INTERNAL CHARGE ESTIMATES FOR SATELLITES IN LOW EARTH ORBIT AND SYSTEM IMPACTS

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ABSTRACT

Space assets are continuously bathed by charged particles making their components susceptible to the effects of spacecraft charging. Low earth orbiting assets with high inclinations pass through the horns of the radiation belts during each polar crossing, transiting through potentially dangerous charged particle populations many times per day. Occasionally these low altitude horns include significant populations of energetic ~1MeV electrons which can penetrate typical spacecraft shielding and accumulate within dielectric materials and on ungrounded conductors, a process known as internal charging. While spacecraft subsystems are designed to shunt charges away from susceptible components, if the electric potential from charge accumulation exceeds the breakdown voltage then an internal electrostatic discharge (IESD) occurs which can cause soft anomalies and permanent damage. The US National Oceanic Atmospheric Administration (NOAA) and European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) operate the POES and MetOp LEO weather satellites. Several POES spacecraft have experienced on-orbit anomalies [1,2] that are suspected to be associated with the accumulation and discharge of ~800keV electrons. Observations from the co-manifested Space Environment Monitor (SEM-2) and a first principles model of charge accumulation [3] are used to develop estimates of electron internal charge accumulation over the lifetime of each POES/MetOp spacecraft for a range of typical discharge time constants. We use these estimates to test for space weather attribution and show that a definitive connection between ~MeV electron IC/IESD cannot be concluded.

1. INTERNAL CHARGE ESTIMATES

The technique of [3] was modified for application to LEO and estimates of IC accumulation were calculated for six time constants (τ): 1, 10, 30, 100, 300 and 1022 (~2.8 years). Mission lifetime fluxes of >800keV electrons and their estimated IC accumulation are shown in Fig. 1 for NOAA-18. Fig. 1 is laid out as follows. Panels from top to bottom are: a) and b) flux (e-/cm2s) observed by the zenith (0-degree) and anti-velocity (90-degree) telescopes, c) and d) accumulated charge estimates (nC/cm^2) from the zenith and anti-velocity telescopes for the time constants 1 (blue), 10 (green), 30 (red), 100 (cyan), 300 (magenta) and 1022 (yellow) days, e) anomaly times, f) quality flags. For all panels, the time range shown is from 2005-06-07 to 2015-12-31. A critical charge density threshold of 6-20nC/cm2 captures most materials in space (see [3] and references therein). Therefore, charge densities >6nC/cm2 in Fig. 1 are shaded with a grey background.

2. DISCUSSION/CONCLUSION

We have created mission lifetime estimates of ~MeV electron charge accumulation for highly inclined LEO orbits to test for IC/ESD attribution to a specific list of on orbit anomalies. There are several periods of elevated or rising IC that are not temporally coincident with reported BVR anomalies. Overall, they are not well correlated with the IC estimates for any of the standard dielectric charge dissipation time constants used. Thus, with the advantage afforded by a larger database and longer period of observation, we are able to show these power system anomalies are generally not attributable in a simple way to deep charging from ~MeV electrons.

3. REFERENCES

1. NOAA Office of Satellite and Product Operations. *NOAA18 EPS Subsystem Summary*. Available: http://www.ospo.noaa.gov/Operations/POES/NOAA18/eps.html. Accessed on February 29, 2016.

2. NOAA Satellite Information System (NOAASIS). *POLAR Spacecraft Status Reports*. Available: http://noaasis.noaa.gov/NOAASIS/ml/podocs/?C=M;O=A. Accessed on February 29, 2016.

3. Bodeau, M. (2010). High energy electron climatology that supports deep charging risk assessment in GEO, 2010–1608.

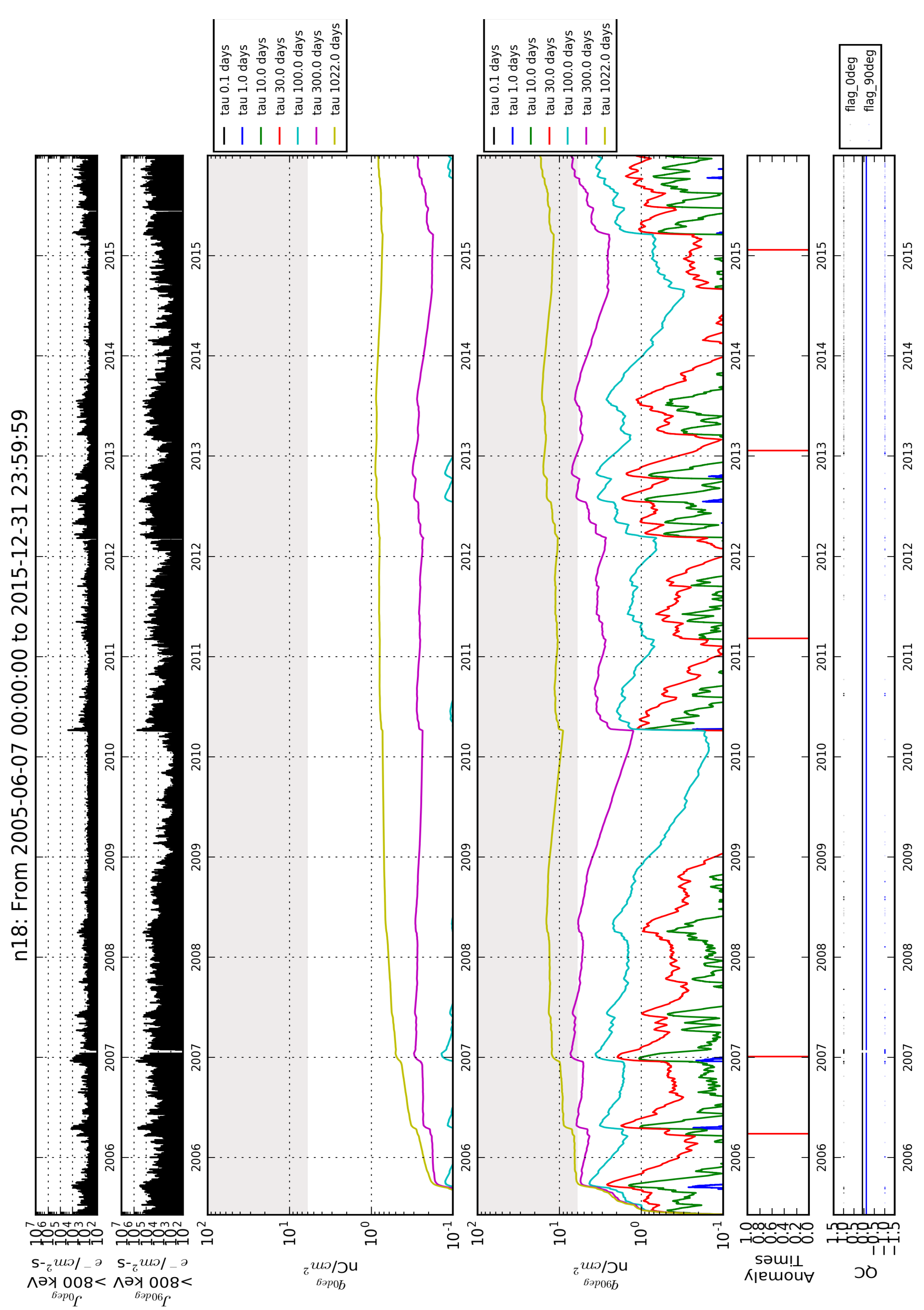

Figure 1: NOAA-18 observed outer radiation belt >800keV electron number fluxes and estimated accumulated charge. See body for description.