Modeling the Lunar Wake During Extreme Plasma Conditions

A. P. Rasca[1], S. Fatemi[2], W. M. Farrell[1], A. R. Poppe[3,4], and Y. Zheng[1]

[1]*NASA/Goddard Space Flight Center, Greenbelt, MD, USA,* [2]*Swedish Institute of Space Physics, Kiruna, Sweden* [3]*Space Sciences Laboratory, University of California, Berkeley, CA, USA* [4]*Solar System Exploration Research Virtual Institute, NASA Ames Research Center, Mountain View, CA, USA*

I. Background

- We investigate the response of the lunar wake to a passing coronal mass ejection (CME) on 2012 March 8 while crossing the Earth's magnetotail.
- In-situ observations are used as simulation input for plasma flow around the Moon while in the nominal solar wind (SW) and while passing through the Earth's magnetotail shortly after the CME shock arrival (disturbed conditions).
- A large-scale global magnetosphere (GM) simulation of the CME event is performed to contextualize a number of significant observations.

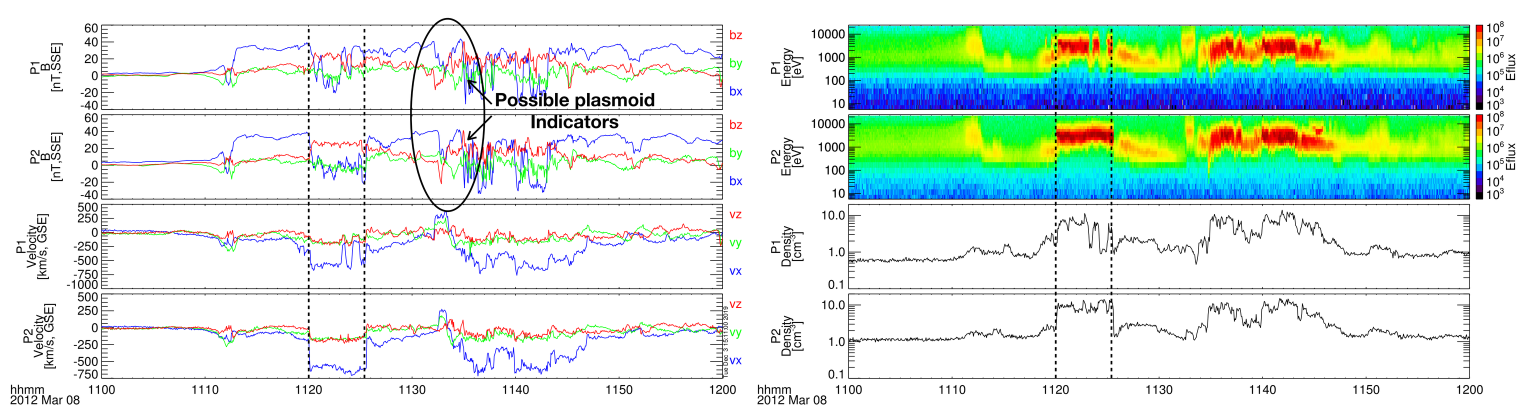
II. Model

- Plasma flows around the Moon are modeled using the Advanced Modeling Infrastructure in Space Simulation (AMITIS) code by Fatemi et al. (2017). AMITIS solves a 3-D hybrid-PIC model by treating electrons as a massless fluid and ions as particles, ideal for scale lengths between the gyro-radii of solar wind electrons and ions.
- Global magnetosphere MHD simulations are run through NASA's Community Coordinated Modeling Center (CCMC) using the Open Geospace General Circulation Model (OpenGGCM) developed by Raeder et al. (1998) to specifically model the Earth's magnetosphere.

III. Input Data

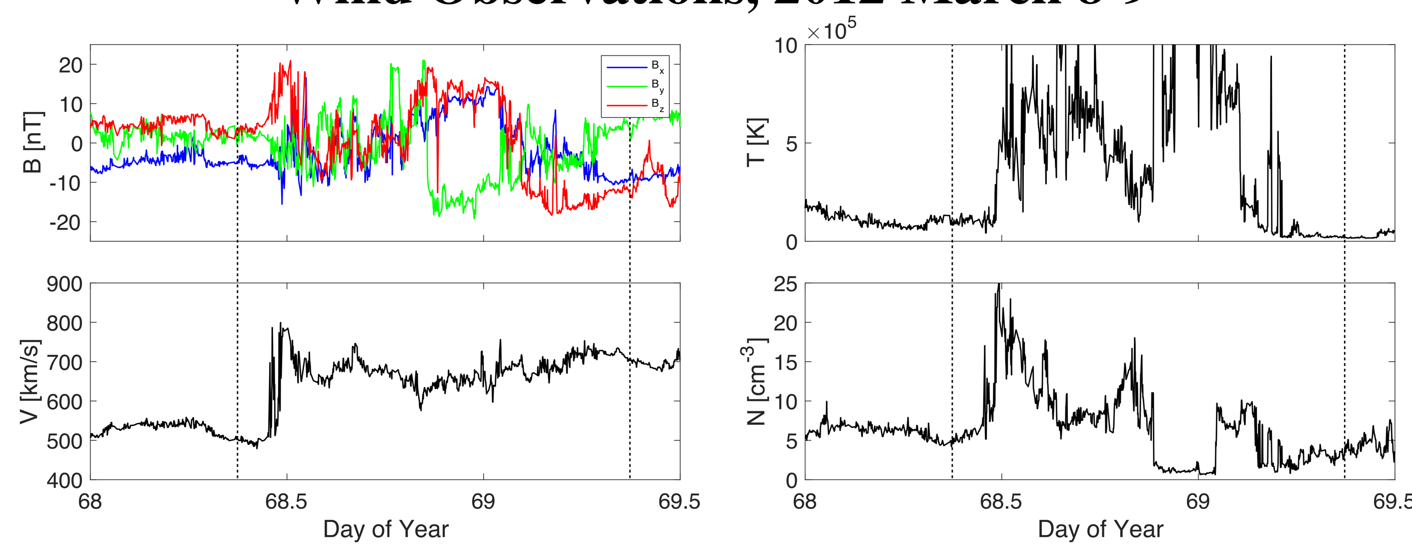
- Hybrid-PIC simulations of the plasma flow around the Moon are first performed using nominal upstream solar wind conditions with a 45° IMF Parker Spiral **(Results IVa)**, similar to pre-CME conditions observed by Wind.
- Observation by the ARTEMIS P1 and P2 spacecraft from 11:20-11:25 UT on 2012 March 8 (between dashed vertical lines below) are used for upstream magnetotail plasma conditions during post-shock CME arrival **(Results IVb)**.

ARTEMIS Observations, 2012 March 8



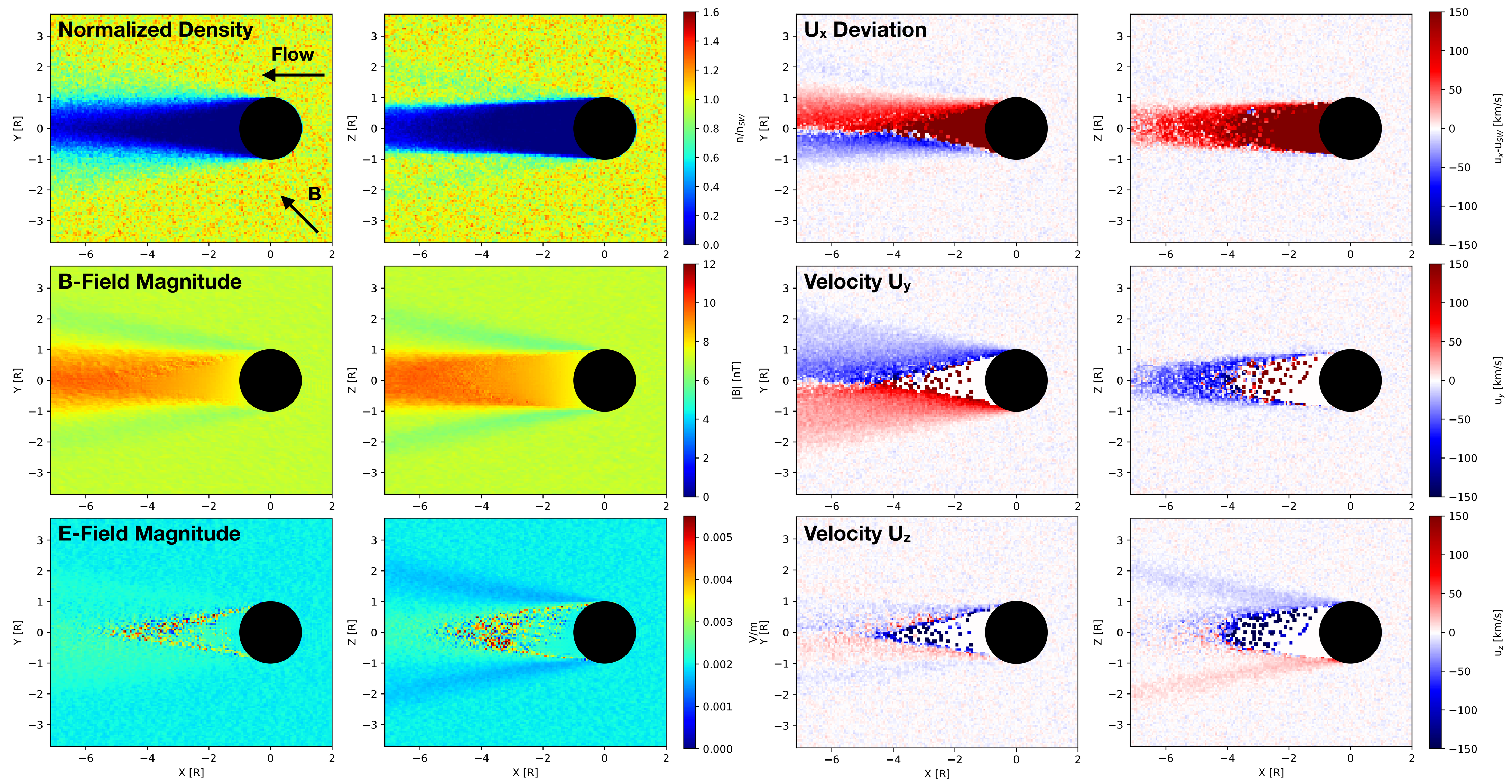
- Plasma data from the Wind spacecraft at Lagrange point L1 during the 24-hour period starting at 9:00 UT on 2012 March 8 is used as time-dependent upstream input for a MHD simulation of the global magnetosphere **(Results Va-Vc)**. Vertical dashed lines below mark the start and end times of the simulation.

Wind Observations, 2012 March 8-9

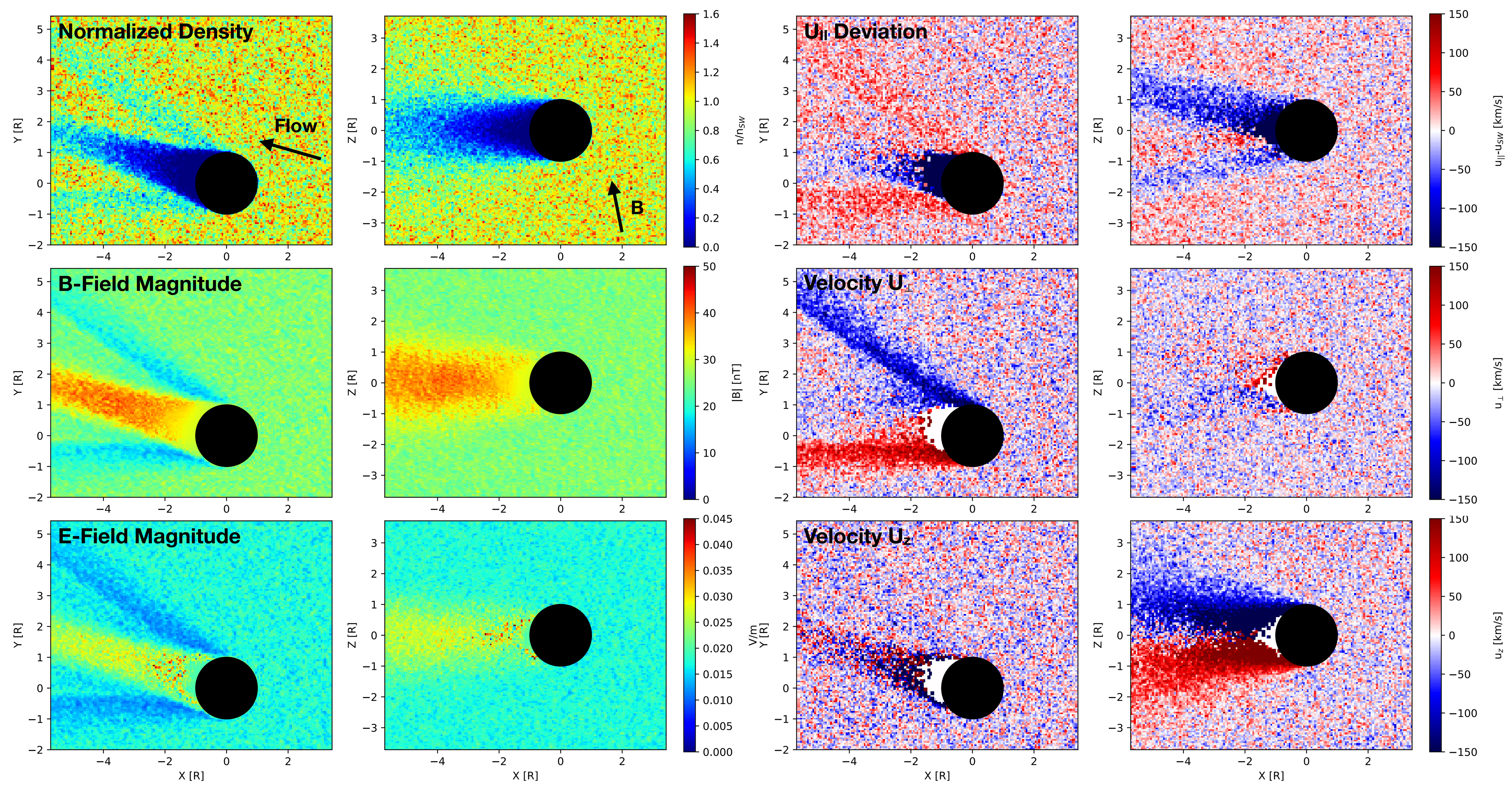


IV. Hybrid-PIC Simulation Results

IVa. Nominal SW Conditions

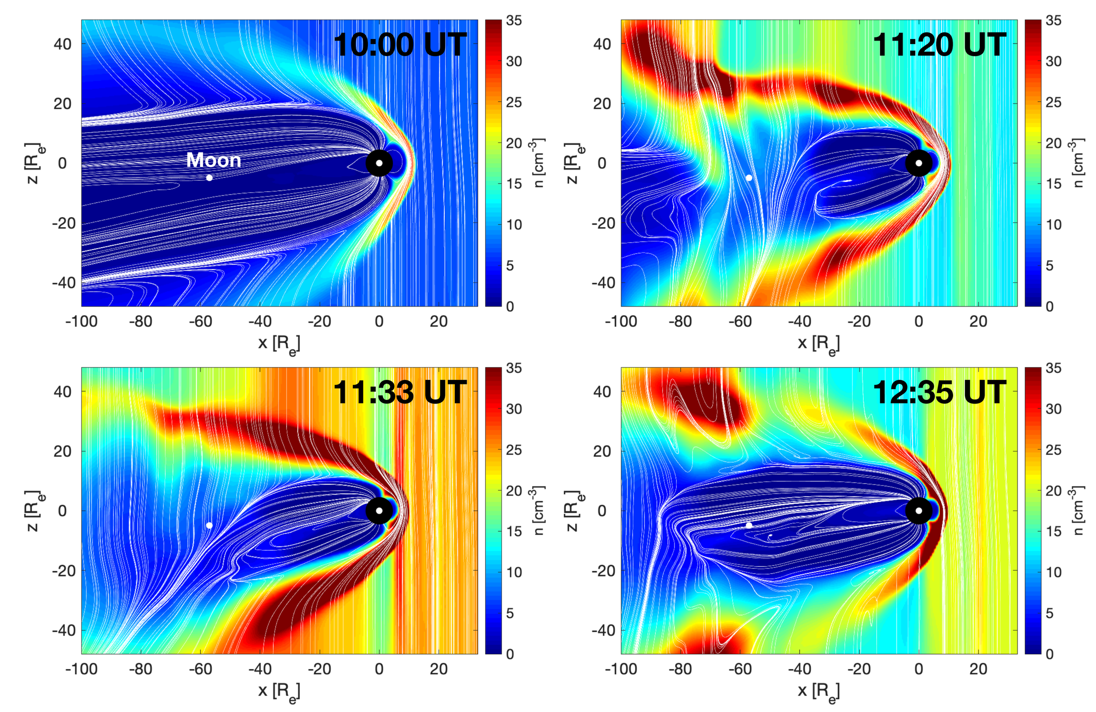


IVb. Disturbed Conditions in the Earth's Magnetotail

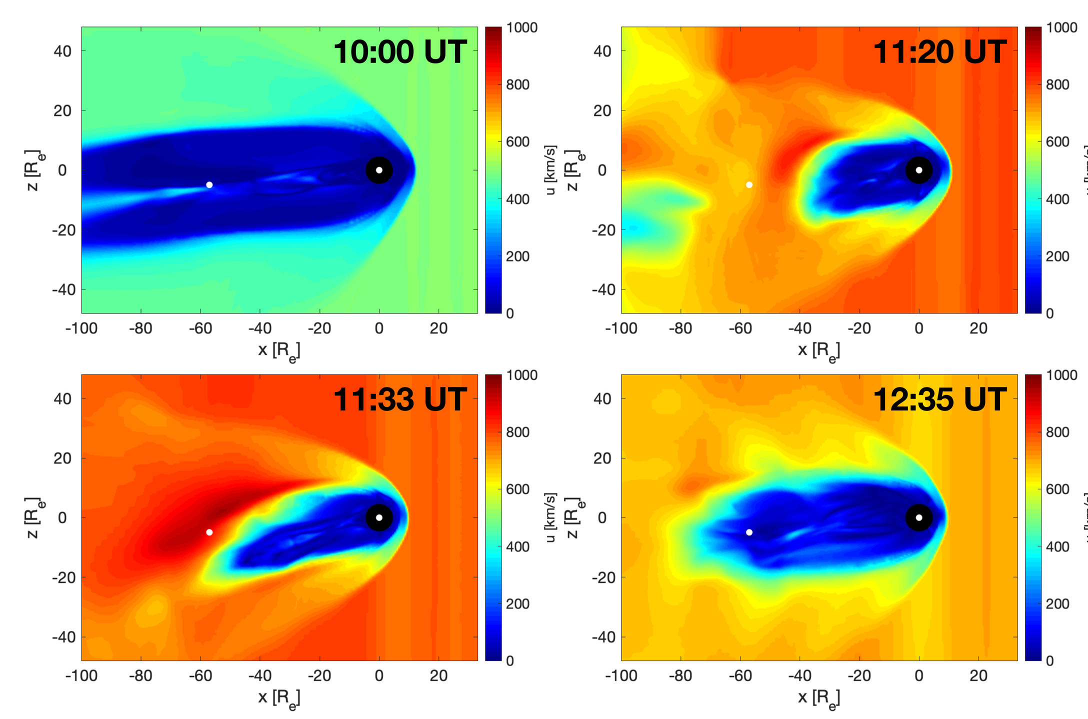


V. MHD Simulation Results

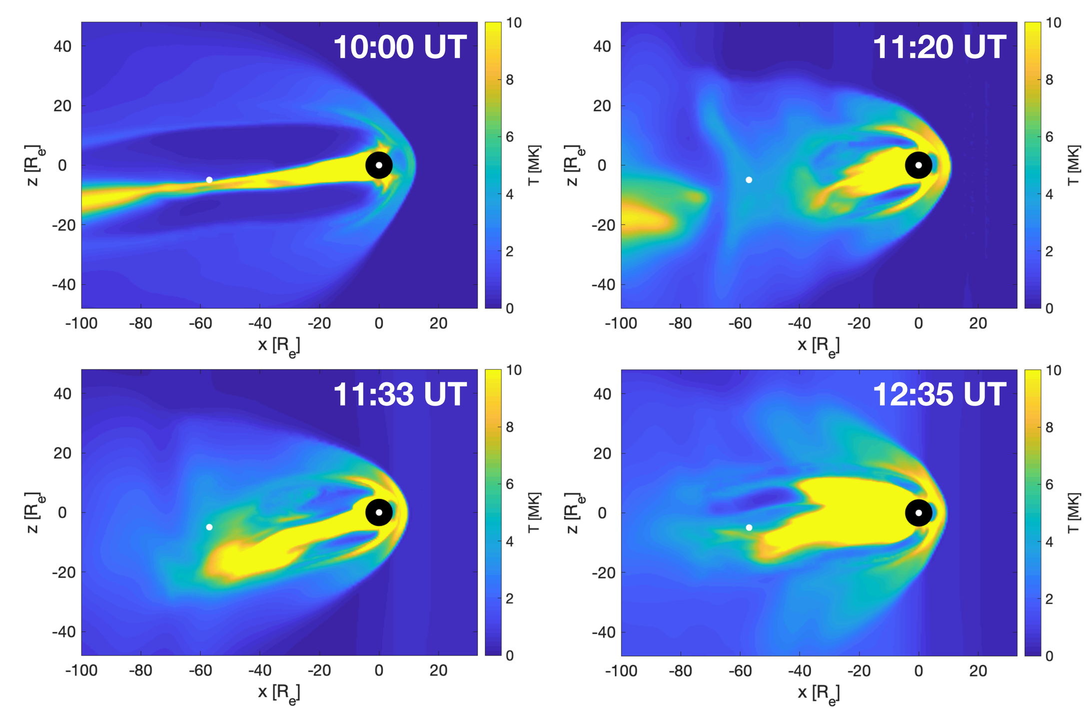
Va. Plasma Density and B-Field



Vb. Plasma Velocity



Vc. Plasma Temperature



VI. Analysis

- The nominal SW and disturbed plasma parameters produce different wake structures, but each are similar to results from Hölmstrom et al. (2012) when defining **B** to be 45° and perpendicular to the plasma flow, respectively.
- In the disturbed magnetotail, the perpendicular **B**-field allows the plasma to refill the wake, resulting in a much shorter wake. We also see rarefaction waves in the xy-plane and enhanced electric and magnetic fields within the wake.
- MHD results indicate that changes near the Moon appear as a result of a warped magnetopause boundary being pushed inward after 11:00 UT, causing the Moon to enter the magnetosheath.
- MHD results also show a number of plasmoids developing and propagating down the tail, including one seen at 11:20 UT that corresponds temporally with plasmoid-like features in the ARTEMIS **B**-field profiles.

Acknowledgments

Hybrid-PIC simulation results were provided by S. Fatemi at the Swedish Institute of Space Physics, Kiruna, Sweden. MHD simulation results have been provided by the Community Coordinated Modeling Center at Goddard Space Flight Center through their public Runs on Request system (http://ccmc.gsfc.nasa.gov). The OpenGGCM Model was developed by the J. Raeder and T. Fuller-Rowell at the Space Science Center, University of New Hampshire.