The acceleration of ultrarelativistic electrons (E>~3 MeV) during geomagnetic storms

H. Zhao[1], D. N. Baker[1], X. Li[1], A. N. Jaynes[2], and S. G. Kanekal[3]

(1) LASP, University of Colorado Boulder, Boulder, CO, United States

(2) Department of Physics and Astronomy, University of Iowa, Iowa City, IA, United States

(3) NASA Goddard Space Flight Center, Greenbelt, MD, United States

Daily-averaged fluxes of relativistic and ultrarelativistic electrons

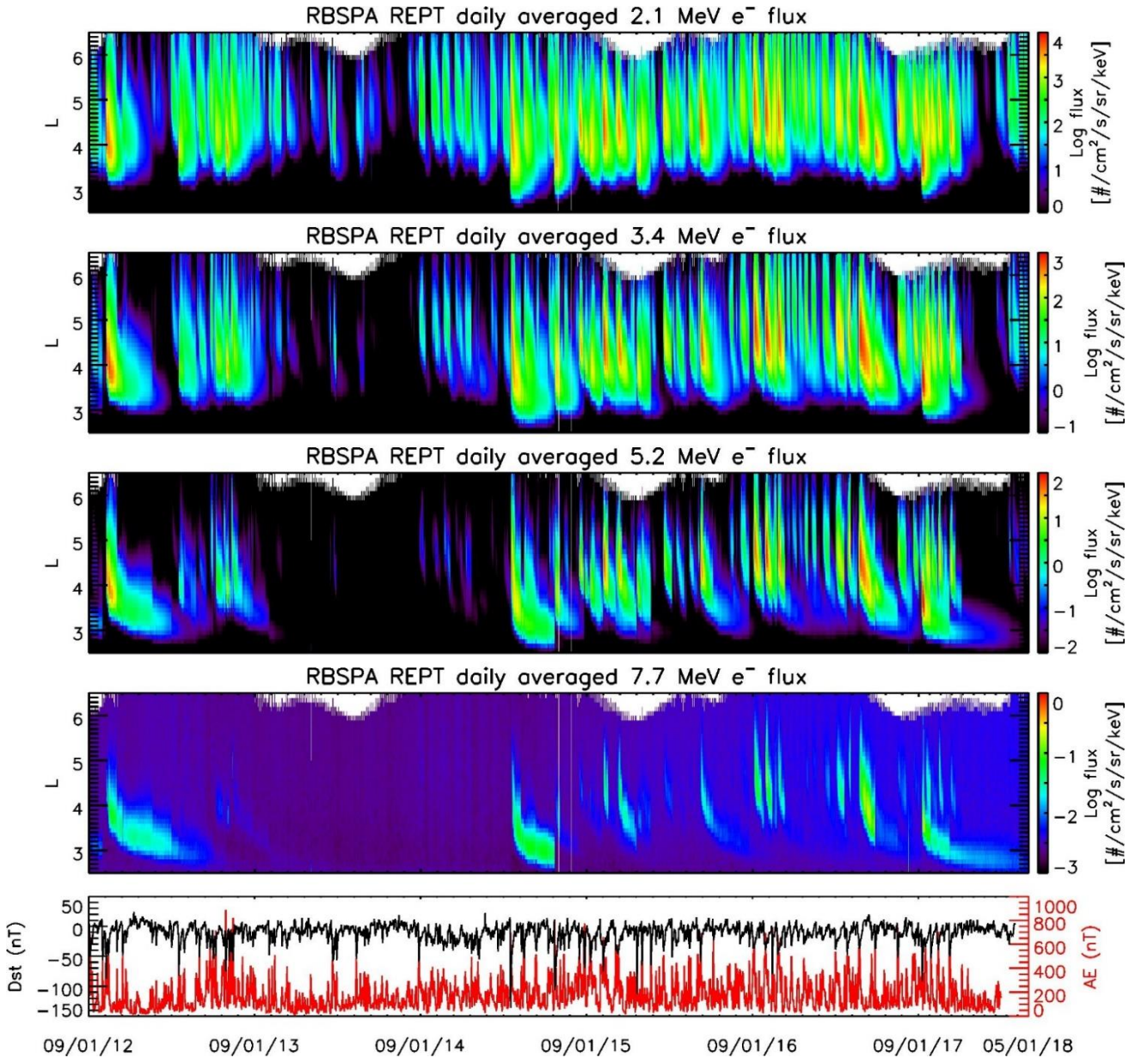
2.1 MeV

3.4 MeV

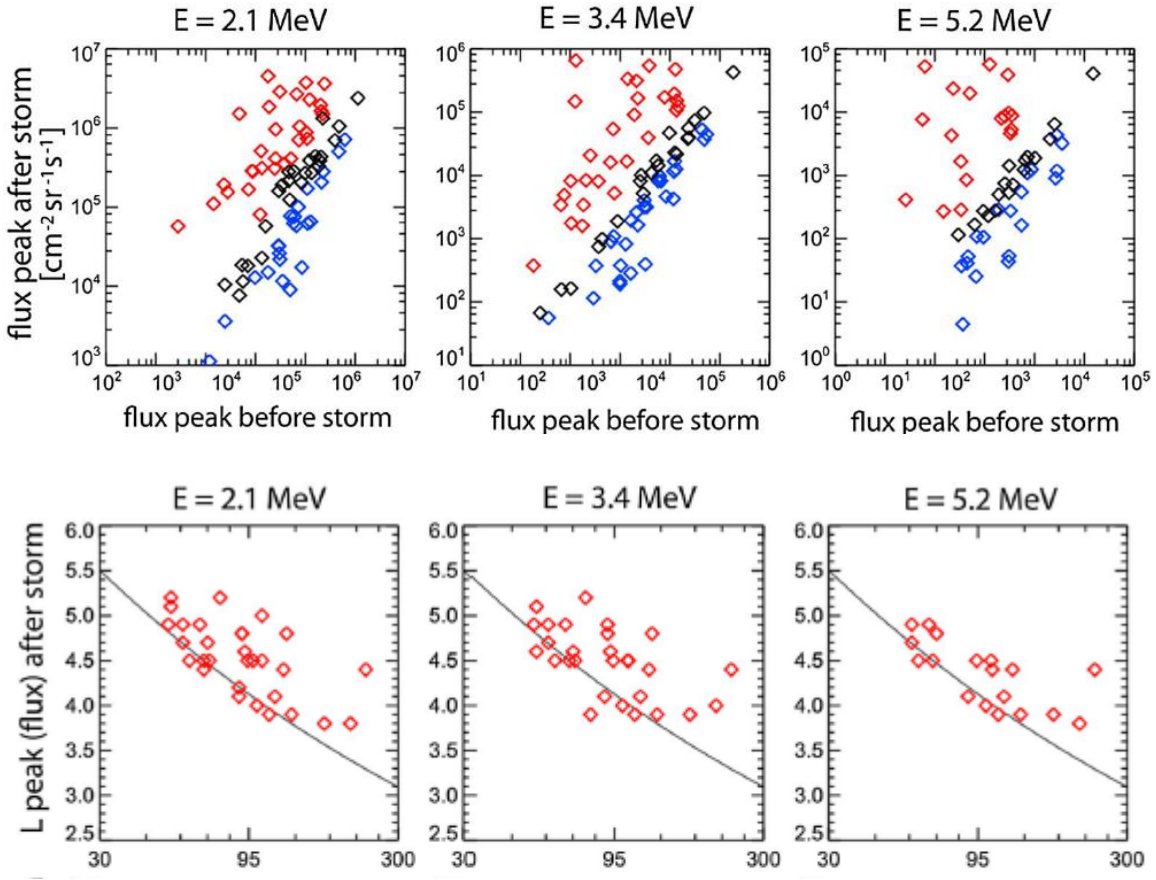
5.2 MeV

7.7 MeV

Dst & AE

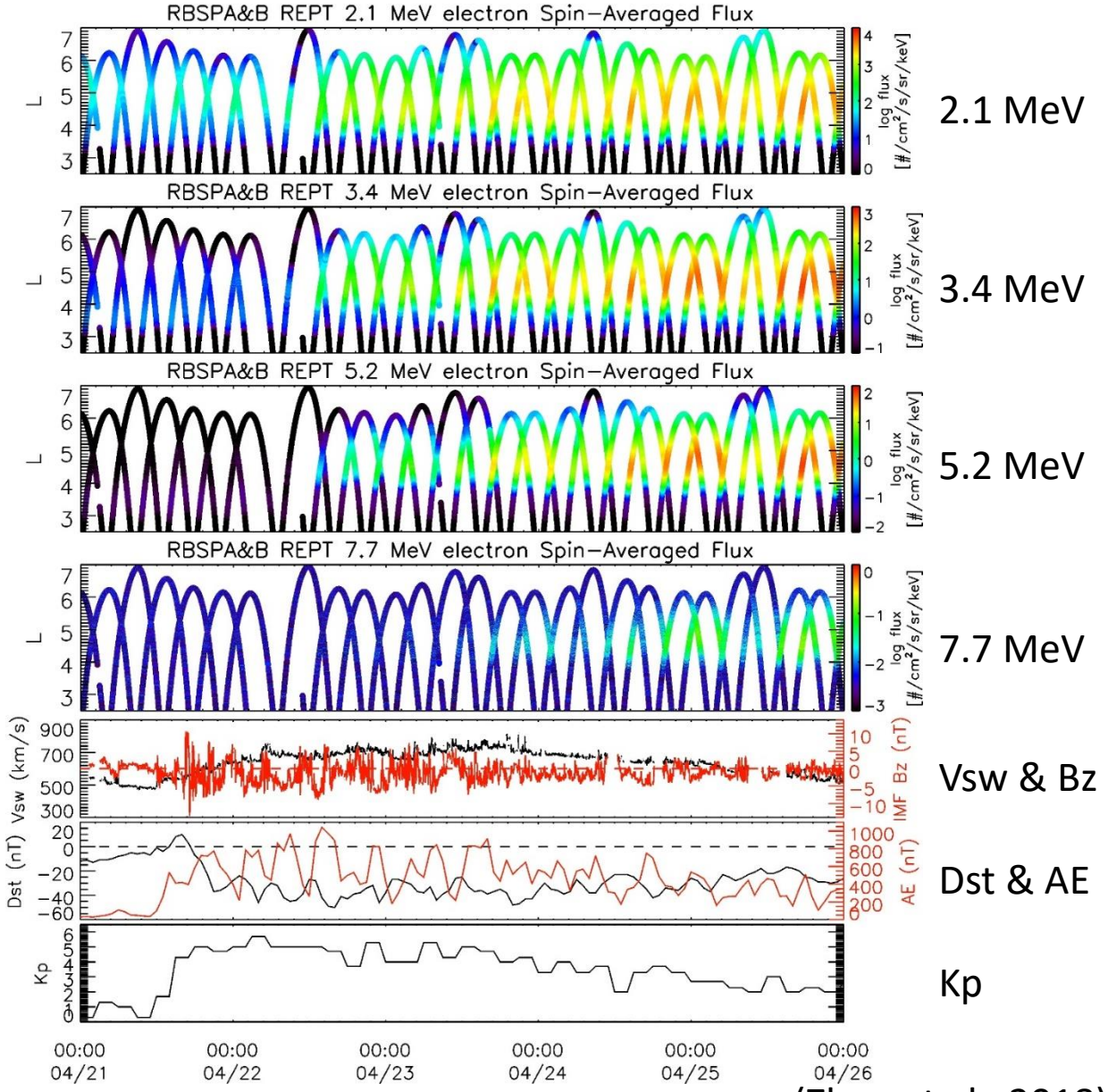


Previous studies



minimum SYM-H

(Moya et al., 2017)

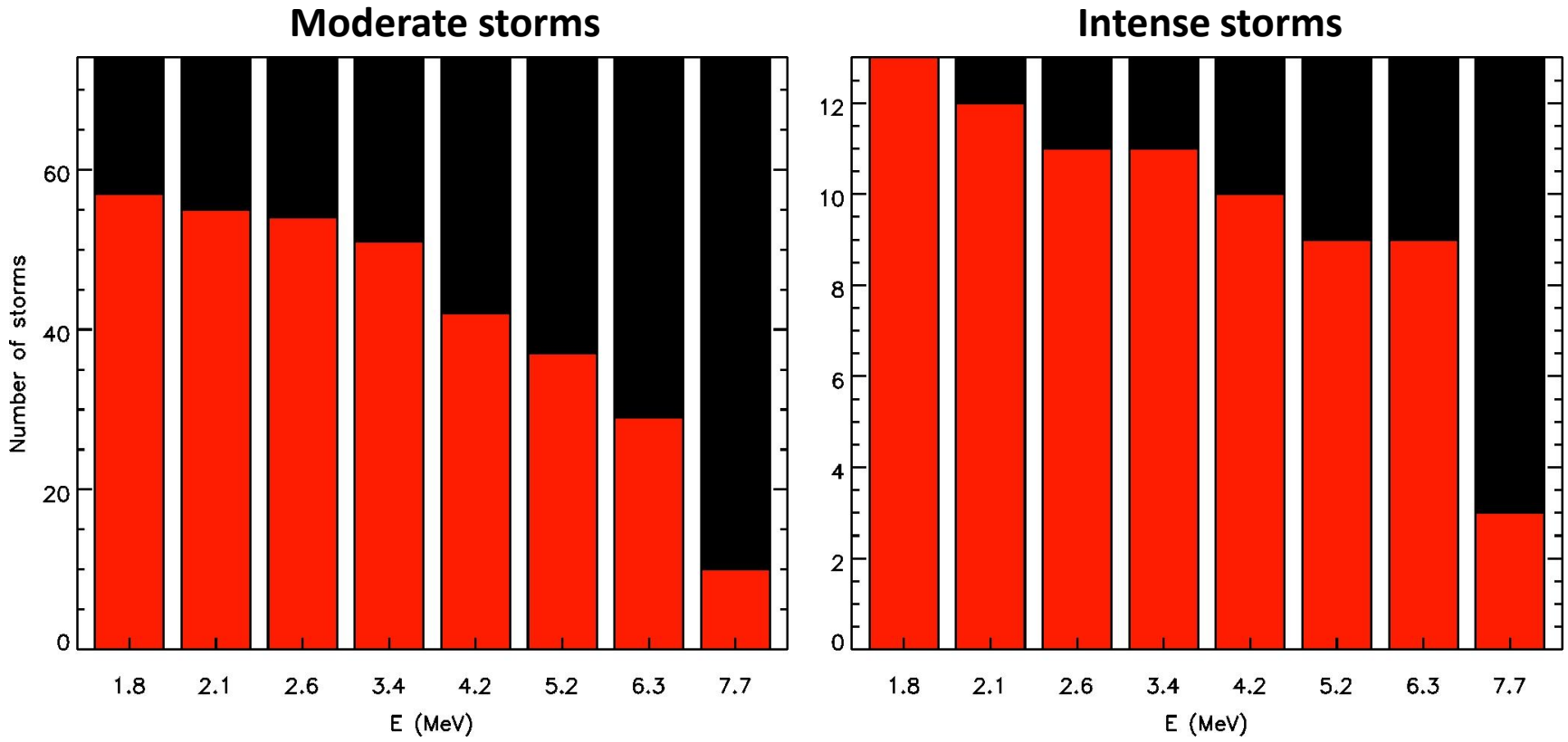


(Zhao et al., 2018)

The effect of geomagnetic storms on the ultrarelativistic electron flux enhancements

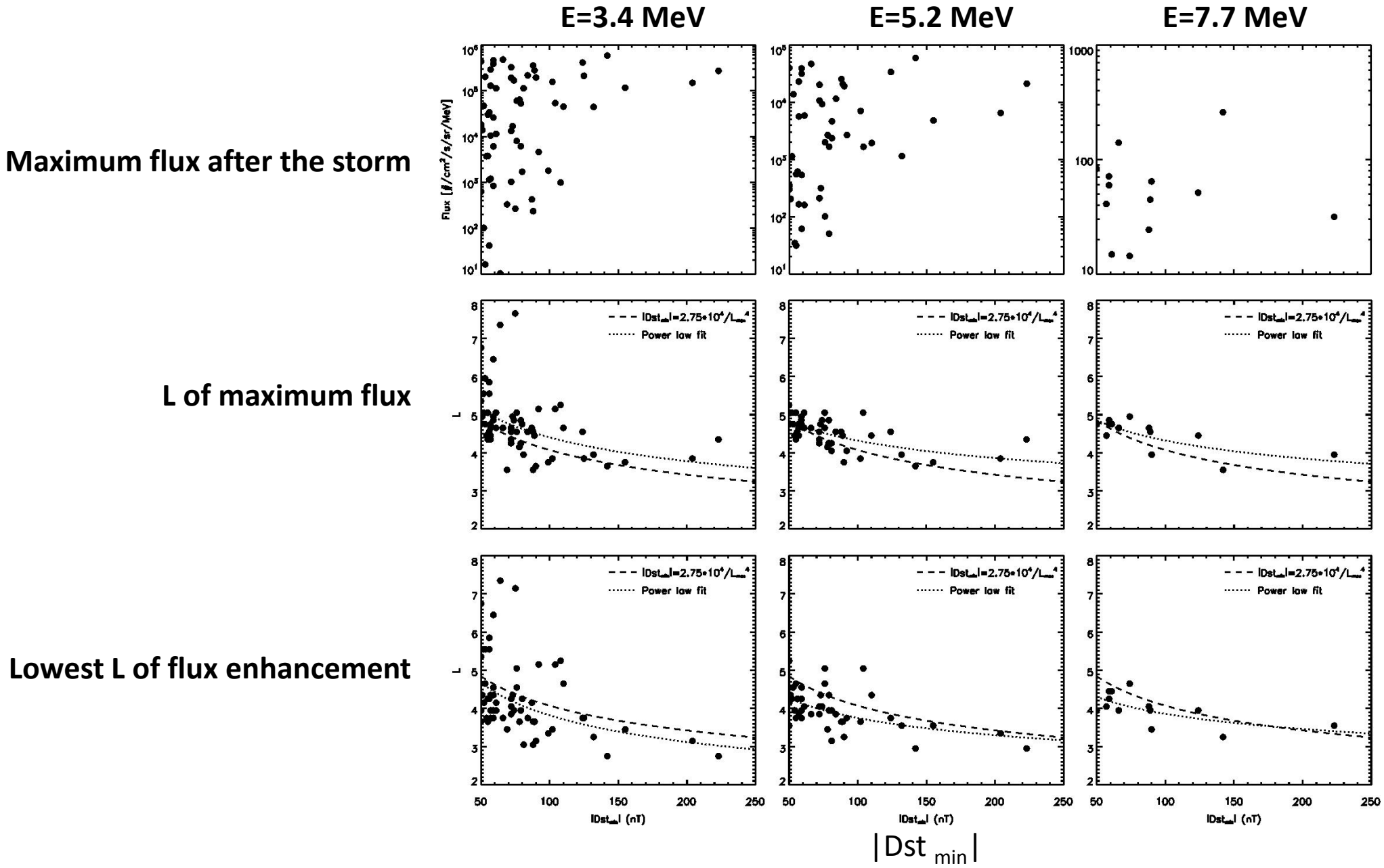
Number of Enhancement

Number of Non-Enhancement

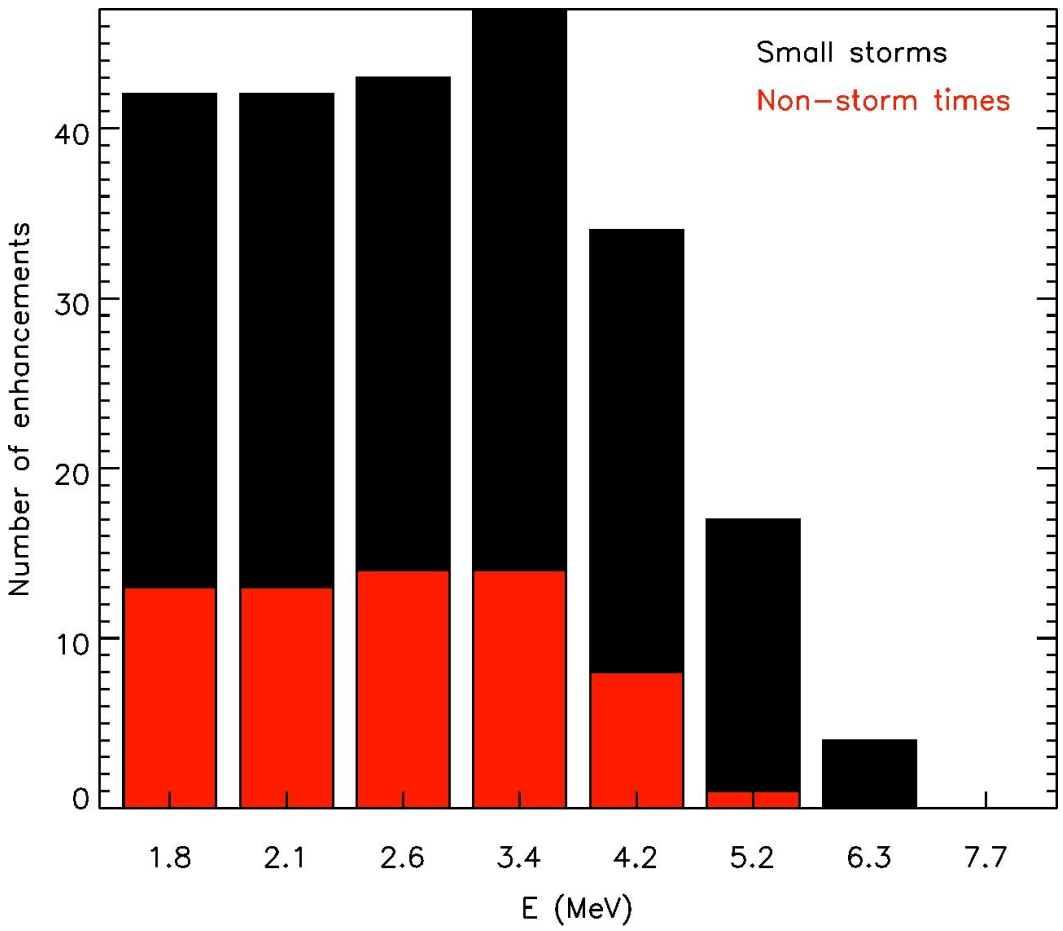


Enhancement: daily-averaged flux enhanced by at least a factor of 3 at an L range > 0.5 from 2 days before the day of minimum Dst to 1-5 days after the day of minimum Dst.

The effect of geomagnetic storms on the ultrarelativistic electron flux enhancements



Flux enhancements during small storms and non-storm times



Enhancements: flux enhanced by at least a factor of 3 at a L range > 0.5 comparing to the day before.

Small storms: from 5 days before to the day of flux enhancement: -50 nT < Dst_{min} < -30 nT & Dst_{max} < 20 nT.

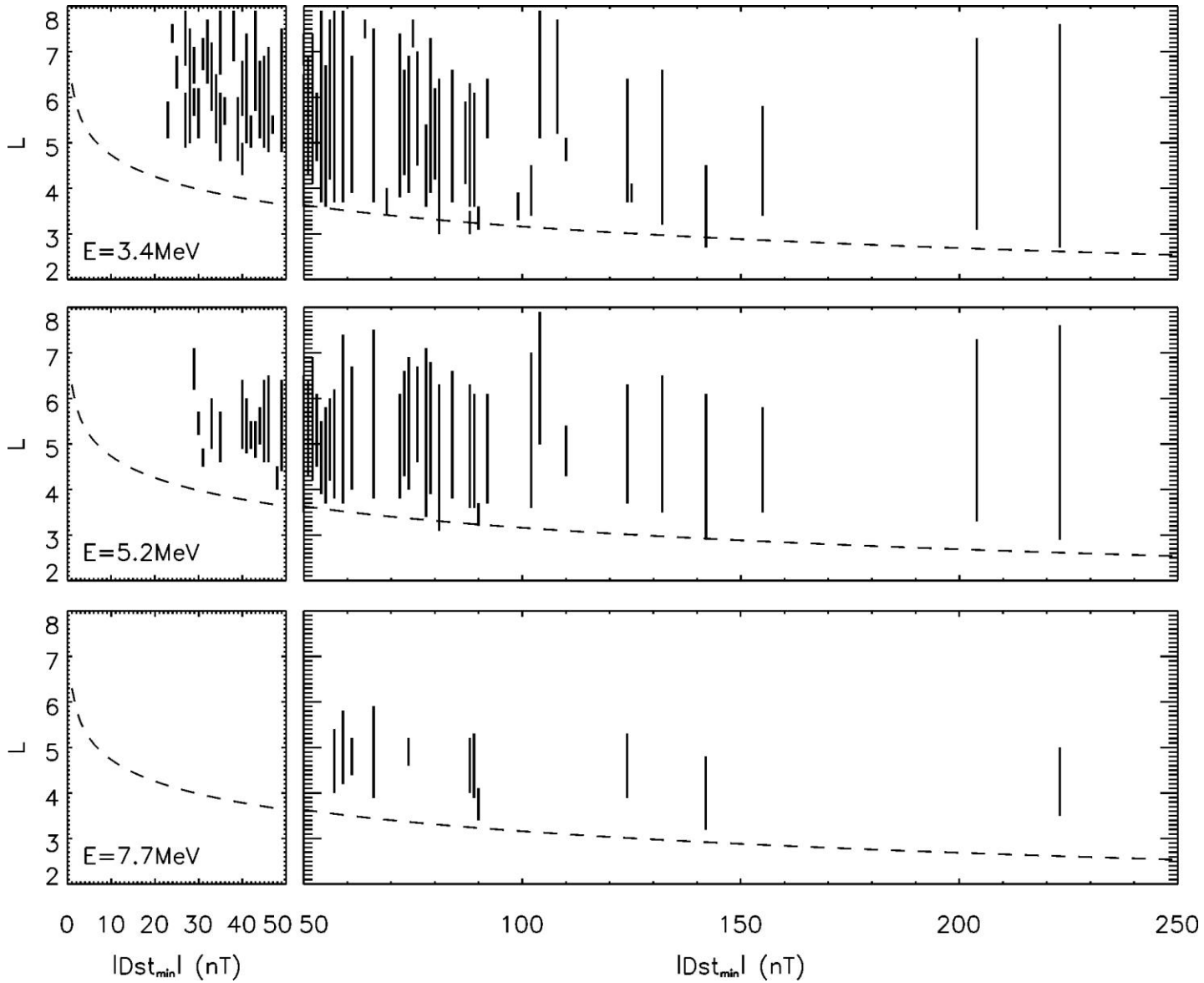
Non-storm times: from 5 days before to the day of flux enhancement: Dst_{min} > -30 nT & Dst_{max} < 20 nT.

L of flux enhancements during non-storm and storm times

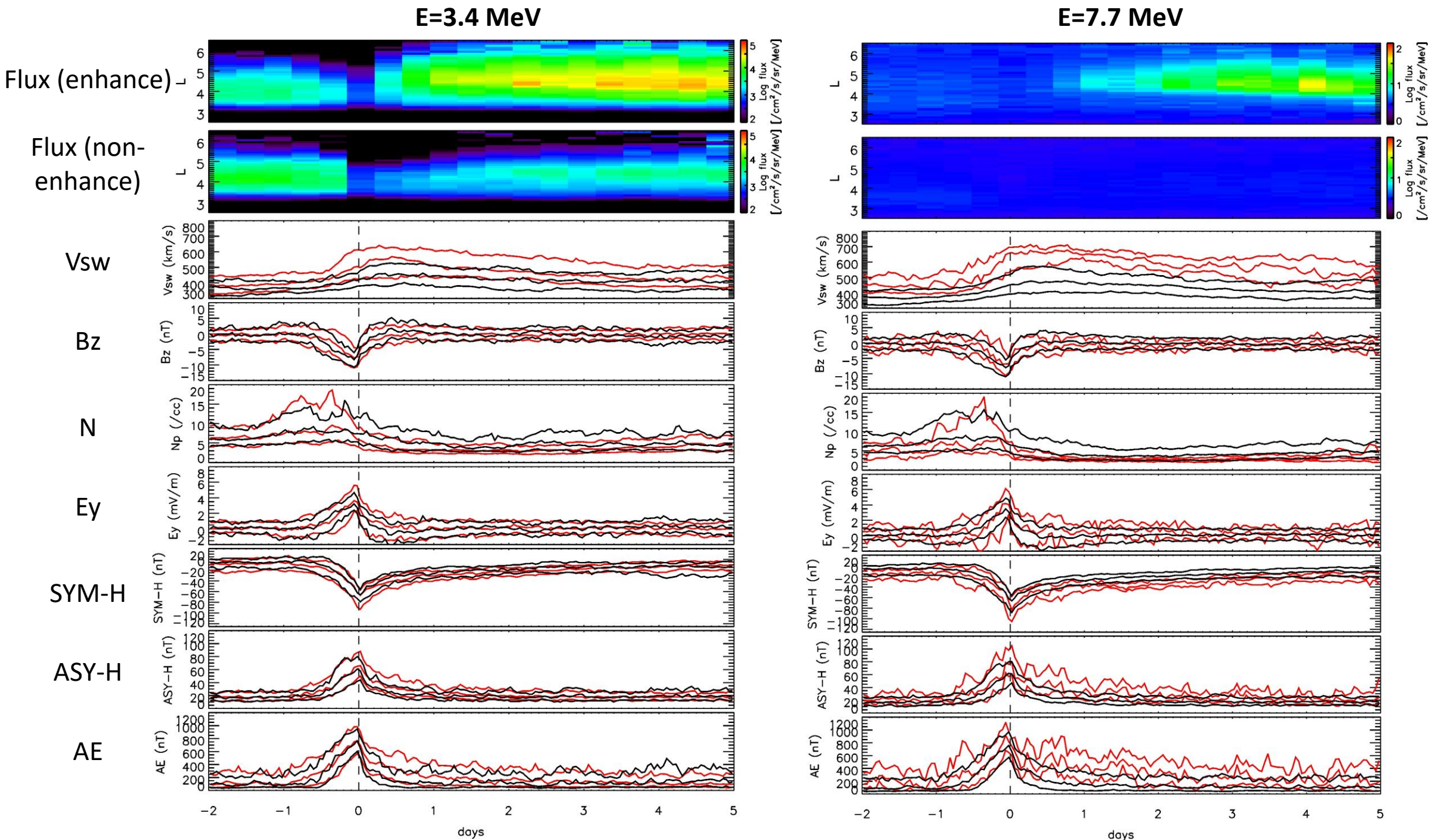
E=3.4 MeV

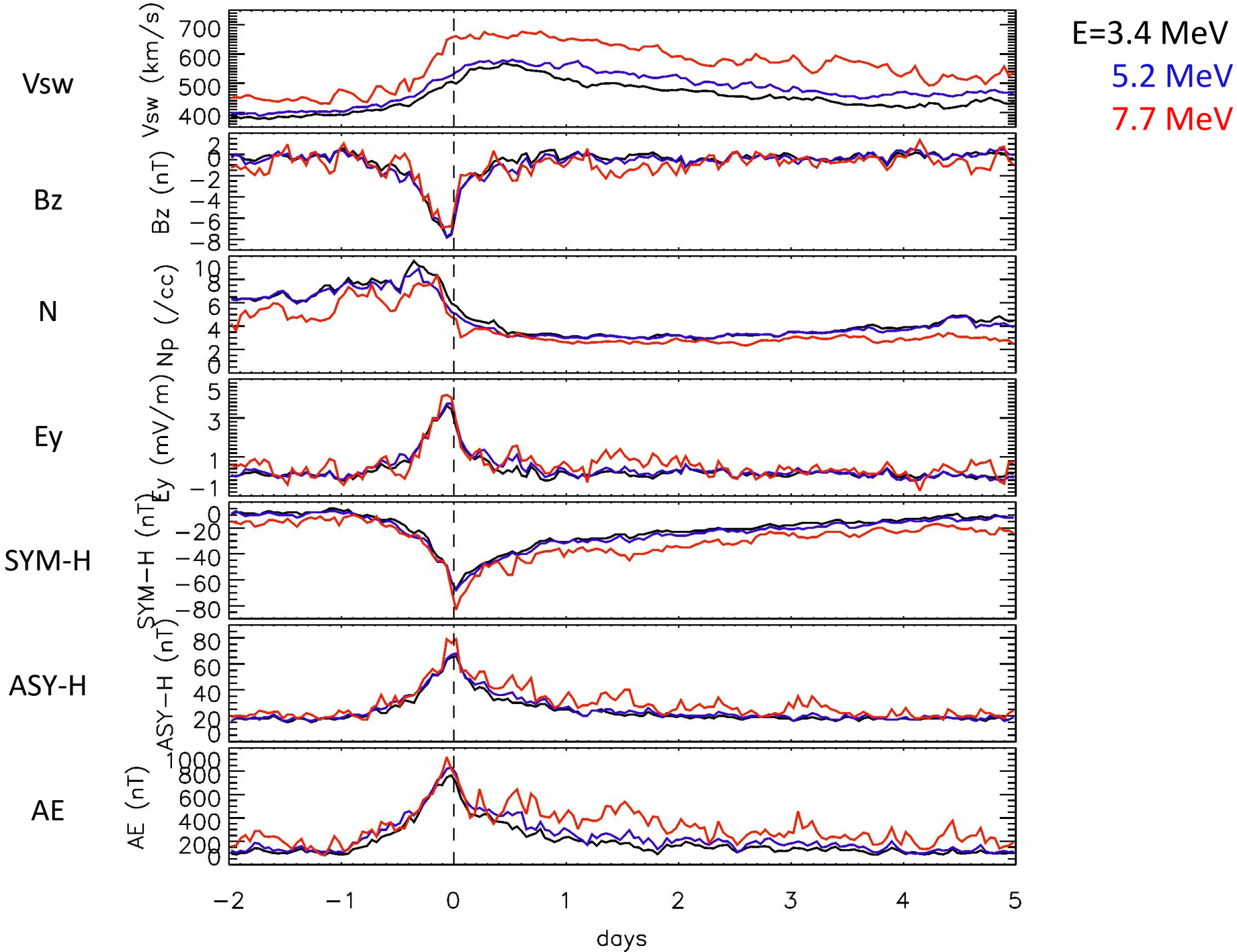
E=5.2 MeV

E=7.7 MeV



pp location [O'Brien and Moldwin, 2003]


E=3.4 MeV
E=7.7 MeV
Flux (enhance)
Flux (non-enhance)
Vsw
Bz
N
Ey
SYM-H
ASY-H
AE
L
Log flux [/cm²/s/sr/MeV]
Vsw (km/s)
Bz (nT)
Np (/cc)
Ey (mV/m)
SYM-H (nT)
ASY-H (nT)
AE (nT)
days


E=3.4 MeV
5.2 MeV
7.7 MeV
Vsw
Bz
N
Ey
SYM-H
ASY-H
AE
Vsw (km/s)
Bz (nT)
Np (/cc)
Ey (mV/m)
SYM−H (nT)
ASY−H (nT)
AE (nT)
days

Summary

We have studied the statistical behaviors of ultrarelativistic electrons during geomagnetic storms using data from REPT instruments from Sep 2012 to April 2018:

- The effect of geomagnetic storms on the acceleration of ultrarelativistic electrons
  - Intense storms are indeed more likely to cause flux enhancements than moderate storms
  - Storms with higher solar wind speed, more sustained southward IMF Bz, and lower solar wind number density are more likely to cause flux enhancements
  - Storms with more intense and sustained substorm activities are more likely to cause flux enhancements

- The energy-dependent acceleration of ultrarelativistic electrons during geomagnetic storms
  - As the electron energy gets higher, the chance of flux enhancement gets lower
  - For 7.7 MeV electrons, moderate to intense storms are required to cause flux enhancements
  - The most effective conditions causing flux enhancements of electrons with higher energies are high solar wind speed and sustained substorm activity.

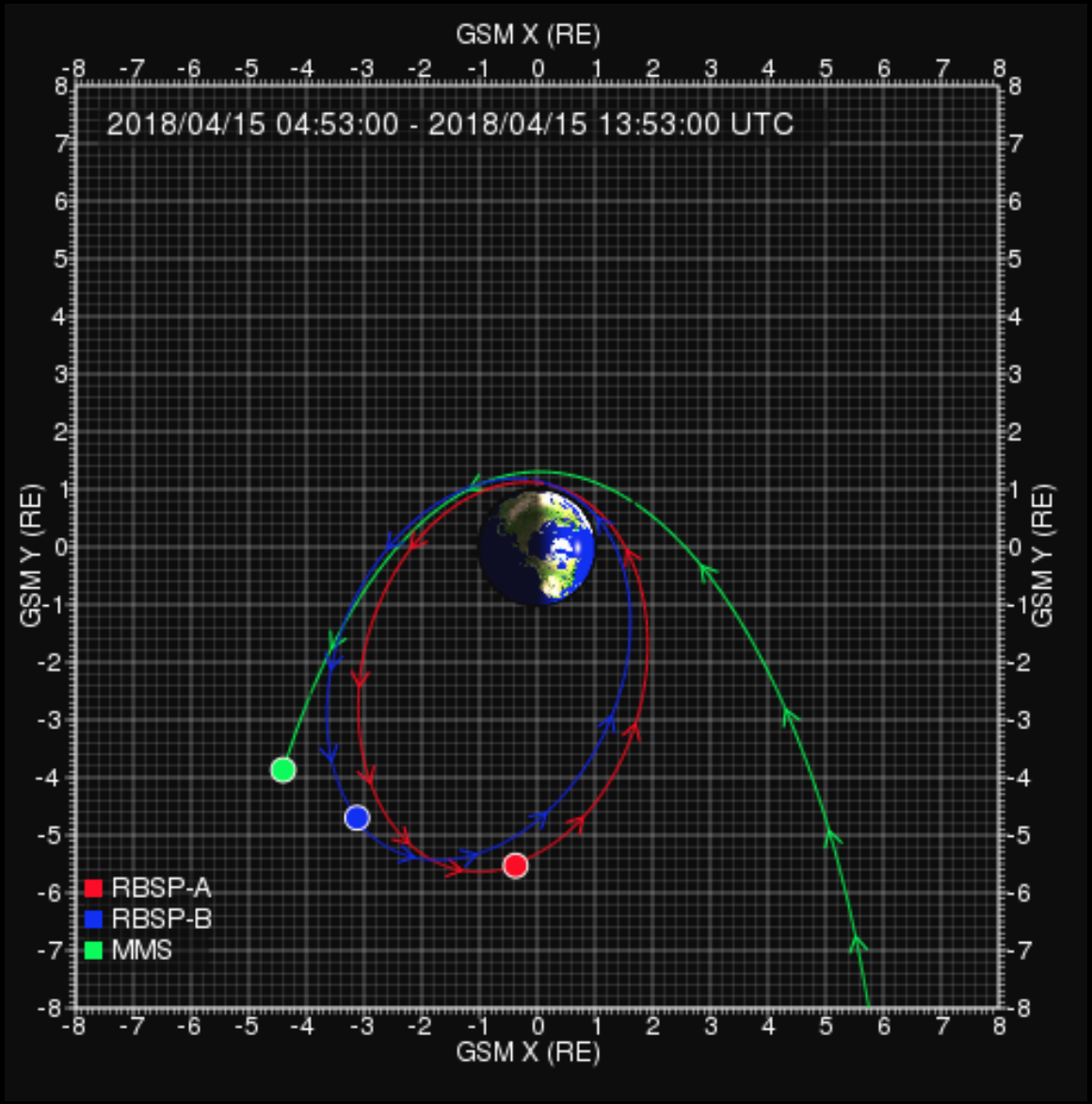
Conjunctive Measurements of Energetic Particle Injections of Van Allen Probes, MMS, and GOES

Nicki Mullins, Hong Zhao, Trevor Leonard

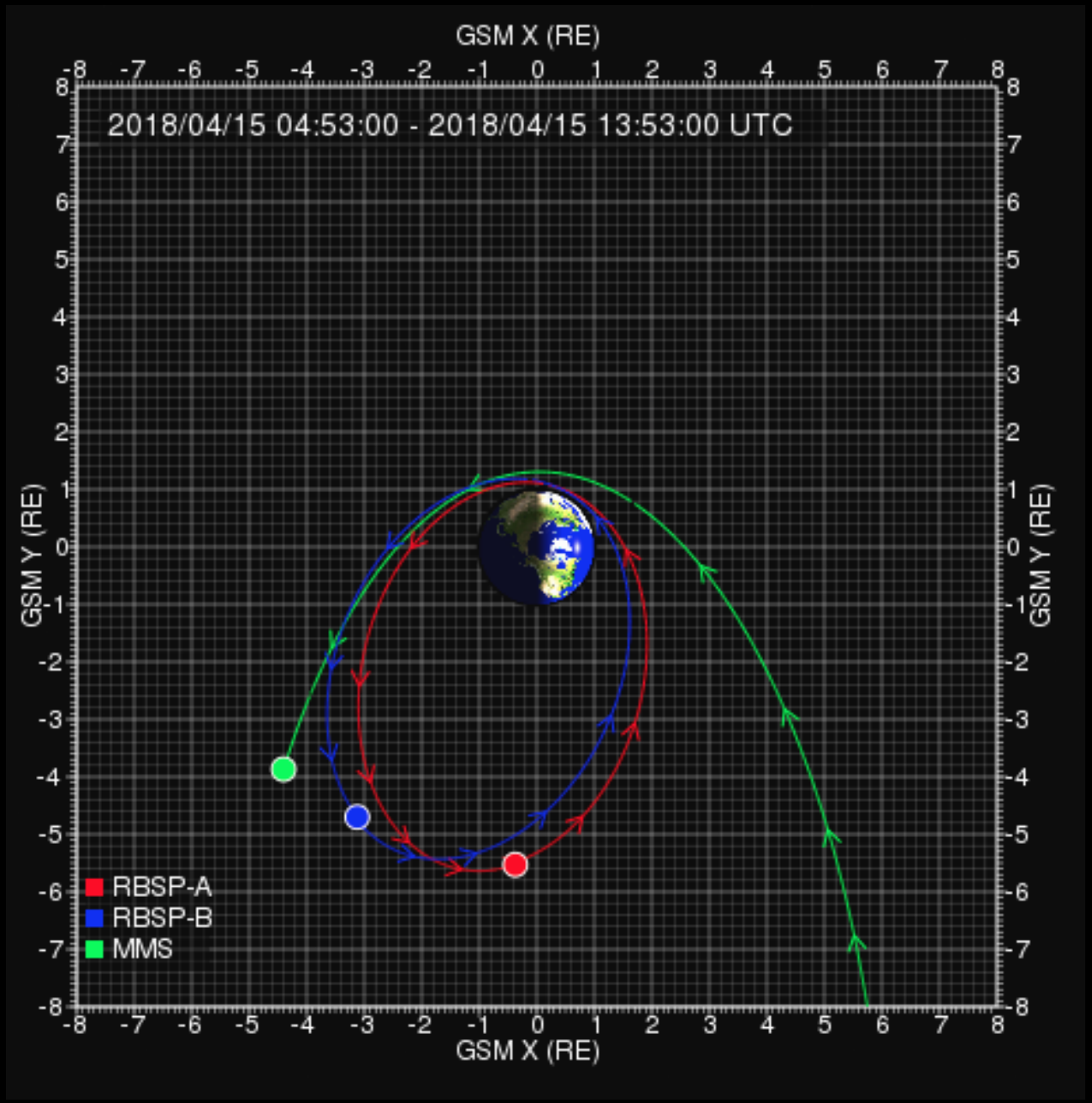
Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**

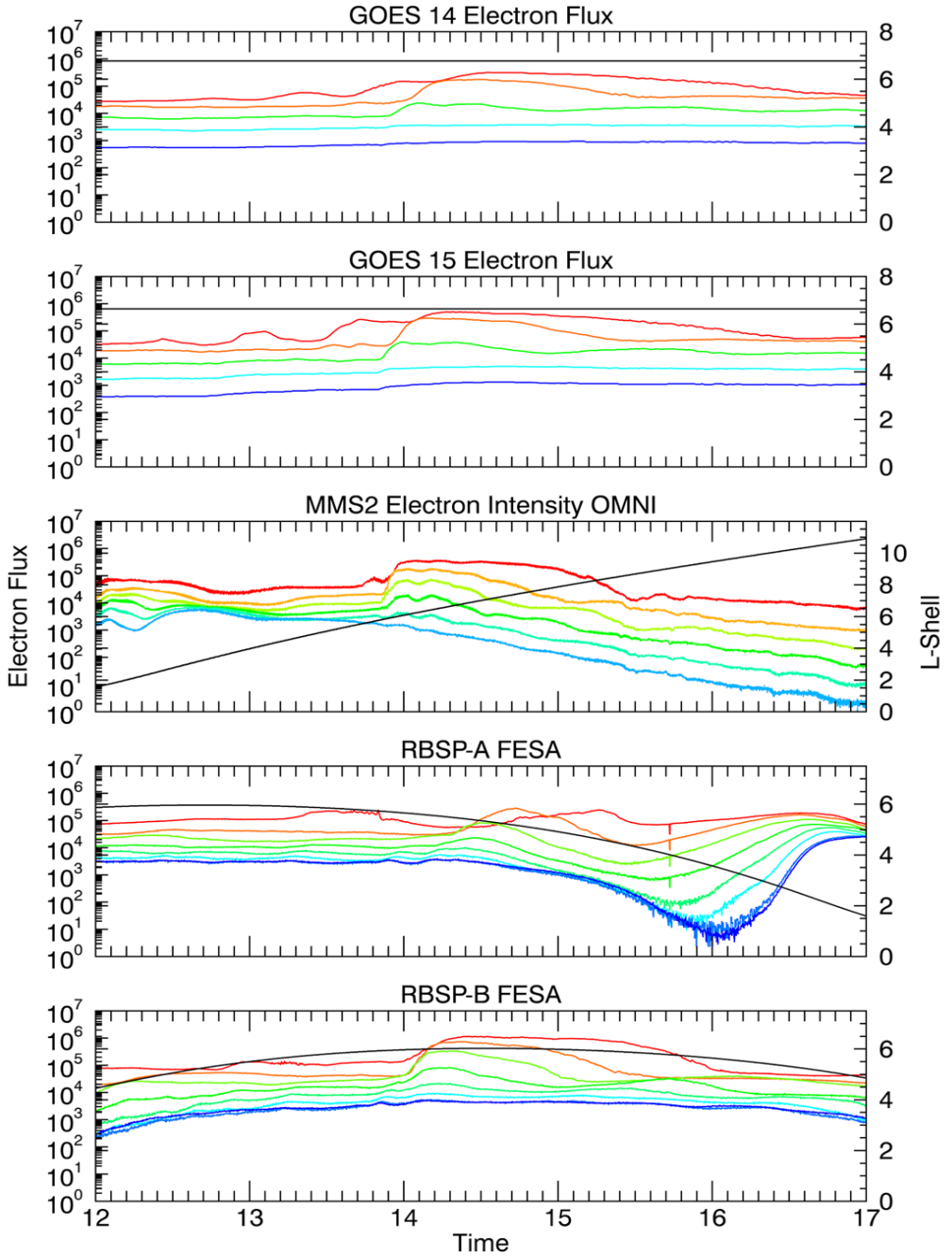
Case Study

- The injection occurred on April 15 2018: MMS and RBSP-B are on similar L-shells.
- RBSP-A is slightly separated in L-shell and inbound.
- GOES are added because they are at a higher L-shell.



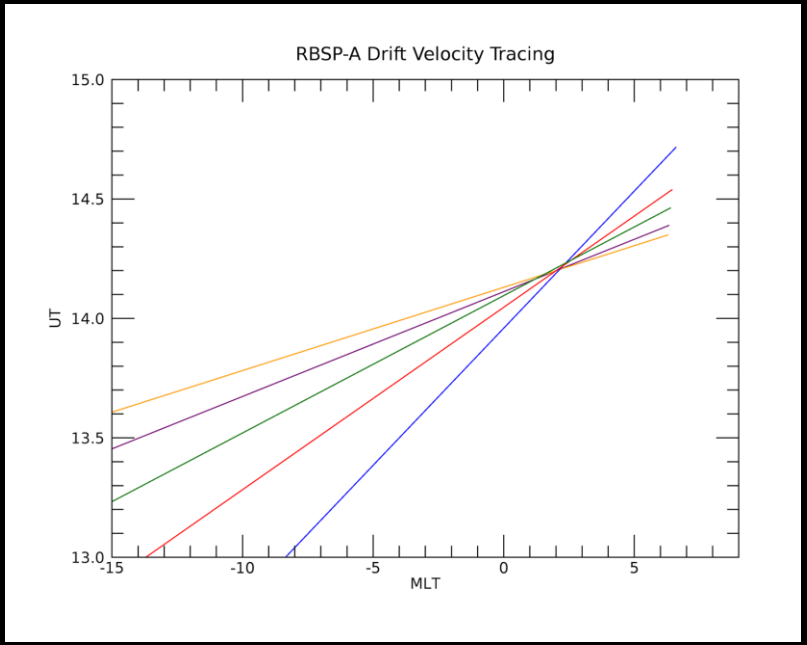
Credit: Van Allen Probes Science Gateway

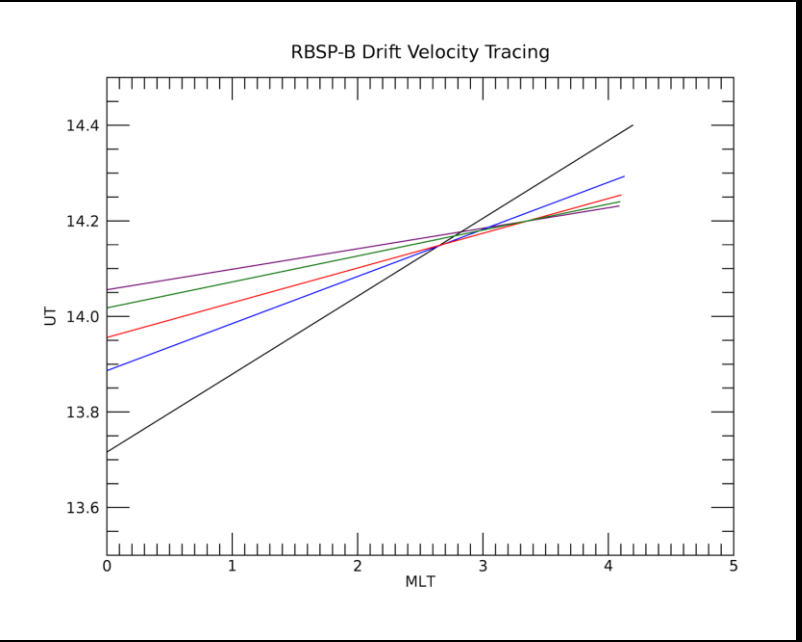

GSM X (RE)
2018/04/15 04:53:00 - 2018/04/15 13:53:00 UTC
GSM Y (RE)
RBSP-A
RBSP-B
MMS


GOES 14 Electron Flux
GOES 15 Electron Flux
MMS2 Electron Intensity OMNI
RBSP-A FESA
RBSP-B FESA
Electron Flux
L-Shell
Time

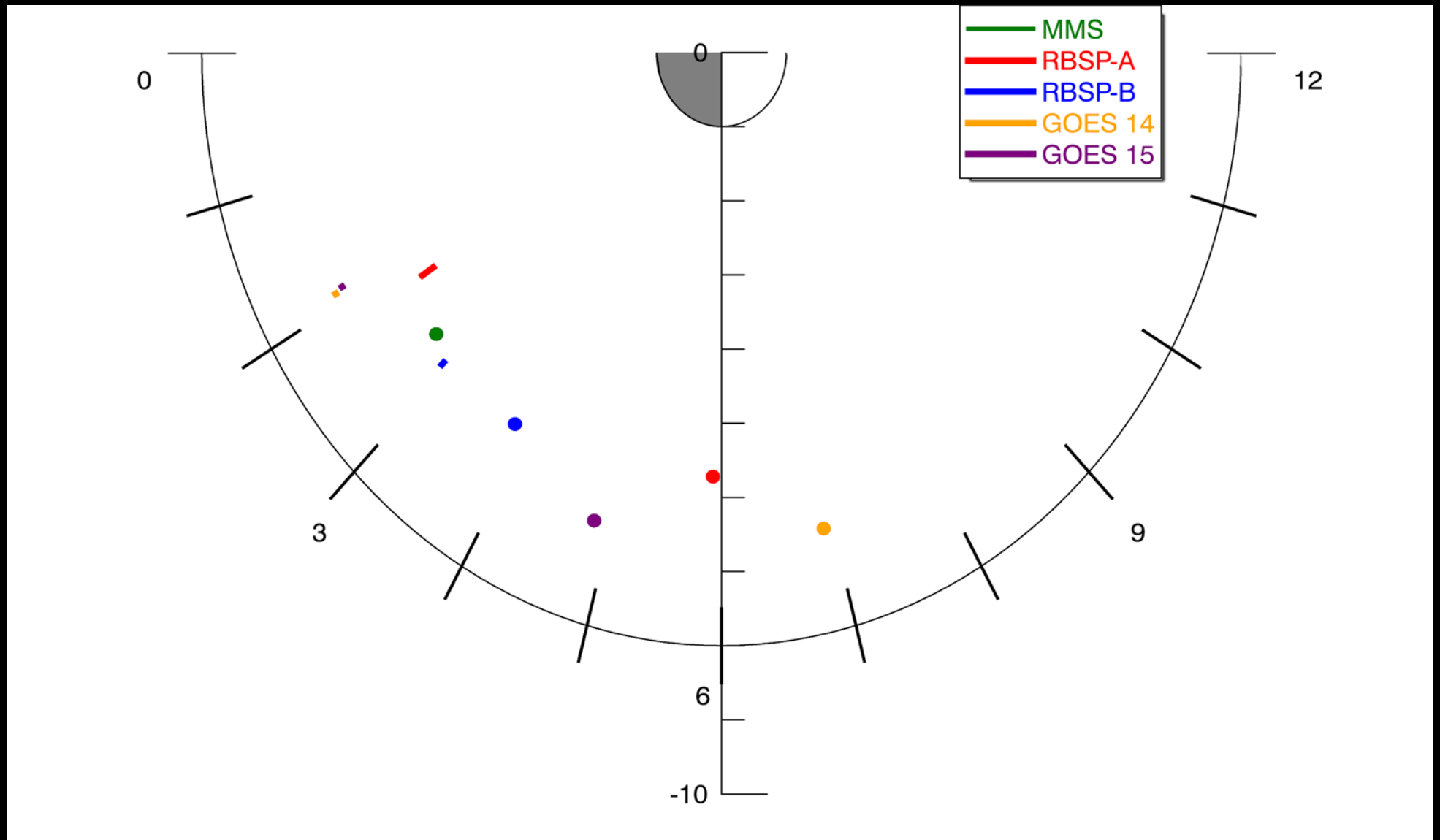
Drift Velocity Tracing

- For dispersed injections
- Assuming a dipole magnetic field and equatorially trapped particles
- Particles in each energy channel are traced backwards
- Ideally there will have been a time and location at which all particles were at the same place, this would be the boundary of the injection region.



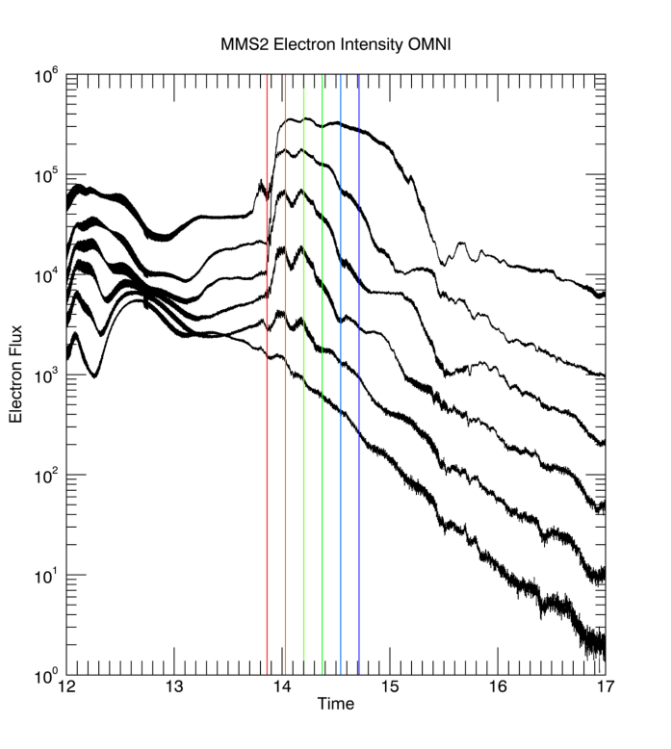


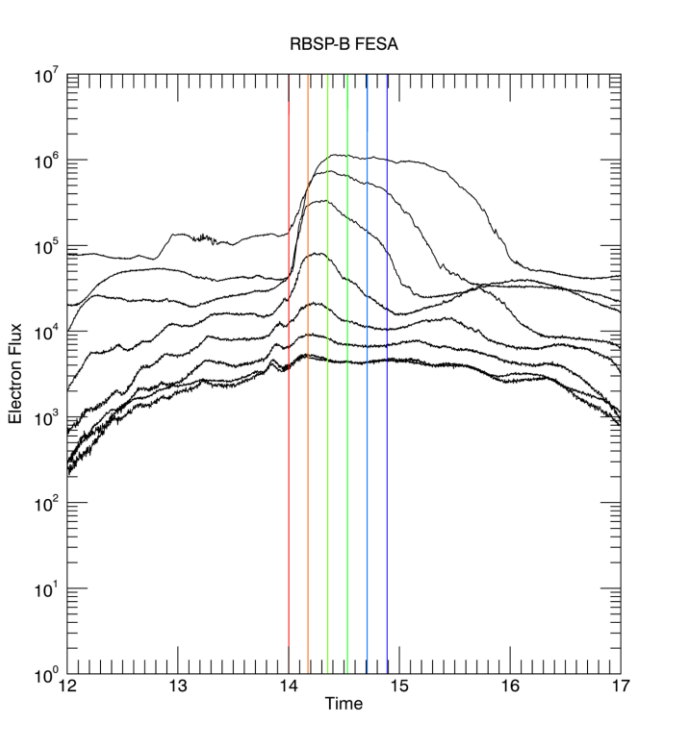
Injection Region

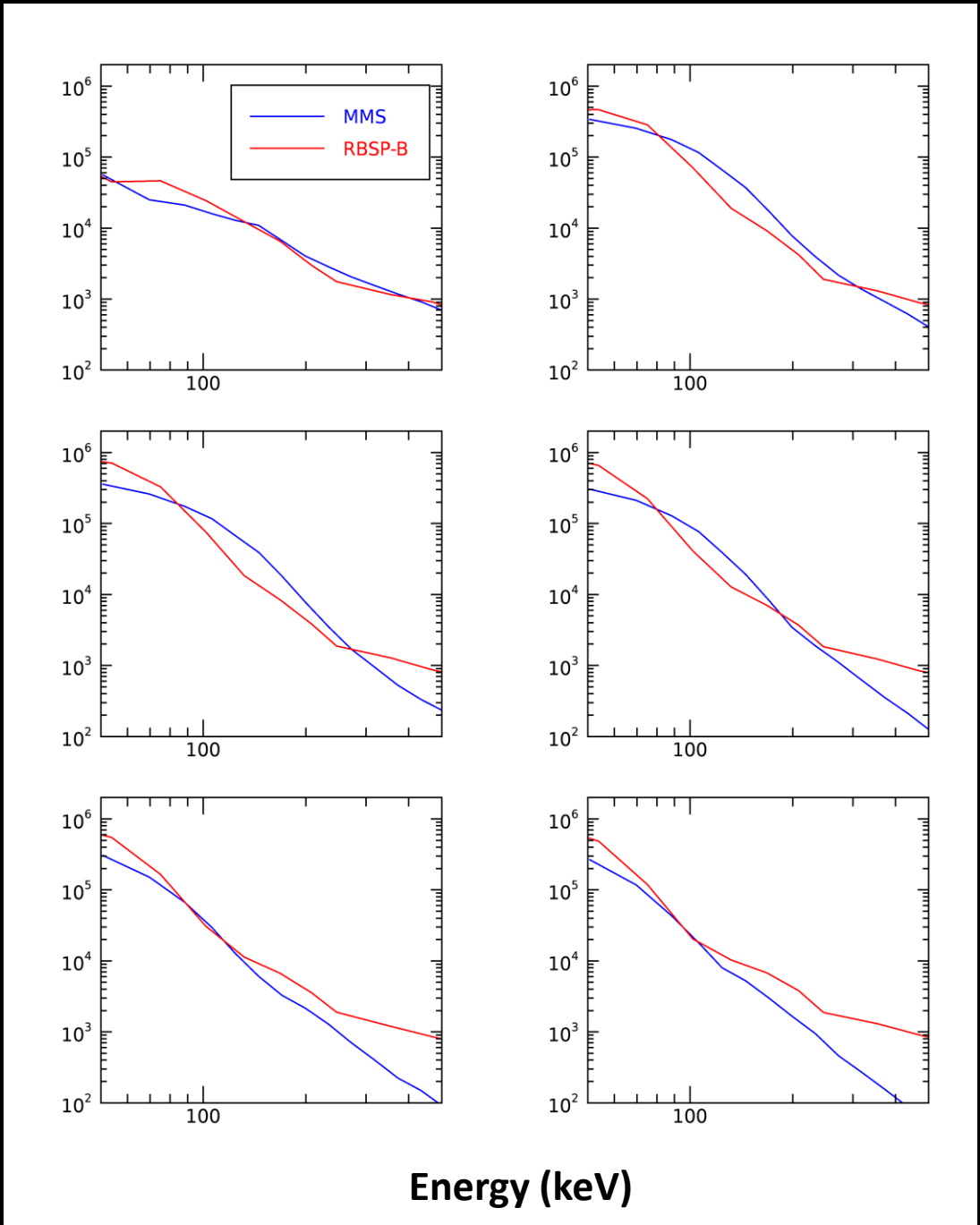


Energy Spectra Comparison

- Energy spectra were compared during the injection to see if they could be used to map the injection progression.







Summary and future work

- An injection event of ~10s – 200 keV electrons occurred on April 15 2018 was observed by both Van Allen Probes, MMS, and GOES satellites.

- Backward tracing results suggest that the eastward boundary of injection region was located at MLT~2 – 3 at L~5 – 6.6, and the injection region was moving Earthward with a speed of ~16 km/s.

- The energy spectra measured by the Van Allen Probes – B and MMS are quite consistent and both showing softening of the energy spectrum as the injection occurred.

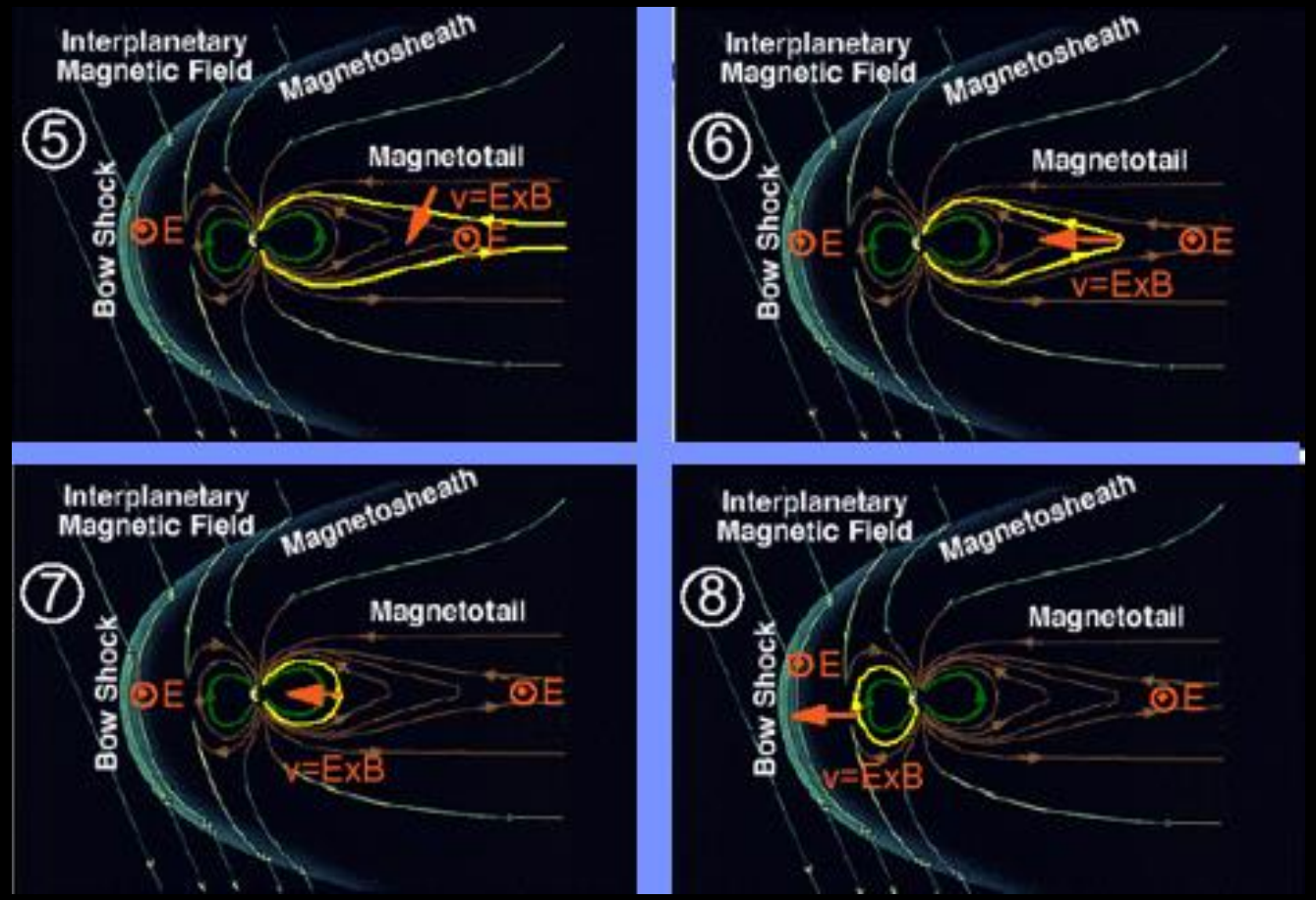
- Future work:
    - Adding data from concurrent magnetic field observations to individual case studies to examine the progression of the injection region.
    - Examining more injections in depth to determine how the correlated observations change as the spatial and L-shell separation increase.

Thank you!

Back-up slides

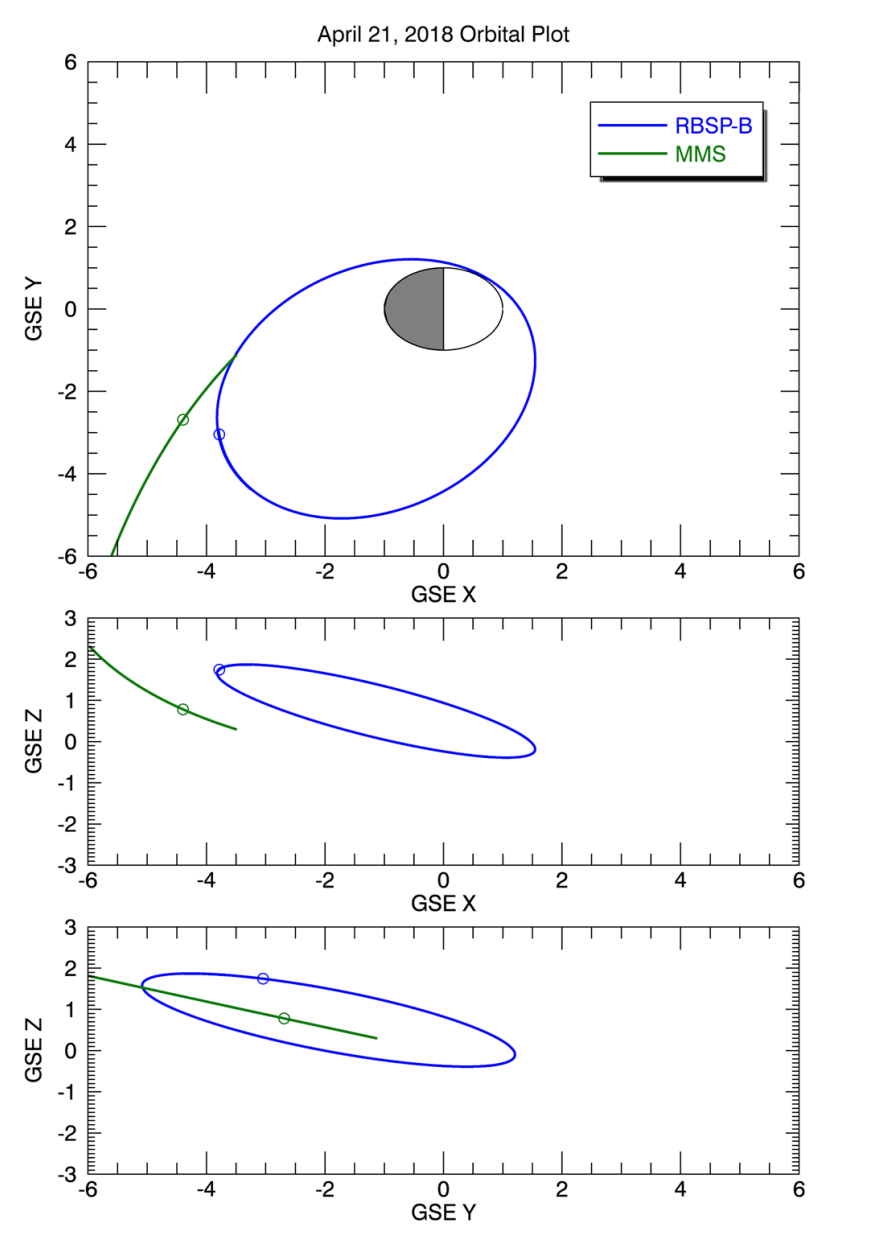
Particle Injections

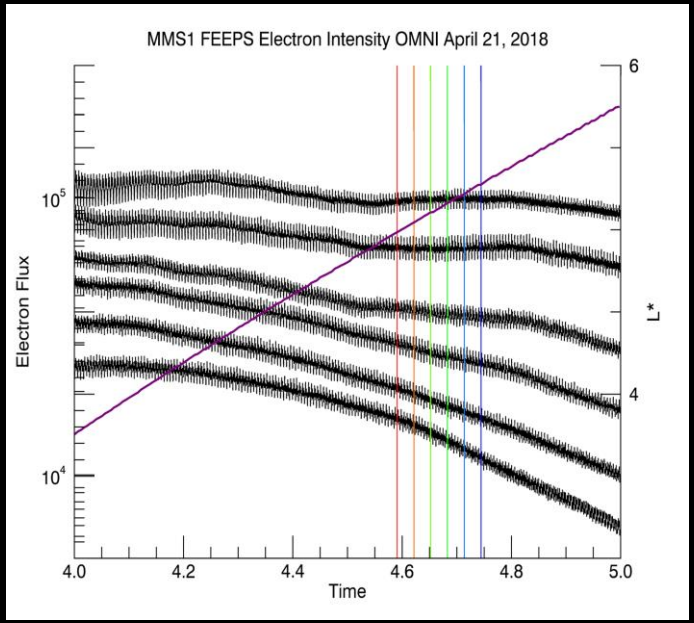
- Fast transport of energetic particles from tens to hundreds of keV.
- Often originate in the magnetotail from magnetic reconnection.
- Dispersed or dispersionless.

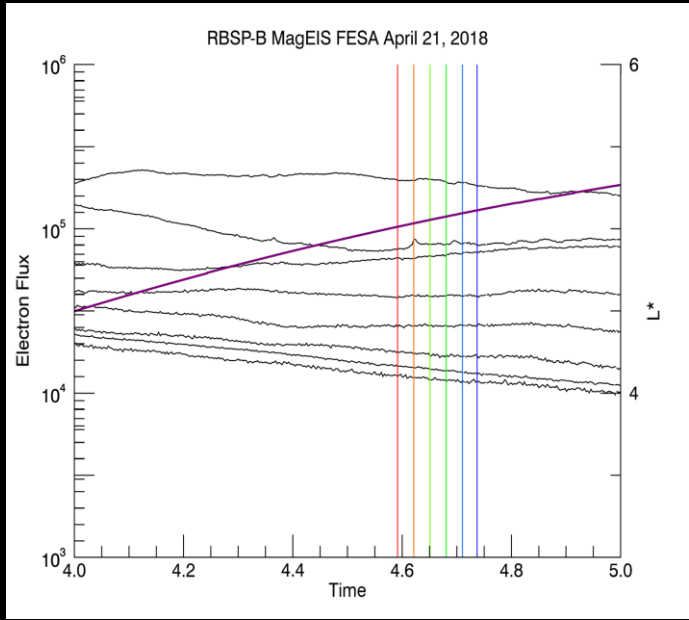


Comparing Spacecraft

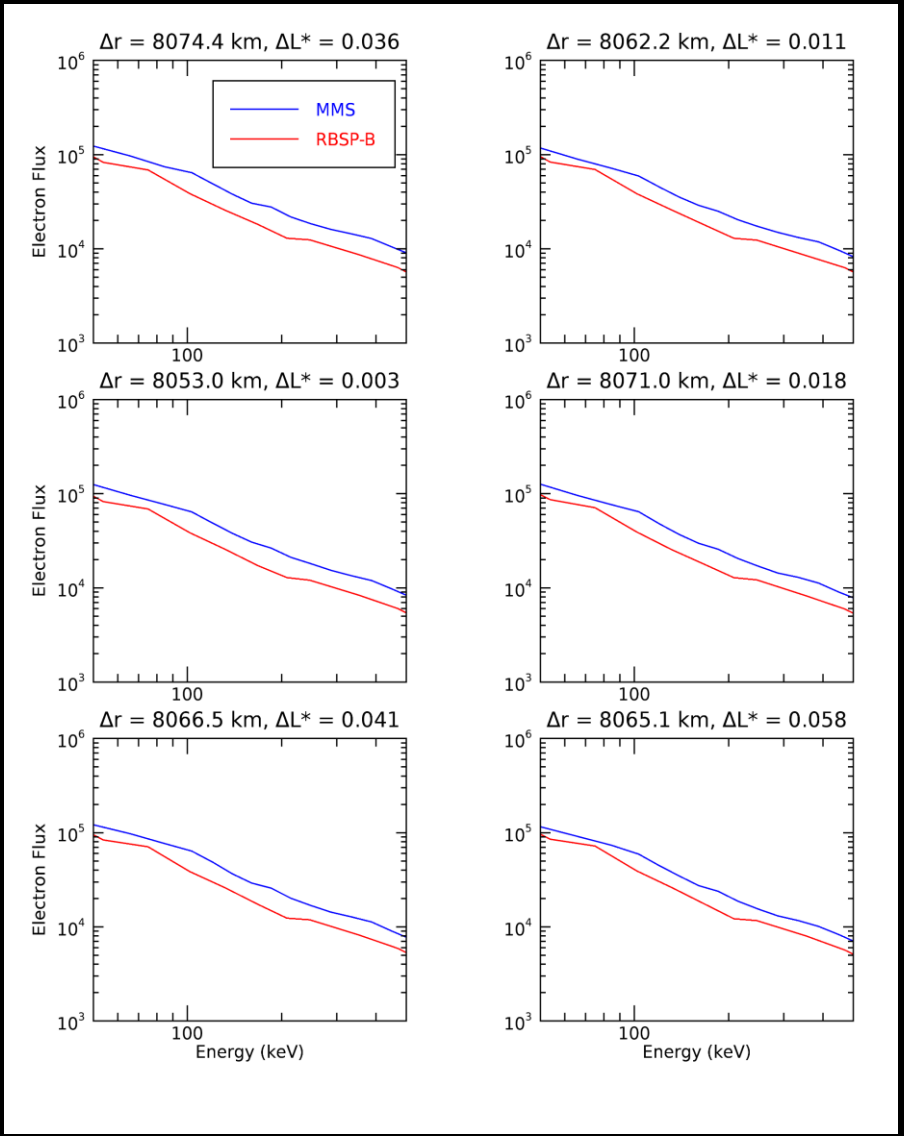
- In order to determine whether the measurements of the Van Allen Probes and Magnetospheric Multiscale are consistent, energy spectra were compared during close conjunctions.
- These conjunctions were chosen based on L-shell primarily and spatial proximity secondarily
- MMS has an apogee of 153,000 km, while RBSP has an apogee of 30,000 km



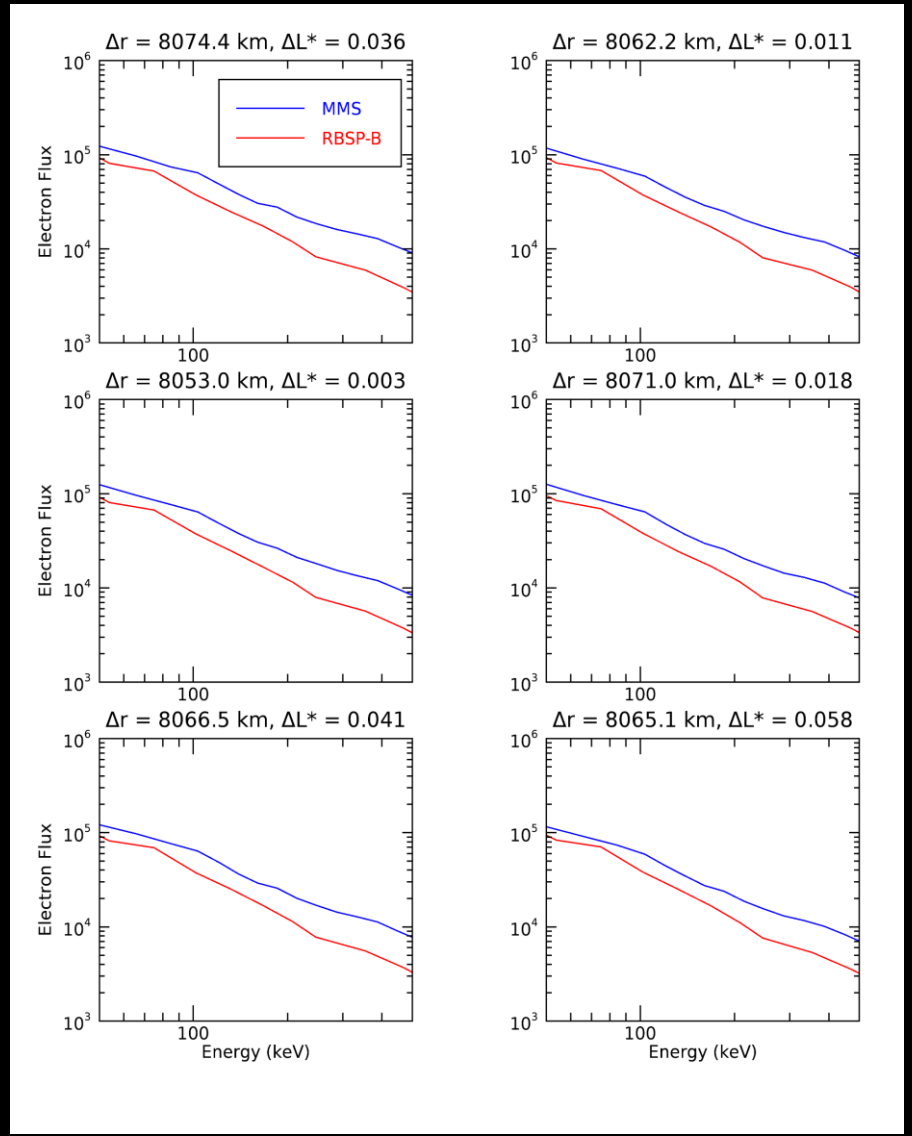


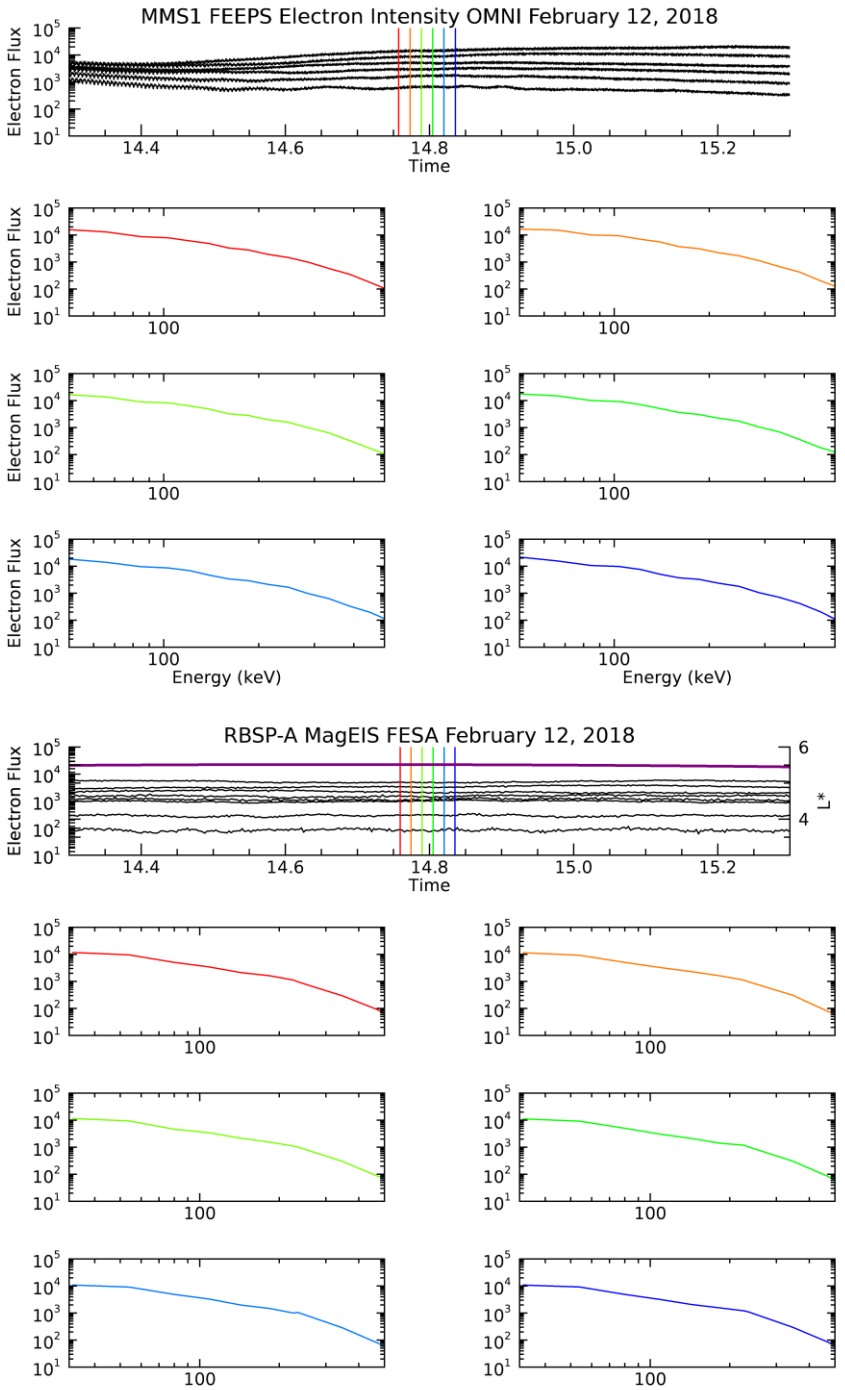


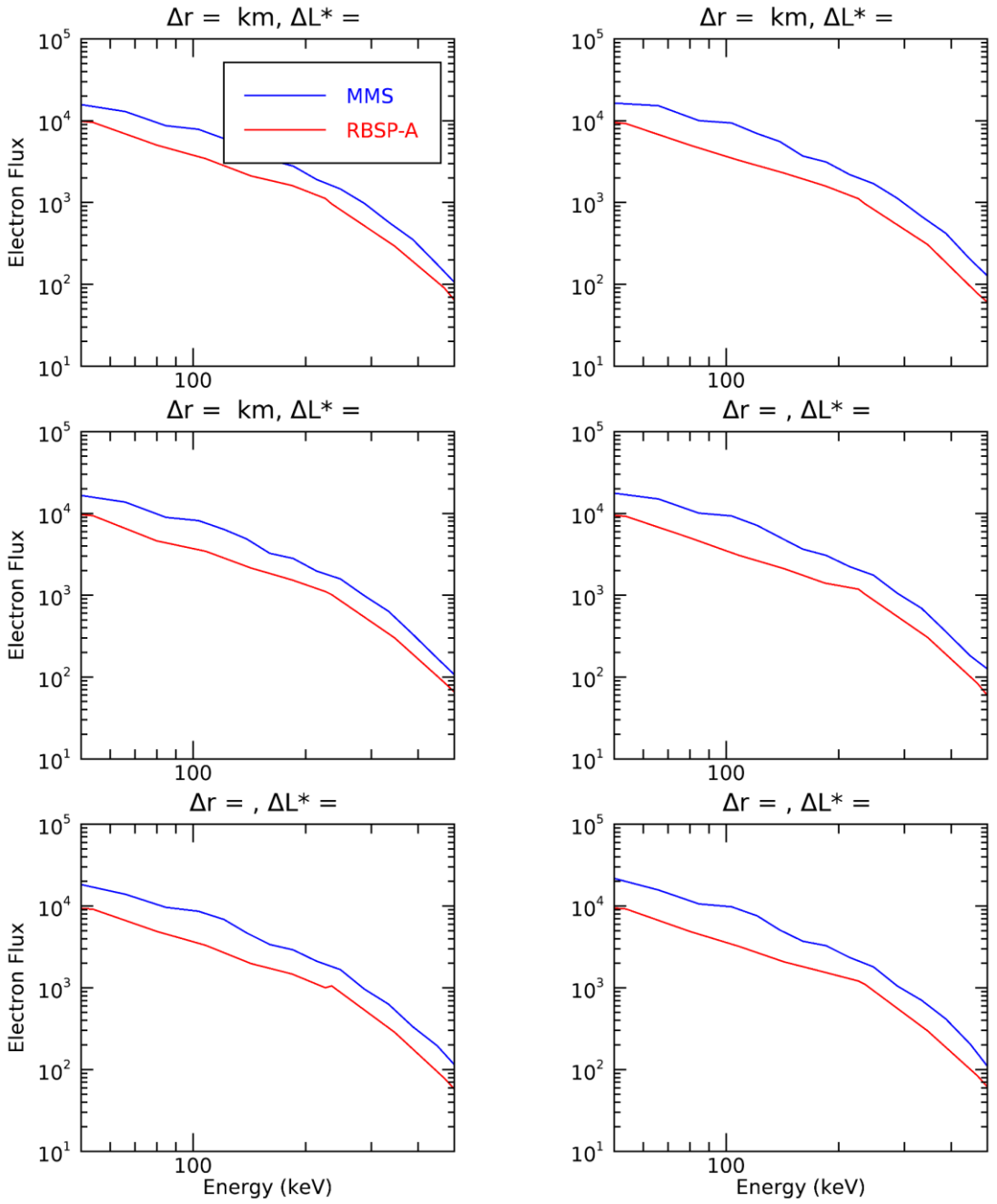
Uncorrected

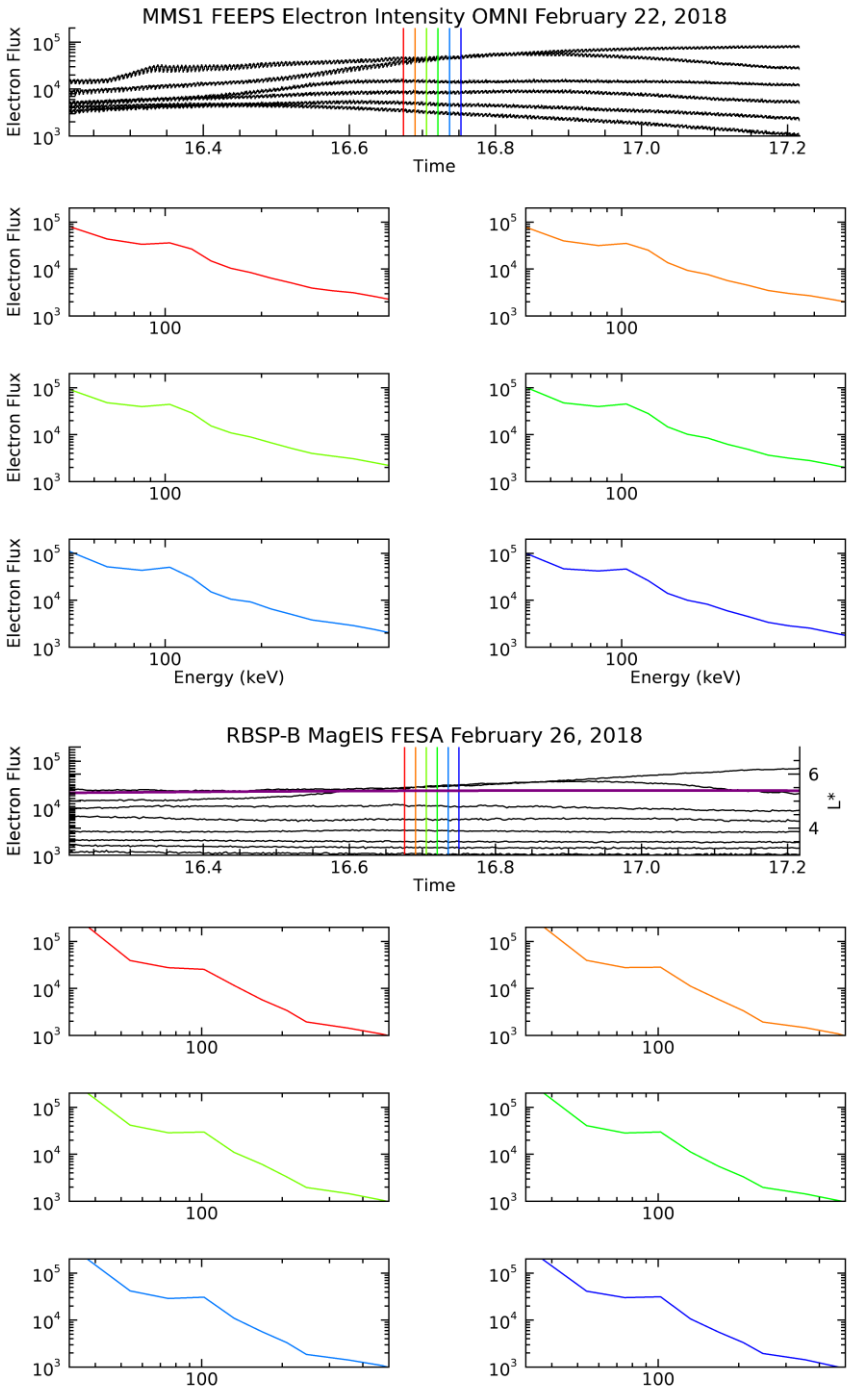


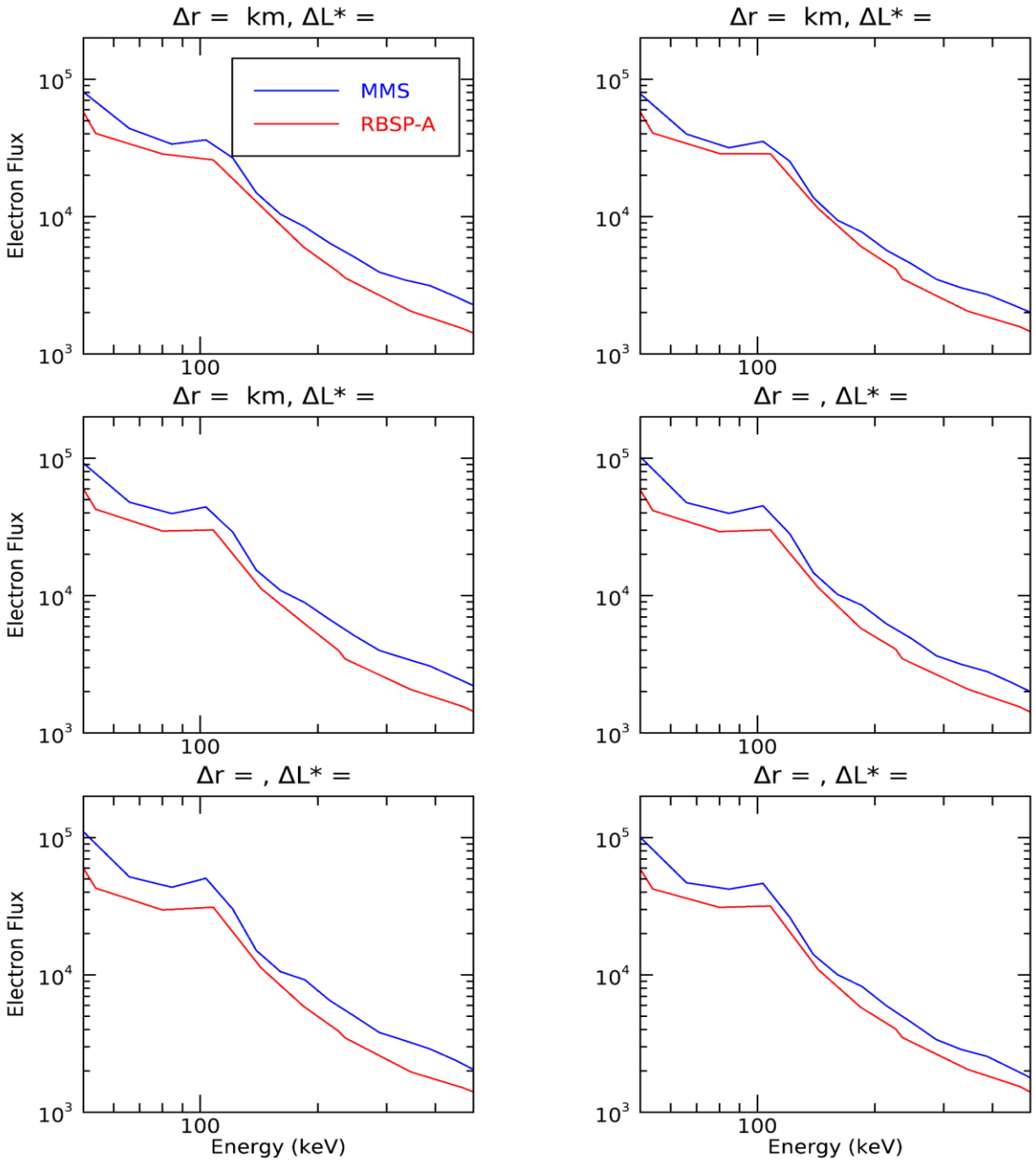
Background-corrected




MMS1 FEEPS Electron Intensity OMNI February 12, 2018
Electron Flux
Time
Energy (keV)
RBSP-A MagEIS FESA February 12, 2018
L*


Δr = km, ΔL* =
Δr = , ΔL* =
MMS
RBSP-A
Electron Flux
Energy (keV)


MMS1 FEEPS Electron Intensity OMNI February 22, 2018
Electron Flux
Time
Energy (keV)
RBSP-B MagEIS FESA February 26, 2018
L*


Δr = km, ΔL* =
Δr = , ΔL* =
MMS
RBSP-A
Electron Flux
Energy (keV)

The Big Picture

- To better determine the properties of particle injections in general, a bigger sample must receive an in depth analysis.
- Looking at April of this year, it seems that only the largest injections are seen below an L-shell of 4, and injections which are observed at higher energies are more likely to penetrate to lower L-shells.