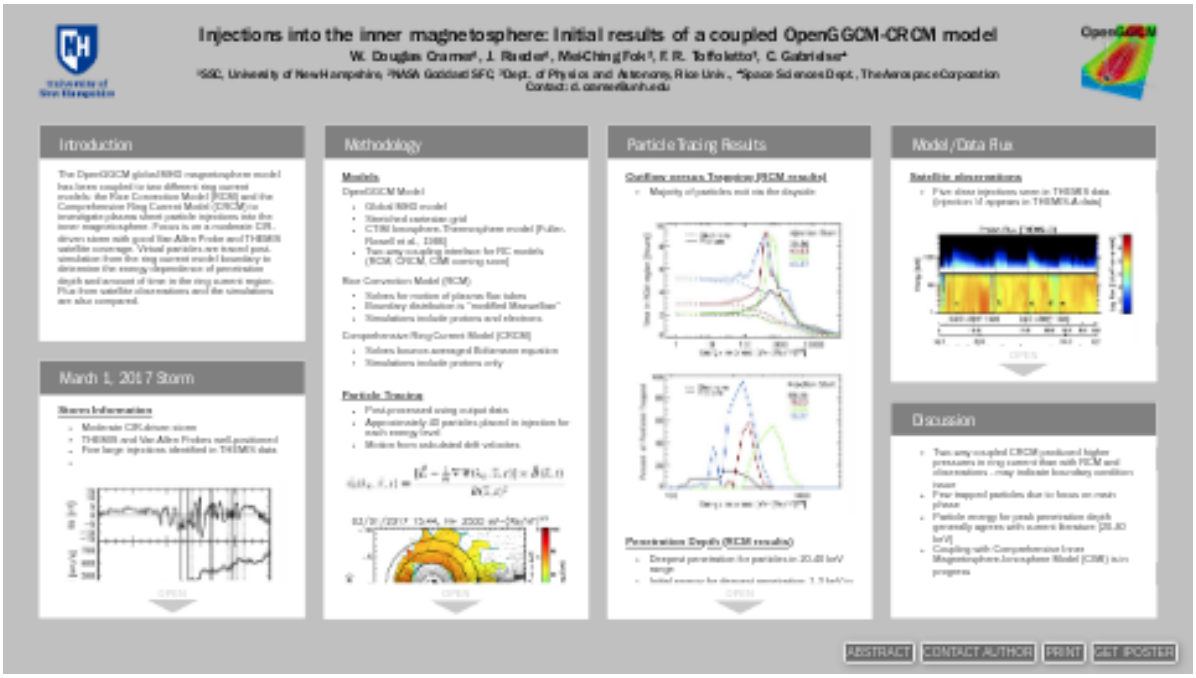
Injections into the inner magnetosphere: Initial results of a coupled OpenGGCM-CRCM model



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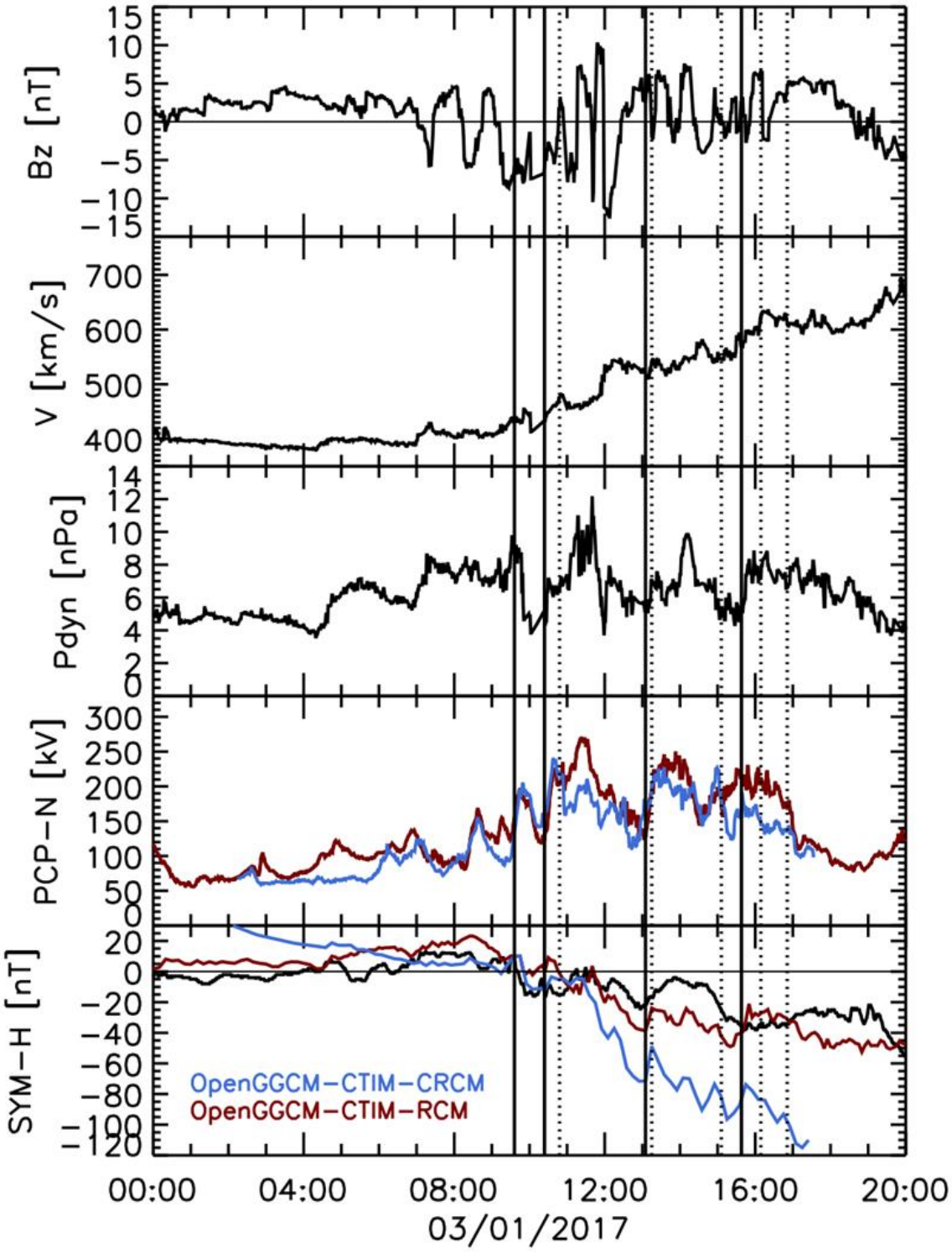
INTRODUCTION

The OpenGGCM global MHD magnetosphere model has been coupled to two different ring current models: the Rice Convection Model (RCM) and the Comprehensive Ring Current Model (CRCM) to investigate plasma sheet particle injections into the inner magnetosphere. The focus is on a moderate CIR-driven geomagnetic storm with good Van Allen Probe and THEMIS satellite coverage. Virtual particles are traced post-simulation from the injection at the ring current model boundary to determine the energy dependence of penetration depth and amount of time in the ring current region. Flux from satellite observations and the simulations are also compared.

MARCH 1, 2017 STORM

Storm Information

- Moderate CIR-driven storm
- THEMIS and Van Allen Probes well-positioned
- Five large injections identified in THEMIS data, four in OpenGGCM-RCM simulation
- Simulated SYM-H similar to actual for OpenGGCM-RCM, but more intense for OpenGGCM-CRCM



March 1, 2017 geomagnetic storm. Vertical lines respresent the time of injections seen in the OpenGGCM-RCM simulation (solid) and THEMIS data (dotted).

METHODOLOGY

Models

OpenGGCM Model

- Global MHD model
- Stretched cartesian grid
- CTIM Ionosphere-Thermosphere model
- Two-way coupling interface for RC models (RCM, CRCM, CIMI coming soon)

Rice Convection Model (RCM)

- Solves for motion of plasma flux tubes
- Boundary distribution is "modifled Maxwellian"
- Simulations include protons and electrons

Comprehensive Ring Current Model (CRCM)

- Solves bounce-averaged Boltzmann equation
- Simulations include protons only

Particle Tracing

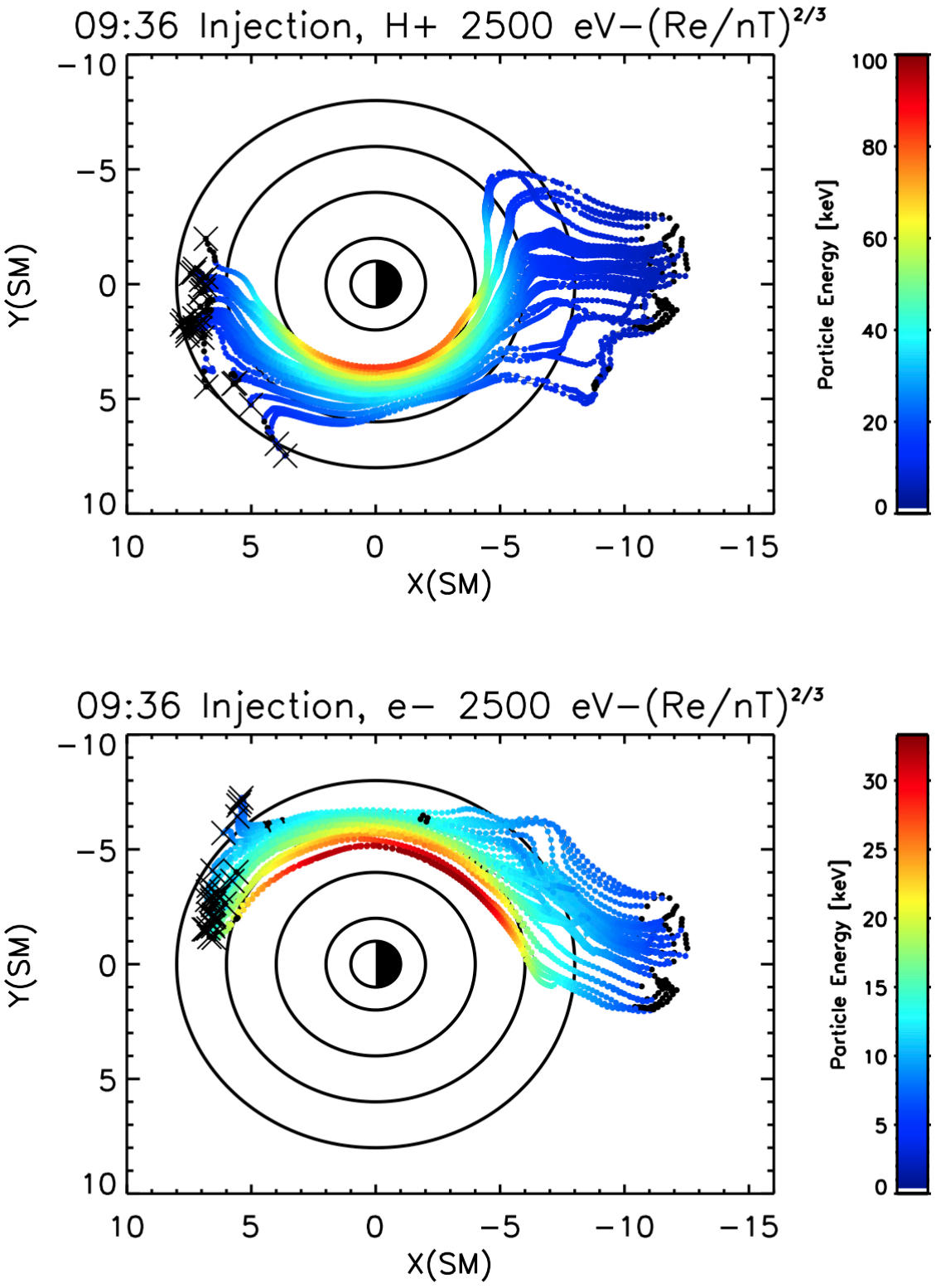
- Approximately 40 particles placed in injection for each energy level
- Post-processed using output data
- Motion from calculated drift velocites
- Decay not considered in analysis

$$\vec{v}_k(\lambda_k, \vec{x}, t) = \frac{[\vec{E} - \frac{1}{q_k}\nabla W(\lambda_k, \vec{x}, t)] \times \vec{B}(\vec{x}, t)}{B(\vec{x}, t)^2}$$

[VIDEO] https://www.youtube.com/embed/6ccEuVQv9-c?rel=0&fs=1&modestbranding=1&rel=0&showinfo=0

[VIDEO] https://www.youtube.com/embed/fnPaMzCNaX4?rel=0&fs=1&modestbranding=1&rel=0&showinfo=0

Particle tracing of (top) 500 and (bottom) 2500 eV-(Re/nT)^(2/3) protons with the OpenGGCM-RCM simulation of the 3/1/2017 geomagnetic storm. Background is equatorial flux in the RCM region. Light solid lines represent equipotentials, lines pointing from “plus” symbols indicate velocity, circles indicate traced particle position with color representing energy.

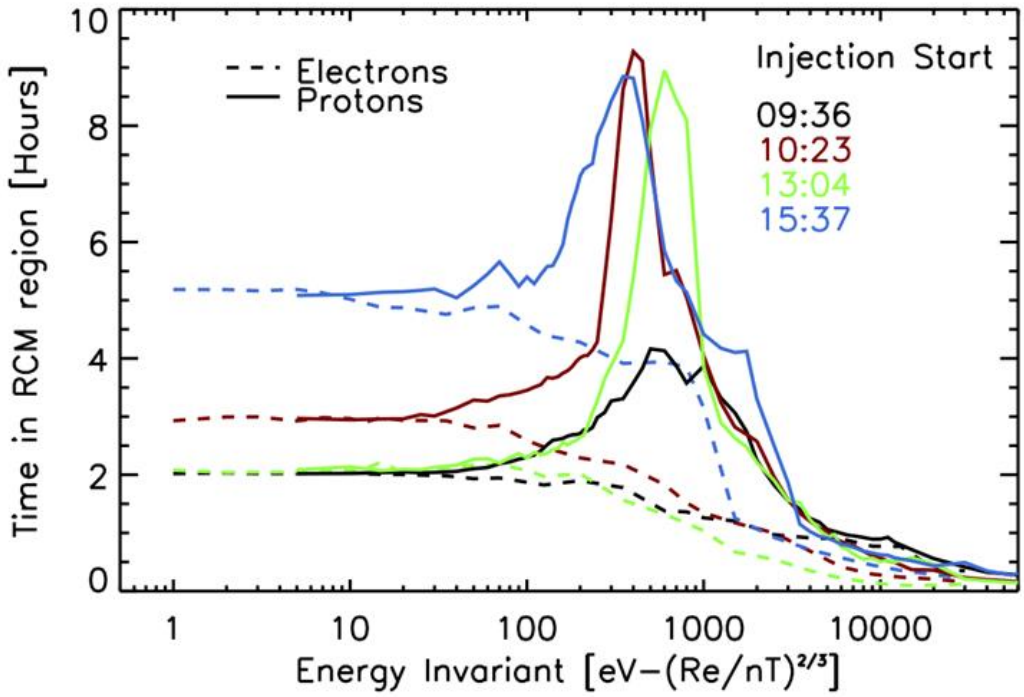


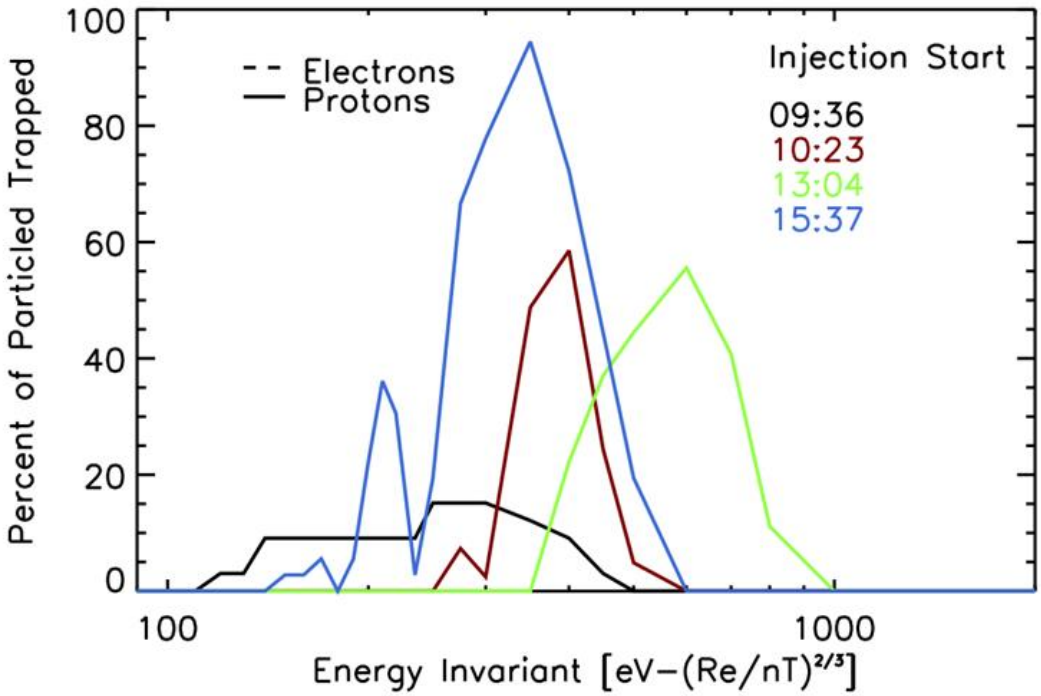
Drift paths for 2500 eV-(Re/nT)^(2/3) test particles during the 09:36 injection: (Top) protons, (Bottom) electrons.

PARTICLE TRACING RESULTS

Time spent in ring current (RCM results)

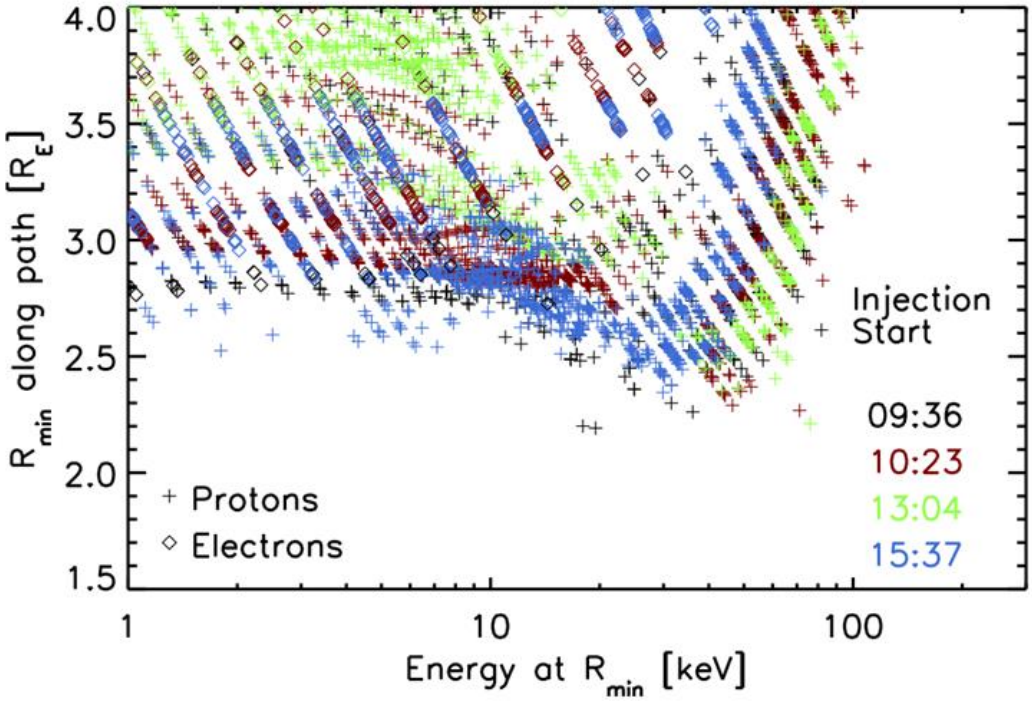
- Majority of particles exit via the dayside
- Protons with energy invariants between 100-1000 eV- (Re/nT)^(2/3) spend most time (equivalent to ~2-20 keV at L=5, ~6-60 keV at L=3)

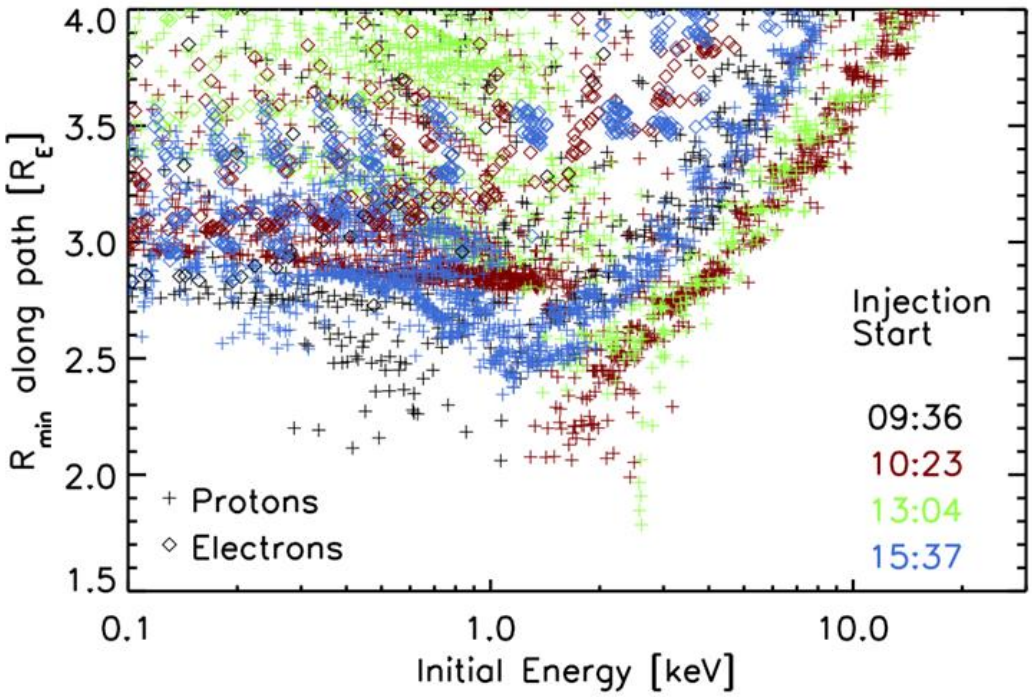




Penetration depth (RCM results)

- Deepest penetration for particles in 20-40 keV range
- Initial energy for deepest penetration: 1-3 keV in plasma sheet

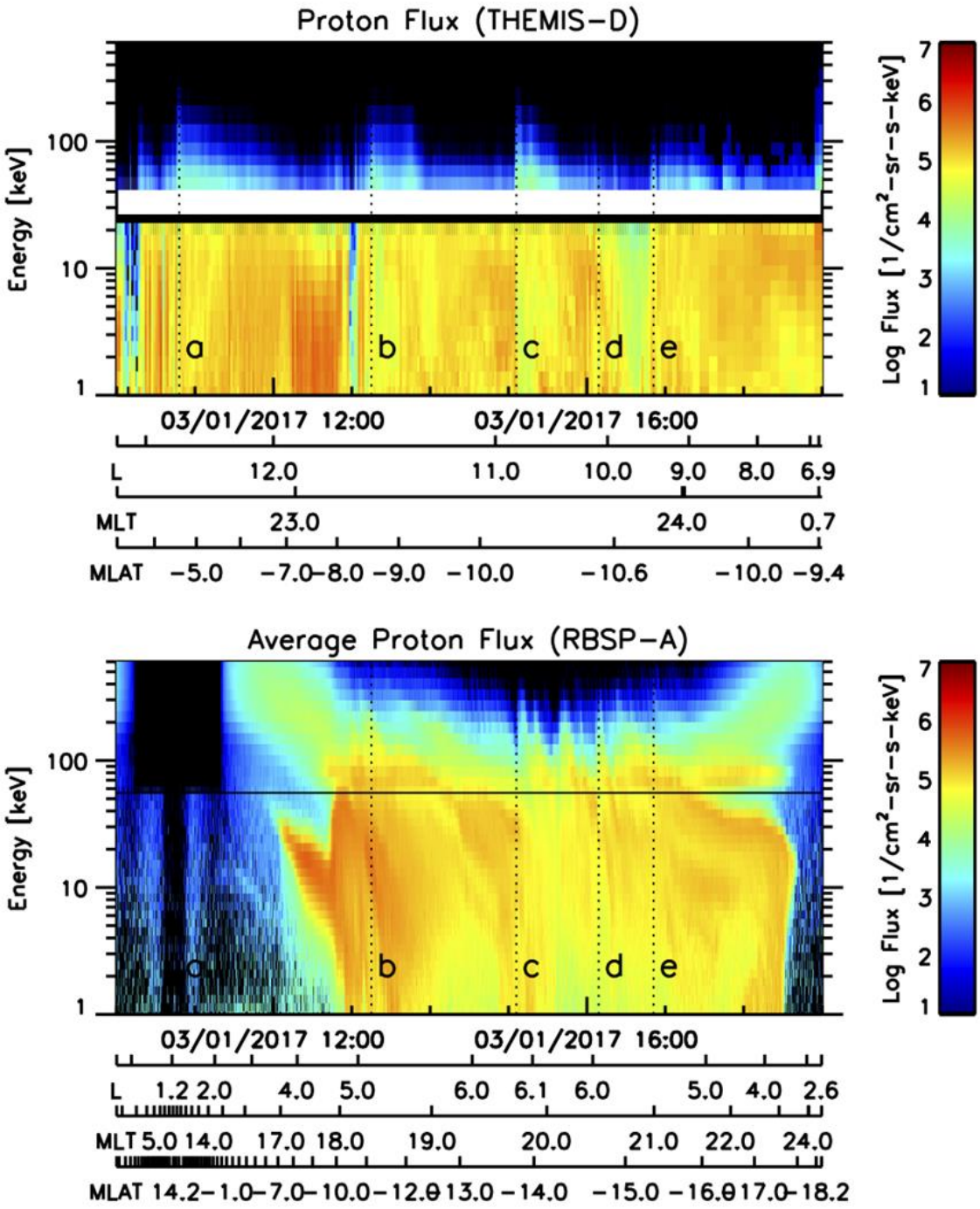




MODEL/DATA FLUX

Satellite observations

- Five clear injections seen in THEMIS data (injection 'd' appears in THEMIS-A data)

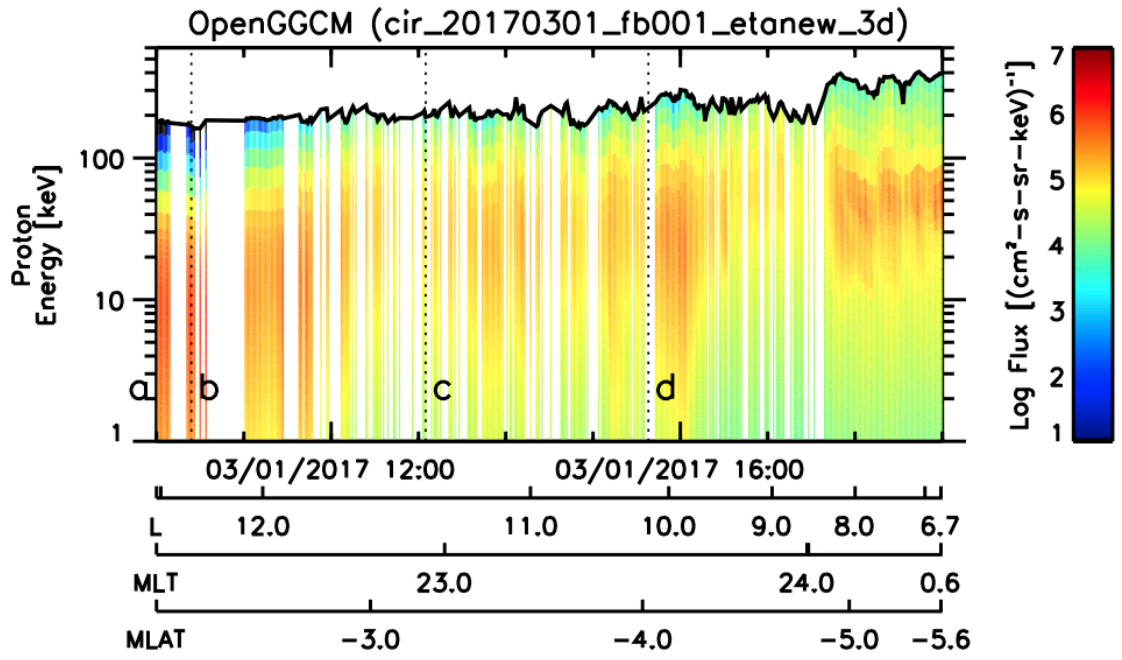


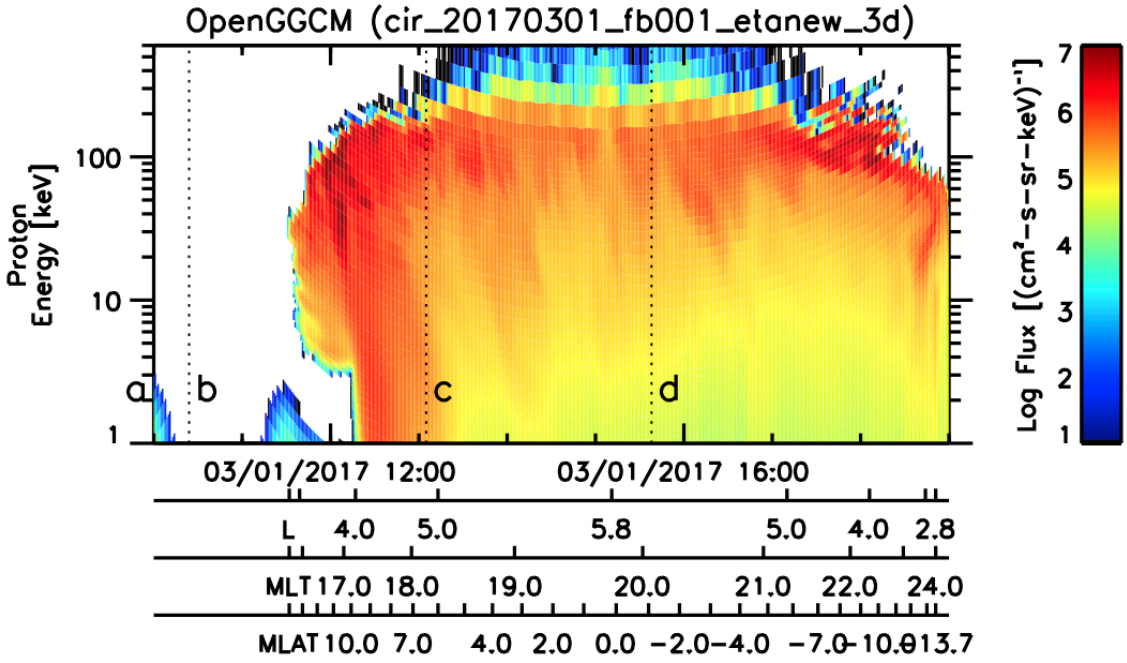
Model fluxes at satellite positions

- Flux only available in model within RCM region, so some flux data not available
- Generally higher than observational values, especially at high energies

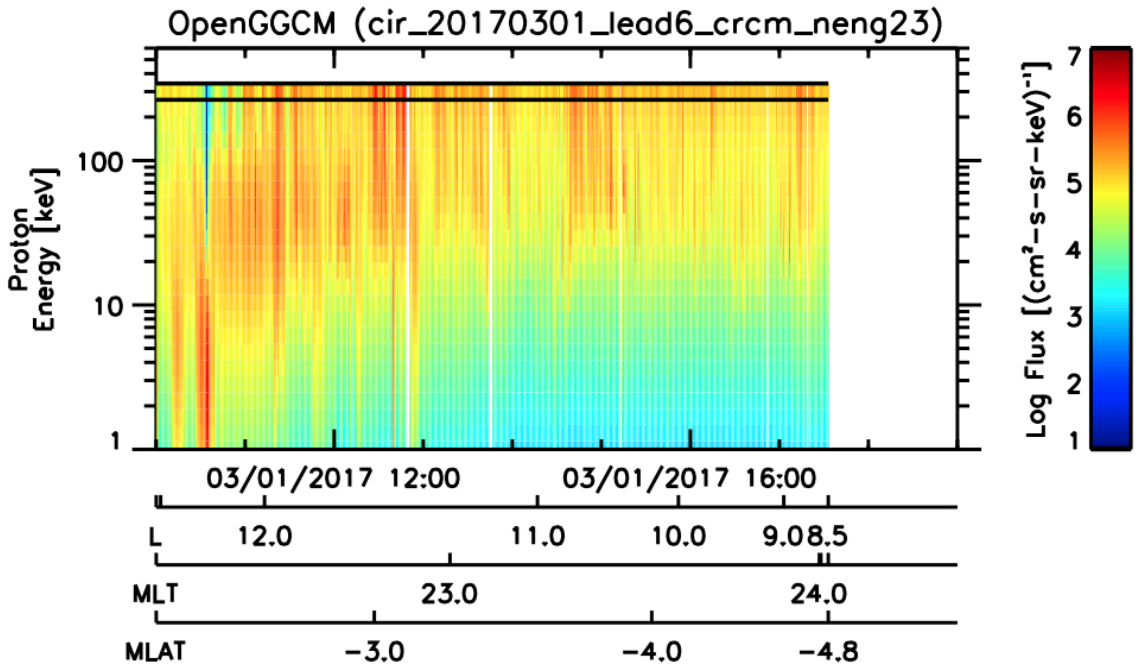
OpenGGCM-CTIM-RCM

- Four major injections noted in time range





OpenGGCM-CTIM-CRCM


OpenGGCM (cir_20170301_lead6_crcm_neng23)
Proton Energy [keV]
100
10
1
Log Flux [(cm²-s-sr-keV)⁻¹]
7
6
5
4
3
2
1
03/01/2017 12:00
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L
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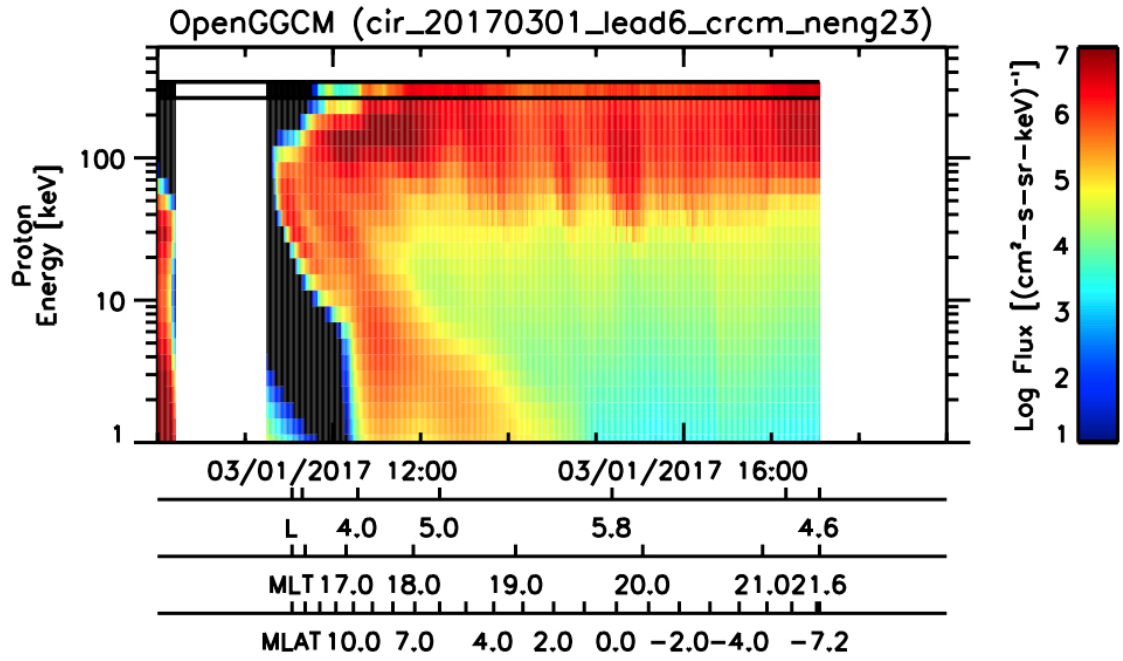
OpenGGCM (cir_20170301_lead6_crcm_neng23)
Proton Energy [keV]
100
10
1
Log Flux [(cm²-s-sr-keV)⁻¹]
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17.0
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21.6
MLAT
10.0
7.0
4.0
2.0
0.0
-2.0
-4.0
-7.2

DISCUSSION

- Particle energy for peak penetration depth generally agrees with current literature (20-40 keV)
- Protons with energy invariants between 100-1000 eV- (Re/nT)^(2/3) spend most time in ring current region
- Few trapped particles due to study focus on main phase injections
- Features in model flux similar to observed, although higher in upper energy channels
- Two-way coupled CRCM produced higher pressures in ring current than with RCM and observations - may indicate boundary condition issue
- Coupling with Comprehensive Inner Magnetosphere-Ionosphere Model (CIMI) is in progress

ABSTRACT

Plasma sheet injections driven by regions of low flux tube entropy (“bubbles”) have been found to contribute significantly to the inner magnetosphere plasma population. However, the effect of individual injections and how they incorporate into the inner magnetosphere is not well understood. This study extends previous work that used the OpenGGCM-RCM coupled model to track injections by coupling with the Comprehensive Ring Current Model (CRCM). The dependence of injection penetration depth and inner magnetosphere plasma energization on initial bubble parameters is examined. Results are compared to previous modeling results and observational data from THEMIS and the Van Allen Probes.