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# Recent changes of two selected glaciers in Hami Prefecture of eastern Xinjiang and their impact on water resources

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ABSTRACT

It is important to understand and quantify glacier changes and their impact on water resources in Hami Prefecture, an extremely arid region in the eastern Xinjiang of northwestern China. Yushugou Glacier No. 6 and Miaoergou Ice Cap in Hami Prefecture were selected in this study. Results showed that the thickness of Yushugou Glacier No. 6 decreased by 20 m with a rate of 0.51 m $y^{-1}$ from 1972 to 2011 and the terminus retreated by 254 m, or 6.5 m $y^{-1}$ for the same period. The thickness along the main axis of Miaoergou Ice Cap decreased 0–20 m during 1981–2007 and the terminus retreat rate was less than 3.0 m $y^{-1}$ in 2013. The melting rate of Miaoergou Ice Cap was smaller than Yushugou Glacier No. 6, which was directly related to the differences of glacier type and elevation. The impact of glacier changes on water resources would be different in the various drainage basins of Hami Prefecture, depending on the proportion of glacier coverage.



## 1. Introduction

Glaciers are considered as important source of water augmenting the flow of streams and rivers, and have significant implications for sea-level change. Due to climate warming, observations have identified a general thinning and retreat of glaciers globally (e.g. Li et al., 2006; Bolch, 2007; Vanlooy and Forster, 2008; Kutuzov and Shahgedanova, 2009; Bolch et al., 2012; Wang et al., 2011b; Wang et al., 2014a, 2014b, 2014c). The glacier runoff derived from changes of glaciers is an important source of fresh water to support the sustained development of the ecological environment, industry, and agriculture of downstream counties in arid regions (Fountain and Tangborn, 1985; Braithwaite and Olesen, 1988; Aizen et al., 1995, 1996; Kaser et al., 2010; Immerzeel et al., 2010, 2012; Jacob et al., 2012; Sorg et al., 2012). Glacier changes including area, length, thickness and volume in the Tianshan Mountains and several other regions are known in detail from aerial photographs, topographic maps, remote sensing images, and in-situ observation data (Aizen et al., 2007; Haeberli et al., 2007; Paul et al., 2007; Surzakov et al., 2007; Bolch et al., 2010; Narama et al., 2010; Li et al., 2010; Wang et al., 2011a, 2013, 2014).

Located in eastern Xinjiang of northwestern China, Hami Prefecture is an extremely arid region, and glacier runoff is the main contributor to water resources. A total of 179 glaciers were distributed in Hami Prefecture with combined area of 155.9 $km^2$ and ice volume of about 8.0 $km^3$ (LIGG, 1986). Investigations were carried out in the Miaoergou Drainage Basin of Hami Prefecture by Lanzhou Institute of Glaciology and Geocryology (LIGG), Chinese Academy of Sciences (now Cold and Arid Region Environmental and Engineering Research Institute, Chinese Academy of Sciences) in the 1970s, and the thickness of Miaoergou Ice Cap was measured in August 1981. In September 2004, Tianshan Glaciological Station, Chinese Academy of Sciences organized a field survey and selected Miaoergou Ice Cap to be a long-term monitored glacier. Tianshan Glaciological Station and Hami Hydrographical Bureau jointly organized field observations of another typical glacier, Yushugou Glacier No. 6, in 2011 to further strengthen the glacier monitoring and assess the impact on water resources of Hami Prefecture. Gao and Luo (2009) found that the temperature of Hami Prefecture increased since 1957, particularly after 1986. Under climate

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warming, intensive ablation of glaciers were observed in recent decades (Li et al., 2007, 2010, 2011; Wang et al., 2008; Wang et al., 2011c). However, few of these studies were based on field survey data and focused on the impact on water resources. It is therefore of paramount importance to understand and quantify the glacier changes in Hami Prefecture and their impact on water resources.

The first aim of this study is thus to present recent changes of Yushugou Glacier No. 6 and Miaoergou Ice Cap. Secondly, the impact of glacier changes on water resources under the background of climate warming is discussed. Study can not only accumulate observation data for the study of glacier changes, but also make possible analysis of the relationship between changes in glacier properties and runoff variability.

## 2. Study area

In the Hami Prefecture (40°53′-45°06'N, 91°07′-96°23'E), the main mountain range is the eastern section of the Tianshan Mountains, including the Harlik and Barkol Ranges from east to west. The Harlik Range contains a total of 122 glaciers with an area of 125.9 km$^2$, covering nine drainage basins, including Yushugou and Miaoergou. A total of 57 glaciers with a combined area of 30.0 km$^2$ are distributed in the Barkol Range, discharging to the Turpan-Hami Basin and Junggar Basin on the northern and southern slopes (LIGG, 1986). Hami Prefecture is particularly characterized by high temperature and evaporation. The precipitation is low in the piedmont, with more than 200 mm above 2000 m a.s.l. and about 25–40 mm on the plains. The amounts of evaporation in Hami City and Naomaohu Gobi reach 2800 and 4418 mm, 80 and 300 times local precipitation, respectively (http://www.hami.gov.cn/; Wang et al., 2011c).

The area of Yushugou Drainage Basin is 308 km$^2$. Nine glaciers with a total area of about 22.85 km$^2$ and ice volume of 1.59 km$^3$ are distributed in this basin, accounting for 14.7% of glacier area and 20% of ice volume, the drainage basin with the largest glacier area and volume in Hami Prefecture (LIGG, 1986; Luo et al., 2002; Gao and Luo, 2009; Ma and Luo, 2009). Located in the upstream of Yushugou Drainage Basin, Yushugou Glacier No. 6 (43°05'N, 94°19'E) is a valley glacier facing towards the west, covering an area of 4.06 km$^2$ and ranging from 4744 m to 3610 m a.s.l. (LIGG, 1986, Fig. 1). Miaoergou Drainage Basin with an area of 372 km$^2$ is to the east of the Yushugou Drainage Basin. Seven glaciers with a total area of 18.43 km$^2$ and ice volume of 1.27 km$^3$ are distributed in this drainage. According to the Glacier Inventory of China (LIGG, 1986), Miaoergou Ice Cap (43°03'N, 94°19'E) covers an area of 3.45 km$^2$ with a total length of 2.4 km. It ranges from 4512 to 3840 m a.s.l. with southwest aspect (Fig. 1).

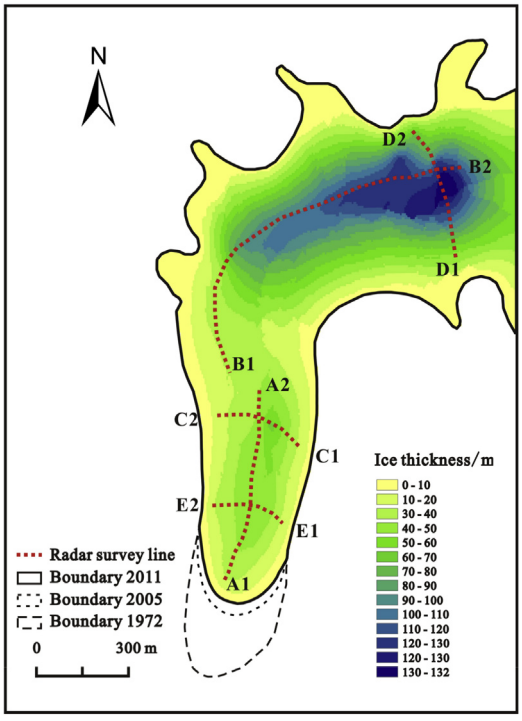


**Fig. 2.** Radar survey lines on the tongue of Yushugou Glacier No. 6, the ice thickness distribution and the glacier terminus changes. The radar survey lines are indicated by the dotted lines. Various line styles represent glacier terminus in the different periods.

## 3. Data and methods

Topographic maps, remote sensing images, GPS survey and ice thickness data used for Yushugou Glacier No. 6 and Miaoergou Ice Cap in this study are shown in Table 1. For Yushugou Glacier No. 6, the ice thickness was measured by An SSI (Sensor Software Inc., Canada) Pulse EKKO-PRO Ground Penetrating Radar (GPR). Five profiles, including two longitudinal profiles (A1–A2 and B1–B2) and three transverse profiles (C1–C2, D1–D2 and E1–E2), were surveyed with a total of 498 points (Fig. 2) to calculate the ice thickness distribution of the glacier tongue accurately. The

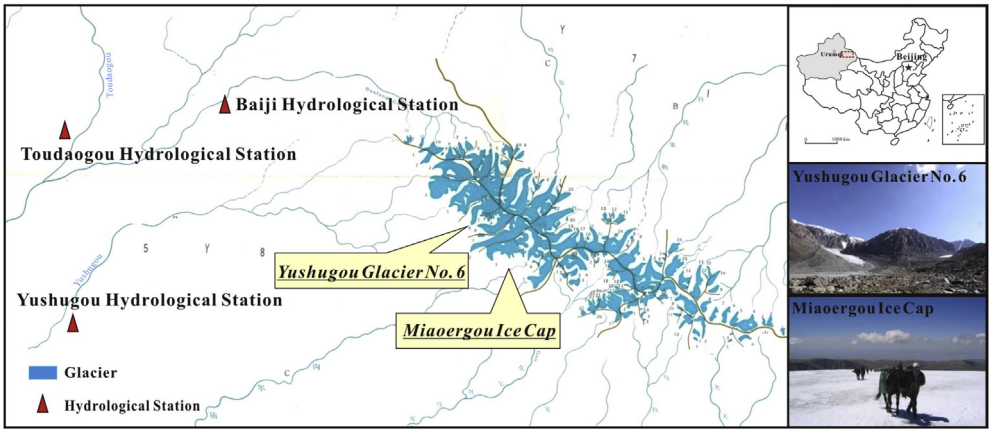


**Fig. 1.** Location of Yushugou Glacier No. 6 and Miaoergou Ice Cap in the Hami Prefecture of Xinjiang, China. Photographs of the two glaciers were taken by Zhongqin Li in 2011 and 2007, respectively.