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Mass balance, runoff and surges of the Bering Glacier, Alaska

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Abstract

The historical net, ablation and accumulation daily balances and runoff of the Bering Glacier, Alaska are determined for the 1951–2011 period with the PTAA (precipitation-temperature-area-altitude) model, using daily precipitation and temperature observations collected at the Cordova and Yakutat weather stations, together with the area-altitude distribution of the glacier. The mean annual balance for this 61-yr period is -0.6 mwe, the accumulation balance is $+1.4$ and the ablation balance is -2.0 mwe. Periodic surges of this glacier transport large volumes of ice to lower elevations where the ablation rate is higher, producing more negative balances and increasing runoff. During the 1993–1995 surge the average ablation balance is -3.3 mwe, over a meter greater than the 1951–2011 average. Runoff from the Bering Glacier (derived from simulated ablation and precipitation as rain) is highly correlated with the four glacier surges that have been observed since 1951. Ice volume loss for the 1972–2003 period measured with the PTAA model is $2.3 \text{ km}^3 \text{ we a}^{-1}$ and closely agrees with losses for the same period measured with the geodetic method.

1 Introduction

The Bering Glacier/Bagley Icefield in Alaska, the largest glacier/icefield complex in North America, is 180 kilometers in length, ranges from sea level to 2445 m altitude and has a total area of 4773 square kilometers. Within the past 100–200 yr, the Bering Glacier began to retreat from its maximum Neoglacial position; however, in the past 100 yr this retreat has been interrupted by at least six surges of substantial amplitude and duration (Molnia and Post, 1995). The folds on the lower glacier shown in Fig. 1 are indicative of a surging glacier.

Measuring the daily mass balance and hydrologic parameters of a glacier as large as the Bering would require a small army of researchers and near-infinite resources. The PTAA model was developed to determine the balance for glaciers of any size

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- 5 Zhang, J., Bhatt, U. S., Tangborn, W. V., and Lingle, C. S.: Climate downscaling for estimating glacier mass balances in Northwestern North America: validation with a USGS benchmark glacier, *Geophys. Res. Lett.*, 34, L21505, doi:10.1029/2007GL031139, 2007.

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Fig. 1. Bering Glacier on 23 August 1979. Photo by Austin Post. Folds on the lower glacier are indicative of a surging glacier.

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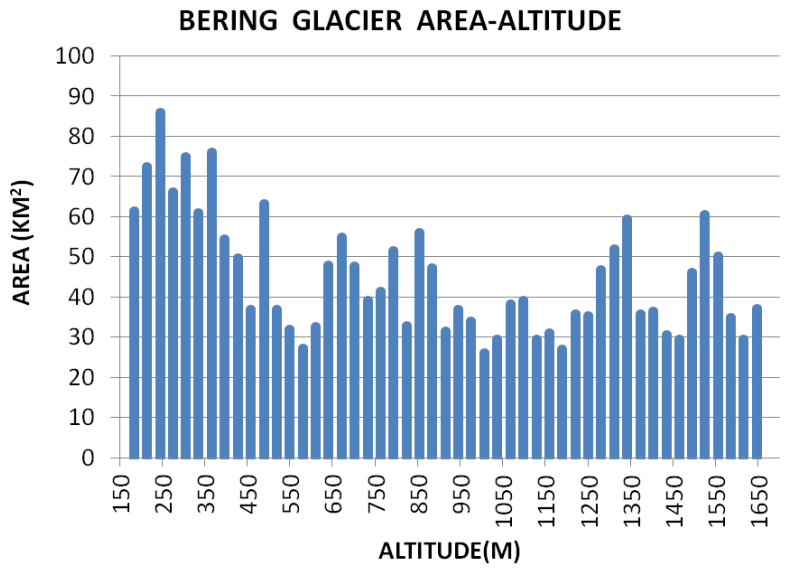


Fig. 2. Area-altitude distribution of the Bering Glacier. The total area of the glacier is 4773 km² and there are 49 altitude intervals spaced at 30.6 m, ranging from 150 to 1650 m in elevation. Latitude 60.302° N Longitude -143.20° W.

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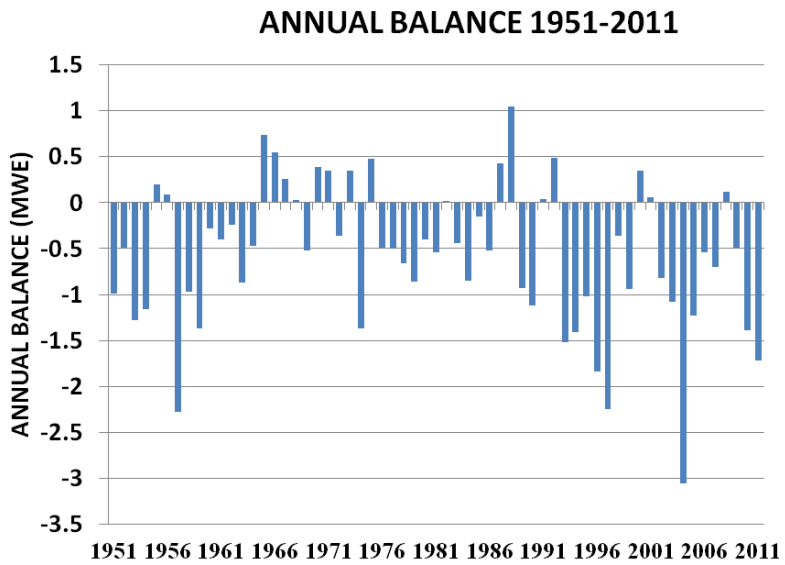


Fig. 3. Annual balance of the Bering Glacier for the 1951–2011 period. The average annual balance is -0.6 mwe. The minimum balance for the period (-3.1 mwe) occurred in 2004.

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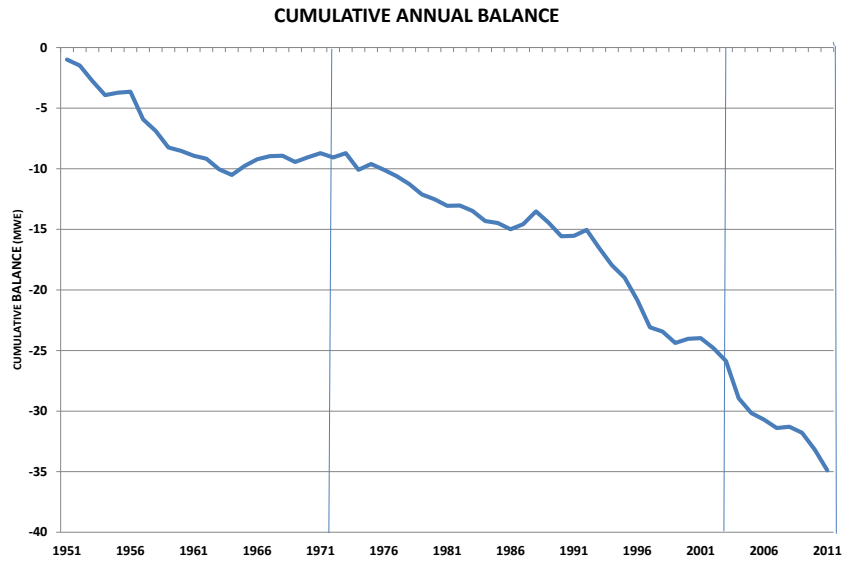


Fig. 4. Cumulative balance of the Bering Glacier. Total thinning during this 61-yr period is 39 m or 0.6 m of ice per year. The vertical lines at 1972 and 2003 delineate the period for which the volume loss determined by the PTAA and geodetic methods are compared.

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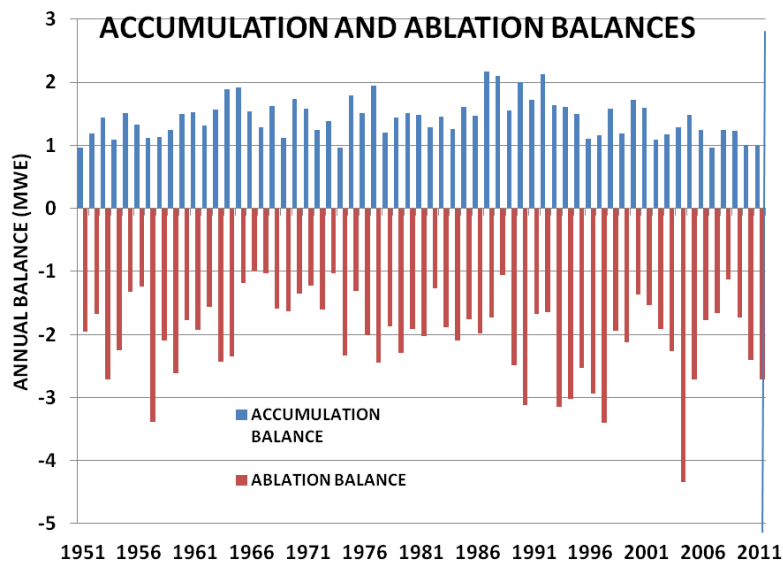


Fig. 5. Accumulation and ablation balances for the 1951–2011 period. The average annual accumulation balance for this period is +1.4 and the average ablation balance is –2.0 (mwe). Maximum ablation (–4.3 mwe) occurred in 2004.

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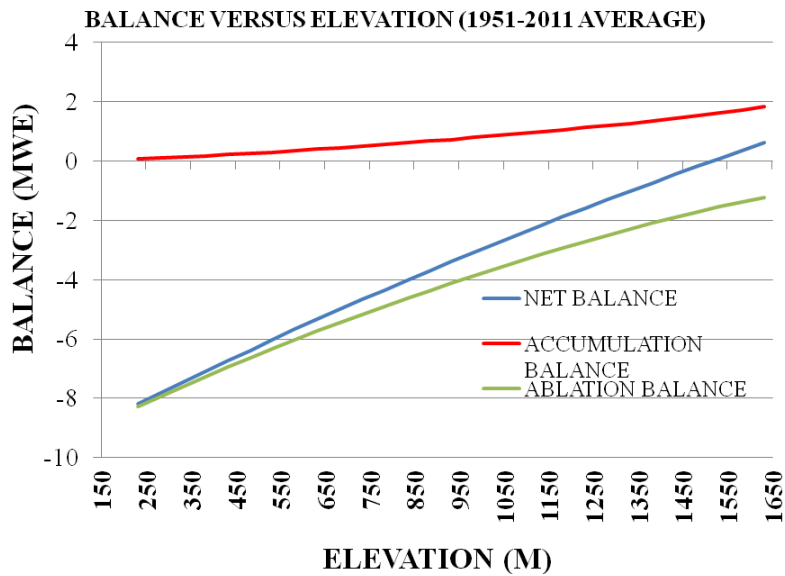


Fig. 6a. Net, accumulation and ablation balances of the Bering Glacier as a function of elevation, averaged for the 1951–2011 period. The ELA (1300 m) is defined as the point at which the net balance crosses the zero balance line.

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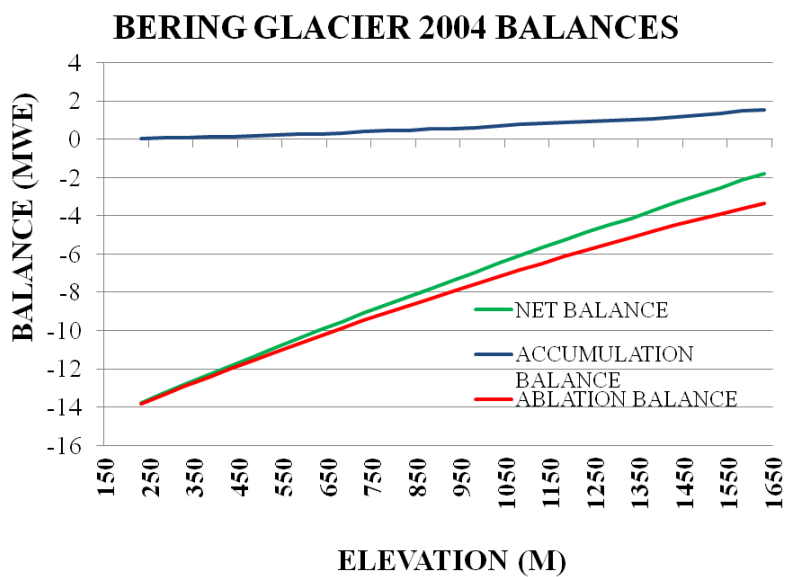


Fig. 6b. Net, accumulation and ablation balances of the Bering Glacier as a function of elevation, averaged for the 2004 period. The ELA is 1850 m, 550 m above average. The balance at the terminus (–14 mwe) is nearly 3 times as negative as on a normal year.

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CALIBRATION MEAN ANNUAL BALANCE VERSUS ITERATION

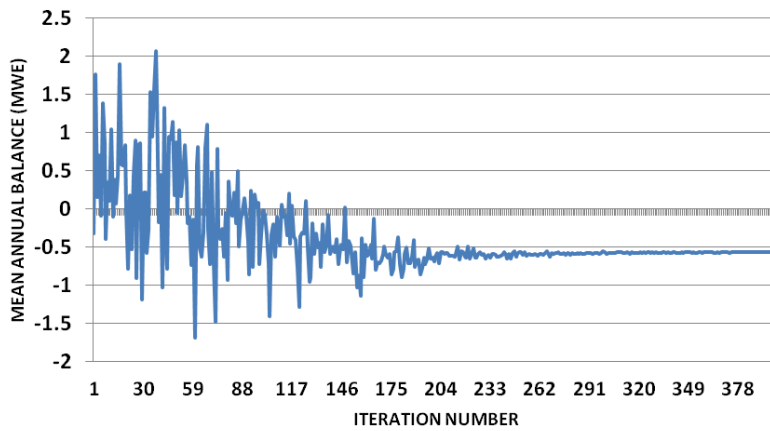


Fig. 7a. Mean annual balance versus iteration number of the optimizing simplex. Balances 1–15 are derived from preset coefficients. Balances 16–350 are calculated automatically from coefficients determined by the simplex optimizing process. When the calibration error reaches a minimum, the average annual balance is -0.6 mwe.

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MEAN ANNUAL BALANCE VERSUS CALIBRATION ERROR

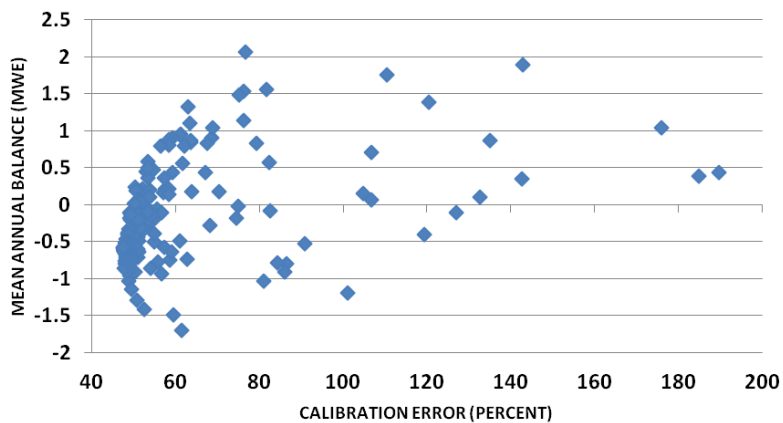


Fig. 7b. Mean annual balance versus calibration error. When the calibration error reached the minimum of about 45 %, the average annual balance is -0.6 mwe. Each point represents the mean annual balance based on 61 yr daily balance determinations.

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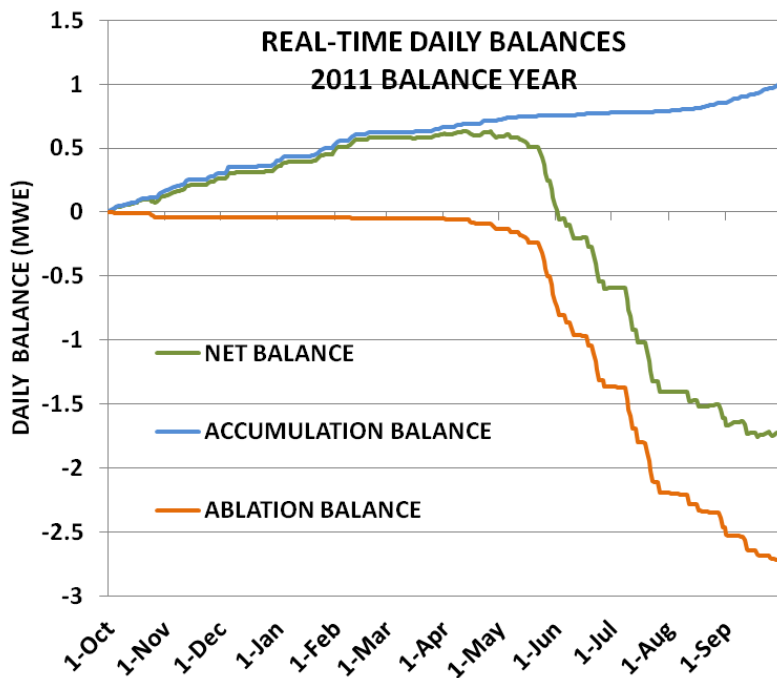


Fig. 8. Daily balances of the Bering Glacier during the 2011 balance year. The final net balance for 2011 on 30 September equals -1.7 mwe, the accumulation balance is 1.0 and the ablation balance is -2.7 mwe. Snow accumulation on the Bering Glacier begins on approximately 1 August each year, thus “winter” balance is a misnomer for this glacier.

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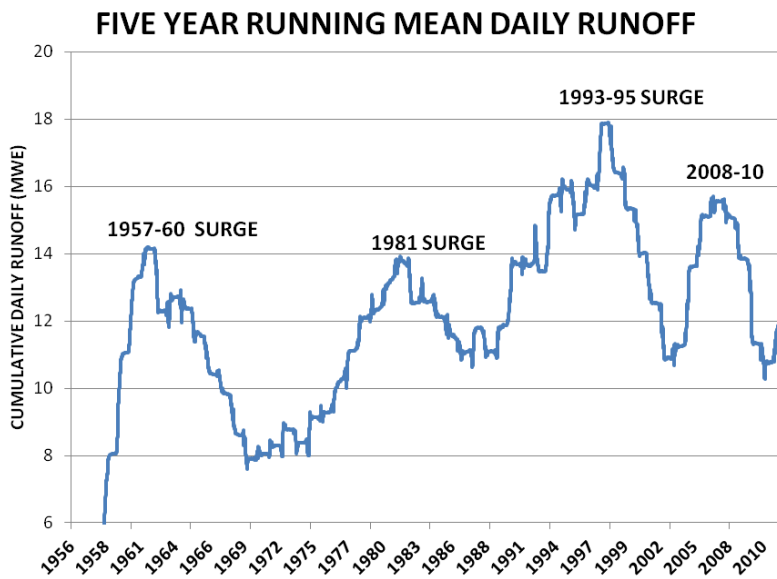


Fig. 9a. Five-year running mean daily runoff (ablation plus precipitation as rain) of the Bering Glacier, and timing of the four observed surges since 1951.

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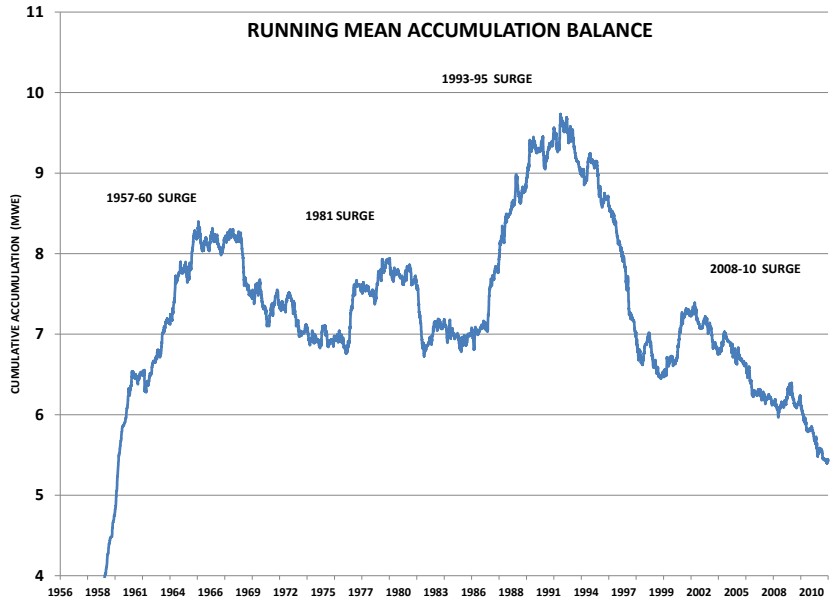


Fig. 9b. The 5-yr running mean of daily snow accumulation on the Bering Glacier, and timing of the four observed surges since 1951.