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Magnetosphere – Ionosphere Responses to a Negative Solar Wind Dynamic Pressure Pulse Event: Global Modeling and Observations

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Negative solar wind pressure pulses are among the most important drivers that can impact the Earth's magnetosphere-ionosphere (M-I) system. Such negative pressure pulses cause rapid expansion of the magnetosphere, leading to magnetic field reconfiguration and altered magnetospheric currents and plasma convection patterns that extend throughout the ionosphere. Abrupt perturbations in ground magnetometer measurements, known as negative sudden impulses (SIs), serve as a direct signature of this magnetospheric reconfiguration. We examine a negative pressure pulse event that occurred on 23 March 2024, characterized by a pressure drop of ~10 nPa shortly before the onset of G2-G4 class geomagnetic storms. The event onset is identified at 14:06 UT, when THEMIS satellite observations recorded a decrease in plasma density. Ground magnetometer data reveal a pronounced SI- signature in the H-component of Earth's magnetic field. Concurrent AMPERE observations indicate a significant weakening of field-aligned current (FAC) densities across high latitudes. At the same time, SuperDARN measurements capture substantial changes in convection patterns following the pressure drop. These coordinated observations demonstrate a rapid and widespread electrodynamic response of the coupled system to the pressure pulse. To interpret these responses, we employed the Multiscale Atmosphere-Geospace Environment (MAGE) model. The MAGE simulation reproduces key features of the observations, including dusk – dawn asymmetries in the SI- signature and the weakening of total FACs. This case study underscores the value of integrating multi-instrument observations with global geospace simulations to advance understanding of pressure pulse-driven M-I coupling.