

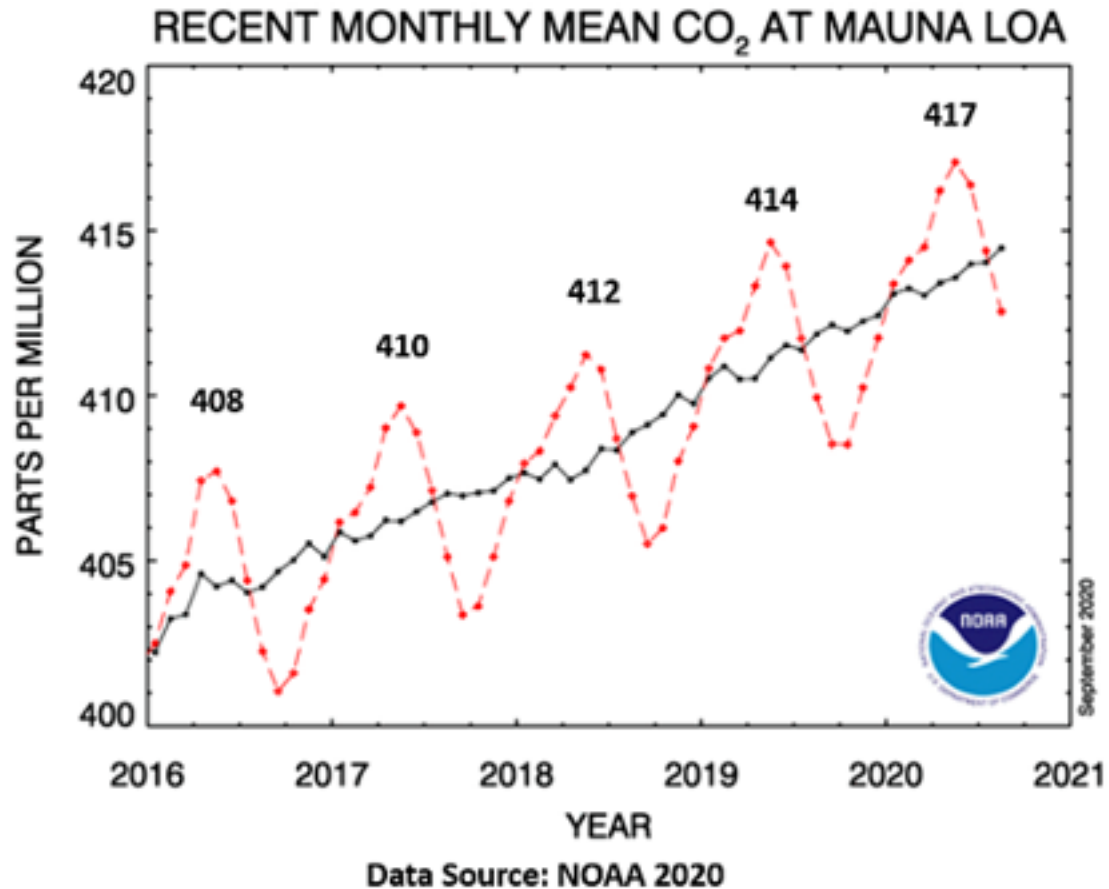
Too Hot, Too Cold, Too Dry, Too Wet What is Happening to Climate Change in Mountains



Hans Schreier, Land & Food Systems, Univ. of British Columbia, Canada

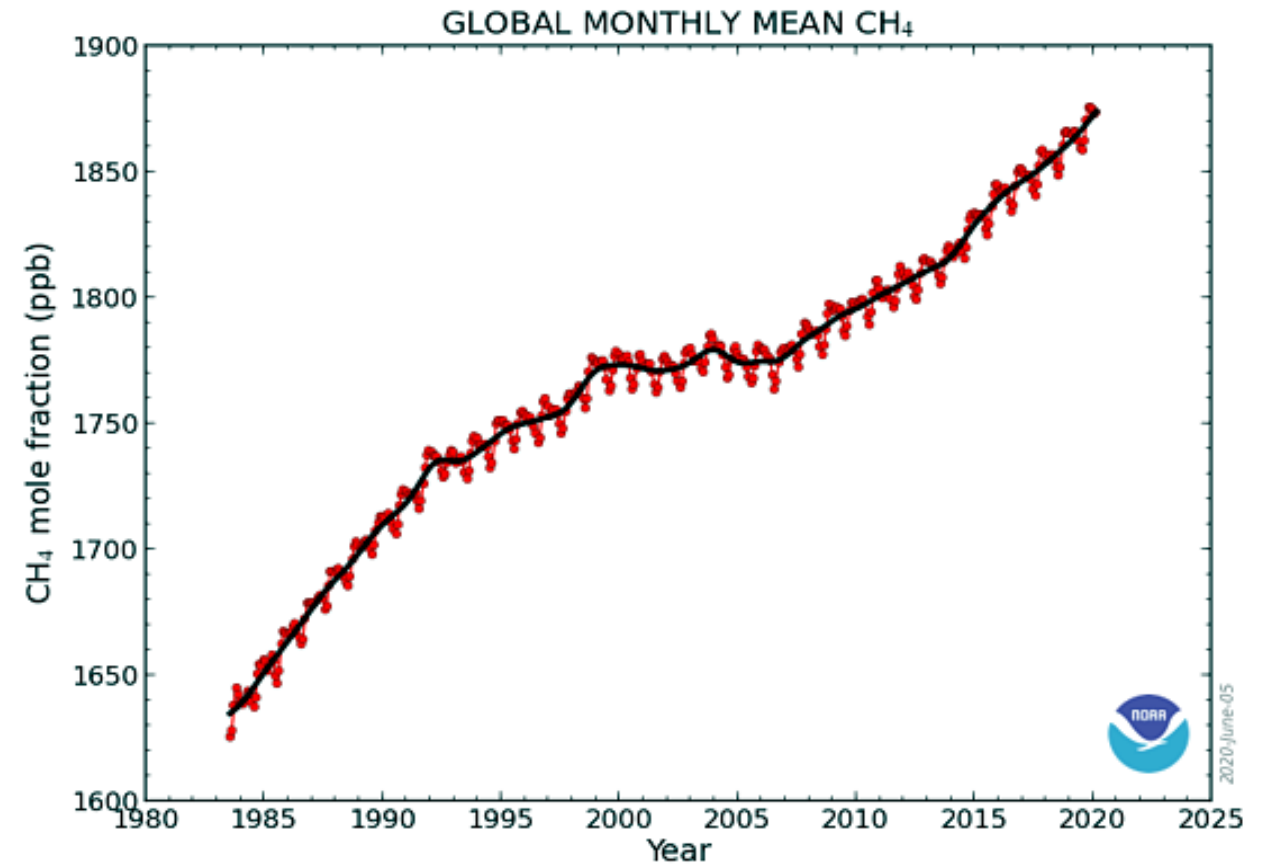
CO₂

Greenhouse Gas Emissions (GHG)



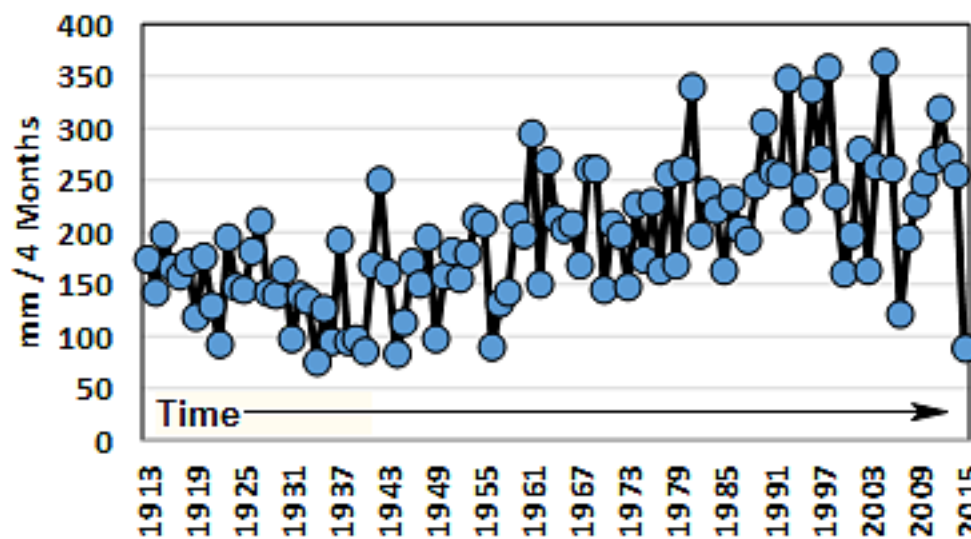
May 2020 Peak 417 ppm

Methane CH₄

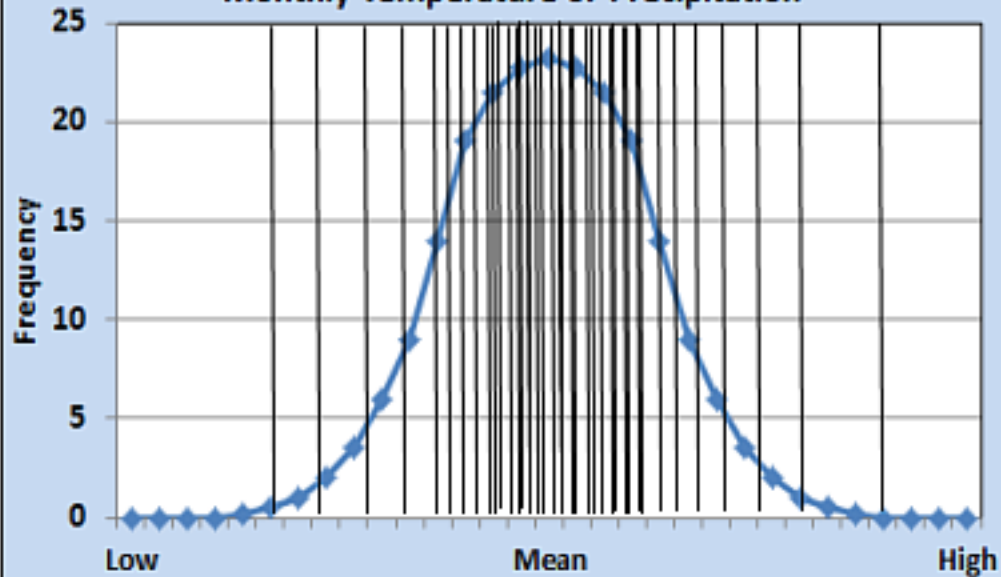


28 x more effective than CO₂ in trapping radiation but shorter Live-cycle.

Precipitation April- August 1913-2015

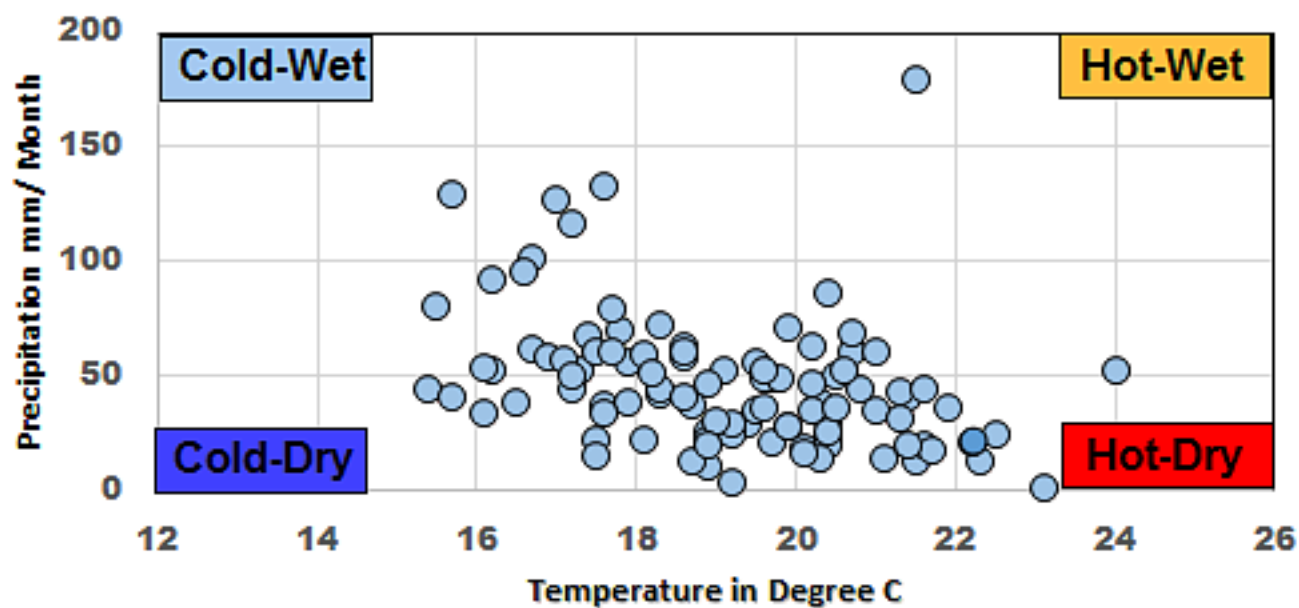


Monthly Temperature or Precipitation

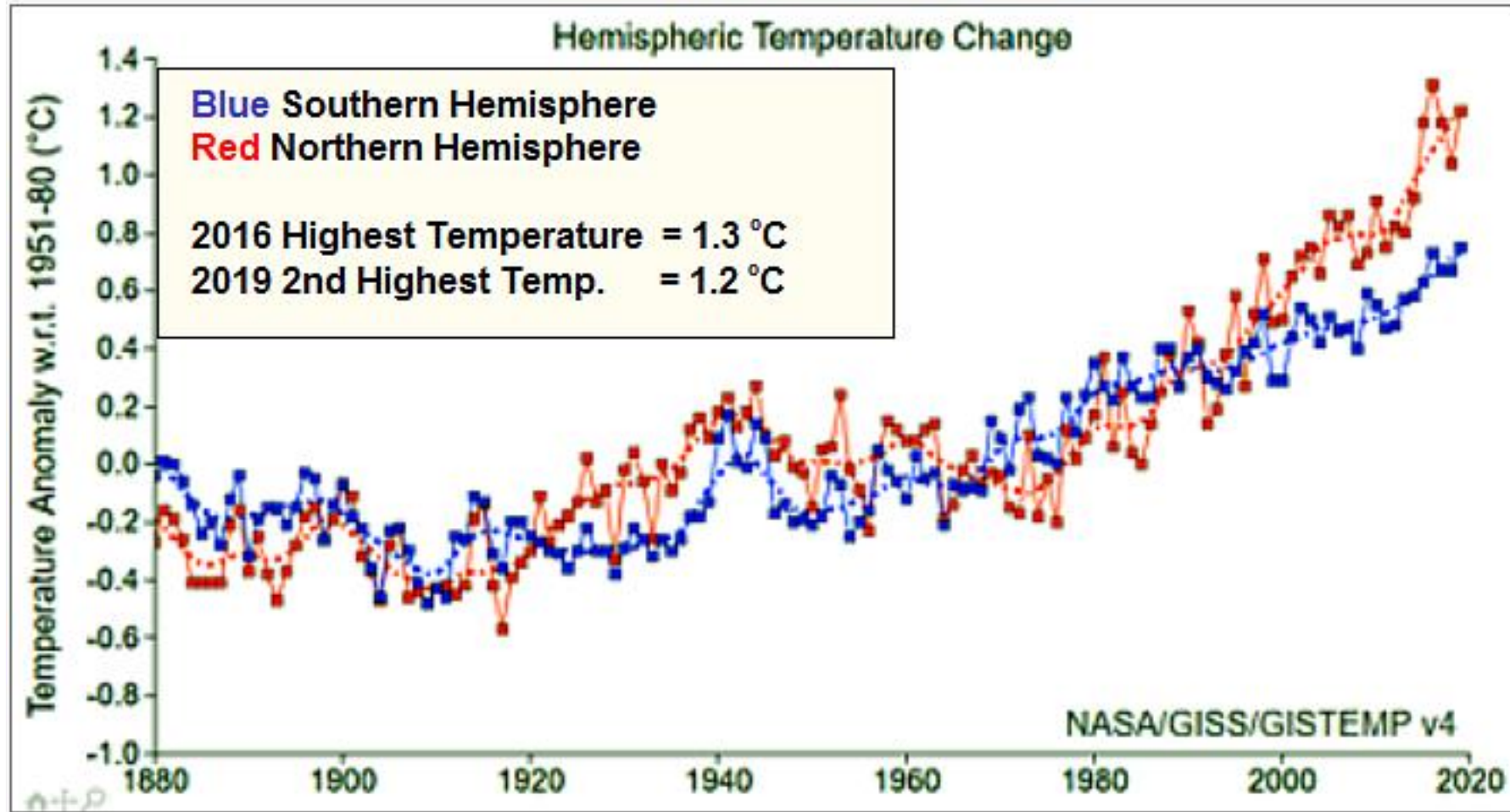


X Y over Time

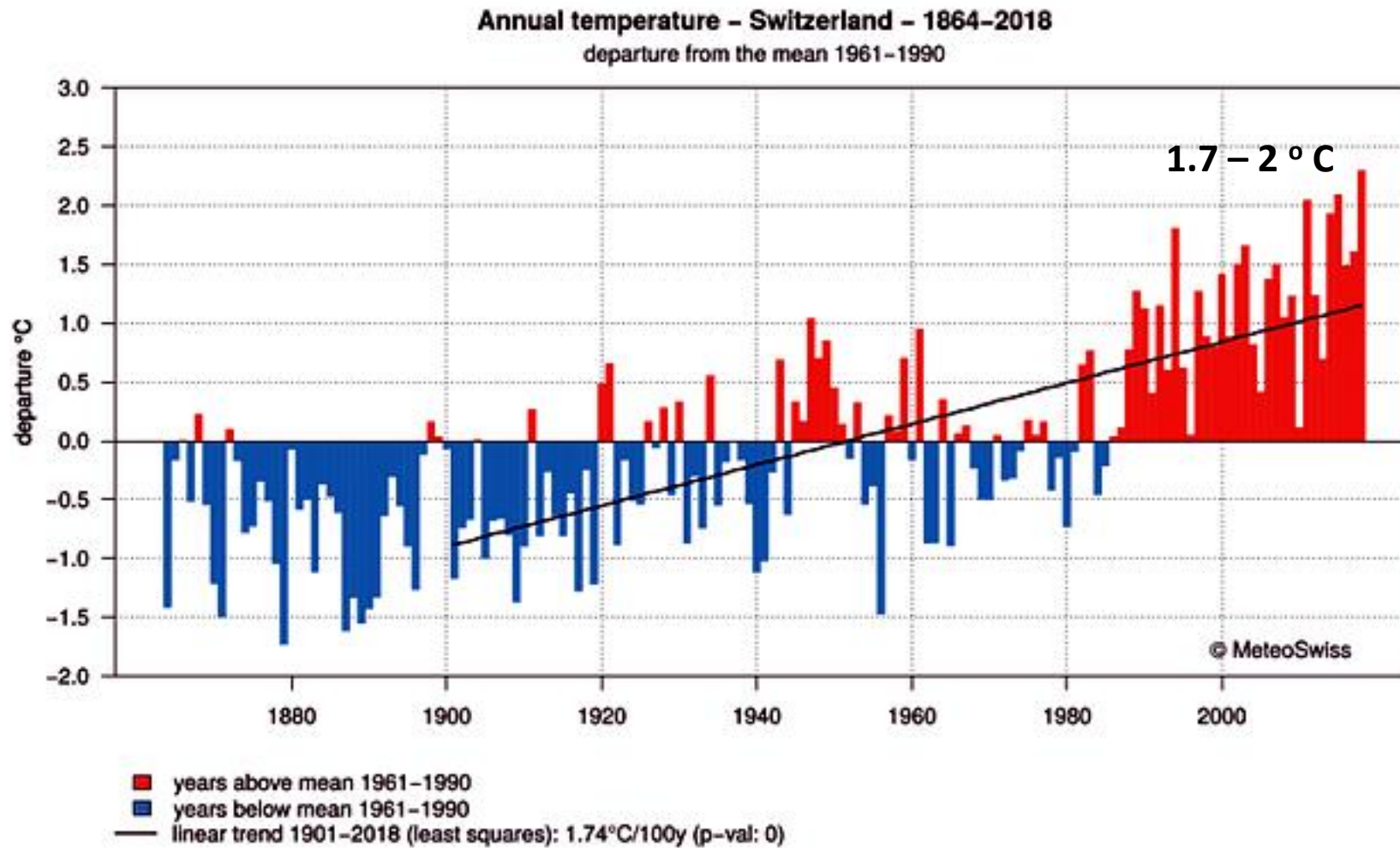
May Temperatures vs. Precipitation 1913-2015



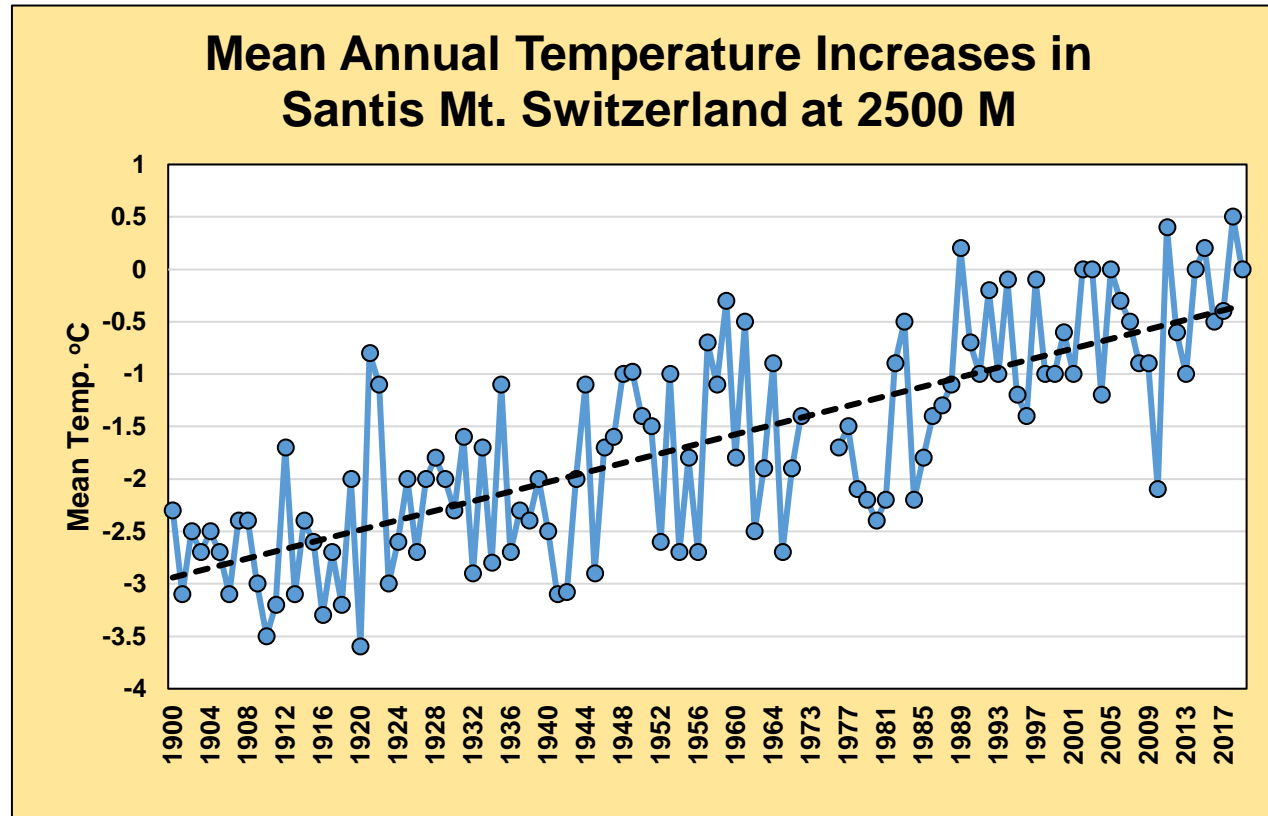
Surface Temperature Changes since 1880



Temperature Change in Switzerland Since 1861



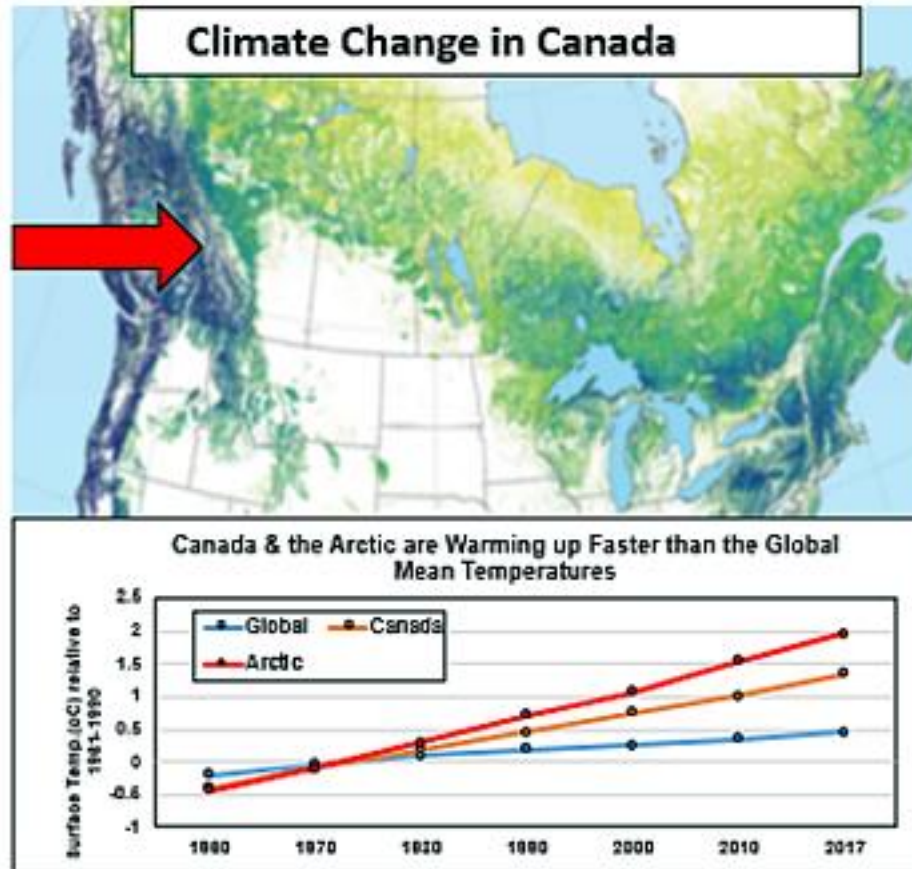
Increase = 2.5 °C over 120 Years



**There are very few
high elevation climate
station with long term
records**

**There is now enough
information available
to show that high
mountains areas are
warming up faster
than many lowland
stations.**

Rapid Temperature Increases in Canada, in B.C. & in the Canadian Arctic



Gov.. Canada 2019: Canada's Changing Climate Report.
<https://changingclimate.ca/CCCR2019/>

1948-2016			
Temperature Change °C			
	B.C.	Canada	Arctic
Annual	1.9 °C	1.7 °C	2.3 °C
Winter	3.7 °C	2.3 °C	4.3 °C
Spring	1.9 °C	1.7 °C	2.0 °C
Summer	1.4 °C	1.5 °C	1.6 °C
Autumn	0.7 °C	1.7 °C	2.3 °C

1948-2012			
Precipitation Change %			
	B.C.	Canada	Arctic
Annual	5%	18%	33%
Winter	-9%	20%	54%
Spring	-18%	25%	42%
Summer	8%	13%	18%
Autumn	12%	19%	32%

Evidence of Global, Mountains & Arctic Temperature Changes

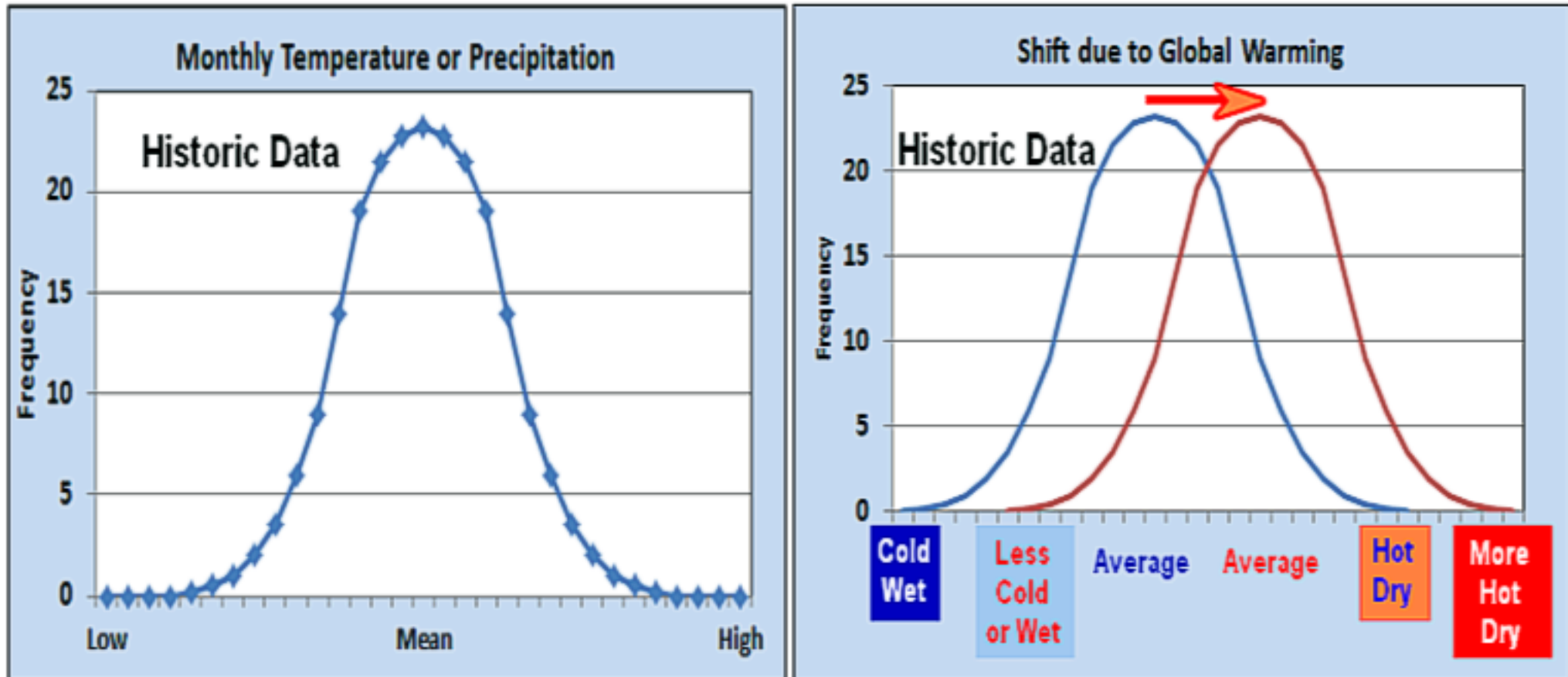
Average Temperature Increases 1900-2016

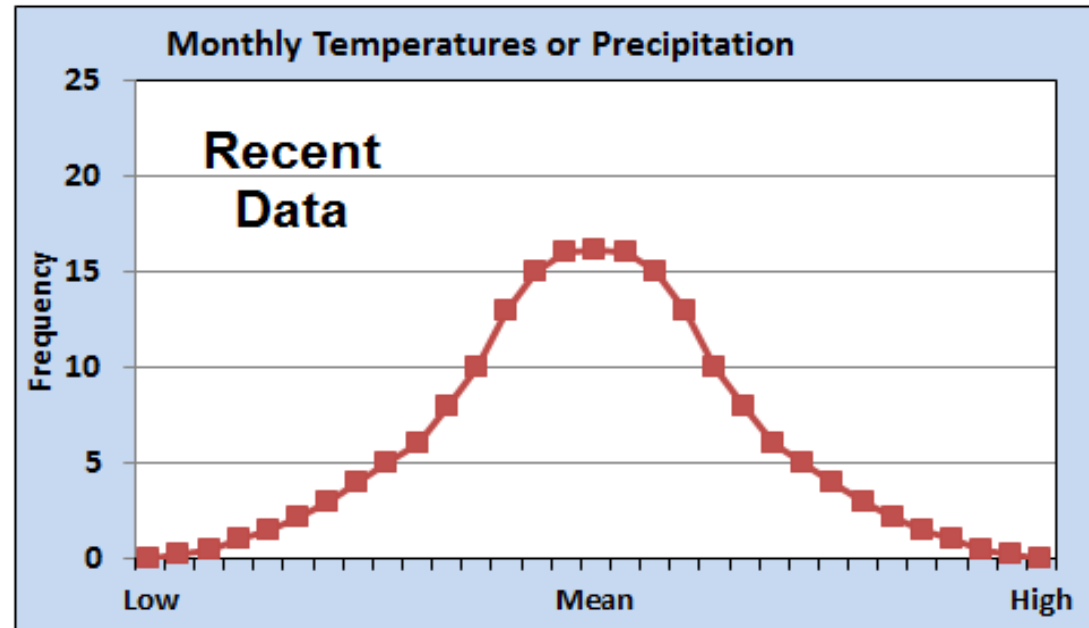
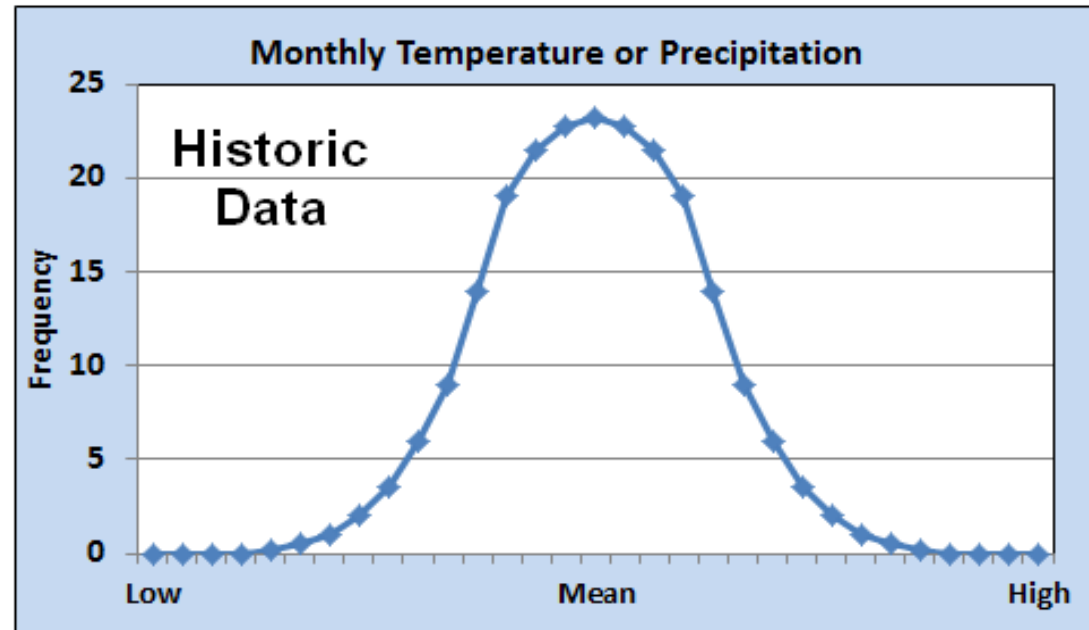
Northern Hemisphere	1.3 °C
Switzerland	1.7-2 °C
Santis Mtn. 2500 m CH	2.5 °C
Canadian Mtn. B.C.	1.9 °C
Canadian Arctic	2.3 °C



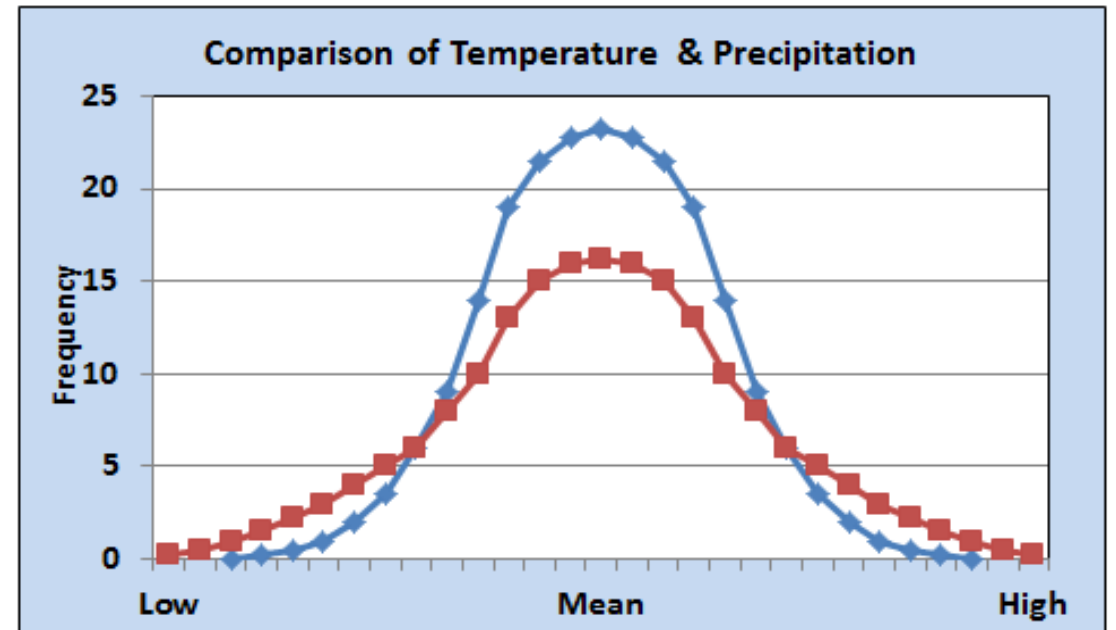
Assumption:

Historic Variability is Unchanged but Global Warming is Increasing

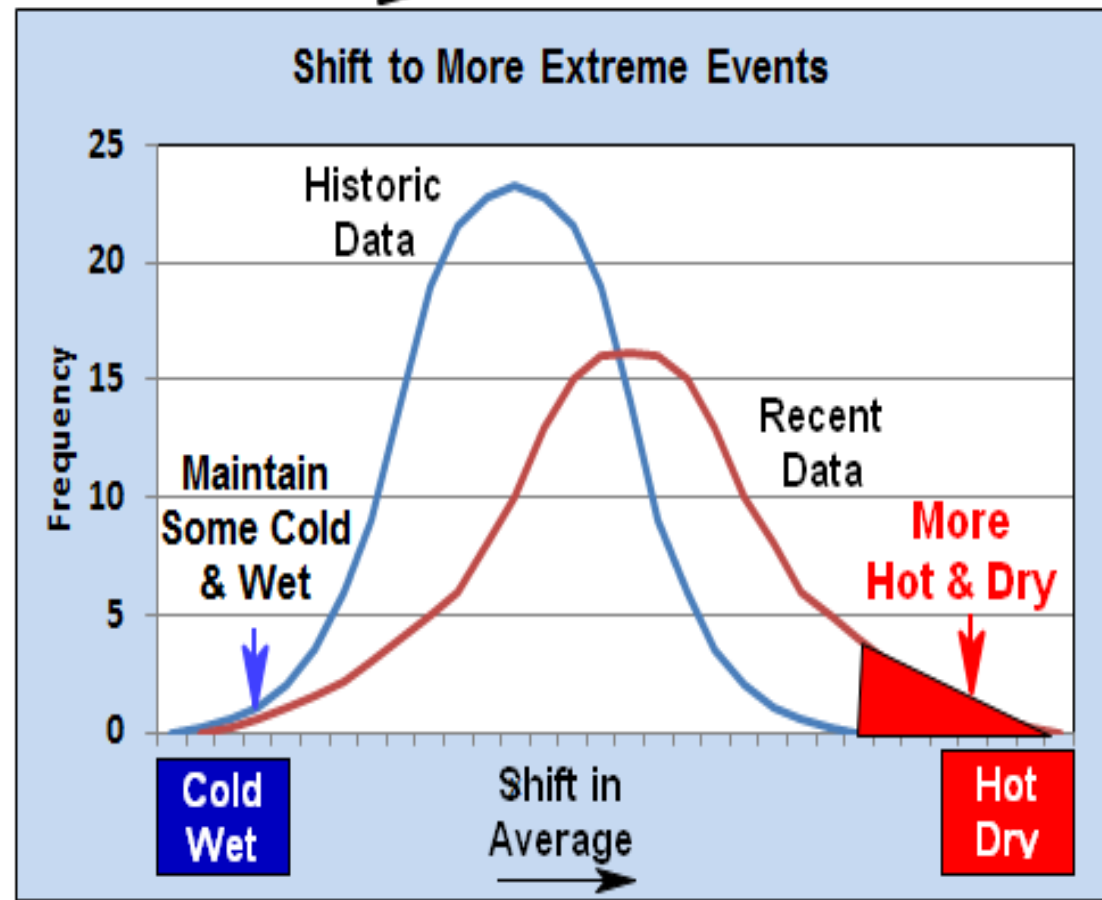
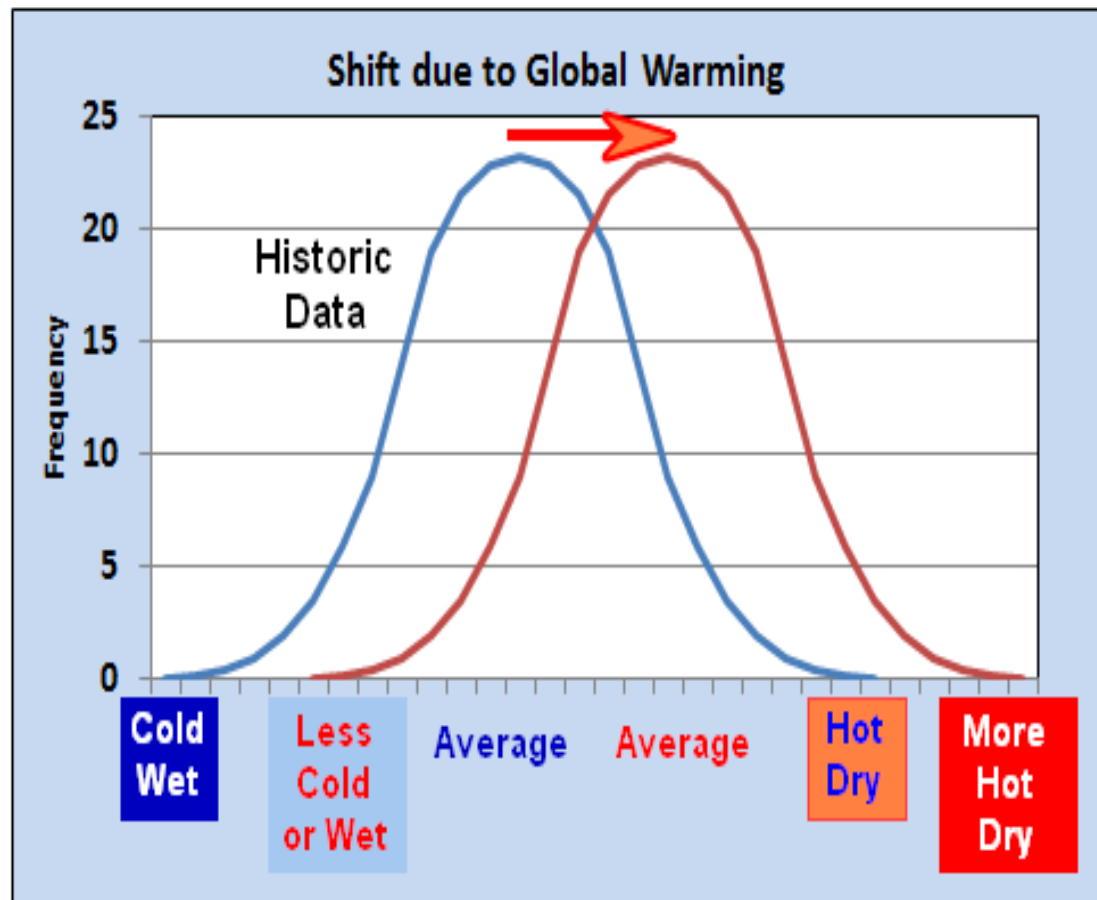




Assumption :
Shift from Historic to More Varariable Data but no Global Warming

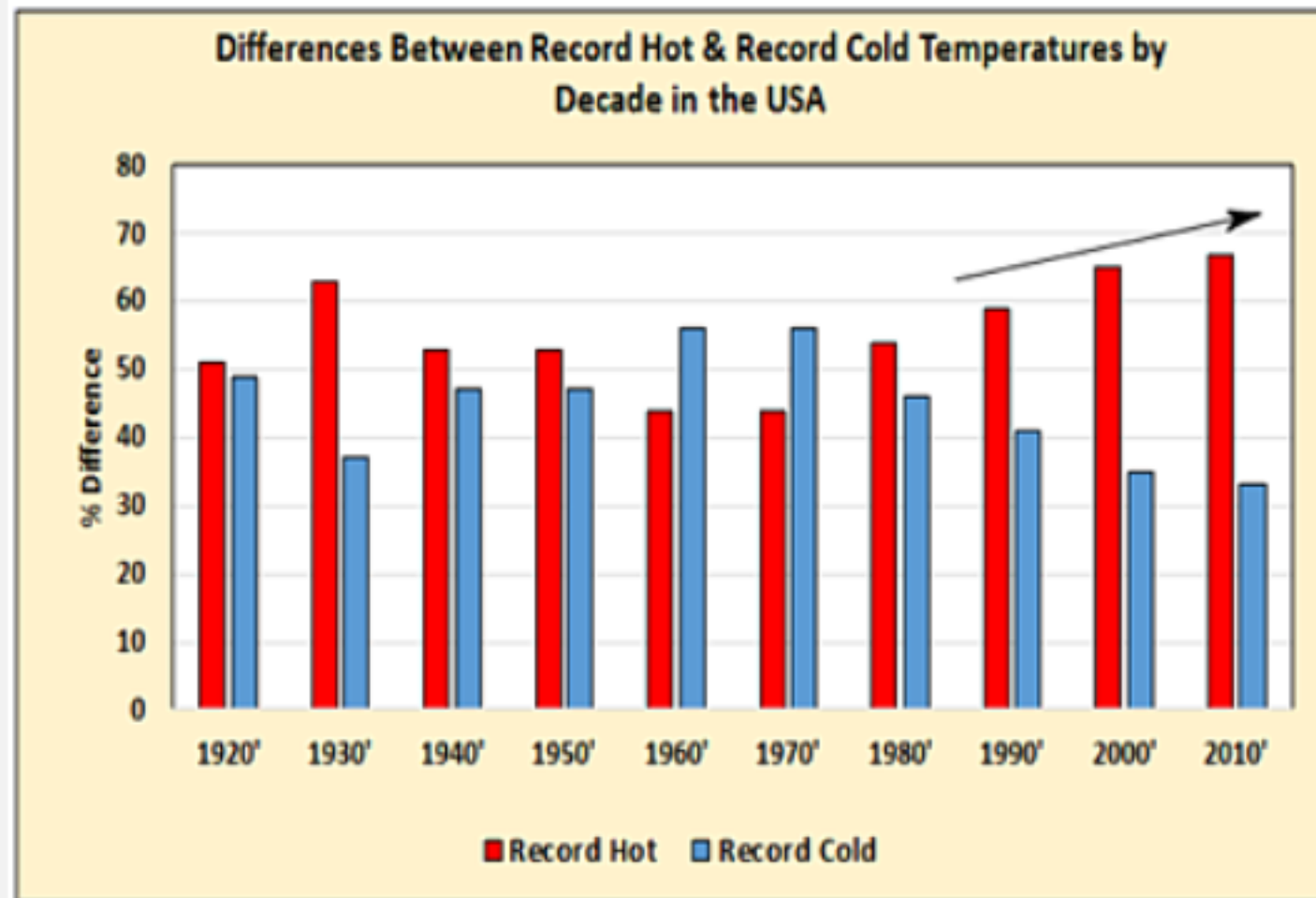


Moving from Left to Right



**Results: We will have more extreme event
Less frequent cold & wet more frequent hot and dry conditions**

Differences Between Record Low and High Temperatures by Decades in the USA

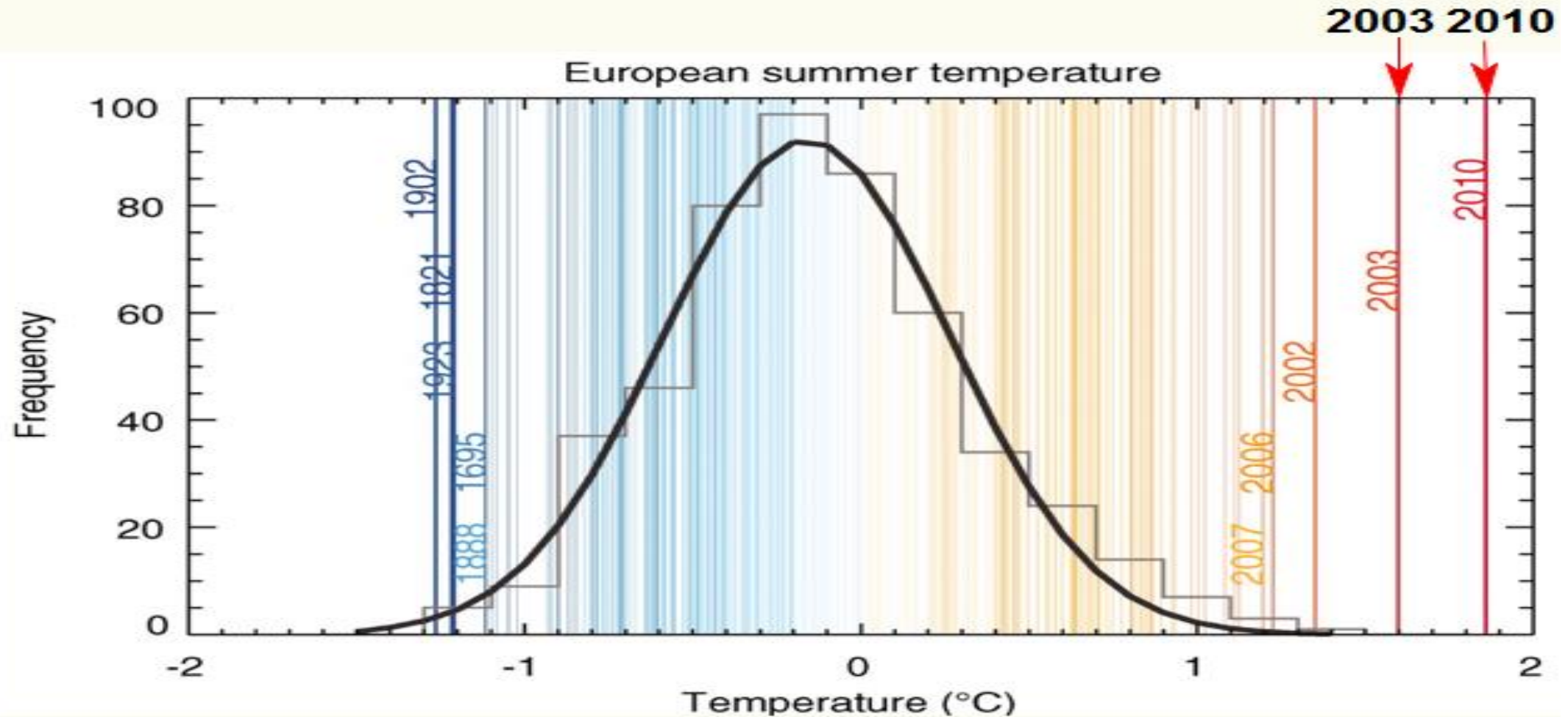


Increasing Record Hot Temperatures and Decreasing Record Low Temperatures 1980'-2010'

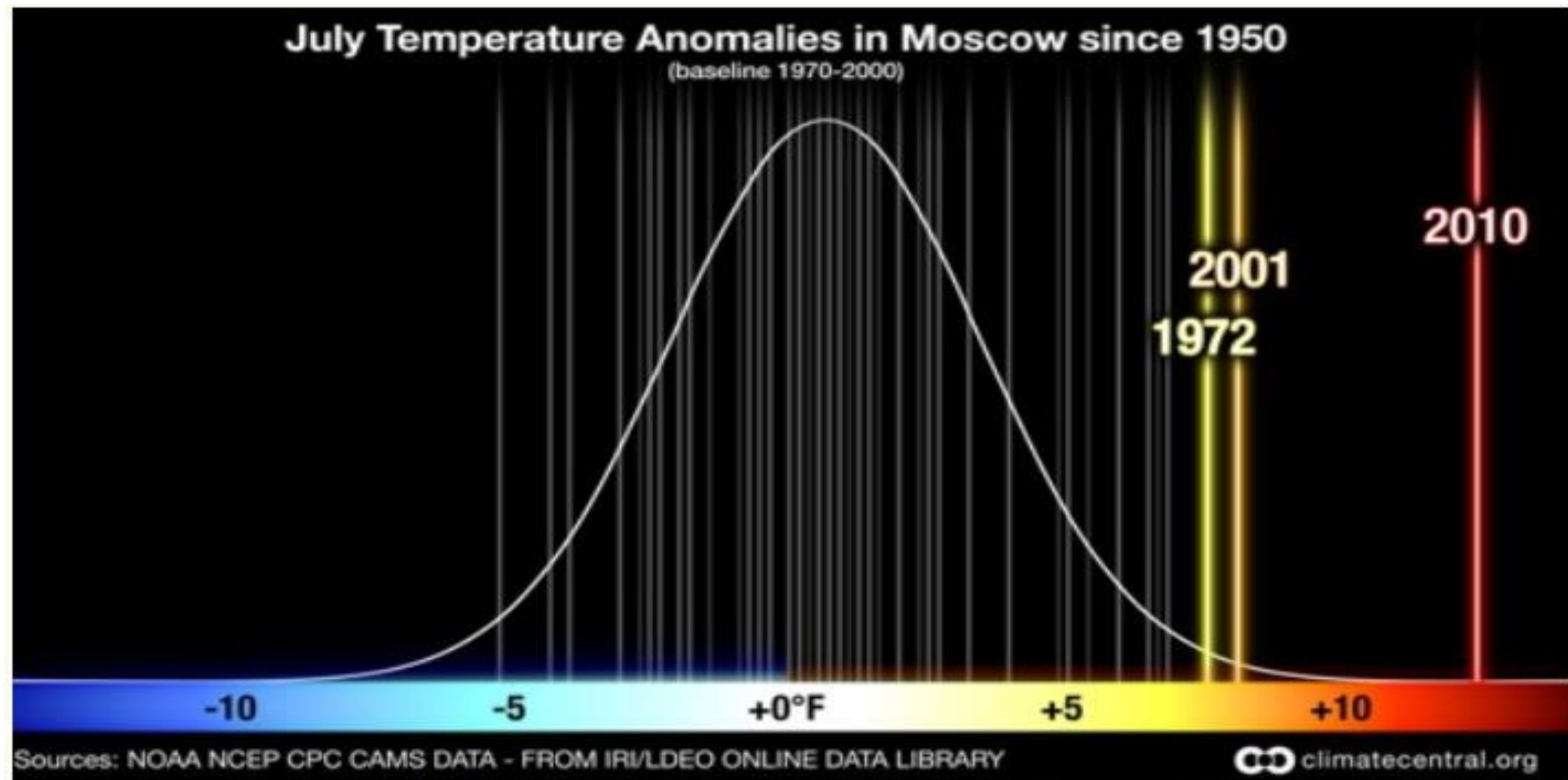
Data Source:

Climate Central 2017

Extreme Events

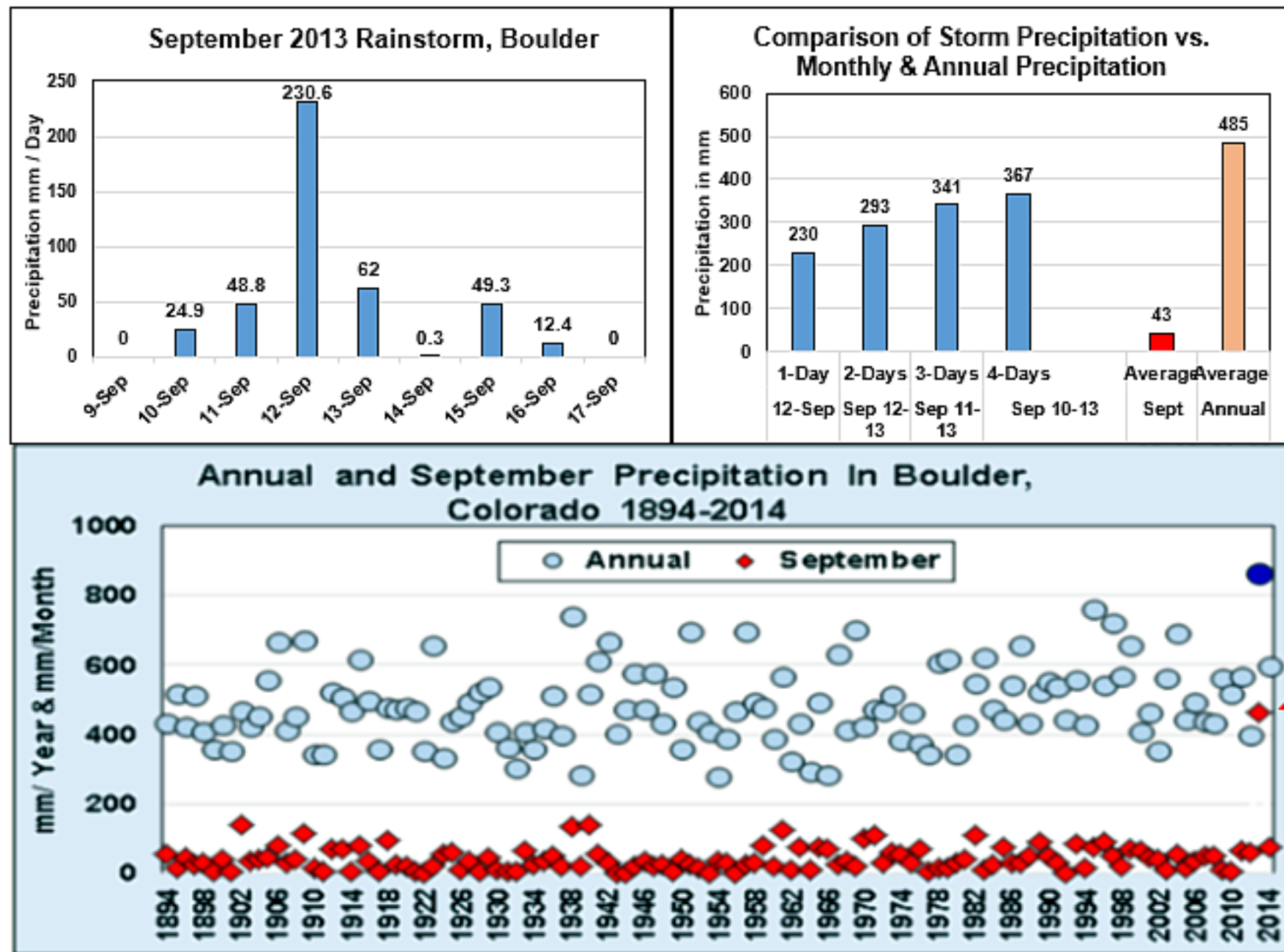


Data Source: Barriopedro et al. 2011. The hot summer of 2010. Redrawing the temperature record Map of Europe. Science: 332(6026):220-224



Anomaly of July 2010 Temperature in Moscow since 1950
Source: NOAA, Climate Central and Tebaldi & Ziemlinski, 2010
(with permission)

Extreme Storm Events in Colorado at 1700 m Elevation

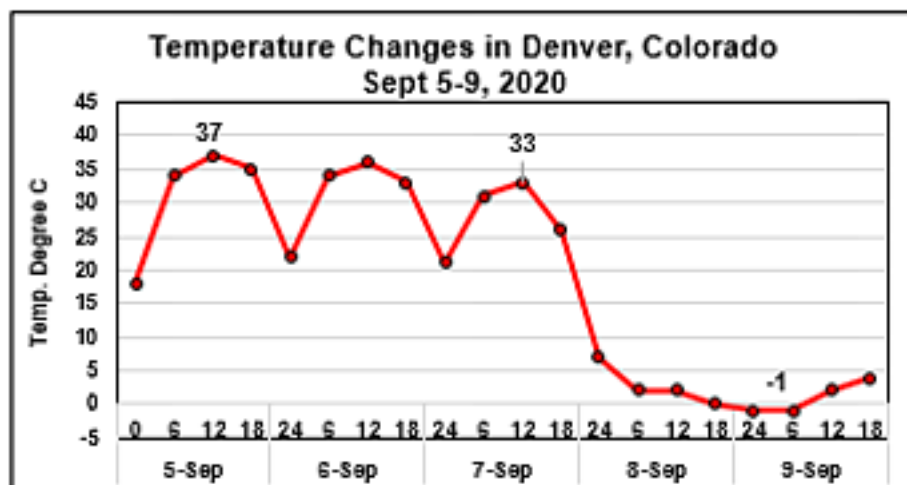


Unusual Climate Event in Colorado Sept 2020

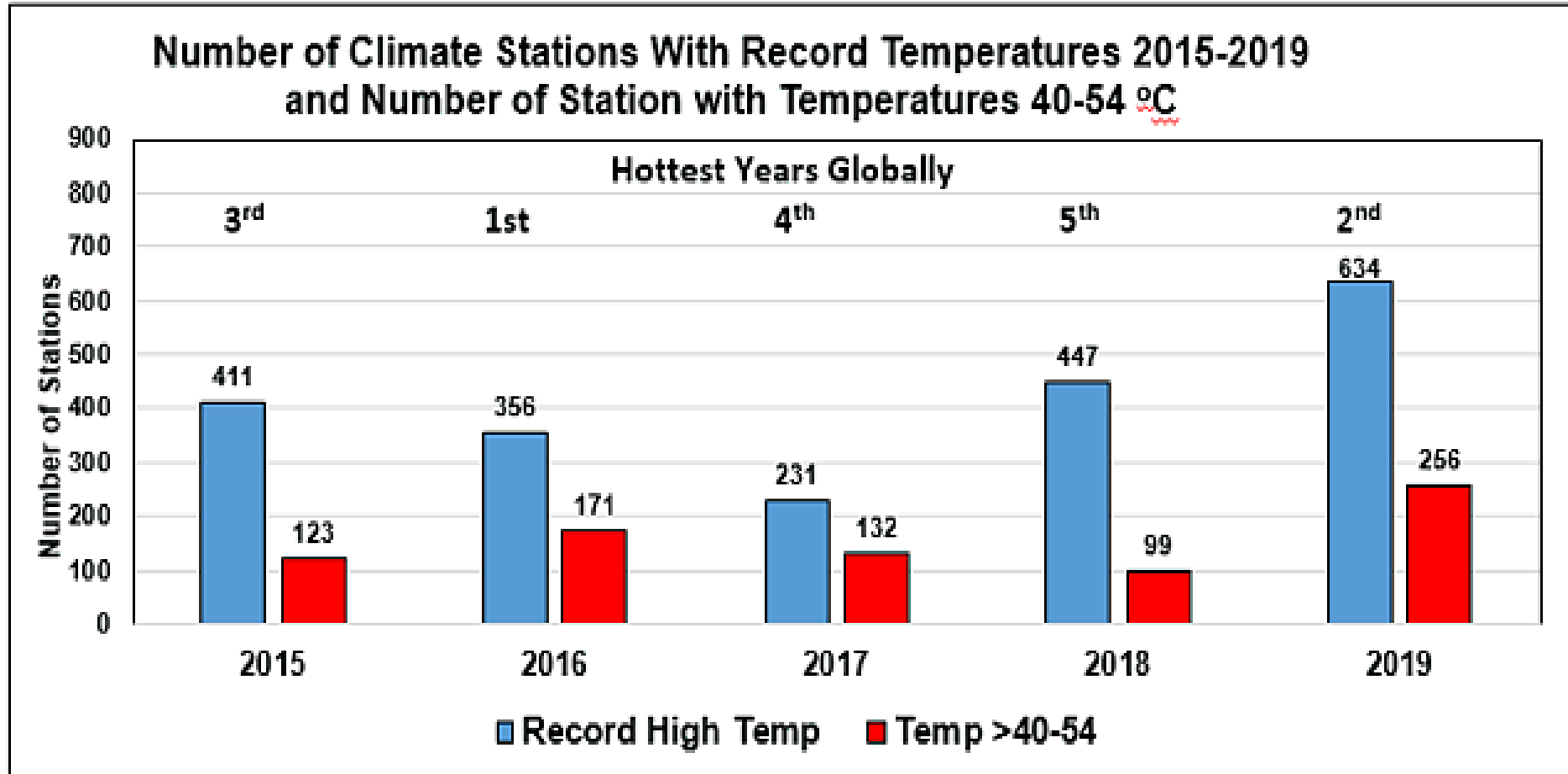
From 37 °C to -1 °C & Snow in 4 Days
From 33 °C to -1 °C & Snow in 2 Days

Colorado Record Hot August 2020
5th Driest August
Wildfires in August >1300 Km²
Spruce Bark Beetle Infestation

September 5-9, 2020 Climatic Event
Temperature Change:
35 Degree Drop in 48 Hours
From 34 Degree C to Snow



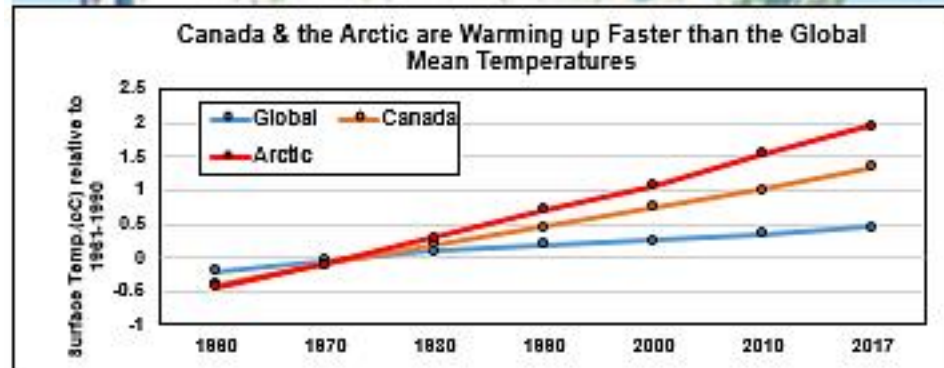
Changes in the Number of Record Temperatures 2015-2020



Highest Ever Temperatures Recorded in Different Countries Between 2015-2020

3rd Hottest Year		Hottest Year		4th Hottest Year		5th Hottest Year		2nd Hottest Year			
2015	Temp.	2016	Temp.	2017	Temp.	2018	Temp.	2019	Temp	*2020	Temp
UAE	51.2	Kuwait	54	Iran	53.7	Algeria	51.3	Syria	50	USA	54.4
China	50.3	Iraq	53.9	China	50.5	Japan	41.1	France	46	Lebanon	45.4
Venezuela	43.6	India	51	Spain	47.3	S-Korea	41	Zimbabwe	45.9	Ghana	44
Ghana	43.3	Niger	49	Chile	45	Taiwan	40.3	Togo	43.5	Taiwan	40.5
Peru	41.6	Burkina Faso	47.5	Ghana	43.8			Vietnam	43.4	Cuba	39.7
Germany	40.3	Thailand	44.6	Comodors	36			Belgium	41.8		
Switzerland	39.7	Botswana	44.3					Angola	41.6		
Cuba	39.3	Cambodia	42.6					Germany	41.2		
Belgium	38.8	Angola	40.7					Luxenburg	40.8		
French Guiana	37.9	Jamaica	38					Netherlands	40.7		
Dominica	35.5	Vanuatu	36.2					Andorra	39.4		
		Marshall Isl	35.6					Jamaica	39.1	Partial Data Jan-Aug	
		Maldives	35					UK	38.7		
								Timor Leste	38.5		

Data Compiled from: M. Herrera 2020, www.mherrera.org/temp.htm



Gov.. Canada 2019: Canada's Changing Climate Report.
<https://changingclimate.ca/CCCR2019/>

1948-2016			
Temperature Change ° C			
	B.C.	Canada	Arctic
Annual	1.9 °C	1.7 °C	2.3 °C
Winter	3.7 °C	2.3 °C	4.3 °C
Spring	1.9 °C	1.7 °C	2.0 °C
Summer	1.4 °C	1.5 °C	1.6 °C
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1948-2012			
Precipitation Change %			
	B.C.	Canada	Arctic
Annual	5%	18%	33%
Winter	-9%	20%	54%
Spring	-18%	25%	42%
Summer	8%	13%	18%
Autumn	12%	19%	32%



Total Size: 660000 km²

Canadian Portion 80000 Km² (15% of Basin)

Produces 40% of annual Streamflow

Highest Vertical Gradient in NA

Canadian Portion:

Population: 150000 People (4% of B.C.)

20 Communities (200-20000 People)

Economic Activities:

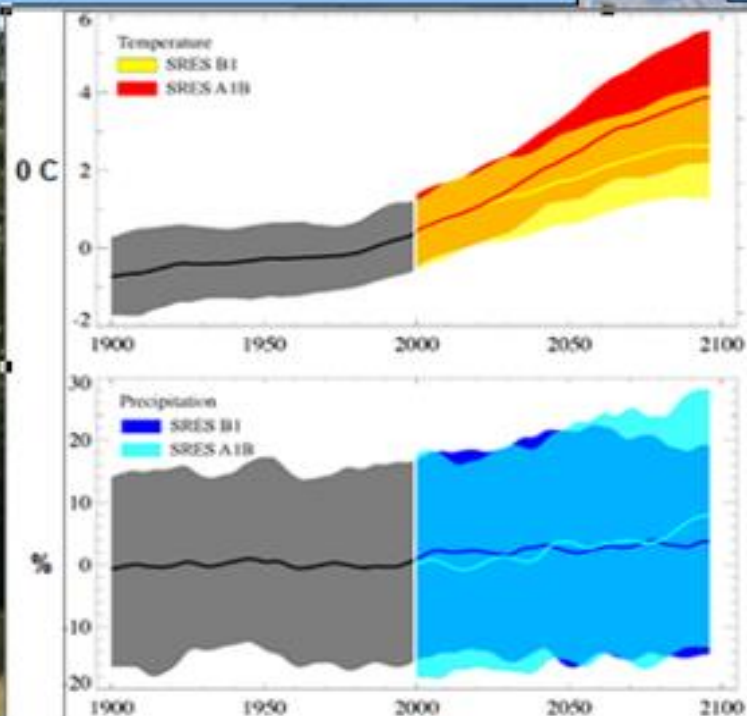
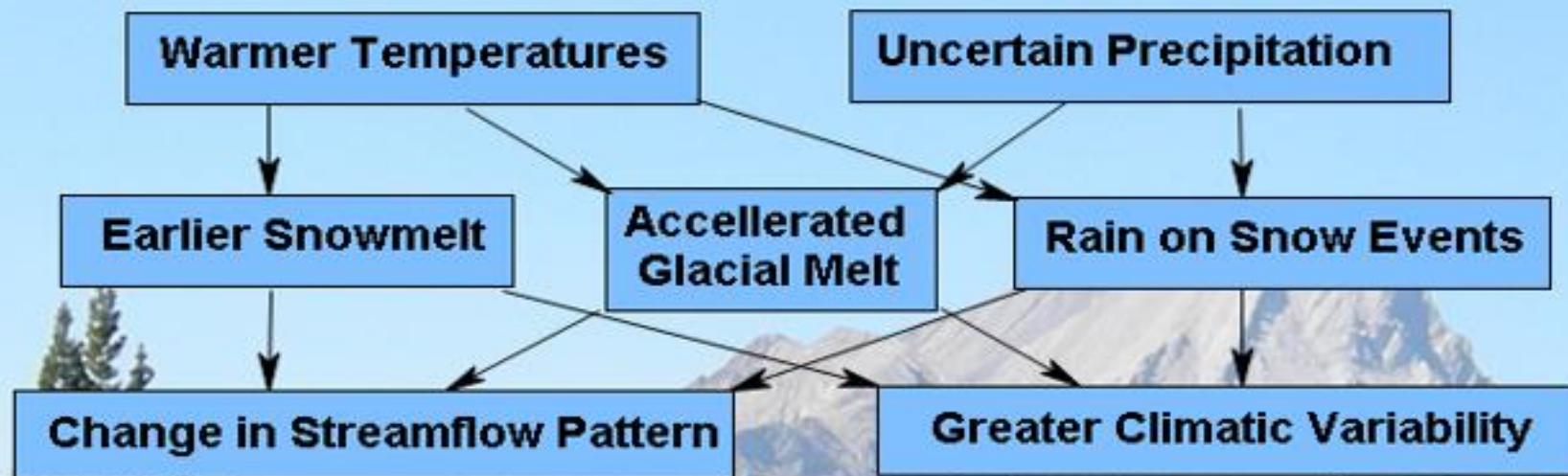
Forestry, Mining (Coal)

Hydro Power (50% of Electricity for B.C.)

Recreation (Winter & Summer)

Minor Agriculture

Key Climate Change Processes in the Northern Hemisphere



Model Consensus:

Temperatures:

Strong Warming in all Seasons particularly in the Summer

Model Consensus:

Precipitation:

**Small Changes in Annual Precipitation
Wetter Winter & Spring
Large Uncertainties!**

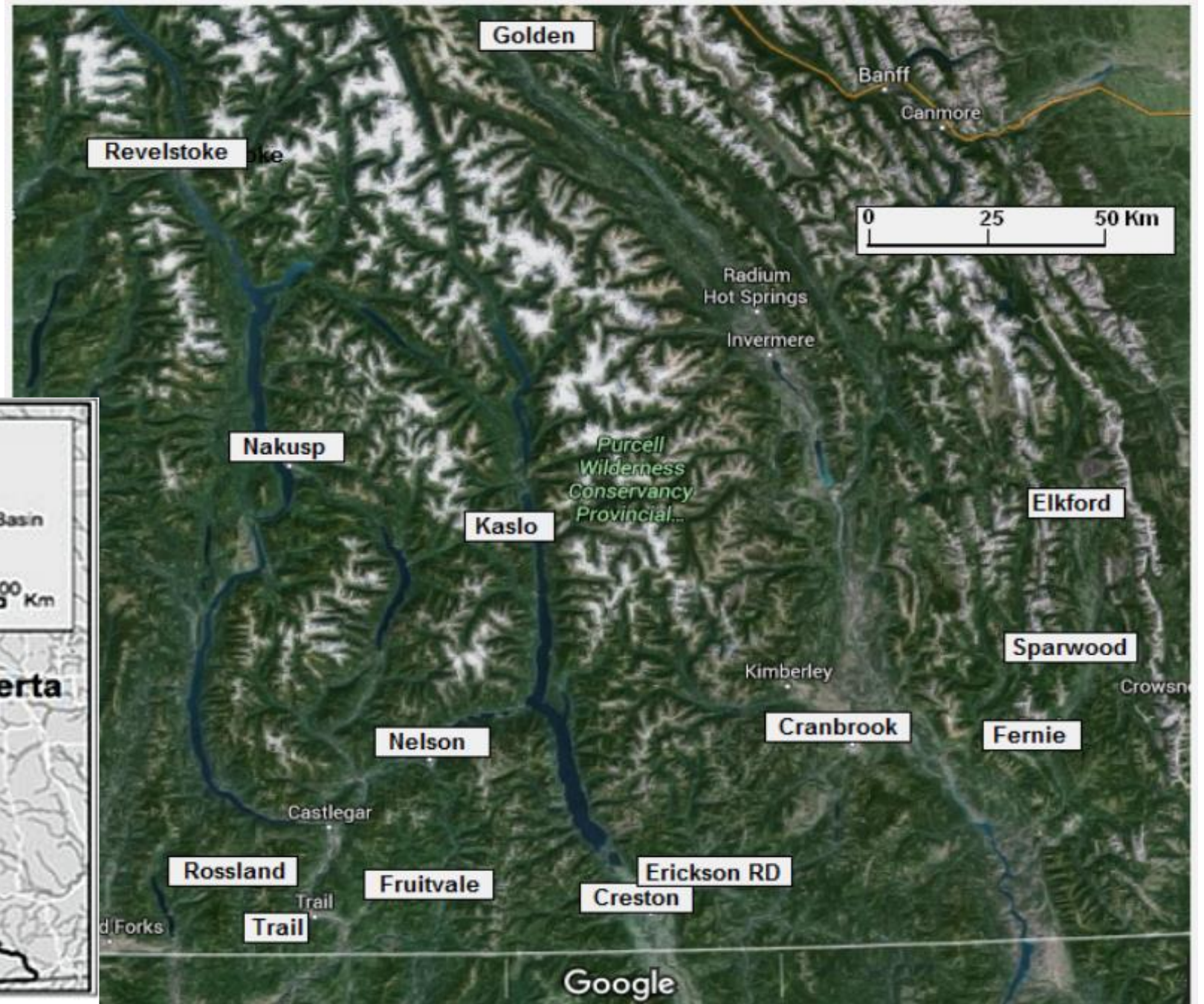
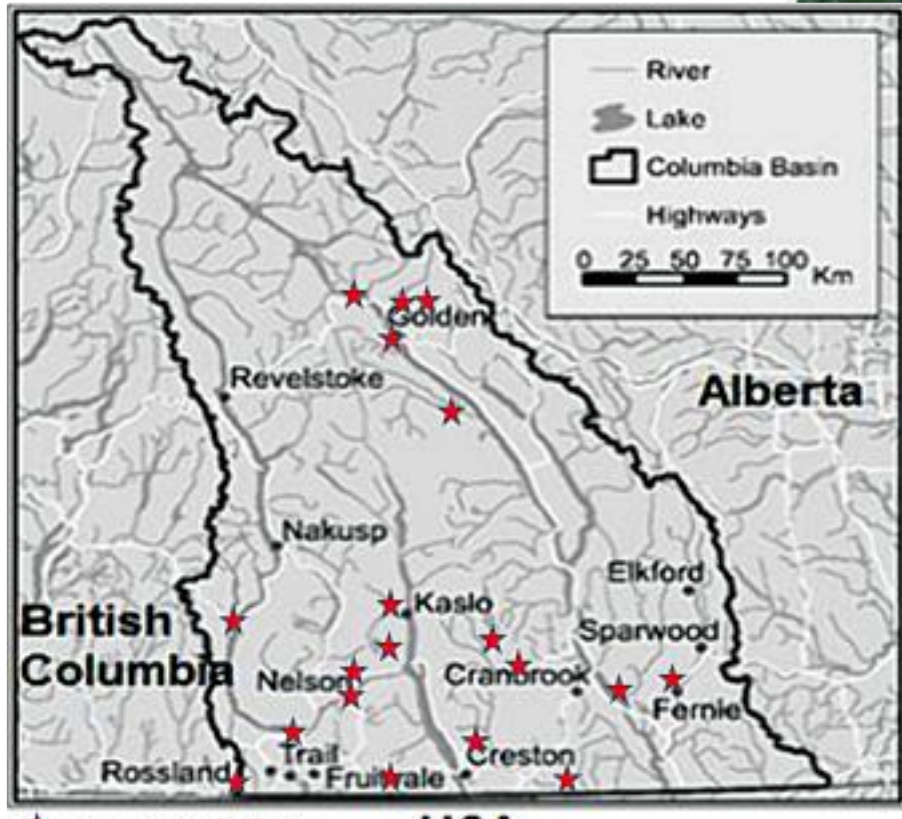
Source: A. Hamlet
(with Permission)

Canadian Portion of Columbia Basin

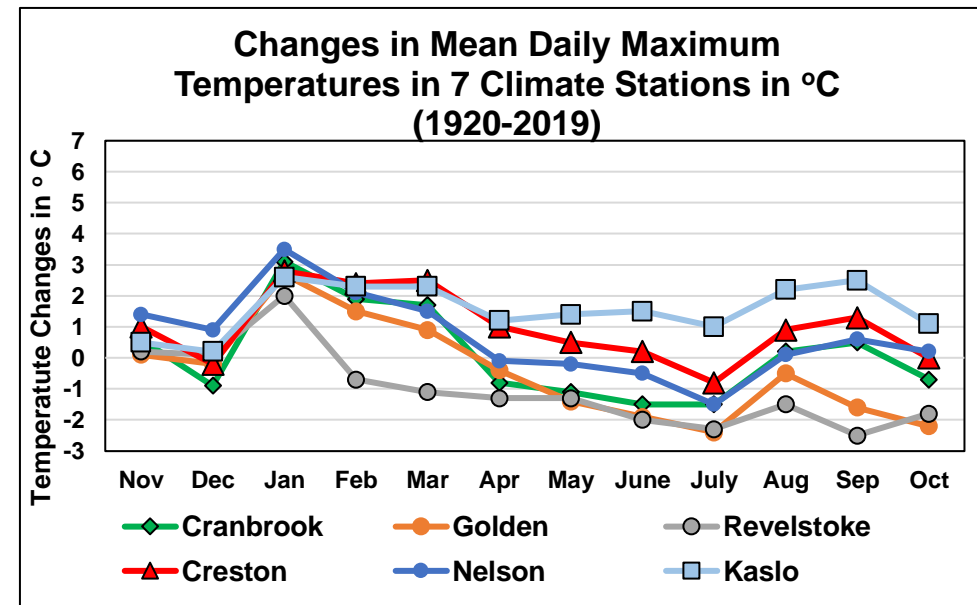
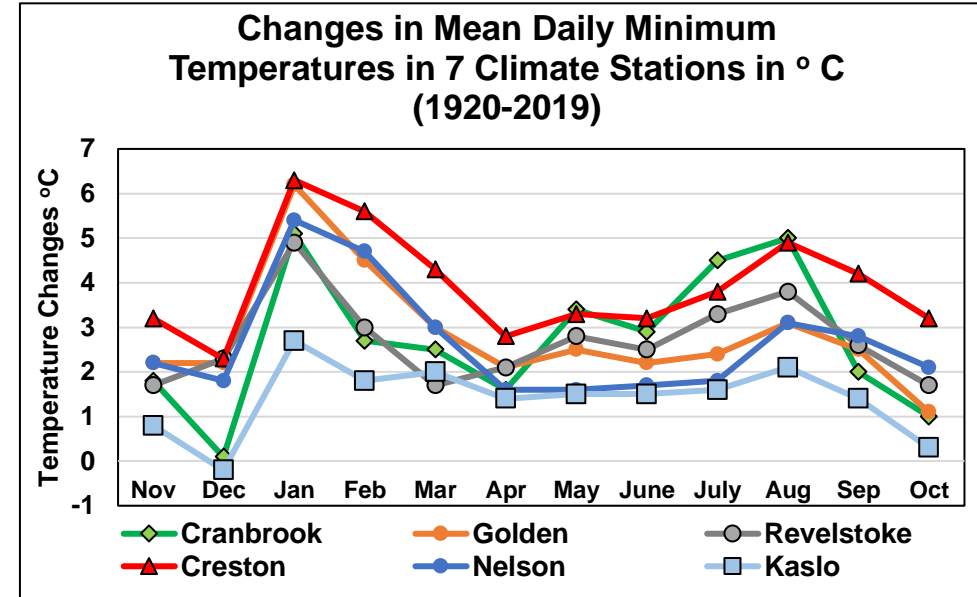
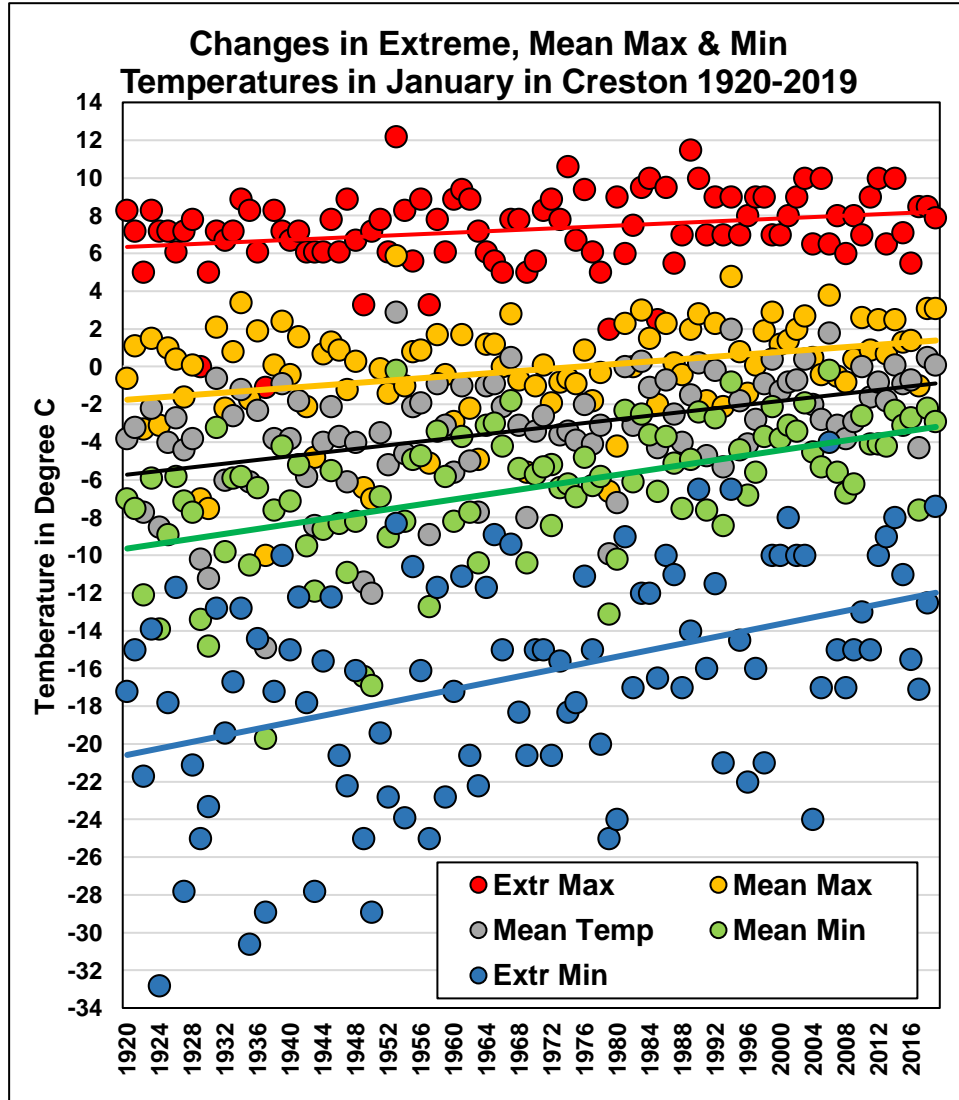
Climate Impact Analysis Based on:

10 Long term Climate Station
(100 year Records) names

18 River Discharge Stations
(50 Year Records) red star

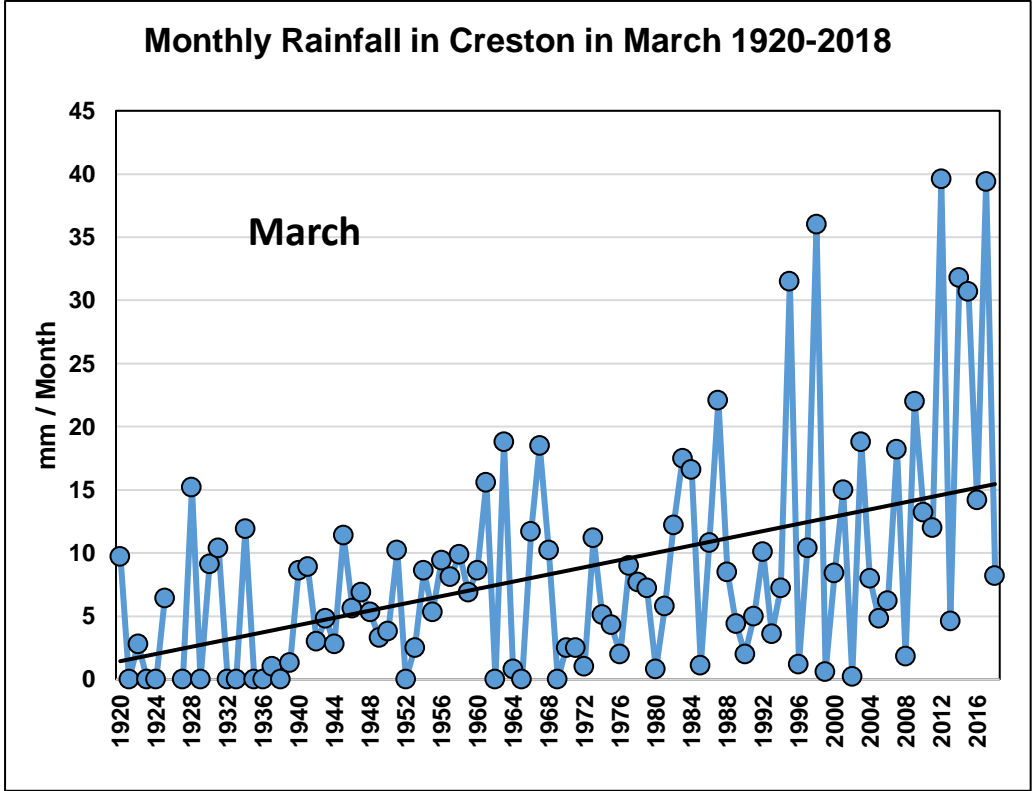


The Minimum Daily Temperatures are Warming up Faster in the Mountains (Data from 7 Stations in the Columbia Basin)

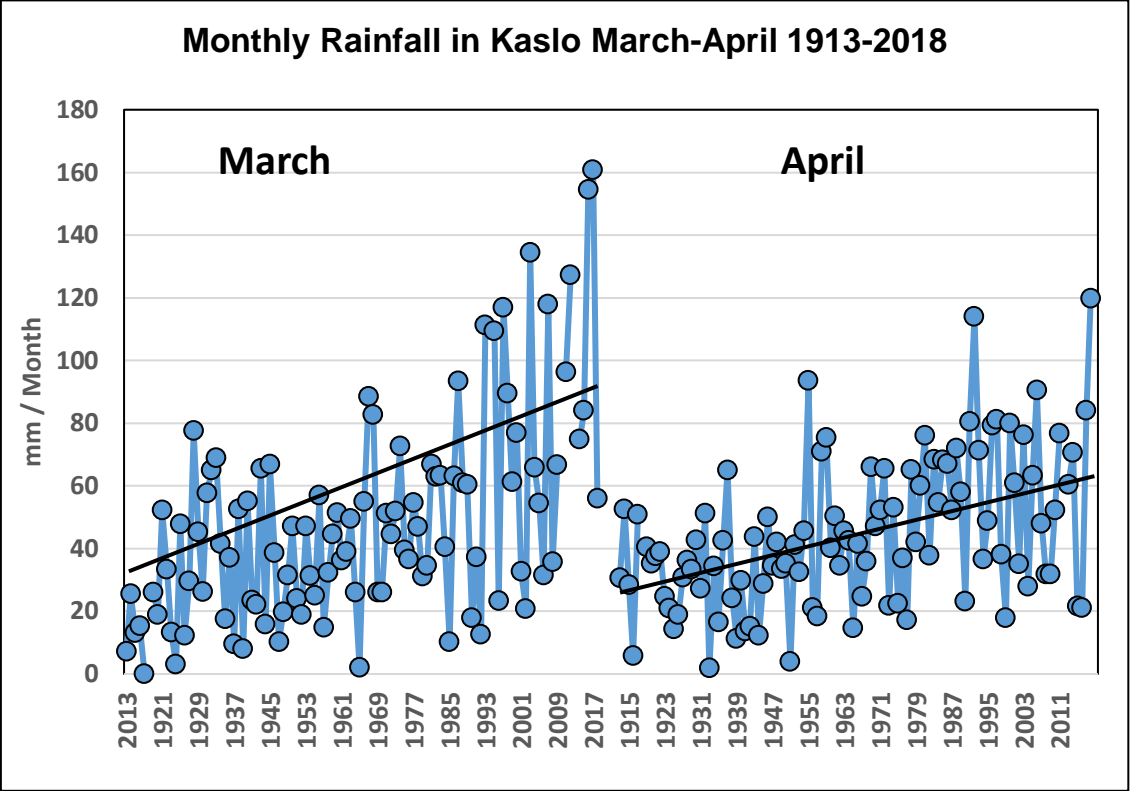


Examples of Increased Variability in Rainfall in the Columbia Basin, B.C.

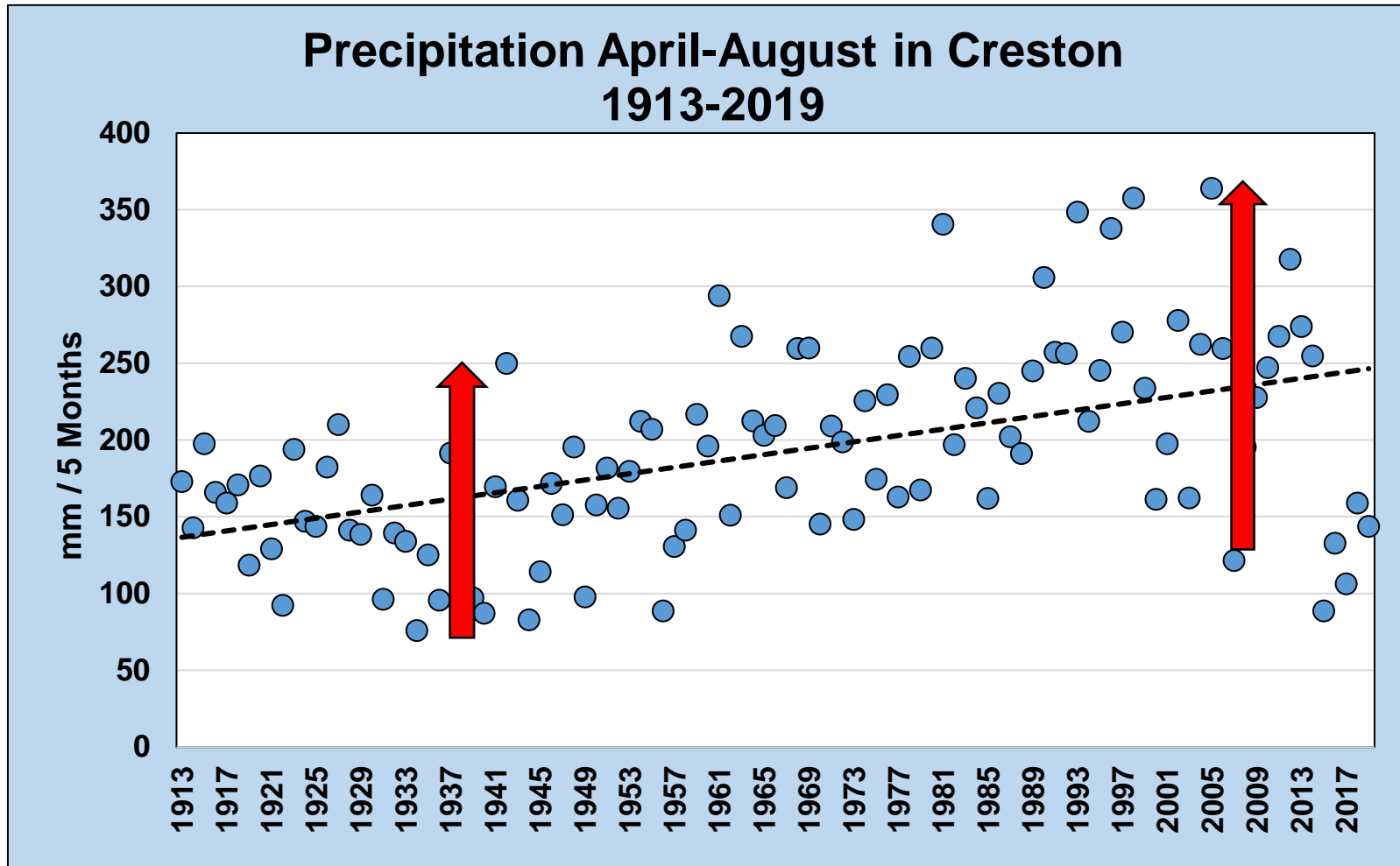
Creston, B.C.



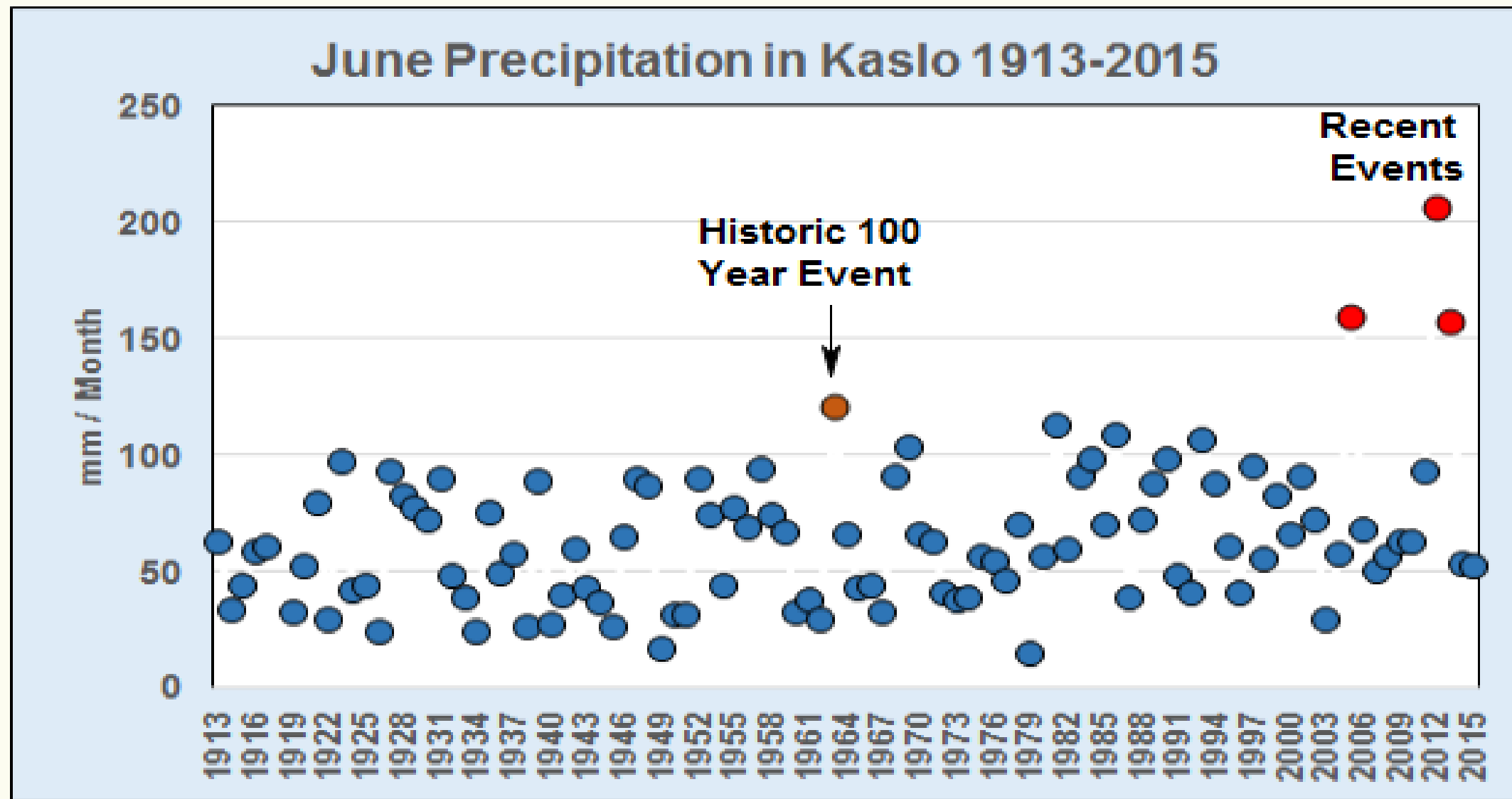
Kaslo, B.C.



Increased Variability in Summer Precipitation



Increased Variability in Precipitation

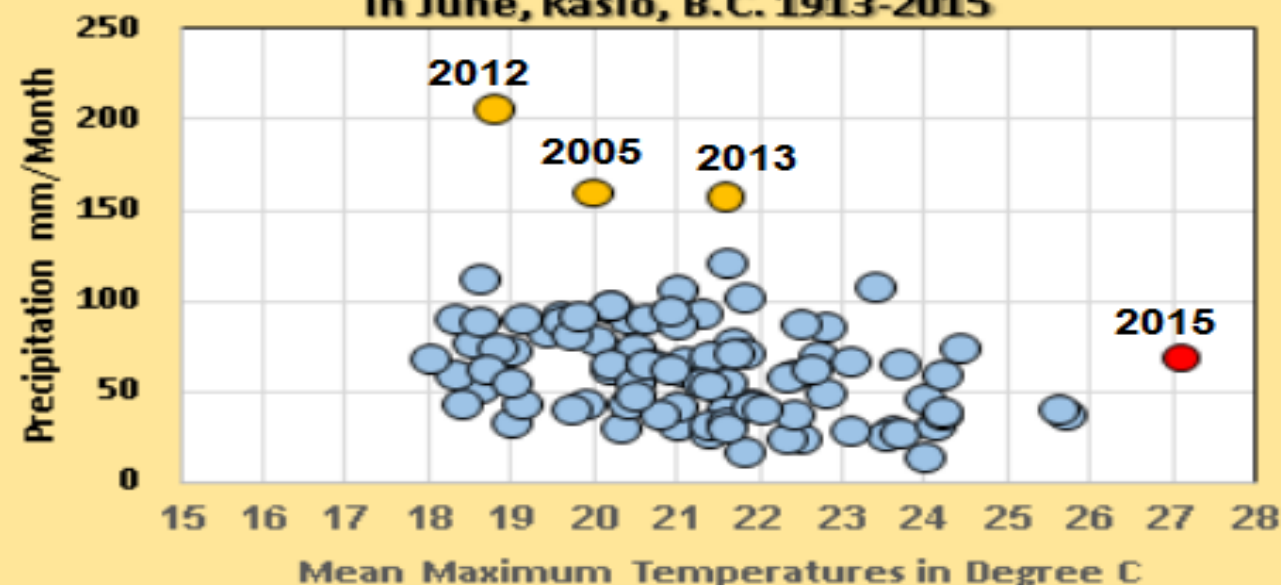


The Precipitation in June in 2005, 2012 and 2013 produced 30-70% more rain than in any other June since records stated in 1913.

2012 Flood Event in Nelson B.C.

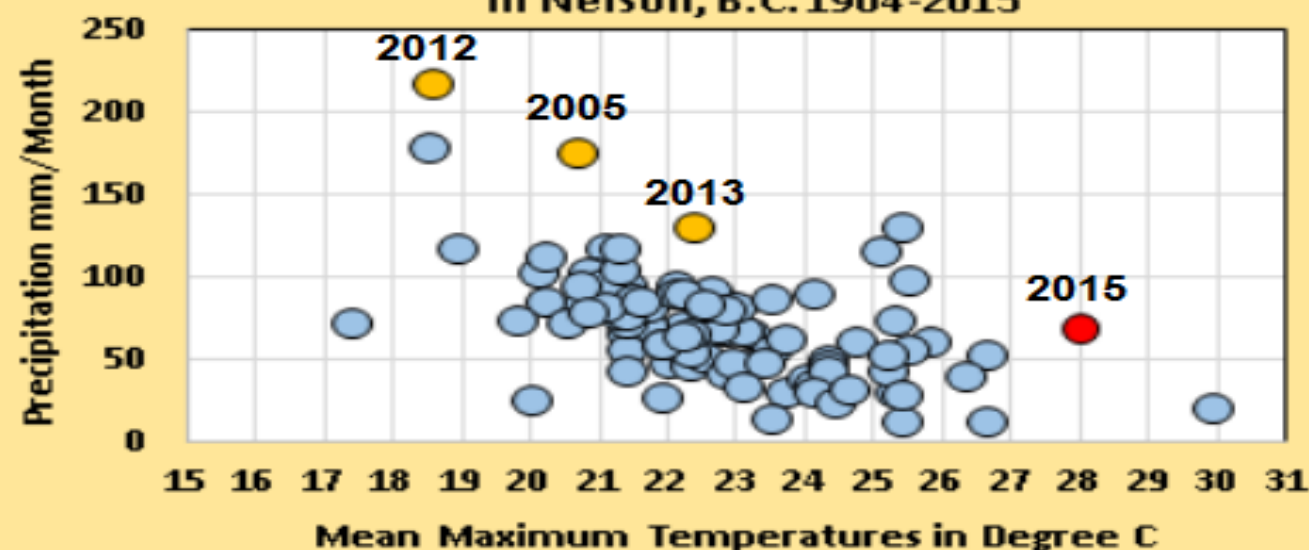


**Mean Maximum Temperatures vs. Precipitation
in June, Kaslo, B.C. 1913-2015**



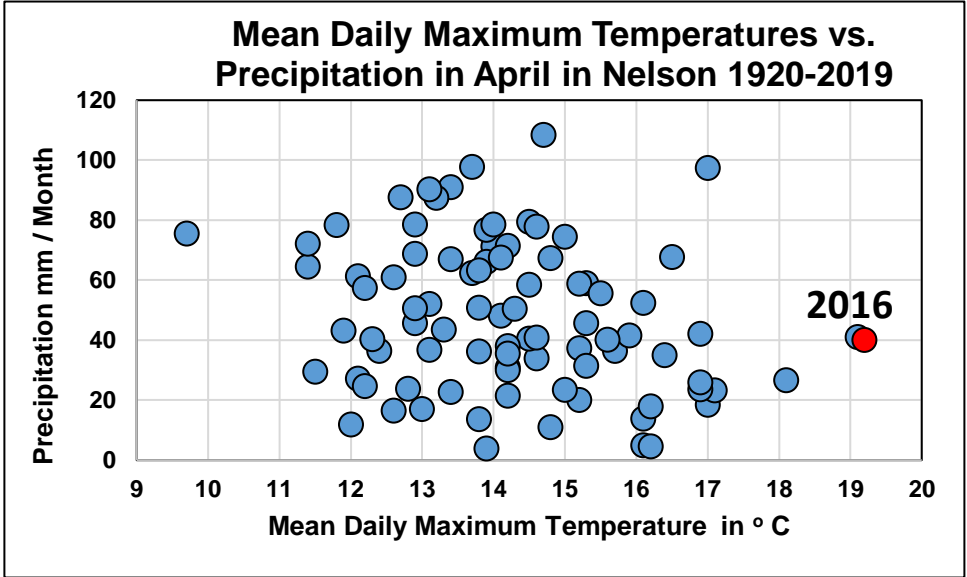
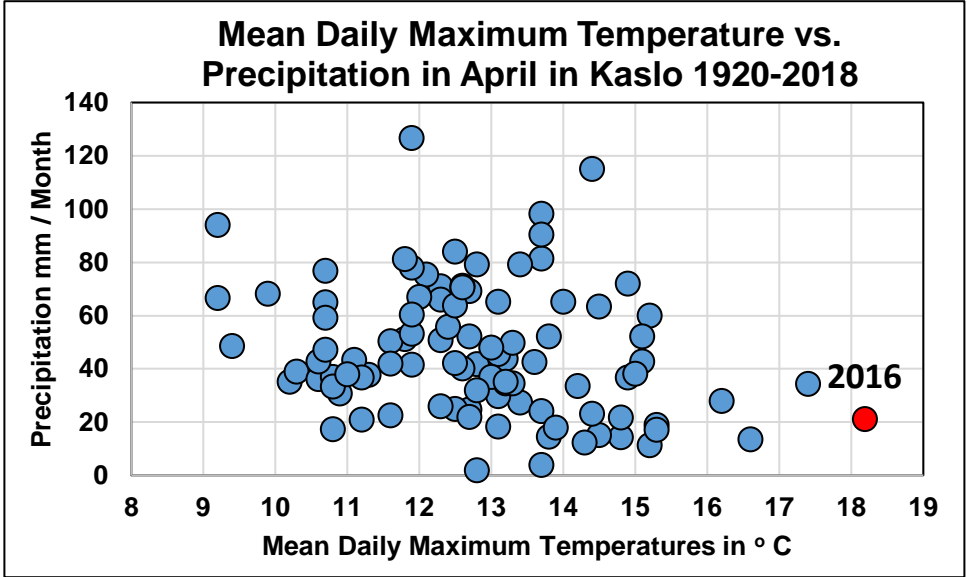
Data Record: 102 Years
Wettest June : 2012- 206 mm
Warmest June: 2015- 27.1°C

**Mean Maximum Temp. vs. Precipitation in June
in Nelson, B.C. 1904-2015**



Data Record: 111 Years
Wettest June : 2012- 216.2 mm
Warmest June: 2015- 28°C

Climate Data Temperature vs. Precipitation



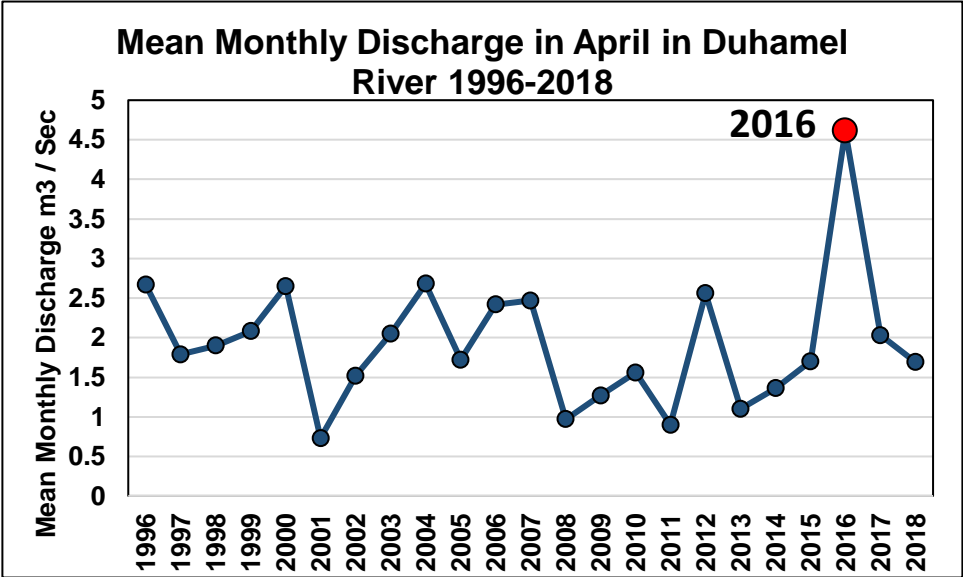
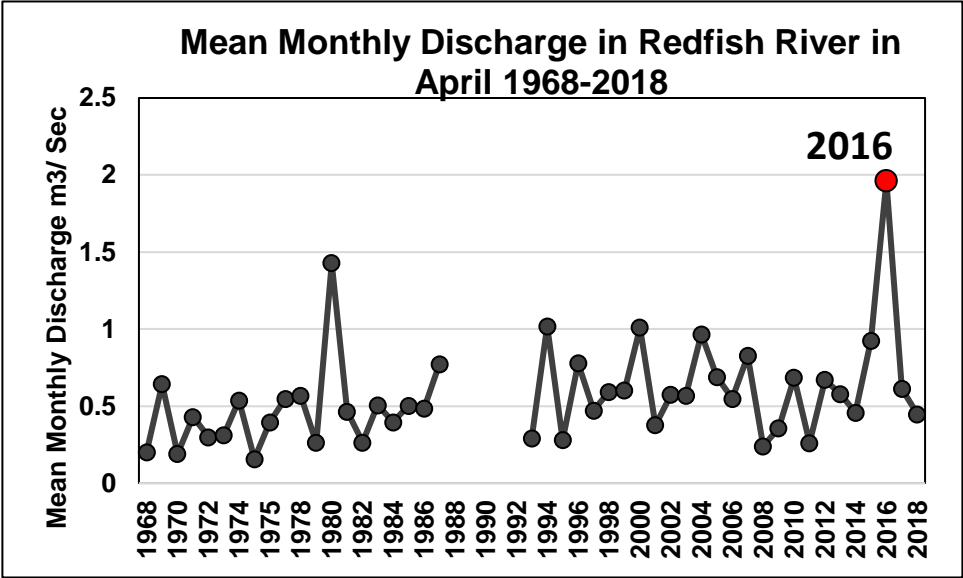
APRIL



Hot & Dry
Leading to
Rapid Snow
Melt & Record
Runoff

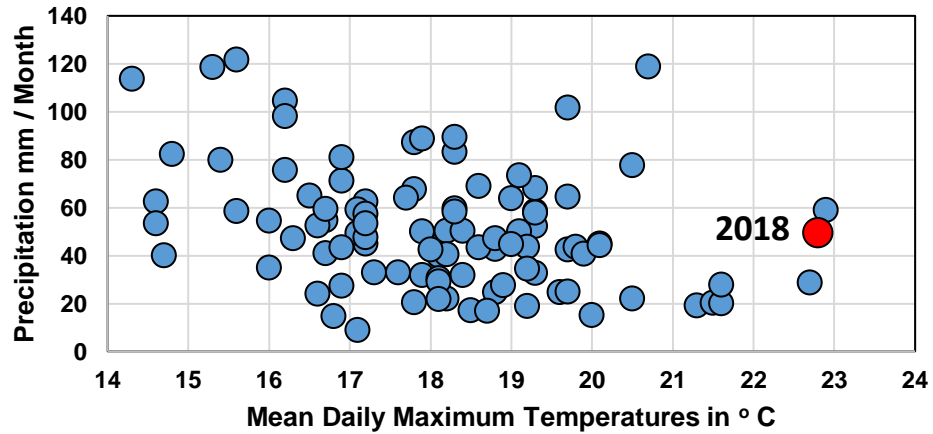


River Discharge Data



May

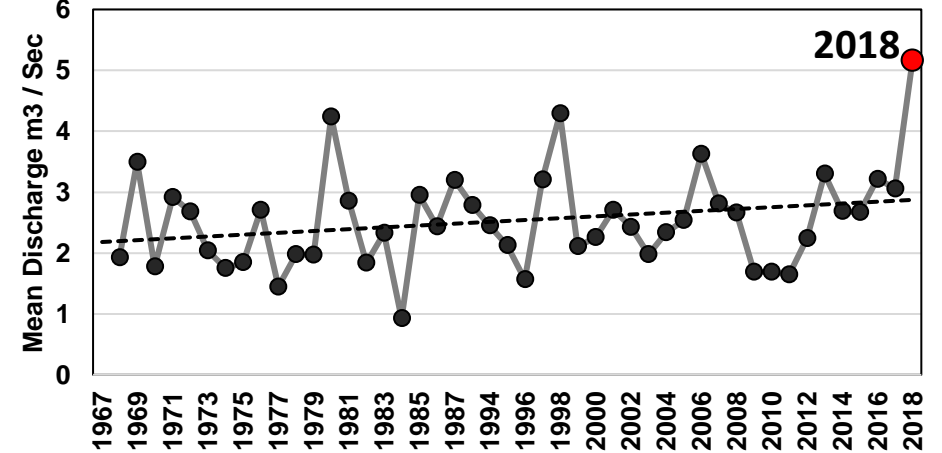
Mean Daily Maximum Temperature vs
Precipitation in May in Kaslo 1920-2018



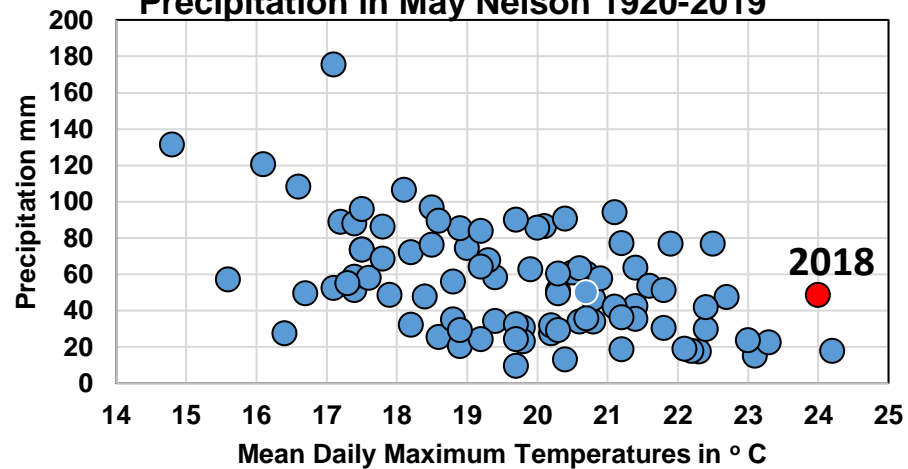
Hot & Dry
Conditions
Leading to
Rapid
Snow Melt
& Record
Runoff



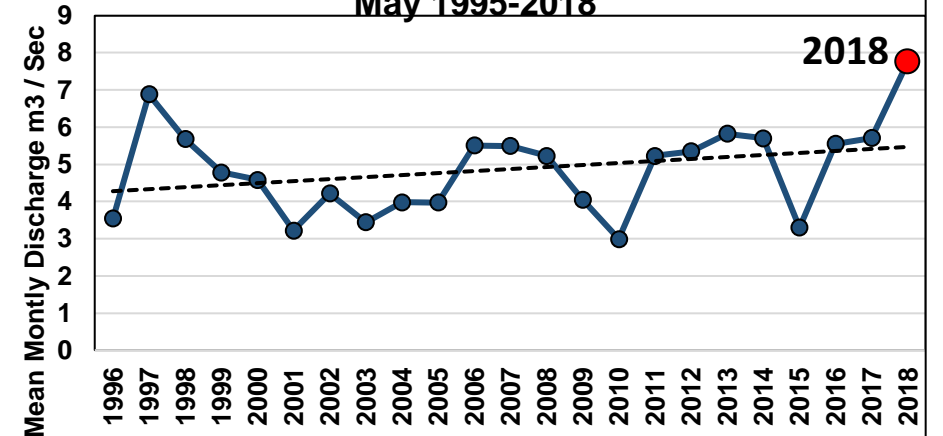
Mean Monthly Discharge in Redfish River in
May 1967-2018

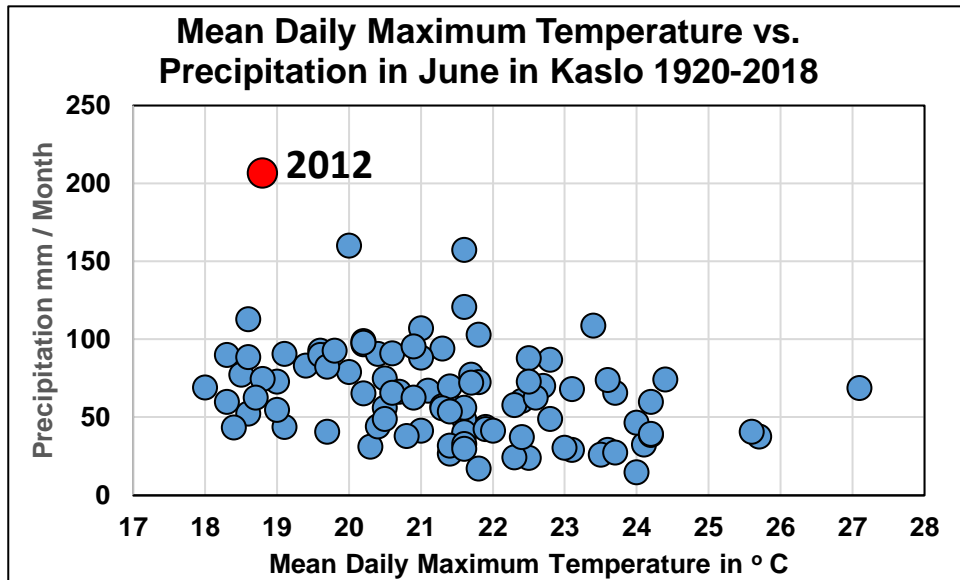


Mean Maximum Daily Temperatures vs.
Precipitation in May Nelson 1920-2019



Mean Monthly Discharge in Duhamel River in
May 1995-2018

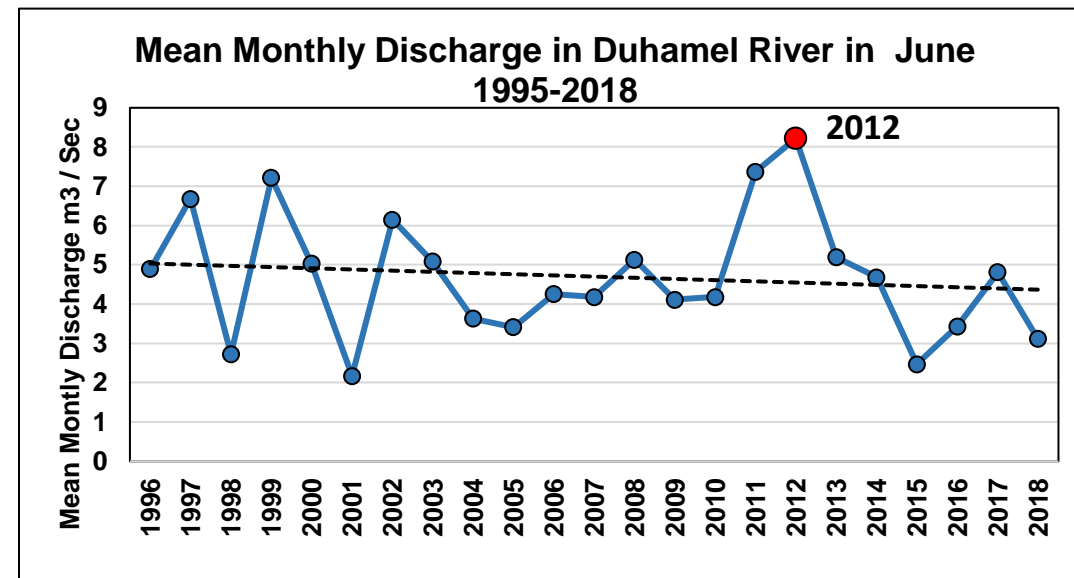
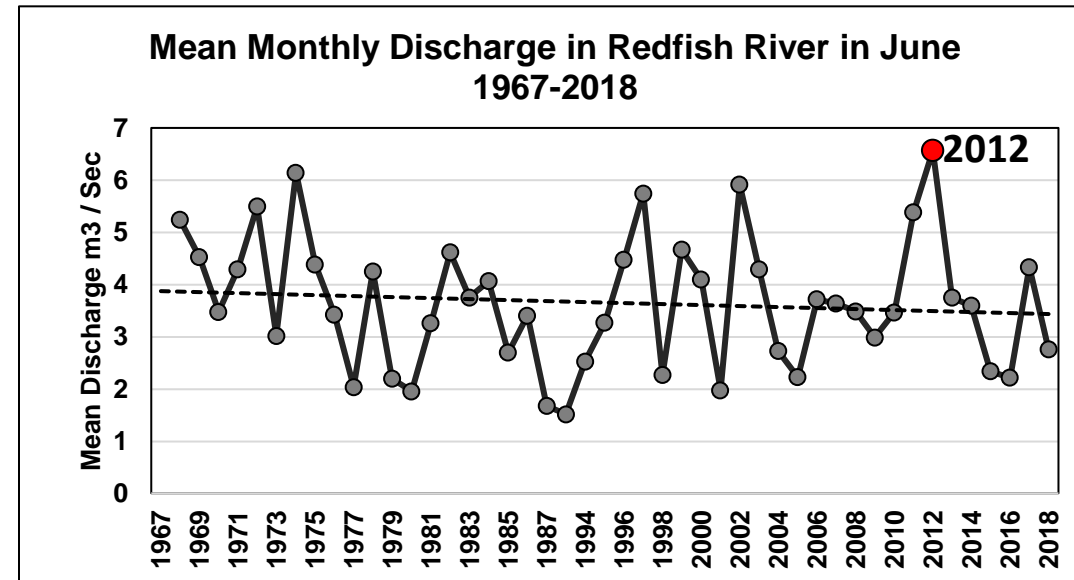




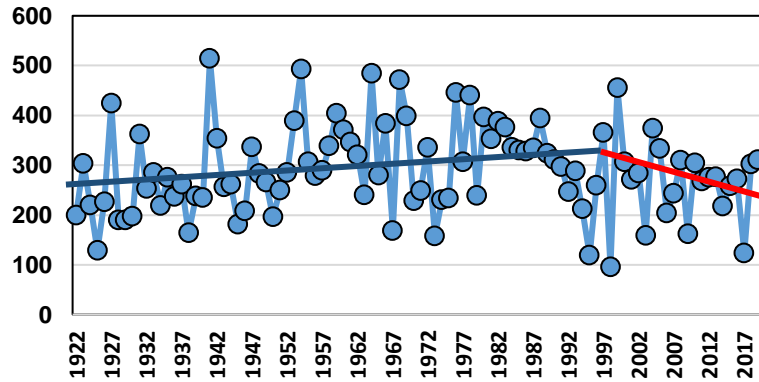
JUNE



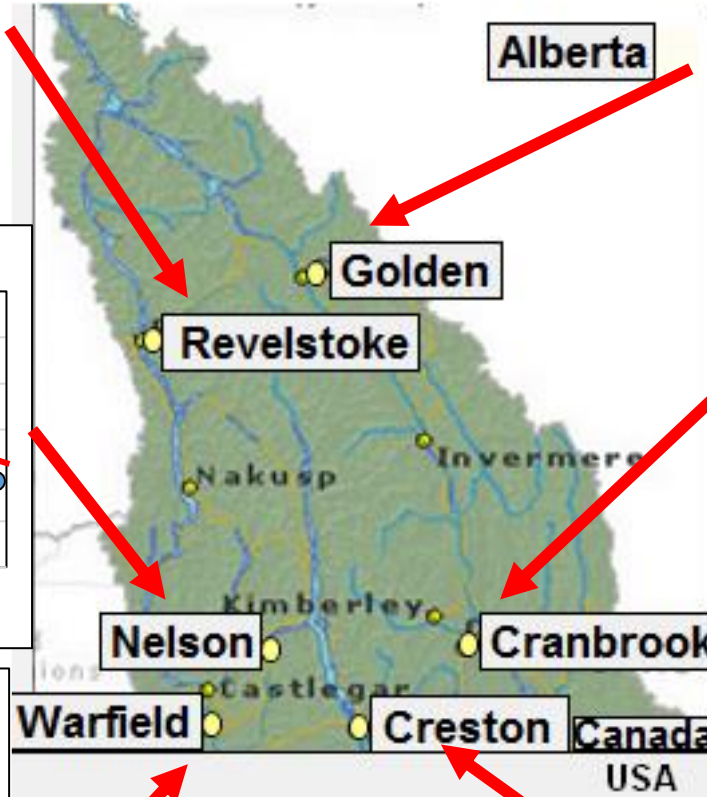
Large Rain
Event Leading
to Record
Discharge



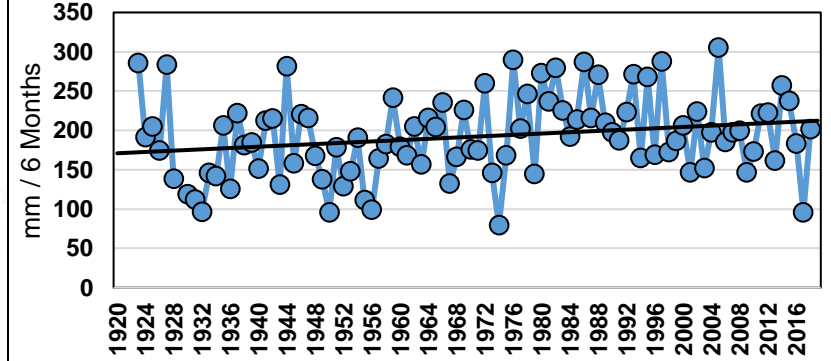
Summer Precipitation (May-Sep) in Revelstoke



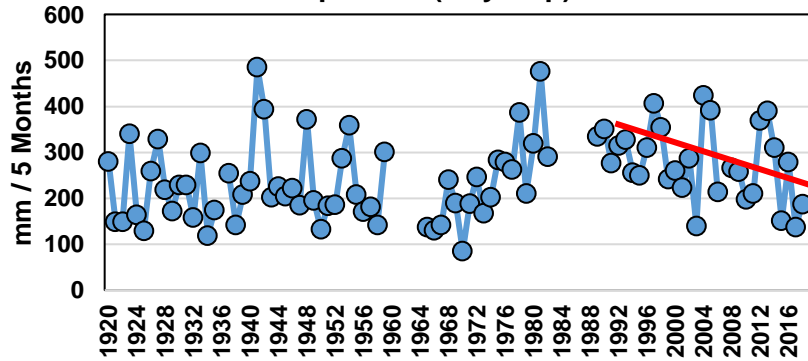
Columbia Basin in Canada
Summer Precipitation Trends
May – Sep 1920-2019



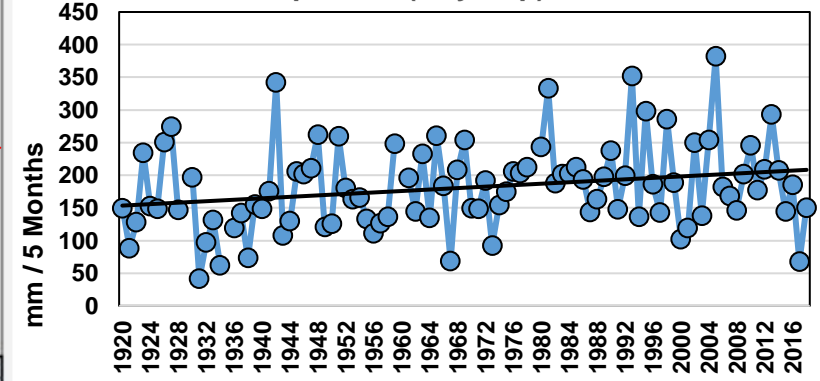
Summer Precipitation (May-Sep) in Golden



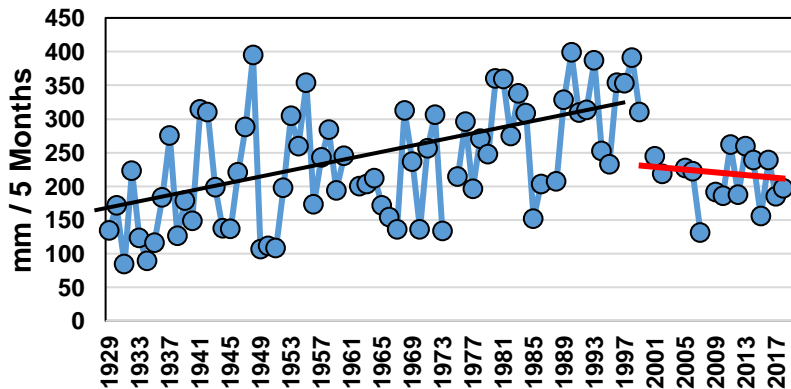
Summer Precipitation (May-Sep) in Nelson



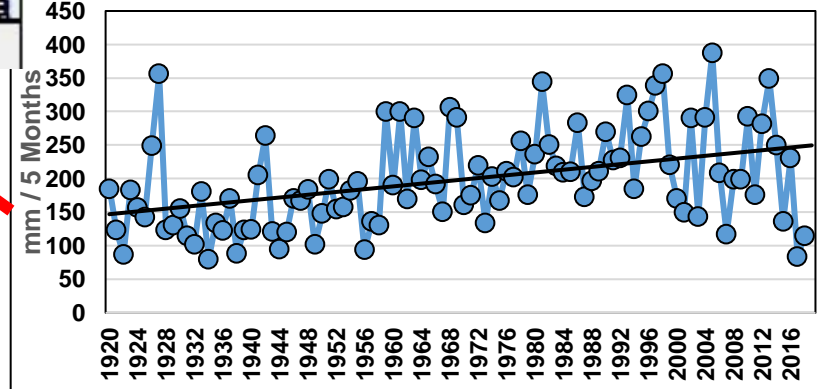
Summer Precipitation (May-Sep) in Cranbrook



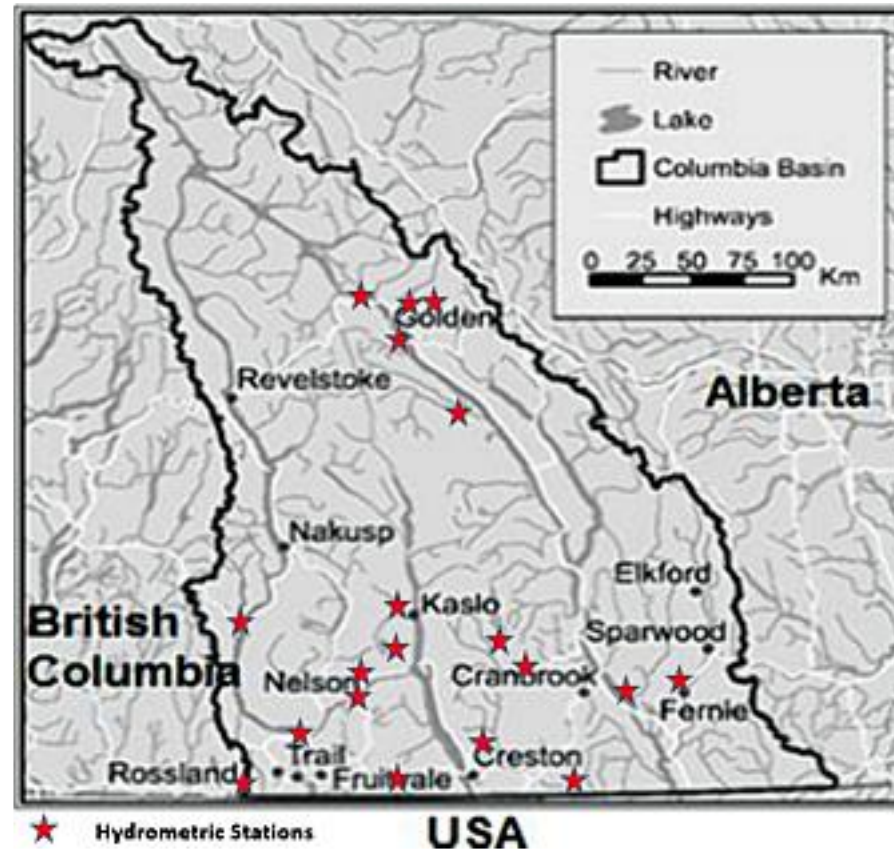
Summer Precipitation (May-Sep) in Warfield



Summer Precipitation (May-Sep) in Creston



Extrapolating Data from Individual Sites and River Basins into A Regional Assessment



Regional Trends Based on 10 Climate Stations and 18 River Discharge Stations








Years when Record Monthly Temperatures were Recorded in 10 Climate Stations –Columbia Basin

Climate Stn.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Revelstoke •	2006	1992	2016*	2016	2018	2015	1985	1967	1950	1944	2016	1930
Nakusp	2006	2010	2010	2016	2018	2015	1998	1998	1998	2014	2016	1991
Kaslo •	2006	2015	2015	2016	2018	2015	2015	2017	1998	2016	1987	1999
Nelson •	1953	2015	2015	2016	2018*	2015	2007	1958	1967	2015*	2016	2002
Castlegar	1994	2015*	2015	2016	2018	2015	2007	2017*	1998	2015	2016	1979
Warfield •	1953	2015	2015	2016	2018*	2015	1985	1967	1967	2015*	2016	1979
Creston •	1953	2015	2015	2016	2018*	2015	2007	2017	1998	2015	2016	1925
Cranbrook •	2006*	1991	1991	2016	2018	2015	2007	2017*	1998	2014	2012	1979
Sparwood	2006	2015	2015	2016	2018	2015	2007	2017*	1998	2014	2016	1999
Golden •	2006	2006	1991	2016	1993	1948	2007	2017	1963	2014	2016	1925

• 100 Year Data Record

* 2nd or 3rd Highest Temperature

Year of Record High Monthly Precipitation in 10 Climate Stations in the Columbia Basin

Climate Stn.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Revelstoke 	1953	1948	2007	1959	2002	2012	1983	1976	2016*	2006	1953	1920
Nakusp	1982	1982	2017	2018	1996	2005	1983	2010	2016	1995	1991	1971
Kaslo 	1935	1979	2017	2018	2016*	2012	1983	1998	2013	1950	2006	1920
Nelson 	1935	2017	2017	1992	1942	2012	1998	1989	1997	2016	2006*	1933
Castlegar	2006	1979	2012	2018*	1996	2012	2012*	1975	1997	2016	1973	1976
Warfield 	1969	1958	2016*	1937	1998	1958	1998	1976	1997	2016	1983	1968
Creston 	2006*	1999	2012	2011	1998	2012*	2012*	2013*	2013*	2006*	2016	1933
Cranbrook 	1935	2017*	1991	2012	2002	2005	1993	1951	2013*	2016	2006	1964
Sparwood	2000	1986	2012	2003	2002	2005	1993	2004	2005	2016	2006	1980
Golden 	1953	1972	2012	2012	2014	2012*	1981	1976	1987	1939	1995	1933

Note: * 2nd of 3rd Highest Precipitation  Stations with a 100 Year Data Record

Years when Record High Discharge Occurred/Month in 18 River Basins in the Columbia Basin

River Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lemon	2015	2015	2015	2016	2018	2012*	2012	1999	2004	2016	2016	2014
Slocan	2005	2015	2015	2016	2018	2012*	2012	1999	1959	1997	2016	1995
Anderson	1994	2015	2015	2016	2018	2012	2012	1982	2004	2016	2016	1995
Duhamel	2005	2015	2015	2016	2018	2012	1999	1999	2004	2016	2016	2014
Redfish	2005	2015	2015	2016	2018	2012	2012*	1976	2004	2016	2016*	1995
Kaslo	2000	2015	2015	2016	2018	2012*	2012	1975	2004	1997	2016*	1995
Big Sheep	1974	2015	2015*	2016	2018	1984	2012	1976	1976	2016	2016	2016
Salmo	1974	2015	2015	2016	2018	1974	1999	1976	1959	2016	2016	1995
Arrow	1974	2015	2015	2016	2018	2012*	1999	1976	1976	2016	2016	1995
Moyie	1935	2015	2007	1934	2018	1974	1954	1993	1959	1997	2016	1941
Bull	2015	2015	2015*	2016	2018	2012	2012*	1976	1959	2016	2016*	1995
Elk	1974	2015	2015*	2016	2018	1974	2012	1976	2004	2005	1999	1979
KickingHorse	2015*	2015	2015	2016	2018	2012*	2012	1976	1976	1997	2016*	1975
Split	2005	2015	2015	2016	2018	2012*	2012	1976	1976	1997	1999	1975
Beaver	2005	2015	2015	2016	2018	2012*	2012	1999	2015	2003	1999	1999
Blaeberry	1981	2015	2015	2016	2018	2012*	2012	1976	1976	2003	2016*	1980
Spillimancheen	2005	2015*	2015	2016	2018	1967	2012*	1976	1976	2003	2003	2003
St. Mary	2005	2015*	2015*	2016	2018	2012*	2012*	1976	2004	2005	2016	1995

* 2nd or 3rd Highest Discharge

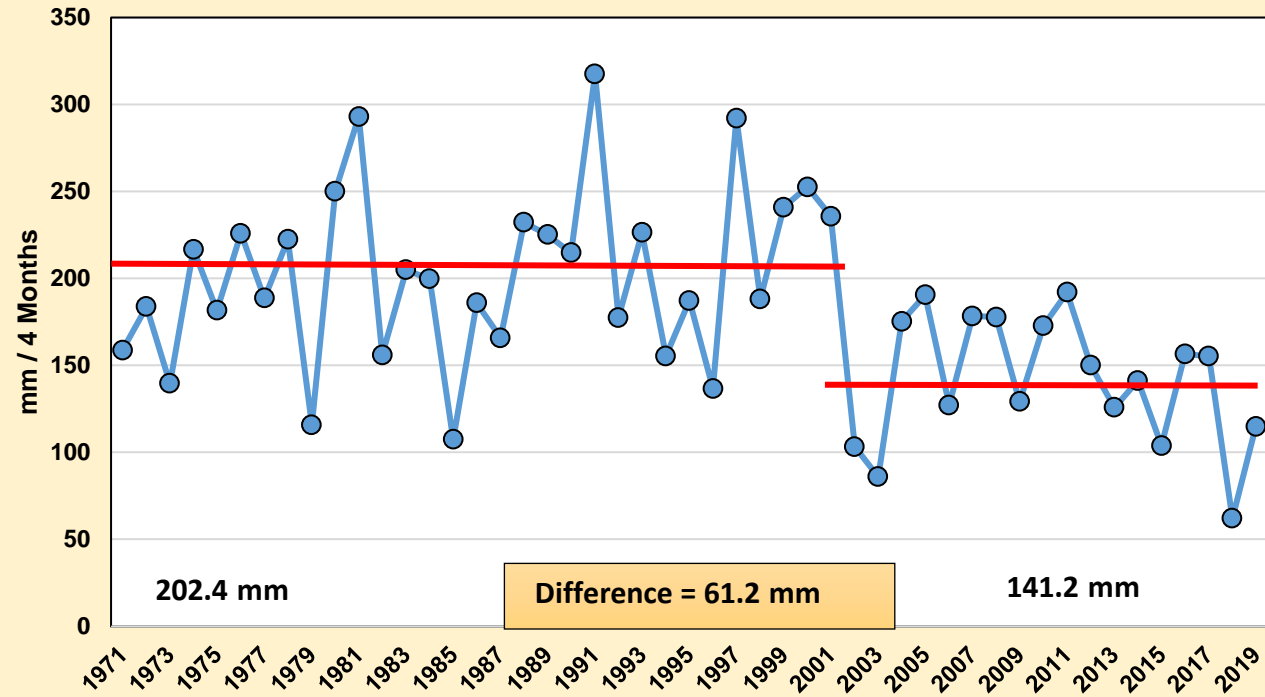
Year of Record Low Mean Monthly Discharge in 18 Rivers in the Columbia Basin

River Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lemon	2001	2001	2018	2008	1984	1987	2015	2015	2003	1986	1987	2001
Slocan	1988	2001	1985	2008	1955	1987	2015	2015	2007	1987	1952	1952
Anderson	2004	2012	1985	1970	2015	1992	2015	2015	2007	2015	1984	2003
Duhamel	2001	2001	2001	2001	2010	2001	2015	2001	2001	2001	2002	2000
Redfish	1985	1985	1985	1975	1984	1993	1977	1994	2017	1974	1979	1976
Kaslo	1988	1988	2002	1984	2001	2015	2015	1987	1987	1987	1987	1987
Big Sheep	1962	1962	1962	2001	1992	1992	2015*	2003	1967	1994	1994	1994
Salmo	2001	2001	1964	2008	1977	1992	2015	2015	2001	1952	1952	1952
Arrow	1979	1979	2001	2001	2015	1992	2015	2015	2001	2015	1979	2009
Moyie	1937	2001	1944	2001	1944	1992	2015	1936	2001	2001	1936	2000
Bull	1988	1988	2001	1970	2001	2001	1977	2001	2001	2001	1978	2009
Elk	1988	2002	2009	2001	2009	2001	1977	2001	2001	2001	1979	1982
KickingHorse	1989	2003	1975	2014	1984	1998	1977	1980	2012	2001	2013	2009
Split	2012	2012	1987	2006	1984	1989	2015	2006	1998	2017	1979	1979
Beaver	2012	2003	1996	2008	2009	1993	1993	2001	1996	2001	2013	2009
Blaeberry	2012	2012	1988	1982	1984	2010	1993	1980	2007	2009	1979	1971
Spillimancheen	1980	1980	1980	1970	1984	2008	1976	1980	1970	1988	1952	2014
St. Mary	1995	1985	1985	2011	1984	2001	2015	2015	2017	2006	1987	1987

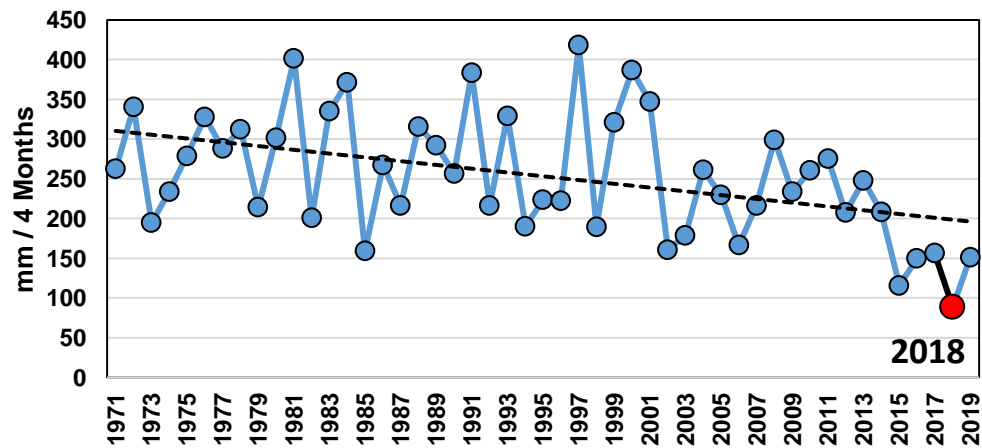
Summary of Record Events 2015-2018 (Temp. Precipitation Discharge)

Months	Record High Monthly Temperatures	Record High Monthly Discharge	Record High Monthly Precipitation	Record Low Monthly Discharge
January	2006			
February	2015	2015		
March	2015	2015	2012	
April	2016	2016		
May	2018	2018		
June	2015	2012	2012	
July	2007	2012		2015
August	2017			2015
September				
October	2015	2016	2016	
November	2016	2016		
December				

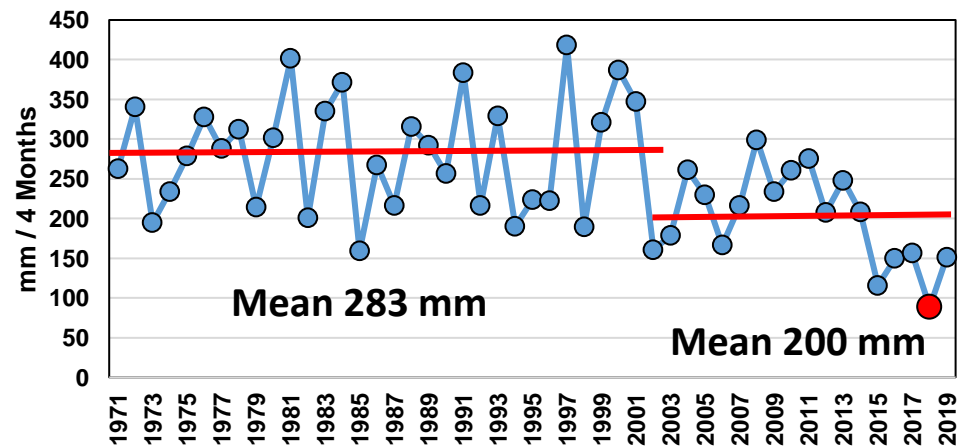
Summer Precipitation (May-Aug) Vancouver Airport 1971-2019



Summer Precipitation (May-Aug) Abbotsford Airport 1971-2019



Summer Precipitation (May-Aug) Abbotsford Airport 1971-2019

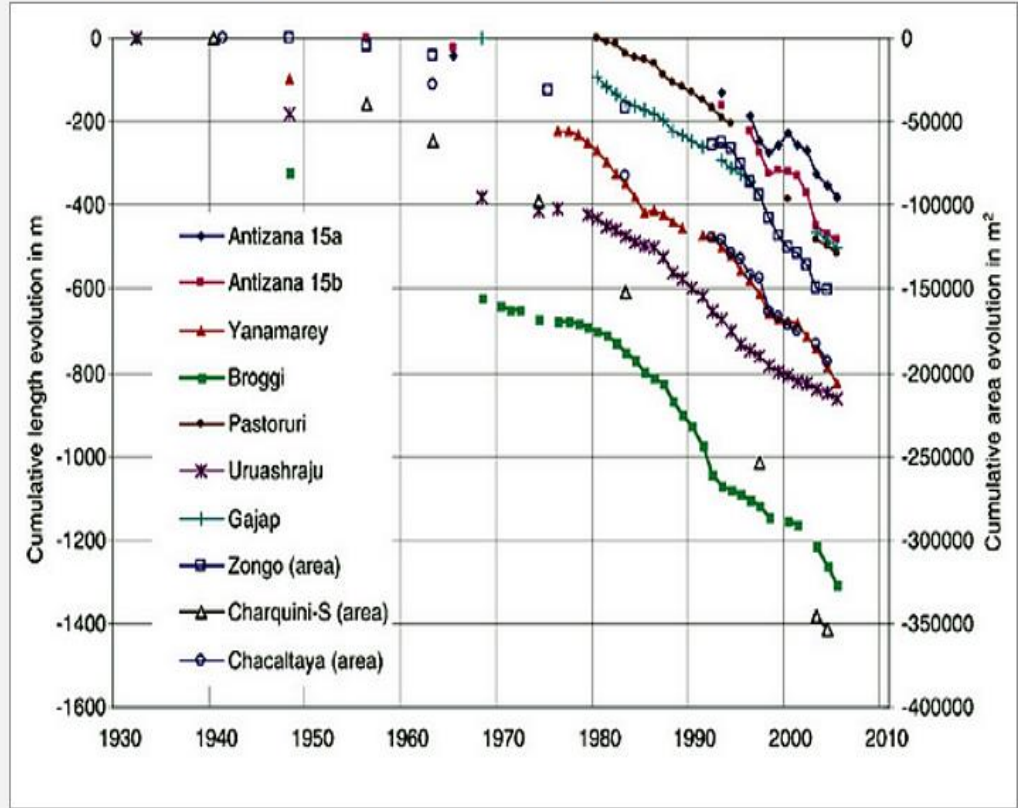


Changing Glaciers

Glacier Recession and Climate Change



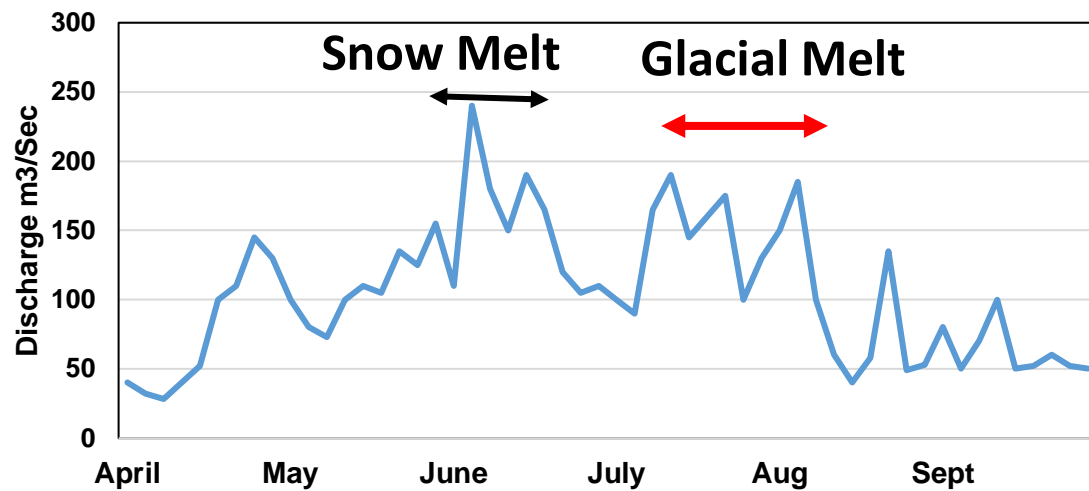
Changes in Length and Volume of Tropical Glaciers in the Andes



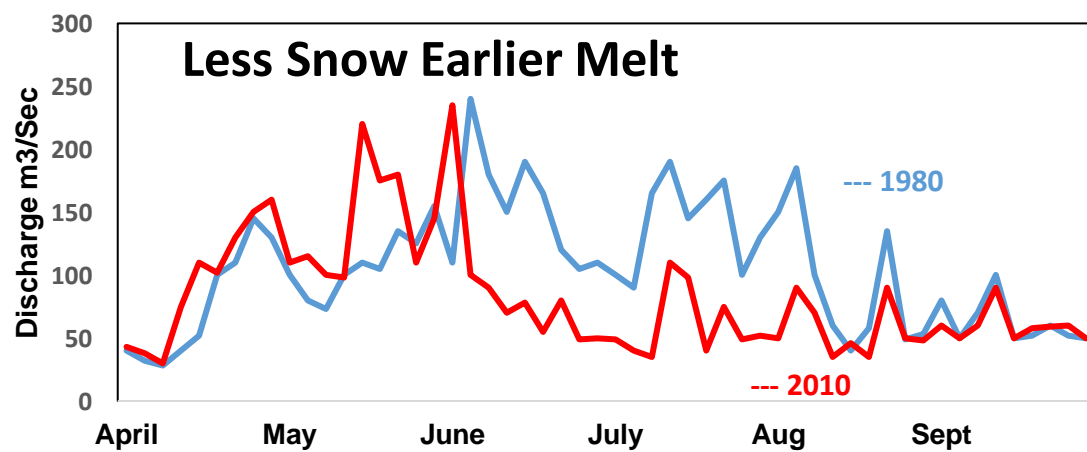
Data Source: Vuille et al. 2008, Earth Sci. Rev. 89:74-90



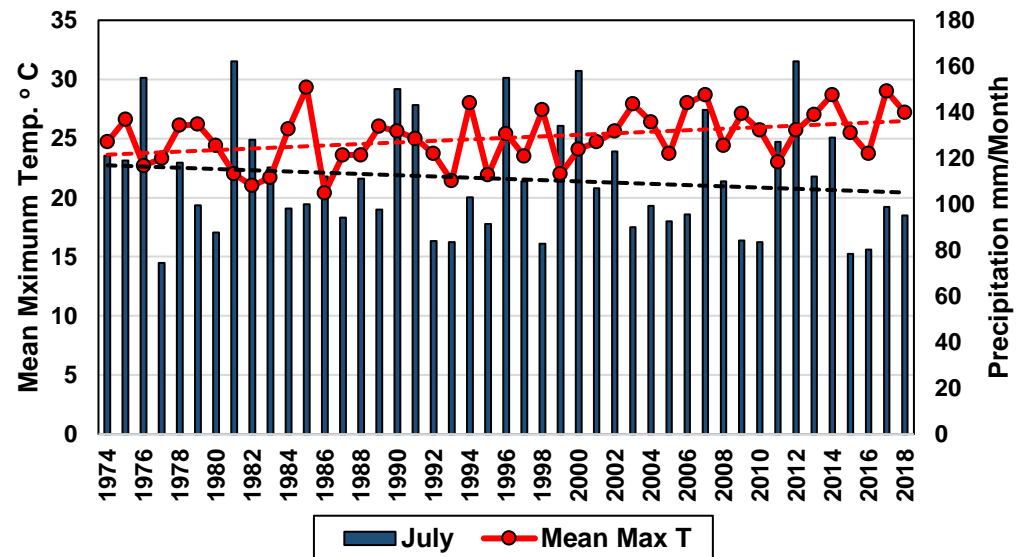
Hydrograph of Glacier Fed Stream



Hydrograph of Glacier Fed Stream & Global Warming



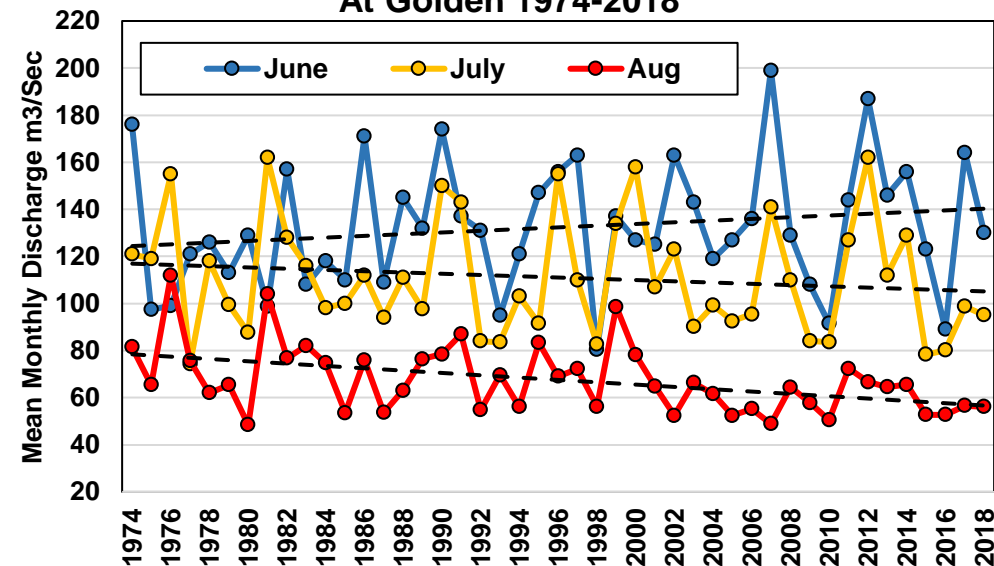
Mean Maximum July Temperature & July Precipitation in Golden 1974-2018



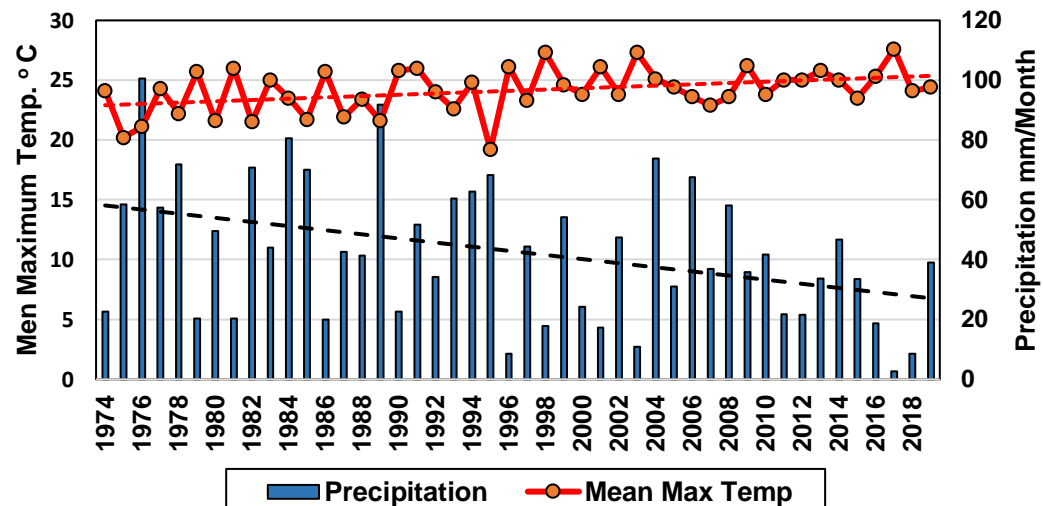
Kiking Horse River



Discharge June-Aug Kiking Horse River At Golden 1974-2018



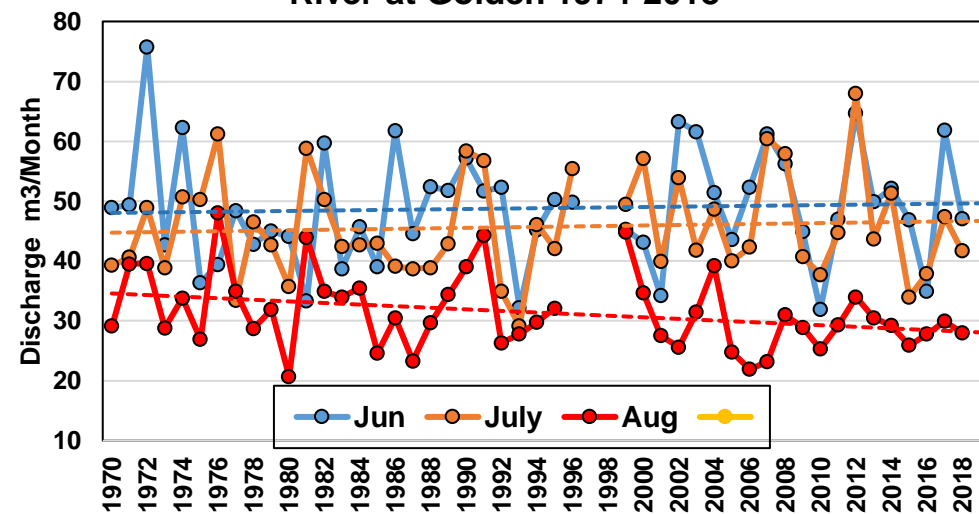
Mean Maximum August Temperatures & August Precipitation in Golden 1974-2019



Blaeberry River



Mean Monthly Discharge June-August Blaeberry River at Golden 1974-2018



Glacier National Park, Montana

Created 1910

Size 400 km²

Lakes 763

GLACIERS IN 1910 = 125

GLACIERS IN 2010 = 25

Total Visitors since 1910

100 Million in 2015

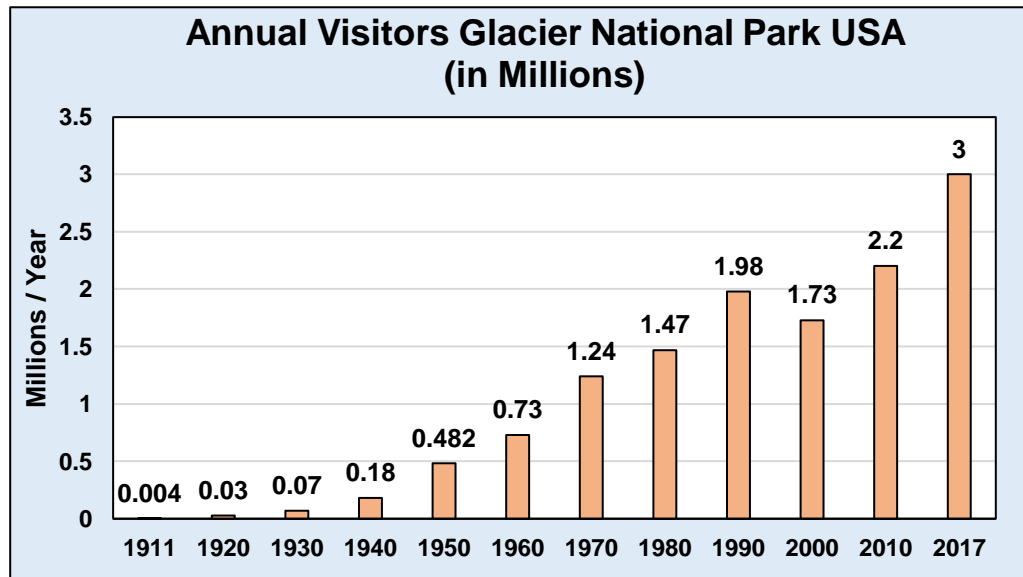


Photo
W. Alden
USGS



Photo B.
Reardon
USGS

Dan Fagre
USGS/USFS
2006 With
Permission

Visit Glacier National Park Before the Glaciers Melt Away!

travelingteichs.com

Glacier National Park, located in Montana, is one of those parks in the US that you should definitely visit, and you should visit VERY SOON! Due to climate change these glaciers are rapidly melting and will most likely completely disappear by 2030.

They will need to change the Name of the Park !

Tam Pokhari Glacial Lake Outburst Flood



Tam Pokhari GLOF



The GLOF seen from Thagnak (photo by: Lapka Goeljen Sherpa)

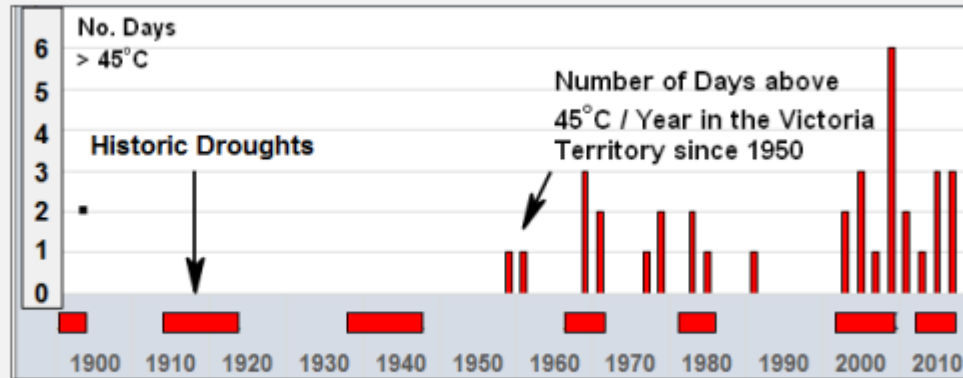
**Inkhu Valley
Before 1998**



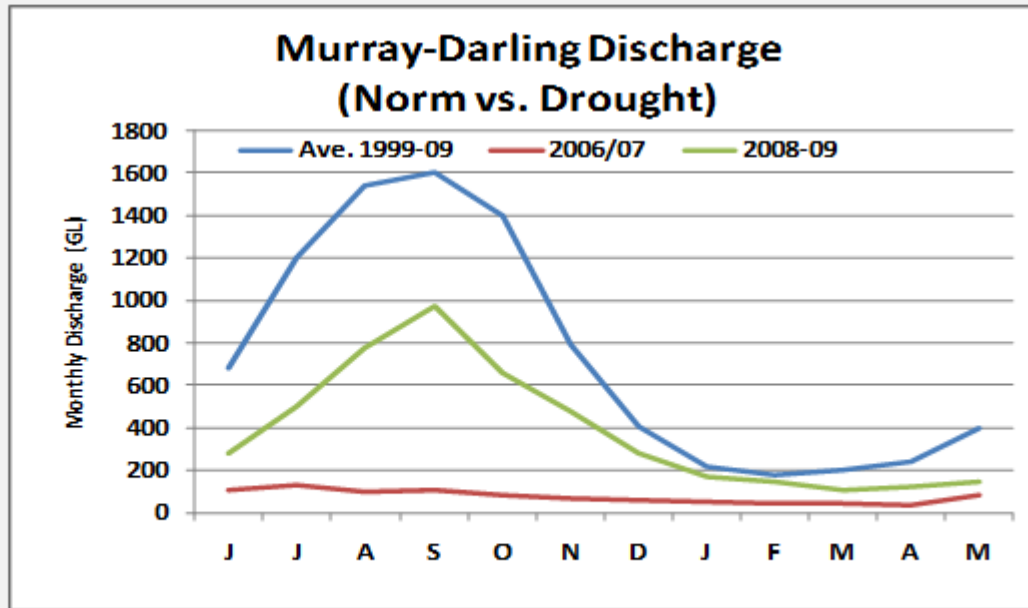
No Doubt About Drought !



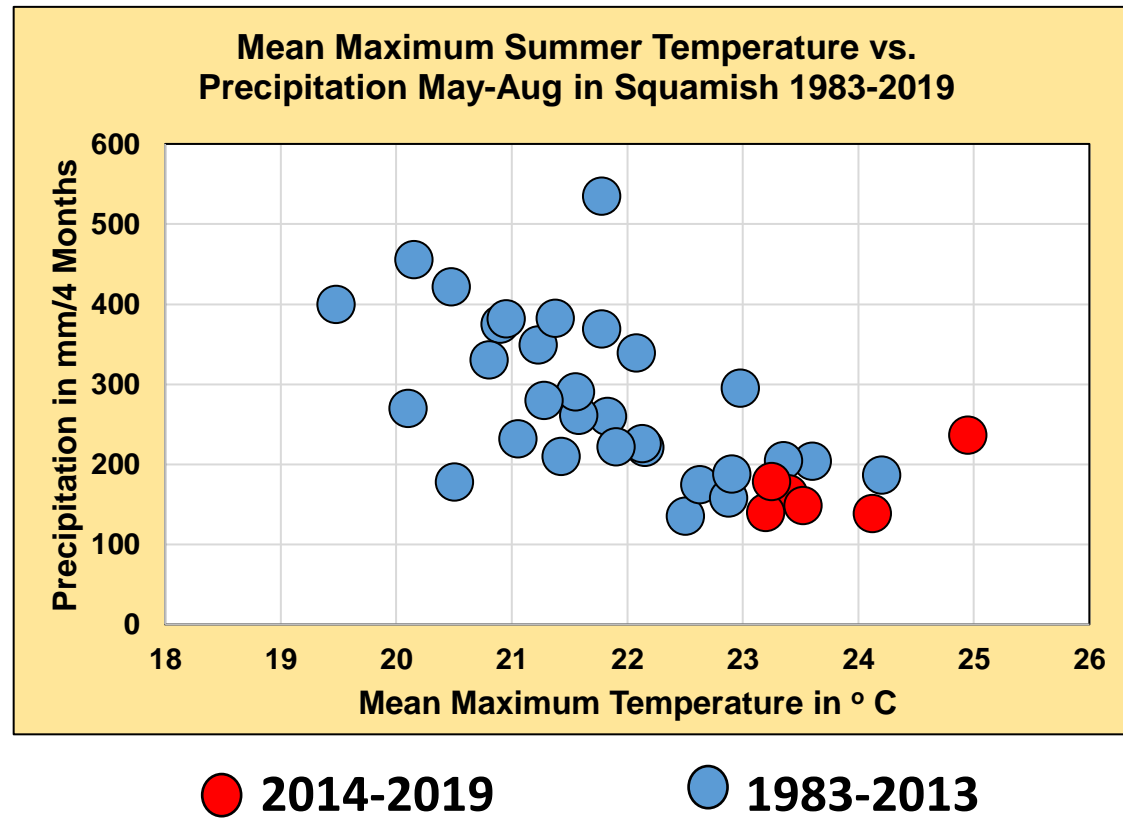
Australian Drought History and Days with Extreme Temperatures > 45°C



Changes in Discharge in the Murray Darling Watershed in Australia; Average Discharge before, during Peak of Drought 2006-07



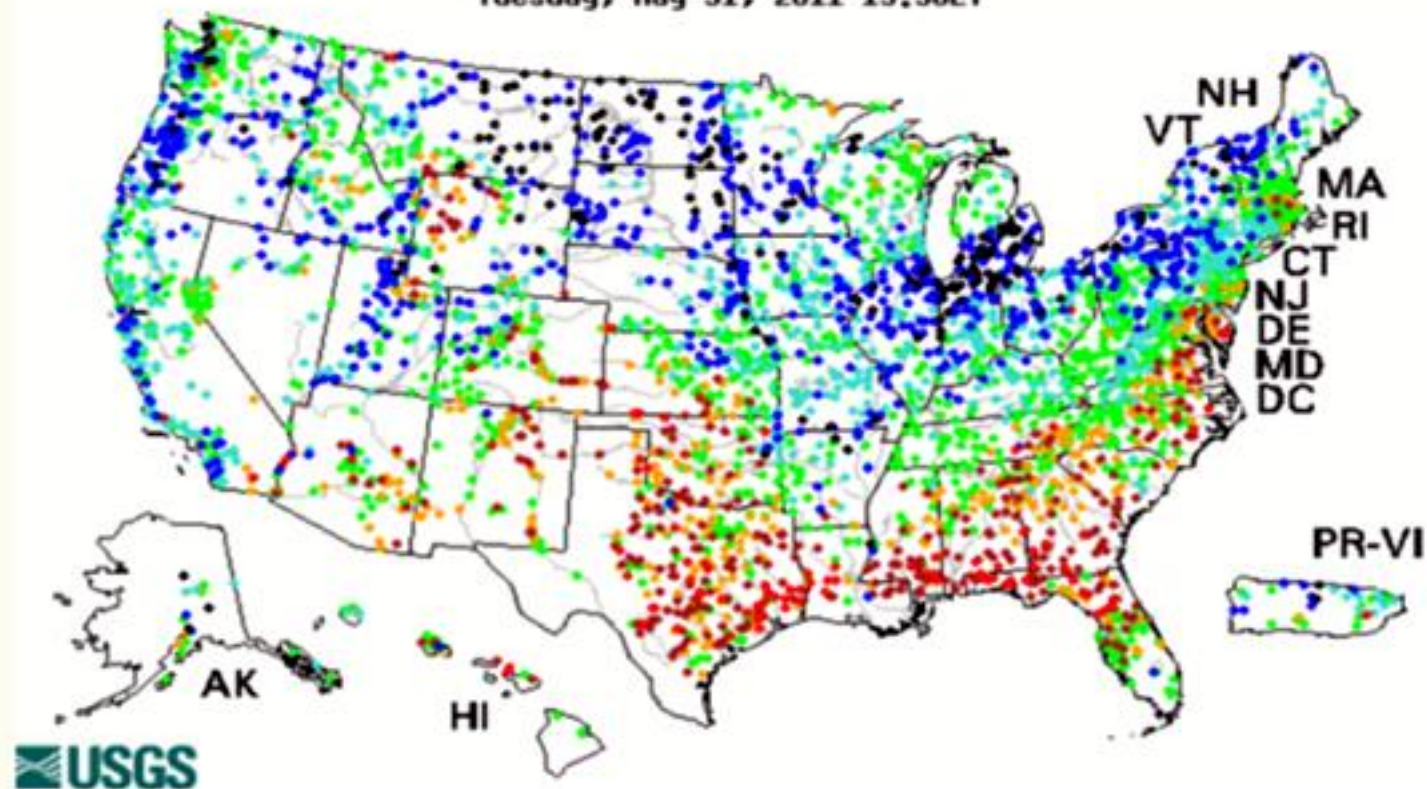
Evidence of Hotter and Drier Summer over the past 7 Years in Squamish, B.C.



Hydrometric
Data: USGS

28 Day
Average
Streamflow
compared to
Historic
Streamflow for
this time of
the Year

Tuesday, May 31, 2011 13:30ET



Choose a data retrieval option and select a location on the map

☐ List of all stations in state, ☒ State map, or ☐ Nearest stations

Explanation - Percentile classes

Low	<10	10-24	25-75	76-90	>90	High
	Much below	Below	Normal	Above	Much above	

Floods

Droughts

Key Factors

Climate & Land Use

Primarily Climate

Predictability

Somewhat

Difficult

**Start and Size is Predictable
Timing is more difficult**

**Start, Size and Length of
Drought is difficult to Predict**

Reasons

**Based on Rainfall, Snow Cover,
Snow Water Equivalent (SWE)
Land Use, Imperviouness,
Antecedent Soil Moisture, lag-
time between Rainfall & Runoff,
Historic Streamflow Record**

**Depends on Climate factors
(Temperatures & Precipitation).
Minor information soil moisture
conditions at start can help.
Historic Record is not
Particularly Useful.**

Preparedness

**Advanced Notice, Some
Time to Respond to Fast
Moving Event**

**Little Advanced Notice, Requires
Adaptive Response. Slow
Progressive Event**



THANK YOU !

1. Decrease CO₂ Footprint

- **GHG Emission Reductions**
- **How to Sequester Carbon**

- **What can you do to Reduce your CO₂ Footprint?**

2. Adaptation Measures

- **Adaptation Priorities**
- **What are the Best Options**

- **What can you do to Adapt to Floods & Droughts?**

