Modeling fluvial discharge from the glacier-dominated Eklutna watershed, Alaska

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Project Overview

Background and Location

The Eklutna River watershed (311 km²), in the Chugach Mountains of Southcentral Alaska, provides 10-15% of electricity and 80% of domestic water for Anchorage, Alaska's largest city. The headwaters are divided into the glacierized West Fork (64 km², 46% ice) and cirque glaciated East Fork (101 km², 12% ice; Figure 1). The watershed functionally "ends" at Eklutna Lake (30 km²), as all water in the lake reservoir is withdrawn for municipal use except during periods of exceptionally high runoff .

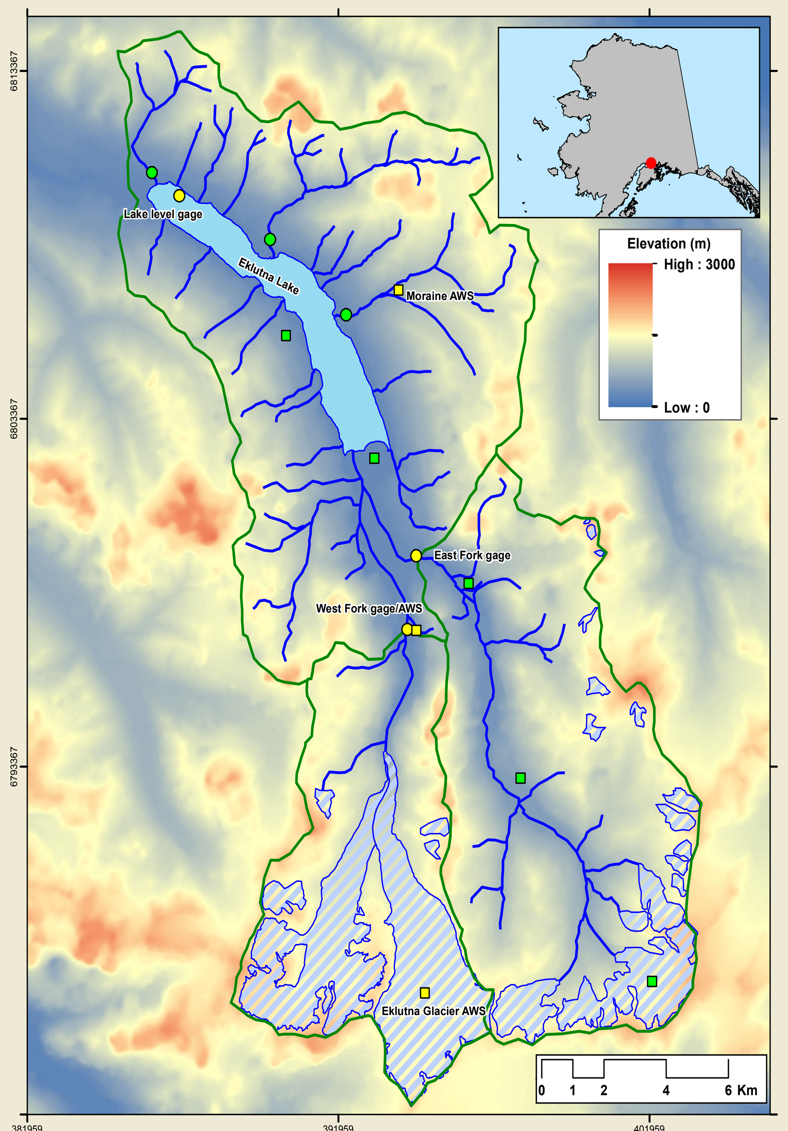

Figure 1: The Eklutna River watershed is outlined in green, further subdivided into three sub-basins: West Fork (southwest), East Fork (southeast), and lake-marginal (north). Striped polygons in southern portion of watershed are glacier cover, and blue polygon in north is Eklutna Lake. River gaging stations are shown as yellow (existing) and green (proposed) squares. Automated weather stations are shown as yellow (existing) and green (2014-15) squares. General location within Alaska shown by red dot on inset map.

Figure 2: Images illustrating the retreat of Eklutna Glacier's terminus between 1915 (upper panel) and 2010 (lower). Glacier ice is just visible (red arrow) in the far background of the lower image. Photo credits: S.R. Capps (1915) and Ron Karpilo (2010).

Motivation

In 2008, Alaska Pacific University (APU) began monitoring mass balance of the Eklutna Glacier (Figure 3), and melt season fluvial discharge from each of the main drainages, the West Fork and East Fork Eklutna River.

We recognized that like Eklutna, most of the state's glaciers are shrinking (Figure 2; Berthier et al. 2010), and that glacier retreat is typically associated with changes in the downstream discharge (Fountain and Tangborn 1985), and quantification of these effects have broad local implications.

Traditional methods are not practical for efficient water resource management and flood forecasting of glacierized drainages, but require advanced methods of hydrological simulations, particularly in light of ongoing climatic changes (Klok et al. 2001; Jasper et al. 2002; Verbunt et al. 2003).

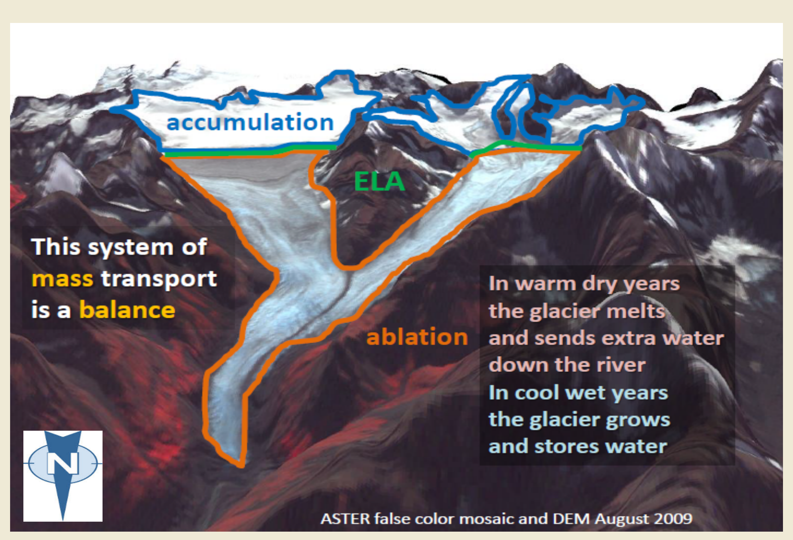

Figure 3: Eklutna Glacier flows from 2100 m to 520 m asl terminus elevation. Equilibrium Line Altitude (ELA) ~1400-1500 m asl. Figure credit Louis C. Sass.

Objectives

With a goal of forecasting glacier melt and fluvial runoff in a changing climate, develop WaSiM (Schulla 1997) as a management tool to model the water budget of Eklutna River, a glaciered watershed used for water and power by the city of Anchorage. Calibrate the model with an existing five-year record of glacier mass balance and fluvial discharge from two sub-basins with differing degrees of glacierization, and validate with two additional years of enhanced data.

Methods

Climate

We measure air temperature and precipitation on-glacier and at the East and West Fork river bridges for headwater weather conditions . We will use the U.S. Natural Resources Conservation Service mid-basin SNOTEL site data as part of our distributed climate network (Figure 5). We will increase our climate network distribution with additional stations in 2014-2015 for WaSiM validation forcing (Figure 1).

Glacier Mass Balance

We measure using standard measurement practices the net thickness of the previous winter's snowpack (spring) and the cumulative summer melt (fall) during annual trips (Figure 4). We will expand our glacier monitoring to include the East Basin in 2014-2015.

Figure 4: Ablation stake used to reveal summer melt.

Fluvial Discharge

We developed ratings, the stage-discharge relationships, for each Fork by plotting measured water surface to their associated discharge measurements. We apply these ratings to time series stage data recorded at both Forks for discharge record computation. The U.S. Geological Survey (USGS) provides lake stage data for volume computation.

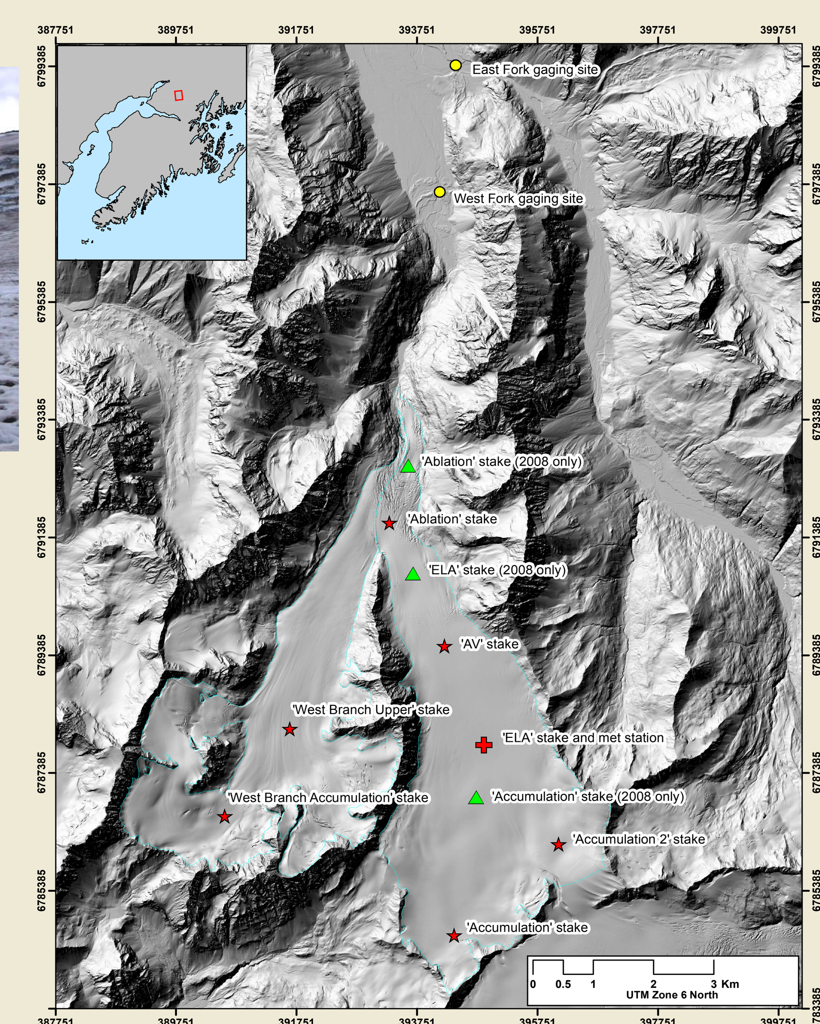

Figure 5: Locations of mass balance stakes in 2008 (green triangles) and subsequent years (red stars), weather station (red cross), and river gages and weather stations (yellow circles).

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Results

Glacier Mass Balance, Melt, and Fluvial Discharge

- Eklutna Glacier mass balance agrees well with measured variability at USGS benchmark Wolverine Glacier
- The glacier surface has deflated by 1.4 m on average equating to a glacier-wide shrinkage rate of -0.85 m w.e
- Glacier reduction is occurring by both terminus retreat (~25 m/yr) and by the unusual mechanism of accumulation zone thinning
- Shrinkage augments runoff from "glacier mining"—inflating the deglaciation discharge dividend, the amount of additional runoff directly attributed to glacier melt (Collins 2008)

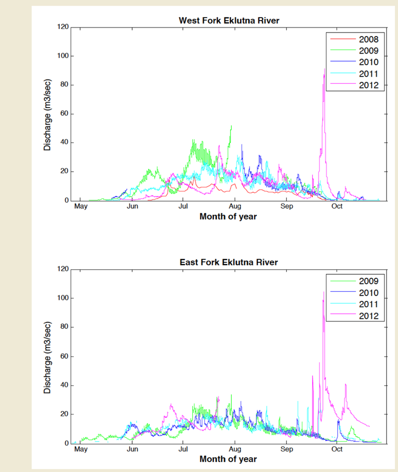

Figure 6: Melt season hydrograph comparison of West and East forks during 2009-2012.

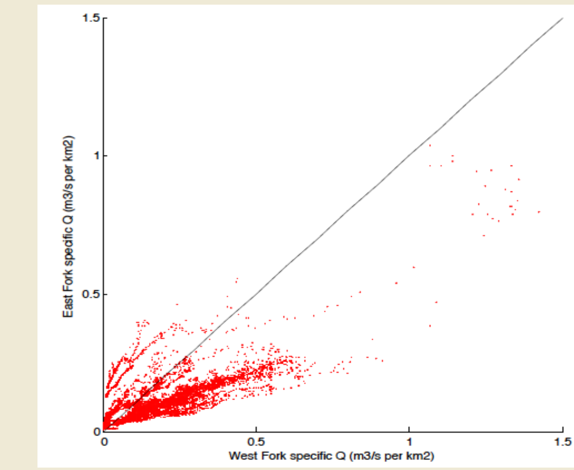

Figure 7: Specific discharge (hourly Q per km² of upstream basin area). Dots below the diagonal show periods of more water production from the West Fork.

- Eklutna Glacier buffered the effects of both dry and wet years, e.g. in 2009, glacier runoff produced 36% of the melt season water usage, according to the water utility's
- The West Fork yielded both more total runoff (Figure 6) and 68% more specific discharge than the East Fork (Figure 7) —implying that the West Fork is more efficient at converting precipitation to runoff
- Changes in the seasonality and peak timing of glacier-sourced runoff are expected, though unconfirmed with our short record (Figure 8)
- Eklutna Lake has spilled only six times since 1983 —most recently in 2012 and 2013 (Figure 9)

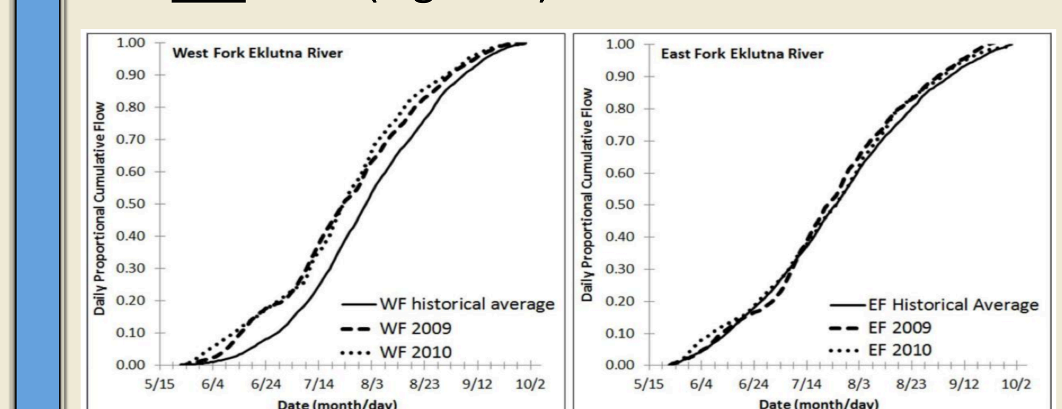

Figure 6: Daily proportional cumulative flow over the course of current (2009-10) and historic melt seasons

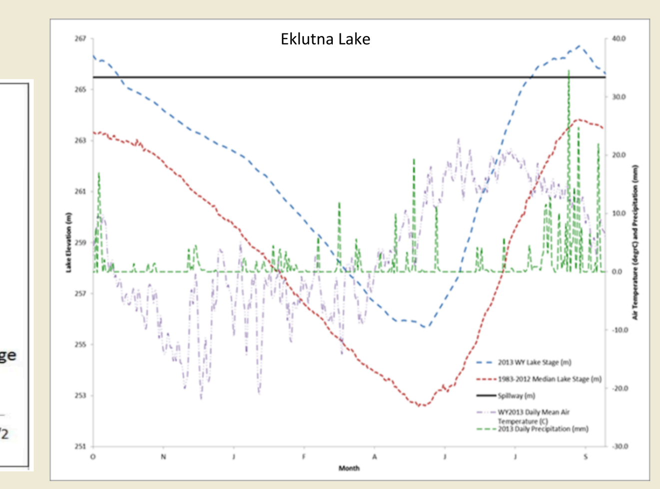

Figure 9: USGS median lake stage for 1983-2013 (red) and WY2013 (blue) curves with SNOTEL climate record. Horizontal black line at 267 m asl denotes spillway crest.

Hydrological Modeling

- Continue existing Eklutna Glacier mass balance and weather monitoring
- Continue gaging both the East Fork and West Fork Eklutna River
- Enhance the program by adding:
    - Stream gages on three minor tributaries,
    - Five precipitation and air temperature stations, and
    - Mass balance monitoring in cirque-glaciated East Basin
- Calibrate and run WaSiM with 2009-2013 data to close watershed budget through University of Alaska-Fairbanks collaboration with Anna Liljedahl
- Inform the glacier sub-module with the *Mass-Balance, Glacier Runoff and Multi-Layer Snow Model,* currently running on 1970-2012 Eklutna Glacier data (Geck and Hock 2011)
- Validate WaSiM with expanded distribution 2014-2015 data
- Collaborate with the U.S. National Weather Service Alaska-Pacific River Forecast Center, and the water and power utility's to establish the validated model as an operational management tool that can project impacts of climatic and glacier changes on basin runoff on varying timescales