

# The Glacier Inventory of China

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**ABSTRACT.** Following recommendations from the International Commission on Snow and Ice for a world glacier inventory, an inventory of glaciers in China was carried out by Chinese glaciologists from 1978 to 2002. Each glacier was measured from aerial photographs and topographical maps and 34 parameters recorded. These parameters were then analyzed statistically for the various river systems in China. Twelve volumes of the Glacier Inventory of China (GIC) have been published, consisting of 22 parts in 21 books. The data were subsequently abridged into a Concise GIC, published in Chinese (2005) and in English (2008), to make the glacier inventory more accessible and better adapted for assessing glacier response to climate change. After the GIC was completed, new aerial photographs became available and remote-sensing techniques became more common. To investigate glacier changes since completion of the first GIC, a second Glacier Inventory of China was initiated in 2007. This 5 year project, supported by the Ministry of Science and Technology, will be undertaken mainly using remote-sensing techniques.

## INTRODUCTION

In September 1978, the International Commission on Snow and Ice (ICSI) held a workshop on World Glacier Inventory in Switzerland, attended by scientists from 19 countries. F. Müller pointed out in his introduction to the workshop (Müller and Scherler, 1980) that completion of a world glacier inventory was important for three reasons. Firstly, it would enrich our knowledge of local, regional and global hydrological cycles and water budgets. Secondly, it would generate the basic data needed for managing freshwater resources and hydropower, and for irrigation, disaster prevention, recreation and tourism. Thirdly, it would provide necessary background information for studying climatic processes and monitoring climate change. His revised guide book (Müller and others, 1977) was accepted by participants at the workshop as the standard for the measurement and calculation of the 40 glacier parameters which are the basis for the World Glacier Inventory. By 1978, five countries – the USSR, Norway, Austria, Switzerland and Sweden – had completed glacier inventories, but most glacierized countries had yet to carry out the task. As head of the Chinese delegation, and on behalf of the Lanzhou Institute of Glaciology and Geocryology (LIGG), now the Cold and Arid Regions Environmental and Engineering Research Institute of the Chinese Academy of Sciences (CAS), Shi Yafeng declared that LIGG would carry out a Glacier Inventory of China (GIC) using these guidelines (Shi and others, 2008a, p. 7, 23–24).

## EARLY STAGE OF THE GLACIER INVENTORY OF CHINA

Smooth progress during the initial stages of the GIC led to the completion of inventories of glaciers in the Qilian Shan, Altai Shan and Tien Shan in northwest China.

In 1979, a GIC working group of some 15 glaciologists and technicians, headed by Wang Zongtai and Liu Chaohai, was set up by LIGG. They studied the guidelines and chose the Qilian Shan for a pilot study. A complete set of aerial photographs and large-scale topographic maps of the

mountains were collected. Glacier distributions were carefully checked with the maps, aerial photographs and field investigations, and 34 glacier parameters measured and calculated from the maps. In 1981, the first volume of the GIC, on the Qilian Shan, was published (Wang and others, 1981). It contained various statistical tables summarizing the glacier parameters in different hydrological basins, 1:250 000 scale maps of the glacier distribution, and two introductory papers. The results of this inventory showed that in the Qilian Shan there were 2815 glaciers covering 1931 km<sup>2</sup> with an estimated ice volume of 93 km<sup>3</sup>.

In 1980, the working group sent a small field team, headed by Liu Chaohai, to investigate the glaciers in the Altai Shan, the northernmost glacierized area in China. The second volume of the GIC followed shortly afterwards in 1982 (Liu and others, 1982). In the Altai Shan there are 403 glaciers covering an area of 280 km<sup>2</sup> with an estimated ice volume of 16 km<sup>3</sup>.

The Chinese Tien Shan have the largest number of glaciers of any mountain range in northwest China. The working group, now enlarged with more scientists and technicians, started to compile the inventory for this region in 1980. At the same time, Zhu Guocai succeeded in producing a radio-echo sounding radar that could accurately measure glacier thickness, significantly improving the ability to calculate ice volumes (Shi and others, 2008b, p.14–21). In 1986 and 1987, the four parts in four books of the Tien Shan glacier inventory volume, the main contributors to which were Liu Chaohai, Wang Yinsheng, Lai Zuming, Xie Weirong and Ding Lianfu, were published (Ding and others, 1986; Lai and others, 1986; Wang and others, 1986; Xie and others, 1987). In the Tien Shan, 9035 glaciers cover 9225 km<sup>2</sup> with an estimated ice storage of 1011 km<sup>3</sup>.

## LATER STAGE OF THE GLACIER INVENTORY OF CHINA

In the late 1980s and early 1990s, the GIC encountered difficulties from reduced resources and personnel so that progress slowed. However, it was possible to publish the

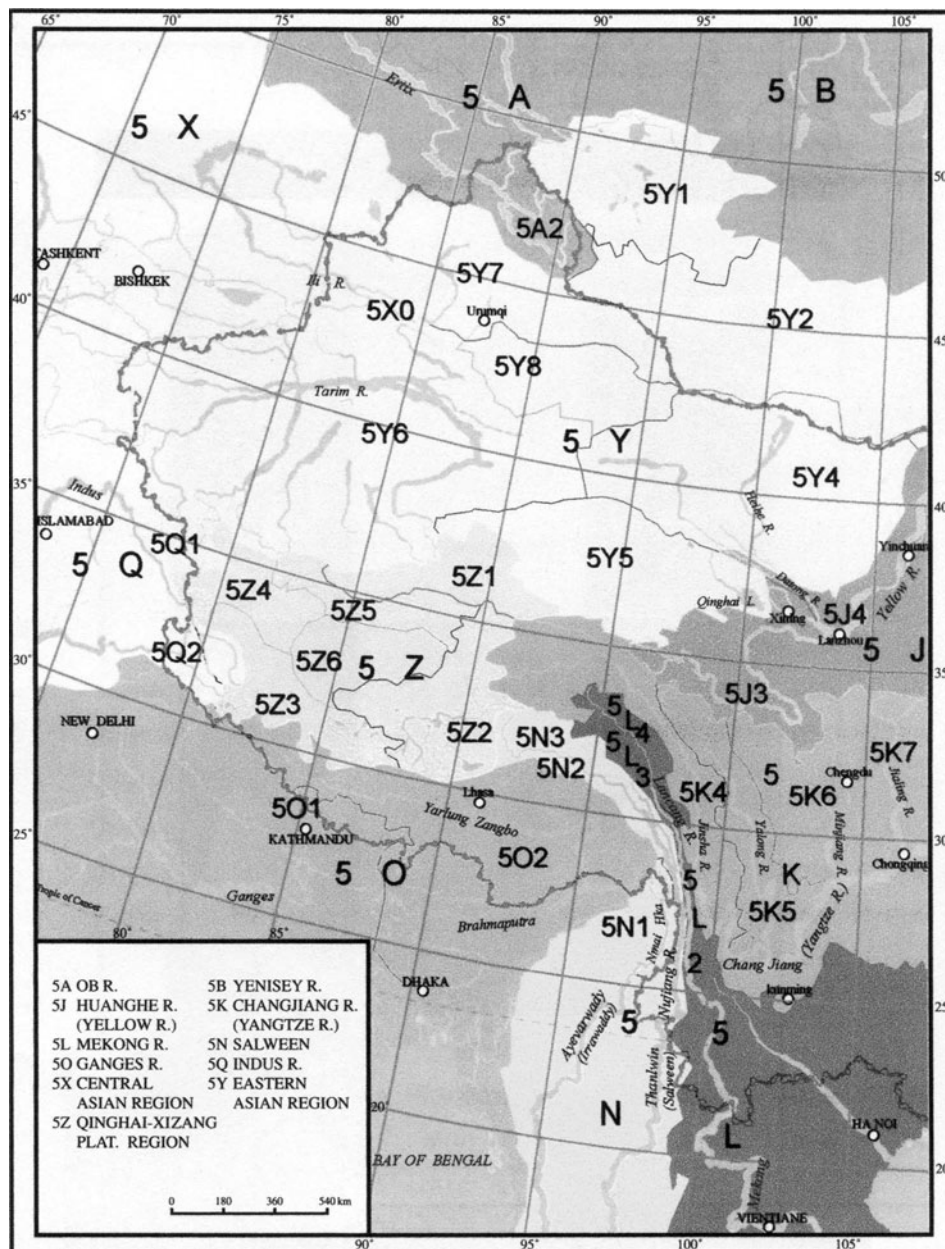


Fig. 1. Hydrological basins in China and adjacent areas related to the GIC (from Shi and others, 2008a).

volume of five parts in five books covering the interior area of the Qinghai–Tibetan Plateau in 1988 (Jiao and Zhang, 1988a,b,c; Yang and An, 1988; Zhang and Jiao, 1988), the main contributors to which were Jiao Keqin, Zhang Zhenshuan and Yang Hui’an. In this vast, desolate and cold plateau area, there were 5341 glaciers covering 7836 km<sup>2</sup> with an estimated ice volume of 777.5 km<sup>3</sup>. Glaciers are highly concentrated along the southern flank of the western Kunlun Shan, where the broad planation surface is at about 6000 m a.s.l. and glaciers cover an area of 3000 km<sup>2</sup>. Puruogangri is the largest icefield. It is located in the mid-eastern part of this interior area and has an area of 422.85 km<sup>2</sup>. One other book, on the Chinese Pamirs, was also published in 1988 (Luo and others, 1988). Between 1989 and 1994, two volumes of the GIC were published: one in a book on the Yarkant river basin in the Karakoram (Yang and An, 1989); and another in four parts in four books on drainage basins in the Kunlun Shan, covering the southern Qaidam basin, and the Yellow River, Hotan river,

Karamiran–Keriya rivers and Miran–Qarqan rivers (Yang and An, 1992a,b, 1994a,b). The principal contributors to these publications were Yang Hui’an and An Ruizhen. In 2001, a revised edition of the original Chinese Pamirs inventory, covering the Kaxgar river basin, was published (Liu and others, 2001), to complete the volume consisting of a part in two books. At that point, we recognized that the Tarim interior basin has the most glaciers, and is the largest glacier-covered area, in China. The number of glaciers here was 11 655, covering an area of 19 878 km<sup>2</sup>, with an estimated ice volume of 2312 km<sup>3</sup>. For the international rivers, it is found that there are 2248 glaciers covering an area of 4297 km<sup>2</sup>, with an ice storage of 3993 km<sup>3</sup> outside of Chinese territory. The vast Taklamakan sandy desert is located in the central lowland area of the Tarim basin which is extremely dry. However, relatively abundant precipitation and numerous glaciers in the surrounding mountains supply rich ice and snow meltwater and mountain runoff, nourishing natural and artificial oases in the

**Table 1.** Glaciers in the internal and external drainage basins of China (from Shi and others, 2008a)

Drainage basins	Number of glaciers		Glacier area		Ice volume	
		%	km <sup>2</sup>	%	km <sup>3</sup>	%
Internal	27 024	58.27	35 469	59.69	3575	63.84
External	19 353	41.73	23 956	40.31	2025	36.16
Total	46 377	100	59 425	100	5600	100

pediment belt and the lowland areas. Glacier meltwater contributes about 38.5% of the total river runoff from the surrounding mountains of the Tarim basin (Shi and others, 2008b, p. 261–268).

The final group of five GIC volumes in three books was published from 1994 to 2002. They covered the following drainage basins: Changjiang (Yangtze) river (Pu, 1994); Lancang (Mekong) and Lujiang rivers (Pu, 2001); and the Ganges (mainly the Yarlung Zangbo) and upper reaches of the Indus river (Mi and others, 2002). The main contributors to these publications were Pu Jianchen, Mi Desheng and Xie Zichu. All the rivers originating in the southeastern Tibetan Plateau belong to the exterior drainage systems, and most of the glaciers are classified as maritime temperate. There are 19 355 glaciers covering an area of 23 956 km<sup>2</sup> with an estimated ice storage of 2025 km<sup>3</sup> (including a small part of the Ob and Yellow rivers). The areas where the maritime-type glaciers develop receive much precipitation and possess plentiful water power. However, the areas suffer from frequent avalanches, serious debris flows and various flood disasters. In the meantime, a large-scale unified glacier inventory database for the GIC was developed by Wu Lizong using Geographical Information System techniques (Wu and Li, 2004).

## CONCISE GLACIER INVENTORY OF CHINA

The 22 parts in 21 books of the 12 volumes comprising the completed GIC (Wu and others, 2004, p. 116–135), with information on glacier distributions in the various hydrological basins of China, are convenient for practical applications, but too numerous to provide a clear and concise overview and scientific assessment of the glaciers in China. We therefore compiled an integrated and simplified review in one book, summarizing the main scientific aspects and data from the statistical analyses. The resultant Concise Glacier Inventory of China was published in Chinese in 2005, and in English in 2008 (Shi and others, 2008a). This book contains some corrections and revisions to the original data and includes some new research results on glacier change and runoff. The hydrological basins identified for the GIC are shown in Figure 1, and data on glacier distribution in the internal and external drainage basins of China are summarized in Table 1. The editor-in-chief of this book was Shi Yafeng, assisted by associate editors Liu Chaohai, Wang Zongtai, Liu Shiyin and Ye Baisheng and 13 other authors. It has been very well received and is considered as a general glaciology of China. In 2006, the success of the Glacier Inventory of China and its associated publications was recognized with the award of the Prize of National Science and Technology Progress (Second Class).

## CONCLUSION AND DISCUSSION

The main deficiency of the GIC described above is the rather long time lag between the aerial photos and printing of the topographical maps. Users of the glacier-inventory data need to consider the time at which the inventory was completed in a specific region.

The measurement of ice thickness and estimation of ice volume were carried out using the ground-based radio-echo sounding techniques developed by the former LIGG and applied to representative glaciers. Airborne radar sounding of ice thickness has yet to be further developed and applied.

It took about 23 years to complete the first GIC, because the manual measurement of the numerous glaciers on the topographical maps and aerial photos is inefficient and time-consuming, and at times the work was delayed by inadequate resources and other priorities.

Glaciers are changing rapidly, so a second GIC, that will use remote-sensing techniques, was started in 2007. This project will take 5 years to complete and will be invaluable for research into glacier change and for assessing water resources.

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