Nonstorm-time Acceleration and Transport of Radiation Belt Electrons

Physical Mechanisms & Favored Conditions

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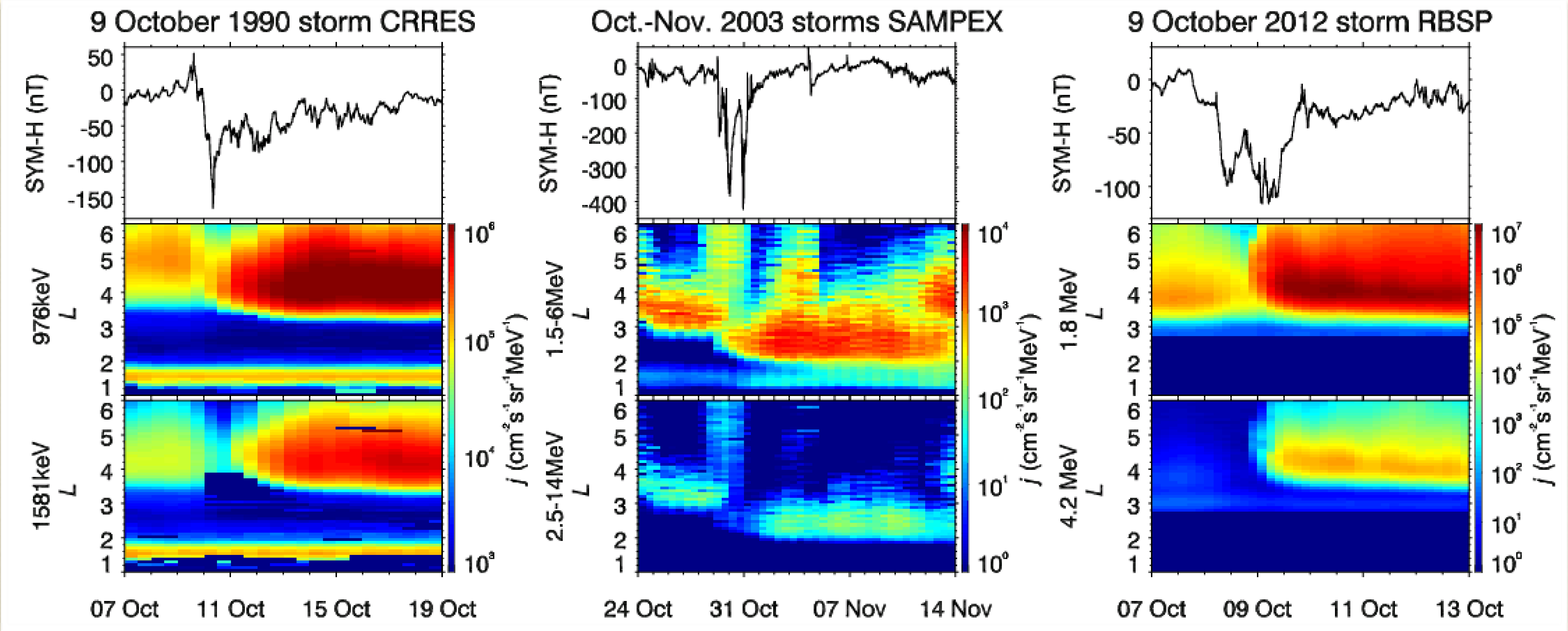
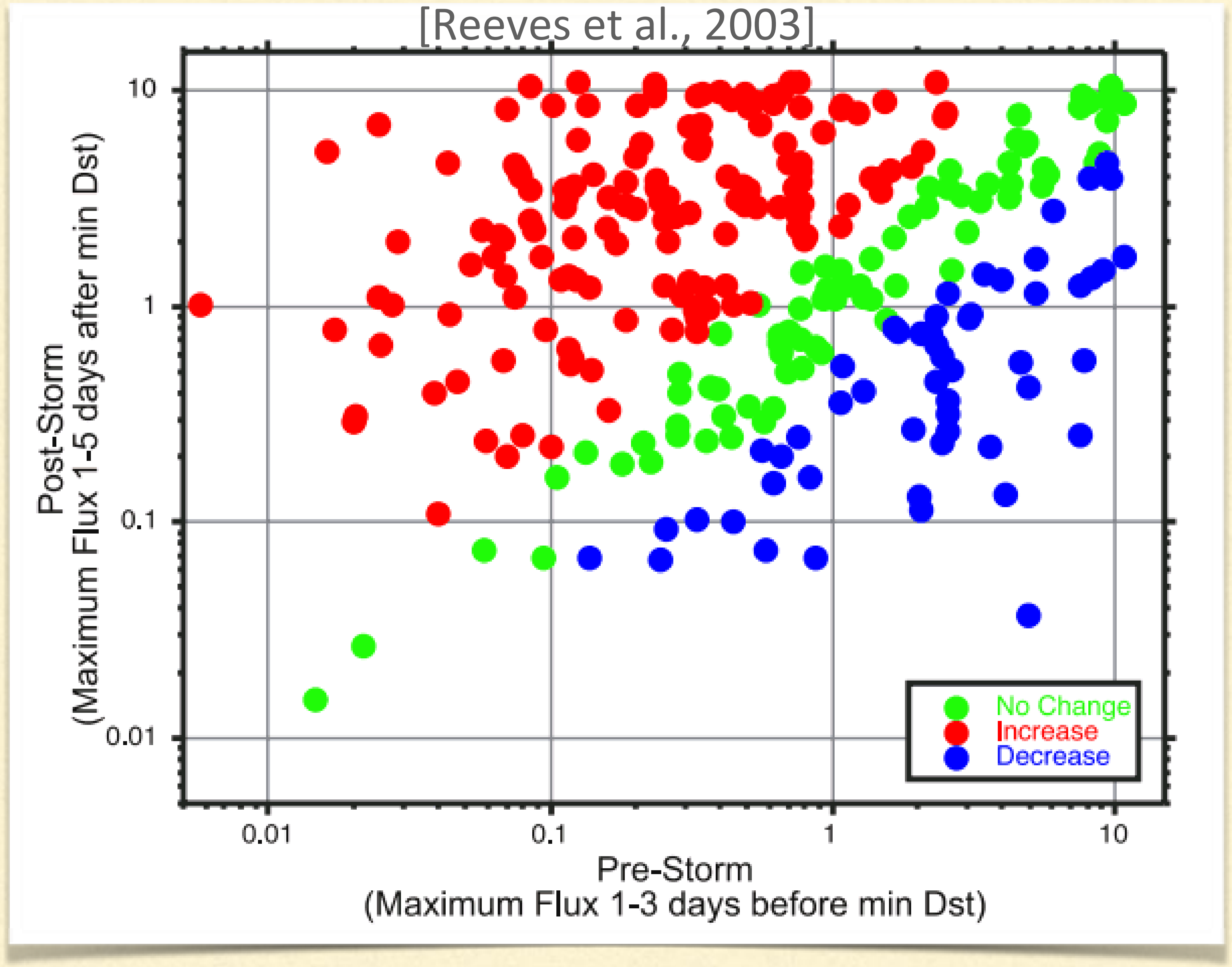
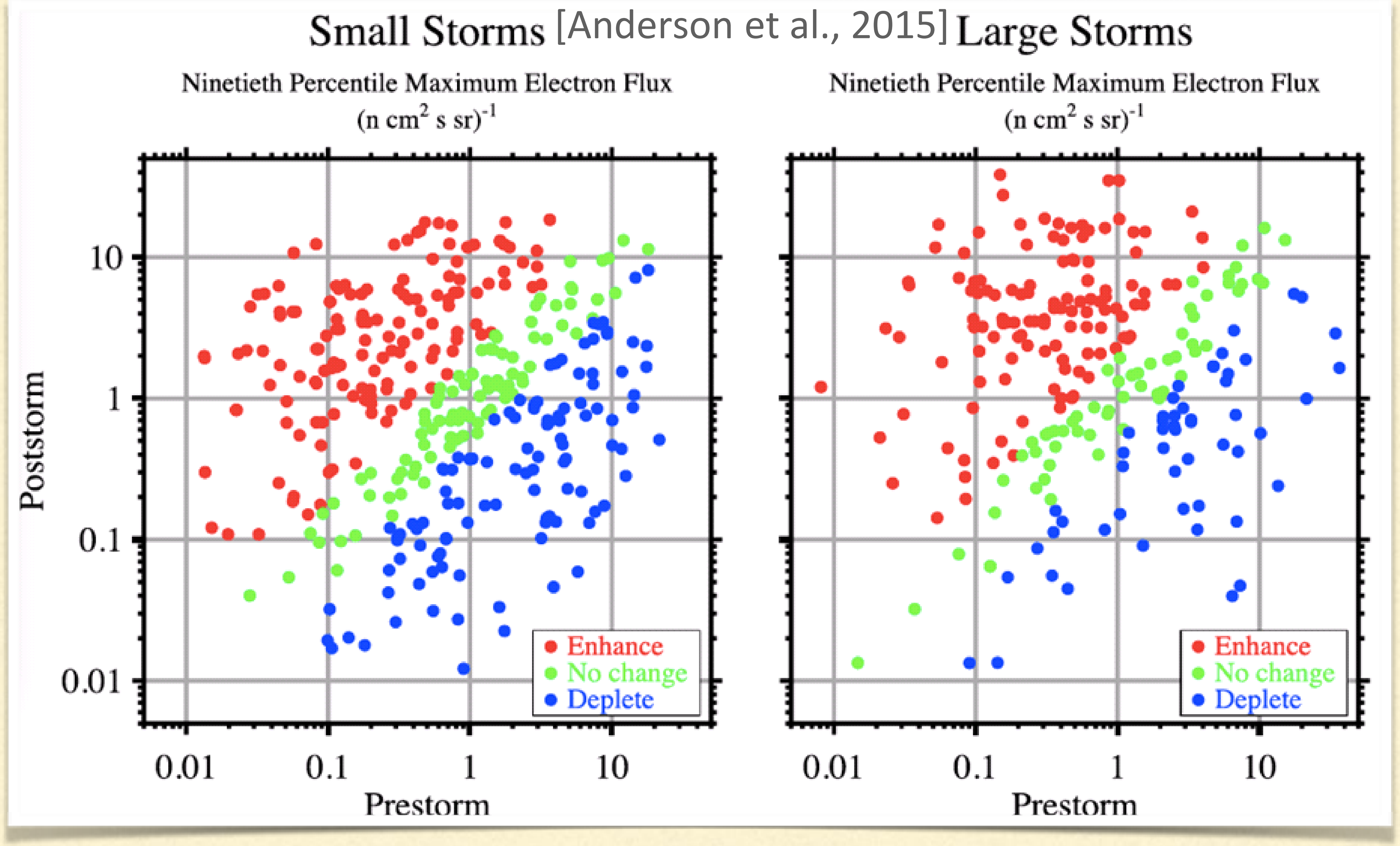
Representative radiation belt storm events



[Brautigam and Albert, 2000; Summers et al., 2002]　　[Baker et al., 2004; Shprits et al., 2006]　　[Reeves et al., 2013; Thorne et al., 2013]

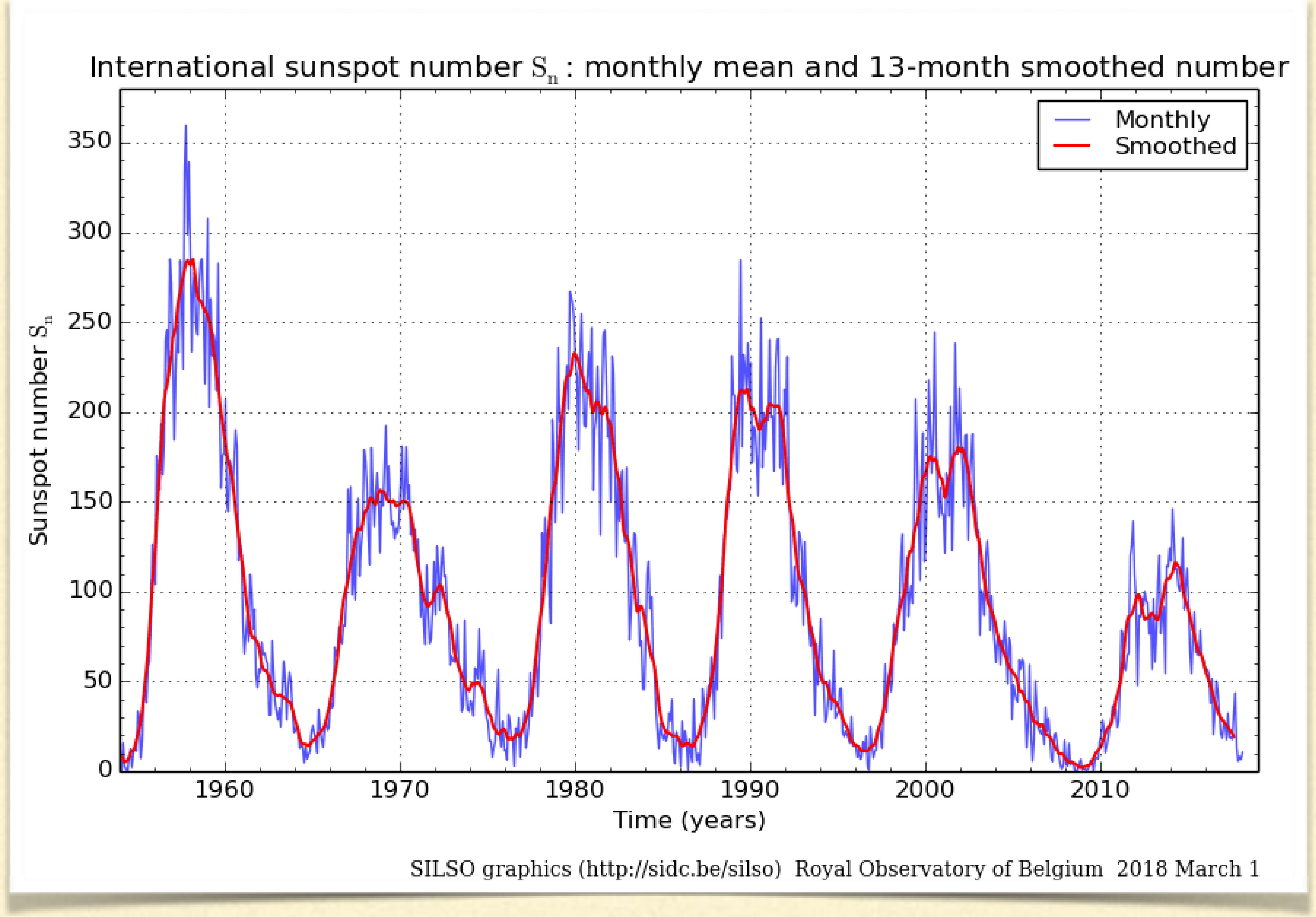
Storm-induced net changes of relativistic electron fluxes

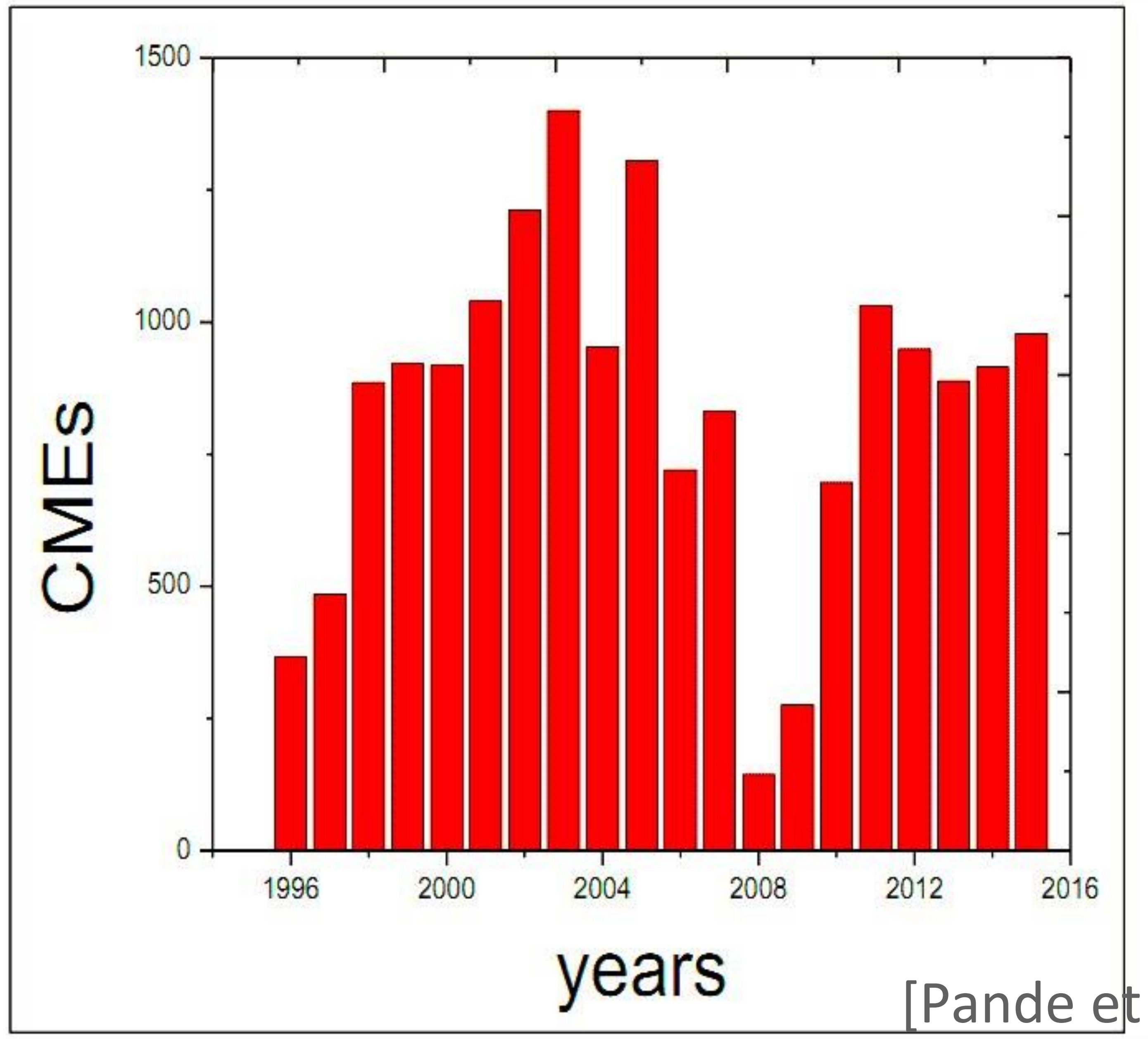


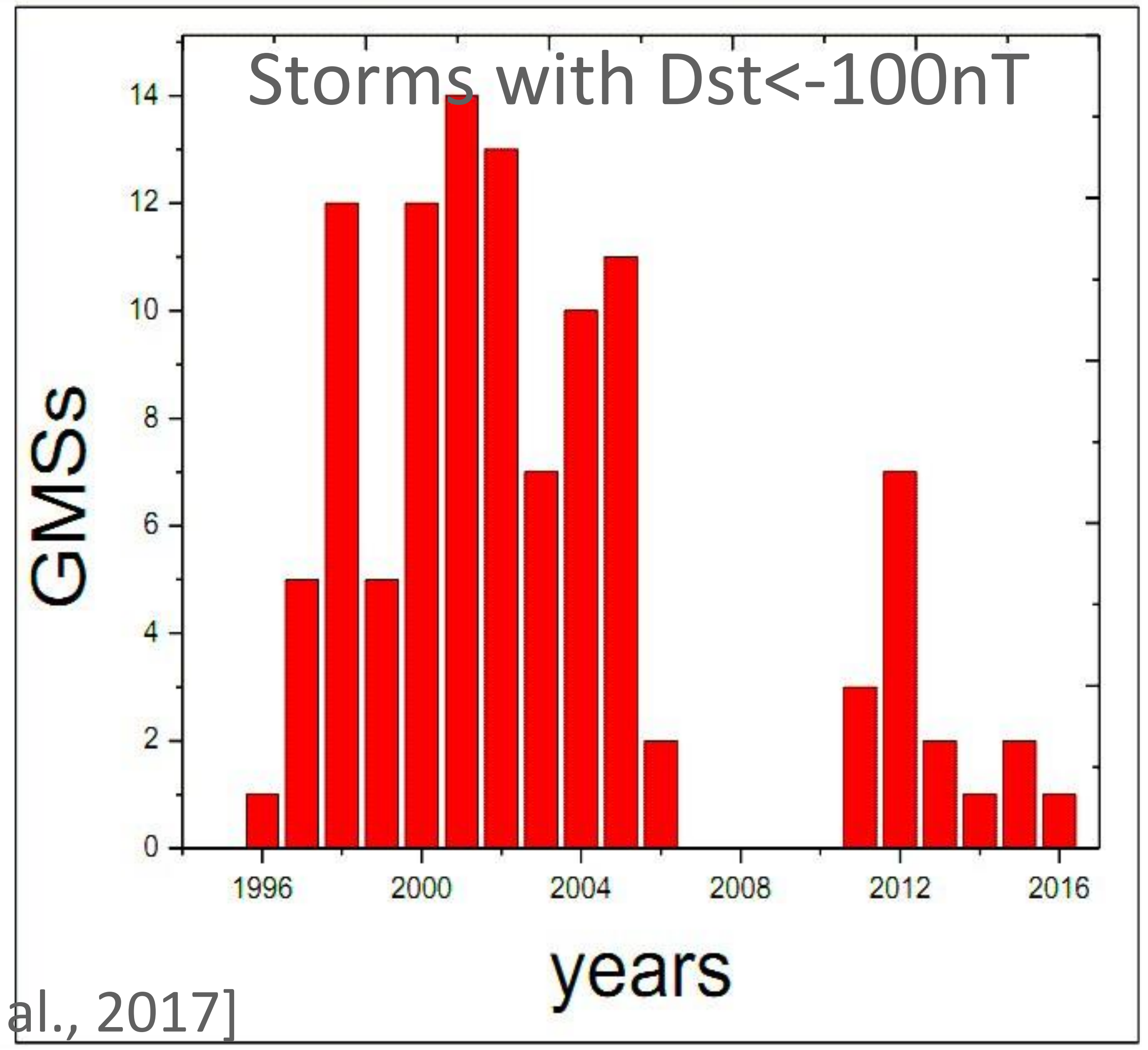


- Storms can either increase or decrease the radiation belt relativistic electron fluxes
- Neither acceleration nor loss mechanisms scale with storm intensities

Solar and magnetospheric conditions for Van Allen Probes







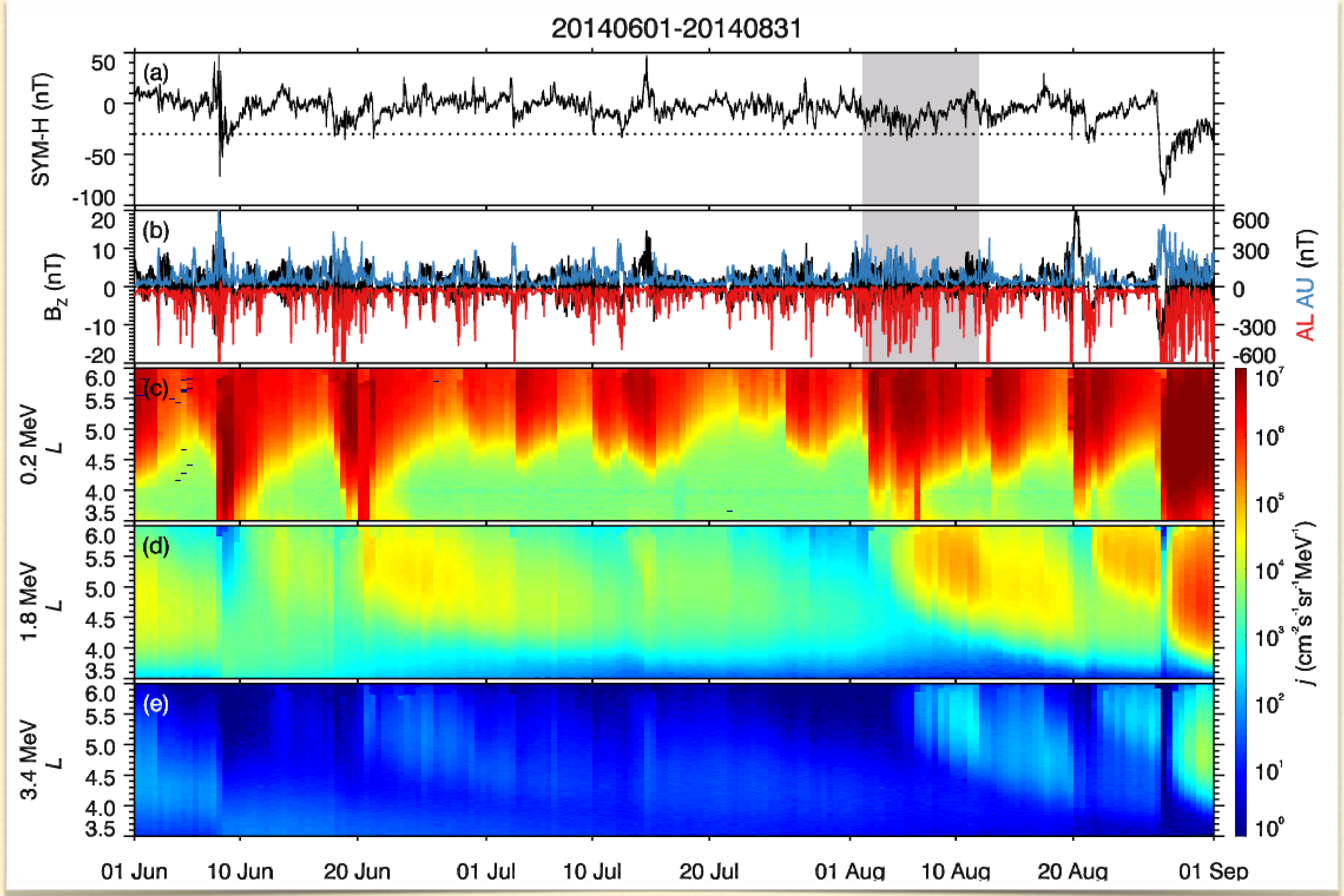
[Pande et al., 2017]

- Weakest solar cycle in 100 years, infrequent occurrence of strong storms
- Nonstorm-time radiation belt dynamics

Nonstorm-time acceleration and transport of radiation belt electrons

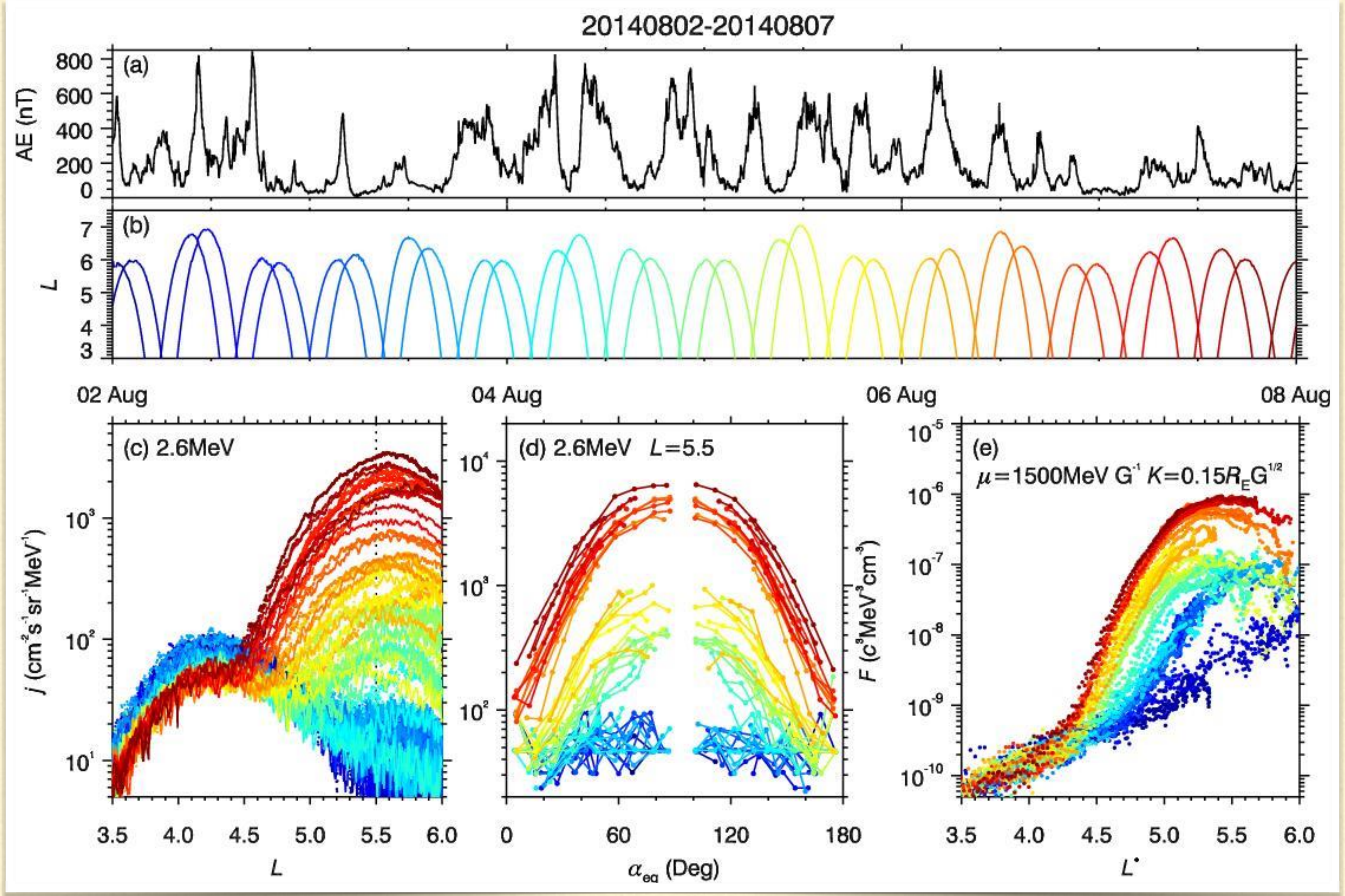
- Physical mechanisms: two representative events
  - Local acceleration during 2-7 Aug. 2014
  - Radial diffusion and adiabatic transport during 16-17 Jan. 2013
- Favored conditions: statistical analysis

Event I: 3-month overview of radiation belt environment



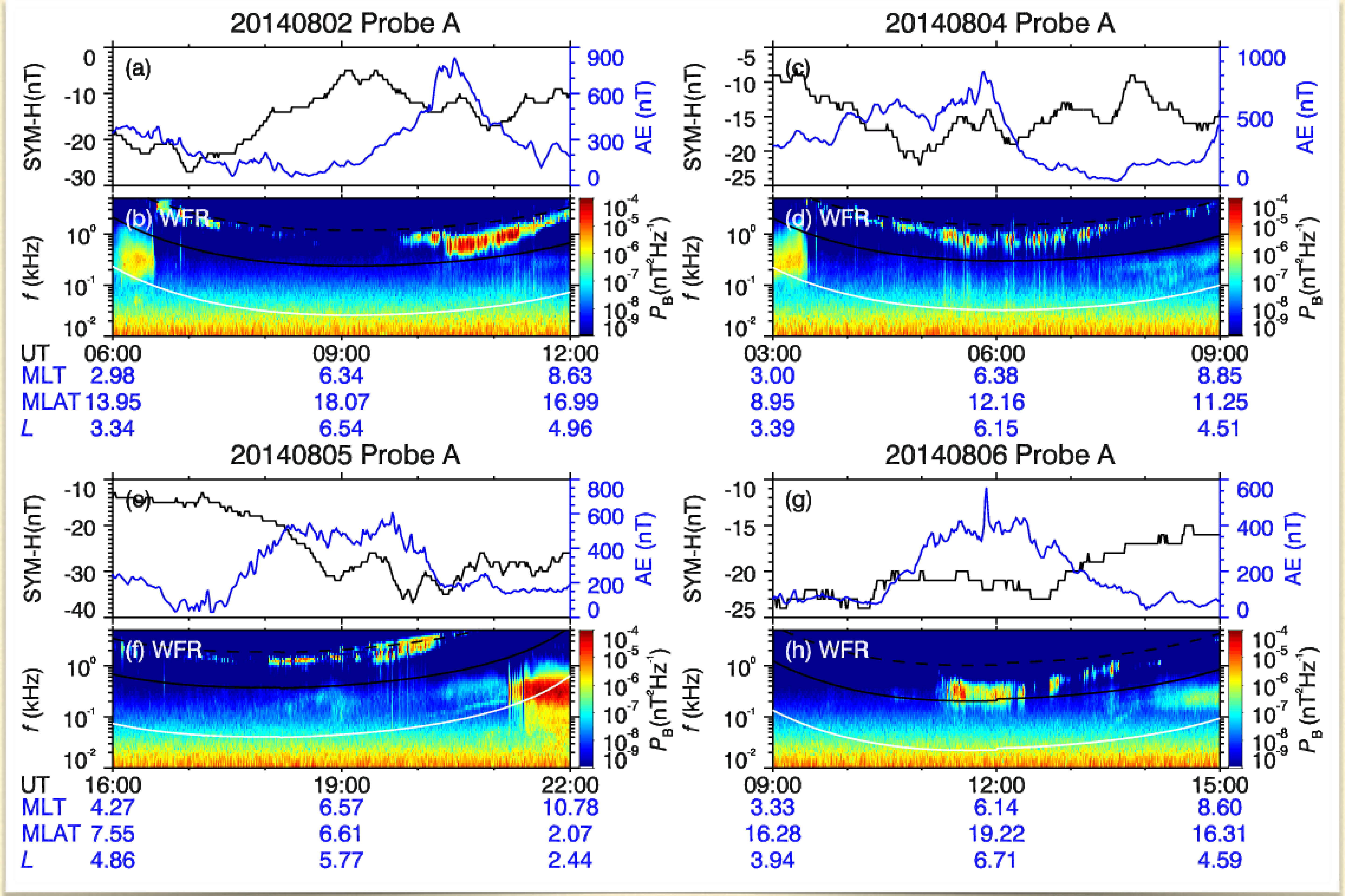
- ~70 days without storms
- Most prominent event during 2-7 Aug. 2014 (shadow)
  - Intense and sustained substorms
  - Continuous injection of seed electrons
  - Enhancement of relativistic electrons

Event I: local acceleration characteristics



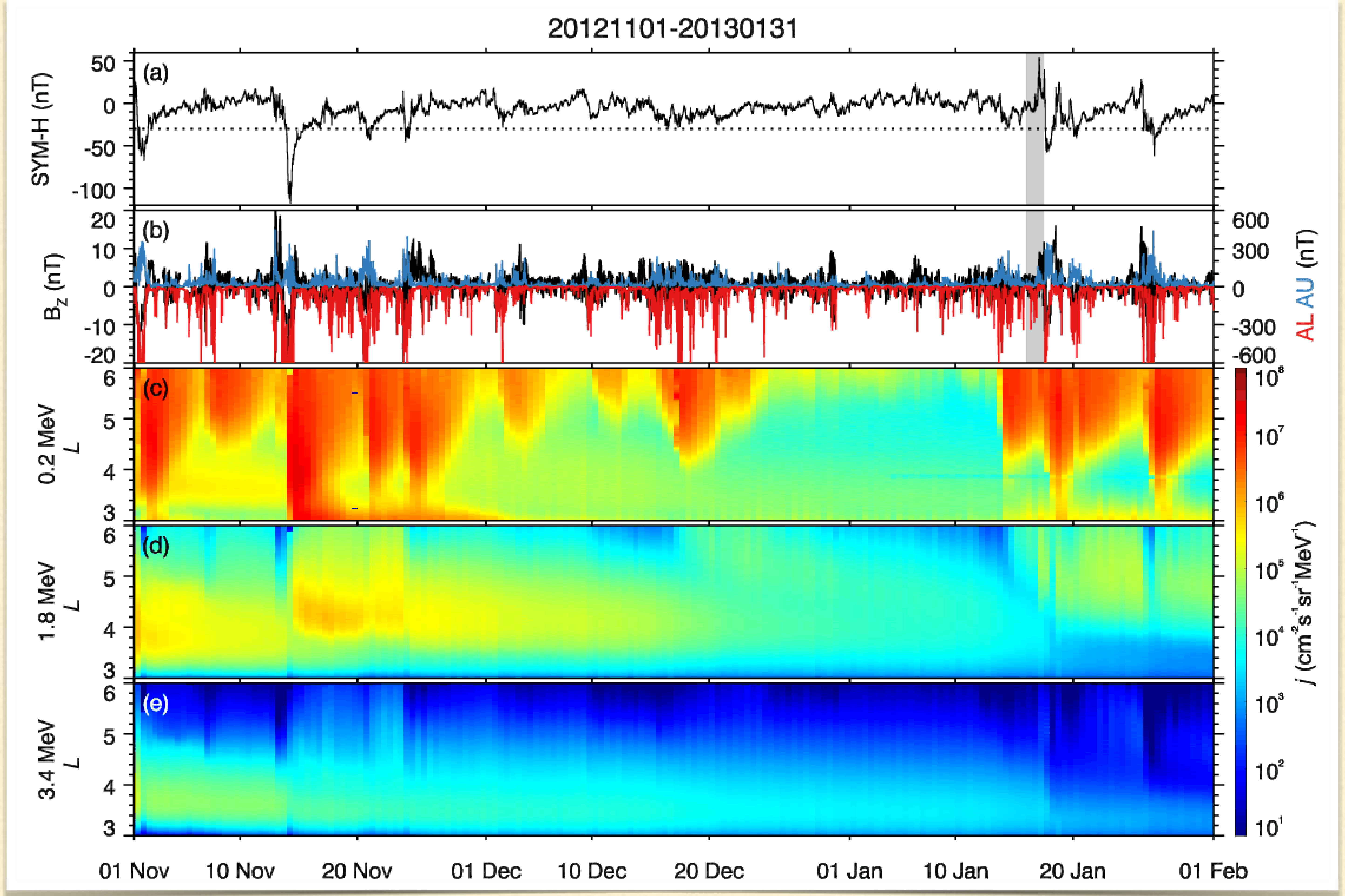
- Pre-event radiation belt centered at L=4.3
- New radiation belt formed at L=5.5 within 5 days
- Flat-top pitch angle distributions
- Peaked phase space densities

Event I: Plasma wave characteristics



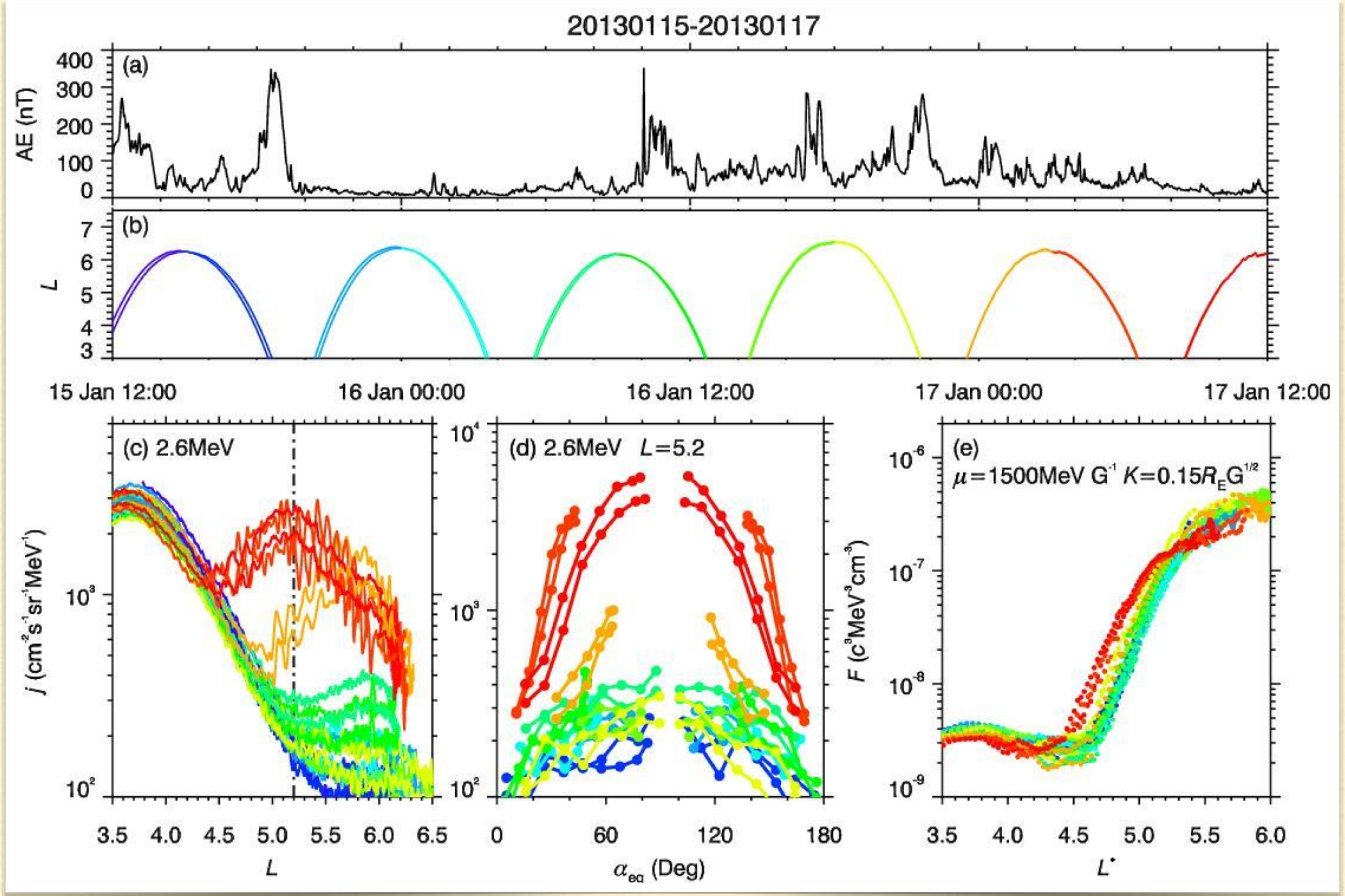
- Substorm injections destabilized chorus waves outside L=4.5
- Chorus might be responsible for the local electron acceleration, similar to the storm situation [e.g., Horne et al., 2003, Reeves et al., 2013]
- Enhanced substorm activities favored the local acceleration

Event II: 3-month overview of radiation belt environment



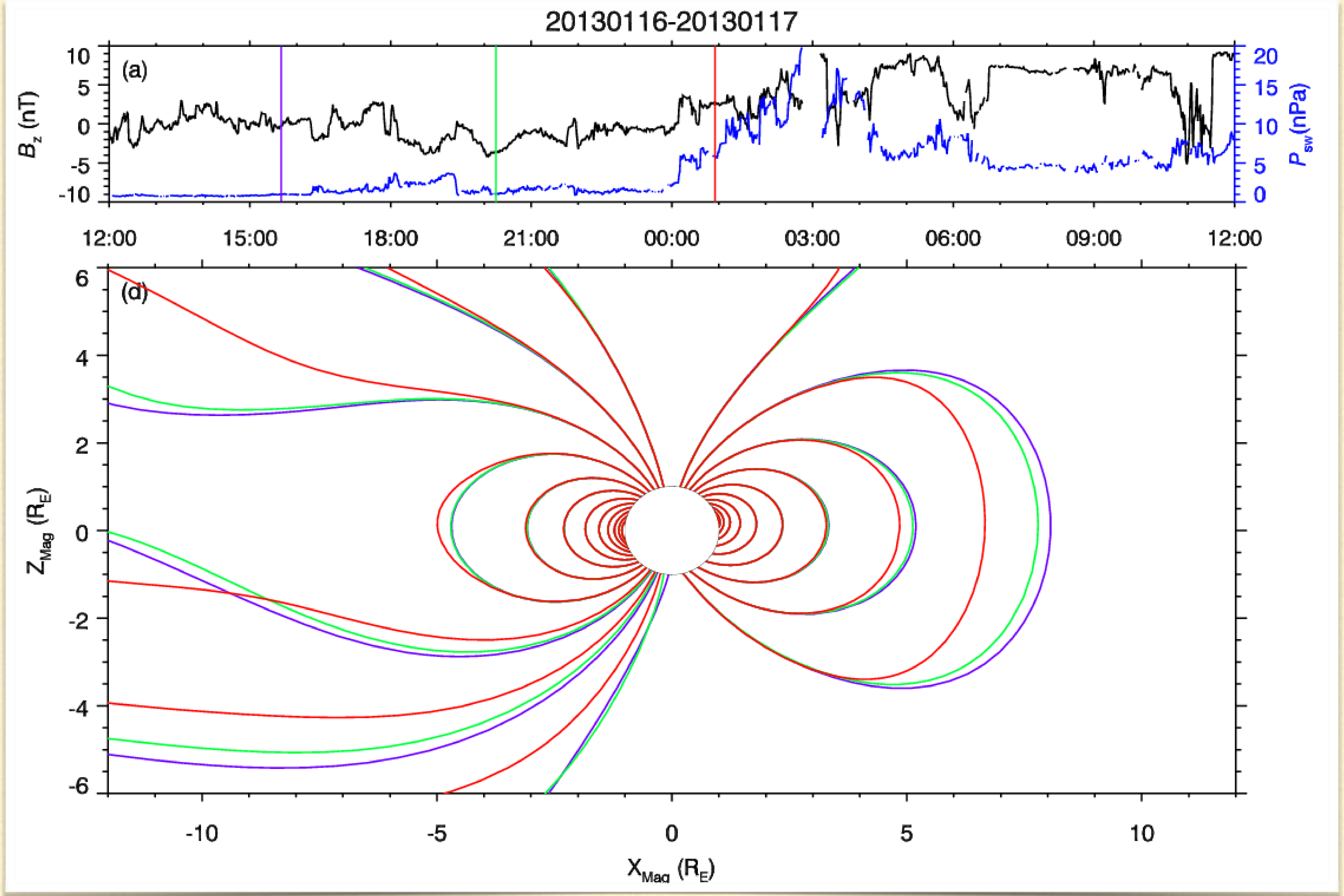
- ~50 days without storms
- Interesting event during 16-17 Jan. 2013 (shadow)
  - Enhanced SYM-H (solar wind dynamic pressure)
  - Enhanced substorm injections before the event

Event II: radial transport characteristics



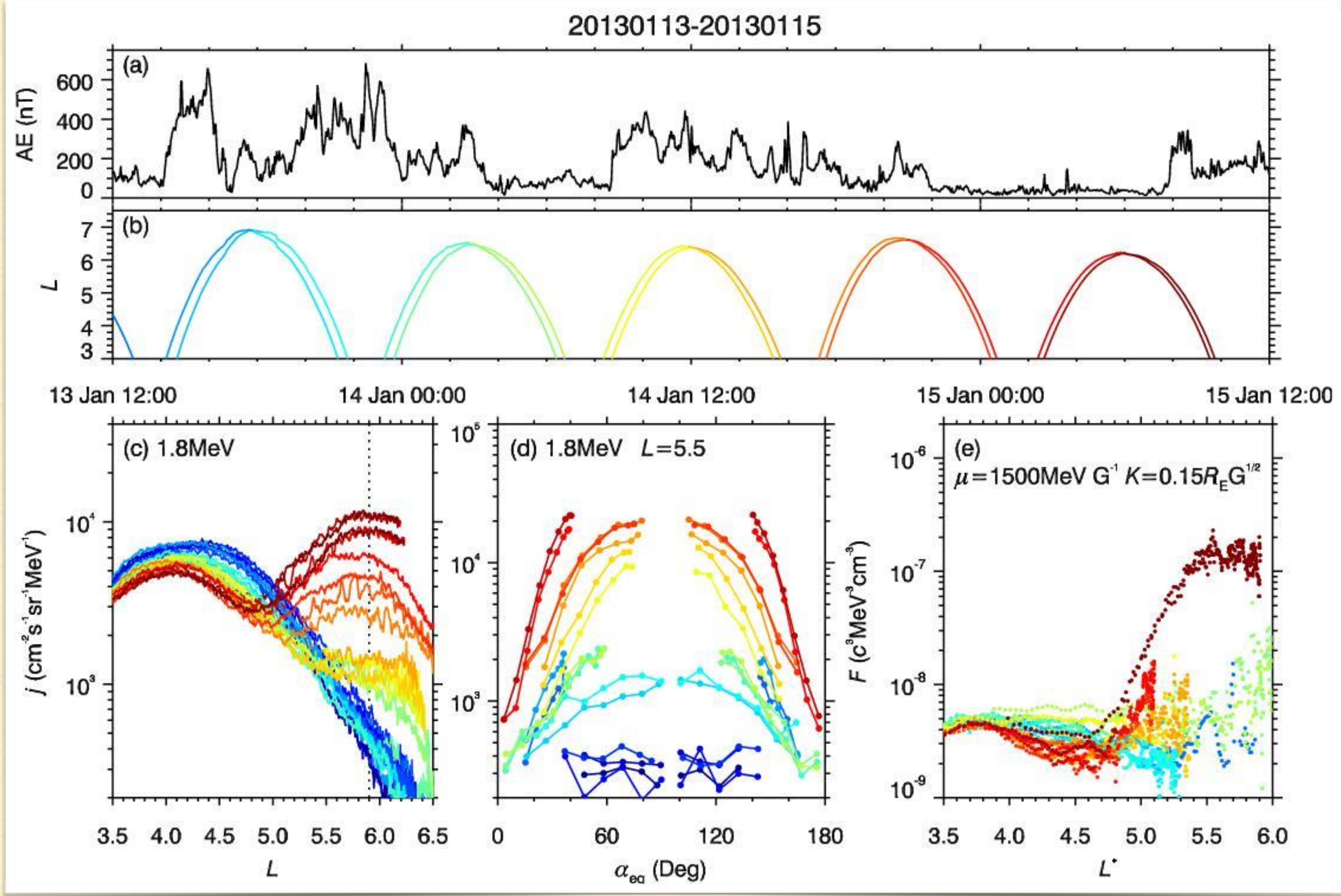
- Pre-event radiation belt centered at L=3.6
- New radiation belt formed at L=5.2 within 2 days
- Very weak substorm activities
- Quasi-periodic oscillations of electron fluxes, drift resonance [e.g., Mann et al., 2013]
- Inward radial diffusion of phase space density

Event II: Magnetic field configurations



- Enhanced solar wind dynamic pressure
- Earthward movement of magnetic field lines
- Steep radial profiles of electron phase space density
- Fully adiabatic transport could contribute to the flux enhancement

Precondition for Event II

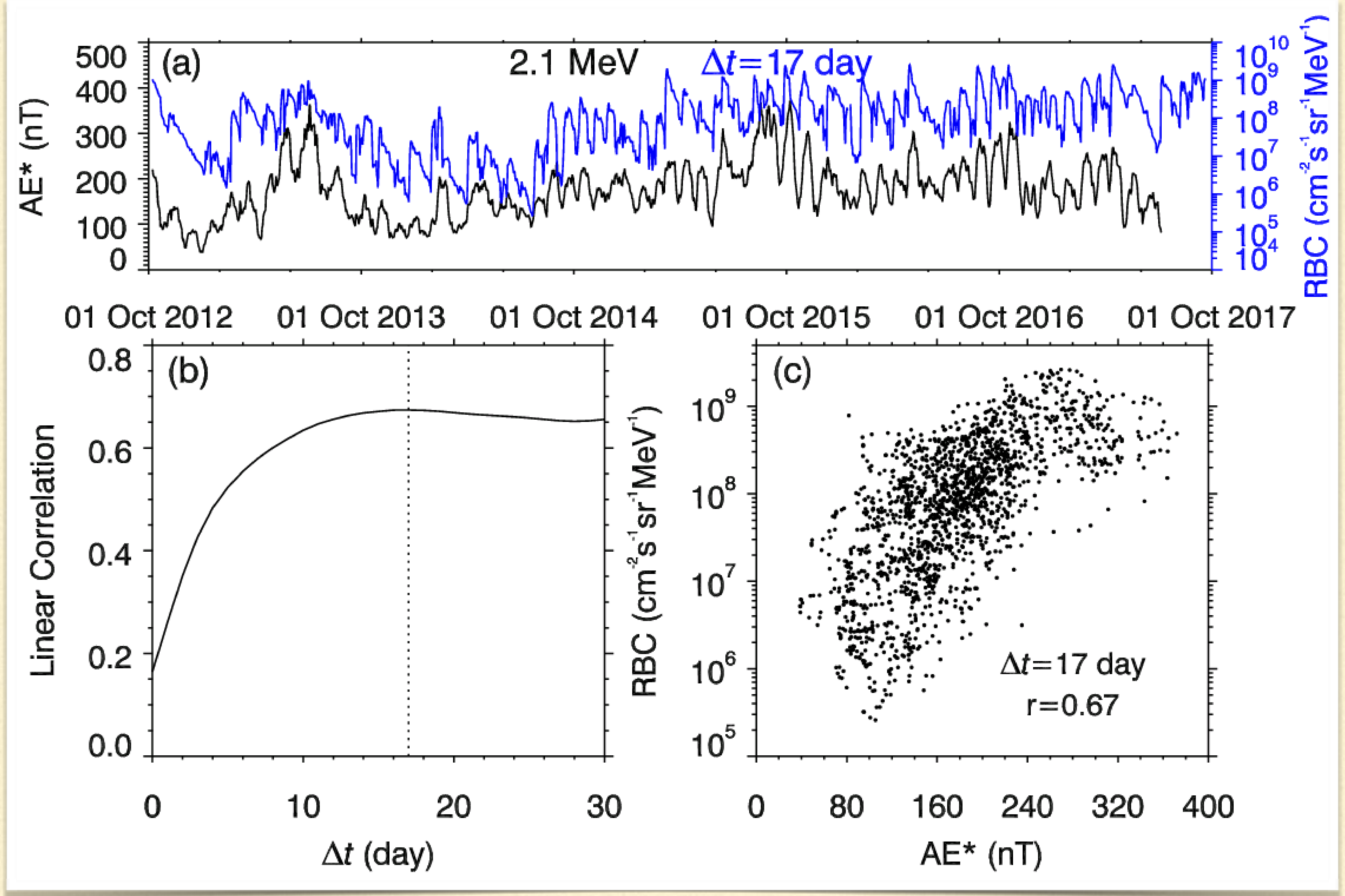


- Enhanced substorm activities before Event II
- Generation of the phase space density peaks
- Allowing the subsequent radial transport

Intense and continuous substorm activities were important for the radiation belt electron acceleration

- Causing the local acceleration
- Creating phase space density peaks to favor the subsequent radial transport (radial diffusion and adiabatic transport)

Correlation between daily RBC (log10) and AE* over ~5 years



- Daily radiation belt content

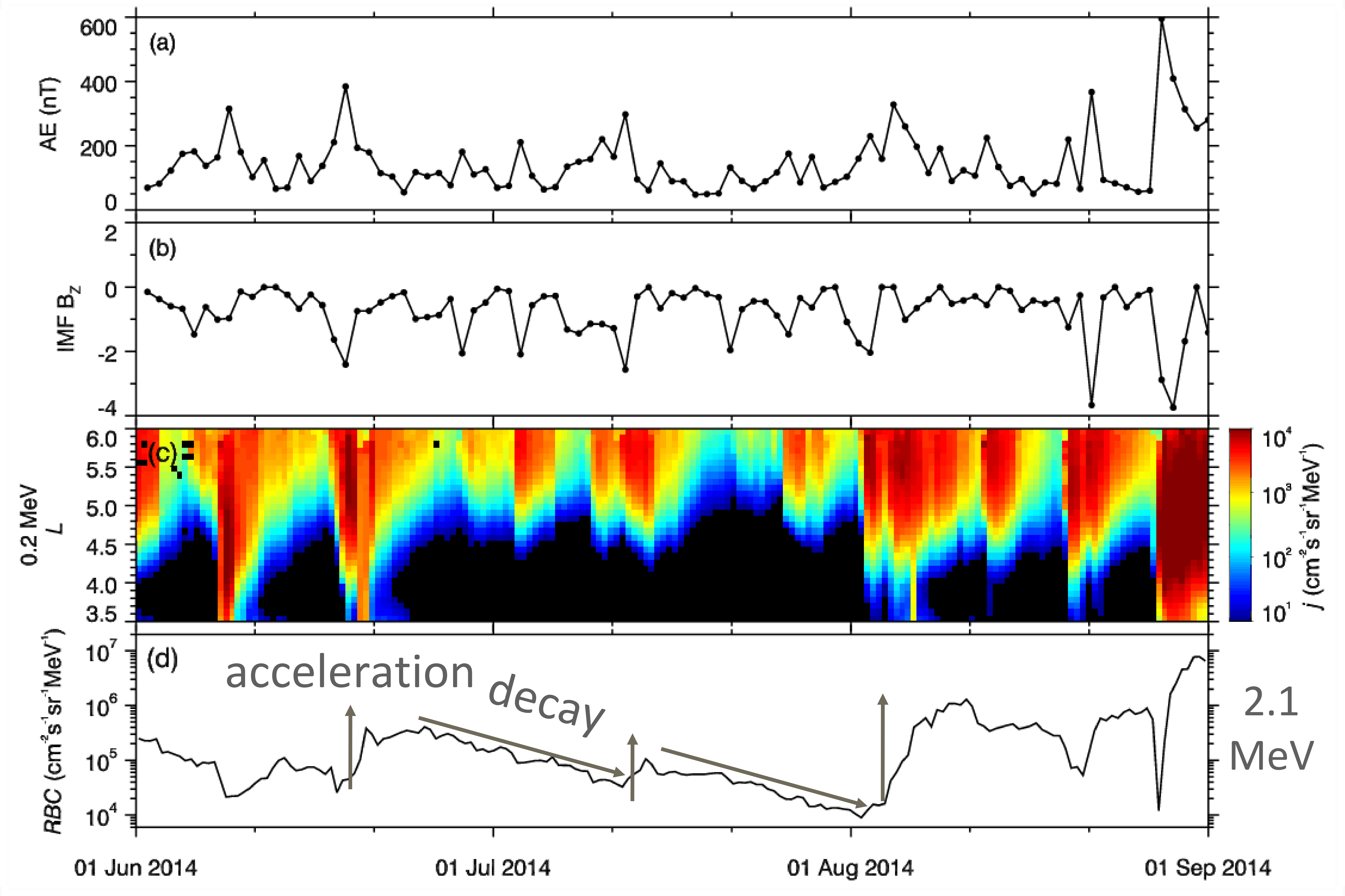
$$\mathrm{RBC(t)} = \int_{L=3}^{L=6} j(t,L)L^2 dL$$

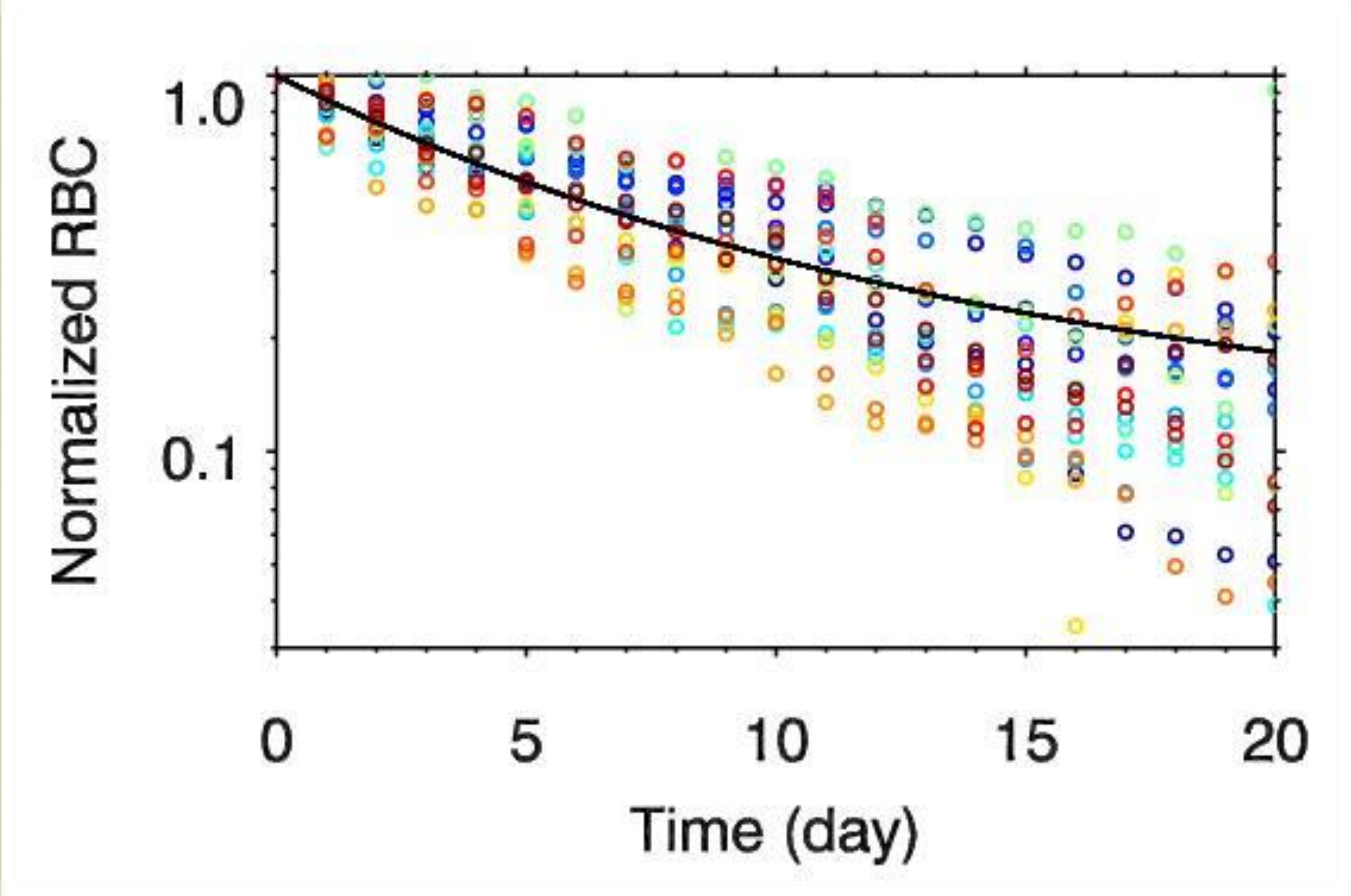
- Averaged AE in the preceding Δt days

$$\mathrm{AE}^*(t) = \frac{1}{\Delta t}\int_{t-\Delta t}^{t} \mathrm{AE}(t)dt$$

- Linear correlation (0.67) peaks at $\Delta t = 17$ day
- Scatter dot plot shows a positive correlation between RBC and AE*

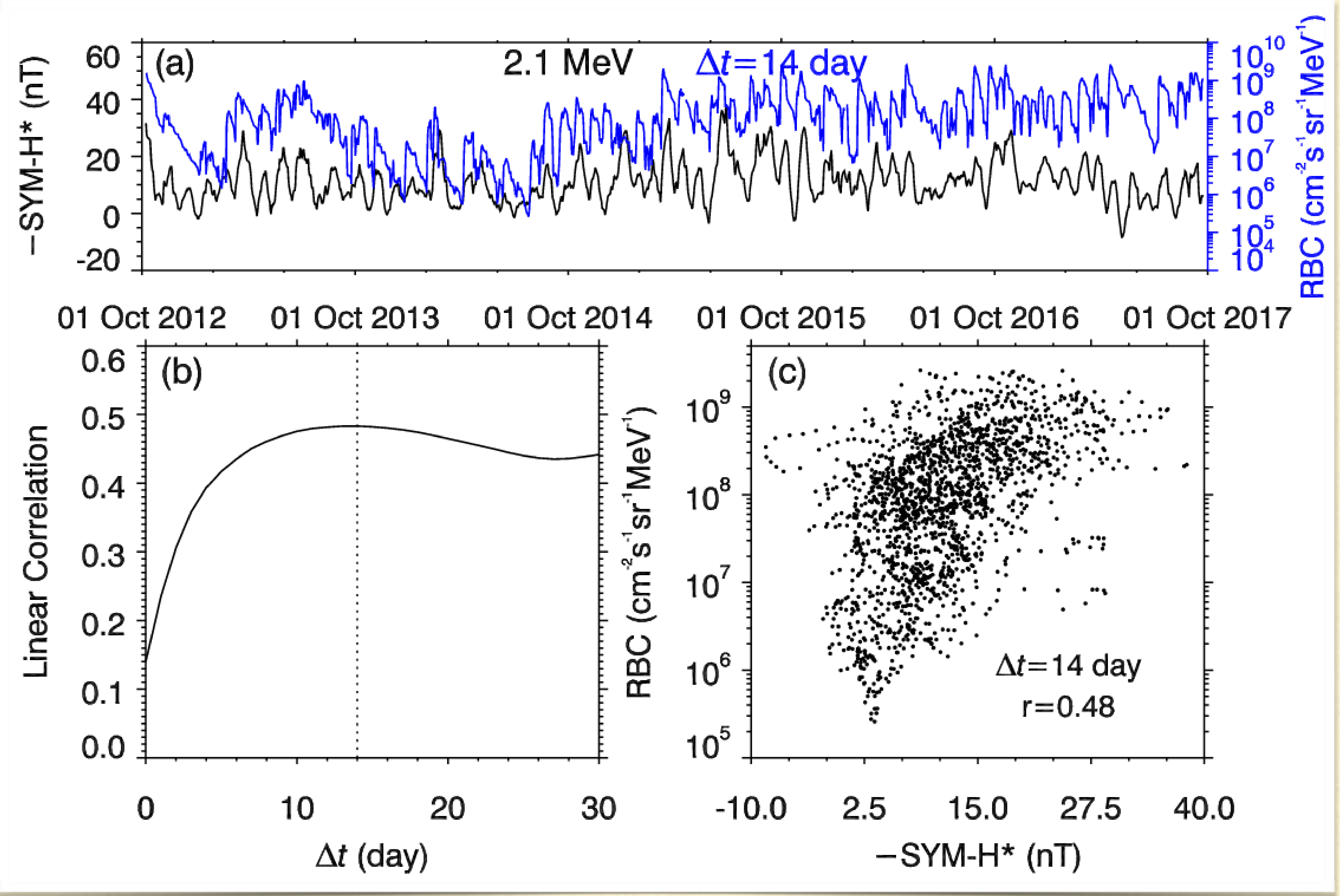
Physical interpretation of optimal averaging time Δt for AE*





- Gradual decay of accelerated electrons
- Δt comparable to electron lifetime

Correlation between daily RBC (log10) and SYM-H* over ~5 years



- Daily radiation belt content

$$\mathrm{RBC(t)} = \int_{L=3}^{L=6} j(t,L)L^2 dL$$

- Averaged SYM-H in the preceding Δt days

$$\mathrm{SYMH}^*(t) = \frac{1}{\Delta t}\int_{t-\Delta t}^{t} \mathrm{SYMH}(t)dt$$

- Linear correlation (0.48) peaks at $\Delta t = 14$ day
- Scatter dot plot shows a triangle-shaped distribution, and particularly when SYM-H* ~0, RBC varies over a wide range

Conclusions

- Frequent observations of nonstorm radiation belt dynamics by RBSP
- Nonstorm mechanisms: local acceleration and/or radial transport, similar to the storm situation
- Importance of substorm activities: causing local acceleration and producing PSD peaks to allow subsequent radial transport
- Positive correlation (0.67) between daily RBC and AE* (averaged AE in preceding 17 days)