

Precipitation Changes in Alaska

A New Normal for Hydrology

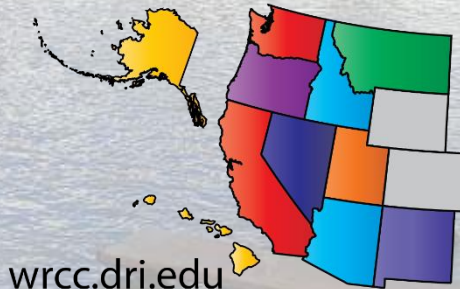
Brian Brettschneider, PhD



International Arctic Research Center

UNIVERSITY OF ALASKA FAIRBANKS

Understanding the Arctic As A System
Reducing Uncertainty in Arctic Climate Change Prediction



wrcc.dri.edu

IPCC Precipitation

Has precipitation increased at the
Global scale?

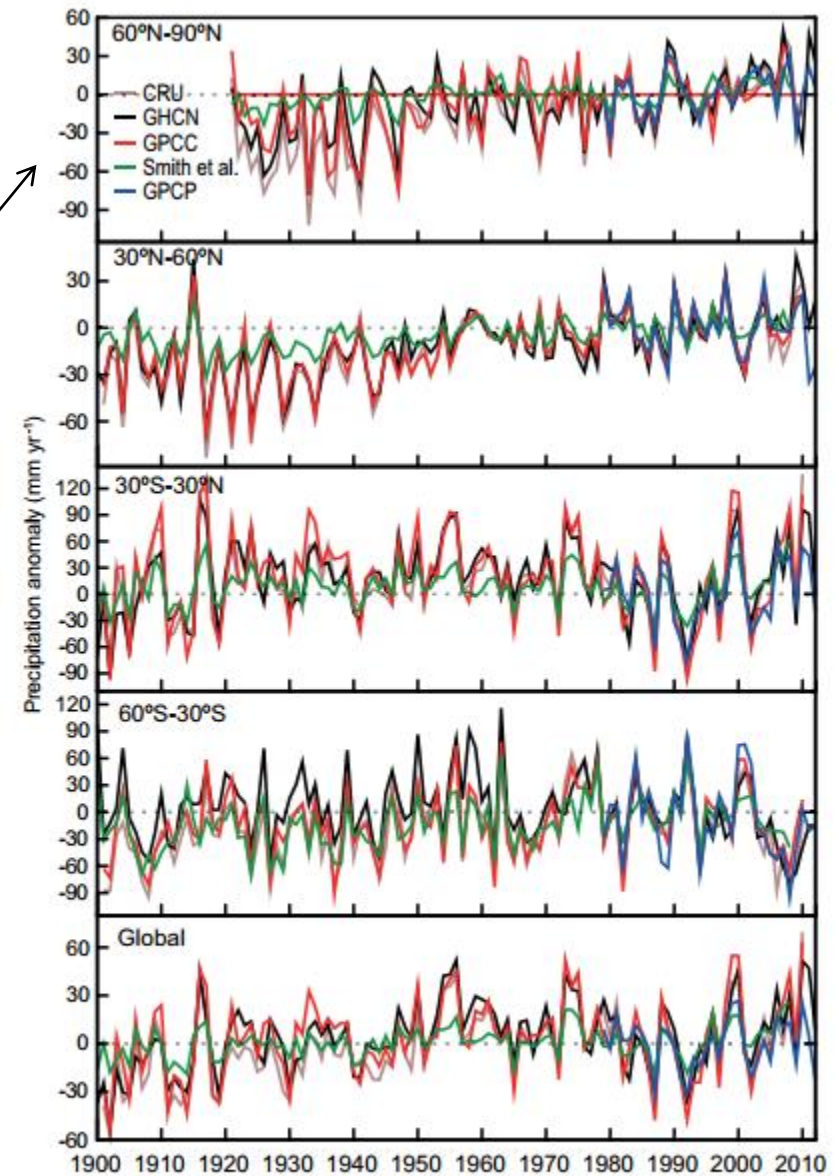


Figure 2.28 | Annual precipitation anomalies averaged over land areas for four latitudinal bands and the globe from five global precipitation data sets relative to a 1981–2000 climatology.

IPCC Precipitation Projections

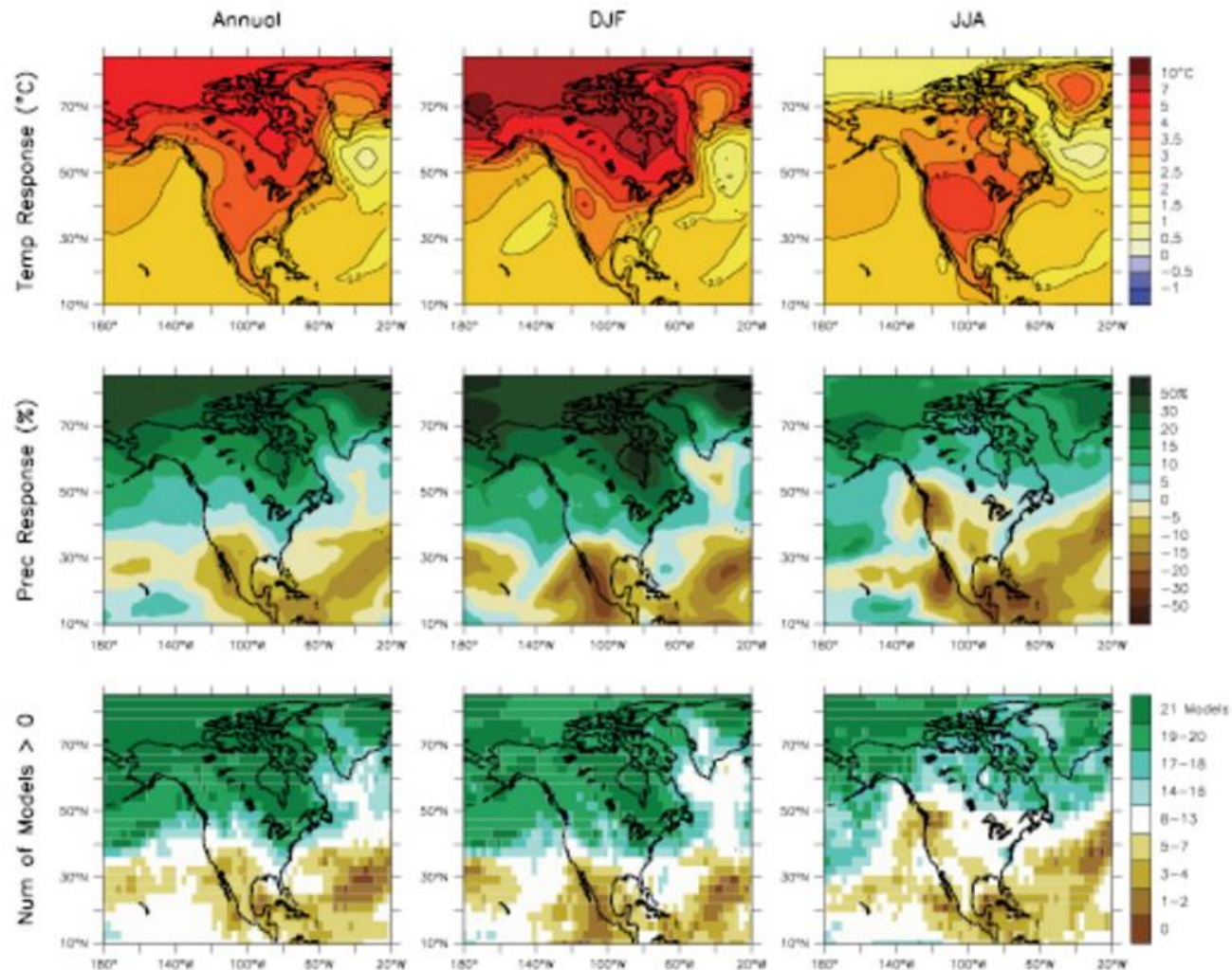


Figure 11.12. Temperature and precipitation changes over North America from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation.

Total Precipitation Trend by Latitude

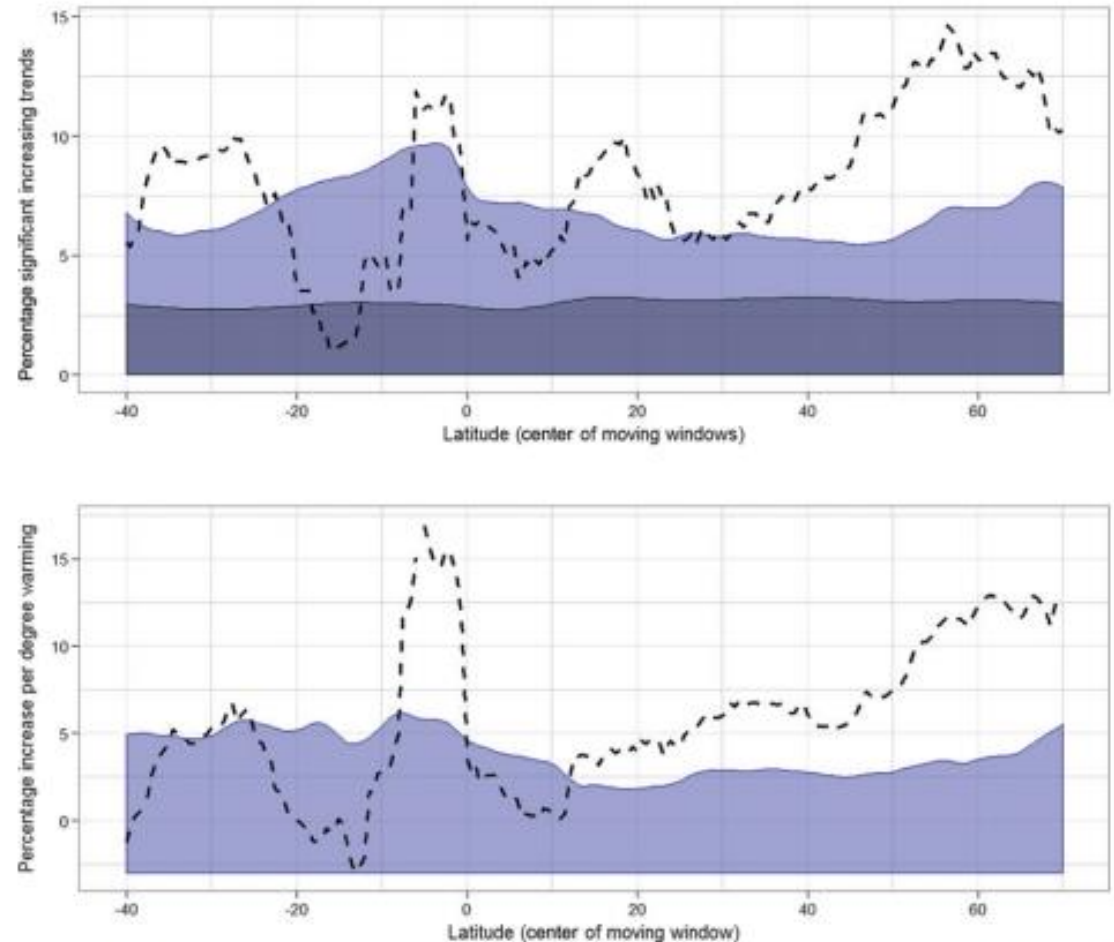
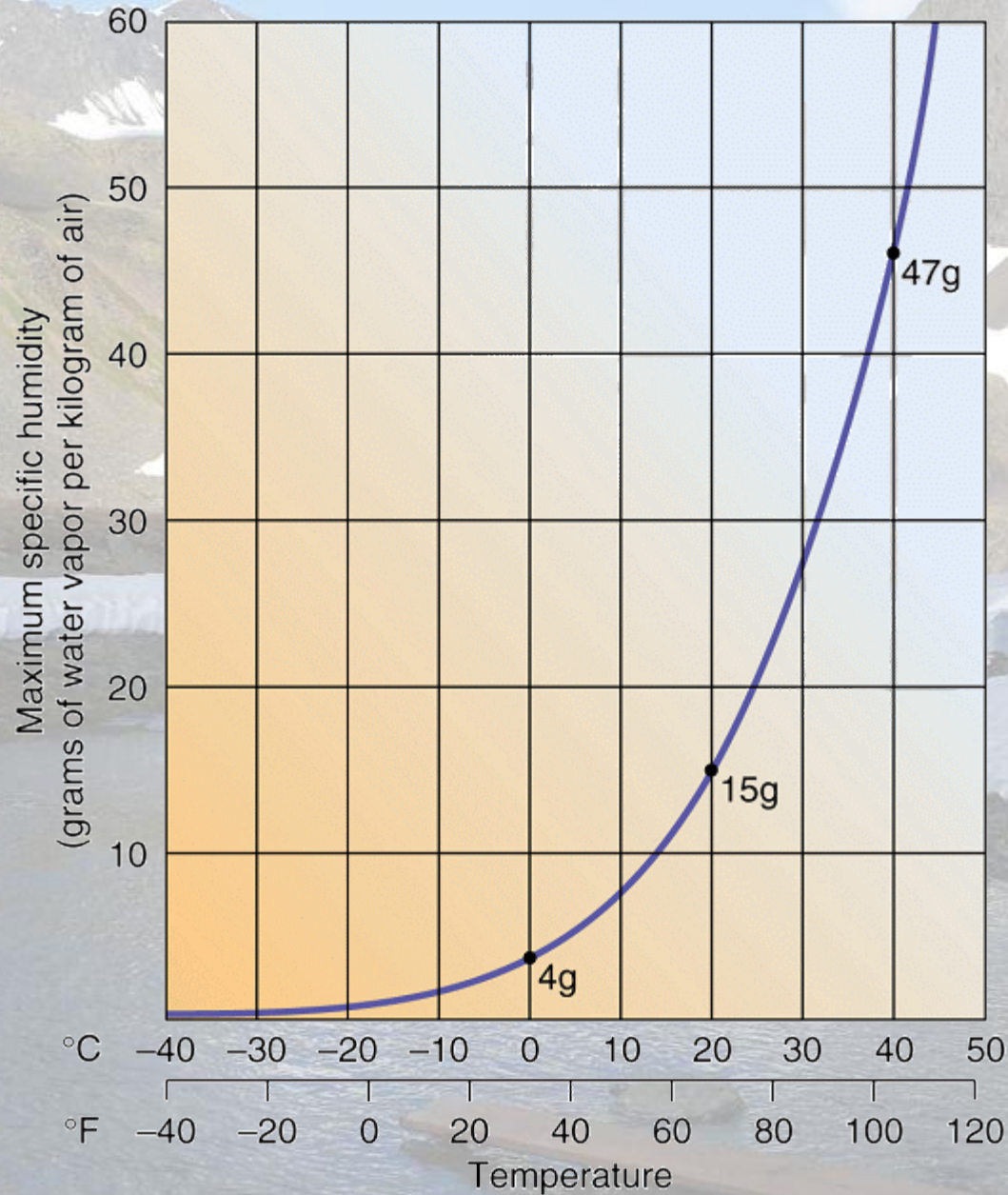


FIG. 12. Variation in the estimated sensitivity of annual maximum precipitation to a 1 K increase in global mean temperature by latitude. (top) The number of stations within each $\pm 5^\circ$ latitude band. (middle) The fraction of stations exhibiting significant positive association, with light blue shading indicating the upper 97.5% confidence bound and dark blue shading indicating the median of the confidence interval. (bottom) Sensitivity (%) of annual maximum precipitation per kelvin warming of global near-surface temperature, with light blue shading indicating the upper 97.5% confidence bound.

[Seth Westra, Lisa V. Alexander, and Francis W. Zwiers, 2013: Global increasing trends in annual maximum daily precipitation. J. Climate, 26, 3904–3918.](#)

Warmer Air Holds More Moisture



Warmer Air Holds More Moisture

Temperature

Mixing Ratio (g/kg)

-40°F/C

0.09

-20°F

0.28

0°F

0.75

20°F

1.85

40°F

4.20

60°F

8.92

80°F

17.90

Will Precipitation Increase All At Once?

Q) We talked about a 25% increase in precipitation. Is that over the course of a year or will the increase be observed in the extreme events?

A) This is a difficult question to answer. The cop-out answer is probably both.

Anchorage Precipitation Recurrence Intervals

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)¹

Duration	Average recurrence interval(years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.079 (0.060-0.110)	0.107 (0.080-0.150)	0.143 (0.105-0.205)	0.172 (0.124-0.250)	0.213 (0.151-0.317)	0.244 (0.170-0.368)	0.275 (0.188-0.422)	0.307 (0.207-0.478)	0.350 (0.230-0.556)	0.383 (0.248-0.618)
10-min	0.107 (0.081-0.149)	0.144 (0.108-0.202)	0.192 (0.141-0.275)	0.231 (0.167-0.336)	0.286 (0.202-0.425)	0.328 (0.228-0.495)	0.369 (0.252-0.566)	0.413 (0.278-0.643)	0.470 (0.310-0.747)	0.514 (0.333-0.830)
15-min	0.125 (0.095-0.174)	0.169 (0.127-0.238)	0.224 (0.165-0.321)	0.271 (0.196-0.394)	0.334 (0.236-0.496)	0.383 (0.266-0.578)	0.432 (0.296-0.663)	0.483 (0.325-0.752)	0.551 (0.363-0.876)	0.601 (0.389-0.970)
30-min	0.166 (0.126-0.231)	0.224 (0.168-0.315)	0.298 (0.219-0.427)	0.359 (0.260-0.522)	0.444 (0.314-0.660)	0.509 (0.354-0.769)	0.574 (0.393-0.880)	0.641 (0.431-0.999)	0.731 (0.481-1.16)	0.798 (0.517-1.29)
60-min	0.227 (0.173-0.315)	0.307 (0.231-0.432)	0.408 (0.300-0.585)	0.492 (0.356-0.716)	0.608 (0.430-0.904)	0.697 (0.485-1.05)	0.786 (0.538-1.21)	0.878 (0.591-1.37)	1.00 (0.659-1.59)	1.09 (0.708-1.76)
2-hr	0.294 (0.224-0.408)	0.397 (0.298-0.558)	0.528 (0.389-0.757)	0.636 (0.460-0.926)	0.786 (0.556-1.17)	0.901 (0.627-1.36)	1.02 (0.696-1.56)	1.14 (0.765-1.77)	1.29 (0.852-2.06)	1.41 (0.916-2.28)
3-hr	0.359 (0.273-0.499)	0.486 (0.365-0.683)	0.645 (0.475-0.924)	0.779 (0.564-1.13)	0.962 (0.681-1.43)	1.10 (0.767-1.67)	1.24 (0.851-1.91)	1.39 (0.935-2.17)	1.58 (1.04-2.52)	1.73 (1.12-2.79)
6-hr	0.524 (0.399-0.728)	0.709 (0.533-0.997)	0.943 (0.694-1.35)	1.14 (0.823-1.66)	1.40 (0.993-2.09)	1.61 (1.12-2.43)	1.81 (1.24-2.78)	2.03 (1.36-3.16)	2.31 (1.52-3.67)	2.52 (1.64-4.07)
12-hr	0.750 (0.571-1.04)	1.02 (0.765-1.43)	1.37 (1.01-1.96)	1.65 (1.19-2.39)	2.02 (1.43-3.08)	2.31 (1.61-3.49)	2.60 (1.76-3.99)	2.90 (1.95-4.52)	3.30 (2.17-5.25)	3.60 (2.33-5.81)
24-hr	1.04 (0.830-1.31)	1.40 (1.11-1.79)	1.90 (1.47-2.47)	2.28 (1.74-3.02)	2.79 (2.09-3.77)	3.19 (2.35-4.38)	3.59 (2.60-5.00)	4.02 (2.87-5.69)	4.58 (3.20-6.61)	5.00 (3.44-7.33)
2-day	1.28 (1.03-1.62)	1.68 (1.33-2.15)	2.24 (1.74-2.92)	2.69 (2.05-3.56)	3.32 (2.48-4.48)	3.83 (2.82-5.25)	4.36 (3.16-6.08)	4.97 (3.55-7.04)	5.78 (4.04-8.35)	6.39 (4.40-9.38)
3-day	1.44 (1.15-1.81)	1.85 (1.46-2.36)	2.44 (1.89-3.17)	2.92 (2.23-3.87)	3.62 (2.71-4.89)	4.20 (3.09-5.76)	4.82 (3.49-6.72)	5.57 (3.97-7.89)	6.56 (4.59-9.48)	7.31 (5.03-10.7)
4-day	1.57 (1.25-1.98)	1.99 (1.57-2.54)	2.61 (2.02-3.39)	3.12 (2.38-4.13)	3.87 (2.89-5.22)	4.49 (3.30-6.16)	5.16 (3.74-7.20)	5.97 (4.26-8.46)	7.05 (4.93-10.2)	7.86 (5.42-11.5)
7-day	1.95 (1.56-2.46)	2.45 (1.94-3.13)	3.16 (2.45-4.12)	3.75 (2.86-4.96)	4.58 (3.43-6.19)	5.26 (3.87-7.22)	5.98 (4.33-8.34)	6.82 (4.86-9.65)	7.92 (5.53-11.4)	8.75 (6.02-12.8)

25% Increase (3.48")

http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_ak.html

Fairbanks Precipitation Recurrence Intervals

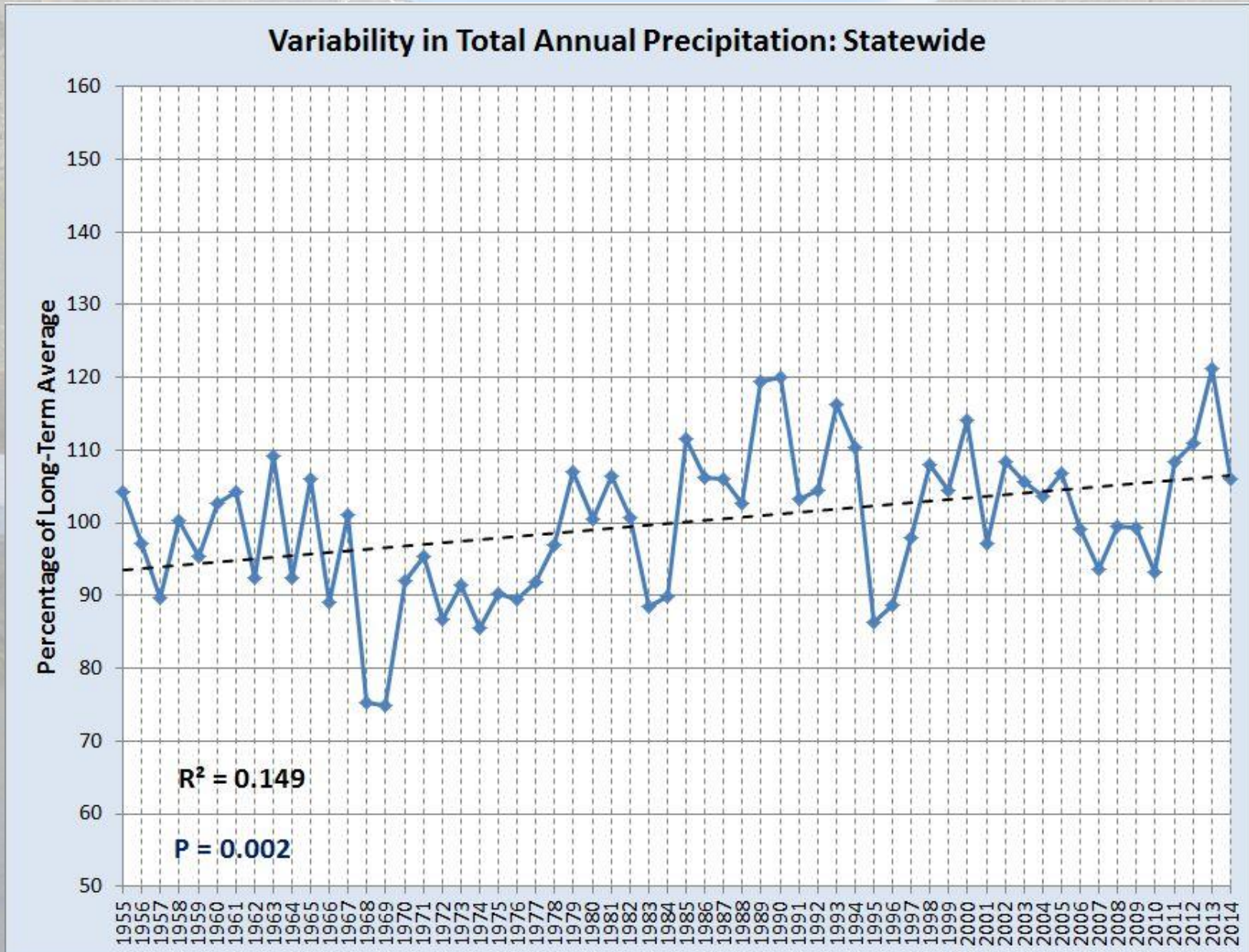
PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)¹

Duration	Average recurrence interval(years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.093 (0.068-0.130)	0.123 (0.089-0.174)	0.174 (0.123-0.251)	0.216 (0.151-0.316)	0.274 (0.188-0.408)	0.319 (0.215-0.483)	0.364 (0.242-0.559)	0.430 (0.281-0.670)	0.518 (0.333-0.823)	0.584 (0.370-0.942)
10-min	0.125 (0.091-0.175)	0.165 (0.119-0.233)	0.234 (0.166-0.337)	0.290 (0.203-0.424)	0.368 (0.252-0.549)	0.428 (0.289-0.648)	0.488 (0.324-0.750)	0.578 (0.378-0.901)	0.695 (0.446-1.10)	0.784 (0.496-1.26)
15-min	0.146 (0.107-0.204)	0.194 (0.140-0.274)	0.273 (0.194-0.393)	0.340 (0.237-0.497)	0.431 (0.295-0.642)	0.501 (0.338-0.758)	0.571 (0.379-0.877)	0.676 (0.442-1.05)	0.813 (0.522-1.29)	0.918 (0.581-1.48)
30-min	0.194 (0.142-0.271)	0.257 (0.186-0.363)	0.363 (0.257-0.523)	0.451 (0.315-0.659)	0.572 (0.392-0.853)	0.665 (0.448-1.01)	0.758 (0.504-1.16)	0.897 (0.587-1.40)	1.08 (0.693-1.72)	1.22 (0.771-1.96)
60-min	0.266 (0.194-0.372)	0.352 (0.254-0.498)	0.497 (0.352-0.716)	0.618 (0.432-0.903)	0.783 (0.536-1.17)	0.911 (0.614-1.38)	1.04 (0.690-1.60)	1.23 (0.804-1.92)	1.48 (0.949-2.35)	1.67 (1.06-2.69)
2-hr	0.315 (0.230-0.440)	0.417 (0.301-0.590)	0.589 (0.418-0.848)	0.732 (0.511-1.07)	0.928 (0.635-1.38)	1.08 (0.728-1.63)	1.23 (0.817-1.89)	1.45 (0.952-2.27)	1.75 (1.12-2.78)	1.98 (1.25-3.19)
3-hr	0.363 (0.265-0.507)	0.480 (0.346-0.679)	0.680 (0.482-0.979)	0.846 (0.591-1.24)	1.07 (0.734-1.60)	1.25 (0.840-1.89)	1.42 (0.942-2.18)	1.68 (1.10-2.62)	2.02 (1.30-3.21)	2.28 (1.44-3.67)
6-hr	0.481 (0.351-0.672)	0.638 (0.461-0.902)	0.900 (0.638-1.30)	1.12 (0.781-1.63)	1.42 (0.971-2.11)	1.65 (1.11-2.50)	1.88 (1.25-2.89)	2.23 (1.46-3.47)	2.68 (1.72-4.26)	3.02 (1.91-4.88)
12-hr	0.634 (0.463-0.886)	0.841 (0.607-1.19)	1.17 (0.828-1.68)	1.44 (1.01-2.11)	1.83 (1.26-2.73)	2.15 (1.45-3.26)	2.49 (1.65-3.82)	2.94 (1.93-4.59)	3.54 (2.28-5.63)	4.00 (2.53-6.45)
24-hr	0.824 (0.748-0.918)	1.09 (0.978-1.23)	1.49 (1.31-1.72)	1.83 (1.57-2.14)	2.33 (1.96-2.79)	2.75 (2.28-3.37)	3.22 (2.62-4.00)	3.81 (3.05-4.82)	4.59 (3.59-5.93)	5.18 (3.98-6.81)
2-day	0.995 (0.903-1.11)	1.31 (1.18-1.48)	1.78 (1.56-2.05)	2.17 (1.87-2.55)	2.75 (2.32-3.30)	3.25 (2.69-3.97)	3.79 (3.08-4.71)	4.46 (3.56-5.63)	5.34 (4.17-6.90)	6.00 (4.62-7.89)
3-day	1.10 (0.999-1.23)	1.45 (1.30-1.63)	1.96 (1.72-2.26)	2.39 (2.06-2.80)	3.02 (2.54-3.62)	3.55 (2.98-4.33)	4.12 (3.35-5.12)	4.83 (3.86-6.11)	5.77 (4.51-7.46)	6.48 (4.99-8.52)
4-day	1.19 (1.08-1.32)	1.55 (1.39-1.75)	2.09 (1.83-2.41)	2.54 (2.19-2.98)	3.21 (2.70-3.85)	3.76 (3.11-4.59)	4.37 (3.55-5.43)	5.11 (4.09-6.46)	6.09 (4.76-7.87)	6.84 (5.26-8.98)
7-day	1.42 (1.29-1.58)	1.82 (1.63-2.05)	2.41 (2.12-2.78)	2.91 (2.51-3.41)	3.65 (3.07-4.38)	4.27 (3.53-5.21)	4.95 (4.03-6.15)	5.80 (4.64-7.33)	6.93 (5.42-8.95)	7.78 (5.98-10.2)

25% Increase (2.91")

http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_ak.html

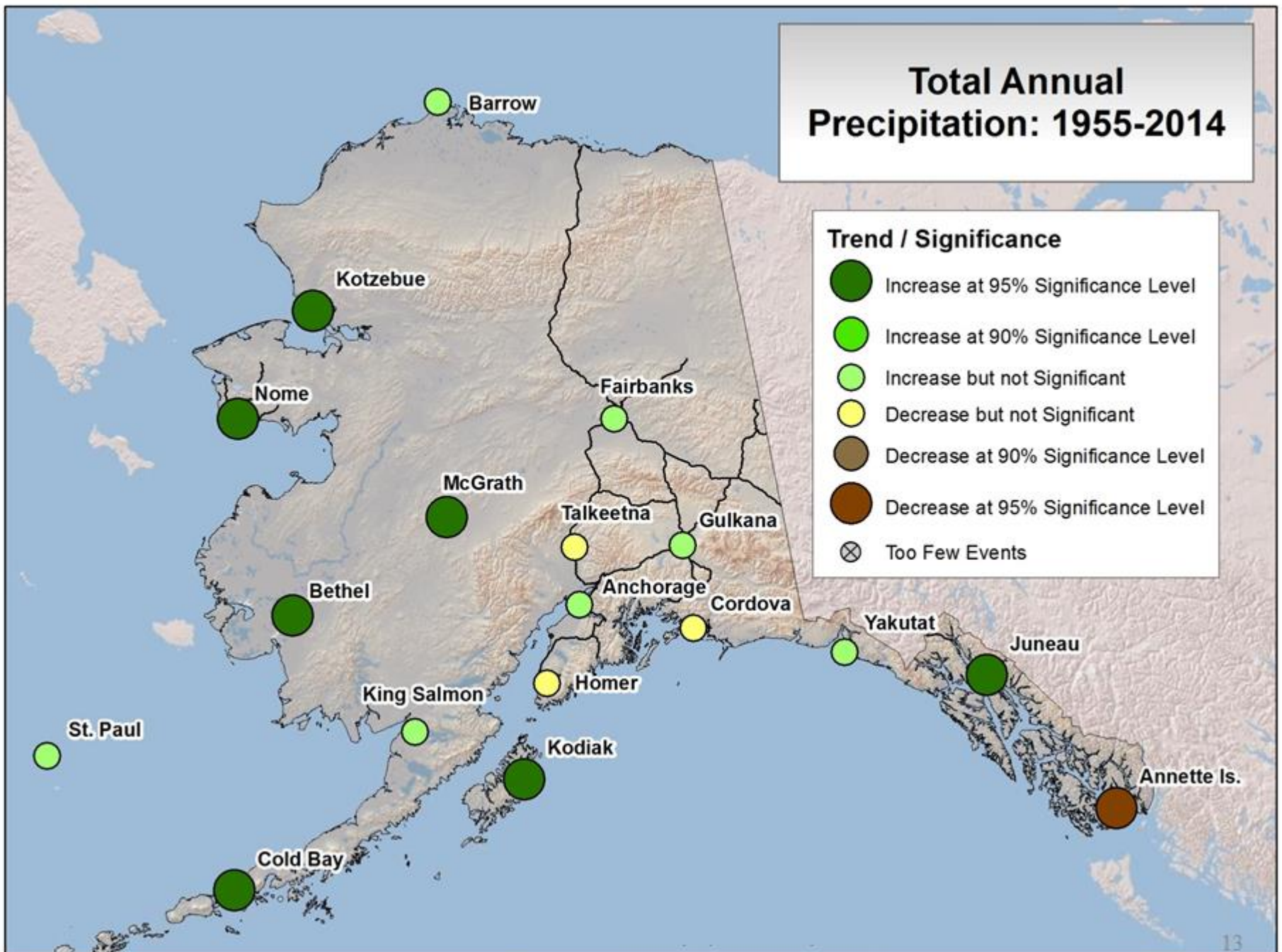
Total Precipitation Trend: 18 Stations



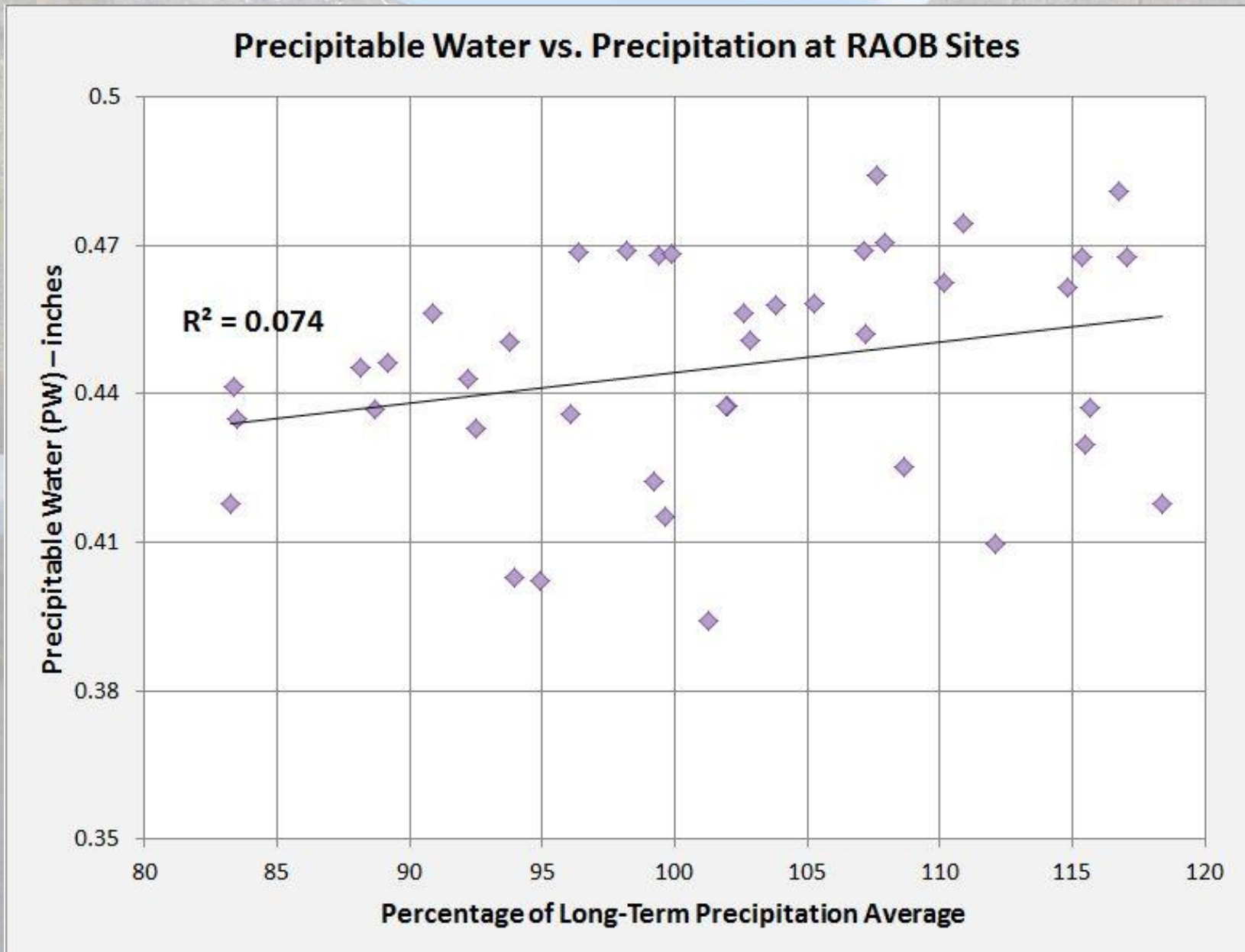
Total Annual Precipitation: 1955-2014

Trend / Significance

- Increase at 95% Significance Level
- Increase at 90% Significance Level
- Increase but not Significant
- Decrease but not Significant
- Decrease at 90% Significance Level
- Decrease at 95% Significance Level
- ⊗ Too Few Events



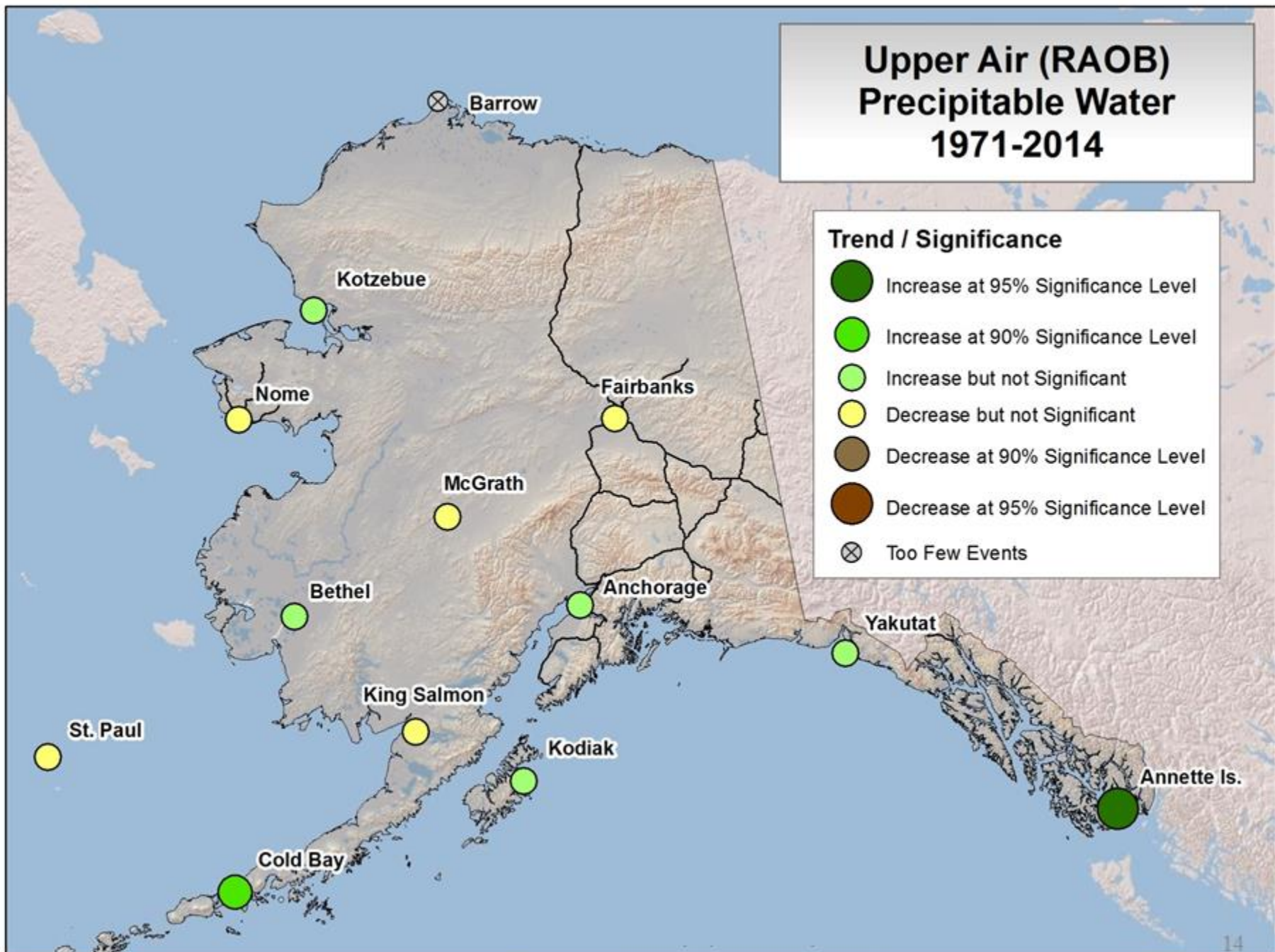
Total Precipitation and PW



Upper Air (RAOB) Precipitable Water 1971-2014

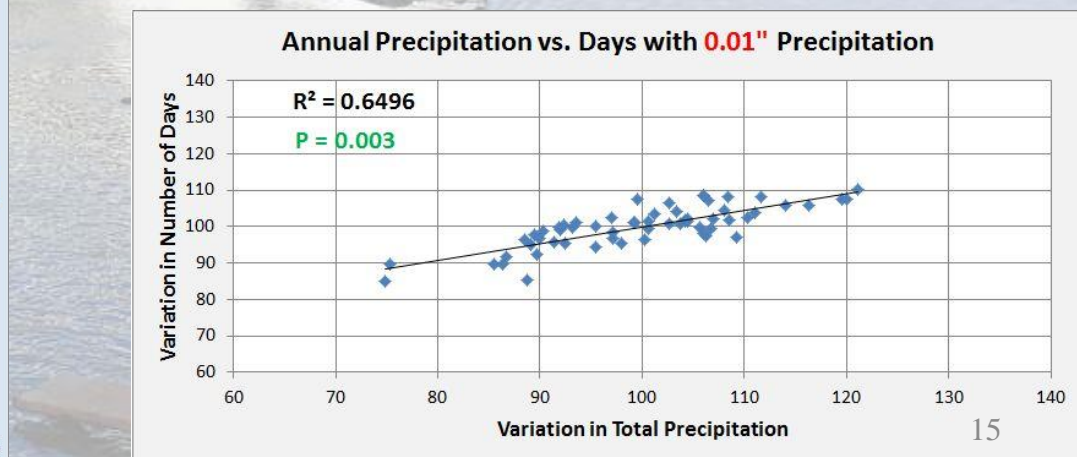
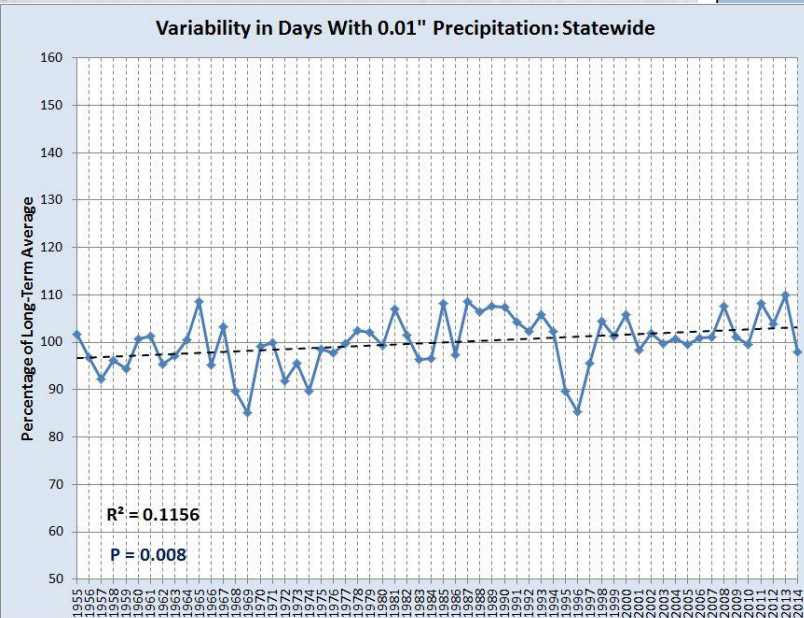
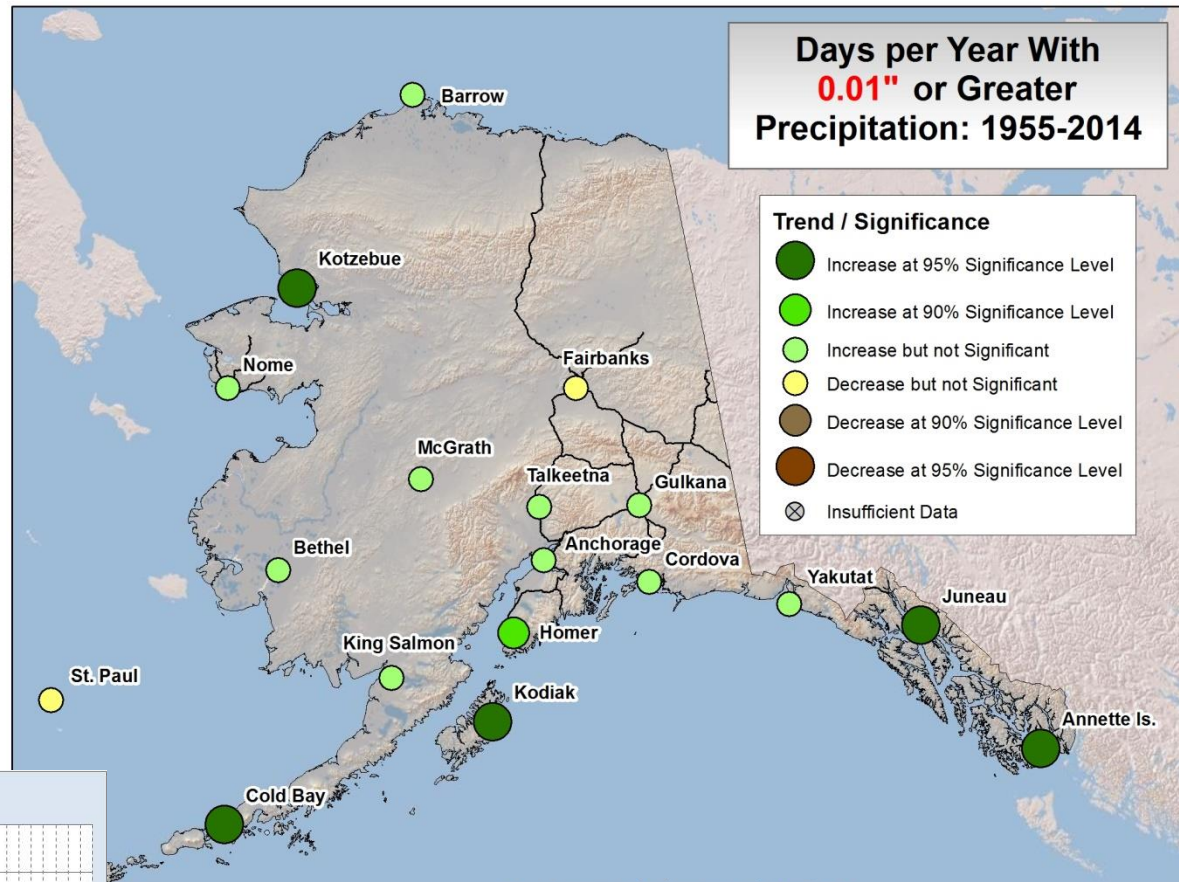
Trend / Significance

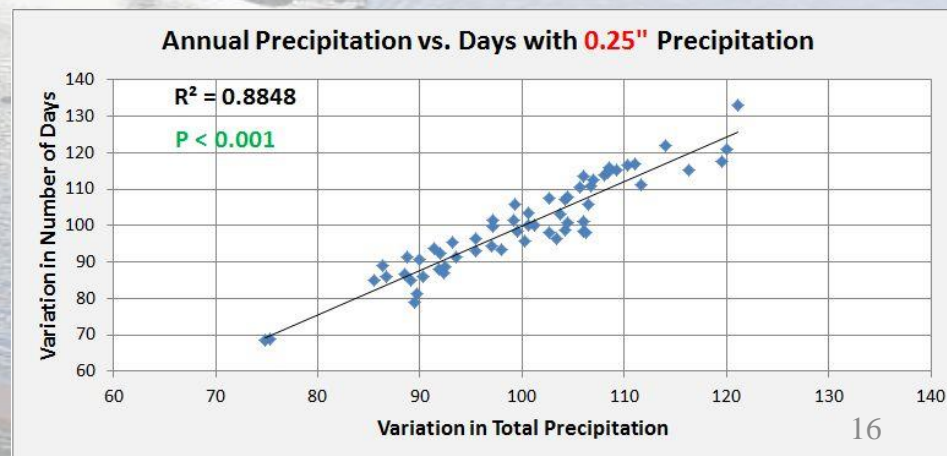
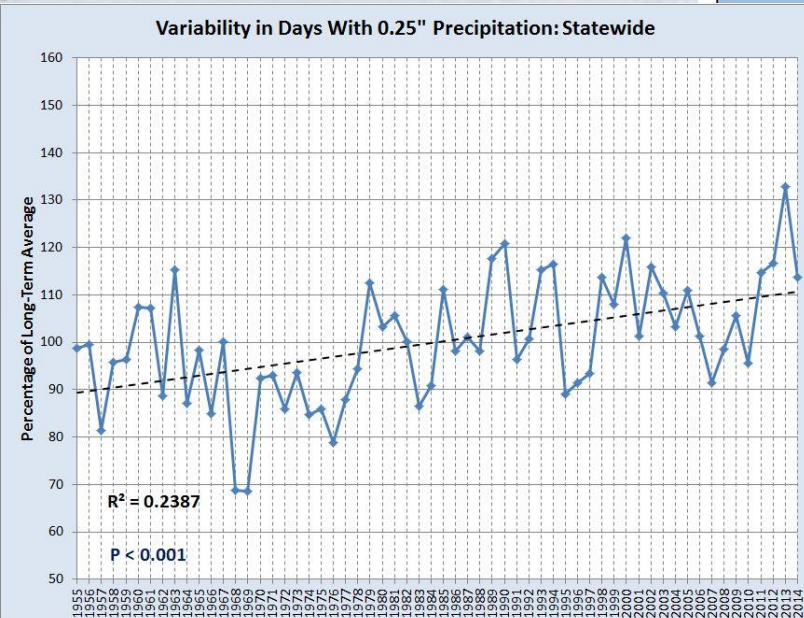
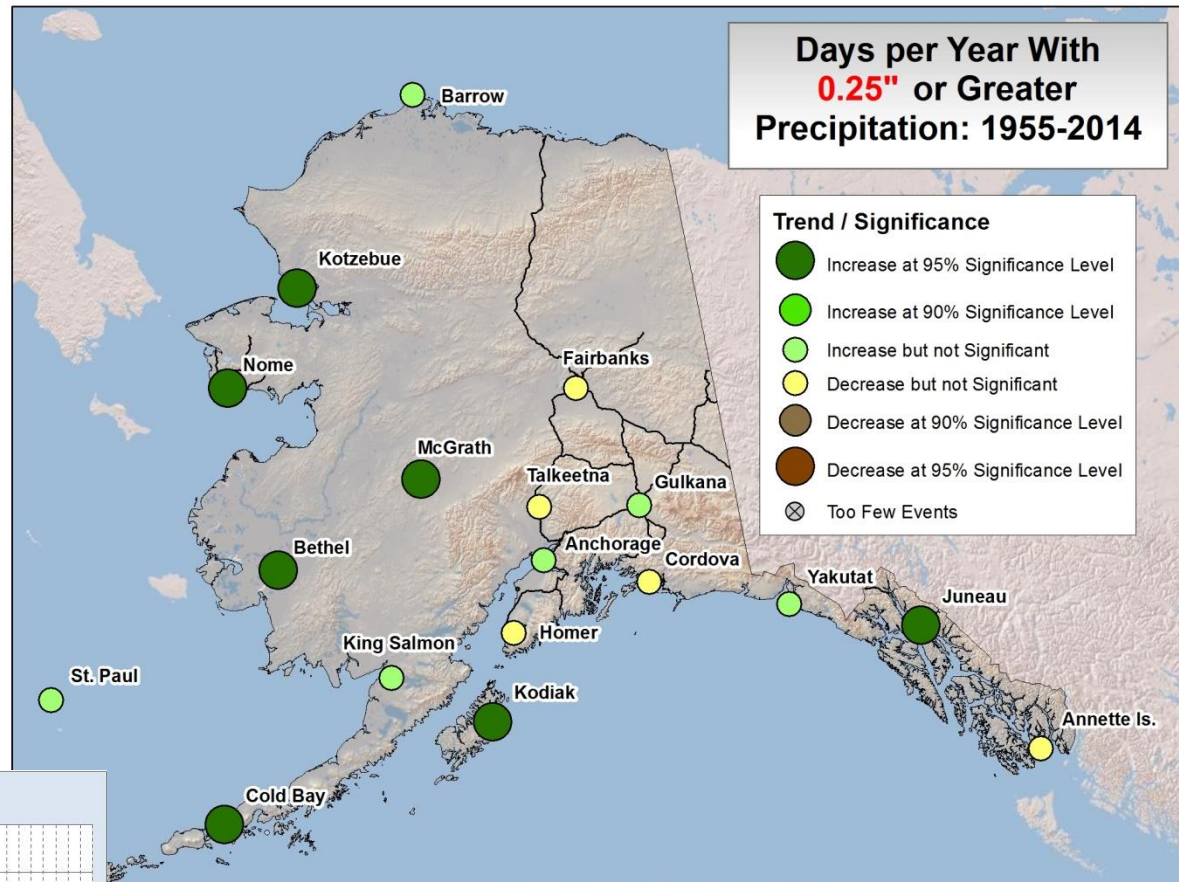
- Increase at 95% Significance Level
- Increase at 90% Significance Level
- Increase but not Significant
- Decrease but not Significant
- Decrease at 90% Significance Level
- Decrease at 95% Significance Level
- ⊗ Too Few Events

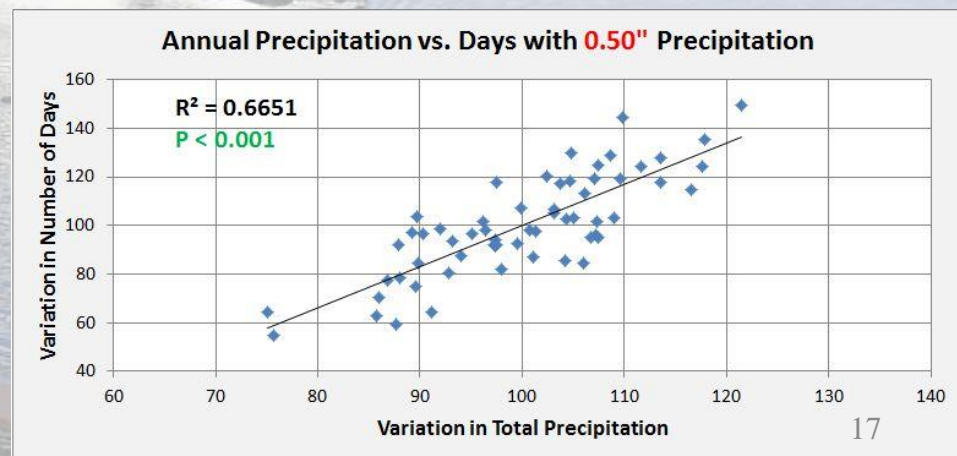
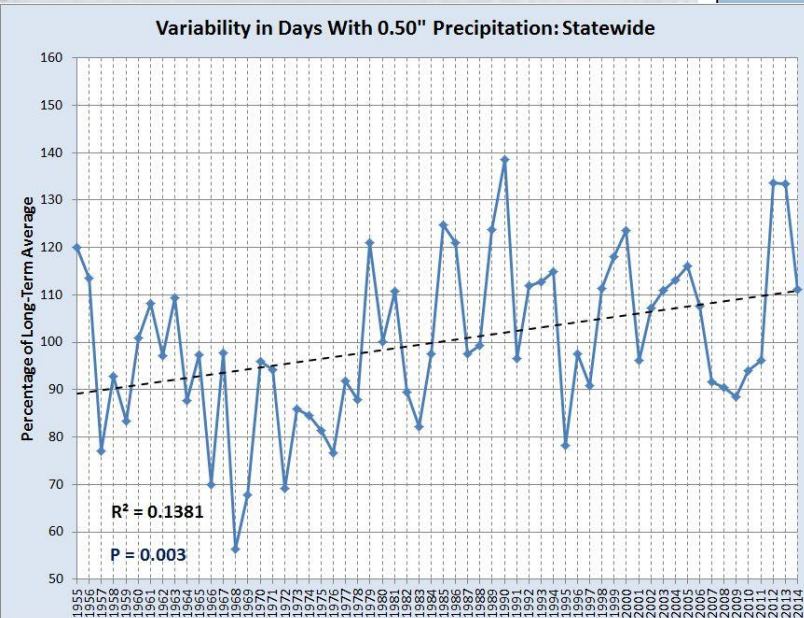
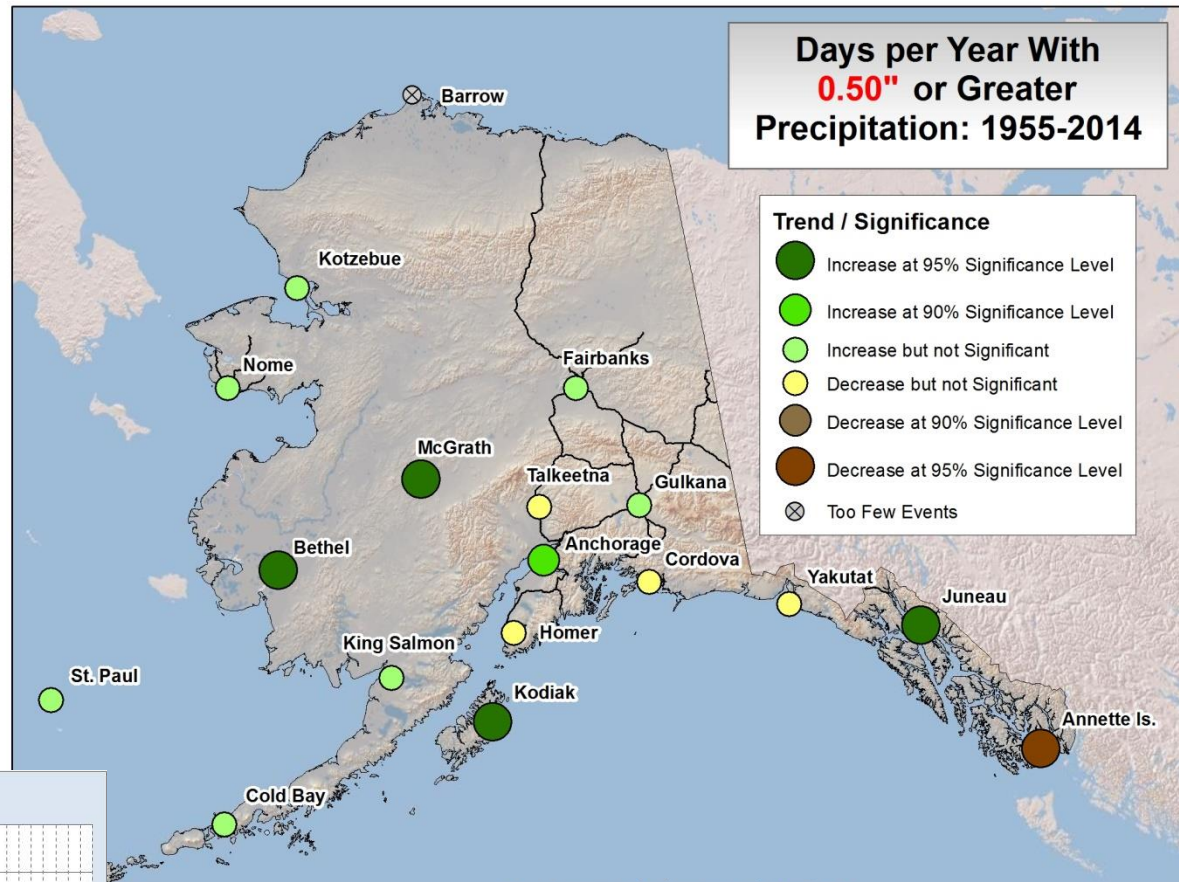


What do we Know?

- 1) There has been a general increase in precipitation.
- 2) There has been a general increase in surface temperatures.
- 3) There has been an increase in upper air temperatures (below 300mb).
- 4) Precipitable water (PW) has not increased much.
- 5) There is a very small relationship between total precipitation and PW.







Interpretation

- 1) The number of days per year for all precipitation categories is increasing.
- 2) Threshold values between 0.10" and 0.50" are increasing at a rate faster than the total annual precipitation with a stronger statistical significance. This implies a larger contribution to annual precipitation.
- 3) Large precipitation events ($>1''$) are increasing but not at a statistically significant level.

Warmer Temperatures Affect Precipitation in Other Ways

For example, If snow melts earlier due to warmer temperatures, green up occurs earlier.

Evapotranspiration rates shoot up dramatically which kicks off the thunderstorm season in the interior.

Evapotranspiration

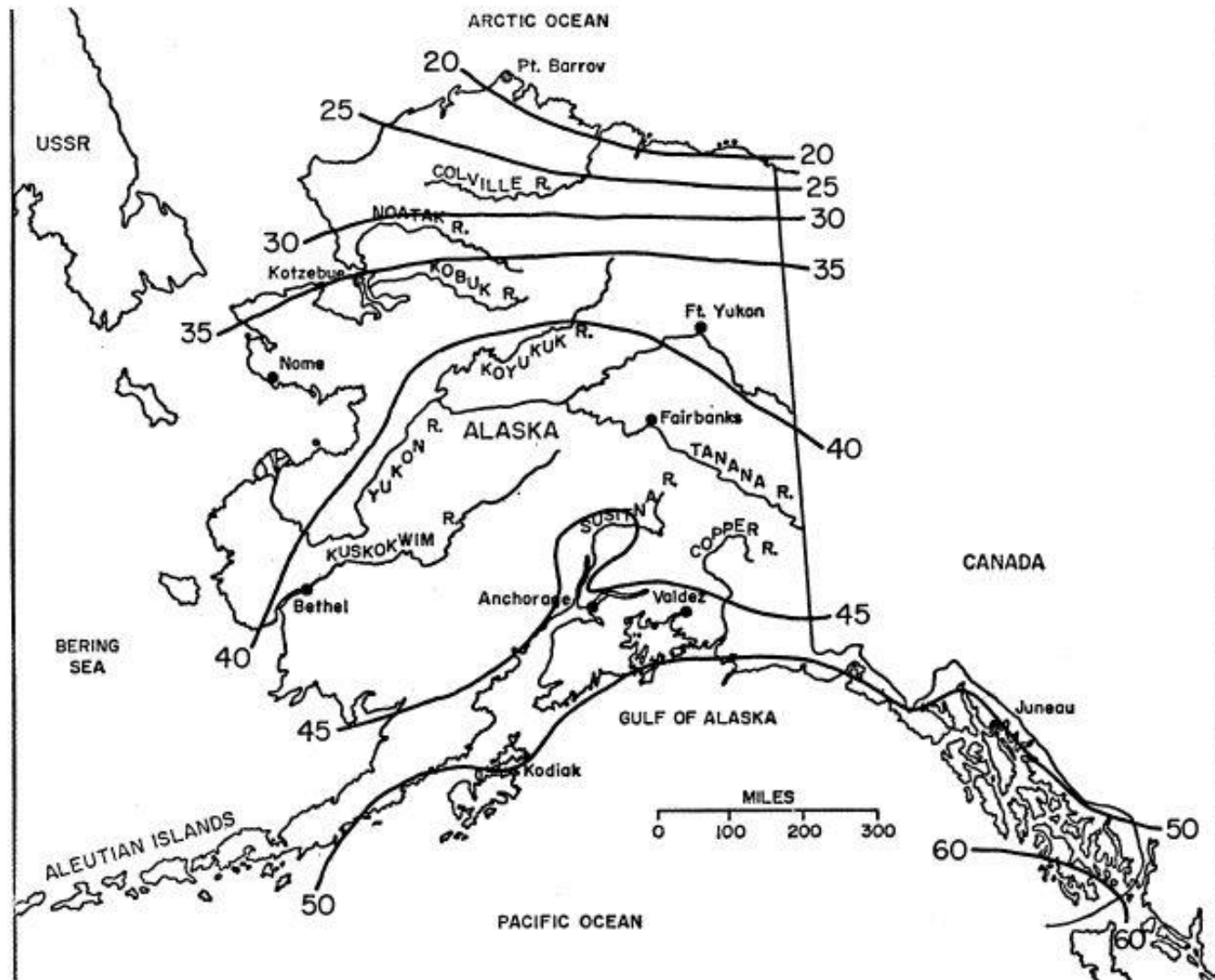
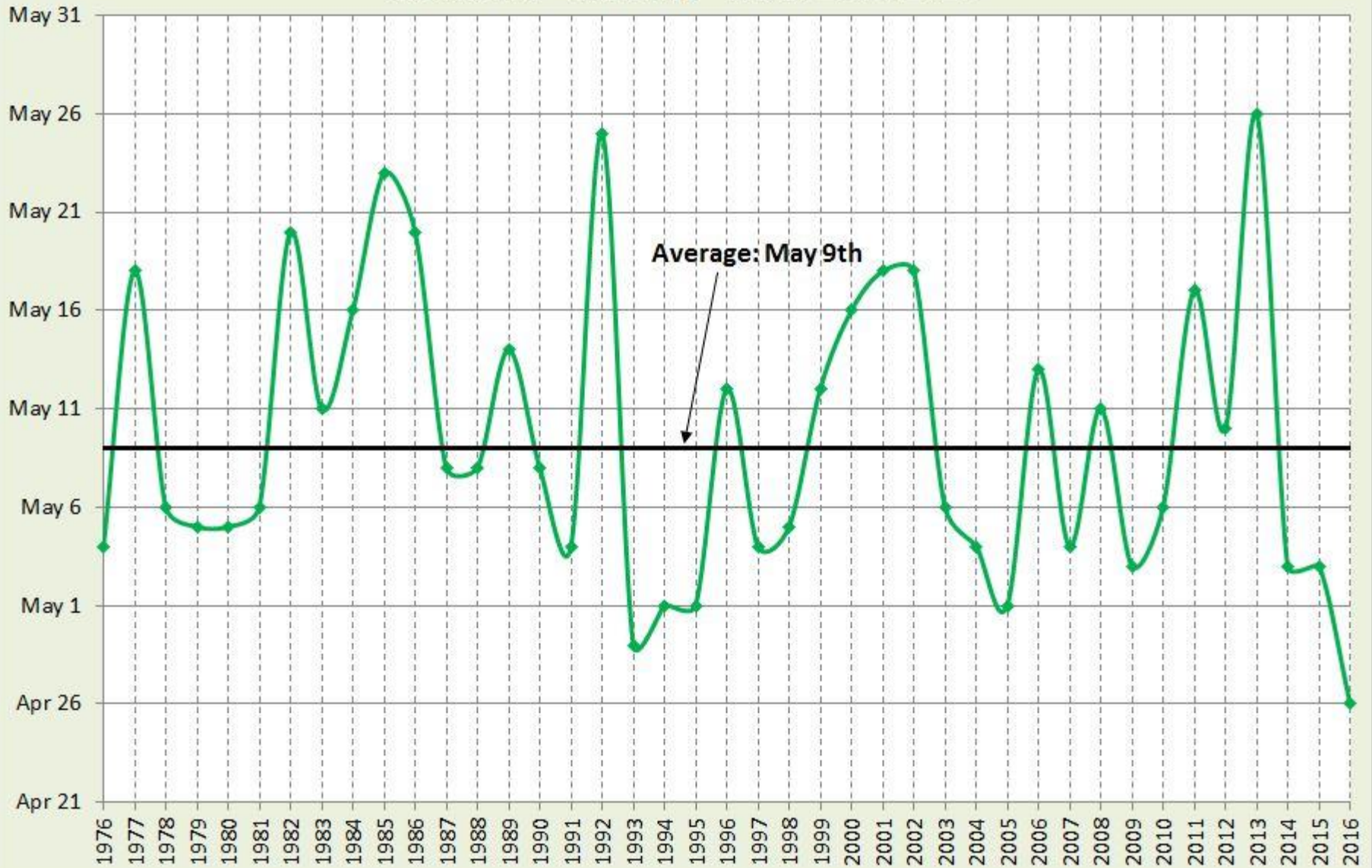


FIG. 4. Mean annual evapotranspiration in centimeters. Data from Patric and Black (1968) who used the Thornthwaite (1948) method of computation.

Newman, James and C. Ivan Branton. 1972. Annual water balance and agricultural development in Alaska. *Ecology* 53, no. 3: 513-9.

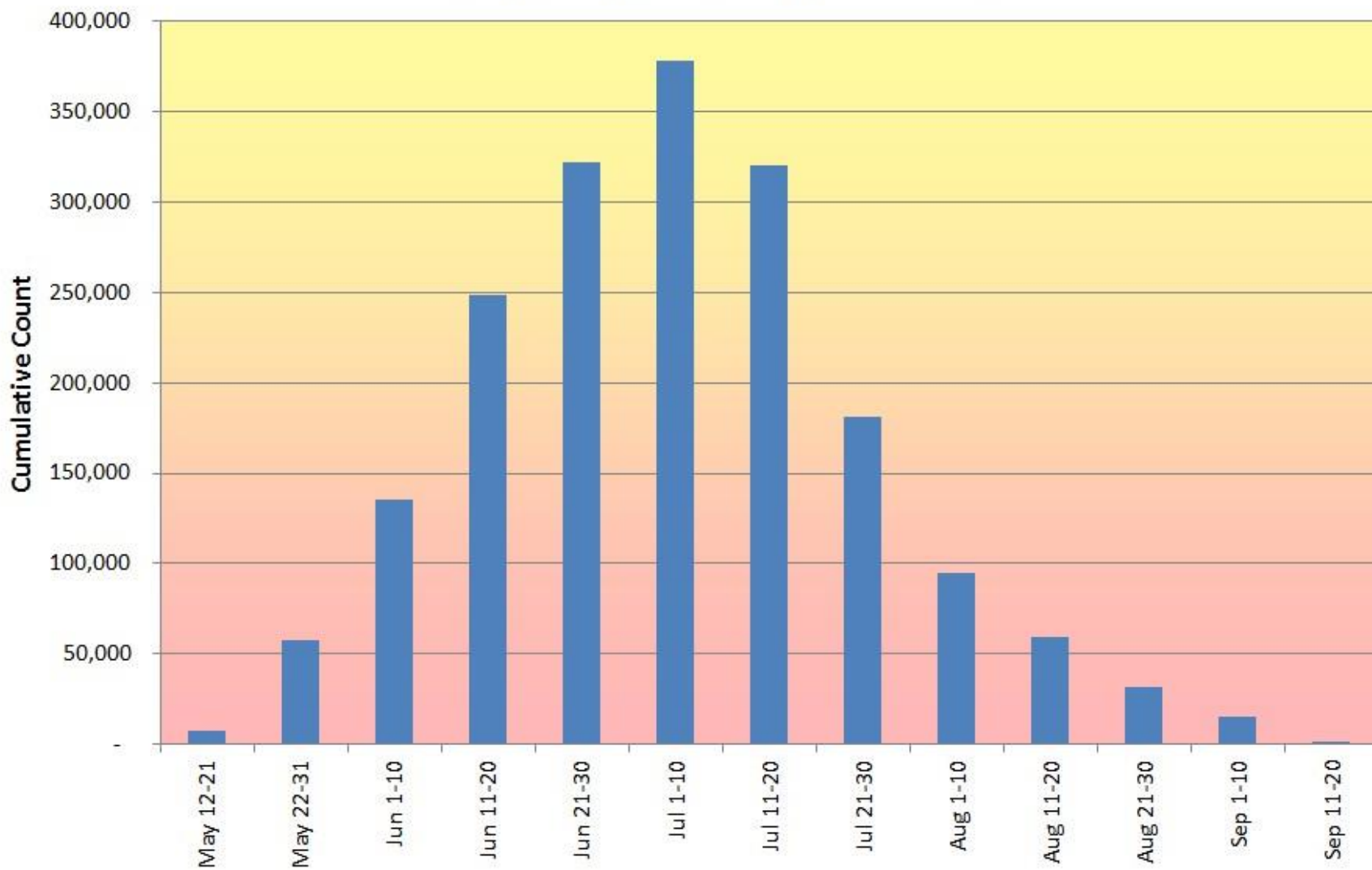
The Effect of Earlier "Green Up"

Fairbanks "Green Up" Date: 1976-2016

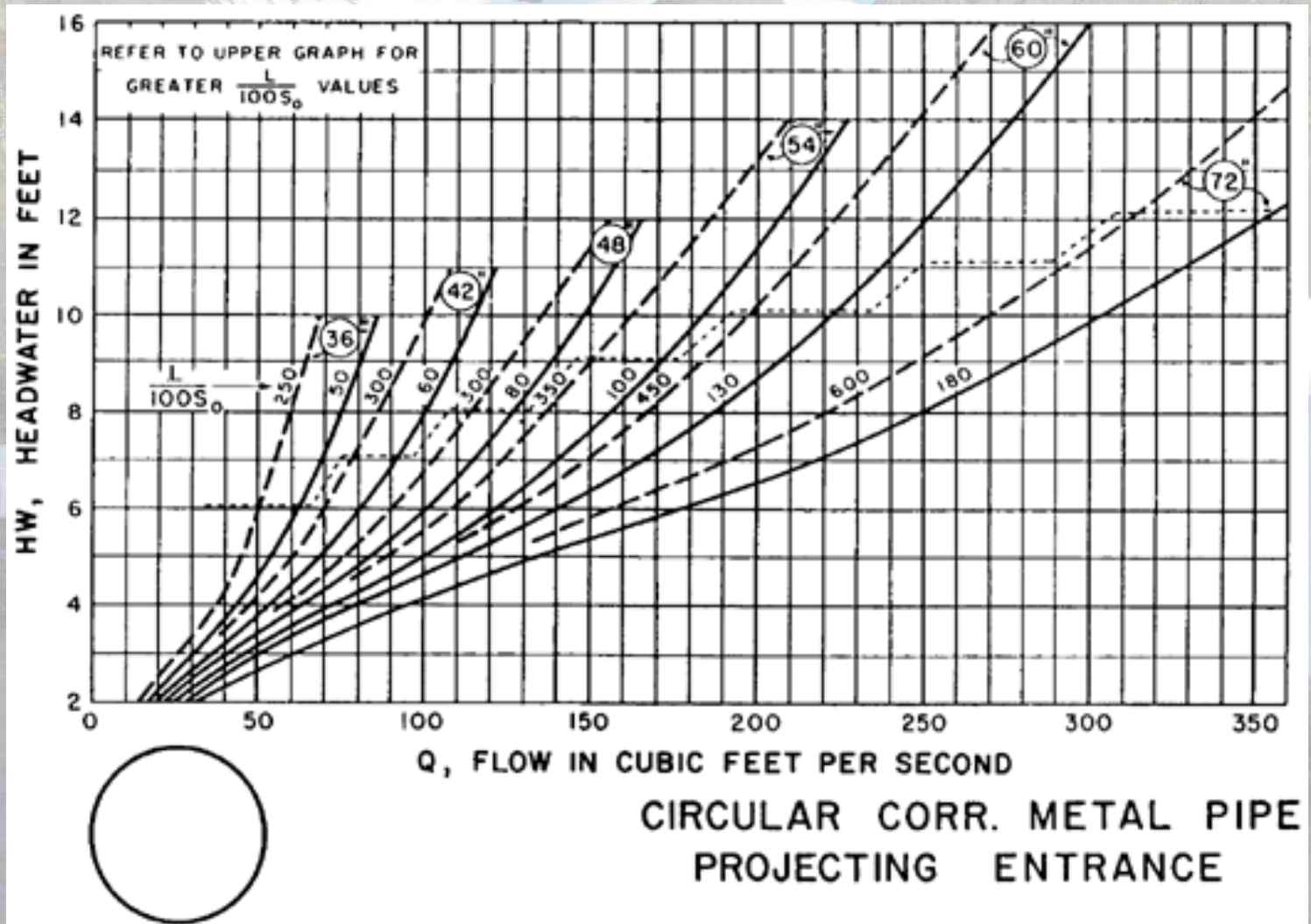


Earlier Melt Off Means Longer Thunderstorm Season

Alaska Lightning Frequency (1986-2012)



Implications for Highway Drainage



Implications for Highway Drainage

- Increased precipitation = increased flow through side-ditches and culverts.
- Melting permafrost = more summer streamflow via groundwater contribution.
- Melting permafrost = thicker active layer can mean rising water table in flat and poorly drained areas.
- Higher temperature = greater evaporation and evapotranspiration.

Implications for Highway Design

- Larger culverts
- Wider ditches
- Longer bridges
- More extreme wet/dry cycles.