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Research progress on simulation of high-altitude glaciers and permafrost on the qinghai-tibet plateau based on hydrological models

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Abstract. The Qinghai-Tibet Plateau's uniqueness: The Qinghai-Tibet Plateau is located in a high-altitude region, with a much higher average elevation than the surrounding areas at the same latitude. It is home to the majority of the world's glaciers and permafrost in the middle and lower latitudes. Glaciers are extremely sensitive to climate change, and the unique glaciers and permafrost on the Qinghai-Tibet Plateau are especially vulnerable. The predecessors simulated and predicted glaciers using the distributed hydrological model and the glacier system model, and frozen soil using the accumulated temperature statistical model and the freezing number model. Simultaneously, these models have gone through a development process from low-end to high-end, which improves the accuracy and fit of the Qinghai-Tibet Plateau study. This paper will compare the advantages and disadvantages of these distributed hydrological models and glacier system models using a literature review method. We discovered that the glacier model's distributed hydrological model can simulate and analyze glacier runoff, and the Glacer's system model can better classify the glacier. The freezing mumer model has made significant contributions to the dynamic change simulation of frozen soil and the estimation of its maximum thawing depth.

Keywords: qinghai-tibet plateau, glaciers, permafrost, climate warming, model.

1. Introduction

Climate change is one of the hot issues in the field of earth sciences today. Global warming of the climate system has become a fact. Almost all regions of the world have experienced a warming process since 1950, and the global average temperature has increased by 0.85°C from 1880 to 2012. In the past 30a, the warming rate of surface temperature per 10a is higher than any period since 1850. Climate warming will lead to a series of environmental problems, such as the melting of the Arctic and Antarctic ice sheets, the retreat of mountain glaciers, and the rise of sea levels, which has attracted widespread attention. Warming affects the cryosphere of glaciers and permafrost. And because of the sensitivity of the cryosphere, it can intuitively reflect changes in climate. This paper adopts the method of table summarization to explore the development and changes of the glacier model and the permafrost model over the years, lists the differences, advantages, and disadvantages of the models in detail, and makes a comparison and summary. It hopes to provide some insightful viewpoints for further study in this field.

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2. Definitions

2.1. Cryosphere

The cryosphere is defined as the layer in which water on the Earth's surface exists in solid form, including permafrost (seasonal and permafrost), glaciers (mountain glaciers, polar ice caps, ice shelves, etc.), perennial snow, snowfall, sea/river/lake ice. Since the temperature increase in the cryosphere is generally greater than that in other regions, the positive feedback of the cryosphere to the climate system can exacerbate climate warming [1]. It is the fastest, most significant, and most indicative of global change, as well as the most direct and vulnerable layer to the climate system [2]. New research suggests that the amount of water that has melted in the cryosphere since 2003 may have overtaken the thermal expansion of ocean water to become the main contributor to sea level rise. Changes in the cryosphere will affect the ecology, hydrology, environment and sustainable development of a region [3].

China's cryosphere contains most of the world's mid-latitude and low-latitude mountain glaciers and permafrost, most of which are distributed on the Qinghai-Tibet Plateau [4]. Recent surveys show that China's cryosphere is undergoing rapid changes, such as retreating glaciers, degrading permafrost, an unstable cryosphere environment, and the resulting increased dangers [1].

2.2. Qinghai-tibet plateau glaciers

There are 36,924 glaciers in the Qinghai-Tibet Plateau, with a total area of 50,657 km and a total glacier reserve of 4,680.5 km, accounting for 79.6%, 85.2%, and 83.6% of modern glaciers in western China. Due to its high altitude and unique geographical location, the Qinghai-Tibet Plateau has special eco-hydrogeological conditions and unique socioeconomic effects [5]. Modern glaciers are the source of many rivers. Glacier water resources are the bodies of water released during the melting period of glaciers; that is, the runoff of glacial meltwater. Meltwater from glaciers flows down the mountain, regulating the multi-year runoff of the rivers under the mountain. Most of the rivers in the Qinghai-Tibet Plateau rely on glaciers to supply their water sources, which play an important role in the development of the national economy in the region. In recent decades, the retreat of glaciers has gradually accelerated, and the river runoff developed in the Qinghai-Tibet Plateau has shown a new pattern of change. The retreat of glaciers in a short time will increase the flow of rivers, but as the glaciers continue to retreat and melt, the amount of meltwater from the glaciers will be greatly reduced, and the rivers mainly supplied by the glaciers will be greatly affected [6]. Related research also confirmed this phenomenon.

3. Qinghai-tibet plateau permafrost

China's permafrost area ranks third in the world, with a total area of about 2.15 million square kilometers of permafrost. China’s high altitude permafrost area ranks first in the world [7]. Most of the frozen soil is distributed on the Qinghai-Tibet Plateau. 53% of the Qinghai-Tibet Plateau is covered by permafrost, which is the highest altitude and low-latitude frozen soil in the world. The area with the largest land area is [8].

The temperature in the Qinghai-Tibet Plateau is higher, the burial is shallower, and it is more significantly affected by the climate [1]. Therefore, the permafrost of the Qinghai-Tibet Plateau is more sensitive to temperature changes, which are considered to be the key indicators of chemistry [2].

Investigations have shown that the climate of the Qinghai-Tibet Plateau has undergone significant changes in recent decades [9], resulting in changes in glaciers and permafrost in the region, which has attracted much attention from social and scientific circles at home and abroad [3]. At the same time, changes in climate and hydrology further affect the ecology and environment of the Qinghai-Tibet Plateau and surrounding areas [10], thereby affecting the socio-economic development of this region and its deeper national interests.

The development of the glacier hydrological model provides a more powerful means for the study of glacier hydrology and water resources. Glacier hydrological models have been developed from the earliest stochastic models [11], physical models [12], and distributed models [13]. The development of

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remote sensing technology has a tortuous development process. In the future, there will be breakthroughs in technology, and the accuracy of models will be improved.

4. Research progress on high-altitude glacier models

4.1. Glacier model

The use of digital simulation is an indispensable method. The predecessors used the distributed hydrological model, the accumulated temperature statistical model, and the freezing number model. This paper summarizes and analyzes the advantages and disadvantages of the following models:

Table 1. Summary of advantages and disadvantages of two different glacier models.

	Author and age	**Specific content of the model**	**Advantages and disadvantages of the model**
Distributed hydrological model	Institute of Water Resources, Chinese Academy of Water Conservancy and Hydropower, 2010	The distributed hydrological model is used to quantitatively calculate the runoff composition and the multi-year change trend of each component in the typical area of glaciers, and the regional water equilibrium method is used to quantitatively evaluate the contribution of glacier changes to the regional hydrological cycle using remote sensing products.	It is relatively progressive, but there are still problems such as scale conversion, spatial parameter calibration, and the effectiveness and stability of numerical algorithms in actual watershed simulations.
Glacier's system model	Unknown	Glaciers in a certain area, regardless of their number, size, orientation, and type, can be called a glacier system as a whole . According to the region, it can be divided into several levels, and the relationship between glaciers in the system can be used as the structure of the glacier system.	By treating multiple glaciers as a whole and cataloguing them, we can analyze their structural characteristics as a whole, so as to draw general conclusions.

4.2. Permafrost model

Table 2. Summary of advantages and disadvantages of two different permafrost models.

	Author and age	**Specific content of the model**	**Advantages and disadvantages of the model**
Statistical model of temperature accumulation	unknown	The effect of permafrost degradation on runoff change was qualitatively clarified, and the control effect of active layer and thawed interlayer on runoff was quantitatively assessed.	The model shows instability.
Freezing number model	Nan etal,2012	Using GIMMS NDVI3g, rainfall, temperature and maximum melting depth data, combined with a variety of statistics and factor identification methods, the contribution rate of precipitation, temperature and maximum melting depth to the change of NDVI on the permafrost zone is quantitatively calculated.	The freezing number model can be used to analyze, simulate and predict the distribution of permafrost, and has been successfully applied in high latitude permafrost areas. However, the freezing number model proposed by Nelson does not have obvious physical significance and is often classified as empirical statistics.

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5. Discussion

With the continuous increase of satellite remote sensing data sources, the innovation and enrichment of glacier area extraction methods have been promoted to a large extent, which are mainly divided into two categories: artificial visual interpretation and computer-aided classification. On the basis of rich professional experience and sufficient on-the-spot investigation, visual interpretation can achieve high accuracy and can effectively distinguish and identify ice bond cover, but this method has low production efficiency and is expensive to extract large-scale glacier areas. The boundaries are easily misplaced. After decades of exploration, the distributed hydrological model/Glacier's system model established by scholars has overcome the classification problem. The distributed hydrological model can accurately perform the hydrodynamic analysis of glacier runoff and monitor the changes of the glacier. Glacer's system The model is simple to operate, widely used, and has higher precision. It can classify and study different types of glaciers and further simulate and analyze the dynamic changes of glaciers under the influence of climate. It is one of the most widely used methods in practice.

The frozen soil shows that the island-shaped permafrost gradually disappears, the upper limit decreases, the thickness decreases, the thickness of the active layer increases, the depth of the seasonal frozen soil decreases, the freezing time is shortened, and the average annual low temperature increases. Although there are many problems in the previous frozen soil model species, which mainly focus on the current and future distribution, especially the reason for the difficulty in collecting sampling points and measurement points, the lack of raw data makes few models able to provide the evolution of permafrost, and no model can outline the Qinghai-Tibet In the degraded zone, the statistical model of temperature accumulation and the freezing mumber model overcome the above factors, especially the quantitative evaluation method established by the distributed model of the freezing mumber model, which is excellent in simulating the dynamic change of frozen soil and estimating its maximum thawing depth contribution.

6. Conclusion

The current state of high-altitude glacier meltwater, as well as models to simulate future high-altitude glacier development trends. These models have experienced a developmental trend from having many flaws to gradually improving, making our study of highland glaciers more accurate. However, it cannot be ignored that these models are more or less flawed, making the results not completely convincing. At present, the glacier model has overcome the classification problem of glaciers and glacier water in the Qinghai-Tibet Plateau. In particular, the Glacer's system model is easy to operate, widely used, and has higher accuracy. It can analyze the typical glaciers in different areas of the Qinghai-Tibet Plateau through field measurement and laser altimetry technology. The characteristics of spatial and temporal differences and the mechanism of their impact on climate change The frozen soil model reflects its response to climate change by simulating the multi-year change characteristics of the frozen soil and further conducting a multi-layer and comprehensive analysis of the ecological and hydrological problems after the degradation of the frozen soil. Efforts should be made to improve the accuracy and precision of the model. Most of the glacier models only study the thickness, area, and end changes of the glacier. In the future, it will be necessary to carry out research on the changes in the movement speed of the glacier, the height of the balance line, etc., so as to fully understand the changing characteristics of the glacier. In the future, the frozen soil model will be used to strengthen systematic research on cryosphere change mechanisms. Through further understanding of the process and change mechanism, it is possible to accurately and quantitatively predict the future development trend of the cryosphere and further clarify its interaction with the hydrosphere and biosphere. influence and chain reaction mechanisms.

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