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Historic and Future Retreat of the Mendenhall Glacier

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Overview: The purpose of this report is to synthesize all available data on historic terminus positions for Mendenhall Glacier and provide updated information on rates of terminus retreat for the full period for which records exist (1760-2021).

We also provide recent modeling results aimed at projecting the location of the terminus in coming decades (2020-2050).

Acknowledgements: Many people have contributed to the ongoing efforts to document the retreat of the Mendenhall Glacier. Roman Motyka reconstructed historical terminus positions and provided many of the terminus positions before 2002. Ellie Boyce measured terminus positions in and around Mendenhall Lake in the early 2000s. Mike Hekkers and students from the Environmental Science Program at UAS including Logan Berner, David Sauer, and Nick Korzen helped to measure terminus positions using handheld GPS during the period 2004-2015. Sanjay Pyare assisted with drone flights to map the terminus in 2020.

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Historic Terminus Positions for Mendenhall Glacier

The Mendenhall Glacier has been retreating continuously since the end of the Little Ice Age in the late 1700's. Terminus positions in the 18th and 19th centuries were reconstructed by mapping terminal and recessional moraines (see Motyka et al., 2003). Since 1895, air photos, USGS topographic maps, and GPS surveys have been used to map the glacier terminus position. In 2020, faculty and students at the University of Alaska Southeast initiated a campaign to survey the glacier terminus annually using drones.

Here we map historic terminus positions between 1760-2021. All maps were created using a 2020 satellite image of the glacier. We also evaluate retreat rates for the Mendenhall over the full period of record based on the mapped terminus positions. Terminus retreat rates are compared for the grounded portion of the terminus and the portion of the terminus sitting (or in some cases floating) in Mendenhall Lake. Similar to previous analyses, we found that the lake-terminating portion of the Mendenhall glacier terminus retreats substantially more rapidly than the grounded portion of the glacier terminus (see Boyce et al., 2007; Motyka et al., 2003).

We highlight the digital maps of the terminus created using drone imagery collected in 2020 and 2021. Images collected using drones were used to produce high-resolution maps of the terminus position, and they also provide three dimensional elevation models that can be used to evaluate how the elevation and thickness of the glacier terminus are evolving over time.

Table 1. Retreat rates for the centerline of the Mendenhall Glacier. Before the Mendenhall Lake became exposed in the early 1900s, glacier retreat averaged less than 12 meters per year. The fastest rates of retreat occurred between 2007 and 2011 when the glacier was retreating through the deepest parts of Mendenhall Lake and iceberg calving rates were high. Time periods were chosen based on the availability of terminus position information.

Time period	**Centerline retreat of Mendenhall terminus**	
1760 to 1832	406 meters (6 m/yr)	1,332 feet (19 ft/yr)
1832 to 1909	856 meters (11 m/yr)	2,808 feet (36 ft/yr)
1909 to 1931	919 meters (42 m/yr)	3,015 feet (137 ft/yr)
1931 to 1942	616 meters (56 m/yr)	2,021 feet (184 ft/yr)
1942 to 1949	585 meters (84 m/yr)	1,919 feet (274 ft/yr)
1949 to 1982	600 meters (18 m/yr)	1,969 feet (60 ft/yr)
1982 to 1997	457 meters (30 m/yr)	1,499 feet (100 ft/yr)
1997 to 2002	74 meters (15m/yr)	243 feet (49 ft/yr)
2002 to 2004	49 meters (25 m/yr)	161 feet (81 ft/yr)
2004 to 2005	42 meters (42 m/yr)	138 feet (138 ft/yr)
2005 to 2007	23 meters (12 m/yr)	75 feet (38 ft/yr)
2007 to 2009	159 meters (80 m/yr)	522 feet (261 ft/yr)
2009 to 2010	118 meters (118 m/yr)	387 feet (387 ft/yr)
2010 to 2011	132 meters (132 m/yr)	433 feet (433 ft/yr)
2011 to 2013	86 meters (43 m/yr)	282 feet (141 ft/yr)
2013 to 2020	284 meters (41 m/yr)	932 feet (133 ft/yr)
2020 to 2021	107 meters (107 m/yr)	351 feet (351 ft/yr)
Total retreat (261 years)	**5,513 meters**	**18,087 feet (3.4 miles)**
average retreat rate	**21 meters/year**	**69 feet/year**

Figure 1. Visualization of Mendenhall terminus retreat rates for the period 1760-2021.

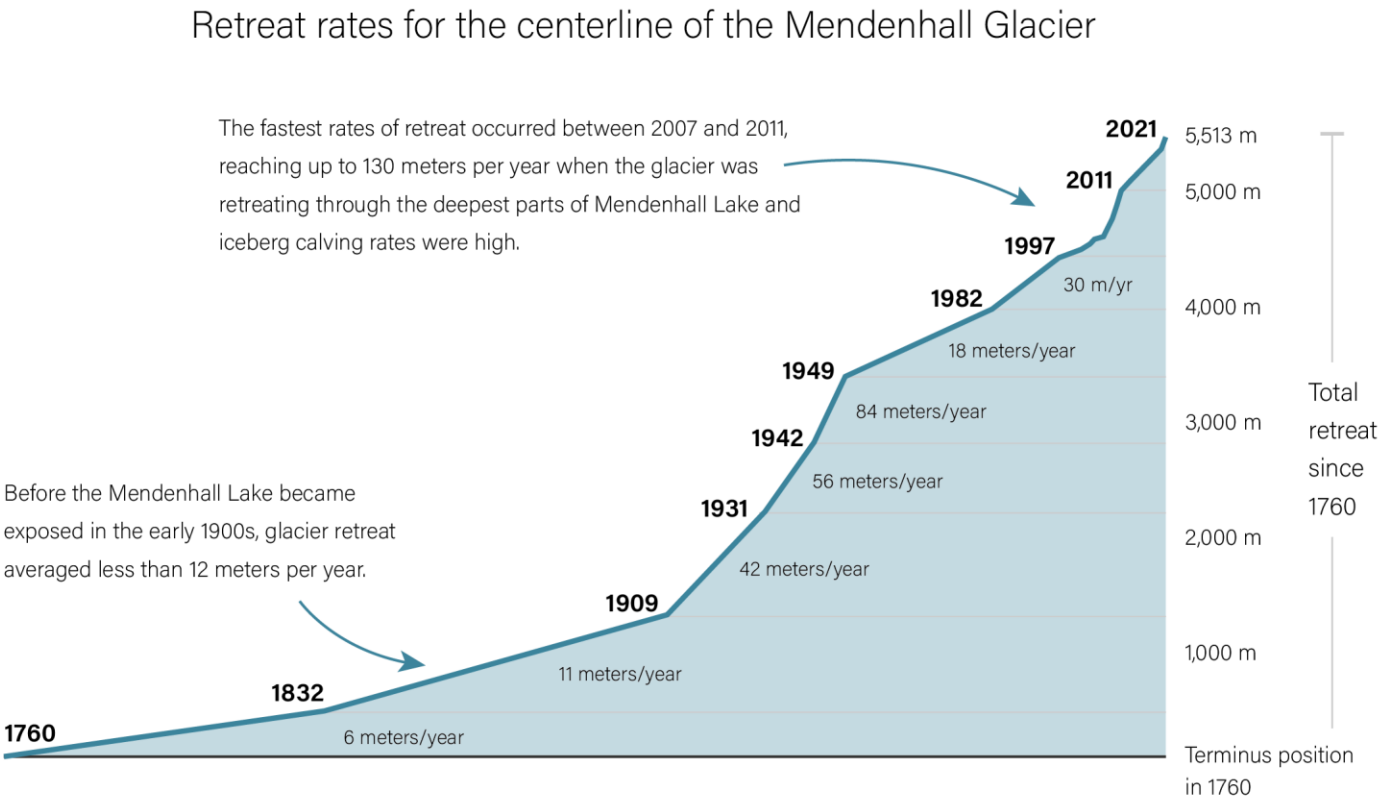


Figure 2: Visualization of Mendenhall terminus retreat rates for the period 1998-2021.

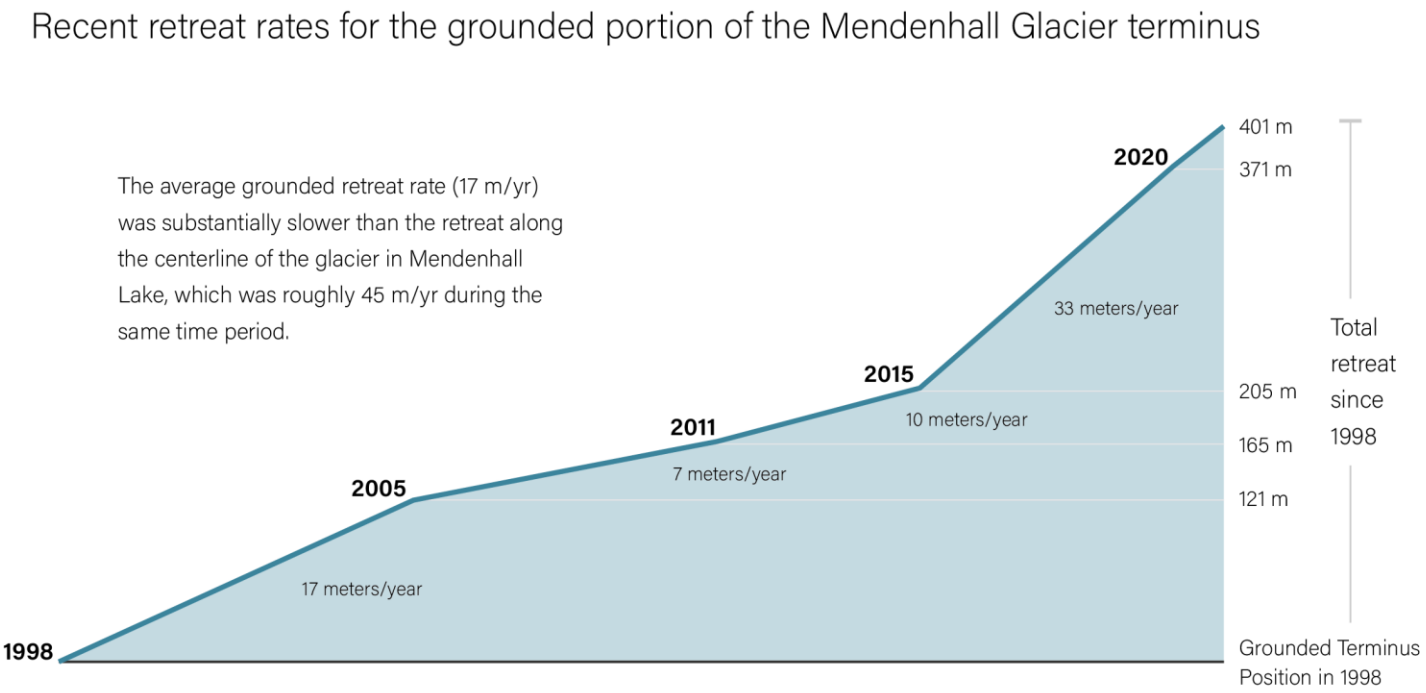


Figure 3. Terminus positions at Mendenhall Glacier from 1760-2021. During this 261-year period, the glacier retreated about 3.4 miles (5.5 km) along its center line.

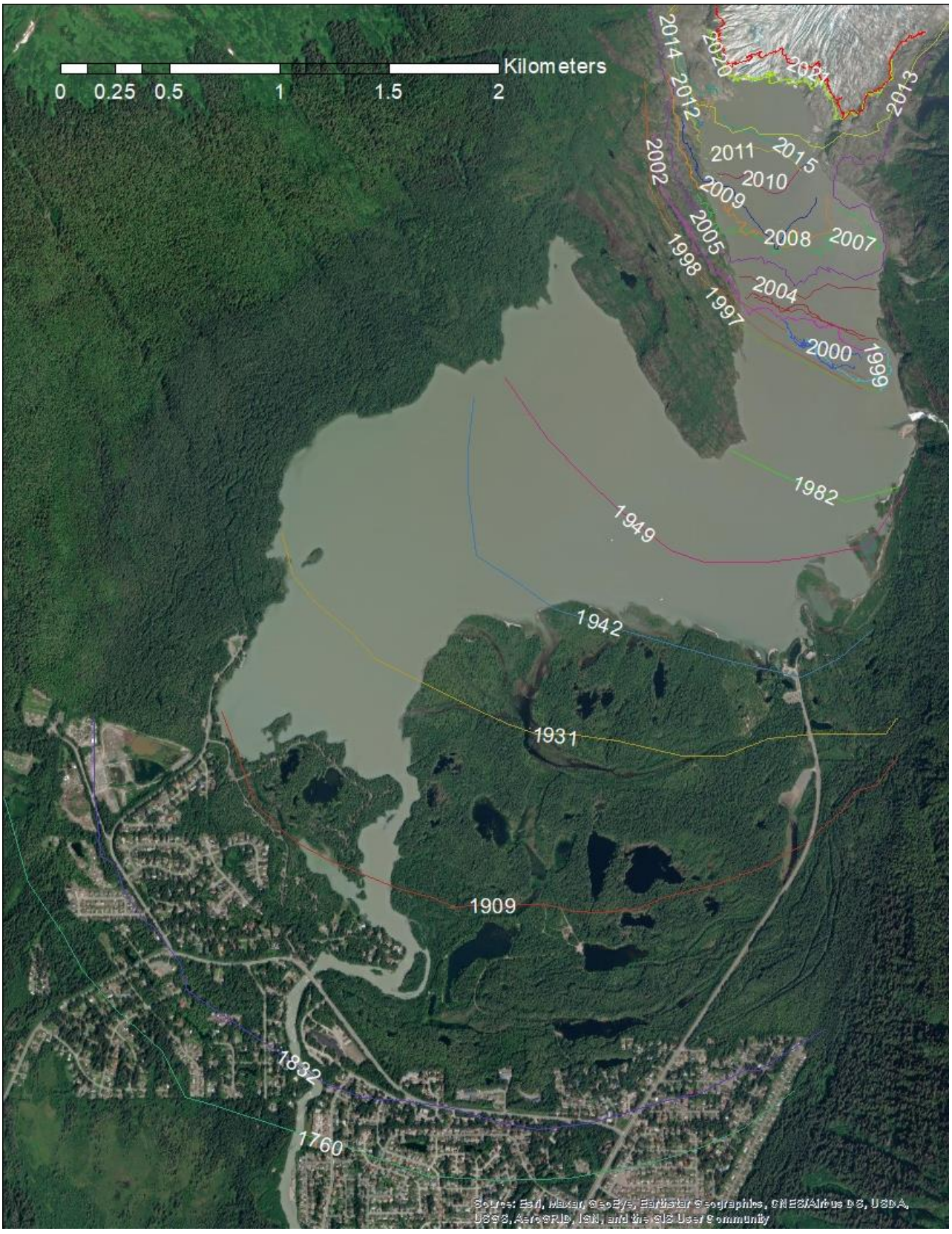


Figure 4. Terminus positions at Mendenhall Glacier from 1760-2021.

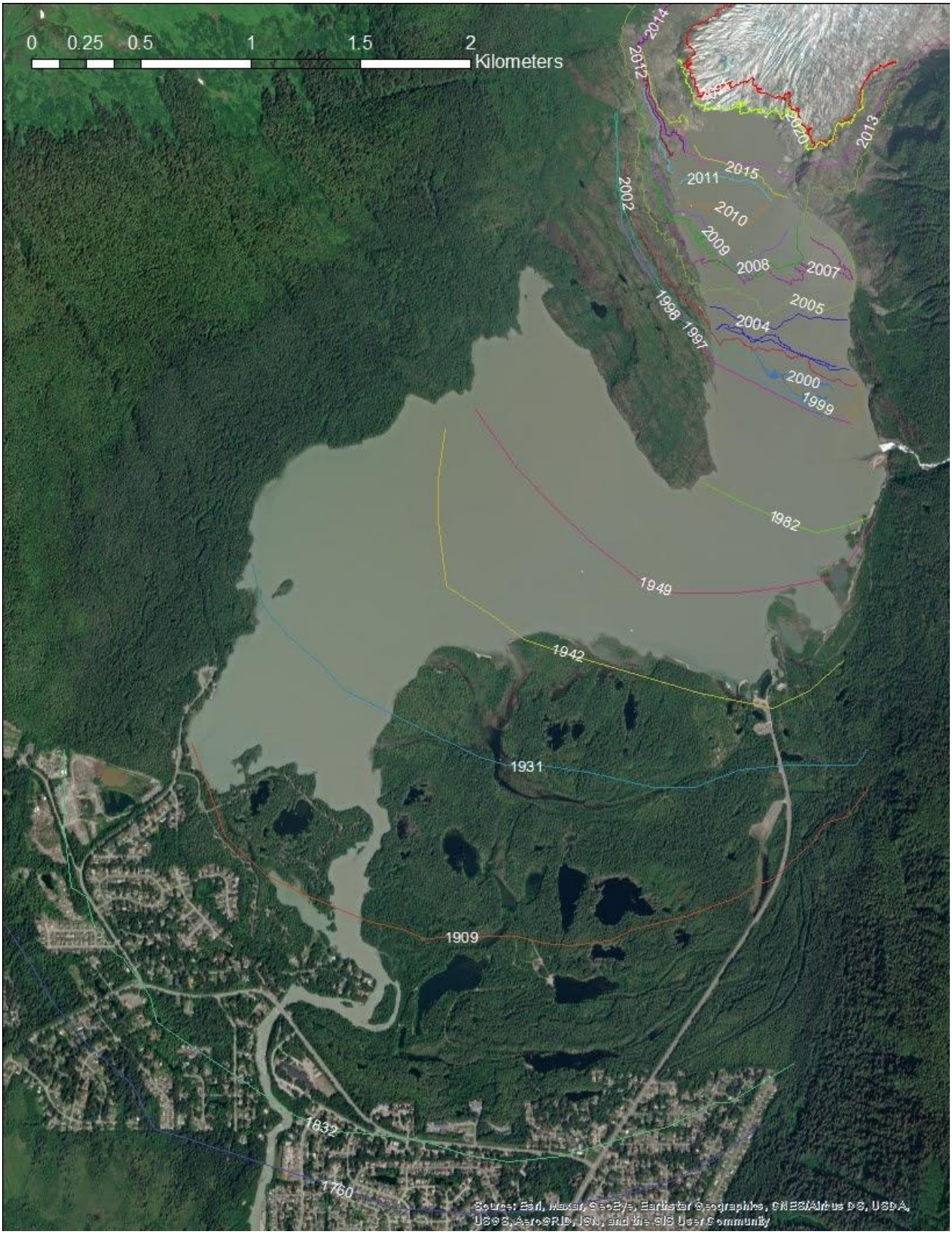


Figure 5. Position of the Mendenhall Glacier terminus from 1997-2021. During this period, the glacier retreated about 0.6 miles (1.0 km) along its center line.

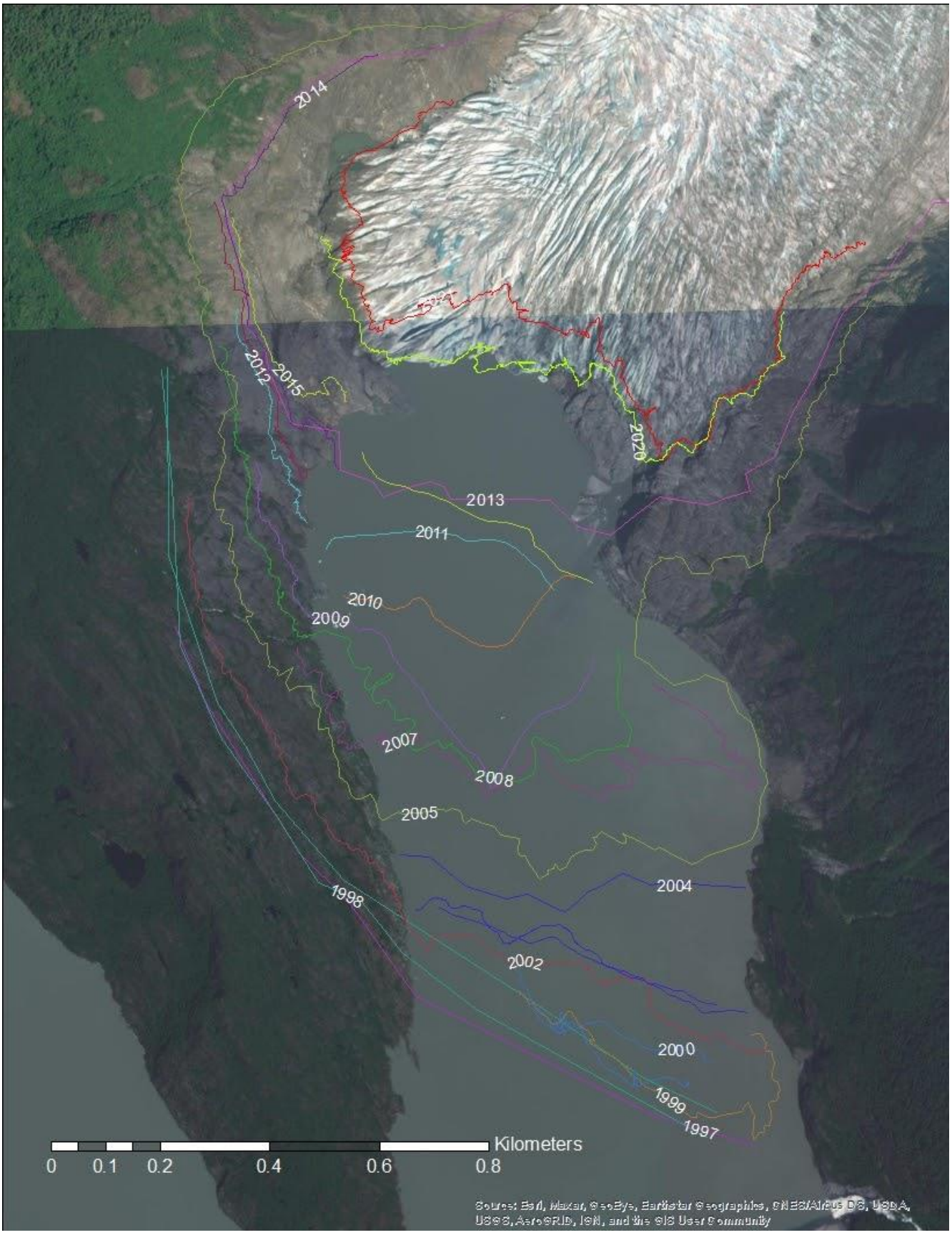


Figure 6. Position of the Mendenhall Glacier terminus from 1997-2021.

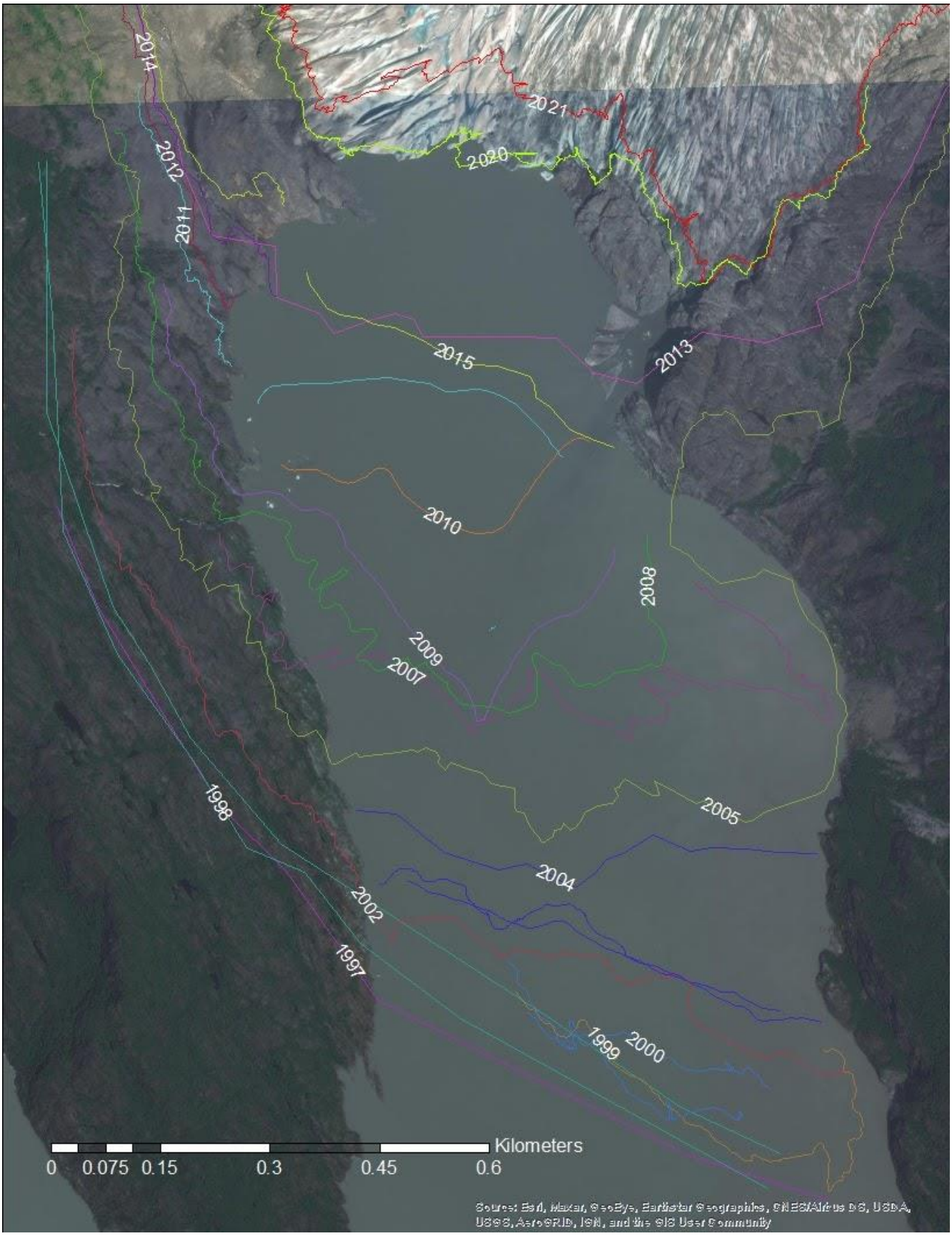


Table 2. Recent retreat rates for the grounded portion of the Mendenhall Glacier terminus on the rock peninsula along the west side of Mendenhall Lake. The average grounded retreat rate (17 m/yr) was substantially slower than the retreat along the centerline of the glacier in Mendenhall Lake, which was roughly 45 m/yr during the same time period.

Time Period	***Retreat of terminus on west side rock peninsula***	
1998 to 2005	121 meters (17 m/yr)	397 feet (57 ft/yr)
2005 to 2011	44 meters (7 m/yr)	144 feet (24 ft/yr)
2011 to 2015	40 meters (10 m/yr)	131 feet (33 ft/yr)
2015 to 2020	166 meters (33 m/yr)	545 feet (109 ft/yr)
2020 to 2021	30 meters (30 m/yr)	98 feet (98 ft/yr)
Total retreat (23 yrs)	**401 meters**	**1,315 feet**
average retreat rate	**17 m/yr**	**57 ft/yr**

Figure 7. Position of the Mendenhall Glacier terminus on the rock peninsula to the west of Mendenhall Lake from 2005-2021. This grounded portion of the terminus retreats more slowly than the portion of the terminus that sits in Mendenhall Lake. Retreat on the bedrock totaled about 920 ft (280 meters) between 2005 and 2021. Retreat rates are shown in Table 2 on the previous page.

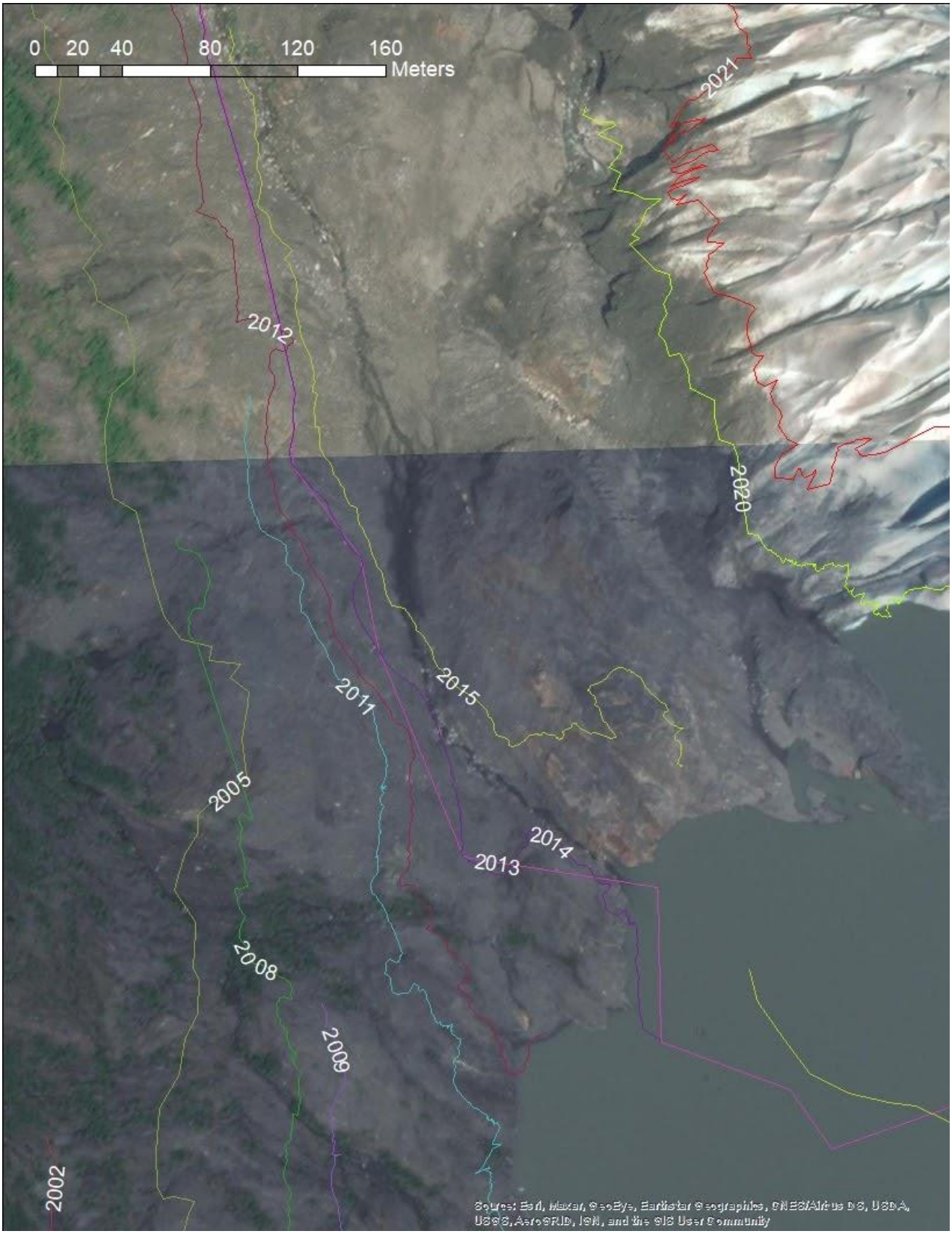


Table 3. Changes in the distance from the location of the Mendenhall Glacier Visitor Center to the Mendenhall Glacier terminus since 1949.

YEAR	***Distance from Visitor Center location to terminus***		
1949	447 meters	1,467 feet	0.3 miles
1982	792 meters	2,598 feet	0.5 miles
2000	1529 meters	5,016 feet	0.95 miles
2011	2308 meters	7,572 feet	1.4 miles
2021	2760 meters	9,055 feet	1.7 miles

Figure 8. Visualization of the distance between the location of the Mendenhall Visitor Center and the terminus of the Mendenhall Glacier for the period 1949-2021.

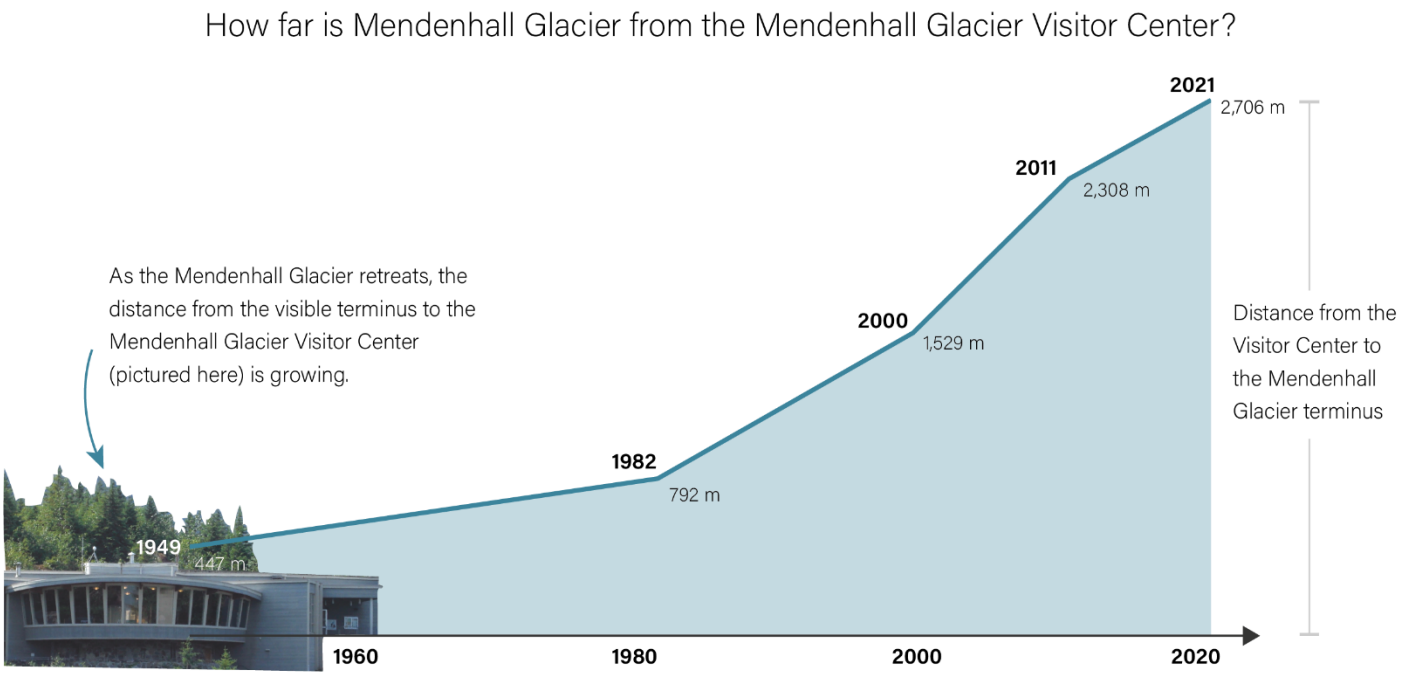
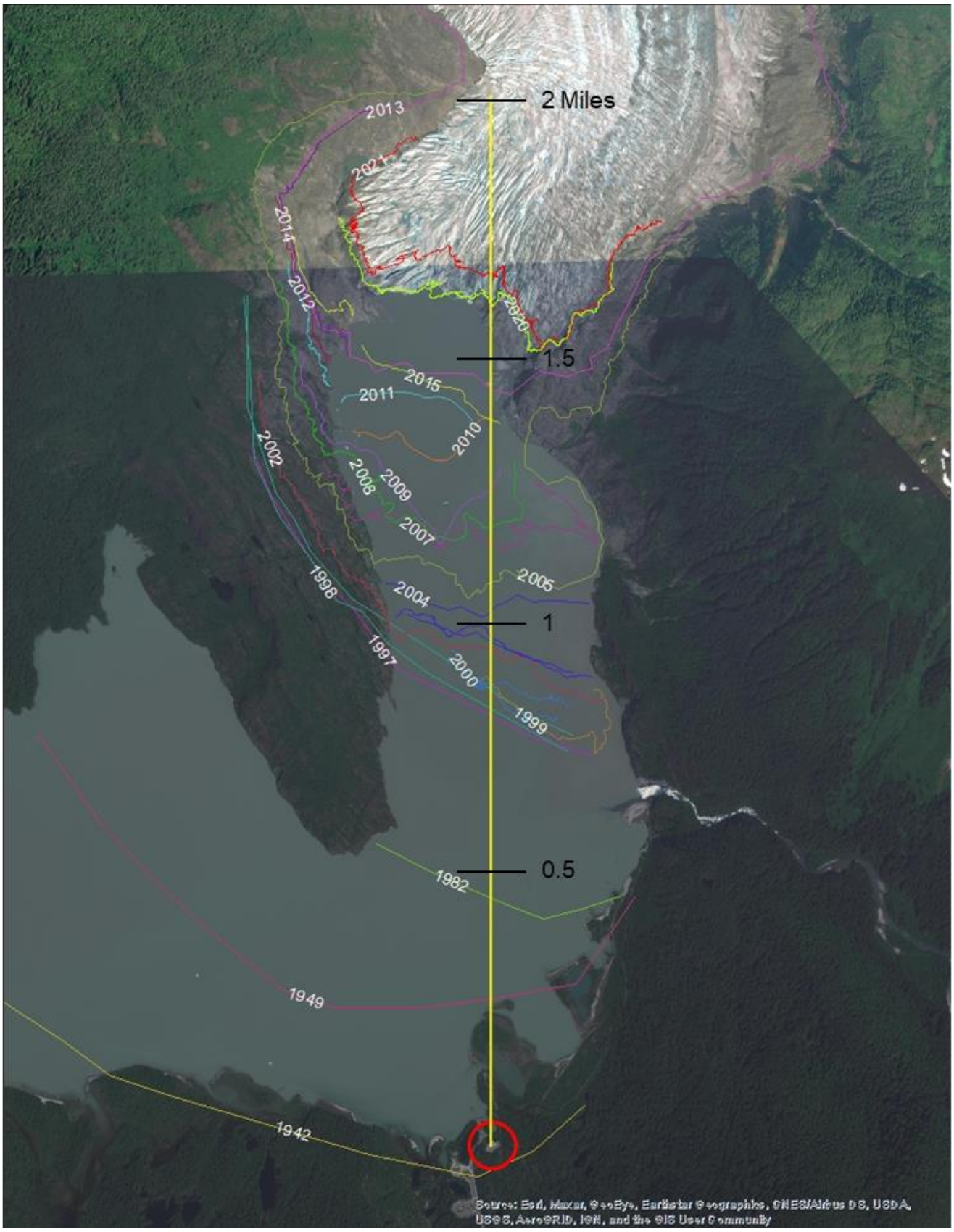


Figure 9. Mendenhall Glacier terminus positions since 1942. The yellow line depicts the distance from the location of the Mendenhall Glacier Visitor Center (red circle) to the terminus of the glacier.



Terminus position mapping for 2020 and 2021

Faculty and students from UAS used drones to image the Mendenhall terminus positions in 2020 and 2021. The glacier outlines from these images have been digitized to create highly accurate outlines of the position of the Mendenhall Glacier terminus.

Figure 10. Elevation-rectified orthoimage of Mendenhall terminus collected in May 2020. The image was created by stitching together 760 individual, overlapping photographs of the terminus area taken by a drone.

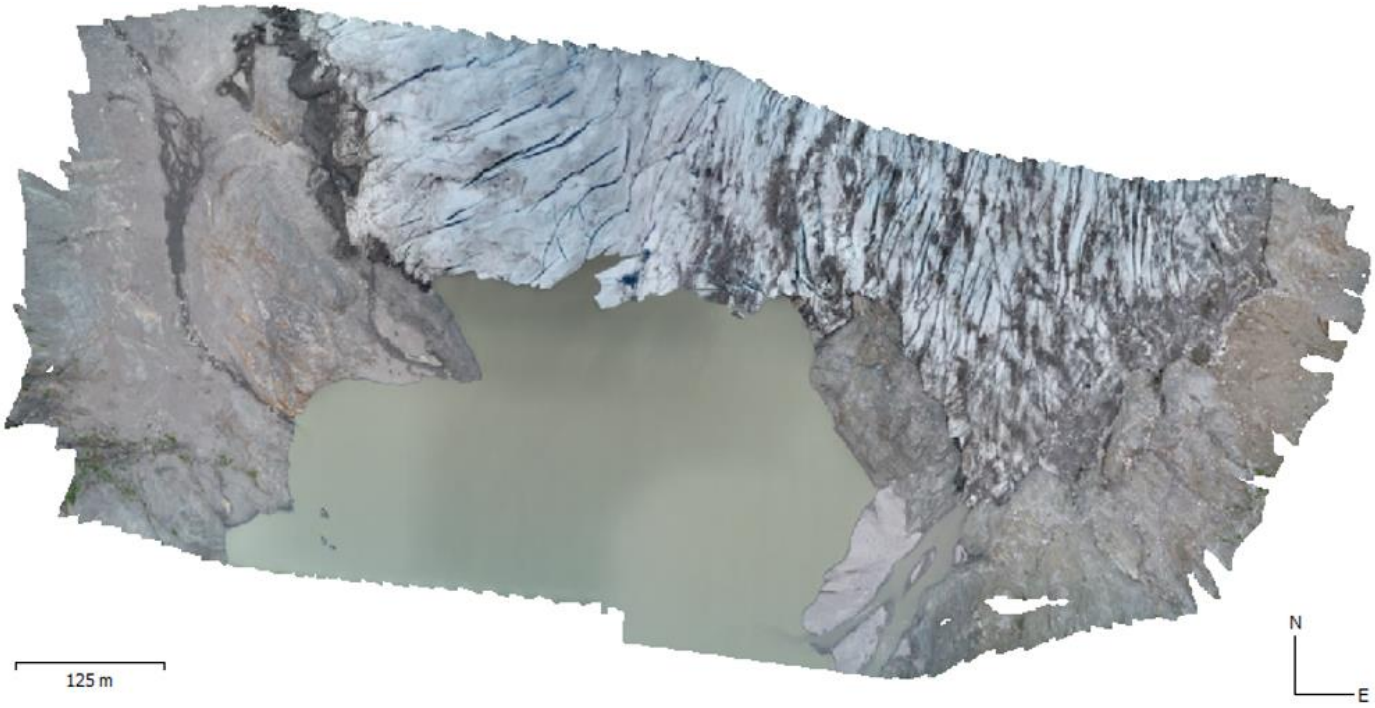


Figure 11. Drone-derived orthoimage of Mendenhall Terminus collected in July 2021.

The elevation-rectified orthoimages were also used to create three dimensional topographic digital elevation models (DEMs) of the Mendenhall terminus. These DEMs can be used to evaluate changes in the thickness of the ice at the terminus over time. In the DEMs, portions of Mendenhall Lake contain roughness artifacts associated with the challenge of resolving elevations from the photos of the lake, which do not contain distinct features that can be matched between photographs.

Figure12. Digital elevation model of the Mendenhall terminus from May 2020.

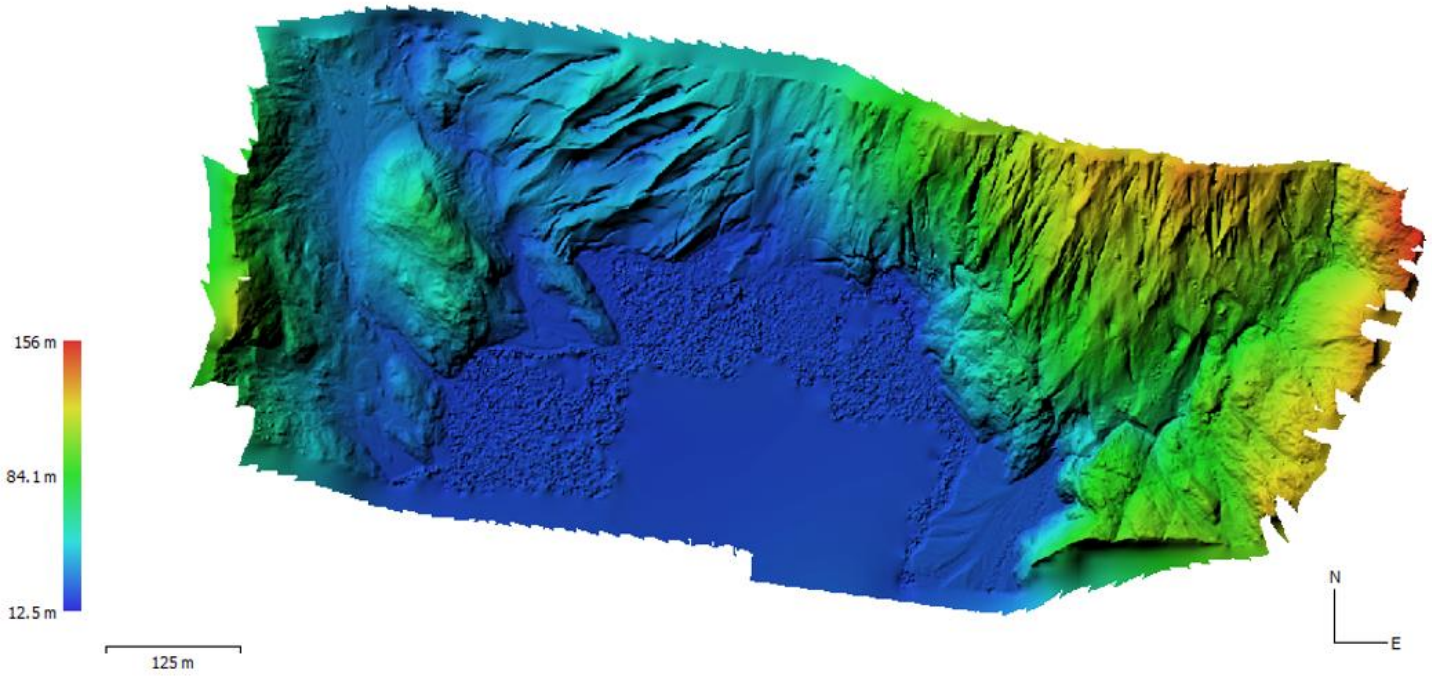


Figure 13. Digital elevation model of the Mendenhall terminus from July 2021.

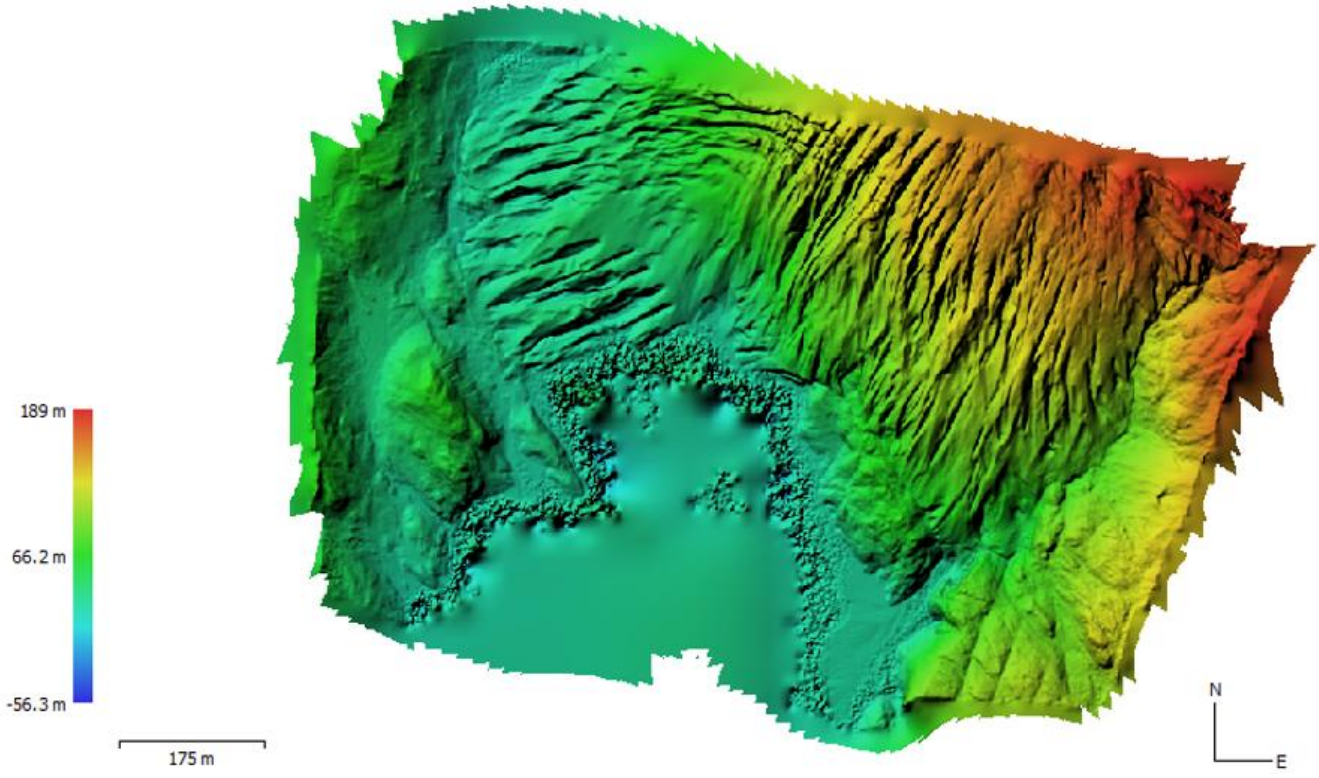


Figure 14. Terminus positions for Mendenhall Glacier in 2020 and 2021. The terminus outlines were digitized from the drone-produced orthoimages.

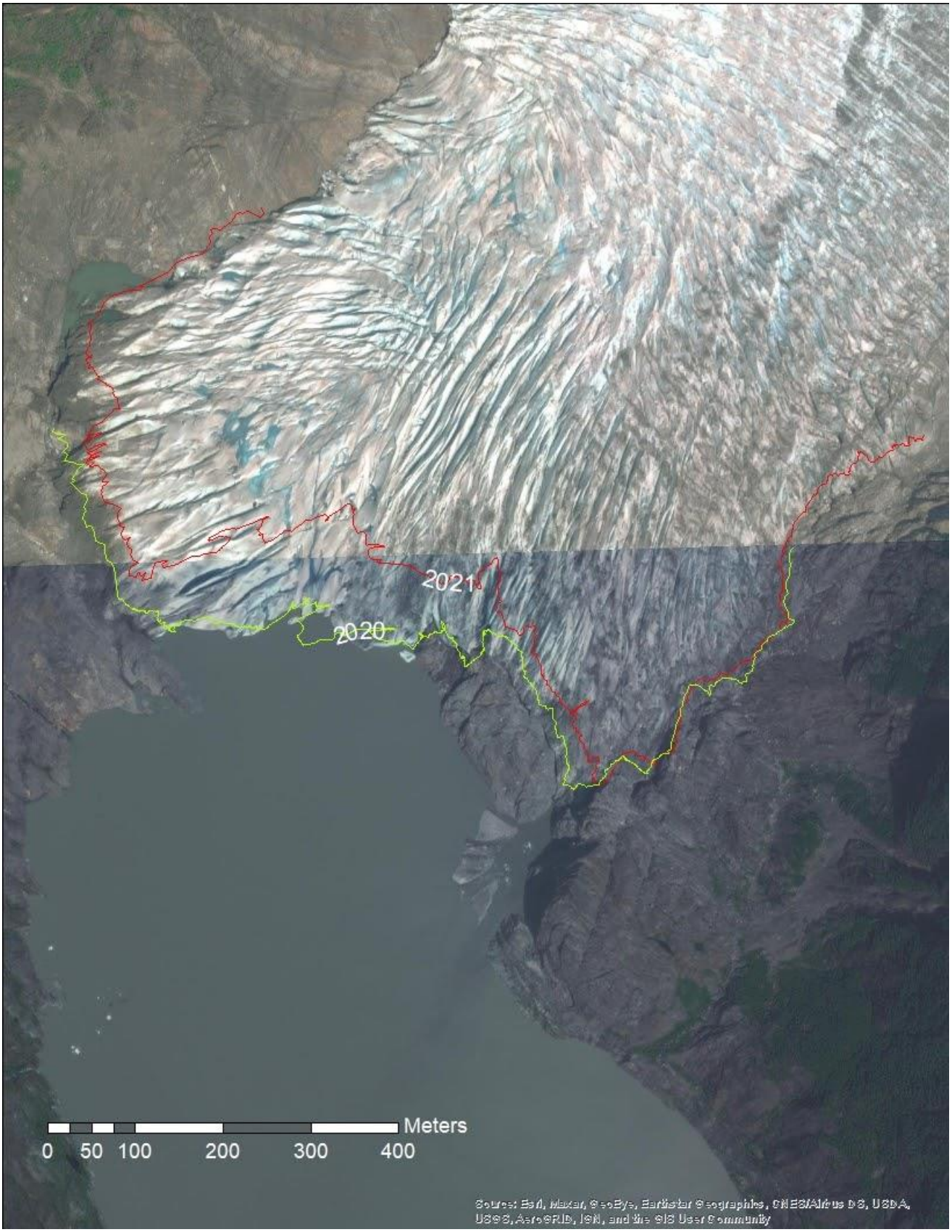


Figure 15. Close-up image of the terminus positions in 2020 and 2021. The retreat of the portion of the terminus in Mendenhall Lake ranged from 60-135 m during this one-year period.

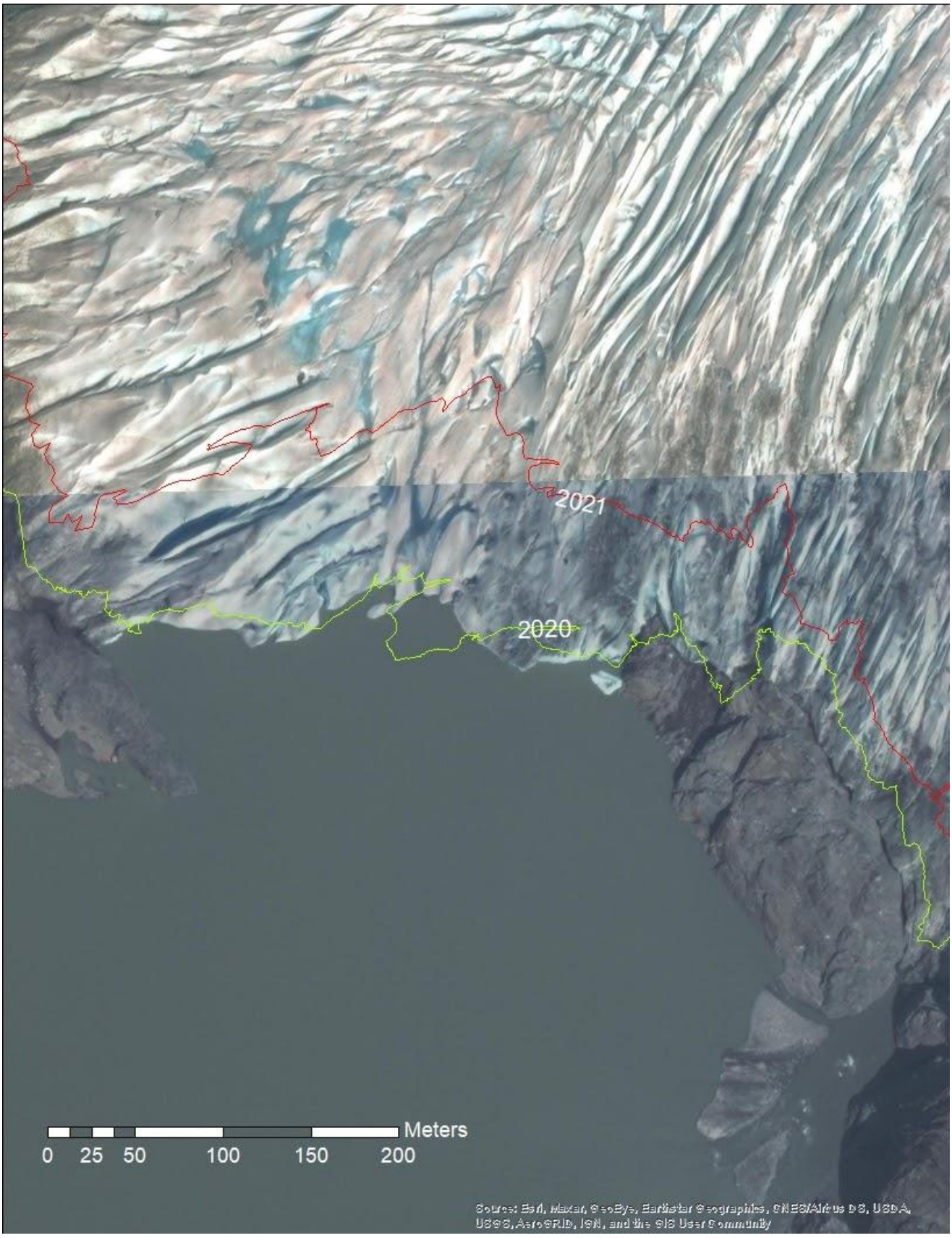


Figure 16. The 2020 to 2021 change in the grounded portion of the terminus on the west side of the glacier. Annual retreat averaged about 30 m in this area where the terminus is grounded.

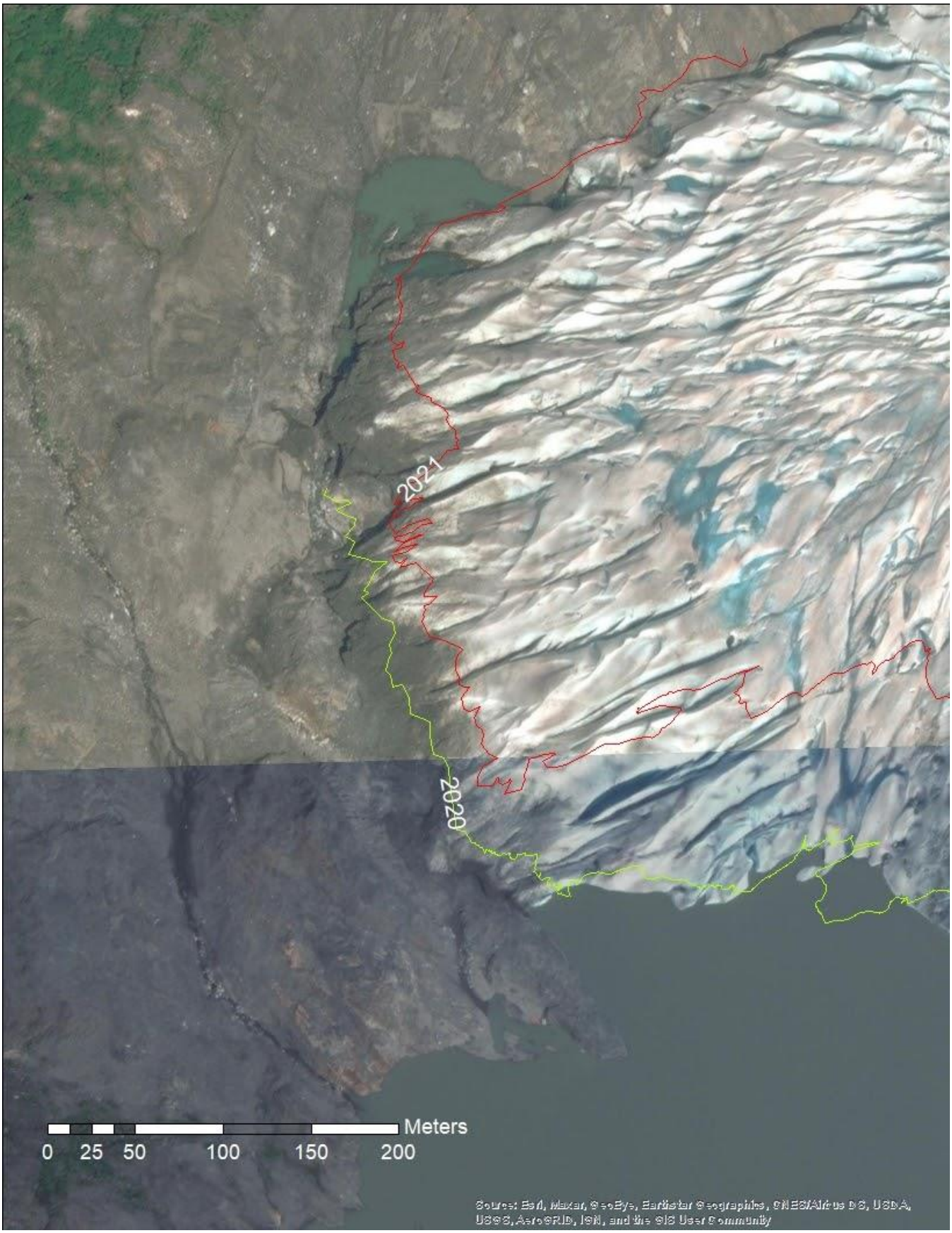


Figure 17. On the east side of the glacier, where the terminus is grounded there was relatively little retreat (≤15 m/yr) between 2020 and 2021.


2021
2020
Meters
0 15 30 60 90 120
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Future Terminus Positions for Mendenhall Glacier (2020-2050)

The Juneau Icefield is experiencing high thinning rates, which can exceed 6 m/yr at low elevations. In the last half of the 20th century, ice thinning rates on Mendenhall Glacier ranged from ~6 m/yr at low elevations to 0 m/yr in the upper portion of the accumulation zone. What follows are projections of how the terminus position and viewshed associated with the Mendenhall Glacier will change in coming decades.

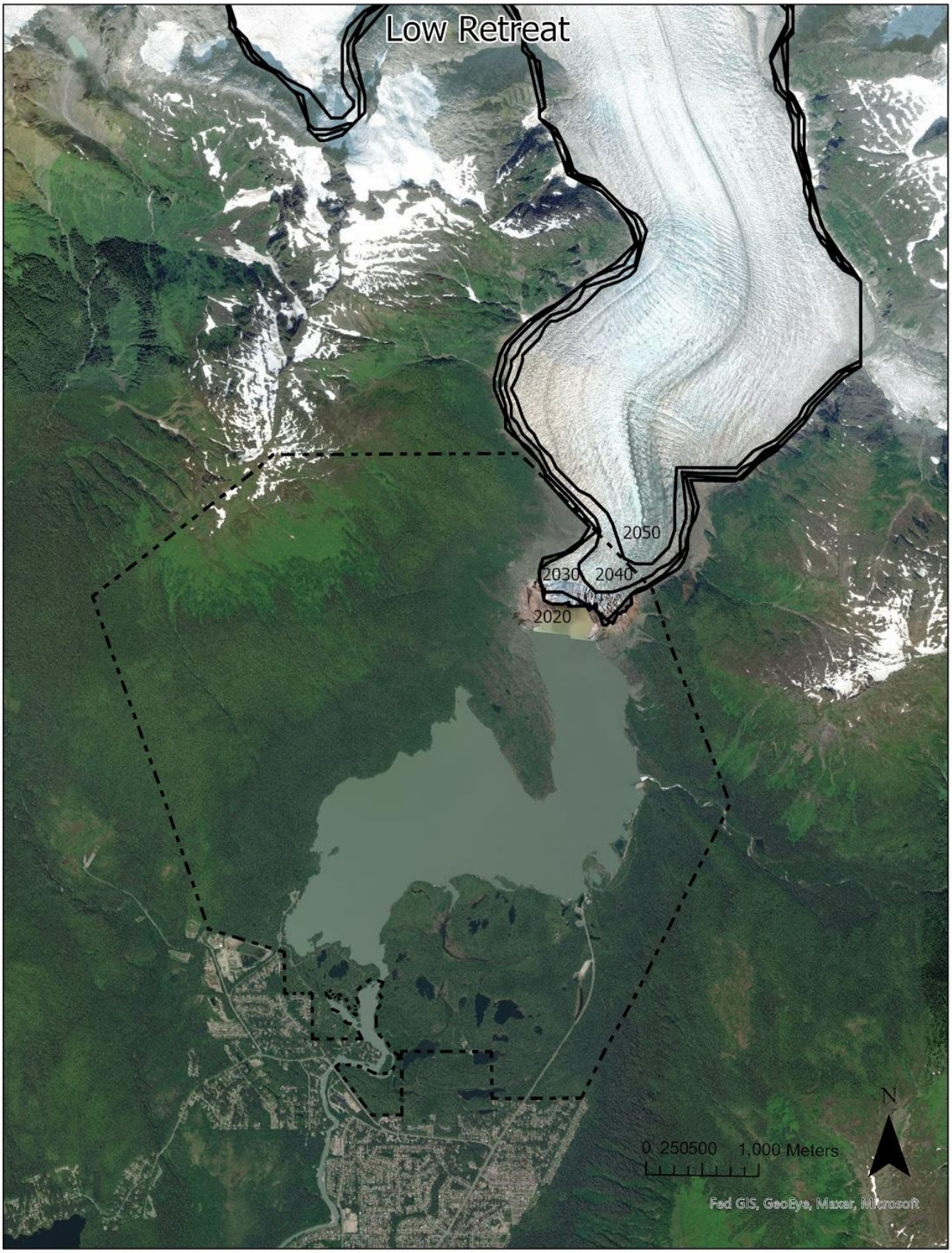


Figure 18. Glacier outline in 2020 with modeled outlines for 2030, 2040, and 2050, from the low thinning rate scenario. The dashed line represents the Mendenhall Glacier Recreation Area (MGRA) boundary.

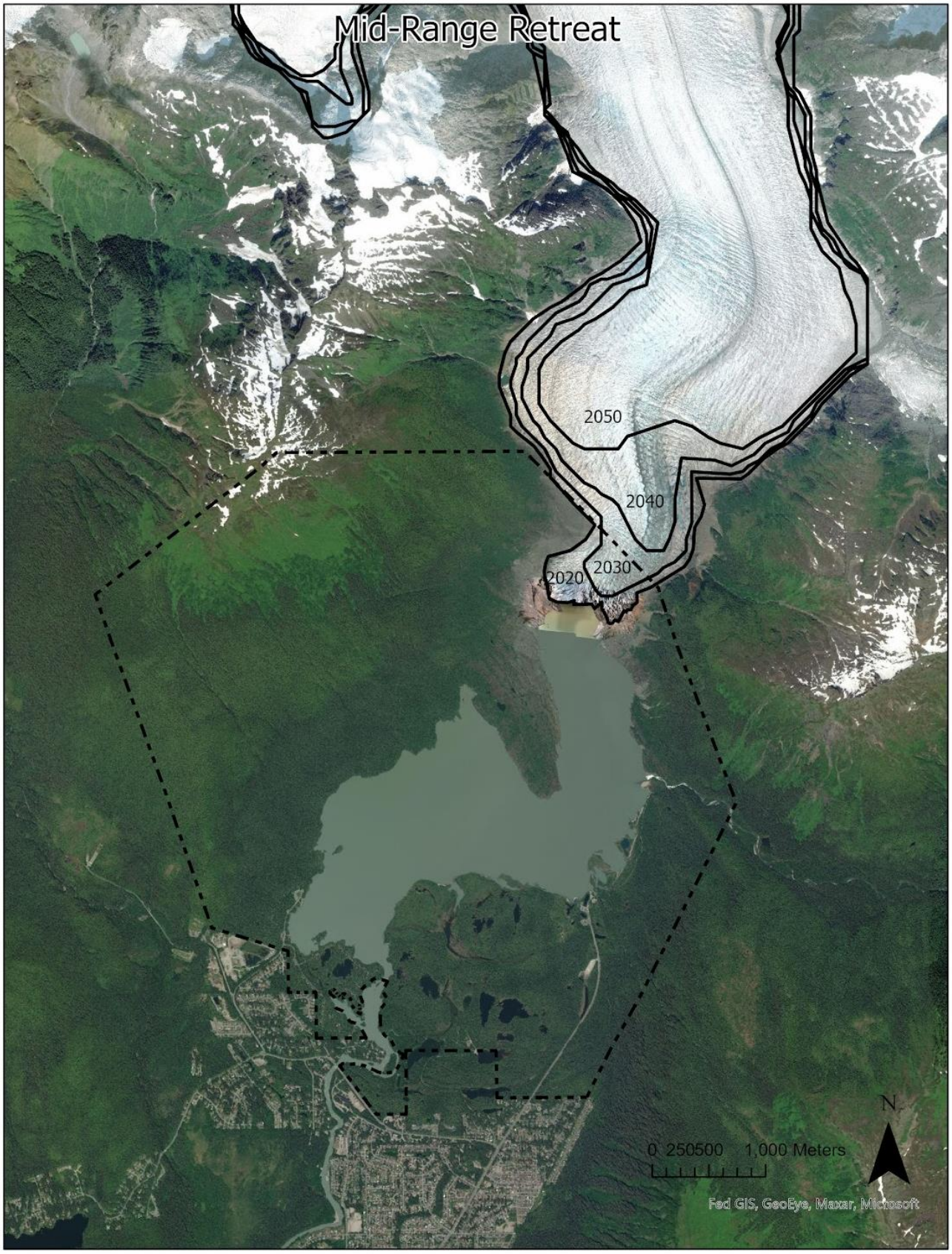


Fig. 19: Glacier outline in 2020 compared to modeled outlines for 2030, 2040, and 2050, from the mid-range thinning rate scenario. The dashed line represents the MGRA boundary.

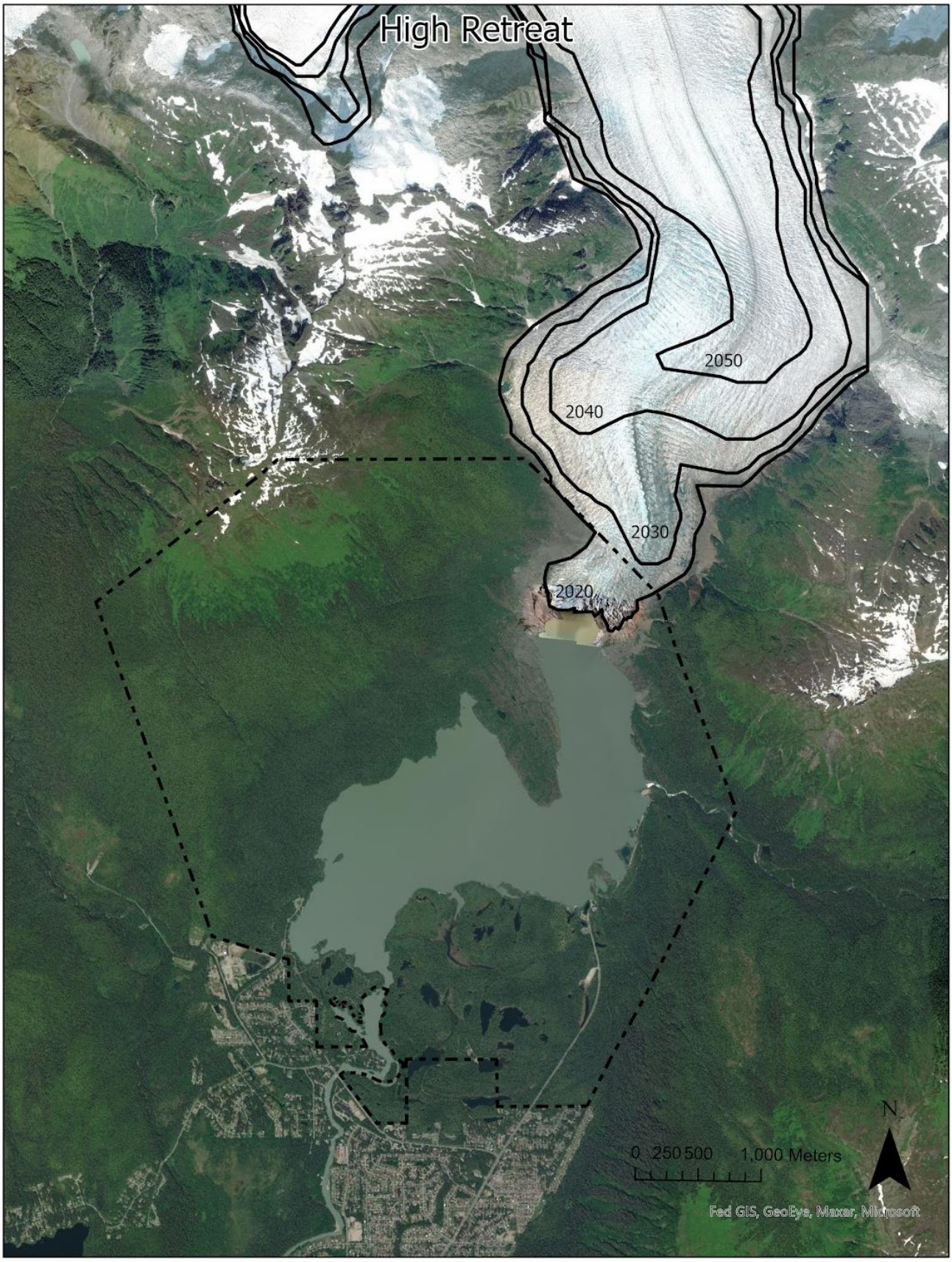


Figure 20. Glacier outline in 2020 compared to modeled outlines for 2030, 2040, and 2050, from the high thinning rate scenario. The dashed line represents the MGRA boundary.

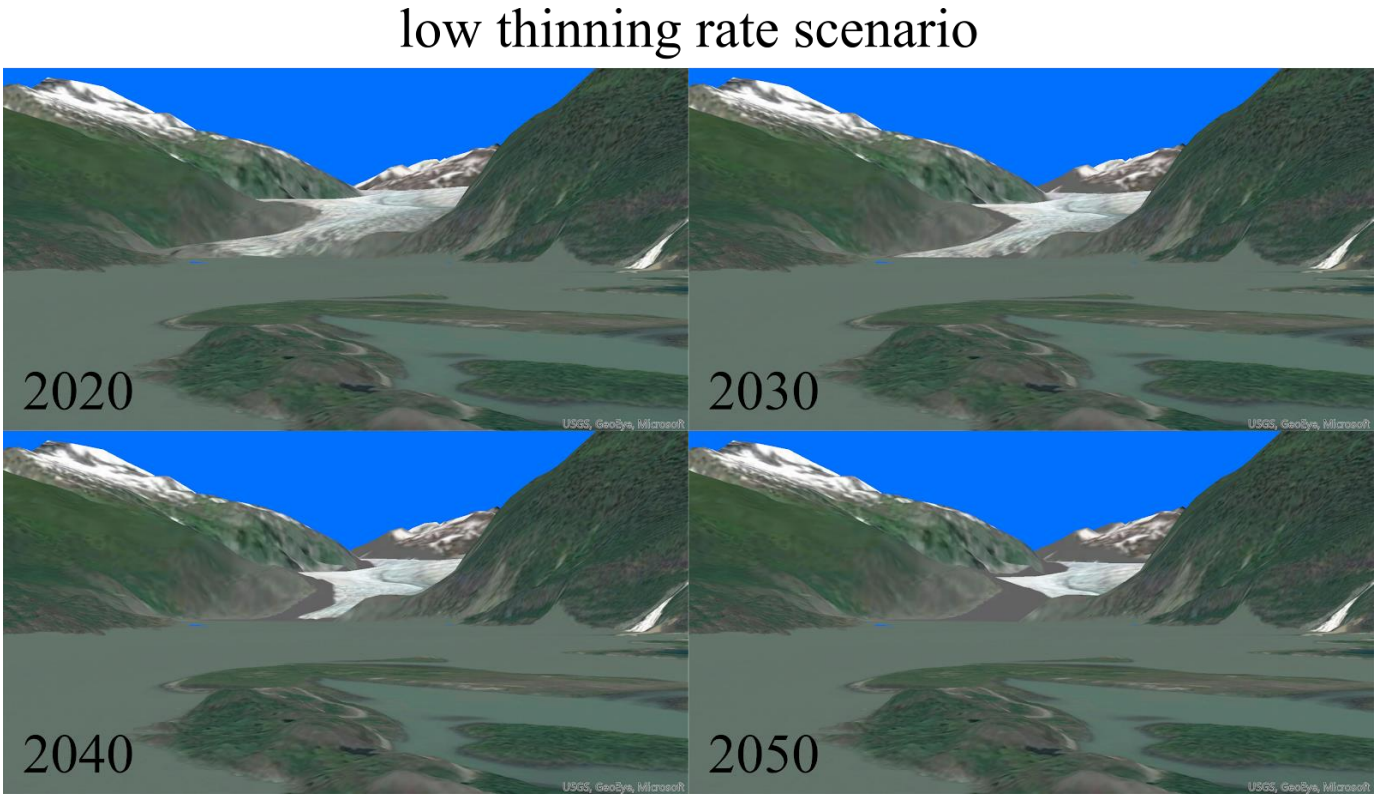


Figure 21. Glacier viewsheds from the Mendenhall Glacier Visitor Center for 2020-2050 from the low glacier thinning rate scenario.

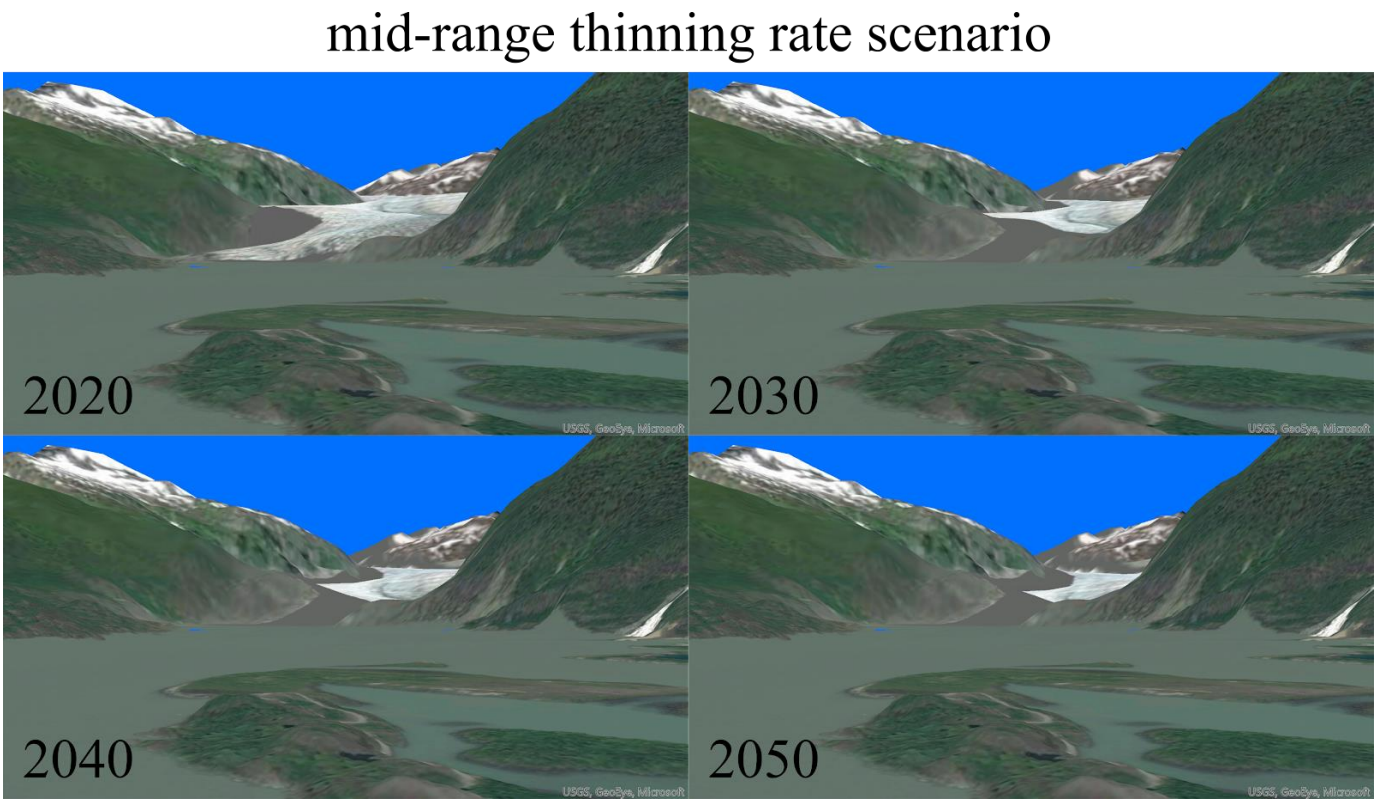


Figure 22. Glacier viewsheds from the Mendenhall Glacier Visitor Center for 2020-2050 from the medium glacier thinning rate scenario.

high thinning rate scenario

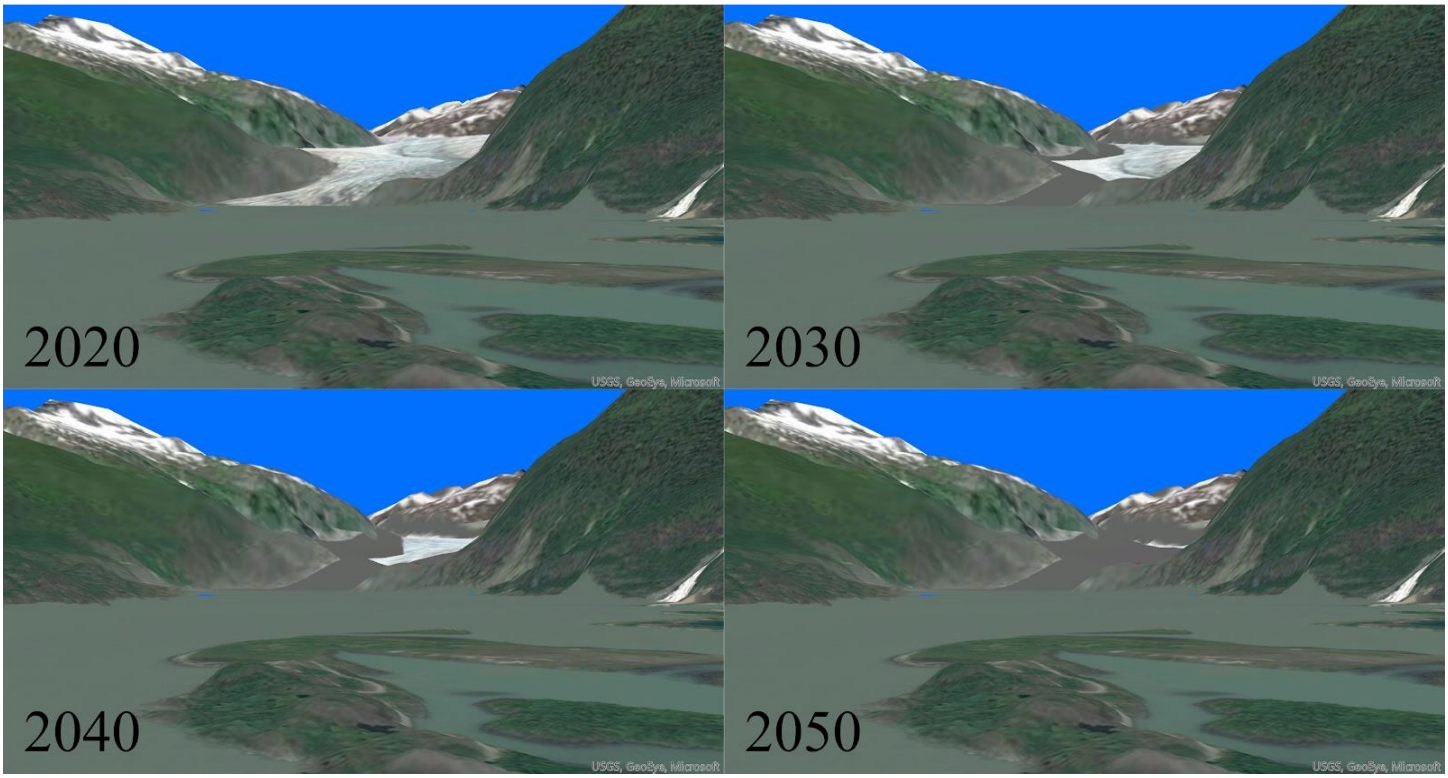


Fig. 23: Glacier viewsheds for the high-range thinning rate scenario.

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