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3D Bow Shock Modeling with and without Apriori Prescribed Shock Shapes

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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 PSW , upstream Mach numbers, interplanetary magnetic field orientation and magnetopause shape and position. Our study employs 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. The use of SVRM means that there is no apriori prescribed shock shape. In addition to SVRM, the bootstrap technique is employed for error calculations in contrast to existing shock models that rarely provide any error estimates at all. We fit a total of 28,287 bow shock crossings identified in observations from the Cluster 1-4, Geotail, IMP-8, Interball-1, MAGION-4, THEMIS A-E and WIND spacecraft.

Even thought 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 significantly limits the validity of the SVRM-produced bow shock models under certain upstream conditions. 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 parametrized by the upstream dynamic pressure and Alfven Mach number values. The use of a prescribed shock shape results in a model usable and more accurate even at the night-side magnetosphere as opposed to a SVRM-based model. We will further discuss in detail the advantages of either method and propose a bow shock model combining both approaches.