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A Virtual Solar Wind Monitor at Mars to Enable Statistical and Comparative Magnetospheric Studies

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Unlike Earth, Mars does not possess an upstream solar wind monitor. This lack of continuous solar wind observations has fundamentally limited scientific studies that investigate solar wind impacts on the Mars space environment. This lack of a dedicated upstream monitor has also limited emerging operational tasks for predicting space weather throughout our solar system. Previous estimates of the solar wind have been pursued through physics-based modeling efforts (e.g. magnetohydrodynamic models) or empirical (e.g. assuming statistical relationships with downstream observations) proxies. Proxies are often based on downstream observations from multiple orbiting spacecraft. These spacecraft pass in and out of the bow shock providing a semi-regularly sampling of the pristine solar wind. The most complete, and ongoing, set of the solar wind's magnetic field and plasma parameters is from the NASA MAVEN spacecraft. MAVEN has orbited Mars since 2014, but additional assets add resolution to this dataset such as including ESA's MEX mission which has been in orbit since 2003, and the CNSA's Tianwen-1 orbiter since 2021.

In this presentation I will discuss the creation of a first continuous solar wind estimation upstream from Mars. This virtual solar wind monitor, or vSWIM (see Azari et al., 2024, doi: 10.1029/2024JH000155) was trained and assessed on MAVEN data. vSWIM is generated from Gaussian process regression, a type of machine learning, and is used to provide predictions, and uncertainties on these predictions, at various temporal resolutions. This has enabled subsequent statistical studies, including for understanding the causation of sinuous aurora a unique Martian aurora. I will conclude with a discussion of scientific studies enabled by vSWIM, including comparative magnetospheric studies, and provide an outlook for vSWIM's multi-spacecraft integration for operational space weather prediction efforts.

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Keyword-2

machine learning

Keyword-3

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Author: Dr AZARI, Abigail (University of Alberta, Alberta Machine Intelligence Institute)

Presenter: Dr AZARI, Abigail (University of Alberta, Alberta Machine Intelligence Institute)

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