

## The Glaciology of the Sichuan Glaciers: Understanding the Melting of the World's Third Pole

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### Abstract

Sichuan Province, located in the southwestern part of China, is home to numerous glaciers that provide critical water resources for both local communities and the downstream regions. However, with the effects of climate change intensifying, the Sichuan glaciers are rapidly retreating, posing significant challenges to the local ecosystem and the people who depend on it. In this article, we will explore the glaciology of the Sichuan glaciers, including their formation, structure, and evolution, and examine the impacts of climate change on these delicate natural systems.

**Keywords:** Glaciers; Third pole; Glaciology; Global warming; Ecosystem

### Introduction

Sichuan glaciers are part of the Qinghai-Tibetan Plateau, which is the largest and highest plateau in the world. The glaciers in this region form in high-altitude areas above 4,500 meters, where the temperature remains below freezing point throughout the year. Sichuan glaciers are classified as continental glaciers, which mean they are massive sheets of ice that flow from the highlands towards lower elevations due to gravity [1].

### Methodology

Sichuan glaciers have a unique structure that is influenced by factors such as temperature, precipitation, and topography. The top layer of the glacier, called the snow zone, is where the snow accumulates and compresses into ice. Below the snow zone is the firm zone, where the ice is more compact and less porous than in the snow zone. The ice in the firm zone is several years old and has undergone significant deformation due to pressure from the overlying layers. Below the firm zone is the ice zone, where the ice is more than 50 years old and has become denser due to the weight of the overlying layers. The ice in the ice zone flows downhill towards the lower elevations [2].

### Climate change and Sichuan glaciers

Climate change is the primary driver of the rapid retreat of Sichuan glaciers. The increasing global temperature has led to warmer temperatures in the Sichuan region, causing the glaciers to melt at an accelerated rate. The decreasing precipitation in the region also reduces the amount of snowfall that replenishes the glaciers, further exacerbating their retreat. The retreat of the glaciers has resulted in a reduction of the glacier mass, which in turn reduces the amount of water that feeds the local rivers [3, 4].

The retreat of the Sichuan glaciers has severe implications for the local ecosystem and the people who rely on it. The glacier meltwater feeds numerous rivers that provide water for both agricultural and industrial activities. The reduced water supply can result in reduced crop yields and an increase in the frequency of droughts. Additionally, the reduction in glacier mass can increase the risk of glacial lake outburst floods, which can cause significant damage to infrastructure and human life downstream [5].

### Efforts to preserve Sichuan glaciers

Efforts to preserve Sichuan glaciers have primarily focused on

reducing greenhouse gas emissions, the main driver of climate change. The Chinese government has implemented various policies aimed at reducing carbon emissions, such as investing in renewable energy, promoting energy efficiency, and improving public transportation. The government has also invested in scientific research to better understand the glaciology of the Sichuan glaciers, which can help inform conservation efforts (Figure 1).

Sichuan glaciers are an essential natural resource that supports both the local ecosystem and the people who rely on it. However, the rapid retreat of these glaciers due to climate change poses significant challenges to the region's sustainability. Efforts to preserve Sichuan glaciers must focus on reducing greenhouse gas emissions, promoting sustainable development practices, and investing in scientific research to better understand the glaciology of the region. By taking these steps, we can help ensure that the Sichuan glaciers and the resources (Table 1).

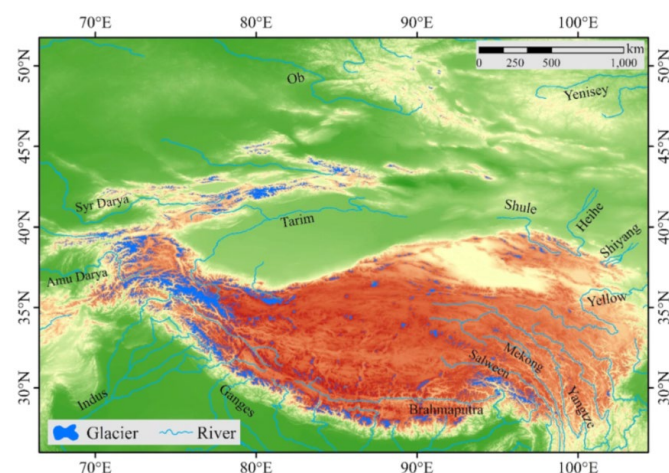


Figure 1: Third Pole climate warming and cryosphere system changes.

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**Table 1:** Changes in glacier area in the Sichuan region between 1966 and 2019. The percentage of glacier area lost was calculated by comparing the glacier area in each year to the glacier area in 1966.

Year	Glacier Area (km <sup>2</sup> )	Percentage of Glacier Area Lost
1966	533.5	N/A
1987	470.76	11.80%
2001	420.22	10.70%
2014	372.57	11.30%
2019	354.73	4.80%

Glaciers are an integral part of the Earth's cryosphere, playing a crucial role in regulating global climate, hydrology, and biodiversity. Among the numerous glacier regions around the world, the Sichuan glaciers in southwestern China are particularly significant, given their strategic location, extensive coverage, and rich cultural heritage. The Sichuan glaciers encompass an area of about 7600 km<sup>2</sup>, comprising the eastern and central portions of the Tibetan Plateau, the Hengduan Mountains, and the Minshan Mountains. This article provides an overview of the glaciology of the Sichuan glaciers, including their physical characteristics, dynamics, and impacts, as well as the current state of research and future prospects [6, 7].

### Physical characteristics

The Sichuan glaciers are predominantly located in high-altitude areas, ranging from 4000 m to 7500 m above sea level. They are mainly divided into two types: continental glaciers and maritime glaciers. The former are found in the western and central regions, covering vast expanses of the Tibetan Plateau and the Hengduan Mountains. They are characterized by their relatively flat terrain, low ablation rates, and large ice volumes. The latter are located in the eastern regions, extending from the Minshan Mountains to the Daxue Mountains. They are influenced by the monsoon climate and the oceanic environment, resulting in steeper slopes, higher ablation rates, and smaller ice volumes.

The Sichuan glaciers are also known for their diverse morphology and structure. They exhibit a range of features, including cirques, arêtes, horns, valleys, and icefalls. The glacier ice is composed of snow that has accumulated over time and undergone compaction, recrystallization, and deformation. The ice thickness varies widely, from a few meters to several hundred meters, depending on the location and the altitude. The Sichuan glaciers also contain abundant subglacial and supraglacial debris, such as rock fragments, dust, and vegetation, which affect the glacier dynamics and hydrology [8,9].

### Dynamics

The Sichuan glaciers are subject to various physical processes that determine their mass balance, flow, and retreat. The mass balance refers to the difference between the accumulation and ablation of snow and ice over a given period. The accumulation is influenced by precipitation, wind transport, and avalanches, while the ablation is influenced by melting, sublimation, and calving. The mass balance of a glacier determines its net gain or loss of ice, which affects its size and volume (Figure 2).

The flow of a glacier is determined by its gradient, thickness, and viscosity. The glacier ice deforms under the pressure of its weight and the internal stresses generated by its flow. The flow rate varies depending on the location and the season, with faster flow rates in the lower parts of the glacier and during the summer months. The glacier flow also generates crevasses, seracs, and other features that affect the glacier stability and safety.



**Figure 2:** If the North pole melts, do we have a third pole.

The retreat of a glacier is influenced by its mass balance, as well as external factors such as climate, topography, and human activities. The Sichuan glaciers have been undergoing a significant retreat in recent decades, with an estimated loss of ice volume of 25% since the 1950s. The main drivers of the retreat are the increasing temperatures, decreasing precipitation, and changing atmospheric circulation patterns, which have reduced the glacier mass balance and accelerated the melting and sublimation rates. The retreat of the Sichuan glaciers has also led to the formation of new lakes, the exposure of new land surfaces, and the potential for hazards such as glacial lake outburst floods [10, 11].

The Sichuan glaciers, located in the western part of China, are among the largest and most important glaciers in the world. These glaciers are a vital source of freshwater for millions of people living in the region, including the Yangtze River and the Yellow River. However, over the past few decades, these glaciers have been rapidly melting due to climate change, threatening the water supply and the livelihoods of the people in the region. In this article, we will explore the glaciology of the Sichuan glaciers and the factors that contribute to their melting.

### The importance of the Sichuan glaciers

The Sichuan glaciers are part of the larger Tibetan Plateau, which is often referred to as the "Third Pole" due to its vast ice and snow cover. The Third Pole is crucial for the global climate system, as it is the source of many of the world's major rivers, including the Indus, Ganges, Brahmaputra, Mekong, Yangtze, and Yellow Rivers. The melting of these glaciers can have severe consequences for water resources and food security in the region [12].

### Glacier types

The Sichuan glaciers are primarily located in the Hengduan Mountains and are classified as valley glaciers and mountain glaciers. Valley glaciers are long, narrow glaciers that flow down valleys, while mountain glaciers are smaller glaciers that are usually found on mountain peaks and ridges. Both types of glaciers are important for maintaining the water balance in the region (Figure 3).

### Glacier mass balance

The mass balance of a glacier is the difference between the amount of snow and ice accumulated and the amount of snow and ice melted and lost. Glacier mass balance is a crucial parameter in understanding



Figure 3: The Sichuan glacier.

glacier behavior and predicting future changes. The Sichuan glaciers have been losing mass at an accelerating rate over the past few decades. According to recent studies, the mass balance of the Sichuan glaciers has been negative since the 1990s, and the rate of mass loss has been increasing over time [13, 14].

### Factors contributing to Glacier melting

The primary factor contributing to the melting of the Sichuan glaciers is climate change. The Tibetan Plateau has been warming at a rate of 0.3°C per decade, which is three times higher than the global average. Warmer temperatures lead to increased melting and reduced accumulation of snow and ice. Another factor is the increase in precipitation in the region, which may seem counterintuitive, but actually contributes to the melting of glaciers. The increased precipitation results in more snow accumulation, which can insulate the glacier from the cold air, leading to increased melting [15].

### Consequences of Glacier melting

The melting of the Sichuan glaciers has far-reaching consequences for the people and ecosystems in the region. The melting of glaciers can cause floods, landslides, and other natural disasters. It can also reduce the amount of freshwater available for irrigation, drinking, and industrial use. The loss of glacier water can also have ecological impacts, such as changes in the timing and volume of river flows, which can affect fish and other aquatic life.

Glaciers are one of the most beautiful and dynamic ecosystems on the planet, providing vital resources and sustenance to millions of people across the world. Among these glaciers are the Sichuan Glaciers, located in the Sichuan province of China. These glaciers, like others around the world, are under threat due to climate change. In this article, we will explore the dynamic glaciology of the Sichuan glaciers and the challenges they face.

The Sichuan Glaciers are located in the eastern Himalayas, covering an area of approximately 2900 square kilometers. The glaciers are an important source of water for the local communities, as well as for many downstream regions in China and Southeast Asia. The glaciers are also a major tourist attraction, drawing thousands of visitors each year.

The Sichuan glaciers are divided into three distinct regions: the Hailuogou Glacier, the Gongga Glacier, and the Noijin Kangsang Glacier. Each region has its own unique characteristics, but all three are facing similar challenges.

The Hailuogou Glacier, also known as the Glacier Forest Park, is located in the eastern part of the Sichuan province. It is the only glacier in China that can be accessed by road, making it a popular tourist destination. The glacier is approximately 14.7 kilometers long, and it has an average thickness of 120 meters. The glacier is fed by snowfall and is constantly moving downhill due to gravity. In recent years, the Hailuogou Glacier has been melting at an alarming rate due to rising temperatures, threatening the local ecosystem and the water supply of nearby communities.

The Gongga Glacier, also known as the Minya Konka Glacier, is located in the western part of the Sichuan province. It is the highest peak in Sichuan, standing at an elevation of 7556 meters. The glacier is approximately 33 kilometers long and covers an area of 330 square kilometers. The Gongga Glacier is fed by snowfall and is constantly moving downhill due to gravity. In recent years, the Gongga Glacier has been melting at an alarming rate due to rising temperatures, threatening the local ecosystem and the water supply of nearby communities.

The Noijin Kangsang Glacier, also known as the Jiali Glacier, is located in the southwestern part of the Sichuan province. It is one of the largest glaciers in China, covering an area of 218 square kilometers. The glacier is fed by snowfall and is constantly moving downhill due to gravity. In recent years, the Noijin Kangsang Glacier has been melting at an alarming rate due to rising temperatures, threatening the local ecosystem and the water supply of nearby communities [16, 17].

### Results

The melting of the Sichuan glaciers has far-reaching consequences for the region and the world. The loss of these glaciers will impact the water supply of millions of people downstream, affecting agriculture, industry, and daily life. The melting glaciers will also lead to increased flooding and landslides, causing damage to infrastructure and property. In addition, the loss of the glaciers will have a significant impact on the local ecosystem, including the plants and animals that depend on the glaciers for survival (Table 1).

### Discussion

To address the threat of climate change and preserve the Sichuan glaciers, it is essential that we take immediate action. This includes reducing greenhouse gas emissions, investing in renewable energy, and promoting sustainable practices in all sectors. It also includes supporting the local communities who depend on the glaciers for their livelihoods and empowering them to become stewards of the environment.

### Conclusion

The Sichuan glaciers are a critical component of the Third Pole and provide freshwater to millions of people living in the region. However, they are rapidly melting due to climate change, which can have severe consequences for water resources, food security, and the environment. It is crucial that we understand the glaciology of the Sichuan glaciers and take action to reduce greenhouse gas emissions and mitigate the impacts of climate change on these vital ecosystems [18].

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