Geophysical Research Abstracts
Vol. 18, EGU2016-5291, 2016
EGU General Assembly 2016

Response of Mercury's Magnetosphere to Solar Wind Forcing: Results of Global MHD Simulations with Coupled Planetary Interior

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As the innermost planet, Mercury arguably undergoes the most direct space weathering interactions due to its weak intrinsic magnetic field and its close proximity to the Sun. It has long been suggested that two processes, i.e. erosion of the dayside magnetosphere due to intense magnetopause reconnection and the shielding effect of the induction currents generated at the conducting core, compete against each other in governing the large-scale structure of Mercury's magnetosphere. An outstanding question concerning Mercury's space weather is which of the two processes is more important. To address this question, we have developed a global MHD model in which Mercury's interior is electromagnetically coupled to the surrounding space environment. As demonstrated in Jia et al. (2015), the new modeling capability allows for self-consistently characterizing the dynamical response of the Mercury system to time-varying external conditions. To assess the relative importance of induction and magnetopause reconnection in controlling the magnetospheric configuration, especially under strong solar driving conditions, we have carried out multiple global simulations that adopt a wide range of solar wind dynamic pressure and IMF conditions. We find that, while the magnetopause standoff distance decreases with increasing solar wind pressure, just as expected, its dependence on the solar wind pressure follows closely a power-law relationship with an index of $\sim$ -1/6, rather than a steeper power-law falling-off expected for the case with only induction present. This result suggests that for the range of solar wind conditions examined, the two competing processes, namely induction and reconnection, appear to play equally important roles in determining the global configuration of Mercury's magnetosphere, consistent with the finding obtained by Slavin et al. (2014) based on MESSENGER observations. We also find that the magnetic perturbations produced by the magnetospheric current systems are spatially non-uniform in nature, and consequently they result in an induced magnetic field at the core that contains significant power in not only the dipole but also high order moments. Based on the simulation results, we determine how the induced magnetic field varies with the external solar wind conditions, and provide quantitative constraints on the ability of Mercury's core to shield the planetary surface from direct solar wind impact.