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

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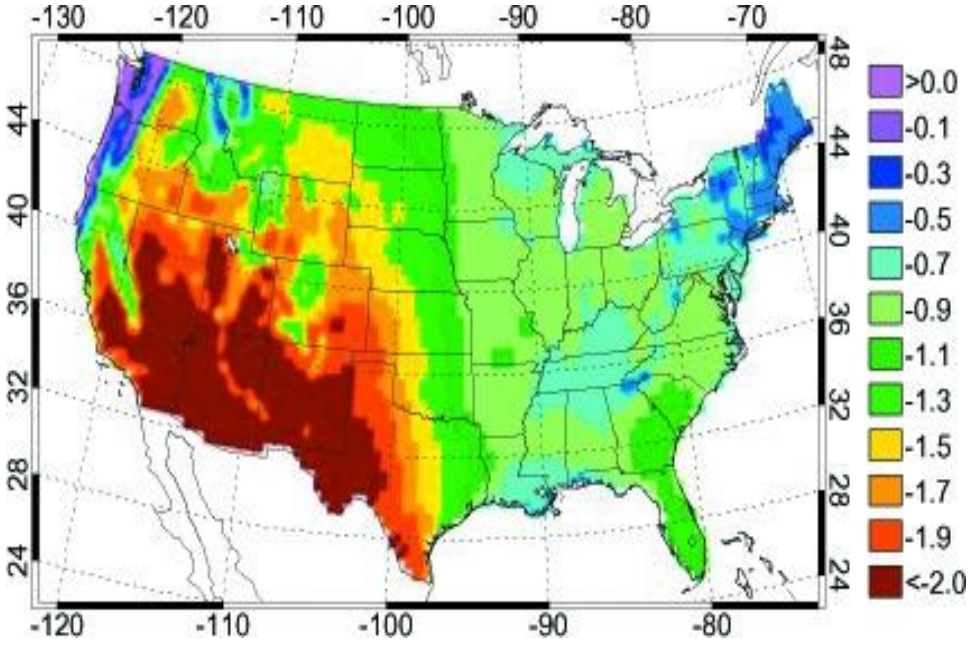
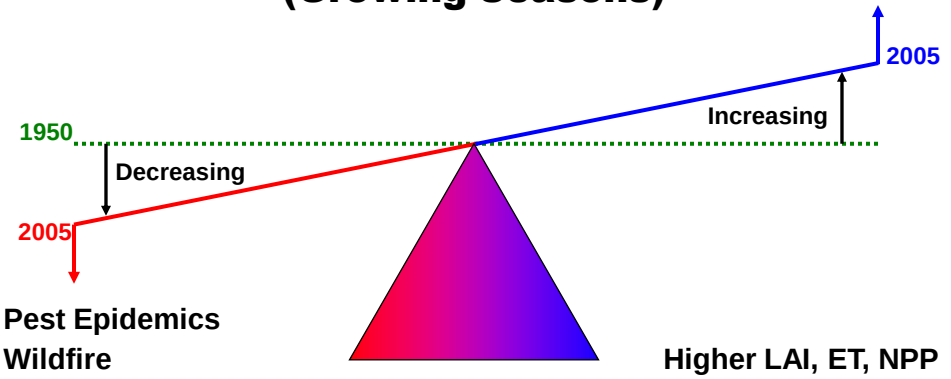
Montana Ecosystem Responses To Climate Trends

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)

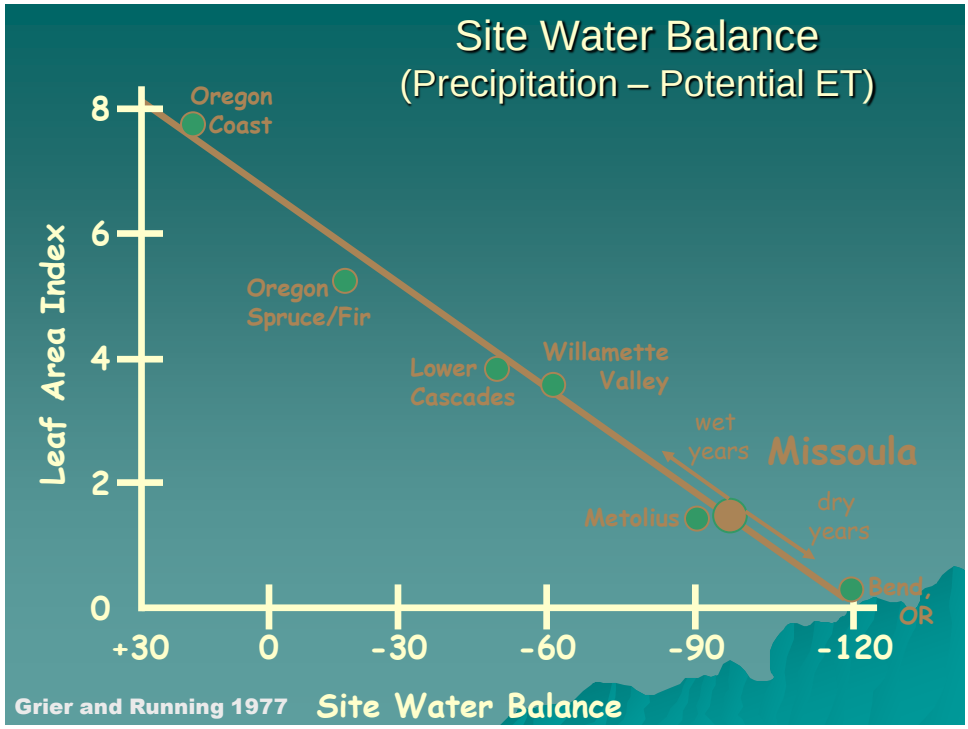


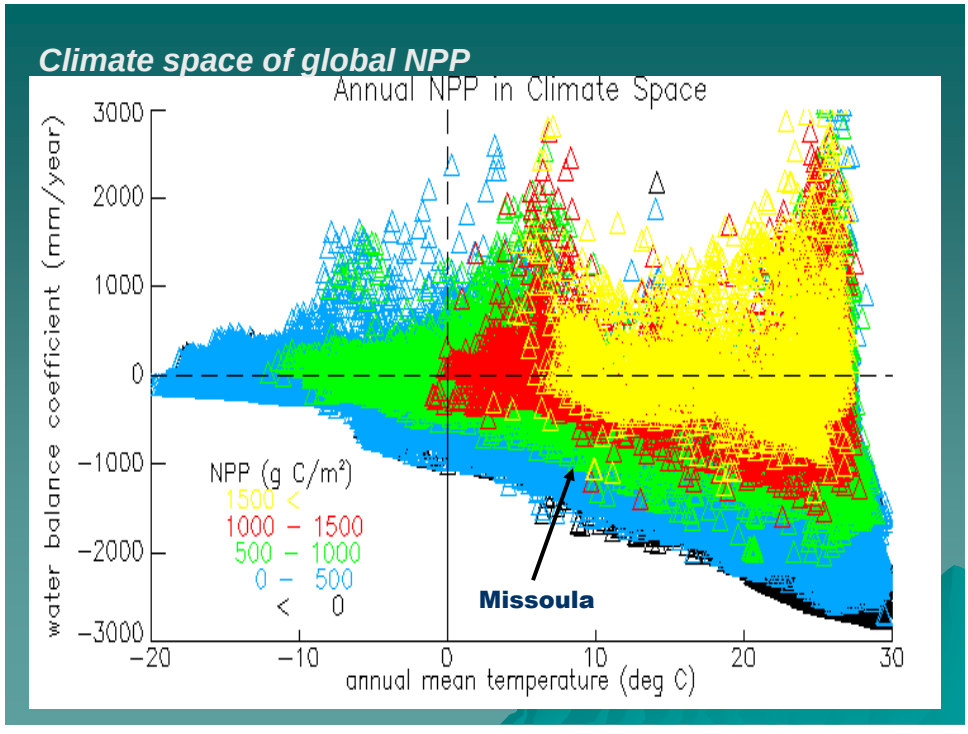
Land Water Balance Tipping Points
(Growing Seasons)



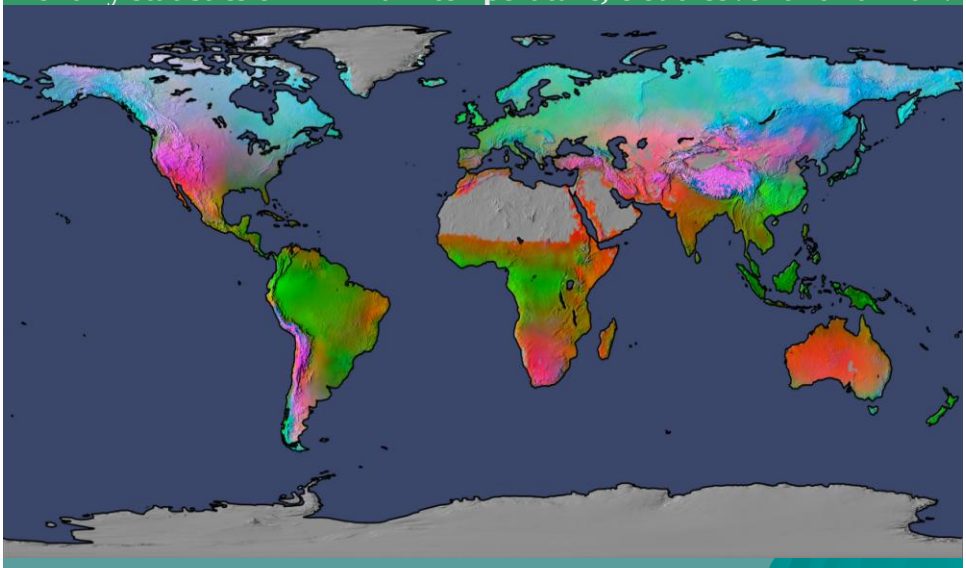
Pest Epidemics
Wildfire
Forest Mortality
Low Streamflows
Reduced Nutrient Cycling
Lower NPP
Biodiversity?
Invasives?

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)

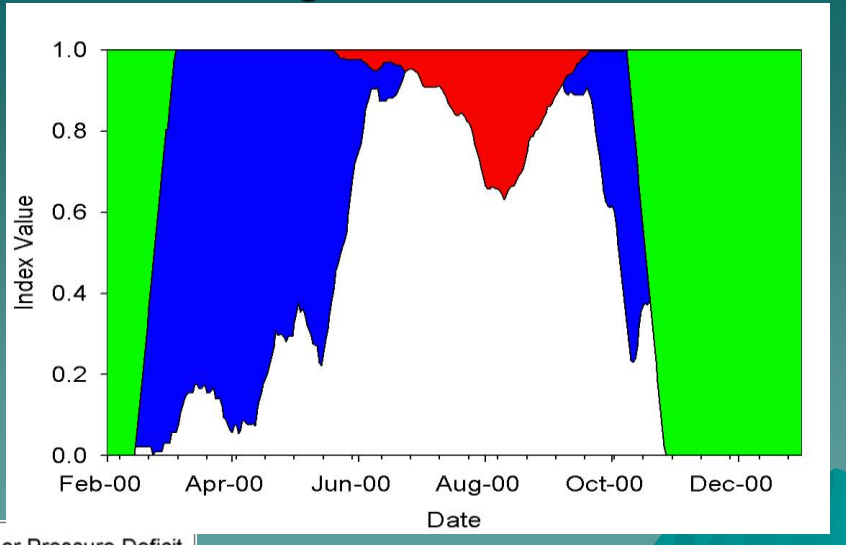
Potential climate limits to plant growth derived from long-term monthly statistics of minimum temperature, cloud cover and rainfall.



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

Nemani et al., Science June 6th 2003

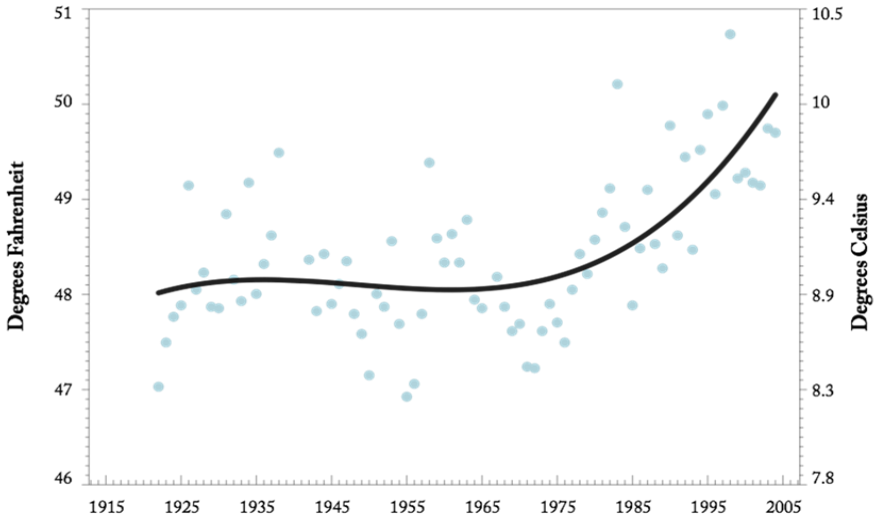
Missoula, Montana USA. Temperate Evergreen Forest



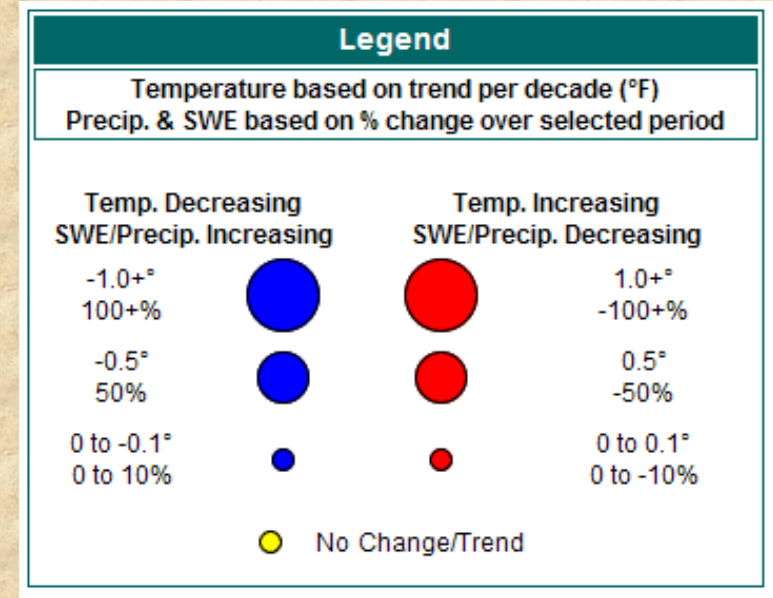
Vapor Pressure Deficit
Daylength
Minimum Temperaure

Jolly et al Global Change Biology 2005

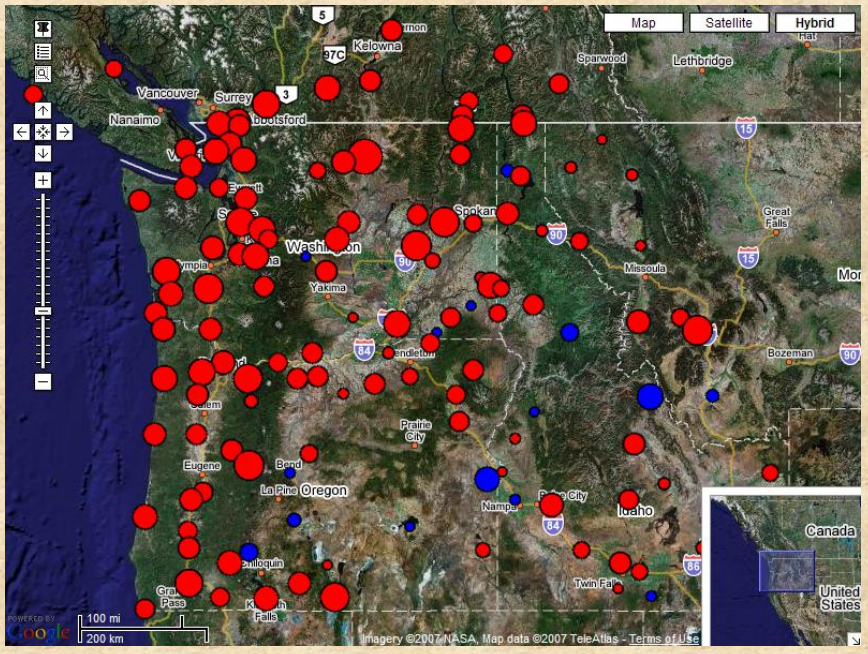
Sea Surface Temperature
(Race Rocks lighthouse, Victoria)



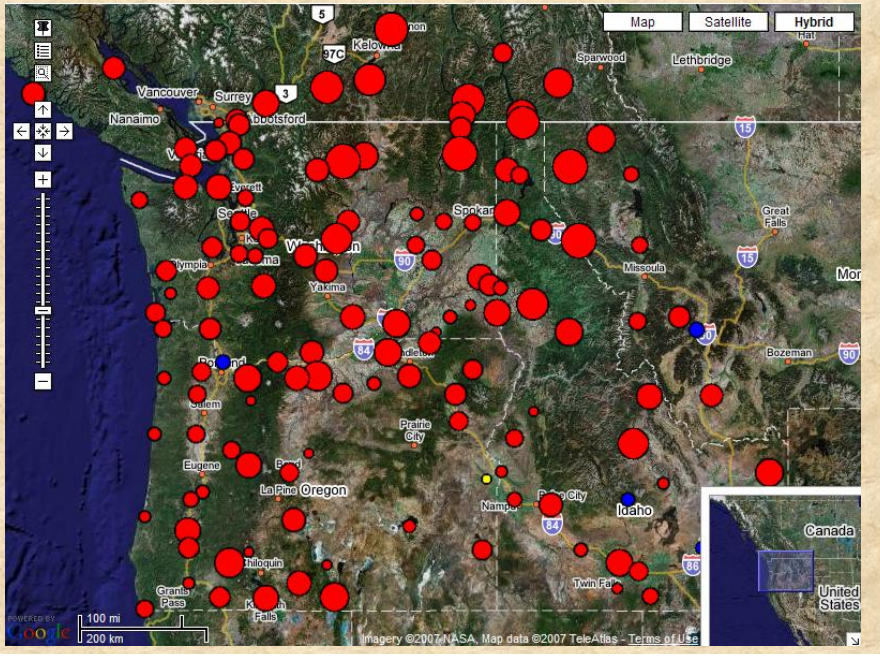
Map Legend



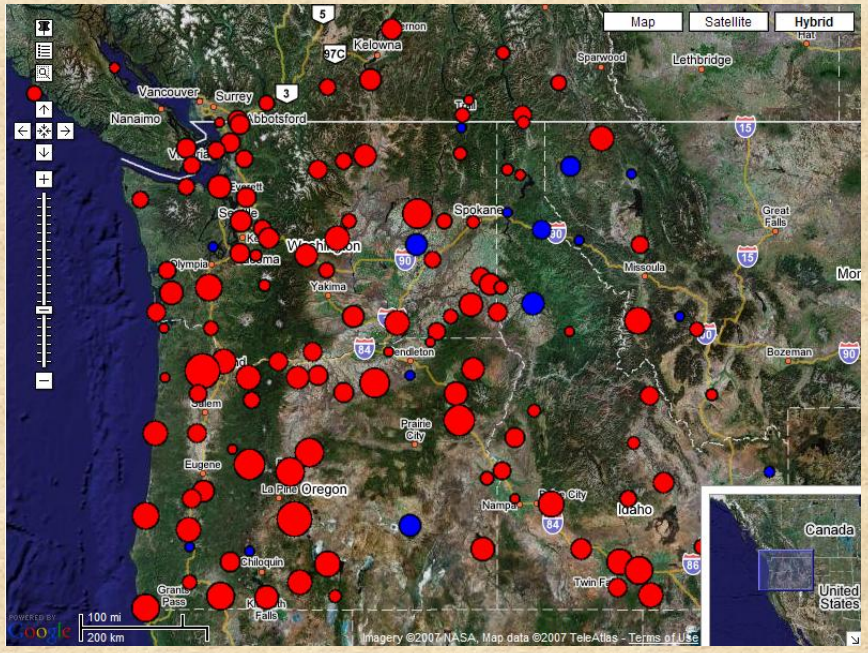
Winter Max Temperature Trend Analysis: 1915-2003



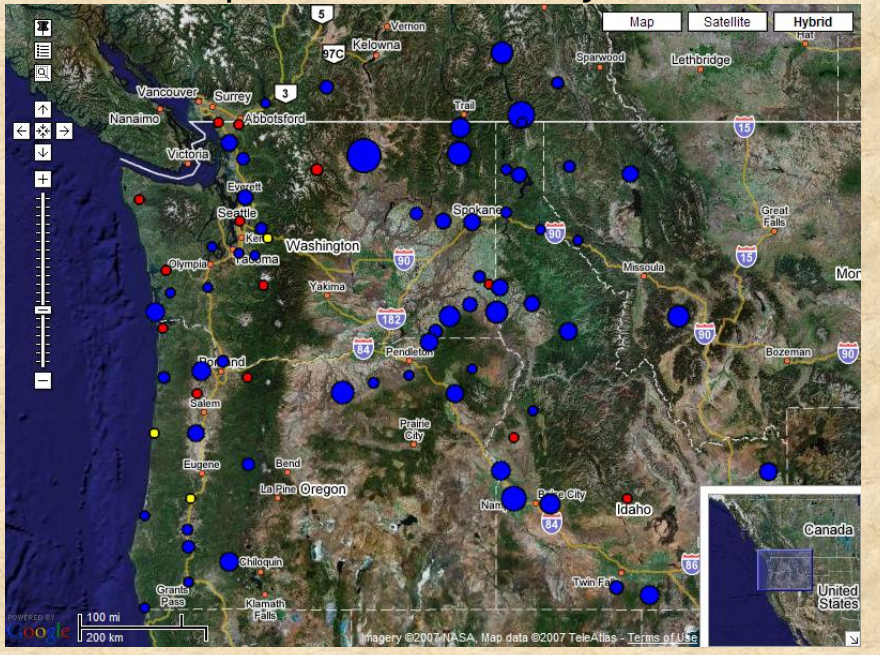
Winter Min Temperature Trend Analysis: 1915-2003

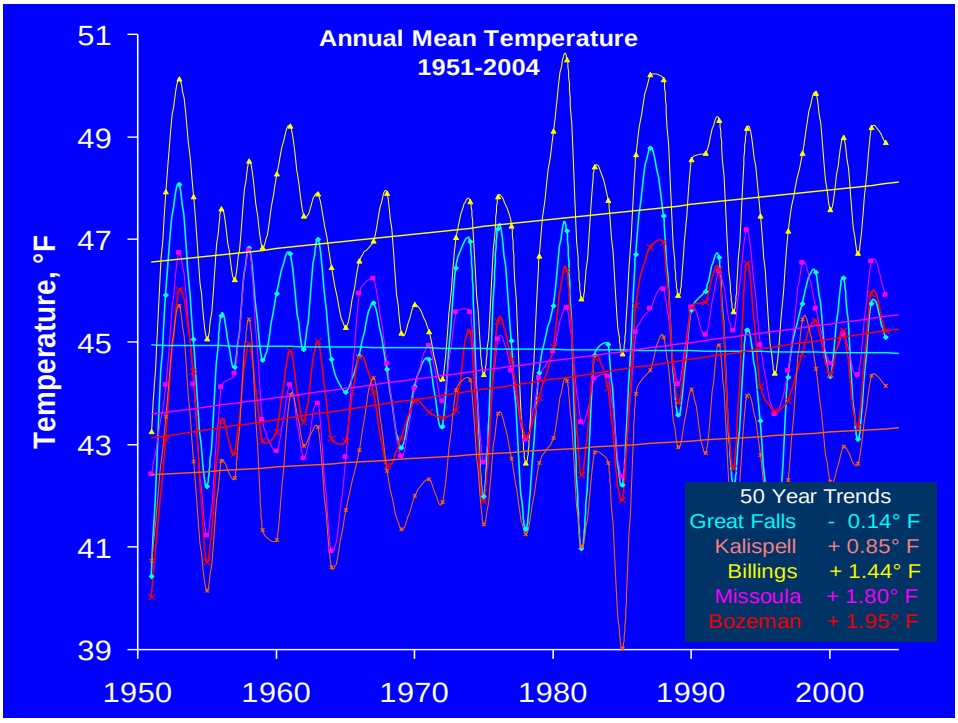


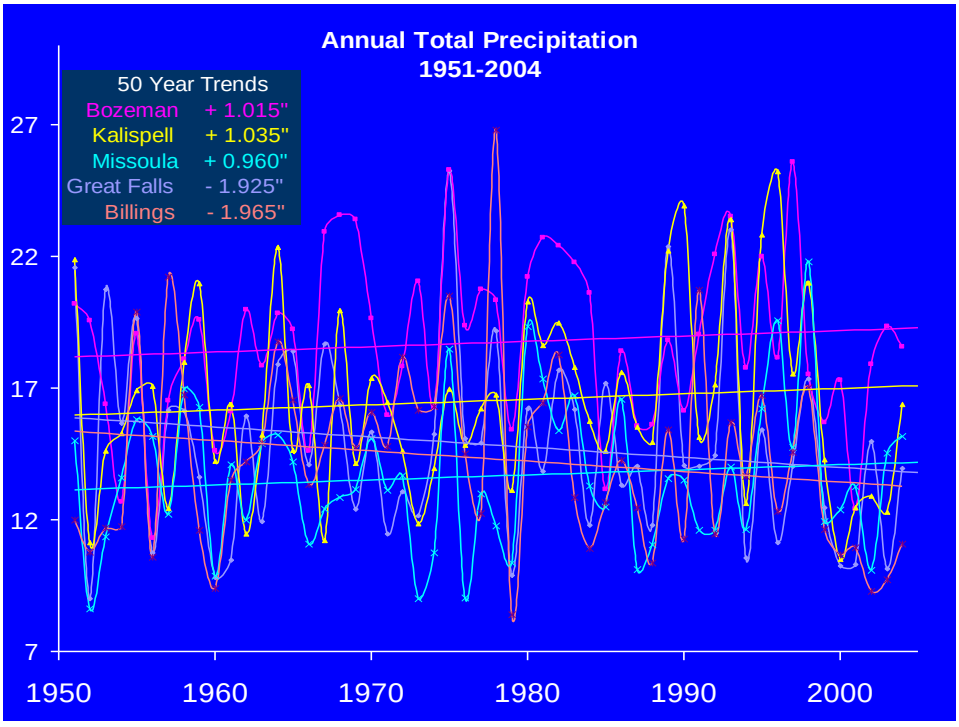
Summer Max Temperature Trend Analysis: 1915-2003

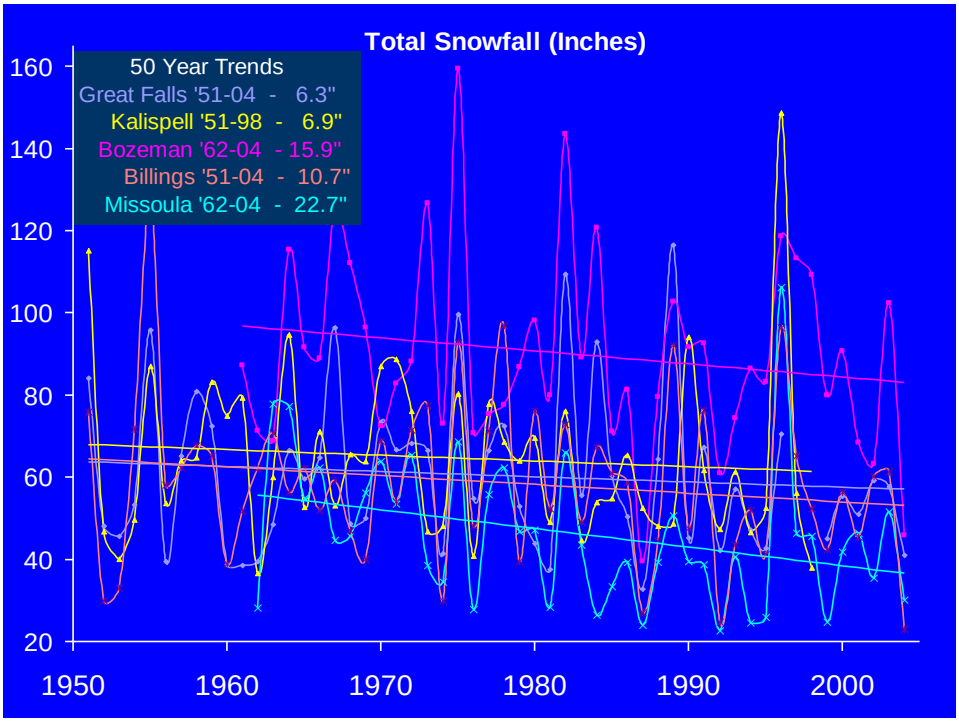


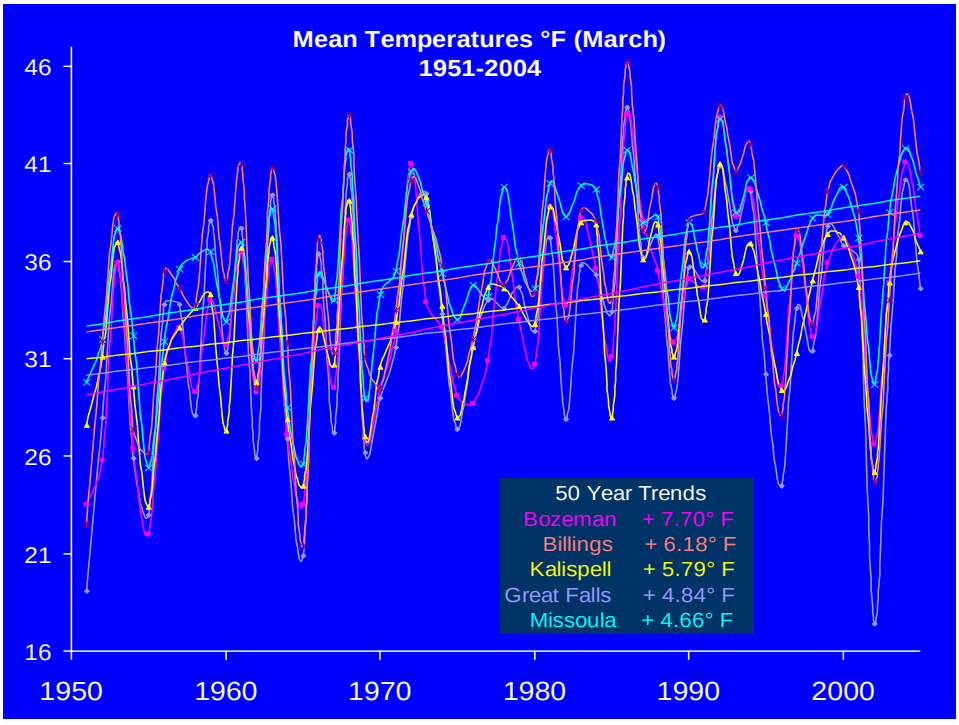
Annual Precipitation Trend Analysis: 1915-2003

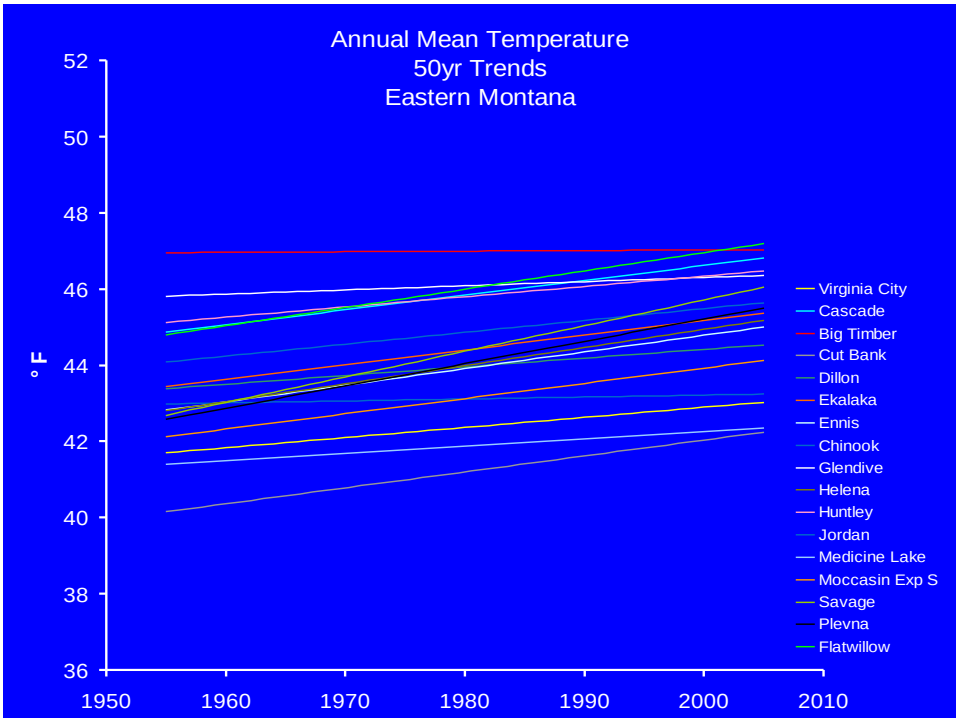


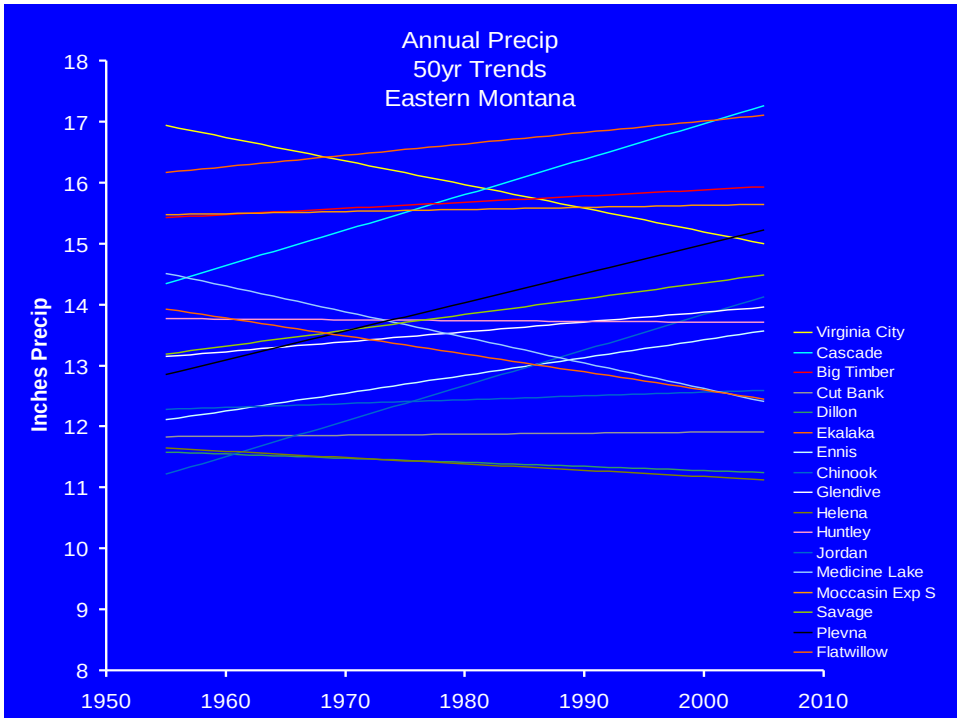

Annual Mean Temperature
1951-2004
Temperature, °F
51
49
47
45
43
41
39
1950
1960
1970
1980
1990
2000
50 Year Trends
Great Falls - 0.14° F
Kalispell + 0.85° F
Billings + 1.44° F
Missoula + 1.80° F
Bozeman + 1.95° F

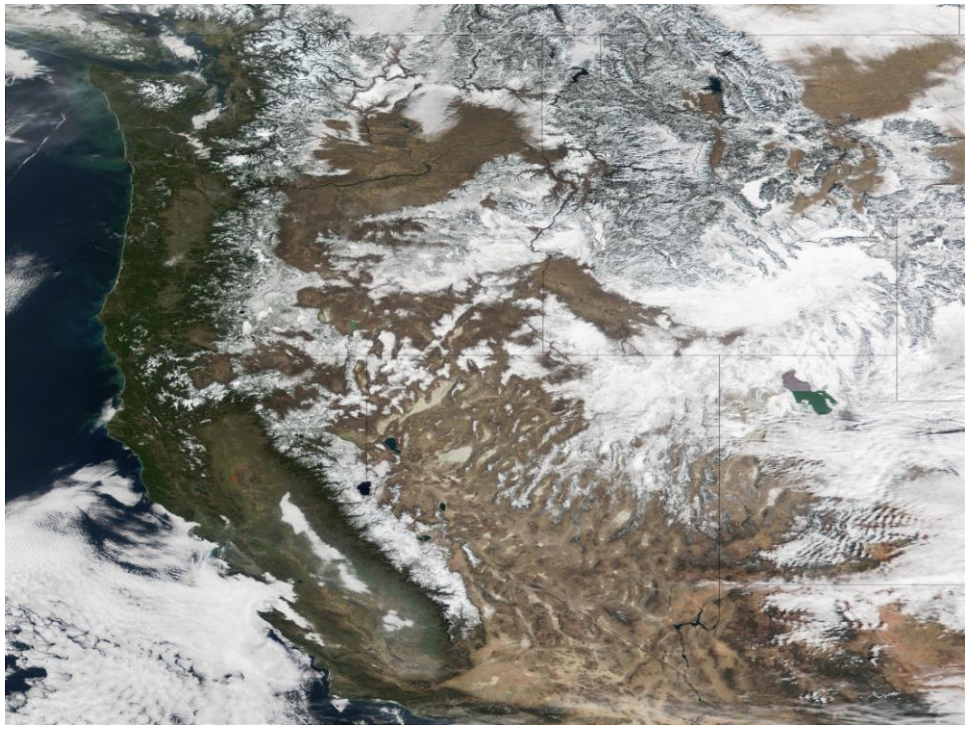

Annual Total Precipitation
1951-2004
50 Year Trends
Bozeman + 1.015"
Kalispell + 1.035"
Missoula + 0.960"
Great Falls - 1.925"
Billings - 1.965"
27
22
17
12
7
1950
1960
1970
1980
1990
2000


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

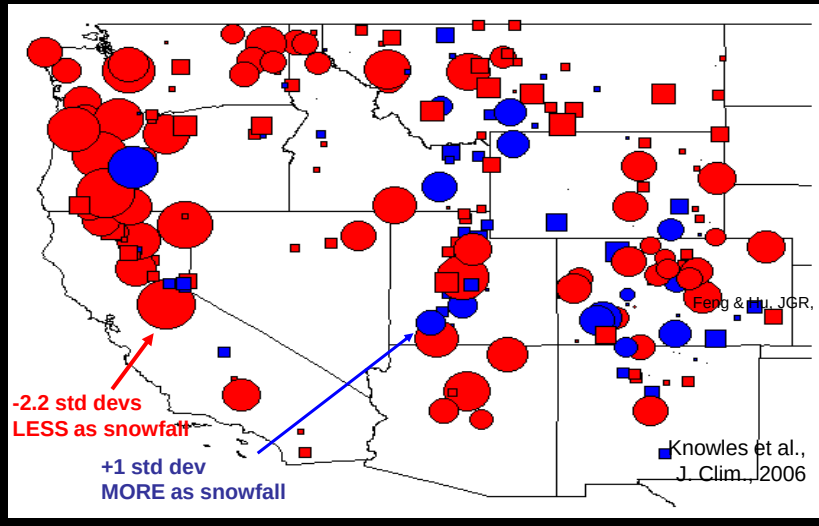

Annual Mean Temperature
50yr Trends
Eastern Montana
° F
52
50
48
46
44
42
40
38
36
1950
1960
1970
1980
1990
2000
2010
Virginia City
Cascade
Big Timber
Cut Bank
Dillon
Ekalaka
Ennis
Chinook
Glendive
Helena
Huntley
Jordan
Medicine Lake
Moccasin Exp S
Savage
Plevna
Flatwillow


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

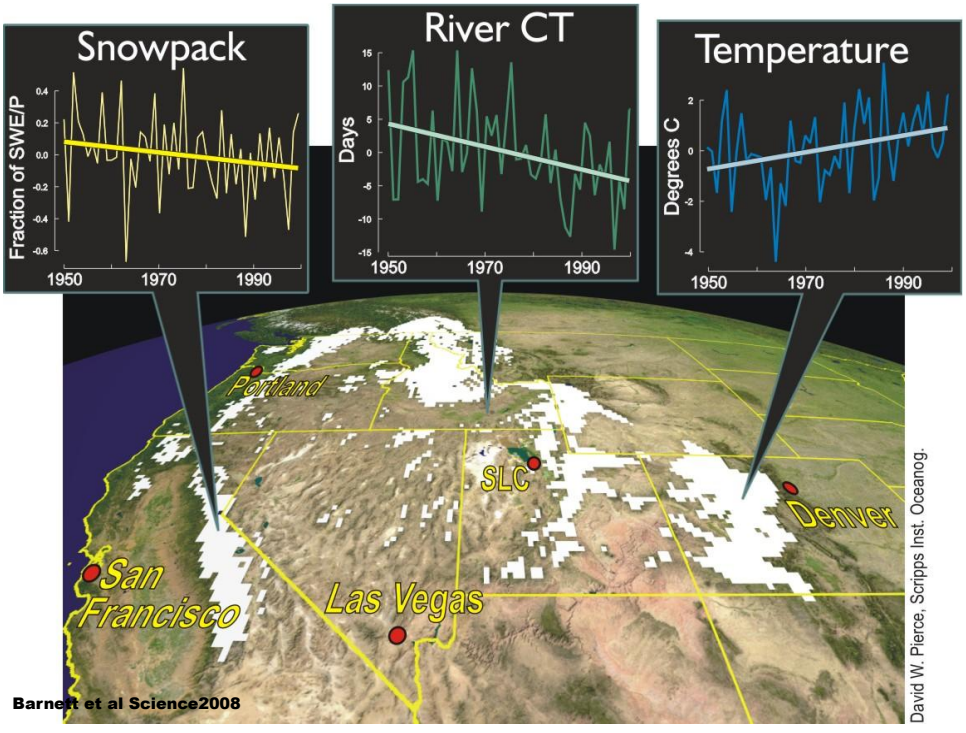


This recent warming already has driven significant hydroclimatic changes.

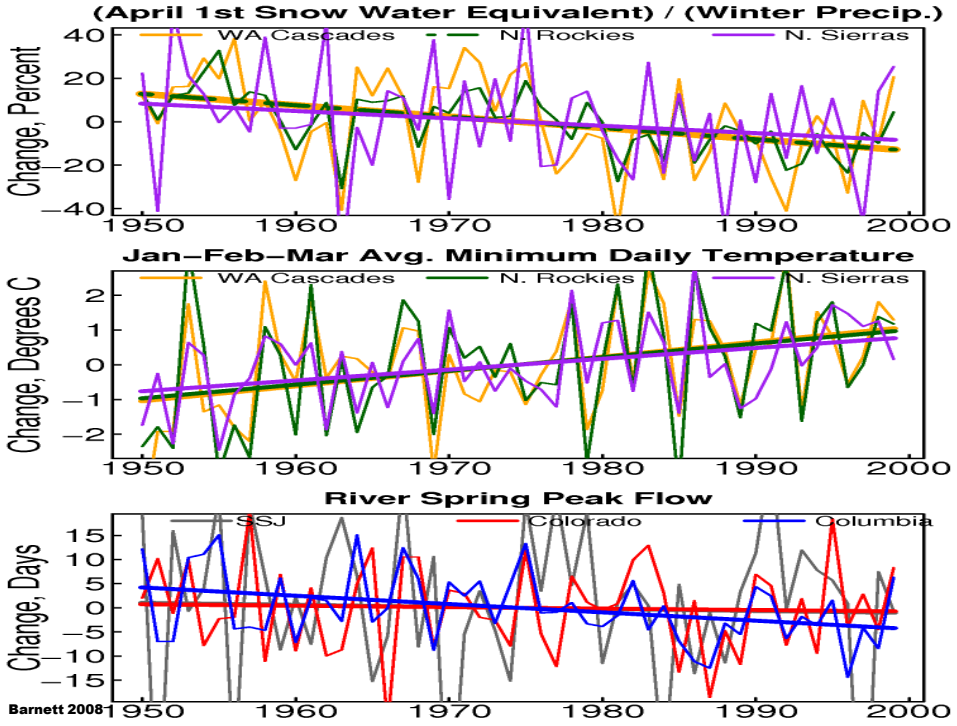
--> Less snow/more rain



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



Barnett et al Science2008



Montana's Streamflow is decreasing and peaking earlier