Understanding the impacts of changing hydro-climate extremes to hydropower resources in SE Alaska

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Introduction

- Understanding hydrologic extremes and their associated impacts is a major challenge due to the complex interactions between the land surface, regional climate and water balance
- How can we estimate these impacts when there is a lack of information at the regional scale?
- Hydropower operations (forecasting) and planning initiatives will benefit from this understanding (i.e. Hamlet et al. 2002, McGuire et al. 2006)
- A proposal for an integrated approach to analysis of hydrologic extremes in Alaska

Research Approach

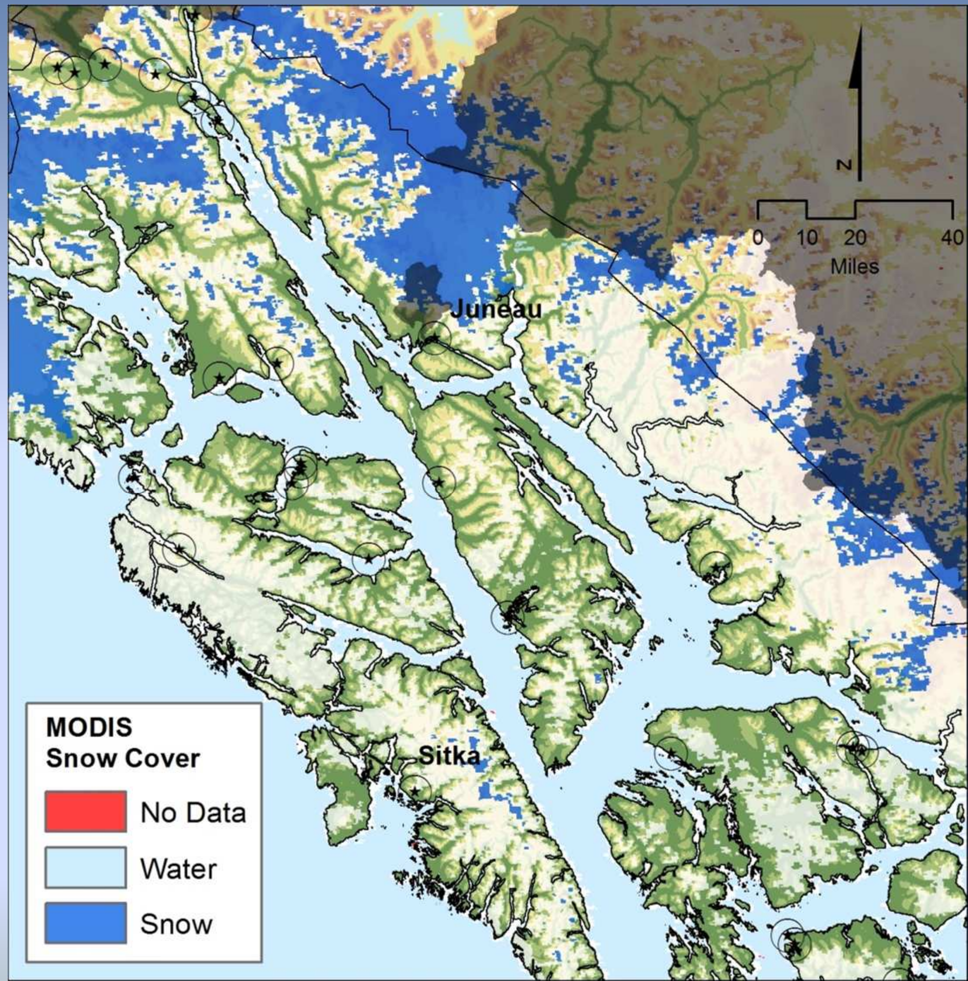
- Build an improved model that simulates hydrologic and land surface interactions processes well, and can run at the appropriate scale for regional analysis:
  - Focuses on the unknown aspects of the hydro-climate regime, i.e. permafrost, glaciers, river ice, and snow cover
- Use this model to improve understanding of connections between extreme hydro-climate events, soil moisture and regional synoptics
  - Questions: Have extreme hydrologic events (high and low flows) in Alaska changed in the past? Are extreme hydrologic events predicted to change in the future?
- Test products in basins across Alaska where applied information is required (interaction with Alaska River Forecast Center, National Weather Service, and University of Alaska SE)
  - i.e. SE Alaska hydropower requirements in Juneau and Sitka

Outline

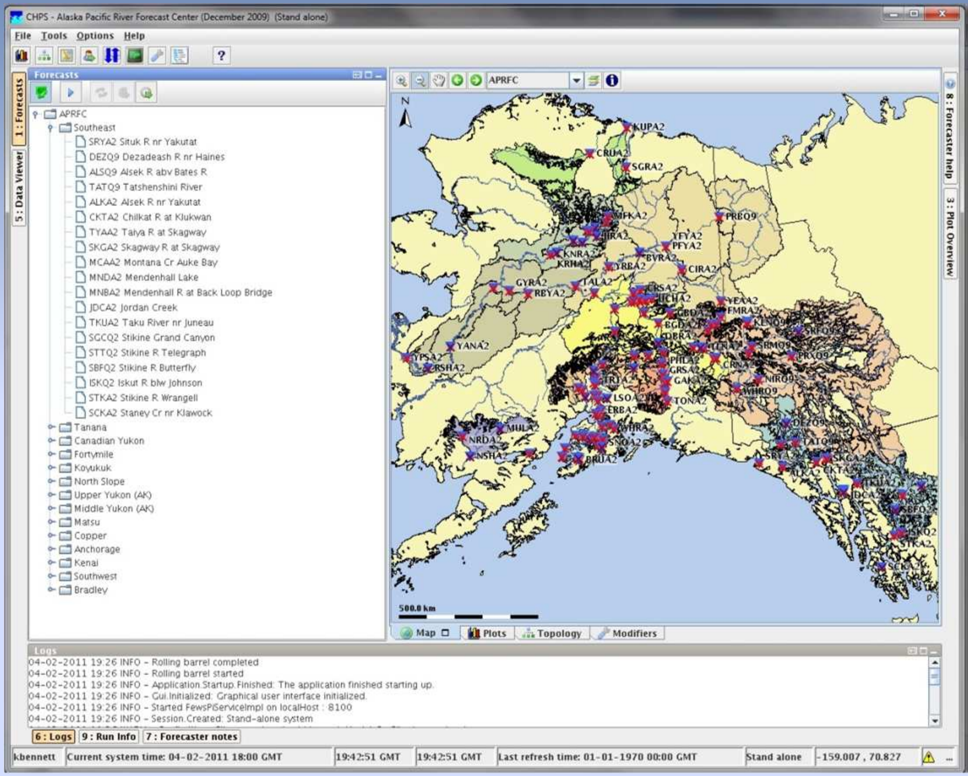
- Study sites proposed to do this work
- Phase 1: first steps
  - CHPS/FEWS Hydrologic forecasting framework tool
  - SAC-SMC/SNOW-17 hydrologic/snow models
  - MODIS snow cover fractions for Alaska
- Phase 2: future directions
  - Building a better model
  - Improved data input
  - Historical analysis: high and low flows
  - Future climate impacts: high and low flows
- Conclusion

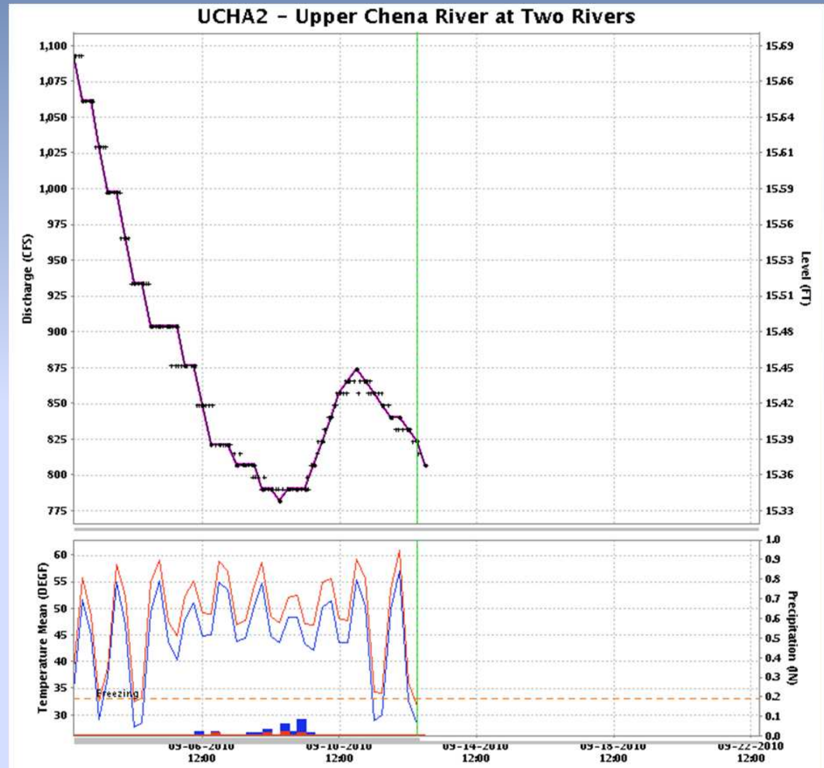
Study Sites

- SE Alaska: Juneau/Sitka hydropower facilities
- Eventually
  - Chena River Basin
  - North Slope (Sag)



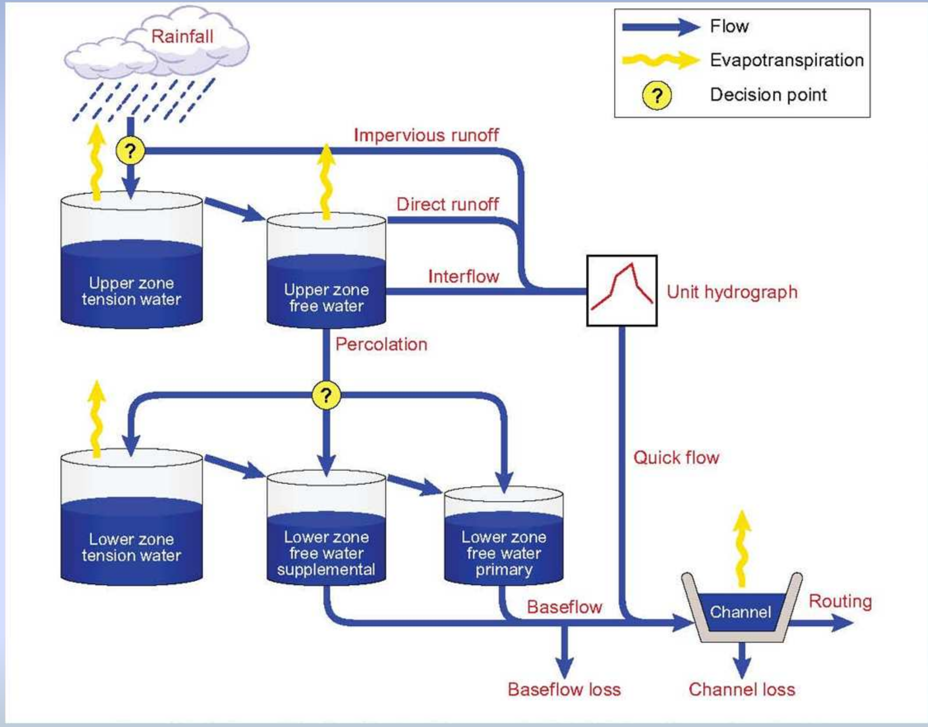
NWS River Forecast Centre Flood Early Warning System: CHPS





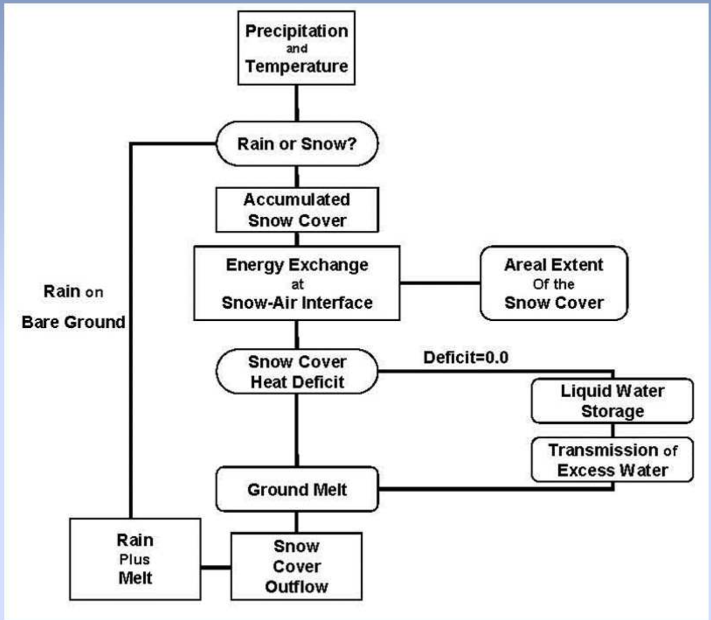
SAC-SMC Hydrologic Model

- Sacramento soil moisture accounting model – conceptual water balance model (Burnash et al. 1973)



SNOW-17

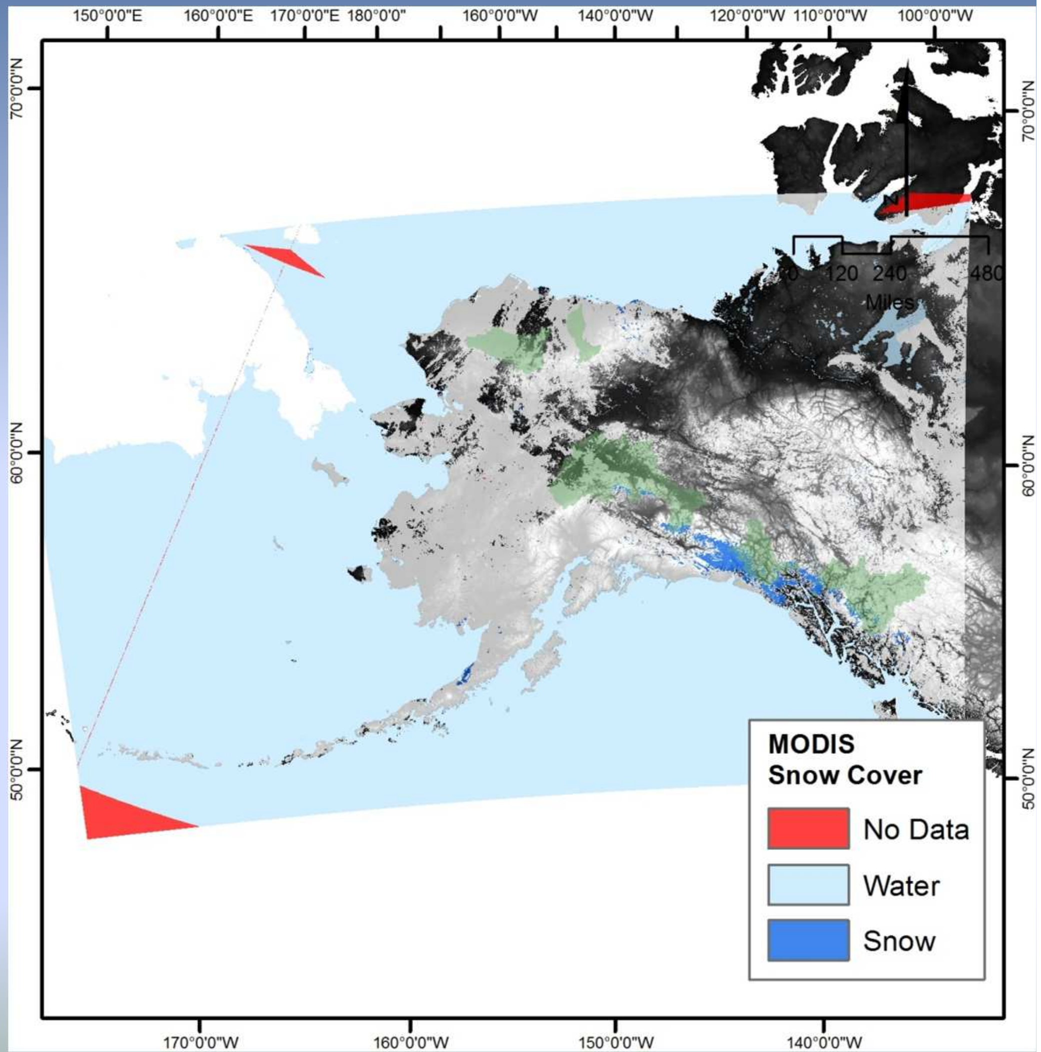
- Air temperature index model
- Inputs are T & P
- Watersheds divided into two or three elevation zones to estimate the melt from the snow cover to a runoff/rainfall model (SAC-SMC)
- Main processes simulated by SNOW-17 are:
  - form of precipitation (snow or rain)
  - accumulation of snow cover
  - energy exchange at the snow-air interface
  - internal states of snow cover (temperature, liquid/frozen water content, density, etc.)
  - transmission of liquid water through the snowpack, and
  - heat transfer at the soil-air interface.



Excerpted from Anderson, 2006

MODIS Imagery: Snow Cover Extent/Fraction

- Widely used MOD10A1, one and eight day images (Hall and Riggs, 2007)
- Images are available across Alaska, at a resolution of 500 m, from February 24th 2000 to present
- GINA: MODIS reprojection tool can be used to display images to Alaska-appropriate geographic realms



First Steps

- Import MODIS imagery into FEWS/CHPS
- Calculate for each watershed snow cover fractions using data from 2000 to 2011
- Update existing snow areal depletion curves (Dery et al. 2005)
- Sensitivity and uncertainty analysis (Tang et al. 2007, Franz et al. 2010)

Future Directions

A “Better” Model

- Model Improvements
  - Different hydrologic/land surface/snow models?
    - Land surface scheme (CLASS 3.7 LSM)
    - Snowmodel (Energy balance model opposed to temperature index model)
    - WaSim-ETH hydrologic model
- Model validation: observed data, snow survey/network sites

Data Improvements

- Data Improvements:
  - MODSCAG: produced by JPL (Painter et al. 2009)
    - Allows snow's spectral reflectance to vary pixel-by-pixel, -> spatial heterogeneity that characterizes snow in rough terrain
    - Improvement over Hall et al. (2007) approach
  - Filtering approaches to convert SCA to SWE (Thirel et al. 2011 in review)

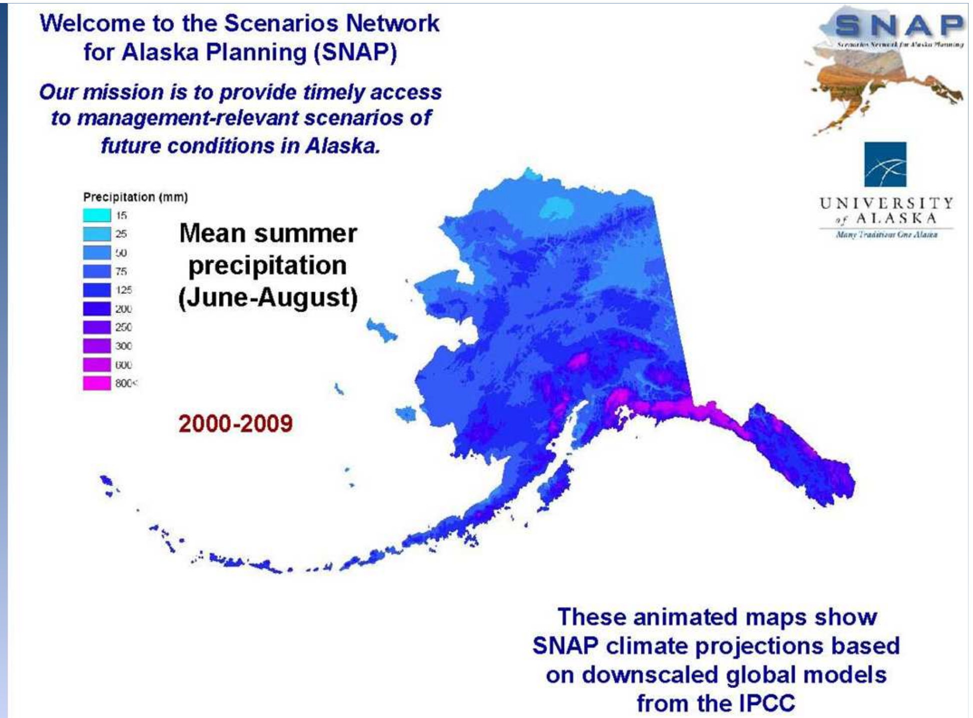
Extreme Events

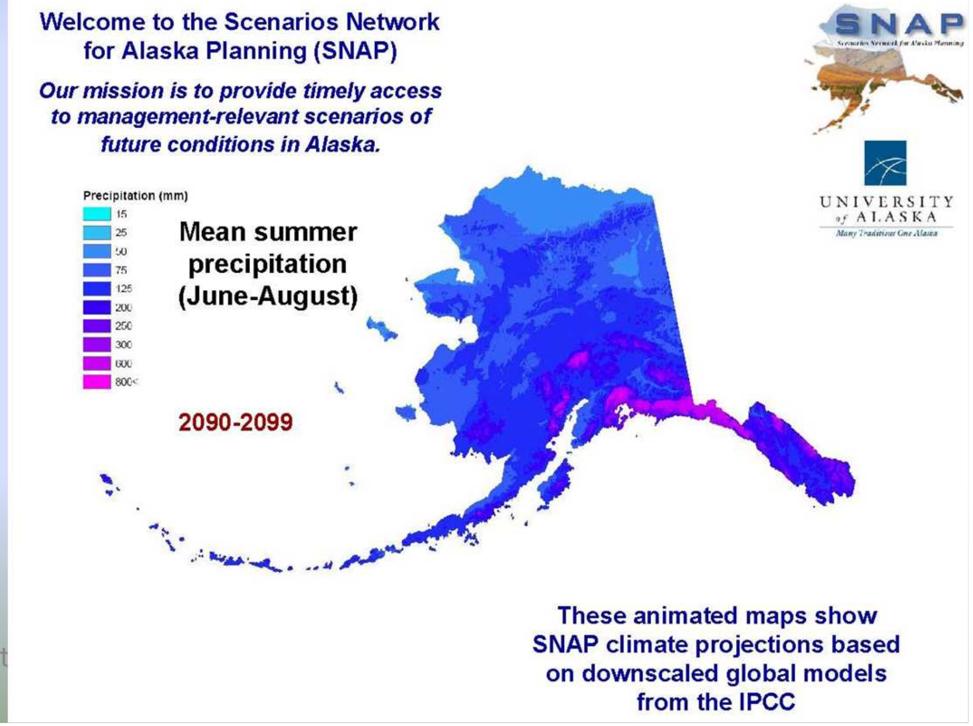
- Summer storm events, single high and low flow events (North Slope, Kane et al. 1999, 2008; Chena River 2003 event, Plumb 2011)

1. Using the model to examine the watershed response and characterize these events (antecedent moisture conditions, snowmelt dynamics, soil moisture in active layer in summer)
2. Climate regimes associated with these events (synoptic classification using self organizing maps SOM, Cassano E. et al. 2006, Cassano J. et al. 2007)
3. Historic and future analyses of events to understand how these events may have changed through time, or might be predicted to change into the future.

Future Climate Impacts

- Improved model to estimate future climate impacts across Alaskan watersheds
- Increased summer precipitation -> more summer high flow events?
- Emphasis on extreme events that will impact communities, industry and ecosystems





Conclusion

- Build an improved model to simulate processes well, at the correct scale, and improve data inputs
- Apply this model in watersheds in Alaska to examine summer high and low flow events
- Link these events to regional synoptic patterns
- Apply results where this information is most needed
    - Forecasts can be used by hydro-power operators in SE Alaska for system optimization and planning initiatives

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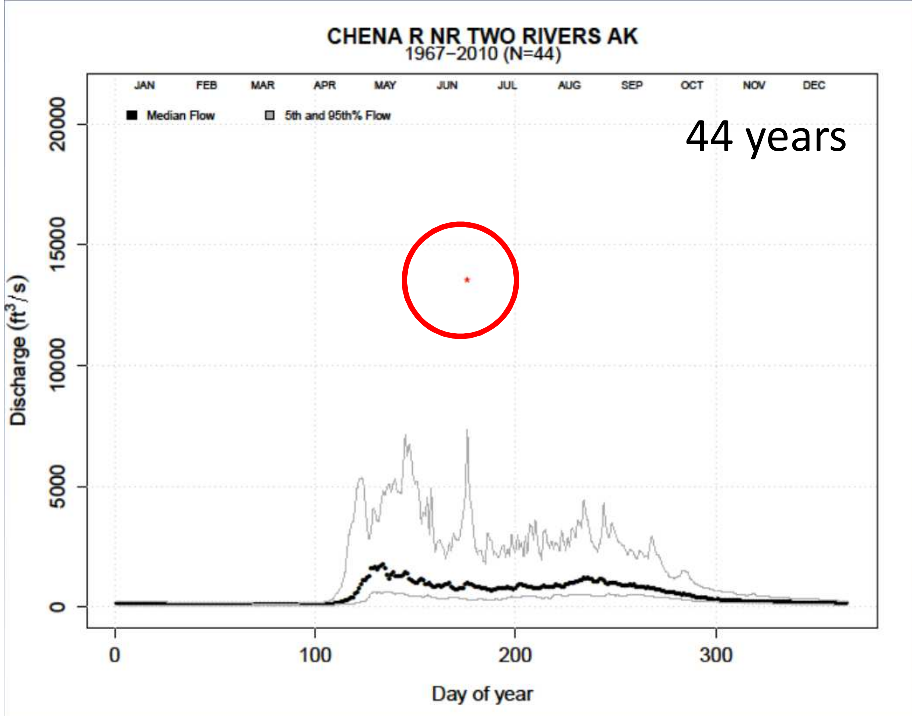
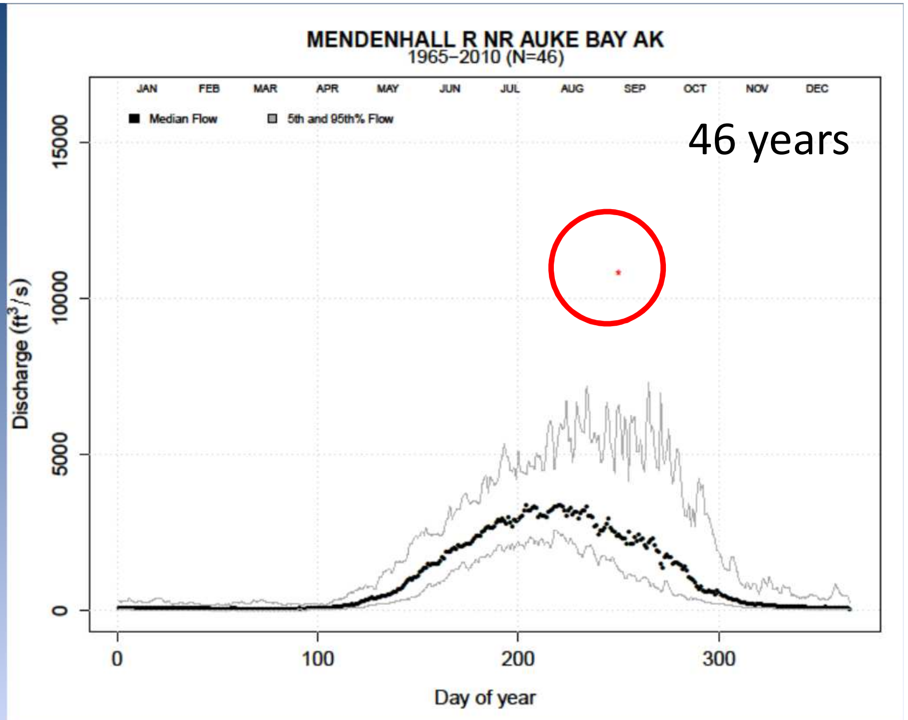
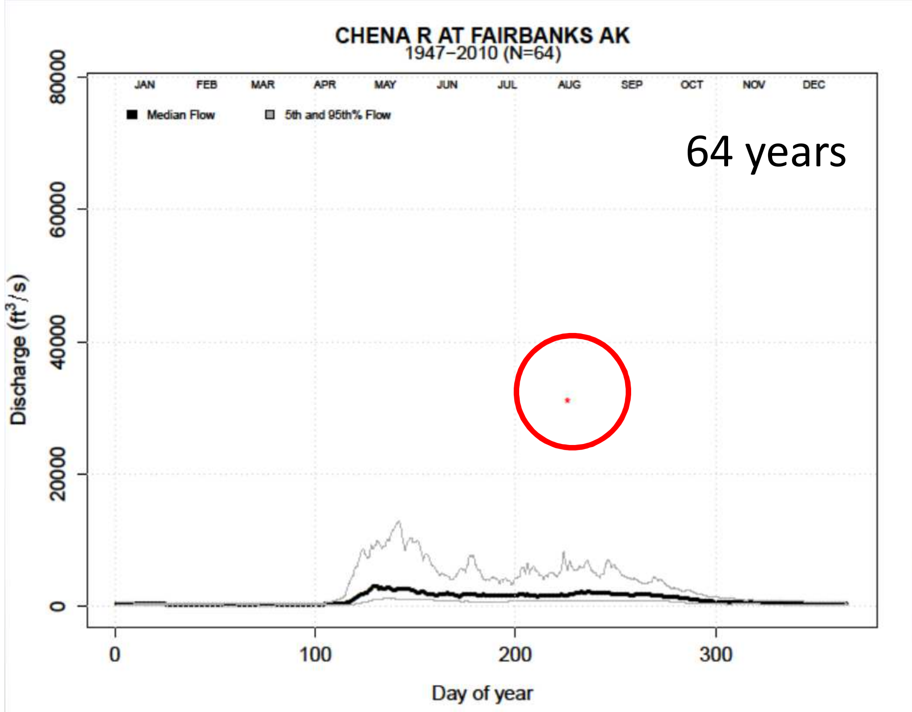
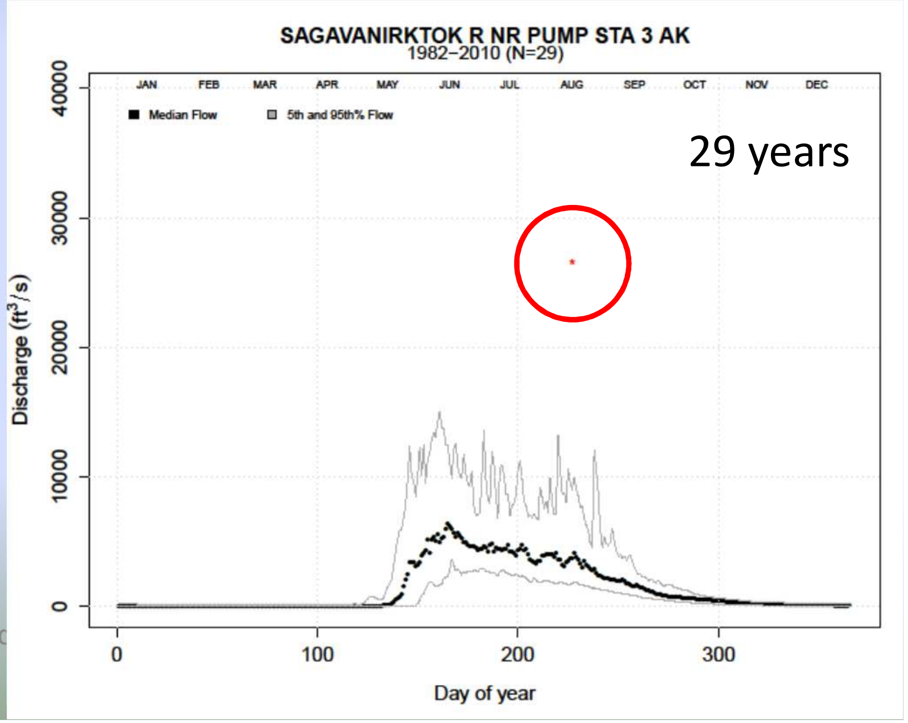

CHENA R NR TWO RIVERS AK
1967–2010 (N=44)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Median Flow
5th and 95th% Flow
44 years
Discharge (ft³/s)
0
5000
10000
15000
20000
0
100
200
300
Day of year


MENDENHALL R NR AUKE BAY AK
1965–2010 (N=46)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Median Flow
5th and 95th% Flow
46 years
Discharge (ft³/s)
0
5000
10000
15000
0
100
200
300
Day of year


CHENA R AT FAIRBANKS AK
1947–2010 (N=64)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Median Flow
5th and 95th% Flow
64 years
Discharge (ft³/s)
0
20000
40000
60000
80000
0
100
200
300
Day of year


SAGAVANIRKTOK R NR PUMP STA 3 AK
1982–2010 (N=29)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Median Flow
5th and 95th% Flow
29 years
Discharge (ft³/s)
0
10000
20000
30000
40000
0
100
200
300
Day of year

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