Considerations for Modeling Freshwater Discharge in Southeast Alaska: An Overview

Streamflow and Watershed Classification Working Group (with special contributions from Janet Curran, David Hill, Joel Trubilowicz)

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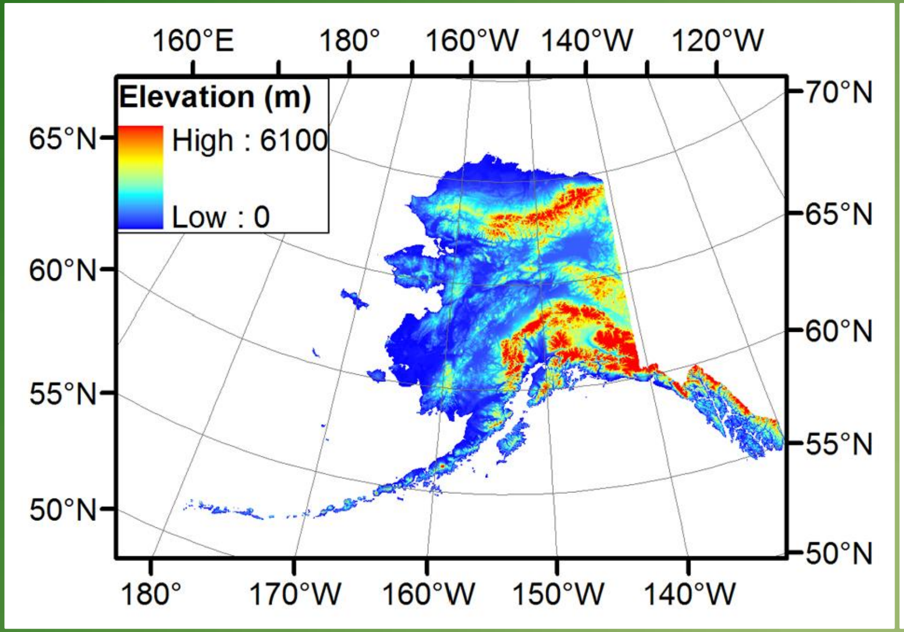
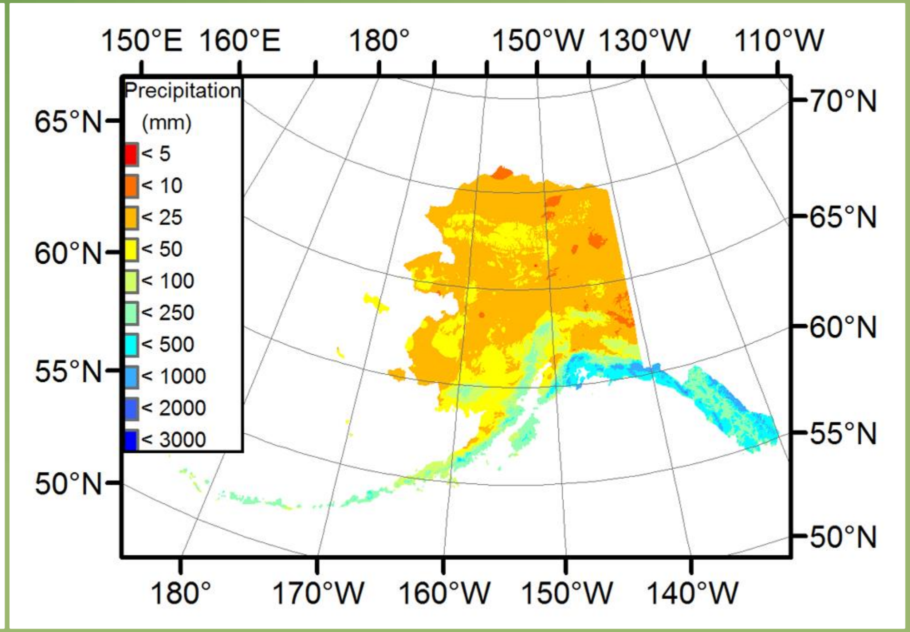
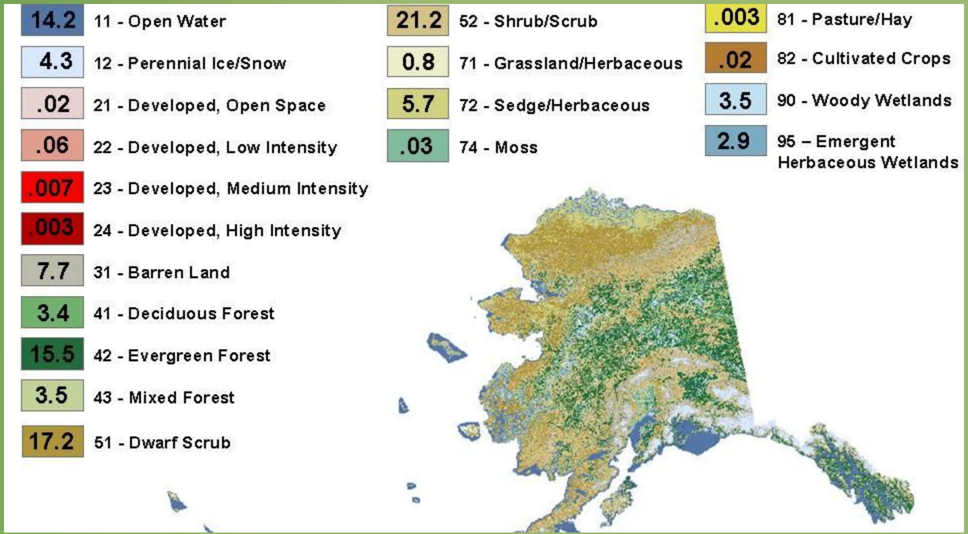
It's Complicated…







By the Numbers

- GOA Drainage Basin = 450,000 sq. km.
- 17% permanent snow / ice
- Annual precipitation ~ 770 cu. km.
- Annual runoff ~720 cu. km.
- Annual glacier volume loss ~ 60 cu. km.
- Annual evapotranspiration ~ 110 cu. km.

Modeling Freshwater Discharge

- Models inform at several levels
  - Characterizing existing conditions (total flow to GOA)
  - Exploring critical processes (impact of ice melt)
  - Estimating impacts of change (shift in snowmelt timing)
- Pairing a question with a relevant modeling approach can be guided by understanding the hydrology and the modeling framework

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Streamflow metrics

- Amount
  - Daily, monthly, annual flow statistics
- Timing
  - Shifts in breakup date, length of high flows, diurnal flow
- Extremes
  - Flood frequency, low-flow frequency, exceedance probability

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What drives streamflow?

- Streamflow patterns are the ‘response’ of a particular landscape (terrain, landcover, etc.) to a particular meteorologic forcing (temp, precip, etc.)
- Viewed as a hydrograph, the influence of various drivers can be identified, measured, and tracked over time

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Rain, snow, and glacier ice

- The basic drivers of streamflow for streams in Alaska are rainfall, snowmelt, and melt of glacier ice. The relative strength and timing of these drivers vary.
- Characterizing basins by their streamflow drivers provides an insightful window into the applicability of the modeling or analysis approach

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Examining long-term seasonal streamflow patterns

- Local and regional categories emerge
  - Wide-ranging in case of snowmelt, for example
  - Can also be specific to a geography: mountain front, lowland, glacierized basin
- Provides perspective not gained from a single year
- Readily compiled from USGS daily streamflow statistics (see next slide)

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National Water Information System: Web Interface

USGS Water Resources (District Access)

Data Category: Surface Water | Geographic Area: Alaska | GO

News - updated September 2012

USGS Surface-Water Data for Alaska

Important News:

For information regarding flood frequency, please consult Table 4 in our 2003 report *Estimating the Magnitude and Frequency of Peak Streamflows for Ungaged Sites on Streams in Alaska and Conterminous Basins in Canada* by Curran and others.

Current Conditions (114 <publicly viewable> sites)

Current conditions at selected sites based on the most recent data from on-site automated recording equipment. Measurements are commonly recorded at a fixed interval of 15- to 60-minutes and transmitted to the USGS every hour. Values may include "Approved" (quality-assured data that may be published) and/or more recent "Provisional" data (of unverified accuracy and subject to revision). Most current data are provisional.

Historical Observations (117 <publicly viewable> sites)

The same data accessed by the Current Conditions link above but including both active and discontinued sites with data for any part of the period October 1, 2007, through the present. Values may include "Approved" (quality-assured data that may be published) and/or more recent "Provisional" data (of unverified accuracy and subject to revision).

Daily Data (505 <publicly viewable> sites)

Summary of all data for each day for the period of record and may represent the daily mean, median, maximum, minimum, and/or other derived value. Values may include "Approved" (quality-assured data that may be published) and/or more recent "Provisional" data (of unverified accuracy and subject to revision). Example.

Statistics (498 <publicly viewable> sites)

Daily **Monthly** **Annual**

Statistics are computed from approved daily mean data at each site. These links provide summaries of approved historical daily values for daily, monthly, and annual (water year or calendar year) time periods.

Peak-Flow Data (666 <publicly viewable> sites)

Annual maximum instantaneous peak streamflow and gage height

Field Measurements (944 <publicly viewable> sites)

Manual measurements of streamflow and gage height. These measurements are used to supplement and (or) verify the accuracy of the automatically recorded observations, as well as to compute streamflow based on gage height.

Introduction

The U.S. Geological Survey's (USGS) National Water Information System (NWIS) is a comprehensive and distributed application that supports the acquisition, processing, and long-term storage of water data. Water Data for the Nation serves as the publicly available portal to a geographically seamless set of much of the water data maintained within NWIS (additional background).

Nationally, USGS surface-water data includes more than 850,000 station years of time-series data that describe stream levels, streamflow (discharge), reservoir and lake levels, surface-water quality, and rainfall. The data are collected by automatic recorders and manual field measurements at installations across the Nation.

Data are collected by field personnel or relayed through telephones or satellites to offices where it is stored and processed. The data relayed through the Geostationary Operational Environmental Satellite (GOES) system are processed automatically in near real time, and in many cases, current data are available online within minutes.

Once a complete day of readings are received from a site, daily summary data are generated and made available online. Annually, the USGS finalizes and publishes the daily data in a series of water-data reports. Approved daily data and peak data are updated annually following publication of the reports.

Tutorial

Tutorial explaining how to perform a surface water retrieval and understand the results

http://waterdata.usgs.gov/ak/nwis/sw

Example:

General categories of seasonal streamflow patterns in Alaska and transboundary waters (from Wiley and Curran, 2003)

Mean daily discharge, compiled from 14-38 years of record.

Modified from Figure 2, Wiley and Curran, 2003, USGS WRIR 03-4114

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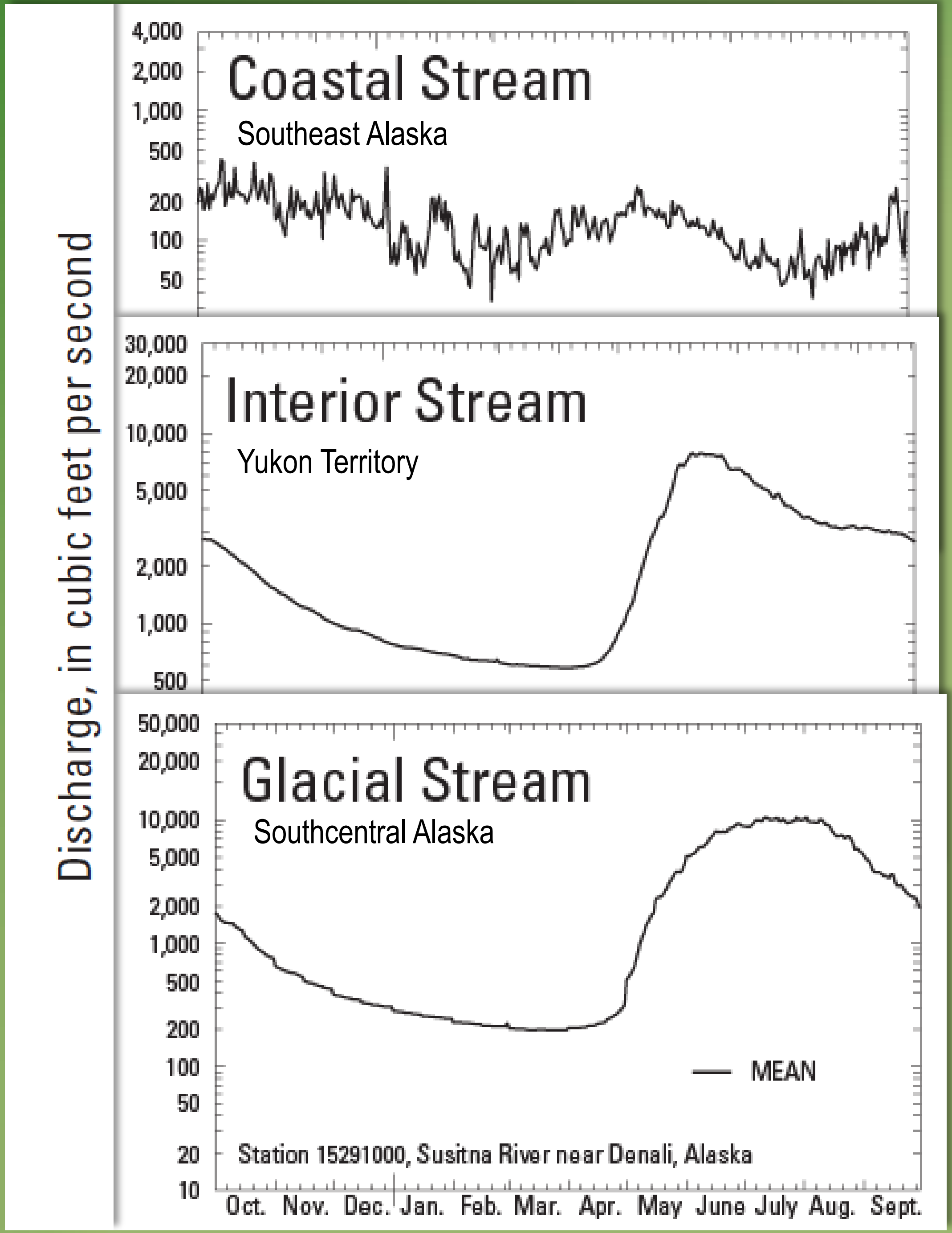

Example: Hydrologic Regime Typing (from Joel Trubilowicz)

- Classify watershed sub-basins into known hydrologic regimes in BC/AK region
  - Identify 'prototype' watersheds
  - Use K-nearest-neighbour classification to fit ungauged basins to most similar prototype
- Use HUC watersheds in Alaska and Freshwater Atlas in BC

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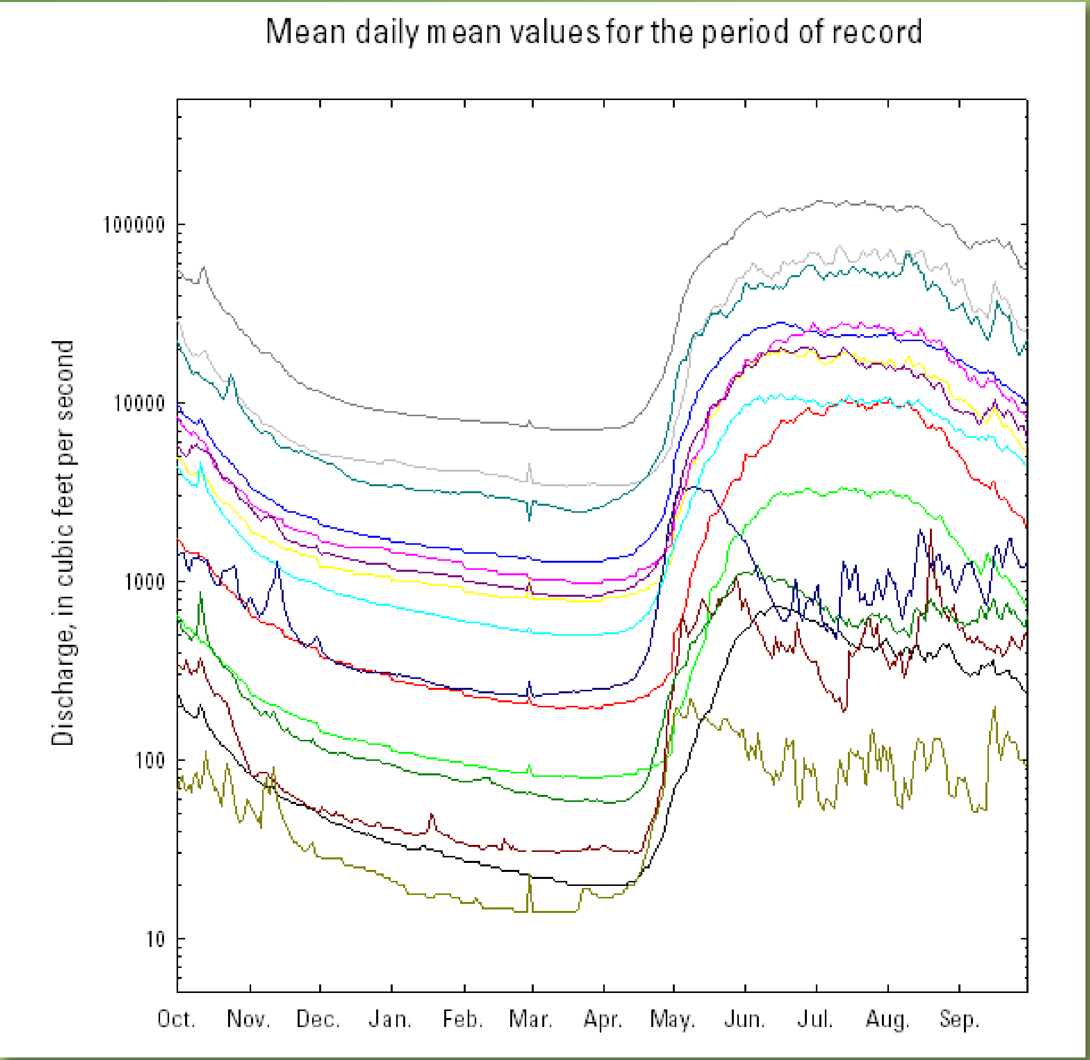
Example: Selecting index stations for estimating daily discharge (Susitna River Basin)

- Hydrograph of all available stations (here by water year) highlighted obvious misfits to exclude from use as index stations
- From Curran, 2012, USGS SIR 2012-5210



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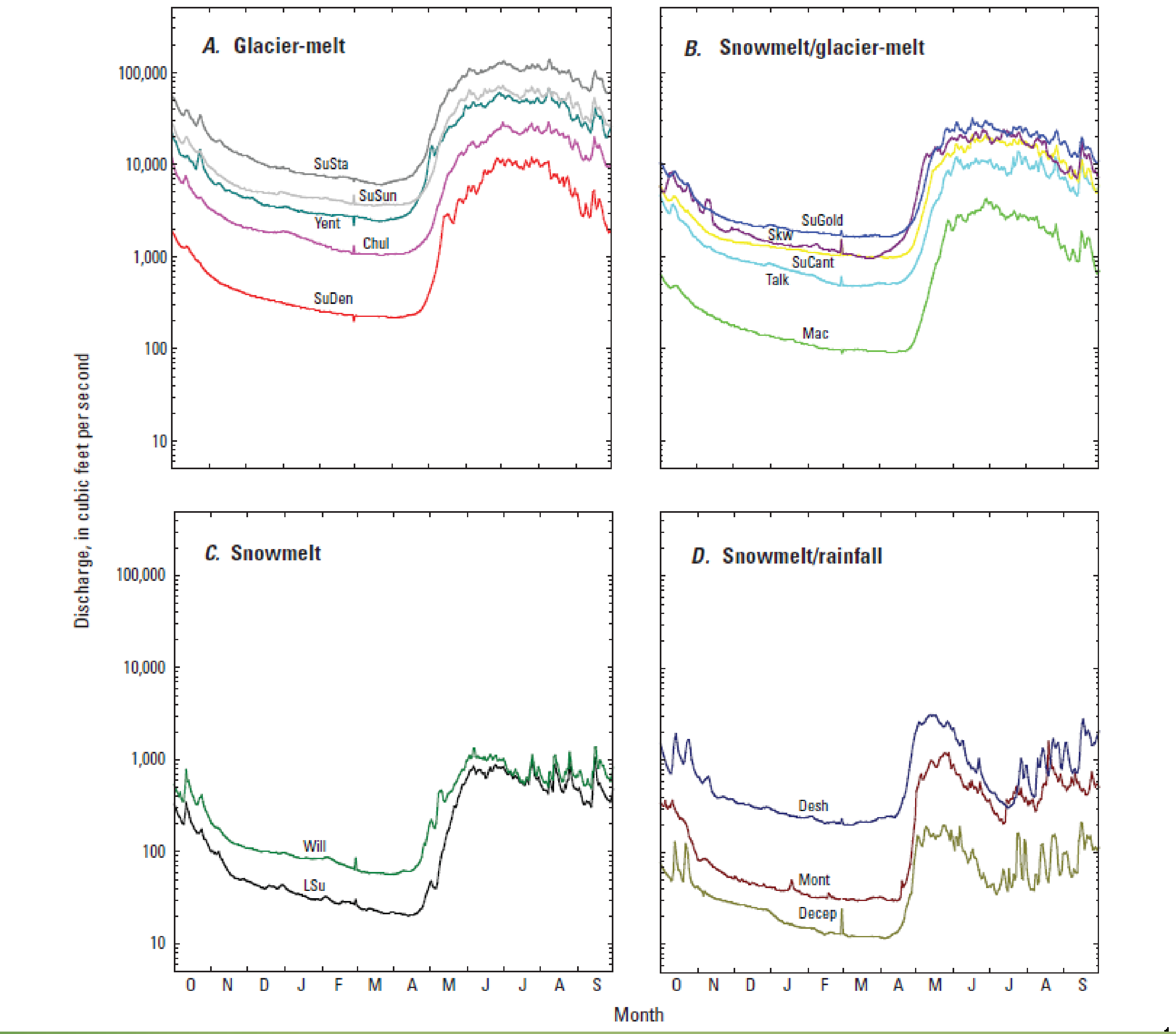
Susitna River basins categorized by streamflow driver



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Streamflow drivers for extremes can be different than for daily flows

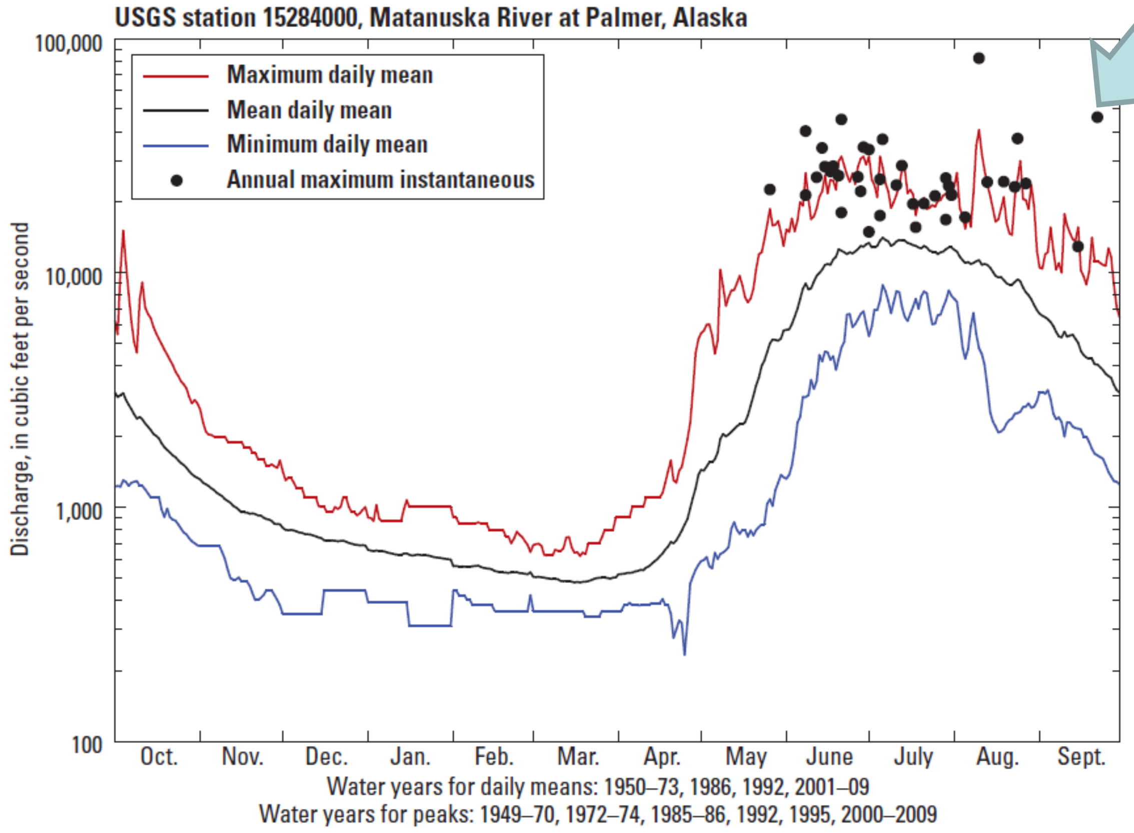

Figure 3. Maximum, mean, and minimum daily mean discharge and annual maximum instantaneous discharge and calendar day of occurrence during the period of record for the Matanuska River at Palmer, Alaska, USGS gaging station 15284000.

Overview of model approaches

- Empirical (relatively easy to build and use)
  - Data driven, observation oriented. Cannot account for process.
  - Ex: Correlate a streamflow metric to watershed data (regression)
- Conceptual (more challenging)
  - Parameterizes processes in terms of readily available data
  - Ex: "Temperature-index" models (snowmelt = function of T)
- Physical or process-based (most challenging)
  - Follow laws of physics and use dynamic analysis to simulate process
  - Require large amts of input and validation data
  - Often incorporates precipitation, melt, evapotranspiration, and other processes

Model considerations

- Input data
  - Specific input data (particular climate dataset) may be required
  - Output is only as resolute, accurate, and process-specific as the input
- Spatial and temporal resolution
  - Is a 1 km grid, point estimate, or watershed-scale estimate suitable?
  - Is a daily, monthly, annual time step needed?

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Model limitations

- Do the model assumptions allow changes in input data? Would using future climate variables violate assumptions?
- Is the model transferable between streams with vastly different streamflow drivers?
- Are the important processes included in the model? (make sure a glacier module is included if intent is to examine effect of reduction in glaciers)

Some existing models for freshwater discharge in Southeast Alaska/Gulf of Alaska

- Empirical:
  - Curran et al. (2016, 2003) – extremes (flood frequency, low-flow frequency) high-flow and low-flow duration
  - Hill et al. (2015; JGR) – monthly flows
  - Shanley and Albert (2014, PLoS ONE)
- Conceptual
  - Wang (2004) – daily flows
  - Moore, Trubilowicz, and Buttle (2012) – water balance model, monthly flows
- Physical
  - Beamer et al. (2016; WRR) – daily flows, 1 km scale

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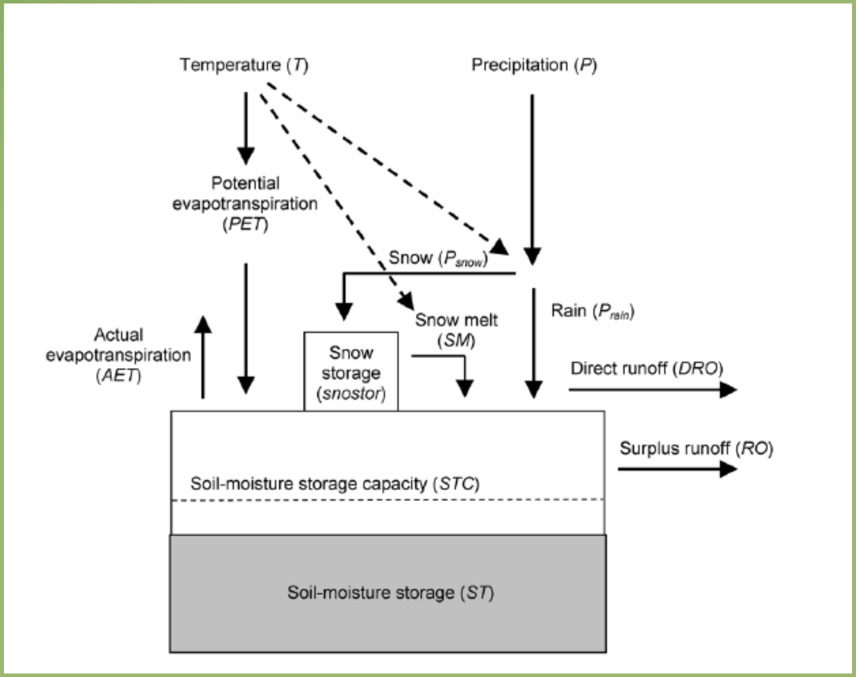
Distributed Climate Water Balance Model (Trubilowicz)

- Conceptually based water balance model
- Monthly time step
- Flexible spatial scale
  - 400 m resolution most common
- Uses gridded climate data as input
  - http://climatewna.com/ClimateWNA.aspx
- Runoff, SWE, ET can be produced as output
- Potentially useful for predicting future scenarios
- Available as an R package
  - https://github.com/jwtrubil/DCWBM



McCabe and Markstrom (2007)

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