Great Solar Storms: 1859 to 2024

A five-event comparison of intensity, evidence, and consequences as technology changed from telegraphs to satellites and power grids.

The main lesson: a storm's damage depends on more than its global intensity. The rate and geography of magnetic change, the ground beneath a network, and the technology exposed all matter.

Comparison at a glance

Event	Dates	Geomagnetic strength	Observed impacts
Carrington Event	1-2 Sep 1859	Estimated Dst roughly -850 to -1,200 nT. Uncertain: modern Dst did not yet exist.	Low-latitude aurora; telegraph networks malfunctioned, sparked, and in some accounts caught fire.
Railroad Storm	13-15 May 1921	Reconstructed Dst -907 +/- 132 nT. Probably comparable to 1859.	Telephone, telegraph, and railroad signaling were disrupted; fires occurred at New York-area rail and telegraph facilities.
Quebec Storm	13-14 Mar 1989	Measured Dst -589 nT. The strongest measured since Dst began in 1957.	Induced currents collapsed Hydro-Quebec's grid. About 6 million people lost power for nine hours.
Halloween Storms	Oct-Nov 2003	Series of extreme events; lowest Dst -422 nT on 20-21 Nov. G5 conditions occurred.	Auroras, satellite and radio disruption, radiation-belt changes, and stress on power and other electrical systems.
May 2024 storm	10-11 May 2024	Dst about -410 nT. G5 - first G5 since 2003.	Aurora seen unusually far from the poles; GPS, radio, and satellite disruptions; widespread satellite orbit adjustments.

What Dst means
Dst stands for *Disturbance Storm Time index*. It tracks how much a geomagnetic storm weakens Earth's magnetic field near the equator, in nanoteslas (nT). More-negative values generally indicate a stronger global storm: about -100 nT is strong, -589 nT marked the 1989 Quebec storm, and about -410 nT marked May 2024. Dst began in 1957, so the 1859 and 1921 figures are reconstructions from historical magnetic records, not direct modern measurements.

How the risk evolved

1859	Telegraph era	Long wires made a new electrical technology vulnerable to induced current.
1921	Rail and wired networks	More extensive communication and railway systems increased the routes through which current could flow.
1989-2024	Networked infrastructure	Power grids, satellites, GPS, aviation, and communications added both exposure and tools for mitigation.

What produced these storms?

The events differ in detail, but share a solar-to-Earth chain: powerful solar eruptions release plasma and magnetic fields; Earth encounters the disturbance; rapid magnetic changes induce currents in technological systems.

A common sequence

1	**Active solar regions erupt** Flares and coronal mass ejections (CMEs) release radiation, plasma, and magnetic fields.
2	**CMEs reach Earth** A favorable magnetic orientation allows energy to couple efficiently into the magnetosphere.
3	**Earth's magnetic field changes rapidly** Auroras intensify, while changes in the field can drive currents through long conductors.
4	**Systems respond** Effects can include radio and navigation errors, satellite drag or charging, and power-grid disturbances.

Event notes

1859: Carrington and Hodgson independently saw the white-light solar flare associated with the famous event. The storm is a benchmark, but its global intensity cannot be measured with the same precision as a modern event.

1921: Historical magnetometer data support a reconstruction near Carrington scale. Its damage to rail-linked communications illustrates the importance of local electrical-network configuration.

1989: The Hydro-Quebec failure made geomagnetically induced current a central operational risk for power systems. It remains the clearest case of a major modern grid outage caused by space weather.

2003: The Halloween sequence included record-setting solar flares and fast CMEs. A later November storm produced the cycle's lowest Dst, while the whole period demonstrated risks to spacecraft and electrical infrastructure.

2024: Multiple CMEs arrived in close succession, driving the first G5 storm since 2003. Forecast warnings and protective operations helped reduce consequences, while the event exposed continued satellite and navigation sensitivity.

Sources

U.S. Geological Survey, *Intensity and impact of the New York Railroad superstorm of May 1921* (2019), doi:10.1029/2019SW002250. NASA Solar Dynamics Observatory, *Space Weather* (1989 Quebec blackout summary). NASA NTRS, *Modeling the Superstorm in November 2003*. NASA, *How NASA Tracked the Most Intense Solar Storm in Decades* (2024). NOAA SWPC, *Space Weather 101* and operational reports. Accessed July 2026.