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A Global 3D Bow Shock Model Valid for a Wide Range of Upstream Mach Numbers

Jan Merka (1), David Sibeck (2), and Yongli Wang (1)

(1) University of Maryland, Baltimore County, Goddard Planetary Heliophysics Institute, Baltimore, United States (merka@umbc.edu), (2) NASA Goddard Space Flight Center, Greenbelt, Maryland, United States

Interaction of the supersonic solar wind with Earth's magnetosphere creates fast mode magnetosonic waves that travel back upstream, combine and steepen to form the bow shock wave. The bow shock wave has been studied for more than four decades but existing models are still often inaccurate. Previous studies established that bow shock shape and position are primarily controlled by solar wind pressure, upstream Mach numbers, interplanetary magnetic ?eld orientation and magnetopause shape and position.

We have collected a total of 28,287 bow shock crossings identi?ed in observations from the Cluster 1-4, Geotail, IMP-8, Interball-1, MAGION-4, THEMIS A-E and WIND spacecraft and use this database to predict bow shock position as a function of solar wind parameters. The large dataset appeared sufficient for employing a modelling technique that does not assume a prescribed shock shape to eliminate a potential bias: The Support Vector Regression Machine (SVRM) technique for mapping multi-dimensional data into a high- dimensional feature space via nonlinear mapping through a selected kernel function and performing a linear regression in this space. After a thorough study, we have concluded that even though the employed number of shock crossings is the largest used by at least an order of magnitude, the fitted data points are still unevenly distributed in the modeled phase space and that severely limits the validity and applicability of the SVRM-produced bow shock models. Therefore, the same database of bow shock crossings is fitted using a method similar to Peredo et al. [1995] which presumes a general 3D second-order bow shock shape parameterized by the upstream dynamic pressure and Alfven Mach number values. The use of a prescribed shock shape results in a model that provides accurate predictions for Alfven Mach numbers as low as 2 and can be used with confidence up to 40 Re along the magnetotail.