Stable oxygen (δ18O) and carbon (δ13C) isotope measurements from a Curaçaoan Massive Starlet Coral core collected from Tugboat Beach, Caracas Bay containing data from 1937 to 2022

Website: https://www.bco-dmo.org/dataset/1006954
Data Type: Other Field Results
Version: 1
Version Date: 2026-09-23

Project
» Collaborative Research: Reconstructions of Southern Caribbean Climate Variability using Contemporaneous and Co-Located Corals and Speleothems (P4Climate Curacao)

Program
» Paleo Perspectives on Present and Projected Climate (P4CLIMATE)

Contributors	Affiliation	Role
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Abstract
These data capture 1-mm variability in the stable oxygen (δ18O) and carbon (δ13C) ratios of cores from a Massive Starlet Coral (Siderastrea siderea (urn:lsid:marinespecies.org:taxname:207516)) core collected from Tugboat Beach, Caracas Bay, Curaçao in February 2023 and in March 2024. Ages of samples, based on internal chronology from annual density banding and seasonal geochemical variability, range from 1937 - 2022 AD. δ18O and δ13C were measured via isotope ratio mass spectrometry (IRMS). These data were used to reconstruct variability and trends in sea surface temperature (SST) for the region over seasonal-to-multidecadal timescales. The generation of such records for Caribbean coral reef ecosystems directly informs our understanding of natural and externally-forced changes to reef metabolism, structure, function, and ultimately stability. These data elucidate gradients in modern Southern Caribbean coral reef metabolism and were collected by a team of researchers associated with an NSF P4Climate-supported award on Southern Caribbean climate change studies.

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Coverage

Location: Southern Caribbean Sea 12.0686°N, 68.8619°W depth 5 m
Spatial Extent: **Lat**:12.0686 **Lon**:-68.8619
Temporal Extent: 1937-02-16 - 2022-10-16

Methods & Sampling

During two separate field campaigns in February 2023 and March 2024, we collected a single skeletal core (TB-01) from a living ~ 1 m tall colony of Massive Starlet coral (*Siderastrea siderea* (urn:lsid:marinespecies.org:taxname:207516)) from Tugboat Beach (12.0686°N, 68.8619°W), a tourist beach located in a semi-enclosed bay on the southeastern end of the island in the town of Jan Thiel. The second field campaign extended the length of the initial core from the first field campaign. This species was targeted due to its hardiness and resilience, slow (3 – 5 mm yr^{-1}) linear extension rate, and consistently robust geochemical proxy calibrations throughout the Caribbean (DeLong et al., 2014; 2023; Moses & Swart, 2006; Saenger et al., 2009). Curaçao also sports relatively high *S. siderea* benthic abundance amongst the island's southeastern reefs (The Waitt Institute, 2017). Although the immediate surrounding bathymetry of the core location is shallow (~5 m), the coral head is located within 50 m of a steep terrace which drops quickly to 30 m depth. Within 200 meters of the sampled coral colony, the seafloor reaches 100 m depth. Skeletal cores were collected vertically from the top of the colony via a 1.5-inch diameter pneumatic air drill. The total core length retrieved was ~50 cm, which was split into 4 sections. These splits were clean, with minimal material loss, minimizing hiatuses in the final coral record. The core was slabbed and x-rayed to identify density banding associated with seasonal growth and to establish a preliminary age model based on the average growth rate. X-ray images showed a coral growth rate of about 5.5mm/yr, allowing for sub-seasonal temporal resolution. On average, each year contained ~5.36 samples equating to roughly a bimonthly resolution. Slabs were sonicated in ultrapure 18.2 MΩ-cm water for 15-30 minutes and dried in an 80°C oven prior to drilling. Thecal walls of slabs were sub-sampled (target mass = 300 mg) at a continuous 1-mm resolution along transects perpendicular to the growth axis using a Sherline Model 4510 drill. Actual powder masses were weighed using a microbalance before being transferred into 12 mL Exetainer borosilicate vials for stable isotope ($\delta^{18}O$ and $\delta^{13}C$) analyses at Vanderbilt University using a ThermoScientific Delta V Isotope Ratio Mass Spectrometer (IRMS) equipped with a GasBench II online preparation and introduction system (e.g. Belanger et al., 2025; de Wet et al., 2024).

The age model for the TB-01 core was constructed using a seasonal tie-point approach, which is standard for high-resolution coral reconstructions. Annual seasonal extrema were identified in the $\delta^{18}O$ record. The $\delta^{18}O$ minima (warmest temperatures) were assigned to October, and the $\delta^{18}O$ maxima (coolest temperatures) were assigned to February. These assignments were corroborated by annual density banding observed in X-ray images, which showed a mean linear extension rate of ~5.5 mm yr^{-1}. Between these fixed seasonal tie-points, ages were assigned to each 1-mm depth increment using linear interpolation. The "Decimal Date" column in the main data file represents the calendar year plus the fraction of the year elapsed (e.g., a value of 2022.79 corresponds to the 288th day of the year, or mid-October). This format allows for precise temporal alignment with instrumental climate indices and satellite SST datasets.

Data Processing Description

For both $\delta^{18}O$ and $\delta^{13}C$, ThermoCalcite and VU Coral in-house carbonate standards were used and are referenced to the IAEA602 and NBS019 standards. Two additional in-house standards, VU Marble and Pol2, were also run as unknowns in each run to quantify run-to-run precision. Data reduction, including drift correction and VPDB normalization, was performed using the USGS LIMS for Light Stable Isotopes data scheme (Coplen, 1998). Both $\delta^{18}O$ and $\delta^{13}C$ are reported as permille deviations relative to Vienna Peedee belemnite (‰ VPDB). In the main data file, the columns for $\delta^{13}C$ and $\delta^{18}O$ standard deviation represent the internal standard deviation (1σ) of the repeated peak integrations (pulses) performed for each individual sample vial during a single GasBench II analysis. These values provide a measure of the analytical stability and precision for that specific sample injection. For the broader context of the project's accuracy and external reproducibility, long-term analytical precision (external - based on repeated analyses of in-house standards) was consistently better than 0.10‰ for $\delta^{18}O$ and 0.14‰ for $\delta^{13}C$.

BCO-DMO Curation Notes

This section documents curation actions performed prior to publication review with the submitter, and additional information relevant to understanding and reusing this dataset. It distinguishes changes made to the submitted (meta)data from unresolved issues and/or enhancements that improve future reuse and interoperability.

CURATION ACTIONS PERFORMED ON DATA

- Loaded TB-01_d18Od13C_BCODMO.csv, with missing values "" and "nd" mapped to null
- Renamed columns to BCO-DMO-conformant, unit-free, alphanumeric+underscore names: "Depth (mm)" to Depth, "Decimal Date" to Decimal_Date, "d13C (permille VPDB)" to d13C, "d13C Std. Dev." to d13C_std_dev, "d18O (permille VPDB)" to d18O, "d18O Std. Dev." to d18O_std_dev
- Converted Decimal_Date (decimal year) into a new Date column formatted as ISO date (YYYY-MM-DD), preserving the original Decimal_Date column
- Output as 1006954_v1_tb01_d18o_d13c.csv

CURATION ACTIONS PERFORMED ON METADATA

- BCO-DMO's standard metadata entry and text formatting steps were performed. See: https://www.bco-dmo.org/how-to/standard-curation-edits

ISSUES POTENTIALLY IMPACTING REUSE

- N/A

Problem Description

Samples at depths (mm) 72, 74, 123, 132, 140, 146, 156, 180, 186, 190, 297, 299, 300, 319, 372, and 446 were compromised during analyses. As a result, the age, depth, and isotope values for these points are not included in the reported dataset.

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Related Publications

Belanger, B. K., Sharp, W. D., Kinsley, C. W., Cai, Y., de Wet, C. B., McKenzie, B. L., & Oster, J. L. (2025). Coeval Holocene Stalagmites Record Multi-Centennial Climate Variability and Drought in the Northern Rocky Mountains, USA. Geophysical Research Letters, 52(17). Portico. https://doi.org/10.1029/2025gl115747
Methods

Coplen, T. B. (1998). A manual for a Laboratory Information Management System (LIMS) for light stable isotopes. Open-File Report. https://doi.org/10.3133/ofr98284
Methods

DeLong, K. L., Flannery, J. A., Poore, R. Z., Quinn, T. M., Maupin, C. R., Lin, K., & Shen, C.-C. (2014). A reconstruction of sea surface temperature variability in the southeastern Gulf of Mexico from 1734 to 2008 C.E. using cross-dated Sr/Ca records from the coral *Siderastrea siderea*. Paleoceanography, 29(5), 403–422. Portico. https://doi.org/10.1002/2013pa002524
Methods

DeLong, K. L., Palmer, K., Wagner, A. J., Weerabaddana, M. M., Slowey, N., Herrmann, A. D., Duprey, N., Martínez-García, A., Jung, J., Hajdas, I., Rose, N. L., Roberts, S. L., Roberts, L. R., Cundy, A. B., Gaca, P., Milton, J. A., Yang, H., Turner, S. D., Huang, C.-Y., et al. (2023). The Flower Garden Banks *Siderastrea siderea* coral as a candidate Global boundary Stratotype Section and Point for the Anthropocene series. The Anthropocene Review, 10(1), 225–250. https://doi.org/10.1177/20530196221147616
Methods

Moses, C. S., & Swart, P. K. (2006). Stable isotope and growth records in corals from the island of Tobago: Not simply a record of the Orinoco. Proceedings of 10th International Coral Reef Symposium, 580–587. https://www.researchgate.net/profile/Christopher-Moses/publication/242741860_Stable_isotope_and_growth_records_in_corals_from_the_island_of_Tobago_Not_simply_a_record_of_the_Orinoco/links/5462d2290cf2c0c6aec1b9c3/Stabl isotope-and-growth-records-in-coral
Methods

Saenger, C., Cohen, A. L., Oppo, D. W., Halley, R. B., & Carilli, J. E. (2009). Surface-temperature trends and variability in the low-latitude North Atlantic since 1552. Nature Geoscience, 2(7), 492–495. doi:10.1038/ngeo552
Methods

de Wet, C. B., Griffith, E. M., Erhardt, A. M., & Oster, J. L. (2024). A Comparative Study of Cave System Calcium Isotope Ratios: Implications for Quantitative Reconstruction of Paleorainfall From Speleothems. Geochemistry, Geophysics, Geosystems, 25(10). Portico. https://doi.org/10.1029/2024gc011691
Methods

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Parameters

Parameter	Description	Units
Depth	Depth in core (shallower is younger)	millimeters
Decimal_Date	Age-modeled year corresponding to depth in core. Represents the calendar year plus the fraction of the year elapsed (e.g., a value of 2022.79 corresponds to the 288th day of the year, or mid-October). This format allows for precise temporal alignment with instrumental climate indices and satellite SST datasets.	unitless
d13C	Sample δ13C value	‰ VPDB
d13C_std_dev	Internal analytical precision of individual sample δ13C measurements (Gasbench II peak pulses)	‰ VPDB
d18O	Sample δ18O value	‰ VPDB
d18O_std_dev	Internal analytical precision of individual sample δ18O measurements (Gasbench II peak pulses)	‰ VPDB
Date	Age-modeled date corresponding to depth in core in ISO format.	unitless

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Instruments

Dataset-specific Instrument Name	ThermoScientific Delta V
Generic Instrument Name	Isotope-ratio Mass Spectrometer
Dataset-specific Description	ThermoScientific Delta V with GasBench II: δ18O and δ13C of samples was determined via isotope ratio mass spectrometry (Delta V with GasBench II, ThermoScientific).
Generic Instrument Description	The Isotope-ratio Mass Spectrometer is a particular type of mass spectrometer used to measure the relative abundance of isotopes in a given sample (e.g. VG Prism II Isotope Ratio Mass-Spectrometer).

Dataset-specific Instrument Name	GasBench II
Generic Instrument Name	Thermo-Fisher Scientific Gas Bench II
Dataset-specific Description	ThermoScientific Delta V with GasBench II: δ18O and δ13C of samples was determined via isotope ratio mass spectrometry (Delta V with GasBench II, ThermoScientific).
Generic Instrument Description	An on-line gas preparation and introduction system for isotope ratio mass spectrometry that is designed for high precision isotope and molecular ratio determination of headspace samples, including water equilibration, carbonates and atmospheric gases. The instrument allows for the use of a dual viscous flow inlet system of repetitive measurements of sample and standard gas on a continuous flow isotope ratio mass spectrometer (CF-IRMS) system. The sample volume is the sample vial (instead of a metal bellows), and the reference gas volume is a pressurized gas tank. The instrument consists of a user programmable autosampler, a gas sampling system, a maintenance-free water removal system, a loop injection system, an isothermal gas chromatograph (GC), an active open split interface, a reference gas injection system with three reference ports, and one or two optional LN2 traps for cryofocusing. The gas sampling system includes a two port needle which adds a gentle flow of He into the sample vial, diluting and displacing sample gas. Water is removed from the sample gas through diffusion traps. The loop injector aliquots the sample gas onto the GC column, which separates the molecular species. The reference gas injection system allows accurate referencing of each sample aliquot to isotopic standards. The system can be used with several options including a carbonate reaction kit that allows injection of anhydrous phospohric acid into sample vials. Note "Finnigan GasBench-II" is the previous brand name of this instrument.

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Project Information

Collaborative Research: Reconstructions of Southern Caribbean Climate Variability using Contemporaneous and Co-Located Corals and Speleothems (P4Climate Curacao)

Coverage: Curacao, Dutch Caribbean

NSF Award Abstract:
Historical and ancient climate data from paleoclimate proxy records can provide the long-term climate context necessary to support coastal Caribbean communities in preparing for, adapting to, and/or mitigating the numerous impacts of anthropogenic climate change. This project will study coral and speleothem carbonates from reef ecosystems and cave environments on the island of Curaçao in the arid Southern Caribbean. Geochemical analyses and dating of these carbonates will be used to generate records of local temperature and aridity that span the interval as Earth warmed from the Last Glacial Maximum (~20 thousand years ago) to present. Coupling these geochemical analyses with monitoring of modern reef and cave environments and numerical modeling will help determine the extent to which Caribbean Sea climates have varied in the past and the role that they play in mediating global climate on seasonal to glacial-interglacial timescales. The proposed research presents a unique opportunity to develop and apply integrated approaches to understand coeval archives of terrestrial and marine climate variability at a single, relatively understudied location. Broader impacts of this research include the dissemination of major findings through community-influenced geoscience curricula development and tiered mentorship opportunities for students from the K-12 through postdoctoral levels. For example, the research will support research exchange opportunities for University of Curaçao students through a targeted cross-institutional partnership with the Caribbean Research and Management of Biodiversity (CARMABI) foundation, in which undergraduate students will work on the Georgia Tech and Vanderbilt campuses where they will be integrated into a diverse, multi-institutional team of PIs, postdocs, and graduate and undergraduate students.

Anthropogenic climate change in the Caribbean Sea is projected to extend seasonal warm periods, increase the frequency and intensity of heavy rainfall events, and increase periods of prolonged drought. Paleoclimate records from speleothem and coral carbonates from the wet tropical Northern and Western Caribbean have provided context for these projections by illustrating the relevant climate drivers and teleconnections over the past several thousand years. However, equally extensive and informative records are notably absent from the arid Southern Caribbean. This project will develop precisely dated, co-located coral and speleothem proxy temperature and hydroclimate records from Curaçao, synthesize these records with other regional and global proxies, and make transformative progress in the understanding of how carbonate minerals in terrestrial and marine ecosystems record past environmental change in this region. Trace element-to-calcium ratios (i.e. Sr/Ca, Mg/Ca, Ba/Ca, etc.) and traditional stable isotopes (δ18O, δ13C, etc.) from actively-precipitating stalagmites, drip waters, modern coral skeletons, and seawater will be further integrated with proxy system models and instrumental data to fingerprint the dominant drivers of terrestrial and marine climate on seasonal to decadal timescales. This understanding will be applied to jointly interpret speleothem and coral proxy records of hydroclimate and SST and develop a comprehensive picture of seasonal to millennial climate evolution since the last deglaciation. This work includes the development of optimal U-Th dating techniques to jointly analyze speleothem and coral carbonates, active seawater and cave monitoring, and the development and application of novel geochemical proxies, including new methods for the analysis of the calcium isotope quantitative precipitation proxy in speleothems via collision cell multi-collector ICP-MS. This award is co-funded by the Division of Earth Sciences and Division of Atmospheric and Geospace Sciences by way of the Paleo Perspectives on Present and Projected Climate Program, as well as the Division of Earth Sciences funds for support of projects that increase research capabilities, capacity and infrastructure at a wide variety of institution types, as outlined in the GEO EMBRACE DCL.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

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Program Information

Paleo Perspectives on Present and Projected Climate (P4CLIMATE)

Website: https://new.nsf.gov/funding/opportunities/paleo-perspectives-present-projected-climate

excerpt from https://new.nsf.gov/funding/opportunities/paleo-perspectives-present-projected-climate (Accessed on 2024-09-04):

Synopsis:

Much can be learned about the climate system using existing historical observations and models of current climate, but those records and models do not reflect the range of climate behavior on multi-decadal to millennial time scales, or capture tipping points, thresholds, and other key features of the climate system. For that, data from geological records or other environmental archives are required.

The PALEO PERSPECTIVES ON PRESENT AND PROJECTED CLIMATE (P4CLIMATE) competition is a coordinated paleoclimate science initiative that is funded by the National Science Foundation (NSF) Divisions of Atmospheric and GeoSpace Sciences (AGS), Earth Sciences (EAR), Ocean Sciences (OCE), and Office of Polar Programs (OPP) in the Geosciences (GEO) Directorate. The annual P4CLIMATE competition supports the scientific objectives of the National Science Foundation by fostering interdisciplinary research and synthesis of climate data.

The goal of the interdisciplinary P4CLIMATE solicitation is to utilize observational and modeling studies to provide paleo perspectives addressing the two research themes: 1) Past Regional and Seasonal Climate; and 2) Past Climate Forcing, Sensitivity, and Feedbacks.

OPP will accept proposals to this solicitation A) with and without fieldwork in the Arctic, and B) only without fieldwork in the Antarctic. Proposals that have fieldwork in Antarctica should be submitted to the annual solicitation for proposals that have fieldwork in Antarctica.

Program Solictiation:
NSF 22-612: Paleo Perspectives on Present and Projected Climate (P4CLIMATE)

Full Proposal Target Date(s):

October 20, 2022

October 20, Annually Thereafter

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Funding

Funding Source	Award
NSF Division of Earth Sciences (NSF EAR)	EAR-2303297
NSF Division of Earth Sciences (NSF EAR)	EAR-2303298

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