Van Allen Probe EFW Measurements of SC Charging

J.Wygant and Van Allen Probe EFW Team

Some Examples of Strong Sunlight Charging
(There are more- check survey plots- panel 5)

Values below are Vsensor – V sc, that is since the values are positive the SC is charging negative)

9/19/2012 40 V

9/30, 2012 40 V

10/13, 2012 140 V_

11/01/2012 140 and 200 V (sensor saturation)

11/14./2012 180 V

3/17/2013 200V (sensor saturation)

We have been lucky.. the power supply rails for our pre-amplifiers are +/-200. We have only exceeded these values for a few hours over the mission.

Van AllenProbe's EFW Instrument Overview

RBSP EFW Features

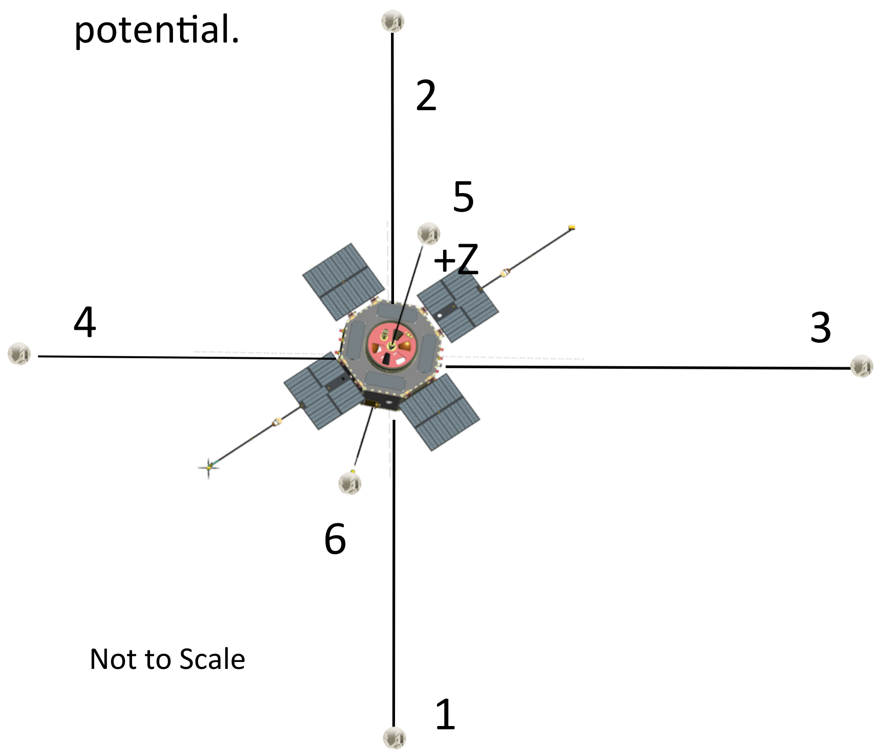
Four spin plane booms (2 x 40 m and 2x 50 m)

Two spin axis stacer booms (2 x 6 m)

Spherical sensors and preamplifiers near outboard tip of boom

Flexible boom cable to power sensor electronics & return signals back to SC

Sensors are current biased by instrument command to be within ~ 1 volt of ambient plasma potential.



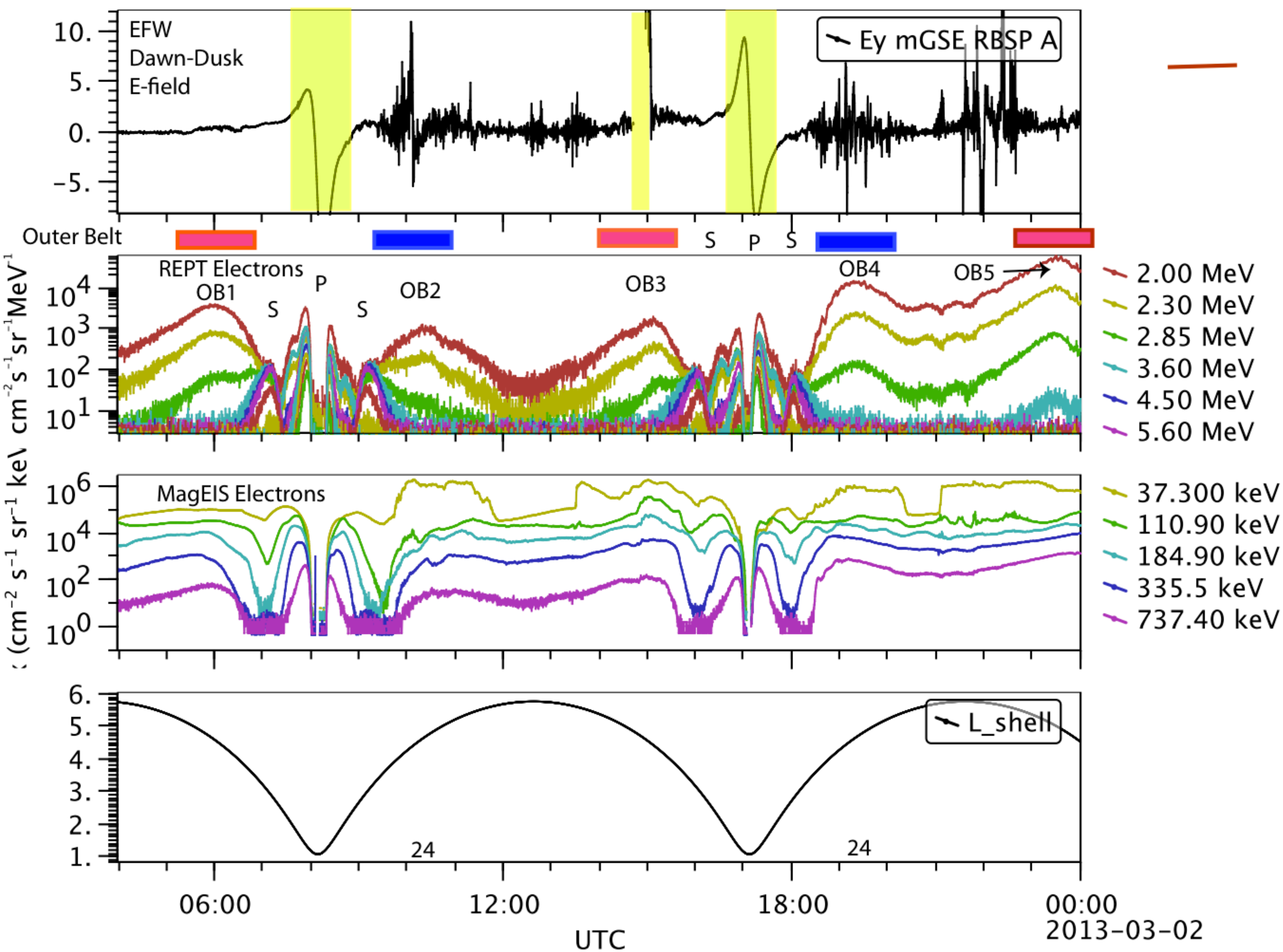
Not to Scale

EFW CPU controll sensor current bias so probes float 1-2 volts negative relative to plasma when photo-emission dominates plasma electron current.

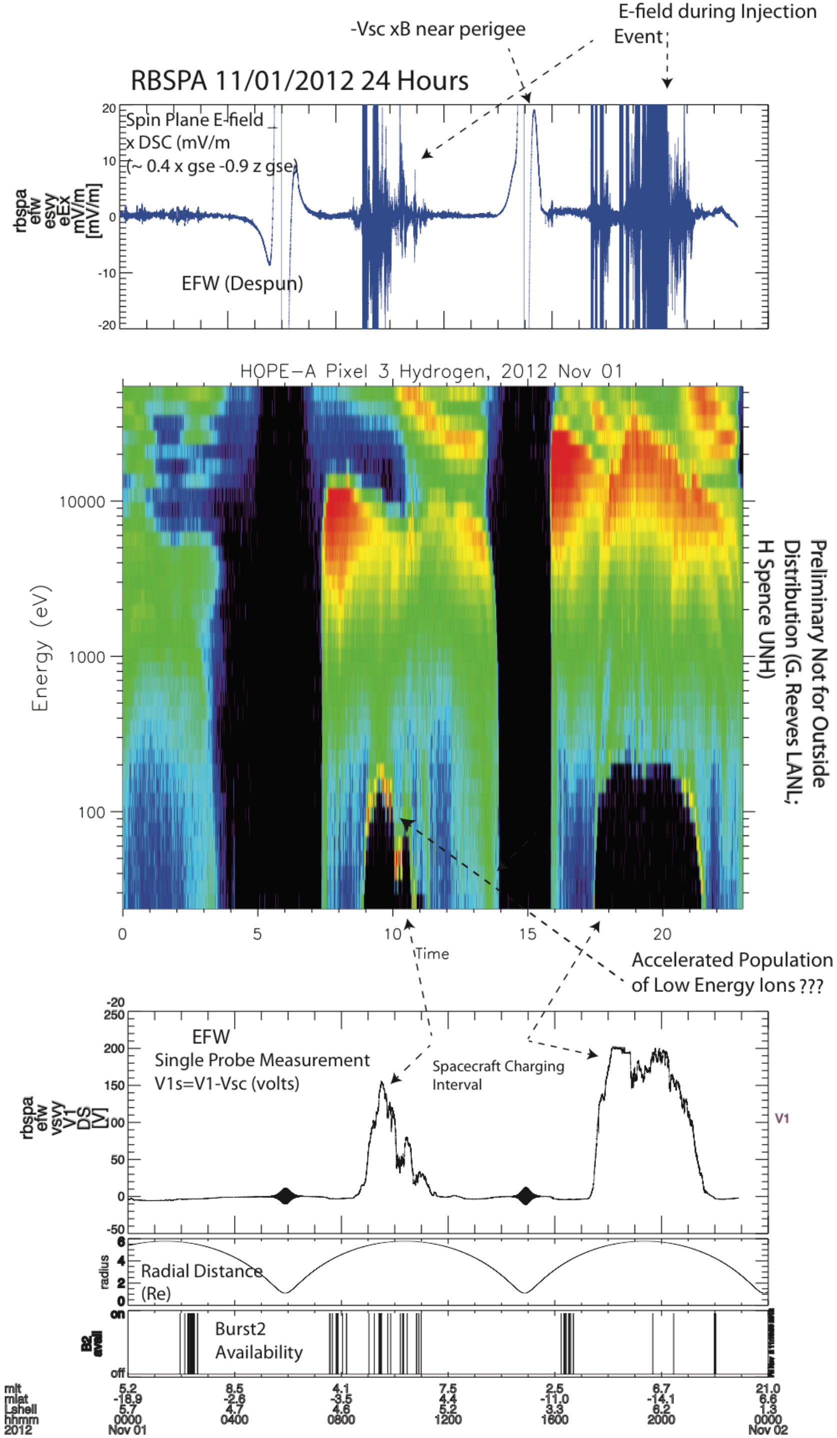
Relevant EFW Science quantities include:

- E-fields:(V1-V2, V3-V4, V5-V6)
- SC-sensor potential (V1s, V2s, V3s, V4s, V5s, V6s)
- SC Potential : (V1+V2)/2, (V3+V4)/2

Electrostatic cleanliness spec: variations of potential across spacecraft surfaces smaller than 1 Volt.



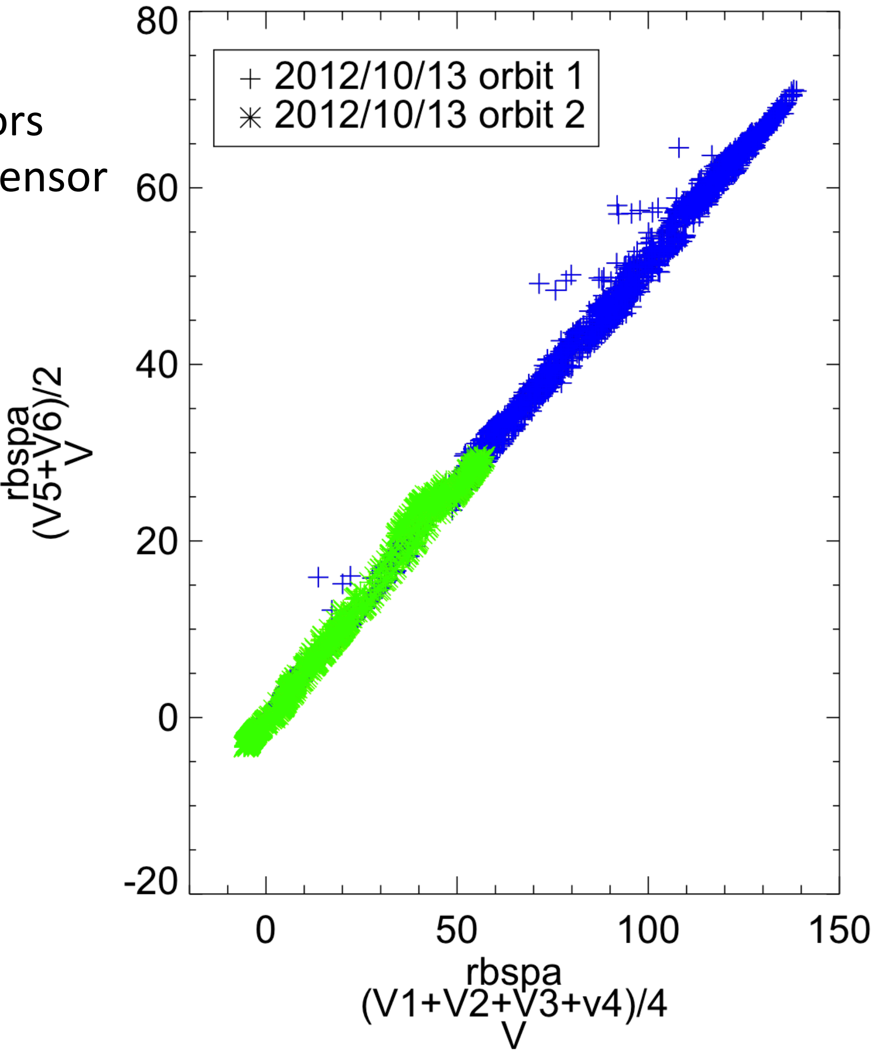
EFW
Dawn-Dusk
E-field
Ey mGSE RBSP A
Outer Belt
S P S
REPT Electrons
OB1 S P S OB2 OB3 OB4 OB5
2.00 MeV
2.30 MeV
2.85 MeV
3.60 MeV
4.50 MeV
5.60 MeV
MagEIS Electrons
37.300 keV
110.90 keV
184.90 keV
335.5 keV
737.40 keV
L_shell
24
24
06:00
12:00
18:00
00:00
2013-03-02
UTC



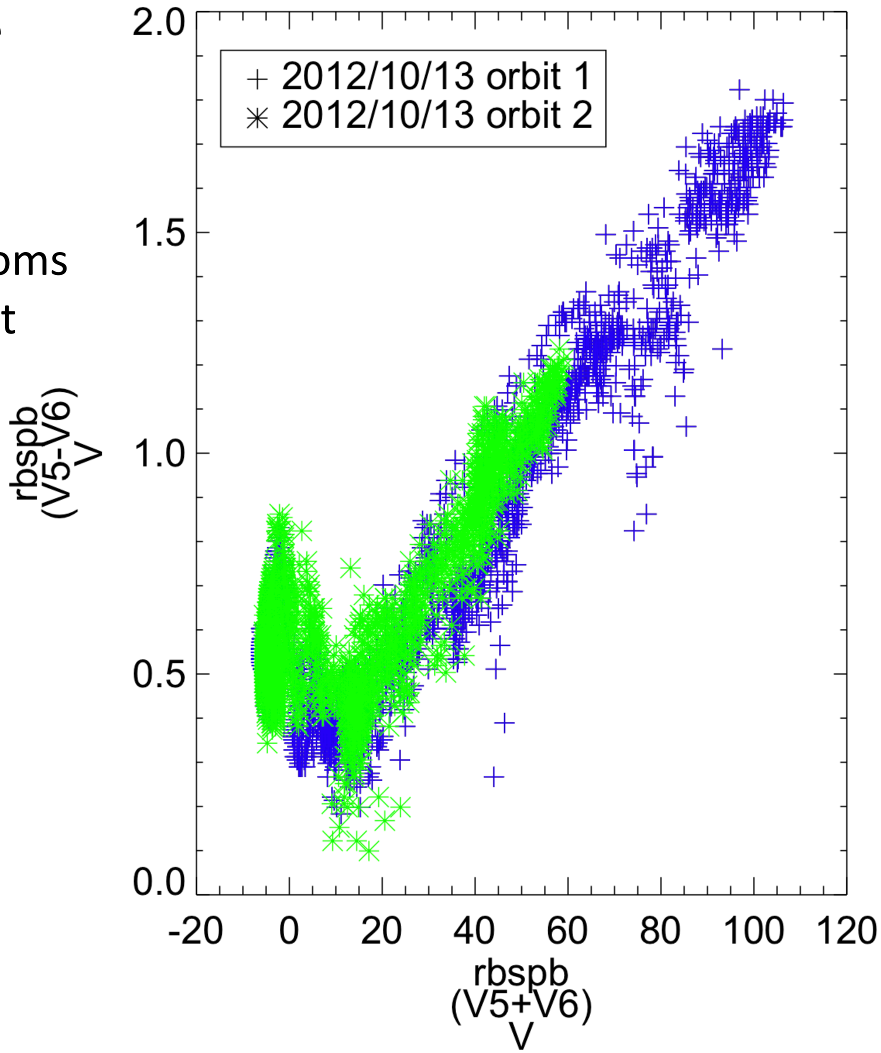
One Day of Van Allen Probe Measurements during a large storm Plot (9 hour orbital period)

Comparison of Hope Ions to EFW measured Spacecraft Potential shows both see about the same spacecraft potential

Sum of Spin axis sensors
vs sum of Spin plane sensor
Slope ~0.5

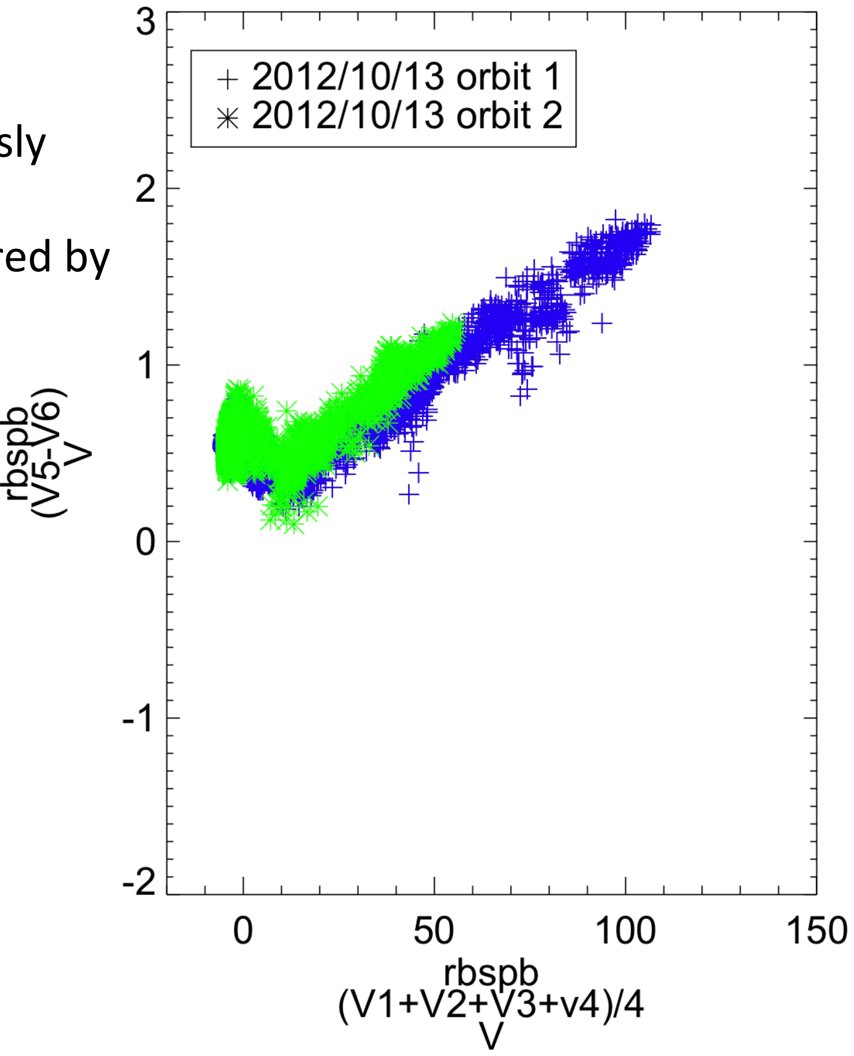


Differential charging
ss measured by the
Fore and aft spin plane
Booms (4 m long) is
small compared to
total charging otential
measured by same booms
It also scales somewhat
Systematically.
It is an error source
that must be modeled
and subtracted



Differential charging is much less than common mode charging

Similar plot as previously
This time v5-v6 vs
Total potential measured by
50m spin plane booms



Differential Charging is much smaller than common mode (using spin plane booms)

Summary

There have been a number (50) of major (<-10 V) spacecraft charging events observed by EFW during the commissioning phase of the mission

The charging events occur in daylight, on the morning side, outside the plasmasphere, near apogee and during strong magnetic activity associated with major geomagnetic storms. AS the apogee precessed arround to the dusk sector the incidence of spacecraft charging decreased sharply. They are associated with injection of 100 eV-1 keV electrons which drift dawnward. There have very few charging events on the dusk side.

The magnitude of the best studied charging event exceeded 100 volts and occurred on October 13, 2012.

The typical duration of the charging events is 1-4 hours.

During the October 13 event, RBSP_A observed the charging event for several hours and then as spacecraft B moved into position it was also subject to charging.
The total combined duration for the two spacecraft is ~6 hours.

For some of the early charging events, the EFW sensors floated to their power supply rails (+/-200 volts)- due to larger than necessary bias currents to the sensors.

When the sensor bias current was decreased the probes were much less vulnerable to the charging, did not saturate, and continued to make good measurements .

Most simulations which result in spacecraft charging in sunlight invoke a non-conducting spacecraft which is driven by plasma electron currents less that the photo-emission current. The non-conducting spacecraft leads to extreme differential charging (100 V to kV).

It has been predicted that large spacecraft charging can not occur in sunlight if the spacecraft is sufficiently conducting.

- The differential charging contribution (1%-3%) as measued by the spin axis booms on the sunlit and dark side of the spacecraft is small compared to the total spacecraft potential variation.

- For the above reason, our tentative conclusion is that the observed charging is caused by large fluxes of electrons those total current significantly exceeds that of the photo-emission saturation current.

Some Points To Consider ....

1) We measure and plot the NEGATIVE of the spacecraft potential relative to a fixed biased probe. (Vi=Viprobe-Vsc). So every thing on the plots is reversed from what you might expect.

2) For example, the spacecraft charges to NEGATIVE potentials because of the strong electron thermal flux from the plasma. This produces a POSITIVE excursion on the plots of V1 or (V1+V2+V3+V4)/2. Don't be confused!

3) When we plot (V1+V2)/2 or (V1+V2+V3+V4/4) we have eliminated the electric field signal which is differential.

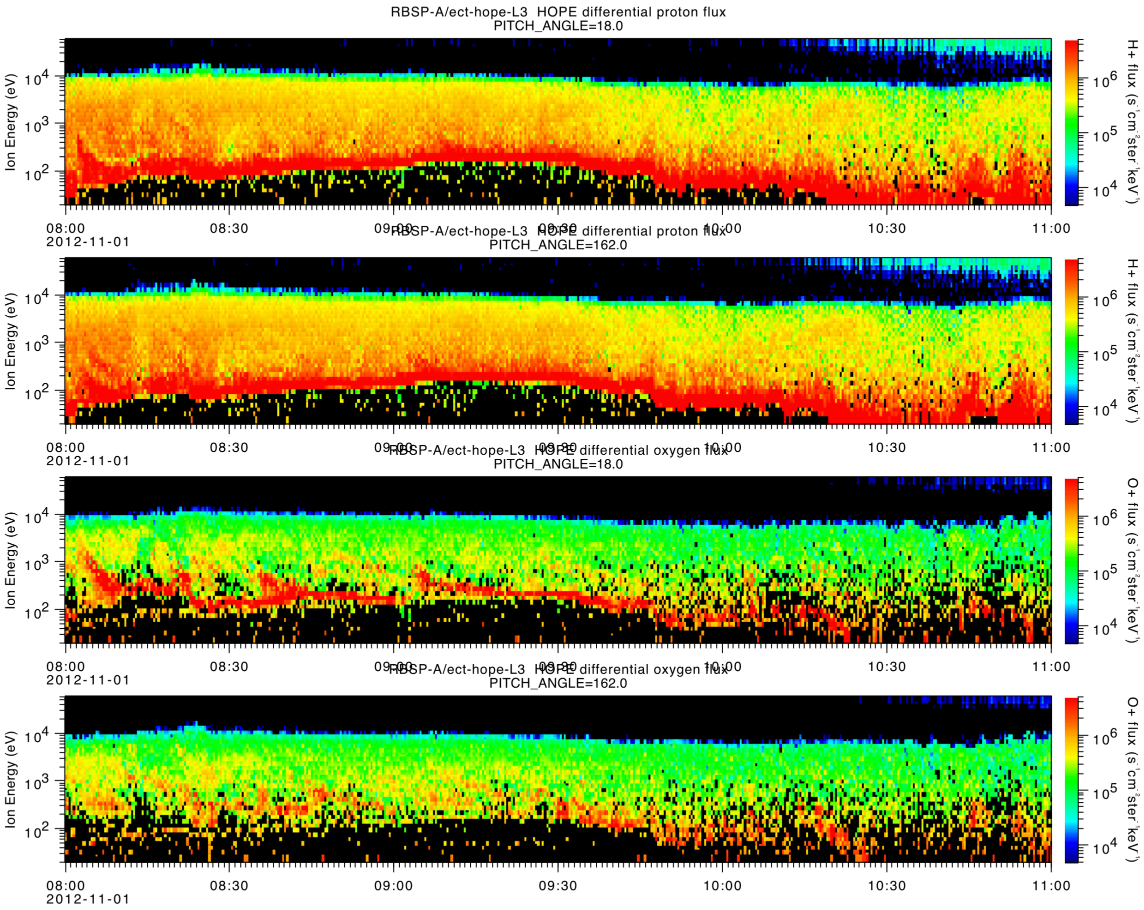
4) It is important to remember the interesting quantity is the spacecraft potential relative to the plasma (infinity?). But we measure the spacecraft potential relative to a fixed biaseded probe. Usually the probe is a stable reference, but occasionally it is not.

.

Some Points Continued ....

5) We can compare the Vsensor-Vsc value that EFW measures to that of the plasma instrument (HOPE) instrument see if the the value of the spacecraft charging corresponds to the Vsensor-Vsc that we measure. Usually it is not too bad

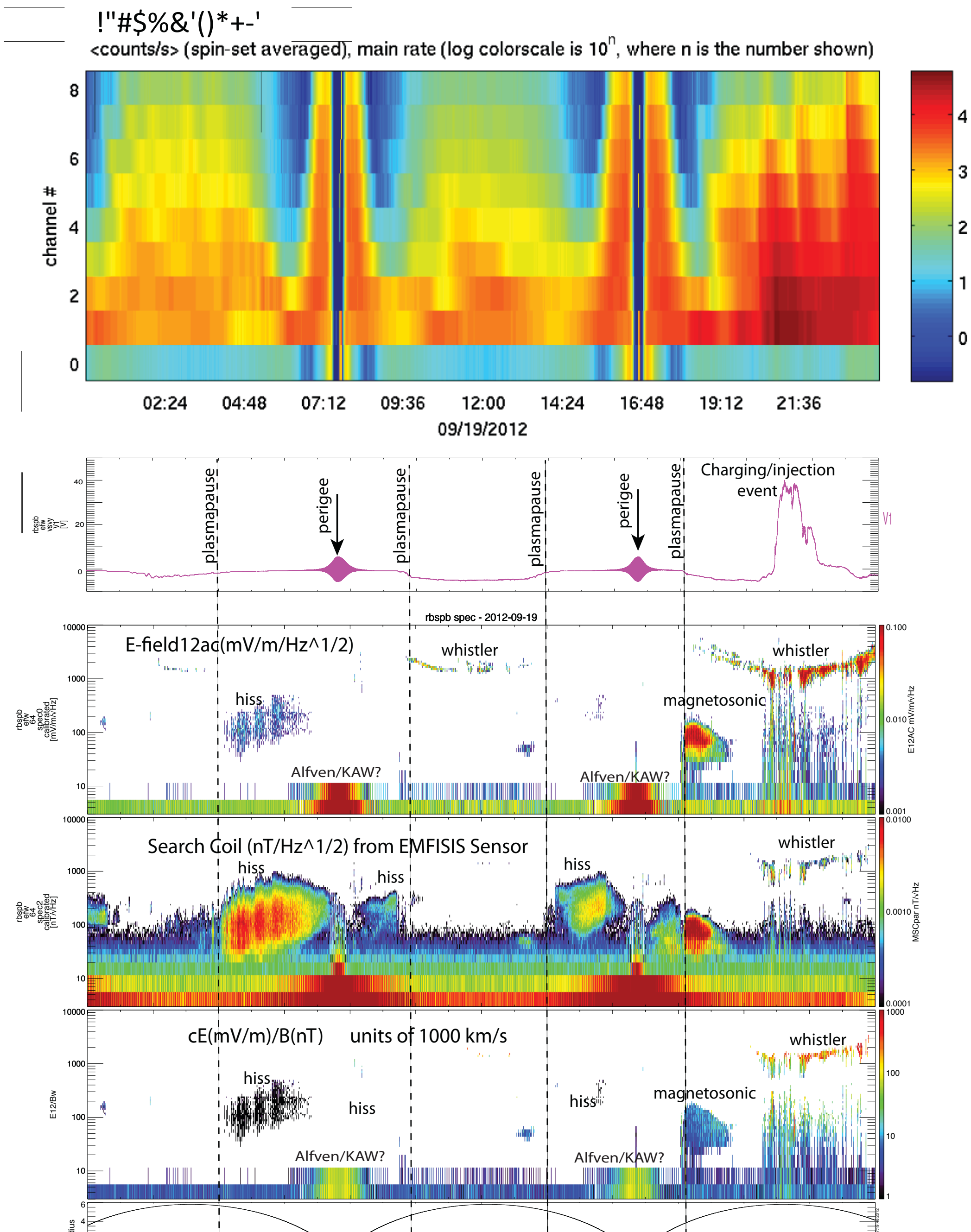
6) The reason why these current biased sensors are usually stable compared to the SC isa fact that we don't completely understand. It probably involves the secondary emission properties of the sensors relative to that of the spacecraft . But we don't know for sure.



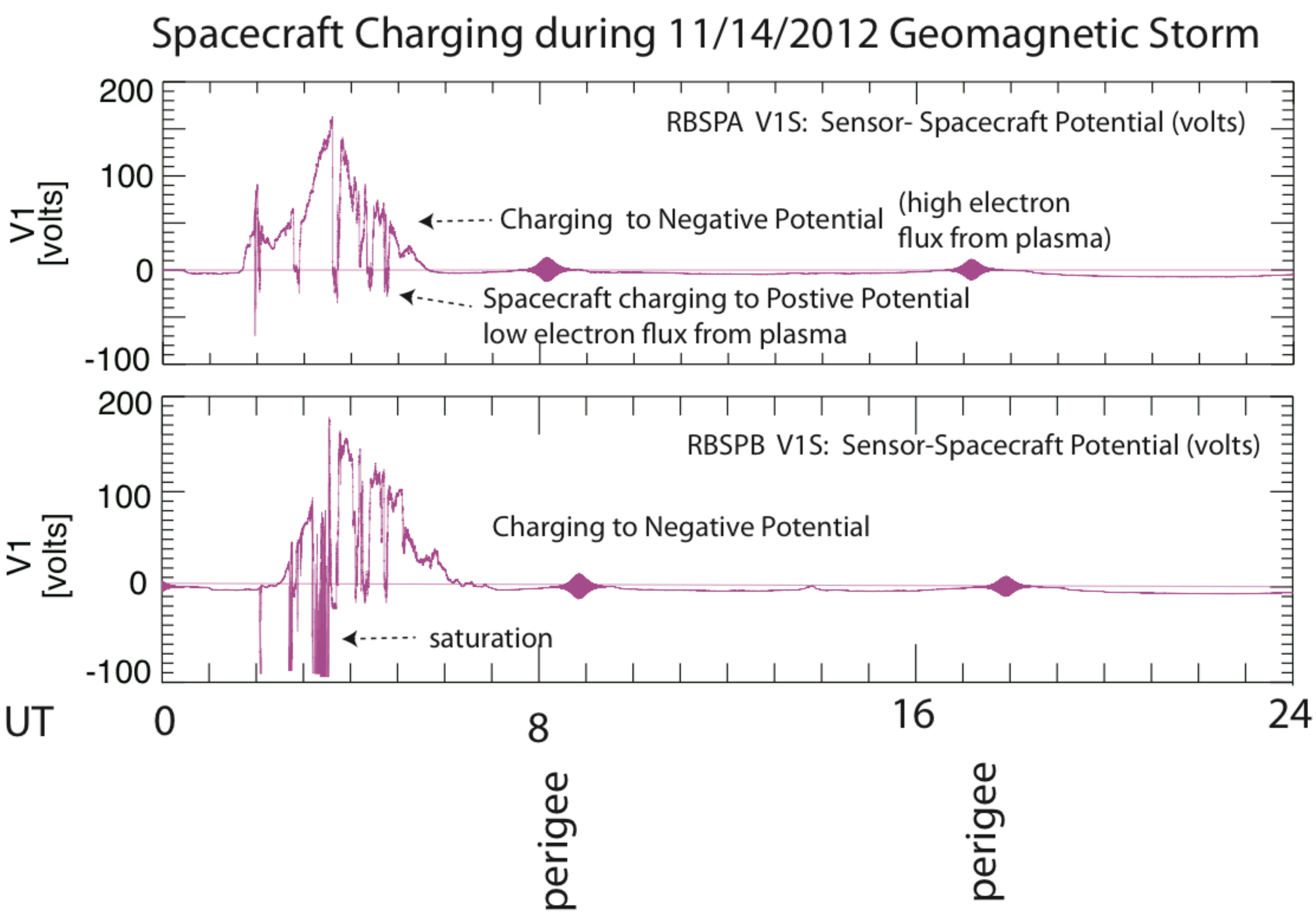
Measurements of of H+ and O+ fluxes from plasma instrument

1) Lowest energy ions observed track spacecraft potential as measured by EFW

2) Cold ion population accelerated up to SC potential.


!"#$%&'()*+-'
<counts/s> (spin-set averaged), main rate (log colorscale is 10^n, where n is the number shown)
channel #
02:24
04:48
07:12
09:36
12:00
14:24
16:48
19:12
21:36
09/19/2012
plasmapause
perigee
plasmapause
plasmapause
perigee
plasmapause
Charging/injection event
V1
rbspb spec - 2012-09-19
E-field12ac(mV/m/Hz^1/2)
whistler
hiss
whistler
magnetosonic
Alfven/KAW?
Alfven/KAW?
E12AC mV/m/√Hz
Search Coil (nT/Hz^1/2) from EMFISIS Sensor
whistler
hiss
hiss
hiss
MSCpar nT/√Hz
cE(mV/m)/B(nT)
units of 1000 km/s
whistler
hiss
hiss
hiss
magnetosonic
Alfven/KAW?
Alfven/KAW?
E12/Bw

Spacecraft Charging Structure and Timing When Probes Are Close Together: Propagation of Boundary Fluctuations and Plasma Sheet Dynamics



A and B separation ~4000 km in azimuth near apogee during charging event

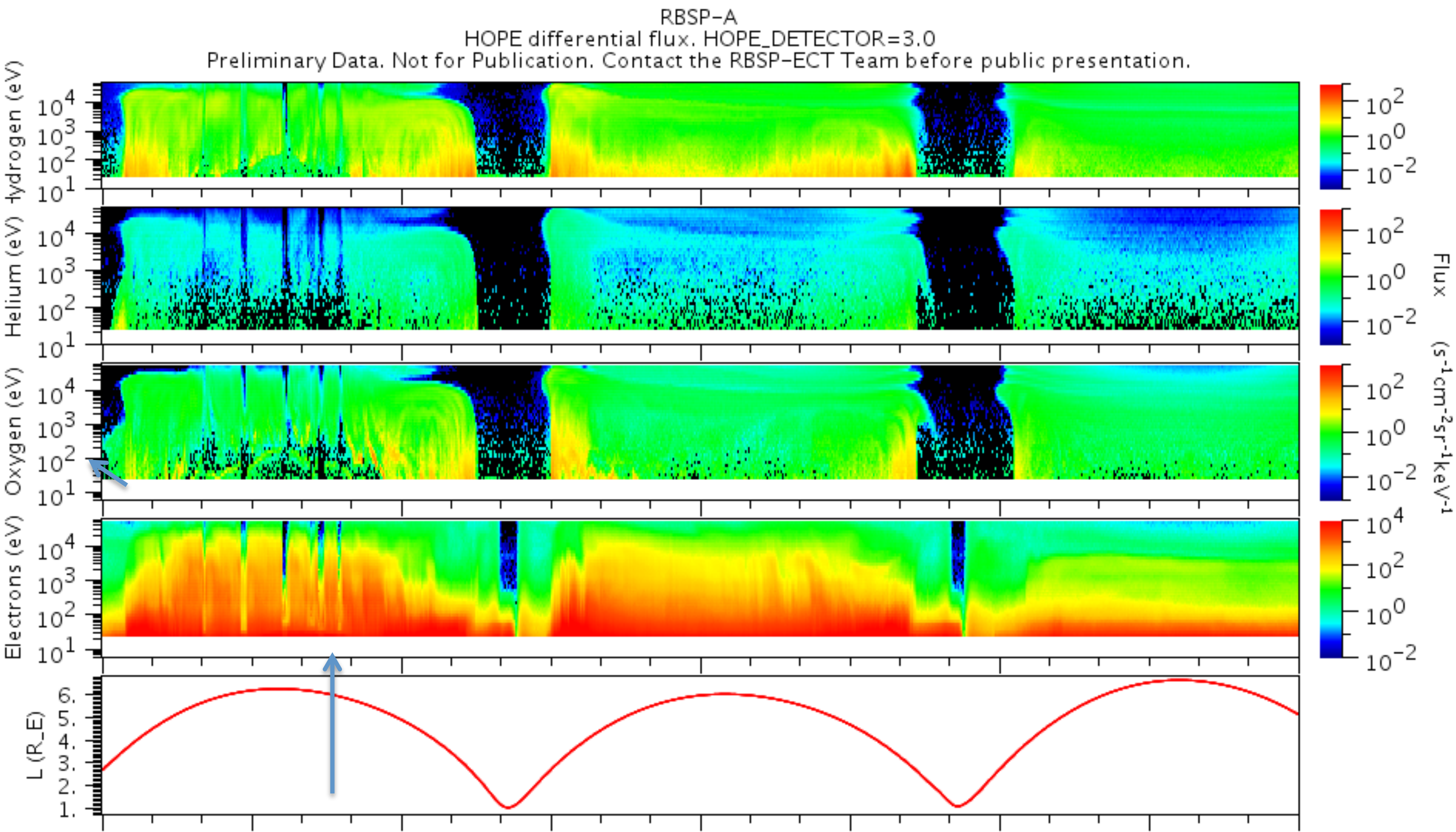
Duration of charging ~4 hours.

Over all charging profile interrupted by brief intervals of charging to negative potential seen by both spacecraft.

Time B and A time delay consistent with sunward velocity off 25-50 km/s

Associated with strong diamagnetic cavities

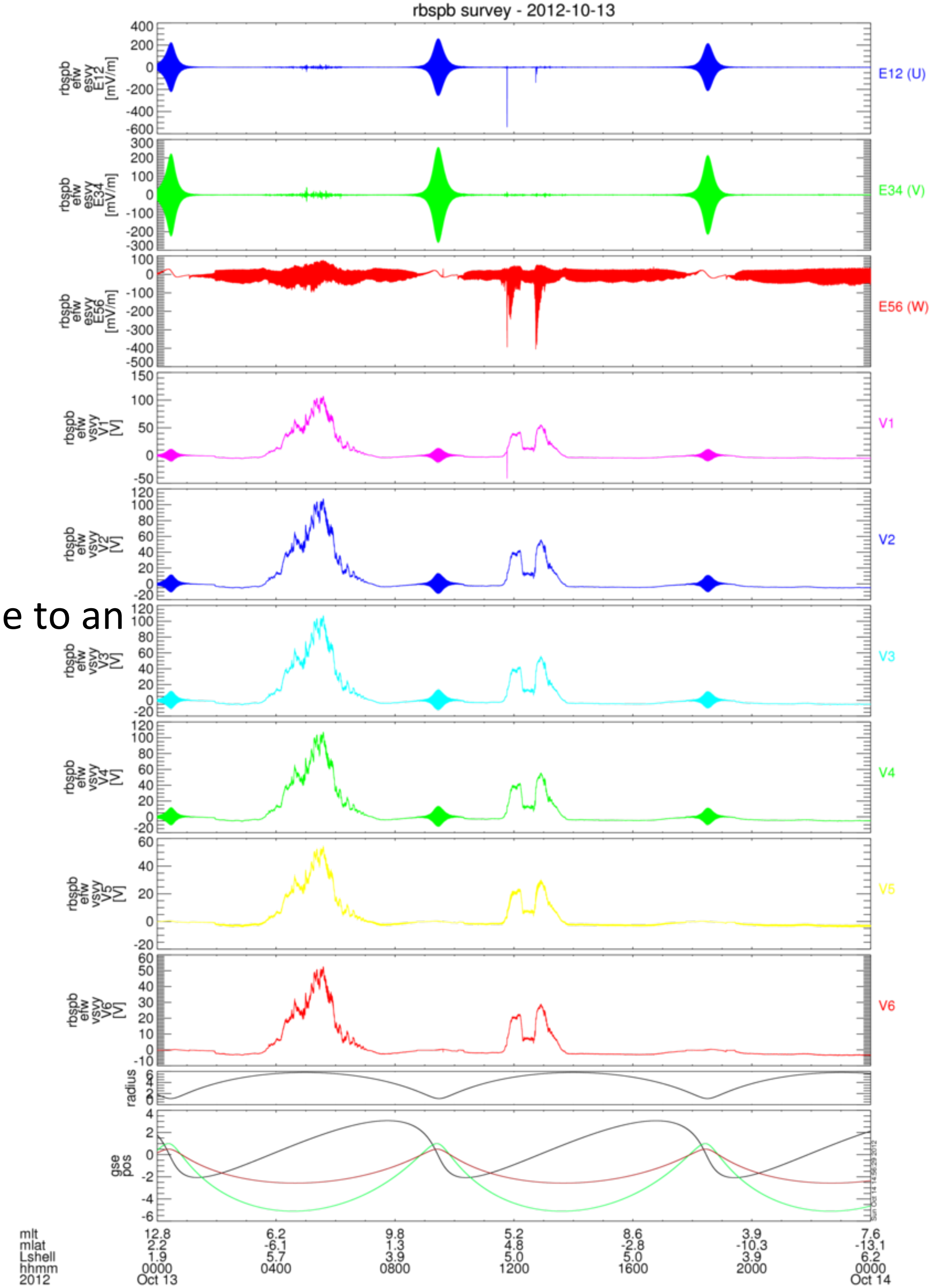
HOPE survey plots on 11/14 storm peak showing plasma drop-outs associated with entry and out of plasma sheet



RBSPb October 13
Charging event
To +120 V

(V5-V6) scales with V1234
Some of this is SC potential structure asymmetry.
A small portion is due to an axial electric field

After bias adjust to -40 nA (before it was -70 nA



RBSP_b
October 13, 2012
0-24 UT

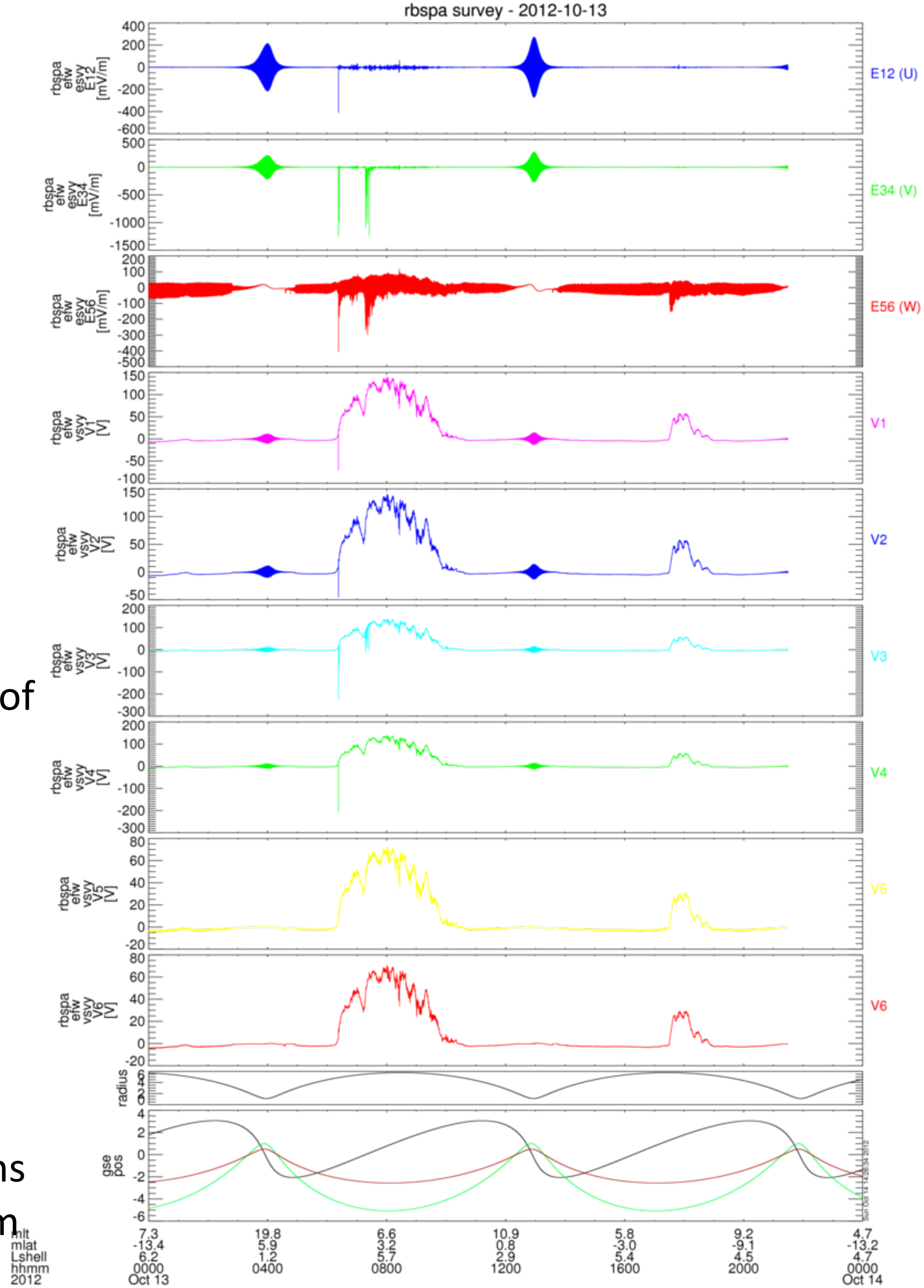
V1= Vsensor1-Vsc

Thus these are plots of proportional to the <u>negative</u> of the spacecraft potential (Vsc)

v1,v2,v3,v4 50 m
Spin plane booms

v5, v6 spin axis booms
(4 meters stroke &5m from center of SC

RBSP_ b
October 13, 2012
0-24 UT
Charging Event
(140 Volts)



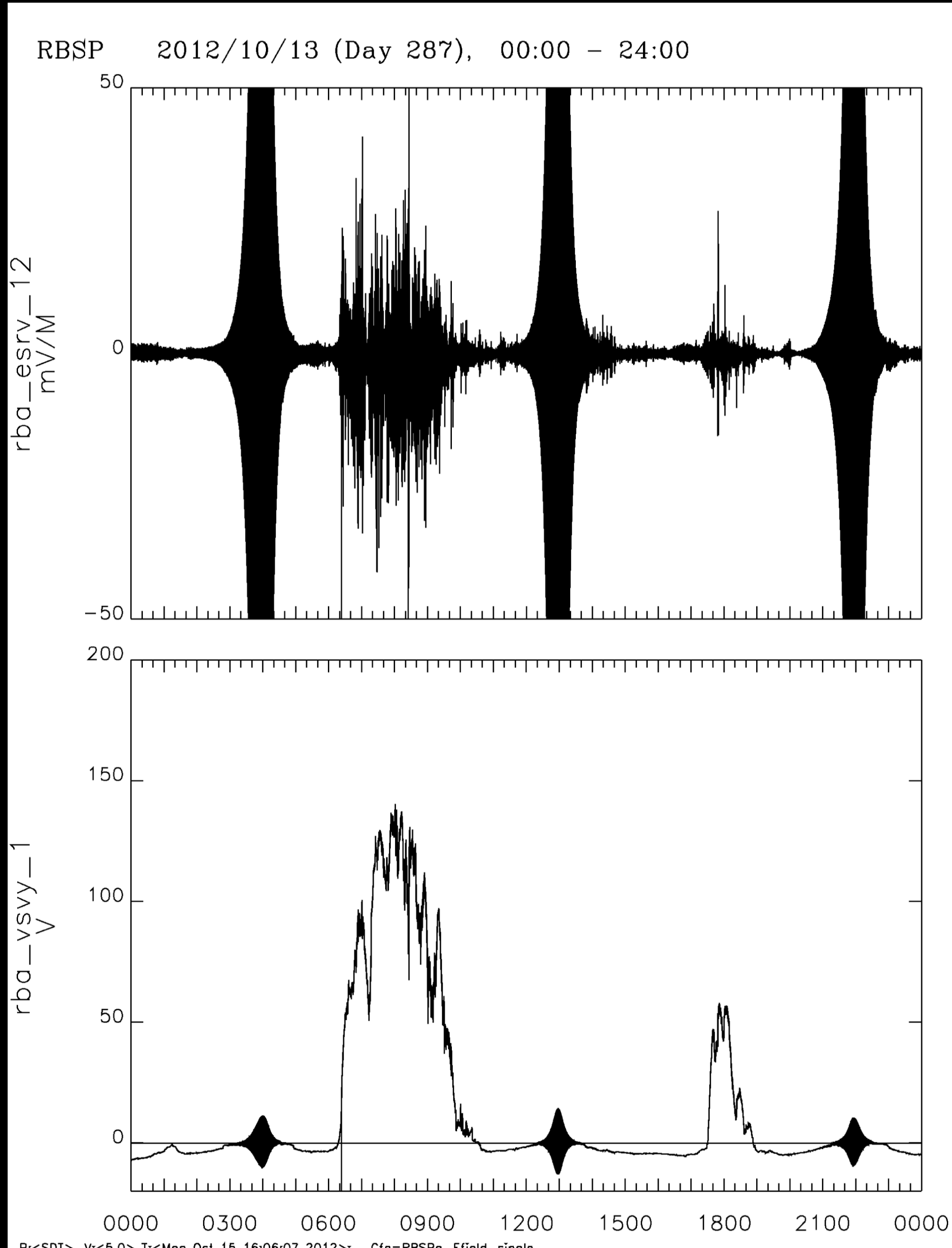
V1= Vsensor1-Vsc

Thus these are plots of proportional to the <u>negative</u> of the spacecraft potential (Vsc)

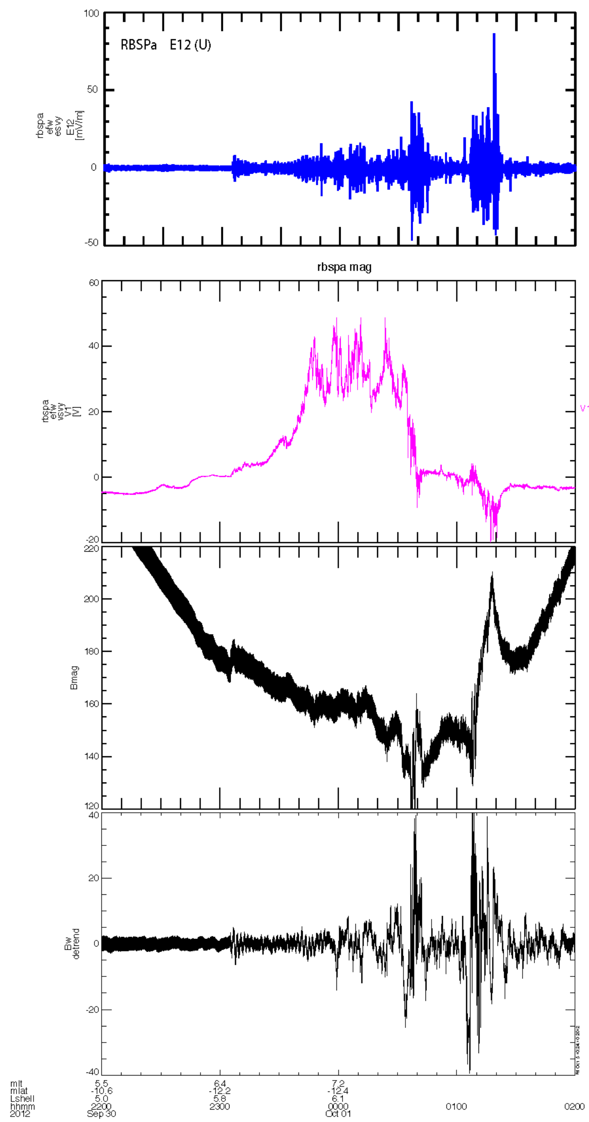
v1,v2,v3,v4 50 m
Spin plane booms

v5, v6 spin axis booms
(4 meters stroke &5m
from center of SC

Back-up slides—
(Other Examples of Charging)


RBSP 2012/10/13 (Day 287), 00:00 - 24:00
rba_esrv_12
mV/M
50
0
-50
rba_vsvy_1
V
200
150
100
50
0
0000
0300
0600
0900
1200
1500
1800
2100
0000
P;<SDT>, V:<5.0> T:<Mon Oct 15 16:06:07 2012>; Cfg=RBSPa_Efield_single

9/30 20:00 UT to 10/1 04:00 UT
Charging to 50 volts



Spin Modulated E-field
(Spin plane-E12 survey

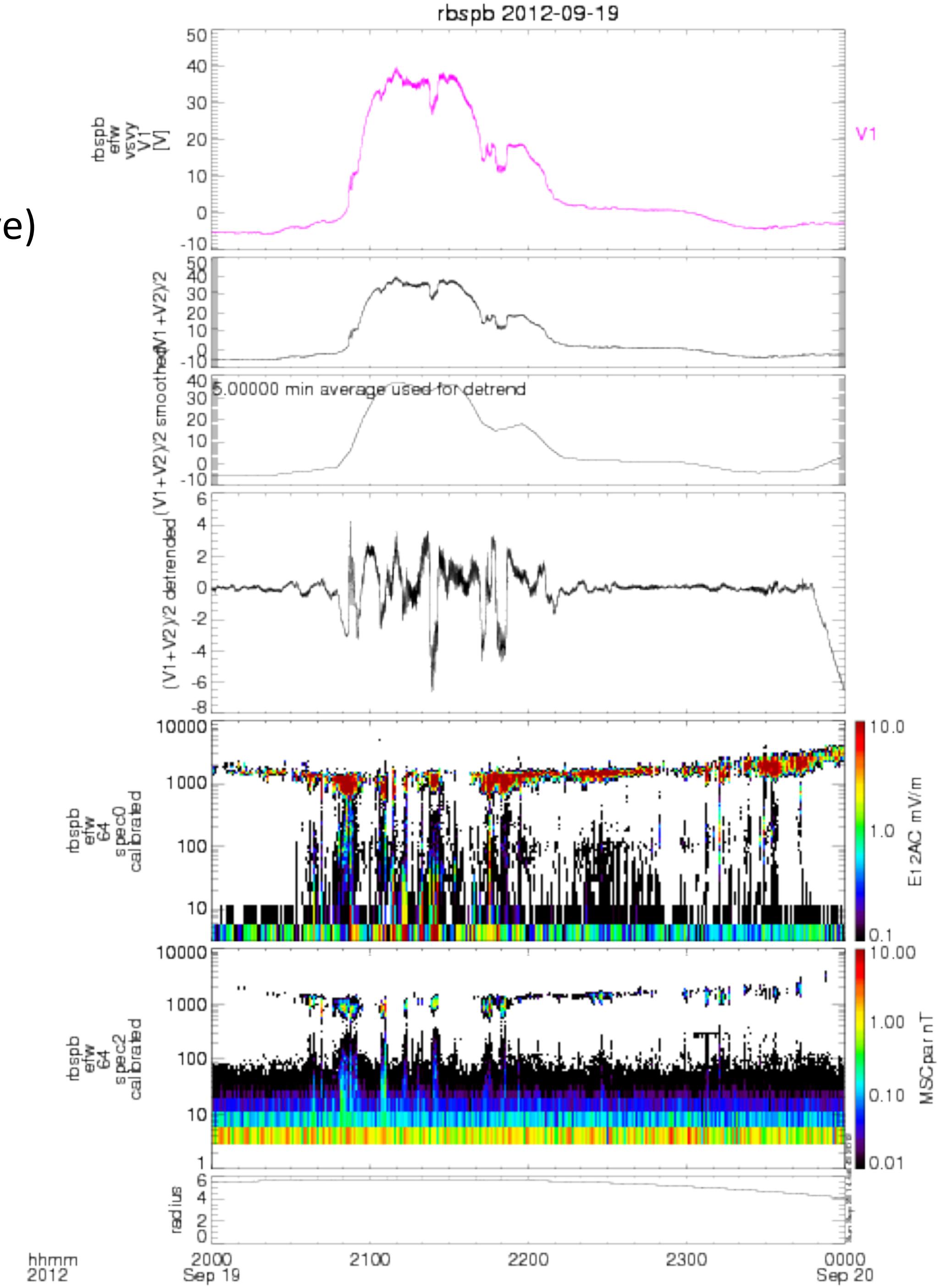
Spacecraft Charging
Due to Energetic Particles

Total B-field Magntitude
(EMFISIS)

Spin Axis B-field component
(mostly perpendicular to B total
average background)

9/19/2012
20UT-24 UT

Charging to (negative)
 40 volts



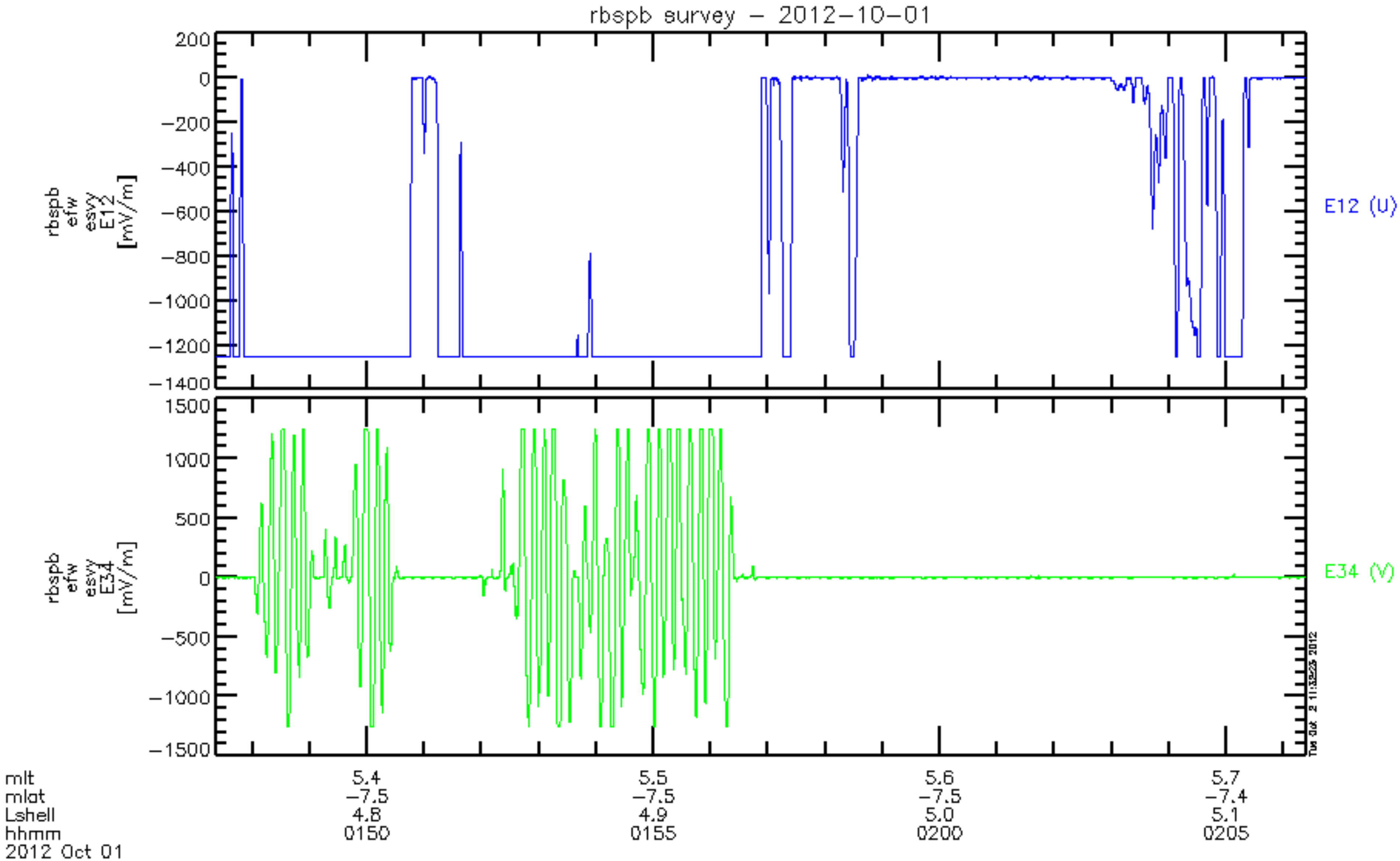
Spacecraft Potential from (V1+V2)/2

Detrended SC Potential

E-Field Spectra

B-Field Spectra

Radial Distance

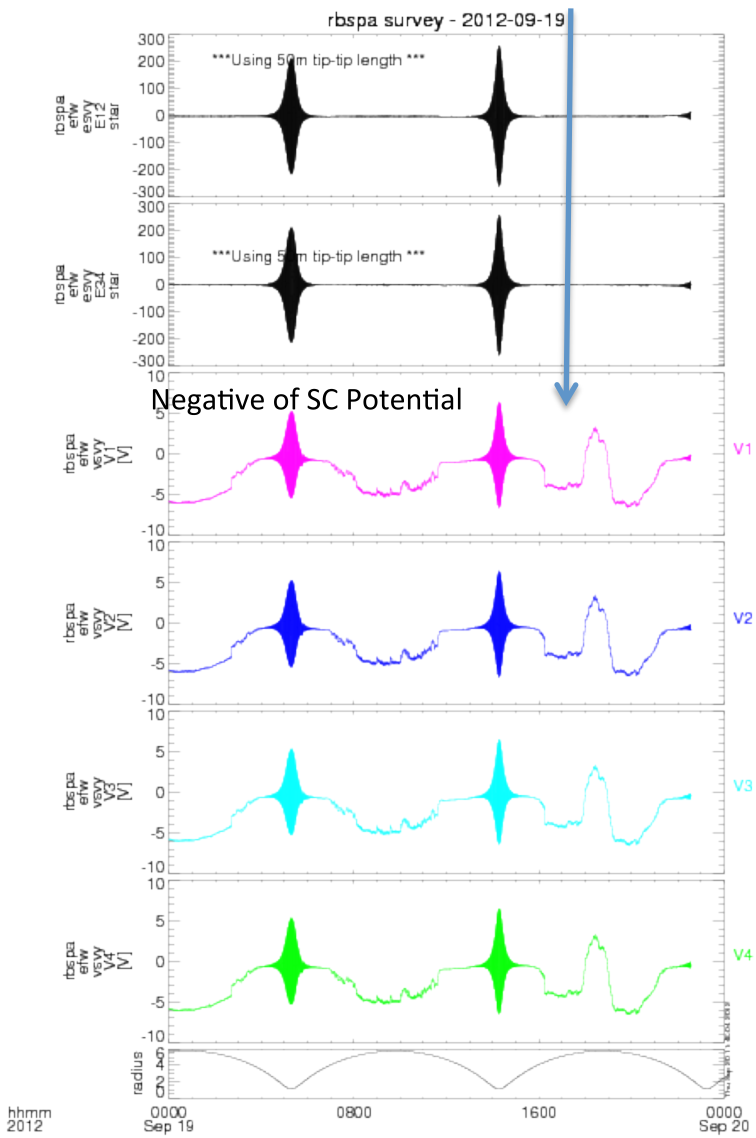


rbspb survey - 2012-10-01
rbspb efw esvy E12 [mV/m]
E12 (U)
rbspb efw esvy E34 [mV/m]
E34 (V)
mlt 5.4 5.5 5.6 5.7
mlat -7.5 -7.5 -7.5 -7.4
Lshell 4.8 4.9 5.0 5.1
hhmm 0150 0155 0200 0205
2012 Oct 01

Two Spacecraft View of Slowly Evolving "Injection" Event (AE ~800)
(using SC Charging as Temporary Proxy for Energetic Particles)

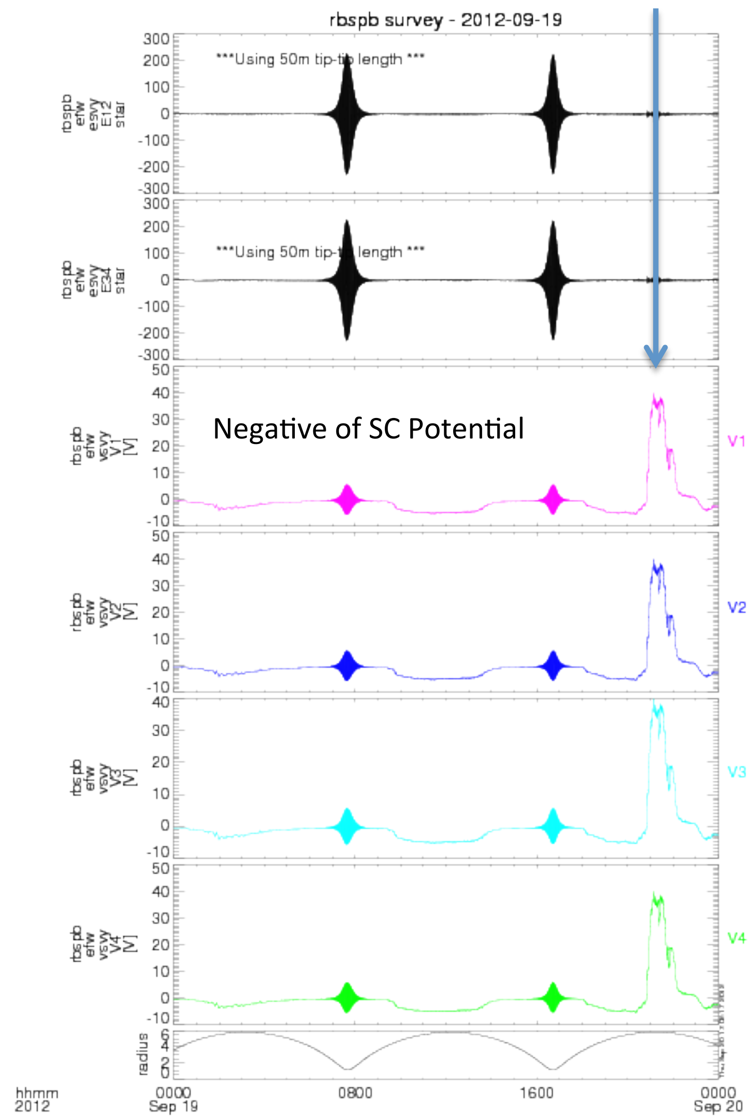
RBSPA Early Stage

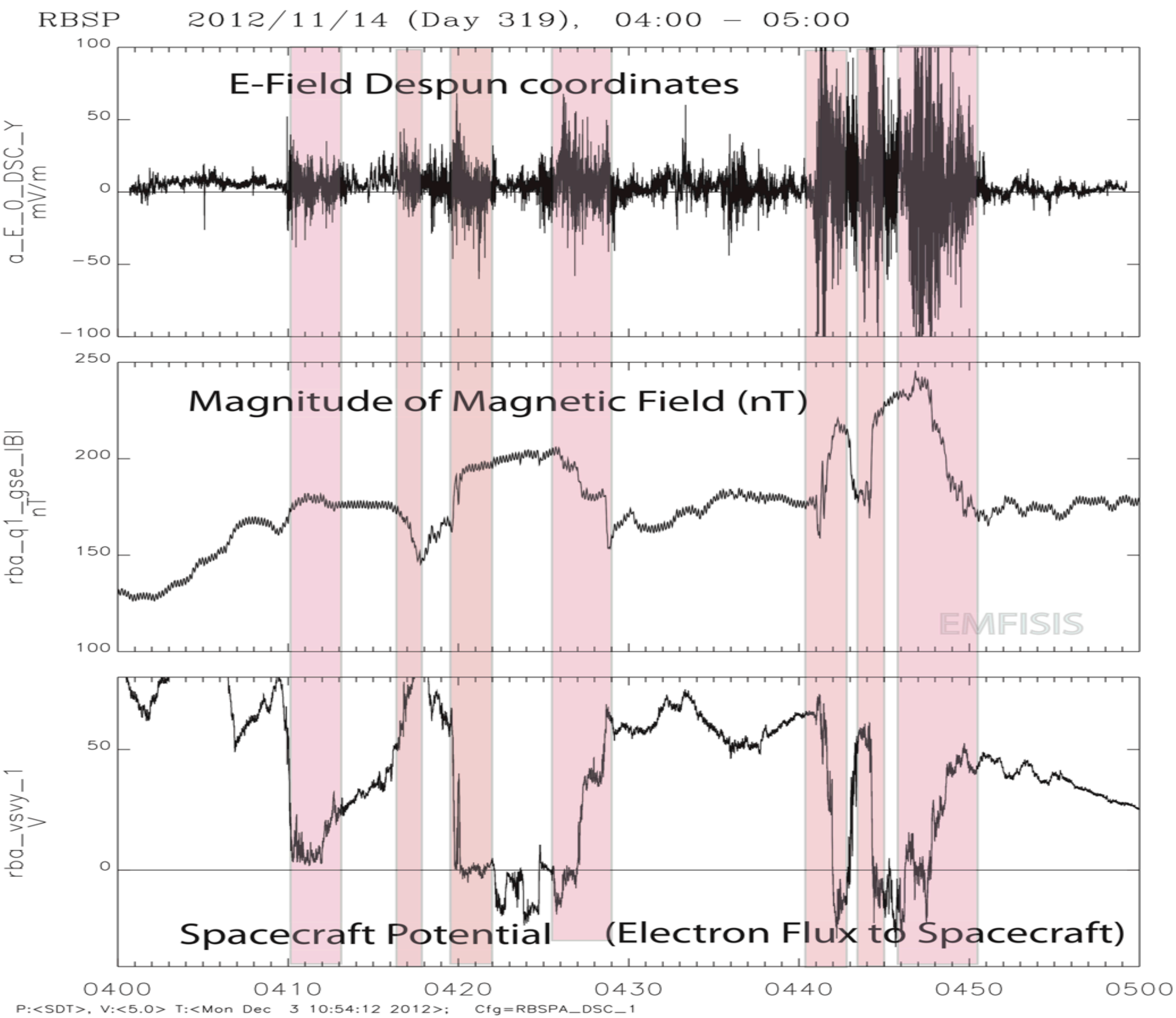
18:00 UT (4 volts)



RBSPB Later Stage

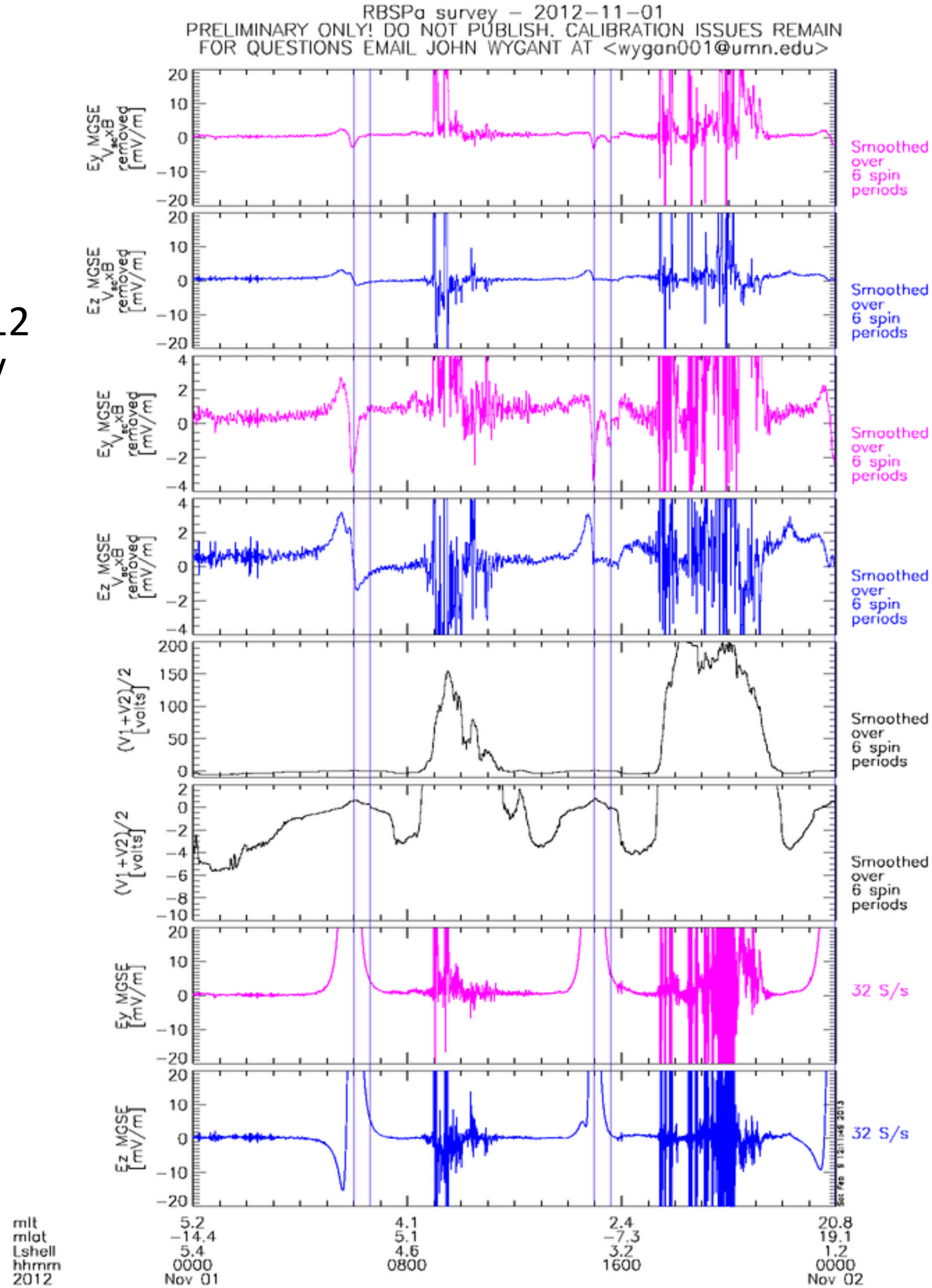
21:50 UT (40 volts)



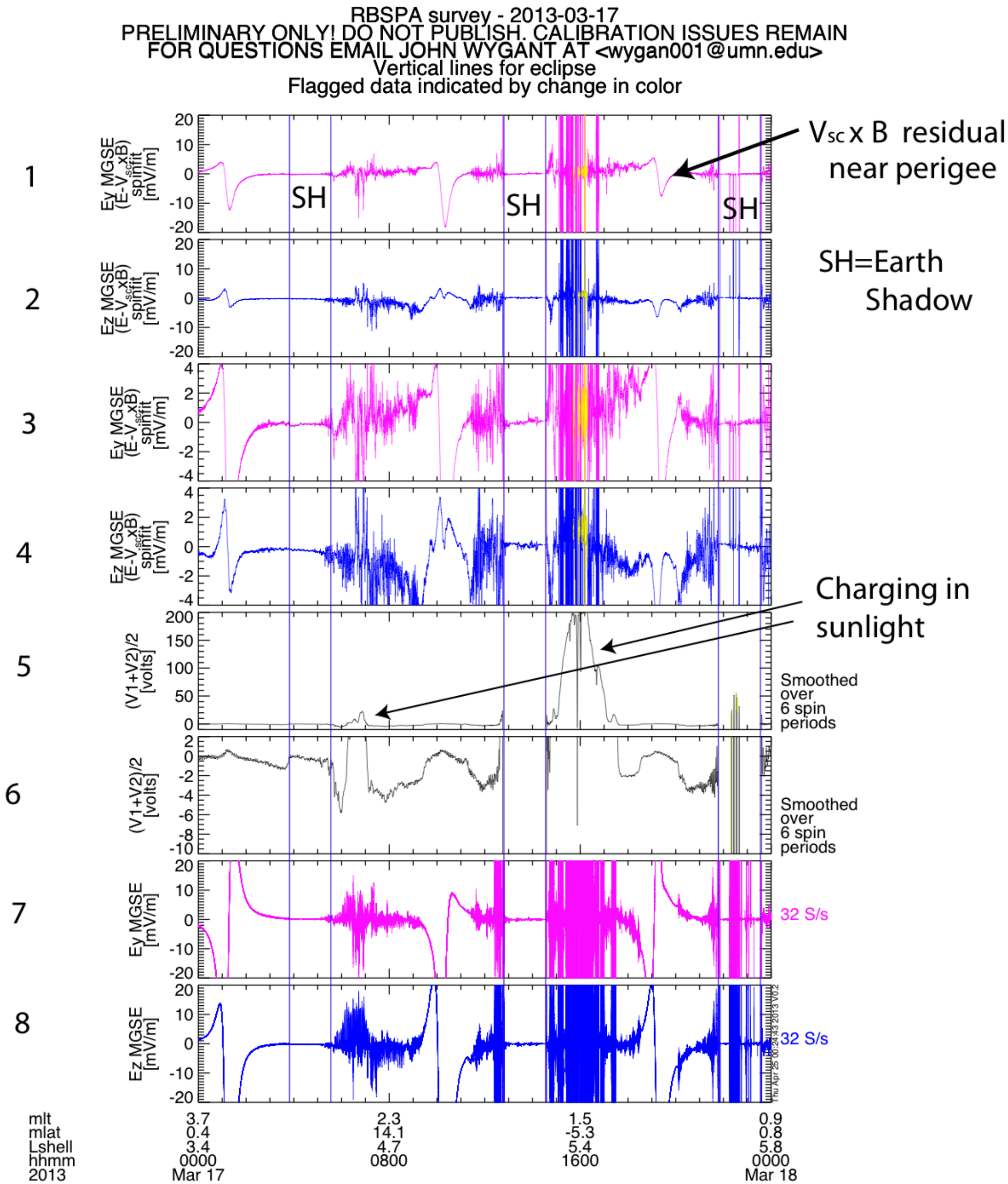


RBSP 2012/11/14 (Day 319), 04:00 - 05:00
E-Field Despun coordinates
a_E_0_DSC_Y
mV/m
Magnitude of Magnetic Field (nT)
rba_q1_gse_IBI
nT
EMFISIS
Spacecraft Potential (Electron Flux to Spacecraft)
rba_vsvy_1
V
0400
0410
0420
0430
0440
0450
0500
P:<SDT>, V:<5.0> T:<Mon Dec 3 10:54:12 2012>; Cfg=RBSPA_DSC_1

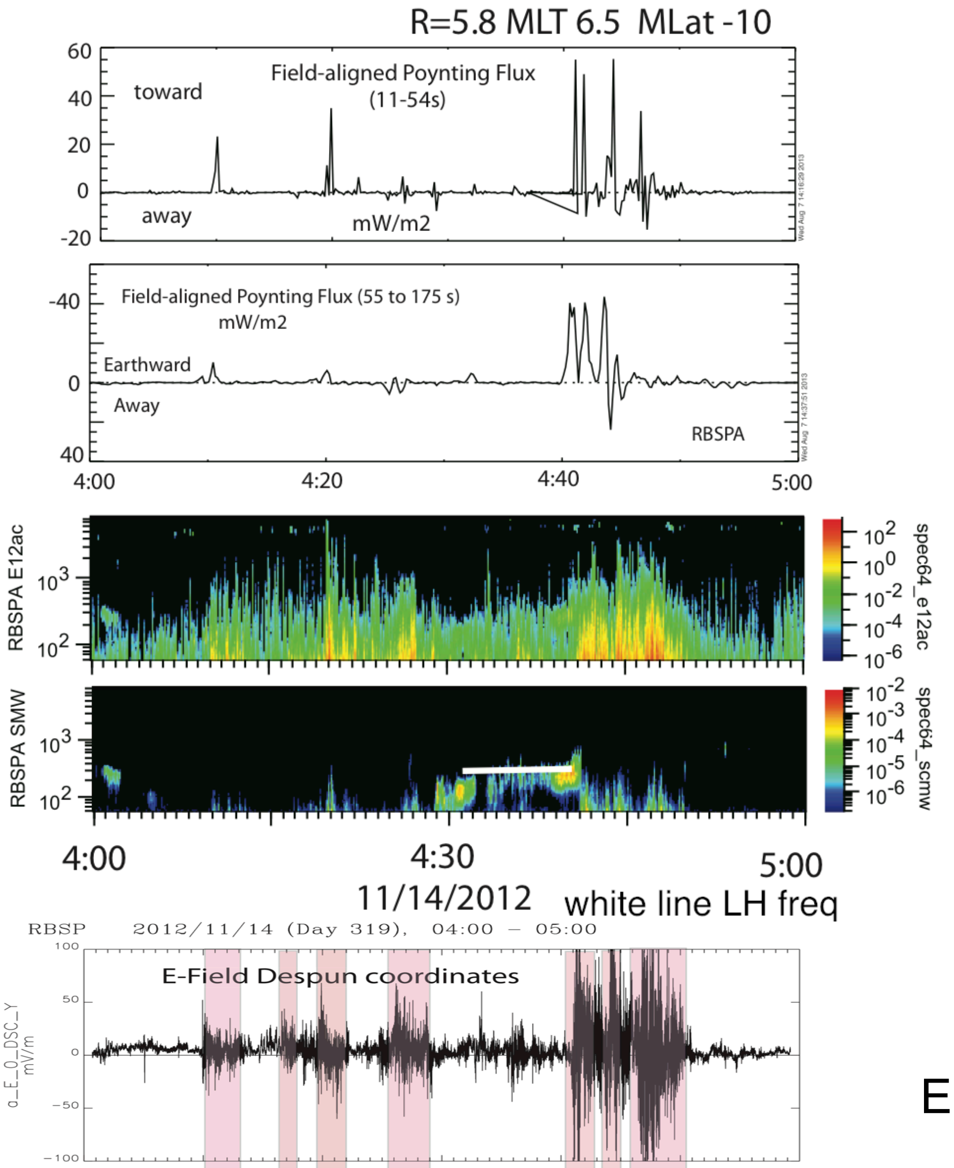
November 1, 2012
Charging to 200V



EFW Survey Plot 3/17/2013



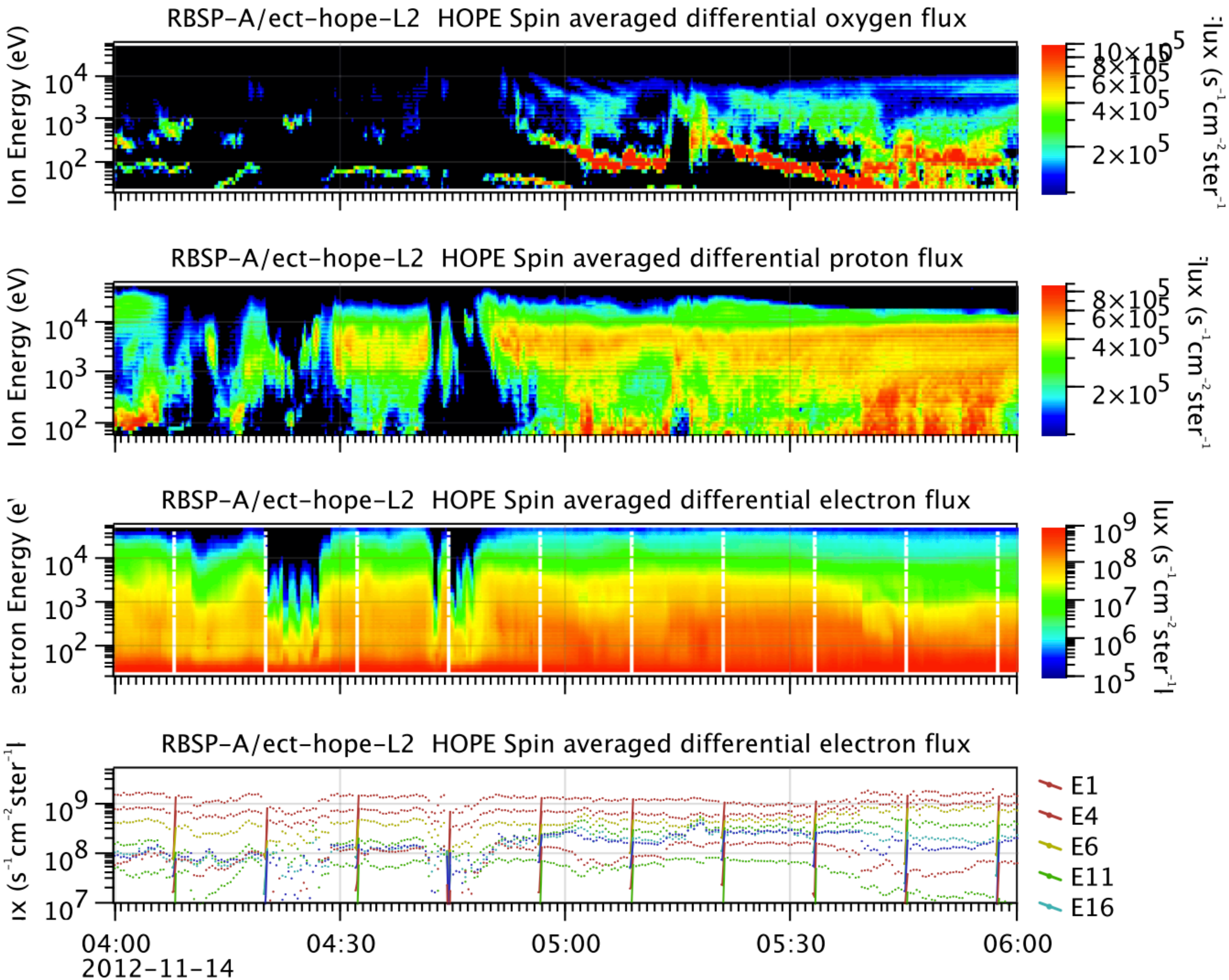
11/14/2013



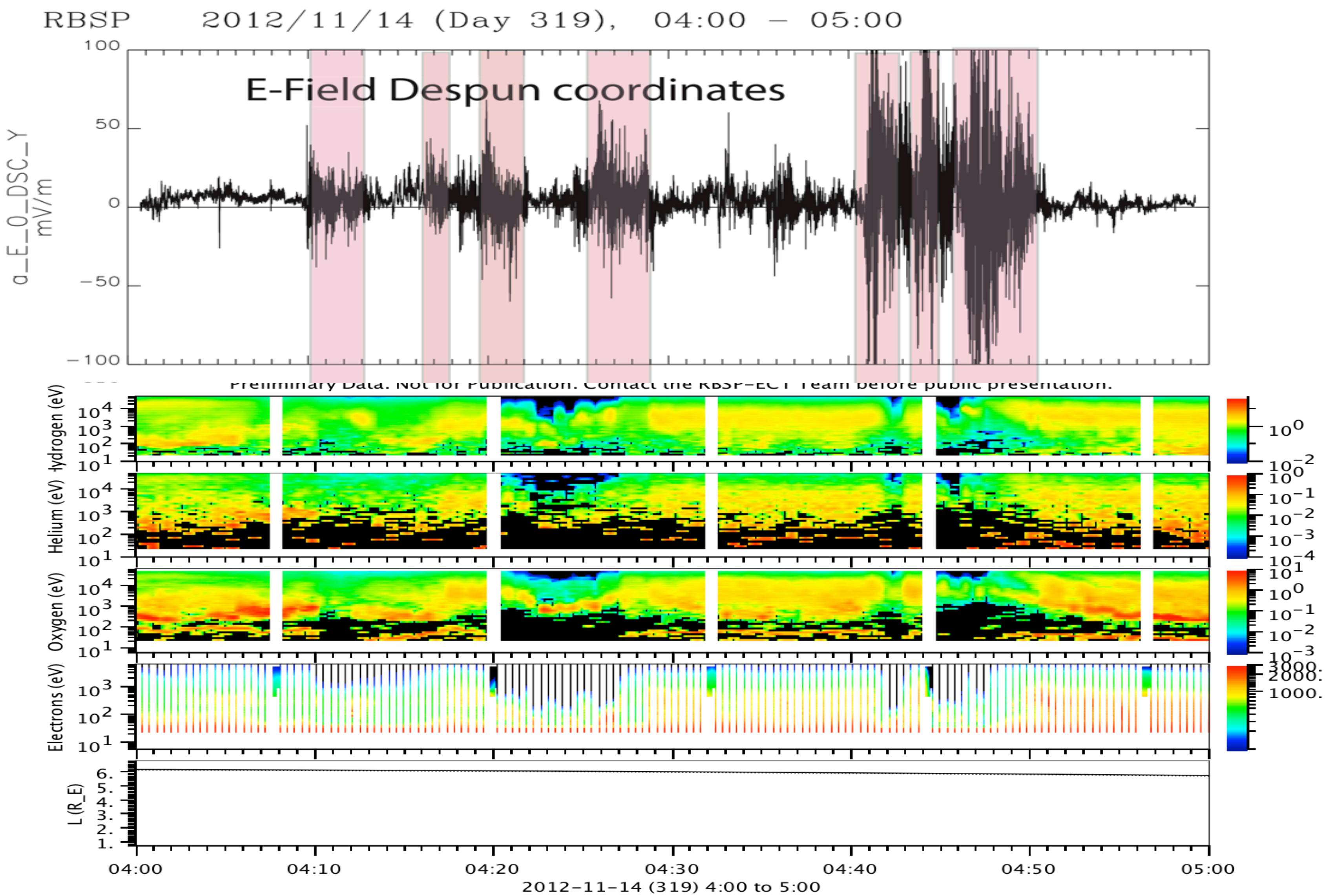
E field dc -16 Hz

4:00

5:00



RBSP-A/ect-hope-L2 HOPE Spin averaged differential oxygen flux
Ion Energy (eV)
RBSP-A/ect-hope-L2 HOPE Spin averaged differential proton flux
Ion Energy (eV)
RBSP-A/ect-hope-L2 HOPE Spin averaged differential electron flux
RBSP-A/ect-hope-L2 HOPE Spin averaged differential electron flux
E1
E4
E6
E11
E16
04:00
2012-11-14
04:30
05:00
05:30
06:00



RBSP 2012/11/14 (Day 319), 04:00 – 05:00
E-Field Despun coordinates
a_E_0_DSC_Y mV/m
Preliminary Data. Not for Publication. Contact the RBSP-ECT Team before public presentation.
Hydrogen (eV)
Helium (eV)
Oxygen (eV)
Electrons (eV)
L (R_E)
Flux
(s⁻¹cm⁻²sr⁻¹keV⁻¹)
04:00
04:10
04:20
04:30
04:40
04:50
05:00
2012-11-14 (319) 4:00 to 5:00