Fact-Checked Science

EVIDENCE REVIEW · SOLAR STORMS

The Sun has two worst cases

Solar eruptions hit Earth in two main ways: a magnetic storm and a shower of particle radiation. Carrington's magnetic storm is among the largest on record. The isotopes in trees and ice record only the particles, and Carrington's particle shower was far smaller than the extreme events they record: at most about three times the biggest of the Space Age, or absent [1 Abstract][1 p. 6].

By Fact-Checked Science · Published October 13, 2026

OUR ANALYSIS marks our own reasoning and calculations, and the verdicts are our assessment. Everything else comes from the numbered sources.

Small only on the radiation yardstick

OUR ASSESSMENT

Top 3

Carrington's magnetic storm ranks among the three largest on record [2 Abstract].

≤ 3×

Its particle shower above 30 MeV was at most about three times August 1972's, and possibly zero [1 Abstract][1 p. 7].

19–27×

Our calculation: the 5259 BCE shower above 200 MeV, against the median ceiling for any Carrington shower (15–38× across the middle half of its range) [3 p. 8][1 Table 1].

THE COMMENT'S CLAIMS

TRUE

"The Carrington event left no isotopes"

A comment quoted, without attribution, on the original infographic

Neither beryllium-10 nor new chlorine-36 measurements in ice show a peak from 1859, and tree rings show no clear, widespread rise; a carbon-14 offset reported in polar trees, statistically significant but unexplained, hasn't been seen in trees from other regions [1 Abstract][1 p. 2][4 Abstract][1 p. 6]. See section 3.

MISLEADING

"It implies the Carrington event was 'small' in comparison to others."

The same comment

Isotopes record only showers of very energetic particles. Carrington's shower was far smaller than the extreme events they record, or absent, but its magnetic storm ranks among the three largest on record. See section 2.

1 · TWO KINDS OF HIT

Solar eruptions hit Earth in two main ways

A big eruption can shake Earth's magnetic field, a geomagnetic storm, and it can shower Earth with fast particles, a solar energetic particle event. The fiercest storms come from eruptions aimed straight at Earth, near the middle of the Sun's disc. The particles reach Earth most easily from the Sun's western side, which the Sun's magnetic field lines connect to Earth [1 p. 8].

Magnetic storm

Hits power grids and other long conductors, pipelines, satellite orbits and navigation signals [5 Abstract][6][7]. Measured by the Dst index, from low-latitude observatories, in nanotesla (nT): the more negative, the stronger the storm [8].

Particle radiation

Hits satellites, astronauts beyond Earth orbit, and passengers and crew on high-latitude flights [9]; Earth's magnetic field and thick atmosphere shield people on the ground [10 p. 6][3 p. 2]. The most energetic particles reach the ground as ground-level enhancements (GLEs), measured since the 1940s, and make the isotopes found in tree rings and ice [3 p. 2][10 p. 3].

OUR ANALYSIS

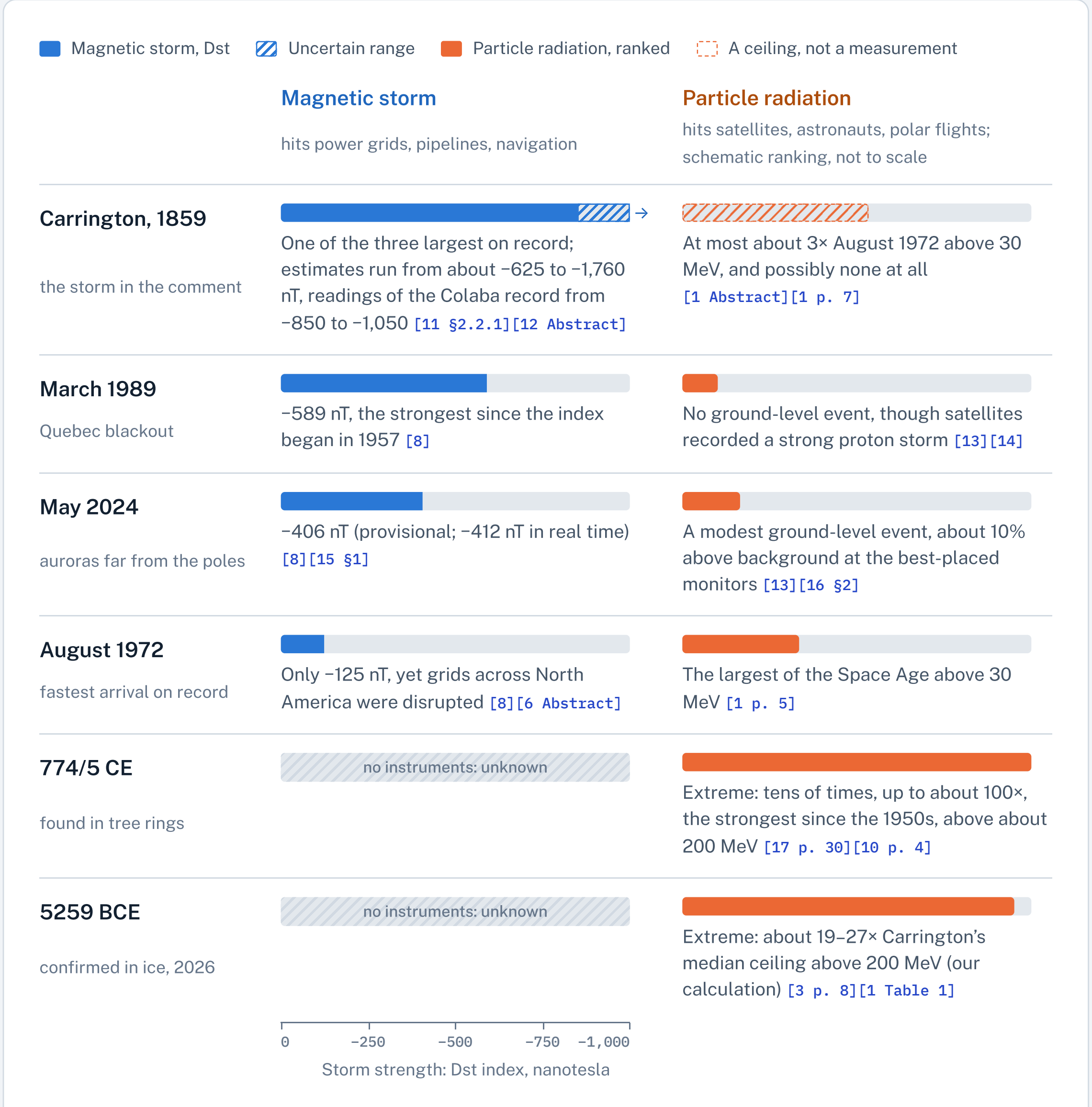
Judging Carrington by isotopes is like judging a hurricane's wind with a rain gauge.

A storm can break wind records with ordinary rainfall. The gauge isn't wrong. It measures something else.

2 · EVERY EVENT GETS TWO SCORES

No event in the record tops both columns

Six events, each scored twice: the magnetic storm on the Dst index, and the particle shower as a rough ranking, because the particle sizes come from different energy ranges and can't share one scale.



	Magnetic storm hits power grids, pipelines, navigation	Particle radiation hits satellites, astronauts, polar flights; schematic ranking, not to scale
Carrington, 1859 the storm in the comment	One of the three largest on record; estimates run from about −625 to −1,760 nT, readings of the Colaba record from −850 to −1,050 [11 §2.2.1][12 Abstract]	At most about 3× August 1972 above 30 MeV, and possibly none at all [1 Abstract][1 p. 7]
March 1989 Quebec blackout	−589 nT, the strongest since the index began in 1957 [8]	No ground-level event, though satellites recorded a strong proton storm [13][14]
May 2024 auroras far from the poles	−406 nT (provisional; −412 nT in real time) [8][15 §1]	A modest ground-level event, about 10% above background at the best-placed monitors [13][16 §2]
August 1972 fastest arrival on record	Only −125 nT, yet grids across North America were disrupted [8][6 Abstract]	The largest of the Space Age above 30 MeV [1 p. 5]
774/5 CE found in tree rings	no instruments: unknown	Extreme: tens of times, up to about 100×, the strongest since the 1950s, above about 200 MeV [17 p. 30][10 p. 4]
5259 BCE confirmed in ice, 2026	no instruments: unknown	Extreme: about 19–27× Carrington's median ceiling above 200 MeV (our calculation) [3 p. 8][1 Table 1]

Storm bars follow Kyoto's Dst index: final values for 1972 and 1989, provisional for 2024 [8]. Carrington's bar is solid to −850 nT, the low end of the estimates read from the Colaba record, and hatched beyond, where it runs off the scale [11 §2.2.1][18 Abstract][12 Abstract]. One global index can miss local effects: August 1972 scored low but still disrupted grids across North America [6 Abstract]. Bar lengths in the particle column only rank the events, by their most energetic particles: above 10 MeV, March 1989 (3,500 particle flux units) outstripped May 2024 (238) [14][16 §6], and the 5259 BCE event was slightly weaker than 774/5 CE [19].

Is Carrington the record?

It is often called the greatest storm on record, but its size is uncertain: estimates of its Dst run from about −625 to −1,760 nT, and those read from the Colaba record from −850 to −1,050 nT [11 §2.2.1][18 Abstract][12 Abstract]. Storms in February 1872 and May 1921 were of comparable strength, which puts all three among the largest yet observed [2 Abstract][20 Abstract].

March 1989 in space

The storm that blacked out Quebec's grid brought no ground-level particle event [5 Abstract][13]. Satellites still recorded a strong proton storm, peaking on March 13 at 3,500 particle flux units above 10 MeV [14].

3 · TWO WINDOWS ON THE PAST

Each record of the past is blind to half

Instruments and eyewitnesses

Magnetometers, telegraph logs and aurora sightings; particle detectors on the ground since the 1940s [3 p. 2].

Sees: magnetic storms, and ground-level particle events in the modern era.

Reaches back: about 180 years for instruments. Reports of possible auroras go back about 2,700 years, to Assyrian records from about 680–650 BCE [21 Abstract].

Tree rings and ice cores

Carbon-14 in wood; beryllium-10 and chlorine-36 in ice.

Sees: only big showers of very energetic particles. Carbon-14 and beryllium-10 mainly record particles above about 235 MeV, chlorine-36 those above about 60 MeV [10 p. 3]. Even the strongest ground-level event on record, in February 1956, can't be reliably seen in beryllium-10 records [3 p. 2]. Completely blind to magnetic storms.

Reaches back: about 15,000 years [10 p. 3].

So the isotopes didn't miss Carrington's storm. They were never able to see it.

What the ice says about 1859

New chlorine-36 measurements show no significant rise around 1859 in three ice-core records. That rules out an extreme particle event: at most, Carrington's shower above 30 MeV was about three times August 1972's, or no shower reached Earth at all [1 Abstract][1 p. 7]. Uusitalo and colleagues report a carbon-14 offset in polar tree rings after 1859, compared with trees at mid-latitudes, with high statistical significance; their own model can't reproduce it. It hasn't been seen in trees from other regions, and Mekhaldi and colleagues don't count it as evidence of a large particle event [4 Abstract][1 p. 6].

4 · TWO BENCHMARKS

Two worst cases, two sets of risks

MAGNETIC-STORM WORST CASE

Carrington, 1859

At risk: power grids and other long conductors, pipelines, satellite orbits and navigation signals [5 Abstract][6][7].

People: no direct harm; the danger is to infrastructure and the services it runs.

How often: rare, and published estimates vary widely; a study of the 1859 storm judged that the probabilities of such extreme storms "cannot be assigned with any reasonable accuracy" [12 Abstract].

RADIATION WORST CASE

774/5 CE and kin

At risk: satellites, astronauts beyond Earth orbit, and passengers and crew on high-latitude flights [10 p. 6][3 p. 2][9].

People on the ground: well shielded by the air and Earth's magnetic field [10 p. 6].

How often: six or seven found in about 15,000 years of records, five of them also confirmed in ice [10 p. 3][3 p. 8]. That averages roughly one every one to two thousand years, but they come irregularly: 774/5 and 993/4 CE were about 220 years apart, while two other gaps exceed 4,500 years [10 p. 5][3 p. 2]. Much of the record hasn't yet been checked year by year [17 p. 34]. The strongest known, in 12,350 BCE, was about 18% stronger than 774/5 CE [10 p. 3].

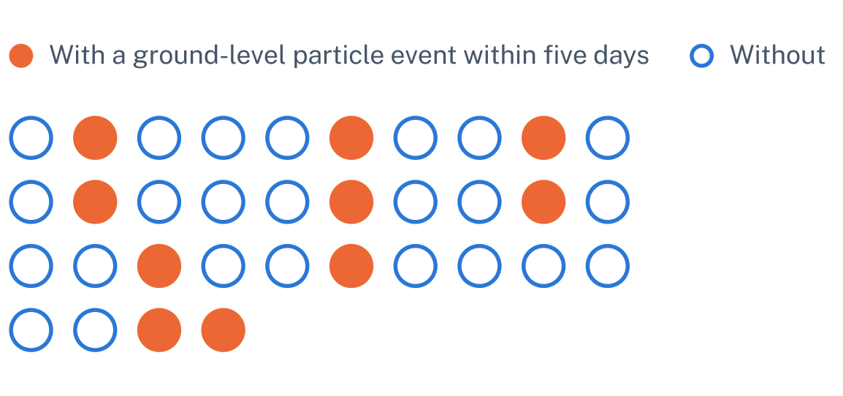
5 · DO THEY COME TOGETHER?

Sometimes, weakly

Mekhaldi and colleagues took the 50 largest geomagnetic storms since 1957, counted by day, merged those on consecutive days into 31 distinct storms, and found 10 within five days of a ground-level particle event, though not necessarily from the same active region on the Sun [1 p. 8].

The largest magnetic storms since 1957

OUR ANALYSIS



Our recount, largest storm first: the 50 days with the lowest hourly Dst in 1957–2024, consecutive days merged into one storm [8], and ground-level enhancements from the international database [13].

OUR ANALYSIS

Following the paper's stated rule with Kyoto's data, we get 34 storms, with the same 10 matches. The paper's 31 appears only with a looser merge, such as grouping by calendar month. Other reasonable definitions give 20–35%.

In 3 of the 10, the only matching particle event came after the storm. May 2024 shows the two can come together on a modest scale.

That fits the Sun's geometry. Carrington's eruption came from near the middle of the disc, so its particles may have missed Earth [1 p. 8].

6 · BOTTOM LINE

Carrington looks small only on the radiation yardstick

OUR ANALYSIS

Its magnetic storm is still often used as the benchmark worst case [1 Abstract], and magnetic storms are what threaten power grids [5 Abstract]. The radiation worst case is a different, rarer kind of event, and much bigger than Carrington's particle shower.

Limits

Storms before 1957 are estimates

The Dst index starts in 1957. The sizes of the 1859, 1872 and 1921 storms are reconstructed from a few observatories, and their estimates differ [11 Abstract][2 Abstract].

A recount, not the paper's list

Mekhaldi and colleagues listed only the 10 storms that came with a ground-level event (their Table 2), not all 31, so our recount follows their stated rule [1 p. 8].

Different energies

The extreme events are compared above about 200 MeV. Carrington's firmest limit is above 30 MeV; the 200 MeV ceiling assumes its spectrum looked like a scaled-up modern event [1 p. 6].

Related checks

PARTLY TRUE A "small" flare? The Disaster Cycle, Fact-Checked

FALSE Superflares and Heinrich events The Disaster Cycle, Fact-Checked

Sources

Bracketed numbers refer to this list; § gives a section, p. a page and Table a table of the source, and Abstract names the part of a work we used. For the 2026 Royal Society papers, p. gives the page of the published PDF, except where a source says we read another version. Links checked October 13, 2026.

1 Mekhaldi, F., Paleari, C. I., Smith, A. M., Aldahan, A., Beer, J., Christl, M., Vockenhuber, C., Hayakawa, H., Curran, M., Erhardt, T., Plummer, C., Simon, K., Wilcken, K., Zheng, M., and Muscheler, R. (2026). ^{36}Cl concentrations from polar ice cores set new constraints on the Carrington event. *Philosophical Transactions of the Royal Society A* 384(2329), 20250257. Published September 10, 2026. CC BY 4.0.

2 Hayakawa, H., Cliver, E. W., Clette, F., Ebihara, Y., Toriumi, S., Ermolli, I., et al. (2023). The Extreme Space Weather Event of 1872 February: Sunspots, Magnetic Disturbance, and Auroral Displays. *The Astrophysical Journal* 959(1), 23.

3 Paleari, C. I., Mekhaldi, F., Christl, M., Gautschi, P., Vockenhuber, C., Anderberg, E., Beer, J., Raisbeck, G., Yiou, F., Brehm, N., Wacker, L., Wilhelms, F., and Muscheler, R. (2026). Ice-core cosmogenic radionuclides support the occurrence of an extreme solar particle storm 5259 BCE (7208 years BP). *Philosophical Transactions of the Royal Society A* 384(2329), 20250347. Published September 10, 2026. CC BY 4.0.

4 Uusitalo, J., Golubenko, K., Arppe, L., Brehm, N., Hackman, T., Hayakawa, H., et al. (2024). Transient Offset in ^{14}C After the Carrington Event Recorded by Polar Tree Rings. *Geophysical Research Letters* 51(5), e2023GL106632.

5 Boteler, D. H. (2019). A 21st Century View of the March 1989 Magnetic Storm. *Space Weather* 17(10), 1427–1441.

6 Knipp, D. J., Fraser, B. J., Shea, M. A., and Smart, D. F. (2018). On the Little-Known Consequences of the 4 August 1972 Ultra-Fast Coronal Mass Ejecta: Facts, Commentary, and Call to Action. *Space Weather* 16(11), 1635–1643.

7 NOAA Space Weather Prediction Center. Geomagnetic Storms. Accessed October 13, 2026.

8 Nose, M., Iyemori, T., Sugiura, M., Kamei, T., Matsuoka, A., Imajo, S., and Kotani, T. (2015). Geomagnetic Dst index [data set]. World Data Center for Geomagnetism, Kyoto. Final hourly values to 2020 and provisional values from 2021, read on October 13, 2026.

9 NOAA Space Weather Prediction Center. Solar Radiation Storm. Accessed October 13, 2026.

10 Vasilyev, V., Usoskin, I., and Krivova, N. (2026). Linking solar magnetism, extreme solar particle events and stellar superflares. *Philosophical Transactions of the Royal Society A* 384(2329), 20250261. CC BY 4.0. We read the accepted version, arXiv:2602.10243; p. gives its page.

11 Cliver, E. W., and Dietrich, W. F. (2013). The 1859 space weather event revisited: limits of extreme activity. *Journal of Space Weather and Space Climate* 3, A31.

12 Tsurutani, B. T., Gonzalez, W. D., Lakhina, G. S., and Alex, S. (2003). The extreme magnetic storm of 1–2 September 1859. *Journal of Geophysical Research: Space Physics* 108(A7), 1268.

13 International GLE Database. List of ground-level enhancements, GLE 5 to GLE 77. Sodankylä Geophysical Observatory and University of Oulu. Accessed October 13, 2026.

14 NOAA Space Environment Services Center. Solar Proton Events Affecting the Earth Environment, 1976–present. Preliminary listing, hosted by NASA's Solar Data Analysis Center; its entries run to 2017. Accessed October 13, 2026.

15 Hayakawa, H., Ebihara, Y., Mishev, A., Koldobskiy, S., Kusano, K., Bechet, S., et al. (2025). The Solar and Geomagnetic Storms in 2024 May: A Flash Data Report. *The Astrophysical Journal* 979(1), 49. We read the accepted version, arXiv:2407.07665; § gives its section.

16 Papaioannou, A., Mishev, A., Usoskin, I., Heber, B., Vainio, R., Larsen, N., et al. (2025). The High-Energy Protons of the Ground Level Enhancement (GLE74) Event on 11 May 2024. *Solar Physics* 300, 73. CC BY 4.0. We read the arXiv version, arXiv:2505.09180.

17 Usoskin, I., Miyake, F., Baroni, M., Brehm, N., Dalla, S., Hayakawa, H., et al. (2023). Extreme Solar Events: Setting up a Paradigm. *Space Science Reviews* 219, 73. CC BY 4.0.

18 Hayakawa, H., Nevanlinna, H., Blake, S. P., Ebihara, Y., Bhaskar, A. T., and Miyoshi, Y. (2022). Temporal Variations of the Three Geomagnetic Field Components at Colaba Observatory around the Carrington Storm in 1859. *The Astrophysical Journal* 928(1), 32.

19 Brehm, N., Christl, M., Knowles, T. D. J., Casanova, E., Evershed, R. P., Adolphi, F., et al. (2022). Tree-rings reveal two strong solar proton events in 7176 and 5259 BCE. *Nature Communications* 13, 1196. CC BY 4.0.

20 Love, J. J., Hayakawa, H., and Cliver, E. W. (2019). Intensity and Impact of the New York Railroad Superstorm of May 1921. *Space Weather* 17(8), 1281–1292.

21 Hayakawa, H., Mitsuma, Y., Ebihara, Y., and Miyake, F. (2019). The Earliest Candidates of Auroral Observations in Assyrian Astrological Reports: Insights on Solar Activity around 660 BCE. *The Astrophysical Journal Letters* 884(1), L18.

METHOD

How this was checked

On October 13, 2026, we checked every statement, number and source on the original infographic, 62 items in all, against three 2026 papers on extreme solar events (two in their published versions, one in its accepted version), Kyoto's Dst index and the international list of ground-level enhancements. We looked up each storm's Dst ourselves and recounted the storms that came with particle events. The check corrected several statements; the change log lists them.

After the page was built, a second reviewer who hadn't seen the drafting redid the storm count from Kyoto's hourly Dst and the list of ground-level events, which matched ours exactly, and checked the sources. The changes that followed: −850 nT is the low end of the estimates read from the Colaba record, not of all published estimates, which start at about −625; Mekhaldi and colleagues did list the 10 storms that came with a ground-level event; the extreme particle events come about once every one to two thousand years on average, with gaps from about 220 to over 5,000 years; the carbon-14 offset in polar trees after 1859 is now described as its authors report it; Carrington's particle shower is called far smaller than the extreme events, not small; and a dozen smaller fixes.

The verdicts and the items tagged "Our analysis" are our own assessment, built on the cited sources: the analogy, the 19–27× comparison, which divides fluences from two papers, and the recount of storms and particle events. The three 2026 papers are open access under CC BY 4.0; the charts are our own, drawn from the numbered sources.

This page was researched and written with Claude, an AI assistant made by Anthropic, and then re-checked against its sources in a separate verification pass.

The verdicts on this page

MISLEADING	Contains something true but leaves a false impression, usually by leaving out key context.
TRUE	The evidence supports the claim.

All ten verdicts, and how we check

CORRECTIONS

Corrections and changes

If we get something wrong, we fix it and record the change below with the date. If a correction changes a verdict, the log says what the old verdict was.

Change log

Oct 13, 2026	Published on factchecked.science after a full check against the sources. Changes from the infographic: added our verdicts on the comment's two claims, and marked the comment as unattributed. Carrington no longer "holds the record" for magnetic storms: its size is uncertain, with estimates from about −625 to −1,760 nT, and storms in 1872 and 1921 were comparable, so it is among the three largest on record; its bar is now solid to −850 nT, the low end of the estimates read from the Colaba record, and hatched beyond. May 2024's Dst is −406 nT in Kyoto's provisional index; −412 nT was the real-time value. The 774/5 CE event was tens of times, up to about 100 times, the strongest event since the 1950s above about 200 MeV, rather than "roughly 100×"; the 5259 BCE comparison is about 19–27 times, our own calculation, not 20–27; Carrington's particle ceiling applies above 30 MeV. March 1989 had no ground-level event but a strong proton storm in space, so its particle bar is longer. The extreme particle events are "six or seven found in about 15,000 years of records, five of them also confirmed in ice," on average about one every one to two thousand years but with very irregular gaps, rather than "seven confirmed … roughly once every 1,500 years." The storm–particle statistic now explains that Mekhaldi et al. count 10 of 31 storms and that our recount with their rule gives 10 of 34, and the dot chart shows the recount. Instruments reach back about 180 years, but aurora reports about 2,700. "Small or absent" became "far smaller than the extreme events, or absent": the ceiling is up to three times the biggest particle event of the Space Age. The carbon-14 offset reported in polar trees after 1859 is now described as its authors report it. The bottom line's "the benchmark for power grids" became "often used as the benchmark worst case", with the grid risk cited separately, and the pipelines and aircraft crews at risk are cited to NOAA. Added the sources' full references, the chlorine-36 result for 1859, the comparable storms of 1872 and 1921, and the limits of this review.

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