NOAA Goes to L1 with DSCOVR

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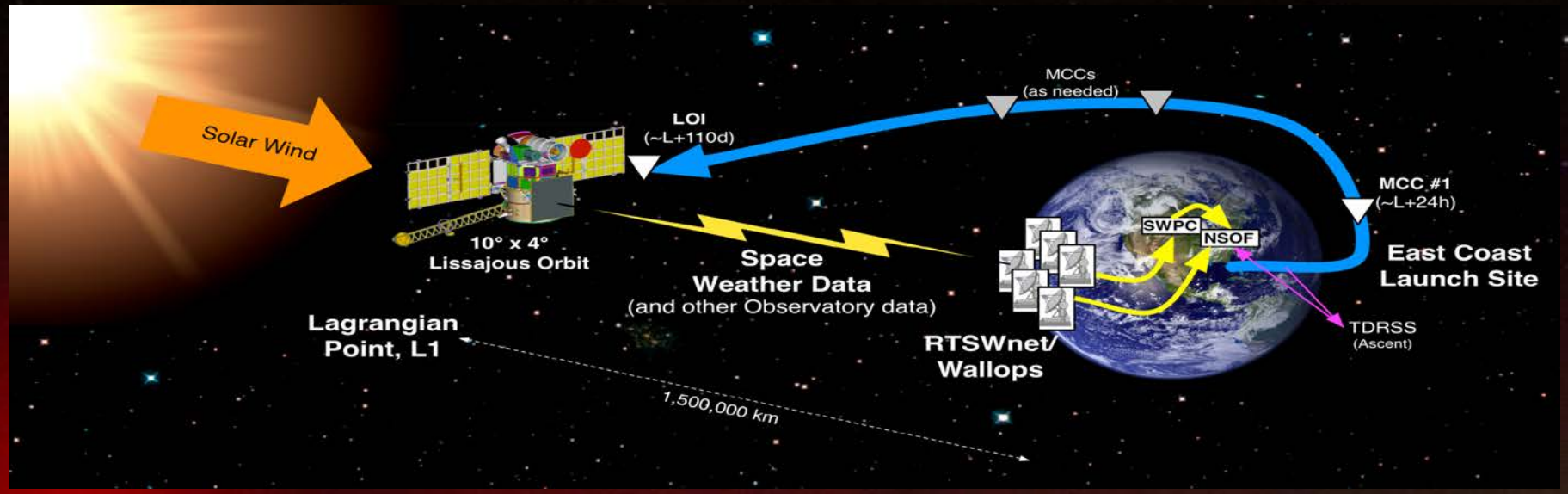
and the NOAA, NASA, DOD, Harvard/SAO, U Michigan teams

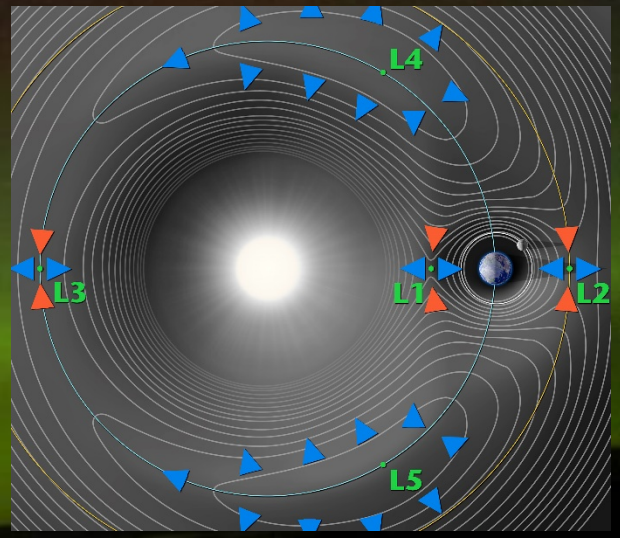
Outline

- DSCOVR the mission
- The Status of the Instruments & Data
  - Magnetometer
  - Faraday Cup
- SWPC providing data and products
- Why DSCOVR is better than ACE
- DSCOVR Archive

DSCOVR – replacing ACE for operations



- The first NOAA mission outside Earth's atmosphere
- Replaces NASA Advanced Composition Explorer for operations, but not for science
- 15 – 60 minute warning of Coronal Mass Ejection (CME) arrival
- Geomagnetic storm intensity gauge
  - Allows SWPC to issue actionable geomagnetic storm warnings



Geomagnetic Storm Impacts

Impacts from geomagnetic storms are wide-ranging with potentially significant consequences.

Satellite Operations

Loss of mission, reduction in capability

Manned Spaceflight

Increased radiation risk

GPS

Precision Agriculture, Surveying, Drilling, Military

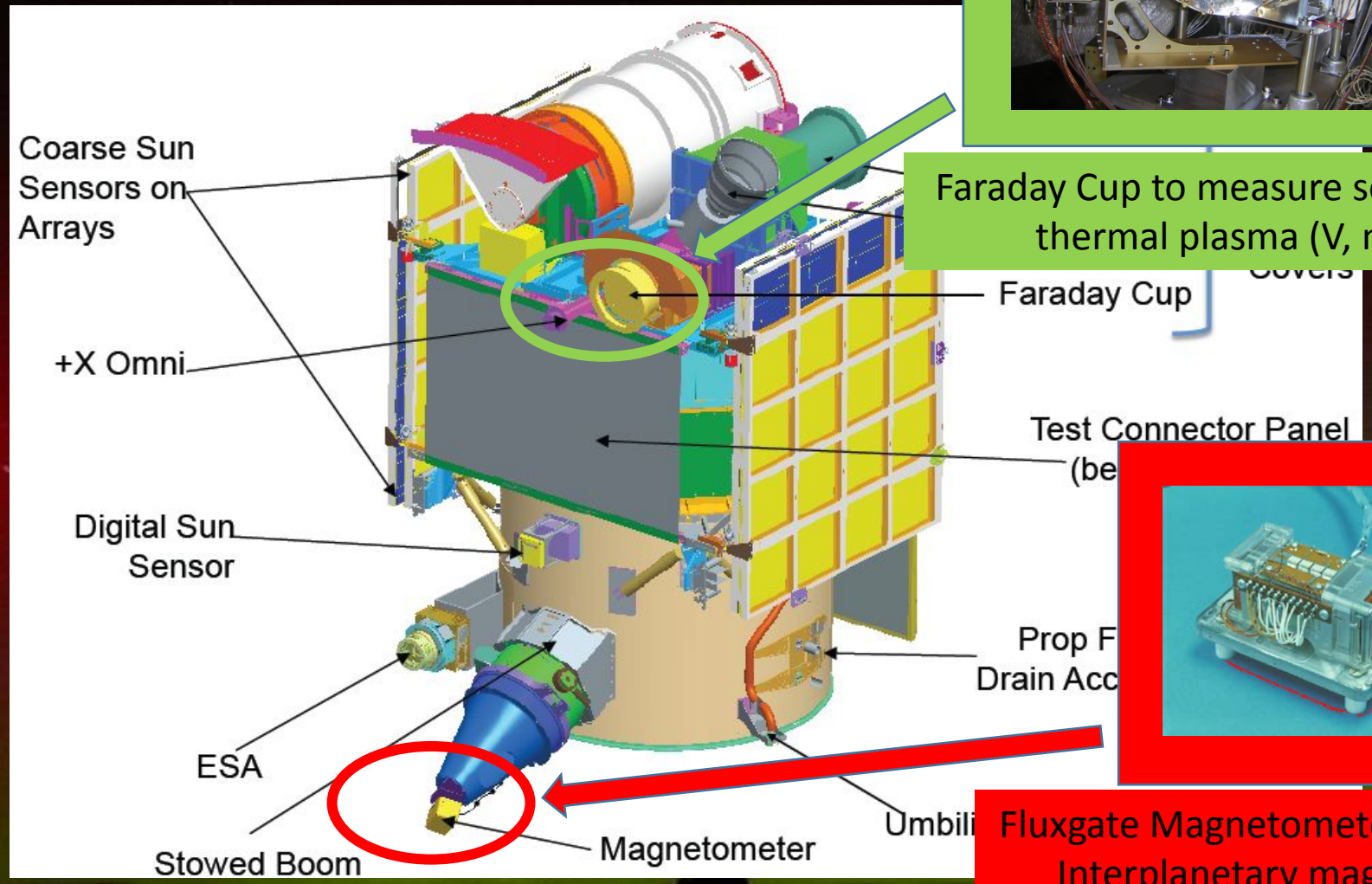
Power Grid Operations

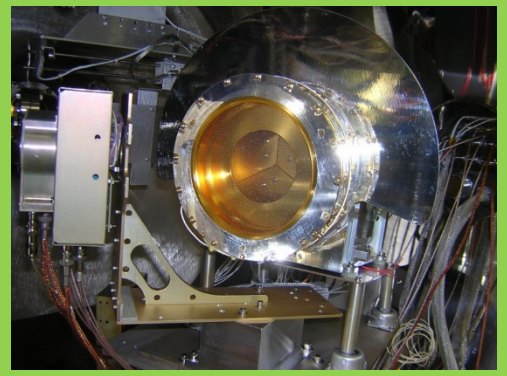
Grid failure, Grid capacity, Component Failure, GPS Timing

Aircraft Operations

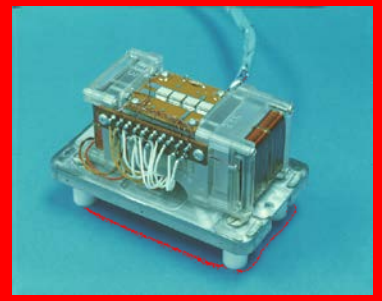
Polar Flights, WAAS, NextGen, Airline Communication

DSCOVR





Faraday Cup to measure solar wind thermal plasma (V, n, T)



Fluxgate Magnetometer to measure Interplanetary magnetic field

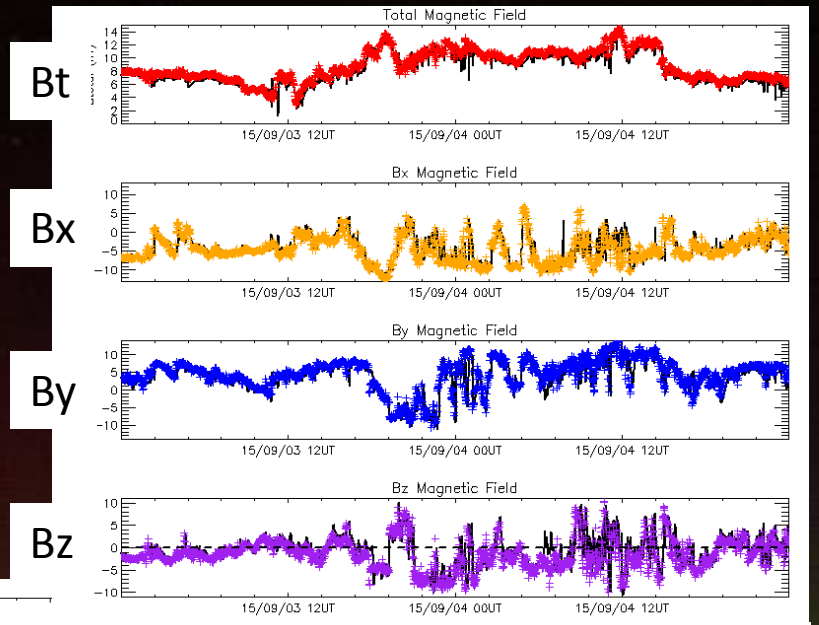
How we got here…

- Feb 11, 2015 Launch!
  - Fuel to last until 2029
- June 8, 2015 In L1 Lissajous Orbit
- October 28, 2015 NOAA takes command of DSCOVR
- So, why no data yet?

But first, the magnetometer

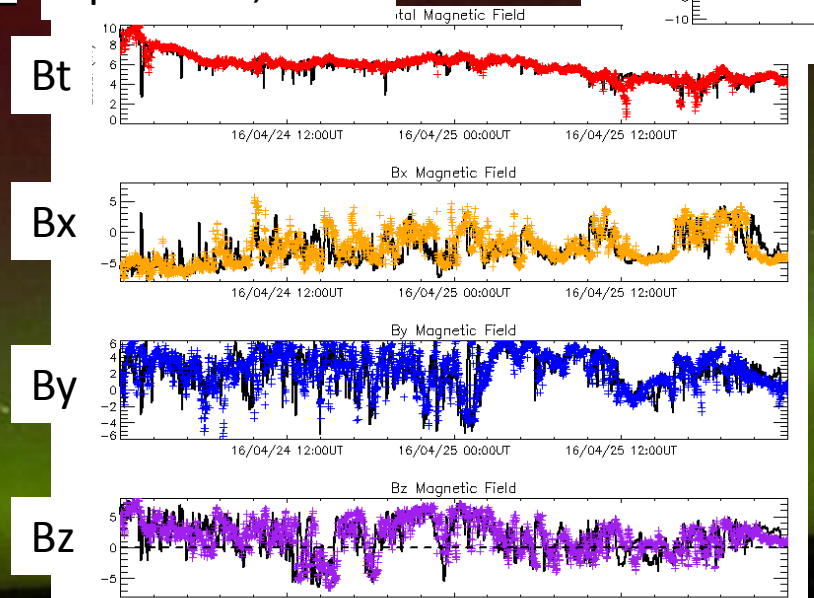
Magnetometer meets NOAA requirements

Requirement	Value	Performance
Range	0.1-100 nT	0.004-65,500 nT
Accuracy	+/- 1 nT	+/- (0.5-0.9) nT
Cadence	1 minute	50 Hz



Sept 3-5, 2015

Apr 24-25, 2016



SWPC will provide 1 second and 1 minute averaged data

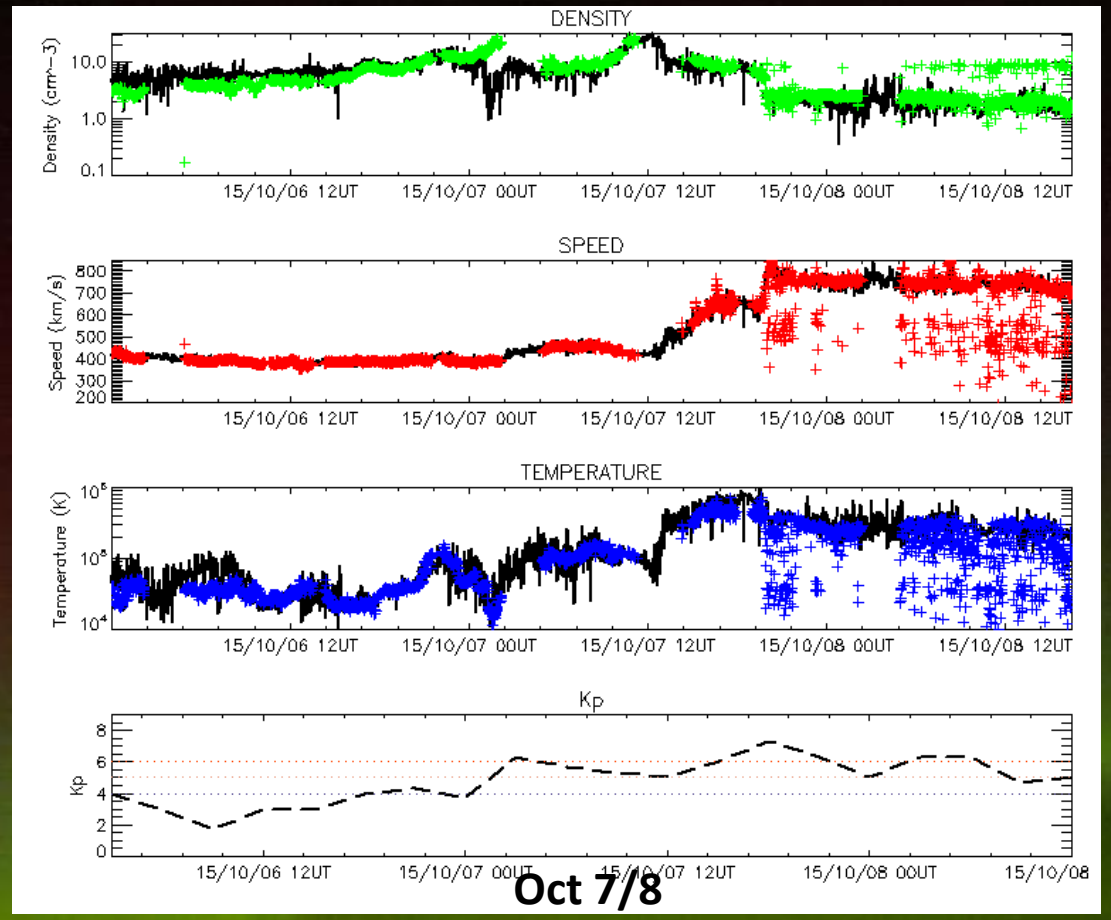
DSCOVR shown in color
ACE in black

The Faraday Cup wasn't meeting requirements

Oct 7/8 CIR/High Speed Stream
- G3 Geomagnetic Storm
- During low densities, data got noisy

- Optimization of the FC was needed
- Extensive recalibration performed Feb 16-Mar 4
- SWPC implemented revised algorithms March 31

Requirement	Required Value	Ground Performance
Velocity Range	200-1250 km/s	168-1340 km/s
Density Range	1-100 cm^{-3}	0.22-219 cm^{-3}
Temperature Range	$4x10^4$-$2x10^6$ K	$3.9x10^4$-$7.3x10^7$ K
Cadence	0.0167 Hz	2 Hz



Oct 7/8

How Does a Faraday Cup Work?

- A voltage V_0 applied at the front of the instrument rejects protons < V_0 and lets through everything > V_0.
  - The protons >V_0 deposit a current on the collector plates
- Stepping up to a higher voltage V_1 does the same
- The difference between what is measured at V_0 and at V_1 tells us how many protons had energy between V_0 and V_1

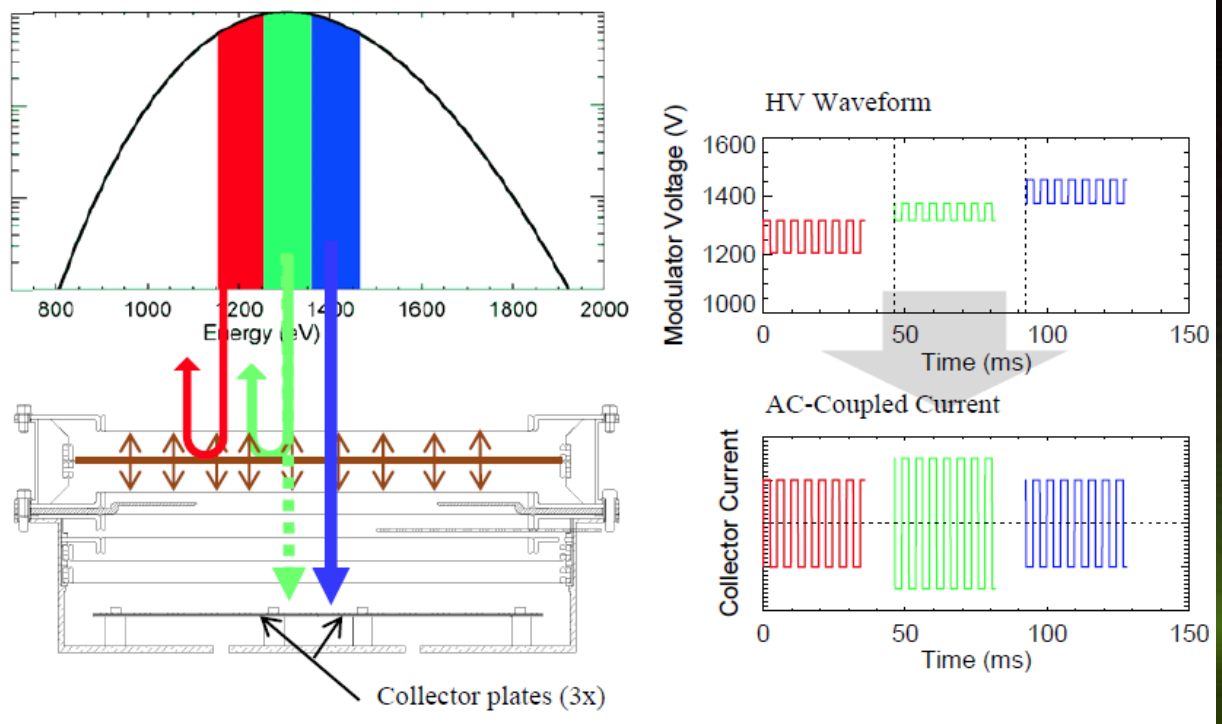
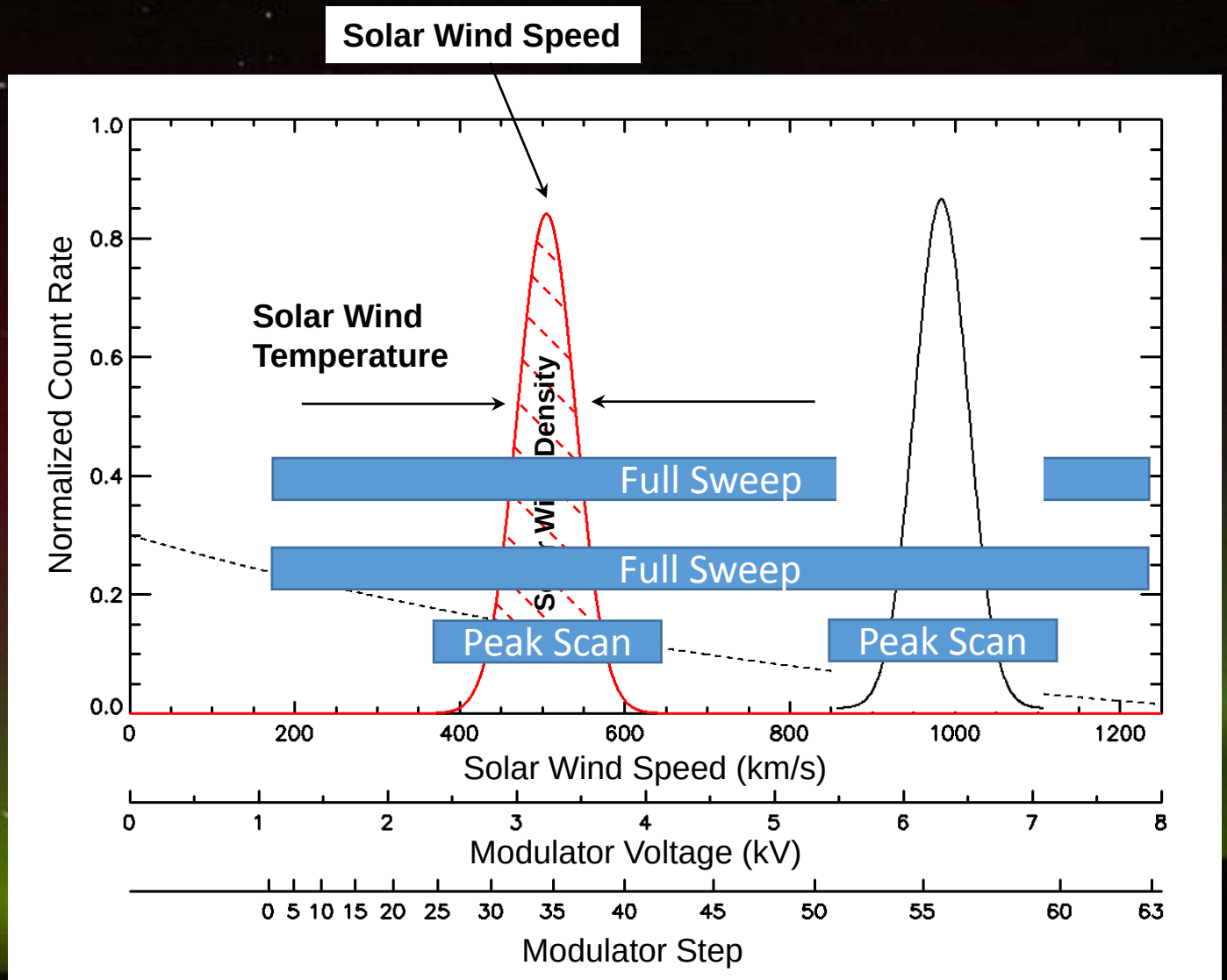


Figure 3.2: The Faraday Cup measurement concept

Faraday Cup Concept of Operations

- First we have to find the solar wind
  - Full sweep (11.5 sec)
- Then we do high time sampling peak scans (3.5 sec) for a while
  - Until a timer runs out (4 hrs) or
  - Until a fast shock comes through
- Then we do another full sweep
- And then go back to peak scan mode

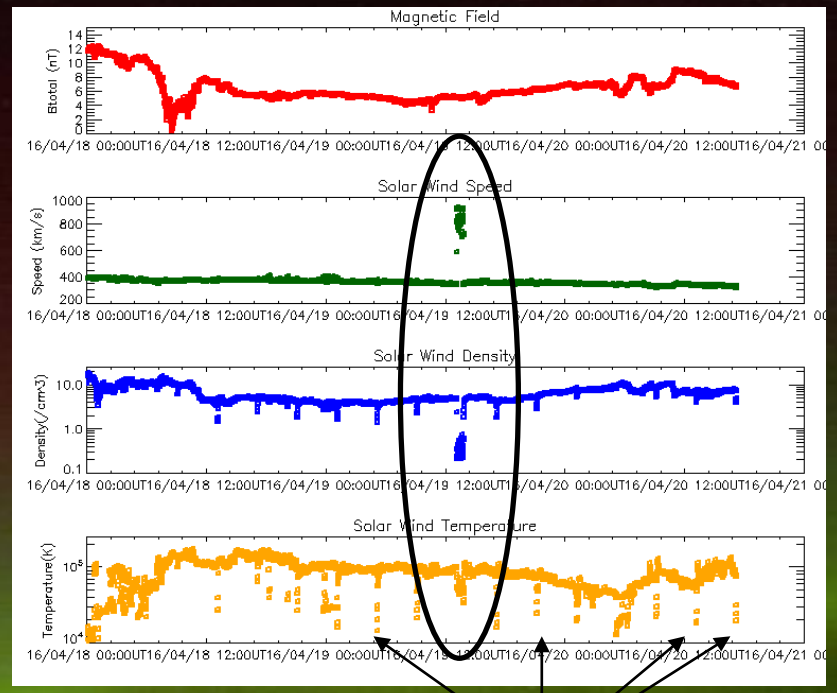


After the latest recalibration

Overall, signal to noise improved by a factor of 20x

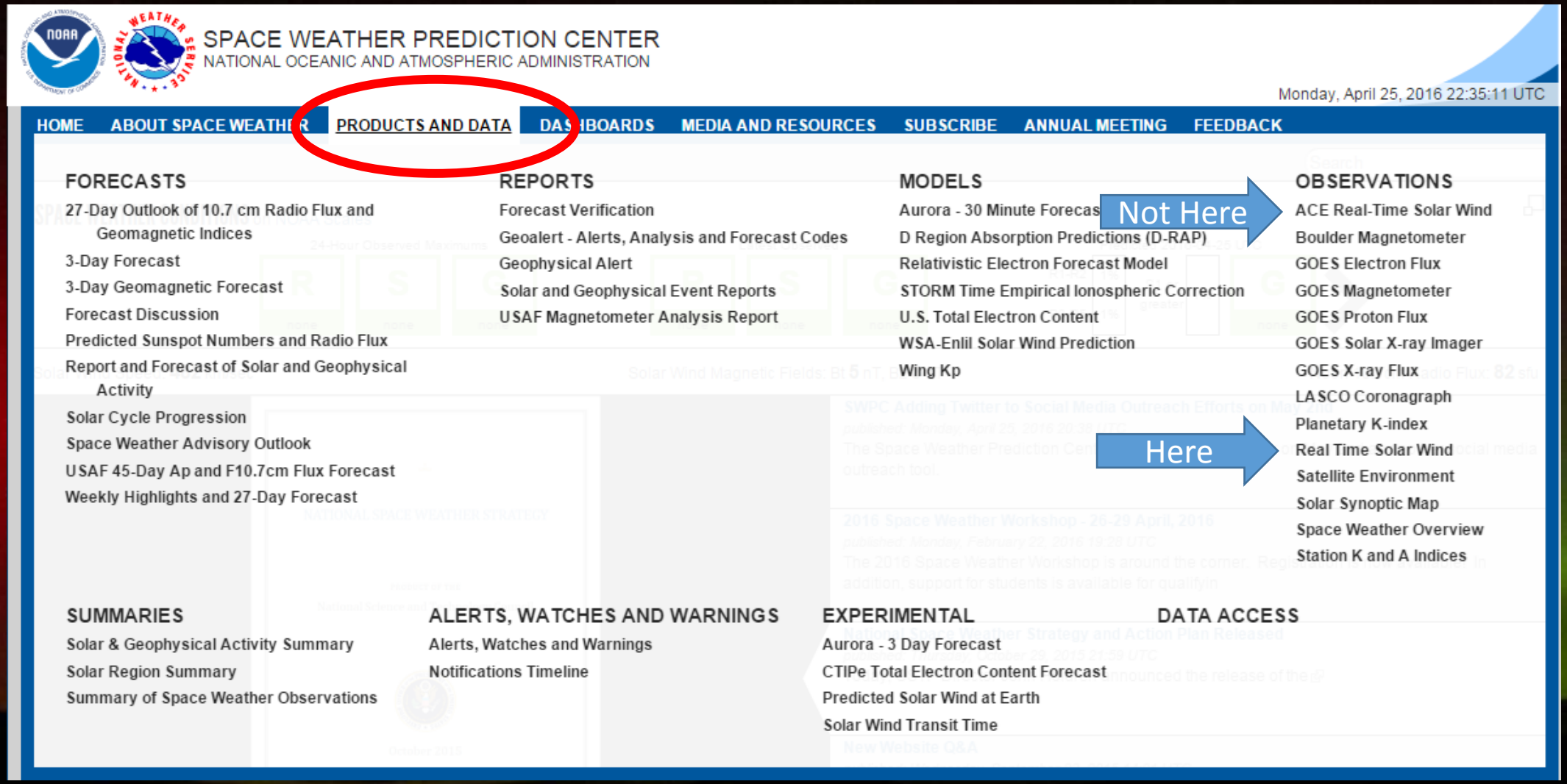
- Longer integration times
  - Peak scan was 1 sec, now 3.5 sec
  - Full scan was 2.5 sec, now 11.5 sec
- Full sweeps stretched to maximum allowed interval (4 hours)
- SWPC provided data will be 12 second and 1 minute averages

- However, two issues remain
  - Hey, where did the solar wind go?
    - Impacts speed, density, and temperature
    - Identified as a software bug
    - Fix still needs to be implemented
  - Full sweeps induce a temporary, variable background current lasting ~5 minutes
    - Impacts density and temperature
    - Investigating removing this in ground processing



So this is why we have moved transition from ACE to DSCOVR to Summer 2016

SWPC Modernizes Our Web Architecture



Try it yourself and give us feedback

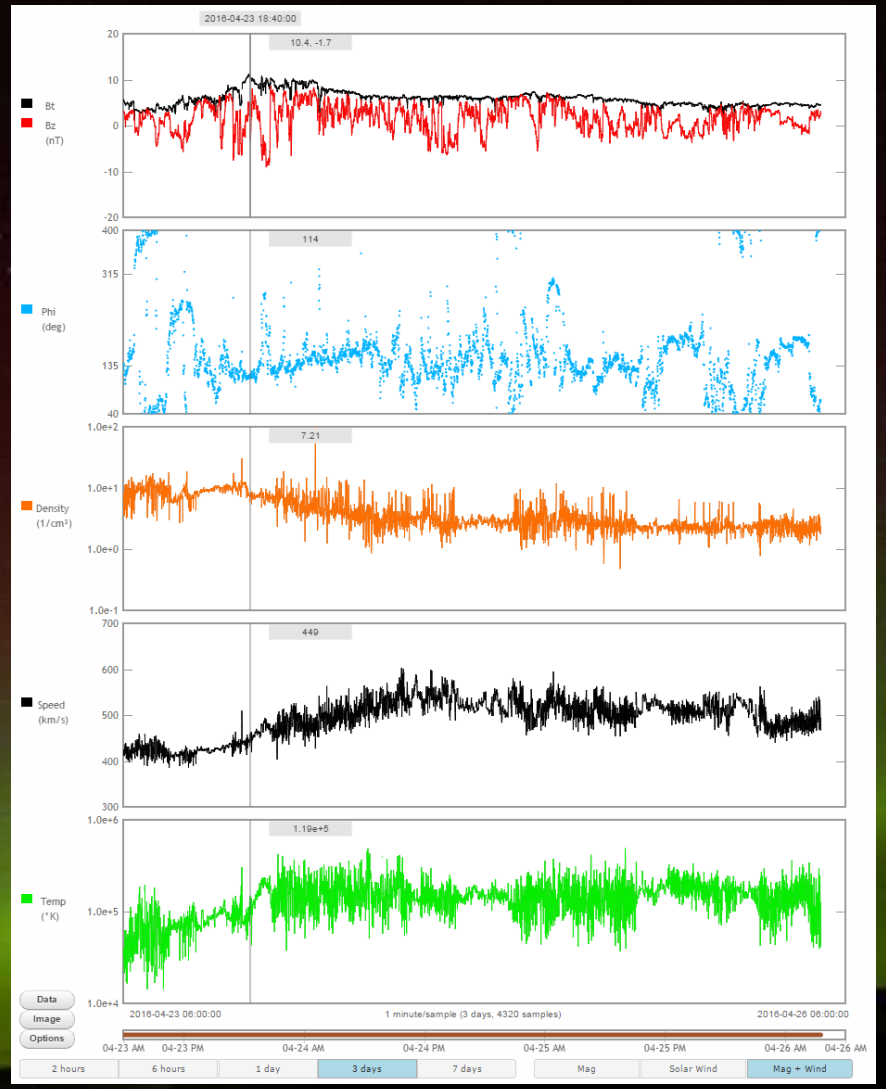
No, that's ACE data

- Default displays available
  - 2 hours to 7 days
  - Mag only, FC only, or subset of both
- Mouse over display of values
- Zoom to highest available resolution
- Download current display to PNG format
- Download displayed data in ascii data format
- Mobile device compatible
  - Not so great on phones

- Data also available via JSON format files

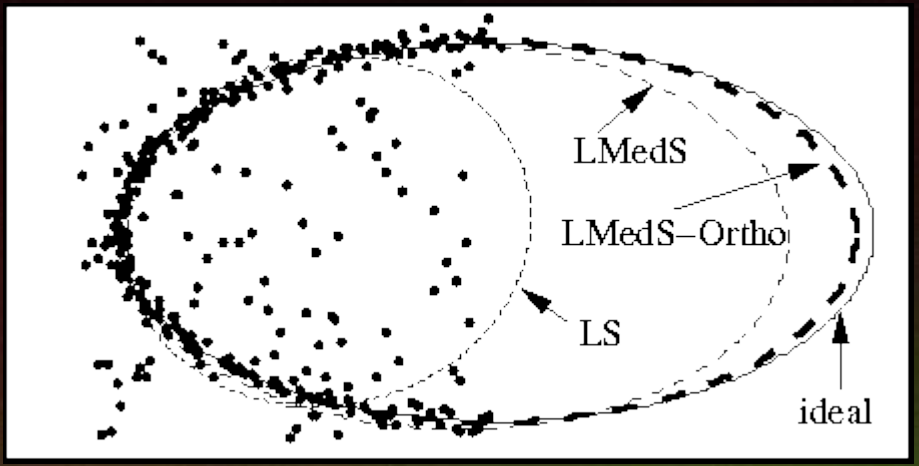
http://services.swpc.noaa.gov/products/solar-wind/

If you start using the JSON's now, when we switch from ACE to DSCOVR, it will be transparent to you.



Robust Averaging of Data

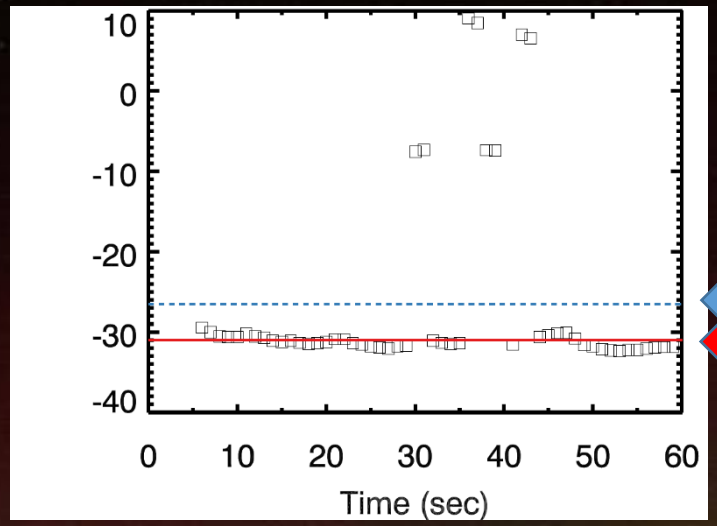
- Data are noisy and outliers will occur
  - Real-time operations -> manual screening not possible
- Use modern, robust statistics, designed to ignore small departures from model assumptions
  - e.g. normally distributed data
- Breakdown point
  - Proportion of incorrect observations an estimator can handle before giving an incorrect result
    - Theoretical limit is 50%
    - Mean has limit of 0 (zero).



Data averaging – no more boxcars

Magnetometer (50 Hz data)

- Hodges-Lehmann Estimator (1963)
  - Breakdown point 29%
  - Form independent pairs, including the pair of each item taken twice
    - n(n+1)/2 pairs
  - Find the median of each pair
  - Find median of the medians

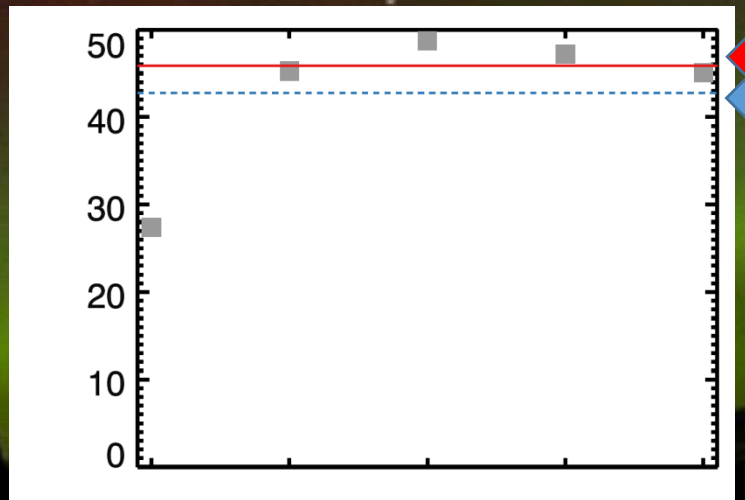


Boxcar

H-L

Faraday Cup

- Huber M-Estimator (Huber 1963)
  - Breakdown point of 50%
  - Iterative scheme
    - Preferred for averages with fewer data points
  - Maximum likelihood type of estimator
    - Huber influence function



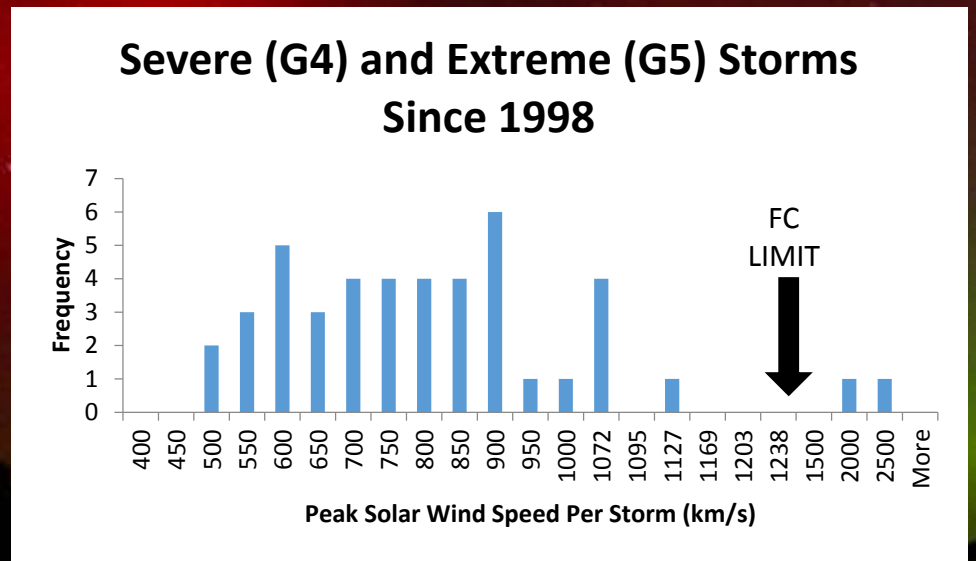
Huber

Boxcar

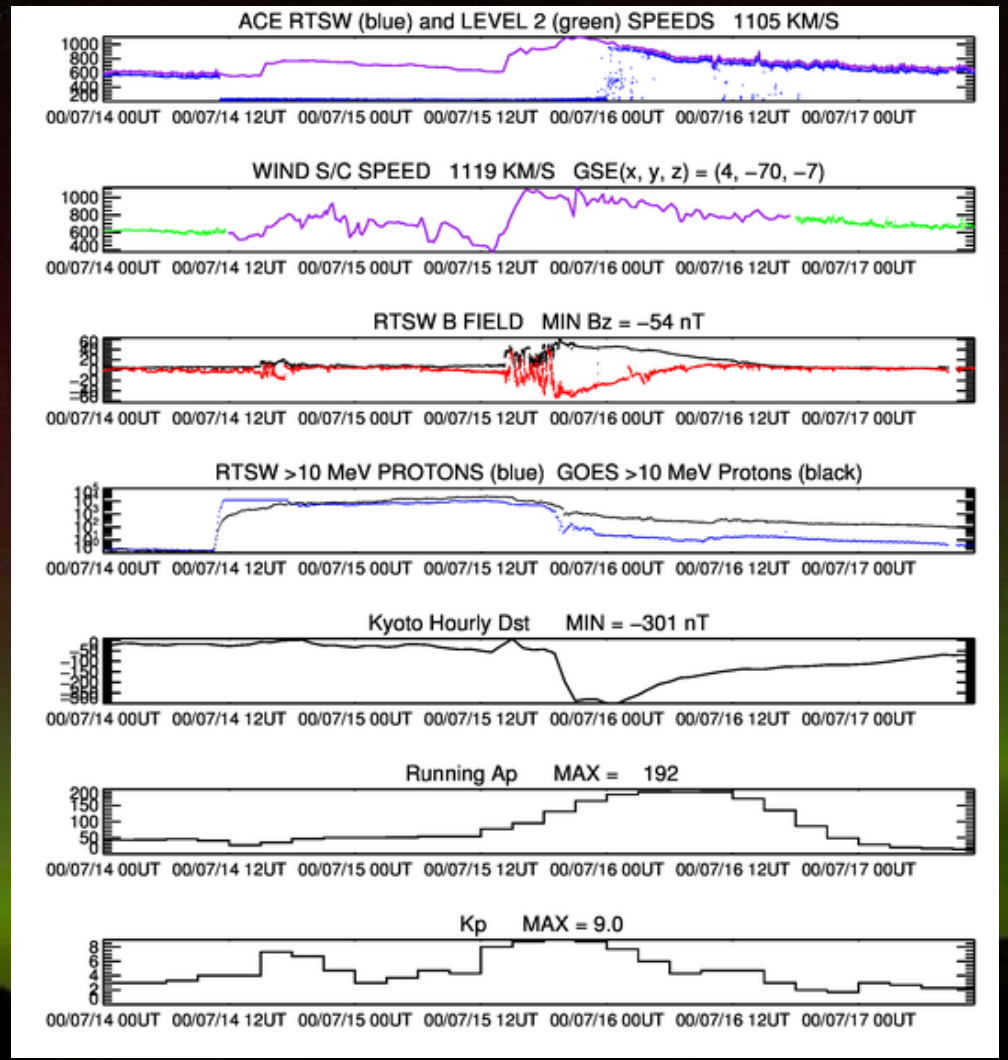
DSCOVR Improves over ACE

DSCOVR will work better than ACE for G4 and G5 storms

- 44 Geomagnetic Storms Reached G4 (Severe) or greater (G5-Extreme) from 1998-2012
  - ACE SWEPAM failed to provide solar wind data for 10 of the events (23%)
    - Due to proton storm contamination
  - DSCOVR FC would have provided data for all but 2 of the events (5%)



Bastille Day Event, July 2000

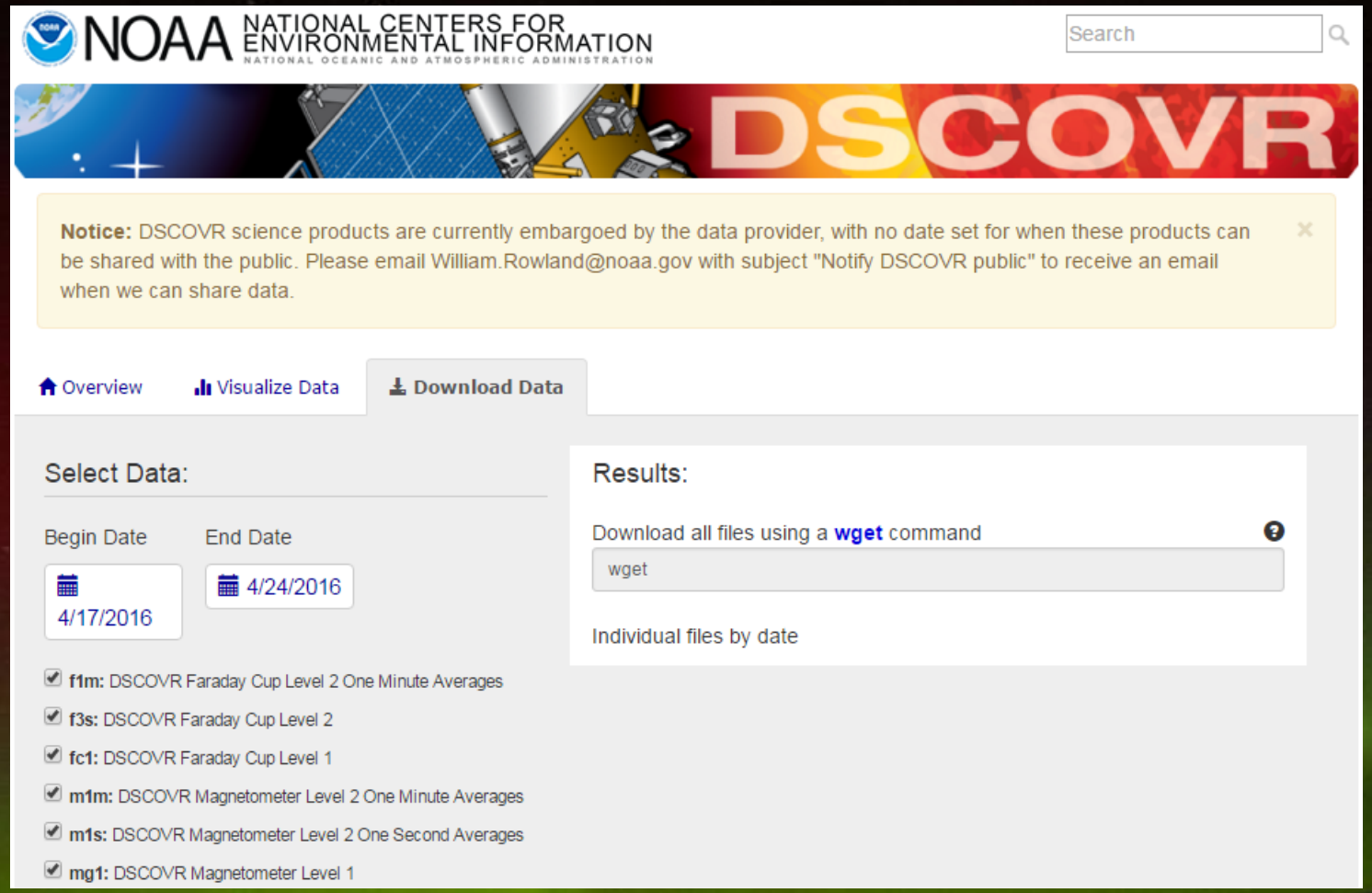


DSCOVR Archive

Estimate switch from ACE to DSCOVR Summer, 2016

At that time, or shortly thereafter, we will release all data, including high time resolution data

Data will be available from NCEI (nee NGDC) at: http://www.ngdc.noaa.gov/dscovr/



Summary

- DSCOVR is on orbit and has fuel to spare
- Magnetometer is performing extremely well
- Faraday cup has required extra work
  - Improved signal to noise 20x
  - We need more time to implement a few more fixes
    - We only identified the latest issues in the last few weeks
    - We are confident these can be fixed and/or mitigated
- SWPC web architecture has been modernized
- DSCOVR will be an improvement
- Data averaging has been modernized as well
- Data from
  - http://services.swpc.noaa.gov/products/solar-wind/
  - http://www.swpc.noaa.gov/products/real-time-solar-wind
  - http://www.ngdc.noaa.gov/dscovr/