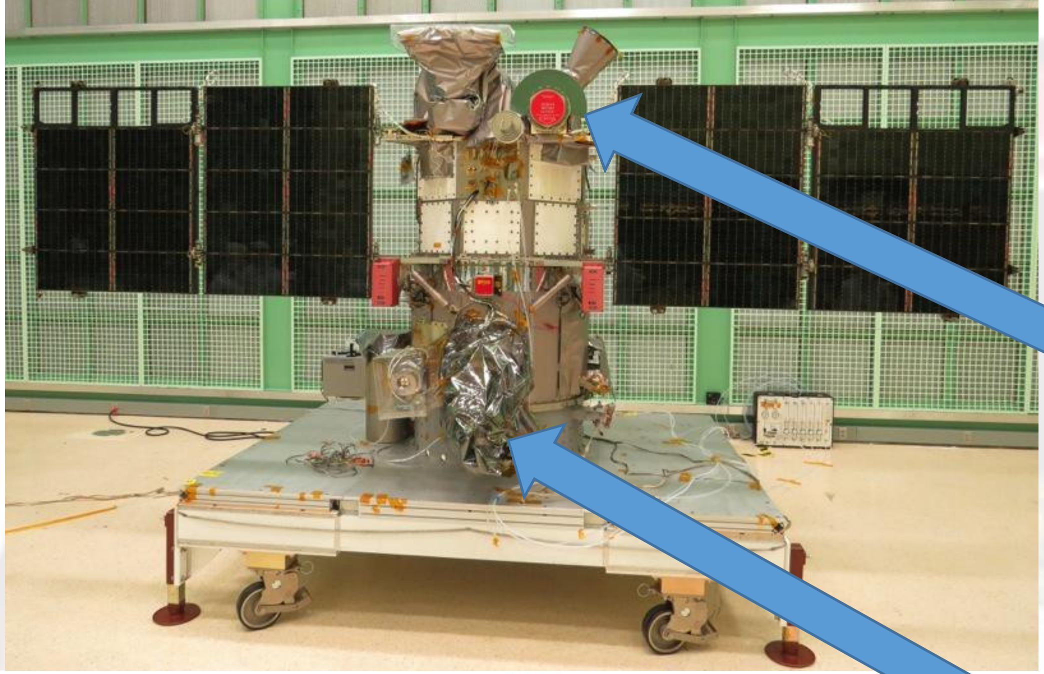
DSCOVR
Halfway to L1

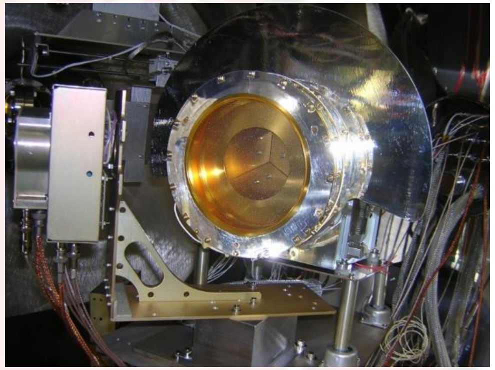
Doug Biesecker and the entire DSCOVR team

SWPC, NGDC, NESDIS, GSFC, USAF, CfA, UMich, SpaceX

NICT, KSWC, DLR



The instruments



<u>Alan Lazarus Faraday Cup</u>

CfA/UofMich & MIT

Solar wind protons and alphas

speed, density & temperature

high time resolution

~0.5 sec in peak tracking mode

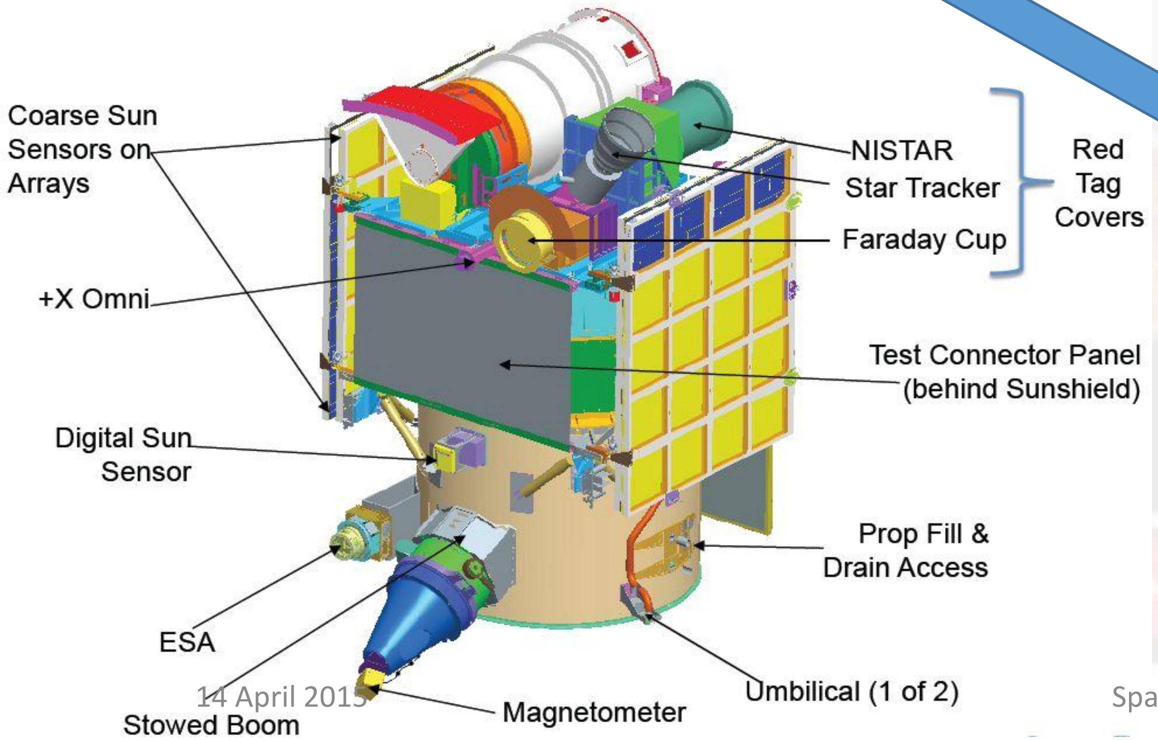
~2.5 sec in full sweep mode

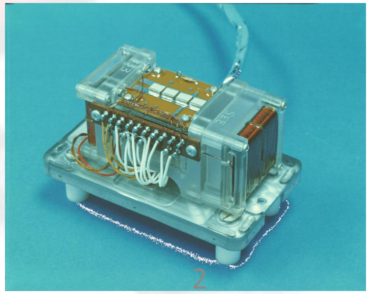
<u>Tri-axial fluxgate Magnetometer</u>

NASA/GSFC

Interplanetary 3-d magnetic field

high time resolution (50 Hz)

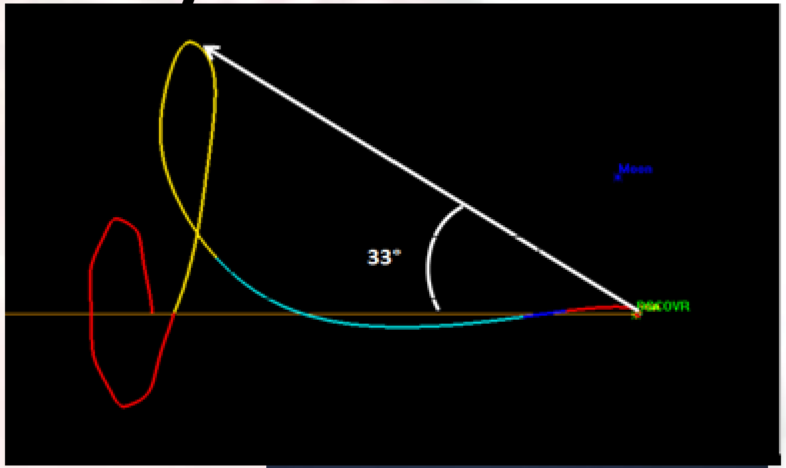




The journey to L1 – 53% of the way there

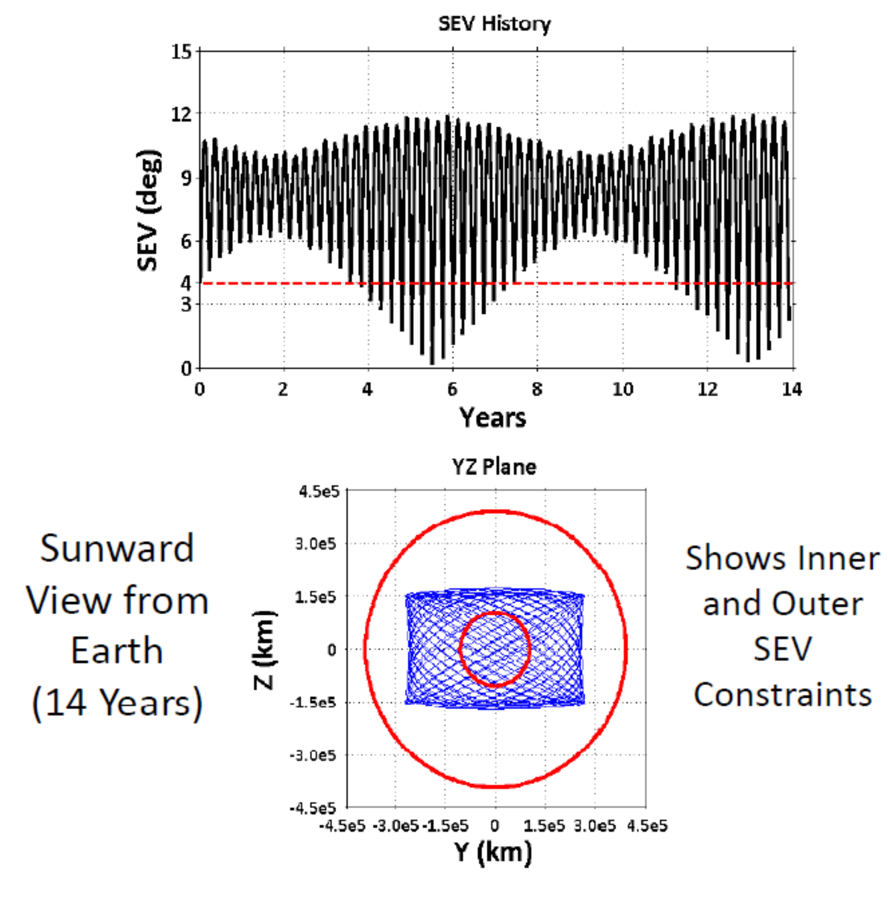
- Feb 11 – Launch
- Feb 15 – Magnetometer turned on and boom deployed
- Feb 17 – Faraday Cup HV turned on
- Apr 14 – Today: Mission Elapsed Time (MET 62 days)
- Apr 27 - Mid Course Correction 2 (burn of ~2 seconds)
- Jun 7-8 - Lissajous Orbit Insertion
  - MET: 116 days
  - 5 hour burn

- Preliminary estimate is ~10 years of fuel
- Transition from NASA to NOAA expected in July

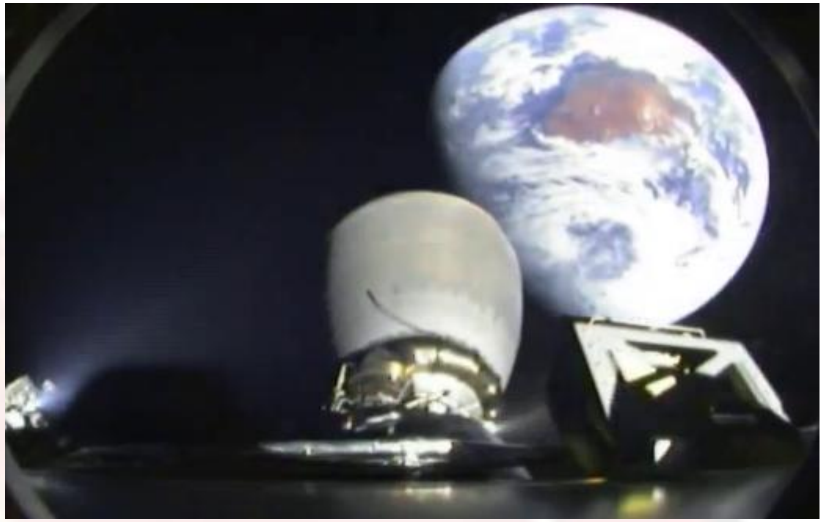


DSCOVR – A Lissajous Orbit

- DSCOVR's orbit very much like ACE, much smaller than Wind.
  - 6-month orbit period
  - Max Sun-Earth-Vehicle Angle of 12°
  - Unlike ACE, we plan to enforce Sun-Exclusion Zone of 4°
    - First encountered @L+3.4 years
    - Avoids solar RFI
    - Fuel Penalty



Instrument Data



Magnetometer

Parameter	Expected Performance
Bx, By, Bz Range	8 ranges: ±4 - ±65536 nT
Bx, By, Bz Accuracy	< ±1 nT

SWPC provided cadence: 1 second & 1 minute

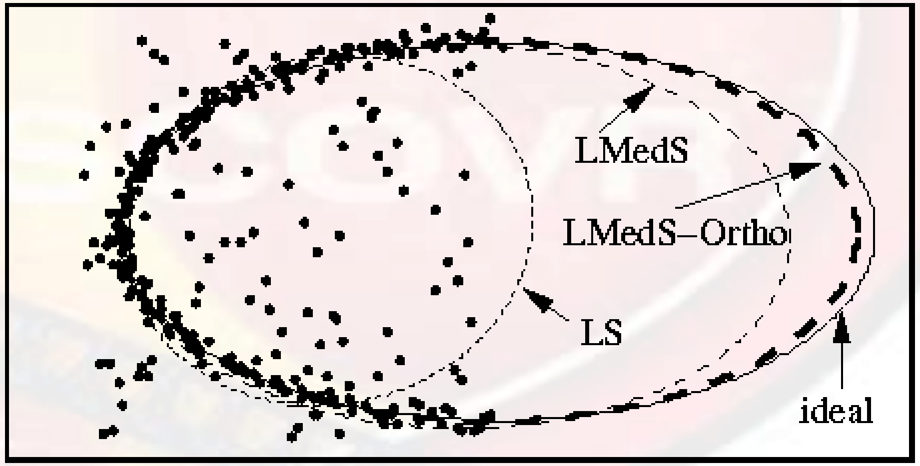
Alan Lazarus Faraday Cup

Parameter	Expected Performance
Velocity Range	168-1340 km/s
Velocity Accuracy	2%
Density Range	0.22-219 cm^{-3}
Density Accuracy	tbd
Temperature Range	$3.9x10^{4}$ $-7.3x10^{7}$ K
Temperature Accuracy	<8.9%

SWPC provided cadence: 3 seconds & 1 minute

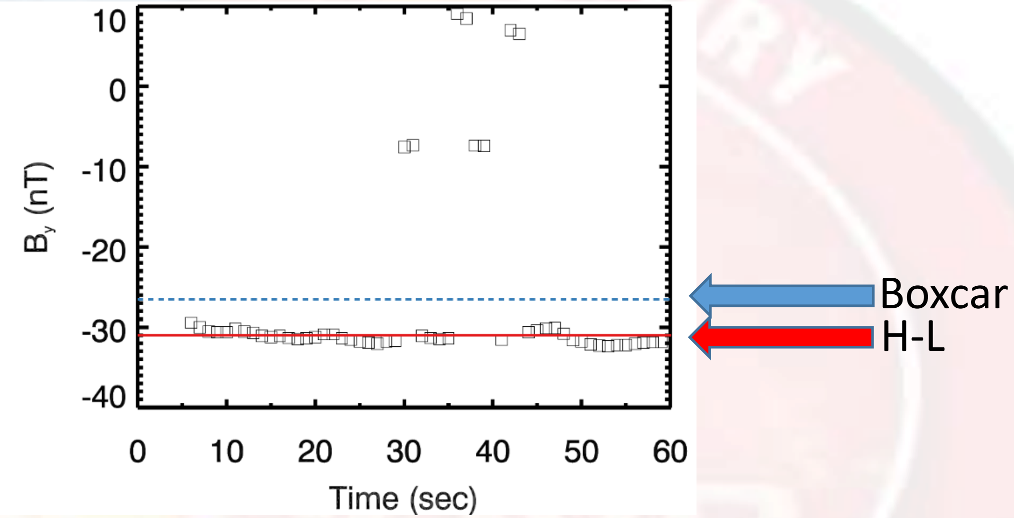
Robust Averaging of Data

- 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).

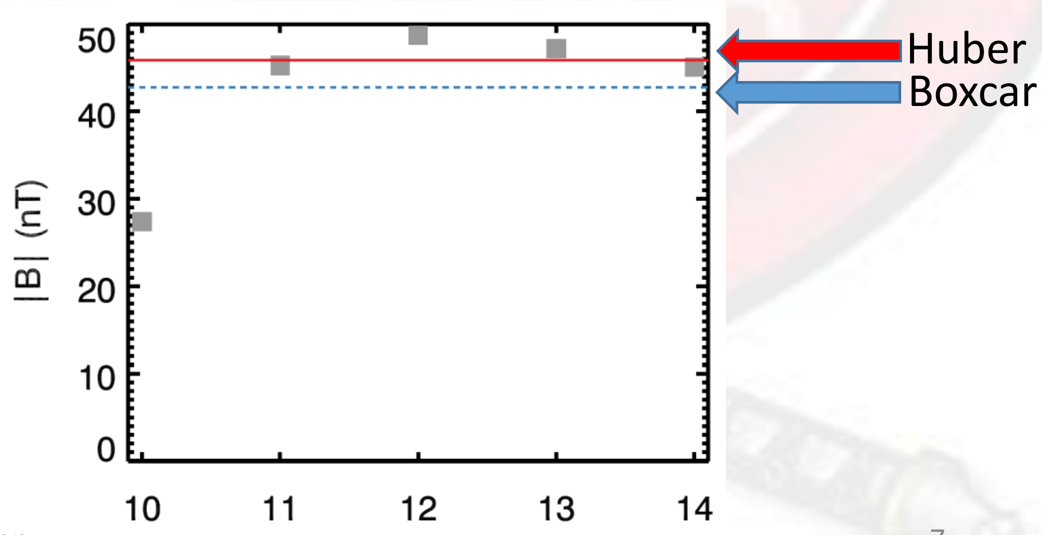


Data averaging– no more boxcars

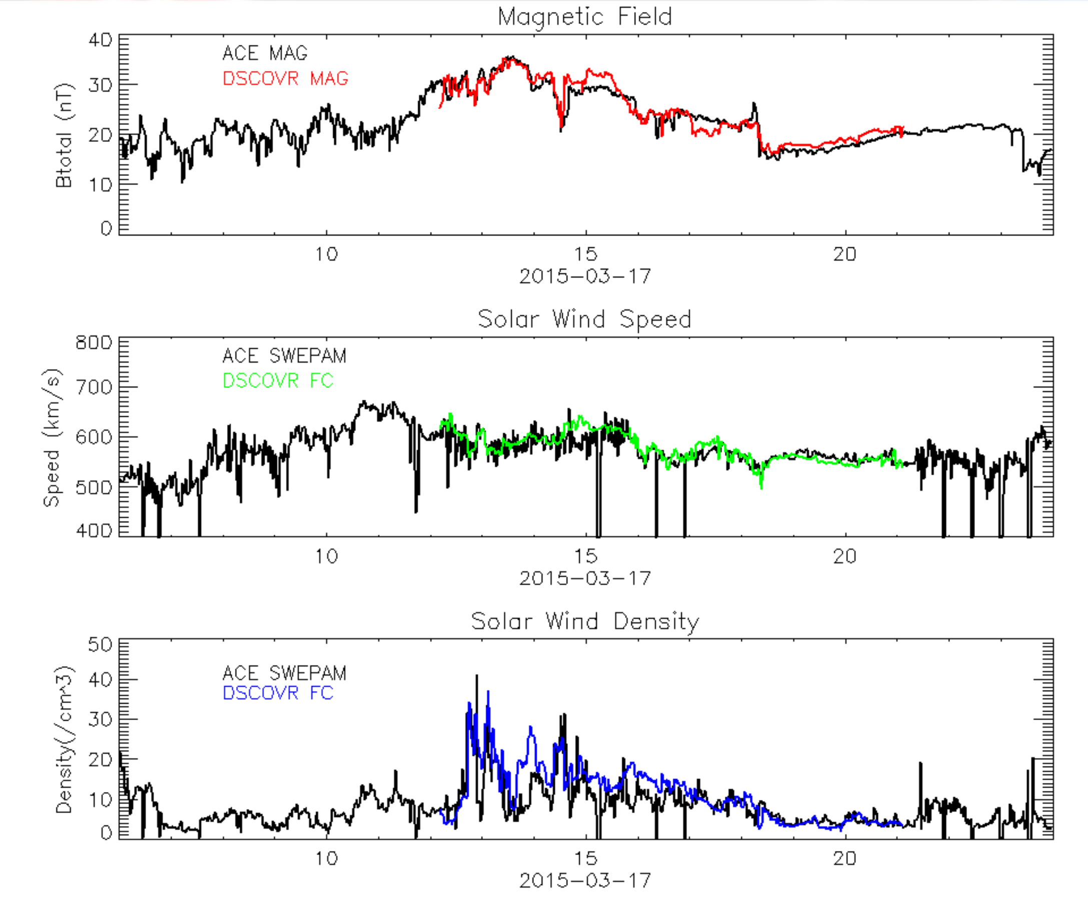
- Magnetometer (50 Hz data)
  - Hodges-Lehmann Estimator (1963)
    - Breakdown point 29%
    - Form independent pairs, including the pair of each item taken twice
      - n(n+1)/2 pairs
    - Find the median of each pair
    - Find median of the medians



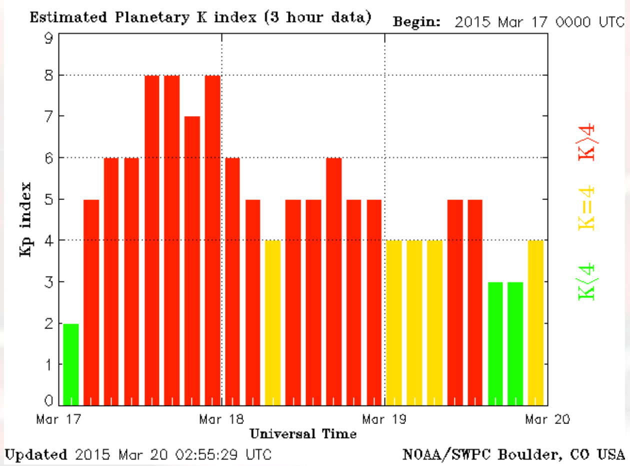
- Faraday Cup (between 0.3-25 Hz)
  - Huber M-Estimator (Huber 1963)
    - Breakdown point of 50%
    - Iterative scheme
      - Preferred for averages with fewer data points
    - Maximum likelihood type of estimator
      - Huber influence function



St. Patrick's Day Storm (17 March 2015)



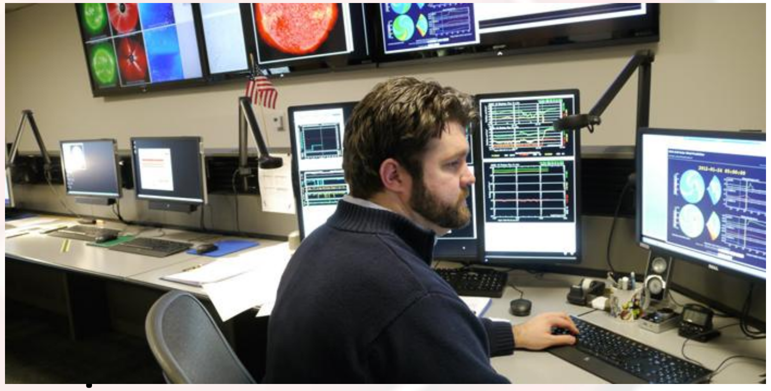
- DSCOVR and ACE overlay looks great!
- Separated by ~338,000 km in Y-Z plane
  - X-axis (radial) ~46,000 km
- Data only during US daytime hours
  - Data flow from Wallops
- Processed in real-time
  - Pre-flight calibrations only



New DSCOVR Space Weather Products

<u>Algorithms Currently in Development at NOAA/SWPC</u>

- Solar Wind Transit Time (Estimated Time of Arrival)
  - To improve prediction of solar wind structure transit time from L1 to Earth
    - onset time of geomagnetic storm warnings
    - input to models (*e.g.* geospace, ionosphere, magnetopause crossing)
- Automatic Solar Wind Regime Identification
  - To increase situational awareness for forecasters and others



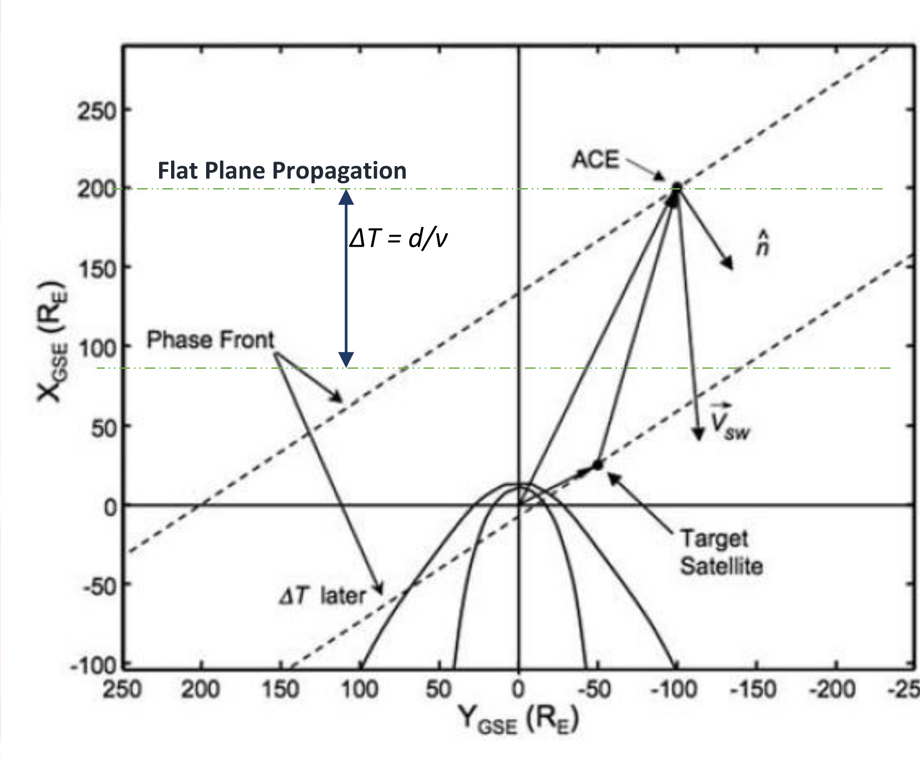
<u>Algorithm Currently in Development at NOAA/NGDC</u>

- Magnetopause Location and Geosynchronous Orbit Crossings
  - To increase situational awareness for satellite operators

<u>New SWPC Webpage for Solar Wind Data</u>

- Doing away with static images

Computing L1 to Earth Transit Time (see *Cash et al.* poster)



Bargatze et al., 2005

- Solar wind phase planes can be tilted from Sun-Earth line
- Assuming flat plane propagation results in errors in calculated arrival time of +/-15 min to over 30 min
- Errors depend on spacecraft distance from Sun-Earth line

- Use *Weimer and King* [2008] method to define the phase plane tilts:

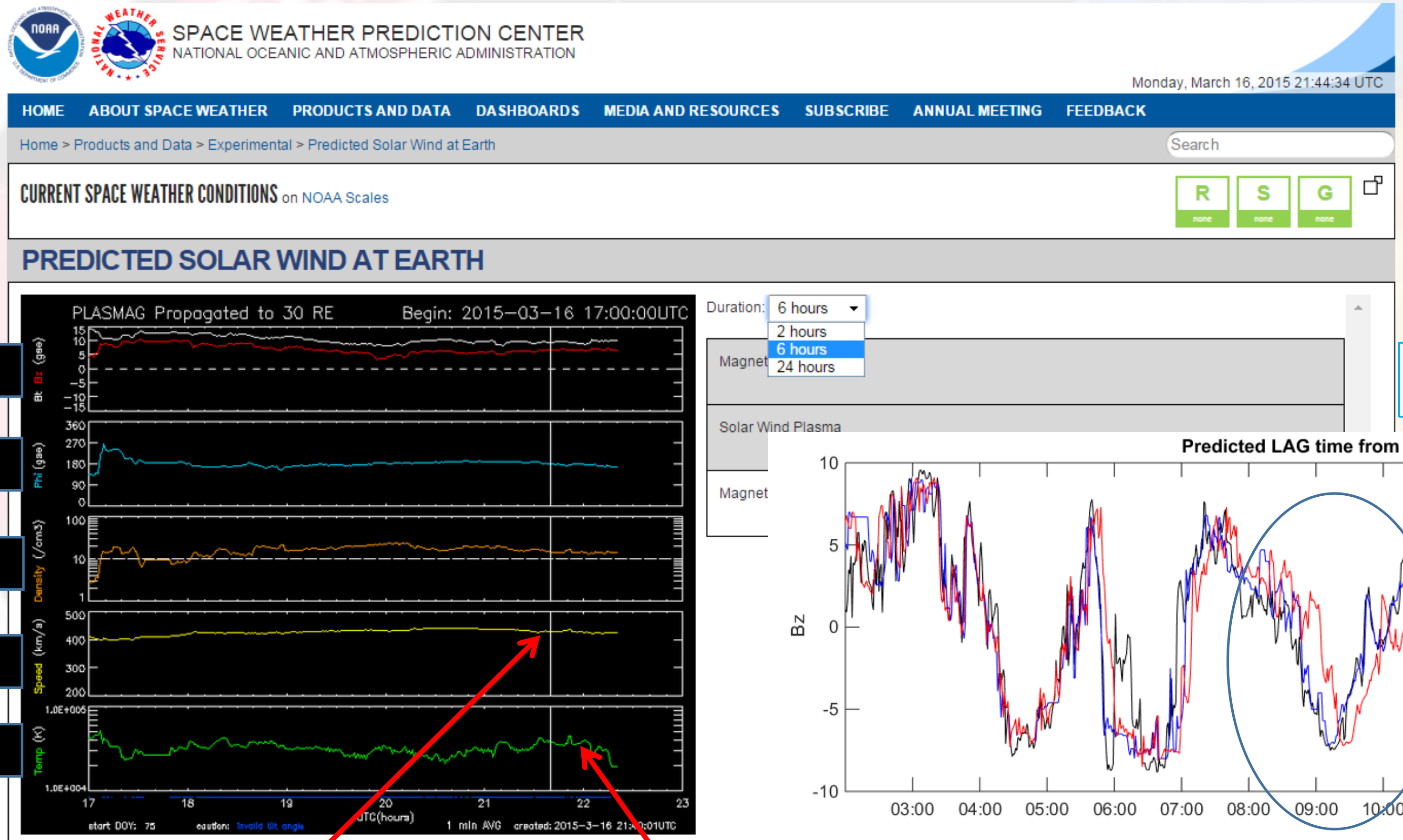
(1) Minimum Variance Analysis with B=0

(2) Cross Product Technique

Tilt angle must agree

Predicted Solar Wind At Earth

http://www.swpc.noaa.gov/products/predicted-solar-wind-earth



Bt, Bz

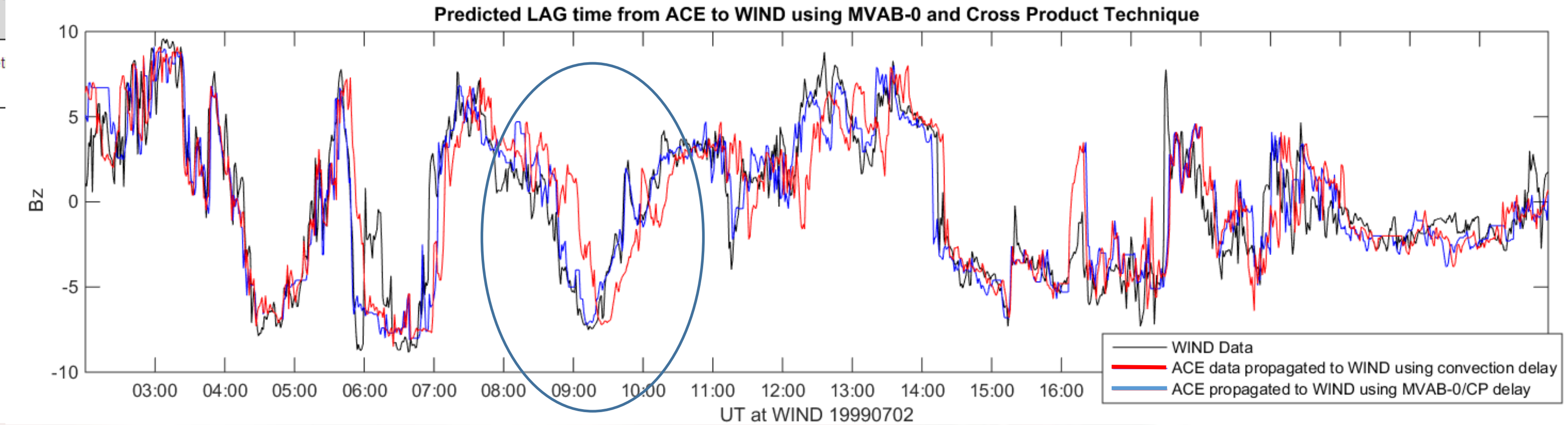
Phi

Den

Speed

Temp

Validation example



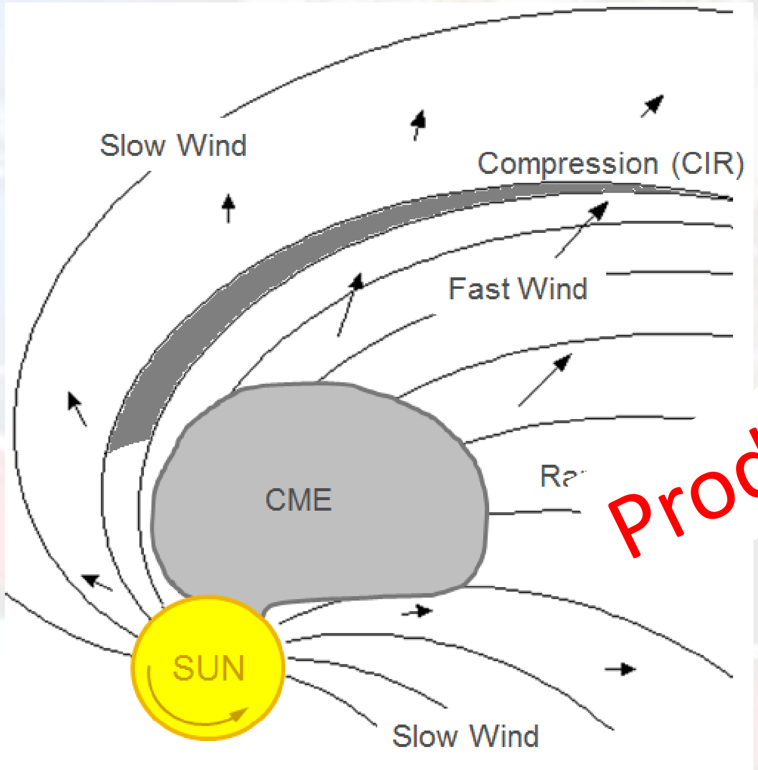
Tilted phase plane method showed statistically significant improvement

Current Time

Solar wind expected to arrive in the near future

Solar Wind Regime Identification Product

Autonomously determine the current solar wind flow regime in order to increase forecasters' situational awareness



Solar wind flow regimes vary <u>according to:</u>

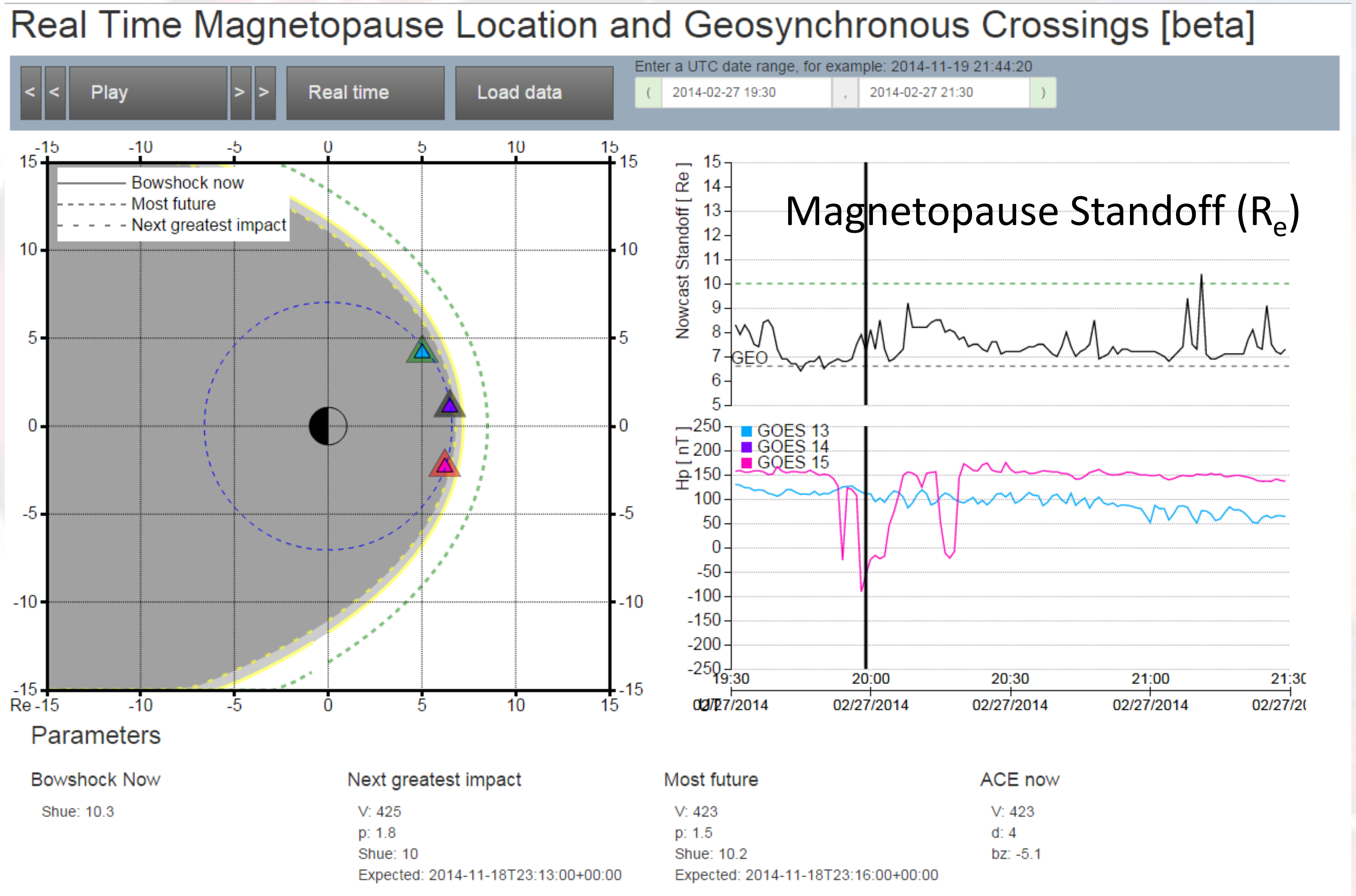
- Density
- Temperat
- Vel
- ion

Product still in development

- c-based decision tree used to tify solar wind regime in real-time
- Based on algorithm used by **Genesis** solar wind mission [*Neugebauer et al.*, 2003]
  - Changes are needed
    - won't have bi-directional e^- info
    - will use alpha particle info

Magnetopause Crossing Product

http://www.ngdc.noaa.gov/stp/mag_pause/

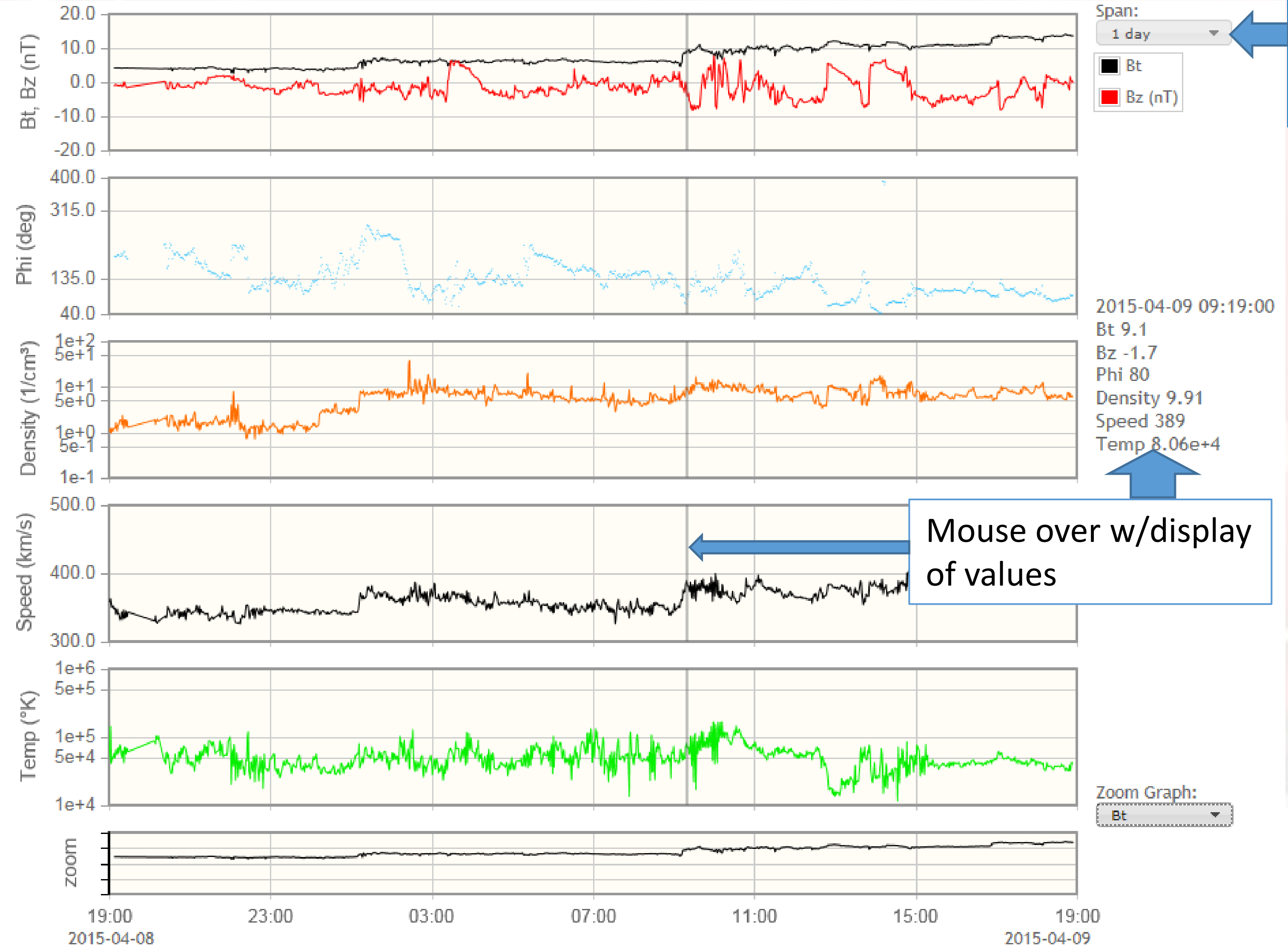


- Real-time forecast and nowcast product (beta)
  - Implementation of Shue *et al.* 1998
  - Displays GOES-13, 14, & 15
  - Driven by predicted solar wind @Earth
    - e.g. New SWPC product
  - Single click gives conditions at time selected

Prototype SWPC web page

jQuery/jqPlot

Interactive display



Choose default time span
2 or 6 hours
1, 3, or 7 days

Mouse over w/display of values

Zoom to any time range

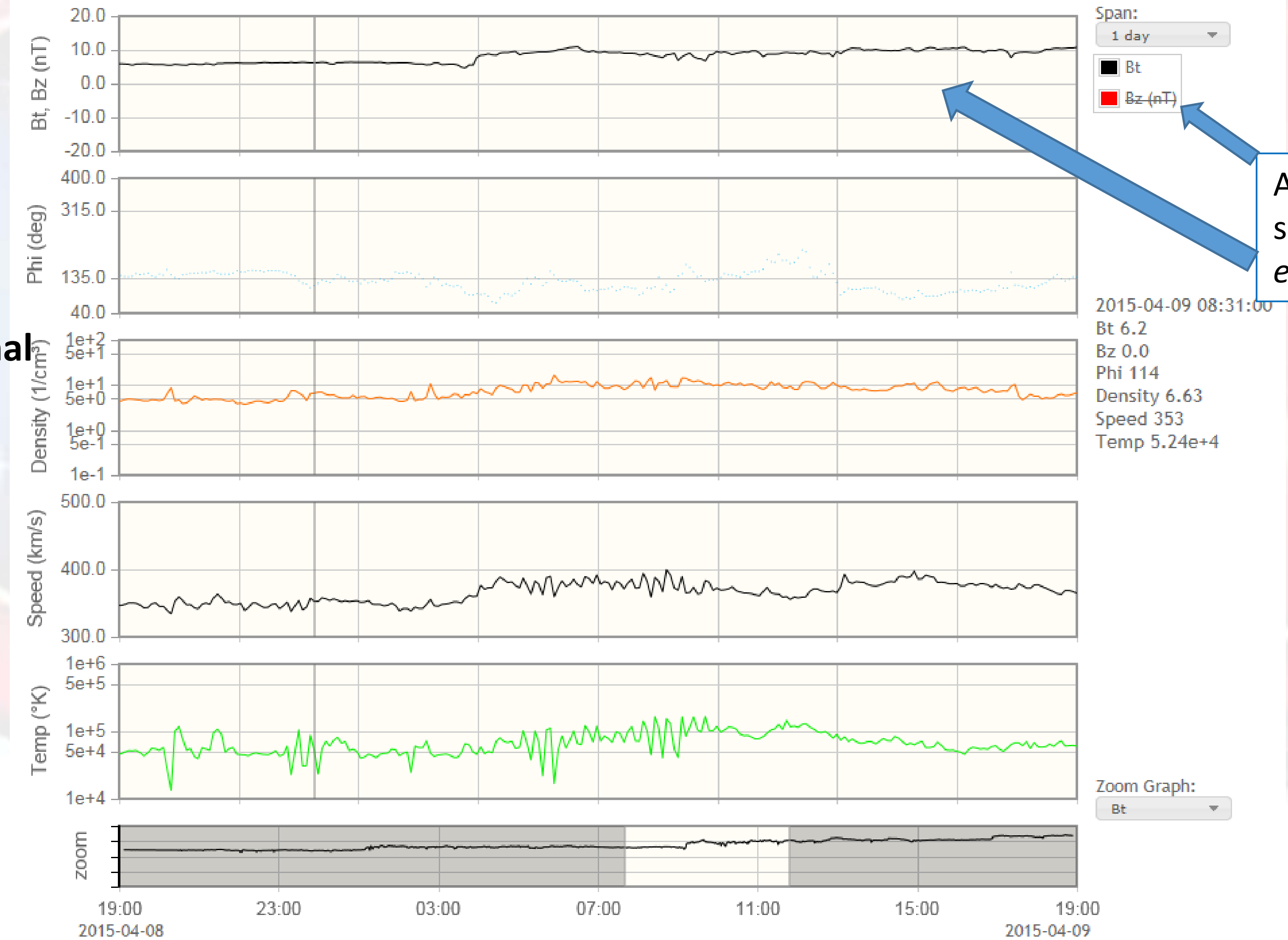
Possibly with high time resolution? 1s, 3s data TBD

Zoom in for more detail with just a click and drag anywhere on the display

Display only the data you want?

Prototype w/ACE available in May?

Expect several iterations before DSCOVR operational date



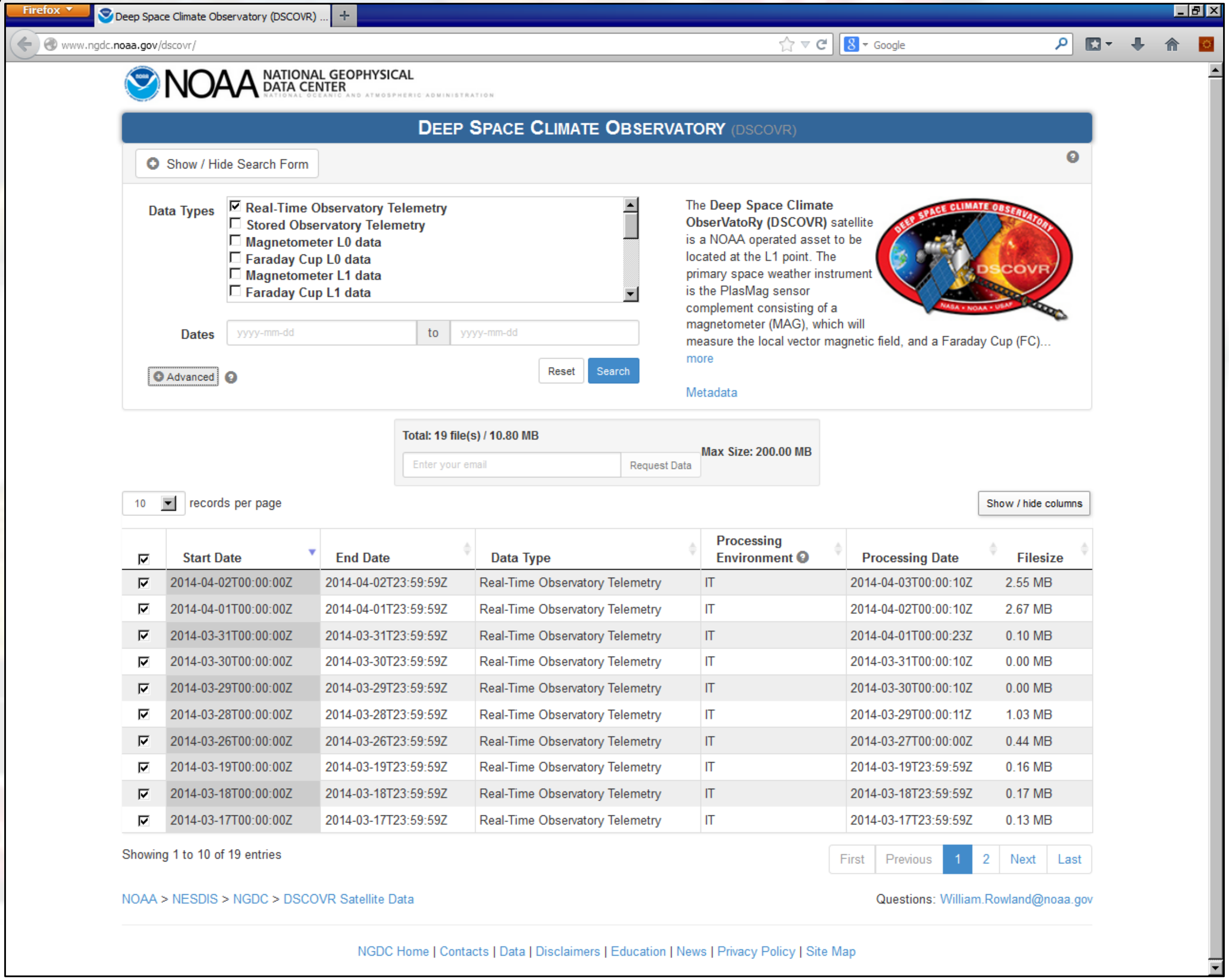
Add/Remove Variables with single click
e.g. Bz

Archive at NOAA/NGDC
(see poster by Rowland *et al.*)

- Reliable and maintainable archive process
  - DSCOVR dataset is one of the first to use NGDC's enterprise Common Ingest
- Generated high quality collection-level metadata
  - ISO compliant at NGDC
  - SPASE compliant entries for VIRBO
- Worked with SWPC to ensure useful documentation within granules
  - "Great! This is some of the best NetCDF I've ever seen" – Anna Milan

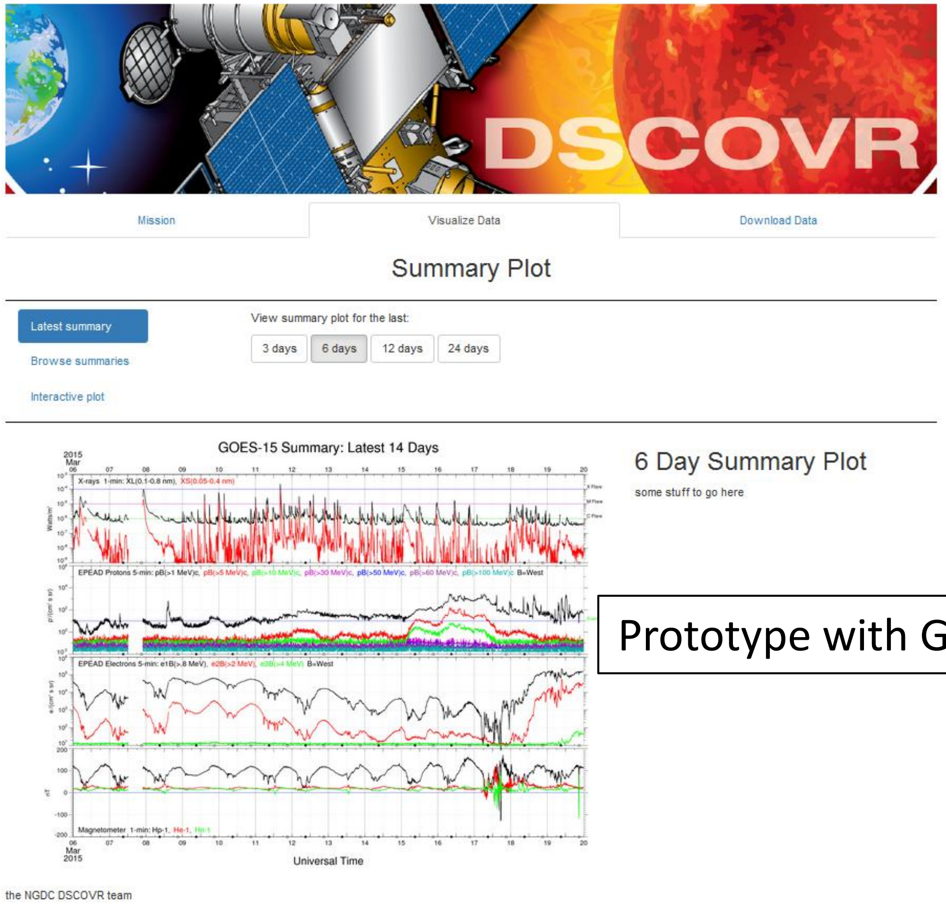
NGDC Asynchronous Access

- Data are accessible via the NGDC EXTract (NEXT)
- User friendly UI
  - Likely basis for other Time-series data sets.
- Further work is planned to expand search capabilities



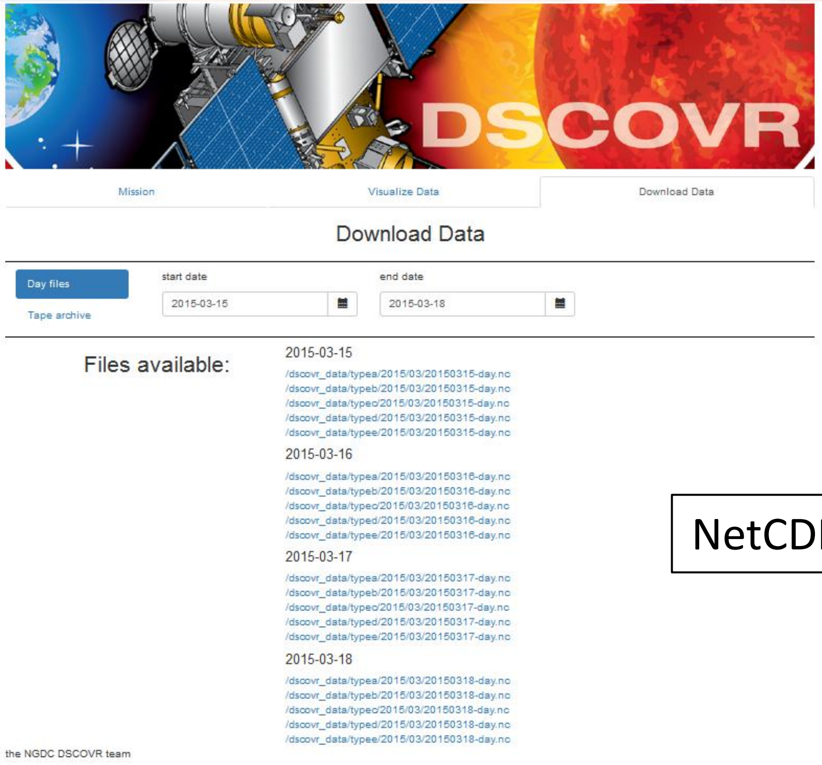
NGDC Synchronous Access

Data Visualization



Prototype with GOES data

Data Download



NetCDF files

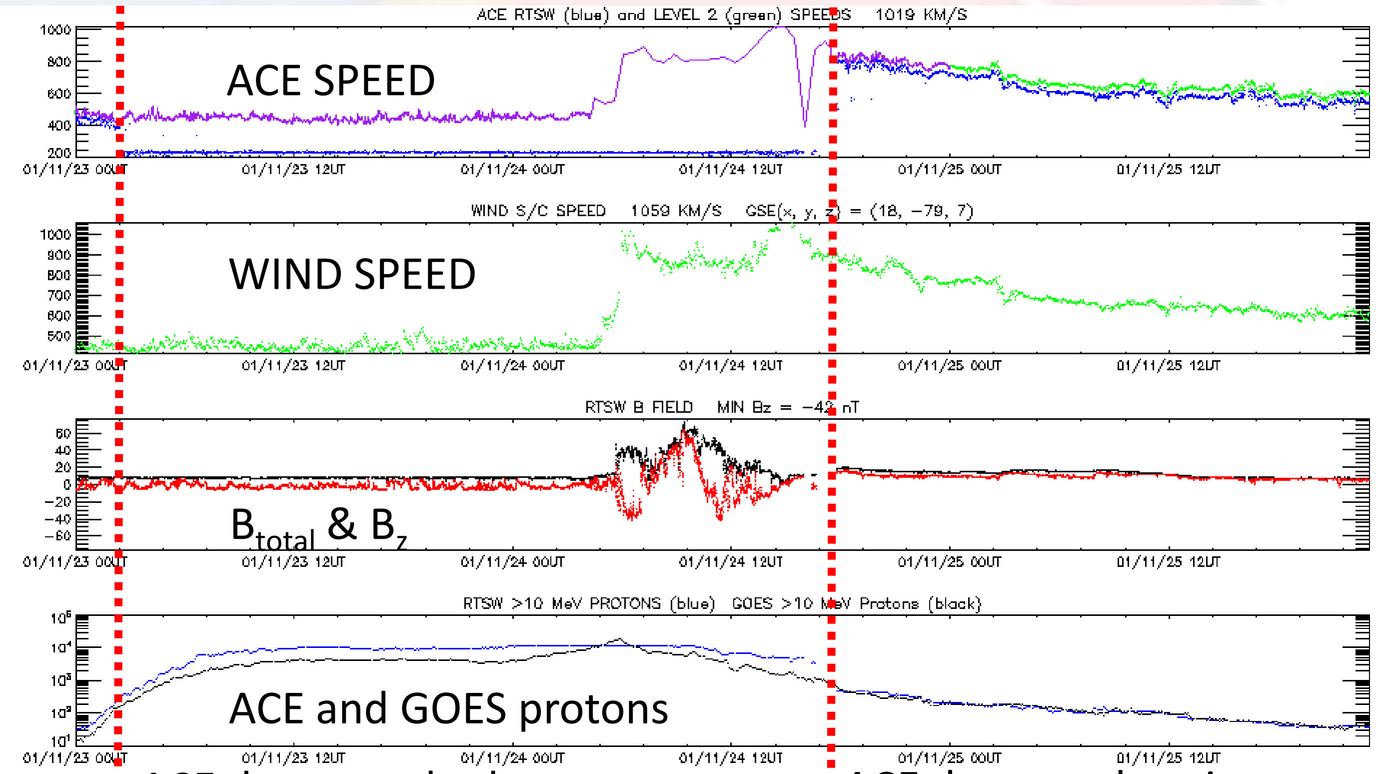
ACE in Real-Time vs DSCOVR
(see Biesecker *et al.* poster)

- Selected all geomagnetic storm events from 1998-2012 meeting ‘any’ definition of severe or extreme.
  - NOAA Scales: Kp >=8- (Severe); Kp=9 (Extreme)
  - Other indices: Dst<=-150 nT; Running Ap >=100
- 44 events meet 1 or more of the above criteria
  - 21 meet Kp, Dst, and Ap criteria
  - 3 events meet Kp=9 (extreme)
- Two main concerns
  - DSCOVR doesn’t fully meet SWPC velocity requirement
  - ACE V, n, T real-time processing fails during proton events

ACE SWEPAM Contamination Issues

- Large proton events confuse the ACE SWEPAM on-board algorithm
  - Skoug *et al.* 2004, Machol *et al.* 2013
- Results in loss of solar wind velocity, density and temperature data
- Blue – Real-time ACE
- Purple – Reprocessed ACE
- Wind worked throughout the event
  - Wind SWE and DSCOVR FC are equivalent instruments
- Identified 23 instances of significant contamination issues impacting ACE SWEPAM

2001-Nov-24

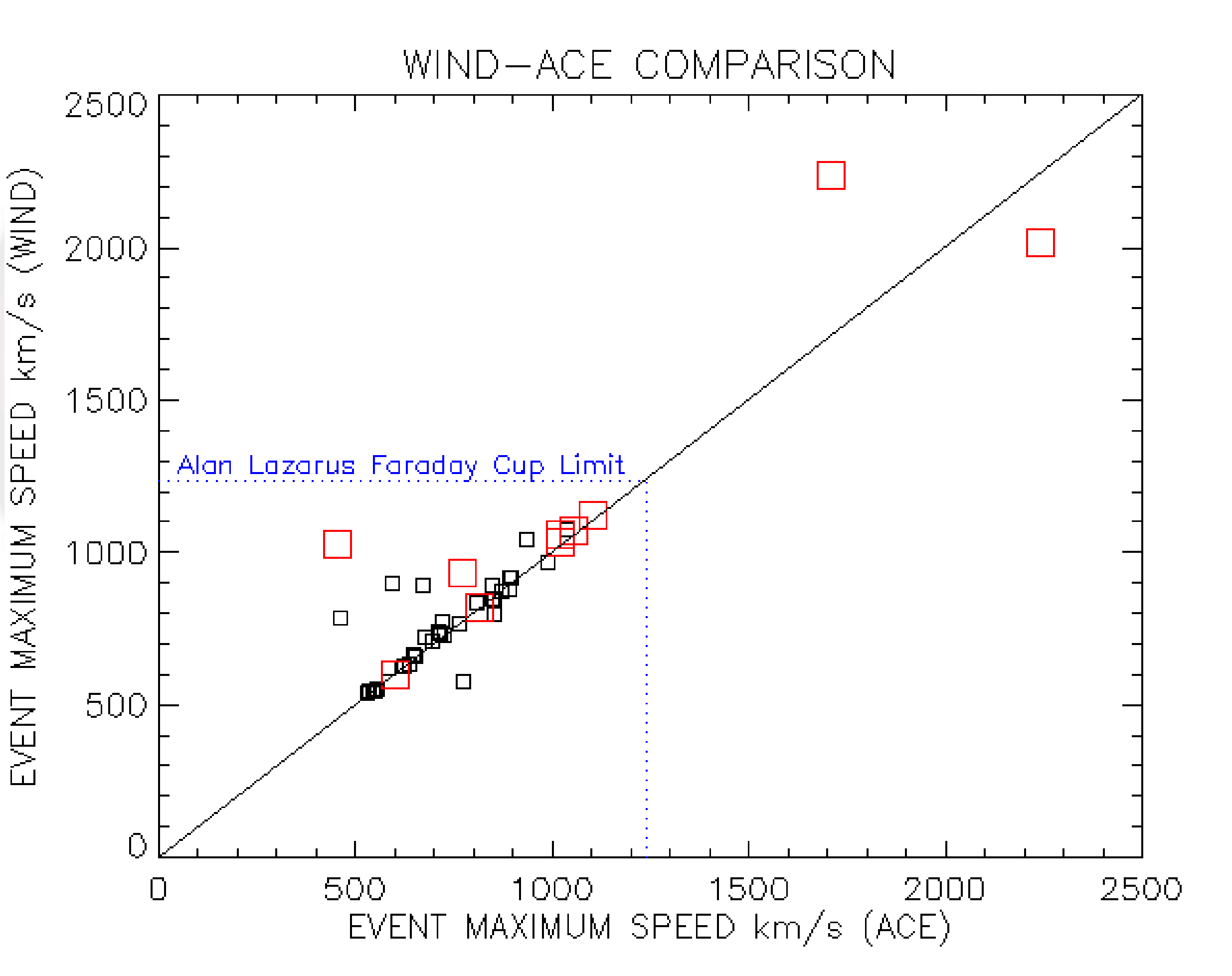


ACE data goes bad

ACE data good again

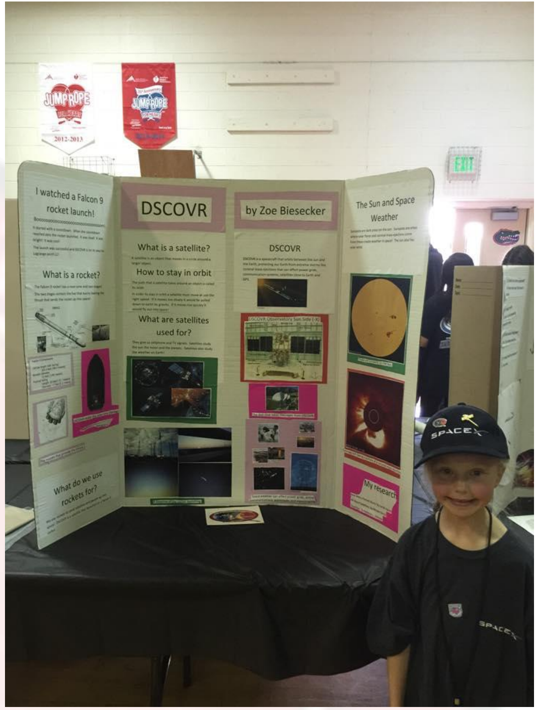
K_p=8+; Dst=-221 nT, A_p=103

DSCOVR Velocity Limit



- DSCOVR limit of 1238 km/s
  - Violated only twice from 1998-2012
    - Halloween storms (10/28 & 10/30)
    - ACE failed on these events as well
  - ACE returned bad data for 10 of 44 severe or extreme events
    - Large red squares
  - In real-time ACE only observed speeds in excess of 1238 km/s once
    - Max of 1280 km/s on 31 Oct 2003

Summary



- DSCOVR is on its way and looking good
- DSCOVR will provide more reliable real-time data
- Access to data in real-time will be up to modern standards
- The new products mentioned here are available now or will be soon
- More products will be available in the years to come thanks to generous funding from NOAA
- Real-Time Solar Wind data brought to you, as always, by
  - (NICT) National Institute of Information and Communications Technology
  - (KSWC) Korean Space Weather Center
  - (DLR) German Aerospace Center
  - (USAF) Air Force Satellite Control Network
  - (NOAA)

Backup slide (30-Oct-2003)