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Magnetospheric Response to Interplanetary Field Enhancements: Coordinated Space-based and Ground-based Observations

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In general, asteroids, meteoroids and dust do not interact with the plasma structures in the solar system, but after a collision between fast moving bodies the debris cloud contains nanoscale dust particles that are charged and behave like heavy ions. Dusty magnetic clouds are then accelerated to the solar wind speed. While they pose no threat to spacecraft because of the particle size, the coherency imposed by the magnetization of the cloud allows the cloud to interact with the Earth's magnetosphere as well as the plasma in the immediate vicinity of the cloud. We call these clouds Interplanetary Field Enhancements (IFEs).

These IFEs are a unique class of interplanetary field structures that feature cusp-shaped increases and decreases in the interplanetary magnetic field and a thin current sheet. The occurrence of IFEs is attributed to the interaction between the solar wind and dust particles produced in inter-bolide collisions. Previous spacecraft observations have confirmed that IFEs move with the solar wind. When IFEs strike the magnetosphere, they may distort the magnetosphere in several possible ways, such as producing a small indentation, a large scale compression, or a glancing blow. In any event if the IFE is slowed by the magnetosphere, the compression of the Earth's field should be seen in the ground-based magnetic records that are continuously recorded. Thus it is important to understand the magnetospheric response to IFE arrival.

In this study, we investigate the IFE structure observed by spacecraft upstream of the magnetosphere and the induced magnetic field perturbations observed by networks of ground magnetometers, including the THEMIS, CARISMA, McMAC arrays in North America and the IMAGE array in Europe. We find that, in a well-observed IFE event on December 24, 2006, all ground magnetometer stations observed an impulse at approximately 1217 UT when the IFE was expected to arrive at the Earth's magnetopause. These ground stations spread across many latitudes and local times, indicating that the impulse can penetrate magnetic shells as well as propagate along field lines. The equivalent currents in the ionosphere inferred from ground magnetometer measurements show a single vortex with a center located in the morning sector where the IFE impacted the magnetopause. Our observations suggest that the IFE-induced current system in the magnetosphere differs from those caused by sudden impulses.