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Earth-Orbiting Spacecraft

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Commentary

The solar-terrestrial events of late October and early November 2003, popularly referred to as the Halloween storms, represent the best observed cases of extreme space weather activity observed to date and have generated research covering multiple aspects of solar eruptions and their space weather effects. In the following article, which serves as an abstract for this collective research, we present highlights taken from 61 of the 74 papers from the Journal of Geophysical Research, Geophysical Research Letters, and Space Weather which are linked under this special issue.

The violent solar eruptions of October–November 2003 are one of the best observed outbreaks of intense solar activity to date. These events, referred to as the Halloween storms, are extreme events in terms of both their source properties at the Sun and their heliospheric consequences. The plasma, particle, and electromagnetic consequences of these events were detected at several locations in the heliosphere thanks to the distributed network of spacecraft. Disturbances associated with two of the October–November 2003 eruptions arrived at Earth in less than a day. Historically, only 13 such "fast transit" events, including the Carrington event of 1 September 1859, have been observed. Remarkably, the two fast transit events in October 2003 occurred on consecutive days, following a delay of over 30 years from the previous such event on 4 August 1972. Several aspects of the Halloween storms, including active region size and potential energy, flare occurrence rate and peak intensity, CME speed and energy, shock occurrence rate, SEP occurrence rate and peak intensity, and the geomagnetic storm intensity, displayed extreme behavior.

As expected, this outbreak of strong solar activity resulted in a broad spectrum of space weather impacts. About 59% of the reporting spacecraft and about 18% of the onboard instrument groups were affected by these storms; electronic upsets housekeeping and science noise, proton degradation to solar arrays, changes to orbit dynamics, high levels of accumulated radiation, and proton heating were observed. Most Earth-orbiting spacecraft were put into safe mode to protect from the particle radiation. Major societal impacts also occurred: ~50,000 people in southern Sweden (Malmoe) experienced a blackout when the oil in a transformer heated up by 10 degrees; surge currents were observed in Swedish pipelines; and several occurrences were noted of degradation and outage of GPS systems. Teams climbing Mount Everest experienced interference on high-frequency radio communication paths.

The solar energetic particle event on 28 October resulted in significant ozone depletion between 40 and 90 km from the ground. A tenfold enhancement in the ionospheric total electron content over the US mainland occurred during 30–31 October. Extraordinary density enhancements in both the magnetosphere and ionosphere coinciding with intervals of southward IMF and high-speed solar wind were observed.