Supporting Information for Cuban coral traces annual hydrologically driven variability of $\delta^{234}U$ values since the end of the Little Ice Age

Sahra Greve[1], N. Frank[1], P. Montagna[2], C. Alonso-Hernández[3], M. Gomez-Batista[4], E. Douville[5], S. Warken[1,6]

[1]Institute of Environmental Physics, University of Heidelberg, Im Neuenheimer Feld 229, 69120 Heidelberg, Germany
[2]Institute of Polar Sciences (ISP), National Research Council, Via Piero Gobetti 101, 40129 Bologna, Italy
[3]IAEA Environment Laboratories 4, Quai Antoine 1er, 98000 Monaco, Principality of Monaco
[4]Centro de Estudios Ambientales de Cienfuegos (CEAC), Cienfuegos, Cuba
[5]Laboratoire des Sciences du Climat et l'Environnement (LSCE), Gif-sur-Yvette 91191, France
[6]Institute of Earth Sciences, University of Heidelberg, Im Neuenheimer Feld 234, 69120 Heidelberg, Germany

Contents of this file

Mississippi Mass calculation

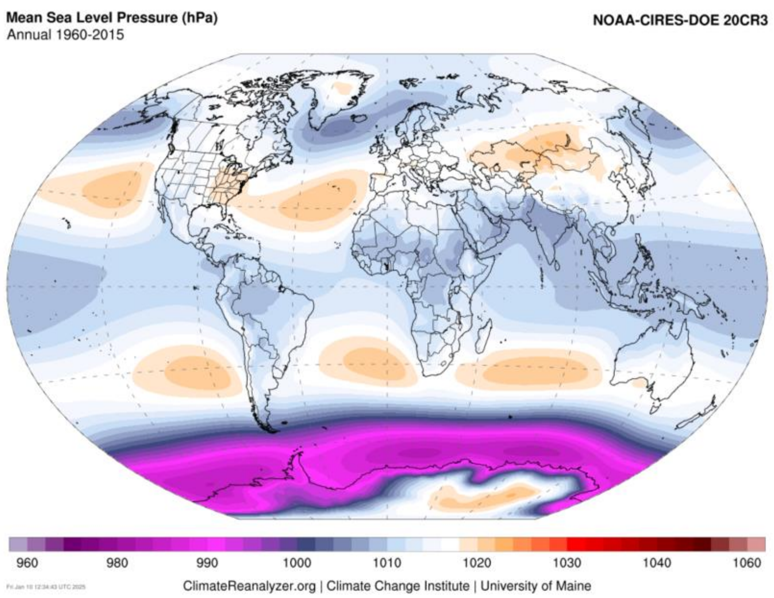
Considering the present-day strong seasonal variability in the U concentration and isotopic composition of the Mississippi River (Grzymko et al., 2007), it cannot be assumed that the uranium concentration and $^{234}U/^{238}U$ activity ratio have behaved conservatively in the Mississippi River over the last 240 years. Binary isotope mixing according to Equation (1) (Roy-Barman et al., 2016) was applied to estimate the potential fraction of the Mississippi River-derived U isotopes in the Gulf of Mexico throughflow.

$$f_r = \frac{\delta_c * C_c - \delta_{sw} * C_{sw}}{\delta_r * C_r - \delta_{sw} * C_{sw}} \quad (1)$$

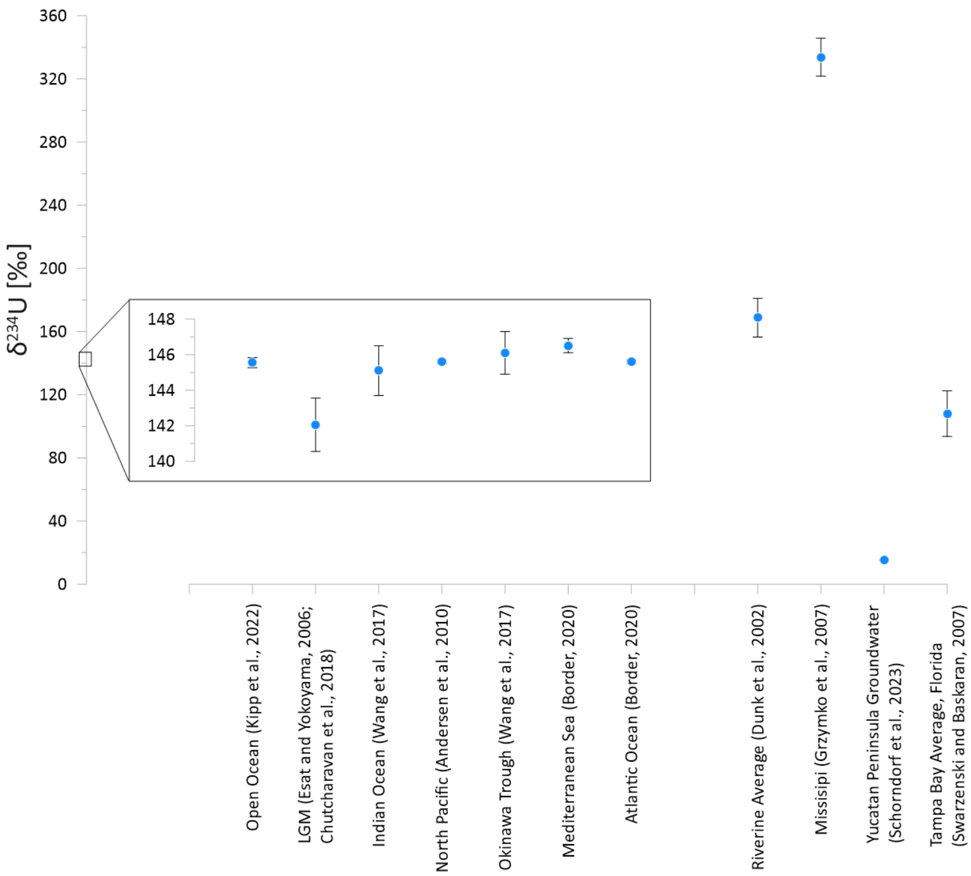
Here, δ_C is the coral $\delta^{234}U$ ratio and C_C is the coral U concentration converted into the corresponding seawater concentration (assuming 3.5 µg/g - 3.3 µg/l at 35,9 PSU). Any other influences on the U concentration, such as temperature, carbonate ion concentration and the coral growth rate, are neglected. Similarly, δ_{SW} is the open ocean seawater $\delta^{234}U$ ratio, and C_{SW} is its U concentration (presumed to be constant, $[U]_{Sw} >> [U]_{river}$). Finally, δ_r is the Mississippi $\delta^{234}U$ ratio range, and C_r is the U concentration range. For this two end-member isotope system, the past seawater U concentration remains unknown but is likely to vary within small ranges of a few percent from modern values. To overcome this difficulty, we here used the mean coral U concentration (2.27 µg/l) as a representative of seawater. Taking these limitations into account, the proportion of Mississippi River freshwater (f_r) reaching the coral site during the LIA, where the highest $\delta^{234}U$ ratios are recorded, is estimated to vary between 0% and 3.0%.

The seawater U concentration may vary independently of open ocean and freshwater mixing, due to evaporation, for example (Ivanovich & Harmon, 1992). Additionally, U incorporation during coral calcification may vary depending on the growth rate (Inoue et al., 2011), seawater pH (Inoue et al., 2011), carbonate ion concentration, dissolved inorganic carbon (DeCarlo et al., 2016; Patterson et al., 2021), and temperature (Ourbak et al., 2006; Patterson et al., 2021), causing subtle changes in the coral U concentration independent of the balance between seawater and freshwater. Consequently, any quantitative estimate will remain speculative without monitoring all the above aspects. Nonetheless, the Mississippi freshwater volume contribution to the Gulf of Mexico throughflow is currently less than a 0.5 ‰ in mass balance (Grzymko et al., 2007; Leaman et al., 1995), leading to subtle salt changes and minor changes in oxygen isotopes overprinted by net evaporation. Hence, we must assume that changes in the U concentration of seawater caused by the contribution of the Mississippi are minimal. Consequently, any observed variations in isotopic composition must reflect a major shift in the supply of U and/or an increase in the δ^{234}U value of river discharge.

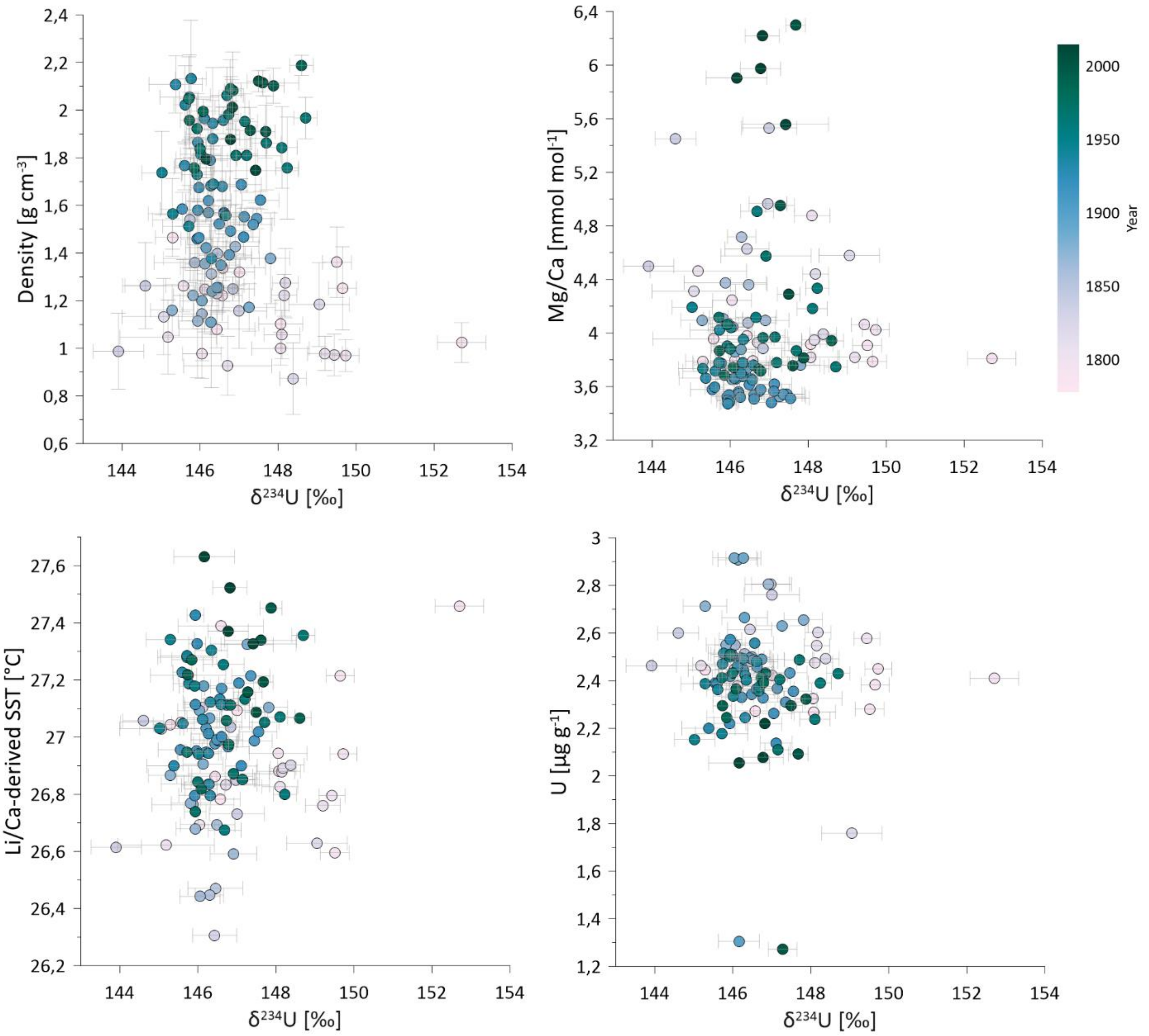
In summary, we suggest that the deviation of the Cuban coral δ^{234}U values from a constant open ocean δ^{234}U value is most likely driven by two independent excess U sources. First, the local runoff coupled with the variance in precipitation on the island of Cuba likely resulted in minor reductions in the U isotope values compared with the open ocean mean values. The observed correlation between a decrease in isotopic composition and an increase in precipitation accounts for approximately 50% of the variability in the δ^{234}U time series from 1850–present. At the end of the LIA period (1778-1846), when the climate cooled in the Northern Hemisphere and the tropical climate was unstable, a second process influenced the time variance of the coral δ^{234}U values. Most likely, the distant influence of the excess ^{234}U contribution from the Mississippi River into the strong persistent throughflow of the Caribbean current caused a moderate and punctuated strong increase in seawater and thus coral δ^{234}U. Both local precipitation and distant freshwater runoff must influence the δ^{234}U time variance and mean of the coral record. Here, these two distinct contributions did not modify the long-term average coral δ^{234}U value, which is identical to the mean global ocean value. In addition, the variance in δ^{234}U is less than ±3 ‰ when the single elevated value in 1792 is excluded. This finding strongly constrains the expected variance in the initial δ^{234}U values of fossil corals within the Caribbean.



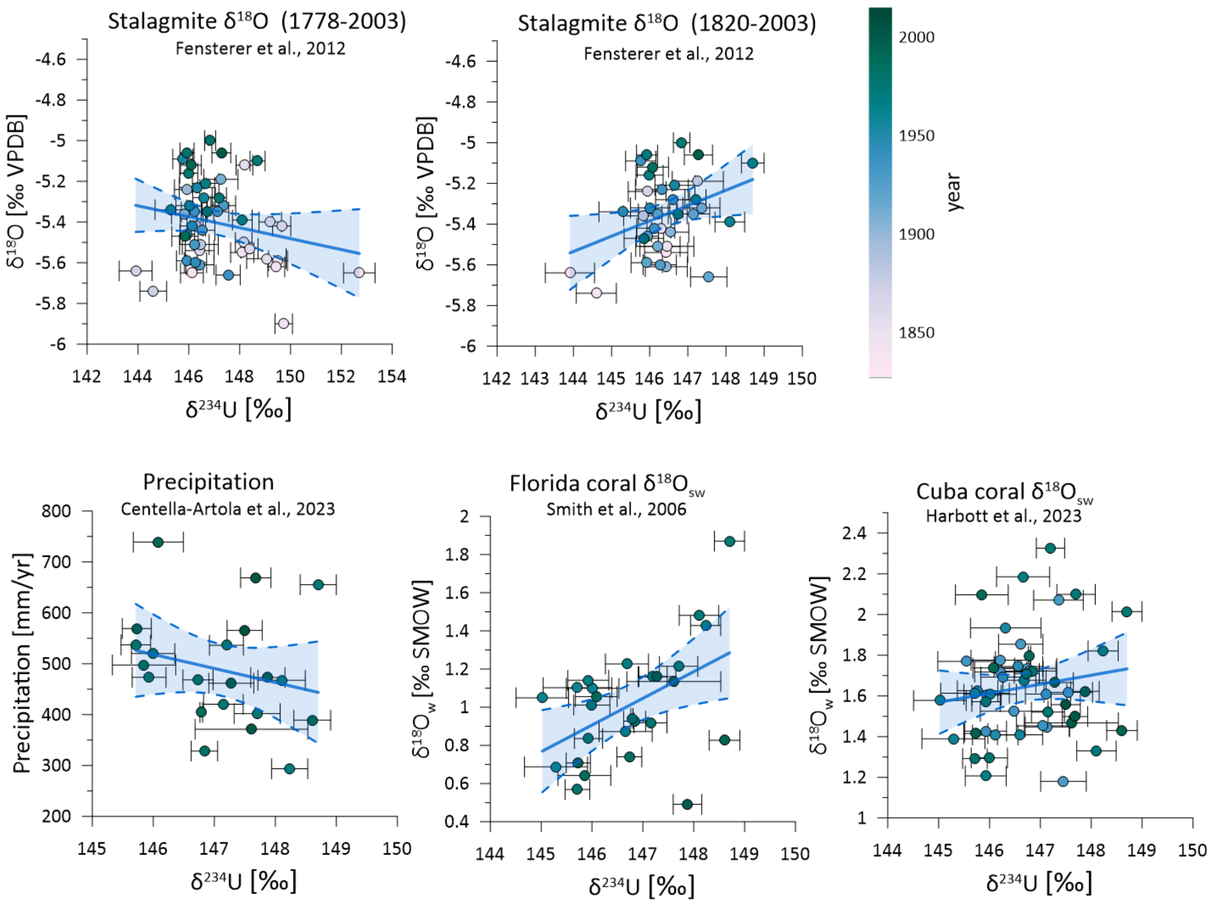
Supplementary Figure S1: Mean annual sea level pressure in hPa spanning 1960 – 2015 using NOAA-Cires-Doe 20CR3. Cuba lies on the southwestern edge of the high-pressure system over the Atlantic and is influenced by the extension of this pressure system.



Supplementary Figure S2. Global and regional $\delta^{234}U$ values compiled from modern marine, riverine, and groundwater sources. Marine values include open ocean, LGM reconstructions, and specific basins (e.g., Indian Ocean, Mediterranean Sea), showing $\delta^{234}U$ generally between ~142‰ and 147‰. Riverine and groundwater sources display broader variability, with particularly high values observed in the Mississippi River and Yucatán Peninsula groundwater. A close-up inset highlights the narrow range of marine $\delta^{234}U$ values relevant for comparison with proxy records.



Supplementary Figure S3. no correlation between the coral density, coral Mg/Ca, Li/Ca derived SST (Alonso-Hernández et al., 2022) or U concentration and δ^{234}U values is visible, implying no δ^{234}U signal variations due to vital effects or diagenesis. Colour scale denotes sample year.



Supplementary Figure S4. Correlations between $\delta^{234}U$ and regional hydroclimate proxies over the past two centuries. Top panels show $\delta^{18}O$ from stalagmites (Fensterer et al., 2012) plotted against $\delta^{234}U$ for the full (1778–2003) and post-1820 intervals. Bottom panels compare $\delta^{234}U$ with annual precipitation from the Cuban coast (Centella-Artola et al., 2023), and seawater $\delta^{18}O$ from Florida (Smith et al., 2006) and Cuba (Harbott et al., 2023) coral records. Shaded regions indicate 95% confidence intervals around linear regressions. Colour scale denotes sample year.

Supplementary Table S1. $\delta^{234}U$ measurements together with concentrations of ^{238}U and ^{234}U of annually integrated CSM_1. $\delta^{234}U$ values are given normalised to HU1 = 0 and HU1 ≠ O after (Cheng et al., 2013). Measurement uncertainties are 2σ analytical errors

Lab. #	Year	$\delta^{234}U$ (‰) (HU1 = 0)	$\delta^{234}U$ (‰) (HU1 ≠ 0)	Error $\delta^{234}U$ (‰)	^{234}U (pg/g)	Error ^{234}U (pg/g)	^{238}U (µg/g)	Error ^{238}U (µg/g)
12021	1777	147.00	145.80	0.39	152.59	0.44	2.42	9.91E-05
12037	1778	146.57	145.37	0.51	144.06	0.70	2.27	3.50E-04
12022	1780	148.07	146.87	0.57	143.30	0.61	2.27	1.25E-04
12038	1781	146.43	145.23	0.97	143.39	1.55	2.26	7.63E-04
12023	1783	146.12	144.92	0.45	151.19	0.35	2.38	1.18E-04
12039	1784	145.15	143.95	0.43	153.88	0.56	2.45	1.40E-04
12039	1784	145.93	144.73	0.48	151.61	0.55	2.45	1.40E-04
12024	1786	149.65	148.45	0.36	151.17	0.40	2.38	8.88E-05
12025	1789	149.51	148.31	0.37	145.86	0.35	2.28	8.13E-05
12026	1792	152.70	151.50	0.62	152.70	0.53	2.41	1.40E-04
12042	1793	148.06	146.86	0.74	147.37	1.37	2.33	5.26E-04
12027	1795	149.73	148.53	0.34	154.70	0.40	2.45	1.13E-04
12043	1796	146.05	144.85	0.50	155.12	0.75	2.45	3.23E-04
12028	1798	149.44	148.24	0.33	162.69	0.48	2.58	1.05E-04

Lab. #	Year	$\delta^{234}U$ (‰) (HU1 = 0)	$\delta^{234}U$ (‰) (HU1 ≠ 0)	Error $\delta^{234}U$ (‰)	^{238}U (pg/g)	Error ^{238}U (pg/g)	^{234}U (µg/g)	Error ^{234}U (µg/g)
12029	1801	148.10	146.90	0.46	158.76	0.74	2.48	1.38E-04
12030	1804	149.20	148.00	0.44	154.93	0.47	2.46	1.22E-04
12032	1810	148.16	146.96	0.33	159.03	0.37	2.55	9.93E-05
12033	1813	148.19	146.99	0.33	161.74	0.56	2.60	1.22E-04
12034	1816	149.05	147.85	0.78	109.21	0.58	1.76	1.08E-04
12035	1819	148.38	147.18	0.34	156.45	0.46	2.49	9.98E-05
12085	1826	146.43	145.23	0.57	162.14	0.39	2.61	1.08E-04
12742	1830	145.55	144.35	0.50	162.89	0.74	2.65	1.95E-04
12086	1831	144.91	143.71	0.64	154.86	0.83	2.46	1.91E-04
12237	1833	147.00	145.80	0.71	174.42	0.21	2.76	6.55E-05
12743	1835	146.97	145.77	0.49	172.83	0.69	2.81	1.68E-04
12087	1836	144.60	143.40	0.52	160.43	0.66	2.60	1.79E-04
12238	1838	145.75	144.55	0.97	174.18	0.23	2.75	8.20E-05
12088	1841	146.84	145.64	0.56	152.50	0.88	2.43	1.66E-04
12089	1846	146.45	145.25	0.71	153.65	1.00	2.48	2.23E-04
12091	1856	146.48	145.28	0.47	156.50	0.59	2.50	1.39E-04
12092	1861	146.05	144.85	0.51	157.41	0.63	2.55	1.50E-04
12243	1863	146.91	145.71	0.60	178.40	0.34	2.81	1.15E-04
12094	1871	145.82	144.62	0.50	158.06	0.68	2.55	1.53E-04
12245	1873	145.29	144.09	0.56	172.51	1.01	2.71	2.39E-04
12095	1876	147.81	146.61	0.49	164.82	0.62	2.66	1.37E-04
12246	1878	145.74	144.54	0.40	180.28	0.60	2.91	1.58E-04
12246	1878	146.13	144.93	0.51	180.49	0.80	2.91	1.85E-04
12096	1881	147.26	146.06	0.67	161.91	0.71	2.63	1.95E-04
12247	1883	146.05	144.85	0.56	180.41	0.55	2.92	1.54E-04
12247	1883	146.23	145.03	0.43	180.81	0.42	2.91	1.18E-04
12248	1888	146.27	145.07	0.45	181.79	0.73	2.91	1.75E-04
12248	1888	146.26	145.06	0.41	180.79	0.55	2.91	1.50E-04
12098	1891	146.31	145.11	0.58	165.23	0.37	2.66	1.16E-04
12250	1898	146.15	144.95	0.52	108.21	0.27	1.31	9.38E-05
12250	1898	146.40	145.20	0.47	108.60	0.22	1.75	2.15E-04
12009	1901	146.43	145.23	0.55	156.06	0.64	2.50	1.42E-04
12008	1903	146.54	145.34	0.49	154.28	0.59	2.49	1.16E-04
12007	1905	146.75	145.55	0.58	154.00	0.52	2.49	1.28E-04
12006	1907	147.45	146.25	0.45	151.55	0.53	2.43	1.12E-04
12005	1908	147.36	146.16	0.49	142.45	0.54	2.31	1.31E-04
12004	1909	146.61	145.41	0.44	153.61	0.63	2.46	1.46E-04
12003	1910	146.22	145.02	0.58	159.71	0.89	2.50	1.92E-04
12002	1911	146.77	145.57	0.53	147.50	0.61	2.33	1.36E-04
11850	1912	147.14	145.94	0.43	148.99	0.60	2.37	1.23E-04
12001	1913	146.49	145.29	0.67	148.97	1.10	2.34	2.00E-04
12000	1915	145.55	144.35	0.57	150.67	0.58	2.39	1.39E-04
11999	1916	146.22	145.02	0.51	147.05	0.56	2.33	1.16E-04
11851	1917	147.55	146.35	0.48	148.37	0.50	2.36	1.31E-04
11998	1918	147.05	145.85	0.52	143.79	0.58	2.26	1.33E-04
11997	1919	145.92	144.72	0.41	140.69	0.64	2.22	1.31E-04

Lab. #	Year	$\delta^{234}U$ (‰) (HU1 = 0)	$\delta^{234}U$ (‰) (HU1 ≠ 0)	Error $\delta^{234}U$ (‰)	^{238}U (pg/g)	Error ^{238}U (pg/g)	^{234}U (µg/g)	Error ^{234}U (µg/g)
11996	1920	147.11	145.91	0.41	134.46	0.47	2.14	1.08E-04
11993	1921	145.97	144.77	0.30	154.46	0.15	2.50	5.36E-05
11852	1922	147.07	145.87	0.51	151.02	0.59	2.43	1.93E-04
11852	1922	146.61	145.41	0.44	146.90	0.33	2.37	1.40E-04
11992	1923	145.94	144.74	0.29	160.20	0.27	2.57	7.70E-05
11991	1924	145.98	144.78	0.22	155.20	0.15	2.51	5.02E-05
11990	1925	146.26	145.06	0.43	151.19	0.28	2.44	7.55E-05
11853	1927	145.94	144.74	0.21	149.59	0.11	2.42	4.40E-05
11988	1928	145.60	144.40	0.24	147.59	0.18	2.39	5.36E-05
11987	1929	146.57	145.37	0.48	157.73	0.64	2.56	1.52E-04
11986	1930	145.38	144.18	0.68	138.11	0.75	2.20	1.76E-04
11985	1931	146.32	145.12	0.36	137.84	0.40	2.25	9.71E-05
11854	1932	146.11	144.91	0.45	152.45	0.55	2.46	1.23E-04
11983	1935	146.27	145.07	0.32	153.59	0.36	2.49	9.10E-05
11982	1936	146.32	145.12	0.69	148.15	1.05	2.42	2.56E-04
11855	1937	145.73	144.53	0.75	154.36	1.27	2.47	2.37E-04
11981	1938	145.76	144.56	0.40	154.39	0.53	2.52	1.16E-04
11980	1939	145.62	144.42	0.29	145.61	0.26	2.36	6.79E-05
11979	1941	146.60	145.40	0.44	154.11	0.57	2.48	1.29E-04
11856	1942	146.34	145.14	0.41	147.62	0.45	2.40	1.14E-04
11857	1947	146.01	144.81	0.52	145.84	0.71	2.33	1.29E-04
11970	1954	146.66	145.46	0.52	146.68	0.50	2.36	1.06E-04
11969	1955	145.93	144.73	0.40	155.47	0.43	2.50	1.09E-04
11859	1957	146.69	145.49	0.42	147.23	0.29	2.37	9.13E-05
11933	1959	148.23	147.03	0.30	152.74	0.31	2.39	7.79E-05
11932	1960	148.10	146.90	0.39	143.46	0.32	2.24	8.29E-05
11931	1963	148.70	147.50	0.30	168.75	0.36	2.43	7.95E-05
11930	1964	147.70	146.50	0.38	158.54	0.53	2.49	1.29E-04
11929	1965	147.20	146.00	0.28	151.70	0.25	2.41	7.32E-05
11861	1967	146.00	144.80	0.36	150.38	0.23	2.43	6.55E-05
11928	1968	147.15	145.95	0.32	133.64	0.23	2.11	6.96E-05
11926	1970	145.71	144.51	0.24	152.46	0.20	2.41	6.25E-05
11925	1971	145.93	144.73	0.28	159.25	0.22	2.51	6.76E-05
11924	1973	146.84	145.64	0.22	153.26	0.15	2.43	5.39E-05
11923	1978	146.73	145.53	0.25	150.17	0.22	2.41	6.08E-05
11862	1981	146.79	145.59	0.02	147.22	0.63	2.39	1.38E-04
11864	1982	145.85	144.65	0.52	140.01	0.57	2.25	1.42E-04
11894	1985	146.08	144.88	0.41	146.10	0.35	2.36	9.83E-05
11893	1988	148.60	147.40	0.30	144.99	0.35	2.30	8.93E-05
11866	1992	145.73	144.53	0.24	142.36	0.18	2.29	5.82E-05
11892	1994	147.88	146.68	0.28	145.25	0.38	2.32	1.07E-04
11876	1998	147.28	146.08	0.37	79.18	0.12	1.27	3.73E-05
11875	1999	147.68	146.48	0.25	130.65	0.19	2.09	6.30E-05
11874	2003	147.50	146.30	0.29	143.38	0.41	2.30	1.13E-04
11870	2012	146.16	144.96	0.78	129.87	0.77	2.05	1.74E-04
11872	2013	146.82	145.62	0.44	138.60	0.47	2.22	9.95E-05

Lab. #	Year	$\delta^{234}U$ (‰) (HU1 = 0)	$\delta^{234}U$ (‰) (HU1 ≠ 0)	Error $\delta^{234}U$ (‰)	^{238}U (pg/g)	Error ^{238}U (pg/g)	^{234}U (µg/g)	Error ^{234}U (µg/g)
11871	2014	146.77	145.57	0.52	130.13	0.52	2.08	1.14E-04

Supplementary Table S2. $\delta^{18}O_w$ of a coral from the Florida Keys (Smith et al., 2006) was calculated with the SST calculated from Sr/Ca ratios by using the equation $Sr/_{Ca} = -0.0282 * SST + 9.962$ (Smith et al., 2006) with this $SST_{Sr/Ca}$, the $\delta^{18}O_w$ is calculated from the measured $\delta^{18}O_C$ by $\delta^{18}O_W = ((SST_{Sr/_{Ca}} - 5.33)/4.519) + \delta^{18}O_c$ (Leder et al., 1996; Ren et al., 2003)

year	$SST_{Sr/Ca}$ (°C)	$\delta^{18}O_w$ (‰ SMOW)
2002	29.54	1.16
2001	28.17	1.13
2000	27.76	1.04
1999	27.38	0.95
1998	24.81	0.49
1997	26.81	0.84
1996	25.89	0.71
1995	27.70	0.98
1994	27.57	0.99
1993	25.87	0.66
1992	26.33	0.83
1991	27.44	0.97
1990	28.94	1.11
1989	28.44	1.06
1988	26.64	0.81
1987	24.24	0.35
1986	26.51	0.64
1985	27.78	0.94
1984	28.28	1.06
1983	26.61	0.75
1982	26.21	0.74
1981	28.36	1.14
1980	26.02	0.68
1979	26.88	0.92
1978	25.70	0.71
1977	26.13	0.93
1976	24.54	0.57
1975	26.26	0.84
1974	25.22	0.57
1973	26.81	0.68
1972	27.02	0.92
1971	27.43	1.01
1970	27.22	0.99
1969	27.86	1.16
1968	28.03	1.21
1967	31.57	1.87
1966	29.80	1.49
1965	29.68	1.37

year	$SST_{Sr/Ca}$ (°C)	$\delta^{18}O_w$ (‰ SMOW)
1964	28.91	1.48
1963	28.42	1.43
1962	28.79	1.47
1961	28.62	1.23
1960	29.20	1.40
1959	27.79	1.14
1958	26.76	0.87
1957	27.73	1.07
1956	29.22	1.42
1955	30.07	1.56
1954	30.32	1.52
1953	29.50	1.22
1952	28.52	1.21
1951	27.94	1.10
1950	27.89	1.05
1949	27.22	0.69
1948	29.25	1.10
1947	27.67	0.92

Alonso-Hernández, C. M., Gómez-Batista, M., Helguera Pedraza, Y., Hernández-Albernas, J., Rico-Esenaro, S. D., Ruiz-Fernández, A. C., Sánchez-Cabeza, J. A., Douville, E., & Montagna, P. (2022). Registro de temperatura superficial del mar (1778-2015) en Orbicella faveolata (Cnidaria: Scleractinia) del arrecife Cayo Santa María, Cuba. In (Vol. 42, pp. 37-53): Revista de Investigaciones Marinas.

Centella-Artola, A., Bezanilla-Morlot, A., Serrano-Notivoli, R., Vazquez-Montenegro, R., Sierra-Lorenzo, M., & Chang-Dominguez, D. (2023). A new long term gridded daily precipitation dataset at high-resolution for Cuba (CubaPrec1). *Data Brief*, *48*, 109294. https://doi.org/10.1016/j.dib.2023.109294

Cheng, H., Lawrence Edwards, R., Shen, C.-C., Polyak, V. J., Asmerom, Y., Woodhead, J., Hellstrom, J., Wang, Y., Kong, X., Spötl, C., Wang, X., & Calvin Alexander, E. (2013). Improvements in 230Th dating, 230Th and 234U half-life values, and U–Th isotopic measurements by multi-collector inductively coupled plasma mass spectrometry. *Earth and Planetary Science Letters*, *371-372*, 82-91. https://doi.org/10.1016/j.epsl.2013.04.006

DeCarlo, T. M., Gaetani, G. A., Cohen, A. L., Foster, G. L., Alpert, A. E., & Stewart, J. A. (2016). Coral Sr-U thermometry. *Paleoceanography*, *31*(6), 626-638. https://doi.org/10.1002/2015pa002908

Fensterer, C., Scholz, D., Hoffmann, D., Spötl, C., Pajón, J. M., & Mangini, A. (2012). Cuban stalagmite suggests relationship between Caribbean precipitation and the Atlantic Multidecadal Oscillation during the past 1.3 ka. *The Holocene*, *22*(12), 1405-1412. https://doi.org/10.1177/0959683612449759

Grzymko, T. J., Marcantonio, F., McKee, B. A., & Mike Stewart, C. (2007). Temporal variability of uranium concentrations and 234U/238U activity ratios in the Mississippi river and its tributaries. *Chemical Geology*, *243*(3-4), 344-356. https://doi.org/10.1016/j.chemgeo.2007.05.024

Harbott, M., Wu, H. C., Kuhnert, H., Jimenez, C., González-Díaz, P., & Rixen, T. (2023). A Warming Southern Gulf of Mexico: Reconstruction of Anthropogenic Environmental Changes From a Siderastrea siderea Coral on the Northern Coast of Cuba. *Paleoceanography and Paleoclimatology*, *38*(12), e2023PA004717. https://doi.org/https://doi.org/10.1029/2023PA004717

Inoue, M., Suwa, R., Suzuki, A., Sakai, K., & Kawahata, H. (2011). Effects of seawater pH on growth and skeletal U/Ca ratios ofAcropora digitiferacoral polyps. *Geophysical Research Letters*, *38*(12), n/a-n/a. https://doi.org/10.1029/2011gl047786

Ivanovich, M., & Harmon, R. S. (1992). *Uranium-series disequilibrium: applications to earth, marine, and environmental sciences. 2. ed*. Oxford (United Kingdom); Clarendon Press;. https://doi.org/https://doi.org/ Other: ISBN: 0 19 854278 X GBN

Leaman, K. D., Vertes, P. S., Atkinson, L. P., Lee, T. N., Hamilton, P., & Waddell, E. (1995). Transport, potential vorticity, and current/temperature structure across Northwest Providence and Santaren Channels and the Florida Current off Cay Sal Bank. *Journal of Geophysical Research: Oceans*, *100*(C5), 8561-8569. https://doi.org/https://doi.org/10.1029/94JC01436

Leder, J. J., Swart, P. K., Szmant, A. M., & Dodge, R. E. (1996). The origin of variations in the isotopic record of scleractinian corals: I. Oxygen. *Geochimica et Cosmochimica Acta*, *60*(15), 2857-2870. https://doi.org/https://doi.org/10.1016/0016-7037(96)00118-4

Ourbak, T., Corrège, T., Malaizé, B., Le Cornec, F., Charlier, K., & Peypouquet, J. P. (2006). A high-resolution investigation of temperature, salinity, and upwelling activity proxies in corals. *Geochemistry, Geophysics, Geosystems*, *7*(3). https://doi.org/10.1029/2005gc001064

Patterson, E., Eanes, S., Lancrete, P., Gothman, A., & Roback, P. (2021). Factors Controlling Coral Skeletal U/Ca Ratios with Implications for their Use as a Proxy for Past Ocean Conditions. *American Journal of Undergraduate Research*, *17*(4), 3-17. https://doi.org/10.33697/ajur.2020.031

Ren, L., Braddock, K. L., Gerard, M. W., Daniel, P. S., & Ove, H.-g. (2003). Deconvolving the δ18O seawater component from subseasonal coral δ18O and Sr/Ca at Rarotonga in the southwestern subtropical Pacific for the period 1726 to 1997. *Geochimica et Cosmochimica Acta*, *67*(9), 1609-1621. https://doi.org/https://doi.org/10.1016/S0016-7037(02)00917-1

Roy-Barman, M., Jeandel, C., Roy-Barman, M., & Jeandel, C. (2016). 129Radioactive and Radiogenic Isotopes. In *Marine Geochemistry: Ocean Circulation, Carbon Cycle and Climate Change* (pp. 0). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198787495.003.0004

Smith, J. M., Quinn, T. M., Helmle, K. P., & Halley, R. B. (2006). Reproducibility of geochemical and climatic signals in the Atlantic coral Montastraea faveolata. *Paleoceanography*, *21*(1). https://doi.org/https://doi.org/10.1029/2005PA001187