☑ Fact-Checked Science

PAPER CHECK · GEOMAGNETIC STORMS AND WEATHER

Do geomagnetic storms change the weather?

A 2026 study says geomagnetic storms have a "profound" effect on weather over North America [1 Abstract]. This page sets out what it reports, tests key numbers against public weather-station data, and places it in 50 years of research on the question.

By Fact-Checked Science · Published October 12, 2026

OUR ANALYSIS marks our own reasoning, and the verdicts are our assessment. Everything else comes from the numbered sources. In the paper [1], §1 is the introduction and §2 the results and discussion.

A testable claim that isn't established yet

OUR ASSESSMENT

5 storms
are all the paper's strongest winter maps can draw on, by our count for December–February 1958–2024: 32 storm hours in 67 years. Other plausible windows give 4 to 6 [2][3]

1 of 40
tests at 10 weather stations came out below p = 0.05 in our check; chance alone would give about 2 [5]

39%
of randomly timed five-storm sets left at least 8 of the 10 stations drier than average, as the real storms did [5]

THE PAPER'S CLAIMS

OVERSTATED

Geomagnetic storms have a profound impact on weather

The paper's abstract and introduction [1 Abstract][1 §1]

Sixty-seven years of hourly data over a continent give the claim some basis, but the main text reports no significance tests or confidence limits [1 §2]. Its three reasons for calling the anomalies real can all arise by chance when few storms are averaged, and by our count its strongest winter maps rest on about five storms [2][3]. At 10 weather stations, strong and moderate winter storms gave nothing beyond what randomly timed storms produce [5]. See section 2.

UNSUPPORTED

Strong storms suppress precipitation, at least in winter

The paper, from its strongest-storm maps [1 §2]

During the five strong winter storms, 8 of 10 stations were drier than average, but randomly timed five-storm sets leave that many dry 39% of the time, because most winter days are drier than an average that a few wet days pull up. Two of the five storms were wetter than average across the stations, and in spring, summer and fall the stations were no drier than chance gives [5]. See section 3.

MISLEADING

Storm impacts are up to two orders of magnitude larger than the solar cycle's effect on global temperature

The paper's abstract and discussion [1 Abstract][1 §2]

The comparison sets the largest local anomalies, averaged over storm hours, against a global long-term effect that the paper puts at 0.1–0.2 K and the review it cites at about 0.07–0.1 K [1 §2][10 §1 ¶4]. The abstract's "up to" marks a maximum, but it doesn't say the storm figure is the largest local value on the maps, or that against regional long-term averages the gap is one order of magnitude [1 Abstract][1 §2]. The ratio reflects averaging, not whether the storm anomalies are real. See section 4.

OVERSTATED

The cosmic ray–cloudiness hypothesis is falsified

The paper's abstract and discussion [1 Abstract][1 §2]

The paper argues that cosmic-ray drops come too late in a storm to show in its storm-hour averages, and that its radiation and precipitation maps and the lack of a latitude pattern don't fit particle-driven cloud changes [1 §2]. By that first argument, though, storm-hour averages can't test a cloud effect reported about a week after the drops [18 Abstract], and the main text doesn't test its anomalies against chance; direct tests had already found no robust cloud response [19 Abstract][20 Abstract]. On particle effects in general the paper is careful: "least consistent" with its results, not ruled out [1 Abstract][1 §2]. See section 4.

1 · WHAT THE STUDY DID AND FOUND

Weather anomalies during storms, growing with storm strength

The study matched 67 years of hourly values of the Dst storm index with ERA5 reanalysis weather data over North America (20–75°N, 64–136°W) [1 Abstract][1 §1][6]. Dst is an hourly index of storm strength in nanotesla (nT): the more negative, the stronger the storm [2]. A reanalysis is a weather model run that folds in past observations to give hourly maps [6]; the author chose this region partly because ERA5 is best constrained by observations there [1 §1].

Method

Storm hours were sorted into four levels of geomagnetic activity, R1 to R4, plus a comparison set of randomly selected times, RN, then averaged by season and over the whole year [1 §2]. The text describes the comparison set as random hours; the Figure 2 caption calls it random days [1 §2, Fig. 2 caption].

The result is 125 maps: 5 levels (including the random set) × 5 averaging periods (four seasons and the whole year) × 5 variables (temperature, pressure, wind speed, precipitation and direct radiation) [1 §2]. Anomalies are shown as a percentage of each variable's standard deviation, on a color scale from −50% to +50% [1 §2].

R1	The least active times
R2	More active than R1
R3	"Moderately strong" storms: Dst between −100 and −200 nT
R4	The strongest storms
RN	Randomly selected times

Activity rises from R1 to R4 [1 §2]. The paper's text gives the range of R3; the ranges of R1, R2 and R4 are in its supporting information, which we haven't read.

Headline findings

- For moderately strong (R3) storms, the largest anomalies reach or exceed 50% of a standard deviation in every season, which is the top of the color scale. The anomalies grow with storm strength [1 §2].
- Winter temperature anomalies reach up to about 6 K for moderately strong storms and up to about 20 K for the strongest [1 §2].
- Strong storms suppress precipitation, at least in winter. The paper says the same holds in summer and, to a lesser extent, in spring and fall [1 §2].
- The largest local, short-term storm anomalies are up to two orders of magnitude larger than the long-term global mean surface temperature effect attributed to solar activity [1 Abstract][1 §2].
- One mechanism "can be ruled out": "The cosmic ray (CR) cloudiness hypothesis is falsified by my results." Particle-precipitation effects in general are "least consistent" with the results [1 Abstract][1 §2].
- A top-down mechanism, acting directly through the ionosphere or through stratospheric chemistry and the polar vortex, "appears to be more likely," though the results "do not directly implicate any specific mechanism" [1 Abstract][1 §2].

In the author's words

> *"Here, I show that geomagnetic storms have a profound terrestrial weather impact."*
>
> Raeder (2026), abstract [1 Abstract]

> *"...solar and geomagnetic storms, which typically last for only about one day, exert significant and immediate impacts on weather conditions."*
>
> Plain language summary [1 Plain Language Summary]

> *"By contrast, the precipitation anomaly is almost entirely negative for R4 storms. In other words, strong geomagnetic storms suppress precipitation, at least in the winter."*
>
> Results and discussion [1 §2]

The paper is open access under CC BY-NC-ND 4.0, a license that doesn't permit adapted versions, so we point to its maps rather than redraw them: see its Figures 1 and 2 [1]. Every chart on this page is our own analysis of public data.

2 · THE PAPER'S CASE, AND CHANCE

Each of the paper's three reasons can also come from chance

The main text reports no significance tests or confidence limits. It concludes that the anomalies are real from three observations [1 §2], and each is also what chance produces when only a few storms are averaged.

> *"From these absences of signals in the Null hypothesis, the strong spatial coherence of the anomalies during storms, and the fact that the intensity of the anomalies increases with the intensity of the storms, I conclude that the anomalies are real and not a statistical artifact."*
>
> Raeder (2026), results and discussion [1 §2]

THE PAPER'S ARGUMENT

The random-time map is quiet

The map for randomly selected times shows "virtually no signal, just some noise" [1 §2].

OUR ANALYSIS

Why noise does this too

Random times scattered over many days average out far more weather than the 32 storm hours, bunched into five storms, that by our count make up the strongest winter level. So a random-time map looks quiet almost automatically. In the author's 2024 poster the random set was 10% of all possible hours [27]; if the paper kept that design, its random maps average thousands of hours. A fair comparison uses random composites of the same size, treated the same way [24 §3.4]; for storms, that means the same number of pseudo-storms, with the same lengths, in the same season.

THE PAPER'S ARGUMENT

The anomalies are spatially coherent

They are coherent across large areas, "especially for pressure and temperature" [1 §2].

OUR ANALYSIS

Why noise does this too

Weather is coherent over thousands of kilometers, and one Arctic outbreak can chill much of the continent. The five strong winter storms left 9 of our 10 stations colder than normal. Randomly timed five-storm sets put at least 9 of 10 stations on the same side of normal 30% of the time [2][3][5].

THE PAPER'S ARGUMENT

The anomalies grow with storm strength

"The magnitude of the anomalies increases with the intensity of the storms" [1 §2].

OUR ANALYSIS

Why noise does this too

Stronger levels contain fewer storms, and averages of fewer samples swing more, so larger anomalies at higher levels are what noise alone gives. The paper itself says the smooth, weak anomalies of its least active level, R1, are "likely due to the large number of storm hours in the R1 category." It also notes that some anomalies change sign between R2 and R3 [1 §2], which a simple dose–response would not produce.

3 · A CHECK WITH PUBLIC DATA OUR ANALYSIS

Ten weather stations show nothing that supports the paper's claims

We rebuilt the storm list from the same Dst index for 1958–2024 [2][3] and compared storm days with daily observations at 10 weather stations [4][5]. Each station result is set against 3,000 sets of randomly timed pseudo-storms, each set with the same number of storms and the same lengths in days, starting in the same season.

STEP 1

Storm days

A UT (Universal Time) day is a strong-storm day if its lowest hourly Dst is −200 nT or below, and a moderate-storm day if it falls between −100 and −200 nT, the paper's range for R3 [1 §2].

STEP 2

Station anomalies

Daily mean temperature and precipitation at 10 North American stations, with the linear trend and seasonal cycle removed, scaled by the day-of-year standard deviation [4][5].

STEP 3

Random storms

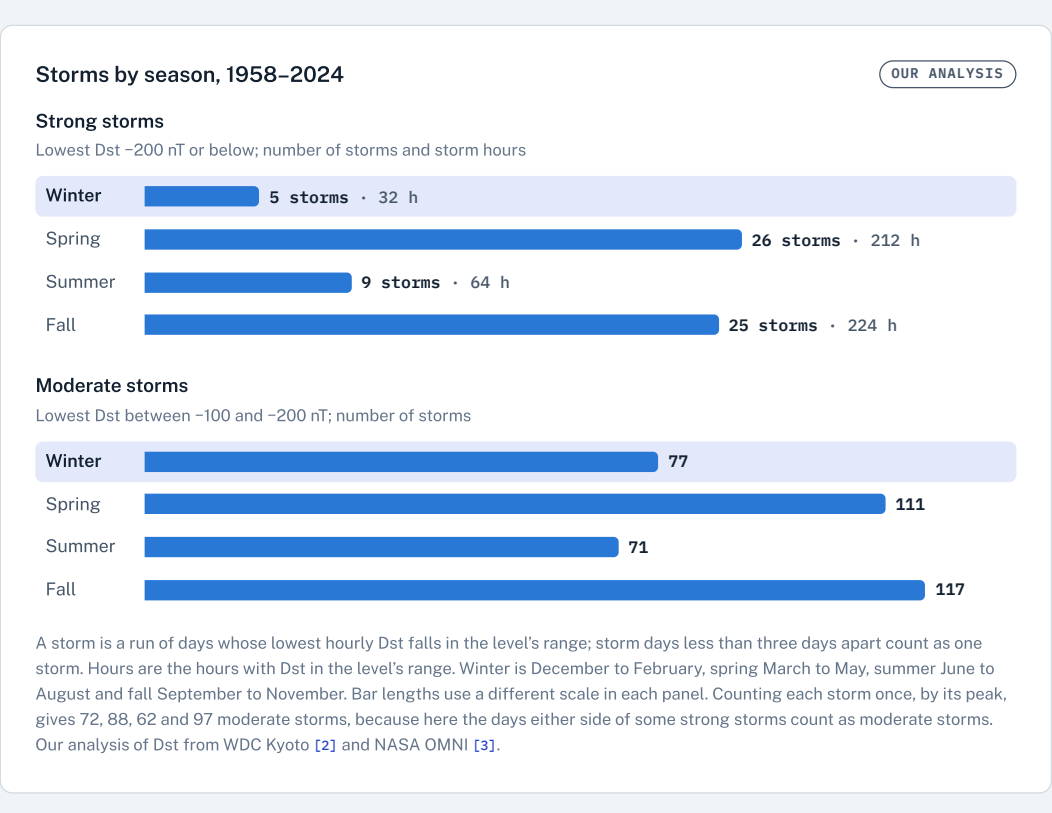
For each station and storm level, 3,000 sets of pseudo-storms with the same number of storms and the same lengths, each starting on a random day in the same season.

STEP 4

Compare

Where does the real storms' average fall among the random sets? Our p is two-tailed: twice the share of random sets at or beyond the real average, on its side of the spread.

How many storms there are


Storms by season, 1958–2024

OUR ANALYSIS

Strong storms

Lowest Dst −200 nT or below; number of storms and storm hours

Moderate storms

Lowest Dst between −100 and −200 nT; number of storms

A storm is a run of days whose lowest hourly Dst falls in the level's range; storm days less than three days apart count as one storm. Hours are the hours with Dst in the level's range. Winter is December to February, spring March to May, summer June to August and fall September to November. Bar lengths use a different scale in each panel. Counting each storm once, by its peak, gives 72, 88, 62 and 97 moderate storms, because here the days either side of some strong storms count as moderate storms. Our analysis of Dst from WDC Kyoto [2] and NASA OMNI [3].

OUR ANALYSIS

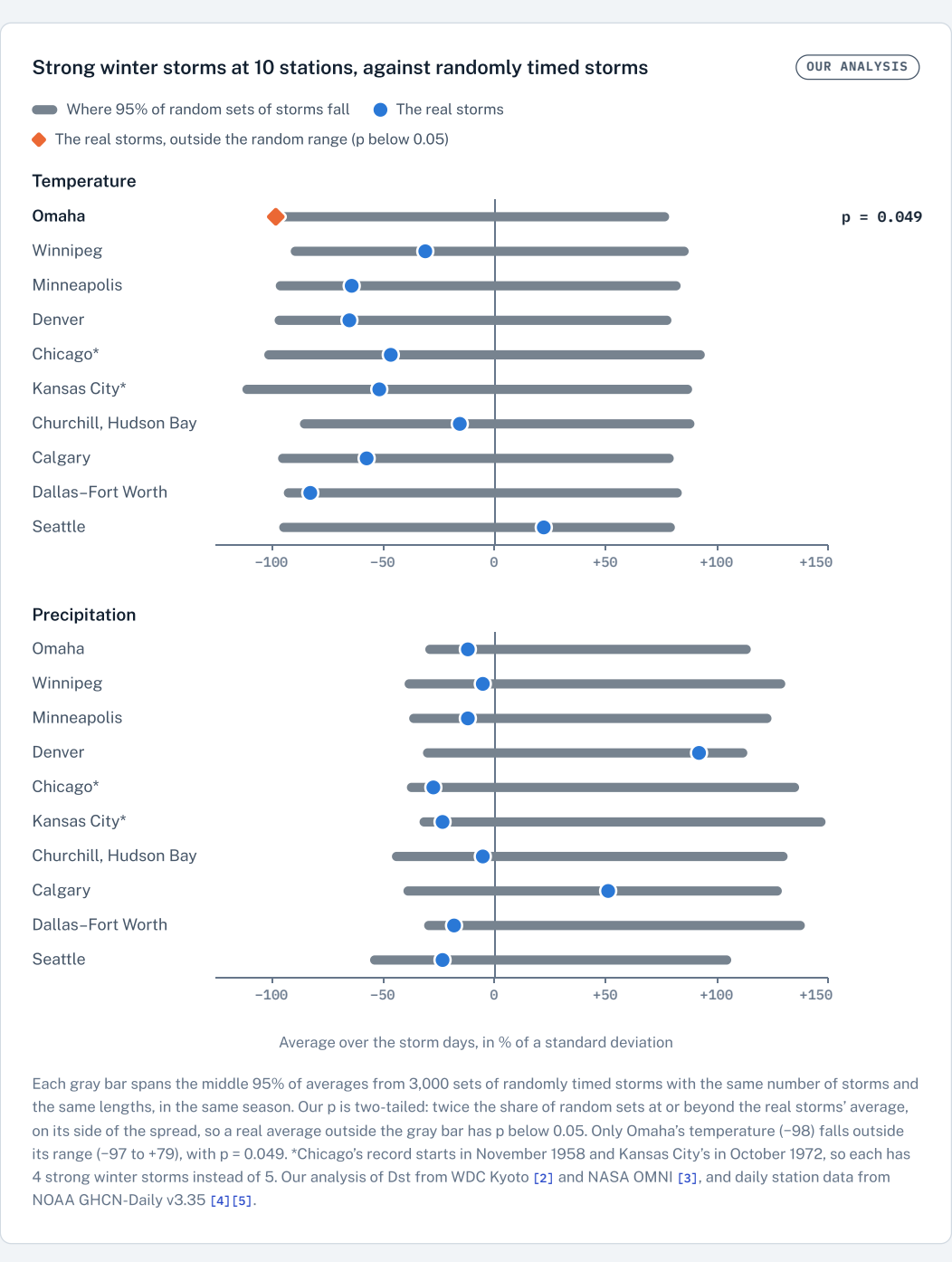
5 storms

The paper's 20 K figure and its winter precipitation result come from its strongest-storm winter maps [1 §2]. If winter means December to February, those maps can draw on just five storms in 1958–2024: February 1958, December 1980, January 1983, February 1986 and February 1992. That is 32 storm hours in 67 years [2][3].

The paper's exact season and year windows are in its supporting information, which we could not check. Other plausible windows give 4 to 6 storms (17 to 38 hours): counting 1957–2023, the years the author's 2024 conference poster used, adds a January 1957 storm, while taking winter as 30 days either side of the December solstice, as the poster also did, gives four [27].

Geomagnetic activity peaks near the equinoxes [26][1 §2], so winter (5) and summer (9) have far fewer strong storms than spring (26) and fall (25). The paper notes that this changes only the number of storm hours and should not by itself bias the results [1 §2]. Our point is about noise, not bias: fewer storms make chance anomalies larger. Quiet hours, by contrast, are plentiful: by our count, December–February 1958–2024 had about 110,000 hours with Dst between 0 and −50 nT, and about 112,000 below zero [2][3]. If the paper kept the thresholds of the author's 2024 poster (0, −50, −100 and −200 nT) [27], these are the likely bounds of its least active level, R1, in winter.

What 10 stations recorded during the strongest winter storms


Strong winter storms at 10 stations, against randomly timed storms

OUR ANALYSIS

Each gray bar spans the middle 95% of averages from 3,000 sets of randomly timed storms with the same number of storms and the same lengths, in the same season. Our p is two-tailed: twice the share of random sets at or beyond the real storms' average, on its side of the spread, so a real average outside the gray bar has p below 0.05. Only Omaha's temperature (−98) falls outside its range (−97 to +79), with p = 0.049. *Chicago's record starts in November 1958 and Kansas City's in October 1972, so each has 4 strong winter storms instead of 5. Our analysis of Dst from WDC Kyoto [2] and NASA OMNI [3], and daily station data from NOAA GHCN-Daily v3.35 [4][5].

TESTS BELOW P = 0.05

OUR ANALYSIS

1 of 40

Omaha temperature (p = 0.049), across 10 stations, 2 variables, and strong and moderate winter storms: about what chance alone predicts (2). Measured by distance from zero instead, 2 of 40, adding Denver precipitation [5].

STATIONS DRIER THAN AVERAGE

OUR ANALYSIS

8 of 10

during the five strong winter storms; Denver and Calgary were wetter. Randomly timed five-storm sets leave at least 8 stations drier 39% of the time [5].

FIVE RANDOM WINTER DAYS

OUR ANALYSIS

59–71%

of the time come out drier than average, depending on the station, because most winter days are drier than an average that a few wet days pull up [5].

Denver was wetter during the strongest storms, the opposite of the paper's claim, by 92% of a standard deviation. Almost all of that came from one snowy day, February 11, 1958, with 9.9 mm of precipitation (+562%) [5]: with five storms, single days decide the result.

Storm by storm

Average of the 10 stations, in % of a standard deviation. Under each date: the storm's lowest Dst and its hours at or below −200 nT.

STORM	TEMPERATURE	PRECIPITATION
Feb 11, 1958 −426 nT · 15 h	−51	+65
Dec 19, 1980 −240 nT · 6 h	−105	−23
Jan 10, 1983 −213 nT · 3 h	+63	+61
Feb 8–9, 1986 −307 nT · 7 h	−96	−20
Feb 9, 1992 −201 nT · 1 h	−9	−35

Averages over the stations with data (8 for February 1958). The 1992 storm reached −201 nT for one hour [2][3][5].

OUR ANALYSIS

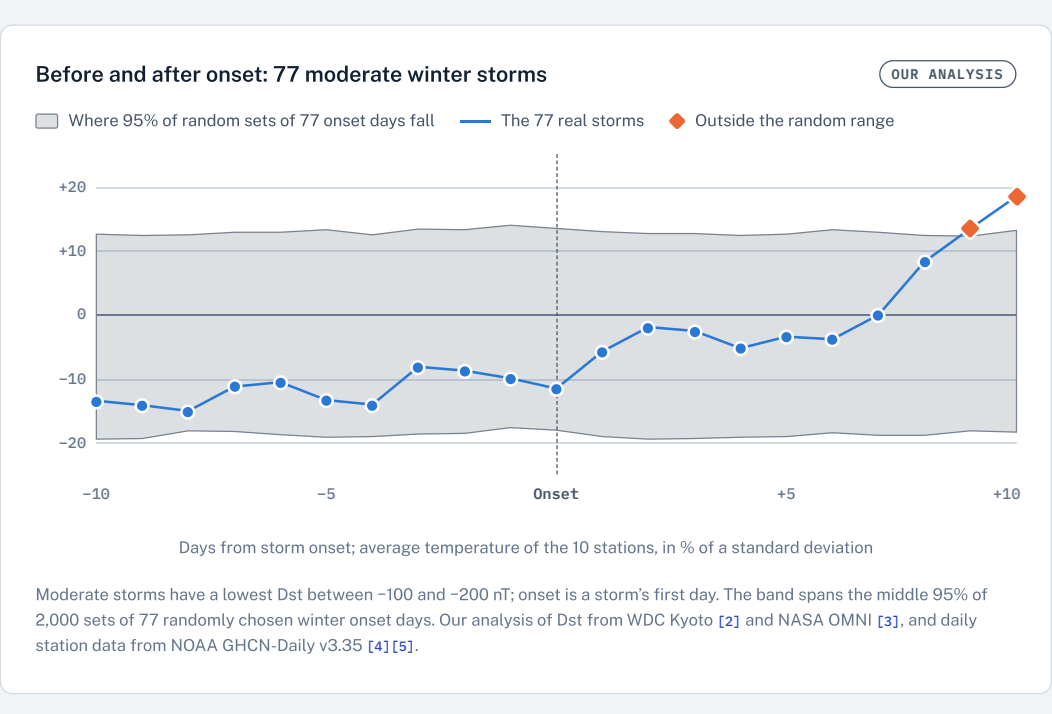
Ordinary winter weather

Two storms fell on cold snaps and one on a warm spell; two of the five were wetter than average across the stations [5].

On those cold-snap days several of our stations ran 10–13 K below normal, the coldest by 12.8 K (Denver, February 9, 1986) [5]. With only five storms, and 15 of the 32 storm hours on one day, February 11, 1958, a day or two of weather dominates any average [2][3].

Before and after storm onset

The paper's main text tests no time lags and lists time-delay effects as further work [1 §2]. We followed the stations' average temperature from 10 days before to 10 days after the start of each of the 77 moderate winter storms.


Before and after onset: 77 moderate winter storms

OUR ANALYSIS

Moderate storms have a lowest Dst between −100 and −200 nT; onset is a storm's first day. The band spans the middle 95% of 2,000 sets of 77 randomly chosen winter onset days. Our analysis of Dst from WDC Kyoto [2] and NASA OMNI [3], and daily station data from NOAA GHCN-Daily v3.35 [4][5].

The station average is already slightly below normal 10 days before the storms begin, by about 8% to 15% of a standard deviation and within the random range, and nothing changes at onset. The only days outside the random range are warm ones, 9 and 10 days after onset [5].

Precipitation in the other seasons

Strong storms and precipitation, by season

SEASON	STRONG STORMS	STATIONS DRIER	RANDOM MEDIAN	RANDOM SETS AS DRY OR DRIER
Winter	5	8 of 10	7	39%
Spring	26	5 of 10	6	74%
Summer	9	6 of 10	6	67%
Fall	25	6 of 10	6	55%

"Random median" is the median number of drier stations across sets of randomly timed storms; the last column is the share of those sets with at least as many drier stations as the real storms. Winter is from our main run; spring, summer and fall come from a separate run with its own random draws, which gives 38% for winter [5].

OUR ANALYSIS

The paper says strong storms also suppress precipitation in summer and, to a lesser extent, in spring and fall [1 §2]. At our stations we found no sign of it: in each of those seasons the number of drier stations was at or below what randomly timed storms typically give, and none of the 30 station tests fell below p = 0.05 [5]. Spring and fall, with 26 and 25 strong storms, are the informative tests: there a completely dry set of storm days would have reached p below 0.05 at every station [5].

What this check is and isn't

A plausibility test, not a replication

It uses 10 stations rather than the ERA5 grid, and daily rather than hourly data: station days are local calendar days, storm days are UT days. It also uses our own anomaly definition, with the linear trend and seasonal cycle removed and values scaled by the day-of-year standard deviation.

Too few winter storms to show drying

With five strong winter storms the check could not have confirmed drying either: even if all 10 stations had been drier, 4% of random sets do the same, and a completely dry set of storm days would reach p below 0.05 at only 2 of the 10 stations [5].

Shorter records, provisional recent data

Chicago's record starts in November 1958 and Kansas City's in October 1972, so each has 4 strong winter storms instead of 5, and 75 and 51 moderate ones. The Winnipeg, Churchill and Calgary records end in 2008–2012, so they have 68–69 moderate winter storms instead of 77 [5]. OMNI's Dst values are provisional from 2021 on, but no strong winter storm falls in those years [3].

Another definition of winter

With winter as 30 days either side of the December solstice, the strong set becomes 4 storms and 17 hours. Four of 40 tests then fall below p = 0.05, all of them wetter-than-normal precipitation during strong storms: three largely from one very wet storm day, November 24, 2001 (30 mm at Omaha, 27 mm at Minneapolis, 7 mm at Calgary), and Churchill's from November 21, 2003 (21 mm). Only 4 of 10 stations were drier [5].

4 · HEADLINE CLAIMS, CHECKED

The numbers are reported accurately; the conclusions go further than the evidence

The left column paraphrases the paper. The middle column draws on the paper, the studies cited here and our station check.

THE PAPER SAYS	WHAT THE EVIDENCE SHOWS	OUR VERDICT
Geomagnetic storms have a profound weather impact [1 Abstract][1 §1].	The main text reports no significance tests or confidence limits. It rests its case on the random-time map, spatial coherence and growth with storm strength [1 §2], all of which chance can produce (section 2). Our station check found 1 of 40 results below p = 0.05, about what chance predicts [5]. Short-term sun–weather claims have repeatedly weakened in new data or under stricter statistics [16 p. 200][23 Abstract][24 Abstract].	OVERSTATED The main text reports no test against chance.
Moderately strong storms induce changes that reach or exceed 50% of a standard deviation in every season [1 §2, Fig. 1 caption].	The 50% accurately describes the R3 maps, and is also the top of their color scale [1 §2]. But it is the largest value anywhere on a continent-wide map, and the main text reports no test of it [1 §2]. At our 10 stations, randomly timed storms matched to the moderate winter storms span about −33% to +28% of a standard deviation, and the real storms gave −18% to +21%, all inside their ranges [5]. Whether the paper's 50% lies beyond chance depends on how its anomalies are scaled and how many independent storms each average holds, both set out in its supporting information.	MISLEADING Size alone doesn't show an effect.
Strong storms suppress precipitation, at least in winter, and also in summer and, to a lesser extent, spring and fall [1 §2].	By our count the strongest winter level rests on about 5 storms, 2 of which were wetter than average across the stations. Eight of 10 stations were drier, which random five-storm sets do 39% of the time [5]. Five storms are too few for single-station tests to confirm drying either way; in spring and fall, with 26 and 25 strong storms, the stations were no drier than chance gives (section 3). ERA5 precipitation is a model forecast field, not an analyzed observation [7].	UNSUPPORTED No drying beyond chance at the stations.
The strongest storms induce winter temperature anomalies of up to about 20 K [1 §2, Fig. 2 caption].	The paper says the gap between such sizes and long-term averages is "consistent with the relatively rare occurrence of strong geomagnetic storms" [1 §2]. Rarity also means large chance anomalies: by our count, five December–February storms and 32 hours, 15 of them on February 11, 1958 [2][3]. Two storms fell on cold snaps (−105% and −96% of a standard deviation across the stations) and one on a warm spell (+63%) [5]; with so few storms, one or two outbreaks dominate the average.	MISLEADING Ordinary winter swings in a tiny sample.
Storm impacts are up to two orders of magnitude larger than the long-term global mean surface temperature effect of solar activity [1 Abstract].	The body is open that it compares "the largest spatially and temporally localized anomalies" with a global solar-cycle effect it puts at 0.1–0.2 K; the review it cites gives about 0.07–0.1 K [1 §2][10 §1 ¶4][10 §4.1 ¶98]. It also notes that against regional long-term averages of about 2 K the gap is one order of magnitude [1 §2]. The abstract's "up to" marks a maximum, but it doesn't say the storm figure is the largest local value on the maps, or that the gap shrinks to one order against regional averages [1 Abstract]. The ratio reflects averaging, not whether the storm anomalies are real.	MISLEADING Different scales in space and time.
The cosmic ray–cloudiness hypothesis is falsified by these results [1 Abstract][1 §2].	The paper's two direct reasons are that cosmic-ray drops are "delayed to the storm main phases," so their effects "should thus not show up as prominently in my results, if at all," and that anomalies appear with small and medium storms too. It adds that the direct-radiation and precipitation maps, and the lack of a latitude pattern, don't fit particle-driven cloud changes [1 §2]. All of these rest on the storm-hour anomalies, and by the first reason a storm-hour average is not where a cosmic-ray cloud effect would show; one was reported about a week after the drops [18 Abstract]. The main text doesn't test the anomalies against chance, and direct tests had already found no robust cloud response [19 Abstract][20 Abstract]. On particle effects in general the paper is careful: the lack of a latitude pattern "does not strictly rule out particle effects but makes these hypotheses less likely," and a particle-driven route through the stratospheric polar vortex "cannot be ruled out" [1 §2].	OVERSTATED This design can't test the hypothesis.
A top-down mechanism, directly through the ionosphere or through stratospheric chemistry and the polar vortex, appears more likely [1 Abstract].	The paper also says its results "do not directly implicate any specific mechanism" [1 §2]; the preference rests on arguing against particle effects with anomalies the main text doesn't test against chance. Its main text tests no time lags and lists them as further work, though its summary calls the impacts "immediate" [1 §2][1 Plain Language Summary]. The polar-vortex route typically reaches the surface over weeks [25 Abstract], while the maps average weather during storm hours; a direct route through the ionosphere could act faster, but the paper tests neither. Our 77 moderate winter storms show no change at onset (section 3). Top-down effects over weeks to seasons have some support (section 5); what is unsupported is that one explains anomalies during storm hours.	UNSUPPORTED Mechanism and timing untested.

How we rated: the verdicts are our assessment, on the site's standard scale. Overstated means the claim has some basis but claims much more than the evidence supports. Misleading means it contains something true but leaves a false impression. Unsupported means no evidence we could find backs it up, though it hasn't been strictly disproven.

5 · WHERE THIS SITS OUR ANALYSIS

The Sun clearly changes the upper atmosphere; quick effects on the weather below are contested

Solar activity certainly affects the upper atmosphere [10]. The debate is about which effects reach the weather we live in, and how quickly. The four tiers below are our grouping of 50 years of sun–weather research; the descriptions paraphrase the studies.

Well established

The upper atmosphere responds

Storms heat the thermosphere, which swells and raises drag on low-orbit satellites [8 Abstract][8 §1]. Energetic particles produce nitrogen oxides high in the polar winter atmosphere; these descend and destroy ozone [9 Abstract][10 §3.1.1]. Over the 11-year cycle, changing solar ultraviolet alters stratospheric ozone by a few percent and temperature by up to about 2 K [10 §3.1.1–3.1.2].

Supported, still debated

Surface patterns over seasons, in polar winter

Reanalysis data for 1957–2006 show polar winter surface temperatures differing by up to about ±4.5 K between years of high and low geomagnetic activity, though the authors could not conclusively show a physical link [11 Abstract]. A chemistry–climate model reproduced such patterns through particle-produced nitrogen oxides, stratospheric ozone loss, a more stable polar vortex and a positive Northern Annular Mode [12 Abstract].

Geomagnetic activity is also linked to a stronger polar vortex and a pressure pattern like the positive North Atlantic Oscillation (NAO) in December–February over 1948–2017 [13 Abstract], but the relationship has not been stable: it was weakly negative in the early 20th century and significantly positive since the 1970s [14 Abstract].

Contested

Effects on weather within days

The Wilcox effect, 1973

In Northern Hemisphere winters, the area of strong low-pressure troughs at the 300-millibar level (about 9 km up) shrank by about 10% around the times solar magnetic sector boundaries swept past Earth [15 Abstract], with the minimum about a day after the boundary [16 p. 200].

A 1978 re-test by Williams and Gerety found the response "no longer evident" in 1974–77 [16 p. 200]. A 2009 study using ERA-40 reanalysis for 1963–2002 found the effect again in the winters of both hemispheres. The exception was the Northern Hemisphere at the 500-millibar level, where the dip was weak in the low-volcanic-aerosol years after 1973 [17 Abstract].

Cosmic-ray drops and clouds, 2009

A 2009 study reported that low clouds held less liquid water after sudden cosmic-ray decreases: up to 7% less for the strongest events, at a minimum about a week later [18 Abstract].

Independent re-analyses found the cloud changes unrelated to the cosmic-ray decreases [19 Abstract], and no response of global cloud cover at any altitude or latitude [20 Abstract].

The Mansurov effect, 1974 on

First reported in 1974 [21]. Changes of about 8 nT in the dawn–dusk component of the solar wind's magnetic field go with high-latitude surface pressure changes of about 1–2 hPa, clearest over Antarctica [22 §1], peaking about a day later in the lower troposphere [22 Abstract].

A 2022 study using ERA5 found that, with tests suited to strongly autocorrelated data, the cyclic response offered as support has "a fairly high probability" of arising by chance [23 Abstract].

Raeder, 2026

Weather anomalies during geomagnetic storms across North America, from 67 years of reanalysis [1].

Reviewed on this page.

The method trap

Why the short-term claims keep splitting

A 2013 methods paper by Laken and Čalogović argued that conflicting results from composite (event-average) studies of solar activity, often sudden cosmic-ray decreases, and the atmosphere come from how the composites are built and analyzed. It showed that minor changes in method can make non-significant data look significant, and set out Monte Carlo methods for tests to guard against this [24 Abstract].

> *"...we also demonstrate how a seemingly significant false positive may be obtained from non-significant data by minor alterations to methodological approaches."*
>
> Laken and Čalogović (2013) [24 Abstract]

OUR ANALYSIS

The pattern, as we read it

The better-supported effects work over weeks to seasons, through the stratosphere, in polar winter [11][12][13]. Claims of weather effects within days to about a week have repeatedly weakened in new data or under stricter statistics [16][19][20][23][24]. Raeder's study belongs with the second group until it passes a matched random test.

6 · STRENGTHS, LIMITATIONS AND WHAT WOULD SETTLE IT OUR ASSESSMENT

Specific, checkable claims, still missing the tests that would settle them

Strengths

- Uses public data (ERA5 reanalysis, the Kyoto Dst index and NASA's OMNI data) [1 Availability Statement] and makes specific regional claims anyone can check.
- Includes a comparison against randomly chosen times [1 §2].
- Publishes all 125 maps, in its supporting information, not just the striking ones [1 §2].
- Is candid that "these results defy a simple explanation" and that they cannot yet confirm or rule out specific coupling processes [1 §1][1 §2].
- Proposes concrete follow-ups: separating flare-linked storms, studying single great storms and time delays, covering the whole globe, and using high-altitude reanalysis data [1 §2].

Limitations

- No significance tests or confidence limits in the main text [1 §2].
- By our count (December–February, 1958–2024) the strongest winter level rests on 5 storms and 32 storm hours [2][3].
- Hours are counted rather than storms [1 §2]. Because the levels are Dst ranges (R3 runs from −100 to −200 nT [1 §2]), the hours of one big storm can fall into several levels. The exact rule is in the supporting information.
- The main text has no lag analysis, so neither the "immediate" effects described in the summary [1 Plain Language Summary] nor the mechanism can be judged. The paper lists time-delay effects as further work [1 §2].
- ERA5 precipitation is a model forecast field, not an analyzed observation. ERA5 is less certain further back in time, especially before satellite data became plentiful around 1979, and where observations are sparse [6][7]. The paper chose North America partly because the reanalysis is best constrained there [1 §1].
- The availability statement points only to the ERA5 and Dst data and mentions no code or list of storm hours [1 Availability Statement].

What would settle it

01
Random pseudo-storms matched in number, length and season, with a significance test across the whole map

02
Lags from 10 days before to 10 days after storm onset

03
Leave-one-storm-out tests, to see whether any single storm drives a result

04
A split-period replication: 1958–1990 against 1991–2024

05
Precipitation checked against station records, not only reanalysis

06
The same storms tested over Europe and Asia

These tests are our suggestions; the paper itself proposes studying single great storms, time delays and the whole globe [1 §2]. Storm-time anomalies that beat matched random storms across the map, survive leaving out any single storm and hold up in both halves of the record would change our verdicts.

OUR ANALYSIS

Where our assessment could be wrong

We have read the paper's main text in full, but not its supporting information, which holds the methods, the ranges of most activity levels and the storm counts. Its random comparison may be better designed than the main text suggests. Our check uses 10 stations and daily data, so an analysis of the full ERA5 grid could find a signal the stations miss. And we have reviewed several weak sun–weather papers recently, which could prime skepticism; we tried to counter that by testing the specific claims with data.

7 · CONCLUSIONS

A hypothesis worth testing, not yet a finding

The author concludes

The author concludes that geomagnetic storms have "not only a significant, but a profound effect" on the atmosphere over North America, on a time scale of hours to days and varying by region and season [1 §1]. The paper finds particle precipitation a less likely cause [1 Abstract][1 §2], and says weather and climate models should be benchmarked against these results [1 §2].

It also acknowledges that "these results defy a simple explanation, but are in line with previous studies, where there is an overlap" [1 §2].

OUR ANALYSIS

Our conclusion

A serious, testable study whose central claim isn't established. By our count its strongest winter maps can draw on only about five storms, its main text reports no formal significance test [1 §2], and at 10 weather stations, winter storms left nothing beyond what randomly timed storms produce. Treat it as a hypothesis, in a field where short-term sun–weather claims have often faded in new data or under stricter statistics.

Our assessment and station check have not been reviewed by the paper's author.

8 · READ IT YOURSELF

Our code and data

Everything behind section 3, so you can check our work or extend it. The paper itself is open access [1].

PY **station_check.py**
Downloads the Dst and station data, rebuilds the storm list, and runs everything in section 3: the station tests, the coherence and dry-station figures, the lag chart, the other seasons and the solstice window · 38 KB

CSV **storms.csv**
All 441 storms in the check, both levels and all seasons, 1958–2024: first and last day, storm days, the UTC start and end of the hours in the level, hours, and lowest Dst with its hour · 42 KB [2][3]

JSON **station-check-results.json**
Every number in section 3, with the stations' record dates, data versions, settings, each station's values on the strong-storm days and the sensitivity checks · 59 KB [5]

Run it

Put `station_check.py` in an empty folder and run `python3 station_check.py`. It needs Python 3 with NumPy and pandas. The first run downloads about 200 MB into a `station_check_data` folder there: NASA's 184 MB OMNI file, 72 monthly pages of Kyoto Dst and 10 GHCN-Daily station files of about 13 MB in all. After the downloads the analysis takes about 30 seconds, and later runs reuse them. Results go to `station_check_results`: `station-check-results.json`, `storms.csv` and `station_tests.csv`, the 40 winter station tests. Both data sets are updated over time, so a later run can differ slightly from ours.

Sources

Bracketed numbers refer to this list; § marks a section, ¶ a numbered paragraph and p. a page of the source. In [1], §1 is the introduction and §2 the results and discussion; Abstract, Plain Language Summary and Availability Statement are its named parts. Links checked October 12, 2026.

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METHOD

How this was checked

On October 12, 2026, we checked every statement, number, quotation and citation on this page against its source: 104 items, checked against the paper's full main text, 26 other sources and a fresh run of our station check. We have not read the paper's 46 MB supporting information, which holds its methods, the ranges of most of its activity levels and its storm counts, so this page leaves out anything only that file could confirm. A second reviewer then read the built page against its sources and re-ran the station check on newly downloaded data; every number matched. Together the checks corrected a number of statements in the original infographic; the change log lists them.

Section 3 is our own analysis of public data: hourly Dst from WDC Kyoto [2] and NASA OMNI [3], and daily station data from NOAA GHCN-Daily, version 3.35 [4][5]. We re-ran it on data downloaded October 11, 2026, and every number on the original infographic reproduced exactly. We redrew the charts from the re-run's output, which corrected seven range bars that had been drawn 4–11% of a standard deviation off. Our p is two-tailed and based on percentiles. The infographic's p, the share of random sets at least as far from zero as the real storms, can't register unusual dryness, because random precipitation averages center below zero. The random comparisons use 3,000 sets of pseudo-storms per station test, 5,000 sets for the coherence and dry-station figures, 20,000 five-day draws per station for the dry-day figure and 2,000 sets for the lag chart. The script we host under Read it yourself produces every number in section 3, including the other seasons and the solstice window.

The verdicts and the items tagged "Our analysis" are our own assessment, built on the cited sources. Our assessment and station check have not been reviewed by the paper's author. The paper is open access under CC BY-NC-ND 4.0, which doesn't permit adapted versions, so we point to its maps rather than redraw them [1]; every chart here is our own analysis of public data.

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.
OVERSTATED	Has some basis but claims much more than the evidence supports.
UNSUPPORTED	No evidence we could find backs it up, though it hasn't been strictly disproven.

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 12, 2026	Published on factchecked.science after a full check against the sources, including the paper's full main text, a re-run of our station check that reproduced every number, and an independent review of the built page. Changes from the infographic: our p is now two-tailed, so 1 of 40 station tests falls below p = 0.05, where the infographic said 2 of 40 (by distance from zero); Denver's precipitation, at p = 0.085, sits inside its random range, and the charts mark only Omaha's temperature. We added that five strong winter storms are too few to confirm drying at single stations, and that Denver's wet result comes almost entirely from one day. Seven range bars were redrawn from the re-run. Chicago's record also starts late (November 1958), so it has 4 strong winter storms, like Kansas City. The storm rule is restated (storm days less than three days apart count as one storm), and the five strong winter storms now carry their assumptions (December–February, 1958–2024; other windows give 4 to 6). The 50% and 20 K claims are restated as the storm-induced changes the paper describes, and the 50% is compared with our moderate storms. The paper rules out only the cosmic ray–cloudiness hypothesis, for more reasons than the infographic gave, and calls particle effects "least consistent" with its results, so we no longer say it rules out particle precipitation or that its abstract overstates its body. The paper puts the solar cycle's effect on global temperature at 0.1–0.2 K; the review it cites gives about 0.07–0.1 K. We removed the nT ranges given for three of the paper's four activity levels, which appear only in its supporting information, limited statements about tests and lags to the paper's main text, and corrected the authors of the 1978 Nature re-test (Williams and Gerety), the exception in the 2009 Wilcox-effect study (the Northern Hemisphere at 500 mb, in low-aerosol years after 1973) and "well over 100,000" winter hours (about 110,000). Restated the verdicts on our standard scale: Not established became Overstated (profound impact) and Unsupported (precipitation), Accurate, not evidence became Misleading (50% of a standard deviation), Not evidence of an effect became Misleading (20 K), Misleading comparison became Misleading, Not supported became Overstated (cosmic ray–cloudiness) and Speculative became Unsupported (top-down mechanism).
Sep 30, 2026	Analysis compiled from the paper as published May 19, 2026, with a station check on public data, as a one-page infographic.

Fact-Checked Science is independent. It isn't affiliated with the channels, presenters or authors whose claims it checks.

Last updated Oct 12, 2026