Internal Charging

Joseph I Minow
EV44/Natural Environments Branch
Spacecraft & Vehicle Systems Department
NASA, Marshall Space Flight Center

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joseph.minow@nasa.gov

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Introduction

NASA Goddard Space Flight Center, Space Weather Research Center (SWRC)
Message Type: Space Weather Alert
Message Issue Date: 2013-07-12T11:35:00Z
Message ID: 20130712-AL-001

Summary:

Significantly elevated energetic electron fluxes in the Earth's outer radiation belt. GOES 13 "greater than 0.8 MeV" integral electron flux is above 10^5 pfu starting at 2013-07-12T11:00Z.

Spacecraft at GEO, MEO and other orbits passing through or in the vicinity of the Earth's outer radiation belt can be impacted.

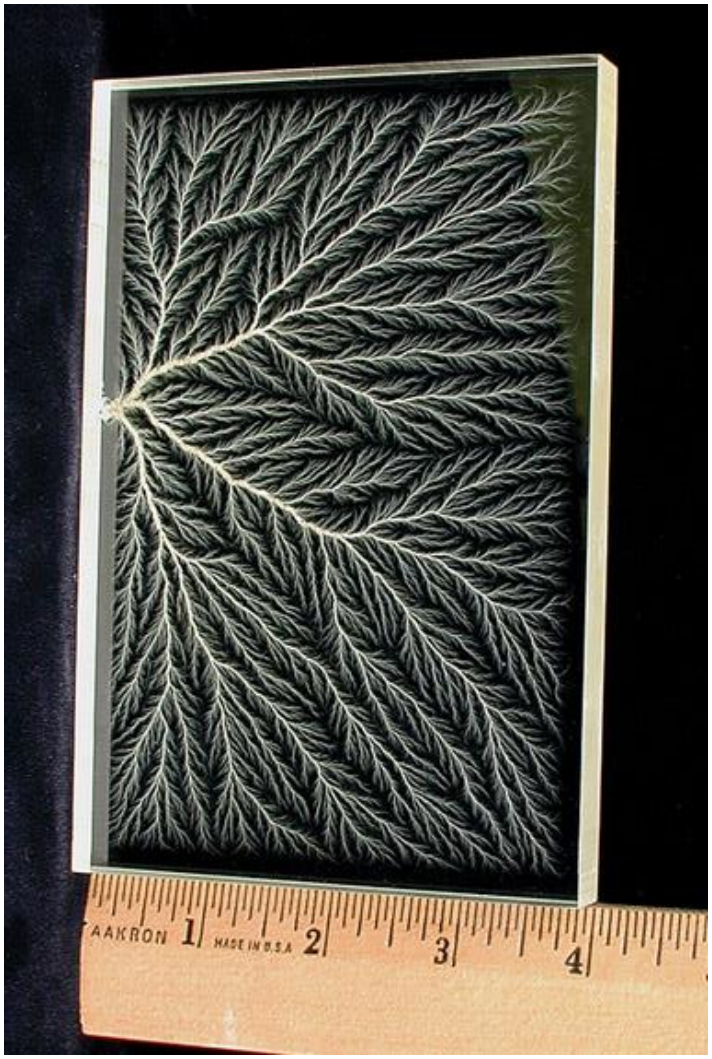
Activity ID: 2013-07-12T11:00:00-RBE-001.

Outline

- Internal charging
- MeV electron threat fluence thresholds
- NUMIT internal charging model
- Real time GEO internal charging tool
- LEO internal charging tool

Internal (Deep Dielectric) Charging

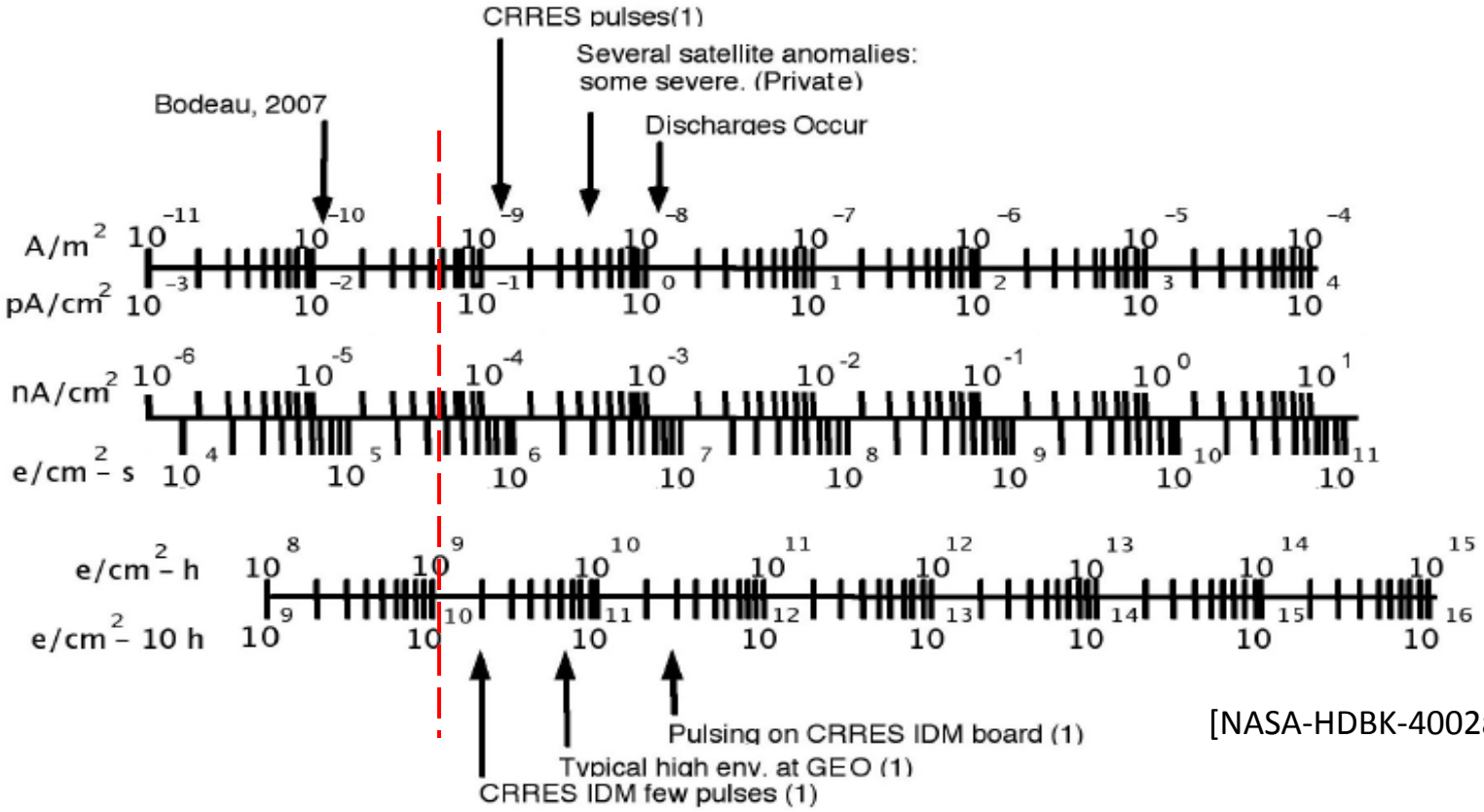
- High energy (>100 keV) electrons penetrate spacecraft walls and accumulate in dielectrics or isolated conductors
- Threat is energetic electrons with sufficient flux to charge circuit boards, cable insulation, and ungrounded metal faster than charge can dissipate
- Accumulating charge density generates electric fields in excess of material breakdown strength, resulting in electrostatic discharge
- System impact is material damage, discharge currents inside of spacecraft Faraday cage on or near critical circuitry, phantom commands, RF noise, and catastrophic damage to critical electronic components



PMMA (acrylic) charged by ~2 to 5 MeV electrons

MeV Electron Threat Fluence Thresholds

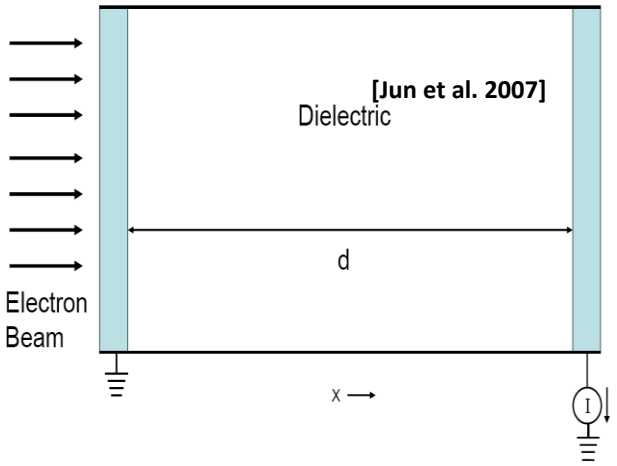
- NASA-HBK-4002A: ~MeV electron flux ≥ 9×10^4 e/cm2-sec-sr
  (10^10 e/cm2 in 10 hours)
- CCMC/SWRC: > 0.8 MeV electron flux > 1×10^5 e/cm2-sec-sr
- NOAA/SWPC >2 MeV electron flux > 1×10^3 e/cm2-sec-sr



[NASA-HDBK-4002a, 2011]

NUMIT Model for EVA Suit Charging

NUMIT (for "numerical iteration") estimates charge deposition, electric field as function of depth in insulating materials due to radiation charging by energetic electrons



Conductor I Ampere meter. Arrow shows positive current direction.

Table 1-2 NUMIT Model, Existing Suit

Layer	Z_{eff}	A_{eff}	Density (g/cm3)	Vol. Resis. (S/m)	κ	RIC (S/m)	RIC Exp	Depth (cm)
								0
1	8.25	17.19	0.429	1.00E+16	2	1.00E+14	0.7	0.114
2	5.484	10.008	1.225	1.00E+12	2	1.00E+14	0.7	0.137
3	6.24	11.99	0.752	1.00E+17	2	1.00E+14	0.7	0.165
4	6.083	11.291	0.501	1.00E+15	4	1.00E+14	0.7	0.193
5	5.484	10.008	3.031	1.00E+12	2	1.00E+14	0.7	0.244
Total								
Total	31.541	60.487	5.938					
Average	6.3082	12.0974	1.1876					
Wt Ave	6.0847	11.555	2.0485					

$$\nabla \bullet \mathbf{D} = \rho$$

$$\mathbf{D} = \varepsilon \mathbf{E}, \qquad \varepsilon = \kappa \varepsilon_0$$

$$\frac{\partial \rho}{\partial t} = -\nabla \bullet \mathbf{J}$$

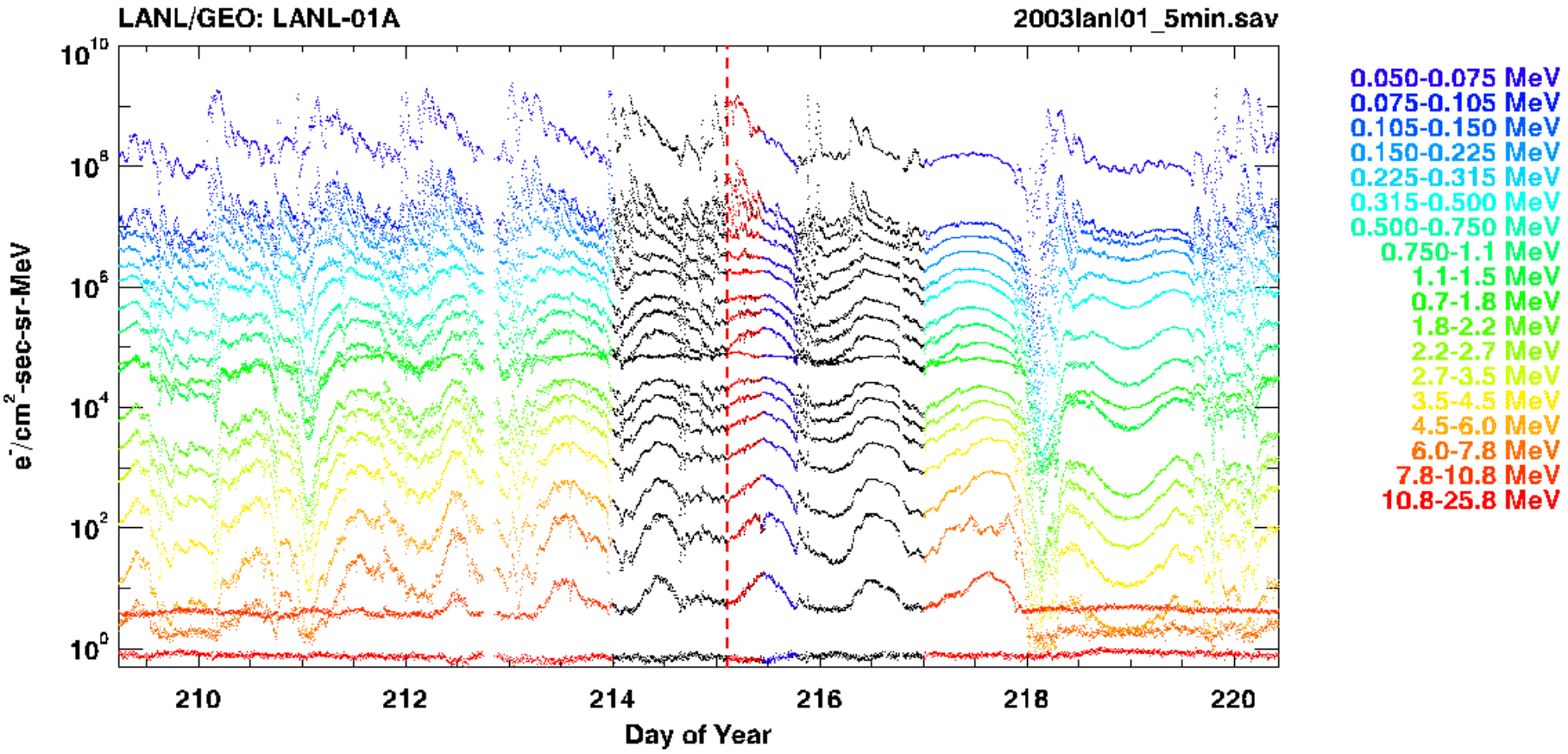
$$\mathbf{J} = \mathbf{J}_R + \mathbf{J}_C = \mathbf{J}_R + \sigma \mathbf{E}$$
$$= \mathbf{J}_R + \left(\sigma_{dark} + \sigma_{radiation}\right)\mathbf{E}$$

$$\sigma_{radiation} = k\left(\frac{d\gamma}{dt}\right)^{\alpha} \qquad 0.5 < \alpha < 1.0$$

Layer Number	Material
---	space (outside of suit)
1	**Teflon/Nomex/Kevlar**
2	**Neoprene coated Nylon**
3	**Dacron polyester**
4	**Urethane coated Nylon**
5	**Nylon chiffon, Nylon Spandex, water cooling tubes**
---	skin (inside suit)

EVA Suit Study Environment

geo_flux_ts_215.11186.txt → test_env.txt



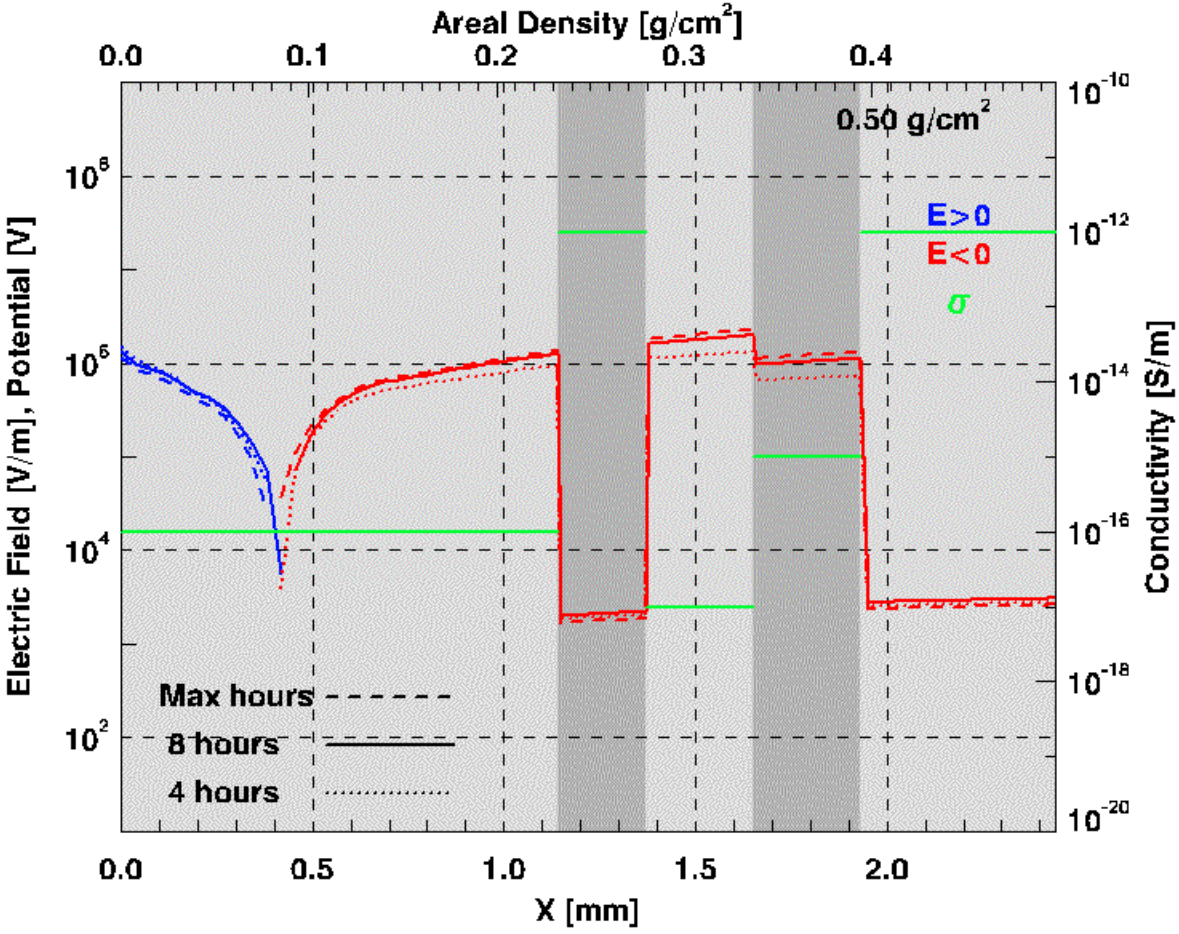
8 hours 16 hours

Interpolation records for filling data gaps

Arms and Lower Torso

Current Design*

Layer	κ	σ (S/m)	Depth (mm)
1	2.0	10^{-16}	1.14
2	2.0	10^{-12}	1.37
3	2.0	10^{-17}	1.65
4	4.0	10^{-15}	1.93
5	2.0	10^{-12}	2.44



Z_{eff} = 6
A_{eff}= 12
2.04 g/cm^3
Kp = 10^{-14} S-sec/m-rad
Δ= 0.7
ΔT = 1.0 sec

*Using material spec for nylon conductivity
σ = 10^{-12} S/m

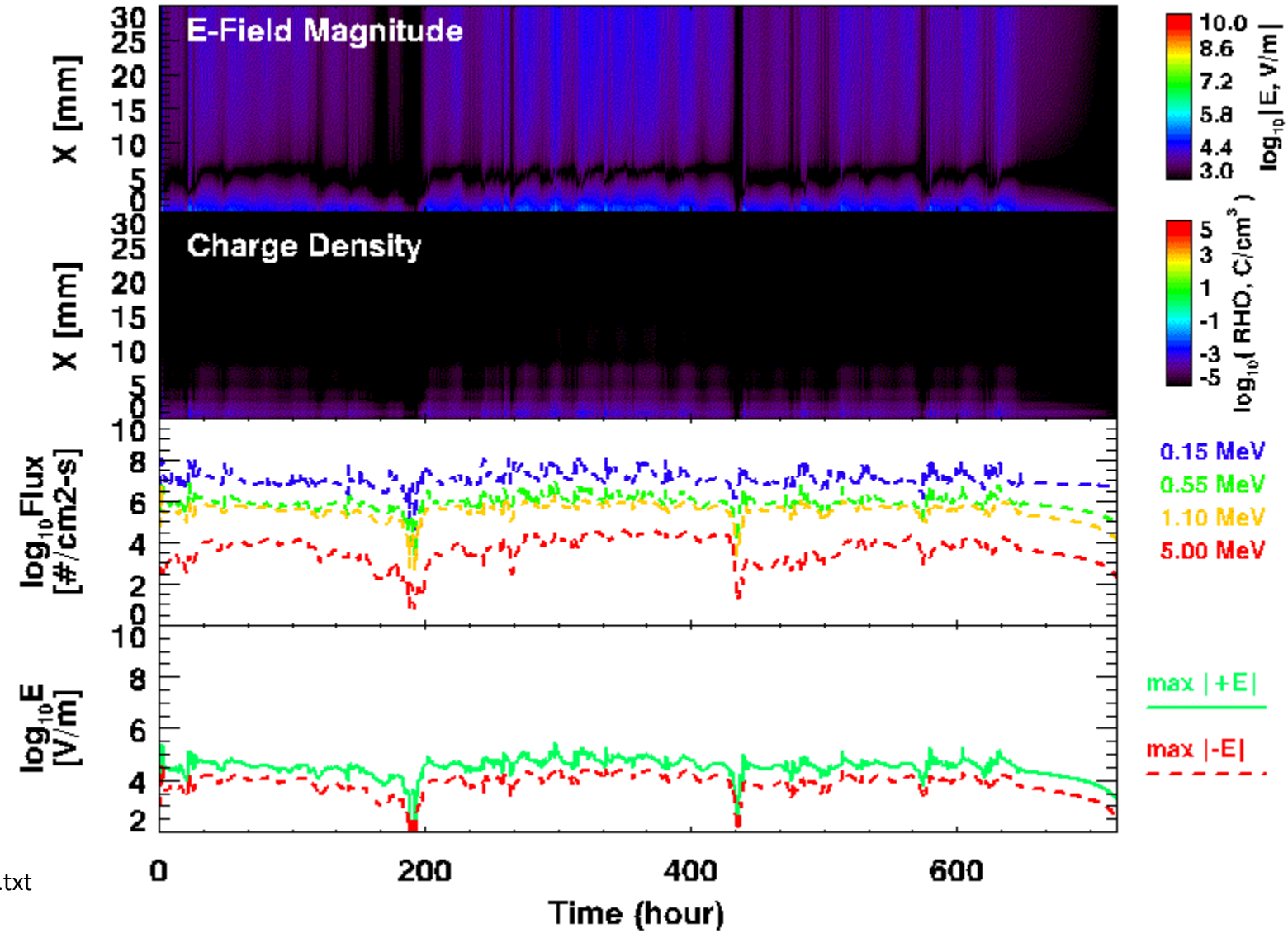
geo_flux_ts_215.11186.txt → test_env.txt

GEO, 30 days, High Conductivity

30 mm
1.14 g/cm3
κ=1.13
10^{-13} S/m
τ~100 sec

Simulated:
30 days
(720 hours)

Δt=30 sec



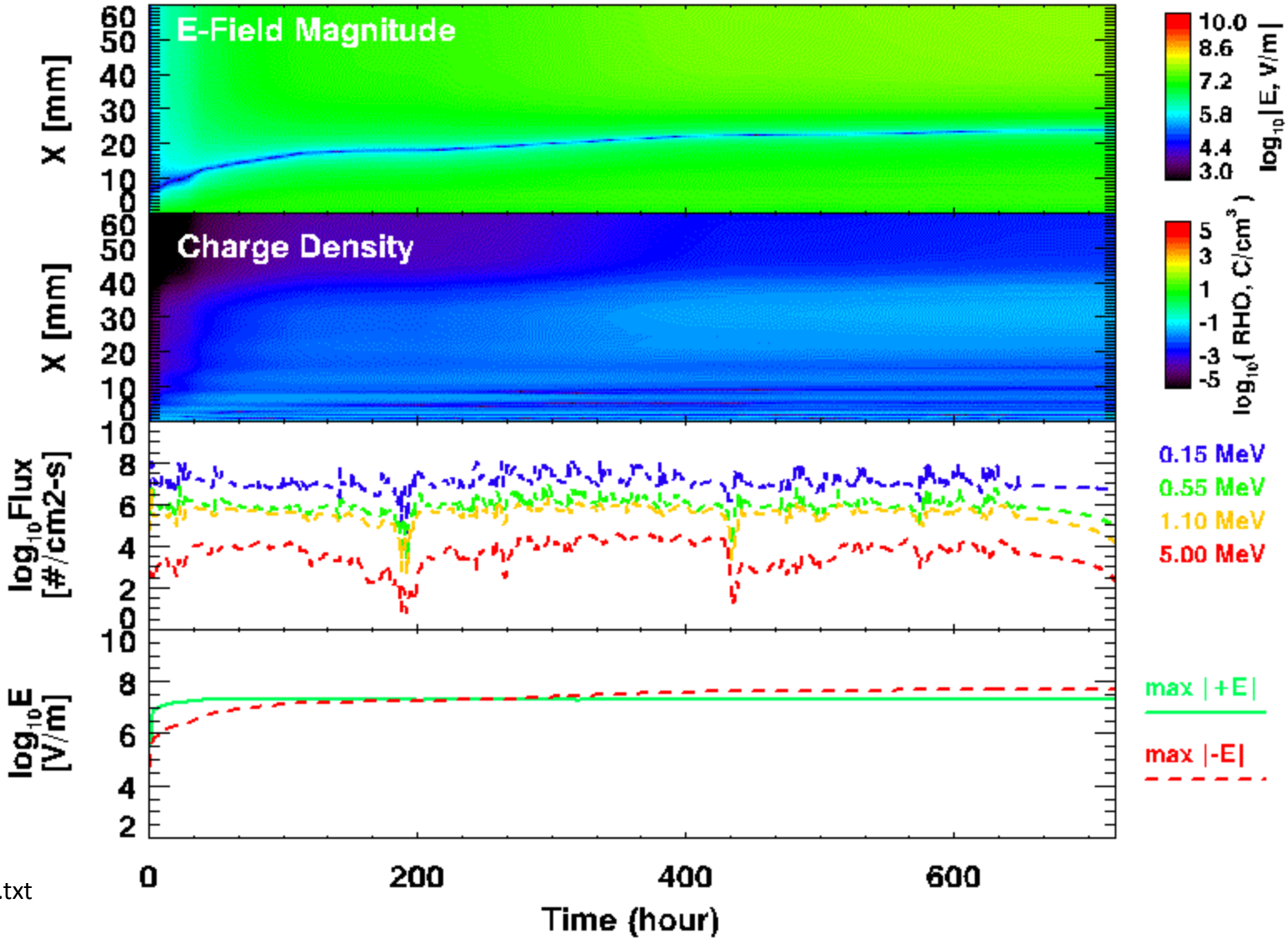
LANL-01 2003
geo_flux_ts_1.0017361.txt
30 days

GEO, 30 days, Low Conductivity

60 mm
1.14 g/cm3
κ=1.13
10^{-19} S/m
τ~1157 days

Simulated:
30 days
(720 hours)

Δt=300 sec

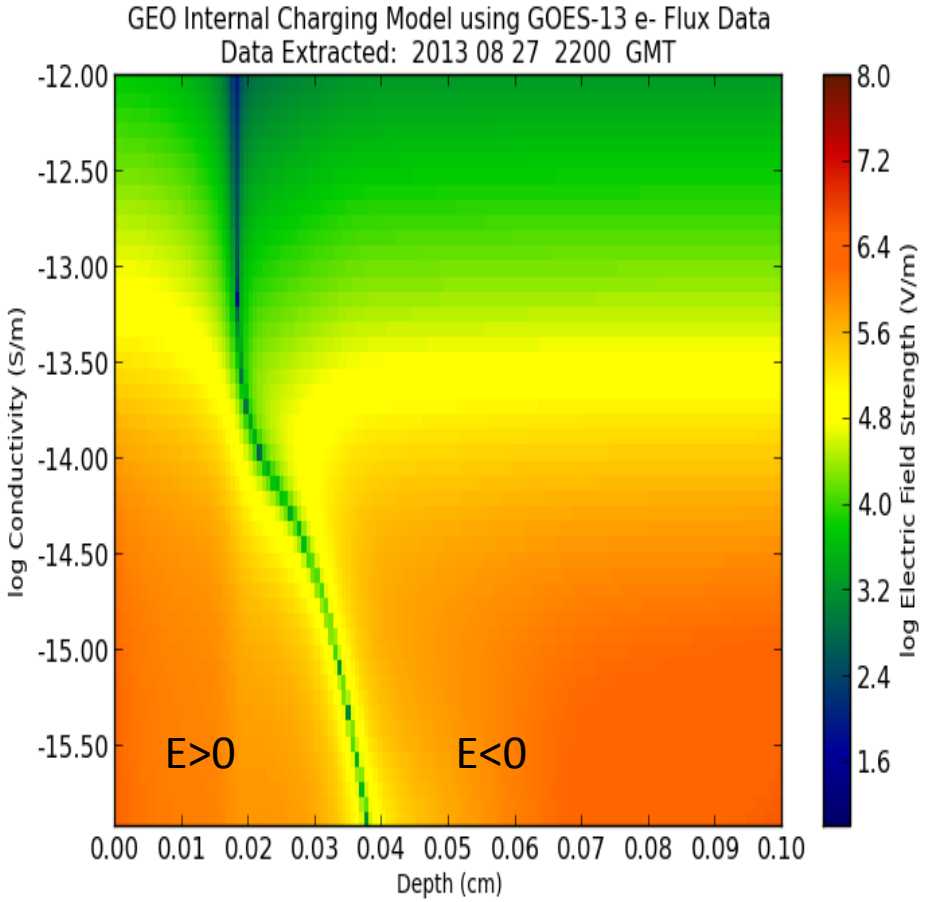


LANL-01 2003
geo_flux_ts_1.0017361.txt
30 days

Geostationary Orbit Internal Charging Tool

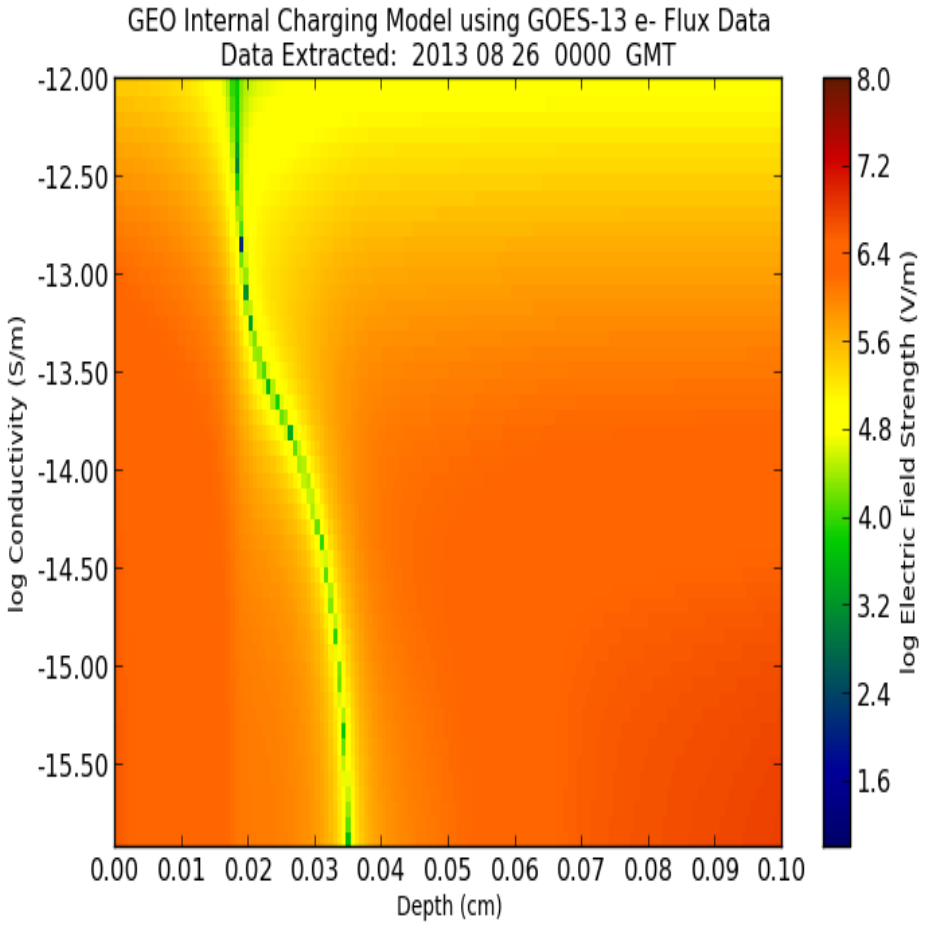
Time constant for charge decay through conduction: $\tau=\kappa\varepsilon_0/\sigma$

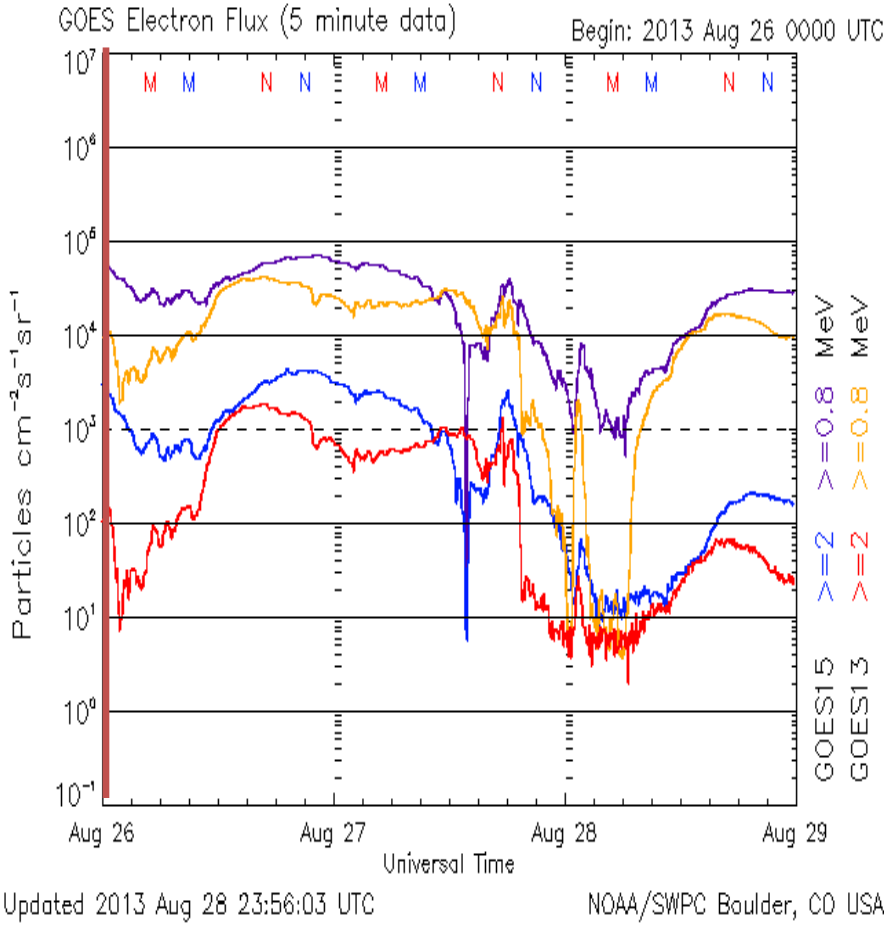
κ	σ (S/m)	τ
2	10^{-12}	~18 sec
2	10^{-13}	~3 min
2	10^{-14}	~30 min
2	10^{-15}	~5 hr
2	10^{-16}	~2 days



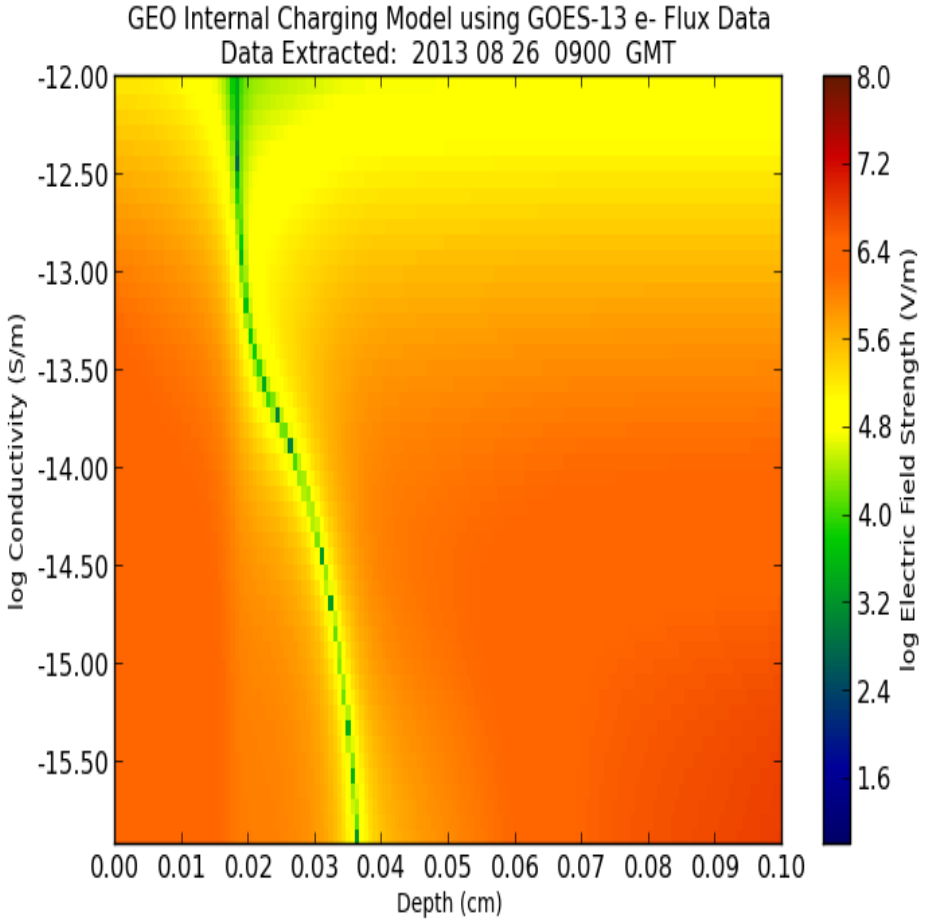
Electric fields resulting from internal (deep dielectric) charging as function of depth in dielectric material and electrical conductivity. Fields are updated at 5 minute intervals using NOAA GOES >0.8 MeV, >2.0 MeV electron data.

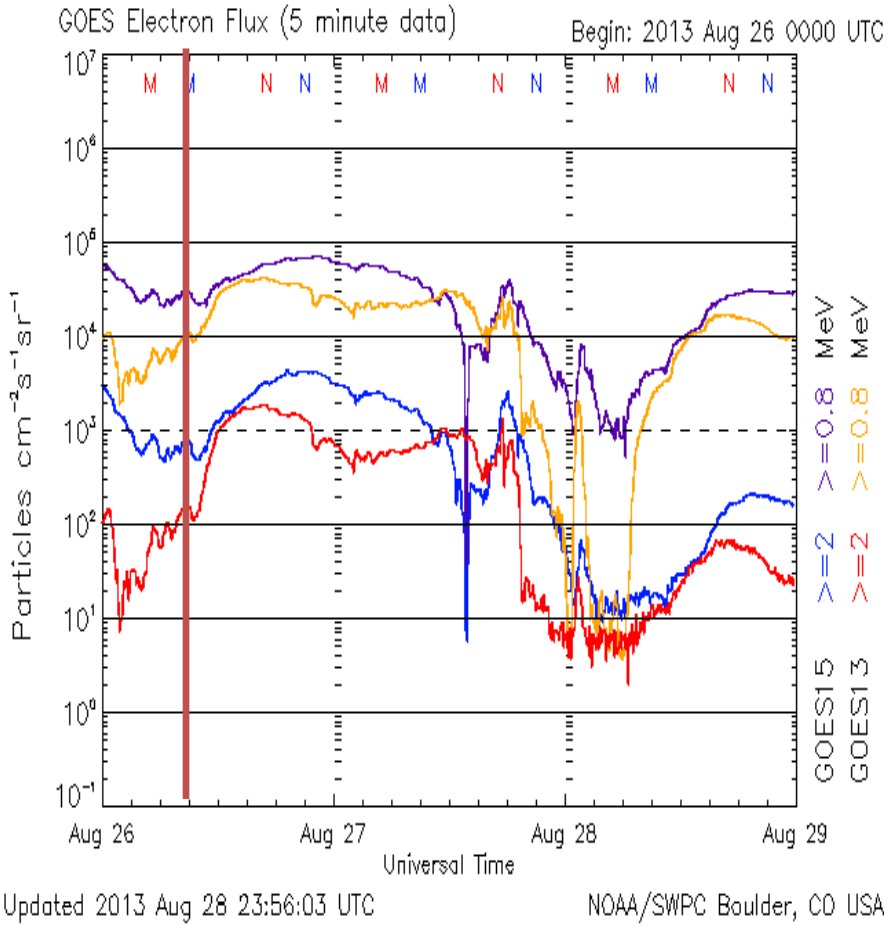
Geostationary Orbit Internal Charging Tool





Geostationary Orbit Internal Charging Tool





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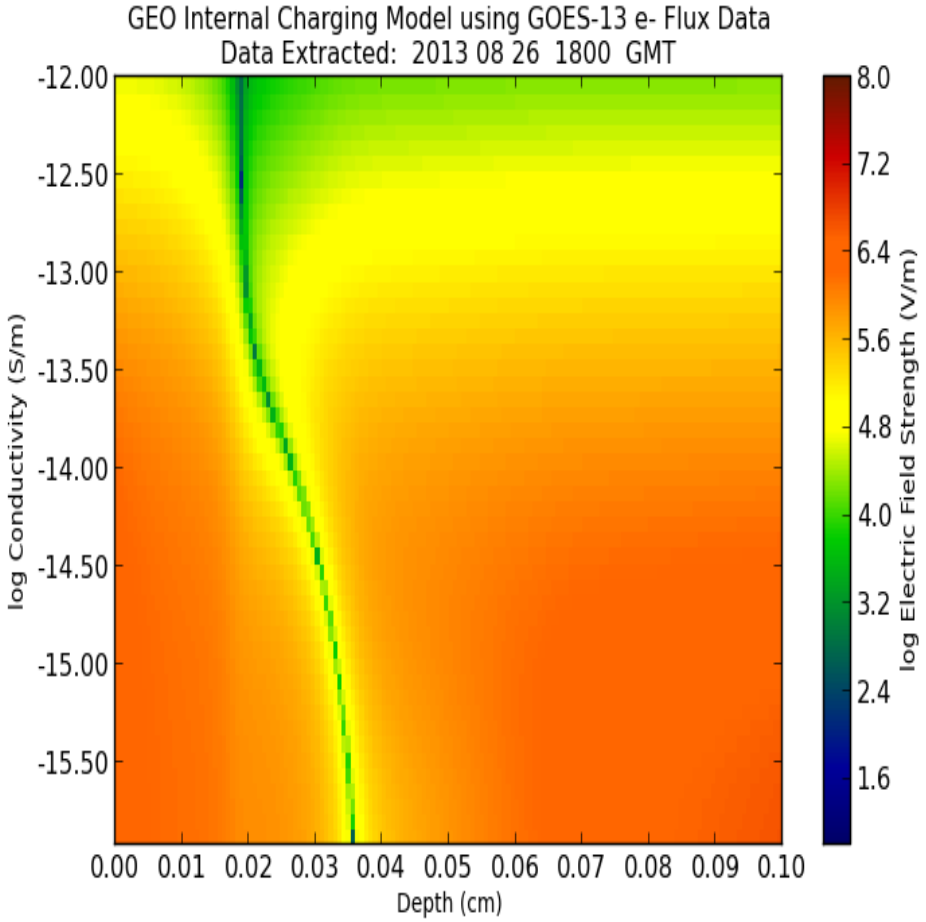
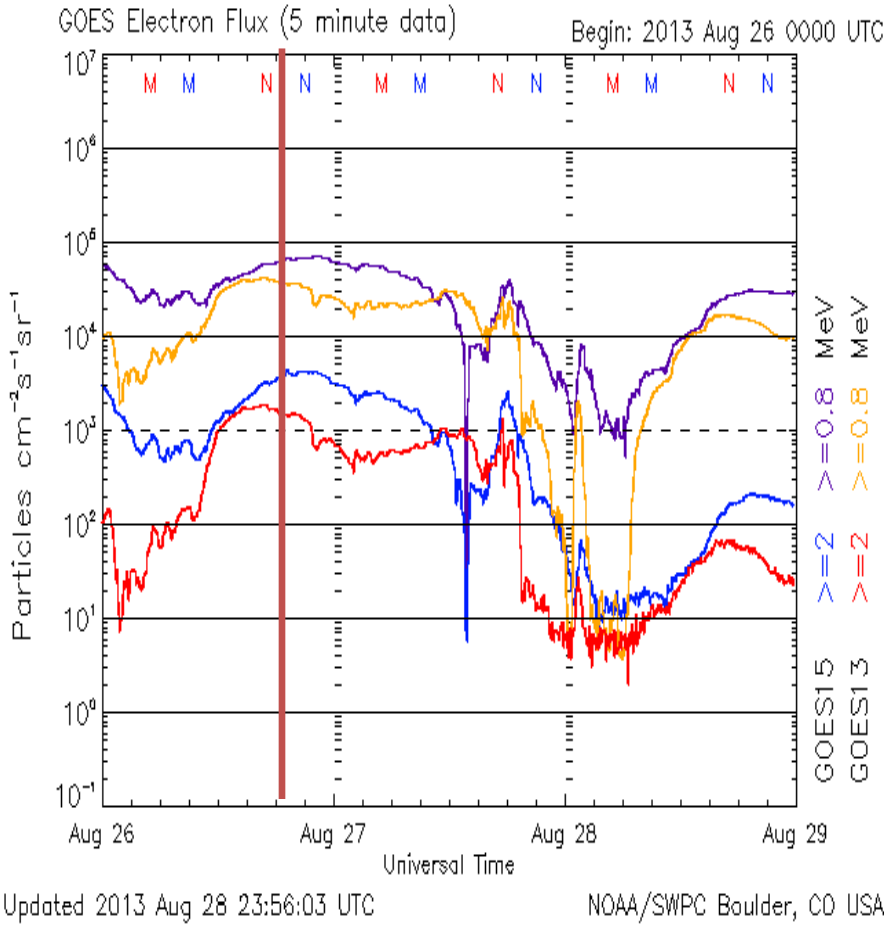
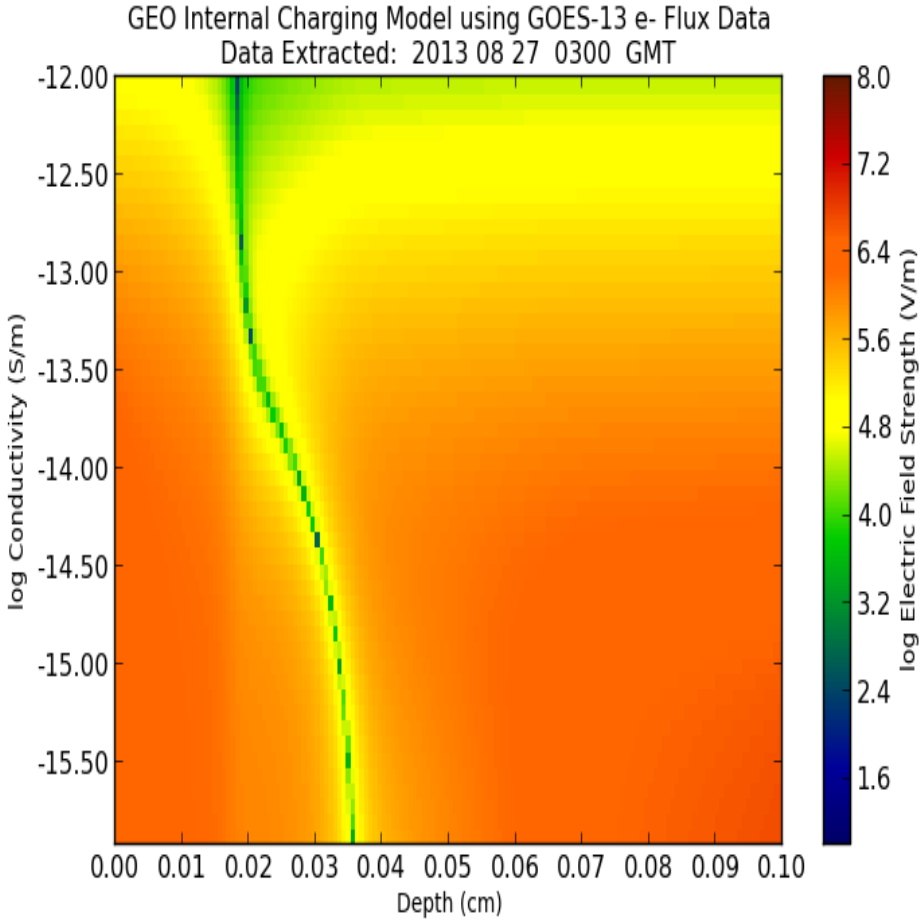
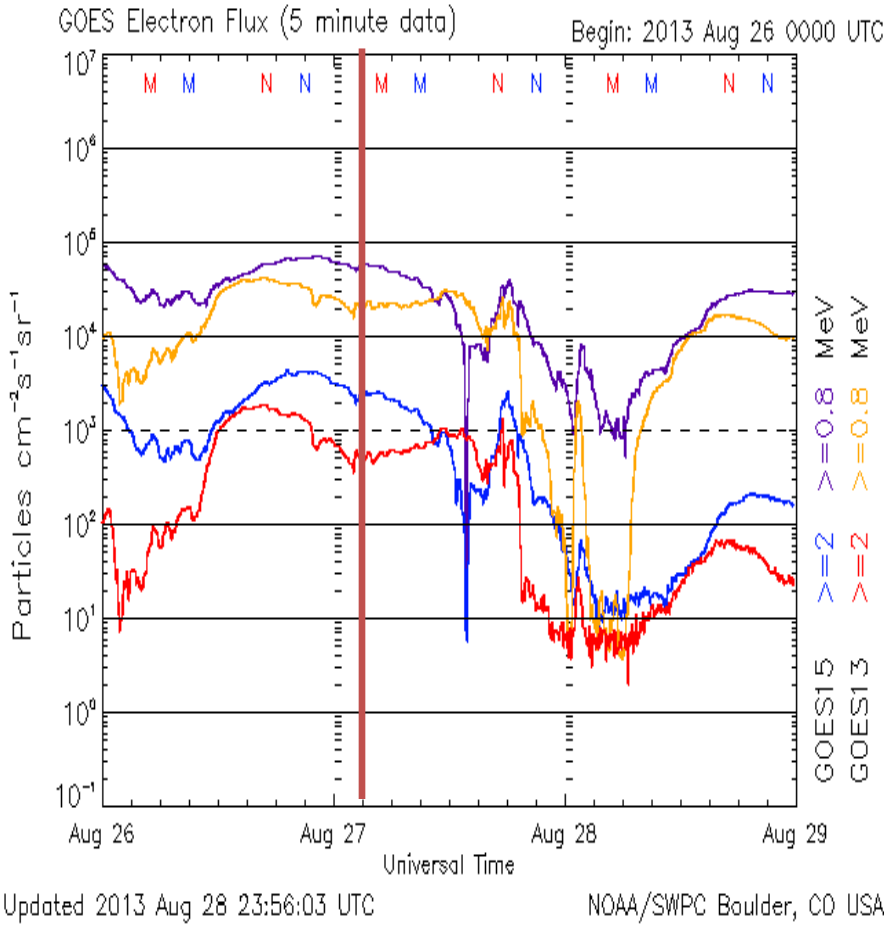




Geostationary Orbit Internal Charging Tool





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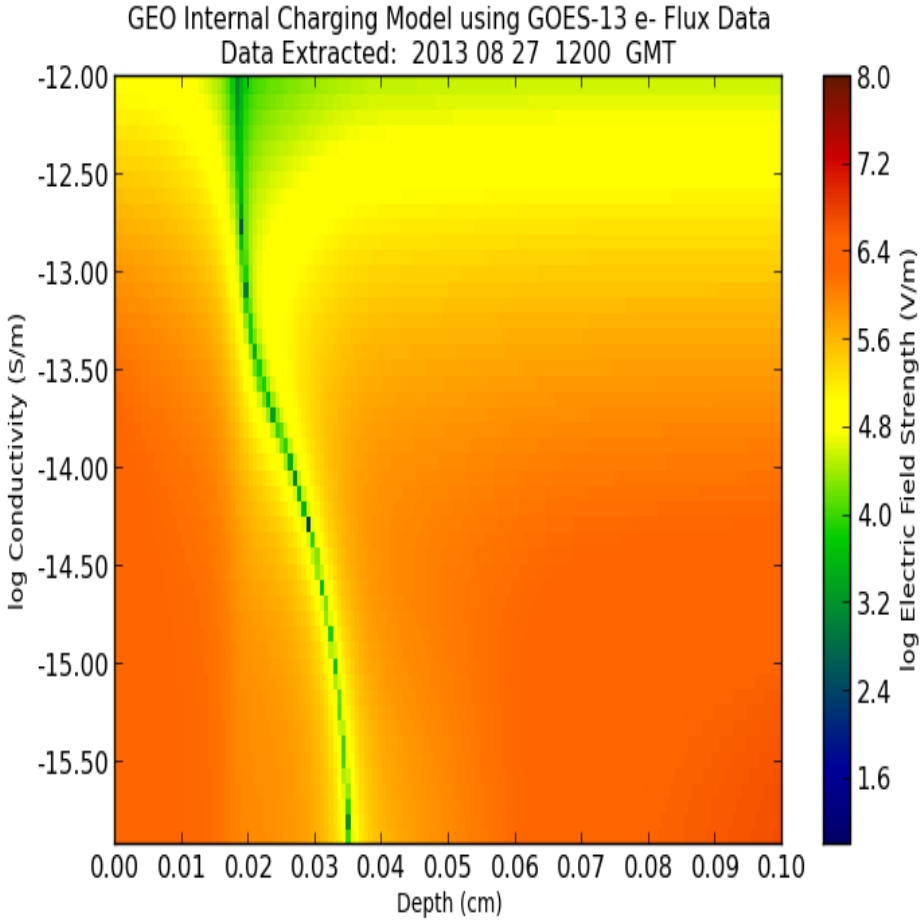

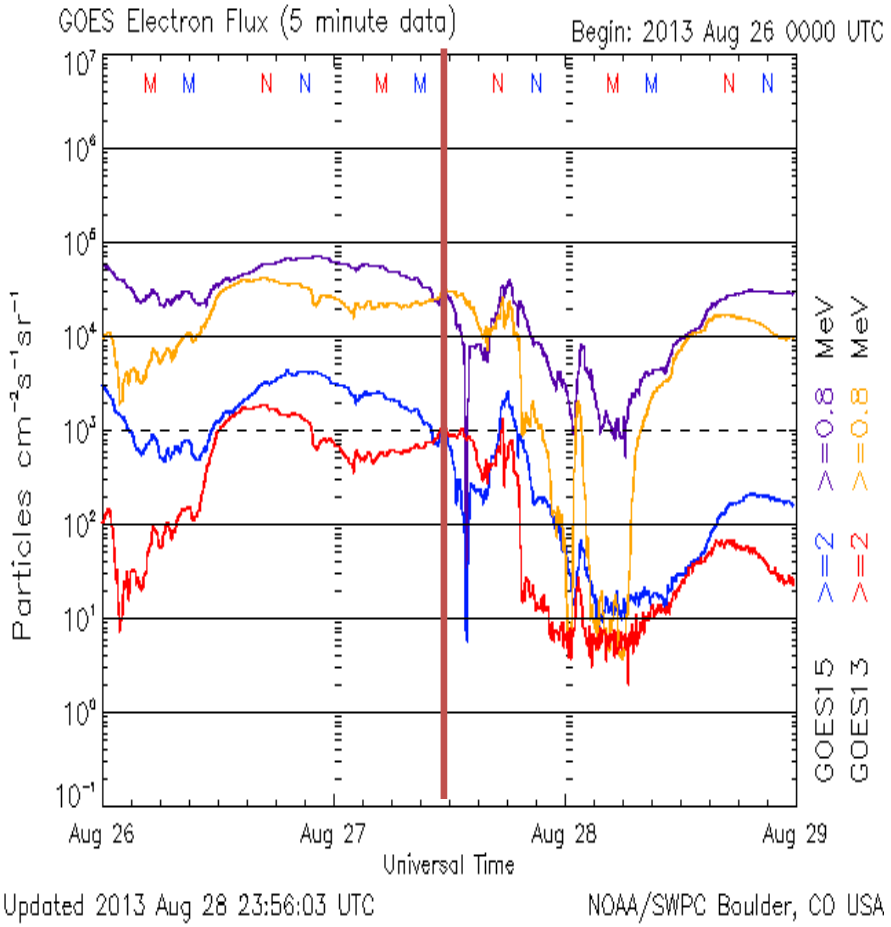

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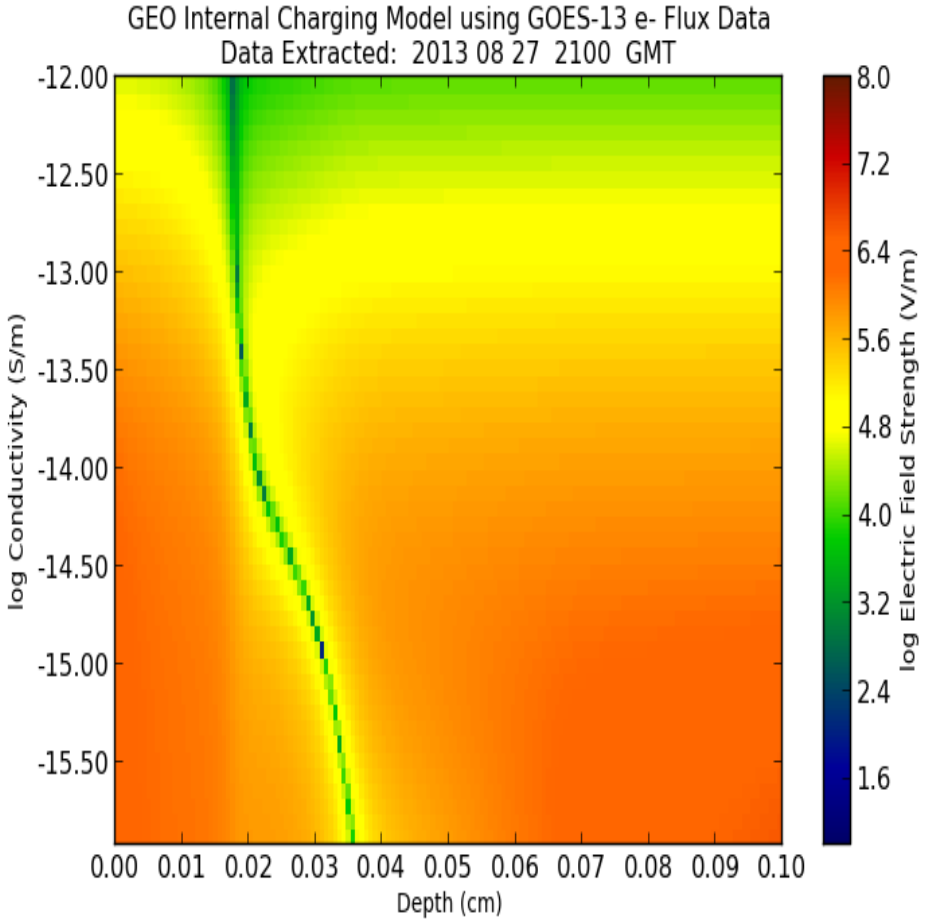

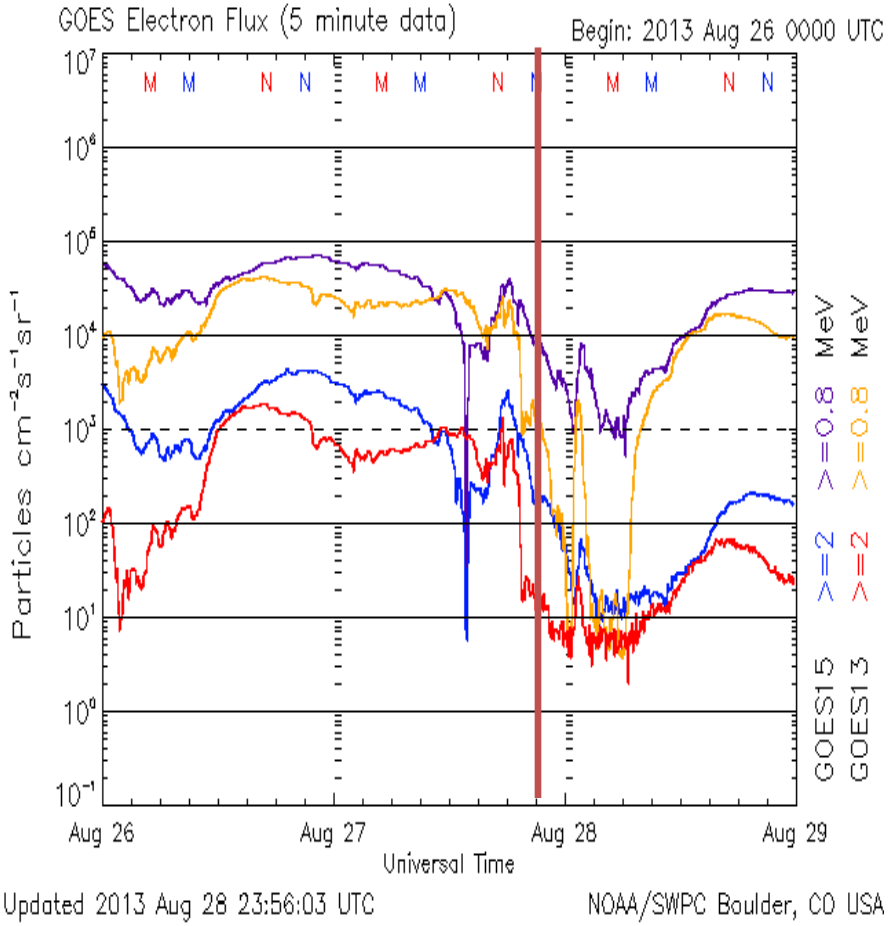

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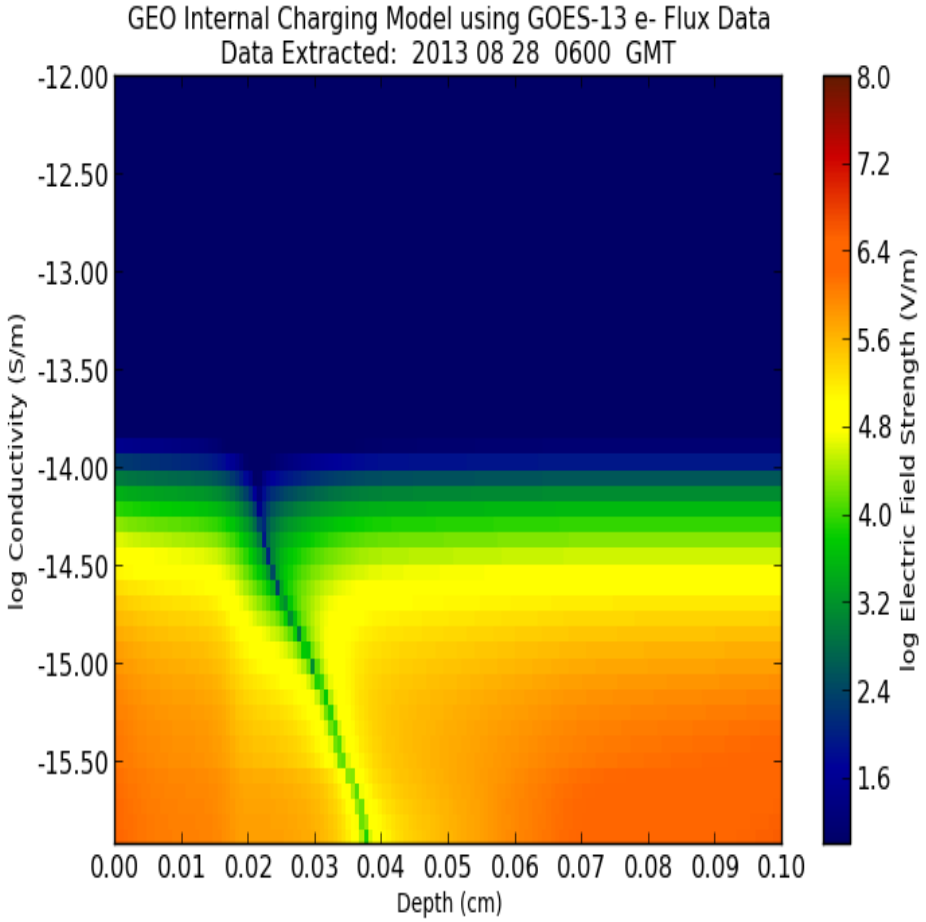

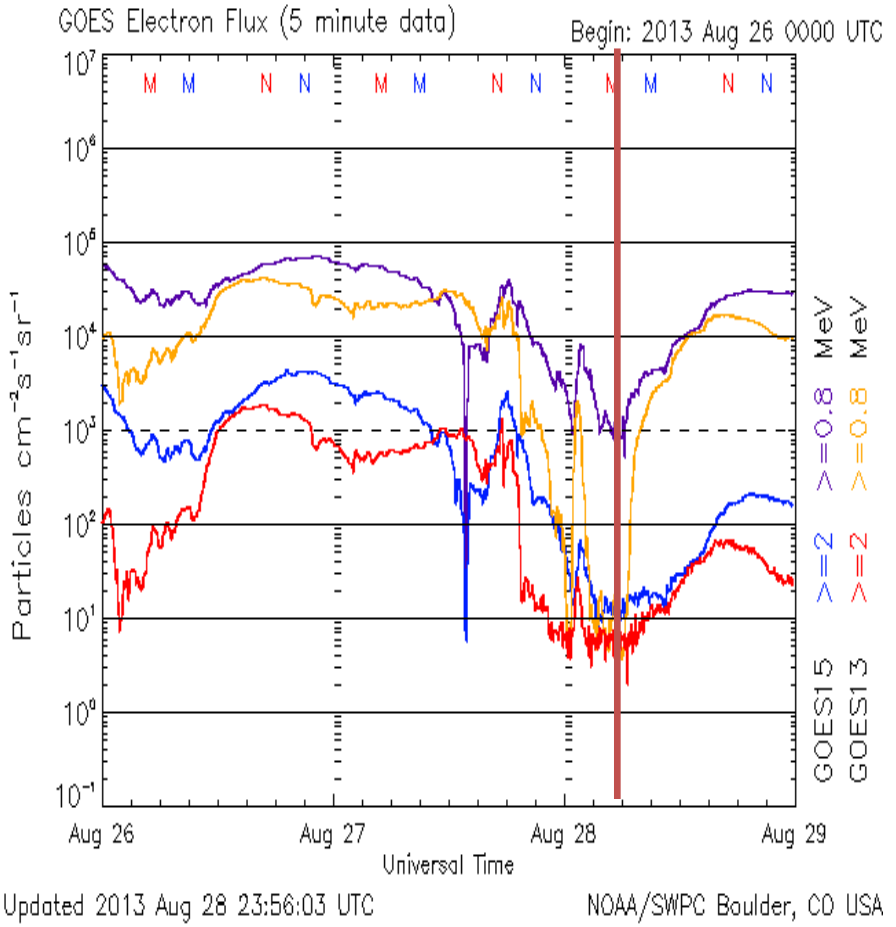

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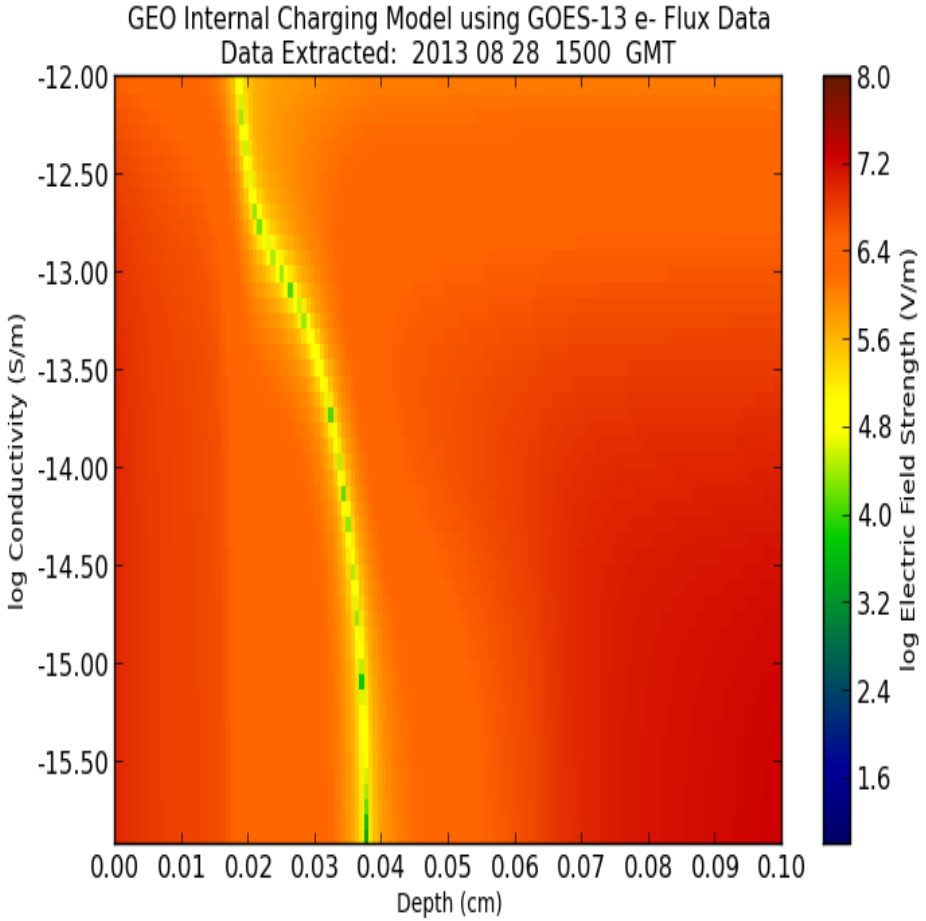
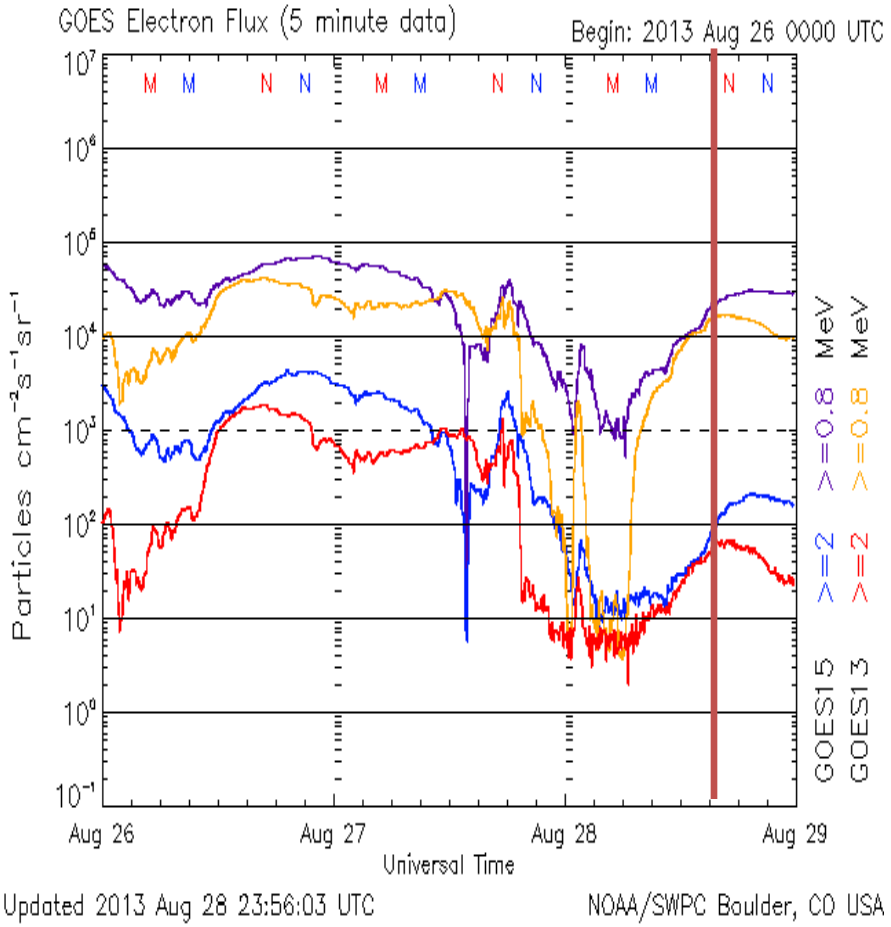
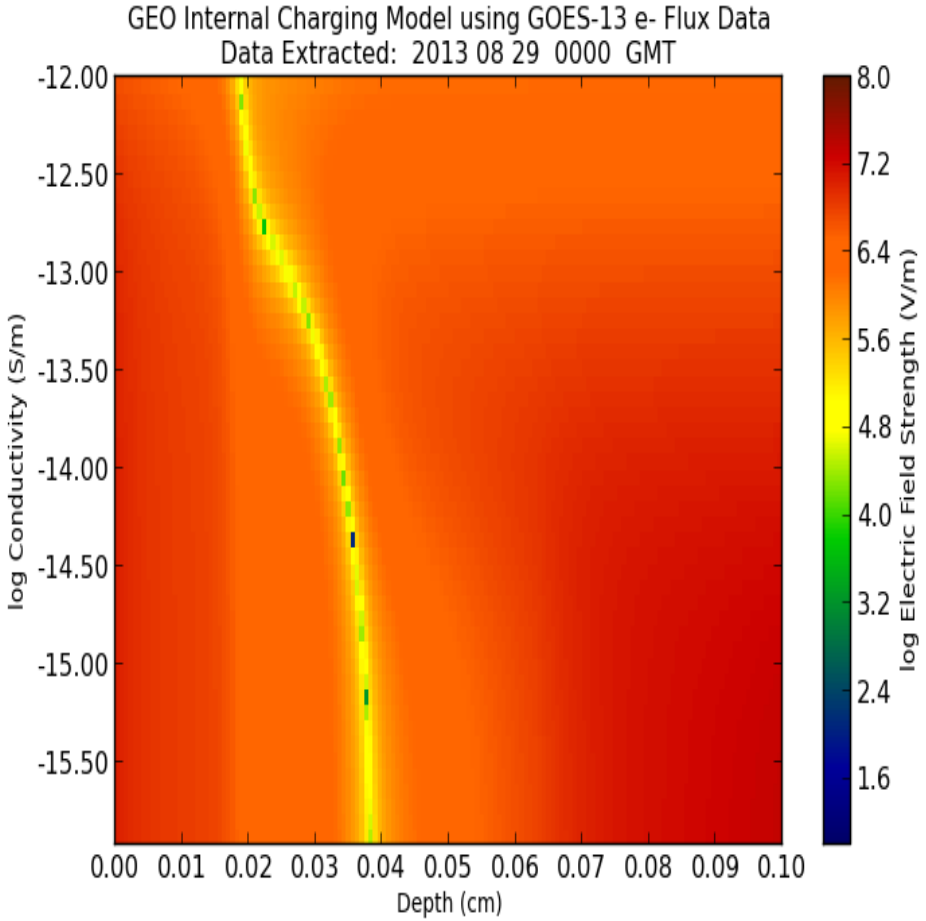
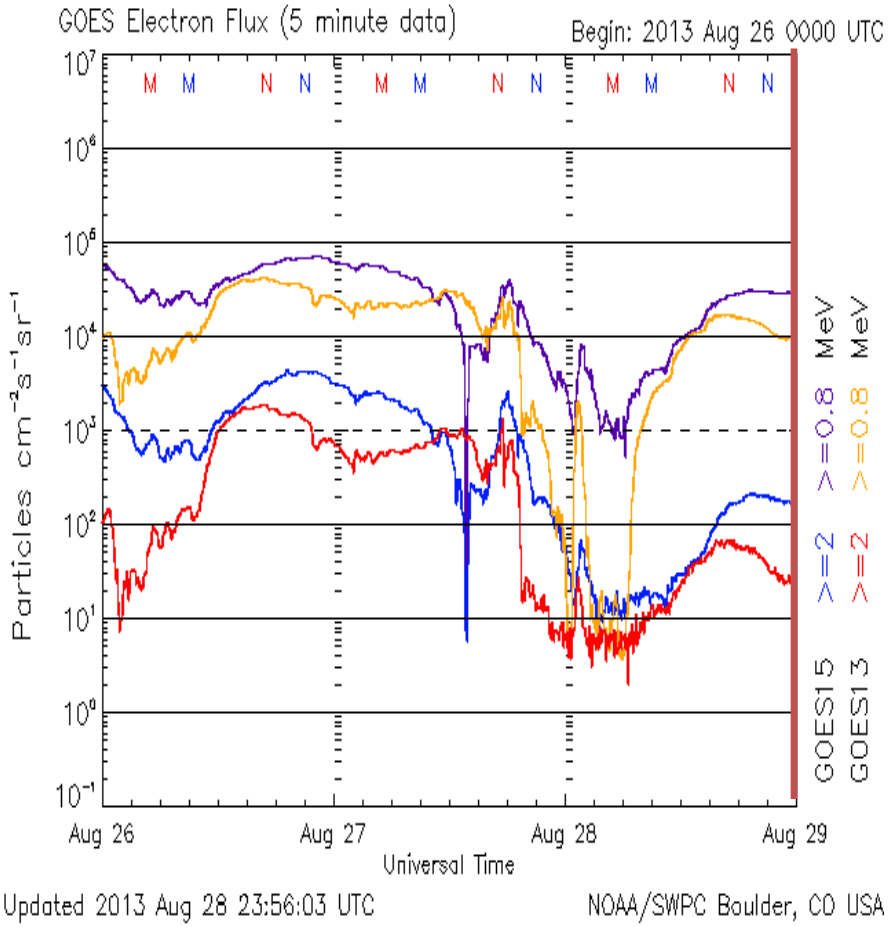


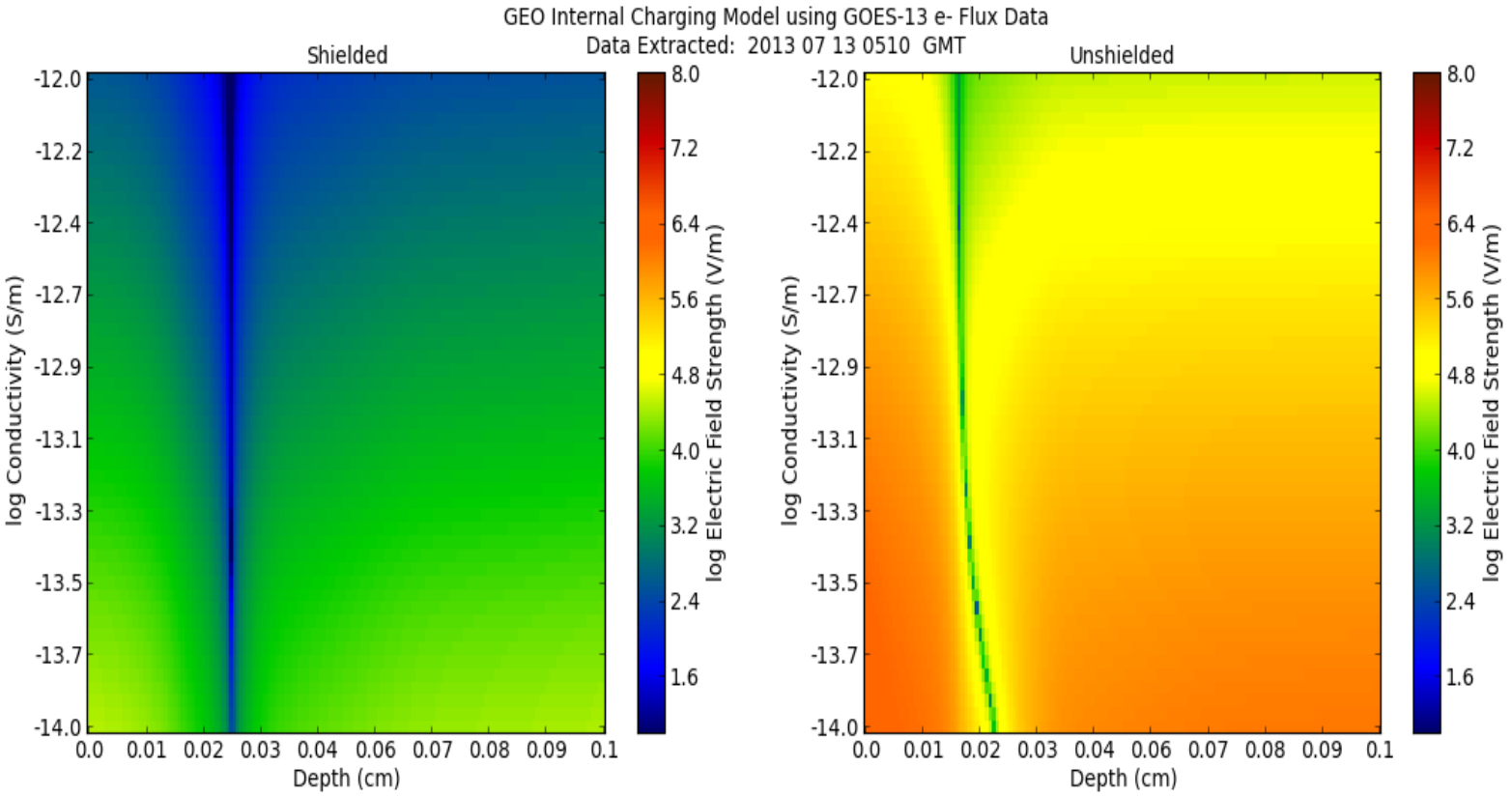


Geostationary Orbit Internal Charging Tool





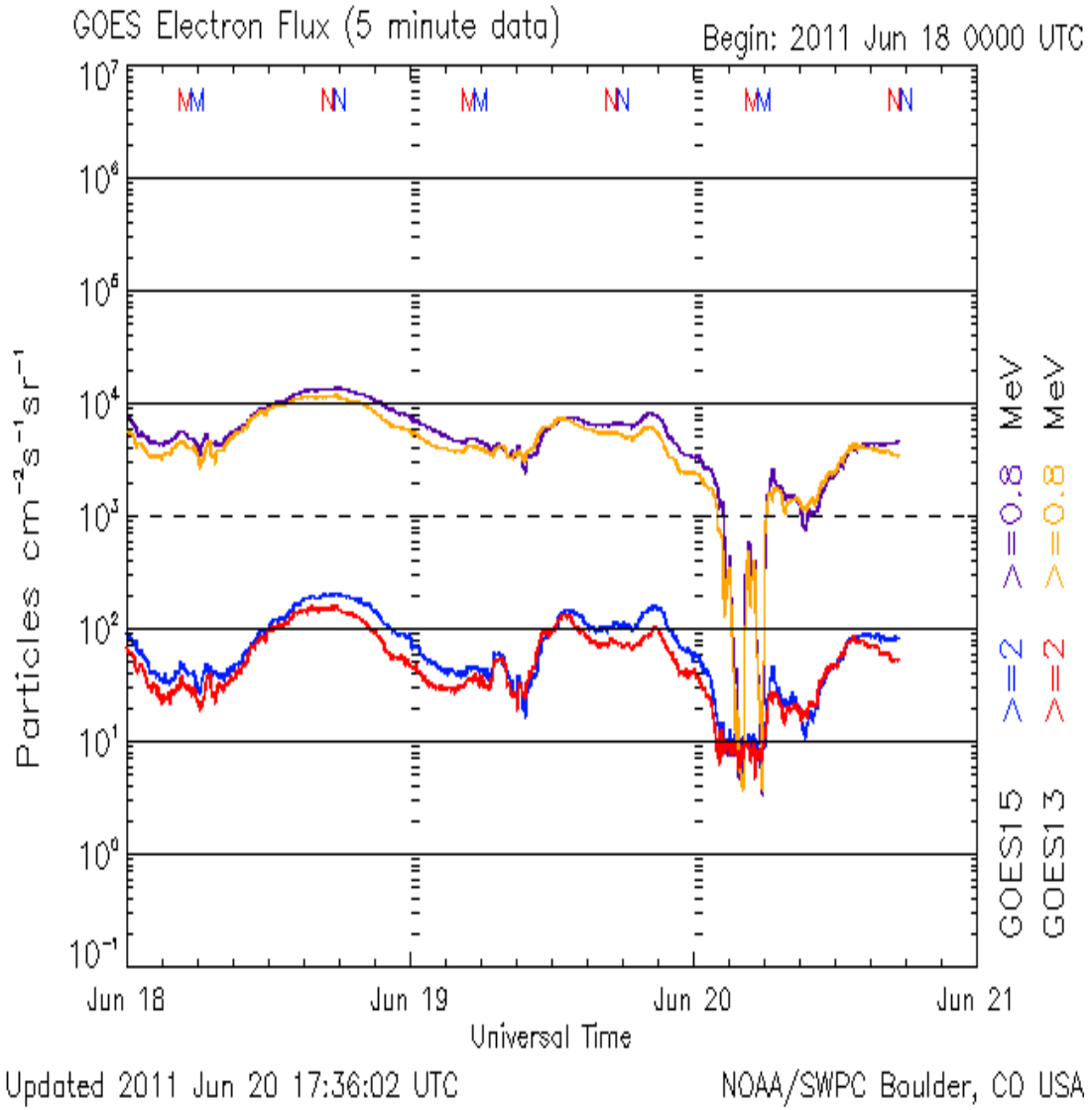
Radiation Shielding Option



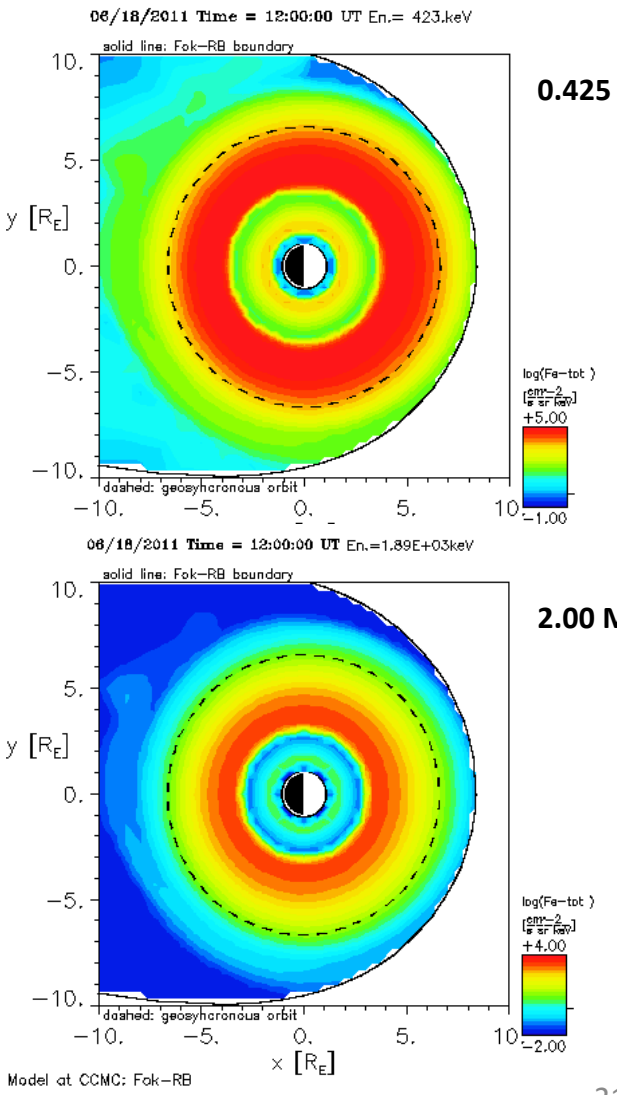
0.069 g/cm2 Al shielding
(0.256 mm)

no shielding

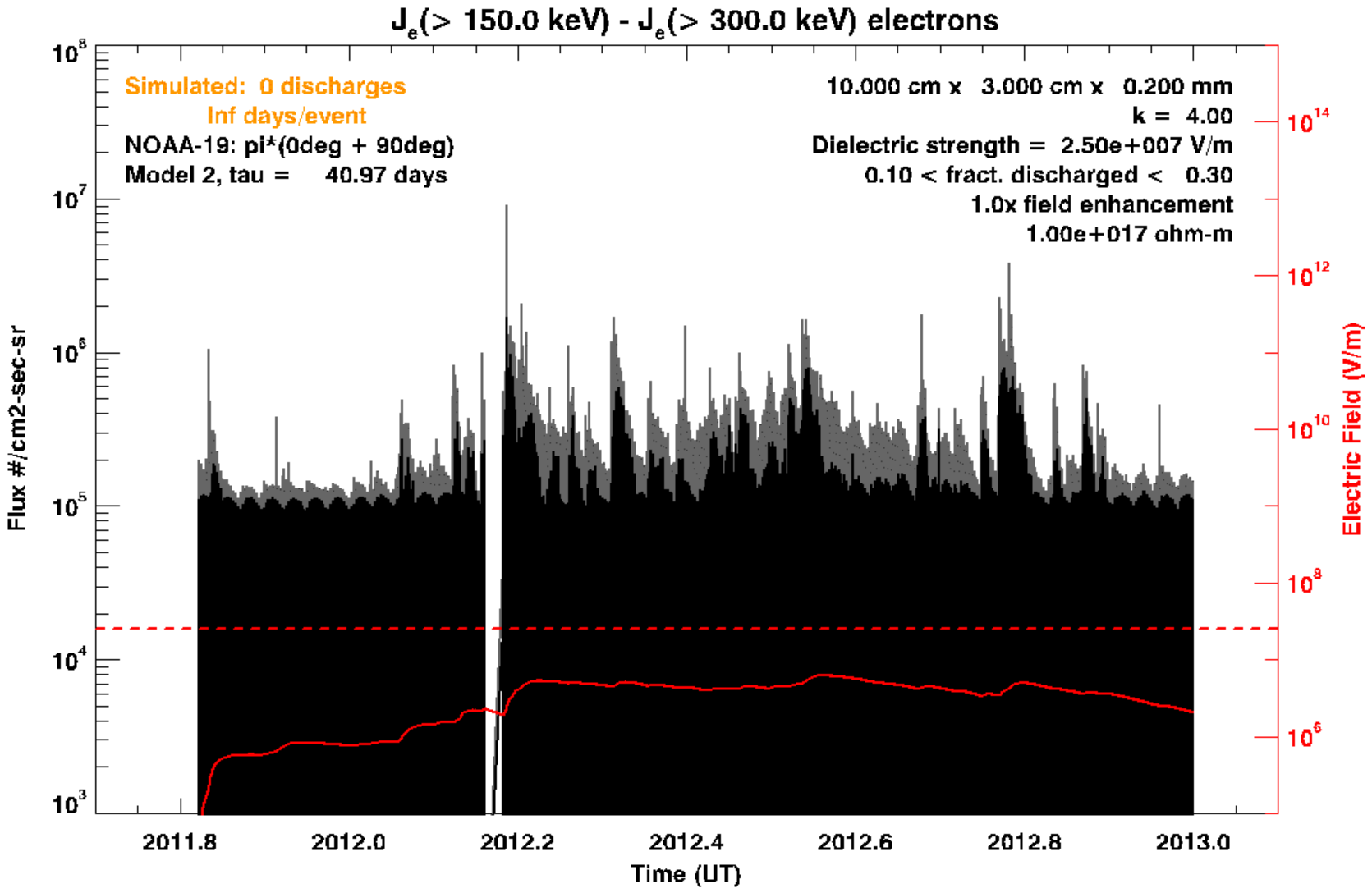
Input Data Options



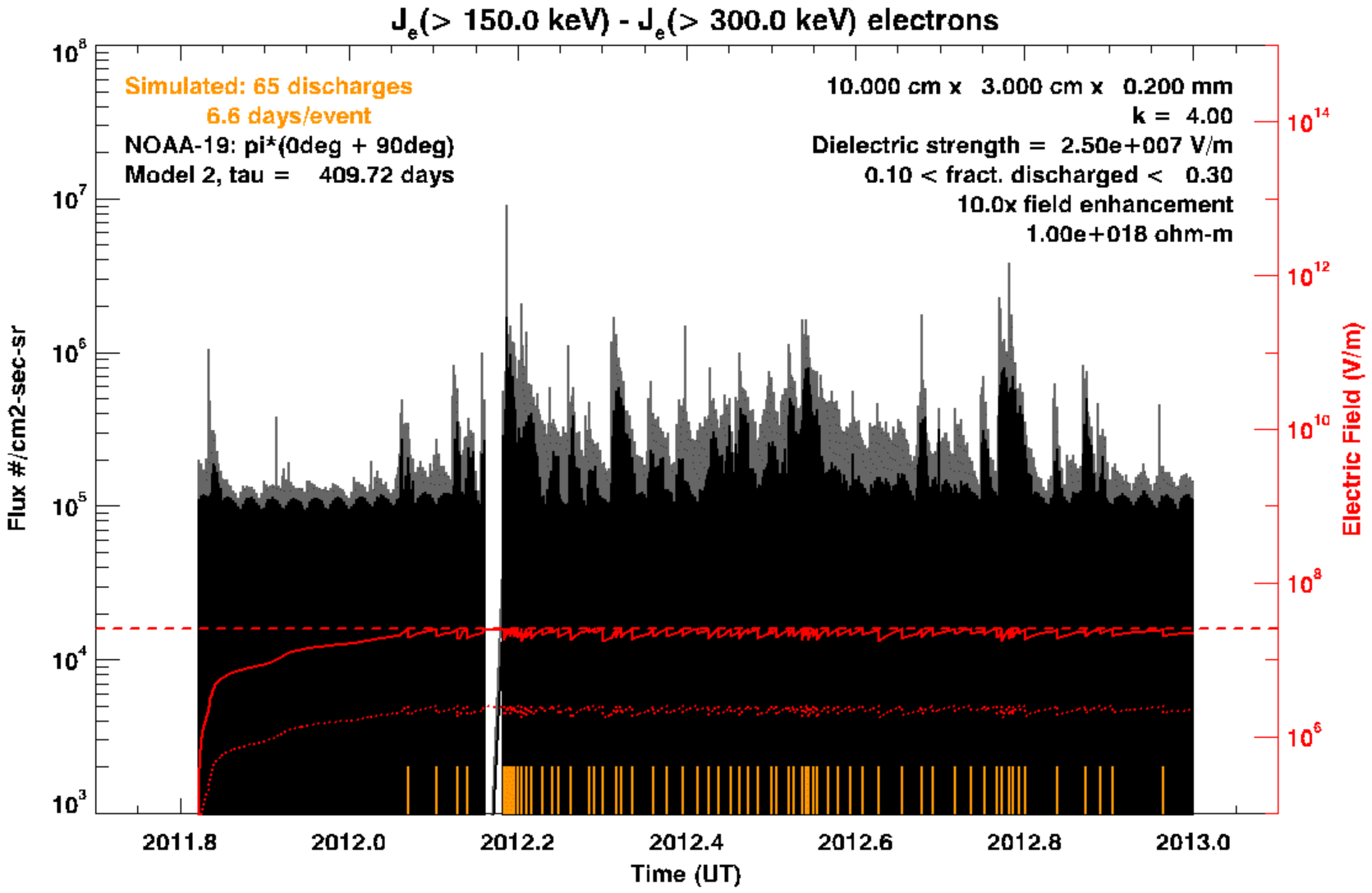
Fok Radiation Belt Model [iswa.ccmc.gsfc.nasa.gov]



LEO Internal Charging Model



LEO Internal Charging Model



LEO Internal Charging Model

```
      Dimensions (LxWxD):  10.000 cm x   3.000 cm x   0.200 mm
      Volume resistivity: 1.000e+018 ohm-m
                   Kappa: 4.0000
     Dielectric strength: 2.500e+007 V/m
      Efield enhancement:  10.0x
             Capacitance: 5.310e-010 Farads
Conduction time constant:   409.7222 days

 Fraction (f) discharged:  0.100 < f < 0.300

       NOAA-19 electrons:   pi*(0deg + 90deg)
         Electron energy:  150.0000 keV -  300.0000 keV
```

Arc	Decimal Year(UT)	Day of Year(UT)	Fraction Discharged	Surface Voltage (Volts) Before and After Arc		Arc Energy (mJoule)	Arc Current (Amp) 0.10 us	1.00 us	10.00 us
0	2012.0710	26.9785	0.2283	500.0	385.9	0.0268	6.06e-001	6.06e-002	6.06e-003
1	2012.1039	39.0314	0.2004	500.0	399.8	0.0239	5.32e-001	5.32e-002	5.32e-003
2	2012.1290	48.2109	0.2537	500.0	373.2	0.0294	6.73e-001	6.73e-002	6.73e-003
3	2012.1399	52.2185	0.2410	500.0	379.5	0.0281	6.40e-001	6.40e-002	6.40e-003
4	2012.1837	68.2398	0.2647	500.1	367.7	0.0305	7.03e-001	7.03e-002	7.03e-003
5	2012.1874	69.5824	0.1438	500.6	428.6	0.0178	3.82e-001	3.82e-002	3.82e-003
6	2012.1891	70.2203	0.1002	500.0	449.9	0.0126	2.66e-001	2.66e-002	2.66e-003
7	2012.1909	70.8707	0.1937	500.1	403.3	0.0232	5.14e-001	5.14e-002	5.14e-003
8	2012.1942	72.0668	0.1379	500.0	431.1	0.0170	3.66e-001	3.66e-002	3.66e-003
9	2012.1965	72.9144	0.1782	500.0	410.9	0.0215	4.73e-001	4.73e-002	4.73e-003
10	2012.2000	74.1920	0.2192	500.0	390.4	0.0259	5.82e-001	5.82e-002	5.82e-003

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Collaboration with CCMC

- MSFC represents a user community utilizing CCMC products in our space environment and effects support for NASA programs
- MSFC will provide GEO internal charging code to CCMC
- CCMC will run the code in real-time using both GOES and RBE model data and provide results via iSWA
- Additional MSFC space environment effects codes, data can be provided to CCMC in the future once they have been sufficiently validated including
  - LEO real time internal charging
  - GEO, LEO surface charging
  - GEO single event upset
  - Solar energetic particle acceleration
  - F2-region Ne, Te along ISS orbit (51.6 km, ~400 km)

ISS image: 11 March 2012