# *New Phytologist* Supporting Information

Article title: **$C_3$ plant carbon isotope discrimination does not respond to $CO_2$ concentration on decadal to centennial timescales**

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The following Supporting Information is available for this article:

**Fig. S1** [$CO_2$] versus $\Delta^{13}C_{plant}$ values for historical species with medium-resolution records of Industrialization.

**Fig. S2** $\Delta^{13}C_{plant}$ values of plants by genus.

**Fig. S3** $\Delta^{13}C_{plant}$ values of plants by family.

**Table S1** All data in .xlsx file. **(See separate file).**

**Table S2** Range of climate variables and atmospheric parameters included in the historical portion of this study.

**Table S3** T-test statistics (assuming unequal variances) comparing the means and ranges of $\Delta^{13}C_{plant}$ values for different taxa in this study.

**Table S4** The relationship between $\delta^{13}C_{CO2}$ and $\delta^{13}C_{plant}$ values for the historical specimens spanning Industrialization.

**Table S5** Sensitivity (S given as ‰ ppm$^{-1}$) for eight species with long historical record.

**Table S6** The relationship between $\Delta^{13}C_{plant}$ values and non-barometric climate variables for historical and modern species sampled in this study.

**Fig. S1** [$CO_2$] values plotted against $\Delta^{13}C_{plant}$ for species with medium-resolution records of the period of Industrialization. Data are for: (a) *Pinus strobus* (Eastern white pine), (b) *Thuja sutchuenensis* (Sichuan arborvitae), (c) *Thuja koraiensis* (Korean arborvitae), (d) *Thuja standishii* (Japanese arborvitae), and (e) *Platycladus orientalis* (Chinese arborvitae). The outer panel shows change in $\Delta^{13}C_{plant}$ vs. [$CO_2$] over Industrialization, while the inner panel shows the range and distribution of $\Delta^{13}C_{plant}$ values for this species. Each of the species occupies different geographic ranges and different ranges of climatic variability, but none shows a significant $\Delta^{13}C_{plant}$ response to rising [$CO_2$] over the period of Industrialization.

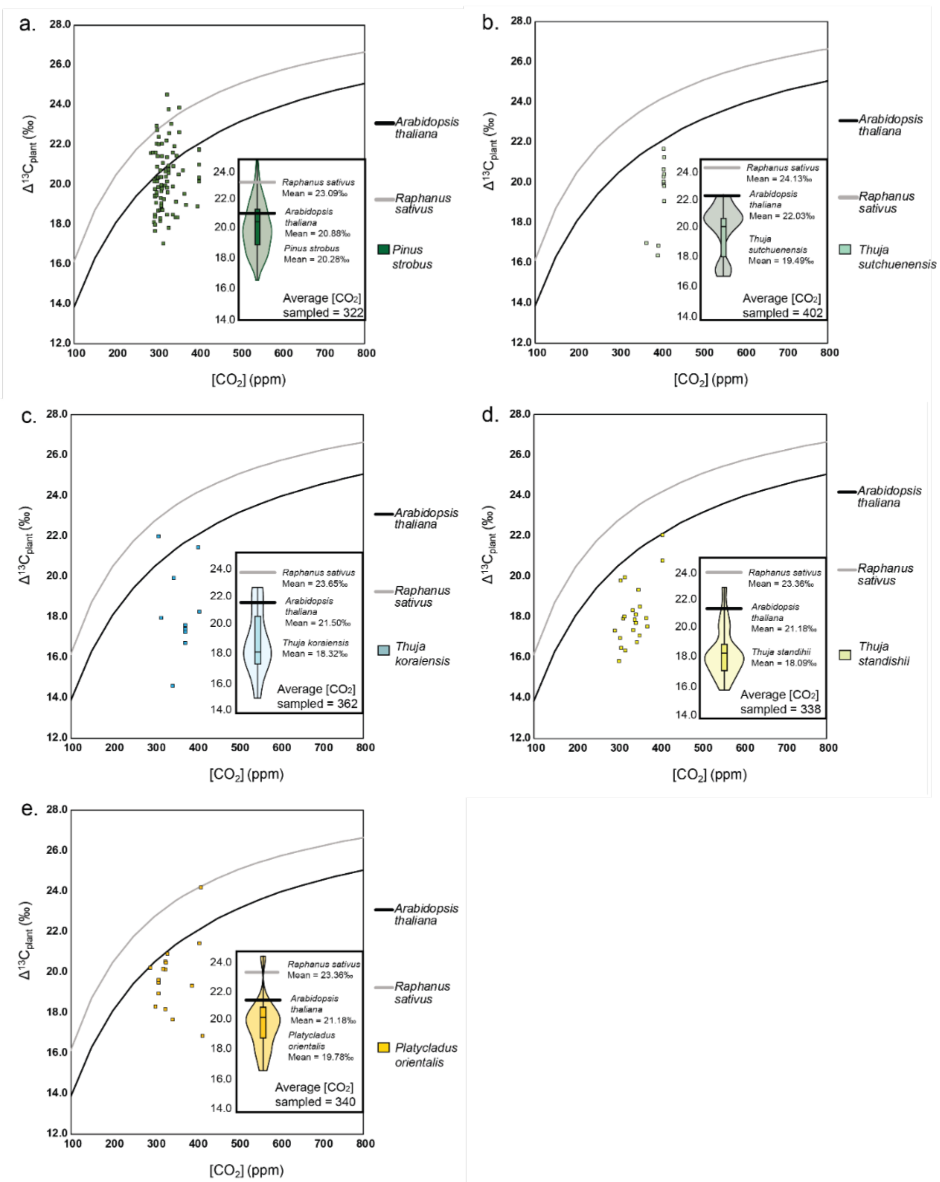

**Fig. S2** Comparison of $\Delta^{13}C_{plant}$ values of plants as sampled in this study, the Schubert & Jahren (2012) model, and from the literature and sorted by genera. Angiosperms are shown to the left of the diagram, while gymnosperms are shown to the right. Genera for which n<10 samples within the literature, were excluded from this figure. Xs denote mean values for each genus, and lines denote median values for each genus. Each box and whisker in this figure shows a different genus with n ≥ 15 represented isotope values from this study, Sheldon et al. (2020) and literature. Boxes show the 75th percentile of data, while whiskers show the remaining 25th percentile of data. Individual dots show outliers.

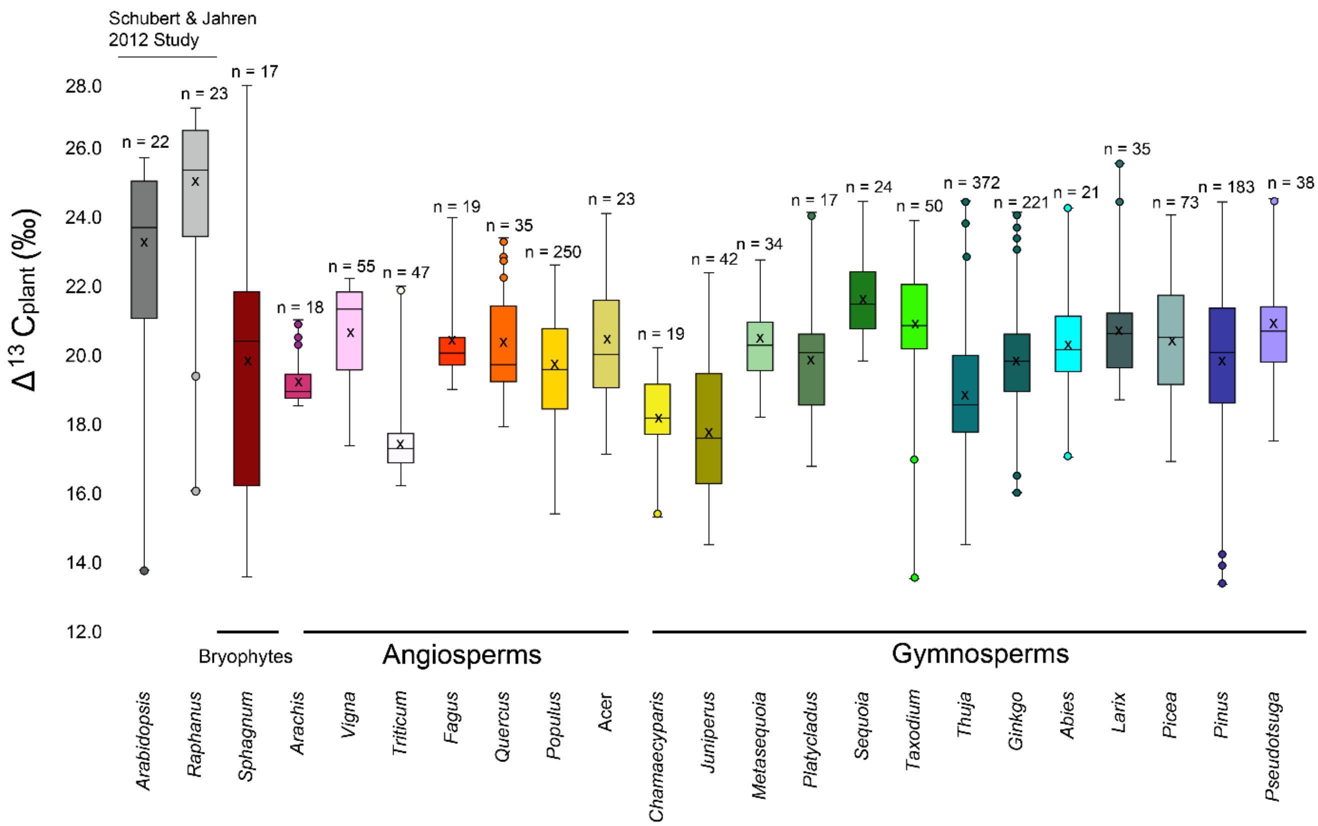

**Fig. S3** Comparison of $\Delta^{13}C_{plant}$ values of plants as sampled in this study, the Schubert & Jahren (2012) model, and from the literature and sorted by family. Angiosperms are shown to the left of the diagram, while gymnosperms are shown to the right. Families for which n<10 samples within the literature were excluded from this figure, except for "other Brassicaceae" – members of the same family as *Arabidopsis* and *Raphanus*, for comparison. Xs denote mean values for each genus. Each box and whisker in this figure shows a different family with n ≥ 15 represented isotope values from this study, Sheldon et al. (2020) and literature (except for Brassicaceae, which is included to show the discrepancy between model species and other Brassicaceae). Boxes show the 75th percentile of data, while whiskers show the remaining 25th percentile of data.

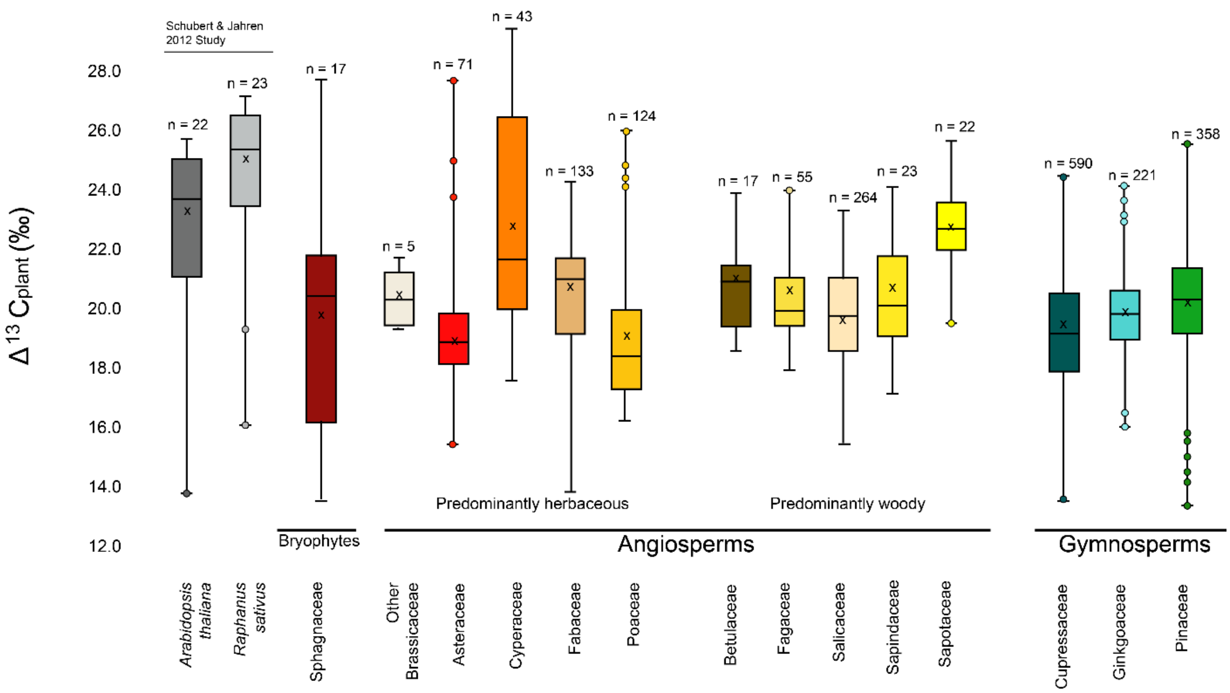

**Table S1** Isotope data measurements for specimens collected in the Earth Systems Science Lab (tab labeled *ESS Lab*) and from literature (tab labeled *Literature*). References for literature and ESS data shown in tab labeled *References*. $\delta^{13}C_{plant}$ values and $\Delta^{13}C_{plant}$ values (calculated using Eq. 2) are listed for ESS Lab and Literature values when known. Climate (PRISM Climate Group 2004) and barometric data (Etheridge et al. 1998; Keeling et al. 2001; White et al. 2015; Eggleston et al. 2016), year, collector, associated publications are listed when known and applicable. N/a denotes information not available. Eq. 2 (see details in main text):

$$\Delta^{13}C_{plant} = \frac{\delta^{13}C_{CO_2} - \delta^{13}C_{plant}}{1 + \frac{\delta^{13}C_{plant}}{1000}}$$

**(for full table, see separate file).**

**Table S2** Range of climate variables included in the historical portion of this study, as collected from PRISM Climate Group (2004), White et al. (2015), and Eggleston (2016).

| Climate, Atmospheric or Temporal Variable | Minimum | Maximum | Mean |
|---|---|---|---|
| Time (Year) | 1804 | 2019 | 1971 |
| [$CO_2$] (ppm) | 283 | 411 | 351 |
| $\delta^{13}C_{CO2}$ (‰) | -8.7 | -6.4 | -7.6 |
| Latitude (°N) | 9.9 | 68.2 | 42.5 |
| Longitude (°E) | -152.3 | 139.9 | -86.7 |
| Mean Annual Precipitation (mm $yr^{-1}$) | 193 | 4368 | 999 |
| Mean Annual Temperature (°C) | -5.6 | 25.0 | 8.0 |
| Maximum Summer Temperature (°C) | 13.3 | 35.9 | 26.2 |
| Elevation (m) | 4 | 2766 | 967 |
| Annual Minimum Vapor Pressure Deficit (hPa) | 0.18 | 6.32 | 1.23 |
| Annual Maximum Vapor Pressure Deficit (hPa) | 0.63 | 21.87 | 10.58 |

**Table S3** Results from t-tests (assuming unequal variances) comparing the means and ranges of *Arabidopsis* (a) and *Raphanus* (b) and families highly sampled from the literature dataset. N/a denotes that the comparison to the model species is not applicable (in the cases that it would involve comparing the model species to itself).

| Taxon | Mean | Standard Deviation | Sample Size | t-Stat | p(T<=t) two-tail value |
|---|---|---|---|---|---|
| *Arabidopsis* | 22.66 | 10.65 | 22 | n/a | n/a |
| Asteraceae | 18.76 | 1.78 | 68 | 5.44 | $4.14 \times 10^{-5}$ |
| Other Brassicace | 20.37 | 0.93 | 5 | 2.80 | 0.02 |
| Cupressaceae | 19.28 | 3.49 | 584 | 4.83 | $7.72 \times 10^{-5}$ |
| Cyperaceae | 20.78 | 11.01 | 212 | 2.58 | $3.39 \times 10^{-3}$ |
| Fabaceae | 20.61 | 2.80 | 134 | 2.89 | $7.76 \times 10^{-3}$ |
| Fagaceae | 20.34 | 1.97 | 54 | 3.22 | $4.25 \times 10^{-3}$ |
| Ginkgoaceae | 19.93 | 2.21 | 221 | 3.89 | $7.88 \times 10^{-4}$ |
| Pinaceae | 20.24 | 3.45 | 356 | 3.45 | $2.28 \times 10^{-3}$ |
| Poaceae | 18.88 | 4.20 | 119 | 5.25 | $3.79 \times 10^{-5}$ |
| Salicaceae | 19.77 | 2.60 | 261 | 4.12 | $4.48 \times 10^{-4}$ |
| Taxon | Mean | Standard Deviation | Sample Size | t-Stat | p(T<=t) two-tail value |
| *Raphanus* | 24.47 | 8.16 | 23 | n/a | n/a |
| Asteraceae | 18.76 | 1.78 | 68 | 9.23 | $2.37 \times 10^{-9}$ |
| Other Brassicace | 20.37 | 0.93 | 5 | 5.33 | $1.37 \times 10^{-4}$ |
| Cupressaceae | 19.28 | 3.49 | 584 | 8.64 | $1.07 \times 10^{-8}$ |
| Cyperaceae | 20.78 | 11.01 | 212 | 5.80 | $1.23 \times 10^{-5}$ |
| Fabaceae | 20.61 | 2.80 | 134 | 6.30 | $1.25 \times 10^{-6}$ |
| Fagaceae | 20.34 | 1.97 | 54 | 6.61 | $5.34 \times 10^{-7}$ |
| Ginkgoaceae | 19.93 | 2.21 | 221 | 7.52 | $1.21 \times 10^{-7}$ |
| Pinaceae | 20.24 | 3.45 | 356 | 7.01 | $3.79 \times 10^{-7}$ |
| Poaceae | 18.88 | 4.20 | 119 | 8.95 | $2.60 \times 10^{-9}$ |
| Salicaceae | 19.77 | 2.60 | 261 | 7.79 | $6.69 \times 10^{-8}$ |

**Table S4** Results showing the relationship between $\delta^{13}C_{CO2}$ and $\delta^{13}C_{plant}$ for each species studied over Industrialization. The first row shows the universal relationship proposed by Arens et al. (2000), and the second shows a generalized relationship that incorporates all 8 of the species we tested. Specimens sampled post-2017 were excluded to focus on the historical portion of this study.

| Measurement | Slope | Intercept |
|---|---|---|
| Arens et al. (2000) | 1.05 | -18.72 |
| Total Historical Dataset (pre-2017) | 1.22 | -17.10 |
| *Pinus strobus* | 1.58 | -15.54 |
| *Platycladus orientalis* | 1.47 | -15.72 |
| *Populus tremuloides* | 1.08 | -18.77 |
| *Thuja koraiensis* | 0.36 | -22.84 |
| *Thuja occidentalis* | 1.31 | -15.66 |
| *Thuja plicata* | 0.95 | -18.53 |
| *Thuja standishii* | 2.46 | -6.77 |
| *Thuja sutchuenensis* | 6.42 | 27.19 |

**Table S5** Sensitivity (S given as ‰ $ppm^{-1}$) for eight species with long historical record. S is compiled for the entire range of [$CO_2$] values spanning the collection, and as pre-1960 (acceleration; Keeling et al. 2001) and post-1960 ranges. Expected sensitivity is calculated using the best-fit function, S (‰ $ppm^{-1}$) = $0.21(28.26)^2 / [28.26+0.21(CO_2 + 25)]^2$ from Schubert & Jahren's (2012) study using data from both *Arabidopsis thaliana* and *Raphanus sativus* growth chamber experiments. S-column cells highlighted in blue indicate actual sensitivities far more negative than expected. S-column cells in red indicate sensitivities far more positive than expected, and S-column cells in white indicate sensitivities matching what is expected. N/a is used when there are no samples collected of the species during the specified time period.

| **Genus** | **Species** | **Age (Range in [$CO_2$])** | **S (‰/ppm)** | **Standard Deviation (‰/ppm)** |
|---|---|---|---|---|
| *Pinus* | *strobus* | Total (286-395) | -0.0117 | 3.019 |
| | | <1960 (286-320) | -0.0421 | n=51 |
| | | >1960 (320-395) | 0.0014 | |
| *Platycladus* | *orientalis* | Total (290-408) | 0.0077 | 1.642 |
| | | <1960 (290-320) | -0.0045 | n=12 |
| | | >1960 (320-408) | 0.0346 | |
| *Populus* | *tremuloides* | Total (288-411) | 0.0078 | 9.078 |
| | | <1960 (288-320) | -0.0441 | n=79 |
| | | >1960 (320-411) | -0.0011 | |
| *Thuja* | *koraiensis* | Total (311-408) | -0.0411 | 0.536 |
| | | <1960 (311-320) | -0.4977 | n=6 |
| | | >1960 (320-408) | 0.0495 | |
| *Thuja* | *occidentalis* | Total (283-408) | 0.0128 | 4.497 |
| | | <1960 (283-320) | 0.0417 | n=85 |
| | | >1960 (320-408) | -0.0012 | |
| *Thuja* | *plicata* | Total (289-411) | 0.0161 | 4.164 |
| | | <1960 (289-320) | -0.0085 | n=163 |
| | | >1960 (320-411) | 0.0338 | |
| *Thuja* | *standishii* | Total (292-408) | 0.0333 | 1.583 |
| | | <1960 (292-320) | 0.0592 | n=15 |
| | | >1960 (320-408) | 0.0474 | |
| *Thuja* | *sutchuenensis* | Total (366-408) | 0.0851 | 0.203 |
| | | <1960 (n/a) | n/a | n=4 |
| | | >1960 (366-408) | 0.0851 | |
| **Expected Sensitivity** | | <1960 (280-320) | 0.0181 | |
| | | >1960 (320-408) | 0.0139 | |

**Table S6** Results showing the statistical relationship between carbon isotope discrimination and non-[$CO_2$] climate variables for each species studied over Industrialization for each species studied over Industrialization. Specimens collected in modern times were included. N/a denotes when climate variables were not accessible for the specified species.

**a** — $R^2$ value

| Species | Mean Annual Precipitation (mm $yr^{-1}$) | Mean Annual Temperature (°C) | Maximum Summer Temperature (°C) | Elevation (m) | Latitude (°N) |
|---|---|---|---|---|---|
| *Pinus strobus* | $4.00 \times 10^{-3}$ | 0.01 | 0.01 | 0.06 | 0.06 |
| *Platycladus orientalis* | $7.00 \times 10^{-4}$ | 0.01 | 0.74 | 0.10 | $3.47 \times 10^{-6}$ |
| *Populus tremuloides* | 0.05 | 0.01 | $3.00 \times 10^{-3}$ | 0.08 | 0.15 |
| *Thuja occidentalis* | $1.00 \times 10^{-3}$ | 0.01 | $4.00 \times 10^{-3}$ | $1.00 \times 10^{-3}$ | 0.01 |
| *Thuja koraiensis* | 0.15 | 0.76 | 0.32 | 0.10 | 0.37 |
| *Thuja plicata* | 0.06 | 0.02 | 0.07 | 0.04 | 0.05 |
| *Thuja standishii* | 0.55 | 0.34 | n/a | 0.03 | 0.25 |
| *Thuja sutchuenensis* | 0.03 | 0.06 | n/a | 0.44 | 0.01 |
| Overall historical study | 0.02 | 0.01 | 0.01 | 0.00 | $4.00 \times 10^{-3}$ |

**b** — p-value

| Species | Mean Annual Precipitation (mm $yr^{-1}$) | Mean Annual Temperature (°C) | Maximum Summer Temperature (°C) | Elevation (m) | Latitude (°N) |
|---|---|---|---|---|---|
| *Pinus strobus* | 0.62 | 0.33 | 0.43 | 0.04 | 0.03 |
| *Platycladus orientalis* | 0.93 | 0.77 | 0.00 | 0.27 | 0.99 |
| *Populus tremuloides* | $1.00 \times 10^{-3}$ | 0.20 | 0.50 | $7.88 \times 10^{-6}$ | $8.87 \times 10^{-10}$ |
| *Thuja occidentalis* | 0.72 | 0.30 | 0.47 | 0.66 | 0.23 |
| *Thuja koraiensis* | 0.52 | 0.05 | 0.43 | 0.53 | 0.08 |
| *Thuja plicata* | $2.00 \times 10^{-3}$ | 0.09 | $3.00 \times 10^{-3}$ | $8.00 \times 10^{-3}$ | 0.01 |
| *Thuja standishii* | 0.09 | 0.22 | n/a | 0.58 | 0.06 |
| *Thuja sutchuenensis* | 0.56 | 0.46 | n/a | 0.02 | 0.75 |
| Overall historical study | $4.00 \times 10^{-3}$ | 0.65 | 0.24 | 0.88 | 0.01 |

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