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Distribution, features and variations of glaciers in China

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Abstract. Since 1975 a new glacier inventory is being made in China with new aerial and ground stereophotogrammetric maps. In Chilien Shan, Tien Shan, Altai and part of the Chinghai-Tibet Plateau there are 17 123 glaciers covering an area of 22 181 km². This represents roughly half of the glaciers in China. The new results show that the previous 1959 survey underestimated the number and the area of glaciers. Analysis of the spatial distribution of the snow line shows clearly the three main sources of precipitation. From the 1950s to 1960s glaciers were retreating but in the 1970s positive mass balances appeared and the snow line descended. Temperature has decreased and precipitation increased since the 1950s and, on the basis of dendroclimatological data, this trend may last until the end of the century with an increase of advancing glaciers.

Distribution, caractéristiques et variations des glaciers en Chine

Résumé. Depuis 1975 on procède à un nouvel inventaire des glaciers de la Chine à l'aide de nouvelles cartes levées par photogrammétrie aérienne et terrestre. Dans le Chilien Shan, le Tien Shan et l'Altaï et une partie du Plateau du Chinghai-Tibet on trouve 17 123 glaciers recouvrant une superficie de 22 181 km². Cela représente en gros la moitié des glaciers chinois. Les nouveaux résultats montrent que le relevé précédent, effectué en 1959, avait sous-estimé le nombre et la superficie des glaciers. L'analyse de la distribution spatiale de la limite des neiges permanentes montre clairement les trois principales sources de précipitations. Des années cinquante aux années soixante les glaciers étaient en décrue; cependant au cours des années soixante-dix les bilans de masse positifs ont fait leur apparition et la limite des neiges s'est abaissée. Depuis les années cinquante la température s'est abaissée, les précipitations sont devenues plus abondantes et, sur la base de données dendroclimatologiques il est possible que cette évolution se poursuive jusqu'à la fin du siècle avec une augmentation du nombre de glaciers en crue.

In West China there is a series of well-known high mountains and plateaux partially covered by perennial snow and glaciers (Fig. 1). The meltwater from the glaciers in Altai, Tien Shan, Chilien Shan, Kunlun Shan and Karakoram offers essential conditions conducive to the development of agriculture under irrigation in northwest China's arid regions. Many large rivers in Asia, such as the Yellow River, the Yangtze River, the Lantsang River, the Ganges and the Indus are all nourished by the glaciers on the Chinghai-Tibet Plateau. In the southeastern part of this plateau and some other places, glacial activities give rise to catastrophic floods and mud-rock flow. Despite the close connections between the glacial activities and people's lives, research on glaciers was badly neglected before liberation with the exception of a few glaciers recorded by travellers, geographers and geologists. But since the founding of the People's Republic of China and especially since the year 1958, under the leadership of the Chinese Communist Party, we have been carrying out continuous and pertinent investigations of glaciers so as to meet the needs of socialist construction. A specialized research organ – Lanchow Institute of Glaciology and Cryopedology (formerly the Investigation Team for the Utilization of Snow and Ice on High Mountains, Academia Sinica) was set up. In addition, the multi-disciplinary expedition organized by the Chinese Academy of Sciences, the Mountaineering Expedition and the Departments of Geography of Lanchow, Peking and Nanking Universities and the Sinkiang Institute of Geography also devoted part of their time to the study of glaciers. Our studies were carried on in Chilien Shan, Tien Shan, Mt Jolmo Lungma and Mt Shisha Pangma in the middle section of the Himalayas and other mountainous regions in the southern part

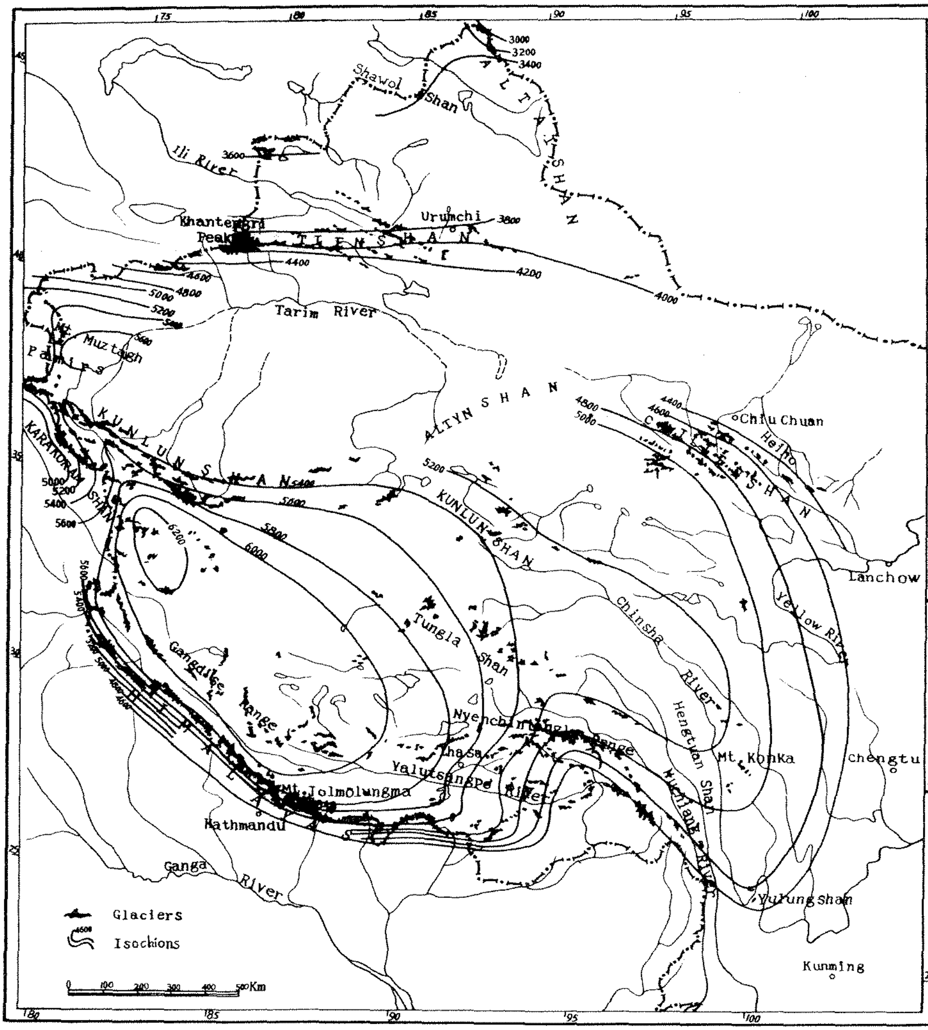

FIGURE 1. Map of distribution of existing glaciers and the snow line elevation in China.

of the Chinghai-Tibet Plateau. In recent years we have also conducted research on the Batura Glacier of the Karakorams inside Pakistan, which had an adverse influence on the building of the Karakoram highway. Though, compared with the past, we have made better progress in the field of glaciology there is still a long way for us to go to keep up with the advances elsewhere in the world. We would like to present a brief report concerning the preliminary results of our research on glaciers in China, cherishing at the same time high hopes of learning from the rich and valuable experience of our colleagues present at this workshop.

Due attention has been paid to making a glacier inventory with the development of glacier research in China. The initial statistics concerning the glaciers in Chilien Shan and Tien Shan, collected in 1958 and 1959, have been cited by Dolgushin (1961) and Lliboutry (1965) respectively. On account of incomplete data, numbers and areas of glaciers in those mountains were very much underestimated. In recent years, with the help of newly compiled aerial maps (1:100 000 and 1:50 000) and stereo-terrestrial photogrammetric maps, we have made inventories of glaciers in several mountainous regions, including name, coordinates, type, orientation, upper limits, elevation of terminus, elevation of firn line, length and area, etc. The glaciers are classified into hanging glaciers, cirque glaciers, cirque valley glaciers, valley glaciers, ice caps and so on.

Some firn line elevations were determined on the spot, while most were diagnosed according to topographical maps or calculated by Höfer's method.

Based on the results of the survey on glaciers in 1959, it was estimated that there are 483 glaciers in Tien Shan with a total area of 1446 km^2, but the recalculations in 1975 testified to the fact that there are 6896 glaciers in Tien Shan with a total area of 9548 km^2. The number of glaciers in Chilien Shan was calculated in 1958 roughly as 941 with an area of 1149 km^2, but the recalculation in 1977 testified to the fact that there are 3306 glaciers with a total area of 2063 km^2 (see Table 1).

TABLE 1. Statistics of inventoried glaciers in China

Mountain	Number	Area [km^2]	Investigator
Altai	457	271	Ren Ping-hui, 1978
Shawol Shan	13	16	Fei Ching-shen, 1978
Tien Shan	6 896	9 548	Ren Ping-hui and others, 1975
Chilien Shan	3 306	2 063	Fei Ching-shen, 1977
Northern slope of Mt Jolmo Lungma	217	772	Wang Li-lun, 1973
West Kunlun (from Yarkand River to 80°31′E)	3 180	4 331	Ying Cheng-fu and others, 1978
Nyinchintangla Range (short of data to the east of Pome)	2 756	4 880	Chang Fan and others, 1978
Animaching	50	139	Kang Nin, 1978
Lhasa Na Shan	248	161	Li Wen-yue and others, 1978
Total	17 123	22 181	

In 1964 the total area of glaciers in China was roughly estimated to be about 44 000 km^2. This figure is sure to undergo a certain change with the completion of our inventory.

Now we would like to deal briefly with snow lines and distributions of glaciers in China in general outline. In west China's mountainous regions lying in the interior of Eurasia at middle latitudes far from the sea, precipitation decreases abruptly and unequally from the marginal mountains to the inner Chinghai-Tibet Plateau, resulting in making the isochions form irregular concentric circles (Fig. 1). From north to south, the snow line elevation of Altai is 3000-3400 m, that of Tien Shan 3600-4400 m and that of Kunlun Shan 5500-5800 m. In the Ali region of Tibet and in the middle section of the Himalayas, the snow line elevation on the northern slope is even as high as 6000-6200 m, which may be the highest snow line elevation in the Northern Hemisphere, but that on the southern slope of the Himalayas descends to 4600-5500 m. The isochion in the southeastern part of the Chinghai-Tibet Plateau has a northerly convex form, which, perhaps, merits our special attention. Here is the main thoroughfare for the monsoon from the Indian Ocean to enter the plateau and the snow line elevation of Aza Glacier descends to 4500 m, about 1500 m lower than that at the same latitudes in west Tibet.

Variations of the snow line elevation clearly show three main sources of precipitation on glaciers in China. The southwestern Indian Ocean monsoon feeds glaciers on the Himalayas, Nyenchintangla Range and in the western part of Hengtuan Shan. The southeasterly Pacific monsoon nourishes glaciers in the eastern part of Hengtuan Shan and northwards, in the eastern section of Chilien Shan. The water vapour brought by the prevailing westerly circulation greatly decreases after entering the middle part of Asia. It is still the main source of alimentation for the development of most of the glaciers in China, including those in Karakoram, Kunlun Shan, Tien Shan, Altai and those in the western section of Chilien Shan.

Major glacier areas in China are distributed in those regions with more precipitation and high altitudes. They are mainly Tomur Khan, Khantengri knot of Tien Shan, West Kunlun Shan (78-82°E), Karakoram near Mt Chogori (K2), the middle section of the Himalayas and the Nyenchintangla Range in the southeastern part of Tibet, etc. In each of these regions there are lots of glaciers with an area amounting to several thousand square kilometres. The Yinsukaiti Glacier on the northern slope of Mt Chogori (K2) in Karakoram is as long as 42 km, maybe the largest glacier within the territory of China. But the longest glacier which has been investigated is the Tomur Glacier on the southern slope of Tomur Peak in Tien Shan, having a length of 36.7 km, the next two are the Kaching Glacier in the southeastern part of Tibet and the Kalage-yule Glacier on the eastern slope of Tomur Peak in Tien Shan, their lengths reaching 35.0 km and 32.8 km respectively.

Several representative glaciers have been chosen to carry on various studies of their properties, such as their accumulation, ablation, radiation and heat balance, ice formation, ice temperature and motion. Since the sixties, we have been classifying them into two types according to their main properties and geographical environments. The first one is called the continental type, which is distributed in Altai, Tien Shan, Chilien Shan, Kunlun Shan and those on the northern slope of the middle and western sections of the Himalayas; the second one is called the maritime type, which is distributed in southeastern Tibet and Hengtuan Shan. In recent years, while conducting research into the glaciers in Tibet, we drew a tentative line between the two types of glaciers.

Continental glaciers are those developed under the continental climate. The annual precipitation in their accumulation areas is less (300-1000 mm in general), the snow line elevation is very high, the annual mean air temperature near the snow line is very low (-6 to -15°C) and the ablation is considerably weaker (the ablation at the terminus averages 1-3.5 m of water per year in general).

The main source of heat for ablation is that of solar radiation and ice formation mainly results from infiltration and congelation. In the lower part of the accumulation area, there is an infiltration congelation zone (a superimposed ice zone), where ice formation was completed in 1-2 years. The above belongs to the infiltration zone and cold infiltration-recrystallization zone, but the recrystallization zone as seen in Antarctica, has never appeared even on the top of Mt Jolmo Lungma. The temperature in the active layer of 15-20 m in thickness belongs to that of the cold type without exception (Fig. 2). Take the glaciers in the western part of Chilien Shan for instance, the temperature in the 10-m deep layer may be lower than -10°C, close to that of the sub-polar glaciers at high latitude. The velocity of motion is comparatively slow. The small glaciers not longer than 10 km flow at a velocity of not more than 40 m per year, while at a certain point on the Rongbuk Glacier with a length of 22 km (on the northern slope of Mt Jolmo Lungma) a maximum velocity of 117 m per year has been observed.

China's maritime glaciers are developed under a monsoon climate. The annual precipitation in the accumulation area of certain glaciers in the Nyenchintangla Range reaches approximately 2500 mm, with a mean air temperature of -2 to -4°C near the snow line. The ablation value at the glacier terminus is 10 m of water per year, and in the heat sources of ablation, turbulent exchange and condensation heat assume

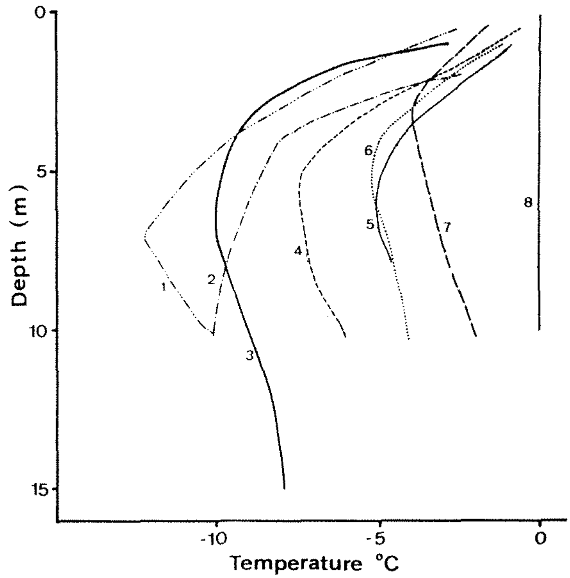

FIGURE 2. Temperature profiles in the active layer in the middle and upper parts of the ablation area of some glaciers in China. 1 – Lachukou Glacier, Chilien Shan, 31/7/76; 2 – July 1st Glacier, Chilien Shan, 18/7/75; 3 – Yanglung River No. 5 Glacier, Chilien Shan, 19/7/77; 4 – Urumchi River No. 1 Glacier, Tien Shan, 19/7/65; 5 – Shuikuan River No. 4 Glacier, Chilien Shan, 10/8/63; 6 – Yepokangara Glacier, Himalayas, 4/5/64; 7 – Rongbuk Glacier, Himalayas, 29/5/66; 8 – Kouhsiang Glacier, Nyenchintangla Range, 6/8/65.

considerable proportions (on Kouhsiang Glacier in the southeastern part of Tibet it is 37 per cent). Ice formation belongs to the temperate infiltration zone. The temperature of ice at the bottom of the active layer is at the pressure melting point all the year round, with only that in the superficial layer falling lower than 0°C in winter. The termini of certain longest glaciers even extend to subtropical forests. The glaciers move at a great velocity. The observed maximum velocity of the ice tongue of Aza Glacier is 276 m per year. Below the ice falls of some valley glaciers, obvious ogives develop.

The Chinese glacial observers in the fifties and sixties reported without exception that all the glaciers were shrinking. Though it was observed in the seventies that most of the glaciers were still receding, positive mass balance values for several glaciers began to appear with a lowering of snow line. Several glaciers in certain mountains showed distinct advances, and some even belong to the surge type.

We have data (in a period of 20 years) concerning the variations of the termini of 22 glaciers in Chilien Shan (all small glaciers not longer than 10 km) which testify to the fact that during 1956-1976 all the termini made a common retreat. The retreat value of eight glaciers in the eastern section of Chilien Shan was 12.5-22.5 m per year, and that of 14 glaciers in the middle and western section was 1.2-2.7 m per year. In recent years the retreating rate reduced. The four glaciers under observation in the past few years all appear positive in their mass balance and the snow line obviously descended. Take July 1st Glacier for instance, the positive value amassed in the three years 1974-1977 is +768 mm. It seems to us that glaciers in Chilien Shan are going through a process from retreat to stability.

We have also fragmentary data concerning six glaciers in Tien Shan. Let us take the well-known Muzart Glacier (located on the ancient Silk Road) 29 km in length. Its terminus retreated at a rate of 15 m per year from 1909 to 1959, but its retreating reduced to 2 m per year from 1964 to 1978. The seven years observation of mass balance of the Urumchi River No. 1 Glacier showed that from 1959 to 1962 the value was negative, with a total output equivalent to -570 mm of water; in the three years 1962-1965 the positive value appeared with a total input equivalent to 570 mm of water. But from 1965 to 1966, a negative value of -357 mm appeared again. From 1962 to 1973, the terminus of this glacier retreated at a rate of 6.9 m per year. It has already been discovered that the Kochikar Glacier (25.5 km in length) on the southern slope of Tomur Peak is in a state of advance, yet the exact value of this advance has not been determined.

Three glaciers on Mt Myztagh and Mt Kungur to the east of the Pamirs retreated at a rate of 1.7-3.7 m per year from 1956 to 1960, but it was discovered in 1978 that these glaciers were obviously advancing. Ten glaciers in west Kunlun Shan to the east of Yarkand River were found to be in a state of advance, one of them by the name of Chuanshuikou Glacier 10 km in length advanced at a rate of 15.5 m per year from 1968 to 1976.

The termini of the valley glaciers on the northern slope of Mt Jolmo Lungma, are all covered with thick supraglacial debris and in more than 50 years their locations underwent no conspicuous changes. Take the Rongbuk Glacier for instance. Its terminus has always remained at the same place, 7.3 km to the north of Rongbuk Lamasery. But the glacier has become thinner and the separation between the trunk and the tributaries and the shrinking phenomena finding expression in ice pyramids are exceptionally clear.

The Aza Glacier in the southeastern part of Tibet is roughly 20 km in length, and its terminus has descended to 2400 m a.s.l. Since the fifties, its terminus has always been in a state of rapid retreat. The retreat rate was 10.8 m per year from 1973 to 1976. There is a glacier in the southern part of Tibet, named Chiangyong Glacier with a length of 5 km. It retreated at a rate of 15 m per year from 1940 to 1965. The retreat decreased to 4 m per year from 1965 to 1975.

Since the fifties the decline of temperature and the increase of precipitation have been the predominant trend in the western part of China. According to the dendro-climatological data obtained from several places, the declining temperature trend will continue till the end of this century or the beginning of the next. From this we predict that the number of advancing glaciers may increase considerably in the days to come. But the relation between the fluctuations of glaciers and the changes of climate is very complex. The law ruling the fluctuations of glaciers is still left to a considerable extent to the systematic study and observation of us all.

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DISCUSSION

See pp. 125-127.