Space Weather: Gap Analysis and Proposed Services

Richard B. Horne

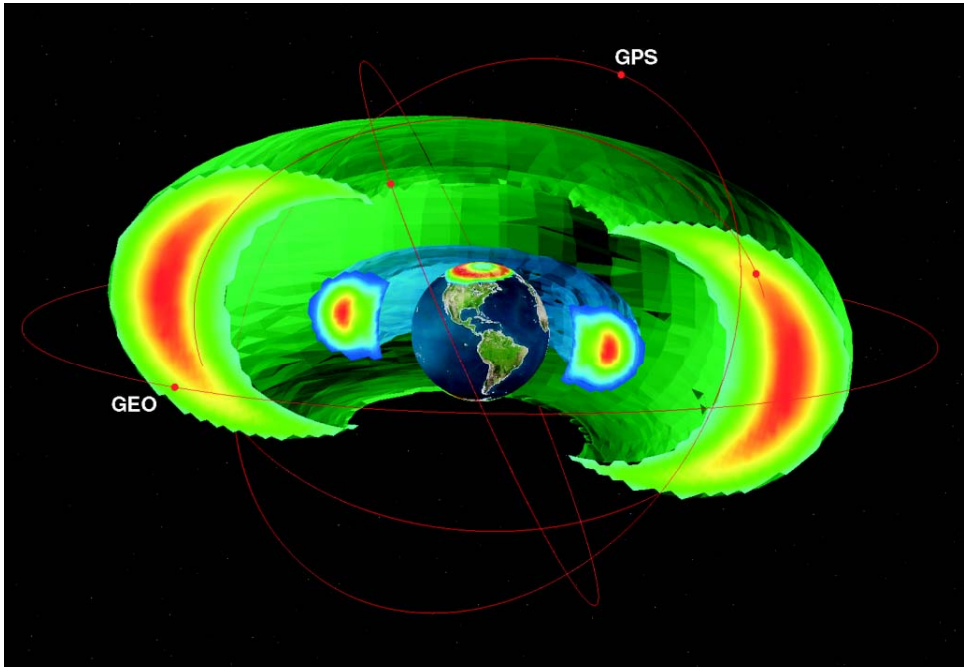
British Antarctic Survey

The research leading to these results was partly funded by the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement No 606716 SPACESTORM

Satellite Operators Meeting, Exeter, 10 March 2015

Space Weather: Gap Analysis and Proposed Services

Richard B. Horne
British Antarctic Survey



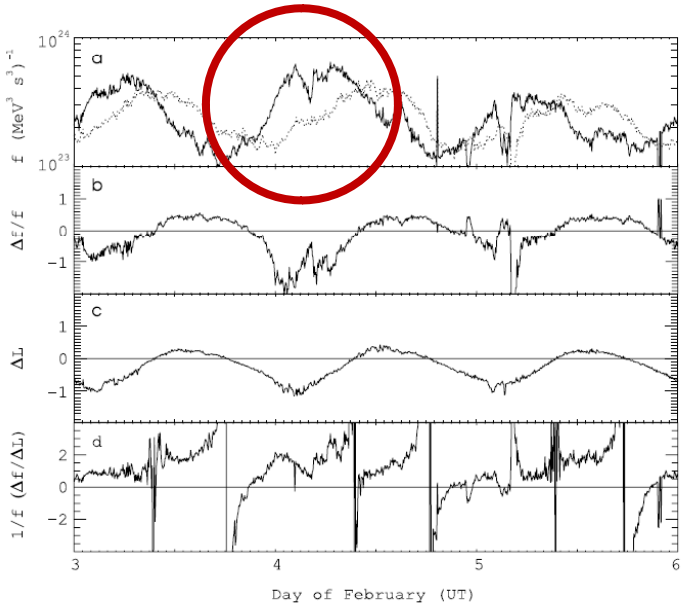
British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

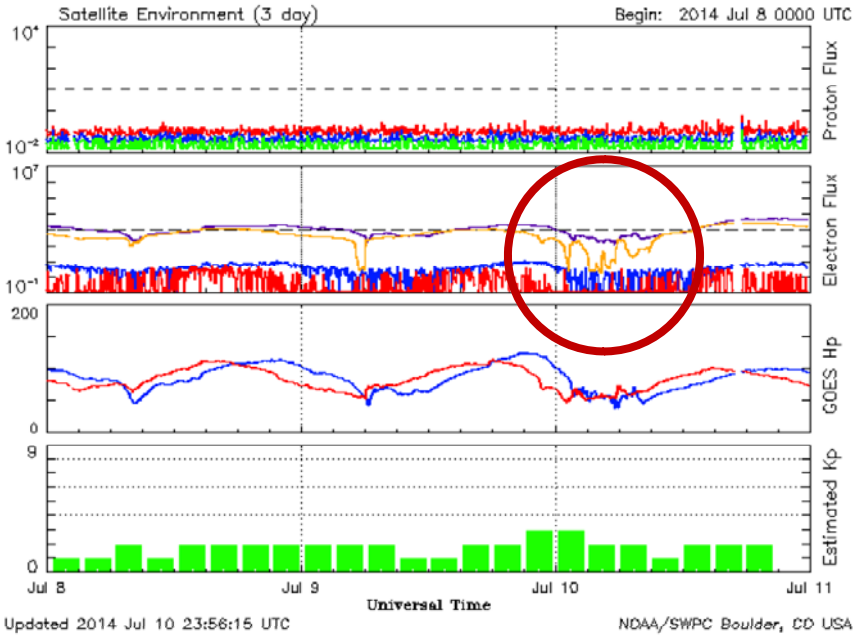
Satellite Operators Meeting, Exeter, 10 March 2015

Gap Analysis

- SWPC focuses on GEO and generic forecasts using point measurements from 2 spacecraft
- SWPC forecasts are a 24 hour average – does not capture enough variation
- At GEO – MeV flux can vary by factor of 10 or more around geostationary orbit – point measurements are not enough
- At KeV – surface charging – flux can vary by > factor of 10 around GEO oribt
  - Bursty, short duration – not captured
- Satellites at MEO (~100) and Slot (few but growing) and LEO (470) are not catered for
- Proton belt variability and solar proton events at Slot, MEO and LEO not catered for

Flux at Geo – Longitude Effects





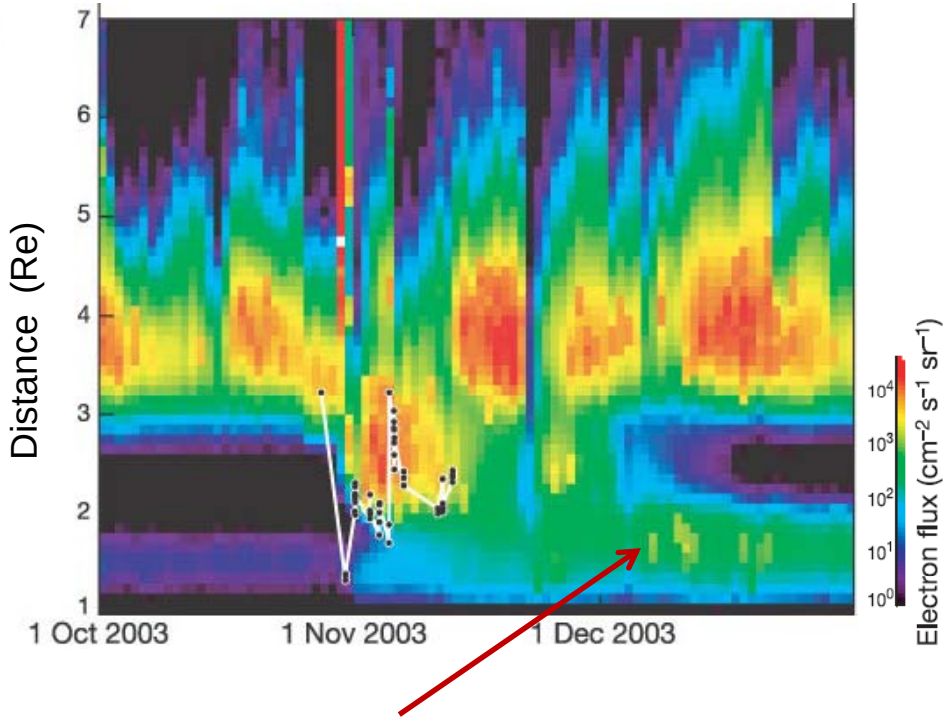
- The flux at Geo varies signifcantly with longitude.
- A measurement at one longitude does not give the flux elsewhere
- Models with the right physics can be used to correct

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

SPACESTORM

Similarities: Space Weather -

> 2 MeV electron flux



- Particles ‘injected’ during a magnetic storm – last for years

1960s high altitude nuclear detonations

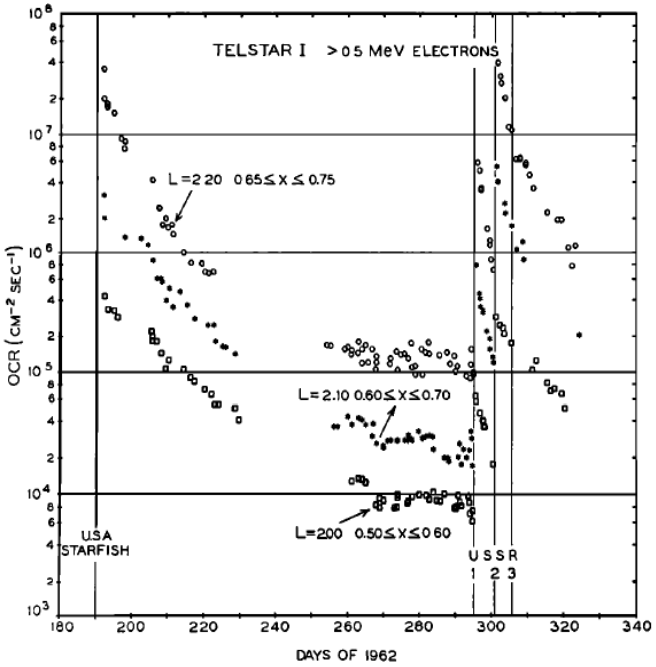


Fig. 8. Decay of >500-kev electrons following the high-altitude nuclear explosions of 1962. The data points for $L = 2.10$ and 2.00 have been displaced downward by one and two decades, respectively. On each L shell, the data are for a range of the coordinate $x = (1 - B_0/B)^{1/4}$.

- High altitude nuclear detonations also inject electrons into the radiation belts and last for years

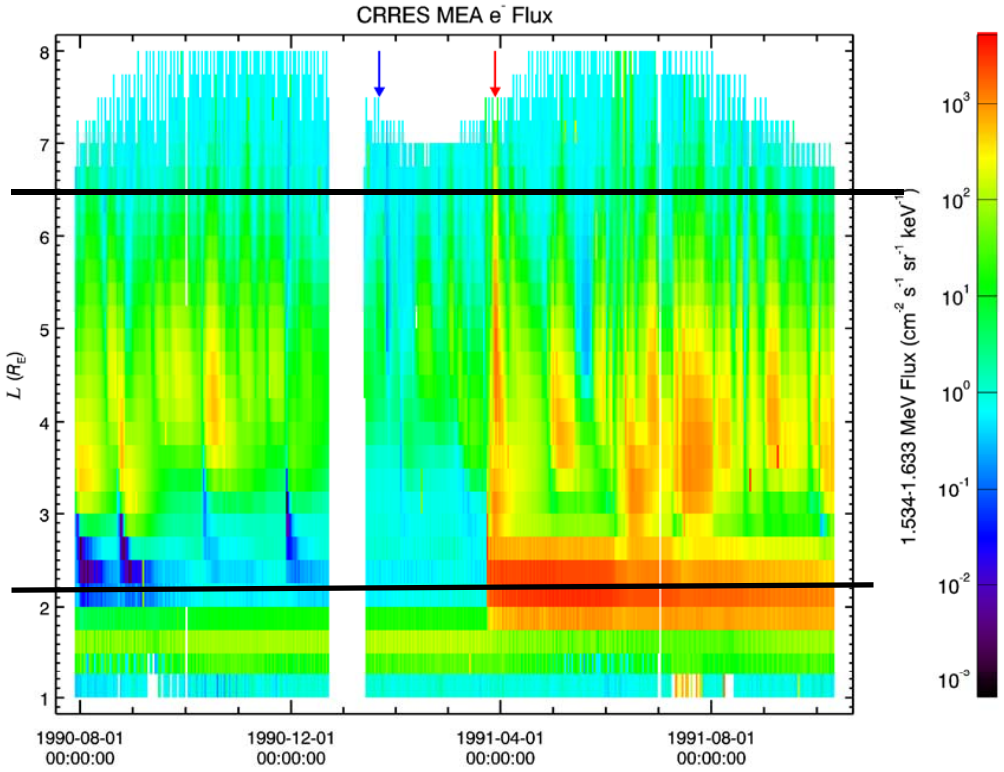
British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

All Electric Propulsion Satellites

- Launch to orbit ~ 100 – 180 days
- Needs full assessment of variable radiation environment
- SPACECSTORM will cover the whole outer belt – electron flux, fluence, charging

Geo orbit

8,000 km



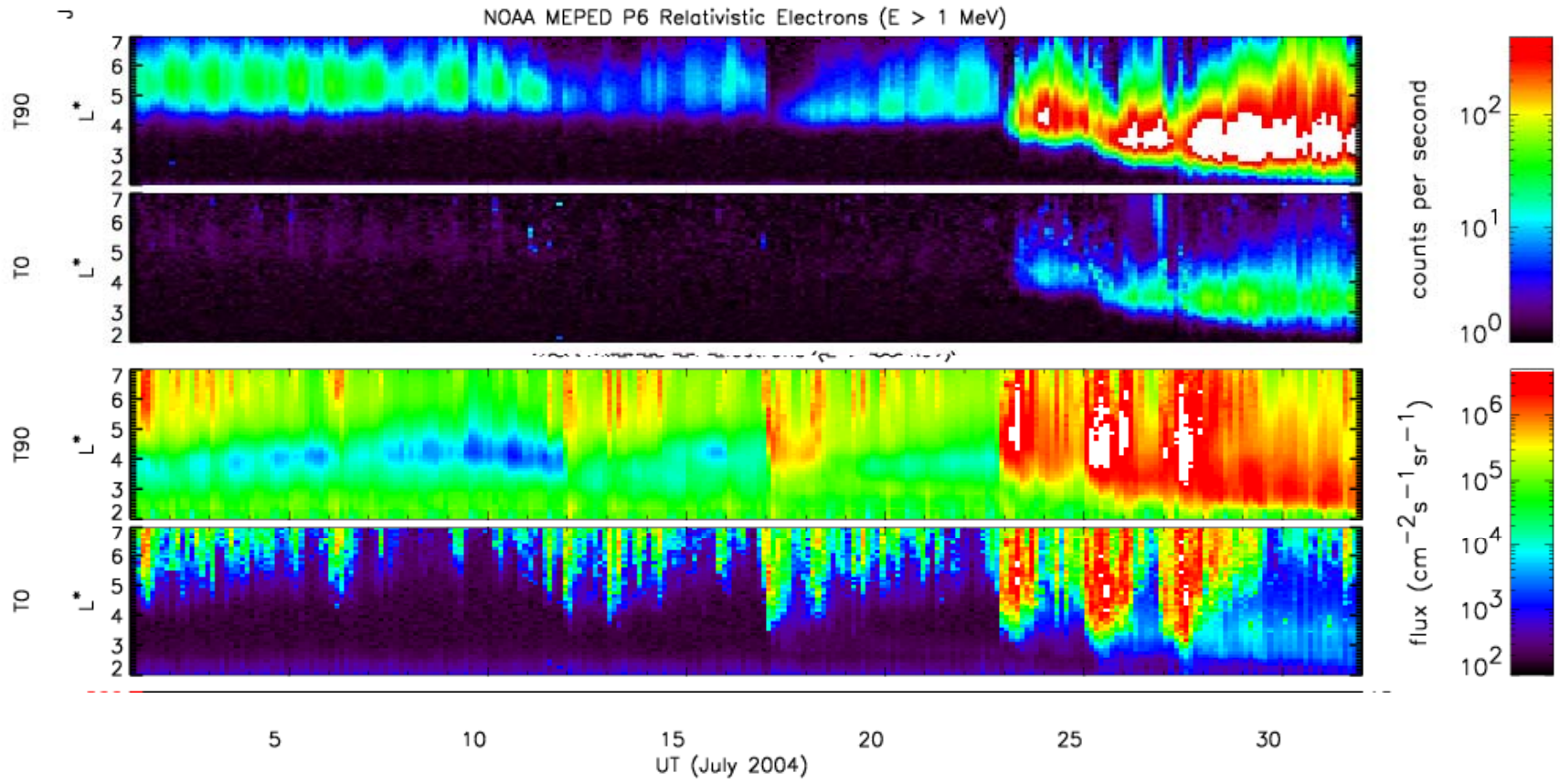
- 1.5 MeV electrons flux from CRRES
- Much higher charging environment after March 1991
- Charging depends on materials
- Note 8,000 km for O3b satellites

- Heynderickx [2014]

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

SPACESTORM

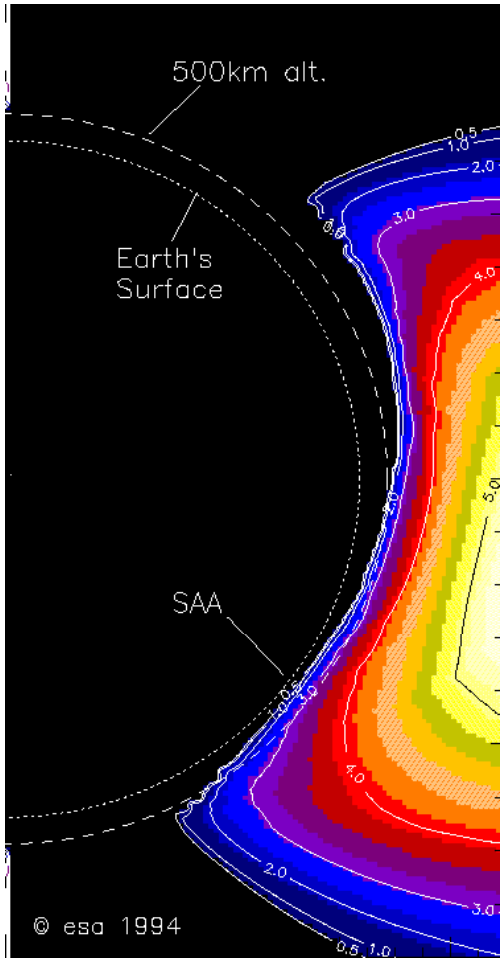
Low Energy Electron Variations - Substorms



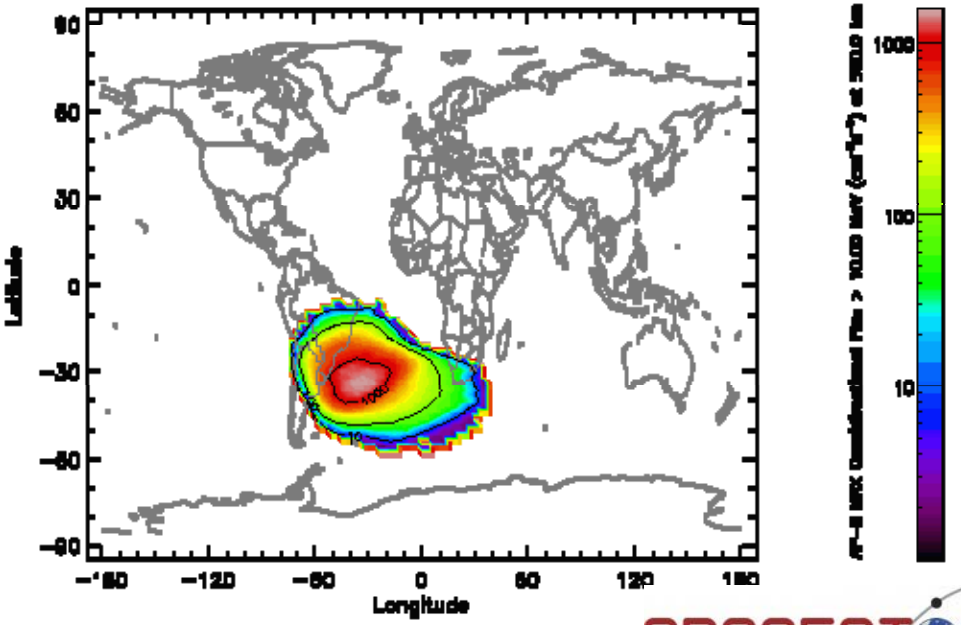
British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

SPACESTORM

Proton Radiation Belt



- Proton belt penetrates closer to the atmosphere over the south Atlantic due to the weakness in the magnetic field
- Hazard to low altitude satellites



British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

SPACESTORM

Needs

- Situation awareness – real time data
- Forecasting – data and models
- Post event analysis – data and models

- Key risk areas to focus on

  - Internal charging - Electron radiation belt – MeV electrons
  - Surface charging - Electron flux – keV
  - Single event upsets – Proton belt, solar protons
  - Solar array degradation – Proton belt, solar protons and GCR
  - Total dose – integration of the above along the orbit for 15 years

Proposed Services - 1

- Real time data access and display
  - Develop better graphics
  - MeV electrons
    - Fluence calculations for particular orbits
    - Geo orbit (GOES), Medium Earth orbit (VAP, Galileo) Slot region (8,000 km) (VAP)
  - KeV electrons
    - Electron flux for different orbits – as above
    - Use GOES, VAP satellites and POES

Proposed Services - 2

- Using models to ‘fill-in’ the missing regions
  - Around geostationary orbit (BAS model)
  - MEO, Slot, LEO (BAS model)
- Services for particular spacecraft
- Extend forecasting times to 24 hours ahead
- Extend models to lower energy – keV electrons for surface charging

Proposed Services - 3

- Developing a model for the Proton radiation belt
  - LEO, 8,000 km
  - Requires new model development (but similar to MeV electrons)

- Forecasting Sun to Earth
  - Coupling radiation belt models to solar wind data
  - Couple radiation models to ENLIL
  - Coupling to the atmosphere

- Coupling radiation models to BATS-R-US to get plasma injections

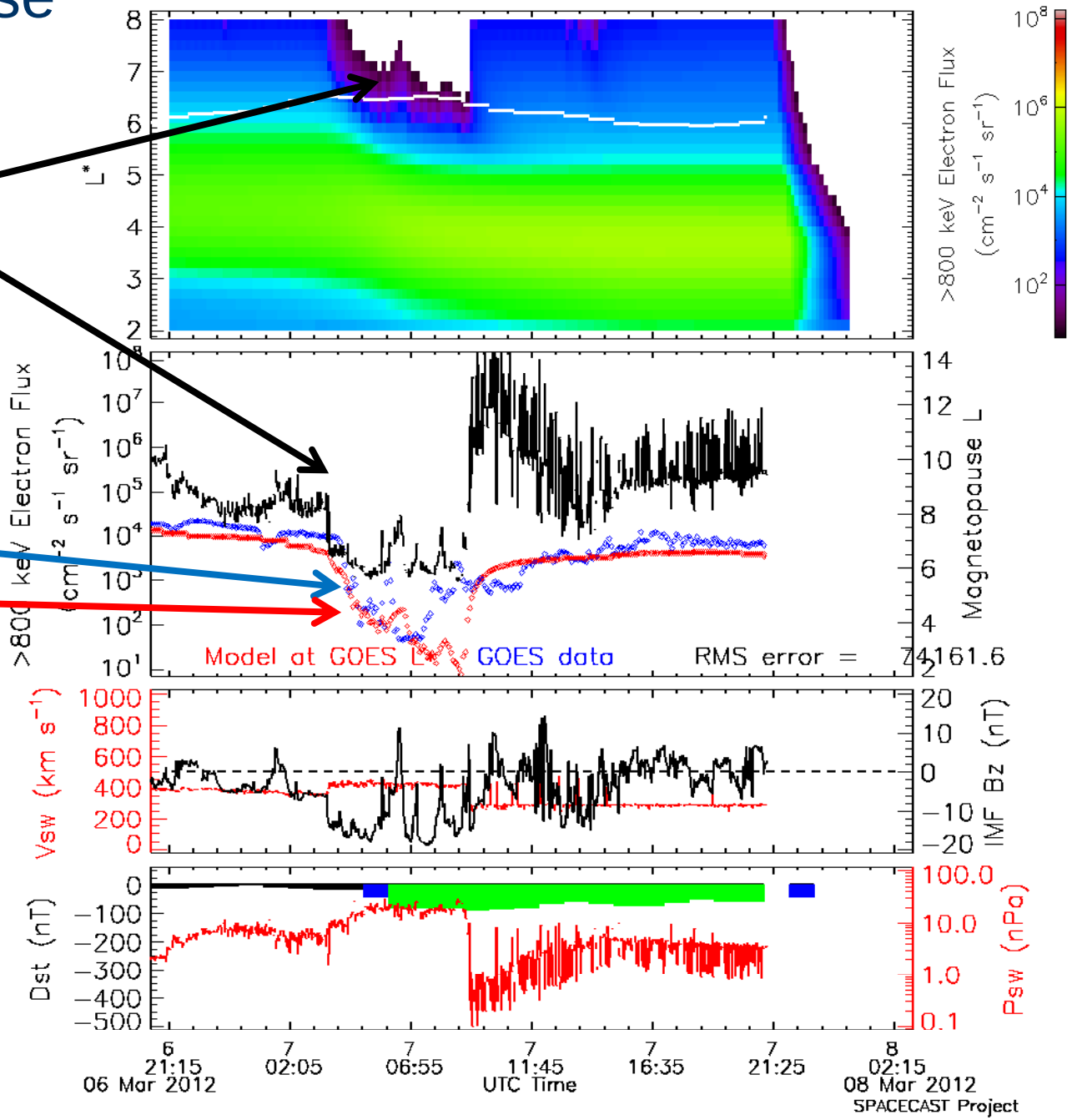
Magnetopause Losses

Magnetopause

Losses outside last closed drift shell

GOES data

BAS model



British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH

Way Forward

- What is the most important user need?
- Which areas can we agree to take forward?
- How do we take this forward?
- Funding opportunities
  - BIS, MOD?