Extreme weather and hydrology:
Lessons learned from the western Canadian floods of 2013 and others
Feb 11-12, 2014 Canmore, Alberta

Extreme streamflow events in Interior Alaskan watersheds

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Introduction

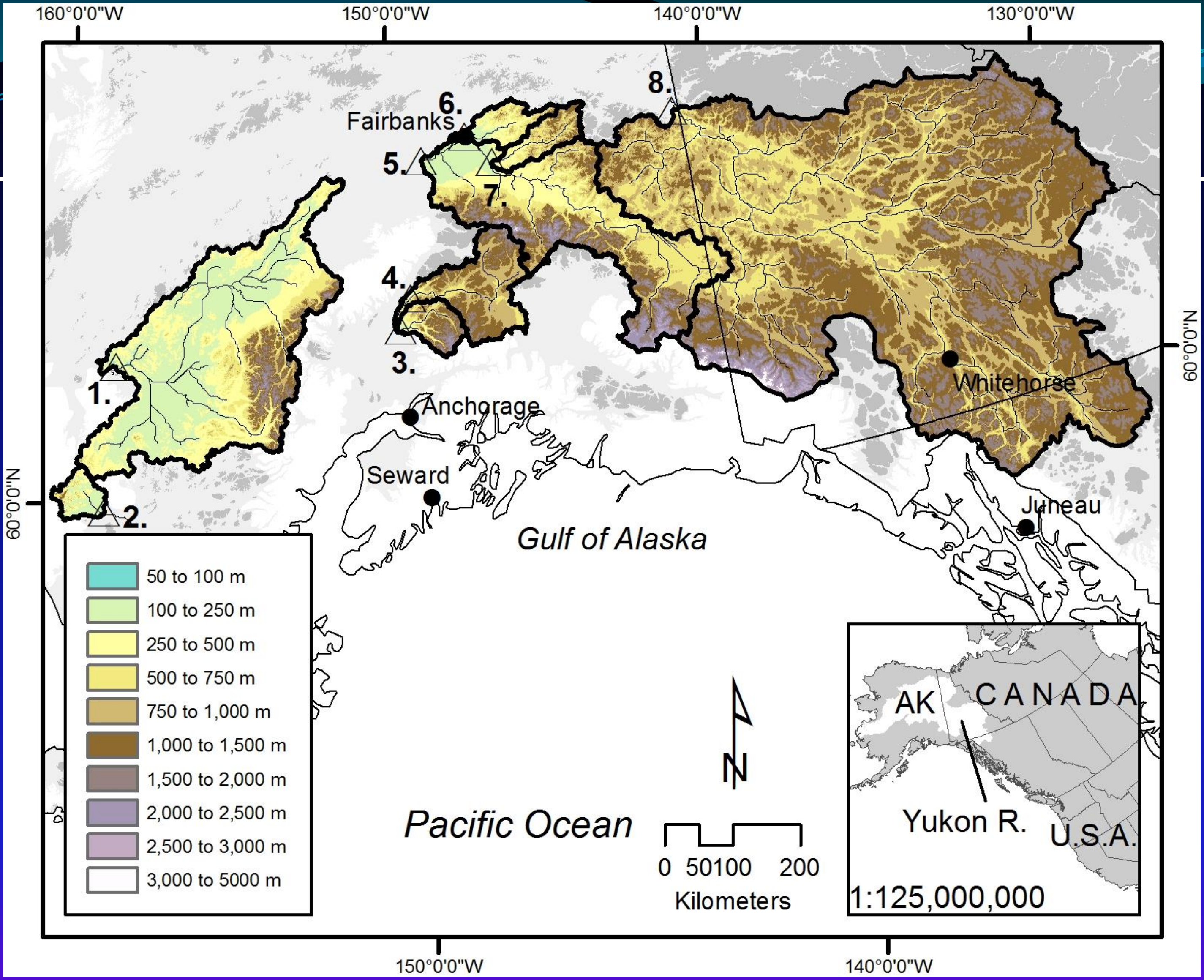
- "Changes in extreme hydro-climate events are one of the most significant ways socioeconomic and natural systems are likely to experience climate change." *Key findings Weather and Climate Extremes in a Changing Climate, Peterson et al. 2008*
- Analyses of changes in frequency and intensity of extreme events have been undertaken globally at the mid-latitudes *IPCC Chapter 3, 2007*
- Comprehensive data analysis of changes in extreme hydro-climate events in the high latitudes is largely absent in recent literature *Stewart, 2011*

Motivation

- Studies of the warm-permafrost Interior boreal forest region of the sub-Arctic are rare, and these systems are notably understudied in Arctic literature
- Much of the work on streamflow changes has been done on mean streamflow not extremes
- Due to lack of high quality, continuous and long term records and data with which to do analysis, there is a paucity of studies on Alaskan streamflow systems
- Attempt to look at changes over the historical period as a baseline for modeling and future changes > next stage of project

Outline

- Historical analysis of extreme hydro-climate across Alaska and in specific basins (8)
  - ClimDEX variables TXx, TNn and Rx5 precipitation for historical period
  - Trends in maximum streamflow
  - Generalize Extreme Value (GEV) for maximum streamflow
- Spring breakup and summer (June) heat wave 2013
  - Spring breakup snow cover extent field survey in a boreal watershed
  - June 2013 climate analysis
    - Temperature difference from the normals
    - Sea level pressure
    - Time series analysis at Alaskan stations using ClimDEX indices for maximum temperature
    - Future projections of extreme temperatures for Fairbanks, Alaska



160°0'0"W
150°0'0"W
140°0'0"W
130°0'0"W
8.
6.
Fairbanks
5.
7.
4.
3.
1.
2.
Anchorage
Whitehorse
Seward
Juneau
Gulf of Alaska
Pacific Ocean
60°0'0"N
60°0'0"N
50 to 100 m
100 to 250 m
250 to 500 m
500 to 750 m
750 to 1,000 m
1,000 to 1,500 m
1,500 to 2,000 m
2,000 to 2,500 m
2,500 to 3,000 m
3,000 to 5000 m
N
0 50100 200
Kilometers
AK
CANADA
Yukon R.
U.S.A.
1:125,000,000
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Study Area

Data Sources

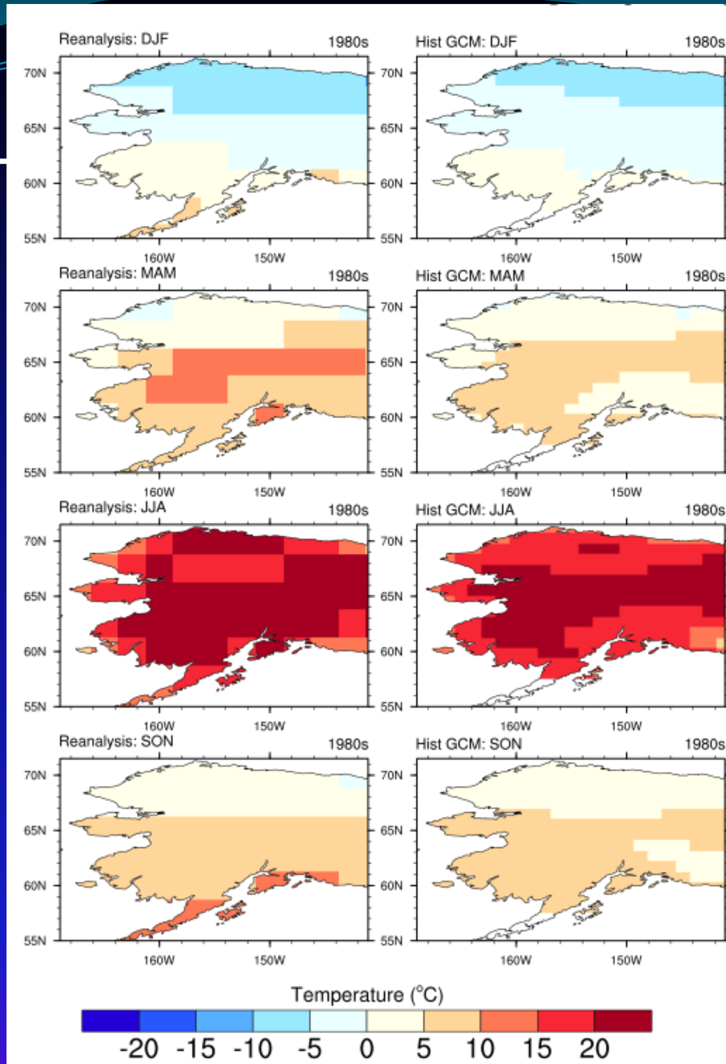
- USGS stream gaging for streamflow
- CRU TS 3.21 for temperature and precipitation downscaled to PRISM/ClimateWNA, averaged for basins for 1951-2010
- ClimDEX EC database used for reanalysis (ERA-40) and GCMs plots for the 1971-2000 baseline
- Climate variability
  - ENSO, PDO, PNA, AO
- Global Historical Climate Network (GHCN) climate stations used for 2013 analysis
- NOAA's ERSL website used to generate 2013 climate plots esrl.noaa.gov/psd/data/composites/day/

Methods – Trends Analysis

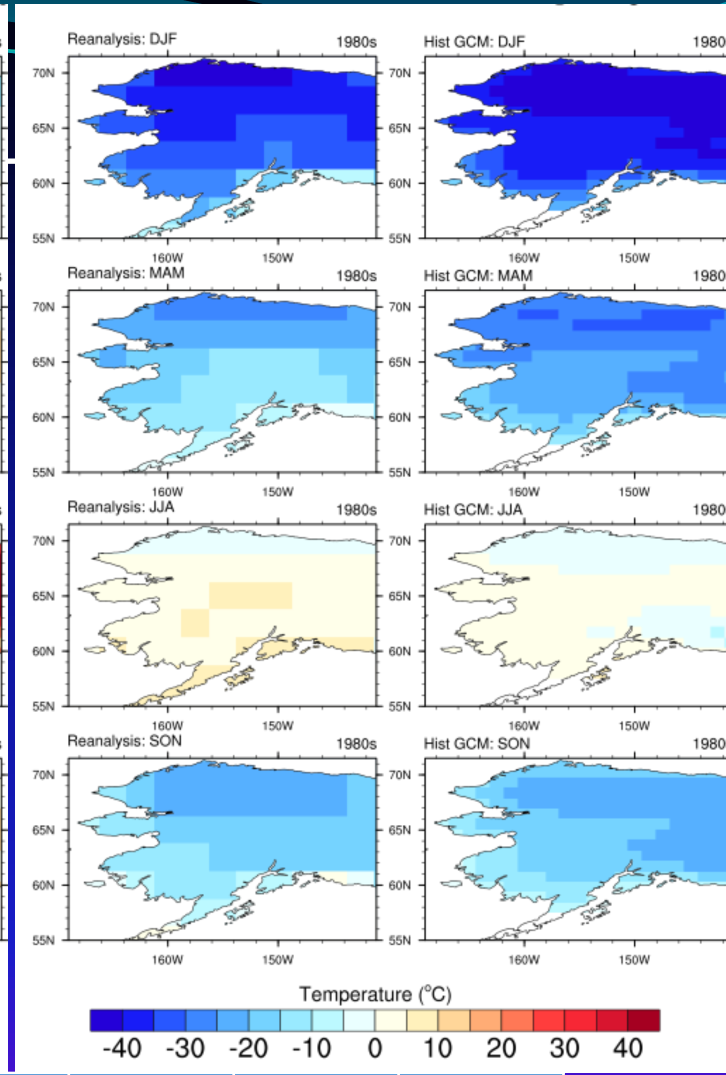
- Trends analysis
  - Theil-Sen slope for trend magnitude, Mann-Kendall for significance (zyp.R)
  - 12 day, monthly, seasonal, annual
  - Records < 70 complete discarded
- Generalized extreme value theory (GEV)
  - GEVcdn (Cannon, 2011) used to model the μ (location), and α (scale) parameters, using a probabilistic extension of the commonly used multilayer perceptron (MLP) neural network
  - Shape (κ) is particularly sensitive, and based on work by Martins and Stedinger (2000), Cannon (2010) applies a prior distribution for that fits many natural processes (Kysey and Picek, 2007)
  - Historical maximum streamflow over the 1951-2012 examined, annual and season time periods
  - Linear stationary, non-linear stationary, and non-linear, non-stationary with 1, 2 and 3 nodes possible

ClimDEX – TXx and TNn

TXx – Max Daily Max Tem

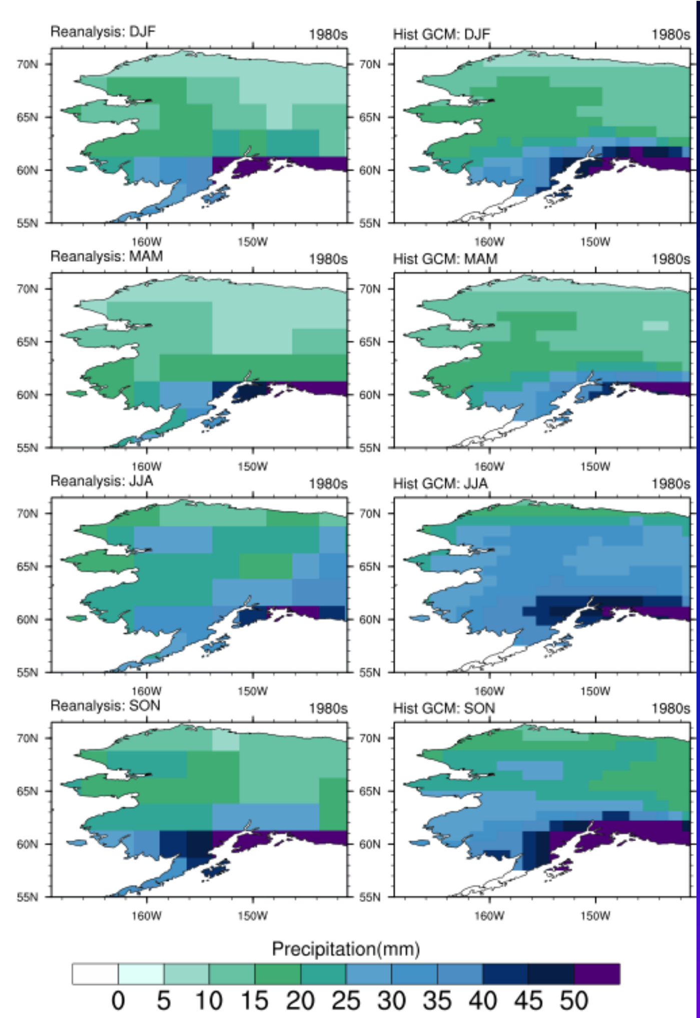


TNn – Min Daily Min Temp



Type	Fairbanks	DJF	MAM	JJA	SON	ANN
TNn	Station	-39.24	-17.3	4.19	-21.38	-49.35
TNn	Reanalysis	-34.55	-15.23	4.34	-16.71	-39.85
TXx	Station	-0.16	15.69	28.66	10.39	31.03
TXx	Reanalysis	-2.69	10.73	24.02	7.1	26.27

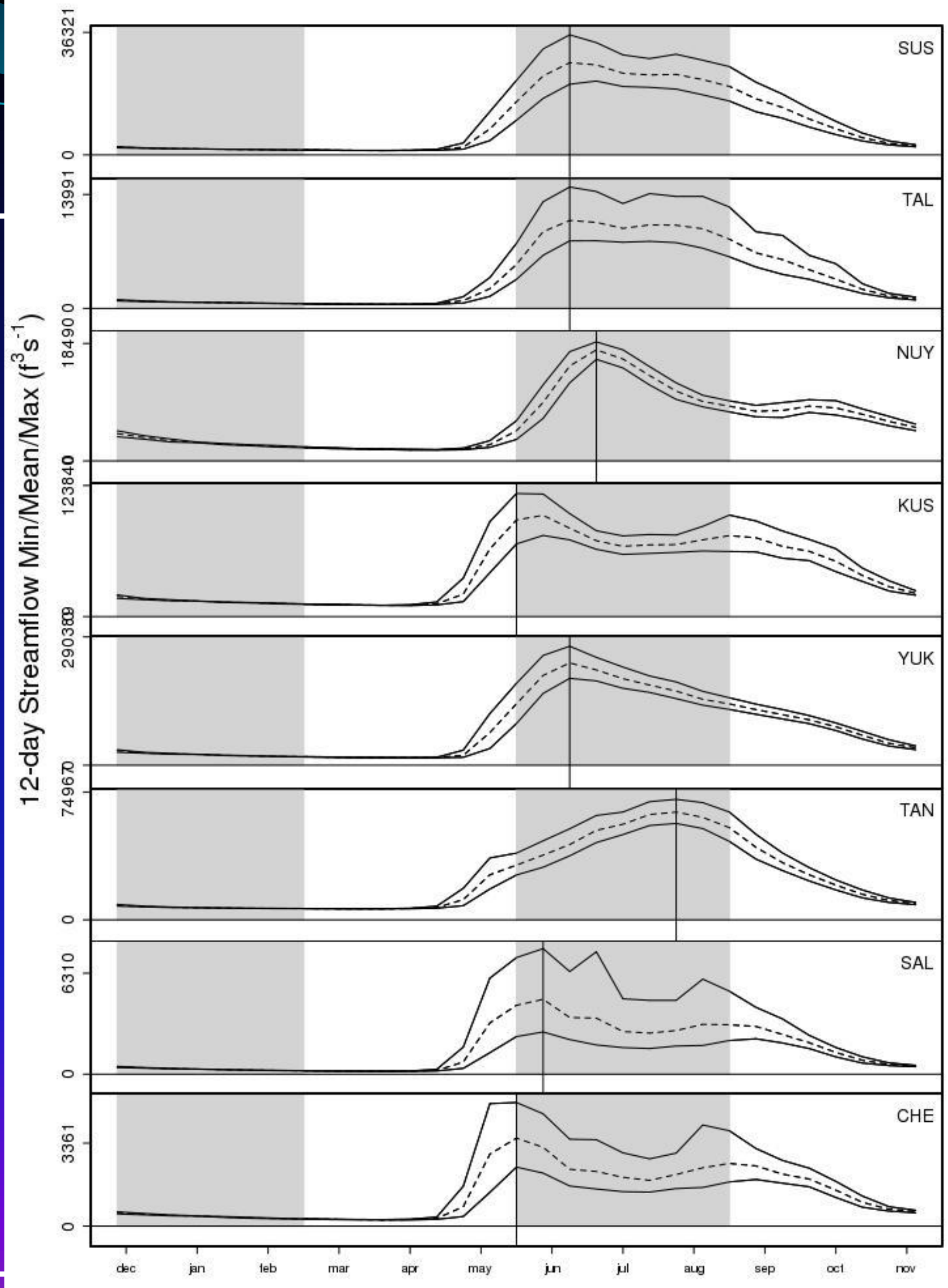
ClimDEX – Rx5 Precip



Fairbanks	DJF	MAM	JJA	SON	ANN
Station	9	6	22	13	35
Reanalysis	11	9	21	15	30

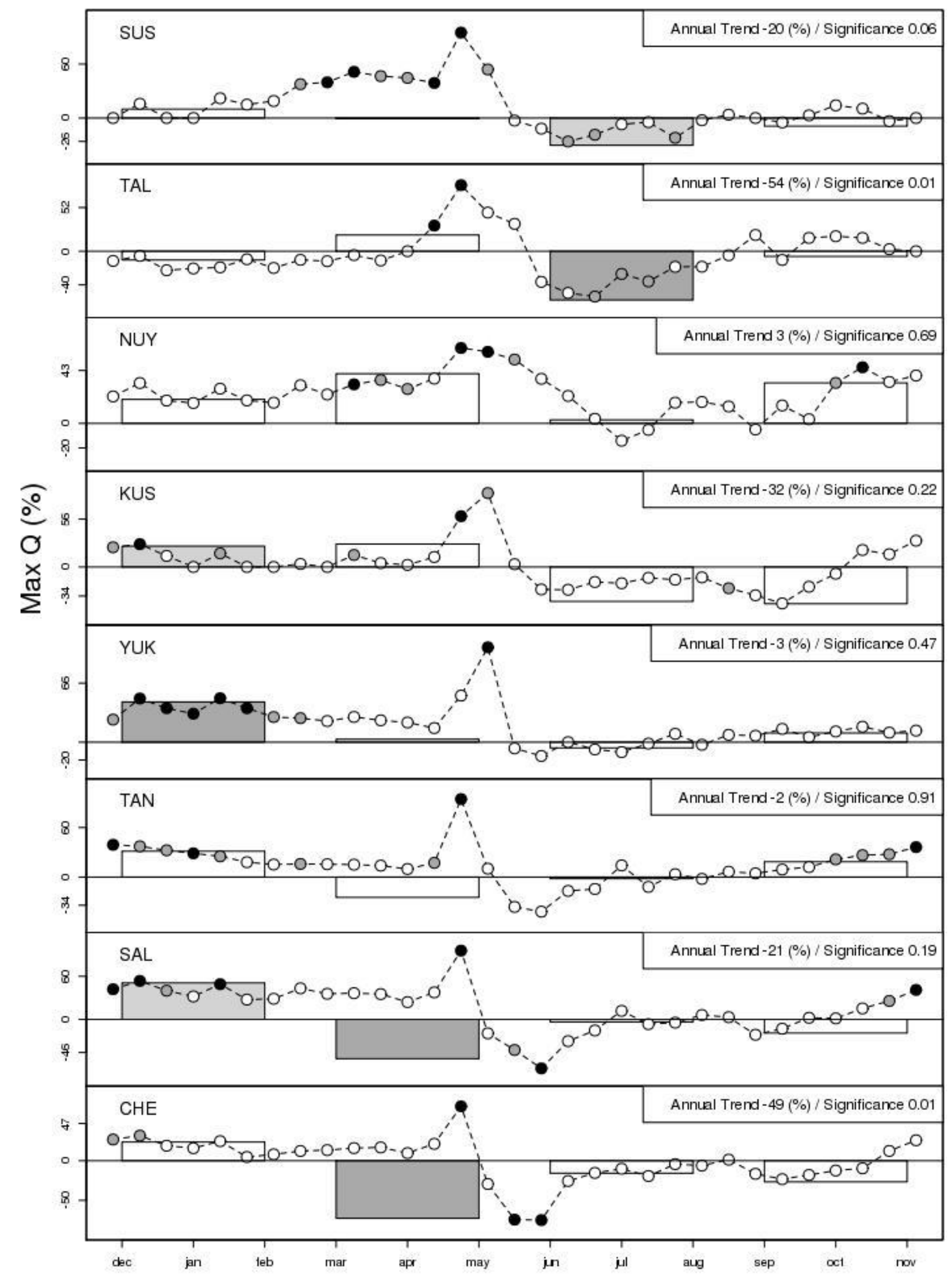
Hydrology

- Susitna, Talkeetna, Tanana and Yukon are glacier driven systems
- Kusko, Salcha and Chena are snowmelt/rainfall
- Nuyakuk is lake dominated
- Bulk of flow passes in summer
- Peak during mid-May to mid-July



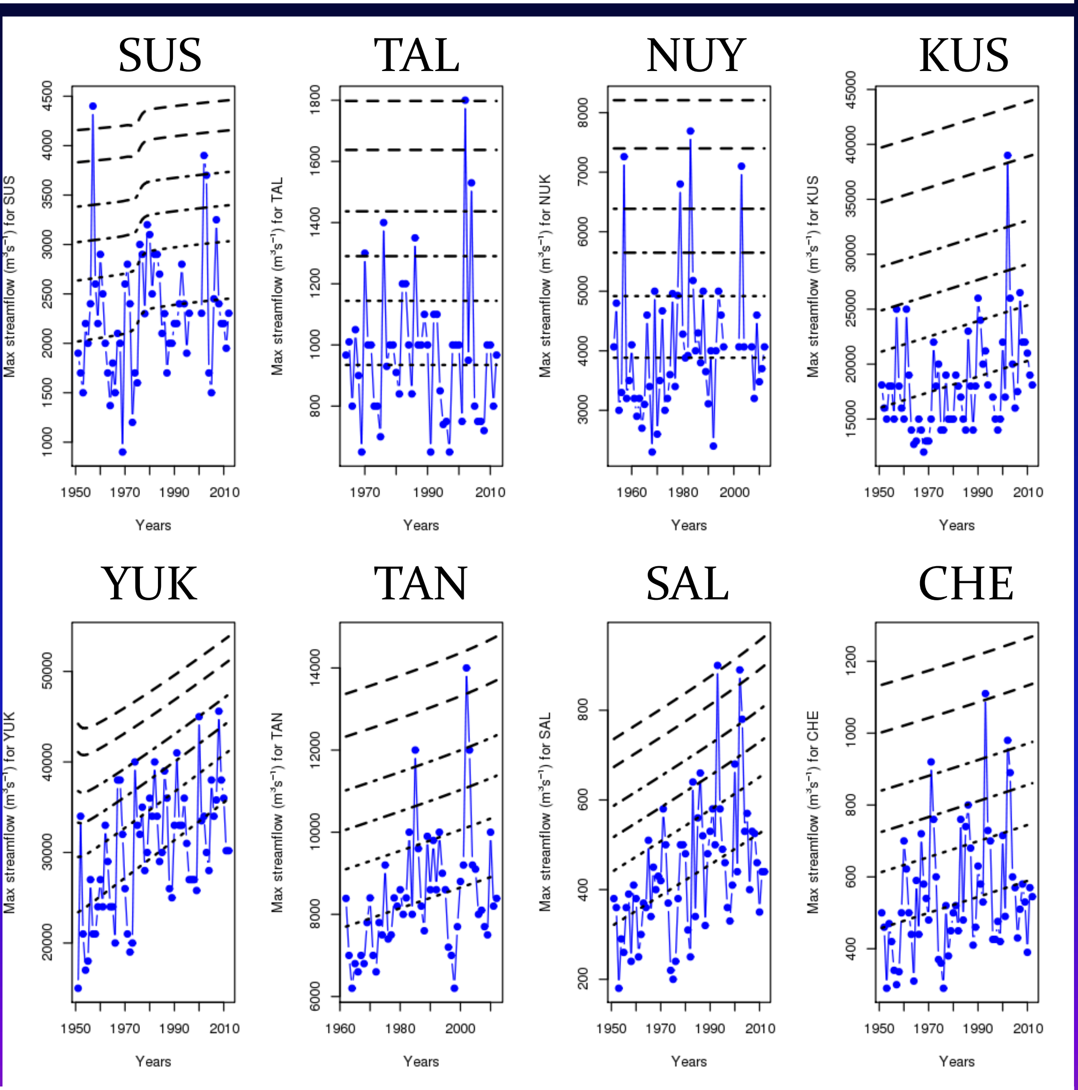
Trend Results

- April-May increase only captured in 12-day flow events
- Most winter and spring increases are statistically significant
- Marked summer declines in glacial systems (Susitna/Talkeetna)
- Annually flows are decreasing
- Winter flow increases



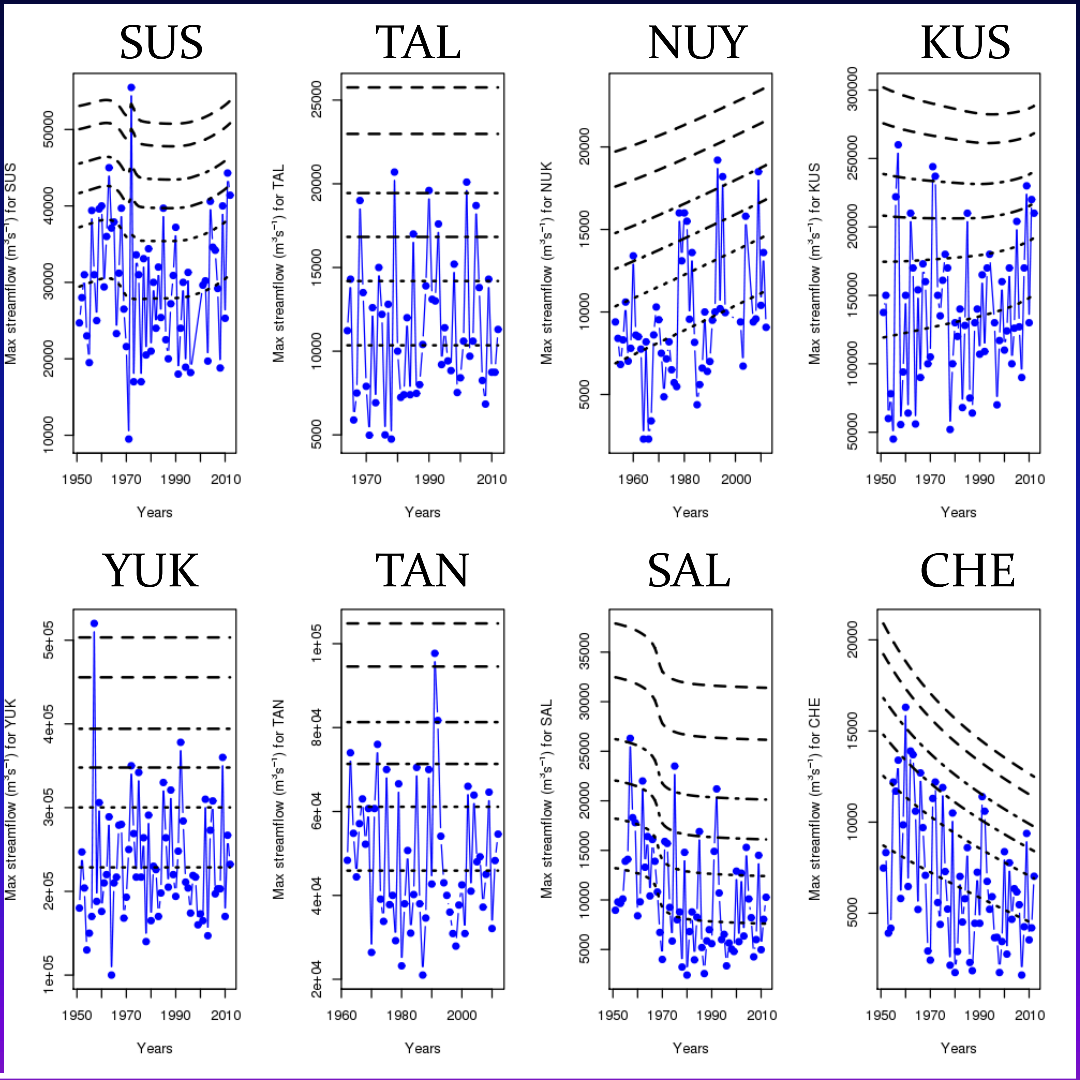
GEV – Winter Flows

- Blue dots/lines are maximum streamflow
- Dashed/dotted lines are 2, 5, 10, 20, 50, 100 year return levels
- Linear nonstationary (LNS) and the simple (1 node) non-linear nonstationary (NLNS) model candidates
- Suggest that the change occurring is associated with a linearly increasing forcing
- Most stations increasing over time, but some are stationary



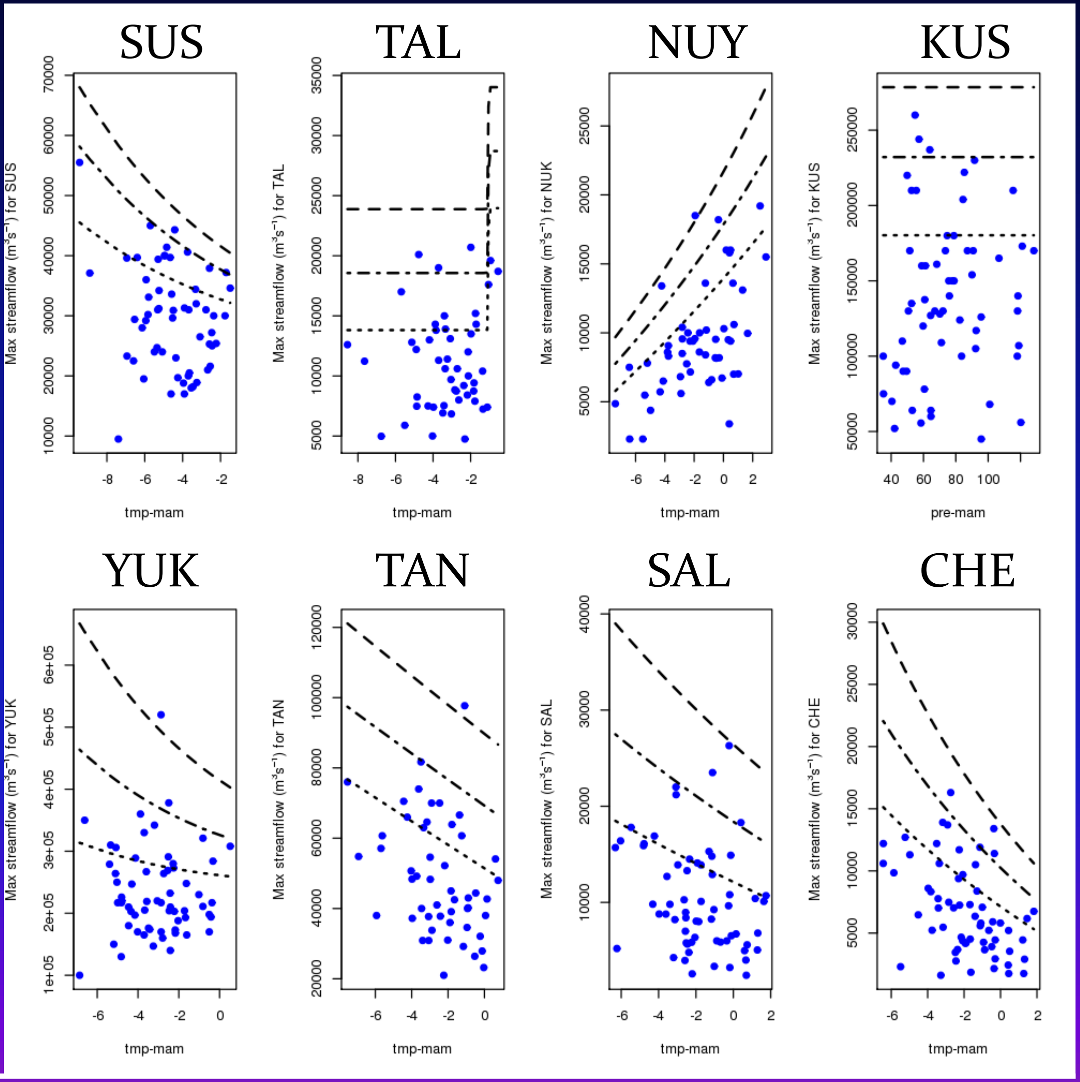
GEV – Spring Flows

- Blue dots/lines are maximum streamflow
- Dashed/dotted lines are 2, 5, 10, 20, 50, 100 year return levels
- Stations exhibit largely stationary (S) and linear nonstationary (LNS) changes
- Three stations where simple non-linear nonstationary (NLNS) models are minimized



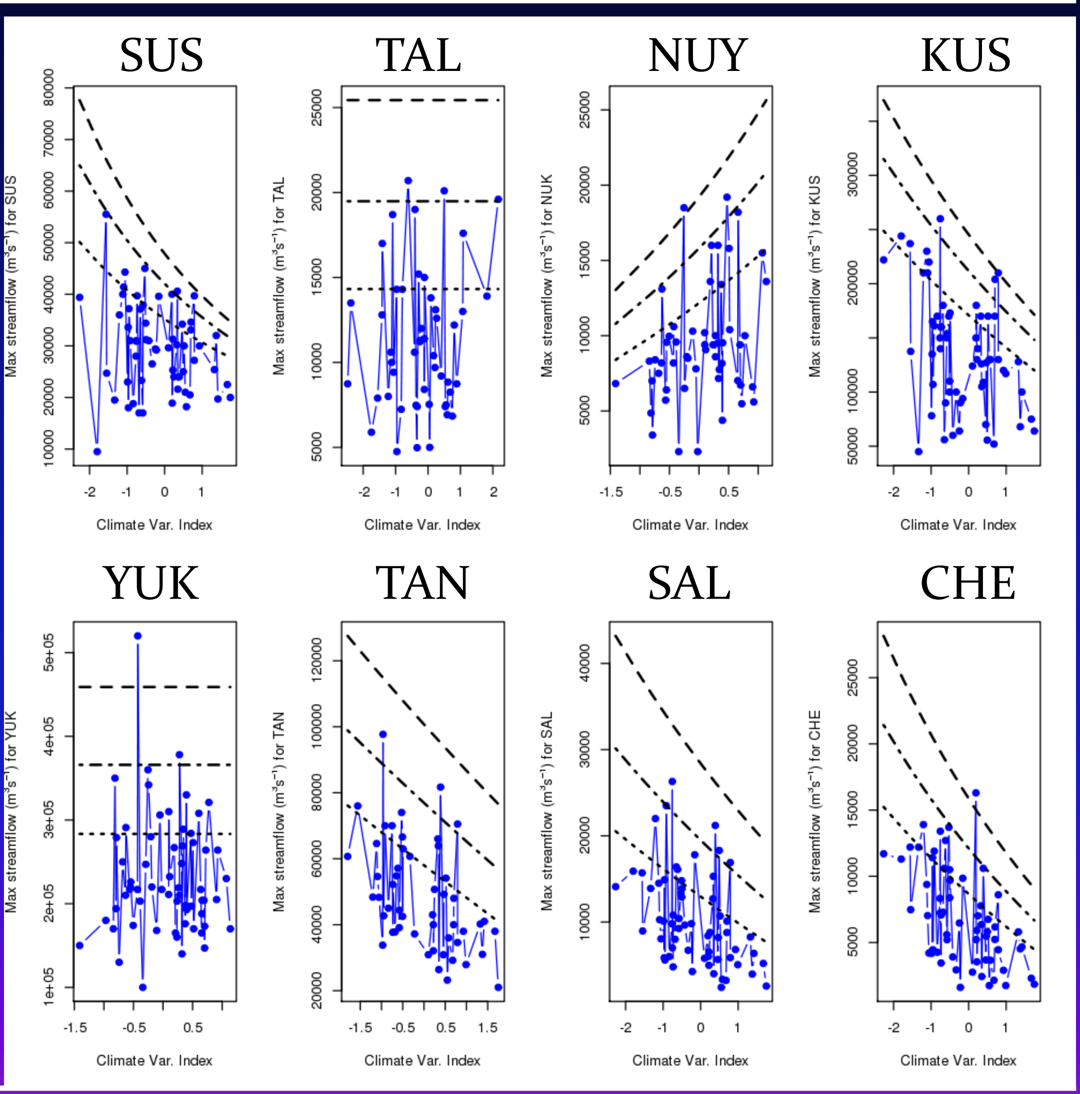
Temp or Precip Covariate

- Preliminary results
- Show MAM is minimized by temperature change
- Kuskokwim and Talkeetna have weak relationship
- All systems are declining maximum streamflow events with increasing MAM temperatures except Nuyakuk, which is increasing
- DJF is minimized by either temperature or precipitation depending on the system (or shows no change)

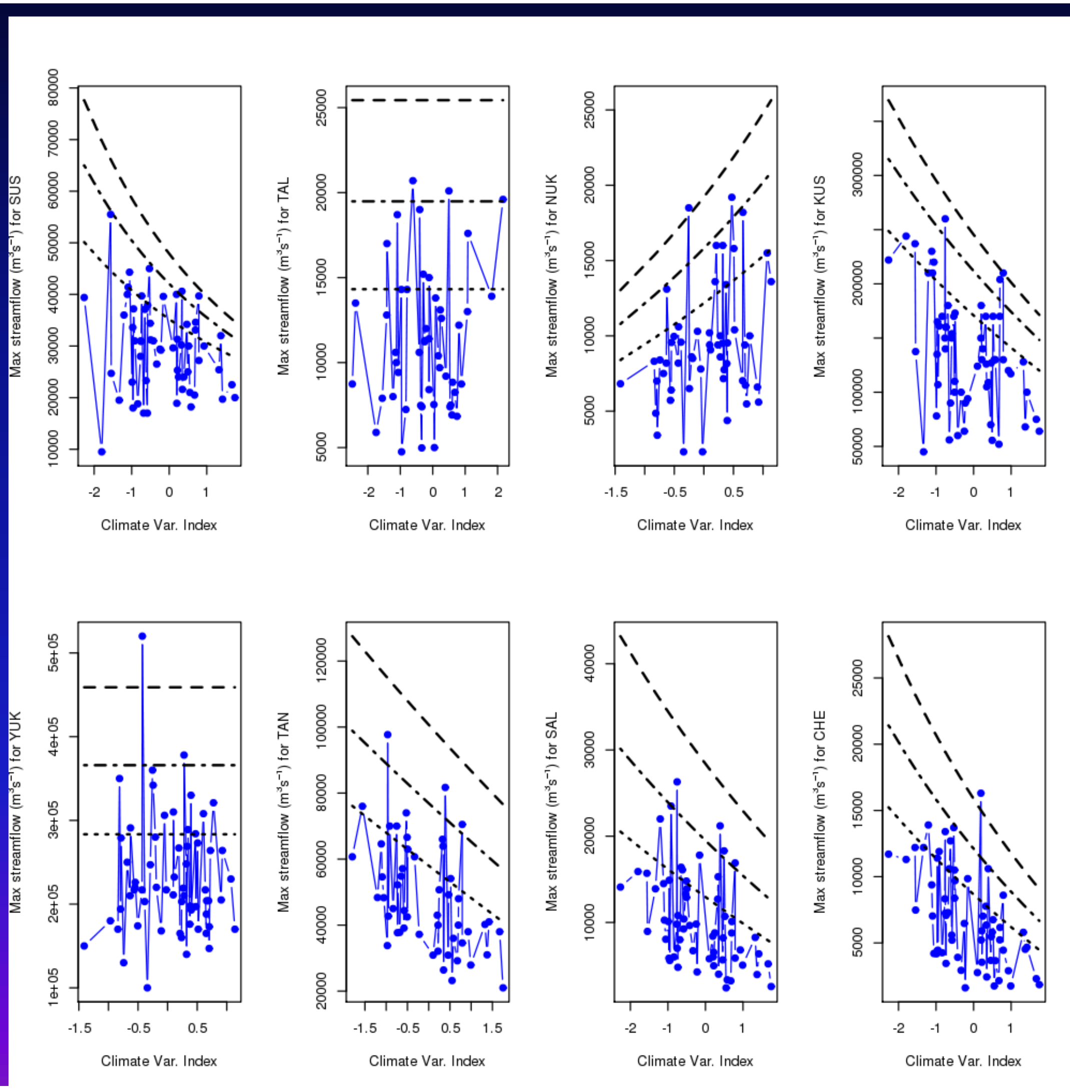


Climate Variability Covariate

- Preliminary results
- MAM is minimized by PDO for all systems
- Nuyakuk fits best with the PNA
- Results visually similar to temperature plots for MAM change

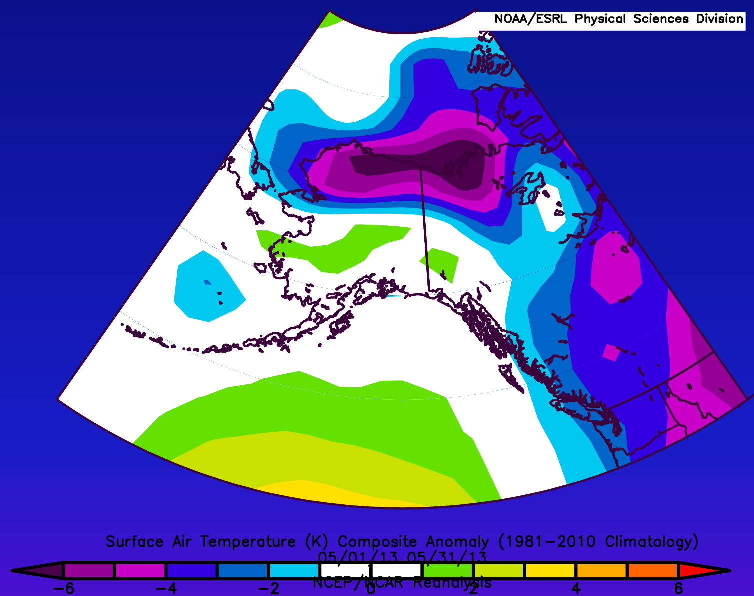


Climate Variability – MAM (PDO)



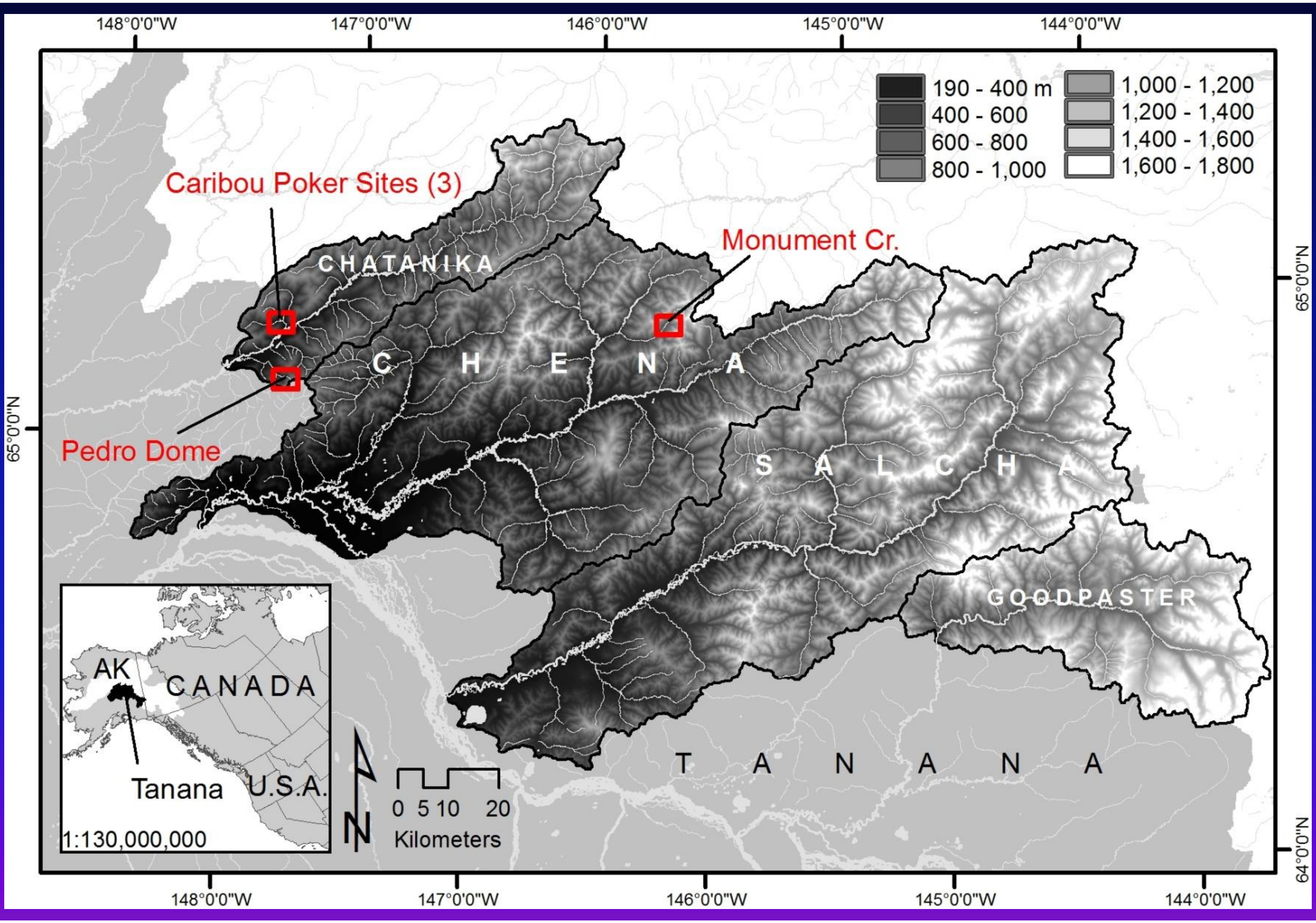
Breakup 2013

- One of the latest breakup on record since 1964
- March and April warm
- May extremely cold weather delayed snow melt



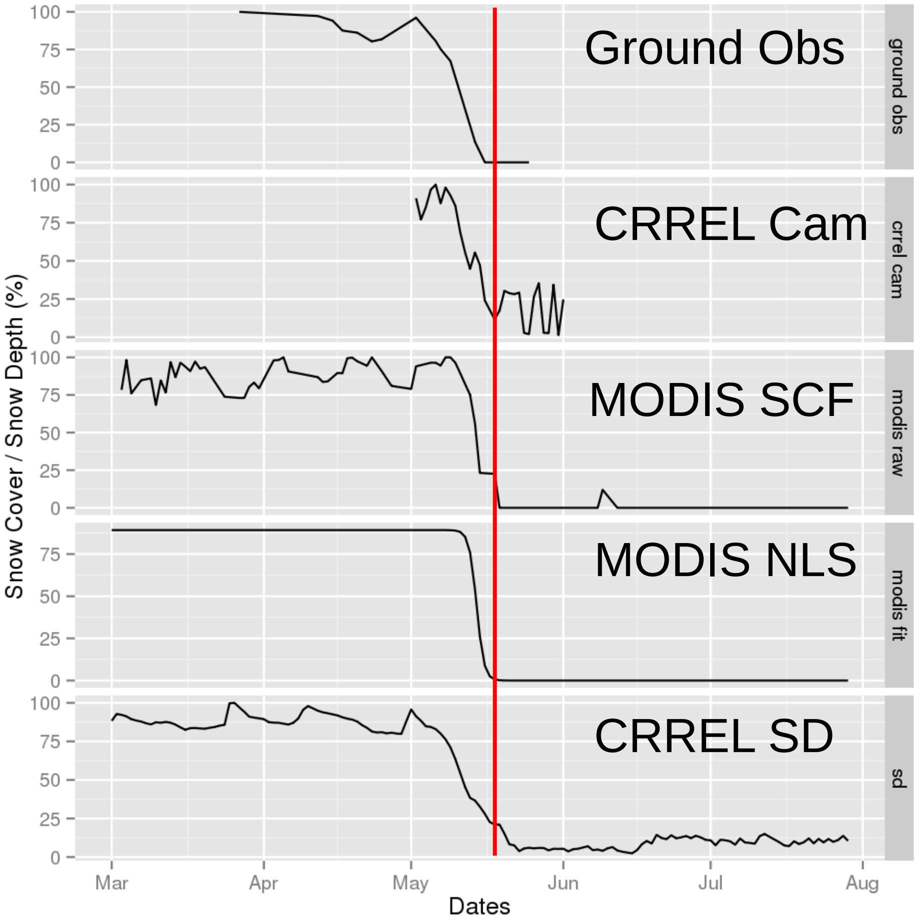
Temperature at Surface May 2013
Change from 1981-2000 climatology

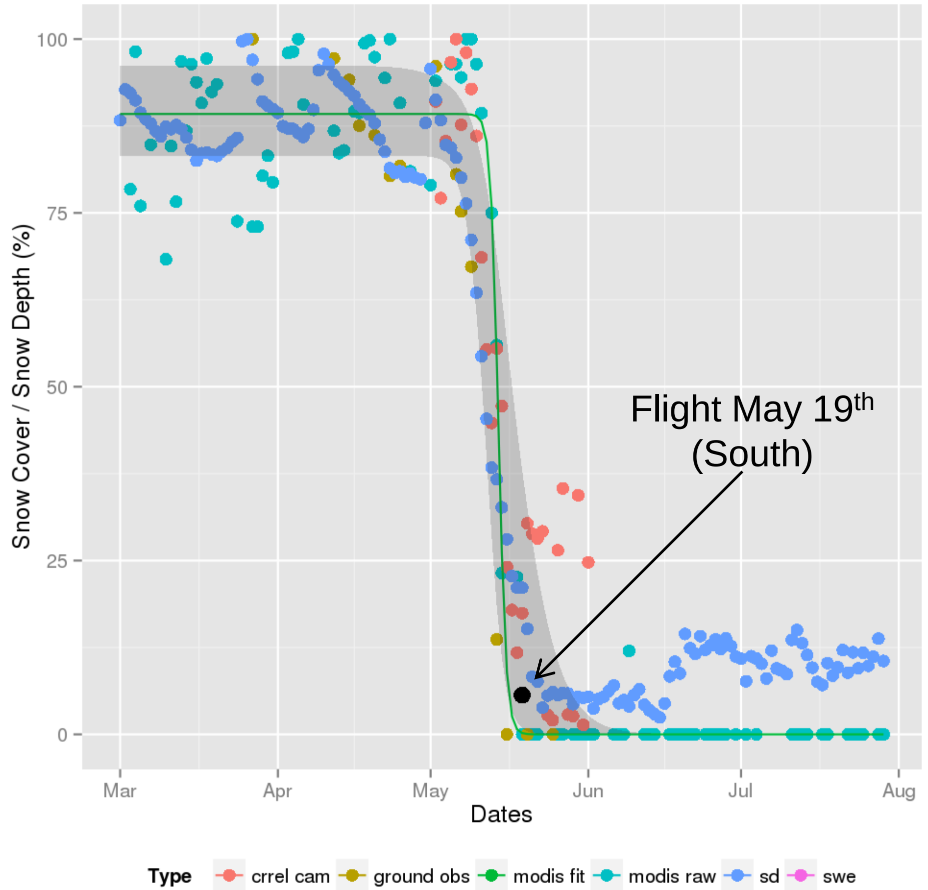
Chena River Snowmelt 2013



CPCRW North Site – May 2013

Results – Lowland (CPCRW)

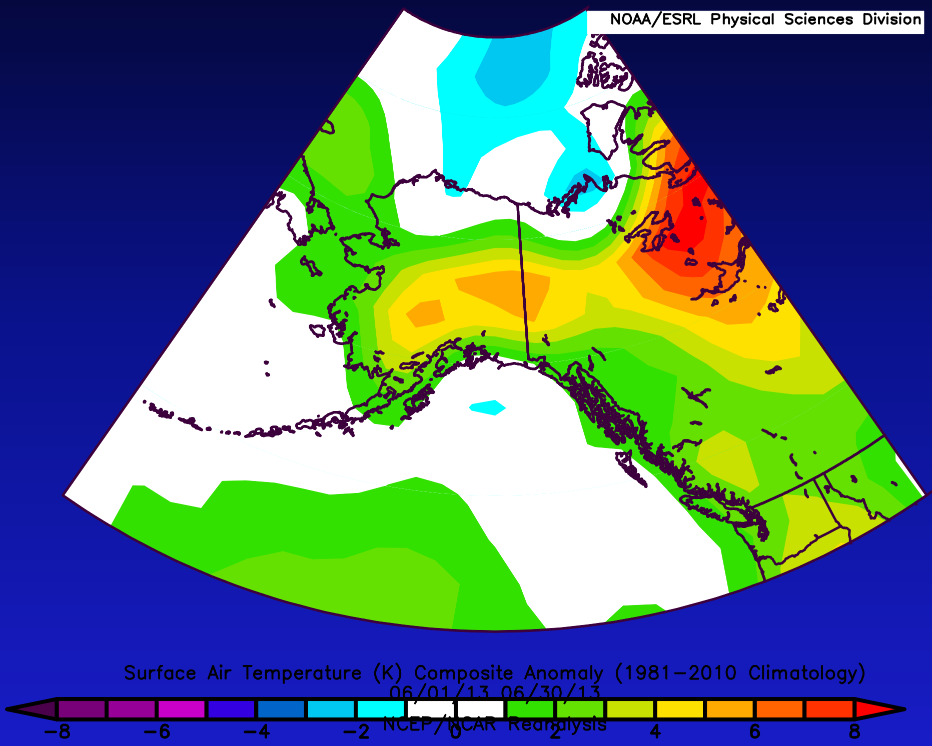


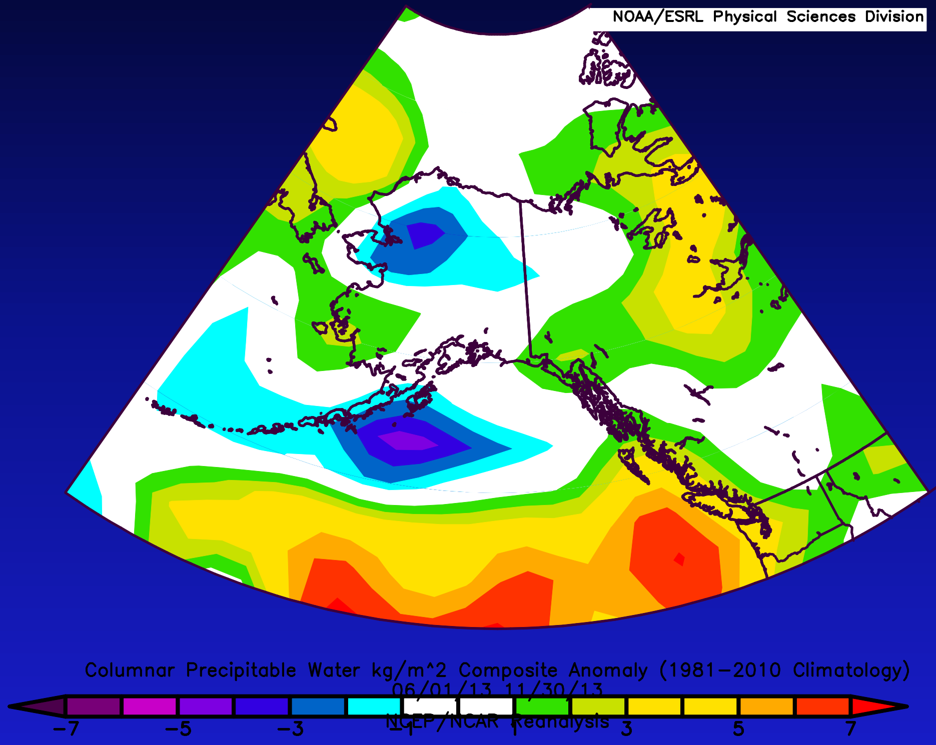


Galena Ice Jam May 2013

Photo credit:
Ed Plumb, NWS

Temperature and Precipitation 2013

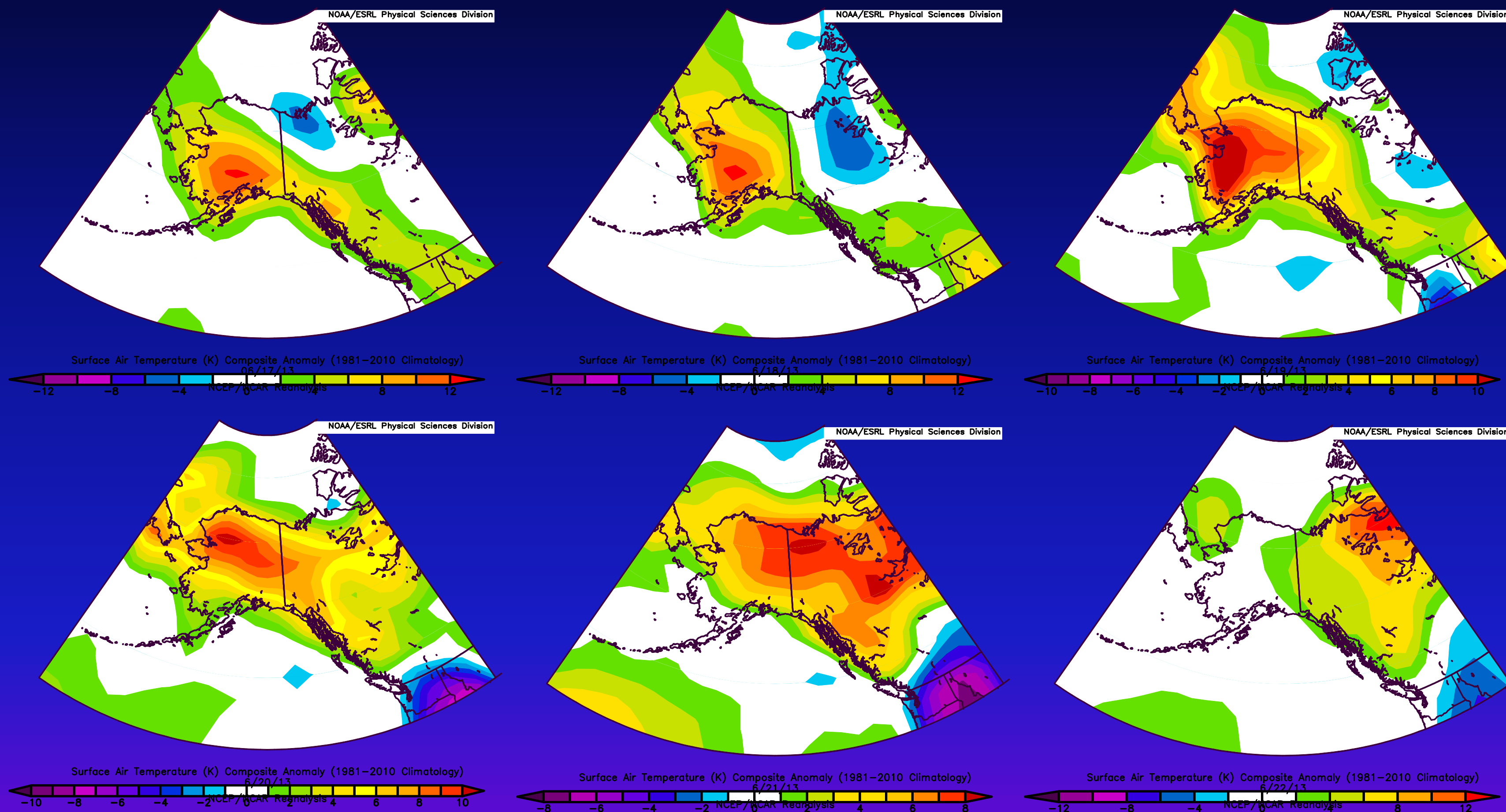




Temperature Change June 2013 (1981-2000 Climatology)

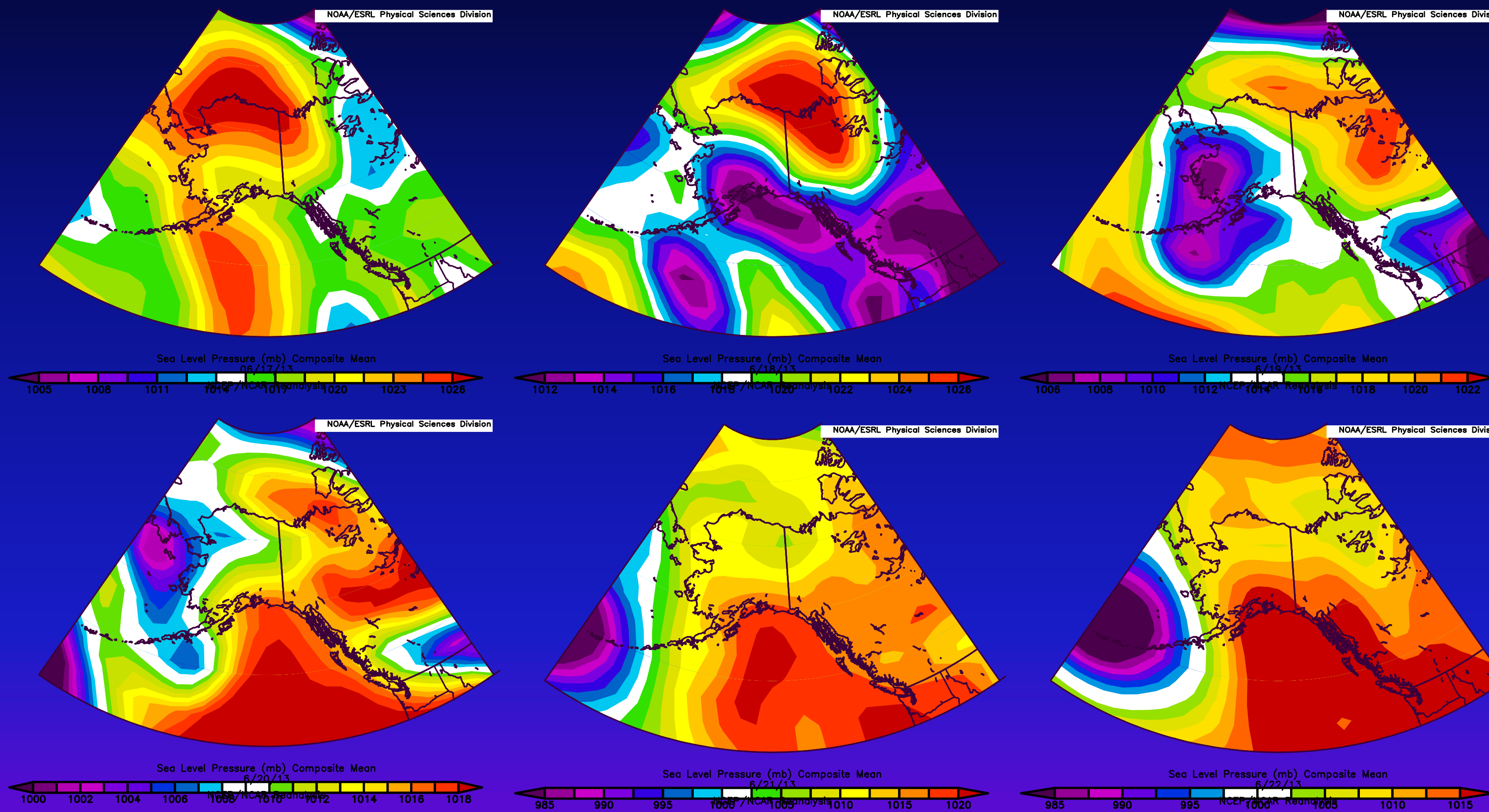
Precipitation Change JJASON 2013 (1981-2000 Climatology)

June 17th to 22nd, 2013 Temperature



Change from 1981-2000 climatology

June 17th to 22nd, 2013 SLP

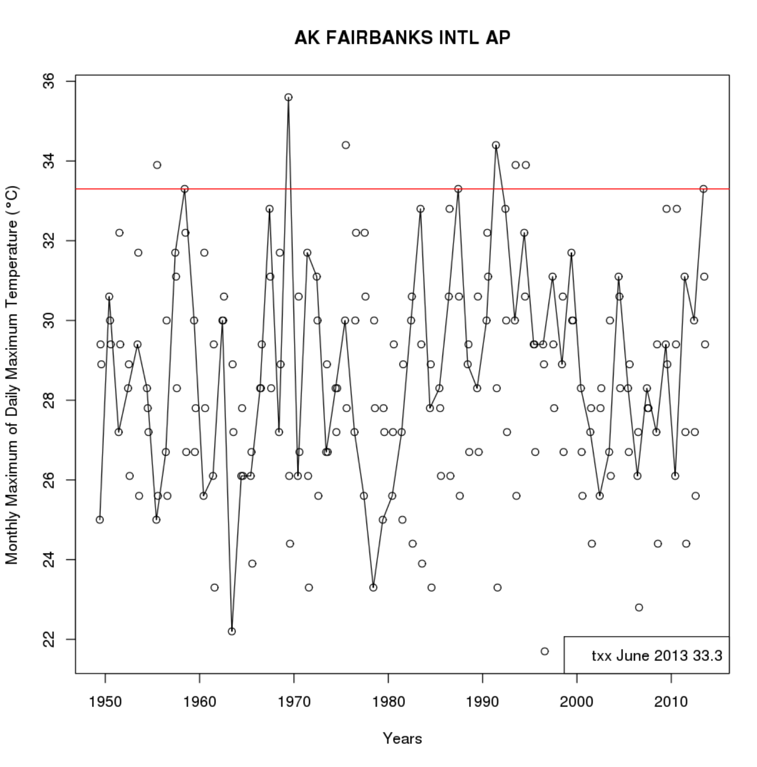


Pressure height fields

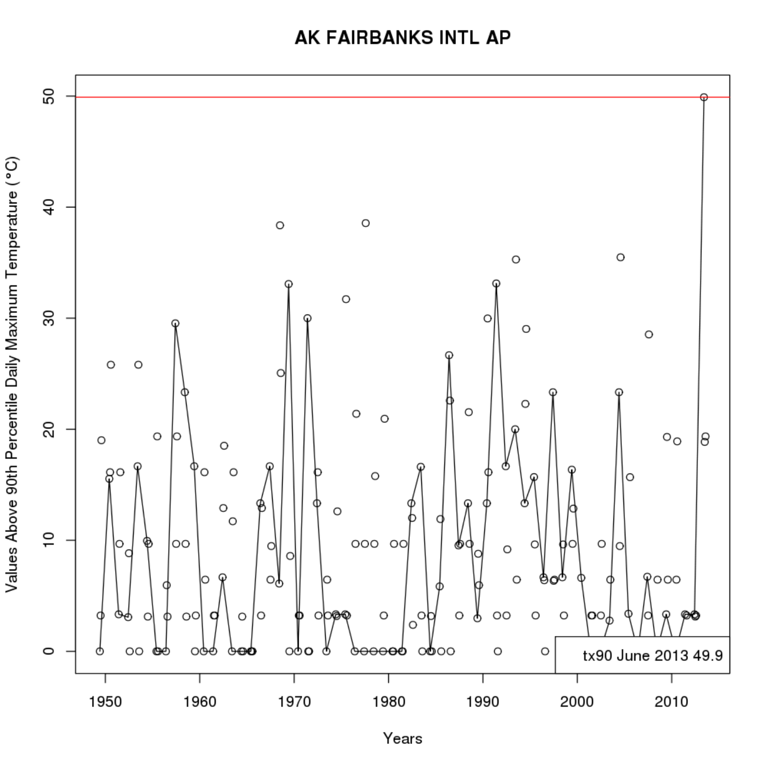
June 2013 Records

- **96° at Talkeetna** on June 17th (previous record 91°F on June 14, 1969 and June 26, 1953 as well as last Sunday, June 16)
- **94° at McGrath** on June 17th (previous record 90° on June 15, 1969 as well as last Sunday June 16)
- **93° at Skwenta** on June 17th (previous record 90° on July 21, 1947)
- **90° at Cordova on June 17th** (previous record 89° on July 16, 1995)
- **90° at Valdez** city site on June 17th (previous record 87° on June 25 and 26, 1953). Valdez has now had four consecutive record-breaking hot days (June 16-19).
- **88° at Seward** on June 17th (previous record 87° on July 4, 1999)
- **88° at Unalakleet** on June 17th (ties previous record set on July 21 and 22, 1977)
- **86° at Nome** on June 19th. (June monthly record and ties all-time record of 86° on July 31, 1977 and July 9, 1968. Previous June record was 83° on three occasions, the latest being June 7, 2004)
- **85° at Kotzebue** on June 19th (ties previous all-time record set on June 22, 1991 and July 5, 1958)
- **79° at Point Lay** on June 19th (ties previous all-time record set on July 14, 2009). Point Lay is on the northern coast of Alaska next to the Arctic Ocean.
- Source: Christopher Burt, June 18, 2013

Fairbanks International Airport

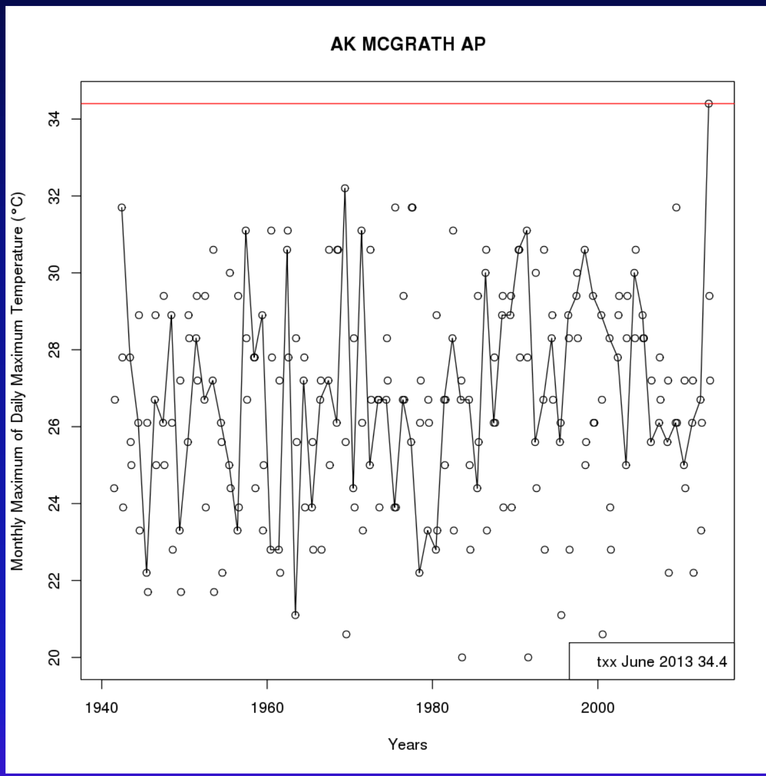


Maximum Daily
Maximum Temperature

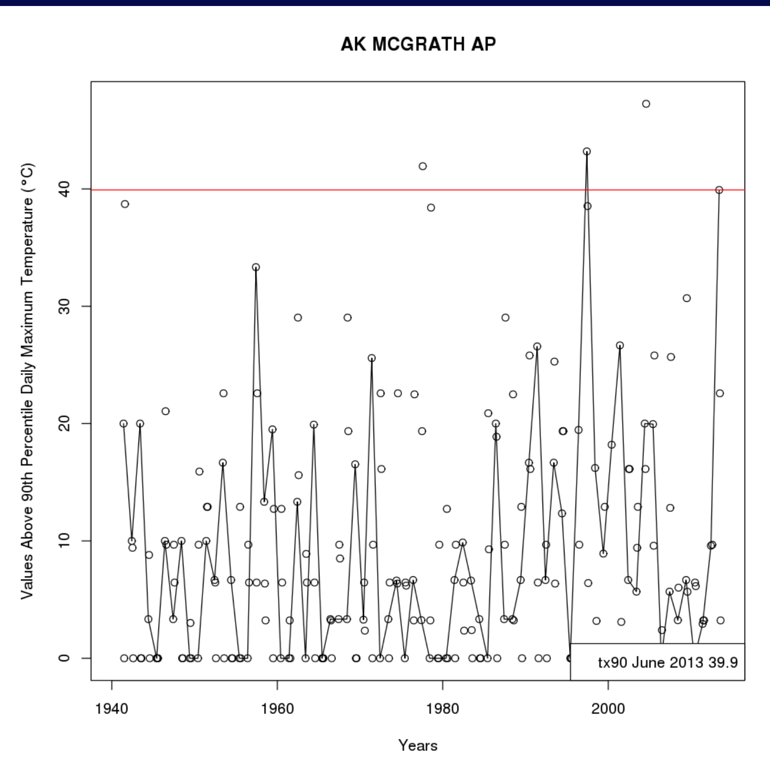


Percentage of Days when
Maximum Temperature > 90^{th}
Percentile

McGrath

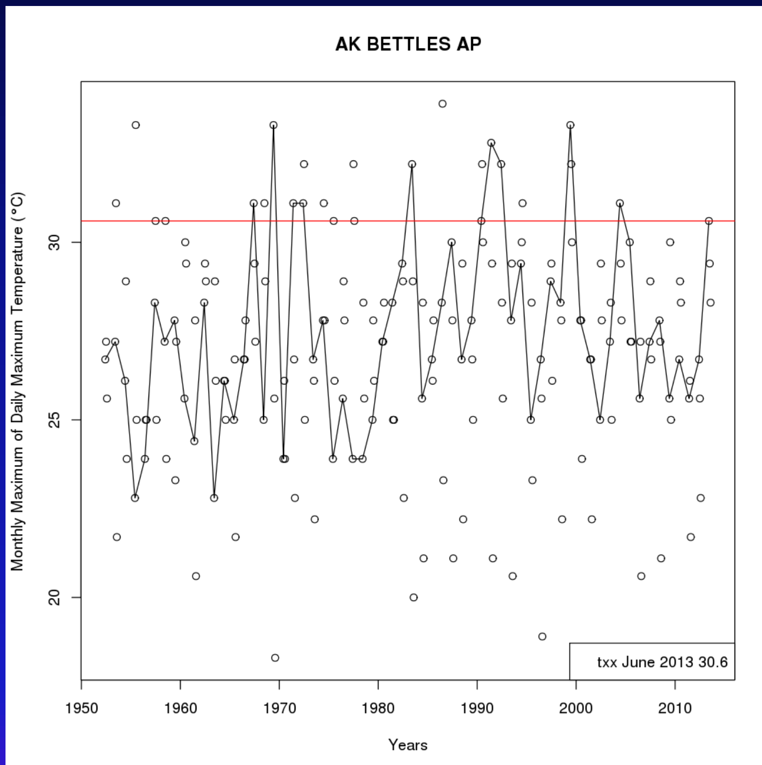


Maximum Daily
Maximum Temperature

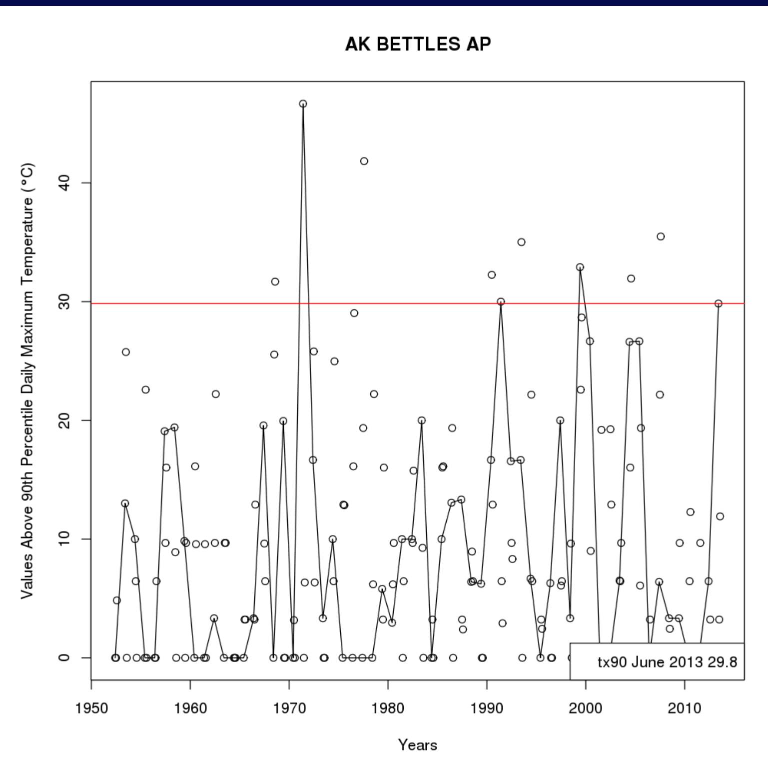


Percentage of Days when
Maximum Temperature > 90th
Percentile

Bettles

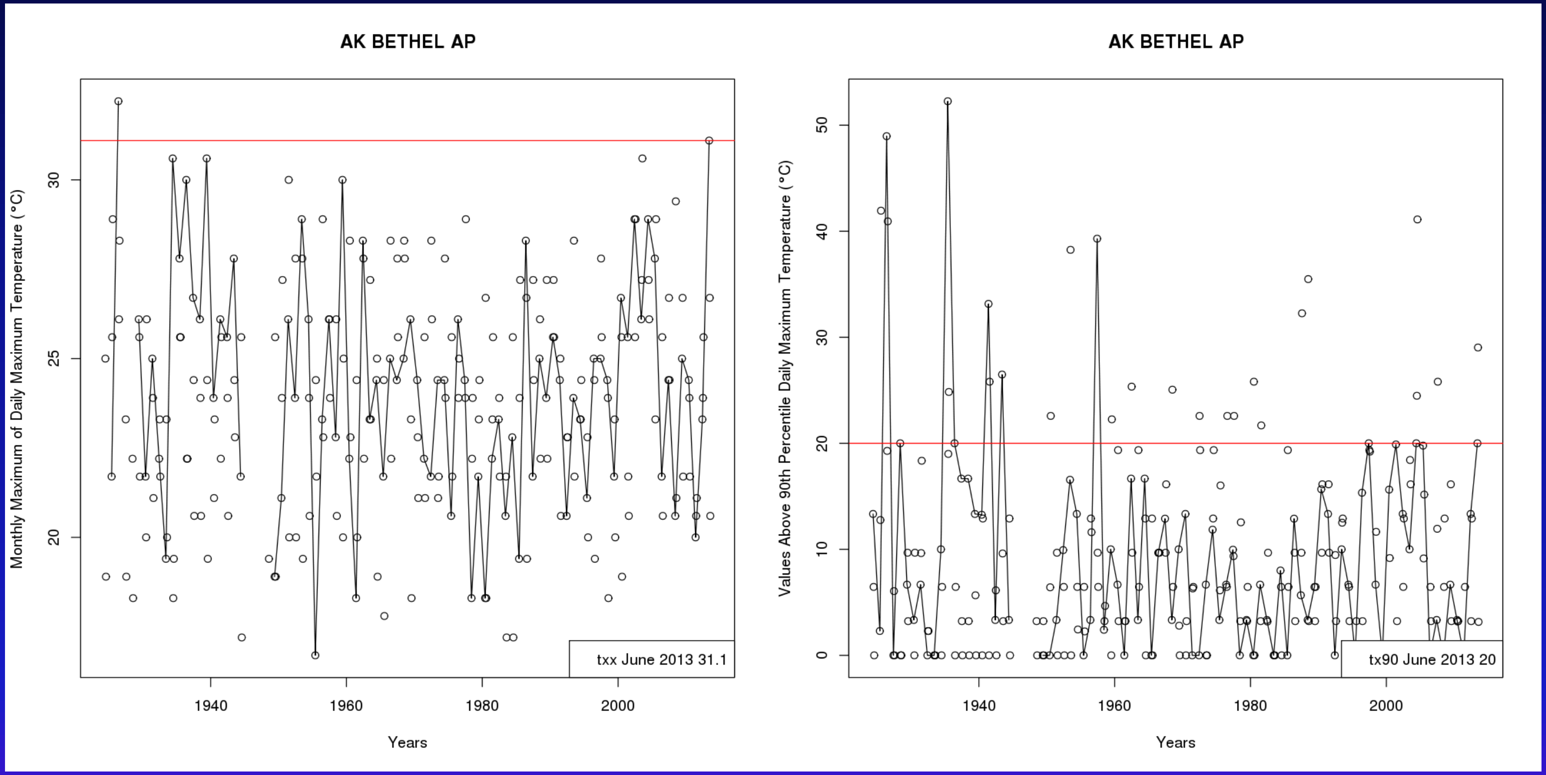


Maximum Daily
Maximum Temperature



Percentage of Days when
Maximum Temperature > 90th
Percentile

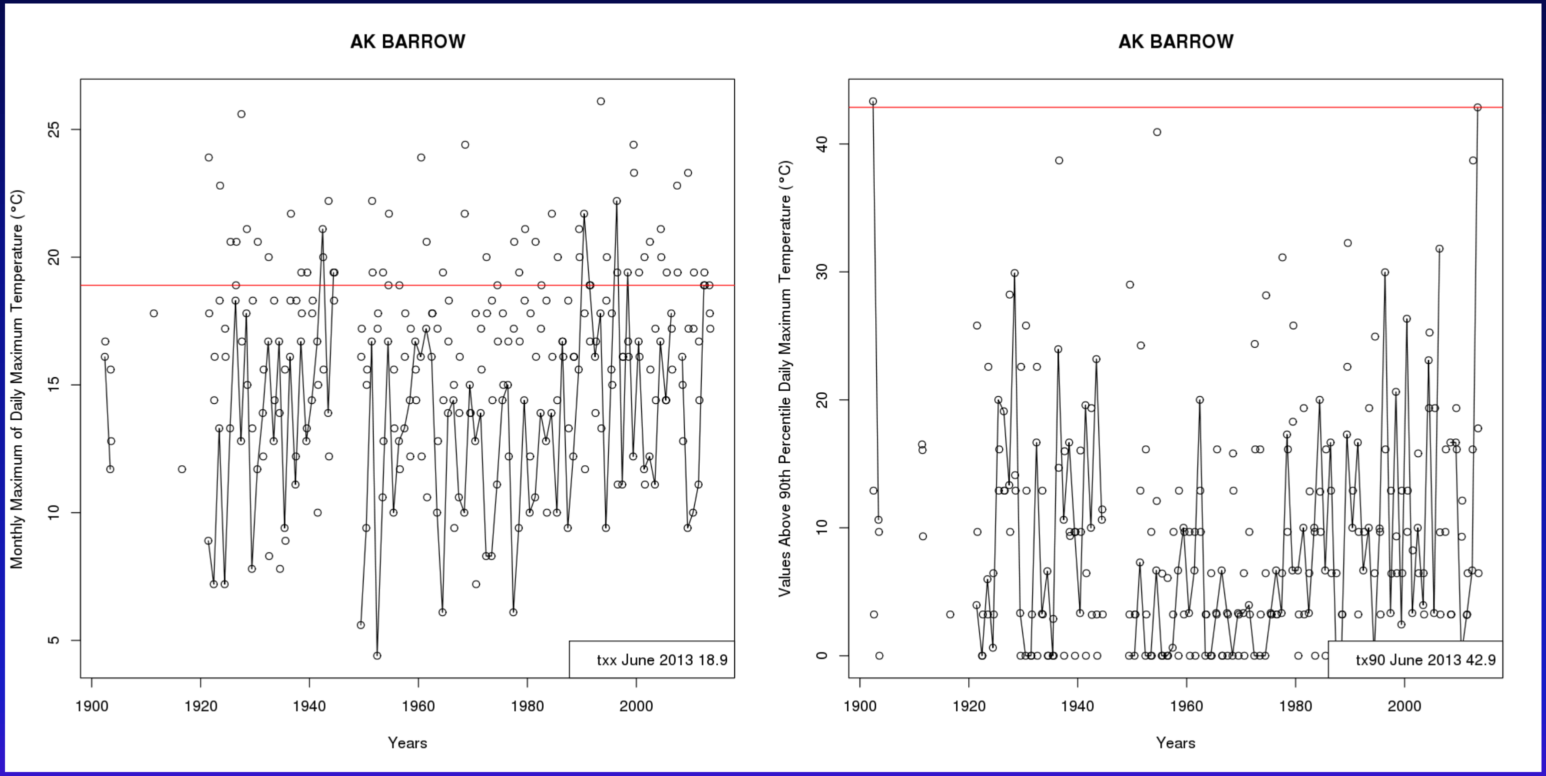
Bethel



Maximum Daily Maximum Temperature

Percentage of Days when Maximum Temperature > 90th Percentile

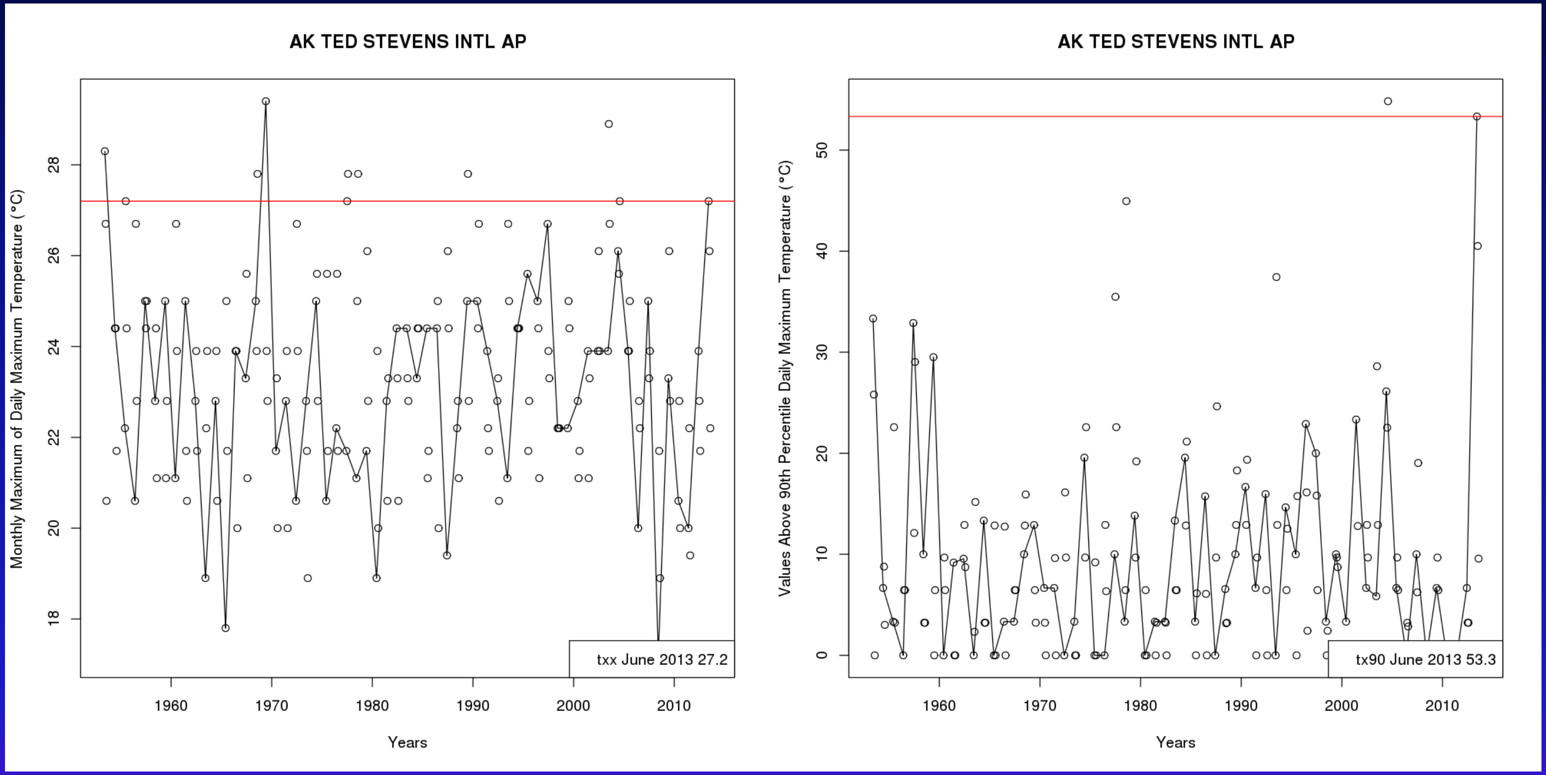
Barrow



Maximum Daily
Maximum Temperature

Percentage of Days when
Maximum Temperature > 90th
Percentile

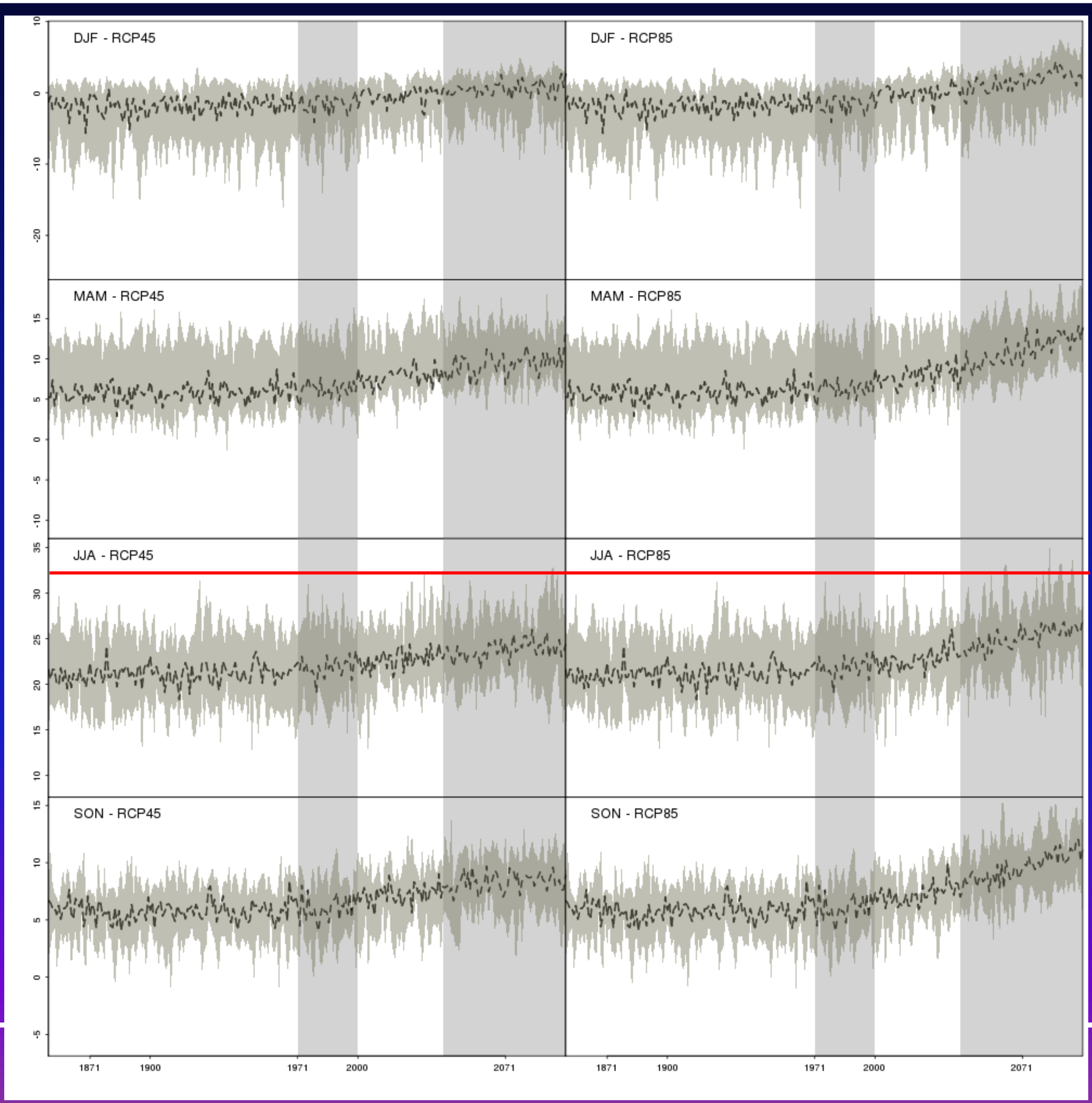
Anchorage



Maximum Daily Maximum Temperature

Percentage of Days when Maximum Temperature > 90th Percentile

ClimDEX Archive – Future TXx



Conclusion

- Trends and GEV analysis illustrate to us that historical maximum streamflow has changed over the 1951-2012 time period
- Snowmelt dominated systems are most markedly declining in spring, and change are linked to temperature at most sites (PDO)
- April increases in flow are not captured by monthly, seasonal or annual trends analysis
- 2013 breakup snow melt, flooding and heat wave is a case study of an extreme event in Alaska and the impact…
- 2014 (warm January, Valdez flood… another extreme year?)

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