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The SISAL database: a global resource to document oxygen and carbon isotope records from speleothems

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Abstract. Stable isotope records from speleothems provide information on past climate changes, most particularly information that can be used to reconstruct past changes in precipitation and atmospheric circulation. These records are increasingly being used to provide "out-of-sample" evaluations of isotope-enabled climate models. SISAL (Speleothem Isotope Synthesis and Analysis) is an international working group of the Past Global Changes (PAGES) project. The working group aims to provide a comprehensive compilation of speleothem isotope records for climate reconstruction and model evaluation. The SISAL database contains data for individual speleothems, grouped by cave system. Stable isotopes of oxygen and carbon (δ^{18}O, δ^{13}C) measurements are referenced by distance from the top or bottom of the speleothem. Additional tables provide information on dating, including information on the dates used to construct the original age model and sufficient information to assess the quality of each data set and to erect a standardized chronology across different speleothems. The metadata table provides location information, information on the full range of measurements carried out on each speleothem and information on the cave system that is relevant to the interpretation of the records, as well as citations for both publications and archived data. The compiled data are available at https://doi.org/10.17864/1947.147.

1 Introduction

Speleothems are inorganic carbonate deposits (mostly calcite and aragonite) that grow in caves and form from drip water supersaturated with respect to $CaCO_3$. Speleothems are highly suitable for radiometric dating using uranium-series disequilibrium techniques. Since they form through continuous accretion, speleothems can provide a highly resolved record of environmental conditions, generally with a temporal resolution ranging from seasonal scale to 100 years, depending on sampling resolution.

Speleothem records are one of the types of record widely used to reconstruct past climate changes (see Bradley, 2015 for an overview of other methods). Speleothem growth is, in itself, an indicator of precipitation availability (Ayliffe et al., 1998; Wang et al., 2004), and variations in annual growth increments have been interpreted as an index of precipitation amount (Fleitmann et al., 2004; Polyak and Asmerom, 2001; Trouet et al., 2009). Many different types of measurements have been made on speleothems, but the most common are the stable isotopes of oxygen and carbon (δ^{18}O, δ^{13}C). Although the interpretation of such records can be complicated, for samples that are deposited close to equilibrium, changes in δ^{18}O are primarily a signal of changes in precipitation amount and source, precipitation temperature, and cave temperature (Affek et al., 2014; Hu et al., 2008; McDermott, 2004; Wang et al., 2008) and have been widely used to reconstruct changing atmospheric circulation patterns (e.g. Bar-Matthews et al., 1999; Cai et al., 2012, 2015; Luetscher et al., 2015; Spötl and Mangini, 2002; Trouet et al., 2009). Changes in δ^{13}C are a more indirect signal of precipitation changes. If not affected by non-equilibrium deposition (Baker et al., 1997), δ^{13}C can reflect the changing abundance of C_3 and C_4 plants above the cave (Baldini et al., 2008; Dorale et al., 1998) or the availability of soil CO_2 during the dissolution of limestone (Genty et al., 2003; Hendy, 1971; Salomons and Mook, 1986). Speleothem records are widely distributed geographically, and this makes them an ideal type of archive for regional climate reconstructions.

An increasing number of climate models explicitly simulate water isotopes as a tool for characterizing and diagnosing the atmospheric hydrological cycle (Schmidt et al., 2007; Steen-Larsen et al., 2017; Sturm et al., 2010; Werner et al., 2011; Haese et al., 2013). Such models are evaluated against modern observations of the isotopic composition of rainwater (see for example Yoshimura et al., 2008; Steen-Larsen et al., 2017). However, evaluations against palaeo-records such as the δ^{18}O records from speleothems can be used to provide an "out-of-sample" test (Schmidt et al., 2014) of these models. Thus, in addition to their use for climate reconstruction, speleothem records are a useful addition to the tools that are used for climate-model evaluation.

More than 500 speleothem data sets have been published to date, 70 % of which have been published in the decade since 2007. There have been some attempts to provide syntheses of speleothem data, particularly in the context of providing climate reconstructions or data sets for model evaluation (e.g. Bolliet et al., 2016; Caley et al., 2014; Harrison et al., 2014; Shah et al., 2013). However, these compilations generally lack sufficient information to allow careful screening of the records to ensure the reliability of the climate interpretation or the quality of the dating of the record. Furthermore, none of them provide comprehensive coverage of the globe.

Table 1. Information on speleothem records (entities) in the SISAL_v1 database. Elevation (Elv) is given in metres above sea level and latitude (Lat) and longitude (Long) in decimal degrees. For convenience, we have given the location of each record, although this information is not available in the database itself. Note that the latitude and longitude of Abaliget, Brown's cave and Uamh an Tartair are given correctly here but are incorrect in the SISAL_v1 database.

Entity name	Site name	Elv (m)	Lat (°)	Long (°)	Region	Citations
AB-DC-01, AB-DC-03, AB-DC-12	Abaco Island cave	−45	26.2300	−77.1600	Bahamas	Arienzo et al. (2017)
AB-DC-09	Abaco Island cave	−45	26.2300	−77.1600	Bahamas	Arienzo et al. (2015, 2017)
ABA_1, ABA_2	Abaliget cave	209	46.1333	18.1666	Hungary	Koltai et al. (2017)
Abissal, Ale-1	Abissal cave	100	−5.6000	−37.7330	Brazil	Cruz et al. (2009)
Ach-1	Achere cave	1534	8.6036	40.3729	Ethiopia	Asrat et al. (2006, 2008)
AB2	Anjohibe cave	131	−15.5300	46.8800	Madagascar	Scroxton et al. (2017)
AB3	Anjohibe cave	131	−15.5300	46.8800	Madagascar	Burns et al. (2016)
ANJB-2	Anjohibe cave	131	−15.5300	46.8800	Madagascar	Voarintsoa et al. (2017c)
MA3	Anjohibe cave	131	−15.5300	46.8800	Madagascar	Voarintsoa et al. (2017a)
MAJ-5	Anjokipoty cave		−15.5784	46.7344	Madagascar	Voarintsoa et al. (2017c)
CC-1_2004	Antro del Corchia	840	43.9800	10.2200	Italy	Drysdale et al. (2004)
CC-1_2009, CC-5_2009, CC-7	Antro del Corchia	840	43.9800	10.2200	Italy	Drysdale et al. (2009)
CC-28	Antro del Corchia	840	43.9800	10.2200	Italy	Drysdale et al. (2007)
CC-5_2005	Antro del Corchia	840	43.9800	10.2200	Italy	Drysdale et al. (2005)
POM2	Ascunsa cave	1050	45.0000	22.6000	Romania	Drăguşin et al. (2014)
BGC6, BGC11, BGC14	Ball Gown cave	100	−17.3000	124.1000	Australia	Denniston et al. (2013b)
BAR-II#L, BAR-II#B	Baradla cave	375	48.4667	20.5000	Hungary	Demény et al. (2017b)
BA-1b, BA-1, BA-2	Baschg cave	780	47.2501	9.6667	Austria	Boch et al. (2011)
Bero-1	Bero cave	1363	8.4241	40.3073	Ethiopia	Asrat et al. (2008), Baker et al. (2010)
Keklik1	Bir-Uja cave	1435	40.4833	72.5833	Kyrgyzstan	Fohlmeister et al. (2017)
BT-1, BT-2.1, BT-2.2, BT-2.3, BT-2.4, BT-2.5, BT-4, BT-6, BT-8, BT-9	Bittoo cave	3000	30.7903	77.7764	India	Kathayat et al. (2016)
BT-2	Botuverá	180	−27.2247	−49.1569	Brazil	Cruz et al. (2005)
BTV21a	Botuverá	180	−27.2247	−49.1569	Brazil	Bernal et al. (2016)
BDinf	Bourgeois–Delaunay cave	100	45.6678	0.5133	France	Couchoud et al. (2009)
BC01-07	Brown's cave	25	27.8894	−82.5186	USA	Pollock et al. (2016)
Boss, BFM-9, F2	Brown's Folly mine	150	51.3800	−2.3700	England (UK)	Baldini (2001), Baldini et al. (2005)
RL4_2006	Buca della Renella	300	44.0800	10.2100	Italy	Drysdale et al. (2006)
RL4_2016	Buca della Renella	300	44.0800	10.2100	Italy	Zanchetta et al. (2016)
RL4_2018	Buca della Renella	300	44.0800	10.2100	Italy	Drysdale et al. (unpublished)
BCC-2, BCC-4, BCC-6, BCC_composite	Buckeye creek	600	37.9825	−79.5894	USA	Hardt et al. (2010)
BCC-8, BCC-10	Buckeye creek	600	37.9825	−79.5894	USA	Springer et al. (2014)
BMS1	Bue Marino cave	0	40.2467	9.6228	Italy	Columbu et al. (2017)
Buffalo Cave Flowstone	Buffalo cave	1140	−24.1428	29.1770	South Africa	Hopley et al. (2007a, b)
BA02	Bukit Assam cave	150	4.0300	114.8000	Malaysia	Carolin et al. (2013)
BA03	Bukit Assam cave	150	4.0300	114.8000	Malaysia	Chen et al. (2016)
BA04	Bukit Assam cave	150	4.0300	114.8000	Malaysia	Partin et al. (2007)
Bu1, Bu2, Bu4, Bu6, BuStack	Bunker cave	184	51.3675	7.6647	Germany	Fohlmeister et al. (2012)
Calcite	Calcite cave		−46.0172	167.7431	New Zealand	Lorrey et al. (2008)
V3	Cango cave		−33.3925	22.2147	South Africa	Vogel (1983), Talma and Vogel (1992), Vogel and Kronfeld (1997)
COB-01-02	Cave of the Bells		31.7500	−110.7500	USA	Wagner et al. (2010)
CWN4	Cave Without a Name	377	29.8852	−98.6208	USA	Feng et al. (2014)

Table 1. Continued.

Entity name	Site name	Elv (m)	Lat (°)	Long (°)	Region	Citations
CC-1	Ceremosnja cave	530	44.4000	21.6500	Republic of Serbia	Kacanski et al. (2001)
Chau-stm6	Chauvet cave	240	44.2300	4.2600	France	Genty et al. (2006)
CHIL-1	Chilibrillo cave	60	9.1741	−79.6164	Panama	Lachniet (2004)
CL26	Clamouse cave	110	43.7100	3.5500	France	McDermott et al. (1999)
Cla4	Clamouse cave	110	43.7100	3.5500	France	Plagnes et al. (2002)
FC12-12, FC12-14, FC12-15	Clearwater cave	120	4.1000	114.8333	Malaysia	Carolin et al. (2016)
Squeeze1	Clearwater/Wind caves connection		4.1000	114.8300	Malaysia	Meckler et al. (2012)
T5	Cold Air cave	1420	−24.0000	29.1833	South Africa	Repinski et al. (1999)
T7_1999	Cold Air cave	1420	−24.0000	29.1833	South Africa	Holmgren et al. (1999), Stevenson et al. (1999)
T7_2001	Cold Air cave	1420	−24.0000	29.1833	South Africa	Lee-Thorp et al. (2001)
T7_2013	Cold Air cave	1420	−24.0000	29.1833	South Africa	Sundqvist et al. (2013)
T8	Cold Air cave	1420	−24.0000	29.1833	South Africa	Holmgren et al. (2003)
ESP03	Cova da Arcoia	1240	42.6100	−7.0900	Spain	Railsback et al. (2011)
CC3	Crag cave	60	52.2500	−9.4300	Ireland	McDermott et al. (1999), McDermott (2001)
ASR, ASM	Cueva de Asiul	285	43.3200	−3.5900	Spain	Smith et al. (2016)
CBD-2	Cueva del Diablo	1030	18.1920	−99.9210	Mexico	Bernal et al. (2011)
CUR4	Curupira cave	420	−15.2002	−56.7839	Brazil	Novello et al. (2016)
DAN-D	Dandak cave	400	19.0000	82.0000	India	Berkelhammer et al. (2010), Sinha et al. (2007)
DP1_2013	Dante cave		−19.4000	17.8833	Namibia	Sletten et al. (2013)
DP1_2016	Dante cave		−19.4000	17.8833	Namibia	Voarintsoa et al. (2017b)
DY-1	Dayu cave	870	33.1330	106.3000	China	Tan et al. (2009)
S3	Defore cave	150	17.1667	54.0833	Oman	Burns (2002)
DSSG-4	DeSoto caverns	150	33.3722	−86.3667	USA	Aharon et al. (2013)
DH2, DH2-D, DH2-E Terminal1, DH2-E Terminal2	Devils Hole	719	36.4254	−116.2920	USA	Moseley et al. (2016)
Dim-E2, Dim-E3, Dim-E4	Dim cave	232	36.5340	32.1056	Turkey	Ünal-İmer et al. (2015)
DV2	Diva cave	680	−12.3667	−41.5667	Brazil	Novello et al. (2012)
D3, D4	Dongge cave	680	25.2800	108.0800	China	Yuan (2004)
D8	Dongge cave	680	25.2800	108.0800	China	Cheng et al. (2016b)
Doubtful	Doubtful Xanadu	960	−45.3735	167.0476	New Zealand	Lorrey et al. (2008)
ARTEMISA	Ejulve cave	1240	40.4500	−0.3500	Spain	Pérez-Mejías et al. (2017)
HOR	Ejulve cave	1240	40.4500	−0.3500	Spain	Moreno et al. (2017)
TKS	Entrische Kirche cave	2119	47.1600	13.1500	Austria	Meyer et al. (2008)
GEX-SPA	Excentrica cave	100	37.1000	−7.7700	Portugal	Ponte et al. (2017)
ED1	Exhaleair cave	685	−41.2833	172.6330	New Zealand	Hellstrom et al. (1998)
FS2_2010	Fort Stanton cave	1864	33.5067	−105.4430	USA	Asmerom et al. (2010)
FS2_2012	Fort Stanton cave	1864	33.5067	−105.4430	USA	Polyak et al. (2012)
FG01	Fukugaguchi cave	170	36.9917	137.8000	Japan	Sone et al. (2013)
FR-0510	Furong cave	480	29.2289	107.9036	China	H.-C. Li et al. (2011)
FR-5	Furong cave	480	29.2289	107.9036	China	T.-Y. Li et al. (2011)
GG1, GG2	Gardener’s Gut	120	−37.7394	175.1033	New Zealand	Williams et al. (2004)
GC08	Green Cathedral cave		4.2333	114.9250	Malaysia	Meckler et al. (2012)
CR1	Grotta di Carburangeli	22	38.1671	13.1615	Italy	Frisia et al. (2006), Madonia et al. (2005)
ER76	Grotta di Ernesto	1167	45.9667	11.6500	Italy	Scholz et al. (2012)

Table 1. Continued.

Entity name	Site name	Elv (m)	Lat (°)	Long (°)	Region	Citations
GP2	Grotte de Piste	1260	33.8400	−4.0900	Morocco	Wassenburg et al. (2016)
stm2, stm4	Gueldaman cave	507	36.4333	4.5667	Algeria	Ruan et al. (2016)
GT05-5	Guillotine cave	740	−42.3108	172.2178	New Zealand	Whittaker (2008)
SSC01, SCH02	Gunung-buda cave (snail shell cave)	150	4.0330	114.8000	Malaysia	Cobb et al. (2007), Moerman et al. (2013, 2014), Partin et al. (2007, 2013b)
Han-9	Han-sur-Lesse cave	180	50.1164	5.1884	Belgium	Vansteenberge et al. (2016)
Han-stm1	Han-sur-Lesse cave	180	50.1164	5.1884	Belgium	Genty et al. (1999)
Han-stm5b	Han-sur-Lesse cave	180	50.1164	5.1884	Belgium	Genty et al. (1998)
HS4_2008	Heshang cave	294	30.4500	110.4167	China	Hu et al. (2008)
HS4_2013	Heshang cave	294	30.4500	110.4167	China	Liu et al. (2013)
HOL-10	Hölloch im Mahdtal	1240	47.3781	10.1506	Germany	Moseley et al. (2015)
HOL-7, HOL-16, HOL-17, HOL-18, HOL-16-17, HOL-comp	Hölloch im Mahdtal	1240	47.3781	10.1506	Germany	Moseley et al. (2014)
HW3	Hollywood cave	130	−41.9500	171.4667	New Zealand	Whittaker et al. (2011)
H5	Hoti cave	800	23.0833	57.3500	Oman	Neff et al. (2001)
HY1, HY2, HY3	Huangye cave	1650	33.5833	105.1167	China	Tan et al. (2010)
MSD, MSL, PD, YT, H82	Hulu cave	90	32.5000	119.1700	China	Wang (2001)
IFK1	Ifoulki cave	1250	30.7080	−9.3275	Morocco	Ait Brahim et al. (2017)
JAR7, JAR14, JAR13	Jaraguá cave	570	−21.0830	−56.5830	Brazil	Novello et al. (2017)
Jeita-1, Jeita-2, Jeita-3	Jeita cave	100	33.9500	35.6500	Lebanon	Cheng et al. (2015)
AF12	Jerusalem west cave	700	31.7833	35.1500	Israel	Frumkin et al. (1999, 2000)
JHU-1	Jhumar cave	600	18.8667	81.8667	India	Sinha et al. (2011)
C996-1, C996-2	Jiuxian cave	1495	33.5667	109.1000	China	Cai et al. (2010b)
JX-2, JX-10	Juxtlahuaca cave	934	17.4000	−99.2000	Mexico	Lachniet et al. (2013)
JX-6	Juxtlahuaca cave	934	17.4000	−99.2000	Mexico	Lachniet et al. (2012)
JX-7	Juxtlahuaca cave	934	17.4000	−99.2000	Mexico	Lachniet et al. (2017)
KL 3	Kalakot cave	826	33.2219	74.4258	India	Kotlia et al. (2016)
Kanaan_MIS5	Kanaan cave	98	33.9069	35.6069	Lebanon	Nehme et al. (2015)
Kanaan_MIS6	Kanaan cave	98	33.9069	35.6069	Lebanon	Nehme et al. (2018)
GK-09-02	Kapsia cave	700	37.6233	22.3539	Greece	Finné et al. (2014)
K1, K3	Katerloch cave	900	47.0833	15.5500	Austria	Boch et al. (2009)
KS06-A-H, KS06-A, KS06-B, KS08-1-H, KS08-1, KS08-2-H, KS08-2	Kesang cave	2000	42.8700	81.7500	China	Cheng et al. (2012, 2016a)
KS08-2-MIS3, KS08-6	Kesang cave	2000	42.8700	81.7500	China	Cheng et al.(2016a)
KC-1, KC-3, KC-Composite	Kinderlinskaya cave	240	54.1500	56.8500	Russia	Baker et al. (2017)
PFU6	Klapferloch cave	1140	46.9500	10.5500	Austria	Boch et al. (2011)
SPA_126, SPA_49	Kleegruben cave	2165	47.0800	11.6700	Austria	Spötl et al. (2006)
KNI-51-0, KNI-51-3, KNI-51-4, KNI-51-7, KNI-51-10, KNI-51-A2-side1, KNI-51-A2-side2, KNI-51-C, KNI-51-F, KNI-51-G, KNI-51-H, KNI-51-I, KNI-51-J, KNI-51-N, KNI-51-O	KNI-51 cave	100	−15.1800	128.3700	Australia	Denniston et al. (2013a)

Table 1. Continued.

Entity name	Site name	Elv (m)	Lat (°)	Long (°)	Region	Citations
KNI-51-11	KNI-51 cave	100	−15.1800	128.3700	Australia	Denniston et al. (2015, 2016)
K11	Korallgrottan cave	540	64.8800	14.0000	Sweden	Sundqvist et al. (2010)
BW-1	Kulishu cave	610	39.6800	115.6500	China	Ma et al. (2012)
Min-stm1	La Mine cave	975	36.0300	9.6800	Tunisia	Genty et al. (2006)
L4	Labyrintgrottan cave	730	66.0600	14.6800	Sweden	Sundqvist et al. (2007)
LH-70s-1	Lancaster Hole	294	54.2209	−2.5168	England (UK)	Atkinson and Hopley (2013)
LH-70s-2, LH-70s-3	Lancaster Hole	294	54.2209	−2.5168	England (UK)	Atkinson and Hoffman (unpublished)
LD12	Lapa Doce cave	680	−12.3667	−41.5667	Brazil	Novello et al. (2012)
LG11, LG3	Lapa grande cave	590	−14.4200	−44.3660	Brazil	Strikis et al. (2011)
LSF16, LSF3	Lapa sem fim cave	341	−16.1503	−44.6281	Brazil	Stríkis et al. (2015)
L03	Larshullet cave	400	66.0000	14.0000	Norway	Linge et al. (2009b)
Leany	Leány cave	420	47.7000	18.8400	Hungary	Demény et al. (2013)
LC-2	Lehman caves	2080	39.0100	−114.2200	USA	Shakun et al. (2011)
LMC-14, LMC-21	Lehman caves	2080	39.0100	−114.2200	USA	Lachniet et al. (2014)
LC-1	Leviathan cave	2400	37.8900	−115.5800	USA	Lachniet et al. (2014)
LR06-B1_2009, LR06-B3_2009	Liang Luar cave	550	−8.5300	120.4300	Indonesia	Griffiths et al. (2009)
LR06-B1_2016, LR06-B3_2016	Liang Luar cave	550	−8.5300	120.4300	Indonesia	Griffiths et al. (2016)
LR06-B3_2013, LR06-C2, LR06-C3_2013, LR06-C5, LR06-C6, LL_Comp_2013	Liang Luar cave	550	−8.5300	120.4300	Indonesia	Ayliffe et al. (2013)
LR07-A8, LR07-A9, LR07-E11	Liang Luar cave	550	−8.5300	120.4300	Indonesia	Griffiths et al. (2013)
LR07-E1, LR06-C3_2011, LR07-E1-D	Liang Luar cave	550	−8.5300	120.4300	Indonesia	Lewis et al. (2011)
LII4, LII4-KH	Lobatse cave	1200	−25.2100	25.6800	Botswana	Holmgren et al. (1994, 1995)
ME-12	Ma'ale Efrayim cave	250	32.0660	35.3952	West Bank	Vaks et al. (2003)
MC01	Macal Chasm	530	16.8830	−89.1080	Belize	Akers et al. (2016), Webster et al. (2007)
MC-S1, MC-S2	Mairs cave	475	−32.1600	138.8300	Australia	Treble et al. (2017)
S1	Mavri Trypa cave	70	36.7360	21.7596	Greece	Finné et al. (2017)
KM-A	Mawmluh cave	1160	25.2622	91.8817	India	Berkelhammer et al. (2013), Breitenbach et al. (2015)
MAW-6	Mawmluh cave	1160	25.2622	91.8817	India	Lechleitner et al. (2017)
MWS-1	Mawmluh cave	1160	25.2622	91.8817	India	Breitenbach et al. (2015), Dutt et al. (2015)
MAXS	Max's cave	325	−37.7394	175.1033	New Zealand	Williams et al. (2004)
ML1	McLean's cave	300	38.0700	−120.4200	USA	Oster et al. (2015)
MB-2, MB-3, MB-5, MB-6	Milchbach cave	1840	46.6167	8.0830	Switzerland	Luetscher et al. (2011)
MC3	Moaning cave	520	38.0717	−120.4660	USA	Oster et al. (2009, 2015)
MOD-22	Modric cave	32	44.2568	15.5372	Croatia	Rudzka et al. (2012)
MO-1	Molinos cave	1050	40.7925	−0.4492	Spain	Moreno et al. (2017)
MO-7	Molinos cave	1050	40.7925	−0.4492	Spain	Moreno et al. (2017), Muñoz et al. (2015)
M1-5	Moomi cave	400	12.5000	54.0000	Yemen	Shakun et al. (2007)

Table 1. Continued.

Entity name	Site name	Elv (m)	Lat (°)	Long (°)	Region	Citations
Mun-stm2, Mun-stm1	Munagamanu cave	475	15.1500	77.9200	India	Genty et al. (unpublished)
NBJ	Natural Bridge caverns	306	29.6900	−98.3400	USA	Wong et al. (2015)
MD3	Nettlebed cave	390	−41.2500	172.6330	New Zealand	Hellstrom et al. (1998)
Gib04a	New St Michael’s cave	325	36.1261	−5.3455	Gibraltar (UK)	Mattey et al. (2008, 2010)
FM3, Oks82	Okshola cave	165	67.0000	15.0000	Norway	Linge et al. (2009a)
OCNM02-1	Oregon caves national monument	1300	42.0981	−123.4070	USA	Ersek et al. (2012)
PX7	Paixão cave		−12.6182	−41.0184	Brazil	Stríkis et al. (2015)
PAL3, PAL4	Palestina cave	870	−5.9200	−77.3500	Peru	Apaéstegui et al. (2014)
PAR01, PAR03, PAR06, PAR07, PAR08, PAR16, PAR24	Paraiso cave	60	−4.0667	−55.4500	Brazil	Wang et al. (2017)
ALHO6	Pau d’Alho cave	340	−15.2055	−56.8000	Brazil	Jaqueto et al. (2016), Novello et al. (2016)
PDR-1	Perdida cave	350	18.0000	−67.0000	Puerto Rico	Winter et al. (2011)
Candela	Pindal cave	24	43.4000	−4.5300	Spain	Moreno et al. (2010), Rudzka et al. (2011)
PC-1	Pinnacle cave	1792	35.9700	−115.5000	USA	Lachniet et al. (2011)
YD01	Pippikin Pot cave	320	54.2143	−2.5123	England (UK)	Atkinson and Hopley (2013), Daley et al. (2011)
POS-STM-4	Postojna cave	529	45.7700	14.2000	Slovenia	Genty et al. (1998)
Q5	Qunf cave	650	17.1667	54.3000	Oman	Fleitmann et al. (2007)
RN1, RN4	Rainha cave	100	−5.6000	−37.7330	Brazil	Cruz et al. (2009)
Ruakuri C	Ruakuri cave	80	−38.2667	175.0667	New Zealand	Williams et al. (2004)
Merc-1, Asfa-3	RukieSSa cave	1618	8.6036	40.3772	Ethiopia	Asrat et al. (2008), Baker et al. (2007)
SAH-A, SAH-B, SAH-AB	Sahiya cave	1190	30.6000	77.8667	India	Sinha et al. (2015)
SB-10, SB-26, SB-27, SB-43, SB-44, SB-49	Sanbao cave	1900	31.6670	110.4330	China	Dong et al. (2010)
SB-12, SB-14, SB-32, SB-58	Sanbao cave	1900	31.6670	110.4330	China	Cheng et al. (2016b)
MF-3	Schafsloch cave	1890	47.2333	9.3833	Switzerland	Häuselmann et al. (2015)
SCH-5	Schneckenloch cave	1285	47.4333	9.8667	Austria	Moseley et al. (2015)
SCH-7	Schneckenloch cave	1285	47.4333	9.8667	Austria	Boch et al. (2011)
SC02, SC03	Secret cave	250	4.0848	114.8503	Malaysia	Carolin et al. (2013)
SE09-6	Seso cave	794	42.4600	0.0400	Spain	Bartolomé et al. (2015)
7H, 7H-2, 7H-3	Sieben Hengste cave	1955	46.7500	7.8100	Switzerland	Luetscher et al. (2015)
MAR_L	Skala Marion cave	41	40.6387	24.5144	Greece	Psomiadis et al. (2018)
So-1	Sofular cave	700	41.4200	31.9300	Turkey	Fleitmann et al. (2009)
2-6	Soreq cave	400	31.7558	35.0224	Israel	Orland et al. (2009)
2N	Soreq cave	400	31.7558	35.0224	Israel	Orland et al. (2012)
Soreq-composite	Soreq cave	400	31.7558	35.0224	Israel	Grant et al. (2012)
SG95	Soylegrotta cave	280	66.0000	14.0000	Norway	Linge et al. (2001)
SPA12, SPA70, SPA128, SPA127, COMNISPA II, SPA133	Spannagel cave	2310	47.0800	11.6700	Austria	Fohlmeister et al. (2013)
SPA121	Spannagel cave	2310	47.0800	11.6700	Austria	Spötl et al. (2008)
SZ2	Suozi cave	700	32.4300	107.1700	China	Zhou et al. (2008)
TM0, TM2	Tamboril cave	200	−16.0000	−47.0000	Brazil	Wortham et al. (2017)
Taurius	Taurius cave	230	−15.5333	167.0167	Vanuatu	Partin et al. (2013a)

Table 1. Continued.

Entity name	Site name	Elv (m)	Lat (°)	Long (°)	Region	Citations
Aurora	Te Anau Fiordland	320	−45.2800	167.7000	New Zealand	Lorrey et al. (2008)
Te Reinga A, Te Reinga B	Te Reinga cave		−38.8200	177.5200	New Zealand	Lorrey et al. (2008)
TM-18a, TM-18b	Tianmen	4800	30.9167	90.0667	China	Cai et al. (2012)
TM-2, TM-5	Tianmen	4800	30.9167	90.0667	China	Cai et al. (2010a)
T1	Timta cave	1900	29.8381	82.0336	India	Sinha et al. (2005)
TC1	Tityana cave	1470	30.6419	77.6521	India	Joshi et al. (2017)
TON-1, TON-2	Tonnel'naya cave	3226	38.4000	67.2300	Uzbekistan	Cheng et al. (2016a)
TR5	Torrinha cave	680	−12.3667	−41.5667	Brazil	Novello et al. (2012)
Trio	Trió cave	275	46.1100	18.1500	Hungary	Demény et al. (2017a), Siklósy et al. (2009)
Chaac	Tzabnah cave	20	20.7300	−89.7160	Mexico	Medina-Elizalde et al. (2010)
SU032	Uamh an Tartair	220	58.1400	−4.9300	Scotland (UK)	Baker et al. (2012)
SU967	Uamh an Tartair	220	58.1400	−4.9300	Scotland (UK)	Baker et al. (2011)
PU-2	Ursilor cave	482	46.5537	22.5695	Romania	Onac et al. (2002)
VSPM1	Valmiki cave	420	15.1500	77.8167	India	Raza et al. (2017)
VSPM4	Valmiki cave	420	15.1500	77.8167	India	Lone et al. (2014)
Vil-car1	Villars cave	175	45.4300	0.7800	France	Wainer et al. (2011)
Vil-stm1	Villars cave	175	45.4300	0.7800	France	Labuhn et al. (2015)
Vil-stm11	Villars cave	175	45.4300	0.7800	France	Genty et al. (2006)
Vil-stm14	Villars cave	175	45.4300	0.7800	France	Genty et al. (2010), Wainer et al. (2009)
Vil-stm27	Villars cave	175	45.4300	0.7800	France	Genty et al. (2003)
Vil-stm6	Villars cave	175	45.4300	0.7800	France	Genty (unpublished)
Vil-stm9	Villars cave	175	45.4300	0.7800	France	Genty et al. (2003, 2010)
WS-B	Wah Shikhar cave	1290	25.2500	91.8667	India	Sinha et al. (2011)
Waiau	Waiau cave	100	−46.0000	167.7300	New Zealand	Lorrey et al. (2008)
WP-1	Wazpretti cave	100	−42.3108	171.4000	New Zealand	Williams et al. (2005)
WSC-97-10-5	White Scar cave	255	54.1656	−2.4419	England (UK)	Atkinson and Hopley (2013), Daley et al. (2011)
WR5	Whiterock cave		4.1500	114.8600	Malaysia	Meckler et al. (2012)
W5	Wolkberg cave	1450	−24.1000	29.8800	South Africa	Holzkämper et al. (2009)
XBL-3, XBL-4, XBL-7, XBL-26, XBL-27, XBL-29, XBL-48, XBL-65	Xiaobailong cave	1500	24.2000	103.3500	China	Cai et al. (2015)
XL-1	Xinglong cave	710	40.5000	117.5000	China	Duan et al. (2016)
XY07-8	Xinya cave	1250	30.7500	109.4700	China	J. Y. Li et al. (2017)
XY-2	Xinya cave	1250	30.7500	109.4700	China	Li et al. (2007)
JFYK7	Yangkou cave	2140	29.0333	107.1833	China	Han et al. (2016), T.-Y. Li et al. (2017), Zhang et al. (2017)
YK5, YK12, YK23, YK47, YK61	Yangkou cave	2140	29.0333	107.1833	China	Li et al. (2014)
YOKG	Yok Balum cave	336	16.2086	−89.0735	Belize	Ridley et al. (2015)
YOKI	Yok Balum cave	336	16.2086	−89.0735	Belize	Kennett et al. (2012)
ZLP1, ZLP2	Zhuliuping cave	1217	26.0167	104.0950	China	Huang et al. (2016)

SISAL (Speleothem Isotope Synthesis and Analysis) is an international working group set up in 2017 under the auspices of the Past Global Changes (PAGES) programme (http://pastglobalchanges.org/ini/wg/sisal, last access: 4 September 2018). The aim of the working group is to compile the many hundreds of speleothem isotopic records worldwide, paying due attention to careful screening and metadata documentation, the construction of standardized age models, and age-model uncertainties, in order to produce a public-access database that can be used for palaeoclimate reconstruction and for climate-model evaluation. In this paper, we document the first publicly available version of the SISAL database, focusing on describing its structure and contents including the information that has been included to facilitate quality control.

2 Data and methods

2.1 Compilation of data

The database contains stable carbon and oxygen isotope measurements made on speleothems, as well as supporting metadata to facilitate the interpretation of these records. All available speleothem data are included, and no attempt was made to screen records on the basis of the time period covered, the resolution of the records, or the quality of the data or age models. Adequate metadata are provided to allow database users to select the records that are suitable for a particular type of analysis. The raw data were either provided by members of the SISAL working group or extracted from data lodged in PANGAEA or from the National Centres for Environmental Information. Additional information on the records was compiled from publications. All the records in the current version of the database (SISAL_v1) are listed and described in Table 1.

2.2 Structure of the database

The data are stored in a relational database (MySQL), which consists of 14 linked tables, specifically site, entity, sample, dating, dating lamina, gap, hiatus, original chronology, δ^{13}C, δ^{18}O, entity link reference, reference, composite link entity and notes. Figure S1 shows the relationships between these tables. A detailed description of the structure and content of each of the tables is given below. The details of the predefined lists for all fields can be found in Table S1.

2.2.1 Site metadata (table name: site)

A site is defined as the cave or cave system from which speleothem records have been obtained. A site may therefore be linked to several speleothem records, where each record is treated as a separate entity. The site table contains basic metadata about the cave or cave system, including site ID, site name, latitude, longitude, elevation, geology, rock age and monitoring (see Table S2). The elevation is that of the cave itself, not the elevation of the land surface above the cave. Since the elevation of the land surface can be obtained from other sources, we include the cave elevation to facilitate making additional lapse rate corrections for oxygen isotopes for high elevation sites (Bowen and Wilkinson, 2002). This also allows an estimation of the depth of the overburden above the speleothem site, and hence an estimate of the time taken for water to reach the cave. The description of the geology and the age of the rock formation (rock_age) is given because this is important for understanding the degree of permeability of the material above the cave. Primary porosity decreases and fracture flow increases as rocks age, which in turn affects the likely speed at which water flows through the host rock and reaches the cave system. The geology field is also useful because it gives an indication of whether the cave is formed in Mg-rich rocks (e.g. dolomite) and thus whether the speleothems are likely to be formed of aragonite, which would require special consideration in terms of oxygen and carbon isotope comparisons with that of calcite (see also Table S3). Only a limited number of descriptive terms are allowed for each field. The age of rock formation follows the standard era, period, epoch terminology as defined by the International Commission on Stratigraphy in 2015 (Cohen et al., 2015). The database includes information on whether the cave site has been monitored: positive returns in this field mean that monitoring of in-cave environmental parameters (e.g. cave air temperature) and/or cave drip chemistry has been carried out periodically for at least one entire season (as opposed to one-off measurements of in-cave conditions when the speleothem was collected). The database does not contain monitoring data, but inclusion of this field facilitates researchers being able to contact the original data providers about monitoring information, which can be useful in understanding if a cave is likely to contain speleothems that have been deposited close to isotopic equilibrium.

2.2.2 Entity metadata (table name: entity)

Each speleothem (or composite speleothem record) has a unique identifier and a unique name. The entity metadata table (Table S3) provides information on the cave environment that can affect speleothem formation. This includes the thickness of the cover above the speleothem, which might affect the time taken for water to reach the drip site feeding the speleothem and hence the responsiveness of the record to individual rain events or seasonal patterns of precipitation (Fairchild and Baker, 2012). The distance of the speleothem from the cave entrance is provided, which, depending on the morphology of a cave, can be a useful indicator of cave ventilation (direct air advection). Ventilation is important as it can control cave air temperature, humidity, evaporation and $p\mathrm{CO}_2$ levels (Fairchild and Baker, 2012; Frisia et al., 2011; Spötl et al., 2005; Tremaine et al., 2011). The entity table also contains a field to document whether any tests have been carried out to establish whether there is oxygen and carbon isotope quasi-equilibrium between the drip water (CO_2–H_2O system) and the speleothem ($CaCO_3$). There are several such tests (see for example Hendy, 1971; Johnston et al., 2013; Mickler et al., 2006; Tremaine et al., 2011), but no attempt is made to identify which test has been applied in the database. The drip type (e.g. seepage flow, seasonal drip, vadose flow; Smart and Friederich, 1987) also provides useful hydrological information: seepage flow shows a small inter-annual variability of discharge and the speleothem record will therefore more likely reflect a long-term average state over several years; other drip types, such as seasonal drip, will indicate the potential to record seasonal or individual rainfall events.

The main focus of the SISAL database is stable isotope measurements, but the entity metadata table also contains information on the kinds of measurements that have been made for a specific speleothem. Only the stable isotope measurements are currently archived in the database. However, listing the range of data available from any speleothem will facilitate future updates of the database to include other types of measurements apart from stable isotopes (i.e. trace elements) and will help researchers in locating speleothems where multiple types of measurements have been done. The entity metadata table contains four fields to facilitate data traceability. The first two fields give the name of the person who was responsible for collating the data, and a DOI or URL for the original data. Some records have been partially or entirely updated since first being published. Although these records are included for data traceability, the entity_status field indicates whether they have been partially updated (e.g. with additional samples and/or improved age models) or completely superseded by a new record. The field corresponding_current indicates which entity (or entities) provides updated information. Information on original publications on specific speleothems is given in the reference table (see Sect. 2.2.11).

2.2.3 Sample metadata (table name: sample)

The sample metadata table (Table S4) contains information on the location of the sample with respect to a reference point, where the reference point can be either the top or the base of the speleothem. It also provides information on the thickness and mineralogy (calcite, secondary calcite, aragonite, vaterite, mixed, not known) of each sample. Since some samples may have mixed mineralogy, it also provides information on whether a correction for aragonite has been applied to $\delta^{18}O$ or $\delta^{13}C$, due to different phosphoric acid fractionation factors.

2.2.4 Dating information (table name: dating)

The dating information table (Table S5) provides information on the radiometric dates used to construct the original age model for each of the speleothem entities, including type of radiometric date (e.g. U series), depth of dated sample, thickness of dated sample and sample weight. Dates that are used to anchor sequences that are dated by lamina counting (see Sect. 2.2.5) are included in the dating information table and identified in date type as an event (i.e. the start or end of a laminated sequence). The degree of precision varies between different dating methods and techniques, for example mass spectrometric U/Th dating generally produces a more precise age than the alpha spectrometry U/Th data method. So the inclusion of the dating method provides a basic measure of the reliability, in terms of analytical precision, of any given date. Sample thickness also influences the dating uncertainty, because thicker samples will integrate more material of different age. Similarly, sample weight can influence precision: samples younger than a few thousand years may contain very low levels of the daughter isotope ^{230}Th (whose accumulation by radioactive decay provides the measure of the sample's age), and so require more material to provide an accurate and precise result. The content of ^{232}Th is included in the dating information table because this value is used for the detrital correction of initial ^{230}Th. Sample mineralogy is also included because this affects the reliability of individual dates (e.g. samples from re-crystallized secondary calcite are not reliable because of the loss of uranium; Bajo et al., 2016).

We provide both the original uncorrected age and the corrected age for each date. The corrected U/Th age is adjusted for detrital contamination; the corrected calibrated ^{14}C age is adjusted for dead carbon. The correction factors used to derive the corrected U/Th or ^{14}C age are included in the dating information table. The decay constant used to calculate the U/Th ages is given because the values used have changed through time (Cheng et al., 2000, 2013; Edwards et al., 1987; Ivanovich and Harmon, 1992). The calibration curve used to convert radiocarbon ages to calendar years in the original publication is also given. Several different standards have been used in the original publications for the modern reference state (e.g. BP(1950), b2k, CE / BCE or the year when U/Th chemical separation was performed) but all of these have been converted to BP(1950) in the database.

Some of the dates listed for a given entity were not used in the original age model, for example because the dating sample was contaminated with organic material or because of age inversions. The dates excluded from the original age model are flagged in the database (date_used) but the other information on these dates is nevertheless included in the dating information table to ensure transparency.

The geochemical characteristics of the sample provide information that is required to assess the quality or reliability of these dates. The ratio of $^{230}Th / ^{232}Th$, for example, is a measure of detrital thorium concentration in the sample and thus provides an initial quality control on each date. A $^{230}Th / ^{232}Th$ activity ratio > 300 is considered a good indicator of a reliable date (Hellstrom, 2006); a higher ratio indicates a cleaner sample with higher accuracy. The thorium corrected errors are also included to provide an indication of the magnitude of the correction related to detrital thorium contamination.

2.2.5 Lamina dating information (table name: dating_lamina)

Variations in the drip-water geochemistry and/or quantity or cave conditions may occur at regular intervals, forming laminae of a range of thicknesses usually linked to surface seasonal climate variations (Fairchild and Baker, 2012). A high-resolution chronology can be established for such records by lamina counting, provided an absolute date is available for either the start or the end of the laminated sequence (e.g. because U/Th dates have been obtained or because the stalagmite was actively growing when collected). The identification of individual lamina can be difficult if they are very thin or of varying width, so best practice is to provide an estimate of the counting uncertainty that propagates from the absolute anchor dates. The lamina dating information table (Table S6) provides the age of each lamina in the sequence and the uncertainty on this dating; the absolute dates used as anchor points are given in the dating information table and identified in the date type field there as an event (see Sect. 2.2.4).

It should be noted that laminae can be formed on a variety of timescales, depending on the frequency that the thresholds for the formation of specific fabrics and mineralogies are crossed. Annual laminations are more likely in regions where there is a clear seasonality in climate or cave environment. In other regions, the lamination may be a result of lower- or higher-frequency variations in, for example, hydrologically effective precipitation (e.g. infiltrated waters) or soil CO_2 production. It is imperative to demonstrate that the laminations are annual (see Table S9) before using lamina counting for dating.

2.2.6 Hiatus place mark information (table name: hiatus)

A prolonged cessation of speleothem growth can occur under unfavourable environmental conditions leading to, for example, undersaturation of drip water or cessation of dripping. Growth hiatuses can often be recognized from structural or mineralogical features, or inferred based on absolute dating. Growth hiatuses have to be taken into account in the construction of age models and thus the hiatus place mark table (Table S7) provides information on the location of such features. The hiatus is referenced to the specific depth at which it occurs, and this depth is considered as an imaginary sample that then appears with a specific sample_id in the sample table. There are some cases in which the hiatus depth was not recorded; in these cases the depth was specified as the imaginary mid-point depth between bracketing samples.

2.2.7 Gap place mark information (table name: gap)

When a composite record is created based on more than one individual speleothem from the same cave system, there may be discontinuities in the overlapping time of the individual records. These gaps are not growth hiatuses, but must be identified to facilitate plotting of the records. The gap place mark information table (Table S8) provides information on the location of sample gaps. The gap is referenced to the specific depth at which it occurs, and this depth is considered as an imaginary sample which then appears with a specific sample_id in the sample table. In composite records where sample depths are not given, the location of a gap can be derived from the sample ordering and the absence of isotopic information for a given sample. In point of fact, this table is empty in version 1 of the database.

2.2.8 Original chronology (table name: original_chronology)

The original chronology table (Table S9) provides an estimate of the age and age uncertainty, according to the original published age model for each sample on which stable isotope measurements have been made. The table also provides information on the type of age model (e.g. linear interpolation between dates, polynomial fit, Bayesian, StalAge; Scholz and Hoffmann, 2011, COPRA; Breitenbach et al., 2012, OxCal; Bronk Ramsey, 2001, 2008) used in the original publication. The fields ann_lam_check and dep_rate_check are included for quality assurance purposes, since they indicate that the assumption that laminae are truly annual has been explicitly tested.

2.2.9 Carbon isotope data (table name: d13C)

The carbon isotope data table (Table S10) contains the carbon isotope measurements. It also provides information on the laboratory precision of each measurement and the standard (PDB or Vienna-PDB) used as a reference.

2.2.10 Oxygen isotope data (table name: d18O)

The oxygen isotope data table (Table S11) contains the oxygen isotope measurements. It also provides information on the laboratory precision of each measurement and the standard (PDB or Vienna-PDB) used as a reference.

2.2.11 Publication information (table name: reference)

This table (Table S12) provides full bibliographic citations for the original references documenting the speleothems, their isotopic records and/or their age models. References on monitoring of the cave may also be provided. There may be multiple publications for a single speleothem record, and all of these references are listed. For convenience, there is also a table (Table S13) that links the publications to the specific entity.

2.2.12 Link composite and entity information (table name: composite_link_entity)

Multiple speleothem records showing a temporal overlap (and a similar signal) can be combined to create a composite record of changes through time. The composite record is treated as a distinct entity in the database. The link composite and entity information table (Table S14) is provided in order to be able to link this composite record to the individual speleothem records from which it was derived. Thus any single composite entity (composite_entity_id) is linked to multiple single entities (single_entity_id)

2.2.13 Notes (table name: notes)

The notes table (Table S15) is provided in order to record additional information regarding the site which cannot be recorded in the fields of the table; this may also include entity specific information.

2.3 Quality control

Individual records in the SISAL database were compiled either by the original authors or from published and open-access material by specialists in the collection and interpretation of speleothem records. In this latter case, the data compilers made every attempt to contact original authors to check that the compiled data were correct. The name of the person who compiled the data is included in the database (entity table, contact) so that they can be consulted in the future about queries or corrections. Individual records for the database were subsequently checked by a small number of regional coordinators, to ensure that records were being entered in a consistent way. Prior to entry in the database, the records were automatically checked using specially designed database scripts (in Python) to ensure that the entries to individual fields were in the format expected (e.g. text, decimal numeric, positive integers) or were selected from the pre-defined lists provided for specific fields. In defining both the formats and the pre-defined lists, the SISAL working group has taken special care to ensure that the entries are unambiguous. Null values for metadata fields were identified during the checking procedure, and checks were made with the data contributors whenever possible to ensure that null fields genuinely corresponded to missing information.

The database contains information designed to allow an assessment of the quality of an individual record. Thus, the entity metadata table contains information on, for example, the distance of the speleothem from the cave entrance in order to allow the user to assess whether cave temperatures are driven by advection of air or conduction through the bedrock. There are several other factors that can affect ventilation, for example the contrast between the cave and external climates, and cave morphology such as the size of the entrance or the number of entrances. Information on these factors is only rarely given in publications; we assume that this information would be more likely to be available if the original authors thought that ventilation was a significant influence on the speleothem record. Including information on distance from the cave entrance is therefore being regarded as a minimal indicator for record quality. Other fields that are included to allow the user to select appropriate records include geology, rock age, speleothem type and drip type.

The database also contains information to allow an assessment of the reliability of the dates used in constructing the original age model. The most important of these fields are those with information on the sample geochemistry (see Sect. 2.2.4), which allows the user to determine whether the samples were sufficiently large and sufficiently pure to yield good U/Th dates. The database also gives information on sample weight, which also addresses this issue. The information on the corrections employed, dating uncertainties and whether the original authors considered the date reliable (and therefore used it in constructing an age model) also provide insights into the reliability of individual chronologies.

The SISAL database is an ongoing effort and continuing efforts to update the records will include updating missing data fields for individual records. Analysis of the data is also useful for verification purposes and may result in corrections of some data. Any such changes to sites and entities included in version 1 of the database will be documented in subsequent updates. The SISAL working group also aims to provide new chronologies in future versions of the database based on Bayesian approaches, namely OxCal (Bronk Ramsey, 1995, 2008), COPRA (Breitenbach et al., 2012) and StalAge (Scholz and Hoffmann, 2011).

2.4 Overview of contents

The first version of the SISAL database contains 211 022 $\delta^{18}O$ measurements, 127 115 $\delta^{13}C$ measurements from 371 speleothem records and 10 composites from 174 cave systems. This represents approximately 58 % of published speleothem records we have identified. Of the 371 speleothem records, 8 have been superseded, 7 provide information for which there are also updates or additional information recorded as separate entities, 6 have dating information but no isotopic records because the individual entities were only used to construct composite records, and 15 do not have age models. The database also contains 6 records that have not been published.

The distribution of sites is global in extent (Fig. 1). The majority (30 %) of the sites are from Europe (53 sites) and there is currently less good representation of sites from other regions. The temporal distribution of records is excellent for the past 2000 years (Fig. 2a) and good for the past 22 000 years (Fig. 2b). Altogether, 142 entities record some

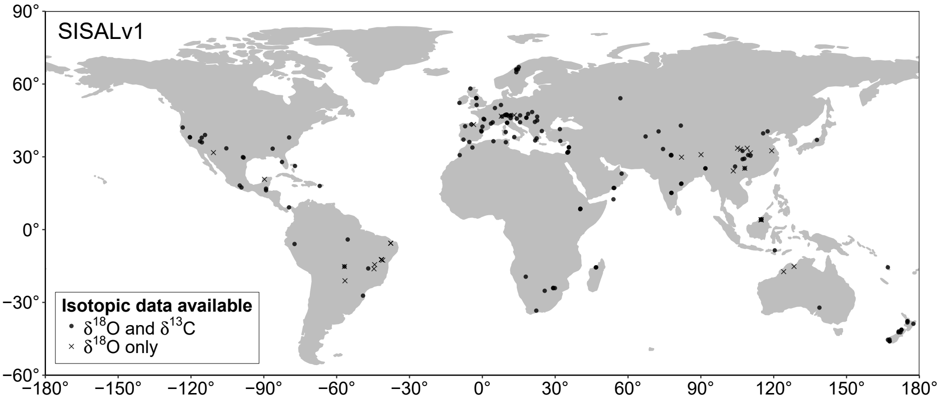

Figure 1. Map of the location of sites in the database. Note that some sites include records for multiple individual speleothems, which are treated as separate entities in the database itself. The sites are coded with different shapes to indicate whether they provide records only for oxygen isotopes, or for both oxygen and carbon isotopes.

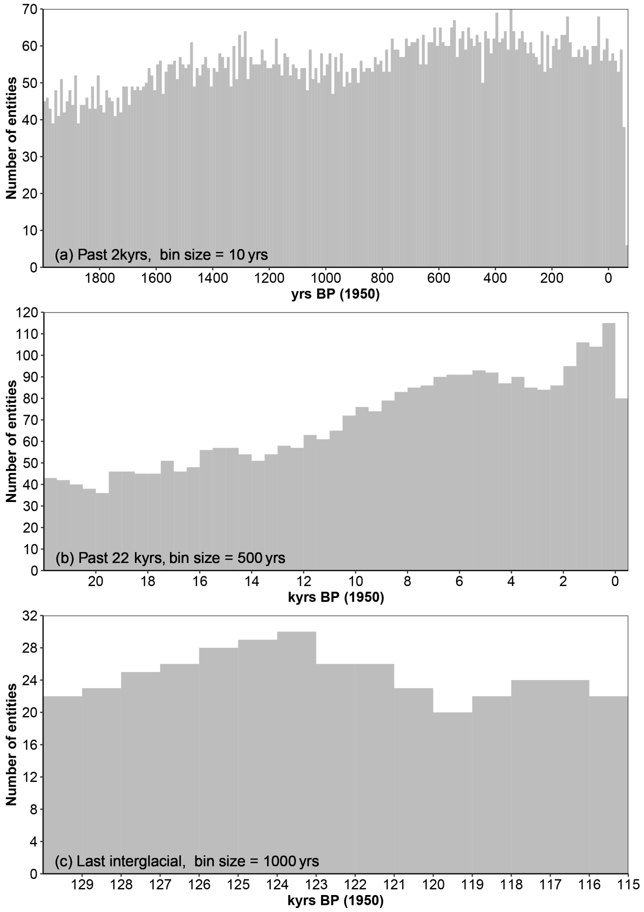

Figure 2. Plot showing the temporal coverage of individual entities in the database. Panel **(a)** shows records covering the past 2000 years (2 kyr BP), **(b)** shows records covering the past 22 000 years (22 kyr BP), and **(c)** shows records that cover the LIG (130–115 kyr BP).

part of the past 2000 years, 87 of which have a resolution ≤ 10 years between samples on average. There are 253 entities recording some part of the past 22 000 years, including 153 with a resolution of ≤ 100 years between samples on average. The database contains 42 entities from the last interglacial period (115 000 to 130 000 years before present), 41 of which have a resolution of ≤ 1000 years between samples on average (Fig. 2c).

3 Data availability

The database is available in SQL and CSV format from https://doi.org/10.17864/1947.147 (Atsawawaranunt et al., 2018). The CSV format of the database is also available from https://www.ncdc.noaa.gov/paleo/study/24070 (last access: 4 September 2018).

4 Conclusions

The SISAL database is based on a community effort to compile isotopic measurements from speleothems to facilitate palaeoclimate analysis. Considerable effort has been made to ensure that there is adequate metadata and quality control information to allow the selection of records appropriate to answer specific questions and to document the uncertainties in the interpretation of these records. The database is publicly available.

The first version of the SISAL database contains 211 022 δ^{18}O measurements and 127 115 δ^{13}C measurements from 371 individual speleothem records, and 10 composites from 174 cave systems. The distribution of sites is global in extent. The temporal distribution is excellent for the past 2000 years and good for the past 22 000 years. There are also records that span the last interglacial period.

The format of the database is designed to facilitate the use of the data for regional- to continental-scale analyses, and in particular to facilitate comparisons with and evaluation of isotope-enabled climate model simulations. The SISAL working group will continue to expand the coverage of the SISAL database and will provide new chronologies based on standardized age models; subsequent versions of the database will be made freely available to the community.

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