The MHD-AEPIC model uses an adaptive particle code to enhance the Michigan Geospace model.

Stormtime Geomagnetic Disturbance Events: Impact of High-Resolution Grid and Adaptive Kinetic Physics

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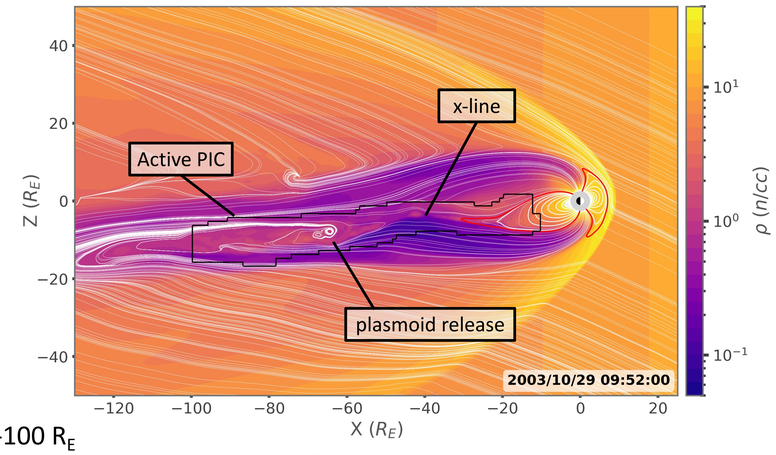
Motivation

- Magnetic reconnection governs the interaction between the solar wind and the magnetosphere.
- Extreme space weather events may push MHD models that rely on numerical reconnection beyond the validated parameter space.
- Kinetic physics is required to better-represent reconnection; however, kinetic simulations are computationally expensive relative to ideal MHD.
- Chen et al. 2023 developed an adaptive particle-in-cell (PIC) code FLEKS that can be embedded into the Geospace model. FLEKS activates and deactivates grid cells as needed to improve efficiency.
- Ground Magnetic Disturbances (GMDs) are closely tied to reconnection and have large impacts on electrical systems on the ground.
- We validate the model under extreme conditions.

Model Configuration

- 29-31 October 2003 'Halloween' Storm
- Surface magnetometer output every 1 minute on 1°x1° grid
- Comparing three models to explore different grid/physics

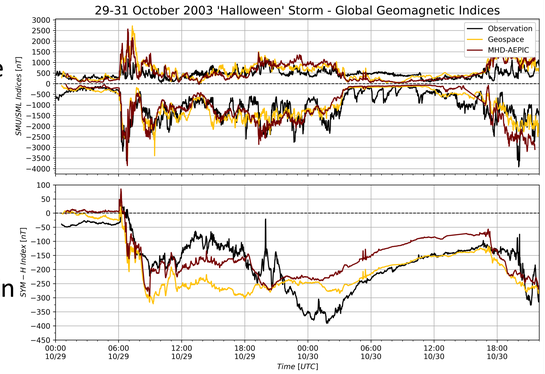
1. **Michigan Geospace**
   - operational SWPC V2 configuration
     - BATSRUS (Global Mag) + RCM (Inner Mag) + RIM (Iono)
2. **MHD-AEPIC model**
   - Geospace coupled to FLEKS PIC model
3. **High-Resolution Geospace**
   - 1/4 R_E grid resolution in magnetotail to -100 R_E
     - same resolution as MHD-AEPIC, but with PIC code deactivated



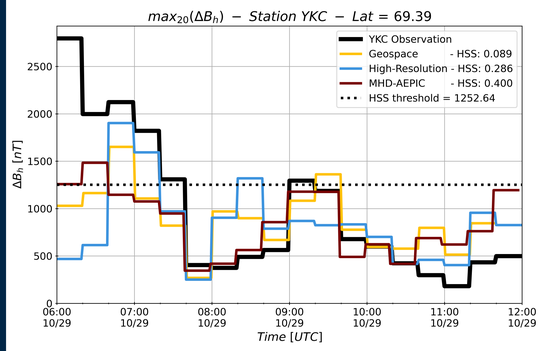
Meridional cut of the MHD-AEPIC run in the y=0 plane from storm main phase. Note the plasmoid release and reconnection x-line covered by the PIC code region.

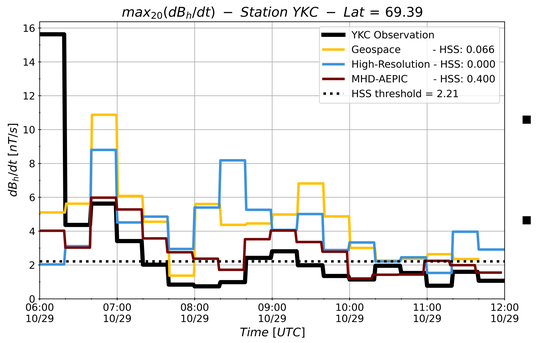
Geomagnetic Indices

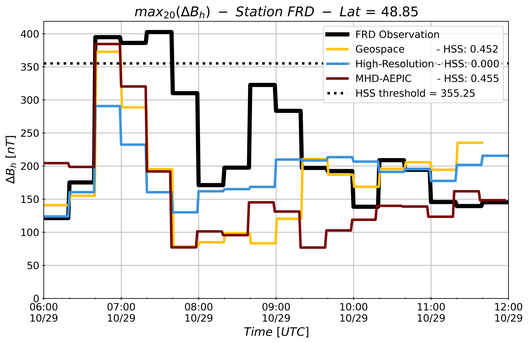
- SuperMAG indices SMU/SML are analogous to auroral AU/AL
- Geospace and MHD-AEPIC perform similarly for these global high-latitude indices.
  - MHD-AEPIC recovers better after the first main phase due to a large plasmoid release

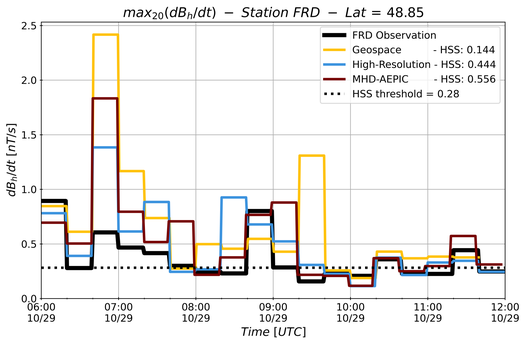


Nightside GMD Validation









- Examine storm main phase (06:00-12:00 UTC on 2003.10.29)
- High-resolution and PIC regions are in the magnetotail -> nightside magnetometer stations should see largest impacts
- Heidke Skill Score (HSS) for maximum observed horizontal dB_h/dt and maximum ΔB_h in 20-minute windows
- HSS threshold set to 90th percentile for each station (dashed horizontal lines)
- **MHD-AEPIC typically produces higher HSS than Geospace or High-Resolution alone.**
- **MHD-AEPIC typically produces smaller dB/dt values than the other models, which is closer to observation.**

The inclusion of particle physics increases GMD modeling skill over both standard Geospace and High-Resolution MHD.

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References:

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