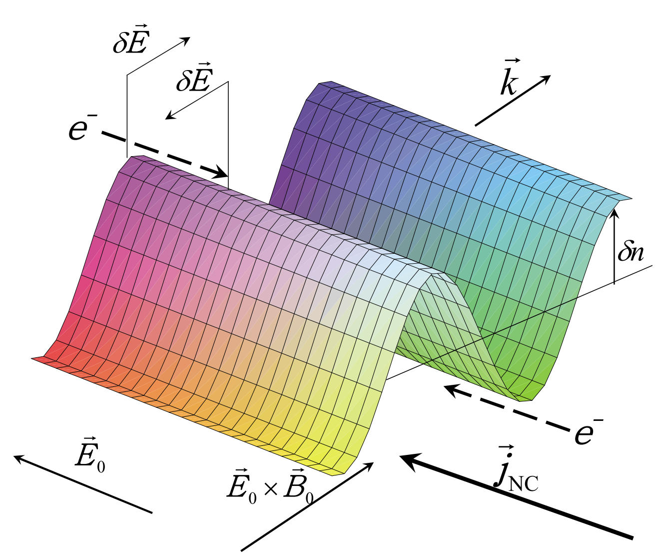
Macroscopic Effects of Microscopic Ionospheric Turbulence

S. Merkin, M. Wiltberger, Y. Dimant, M. Oppenheim, J. Lyon

Two-stream instability: Global effects

Farley-Buneman (two-stream) instability affects ionospheric conductance globally via two mechanisms:

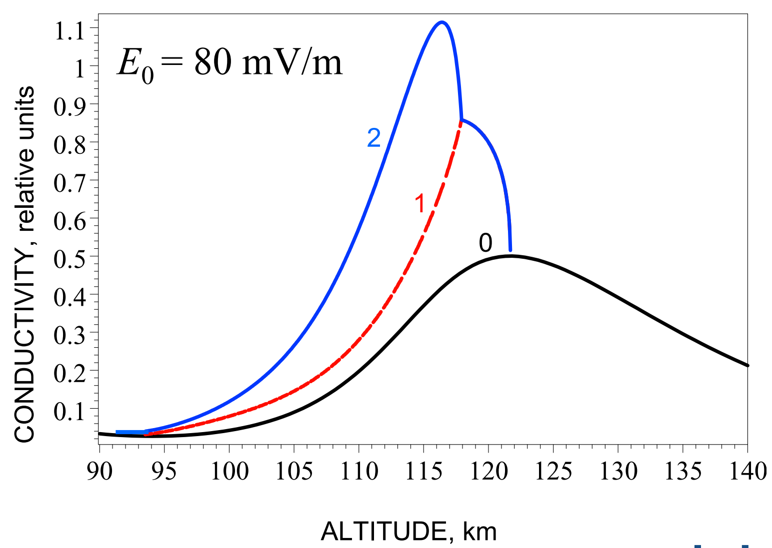
1. Anomalous electron heating (AEH) — (rough estimates):
   - ➡ Threshold electric field $(E_{\rm th} \sim 20{\rm mV/m})$
   - ➡ Te increases $(T_e \sim E/E_{\rm th})$
   - ➡ Recombination rate decreases $(\alpha_{e,i} \sim 1/T_e)$
   - ➡ Plasma density increases $(n \sim 1/\sqrt{\alpha_{e,i}})$
   - ➡ Conductivity increases $(\Sigma_{\rm P}, \Sigma_{\rm H} \sim n \sim \sqrt{E/E_{\rm th}})$
2. Nonlinear DC current (NC, e.g., Oppenheim 1997)



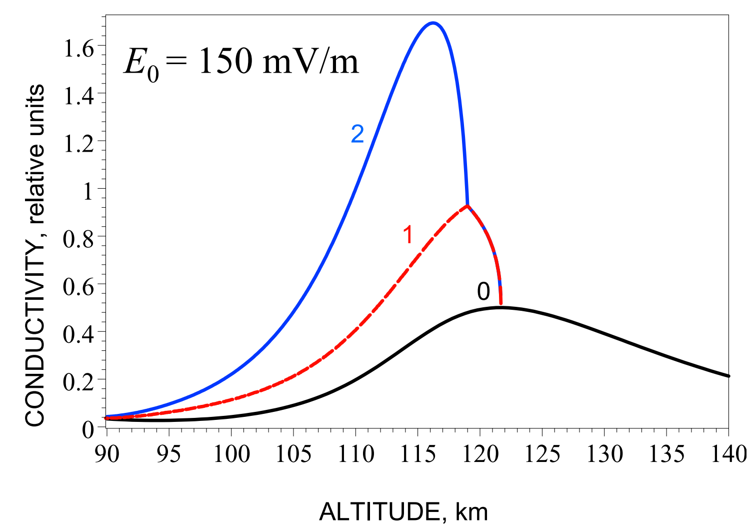
Dimant&Oppenheim [2011a]

Two-stream instability: Global effects

Conductance multipliers (theory + PIC simulations)

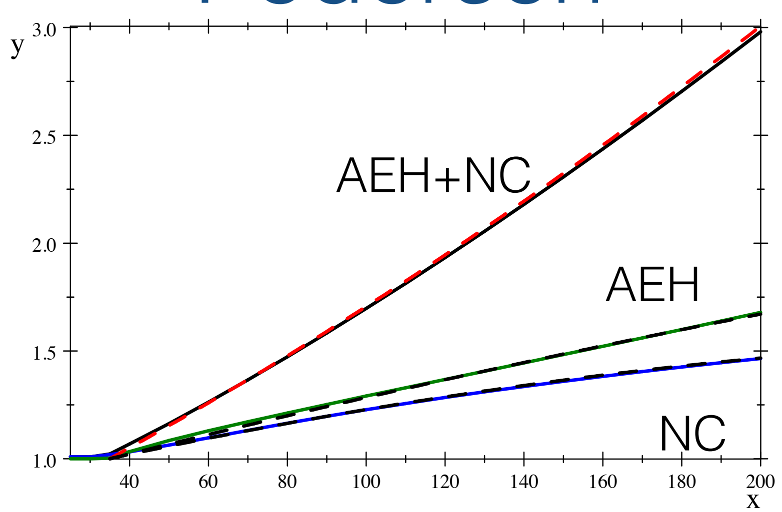


0. Undisturbed
1. NC
2. AEH+NC

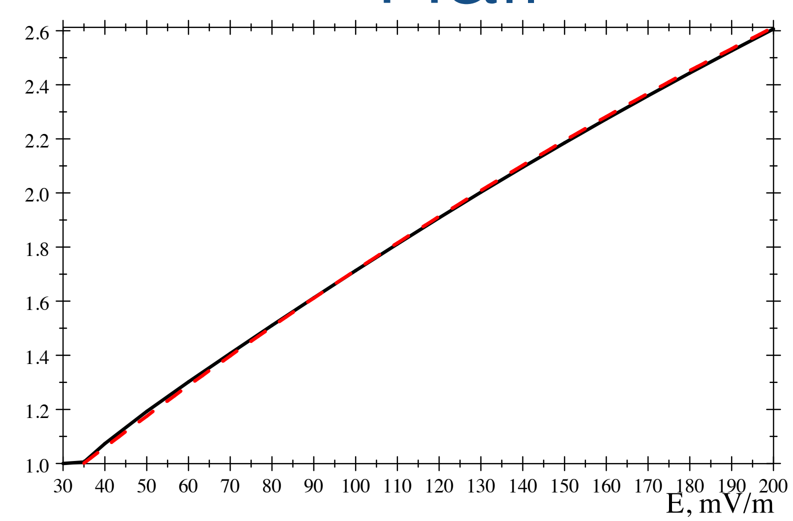


Height-integrated

Pedersen



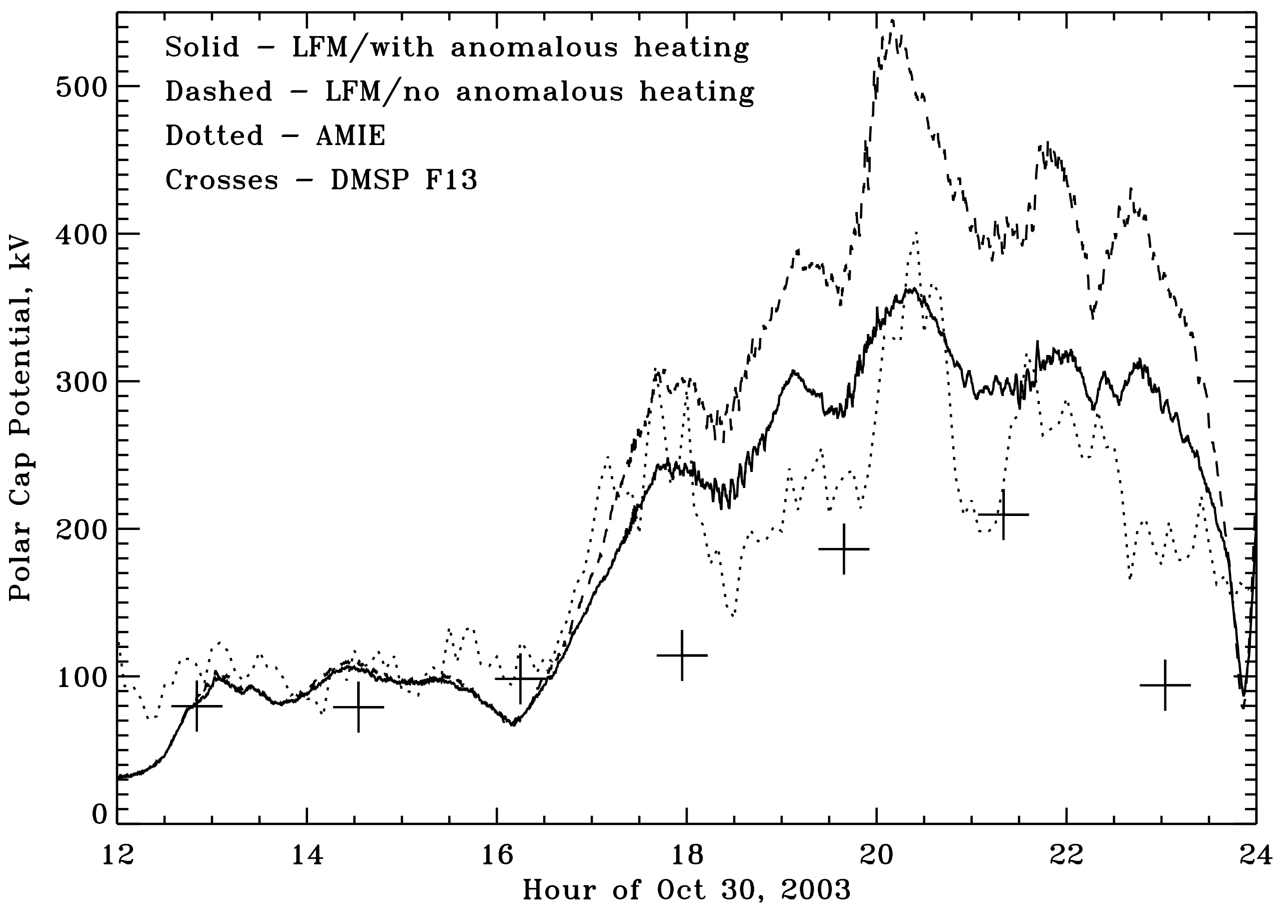
Hall



Dimant&Oppenheim [2011b]

First test: Halloween storm 2013

Effect of including the conductance multipliers in a global MHD model: Used simplified multipliers and only AEH effect

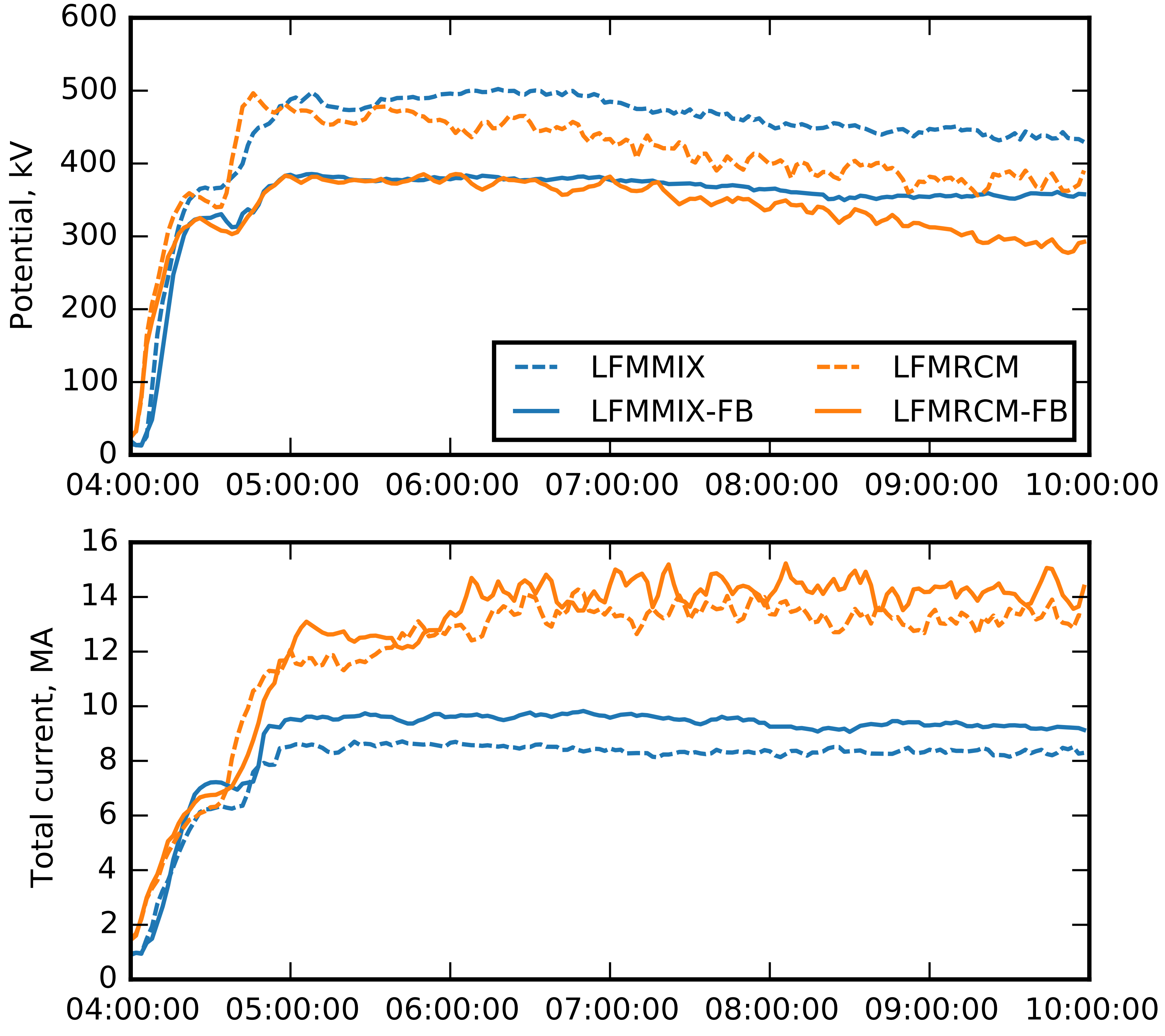


Merkin et al. [2005]

Include LFM-RCM coupling

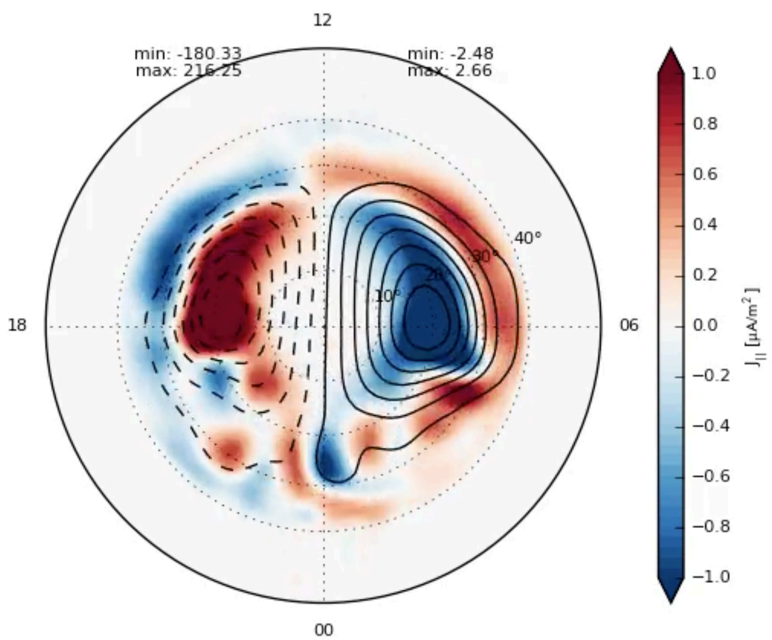
And more accurate conductance model (FB=AEH+NC)

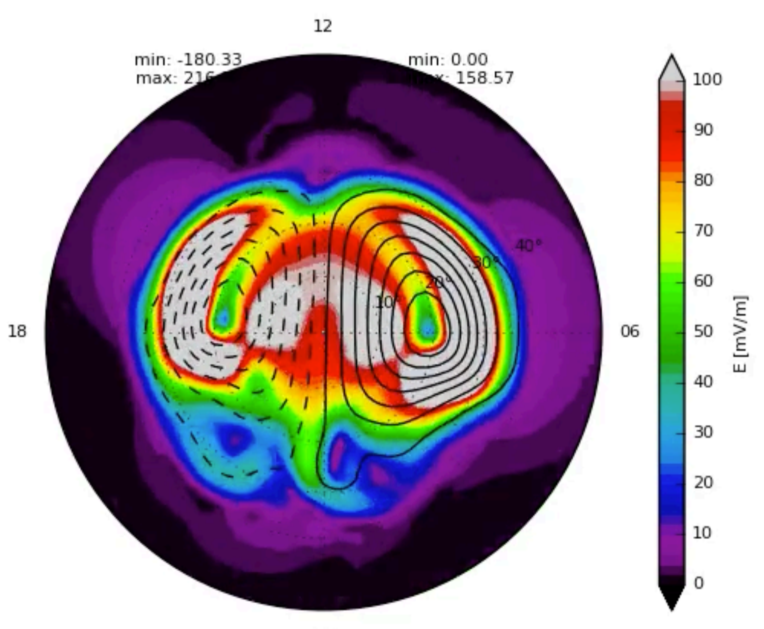
Bz=-30 nT driving



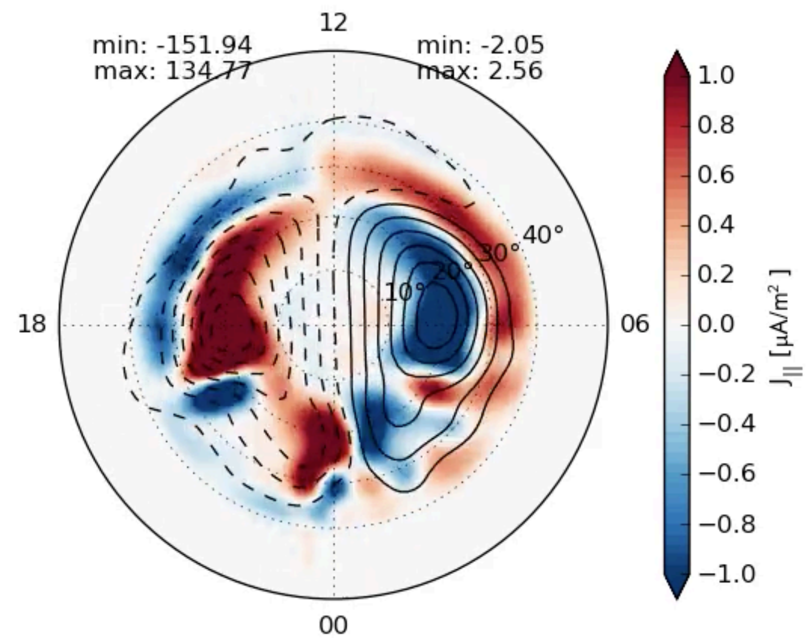
Test LFM-RCM simulation: constant IMF Bz=-30 nT

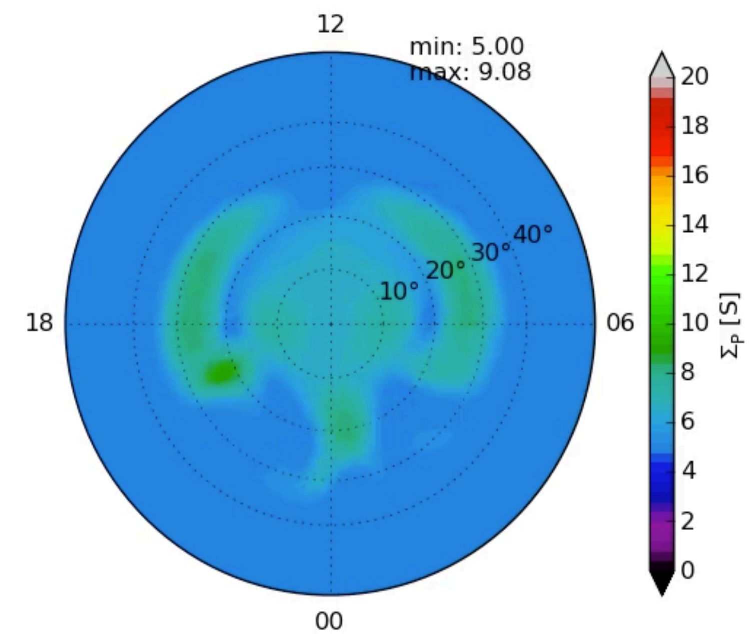
No corrections

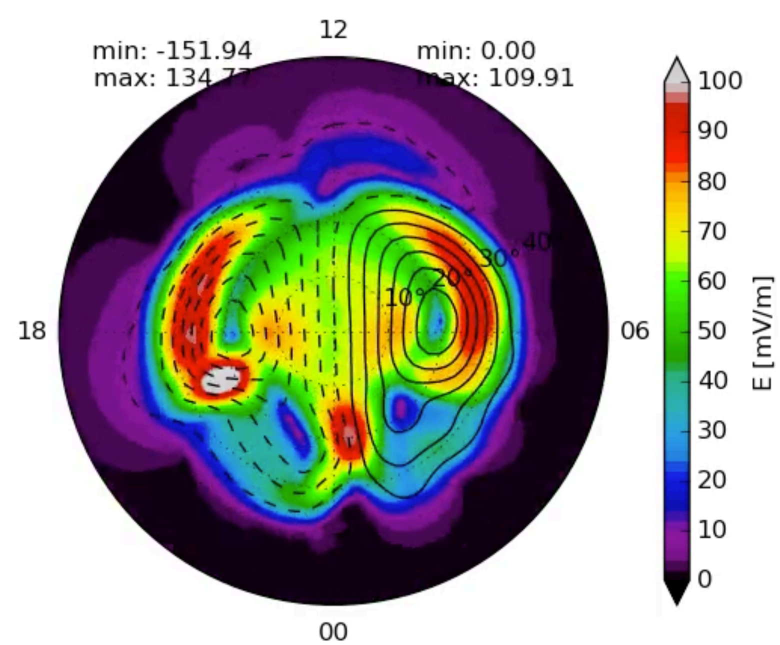




Turbulent corrections

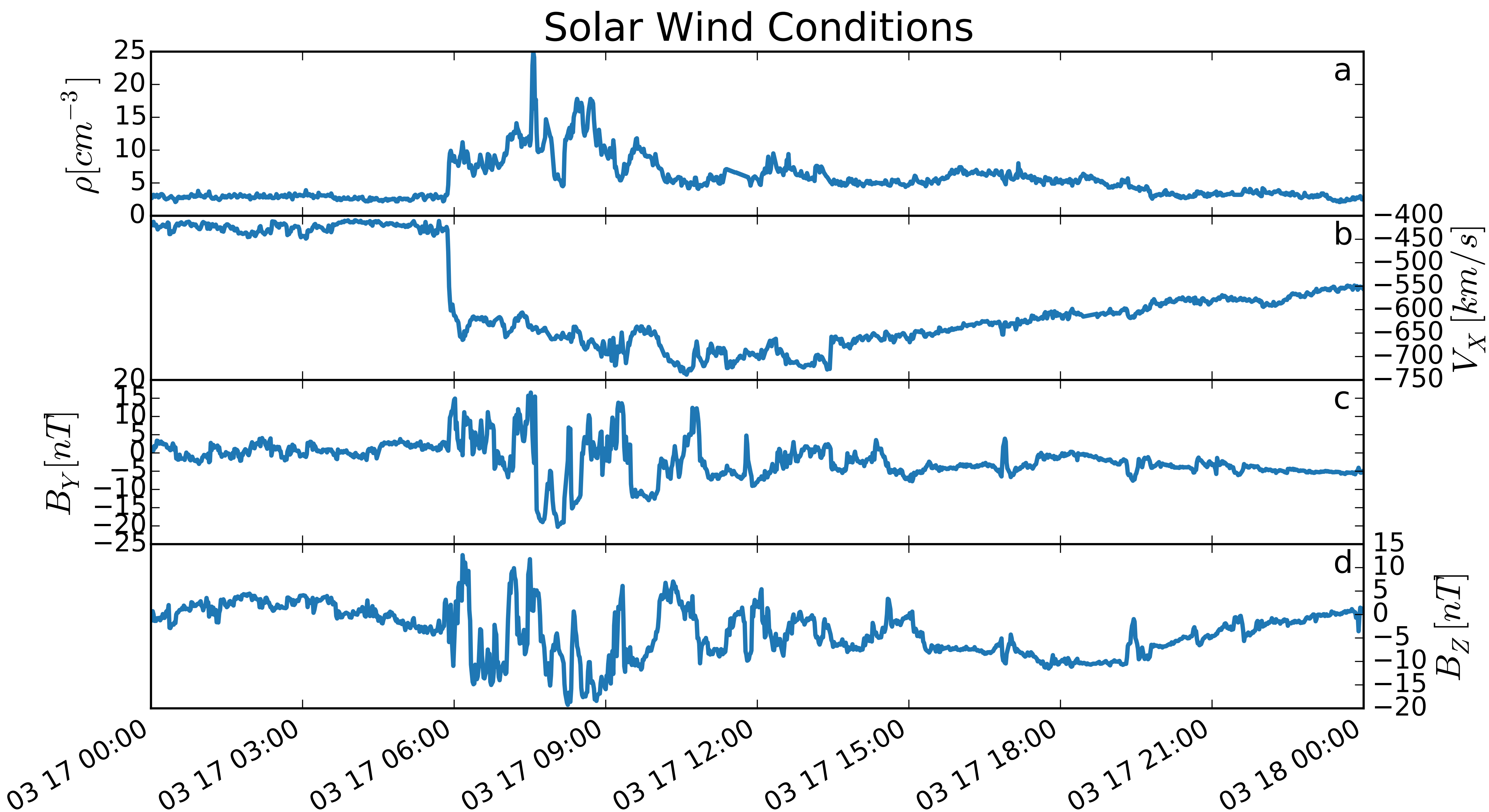






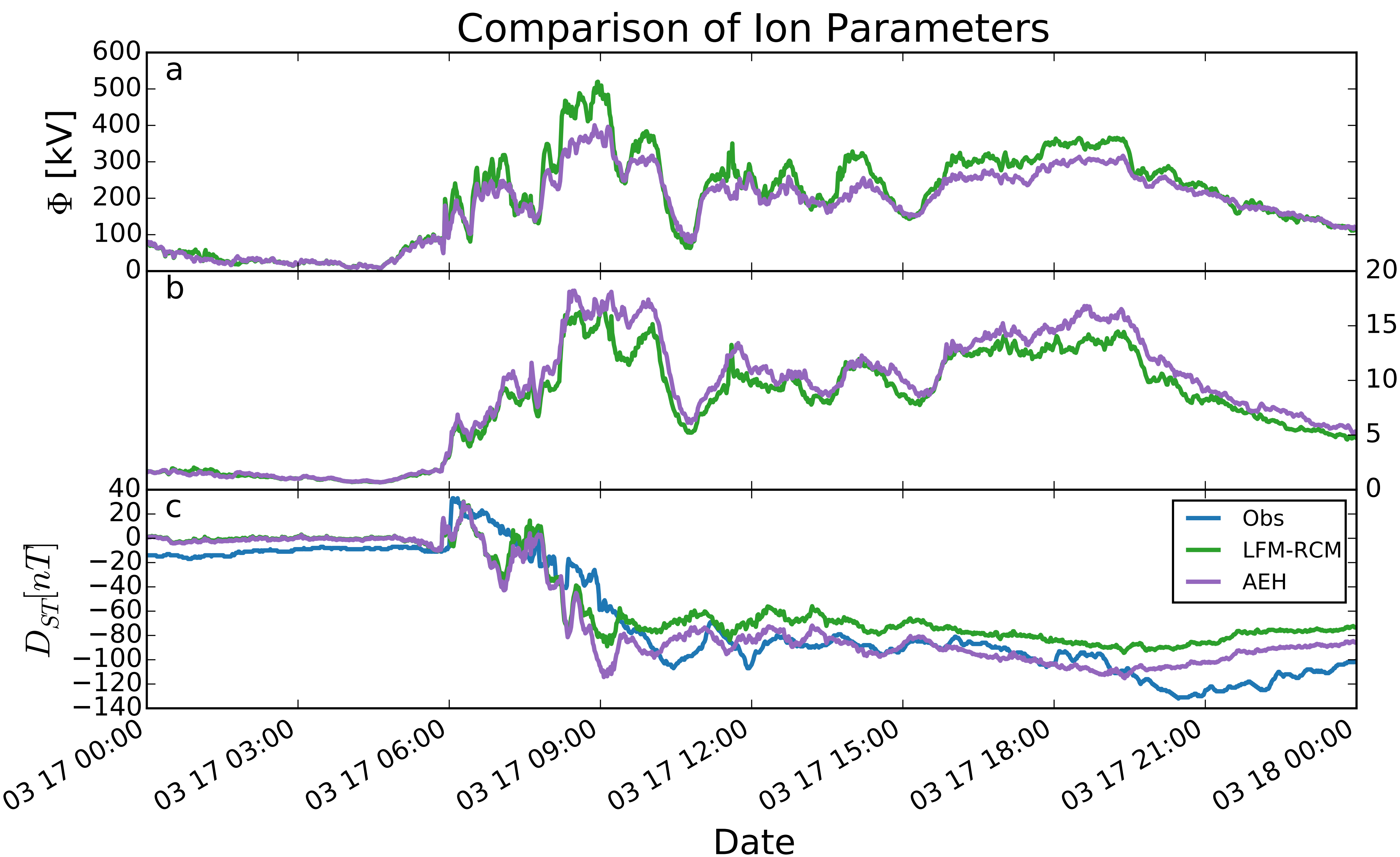
- Pedersen conductance enhanced where E is strong
- E and Φ significantly reduced
- Unlike uncoupled LFM, strongest effect in electrojet

Real storm-time simulation



Wiltberger et al., in preparation, [2016]

Real storm-time simulation



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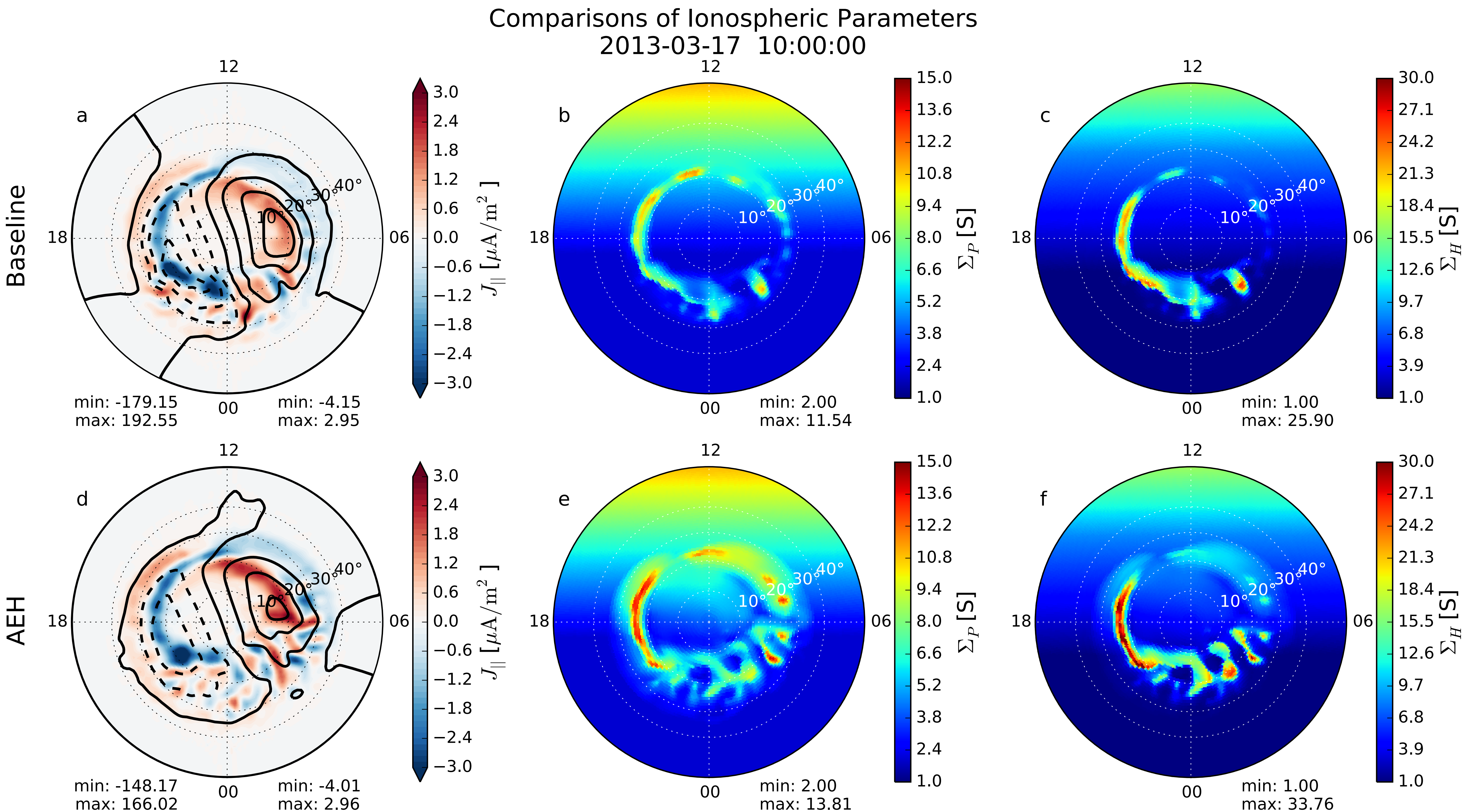

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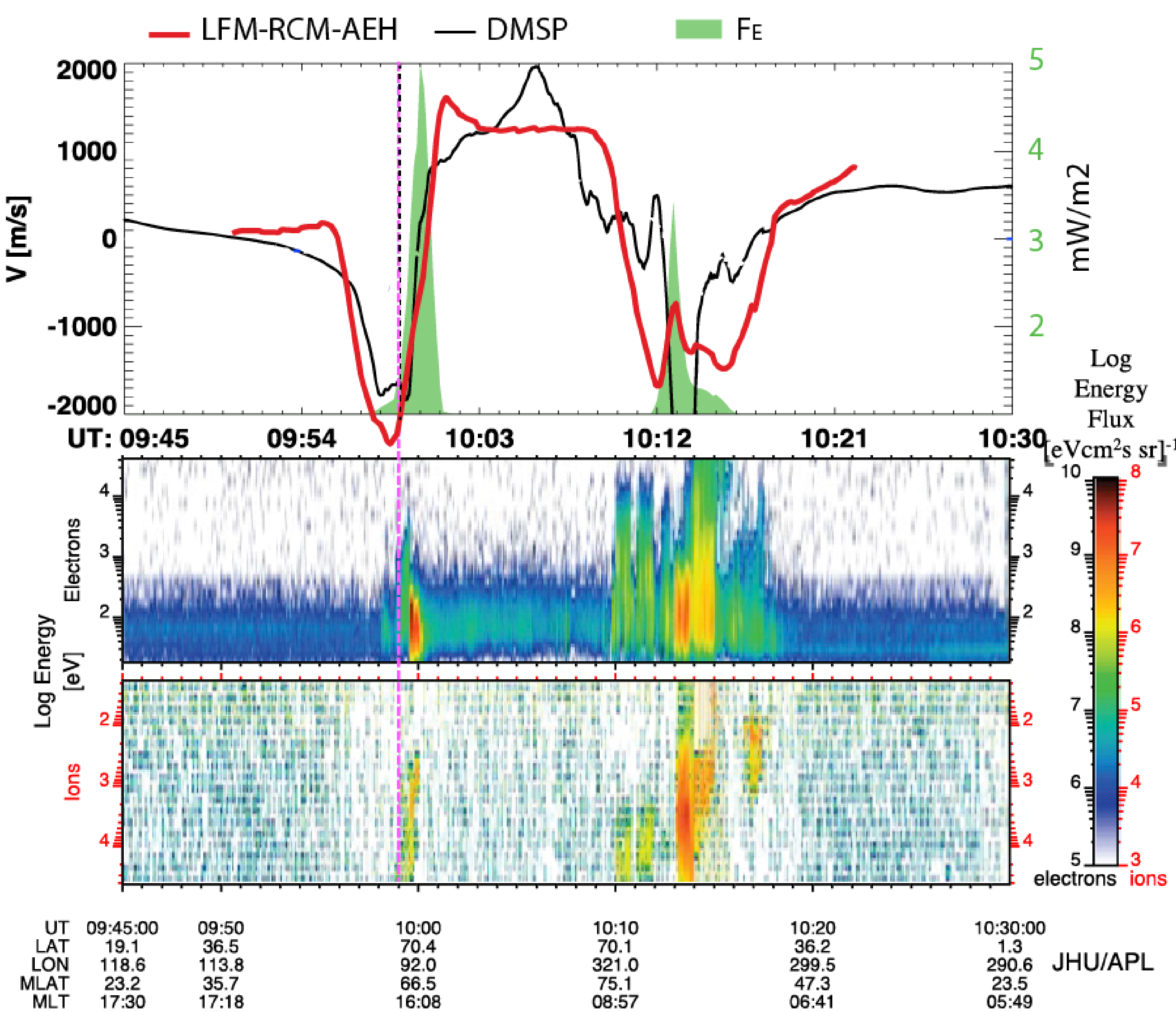
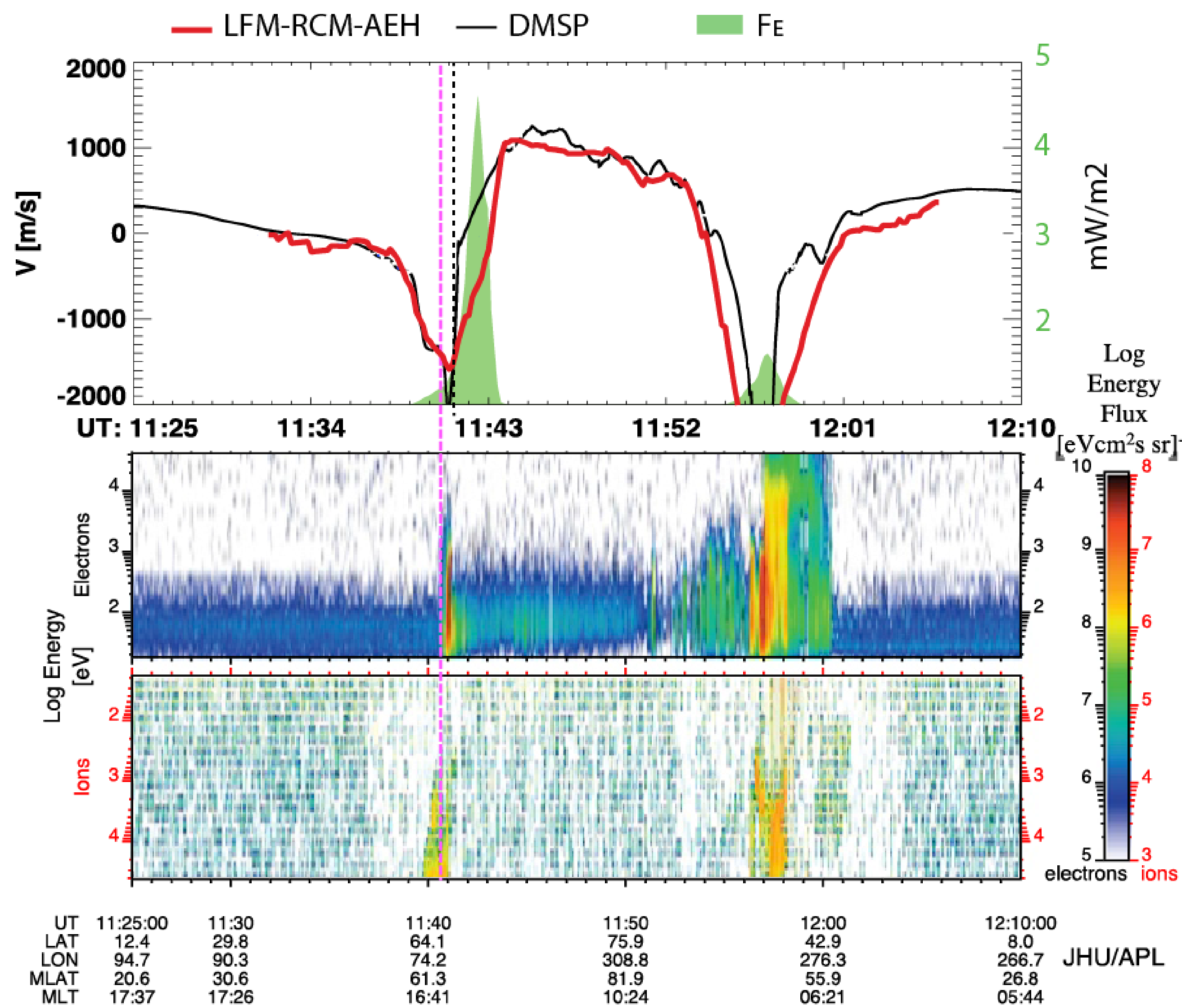
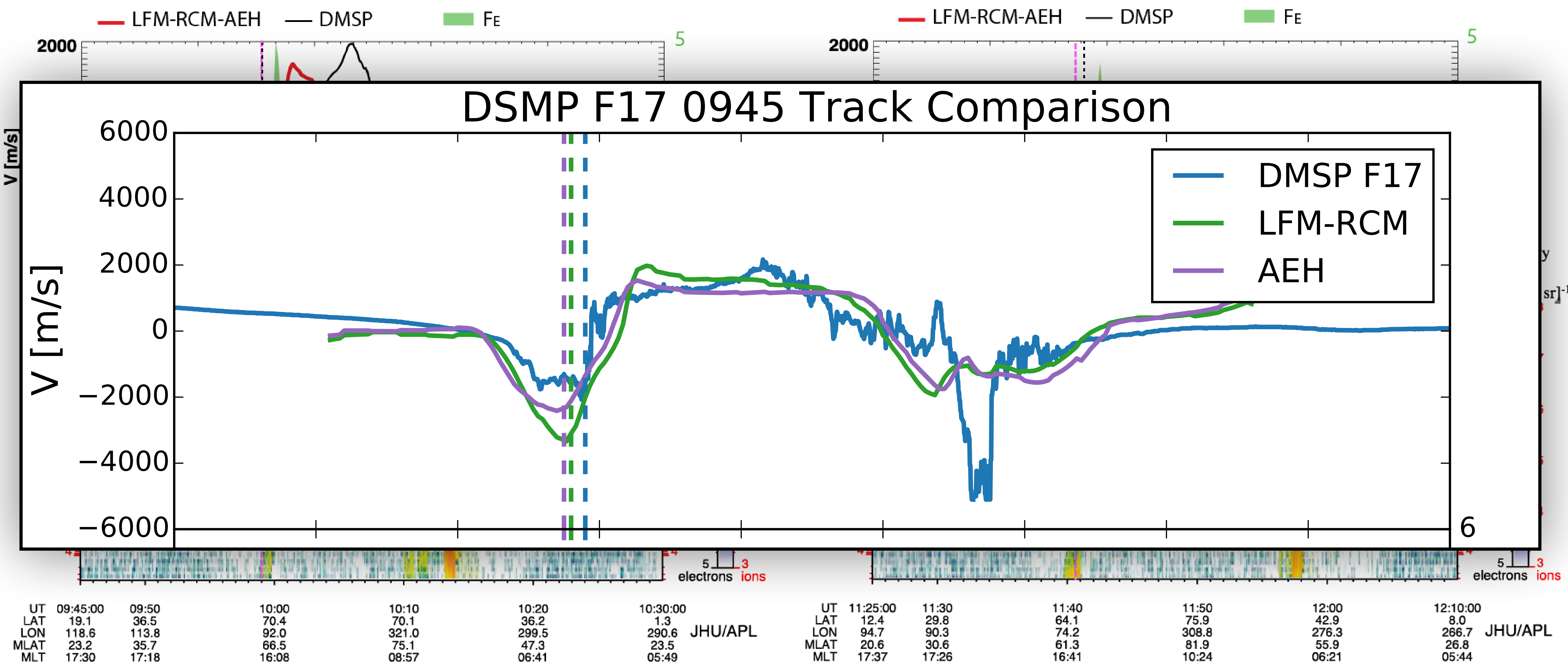




- Strong agreement on dusk side.
- Dawn side problematic: electron drifts? precipitation in R2 area?

**Vertical lines mark equator ward edge of electron precipitation in simulation and data*

Real storm-time simulation



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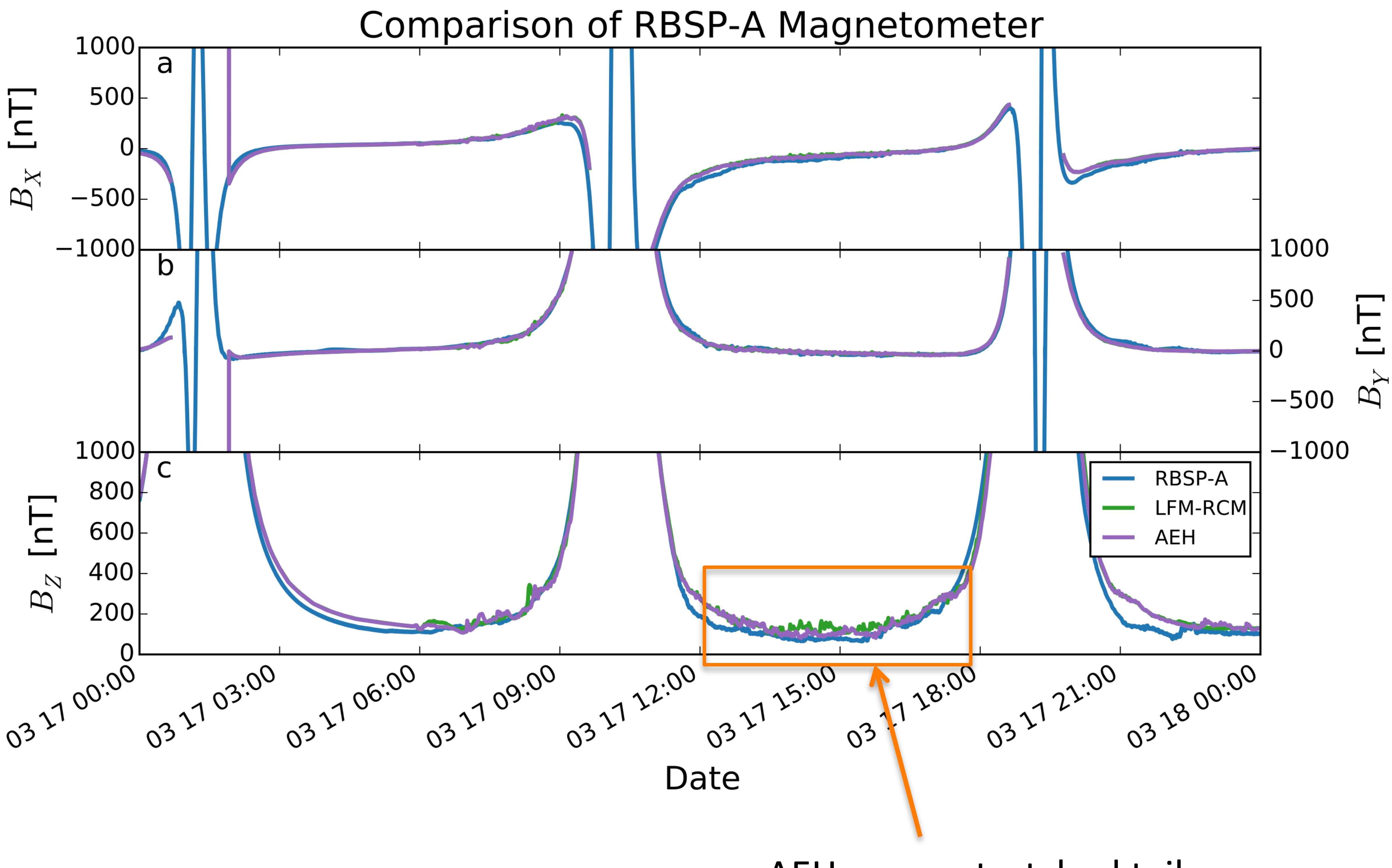
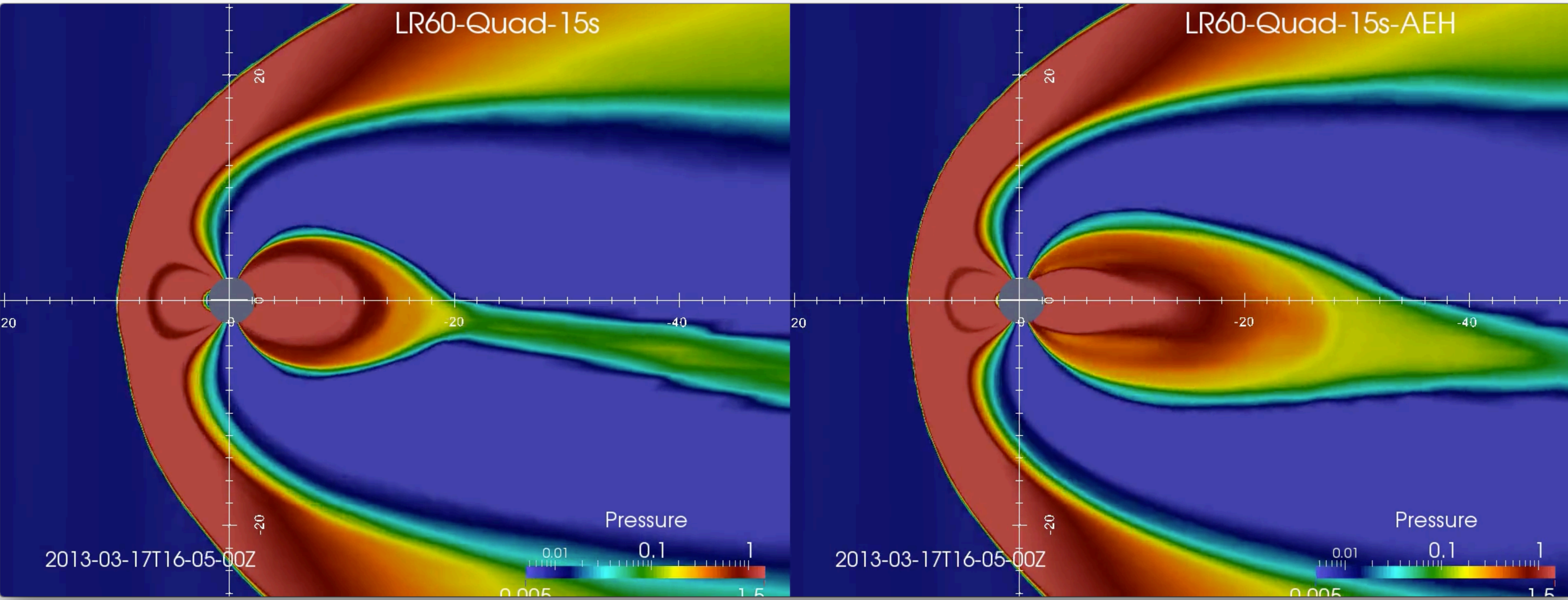


Wiltberger et al., in preparation, [2016]

Real storm-time simulation

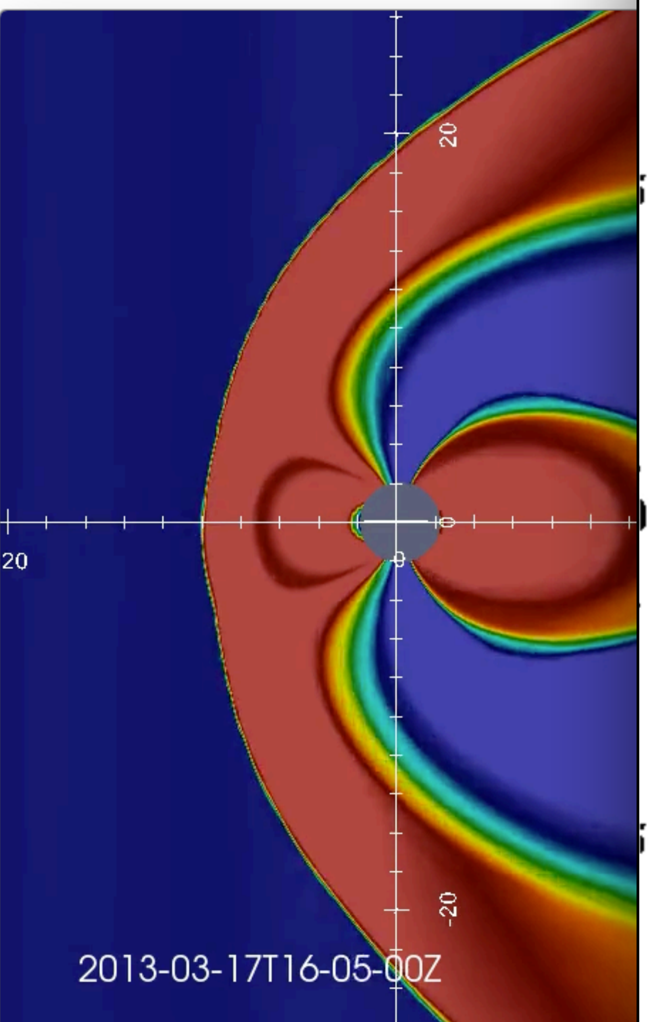
Pressure in meridional plane

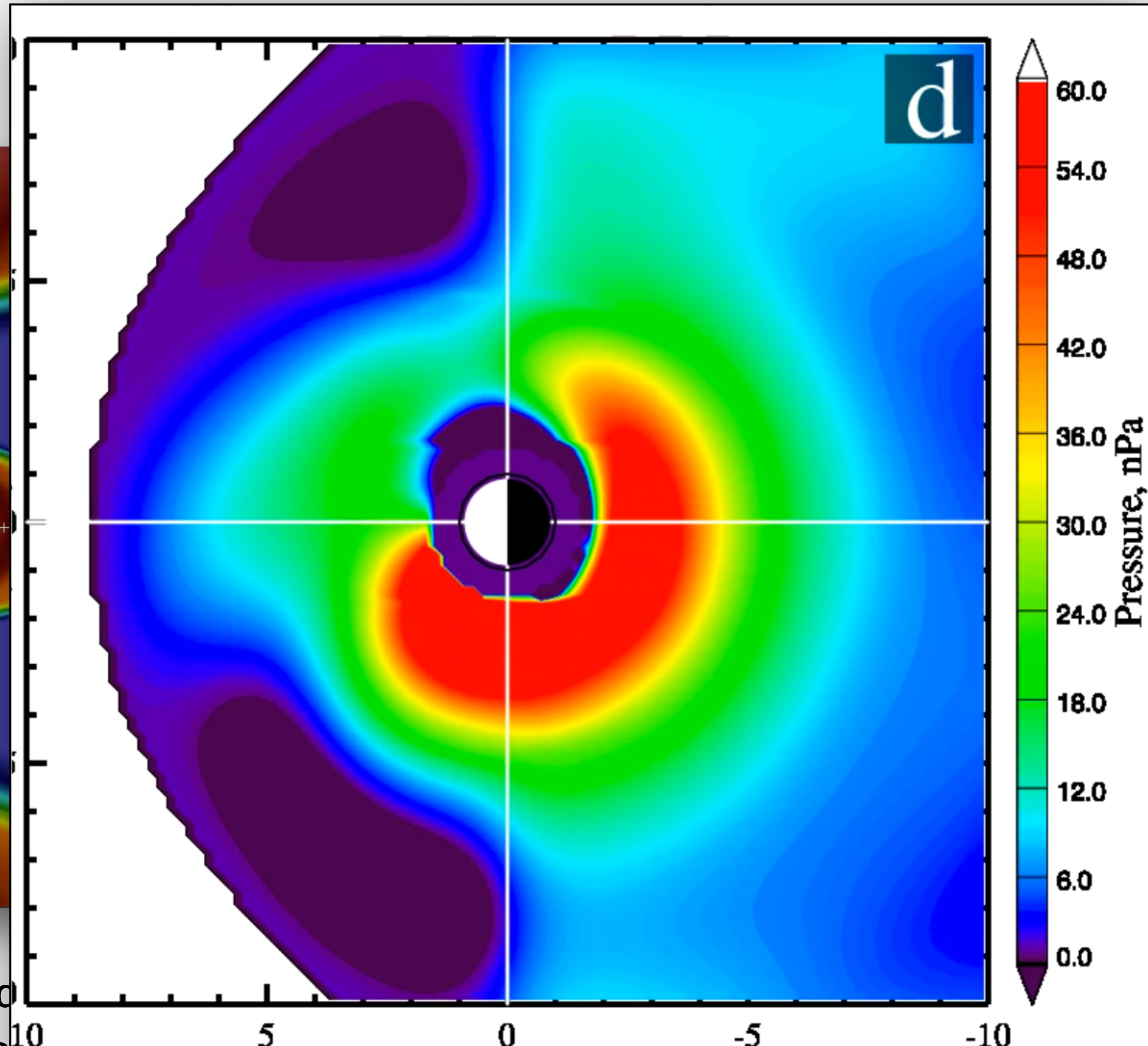


- It's not this different all the time
- AEH has stronger pressure peak = more stretched tail?
- Peak pressure ~100 nPa. RBSP 15 nPa (Gkioulidou et al., 2015) but above equator.
- More stretched tail — better agreement with RBSP? Hypothesis — needs verification

Wiltberger et al., in preparation, [2016]

Real storm-time simulation





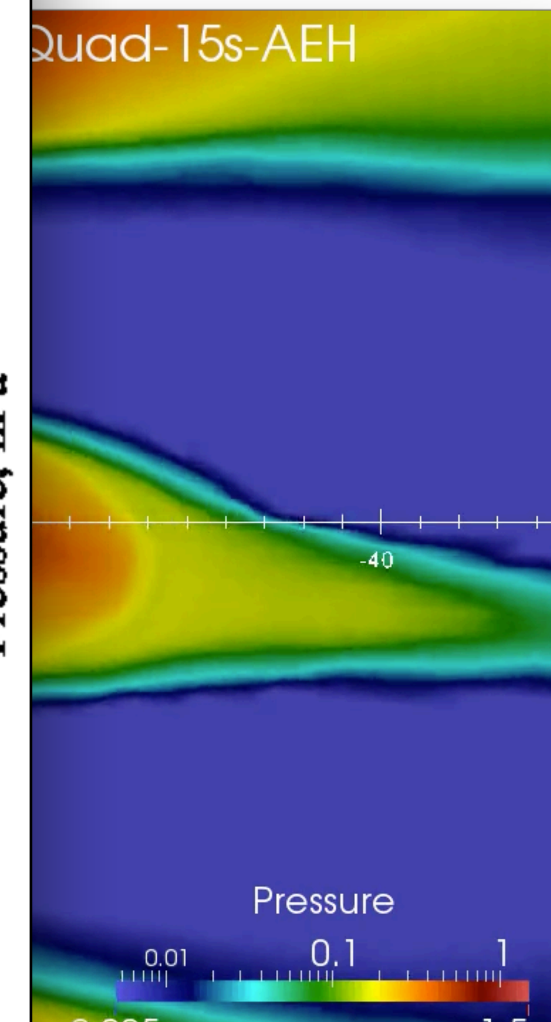


Figure credit: G. Stephens

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- Ionospheric micro-scale turbulence has significant macro-scale effects on the magnetosphere-ionosphere system.

- Reduces the strength of convection in the magnetosphere, leads to better agreement with ionospheric data.

- Important non-linear feedback loop: ionospheric turbulence leads (at times) to stronger ring current pressure peak, more stretched tail.