CMIT/LFM – Status and Plans

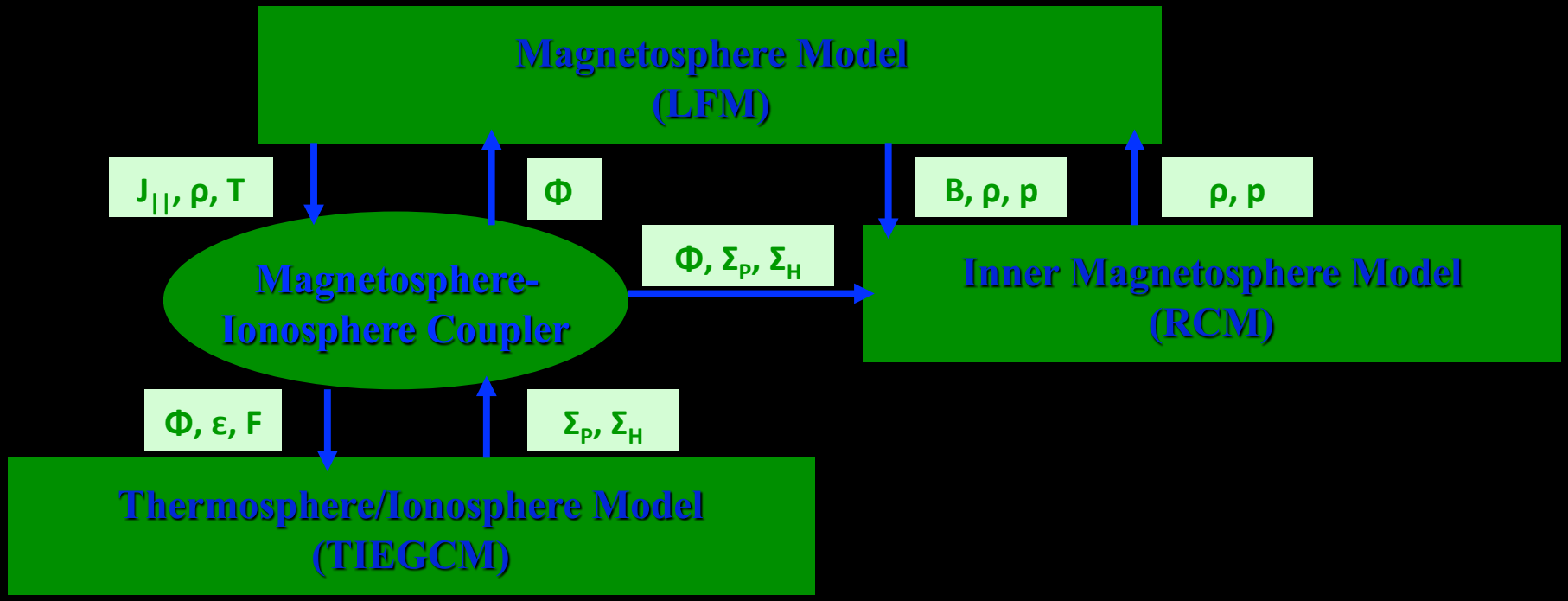
M. Wiltberger
NCAR/HAO

CMIT/LFM Development Team – J. G. Lyon, V. Merkin, R. Varney, W. Wang, B. Zhang

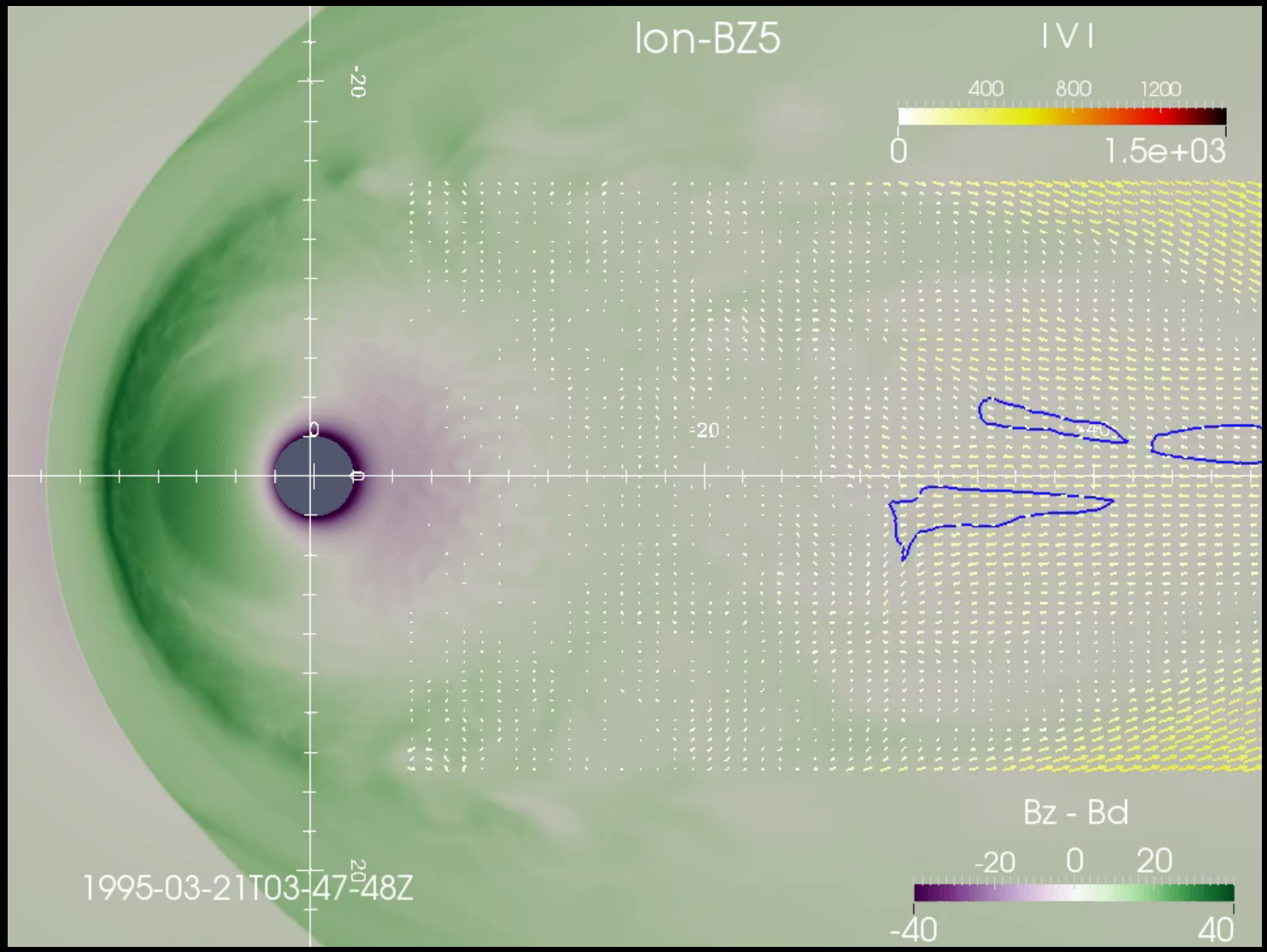
Outline

- Overview CMIT and its components
- High Resolution LFM Studies
- CMIT Studies
- LFM-RCM Studies
- MFLFM Studies
- Conclusions

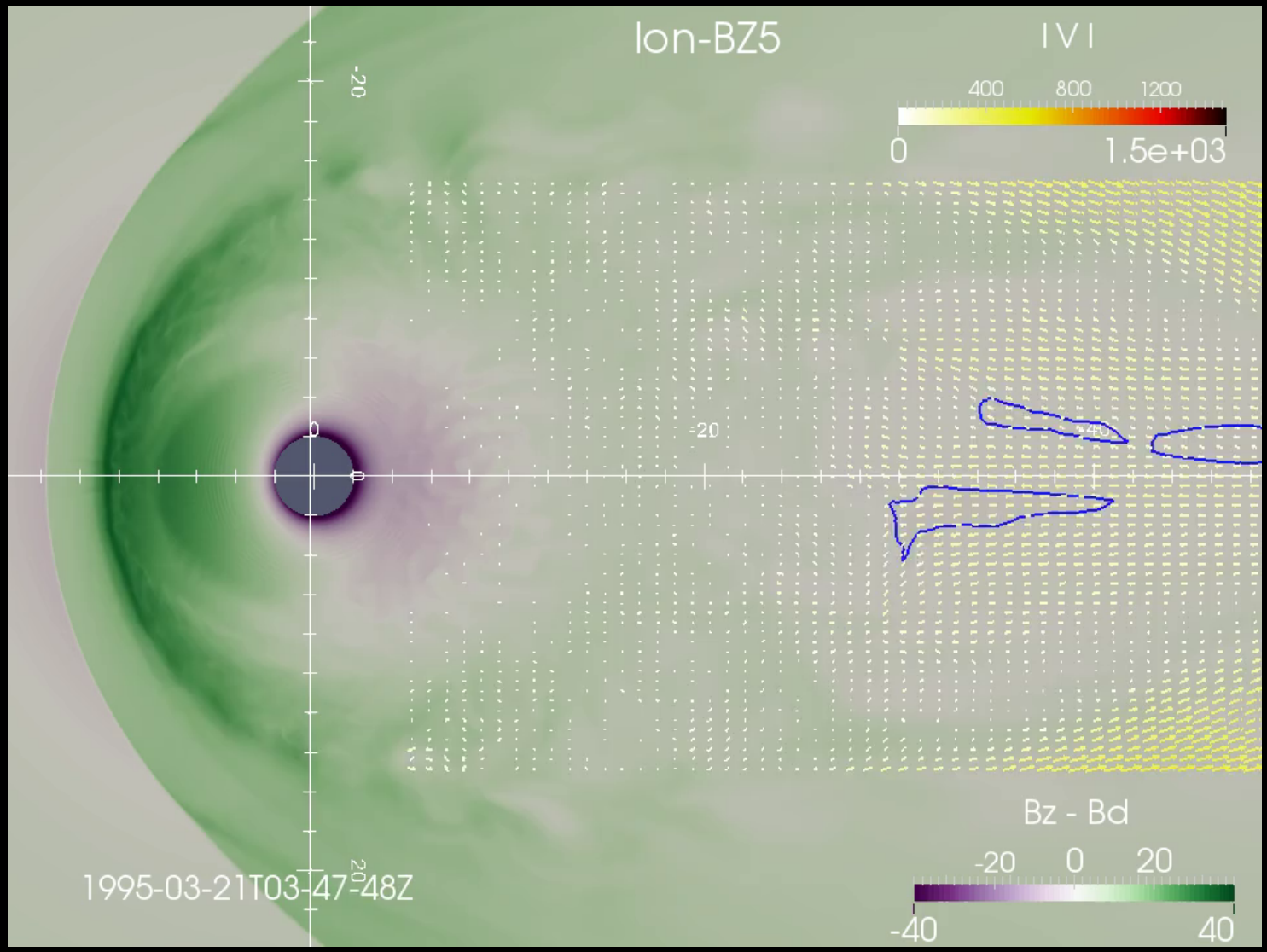
CMIT Model System



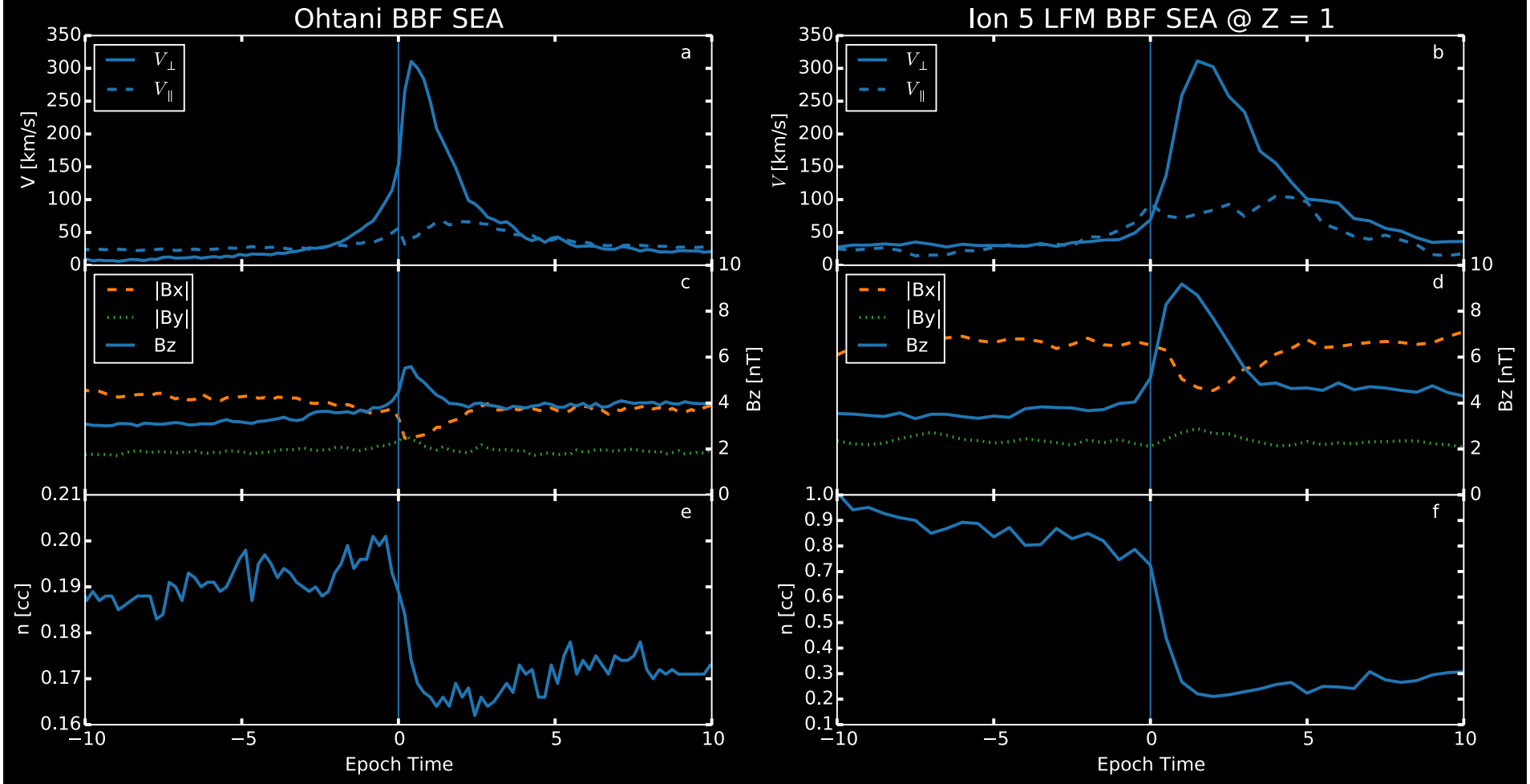
BBFs in High Res LFM



BBFs in High Res LFM

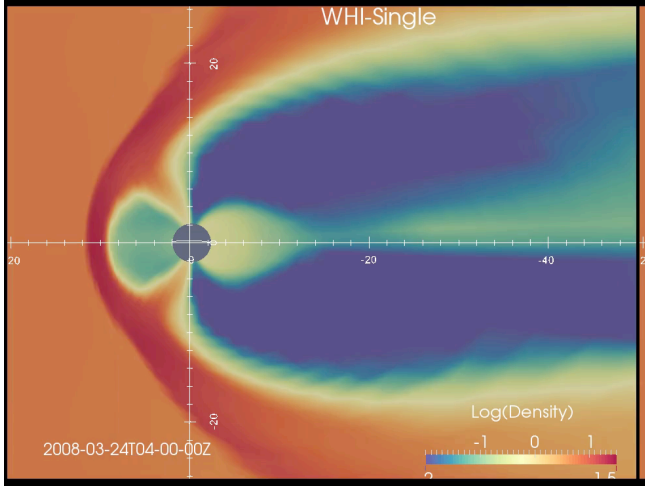


Superposed Epoch Analysis

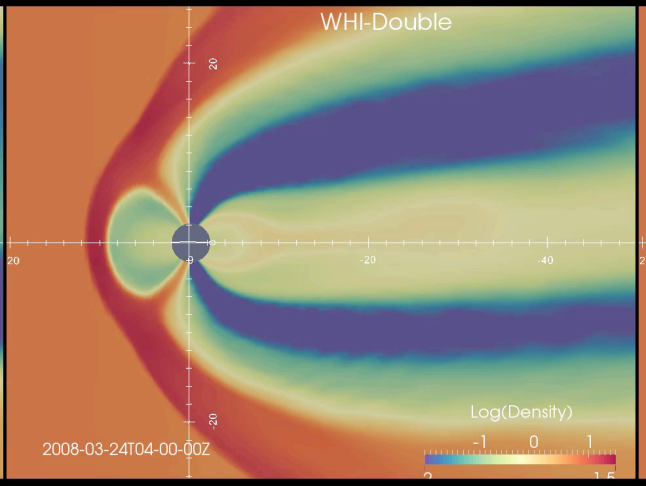


WHI at Multiple Resolutions

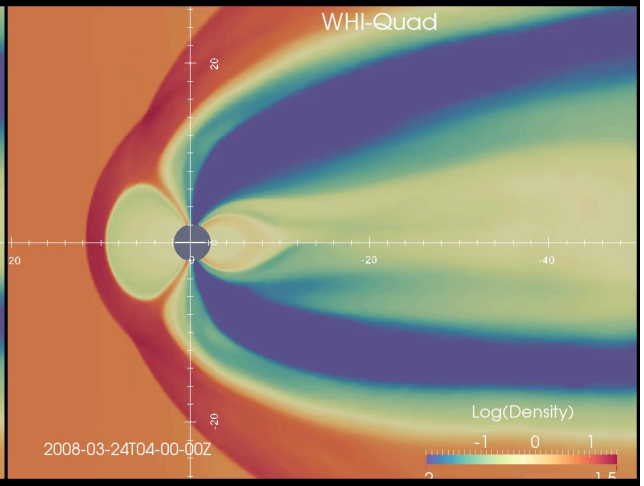
WHI Single



WHI Double

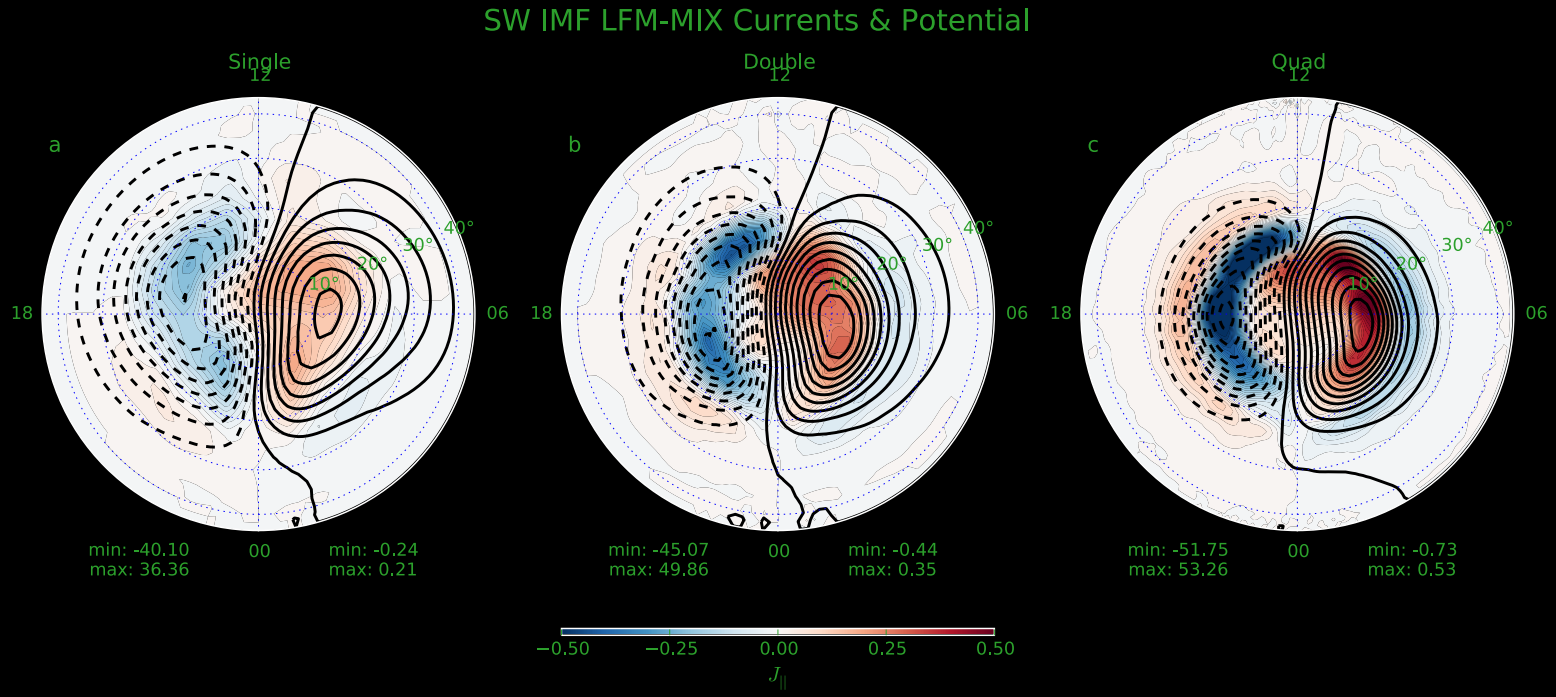


WHI Quad



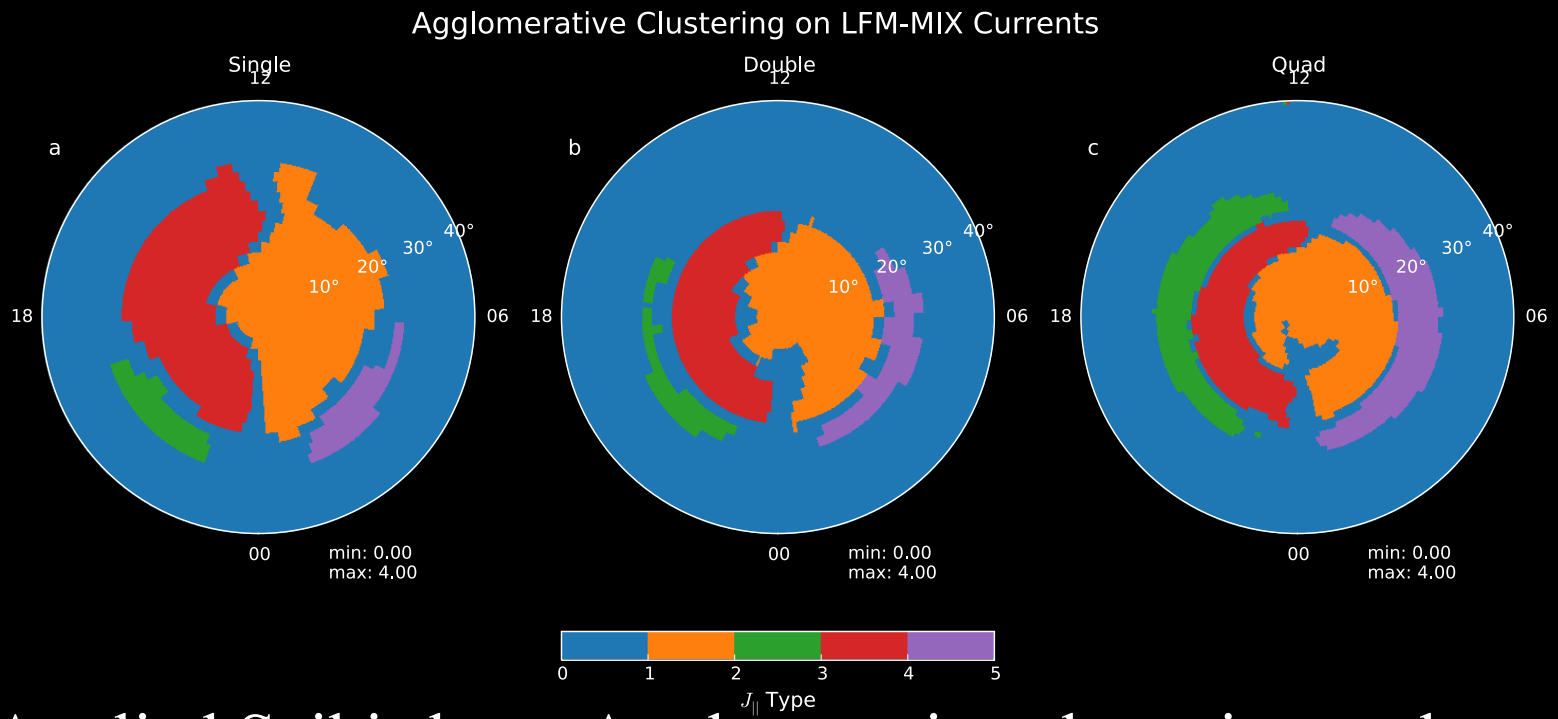
- Simulations conducted at 3 resolutions
  - Single – 53x24x32
  - Double – 53x48x64
  - Quad – 106x96x128
- Each run covered the full 27 days
  - 2 min dump cadence yields 20160 LFM and MIX files
    - Quad resolution >2.5 TB and took over 385K core hours to complete
  - SuperMAG has 206 magnetometer stations available
  - Qualifies as 'Big Data' in my book

SW Bin Across Resolutions



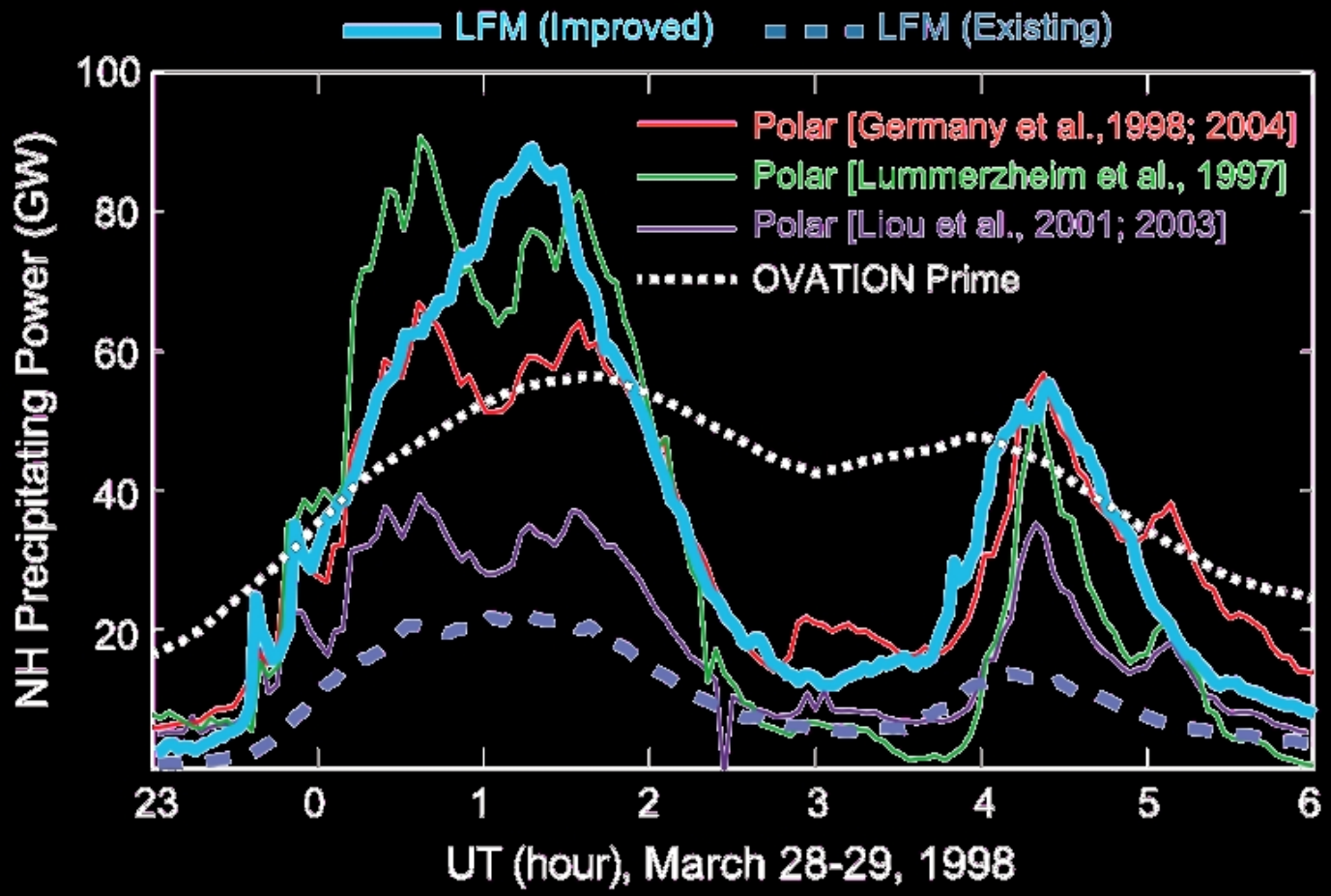
- FAC changes
  - Strength Increases as resolution increases
  - R2 currents become more apparent as resolution increases
- CPCP changes
  - Modest increase with increasing resolution
  - Shielding to higher latitudes at higher resolutions

FAC Classification



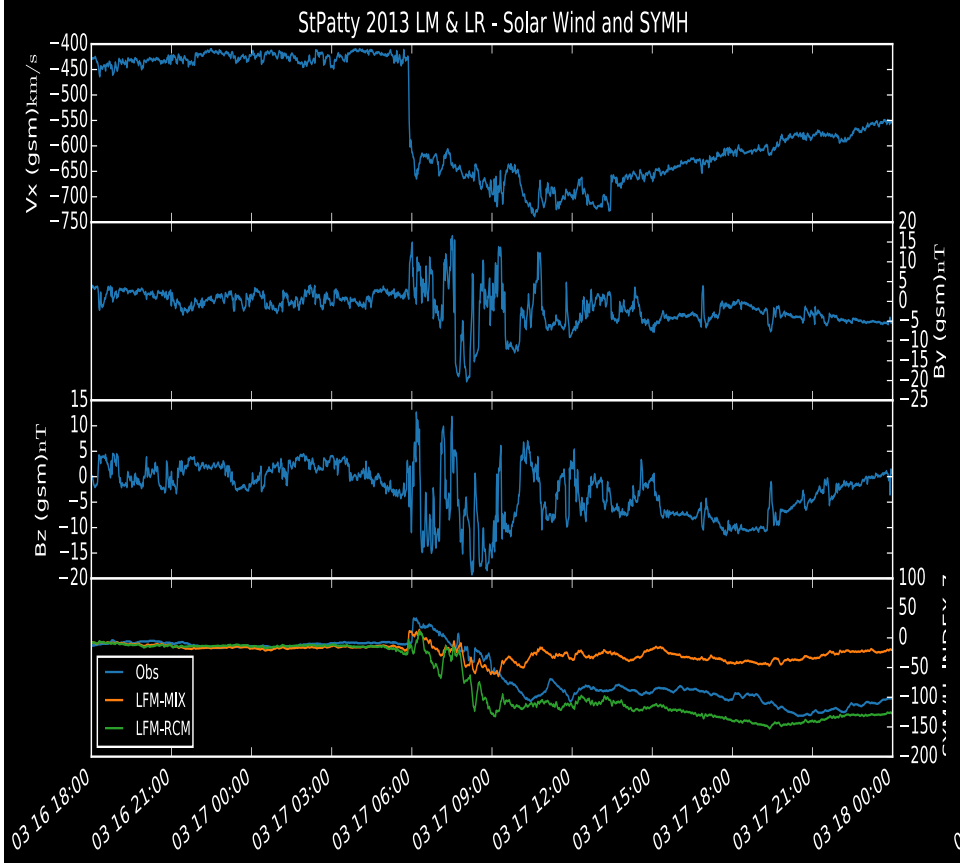
- Applied Scikit-learn Agglomerative clustering tool
  - Separated currents in pos/neg and applied threshold
    - Lower threshold needed for single resolutions
  - Automatically identify R1 and R2 for all resolutions
  - Works well for all non-northward IMF values
    - K-means is faster, but not quite as nice results

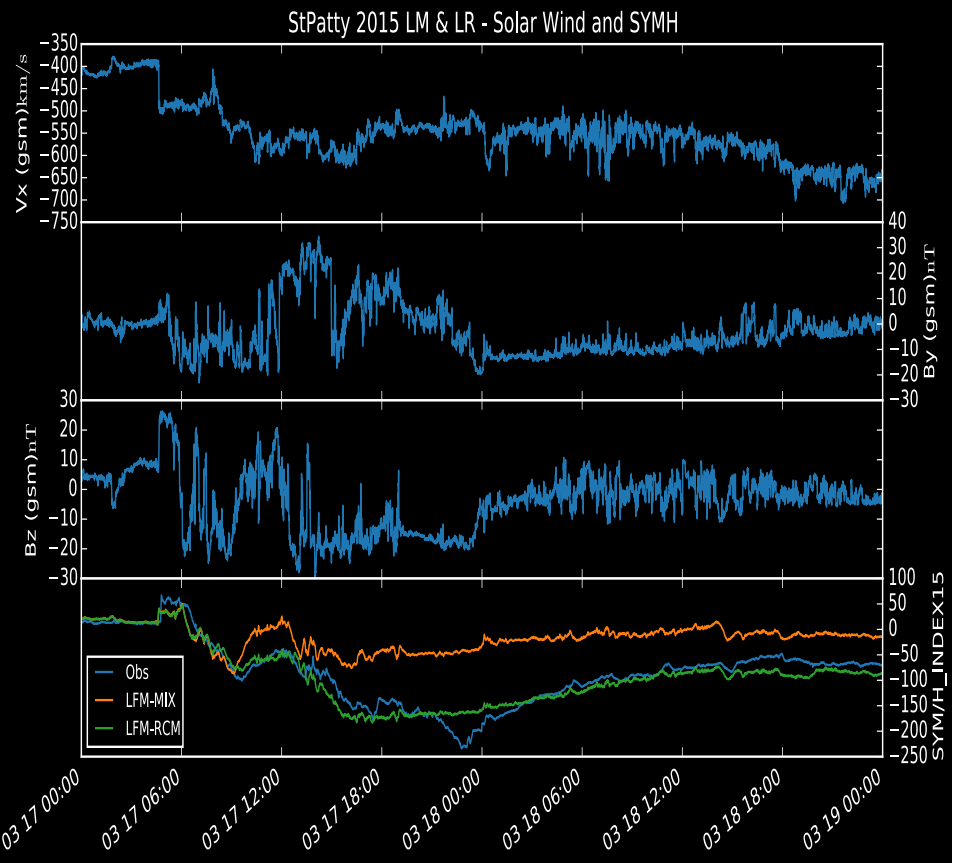
CMIT – Improved Precipitation Model



- Zhang et al. 2015 introduced a new electron precipitation model which includes three categories of precipitation

Tale of Two St Patty's Days

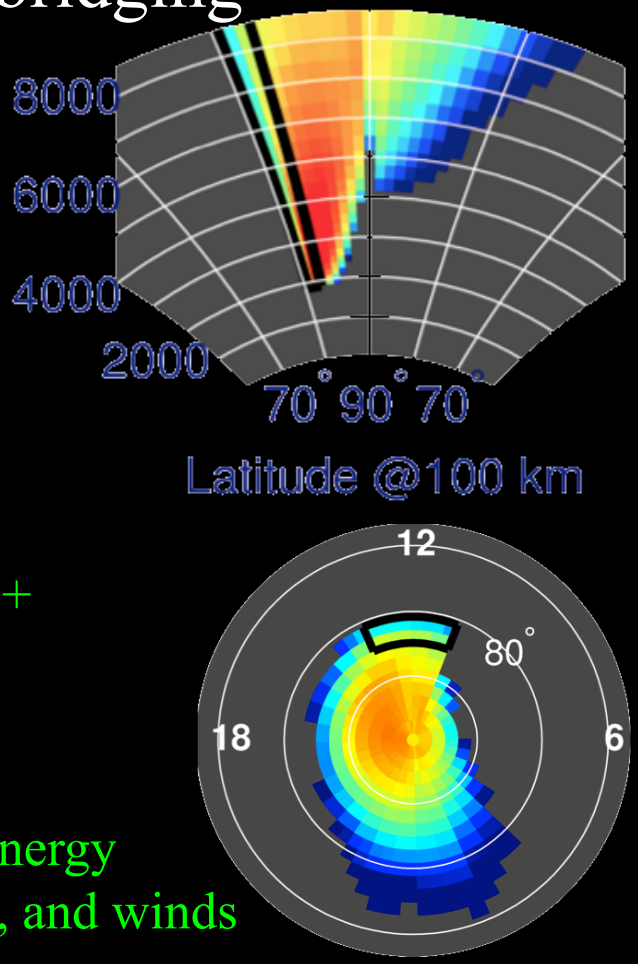




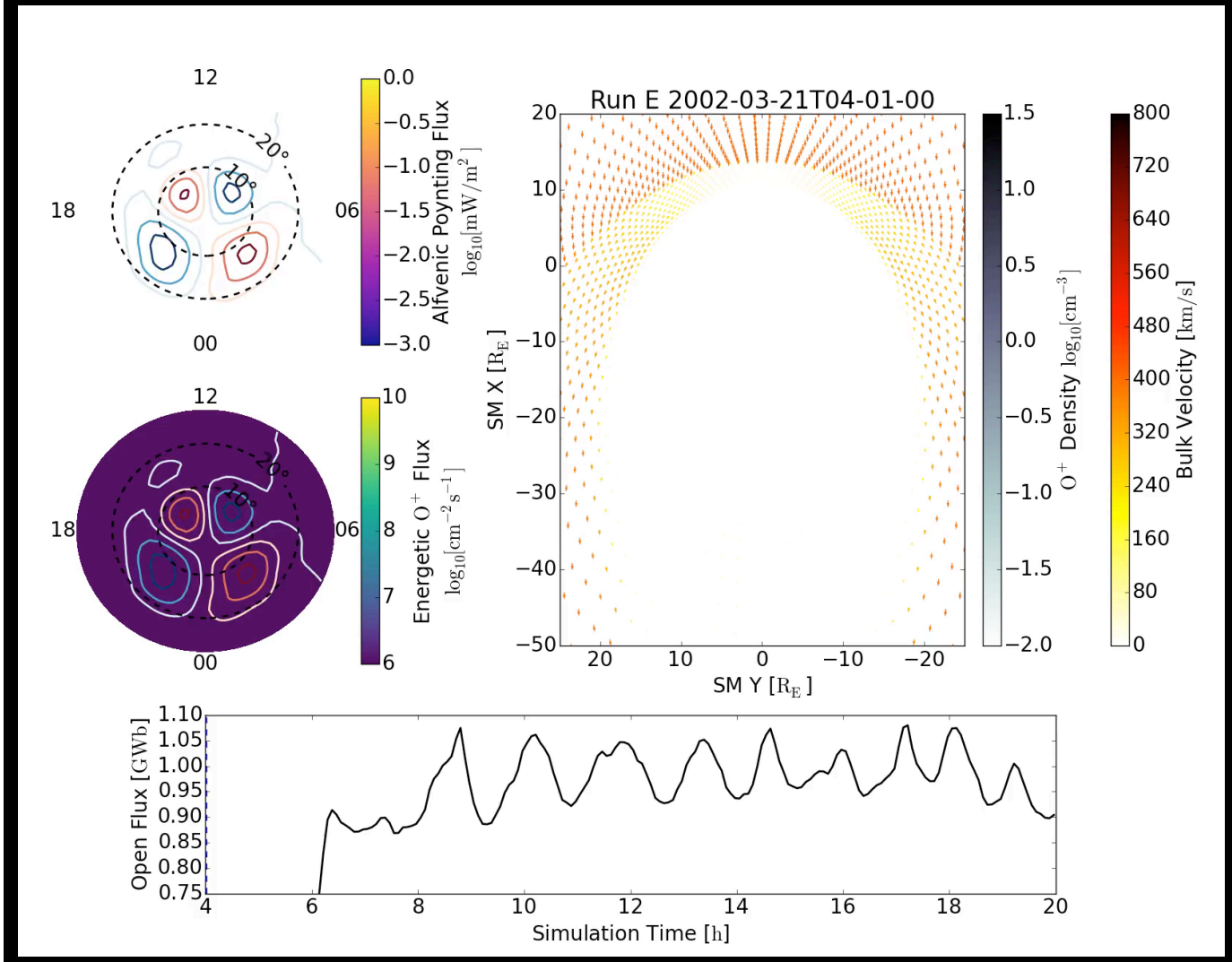
- LFM-RCM simulations show significant improvements in D_{ST} predictions

Ionosphere Polar Wind Model

- High-latitude plasma transport model bridging the magnetosphere ionosphere gap
  - Computational domain
    - 97 to 8400 km altitude
    - All MLT and latitudes poleward of L=4
  - Calculates
    - Ion transport of H+, He+, and O+
    - Photochemistry only for 6 other ions
    - Electron energy equation
    - Phenomenological treatment of nonthermal O+ accelerated by WPI
  - Requires
    - High-latitude potential pattern
    - Precipitating number flux and characteristic energy
    - Thermosphere neutral temperatures, densities, and winds

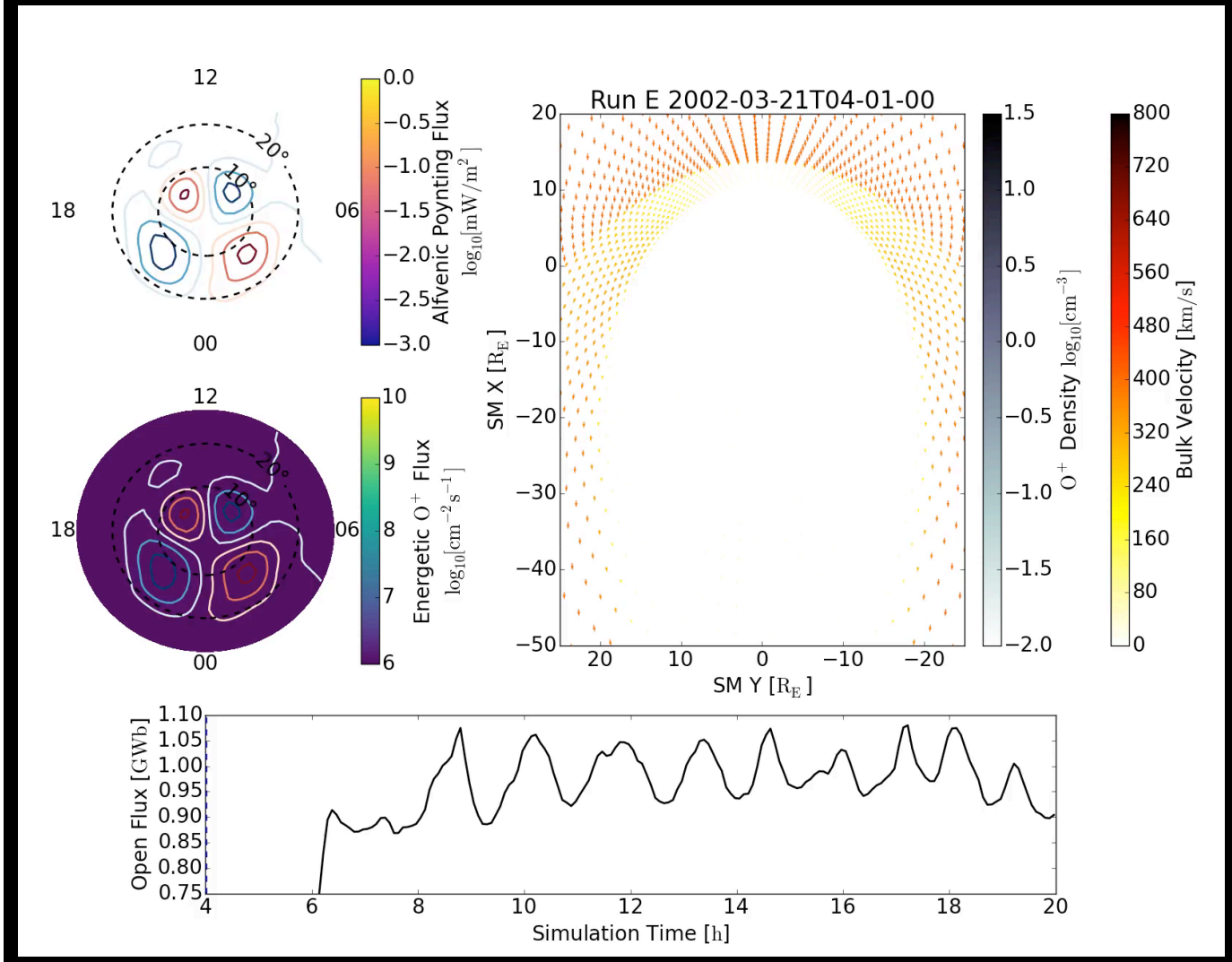


Sawteeh Oscillations



- Varney et al. just submitted a paper showing sawteeth oscillations in coupled MFLFM-IPWM
  - First time in simulations with polar wind model

Sawteeh Oscillations



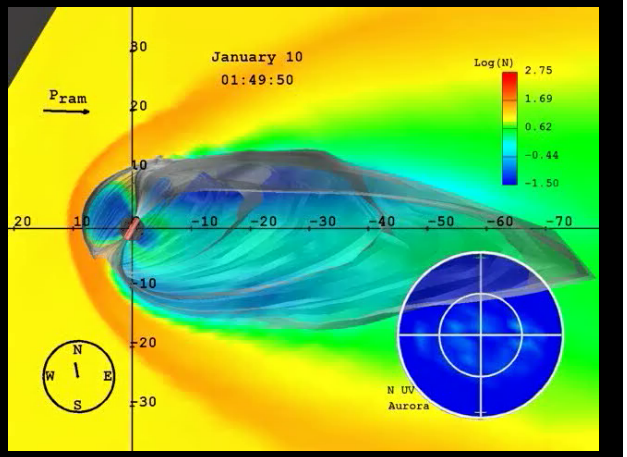
- Varney et al. just submitted a paper showing sawteeth oscillations in coupled MFLFM-IPWM
  - First time in simulations with polar wind model
  - Appears to be driven by outflow originating from auroral regions

Conclusions

- High resolution LFM studies show good agreement with BBFs and improve FAC and CPCP patterns
- New precipitation model implemented
- LFM-RCM appears to be working for realistic events with strong driving and dipole tilts
- MFLFM is now coupled with IPWM for realistic polar wind outflow studies

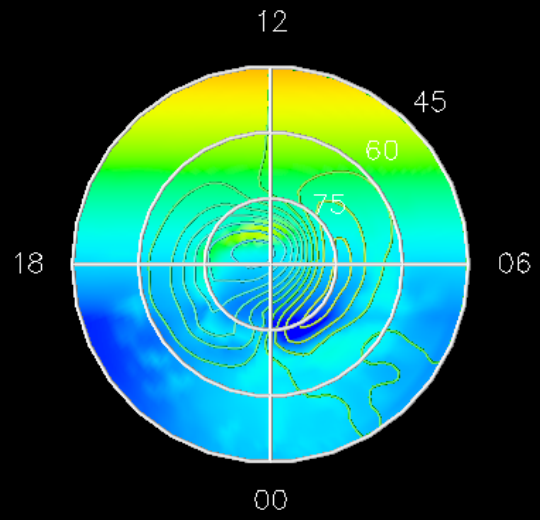
LFM Magnetospheric Model

- Uses the ideal MHD equations to model the interaction between the solar wind, magnetosphere, and ionosphere
  - Computational domain
    - 30 R_E < X < -300 R_E & ±100R_E for YZ
    - Inner radius at 2 R_E
  - Calculates
    - full MHD state vector everywhere within computational domain
  - Requires
    - Solar wind MHD state vector along outer boundary
    - Empirical model for determining energy flux of precipitating electrons
    - Cross polar cap potential pattern in high latitude region which is used to determine boundary condition on flow



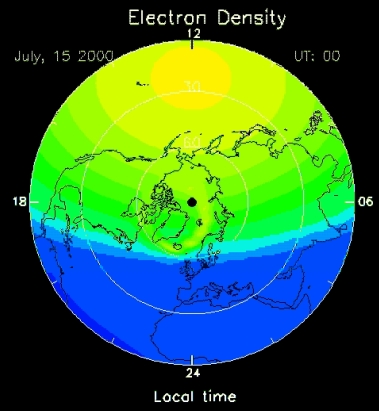
MIX - Electrodynamic Coupler

- Uses the conservation of current to determine the cross polar cap potential
  - Computational domain
    - 2D slab of ionosphere, usually at 120 km altitude and from pole to 45 magnetic latitude
  - Calculates
    - $\nabla \cdot \left(\Sigma_P + \Sigma_H \right) \nabla \Phi = J_{\parallel} \sin(\eta)$
  - Requires
    - FAC distribution
    - Plasma T and ρ to calculate energy flux of precipitating electrons
    - F107 or conductance



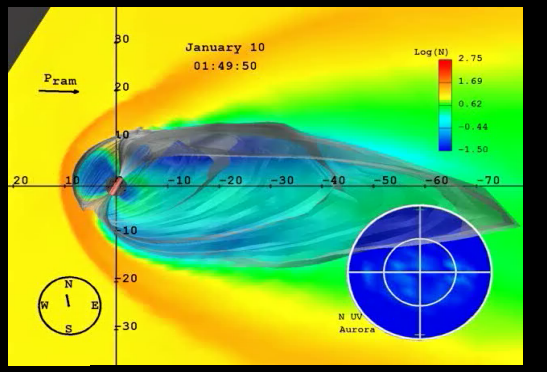
TIEGCM Model

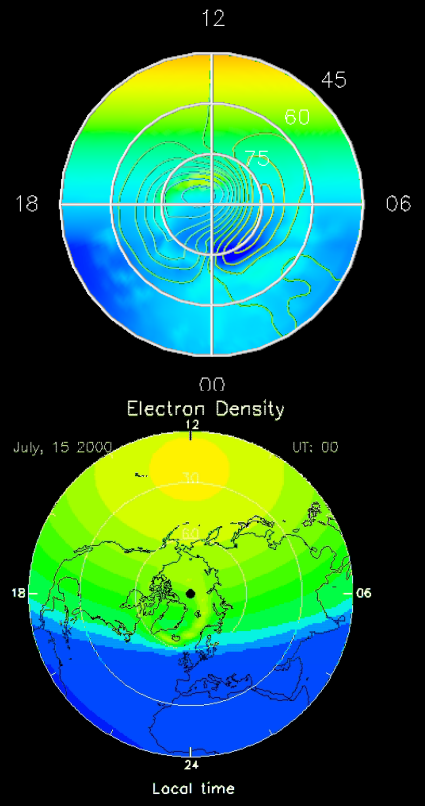
- Uses coupled set of conservation and chemistry equations to study mesoscale process in the thermosphere-ionosphere
  - Computational domain
    - Entire globe from approximately 97km to 500km in altitude
  - Calculates
    - Solves coupled equations of momentum, energy, and mass continuity for the neutrals and O^+
    - Uses chemical equilibrium to determine densities, temperatures other electrons and other ions (NO^+, O_2^+,N_2^+,N^+)
  - Requires
    - Solar radiation flux as parameterized by F10.7
    - Auroral particle energy flux
    - High latitude ion drifts
    - Tidal forcing at lower boundary



CMIT Model

- Couples the LFM magnetosphere model with the TIE-GCM thermosphere-ionosphere model via the MIX electrodynamic coupler
  - Uses Overture and Intercomm to handle grid interpolations and message passing
  - Potential and electron flux information passed to TIEGCM every two minutes with conductivities held constant during interm MIX updates





Multi-Fluid LFM Magnetospheric Model

- Uses the multi-fluid MHD equations to model the interaction between the solar wind, magnetosphere, and ionosphere
  - Computational domain
    - 30 R_E < x < -300 R_E & ±100R_E for YZ
    - Inner radius at 2 R_E altitude
  - Calculates
    - Solves mass, parallel and perpendicular momentum, and plasma energy for each plasma species
    - Self consistent magnetic field configuration
  - Requires
    - Solar wind MHD state vector along outer boundary
    - Empirical model for determining energy flux of precipitating electrons
    - Cross polar cap potential pattern in high latitude region which is used to determine boundary condition on flow
    - Specification of plasma outflow from inner boundary