Simulation of Theoretical Most-Extreme Geomagnetic Sudden Commencements

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We report results from a numerical simulation of geomagnetic sudden commencements driven by solar wind conditions given by theoretical-limit extreme coronal-mass ejections (CMEs) estimated by Tsurutani and Lakhina [2014]. The CME characteristics at Earth are a step function that jumps from typical quiet values to 2700 km/s flow speed and a magnetic field magnitude of 127 nT. These values are used to drive three coupled models: a global magnetohydrodynamic (MHD) magnetospheric model (BATS-R-US), a ring current model (the Rice Convection Model, RCM), and a height-integrated ionospheric electrodynamics model (the Ridley Ionosphere Model, RIM), all coupled together using the Space Weather Modeling Framework (SWMF). Additionally, simulations from the Lyon-Fedder-Mobarry MHD model are performed for comparison. The commencement is simulated with both purely northward and southward IMF orientations. Low-latitude ground-level geomagnetic variations, both B and dB/dt, are estimated in response to the storm sudden commencement. For a northward interplanetary magnetic field (IMF) storm, the combined models predict a maximum sudden commencement response, Dst-equivalent of +200 nT and a maximum local dB/dt of ~200nT/s. While this positive Dst response is driven mainly by magnetopause currents, complicated and dynamic Birkeland current patterns also develop, which drive the strong dB/dt responses at high latitude. For southward IMF conditions, erosion of dayside magnetic flux allows magnetopause currents to approach much closer to the Earth, leading to a stronger terrestrial response (Dst-equivalent of +250 nT). Further, high latitude signals from Region 1 Birkeland currents move to lower latitudes during the southward IMF case, increasing the risk to populated areas around the globe. Results inform fundamental understanding of solar-terrestrial interaction and benchmark estimates for induction hazards of interest to the electric-power grid industry.

Keywords: Space Weather, Geomagnetically Induced Currents, Magnetosphere

