# Electric Fields and the Build-up of the Ring Current

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# The Issue

- Inductive vs Convective Electric Fields
  - Inductive: from dB/dt in dipolarizations
    - » Short-lived and spatially localized
  - Convective: from night-to-day B-field pressure gradient
    - » Long-lived and throughout the magnetosphere
- *The big question:*
- What is the relative contribution of convective and inductive electric fields in ring current formation?

# Daglis and Axford [JGR, 1996]

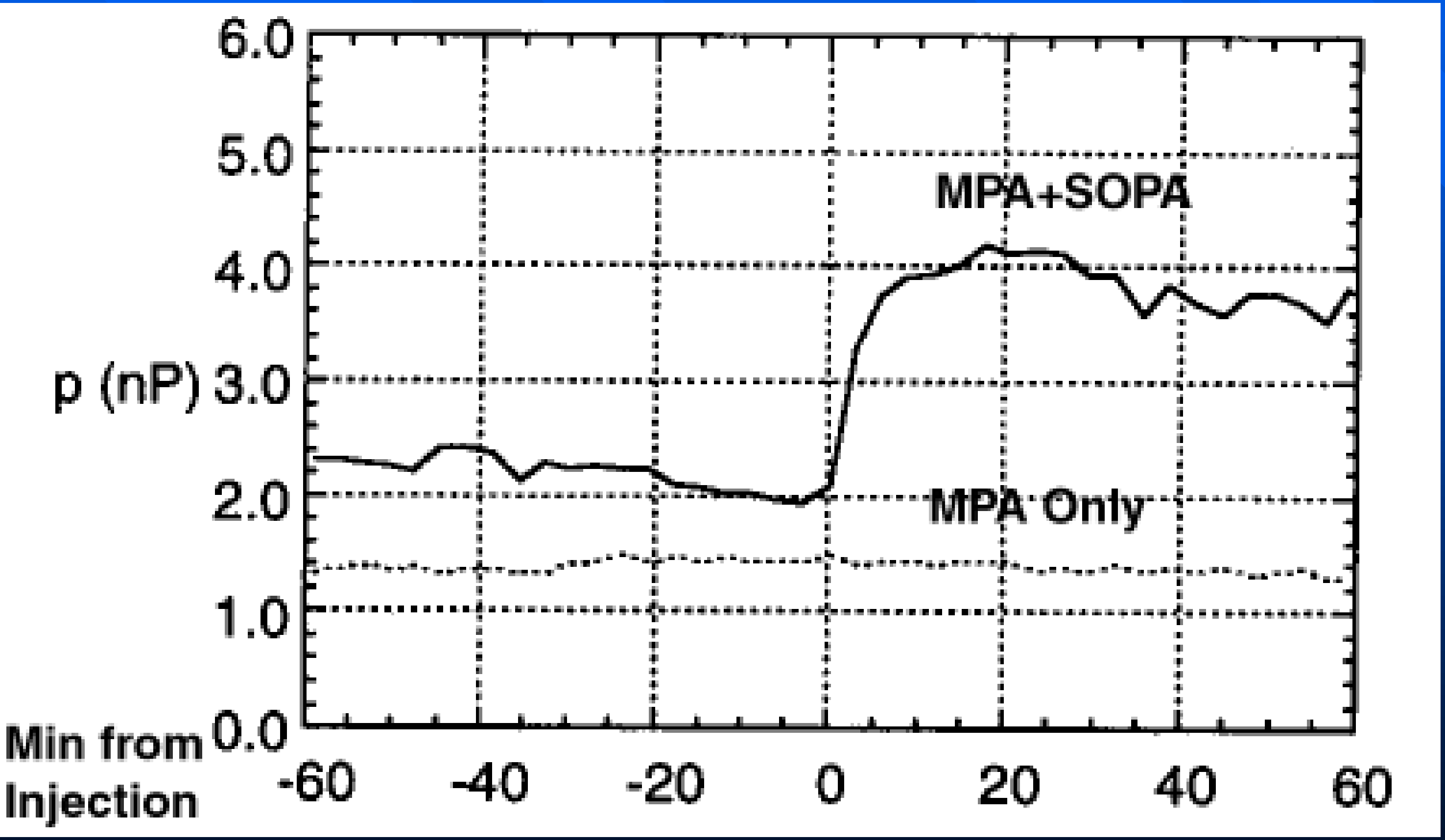
- AMPTE substorm data at 7-9 $R_E$
  - No change at low energies Big change at high energies
  - For both all ion species

# Birn et al. [JGR, 1997a]

- Isolated substorms only influence the SOPA fluxes (E>40 keV) at geosynchronous orbit
  - MPA fluxes (E<40 keV) shows little/no increase

# Birn et al. [JGR, 1997b]

- Confirmed with a superposed epoch study of 58 isolated substorms for 5 LT bins



# McPherron [AGU Mon v98, 1997]

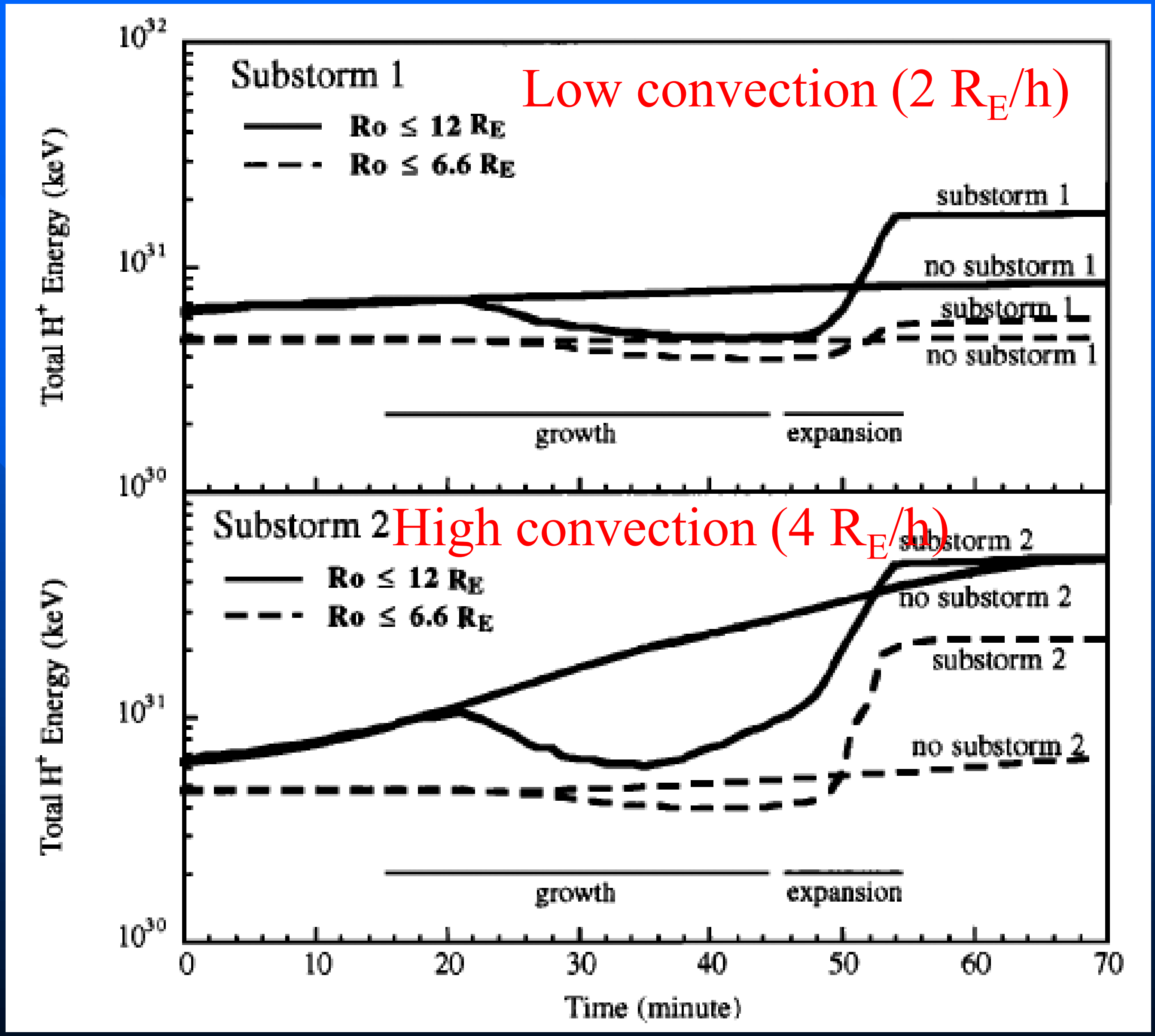
- Prediction efficiencies for Dst' favor convection
  - Removing SW influence, residual AL cannot predict residual Dst'
- Big assumptions here

**Table 1.** Prediction Efficiencies Obtained With Various Input-Output Functions ($\Delta t = 1$ Hr).

| INPUT - OUTPUT | PREDICTION EFFICIENCY |
|---|---|
| Pdyn - Dst | 9% |
| Coup - Dst′ | 76% |
| Coup - AL | 61% |
| Coup - Injection | 49% |
| AL - Dst′ | 71% |
| AL - Injection | 41% |
| Res(AL) - Res(Dst′) | 10% |
| Res(AL) - Res(Injection) | 2% |

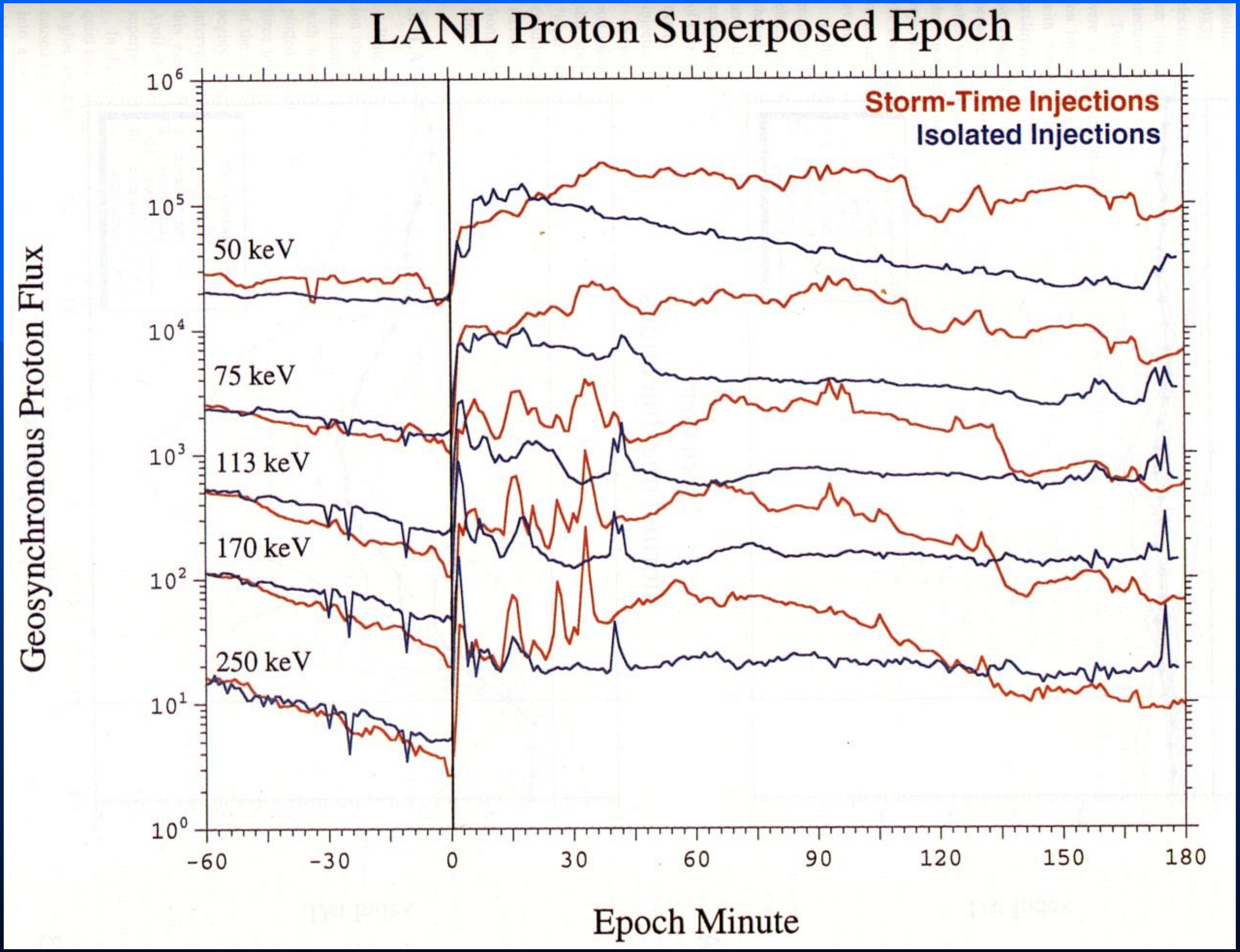
# Fok et al. [JGR, 1999]

- Modeling a storm-time substorm
  - T89 and V-S
- Convection during a substorm helps build the L<6.6 ring current
  - But: only 1 h
- See also: Keller et al. [JGR, 2005]



# Reeves and Henderson [JGR, 2001]

- Storm-time substorm injections vs. isolated injections
  - Similar!
  - Longer lasting flux increases
  - Convective influence?

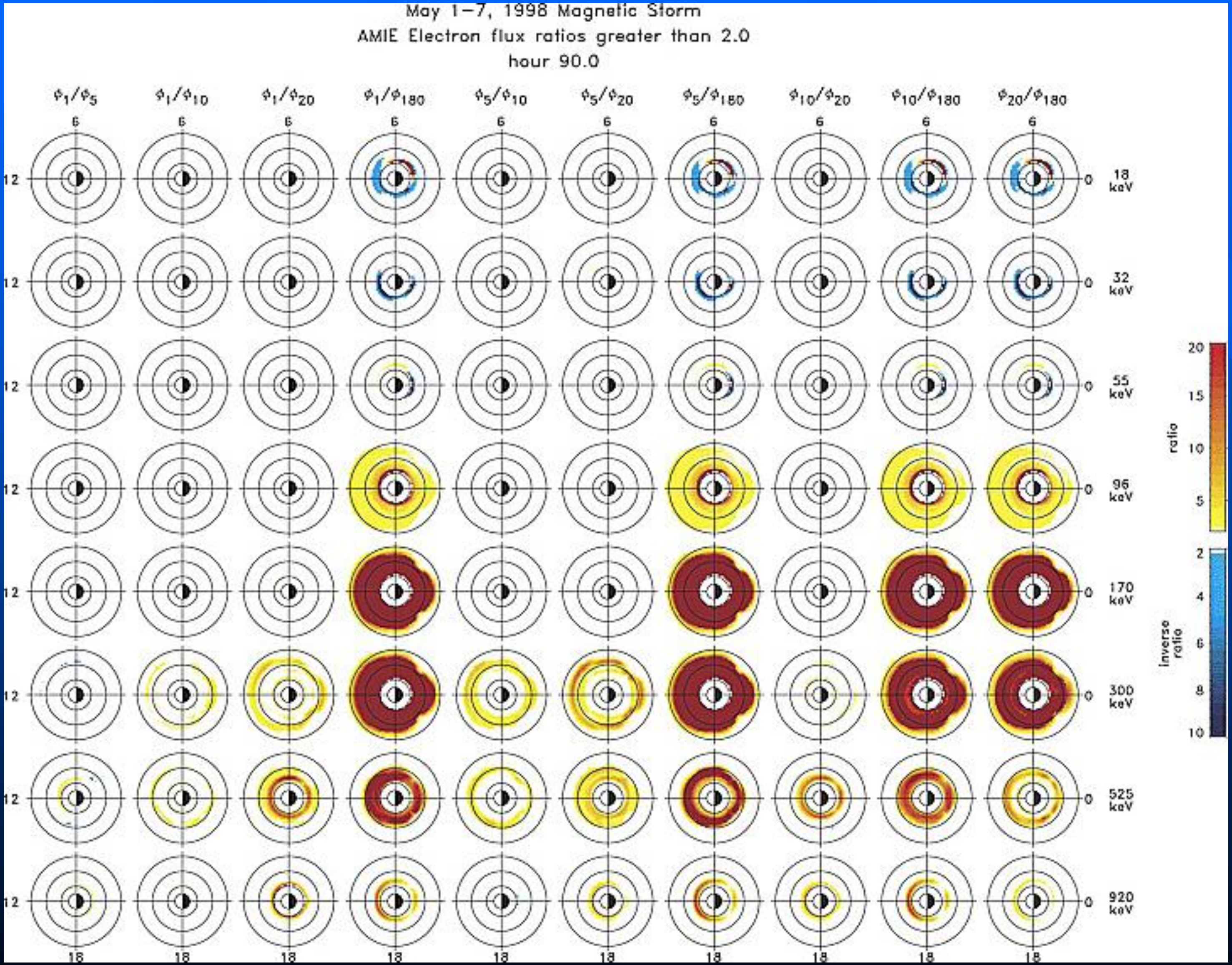


# Khazanov et al. [JGR, 2004]

- Used AMIE potentials to drive a ring current model
  - Used various time-averages of the AMIE potentials:
  - 1, 5, 10, 20, and 180 minutes
  - Calculated ratios the flux results
- Main finding:
  - ≤10-minute AMIE cadence yields significant flux enhancement at 100s of keV
  - Basically no change at lower energies

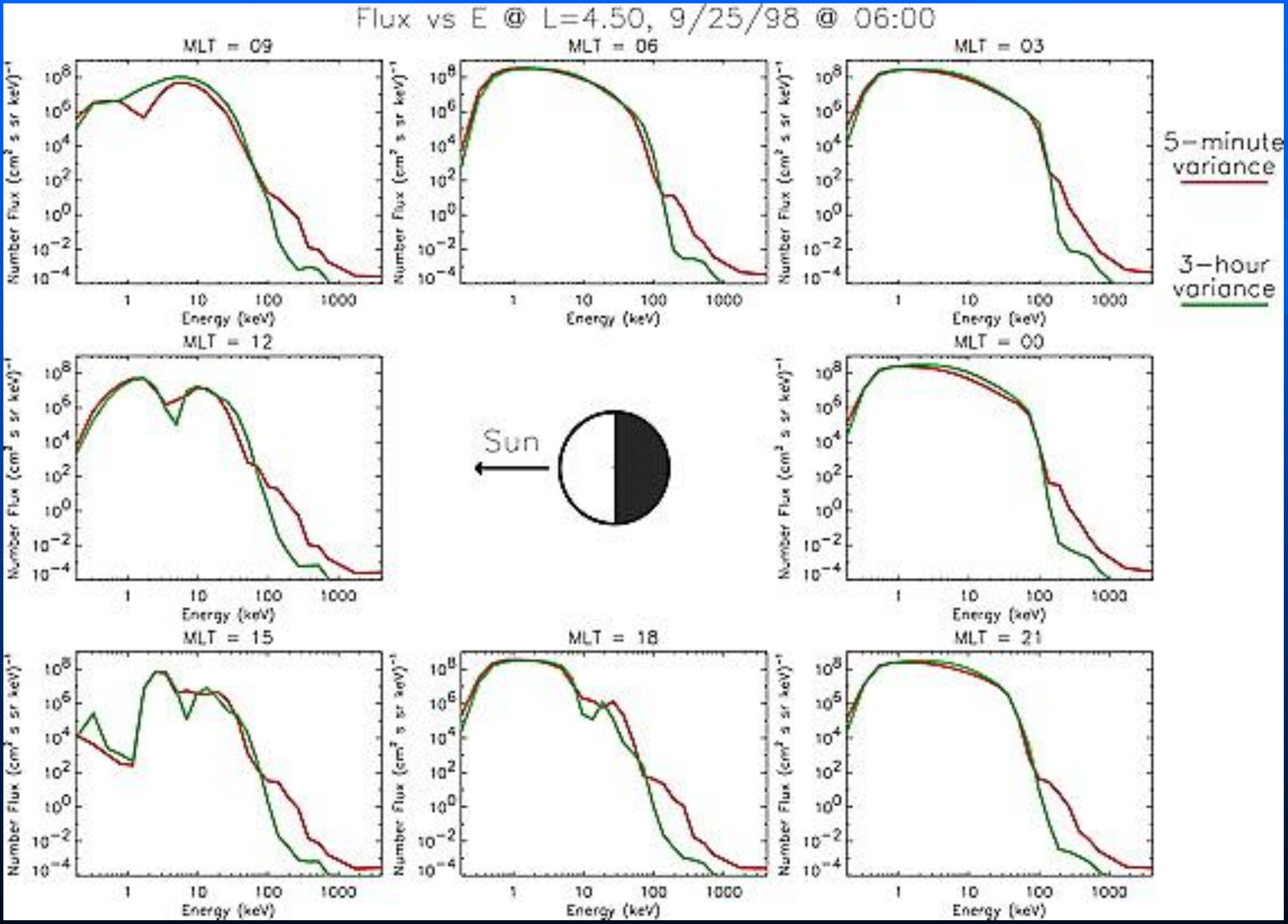
# The Khazanov-04 Flux Ratios

- High cadence/low cadence during recovery phase



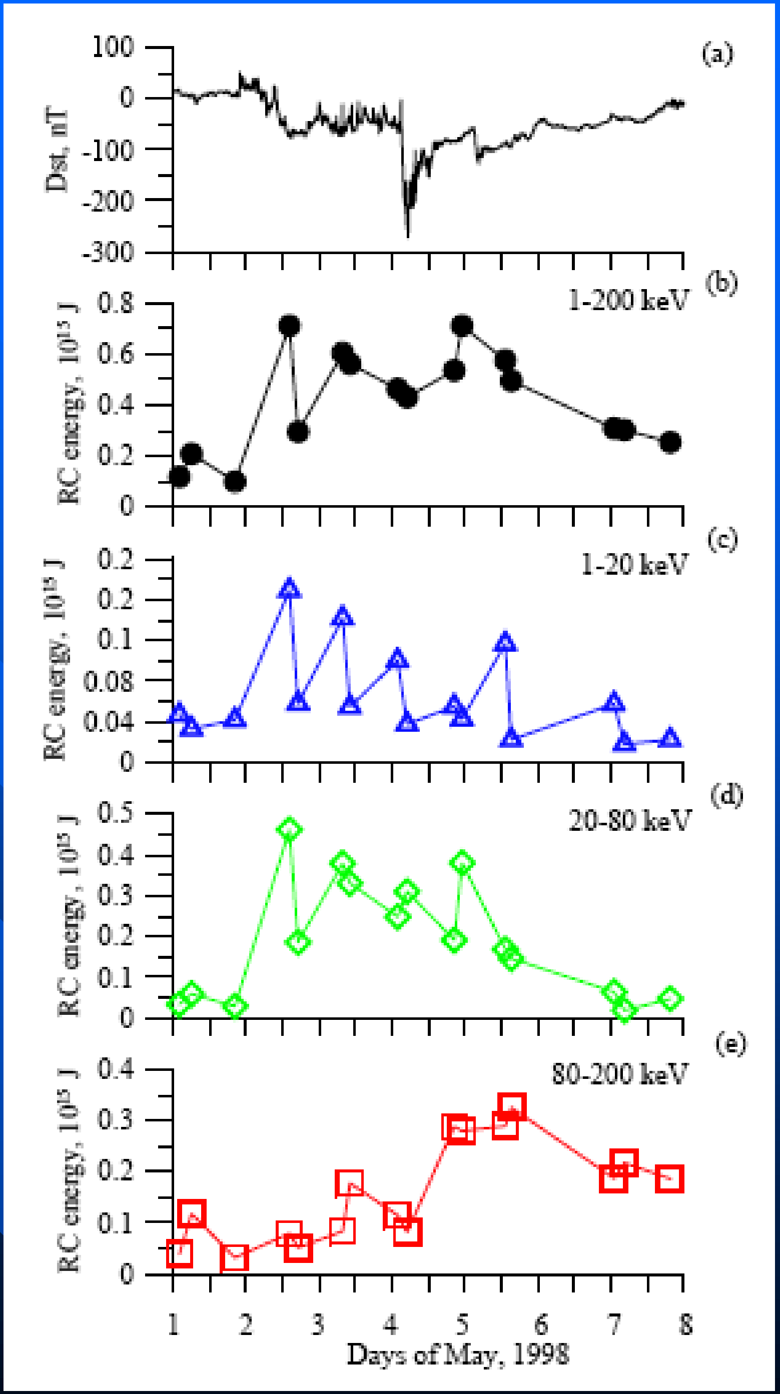
# More from Khazanov-04

- My modeling results show this also
  - High-time resolution self-consistent E-field pumps up the tail



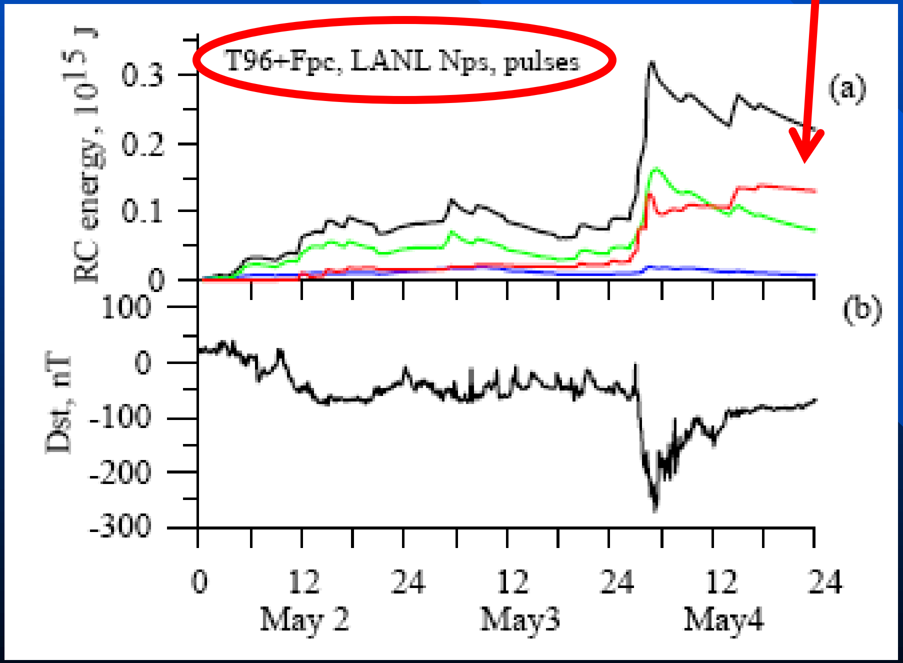
# Ganushkina et al. [AG, 2005]

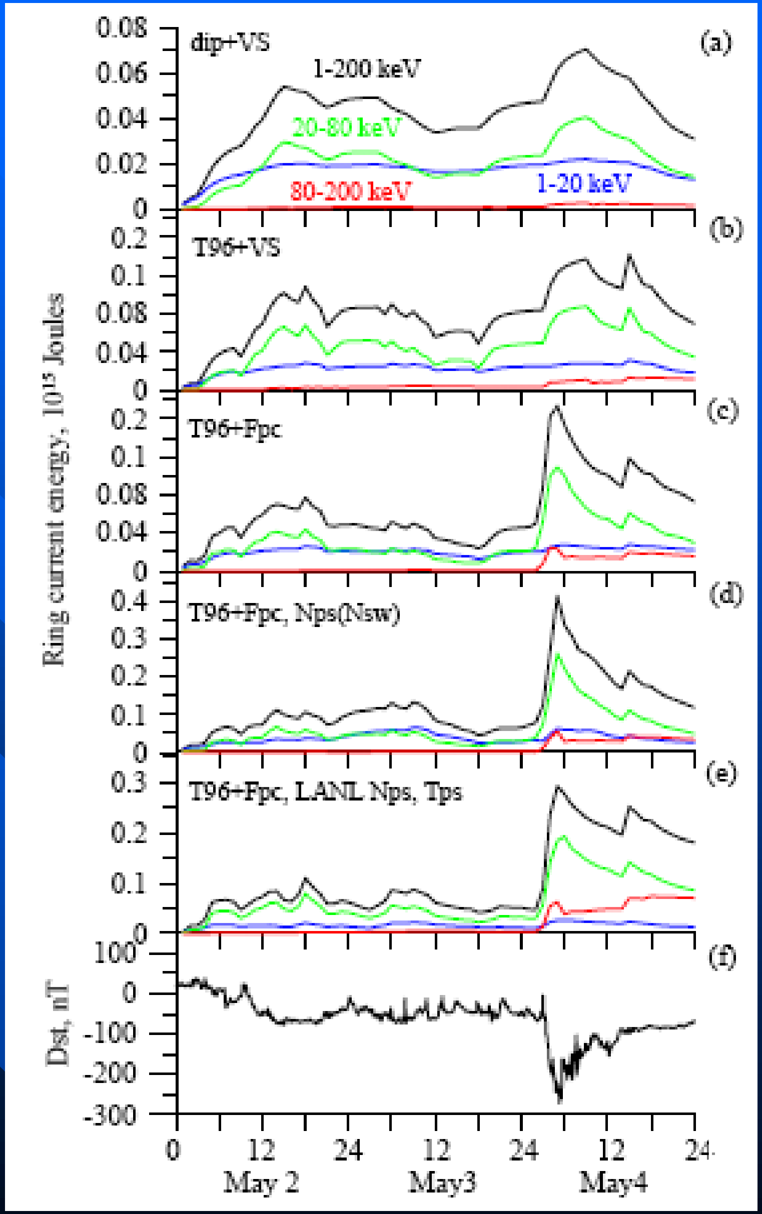
- More modeling of the May 1998 storm
- Trying to match the Polar observations of energy density for specific energy ranges
  – Rise of high-energy tail late in recovery



# Ganushkina-05 Model Results

- Explored several E and B field choices (and ion BC)
  - Only impulsive E-fields created the high-energy tail in the recovery phase



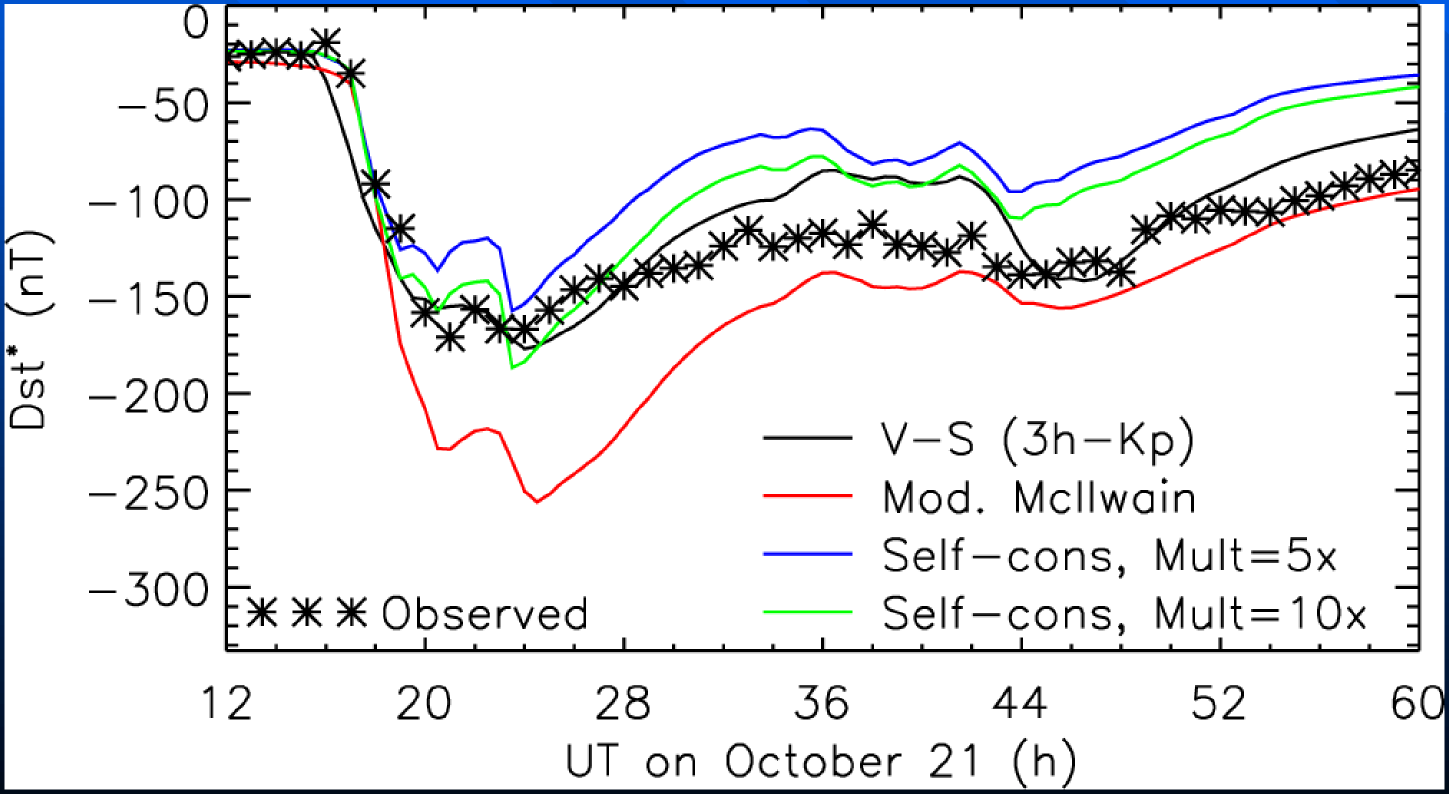



# New Modeling Results

- Energy content from HEIDI model for several storms
  - HEIDI: Hot Electron and Ion Drift Integrator
  - Formerly the Michigan version of RAM
- Two ways of calculating energy content for specific energy ranges
  - Follow the adiabat:  define energy ranges at outer boundary and track energization
  - Hold energy constant: integrate over energy range, regardless of location

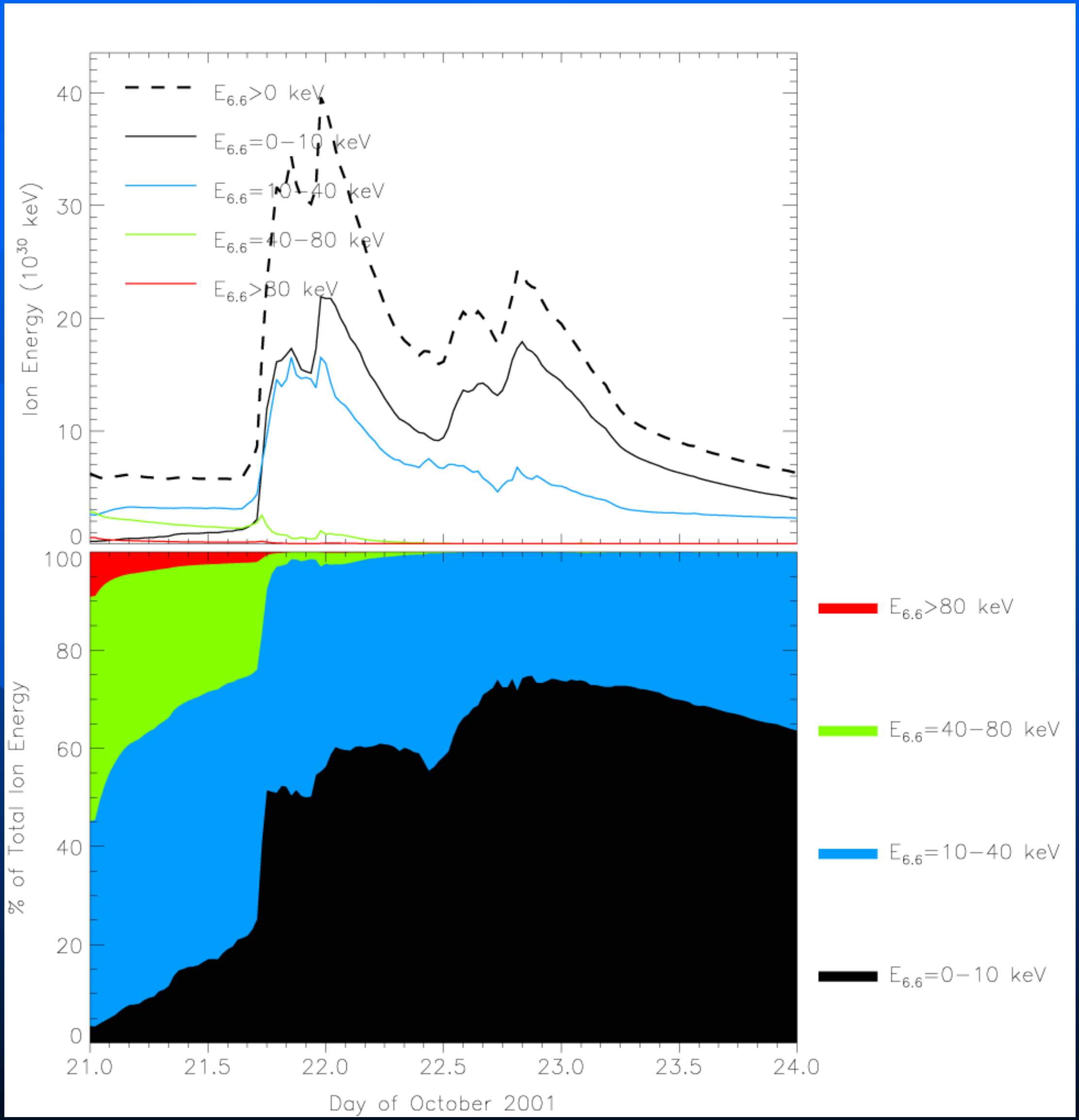
# October 21, 2001 Storm

- See Liemohn et al. [JGR, 2006]
  - Robust data-model comparison study of this storm
- Volland-Stern and self-consistent E-fields model runs matched many data sets very well



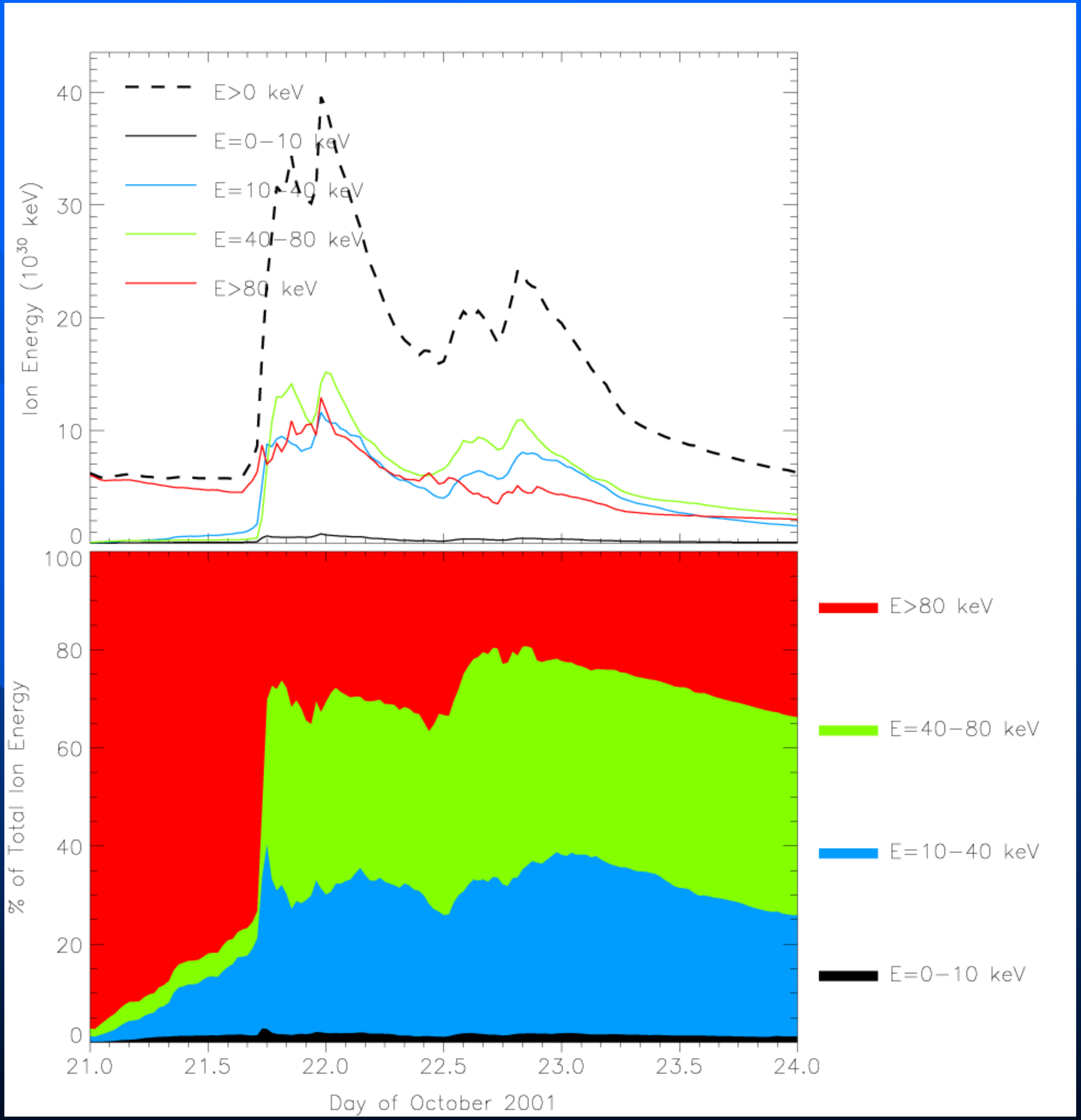
# October 2001: Self-Consistent E-field

- $E_{6.6}$ results
  - Integrated by the particle energy at the source
- It's all from the MPA range
  - Different for the 2 main phases, though



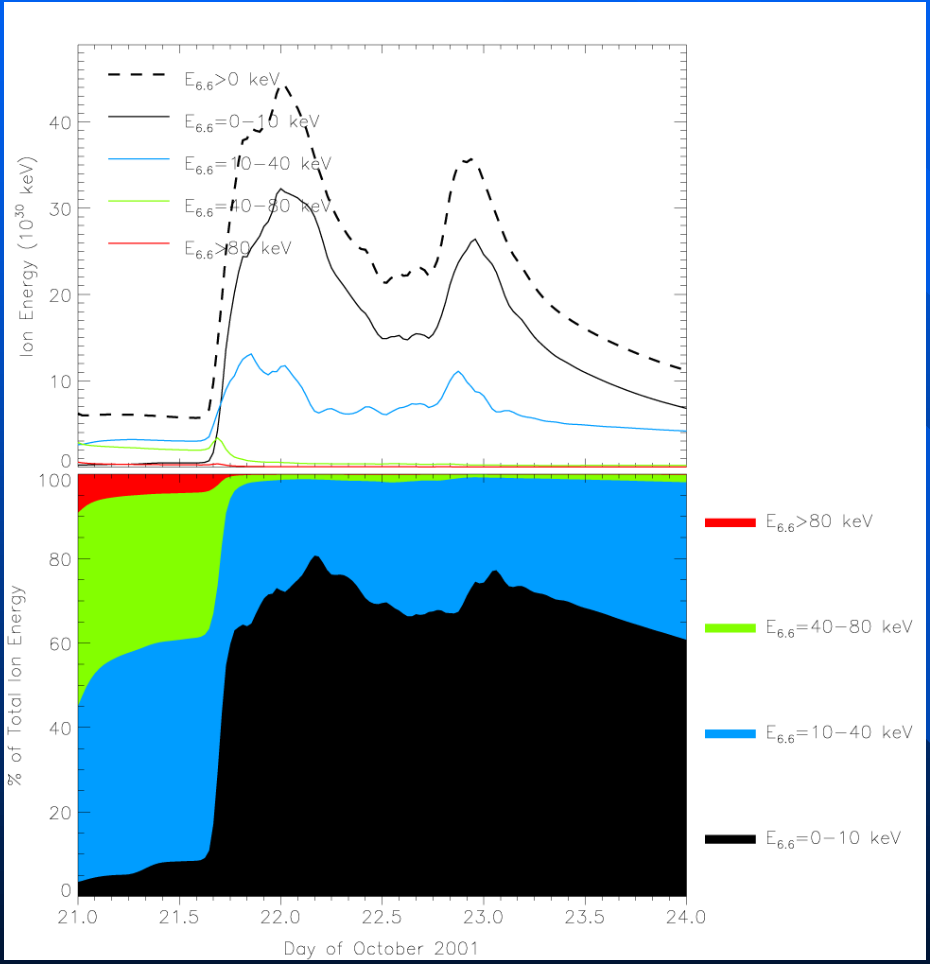
# October 2001: Self-Consistent E-field

- $E_{const}$ results
  - Pre-storm: all high-energy ions
  - During and after: evenly split over 3 of the 4 ranges
- Differences with $E_{6.6}$ plot:
  - Low-energy is source, but they are energized

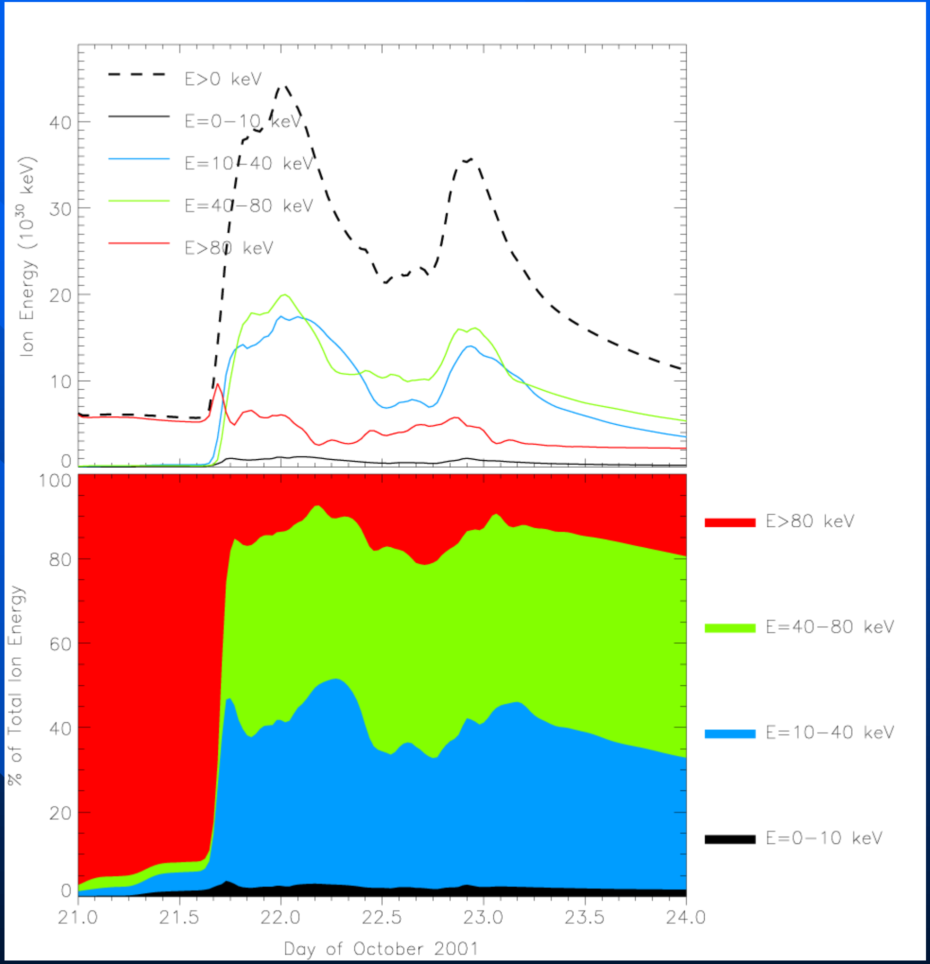


# October 2001: 3-h Kp V-S E-field

- $E_{6.6}$ results

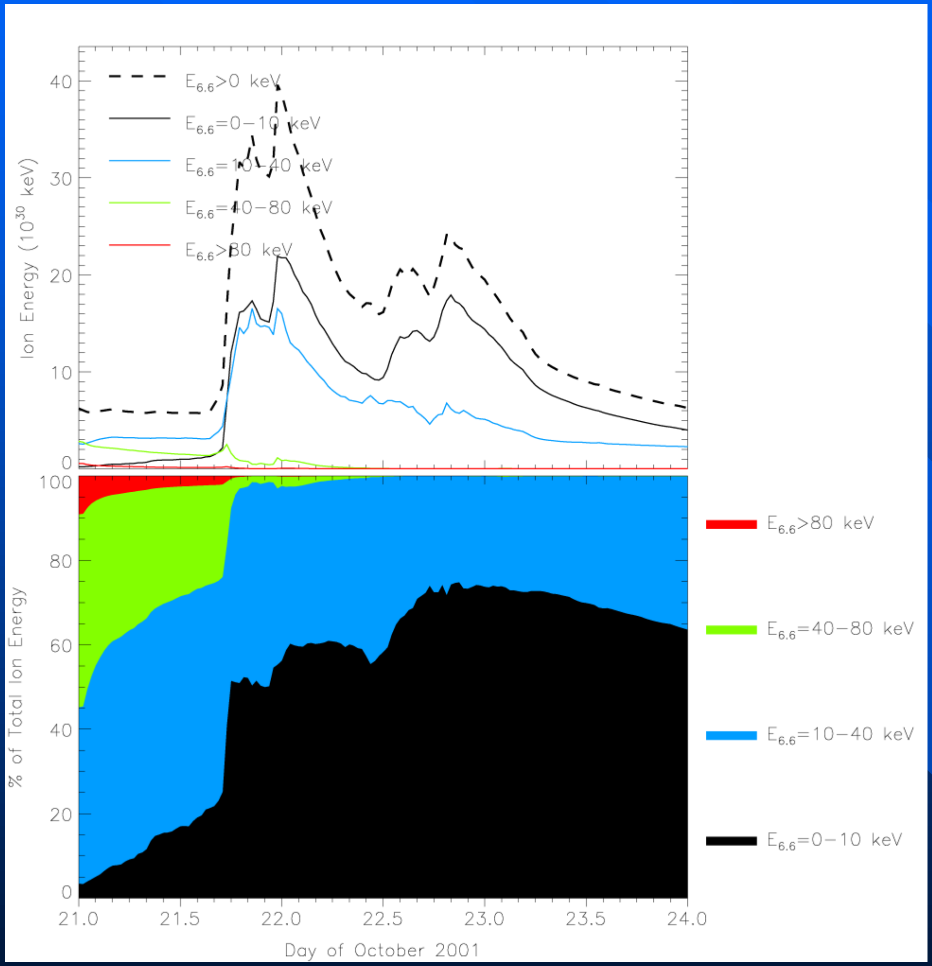


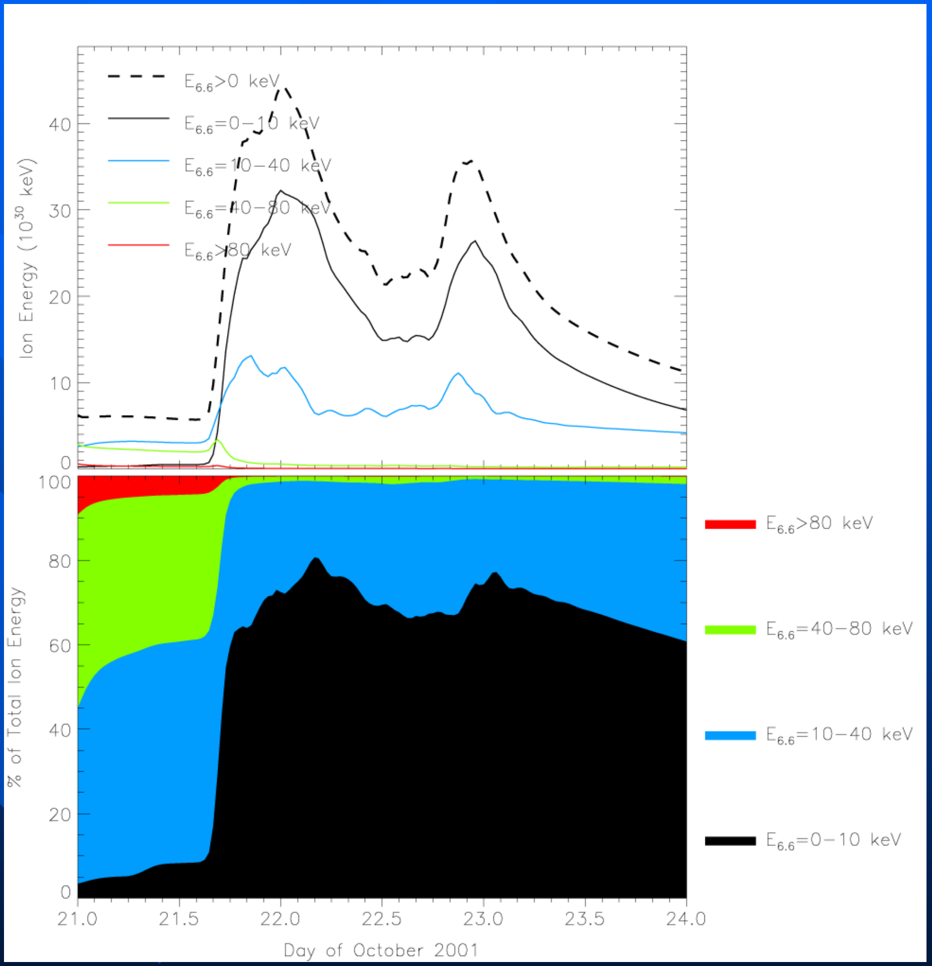

$E_{const}$ results



# October 2001: E-field Comparison

Self-consistent E-field | Volland-Stern E-field

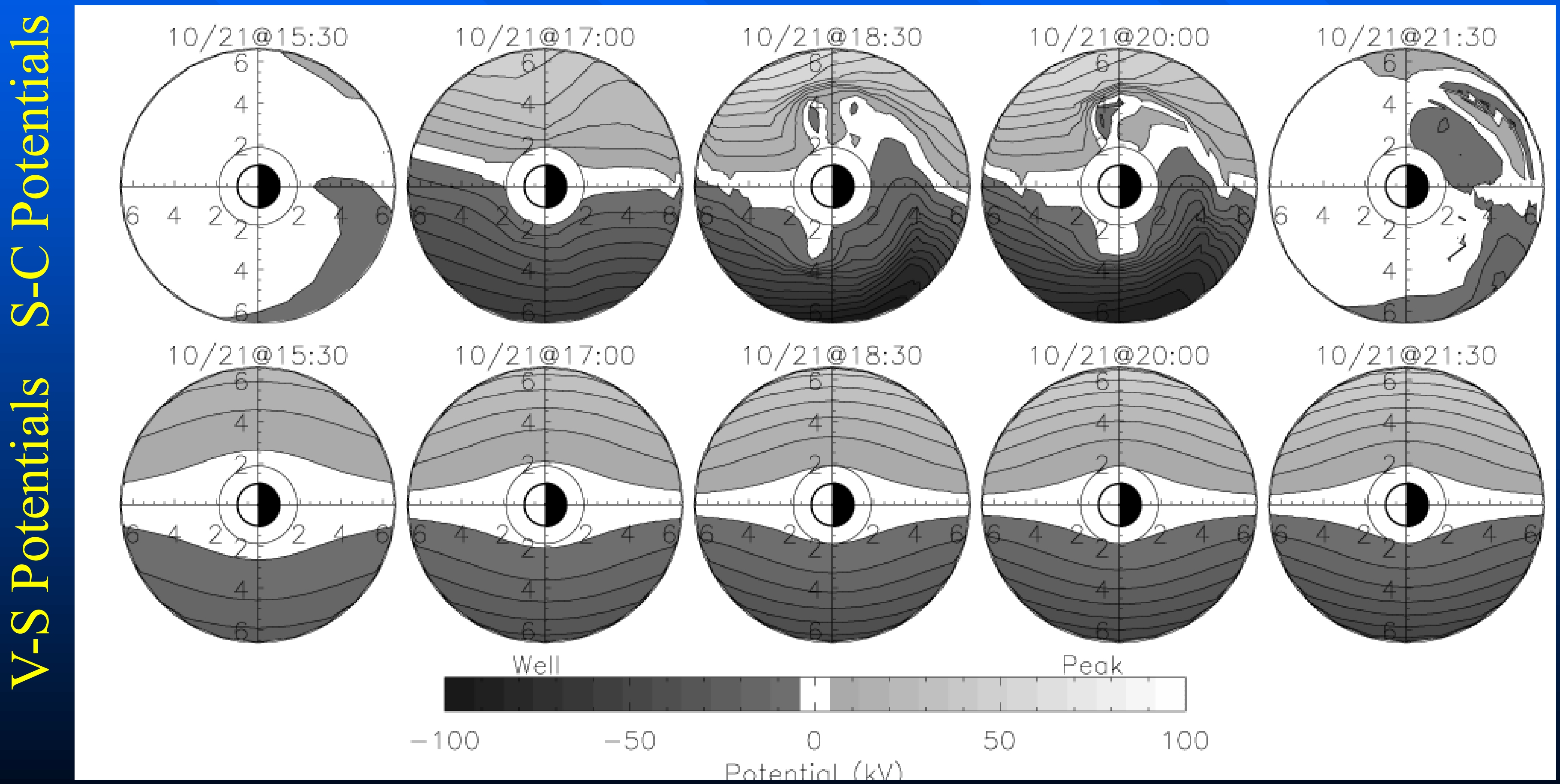



Differences: mostly in the "black and blue" split

# Electric Field Patterns

- Big difference in the inner magnetosphere
  - Lots of fine structure in the self-consistent potentials



# Summary of Results

- The ring current can be reproduced by convecting the main plasma sheet inward
  - Good data-model comparison without many SOPA-range (E>40 keV) ions crossing geosynchronous orbit
  - High-energy tail of ring current: energized from the MPA-range (E<40 keV) ions at L=6.6
- Other important points:
  - Substorms inject SOPA-range ions into the inner magn.
  - High-E ions can contribute if they get in
  - High-res E-field causes radial diffusion, enhances tail
  - E-field pulses cause preferential trapping of high-E ions
  - Natasha Ganushkina is back at Michigan starting *today*

# Penultimate Slide

- What is the relative contribution of convective and inductive electric fields in ring current formation?
  - I don't know, for sure, but I think it heavily favors convective flow over inductive injections.
- *The $64 question:*
- Can RBSP resolve this issue?
  - I hope so.

# How to Resolve It: Some Questions

- What is the fine-structure of the electric field in the inner magnetosphere?
- What is the breakdown of this electric field between inductive and convective sources?
- What is the relative contribution of ions in the energetic tail of the distribution?
- How do all of these relationships vary with magnetic activity and/or solar wind driver?