C13A-07 Hubbard Glacier Update: Another Closure of Russell Fjord in the Making?

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ABSTRACT

Hubbard Glacier is located near the community of Yakutat in southeastern Alaska. It is the largest non-polar temperate tidewater glacier in the world and has been advancing since 1890 AD, currently at a rate of 35 m a^{-1}. Hubbard Glacier has twice closed off Russell Fjord at Gilbert Point, creating enormous glacier dammed lakes, once in 1986 and again 2002. Both dams failed catastrophically, producing two of the largest outburst floods in historic times. Past closures were facilitated by the terminus pushing glaciomarine sediments above tidewater, thus limiting calving losses and allowing the glacier to advance rapidly across a 200-300 m gap that typically exists between Gilbert Point and the ice face. A subglacial stream deposit formed near the same location as push moraines during past dam forming events, causing concern that a new closure may occur, perhaps as early next May. Such an occurrence is of concern to local inhabitants because sustained damming of Russell Fjord will cause the lake to overflow into the Situk River, dramatically changing the landscape, creating floods, destroying fish habitats, and threatening structures. In this poster we present results of October 2007 field measurements and remote sensing investigations on the evolution of the ice-marginal deposit and provide updates on the potential for another closure of Russell Fjord.

1. BACKGROUND

Hubbard Glacier, with an area of 3400 km^2, is the largest non-polar tidewater glacier in the world. It descends over 120 km from its origins, on the flanks of Mount Logan (5959 m) in Yukon, Canada, to sea level where it terminates in Disenchantment Bay and Russell Fjord near Yakutat, Alaska (Fig. 1). Hubbard Glacier is considered to be in the advance phase of the so-called tidewater glacier cycle (Trabant and others, 2003). The broad terminus of Hubbard Glacier advanced approximately 620 m from 1992 to 2006 at an average rate of 35 m a^{-1}. Superimposed on this steady advance have been summer-fall retreats, followed by winter-spring re-advances, which average 150 m but can be as large as 500 m (Ritchie et al., submitted). However, a section of the terminus, near a narrow gap (Fig. 2, Gilbert Point), exhibited little to no mean advance during this time period but displayed seasonal fluctuations of 300 - 500 m.

Hubbard Glacier has a history of blocking the seaward entrance to Russell Fjord, which has a relatively large freshwater catchment area, thus creating a glacier-dammed lake (Figs. 1, 2, 3). Twice in recent history the glacier has temporarily blocked the entrance to Russell Fjord; on both occasions the dam failed catastrophically creating the largest outburst floods in historic times (Motyka and Truffer, 2007). Shallow waters near Gilbert Point facilitated the first closure when a finger of ice moved forward and created an ice and push-moraine dam in May of 1986. The subsequent dam failure and lake outburst in October of 1986 eroded the sediments near Gilbert Point to depths of 35 m or more. In June of 2002 an ice and push-moraine dam at the same location once again closed the entrance to Russell Fjord (Motyka and Truffer, 2007). Heavy rain in August, 2002 caused Russell Fjord to overtop the moraine dam and rapid erosion resulted in dam failure accompanied by an outburst flood. The possibility of a sustained closure of Russell Fjord is of concern to Yakutat residents as it may result in negative consequences for the Situk River, an important economic resource.

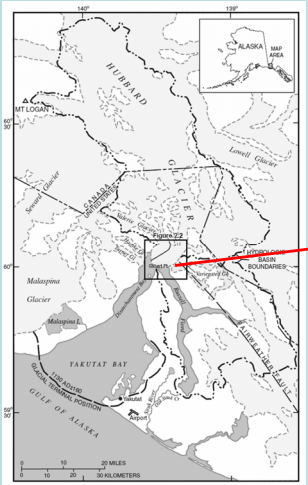

Figure 1. In the early 1100s, Hubbard Glacier was in an advanced state, terminating near the entrance to Yakutat Bay from the Gulf of Alaska and the modern town of Yakutat. Around 1300 AD it started a retreat that lasted through the entire Little Ice Age (LIA) and terminated at the head of Disenchantment Bay. The glacier has advanced 2.5 km since 1895, despite the widespread glacier recession in the region. Hubbard Glacier's equilibrium line altitude (ELA, grey line indicates approximate position) is located in a relatively steep section, making the glacier less sensitive to ongoing or future climate change. Currently, the glacier leaves only a small gap (~300 m in summer 2004) between itself and Gilbert Point. Russell Fjord is connected to Disenchantment Bay by this tidal channel.

2. GILBERT POINT

Despite repeated spring advances that bring the terminus to within 150 m or less of Gilbert Point, no closures have occurred since 2002. Motyka and Truffer (2007) argued that the reasons seasonal advances have not closed Russell Fjord are due to a combination of water depth in the channel, strong tidal currents, and strong seasonal influx of warm (up to 11°C) ocean water. These conditions seasonally increase calving and submarine melting of the ice cliff, thereby forcing retreat of the terminus at Gilbert Point. They argued that the key to shutting down this process is reduction in water depth and that future closures will depend in part on continued sedimentation in the channel at Gilbert Point. Ritchie et al. (submitted) suggested that instabilities at tributary glaciers may also affect processes at Gilbert Point.

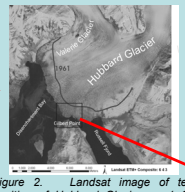

Figure 2. Landsat image of terminus position of Hubbard Glacier on 1 October 2000. Terminus position in 1961 shown by black boundary. Generally, the glacier has steadily advanced but has seasonal oscillations of 100 to over 400 m. A more complicated picture presents itself around Gilbert Point, where the 2002 outburst flood substantially eroded the ice face and caused a local retreat. Boxed area roughly defines region of past closures.

The 2002 outburst scoured the channel to depths of up to 60 m but a remnant shallow reef west of Gilbert Point is visible on all subsequent surveys (Fig.3). This reef appears to have formed a barrier to the moraine pushed forward by the glacier in 2002 and helped to close off the channel. Annual bathymetric surveys of the Gilbert Point region have documented a gradual decrease in water depth due to sedimentation in the deeper parts of the channel but at a relatively slow rate (5 m a^{-1}) (Motyka and Truffer, 2007). However, events during this past summer appear to have hastened sediment deposition, causing concern that another spring closure may be in the making.

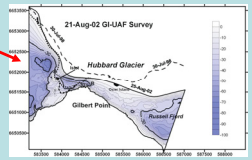

Figure 3. Bathymetric survey of the Gilbert Point area nine days after the start of the 2002 outburst flood. Depths are in m (mllw). The 30-Jul-98 terminus position is shown for comparison. The lateral extent of the 7-Jul-02 ice and moraine dam (heavy dashed lines) also shown. Sediments from the 2002 advance filled in regions west of Gilbert Point. The 2002 outburst then stripped sediments from the gap creating a 60 m deep hole where the ice and moraine dam once stood. However, the topography west of the point remained relatively intact, perhaps because of an underlying bedrock reef. This shallow area remained in all succeeding surveys (Motyka and Truffer, 2007).

Figure 4. Glaciofluvial sediments exposed at the ice face appear on this photo taken 8-11-07. Subglacial stream discharging from terminus (red arrow) is a likely source of the sediment. (Photo: Bruce Molnia, USGS Ret.)

Figure 5. This photo taken about noon on 8-26-07 at mid to high tide shows a fan of sediment covered with icebergs stretching outward from a glacier spur towards shore. This ice spur abuts an underwater "sill"; the debris overlays it (see Fig. 9). The subaerial fan measured about 400 by 230 m. The main trunk of the Hubbard Glacier lies in the background. (Photo: Anthony Arendt, NASA Goddard).

Figure 6. This noon photo of 8-31-07 at mid to low tide shows the location of the fan in relation to the gap between the terminus and Gilbert Point. The ice-marginal deposit seems diminished in size, suggesting it was being actively eroded. The fan disappeared from view by Sept 15th and the ice spur collapsed soon afterward. (Photo: George Kalli, ACE).

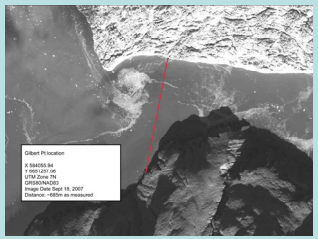

Figure 7. This image of Gilbert Point is part of a larger QuickBird image taken on 9-18-07. The location of the CRREL time-lapse camera and laser distance ranger are also shown. The sediment pile has disappeared and the ice spur has just about calved back to the main terminus line.

3. August 2007 -- Glaciofluvial Sedimentation at the Ice Margin

The earliest indication of localized sedimentation at the ice margin is the subaerial appearance of a glaciofluvial moraine on August 10, as revealed by CRREL's time lapse digital camera (see Fig. 7 for location): (see time-lapse movie). Unfortunately, the frames just barely catch the east side of the sediment. However, an aerial photo taken by Bruce Molnia (USGS, ret.) on August 11 clearly shows a subglacial outlet stream and deposition of sediment at the ice margin (Fig. 4). Continued development of the ice spur and glaciofluvial moraine is captured in the Gilbert Point time-lapse sequence, in SAR images, and in aerial photos taken by Anthony Arendt (NASA Goddard) on August 25 (Fig. 5). The exposed area of the sediment fan measured about 400 m by 250 m by this time and a narrow ice spur connected it to the main terminus. Both were still in place on August 31 (Fig. 6) but SAR and time-lapse images show the fan gradually diminishing in size during early September, perhaps as a result of erosion by tidal currents. Sediments are no longer visible on SAR or time lapse images by Sept 15th and the ice spur itself disintegrated and was completely gone on or about Sept 19th (Fig. 7).

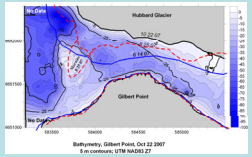

Figure 8. We conducted a bathymetric survey on Oct 22, 2007 and the results are shown above. Accuracy for shallower depths is ~ ± 1. The glacier terminus outline is from a SAR image taken the same day as the survey. Also shown (in red) are the approximate position of the glacier terminus and the ice-marginal glaciofluvial moraine as resolved from a SAR image taken 8-25-07 and (in blue) the terminus position on 6-14-07. The uncertainties in SAR positions are ~ ± 20 m. The closest approach of the terminus occurred on or about 6-14-07, about 120 m from Gilbert Point, as resolved by both SAR imagery and the CRREL distance ranger

4. BATHYMETRY

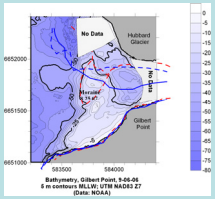

Figure 9. Bathymetry from Sept 07, 2006 NOAA survey of Disenchantment Bay. The survey was limited to west of Gilbert Point because of unsafe conditions in the gap. The regions of no soundings are marked on the map but the "sill" is well represented and in places is shallower than 5 m below MLLW. The terminus boundary is from a SAR image of 9-06-06. Also shown are three 2007 terminus positions: 1) dashed red is the terminus on 8-25-07; 2) solid blue is the terminus on 6-14-07; 3) dashed blue is its position on 7-01-07. Note the terminus abuts or slightly overrides the "sill" for all three positions and that the mid- to late June terminus retreat seems to be mostly confined to the gap. Subsequent SAR images show the terminus continuing to abut the sill through July and it was there that the subglacial stream deposit grew sufficiently to be exposed in early August.

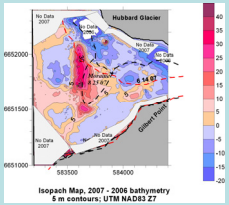

Figure 10. Isopach map comparing 2007 to 2006 bathymetry. The isopach map is best defined for the regions where both surveys had good data coverage, which happens to be the center of the map, right over the "sill." Surveys are accurate to about ± 2 m for deeper regions. The glaciofluvial fan deposit and terminus position from 8-25-07 is superimposed onto the map to show their relationship to where submarine sediment accumulated. Interestingly, most of the accumulation occurred to the west of the moraine, over 30 m in places. This sediment load is perched on the sill over a steep drop-off to the west (cf. Fig. 9). Sediment also accumulated directly over the sill and some sediment has filled in parts of the channel between Gilbert point and the terminus. However, it appears that parts of the channel have been scoured and deepened, perhaps from increased tidal currents.

5. DISCUSSION

It is interesting that rapid sediment build-up on the sill area didn't lead to a closure this past summer. However, the summer retreat was already underway when the ice front began to stabilize adjacent to the sill and glaciofluvial deposits. Calving retreats on either side of the ice spur probably helped prevent a closure. The retreat of the ice face isolated the spur and sediments, exposing both to increased erosion and wastage by tidal currents, which were probably higher than normal given the narrow channel. What is perplexing is why a subglacial stream would discharge over the sill rather than on either side of it where water was deeper.

The glacier may have eroded sediments in the gap entrance during its spring advance (Fig. 10). When the 6-14-07 terminus position is plotted on the isopach map, it falls right over the scour east of the sill and there is a pile of debris built up just ahead of this terminus position, perhaps shoved forward by ice advance. High tidal currents in the restriction probably eroded the channel to the south of the sill.

What does the increase in sediment bode for spring 2008? It is difficult to say. The main channel remains relatively deep. The last closure occurred east of the sill: morainal material was pushed up and onto the sill from the NE as well as towards Gilbert Point (cf. Fig. 3). However, if the terminus is able to advance as far as it did last June, then it will likely reactivate any debris remaining on top of the sill. Some of it may be pushed and "spill over" into the deep water to the east (Fig. 9), but enough sediment may be pushed south to fill in the channel. This would lead to a closure if erosion by tidal currents couldn't keep up with the sediment flux. Our guess is that there is at least a 50% chance of this happening but it is only a guess.

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