The 2009-10 surge of Lowell Glacier, Yukon, and its historical context

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Introduction

Lowell Glacier

There is widespread evidence that mountain glaciers in southwestern Yukon and southeastern Alaska are thinning and retreating[1]. This region hosts one of the highest concentrations of surge-type glaciers in the world[2]. Surge-type glaciers are characterized by oscillations between long periods (10-100y) of slow ice velocities (often < 0.1 m d⁻¹), and short periods (~10 y) of fast ice velocities (an order of magnitude higher, or more). These are termed the quiescent and active phases, respectively. Lowell Glacier (60°17’N, 138°13’W) is a large temperate valley glacier in the St Elias Mountains, Yukon (Fig. 1). It is connected to Dusty Glacier (also surge-type) via a large icefall (Fig. 2A).

Lake Alsek

In the past, large surges of Lowell Glacier have advanced across the Alsek River, forming an ice-dammed Lake Alsek (Fig. 2B). It is connected to Dusty Glacier (also surge-type) via a large icefall (Fig. 2A). The glacier is ~65 km long, ~5 km wide and covers ~220 km². Features indicative of surging such as looped moraines and extensive crevassing can be seen in Fig. 2BC.

Objectives

The objectives of this research are twofold: first, identify and study the characteristics of the surges of Lowell Glacier from 1948-2012, with particular attention to the most recent 2009-2010 surge; and second, assess the possibility that Lowell Glacier could again block the Alsek River and flood the present location of Haines Junction[3] (Fig. 1, green line).

Aerial photography and satellite imagery

Six air photos from the National Air Photo Library of Canada (from 1948-1972) and 88 Landsat images (from 1977 and 2006) were used to identify the surges, determine their duration, and measure the ice surface area, terminus extent, and ice surface velocity. Due to the limited availability of images the duration of the surge phases are considered maximum estimates, and the ice velocities are considered minimum estimates.

Digital elevation models and GPS measurements

Two digital elevation models (DEMs) were used to evaluate the ice surface elevation of Lowell Glacier in 1977 and 2006. The 1977 DEM is from the Canadian Digital Elevation Dataset (CDED) and the 2006 DEM is from the Advanced Spaceborne Thermal Emissions and Reflection Radiometer (ASTER) satellite platform. The DEHS represent comparable stages in the surge-cycle as they each represent the glacier, respectively, 7 from the Advanced Spaceborne Thermal Emissions and Reflection Radiometer (ASTER) satellite platform. The velocities shown are minimum estimates because of the limited imagery available. The active phase velocities do not show any strong trends over time.

Results

Five surges identified between, becoming more frequent

Lowell Glacier has surged five times since the late 1940s. The active phases were in 1948-50, 1968-70, 1983-84, 1998-99, and 2009-10. The quiescent phase duration has decreased steadily from ~18 ± 1y (1950-60) to ~12 ± 1y (1999-2000), see Fig. 3A. The active phase duration has also been on a steady decline from ~2 ± 1y (1948-50) to 0.7 ± 0.1y (2009-10), see Fig. 3D. The full surge cycle from 1948-68 was 20 years, the last full surge cycle was from 1998 to 2009, 5 years shorter. The time between the last image of the quiescent phase and the first image with evidence of surging was used to bracket the uncertainty of these values.

Surges begin updglacier

During quiescence, Lowell Glacier flows fastest updglacier, and slowest downglacier. Conversely, during the active phase of the surge, Lowell Glacier flows fastest near the terminus, and slowest upglacier, see Fig. 3A. Because of the limited imagery available, the active phase velocities do not show any strong trends over time.

Surges are smaller and shorter

Fig. 3B shows that the net active phase advance has decreased from 2.89 ± 0.06 km (1983-84) to 2.38 ± 0.06 km (1998-99), to 2.07 ± 0.06 km (2009-10). A similar exercise was conducted to measure the ice surface area of Lowell Glacier. We found that the net advance of the active phase has decreased from 16.95 ± 0.6 km (1983-84) to 11.2 ± 0.1y (2009-10), see Fig. 3C. The 2009-10 net advance was 29% shorter in distance and 60% smaller in area than the 1983-84 surge.

Glacier is thinning

The comparison of our two DEMs by raster differenceing revealed that the terminus of Lowell Glacier from 1977 to 2006 has lowered between 50-100 m, representing a rate of change between -1.7 and -3.4 m a⁻¹. Thinning in the mid-glacier and the up-glacier sections of Lowell Glacier from 1977 to 2000 has been between 20-50 m a⁻¹, representing -0.7 and -1.7 m a⁻¹.

Conclusion

Flooding of Haines Junction, unlikely

For an ice-dammed lake to flood Haines Junction it would have to be 615 m asl. Such a lake would have a shoreline of 2300 km long, and an area of 195km² (see Fig. 1, green outline). The terminus of Lowell Glacier is currently at 530 m asl. This means that should Lowell Glacier surges across the Alsek River (at its current thickness) and create an ice-dammed lake, it would only reach the height of the ice-dam. That lake (at 530 m asl) would have a shoreline of 78 km and an area of 22 km², 173 km shorter than the flood requirement (see Fig 1 in pink).

References