Global convection in Earth's middle-to-inner magnetosphere

An outstanding mystery targeted by the Van Allen Probes mission

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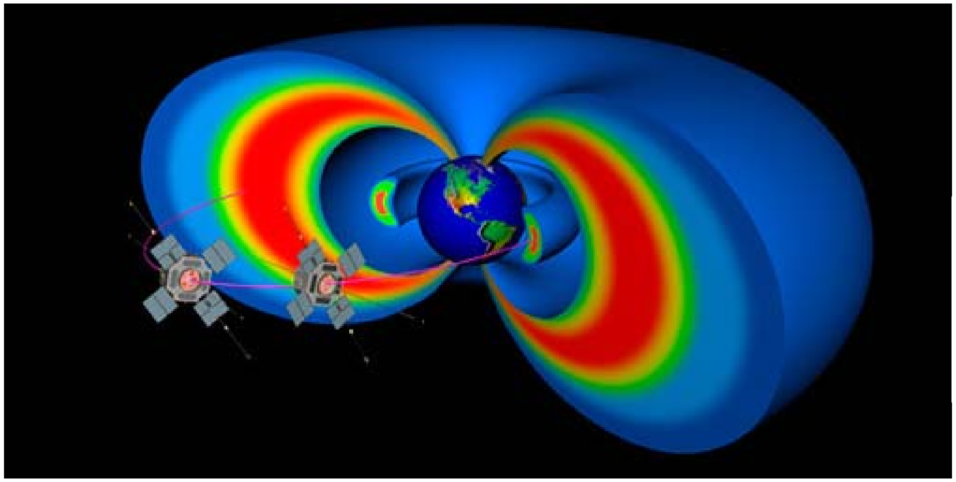
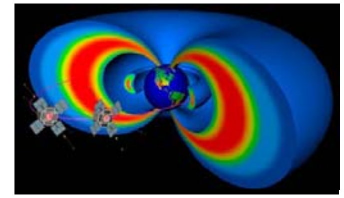
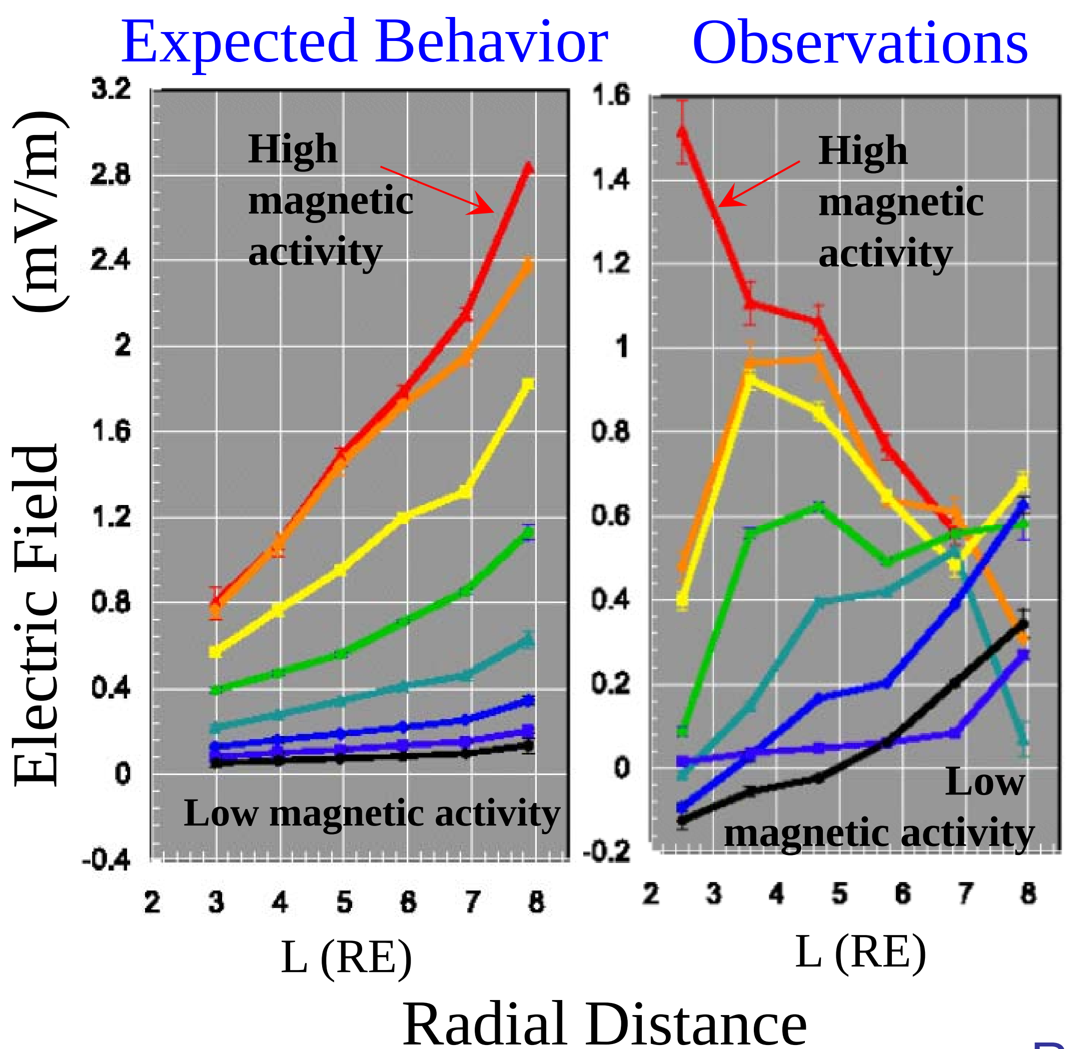


CRRES Electric field measurements revealed unexpected behavior for inner-magnetosphere global electric fields



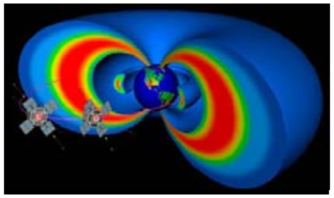


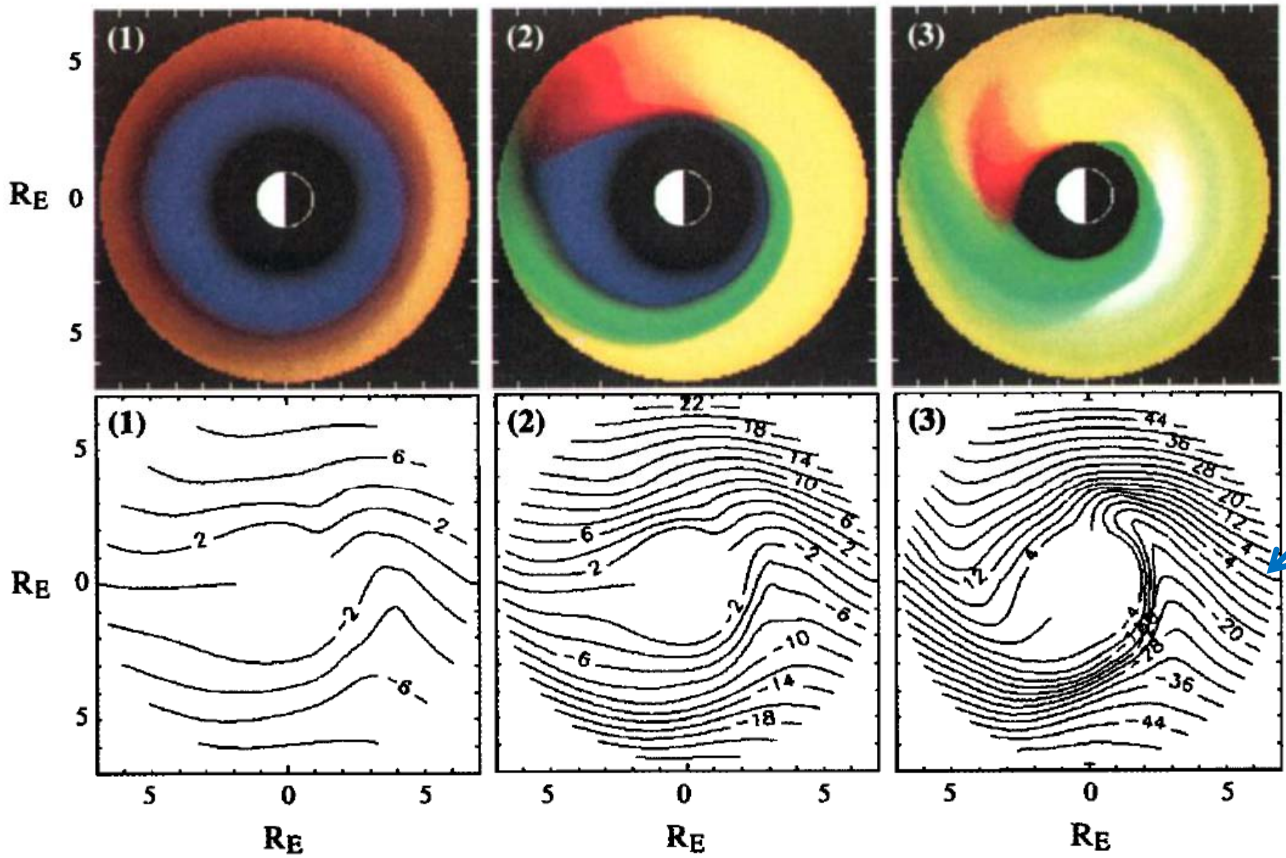
- This result has been controversial.
- The focus of skepticism has been on the inverted radial dependence.
- Less attention has been paid to the fact that the distant electric fields appear not to increase with increasing activity
- Some skepticism has focused on the fact that only 2D electric field measurements were made (dawn-dusk).
- With 3D measurements the Van Allen Probes mission will hopefully resolve the measurement uncertainties.
- It is important that this issue be resolved.

Roland and Wygant, 1998

The issue is important because:

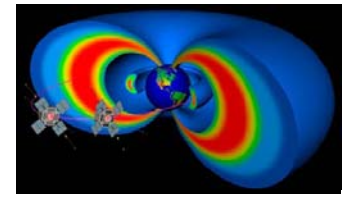
Global electric field increases are central to prevailing global transport models in Earth's inner magnetosphere (1)





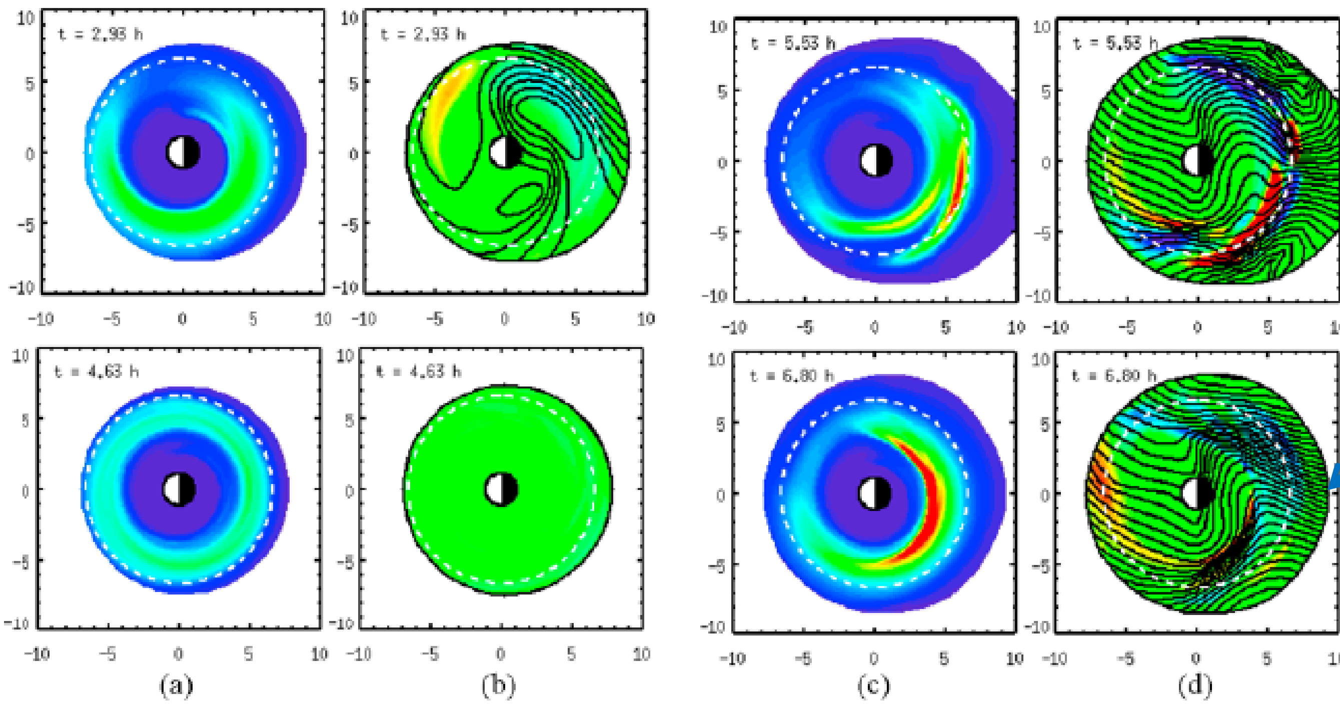
Enhanced global convection field during active periods

Fok et al., JGR, 2001



The issue is important because:

Global electric field increases are central to prevailing global transport models in Earth's inner magnetosphere (2)

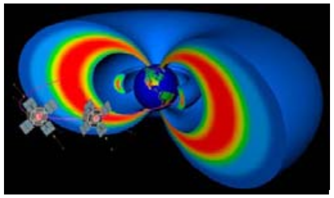


3 kV contours

Enhanced global convection field during active periods

Buzulukova et al., 2010

What role does global convection play in the transport to the ring current regions?



Two Hypotheses:

1) <u>The conventional hypothesis</u>:

   The global convection electric fields increase as a function of geomagnetic conditions (e. g. Kp) and allow increasingly deep direct access of magnetotail plasmas into the middle-to-inner regions.

   Transient injections occur "on top of" this nominal pattern.

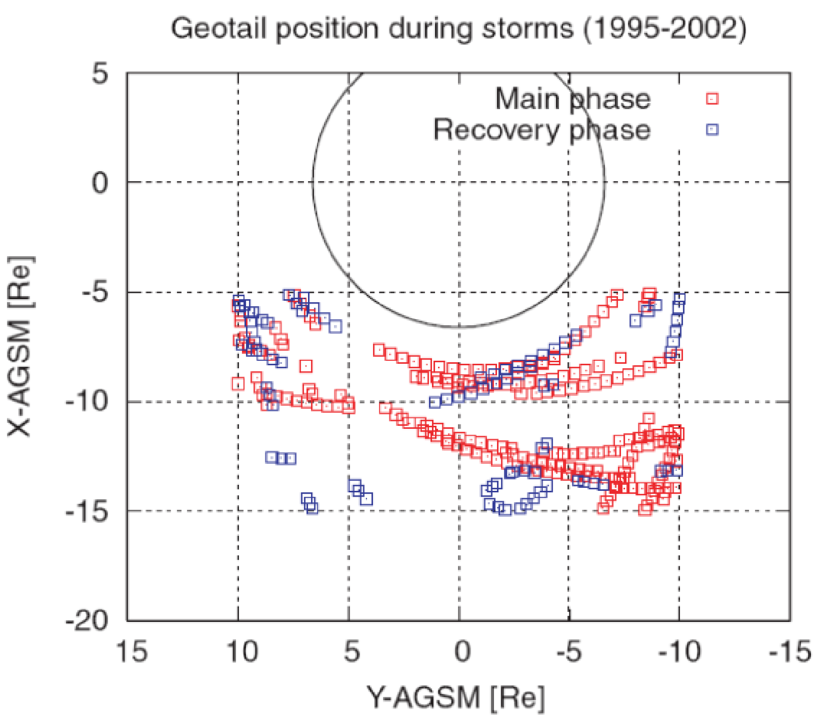
2) <u>A less conventional hypothesis</u>:

   Transient (inductive?) electric fields inject and provide the principal access of magnetotail plasmas into the middle-to-inner magnetosphere to radial positions that decrease as geomagnetic conditions (e. g. Kp) increase.

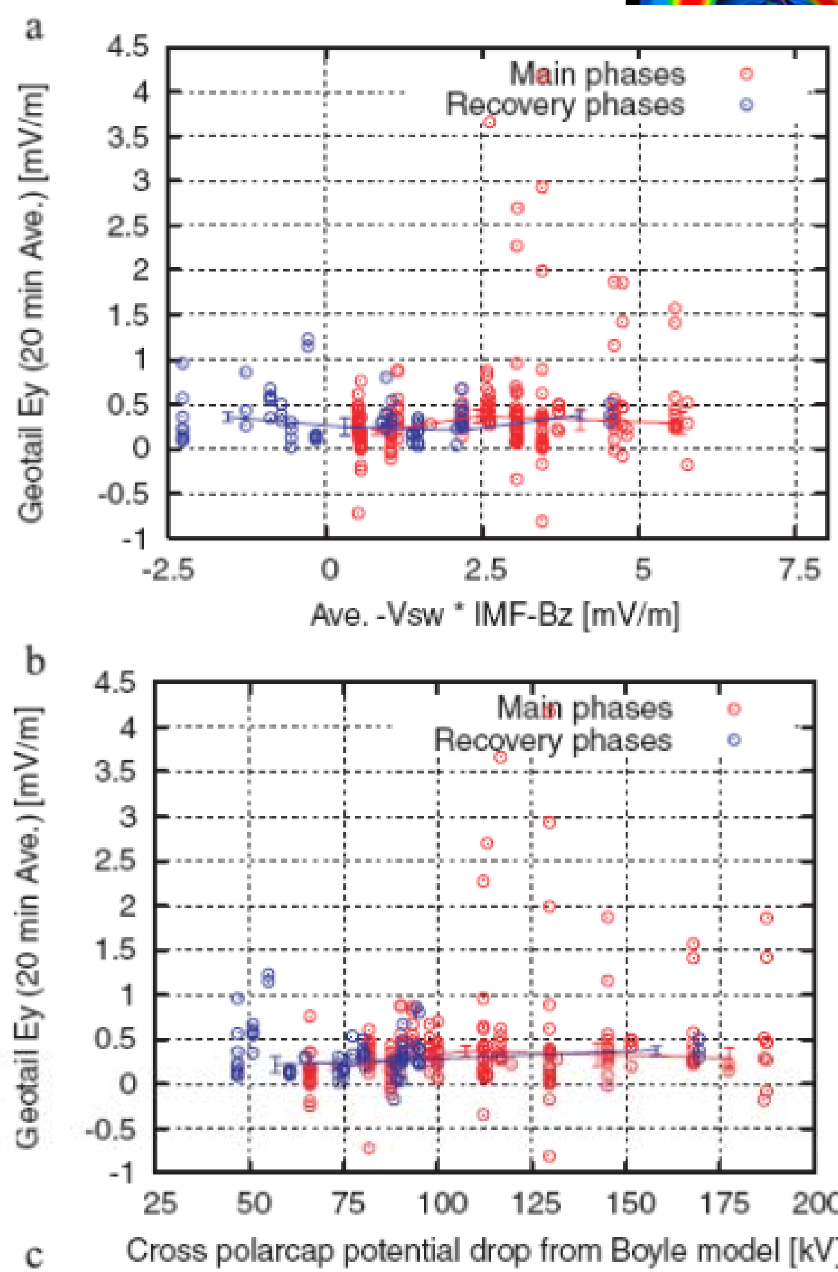
   The injected plasmas populate and fill out the somewhat variable global convective electric field pattern.

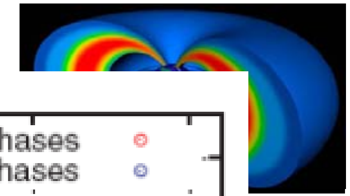
What does the evidence say?

Geotail observations are fully consistent with the CRRES finding that global convective fields do not increase at the base of the magnetotail .



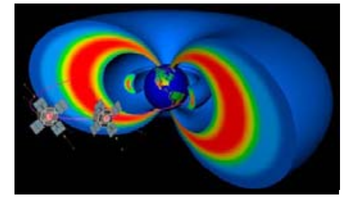
Hori et al. 2005

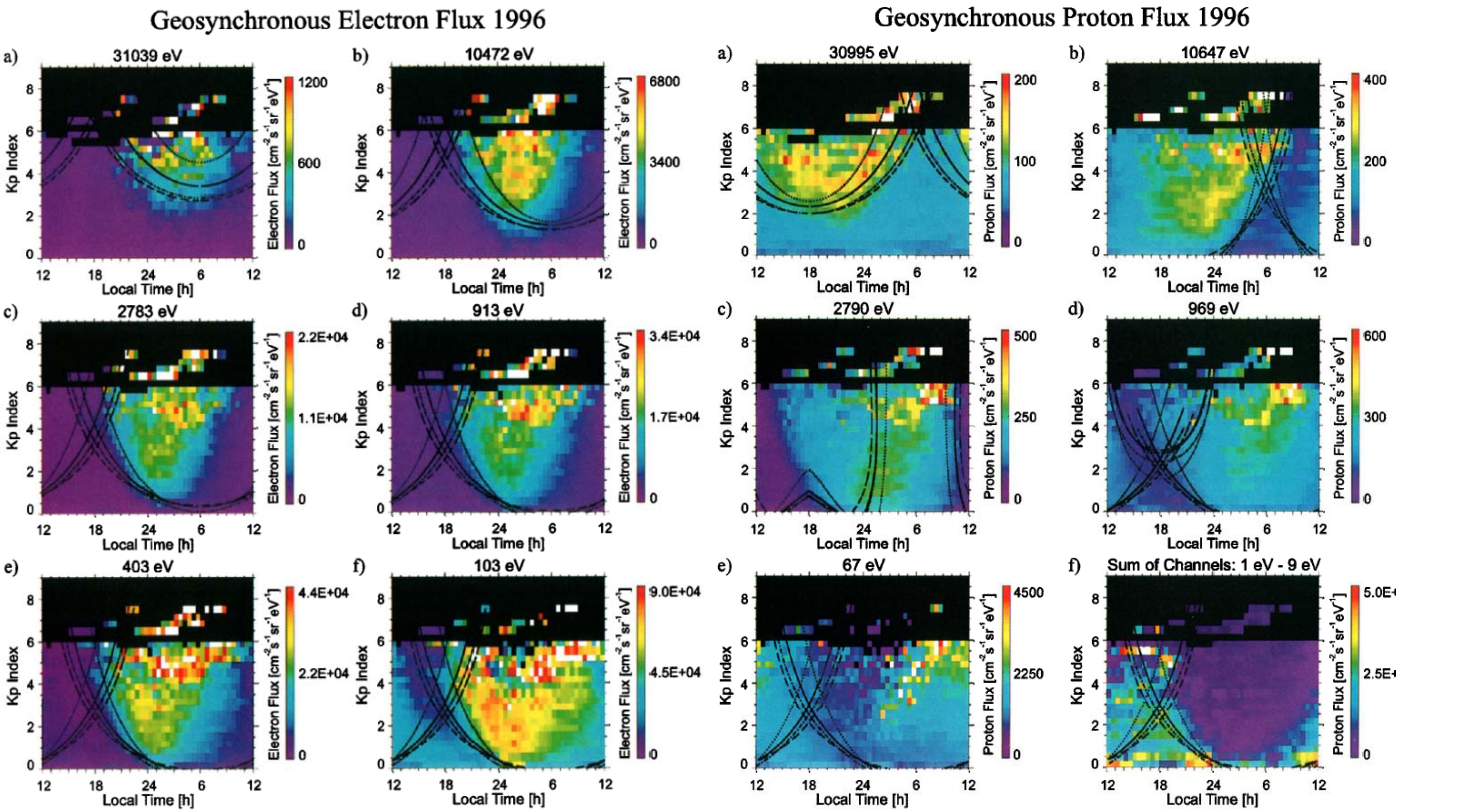




Statistical ordering of particle measurements has been used to support the enhanced global convection picture

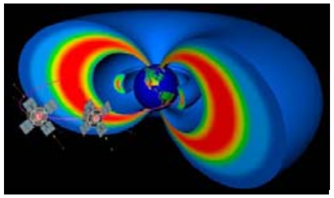
But, ions are poorly ordered and either hypothesis may suffice for electrons as the following slides indicate

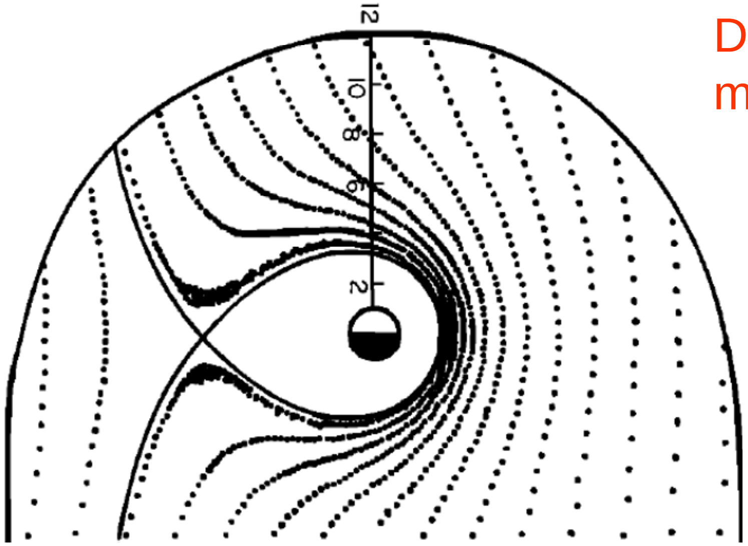




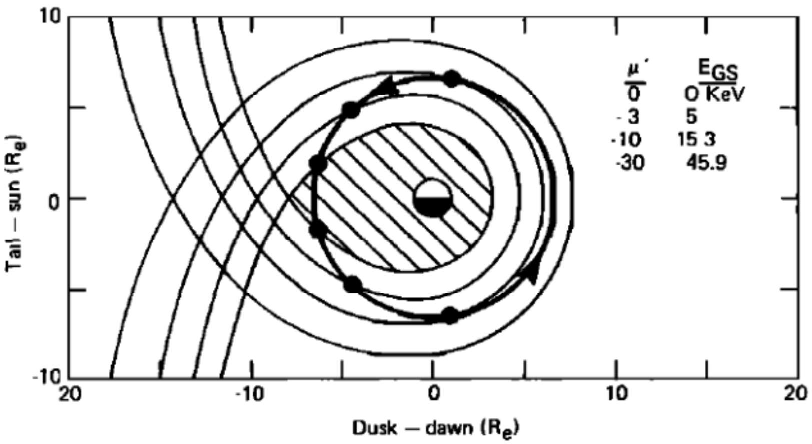
Korth et al., 1999

A substantial literature exists interpreting energy dispersion signatures with global quasi-steady convection



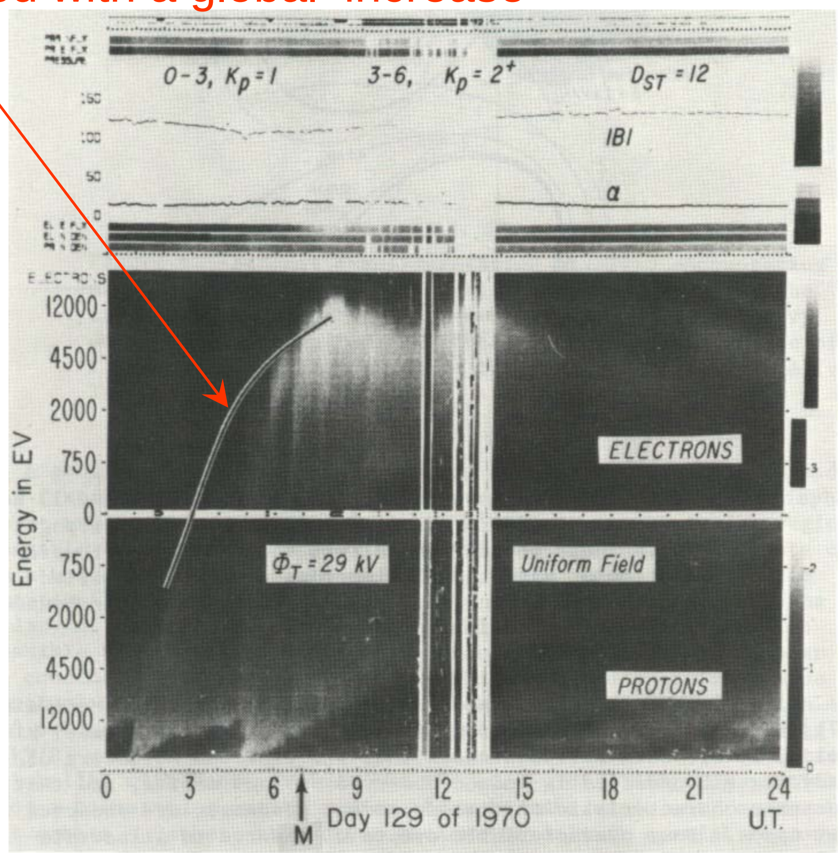


Kavanagh et al., 1968



Mauk and Meng, 1983b

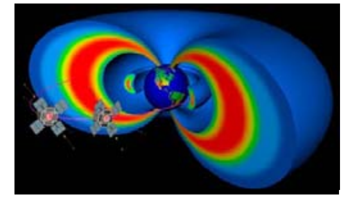
Dynamic global convection dispersion modeled with a global increase

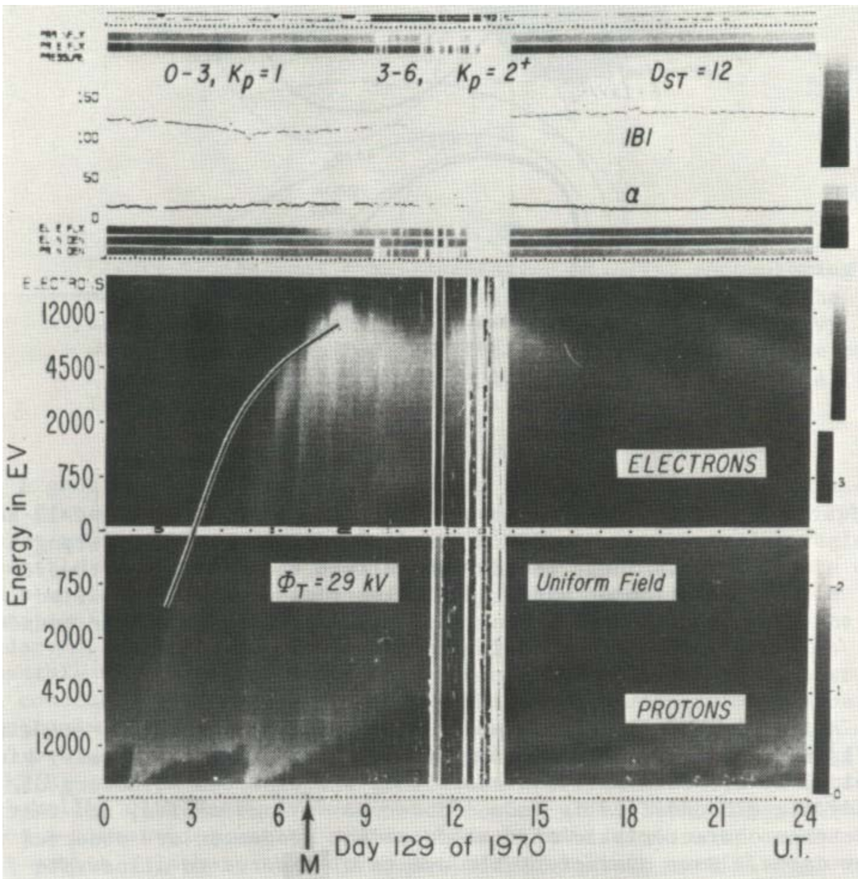


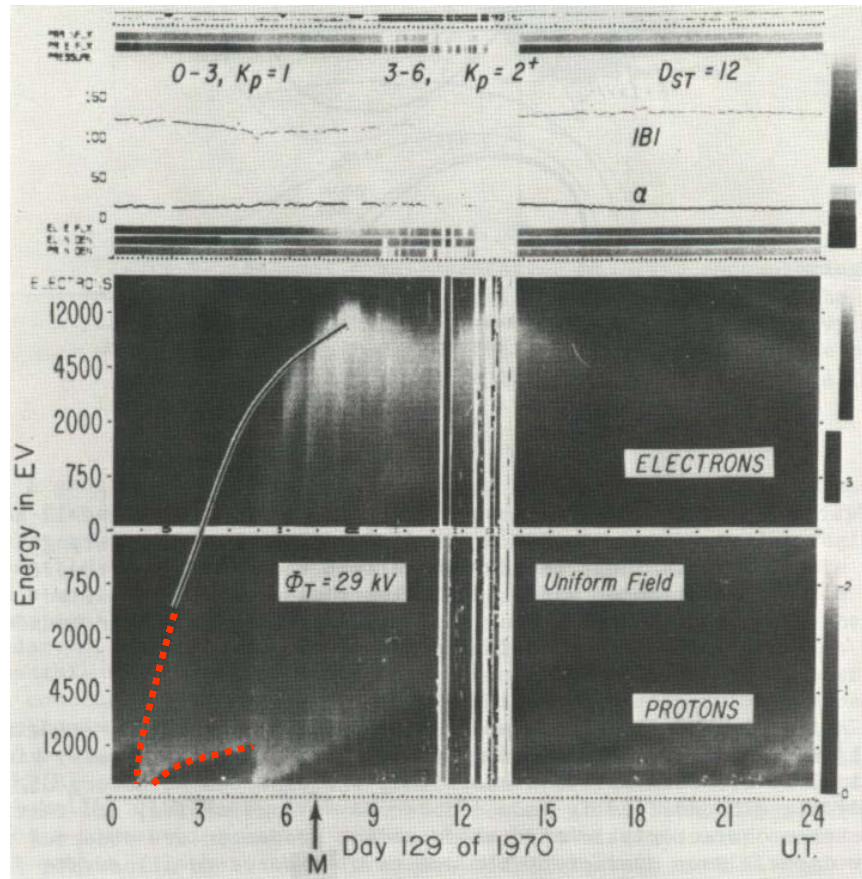
Kivelson et al. 1979

McIlwain sensor on Geosynchronous ATS-5

However, the literature supporting global steady convection focuses on selected portions of the data.



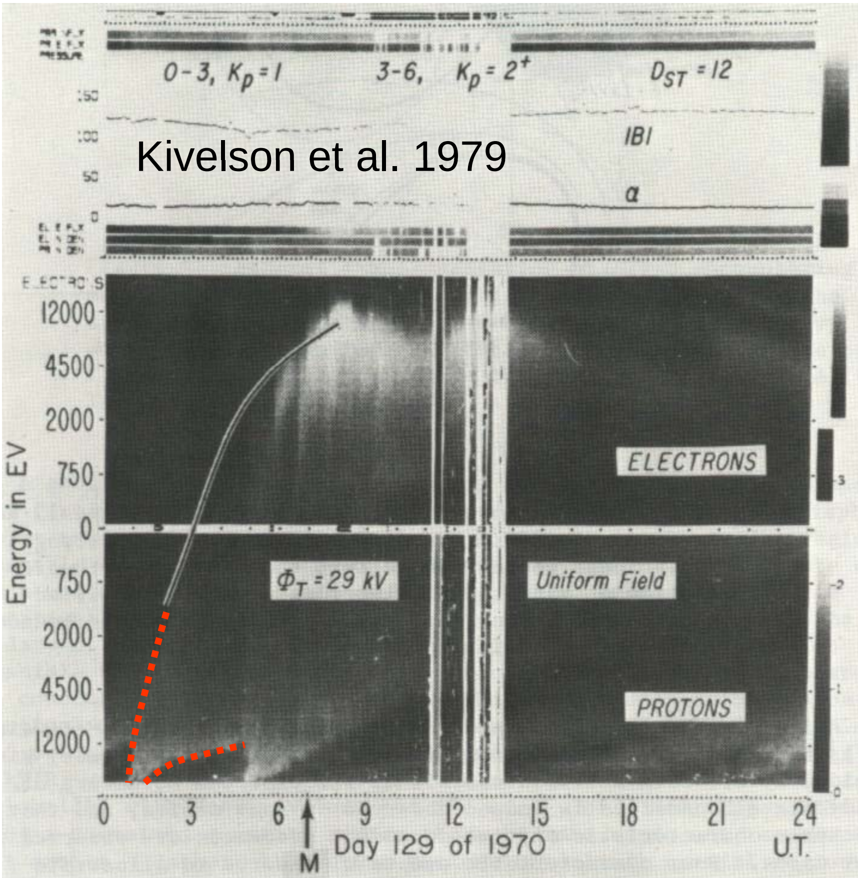




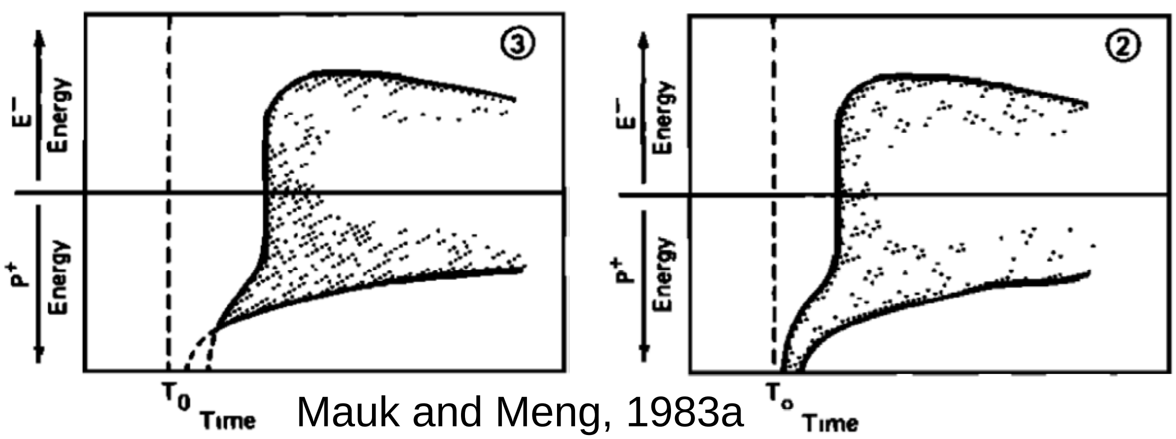
Kivelson et al. 1979

In this example, ion signatures highlighted here are not explained by the standard global convection configuration.

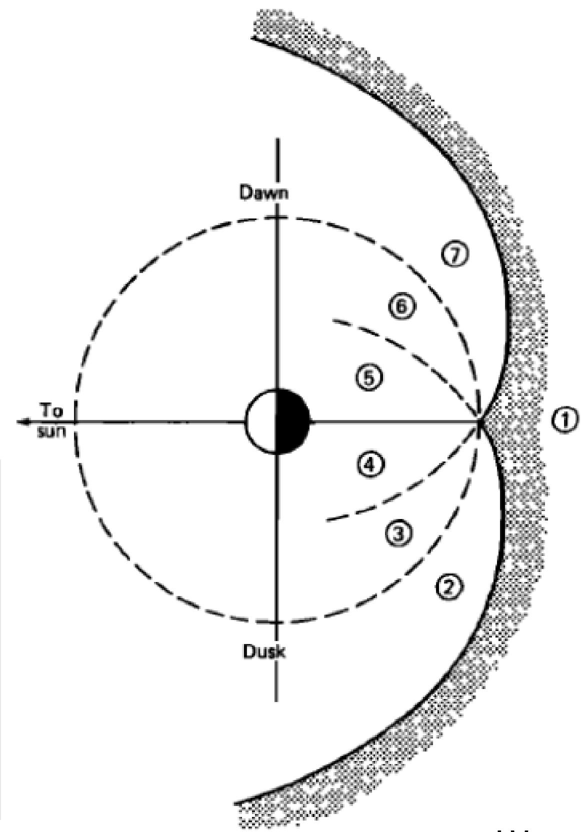
The explanations of “complete” signatures (electrons + ions) require dynamic injection modeling



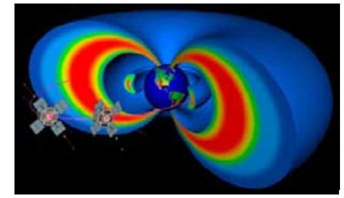
Kivelson et al. 1979

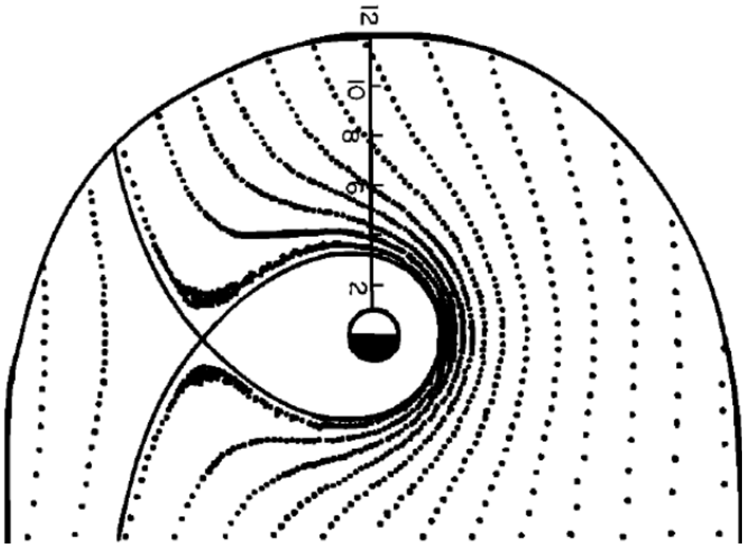


Mauk and Meng, 1983a

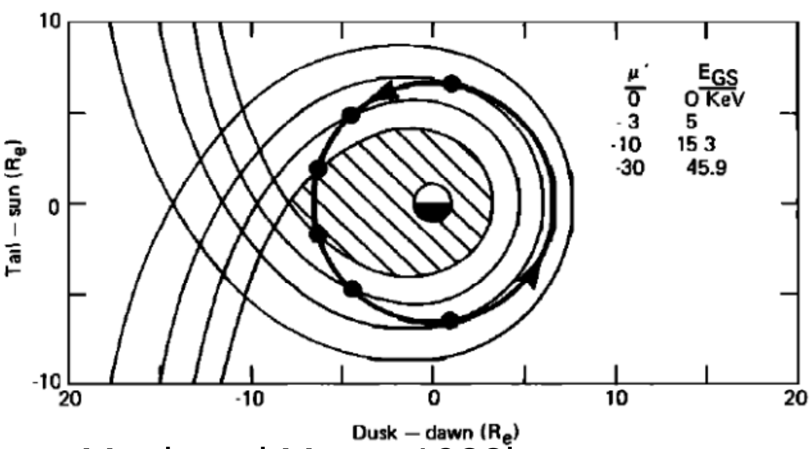


Another example where only electron data is used to support a global convection picture



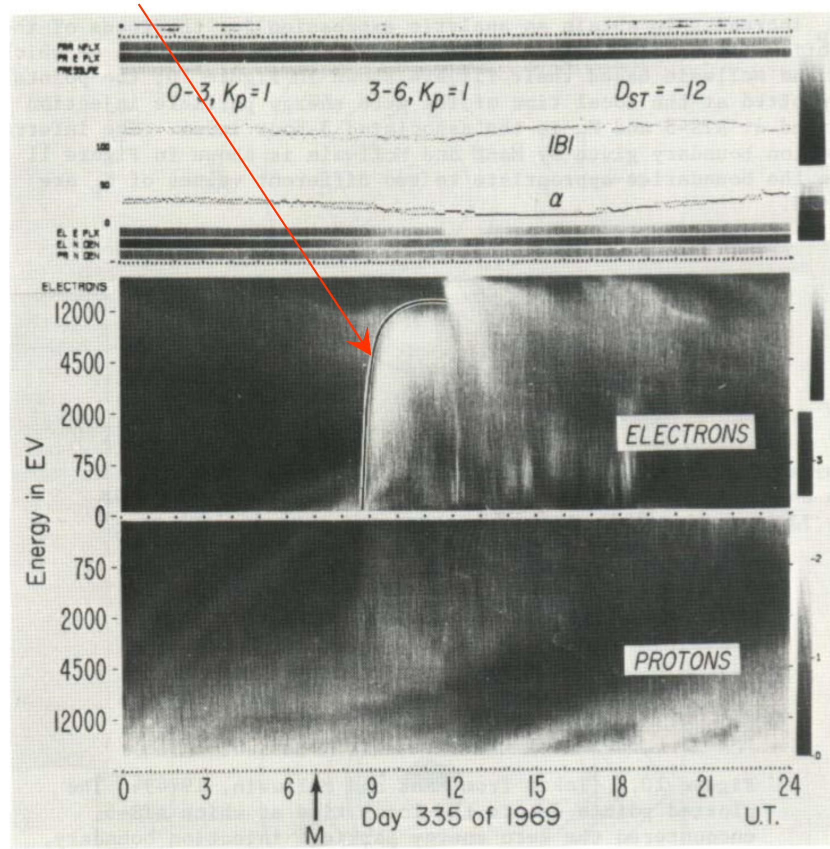


Kavanagh et al., 1968

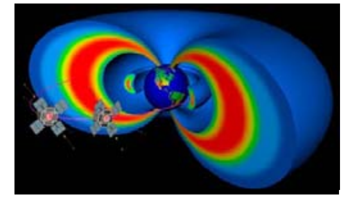


Mauk and Meng, 1983b

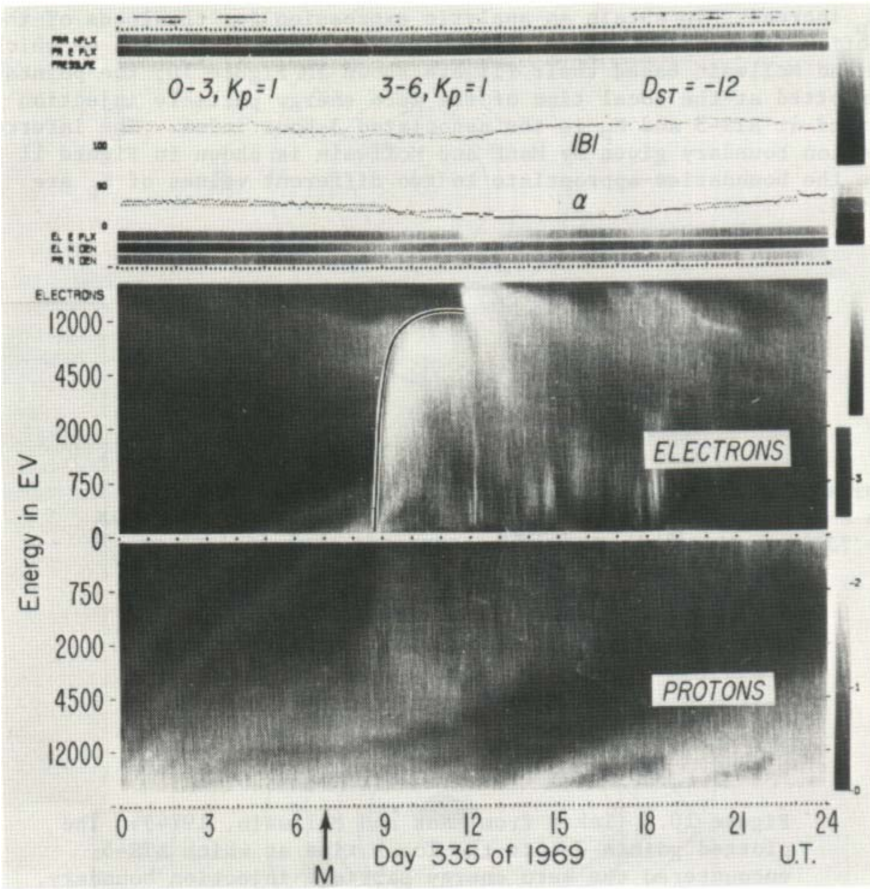
Convection model

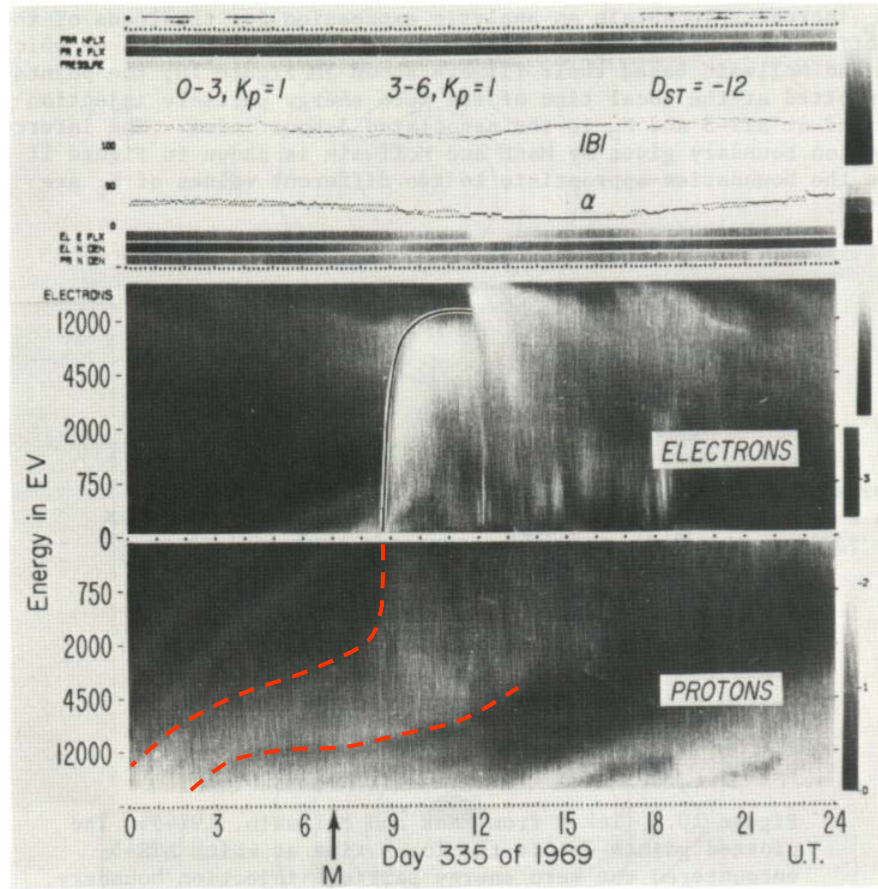


Kivelson et al. 1979
McIlwain sensor on ATS-5



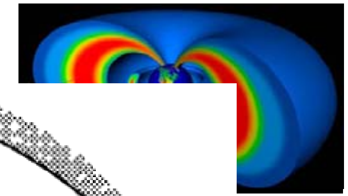
Again, the ion signatures highlighted are not explained by the global convection configuration.

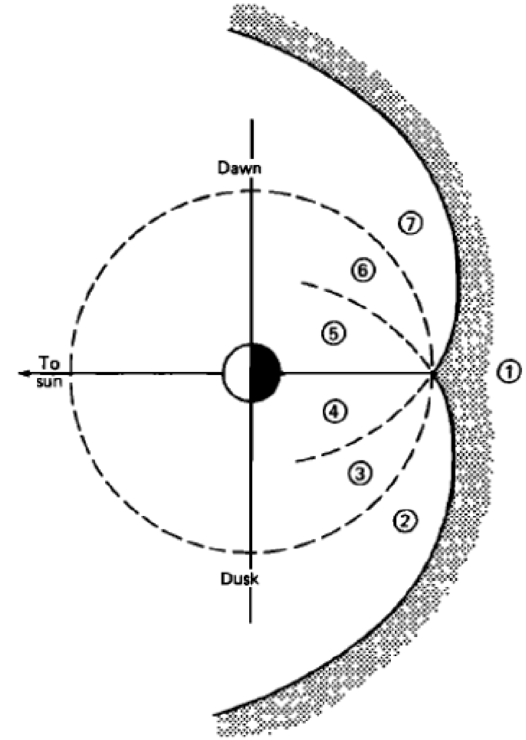


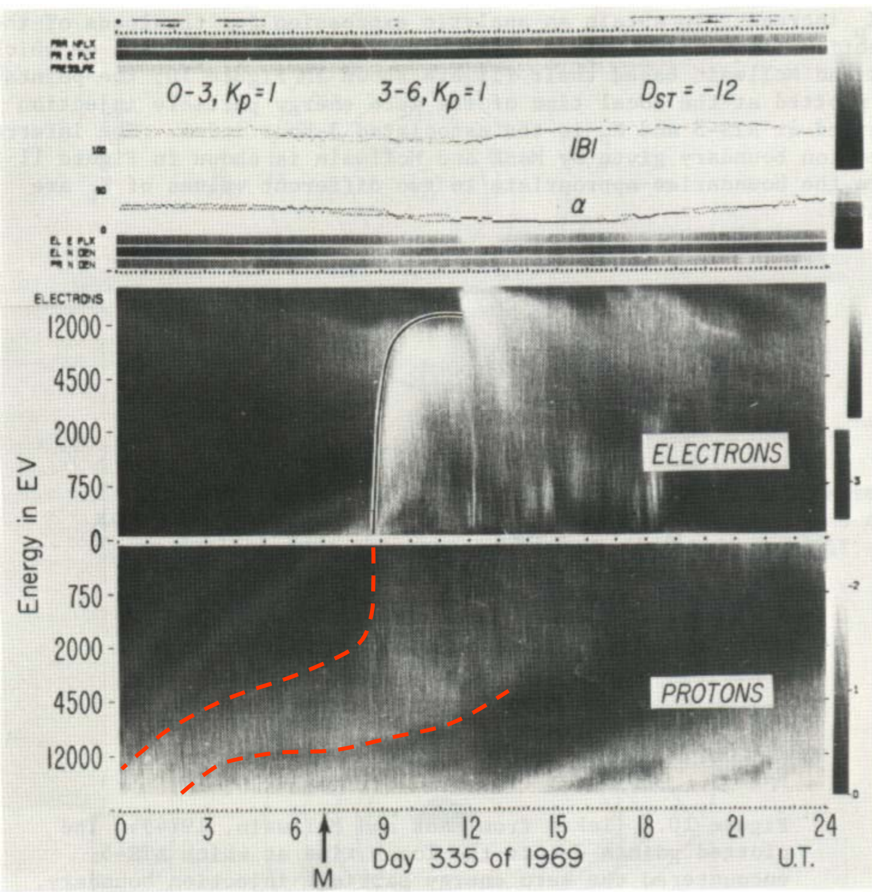


Kivelson et al. 1979

The modeling of “complete” quiet time signatures again appears to require dynamic injection modeling

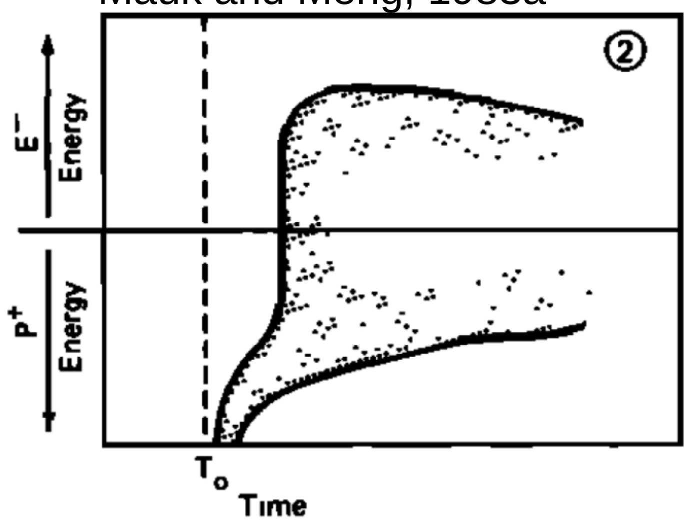


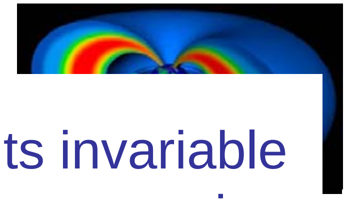




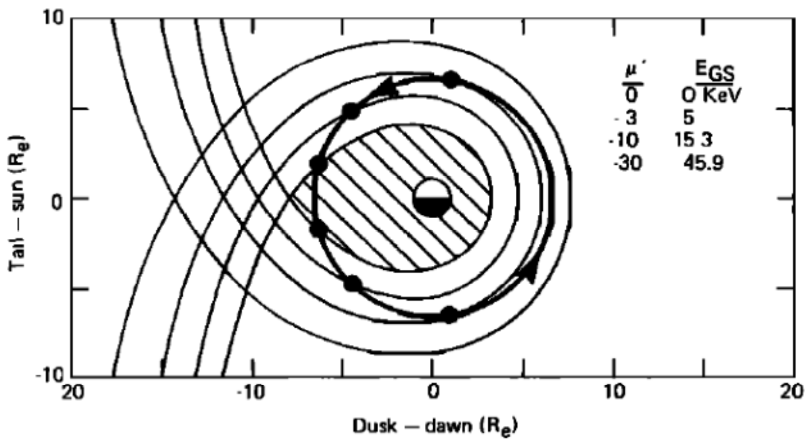
Kivelson et al. 1979

Mauk and Meng, 1983a





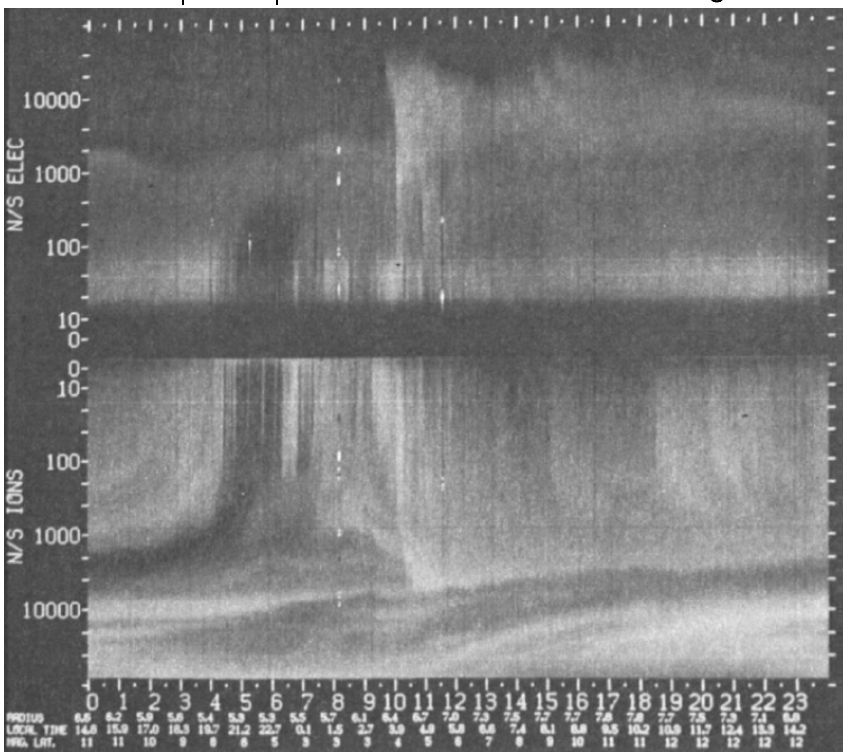
Also, dusk plasma dropouts invariable have the wrong dispersion sense in both electrons and ions to be explained by steady global convection.

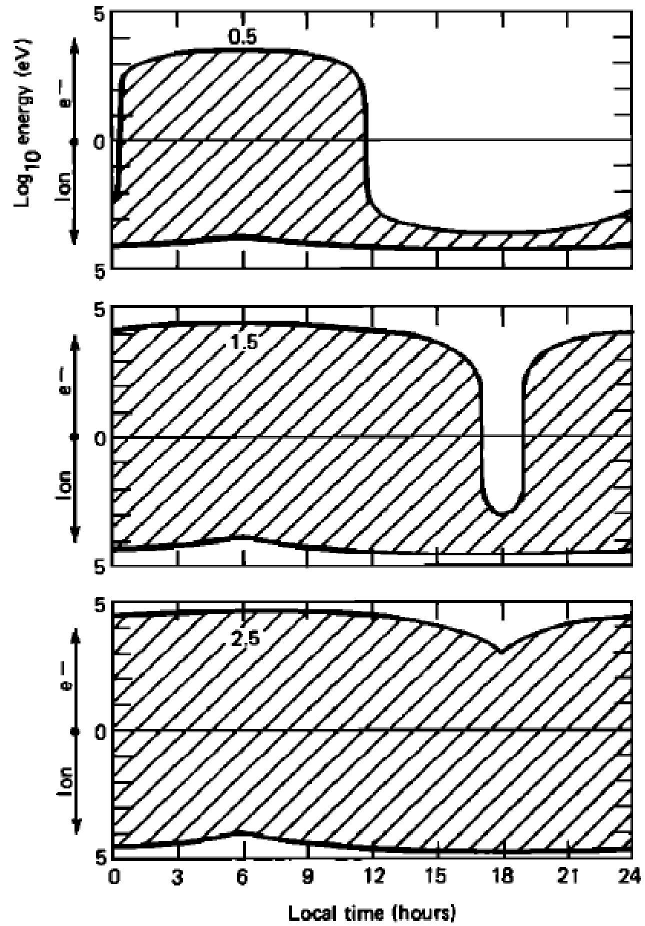


12 hr

0+ | 0 | = Kp

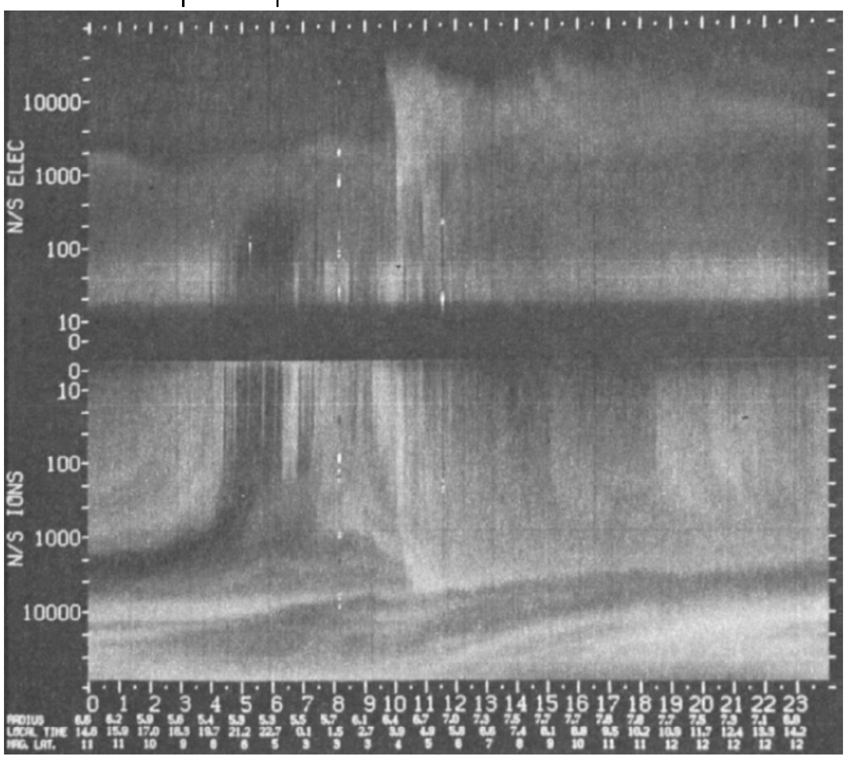
Mauk and Meng, 1983b

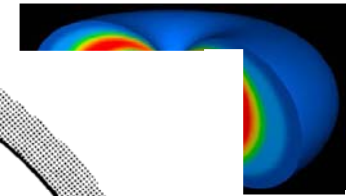


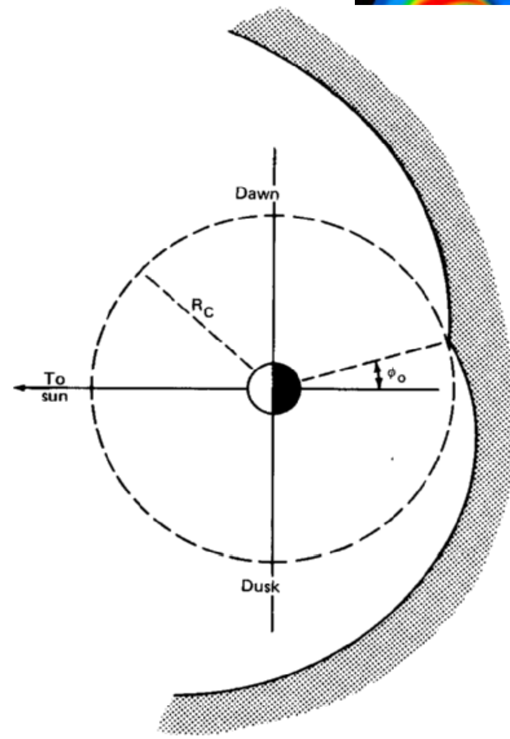


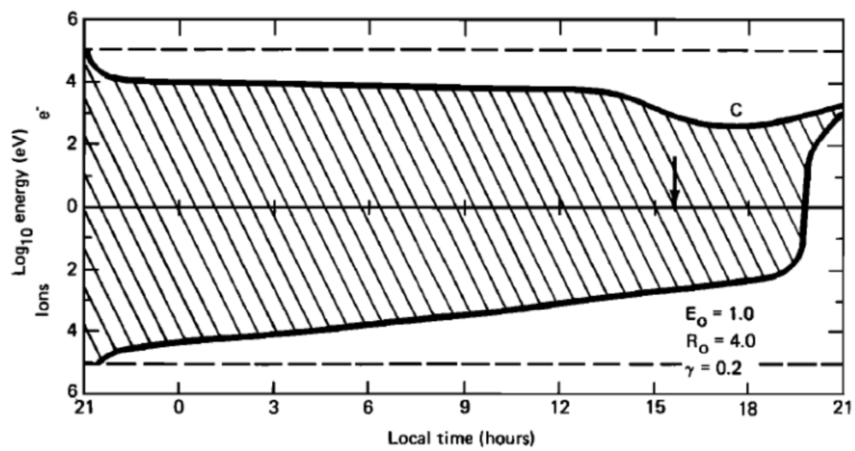
Again, dynamic injection modeling appears required to explain even very quiet-time signatures

12 hr
0+ | 0 | = Kp



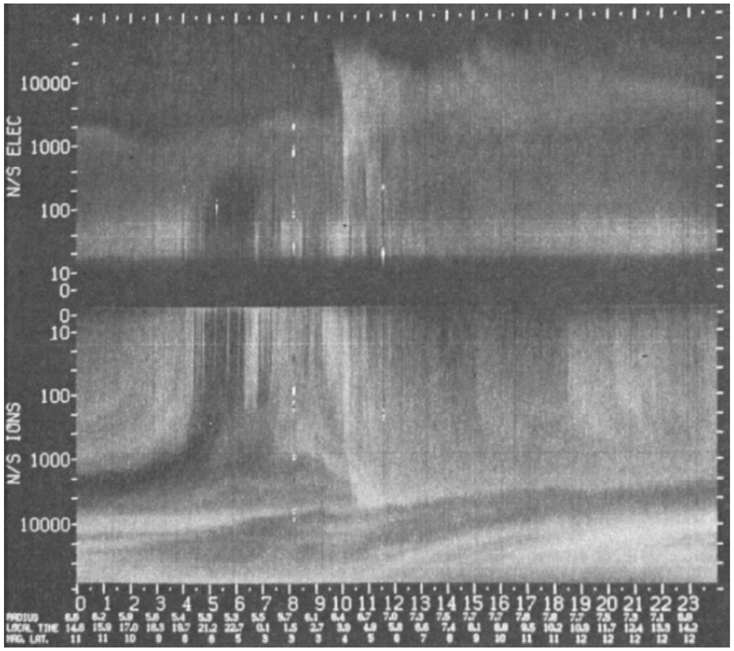


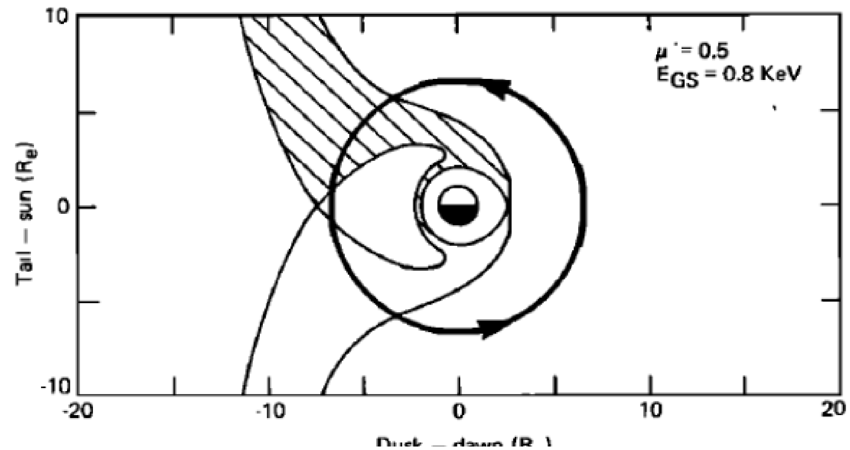


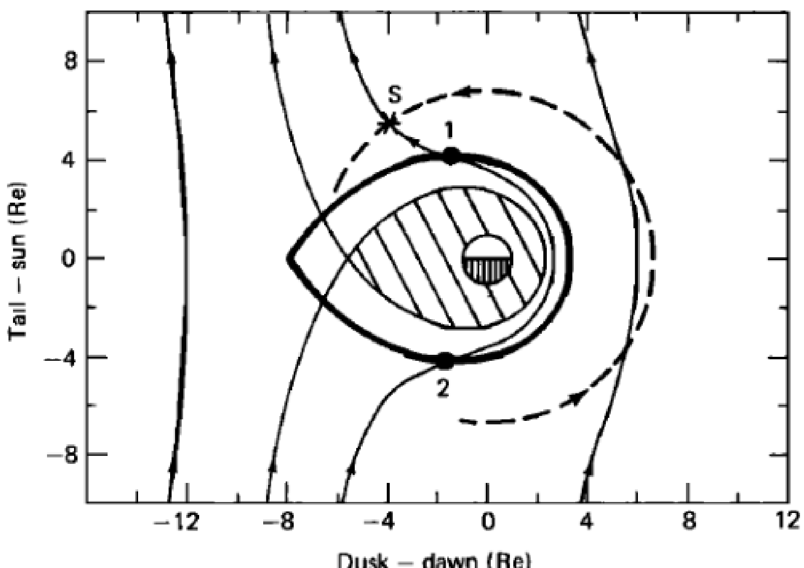


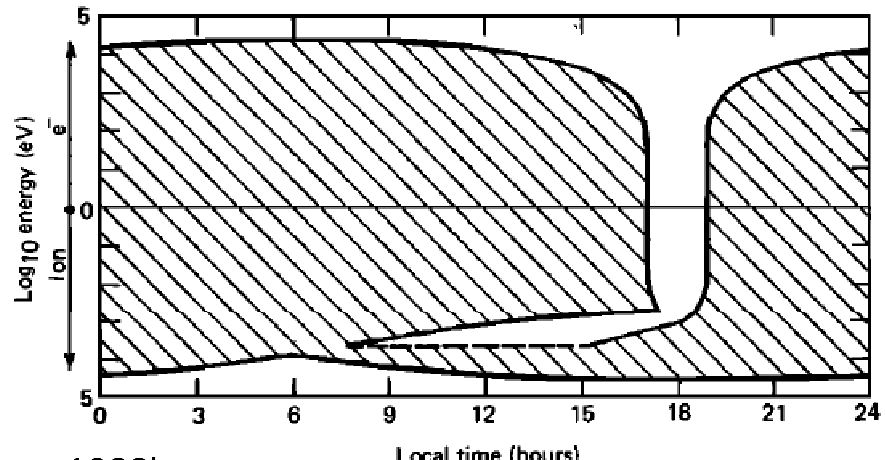
Mauk and Meng 1983b

The dispersion senses are not corrected by including global dynamics nor by including losses for deeply penetrating particles



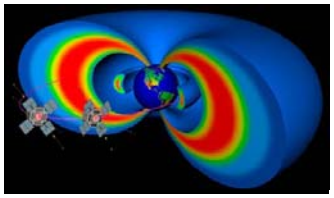






Mauk and Meng, 1983b

Conclusions



- <u>Hypothesis #1</u>, that global convection provides direct plasma access to the middle-inner magnetosphere, does not appear to be supported by electric field measurements nor particle dispersion analyses of <u>complete</u> ion-electron signatures.

- <u>Hypothesis #2</u>, that transient (inductive?) injections provide the principal plasma access to the middle-inner magnetosphere, is better supported by electric field and complete particle dispersion analysis.

- If these conclusions are confirmed, the Van Allen Probes must confront an inner magnetosphere that acts primarily as a generator of fields and currents, not as a shield.

- 3D electric fields and total pressure measurements on Van Allen Probes will aid this confrontation.