☑ Fact-Checked Science

PAPER CHECK · SPACE WEATHER

At five stations, May 2024's GPS scintillation was near the top; the paper compares no storm

Seven researchers map where GPS signals scintillated over Canada in the storm of May 10–11, 2024: first at cusp latitudes, then spreading equatorward, largely along the electrojets [1 p. 1]. We read the paper in full, and CHAIN's public files reproduce the order of its timeline [28]. The paper compares no storm. In our own comparison, at five stations at 56–63°N, on a 30-s phase sigma read once a minute that fast plasma flow partly inflates, May 2024 comes third of 13 storms on phase scintillation and fourth on amplitude, with season uncontrolled. In a polar-cap panel we added after seeing the data, it stays below the autumn and winter storms, when scintillation there peaks; on May 11 the polar cap was no higher than quiet days.

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OUR ANALYSIS marks our own reasoning and calculations: the comparison of 13 storms in CHAIN's public files, the order of the timeline we re-read from them, the check against NASA's OMNI file, the ranks by index, and our reading of what the paper does and does not test; the verdicts are our assessment. "Post hoc" marks checks we added after seeing the data. Everything else comes from the numbered sources. For the paper [1], read in full, p. gives a page of the PDF, § a section and Fig. a figure; no figure is redrawn or digitised, and anything read off one by eye says so. Elsewhere p. gives a page and Abstract the part of a source we rely on.

Near the top for phase scintillation at these stations, on this index

OUR ASSESSMENT

3rd of 13

storms with Dst at or below −150 nT since 2015, on phase scintillation, at five stations at 56–63°N, on a 30-s phase sigma read once a minute from public files. That index partly tracks fast plasma flow rather than diffraction, season is uncontrolled, and the top three can't be firmly separated: May 2024 came first in 19% of draws resampling single hours and in the top three in 79%, shares that are optimistic; in 6-hour blocks, post hoc, 9% and 47%. Our analysis [28]

4th of 13

on amplitude scintillation, same stations, same files: S4 above 0.3 in 0.140% of satellite-minutes. Fourth by 0.005 points, on one station's figure, and far behind the top two (1.04%, 0.55%). The paper's 1-s index, which catches more of it, isn't in the public files. Our analysis [28][1 §3.6]

1.8–3.5%

of satellite-minutes with phase scintillation at Eureka, Arctic Bay and Sachs Harbour in the recovery phase on May 11, down from 28–44% in the main phase and no higher than quiet April days. Themens and colleagues, using this network among others, report this suppression [5 p. 9]; the public files confirm it; this paper's summary of them doesn't mention it. Our analysis [28]

THE PAPER'S CLAIMS

TRUE

"the most intense in recent decades"

The paper's abstract [1 p. 1]

Deepest Dst since November 2003, 20.5 years [30]; deepest SYM-H since March 1989, 35.2 years [31]; highest daily Ap since November 1960; first Kp 9 since October 2003 [32] (our arithmetic). It's an opening phrase, with no index or citation, not a finding of the paper; §1 says "one of the most intense" [1 p. 2]. Balan and colleagues agree on size [3 Abstract]. See section 5.

UNCONFIRMED

Geo-effectiveness "was enhanced by a complex interaction of multiple merging" ICMEs with a dense sheath

The paper's summary [1 §5 p. 21]

The merging is documented [24 Abstract][15 p. 1], and the dense plasma shows in NASA's record [29]. The enhancement is stated, not tested: the paper has no counterfactual and no other storm. A source it cites finds that the counterpart on Earth's side carried less magnetic energy than the one at STEREO-A [15 p. 1], and Balan and colleagues argue the front made the ICME less geoeffective [3 Abstract]. See section 3.

TRUE

"The most immediate response was observed at very high latitudes in the cusp region", spreading equatorward

The paper's abstract [1 p. 1]

CHAIN's public files show much the same order: phase scintillation within 2–8 minutes of the shock at five stations at 74–82° magnetic latitude, though three of them already met the test before it; 16 minutes at Eureka, the northernmost, later than Rankin Inlet's 13; 13–47 minutes at 66–71°; 64 at 63° and 130 at 60° (our analysis) [28]. A study using this network among others describes the same spread [5 p. 1]. See section 3.

TRUE

Scintillation "can degrade GPS positional accuracy"

The paper's introduction [1 §1 p. 2]

A general statement, and well supported [21 Abstract]. The paper itself measures no position error or tracking. Others do, for May 2024. Of positioning services in the Arctic, one study says "For many users, they would be unusable for up to 37 consecutive hours" [6 p. 1]; at one test receiver near Tromsø, network RTK was in practice unavailable for all 37 [6 p. 22]. Precise-positioning outages reached 49° magnetic latitude [7 Abstract], and errors reached 70 m in the central US, attributed to strong scintillation and cycle slips [8 Abstract]. Not all of that is scintillation. See section 7.

UNCONFIRMED

Irregularities "most likely produced by the gradient-drift instability mechanism"

The paper's summary [1 §5 p. 22]

Its discussion says "consistent with" [1 p. 17] and "most likely the GDI", the same instability [1 p. 20]; the summary repeats that [1 p. 22]. The evidence is where scintillation sits relative to auroral arcs and current reversals, at one station; the paper measures no density gradient or electric-field geometry. The idea is reasonable. Another May 2024 study, using this network among others, invokes two instabilities and says it lacks direct proof [6 p. 21]. See section 8.

1 · WHAT WE READ

The whole paper, peer reviewed and open access

We read the paper in full [1]. It is open access under CC BY-NC-ND 4.0, so we quote short phrases and redraw and digitise no figure; every chart here is our own analysis of public data. S0 News linked the paper on November 4, 2026 [2].

What the record shows

A full paper in *Earth, Planets and Space*, peer reviewed: received October 30, 2025, accepted October 4, 2026, published October 29, 2026; 25 pages. Seven authors at the University of New Brunswick, UCLA, Natural Resources Canada, the University of Saskatchewan and the University of Calgary. It states NASA funding for one author, and CHAIN's support from the Canada Foundation for Innovation, the New Brunswick Innovation Foundation and the Canadian Space Agency, and declares no competing interests [1 p. 22].

2 · WHAT THE PAPER DID

One storm, one sector, many instruments, and no other storm to compare

The paper maps where and when GPS signals scintillated over Canada from 16:00 UT on May 10 to 16:00 UT on May 11, 2024, and sets that against radar, magnetometer, radio-absorption and all-sky records [1 §§2–3]. It's a careful case study. It doesn't measure position errors. It cites one study that compared the storm's substorms with other superstorms [1 p. 2][14 Abstract], but makes no comparison of its own.

THE RECEIVERS

50 Hz

CHAIN's monitors record L1 power and phase at that rate, 100 Hz at Churchill. Ordinary 1-Hz receivers add a proxy index [1 §§2.1–2.2][1 p. 20]

THE THRESHOLD

0.1 rad

σφ above this, or the proxy above 2 mm/s, counts as scintillation on its occurrence maps. Fig. 8's label adds elevation above 30° [1 Fig. 8]. It's a low bar, in the lead author's words "weak scintillation" [17 p. 533], so a share above it measures how widespread the disturbance was, not how strong

THE STATIONS

12

CHAIN stations appear in its figures, by our count, from Eureka at 80°N to Ottawa at 45.4°N [1 Figs. 3–4][1 Fig. 15]

The paper's terms, in plain words

TERM	WHAT IT MEANS HERE
Scintillation	Rapid fluctuations in a radio signal's amplitude and phase after it crosses irregularities in the ionosphere [1 p. 2]
S4	The amplitude index: the standard deviation of received power, divided by its mean [1 §3.2]
σφ	The phase index: the standard deviation of the L1 phase in radians, after filtering out changes slower than 0.1 Hz [1 §3.2]. Fast plasma flow raises it even without small-scale diffraction [1 p. 20]
30-s and 1-s	The time over which an index is computed. A short window catches brief fades; with fewer samples it also swings higher [1 p. 20]
Cusp	The dayside region of the high-latitude ionosphere where scintillation is common; about 72.5–80° geomagnetic latitude near noon in the lead author's earlier work [17 p. 535]
Electrojets	Strong east–west currents in the auroral ionosphere, inferred here from ground magnetometers [1 §3.5]
ICME	Interplanetary coronal mass ejection: what a coronal mass ejection becomes out in the solar wind [1 p. 2]

What the paper finds

Both indices rose after the interplanetary shock at 17:05 UT, first at cusp latitudes, then spreading equatorward as the southward field expanded the oval [1 p. 5][1 p. 17]. Strong scintillation sat largely within electrojets or at their edges, and mostly near the boundaries between downward and upward currents [1 p. 1]. On May 11 the 30-s index showed weak or no amplitude scintillation at auroral latitudes [1 §3.2], while 1-s indices at Fort Smith and Churchill picked up short-lived fades during auroral absorption events [1 §3.6][1 p. 20].

OUR ANALYSIS

What the text gives

Times, thresholds and latitudes, but no occurrence percentage, count or statistical test: "significantly" and "clear correlation" carry no number, and the results are in the figures [1 p. 1][1 p. 20]. That's normal for a case study, but it means "largely" and "mostly" can't be checked from the text, and we didn't re-run the currents. As a description the electrojet result stands: another May 2024 study, using this network among others, finds scintillation within both electrojets, though "not a constant feature" [6 p. 1]. And the authors say collocation is partly to be expected, since fast flows raise σφ [1 p. 17].

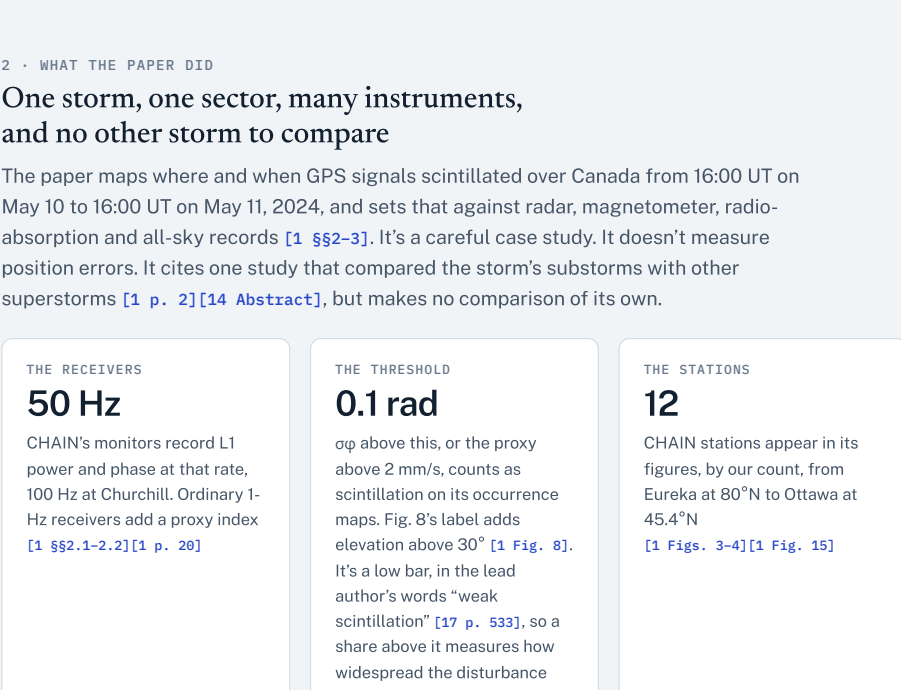
3 · THE TIMELINE, RE-READ

CHAIN's public files reproduce the order; the solar-wind account holds, with one slip, one disputed label and a corotating region we couldn't trace

We re-read the order of first response from CHAIN's public files at 15 stations, on a 30-s phase sigma read once a minute, with the paper's threshold: the first minute after 17:05 UT in which at least two GPS satellites above 30° elevation show σφ above 0.1 rad [28]. The paper's Resolute Bay, Cambridge Bay, Taloyoak, Iqaluit, Gillam and Ottawa aren't in the public files for May 2024, so these are other stations of the same network. We did not re-run its currents, its 30-s S4, its 1-s indices or its proxy.

How long after the shock each station's phase index first rose

OUR ANALYSIS



Minutes after the shock at 17:05 UT on May 10, 2024; stations by magnetic latitude, north to south

Our analysis of CHAIN's public ISMR files [28]; Ottawa's time, about 19:00 UT, is from the paper's text [1 §3.3], and nothing is read off its figures. Mag. is magnetic latitude: a centred dipole from IGRF-14's terms for May 2024 [38], our arithmetic, rough and not AACGM. Ordering by it is post hoc; the rules ordered by geographic latitude. It fits Rankin Inlet responding before its geographic neighbours: without Eureka, the rank correlation with onset is −0.95 by magnetic latitude and −0.92 by geographic. Arctic Bay, Sachs Harbour and Gjoa Haven already met the test in 9, 2 and 3 of the minutes from 16:00 UT to the shock, so their first minutes after it mean less than the others'.

OUR ANALYSIS

"Within an hour"

The paper's summary says the spread reached auroral and nominally sub-auroral latitudes "within an hour" [1 §5 p. 21]. Its own text puts Ottawa at about 19:00 UT, close to two hours after the shock [1 §3.3][1 p. 20]. The public files give 47 minutes at Rabbit Lake (58.2°N), 64 at Fort McMurray (56.6°N) and 130 at Ministik Lake (53.4°N) [28].

The paper's solar-wind account, against NASA's one-minute OMNI file

OUR ANALYSIS

THE PAPER [1 §3.1]	OMNI [29]
Shock at 17:05 UT	Field strength jumps from 4 to 22 nT at 17:04 UT; SYM-H reaches +88 nT at 17:15 UT
Speed reached about 1,000 km/s	1,025.9 km/s at 01:17 UT on May 12; at most 806 km/s up to 03:00 UT on May 11
Dynamic pressure about 60 nPa	61.6 nPa at 20:08 UT on May 10; one minute at 70.0 nPa at 09:42 UT on May 11
SYM-H down to −518 nT	−518 nT at 02:14 UT on May 11 [31]
Field mostly southward for 24 hours, apart from one large swing	Southward in 87.4% of the 1,318 minutes with data in the 24 hours from 17:05 UT. The largest northward spell runs 22:32–23:07 UT, to +52.5 nT; shorter ones reach +18 nT
A dense sheath	Median 36 protons per cm³ from 17:05 to 23:00 UT, peak 62

One slip and one disputed label

Field strength

The paper says the field peaked at about 80 nT [1 §3.1]; OMNI's one-minute file peaks at 70.0 nT [29], Hajra and colleagues give about 71 nT [13 p. 6] and Spogli and colleagues 74 nT [23 p. 6].

A second commencement

The paper says the second impact, near 22:18 UT, also caused a sudden storm commencement [1 §3.1]. The label is disputed. Ebre's provisional list has only the 17:05 UT one on May 10 [33]; Hajra and colleagues find a fast wave at about 22:12 UT, with a sudden impulse of 136 nT beside it [13 pp. 5–6]; Spogli and colleagues call it "a second shock" [23 p. 6]. OMNI's SYM-H jumps from about −300 to −176 nT between 22:30 and 22:35 UT [29], so a ground impulse is documented, and only the words are in doubt.

What drove it

What "enhanced" rests on

§3.1 cites three works [1 p. 5]. One is on May 2024: Pal and colleagues find interaction among five ICMEs, say such interaction may produce intense, long-lived storms, and report that the counterpart at STEREO-A held 1.6 times the magnetic energy and 2.8 times the helicity of the one at Wind, near Earth [15 p. 1]. The other two concern other events, and we did not read them [34][35]. So the merging is well documented. Whether it raised this storm's effects is a separate question that this paper doesn't test.

"A corotating interaction region"

§3.1 also says the ICMEs interacted with "a corotating interaction region" from a coronal hole [1 p. 5]. Nothing we read identifies one in May 2024: Pal and colleagues' text doesn't use those terms [15], Spogli and colleagues mention high-speed streams but no corotating region or coronal hole [23 p. 6], and we did not read the two other citations [34][35]. OMNI shows dense, slow plasma ahead of the shock, 14–17 protons per cm³ at about 450 km/s from about 15:30 UT, which identifies nothing by itself [29].

OUR ANALYSIS

Beside Balan and colleagues' paper

Another paper on this storm, by Balan and colleagues, finds "some aspects" of its geo-effectiveness "comparatively weak" and calls the ICME "less geoeffective", set against those that caused power outages in 1989, 2001 and 2003 [3 Abstract] (our check of it). On size the two agree: "2nd most intense" in the space age and "the most intense in recent decades" both put May 2024 near the top [3 Abstract][1 p. 1]. On geo-effectiveness they point in opposite directions, but they share no baseline: one compares May 2024 with outage storms, on some aspects; this one implies a comparison with a simpler storm that it never makes. Neither tests the other's statement. Scintillation isn't among the effects Balan and colleagues call weak: their abstract doesn't name it, and no reference title we could resolve mentions scintillation or GPS, though its "technological problems" could take it in [3 Abstract].

4 · GPS DOWN IN A SUPERSTORM?

Degraded widely for hours, and unusable for many precise users; the paper maps the signal, not the harm, and compares no storm

In part. The paper maps phase and amplitude scintillation spreading from the cusp to auroral and sub-auroral latitudes after the shock, as the southward field expanded the dayside oval, and reaching Ottawa about two hours later [1 p. 5][1 p. 17][1 §3.3]. It says scintillation can degrade GPS accuracy, but it measures no position error itself [1 §1 p. 2]. Others' records for the storm show navigation degraded widely for hours and, for many users of accurate positioning in the Arctic, unusable; none shows GPS lost outright.

What others recorded for May 2024

Accurate positioning services in the Arctic unusable for many users for up to 37 consecutive hours [6 p. 1]; precise-positioning outages reaching about 49° magnetic latitude for about 15 hours [7 Abstract]; precise-positioning errors up to 70 m in the central US [8 Abstract]; L1 position errors typically under 10 m over the UK and around 60 m over the Americas, while UK airlines reported no major disruption [12 p. 13][12 p. 14]. Scintillation is one cause among several (section 7).

OUR ANALYSIS

What it means, and where it stops

So the paper and those records support the idea that a superstorm can degrade satellite navigation over a wide area for hours, most of all for precise users. They don't show it knocked out for everyone: in CHAIN's files research receivers almost never lost L1 lock in any storm, though L2 lock losses, a measure added after seeing the data, rose about six times over quiet days [28]; and nothing we read reports an accident, which is the limit of a search (section 7). The paper ties the spread to the expansion of the dayside oval and the open–closed boundary [1 p. 17], and another paper on this storm puts the oval's nightside edge below 50° magnetic latitude from postmidnight to dawn [4 Abstract] (our check of it). How a bigger storm would compare, the paper can't say: it compares none. In our comparison at five stations the three deepest of the 13 storms take the top three places on phase scintillation, but not in order of depth, and on May 11 the storm's own heating left the polar cap quiet [5 p. 1] (section 6).

5 · "MOST INTENSE IN RECENT DECADES"

Two to six decades, depending on the index: true, and an opening phrase

The abstract opens with it, naming no index and citing nothing [1 p. 1]. The body softens it to "one of the most intense", through a preprint [1 p. 2][27]. An opening phrase isn't a finding, so we check it only against the records.

May 2024 against the last storm as strong or stronger, index by index

OUR ANALYSIS

INDEX	MAY 2024	LAST AS STRONG OR STRONGER	GAP
Dst, hourly	−406 nT, provisional	−422 nT, November 20, 2003 [30]	20.5 years
SYM-H, one-minute, from 1981	−518 nT	−720 nT, March 14, 1989 [31]	35.2 years
Kp, three-hourly	9 on May 11	9 on October 30, 2003 [32]	20.5 years
Ap, daily, from 1932	271 on May 11	280 on November 13, 1960 [32]	63.5 years

Dst and SYM-H as on our page on Balan and colleagues. Others say much the same: strongest in two decades or since 2003 [7 Abstract][23 p. 1], since the 2003 Halloween storm [24 Abstract], among the strongest in 20 years [25 Abstract], the lowest SYM-H in several decades [26 Abstract], second by SYM-H since 1981 [14 Abstract]. A return-period estimate is less dramatic: about 1 in 12.5 years by intensity, 1 in 41 by duration [5 p. 1].

6 · OUR COMPARISON

Third of 13 at these stations on this index; fourth on amplitude; in the polar cap, below the autumn and winter storms

The paper doesn't ask how May 2024 compared with other storms at the same stations. The lead author has also studied the March 2015 storm [18 Abstract], but this paper makes no comparison. CHAIN's public files allow a rough one. Every number in this section is ours, from a 30-s phase sigma read once a minute and a 60-s S4, not the paper's own 30-s S4 or 1-s indices [28]. "Post hoc" marks what we added after seeing the data.

FIXED FIRST

Storms

Every storm with Kyoto's hourly Dst at or below −150 nT since 2010: 13, none before 2015 [30]. A 24-hour window from 10 hours before the Dst low, which for May 2024 is the paper's own 16:00–16:00 UT.

FIXED FIRST

Stations

Those with files for at least 18 of the 24 hours in every window. That leaves five: Rankin Inlet, Fort Simpson, Fort Smith, Rabbit Lake and Fort McMurray, at 56–63°N. A second panel of ten covers the nine storms since 2023.

FIXED FIRST

Index

GPS satellites above 30°. σφ is the file's 30-s phase sigma, read once a minute, above 0.1 rad, the paper's threshold. S4 is the file's 60-s index, above 0.3. Each station counts equally.

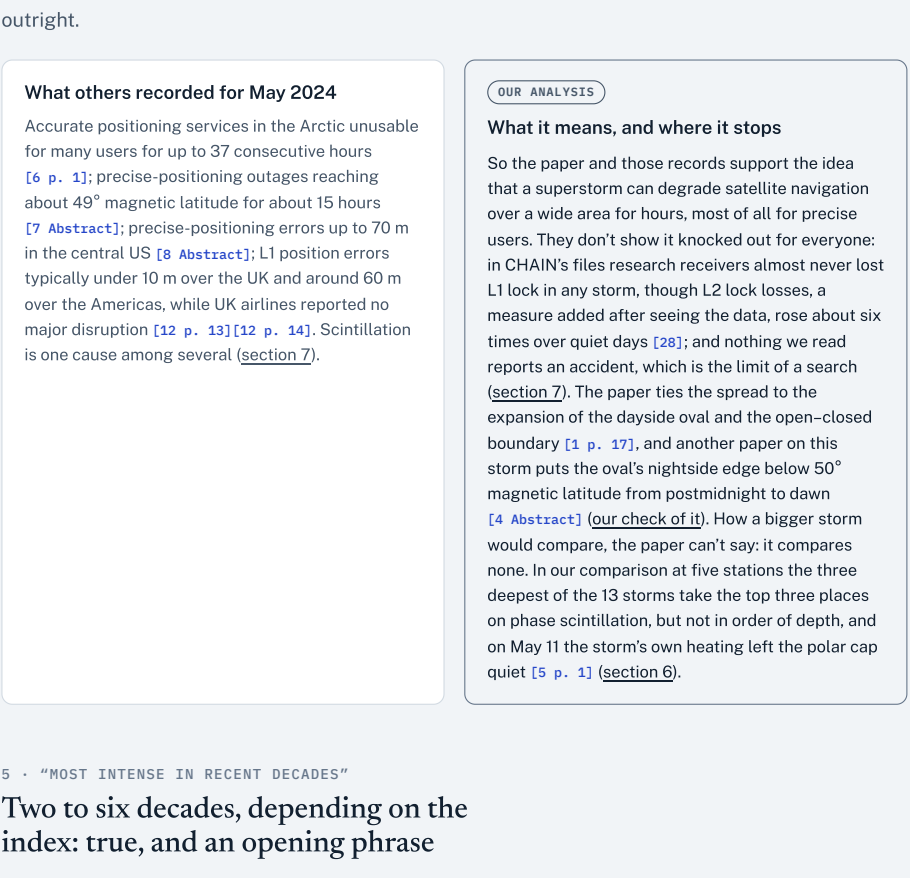
FIXED FIRST

Reading rule

Rank 1–3 of 13 and at least twice a quiet baseline: near the top for a storm of this class at these stations. Rank 4–9: middling. Rank 10–13: weak for a storm of this class. If phase and amplitude disagree, report both. (The hosted rules name the bands in other words; the ranks and the test are as fixed.)

May 2024 against 12 other storms and quiet days, on the same files

OUR ANALYSIS



Percent of GPS satellite-minutes above 30° elevation in a 24-hour window; the three panels have their own scales

Our analysis of CHAIN's public ISMR files, cited as Jayachandran and colleagues (2009) [28]; Dst from Kyoto, final to 2018 and provisional from 2023 [30]. Nothing is taken from the paper's figures. The five stations are at 56–63°N. The third panel, the mean of Eureka and Arctic Bay, isn't in the rules: we added it after seeing the data, and chain_posthoc.py builds it. They have comparable files only since 2023, and Arctic Bay reads 12% on quiet days, so its level needs care. There all five windows above May 2024 fall in October to January, and all three below it in March to August. Sachs Harbour, not in that panel, ranks May 2024 third of 6.

OUR ANALYSIS

What the rule gives

Phase: third of 13, at these stations, on this index, in 41.3% of satellite-minutes, about 20 times quiet days. By the rule, that is near the top for phase scintillation here.

Amplitude: fourth of 13, at 0.140%, the rule's middling band. It's fourth by 0.005 points, on one station's figure, and far behind the top two (1.04%, 0.55%): 48 of August 2018's 51 hits are at Fort Simpson (post hoc). The rule's rank stands. Amplitude scintillation on this 60-s index is rare in every storm.

The two disagree, so we report both. The three deepest storms take the top three places on phase, in a different order from their depth (Spearman 0.67, a description only). Depth doesn't settle the order among them.

What "third of 13" is, and isn't

Five stations at 56–63°N, 63–71° by magnetic latitude (post hoc), none in the polar cap, none of the paper's first responders.

A 30-s phase sigma read once a minute, and a 60-s S4, from public files, not the paper's own 30-s S4 or 1-s indices.

A low bar. σφ above 0.1 rad is what the lead author calls "weak scintillation" [17 p. 533]. The share says how widespread the disturbance was, not how strong. Above 0.5 rad May 2024 is third too, at 4.96%.

σφ is partly fast flow, not only diffraction, as this paper and others say [1 p. 20][6 p. 22], and one study says of the 1-minute index in particular [16 Abstract].

Season is uncontrolled. The two storms ahead fall in October and January; the lead author's climatology puts the oval's maxima at the equinoxes, and the cusp's and polar cap's in autumn and winter [17 p. 531][17 p. 536]. Among the five storms within 60 days of May 10, May 2024 comes first.

The top three can't be firmly separated. Resampling single hours, May 2024 comes first in 19% of draws and in the top three in 79%. Hours follow one another closely, so those shares are optimistic: in 6-hour blocks, 9% and 47% (post hoc).

Second against third turns on one hour. Drop each window's first hour, for May 2024 the quiet hour before the shock, and it's second, at 43.3% against October 2024's 43.0% (post hoc).

How far the rank moves, five stations unless stated

OUR ANALYSIS

CHECK	RESULT FOR MAY 2024
Resampling single hours, 2,000 draws	σφ 95% range 30.8–52.3%; S4 0.05–0.27%, in the top three in 46% of draws. Hours follow one another closely, so these shares are optimistic
Resampling 6-hour blocks (post hoc)	σφ 95% range 25.8–58.1%, first in 9% of draws, in the top three in 47%
Leaving out one station at a time	σφ second or third; S4 third or fourth
Elevation above 20°, or the file's 60-s phase sigma	σφ stays third; S4 stays fourth
First 12 hours of the window	σφ third at 47.2%, behind October 2024 (60.3%) and November 2023 (49.0%); S4 second
Last 12 hours	σφ second at 35.7%, behind January 2026 (46.3%); S4 zero, tied with seven other storms (ties counted post hoc)
Moving the window (post hoc)	Second to eighth across 14 placements; second if the hour before the shock is dropped. From each storm's first commencement inside the window, second: 43.4% against October 2024's 42.8%, with January 2026 first at 46.3% [33]
Within 60 days of May 10 (five storms)	First on σφ above 0.1 rad, σφ above 0.5 rad and S4 above 0.3
March to August, seven storms (post hoc)	First, 41.3% against 31.3%. First at each of the 15 public stations too
By each station's local time (post hoc)	σφ second on the dayside (56.7%, behind October 2024's 60.7%), seventh on the nightside (24.8%), so third place is a blend
Peak hours of the window (post hoc)	σφ first in its peak hour (93.2% against 89.5%), second over 3 and 6 hours, fifth over 12; S4 third on each
σφ above 0.5 rad	Third, 4.96%, behind October 2024 (7.65%) and January 2026 (7.01%)
The thresholds of a study of these files: 60-s σφ above 0.2 rad, S4 above 0.2, elevation above 20° [19 p. 4]	σφ third; S4 third at 1.39%, behind October 2024 (3.89%) and January 2026 (1.87%)
S4 without Fort Simpson (post hoc)	Third
Ten stations, nine storms since 2023	σφ third of 9, 35.3%; S4 fifth of 9, though two station-windows there have abnormal S4 (see below)

The polar cap, and May 11

What Themens and colleagues report

Using this network among others, they track scintillation from the cusp to a tongue of ionization and patches over the polar cap, then its clearing after the interplanetary field's reversal at 22:30 UT. Heating and composition changes removed the F2 layer on May 11, leaving "only very minor polar cap σPhi" while the storm went on, and "significantly reduced impacts on GNSS" [5 p. 1][5 p. 9]. Another study reports the same kind of depletion in the dayside auroral region that day [20 Abstract].

OUR ANALYSIS

The public files confirm it

At Eureka, Arctic Bay and Sachs Harbour the phase index falls from 28–44% in the main phase to 1.8–3.5% in the recovery phase, no higher than quiet April days (4.9, 12.4 and 3.6%; at the same UT hours 5.2, 12.7 and 4.4%, post hoc) [28]. This paper's summary of Themens and colleagues stops at the tongue of ionization and patches and doesn't mention the suppression [1 p. 2][1 p. 17]. By eye, its Figs. 3 and 8 show the fall.

OUR ANALYSIS

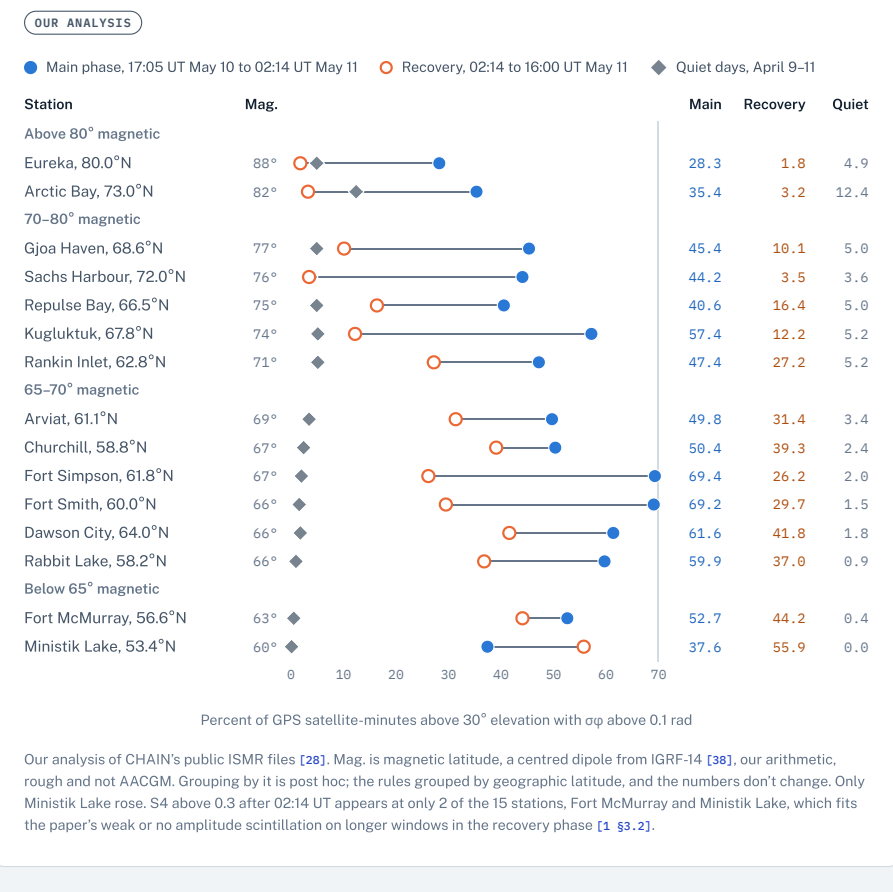
Over the whole window, the polar-cap rank is close to a season split (post hoc)

Eureka and Arctic Bay, at 88° and 82° magnetic latitude, have comparable files only since 2023. Averaged, they put May 2024 at 13.9%, sixth of 9: 11.9% and 15.9%, against 36.7% and 38.3% in October 2024 [28]. This panel isn't in the rules, whose bands don't cover it; we added it after seeing the data. All five windows above May 2024 fall in October to January and all three below it in March to August, as the lead author's climatology would lead one to expect: occurrence in the cusp and polar cap is "highest in the autumn and winter months and lowest in summer" [17 p. 531].

Within 60 days of May 10 it's first of 3, by a hair (13.9, 13.4 and 12.2%). Among March to August windows May 2024 is first at all 15 public stations, so every storm above it, at every station, falls in September to February. At Eureka and Arctic Bay those margins are thin (11.9 against 11.5, 15.9 against 15.3); on the five-station panel they aren't. Sachs Harbour, at 76° magnetic, ranks May 2024 third of 6. Four of the five windows above it in the panel come after a possible receiver change at Arctic Bay (section 10). The quiet May 11 is what Themens and colleagues put down to the storm's own heating and composition change [5 p. 1], so it isn't simply a sign of a weak storm. No measure falls in our rule's lowest band, ranks 10–13.

In the storm's second half, phase scintillation fell most in the far north and least toward the equator

OUR ANALYSIS



Percent of GPS satellite-minutes above 30° elevation with σφ above 0.1 rad

Our analysis of CHAIN's public ISMR files [28]. Mag. is magnetic latitude, a centred dipole from IGRF-14 [38], our arithmetic, rough and not AACGM. Grouping by it is post hoc; the rules grouped by geographic latitude, and the numbers don't change. Only Ministik Lake rose. S4 above 0.3 after 02:14 UT appears at only 2 of the 15 stations, Fort McMurray and Ministik Lake, which fits the paper's weak or no amplitude scintillation on longer windows in the recovery phase [1 §3.2].

What came first, and what came after seeing the data

Written before any storm file was opened

The rules above, hashed before any storm file was fetched, and two additions hashed before any was opened: the extra onset measures, and a clock screen. The screen is there because Zhao and colleagues, using these same files, say "receiver clock failures exist" in them [19 p. 4]. It flagged Kugluktuk in 2015–2018, Repulse Bay in 2018 and Sachs Harbour in January 2025, none of them in a window either panel uses. Station ranks above leave those windows out.

OUR ANALYSIS

Added or changed afterwards, and marked so

L2 lock losses, added after a test of the code on two windows showed L1 lock losses near zero. **Station ranks without flagged windows, and the top-three share,** added after a first look at the ranks. **The quiet baseline** was to be April 9–15; a restart and then a slow link left it at April 9–11, 22–25 of the 56 planned hours. It enters only the ratio to quiet days, whose test is "at least twice", so "about 20 times" is approximate and no rank depends on it. **Seen by eye, not screened:** abnormal S4 at Eureka in October 2024 and Ministik Lake in April 2023 inflate the ten-station S4 figures; the five-station panel has neither.

Everything marked post hoc: the Eureka and Arctic Bay panel, the season split, the block resampling, the moved windows, the local-time split, the peak hours, S4 without Fort Simpson, the tied ranges and the magnetic latitudes. These came after the page was built and after a fresh reviewer's exploratory runs, which we re-derived in our own script under a new hashed addendum. They show how far the framing moves. They don't replace the rule's result, and they move no verdict.

7 · DID IT DO HARM?

The paper measures none; others report real trouble for GPS users

The paper is about the signal. Its only words on harm are a general sentence and two citations in its introduction [1 p. 2]. These are the published records we found. Farming is on our page on Balan and colleagues.

What others report for May 2024

SOURCE, WHAT WE READ	WHAT IT REPORTS
Jacobsen and colleagues, 2025 Full text	Of positioning services in the Arctic: "For many users, they would be unusable for up to 37 consecutive hours" [6 p. 1]. A network RTK service near Tromsø, about 70°N, tested with monitor receivers that stand in for users. One beside a network receiver saw no noticeable increase in error [6 p. 19]. One 1.2 km away saw errors of several tens of centimetres [6 p. 21]. Two about 12 km away lost fixed solutions for intervals of up to hours; the service was, in practice, "unavailable for TM04", one of the two, "for the entire 37 h duration". The authors' dominant cause: plasma structures too small for the network to model, mostly not small enough for amplitude scintillation, while phase varied strongly [6 p. 22]
Yang and Morton, 2025 Abstract only	Over 5,800 receivers: precise-positioning outages reaching about 49° magnetic latitude in the north for about 15 hours and 48° in the south for about 20, put down to carrier-phase cycle slips [7 Abstract]
Younas and colleagues, 2025 Abstract only	Precise-positioning errors up to 70 m in the central US in the main phase on May 10, put down to strong scintillation and cycle slips near the ionospheric trough. A second solution mode, PPK, turned unstable from the storm's arrival into the recovery phase, which coincides with reported outages of farm equipment. In the southwest US, errors of 10–20 m with little scintillation, put down to signal bending [8 Abstract]
Younas and colleagues, 2026 Abstract only	In Antarctica, errors peaking at 28 m, the tongue of ionization doing the most [9 Abstract]
Danilchuk and colleagues, 2025 Abstract only	Kinematic precise-positioning errors 1.5–5 times higher at the auroral oval's boundary [10 Abstract]
Fiori and colleagues, 2025 Abstract only	Evaluates Canadian radio and GNSS impacts from Transport Canada's occurrence reports and reported outages of the Wide Area Augmentation System; its abstract gives no numbers [11 Abstract]
Horne and colleagues, 2026 Full text	L1 position errors typically under 10 m over the UK, around 60 m over the Americas at 20:00–23:00 UT on May 10; US farmers using GNSS-guided tractors had to stop planting. UK airlines, rerouted south, reported no major disruption, with few aircraft exposed [12 p. 13][12 p. 14]

OUR ANALYSIS

What this does and doesn't show

The trouble was real for users who need centimetres, and not only for them, and it varied with distance from a base station and with method. Scintillation is one cause among others: steep gradients, cycle slips and signal bending all appear in these accounts, and the best-documented high-latitude case points to structures that show in phase variations rather than amplitude scintillation. In our CHAIN files, research receivers' L1 tracking above 30° almost never broke in any storm, at most 0.85 lock losses per 100 satellite-hours on the five stations, while L2 lock losses rose about six times over quiet days in May 2024 and were higher still in October 2024 and January 2026 [28]. That measure was added after seeing the data, and fits an account of March 2015 in which losses of lock came on L2 [22 Abstract]. Nothing we read reports an accident; that's the limit of a search, not proof.

8 · WHAT STAYS OPEN

The mechanism is an inference, and the 1-s claim has no yardstick

Gradient drift

The paper's case is collocation: 1-s scintillation near current reversals and under auroral arcs at Fort Smith, with one all-sky keogram and one image, read with a study of a substorm in Alaska that the paper cites and we did not read [1 §3.6][36]. Its discussion and summary both call gradient-drift instability the likeliest source [1 p. 20][1 p. 22]. That's a fair reading of collocation at one station, but no gradient or field geometry was measured. Testing it would need the density gradient and the electric field together, along the same line of sight.

"Rarely seen"

The paper says 1-s S4 values "at times exceed 0.6, which is rarely seen at high latitudes" [1 p. 20]. We leave this unverified. The public files have no 1-s S4, the paper gives no baseline at 1 s, and it adds that with fewer samples 1-s S4 "can be more variable thus reaching higher peaks" [1 p. 20]. On the 60-s index, S4 above 0.6 is rare in every storm we read, at most 0.06% of satellite-minutes on the five stations (our analysis) [28], and a study of these same files calls strong amplitude scintillation rare at these latitudes [19 p. 6]. A 1-s study suggests amplitude scintillation is commoner there than thought [16 Abstract].

9 · REPEAT OUR NUMBERS

The rules, the scripts and the derived numbers; CHAIN's own files stay with CHAIN

The rules came first, each with its hash and time; what came after them is listed in section 6. Re-running the comparison on the files we read gave the outputs below byte for byte. We have not repeated the download from an empty folder.

PY **fetch_chain.py**
Fetches CHAIN's files by URL, with curl, at about 100 requests a minute; it holds no data · 5 KB

TXT **quiet-files-read.txt**
The names of the quiet-day files our run read, so that a re-run can match it · 6 KB

PY **chain_compare.py**
The comparison: panels, measures, ranks, resampling, clock screen, onsets, main against recovery; standard library only. Its output breaks ties by date · 30 KB

JSON **chain_compare.json**
Its output: derived numbers only · 154 KB

CSV **chain_station_window.csv**
Each station in each window: counts and percentages, no CHAIN records · 18 KB

PY **chain_posthoc.py** and **chain_posthoc.json**
Everything marked post hoc, with its output, including how the Eureka and Arctic Bay panel is built · 27 KB and 32 KB

PY **omni_timeline.py** and **omni_preshock.py**
The check against OMNI, and the plasma ahead of the shock, with outputs here and here · 6 KB and 2 KB

PY **intensity_ranks.py**
The index table in section 5, with its output · 3 KB

TXT **RULES_before_running.txt**
The rules, hashed before any storm file was fetched · 7 KB

TXT **RULES_addendum_1.txt** and **RULES_addendum_2.txt**
Extra onset measures and the clock screen, hashed before any file was opened · 2 KB and 2 KB

TXT **RULES_addendum_3.txt** and **RULES_addendum_4.txt**
L2 lock losses, post hoc, and the shortened quiet baseline, a deviation · 1 KB and 2 KB

TXT **RULES_addendum_5.txt**
The checks added after a fresh review, all post hoc, hashed before their script ran · 5 KB

TXT **rules_sha256.txt**
The SHA-256 of each rules file and of each version of the scripts, with times · 2 KB

Run it

`python3 -I fetch_chain.py <folder> --quiet-list quiet-files-read.txt` fetches about 4,400 files, 257 MB, in an hour or more. Then `python3 -I chain_compare.py <folder> <Dst CSV> <GFZ file> <output folder>` runs on those files, Kyoto's Dst CSV and GFZ's file. `python3 -I chain_posthoc.py <folder> <Dst CSV> chain_compare.json <output folder>` then gives the post hoc checks. Without the list it fetches the whole quiet week the rules first named, which changes only the ratio to quiet days. Two of our quiet-day files were truncated in transit and skipped, so a clean re-fetch may differ slightly there.

`omni_timeline.py` and `omni_preshock.py` take OMNI's May 2024 file and an output path. `intensity_ranks.py` takes GFZ's file, the numbers on our page on Balan and colleagues and an output path.

The data and their terms

CHAIN: free for informational, research and educational use. Its policy bars redistribution of its data in any format without written agreement, and asks to be told of publications that use them. So we host no CHAIN file, only numbers derived from them; cite Jayachandran and colleagues (2009), *Radio Science* 44, RS0A03 [28]. **OMNI:** NASA's public data, credited to its authors [29]. **GFZ's Kp and Ap:** CC BY 4.0 [32]. **Kyoto's Dst and SYM-H:** for scientific, non-commercial use, with acknowledgement of the data suppliers and the WDC [30][31]. **Ebre's list:** under ISGI's policy, which asks for the acknowledgement below [33].

Acknowledgements

We thank the Canadian High Arctic Ionospheric Network for its public files: Jayachandran and colleagues (2009), *Radio Science* 44, RS0A03, doi:10.1029/2008RS004046 [28].

The results on this page rely on the Dst and SYM-H indices calculated and made available by the World Data Center for Geomagnetism, Kyoto, from data collected at magnetic observatories. We thank the data suppliers and the WDC for Geomagnetism, Kyoto [30][31].

Our check of the window relies on sudden commencements listed by the Observatori de l'Ebre, an ISGI Collaborating Institute, from data collected at magnetic observatories. We thank the involved national institutes, the INTERMAGNET network and ISGI (isgi.unistra.fr) [33].

Kp and Ap are from the Geomagnetic Observatory Niemegk, GFZ Helmholtz Centre for Geosciences, and F10.7 from the Dominion Radio Astrophysical Observatory and Natural Resources Canada [32]. The solar-wind data are from NASA's Space Physics Data Facility [29].

10 · LIMITS

What this check could and couldn't see

The paper's own indices

Its 30-s S4, its 1-s indices and its proxy can't be rebuilt from the public files, and we fetched no 50-Hz data. We did not re-run its currents, radar or riometer work, or test its collocation claims beyond its figures.

Other stations and receivers

The paper's first responders and Ottawa aren't in the public files for May 2024 [28]. Our comparison stands on five stations at 56–63°N. Whether receivers stayed unchanged we know only indirectly. Median signal strength above 60° drifts down about 1–2 dB from 2015 to 2024 at the five. At Arctic Bay it steps up about 2 dB between August and October 2024, and median S4 rises there and at Eureka, which may be a change of hardware or processing; we can't confirm it. σφ's floor shows no such step (post hoc).

Uncontrolled differences

Season, local time at arrival, solar flux and receiver age differ between storms. We report them and adjust for none. By each station's local time, May 2024 is second on the dayside and seventh on the nightside (post hoc).

A window built on May 2024's shape

Ten hours before the Dst low is the paper's own start for May 2024. Against Ebre's lists it cuts the start of other storms: December 2015 by about 20 hours, January 2025 by about 13, January 2026 by about 11, March 2015 by about 7, March and April 2023 by 1–2. It pads November 2025 with about 5–6 quiet hours, and May 2024 with 65 minutes [33]. Moving it moves the rank (section 6).

A shortened quiet baseline

April 9–11 rather than April 9–15, plus two files from 00 UT on April 12, at Fort Simpson and Fort Smith, which make no difference that matters (2.01% with them, 2.03% without). It enters no rank.

Checks after the fact

Everything marked post hoc was chosen after seeing the data, most of it first run by a fresh reviewer. It shows sensitivity. The rule's result stands, and those checks can't confirm it or overturn it.

Sources read in part

Yang and Morton, Younas and colleagues, Danilchuk and colleagues and Fiori and colleagues are abstracts only, paraphrased: their numbers and methods are as their abstracts give them. The paper's citations [34], [35] and [36] were not read, and one preprint is known only by its record [27].

What would change these verdicts

01
30-s and 1-s indices from CHAIN's 50-Hz files for these storms, with season and local time matched. That could move May 2024's place on amplitude in particular.

02
The full texts of Fiori and colleagues and of Yang and Morton: how many users, how far, how long, and whether anyone was hurt.

03
Density gradient and electric field measured together in these arcs, or a model run with and without the merging, which would move "Gradient drift" or "Merging ICMEs" toward True or away from it.

OUR ANALYSIS

Bottom line: a careful map of one storm, the order of whose timeline reproduces from public files; it compares no other storm.

At five stations at 56–63°N, on a 30-s phase sigma read once a minute and partly driven by fast flow, with season uncontrolled, May 2024 is third of 13 storms on phase and fourth on amplitude, close to third and far behind the top two. In the polar cap it stays below the autumn and winter storms, and fell quiet on May 11. Neither of the paper's causes is tested: the merging's effect is stated, and gradient drift inferred from collocation at one station.

Related checks

FALSE More auroras from less solar input? The Disaster Cycle, Fact-Checked

Sources

Bracketed numbers refer to this list. For the paper [1], read in full, p. gives a page of the publisher's PDF, § a section and Fig. a figure; no figure is redrawn or digitised, and anything read off one by eye says so. For the other sources, p. gives a page of the copy named in the entry and Abstract the abstract; where only an abstract or a record was read, the entry says so, and abstracts under a publisher's standard terms are paraphrased, apart from the short phrases of Balan and colleagues' abstract that we set beside this paper's. nT is the nanotesla, nPa the nanopascal, rad the radian, UT universal time, and σφ and S4 are the phase and amplitude indices explained in section 2. Magnetic latitudes are a centred dipole, rough and ours. Source 37 was removed when the page was revised on November 6, 2026. Links checked November 4, 2026.

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METHOD

How this was checked

On November 4, 2026, we checked every statement on this page about the paper against its full text, the publisher's PDF and web page: its stations, indices, thresholds, results, caveats, data statement, funding and competing interests, and everything it says, and does not say, about other storms, harm, Earth's field and the poles. We looked at some of its figures by eye and digitised none. The page also rests on nine other papers whose full text we had, read for the passages we cite; fourteen read only as abstracts, as the source list marks; four known only as records, all of them the paper's citations, and one through our page on it; CHAIN's public scintillation files; NASA's OMNI; Kyoto's Dst and SYM-H; GFZ's Kp, Ap and F10.7; Ebre's list of sudden commencements; and IGRF-14's dipole terms. Every quotation was checked word for word against its saved source.

The verdicts and the items tagged "Our analysis" are our own assessment, built on the cited sources. They cover the comparison of 13 storms, the reading rule we set for it, the timeline we re-read from the public files, the check against OMNI, the ranks by index, and our reading of what this paper and Balan and colleagues' abstract do and do not test. "Third of 13" is a statement about five stations at 56–63°N and one 30-s phase sigma read once a minute, with season uncontrolled, and we don't mean more by it.

We wrote the comparison's rules and hashed them before fetching any storm file, and two additions before opening any; after a test of the code on two windows we added one measure, L2 lock losses, and after a first look at the ranks two ways of reporting them, all marked. A restart and a slow link then cut the quiet baseline from April 9–15 to April 9–11, a logged deviation that affects no rank. Re-running the comparison on the same files gave its outputs byte for byte; we did not repeat the download from an empty folder. A fresh reviewer then recomputed the comparison in separate code and found the arithmetic sound. Its exploratory checks led us to a last hashed addendum and script: everything marked post hoc on this page, which we re-derived ourselves. None of it replaces the rule's result or moves a verdict. We could not recompute the paper's 30-s S4, its 1-s indices, its proxy index or its currents, because the 50-Hz files were not fetched and the rest lies outside the public scintillation files; we leave its 1-s claim unverified. We could not read in full Yang and Morton, Younas and colleagues, Danilchuk and colleagues, or Fiori and colleagues. CHAIN's terms bar redistribution of its data, so we host derived numbers and scripts only.

On November 6, 2026, the page was revised to review the paper on its own: no transcript of the S0 News episode that linked it was available, and without one the site no longer comments on how an episode presented a paper. The verdict on the link's label and the section on it were removed. Section 4 now asks what the paper means for the idea of a superstorm that takes GPS down, from sources already cited here; its checks of "enhanced" and of a corotating interaction region moved unchanged to section 3, beside a shorter comparison with Balan and colleagues' abstract; and section 6 now describes its reading rule by its ranks, while the hosted rules files are unchanged. The source that served only a comparison between two episodes was removed, and the others keep their numbers. Nothing was fetched again and no number was recomputed; the verdicts on the paper's claims are unchanged. A fresh reviewer then checked the revision against the saved texts; it widened section 3's heading, gave the citation of Wang and colleagues a locator, corrected a page reference and the oval it names, and reworded the bottom line on gradient drift and smaller points.

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

UNCONFIRMED	Rests on a preliminary result that hasn't been confirmed.
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

Nov 6, 2026	Revised to review the paper on its own. No transcript of the S0 News episode that linked it was available, and without one the site no longer comments on how an episode presented a paper. The verdict on the link's label is removed; the section on it is replaced by one on what the paper means for the idea of a superstorm that takes GPS down, and its checks of the paper's solar-wind account move to section 3; the page's other mentions of the episode are removed or reworded; the source that served only a comparison between two episodes is removed, and the other sources keep their numbers; the verdicts on the paper's claims are unchanged. A fresh review of the revision then widened section 3's heading, corrected a page reference and reworded the bottom line on gradient drift.
Nov 4, 2026	Published on factchecked.science after a full check against the sources. Built from the paper's full text, the episode's title and link labels (no transcript was available), published accounts of the storm's effects on GPS, and our own comparison of 13 storms in CHAIN's public files, whose rules, scripts and derived numbers are hosted; no figure of the paper is redrawn or digitised. A fresh reviewer then checked the finished page; that review narrowed the title to five stations, corrected our reading of the paper's discussion of gradient drift, turned one "slip" into a disputed label, showed that the polar-cap rank is close to a season split and that tied ranks had been broken by date, corrected what we said of Jacobsen and colleagues, and led to the checks marked post hoc.

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