Fact-Checked Science

PAPER CHECK · RADIOCARBON IN THE OCEAN

Cosmic rays drove the biggest swing. The ice-age role needs a second model.

A 2026 model study re-simulated the marine radiocarbon reservoir age, the offset that dates on shells, corals and foraminifera must be corrected for, over the past 50,000 years [1]. Its Laschamps result holds up well; its case for climate's smaller role rests on one coarse model whose overturning swings are not timed to the real Heinrich and Dansgaard–Oeschger events and whose glacial ocean is too well ventilated [1 p. 2–3][2 Fig. S1]. We checked six of its main claims against the paper, its supplement and peer review file, and the authors' archived model output [2][3][4].

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.

A real upgrade, with one big caveat

OUR ASSESSMENT

≈1,200

years: the peak reservoir age near 42 ka, just before the Laschamps field minimum. The production-forced run gives a similar peak [1 p. 2–3].

600–700

years: the climate-only run before 14 ka, with no peak [1 p. 3].

−379

years: the bias of the model's glacial surface ocean across all sites. Too young, which would understate climate's role [1 p. 2].

THE PAPER'S CLAIMS

TRUE

The reservoir-age peak near 42 ka is a production effect

The paper, from its three runs [1 p. 2–3]

Basic disequilibrium physics: when atmospheric ^{14}C climbs fast, the ocean falls behind. The production-forced run gives a similar peak, the climate-only run shows none, and both the earlier LSG runs and the Marine20 box model show the same peak [1 p. 2–3][6 §5]. See section 2.

TRUE

CLIMBER-X fits low-latitude corals better than the older LSG model, for 13–25 ka

The paper [1 p. 2]

As the authors limit it. The bias in the corals' Δ^{14}C, their ^{14}C content measured against a standard in parts per thousand (‰), shrinks from −25‰ to −7‰, and the scatter slightly, from an RMSE of 45‰ to 40‰ [1 p. 2, §Methods][2 Table S1]. But the test covers only 13–25 ka and five reef areas, and in 1950 the model is too old in the tropics [1 p. 2][4]. See section 4.

PARTLY TRUE

Changes in ^{14}C production dominate short-term swings in reservoir age

The paper's abstract [1 p. 1]

True of the model's 50°N–50°S means: even when the model's overturning collapses, in Heinrich Stadial 1 and near 43–45 ka, the climate-only mean shifts by only about 20–40 years [1 p. 3][2 Fig. S1][4]. But those swings are not timed to the real Heinrich Stadials 2–5 or Dansgaard–Oeschger events, the glacial ocean is too well ventilated, and global means smooth out the swings that individual archives record [1 p. 2–3][6 §6]. See section 3.

PARTLY TRUE

Glacial climate's influence on reservoir ages is slow and damped

The paper's abstract [1 p. 1]

"Slow" holds: in the climate-only run, ages follow CO$_2$ [1 p. 3]. "Damped" holds inside the model, where reservoir ages barely respond to its own overturning collapses [1 p. 3][4]. But its glacial ocean is too young (surface −379 years, interior −483 years) with too little sea ice, all of which would shrink climate's effect [1 p. 2, §Methods][2 Table S1]. See section 4.

UNCONFIRMED

During the Laschamps excursion, the air's north–south ^{14}C gradient was up to twice as large as reconstructions suggest

The paper's abstract and text [1 p. 1, p. 3–4]

The production-forced run reaches up to 13‰, against a reconstructed long-term range of 4.5–7‰ [1 p. 3–4]. That comes from a three-zone atmosphere with constant mixing and globally uniform production, set against a reconstruction that relies on statistical modeling before about 13 ka; the authors call it a hypothesis [1 p. 3–4, §Methods]. See section 2.

TRUE

Testing ocean models with radiocarbon needs millennia of transient history, not centuries

The paper's abstract and text [1 p. 1–2]

Sound in principle, and shown here in one model: two runs reaching 1950 by different routes end with different deep-ocean biases [1 p. 2]. But their overall fit is similar [2 Table S1], and a reviewer noted that the long run also brings a different climate history into 1950 [3 pp. 7–8]. It is a different starting point, not automatically a better one. See section 5.

1 · WHAT THE STUDY DID

A coupled Earth system model re-simulates 50,000 years of reservoir ages

Carbon in seawater looks older than the air above it. That offset, the marine reservoir age, has to be corrected for when radiocarbon-dating marine shells, corals or foraminifera [1 p. 1]. In *Communications Earth & Environment*, published September 22, 2026, M. Butzin, F. Adolphi and G. Lohmann (Alfred Wegener Institute; MARUM and University of Bremen) re-simulate it for the past 50,000 years with an Earth system model of intermediate complexity [1].

Model

CLIMBER-X, with radiocarbon added

The climate core of CLIMBER-X (version 3) with radiocarbon added; 5° × 5° grid, 23 ocean levels, up to about 10,000 simulated years a day [1 §Methods].

Forcing

Run forward from 70 ka

Orbital insolation, greenhouse gases, ice sheets (with meltwater) and sea level. After a 20,000-year spin-up under 1850 conditions, the model runs forward from 70 ka. Time-varying radiocarbon forcing begins at 55 ka, the current limit of ^{14}C reconstructions; before that it is held constant [1 §Methods].

Three runs

— IntSH20

Driven by the reconstructed atmosphere

Atmospheric ^{14}C prescribed from IntCal20 north of 30°N, from SHCal20 south of 30°S, and from their average in between [1 §Methods].

— P_pmag

Production-forced

^{14}C production calculated from paleomagnetic field strength [1 §Methods].

--- P_const

Climate only

Constant ^{14}C production, so the run shows the effect of glacial–interglacial climate alone [1 p. 3, §Methods].

What it replaces

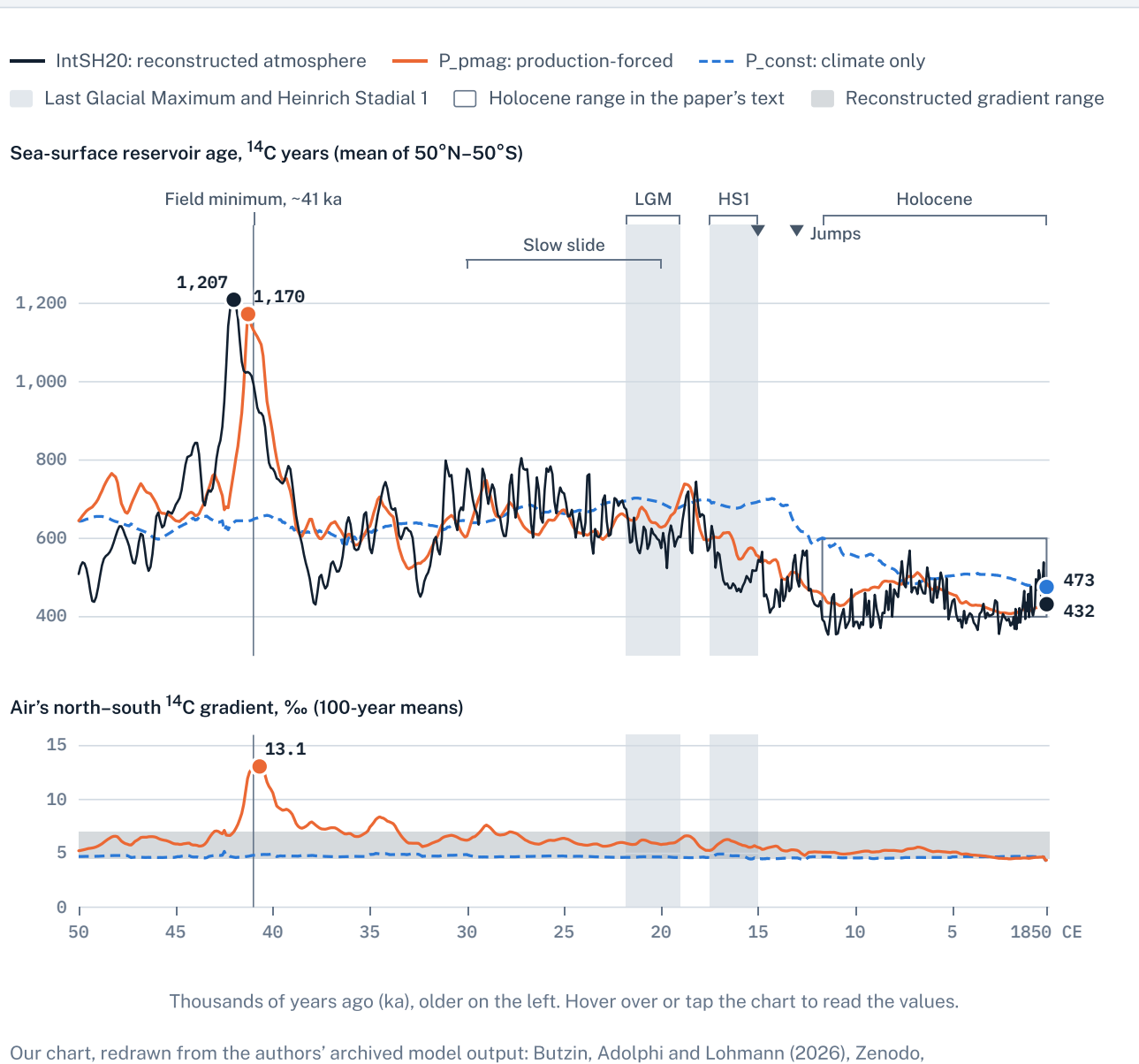
The new model replaces the authors' older, uncoupled LSG ocean runs, whose reservoir ages supplied first-order corrections for the coral and foraminifera records built into the IntCal20 calibration curve (all but the Cariaco Basin record, which was adjusted separately during curve construction) [1 p. 1][5][6 §1].

Marine20, the curve used to date marine samples, comes from a simpler box model. It used the LSG runs as a cross-check and points users at polar sites to them [6 §1, §6].

2 · RESERVOIR AGES THROUGH TIME

Ages peak at about 1,200 years just before the Laschamps field minimum

Sea-surface reservoir ages, averaged between 50°N and 50°S, in the paper's three runs, redrawn from the authors' archived model output [4]. The labels mark the events the paper describes [1 p. 2–3].



Our chart, redrawn from the authors' archived model output: Butzin, Adolphi and Lohmann (2026), Zenodo, doi:10.5281/zenodo.22146799, CC BY 4.0 [4]. The curves are the sea-surface means between 50°N and 50°S that the paper plots in its Fig. 1, drawn at every archived step (every 100 years, and every 50 years over the last 2,000 years) from 50 ka, where the paper's figure starts, to 1850 CE [1 Fig. 1]. Between 55 and 50 ka the archive keeps only one value per 1,000 years [4]. The gradient is the north-minus-south difference in atmospheric Δ^{14}C, in 100-year means. Values marked on the chart are the archived ones, which the paper's text rounds, for example 1,207 to about 1,200 [1 p. 2–4]. Our line colors differ from the paper's Fig. 1, which shows IntSH20 in blue, P_const in orange and P_pmag in green [1 Fig. 1].

42 KA

Laschamps peak

Ages reach about 1,200 years at 42 ka, shortly before the geomagnetic field minimum near 41 ka, when production changes fastest [1 p. 2]. The production-forced run gives a similar peak, of almost 1,200 years, around 41 ka, while the climate-only run stays between 600 and 700 years [1 p. 3].

ABOUT 41 KA

North–south gradient

In the production-forced run, the air's north–south ^{14}C gradient reaches up to 13‰, almost twice what reconstructions suggest [1 p. 3–4]. Gray band: reconstructed long-term range, 4.5–7‰. Blue dashed line: climate-only run, 4.7‰ [1 p. 3].

30–20 KA

Slow slide

A slow decline from about 700 to about 600 years, with century-scale wiggles of about ±100 years [1 p. 2].

19.0–21.8 KA

Last Glacial Maximum

About 600 years, from 300 in the subtropics to about 1,600 in the Southern Ocean; 670 with the polar oceans included [1 p. 2].

15.0–17.5 KA

Heinrich Stadial 1

The model's Atlantic overturning shuts down. In the climate-only run, the deglacial drop in reservoir age lags the CO$_2$ rise by about 4,000 years [1 p. 3].

NEAR 15 AND 13 KA

Brief jumps

Excursions of 100 to 200 years, shortly before the Bølling–Allerød and the Younger Dryas [1 p. 2].

11.7 KA TO 1850

Holocene

After a deglacial decline to about 400 years, the paper describes Holocene values between 400 and 600 (the outlined box) [1 p. 2]. The archived curve spends about a third of the Holocene below 400 years, dipping as low as about 355 [4].

1850 CE

End of the Fig. 1 curves

430 years, the preindustrial global mean. The climate-only run ends at 470 [1 p. 2–3].

3 · WHAT MOVES THE RESERVOIR AGE

In the model, fast swings follow the air's ^{14}C supply and the slow drift follows glacial climate

Two chains of cause and effect, as the paper describes them [1 p. 1–3]. Comparing the production-forced run with the climate-only run separates the two [1 p. 3].

— Fast: cosmogenic production

01

The field weakens

Earth's magnetic field weakens during the Laschamps excursion, reaching a minimum around 41 ka [1 p. 2].

02

Production rises

More cosmic rays reach the atmosphere, so ^{14}C production rises, peaking around 41 ka [1 p. 3, §Methods].

03

The air outpaces the ocean

Atmospheric ^{14}C climbs faster than the surface ocean can take it up [1 p. 2][5].

04

The gap widens

Reservoir ages peak near 1,200 years at 42 ka, before the atmospheric ^{14}C peak [1 p. 2].

--- Slow: glacial climate

01

Low glacial CO$_2$

Glacial CO$_2$ is low; the model takes it from an ice-core record [1 §Methods].

02

Slower exchange

With less CO$_2$ in the air, ^{14}C exchange between air and sea slows [1 p. 3, §Methods].

03

Ages hold steady

Climate-only reservoir ages stay between 600 and 700 years before 14 ka [1 p. 3].

04

A late decline

Rising deglacial CO$_2$ lowers them to 470 by 1850, but about 4,000 years late. The overturning shutdown in Heinrich Stadial 1 temporarily raises atmospheric ^{14}C, which offsets the CO$_2$ effect [1 p. 3].

In the authors' words MRA is the paper's abbreviation for marine reservoir age, and $^{14}P_C$ for the cosmogenic ^{14}C production rate.

> *"Short-term reservoir age variations are dominated by changes in cosmogenic radiocarbon production, while glacial-interglacial climate variations exert slower and damped effects."*
>
> Butzin et al. (2026), abstract [1 p. 1]

> *"Taken together, these findings prove the significant influence of cosmogenic ^{14}C production variations onto the MRA history and that MRA excursions may reflect $^{14}P_C$ changes rather than ocean ventilation changes."*
>
> Butzin et al. (2026) [1 p. 3]

> *"Prior to the deglaciation, the variability is probably too low because Heinrich Stadials HS2–HS5 are not resolved by the PaleoMIST reconstruction which uses a time step of 2500 years."*
>
> Butzin et al. (2026), on atmospheric Δ^{14}C in the climate-only run [1 p. 3]

OUR ANALYSIS

A muted response, and an open question

Before the deglaciation, the model's ice-sheet forcing (one value every 2,500 years, interpolated) does not reproduce the real Heinrich Stadials 2–5 or Dansgaard–Oeschger events. The model does simulate overturning collapses, in Heinrich Stadial 1 and near 43–45 ka, when the Atlantic overturning falls from its long-term average of 17 sverdrups (million cubic meters a second) to about 3–6 [2 Fig. S1][4]. But its climate-only 50°N–50°S reservoir age moves by only about 20–40 years when they happen, a response the authors call muted [1 p. 3][4]. Whether that weak response is realistic, in a glacial ocean that is too well ventilated, is untested, and 50°N–50°S means smooth out the regional swings that individual archives record [1 p. 2][6 §6].

4 · HOW IT CHECKS OUT AGAINST THE REAL OCEAN

Close for low-latitude corals, off for the glacial sea surface

Comparisons reported in the paper. Bias is the model mean minus the observed mean [2 Table S1].

FIT	COMPARISON	KEY NUMBERS	THE PAPER'S READING
✓ Close	**Tropical and subtropical corals, 13–25 ka**	Bias −7‰ in surface Δ^{14}C; earlier LSG model −25‰	Roughly in line with the observations and, for this period at low latitudes, more realistic than LSG [1 p. 2][2 Table S1]
◑ Mixed	**Pre-bomb ocean, 1950 CE**	320 years vs about 290 estimated from GLODAP data, 50°N–50°S	Large-scale pattern captured; too old in the tropics, especially the eastern upwelling zones, and in the northern North Atlantic; too young in the Southern Ocean [1 p. 2, Fig. 3]
✕ Off	**Glacial surface ocean, 19.0–21.8 ka**	Bias −379 years across all sites	Too young. The gap is clearest at subarctic and subantarctic sites, where observed ages of about 2,000 years or more are not reproduced, probably because the model has too little sea ice there. The authors think the old LSG polar values were spuriously high [1 p. 2]
◑ Mixed	**Glacial ocean interior (benthic–atmospheric ages), 19.0–21.8 ka**	Bias −483 years overall, Atlantic and Pacific sites	Qualitatively in line with observations, the authors say: the North Atlantic is ventilated more deeply than the North Pacific, as observed, but the whole Pacific below about 1.5 km is too young. LSG, with much older polar surface water, also missed the old Pacific ages. Neither model includes ^{14}C-free geologic carbon released at the seafloor, which is one proposed explanation [1 p. 2–3][2 Table S1]
✕ Off	**Atmospheric Δ^{14}C in the production-forced run**	Peak about 650‰ vs about 700–800‰ reconstructed	Peak close in size but mistimed; does not reproduce the rebound to about 500‰ between 33 and 25 ka; about 50‰ instead of 0‰ in 1850 CE [1 p. 3]

Benthic–atmospheric ages measure how much older the carbon in deep water looks than the air's at the same time, a gauge of how well the deep ocean is ventilated [1 p. 2]. The −483-year figure is the overall bias of benthic–atmospheric ages at the Last Glacial Maximum, across Atlantic and Pacific sites. The supplement calls such values illustrative rather than exact, because zonal means are compared with observations at different longitudes; the Pacific below about 1.5 km is the part the text singles out [1 p. 2–3][2 Table S1].

5 · ALSO FROM THE PAPER

Younger than the old model, and best tested over millennia

Three further results, as the paper reports them [1 p. 2–3].

Systematically younger than the old model

CLIMBER-X reservoir ages run parallel to the earlier LSG estimates but lower. The main text credits weaker vertical mixing in the upper ocean and stronger near-surface winds, which both shrink the ^{14}C gap between the sea surface and the air [1 p. 2]. The abstract says something different; see "A mechanism stated two ways".

Test ocean models over millennia, not centuries

Two runs reach 1950 by different routes: one through the past 70,000 years, one started straight from an equilibrium spin-up. They end with different patterns of bias in deep-ocean ^{14}C ages [1 p. 2, Fig. 4], although their overall fit statistics are similar [2 Table S1].

A Heinrich Stadial 1 shutdown is not ruled out by radiocarbon in this model

In this model the overturning shuts down in Heinrich Stadial 1, yet North Atlantic benthic–planktic ages (the radiocarbon age of bottom-dwelling minus surface-dwelling foraminifera, an ocean-circulation proxy [8]) stay below 1,500 years, which the authors call "by no means unrealistic" [1 p. 3]. A 2023 multiproxy study had rejected a collapse, partly because its simulated collapses gave benthic–planktic ages above 2,500 years, which no reconstruction shows [8 p. 351].

6 · OUR ASSESSMENT

Strong on the Laschamps peak, weaker on climate's small part

This section is our assessment of the paper, not the authors' conclusions.

OUR ANALYSIS

A candid upgrade on the ocean model whose reservoir ages went into the IntCal20 calibration curve [1 p. 1][5]. The case that cosmic-ray production drives the sharpest swing, the peak near 42 ka, is strong [1 p. 2–3]. The case that glacial climate plays only a slow, muted part is weaker. Before the deglaciation the model's overturning swings are not timed to the real events, its reservoir ages respond only weakly to them, and its glacial ocean is too well ventilated [1 p. 2–3][2 Fig. S1].

Credit where it's due

Honest self-correction

The authors replace their own LSG approach, which supported the marine corrections in IntCal20, and say plainly that it "is no longer up to date" [1 p. 1].

A clean experiment

Running the model once with constant ^{14}C production and once with production driven by the magnetic field separates the two drivers. Forcing with production also keeps the global ^{14}C budget closed [1 p. 3].

Open, and reviewed in the open

The radiocarbon code added to CLIMBER-X and the simulation results behind the figures are on Zenodo under CC BY 4.0 [4], and the peer review file is public [3]. Andreas Schmittner was one of the two reviewers; the other was anonymous [1 p. 8][3 p. 1].

Claim check

How far each headline claim holds, and why. The verdicts are our assessment of the claims as the authors make them.

THE PAPER'S CLAIM	OUR VERDICT	WHAT HOLDS UP	WHAT LIMITS IT
The reservoir-age peak near 42 ka is a production effect	TRUE	Driven by the reconstructed atmosphere, the model peaks at 42 ka, just before the field minimum near 41 ka, when production changes fastest [1 p. 2]. Driven by production, it gives a peak of almost 1,200 years around 41 ka; the climate-only run stays at 600–700 years [1 p. 3]. The earlier LSG runs and the Marine20 box model show the same peak, ahead of the atmospheric ^{14}C maximum, and Marine20 says these high values are "likely predominantly driven" by the rise in atmospheric Δ^{14}C [5][6 §5].	The model's overturning swings before the deglaciation are not timed to the real Heinrich and Dansgaard–Oeschger events, so real regional reservoir ages near 42 ka could also carry ventilation signals [1 p. 3][2 Fig. S1].
CLIMBER-X fits low-latitude corals better than LSG, 13–25 ka	TRUE	The mean bias falls from −25‰ to −7‰ and the RMSE from 45‰ to 40‰; the correlation is about the same, 0.91 vs 0.92 [1 p. 2][2 Table S1]. The authors limit the claim themselves: "at least between 13 and 25 ka BP and in the low-latitude regions" [1 p. 2].	The test is narrow: one variable, one window, five reef areas [4]. In 1950 the model's tropics are too old [1 p. 2].
Production changes dominate short-term variability	PARTLY TRUE	It holds for the model's 50°N–50°S means. The production-forced run captures the main features of the run driven by the reconstructed atmosphere, while the climate-only run stays smooth, moving by only about 20–40 years when the model's overturning collapses [1 p. 3][2 Fig. S1][4]. Marine20's box model likewise found atmospheric Δ^{14}C changes dominate, though it too omits millennial overturning changes [6 §5].	It is not established for marine archives in general. The model's own overturning collapses barely move its 50°N–50°S mean, but they are not timed to the real Heinrich Stadials 2–5 or Dansgaard–Oeschger events, and whether that weak response is realistic is untested [1 p. 3][2 Fig. S1]. Global means also hide regional swings: Marine20 notes several-century offsets in Iberian Margin records during Heinrich Stadial 1 [6 §6].
Glacial climate's influence is slow and damped	PARTLY TRUE	"Slow" holds. In the climate-only run, ages follow CO$_2$: 600–700 years before 14 ka, falling to 470 by 1850 [1 p. 3]. So does "damped", inside the model: its reservoir ages barely respond to its own overturning collapses [1 p. 3][4].	But the simulated glacial ocean is too young at the surface (−379 years) and in the interior (−483 years), with too little sea ice; all of these would shrink climate's effect [1 p. 2, §Methods][2 Table S1]. In the Bern3D model, Dinauer et al. could reach glacial atmospheric Δ^{14}C only by assuming "a drastic reduction of air–sea exchange efficiency in the polar regions"; they also allowed that the remaining discrepancies may come from underestimated ^{14}C production or a biased-high Δ^{14}C record [7 Abstract]. A 2026 conference abstract co-authored by Adolphi suggests that glacial climate–carbon-cycle interactions are not adequately represented in current models [9].
The north–south ^{14}C gradient in the air was up to twice previous estimates during the Laschamps	UNCONFIRMED	The production-forced run gives up to 13‰, against a reconstructed long-term range of 4.5–7‰ [1 p. 3–4].	The result comes from a three-zone atmosphere with constant mixing and globally uniform production, tuned to the Holocene gradient [1 §Methods]. It is compared with a reconstruction that relies on statistical modeling before about 13 ka; the authors call it a hypothesis to be tested with more observations [1 p. 4]. Independently dated Southern Hemisphere ^{14}C records spanning the Laschamps could test it; the published kauri series was dated by splicing its ^{14}C into the Hulu Cave record, so on its own it cannot pin down the gradient [10].
Testing ocean models with radiocarbon needs millennia of transient history	TRUE	Two runs reaching 1950 and 1990 by different routes end with different patterns of deep-ocean ^{14}C-age bias [1 p. 2, Fig. 4]. This fits the millennial ventilation of the deep ocean [1 p. 1].	It is shown in only one model. The overall fit is similar for both runs (1950 bias +92 vs +82 years, RMSE 185 vs 189), so the long run is a different starting point, not demonstrably a better one [2 Table S1]. A reviewer noted that the differences also reflect the runs' different climate histories, and the authors widened their wording to match [3 pp. 7–8].

Also worth flagging

Overstated wording

The paper says the experiments "prove the significant influence" of changes in ^{14}C production on reservoir ages [1 p. 3]. That is strong language for one 5° model whose ^{14}C scheme holds dissolved inorganic carbon constant and uniform, prescribes CO$_2$ and leaves out the organic carbon cycle [1 §Methods]. The authors put the error from these simplifications at under 5%, and the same sentence hedges that excursions "may reflect" production changes [1 p. 3, §Methods].

A mechanism stated two ways

The abstract credits the younger ages to "stronger vertical mixing and air sea exchange rates" in the new model. The main text says "weaker vertical mixing in the upper ocean and stronger near-surface winds" [1 p. 1–2]. The main-text version is the one the authors adopted after a reviewer questioned their first explanation. In their reply they note that the old model's vertical mixing was up to three times stronger in the upper 500 m [3 p. 6]. It is also the version that fits younger surface water.

A model-dependent rebuttal

The pushback against Pöppelmeier et al. (2023) rests on radiocarbon ages simulated with CLIMBER-X. Its ocean is a close relative of the Bern3D ocean used in that study: both build on the frictional-geostrophic model of Edwards and Marsh [1 §Methods][7 App. A][8 §Methods]. That study rejected a collapse using four proxies, not radiocarbon alone [8 p. 350–351]. The authors also cite a new high-resolution ^{14}C record from the western equatorial Atlantic, which two of them co-authored [1 p. 3][3 p. 3][11]. The radiocarbon signature of a shutdown looks model-dependent rather than settled.

The glacial Δ^{14}C puzzle stays open

A 2026 EGU conference abstract by Wall, Lamy, Lembke-Jene, Lachner, Winkler and Adolphi (a co-author of this paper) says its results indicate that "uncertainties in cosmogenic production alone cannot explain the radiocarbon anomaly associated with the Laschamps event", and suggests that climate–carbon-cycle interactions in glacial times "are not adequately represented in current models" [9]. It is a conference abstract, not a peer-reviewed paper.

If you date marine samples

Low-latitude open ocean

Probably closer to reality than the old LSG estimates, at least for 13–25 ka, where the coral test applies [1 p. 2]. The paper does not compare its results with Marine20 or say whether they will feed a future calibration update.

Polar, subpolar, coastal or upwelling sites

Not solved. CLIMBER-X misses the high glacial values at subarctic and subantarctic sites and, like LSG, underestimates them at coastal and upwelling sites. The authors think LSG's polar values were spuriously high [1 p. 2]. Marine20 is not meant for polar regions either [6 §1].

Samples from about 40 to 45 ka

Expect reservoir ages far from constant. In the run driven by the reconstructed atmosphere, the 50°N–50°S mean rises from typical glacial values of about 600–650 years to about 1,200 years at 42 ka, roughly doubling [1 p. 2][4]. A constant correction could be off by several centuries near the peak. Marine20, the standard marine curve, already varies through time and peaks at about 1,400 years here [6 §5].

7 · WHAT WOULD SETTLE IT

Time the ocean's abrupt changes to the real events, then try a second model

Five tests that would show whether climate's effect stays this weak once the model's abrupt ocean changes match the real ones, and whether the larger gradient is real. These are our suggestions, not the authors'.

01
Time the overturning changes to the real Heinrich and Dansgaard–Oeschger events, ideally in a model with realistic glacial sea ice, and check whether reservoir ages still respond as weakly as in CLIMBER-X.

02
Report reservoir-age histories at more archive sites, not only 50°N–50°S means.

03
Push glacial sea ice and Southern Ocean stratification toward reconstructions, and see whether climate's share grows.

04
Run a second model, such as Bern3D, with the same production forcing.

05
Test the larger north–south gradient against independently dated Southern Hemisphere ^{14}C records spanning the Laschamps; the published New Zealand kauri series takes its calendar dates from the Hulu Cave record [10]. The authors also say more observations from that period would test it [1 p. 4].

Results like these could move our verdicts on claims 3, 4 and 5 either way.

Sources

Bracketed numbers refer to this list. p. is a page of the PDF for [1] and [3] and a journal page for [8]; § is a section, and Fig., Table and App. are a figure, table or appendix. Links checked October 12, 2026.

1 Butzin, M., Adolphi, F., and Lohmann, G. (2026). Cosmogenic radiocarbon production and glacial cycles control marine radiocarbon archive variations. *Communications Earth & Environment* 7, 781. CC BY 4.0.

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11 Jena, P. S., Chiessi, C. M., Beese, I., Butzin, M., Dias, B. B., Campos, M. C., Lohmann, G., and Mulitza, S. (2026). Centennial-scale intensifications of the Atlantic Meridional Overturning Circulation during Heinrich Stadial 1. *Nature Communications* 17, 6603. CC BY-NC-ND 4.0.

METHOD

How this was checked

On October 12, 2026, we checked every statement, number, quotation and citation on this page against its source: the paper [1], its supplement [2] and peer review file [3], the authors' archived model output [4] and seven further sources [5]–[11]. That came to 63 items across the two panels of the original infographic: 33 confirmed as written, 23 clarified, 4 softened and 3 corrected. Nothing was fabricated. A fresh reviewer then read the built page against the sources and the authors' archive, which led to further fixes. The change log lists the corrections.

This is a paper check, so we didn't re-run the model. To test the numbers the paper quotes, we read the authors' archived output, and they match, except that the archived Holocene curve falls below the paper's 400–600 range about a third of the time: a peak of 1,207 years at 42.0 ka, Last Glacial Maximum means of 602 and 672 years, 322 years in 1950 CE and a gradient maximum of 13.2‰ [4]. The chart in section 2 is ours, drawn from the same archive at every archived step from 50 ka to 1850 CE. The figures on the model's overturning collapses (from a long-term average of 17 sverdrups to about 3–6) and on the climate-only run's 20–40-year response to them are also our reading of that archive.

The verdicts, section 6, the suggestions in section 7 and the items tagged "Our analysis" are our own assessment, built on the cited sources. The original infographic rated its confidence in each claim on a four-point scale; we restated those ratings as verdicts on our standard scale.

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

The verdicts on this page

UNCONFIRMED	Rests on a preliminary result that hasn't been confirmed.
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 12, 2026	Published on factchecked.science after a full check against the sources and a final read of the built page by a fresh reviewer. The check changed several lines of the original two-panel infographic. It said that before the deglaciation the model has no Heinrich or Dansgaard–Oeschger events and "cannot produce the ocean changes that would compete"; the model does simulate overturning collapses, though not timed to the real events, and its climate-only reservoir ages barely respond to them, so the caveat on climate's role now says that, and that whether such a weak response is realistic is untested. It called the authors' old LSG model the one "behind today's marine corrections"; its reservoir ages gave first-order corrections for the coral and foraminifera records inside the IntCal20 calibration curve, while Marine20, the marine curve, comes from a simpler box model. The 1950 comparison is now labeled "pre-bomb, 1950 CE". The −483-year bias was labeled as the glacial deep Pacific's; it is the overall glacial benthic–atmospheric bias across Atlantic and Pacific sites, and that row is now "Mixed", since the authors call the result qualitatively in line with observations. The atmosphere row now says the simulated peak is close in size to the reconstructed one but mistimed, and that the 50‰ figure is for 1850 CE. The Heinrich Stadial 1 card said a shutdown "fits the radiocarbon"; it now says a shutdown is not ruled out by radiocarbon in this model. The infographic said the north–south ^{14}C gradient "doubled during the Laschamps"; the paper says it was up to twice as large as reconstructions suggest. We added that Dinauer et al. also allowed production-side explanations, that the 2026 EGU abstract "suggests" rather than concludes, that the low-latitude improvement is over the old LSG estimates rather than Marine20, that the published kauri series is dated through the Hulu Cave record and so cannot test the gradient on its own, and that the reviewer's point about the long test run was its different climate history. We noted that the archived Holocene curve spends about a third of the time below the paper's 400–600 years, dipping to about 355, and redrew the chart from the authors' archived curves instead of values quoted in the text. The page has a new title, because the original headline ("Cosmic rays set the swings. Ice ages set the drift.") restated two claims we rate Partly true. Restated the verdicts on our standard scale: Solid (4 of 4) and Good (3 of 4) are now True, Partial (2 of 4) is Partly true, and Tentative (1 of 4) is Unconfirmed.
Oct 5, 2026	Analysis compiled from the paper as published September 22, 2026, as a two-panel infographic.

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Last updated Oct 12, 2026