Using Effective Resistivity Maps Derived From Data Mining for Global MHD Simulations of the Magnetosphere

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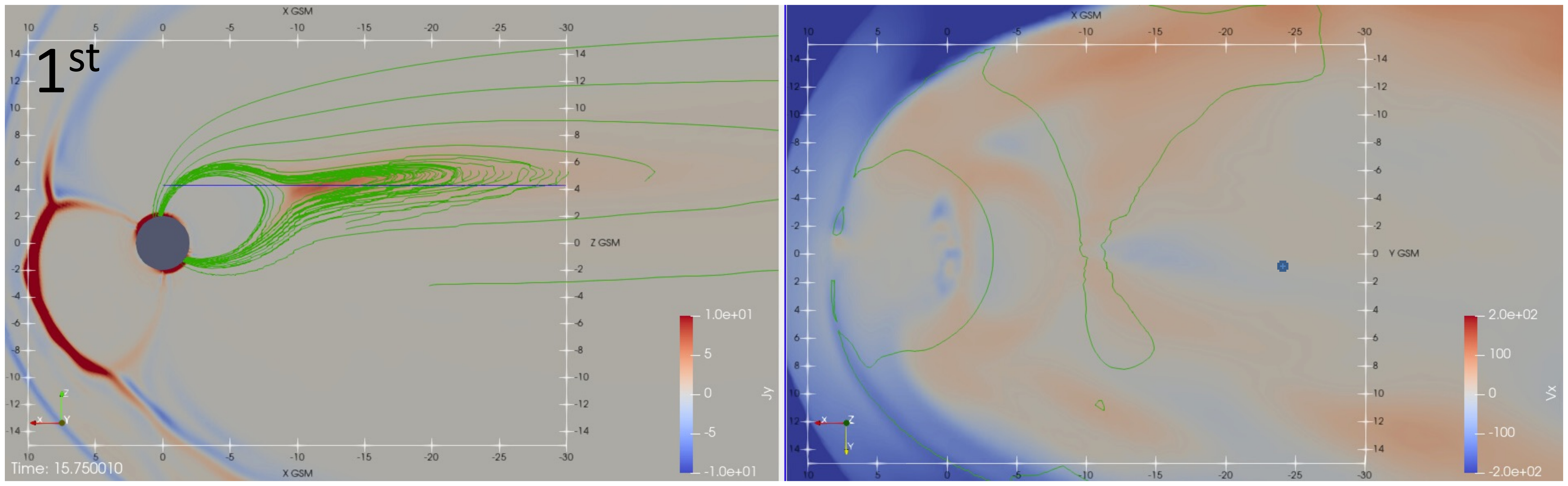
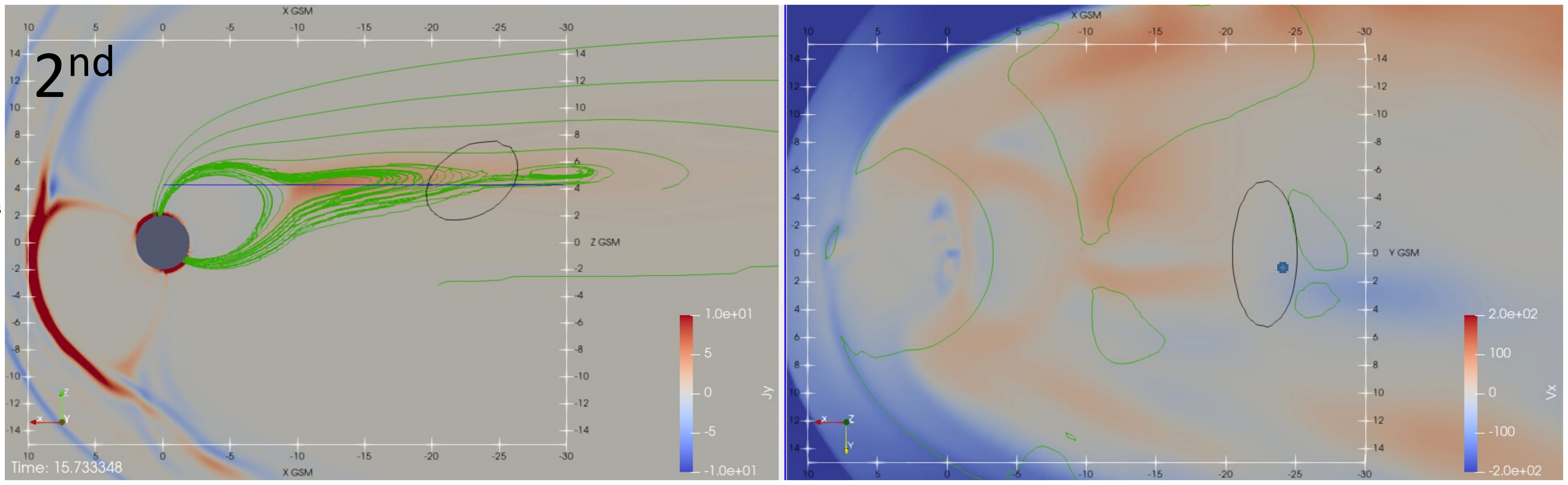
Abstract

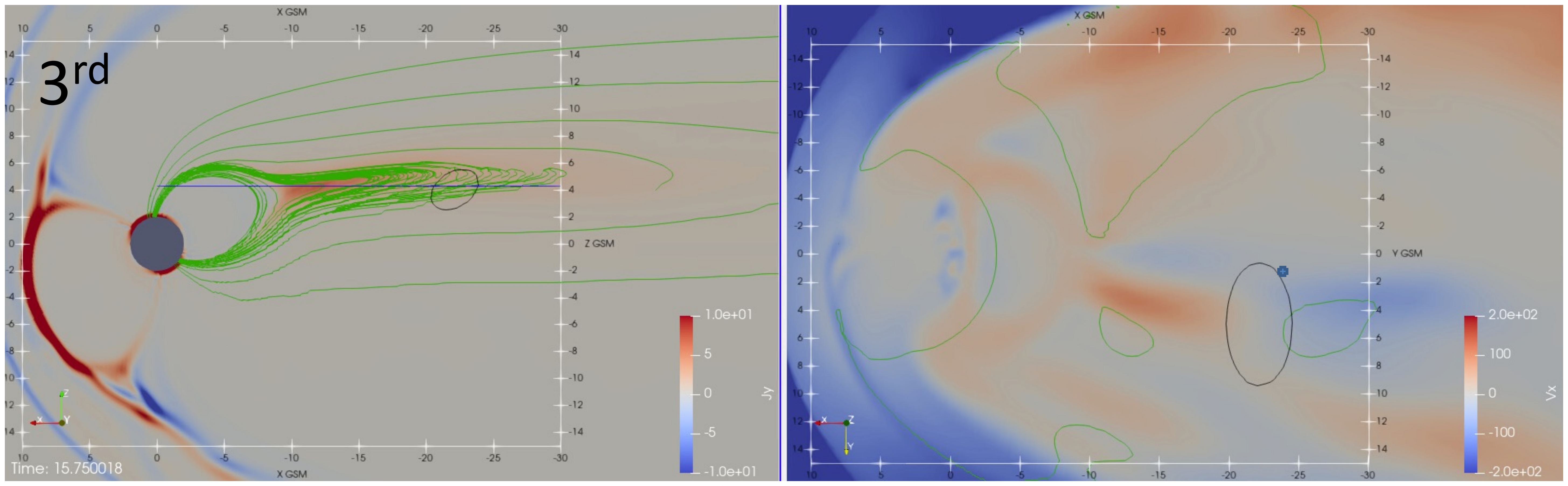
- Magnetic reconnection in the magnetotail is an important driver of space weather (Angelopoulos 2008, Angelopoulos et al. 2020)
- Global MHD simulations have difficulty reproducing the correct timing and location of x-lines since the formation process is inherently kinetic (Sitnov et al. 2019)
- By mining the data from different missions using k-Nearest Neighbors an accurate representation of the Earth's magnetic field can be reproduced (Stephens et al. 2019)
- Using this method, the timing and location of many x-lines agree with MMS results
- We present a few test simulations using the Global MHD code GAMERA (Zhang et al. 2019) that show how localized explicit resistivity can effect the global dynamics and x-line location

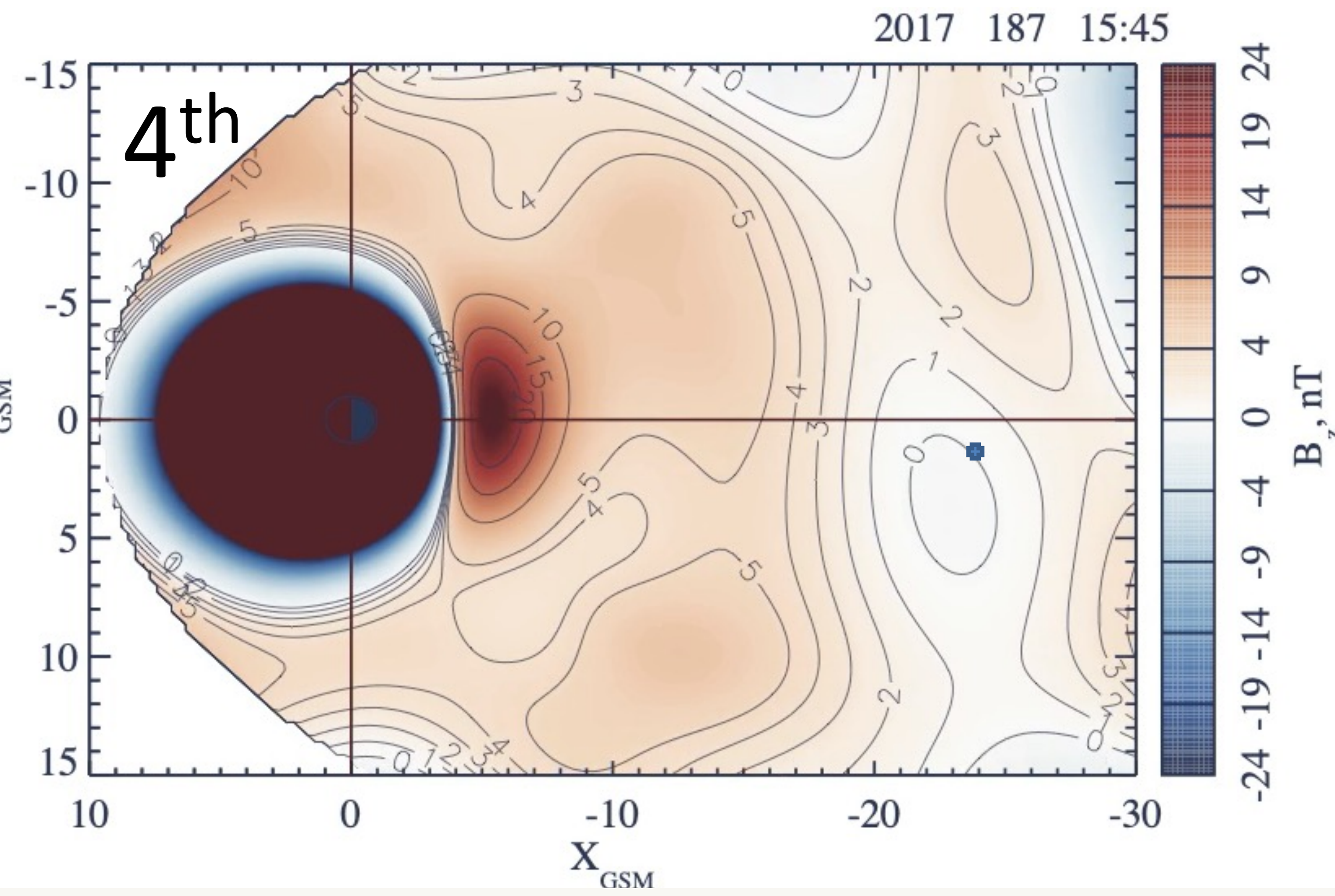
Images (GSM coordinates)

- At approximately 15:45 UT on July 6, 2017 MMS observed an ion diffusion region. DM results at the exact time and location of MMS show an o-line in agreement with MMS. We show results from quad resolution GAMERA simulations and DM results in 4 images. The approximate location of MMS is represented as a blue dot in all 4 images. The first 3 images consists of GAMERA simulations in two panels:
  - The left shows the dawn-dusk current in the meridional plane, magnetic field lines in green, and the region of localized resistivity ($\eta_{max} \simeq 40{,}000\ \Omega m$ as in Hesse et al. 1994). The blue line indicates the plane for the right panel, which is approximately the plane of the current sheet.
  - The right shows V_x flows in this plane. Contours of B_z equal to 0 are in green. Regions of resistivity are in black.
- X-lines can be identified in the right panel by diverging flows near areas where B_z=0 since z is approximately the reconnected magnetic field.
- The 1st image has no resistivity and shows an x-line forming around X = -12 R_E
- The 2nd image includes localized resistivity across the current sheet and centered on the midnight line. An x-line can be seen around X = -24 R_E with some dawn-dusk asymmetry.
- The 3rd image includes localized resistivity where we expect to see an x-line according to the data mining (DM) results, i.e. around X = -22 R_E and $-6 < Y/R_E < -1$. Importantly an x-line forms at almost this exact location as can be seen by the diverging flows. Additionally the field lines can be seen to form an x-line in the X-Z plane (not shown).
- The 4th image shows the DM results at the same time and also along Z=4.3 R_E just like the other 3 images. The image shows B_z with contours of B_z. X-lines can be identified by the Earthward part of B_z=0 contours, whereas the tailward component is an o-line. There is a clear x-line on the dusk side at X = -22 R_E.









Conclusion

- Without resistivity global MHD simulations produce x-lines far too close to the Earth, around X (GSM) = -12 R_E and at the wrong time. In reality reconnection rarely occurs that close, only for large storms.
- By including resistivity further down the tail we can "encourage" reconnection to take place at a location that is in agreement with DM results. Further, this reconnection actually suppresses near Earth reconnection by introducing additional flux earthward that widens the current sheet. **Amazingly we can produce x-lines in our simulations that are significantly closer to the time and location of MMS observations of ion diffusion regions.**
- Next steps are:
  - To test other resistivity models, i.e. current dependent resistivity as explored in Birn et al. 2000 or Raeder 2003
  - Implement time dependent regions of localized resistivity by mapping the location of x-line derived in DM results to GAMERA, i.e. effective resistivity maps

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