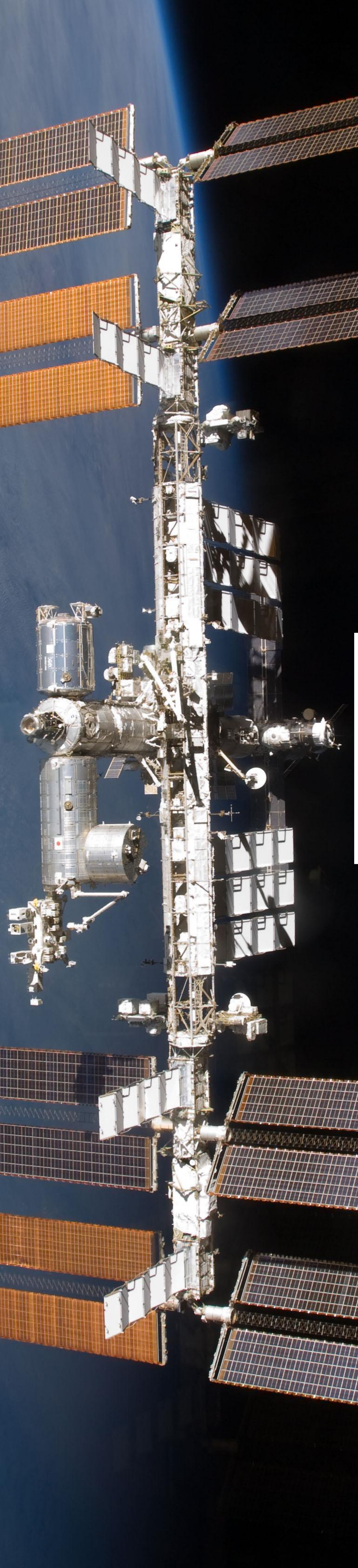

SA13B-1900 Auroral Charging of the International Space Station

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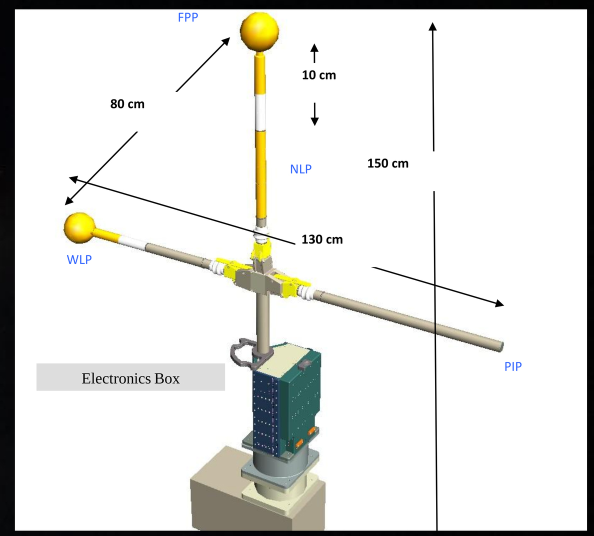
Introduction

Electrostatic potential variations of the International Space Station (ISS) relative to the space plasma environment are dominated by interaction of the negatively grounded 160 volt US photovoltaic power system with the plasma environment in sunlight and inductive potential variations across the ISS structure generated by motion of the vehicle across the Earth's magnetic field [*Minow et al.* 2010]. Auroral charging is also a source of potential variations because the 51.6° orbital inclination of ISS takes the vehicle to sufficiently high magnetic latitudes to encounter precipitating electrons during geomagnetic storms. Analysis of auroral charging for small spacecraft or isolated insulating regions on ISS predict rapid charging to high potentials of hundreds of volts [*Purvis et al.* 1994] but it has been thought that the large capacitance of the entire ISS structure on the order of 0.01 F [*Carruth et al.* 2001; *Koontz et al.* 2010] will limit frame potentials to less than a volt when exposed to auroral conditions [*Koontz et al.*, 2010].

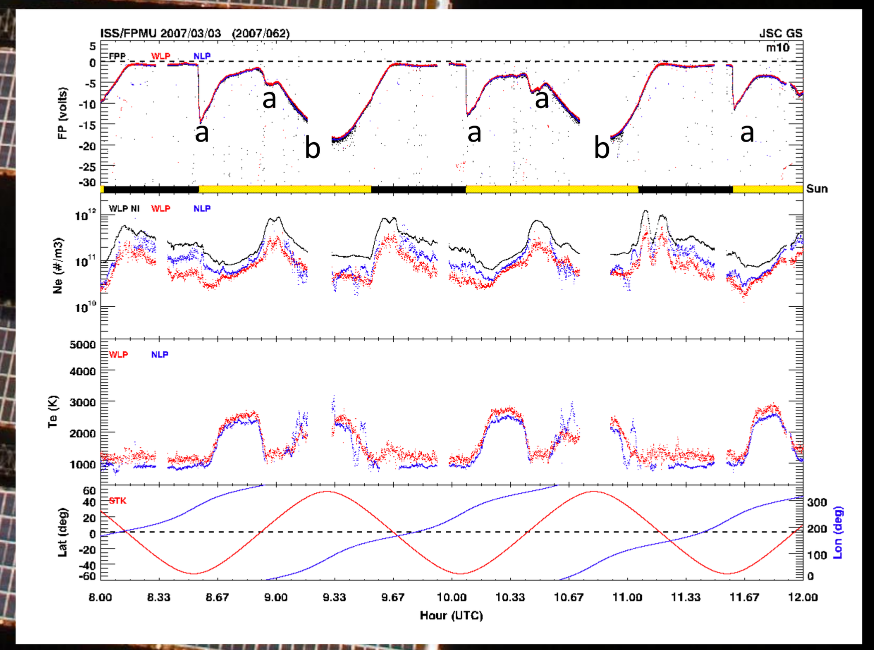
We present three candidate auroral charging events characterized by transient ISS structure potentials varying from approximately 2 to 17 volts. The events occur primarily at night when the solar arrays are unbiased and cannot therefore be due to solar array current collection. ISS potential decreases to more negative values during the events indicating electron current collection and the events are always observed at the highest latitudes along the ISS trajectory. Comparison of the events with integral >30 keV electron flux measurements from NOAA TIROS spacecraft demonstrate they occur within regions of precipitating electron flux at levels consistent with the energetic electron thresholds reported for onset of auroral charging of the DMSP and Freja satellites. In contrast to the DMSP and Freja events, one of the ISS charging events occur in sunlight.



Sensor	Measured Parameter	Rate (Hz)	Effective Range
FPP	V_F	128	-180 to +180 V
WLP	N T_e V_F	1	10^9 to $5{\cdot}10^{12}$ m^{-3} 500 to 10,000 K -20 to 80 V
NLP	N T_e V_F	1	10^9 to $5{\cdot}10^{12}$ m^{-3} 500 to 10,000 K -180 to +180 V
PIP	N	512	$1.1{\cdot}10^{10}$ to $4{\cdot}10^{12}$ m^{-3}

The FPMU instrument suite includes a Floating Potential Probe (FPP), Plasma Impedance Probe (PIP), Wide-sweep Langmuir Probe (WLP), and Narrow-sweep Langmuir Probe (NLP). FPMU was developed by Space Dynamics Laboratory in collaboration with Utah State University [*Swenson et al.*, 2003a,b; *Barjatya et al.*, 2009] and deployed on ISS in 2006. FPMU was mounted to a camera port on the S1 (starboard) Truss from August 2006 to November 2009 and moved to the current location on the P1 (port) Truss. Data is encoded in a video signal and down linked via the Ku-band video system. The camera interface allows for high bandwidth telemetry (6,776 12-bit words, 1 32-bit word) each second.

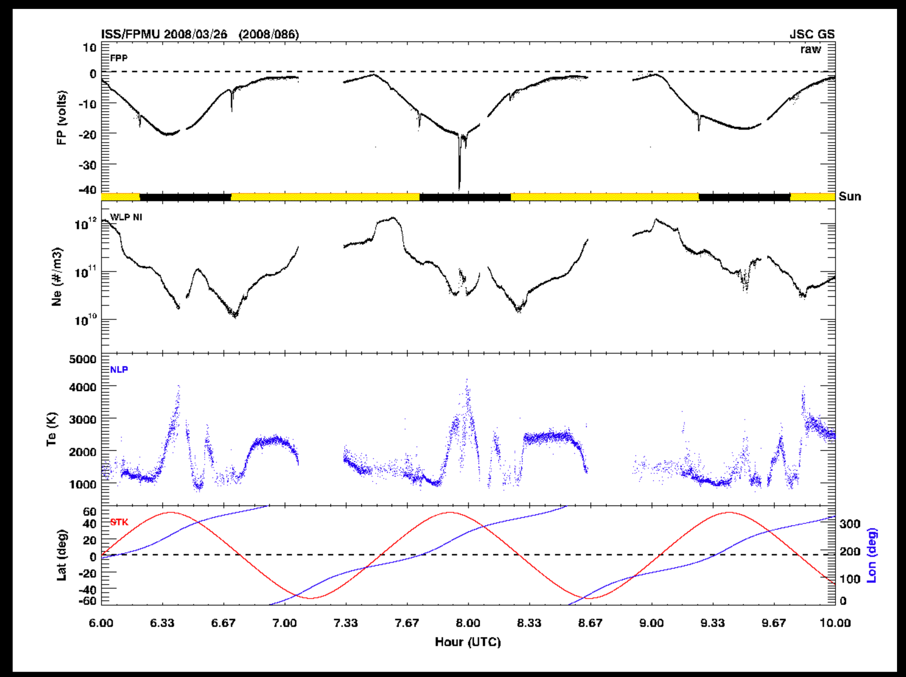
Following initial checkout and on-orbit validation [*Coffey et al., 2008; Wright et al., 2008*], FPMU data has been used to verify ISS charging models, characterizing charging environments in support of Shuttle and ISS based EVA's, observations in coordination with ISR World Days, supporting ISS payloads, and other related engineering and science support activities.

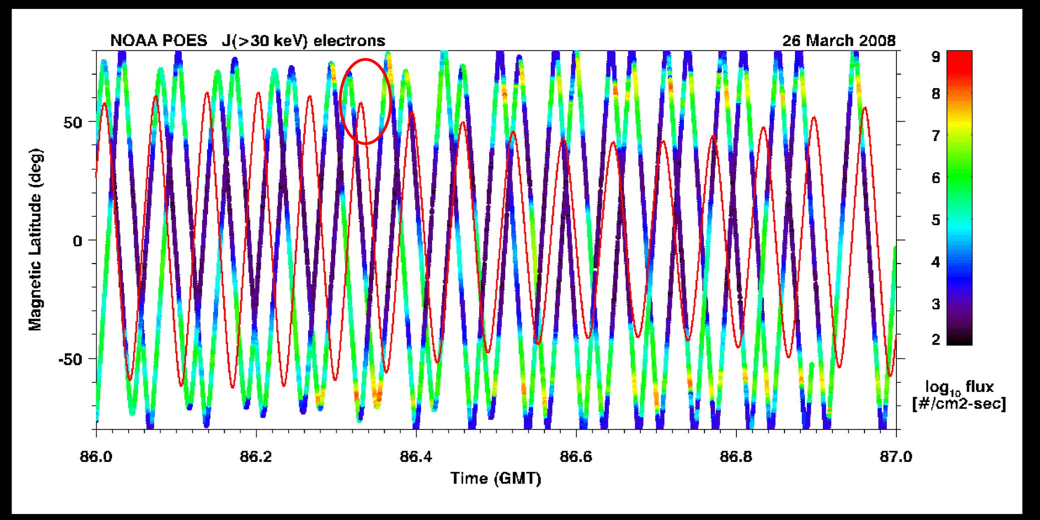


FPMU data records showing examples of (a) solar array charging and (b) inductive (vxB)-L potential variations. No evidence of auroral charging is present during this period. The best estimates of the electron temperature is obtained from the NLP and plasma density from the WLP Ni values assuming quasi-neutrality and the best measurement of floating potential is obtained from the FPP.

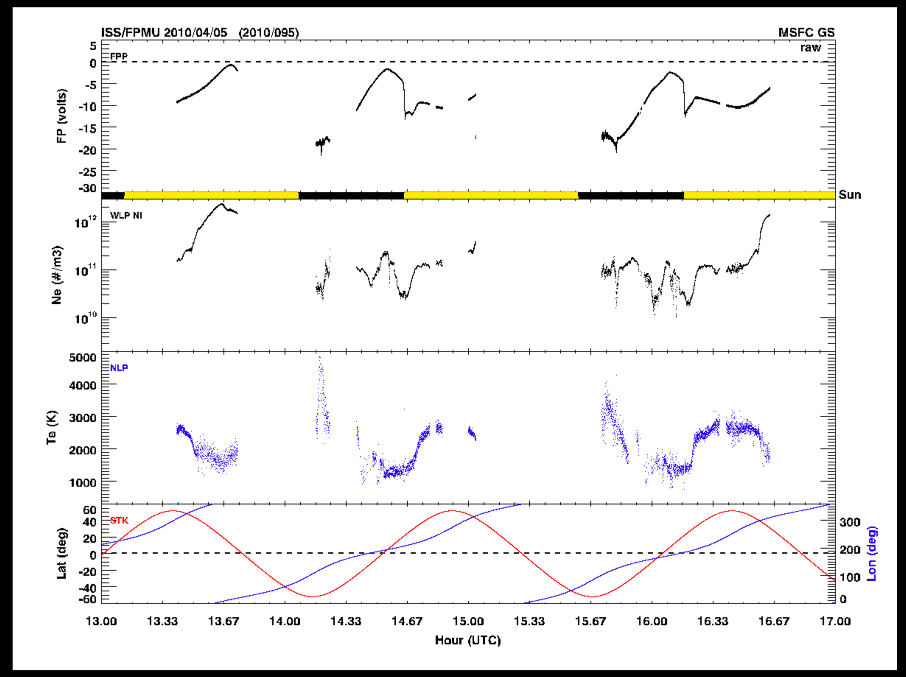
Example Auroral Charging Events

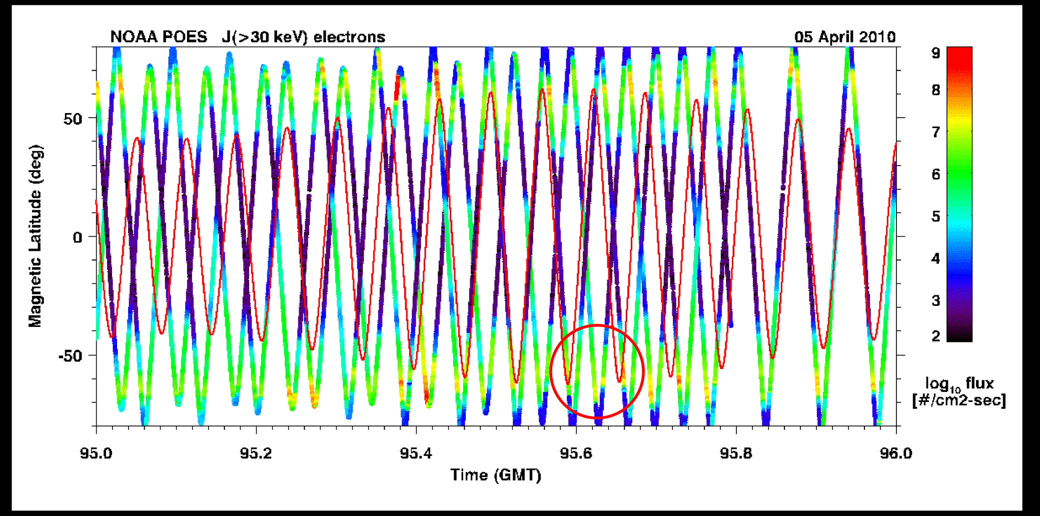
In-situ precipitating auroral electron flux measurements are not available on ISS for these events. Integral electron flux J(>30 keV) from NOAA-15, -16, -17, -18, -19 and Metop-2 are used to establish the presence of energetic auroral electrons during the events. Electron flux averaged over 16 seconds is coded in color along the NOAA and Metop satellite orbit and the ISS orbit is indicated in red.



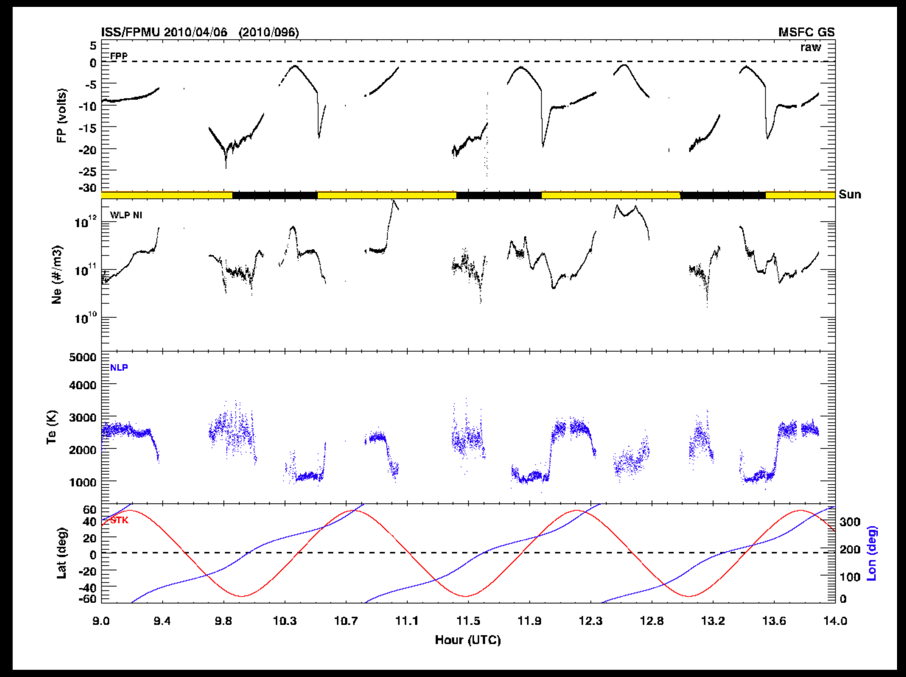


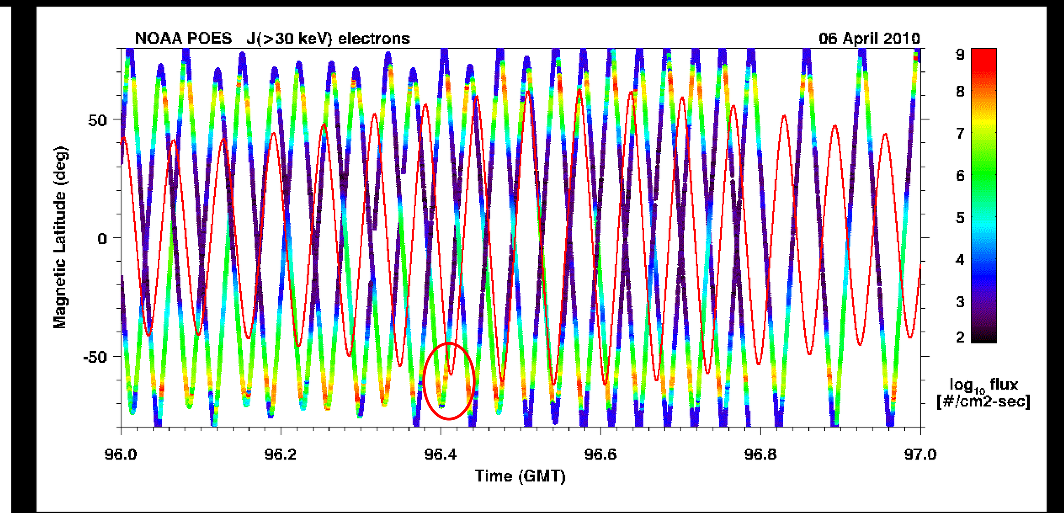
A single ~17 volt charging event at high northern latitude. Electron density is ~0.5 to 1.0 x10^{11} 1/m^3 during the event. This example is one of the largest ISS auroral charging events observed in the FPMU records to date. NOAA coverage is poor during the event in the northern hemisphere but shows J(>30 keV) precipitation in the conjugate hemisphere with a flux of ~1 to 5x10^7 1/cm^2-sec-sr.





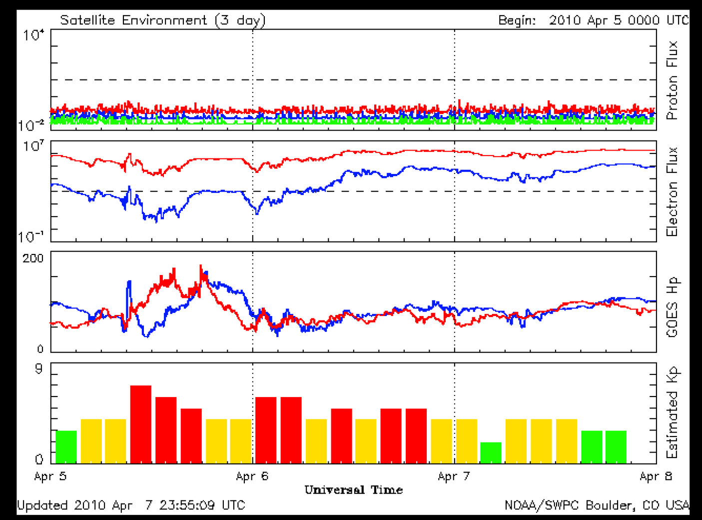
Two examples of small ~1 to 2 volt charging events at high southern latitudes during night. Electron density is ~10^{11} 1/m^3 during the events and the J(>30 keV) flux is ~ 10^7 to 10^8 1/cm^2-sec-sr.

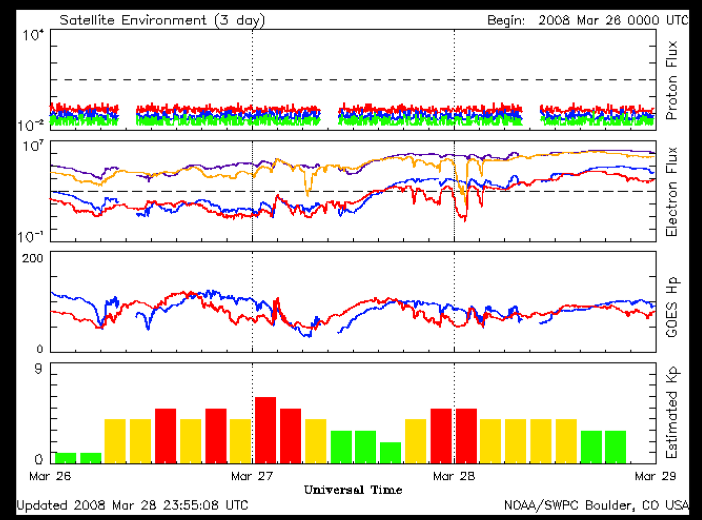




A sunlight charging event of ~5 volts before ISS enters eclipse just before about 10 UT. Electron density is ~10^{11} 1/m^3 during the event and the J(>30 keV) flux is ~ 10^7 to 10^8 1/cm^2-sec-sr. Sunlight charging events have not been reported previously from polar, low Earth orbit satellites.

Geomagnetic Activity Summary





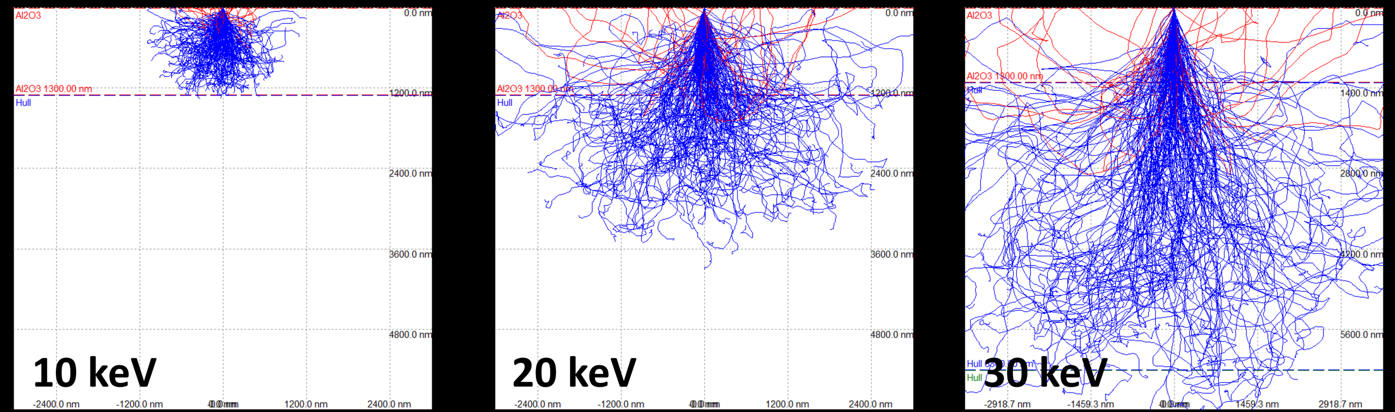
Discussion

Analysis of DMSP and Freja spacecraft charging in auroral environments [*Gussenhoven et al., 1985; Yeh et al., 1987; Frooninckx and Sojka, 1992; Anderson and Koons, 1996; Wahlund et al., 1999]* have shown that three conditions are required for charging to negative potentials exceeding 100 volts:

- spacecraft in eclipse
- integral electron flux J(>10 keV) exceeds 10^8 1/cm^2-s-sr
- ambient ion densities less than 10^9 to 10^{10} 1/m^3

These conditions assure that current collection is dominated by electrons at energies where secondary electron yields are too small to reduce the current collection and there is insufficient background plasma to reduce the accumulating charging density on the spacecraft surface. Dark conditions eliminate the photoemission currents which also serve to reduce the accumulating electron surface charge density.

The ISS events are much smaller than the >|-100 volt| potentials observed on DMSP and Freja but are interesting for two reasons. First, in contrast to DSMP and Freja which had significant areas of conductive materials exposed to the space environment, ISS is nearly covered by insulating material. FPMU measures the local potential of the spacecraft ground relative to the space environment but provides no information on the local potential of the various insulating surfaces. We believe that the potentials observed in regions of auroral precipitation are the result of current collection by energetic >30 keV electrons which penetrate the 1300 nm anodized aluminum coating used for thermal control on the pressurized US, ESA, and JAXA modules. Electrons penetrating this coating deposit charge directly in the grounded aluminum substrate. Second, the sunlight charging event which has not been reported for either the DMSP or Freja spacecraft is possible on ISS because the photoemission process is restricted to the surface of the anodized coating and unable to suppress the voltage due to accumulation of the penetrating energetic electrons at depths exceeding the anodized coating.



CASINO Monte Carlo model simulations of energetic electron penetration of 1300 nm Al_2O_3 (anodized coating) on Al substrate demonstrating how the ~10 keV electrons associated with severe DMSP and Freja charging events are a surface charging process while an appreciable fraction of ~20 keV to ~30 keV auroral electrons penetrate the coating to charge the ISS frame.

Future work will involve additional FPMU observation campaigns during geomagnetic storm events to increase our collection of candidate charging events. In addition, we will work with the full 2-second time resolution NOAA and Metop-2 records which will better characterize the transient nature of the auroral precipitation than the 16-second records used here.

Acknowledgements

Geomagnetic activity summary plots were obtained from the NOAA Space Weather Prediction Center and NOAA POES , Metop data from the NOAA National Geophysical Data Center. The CASINO code is available from *http://www.gel.usherbrooke.ca/casino/index.html*.

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