Division III Reporter Review: Global Dynamics

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Task and Scope

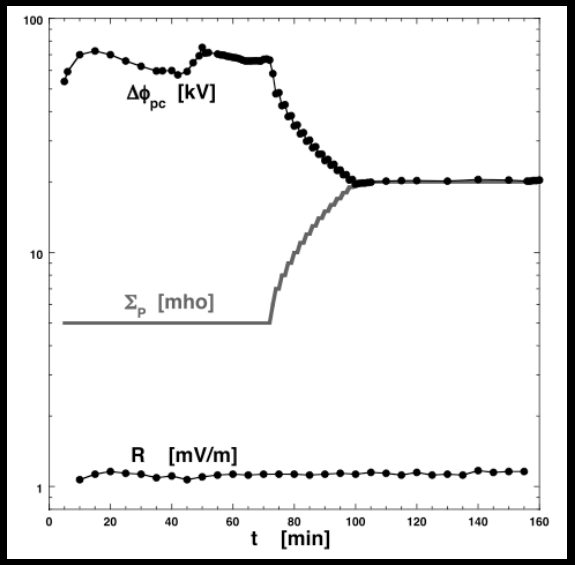
- Provide a review of the literature related to modeling the interaction of the magnetosphere-ionosphere system with the solar wind on a global scale
- Scope
  - Only included peer reviewed publications in major journals, e.g. JGR, GRL, SW, AG, JASTP, from 7/07 to 7/09
  - Reporting content of papers not providing any scientific assessment
  - Papers must have a global modeling as a significant component
  - Only 30 minutes so the coverage is not comprehensive
    - Apologies to papers I may have had to skip for time

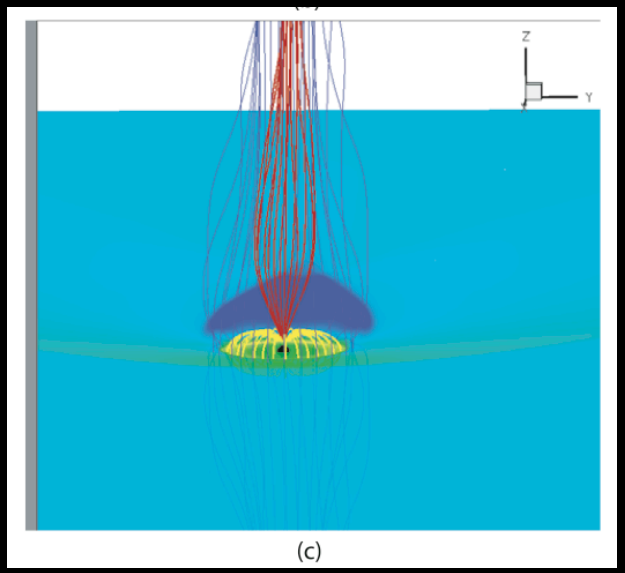
Broad Topic Areas

- Polar Cap Potential Saturation
  - Modeling efforts to understand the nonlinear saturation of the polar cap potential
- Substorms
  - Efforts to model the onset and evolution of substorms
- Dayside Reconnection
  - Structure and dynamics of the magnetic reconnection process on the dayside especially FTEs
- Validation and Verification
  - Studies assessing the accuracy of global models
- Multifluid Modeling
  - Developments related to modeling with more than one fluid including ionospheric outflow
- Energy conversions
  - Using models to study the transfer of energy between regions
- Miscellaneous
  - Papers that didn't fit, but had neat ideas

Polar Cap Potential Saturation

- Borovsky et al., JGR, 2009
  - Used the BATSRUS model at the CCMC
    - Modified to include a high resistivity spot on magnetopause
  - Local reconnection rate is independent of Ψ_P
  - Shape and location of magnetosphere changes with Ψ_P
  - Solar wind acts as a current limited voltage source
  - Provides a summary of 9 saturation models



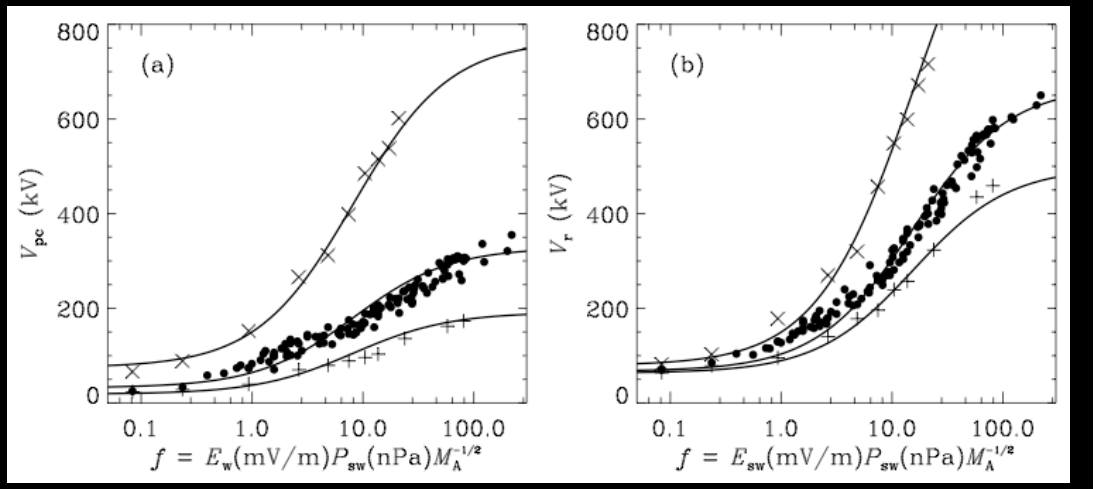


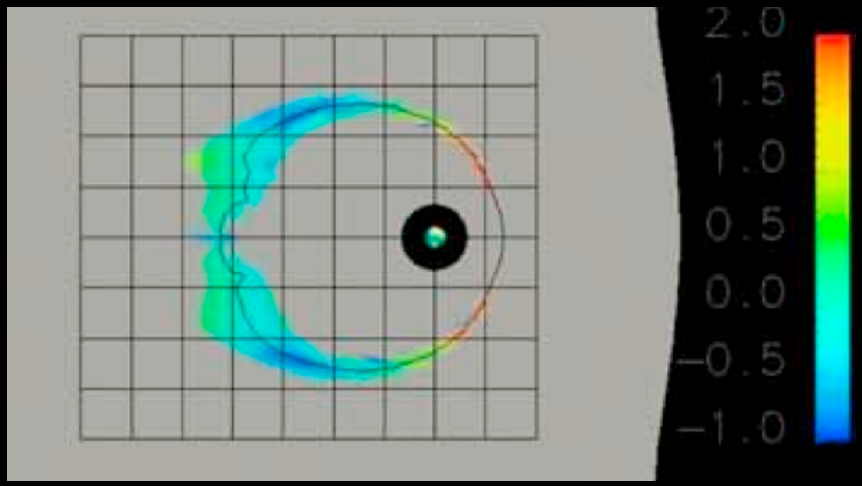
- Kivelson and Ridley, JGR, 2008
  - Used the BATSRUS model
  - When solar wind impendence exceeds ionospheric impendence Alfven waves are partial reflected limiting the signal to the polar cap

$$\frac{\Phi_{PC}}{\Phi_{SW}} = \frac{2\Sigma_A}{\Sigma_P + \Sigma_A}$$

Polar Cap Potential Saturation II

- Peng et al., JGR, 2009
  - Used the PPMLR Model
  - Find that Φ_{PC} and Φ_{R} have similar saturation characteristics especially when parameterized as function of E_{SW},P_{RAM} and M_A
  - Φ_{P} sets the level at which saturation occurs

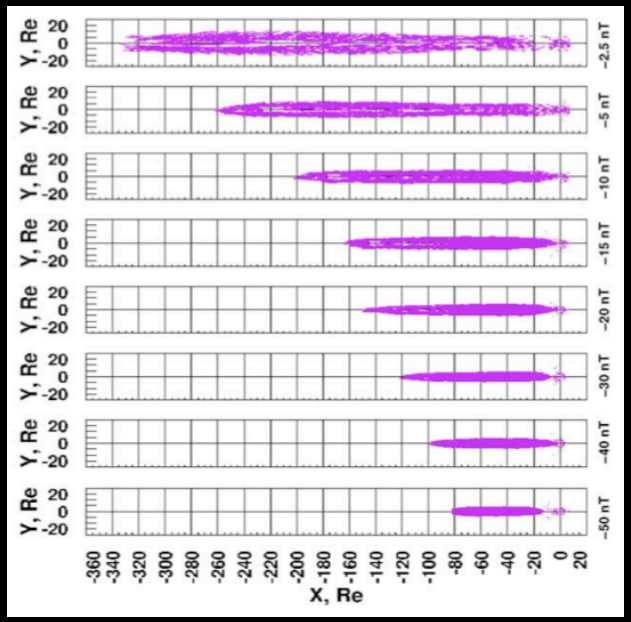




- Lopez et al., JGR, 2009
  - Used the LFM model
  - Noted that while Φ_{PC} saturates the ring current injection rate does not
  - In these simulation results the reconnection line moves earthward injecting flux tubes with lower PVΦ which can penetrate further

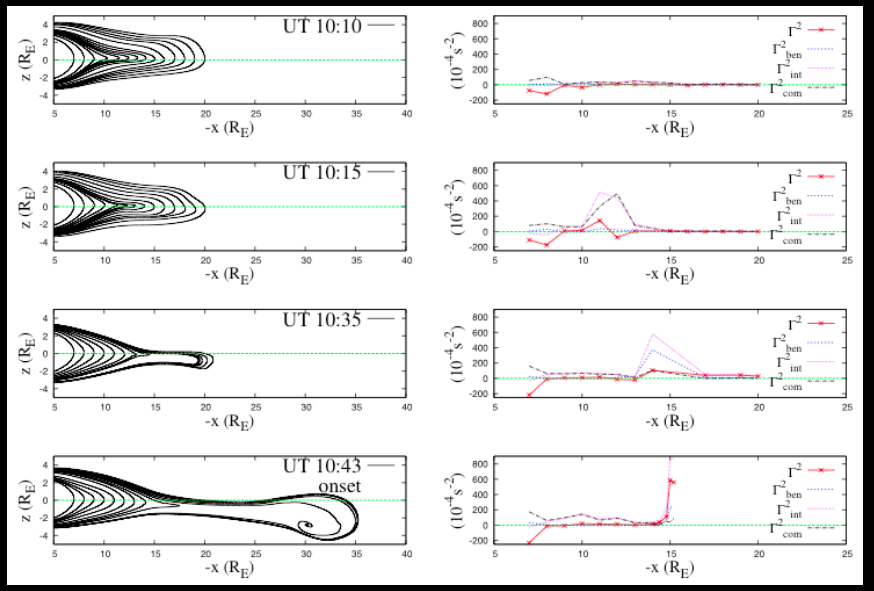
Polar Cap Potential Saturation III

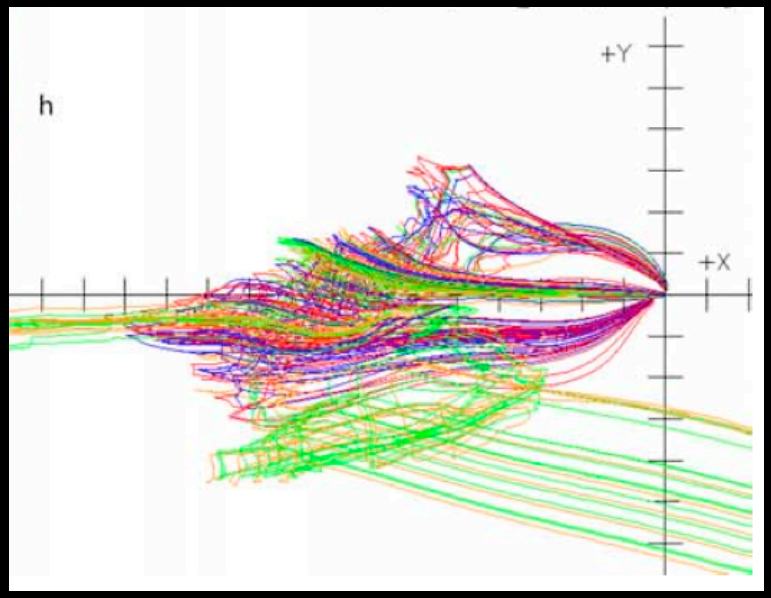
- Merkin et al., JGR, 2007
  - Used the LFM Model
  - Found that in addition to Ψ_{PC} saturating the A_{PC} also saturates
    - A_{PC} saturates faster then Ψ_{PC} as IMF increases
    - A_{PC} saturation is a result of lobes bulging sunward and shielding the dipole from reconnection



Substorms

- Zhu et al., AG, 2009
  - Used the OpenGGCM Model
  - Event study of 23 March 2007 substorm onset
    - Well observed by THEMSIS
  - Noted a correlation between the breaching of the ballooning stability condition and the initial onset of the substorm in the simulation

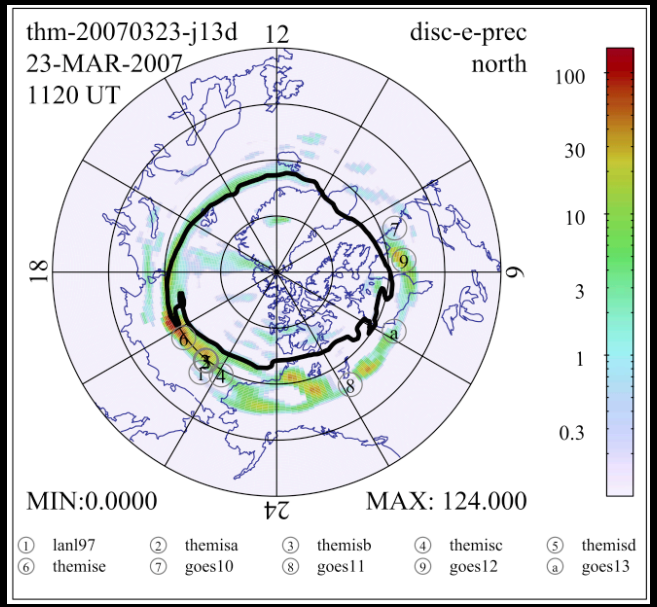


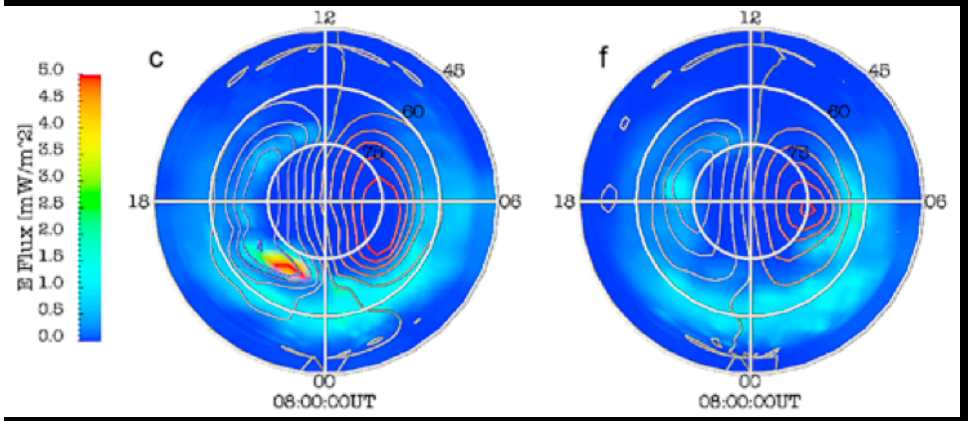


- Farr et al., JGR, 2008
  - Used the LFM model
  - Examined the 3D structure and evolution of plasmoid during a substorm on 11 Aug 2002
    - Results agreed well with multiple observations
    - Flux ropes are highly structured with winding of open and closed field lines and asymmetries tailward motion

Substorms II

- Raeder et al., SSR, 2008
  - Used the OpenGGCM Model
  - Event study of 23 March 2007 substorm onset
  - Results show agreement with multiple satellite observations
  - Used simulation results to illustrate placement of satellites during event

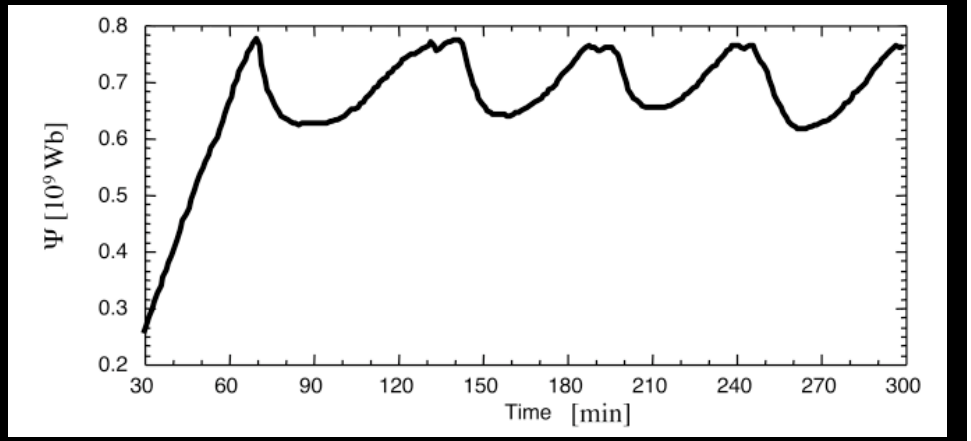




- Wiltberger et al., JGR, 2009
  - Used the LFM model
  - Examined the seasonal variation in response of the MI coupling when changes in solar wind driving are eliminated
  - Developed a model for particle precipitation that acts as a proxy for solar illumination and results in enhanced activity during equinox

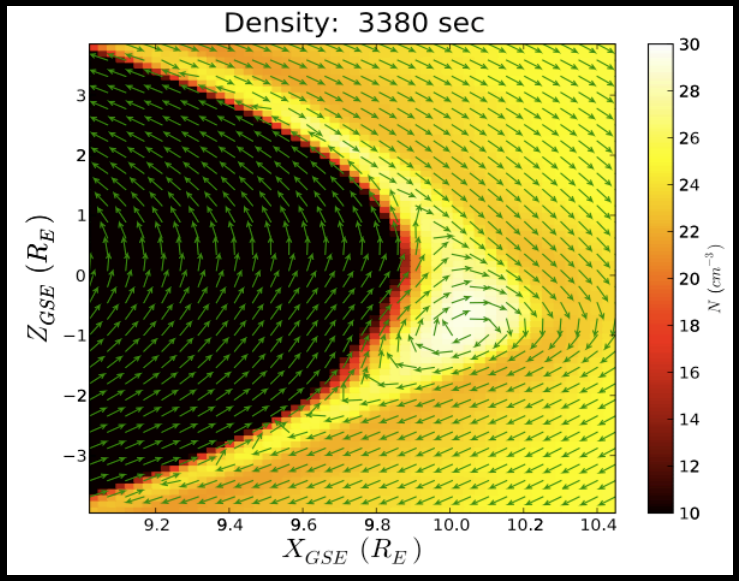
Substorms III

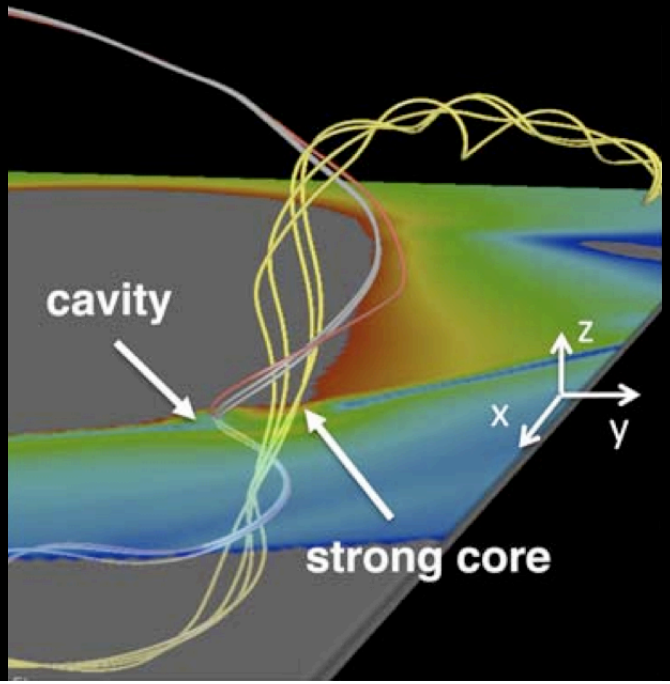
- Kuznetsova et al., JGR, 2007
  - Used the OpenGGCM Model
  - Modified the resistivity near the diffusion region to emulated kinetic effects by including nongyrotopic corrections in the induction equation
  - Obtained periodic loading/unloading cycle in magnetotail dynamics



Dayside Reconnection

- Dorelli and Bhattacharjee, JGR, 2009
  - Used the OpenGGCM Model
  - Used high grid resolution to examine the formation of FTEs during steady solar wind conditions
    - FTEs occur at MP when IMF southward
    - No dipole tilt required
    - FTEs contain complex topology

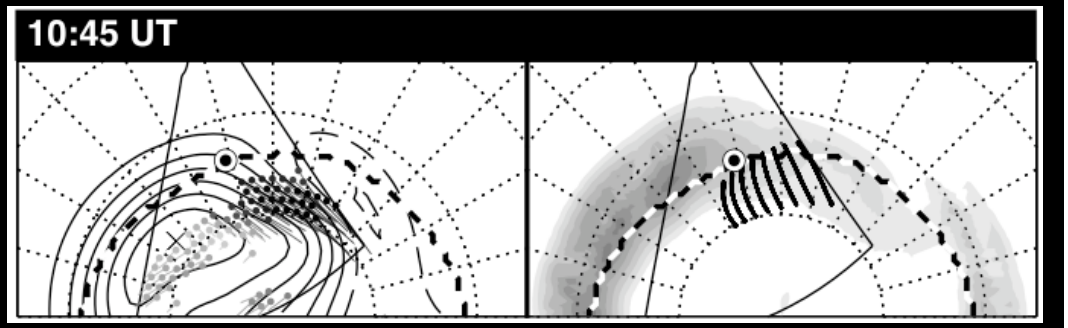


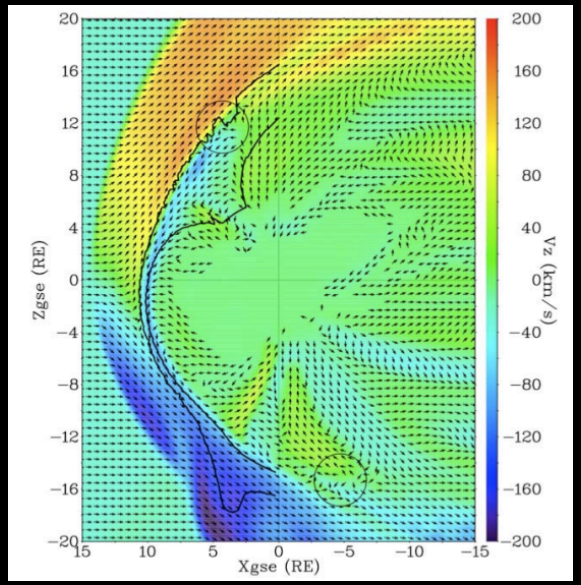


- Kuznetsova et al., GRL, 2009
  - Used the BATSRUS model
  - Examined simulations with high spatial and temporal resolution to resolve cavities of weak magnetic field in the wakes of FTEs
    - Results agree well with recent multi-point Cluster observations
    - Core and cavity move together toward the flanks

Dayside Reconnection II

- Daum et al., JGR, 2008
  - Used the BATSRUS Model
  - Event study of 14 March 2001
    - Well observed by Cluster and SuperDARN
  - Combined simulation results with Cooling FTE motion model to examine the temporal evolution of the FTE and found good correlation with observations

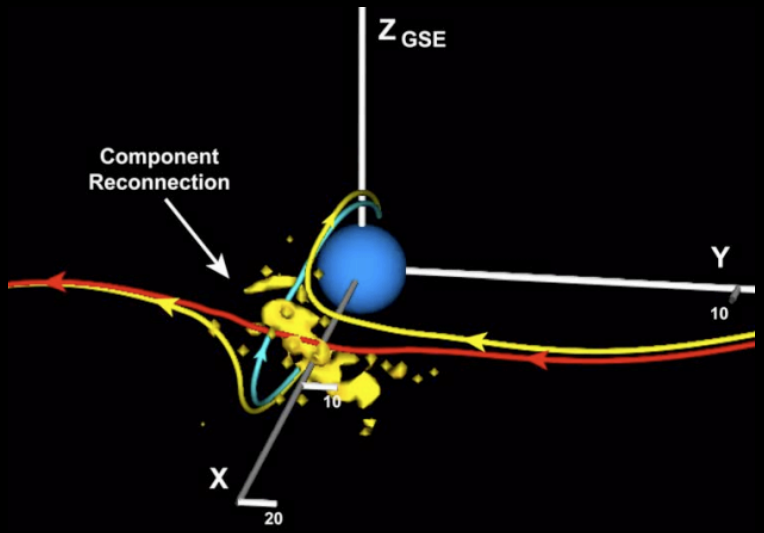


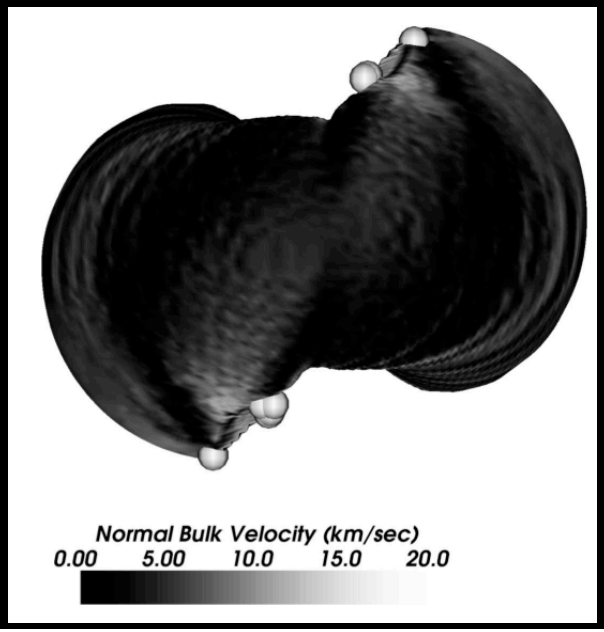


- Li et al., JGR, 2009
  - Used the OpenGGCM model
  - Event study of 3 June 2007
    - Well observed by THEMIS
  - Model reproduces the cold dense boundary layer
  - Reconnection starts in northern hemisphere and then southern hemisphere
    - This process allows the trapping of magnetosheath plasma and creation of the boundary layer

Dayside Reconnection III

- Berchem et al., JGR, 2008
  - Used the UCLA MHD Model
  - Event studies of 8 May 2004 and 6 April 2004
    - Well observed by Cluster and Double Star TC-1
  - Examined configuration of reconnection with -Bz and By
    - Antiparallel and component merging both occurring
    - Spread of merging region function of resistivity

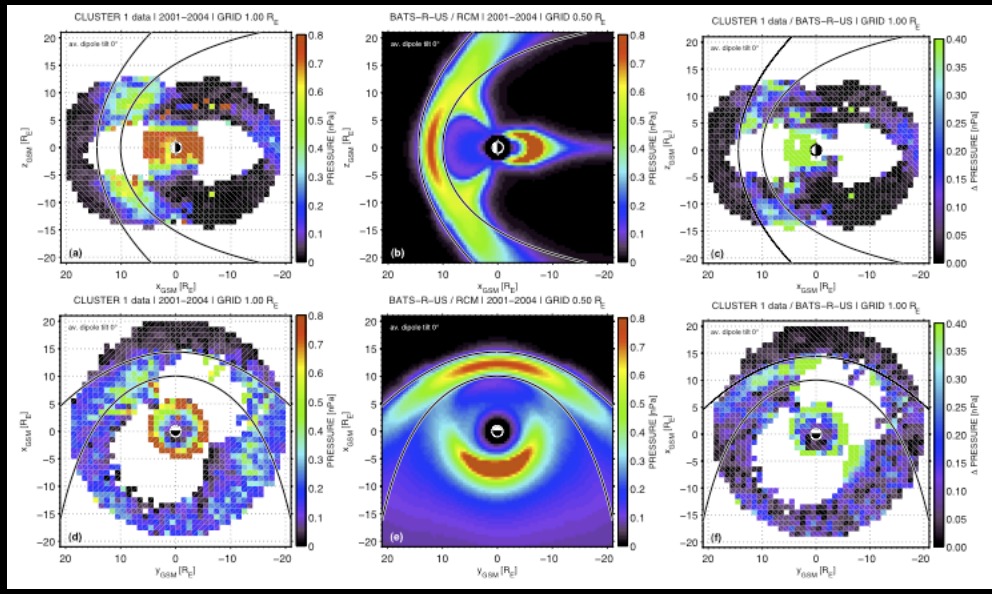


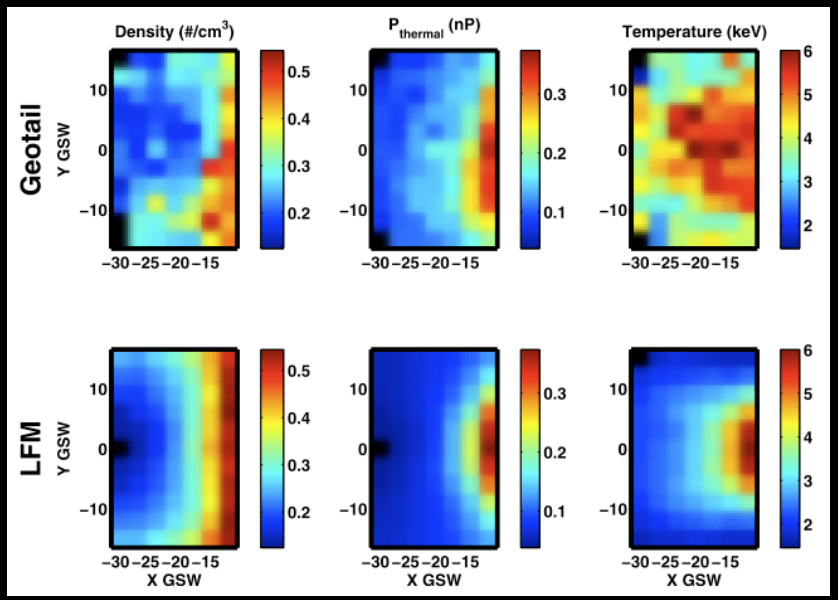


- Dorelli and Bhattacharjee, PoP, 2008
  - Used the OpenGGCM model
  - Studies the theory magnetic reconnection in 3D under northward and southward IMF
  - Concludes that MP reconnection is of two types
    - Vasyliunas - plasma flow across seperatrices - northward
    - Green - violation of magnetic flux conservation - southward

Verification and Validation

- Daum et al., AG, 2008
  - Used the BATSRUS Model
  - Comparison of 2001-2004 Cluster data to simulation results
    - Quasi time-accurate simulations where computed for 6 day averages solar wind conditions
  - Agreement found between simulations results and observations even when density was reduced by 50%

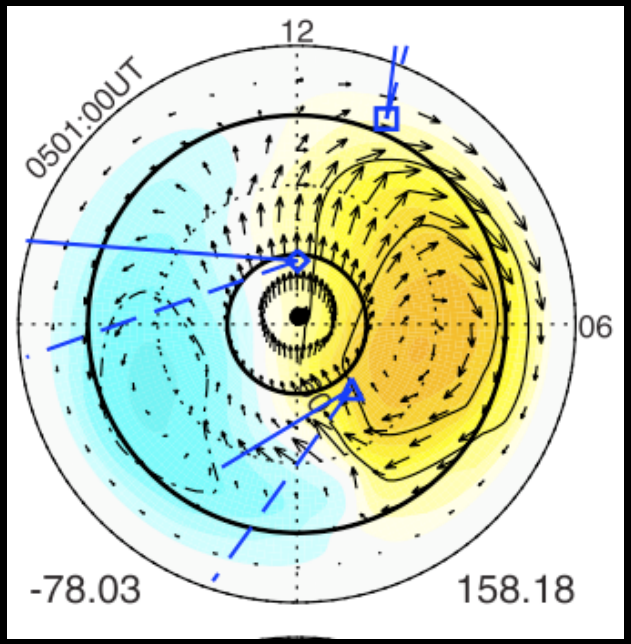


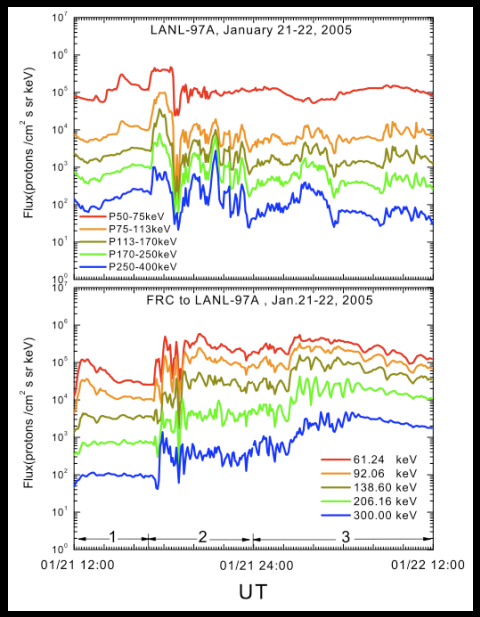


- Guild et al., JGR, 2008a,b
  - Used the LFM model
  - Comparison of 6 years of Geotail data with 2 months of LFM simulation results
    - Ensured statistical similarity between solar wind conditions
  - Compared average values and flow variabilty for central plasma sheet
    - LFM reproduces gross features of plasma sheet, but it too dense and cool
    - Higher resolution allows for BBFs improving agreement with velocity distributions

Validation and Verification II

- Yu and Ridley, SW, 2008
  - Used the BATSRUS Model
  - Event study of 4 May 1998 magnetic storm
    - Compares with 150 ground magnetometer stations
  - Metric analysis yields several results
    - RMS errors vary widely for stations
    - Db/dt better capturing events, but high FAR

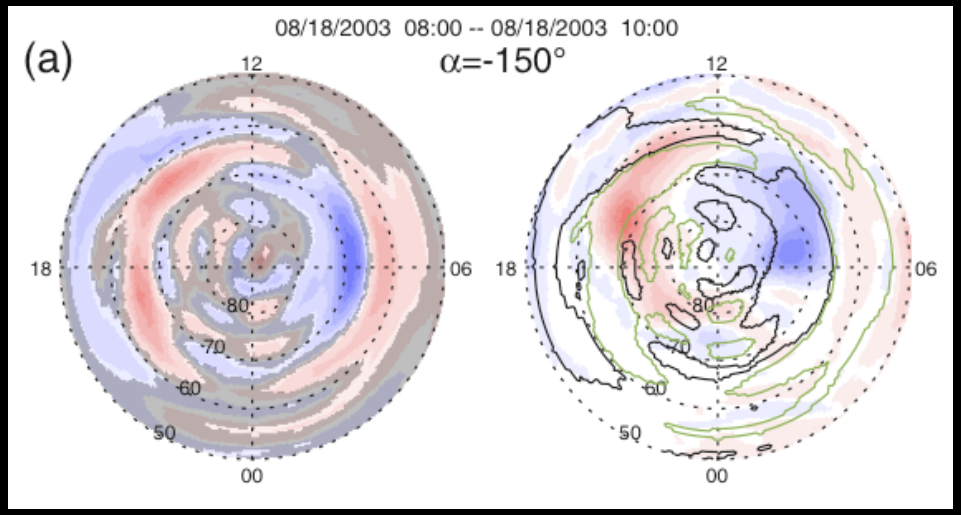


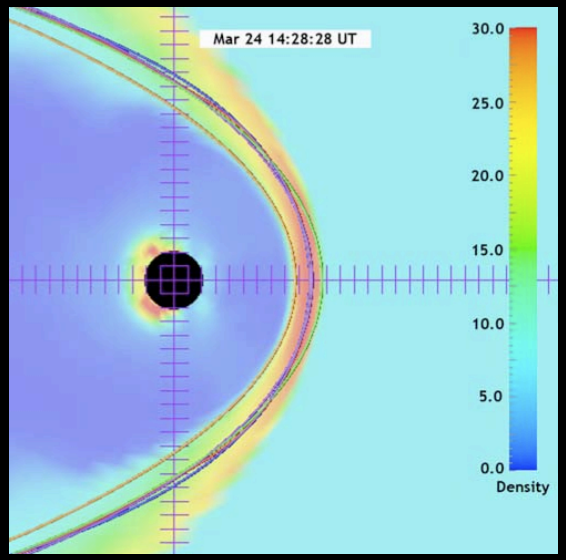


- Taktakishvili et al., SW, 2008
  - Used the BATSRUS + FRC model
  - Event studies for 21-22 Jan 2005 and 10-11 Aug 2000
    - Compared against LANL observations
    - Computes correlation based metrics
  - Works fairly well during strong driving, but maybe missing some magnetospheric dynamics during steady southward IMF conditions

Validation and Verification III

- Korth et al., AG, 2008
  - Used the LFM Model
  - Event studies 17-19 Aug 2003 and 19-21 Mar 2001 magnetic clouds
    - Compared with Iridium and DMSP observations
  - Good morphological agreement, but simulated currents are a factor of 2 larger
  - Region 2 currents are in simulation are much weaker than observed

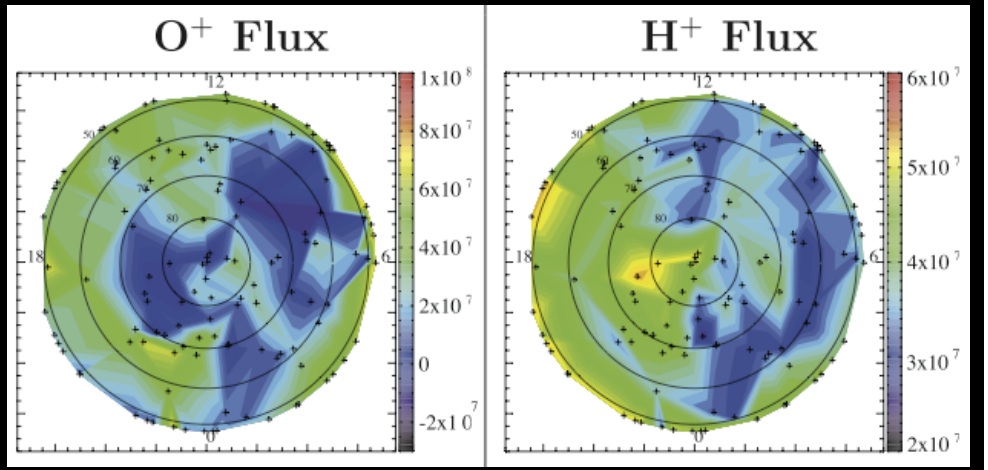


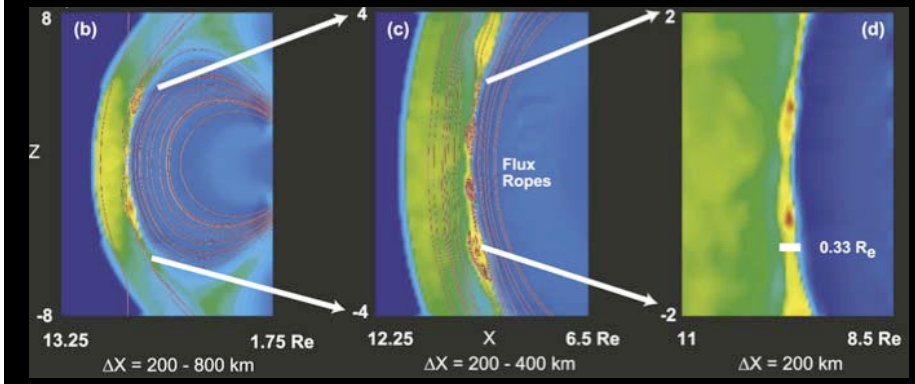


- Garcia and Hughes, JGR, 2007
  - Used the LFM model
  - Comparison of model results with empirical MP models
  - LFM MP more earthward then empirical models
    - 0.5-1.0 R_E at noon and 1.0-2.0 R_E at dusk
  - Show that deficiency is due in part to weak ring current in LFM

Multifluid Modeling

- Glocer et al., JGR, 2009
  - Used the SWMF
    - Adds a Polar Wind Outflow Model (PWOM)
  - Event studies for two geomagnetic storms
  - Multispecies MHD is used track the evolution and impact of O+
    - Reduces RMS error of GOES magnetic field comparison by 50%

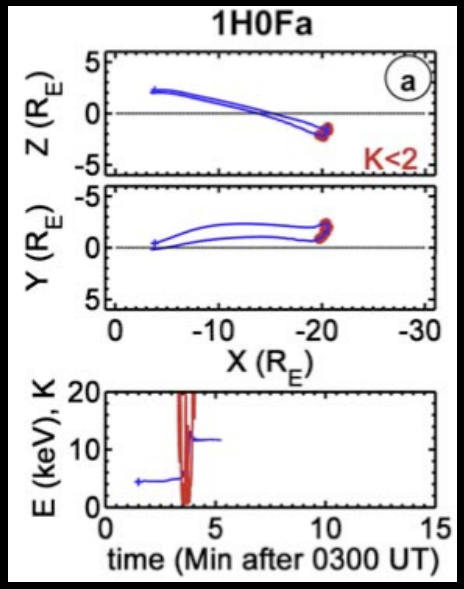




- Winglee, JGR, 2008
  - Used the UW model
  - Multifluid/Multiscale techniques are used to examine reconnection along the magnetopause
  - Simulation produces FTEs with characteristics similar to observations
  - Small scale processes can effect global parameters like polar cap potential by 20%

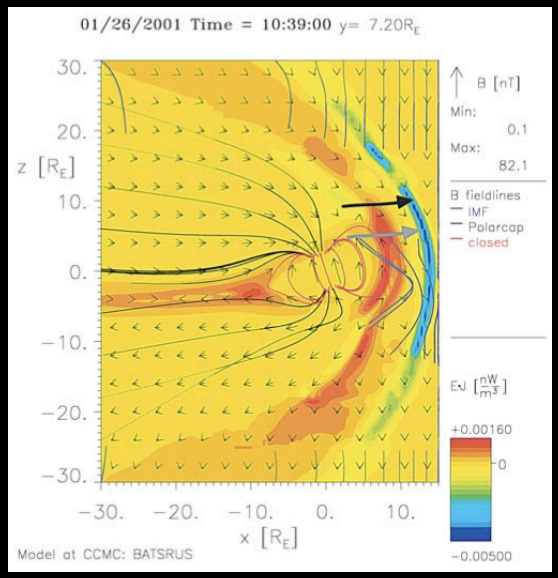
Multifluid Modeling II

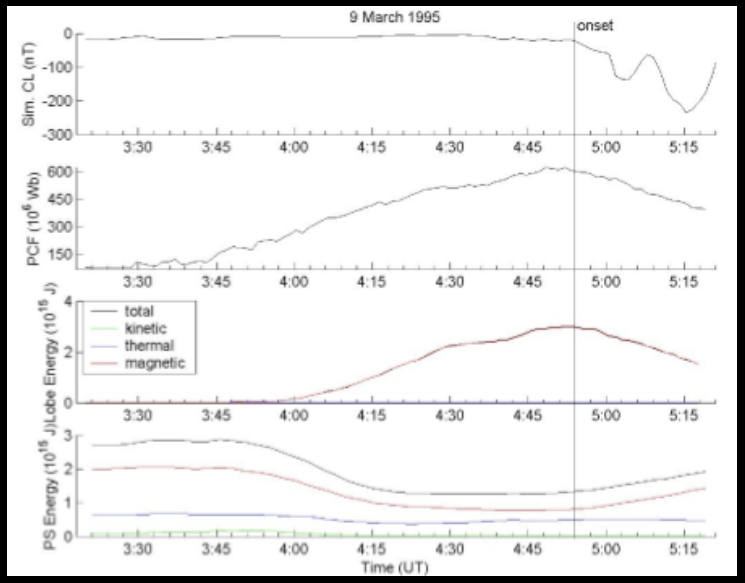
- Bosqued et al., JGR, 2009
  - Used the UCLA MHD model
    - Not truly multifluid, but has ionospheric H+
  - Event study during 14 Feb 2001
    - Compared with Cluster observations
  - Simulations show ions returning to Cluster location poleward of their source with correct energy dispersion



Energy Conversion

- Rosenqvist et al., GRL, 2008
  - Used the BATSRUS Model
  - Load and generator regions identified in Cluster observations are compared with simulation results
    - Model reproduces both types of regions
    - Magnitude of energy conversion agrees well
    - Model fails to capture sharp MP

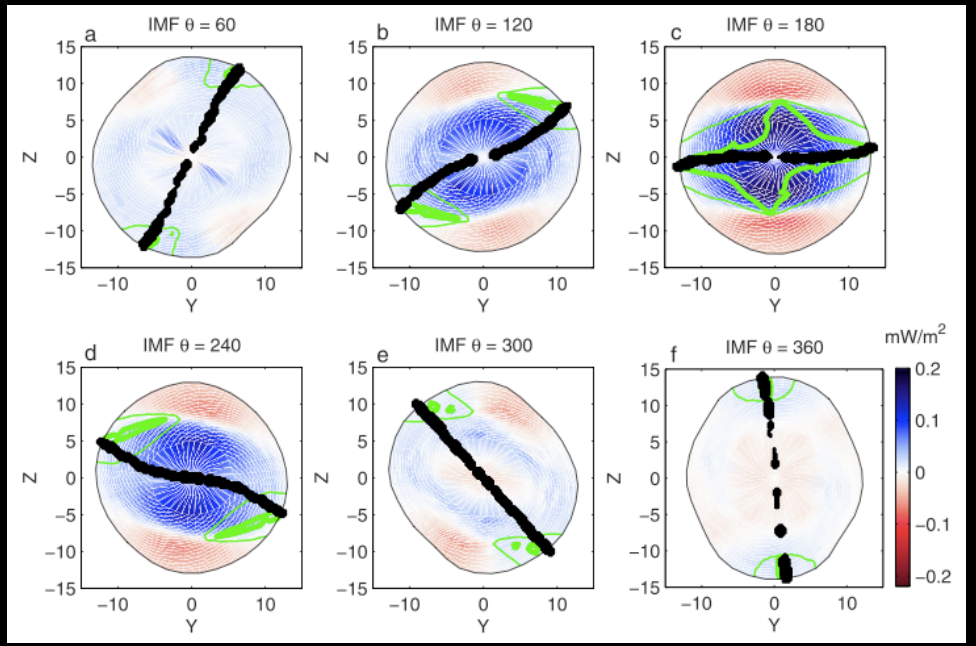




- Brogl et al., AG, 2009
  - Used the LFM model
  - Event studies for 9 Mar 1995, 10 Dec 1996, and 27 Aug 2001 substorms
  - Examined energy evolution during growth and expansion phases
    - Plasma sheet energy increase during growth phase from compression
    - At onset and throughout expansion phase magnetic lobe energy is transferred into plasma sheet

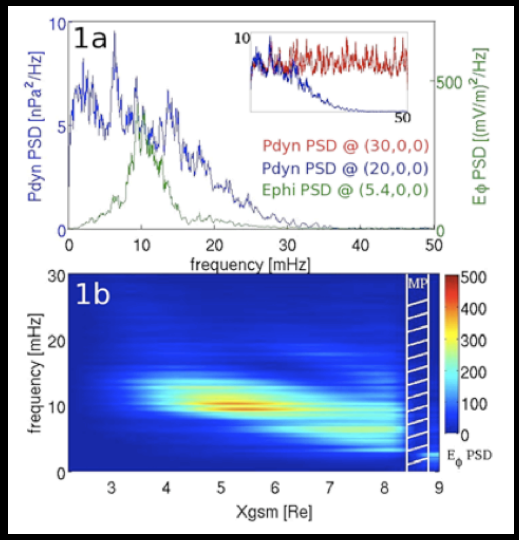
Energy Conversion II

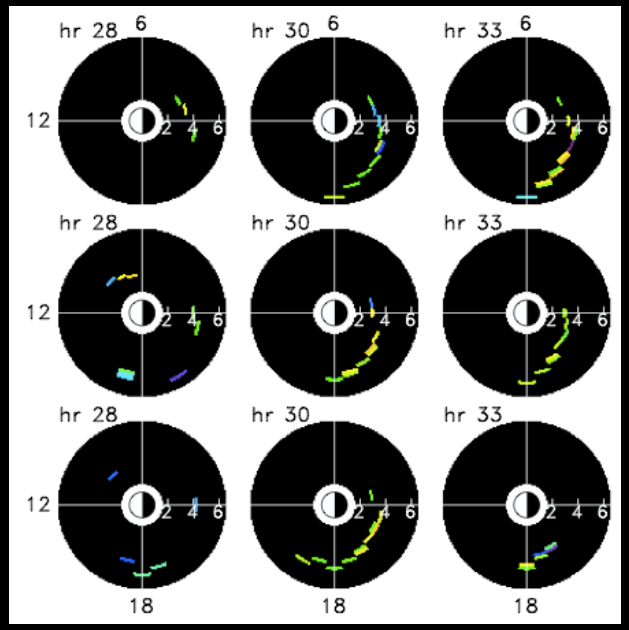
- Laitinen et al., JGR, 2007
  - Used the GUMICS Model
  - Examined the conversion of energy at the magnetopause
    - Reconnection line location is consistent with component reconnection hypothesis
    - Efficiency of conversion depends upon IMF direction and dynamic pressure
    - Density has weak effect



Miscellaneous - Waves

- Claudepierre et al., GRL, 2009
  - Used the LFM Model
  - Use simulations with ULF waves in upstream solar wind to show these waves can drive ULF pulsations within the magnetosphere
  - Found that the magnetosphere has natural resonant frequencies that can be excited

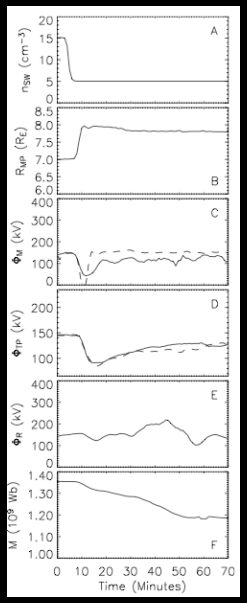


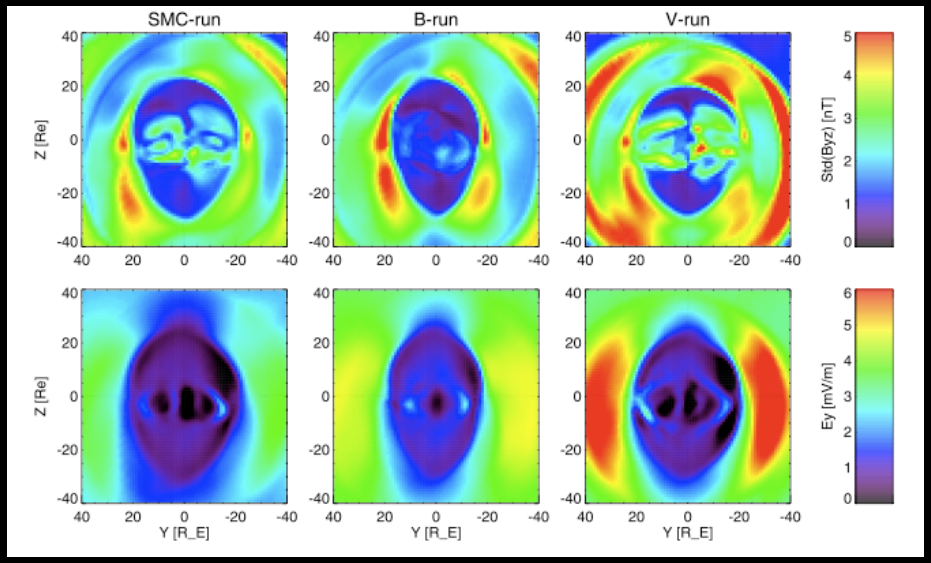


- Gamayunov et al., JGR, 2009
  - Documents development of RC and EMIC wave model
    - Also includes MI coupling, magnetospheric E field, and plasmasphere
  - Need to model plasmasphere in order to get EMIC dist correct
  - Must include potential pattern reconfiguration time

Miscellaneous - Driving

- Ober et al., JGR, 2007
  - Used the ISIM Model
  - Examined the response of Ψ_{PC} to density pulses in the solar wind
    - responds immediately to changes pulses
    - Magnitude of response depends upon time rate of change of pulse
    - Responses are transient
    - Changes in reconnection rate effect open flux not Ψ_{PC}

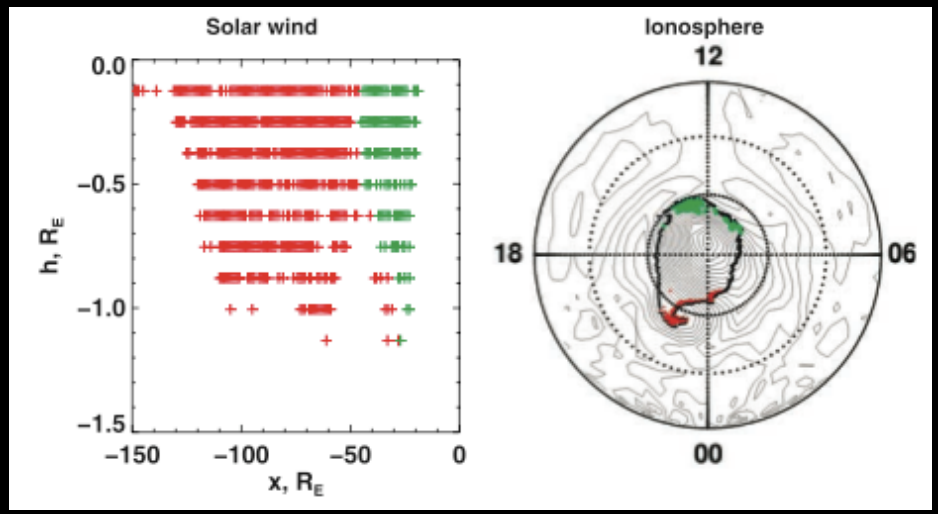


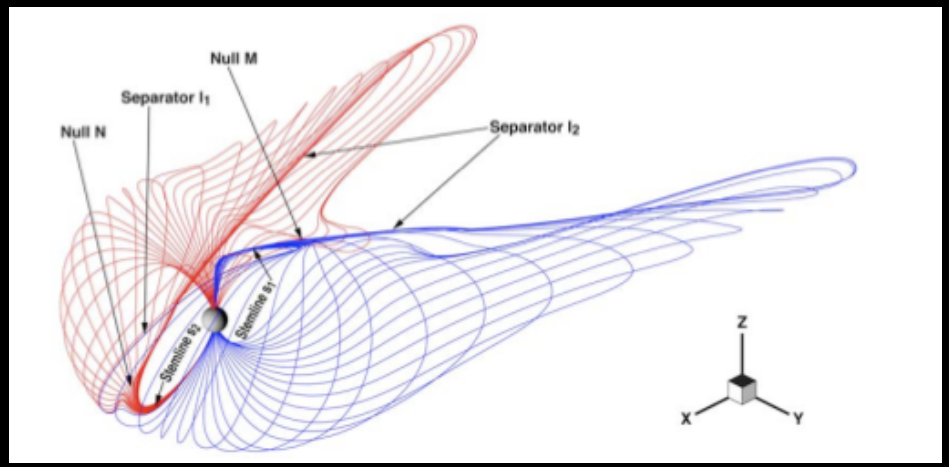


- Pulkkinen et al., GRL, 2007
  - Used the LFM Model
  - Simulated a SMC interval and then modified the solar wind conditions to independently increase V and B by 50%
    - B increase moves reconnection earthward, but leaves as SMC
    - V increase result in more activity

Miscellaneous - IMF B_Y

- Merkin and Crooker, JGR, 2008
  - Used the LFM Model
  - Used the concept of interchange reconnection to explain the transport of flux within the magnetosphere
    - Remote reconnection occurs when foot points cross open/closed boundary, but foot points remain firmly rooted closed circulation cells
    - Field line foot points jump from one side of polar cap to other

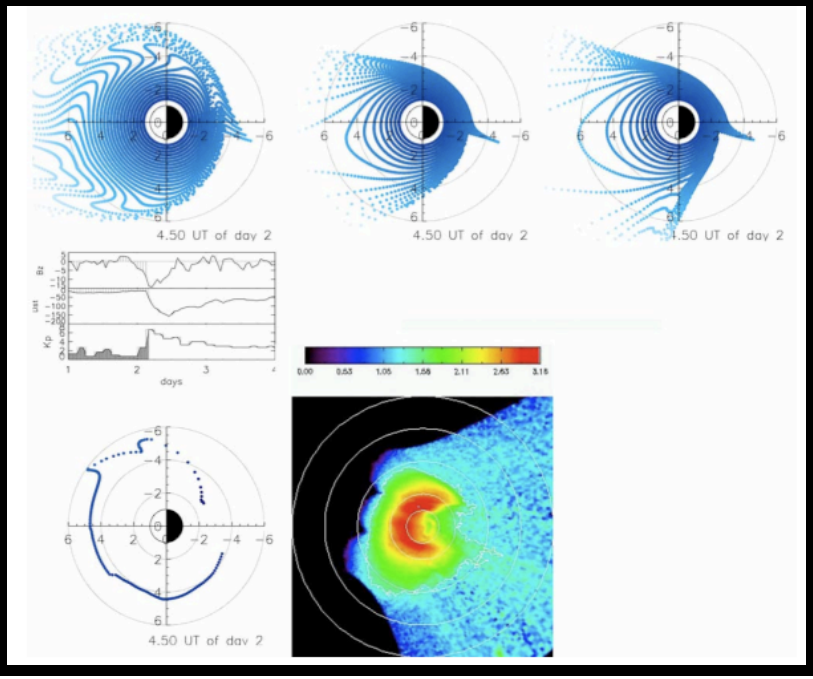


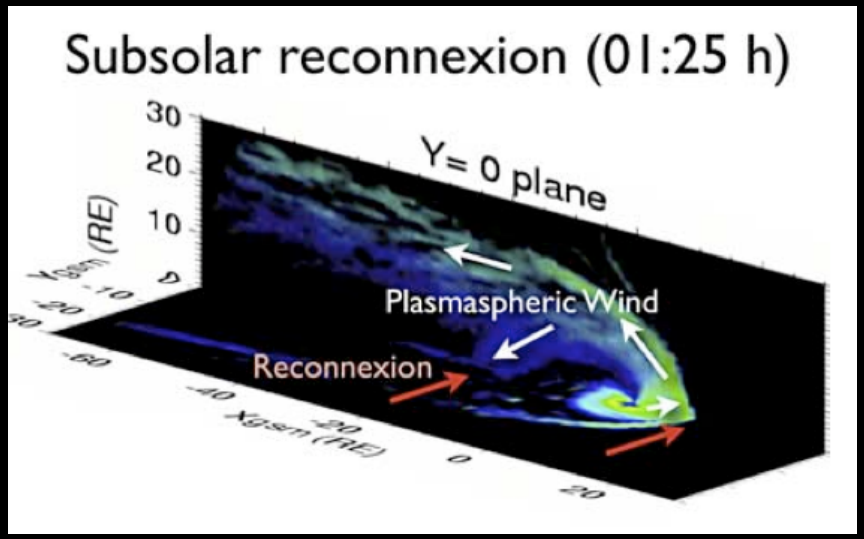


- Watanabe et al., JGR, 2007
  - Used the BATSRUS Model
  - Examined the origin of the potential asymmetry seen during IMF B_Y periods
    - For $+B_Y$ NH duskside [illegible] greater than SH
  - Concludes that is a result reconnection of over draped lobe field lines and closed flank side fields

Miscellaneous - Plasmasphere

- Moore et al., JGR, 2008
  - Used the LFM and CRCM Models
  - Ober plasmasphere model embedded within each domain
  - Idealized conditions
    - -Bz with +Bz interval
  - A plasmaspheric plume develops, but most of it is lost from the magnetosphere





- Pierrard et al., JGR, 2008
  - Convection E models and ideal MHD
    - E5D, VS, Weimer
  - Event studies on 28 Oct 2001 and 17 Apr 2002
    - Compare with MAGE EUV obs
  - Find that each E field model produces plumes and tails, but shape depends upon formation model examined

Conclusions

- Global scale simulations have been used to examine a wide range of scientific questions
  - Efforts continue to verify and validate the results coming from these simulations
  - Providing insight on the mechanisms leading to the saturation of the polar cap potential
  - Continuing success in modeling substorms
  - A useful tool in the study of 3D reconnection
- CCMC is broadening the utilization of global models
  - Not a model developer, so continued support to the development community is needed