Project Details

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Program Element: Focused Science Topic

Topic: Space Weather at Terrestrial Planets

Project Title:
Solar Wind Interaction with the Mars Upper Atmosphere: The Impact of ICME Events

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Summary:
The study of the solar wind interaction with Mars upper atmosphere/ionosphere has recently received a great deal of attention, especially the investigation of ion escape fluxes due to its potential impact on the long-term evolution of the Mars atmosphere (e.g., loss of water) over its history. However, accurate estimations of ion escape fluxes from spacecraft data are difficult due to the complex geometry of the loss regions around Mars. This limitation necessitates global simulations, which couple the thermosphere/ionosphere and solar wind interaction regions for Mars. Such models can accommodate upstream solar wind conditions, solar EUV/UV irradiance conditions, and Mars planetary conditions self-consistently.

The major science goal of this current project is to investigate the responses of the Mars upper atmosphere/ionosphere to historical ICME events. Specific science goals include: (1) Investigate the 2-way coupled model (SWMF system) responses to specific ICME events. Simulate ICME upstream solar wind conditions for ICME events that have previously been observed and studied at Earth. Compare the Mars system model responses to available Mars datasets (e.g. MGS, Mars Express). (2) Contrast the Earth and Mars responses (both observed and modeled) to the same ICME events. Identify and quantify the role of the most important processes that drive major differences between the two planets. Determine how these processes that regulate ion losses are dependent on specific features of ICMEs.

We will simulate the space weather at Mars by coupling together four multi-fluid MHD models whose domains combine to encompass the solar atmosphere from the chromosphere to interplanetary space extending to Mars where the solar wind will be coupled to the Mars upper atmosphere. Specific tasks include the following: (1) We will modify the SWMF framework to provide a 2-way coupling to interactively link the Mars GITM code and the Mars multi-fluid MHD code. (2) Test the SWMF coupled system in a 1-way linked configuration (upward then downward) to establish two baselines against which 2-way coupling can be compared. (3) Finalize a fully 2-way coupled system, activating both upward and downward coupling capabilities. Compare the SWMF model outputs from this coupled configuration with each of the 1-way coupled configurations above for the same upstream solar wind conditions. This will be accomplished making use of both available Mars spacecraft datasets and coupled global model simulations to produce self-consistent interaction of the solar wind environment with the Mars upper atmosphere/ionosphere. For specific ICME events, simulated solar wind conditions will be used to drive the coupled model system. Model data comparisons will then be used to validate the models. The solar corona will be simulated with AWSoM, which describes the solar wind as a two-temperature plasma (electrons and protons) driven by Alfven wave turbulence. This model is coupled to an inner heliosphere model, which propagates the solar wind to Mars.

This project will make the following contributions to the focused science team: (1) Quantitatively link the extremes of solar wind variability during ICMES events the corresponding TI responses for the first time, which will benefit disparate Mars upper atmosphere communities. (2) Modeling will provide a context for ICME signatures in the Mars upper atmosphere densities and temperatures for events observed by MAVEN, which will be most useful for Mars data interpretations studies making use of models. (3) The modeling will permit both Earth and Mars scientist to contrast the relative responses by Earth and Mars to ICME events, thereby uncovering physical reasons for the difference responses. (4) Predicted particle fluxes will be available for use

by other modelers, which provides a way to compare model responses to the same forcing. This is needed in Aeronomy studies if possible.

Publication References:

Summary: no summary

Reference: Szente, J.; Toth, G.; Manchester, W. B., IV; van der Holst, B.; Landi, E.; Gombosi, T. I.; DeVore, C. R.; Antiochos, S. K.; (2017), Coronal Jets Simulated with the Global Alfvén Wave Solar Model, The Astrophysical Journal, Volume 834, Issue 2, article id. 123, 20 pp, doi: 10.3847/1538-4357/834/2/123

Summary: no summary

Reference: Kocher, M.; Lepri, S. T.; Landi, E.; Zhao, L.; Manchester, W. B., IV; (2017), Anatomy of Depleted Interplanetary Coronal Mass Ejections, The Astrophysical Journal, Volume 834, Issue 2, article id. 147, 13 pp, doi: 10.3847/1538-4357/834/2/147