The Slow Advance of a Calving Glacier: Hubbard Glacier, Alaska

by

D.C. Trabant[1], R.M. Krimmel[2], K. Echelmeyer[3], S. Zirnheld[3], D. Elsberg[3]

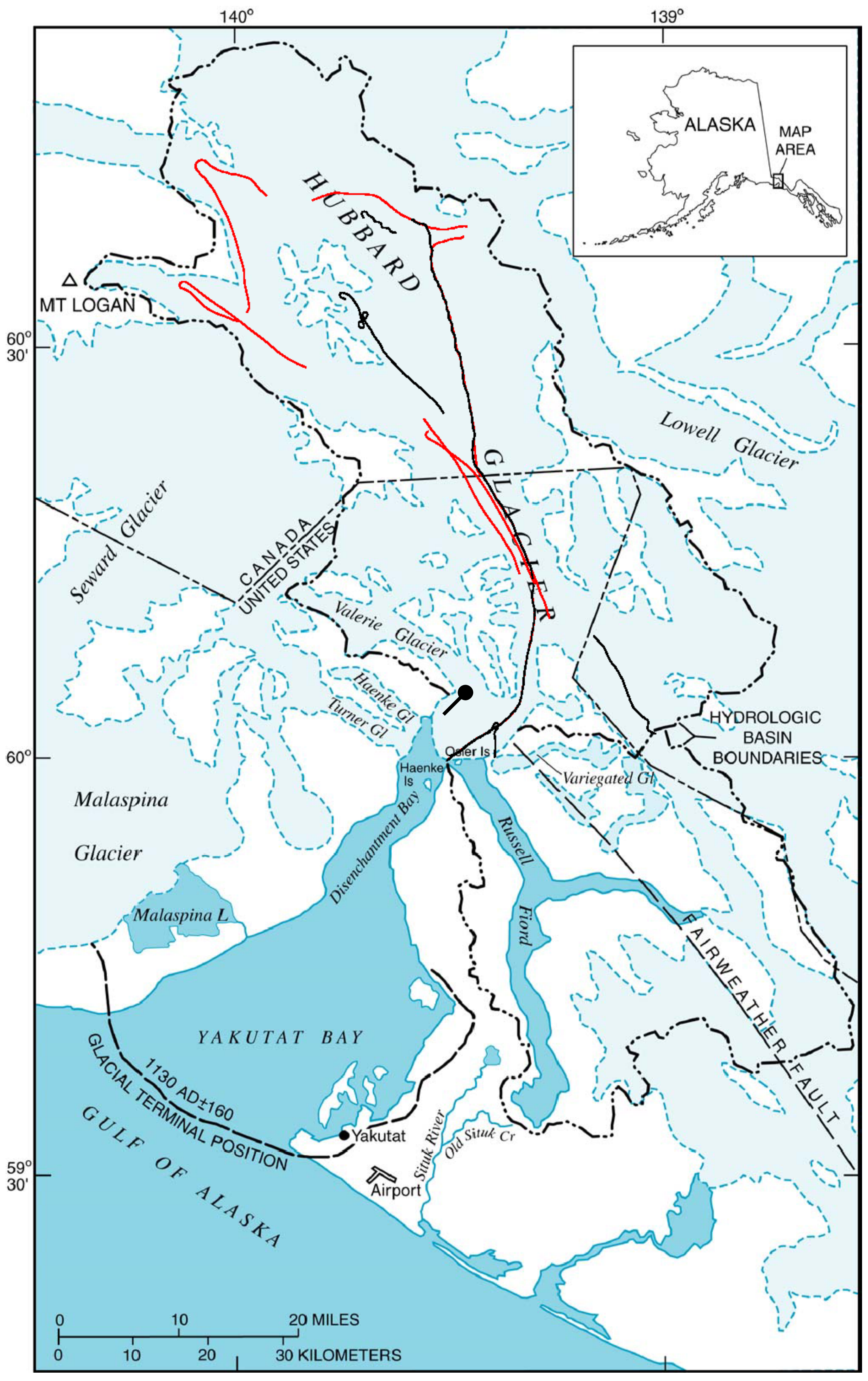
[1]*U.S. Geological Survey, Fairbanks, AK, 99775*

[2]*U.S. Geological Survey, Tacoma, WA, 98402*

[3]*Geophysical Institute, University of Alaska, Fairbanks, AK 99775*

ABSTRACT

Hubbard Glacier is the largest tidewater glacier on the North American continent. It has been thickening and advancing toward the Gulf of Alaska since it was first mapped by the International Boundary Commission in 1895 (Davidson, 1903). This is in stark contrast with most glaciers, which have thinned and retreated during the last century. This atypical behavior is an important example of the calving glacier cycle. If Hubbard Glacier continues to advance, it will close the seaward entrance of Russell Fjord and create the largest glacier-dammed lake on the North American continent in Historic times. This poster shows the measured changes in ice thickness, ice speed, terminus advance, and fjord bathymetry of Hubbard Glacier. The lower regions of the glacier have thickened by more than 80 m in the last 40 years, and the entire glacier has increased in volume by 12 km^3 during that time. Ice speeds are decreasing near the calving face from a high of 16.5 m d^{-1} in 1948 to 11.5 m d^{-1} in 2001. The calving terminus advanced at a rate of about 16 m a^{-1} between 1895 and 1948 and accelerated to 32 m a^{-1} since 1948. However, since 1986, the advance of the part of the terminus in Disenchantment Bay has slowed to 28 m a^{-1}. NOAA bathymetric data from 1978 and 1999 show that the sub-sea lee-face of the terminal moraine is advancing at an average rate of 32 m a^{-1}; confirming the long term advance rate determined from the subaerial calving face in Disenchantment Bay.

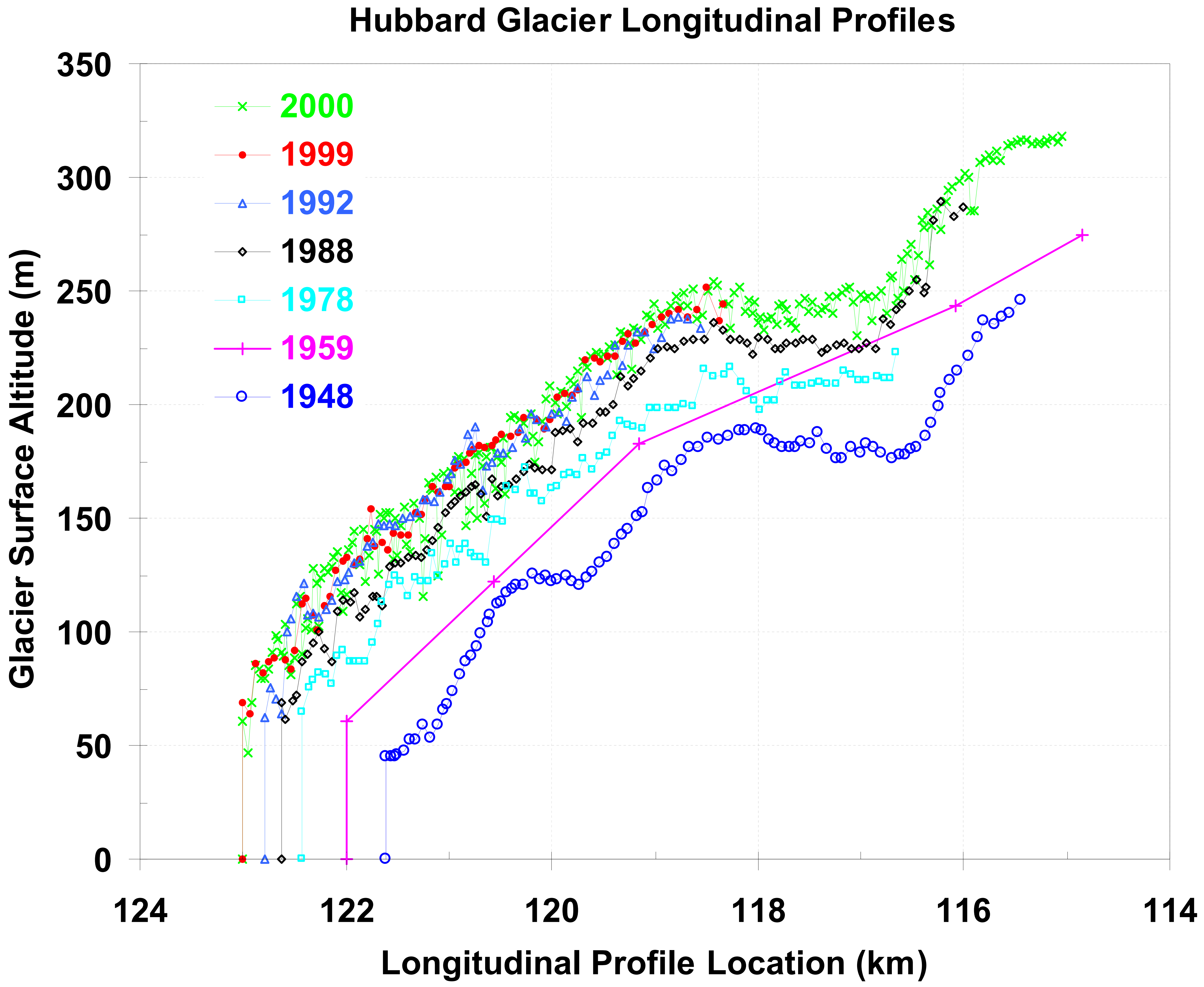


HISTORIC OBSERVATIONS

Hubbard Glacier has a long documented history. Hubbard Glacier filled all of Yakutat Bay in about 1130 A.D (Plafker and Miller, 1958). Russell (1891) and Gilbert (1904), interpreting records of the visits by Malaspina in 1792 and Vancouver in 1794, place the terminus of Hubbard Glacier south of Haenke Island (see figure above). Tarr and Martin (1914) report that Russian maps dating from the early 1800's show the terminus just north of Haenke Island and a lake in the Russell Fjord basin. The oral history of the Tlingit Indians of Yakutat includes a description of the emptying of the lake in Russell Fjord about 1860 (de Laguna, 1972). I.C. Russell's (1891) small map of Hubbard Glacier shows the terminus about 2 km north of Osier Island. During his second visit, Russell (1893) recognized that the fjord, which was later named for him, had been a glacier-dammed lake. The first surveyed position of the terminus of Hubbard Glacier was produced by the International Boundary Commission in 1895 (Davidson, 1903), just before the Harriman expedition's visit in 1899 (Gannett, 1902). Twentieth century investigative highlights include: marine geologic investigations by Gilbert (1904), Wright (1972), Carlson and others (1978 and 1992), and Carlson (1989); glaciological investigations by Tarr and Martin (1906 and 1914), Tarr and Butler (1909), Post (1965 and 1967), Post and Mayo (1971), Brown and others (1982), Mayo (1988a&b, 1989), and Trabant and others (1991); geological investigations by Plafker and Miller (1958); oceanographic investigations by Royer (1975) and Reeburgh and others (1976); and hydrologic investigations by Mayo (1986), Seitz and others (1986), and National Oceanographic and Atmospheric Administration (1978 and 1999).

HUBBARD GLACIER

Hubbard Glacier is currently about 123-km long, with a calving face that is 11.4 km in length and, seasonally, as high as 100 m above sea level. Ice radar thickness measurements in August 1986 (Mayo, 1989 and Trabant and others, 1991) showed that the glacier bed reaches as deep as 414 m below sea level about 1.5 km upstream from the terminus. Since 1895, it has advanced about 2.5 km into Disenchantment Bay. This slow, but persistent advance is the latest phase of a long-period cycle of alternating slow advances and drastic retreats that has persisted throughout middle- and late-Holocene in nearly all of Alaska's calving glaciers (Post, 1975, 1980a,b,c, and d). This cycle has been described by Post (1975) as the calving glacier cycle.



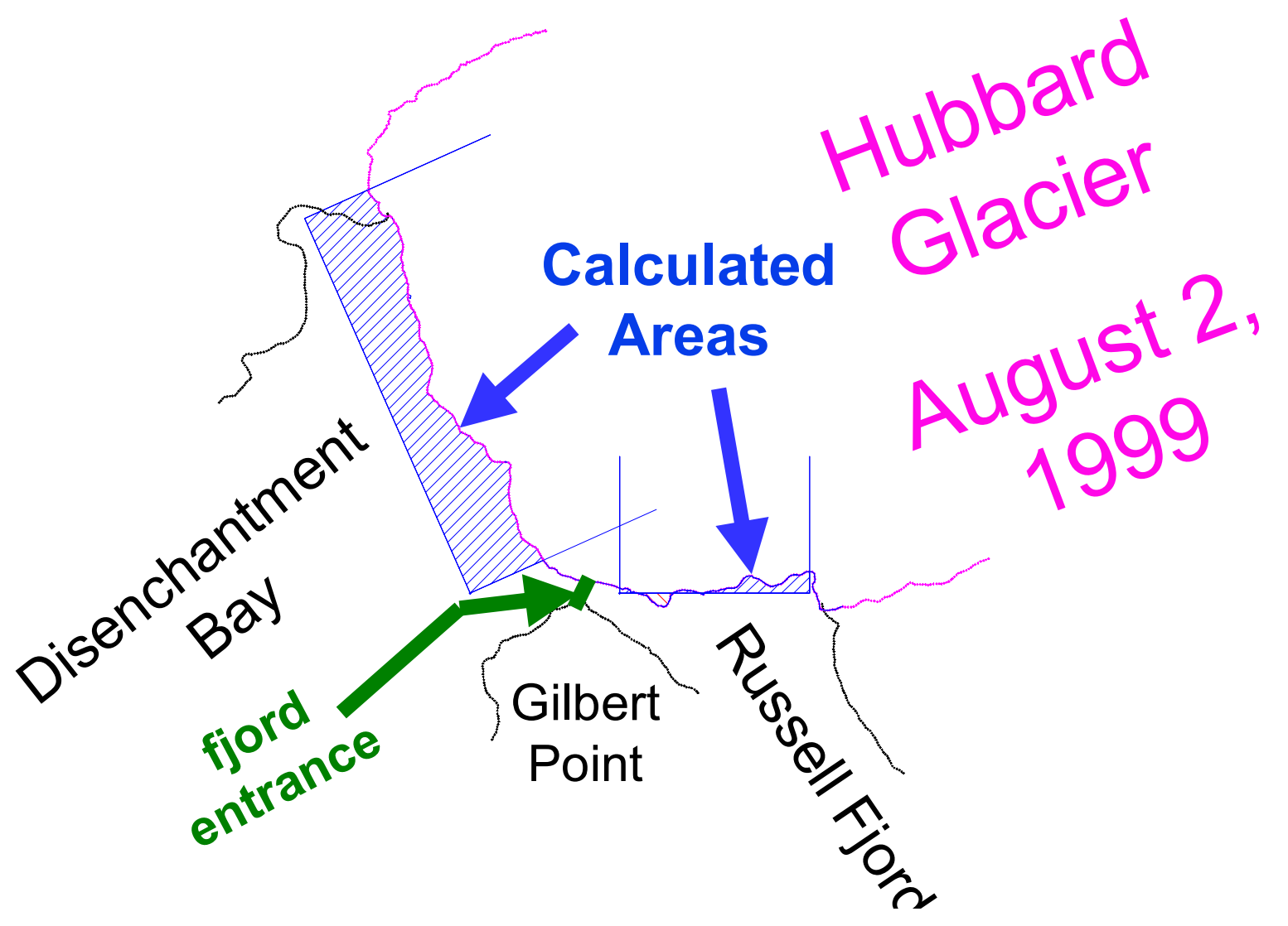
Longitudinal profiles on the terminal lobe of Hubbard Glacier. The 2000 profile is from the airborne laser profiling system; the scatter is caused by crevassing. The 1959 profile is taken from the published USGS Mount St. Elias 1:250000 scale quadrangle. The rest were photogrammetrically determined from aerial photography along the line flown by the aerial-profiler in 2000.

CALVING GLACIER CYCLE

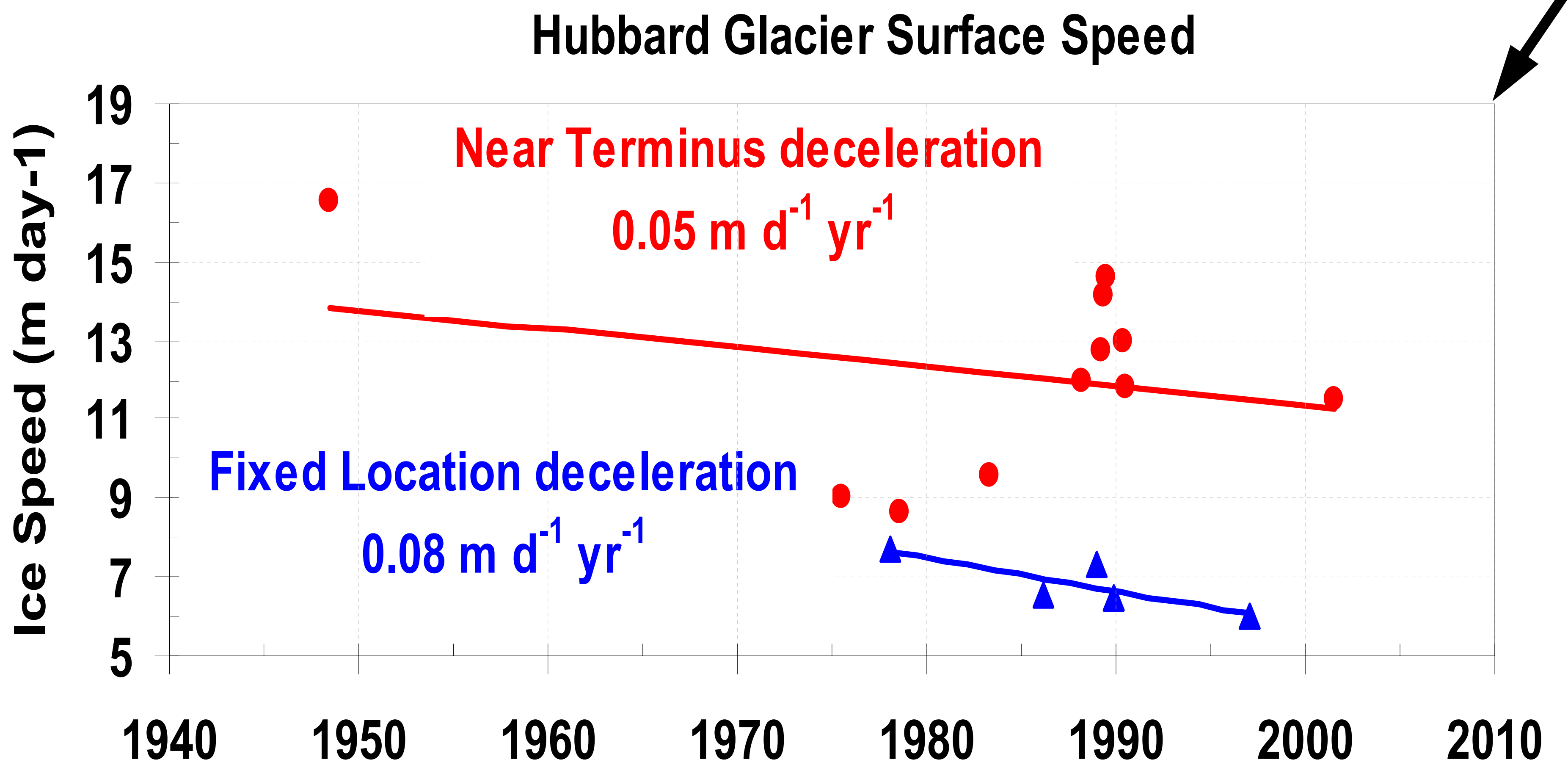
Post (1975) described the processes that control the advance and retreat cycles of calving temperate glaciers. The original description has been augmented by Trabant and others (1991) and Post and Motyka (1995). The tenets of the hypothesis are that: (1) the primary factor that influences the advance and retreat of temperate calving glaciers is the water depth at the calving face; (2) the cycling is not directly related to climate, except perhaps for the initiation of retreat; and (3) the advance and retreat cycling will continue as long as the glacier continues to calve. The hypothesis of the calving glacier cycle has been used in explanations of the anomalous advance and retreat behavior of several calving glaciers in Alaska, such as Portage (Mayo and others, 1977), Taku (Motyka and Post, 1994), Taku and Le Conte (Post and Motyka, 1995), Columbia (preeminently by Post, 1975), and the contrasting advance of Harvard Glacier and retreat of it neighbor, Yale Glacier (Field, 1975).

http://ak.water.usgs.gov/glaciology/

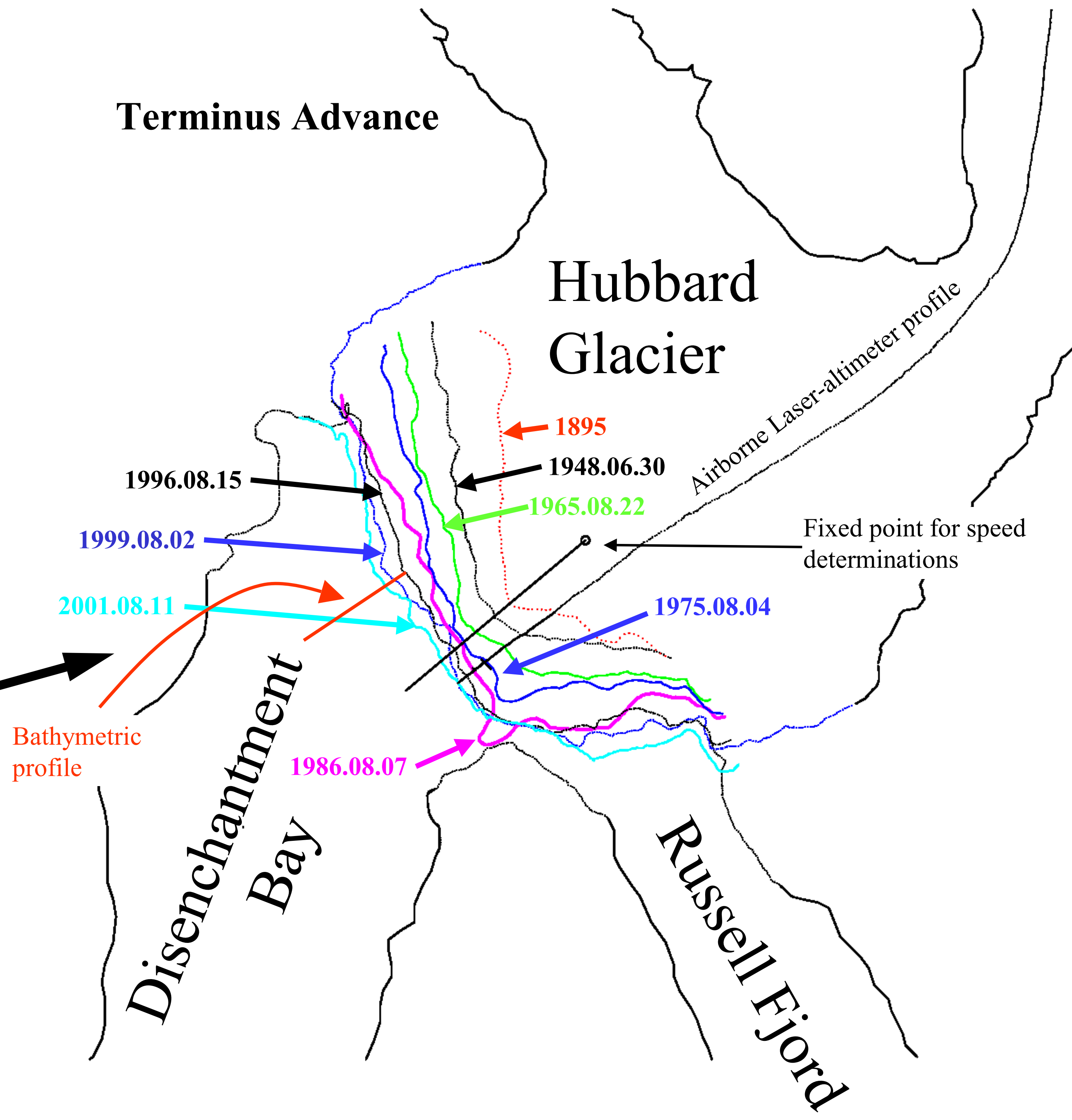
Width-averaging procedure

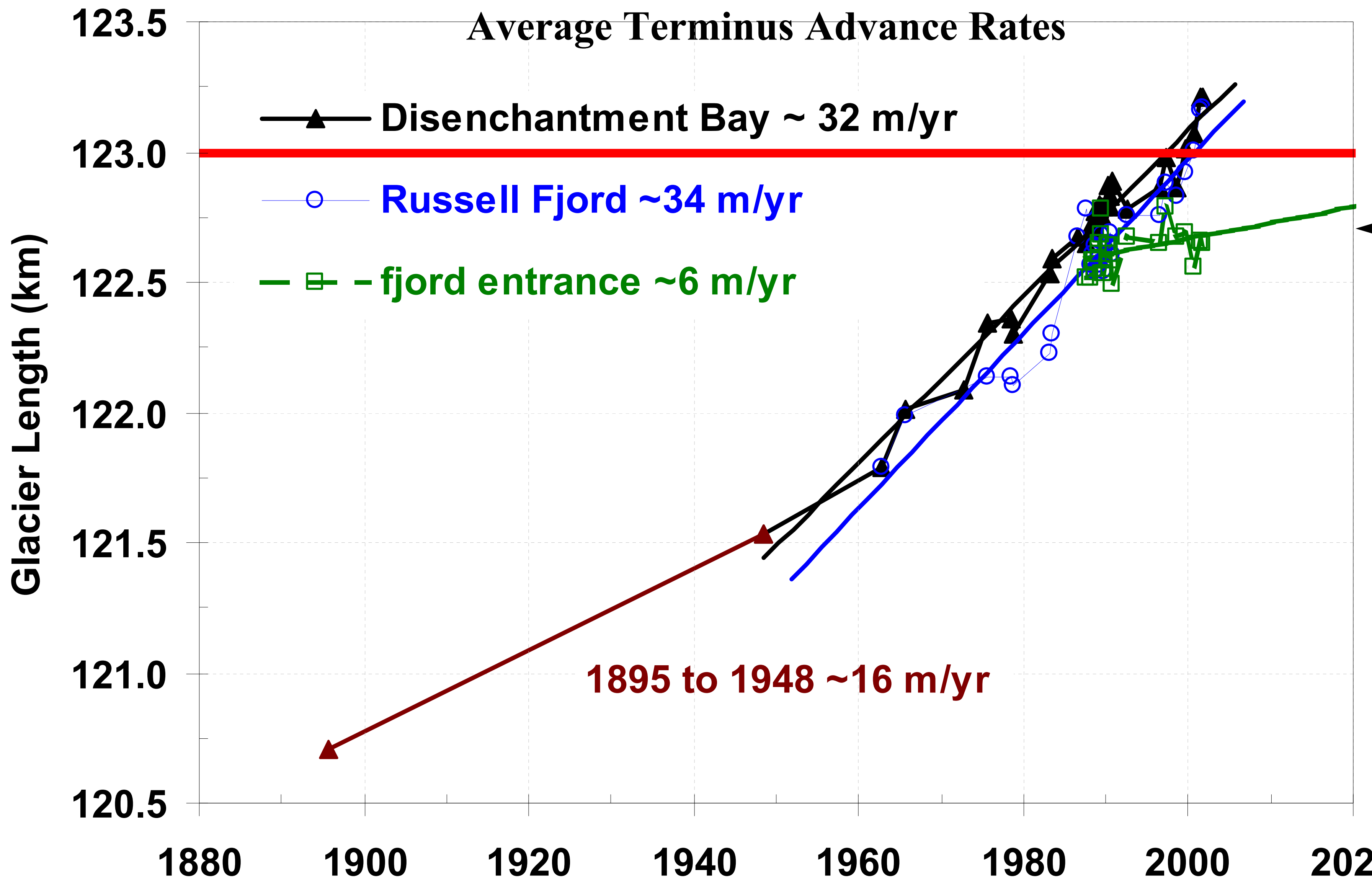


Surface ice speeds on Hubbard Glacier were photogrammetrically determined from displacements of crevasses and seracs. The “fixed location” is about 3 km above the 1997 terminus near the center of the glacier (see below). The linear rate of deceleration at the fixed location is about 0.08 m d^{-1} a^{-1}, and is influenced by the changing strain rate as the distance to the calving face changes. However, the five speed determinations at the fixed point were selected to eliminate seasonal speed variations. The 11 “near terminus” speeds where interpolated as close to the calving face as possible, along a flow line down glacier from the fixed location. The rate of deceleration of the near-terminus speeds is about 0.05 m d^{-1} a^{-1}; the seasonal speed variation was not selectively removed from this data subset.



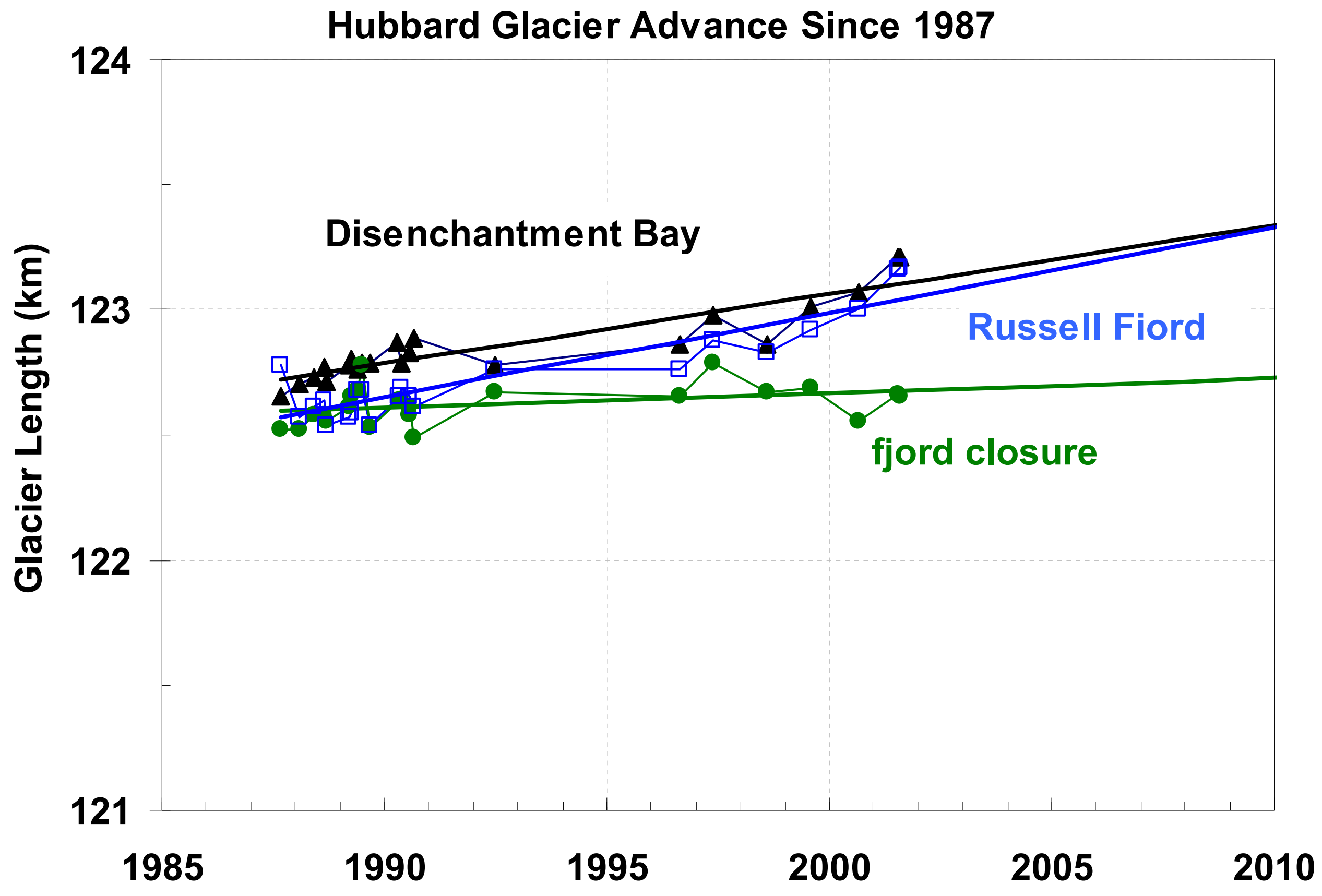
Terminus locations for Hubbard Glacier, 1895, 1948, 1965, 1975, 1986, 1996, 1999, and 2001 from aerial photography and satellite images. The curving line is the ground track of the airborne laser profiling data. The small circle is the “fixed location” used for interpolating glacier surface speed and the ray attached to the circle was used for defining the “near terminus” ice speeds plotted in the figure above. The bathymetric profiles (below right) are along the red longitudinal line. NOTE: Hubbard Glacier blocked the entrance to Russell Fjord from May to October, 1986; the August 1986 terminus line shows the ice dam.





Advance of Hubbard Glacier since 1895. The linear trend advance rate prior to 1948 was about 16 m a^{-1}. Between 1948 and 2001, the termini in Disenchantment Bay and Russell Fjord advanced at average rates of 32 m a^{-1} and 34 m a^{-1} respectively.

Since the temporary damming of Russell Fjord in 1986, the terminus in Disenchantment Bay has slowed to 28 m a^{-1}; in Russell Fjord, the terminus continues to advance at 34 m a^{-1}; and the terminus near the entrance to Russell Fjord is advancing at about 6 m a^{-1}. The entrance to Russell Fjord will close when the glacier length reaches 123 km in that area.



1978 and 1999 bathymetric surveys by the National Oceanic and Atmospheric Administration were compared to evaluate the displacement of the submarine terminal moraine of Hubbard Glacier. The profile (below right) shows an average advance rate of about 10 m a^{-1}. The integrated average advance rate of 2.1 km width of the seaward face of the moraine between –120 m and –170 m depth is 32 m a^{-1}; very good agreement with the average rate of terminus advance.

August 1986 ice-dam push-moraine closure of Russell Fjord.