Changes in Central Asia's Water Tower: Past, Present and Future

Known as the "water tower of Central Asia", the Tienshan Mountains is the main water source and ecological barrier in this region. It is about 2,500 kilometers long and 250 to 350 kilometers wide, spanning regions of Uzbekistan, Kyrgyzstan, south-eastern Kazakhstan, and the Xinjiang Uyghur Autonomous Region in China. It consists of a series of mountains, basins and valleys, and boasts one of the most developed glacier mountains in the world. The Tienshan Mountains feeds the majority of the area's rivers through a combination of ice and snow melt water in the alpine areas, precipitation in the mid-altitude forests, and fissure water in the low altitude areas. The characteristics of the form, supply and conversion of the water resources are unique in the world and are highly representative in the arid regions.

The rapid warming affects the energy and mass balance of glacier surfaces, and alters the original glacier/snow melt processes, thereby affecting the total water storage and river recharge. Changes in the water system, glacier dynamics and impacts of climate change on runoff in Central Asia have become hot spots in global change research.

Recently, a group of scientists, led by Prof. CHEN Yaning at the Xinjiang Institute of Ecology and Geography, CAS, analyzed the changes in temperature and precipitation of this region, and investigated the resulting changes in glacier and snow cover based on multisource data, including *in situ* observations, reanalysis data and remote sensing images. Further, the hydrological processes and water resources in the Tienshan Mountains were systematically studied. As a result, they identified a noticeable warming and the accompanying fluctuant precipitation changes over the past half century. At a rate of 0.3 °C per decade, this obvious warming is much stronger than the global average. Spatially, temperatures rose the fastest in the Middle and East Tienshan Mountains.

The rapid warming along with changes in precipitation caused changes in glacier/snowmelt processes, thereby affecting the runoff and water storage. The snowfall fraction (ratio of snowfall to precipitation) experienced a downward trend, along with a shift from snow to rain. Approximately 97.52% glaciers in the Tienshan Mountains showed retreating trends. Higher glacier degradation rates were recorded during the years from 2000 to the 2010s, compared to the decades from the 1960s to the year 2000 for the North Tienshan Mountains and the Bogda Peak in the

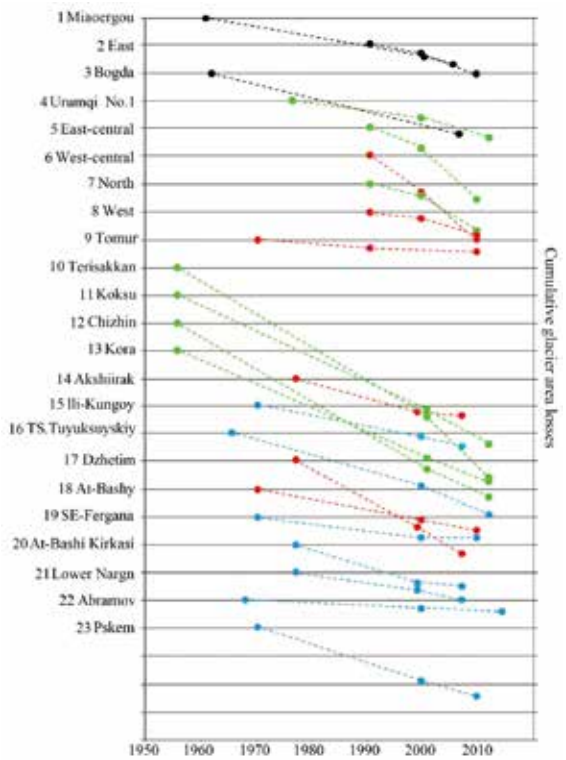

Figure 1: Recent shrinkage of selected glaciers in the Tienshan Mountains. The colors represent sub-regions, with blue representing the West Tienshan Mountains, red representing the Middle Tienshan Mountains, green representing the North Tienshan Mountains, and black representing the East Tienshan Mountains. Lines represent 10% units, the first measurement equals 100% of glaciers in the reference year.

eastern part of the Tienshan Mountains (Figure 1). Snow cover shows a decreasing trend, with the declining trends of maximum and minimum snow cover areas being 672 km^2/a and 60 km^2/a, respectively.

River runoff responds in a complex way to changes in climate and the cryosphere. It appears that catchments with a higher fraction of glacierized area showed mainly increasing runoff trends, while river basins with less or no glacierization exhibited large variations in the observed runoff changes. The total water storage in the Tienshan Mountains also experienced a significant decreasing trend, with an average decreasing rate of 3.72 mm per year (aggregating 2.23 billion cubic meters per year). The strongest reduction of water storage was mainly distributed in the middle Tienshan Mountains, consistent with the areas showing the highest temperature increasing trend (0.4—0.8°C per decade). The rapid increase in temperature accelerates the melting of glaciers and snow cover, and reduces their accumulations, which is an important factor leading to the decrease of water storage (Figure 2). In future, water storage levels are expected to show deficits for the next half-century based on a 21-GCM ensemble from CMIP5.

"The predicted ongoing warming and further reduction in glaciers and snowcover will inevitably influence the available water supply in Central Asia," explained senior researcher CHEN Yaning, coauthor of this paper. "And some rivers might run out of water in the dry season, within just a few decades," he added.

This study is part of a program funded by the National Natural Science Foundation of China, focusing on effects of climate change on water cycle and water resources in the Tienshan Mountains. The discovery is published in *Scientific Report*, a journal under the Nature Publishing Group. The findings represent a new understanding on the water resources of the Tienshan Mountains under climate change, shedding light on the water resources research in this data-scarce "Water Tower" of Central Asia. This research is also believed to serve the water managers, given the importance of the Tienshan region as the major water source for Central Asia and the heart of the new Silk Road.

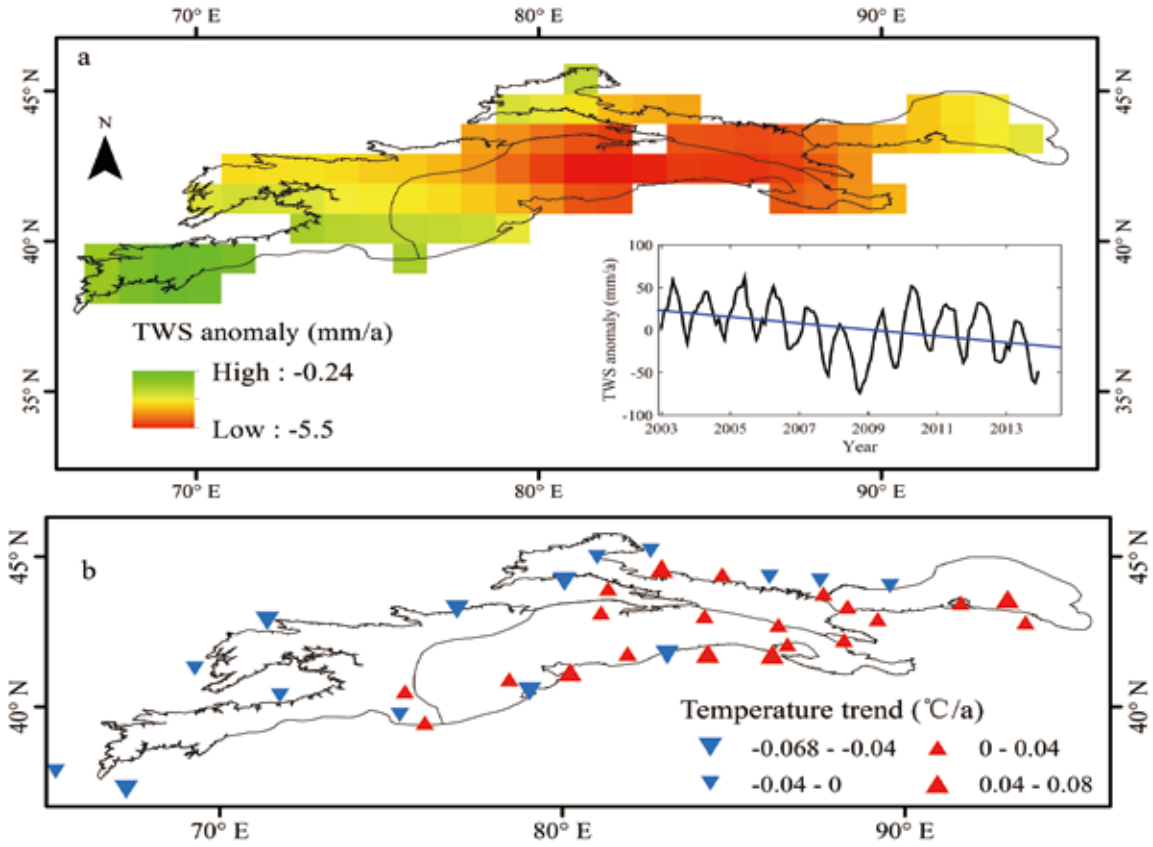

Figure 2: Terrestrial water storage variation (a) and temperature trend (b) from 2003 to 2013 in the Tienshan Mountains