☑ **Fact-Checked Science**

PAPER CHECK · CLIMATE

Re-dated Russian bogs: no clear cooling at solar minima, and dates less precise than stated

A 2026 paper in *Radiocarbon* re-dates temperature records from three bogs in north-western Russia and concludes that their short cold and warm phases are synchronous with solar activity, which, it suggests, is one of the main causes of short-term Holocene climate change [1 Abstract]. Tested against random placement with the phases and grand solar minima of the study's 2022 version, every cold phase does overlap a minimum, but the warm phases do too, the minima fall in cold and warm phases about as often as the time each covers predicts, and the bogs are not detectably colder at the minima [3][4 Tables 4–5]. We could not read the paper's main text, which is paywalled; we read its abstract, its two supplementary files and the 2022 Russian-language version with the same tables [2][4]. The re-dating was worth doing, but the one model run the supplement prints fails its own software's checks [2 pp. 7–10][9].

By Fact-Checked Science · Published October 26, 2026

OUR ANALYSIS marks our own reasoning and calculations, including every count from the supplement's tables and every test of the match against chance, and the verdicts are our assessment. Everything else comes from the numbered sources. The paper's main text [1] could not be read, so Abstract is its abstract on Cambridge Core; [2] and [3] are its two supplementary files, cited by page and table; [4] is the 2022 Russian-language version of the study, cited by its printed pages, and quoted in our translation.

A weak match with the Sun that warm phases share too, and dates less precise than they look

OUR ASSESSMENT

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grand solar minima on the 2022 version's list fall in its warm phases, five in the warmest; 6 fall in its cold phases, where their share of the time predicts 4.7, by our analysis [4 Tables 4–5]

−0.10 °C

the three bogs' temperature at those minima, against their own trend: a difference random dates give 8% of the time, and one that all but vanishes with a complete list of minima, by our analysis [3][4 Table 5][10 Table 1]

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dates in the one model run the supplement prints fall below the 60% agreement that the OxCal program's manual expects [2 pp. 7–10][9]

THE PAPER'S CLAIMS

TRUE

Short swings in atmospheric carbon-14 can shift dates by up to 300 years

The paper: they "could lead to a dating error of up to 300 years" [1 Abstract]

The 2022 version's example is a flat stretch of the calibration curve, where radiocarbon ages of 2,430–2,500 years cover about 300 calendar years [4 p. 136]. In IntCal20 they cover 264, from 2,701 to 2,437 years ago [8], by our analysis. The bogs' 1990s chronologies used uncalibrated ages, so re-dating them is worthwhile [4 p. 137]. See section 2.

OVERSTATED

Modelling gave a refined calendar chronology

The paper: "Using this model, a refined calendar chronology was established." [1 Abstract]

The one run the supplement prints, for one bog, gives ages to within 5–25 years where the dates themselves allow a median 413, and OxCal flags 32 of its 45 dates, and the model as a whole, as in poor agreement [2 pp. 7–10][9]. Table S1 reports an earlier run instead, whose ages fit the dates better but whose diagnostics aren't printed; and its stated precision, a median ±35 years, is far finer than the 200 years a typical sample took to form [2 pp. 7–10][3 Table S1], by our analysis. See section 2.

PARTLY TRUE

The three bogs swung together, in step with other records

The paper: its chronology "demonstrates the synchronicity of short-term climate fluctuations" and "In most cases, it agrees well" with other records [1 Abstract]

Four of the six main cold events in a widely cited review fall in the 2022 version's cold phases, more than chance would put there (chance does as well 3% of the time); two, about 8,200 and 6,300 years ago, fall in its warm phases [14][4 Table 4]. Between the bogs, phase ages differ by 100–250 years, so synchrony can be claimed only to within a couple of centuries, and short-term swings move together beyond chance for one pair of the three, by our analysis [4 Table 4][3]. See section 3.

OVERSTATED

Cold phases coincide with grand solar minima

The paper: "The synchronicity of short-term climate fluctuations and variations of solar activity in the Holocene has been established" [1 Abstract]

In the 2022 version the phases are set beside the minima "within the dating error" (our translation), with no statistic or test against chance [4 p. 157, Table 4]. Tested with its phases and list, every cold phase does overlap a minimum, which random placement manages only 4% of the time; but allow 100 years, about the dates' own error, and chance does almost as well (13%). Warm phases overlap minima as reliably, the minima fall in cold and warm phases about in proportion to the time each covers, and the bogs are not detectably colder at the minima, by our analysis. Some basis, then, but far from established. See section 4.

OVERSTATED

Solar activity is a main cause of short Holocene climate swings

The paper, of the synchronicity it reports: "it suggests that changes of solar activity are one of the main causes of short-period climate fluctuations in the Holocene" [1 Abstract]

A solar influence on Holocene climate is plausible and widely studied [19][12], and one review counts low solar activity among the processes that probably played a major role in Holocene cold events [14]; over the last millennium its effect was probably small [17][18]. The abstract only suggests a main solar cause, but it rests the suggestion on a synchronicity this study's data don't establish, and the 2022 version notes high solar activity during its coldest phase [4 p. 149]. See section 6.

1 · WHAT THE STUDY DID

Bog dates from the 1990s, re-dated and set beside temperatures read from pollen graphs

Khikmat Arslanov and four colleagues, at St Petersburg State University, the Ioffe Institute in St Petersburg and the Sobolev Institute of Geology and Mineralogy in Novosibirsk, re-dated radiocarbon dates measured in the 1990s on three raised bogs in north-western Russia, paired them with temperatures reconstructed from pollen, and compared the cold and warm phases they found with records of solar activity [1][4 pp. 135–138]. The paper appeared online in *Radiocarbon* on October 19, 2026 [1][6].

What we could read: the abstract, the supplement and the 2022 version

The paper's main text is behind a paywall. Its Cambridge Core page shows the abstract and the references, with "Article purchase" marked "Temporarily unavailable", and we found no other copy [1]. So we read the abstract, the two supplementary files, which are free [2][3] (a second copy of the first, from a separate download, matched ours byte for byte), and an earlier Russian-language version of the same study, from 2022, through the Internet Archive's copy, because the journal's own site didn't answer [4].

That version's Tables 1–3 are, value for value, the 2026 paper's Tables S1–S3, and it reaches the same conclusion [4][3]. Where this page speaks of the study's phases, its list of grand minima or its examples, it means those of the 2022 version; the 2026 main text may differ. Where that would change a verdict, the page says so: claims 2, 3 and 4 would need another look if the main text reports a test against chance, other phases or other ages. If you have the article, please tell us through the correction form, and we will revise the page.

The data

146 dated samples from three raised bogs: Nikolsko-Lyutinskoye in the Novgorod region (45), Shirinsky Mokh in the Leningrad region (53) and Sambalskoye in southern Karelia (48) [3 Tables S1–S3][4 p. 137]. Each is a slice of peat, most of them 10 cm thick, dated by radiocarbon in the 1990s [4 p. 136][7 p. 28].

For each slice the tables give its radiocarbon age, its calibrated age, its “modelled” age and ΔT, how far mean annual temperature then differed from today’s, in °C [3]. ΔT was reconstructed from the slice’s pollen by V. A. Klimanov’s statistical method, whose error is given as ±0.6 °C [7 p. 40], and drawn in the 1990s as graphs against radiocarbon age; the new study read the values off those graphs [1 Abstract][4 p. 138].

An earlier version of the same study

In 2022 four of the five authors published the study in Russian, in *Uchenye Zapiski Kazanskogo Universiteta*, under almost the same English title, with the same Tables 1–3 and the same conclusion [4]. The 2026 paper’s reference list, as deposited with Crossref, doesn’t include it [6]; we could not check whether the main text mentions it. On this page it is the version of the study we could read in full, and we quote it in our own translation.

STEP 1

Re-date

Each bog’s dates go into an age–depth model in the OxCal program, which ties them together by depth: the P_Sequence model, the paper’s “Bronk Ramsey’s model” [1 Abstract][4 p. 138][9].

STEP 2

Read the temperatures

ΔT values are read off the 1990s graphs and paired with each slice’s modelled age [1 Abstract][4 p. 138].

STEP 3

Pick the phases

Cold and warm phases are picked from the ΔT values and pooled across the three bogs into one list [4 Table 4].

STEP 4

Compare with the Sun

The phases are set beside lists of grand solar minima and maxima and records of carbon-14 and beryllium-10, and judged without any statistic, “within the dating error” (our translation) [4 p. 157, Tables 4–6].

What we could not read, and so do not rate

QUESTION	STATUS
The 2026 main text’s list of phases and its comparison with the Sun	Unverified; we use the 2022 version’s [4 Tables 4–6]
Whether the main text tests the match against chance or reports any statistic	Unverified; the 2022 version reports none [4]
Which ages and which calibration curve the main text uses	Unverified; see section 2
Whether the main text mentions the 2022 version; its funding, competing interests, received and accepted dates	Unverified; the 2022 version was funded by the Russian Foundation for Basic Research [4 p. 158]
Journal, date, authors, licence, abstract, references and the two supplementary files	Known [1][2][3][6]

2 · THE DATING

Re-dating was worth doing, but the model run the supplement prints doesn’t fit its own dates

A radiocarbon age has to be converted into a calendar age with a calibration curve built from tree rings; where the curve runs flat, one radiocarbon age matches centuries of calendar time [8]. The authors tied each bog’s dates together with OxCal’s P_Sequence model, which assumes the peat grew in order, deeper being older [4 p. 138][9].

THE 2022 VERSION’S EXAMPLE PLATEAU

OUR ANALYSIS

264 years

of calendar time for radiocarbon ages of 2,430–2,500 years in IntCal20; the 2022 version says about 300 [8][4 p. 136]

DATES IN POOR AGREEMENT

OUR ANALYSIS

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in the supplement’s model run, 14 of them at 0%, counted from its table [2 pp. 7–10]

TABLE S1 AGAINST THAT RUN

OUR ANALYSIS

141 years

the median gap between the two sets of modelled ages for the same 45 samples, up to 483 [2 pp. 7–10][3 Table S1]

A real problem, worth fixing

OUR ANALYSIS

The 2022 version gives its example: radiocarbon ages of 2,430–2,500 years spread over about 300 calendar years, 2,670–2,370 years ago, so a slice of peat formed in 300 years can show almost the same radiocarbon age throughout [4 p. 136]. IntCal20, the current calibration curve, agrees: ages of 2,430–2,500 years cover calendar ages from 2,701 to 2,437 years ago [8]. The phases these bogs were assigned in the 1990s were dated in uncalibrated radiocarbon years [4 p. 137][7 p. 42], so re-dating them is a sensible step, and claim 1 holds.

The one model run the supplement prints

What the supplement shows

Supplementary file 1 is “P_Sequence modeling of 14C data for the Nikolsko-Lyutinskoye bog”: the OxCal code, the plot and the table of results of one run, made with OxCal 4.4.4 and IntCal20 and dated “6/4/26” [2 pp. 1–10]. The code fixes the model’s stiffness, k, at 700 events per centimetre [2 p. 1]. The other two bogs have no printout [2].

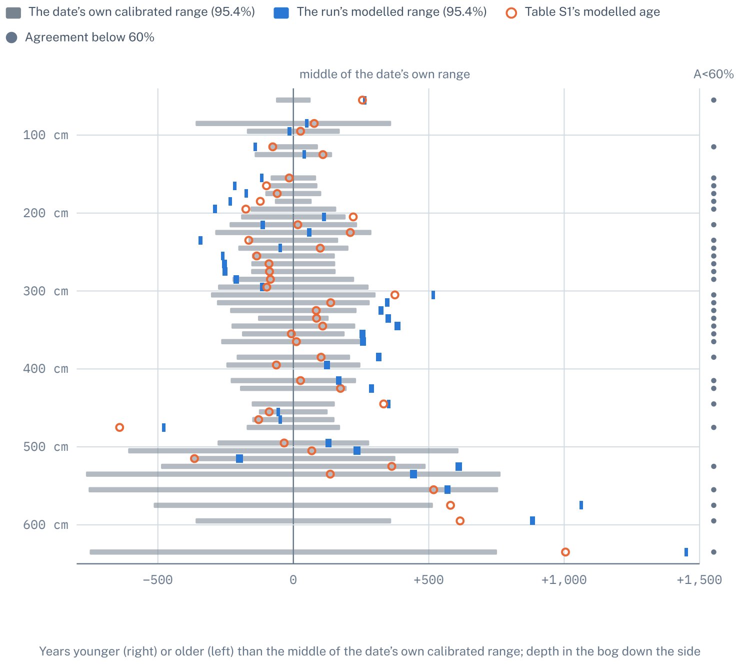
What OxCal checks

For each date, OxCal reports an agreement index, A, which “should usually be over 60%”, and for the model as a whole two more, shown in the header of its table, with the same threshold; the manual warns that “it is very easy to construct a model which is clearly at variance with the observational data” [9].

On k it says: “For sedimentary sequences the ‘event scale’ is typically in the 1mm-1cm range”, a k of 1–10 per centimetre, and that a high enough k makes the model nearly the same as one with perfectly uniform growth [9].

The supplement’s run, date by date, beside Table S1

OUR ANALYSIS



Nikolsko-Lyutinskoye, 44 of the 45 dates; the youngest, at 51 cm, has a calibrated range that runs off the end of the curve. Our chart of the numbers in the OxCal table the supplement prints and in Table S1; no figure from the paper is redrawn [2 pp. 7–10][3 Table S1].

OUR ANALYSIS

The run doesn’t fit its own dates

In this run 32 of the 45 dates fall below the 60% that OxCal expects, 14 of them at 0%, and both model-wide indices in the table’s header read 0% [2 pp. 7–10][9]. For 25 of the 45 dates, the modelled age lies outside the range the date itself allows at 95.4% probability; the deepest, LU-3505, is calibrated to 14,948–13,444 years ago and modelled at 12,749–12,743 [2 p. 7].

The modelled ranges are 5–25 years wide, against a median 413 for the dates’ own ranges. A model with k = 700 per centimetre, 70 to 700 times the values the manual gives as typical, is close to rigid, and narrow ranges that miss many dates are what such a model gives [2 p. 1][9]. The main text may explain the choice; we couldn’t read it.

OUR ANALYSIS

Table S1 isn’t this run

Tables S1–S3 repeat the 2022 tables value for value, and the 2022 ages came from an earlier OxCal version with the earlier curve, IntCal13 [3][4 pp. 138–139]. For the same 45 samples, Table S1’s modelled ages differ from this run’s by a median 141 years, by more than 100 for 34 of them, and by 483 for LU-3499: 11,589 years in Table S1, 11,109–11,103 in the run [2 p. 7][3 Table S1].

The 2022 version says the calibrated ages of most samples agree with the modelled ages within two standard errors [4 p. 138]; in Tables S1–S3, 106 of the 145 do, and Table S1’s ages sit inside the dates’ own IntCal20 ranges for 33 of 44 dates, against 19 for the printed run [3][2 pp. 7–10]. That earlier run’s agreement indices are not printed. The 2026 paper’s reference list includes IntCal13 but not IntCal20 [6]; which ages the main text uses, we couldn’t check.

OUR ANALYSIS

Precise to decades, but each slice took centuries to form

Tables S1–S3 give the modelled ages a median uncertainty of ±35 years, and 63 of the 145 are ±30 or less [3]. Yet by those same ages, each dated slice took a median 195 years to form, and one about 670. The authors write that where peat grew 0.29 mm a year, a 10-cm slice formed over 345 years, and its ΔT value is “a smoothed average over so long an interval” (our translation) [4 p. 143]. All 20 grand minima on the 2022 version’s list lasted 30–160 years [4 Table 5]. A sample can’t date a decades-long event more finely than the centuries it averages.

Claim 1 is True. Claim 2 is Overstated: the re-dating is a real step, and the tabled ages pass the authors’ own check, but the one model the supplement shows fails its own diagnostics, the tables come from an earlier run whose diagnostics aren’t shown, and the precision claimed is far finer than the samples allow.

3 · THE CLIMATE PHASES

Nine cold and six warm phases, with no stated rule for their limits, pooled across the three bogs

The 2022 version lists the phases in its Table 4, with each bog’s ages and the pooled “limit values” used for comparison [4 Table 4]. It says the three bogs’ phases agree, “in most cases”, within an error of 200–250 years (our translation) [4 p. 143].

The phases, as the 2022 version’s Table 4 gives them

PHASE (OUR TRANSLATION)	KIND	YEARS BEFORE 1950	ΔT, °C
Little Ice Age cold phases	Cold	330–120, 614–420, 890–650	−0.42 to −1.6
Medieval warm stage	Warm	1423–920	+0.13 to +1.30
Subatlantic cold stage	Cold	1619–1210	+0.19 to −0.86
Roman warm period	Warm	2344–1730	+0.34 to +1.40
Cooling at the Subatlantic–Subboreal boundary	Cold	2820–2410	+0.04 to +0.50
Subboreal warm stage	Warm	4409–3001	+0.96 to +2.0
Cooling at the Subboreal–Atlantic boundary	Cold	4869–4533	−0.22 to −1.10
Warmest stage of the Atlantic period	Warm	6768–4964	+0.64 to +2.20
Atlantic cold phase	Cold	7340–7190	0 to +0.2
Early Atlantic warming	Warm	8767–7439	+1.0 to +1.87
Cooling at the Atlantic–Boreal boundary	Cold	9397–9085	−0.50 to −2.50
Boreal warming	Warm	10205–9420	+1.0 to −1.9
Cooling at the Boreal–Preboreal boundary and in the Preboreal	Cold	11589–10260	−3.0 to −3.7

The pooled “limit values”, with the ΔT range the table gives for each pooled phase and its years as it prints them [4 Table 4]. ΔT is relative to today, so a “cold” phase can be warmer than today but cooler than its neighbours. The 2022 text gives slightly different limits for three phases, 4869–4340, 1584–1210 and 6368–4960 years ago [4 pp. 143, 146, 151]; with those, 7 of the 20 minima fall in cold phases against 5.1 expected, which chance gives 22% of the time, by our analysis.

OUR ANALYSIS

Do the three bogs move together?

Not demonstrably. Within a phase, the bogs’ own ages often differ by 100–250 years, so synchrony can be claimed only to within a couple of centuries: the three Little Ice Age cold samples are at 253, 614 and 890 years ago in one bog, 120, 420 and 650 in another and 331 and 576 in the third [4 Table 4]. Taking each bog’s ΔT, removing its slow trend with a 1,500-year running mean and correlating what is left, only one pair of the three moves together beyond chance [3]:

PAIR	R	CHANCE
Nikolsko-Lyutinskoye and Sambalskoye	0.43	$p = 0.04$
Nikolsko-Lyutinskoye and Shirinsky Mokh	0.05	$p = 0.35$
Sambalskoye and Shirinsky Mokh	0.17	$p = 0.14$

With a 1,000-or 3,000-year running mean the picture is the same. Dating errors would weaken these correlations even if the swings were synchronous, so this shows that the synchrony is not demonstrated, not that it is absent. The authors note that the agreement is clearer where peat grew faster than 0.4–0.5 mm a year [4 p. 146].

OUR ANALYSIS

Against other records

A widely cited review of Holocene temperature, moisture and glacier records analysed six main cold events of the last 10,000 years, about 8,200, 6,300, 4,700, 2,700, 1,550 and 550 years ago; it found no regular cycle, and conditions during each event that varied greatly from place to place [14]. Four fall in the 2022 version’s cold phases, more than chance would put there: shifting the six together at random puts four or more in those phases 3% of the time, by our analysis. Two do not: the 8,200-year event, which the 2022 version itself discusses in records from Finland, Estonia and Latvia [4 p. 148], falls in its “early Atlantic warming”, and the 6,300-year event in its warmest stage [4 Table 4].

Two of the cold phases never fall below today’s temperature: ΔT stays between +0.04 and +0.50 °C in 2820–2410 and between 0 and +0.2 °C in 7340–7190 [4 Table 4]. Each rests on one to three samples per bog, 0.6–1.5 °C below the neighbouring samples, one to two and a half times the ±0.6 °C error of a single value [3][7 p. 40]; at Shirinsky Mokh the lowest value in 2820–2410, +0.12 °C, is barely below the next sample, +0.17 °C, which the table’s pooled limits put in the Roman warm period, by our analysis.

Claim 3 is Partly true: the bogs share the broad Holocene pattern, and the cold phases agree with four of six main cold events elsewhere, more than chance would give; but two of those events fall in warm phases, and the bogs’ own short-term synchrony is shown for one pair only.

4 · THE MATCH WITH THE SUN

Cold phases do overlap grand minima, but so do warm ones, and the bogs are not detectably colder at the minima

The 2022 version sets its phases beside a list of grand solar minima and maxima, spells of decades to a century or more of unusually low or high activity, compiled from Usoskin and colleagues (2007) and Inceoglu and colleagues (2015), and beside carbon-14 and beryllium-10 records, and judges the match “within the dating error” (our translation) [4 p. 157, Tables 4–6][10][11]. It gives no statistic and no test against chance [4].

In the authors’ words

The 2026 abstract, which only suggests a main solar cause; the 2022 version’s English abstract, which concluded that climate depends mainly on the Sun; and the 2022 conclusion, in our translation.

> *“The synchronicity of short-term climate fluctuations and variations of solar activity in the Holocene has been established, and it suggests that changes of solar activity are one of the main causes of short-period climate fluctuations in the Holocene.”*
>
> Arslanov et al. (2026) [1 Abstract]

> *“It was concluded that short-term climate change depends mainly on variations in solar activity, which is important for predicting and modeling climate shifts.”*
>
> Arslanov et al. (2022), English abstract [4 p. 162]

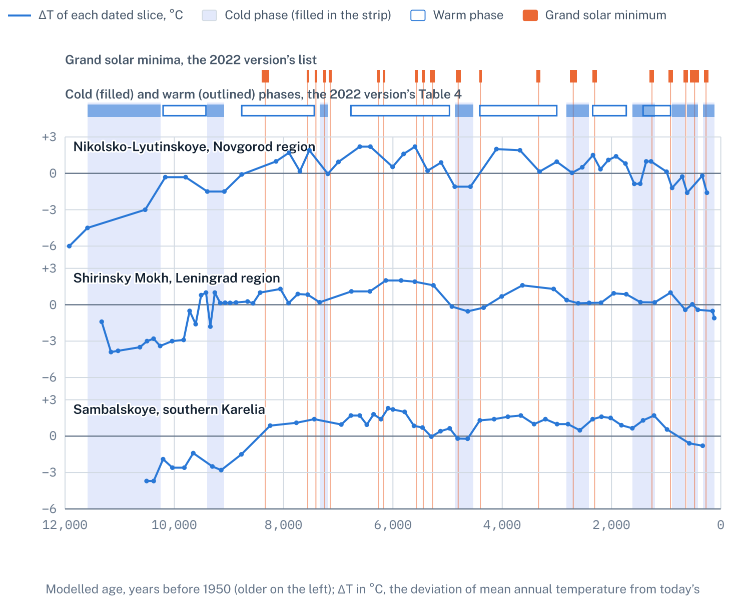
> *“In most cases a correlation is observed between the chronology of the cooling phases and minima of solar activity of similar age throughout the Holocene, but the clearest correlation is observed over the last few thousand years.”*
>
> Arslanov et al. (2022), our translation [4 p. 157]

How the comparison was made

Table 4 of the 2022 version sets each phase beside a “cosmogenic” age: for example, the cold stage of 1619–1210 years ago beside a grand minimum at 1310 ± 40, and the warmest Atlantic stage beside four grand maxima [4 Table 4]. Those ages count years before 2000, while the phases count years before 1950, an offset of 50 years; counted both from 1950, the table pairs phases with minima up to 133 years outside them, and the coldest phase, 11,589–10,260 years ago, with an interval that lies wholly outside it, 10,250–10,100 years ago. Of the three Little Ice Age phases it says that, “taking into account the sources of dating error given above”, they “can be correlated with the well-established minima of solar activity” of Maunder, Spörer and Wolf (our translation) [4 p. 144].

The three bogs, the 2022 version’s phases and its grand solar minima

OUR ANALYSIS



Our chart of the numbers in Tables S1–S3 and in the 2022 version’s Tables 4 and 5; no figure from the paper is redrawn [3][4 Tables 4–5]. The 2022 version’s list of minima ends 8,335 years ago. One sample older than 12,000 years, at Nikolsko-Lyutinskoye, is off the chart.

Our test against chance

STEP 1

Rules first

We wrote the rules into our script before scoring: the 2022 version’s phases and 20 minima, no margin or a margin of 250 years, the top of the 200–250 years within which the authors say their bogs’ phases agree, and, as a check, Usoskin and colleagues’ complete list of 27 grand minima [4 p. 143, Tables 4–5][10 Table 1]. Two checks came after the first run without changing these rules, the bogs’ synchrony and the “as few or fewer” count, and after a fresh review a scan of margins and the counts of sections 2 and 3, with separate random draws.

STEP 2

The same phases, placed at random

Does each cold phase contain a minimum? We moved all the phases together by a random offset, keeping their spacing, and also one by one, 20,000 times each, with margins from 0 to 250 years.

STEP 3

Where the minima fall

Do the minima fall in cold phases more often than the time those phases cover? We moved the whole list of minima, keeping its clusters.

STEP 4

Temperatures at the minima

Is ΔT lower at the minima than at random dates, once each bog’s slow trend is removed? And does it follow the Sun’s brightness, reconstructed by Steinhilber and colleagues [12]?

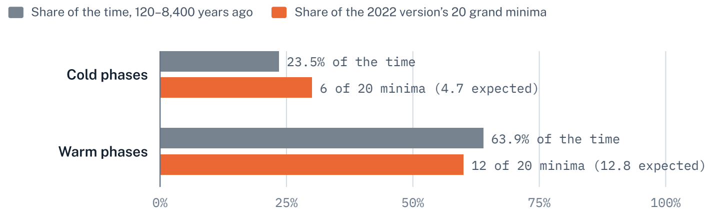
The tests, side by side

TEST	THE STUDY’S DATA	CHANCE	HOW OFTEN CHANCE DOES AS WELL
Cold phases holding a minimum, strict overlap	**7 of 7**	**4.3 on average**	**4%**
The same, with a margin of 100 years, about the dates’ own error	7 of 7	5.5	13%
The same, with 133 years, the widest gap the 2022 version’s Table 4 accepts	7 of 7	5.8	20%
The same, with 250 years, the agreement it claims between the bogs	7 of 7	6.6	60%
Usoskin’s 27 minima, strict overlap (nine cold phases)	9 of 9	6.0	6%; 2% placing the phases one by one
Warm phases holding a minimum, strict overlap	5 of 5	4.7	68%
Minima inside cold phases (23.5% of the time)	**6 of 20**	**4.7**	**32%**
Minima inside warm phases (63.9% of the time)	**12 of 20**	**12.8**	**50% as few or fewer; a solar cause predicts fewer**
Usoskin’s 27 minima inside cold phases (31.3% of the time)	8 of 27	8.4	67%
ΔT at the 20 minima, 1,500-year trend removed	**−0.10 °C**	**+0.01 ± 0.09 °C**	**8%**
ΔT with a 1,000-or 3,000-year trend removed, the 20 minima	−0.08 / −0.14 °C		11% / 6%
ΔT at Usoskin’s 27 minima, 120–11,600 years ago	−0.01 °C	0.00 ± 0.05 °C	41%
ΔT at the 22 of them in the same window as the 20	−0.03 °C	+0.02 ± 0.06 °C	28%
Correlation of ΔT with solar irradiance, 120 samples	r = 0.03	spread ±0.11	38%

Our analysis of the paper’s Tables S1–S3 and its 2022 version’s Tables 4–6, with Usoskin and colleagues’ list and Steinhilber and colleagues’ irradiance record [3][4 Tables 4–6][10 Table 1][12]. 20,000 random draws per test, 5,000 for the correlation; the scan of margins and the same-window check use separate draws. The window is 120–8,400 years ago with the 2022 version’s 20 minima and 120–11,600 with Usoskin’s 27. For grand maxima, over 120–8,800 years ago: all five warm phases in that window hold one, which chance gives 17% of the time, and 1 of 13 falls in a cold phase, against 2.9 expected, a shortfall chance gives 8% of the time.

The minima fall in cold and warm phases about in proportion to the time each covers

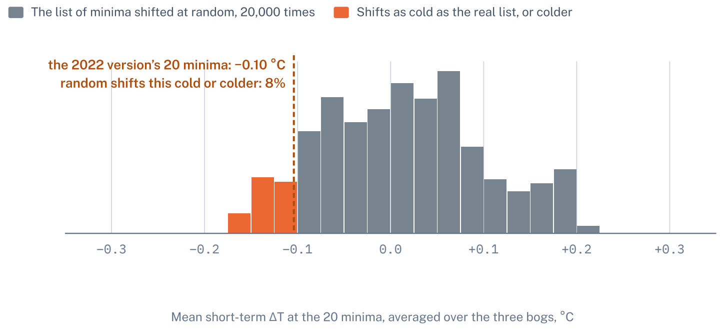
OUR ANALYSIS



Our analysis of the 2022 version’s Tables 4 and 5 [4 Tables 4–5]. The phases overlap between 1,423 and 1,210 years ago, where one minimum falls, so it counts in both.

The bogs are not detectably colder at the minima than at random dates

OUR ANALYSIS



ΔT minus its 1,500-year running mean, read at each minimum; our analysis of Tables S1–S3 and the 2022 version’s Table 5 [3][4 Table 5]. The spread of short-term ΔT within a bog is 0.39–0.66 °C, so 0.10 °C is a sixth to a quarter of it, and a sixth of the ±0.6 °C reconstruction error [7 p. 40].

OUR ANALYSIS

Reading the results

Counted strictly, every cold phase overlaps one of the 2022 version's minima, which random placement manages 4% of the time, and 6% with Usoskin and colleagues' list. That is the result that most favours the paper, and it depends on the margin: allow 100 years, about the dates' own statistical error, and chance does as well 13% of the time; 133 years, the widest gap the 2022 version's own table accepts, 20%; 250 years, the agreement it claims between the bogs, not a margin it names for the Sun, 60% [4 pp. 138, 143, 157, Table 4]. Overlap alone says little, though: the warm phases, which cover nearly two-thirds of the time, overlap minima just as reliably.

The tests that can tell are where the minima fall and how warm the bogs were at them. The minima fall in cold and warm phases about in proportion to the time each covers: 12 of the 20 sit in warm phases, five of them in the warmest of all, 6,768–4,964 years ago. With the 2022 version's minima, ΔT averages 0.10 °C below its trend, which random dates match 8% of the time; with Usoskin and colleagues' complete list it is 0.01 °C, and 0.03 °C for the 22 of their minima in the same window. Among a dozen such tests, a few results near 5% are what chance gives.

The phases come from the 1990s stage scheme, which dated its cold stages without any solar comparison, but the 2022 version gives no rule for their limits, which it set in the same study as the comparison [7 p. 42][4 Table 4]. Our test has a limit of its own: it uses the authors' modelled ages, which section 2 shows are less precise than stated, and dating errors of 100–200 years would blur a real link. So the hints are weak and not specific to cold phases; they don't show a link, but they can't rule out a weak one.

Claim 4 is Overstated: there is some basis, a strict overlap that beats chance and a slight, non-significant cooling at the 2022 version's minima, but neither survives a century's margin, a check of specificity or a complete list of minima, so "has been established" claims much more than the evidence supports.

5 · RADIOCARBON ON BOTH SIDES

The dates and most of the solar record rest on the same tree-ring carbon-14

When the Sun is quiet, more cosmic rays reach the atmosphere and more carbon-14 forms: the isotopes' production "depends inversely on solar activity" [13 §3]. So the ages of the bog samples and the solar record they are compared with are not independent.

Where the solar records come from

The sunspot reconstruction and list of grand minima of Usoskin and colleagues were built "from 14C data by means of a physics-based model" [10 Abstract]; the other source of the 2022 version's list used beryllium-10 and carbon-14 [11]; and the 2022 version also compares with carbon-14 in tree rings directly [4 Fig. 4]. Apart from the instrumental records of the last 400 years, sunspot counts among them, only the beryllium-10 records of ice cores are independent of carbon-14; it uses them in two figures, one of the last 400 years and one, smoothed, of the last 6,000 [4 Figs. 6–7].

The bog ages are radiocarbon dates calibrated on IntCal, whose last 13,900 years are built from tree rings [8]; in the 2022 version and the 1999 paper, nothing independent, such as a volcanic ash layer, anchors them [4][7].

OUR ANALYSIS

Why it matters, and why it isn't the answer

A rise in the air's carbon-14 holds radiocarbon ages steady while calendar years pass, which is what a flat stretch of the calibration curve is, and a date on it can belong anywhere along it. So the samples are dated least precisely exactly where the comparison matters. The 2022 version's own example plateau, 2,701–2,437 years ago in IntCal20, lies between two minima on its list, at 750 BC and 360 BC [8][4 Table 5]. Comparing events across records without carrying their dating uncertainty can merge separate events into one, or split one into two [16].

This doesn't create the match by itself: the temperatures come from pollen, not carbon-14. Circularity is a reason a match could look better than it is; it cannot produce the lack of one.

6 · THE SUN AND HOLOCENE CLIMATE

A solar influence is worth studying, but it is one driver among several, and over the last millennium probably a modest one

Reconstructions from carbon-14 and beryllium-10 put the Sun in a grand minimum about a sixth of the time over the last 11,000 years [13 §4.2.2][10 §3.1]. How much those changes moved climate is debated.

Evidence for a solar imprint

A 2001 study found that ice drifting in the North Atlantic followed the production of carbon-14 and beryllium-10 through the Holocene, and proposed the Sun as the cause [19]. A 2012 record combining both isotopes agreed with an Asian climate record in many periods but not in others, which its authors put down to other forcings [12]. The rise in the Sun's average brightness from the Maunder Minimum of the late 1600s to today has been estimated at about 0.9 ± 0.4 watts per square metre, under a tenth of a per cent [20].

One of several likely causes

The review of Holocene cold events found no clear cycle and named meltwater in the North Atlantic, low solar activity, volcanic eruptions and changes in the ocean's overturning circulation as processes that probably played a major role, with internal variability also involved [14]. A 2023 review of solar activity over millennia calls the role of solar variability in climate "far from being clear" [13 §4.4.2].

In other studies' words

From their abstracts.

> *"We instead conclude that solar forcing probably had a minor effect on Northern Hemisphere climate over the past 1,000 years, while, volcanic eruptions and changes in greenhouse gas concentrations seem to be the most important influence over this period."*
>
> Schurer, Tett and Hegerl (2014) [17 Abstract]

> *"A substantial portion of pre-industrial (1300–1800 CE) variability at multidecadal timescales is attributed to volcanic aerosol forcing."*
>
> PAGES 2k Consortium (2019) [18 Abstract]

> *"Our results demonstrate that solar-type signals can be the product of random variations alone, and that a more critical approach is required for their robust interpretation."*
>
> Turner et al. (2016), on nine peat records [15 Abstract]

OUR ANALYSIS

The 2022 version's own exception

The coldest phase in the study, 11,589–10,260 years ago, comes at the end of the last ice age. The 2022 version cites a 2008 review that explains early-Holocene cold by meltwater and a weaker Atlantic circulation, and adds: "Note that 11,000–10,300 years ago solar activity was also high" (our translation) [4 pp. 148–149]. The 2026 abstract still suggests that solar activity is one of the main causes of the short-term swings [1 Abstract], more cautiously than the 2022 version's "depends mainly" [4 p. 162]. A solar influence is plausible, but this study's data add no evidence for it that survives a test against chance, so even the suggestion of "one of the main causes" claims much more than they support: claim 5 is Overstated.

7 · WHAT S0 NEWS SAID

The episode linked the paper as "Solar Forcing Short Term Climate"; what it said about it, we could not check

S0 News linked the paper in the description of its episode of October 25, 2026, under the label "Solar Forcing Short Term Climate" [5]. No transcript was available, so we could not check what the presenter said about it. The label restates the paper's own conclusion, which we rate in claim 5.

8 · LIMITS

What this check can't tell us

The main text, unread

Its phases, its comparison, any statistics and the ages it uses may differ from the 2022 version and the supplement [1][4].

The authors' ages

Our tests use the modelled ages of Tables S1–S3, whose precision section 2 questions; errors of a century or two would hide a real centennial link [3].

Pollen temperatures, read off graphs

We did not compare the ΔT values with the 1990s graphs they were read from, or test Klimanov's method [7 p. 40].

Two lists of minima

The 2022 version's list is compiled from two studies and stops 8,335 years ago; we checked it against the complete list of one reconstruction, not against the newer list of 25 in a 2023 review [10][13 §4.2.2].

One model run

The supplement prints OxCal output for one bog; the other two bogs' models are unknown [2].

One study

We checked this study, not the whole literature on the Sun and Holocene climate; section 6 gives its outline.

What would change these verdicts

01

02

03

The 2026 main text showing a test of the match against chance, or phases and ages that differ from those we tested.

Cold anomalies at grand minima beyond chance in independently dated, finely sampled records, such as annually layered lake sediments, with the phases fixed before the comparison.

An age model for these bogs that passes OxCal's agreement checks, with the tables reporting its ages.

These follow the rules of our out-of-sample test of a solar–earthquake claim: freeze the method before scoring, test against a null that keeps the data's clustering, and hold back data or wait for new events.

9 · READ IT YOURSELF

The script, the numbers and the sources

Every count and test of ours on this page comes from one script, run on the study's tables and two public data files.

PY **holocene_checks.py**
The checks of the supplement's model run and tables, the plateau in IntCal20, the five tests against chance and the checks added after review · 26 KB

CSV **tables_s1_s3.csv**
Tables S1–S3: each sample's depth, radiocarbon, calibrated and modelled ages and ΔT · 11 KB [3]

CSV **figS1_oxcal.csv**
The supplement's OxCal table for Nikolsko-Lyutinskoye: each date's ranges and agreement index · 3 KB [2 pp. 7–10]

CSV **phases_2022_table4.csv**
The 15 phases of the 2022 version's Table 4 · 2 KB [4 Table 4]

CSV **grand_minima_2022_table5.csv** and **grand_maxima_2022_table6.csv**
The 2022 version's 20 grand minima and 14 grand maxima · 1 KB [4 Tables 5–6]

CSV **grand_minima_usoskin2007_table1.csv**
Usoskin and colleagues' 27 grand minima since 9500 BC · 1 KB [10 Table 1]

Run it

It needs only Python 3. Put the script and the six data files above in one folder with two public files under their own names: Steinhilber and colleagues' steinhilber2012.txt from NOAA [12] and the intcal20.14c curve [8]. Then run `python3 -I holocene_checks.py <folder>`. It prints every count and test of ours on this page in about three minutes; its random draws are seeded, so it gives the same numbers every time.

The paper's abstract and supplementary files are on Cambridge Core [1][2][3], and the 2022 version is in the Internet Archive [4].

Sources

Bracketed numbers refer to this list. For the paper [1], Abstract means its abstract on Cambridge Core, the only part of its text we could read. For its supplementary files, p. gives a page of [2] and Table a table of [3]. For the 2022 version [4] and the 1999 paper [7], p. gives a printed page and Table and Fig. a table and figure; quotations from [4] are our translation from the Russian, except from its English abstract. For the episode [5] there is no transcript. For the other sources, § gives a numbered section, Table a table and Abstract the abstract; where only an abstract was read, the entry says so, and abstracts read only through an index are paraphrased, not quoted. Links checked October 26, 2026.

1 Arslanov, Kh. A., Dergachev, V. A., Maksimov, F. E., Kudryavtsev, I. V., and Kuzmin, Y. (2026). Chronology of the short-term climate changes during the Holocene in northwestern Russia and its correlation with the solar activity variations. *Radiocarbon*, First View, pp. 1–15. Published online October 19, 2026. Peer reviewed; © the authors, published by Cambridge University Press for the University of Arizona under Cambridge's standard terms, not open access. Abstract only: its Cambridge Core page shows the abstract and the references, with purchase marked "Temporarily unavailable", and we found no other copy. No figure of the paper is redrawn.

2 Arslanov, Kh. A., et al. (2026). Supplementary material 1: "Figure S1. P_Sequence modeling of 14C data for the Nikolsko-Lyutinskoye bog", the OxCal code, plot and table of results of one model run (PDF, 10 pages). Free on Cambridge Core. Read in full; p. gives its page. A second copy, from a separate download, matched ours byte for byte.

3 Arslanov, Kh. A., et al. (2026). Supplementary material 2: Tables S1–S3, the radiocarbon, calibrated and modelled ages and ΔT of every dated sample from Nikolsko-Lyutinskoye, Shirinsky Mokh and Sambalskoye (Word file). Free on Cambridge Core. Read in full.

4 Arslanov, Kh. A., Dergachev, V. A., Maksimov, F. E., and Kudryavtsev, J. V. (2022). Chronology of the short-term climate change during the Holocene in Northwestern Russia and its correlation with the solar activity variations (in Russian: Хронология короткопериодных вариаций климата в голоцене на Северо-Западе России и корреляция с вариациями солнечной активности). *Uchenye Zapiski Kazanskogo Universiteta. Seriya Estestvennye Nauki* 164(1), 135–165. Received December 5, 2020; peer reviewed (single anonymous, as the Directory of Open Access Journals lists the journal); open access. Read in full, in the Internet Archive's copy of May 19, 2023, because the journal's site did not answer. p. gives its printed page; quotations are our translation, except from its English abstract (p. 162).

5 SpaceWeatherNews (S0) (October 25, 2026). Wheels Coming Off (the Planet) | S0 News Oct.25.2026. YouTube video, https://www.youtube.com/watch?v=uB8nBnEHe7A. No transcript was available; the episode's words about the paper could not be checked. The label "Solar Forcing Short Term Climate" is the episode's own, on its link to the paper in the video's description.

6 Crossref. Metadata record for doi:10.1017/rdc.2026.10268. Retrieved October 26, 2026: published online October 19, 2026, pages 1–15; 49 references, among them IntCal13 but neither IntCal20 nor the 2022 version [4]; licence URL https://www.cambridge.org/core/terms.

7 Arslanov, Kh. A., Saveljeva, L. A., Gey, N. A., Klimanov, V. A., Chernov, S. B., Chernova, G. M., Kuzmin, G. F., Tertychnaya, T. V., Subetto, D. A., and Denisenkov, V. P. (1999). Chronology of vegetation and paleoclimatic stages of northwestern Russia during the Late Glacial and Holocene. *Radiocarbon* 41(1), 25–45. Free on Cambridge Core. Read: Table 1 and the sections on the climate reconstruction; p. gives its page.

8 Reimer, P. J., Austin, W. E. N., Bard, E., Bayliss, A., Blackwell, P. G., Bronk Ramsey, C., et al. (2020). The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* 62(4), 725–757. CC BY 4.0. Abstract read; our analysis uses its data file, intcal20.14c.

9 Bronk Ramsey, C. OxCal online manual: Analysis operations (the P_Sequence model and its parameter k) and Analysis details (agreement indices). University of Oxford; accessed October 26, 2026.

10 Usoskin, I. G., Solanki, S. K., and Kovaltsov, G. A. (2007). Grand minima and maxima of solar activity: new observational constraints. *Astronomy & Astrophysics* 471(1), 301–309. Read in full in the authors' preprint, arXiv:0706.0385v1; § gives a section, and Table 1 is its list of 27 grand minima.

11 Inceoglu, F., Simoniello, R., Knudsen, M. F., Karoff, C., Olsen, J., Turck-Chiéze, S., and Jacobsen, B. H. (2015). Grand solar minima and maxima deduced from ^{10}Be and ^{14}C: magnetic dynamo configuration and polarity reversal. *Astronomy & Astrophysics* 577, A20. Not read; listed as the second source the paper names for its lists of grand minima and maxima [4].

12 Steinhilber, F., Abreu, J. A., Beer, J., Brunner, I., Christl, M., Fischer, H., Heikkilä, U., Kubik, P. W., Mann, M., McCracken, K. G., Miller, H., Miyahara, H., Oerter, H., and Wilhelms, F. (2012). 9,400 years of cosmic radiation and solar activity from ice cores and tree rings. *Proceedings of the National Academy of Sciences* 109(16), 5967–5971. Abstract only, paraphrased; our analysis uses its total solar irradiance from NOAA's World Data Service for Paleoclimatology, steinhilber2012.txt, downloaded October 26, 2026.

13 Usoskin, I. G. (2023). A history of solar activity over millennia. *Living Reviews in Solar Physics* 20, 2. CC BY 4.0. Read in the sections cited; § gives a section.

14 Wanner, H., Solomina, O., Grosjean, M., Ritz, S. P., and Jetel, M. (2011). Structure and origin of Holocene cold events. *Quaternary Science Reviews* 30(21–22), 3109–3123. Abstract only, from the University of Bern repository's record with DataCite; paraphrased, not quoted.

15 Turner, T. E., Swindles, G. T., Charman, D. J., Langdon, P. G., Morris, P. J., Booth, R. K., Parry, L. E., and Nichols, J. E. (2016). Solar cycles or random processes? Evaluating solar variability in Holocene climate records. *Scientific Reports* 6, 23961; corrected June 27, 2016. CC BY 4.0. Read in full.

16 Blaauw, M., Christen, J. A., Mauquoy, D., van der Plicht, J., and Bennett, K. D. (2007). Testing the timing of radiocarbon-dated events between proxy archives. *The Holocene* 17(2), 283–288. Abstract only, from Crossref; paraphrased, not quoted.

17 Schurer, A. P., Tett, S. F. B., and Hegerl, G. C. (2014). Small influence of solar variability on climate over the past millennium. *Nature Geoscience* 7(2), 104–108. Abstract only, from the publisher's page.

18 PAGES 2k Consortium (Neukom, R., Barboza, L. A., Erb, M. P., Shi, F., Emile-Geay, J., Evans, M. N., et al.) (2019). Consistent multidecadal variability in global temperature reconstructions and simulations over the Common Era. *Nature Geoscience* 12(8), 643–649. Abstract only, from the publisher's page.

19 Bond, G., Kromer, B., Beer, J., Muscheler, R., Evans, M. N., Showers, W., Hoffmann, S., Lotti-Bond, R., Hajdas, I., and Bonani, G. (2001). Persistent solar influence on North Atlantic climate during the Holocene. *Science* 294(5549), 2130–2136. Abstract only, from Crossref; paraphrased, not quoted.

20 Steinhilber, F., Beer, J., and Fröhlich, C. (2009). Total solar irradiance during the Holocene. *Geophysical Research Letters* 36(19), L19704. Abstract only, from Crossref; paraphrased, not quoted.

METHOD

How this was checked

On October 26, 2026, we tried every route the site

The verdicts on this page

allows to the paper's main text: its Cambridge Core page, the DOI, Crossref, OpenAlex and web searches. Cambridge offers only the abstract and the references, with purchase marked "Temporarily unavailable", and we found no other copy. So the page rests on the paper's abstract and its two supplementary files (a second copy of the first, from a separate download, matched ours byte for byte); the 2022 Russian-language version of the same study, by four of the five authors, read in full through the Internet Archive's copy because the journal's site did not answer; the 1999 paper that first published the dates of two of the bogs; the episode's description, there being no transcript; and 13 further sources on calibration, solar activity and Holocene climate (5 read in full or in the parts cited, 7 as abstracts and one only as a record): about 200 numbers, quotations and statements in all. Quotations from the 2022 version are our translation; abstracts that reached us only through an index are paraphrased, not quoted.

The verdicts and the items tagged "Our analysis" are our own assessment, built on the cited sources. They include every count and comparison from the supplement's OxCal table and its Tables S1–S3, the plateau in IntCal20, the synchrony of the three bogs, the comparison with other records' cold events, every test of the solar match against chance, and our reading of what the abstract, the supplement and the 2022 version do and do not say. The 2026 main text could change three of them: if it reports a test against chance, other phases or other ages, claims 2, 3 and 4 would need another look. If you have the article, please tell us through the correction form, and we will revise the page.

Our script, holocene_checks.py, is hosted under Read it yourself with its six small input files, taken from the paper's supplementary tables, the 2022 version's Tables 4–6 and Usoskin and colleagues' list of grand minima; with two public data files it prints every count and test of ours on this page, and its random draws are seeded, so it reproduces exactly. We could not check the model runs for Shirinsky Mokh and Sambalskoye, which the supplement does not print, or the ΔT values against the 1990s graphs they were read from. No figure from the paper is redrawn: the four charts are our own, of numbers from its tables and of our tests.

After the page was built, a second reviewer who hadn't seen the drafting re-ran the script, which reproduced every number, re-read the supplement and the 2022 version, and checked every quotation and reference. The changes that followed: the match with the minima is now reported at every margin from 0 to 250 years, and since the strict overlap does beat chance, claim 4 is rated Overstated rather than Unsupported, and the title no longer says "no better than chance"; the two cold phases that stay above today's temperature are described as levels, with their dips below the neighbouring samples; the comparison with other records' cold events gives its four hits and their chance level as well as its two misses; the phases, the list of minima and the examples are marked as the 2022 version's; the abstract's "suggests" is restored in claim 5; and about twenty smaller fixes.

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.

OVERSTATED	Has some basis but claims much more than the evidence supports.
PARTLY TRUE	Part of the claim holds up and part doesn't.
TRUE	The evidence supports the claim.

All ten verdicts, and how we check

CORRECTIONS

Corrections and changes

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

Change log

`Oct 26, 2026`

Published on factchecked.science after a full check against the sources. Built from the paper's abstract and two supplementary files, the 2022 Russian-language version of the same study, the literature on radiocarbon calibration, solar activity and Holocene climate, and our own test of the solar match against chance with the study's own tables, since the paper's main text could not be read; five of the paper's claims rated on the site's scale, with four charts of our own. Before publication a fresh review changed claim 4 from Unsupported to Overstated, now that the match is reported at every margin, retitled the page, and corrected the description of two cold phases and of the comparison with other records.

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