

# **Dendrochronological records of late Holocene and recent glacier fluctuations of Eagle, Herbert, and Mendenhall Glaciers, Southeast Alaska**

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## **Introduction**

Glaciers play a prominent role in climatic research, since they are important monitoring agents and their fluctuations carry information on past climates. Dendroglaciology allows dendrochronological techniques to be applied to the reconstruction of glacier fluctuations (Schweingruber 1988, 1996, Luckman 1995). In Southeast Alaska, glaciers extended into forested areas enabling dendrochronological techniques to be applied to the reconstruction of glacial dynamics in two ways: (1) Advancing glaciers in the past tilted and overran trees whose remnants, sub-fossil wood, allow former glacial advances to be dated. (2) Retreating glaciers leave bare areas that are rapidly reforested due to the favorable climate. Tree rings provide a precise date for advance or, in this case, for retreat when terminal moraines became ice-free.

The Eagle, Herbert and Mendenhall Glaciers are all part of the Juneau Icefield located in the Juneau area, Southeast Alaska (Fig. 1). In a previous study, Lacher (1999) found that the forefields of the Herbert and Mendenhall Glaciers have several well-developed, densely vegetated terminal moraines dating back to the Little Ice Age ca. 1750 to 1960 AD. He collected subfossil wood and built floating chronologies, but these chronologies could not be linked to recent chronologies and thus they could not be calendar dated. To continue this work, we sampled living trees from different stands near the Eagle Glacier and also subfossil snags in the forefields of all three glaciers. Furthermore, *in situ* stumps that were rooted in a lower soil level were collected in the riverbeds of the Mendenhall and Herbert Rivers. Our objectives are: (1) to reconstruct fluctuations of Eagle glacier, (2) to establish continuous tree-ring chronologies for the last millennium and (3) finally to gain insight into the climatic history of the region. Here, we report the dating of glacial stands in the forefield of Eagle Glacier.

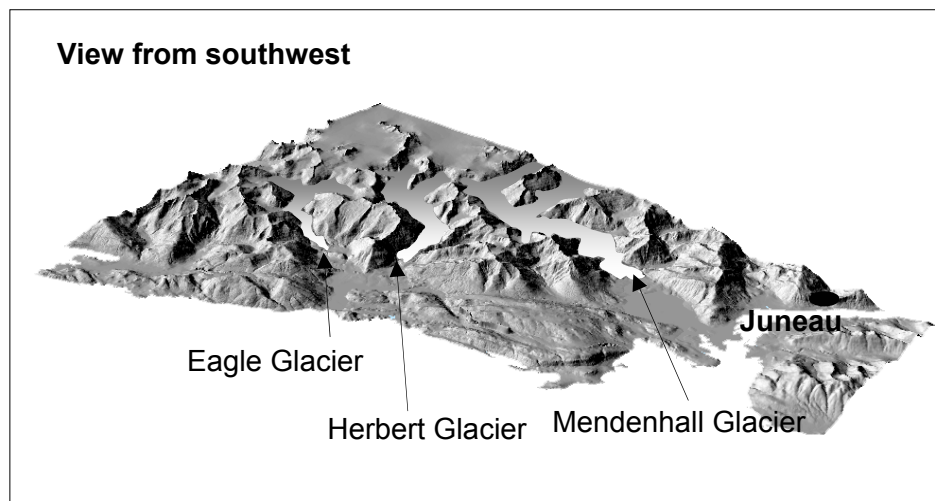
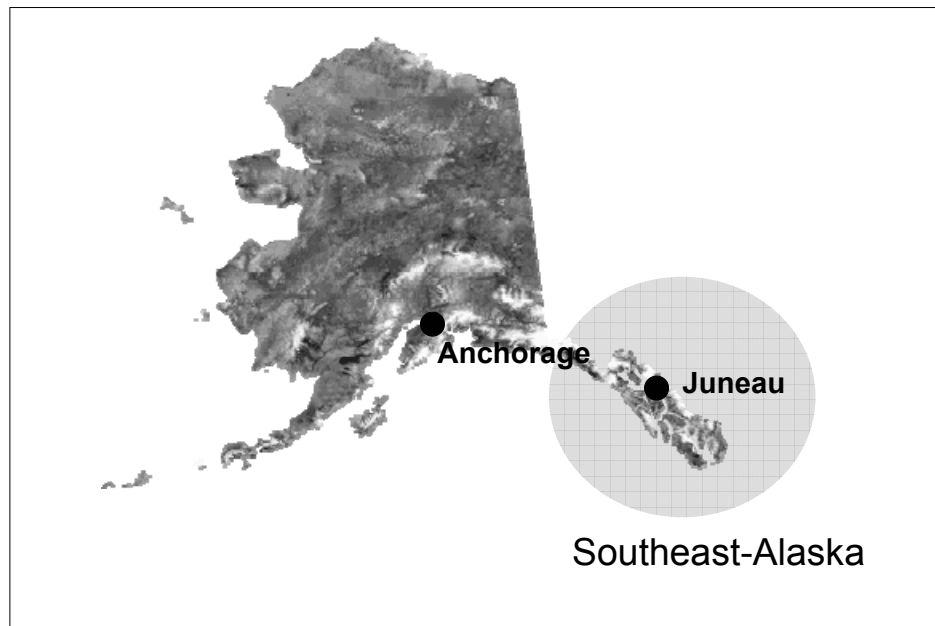


Figure 1: Location of the site.

### Material and methods

**Mapping:** The positions of lateral and terminal moraines were mapped by following the moraine walls with a field GPS. All GPS data were plotted on an orthophoto to determine the exact positions of the moraines. We separated the forefield into three segments suggested by its topography: (A) west of the river, (B) in between river and hill slope, and (C) east of the hill slope (Fig. 2). To reconstruct the retreat of the glacier we estimated the distances between all moraine walls and the oldest terminal moraine (representing the maximum extension of the Little Ice Age) along a line in each of the segments.

**Sampling:** On 23 different moraines tracts, a total of 370 trees were sampled: in front of, on and behind every moraine wall. Two increment cores (at ca. 180°) from Sitka spruce (*Picea sitchensis*) were taken at a height as close as possible to the germination point, but without root disturbance. After air-drying, the cores were mounted on wooden blocks and polished with progressively finer sandpaper. Annual ring widths were measured to the nearest 1/100

mm using the TSAP tree-ring measurement system (Rinn 1996). The core pairs of every tree were crossdated to detect missing or false rings.

Dates of glacial stands assigned by tree rings remain uncertain until corrections can be made for pith errors, sampling height, and the local ecesis value (Sigafos and Hendricks 1961, Smith et al. 1995, Villalba and Veblen 1997). The ecesis value, or the time lapse between surface stabilization and the germination of the first seedling, was estimated as 5 to 8 years for Sitka spruce in the Juneau area (Lawrence 1950, Lacher 1999). Our own observations confirm this value also for the Eagle Glacier region.

Sampling-height errors arise when the first growth rings are lost due to sampling above rooting system crowns (McCarthy et al. 1991). In order to calibrate the missing years, 12 Sitka spruce saplings of 140 cm height were cut at the germination point level. They were then divided into 10 cm-length segments; ages for all segments were determined by counting the annual rings. Using these results, the ages of all increments cores were corrected for the number of missing years estimated from the coring height and a site chronology was built for every moraine.

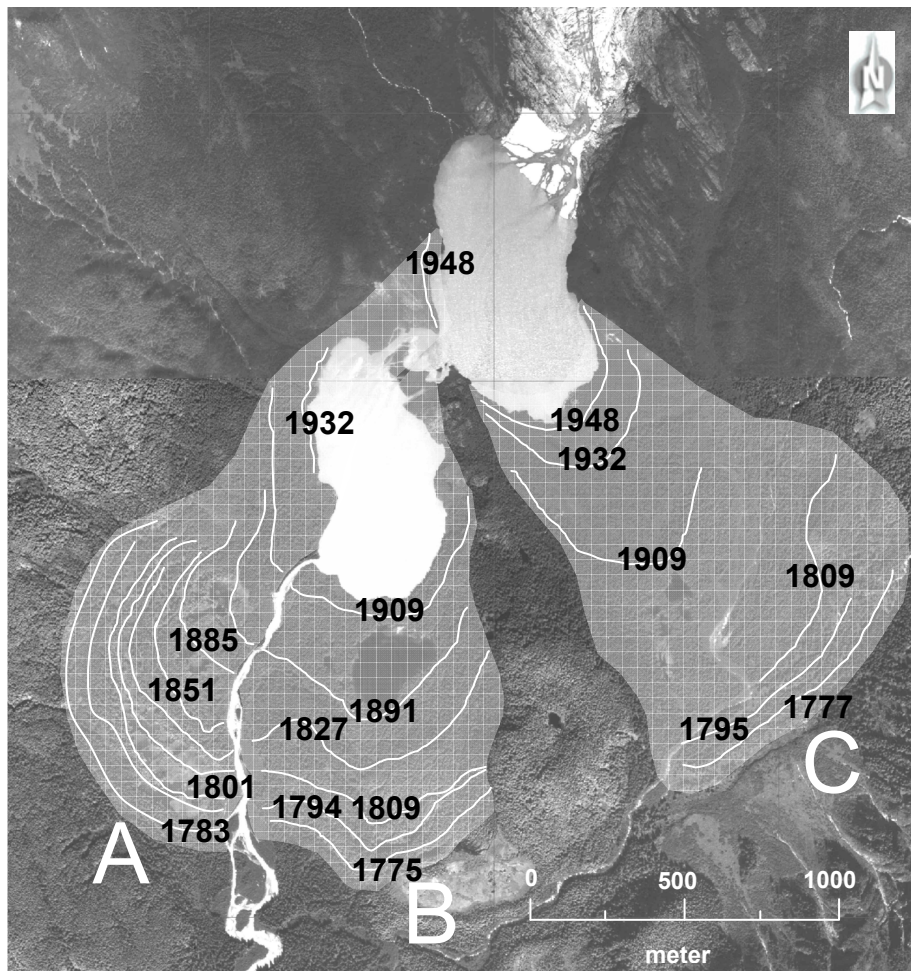


Figure 2: Moraines in the forefield of the Eagle Glacier. The years given are the estimated dates of ice retreat. (Orthophoto USFS, 1996)

## Results and discussion

Our results show that the maximum extension of Eagle Glacier in 1775 (Fig. 2) is slightly earlier than the maximum advance in 1785 estimated by Lawrence (1950) in a previous study. However, Lawrence only investigated the west, orographic right side of the river, where we found the oldest tree germinated between 1783 and 1786 (including ecesis value). In our study, the oldest moraine was formed in the intermediate segment only accessible by boat.

The retreating Eagle Glacier provides a series of 11 well-developed stands (Fig. 2). In the 18<sup>th</sup> century it left two terminal moraines, and in the 19<sup>th</sup> century six small ones. Three moraines were formed in the 20<sup>th</sup> century. A lake emerged after 1932, and a second one after 1948. We have two confirmations of our age determinations: a map published by A. Knopf in 1912, showing the ice margin in 1909 and a map published by D.B. Lawrence in 1950, showing the ice margin in 1948.

According to our study, advances among all land-terminating Juneau Icefield glaciers parallel the Neoglacial maximum of Eagle Glacier. The Taku and Herbert Glaciers were the first to retreat after 1750/51, followed by the Mendenhall (1754/55), Twin Lakes (1775/77), and Gilkey Glaciers (1783) (Heusser and Marcus 1964, Lacher 1999, Lawrence 1950). These data illustrate a general condition of recession beginning in the mid 18<sup>th</sup> century; the high synchronicity between the retreats of the different glaciers implies a major shift in climate affecting the Juneau Icefield at that time (Motyka and Begét 1996).

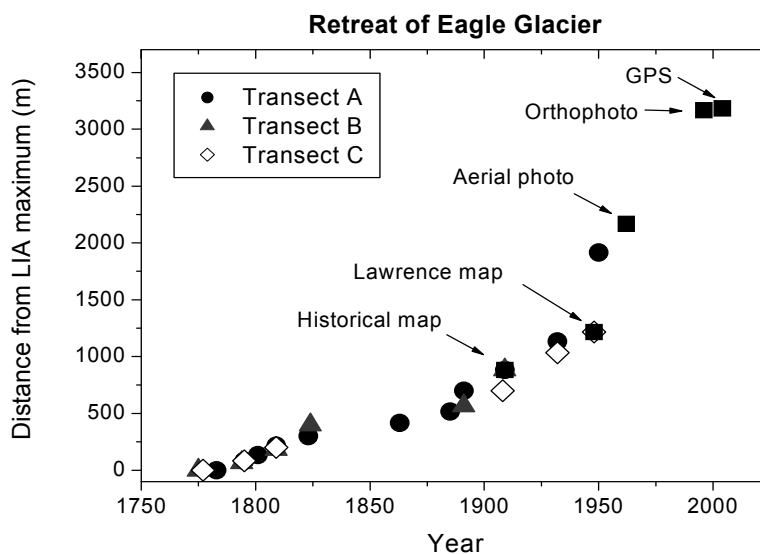


Figure 3: Recession pattern of Eagle Glacier, reconstructed separately for the segments A, B and C. The approximate distance between the dated moraines and maximum extension have been measured on the orthophoto.

Our estimates of moraine ages contain uncertainty because: (1) we cannot exclude not having sampled the oldest tree and (2) the error associated with the increasing 'root-undisturbed' sampling height becomes higher with increasing tree age. However, two aerial

photographs support our findings, one taken by the U.S. Navy in 1929, and the other taken on behalf of the U.S. Forest Service in 1962.

Our reconstruction of the withdrawal of the Eagle Glacier shows that the recession rate has strongly accelerated over time. While the glacier retreated 500 m from 1775 to 1850, by 1950 it had melted another 1250 m thereby losing about 10% of its length. This retreat pattern corresponds with many other land-terminating, maritime influenced glaciers around the Gulf of Alaska (Wiles and Calkin 1994). It in turn suggests that there has been a general warming in this region during the last decades.

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