



Substorm-associated effects in the variations of low energy electron fluxes in the inner magnetosphere: Does the substorm's strength matter?

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**Unsolved Problems in Magnetospheric Physics
Workshop, Scarborough UK, September 6-12, 2015**



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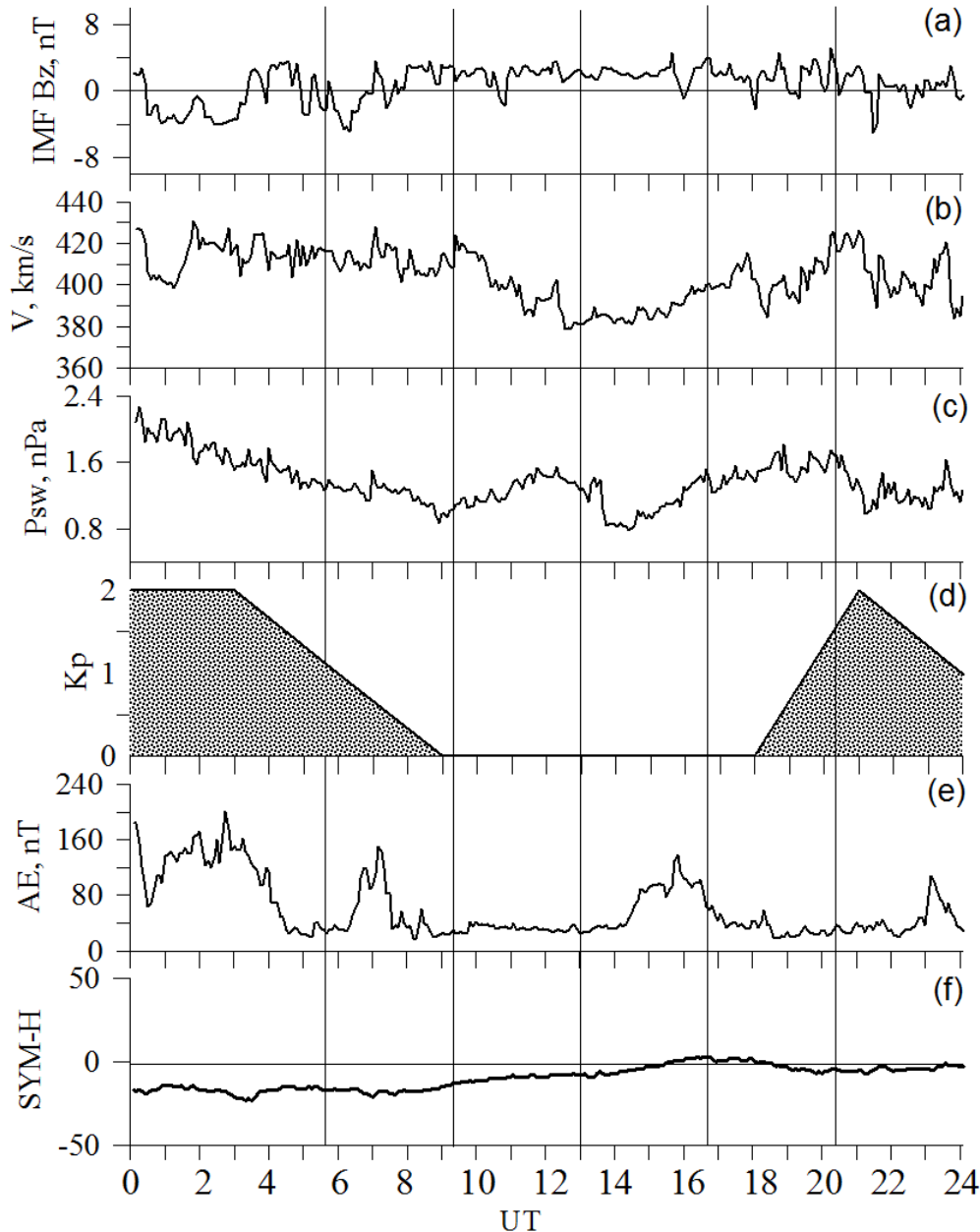
Why are we interested in low energy electrons (< 200 keV) in the inner magnetosphere?

- The distribution of low energy electrons, the seed population (10 to few hundreds of keV), is critically important for radiation belt dynamics.
- Chorus emissions (intense whistler mode waves) excited in the low-density region outside the plasmapause are associated with the injection of keV plasma sheet electrons into the inner magnetosphere.
- Surface charging by electrons with < 100 keV can cause significant damage and spacecraft anomalies.
- The electron flux at the keV energies is largely determined by convective and substorm-associated electric fields and varies significantly with geomagnetic activity driven by the solar wind – **variations on time scales of minutes!**
No averaging over an hour/day/orbit!

It is not easy to model (nowcast) and forecast low energy electrons

- Following low energy electrons in large-scale **magnetic and electric fields**:
Correct models for these fields are extremely hard to develop
- Specification of a correct **initial conditions in the plasma sheet** is very nontrivial
- **Coefficients for radial diffusion** when electrons move from the plasma sheet ($10 R_e$) to inner regions ($<6 R_e$) are far from being exact.
- How to introduce low energy electrons' losses correctly? Electron lifetimes due to interactions with chorus and hiss, other waves, are they important?
- **MAIN FACTOR: SUBSTORMS.**
Substorms play a significant role in keV **electron transport and energy increase.**
How to include them properly?

November 25, 2011

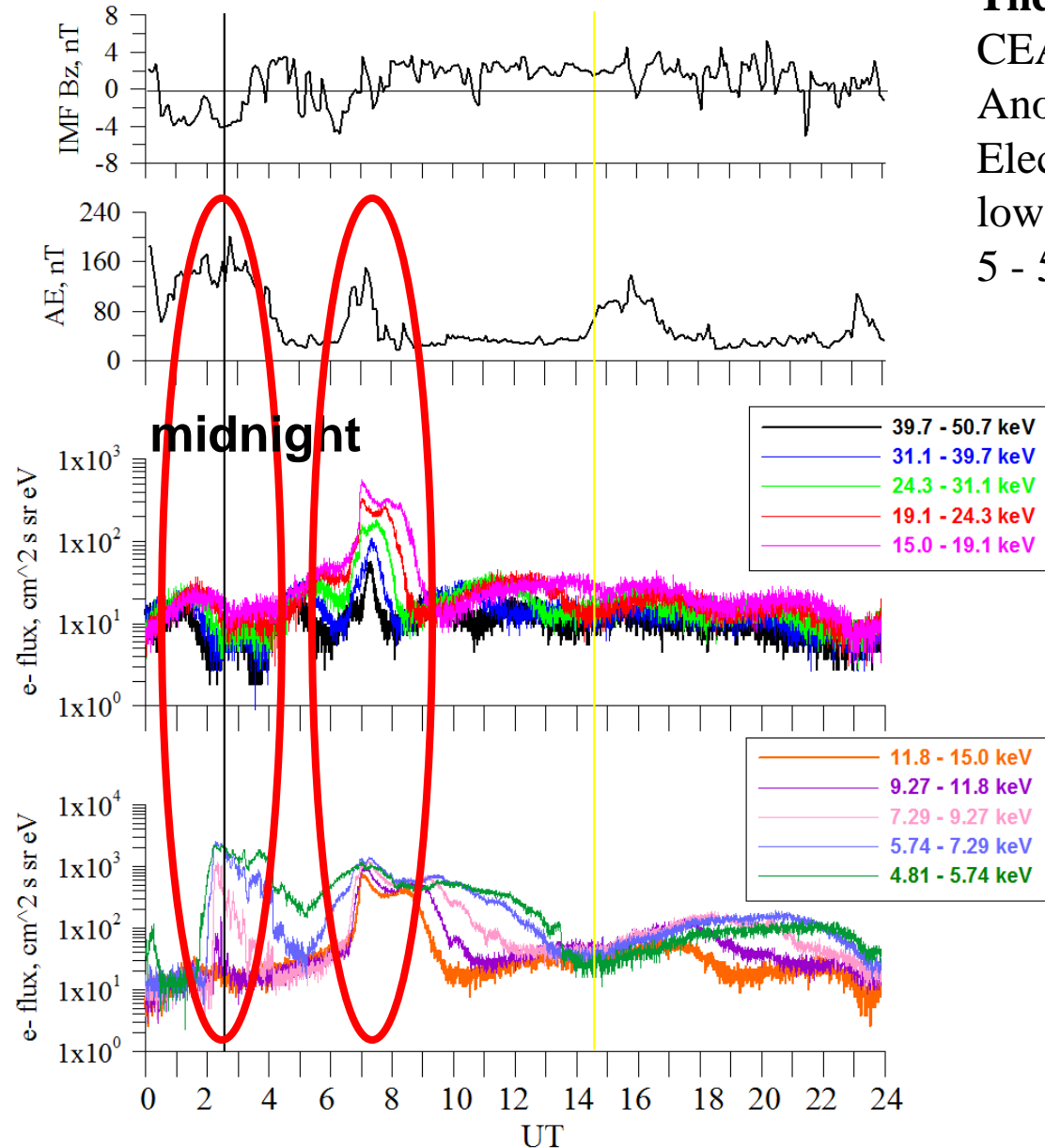


**No storm is needed
for 2-3 orders of
magnitude increase
of low energy electron
fluxes at
geostationary orbit**

Rather quiet event

5-50 keV electrons during quiet event

November 25, 2011



The data: AMC 12 geostationary satellite, CEASE-II (Compact Environmental Anomaly Sensor) instrument with Electrostatic Analyzer (ESA) for measuring low energy electron fluxes in 10 channels, 5 - 50 keV.

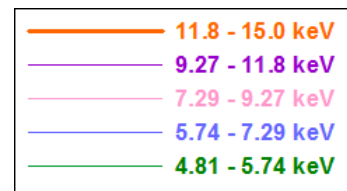
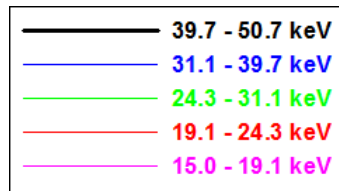
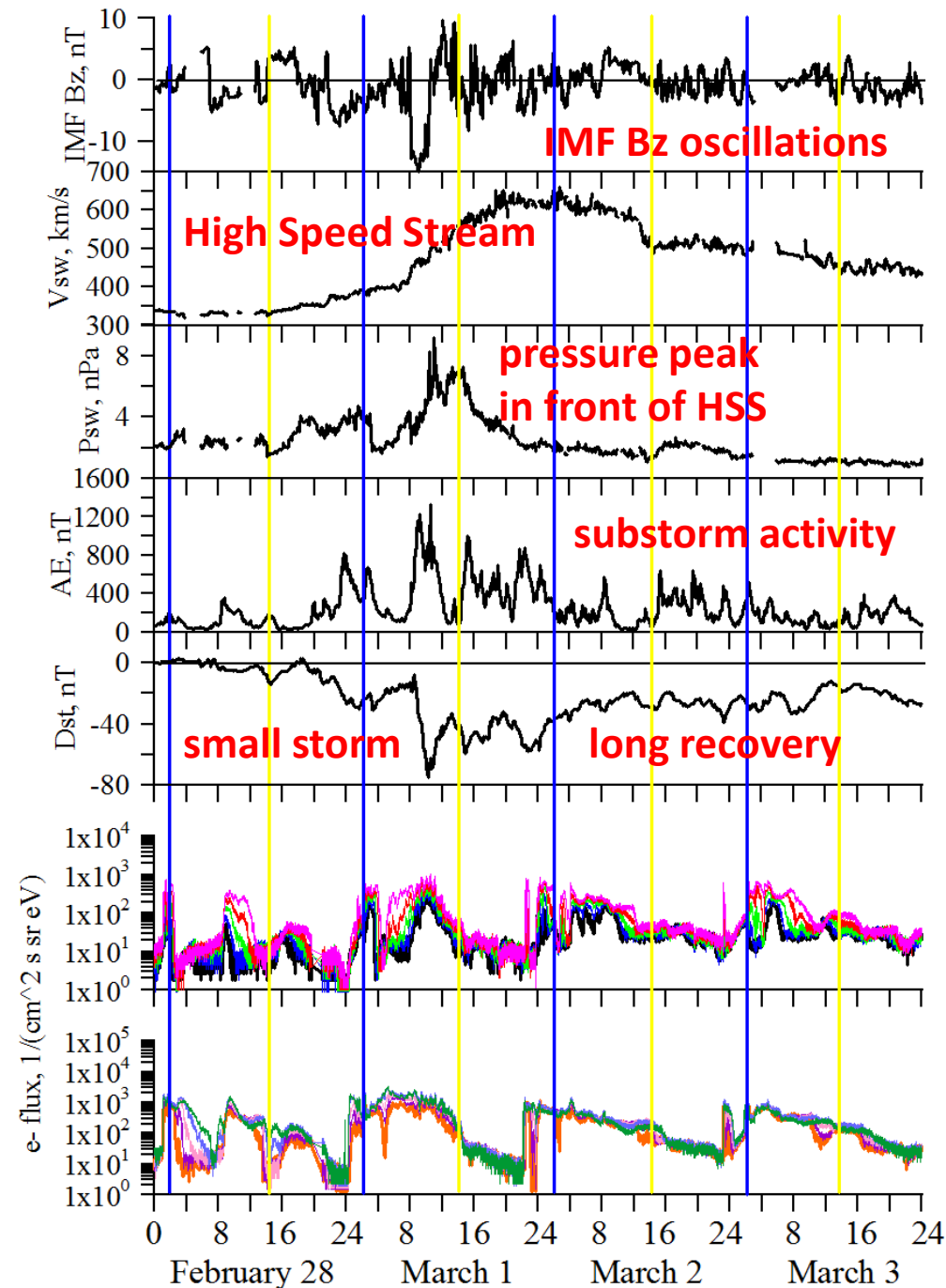
- **Flux increases** are related to **AE peaks** only (less than 200 nT, small, isolated substorms)
- The lower the energy, the larger the flux
- Electrons of different channels behaves differently:
 - 1st peak (AE=200 nT) at midnight seen for energies > 11 keV
 - 2nd peak (AE=120 nT) at dawn, increase in all energies

Not a unique case

February 28 - March 3, 2013

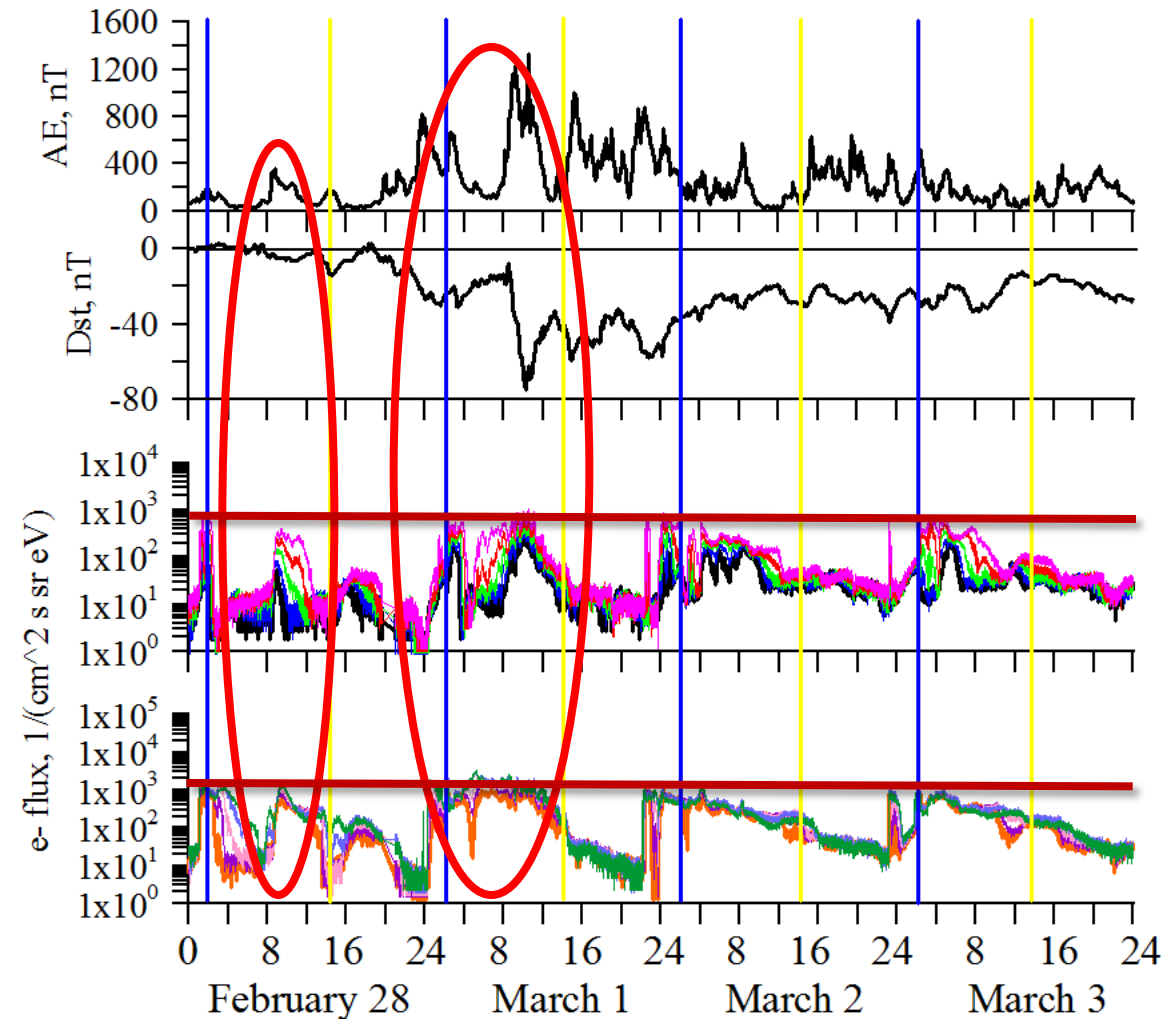
CIR-driven storm

Small, CIR-driven storm with
Dst of 75 nT,
IMF Bz of -5 -10 nT,
Vsw from 350 to 650 km/s,
Psw peak at 8 nPa,
AE peaks of 800-1200 nT



Similar increase in electron fluxes during AE = 400 nT and AE=1200 nT

February 28 - March 3, 2013



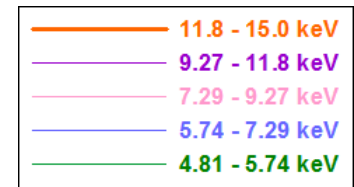
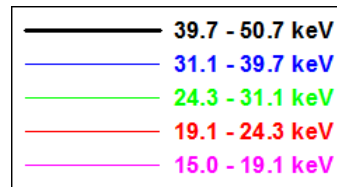
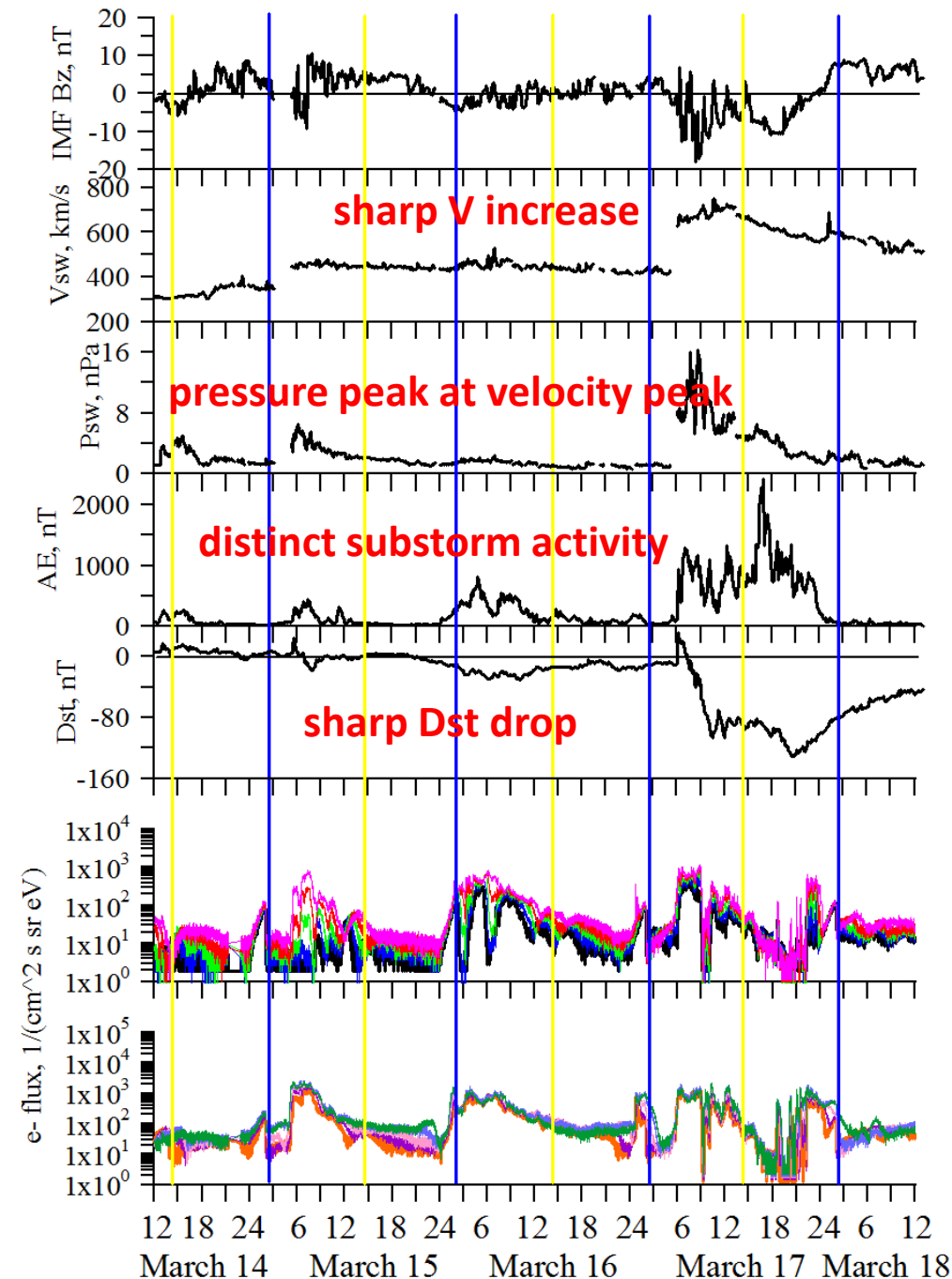
AMC12 electron data

- peaks in both 15-50 keV and 5-15 keV electron fluxes show correlation with AE
- 2 orders of magnitude increase
- all energies increase at midnight, when AE is only 200 nT
- same order of increase for AE = 800 nT and even for 1200 nT

March 14-18, 2013

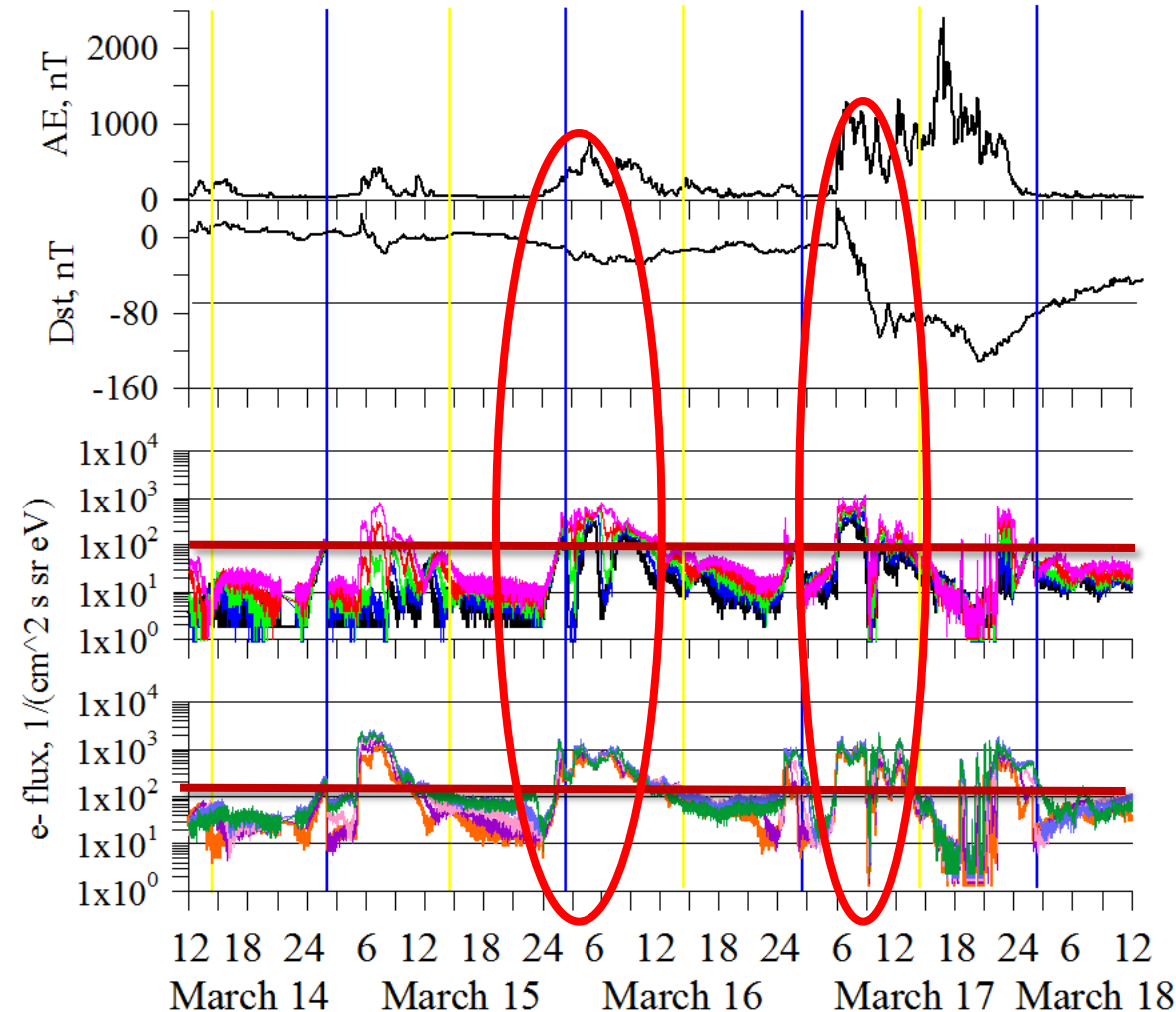
CME-driven storm

Moderate, CME-driven storm
with **Dst** of **130 nT**,
IMF Bz reaching **-20 nT**,
Vsw from 400 to 700,
Psw peak at 16 nPa,
AE peaks of 1000-2500 nT



Similar increase in electron fluxes during AE = 500 nT and AE=1500 nT

March 14-18, 2013

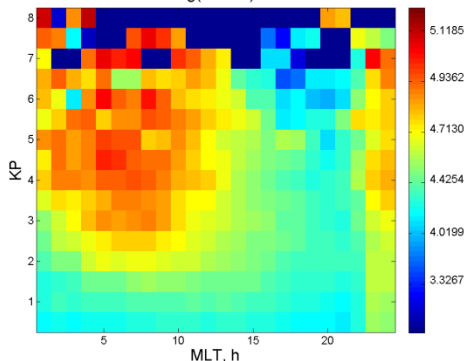


AMC12 electron data

- peaks in both 15-50 keV and 5-15 keV electron fluxes show clear correlation with AE peaks
- 2 orders of magnitude increase
- during quiet period before storm peaks with AE = 500 nT similar to peaks with AE over 1000 nT at storm time

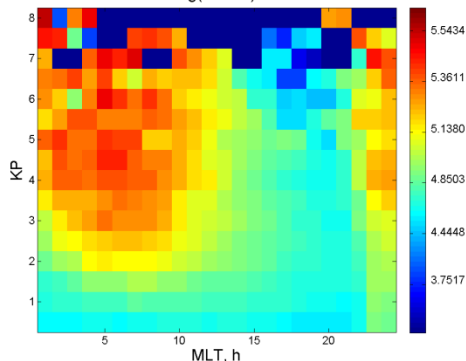
39.7-50.7 keV

log(FLUX0)



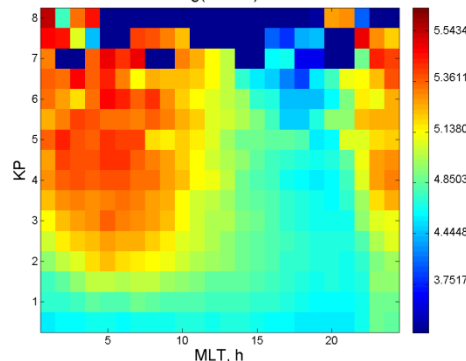
31.1-39.7 keV

log(FLUX1)



24.3-31.1 keV

log(FLUX2)



Log(flux)

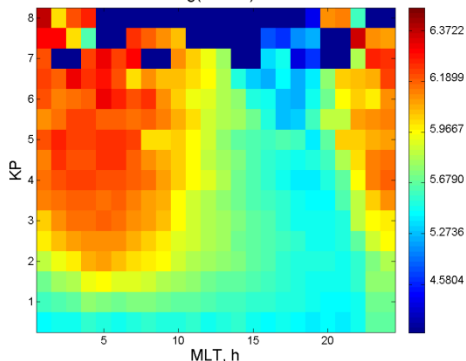
Flux(MLT, Kp)

**Can we state
that low energy
electron fluxes
are organized
by Kp?**

**Kp:
3 hour index**

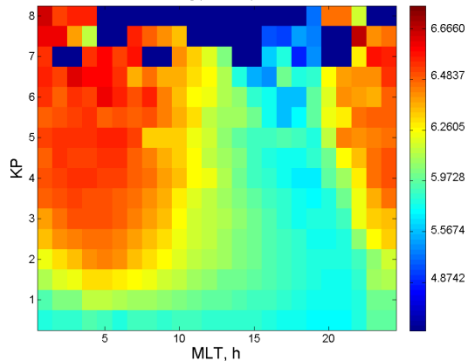
19.1-24.3 keV

log(FLUX3)



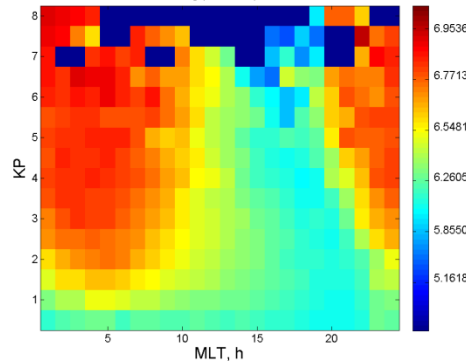
15.0-19.1 keV

log(FLUX4)



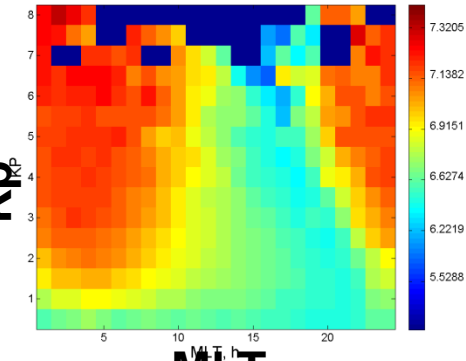
11.8-15.0 keV

log(FLUX5)



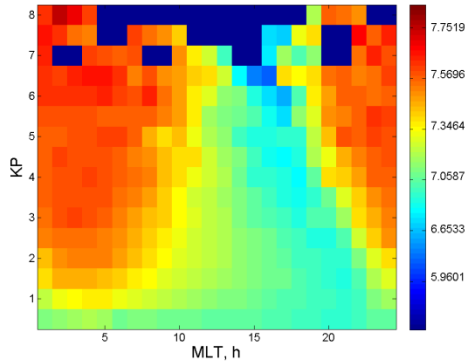
9.27-11.8 keV

log(FLUX6)



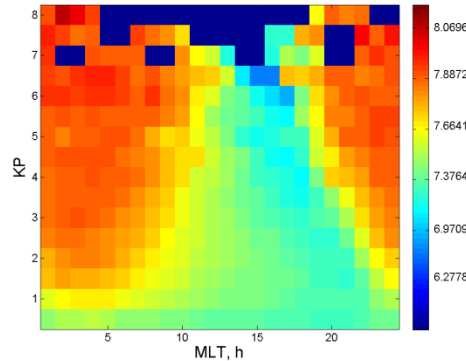
7.29-9.27 keV

log(FLUX7)



5.74-7.29 keV

log(FLUX8)

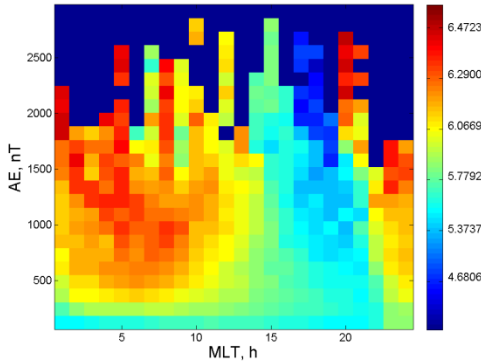


Kp

MLT

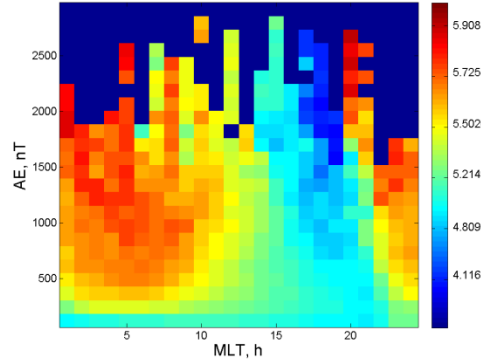
39.7-50.7 keV

log(FLUX0)



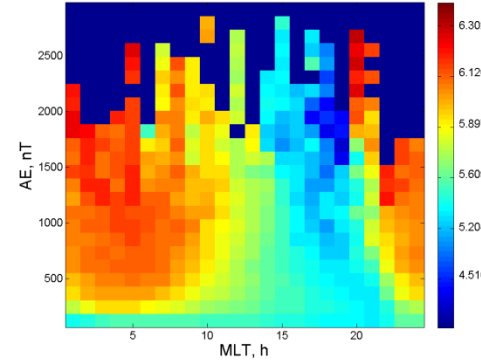
31.1-39.7 keV

log(FLUX1)



24.3-31.1 keV

log(FLUX2)



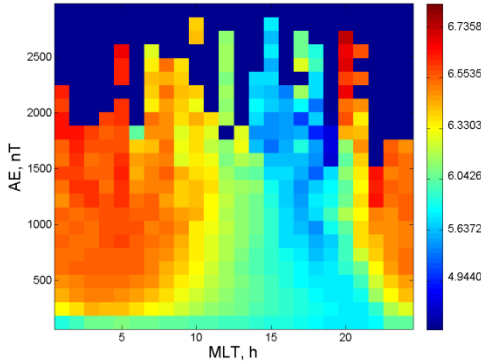
Log(flux)

Flux(MLT, AE)

The higher the energy, the less distributed the flux peak

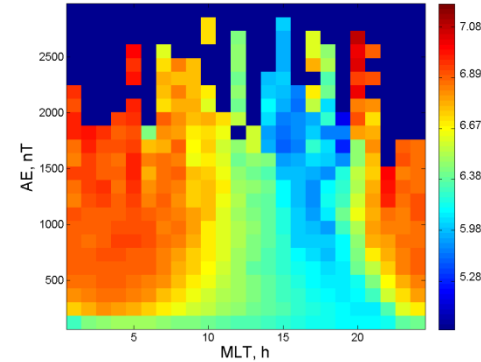
19.1-24.3 keV

log(FLUX3)



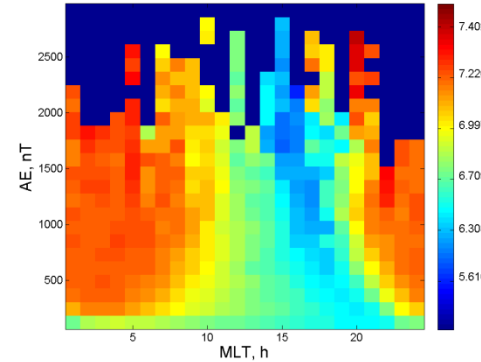
15.0-19.1 keV

log(FLUX4)



11.8-15.0 keV

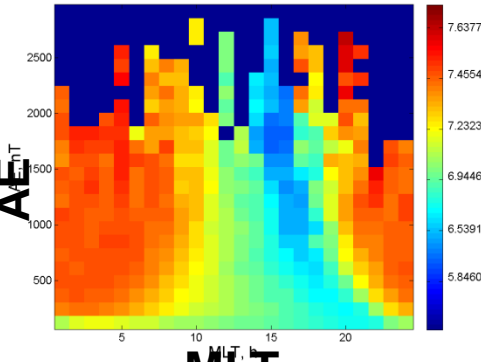
log(FLUX5)



No distinct dependence on AE strength

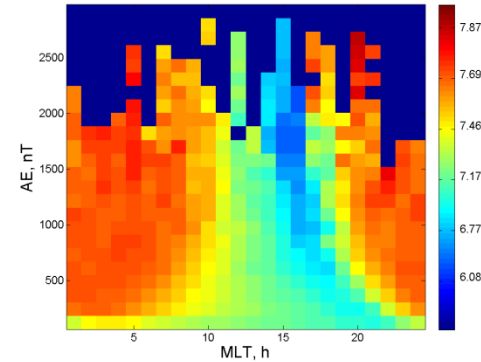
9.27-11.8 keV

log(FLUX6)



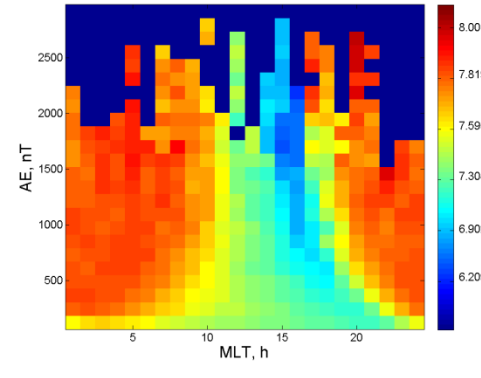
7.29-9.27 keV

log(FLUX7)

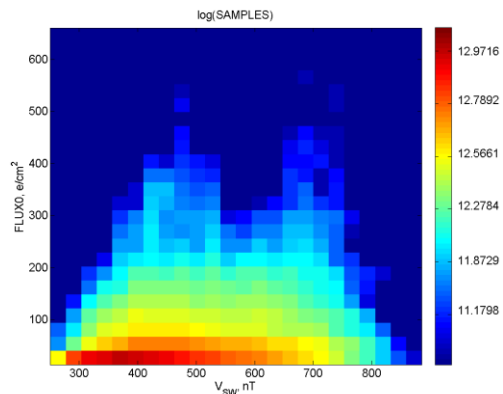


5.74-7.29 keV

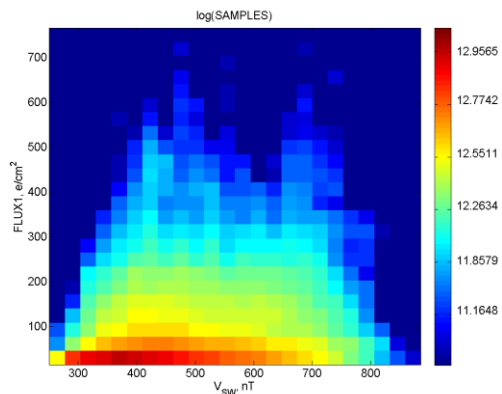
log(FLUX8)



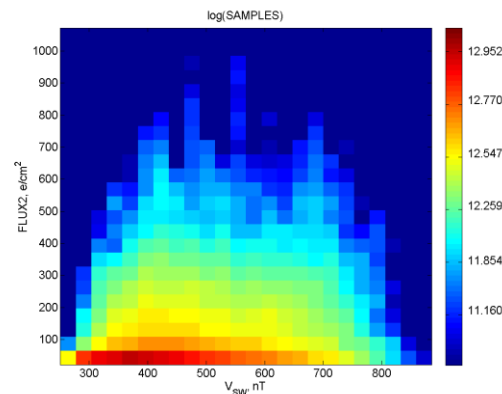
39.7-50.7 keV



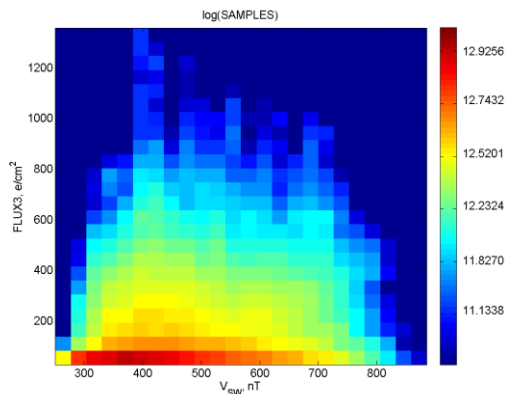
31.1-39.7 keV



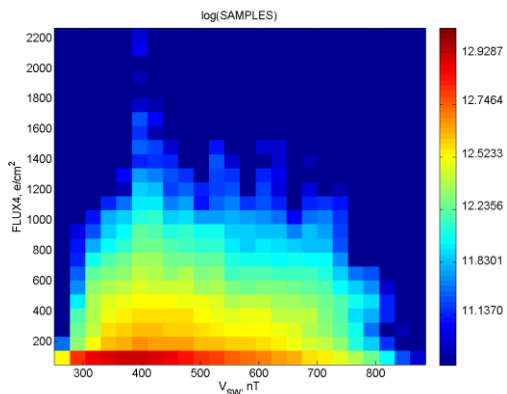
24.3-31.1 keV Log(samples)



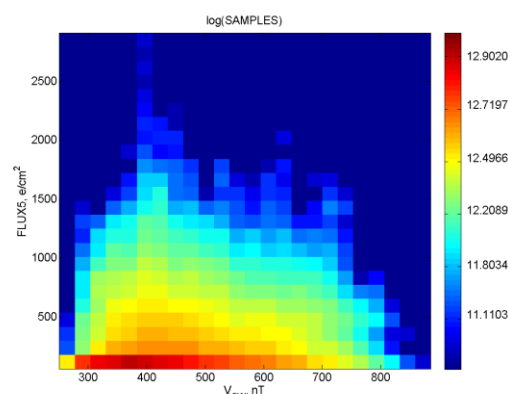
19.1-24.3 keV



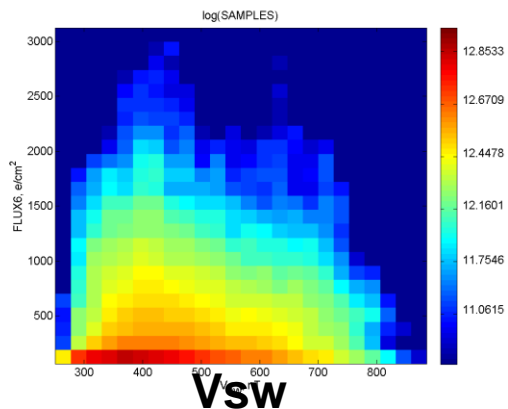
15.0-19.1 keV



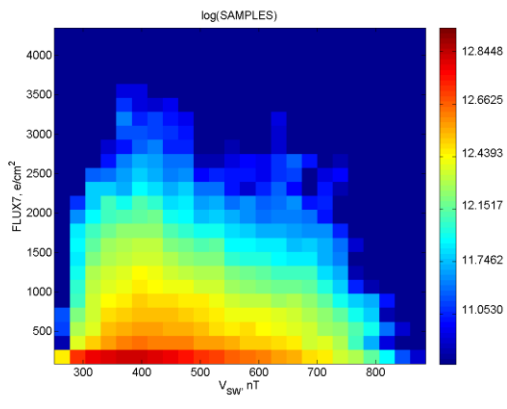
11.8-15.0 keV



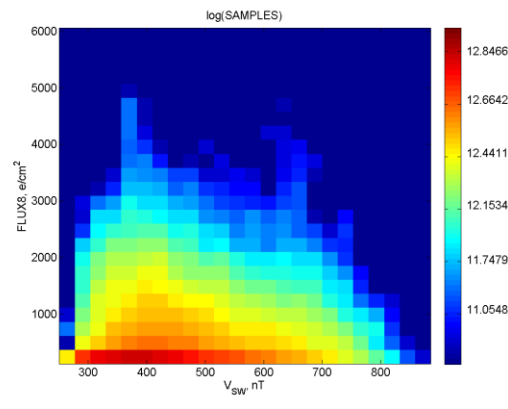
9.27-11.8 keV



7.29-9.27 keV



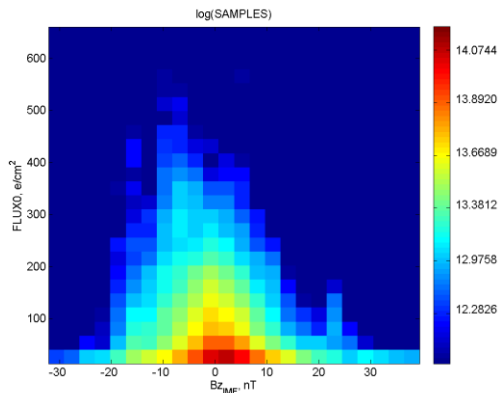
5.74-7.29 keV



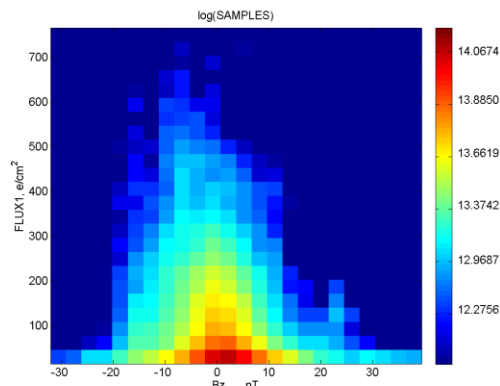
flux

Vsw

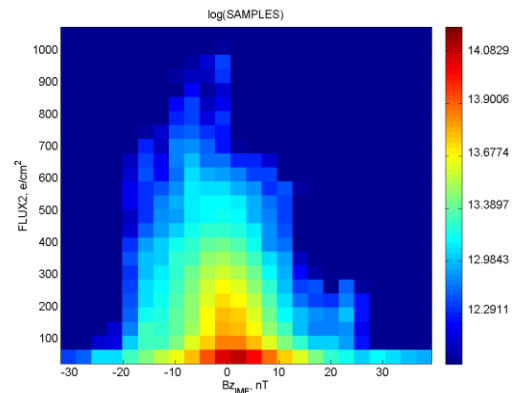
39.7-50.7 keV



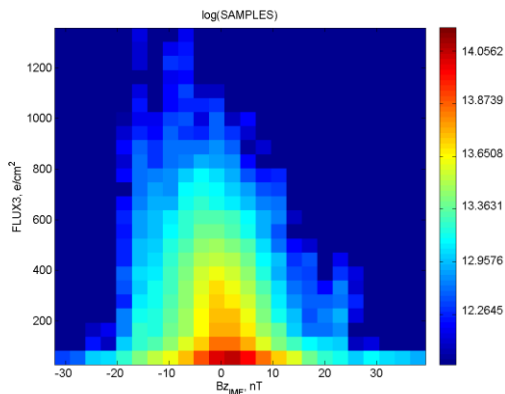
31.1-39.7 keV



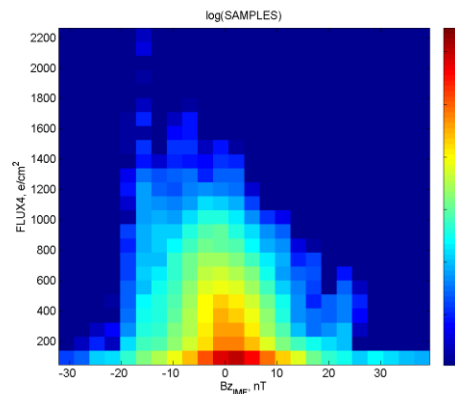
24.3-31.1 keV Log(samples)



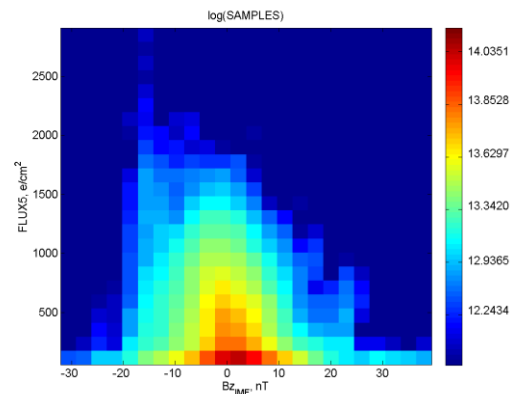
19.1-24.3 keV



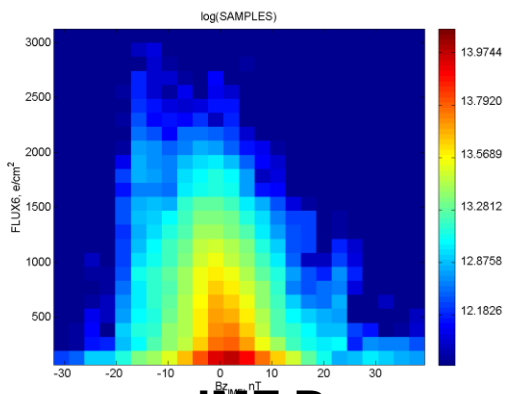
15.0-19.1 keV



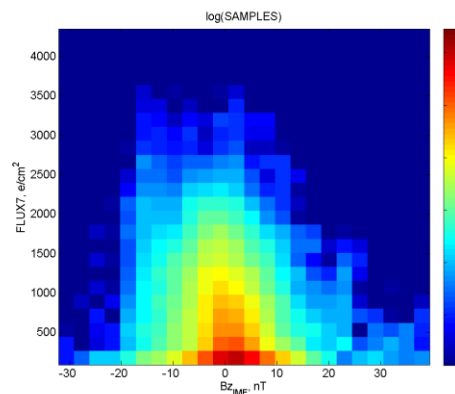
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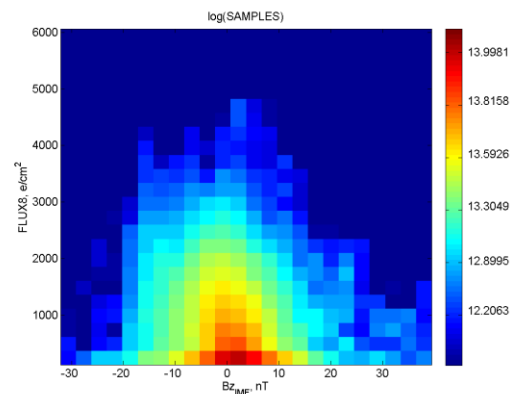
9.27-11.8 keV



7.29-9.27 keV



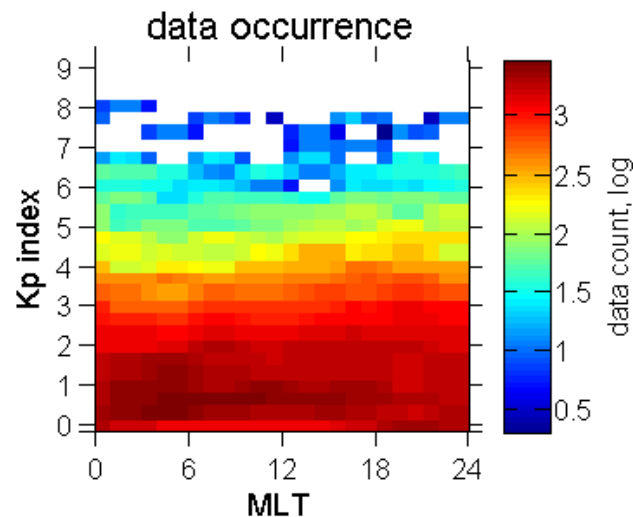
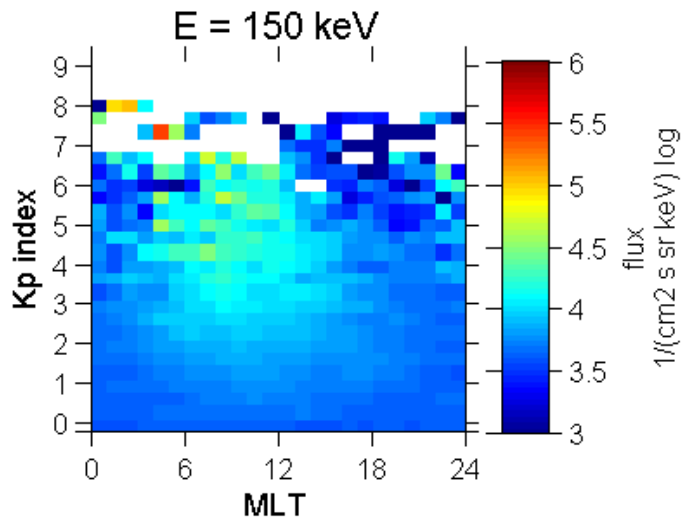
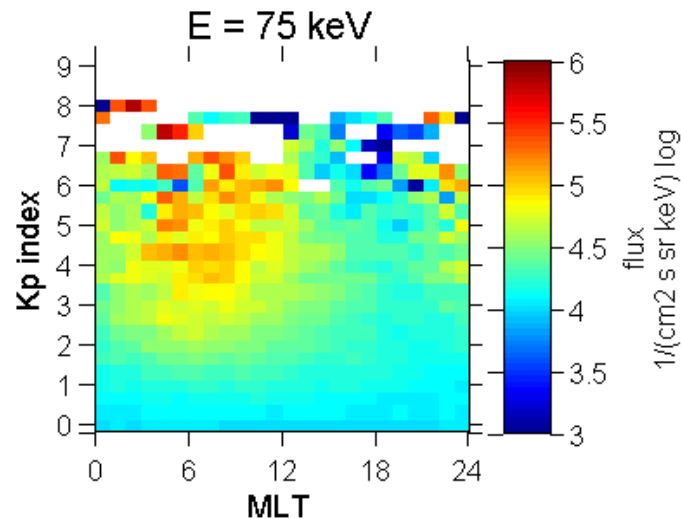
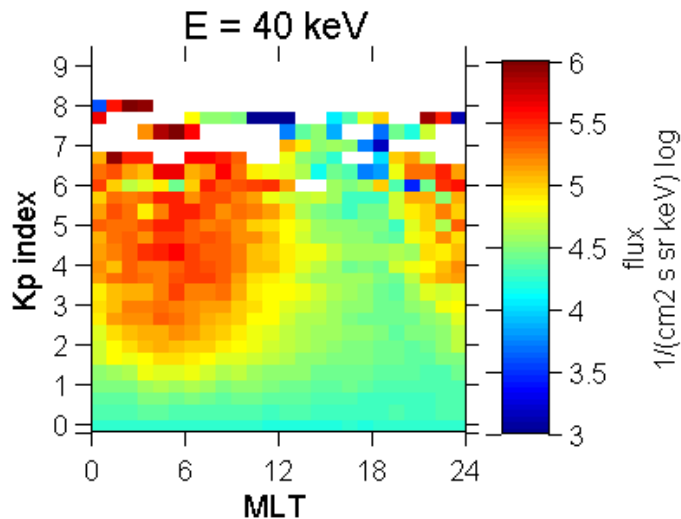
5.74-7.29 keV



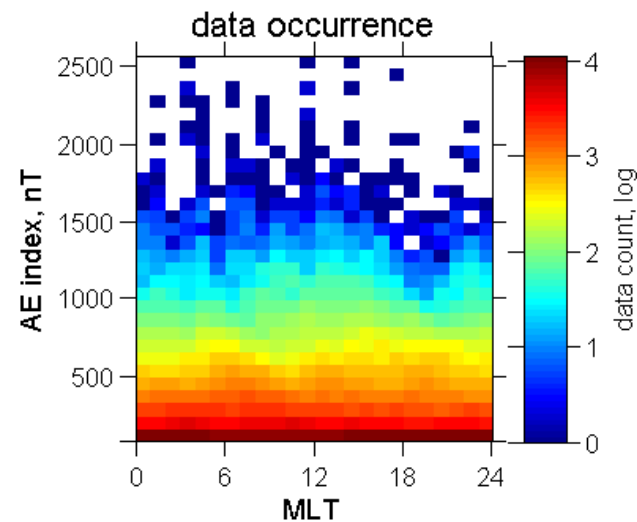
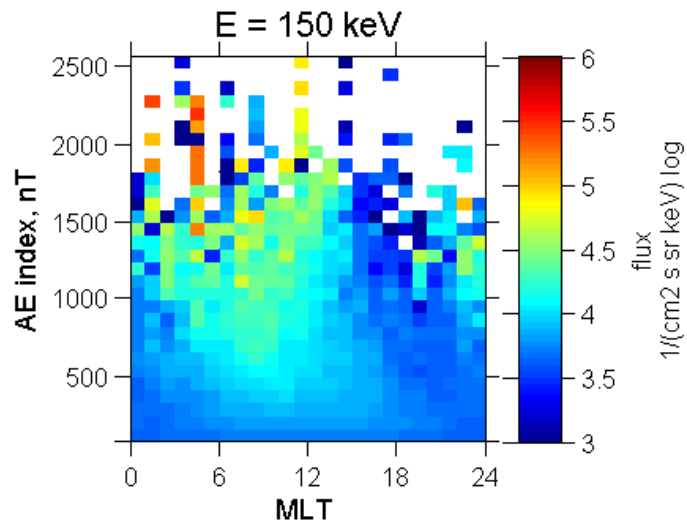
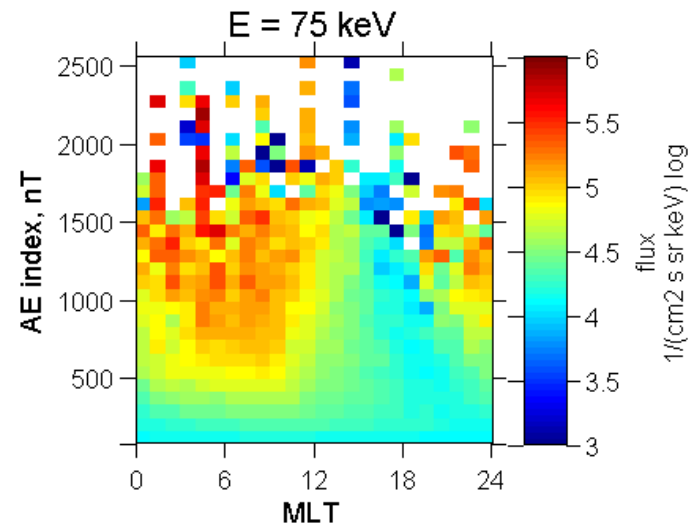
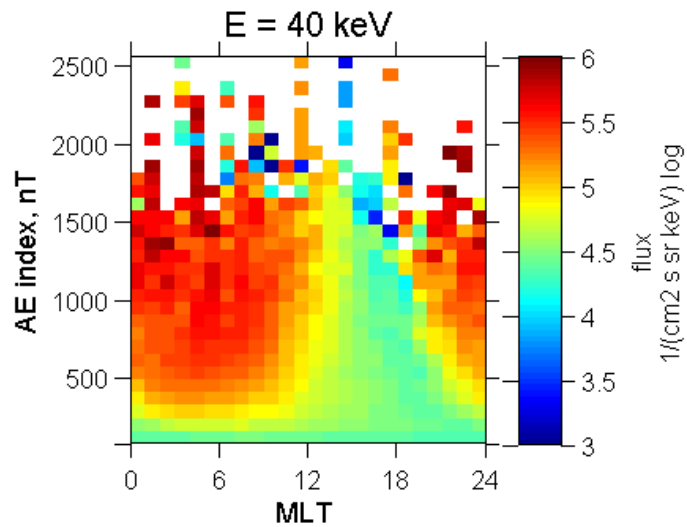
IMF Bz

flux

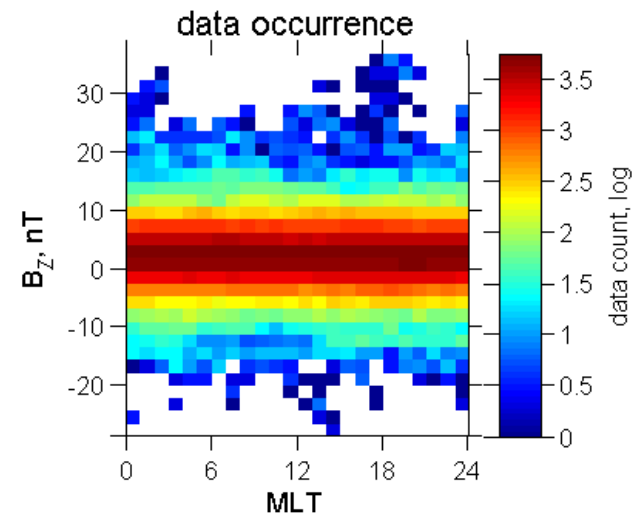
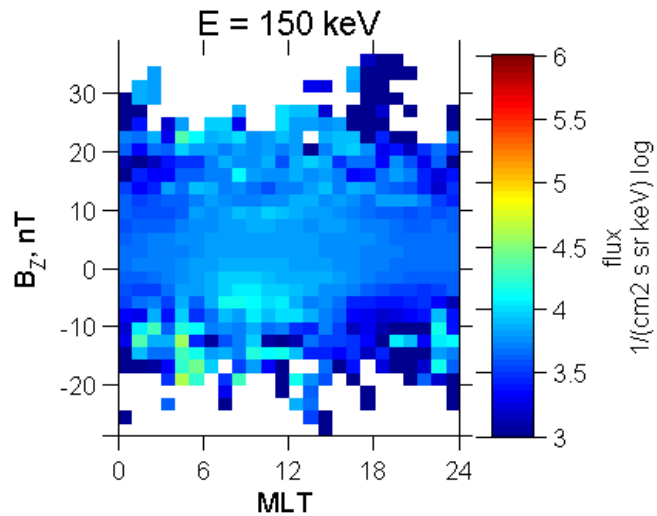
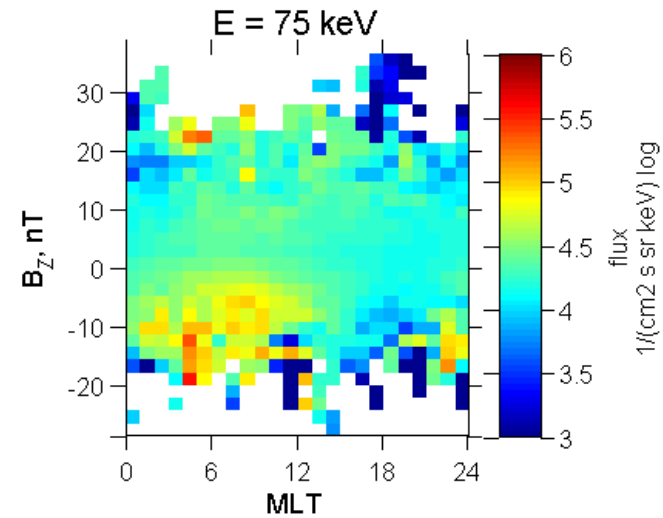
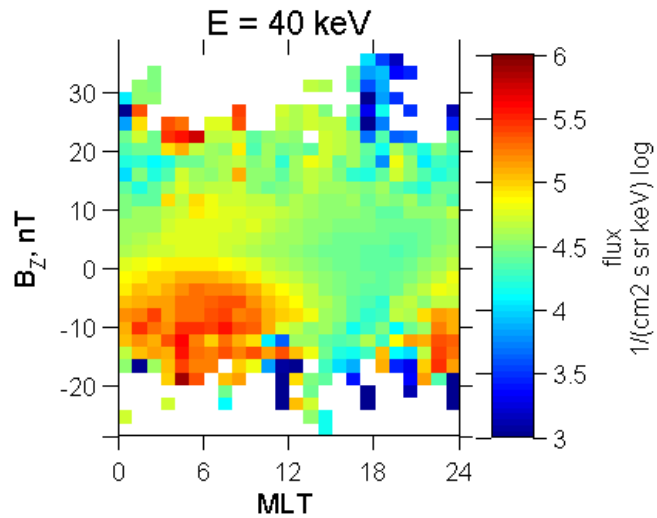
GOES 13 MAGED electron fluxes (MLT, Kp)



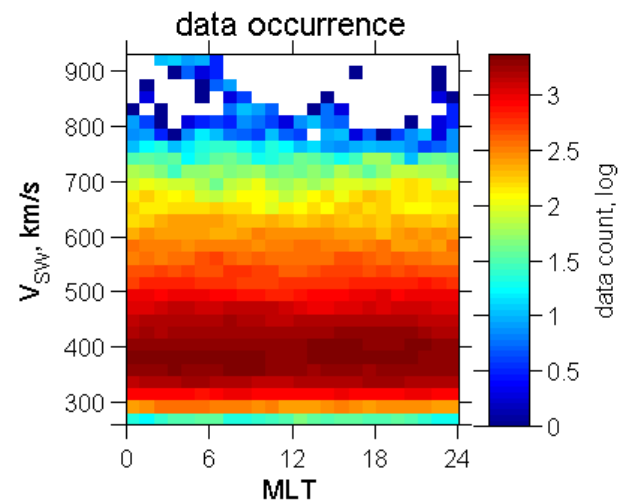
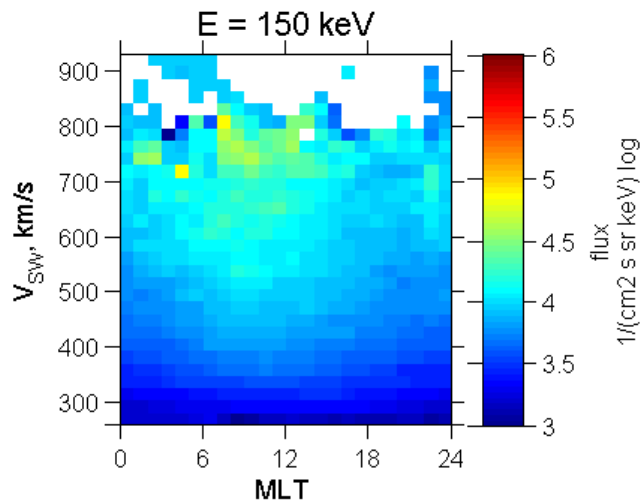
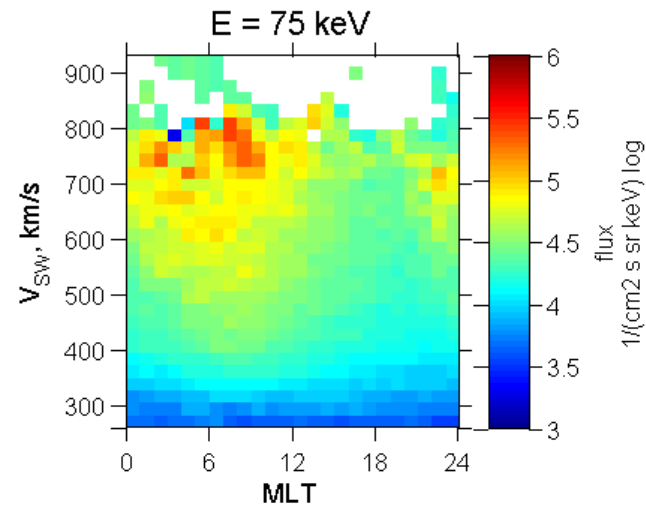
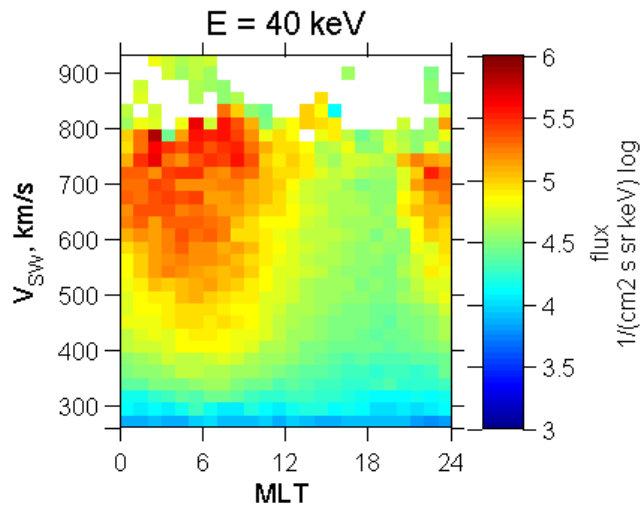
GOES 13 MAGED electron fluxes (MLT, AE)



GOES 13 MAGED electron fluxes (MLT, IMF Bz)



GOES 13 MAGED electron fluxes (MLT, Vsw)



GOES 13 MAGED electron fluxes, development of empirical model

$$q_{\text{EMP}} = a1 \cdot 10^{V_{\text{SW}}} \cdot (a2 \cdot \text{sMLT} + a3 \cdot \text{cMLT} + a4) \\ + b1 \cdot \exp\left(-\frac{|\text{MLT} - b2|}{5} - \left(\frac{B_z + 11}{6}\right)^2\right) \\ + c1 \quad (3)$$

Here

$$\text{sMLT} = \sin\left(\frac{\pi}{12} \cdot \text{MLT}\right) \quad (4)$$

$$\text{cMLT} = \cos\left(\frac{\pi}{12} \cdot \text{MLT}\right) \quad (5)$$

???

1. Electron (<200 keV) transport from the near-Earth plasma sheet to geostationary (inside) can not be modeled, even if particles move in IMF and SW dependent electromagnetic fields and boundary conditions, even during rather quiet times.
2. Need to include substorms. How?
3. Like electromagnetic pulse (great review given in Christine Gabrielse's talk)? What are the parameters? Most probably, not the amplitude. Location? MLT-width?
4. Do we need different representations for different types of substorms (isolated substorms, storm-time substorms)?
5. Low energy electrons (at geostationary) are not organized by AE, KP-organization misses dynamics, IMF BZ and V_{sw} are main parameters. For specific events: See 1. Present IMF and SW dependent models fail to represent the observed peaks associated with substorm activity (?)