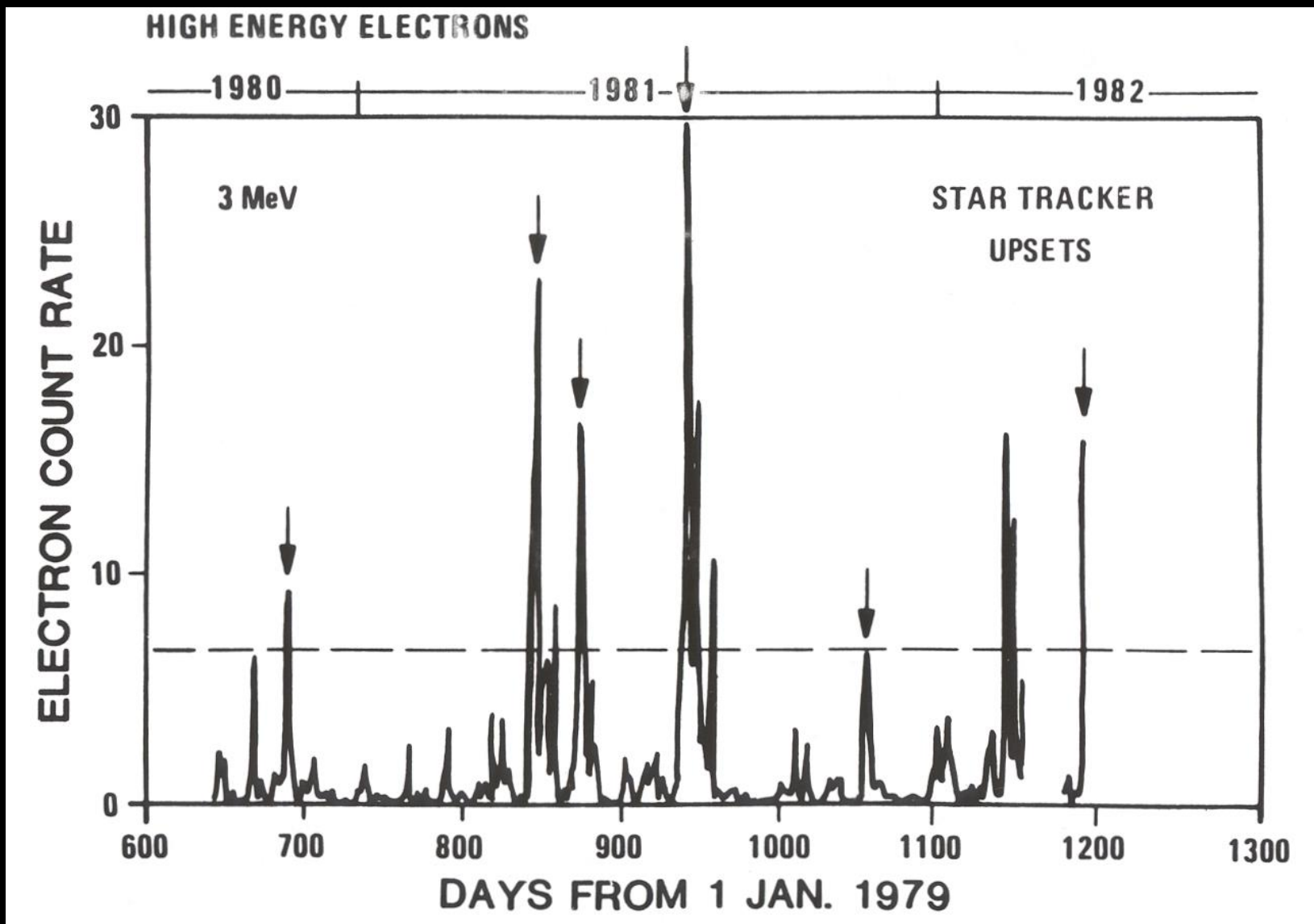


# Satellite Anomalies and the Radiation Belts

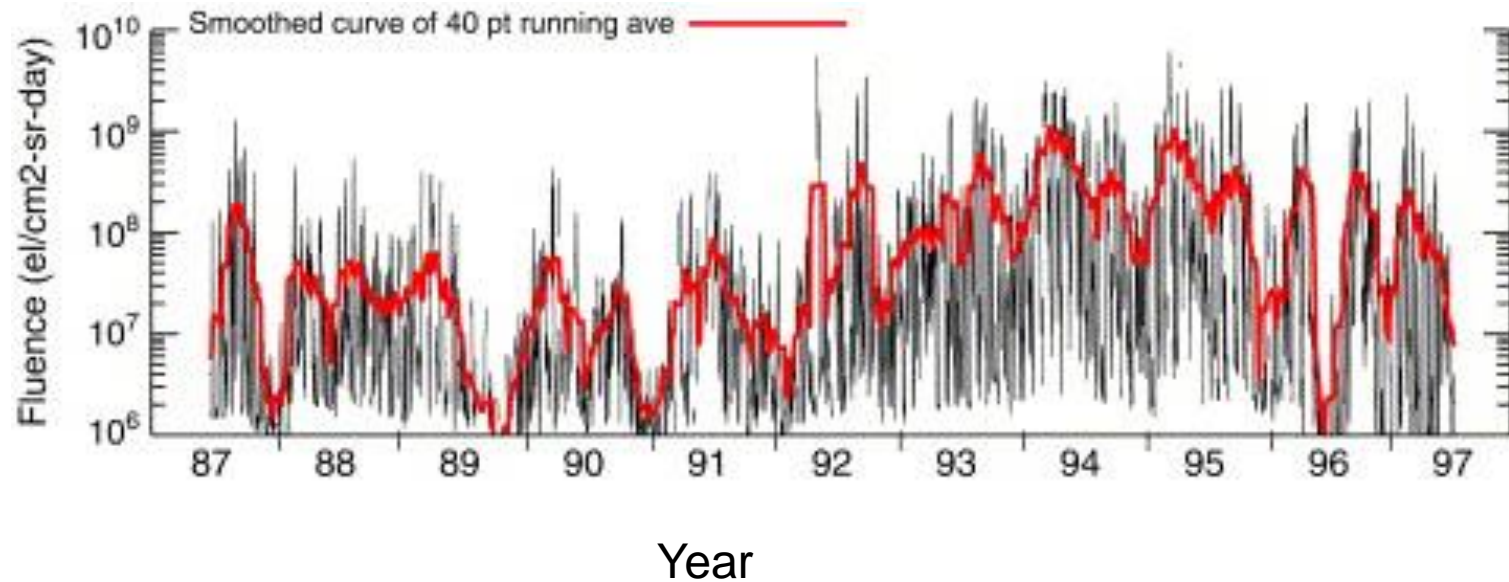
Daniel Baker and Hong Zhao  
Laboratory for Atmospheric and Space Physics,  
U of Colorado-Boulder

Thanks to Van Allen Probes and GOES Teams

# Early Study: GEO Anomalies



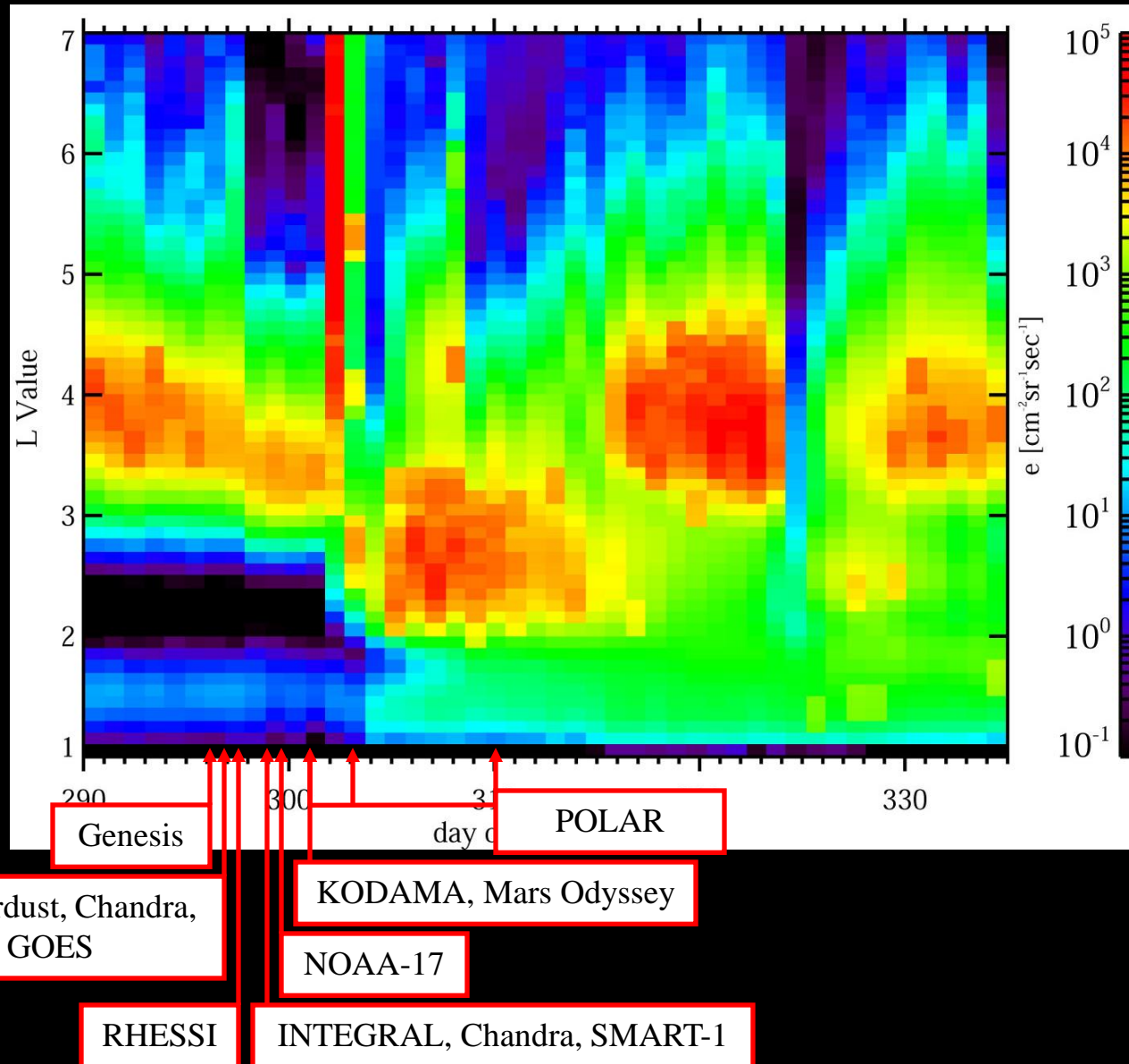
# Multi-Year Run of Geostationary Orbit Data



Example: 10 years of  $E > 2$  MeV GOES Electron Fluences

[H.-L. Lam, JASTP, 2004]

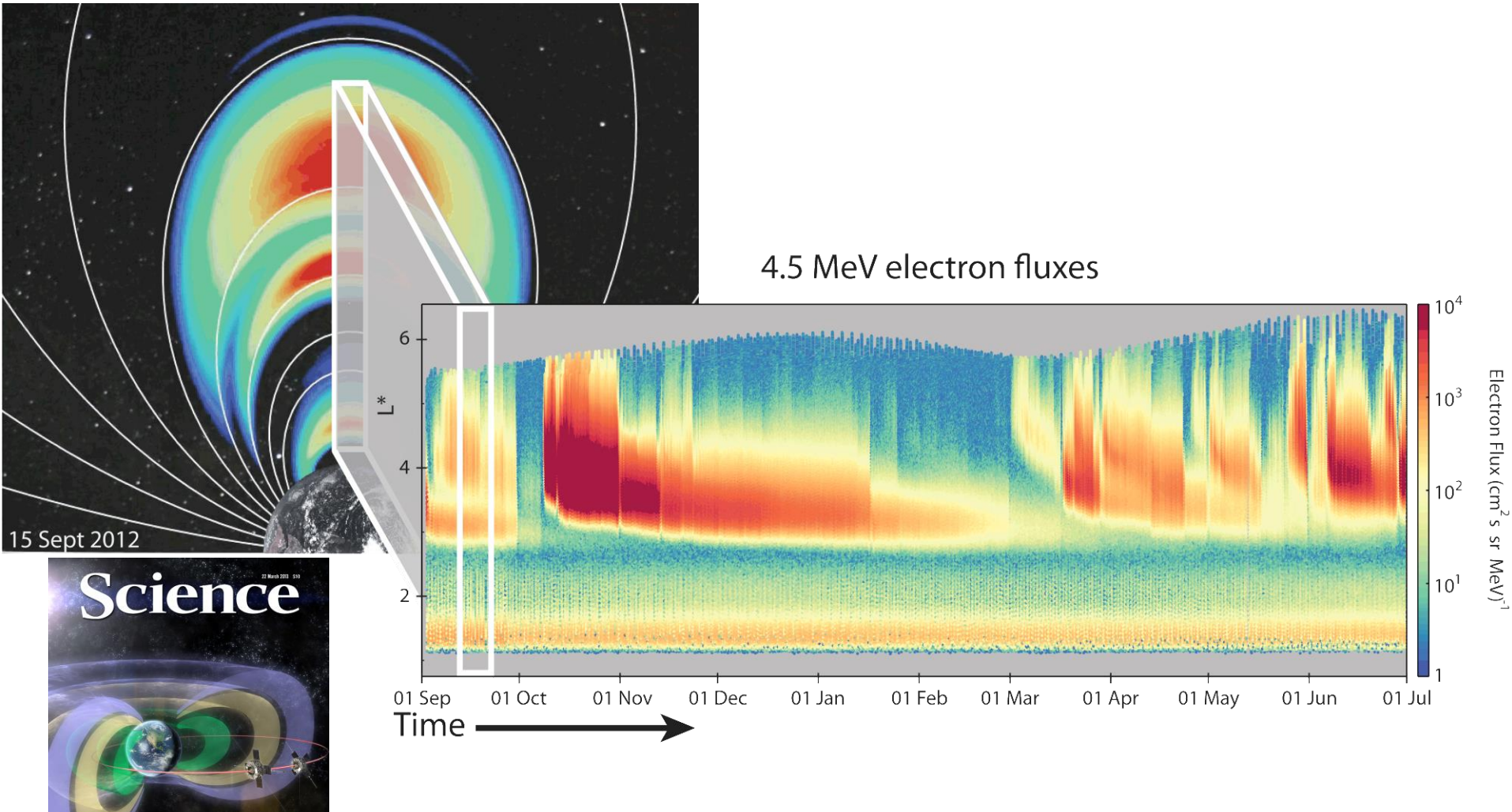
# Spacecraft Anomalies: October-November



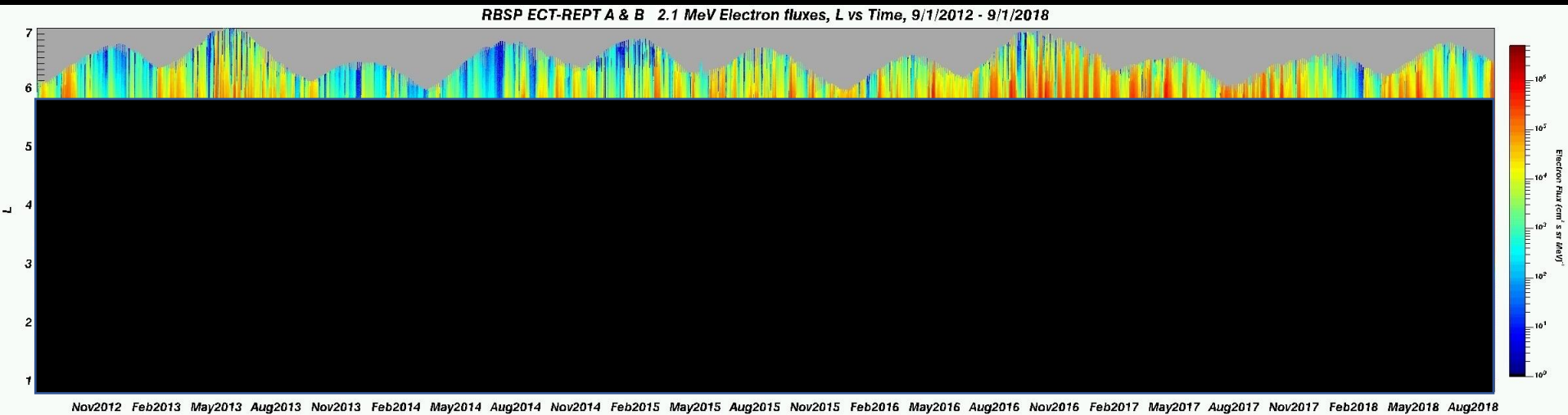


# Van Allen Probes Observations

## Acceleration, Remanence, and Sudden Loss



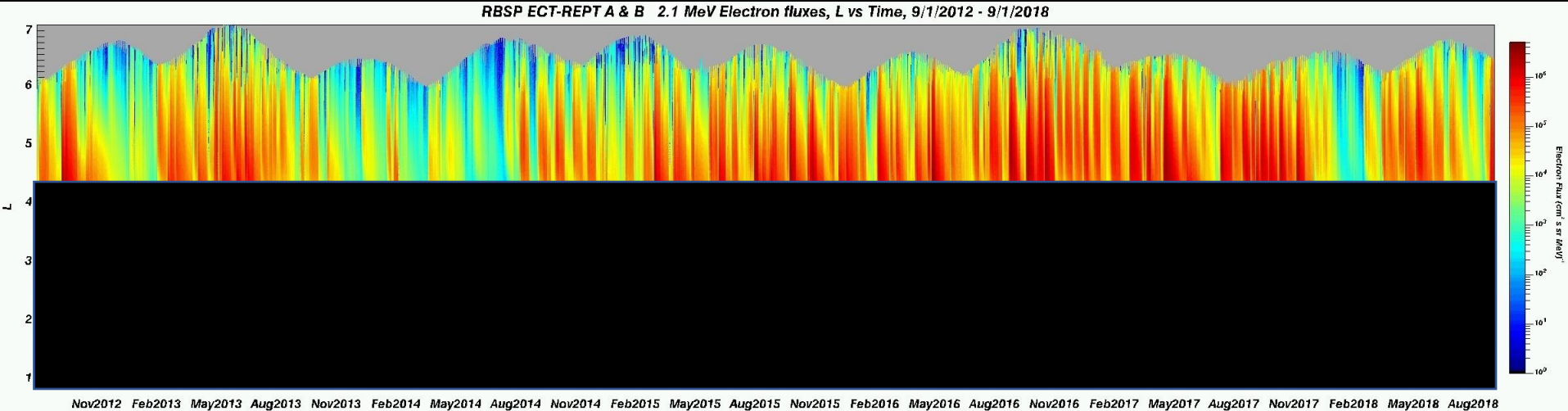
# GEO: The Tip of the Iceberg



Van Allen Probes: September 2012 to September 2018

Looking at  $E \sim 2$  MeV electrons just  
around geostationary orbit ( $L > \sim 6.0$ )

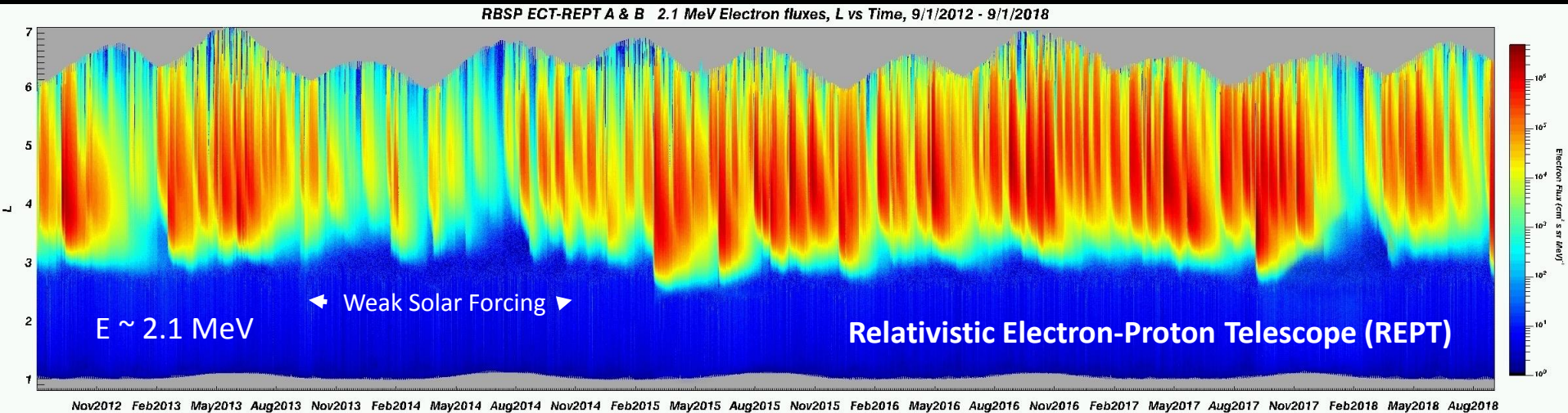
# GPS: Beneath the Tip of the Iceberg



Van Allen Probes September 2012 to September 2018

Examining  $E \sim 2$  MeV electron fluxes over the range obtainable from Global Positioning System operational sensors ( $L > \sim 4.2$ )

# Van Allen Probes: The Whole Iceberg

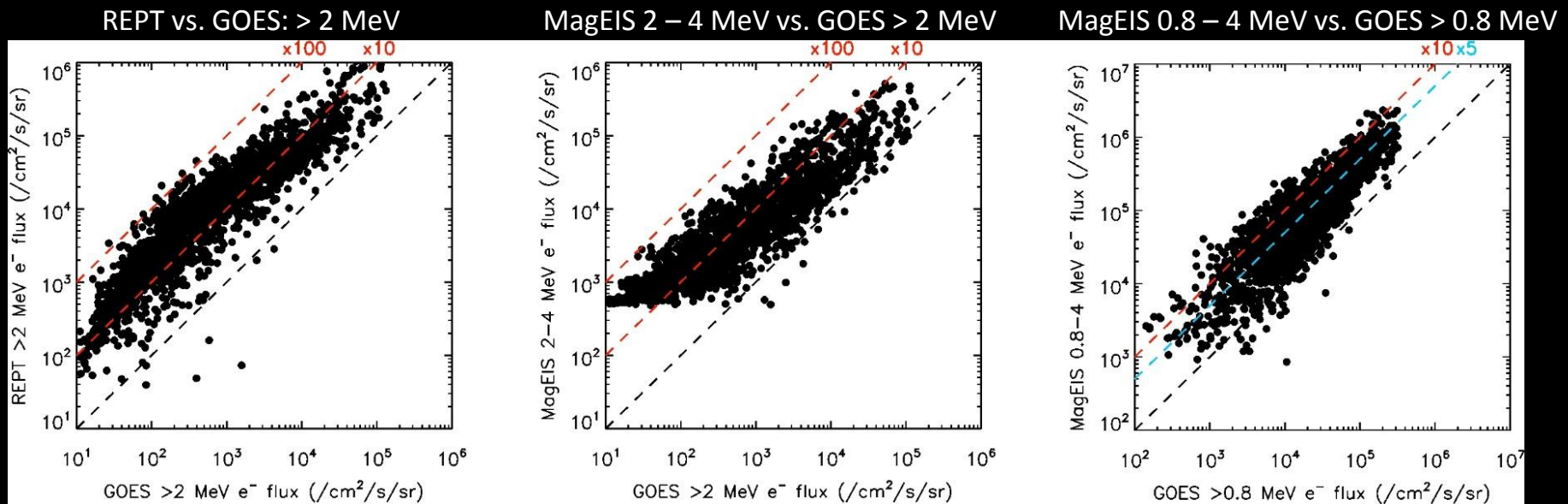


Van Allen Probes September 2012 to September 2018

Measuring the full range of radial distances in the radiation belts for relatively fine differential energy slices has been a key contribution of the Van Allen Probes mission



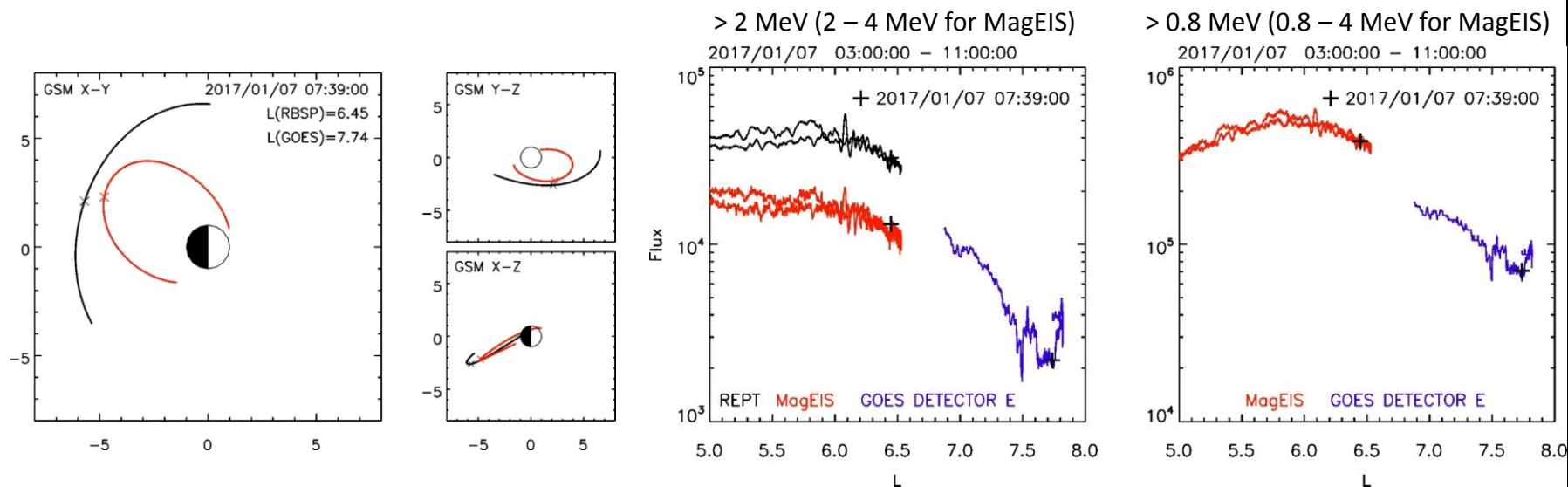
# Comparison of Van Allen Probes daily-averaged fluxes at L=6.0 versus GOES daily-averaged fluxes



All data used in this slide and hereafter are from RBSPA and GOES 15 E detector. L's are McIlwain L in T89D model.

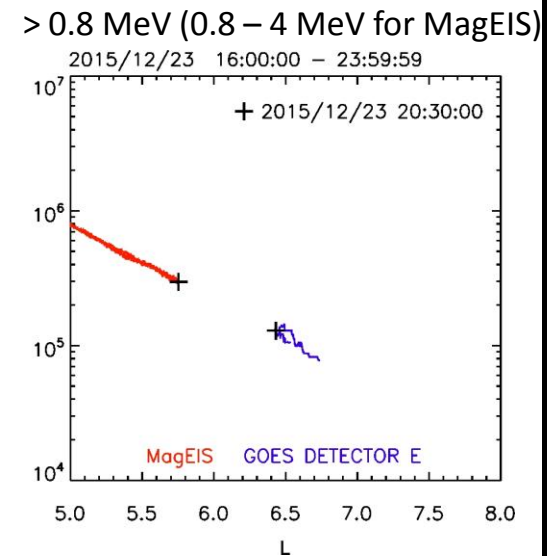
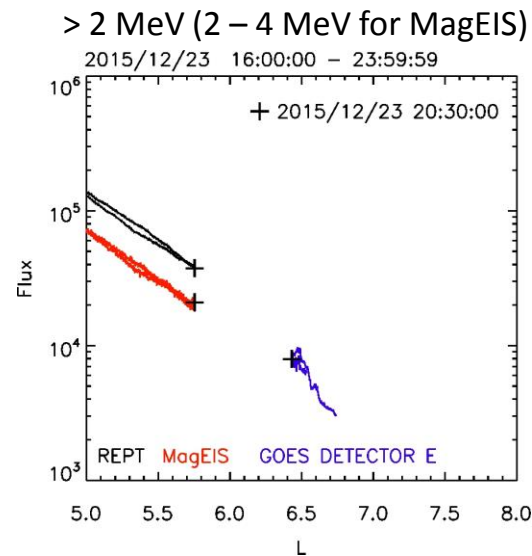
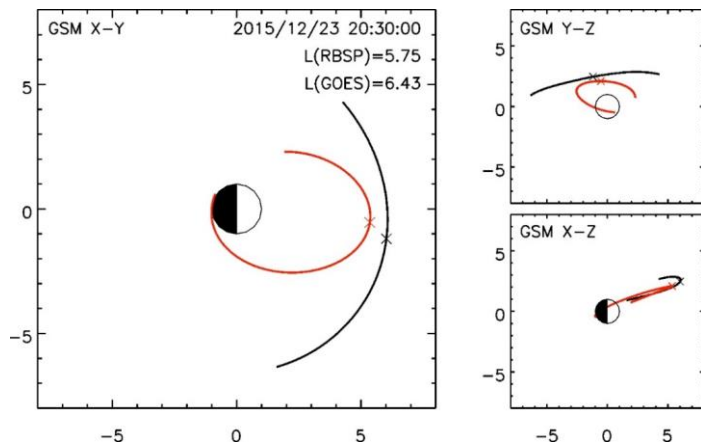
REPT and MagEIS data integration: used IDL internal function to interpolate and integrate fluxes

# Detailed Comparison During Close Conjunctions: Non-storm Period 7 January 2017



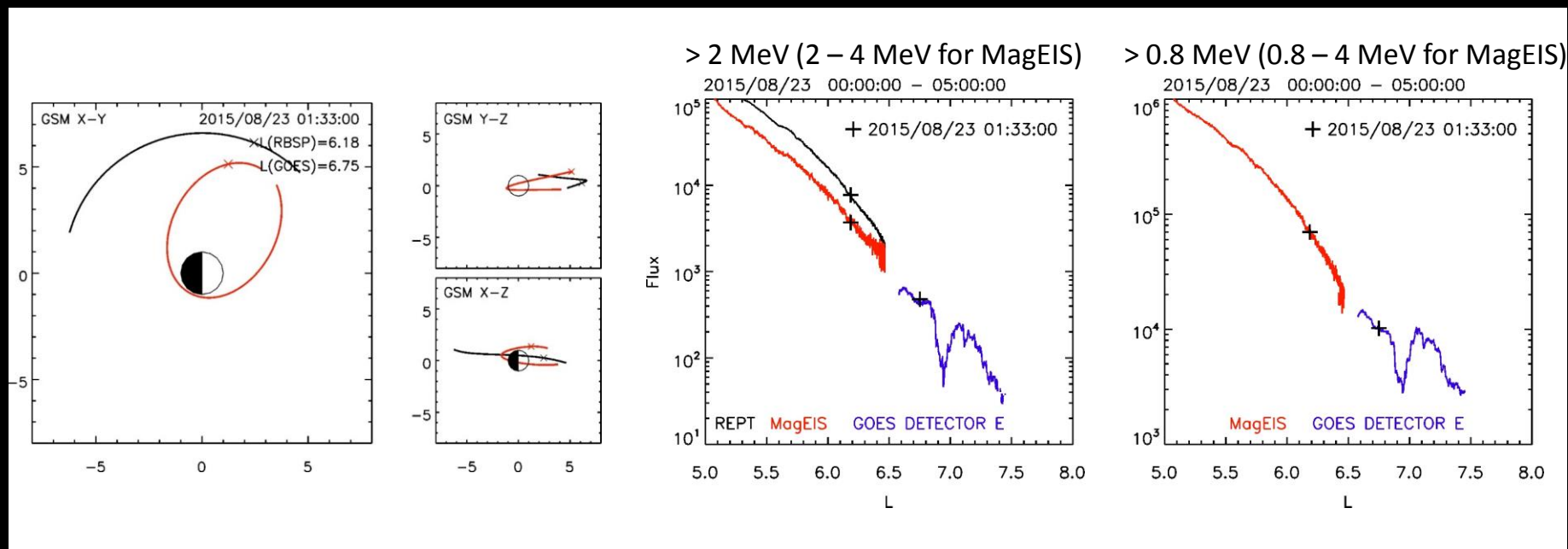
Similar MLT and MLAT near the apogee of the Van Allen Probes

# Comparison: Recovery Phase of an Intense Storm 23 December 2015



# Detailed Comparison: Small Storm

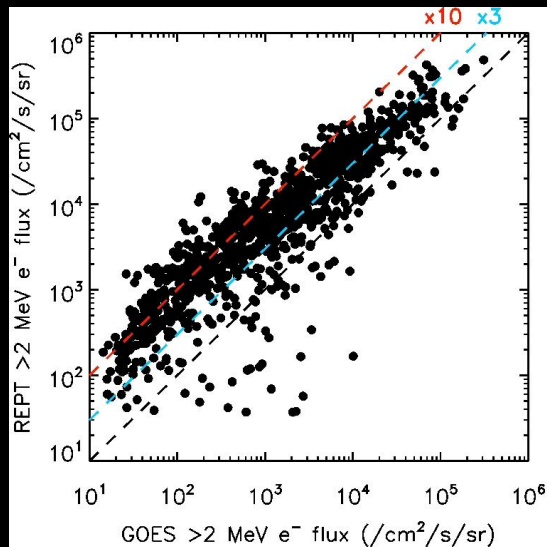
## 23 August 2015



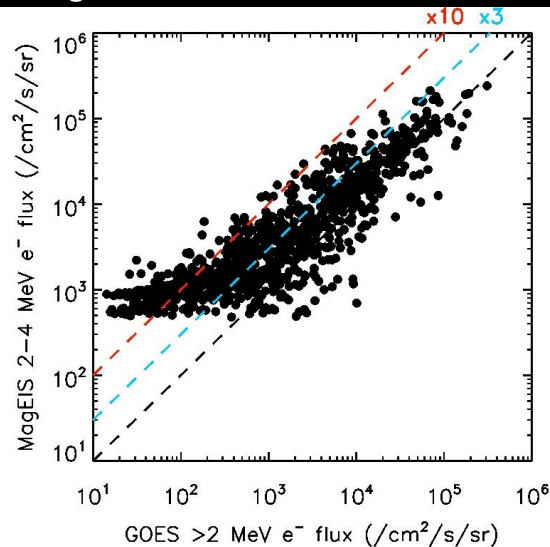
Close conjunctions between the Van Allen Probes and GOES:  
Similar MLT while fluxes were low

# Comparison of Van Allen Probes versus GOES daily-averaged fluxes at L=6.6

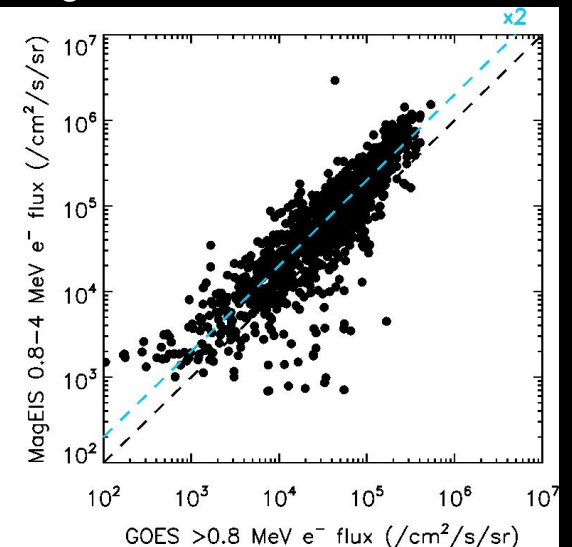
REPT vs. GOES: > 2 MeV



MagEIS 2 – 4 MeV vs. GOES > 2 MeV



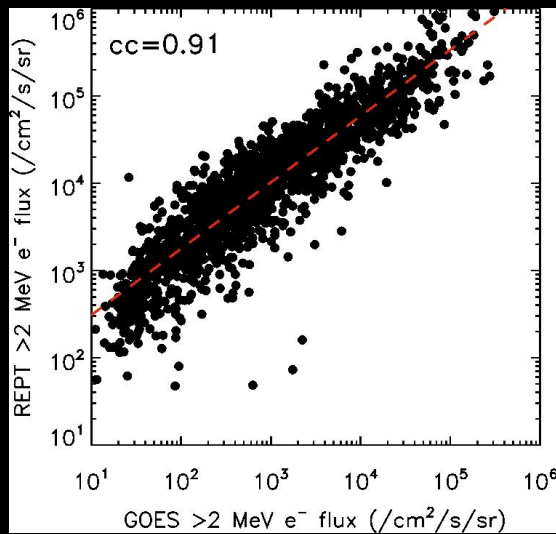
MagEIS 0.8 – 4 MeV vs. GOES > 0.8 MeV



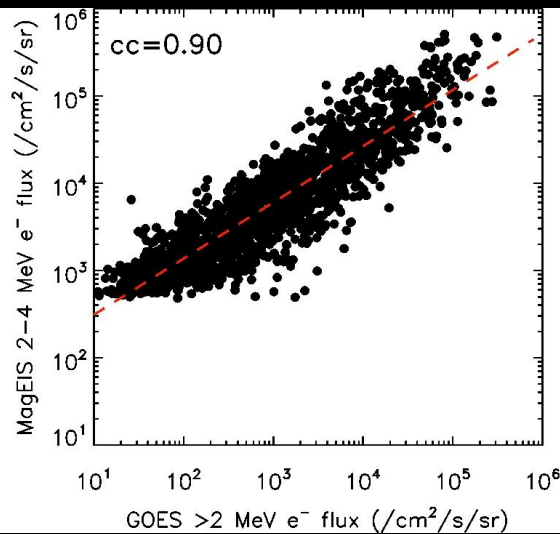


# Comparisons of GOES at L=6.6 with Van Allen Probes at L=6

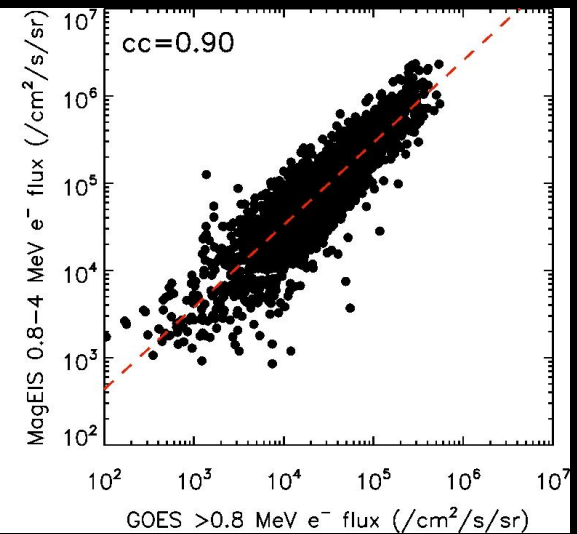
REPT vs. GOES: > 2 MeV



MagEIS 2 – 4 MeV vs. GOES > 2 MeV

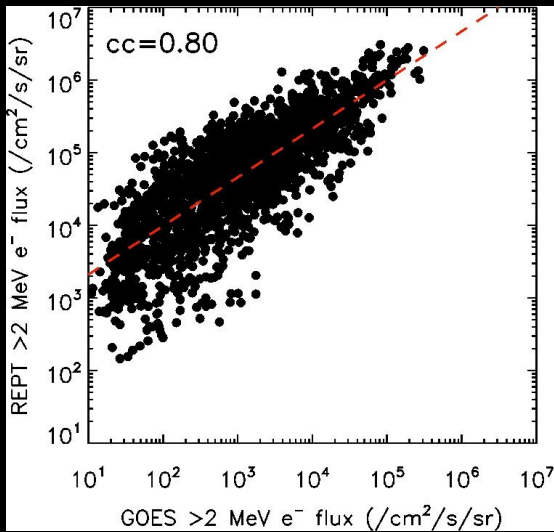


MagEIS 0.8 – 4 MeV vs. GOES > 0.8 MeV

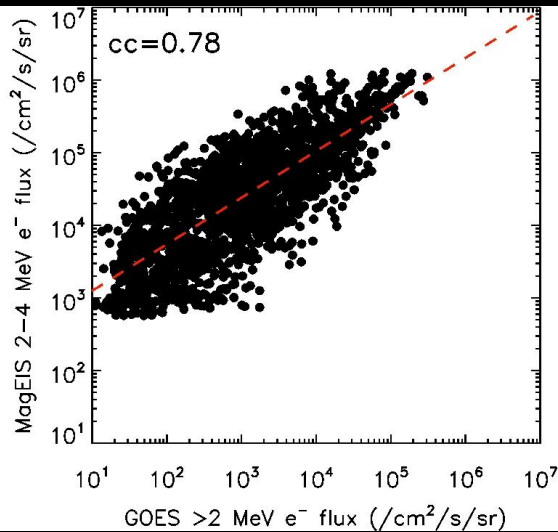


# Comparisons of GOES at L=6.6 with Van Allen Probes at L=5

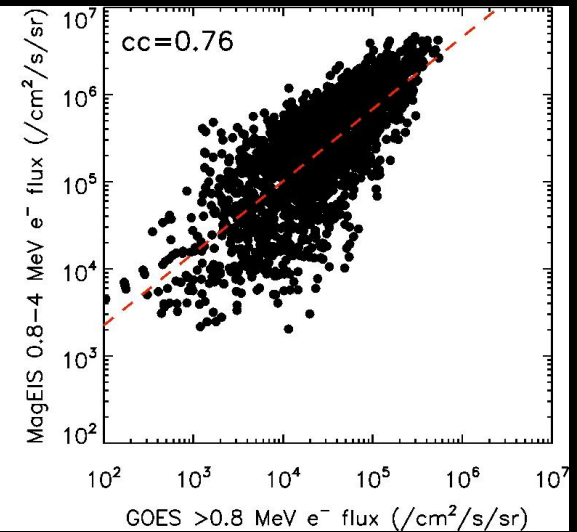
REPT vs. GOES: > 2 MeV



MagEIS 2 – 4 MeV vs. GOES > 2 MeV

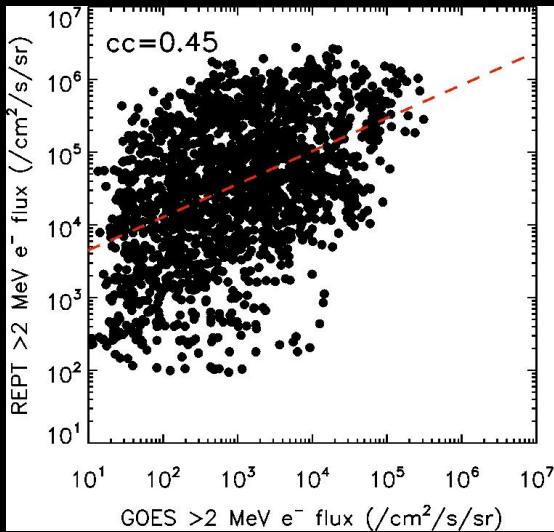


MagEIS 0.8 – 4 MeV vs. GOES > 0.8 MeV

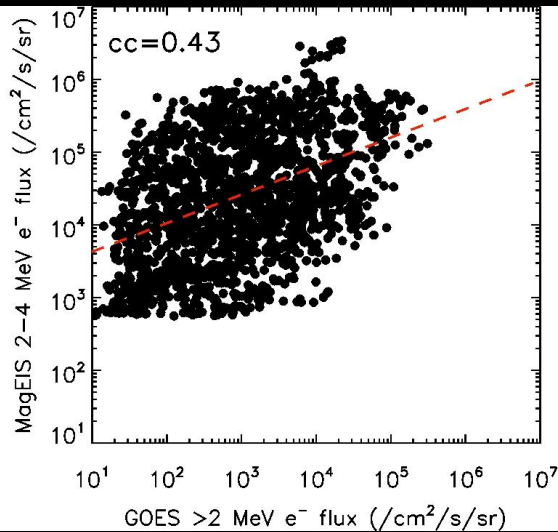


# Comparisons of GOES at L=6.6 with Van Allen Probes at L=4

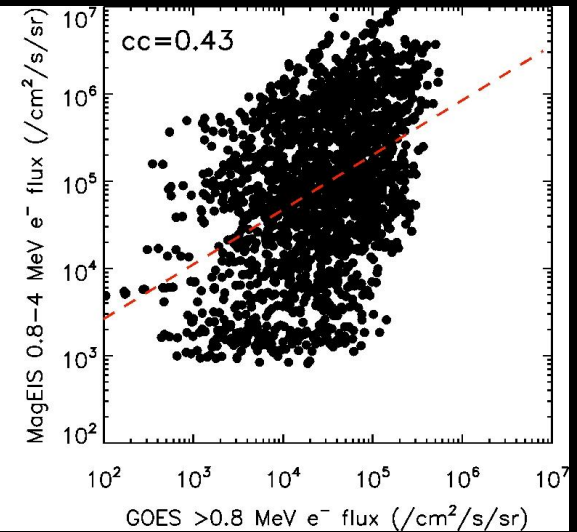
REPT vs. GOES: > 2 MeV



MagEIS 2 – 4 MeV vs. GOES > 2 MeV

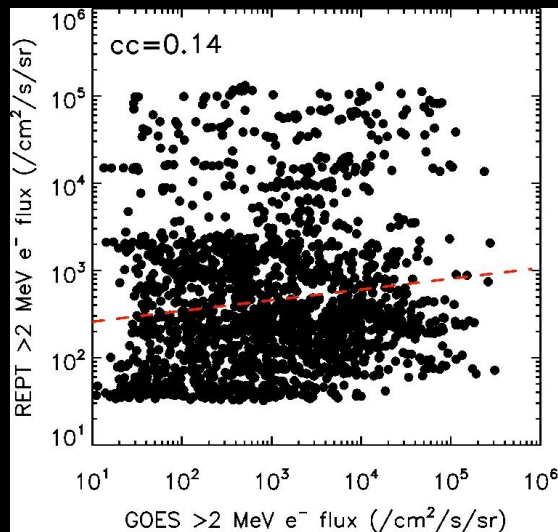


MagEIS 0.8 – 4 MeV vs. GOES > 0.8 MeV

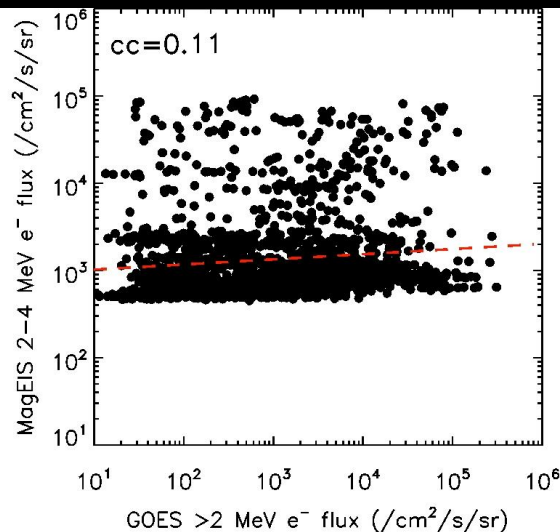


# Comparisons of GOES at L=6.6 with Van Allen Probes at L=3

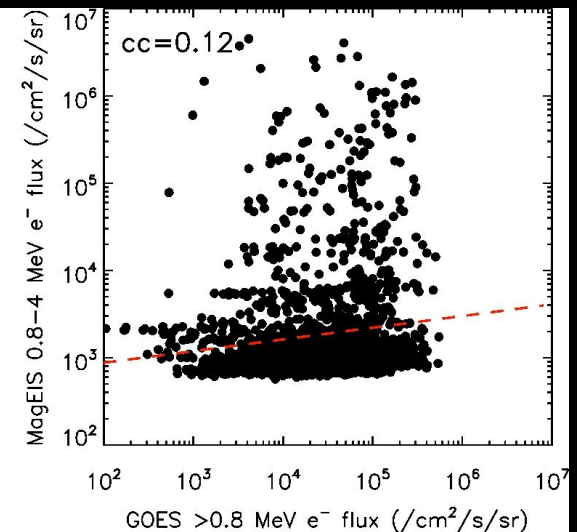
REPT vs. GOES: > 2 MeV



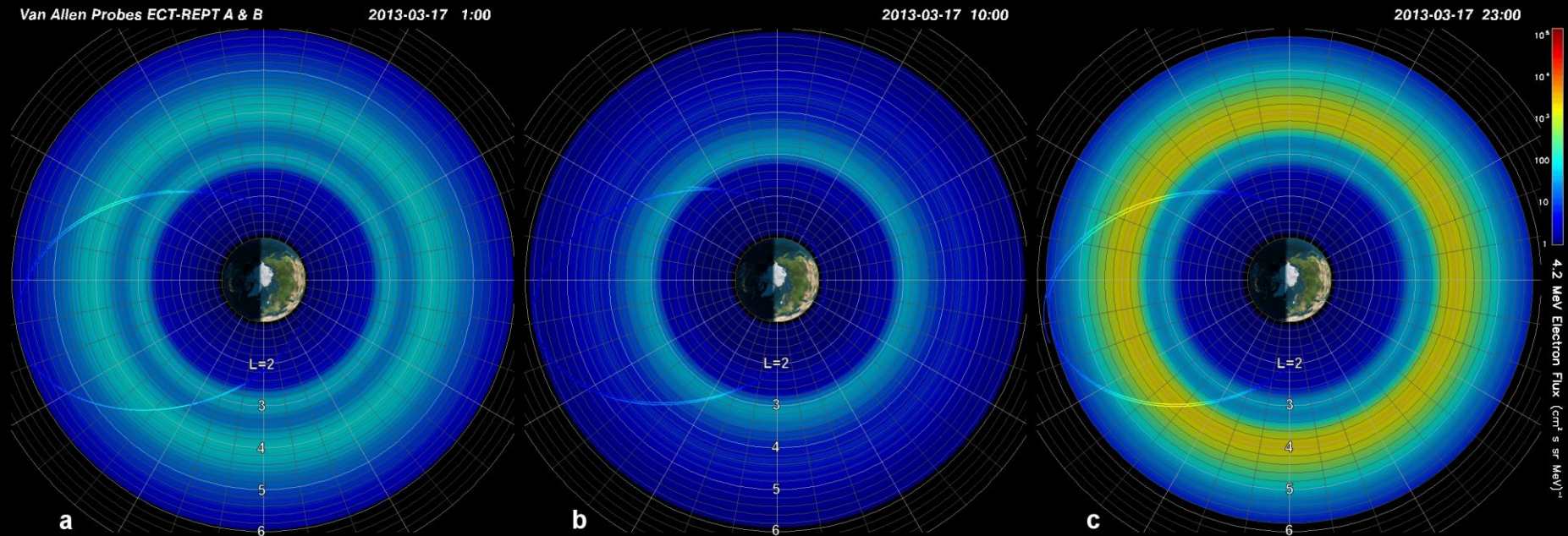
MagEIS 2 – 4 MeV vs. GOES > 2 MeV



MagEIS 0.8 – 4 MeV vs. GOES > 0.8 MeV



# The Polar View in March 2013: Three Successive Orbit Periods



Before IP Shock

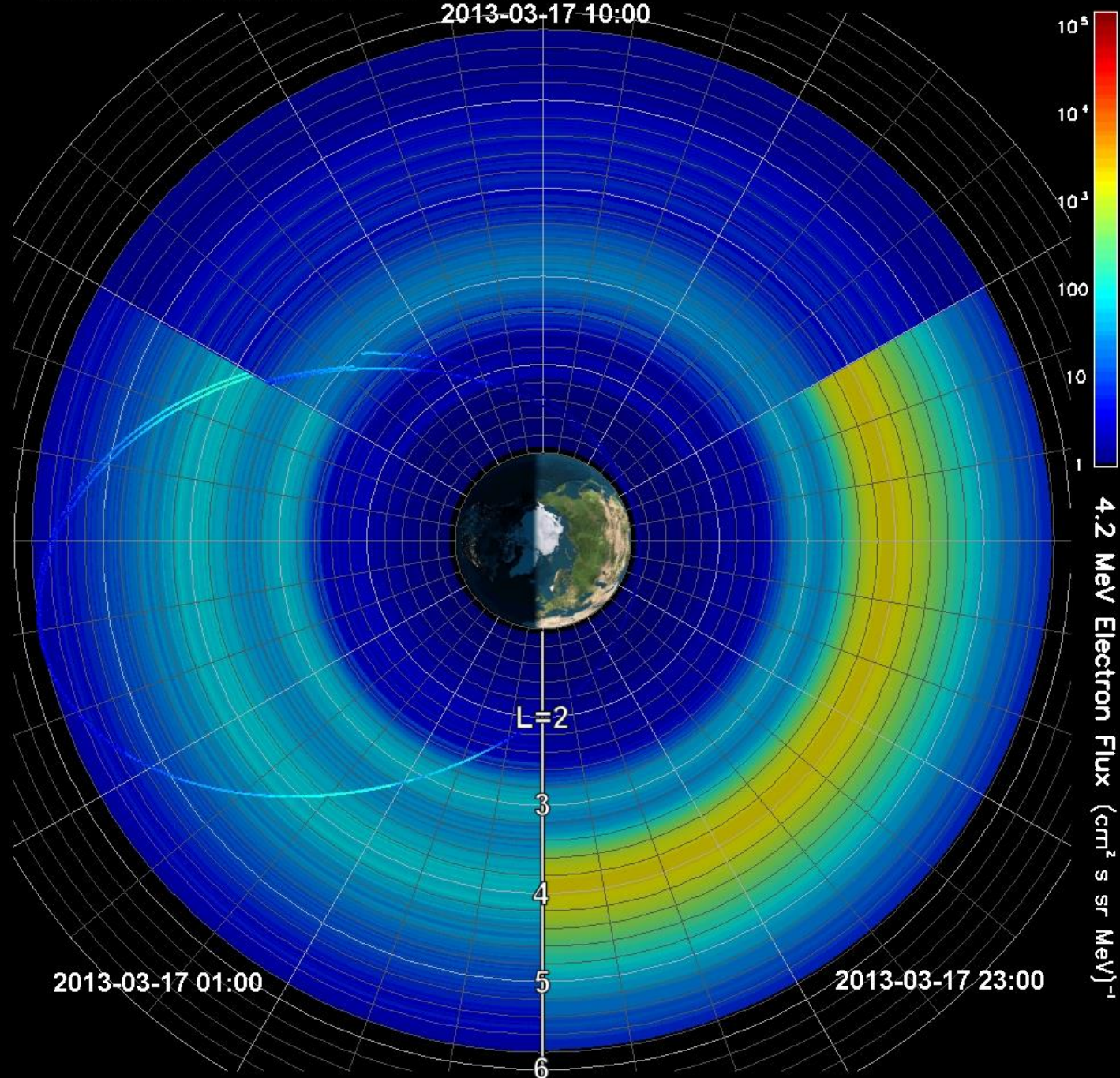
Right After Shock

Half Day Later



# Van Allen Probes ECT-REPT A & B

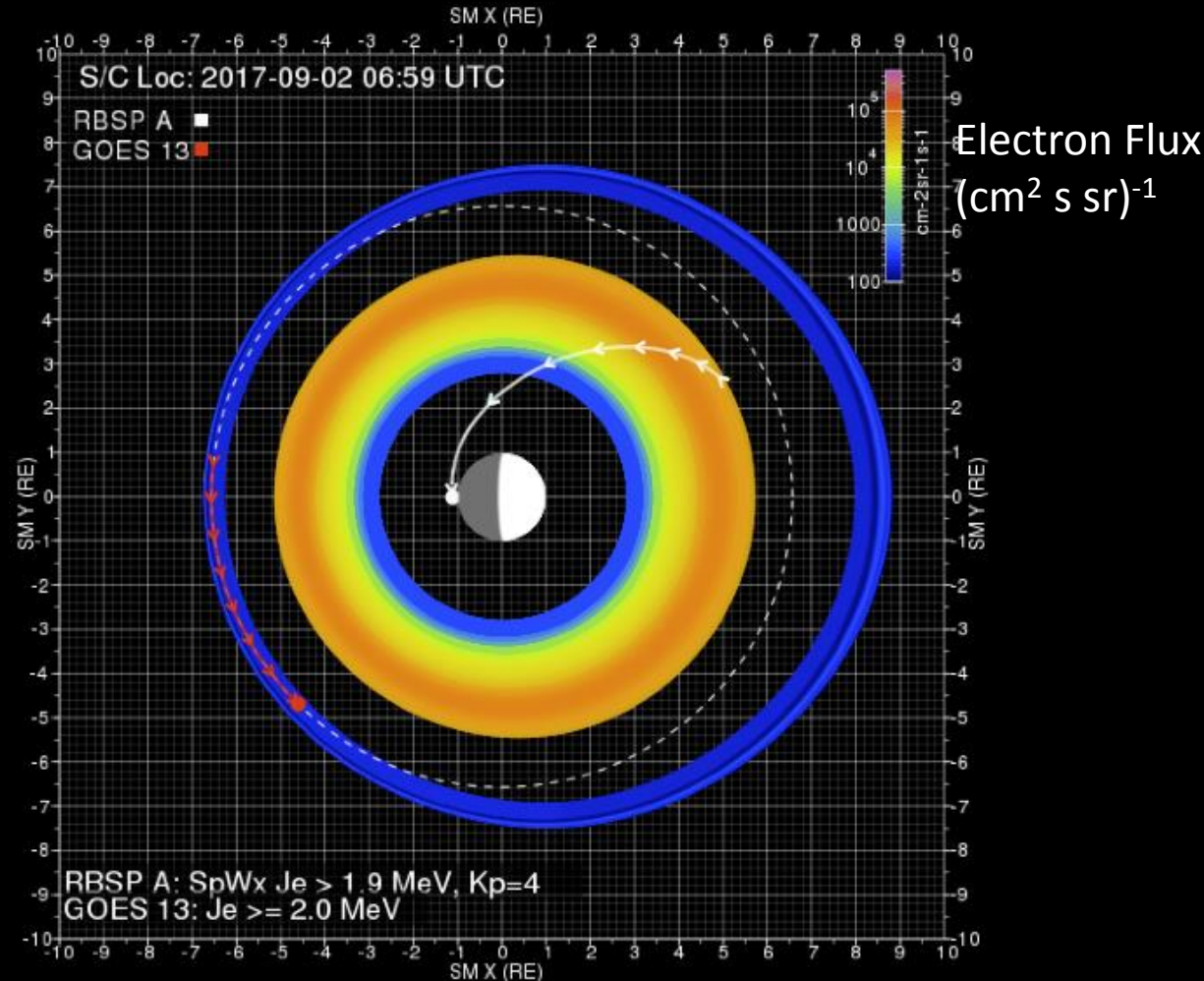
2013-03-17 10:00



# SWPC Experimental Test Product >2 MeV Electrons

## NASA Van Allen Probe Inside GEO and GOES

- **Complements GOES observations of electron flux at GEO with flux inside GEO**
- **GOES and Van Allen Probe Orbits shown; sun on right; bottom of scale (blue) is alert threshold**
- **New test product for forecasters and satellite operators inside of GEO**



SWPC (Singer, Steenburgh, and Onsager) collaboration with JHUAPL and NASA (Ukhorskiy, Romeo, Fox, and Kessel)

# Conclusions

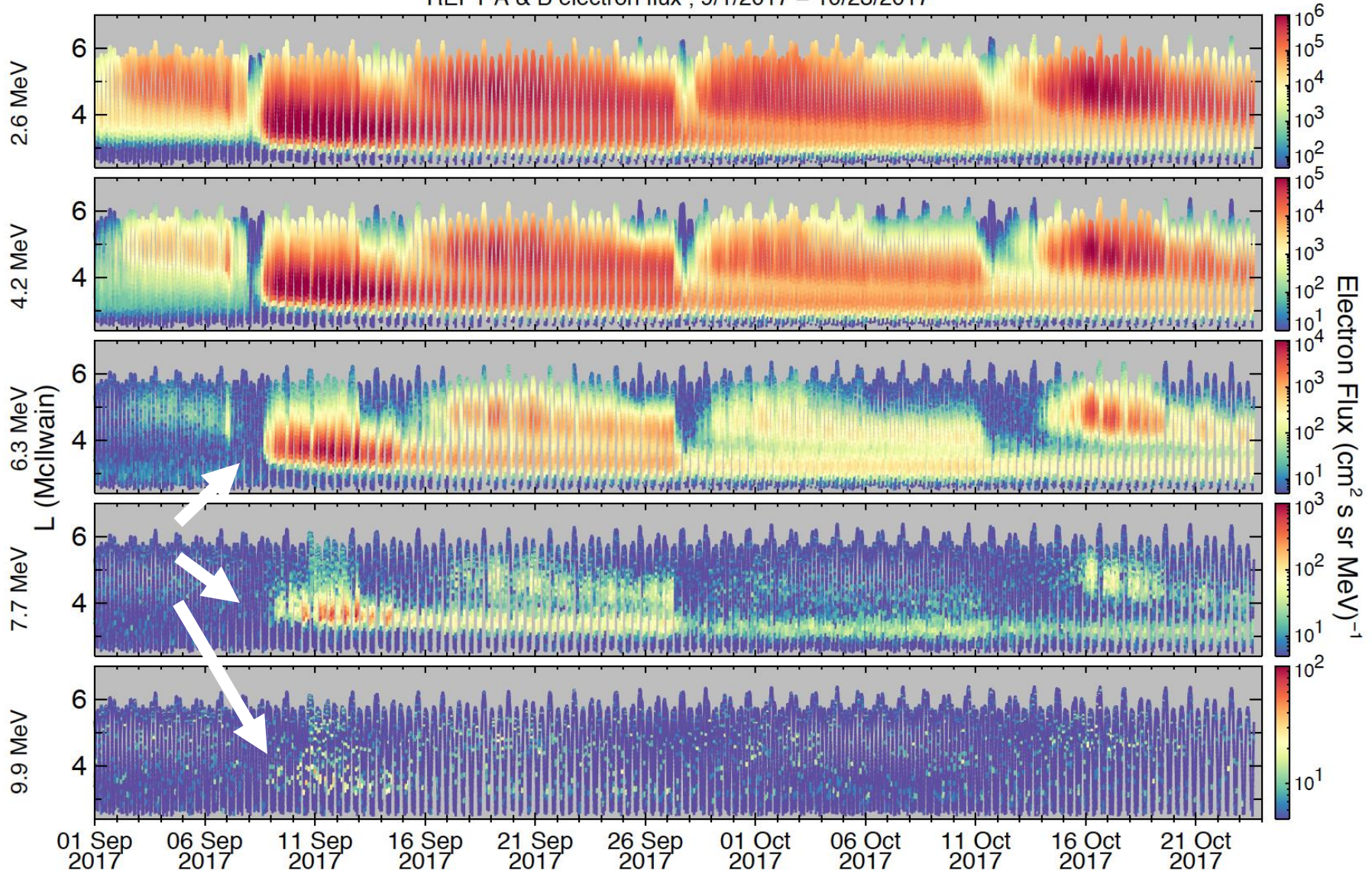
- Results from Van Allen Probes daily flux averages ( $L \sim 6.0$ ) demonstrate very large differences with simple daily flux averages of corresponding GOES  $E > 0.8$  and  $E > 2.0$  MeV electrons.
- Careful detailed comparisons show that much of the observed difference arises from the fact that GOES seldom is at the nominal  $L = 6.6$  location.
- Specific event comparisons clearly reveal that very strong radial flux gradients tend to exist between  $L \sim 6$  and  $L \sim 7.5$ .
- We also find that pitch angle distribution properties of the electrons probably contribute to the observed average flux discrepancies.
- GEO observations remain crucial for SWx and anomaly resolution purposes, but we urge considerable caution in using “brute force” daily-average flux values from GEO sensors as being indicative of all outer Van Allen zone energetic electron flux properties.



Questions?

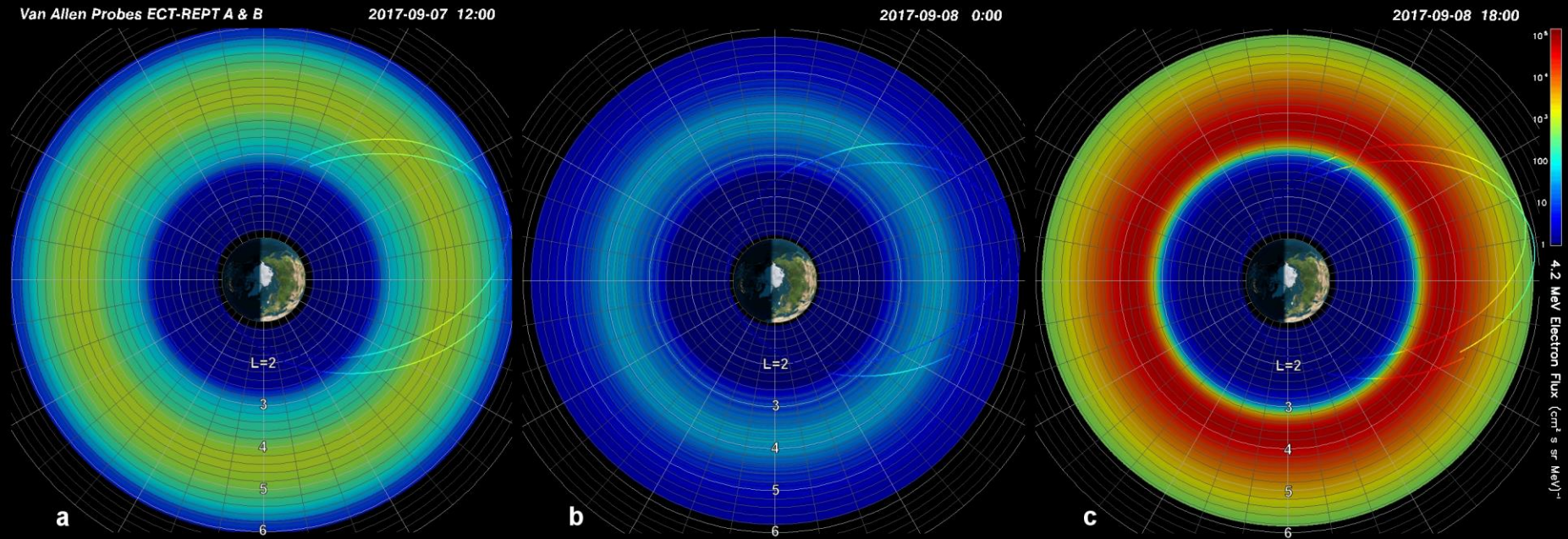
# Remarkable Loss and Reacceleration

REPT A & B electron flux , 9/1/2017 – 10/23/2017





# The Polar View in September 2017: Three Successive Orbits



Before IP Shock

Right After Shock

18 Hours Later



# Van Allen Probes ECT-REPT A & B

2017-09-08 0:00

