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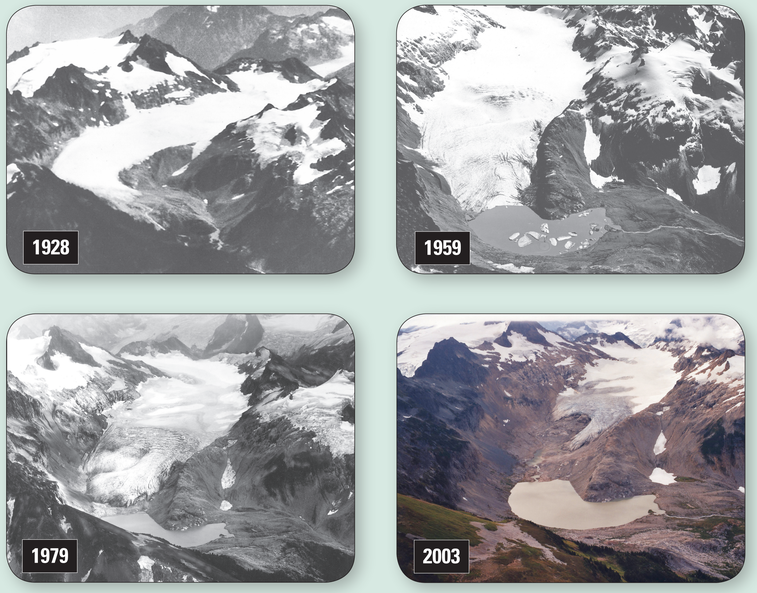
Glacier Mass-Balance Fluctuations in the Pacific Northwest and Alaska, USA

Edward G. Josberger, William R. Bidlake, Rod S. March, and Ben W. Kennedy

Introduction

The USGS Benchmark Glacier Program began as a result of the International Geophysical Year (Meier and others, 1971), and now that the International Polar Year is approaching, it is fitting to examine the unique record of seasonal mass balances of the three USGS Benchmark Glaciers: South Cascade Glacier in the North Cascade Mountains of Washington, Wolverine Glacier near the southern coast of Alaska, and Gulkana Glacier in the interior of Alaska. These glaciers are representative of a large number of glaciers within each region, with each region representing a different climate. The records clearly show the dramatic glacier shrinkage that has occurred in each region. The sequence of photographs below illustrates the changes of South Cascade Glacier.

Data from the USGS Benchmark Glaciers have been extensively used to investigate the relation between glacier mass balance and climate fluctuations as characterized by various indices (Walters and Meier, 1989, Hodge and others, 1998, and Bitz and Battisti, 1999). The mass balance records are now 10 to 15 years longer since many of these studies took place. This poster presents the complete mass balance record, winter, summer, and net, for the Benchmark Glaciers and although many correlations remain unchanged, there are new trends and some changes in important correlations to consider.



Photographic record of South Cascade Glacier retreat.

Mass Balance and Turnover

More than 40 years of net and seasonal mass balance records for three USGS Benchmark Glaciers (figs. 1 and 2) show annual and inter-annual fluctuations that reflect the controlling climatic conditions. South Cascade and Wolverine Glaciers are strongly affected by the warm and wet maritime climate of the northeast Pacific Ocean, and the winter balances are strongly related to the Pacific Decadal Oscillations (PDO). Gulkana Glacier is more isolated from maritime influences and the net balance variation is more closely linked to the summer balance. By the late 1970s, mass-balance records for the three glaciers were long enough to reflect the 1976-77 shift in PDO from negative to positive. Both maritime glaciers responded, with net balance of South Cascade Glacier becoming consistently negative and that of Wolverine Glacier becoming predominantly positive as a result of a shift in the winter storm track. The overall trend of negative mass balance continued through 2004 for South Cascade Glacier, where the 1977 to 2004 cumulative net balance was about –22 meters water equivalent (mweq). After a gain of about 7 mweq, the trend of positive net balance for Wolverine Glacier ended in 1989. Beginning in 1989, the net balance trend for Wolverine Glacier became predominantly negative and the cumulative net balance for 1989 to 2004 was about –14 mweq. Net balance of Gulkana Glacier did not respond appreciably to the 1976-77 PDO shift. The cumulative net balance for Gulkana Glacier from the beginning of the record (1966) through 1988 was about –3 mweq. The major change in trend of mass balance occurred in 1989, when net balance became almost exclusively negative. The cumulative net balance during 1989 through 2004 was about –13 mweq. As a result, trends in net balance had become strongly negative for more than a decade at all three USGS Benchmark Glaciers. The recent increasingly negative trends in net balance at all three USGS Benchmark Glaciers has resulted in the loss of a significant fraction of the ice contained in each glacier. Estimates of ice volumes, obtained from ice penetrating radar surveys of bed topography and ice surface elevations from aerial photography, show that the South Cascade Glacier contained 0.32 km^3 in 1928 and only 0.16 km^3 in 2003. For comparison, volume estimates from 1650 and 1890, neoglacial maxima, obtained from dated moraines and valley trim lines (Miller, 1968) show that South Cascade Glacier had a maximum volume of 0.49 km^3. Similarly, Gulkana Glacier contained 3.7 km^3 in 1890, and 2.8 km^3 1999.

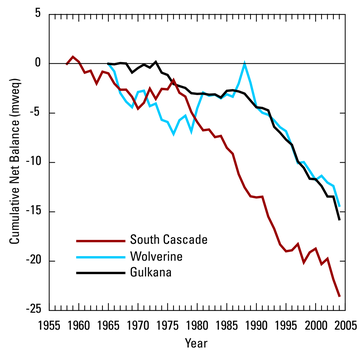


Figure 1. Cumulative net balance for South Cascade, Wolverine, and Gulkana Glaciers. (U.S. Geological Survey, 2006 and Bidlake and Others, 2005.)

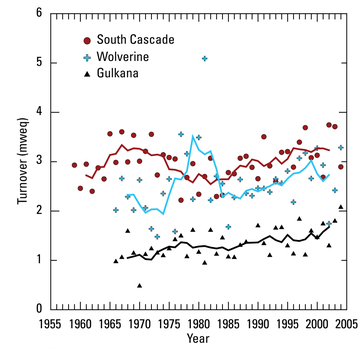


Figure 3. Annual turnover for the three glaciers. Lines are 5-year running averages. (Data from figure 2.)

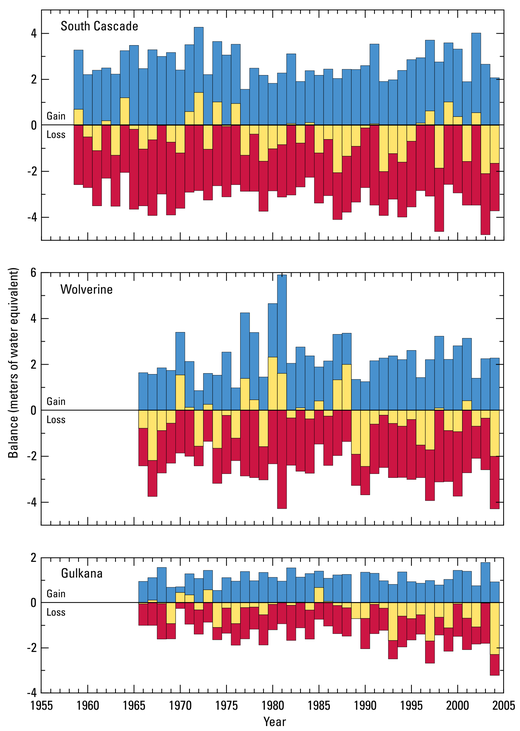


Figure 2. Time series of winter balance (blue), summer balance (red), and net balance (yellow) for the three glaciers. (U.S. Geological Survey, 2006 and Bidlake and Others, 2005.)

The mass balance fluctuations (fig. 1) reflect changes in climatic forcing. For example, the well known relation between conditions in the Gulf of Alaska, as exemplified by the winter PDO index, and winter balance for the two maritime glaciers (Bitz and Battisti, 1999) has become weaker with time. For South Cascade Glacier, the correlation coefficient was -0.79 for the 1966 to 1988 period, and weakened to -0.65 for the 1988 to 2004 period. Concurrently, the coefficient from Wolverine Glacier decreased from 0.62 to 0.38 for the same intervals. Furthermore, for the period 1983-2004, all three glaciers show a positive trend in the annual turnover (fig. 3), which is the annual flux of water through a glacier system; it is a measure of the hydrologic activity of a glacier (Dyurgerov and Meier, 2000). Combined, these two factors could indicate a scale of climate change larger than that characterized by the PDO as all three USGS Benchmark Glaciers are in rapid recession simultaneously.

Conclusions

The decades-long mass balance records from the USGS Benchmark Glacier Program show:

- Glacier retreat accelerated after 1976 for South Cascade Glacier, Washington, and after 1988 for Gulkana and Wolverine Glaciers in Alaska.
- Summer balances for the past 7 years are either the most negative or among the most negative on record for each Benchmark Glacier.
- Increasing glacier turnover rates, primarily as a result of increased summer melting, indicate a more energetic hydrologic cycle.
- Correlations of the maritime-glacier winter balances with the PDO have weakened, suggesting that these once-dominant relations are being overwhelmed by a climate change on a larger scale.

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For additional information:

USGS Washington Water Science Center, *http://wa.water.usgs.gov/*

Edward G. Josberger: ejosberg@usgs.gov 253-552-1643

William R. Bidlake: wbidlake@usgs.gov 253-552-1641

USGS Alaska Water Science Center, *http://ak .water.usgs.gov/*

Rod S. March: rsmarch@usgs.gov 907-479-5645 ext. 241

Ben W. Kennedy: bkennedy@usgs.gov 907-479-5645 ext. 244

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U.S. Geological Survey

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