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Dataset of Glaciers Changes in the Northern Hemisphere in the Past 2000 Years

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Abstract: Global climate change has a significant impact on the glacier. Glaciers record the climate change in the global on a century, millennium, and even longer time scales, which is of great significance to the study of climate change. Glaciers in the northern hemisphere cover a large area and are mainly distributed in the Tibetan Plateau, the Alps, Greenland, Alaska, and other places. The dataset of glaciers changes in the northern hemisphere in the past 2,000 years was reconstructed based on temperature or the coupling relationship between temperature and precipitation, oxygen isotopes in air bubblies of ice core, and the linkage of "glacier-lake". The temporal resolution of the data is one year. The dataset is archived in .shp, .docx, and .xlsx data formats, and consists of 10 data files with a data size of 136 KB (Compressed into one single file with 87.6 KB). The results show that under the influence of climate change, glaciers in different regions of the northern hemisphere have experienced advanced or retreated in different periods in the past 2,000 years. On the whole, however, it shows that all glaciers have had a retreat trend during the last several decades.

Keywords: glaciers; climate change; Tibetan Plateau; the Alps; Greenland

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Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2022.02.01.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2022.02.01.V1.

1 Introduction

Glaciers are the largest reservoir of fresh water on earth. It is estimated that the total amount of glaciers account for 2% of the global water and about 80% of the global available fresh water[1]. Glaciers are not only the driving factor of global climate change but also record the climate information on the century, millennium, and even longer time scale. It is particularly sensitive to global climate change and is of great significance to reveal its response to global

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[2] Ren, P. J., Yu, W. S., Xu, B. Q., *et al*. Dataset of glaciers changes in northern hemisphere during the past 2000 years [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2022. https://doi.org/10.3974/geodb.2022.02.01.V1. https://cstr.escience.org.cn/CSTR:20146.11.2022.02.01.V1.

climate change[2]. Glaciers in the northern hemisphere have retreated under the influence of global warming. Reconstructing the glaciers changes in the northern hemisphere in the past 2,000 years can better understand the glaciers changes on the scale of the past millennium and the impact of climate change on glaciers changes, and provide data support for revealing the response of modern glaciers to climate change and studying global climate change. Because of this, this dataset of changes of 22 glaciers in the northern hemisphere in the past 2,000 years were reconstructed, including 8 glaciers in the Tibetan Plateau, 1 glacier in Siberia, 1 glacier in the Alps, 3 glaciers in Alaska, 8 glaciers in Greenland and 1 glacier in Rocky Mountain (Figure 1). The main methods are temperature or the coupling relationship between temperature and precipitation, oxygen isotopes in air bubbles of ice core, and linkage of "glacier-lake".

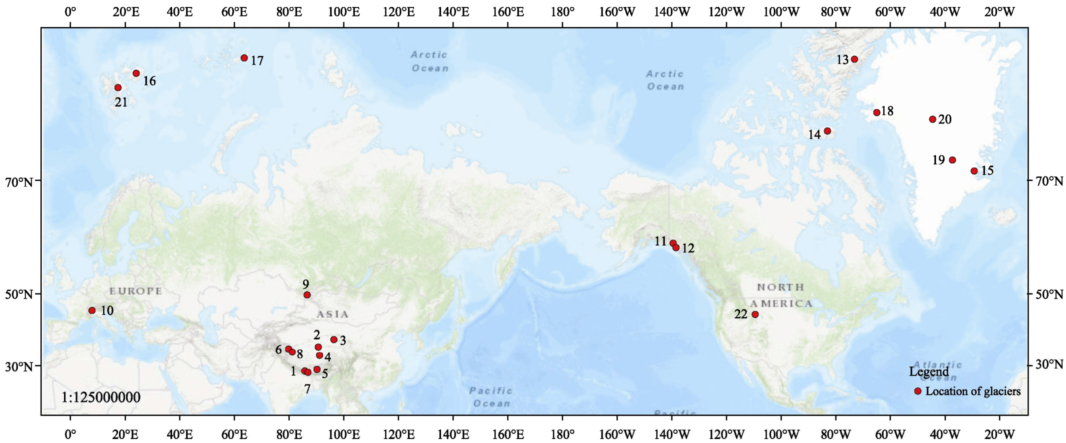

Figure 1 Location of reconstructed 22 glaciers in the northern hemisphere

(1-Dasuopu Glacier, 2-Malan Glacier, 3-Dunde Ice Cap, 4-Longxiazailongba Glacier, 5-Qiangyong Glacier, 6-Glacier in the upper reaches of Lake Aksai-chin, 7-No.2 Glacier in Mt. Qomolangma, 8-Depchangdak Glacier, 9-Belukha Glacier, 10-Colle Gnifetti Glacier, 11-Eclipse Icefield, 12-Logan Glacier, 13-Agassiz Ice Cap, 14-Devon Ice Cap, 15-Renland Glacier, 16-Austfonna Ice Cap, 17-Windy Ice Cap, 18-Akademii Nauk Ice Cap, 19-Top Glacier of Greenland, 20-Crete Glacier, 21-Lomonosovfonna Glacier, 22-Beartooth Plateau Glacier)

2 Metadata of the Dataset

The metadata of the Dataset of glaciers change in the northern hemisphere during the past 2,000 years[3] are summarized in Table 1. They include the dataset full name, authors, data year, temporal resolution, data format, data size, data publisher, and data sharing policy, etc.

3 Methods

3.1 Raw Data

The raw data include the published stable isotope record of ice core and accumulation data. Meanwhile, the stable isotope record of ice core and accumulation data, element in lake sediment data, and stable isotopes data in air bubbles of ice core in this study were used. Whether published data or the raw data of this study, the study methods and processes of these raw data are similar. The specific process is as follows: (1) drilling ice cores from glaciers; (2) cutting the ice core into pieces from top to bottom in the laboratory; (3) the

Table 1 Metadata summary of the Dataset of glaciers changes in northern hemisphere during the past 2,000 years

Items	Description
Dataset full name	Dataset of glaciers changes in northern hemisphere during the past 2000 years
Dataset short name	GlacierChangeNHPast2000
Authors	Ren, P. J., State Key Laboratory of Tibetan Plateau Earth System, Environment and Resources (TPESER), Institute of Tibetan Plateau Research, Chinese Academy of Sciences, renpengjie@itpcas.ac.cn Yu, W. S., State Key Laboratory of Tibetan Plateau Earth System, Environment and Resources (TPESER), Institute of Tibetan Plateau Research, Chinese Academy of Sciences, yuws@itpcas.ac.cn Xu, B. Q., State Key Laboratory of Tibetan Plateau Earth System, Environment and Resources (TPESER), Institute of Tibetan Plateau Research, Chinese Academy of Sciences, baiqing@itpcas.ac.cn Zhang, X. L., State Key Laboratory of Tibetan Plateau Earth System, Environment and Resources (TPESER), Institute of Tibetan Plateau Research, Chinese Academy of Sciences, zhangxiaolong@itpcas.ac.cn Li, J. L., State Key Laboratory of Tibetan Plateau Earth System, Environment and Resources (TPESER), Institute of Tibetan Plateau Research, Chinese Academy of Sciences, jlli@itpcas.ac.cn
Geographical region	Tibetan Plateau, Siberia, Alps, Alaska, Greenland, Rocky Mountains
Year	Past 2,000 years
Temporal resolution	One year
Data format	.shp, .docx and .xlsx
Data size	136 KB (Compressed into one single file with 87.6 KB)
Foundation	Ministry of Science and Technology of P. R. China (2017YFA0603303）
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten per cent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset [4]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

stable isotope composition of ice core fragments and the stable isotope composition of ice core wrapped gas were determined by stable isotope mass spectrometer; (4) retrieving the ice core accumulation data by stable isotope record of the ice core.

The study method and process of the lake sediments data in this study are as follows: (1) drilling sediment core from lakes; (2) cutting the lake sediment core into pieces from top to bottom in the laboratory; (3) quantitative analyzing the Na, Mg, Al, K, Ca, and Fe using a Thermo X-7 inductively coupled plasma-mass spectrometer[5].

3.2 Data Processing

The 22 glaciers changes in the northern hemisphere in the past 2,000 years were reconstructed based on the coupling relationship between temperature and precipitation, oxygen isotopes in air bubbles of ice core, and linkage of "glacier-lake". The dataset format refers to Solomina *et al*.[6].

The coupling relationship of "temperature + precipitation" is mainly based on: when the temperature decreases and the precipitation increases, the glaciers advance; On the contrary, when the temperature increases and the precipitation decreases, the glaciers melt. If there is only a temperature series, the temperature increase corresponds to glaciers melting, and the temperature decrease corresponds to glaciers' advance.

Oxygen isotopes in air bubbles of ice core that measure the isotope value of gas which was drilled from ice core, and then reconstruct the temperature change history. The stronger the glaciers melting, the easier the isotope exchange between glaciers and gas, resulting in the gas isotope being lower. Therefore, the period of the negative value of oxygen isotopes in air bubbles of ice core indicates the period of glacier advances, and the period of the positive value indicates the period of glacier retreat.

Figure 2 shows a diagram of the Linkage of "glacier-lake". Linkage of "glacier-lake" is that the difference (Δ age) between the sedimentary age of proglacial lake sediments and the sporopollen ^{14}C age in the same layer is a good index to reflect the intensity of glaciers ablation [7]. On the premise that the atmospheric dry and wet deposition remains unchanged, the old atmospheric dust deposited in the glaciers is released with the strengthening of glaciers melting and flows into the lake deposition, corresponding to the warmer climate period; When the glacier melts weakly or the glacier advances, the bedrock is pushed to flow into the lake, increasing of bedrock contribution, which corresponds to the colder climate period. Therefore, the indexes and elements are standardized to obtain the dominant elemental PC1 contribution time series of old atmospheric dust and 6 major (Na, Mg, Al, K, Ca, and Fe) and 26 traces (Li, Sc, Ti, V, Cr, Mn, Co, Ni, Cu, Zn, As, Rb, Sr, Y, Zr, Nb, Cd, Cs, Ba, Hf, Ta, Tl, Pb, Bi, Th, and U) elements in bedrock, to indicate the changes of glaciers.

Information about the reconstructed glaciers changes dataset is shown in Table 2.

4 Data Results and Validation

4.1 Data Composition

The formats of the dataset of glaciers changes in the northern hemisphere in the past 2,000 years are .shp, .docx and .xlsx, including 22 glaciers names, geographical regions, advancing or retreating periods, and other elements (Table 3, 4）.

4.2 Data Products

4.2.1 Coupling Relationship between Temperature and Precipitation

The glaciers changes are reconstructed according to the coupling relationship between temperature and precipitation. It is found that the advanced periods of Dasuopu Glacier in

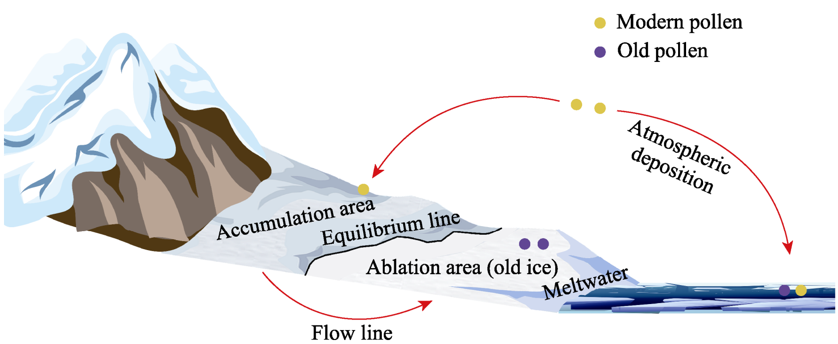

Figure 2 Linkage of "glacier-lake" showing accumulated of old pollen in ablation area and its release to proglacial lake through meltwater (refer to Zhang *et al*.[7])

Table 2 Summary of relevant information of the dataset of glaciers changes in the northern hemisphere in the past 2,000 years

No.	Glaciers	Location	Region	Reconstruction method	Source of raw data
1	Dasuopu Glacier	Mount Shishapangma	Tibetan Plateau	Coupling relationship between temperature and precipitation	[8]
2	Malan Glacier	Hoh Xil	Tibetan Plateau	Temperature	[9]
3	Dunde Ice Cap	Tsaidam Basin	Tibetan Plateau	Coupling relationship between temperature and precipitation	This study
4	Longxiazailongba Glacier	Tanggula Mountains	Tibetan Plateau	Oxygen isotopes in air bubbles of ice core	This study
5	Qiangyong Glacier	Yangzhuoyongcuo Basin	Tibetan Plateau	Linkage of “glacier-lake”	This study
6	Glacier in the upper reaches of Lake Aksai-Chin	Kunlun Mountains	Tibetan Plateau		This study
7	No.2 Glacier in Mt. Qomolangma	Mt. Qomolangma	Tibetan Plateau		This study
8	Depchangdak Glacier	Ali	Tibetan Plateau		This study
9	Belukha Glacier	Altai Mountains	Siberia	Coupling relationship between temperature and precipitation	[10]
10	Colle Gnifetti Glacier	Switzerland	Alps	Temperature	[11]
11	Eclipse Icefield	Canada	Alaska	Coupling relationship between temperature and precipitation	[12]
12	Logan Glacier	Alaska	Alaska		[13]
13	Agassiz Ice Cap	Canada	Alaska	Temperature	[14,15]
14	Devon Ice Cap	Nunavut	Greenland		[16,17]
15	Renland Glacier	East Greenland	Greenland		[18]
16	Austfonna Ice Cap	Svalbard Islands	Greenland		[19]
17	Windy Ice Cap	Franz Josef Islands	Greenland		[20]
18	Akademii Nauk Ice Cap	Arctic	Greenland		[21]
19	Top Glacier of Greenland	Greenland	Greenland	Coupling relationship between temperature and precipitation	[22]
20	Crete Glacier	Central Greenland	Greenland		[23]
21	Lomonosovfonna Glacier	Svalbard Islands	Greenland	Temperature	[24]
22	Beartooth Plateau Glacier	Wyoming	Rocky Mountains		[25]

Mount Shishapangma were 1851–1857, 1870–1875, 1883–1890, 1908–1915, and 1966–1973, and the retreated periods were 1848–1851, 1862–1870, 1875–1883, 1890–1903, 1915–1966, 1973–1980 and 1985–1994, specially since 1915, the melting of the glacier has shown an increasing trend (Figure 3). Using similar methods, 16 glaciers were reconstructed, including Malan Glacier, Dunde Ice Cap, Belukha Glacier, Colle Gnifetti Glacier, Eclipse Icefield, Logan Glacier, Agassiz Ice Cap, Devon Ice Cap, Renland Glacier, Austfonna Ice Cap, Windy Ice Cap, Akademii Nauk Ice Cap, Top Glacier in Greenland, Crete Glacier, Lomonosovfonna Glacier, and Beartooth Plateau Glacier (see the dataset file for details).

Table 3 Periods of glaciers advances

No.	Glaciers	Region	Location	Reconstruction Method	Centuries	Source of Raw Data
1	Dasuopu Glacier	Tibetan Plateau	Mount Shishapangma	Coupling relationship between temperature and precipitation	1851–1857, 1870–1875, 1883–1890, 1908–1915, 1966–1973	[8]
2	Malan Glacier		Hoh Xil	Temperature	1690–1773	[9]
3	Dunde Glacier		Tsaidam Basin	Coupling relationship between temperature and precipitation	–	This study
4	Longxiazailongba Glacier		Tanggula Mountains	Oxygen isotopes in air bubbles of ice core	100–300, 1200–1900	This study
5	Qiangyong Glacier		Yangzhuoyongcuo Basin	Linkage of “glacier-lake”	600–800, 1050–1850	This study
6	Glacier in the upper reaches of Lake Aksai-Chin		Kunlun Mountains	Linkage of “glacier-lake”	1811–1970	This study
7	No.2 Glacier in Mt. Qomolangma		Mt. Qomolangma	Linkage of “glacier-lake”	1920–1940, 1993–1972	This study
8	Depchangdak Glacier		Ali	Linkage of “glacier-lake”	–	This study
9	Belukha Glacier	Siberia	Altai Mountains	Coupling relationship between temperature and precipitation	1825–1832, 1884–1890	[10]
10	Colle Gnifetti Glacier	Alps	Switzerland	Temperature	1000–1360, 1845–1878	[11]
11	Eclipse Icefield	Alaska	Canada	Coupling relationship between temperature and precipitation	1976–1992	[12]
12	Logan Glacier		Alaska	Coupling relationship between temperature and precipitation	1825–1925	[13]
13	Agassiz Ice Cap		Canada	Temperature	1815–1858	[14,15]
14	Devon Ice Cap	Greenland	Nunavut	Temperature	–	[16,17]
15	Renland Glacier		East Greenland	Temperature	1450–1700	[18]
16	Austfonna Ice Cap		Svalbard Islands	Temperature	1470–1493, 1580–1621, 1737–1773	[19]
17	Windy Ice Cap		Franz Josef Islands	Temperature	1425–1470, 1560–1590, 1750–1773	[20]
18	Akademii Nauk Ice Cap		Arctic	Temperature	1937–1948	[21]
19	Top Glacier of Greenland		Greenland	Coupling relationship between temperature and precipitation	493–800, 1260–1820	[22]
20	Crete Glacier		Central Greenland	Coupling relationship between temperature and precipitation	1620–1665, 1760–1800	[23]
21	Lomonosovfonna Glacier		Svalbard Islands	Temperature	810–850, 900–980, 1250–1850	[24]
22	Beartooth Plateau Glacier	Rocky Mountains	Wyoming	Temperature	630–800, 1050–1400, 1690–1775	[25]

4.2.2 Oxygen Isotopes in Air Bubbles of Ice Core

The temperature records of the past 3,600 years were reconstructed using the oxygen isotopes in air bubbles of the ice core in the Longxiazailongba Glacier (Figure 4). It can be seen that there were three periods of glacier advances (1600 B.C.–400 B.C., 100–300 A.D., 1200–1900 A.D.) and three periods of glacier retreats (400 B.C.–100 A.D., 300–1200 A.D., 1900 A.D. to the present).

Table 4 Periods of glaciers retreats

No.	Glaciers	Region	Location	Reconstruction Method	Centuries	Source of raw data
1	Dasuopu Glacier	Tibetan Plateau	Mount Shisha-pangma	Coupling relationship between temperature and precipitation	1848–1851, 1862–1870, 1875–1883, 1890–1903, 1915–1966, 1973–1980, 1985–1994	[8]
2	Malan Glacier		Hoh Xil	Temperature	1450–1690, 1773–2000	[9]
3	Dunde Glacier		Tsaidam Basin	Coupling relationship between temperature and precipitation	>1950	This study
4	Longxiazailongba Glacier		Tanggula Mountains	Oxygen isotopes in air bubbles of ice core	300–1200, >1900	This study
5	Qiangyong Glacier		Yangzhuo-yongcuo Basin	Linkage of "glacier-lake"	100–600, 850–1050, >1850	This study
6	Glacier in the upper reaches of Lake Aksai-Chin		Kunlun Mountains	Linkage of "glacier-lake"	>1970	This study
7	No.2 Glacier in Mt. Qomolangma		Mt. Qomo-langma	Linkage of "glacier-lake"	1940–1972, 1993–2020	This study
8	Depchangdak Glacier		Ali	Linkage of "glacier-lake"	1733–1910	This study
9	Belukha Glacier	Siberia	Altai Mountains	Coupling relationship between temperature and precipitation	1840–1851, 1870–1881, 1898–1990, 1960–2000	[10]
10	Colle Gnifetti Glacier	Alps	Switzerland	Temperature	>1878	[11]
11	Eclipse Icefield	Alaska	Canada	Coupling relationship between temperature and precipitation	1932–1976	[12]
12	Logan Glacier		Alaska	Coupling relationship between temperature and precipitation	1749–1825, 1960–1965	[13]
13	Agassiz Ice Cap		Canada	Temperature	1741–1815, >1858	[14,15]
14	Devon Ice Cap	Greenland	Nunavut	Temperature	1850–1960	[16,17]
15	Renland Glacier		East Greenland	Temperature	1250–1450, 1700–2000	[18]
16	Austfonna Ice Cap		Svalbard Islands	Temperature	1773–2000	[19]
17	Windy Ice Cap		Franz Josef Islands	Temperature	1220–1380, 1773–2000	[20]
18	Akademii Nauk Ice Cap		Arctic	Temperature	1885–1937, 1973–2000	[21]
19	Top Glacier of Greenland		Greenland	Coupling relationship between temperature and precipitation	800–1044, 1820–1900	[22]
20	Crete Glacier		Central Greenland	Coupling relationship between temperature and precipitation	1888–1980	[23]
21	Lomonosov-fonna Glacier		Svalbard Islands	Temperature	850–900, 980–1010, 1850–2000	[24]
22	Beartooth Plateau Glacier	Rocky Mountains	Wyoming	Temperature	800–1050, 1775–1950	[25]

4.2.3 Linkage of "Glacier-Lake"

The change of Qiangyong Glacier was reconstructed by using the linkage of "glacier–lake". It can be seen that the periods of glacier advances were 560 B.C.–100 A.D., 600–800 A.D., 1050–1850 A.D., and the periods of glacier retreats were 100–600 A.D., 850–1050 A.D., 1850 A.D. to the present (Figure 5). Similar methods are used to reconstruct the changes in the West Kunlun Glacier, Depchangdak Glacier and No.2 Glacier in Mt. Qomolangma (see the dataset file for details).

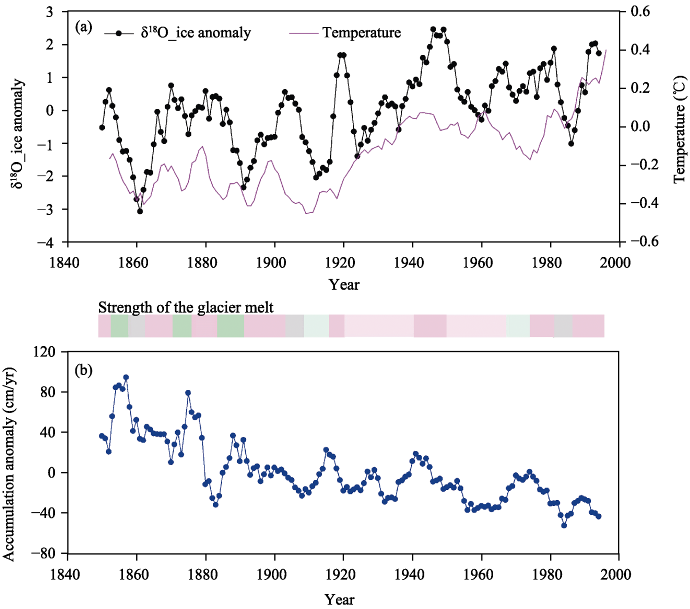

Figure 3 Reconstruction of the Dasuopu Glacier changes based on the coupling relationship between temperature and precipitation

(Notes: a. The black line represents the $\delta^{18}O$ anomaly of ice core ($\delta^{18}O$_ice Anomaly) derived from the Dasuopu Glacier, the purple line represents the temperature of the northern hemisphere (NH Temperature); b. the accumulation anomaly of the ice core in Dasuopu Glacier. Strength of the glacier melt: the darker the pink and the stronger the glacier melt, the darker the green and the stronger the glacier accumulation)

5 Discussion and Conclusion

Climate change on a long-timescale was recorded in the glaciers. They are not only significantly affected by global climate change, but also have a significant impact on global climate change. It is of great scientific significance to reveal the mechanism of climate change. This dataset inverses the changes of 22 glaciers in the northern hemisphere in the past 2,000 years, and reveals the response of glaciers to climate change based on temperatureor the coupling relationship between temperature and precipitation, oxygen isotopes in air bubbles of ice core, linkage of “glacier-lake”. From the results, the dataset reflects the fluctuating changes in advanced and retreated of 22 glaciers in the recent 2,000 years. However, the glacier changes in the past 2,000 years present a retreated process generally. This dataset provides reference and support for the study of glaciers changes and climate change. It is of great significance to reveal the interaction between climate change and glaciers.

Author Contributions

Yu, W. S. and Xu, B. Q. designed the algorithms of dataset, and modified the data paper; Ren, P. J. wrote the data paper, made and sorted out the dataset; Zhang, X. L. and Li, J. L.

collected basic data.

Conflicts of Interest

The authors declare no conflicts of interest.

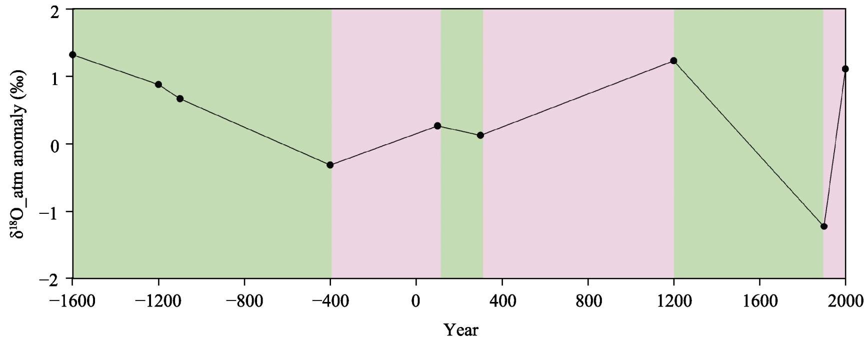

Figure 4 Reconstruction of the Longxiazailongba Glacier changes based on the oxygen isotope in air bubblies of the ice core derived from the Longxiazailongba Glacier

(Notes: The green represents the periods of glacier advances; the pink represents the period of glacier retreats)

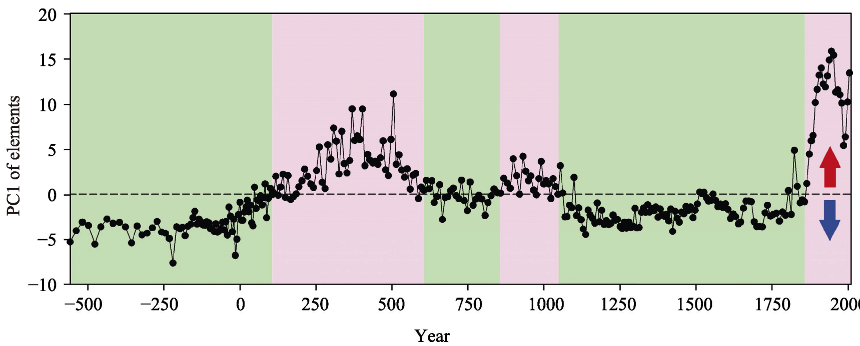

Figure 5 Reconstruction of the Qiangyong Glacier changes based on the PC1 of elements of the sediment derived from the Qiangyong Lake using the linkage of "glacier-lake"

(Notes: The green shadows represent the periods of glacier advances; the pink shadows represent the periods of glacier retreats; the blue arrow represents the glacier advances, and the red arrow represents the glacier retreats)

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