Project Details

ROSES ID: NNH15ZDA001N
Selection Year: 2015
Program Element: Focused Science Topic

Topic: Space Weather at Terrestrial Planets

Project Title:
Space weather at Mercury: The effect of interplanetary coronal mass ejections on Mercury's atmosphere and magnetosphere

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Summary:
The MESSENGER mission has found that Mercury has a magnetic field strong enough to stand off the solar wind from the surface under average solar wind conditions. However, the degree to which the surface is shielded under extreme conditions, especially interplanetary coronal mass ejection (ICME) impacts, is not known. The high subsolar pressure and intense reconnection accompanying these events will tend to expose the surface to direct solar wind impact. However, Mercury has a very large electrically conducting core, which is expected to decrease the compressibility of the magnetosphere due to solar wind-driven induction currents. Mercury's tenuous atmosphere is maintained by photo-desorption, micrometeorite impact vaporization, and sputtering from the surface. In this manner the solar wind in the inner solar system, Mercury's magnetosphere, atmosphere, and the planet itself are all coupled and believed to respond strongly to solar activity. The primary goal of this investigation is to discover response of Mercury's atmosphere and magnetosphere to ICMEs. Our investigation will use numerical simulations and MESSENGER observations of Mercury's atmosphere and magnetosphere to: 1) understand and characterize the structure of ICMEs at Mercury's orbit (0.3 -0.5 AU); 2) discover the changes in the magnetosphere during ICME impact especially changes in configuration and internal dynamics that will affect the flux of solar wind and magnetospheric charged particle flux to the surface and produce sputtered neutrals; and 3) determine the average and maximum effect of ICME impact on Mercury's atmosphere. The propagation and modeling of ICMEs to Mercury in the MESSENGER observations will be carried out using WSA-ENLIL and the Alfven Wave Solar Model (AWSoM) MHD simulations. These models will also be used to reconstruct historical events, such as the Bastille Day 2001 and Halloween 2003 ICMEs, but as they would have appeared at Mercury's orbit. The magnetosphere will be modeled with the BATSRUS global MHD model with embedded and two-way coupled Particle-in-Cell (PIC) domains using the iPIC3D code. The use of Hall MHD in combination with embedded regional PIC (MHD-EPIC) allows a proper representation of the fast reconnection. This is necessary because of the very high reconnection rates measured by MESSENGER. The interior of Mercury will be modeled as a layered finite resistivity body that allows for induction currents. The response of Mercury's neutral exosphere, including sources/losses and transport of neutrals and photo-ions, will be investigated with the Adaptive Mesh Simulator (AMPS). The BATSRUS, iPIC3D and AMPS models are integrated into the Space Weather Modeling Framework (SWMF) and coupled together. This sophisticated coupled model can capture the response of the exospheric neutral and ion species to ICMEs by accounting for the variation of the sputtering source. The results of these simulations will be compared, validated, and used to guide analysis of the observations returned by the MESSENGER mission. Our contribution to the Space Weather at the Terrestrial Planets Focused Science Topic will be the improved understanding, characterization and modeling of the effects of ICME impact on surface bounded exospheres (Mercury and Moon) and intrinsic field magnetospheres of terrestrial-type bodies (Mercury and Earth).

Publication References:

Summary: no summary

Reference: Baker, Daniel N.; Dewey, Ryan M.; Lawrence, David J.; Goldsten, John O.; Peplowski, Patrick N.; Korth, Haje; Slavin, James A.; Krimigis, Stamatios M.; Anderson, Brian J.; Ho, George C.; McNutt, Ralph L.; Raines, Jim M.; Schriver, David; Solomon, Sean C.; (2016), Intense energetic electron flux enhancements in Mercury's magnetosphere: An integrated view with high-resolution observations from MESSENGER, Journal of Geophysical Research: Space Physics, Volume 121, Issue 3, pp. 2171-2184, doi: 10.1002/2015JA021778

Summary: no summary

Reference: Sun, W. J.; Fu, S. Y.; Slavin, J. A.; Raines, J. M.; Zong, Q. G.; Poh, G. K.; Zurbuchen, T. H.; (2016), Spatial distribution of Mercury's flux ropes and reconnection fronts: MESSENGER observations, Journal of Geophysical Research: Space Physics, Volume 121, Issue 8, pp. 7590-7607, doi: 10.1002/2016JA022787

Summary: no summary

Reference:
Poh, Gangkai; Slavin, James A.; Jia, Xianzhe; DiBraccio, Gina A.; Raines, Jim M.; Imber, Suzanne M.; Gershman, Daniel J.; Sun, Wei-Jie; Anderson, Brian J.; Korth, Haje; Zurbuchen, Thomas H.; McNutt, Ralph L.; Solomon, Sean C.; (2016), MESSENGER observations of cusp plasma filaments at Mercury, Journal of Geophysical Research: Space Physics, Volume 121, Issue 9, pp. 8260-8285, doi: 10.1002/2016JA022552

Summary: no summary

Reference: Karlsson, Tomas; Liljeblad, Elisabet; Kullen, Anita; Raines, Jim M.; Slavin, James A.; Sundberg, Torbjörn; (2016), Isolated magnetic field structures in Mercury's magnetosheath as possible analogues for terrestrial magnetosheath plasmoids and jets, Planetary and Space Science, Volume 129, p. 61-73, doi: 10.1016/j.pss.2016.06.002