Global Warming and Montana Ecosystems: Its all about water balance

Steven W. Running
Numerical Terradynamic Simulation Group
College of Forestry and Conservation
University of Montana

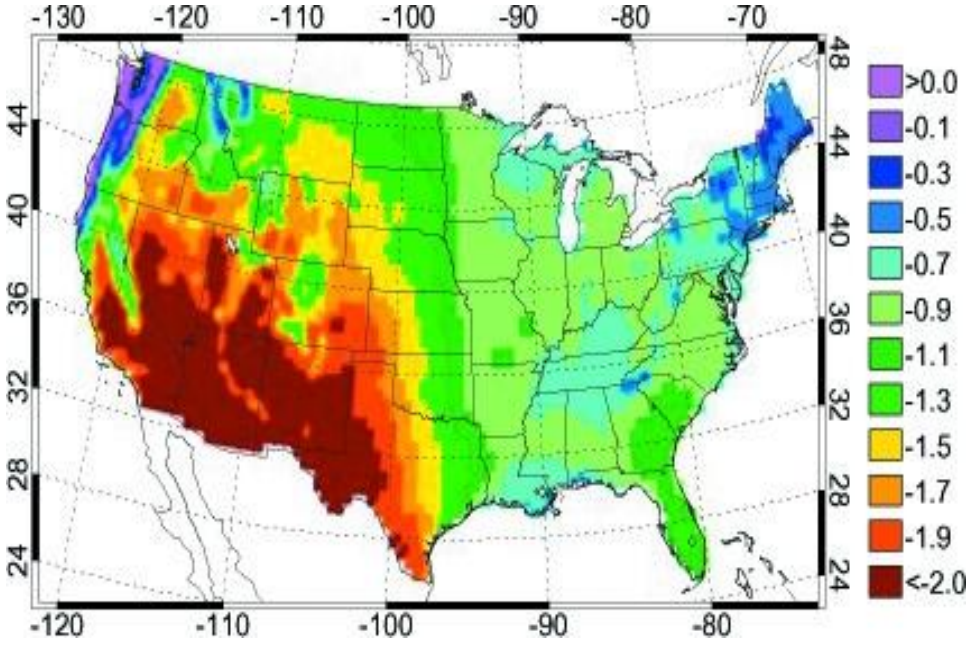
Ecology Seminar

September 3, 2008

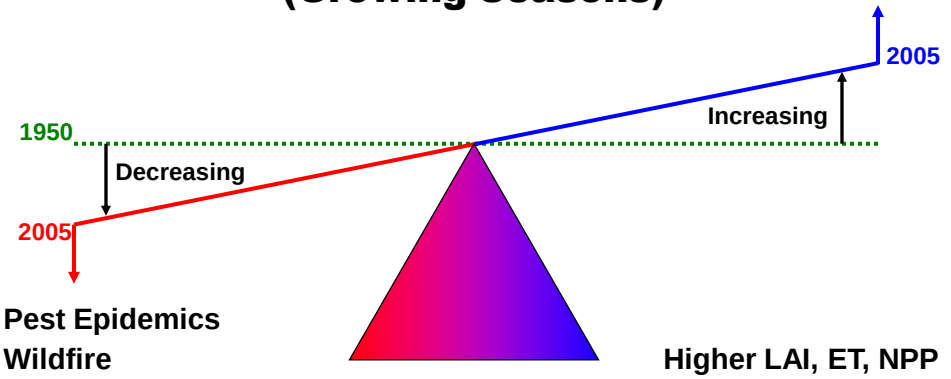
Montana Ecosystem Responses To Climate Trends

Water balance and Disturbance dynamics Will be more important than pure temperature responses

Geographic Variation in Annual Water Balance
(Precip - *Potential* ET, meters per year)

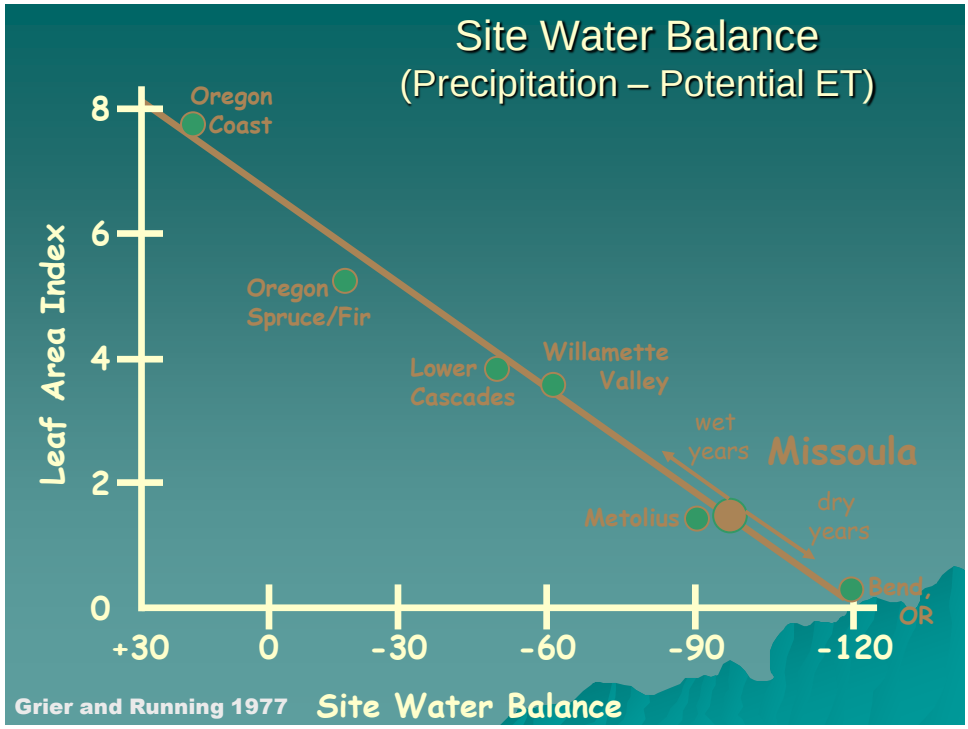


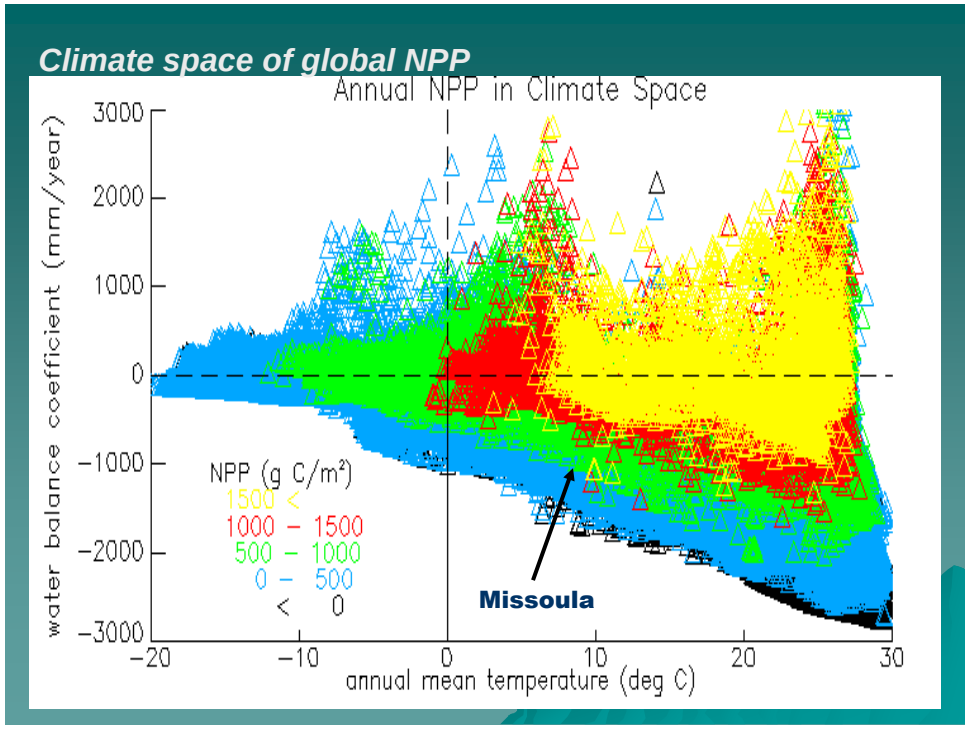
Land Water Balance Tipping Points
(Growing Seasons)



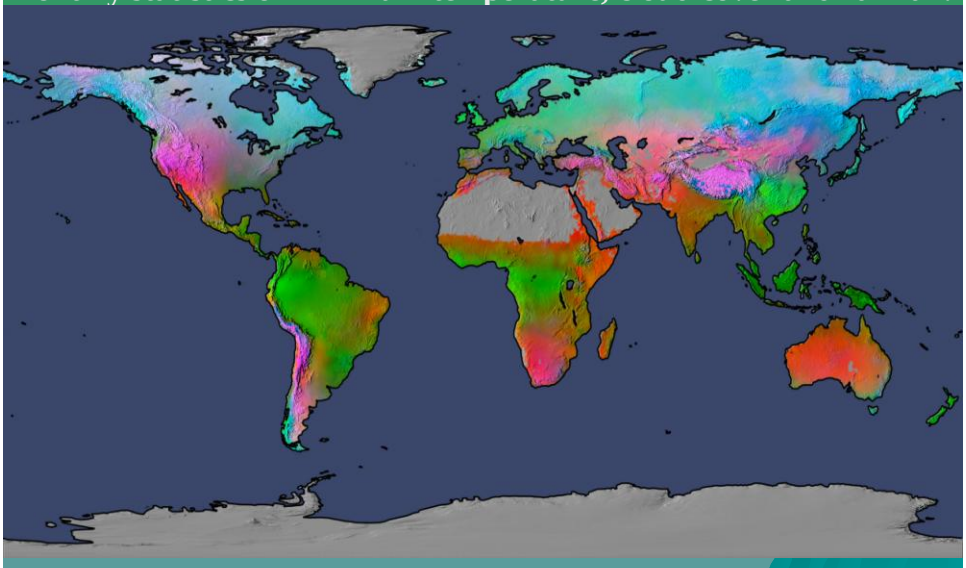
Pest Epidemics
Wildfire
Forest Mortality
Low Streamflows
Reduced Nutrient Cycling
Lower NPP
Biodiversity?
Invasives?

Higher LAI, ET, NPP
Higher Streamflows
Streambank Erosion
Insect-borne diseases
Human Health
Improved wildlife habitat?
Biodiversity?


Site Water Balance
(Precipitation – Potential ET)
Leaf Area Index
8
6
4
2
0
Oregon Coast
Oregon Spruce/Fir
Lower Cascades
Willamette Valley
wet years
Missoula
dry years
Metolius
Bend, OR
+30
0
-30
-60
-90
-120
Grier and Running 1977
Site Water Balance


Climate space of global NPP
Annual NPP in Climate Space
water balance coefficient (mm/year)
3000
2000
1000
0
−1000
−2000
−3000
NPP (g C/m²)
1500 <
1000 – 1500
500 – 1000
0 – 500
< 0
Missoula
−20
−10
0
10
20
30
annual mean temperature (deg C)

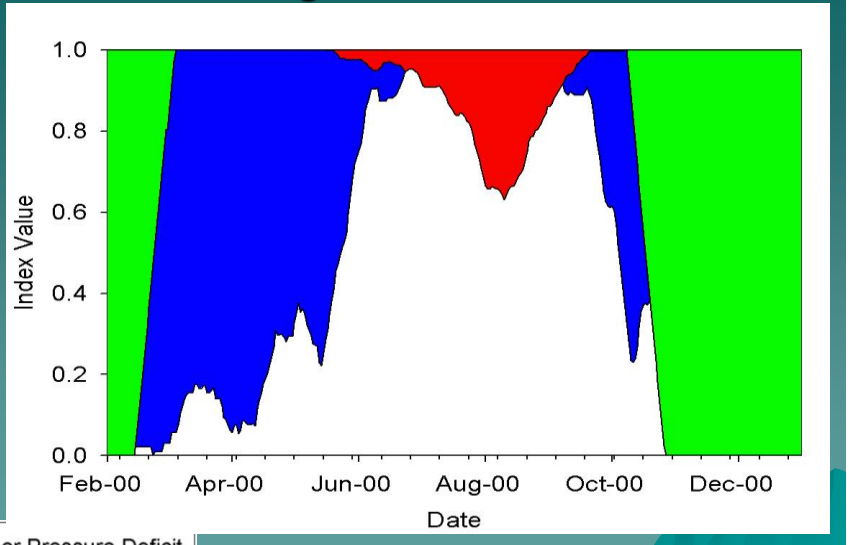
Potential climate limits to plant growth derived from long-term monthly statistics of minimum temperature, cloud cover and rainfall.



Water = 40%, Temperature = 33%, Radiation = 27%

Nemani et al., Science June 6th 2003

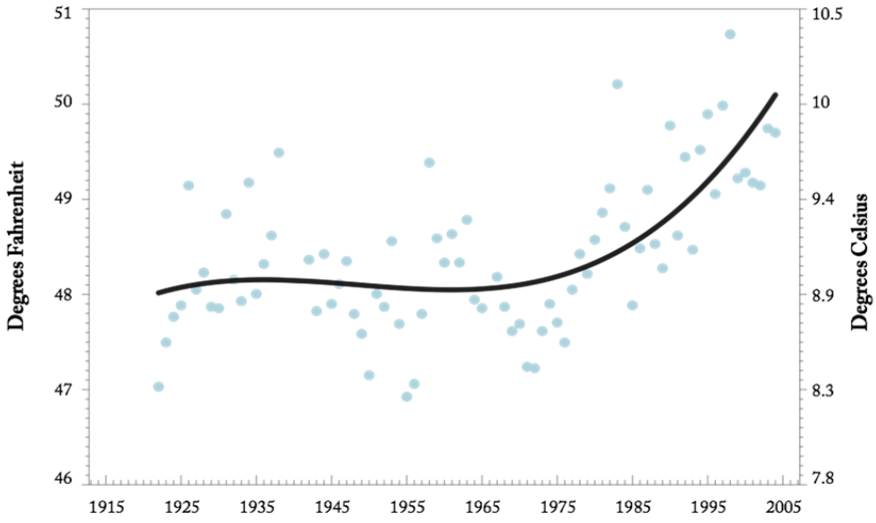
Missoula, Montana USA. Temperate Evergreen Forest



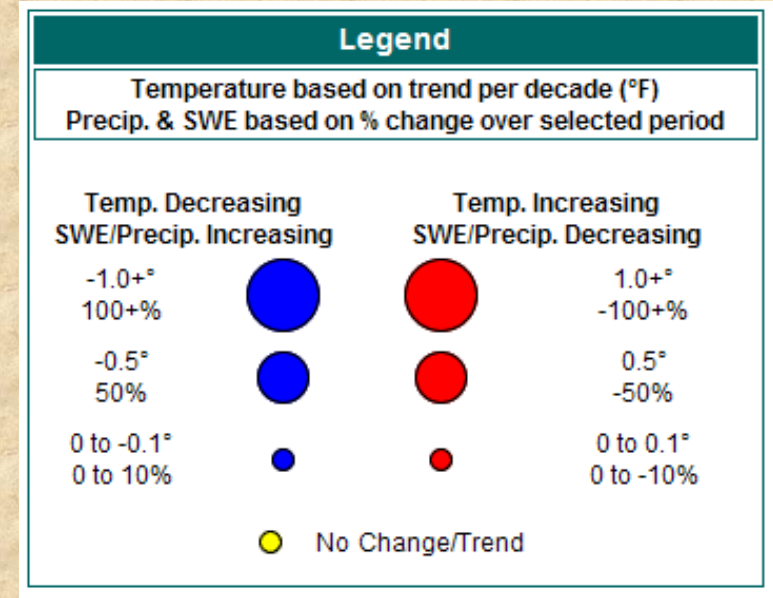
Vapor Pressure Deficit
Daylength
Minimum Temperaure

Jolly et al Global Change Biology 2005

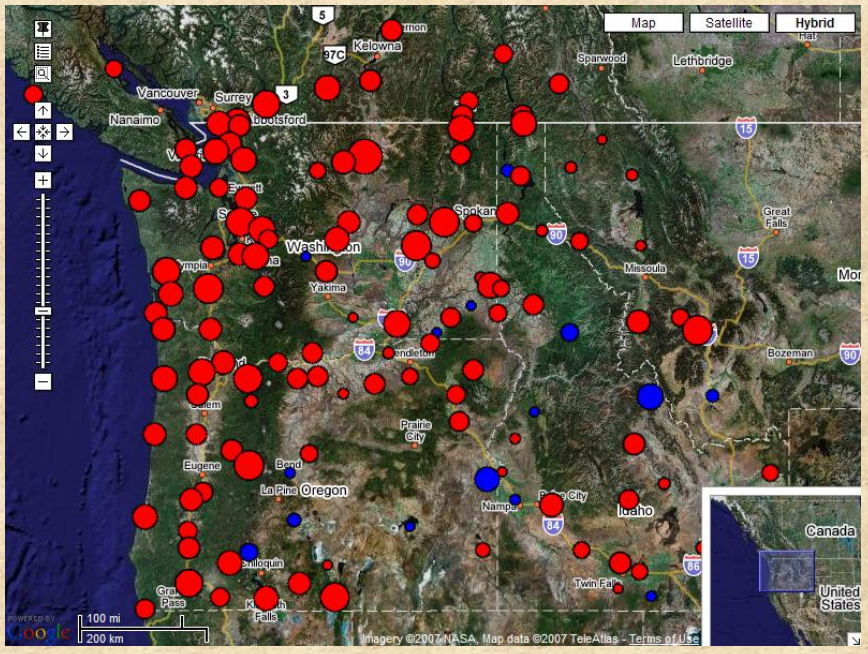
Sea Surface Temperature
(Race Rocks lighthouse, Victoria)



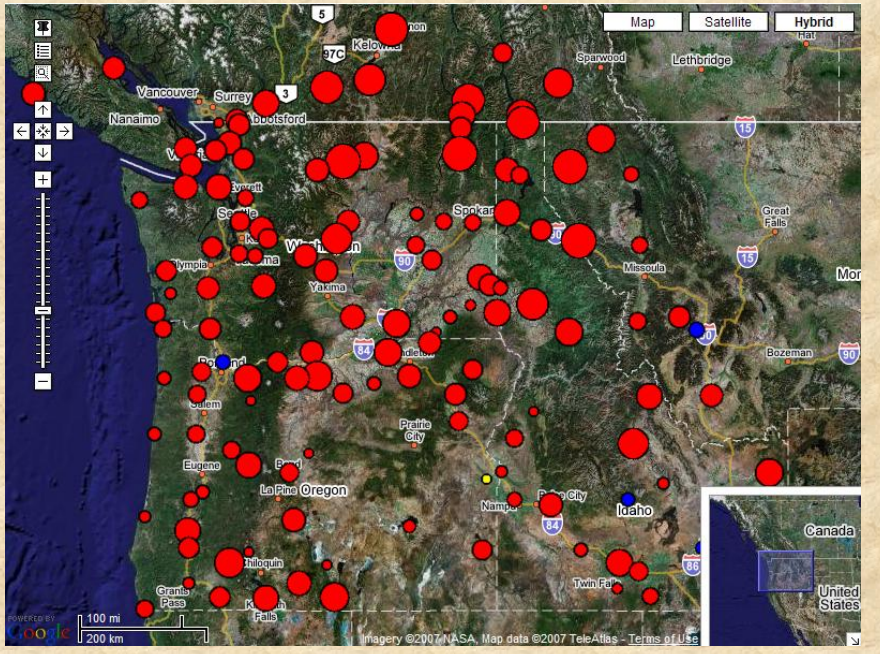
Map Legend



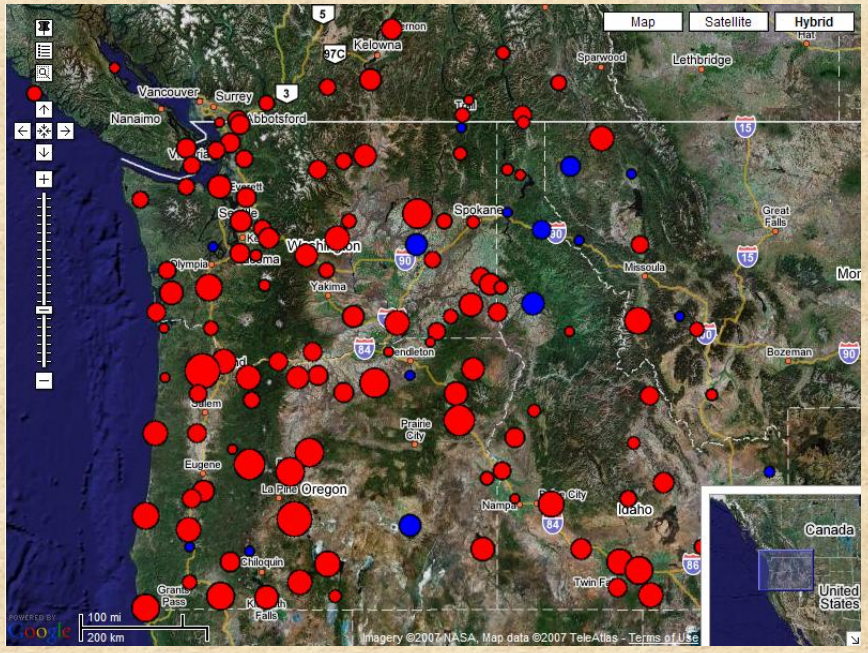
Winter Max Temperature Trend Analysis: 1915-2003



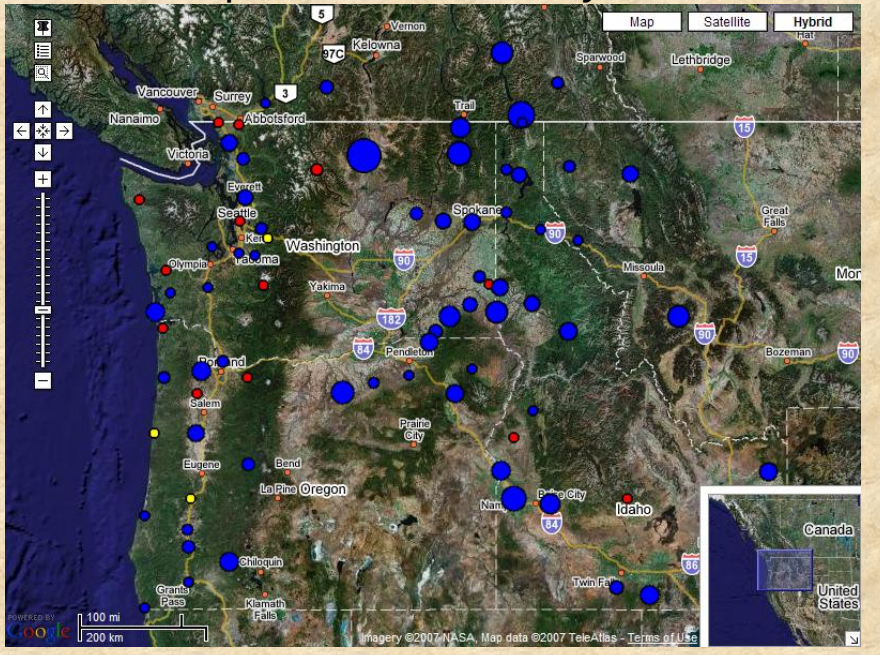
Winter Min Temperature Trend Analysis: 1915-2003

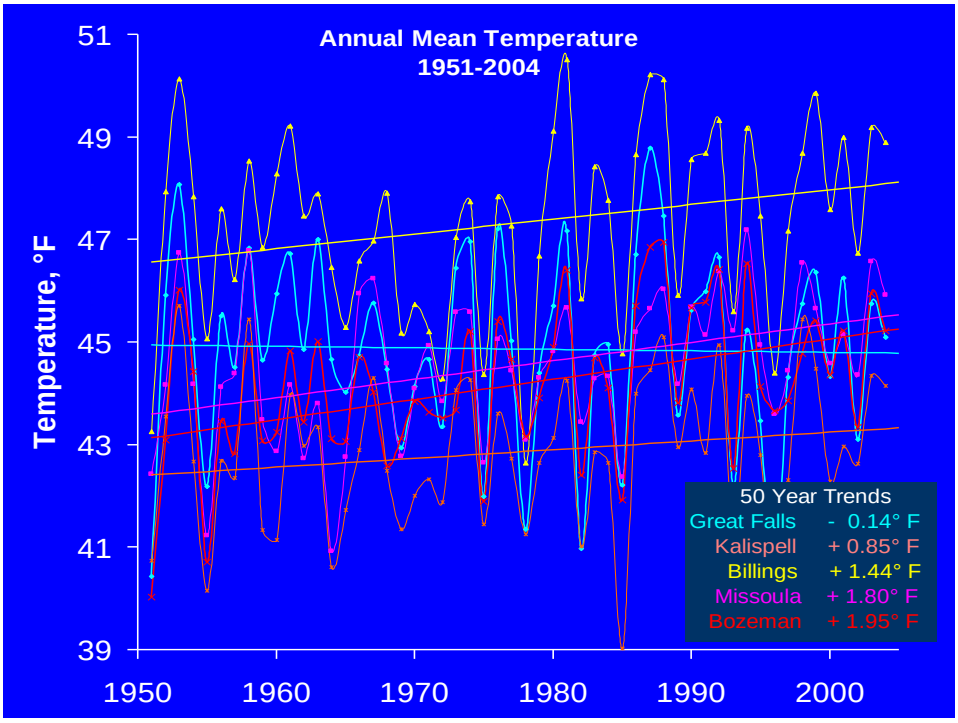


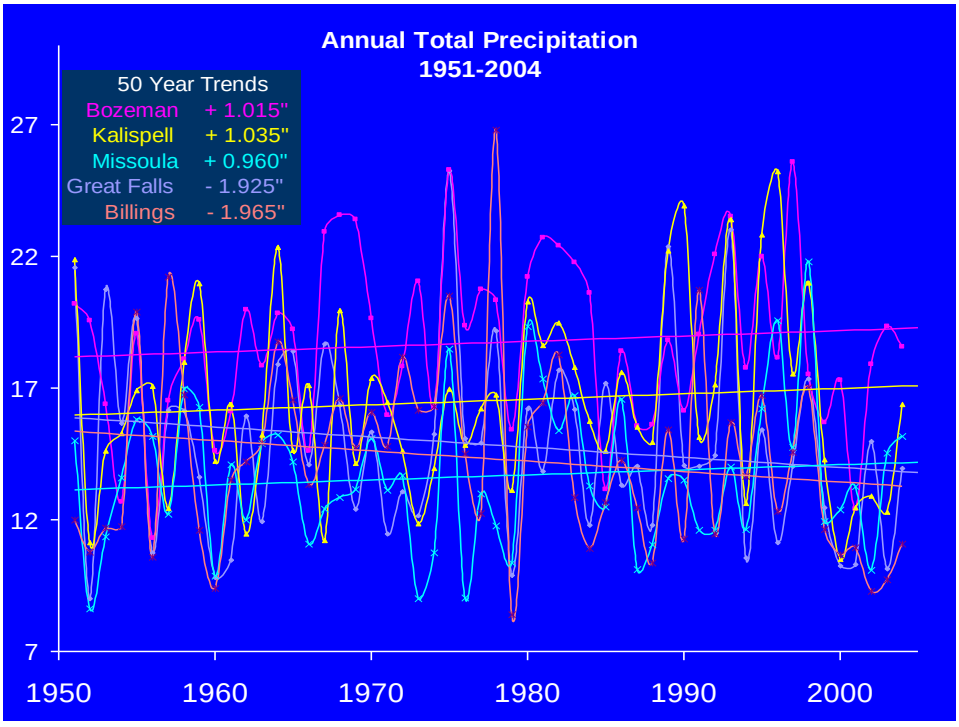
Summer Max Temperature Trend Analysis: 1915-2003

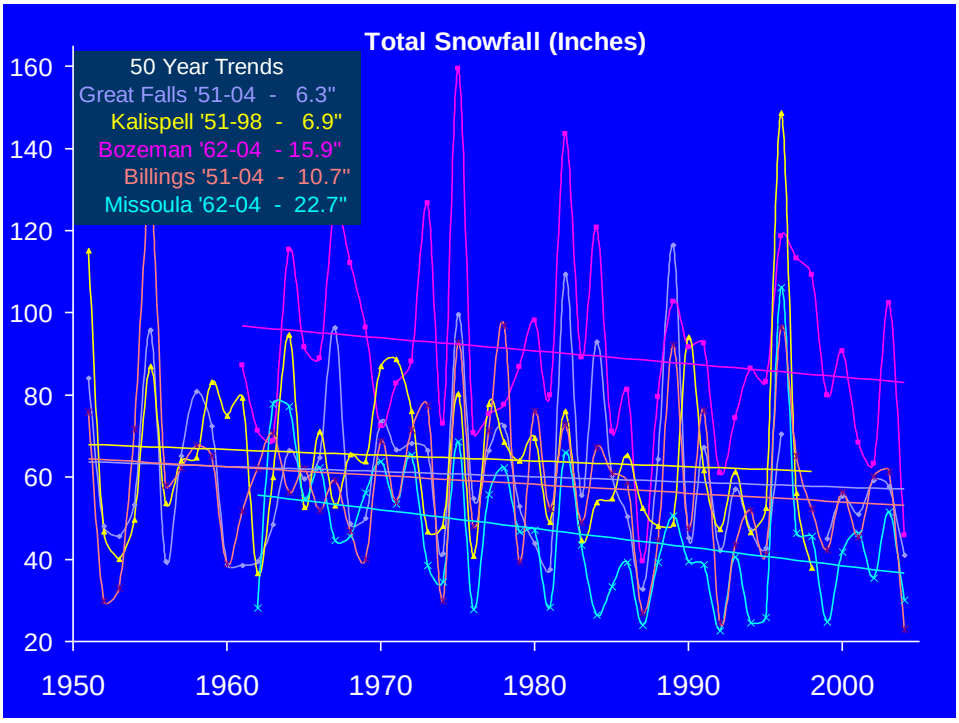


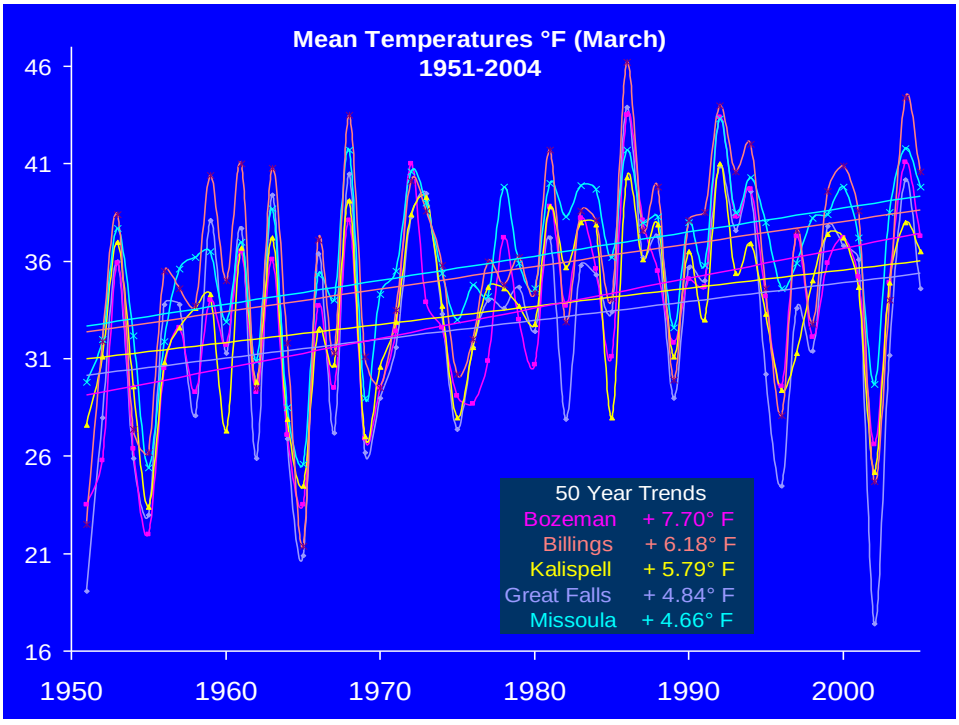
Annual Precipitation Trend Analysis: 1915-2003

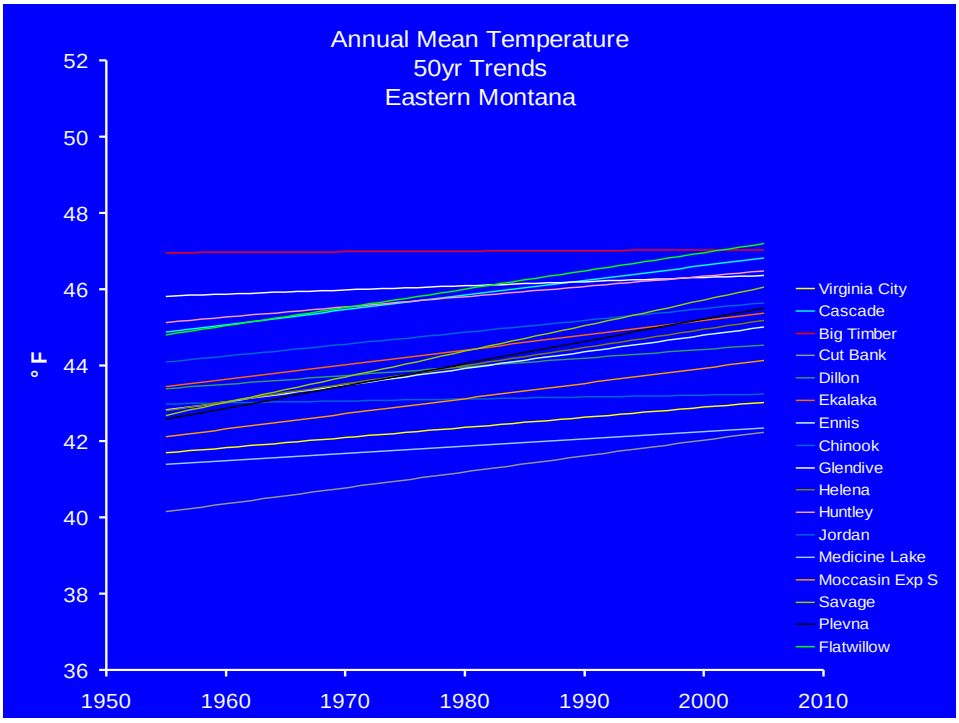


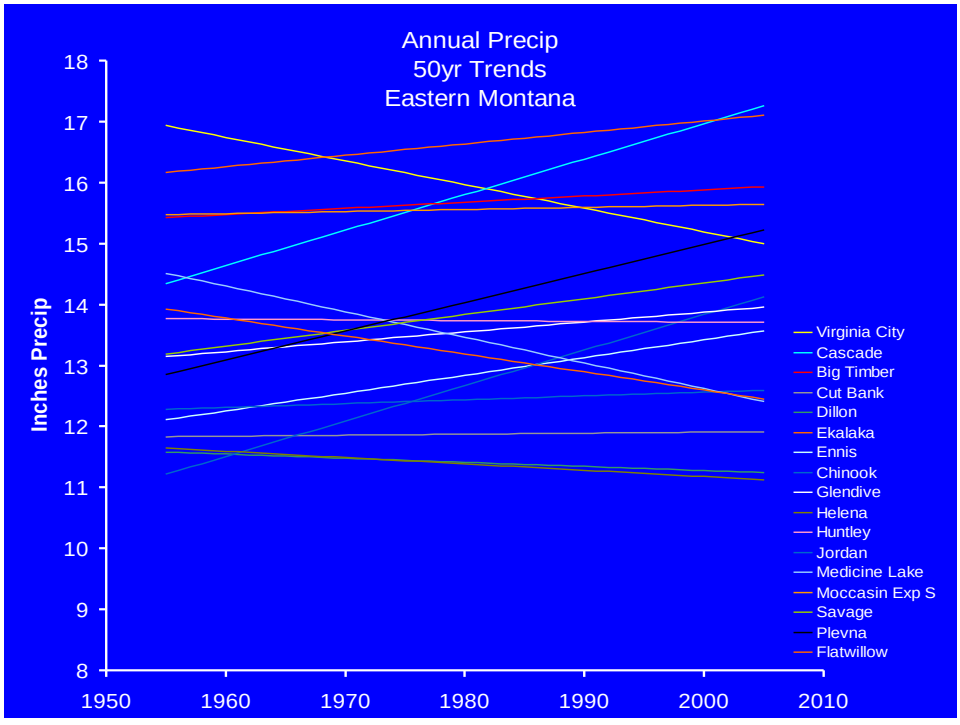

Annual Mean Temperature
1951-2004
Temperature, °F
51
49
47
45
43
41
39
1950
1960
1970
1980
1990
2000
50 Year Trends
Great Falls - 0.14° F
Kalispell + 0.85° F
Billings + 1.44° F
Missoula + 1.80° F
Bozeman + 1.95° F

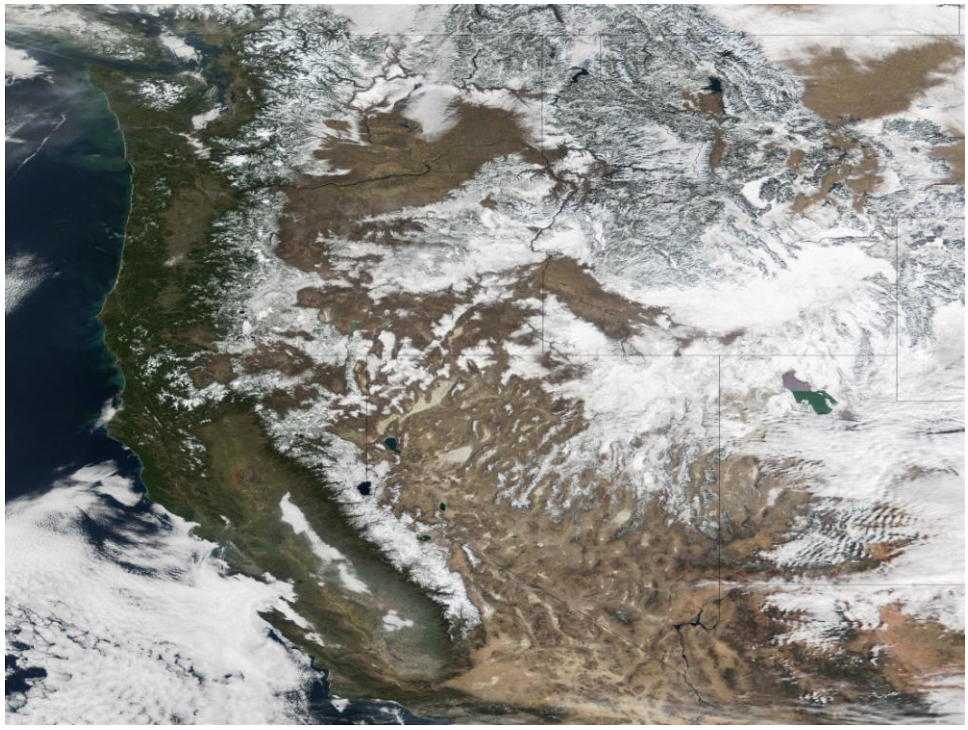

Annual Total Precipitation
1951-2004
50 Year Trends
Bozeman + 1.015"
Kalispell + 1.035"
Missoula + 0.960"
Great Falls - 1.925"
Billings - 1.965"
27
22
17
12
7
1950
1960
1970
1980
1990
2000


Total Snowfall (Inches)
50 Year Trends
Great Falls '51-04 - 6.3"
Kalispell '51-98 - 6.9"
Bozeman '62-04 - 15.9"
Billings '51-04 - 10.7"
Missoula '62-04 - 22.7"
160
140
120
100
80
60
40
20
1950
1960
1970
1980
1990
2000


Mean Temperatures °F (March)
1951-2004
50 Year Trends
Bozeman + 7.70° F
Billings + 6.18° F
Kalispell + 5.79° F
Great Falls + 4.84° F
Missoula + 4.66° F
46
41
36
31
26
21
16
1950
1960
1970
1980
1990
2000

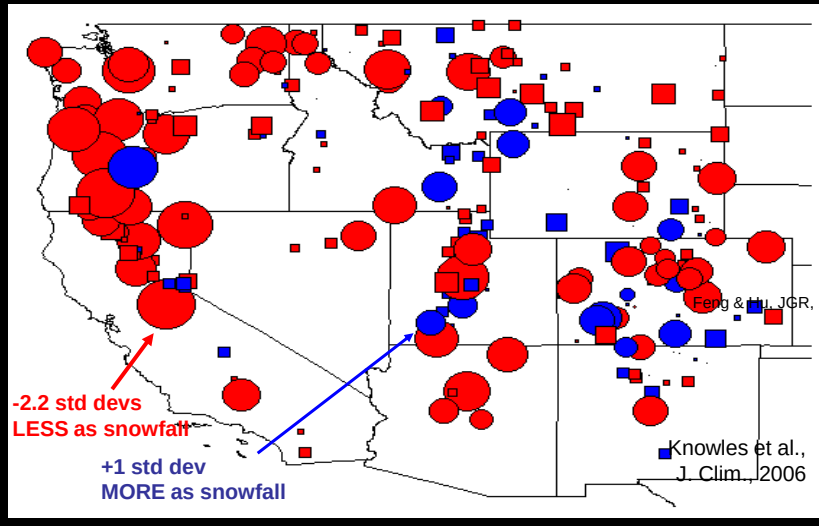

Annual Mean Temperature
50yr Trends
Eastern Montana
° F
52
50
48
46
44
42
40
38
36
1950
1960
1970
1980
1990
2000
2010
Virginia City
Cascade
Big Timber
Cut Bank
Dillon
Ekalaka
Ennis
Chinook
Glendive
Helena
Huntley
Jordan
Medicine Lake
Moccasin Exp S
Savage
Plevna
Flatwillow


Annual Precip
50yr Trends
Eastern Montana
Inches Precip
18
17
16
15
14
13
12
11
10
9
8
1950
1960
1970
1980
1990
2000
2010
Virginia City
Cascade
Big Timber
Cut Bank
Dillon
Ekalaka
Ennis
Chinook
Glendive
Helena
Huntley
Jordan
Medicine Lake
Moccasin Exp S
Savage
Plevna
Flatwillow

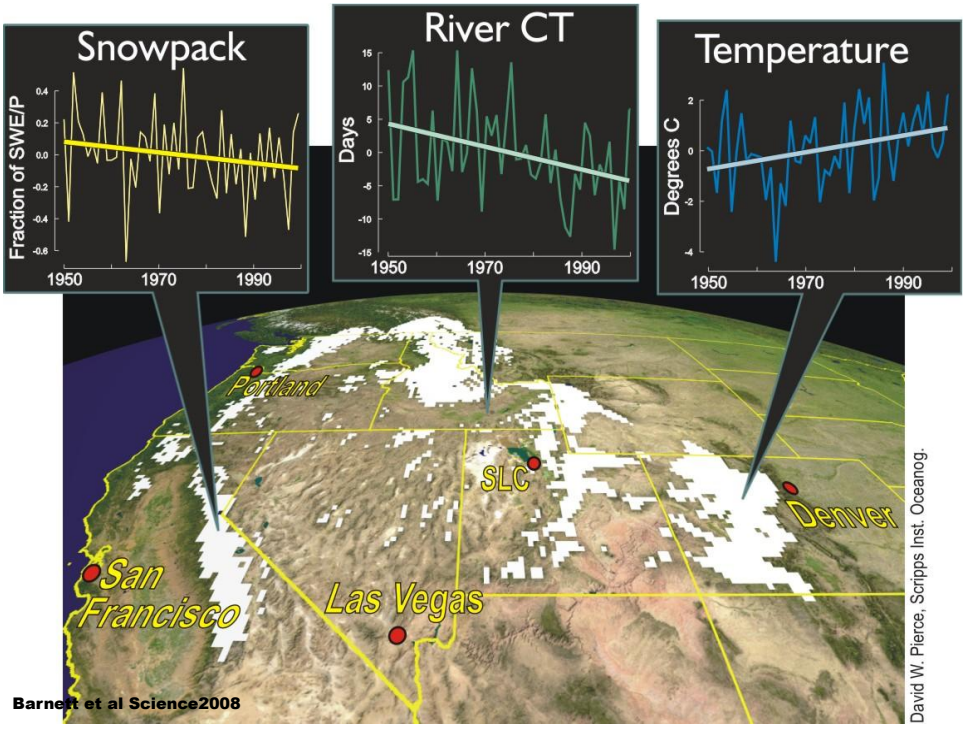


This recent warming already has driven significant hydroclimatic changes.

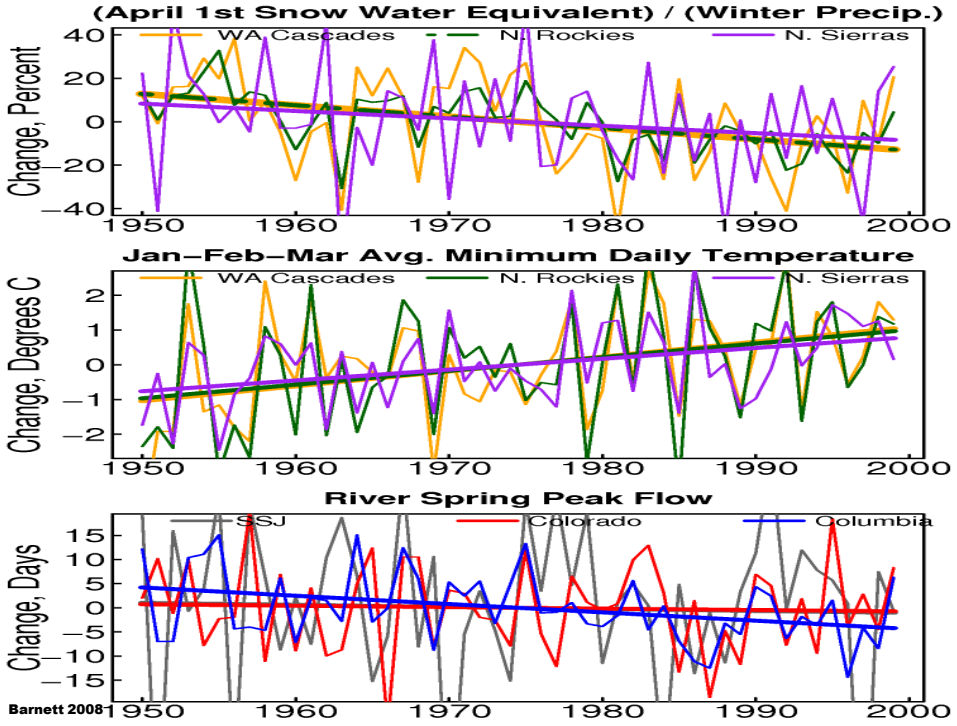
--> Less snow/more rain



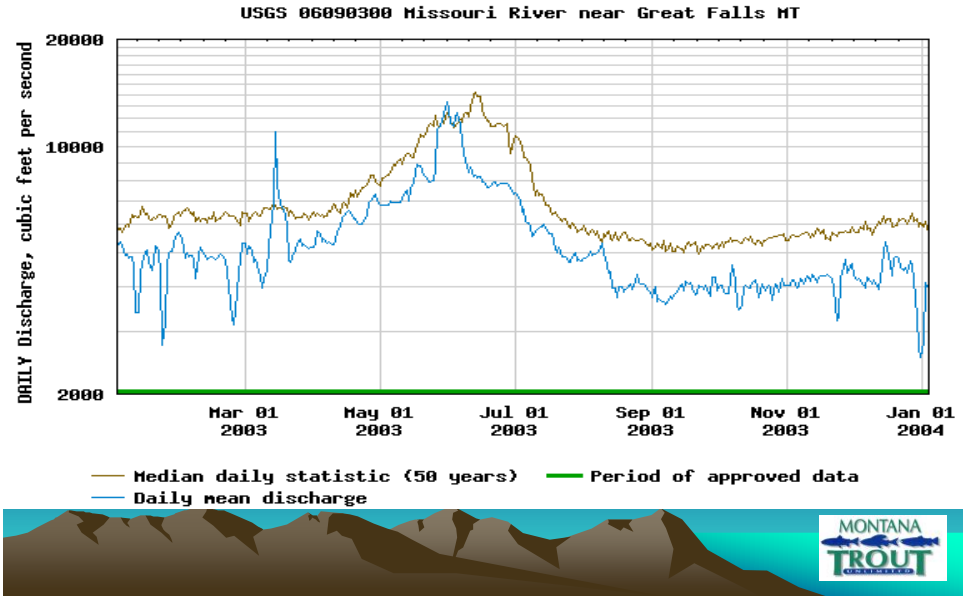
March 4 2007, 7,000ft, North-slope Bitterroot Mtns, Montana

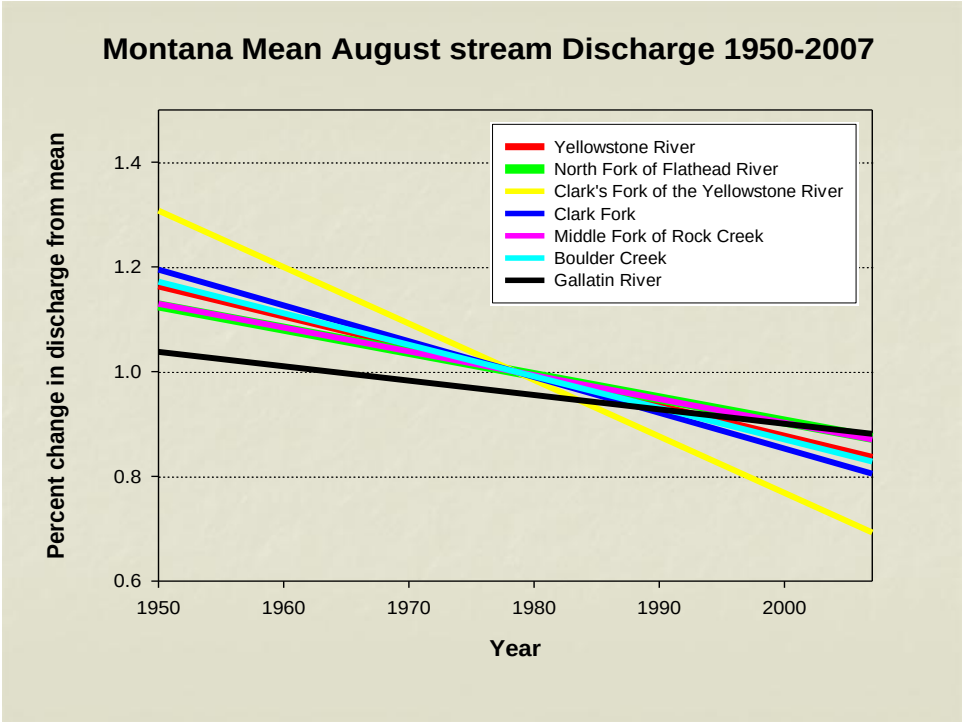


Barnett et al Science2008



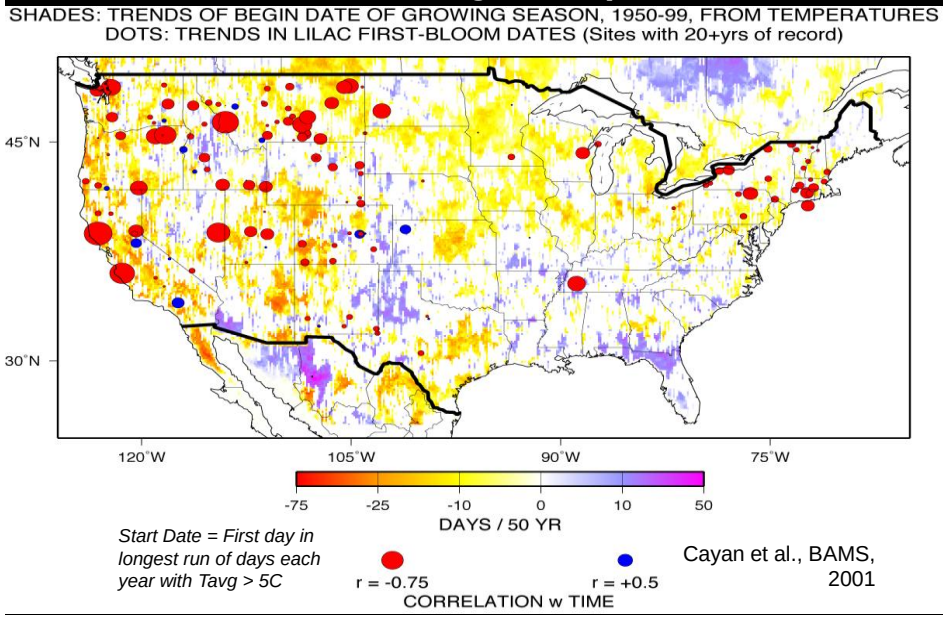
Montana's Streamflow is decreasing and peaking earlier




Montana Mean August stream Discharge 1950-2007
Percent change in discharge from mean
1.4
1.2
1.0
0.8
0.6
1950
1960
1970
1980
1990
2000
Year
Yellowstone River
North Fork of Flathead River
Clark's Fork of the Yellowstone River
Clark Fork
Middle Fork of Rock Creek
Boulder Creek
Gallatin River


ECOSYSTEM RESPONSES
2007 6 8

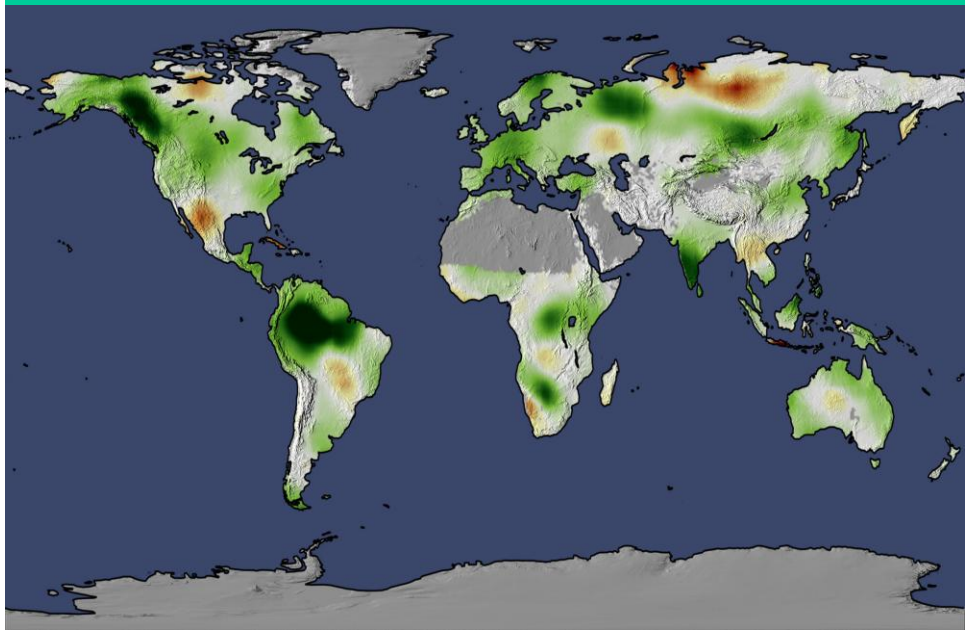
The warming has lengthened growing seasons and hastened green-up dates.



Start Date = First day in longest run of days each year with Tavg > 5C

Cayan et al., BAMS, 2001

Change in Terrestrial NPP from 1982 to 1999.

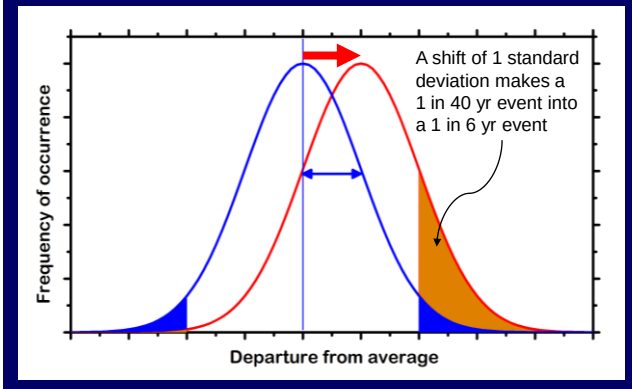


Nemani et al., Science June 6th 2003

Calculus of extremes

The distribution of weather events around the climatic average often follows a 'bell-shaped' curve.

Climate change can involve change in the average, or the spread around the average (standard deviation), or both.



A shift in the distribution of temperatures has a much larger relative effect at the extremes than near the mean.

IPCC - WGI

Missoula July 07 Records

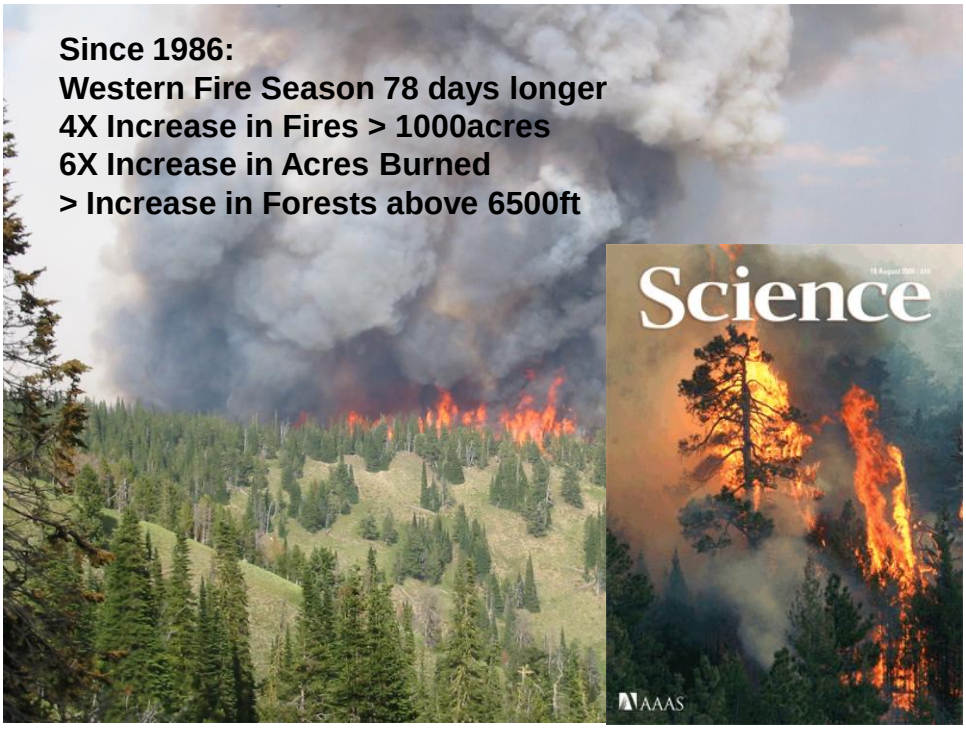
- Hottest Temperature Ever – 107
- Warmest Night Ever – 71
- Average Temp – 78.1 – 11.2 F above average
  - Breaks the old record by 3.3F
- Most number of 100 F days – 11
  - Old record – 6 in 1936
- Most number of nights 60F and above – 18
  - Old record – 10 in 1985
- Driest July on record at Missoula Airport
  - 0.03" – old Airport record is 0.09"

From Gene Petrescu, NWS, Missoula

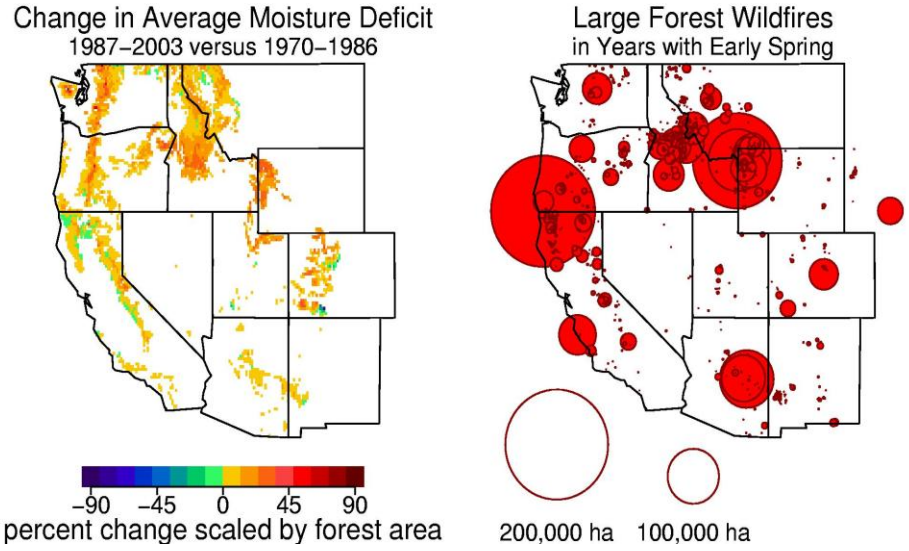
THIS WILL BE A NORMAL JULY IN 2050!!

Space Shuttle picture of Montana Fires August 13, 2007

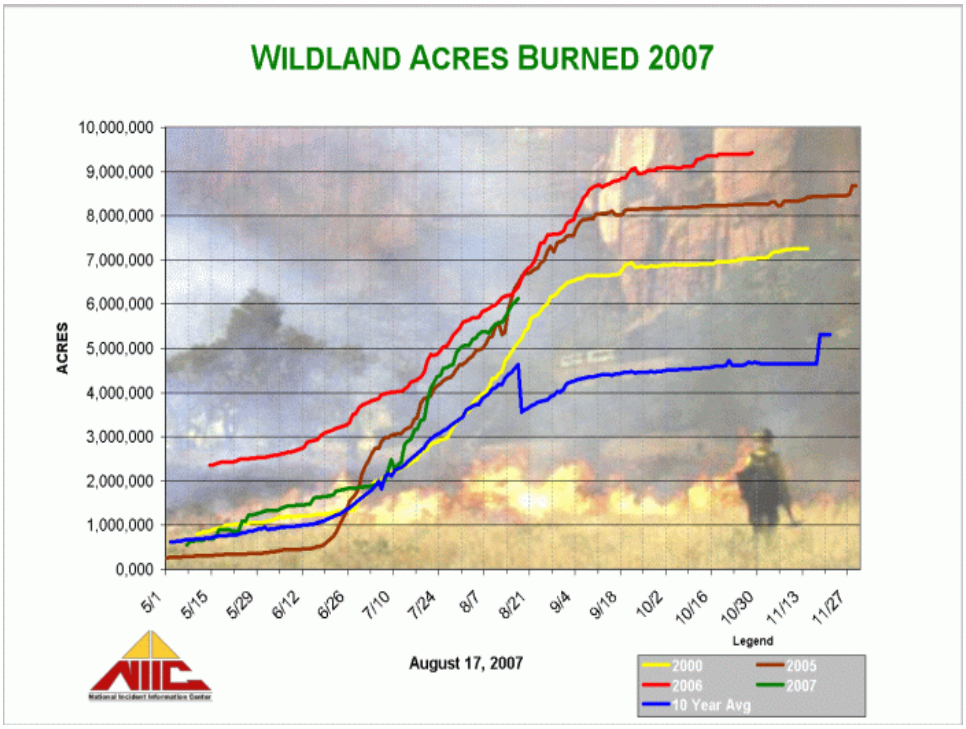
Since 1986:
Western Fire Season 78 days longer
4X Increase in Fires > 1000acres
6X Increase in Acres Burned
> Increase in Forests above 6500ft



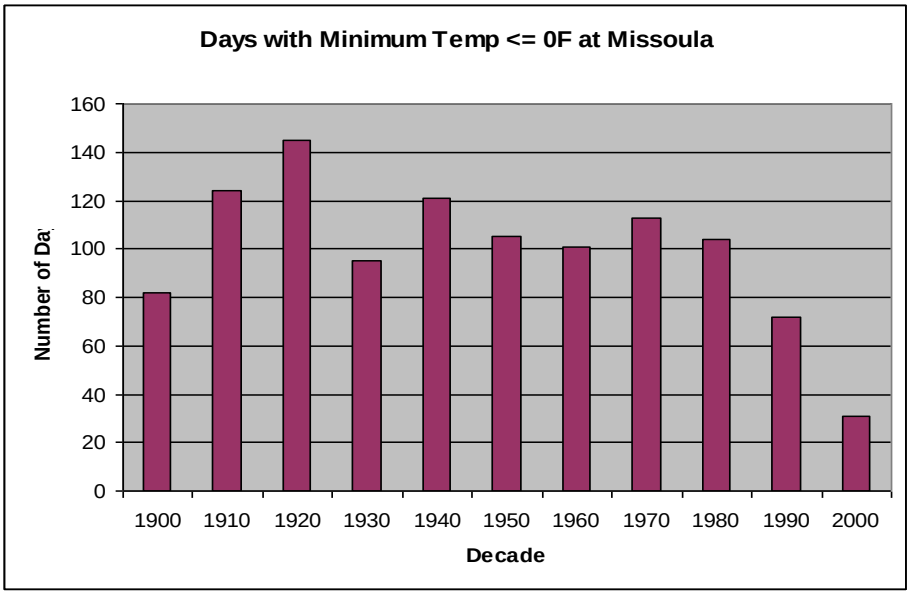
Wildfires accelerate 1970 – 2003 with early snowmelt, longer, drier summers



Westerling et al Science 2006, Running, Science 2006



DAYS/Decade <0degF



From Gene Petrescu, NWS, Missoula

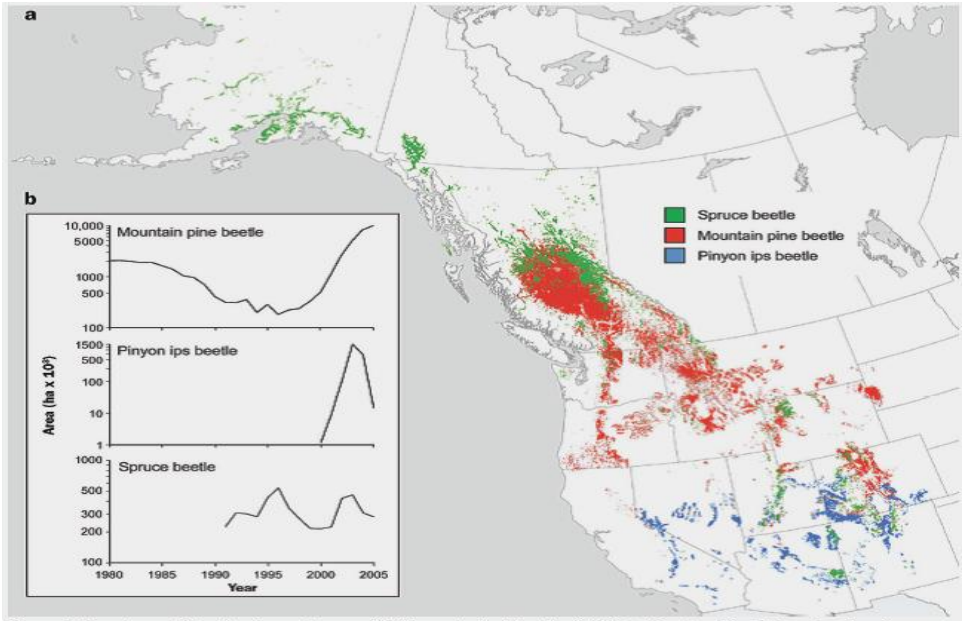
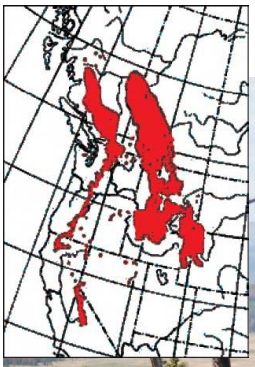


Figure 1. Recent mortality of major western conifer biomes to bark beetles. (a) Map of western North America showing regions of major eruptions by three species. (b) Sizes of conifer biome area affected by these three species over time. Data are from the Canadian Forest Service, the British Columbia Ministry of Forests and Range, and the US Forest Service.

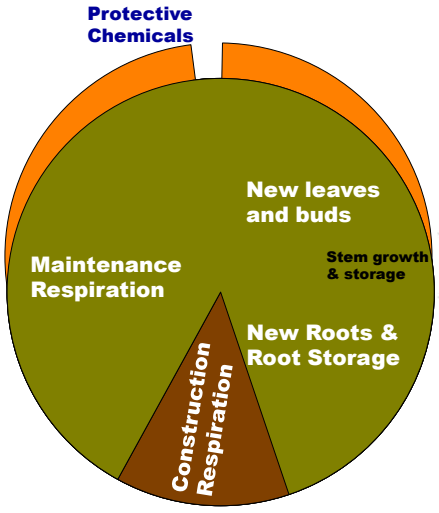
Raffa et al Bioscience 2008.

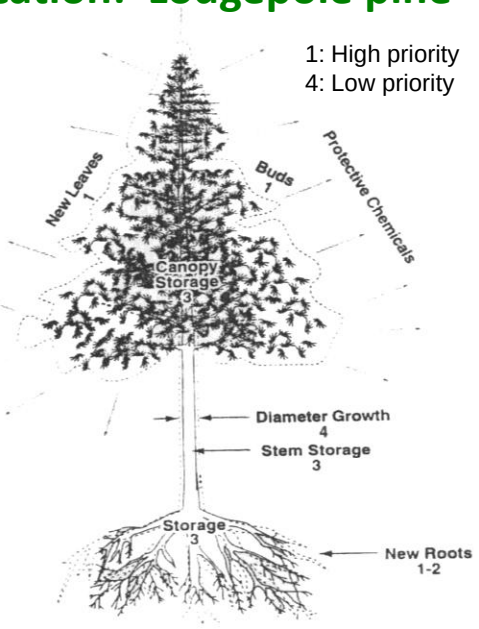


Union Pass, WY August 2008

Whitebark Pine Dubois WY Aug 08

Potential Carbon Allocation: Lodgepole pine





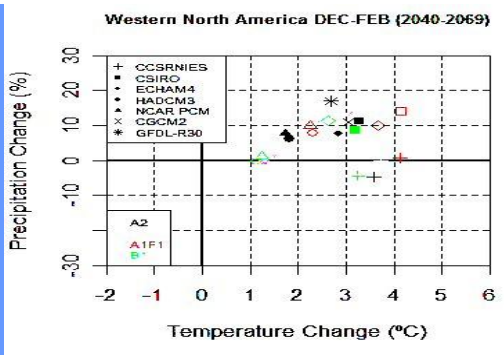
After Waring & Pitman, 1985

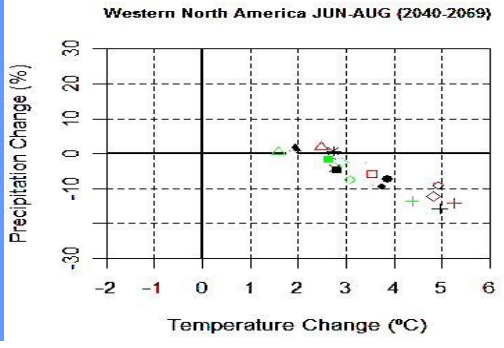
IPCC 4th Assessment GCMs

All Year
3 deg warmer

BUT
Winter – wetter

Summer – drier





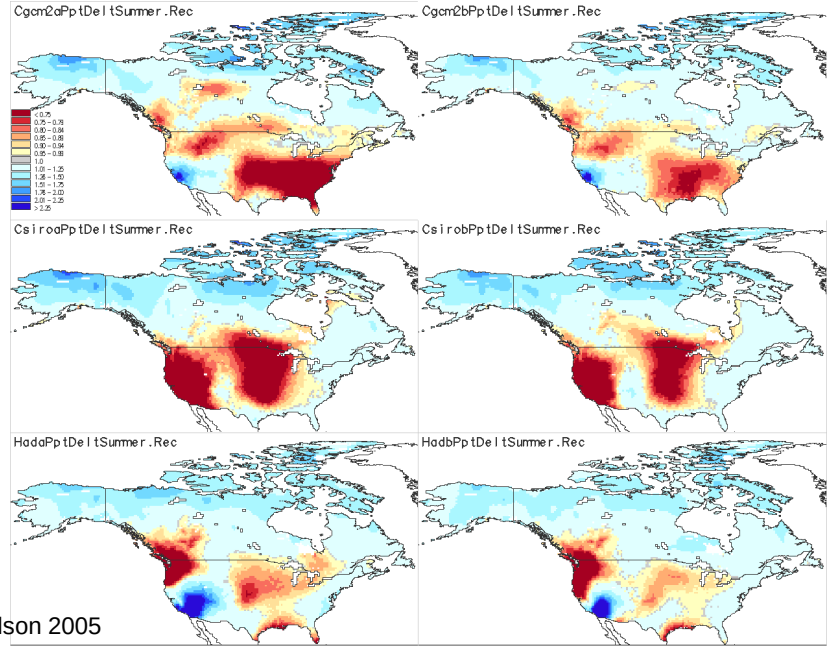
Precipitation % Change 2070-2099
Summer (Jun – Aug)

A2 B2

CGCM2

CSIRO

HADCM3



R. Neilson 2005

By 2050 Global Climate Models project Montana to be 5deg F. warmer in summer, but receive 10% less rainfall

40% Increase in Summer Evaporative Demand!

Water Management
Recreation versus Agriculture

The MonDak Region has an enormous amount of potential for irrigation development.