Characteristics of Extreme Auroral Charging Events

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ISS image: 7 March 2012

Introduction

Today's presentation describes preliminary results from a study of extreme auroral charging in low Earth orbit. Goal of study is to document characteristics of auroral charging events of importance to spacecraft design, operations, and anomaly investigations

Outline

- Identifying charging in DMSP SSJ records
- Event sources and assembling study set
- Characteristics of extreme charging
  - Potential time history for study set
  - Maximum and mean potentials
  - Event durations
  - Correlation of potentials with electron integral number flux
  - Frame charging/discharging rates
  - Correlation of potentials with Kp indices
  - Latitudes of extreme events
- Implications for ISS

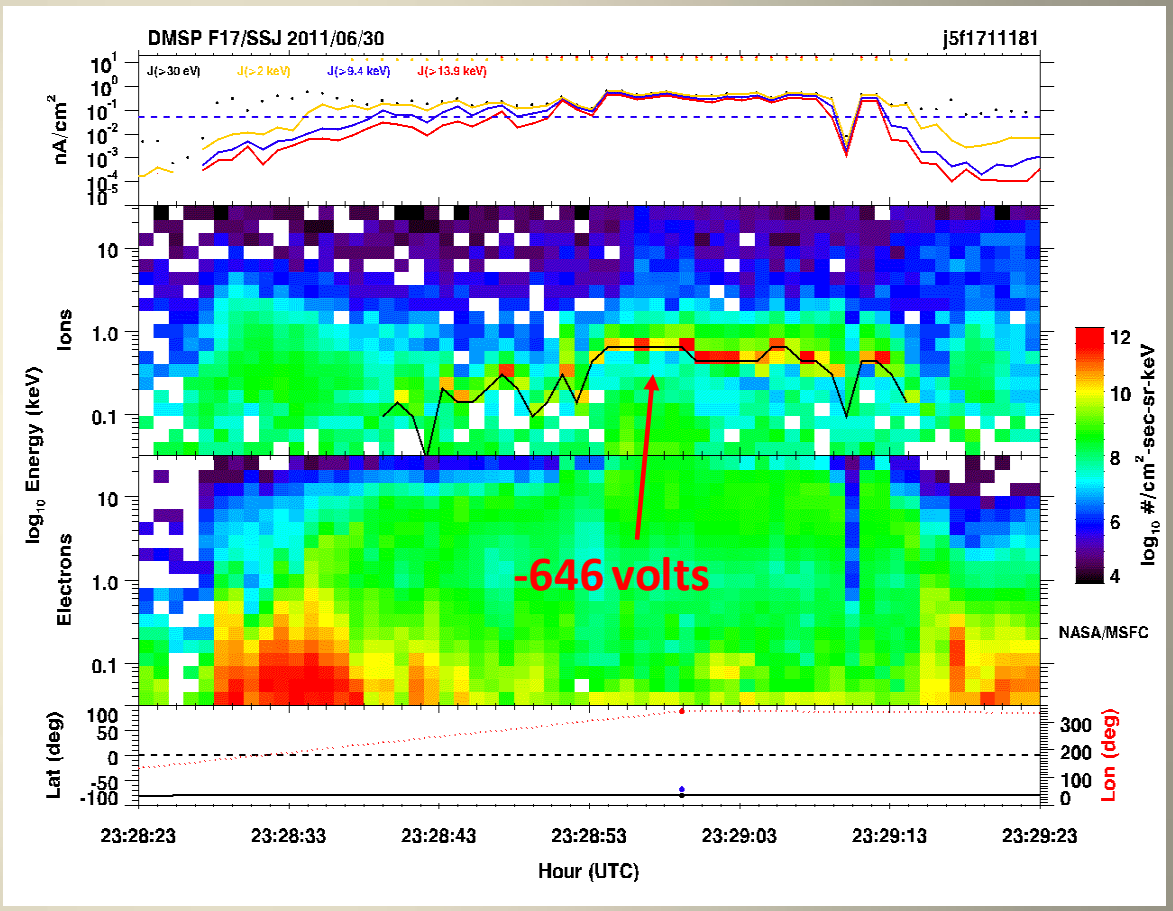
SSJ4, SSJ5 Electrostatic Analyzer “Ion Line”

- Low energy background ions accelerated by spacecraft potential show up as sharp “line” of high ion flux in single channel

$$E = E_0 + q\Phi$$

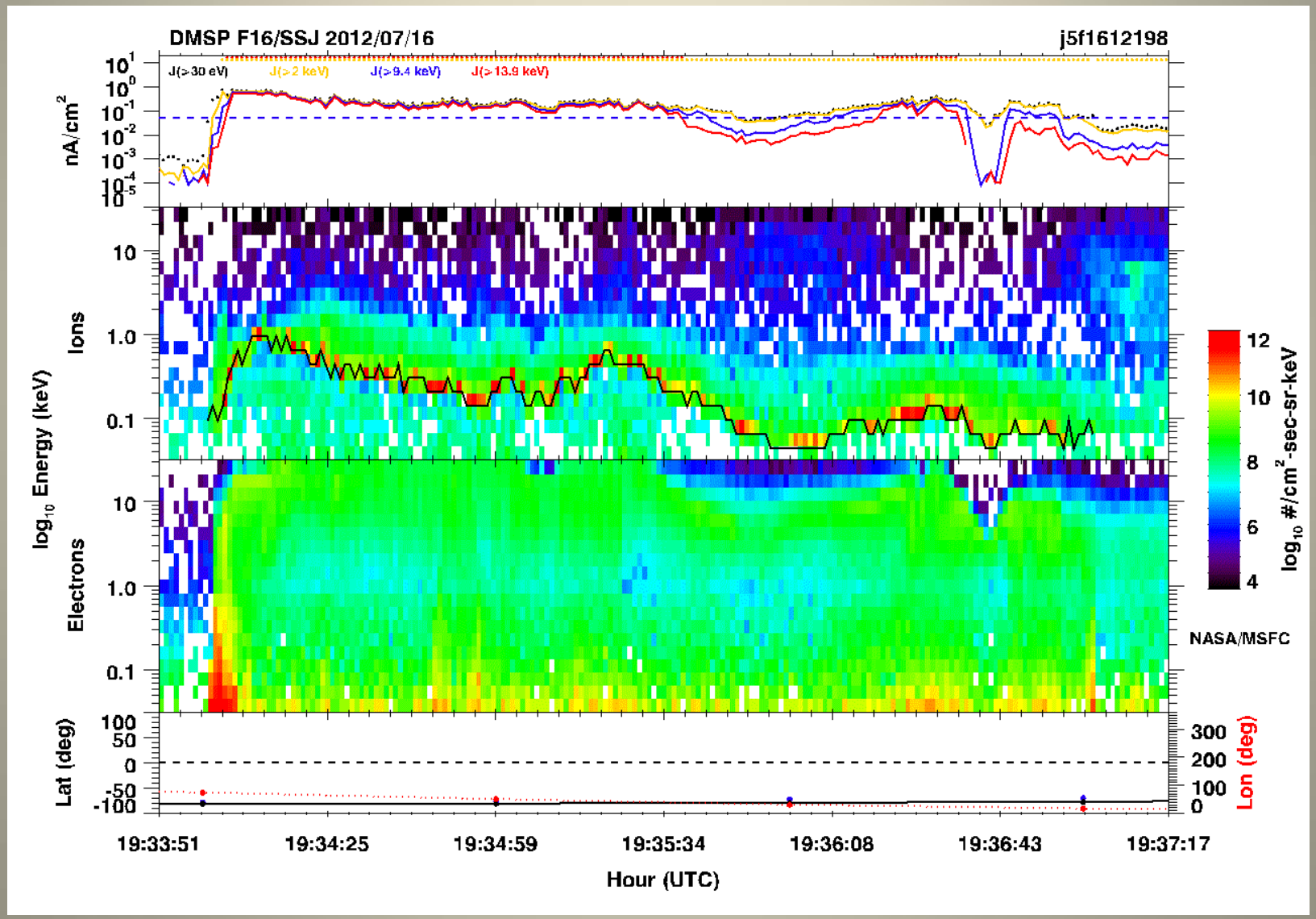
- Assume initial energy E_0 ~ 0 with single charge ions (O^+, H^+) and read potential (volts) directly from ion line energy (eV)

- DMSP SSJ4, SSJ5
  - Electrons: 20 channels
    30 eV to 30 keV
  - Ions: 20 channels
    30 eV to 30 keV
  - Nominal channel energies imbedded in files used for this study



Database Generation Example

- Software identifies the “ion line” and generates a time series file stored in data base than is post-processed for characterizing charging event properties



Study Data Set

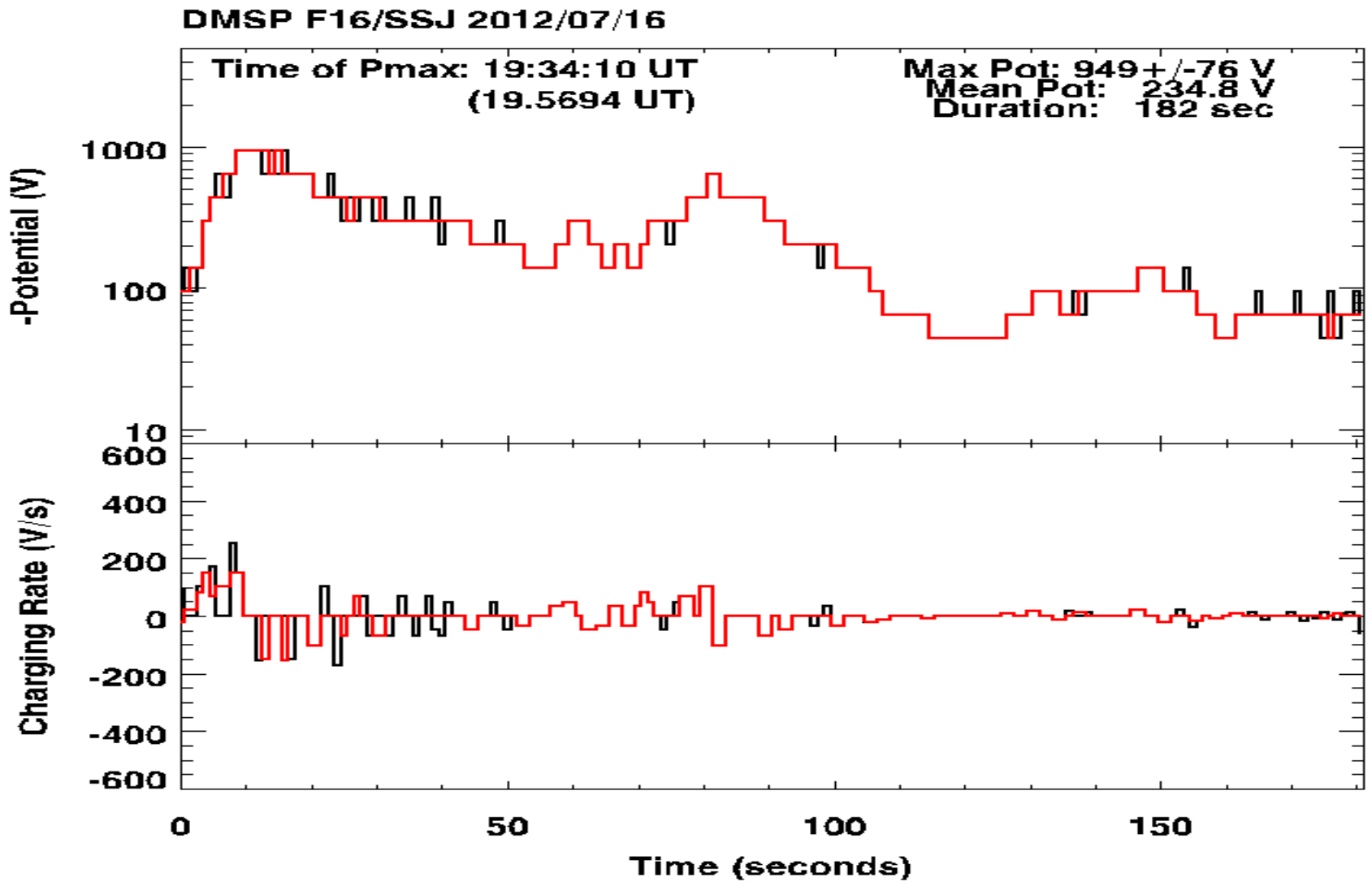
- Criteria: Charging events with maximum negative potential $|-\Phi| \geq 400\,V$

- Charging events from variety of previous studies, newly identified events

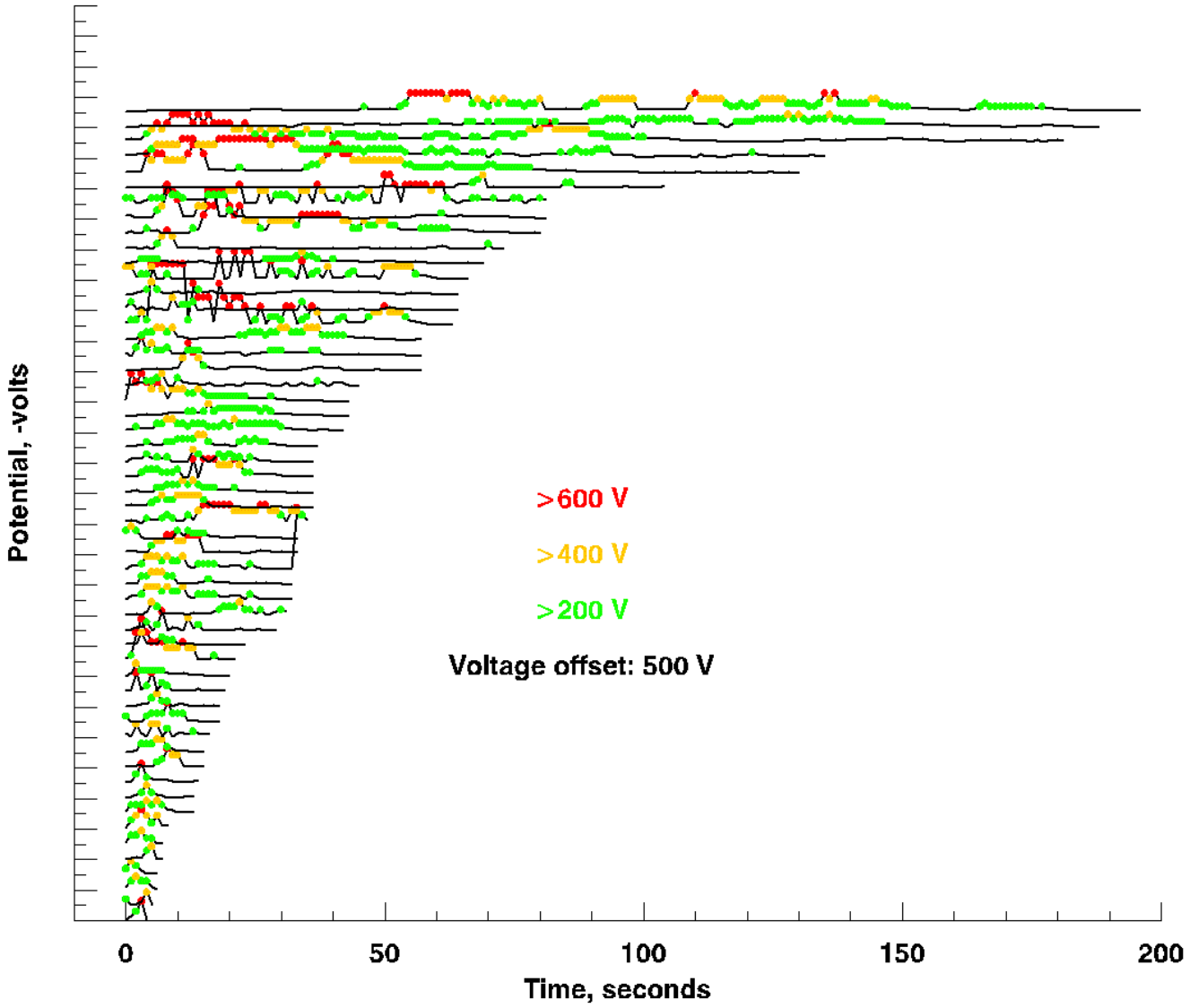
Source	Satellites	Events $|-\Phi| \geq 400\,V$
Gussenhoven et al., 1985	F7	1
Frooninckx, 1991;Frooninckx and Sojka, 1992	F6,F7	16
Anderson and Koons, 1996	F13	1
Anderson, 2012	F12, F13	2
Colson, 2011	F16, F17, F18	14
Colson et al., 2012	F16, F17, F18	5
Parker and Minow, 2013	F16	2
Chandler et al., 2013	F16	7
This work	F12, F16, F17	5
Total		53

- No pretense at this stage of work that study represents a statistically unbiased collection of charging events, more of a proof of concept for study methodology

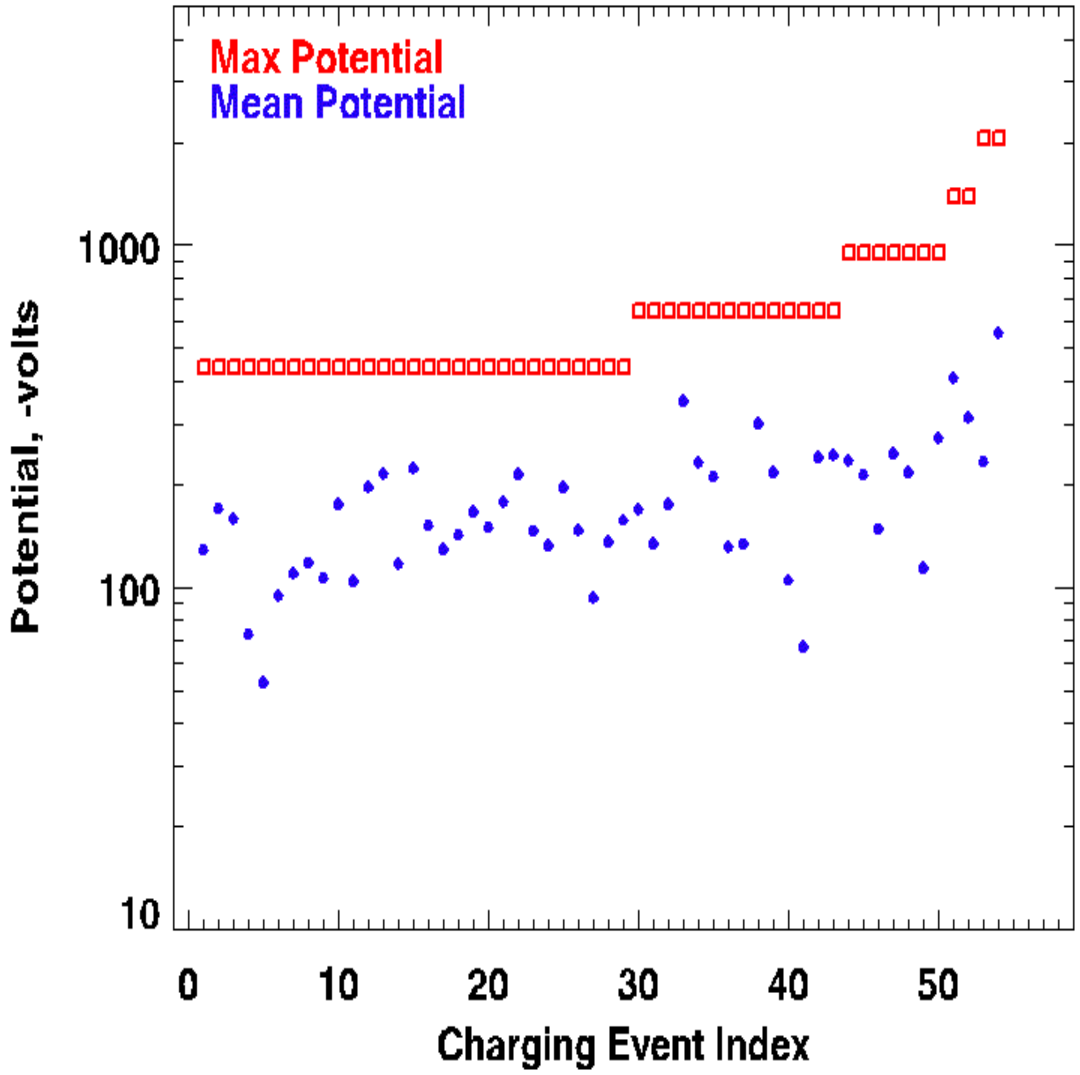
Potential Time Series, Charging Rates



Potential Time Histories

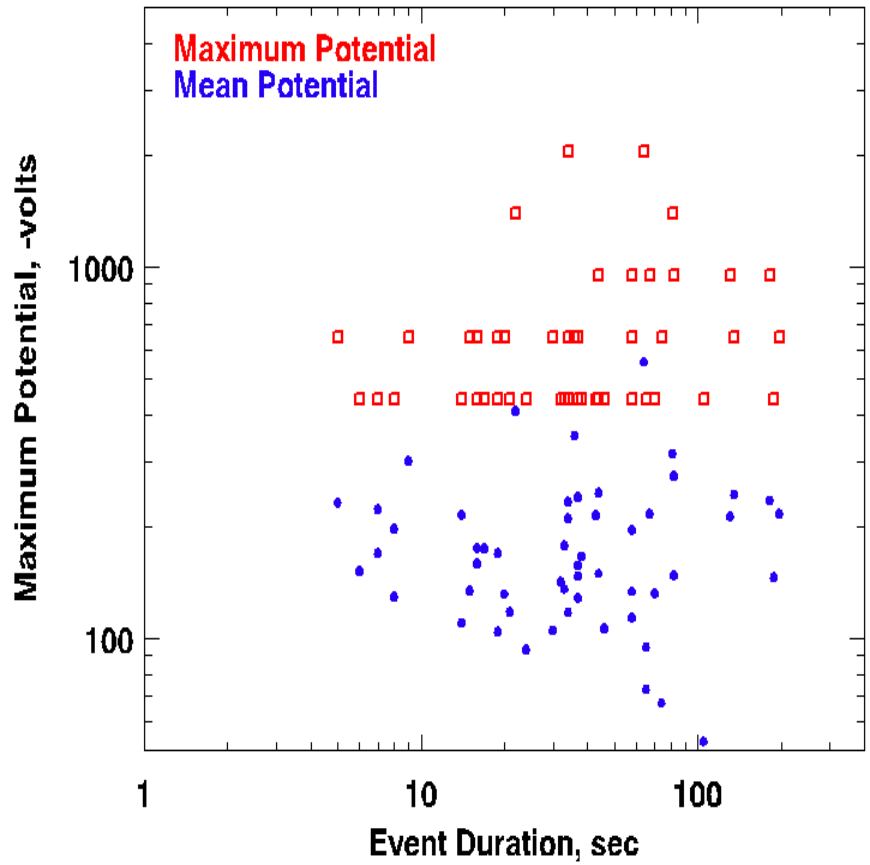


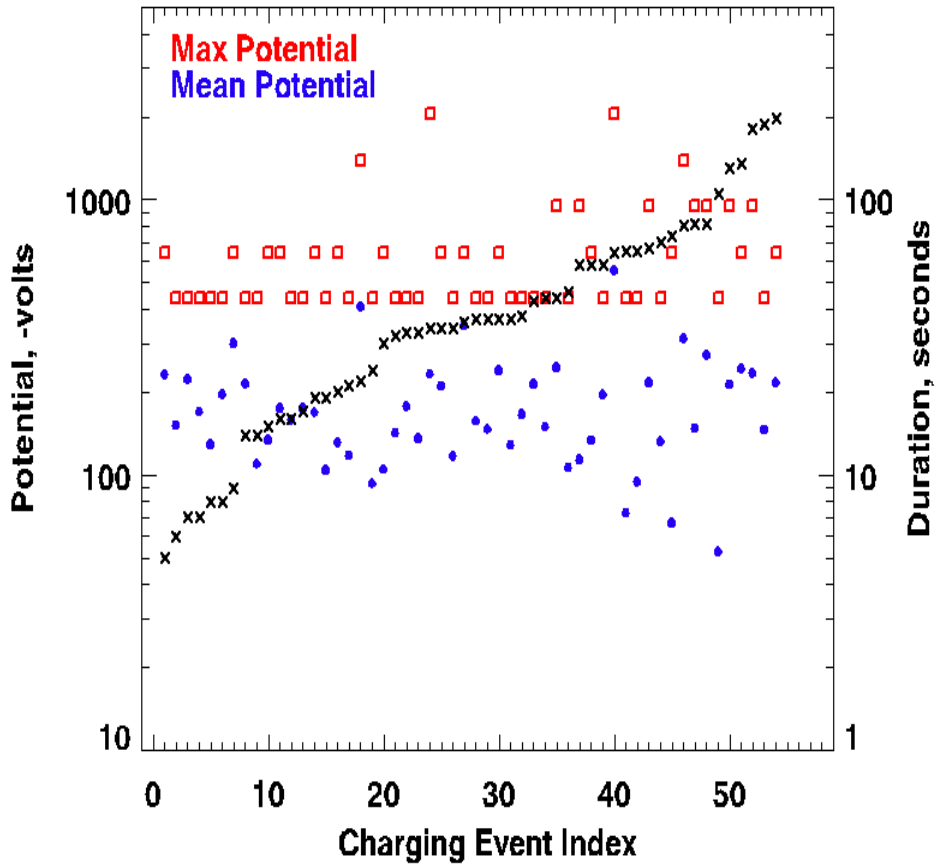
Maximum and Mean Potentials



Potential (volts)	# seconds ≥potential	% records ≥ potential
6460	0	0.00
4400	0	0.00
3000	0	0.00
2040	8	0.30
1392	13	0.49
949	48	1.80
646	165	6.20
440	384	14.44
300	655	24.62
204	966	36.32
139	1308	49.17
95	1635	61.47
65	1992	74.89
44	2287	85.98
30	2660	100.00

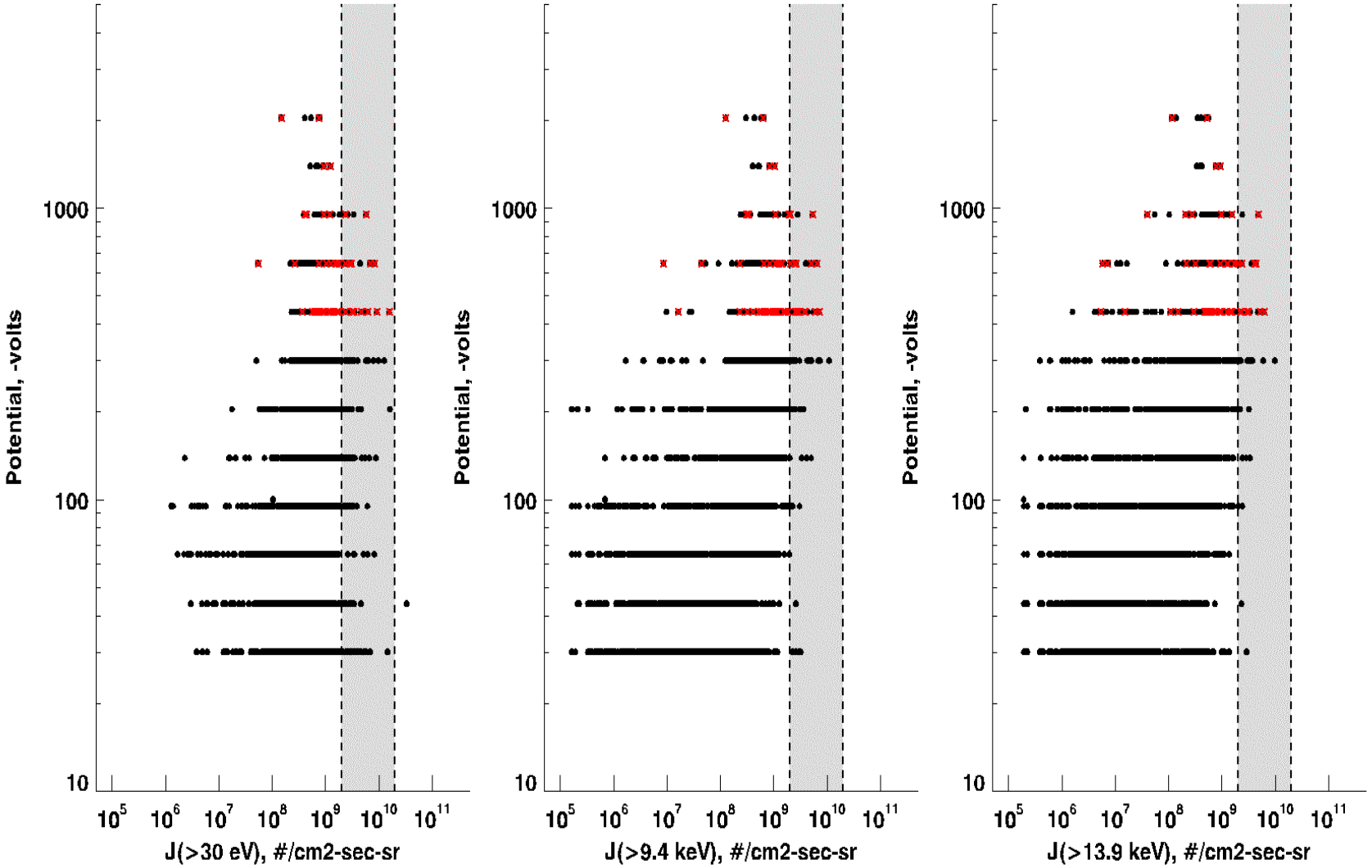
Event Durations



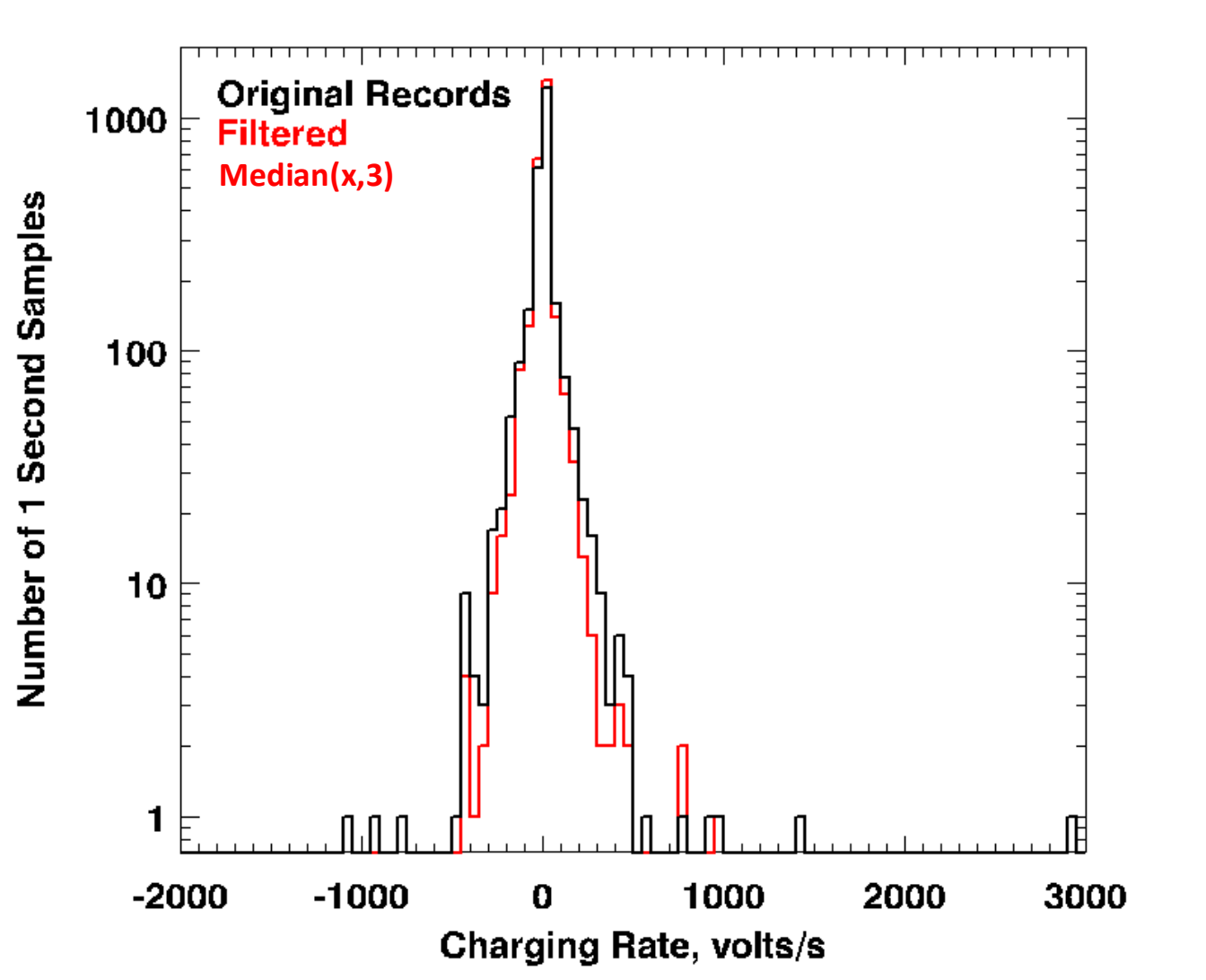


Correlation with Integral Number Flux

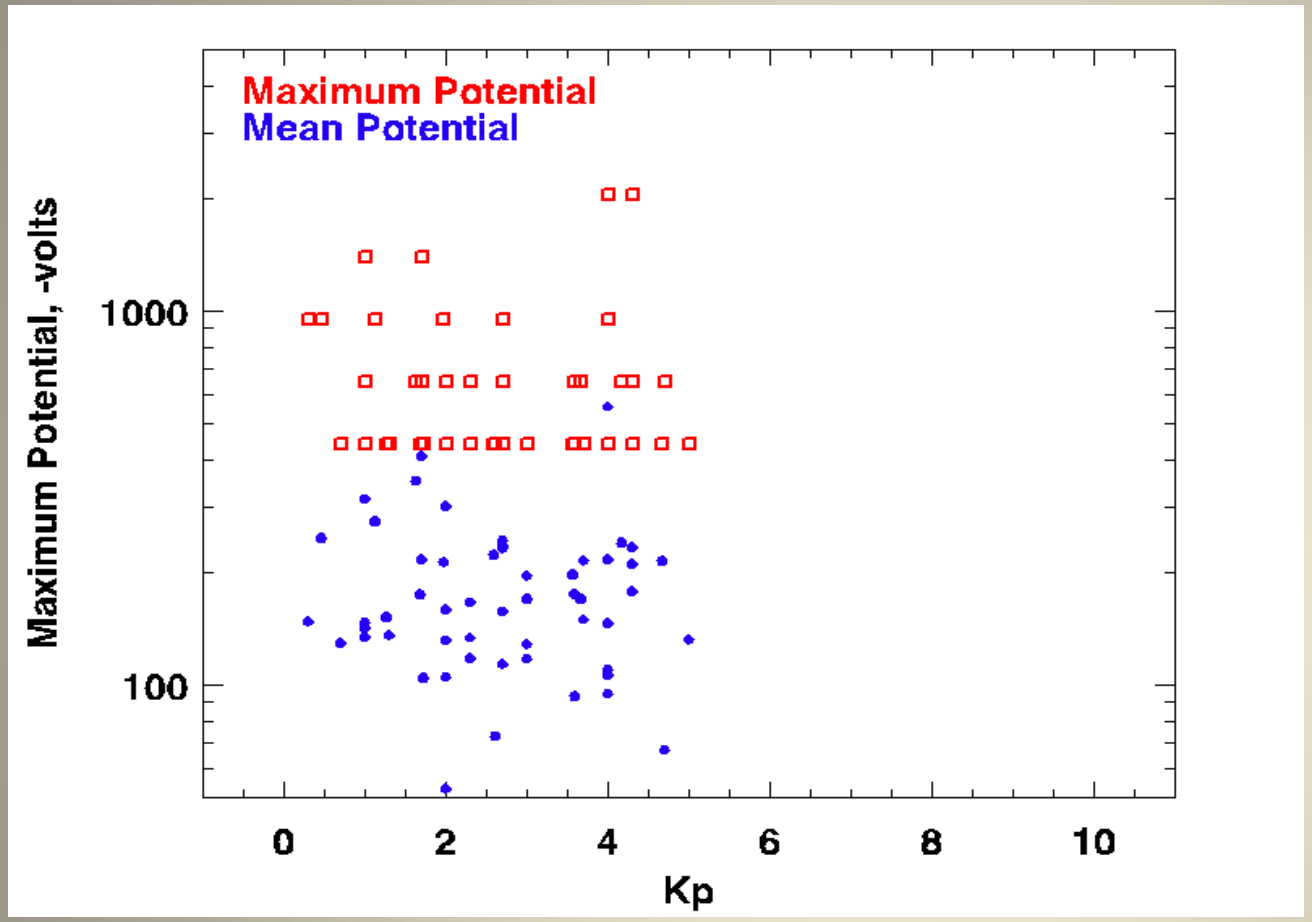
All potentials in event **Maximum Potential** **1-10 nA/cm2**



Frame Charging/Discharging Rates

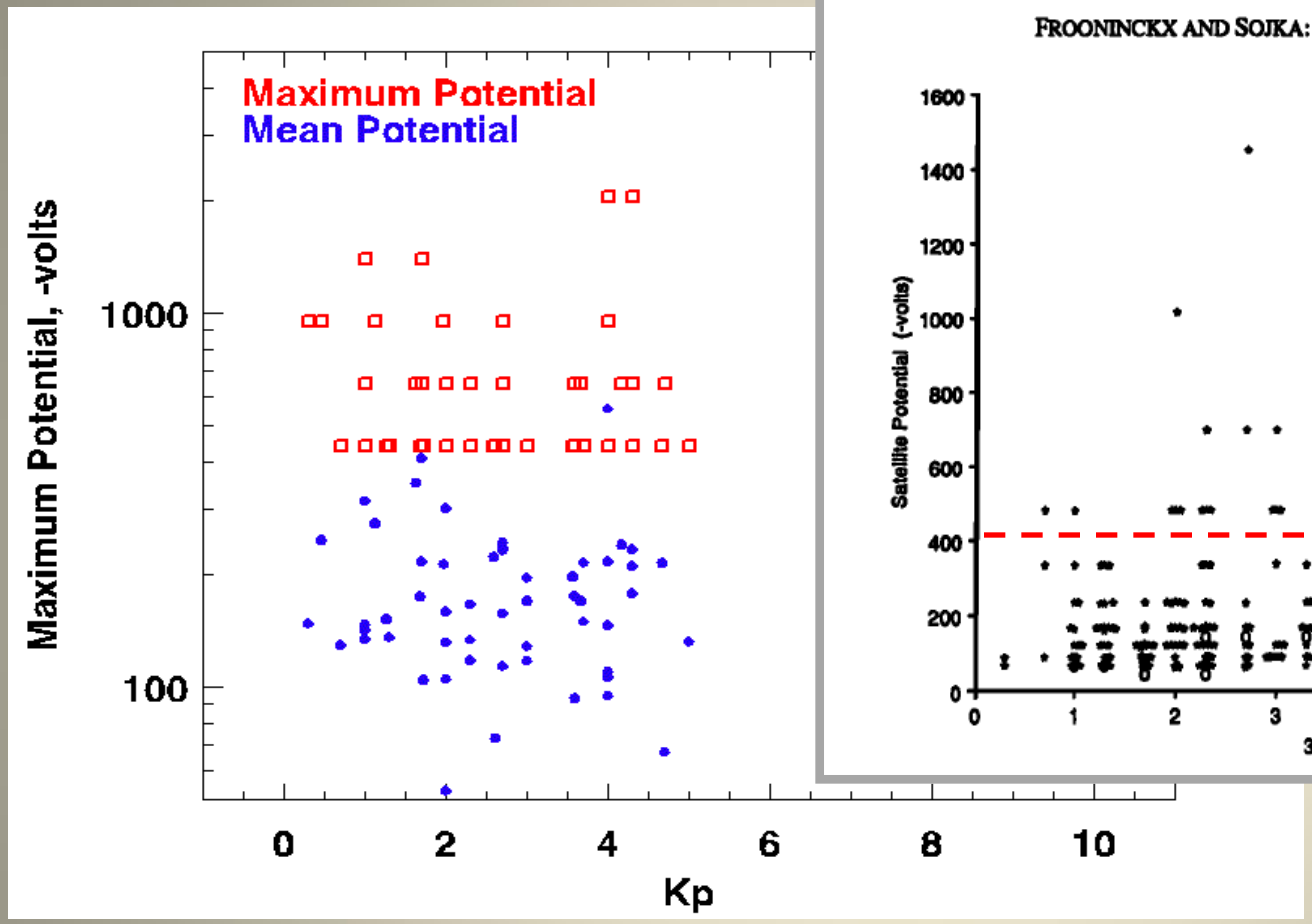


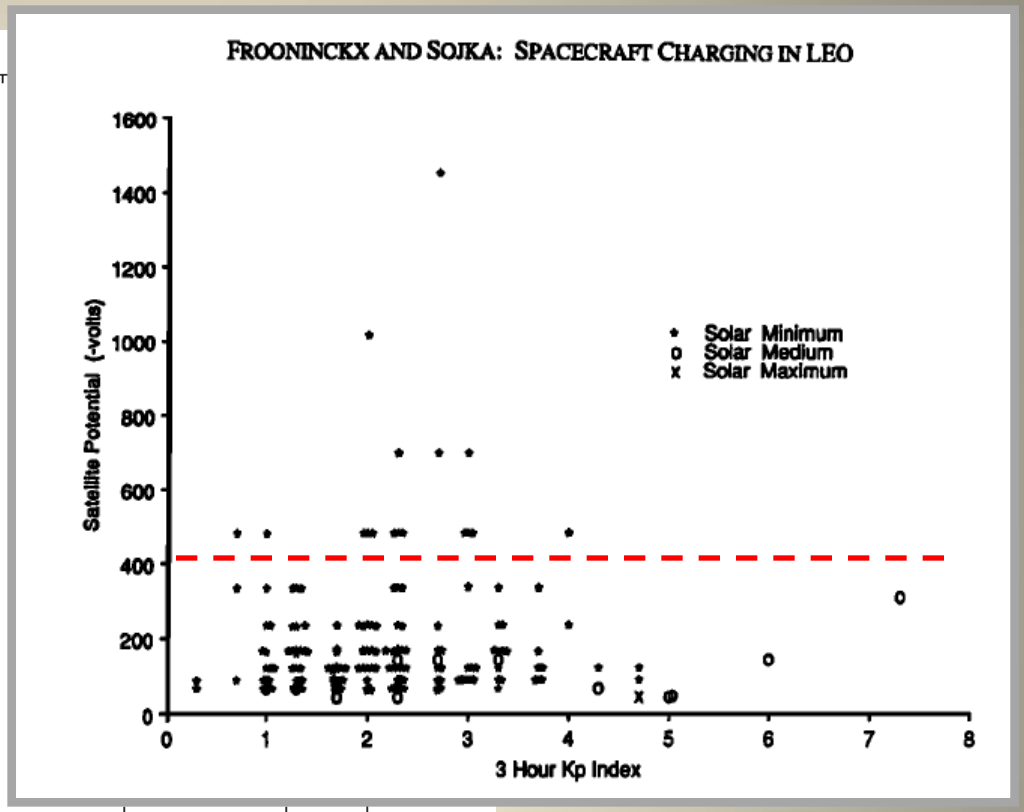
Correlation with Kp Index



Consistent with Frooninckx and Sojka, 1992 results

Correlation with Kp Index

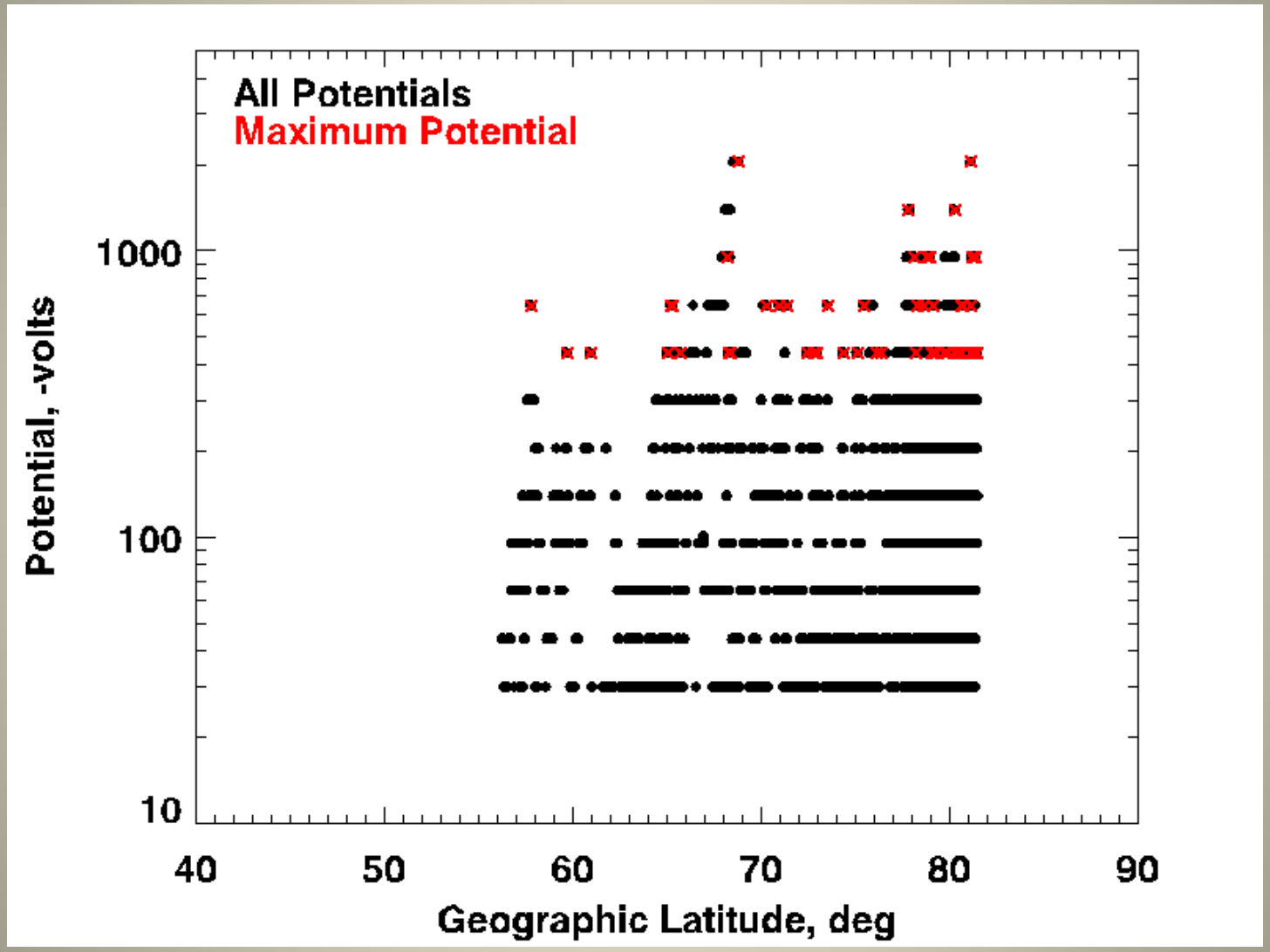




Consistent with Frooninckx and Sojka, 1992 results

Kp index does not order strong auroral charging!

Latitudes of Extreme Events



Implications for ISS

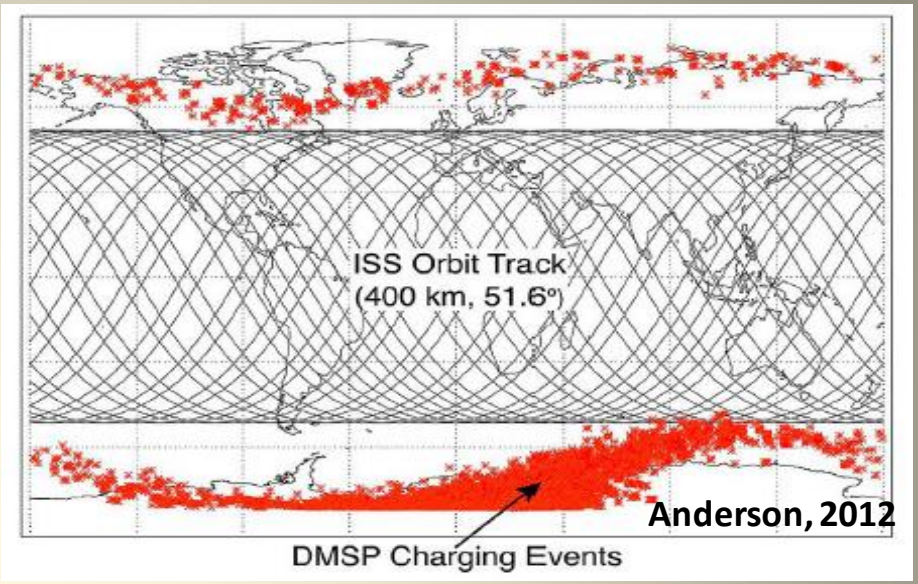
- ISS orbit encounters regions where DMSP charging in excess of 100 V has been identified (Anderson, 2012)

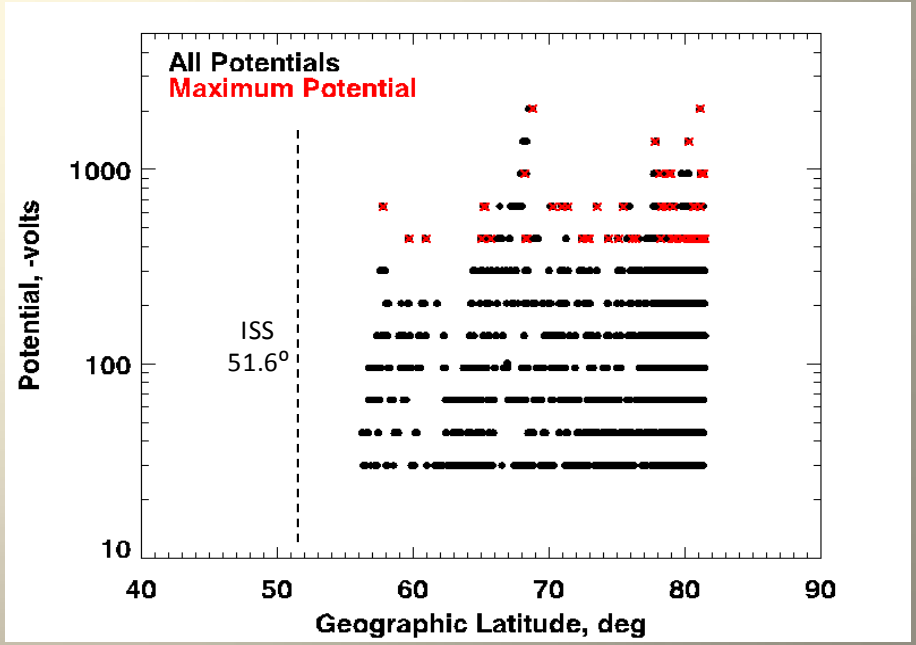
- Latitude distributions of potentials from extreme events in this study show minimum latitudes of:

  All potential values 56.8°

  Maximum potential 57.8°

- Application to ISS
  - Study needs to be extended to events in the -80 V to -100 V range where dielectric coatings on ISS arc to determine possible threat to ISS
  - ISS may not charge to same large potentials in same environment as DMSP due to larger capacitance





ISS image: 11 March 2012

Charging Time Series File

```
#--------------------DMSP Charging Event---------------------
# DMSP_CE_f16_2012-07-16_19:34:10__949.txt
# Satellite: f16
#      Date: 2012/07/16
# Data file: j5f1612198
# First/Last Time: 19:34:00   19:37:01
#     Max V: 949 +/- 76 Volts
#    Mean V:   234.8 Volts
#Time Max V: 19:34:10 UT   (19.5694 UT)
#  Duration:   182 sec
# Max V  lat/lon (deg deg):  -81.383   69.100
# Max V mlat/mlt (deg hr):   -78.367   18.264
#
# Number of seconds >= V:
#>=6460 V:             0
#>=4400 V:             0
#>=3000 V:             0
#>=2040 V:             0
#>=1392 V:             0
#>= 949 V:             6
#>= 646 V:            17
#>= 440 V:            38
#>= 300 V:            64
#>= 204 V:            87
#>= 139 V:           109
#>=  95 V:           134
#>=  65 V:           165
#>=  44 V:           182
#>=  30 V:           182
#
```

Charging Time Series File (continued)

# UT Hr	Seconds	Pot (volt)	Rate (volt/s)	glat (deg)	glon (deg)	mlat (deg)	mlon (deg)	mlt (Hr)	J(>30eV) <----	J(>9.4keV) #/cm2-sec-sr	J(>13.9keV) ---->
19.5669	0.0	95	88.08	-81.398	72.610	-78.847	50.077	18.275	6.96e+07	1.95e+05	1.95e+05
19.5672	1.0	139	-0.30	-81.397	72.220	-78.793	50.053	18.274	5.59e+08	1.88e+07	5.35e+06
19.5675	2.0	95	-0.30	-81.395	71.830	-78.740	50.030	18.273	7.16e+08	2.44e+07	6.61e+06
19.5678	3.0	139	102.24	-81.393	71.440	-78.687	50.007	18.272	1.49e+09	2.88e+08	3.73e+07
19.5681	4.0	300	150.57	-81.392	71.050	-78.633	49.983	18.270	9.00e+08	4.04e+08	2.44e+08
19.5683	5.0	440	172.94	-81.390	70.660	-78.580	49.960	18.269	1.46e+09	1.20e+09	1.04e+09
19.5686	6.0	646	0.00	-81.388	70.270	-78.527	49.937	18.268	1.31e+09	1.14e+09	9.93e+08
19.5689	7.0	440	1.42	-81.387	69.880	-78.473	49.913	18.267	1.30e+09	1.10e+09	9.63e+08
19.5692	8.0	646	254.41	-81.385	69.490	-78.420	49.890	18.265	1.30e+09	1.11e+09	9.83e+08
19.5694	9.0	949	151.12	-81.383	69.100	-78.367	49.867	18.264	1.21e+09	1.08e+09	9.71e+08
19.5697	10.0	949	0.00	-81.382	68.710	-78.313	49.843	18.263	1.25e+09	1.12e+09	1.03e+09
19.5700	11.0	949	-0.00	-81.380	68.320	-78.260	49.820	18.262	1.26e+09	1.03e+09	9.21e+08
19.5703	12.0	949	-152.69	-81.378	67.930	-78.207	49.797	18.261	1.37e+09	1.20e+09	1.06e+09
19.5706	13.0	646	-2.08	-81.377	67.540	-78.153	49.773	18.259	1.28e+09	1.11e+09	9.66e+08
19.5708	14.0	949	0.00	-81.375	67.150	-78.100	49.750	18.258	1.04e+09	9.29e+08	8.41e+08
19.5711	15.0	646	2.08	-81.373	66.760	-78.047	49.727	18.257	1.23e+09	1.15e+09	1.04e+09
19.5714	16.0	949	2.08	-81.372	66.370	-77.993	49.703	18.256	1.11e+09	1.03e+09	9.46e+08
19.5717	17.0	646	-151.12	-81.370	65.980	-77.940	49.680	18.254	7.50e+08	6.85e+08	6.32e+08
19.5719	18.0	646	0.00	-81.368	65.590	-77.887	49.657	18.253	7.11e+08	6.57e+08	6.13e+08
19.5722	19.0	646	-0.00	-81.367	65.200	-77.833	49.633	18.252	6.86e+08	6.36e+08	5.84e+08
19.5725	20.0	646	-102.74	-81.365	64.810	-77.780	49.610	18.251	6.08e+08	5.49e+08	4.88e+08
19.5728	21.0	440	-102.39	-81.363	64.420	-77.727	49.587	18.250	5.23e+08	4.75e+08	4.32e+08
19.5731	22.0	440	102.39	-81.362	64.030	-77.673	49.563	18.248	6.51e+08	5.94e+08	5.39e+08
19.5733	23.0	646	-1.42	-81.360	63.640	-77.620	49.540	18.247	5.91e+08	5.19e+08	4.62e+08
19.5736	24.0	440	-173.39	-81.358	63.250	-77.567	49.517	18.246	3.97e+08	3.27e+08	2.69e+08
← Records removed →											
19.6164	178.0	65	10.58	-77.638	16.132	-69.848	46.715	18.099	1.30e+08	2.30e+07	8.55e+06
19.6167	179.0	65	14.96	-77.600	15.900	-69.800	46.700	18.099	1.10e+08	1.79e+07	8.75e+06
19.6169	180.0	95	-0.21	-77.555	15.742	-69.753	46.687	18.098	9.98e+07	1.16e+07	5.79e+06
19.6172	181.0	65	-60.06	-77.510	15.583	-69.707	46.673	18.097	1.26e+08	1.04e+07	3.28e+06