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Temperature Series for 19 Caves Across the Western Italian Alps

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ABSTRACT

Caves represent challenging systems for monitoring temperature dynamics. While caves are often portrayed as textbook examples of systems with high thermal inertia and minimal annual temperature variability (typically less than 1°C in their deepest sections), the reality is more complex. Site-specific climatic anomalies, particularly in shallow caves, introduce significant variation. To better understand these localized conditions, long-term temperature records from multiple caves with diverse characteristics within a single region are needed. This paper presents a dataset comprising air temperature records from 19 (mostly shallow) caves in the Piedmont region (Western Italian Alps), collected in 2012 and from 2019 to 2025. Temperature sensors were deployed at two distinct locations in each cave—one at the entrance and one in internal sectors—capturing thermal signals and buffering effects. This yielded a dataset suitable for both climatological modelling and ecological applications. Calculation of data uncertainty was performed through post-calibration corrections. The complete dataset is available in figshare (https://doi.org/10.6084/m9.figshare.29108090.v1). This resource is intended to support empirical testing of thermal models, improve the accuracy of climate studies in subterranean ecosystems, and facilitate comparative analyses across cave types. The development of a high-quality dataset with strong ecological relevance provides a basis for interdisciplinary research at the intersection of climate science, speleology, and subterranean biology. The dataset is particularly suited for investigating ecological thresholds in thermally constrained cave fauna, being interoperable with faunal datasets available from the same area, as well as for evaluating cave microclimates as early indicators of surface climate anomalies.

Alice Cimenti, Lorenzo Cresi and Olga Pisani contributed equally to this paper.

Dataset details:
Identifier: 10.6084/m9.figshare.29108090
Creator: Lorenzo Cresi
Dataset correspondence: marco.isaia@unito.it
Title: Temperature series for 19 caves across the Western Italian Alps v0.1
Publisher: figshare.com
Publication year: 2025
(Resource type): Dataset (Version): 0.1

1 | Introduction

Understanding temperature variability in caves requires reliable, long-term monitoring systems capable of operating under challenging environmental conditions typical of subterranean settings. Although caves are often described as thermally stable (Culver and Pipan 2010), their internal climate conditions respond in complex ways to external meteorological forcing and cave-specific geomorphology, making empirical data essential for resolving short- and long-term dynamics (Badino 2010; Smithson 1991). These dynamics influence a wide range of research fields, including paleoclimate reconstruction, microclimate modelling, ecological specialization and conservation biology (Sánchez-Fernández et al. 2018; Mammola et al. 2019). Yet robust datasets supporting these investigations remain rare because long-term measurements require instrumentation capable of operating for months or years in high-humidity, low-light, and difficult-to-access environments (Mejía-Ortíz et al. 2020; Mammola et al. 2019).

The increasing availability of compact automatic stations, such as iButton devices (General Analog Devices 2010; Analog Devices 2015), has opened new opportunities for systematic temperature monitoring in caves. These sensors are widely used in microclimate research because of their small size, low cost and long battery life. However, their performance in saturated or near-saturated environments is highly variable, and uncertainties associated with sensor drift, device-to-device variability, and poor absolute accuracy remain largely undocumented (Medina et al. 2023). Moreover, many cave-monitoring initiatives rely on ad hoc deployments with little standardization (Cimenti et al. 2024), resulting in datasets that are difficult to compare across caves or regions and that often remain inaccessible outside local research groups (Mammola et al. 2019).

In this context, mountain regions provide valuable opportunities to study how variations in surface weather and climate. Over the past century the Alps have warmed by roughly 0.3°C–0.4°C per decade in winter since ~1970, totaling about 2°C above pre-industrial levels, with strongest warming at lower and mid-elevations (Monteiro and Morin 2023; Dumont et al. 2025). Winter precipitation shows no clear long-term trend in total annual amounts but a shift toward slightly wetter winters and drier summers, and toward more precipitation falling as rain instead of snow at low elevations (Napoli et al. 2019; Beniston 2012). Despite locally stable or even increasing winter precipitation, Alpine snow depth, snowfall and snow cover duration have declined strongly at low and midelevations (e.g., −7% to 15% per decade in winter snow depth and cover, −8.4% per decade in seasonal mean snow depth), and high elevations (above 3000 m a.s.l.) show significant negative trends in length of season with an average of −17 days per decade (Bozzoli et al. 2024; Bertoldi et al. 2023; Fugazza et al. 2021). Concurrently, Alpine permafrost has exhibited widespread warming of roughly 0.04°C per year at around 60 m depth increasing active layer thickness, and progressive degradation, particularly at lower elevation and marginal permafrost sites, reflecting the strong sensitivity of ground thermal regimes to rising air temperatures (Coppa et al. 2025).

Climate variations are transmitted and modified within caves. Cave monitoring and modelling studies show that air temperatures inside caves track the outside mean annual temperature, but with reduced seasonal swings and a time lag due to surrounding rock 'thermal inertia' (Medina et al. 2023). Recent multi-site work across climates confirms that warming at the surface will therefore propagate underground, raising cave temperatures and potentially altering airflow, hydrology, and subterranean ecosystems (Mammola et al. 2019). Therefore, caves in the Alpine region allow researchers to investigate how regional climate signals interact with subterranean microclimates. To obtain reliable, long-term temperature records in these settings, it is essential to use consistent field methods and standardized protocols for data cleaning, validation, and uncertainty quantification.

Here we present a curated, temperature dataset from 19 caves of the Piedmont region in the Western Italian Alps (Appendix S1). The dataset includes paired entrance–interior measurements collected over multiple monitoring campaigns between 2012–2013 and 2020–2025, using several models of iButton devices. All series have been processed through quality control procedures to assess uncertainty (Cimenti et al. 2026), and a dedicated metrological characterization of the sensors was performed at the Italian Istituto Nazionale di Ricerca Metrologica (INRiM) following GUM guidelines (Guide to the Expression of Uncertainty in Measurement). Together, these components provide a combination of (i) multi-cave coverage, (ii) multi-year time duration, and (iii) quantified measurement uncertainty.

By making this dataset openly available, our goal is to support diverse applications ranging from cave-climate modelling to ecological studies of subterranean species that depend on highly constrained thermal niches (Colado et al. 2022; Pallarés et al. 2019). More broadly, the dataset offers a reproducible framework for long-term cave-temperature monitoring, providing a benchmark for future regional and international initiatives.

2 | Data Description and Development

The dataset collection consists of temperature time series observational records from 19 caves in the Piedmont region, Italy. A detailed description and the geographic location of the 19 caves are provided in Appendix S1. We recorded air temperature data using two devices per cave: one placed at the entrance and another deep inside the cave. The sensors were located directly on the rock surface in places which wouldn't be submerged during flooding events and hidden with rocks to prevent stealing or sabotage actions. The device at the entrance was positioned between 1 and 3 m from the cave entrance at a point where it was not directly exposed to sunlight or precipitation. The device inside has been positioned as far inside as possible, choosing a location where it is still easy to find and reach. We stored each series in a separate CSV file, corresponding to a unique combination of cave and sensor location (i.e., entrance, interior) and contains timestamped temperature measurements. Variables include CAVE (site name), LOCATION (sensor position), VALUE (temperature in °C), and TIMESTAMP (ISO 8601-formatted date-time). All files are encoded in UTF-8 and formatted with comma delimiters.

The dataset presented here was subjected to a standardized quality control procedure following the Cave Air Temperature Quality Control (CAT-QC) framework (Cimenti et al. 2026). The procedure consisted of four main steps: (i) assessment of data completeness and identification of missing values and gaps; (ii) detection of physically implausible ('non-sense') values based on conservative temperature thresholds; (iii) identification of statistical outliers using multiple complementary approaches with increasing sensitivity, accounting for overall variability, seasonal patterns, and short-term fluctuations; and (iv) a final manual inspection to distinguish true sensor errors from genuine environmental signals. A more detailed explanation is presented in the companion paper (Cimenti et al. 2026). The application of CAT-QC enabled the identification and removal of non-sense values due to instrument malfunction and including all data recorded in non-cave environments (e.g., during office testing), resulting in a refined dataset of 160,460 validated records. In addition, CAT-QC flagged statistical outliers, were retained in this version to preserve dataset completeness and flexibility for future applications. As a result, users should be aware that some biases may persist and are encouraged to consult the companion paper for guidance on data interpretation.

2.1 | Data Collection

We measured air temperatures at two points inside each cave: one at the cave entrance and the other in internal sectors inside the cave (Table 1). We carried out a first cave temperature monitoring in 2012–2013 for approximately 6 months (within June 2012 and July 2013, Table 2) using iButton devices model DS1923 (accuracy ±0.5°C, resolution 0.0625°C). Following we monitored continuously from autumn 2020 until winter 2024–2025 (Table 2), using iButton devices model DS1922L, DS1925 (accuracy ±0.5°C, resolution 0.0625°C, Analog Devices 2015), and DS2422 (accuracy ±1°C, resolution 0.0625°C, General Analog Devices 2010). From 2020 to 2025, the devices were set to record air temperature with 6-h intervals (e.g., at 0 am, 6 am, 12 pm, and 6 pm). To effectively collect the data, the devices were replaced every year in autumn.

iButtons combine a thermometer and a data logger in a single compact unit. They rely on a battery for self-sustaining and energy supply, which should allow for a time of use of multiple years of records. Storage-wise, the devices are capable of recording 8 kB in 8 or 16 bit (WDSEN 2022).

Despite the iButton resolution of 0.0625°C, the uncertainty remains too high to record small temperature fluctuations in subterranean environments, where temperature variation can be below a tenth of a degree per year (e.g., in Grotta inferiore del Caudano). Therefore, we implemented a thermometer characterization procedure consisting of a laboratory-based calibration and uncertainty assessment of the devices model DS1922L and DS2422 used between 2020 and 2024. The characterization is detailed in Appendix S2. Since the devices model DS1923 used in 2012–2013 were no longer available, it was not possible to implement a characterization for the devices used during that period.

2.2 | Calculation of Data Uncertainty

To reduce the uncertainty associated with the temperature values recorded by the iButton devices, a post-deployment characterization was performed at INRiM. The characterization followed the recommendations of the GUM protocol (Guide to the Expression of Uncertainty in Measurement) and involved 22 iButton thermometers (18 DS1922L and 4 DS2422) that had previously been deployed in caves between 2020 and 2025. Full methodological details are provided in Appendix S2.

Characterization involved exposing the sensors to controlled temperature conditions across multiple configurations, using high-precision reference thermometers (uncertainty down to ±0.005°C). For each iButton and test condition, the average deviation from the reference temperature (ΔT) was calculated. These values were used to estimate both the absolute uncertainty on uncorrected measured data (Tmeas) and, where possible, to derive calibration curves to correct systematic measurement errors.

For the DS1922L model, a linear calibration function was derived:

$$\Delta T = m \times T_{\mathrm{meas}} + q$$

where $m = 0.0041$ and $b = 0.14$. Corrected temperatures (T_{corr}) were computed as:

$$T_{\mathrm{corr}} = T_{\mathrm{meas}} - \Delta T$$

The absolute uncertainty on uncorrected measured data was estimated to be ±0.2°C. After applying the calibration curve, this was reduced to ±0.09°C. An additional uncertainty component due to data dispersion among devices (under homogeneous thermal conditions) was estimated at ±0.05°C. This latter value quantifies the between-sensor variability and can be used when comparing temperature time series acquired with different DS1922L units.

For the DS2422 model, a complete characterization could not be performed due to the limited number of units available. However, all four tested sensors exhibited a consistent systematic underestimation of the reference temperature by approximately 1°C–2°C. This offset was observed under all test conditions and was not associated with increased random noise, suggesting good temporal stability but poor absolute accuracy. Due to this limitation, no calibration function was applied to DS2422 devices, and their measurements should be interpreted with caution when absolute temperature accuracy is required.

3 | Dataset Access

The dataset is provided in CSV format, and it is accessible in Figshare.com via the following link: https://doi.org/10.6084/m9.figshare.29108090.v1. No registration is required to access the data.

TABLE 1 | List of monitored caves and their characteristics. Characteristics of caves are derived from the official speleological cadaster of the region (Catasto Speleologico Piemontese e Valdostano 2025; https://catastogrotte-piemonte.net/). Modified from Cimenti et al. (2026).

Cave name	Municipality	Speleological cadaster number	Speleological cadaster link	WGS84 coordinates (entrance)	Elevation (m a.s.l.)	Development (m)	Distance from the entrance external datalogger (m)	Distance from the entrance internal datalogger (m)	Corresponding file name
Grotta delle Arenarie	Valduggia	PI2509	https://catastogrotte-piemonte.net/caves-view-1759.html	45.711919° 8.3145207°	770	3000	1	70	c1_arenarie_PI2509
Buco dell'Aria Calda	Vignolo	PI1102	https://catastogrotte-piemonte.net/caves-view-1030.html	44.3484026° 7.4623675°	852	115	1	20	c2_ariacalda_PI1102
Grotta Occidentale del Bandito	Roaschia	PI1003	https://catastogrotte-piemonte.net/caves-view-931.html	44.290002° 7.427431°	714	690	1	50	c3_bandito_PI1003
Grotta di Bercovei	Sostegno	PI2503	https://catastogrotte-piemonte.net/caves-view-1753.html	45.6606509° 8.2654061°	415	170	1	150	c4_bercovei_PI2503
Grotta di Bossea	Frabosa Soprana	PI0108	https://catastogrotte-piemonte.net/caves-view-36.html	44.241548° 7.8398498°	836	2800	1	1700	c5_bossea_PI0108
Grotta inferiore del Caudano	Frabosa sottana	PI121	https://catastogrotte-piemonte.net/caves-view-50.html	44.2930025° 7.7905788°	778	3440	2	800	c6_caudano_PI121
Grotta di Chiabrano	Perrero	PI1621	https://catastogrotte-piemonte.net/caves-view-1396.html	44.9470661° 7.1060462°	1080	27	1	6	c7_chiabrano_PI1621

(Continues)

TABLE 1 | (Continued)

Cave name	Municipality	Speleological cadaster number	Speleological cadaster link	WGS84 coordinates (entrance)	Elevation (m a.s.l.)	Development (m)	Distance from the entrance external datalogger (m)	Distance from the entrance internal datalogger (m)	Corresponding file name
Grotta La Custreta	Sparone	PI1593	https://catastogrotte-piemonte.net/caves-view-1368.html	45.4463179° 7.5458605°	1350	180	1	26	c8_custreta_PI1593
Tuna dal Diaou	Roreto Chisone	PI1591	https://catastogrotte-piemonte.net/caves-view-1366.html	45.0262921° 7.1218405°	1392	140	1	50	c9_diaou_PI1591
Tana della Dronera	Vicoforte Mondovì	PI151	https://catastogrotte-piemonte.net/caves-view-79.html	44.3440187° 7.8459223°	525	134	2	80	c10_dronera_PI151
Balma Fumarella	Gravere	PI1597	https://catastogrotte-piemonte.net/caves-view-1372.html	45.1270119° 7.0319789°	864	47	1	15	c11_fumarella_PI1597
Buca del Ghiaccio della Cavallaria	Brosso	PI1609	https://catastogrotte-piemonte.net/caves-view-1384.html	45.5182779° 7.7952332°	1550	24	2	16	c12_ghiaccio_PI1609
Ghieisa d'la Tana	Angrogna	PI1538	https://catastogrotte-piemonte.net/caves-view-1313.html	44.8492344° 7.2226677°	841	50	1	12	c13_ghieisa_PI1538
Buco del Maestro	Paesana	PI1148	https://catastogrotte-piemonte.net/caves-view-1076.html	44.6845875° 7.2363044°	750	17	1	8	c14_maestro_PI1148

(Continues)

TABLE 1 | (Continued)

Cave name	Municipality	Speleological cadaster number	Speleological cadaster link	WGS84 coordinates (entrance)	Elevation (m a.s.l.)	Development (m)	Distance from the entrance external datalogger (m)	Distance from the entrance internal datalogger (m)	Corresponding file name
Grotta Testa di Napoleone-1	Borgone	PI1569	https://catastogrotte-piemonte.net/caves-view-1344.html	45.1144036° 7.2605897°	450	50	1	25	c15_napoleone_PI1569
Buco del partigiano	Roccabruna	PI1315	https://catastogrotte-piemonte.net/caves-view-1243.html	44.506897° 7.2932269°	1170	13	2	11	c16_partigiano_PI1315
Grotta del Pugnetto	Mazzenile	PI1501	https://catastogrotte-piemonte.net/caves-view-1276.html	45.2722721° 7.4124256°	820	765	1	500	c17_pugnetto_PI1501
Borna del Servais B	Ceres	CAPI1756	https://catastogrotte-piemonte.net/artificials-view-331.html	45.322528° 7.327619°	1387	17	2	12	c18_servais_CAPI1756
Sotterranei del forte (A) di Vernante Opera 11, Tetto Ruinas	Vernante	CAPI622	https://catastogrotte-piemonte.net/artificials-view-858.html	44.2522208° 7.527921°	784	91	3	50	c19_vernante_artificial

TABLE 2 | Starting and ending dates of temperature series and date of device replacement of each year and cave. NA indicates that the data are not available for that period or the device got lost.

		2012–2013			2020–2024				
Cave name	**Series**	**Start**	**End**	**Device model**	**Start**	**End**	**Device placement and replacement**	**Placed device model**	**Gaps (%) over 4 years**
Grotta delle Arenarie	Internal	2012-10-16	2013-06-14	DS1923	2020-11-12	2024-10-27	2020-11-12	DS1922L	25
							2021-11-24	DS1922L	
							2022-11-21	NA	
							2023-11-07	DS1925	
	Entrance	2012-10-16	2013-06-14	DS1923	2020-11-12	2024-10-27	2020-11-12	DS1922L	0
							2021-11-24	DS1922L	
							2022-11-21	DS1922L	
							2023-11-07	DS1925	
Buco dell'Aria Calda	Internal	2012-06-05	2013-07-13	DS1923	2020-10-21	2024-11-13	2020-10-21	DS1922L	50
							2021-11-30	NA	
							2022-12-16	NA	
							2023-10-20	DS1925	
	Entrance	2012-06-05	2013-07-13	DS1923	2020-10-21	2024-11-13	2020-10-21	DS1922L	25
							2021-11-30	DS1922L	
							2022-12-16	NA	
							2023-10-20	DS1925	
Grotta Occidentale del Bandito	Internal	2012-06-05	2013-06-01	DS1923	2020-10-21	2022-12-16	2020-10-21	DS1922L	75
							2021-11-30	NA	
							2022-12-16	NA	
							2023-10-20	NA	
	Entrance	2012-06-05	2013-06-01	DS1923	2020-10-21	2022-12-16	2020-10-21	DS1922L	50
							2021-11-30	DS1922L	
							2022-12-16	NA	
							2023-10-20	NA	

(Continues)

TABLE 2 | (Continued)

		2012–2013			2020–2024				
Cave name	**Series**	**Start**	**End**	**Device model**	**Start**	**End**	**Device placement and replacement**	**Placed device model**	**Gaps (%) over 4 years**
Grotta di Bercovei	Internal	2012-11-20	2013-06-14	DS1923	2020-11-12	2024-11-03	2020-11-12	DS1922L	0
							2021-11-24	DS1922L	
							2022-11-21	DS1922L	
							2023-11-07	DS1925	
	Entrance	2012-11-20	2013-06-14	DS1923	2020-11-12	2024-10-22	2020-11-12	DS1922L	0
							2021-11-24	DS1922L	
							2022-11-21	DS1922L	
							2023-11-07	DS1925	
Grotta di Bossea	Internal	2012-07-19	2013-05-23	DS1923	2020-10-16	2025-01-16	2020-10-16	DS1922L	25
							2021-11-30	NA	
							2022-12-28	DS2422	
							2024-01-18	DS1925	
	Entrance	2012-07-19	2013-05-23	DS1923	2020-10-16	2025-01-16	2020-10-16	DS1922L	0
							2021-11-30	DS1922L	
							2022-12-28	DS1922L	
							2024-01-18	DS1925	
Grotta inferiore del Caudano	Internal	2012-06-23	2013-05-08	DS1923	2020-10-16	2025-01-16	2020-10-16	DS1922L	0
							2021-11-30	DS2422	
							2022-12-28	DS1922L	
							2023-12-19	DS1925	
	Entrance	2012-06-23	2013-05-08	DS1923	2020-10-16	2025-01-16	2020-10-16	DS1922L	25
							2021-11-30	NA	
							2022-12-28	DS1922L	
							2023-12-19	DS1925	

(Continues)

TABLE 2 | (Continued)

		2012–2013			2020–2024				
Cave name	Series	Start	End	Device model	Start	End	Device placement and replacement	Placed device model	Gaps (%) over 4 years
Grotta di Chiabrano	Internal	2012-10-04	2013-05-08	DS1923	2020-10-20	2024-10-13	2020-10-20	DS1922L	0
							2021-10-22	DS1922L	
							2022-10-10	DS1922L	
							2023-10-26	DS1925	
	Entrance	2012-10-04	2013-05-08	DS1923	2020-10-20	2024-10-13	2020-10-20	DS1922L	25
							2021-10-22	DS1922L	
							2022-10-10	NA	
							2023-10-26	DS1925	
Grotta La Custreta	Internal	2012-09-28	2013-07-12	DS1923	2020–11–17	2022-10-18	2020–11–17	DS1922L	50
							2021-10-27	DS1922L	
							2021-10-27	NA	
							NA	NA	
	Entrance	2012-09-28	2013-07-12	DS1923	2020–11–17	2021-10-27	2020–11–17	DS1922L	75
							2021-10-27	NA	
							2022-10-18	NA	
							NA	NA	
Tuna dal Diaou	Internal	2012-10-04	2013-05-15	DS1923	2020-10-20	2024-10-13	2020-10-20	DS1922L	25
							2021-10-22	DS1922L	
							2022-10-10	NA	
							2023-10-26	DS1923	
	Entrance	2012-10-04	2013-05-15	DS1923	2020-10-20	2024-10-13	2020-10-20	DS1922L	0
							2021-10-22	DS1922L	
							2022-10-10	DS1922L	
							2023-10-26	DS1923	

(Continues)

TABLE 2 | (Continued)

Cave name	Series	2012–2013 Start	2012–2013 End	2012–2013 Device model	2020–2024 Start	2020–2024 End	Device placement and replacement	Placed device model	Gaps (%) over 4 years
Tana della Dronera	Internal	2012-07-19	2013-05-23	DS1923	2020-10-27	2025-01-16	2020-10-27	DS1922L	25
							2021-11-30	DS1922L	
							2022-12-16	NA	
							2023–11–17	DS1925	
	Entrance	NA	NA	NA	2020-10-27	2025-01-16	2020-10-27	DS1922L	25
							2021-11-30	NA	
							2022-12-16	DS1922L	
							2023–11–17	DS1925	
Balma Fumarella	Internal	2012-06-07	2013-05-15	DS1923	2023-10-13	2024-10-09	2020-10-09	NA	75
							2021-10-19	NA	
							2022-10-25	NA	
							2023-10-13	DS1925	
	Entrance	2012-06-07	2013-05-15	DS1923	2021-10-19	2024-10-09	2020-10-09	NA	25
							2021-10-19	DS1922L	
							2022-10-25	DS2422	
							2023-10-13	DS1925	
Buca del Ghiaccio della Cavallaria	Internal	2012-06-02	19-06-2013	DS1923	2020–11–17	2022-10-18	2020–11–17	DS1922L	50
							2021-10-27	DS1922L	
							2022-10-18	NA	
							NA	NA	
	Entrance	2012-06-02	19-06-2013	DS1923	2020–11–17	2022-10-18	2020–11–17	DS1922L	50
							2021-10-27	DS2422	
							2022-10-18	NA	
							NA	NA	

(Continues)

TABLE 2 | (Continued)

Cave name	Series	2012–2013 Start	2012–2013 End	2012–2013 Device model	2020–2024 Start	2020–2024 End	Device placement and replacement	Placed device model	Gaps (%) over 4 years
Ghieisa d'la Tana	Internal	2012-10-11	2013-05-15	DS1923	2020-10-27	2022-12-07	2020-10-27	DS1922L	50
							2021-11-20	DS1922L	
							2022-12-07	NA	
							2023-12-27	NA	
	Entrance	2012-10-11	2013-05-15	DS1923	2020-10-27	2024-12-10	2020-10-27	DS1922L	0
							2021-11-20	DS1922L	
							2022-12-07	DS1922L	
							2023-12-01	DS1925	
Buco del Maestro	Internal	2012-10-04	2013-05-25	DS1923	2020-10-20	2024-12-10	2020-10-20	DS1922L	0
							2021-10-22	DS1922L	
							2022-12-07	DS1922L	
							2023-12-01	DS1925	
	Entrance	2012-10-04	2013-05-25	DS1923	2020-10-20	2022-12-07	2020-10-20	DS1922L	50
							2021-10-22	DS1922L	
							2022-12-07	NA	
							2023-12-01	NA	
Grotta Testa di Napoleone-1	Internal	2012-06-07	2013-05-15	DS1923	2020-10-09	2022-10-25	2020-10-09	DS1922L	50
							2021-10-19	DS1922L	
							2022-10-25	NA	
							NA	NA	
	Entrance	2012-06-07	2013-05-15	DS1923	2020-10-09	2021-10-19	2020-10-09	DS1922L	25
							2021-10-19	NA	
							2022-10-25	NA	
							NA	NA	

(Continues)

TABLE 2 | (Continued)

		2012–2013			2020–2024				
Cave name	**Series**	**Start**	**End**	**Device model**	**Start**	**End**	**Device placement and replacement**	**Placed device model**	**Gaps (%) over 4 years**
Buco del partigiano	Internal	2012-06-03	2013-05-12	DS1923	2020-10-17	2024-09-27	2020-10-17	DS1922L	0
							2021-10-30	DS1922L	
							2022-10-02	DS1922L	
							2023-10-01	DS1925	
	Entrance	2012-06-03	2013-05-12	DS1923	2020-10-17	2024-09-27	2020-10-17	DS1922L	25
							2021-10-30	DS1922L	
							2022-10-02	NA	
							2023-10-01	DS1925	
Grotta del Pugnetto	Internal	2012-05-26	2013-06-02	DS1923	2020-10-29	2024-11-28	2020-10-29	DS1922L	50
							2021-10-14	NA	
							2022-11-14	NA	
							2023-11-29	DS1925	
	Entrance	2012-05-26	2013-06-02	DS1923	2020-10-29	2024-11-28	2020-10-29	DS1922L	25
							2021-10-14	NA	
							2022-11-14	DS1922L	
							2023-11-29	DS1925	
Borna del Servais B	Internal	2012-06-01	2013-05-30	DS1923	2020-10-29	2022-11-15	2020-10-29	DS1922L	25
							2021-10-14	DS1922L	
							2022-11-15	DS1922L	
							2023-11-29	NA	
	Entrance	2012-06-01	2013-05-30	DS1923	2020-10-29	2024-11-28	2020-10-29	DS1922L	25
							2021-10-14	NA	
							2022-11-15	DS1922L	
							2023-11-29	DS1925	

(Continues)

TABLE 2 | (Continued)

Cave name	Series	2012–2013			2020–2024				Gaps (%) over 4 years
		Start	End	Device model	Start	End	Device placement and replacement	Placed device model	
Sotterranei del forte (A) di Vernante Opera 11, Tetto Ruinas	Internal	2012-06-05	2013-07-13	DS1923	2020-10-21	2024-11-14	2020-10-21	DS1922L	0
							2021-11-30	DS1922L	
							2022-12-23	DS1922L	
							2023-10-20	DS1925	
	Entrance	2012-06-05	2013-07-13	DS1923	2020-10-21	2024-11-14	2020-10-21	DS1922L	25
							2021-11-30	DS1922L	
							2022-12-23	NA	
							2023-10-20	DS1925	

Future extensions to the dataset may include additional years of temperature recordings or expanded geographic coverage.

4 | Potential Dataset Use and Reuse

Our dataset is aimed to be suitable for a wide range of scientific applications. Its structured format and documented uncertainty make it an ideal resource for researchers working at the intersection of climate science, ecology, conservation biology, geoscience, and environmental monitoring. However, some limitations should be considered. First, despite the rigorous CAT-QC protocol and thermometer characterization, the resolution and uncertainty of some sensors may not capture temperature changes below 0.05°C, which may be ecologically relevant in internal cave sectors. Second, temporal gaps and uneven coverage across years—especially during the early (2012–2013) phase—may limit time-series continuity for trend analysis. Third, the dataset focuses solely on air temperature; additional variables such as humidity or air flow are not included but may influence cave thermal regimes. Despite these constraints, the dataset remains a valuable, openly accessible resource for advancing the study of subterranean environments in a changing climate.

Notwithstanding these limitations, the dataset enables evaluation of theoretical models of cave climate dynamics, including thermal lag, signal attenuation, and surface-to-subterranean temperature transmission. The dual-sensor setup (entrance vs. interior) allows for comparative studies on the buffering capacity of cave systems in response to seasonal and long-term atmospheric changes (Domínguez-Villar et al. 2013).

In ecology, these temperature series are particularly relevant for assessing climate sensitivity thresholds in cave-dwelling fauna, many of which are sensitive to temperature dynamics and restricted to narrow microclimatic niches (Vaccarelli et al. 2023). Additionally, the data may support studies on habitat suitability modelling, microrefugia potential, and species persistence under future climate scenarios (Mammola and Leroy 2018). The fauna of these caves is documented in a monographic work by Lana et al. (2021). For subterranean spiders, interoperable, high-quality data—including phylogenetic information and functional traits—are available in a digitized format (Nicolosi et al. 2025).

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are openly available in figshare.com at https://doi.org/10.6084/m9.figshare.29108090.v1.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Appendix S1:** Study sites description. **Appendix S2:** Calculation of data uncertainty.