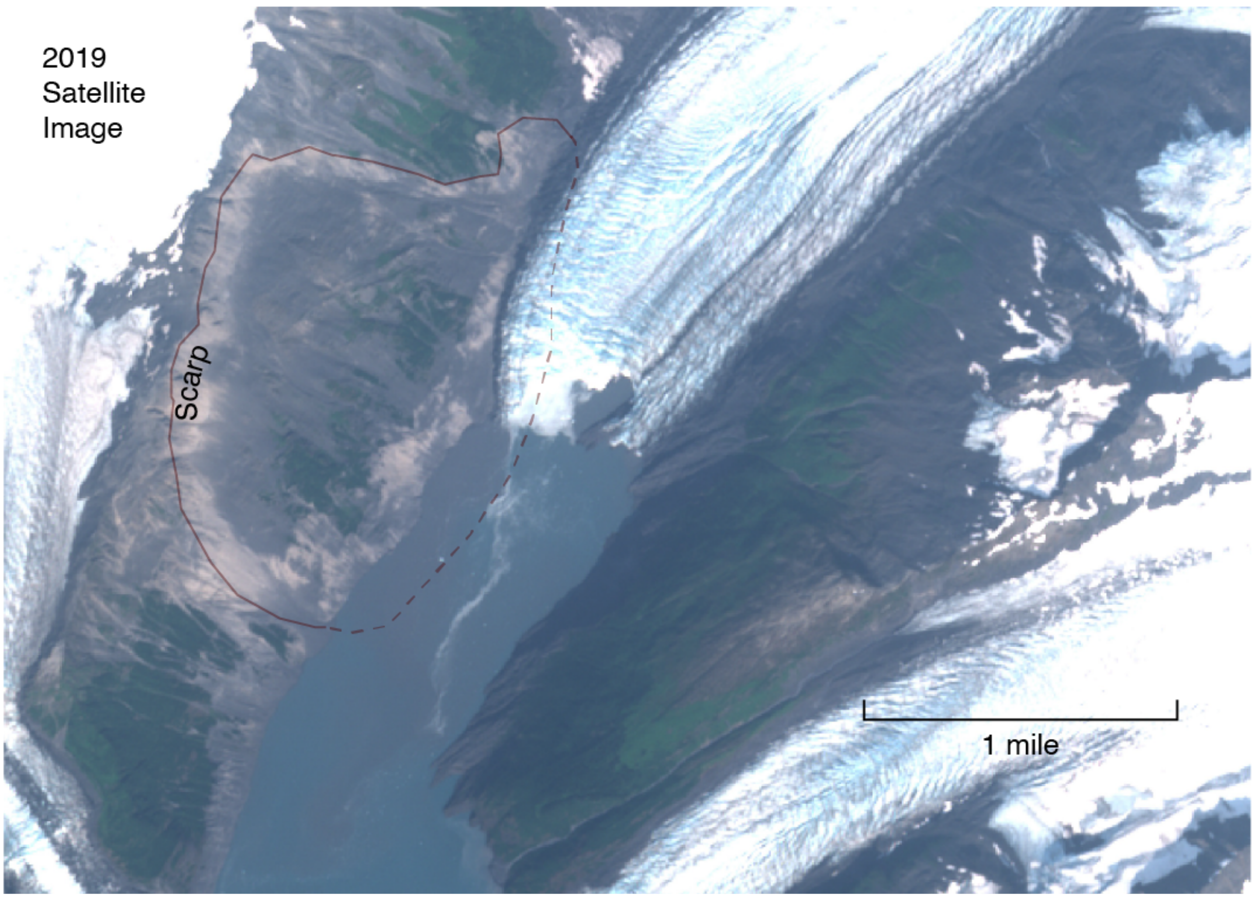
May 14, 2020

A recently discovered unstable slope in Barry Arm could lead to a landslide-generated tsunami

We, a group of scientists with expertise in climate change, landslides, and tsunami hazards, have identified an unstable mountain slope above the toe of Barry Glacier in Barry Arm, 60 miles east of Anchorage, that has the potential to fail and generate a tsunami. This tsunami could impact areas frequented by tourists, fishing vessels, and hunters (potentially hundreds of people at one time). We believe that it is possible that this landslide-generated tsunami will happen within the next year, and likely within 20 years.

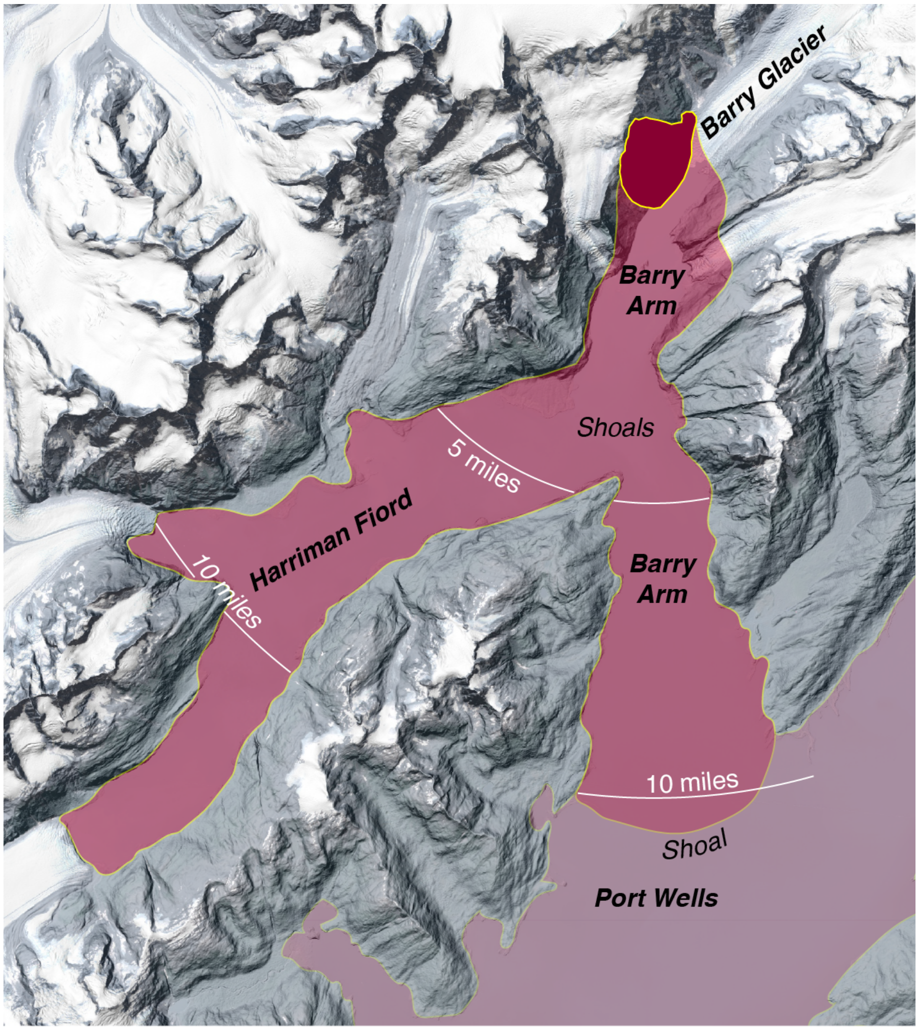


The slow-moving landslide we have identified along Barry Arm is well-defined by a band of terrain called a “scarp” where the motion of the landslide has steepened the slope.

Landslides have set off giant waves elsewhere in Alaska and Greenland during the past decade. In Taan Fiord (Icy Bay, Alaska), a landslide that began moving slowly decades ago suddenly failed in October 2015. The resulting tsunami reached elevations of 633 feet near the landslide, and 35 feet 15 miles away. At Karrat Fiord, west Greenland, a landslide in June 2017 similarly produced a tsunami that killed four people and destroyed a large portion of the town of Nuugaatsiaq, 20 miles away. Surviving villagers still have not returned because a nearby slope is deforming and threatening to fail. The unstable slope in Barry Arm is much bigger than either of these examples, and thus has the potential to produce a larger tsunami that could have impacts throughout Prince William Sound.

Slopes like this can change from slow creeping to a fast-moving landslide due to a number of possible triggers. Often, heavy or prolonged rain is a factor. Earthquakes commonly trigger failures. Hot weather that drives thawing of permafrost, snow, or glacier ice can also be a trigger. Commonly, large landslides are preceded by rockfalls and other signs of increasing instability.

We have only preliminary results showing the potential spread of the tsunami. The effects would be especially severe near where the landslide enters the water at the head of Barry Arm. Additionally, areas of shallow water, or low-lying land near the shore, would be in danger even further from the source. A minor failure may not produce significant impacts beyond the inner parts of the fiord, while a complete failure could be destructive throughout Barry Arm, Harriman Fiord, and parts of Port Wells. Our initial results show complex impacts further from the landslide than Barry Arm, with over 30 foot waves in some distant bays, including Whittier. Field measurements and further analysis could allow us to make these estimates more accurate and specific.



Landslide
Highest danger - severe tsunami even for a partial failure
Reduced danger - variable tsunami impact depending on local factors

The risk from tsunamis is especially high in Barry Arm and Harriman Fiord. Initial analysis suggests that a complete failure of the slide mass would completely fill upper Barr Arm with debris, and generate a tsunami hundreds of feet tall in outer Barry Arm and in Harriman Fiord. Beyond these confined water bodies the tsunami would still be likely to be dangerous in shoals and onshore near the beach, but it would be unlikely to pose a hazard to vessels that are in deeper water bodies. In the event of a complete failure of the unstable slope, the tsunami would have impacts well beyond the bounds of this map.

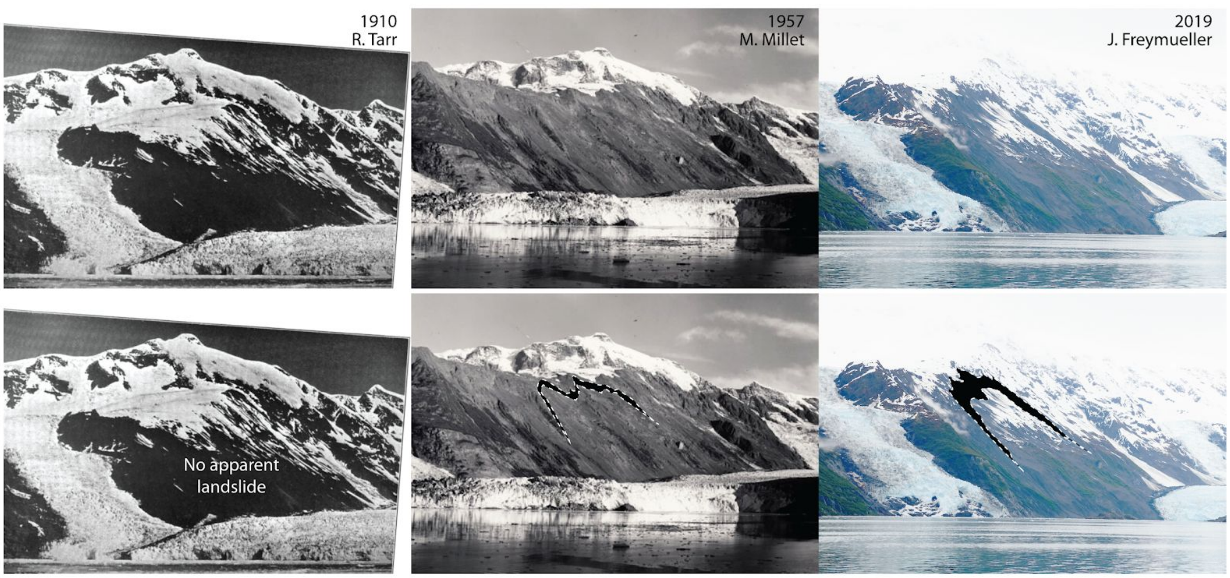
What scientists need from local communities

The work that we have begun is meant to help those who visit or otherwise rely on the waters of Barry Arm and Harriman Fiord - please let us know what we can do that best serves that goal. What specific questions are most important to you? What could be done to reduce the danger to people who want to visit or work in Barry Arm?

Also, photographs or other documentation of what you have seen when you have been in Barry Arm, including small rock-falls and landslides, will help us understand the hazard and may show evidence in some change in the slope.

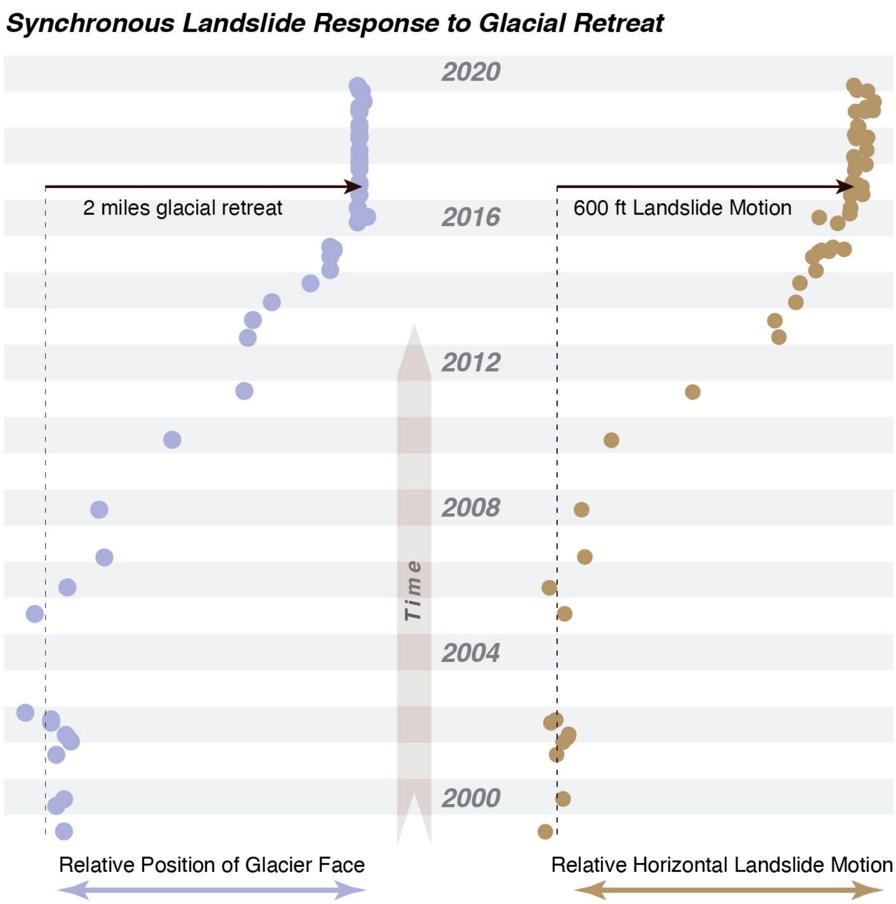
What we're doing

We are working with the Alaska Department of Natural Resources, Division of Geological and Geophysical Survey (DGGS), and have contacted the US Geological Survey to request their help to begin monitoring as soon as possible. Ultimately we hope that our work would make it possible for the National Tsunami Warning Center (NTWC) to monitor this landslide. The NTWC currently provides warnings for earthquake-generated tsunamis, but does not have a mechanism for providing stand-alone landslide-generated tsunami warnings. So far, the analysis of the Barry Arm landslide and tsunami has relied on volunteer efforts and ongoing, funded studies that do not specifically target Barry Arm.



The slopes above Barry Arm, with Mt. Gannett in the background, have been photographed numerous times, including in 1910, when there was no sign of glacial deformation. By 1957 the landslide had begun to move, leaving a distinct scar on the hillside. Between 2009 and 2015 the slide moved further, leaving the larger scar visible in a photo from 2019.

We conducted analyses using the photographs and measurements of elevation that were collected previously from satellites and aircraft. By comparing successive images of the area, we can see that the landslide moved 600 feet (185 m) down the slope between 2009 and 2015, at the same time as Barry Glacier was retreating past the toe of the landslide. A preliminary analysis of satellite radar data from 2019 by Mylène Jacquemart, University of Colorado, suggests that parts of the slope are still moving, albeit currently at much lower rates than in 2009-2015. We also examined the topography in order to produce a preliminary estimate of how much rock is involved in the landslide.

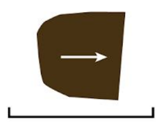
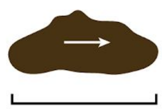
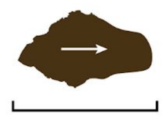
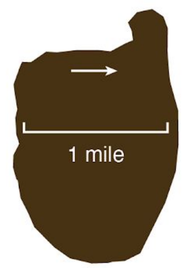


Glacial retreat in recent years follows a similar pattern to landslide motion, suggesting that the landslide was in part supported by the glacier, and is shifting as that support is removed. This analysis was produced by Chunli Dai of The Ohio State University, using Aster and Landsat satellite imagery.

Preliminary tsunami model simulations by Patrick Lynett, University of Southern California show a tsunami reaching hundreds of feet in elevation along the shoreline in Barry Arm and Harriman Fiord. This model assumes most of the landslide mass fails at once. The tsunami would propagate throughout Prince William Sound, including into bays and fiords far from the source. The results suggest that there could be a destructive tsunami in Whittier about 20 minutes after the landslide, reaching over 30 feet above the tide. Valdez, Tatitlek, and Cordova could see noticeable waves of a few feet that are unlikely to impact anyone onshore, but could produce dangerous currents at docks and in harbors. Chenega Bay appears largely insulated from the tsunami, and no significant wave is expected outside Prince William Sound. It is also possible that the landslide may result in a partial or gradual collapse, which would produce a less severe tsunami, with impacts primarily within Barry Arm and Harriman Fiord. Considerable effort is needed to maximize the accuracy of the tsunami model results, however based on testing of the model on other tsunamis we expect that these preliminary simulations accurately reflect what might happen far outside of Barry Arm and Harriman Fiord, assuming there is a complete or nearly complete failure of the landslide mass. In other words, we believe these initial results are sufficiently detailed to support initial assessment of the hazard faced in Prince William Sound.

We have also compared this slope to other similar slopes in the glaciated mountains of coastal southern Alaska, as a way of understanding if and when this failure might happen. Four sites are quite similar - Lituya Bay, Taan Fiord, Grewingk Lake, and Tidal Inlet. Three of these have produced tsunamis that reached hundreds of feet up nearby slopes, while Tidal Inlet has not failed, despite an obvious instability in the slope and over 100 years since glacial retreat there. In the case of Taan Fiord and Grewingk Lake, the landslide happened during the time when the glacier was retreating from the toe of the unstable slope. Because the glacier in Lituya Bay retreated about 400 years ago, we don't know what happened in the first 150 years after retreat, but in the subsequent 250 years there were 5 or more large landslides and associated tsunamis. These case histories provide a general picture showing that it's common (at least half of the four cases) for slope failures to happen at the same time as the glacier retreats. Barry Glacier is in the process now of retreating away from the landslide toe, so it is plausible failure could happen any time. If the slope doesn't fail immediately, failure is still likely as time passes, as demonstrated by repeated failures in Lituya Bay. However, it is also possible that the slope will eventually stabilize for centuries or millennia.

The Barry Arm slope instability compared to Alaska's largest tsunami-generating landslides

Water Body	**Lituya Bay**	**Grewingk Lake**	**Taan Fiord**	**Barry Arm**
Landslide area (Arrow indicates downhill)				
Failure Year	1958	1967	2015	
Max tsunami runup	1720 feet	200 feet	633 feet	
Volume	40 million cubic yards	110 million cubic yards	80 million cubic yards	650 million cubic yards
Elevation (center of mass)	2000 feet	1100 feet	820 feet	1300 feet
Slope	40°	33°	25°	36°
Energy ($\times 10^{14}$ J)	4.6	7.4	3.8	51.0

The unstable slope in Barry Arm is larger than recent historic landslide-generated tsunamis, and perched higher on a steeper slope than either the 1967 Grewingk or 2015 Taan landslides. The potential energy is approximately 10 times greater than any of these previous events.

To inform and refine hazard mitigation efforts, we would like to pursue several lines of investigation: Detect changes in the slope that might forewarn of a landslide, better understand what could trigger a landslide,and refine tsunami model projections. By mapping the landslide and nearby terrain, both above and below sea level, we can more accurately determine the basic physical dimensions of the landslide. This can be paired with GPS and seismic measurements made over time to see how the slope responds to changes in the glacier and to events like rainstorms and earthquakes. Field and satellite data can support near-real time hazard monitoring, while computer models of landslide and tsunami scenarios can help identify specific places that are most at risk.

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