Extreme Relativistic Electron Fluxes at Geosynchronous Orbit

N. P. Meredith[1], R. B. Horne[1], J. D. Isles[1] and J. V. Rodriguez[2,3]

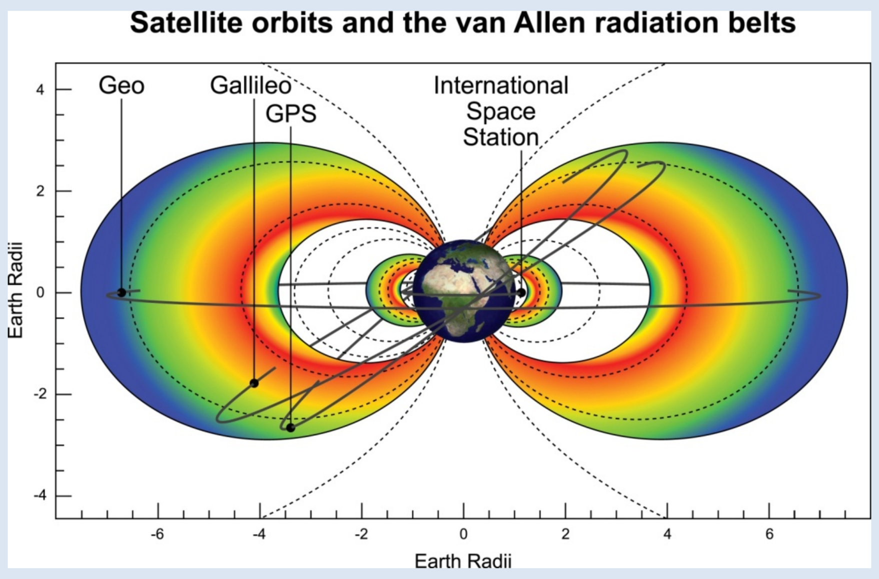
[1]British Antarctic Survey; [2]University of Colorado Boulder; [3]National Geophysical Data Center, Boulder

1. Introduction

Relativistic electrons (E > 1 MeV) cause internal charging on satellites and are an important space weather hazard. A key requirement in space weather research concerns extreme events and knowledge of the largest flux expected to be encountered over the lifetime of a satellite mission. This is important both from scientific and practical points of view since satellite operators, engineers and insurers need this information to better understand the effects of extreme space weather on their spacecraft. Here we conduct an extreme value analysis of the daily average E > 2 MeV electron fluxes from the Geostationary Operational Environmental Satellites (GOES) during the 19.5 year period from 1st January 1995 to 30th June 2014 and determine the one in 10, one in 50 and one in 100 year space weather event.

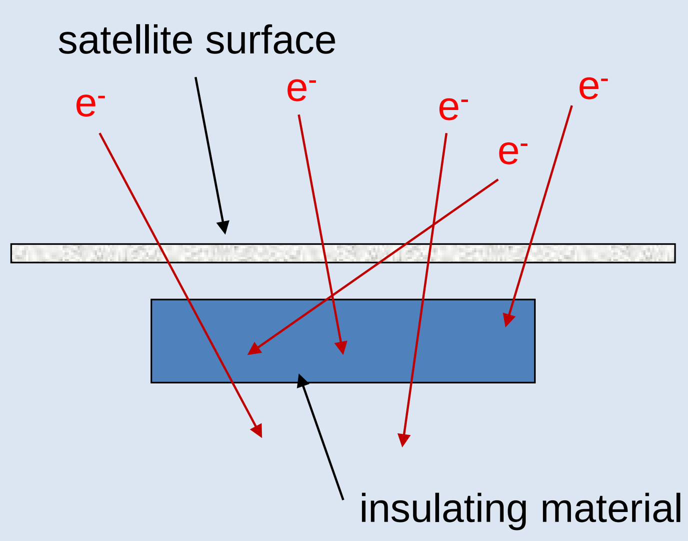
2. Geosynchronous Orbit

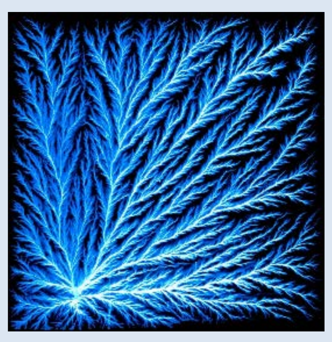
- There are over 500 operational satellites in geosynchronous orbit
- It is an important orbit both for communications and weather satellites
- Satellites in this orbit are located in the Earth's outer radiation belt where they are exposed to varying fluxes of relativistic electrons



3. Radiation Damage

- Relativistic electrons can penetrate satellite surfaces and embed themselves in insulating materials and ungrounded conductors
- The charge can build up over time resulting in the build up of high electric fields which may exceed that required for breakdown leading to an internal electrostatic discharge
- The subsequent discharge can damage components and, in rare cases, may even destroy a satellite



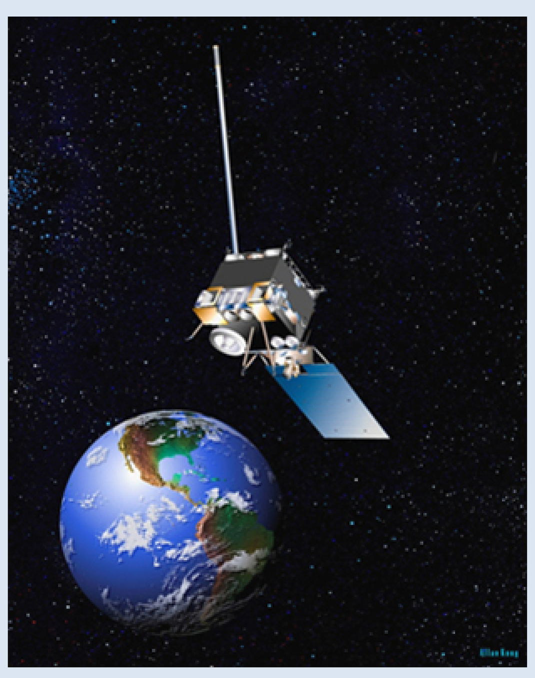


4. Motivation

- Satellite operators and engineers require realistic estimates of the highest fluxes of relativistic electrons that are likely to be encountered in GEO
  - to assess the impact of an extreme event
  - to improve resilience of future satellites
- Satellite insurers require this information
  - to ensure satellite operators are doing all they can to reduce risk
  - to help them evaluate realistic disaster scenarios

5. Data Analysis

- Use GOES E > 2 MeV electron data from 1st January 1995 to 30th June 2014
- Use 5 minute resolution E > 2 MeV electron data from 7 GOES satellites
- Use "science-quality" data corrected for proton contamination and dead time
- GOES satellites operate at two primary locations and we independently analyse the data from GOES East and GOES West



Typical Orbital Parameters

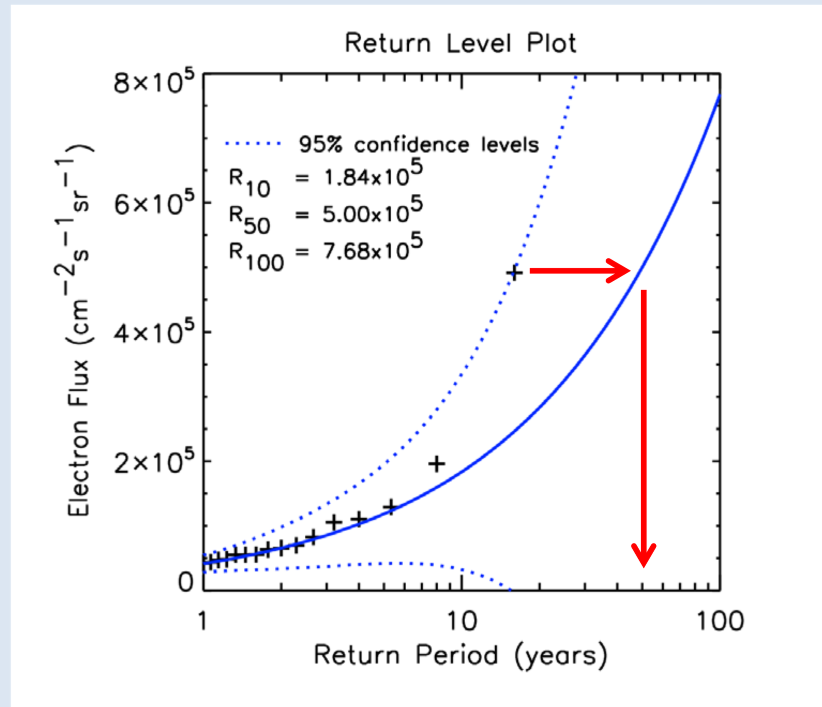
Altitude: 35,800 km
Inclination: 0º

6. Extreme Value Analysis

To determine the 1 in N year fluxes of relativistic electrons we conduct an extreme value analysis of the daily average E > 2 MeV electron fluxes from GOES East and GOES West using the exceedances over a threshold approach. For this approach the appropriate distribution function is the generalised Pareto distribution (GPD).We fit the GPD to the tail of the distribution using maximum likelihood estimation and determine the 1 in N year flux levels from the fitted parameters [Meredith *et al*., Space Weather, 2015].

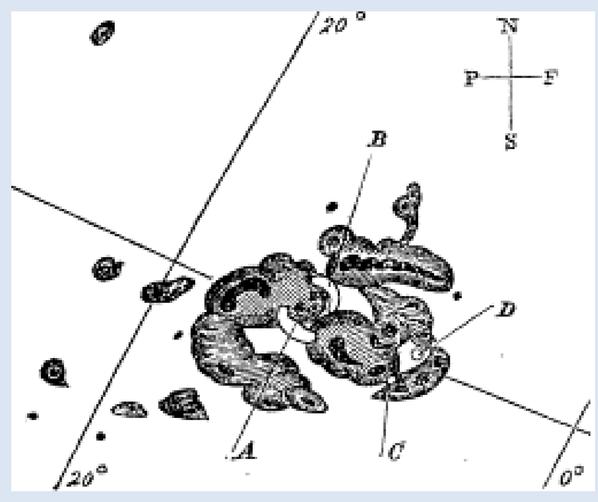
7. Results

- One in 10 year flux
  - 1.8×10^5 $cm^{-2}s^{-1}sr^{-1}$
- One in 50 year flux
  - 5.0×10^5 $cm^{-2}s^{-1}sr^{-1}$
- One in 100 year flux
  - 7.7×10^5 $cm^{-2}s^{-1}sr^{-1}$
- Largest flux observed in the study period is equivalent to a one in 50 year event



8. Return Level of a Carrington Type Event

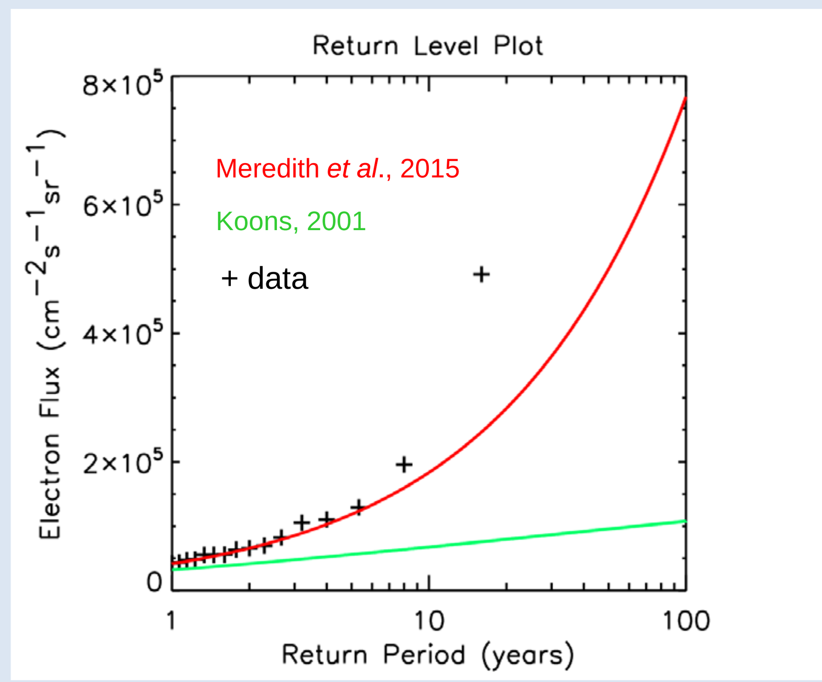
- Largest space weather event of the last 200 years is widely regarded to be the Carrington event of 1859
- Historical auroral records suggest the return period of a Carrington type event is 150 years [Lloyds, 2013]
- Our results show that the return level for a one in 150 year event at GOES West is10^6 $cm^{-2}s^{-1}sr^{-1}$



Carrington, 1859

9. Comparison with Earlier Studies

- Our results are significantly larger than those presented in Koons [2001]
- The one in 10 year event at GOES West is about a factor of 2.7 times that estimated by Koons [2001]
- For more extreme events, the one in 100 year event at GOES West is about a factor of 7 times that estimated by Koons [2001]



10. Conclusions

- The one in 10, one in 50 and one in 100 year events at GOES West are 1.8×10^5 5.0×10^5 and 7.7×10^5 $cm^{-2}s^{-1}sr^{-1}$ respectively
- Our results suggest that the largest event seen during the study period was a one in 50 year event
- The new results have been used to update the National Risk Assessment, in the evaluation of satellite tenders and are currently being used to evaluate the effect of extreme fluxes on satellite components

11. Acknowledgements

- The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreements number 606716 (SPACESTORM) and is also supported in part by the UK Natural Environment Research Council.

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL