INTELLIGENCE UPDATE

Why didn’t data center operators notice the 2024 solar storms?


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Through 2024 and 2025, the Sun is in “solar maximum” — a high point in the ebb and flow of the star’s magnetic activity during its 11-year solar cycle. Around these highs, astronomers observe more sunspots on its surface and more frequent and stronger solar events, including coronal mass ejections (CMEs). CMEs threaten to disrupt not only satellite services but also the Earth’s terrestrial power grid infrastructure and, in turn, data centers.

October 10 was the second time in 2024 that a CME reached Earth, producing the usual results: aurorae, radio disruption and mainstream press coverage. Earlier in 2024, a CME in May was even more powerful. This event was the most intense to reach Earth in more than 20 years, since 2003, when a solar storm permanently damaged more than a dozen high-voltage transformers in South Africa, as well as causing localized power outages in Sweden.

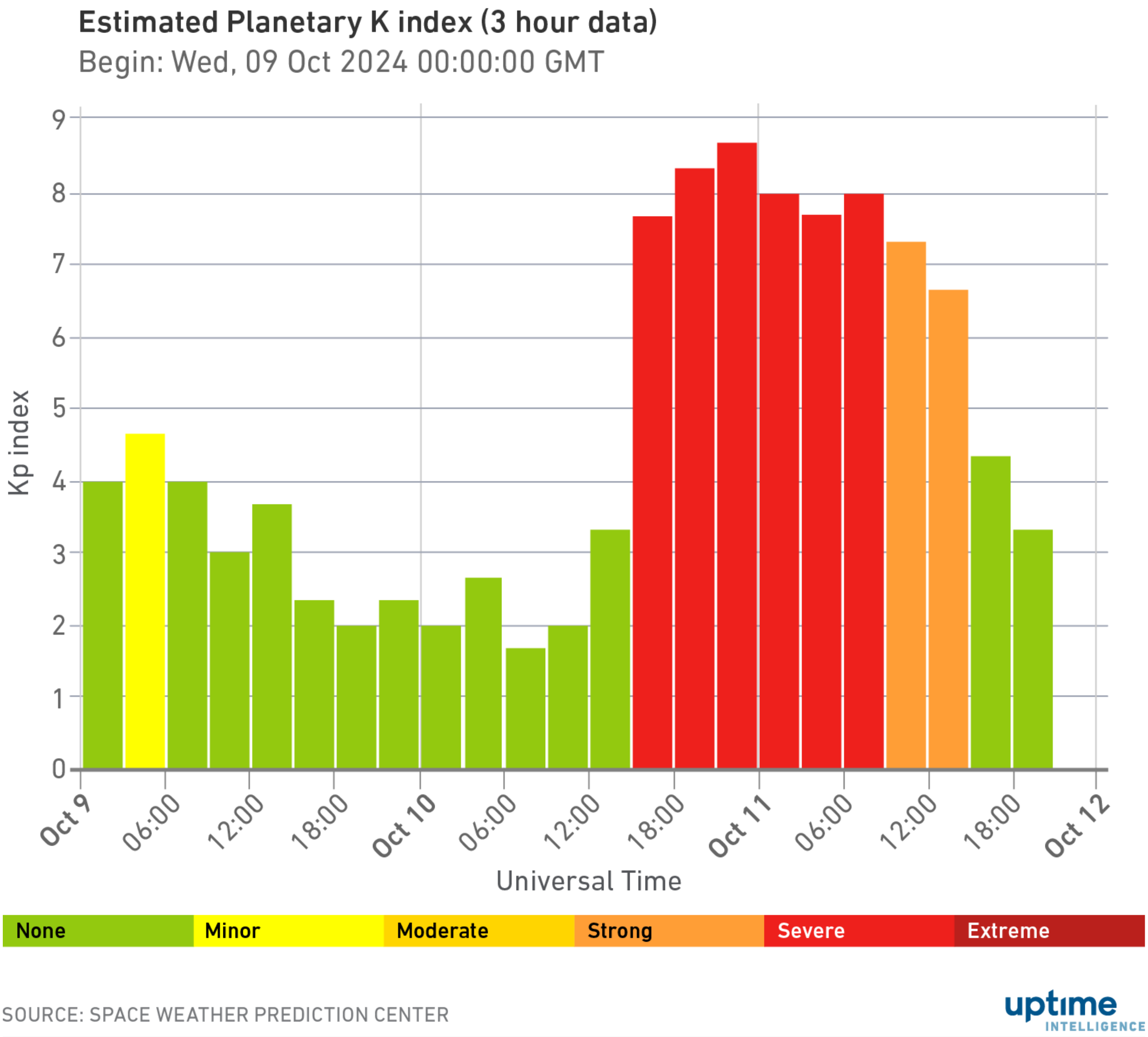
Following a major solar storm, Uptime Intelligence interviews data center operators to record their experiences (if any) and monitors press coverage for effects on data centers or power grids. We have found no evidence of disruption resulting from the 2024 events. If not for the shimmering aurorae and publicized forecasts from the Space Weather Prediction Center (SWPC), data center operators may not have noticed the solar storms at all. Digital infrastructure was spared the violence of the Sun thanks to a combination of grid provider preparations, data center operators’ own power autonomy and a dose of good luck.

How extreme is extreme?

The SWPC, a US government sub-agency, observes solar storms and warns infrastructure operators about the geomagnetic disturbances (GMDs) that might follow. Fortunately, most solar storms miss Earth (it is a small target at an average distance of 93 million miles, or 150 million km). Nevertheless, the CMEs in May and October both reached Earth.

The SWPC classed the GMD in May 2024 at G5 or Extreme, which is the highest category on its Kp-index. The scale, which measures magnetic fluctuations using magnetometers at several observatories, is open-ended because the real-world magnetic strength of a storm can exceed the category’s threshold. The GMD in October 2024 was much weaker: it peaked in the second-highest category, G4 or Severe, as measured by the strength of magnetic disturbance (see **Figure 1**).

Figure 1. The solar storm in October 2024 peaked at Severe



In comparison, the Carrington Event of 1859 — the most intense geomagnetic event in recorded history — set a high bar for solar storms. When it reached Earth, the resulting GMD was an estimated two to four times more intense (in terms of change to the Earth's magnetic field) than anything observed in 2024. In 1859, the world did not have much large-scale electrical infrastructure, which was mostly in the form of telegraph cables, for the GMD to affect. Still, telegraph operators were caught off guard when induced currents produced sparks and fires in their offices. A comparable event today would likely prove highly damaging, potentially resulting in satellite service downtime and more widespread power grid outages.

The stewards of today's power grids, telecommunications and data centers have more information and safeguards at their disposal in the event their infrastructure faces another "Carrington-class" GMD (an unofficial designation). The SWPC category names (Minor, Moderate, Strong, Severe and Extreme) tend to accurately describe a GMD's effects on radio and satellite communications. The same GMD will cause less disruption to grids and their customers — if any.

For data centers, it's about the grid

When a major solar event, such as a CME, hits Earth, the resulting GMD induces currents in miles-long electrical conductors. In 1859, only telegraph lines fit the description — today, GMDs affect the power grid's high-voltage transmission lines (See *Data centers weather solar storms*).

Knocking the power grid offline is the primary risk associated with GMDs. The most extreme events can damage and destroy high-voltage transformers (through overheating), which are not only costly but, more importantly, slow to replace. In a worst-case scenario, manufacturers — of which there are only a handful — would struggle to meet demand for replacements, causing normal lead times of 12 to 18 months to extend almost indefinitely. Worse still, some of the transformer manufacturing plants and their supply chains may be exposed to the same GMD, possibly losing grid power too.

Short of extreme cases, solar events are routine for electricity grid operators; they can compensate for voltage fluctuations or power down their equipment in a controlled fashion to protect it and ensure a smooth restart. Some grid operators have deployed GMD protection equipment (such as passive shunt filters to act as harmonic sinks, or active filters in some cases to cancel targeted harmonics on the grid) on their transmission infrastructure, but this is not yet standard practice.

Many data center operators are prepared for minor interruptions or degradations in grid power supply by virtue of their on-site double-conversion UPS systems and backup generators. When a GMD follows a solar storm and the utility successfully compensates for the induced currents, this can produce increased harmonic distortion in the AC power wave by the time it reaches data center power systems. UPS double conversion, the most common type in mission-critical applications, can filter only a defined maximum amount of this harmonic distortion.

If power quality degrades severely or the grid operator powers down as a precaution, mission-critical facilities will transfer to the backup generators. For a widespread grid disturbance, the primary concern is diesel fuel. Most data centers have fuel storage for at least 12 hours at full load, with more risk-averse operators opting for several days' worth of storage.

Most sites should be able to operate for much longer than their design capability because they run at only fractional capacity. However, if it takes longer for the grid to return to normal, high demand for diesel in a large area may outstrip supply enough to deplete storage tanks in fuel stations. Fuel distribution networks have limited ability to react to sudden surges in demand, and the number of available tankers may be unable to keep up with delivery requests either.

By chance, the geomagnetic disturbances of 2024 reportedly did not call for such a response from power utilities or data centers. The precise effects of a given solar storm on infrastructure are difficult to forecast. No one discipline of engineering or natural sciences can claim a thorough understanding of the three-way interaction between the Earth's magnetic field, soil and infrastructure. Computer simulation of the complexity of these systems' interactions is still not feasible.

The SWPC forecasts can be crucial for operators of power grids that may be at risk, affording them hours or days to prepare for potential disruptions. Grid operators or their customers may tend to act cautiously until they observe the real effects on their equipment.

Risk assessment for solar storms

Major solar storms will continue to affect infrastructure on Earth. Data center operators can take steps to protect their facilities from potential power problems that may come with future GMDs.

- Operators can review the testing and maintenance schedules for their backup generators, UPS and switchgear to ensure that generators start, synchronize and accept IT load without problems. Extended load testing of generators for several hours can help to root out lurking and potentially catastrophic failures in some engines.
- Operators need to assess their on-site fuel storage to ensure there is sufficient fuel capacity for the expected load. This would provide sufficient power autonomy for the vast majority of grid outages, whether these are due to solar storms or other events.
- Shedding non-critical IT and ancillary loads will extend generator runtime on a single tank. In particular, enterprises and IT services providers can build a workload response plan that chooses to either gradually throttle or gracefully shut down non-critical systems based on their respective availability and quality of service requirements. Even though this practice is not yet common, some Uptime Institute member organizations have similar plans in place for grid failure, and runtime gains can be substantial.
- Crucially, operators can assess the risks to their refueling plans. The risk profile of solar storms is similar to that of other natural disasters affecting a large area because they can take the power grid offline for several days or possibly even weeks. Demand overwhelming supply, outages at fuel distribution centers, or unavailability of tankers can all affect fuel resupply to sites.
- Operators can follow the SWPC as well as communicate with their grid operators and fuel suppliers in preparation for any event.

The Uptime Intelligence View

Many data centers have sufficient backup power to handle the grid degradations or interruptions that may occur from Severe or Extreme solar storms. In some regions, their grid suppliers are also shoring up their defenses, reducing the need for data centers to run generators. Interactions between space weather and the Earth’s infrastructure remain complex. Grids and data centers did not face a worst-case scenario in 2024, but operators may still see value in monitoring space weather forecasts, testing backup power systems regularly and fostering close collaboration with power and fuel suppliers.

Other related reports published by Uptime Institute include:
Data centers weather solar storms

ABOUT THE AUTHOR

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About Uptime Institute

Uptime Institute is the Global Digital Infrastructure Authority. Its Tier Standard is the IT industry's most trusted and adopted global standard for the proper design, construction, and operation of data centers – the backbone of the digital economy. For over 25 years, the company has served as the standard for data center reliability, sustainability, and efficiency, providing customers assurance that their digital infrastructure can perform at a level that is consistent with their business needs across a wide array of operating conditions.

With its data center Tier Standard & Certifications, Management & Operations reviews, broad range of related risk and performance assessments, and accredited educational curriculum completed by over 10,000 data center professionals, Uptime Institute has helped thousands of companies, in over 100 countries to optimize critical IT assets while managing costs, resources, and efficiency.