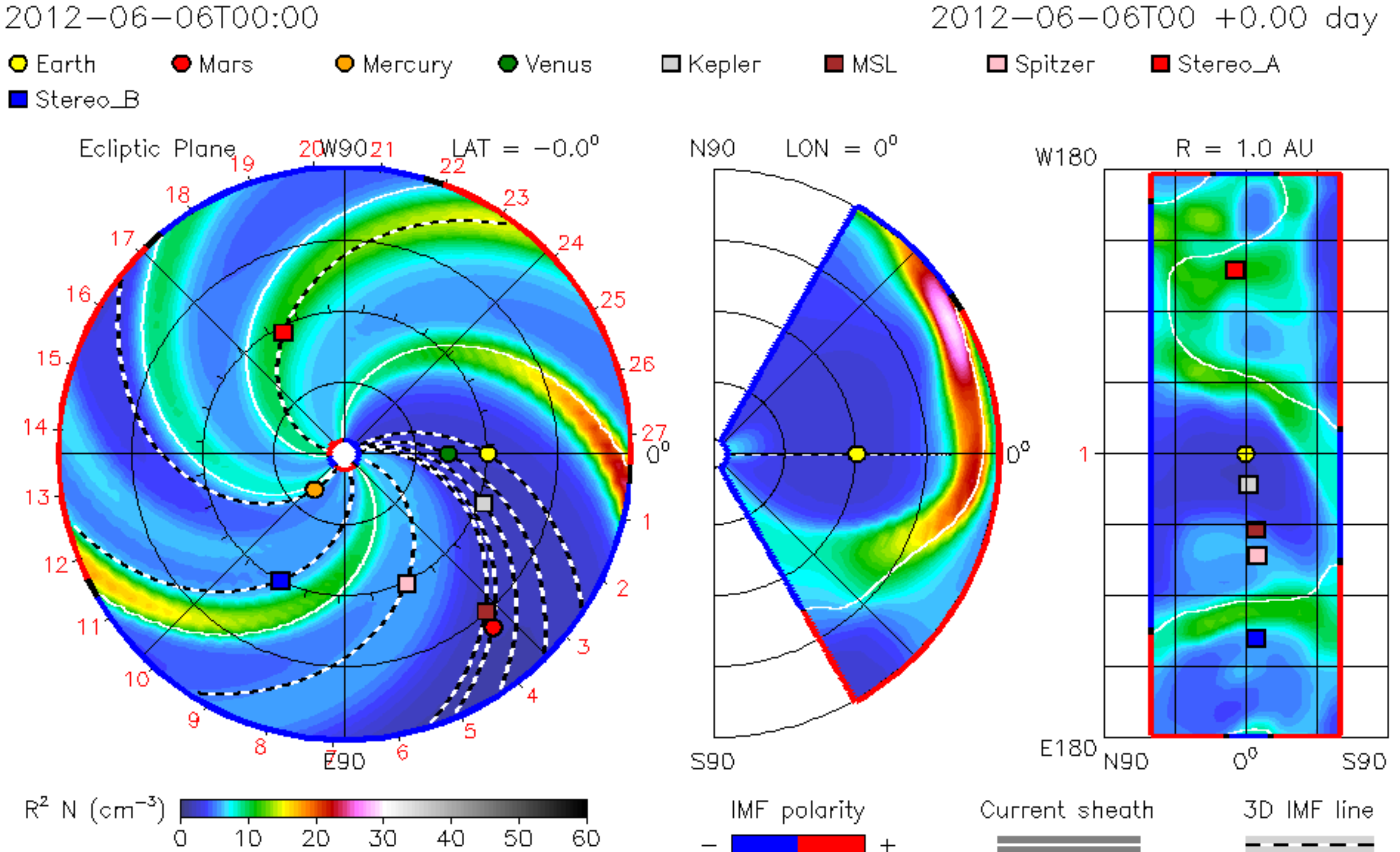
There are several ways that chains of events that can develop. We commonly divide them into the following areas, though many events are a combination of several, or even all of them.

1) High-speed streams: Inhomogeneities in the solar wind can drive activity at geospace. The most common space weather effect is elevated radiation belt electrons. Transit time from Sun to geospace is typically 2-4 days, with responses lasting up to several days.
2) Flares: Energetic wavelengths of light from a sudden release of magnetic energy on the Sun deposit in the ionosphere. The light propagates independently of the magnetic field structure, and takes just 8 minutes to reach Earth. Subsequent effects can last hours.

Chain of Events
(from the standpoint of physics)

3) Coronal Mass Ejections: Expulsions of magnetic field and mass from the Sun propagate through the heliosphere and impact geospace. These magnetic fields can be very strong when compared to the magnetosphere, and can drive strong geomagnetic activity. Timescale is 12 hours for a very very fast CME to reach Earth, and up to a week for the slow ones. The geomagnetic response can last days.
4) Energetic particles (SEPs): Shocks on the Sun and in the solar wind accelerate protons (mostly) to high energies. The impacts are a combination of the driver (CME), the medium (solar wind), and the location of impact (magnetosphere, spacecraft, etc.). SEPs can take as little as a half an hour to arrive at Earth, but the duration of impact can be complex.

Chain of SEP events



Why would the forecaster chain of events be any different?

1) Events develop in "real time." Constructing the chain *after the fact* is difficult; forecasting requires you to make assessments based only on what you know, not what you will know.
2) Some data are available immediately, some arrive later (either due to contact schedules or delayed detection), some never arrive (i.e. when you wish you had a measurement at a particular location but don't)

Why would the forecaster chain of events be any different?

3) Some models and simulations are available quickly, and some take a while to run and produce results.

4) End users need different types of information. Some need it quickly, some need more detailed information and can receive it a little later.

5) For these reasons, we often iterate in our predictions, and provide updates.

Linkage of space weather events (example 1, flare/CME)

- Flare/CME
- SEP (if any)
- CME arrival (in-situ data)
- Geomagnetic storm (indicated by Kp, or Dst)
- Other impacts (ring current/radiation belt dynamics, aurora, enhanced total electron content,)

Flare/CME examples

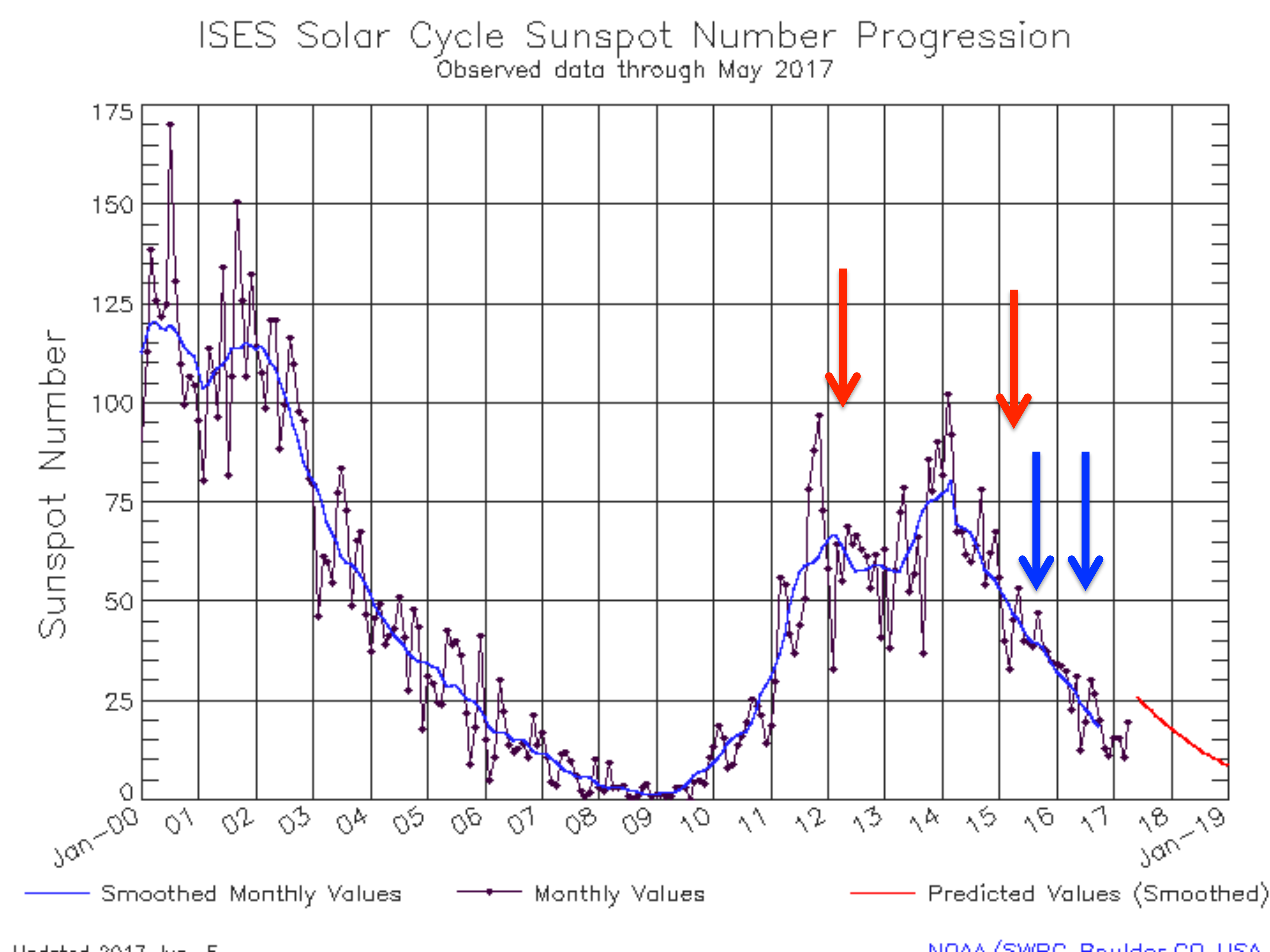
- March 7, 2012 event
  - http://bit.ly/March7_2012_event
  - https://goo.gl/MhUp5O (an alternative view)
- The March 15, 2015 storm
  - http://bit.ly/20150317_geomagnetic_storm

Coronal Hole High Speed Streams (HSS)

- Coronal hole HSS
  - Also leads to geomagnetic storms, but long duration and weaker (Kpmax 6 to 7, not exceeding 7)
  - Enhancement of the outer edge of the outer radiation belt (e.g., effective for pumping up the energetic electron flux at GEO orbit)
  - Examples:
    - 2015-06-07
      - http://bit.ly/HSS_20150607_extended
      - https://goo.gl/CRqv3h
    - 2016-05-07 (Kp=7)
      - https://goo.gl/XwppcY

Exception
many x-class flares, no accompanying CMEs

- AR2192 X class flares and the Oct 14 CME
  - http://bit.ly/AR2192_XclassFlares_oct14CME


ISES Solar Cycle Sunspot Number Progression
Observed data through May 2017
Sunspot Number
175
150
125
100
75
50
25
0
Jan-00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
Jan-19
Smoothed Monthly Values
Monthly Values
Predicted Values (Smoothed)

Other Examples

- The Jan 23 – 27, 2012 SEP events
  - https://goo.gl/H1qWYb
- AR 1429 timeline
  - https://goo.gl/GPLJkX
- The Galaxy 15 Event
  - http://bit.ly/galaxy15_charging_event

More (Other layouts)

- http://swrc.gsfc.nasa.gov/main/demo
  - Examine various layouts here