What role do glaciers play in subarctic hydrology?

Anne Gaedeke[1]

Anna Liljedahl[1], Tiffany Gatesman[1],

Thomas Douglas[2], Shad O'Neel[3]

1 UNIVERSITY OF ALASKA FAIRBANKS

2 US Army Corps of Engineers ®
Cold Regions Research and Engineering Laboratory

3 USGS science for a changing world

Jarvis Creek

Motivation

- Increasing discharge in glacier and permafrost afffected regions
  (McClelland et al., 2004; Peterson et al., 2002; Walvoord and Striegl, 2007)

- Increasing baseflow in Yukon and Mackenzie Rivers

→ attributed to thawing permafrost and changes in weather patterns
  (Walvoord and Striegl, 2007; St. Jacques and Sauchyn, 2009)

- Increasing glacier wastage globally and in Alaska
  (e.g. *Arendt et al., 2002; Hock et al., 2009; Larsen et al., 2015; Nolan et al., 2005)*

Aim of the study

Assess the role of glaciers on subarctic hydrology

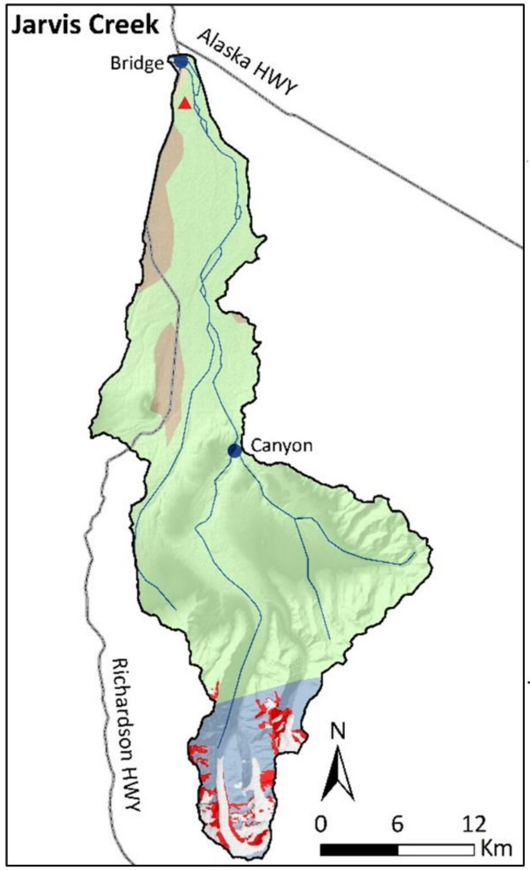
→ By gaining an increased understanding of the linkages between glaciers, climate and hydrology

Research Questions:

- What are the mechanisms behind the observed increase in baseflow on regional scale? (Long-term variations in climate & glacier mass balance)
- Which pathways does glacier wastage take before reaching the ocean?

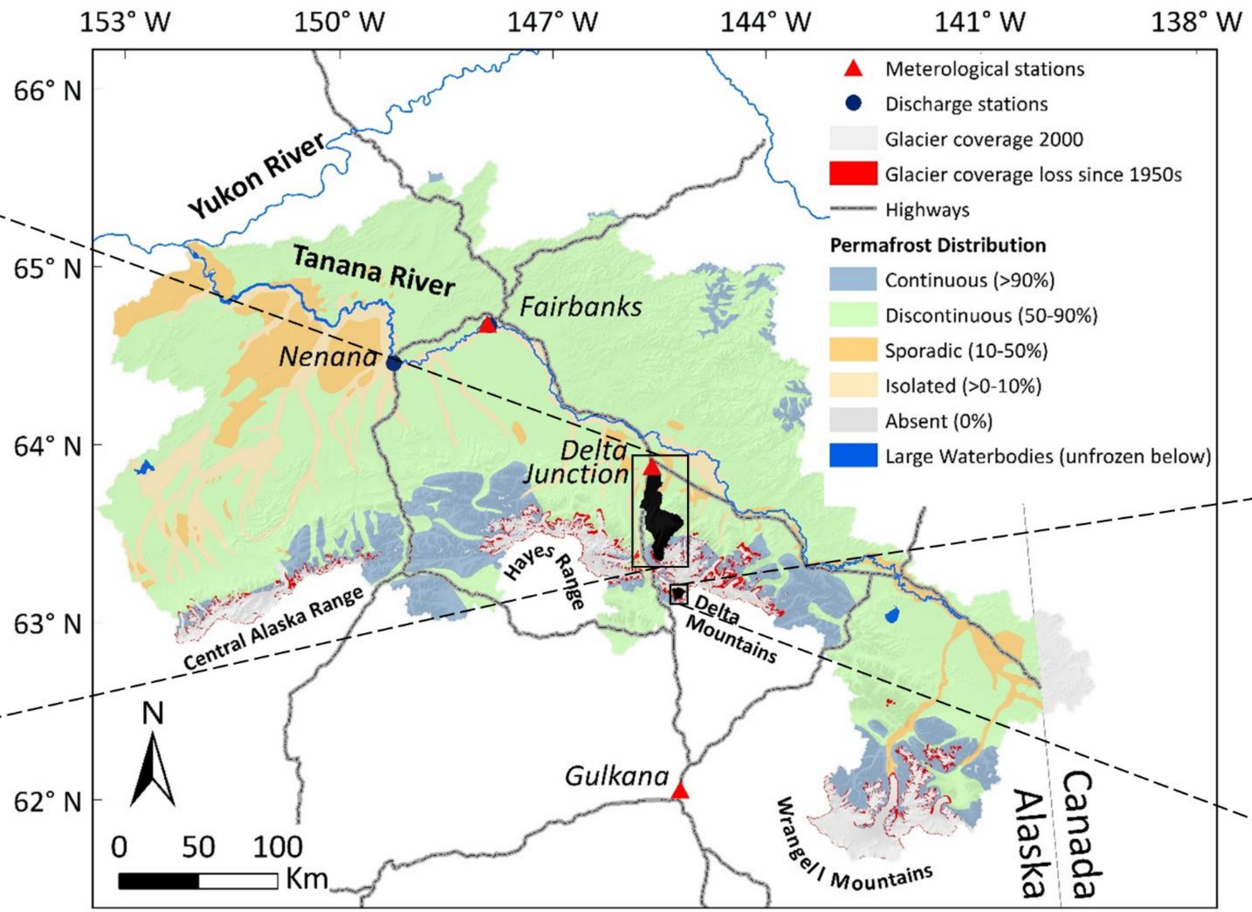
Study Area - Tanana R. watershed

Jarvis Creek (630 km²)
North facing Alaska Range



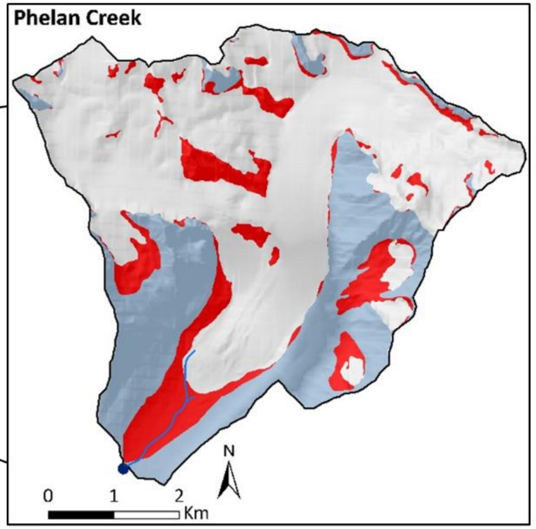
Glacier coverage: ~3%

Tanana (12,000 km²)



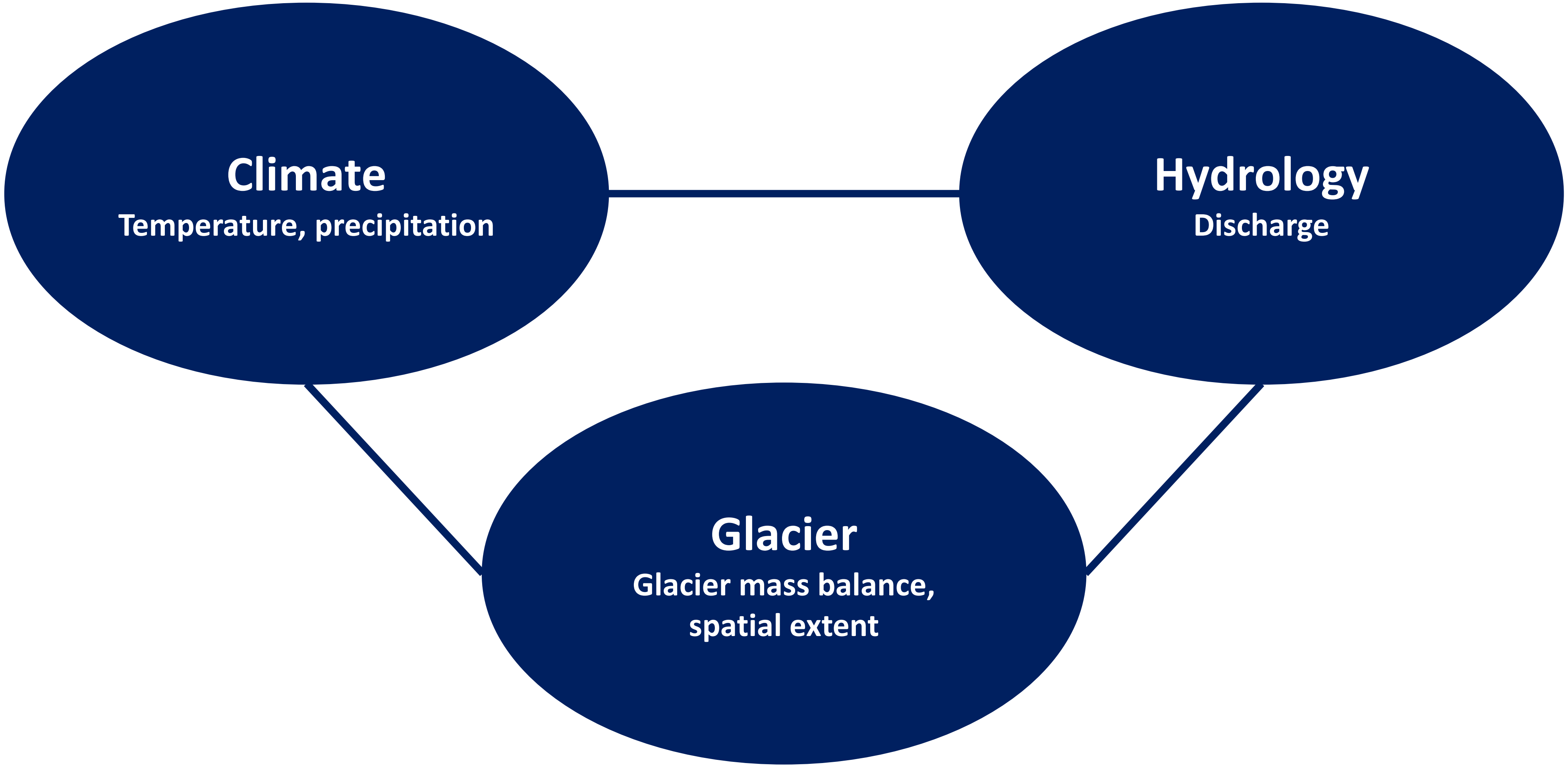
Glacier coverage: ~4%

Phelan Creek (31 km²)
South facing Alaska Range, USGS Benchmark Gulkana Glacier



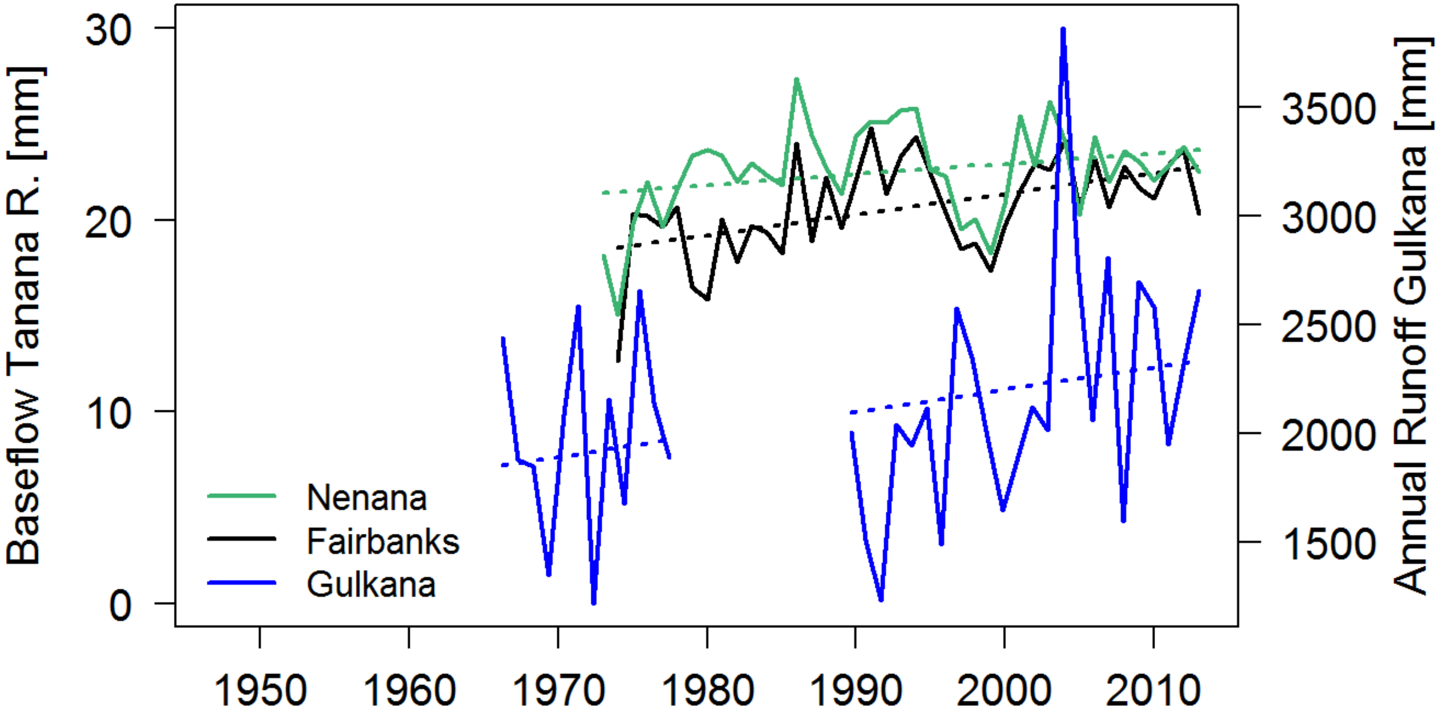
Glacier coverage: ~60%,

Data sources



→ Combines a number of data sources from different agencies: GHCN-D, USGS, UAF, Digital Chart of the World (DCW), Global Land Ice Measurements from Space (GLIMS), Randolph Glacier Inventory

Increasing winter baseflow in Tanana River watershed



Station	Annual runoff [%]	Winter baseflow [%]	Baseflow contribution [%]
Fairbanks (1974-2014)	+11	**+23**	6.8
Nenana (1973-2014)	+8	+8	6.9
Phelan (1967-2014, 1979-1989 missing)	**+23**	-	-

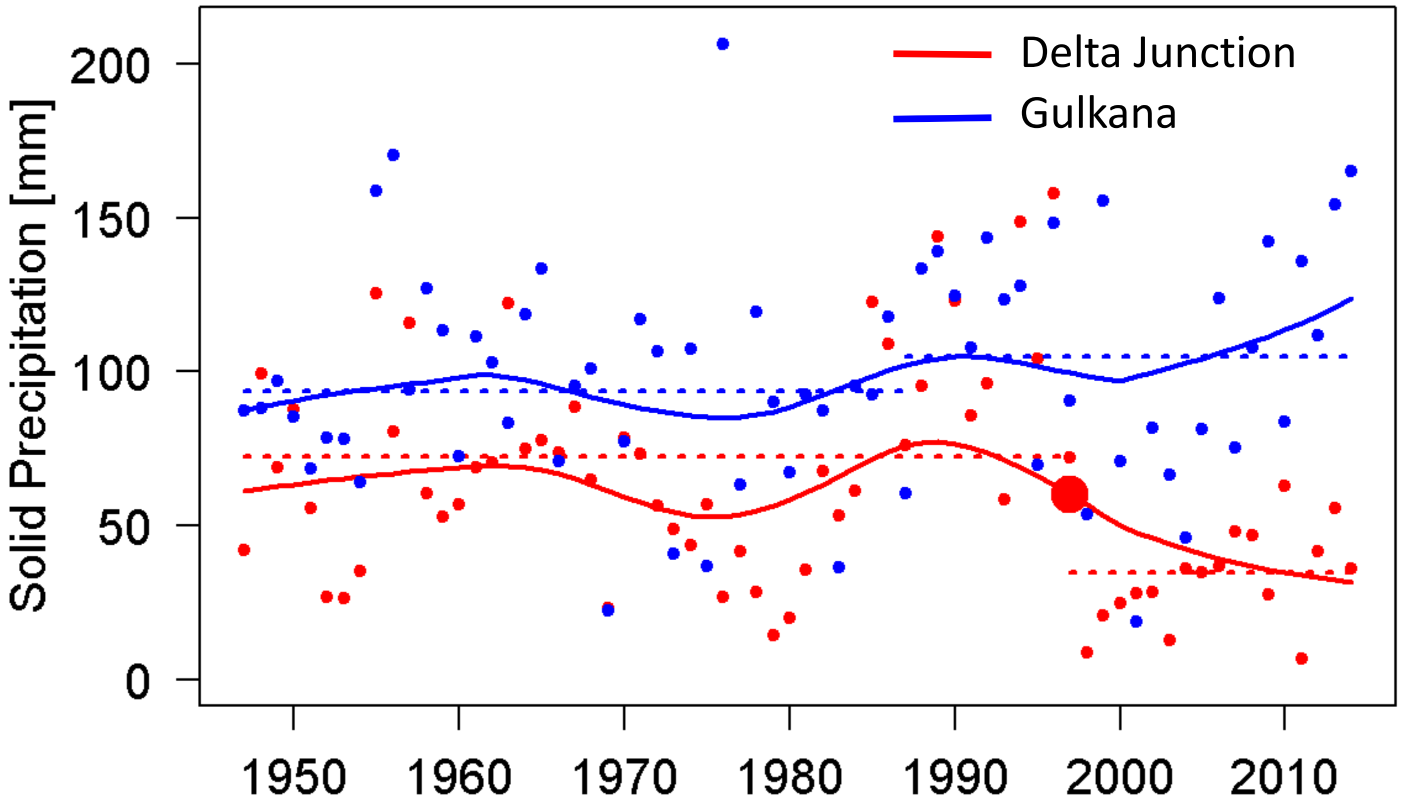
bold values are significant at $p < 0.05$

→ Increasing annual runoff and winter baseflow (January-March) in Tanana River (Fairbanks and Nenana)

→ Significant increase in winter baseflow at Fairbanks ($p < 0.05$)

→ Significant increase in annual runoff at Phelan Creek, Gulkana Glacier ($p < 0.05$)

Long-term variations in precipitation (1947-2014)

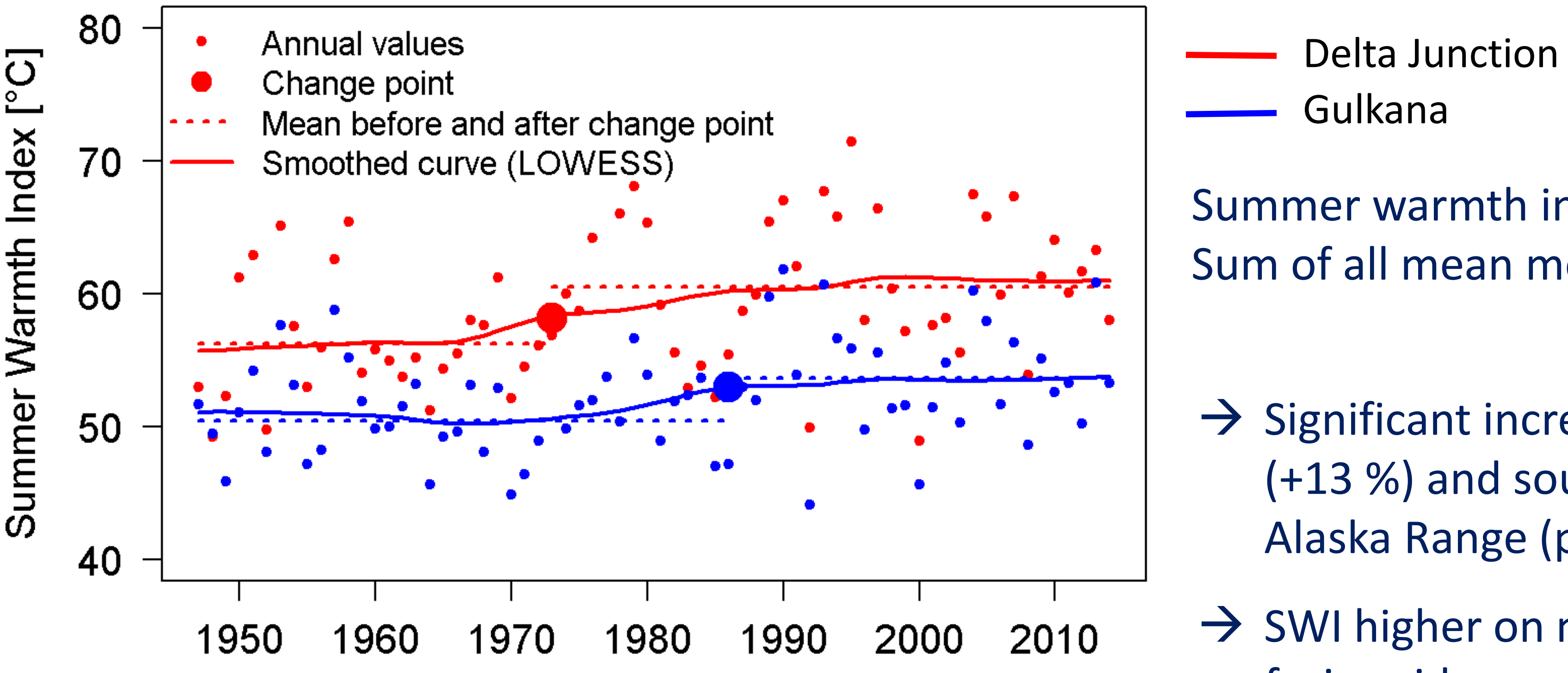


→ South facing side of the Alaska Range receive more winter precipitation than north-facing side (months with temperature < 0°C)

→ Since ~2000, increasing winter precipitation at the south facing side (+17 %) and decreasing on the north facing side (-40 %)

* Long-term trends not statically significant ($p > 0.05$)
* Change point at Big Delta is statistically significant ($p < 0.01$)

Long-term variations in summer warmth index (1947-2014)

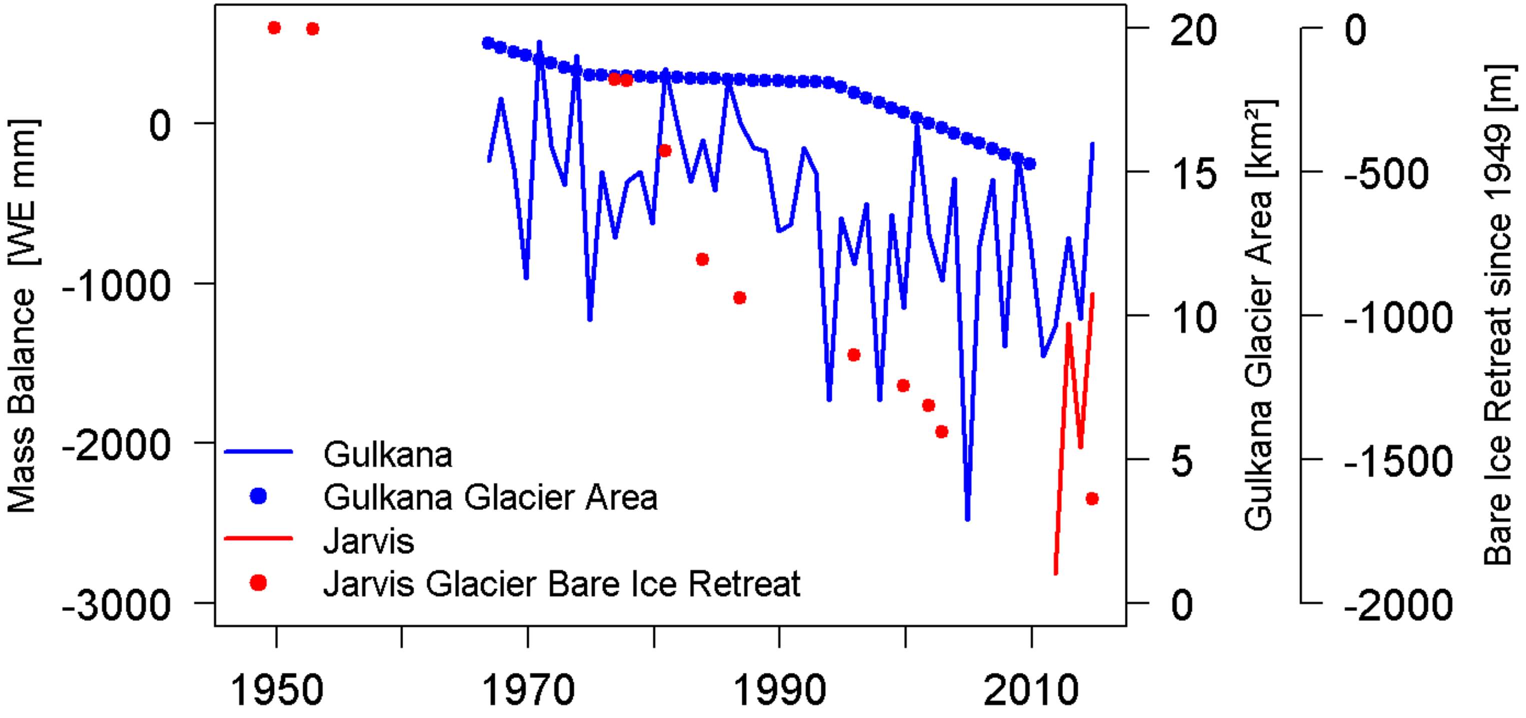


Summer warmth index (SWI):
Sum of all mean monthly air temperature > 0 °C

→ Significant increase in SWI both on north (+13 %) and south facing (+8 %) side of the Alaska Range ($p < 0.05$)

→ SWI higher on north compared to south-facing side

Long-term variations in glacier mass balance and glacier retreat/thinning



Change in glacier coverage [km^2]

	Tanana	Jarvis	Phelan
1950	5653	32.0	22.3
2000	5010	21.1	18.2
Reduction [%]	**11**	**34**	**18**

→ Negative glacier mass balance on both the north- and south-facing side of the Alaska Range

→ Retreat and thinning of glaciers

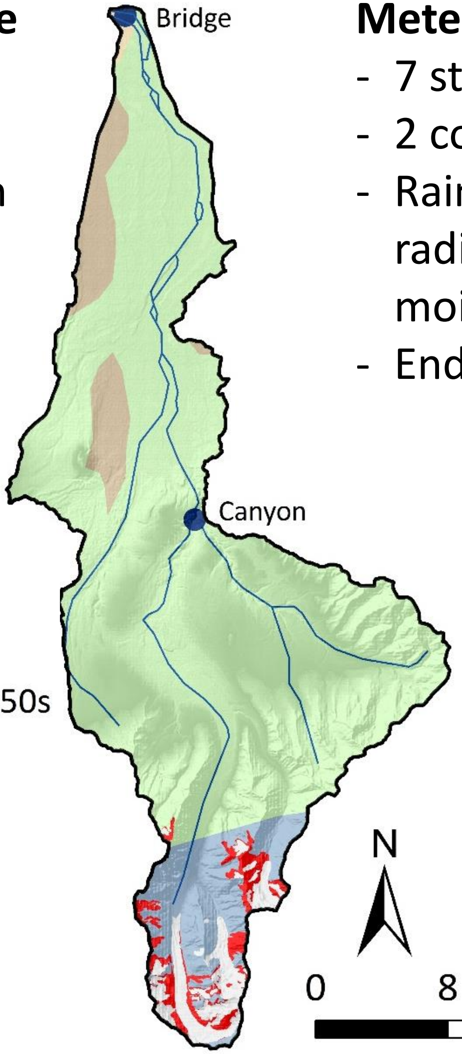
→ Glacier mass balance more negative on the north- compared to south-facing side

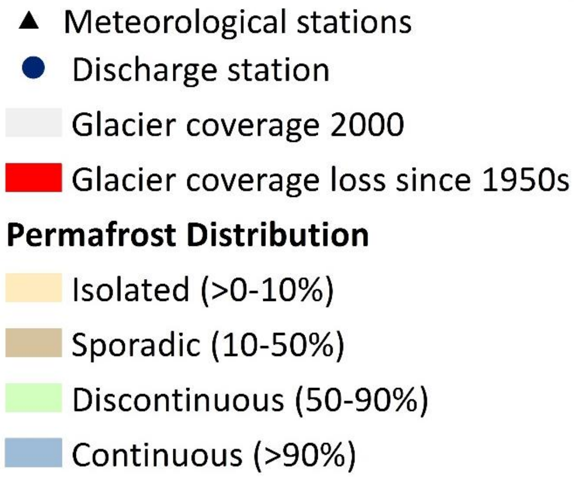
Jarvis Creek watershed

Intensive measurement network to gain a deeper understanding of linkages between glaciers & hydrology

Discharge

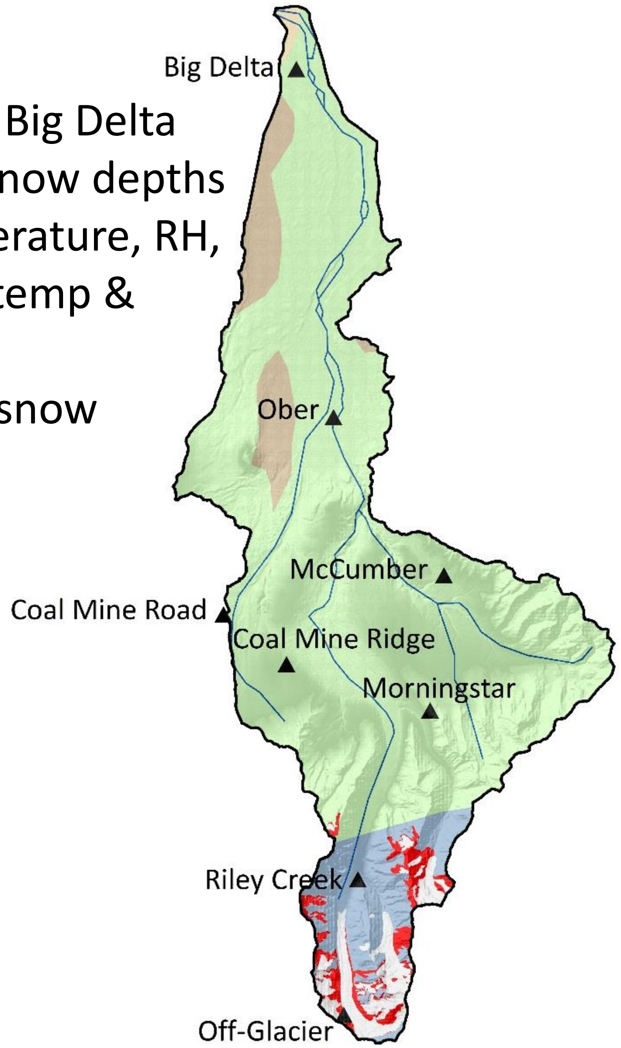
- Bridge
- Canyon



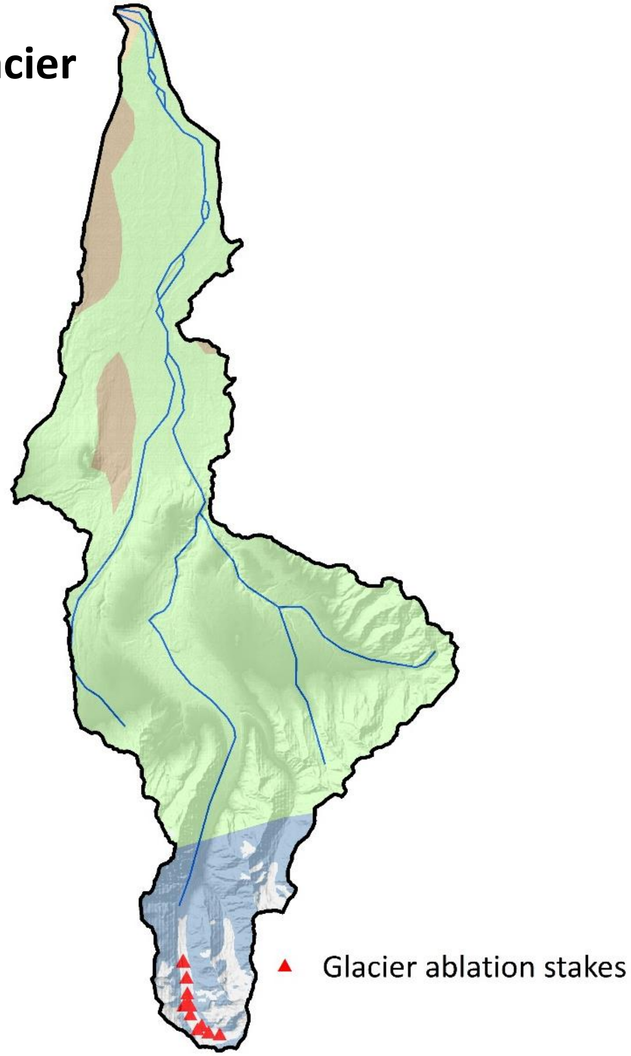


Meteorology

- 7 stations plus Big Delta
- 2 continuous snow depths
- Rain, air temperature, RH, radiation, soil temp & moisture
- End-of-winter snow

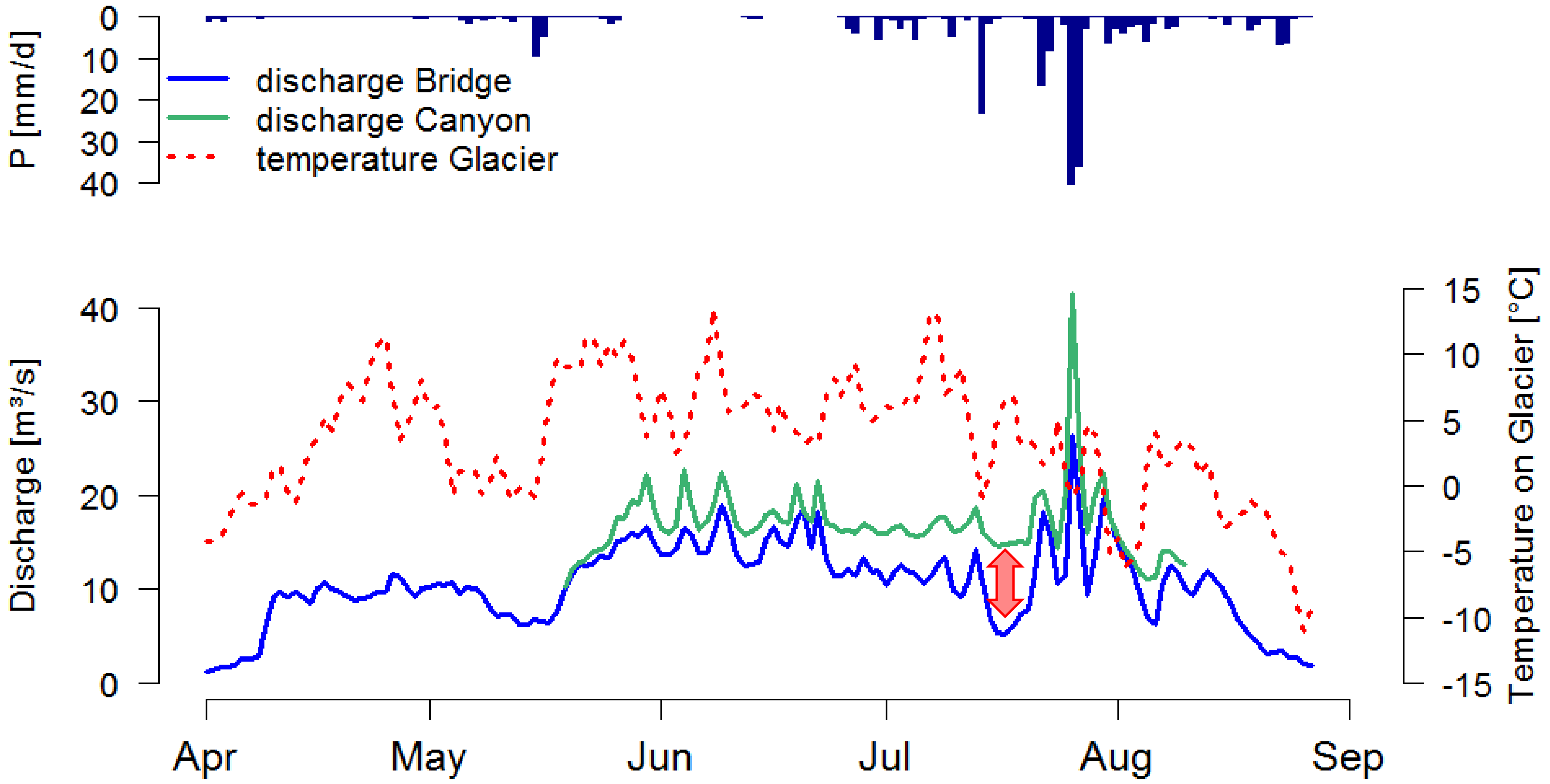


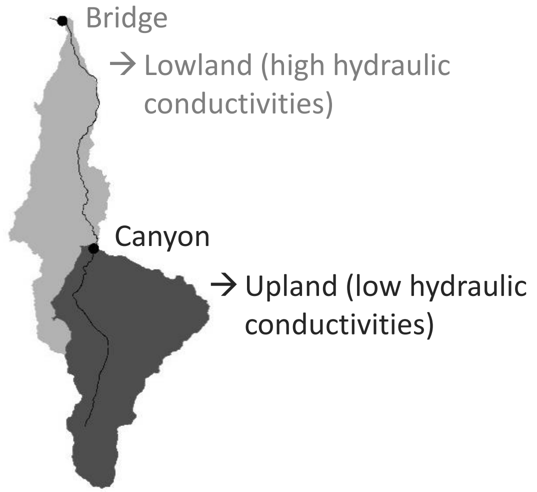
Glacier



What pathways does glacier wastage take before reaching the ocean? → streamflow & aquifer recharge

Discharge at Jarvis Bridge and Canyon in 2015





Loss of discharge between Canyon & Bridge: ~30%

What role do glaciers play in subarctic hydrology?

Summary:

→ Meteorological variables cannot alone explain the increase in winter baseflow and annual runoff in Tanana River

→ Meteorological variables support decreased glacier coverage and negative glacier mass balances

→ Glaciers on north-facing side of the Alaska Range are more affected compared to the south-facing side (attributed to meteorological variables)

→ Alaska Range headwater streams are losing water to the aquifer

→ → → We postulate that the reduced glacier coverage, via increased aquifer recharge, is the primary cause of the observed increase in late winter baseflow of the Tanana River

→ → → Our results suggest that glaciers do not only directly support streamflow in the headwater basins during summer months, but also affect the larger scale hydrological regime of subarctic glacierized watersheds

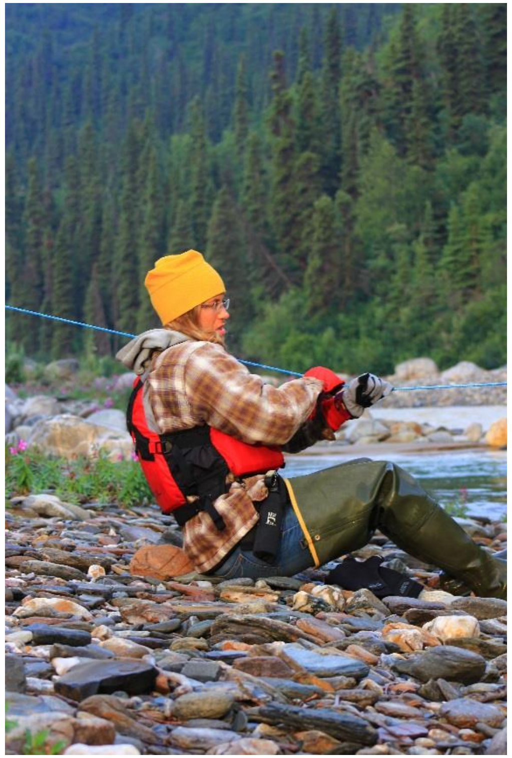
Thank You! Any questions?

Collaborators:

- Salcha-Delta Soil and Water Conservation District
- U.S. Army Fort Wainwright
- Cold Regions Research and Engineering Laboratory (CRREL)
- Alaska Division of Geological & Geophysical Surveys
- Colorado State University
- U.S. Geological Survey

Funding:

ARCSS #1304905



My personal experience as being new to Arctic research

- “What do you mean, there is no data?!”
- “There are so many data gaps!”
- “How come precipitation is only measured continuously during summer?”

Arctic Landscape Conservation Cooperative’s
“Imiq Hydroclimate Database & Data Portal” has been a valuable tool
for me in *identifying* existing data sources:
http://arcticlcc.org/projects/imiq/data-portal/