Space Environmental Conditions Surrounding NPP VIIRS Anomalies

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NPP VIIRS Anomaly Summary

- Summary provided by Raytheon specifies 5 events
  - 4 Events are identical in behavior starting with the loss of comm on both 1394 Bus A & Bus B
    - 11/25/2011 @ 16:35, 02/18/2012 @ 04:14, 03/10/2012 @ 04:13, 03/28/2012 @4:13
  - A similar event occurred on 02/11/2012 @ 4:45 UT with the loss of comm on only 1394 Bus B
    - An investigation of this event has pointed to a code within the 1394 driver software which resides in the single board computer's DRAM. That memory unit is a commercial part and has known radiation susceptibility.

Space Weather and Anomalies

- Possible space weather related causes
  - Spacecraft surface charging and discharge- not likely
  - Internal charging and discharge-not likely
  - Single Event Upset-probable
- Analysis method
  - Use data from 5 POES satellites and the MetOP-A satellite that carry the Space Environment Monitor-2 that monitors the particle radiation responsible for the 3 types of anomalies
  - All are at ~850 km polar orbits similar to NPP

Single Event Upset Analysis

- Preferable Conditions
  - Single Event Upsets (SEU's) occur when a single very energetic ion passes through a component causing bit flips or latch-ups
  - Most likely in the South Atlantic Anomaly (SAA) where very energetic protons are always present
  - Can occur during solar proton events
    - Protons from the sun fill the low altitude polar regions lasting several days.
    - The lowest energy proton fluxes are comparable to those in the SAA but decrease more rapidly at the higher energies
  - Can be caused by Galactic Cosmic Rays which are protons and heavier ions that reach Earth from outside the solar system
    - GCR fluxes are most intense over the magnetic poles and decrease toward the equator
    - GCR fluxes are always present at low levels and vary slowly
- Events are likely SEU's caused by >35 MeV energetic protons and GCR's
  - 4 events occurred in the heart of the SAA
  - No anomalies occurred during 4 solar proton events that had >16 MeV proton fluxes comparable to those in the SAA but much lower >35 MeV proton fluxes
  - 1 event occurred where GCR's are present (The lower GCR fluxes would make the anomaly occurrence rate in this region lower)
  - The engineering investigation of the event on 2/11/2012 is consistent with a single event upset due to a commercial part that has known radiation susceptibility.

Details of Single Event Upsets Analysis

- 4 events occur in the South Atlantic Anomaly where high energy protons can cause single event upsets
  - Figure 1: Event locations (white circles) with the flux of >35 MeV protons compiled from all POES satellites on March 28th 2012. (Grey indicates no data due to limited orbital coverage). Plots of data from the other event times show similar patterns because SAA fluxes do not vary significantly.

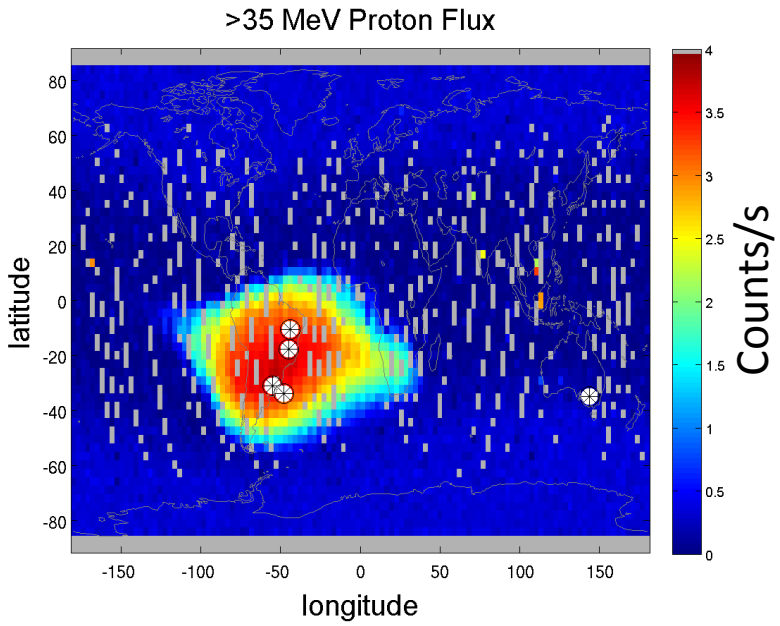


Figure 1

Details of Single Event Upsets Analysis

- No anomalies occurred during the 4 solar proton events since the NPP launch
  - Figure 2: GOES solar proton flux for the Nov 26-30th event
  - Figure 3: GOES solar proton flux for the Jan 23-27th event
  - Figure 4: GOES solar proton flux for the March 7-13th event
  - Figure 5: GOES solar proton flux for the May 17-20th event

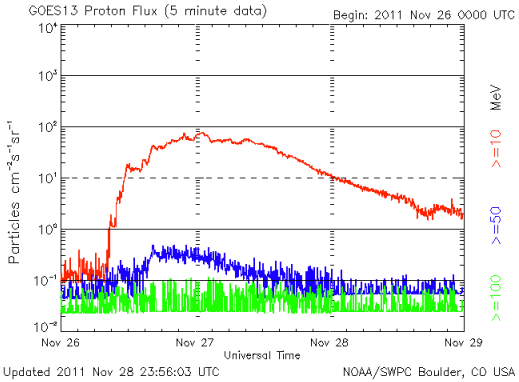


Figure 2

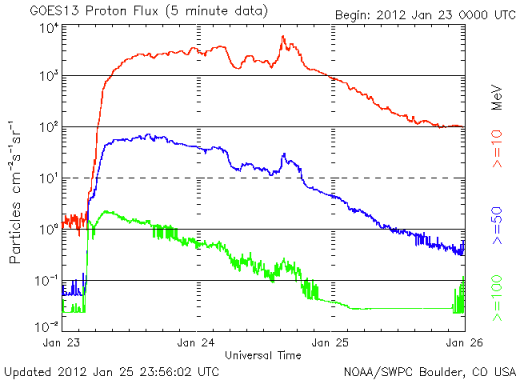


Figure 3

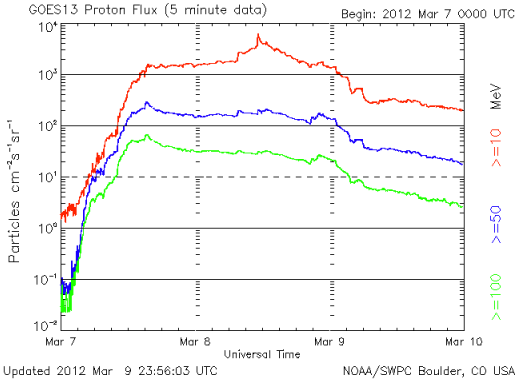


Figure 4

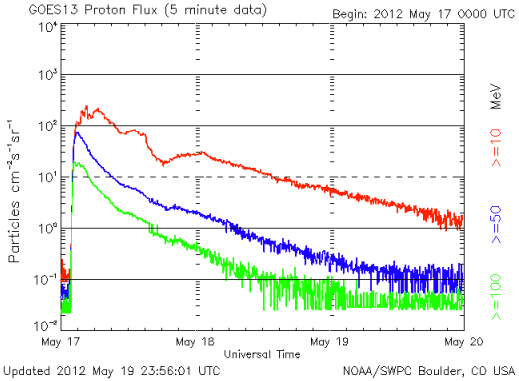


Figure 5

Details of Single Event Upsets Analysis

- All 4 solar proton events had >16 MeV flux levels comparable to those in the SAA but the >35 MeV flux levels were lower than in the SAA.
  - Figure 6: Event locations (white circles) with >16 MeV proton flux compiled from all POES satellites on Jan 23 2012. (Grey indicates no data due to limited orbital coverage).
  - Figure 7: Event locations with >35 MeV proton flux compiled from all POES satellites on Jan 23 2012.

Figure 6

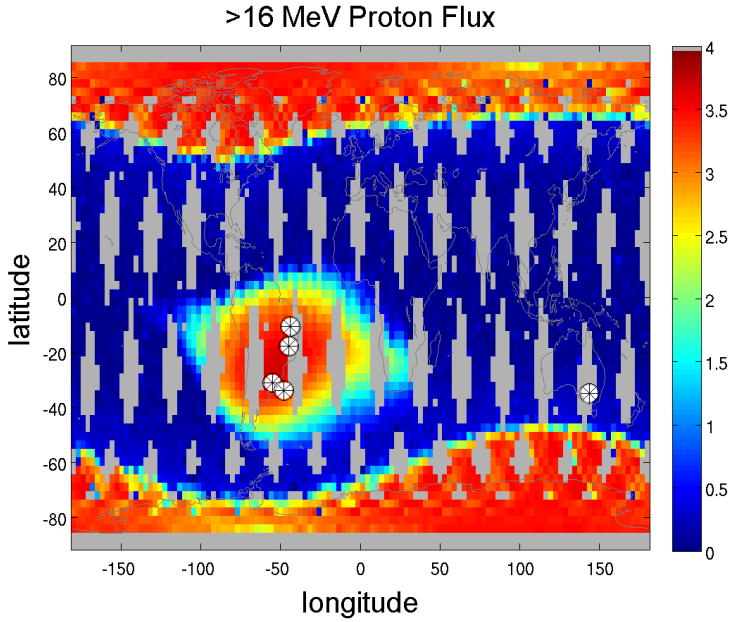
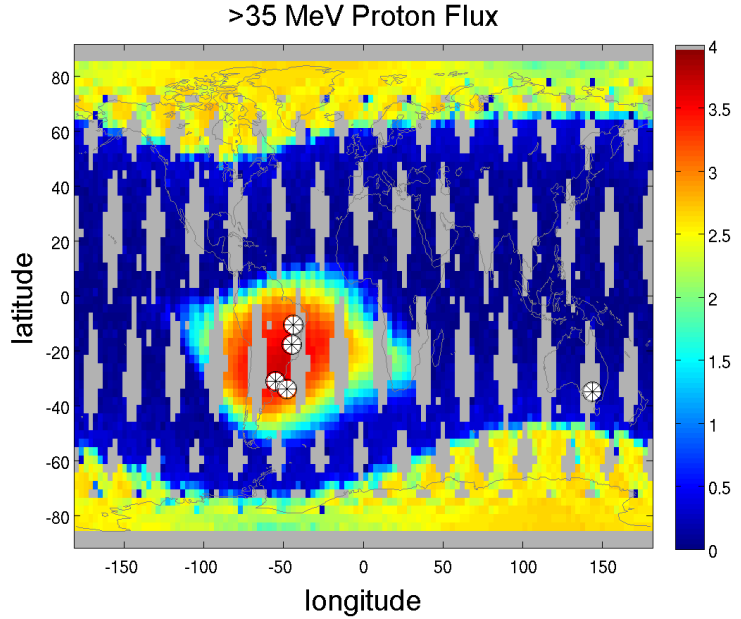


Figure 7



Details of Single Event Upsets Analysis

- 1 anomaly occurred in the region where GCR's are present
  - Figure 8: Event locations with GCR's from the >35 MeV proton measurement. Although GCR's include protons and heavy ions this instrument does not separate the components. The scale has been changed to highlight the lower flux GCR's.

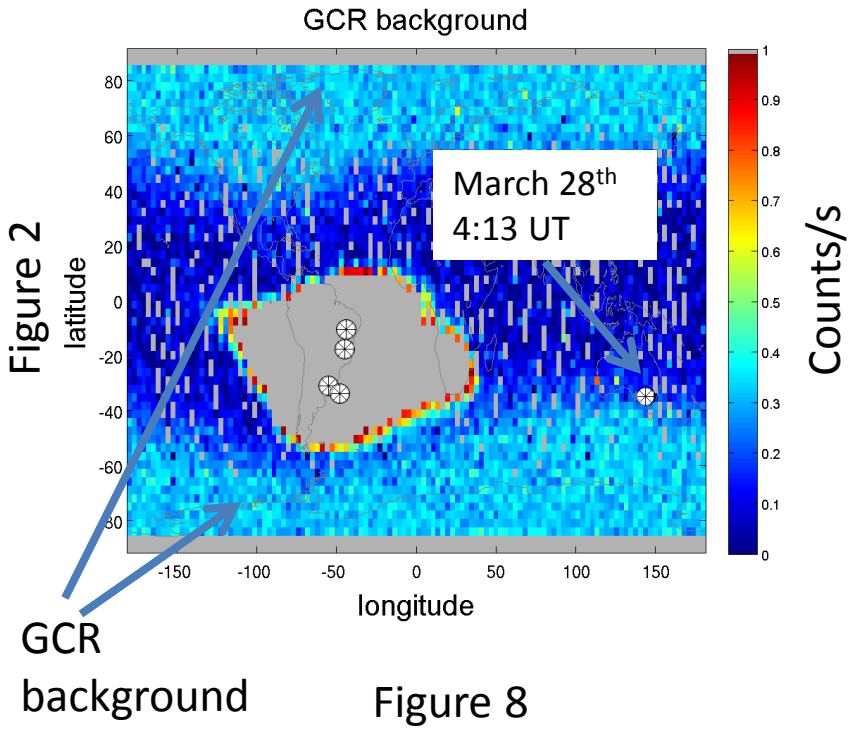


Figure 8

Spacecraft Surface Charging Analysis

- Preferable Surface Charging conditions
  - Most likely in auroral regions where low/medium energy protons/electrons that can collect on surfaces are present
  - Most likely in darkness where there is not photo-electron emission
  - A sudden discharge when the satellite is charged to high potentials may cause anomalous behavior
- Surface Charging is ***not*** likely responsible because
  - Events did not occur in auroral region where there are high fluxes of low/medium energy particles
  - All events occurred at much lower geomangetic latitudes than statistical surface charging locations compiled from the DMSP satellite

Details of Spacecraft Surface Charging Analysis

- No events occur in the auroral region where the low/medium energy proton/electron flux is highest
  - Figure 9:Event locations with respect to 8 keV electron flux compiled from all POES/MetOp satellites on March 28th, 2012. (Grey indicates no data). Plots of data from the other event times show similar patterns.
  - Apparent flux in the South Atlantic is contamination due to high energy protons that penetrate through the instrument and should be ignored.
- The March 28th event occurs in a region where some medium energy electrons are present but at low levels
  - Figure 10: Event locations with respect to >30 keV electron flux compiled from all POES/MetOp satellites on March 28th 2012 . (Grey indicates no data)
  - The >30 keV detector is more sensitive and shows some medium energy electron flux at the location of the March 28th event but the flux is 3 orders of magnitude lower than in the auroral region and not expected to cause charging.
  - Apparent flux in the South Atlantic is contamination due to high energy protons that penetrate through the instrument and should be ignored.

Figure 9

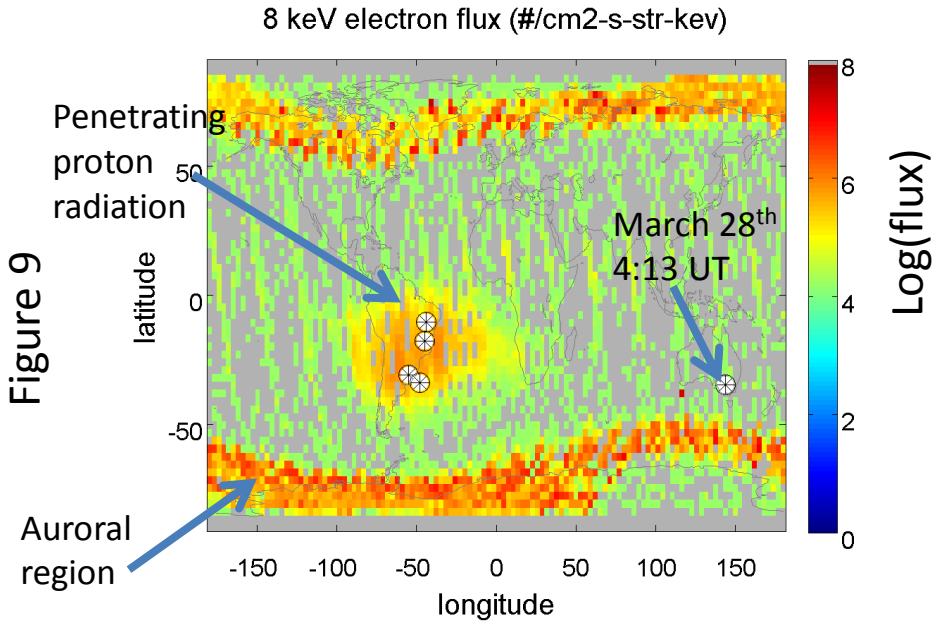
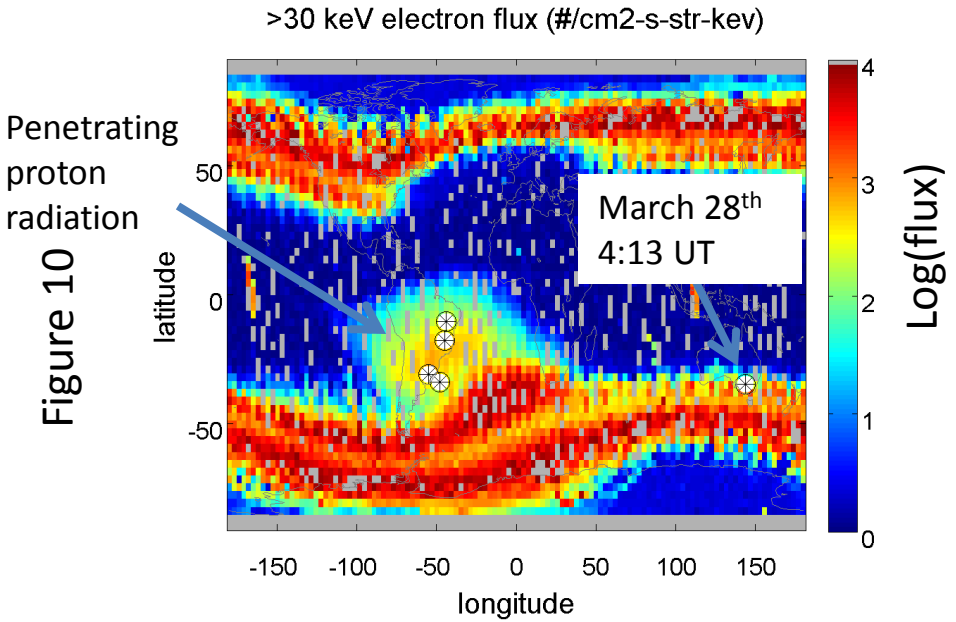


Figure 10



Details of Spacecraft Surface Charging Analysis

- The March 28th event was in sunlight where surface charging is less likely as shown in Figure 11
- All events were at lower magnetic latitudes than statistical distributions of surface charging from the DMSP satellites also at 850 km altitude polar orbits
  - Figure 12 shows the location of the March 28th event, the event at the highest geomagnetic latitude(14 MLT, 42 mlat), with respect to DMSP charging locations [Anderson 2000]

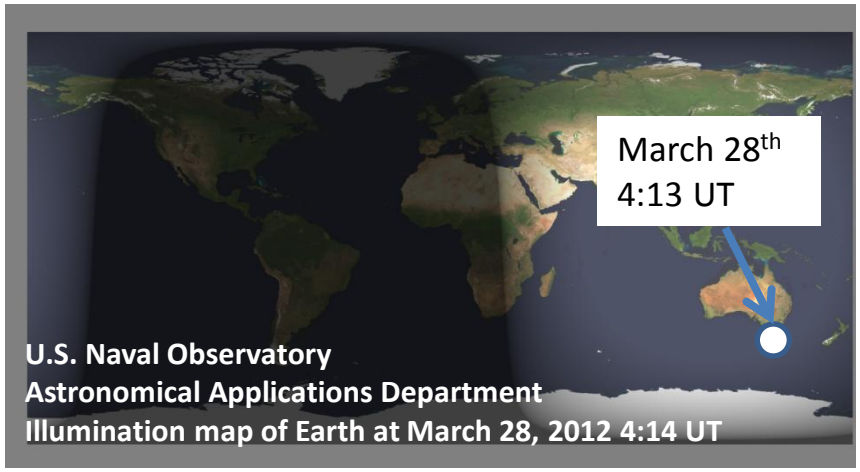


Figure 11

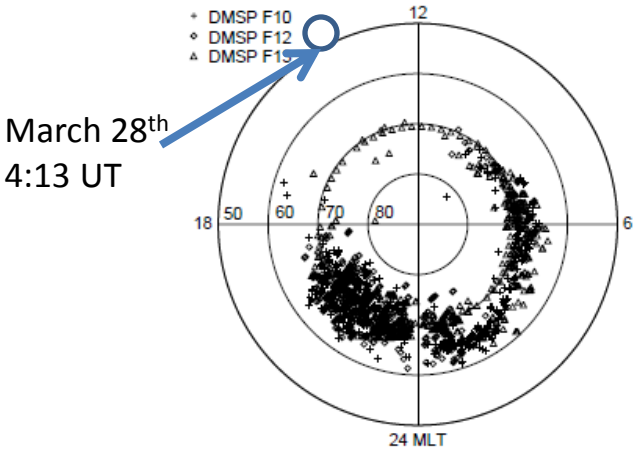


Figure 2. MLT and MLAT distribution of 2824 1-second SSJ/4 sweeps associated with the 704 charging events.

Figure 12

Anderson, P.C., Surface Charging in the auroral zone on DMSP spacecraft in LEO, 6th Spacecraft Charging and Technology Conference, AFRL-VS-TR-20001578, 2000.

Internal Charging Analysis

- Preferable conditions for internal charging
  - Discharges due to internal charging occur after accumulated electrons within dielectric material reach a critical threshold
  - The time of the discharge depends on the electron flux levels in the space environment and the decay time of the dielectric material
  - Typically, electrons must have energy >1 MeV in order to pass through shielding and accumulate internally
- Internal charging is not likely the cause because
  - 4 events occurred in the SAA and 1 in the inner electron radiation belt where >MeV electrons are present
  - However, the daily fluence of >300 keV electrons was not unusually high or sustained prior to the events

Details of Internal Charging Analysis

- High energy electron flux is not enhanced in any systematic way prior to the events
  - Figure 13 shows the >300 keV electron flux measured by all the POES/MetOp satellites integrated over all latitudes and longitudes for each day.
  - Black lines mark the times of the anomalies.

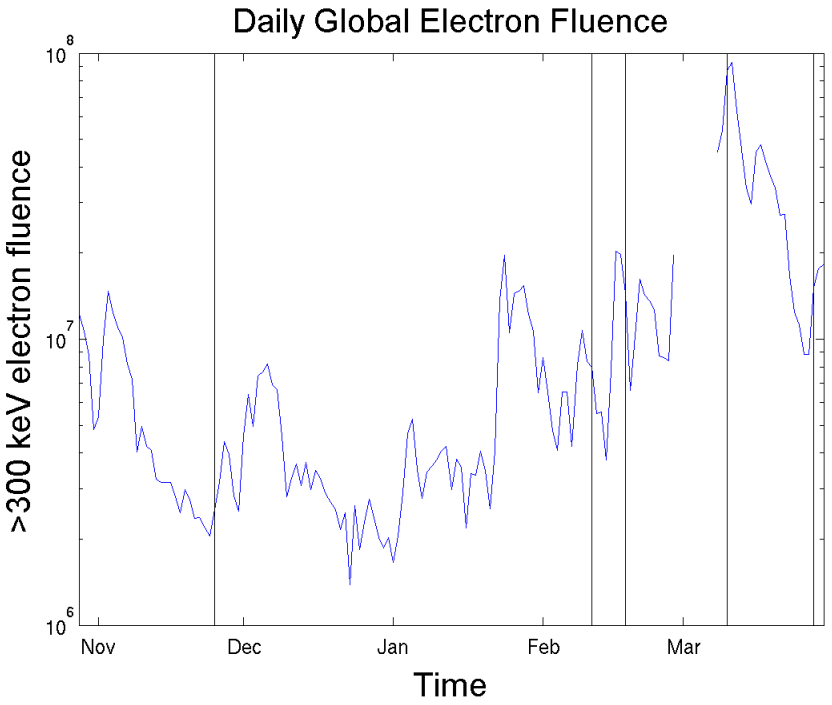


Figure 13

Summary

- The VIIRS on NPP has suffered 5 anomalies since launch in Oct 2011.
- Based on measurements of the particle radiation environment from the POES/MetOp satellites at the time of the anomalies, they are most likely single event upsets caused by energetic protons and Galactic Cosmic Rays.
- Given the stable nature of the energetic protons in the South Atlantic Anomaly and the GCR's over the polar regions there will likely continue to be similar anomalies in these regions.
- Sporadic solar proton events that produce energetic protons over the polar regions lasting hours to days have not caused an anomaly to date but may in the future.