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Brief communication: An active subglacial lake beneath the upper Institute Ice Stream, West Antarctica, missing from existing inventories

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Brief communication: An active subglacial lake beneath the upper Institute Ice Stream, West Antarctica, missing from existing inventories

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Abstract. We report an active subglacial lake beneath the upper Institute Ice Stream, West Antarctica (82.21° S, 68.85° W) absent from published inventories; the nearest catalogued lake is 70 km away. ICESat-2 laser altimetry and stereo elevation models independently record surface uplift of up to 5.9 m between 2012 and 2021 ($+0.13 \pm 0.03\,\mathrm{km}^3$), a fall of 8.7 ± 0.5 m at the centre of a 45 km^2 outline between late 2021 and mid-2023 ($-0.17 \pm 0.02\,\mathrm{km}^3$), and slow recharge since. Two bed compilations route overflow 54–64 km north-north-east to the grounding line. Radar confirmation is still needed.

1 Introduction

Active subglacial lakes are identified from localized rises and falls of the ice-sheet surface as water fills and drains beneath the ice (Smith et al., 2009). Altimetry inventories now hold about 150 such lakes in Antarctica, alongside several hundred radar-detected lakes (Siegfried and Fricker, 2018; Livingstone et al., 2022; Wilson et al., 2025). Coverage is uneven: the latest continent-wide detection used CryoSat-2 swath processing, restricted to the SARIn-mode margin (Wilson et al., 2025), and the most recent ICESat-2 analysis re-examined 158 previously documented lakes rather than searching for new ones (Sauthoff et al., 2026). Lakes inland of the SARIn mask, or lakes whose activity post-dates published surveys, can therefore remain undetected.

The Institute and Möller ice streams drain the Weddell Sea sector of the West Antarctic Ice Sheet into the Filchner–Ronne Ice Shelf. Several active lakes were identified there from ICESat (Smith et al., 2009), and targeted radio-echo sounding over one of them found no deep, specular water body, showing that active lakes can store water without a classic radar signature (Siegert et al., 2014). Here we describe an uncatalogued lake in the upper Institute Ice Stream catchment, called U07 below, found by searching the ICESat-2 gridded height-change product for localized fill–drain signals away from published lake outlines. We document its geometry and volume history with three independent elevation records and assess its hydraulic setting with two bed compilations.

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2 Data and methods

2.1 Surface-elevation change

We used ICESat-2 ATL15 version 6, which gives gridded height change at 1 km and quarterly resolution from 2019.0 to 2026.5 (Smith et al., 2026a, b). For the drain event, the height change between the 2021.75 and 2023.50 epochs was referenced to its median over a 20–40 km annulus around the site. The lake outline is the connected region containing the site where this ring-referenced change is ≤ -1.0 m, a threshold more than ten times the annulus median absolute deviation (0.07 m). Volume is the integral of the change over the outline. Alternative thresholds (0.3–2.0 m, and 25–65 % of the robust peak) were used to bound the area.

ATL11 version 7 along-track time series (Smith et al., 2025) supply 65 pair-track segments from 25 reference ground tracks within 20 km of the site. At every ATL11 reference point, the drain was computed as the mean height in cycles between 2023.20 and 2023.70 minus the mean in cycles between 2021.50 and 2021.90, referenced to the median over points 8–20 km away on the same track. These values were compared with the ATL15 drain field interpolated to the same locations.

Reference Elevation Model of Antarctica (REMA) 2 m strip elevation models (Howat et al., 2022) were read at 32 m resolution. Strip pairs were differenced, co-registered with a robust plane fit over an 8–18 km annulus (independently of ICESat-2) and integrated over the ATL15 drain outline. The fill was measured from a December 2012 strip to six strips from October 2019 to March 2021, and the drain from two strips of December 2020 and March 2021 to three strips of October 2022 to September 2023 (six pairs each). Uncertainty combines the scatter between pairs with the median absolute deviation of the annulus integrated over the outline. A time series was formed by network least squares from 64 m differences of the median within 3 km of the site minus the median over a 7–15 km annulus. Pairs with annulus deviation above 0.5 m were excluded.

As an additional check we extracted the public Centre for Polar Observation and Modelling (CPOM) 5 km cumulative height-change grids, which combine ERS-2, Envisat and CryoSat-2 data through 7 April 2026 (Shepherd et al., 2019; CPOM, 2026). U07 lies about 16 km inland of the CryoSat-2 SARIn mask, in the low-resolution-mode zone.

2.2 Hydraulic potential

Subglacial hydraulic head was computed as $h = (\rho_\mathrm{i}/\rho_\mathrm{w})\, z_\mathrm{s} + (1 - \rho_\mathrm{i}/\rho_\mathrm{w})\, z_\mathrm{b}$, with $\rho_\mathrm{i} = 917\,\mathrm{kg\,m^{-3}}$, $\rho_\mathrm{w} = 1000\,\mathrm{kg\,m^{-3}}$, and surface and bed elevations z_s and z_b (Shreve, 1972). The head uncertainty is about 0.083 times the bed uncertainty. We computed it separately from Bedmap3 (Pritchard et al., 2025, 2024) and BedMachine Antarctica version 4.1 (Morlighem et al., 2020; Morlighem, 2025), both at 500 m, over a 560 km window. Closed depressions were filled with a priority-flood algorithm seeded at the ice-sheet margin (Barnes et al., 2014). The overflow path is the steepest-descent (D8) route on the filled surface from the pour point of the depression containing the site.

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2.3 Comparison with published lakes

Distances were measured from the site to the outlines of Siegfried and Fricker (2018), which include Smith et al. (2009), to the outlines of Wilson et al. (2025), to the 675 Antarctic lakes with coordinates in Livingstone et al. (2022), and to all 7972 time-evolving outlines released by Sauthoff et al. (2026). Literature, preprint servers and conference abstracts were searched up to 11 November 2026.

3 Results

3.1 Fill and drain history

All three elevation records show the same sequence (Figs. 1 and 2). REMA shows the surface over U07 rising steadily from 2012 to 2021. Over the 45 km^2 outline the mean uplift was $+2.86 \pm 0.23$ m, peaking at +5.9 m, which gives a fill volume of $+0.13 \pm 0.03$ km^3. The uncertainty is dominated by the 0.54–0.70 m annulus deviation over the eight-year baseline; the scatter between pairs is only 0.01 km^3. ATL15 shows a nearly flat surface from 2019 to mid-2021, rapid lowering from 2021.75 that is fastest in 2022, a minimum in mid-2023 and gradual recovery afterwards. By 2026.5 the ATL15 site pixel had regained 3.8 m of its 9.1 m fall.

For the 2021.75–2023.50 drain, ATL15 gives -8.50 m at the site pixel and -0.167 km^3 over the preferred 45 km^2 outline. The threshold ensemble gives 17–60 km^2. The closest ATL11 track, 0.64 km from the site, records -8.36 m, where ATL15 gives -7.50 m. Across 8036 ATL11 points within 10 km, the two products agree closely: ATL15 equals 0.95 times ATL11 (least-squares fit to the 1381 points with drain of at least 0.5 m), with a median difference of +0.03 m and a median absolute difference of 0.045 m (Fig. 2b). The REMA drain pairs give a site change of -9.2 m and an outline volume of -0.171 ± 0.021 km^3. Our best estimates for the drain are a centre amplitude of -8.7 ± 0.5 m and a volume of -0.17 ± 0.02 km^3, released over about 1.75 years at a mean rate of about 3 $m^3\ s^{-1}$. The drain volume exceeds the measured fill because the 2023 trough lies below the December 2012 surface (Fig. 2a). The recharge before 2012 is not observed.

The CPOM grid cell containing U07 changes by +1.02 m (2013.25–2021.65) and -1.23 m (2021.65–2022.81), with an uncertainty of about 0.4 m. Sign and timing are consistent, but the cell-minus-surroundings difference is only +0.02 and -0.23 m, so at 5 km resolution in the low-resolution-mode zone this product can neither confirm nor rule out a lake of this size.

3.2 Hydraulic setting

Bedmap3 gives an ice thickness of 1634 m, a bed at -1349 m, and a bed uncertainty of 155 m at the site; BedMachine v4.1 gives 1598 m, -1333 m and 73 m. In both products U07 sits in an open hydraulic trough 69–70 m below the median head of the 15–40 km annulus (Fig. 3). The enclosed depression is smaller and less certain: 21 km^2 and 23 m deep in Bedmap3 (head uncertainty about 13 m), and 16 km^2 and 14 m deep in BedMachine (about 6 m). In both products, the overflow from U07 runs 24–28° east of north for 54 km (Bedmap3) or 64 km (BedMachine). It ends within 0.5 km of floating ice at the grounding

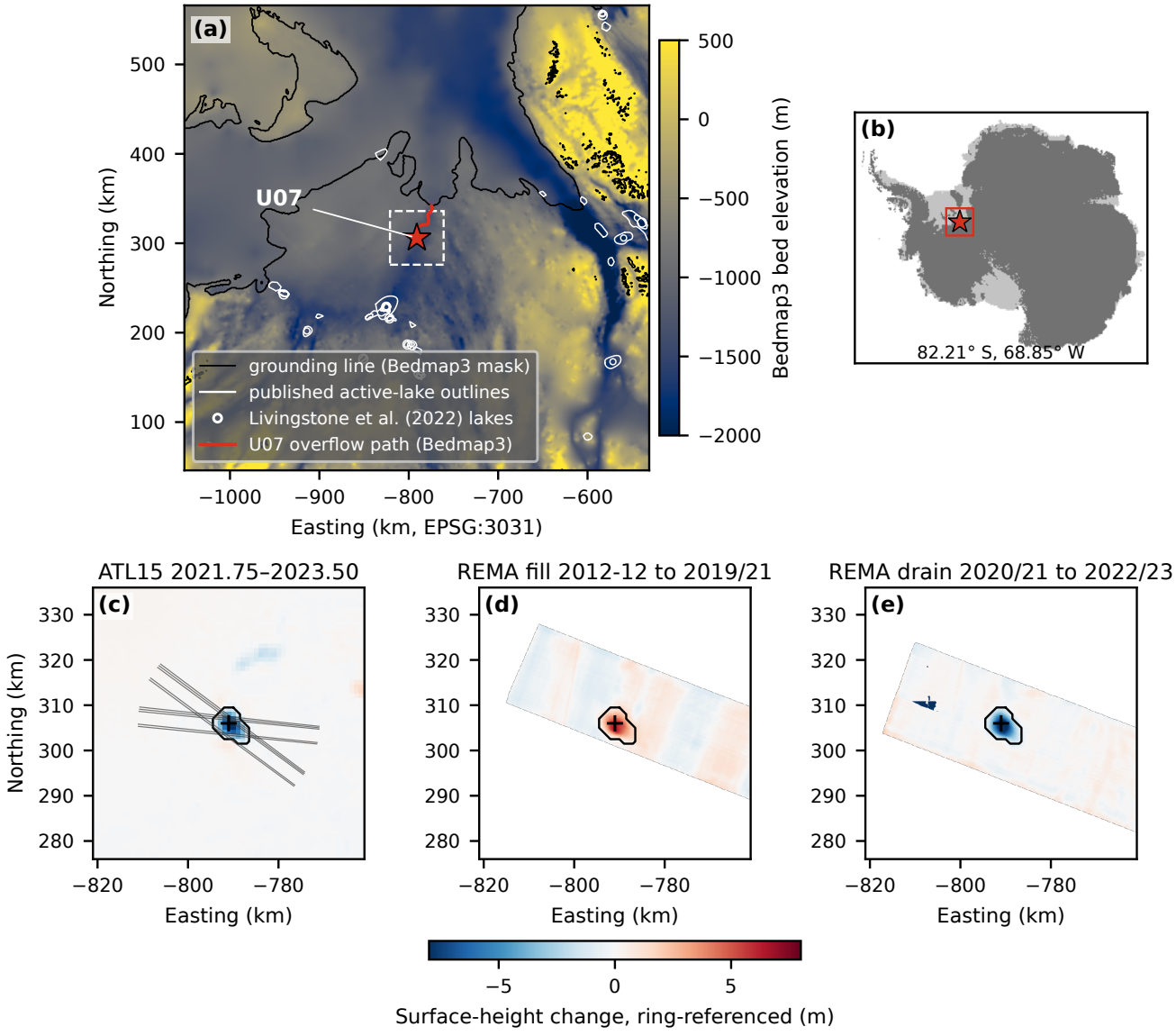


Figure 1. Location and surface expression of U07. **(a)** Bedmap3 bed elevation (Pritchard et al., 2025) in the Institute–Möller sector, with the grounding line from the Bedmap3 mask, published active-lake outlines (Siegfried and Fricker, 2018; Leong and Horgan, 2022; Wilson et al., 2025) and lake points (Livingstone et al., 2022), and the Bedmap3 overflow path from U07. The dashed box marks the extent of panels (c)–(e). **(b)** Location in Antarctica. **(c)** ICESat-2 ATL15 height change, 2021.75–2023.50, referenced to a 20–40 km annulus, with the 45 km^2 drain outline (black) and ATL11 tracks passing within 3 km (grey). **(d)** REMA fill, median of six strip differences from December 2012 to October 2019–March 2021, plane-corrected on an 8–18 km annulus. **(e)** REMA drain, median of six strip differences from December 2020/March 2021 to October 2022–September 2023. The isolated dark pixels west of the lake in (e) are an edge artefact of a single strip. DEM(s) created by the Polar Geospatial Center from Vantor imagery.

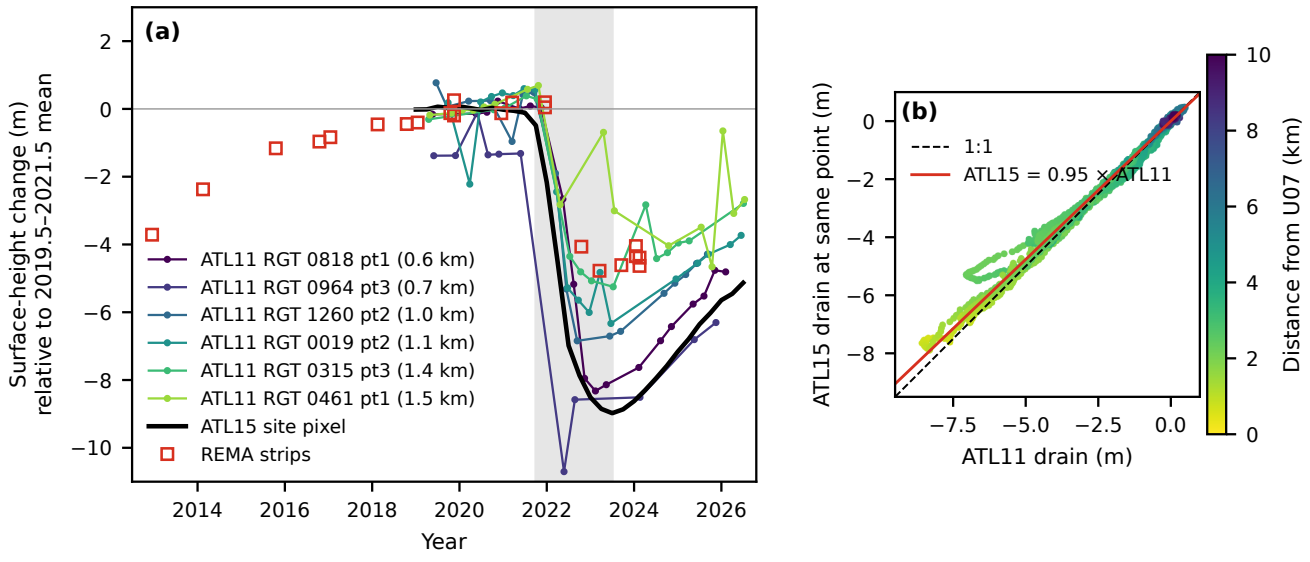


Figure 2. Time series and cross-validation. **(a)** Surface-height change at U07 relative to the 2019.5–2021.5 mean. ATL15 site pixel (referenced to a 20–40 km annulus). ATL11: median of points within about 0.5 km of the closest approach of the six track segments passing within 1.5 km, referenced to the median over 8–20 km on the same track; 18 of 175 cycle values that departed by more than 2.5 m from a three-cycle running median were omitted (cross-track sampling of a steep surface bowl). REMA: network least-squares series of the median within 3 km minus the median over a 7–15 km annulus; one December 2014 strip with poor annulus coverage was excluded. Shading marks the 2021.75–2023.50 drain window. **(b)** Ring-referenced drain from ATL11 at 8036 points within 10 km against ATL15 interpolated to the same points, coloured by distance from U07, with the 1:1 line and the least-squares fit (ATL15 = 0.95 × ATL11). DEM(s) created by the Polar Geospatial Center from Vantor imagery.

line of the Institute and Möller ice streams. No published lake lies within 15 km of either path. The known Institute lakes lie up-gradient to the south, so U07 is not downstream of them.

3.3 Relation to published inventories

The nearest published active-lake outline is Institute_E1 of Siegfried and Fricker (2018), 70.2 km from the site. The nearest of the evolving outlines of Sauthoff et al. (2026) is 72.6 km away, the nearest lake of Wilson et al. (2025) is 79.3 km away, and the nearest entry in Livingstone et al. (2022) is 84.3 km away. The nearest ICESat-2 cluster of the 2018–2021 preprint inventory of Leong and Horgan (2022) is 81.4 km away. We found no paper, preprint, abstract or dataset that describes elevation change at this location.

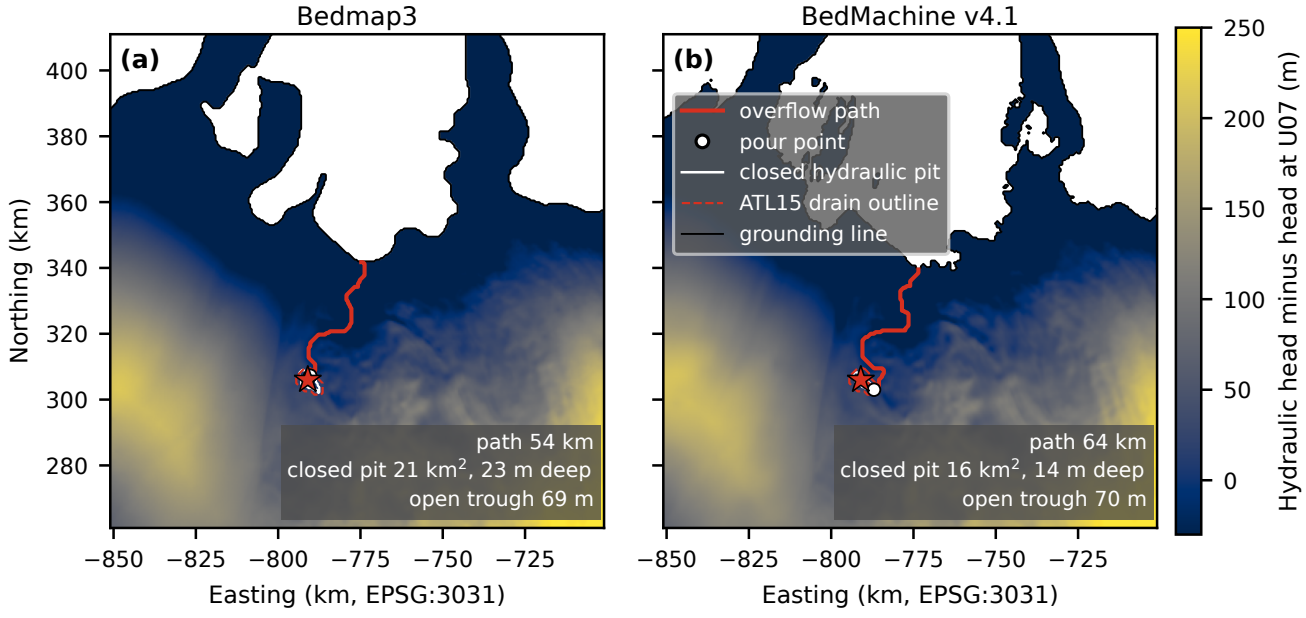


Figure 3. Subglacial hydraulic head relative to U07 from **(a)** Bedmap3 and **(b)** BedMachine Antarctica v4.1, with the grounding line, the closed hydraulic depression containing U07, its pour point, the overflow path to the grounding line and the ATL15 drain outline. White areas are floating ice or ocean.

4 Discussion

U07 was probably missed for three reasons. It lies inland of the CryoSat-2 SARIn mask that bounds swath-based catalogues (Wilson et al., 2025). Its drain began in late 2021, after the periods analysed by earlier regional ICESat-2 studies. The study that does span 2025 tracked only documented lakes (Sauthoff et al., 2026). The 2012–2021 fill was slow (about 0.4 m a^{-1} at the centre), and ICESat-2 observations before 2021.75 show almost no signal, so the lake is easily overlooked outside its drain.

Several limitations apply. First, the bed at U07 is interpolated: BedMachine v4.1 marks the site cell as interpolated with no radar pick. The closed depression is therefore only a few times the head uncertainty, whereas the 70 m trough and the north-north-east overflow are consistent in both products. Second, no radio-echo sounding or in situ observation exists at the site. As at other Institute lakes, water may be stored without a bright, flat radar reflector (Siegert et al., 2014). Third, 1.6 km of ice smooths and attenuates the basal signal, so our volumes are surface-based estimates, not direct measurements of water volume. Fourth, the public CPOM product cannot test a lake of this size in this zone. Finally, despite the literature search, an unpublished or concurrent analysis of the same signal cannot be excluded.

If the route is correct, U07 drains towards the Institute–Möller grounding line. Lake drainage there could add episodic subglacial discharge, averaging about 3 m^3 s^{-1} during 2022–2023, to the Filchner–Ronne Ice Shelf cavity. A radar survey

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across the 45 km^2 outline and continued ICESat-2 monitoring of the current recharge would test our interpretation and constrain the next drainage.

5 Conclusions

Three independent surface-elevation records, ICESat-2 ATL15, ICESat-2 ATL11 and REMA strip DEMs, record a full fill–drain cycle at an active subglacial lake beneath the upper Institute Ice Stream that is not in published inventories. The lake filled by about 0.13 km^3 between 2012 and 2021, drained about 0.17 km^3 between late 2021 and mid-2023, and has been refilling since. Two bed compilations agree that it occupies a hydraulic trough whose overflow reaches the grounding line without passing other known lakes. We recommend that it be added to active-lake inventories and targeted for radar survey.

Code and data availability. All input data are public. ICESat-2 ATL15 v006 and ATL11 v007 are available from the NASA National Snow and Ice Data Center (https://doi.org/10.5067/ATLAS/ATL15.006, https://doi.org/10.5067/ATLAS/ATL11.007). REMA strips v4.1 are available from the Polar Geospatial Center (https://doi.org/10.7910/DVN/X7NDNY). Bedmap3 is available from the UK Polar Data Centre (https://doi.org/10.5285/2d0e4791-8e20-46a3-80e4-f5f6716025d2). BedMachine Antarctica v4 (product version 4.1) is available from NSIDC (https://doi.org/10.5067/POJQI54A45HX); we read it from the ESA EarthCODE Zarr copy of NSIDC-0756 V04.1. CPOM height-change grids are available at https://www.cpom.ucl.ac.uk/landice/downloads.php. The processing scripts, the U07 outline, the time series and the plot data will be deposited on Zenodo; available from the author on request.

Author contributions. CA designed the study, carried out the analysis and wrote the manuscript.

Competing interests. The author declares that he has no conflict of interest.

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