Lessons learned from Alaskan tidewater glaciers

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Geophysical Institute
University of Alaska Fairbanks

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Outline

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- The physics of ice-ocean interaction is not location dependent
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- This allows for dynamic thinning, etc
- But lake-calving glaciers share that
- With the retreat of an ice sheet it is well possible that tidewater glaciers become less common and lake calving glaciers become more common!

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- Tidewater glacier behavior can be asynchronous with climate → large variability
- Glacier bed topography matters (grounding line instability)
- Oceans matter
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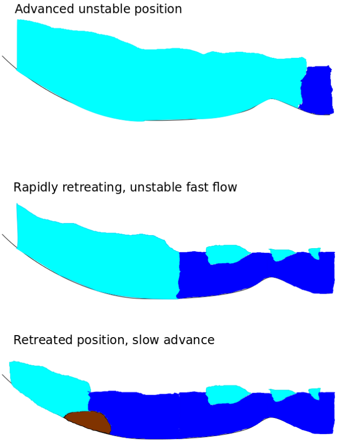
The tidewater glacier cycle



- In the advanced stage a TWG is near zero surface mass balance
- A small change in climate can trigger a retreat
- Retreat is unstoppable as long as the terminus is in deep water
- Re-advance is governed by the rate of sediment deposition, which generates a shallow water environment

Austin Post

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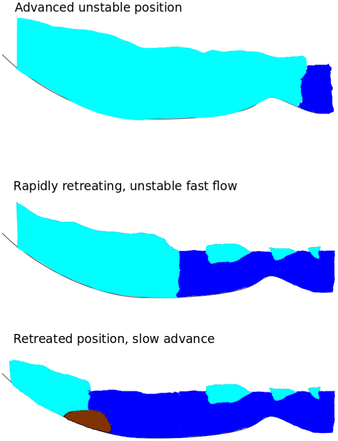

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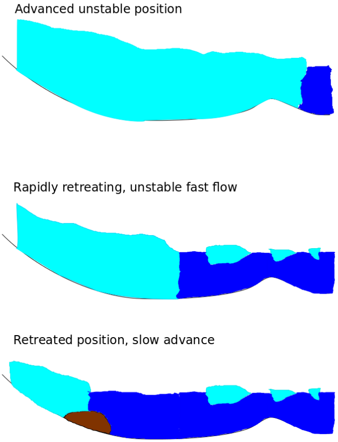

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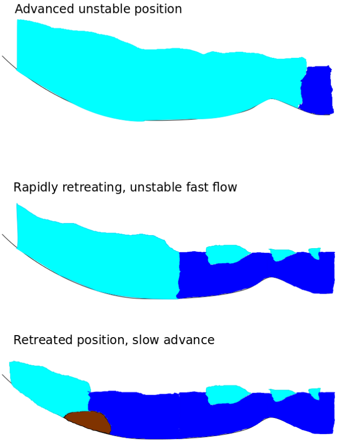

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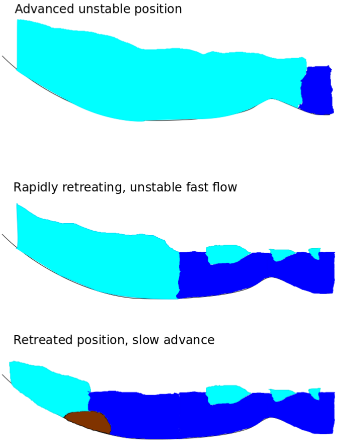

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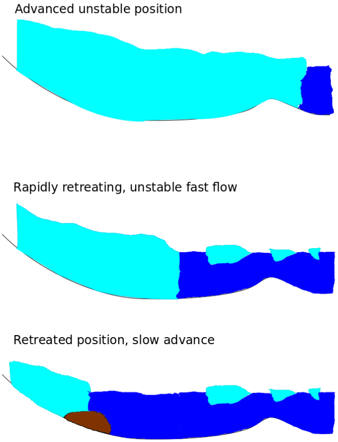

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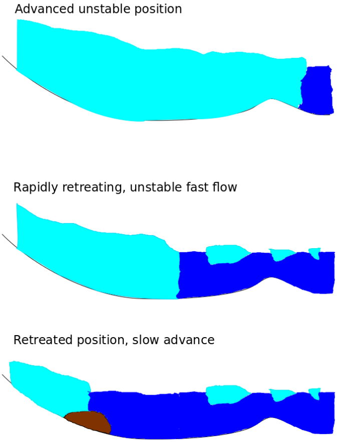

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Southeast Alaska: Asynchronous behavior

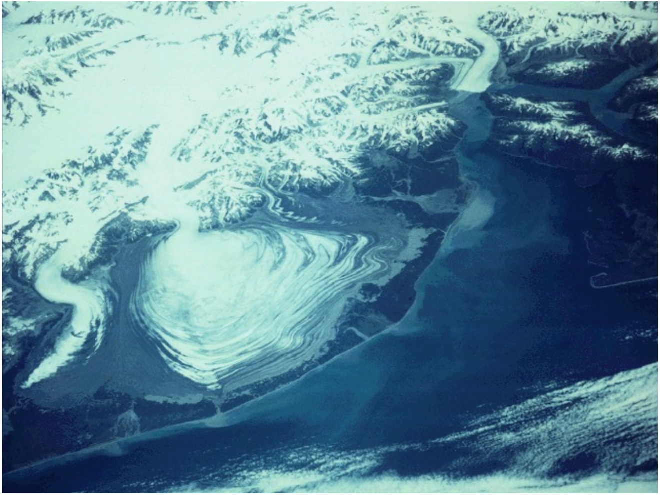
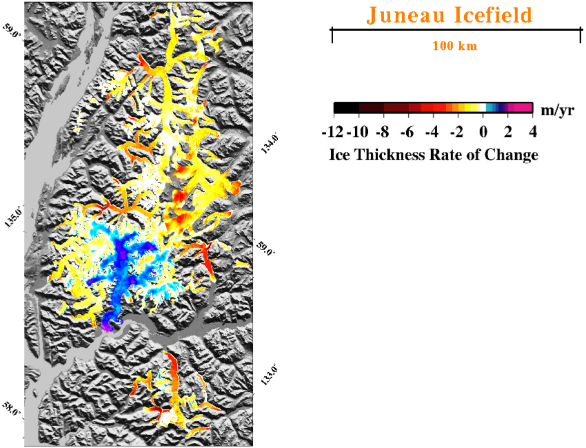


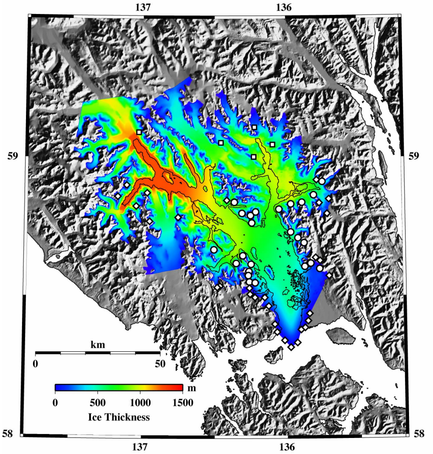
Image: Space Shuttle, 1995

Example, Juneau Icefield: 1950s - 2000



Larsen et al., 2007, JGR

Disintegration of an icefield: Glacier Bay



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- Global sea level equiv.: 8 mm

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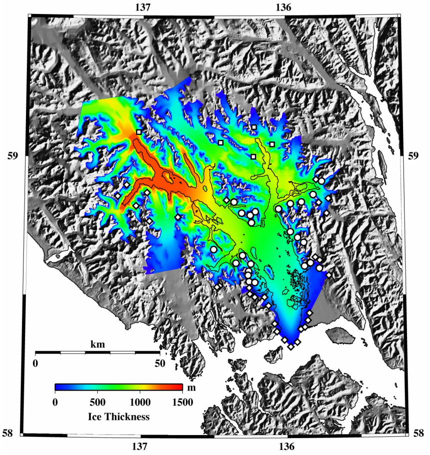

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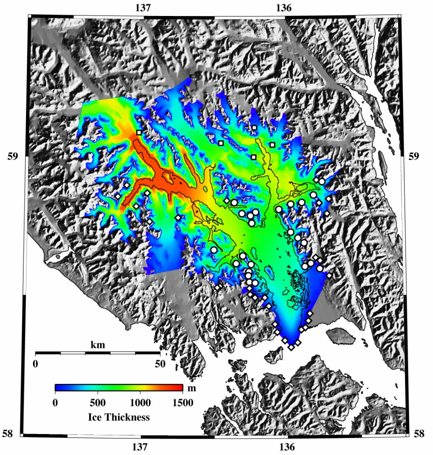

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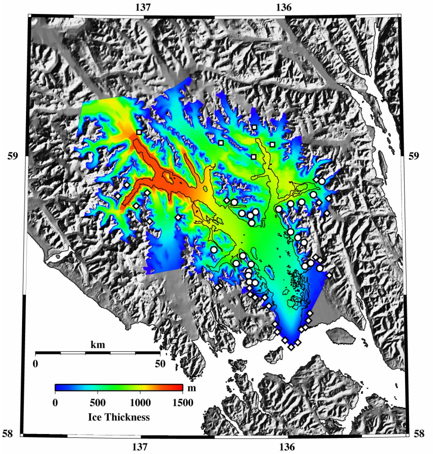

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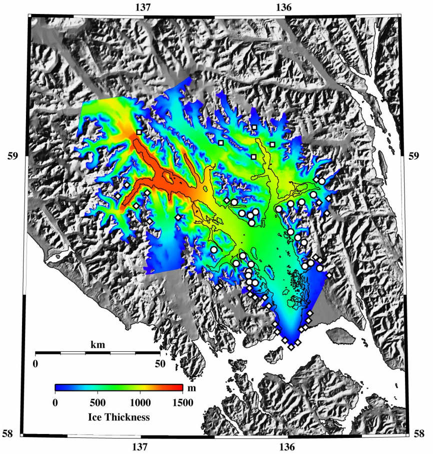

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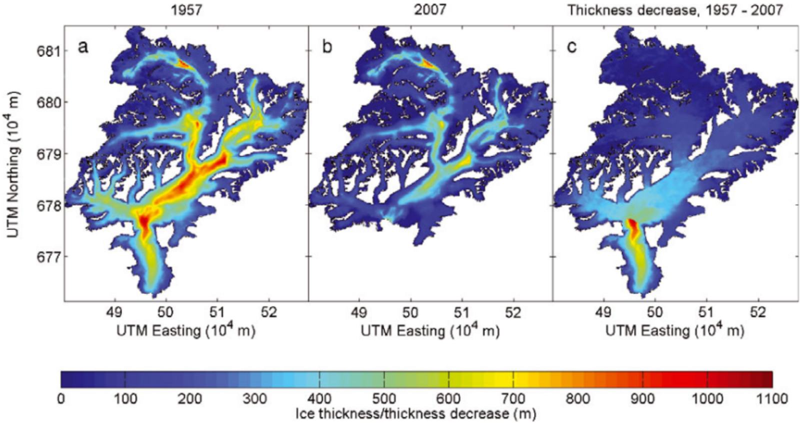
Coupling of icefield to outlet?



Thinning at Columbia Glacier does currently not spread to upper areas, despite 20+ years of retreat (McNabb et al., 2012, JGR)

Take home lessons

- Tidewater glaciers show highly variable behavior and are not always good indicators of current climate
- Tidewater glaciers can be unstable in both advance and retreat, particularly when glacier beds have reversed slopes
- Typical retreat patterns combine thinning, retreat, and acceleration

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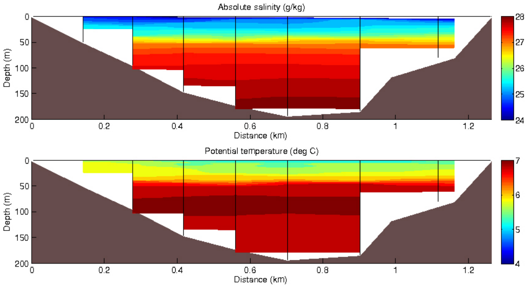
Outline

LeConte Glacier

Fjord physical properties



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- Temperature forcing is large: 8°C

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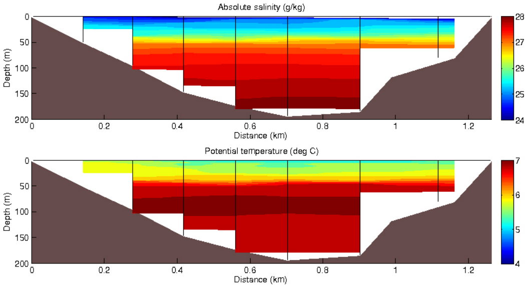

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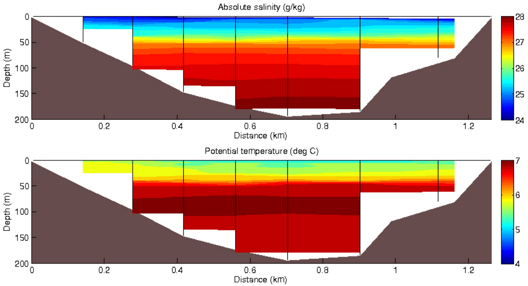

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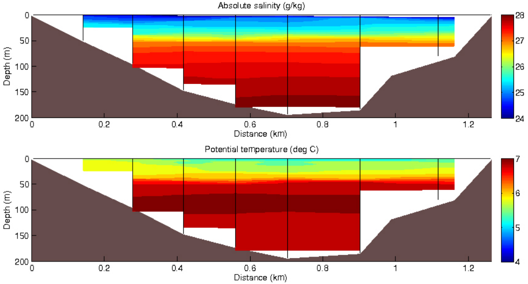

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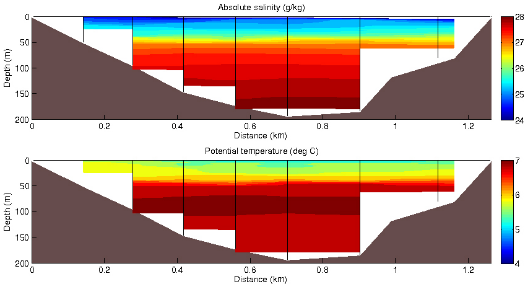

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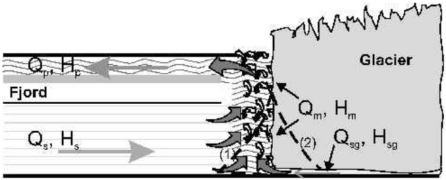

Motyka et al., 2003, Ann. Glac.

- Heat is supplied by warm and saline ocean bottom water
- Melting takes place at vertical ice face
- Circulation is driven by subglacial discharge (plume model)
- derived melt rates can be a significant portion ($> 50\%$) of the ice flux

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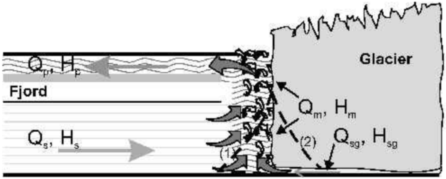

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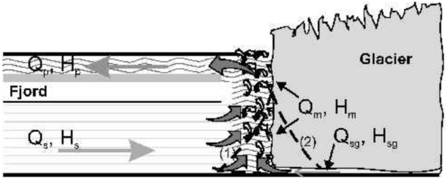

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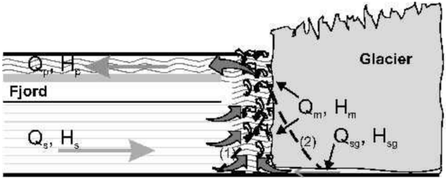

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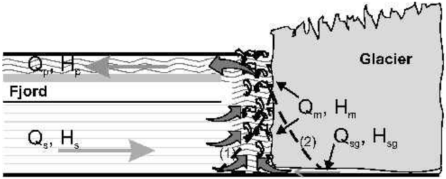

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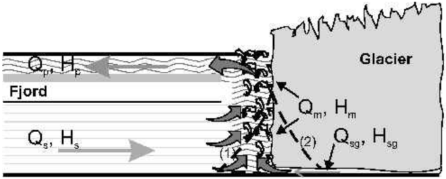

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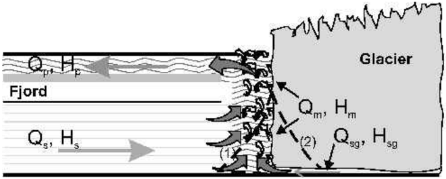

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Ocean forcing in Gulf of Alaska

- High summer ocean temperatures are common (Columbia, LeConte, Hubbard, Icy Bay)
- Alaska fjords are sill dominated
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- Tidewater glaciers can erode channels significantly below sea level
- Tidewater glaciers can move significant amounts of sediment

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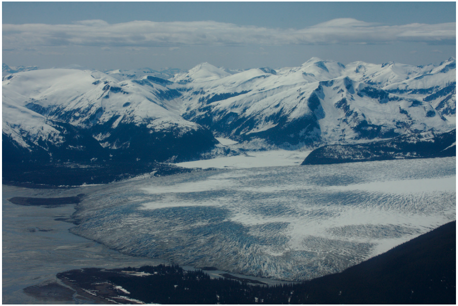

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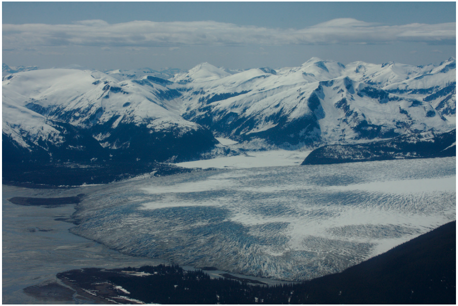

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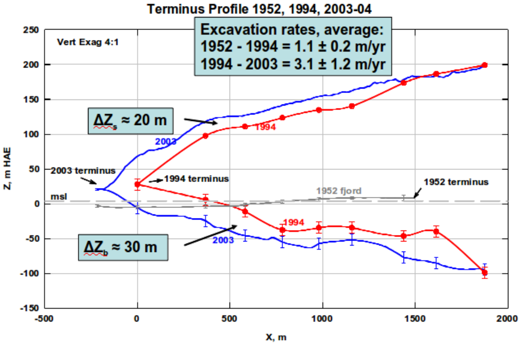
Sediment evacuation



Motyka et al., 2006, GRL

Some implications

- Sediment transport creates and progrades terminal moraines that protect the glacier from rapid calving
- Glacier erosion creates troughs that are based considerably below sea level, creating unstable conditions
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So what about Greenland

- Bedrock geometry is important, but lateral fluxes might play a role in delaying retreat
- Coupling of the ice sheet to changes near the front?
- Oceans: forcings are not as strong, so other effects (tidal, wind) might play a larger role
- Erosion and sediment deposition: rates are likely slower, nonetheless important in the long term

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