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Dataset Paper

Global Speleothem Oxygen Isotope Measurements Since the Last Glacial Maximum

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This synthesis of thirty-six sites (sixty cores with over 27 000 measurements) located around the world facilitates scientific research on the climate of the last 21 000 years ago obtained from oxygen isotope (δ^{18}O or delta-O-18) measurements. Oxygen isotopes in speleothem calcite record the influence of ambient temperature and the isotopic composition of the source water, the latter providing evidence of hydrologic variability and change. Compared to paleoclimate proxies from sedimentary archives, the age uncertainty is unusually small, around +/−100 years for the last 21 000-year interval. Using data contributed to the World Data Center (WDC) for Paleoclimatology, we have created consistently formatted data files for individual sites as well as composite dataset of annual to millennial resolution. These individual files also contain the chronology information about the sites. The data are useful in understanding hydrologic variability at local and regional scales, such as the Asian summer monsoon and the Intertropical Convergence Zone (as discussed in the underlying source publications), and should also be useful in understanding large-scale aspects of hydrologic change since the Last Glacial Maximum (LGM).

1. Introduction

Speleothems are precipitated calcium carbonate deposits in caves. Stalagmites grow from the ground up in caves, stalactites are the formations that hang from the ceilings, and flowstones are sheetlike deposits that form on walls and floors. Oxygen isotope measurements from cave deposits provide some of the highest-resolution and best-dated information about past fluctuations in temperature and precipitation. Over the past decade, a relatively dense network of sites has been measured spanning the time period from the Last Glacial Maximum (LGM; 21 000 years ago) to present. These sites yield data that address key scientific questions surrounding climate sensitivity to greenhouse gas concentrations, nonlinear responses and thresholds in the climate system, and the skill of state-of-the-art climate models in reproducing states different from the present one.

The ratio of two stable isotopes of oxygen, ^{16}O and ^{18}O, is used by paleoclimatologists as tracers of the hydrologic cycle. This is possible because the amount of one relative to the other is altered as water goes through phase changes such as evaporation and condensation. Thus, the measure δ^{18}O (delta-O-18), which is defined as

$$\delta^{18}\mathrm{O} = \left(\frac{{}^{18}\mathrm{O}/{}^{16}\mathrm{O}_{\text{sample}} - {}^{18}\mathrm{O}/{}^{16}\mathrm{O}_{\text{standard}}}{{}^{18}\mathrm{O}/{}^{16}\mathrm{O}_{\text{standard}}}\right) \times 1000, \quad (1)$$

has climatological significance. The standard for carbonates such as cave deposits is the Pee Dee Belemnite (PDB), a Cretaceous marine fossil [1]. Samples with negative δ^{18}O have less ^{18}O relative to ^{16}O than Pee Dee Belemnite. Following depletion of this original standard, a new reference standard that was calibrated to PDB and known as Vienna PDB (VPDB) is also used [2].

Several factors influence the oxygen isotopic variability in precipitation, and subsequently in the speleothem calcite that is formed, specifically a temperature effect, a continental effect, an elevation effect, and an amount effect (see, e.g., [3]).

Common to all of these effects is that fact that equilibrium fractionation of the two isotopes during condensation results in ^{18}O being preferentially concentrated in the liquid phase over the vapor phase (i.e., rain has a higher $\delta^{18}O$ than the vapor that sources it). Thus, as precipitation forms from a moist air mass, the $\delta^{18}O$ of the vapor in the air mass will decrease. Since the offset in $\delta^{18}O$ between vapor and precipitation is nearly constant, both the vapor and the precipitation formed from it will become more depleted in ^{18}O (i.e., their $\delta^{18}O$ values will decrease) as more and more condensation occurs, a process known as Rayleigh distillation (see, e.g., [4]). The temperature effect relates to the fact that more condensation occurs when temperatures drop. The continental effect refers to the progressive depletion of ^{18}O with distance from oceanic sources of water. The elevation effect results from condensation that occurs as air masses ascend due to topography. The amount effect describes the tendency for depleted isotopic values to correspond with increasing monthly or annual precipitation amount. In addition to Rayleigh distillation, the amount effect is also caused by the tendency for high-intensity rainfall to have more large raindrops that retain the depleted isotopic composition present higher in the atmosphere, and also by decreased reevaporation of falling raindrops in humid conditions [3].

In addition to these effects on rainwater composition, other factors influencing speleothem $\delta^{18}O$ are ice volume and source (ocean) temperature [5]. The increase in ice volume accounts for an approximately 1.0–1.2 per mil enrichment in $\delta^{18}O$ of the global ocean at the Last Glacial Maximum relative to today owing to ^{16}O preferentially stored in continental glacial ice, and it is apparent in most of the records compiled here. Similarly, the effect of the average 4°C cooler [6] glacial ocean on isotope fractionation during evaporation from the ocean should be evident in the records that reach the LGM.

Cave deposits record these $\delta^{18}O$ changes in their calcium carbonate. These mineral deposits form as rainfall seeps through carbonate bedrock and enters underground caverns as groundwater. Then, degassing of carbon dioxide from the groundwater may cause the precipitation of calcium carbonate ($CaCO_3$) that, as long as certain environmental conditions are met in the cave, contains the oxygen isotopic signature of the original rainfall [7]. Isotopic fractionation can also occur due to other environmental processes in the soil, epikarst, and cave systems (e.g., during infiltration and evaporation), as described in greater detail in [8]. For example, cave temperature impacts $\delta^{18}O$ through the temperature-dependent fractionation of oxygen during calcite formation [9]. Many sampled caves, particularly those from tropical locations, were originally chosen by scientists to minimize the influence of changing cave temperature, and at these locations, the cave temperature effect has been discounted as negligible. Likewise, scientists typically select caves to sample with the goal of minimizing other complicating influences, but uncertainties still exist.

Stalagmites, stalactites, and other cave deposits may be annually banded or contain elements that can be used in radiometric dating (e.g., uranium-series dating). Speleothems are particularly useful for generating climate records spanning up to several hundred thousand years (see, e.g., [10]) with age precision close to ±0.5% [11]. This precision can be significantly better than records relying on radiocarbon dating, which is complicated by radiocarbon calibration and reservoir age corrections.

This dataset paper describes a compilation of speleothem $\delta^{18}O$ measurements since the LGM. All of these measurements were previously archived by the original principal investigators (PIs) at the World Data Center (WDC) for Paleoclimatology. The WDC for Paleoclimatology is operated by the National Oceanic and Atmospheric Administration's National Climatic Data Center (NOAA's NCDC) and provides a long-term archive of paleoclimate data. (All datasets archived at the WDC for Paleoclimatology are available to the public at no cost at http://www.ncdc.noaa.gov/paleo/speleothem.html and no registration is required. Users are requested to cite the original references and this dataset paper when using the compilation. Additionally, please include the URL retrieved and the date accessed.) This compilation improves upon the existing data archive by including standardized units, machine-readable file formats, and data composites at annual to milennial resolution. The objective of this dataset paper is to make these data more accessible to the specialist and nonspecialist alike, and the objective of the compilation is to facilitate research on past hydrologic variability.

2. Methodology

The original laboratory measurements followed procedures standardized by the speleothem community, allowing the data to be combined into a homogenized dataset. The PIs used standard laboratory methods of sampling (e.g., microdrilling, micromiling, or laser ablation) and measurement using a mass spectrometer with automated carbonate preparation system (see, e.g., [8, 11]). Both the accuracy and the precision of the $\delta^{18}O$ measurements are on the order of ±0.1‰ (see, e.g., [12]). The age control for all cores was based on uranium-series dating, performed on either a Thermal Ionization Mass Spectrometer (TIMS) or Multicollector Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS), following standard practices [13, 14], with a precision close to ±0.5% [11].

We selected all speleothem $\delta^{18}O$ time series from the WDC with measurements spanning at least several thousand years of the last 21 000 years. We standardized all age units to calendar years before present, where present is 1950 A.D. Uranium-series dating provides absolute ages, but PIs often define the present year differently. We also converted any $\delta^{18}O$ measurements reported relative to the Standard Mean Ocean Water (SMOW, also equivalent to VSMOW) standard to the PDB standard using the following equation [15, 16]:

$$\delta^{18}O_{PDB} = 0.97002 * \delta^{18}O_{SMOW} - 29.98. \qquad (2)$$

Six time series required this conversion; all other measurements were originally reported relative to the PDB standard. This linear conversion does not alter the interpretation of any time series; it merely ensures that all units are consistent with the community's standard. The time series have not been corrected for changes in $\delta^{18}O$ due to the reduction in global ice volume since the LGM. As discussed in the previous section, the magnitude of this effect is approximately 1.0–1.2 ‰ and the same for all records [17, 18].

3. Dataset Description

The dataset associated with this Dataset Paper consists of 14 items which are described as follows.

Dataset Item 1 (Table). Metadata information for each of the sixty cores (i.e., site name, core name, latitude, longitude, principal investigator, and journal citation). Also provided in these metadata are Universal Resource Locators (URLs) for machine-readable ASCII files for each core, which give more complete information about site-specific metadata, dating methods, and all raw data (Figure 2).

Column 1: Core Index
Column 2: Site Name
Column 3: Core Name
Column 4: Latitude
Column 5: Longitude
Column 6: Principle Investigator
Column 7: Citation
Column 8: Date Accessed
Column 9: File URL

Dataset Item 2 (Table). A compilation of speleothem oxygen isotope records including quality-controlled values from 60 cores at 36 sites (Figure 1; Table 1), for a total of 27 981 $\delta^{18}O$ values. The R code to read this csv file is as follows: speleo <-read.csv("548048.item.2.csv",header=TRUE). The spatial distribution of these sites is constrained by the environmental conditions necessary for cave formation (e.g., soluble bedrock and climate conducive to dissolution and deposition processes) as well as by cave exploration and documentation. These time series span part or all of the last deglaciation and Holocene and are provided on a common age scale (calendar years before present, where present equals 1950 A.D.) and with common measurement units (per mil PDB). Data for all sixty cores are presented in three columns. The first column is Core Index, which identifies the core according to the metadata table (Dataset Item 1); the second column is Age in calendar years BP; the third column is Delta-O-18 of Calcium Carbonate in per mil PDB.

Column 1: Core Index
Column 2: Age (cal yr BP)
Column 3: Delta-O-18 of Calcium Carbonate (‰)

Dataset Item 3 (Table). An average of samples aggregated over 1-year intervals (annual) from the original raw data located at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv (Dataset Item 1 (Table)). The first column is Age that presents the date of 1-year interval in calendar years before present (cal yr BP). Columns 2–61 present the average of aggregated $\delta^{18}O$ of calcium carbonate (per mil PDB) for each core (60 cores). Missing values are identified by "NaN."

Column 1: Age (cal yr BP)
Column 2: Core 1
Column 3: Core 2
⋮
Column 59: Core 58
Column 60: Core 59
Column 61: Core 60

Dataset Item 4 (Table). A count of samples aggregated over 1-year intervals (annual) from the original raw data located at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv (Dataset Item 1 (Table)). The first column is Age that presents the date of 1-year interval in calendar years before present (cal yr BP). Columns 2–61 present the count of aggregated $\delta^{18}O$ of calcium carbonate (per mil PDB) for each core (60 cores). Missing values are identified by "NaN."

Column 1: Age (cal yr BP)
Column 2: Core 1
Column 3: Core 2
⋮
Column 59: Core 58
Column 60: Core 59
Column 61: Core 60

Dataset Item 5 (Table). Standard deviation of samples aggregated over 1-year intervals (annual) from the original raw data located at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv (Dataset Item 1 (Table)). The first column is Age that presents the date of 1-year interval in calendar years before present (cal yr BP). Columns 2–61 present the standard deviation of aggregated $\delta^{18}O$ of calcium carbonate (per mil PDB) for each core (60 cores). Missing values are identified by "NaN."

Column 1: Age (cal yr BP)
Column 2: Core 1
Column 3: Core 2
⋮
Column 59: Core 58
Column 60: Core 59
Column 61: Core 60

Dataset Item 6 (Table). An average of samples aggregated over 10-year intervals (decadal) from the original raw data

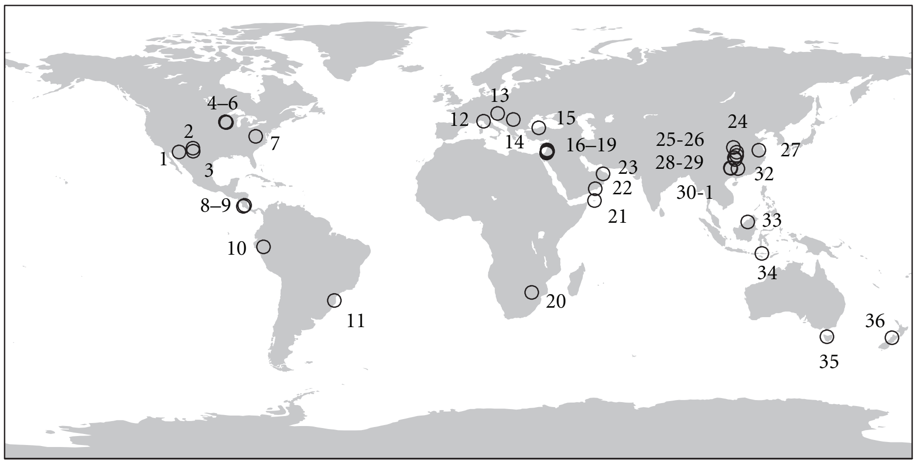
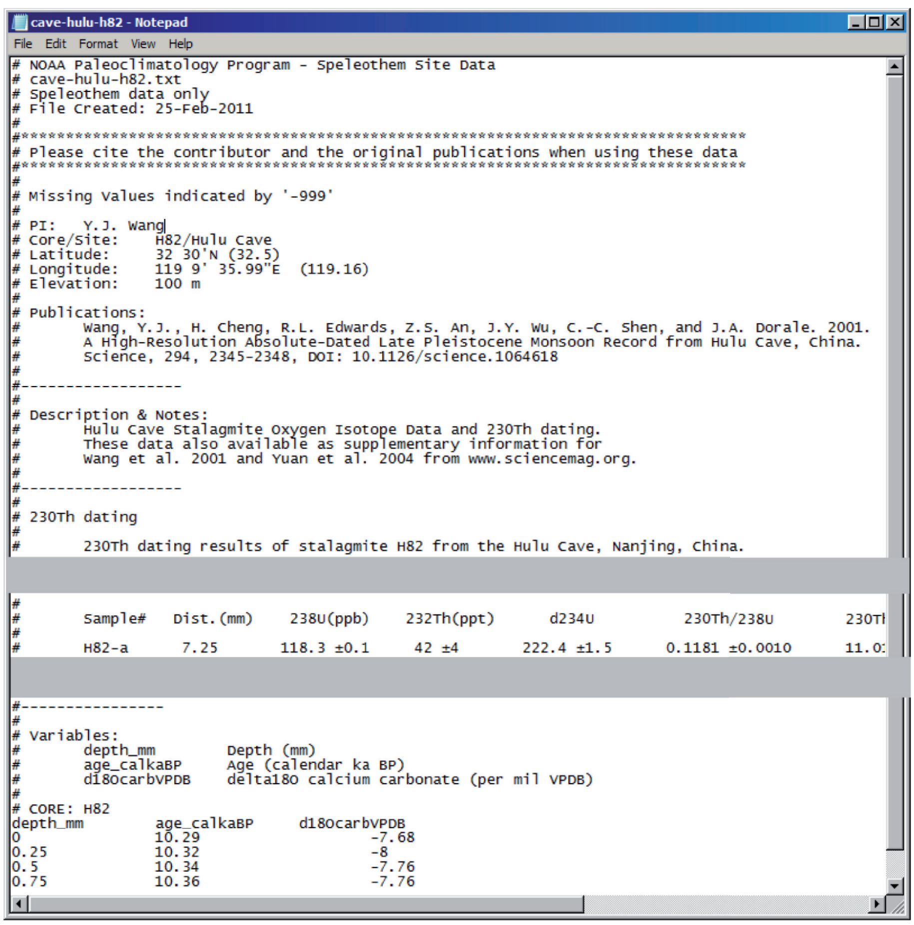


Figure 1: Location of speleothem cores included in data product. Numbers refer to the sequence in Table 1.



```
cave-hulu-h82 - Notepad
File Edit Format View Help
# NOAA Paleoclimatology Program - Speleothem Site Data
# cave-hulu-h82.txt
# Speleothem data only
# File Created: 25-Feb-2011
#
#*****************************************************************************
# Please cite the contributor and the original publications when using these data
#*****************************************************************************
#
# Missing Values indicated by '-999'
#
# PI:    Y.J. Wang
# Core/Site:     H82/Hulu Cave
# Latitude:      32 30'N (32.5)
# Longitude:     119 9' 35.99"E  (119.16)
# Elevation:     100 m
#
# Publications:
#       Wang, Y.J., H. Cheng, R.L. Edwards, Z.S. An, J.Y. Wu, C.-C. Shen, and J.A. Dorale. 2001.
#       A High-Resolution Absolute-Dated Late Pleistocene Monsoon Record from Hulu Cave, China.
#       Science, 294, 2345-2348, DOI: 10.1126/science.1064618
#
#-----------------
#
# Description & Notes:
#       Hulu Cave Stalagmite Oxygen Isotope Data and 230Th dating.
#       These data also available as supplementary information for
#       Wang et al. 2001 and Yuan et al. 2004 from www.sciencemag.org.
#
#-----------------
#
# 230Th dating
#
#       230Th dating results of stalagmite H82 from the Hulu Cave, Nanjing, China.

#
#       Sample#   Dist.(mm)    238U(ppb)     232Th(ppt)      d234U          230Th/238U        230Th
#
#       H82-a       7.25       118.3 ±0.1     42 ±4       222.4 ±1.5     0.1181 ±0.0010      11.0

#----------------
#
# Variables:
#       depth_mm          Depth (mm)
#       age_calkaBP       Age (calendar ka BP)
#       d18ocarbVPDB      delta18O calcium carbonate (per mil VPDB)
#
# CORE: H82
depth_mm         age_calkaBP     d18ocarbVPDB
0                10.29                   -7.68
0.25             10.32                   -8
0.5              10.34                   -7.76
0.75             10.36                   -7.76
```

Figure 2: Sample machine-readable ASCII file for an individual speleothem core. Horizontal gray bars indicate the location of text cut for display purposes.

located at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv (Dataset Item 1 (Table)). The first column is Age that presents the midpoint age of 10-year interval in calendar years before present (cal yr BP). Columns 2–61 present the average of aggregated $\delta^{18}O$ of calcium carbonate (per mil PDB) for each core (60 cores). Missing values are identified by "NaN."

Column 1: Age (cal yr BP)

Column 2: Core 1

Table 1: Sites included in data product.

Site name	Latitude (°N)	Longitude (°E)	Numbers of cores	Time range (kyr BP)*	Citation
(1) Cave of the Bells	31.8	−110.8	1	11.5–22.0	[22]
(2) Fort Stanton Cave	33.3	−105.3	1	11.4–22.0	[23]
(3) Pink Panther Cave	32.1	−105.2	1	0–12.1	[24]
(4) Cold Water Cave	43.5	−92.0	3	0–8.6	[25]
(5) Mystery Cave	43.6	−92.3	1	0–7.5	[26]
(6) Spring Valley Caverns	43.8	−92.4	2	0–8.5	[26]
(7) Buckeye Cave	38.0	−80.4	3	0–7.8	[27, 28]
(8) Terciopelo Cave	10.2	−85.3	1	6.5–7.9	[29]
(9) Venado Cave	10.6	−84.8	1	4.9–8.8	[30]
(10) Cueva del Tigre Perdido	−5.9	−77.3	2	0–13.4	[31]
(11) Botuverá Cave	−27.2	−49.2	2	0–22.0	[20, 32]
(12) Buca della Renella	44	0	1	1.3–7.0	[33]
(13) Katerloch Cave	47.1	15.6	2	7.1–10.4	[34]
(14) Poleva Cave	44.7	21.8	1	2.4–11.5	[35]
(15) Sofular Cave	41.4	31.9	1	0–21.6	[36]
(16) Jerusalem West Cave	31.8	35.2	1	0–22.0	[37]
(17) Ma'ale Efrayim Cave	32.1	35.4	1	16.6–19.2	[38]
(18) Peqiin Cave	32.6	35.2	1	14.0–22.0	[39]
(19) Soreq Cave	31.4	35.0	1	0–22.0	[39]
(20) Cold Air Cave	−24.0	29.1	2	0–22.0	[40, 41]
(21) Moomi Cave	12.5	54	1	11.1–22.0	[42]
(22) Qunf Cave	17.2	54.3	1	0–10.6	[43]
(23) Hoti Cave	23.1	57.4	1	6.0–9.6	[44]
(24) Jiuxian Cave	33.6	109.1	2	0–8.6	[45]
(25) Heshang Cave	30.4	110.4	1	0–9.5	[46]
(26) Sanbao Cave	31.7	110.4	7	0–19.2	[10, 47]
(27) Hulu Cave	32.5	119.2	4	6.0–22.0	[48]
(28) Lianhua Cave	29.5	109.5	1	0–6.6	[49]
(29) Yaoba Don Cave	28.8	109.8	1	19.1–22.0	[50]
(30) Dongge Cave	25.3	108.1	3	0–15.8	[12, 19, 51]
(31) Yamen Cave	25.5	107.9	1	7.3–16.3	[52]
(32) Xiangshui Cave	25.2	110.9	1	19.7–22.0	[50]
(33) Gunung Buda	4.0	114.8	3	0–22.0	[21]
(34) Liang Luar Cave	−8.5	120.4	2	0–12.6	[53]
(35) Lynds Cave	−41.6	146.2	1	5.1–8.9	[54]
(36) New Zealand composite	−42	172	1	0–22.0	[55]

*kyr BP: kiloyears before present (present equals 1950 A.D.).

Column 3: Core 2

⋮

Column 59: Core 58

Column 60: Core 59

Column 61: Core 60

Dataset Item 7 (Table). A count of samples aggregated over 10-year intervals (decadal) from the original raw data located at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv (Dataset Item 1 (Table)). The first column is Age that presents the midpoint age of 10-year interval in calendar years before present (cal yr BP). Columns 2–61 present the count of aggregated δ^{18}O of calcium carbonate (per mil PDB) for each core (60 cores). Missing values are identified by "NaN."

Column 1: Age (cal yr BP)

Column 2: Core 1

Column 3: Core 2

⋮

Column 59: Core 58

Column 60: Core 59

Column 61: Core 60

Dataset Item 8 (Table). Standard deviation of samples aggregated over 10-year intervals (decadal) from the original raw data located at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv (Dataset Item 1 (Table)). The first column is Age that presents the midpoint age of 10-year interval in calendar years before present (cal yr BP). Columns 2–61 present the standard deviation of aggregated δ^{18}O of calcium carbonate (per mil PDB) for each core (60 cores). Missing values are identified by "NaN."

Column 1: Age (cal yr BP)
Column 2: Core 1
Column 3: Core 2
⋮
Column 59: Core 58
Column 60: Core 59
Column 61: Core 60

Dataset Item 9 (Table). An average of samples aggregated over 100-year intervals (centennial) from the original raw data located at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv (Dataset Item 1 (Table)). The first column is Age that presents the midpoint age of 100-year interval in calendar years before present (cal yr BP). Columns 2–61 present the average of aggregated δ^{18}O of calcium carbonate (per mil PDB) for each core (60 cores). Missing values are identified by "NaN."

Column 1: Age (cal yr BP)
Column 2: Core 1
Column 3: Core 2
⋮
Column 59: Core 58
Column 60: Core 59
Column 61: Core 60

Dataset Item 10 (Table). A count of samples aggregated over 100-year intervals (centennial) from the original raw data located at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv (Dataset Item 1 (Table)). The first column is Age that presents the midpoint age of 100-year interval in calendar years before present (cal yr BP). Columns 2–61 present the count of aggregated δ^{18}O of calcium carbonate (per mil PDB) for each core (60 cores). Missing values are identified by "NaN."

Column 1: Age (cal yr BP)
Column 2: Core 1
Column 3: Core 2
⋮
Column 59: Core 58
Column 60: Core 59
Column 61: Core 60

Dataset Item 11 (Table). Standard deviation of samples aggregated over 100-year intervals (centennial) from the original raw data located at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv (Dataset Item 1 (Table)). The first column is Age that presents the midpoint age of 100-year interval in calendar years before present (cal yr BP). Columns 2–61 present the standard deviation of aggregated δ^{18}O of calcium carbonate (per mil PDB) for each core (60 cores). Missing values are identified by "NaN."

Column 1: Age (cal yr BP)
Column 2: Core 1
Column 3: Core 2
⋮
Column 59: Core 58
Column 60: Core 59
Column 61: Core 60

Dataset Item 12 (Table). An average of samples aggregated over 1000-year intervals (millennial) from the original raw data located at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv (Dataset Item 1 (Table)). The first column is Age that presents the midpoint age of 1000-year interval in calendar years before present (cal yr BP). Columns 2–61 present the average of aggregated δ^{18}O of calcium carbonate (per mil PDB) for each core (60 cores). Missing values are identified by "NaN."

Column 1: Age (cal yr BP)
Column 2: Core 1
Column 3: Core 2
⋮
Column 59: Core 58
Column 60: Core 59
Column 61: Core 60

Dataset Item 13 (Table). A count of samples aggregated over 1000-year intervals (millennial) from the original raw data located at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv (Dataset Item 1 (Table)). The first column is Age that presents the midpoint age of 1000-year interval in calendar years before present (cal yr BP). Columns 2–61 present the count of aggregated δ^{18}O of calcium carbonate (per mil PDB) for each core (60 cores). Missing values are identified by "NaN."

Column 1: Age (cal yr BP)
Column 2: Core 1

Column 3: Core 2

⋮

Column 59: Core 58

Column 60: Core 59

Column 61: Core 60

Dataset Item 14 (Table). Standard deviation of samples aggregated over 1000-year intervals (millennial) from the original raw data located at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv (Dataset Item 1 (Table)). The first column is Age that presents the midpoint age of 1000-year interval in calendar years before present (cal yr BP). Columns 2–61 present the standard deviation of aggregated $\delta^{18}O$ of calcium carbonate (per mil PDB) for each core (60 cores). Missing values are identified by "NaN."

Column 1: Age (cal yr BP)

Column 2: Core 1

Column 3: Core 2

⋮

Column 59: Core 58

Column 60: Core 59

Column 61: Core 60

4. Concluding Remarks

This dataset paper documents a new compilation of speleothem $\delta^{18}O$ measurements available at the World Data Center for Paleoclimatology. These data can be interpreted in terms of the climatic and environmental factors influencing isotopic fractionation, as described previously. The measurements themselves are among the highest quality of any paleoclimate proxy archive, particularly in terms of their accuracy, precision, and resolution. The contributions of the new data compilation are to further standardize the units of these $\delta^{18}O$ time series and to provide them in a machine-readable format that enables more complex analyses to be undertaken in the future.

One important type of research this compilation will facilitate is the description of the spatial and temporal patterns of abrupt climate changes around the globe since the LGM. For example, Figure 3 shows time series from China [19], Brazil [20], and Borneo [21]. For all three time series, more negative $\delta^{18}O$ values indicate wetter conditions. At Dongge Cave in China, the Bølling-Allerød and the Younger Dryas abrupt climate change events are apparent as relatively wet and dry periods, respectively. Climate changes of the opposite direction occurred at Botuverá Cave in Brazil, consistent with the idea of global shifts in the Intertropical Convergence Zone between more northerly and more southerly positions at these time intervals [19, 20]. In Borneo, on the other hand, no abrupt climate changes are observed. The smooth shape of that time series suggests a limited potential for abrupt shifts in the Western Pacific Warm Pool [21].

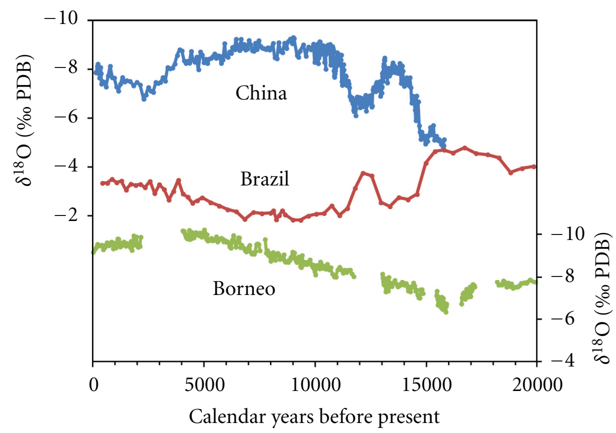


Figure 3: Time series of $\delta^{18}O$ from caves in China (Dongge Cave [19]), Brazil (Botuvera Cave [20]), and Borneo (Gunung Buda National Park [21]). In each case, more negative values of $\delta^{18}O$ indicate wetter conditions. Two vertical shaded bars show the timing of the Younger Dryas (YD) and Bølling-Allerød (B/A).

Another important application of this dataset will be to compare speleothem $\delta^{18}O$ with simulated values from global coupled climate models that incorporate water isotope tracers. Such direct model-data comparisons may help to test and to improve the representation of the hydrologic cycle in the models being used to generate future climate projections.

Dataset Availability

The dataset associated with this Dataset Paper is dedicated to the public domain using the CC0 waiver and is available at http://dx.doi.org/10.7167/2013/548048/dataset. In addition, the comma-separated values (.csv) file of all measurements is accessible at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-0-22k.csv. The comma-separated values files with $\delta^{18}O$ values averaged to annual, decadal, centennial, and millennial resolution are also available. For each resolution, three files exist that separately contain the average (avg), the count (count), and standard deviation (stdev) of values contributing to the average. These files are accessible at ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-1yr-avg.csv, ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-1yr-count.csv, ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-1yr-stdev.csv, ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-10yr-avg.csv, ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-10yr-count.csv, ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-10yr-stdev.csv, ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-100yr-avg.csv, ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-100yr-count.csv, ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-100yr-stdev.csv, ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-1000yr-avg.csv, ftp://ftp.ncdc.noaa.gov/pub/data/paleo/syntrace/speleothem/speleothem-d18o-1000yr-count.csv, and ftp://ftp

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Disclosure

The authors declare that they have no competing financial interests.

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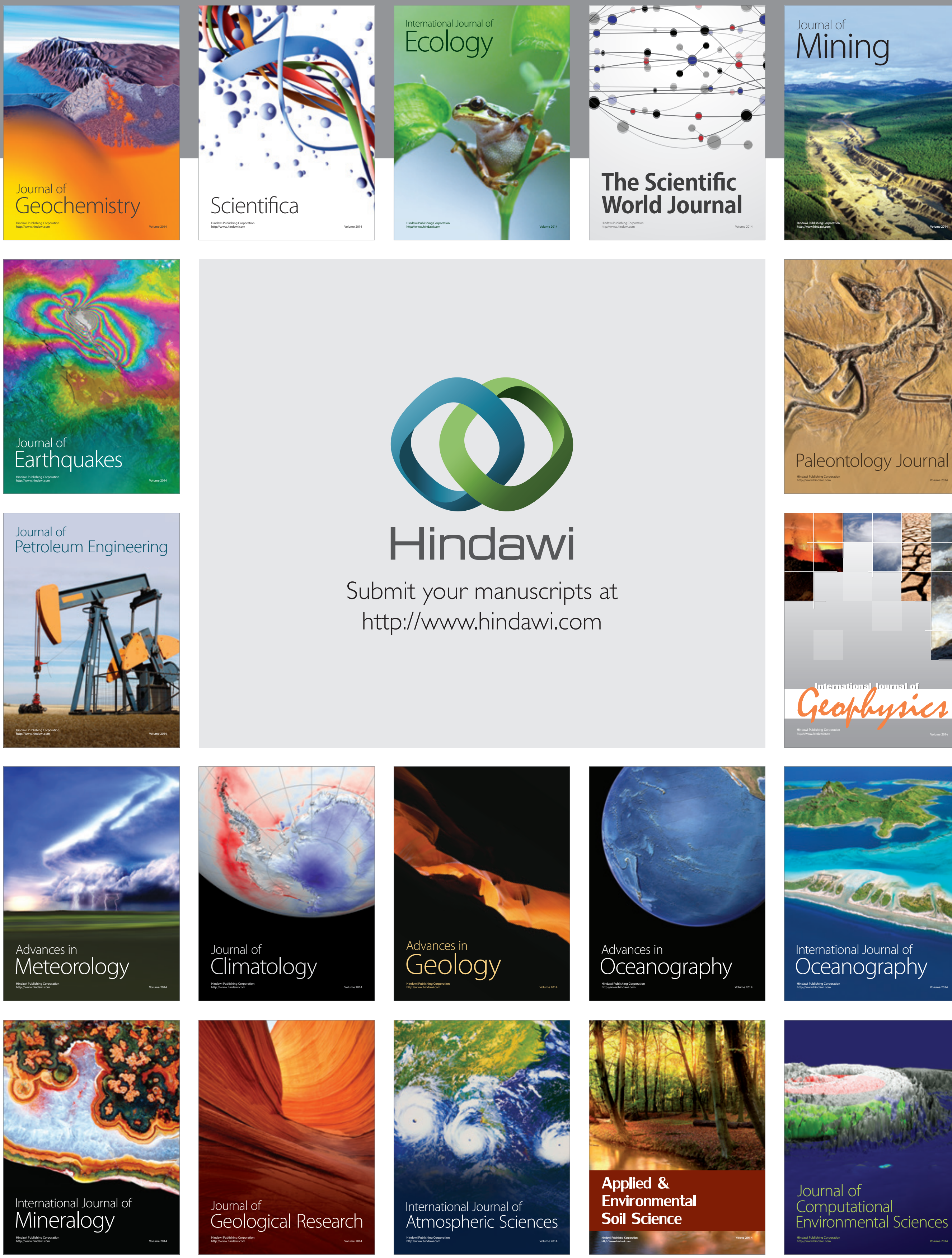

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