
# Mapping of Instrumental Climate Change Trends & Modelling Watersheds

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# Climate and Extreme Weather

Climate change is described using:

- average changes in temperature
- average changes in precipitation.

Most social and economic costs associated with climate change will result from a shift in:

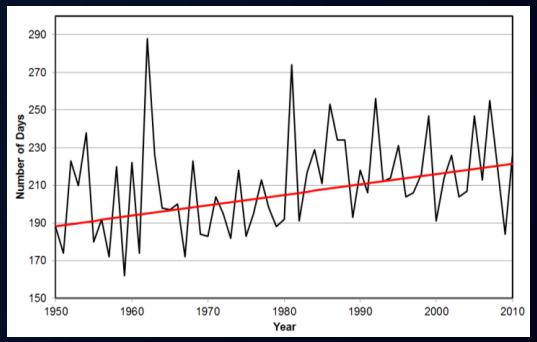
- Frequency of extreme events
- Severity of extreme events

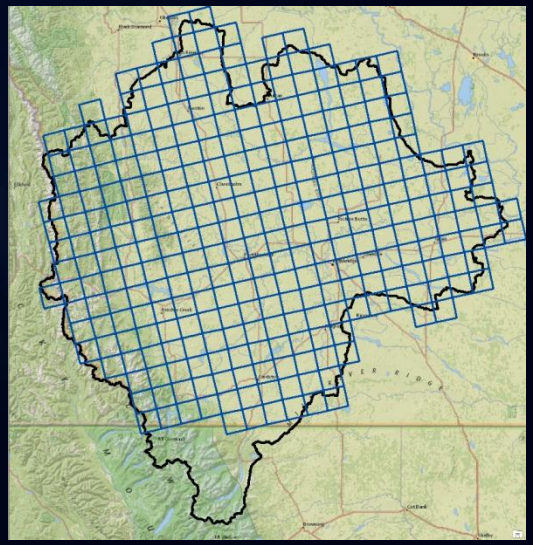
Risk analysis is required

- What is the chance of a certain event to happen?

# Climate and Extreme Weather

- We have calculated many climate indices for the period 1950 – 2010 for 7000 climate grid cells.
- Trends and their significance levels were then computed.
- Soon, we can calculate trends for the period 1950 – 2050.

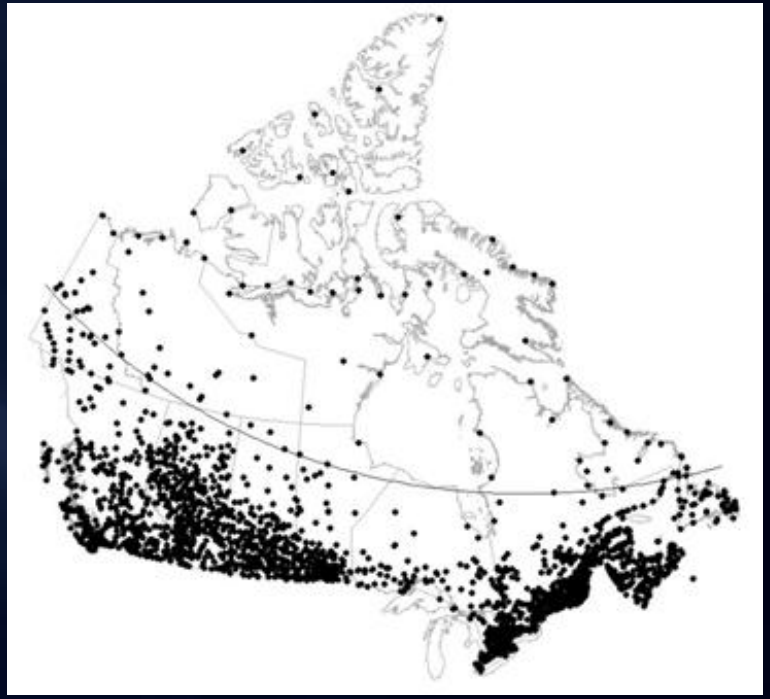


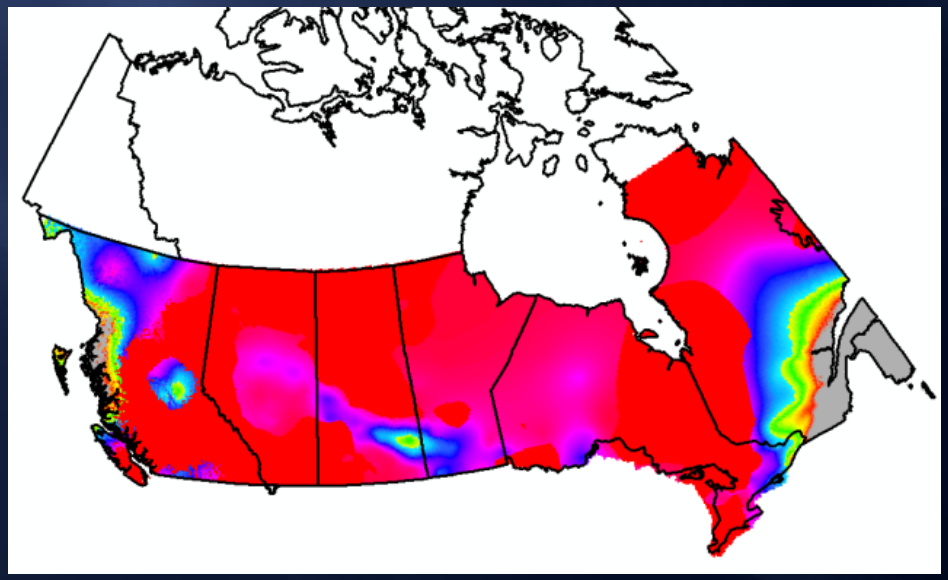



# INTERPOLATED DAILY MAX-MIN TEMPERATURE AND PRECIPITATION (1961-2003)

Collaborative between:

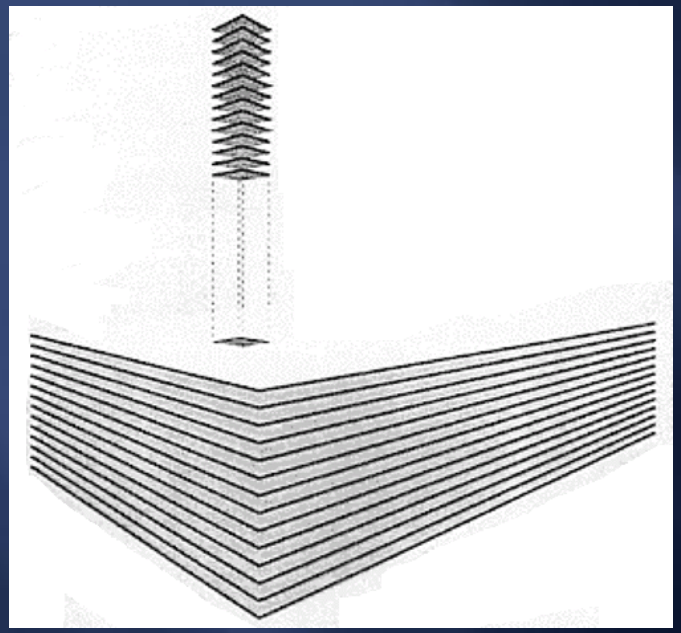
- Environment Canada (data)
- Canada Climate Service (data)
- Natural Resources Canada (interpolation)
- Australian National University (interpolation)





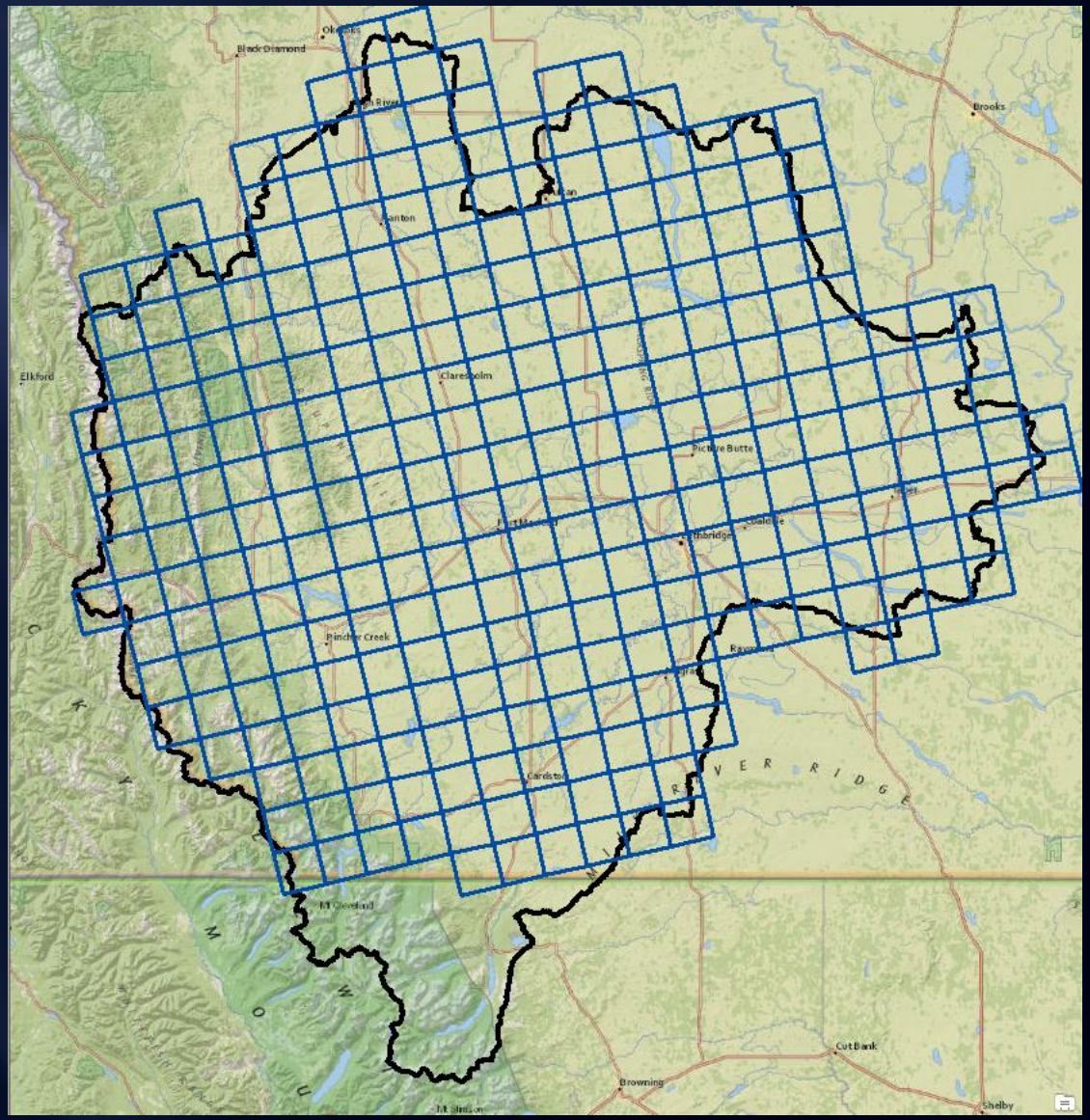
Published by the National Land and Water Information Service (NLWIS).

# 10 KM CLIMATE GRIDS (“TOWNSHIP GRIDS”)



22,280 daily layers for

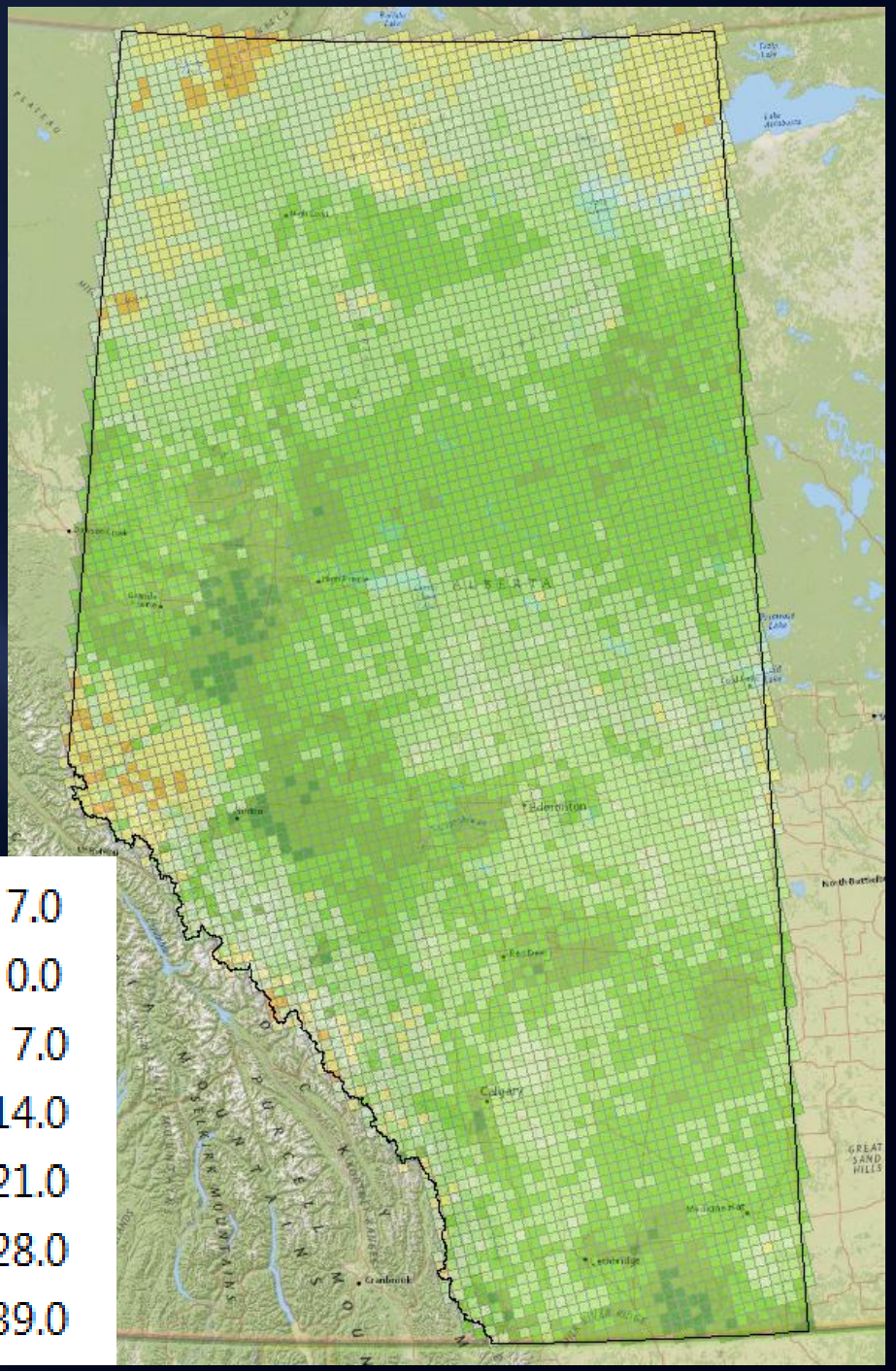
- Precipitation
- Minimum temperature
- Maximum temperature



# Alberta
# 1950-2010
# Change in growing season length
# [in days]

Alberta maps will be created for:

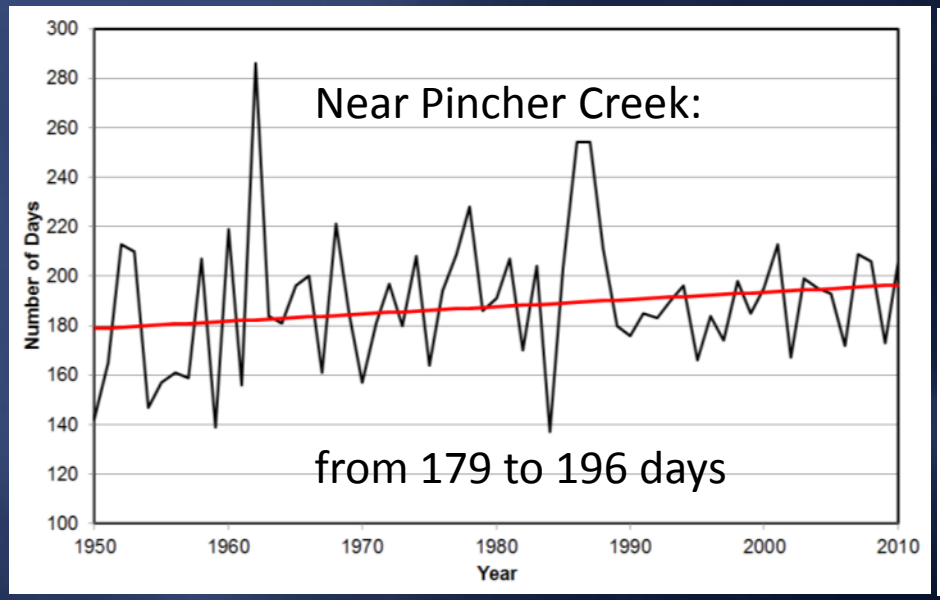
- Many climate indices
- PET
- Future climates
- Drought indices
- Crop yields

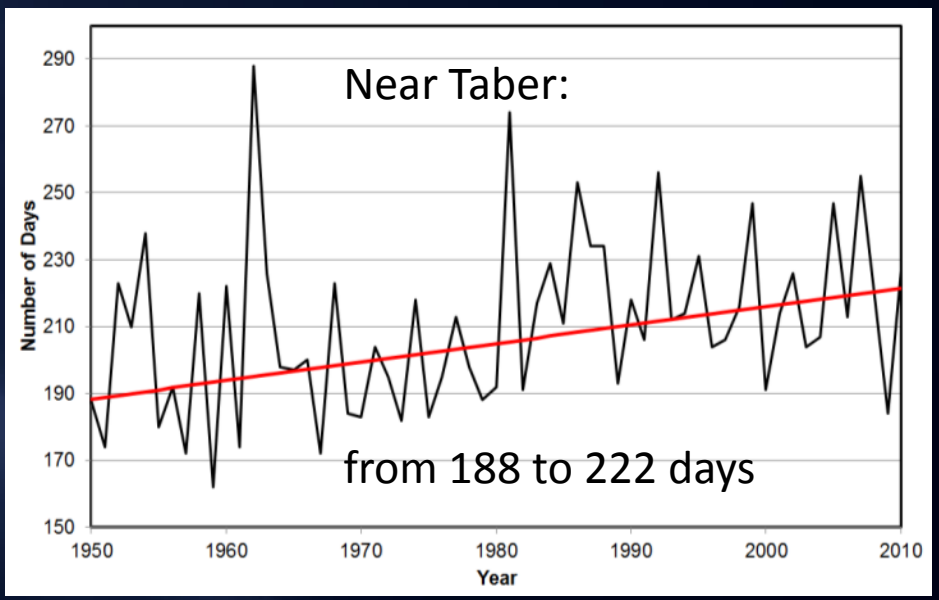


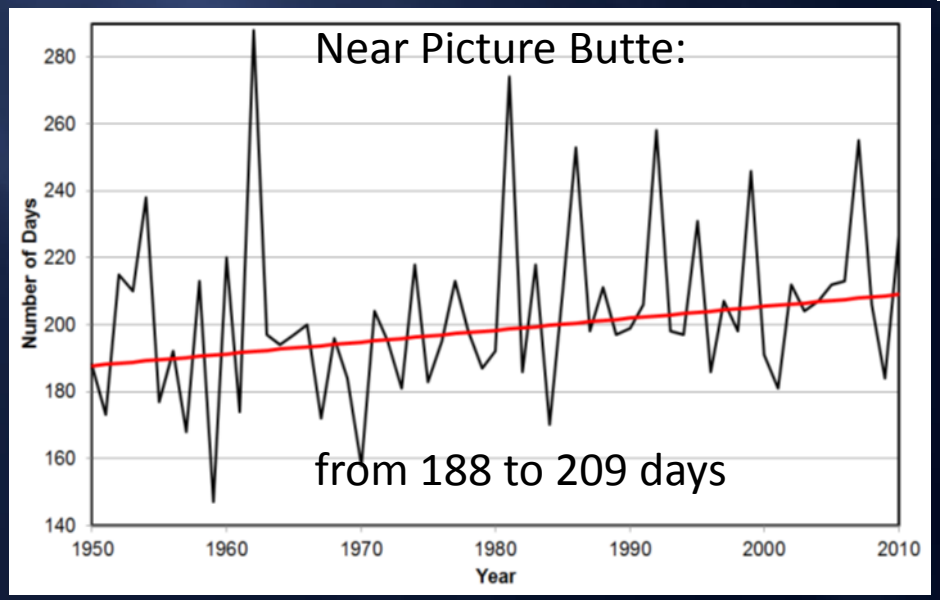
| Variable | Description | Units |
|---|---|---|
| Tmax >= threshold temperature | Annual count when the daily maximum temperature >= chosen threshold temperature, e.g. 25°C | Days |
| Tmax <= threshold temperature | Annual count when the daily maximum temperature <= chosen threshold temperature, e.g. 2°C | Days |
| Tmin >= threshold temperature | Annual count when the daily minimum temperature >= chosen threshold temperature, e.g. 5°C | Days |
| Tmin <= threshold temperature | Annual count when the daily minimum temperature <= chosen threshold temperature, e.g. 0°C | Days |
| Frost days | Annual count when daily minimum temperature < 0°C | Days |
| Growing season Length | Annual count between first span of at least 6 days with Tmean >5°C and first span after July -of 6 days with TMean < 5°C | Days |
| Heat wave days | Count of days in a year that are 5 °C higher than during the 1961-1990 period | Days |
| Ice days | Annual count when daily maximum temperature <0°C | Days |
| Max Tmax | Monthly maximum value of daily maximum temp | °C |
| Max Tmin | Monthly maximum value of daily minimum temp | °C |
| Min Tmax | Monthly minimum value of daily maximum temp | °C |
| Min Tmin | Monthly minimum value of daily minimum temp | °C |
| Cool nights | Percentage of days when TN<10th percentile | % |
| Cool days | Percentage of days when TX<10th percentile | % |
| Warm nights | Percentage of days when TN>90th percentile | % |
| Warm days | Percentage of days when TX>90th percentile | % |
| Consecutive dry days | Maximum number of consecutive days with RR<1mm | Days |

| Variable | Description | Units |
|---|---|---|
| Accumulated precipitation over 5 days | Annual maximum sum of 5-day precipitation | Mm |
| Simple precipitation intensity index | Annual fraction of annual precipitation sum divided by the number of precipitation days > 1mm | Mm |
| Very wet years | Annual total precipitation when above the 1961-1990 period 95$^{th}$ percentile | Years |
| Annual precipitation | Annual sums of daily precipitation | mm |
| Warm spell duration indicator | Annual count of days with at least 6 consecutive days when TX>90th percentile | Days |
| Cold spell duration indicator | Annual count of days with at least 6 consecutive days when TN<10th percentile | Days |
| Diurnal temperature range | Monthly mean difference between TX and TN | °C |
| Max 1-day precipitation amount | Monthly maximum 1-day precipitation | mm |
| Max 5-day precipitation amount | Monthly maximum consecutive 5-day precipitation | mm |
| Simple daily intensity index | Annual total precipitation divided by the number of wet days (defined as precipitation >= 1.0mm) in the year | mm/day |
| Number of heavy precipitation days | Annual count of days when daily precipitation >=10mm | Days |
| Number of very heavy precipitation days | Annual count of days when daily precipitation >=20mm | Days |
| Number of days above nn mm | Annual count of days when daily precipitation >= nn mm, nn is user defined threshold | Days |
| Consecutive wet days | Maximum number of consecutive days with precipitation >= 1mm | mm |
| Very wet days | Annual total PRCP when RR>95$^{th}$ percentile | mm |
| Extremely wet days | Annual total PRCP when RR>99$^{th}$ percentile | mm |
| Annual total wet-day precipitation | Annual total PRCP in wet days (RR>=1mm) | mm |
| Growing degree days >=0°C | Annual sum of daily temperatures >= 0°C | °C |
| Growing degree days >=5°C | Annual sum of daily temperatures >= 5°C | °C |
| Growing degree days >=10°C | Annual sum of daily temperatures >= 10°C | °C |
| Beginning day of growing season | First day of span of at least 6 days with Tmean >5°C | °C |
| End day of growing season | Last day of span of at least 6 days with Tmean <5°C | °C |

# Historical Trend in Growing Season Length



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# 1950-2010
# Change in growing season length
# [in days]

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- PET
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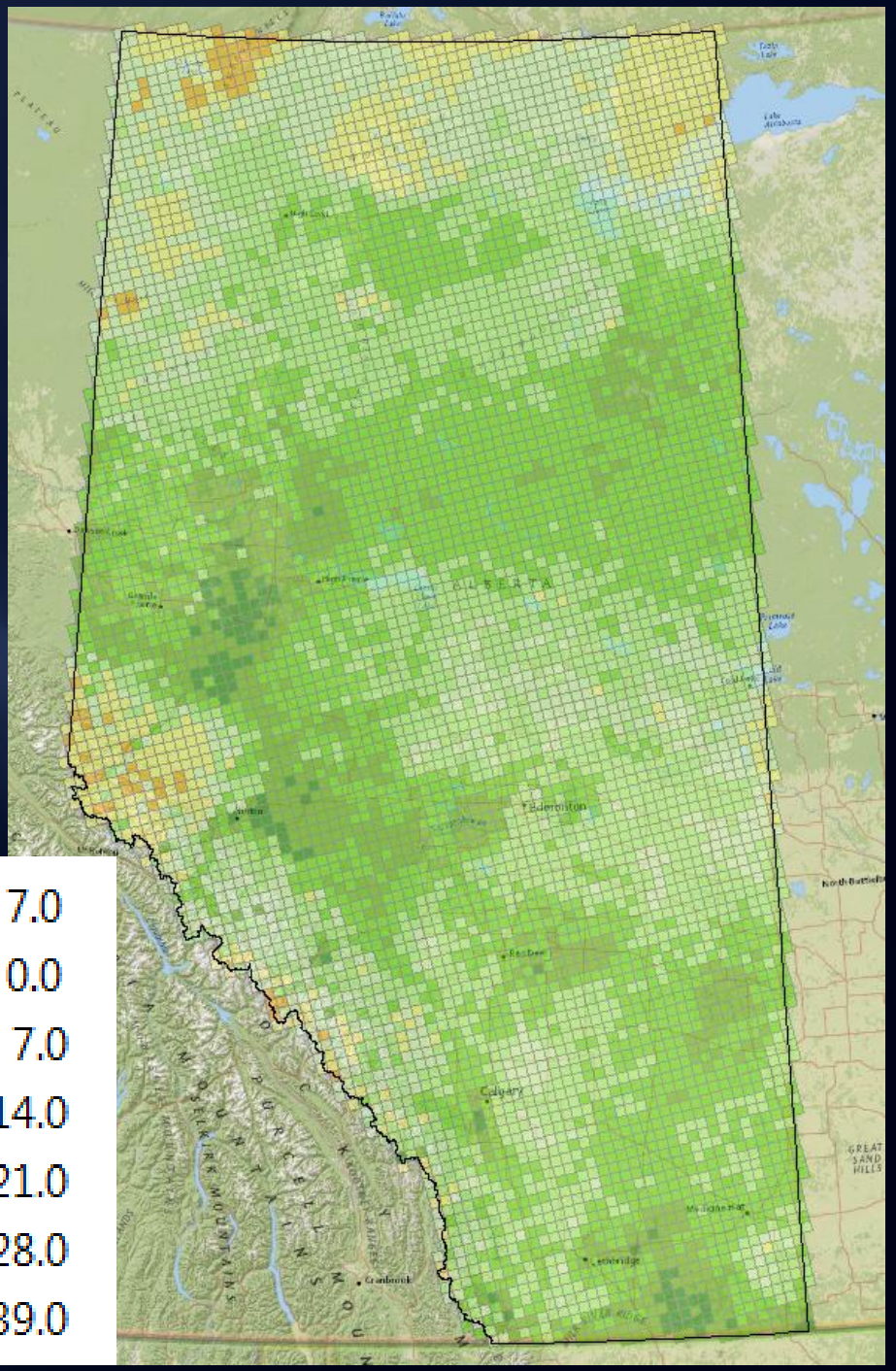
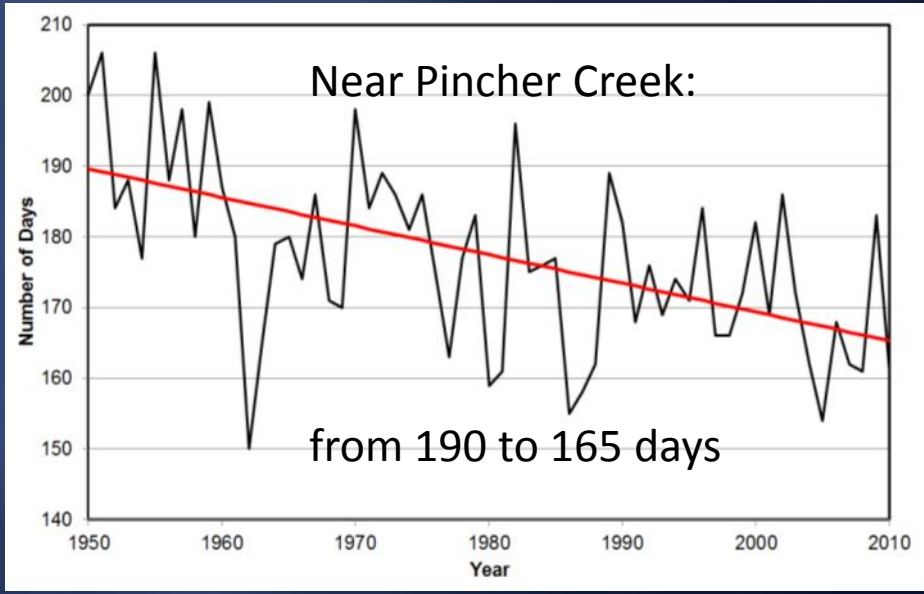
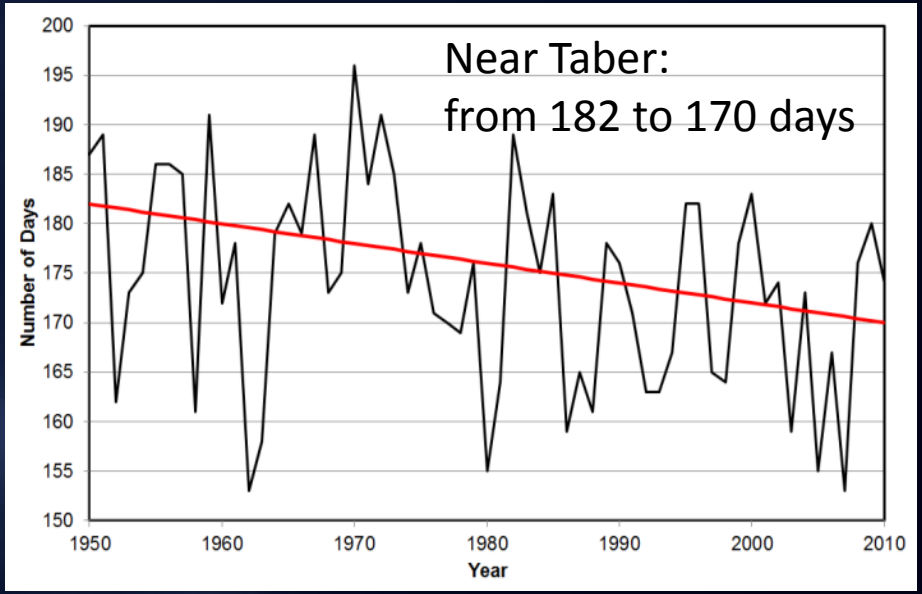
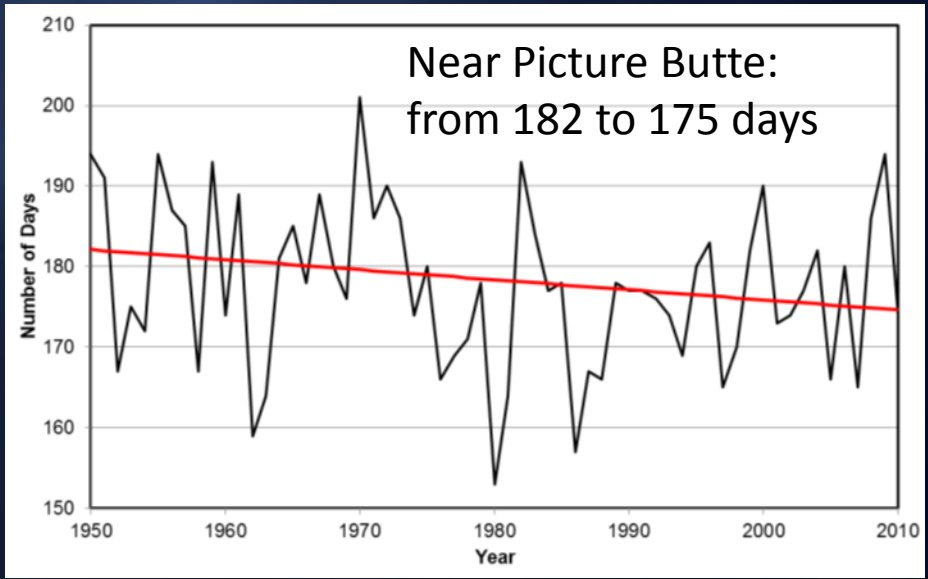
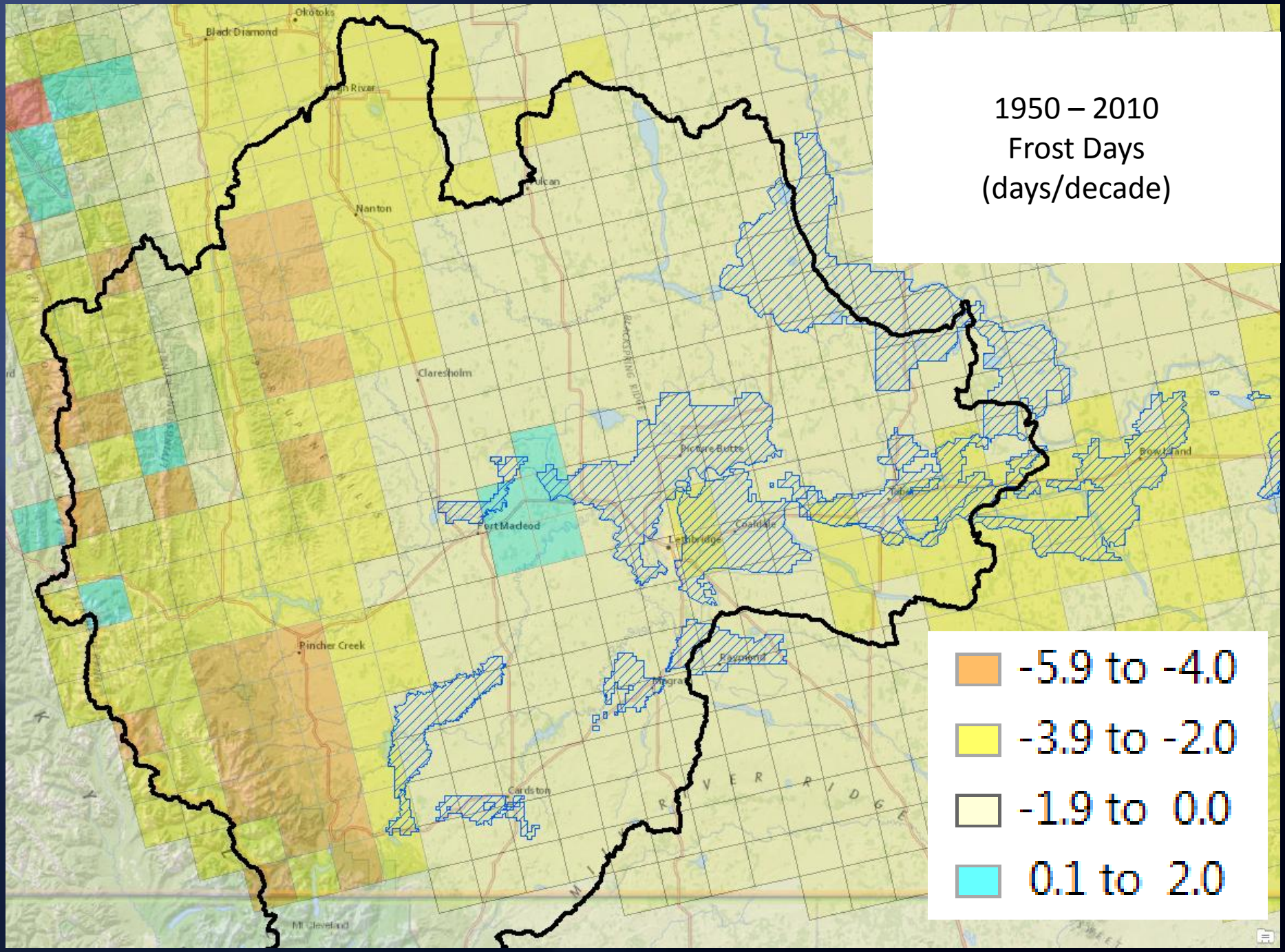


# TREND IN NUMBER OF FROST DAYS

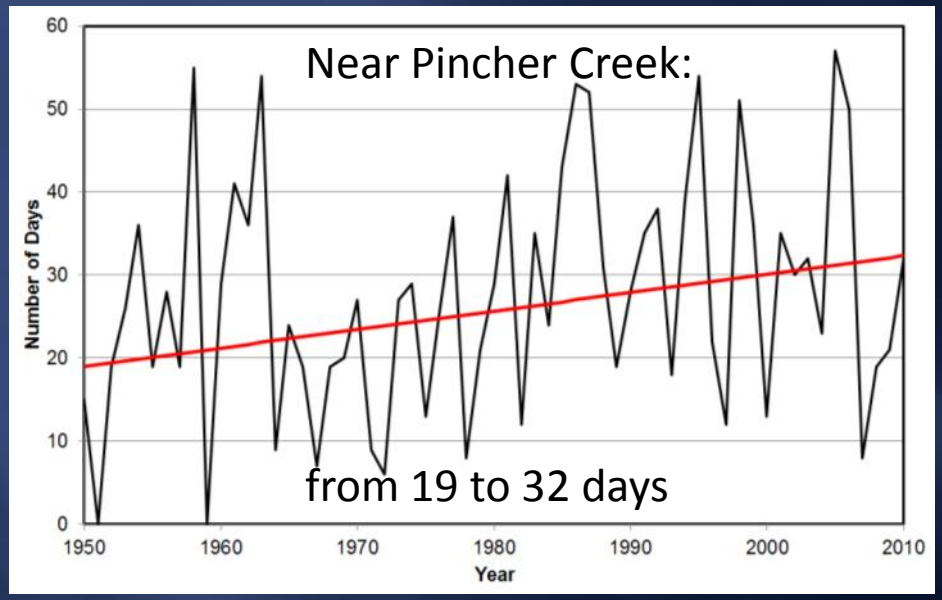


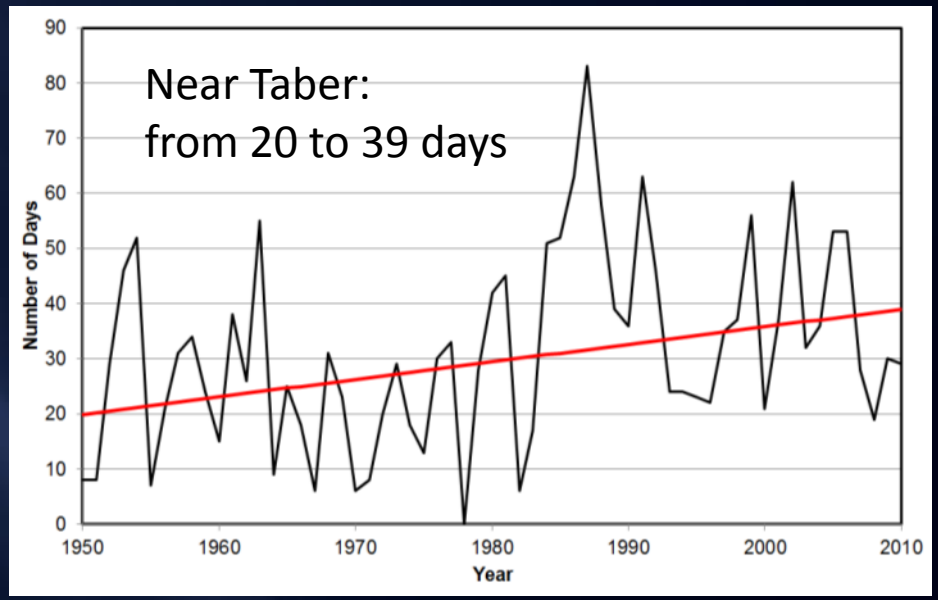



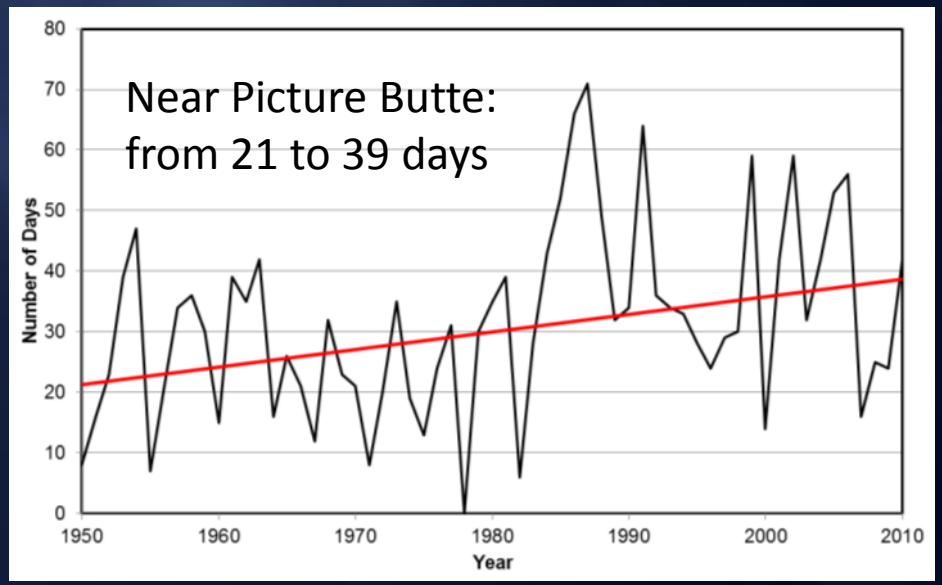




1950 – 2010
Frost Days
(days/decade)
-5.9 to -4.0
-3.9 to -2.0
-1.9 to 0.0
0.1 to 2.0
Okotoks
Black Diamond
Nanton
Vulcan
Claresholm
Fort Macleod
Pincher Creek
Cardston
Picture Butte
Coaldale
Raymond
Brownfield
Mt. Cleveland

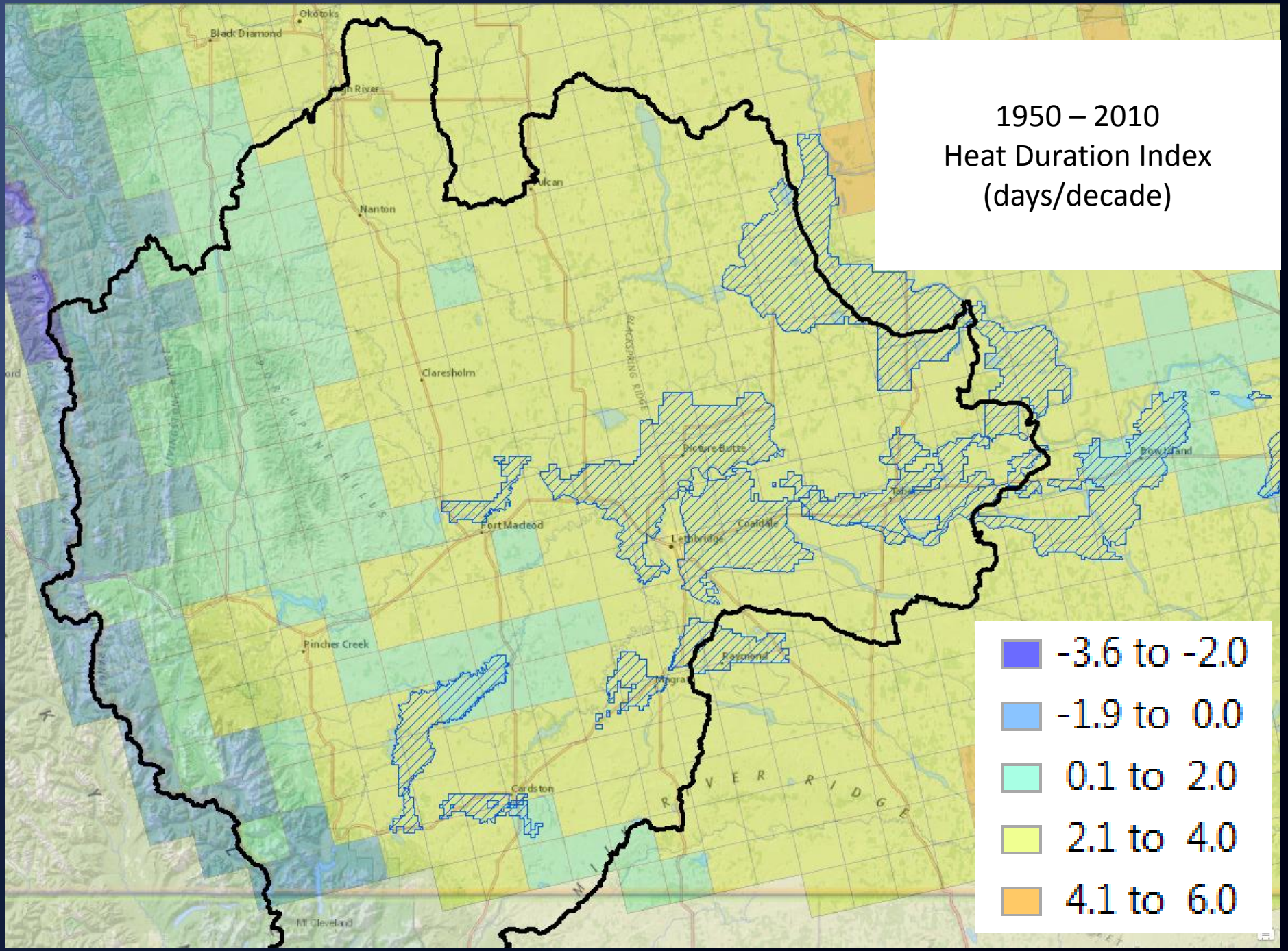
# TREND IN NUMBER OF AT LEAST 5 CONSECUTIVE DAYS WITH TEMPERATURES ABOVE 5°C OVER NORMAL



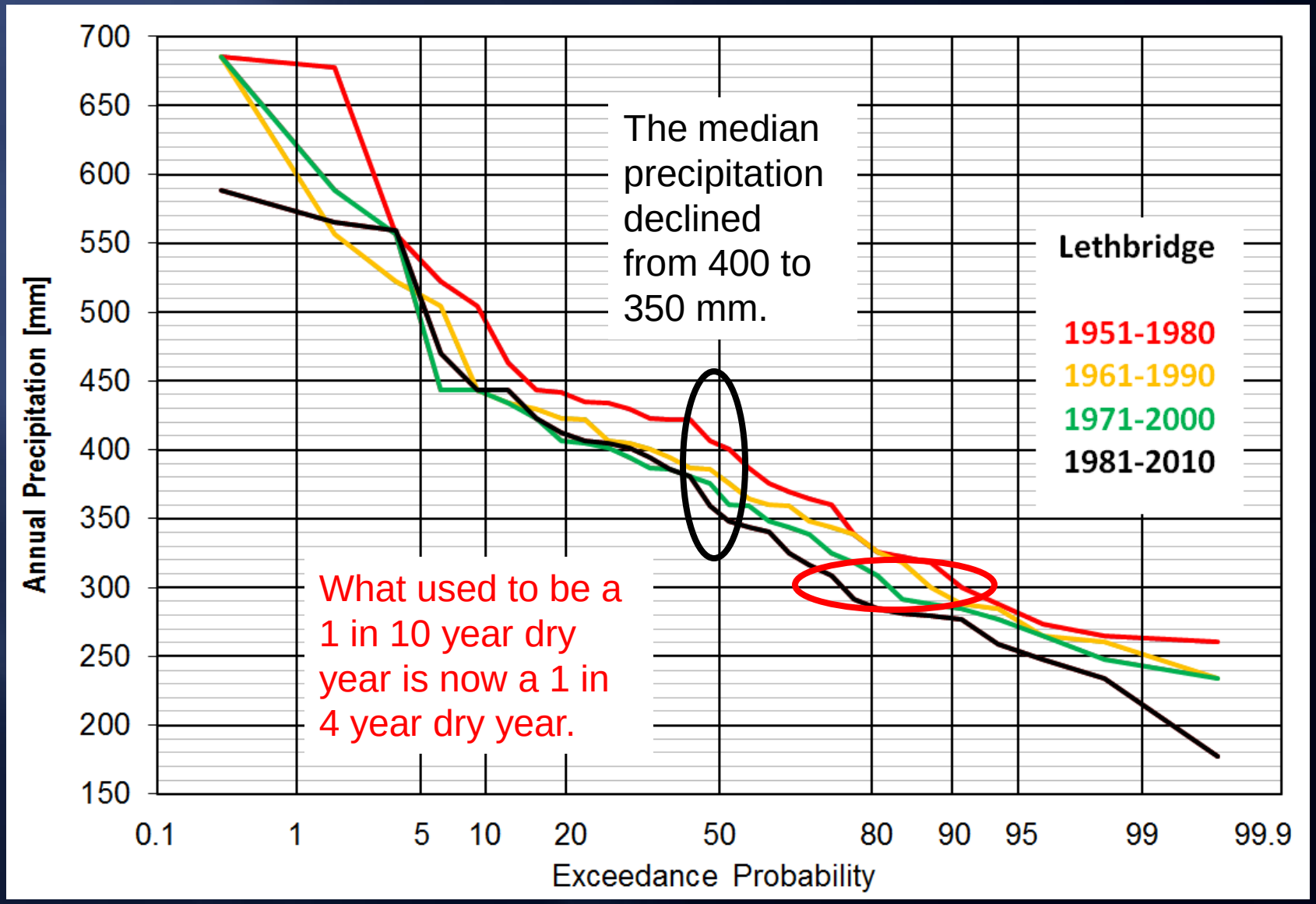



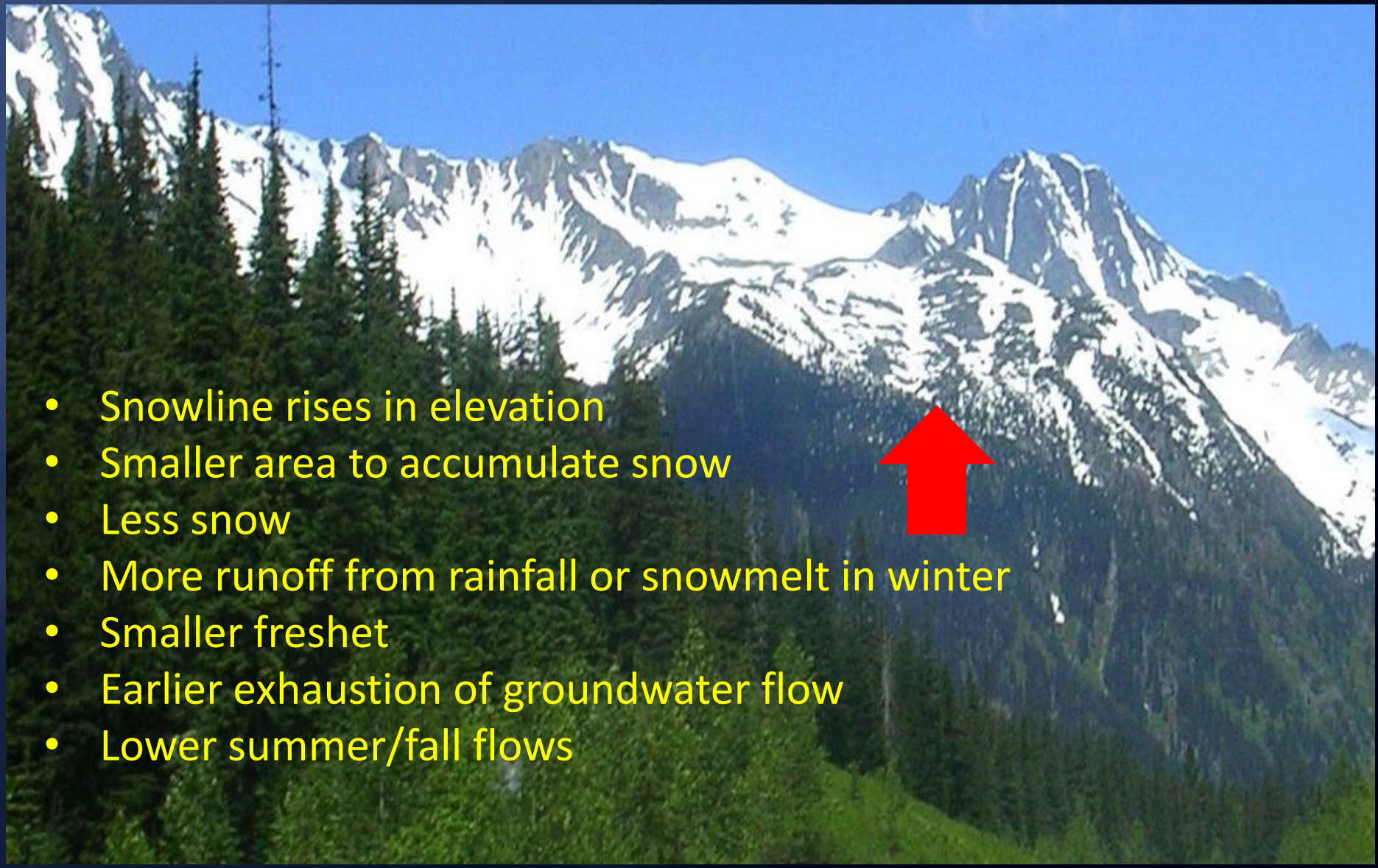

*"Heat Waves"*


1950 – 2010
Heat Duration Index
(days/decade)
-3.6 to -2.0
-1.9 to 0.0
0.1 to 2.0
2.1 to 4.0
4.1 to 6.0
Okotoks
Black Diamond
Nanton
Vulcan
Claresholm
Fort Macleod
Pincher Creek
Cardston
Picture Butte
Coaldale
Lethbridge
Raymond
Taber
Milk River
Mt Cleveland

# What is the chance of annual precipitation being over a certain value in Lethbridge?

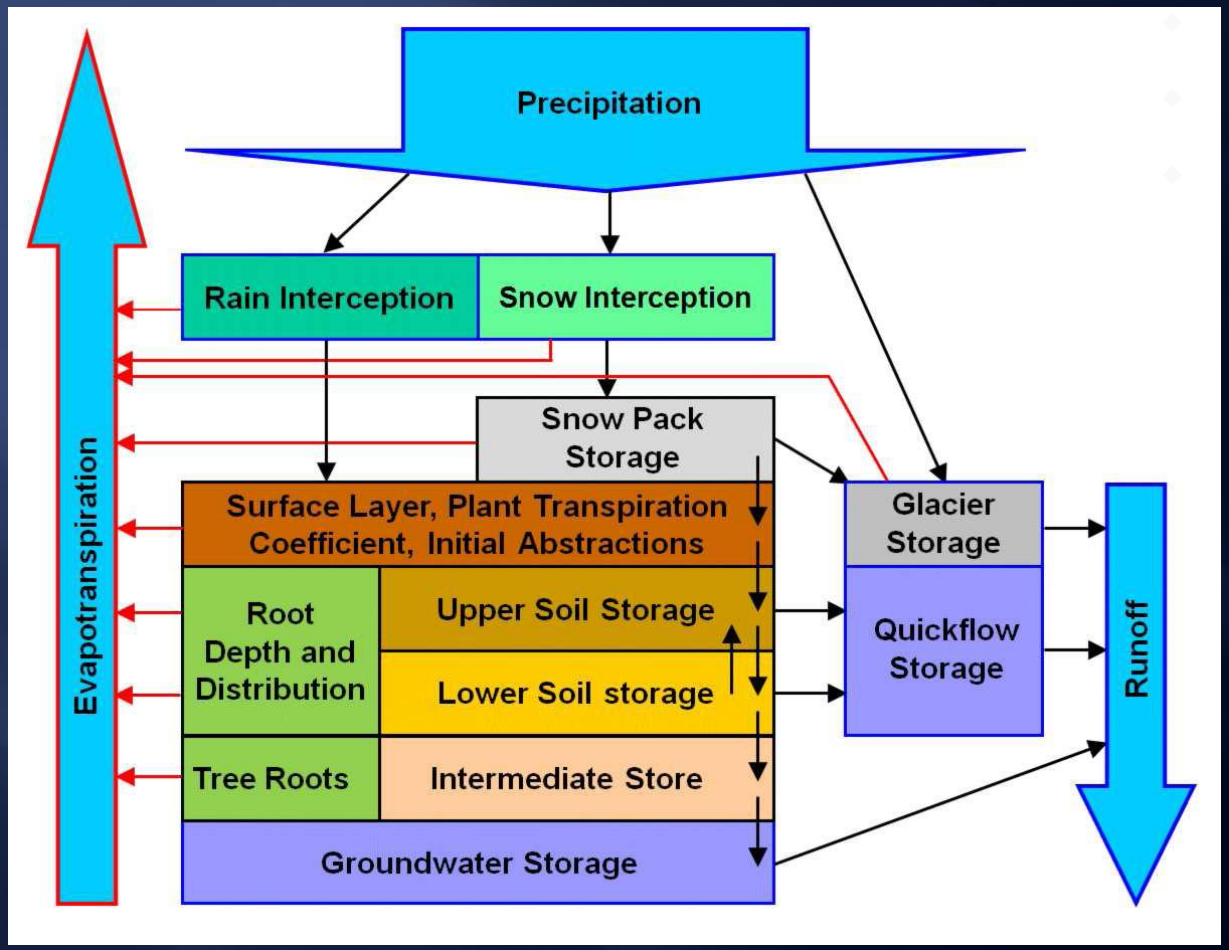


# Impacts of Climate Change



- Snowline rises in elevation
- Smaller area to accumulate snow
- Less snow
- More runoff from rainfall or snowmelt in winter
- Smaller freshet
- Earlier exhaustion of groundwater flow
- Lower summer/fall flows

# ACRU agro-hydrological modelling system




Multi-purpose

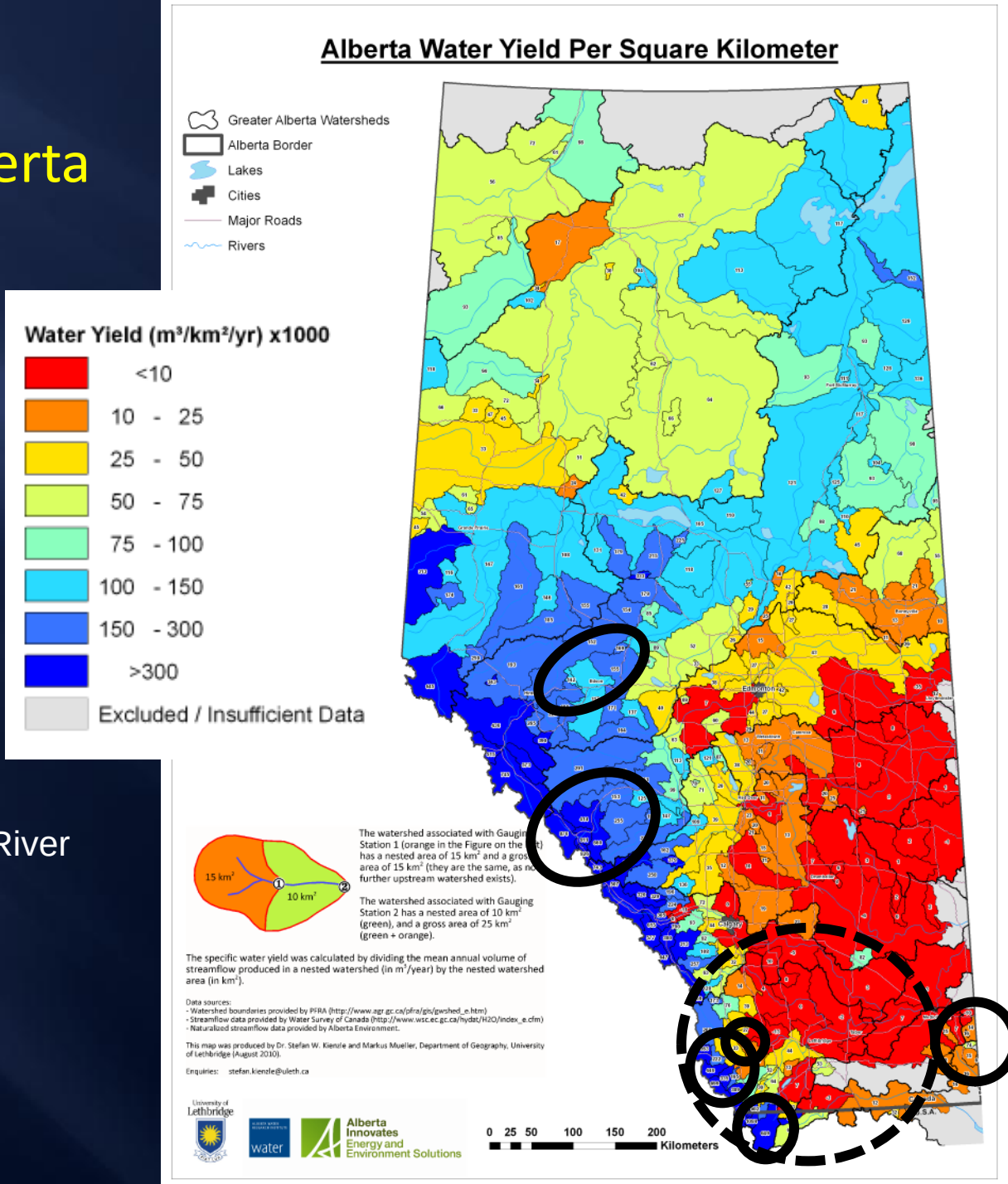
Multi-level

Integrated physical model

- Actual evaporation
- Soil water and groundwater storages
- Snow
- (Glaciers)
- Land cover and abstraction impacts on water resources
- Streamflow at a daily time step.

The ACRU model is used as a translator of climate change and land cover scenarios into hydrological responses.

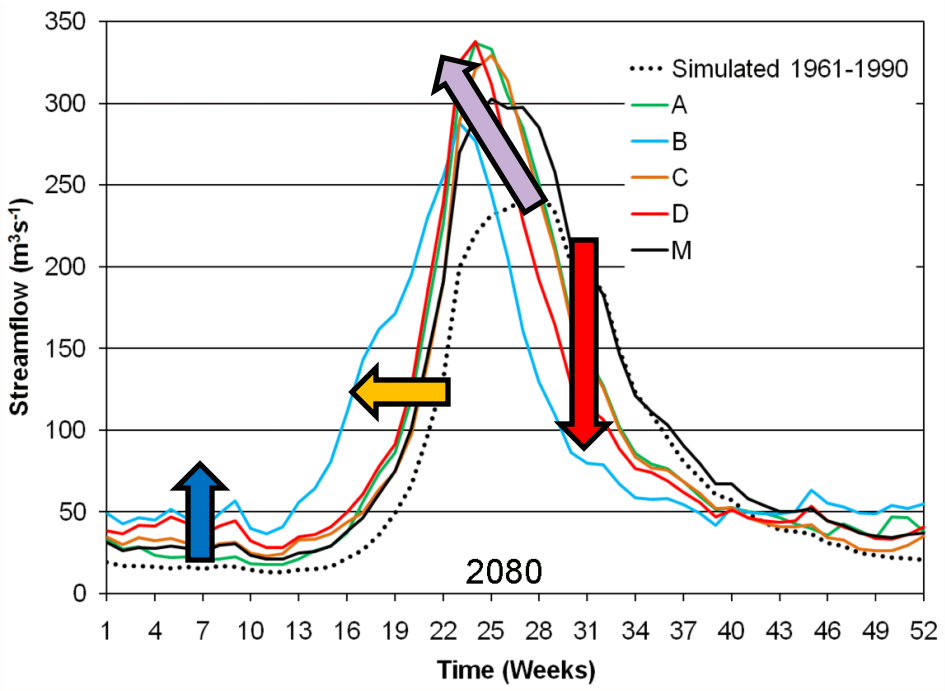
# Water Yield in Alberta

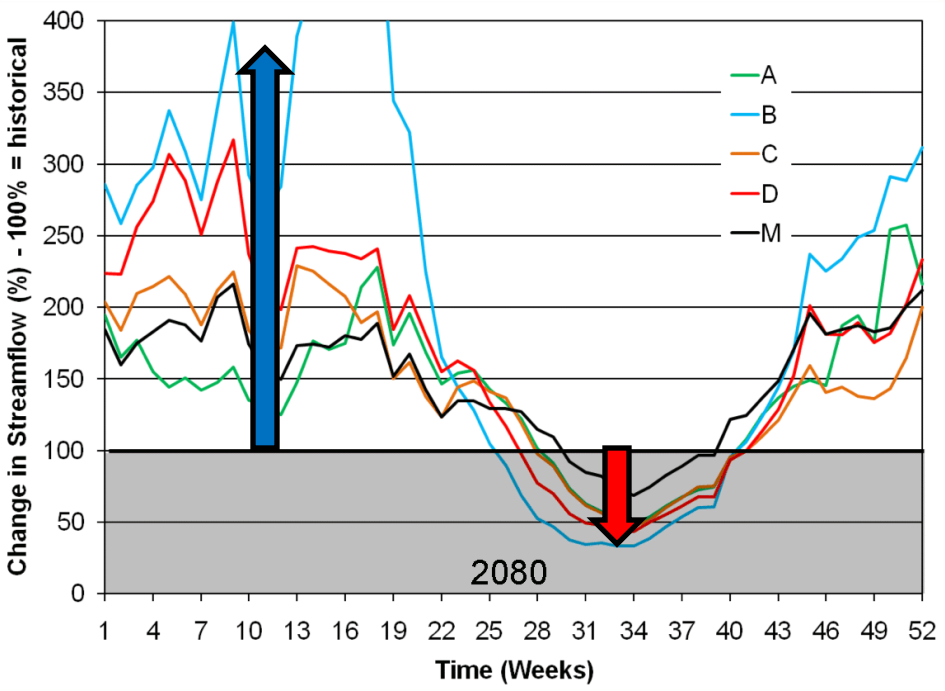



ACRU Simulations in:

- Upper North Saskatchewan River
- Castle River
- St. Mary's River
- Beaver Creek
- Swift Current Creek
- Oldman River
- McLeod River

# Cline River: Streamflow Impacts 2040-2069

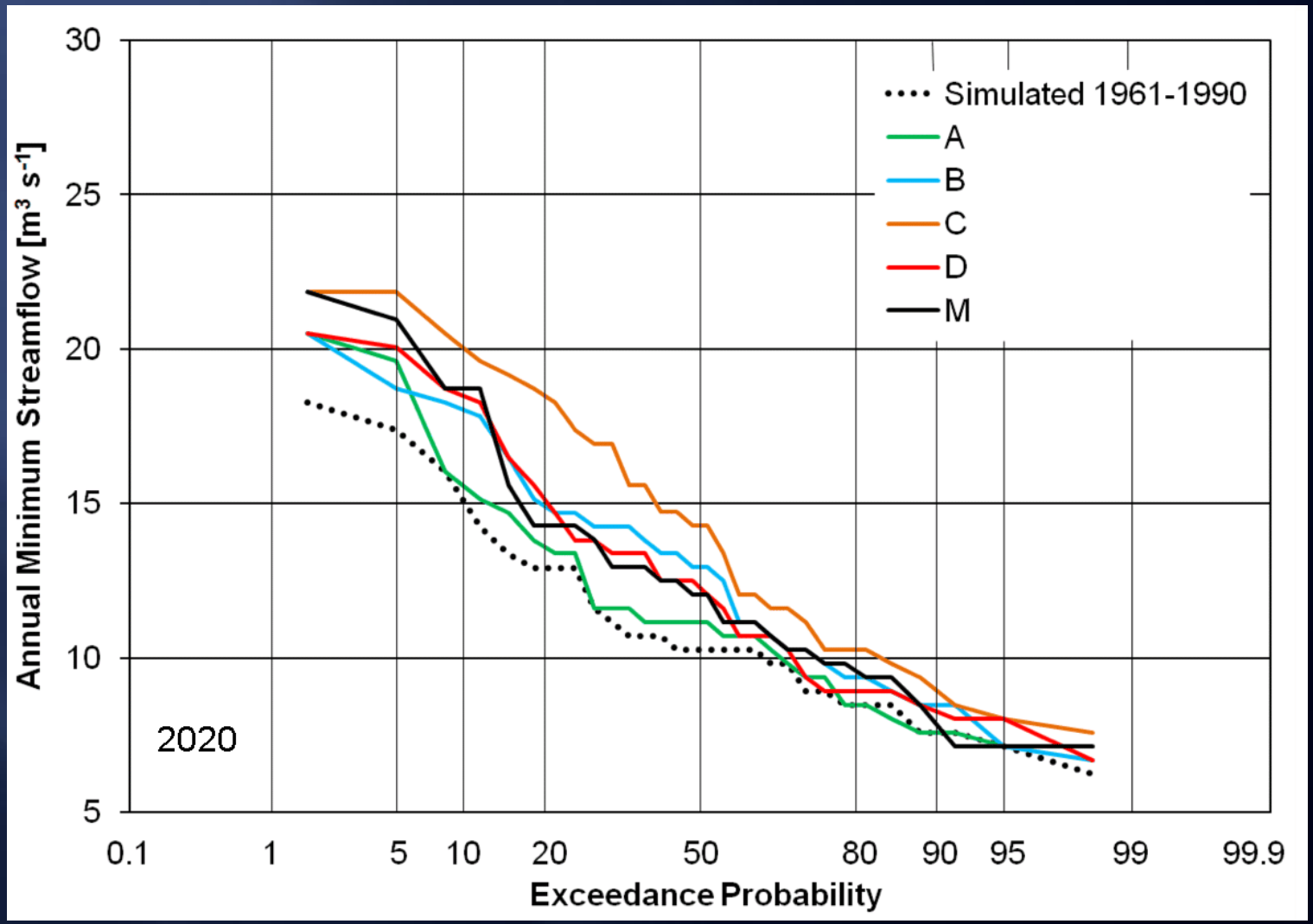



$m^3/s$

% over/under Base
Base = 1961-1990

# Cline River: Annual Minimum Streamflow Exceedance Probability: 2020

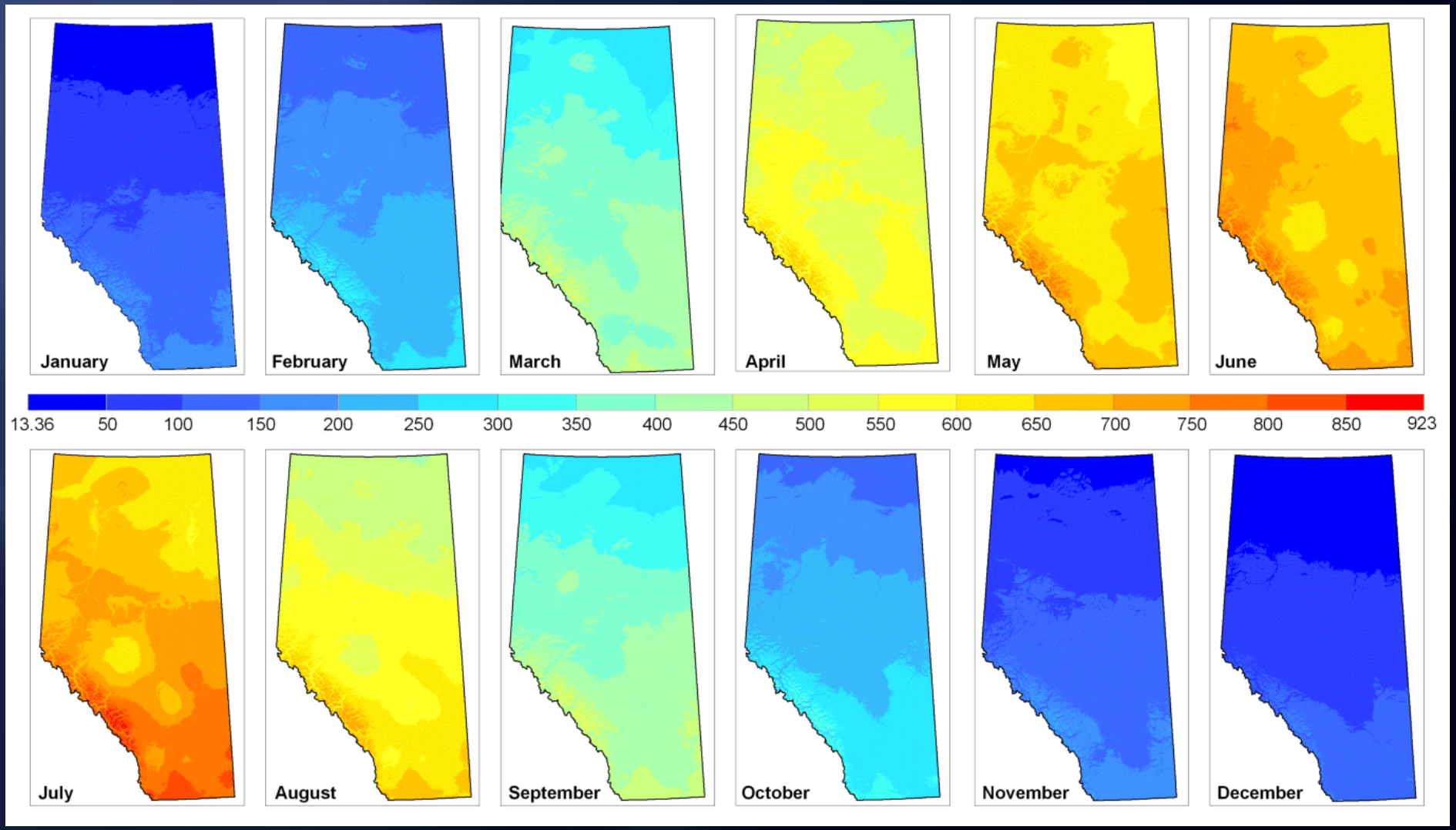


# Simulating impacts of land cover on water yield

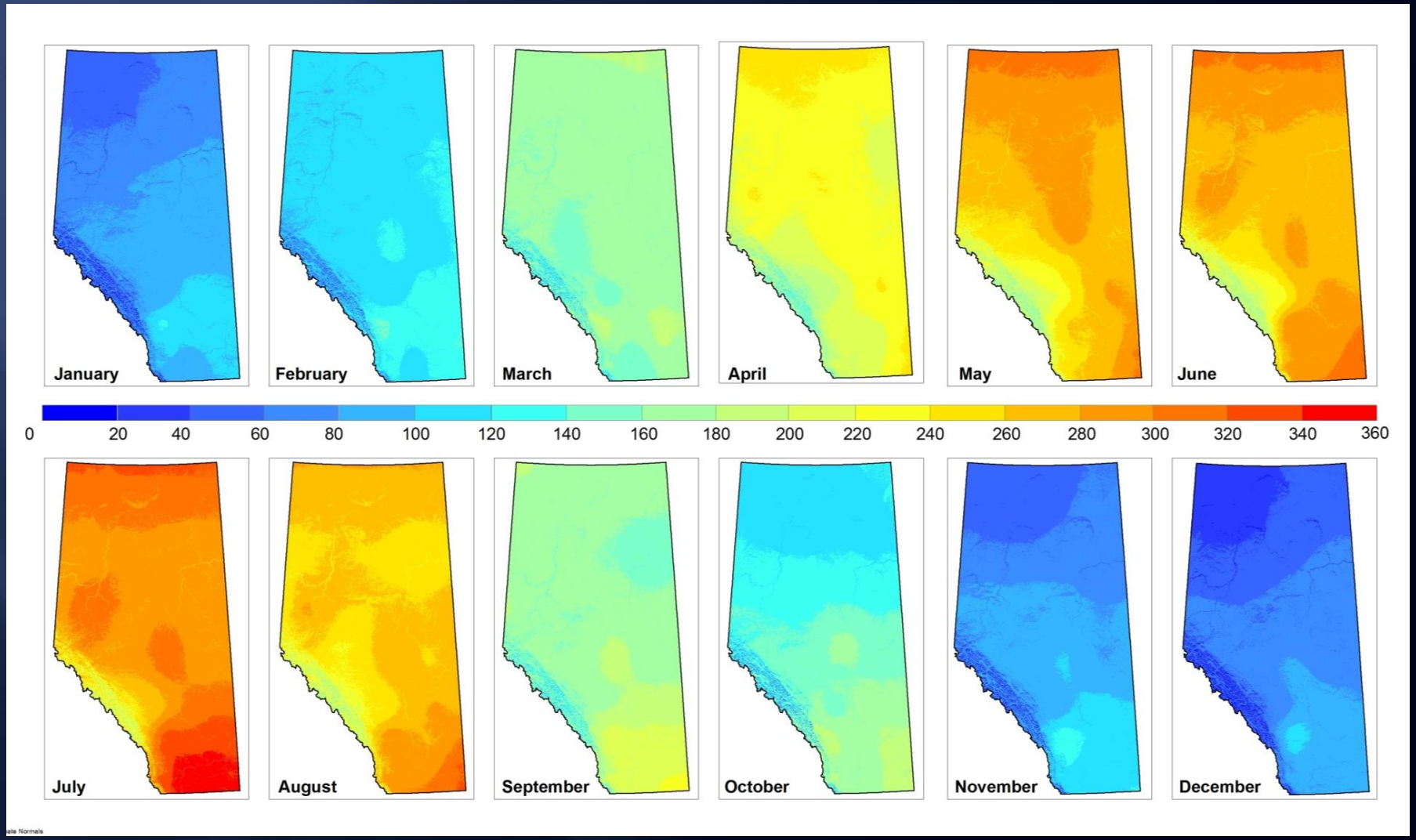
| Scenario | | Mean annual runoff (mm) | | | |
|---|---|---|---|---|---|
| | | Lions MC (MAP = 979 mm) | | Karkloof MC (MAP = 1 081 mm) | |
| A | Baseline land cover | 233.4 | | 345.6 | |
| B | Present land use | 204.5 | (–12.4%) | 277.6 | (–19.7%) |
| C | Baseline + irrigation | 180.2 | (–22.8%) | 319.7 | (–7.5%) |
| D | Baseline + afforestation | 192.9 | (–17.4%) | 272.0 | (–21.3%) |
| E | Baseline + 2 × afforestation | 178.4 | (–23.6%) | 241.6 | (–30.1%) |

# Mean Monthly Incoming Solar Radiation

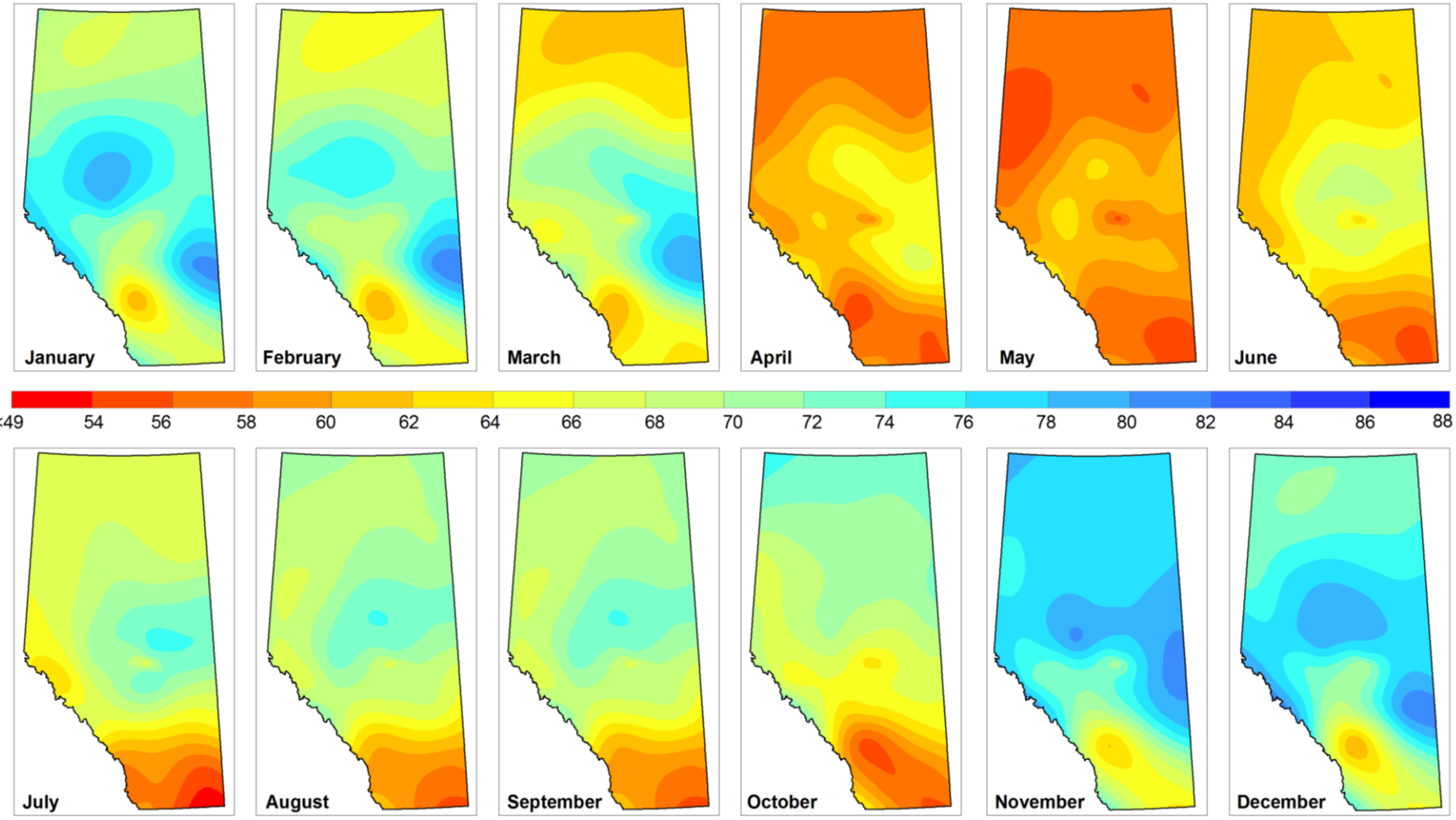
[MJ m-2 month-1]



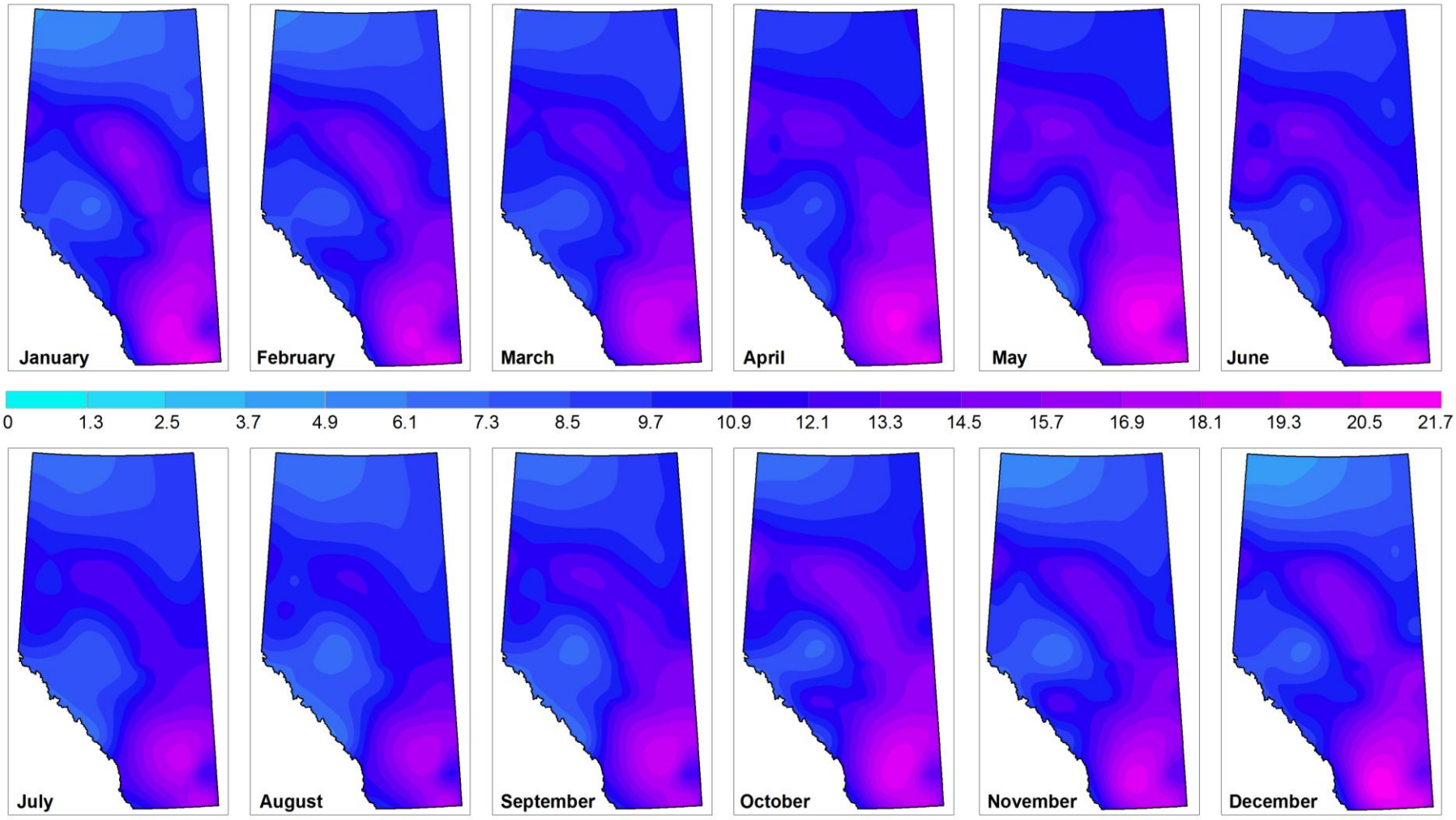
# Mean Monthly Sunshine Hours

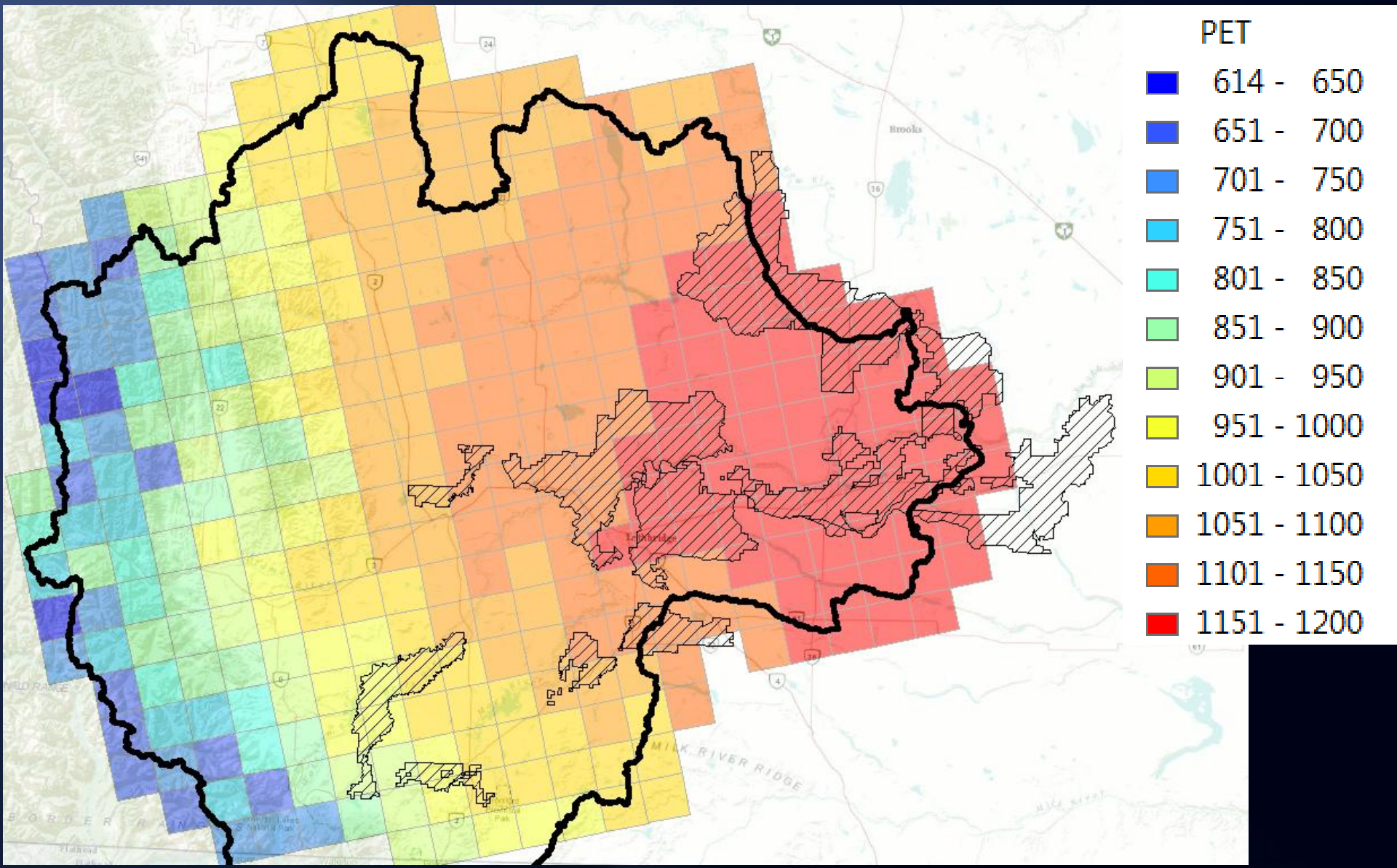


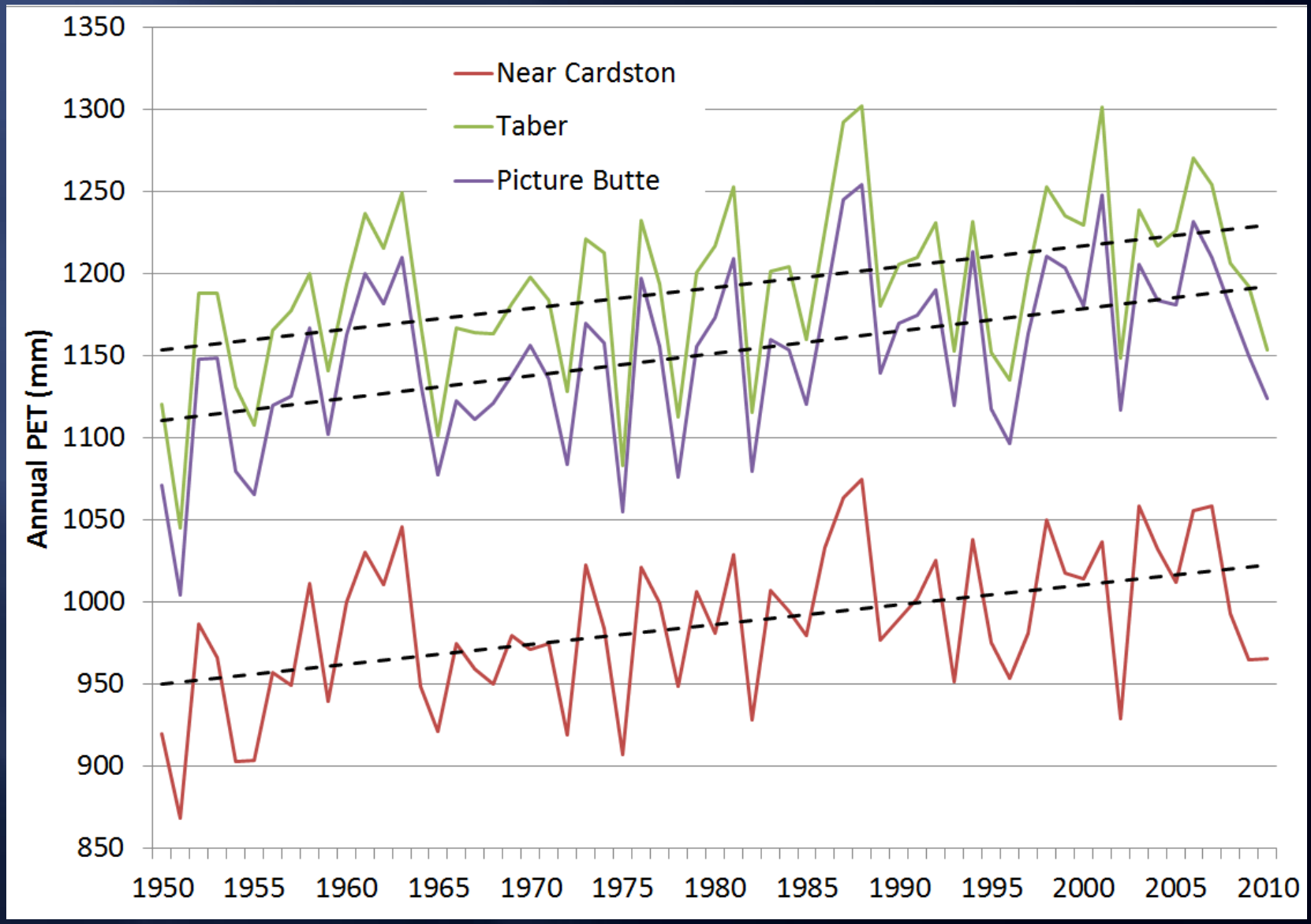
# Mean Monthly Relative Humidity [%]



# Mean Monthly Wind Speed [km/hr]




PET
614 - 650
651 - 700
701 - 750
751 - 800
801 - 850
851 - 900
901 - 950
951 - 1000
1001 - 1050
1051 - 1100
1101 - 1150
1151 - 1200
Brooks
Lethbridge
MILK RIVER RIDGE


Near Cardston
Taber
Picture Butte
Annual PET (mm)
1350
1300
1250
1200
1150
1100
1050
1000
950
900
850
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

Nash-Sutcliff_18Oct2013.xlsx - Microsoft Excel

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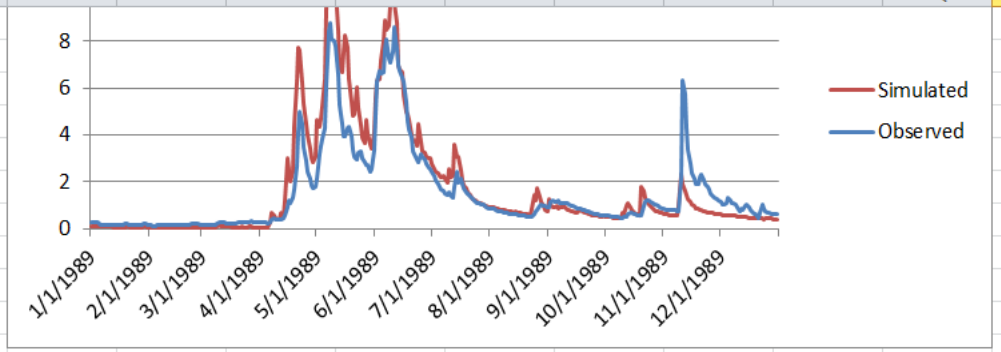
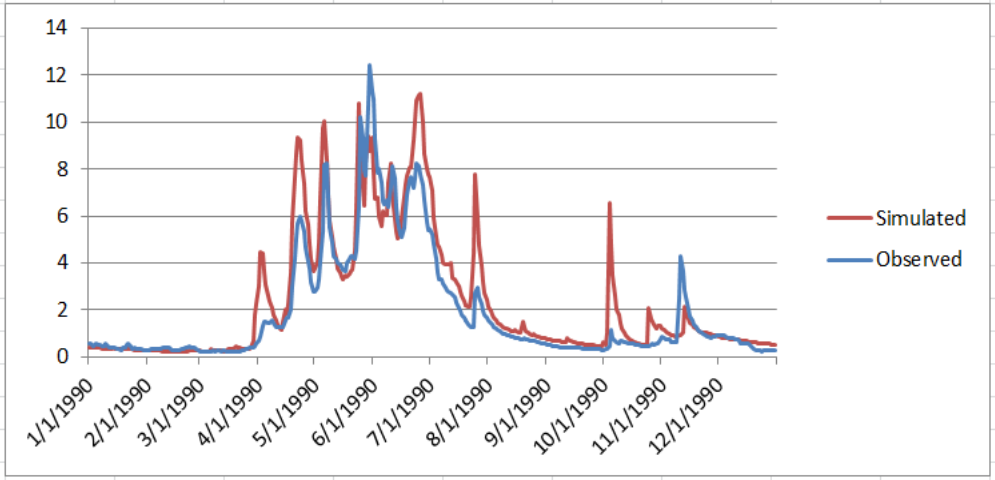
R185

| A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|
| 1971 | 10 | 21 | ######## | 197110 | | 0.26 |
| 1971 | 10 | 22 | ######## | 197110 | | 0.25 |
| 1971 | 10 | 23 | ######## | 197110 | | 0.25 |
| 1971 | 10 | 24 | ######## | 197110 | | 0.25 |
| 1971 | 10 | 25 | ######## | 197110 | | 0.25 |
| 1971 | 10 | 26 | ######## | 197110 | | 0.25 |
| 1971 | 10 | 27 | ######## | 197110 | | 0.24 |
| 1971 | 10 | 28 | ######## | 197110 | | 0.24 |
| 1971 | 10 | 29 | ######## | 197110 | | 0.23 |
| 1971 | 10 | 30 | ######## | 197110 | | 0.23 |
| 1971 | 10 | 31 | ######## | 197110 | | 0.22 |
| 1971 | 11 | 1 | ######## | 197111 | | 0.22 |
| 1971 | 11 | 2 | ######## | 197111 | | 0.21 |
| 1971 | 11 | 3 | ######## | 197111 | | 0.21 |
| 1971 | 11 | 4 | ######## | 197111 | | 0.21 |
| 1971 | 11 | 5 | ######## | 197111 | | 0.21 |
| 1971 | 11 | 6 | ######## | 197111 | | 0.2 |
| 1971 | 11 | 7 | ######## | 197111 | | 0.2 |
| 1971 | 11 | 8 | ######## | 197111 | | 0.2 |
| 1971 | 11 | 9 | ######## | 197111 | | 0.21 |
| 1971 | 11 | 10 | ######## | 197111 | | 0.21 |
| 1971 | 11 | 11 | ######## | 197111 | | 0.22 |
| 1971 | 11 | 12 | ######## | 197111 | | 0.22 |
| 1971 | 11 | 13 | ######## | 197111 | | 0.22 |
| 1971 | 11 | 14 | ######## | 197111 | | 0.22 |
| 1971 | 11 | 15 | ######## | 197111 | | 0.21 |
| 1971 | 11 | 16 | ######## | 197111 | | 0.21 |
| 1971 | 11 | 17 | ######## | 197111 | | 0.21 |
| 1971 | 11 | 18 | ######## | 197111 | | 0.2 |
| 1971 | 11 | 19 | ######## | 197111 | | 0.2 |

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Data-Stats | **Data-Graphs** | Daily Streamflow Graph | Monthly Streamflow Graph | Data-Daily Probability | Daily Probabi