



Statistics of sudden particle enhancements at low L-shells and their role as a source of Earth's inner electron radiation belt

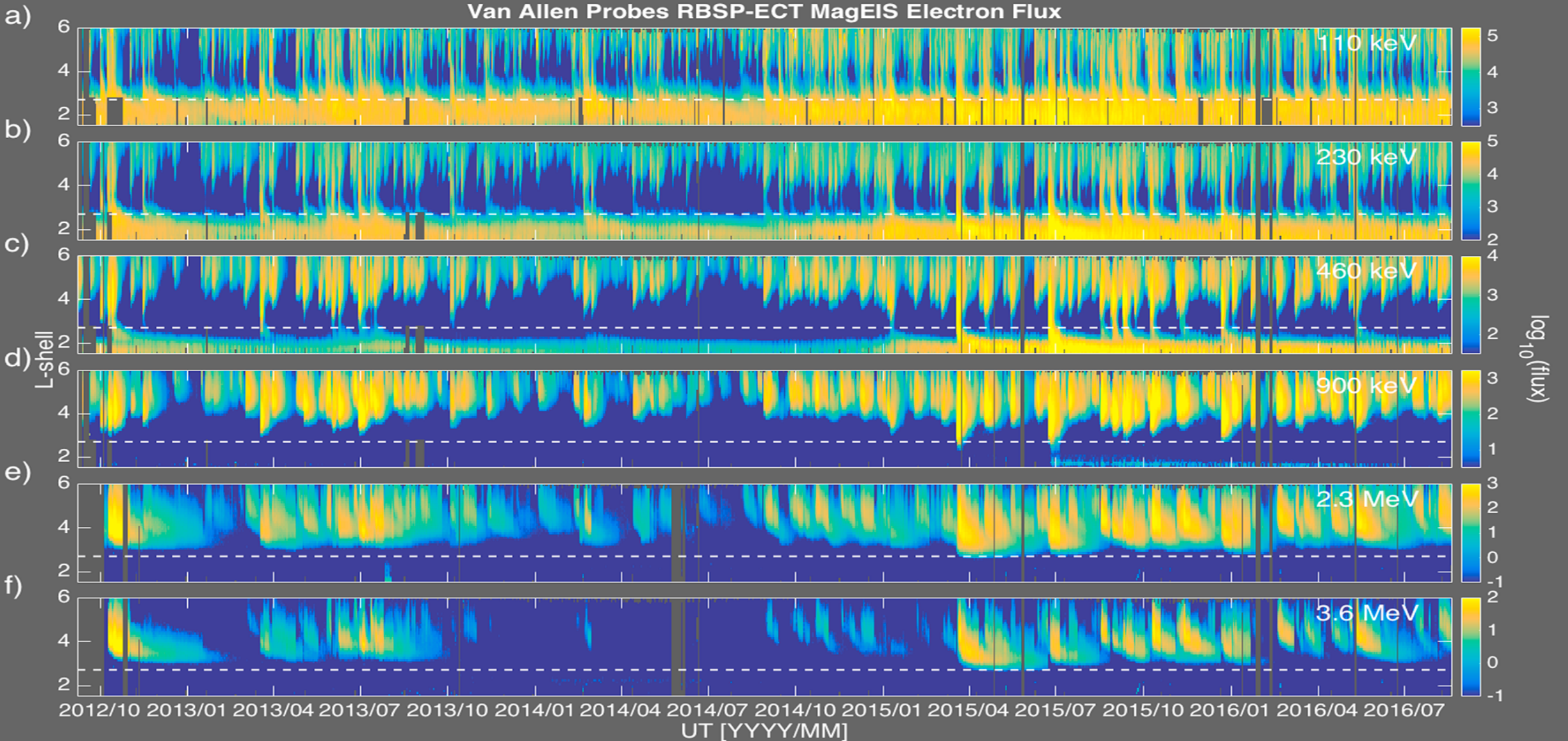
***Drew L. Turner¹,
J. F. Fennell¹, S. G. Claudepierre¹, J. B. Blake¹, T. P. O'Brien¹,
J. Roeder¹, J. H. Clemmons¹, H. Spence², and G. D. Reeves³***

¹The Aerospace Corporation
²University of New Hampshire
³Los Alamos National Laboratory

4-9 March 2018

Earth's Electron Radiation Belts

New insights from the Van Allen Probes Era

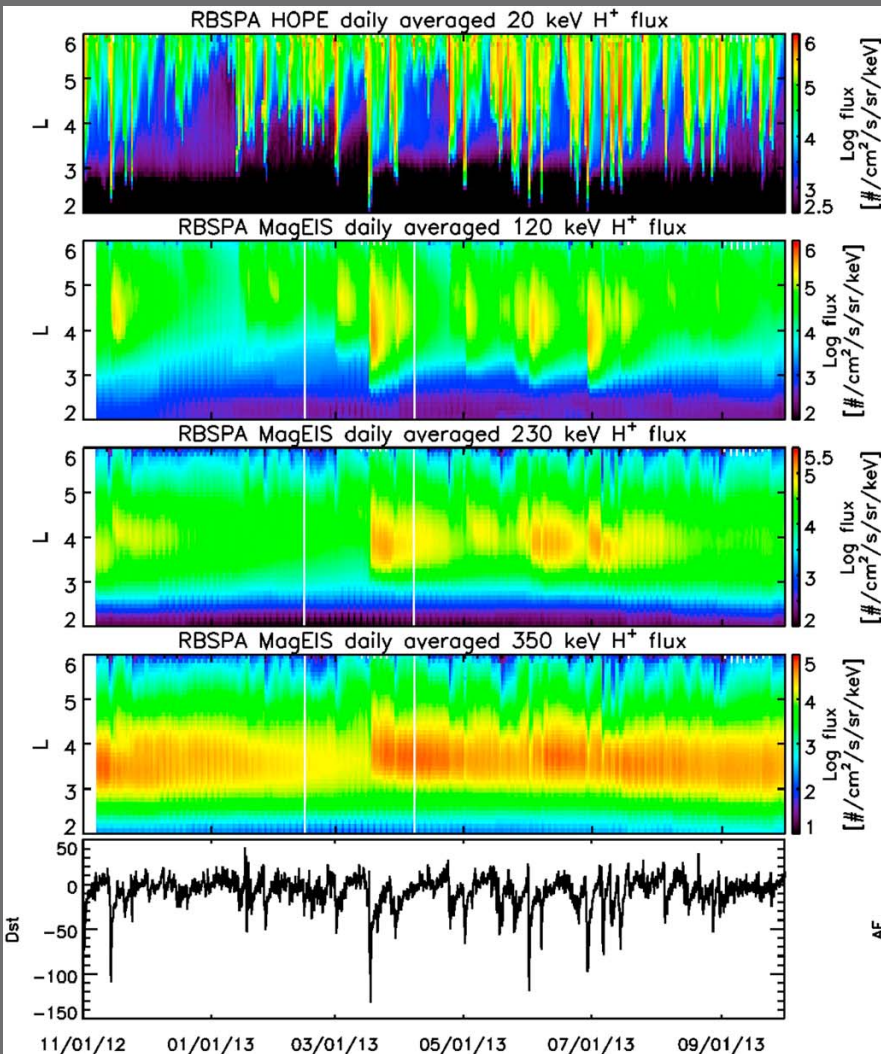




Electrons in the Inner Radiation Belt

Sudden particle enhancements at low L-shells (SPELLS)

Protons



Electrons

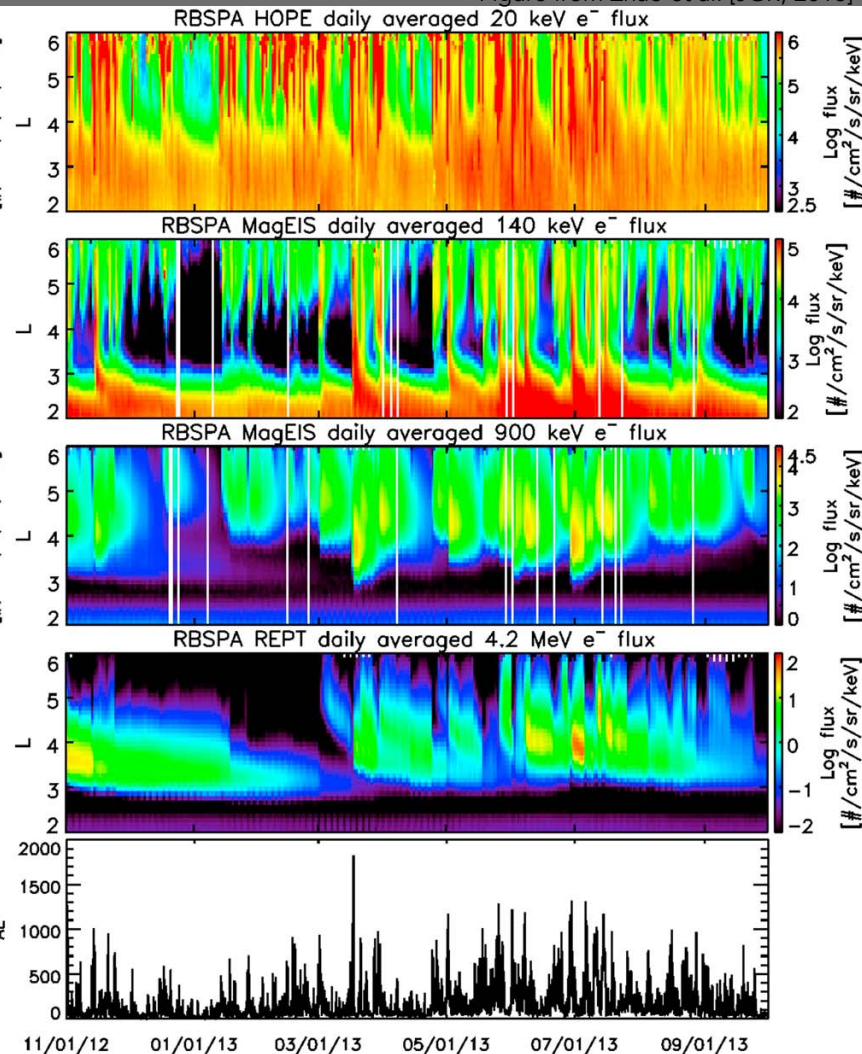
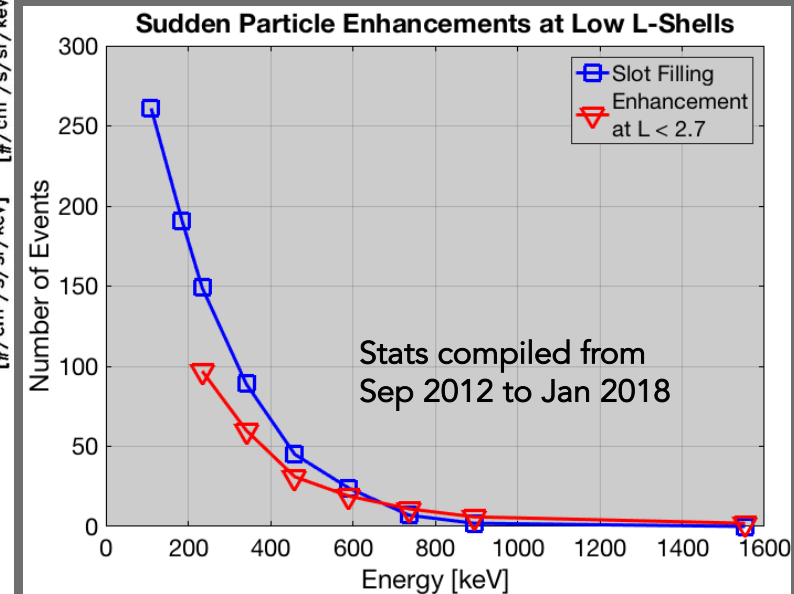


Figure from Zhao et al. [JGR, 2016]

SPELLS are common but only for electrons and they occur within the plasmasphere: they are not simply a result of enhanced global convection

Figure updated from Turner et al. [JGR, 2016]

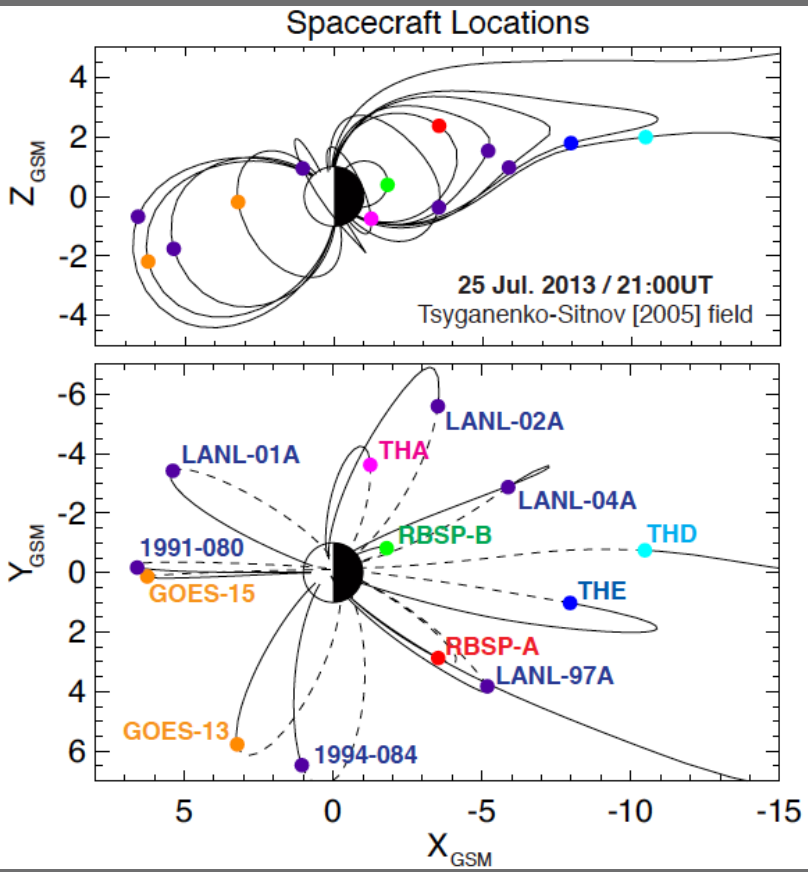
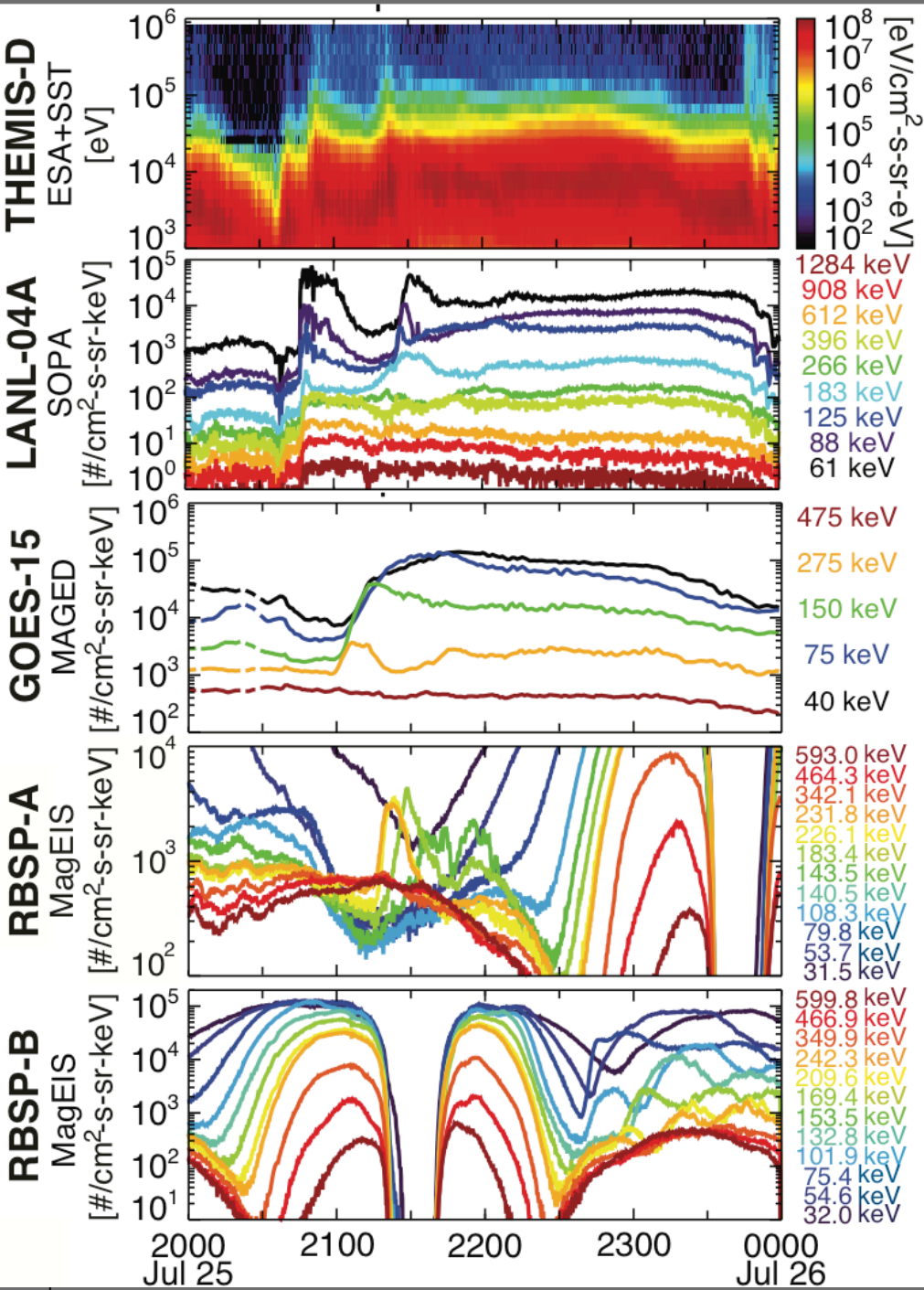




Electrons in the Inner Radiation Belt

Sudden particle enhancements at low L-shells (SPELLS)

- Turner et al. [GRL 2015]:
 - SPELLS are not the innermost extent of classic substorm injections, but...
 - SPELLS injection events are localized in MLT
- See also Zhao et al. [JGR 2017] for species and MLT dependencies



Figures from Turner et al. [GRL, 2015]

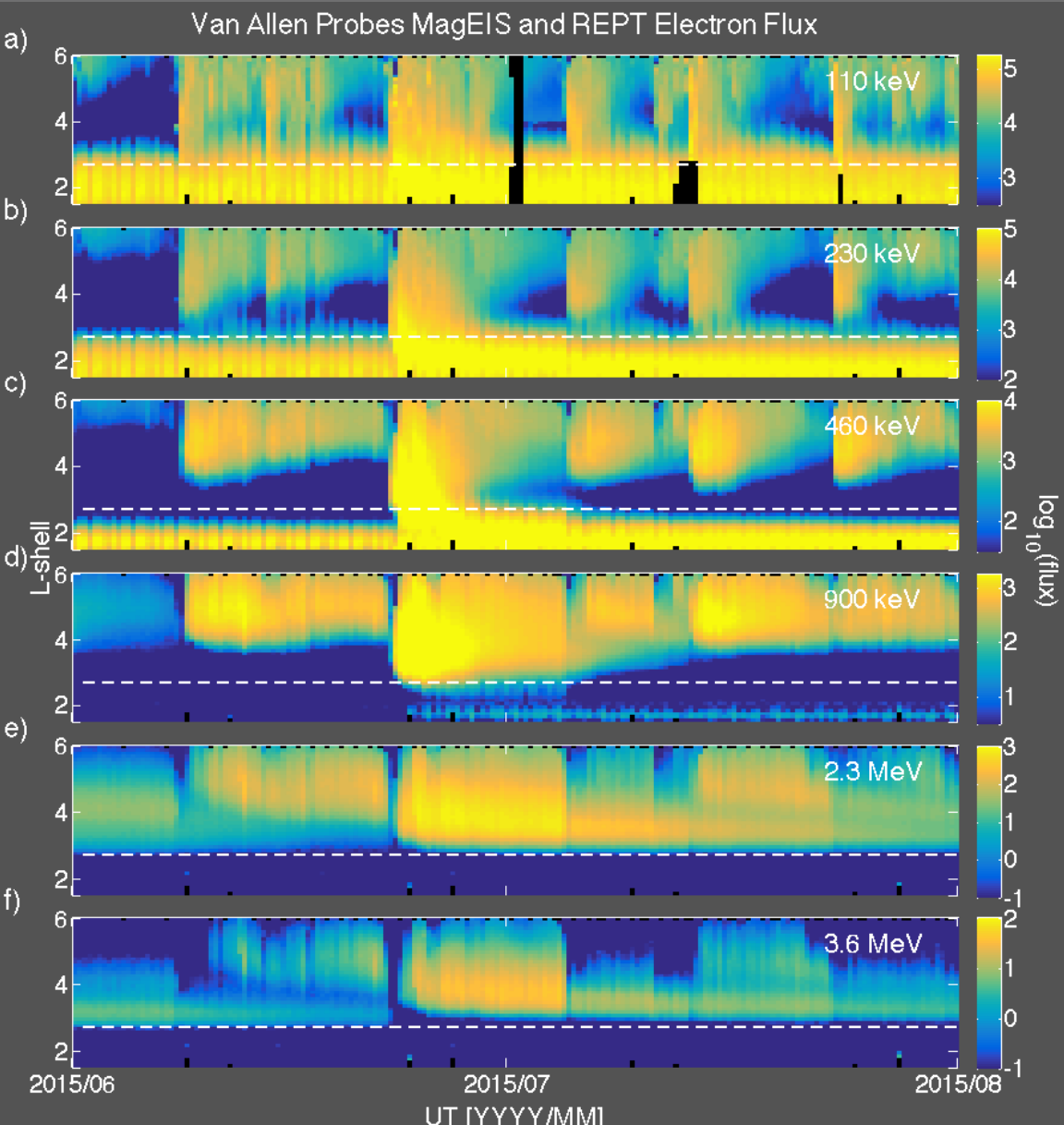
The physical mechanism responsible for SPELLS remains an open question...



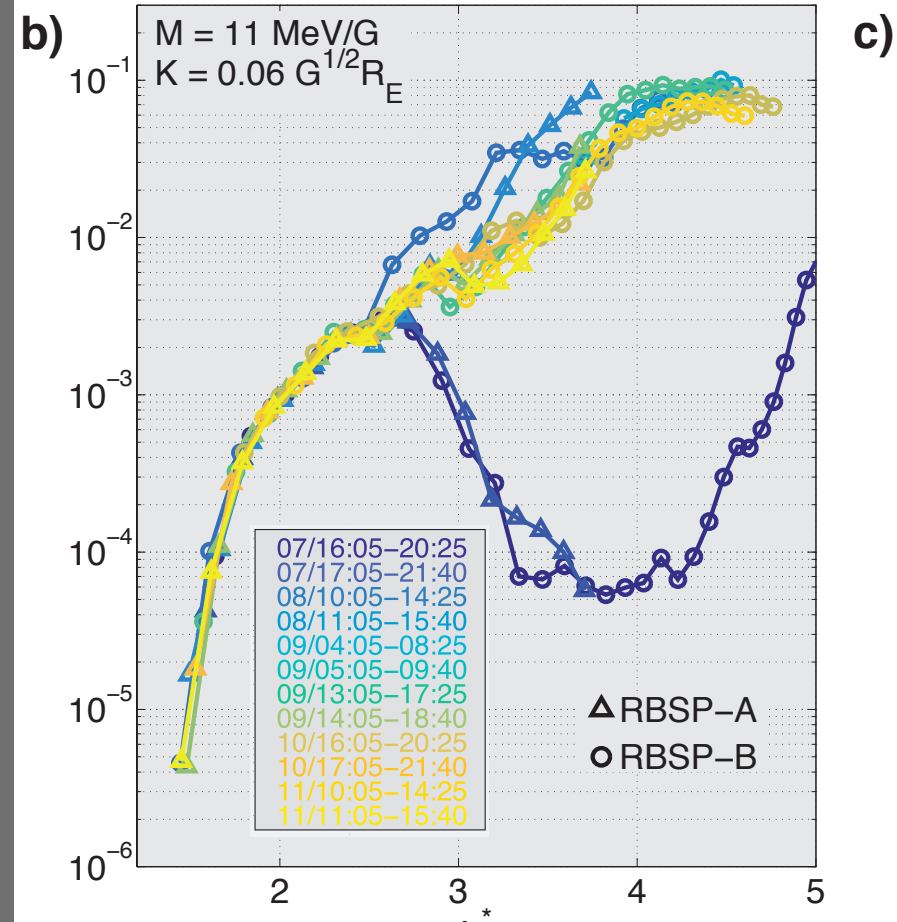
SPELLS Example Case: 08 June 2015

SPELLS are a source of inner belt electrons

- Turner et al. [GRL 2015; JGR 2016]:
 - Sudden particle injections at low-L are associated with traditional substorm injections but do not result directly from them
 - Not just global convection: protons not injected at same energies; injections are inside the plasmasphere
 - SPELLS are too fast to be from radial diffusion (also not consistent with energies)



RBSP-A and -B Electron PSD for Fixed M and K



Figures from Turner et al. [JGR, 2016]

Again, the physical mechanism responsible for SPELLS remains an open question...

SPELLS and the Dominant Source of Inner Belt Electrons

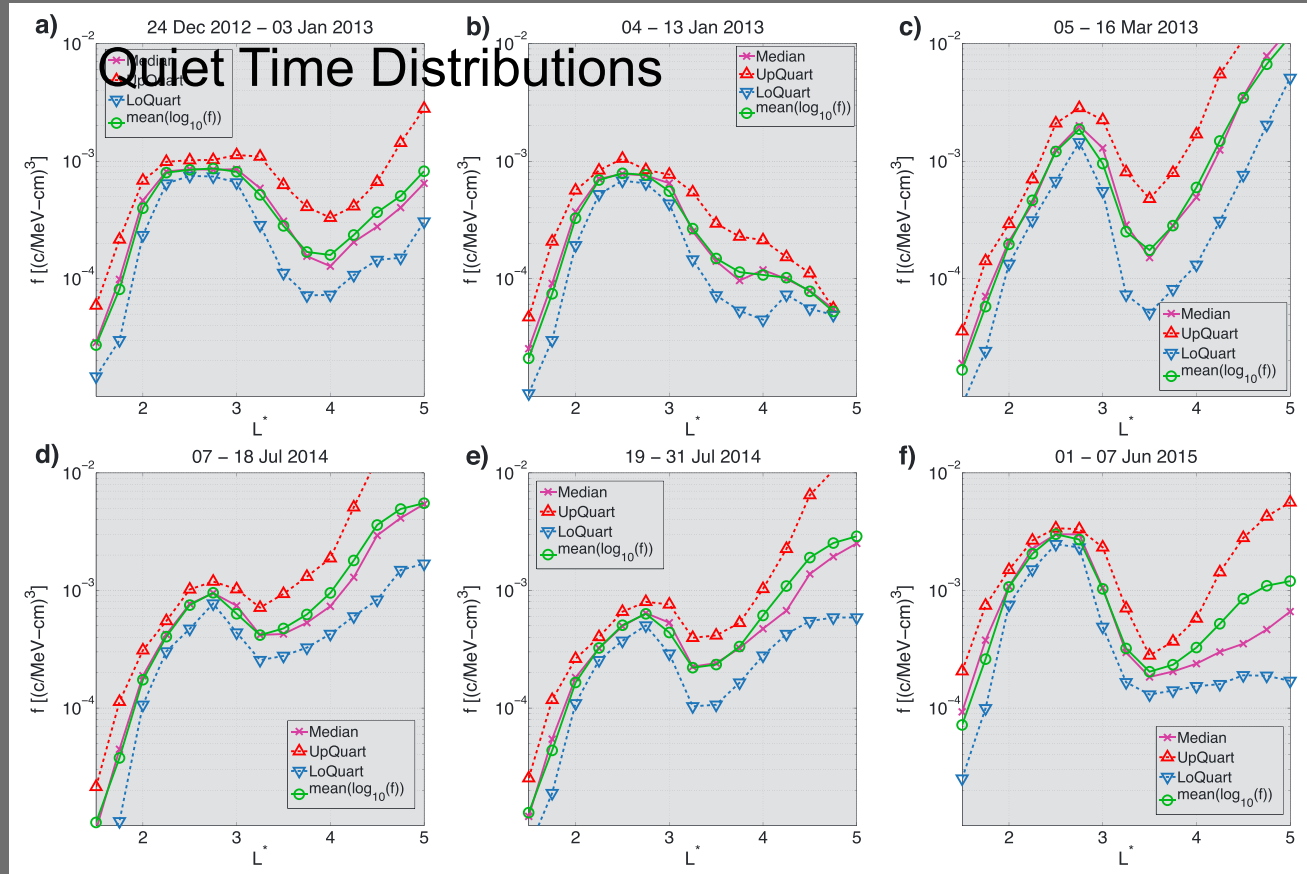
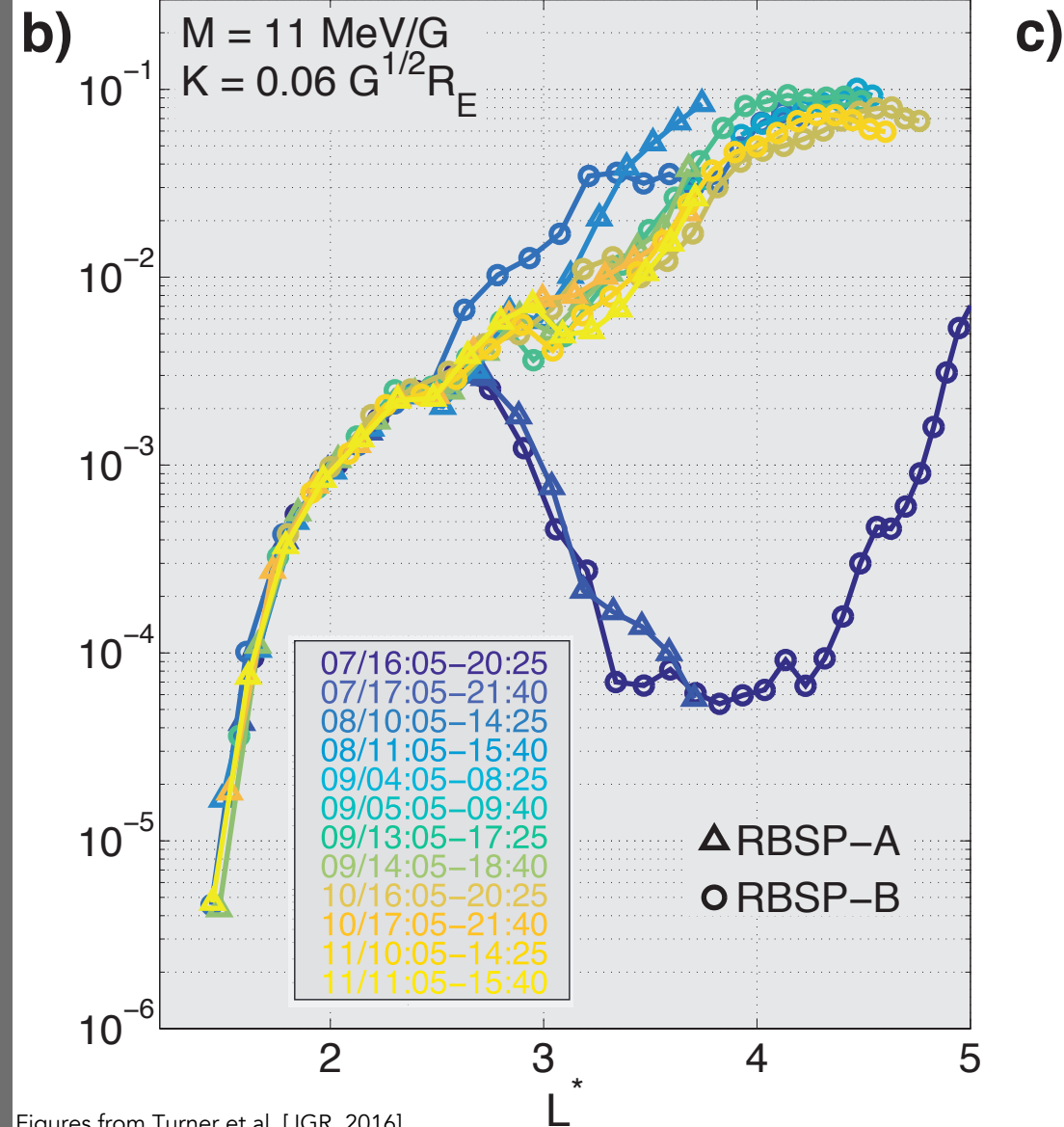


Comparing to normal conditions

- Turner et al. [JGR 2016]: These low-L injections are the dominant source of 10s to 100s of keV electrons in the inner belt
 - The PSD distributions of electrons in the inner belt are typically peaked during quiet times and normal/average conditions
 - Inward radial diffusion can only act in the few days after SPELLS
 - SPELLS represent an “on/off” source from higher L, resulting in the formation of the peaked distributions [e.g., Chen et al. NatPhys 2007]

SPELLS Distributions

RBSP-A and -B Electron PSD for Fixed M and K





Structure and Morphology of the Electron Radiation Belts

The critical role of hiss (a.k.a., Lyons and Thorne [1973])

March 2013: SPELLS and structure of the electron radiation belts

Electron lifetimes (log in days) from interactions with observed hiss waves

Figure from Ripoll et al. [GRL, 2016]

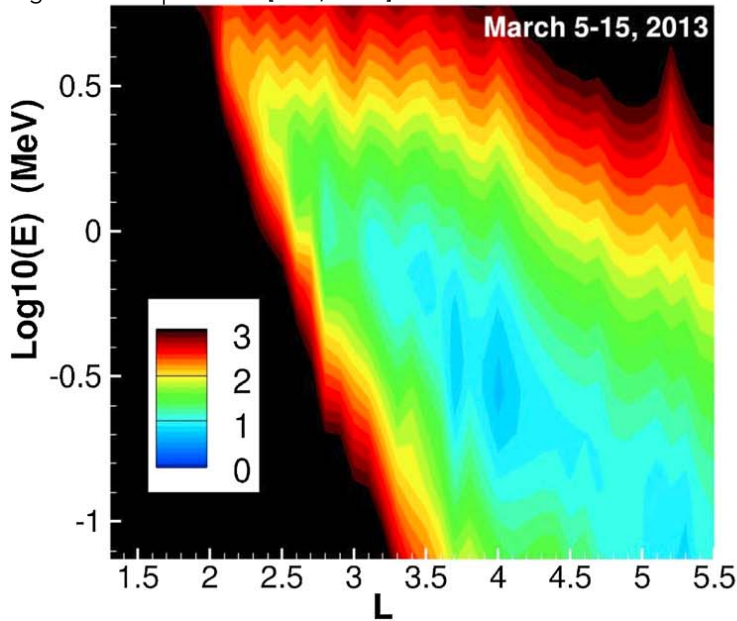
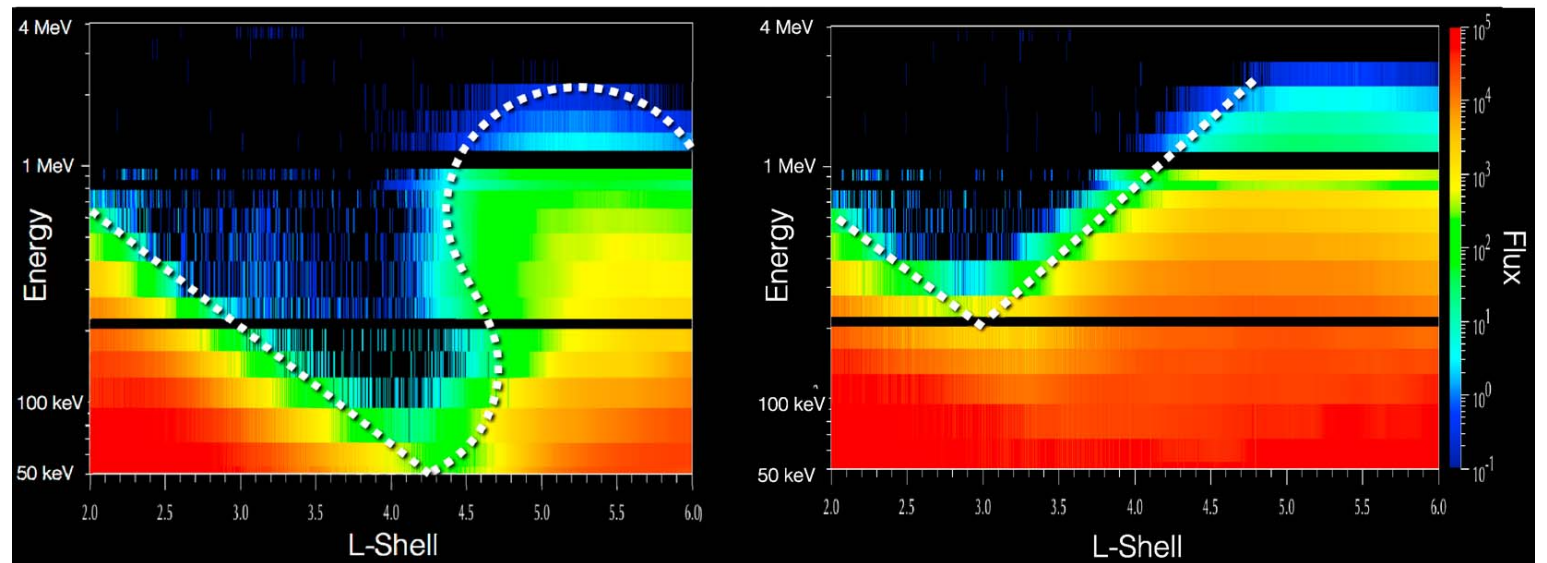
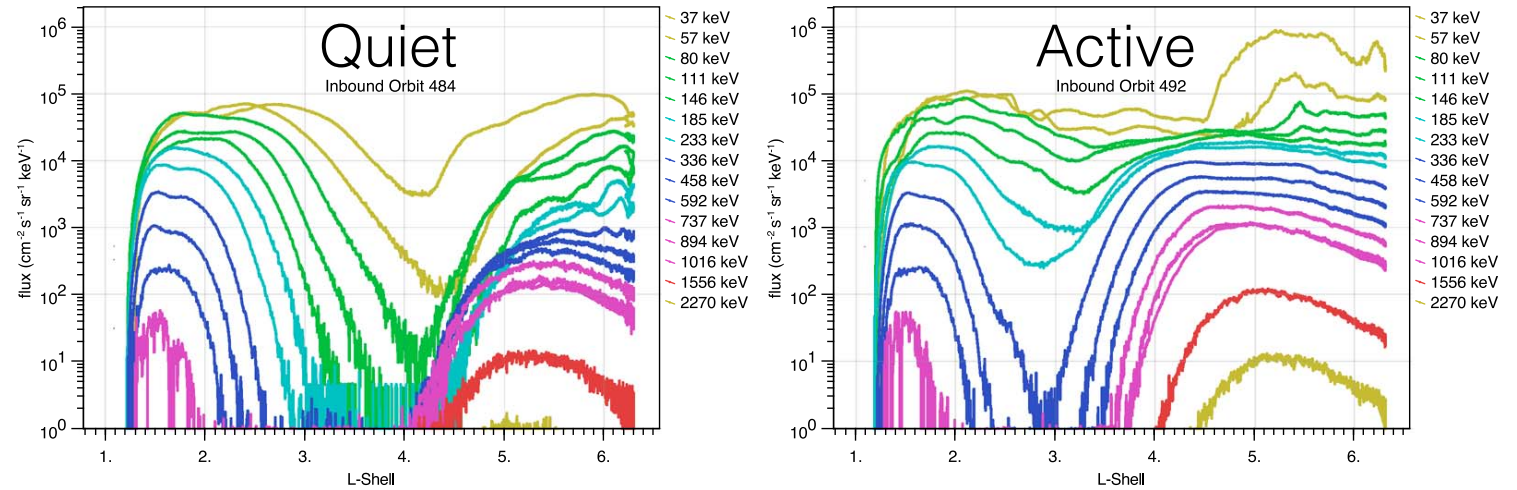


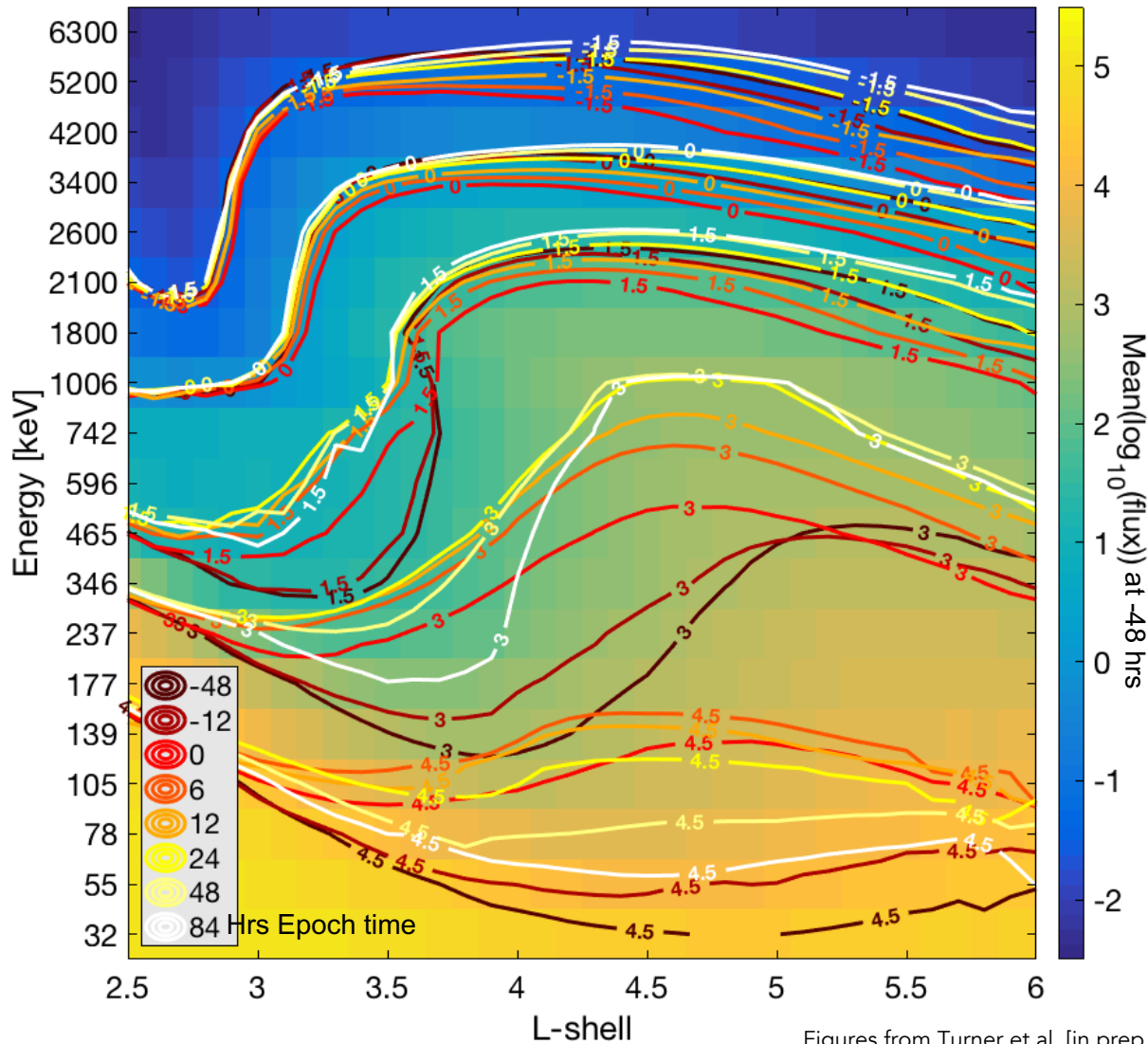
Figure from Reeves et al. [JGR, 2016]



Structure and Morphology

SPELLS and losses from hiss

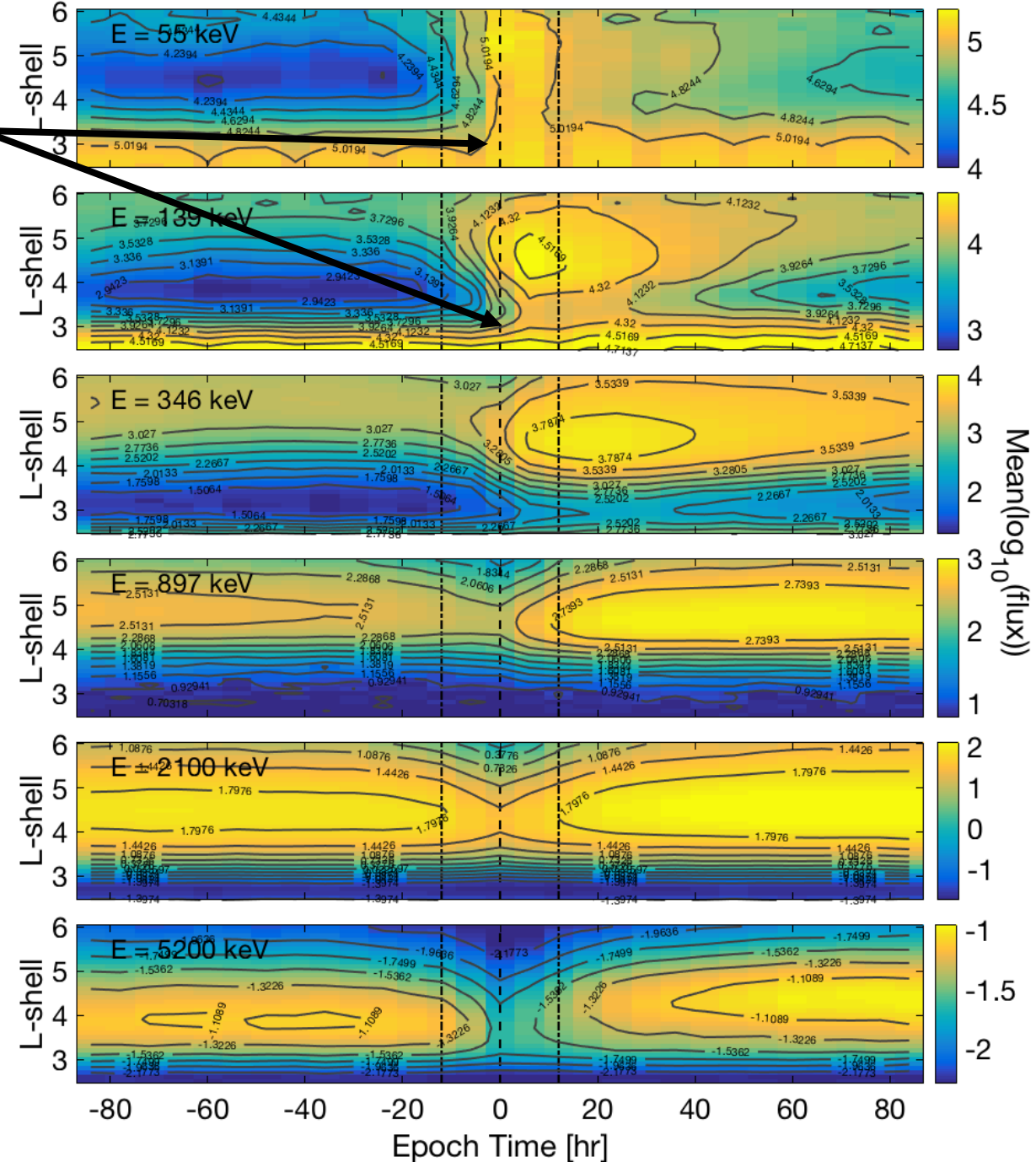
Statistics from 110 storms...



Figures from Turner et al. [in prep.]

SPELLS

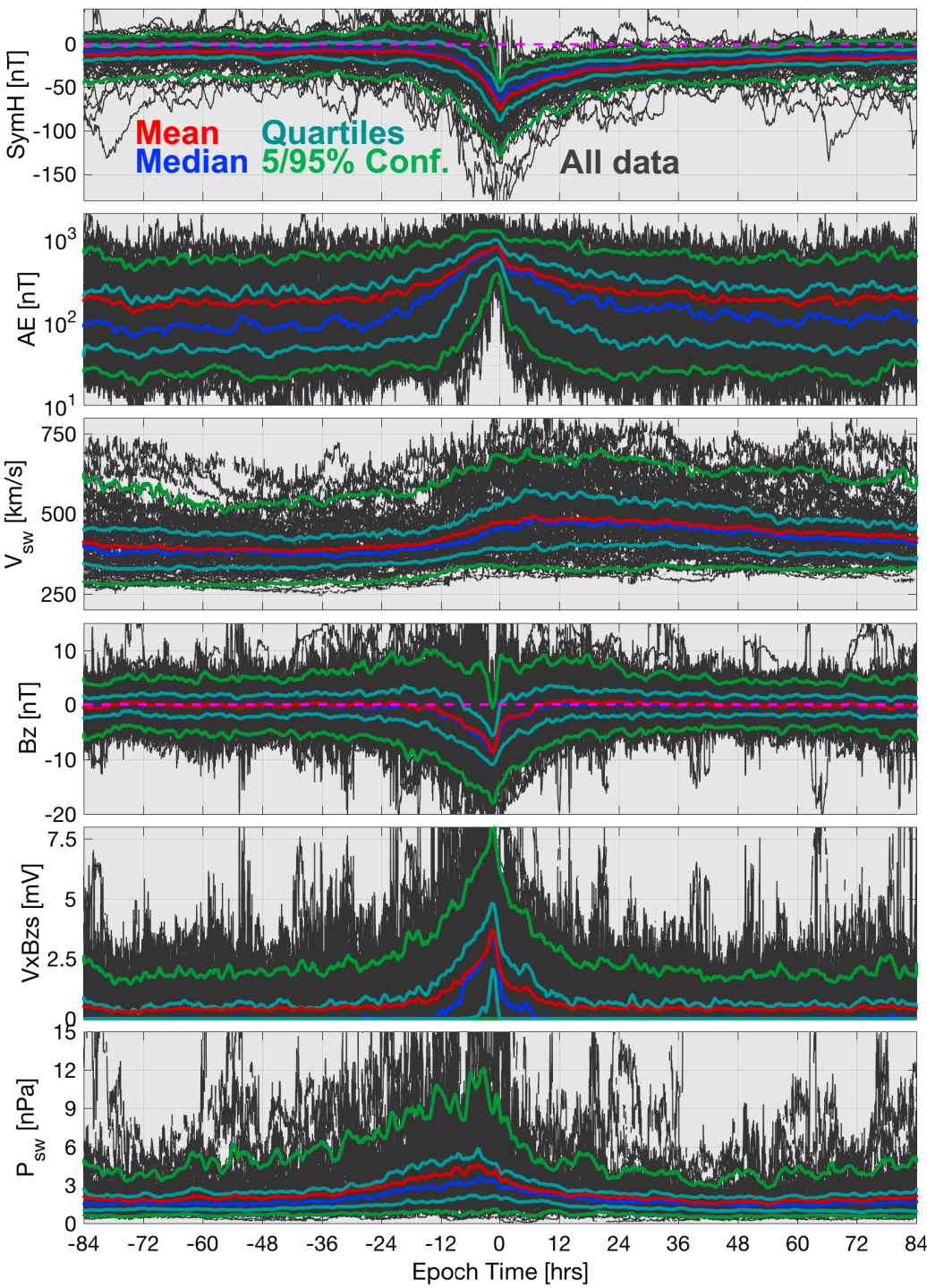
Mean Response to All Storms





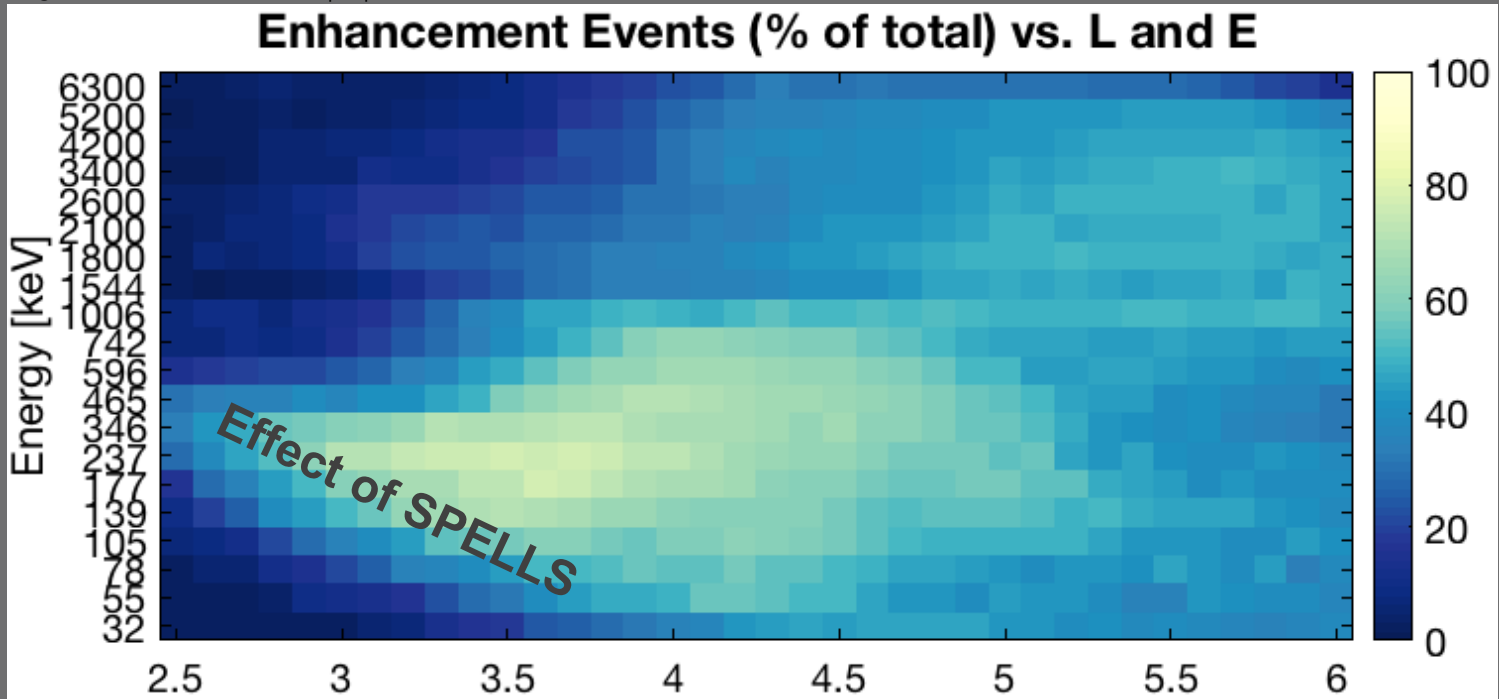
Driving Conditions for SPELLS

Solar wind and geomagnetic conditions: Statistics

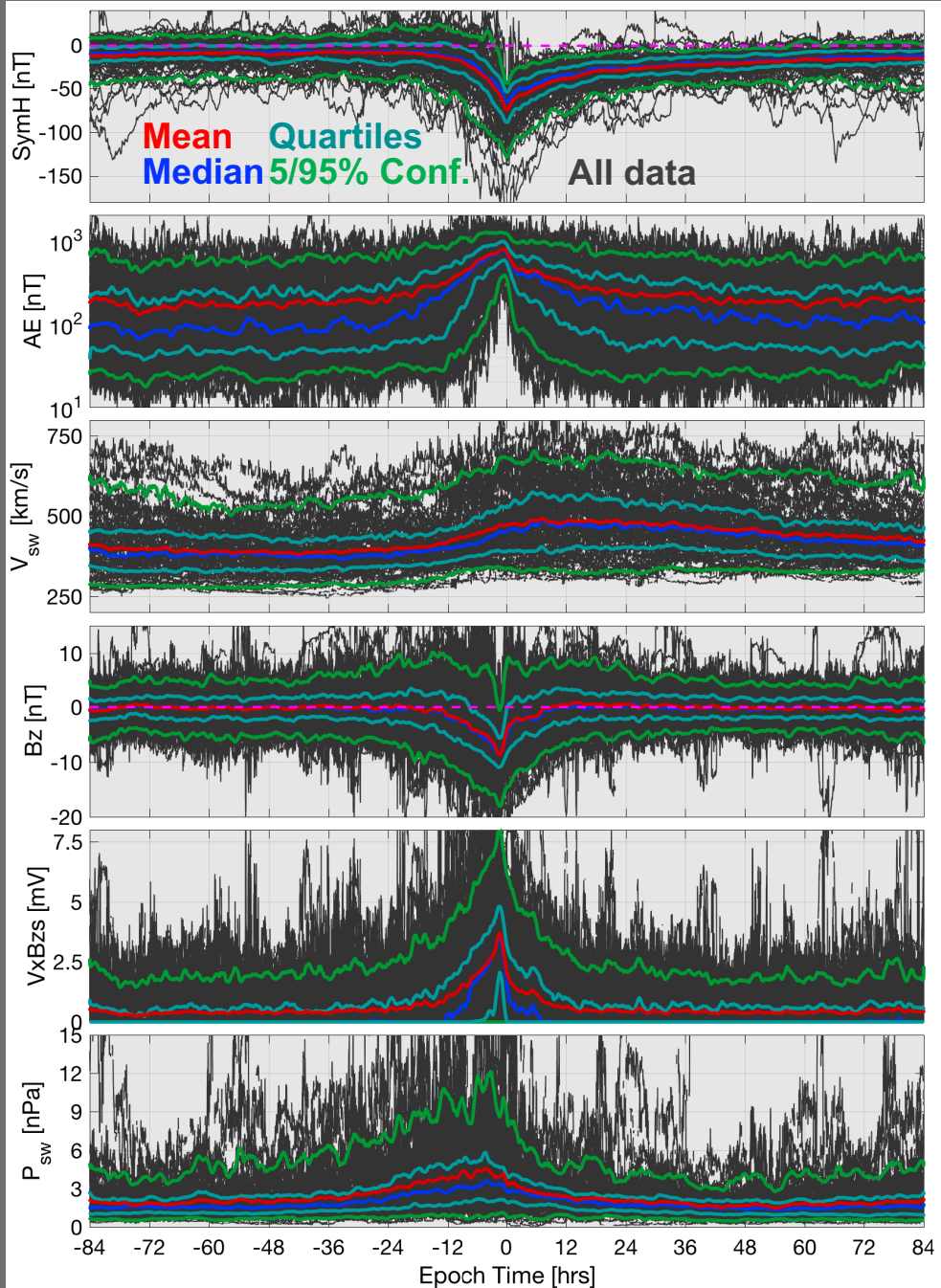


- Are there any quantities that distinguish between those events that:
 - Result in SPELLS?
 - Result in the highest energy SPELLS?
- This study is ongoing...

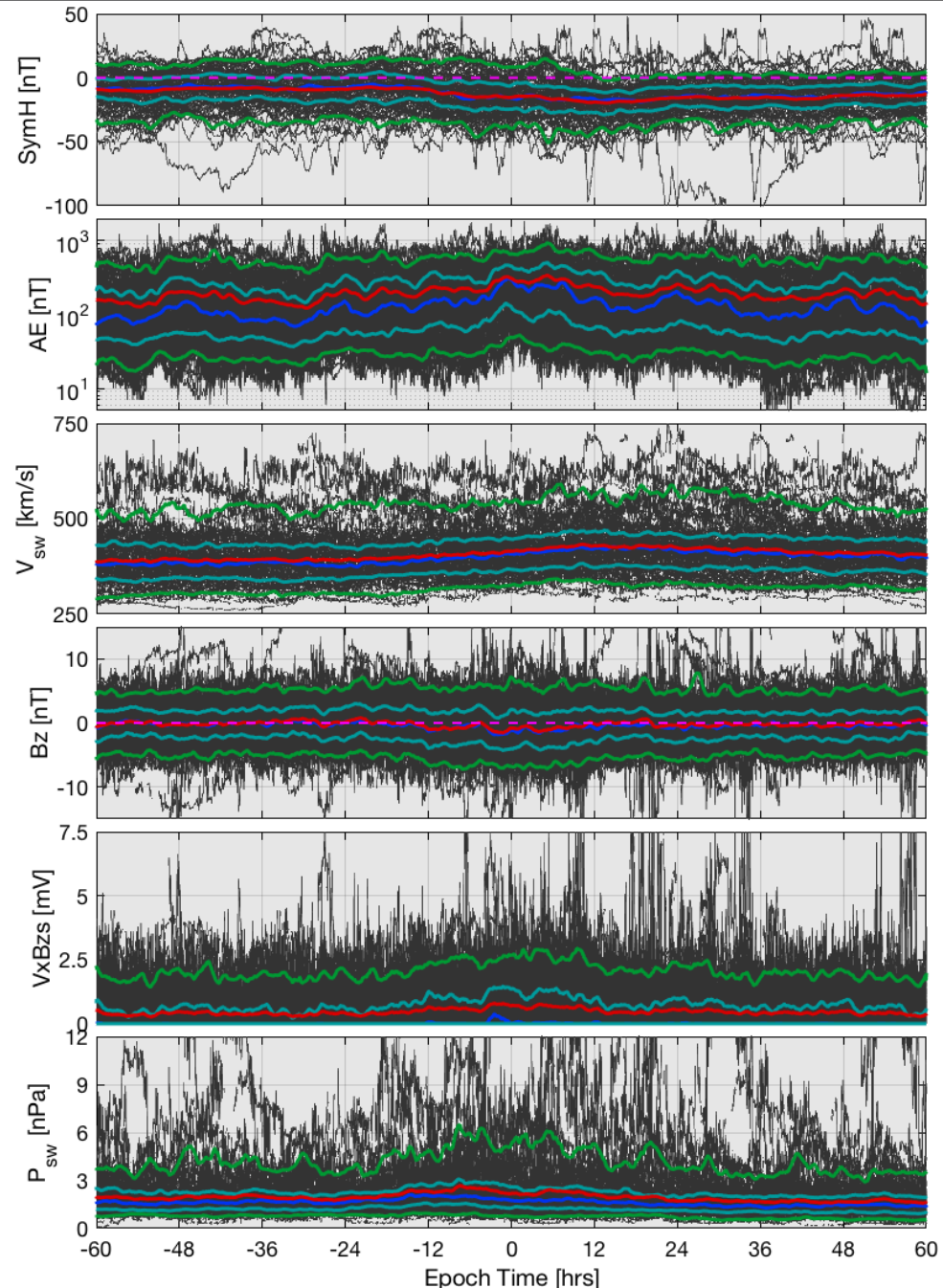
Figures from Turner et al. [in prep.]



110 Storms



143 SPELLS



Solar Wind Driving

Comparing SPELLS to Storms

Nothing really clear for SPELLS here... even when only for subset of >200 keV SPELLS



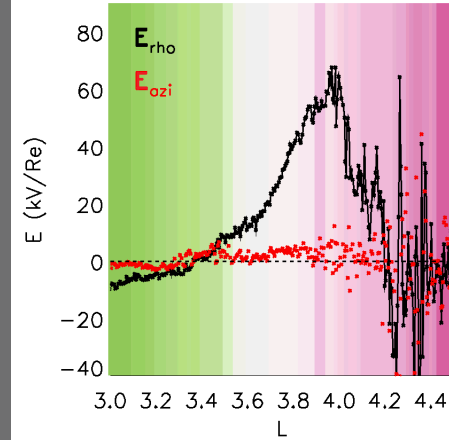
SAPS and SPELLS

All credit here to Solene Lejosne at Berkeley

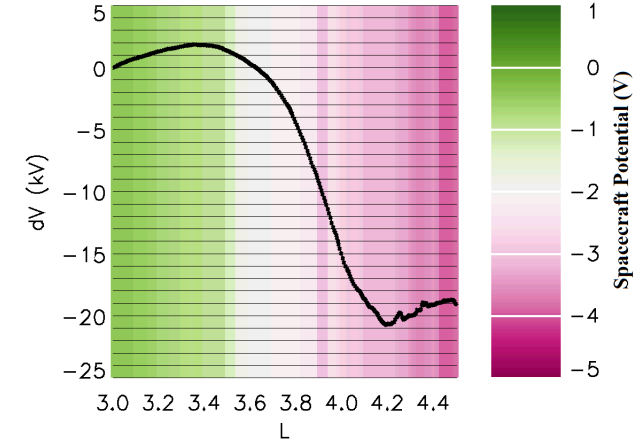
- Sub-Auroral Polarization Streams involve a radial E-field enhancement localized in the evening MLT sector during active periods
 - SAPS potential drops up to 10s of kV (how much stronger?)
 - E-field the correct orientation to result in electron motion inward (acceleration) and protons outward (deceleration): species dependent, consistent with SPELLS
 - SAPS are localized in MLT, consistent with SPELLS
- SAPS and SPELLS are correlated...

Van Allen Probe B, 1 March 2013 15:10 UT

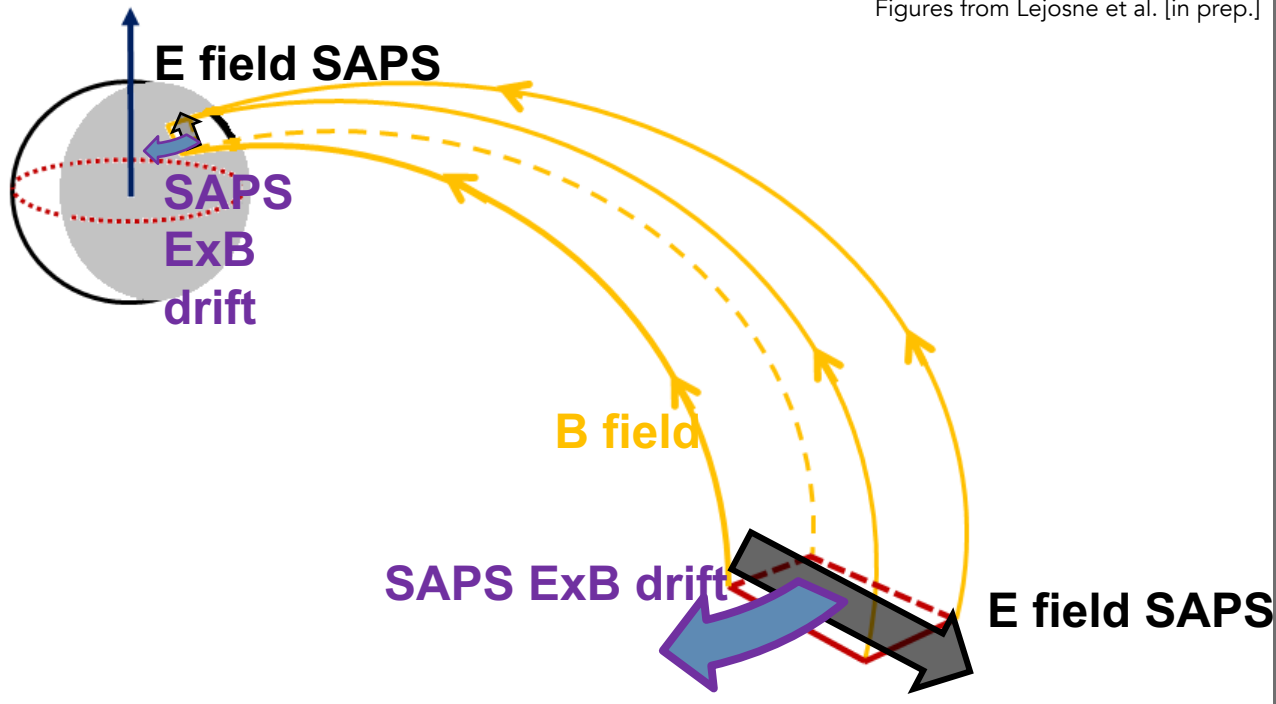
a) Components of the Electric Field



b) Estimation of the Potential Drop



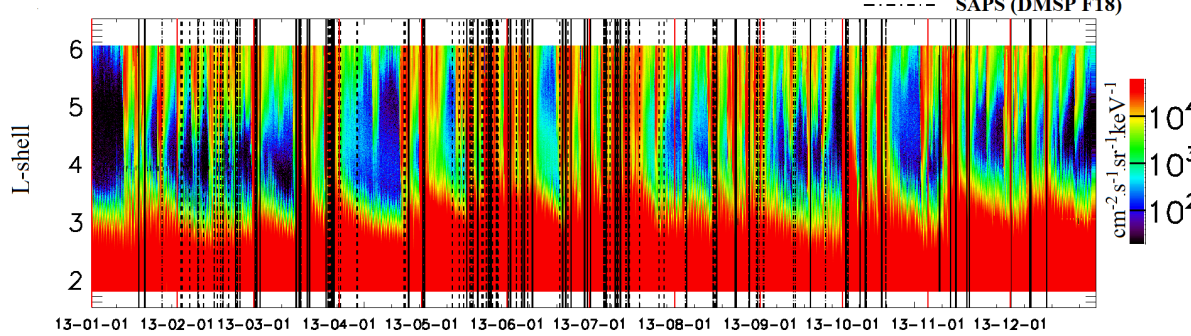
Figures from Lejosne et al. [in prep.]



SAPS provide best hypothesis yet for SPELLS... but much work yet to be done to support this

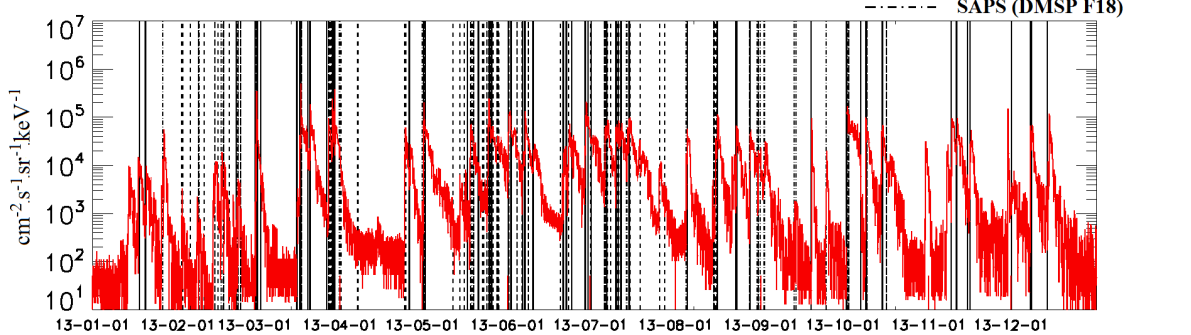
a)

110 keV electron flux



b)

110 keV electron flux at L=4





Conclusions

SPELLS and electrons in Earth's inner radiation belt

- SPELLS occur during active conditions in Earth's magnetosphere
 - *Their occurrence rate is exponentially higher for electrons at lower energies, down to at least 100 keV*
 - *They can occur independent of geomagnetic storms*
 - *They are not the result of inward radial diffusion or enhanced global convection*
- *The responsible physical mechanism is still unidentified, but it must be an energy and species dependent process that is localized in MLT [Turner et al., GRL 2015; Zhao et al., JGR 2017]*
- *SPELLS are the dominant source of 10s of keV to ~1 MeV electrons in Earth's inner radiation belt [Turner et al., JGR 2016]*
- The studies of preferential driving conditions and the underlying mechanism is ongoing... could they result from SAPS E-fields???