Mass Balance Changes of Continental and Maritime Glaciers in Western China and Their Response to Climate: Postprint

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Abstract

To understand the mass balance variations of continental and maritime glaciers in western China and their response to climate change against the backdrop of global warming, this study analyzes the characteristics and differences in mass balance changes of two glaciers from 1980 to 2015, using Urumqi Glacier No. 1 at the source of the Urumqi River in the Tianshan Mountains and Parlung Glacier No. 94 in southeastern Tibet as examples, in conjunction with meteorological data from Daxigou and Chayu stations. The results indicate that over the 36-year period, the mass balance of both Urumqi Glacier No. 1 and Parlung Glacier No. 94 exhibited an overall declining trend, with cumulative mass balances reaching -17102 and -8159 mm w.e., respectively, corresponding to glacier thickness reductions of 19 m and 9.01 m, with abrupt changes occurring around 1996 and 2004, respectively. During the same period, the annual mean temperature in the regions where the two glaciers are located showed a significant upward trend, while precipitation displayed distinct change patterns; the intra-annual temperature distribution was similar between the two, but precipitation distribution differed substantially. Preliminary analysis suggests that rising temperature is the primary cause of mass loss for both Urumqi Glacier No. 1 and Parlung Glacier No. 94. Differences in the magnitude of temperature and precipitation changes in the glacier areas and variations in topographic factors (slope, glacier area) render Urumqi Glacier No. 1 more sensitive to climate change than Parlung Glacier No. 94. Given that the current monitoring period for maritime glacier mass balance is relatively short, continuous glacier observation must be enhanced to further investigate mass balance changes and processes of glaciers in western China.

Full Text

Abstract

Glacier mass balance is a key parameter for monitoring changes in the Earth's climate system due to its direct and delayed response to local atmospheric conditions. Considering the reliability of mass balance observations and data quality, Urumqi Glacier No. 1 (UG1) in the Tianshan Mountains and Parlung No. 94 Glacier (PG94) in the Gangrigabu Range were selected as reference glaciers for continental glaciers in the arid region of northwestern China and temperate glaciers in the southeastern Tibetan Plateau, respectively. Thus, it is reasonable to use UG1 and PG94 as sample glaciers to indicate mass balance fluctuations and their response to climate change for both continental and temperate glaciers in western China. Combined with meteorological data from Daxigou and Zayu stations, variations in glacier mass balance and discrepancies between UG1 and PG94 from 1980 to 2015 were analyzed. The results indicate that the annual mass balance of UG1 and PG94 showed decreasing trends of -15.70 ($P < 0.01$) and -35.15 mm w.e. a^{1} ($P < 0.001$), respectively. The cumulative mass balance over 36 years was -17102 mm w.e. for UG1 and -8159 mm w.e. for PG94, equivalent to ice thickness reductions of 19 m and 9.01 m. Their mutation points occurred in 1996 and 2004 at the 0.05 significance level, respectively. The annual mean temperature showed significant increasing trends of 0.5°C · (10a)^{1} for UG1 and 0.3°C · (10a)^{1} for PG94 ($P < 0.001$), with mutation points in 1996 and 2000 at the 0.05 level, respectively. Annual precipitation exhibited different trends over the 36-year period: UG1 showed an increasing trend [34 mm · (10a)^{1}, $P < 0.05$], while PG94 showed a decreasing trend [-57 mm · (10a)^{1}]. The precipitation mutation point occurred in 1988 for UG1 and in 1982 and 2009 for PG94 at the 0.05 level. The intra-annual temperature distribution was similar for both glaciers, but precipitation distribution differed between the two glacial regions. For UG1, 66% of annual precipitation was concentrated in summer, whereas for PG94, spring and summer precipitation accounted for 38% and 37% of annual precipitation, respectively. Correlation analysis between glacier mass balance and temperature/precipitation revealed that mass balance correlates more closely with temperature than with precipitation, particularly summer temperature. Glacier mass balance response is affected not only by regional climate conditions but also by topographic factors. The mass balance variation was greater in UG1 than in PG94 due to larger increases in annual and summer mean temperature at UG1 over the past 36 years. Furthermore, UG1 has steeper slopes and a smaller area than PG94, making it more sensitive to recent climate warming. Given the relatively short monitoring history of temperate glacier mass balance, continued strengthening of glacier mass balance observations is necessary to provide scientific data for understanding glacier mass balance changes and processes in western China.

Keywords: glacier mass balance; continental glaciers; temperate glaciers; Urumqi Glacier No. 1; Parlung No. 94 Glacier; climate change

3.1 Trends in Mass Balance, Temperature, and Precipitation

From 1980 to 2015, the MK test for annual mass balance of UG1 glacier showed a significant decreasing trend, with values ranging from -1327 to 106 mm w.e. [Figure 3a: see original paper], and a mutation point occurred in 1996. In 1996, the mass balance of UG1 was -475 mm w.e., which was significant at the 0.05 level. The mass balance was -249 mm w.e. during 1980–1996 and -10 mm w.e. during 1996–2015 (10-year average). From 1980–1991, the mass balance was -677 mm w.e., after which it turned positive, reaching 428 mm w.e. in 1991.

For PG94 glacier, the annual mass balance mutation point occurred in 2002. The mass balance ranged from -1930 to 736 mm w.e. [Figure 3b: see original paper], with a mutation point in 2004 at -227 mm w.e., significant at the 0.05 level. The mass balance was -227 mm w.e. during 1980–2004 and -10 mm w.e. during 2004–2015 (10-year average).

The annual mean temperature showed significant increasing trends of 0.5°C·(10a) ^{1} for UG1 and 0.3°C·(10a) ^{1} for PG94 ($P < 0.001$), with mutation points in 1996 and 2000 at the 0.05 level, respectively. Precipitation trends differed between the two glaciers: UG1 showed an increasing trend [34 mm·(10a) ^{1}, $P < 0.05$], while PG94 exhibited a decreasing trend [-57 mm·(10a) ^{1}]. The precipitation mutation point occurred in 1988 for UG1 and in 1982 and 2009 for PG94 at the 0.05 level.

The intra-annual temperature distribution was similar for both glaciers, but precipitation distribution differed significantly. For UG1, 66% of annual precipitation was concentrated in the summer period, whereas for PG94, spring and summer precipitation accounted for 38% and 37% of annual precipitation, respectively. Correlation analysis between glacier mass balance and temperature/precipitation showed that mass balance correlates more closely with temperature than precipitation, particularly summer temperature. The response of glacier mass balance is affected not only by regional climate conditions but also by topographic factors. The variation was greater in UG1 than in PG94 due to larger increases in annual mean and summer temperature at UG1 over the past 36 years. Furthermore, UG1 has larger slopes and a smaller area than PG94, making UG1 more sensitive to recent climate warming.

FIGURE:2 Topography and observational network (a. Urumqi Glacier No.1; b. Parlung No.94 Glacier). The black dots represent the distribution of ablation stakes.

FIGURE:3 Mass balance, temperature, and precipitation changes for UG1 and PG94 glaciers from 1980–2015.

Note: Figure translations are in progress. See original paper for figures.

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