glenglat: A database of global englacial temperatures

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Abstract. Measurements of englacial temperatures have been collected since the earliest years of glaciology, with the first measurements dating back to the mid-19$^{\text{th}}$ century. Although temperature is a defining characteristic of any glacier – and is notoriously laborious to collect – no effort had yet been made to gather all existing measurements. In an attempt to make existing ice temperature data more accessible, we present glenglat, a global englacial temperature database compiled from 242 literature sources and nine data submissions and composed of 1 142 163 measurements of depth and temperature from 690 boreholes located on 186 glaciers outside of the ice sheets. Alongside recent compilations for the ice sheets (Løkkegaard et al., 2023; Vandecrux et al., 2023), most published englacial temperature measurements are now readily available to the research community.

Here, we review the variety of glacier thermal regimes that have been measured and summarize the spatial, temporal, and climatic coverage of measurements relative to global glacierized area. Measurements of cold and polythermal glacier ice greatly outnumber those of temperate ice. Overall, temperature has been measured in fewer than 1 ‰ of all glaciers, and only 20 % of borehole locations have been measured more than once, highlighting the large potential to investigate changing temperature conditions by repeating past measurements. The database is developed on GitHub (www.github.com/mjacqu/glenglat) and published to Zenodo (https://doi.org/10.5281/zenodo.11516611; Jacquemart et al., 2025). It consists of four relational tables and detailed machine-actionable and human-readable metadata. The GitHub repository also provides submission instructions (including a spreadsheet template and validation tools), in the hopes that investigators can help us keep glenglat complete and current going forward. We hope that glenglat can help improve our understanding of glacier thermal regimes, help refine glacier thermodynamic models, or shed insight into hazardous glacier instabilities in a warming world.

1 Introduction

The englacial temperature is a defining characteristic of any glacier. It influences glacier flow dynamics and subglacial hydrology, it can be a decisive factor for glacier hazards, and it can serve as an archive of past climate. To illustrate, ice viscosity and deformation rate depend directly on ice temperature (Deeley and Woodward, 1908; Glen, 1954;

Cuffey and Paterson, 2010); only temperate (basal) ice permits glacier sliding over the bed (Cuffey and Paterson, 2010); impermeable cold ice can serve as a barrier for water, controlling sub- and englacial water flow and possibly contributing to the formation of hazardous water accumulations within the ice or in glacier sediment beds (Irvine-Fynn et al., 2011; Vincent et al., 2012; Gilbert et al., 2012; Kääb et al., 2018; Gilbert et al., 2018; Jacquemart et al., 2020; Kääb et al., 2021). Under cold conditions, the variations of temperature with depth are a window into the past evolution of atmospheric temperatures, making englacial temperature changes an important climate variable (e.g., Gilbert et al., 2010). Ice temperatures and glacier flow regimes also have implications for glacial archaeology, defining how well artifacts can survive in the ice (Pilø et al., 2023). Finally, ice temperature records also serve to validate thermo-mechanical glacier models, which an important tool for improving our understanding of glacier systems.

Glaciers are typically categorized either as temperate, cold, or polythermal. Temperate ice is at the pressure melting point, cold ice is below the pressure melting point, and polythermal glaciers contain both cold and temperate ice. The pressure melting point depends mostly on the ice overburden pressure (and to a lesser extent, the presence of air bubbles and other impurities), such that under temperate conditions ice temperature decreases with depth at around $6.5 \times 10^{-4}\,^{\circ}\mathrm{C}$ to $7.5 \times 10^{-4}\,^{\circ}\mathrm{C}$ per meter (Paterson, 1971; Harrison, 1972; Jania et al., 1996). More generally, the englacial temperature is determined by the complex interaction between the surface energy balance, the geothermal heat flux, and internal heating from ice deformation, basal friction, and refreezing of meltwater (Cuffey and Paterson, 2010). Available heat is transferred through the ice and firn via conduction and advection by ice and water flow. The superposition of these processes can lead glaciers to be fully cold or temperate, or simultaneously contain cold and temperate ice in a wide variety of spatial configurations (Blatter and Hutter, 1991; Irvine-Fynn et al., 2011).

Ongoing human-driven climate change is leading to substantial changes of englacial temperatures, evidence of which is clear in (few existing) repeat measurements. At Dôme du Gouter in the French Alps, for example, a warming of 1.5 °C has been recorded at a depth of 50 m between 1994 and 2017 (Vincent et al., 2020). Long-term measurements at Golle Gnifetti (Swiss Alps) between 1991 and 2023 reveal the same amount of warming at a depth of 20 m (Gastaldello and Hoelzle, 2024b). This warming can have several consequences. For one, meltwater infiltrating cold firn can degrade or destroy the archive of past climatic conditions that can be stored in firn or ice cores (Mattea et al., 2021; Gabrielli et al., 2016). In steep terrain, warming at the glacier bed can lead to wide-spread sliding and destabilization of entire glaciers, increasing the probability of very large ice avalanches, similar to the one observed at Altels in Switzerland in 1895 (Heim et al., 1895; Faillettaz et al., 2011). Counterintuitively, warming can also lead some glaciers to cool, because their disappearing firn cover reduces the amount of englacial warming that stems from the latent heat release of refreezing meltwater (Gilbert et al., 2012; Huss and Fischer, 2016; Irvine-Fynn et al., 2011). A similar effect may also occur in areas still covered by firn, if the refreezing meltwater creates impermeable ice layers that prevent water percolation into the firn, thereby (locally) limiting the latent heat release (Vincent et al., 2020).

Measuring englacial temperatures is a laborious process; (deep) ice temperature measurements are therefore comparatively rare. Those that exist were typically collected for one of several reasons: To gain an understanding of glacier dynamics and englacial temperatures directly (e.g., Agassiz, 1847; Blatter and Haeberli, 1984; Clarke et al., 1984; Copland et al., 2003; Ryser et al., 2013; Gilbert et al., 2010; Vincent et al., 2020; Troilo et al., 2021; Karušs et al., 2022), in connection with the retrieval of ice cores used to reconstruct past climatic changes (e.g., Thompson et al., 1990, 2018; Kinnard et al., 2006; Schwikowski et al., 2013; Kinnard et al., 2020), or as part of operational glacier monitoring efforts to document current climate change (e.g., Hoelzle et al., 2020). The data resulting from such efforts are largely hidden away in scientific literature spanning more than a century, and are therefore not readily available as a community resource. At the same time, there is an increasing need to understand how englacial temperatures – and their changes over time – relate to glacier dynamics, climate change, and glacier hazards (Gilbert and Vincent, 2013; Colgan et al., 2015; Gilbert et al., 2015; Kääb et al., 2018; Machguth et al., 2023b). In order to make englacial temperature data from glaciers around the world more widely available, we have compiled glenglat, a global englacial temperature database, sourced – largely, but not exclusively – from published literature. In the following, we describe how englacial temperatures are measured in the field (Sec. 2.1), how we found and compiled these measurements (Sec. 2.2), and how the resulting glenglat database is structured and managed (Sec. 2.3). In Section 3, we present and discuss the content of glenglat (version 1.0), and close with instructions for how others can contribute additional data (Sec. 3.5). We hope that glenglat can serve as a community resource to help improve our understanding of ongoing changes in the cryosphere and that it will grow over time with the addition of past and future englacial temperature measurements.

2 Methods and Data

2.1 Measurement methods

Englacial temperature measurements are typically made by placing one or more thermistors in a borehole (Fig. 1. Boreholes are drilled with either mechanical (reviewed in Talalay, 2016) or thermal (reviewed in Talalay, 2020) drills, or a combination thereof. The advantage of mechanical drilling is that temperatures can be reliably measured after a short time. Thermal drilling (e.g., steam or hot water) significantly raises the temperature of the borehole, which subsequently needs time to re-adjust to the temperature of the surrounding ice (typically a several days to a few weeks Laternser, 1992; Miles et al., 2018). Depending on the measurement techniques and objectives, borehole temperatures are measured only once, or the thermistor chain is left in the hole (which is allowed to freeze up or kept open with a casing or fluid) and either remeasured manually or equipped with an automatic logger. A recent innovation replaces discrete thermistors with a fibre optic cable (distributed temperature sensing (DTS), Law et al., 2021), which can provide measurements with an unprecedented vertical resolution, especially in deep boreholes where the required number of thermistors would be prohibitively expensive.

Figure 1. Photographs illustrating methods for measuring glacier temperatures: (a) drilling a shallow borehole with a handheld mechanical auger on Griesgletscher, Switzerland (photo by Matthias Huss), (b) drilling a deep borehole with a hot water drill and a large array of fuel drums and pumps to heat and pressurize the water on Rhonegletscher, Switzerland (photo by Raphael Moser), and (c) a typical string of thermistors used to measure temperature at different depths in a borehole (photo by Mylène Jacquemart)

2.2 Data compilation

Most data included in glenglat are sourced from published literature and datasets. Publications were initially found by searching Google Scholar (https://scholar.google.com) and Google Dataset Search (https://datasetsearch.research.google.com) for combinations of the English words glacier, ice, temperature, thermal, regime, englacial, borehole, drill(ing), measurement, and record, as well as 冰川温度钻孔 and скважина температуры ледника ("glacier borehole temperature" in Chinese and Russian, respectively). We then recursively sought out publications referenced in previously-identified publications, striving to find the most complete and original data source for each measurement. Tracking down references was made more difficult by the practice of journals (primarily European and North American ones using Latin script) of not publishing references in their original form (e.g., "термический"), but only translations ("temperature") or phonetic transcriptions ("termicheskiy"). Finding these often involved reconstructing the original reference, since the modified form did not appear in search results. When we were unable to find the full text of a publication online or in print in nearby libraries, we requested it from the Swiss Library Service Platform (SLSP) document delivery service through the University of Bern (ub.unibe.ch). In addition to extracting data from publications, we solicited data submissions on CRYOLIST (cryolist.org), at the 2023 Alpine Glaciology Meeting in Birmensdorf, Switzerland, and through personal communications. References to all the data sources can be found in the bibliography of this publication (see Appendix A for a list of glaciers and corresponding references) and within glenglat itself (Sec. 2.3).

For this first version of glenglat, we selected only firn and/or ice temperature measurements with a well-defined depth. This means that we did not take into account measurements made in tunnels dug into glaciers at undefined depths. We disregarded publications that provided measurements that were made exclusively in seasonal snow, but did not remove shallow measurement points of deeper measurements in firn or ice. Where shallow measurements were provided alongside deeper ones, we did also include these. We also focused on glaciers and omitted measurements from the Antarctic and Greenland ice sheets, to a large degree because data from the ice sheets have already been compiled by Løkkegaard et al. (2023) and Vandecrux et al. (2023).

For each measurement, we extracted depth and temperature data and their associated metadata (see below). Submitted or published data in machine-readable formats were added directly to the database, data published numerically in text or tables were transcribed with the help of Optical Character Recognition (OCR), and data represented graphically (e.g., as a plot of temperature versus depth) were digitized using the open-source software Plot Digitizer (https://plotdigitizer.sourceforge.net/). For plots that used points to indicate each measurement (Fig. 3a), we digitized the values at each point. For plots using a continuous line (Fig. 3b), such that the locations of the measurements along the line are unknown, we used a point density sufficient to reproduce the original line.

Metadata associated with the temperature measurements were compiled from one or more sources to the best of our abilities (see Tables 1 – 4). For example, borehole coordinates were either extracted directly from text, digitized from a map with defined axes (e.g., latitude and longitude) using Plot Digitizer, digitized from a map (without such axes) visually georeferenced to a global basemap using the QGIS Freehand Raster Georeferencer plugin (https://plugins.qgis.org/plugins/FreehandRasterGeoreferencer/), or approximated on global basemaps with the help of terrain features, glacier morphology, or elevation information. Borehole elevation was published as text in most cases, though we did occasionally have to approximate elevation from provided contour lines or by comparison to an independent topographic map. Other metadata included the measurement and drilling dates, the drill type (mechanical, thermal, or combined), the depth of the firn-ice interface (i.e., whether the measurements are in firn, ice, or both), whether the borehole reached the glacier bed, and the uncertainty of the temperature measurements.

2.3 Data structure and management

Glenglat is packaged and described following the Frictionless Tabular Data Package standard (Walsh et al., 2017), version-controlled and tested on GitHub (https://github.com/mjacqu/glenglat), and published to Zenodo (https://doi.org/10.5281/zenodo.13334175). Data and metadata (Tables 1 – 4) are stored using common text file formats to ensure that they are human-readable, machine-actionable, and compatible with line-based version-control systems like Git. The data are structured as a four-table relational database stored as CSV (comma-separated values) files. The source table (Tab. 1) contains a full reference to each data source that we used. Names in non-Latin scripts (Cyrillic, Hangul, and Chinese characters) are accompanied by a latinized form, and non-English titles are accompanied by an English translation. The borehole table (Tab. 2) describes the drill site – including the location, elevation, drill method, and reported uncertainty of the temperature measurements. The profile table

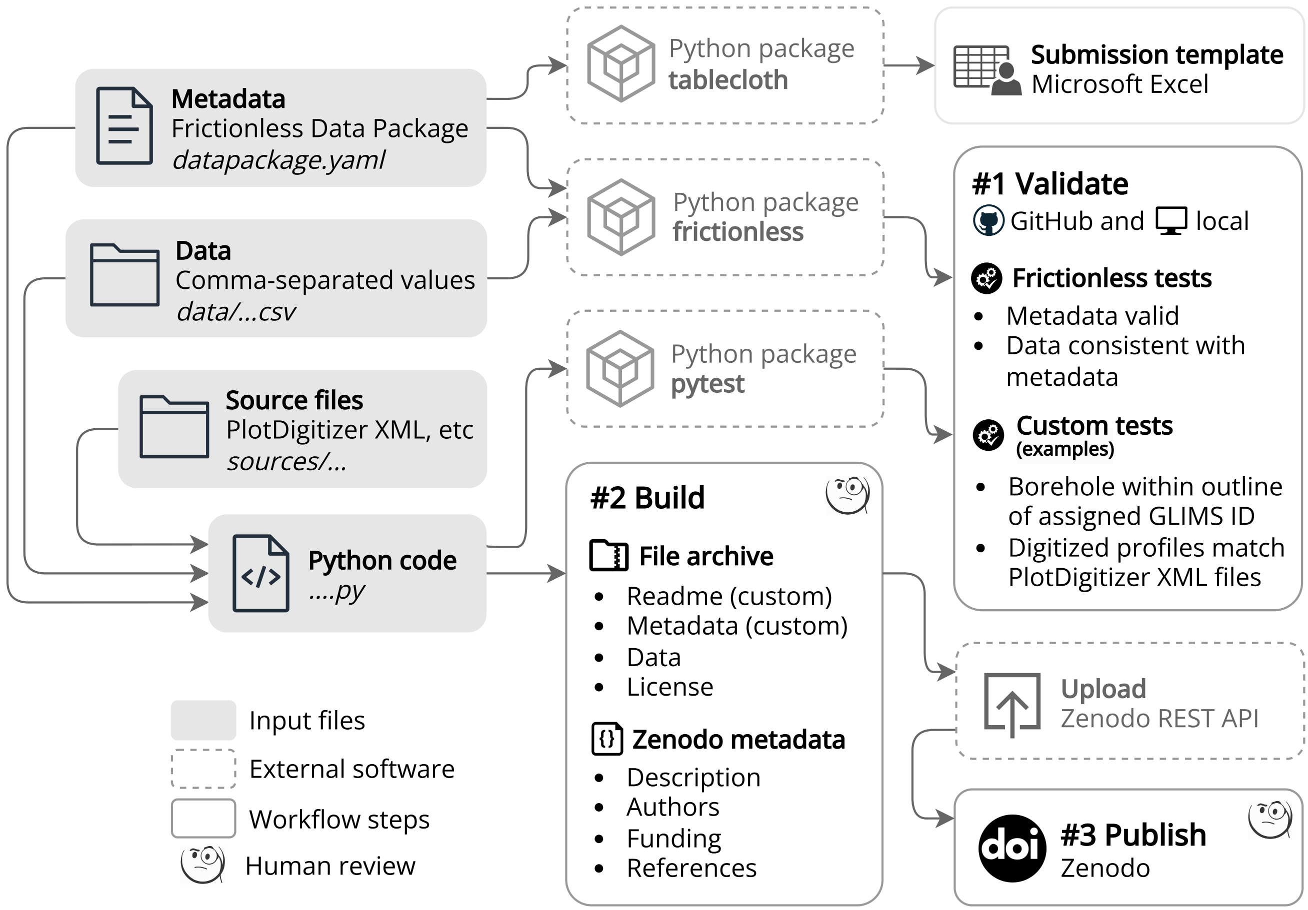

Figure 2. Glenglat testing and publishing workflow. The input files (in gray) are those version-controlled in the Git repository.

(Tab. 3) describes each temperature-depth profile – including the timing of the measurement and whether or not the measurement was made after the borehole was known to have reached thermal equilibrium. Finally, the measurement table (Tab. 4) contains the measurements of temperature with depth. To improve manageability of the CSV files, data from boreholes with time-series measurements (i.e., with hundreds of profiles), the profile and measurement tables are stored in separate, source-specific CSV files. Supporting these tabular data are files that, for each source, document how and from where the data were extracted. For submissions, these include data files and email correspondence. For publications, these include the key text passages, tables, maps, or figures that served as the sources for the data. Additional files can be used to reproduce how numeric values were digitized from maps and figures using Plot Digitizer (*.xml) or georeferenced and digitized using QGIS (*.pgw, *.{png|jpg}.aux.xml, and *.geojson).

The tabular data are described in a single YAML (https://yaml.org) metadata file (datapackage.yaml). This file lists general attributes of the database – like name, description, version, license, and contributors – as well as a detailed description of the structure and content of each tabular data file. The CSV Dialect (Pollock, 2021) specifies how exactly the CSV files are structured, while the Table Schema (Walsh and Pollock, 2021) specifies the name and data type of each column, the constraints on each column's values, and the foreign-key relations between tables.

This metadata architecture allows data maintainers and contributors to use Frictionless Framework (https://framework.frictionlessdata.io) to test that the metadata is correctly structured and that the data are consistent with the metadata. These tests are run automatically in a continuous-integration pipeline on GitHub using Frictionless Repository (https://repository.frictionlessdata.io), ensuring the integrity of the database whenever any file is modified. Additional custom tests, which cannot be expressed by the metadata, further verify the integrity of the dataset, for example that all people who contributed data (referenced as a personal communication in table source) are listed as contributors in datapackage.yaml. Using software built on the Frictionless Tabular Data Package standard (https://github.com/ezwelty/tablecloth), we can also render the metadata as an interactive spreadsheet template with dropdown menus and real-time validation, lowering the bar for future data contributors.

We publish the database to Zenodo using a custom build process. The uploaded file archive and detailed Zenodo metadata are generated automatically from the contents of the GitHub repository and submitted using the Zenodo REST API (https://developers.zenodo.org). Zenodo manages the DOIs for glenglat, registering a concept DOI encompassing all versions (https://doi.org/10.5281/zenodo.11516611) and a version DOI for each new version (https://doi.org/10.5281/zenodo.13334175). To keep the structure simple and the download small, Zenodo releases contain only the CSV files (data/*.‘), a license (LICENSE.md), simplified documentation (README.md), and a version of the metadata (datapackage.yaml) converted to JSON.

Table 1. Main columns of the source table (data/source.csv); a full description is provided in datapackage.yaml. Column names and categorical values closely match the Citation Style Language (CSL) 1.0.2 specification (Zelle et al., 2015). The primary key is indicated with a *.

Column	Type/Units	Description
id*	string	Unique identifier, constructed from author name and year (e.g., zagorodnov1981), referenced from other tables either formally in a foreign key or informally within free-form text.
author	string	Author names (optionally followed by their ORCID in parentheses) as a pipe-delimited list.
year	YYYY	Year issued (published, communicated, last updated)
type	string	Type (e.g., journal article, book chapter, dataset, personal communication)
title	string	Title of the work
url	string	URL (DOI if available)
language	string	Language as ISO 639-1 two-letter language code.
container_title	string	Title of the container (e.g., journal, book, data repository)

Table 2. Columns of the borehole table (data/borehole.csv). Primary keys are indicated with a *, foreign keys with a °.

Column	Type / Units	Description
id*	integer	Unique identifier
source_id°	string	Identifier of the source of the earliest temperature measurements (and the source of all borehole metadata, unless otherwise stated in notes).
glacier_name	string	Glacier or ice cap name (as reported).
glims_id	string	Global Land Ice Measurements from Space (GLIMS) glacier identifier.
location_origin	string	Origin of location (latitude, longitude): - submitted: Provided in data submission - published: Reported as numbers in original publication - digitized: Digitized from published map with complete axes - estimated: Estimated from published plot by comparing to a map - guessed: Estimated with difficulty (e.g., by comparing elevation to a map)
latitude	degrees	Latitude in the EPSG 4326 spatial reference system.
longitude	degrees	Longitude in the EPSG 4326 spatial reference system.
elevation_origin	string	Origin of elevation; same categories as for location_origin.
elevation	meters	Elevation above sea level of the drilling site.
mass_balance_area	string	Mass balance area: Ablation area, near the equilibrium line, or accumulation area
label	string	Borehole name (e.g., as labeled on a plot).
date_min	YYYY-MM-DD	Begin date (or first possible date) of drilling (e.g., 2019: 2019-01-01).
date_max	YYYY-MM-DD	End date (or last possible date) of drilling (e.g., 2019: 2019-12-31).
drill_method	string	Drilling method: mechanical, thermal, or combined.
ice_depth	meters	Starting depth of ice. Infinity (INF) indicates that ice was not reached.
depth	meters	Total borehole depth (not including drilling in the underlying bed).
to_bed	boolean	Whether the borehole reached the glacier bed.
temperature_uncertainty	degrees Celcius	Estimated temperature uncertainty (as reported).
notes	string	Additional remarks about the study site, the borehole, or the measurements therein.
curator	string	Names of people who added the data to the database, as a pipe-delimited list.
investigators	string	Names of people and/or agencies who performed the work, as a pipe-delimited list.
funding	string	Funding sources as a pipe-delimited list.

Table 3. Columns of the profile table (data/profile.csv and data/**/profile.csv). The ** indicates subdirectories that hold separate profile.csv and measurement.csv files from boreholes with many profiles (e.g., from automated loggers). The subdirectories are labeled source.id-glacier, where glacier is a simplified version of the glacier name (e.g. flowers2022-little-kluane). (Composite) primary keys are indicated with a *, foreign keys with a °.

Column	Type / Units	Description
borehole_id*°	integer	Borehole identifier.
id*	integer	Borehole profile identifier (starting from 1 for each borehole).
source_id°	integer	Source identifier.
measurement_origin	string	Origin of measurements:
		- submitted: Provided as numbers in data submission
		- published: Numbers read from original publication
		- digitized-discrete: Digitized from discrete points of depth versus temperature
		- digitized-continuous: Digitized from a continuous line plot
date_min	YYYY-MM-DD	First possible date of measurement (e.g., 2019: 2019-01-01).
date_max	YYYY-MM-DD	Last possible date of measurement (e.g., 2019: 2019-12-31).
time	hh:mm:ss	Measurement time.
utc_offset	hours	Time offset relative to Coordinated Universal Time (UTC).
equilibrated	boolean	Whether temperatures have equilibrated following drilling.
notes	string	Additional remarks about the profile or the measurements therein.

Table 4. Columns of the measurement table (data/measurement.csv and data/**/measurement.csv). The ** indicates subdirectories that hold separate profile.csv and measurement.csv files from boreholes with many profiles (e.g., from automated loggers). The subdirectories are labeled source.id-glacier, where glacier is a simplified version of the glacier name (e.g. flowers2022-little-kluane). (Composite) primary keys are indicated with a *, foreign keys with a °.

Column	Type / Units	Description
borehole_id*°	integer	Borehole identifier.
profile_id*°	integer	Borehole profile identifier.
depth*	meters	Depth below the glacier surface.
temperature	degrees Celsius	Measured temperature.

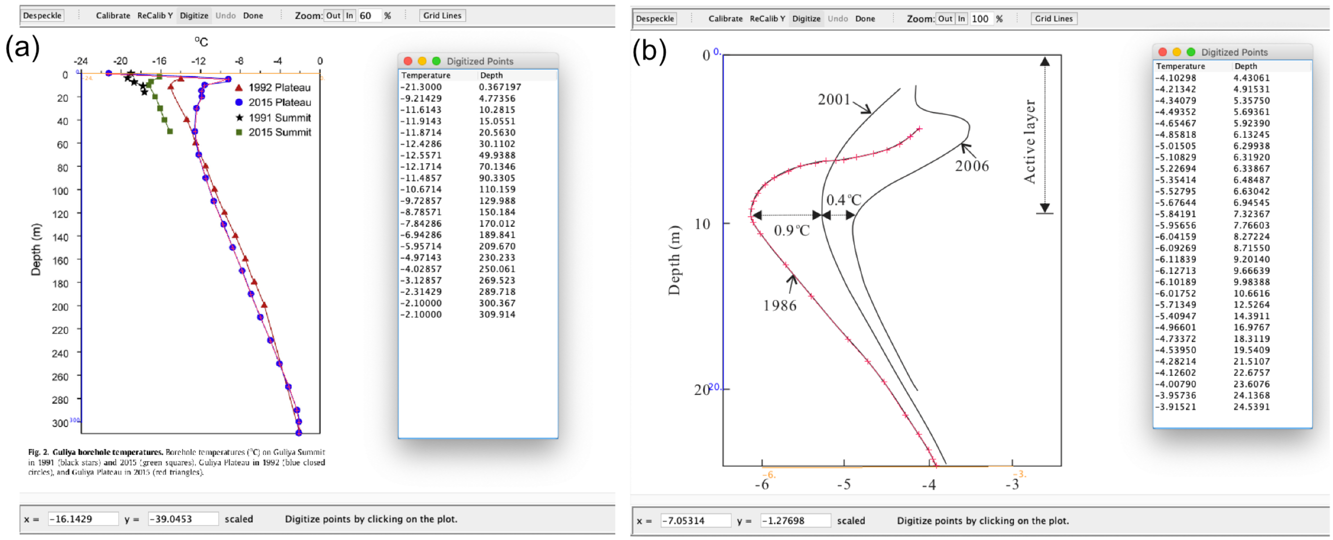

Figure 3. Screenshots of the digitization process with Plot Digitizer, where temperature versus depth is either plotted as (a) discrete points for each measurement or (b) a continuous line with unknown measurement locations. Data is from (a) 古里雅冰帽 (Guliya Ice Cap, GLIMS ID G081455E35226N) and (b) 天山1号冰川 (Urumqi Glacier No. 1, GLIMS ID G086810E43111N).

2.4 Errors from digitization and data reproduction

In addition to the uncertainty of the original measurements, errors are introduced when the measurements are reproduced in tables or figures (henceforth "reproduction error"), and again when these reproductions are digitized (henceforth "digitization error"). Such errors can multiply if the data is shared between researchers or digitized from older publications and reprinted in subsequent publications. In 80 cases, we acquired the same temperature profile from two different sources (a published figure replaced by a data submission, table, or better figure), allowing us to assess the magnitude of reproduction errors (inclusive of digitization errors). In order to quantify the digitization error in isolation, 177 temperature profiles were digitized by two different people. This exercise also allowed us to refine our method by identifying avoidable human errors and software quirks (e.g. wrong scaling of an axis, misplaced points). We calculated both these errors from profile pairs as the difference between their temperatures after interpolating (but never extrapolating) the temperatures of one to match the depths of the other.

3 Results and Discussion

As far as we know, glenglat is the largest collection of englacial temperature measurements. It contains 1 142 163 measurements of depth and temperature, organized into 147 583 profiles from 690 boreholes (Fig. 4). We included 17 873 profiles (for 79 boreholes) from nine data submissions. The remaining data were extracted from 175 primary

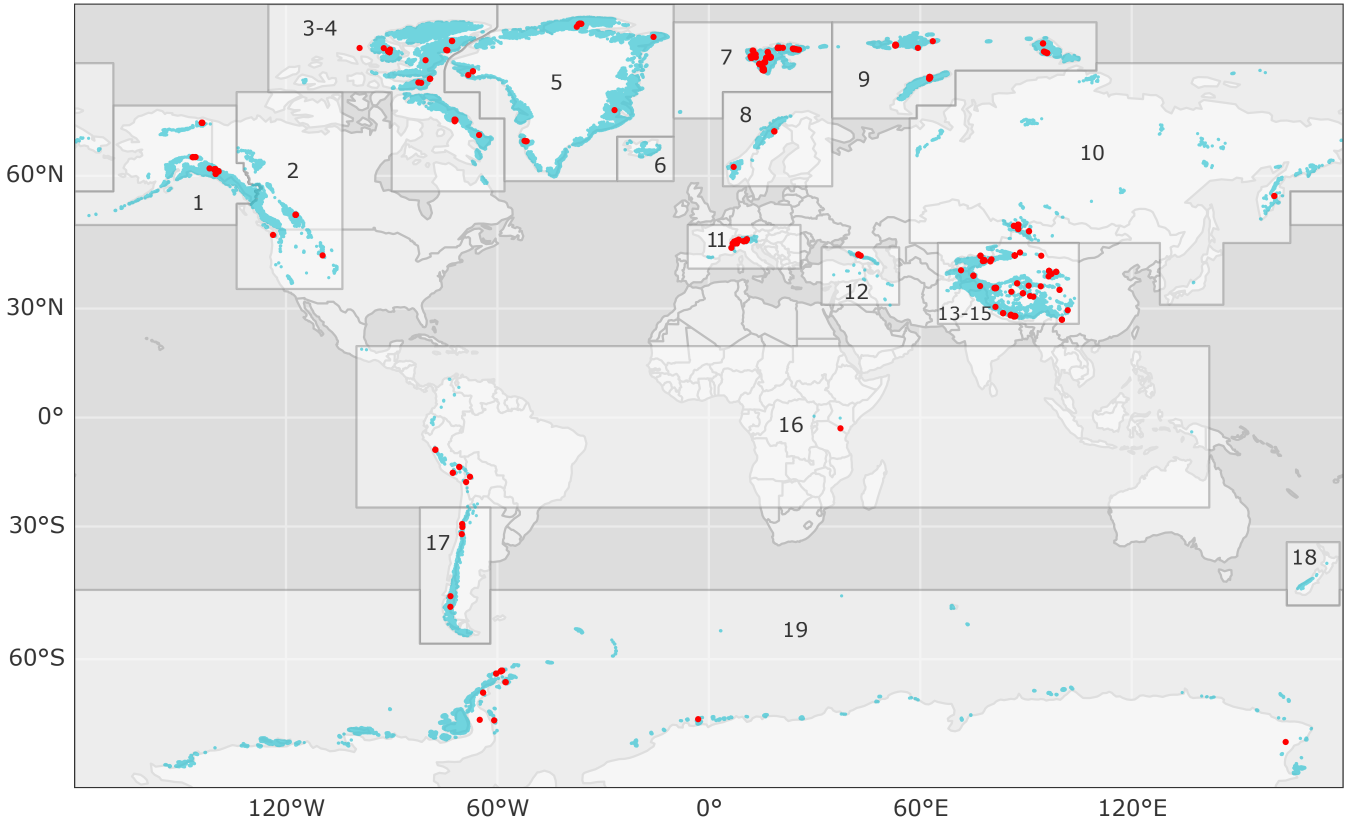

Figure 4. Spatial distribution of temperature measurements recorded in glenglat. Boreholes are plotted in red, glaciers in light blue (according to the Randolph Glacier Inventory 7.0; RGI Consortium, 2023) in light blue. The Global Terrestrial Network for Glaciers (GTN-G) Glacier Regions (GTN-G, 2017) are shown in grey and numbered; these correspond to the region numbers in Fig. 6.

sources (see Tab. A1), with an additional 66 secondary sources helping to further populate the metadata. Non-English sources make up 28 % (49) of all primary sources but 40 % (40) of those published before the year 2000.

3.1 Thermal regimes and borehole depths

A variety of thermal structures can be identified in the temperature profiles (Fig. 5). The borehole from the Devon Ice Cap (Nunavut, Canada; data from Paterson and Clarke, 1978) is an example of fully cold conditions. At depth, the temperature increases at a rate largely determined by the geothermal heat flux (heat conduction from the Earth's interior). In contrast to the fully cold conditions, profiles can be fully temperate, such as on Hansbreen (e.g., Svalbard; data from Jania et al., 1996) where the ice temperature decreases with depth in accordance with the lowering of the pressure melting point. Between these two endmembers, there is a lot of variety. At Grenzgletscher (Switzerland; data from Ryser et al., 2013; Hoelzle et al., 2011) and White Glacier (Axel Heiberg Island, Canada;

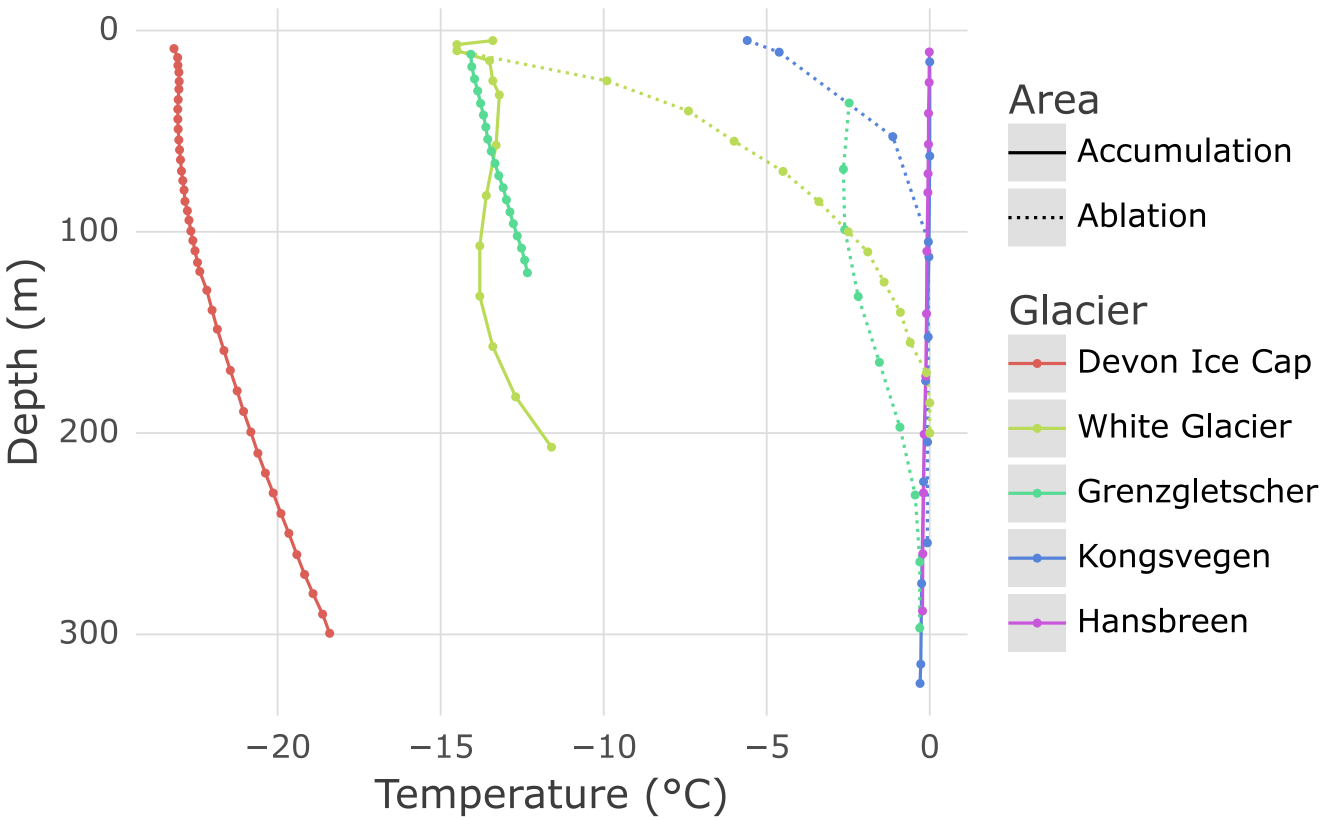

Figure 5. Measured profiles demonstrating the range of englacial temperatures and some typical profile shapes – from fully cold (Devon Ice Cap Paterson and Clarke, 1978) to fully temperate (Hansbreen Jania et al., 1996). Measurements from accumulation areas are plotted with solid lines, those from ablation areas with dotted lines.

data from Blatter, 1987), for example, the ice in the accumulation area is colder than the ice in the ablation area, indicating that the cold ice is warmed (e.g., by shear heating and latent heat release) as it advects down from the accumulation area. The opposite is true at Kongsvegen (Svalbard; data from Björnsson et al., 1996), where the latent heat release of refreezing meltwater and precipitation is large enough to eliminate the winter cold wave and create temperate firn and ice in the accumulation area. In the ablation area lower on the glacier, meltwater and precipitation can run off, allowing the near-surface ice to cool into a layer of cold ice superimposed on the temperate ice.

The temperatures measured in the boreholes range from temperate (i.e., at the pressure melting point) to $-33.5\,^{\circ}\mathrm{C}$ (the lowest temperature at 15 m depth is $-31.7\,^{\circ}\mathrm{C}$). The majority (75 %) of boreholes deeper than 15 m are in cold or polythermal ice (defined as those where the maximum measured temperature is colder than $-0.5\,^{\circ}\mathrm{C}$), with only

Region	Name	Glaciers	Boreholes (all)	Boreholes (>15m)
1	Alaska	11	59	27
2	Western Canada and USA	3	15	1
3–4	Arctic Canada	14	84	61
5	Greenland Periphery	9	16	4
7	Svalbard and Jan Mayen	30	80	46
8	Scandinavia	2	5	5
9	Russian Arctic	13	61	14
10	Asia, North	10	22	9
11	Central Europe	23	191	120
12	Caucasus and Middle East	4	9	8
13–15	Asia, South & Central	42	112	76
16	Low Latitudes	8	10	9
17	Southern Andes	5	5	4
19	Antarctic and Subantarctic	12	21	12

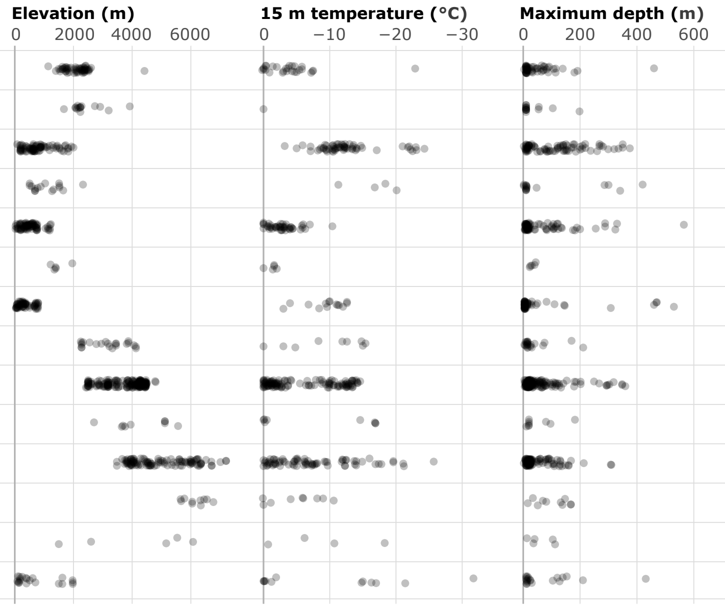

Figure 6. Overview of borehole counts (all and those deeper than 15 m) and surface elevation, 15 m temperature, and maximum measured depth for each borehole (each represented by a dot) by region (see Fig. 4).

about 7 % of all boreholes showing fully temperate conditions (i.e., the lowest measured temperature is warmer than −0.5 °C). This is not surprising. For one, temperate (or even partially temperate) ice is of little interest to ice-core investigations because it does not retain a memory of past climatic conditions (though research for dating temperate cores is ongoing, see e.g., Di Stefano et al., 2024). Secondly, temperate ice measurements are deemed less interesting, therefore, englacial temperature measurements are rarely carried out on glaciers that are assumed to be fully temperate, and if temperate conditions are measured, the results are rarely published. However, such measurements would be very valuable to train and calibrate models that predict glacier thermal regimes at regional to global scales. At present, it may be possible to train a model to accurately identify cold or polythermal glaciers, but it would be harder to constrain the boundaries – in terms of elevation, latitude, mean air temperature, etc. – between cold and temperate ice.

The median of the maximum-measured-depths in all boreholes in glenglat is 22 m (see Fig. 6). A total of 485 boreholes (70 %) were measured at depths greater than 15 m, and 148 (21 %) deeper than 100 m. Only 134 (19 %) are known to have reached the glacier bed, including the deepest, an 724 m ice core borehole drilled on Ледник Академии Наук (Akademii Nauk Ice Cap, Severnaya Zemlya, Russia; Kotlyakov et al., 2004).

Of 165 boreholes with a reported ice surface depth (an attribute that was added later and thus likely incomplete with respect to the available literature), 92 actually reached ice, whether at 0 m depth (for 68 boreholes) or below a maximum of 34 m of snow and firn on 慕士塔格冰川(Muztagh Glacier, Xinjiang, China 李真[Li Zhen] et al., 2004). Unfortunately, whether a borehole was drilled into snow, firn, ice, or a combination thereof is not always known.

For applications where this is relevant, the stratigraphy can often be estimated – if not explicitly reported – from the depth of the borehole and its location on the glacier (e.g., ablation or accumulation area). Further complicating borehole stratigraphy, repeat measurements in the same borehole typically define depth relative to the glacier surface at the time of the initial drilling or thermistor installation, despite accumulation and ablation that may occur in the interim. This can lead to spurious and above-zero temperature measurements if thermistors melt out over time. Only in very rare cases (e.g., in Harrison et al., 1975) are the changes of the surface elevation recorded in detail.

3.2 Climatic conditions

Compared to the average climatic conditions at the locations of all glaciers in the Randolph Glacier Inventory 7.0 (RGI Consortium, 2023), the locations selected for englacial temperature measurements are biased towards cold and dry conditions (Fig. 7a). Most boreholes are in locations where the total annual precipitation is less than $1\,\mathrm{m\,yr^{-1}}$ and the mean annual air temperature is below $-5\,°\mathrm{C}$. This focus on regions with a continental climate is again not surprising, because the high accumulation rates and warmer air temperatures of maritime climates are more likely to lead to temperate ice – which is considered less interesting – or high ice fluxes – which are not desirable for ice core measurements (e.g., Vance et al., 2016; Bohleber, 2019).

To explore the controls on englacial temperatures, we take the 15 m temperature – the depth at which seasonal temperature variations have mostly disappeared (see Fig.8) – as an indicator of the local glacier thermal regime. Comparing borehole temperatures measured since 1960 to the mean annual air temperature (MAAT) (ERA5-Land from Muñoz Sabater, 2019) of the ten years prior to the borehole measurement reveals that temperate ice can occur over a wide range of surface air temperatures (Fig. 7b). Englacial temperatures generally decrease with decreasing air temperature, but they are also consistently warmer than the temperatures at the surface. This is expected, given the numerous processes that can deliver heat into the glacier (latent heat release and geothermal, frictional, and strain heating). This warm bias is smallest at the coldest surface temperatures (presumably because there is little melt) – but can still be up to $+10\,°\mathrm{C}$ at $-20\,°\mathrm{C}$. It reaches a maximum of $+15\,°\mathrm{C}$ at $-15\,°\mathrm{C}$, before gradually decreasing towards warmer temperatures only because ice cannot be any warmer than the melting-point. Temperate ice does not seem to occur where the mean annual air temperature is below $\sim\!-15\,°\mathrm{C}$. It is unclear, however, whether the absence of temperate ice in colder climates is real or due to the undersampling of temperate glaciers.

The trends and boundaries in Fig. 7b need to be evaluated with respect to possible caveats of the chosen dataset, and are intended only to show broad patterns. ERA5-Land (and other reanalysis products) may not be able to represent the true variability of temperature fields or precipitation patterns in complex alpine terrain. The observed 'warm-bias' could therefore partly be due to biases within this dataset, and the 2-m air temperature is in reality not the true surface boundary condition. Beyond this, the chosen lapse-rate (in our case $-6.5\,°\mathrm{C\,km^{-1}}$) changes the relationship between air temperature and englacial temperature, though we found that it mostly affects the positions of the data points relative to the 1:1 line, while the overall shape remains stable. In reality, of course, englacial temperatures are controlled by much more than mean annual air temperature and precipitation, and the

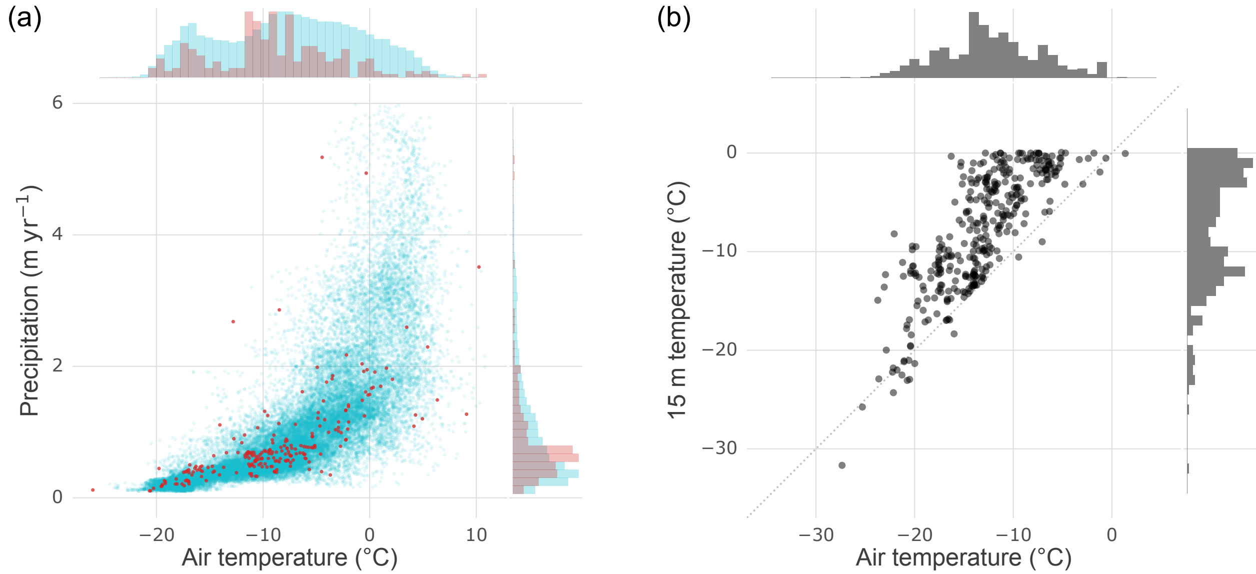

Figure 7. a) Distribution of 2000-2019 mean annual 2 m air temperature and total annual precipitation for the locations of glenglat boreholes (red) and locations of all RGI 7.0 glaciers (blue). b) Englacial temperatures (1960 to present) at 15 m depth versus mean annual air temperature at the borehole location for the ten years prior to the borehole measurement. Air temperatures were adjusted to the elevation of the borehole using a lapse-rate of $-6.5\,^{\circ}\mathrm{C\,km^{-1}}$. The climate data is from ERA5-Land (Muñoz Sabater, 2019).

consideration of 15 m temperatures further ignores that: i) temperate ice can exist at deeper locations within the ice even under very cold conditions (e.g., due to shear heating Blatter, 1987), ii) ice temperatures can be controlled by glacier dynamics more than by climate (e.g., emergence of cold ice in the ablation area of a glacier in a temperate climate Ryser et al., 2013), and iii) ice at depth has a memory of past surface temperatures, which can lead to complex patterns of englacial temperatures that are not reflected in the 15 m temperature. Despite these caveats, the large number of englacial temperature measurements available in glenglat makes it possible, for the first time ever, to investigate global patterns of englacial temperatures and hopefully find more robust ways of predicting the thermal regime of all glaciers in a region or worldwide.

3.3 Spatial, temporal, and elevation distributions

The 690 boreholes in glenglat are located on 186 individual glaciers (based on their GLIMS IDs) scattered across the world (see Figs. 4 and 6). This represents less than 1 ‰ of all glaciers worldwide, illustrating both how laborious englacial temperature measurements are (see Appendix A) and how interest in this glacier variable remains relatively limited. Two thirds of all boreholes (68 %) are in either Arctic Canada (84), Svalbard and Jan Mayen (80), Central Europe (191 – albeit with 79 on a single glacier: Grenzgletscher), and South and Central Asia (112). Conversely,

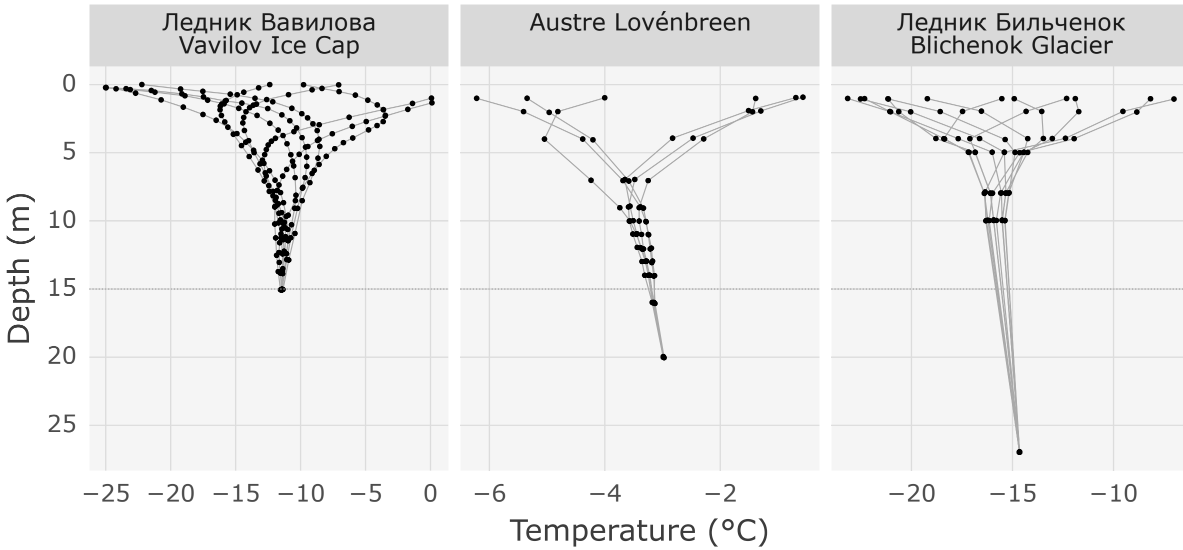

Figure 8. Examples of temperature profiles measured in the same borehole at different times of year, showing the elimination of seasonal surface temperature variations at a depth of around 15 m. Data from Vavilov Ice Cap (Н. И. Барков [N. I. Barkov] et al., 1988), Austre Lovénbreen (孙维君[Sun Weijun] et al., 2016), Blichenok Glacier (Shiraiwa et al., 2001).

there are only five boreholes in all of Scandinavia or the Southern Andes, and none in Iceland or New Zealand. If we envision using global or regional models to constrain thermal regimes spatially, by elevation, by temperature or precipitation regime, or based on glacier dynamics, we ideally need measurements that span the transition and range of conditions where glaciers exist. In this context it is important to understand what data is present in a possible training dataset. In the following, we therefore briefly discuss the temporal and spatial patterns of the data in glenglat.

The surface elevations of boreholes in glenglat range from 25 m asl (Erikbreen, Svalbard; Ødegård et al., 1992) to 7200 m asl (Dasoupu Glacier, China; Yao et al., 2002) (elevation above sea level assumed henceforth). Compared to the elevation distribution of glaciers worldwide (as represented by RGI 7.0), elevations above 2000 m are oversampled while elevations between 750 m and 1500 m are undersampled (Fig. 9). This sampling bias may have several causes. Topographic saddles and summits of very high elevation glaciers ($>$ 4500 m) are of particular interest to ice core science because ice flow, accumulation, and melt are minimal and a maximum number of annual ice layers can be preserved. The middle elevations (2000 m to 4500 m) are likely oversampled because they circumvent many of the challenges of work at very high elevations, allowing for simpler (helicopter) logistics and reasonable working conditions. Additionally, this is the elevation range of glaciers in Central Europe (region 11, see Figs. 4 and 6), which are historically overstudied compared to other regions. Below 2000 m, most of the data comes from Svalbard and Jan Mayen (region 7) and Arctic Canada (regions 3-4). Though there are many measurements from these regions, lower

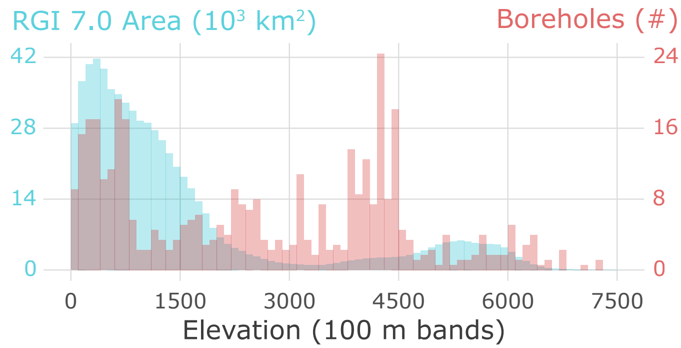

Figure 9. Elevation distribution of glenglat boreholes (red) compared to the elevation distribution of all RGI 7.0 glaciers (blue). Higher elevations, especially between 2000 m and 4500 m, are oversampled while low elevations are undersampled.

elevations remain undersampled, likely because i) there is a very large glacierized area in this elevation band, ii) there is lack of interest in measurements from temperate ice (e.g., the large low-lying glaciers along the west coast of Alaska), iii) the tongues of tidewater glaciers – which make up a large portion of this band – are notoriously difficult to access, and iv) when accessing land-terminating glaciers in these remote regions, working on their low-elevation tongues is easier than accessing the higher accumulation areas (750 m to 1500 m).

The earliest measurement in glenglat stems from 1842, when Louis Aggasiz and colleagues drilled a 60 m borehole in temperate ice on Unteraargletscher (Agassiz, 1847) in Switzerland (see Fig. 10). With the exception of other early outliers (1911, Vallot (1913): 1938, Hughes and Seligman (1939); 1948, Sharp (1951)), wide-spread measurement does not begin until the late 1950s – to a large part motivated by the 1957/1958 International Geophysical Year – by when drilling technology and motorized transport were developed enough to allow increasingly ambitious expeditions to remote areas. Mid-century measurements likely remain underrepresented in glenglat because of early and obscure publications that were never indexed or published online. After sustained activity since the 1970s, measurements decline beginning in 2015, which may be the result of a lag between data collection and publishing, reduced interest and funding for complex field campaigns, a shift of focus from glaciers to ice sheets, or increased emphasis on modeling and remote sensing.

In only 156 boreholes (20 %) were temperatures measured more than once. The most frequently measured borehole is on Hintergrat Glacier (Italy; Carturan et al., 2023a), with five years of hourly measurements (2011-2016). The longest monitored borehole is CG05-1 on Grenzgletscher (Switzerland; Hoelzle, 2014; Darms, 2009; Hoelzle, 2017), drilled in 2005 and measured 4 times over 8 years (2007-2015). The lifetime of a single borehole is limited by creep closure, internal deformation, and other forces that inevitably lead to equipment failure, so to achieve longer records, a new borehole is drilled and instrumented nearby. A cursory review of boreholes within ∼100 m reveals only a few locations with multi-borehole records spanning more than 20 years, all of which are the result of deliberate repeat studies (Vincent et al., 2020; Hoelzle et al., 2011; Thompson et al., 2018; В. Н. Михаленко [V. N. Mikhalenko]

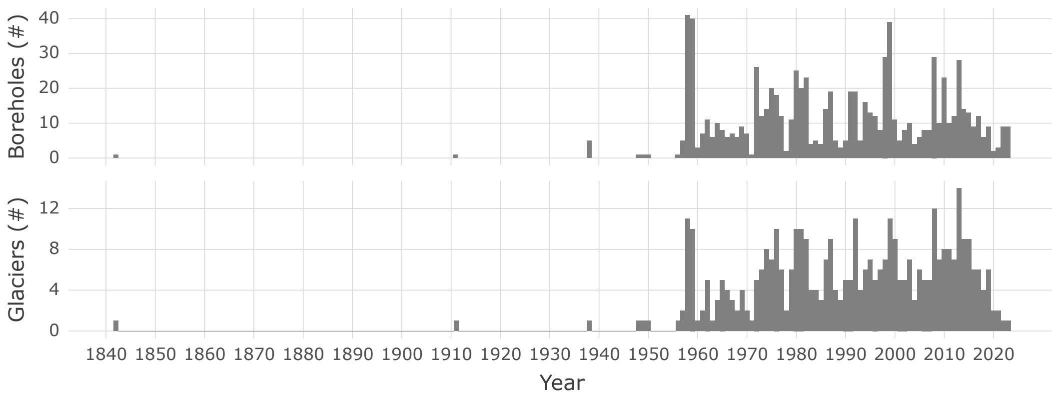

Figure 10. Number of measured boreholes (top) and number of measured glaciers (bottom) for each year. We assume that early measurements are still underrepresented, because some publications were not archived. The drop-off towards more recent years may be due to the lag between drilling and publication.

et al., 2005b; Rabus and Echelmeyer, 2002), although clusters of more distant boreholes suggest opportunities for retroactive comparisons. The wide range of measurement dates in glenglat could present a challenge for training or calibrating numerical models, as it requires longer model runs and inputs (e.g., climate reanalysis) from earlier periods with less and lower-quality data.

Conversely, the low percentage of boreholes that have been measured more than once indicate that there is a large potential for repeat measurements that would yield insight into how englacial temperatures have changed. An identification procedure for high-value sites for repeat measurements could focus on sites with deep boreholes (e.g., more than 30 m), predominantly cold englacial temperatures, high measurement accuracies (low reported uncertainties), and a last measurement dating back around twenty years or more. Ignoring surge-type glaciers, a search of glenglat reveals high-value repeat-measurement sites in many different regions and climates. Some examples that fall into this category include Illimani Volcano (Bolivia, 138 m, measured in 1999), Vavilov Glacier (Russian Arctic, up to 460 m, last measured in 1985), or Åsgårdfonna (Svalbard, 185 m, measured in 1993).

3.4 Error analysis

In our analysis, we distinguish between three sources of uncertainty in the reported englacial temperatures: the reported uncertainty of the original measurements, errors introduced by their subsequent textual or graphical reproduction, and errors associated with the digitization of graphical reproductions.

The measurement uncertainty encompasses a wide range of instrumental, methodological, and environmental factors. The design and calibration of a thermistor determines the precision and accuracy with which it measures temperature. Whether the measured temperature differs from the temperature of the glacier is primarily determined by the extent to which the borehole reached thermal equilibrium following drilling and sensor installation, or the method by which an equilibrium temperature is extrapolated from a sensor cooling curve. Secondary sources of thermal disturbance include "wind pumping" (air circulation within firn or snow caused by surface pressure changes; Clarke et al., 1987), sensor electronics (Ryser et al., 2013), and artificial thermal coupling with the surface (e.g. the black tubing used in Davis, 1967). Finally, the uncertainty in the measurement depth translates to an uncertainty in the temperature at that depth, especially in areas with steep temperature gradients (e.g., near the surface).

Temperature measurement uncertainty is reported for 65 % of the boreholes included in glenglat (0.01 °C to 1.0 °C; see Fig. 11). It is rarely specified which sources of error the value represents, but sensor design and calibration are often the only factors discussed. Other glenglat attributes like drilling method, drilling and measurement dates, whether and how equilibrium was reported to have been reached, and repeat measurements from the same borehole are thus helpful for independently assessing measurement uncertainty. Contrary to the suggestion of Løkkegaard et al. (2023) that sensor accuracy has improved substantially since 1950, we found no significant change in reported temperature uncertainties over time. This could reflect increased caution in error reporting, an acknowledgment that sensor accuracy is only one component of the total uncertainty, or indeed that the accuracy of the typical englacial temperature measurement has not improved significantly.

Depth measurement uncertainty is so rarely reported that no provision was made to track it in glenglat. In many cases, it is also not specified from which reference surface depth was measured or whether this reference changed over time (e.g., upper glacier surface at the time of installation, snow-ice boundary at the time of measurement). As the glacier surface changes, so does the depth of the sensors relative to this surface, and this can complicate the comparability of measurements through time.

Fig. 11 presents the reported measurement uncertainties alongside errors introduced by data reproduction and digitization. For the sake of comparison, we describe each distribution by the 0.5 (median), 0.68, and 0.95 quantiles (of the absolute values). For measurement uncertainties, these are 0.1 °C, 0.2 °C, and 0.3 °C. Reproduction errors were calculated as the difference between temperatures for the same profile retrieved from a figure versus either a table or another figure (and thus include digitization error). They are typically smaller than measurement uncertainties (0.08 °C, 0.14 °C, 0.57 °C), especially at depths greater than 15 m (0.05 °C, 0.11 °C, 0.33 °C). The largest of these are due to different measurements being included (the impact of which is greatest near the surface, where temperature gradients are the steepest), actual differences in the reported temperatures, or poor figure quality (e.g. non-square axes from hand drawing or bad scanning, high °C/pixel scale). Random digitization errors (isolated from reproduction errors) were calculated as the difference between temperatures for the same profile and figure digitized by two different people. They are smaller (0.03 °C, 0.05 °C, 0.23 °C) and sensitive to the interaction between figure scale and temperature gradient. The °C/pixel size of the figures' digitized temperature axes – an imperfect proxy for their effective resolution – range from 0.002 °C to 0.109 °C (median 0.016 °C) and are weakly correlated with the digitization errors ($R^2 = 0.058$, slope = 1.29). However, the m/pixel size of the depth axis – once converted to °C based on the local slope of the profile – range from 0.000 °C to 1.007 °C (median 0.007 °C) and explain the observations much better ($R^2 = 0.483$, slope = 1.26).

Figure 11. Distribution of the reported measurement uncertainties alongside distributions of the absolute values of the reproduction errors (comparing the same measurement from different sources) and digitization errors (comparing the digitization of the same measurement by two different people). The y-axis uses square-root scaling to accentuate differences near 0 °C. For each distribution, horizontal lines are drawn at the 0.05, 0.5 (median), and 0.95 quantiles.

A full assessment of uncertainty would require a careful evaluation of each profile (e.g. Løkkegaard et al., 2023), including a review of the original sources, since these often contain more details than could be integrated into glenglat. However, we can provide some general guidance to users: Favor data with low reported measurement uncertainties sourced from textual reproductions (measurement_origin "submitted" or "published"), inspect the source of digitized data (measurement_origin "digitized-discrete" or "digitized-continuous"), favor profiles known to have reached thermal equilibrium (equilibrated), and avoid interpolation at depths with steep temperature gradients.

Reducing and quantifying uncertainties will be crucial for detecting and correctly interpreting the long-term thermal evolution of glaciers and ice sheets, so we urge future campaigns to carefully assess uncertainties and thoroughly and precisely describe their measurements. To eliminate reproduction and digitization errors in the future, new and existing measurements should be published somewhere as text, for example by submitting them directly to glenglat (see Sec. 3.5).

3.5 Future additions

We hope that glenglat can serve not only as a valuable resource for glaciological research today but also as a long-lived data repository for additional past and future englacial temperature measurements. The dataset is currently hosted at https://github.com/mjacqu/glenglat. To encourage and facilitate submissions, we have included detailed instructions, a Microsoft Excel spreadsheet template, and a tutorial showing how to self-validate the data prior to submission using the Frictionless Python package. We have done our best to populate all fields of the database, but certain columns were added at a later stage of the database creation process, and we were not able to revisit every source every time. Therefore, not all columns are equally well populated. Additions to or refinements of existing entries are welcome any time, either by emailing the authors or by creating an issue at https://github.com/mjacqu/glenglat/issues. Community members are also welcome to take on existing issues and contribute to the improvement of the dataset in this way. Anyone who submits data to glenglat will be invited to become a co-author on future releases of the dataset (see detailed authorship policy at https://github.com/mjacqu/glenglat/tree/main?tab=readme-ov-file#authorship-policy).

4 Conclusions & Outlook

Based on an extensive literature search and data submissions, we have created glenglat, the first (to our knowledge) englacial temperature database for all glaciers outside of the ice sheets. Together with the recent compilations of deep boreholes in Greenland by Løkkegaard et al. (2023) and of shallow measurements for Greenland and Antarctica compiled in the SUMup collaborative database (Vandecrux et al., 2023), most published englacial temperature measurements are now readily available to researchers. Depending on community needs, it may be worth combining these datasets into one, for lower maintenance overhead, ease of use, and because the distinction between ice sheet and glacier will become increasingly arbitrary as glaciers detach from the retreating ice sheet margins. Subsurface variables like density (as in SUMup) or stratigraphy (as in glenglat, but only for the depth of the snow/firn-ice transition) may be worth adding, especially since these are often measured alongside temperature. Another enhancement would be to include qualitative temperature information, namely whether a borehole was measured as temperate (but no actual measurements were reported) and the presence and depth of a cold-temperate transition surface (often extracted from ice-penetrating radar profiles as an indicator of the glacier thermal regime; (e.g., Björnsson et al., 1996; Ødegård et al., 1992, 1997; Pettersson et al., 2003; Wilson et al., 2013)).

We believe that glenglat can contribute to better modelling and understanding of englacial temperatures, their spatial distribution, and their changes in a warming world – most directly as an unparalleled source of observational data for model training and validation. For measurements to better reflect global glacier conditions, however, we see a general need for more measurements (or reporting thereof) from temperate glaciers, warmer climates, elevations between 750 m and 1500 m, and underrepresented regions (e.g., Iceland, New Zealand, Scandinavia). Glenglat also presents new opportunities to investigate changes in englacial temperatures over time, both by making more evident the existence of repeat measurements and documenting a century of early measurements that could now be deliberately repeated.

5 Code and data availability

Glenglat is maintained as a Git repository hosted at https://github.com/mjacqu/glenglat and published to Zenodo (e.g., version 1.0.0-rc4, to which this manuscript refers: https://doi.org/10.5281/zenodo.14696283, Jacquemart et al., 2025). Glenglat is licensed under Creative Commons Attribution 4.0 International, though the repository's license does not extend to figures, tables, maps, or text extracted from publications. These are included in the sources folder for transparency and reproducibility. Full PDFs of the original sources will gladly be shared upon request at any time.

Dataset citation: Jacquemart, M., Welty, E. et al., (2025). glenglat: Global englacial temperature database. Zenodo. https://doi.org/10.5281/zenodo.11516611. To cite a subset of the data, we recommend referencing this publication, the dataset, as well as the original source directly or as prefix to the glenglat citation (e.g. "Flowers et al. (2011), in: ...").

The GitHub repository contains all of the Python code for the tests, build process, and Zenodo publishing described above. It also contains a Jupyter notebook with tutorials on how to download the data from Zenodo, read the data into Python, and produce statistics and plots similar to those in this paper. It can be run in Google Colab (https://colab.research.google.com).

ERA-5 Land climate reanalysis data (Muñoz Sabater, 2019) was downloaded from the Copernicus Climate Change Service.

Author contributions. MJ conceived the project, and together with EW, designed, implemented, and populated the database. EW managed the testing and publishing pipelines, and MJ and EW wrote the manuscript. MG curated the Colle Gnifetti dataset, including a (re-)evaluation of all associated uncertainties. GC re-digitized a large subset of figures from which data were sourced, providing the basis for the digitization error-assessment. All authors have read, edited, and approved the manuscript.

Competing interests. The authors declare that they have no conflict of interest.

Acknowledgements. We thank the countless people who contributed to the planning, execution, and processing of the englacial measurements included in glenglat. As an (imperfect) proxy of who they are, we list the names of all authors who were involved in the publications from which we drew data in Appendix B. We are grateful to Gwenn Flowers, Shin Sugiyama, Tika Ram Gurung, Rainer Prinz, Martina Barandun, Olivier Gagliardini, Lonnie G. Thompson, and 张通 (Tong Zhang) for submitting data to us. Lander Van Tricht shared the results of his own literature search with us. Thank you to Daniel Farinotti and Matthias Huss for offering valuable suggestions and discussions along the way. We are particularly indebted to the librarians around the world who tracked down obscure references, including Lkhagvadulam Esterhammer and Monika Kriemler at the University of Zürich, staff at the Royal Danish Library in Copenhagen, and Tatiana A. Ustinova at the Russian State Library in Moscow. Finally, we thank William Colgan, Martin Hoelzle, and Baptiste Vandecrux (editor) for their constructive feedback.

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Appendix A: References by glacier and region

Table A1: Summary of englacial temperature measurements contained in glenglat, sorted by glacier region, then by glacier (as defined by groups of boreholes with matching glacier name or GLIMS ID), with borehole count, profile count, maximum depth, minimum temperature (at all depths and at 15 m depth, if available), range of years, and sources.

Region	Glacier names	GLIMS IDs	BH count	Profile count	Depth [m] max	Temp. [°C] min	Temp. [°C] 15 m	Year min–max	Sources
1	Black Rapids Glacier	G213683E63392N	3	6	12	-14.0		1973–1973	Harrison et al. (1975)
1	Fox Glacier	G219698E61200N	6	6	48	-8.1	-7.6	1969–1969	Classen (1970)
1	Jarvis Glacier	G214333E63481N	2	2 995	72	-8.2		2017–2018	Lee (2019); Lee et al. (2020)
1	Little Kluane Glacier	G220578E60873N	1	17 873	191	-0.3		2019–2021	Flowers (2022)
1	McCall Glacier	G216152E69302N	27	56	180	-12.4	-4.8	1957–2008	Orvig and Mason (1963); Trabant et al. (1975); Rabus and Echelmeyer (2002); Weller et al. (2007); Delcourt et al. (2013)
1	North Glacier	G220859E60905N	1	1	70	-3.0	-3.0	2011–2011	Wilson (2012); Wilson et al. (2013); Flowers (2022)
1	Russell Glacier	G218192E61498N	1	1	460	-23.1	-22.9	2002–2002	Thompson et al. (2004); Urmann (2009)
1	Seward Glacier	G219787E60289N	3	10	62	-13.0		1948–1950	Sharp (1951)
1	South Glacier	G220869E60822N	1	14 914	82	-2.4		2011–2014	Flowers et al. (2011); Wilson et al. (2013); Flowers (2022)
1	Steele Glacier	G219819E61242N	3	3	114	-6.7	-4.9	1972–1974	Jarvis and Clarke (1974); Clarke and Jarvis (1976)
1	Trapridge Glacier	G219646E61222N	11	11	88	-8.4	-7.3	1972–1980	Jarvis and Clarke (1975); Clarke et al. (1984)
2	Athabasca Glacier	G242719E52168N	13	16	198	-5.8		1967–1986	Paterson (1971, 1972)
2	Blue Glacier	G236316E47813N	1	2	104	-0.2	-0.0	1969–1969	Harrison (1972)
2	Upper Fremont Glacier	G250390E43132N	1	1	10	0.0		1990–1990	Naftz and Smith (1993)
3	Agassiz Ice Cap	G288743E80950N	3	3	335	-24.6	-24.3	1977–1984	Clarke et al. (1987); Vinther et al. (2008)
3	Devon Ice Cap	G278488E75058N G277553E75571N	3	3	299	-23.2	-23.1	1972–2000	Paterson and Clarke (1978); Kinnard et al. (2006); Mankoff et al. (2022); Mankoff (2022e); Løkkegaard et al. (2023)
3	John Evans Glacier	G285646E79663N	4	4	15	-12.2	-12.2	1997–1999	Copland et al. (2003)
3	Laika Ice Cap	G280856E75887N	5	5	87	-11.2	-10.4	1975–1975	Blatter (1985); Blatter and Kappenberger (1988)
3	McGill Ice Cap	G266878E79842N G269900E79733N	2	2	38	-22.6	-22.0	1962–1962	Harrison (1963); Müller (1963a, b, 1976)
3	Meighen Ice Cap	G260810E79982N	1	3	121	-23.1	-17.1	1965–1967	Koerner (1968); Paterson (1968)
3	Prince of Wales Ice Cap	G279351E78361N	1	1	176	-21.3	-21.0	2005–2005	Mankoff et al. (2022); Mankoff (2022b); Løkkegaard et al. (2023)
3	White Glacier	G269329E79672N	48	90	375	-20.4	-14.9	1959–1981	Müller (1961); Harrison (1963); Müller (1963a, 1976); Blatter (1985, 1987)
4	Barnes Ice Cap	G287731E69650N G287718E69797N G288059E69709N	16	16	281	-11.1	-10.9	1973–1977	Hooke (1976); Classen (1977); Hooke et al. (1980); Gilbert et al. (2016)
4	Penny Ice Cap	G294456E67304N	1	1	176	-12.8	-12.2	1996–1996	Mankoff et al. (2022); Mankoff (2022c); Løkkegaard et al. (2023)
5	Flade Isblink Ice Cap	G344790E81287N	1	1	420	-17.4		2006–2006	Lemark (2010); Mankoff et al. (2022); Mankoff (2022d); Løkkegaard et al. (2023)
5	Hans Tausen Ice Cap	G323085E82488N	1	1	341	-20.8	-20.0	1995–1995	Hammer (1995); Reeh (1995); Steffensen et al. (2001)
5	Hare Glacier	G323403E82808N G322065E82674N	6	6	286	-21.0	-16.9	1994–1995	Thomsen et al. (1996); Reeh et al. (2001)
5	Hurlbut Gletscher	G292196E77316N	2	8	15	-18.2		1957–1957	ark (1959, 1960); Fristrup (1960a, b, 1961)
5	Mitdluagkat Gletscher	G322197E65696N	1	1	15	-1.0		1958–1958	Fristrup (1960a, 1961); Hasholt (1987)
5	Napassorssuaq Gletscher	G314725E60307N	1	1	7	-0.7		1957–1957	ark (1959, 1960); Fristrup (1960a, 1961); Weidick (1988)
5	Nunatarssuaq Ice Cap	G292408E76864N	2	343	2	-8.6		2017–2017	Abermann et al. (2020); Prinz et al. (2022)
5	Qaanaaq Glacier	G290838E77522N	3	3	13	-11.9		2014–2014	Tsutaki et al. (2017)
5	Renland Ice Cap	G333444E71216N	1	1	300	-18.7	-18.4	1988–1988	Mankoff et al. (2022); Mankoff (2022a); Løkkegaard et al. (2023)
5	Sermikavsak	G307173E71231N	1	1	7	-3.2		1957–1957	Møller (1959); Fristrup (1960a, 1961)
5	Sukkertoppen Ice Cap	G307609E66296N G308051E66298N	4	4	12	-4.6		1964–1964	Rundle (1965)
5	Tuto Ramp	G291955E76463N	1	12	47	-22.1	-11.5	1961–1962	Davis (1967)

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Table A1: Summary of englacial temperatures contained in glenglat, and their sources (continued).

Region	Glacier names	GLIMS IDs	BH count	Profile count	Depth [m] max	Temp. [°C] min	Temp. [°C] 15 m	Year min–max	Sources
7	Amundsenisen Ледниковогоплато Амундсена	G015444E77229N	1	3	13	-9.5		1980–1980	В. С. Загороднов [V. S. Zagorodnov] (1981)
7	Austfonna	G024340E79634N G025297E79771N G023619E79932N G024143E79973N	14	15	565	-16.4	-4.5	1987–1999	В. С. Загороднов [V. S. Zagorodnov] et al. (1990); Watts et al. (1997); Watanabe et al. (2001)
7	Austre Brøggerbreen	G011895E78886N	2	2	108	-4.2	-4.2	1990–1992	Hagen (1992); Björnsson et al. (1996)
7	Austre Grønfjordbreen	G014342E77910N	12	30	83	-8.5	-2.2	1966–2014	Е. М. Зингер [E. M. Singer] and В. И. Михалёв [V. I. Mikhalev] (1967); В. С. Загороднов [V. S. Zagorodnov] and И. А. Зотиков [I. A. Zotikov] (1981); Ю. Я. Мачерет [Y. Y. Macheret] et al. (1985); Kotlyakov et al. (2004); Р. А. Чернов [R. A. Chernov] et al. (2015)
7	Austre Lovénbreen	G012161E78870N	3	17	20	-6.2	-3.2	2009–2011	孙维君[Sun Weijun] et al. (2016)
7	Bertilbreen Ледник Бертиль	G016264E78699N	3	3	108	-11.5	-5.6	1980–1980	В. С. Загороднов [V. S. Zagorodnov] (1981)
7	Bogerbreen Ледник Багер	G015633E78130N	1	1	7	-7.3		1980–1980	В. С. Загороднов [V. S. Zagorodnov] (1981)
7	Erikbreen	G012478E79621N	5	10	20	-8.7	-3.5	1990–1992	Ødegård et al. (1992)
7	Finsterwalderbreen	G015235E77463N	2	2	189	-4.5	-3.1	1994–1995	Ødegård et al. (1997)
7	Fridtjofbreen	G014442E77835N	1	1	115	-5.2	-3.9	1981–1981	Ю. Я. Мачерет [Y. Y. Macheret] et al. (1985)
7	Hansbreen	G015592E77097N	6	6	330	-9.1	-3.5	1979–1995	Jania et al. (1996)
7	Høghetta	G016639E79309N	1	1	86	-13.3	-10.4	1987–1987	Kawamura et al. (1991)
7	Irenebreen	G012138E78665N	1	12	10	-5.8		2008–2009	Sobota (2011)
7	Kongsvegen	G013044E78792N	2	2	324	-5.6	-4.3	1990–1992	Hagen (1992); Björnsson et al. (1996)
7	Lomonosovfonna Ледниковое Плато Ломоносова	G018042E78675N G018391E78924N G017025E78797N	4	15	122	-11.4	-2.4	1965–2013	Е. М. Зингер [E. M. Singer] et al. (1966); В. С. Загороднов [V. S. Zagorodnov] and И. А. Зотиков [I. A. Zotikov] (1981); van de Wal et al. (2002); Kotlyakov et al. (2004); Marchenko et al. (2017)
7	Midre Lovénbreen	G012039E78878N	2	2	133	-3.6	-3.3	1990–1992	Hagen (1992); Björnsson et al. (1996)
7	Nordenskiöldbreen Ледник Норденлельдв	G017371E78745N	2	2	26	-7.1	-4.4	1965–1965	Е. М. Зингер [E. M. Singer] et al. (1966)
7	Scott Turnerbreen	G015894E78097N	2	2	54	-11.1	-7.2	1993–1993	Hodgkins et al. (1999)
7	Snøfjellafonna	G013542E78988N	1	1	80	-3.4	-1.8	1992–1992	Kameda et al. (1993)
7	Vestfonna	G019951E79875N G020879E79901N G019797E80009N	6	11	200	-23.6	-2.7	1956–1995	Palosuo and Schytt (1960); Schytt (1964); В. М. Котляков [V. M. Kotlyakov] (1985); Palosuo (1987); Watanabe et al. (2001); Kotlyakov et al. (2004)
7	Waldemarbreen	G012079E78681N	3	23	10	-7.6		2007–2019	Sobota (2009); Karušs et al. (2022)
7	Werenskioldbreen	G015442E77070N	4	4	15	-4.2	0.0	1970–1970	Baranowski (1975)
7	Åsgårdfonna	G017048E79443N	2	2	182	-7.9	-6.1	1993–1993	Uchida et al. (1996)
8	Nigardsbreen	G007099E61715N	1	1	44	-0.8	-0.1	1987–1987	Kawamura et al. (1989)
8	Storglaciären	G018569E67903N	4	15	40	-9.0	-2.0	1965–2002	Schytt (1966, 1968); Pettersson et al. (2003)
9	Academy of Sciences Glacier Akademii Nauk Ice Dome Ледник Академии Наук	G096063E80433N	3	3	743	-14.7		1986–2001	А. М. Саватюгин [A. M. Savatyugin] and В. С. Загороднов [V. S. Zagorodnov] (1988); В. С. Загороднов [V. S. Zagorodnov] (1989); Zagorodnov and Arkhipov (1990); Л. М. Саватюгин [L. M. Savatyugin] et al. (2001); Fritzsche et al. (2002); Kotlyakov et al. (2004)
9	Churlyanis Cupola Sedov Glacier Купол Чурляниса ледник Седова	G053403E80271N G053047E80333N G053032E80282N G052977E80310N	31	134	82	-27.5		1958–1959	Н. Г. Разумейко [N. G. Razumeiko] (1960, 1963)
9	Jackson Cupola Купол Джексона	G053200E80194N	1	13	20	-22.3		1959–1959	Н. Г. Разумейко [N. G. Razumeiko] (1963)
9	Salm Island Glacier ледник Остров Сальм	G059273E79977N	1	1	14	-18.0		2005–2005	Kubyshkin et al. (2006)
9	Shokalsky Glacier Ледник Шокальского	G062464E75974N G062675E76121N	16	38	30	-29.0		1958–1959	И. Ф. Хмелевской [I. F. Khmelevskoy] (1963, 1964)

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Table A1: Summary of englacial temperatures contained in glenglat, and their sources (continued).

Region	Glacier names	GLIMS IDs	BH count	Profile count	Depth [m] max	Temp. [°C] min	Temp. [°C] 15 m	Year min–max	Sources
9	Vavilov Glacier Vavilov Ice Cap Купол Вавилова Ледник Вавилова	G095294E79482N G096481E79287N G095612E79448N	8	21	470	-25.0	-12.6	1974–1985	В. Р. Барбаш [V. R. Barbash] et al. (1981); В. А. Морев [V. A. Morev] and В. А. Пухов [V. A. Pukhov] (1981); Н. И. Барков [N. I. Barkov] et al. (1988); В. А. Морев [V. A. Morev] et al. (1988); Kotlyakov et al. (2004)
9	Vetreniy Ice Dome	G063846E80729N	1	1	308	-11.4	-6.8	1997–1997	Kotlyakov et al. (2004)
10	Belukha Glacier	G086577E49799N	1	1	75	-17.2		2001–2001	Olivier et al. (2003)
10	Blichenok Glacier	G160474E56097N	2	14	211	-23.2	-15.5	1996–1999	Shiraiwa et al. (1997, 2001)
10	Halasi Glacier 哈拉斯冰川	G087783E49100N	3	6	8	-4.0		1980–1980	王立伦[Wang Lilun] et al. (1983); 刘时银[Liu Shiyin] et al. (2012); Guo et al. (2015)
10	Khukh Nuru Uul glacier	G090853E48651N	1	1	70	-13.8	-12.6	2009–2009	Herren et al. (2013)
10	Maliy Aktru Glacier ледник Малый Актру	G087761E50048N G087720E50060N	10	15	30	-11.4	-8.4	1980–1982	С. А. Никитин [S. A. Nikitin] (1986)
10	Sofiyskiy Glacier	G087759E49791N	2	2	25	-0.3	-0.0	2000–2001	Fujii et al. (2002)
10	Tsambagarav Glacier	G090847E48595N	1	1	40	-13.4	-12.0	2008–2008	Liu et al. (2009); Davaa (2016); Khalzan et al. (2022)
10	Vodopadniy Glacier ледник Водопадный	G087789E50050N	1	2	12	-15.7		1981–1982	С. А. Никитин [S. A. Nikitin] (1986)
10	Western Belukha Plateau	G086544E49802N	1	1	170	-15.7	-14.8	2003–2003	Takeuchi et al. (2004)
11	Altelsgletscher	G007671E46431N	3	22	21	-6.4	-0.4	1991–1991	Laternser (1992)
11	Breithornplateau Gornergletscher Grenzgletscher	G007908E45948N G007800E45965N G007875E45922N	82	115	359	-17.0	-14.6	1975–2021	Haeberli (1976); Oeschger et al. (1977); Gäggeler et al. (1983); Blatter and Haeberli (1984); Haeberli and Funk (1991); Laternser (1992); Lüthi (1999); Keck (2001); Lüthi and Funk (2001); Suter et al. (2001, 2002); Schwerzmann et al. (2006b); Darms (2009); Eisen et al. (2009); Hoelzle (2009); Hoelzle et al. (2011); Diez et al. (2013); Ryser et al. (2013); Hoelzle (2014); Mayewski (2014); Hoelzle (2017); Bohleber et al. (2018); Hoelzle et al. (2020); Mattea (2020); swi (2021); Hoelzle (2022); Gastaldello and Hoelzle (2024a, b)
11	Fieschergletscher	G008144E46504N	3	3	153	-6.8	-2.0	2003–2003	Schwerzmann et al. (2006b, a)
11	Glacier de Taconnaz Glacier des Bossons Taconnaz Glacier	G006844E45863N G006865E45868N	41	41	126	-15.1	-14.2	1911–2017	Vallot (1913); Lliboutry et al. (1976); Jouzel et al. (1984); Suter et al. (2002); Vincent et al. (2007); Gilbert and Vincent (2013); Gilbert et al. (2015); Vincent et al. (2020)
11	Glacier de Tête Rousse	G006819E45856N	19	41	70	-2.8	-2.7	2010–2023	Gilbert et al. (2012); Vincent et al. (2012); Gagliardini and Vincent (2023)
11	Glacier du Pelvoux	G006408E44900N	1	1	13	-0.2		1983–1983	Jouzel et al. (1984)
11	Glacier du Sex Rouge	G007212E46327N	2	2	35	-1.1	-0.5	2013–2014	Signer (2014)
11	Grubengletscher	G007996E46168N	6	6	46	-2.3	-2.3	1974–1975	Haeberli (1976)
11	Hintereisferner	G010752E46802N	6	70	15	-4.7	-0.3	1972–1976	Markl and Wagner (1977)
11	Hintergrat Glacier	G010554E46507N	1	41 581	10	-8.9		2011–2016	Gabrielli et al. (2016); Carturan et al. (2023a, b)
11	Jungfraufirn	G008032E46504N	10	33	20	-13.6	-3.6	1938–1991	Hughes and Seligman (1939); Laternser (1992); Suter et al. (2001)
11	Lysgletscher	G007846E45906N	6	6	22	-10.0	-5.5	1999–1999	Suter et al. (2002); Gastaldello and Hoelzle (2024a)
11	Mont Blanc	G006867E45829N	2	2	18	-17.1		1983–1998	Jouzel et al. (1984); Suter et al. (2002)
11	Sphinxgrat	G007985E46549N	1	1	10	-6.0		1981–1981	Haeberli and Alean (1985)
11	St. Annafirn	G008601E46597N	2	2	8	-1.3		2013–2014	Signer (2014)
11	Titlis-Gletscher	G008427E46774N	1	1	15	-0.7	-0.7	1979–1980	Haeberli and Alean (1985)
11	Unteraargletscher	G008187E46569N	1	1	60	0.0		1842–1842	Wild et al. (1842); Agassiz (1847)
11	Vadret da Morteratsch	G009927E46382N	1	1	42	-2.8	-2.2	2002–2002	Schwerzmann et al. (2006b)
11	Vadret dal Corvatsch	G009822E46416N	10	41	18	-9.1	-2.6	1999–2002	Hager (2002); Haeberli et al. (2004)
11	Vedretta Alta dell'Ortles	G010536E46513N	4	62 324	75	-9.4		2009–2016	Gabrielli et al. (2010, 2012, 2016); Carturan et al. (2023a, b)
12	Bezengi Glacier Ледник Безенги	G043100E43030N	1	1	80	-0.6	-0.5	1966–1966	Т. В. Псарёва [T. V. Psareva] (1968); Khromova et al. (2022)
12	Djankuat Glacier Ледник Джанкуат	G042766E43192N	5	5	55	-19.5	-0.5	1971–1971	gid (1978)

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Table A1: Summary of englacial temperatures contained in glenglat, and their sources (continued).

Region	Glacier names	GLIMS IDs	BH count	Profile count	Depth [m] max	Temp. [°C] min	Temp. [°C] 15 m	Year min–max	Sources
12	Garabashi Glacier Ледник Гарабаши	G042470E43307N	4	19	20	-13.0		1958–1988	М. Я. Плам [M. Ya. Plam] (1962); В. С. Загородnов [V. S. Zagorodnov] et al. (1992)
12	Mount Elbrus	G042429E43293N G042488E43308N	4	4	182	-17.3	-16.9	2004–2020	В. Н. Михаленко [V. N. Mikhalenko] et al. (2005a); Mikhalenko et al. (2015); В. Н. Михаленко [V. N. Mikhalenko] et al. (2021)
13	Abramov Glacier	G071570E39610N	2	2	19	-0.3	-0.1	2013–2013	Barandun (2018, 2024)
13	Ashu-Tor Glacier ледник Ашу-Тор	G078182E42041N	1	1	20	-7.6		?–1962	А. Н. Диких [A. N. Dikikh] (1965); С. С. Кутузов [S. S. Kutuzov] (2012); Van Tricht et al. (2021); Алексей Викторович Цветков [Aleksey Viktorovich Tsvetkov] (2023)
13	Batysh Sook Glacier	G077749E41787N	1	5	15	-6.3	-0.6	2013–2017	Barandun (2023)
13	Bogda Fan-Shaped Diffluence Glacier	G088313E43812N	1	4	20	-3.0	-1.5	1981–1981	仇家琪[Qiu Jiaqi] and 邓养鑫[Deng Yangxin] (1983); 任贾文[Ren Jiawen] (1983); 刘时银[Liu Shiyin] et al. (2012); Guo et al. (2015)
13	Central Tuyuksu Glacier Ледник Туюксу Центральный	G077080E43049N	5	119	52	-16.1		1957–1959	Vilesov (1961); Е. Н. Вилесов [E. N. Vilesov] (1962a, b, c); Г. А. Цыкинаи [G. A. Tsykina] and Е. Н. Вилесов [E. N. Vilesov] (1963)
13	Chongce Ice Cap 崇测冰帽	G081119E35239N	7	13	130	-16.4	-16.0	1987–2012	Huang (1990); Shao and Liu (1990); 周韬[Zhou Tao] (1990); Hou et al. (2018)
13	Crescent River Glacier No. 15 月牙河15号冰川	G087444E36402N	2	2	18	-8.2	-7.4	1988–1988	苏珍[Su Zhen] (1998); 刘时银[Liu Shiyin] et al. (2012); Guo et al. (2015)
13	Davydov Glacier Ледник Давыдова	G078204E41844N	1	4	30	-5.8	-2.5	1985–1985	Е. В. Василенко [E. V. Vasilenko] (1988)
13	Dunde Ice Cap	G096414E38091N	1	1	136	-7.3	-6.7	1984–1984	Thompson et al. (1990)
13	Geladandong Ice Cap	G091151E33199N	1	1	87	-12.1	-5.0	2004–2004	Wang and Pu (2005)
13	Grigoriev Glacier Grigoriev Ice Cap Ледник Григорьева	G077894E41995N G077923E41963N	14	1 900	87	-22.9	-6.1	1962–2023	А. Н. Диких [A. N. Dikikh] (1965); В. Н. Михаленко [V. N. Mikhalenko] (1989); Thompson et al. (1993, 1997); С. М. Архипов [S. M. Arkhipov] et al. (2004); В. Н. Михаленко [V. N. Mikhalenko] et al. (2005b); Takeuchi et al. (2014); Kronenberg et al. (2022); Kronenberg (2022); Machguth et al. (2023a, b)
13	Guliya Ice Cap 古里雅冰帽	G081455E35226N G081480E35252N	7	7	310	-21.3	-17.8	1990–2015	姚檀栋[Yao Tandong] et al. (1992); Thompson et al. (1995a, 2018)
13	Guozha Glacier 郭扎冰川	G081064E35246N	1	2	12	-6.4		1987–1987	Shao and Liu (1990)
13	Halong Glacier 哈龙冰川	G099492E34764N	2	2	10	-7.3		1981–1981	王文颖[Wang Wenying] (1987); 苏珍[Su Zhen] (1998); 刘时银[Liu Shiyin] et al. (2012); Guo et al. (2015)
13	July 1st Glacier	G097755E39237N	1	4	8	-8.9		2002–2002	Matsuda et al. (2004)
13	Laohugou Glacier	G096524E39457N	4	4	109	-10.3	-8.0	2010–2011	Wang et al. (2018)
13	Malan Glacier	G090770E35803N	1	1	100	-9.3	-4.7	1999–1999	Sun et al. (2021)
13	Meikuang Glacier 煤矿冰川	G094184E35669N	1	1	16	-7.0	-6.2	1989–1989	苏珍[Su Zhen] (1998); 刘时银[Liu Shiyin] et al. (2012); Guo et al. (2015)
13	Miaoergou Glacier	G094316E43053N	1	1	60	-8.3	-6.4	2005–2005	刘亚平[Liu Yaping] et al. (2006); Takeuchi et al. (2008); Liu et al. (2009); Jiao et al. (2023)
13	Muztagh Glacier 慕士塔格冰川	G075086E38293N	5	5	78	-26.2	-25.8	2002–2003	邬光剑[Wu Guangjian] et al. (2003); 李真[Li Zhen] et al. (2004)
13	Puruogangri Ice Cap	G089122E33894N	3	4	213	-9.9	-9.7	2000–2000	蒲健辰[Pu Jianchen] et al. (2002); Thompson et al. (2006); Liu et al. (2016)
13	Qiangtang No. 1 Glacier	G088700E33291N	1	1	109	-11.4	-7.7	2014–2015	Li et al. (2017)
13	Qingbingtan Glacier No. 72	G079894E41774N	3	3	10	-1.7		2008–2008	Wang et al. (2017)
13	Shule Nanshan Glacier	G097261E38695N	1	1	92	-9.9	-7.8	2007–2007	Liu et al. (2009)
13	South Inylchek Glacier	G079787E42137N	1	1	160	-12.0	-12.0	2000–2000	Aizen et al. (2001); Thompson (2022)
13	Urumqi Glacier No. 1 乌鲁木齐1号冰川	G086810E43111N G086801E43117N	24	26	107	-8.8	-7.4	1981–2006	任贾文[Ren Jiawen] et al. (1985); Huang (1990); Zhang et al. (1993); 李忠勤[Li Zhongqin] et al. (2011)
13	Xiao Dongkemadi Glacier 小冬克玛底冰川	G092063E33082N	1	2	15	-11.0	-7.3	1992–1993	蒲健辰[Pu Jianchen] et al. (1995)
13	Yanglong River Glacier No. 5 羊龙河5号冰川	G098570E39226N	3	27	16	-10.7	-8.2	1977–1977	任贾文[Ren Jiawen] and 黄茂桓[Huang Maohuan] (1981)
13	Zangser Kangri Glacier	G085843E34297N	1	1	127	-12.4	-12.3	2009–2009	An et al. (2016)

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Table A1: Summary of englacial temperatures contained in glenglat, and their sources (continued).

Region	Glacier names	GLIMS IDs	BH count	Profile count	Depth [m] max	Temp. [°C] min	Temp. [°C] 15 m	Year min–max	Sources
14	Singhi Glacier 特拉木坎力冰川	G077054E35619N	1	1	10	-1.8		1987–1987	苏珍[Su Zhen] (1998); 刘时银[Liu Shiyin] et al. (2012); Guo et al. (2015)
15	Baishui Glacier No. 1	G100187E27104N	4	13	21	-2.8	-0.5	1982–2010	Huang (1990); Du et al. (2013)
15	Dagongba Glacier	G101855E29563N	1	1	15	-0.9		1982–1982	Huang (1990)
15	Dasuopu Glacier	G085752E28395N	2	2	168	-14.4	-13.8	1997–1997	Thompson et al. (2000); Yao et al. (2002); Thompson (2022)
15	East Rongbuk Glacier	G086939E28060N	3	3	109	-10.9	-9.2	2002–2008	Hou et al. (2004, 2007); Zhang et al. (2013); 张通[Zhang Tong] (2022)
15	Gyabrag Glacier 加布拉冰川	G086633E28122N	1	1	69	-9.1	-7.7	2005–2005	Liu et al. (2009)
15	Khumbu Glacier	G086820E27978N	3	3	131	-3.3	-3.2	2017–2017	Miles et al. (2018, 2019); Hubbard et al. (2021)
15	Naimona'nyi Gacier	G081317E30454N	1	1	159	-9.6	-9.4	2006–2006	Thompson et al. (2018); Thompson (2022)
15	Rikha Samba Glacier	G083488E28819N	3	6 134	10	-10.6		2014–2015	Gilbert et al. (2020); Gurung (2022)
15	Trambau Glacier	G086537E27874N	1	1	78	-1.3		2019–2019	Tsushima et al. (2021)
15	Yala Glacier	G085612E28242N	2	2	60	-1.0	-1.0	1981–1982	Iida et al. (1984); Watanabe et al. (1984)
16	Illimani Volcano	G292220E16653S	1	1	138	-9.0	-8.1	1999–1999	Gilbert et al. (2010)
16	Mount Kilimanjaro	G037352E03058S	1	1	51	-1.6	-1.1	2000–2000	Thompson et al. (2002); Thompson (2022)
16	Nevado Huascarán	G282414E09082S G282415E09115S	3	3	167	-9.0	-5.9	1993–2019	Thompson et al. (1995b); Thompson (2022); Thompson et al. (2023)
16	Nevado Sajama	G291113E18113S	1	1	132	-11.3	-10.6	1997–1997	Thompson et al. (1998); Vimeux et al. (2009); Thompson (2022)
16	Quelccaya Ice Cap	G289183E13941S G289167E13923S	2	2	168	-7.2	0.0	1976–2003	Thompson (1980); Zagorodnov et al. (2005); Vimeux et al. (2009); Thompson (2015, 2022)
16	Volcán Coropuna	G287357E15537S	2	2	147	-11.1	-9.0	2003–2003	Zagorodnov et al. (2005, 2006); Vimeux et al. (2009); Thompson (2022)
17	Glaciar La Ollada	G289889E31964S	1	1	104	-18.5	-18.3	2005–2005	Schwerzmann et al. (2006b)
17	Glaciar Nef	G286668E46885S	1	1	13	-0.1		1996–1996	Matsuoka and Naruse (1999)
17	Glaciar San Rafael	G286620E46550S	1	1	16	-11.9	-11.6	2005–2005	Vimeux et al. (2008)
17	Guanaco Glacier	G289989E29347S	1	4	112	-8.0	-6.2	2008–2011	Kinnard et al. (2020); Masiokas et al. (2020)
17	Pío XI glacier	G286372E49263S	1	1	40	-0.9	-0.7	2006–2006	Schwikowski et al. (2013)
17	Tapado Glacier	G290072E30145S	1	1	36	-12.4	-10.7	1992–1992	Ginot et al. (2006)
19	Blåskimen Island Ice Rise	G356949E70424S	1	1	19	-16.4	-16.3	2012–2014	Goel et al. (2017a, b)
19	Bruce Plateau	G295982E66134S	2	6	431	-15.8	-15.1	2010–2010	Zagorodnov et al. (2012)
19	Collins Ice Cap	G301284E62099S G301112E62165S	7	16	30	-6.1	-2.0	1992–1992	韩建康[Han Jiankang] et al. (1995)
19	Dolleman Island	G299288E70606S	1	1	128	-17.2	-17.0	1986–1986	Nicholls and Paren (1993)
19	Dyer Plateau		1	1	104	-21.8	-21.4	1989–1989	Nicholls and Paren (1993)
19	James Ross Island Ice Cap	G302228E64270S	2	2	10	-14.2		1976–1977	Aristarain and Delmas (1981)
19	Johnsons Glacier	G299645E62671S	2	2	153	-0.2	-0.2	2016–2016	Sugiyama et al. (2019); Sugiyama (2022)
19	King George Island Ice Cap	G301226E62159S	1	3	15	-1.8		1986–1986	任贾文[Ren Jiawen] (1990)
19	Nelson Island Ice Cap	G301002E62274S G300887E62269S	3	12	13	-1.6		1986–1986	任贾文[Ren Jiawen] (1990)
19	Styx Glacier		1	1	210	-33.5	-31.7	2016–2016	Han et al. (2015); Yang et al. (2018)

Appendix B: Authors of all sources

Names of all the authors of all the sources used to compile the data in glenglat. Names in non-Latin script are followed by a latinized form in square brackets. The list is sorted alphabetically by (Latin) family name, which is capitalized. The latinized form preserves the order of the original, which is [family given] for Chinese, Japanese, and Korean names.

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