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Introduction

Global warming, characterized by a rise in the average temperature of the Earth's oceans and atmosphere, has been a cause of concern around the world. One of the main causes of global warming is increased carbon dioxide (CO2) emission into the atmosphere. Some of the warming is natural. Glaciers grow and shrink in response to changes in snowfall and air temperature, two atmospheric phenomena strongly impacted by global warming. Glacier mass balance, defined as the net gain or loss of snow and ice over the course of the year, indicates a net positive or negative change on the size of the glacier, and a warming climate will likely cause glacier shrinkage and a negative change in mass balance. Glaciers losing mass are also consistent with warming trends in U. S. and global temperatures. evidence of a warming Earth. These measurements provide greater insight into the correlations between glacier retreat or decrease in mass balance with global warming.

Methods

1. Glacier Mass Balance Change Observations 1959-2005:

Scientists have collected detailed measurements to determine the mass balance of glaciers, which is the net gain or loss of snow and ice over the course of many years.

2. Glacier Repeat Photographic Change Observations 1900-2010:

we analyzed time-series photographs of 46 North American glaciers from the U.S. Geological Survey, and the Glaciers of the American West Project (Figure 1).

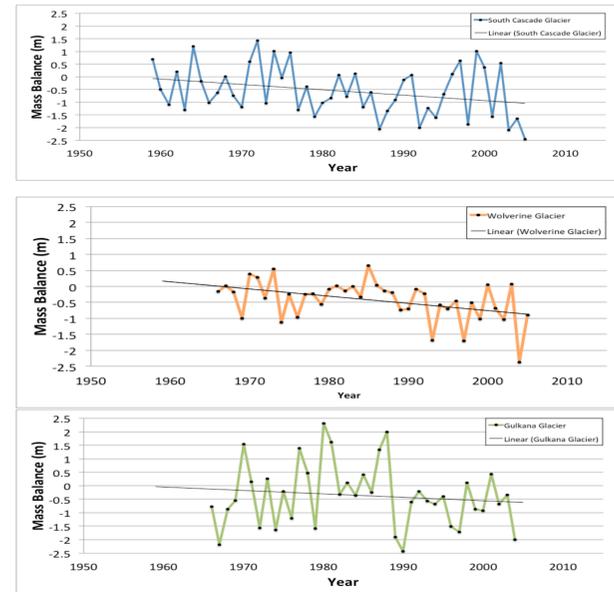
3. Glacier Length Change Observations Over the Past Few Centuries:

We used two sets of measurements to evaluate changes in the length of 12 North American glaciers through time (Figure 2).

Results

Glacier Mass Balance Change Observations 1959-2005 from the USGS Monitoring

The mass balance of each of the three glaciers showed high inter-annual variability, but each glacier showed a trend of mass balance decrease overall (Figure 1).



Measurement of annual glacial mass balance for South Cascade glacier (Top), Wolverine glacier (Middle), and Gulkana glacier (Bottom). Trend lines are linear fits to the data.

Glacier Repeat Photographic Change Observations 1900-2010:

The photographic images show retreat in glaciers and also length measurements of some North American glaciers decreased. Of the 46 glaciers we analyzed from aerial photographs 100% showed glacial retreat

Glacier Length Change Observations Over the Past Few Centuries from the World Glacier Monitoring Service

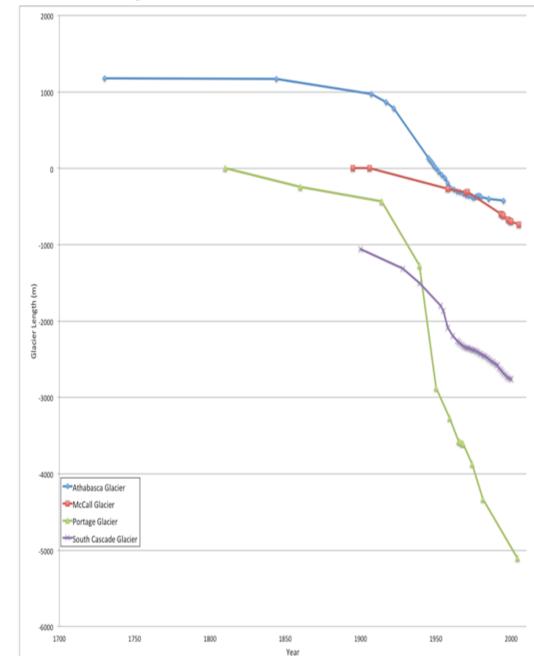
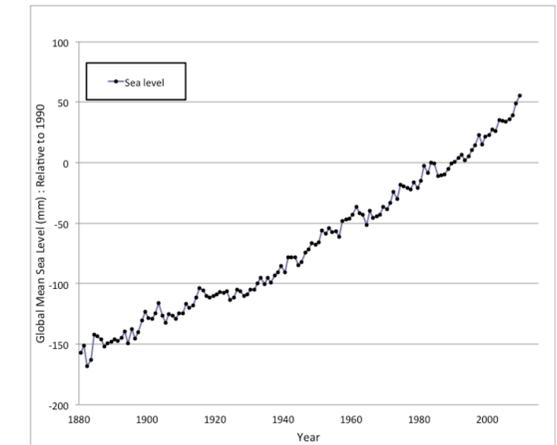


Table 1: Length data for the eight glaciers for which retreat distances were measured comparing glacier length on maps from 1957 and aerial photographs from 2000 to 2005.

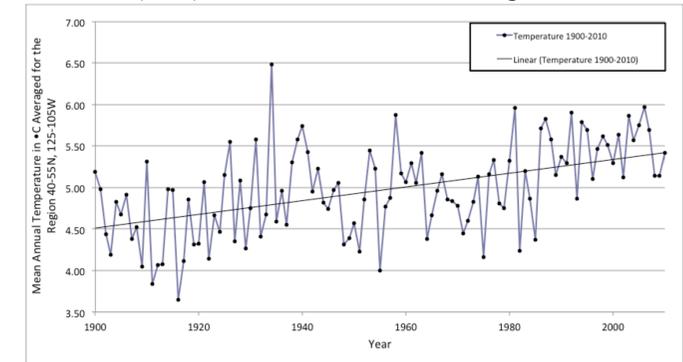
Table with 5 columns: Name, Glacier Location, Glacier Map Length (m), Glacier Length decrease (m), Glacier length Uncertainty. Rows include Blue, McCall, West Gulkana, Worthington, Lemon Creek, Polychrome, Little Jarvis, and Bear Lake.

Comparison with Sea Level Rise, Temperature Increase

Even though there are inter-annual variations, the sea level and temperature show an increasing trend for the last 100 years (Figure 4).



Sea Level 1900-2010: Sea level has increased 21 cm in 130 years; Meier et al (2007) attribute 60% of this to small glaciers.



Temperature increase: One degree C in 100 years

Conclusions

Overall all the glaciers retreated over the last 100 years. The significance of the photo data is that it gives use more insight on glaciers before the 1950's when monitoring of most North American glaciers started. The length data of the eight glaciers for which retreat distances were measured comparing glacier length on maps from 1957 and aerial photographs from 2000 to 2005 show retreat over the last 50 years throughout Alaska. We determined from these data sets that glaciers are retreating since 1900 and are now retreating at a faster rate.

References

Brohan, P., J. J. Kennedy, et al. (2006). "Uncertainty estimates in regional and global observed temperature changes: a new dataset from 1850." J. Geophysical Research 111: D12106. Church, J. A. and N. J. White (2011). "Sea-level rise from the late 19th to the early 21st century." Surv. Geophys. Haeblerli, W., H. Bosch, et al., Eds. (1988). World Glacier Inventory Status 1988. Teufen, UNESCO. Leclercq, P. and J. Oerlemans (in press). "Global and hemispheric temperature reconstruction from glacier length fluctuations." Journal of Climate. Meier, M. F., M. Dyurgerov, et al. (2007). "Glaciers dominate eustatic sea-level rise in the 21st century." Science 317: 1064-1067. Molnia, B. (2007). "Late Nineteenth to early twenty-first century behavior of Alaskan glaciers as indicators of changing regional climate." Global and Planetary Change 56: 23-56.

Muir Glacier/Glacier Bay National Park and Preserve, Alaska



Fig. 1. Photograph of the Muir Glacier from the USGS Repeat Photography Project

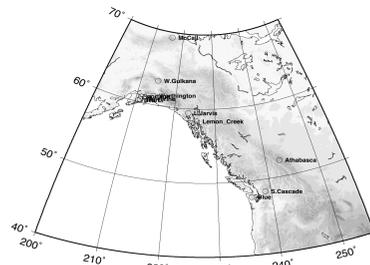
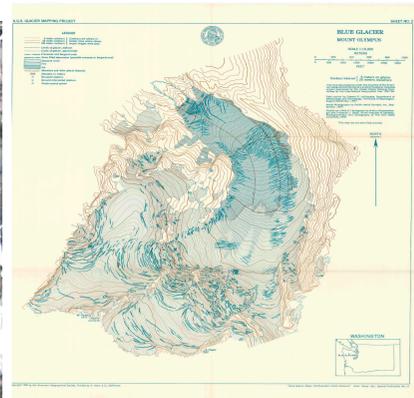
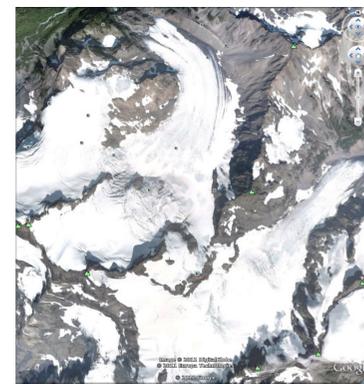


Fig 2. Map of 12 North American Glaciers



Google Earth (2000-2005) (left) and the 1957 topo maps (right) used to measure glacier length decrease for eight glaciers