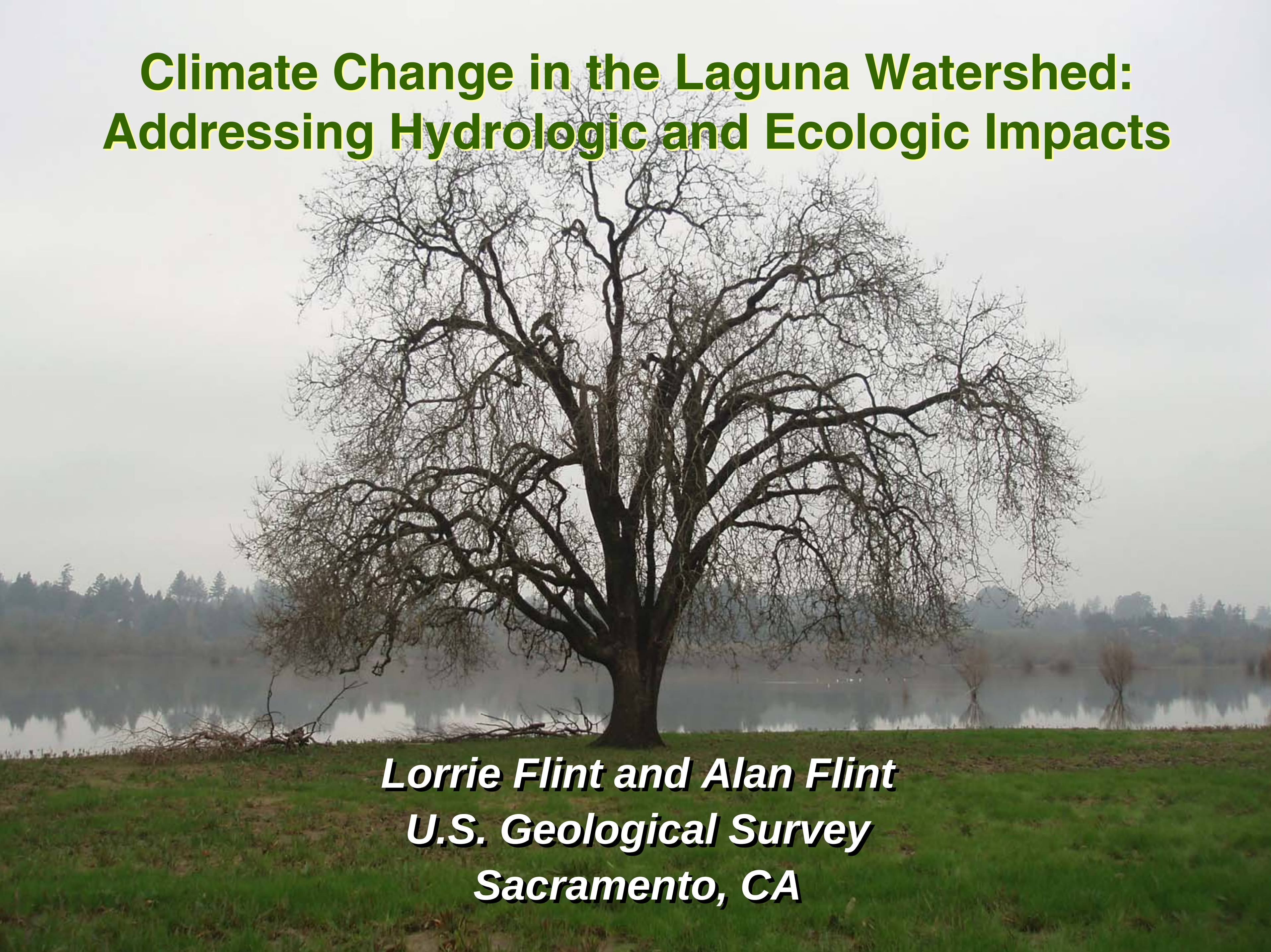
Climate Change in the Laguna Watershed: Addressing Hydrologic and Ecologic Impacts



Lorrie Flint and Alan Flint
U.S. Geological Survey
Sacramento, CA

Global Warming

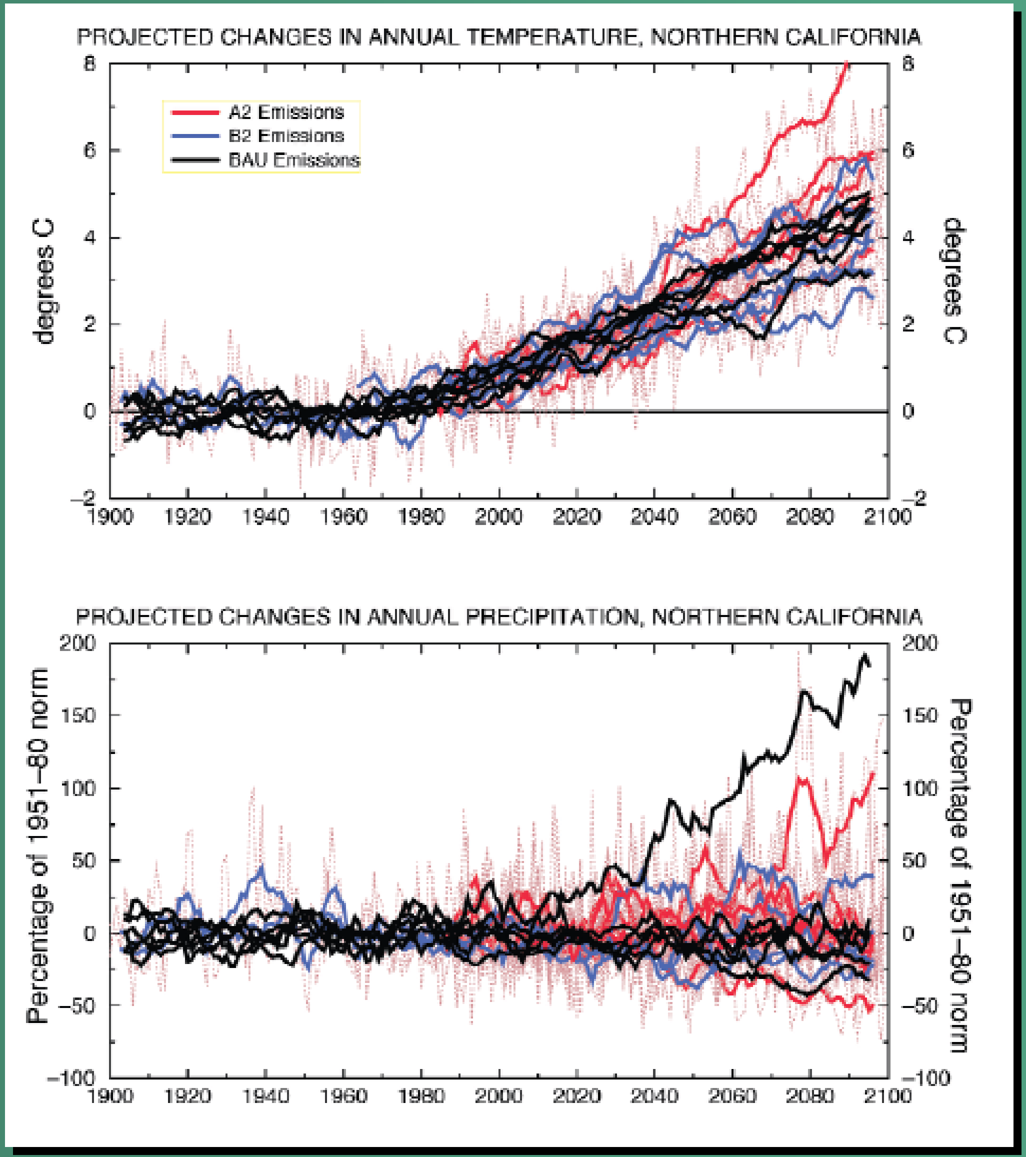
- The increase in the earth's temperature as a result of greenhouse gas emissions
- Effects oceans and jet streams
- Better termed "climate change" when we're considering regional or local effects
- Variability in the amounts and timing of precipitation along with increases in air temperature, generally translates into increases in extremes

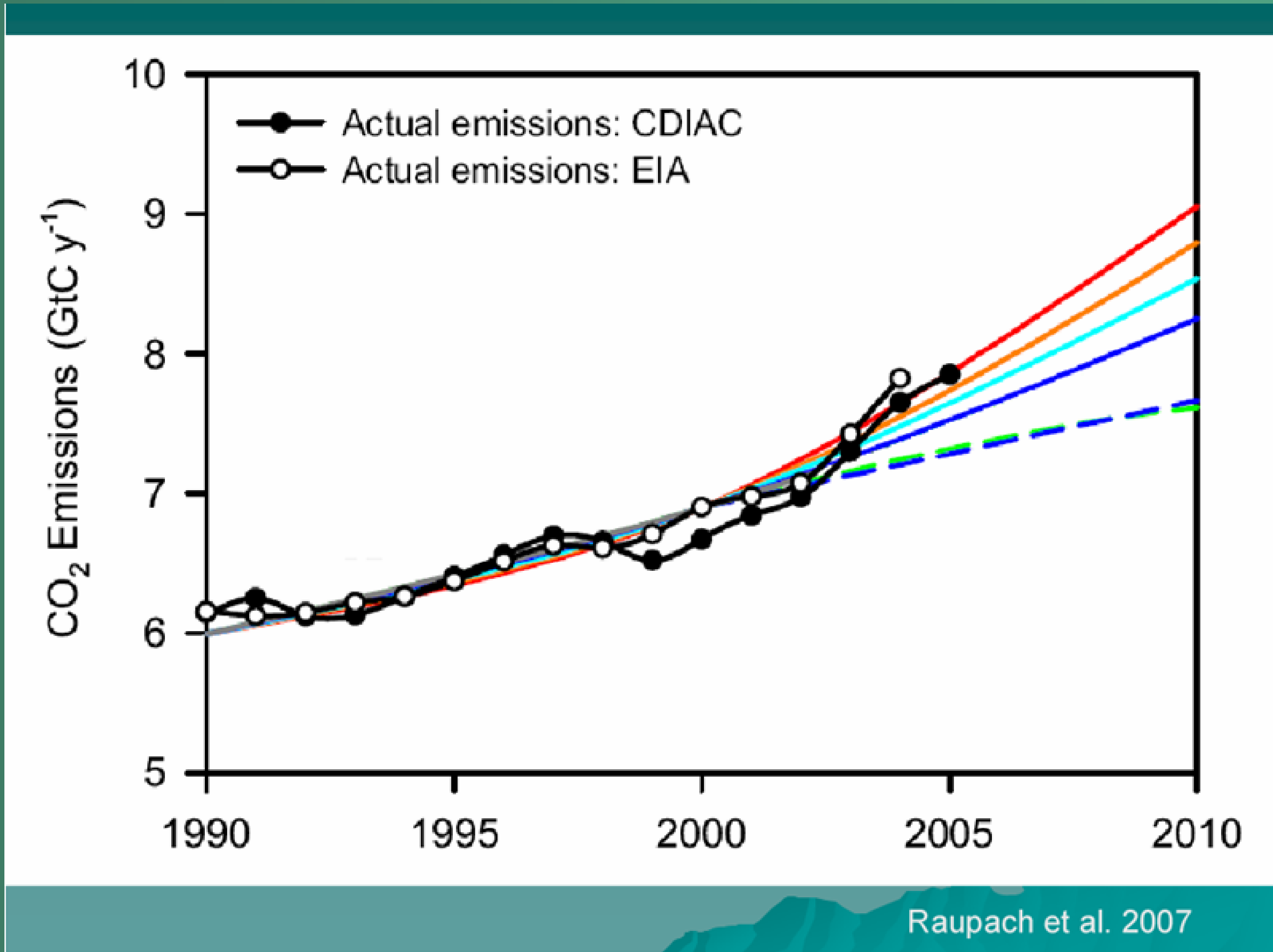
Outline

- A little about climate change
- Tools
- Effects on hydrology
- Applications to ecology
- Implications for the Laguna

Climate Change Projections

- Multiple models using different emission scenarios





Courtesy Jeff Burgett, 2009

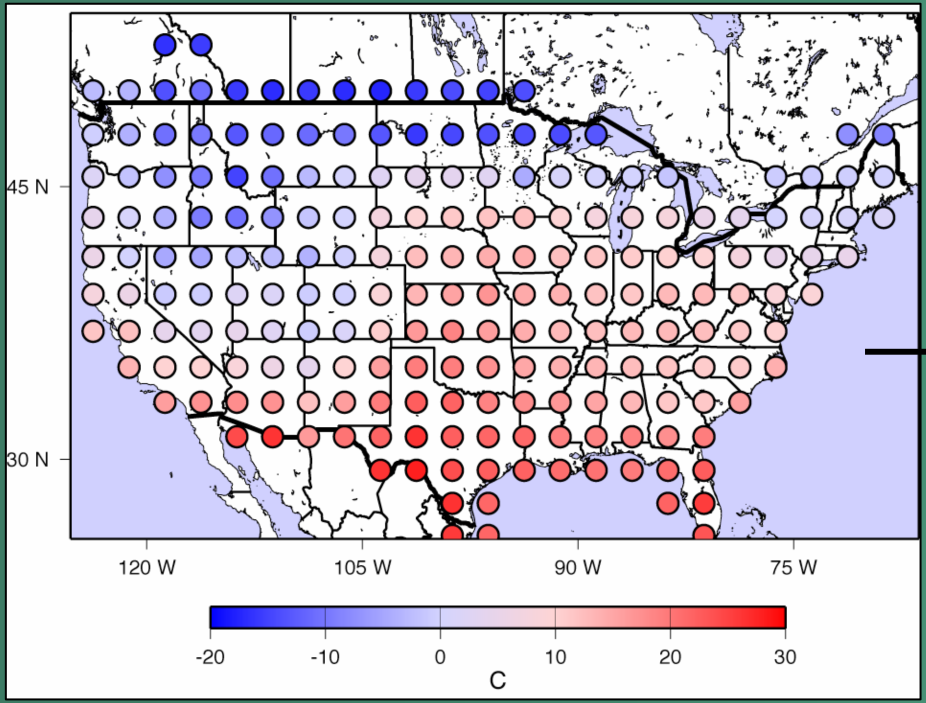
Climate Change Scenarios

- State of California is currently using 12 projection scenarios: 6 models and 2 emission scenarios, to investigate possible future climate changes
- IPCC Fourth climate assessment provides recent model simulations
- Emission scenarios
  - A2: medium-high emissions
  - B1: low emissions
- Geophysical Fluid Dynamics Lab (GFDL)

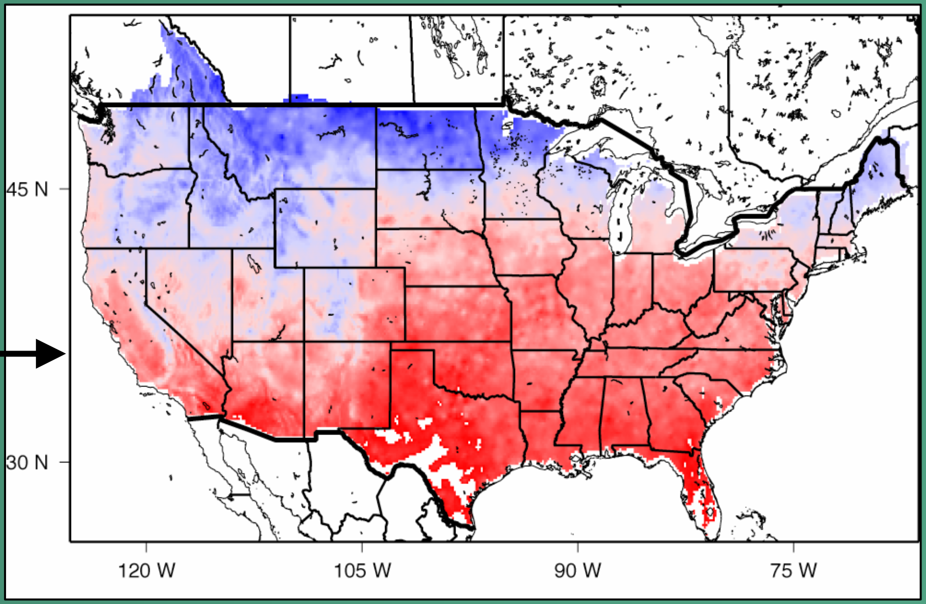
Global Climate Models (GCMs) →Climate Change Scenarios

- Climate model data, precipitation and air temperature, are available from the IPCC at 2.5 degree resolution, ~275-km
- Model scenarios were downscaled to 1/8 degree, 12-km using a constructed analogues method by Hidalgo et al. (2007)

GCM output

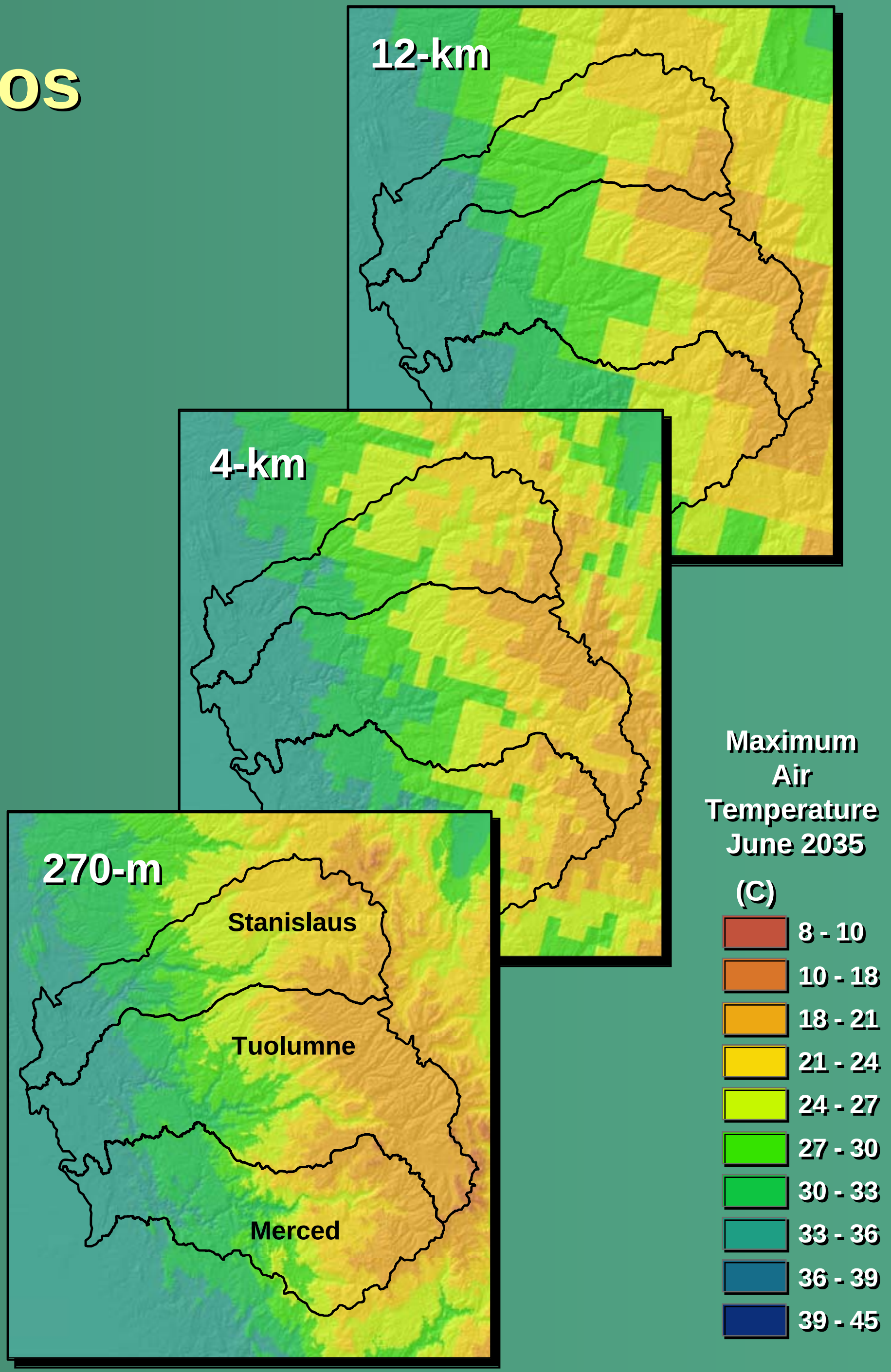


Downscaled



Climate Change Scenarios

- Climate model data at 2.5 degree resolution were downscaled to 1/8 degree, 12-km using a constructed analogues method by Hidalgo et al. (2007)
- These data were further downscaled to 4-km using a gradient-inverse-distance-squared (GIDS) method
- Statistical transformation was used to ensure that the climate model and historical data have similar statistical properties: the mean and standard deviation of the 1970-2000 period were used for corrections
- Data was further downscaled to 270-m using GIDS for model application



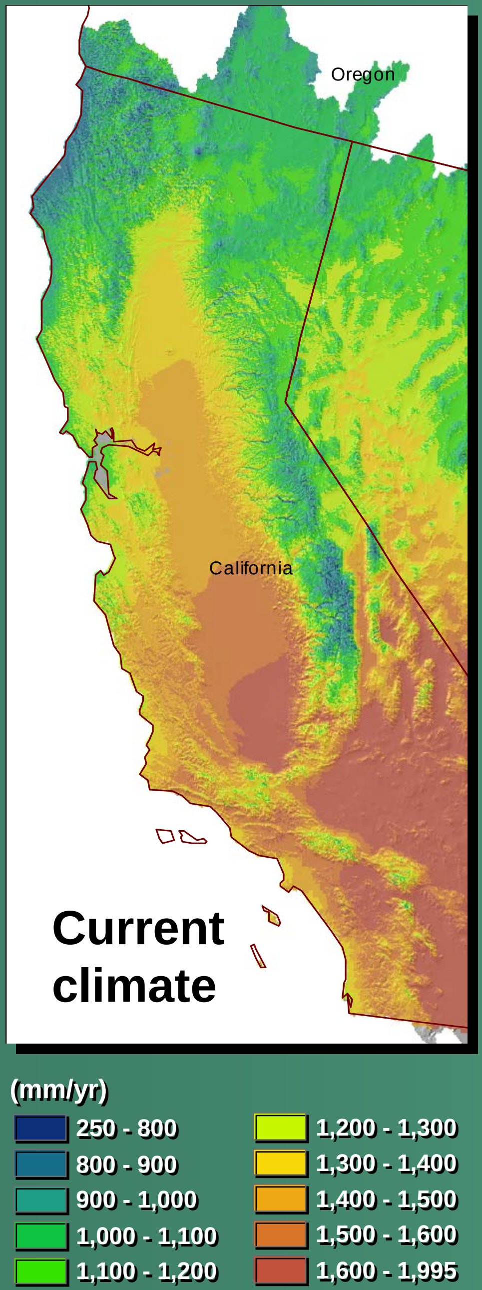
Recharge and Runoff

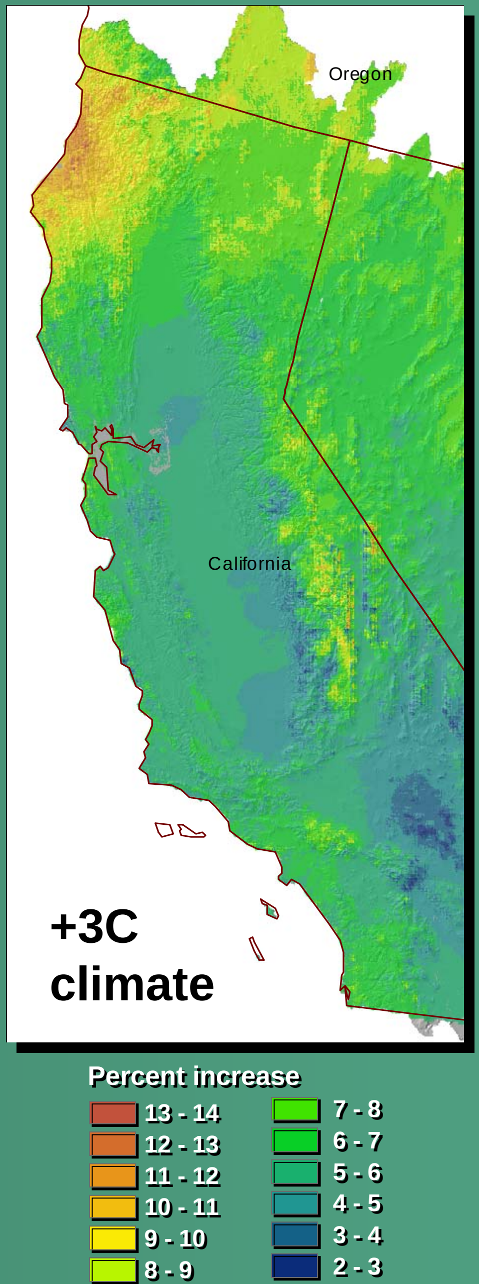
- Basin Characterization Model (BCM)
  - run in FORTRAN
  - uses grid-based data at any DEM resolution
  - calculates in-place recharge or generated runoff
- Potential evapotranspiration (Priestley-Taylor)
  - solar radiation modeled using topographic shading and cloudiness
  - vegetation density
- Snow accumulation and melt based on NWS Snow-17 Model
- Soils (STATSGO): hydraulic properties and depth determine soil storage
- Geology (state maps) is used to estimate bedrock permeability
- Precipitation and air temperature available using PRISM datasets and downscaled GCMs for future climates

Hydrology and Ecology in a Changing Climate

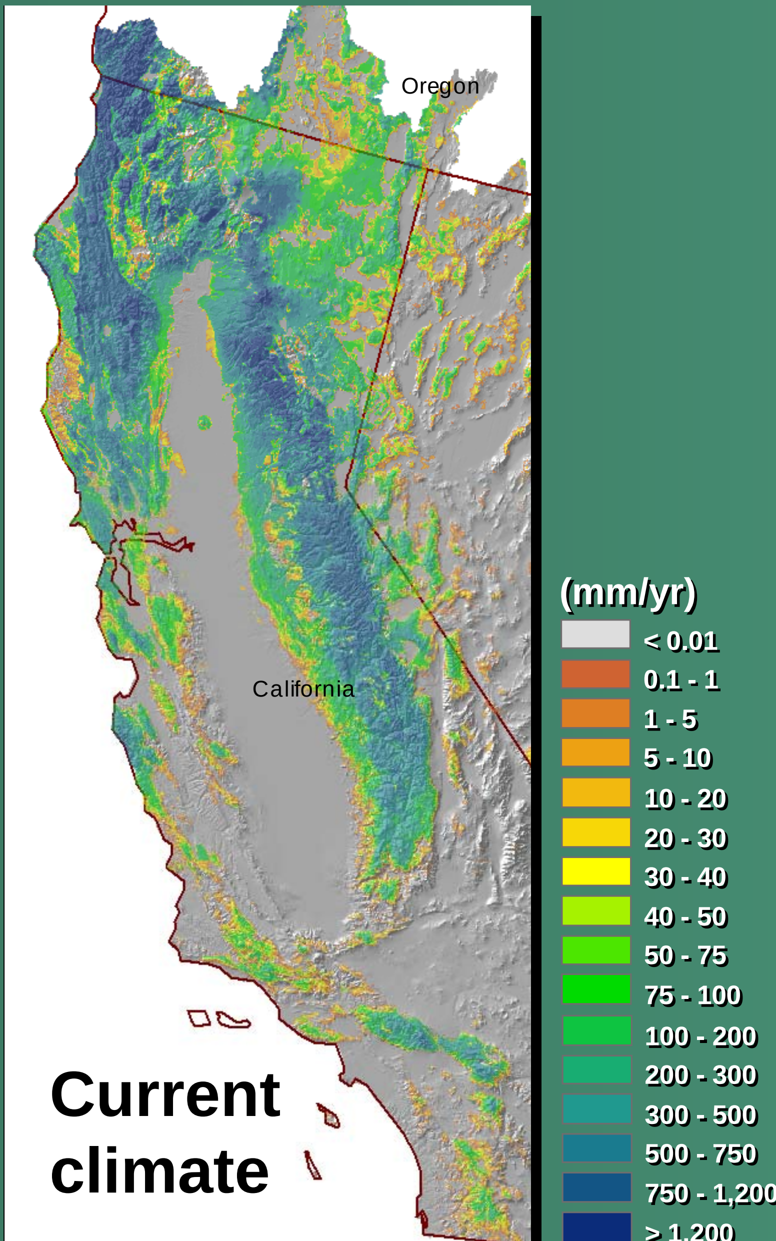
- **Distributions of water flow, snow accumulation and melt, soil conditions, and other environmental attributes under climate change scenarios are necessary, at relevant resolution, for resource management and can provide the framework for local detailed process models**
  - **Streamflow**
    - **Volume, timing, temperature, peaks**
    - **Capacity to transport sediment**
  - **Soil moisture**
  - **Maximum and minimum air temperature**
  - **Evapotranspiration**
  - **Energy loading**

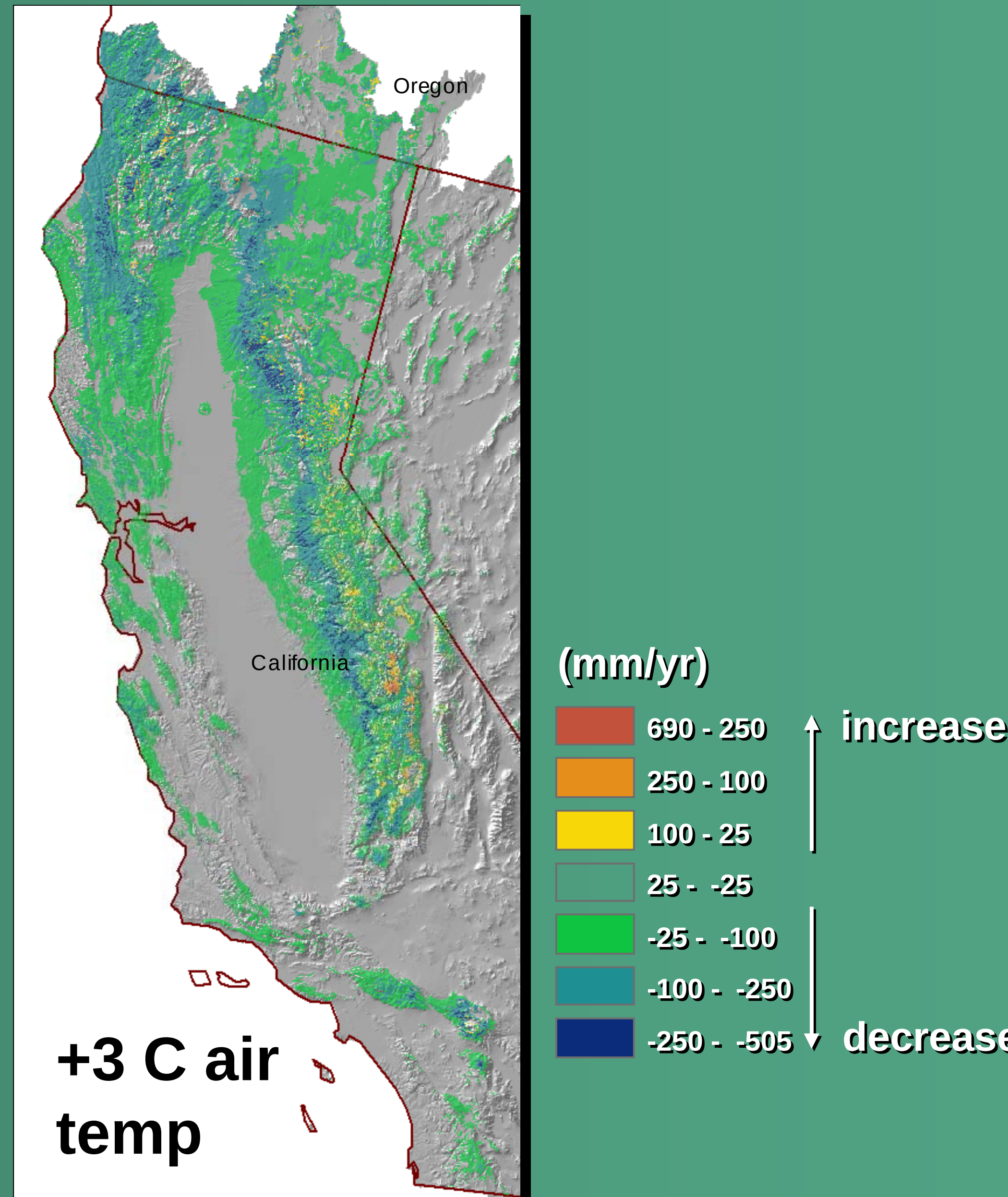
Annual Potential Evapotranspiration



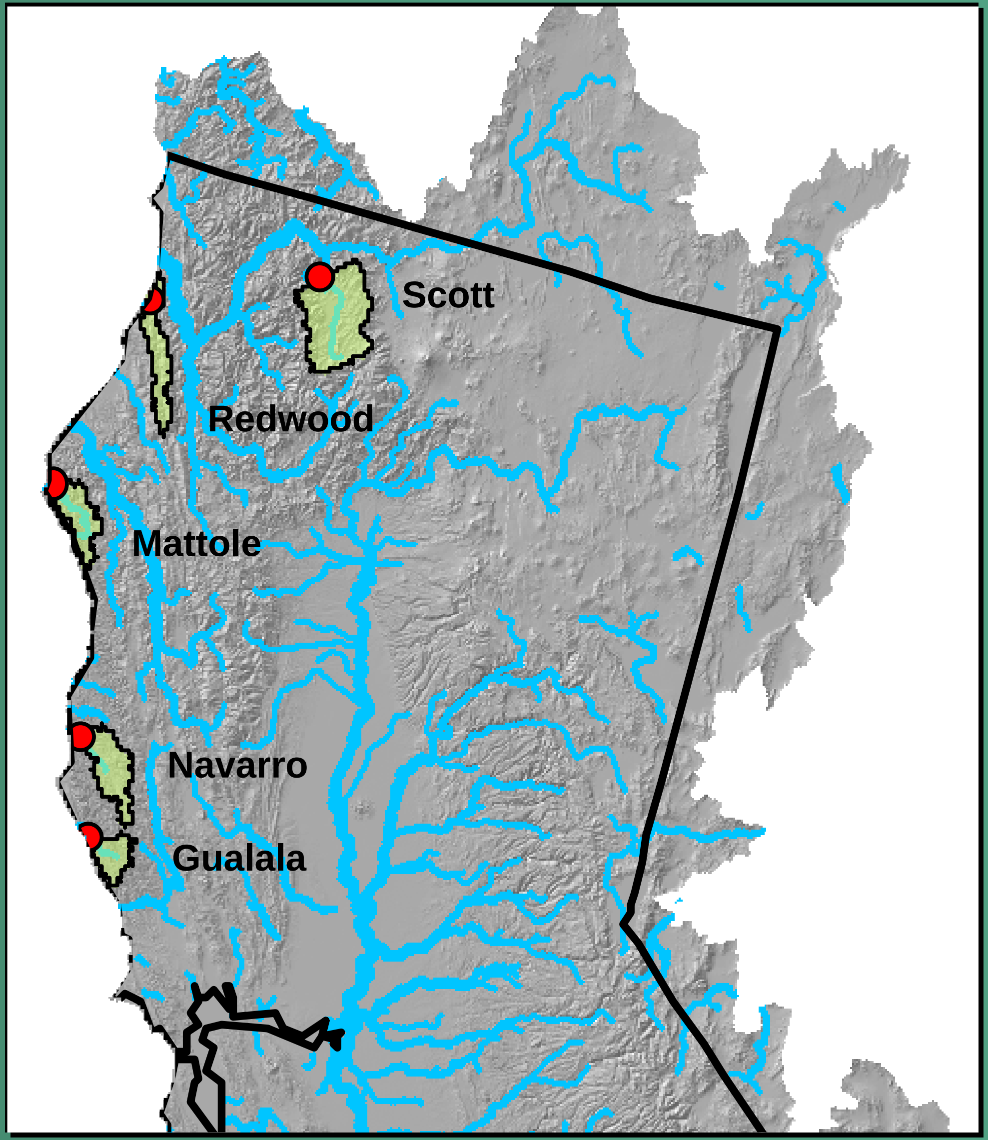


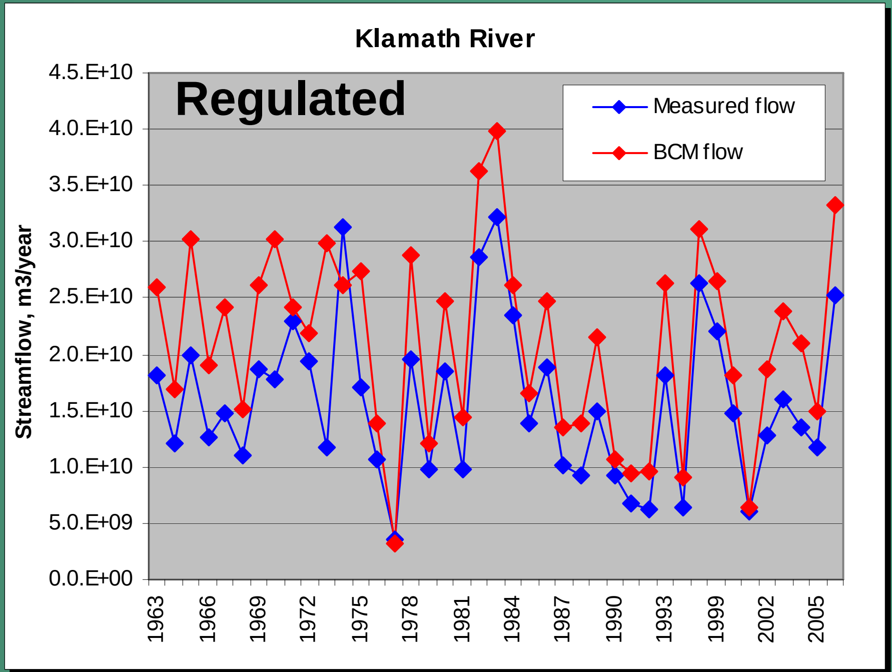
Generation of Annual Runoff



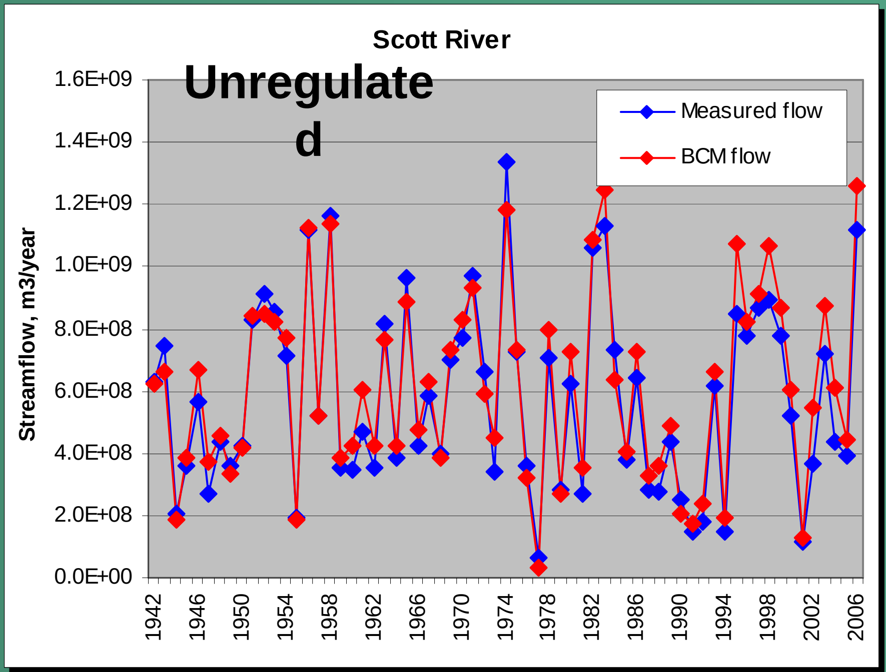


Runoff in Northern California coastal basins due to climate change



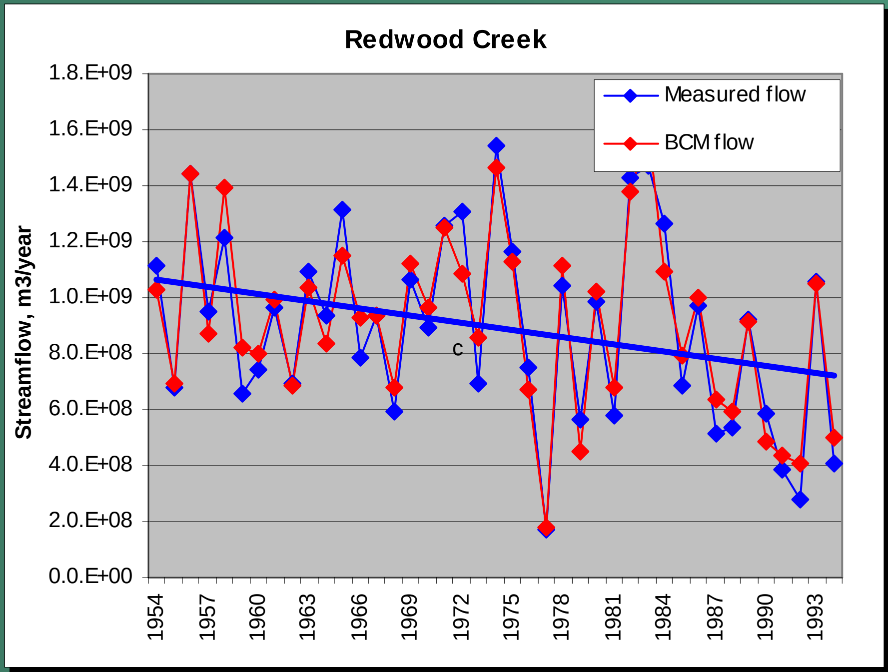


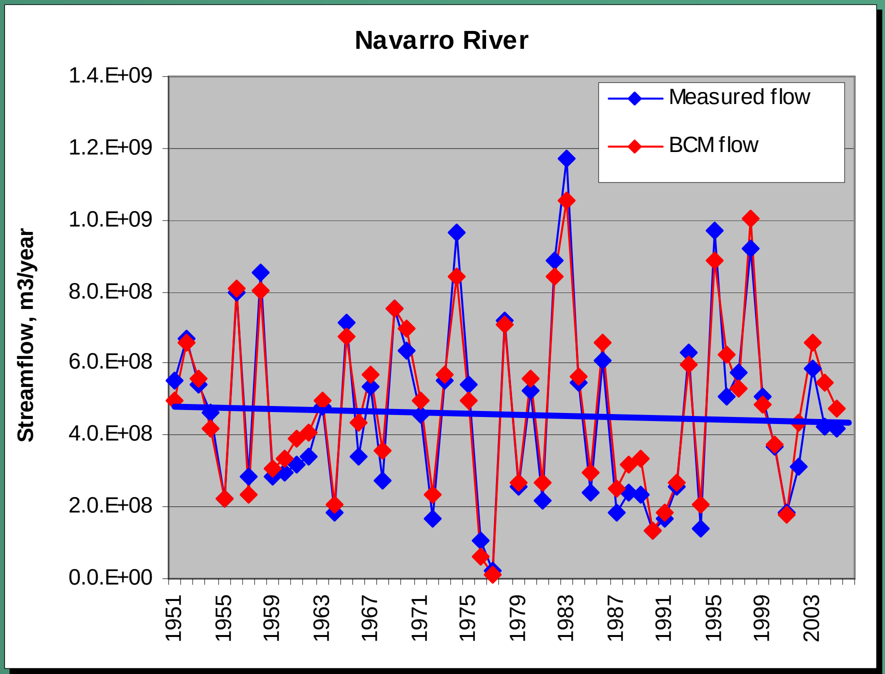
Klamath River
Regulated
Measured flow
BCM flow
Streamflow, m3/year
4.5.E+10
4.0.E+10
3.5.E+10
3.0.E+10
2.5.E+10
2.0.E+10
1.5.E+10
1.0.E+10
5.0.E+09
0.0.E+00
1963 1966 1969 1972 1975 1978 1981 1984 1987 1990 1993 1999 2002 2005



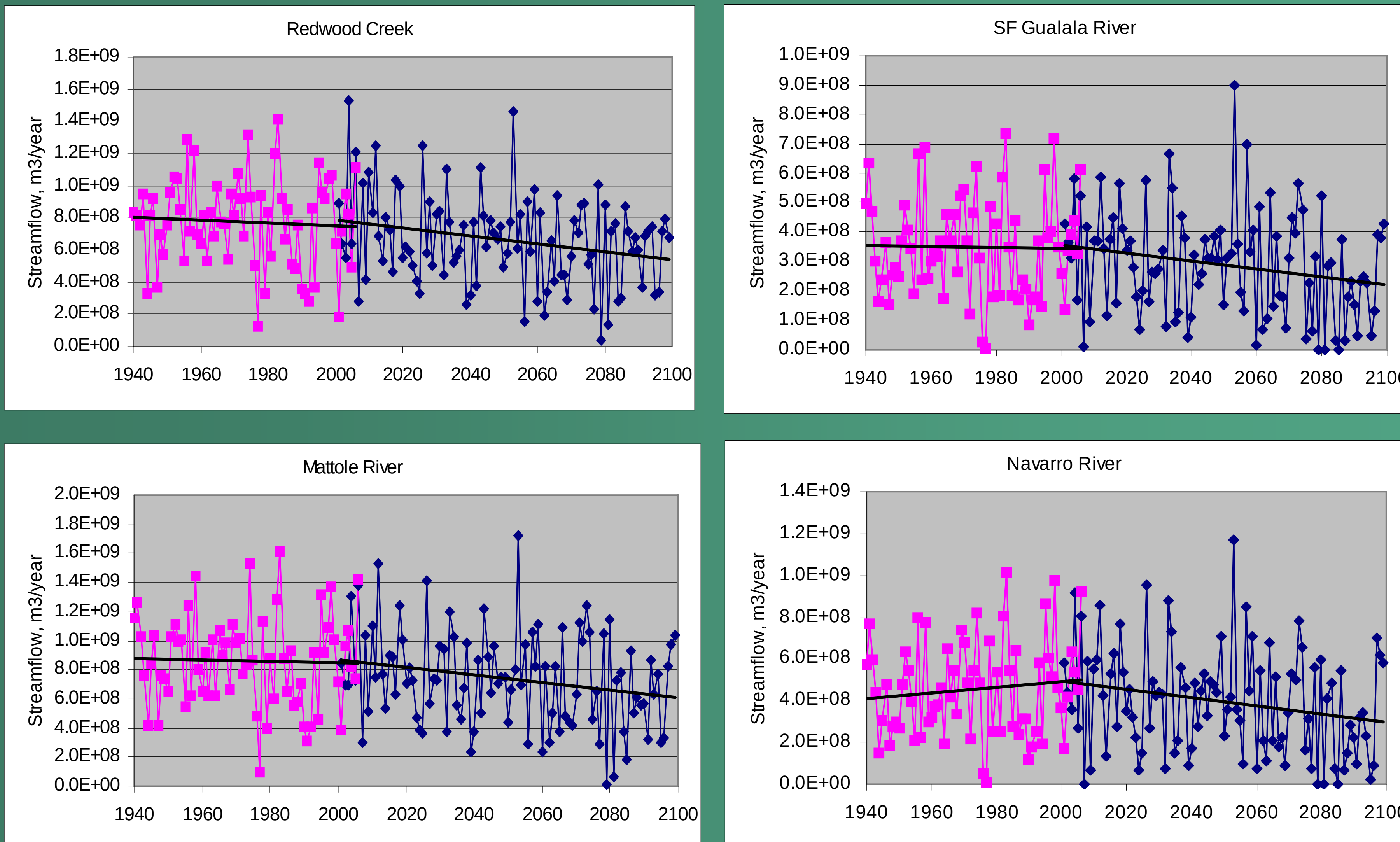
Scott River
Unregulate
d
Measured flow
BCM flow
Streamflow, m3/year
1.6E+09
1.4E+09
1.2E+09
1.0E+09
8.0E+08
6.0E+08
4.0E+08
2.0E+08
0.0E+00
1942 1946 1950 1954 1958 1962 1966 1970 1974 1978 1982 1986 1990 1994 1998 2002 2006

Northern California

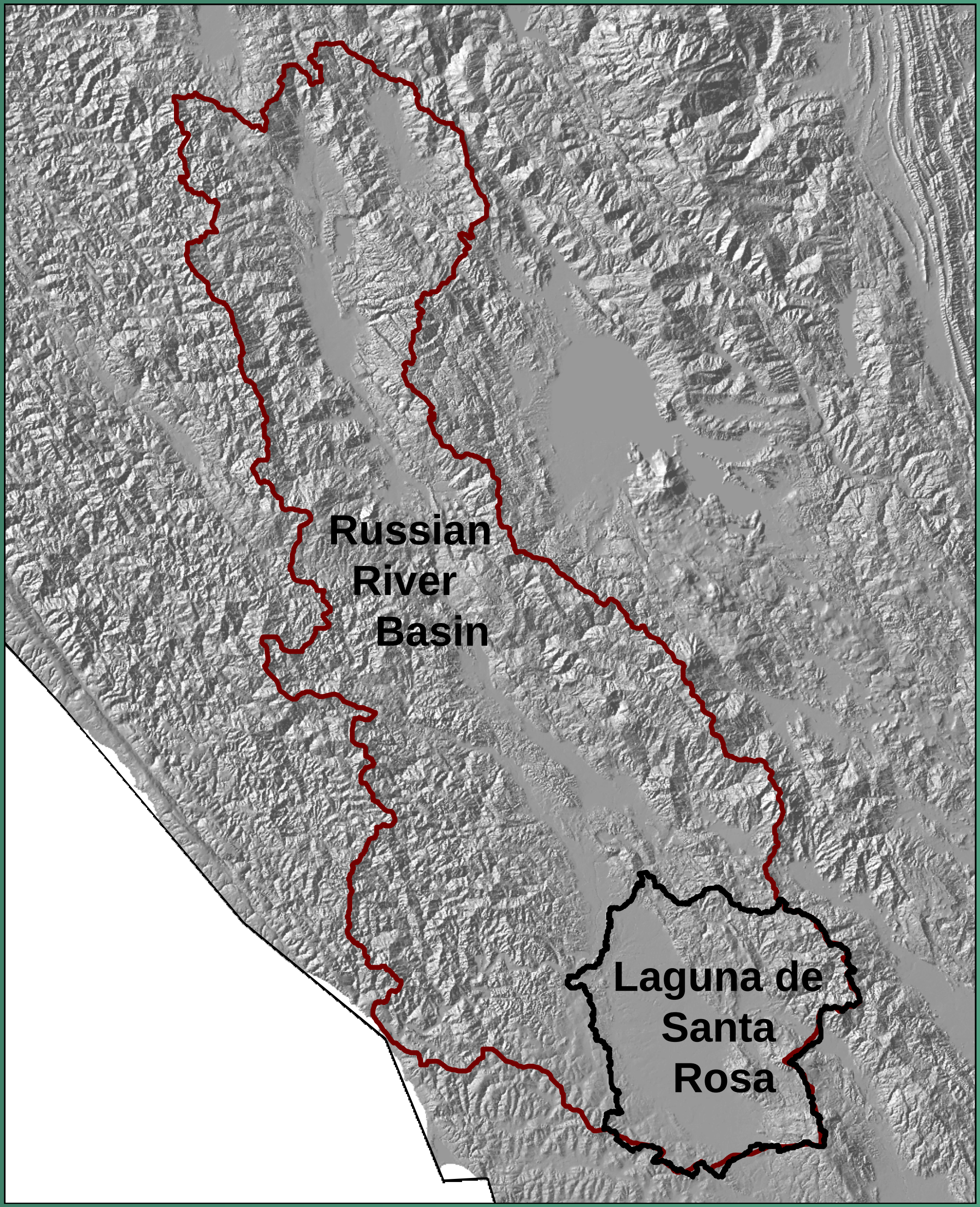




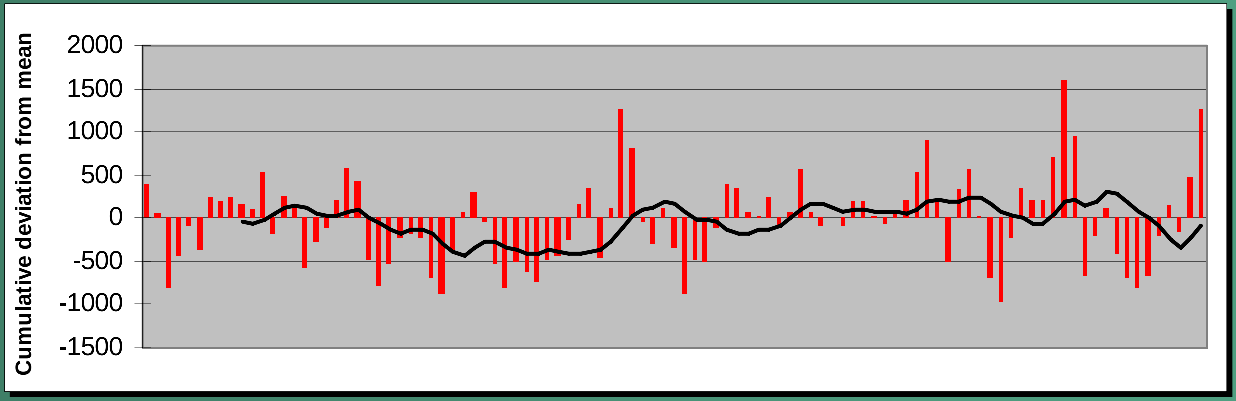
Northern California

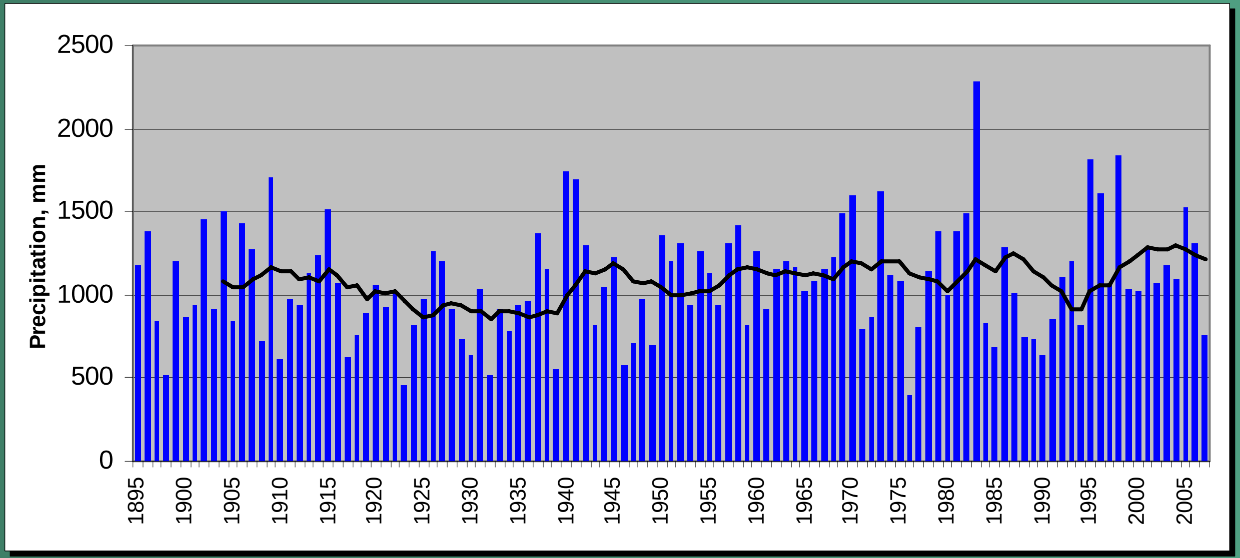


Future Climate (GFDL-A2)


Russian
River
Basin
Laguna de
Santa
Rosa

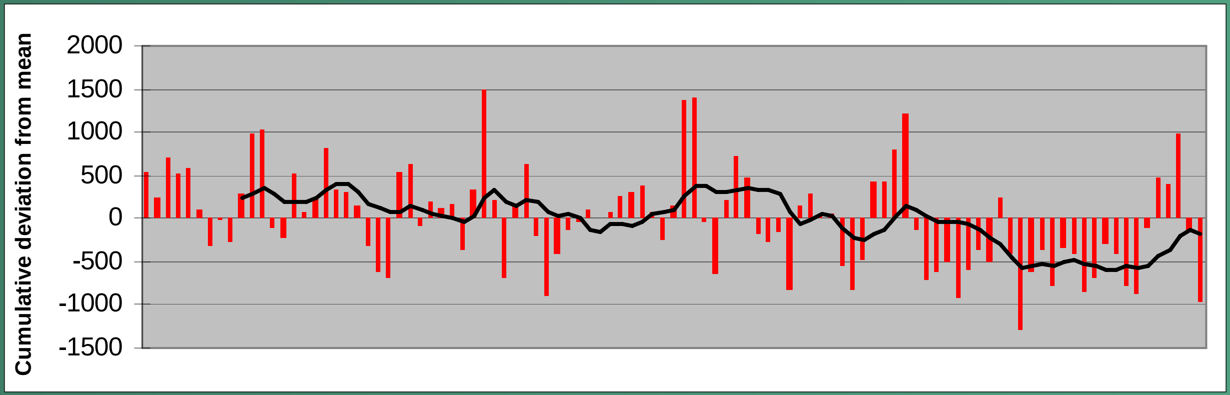
Russian River Basin

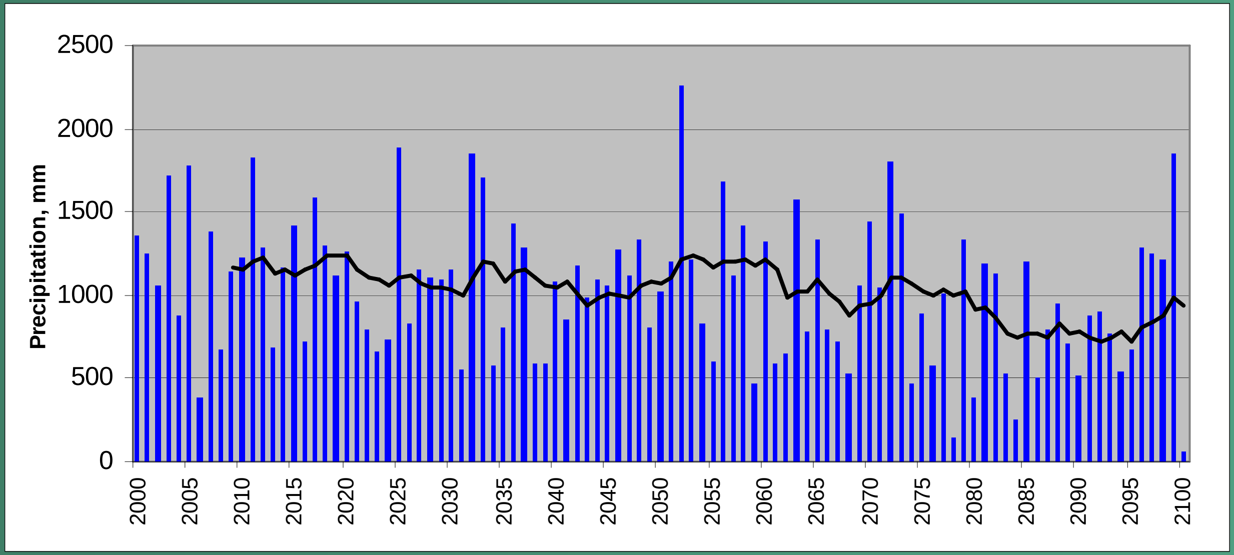




Historical Climate

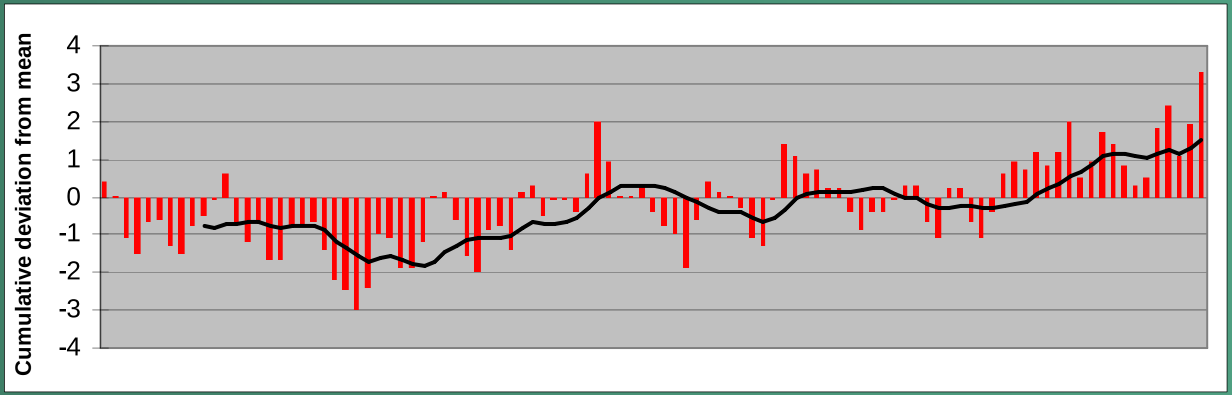
Russian River Basin

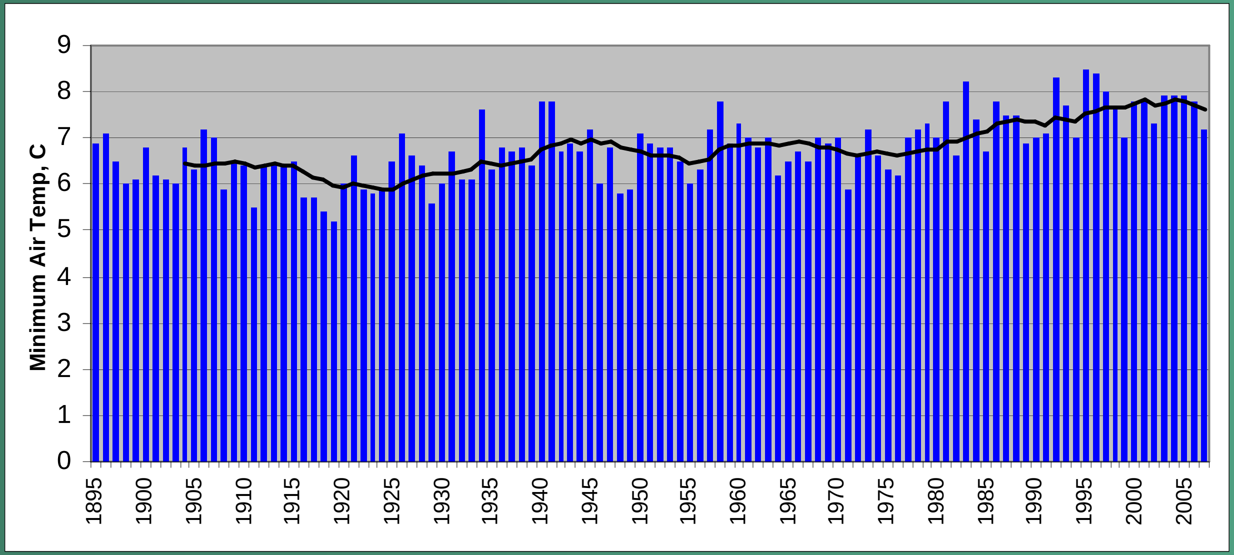




Future Climate (GFDL-A2)

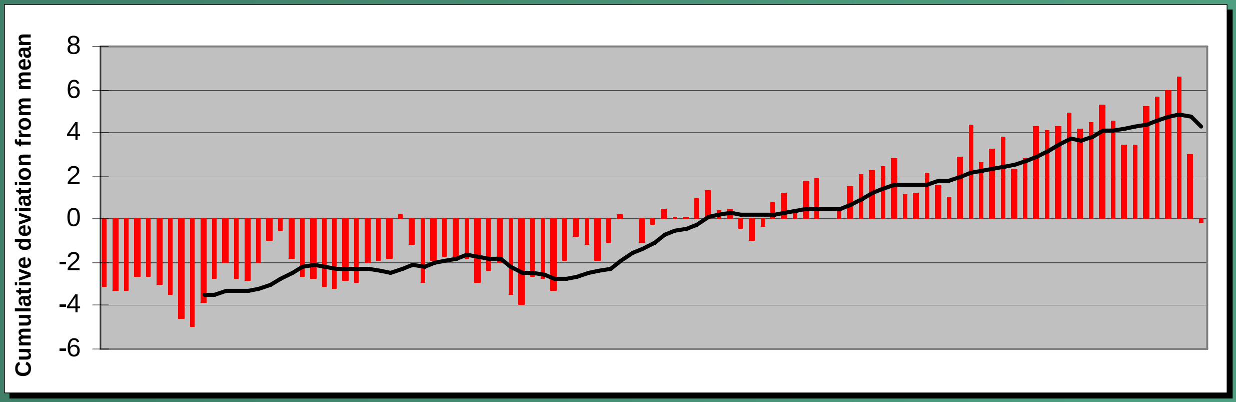
Russian River Basin

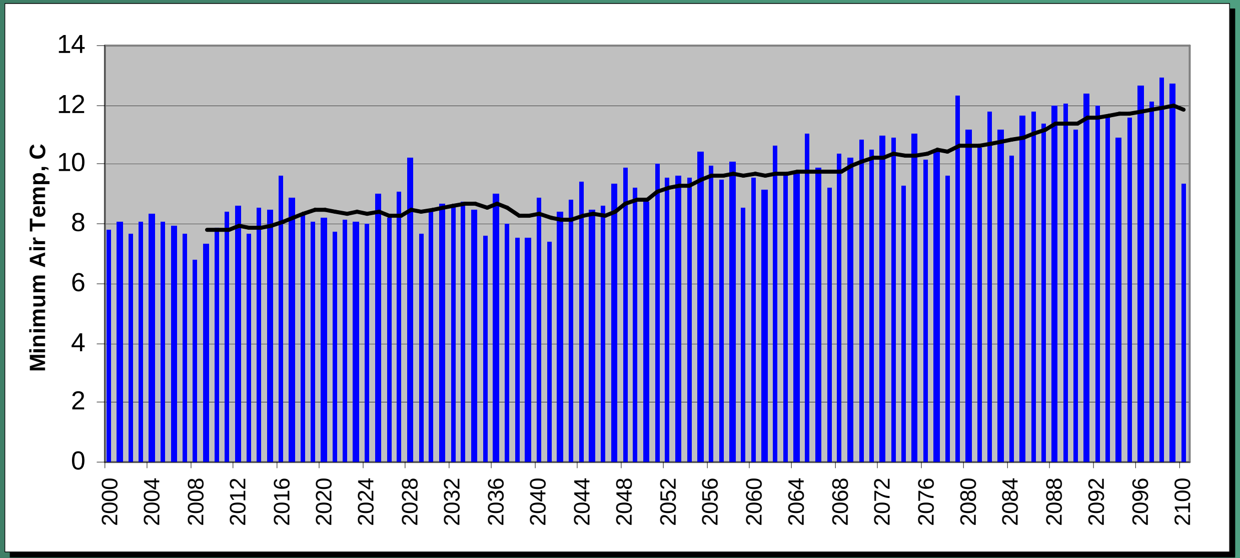




Historical Climate

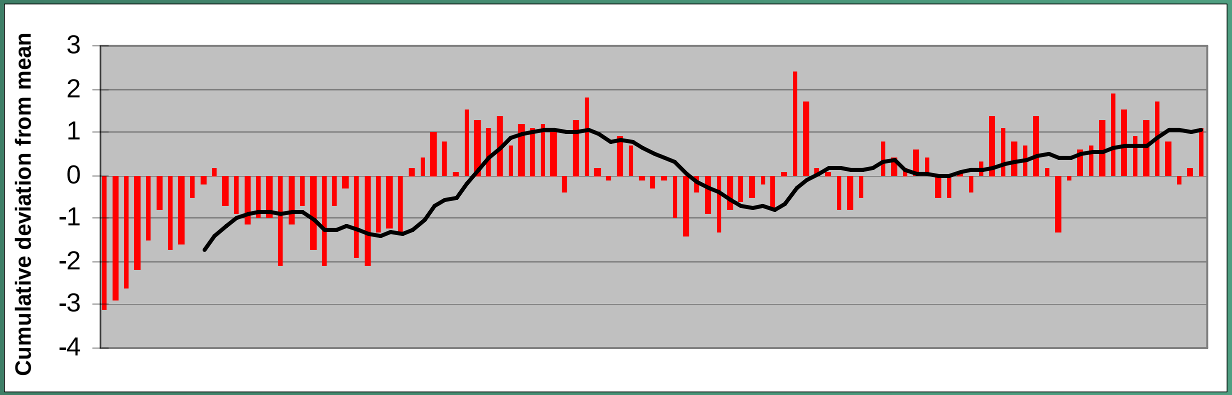
Russian River Basin

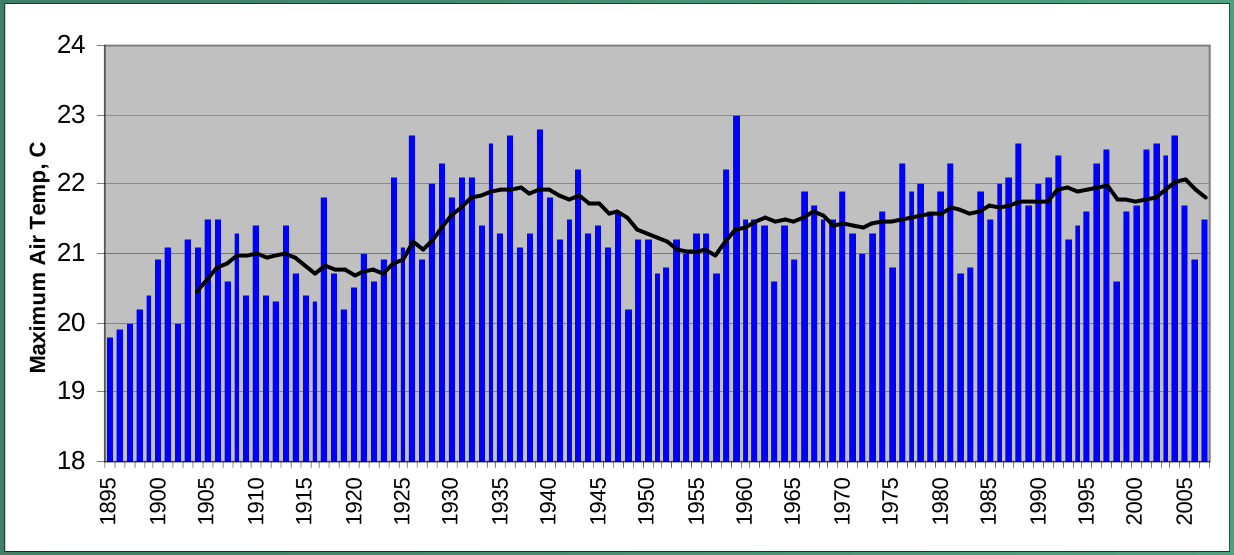




Future Climate (GFDL-A2)

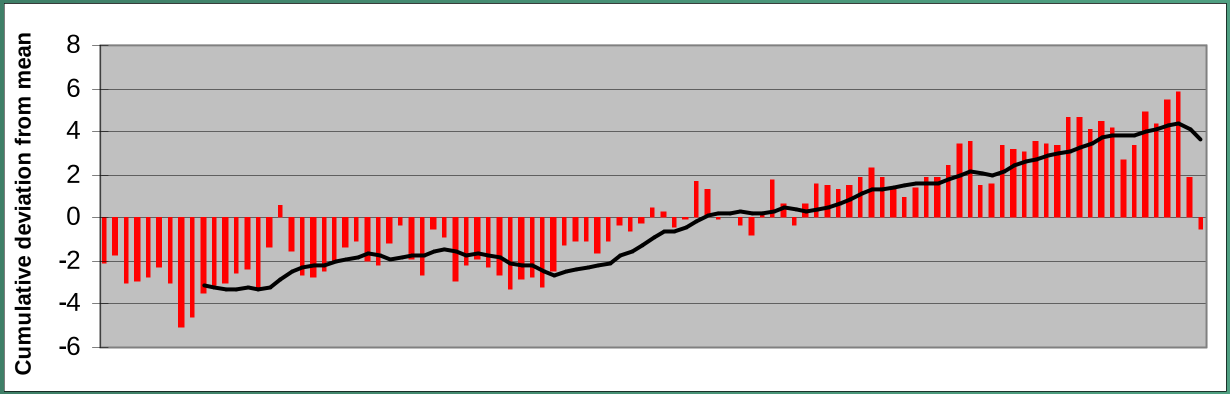
Russian River Basin

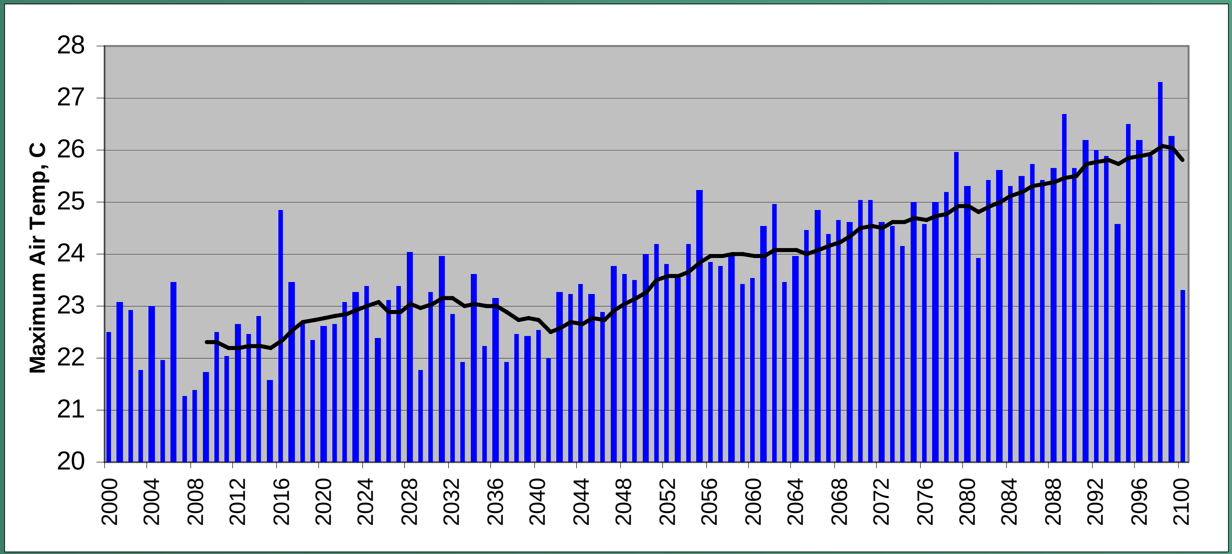




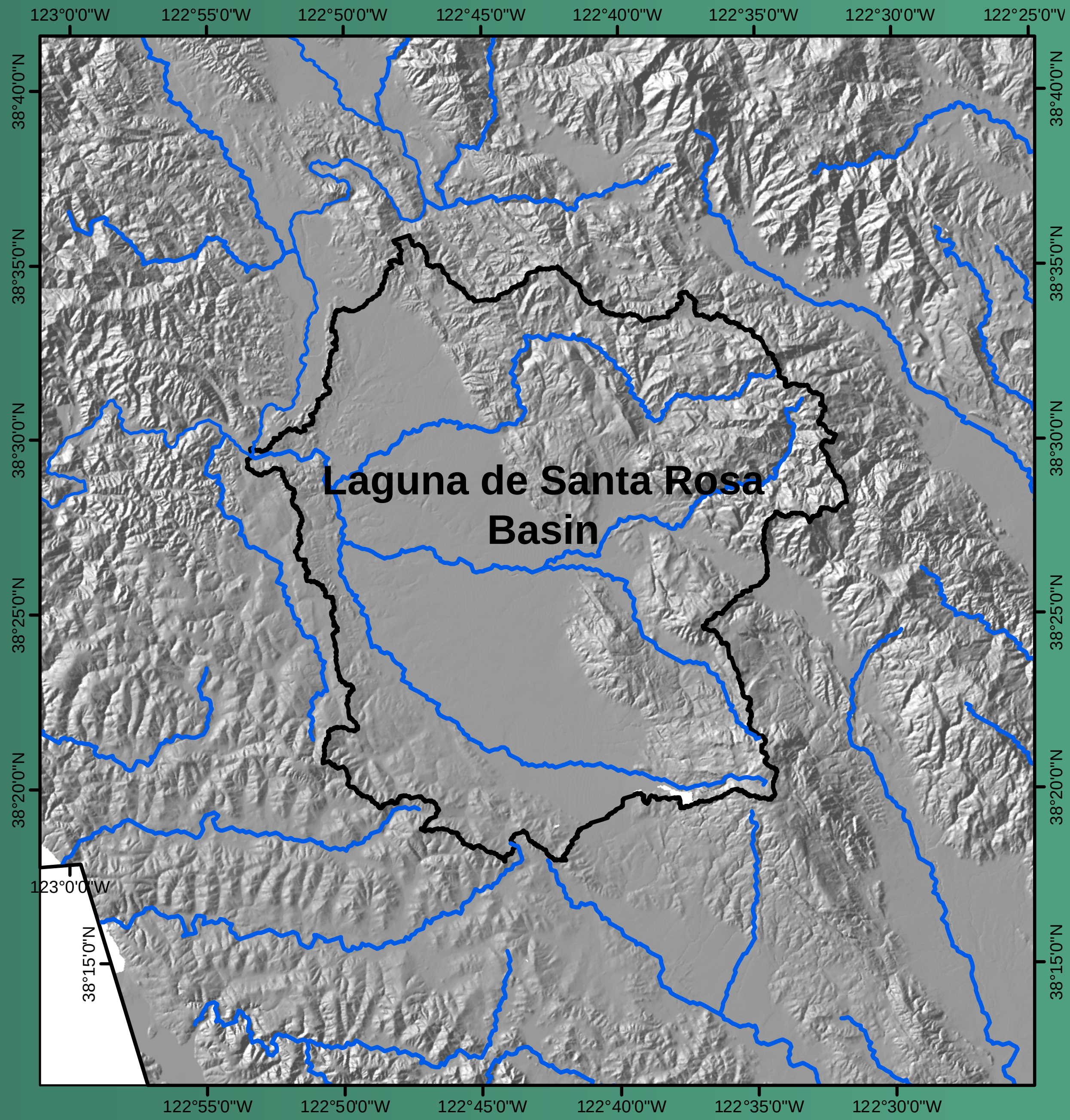
Historical Climate

Russian River Basin

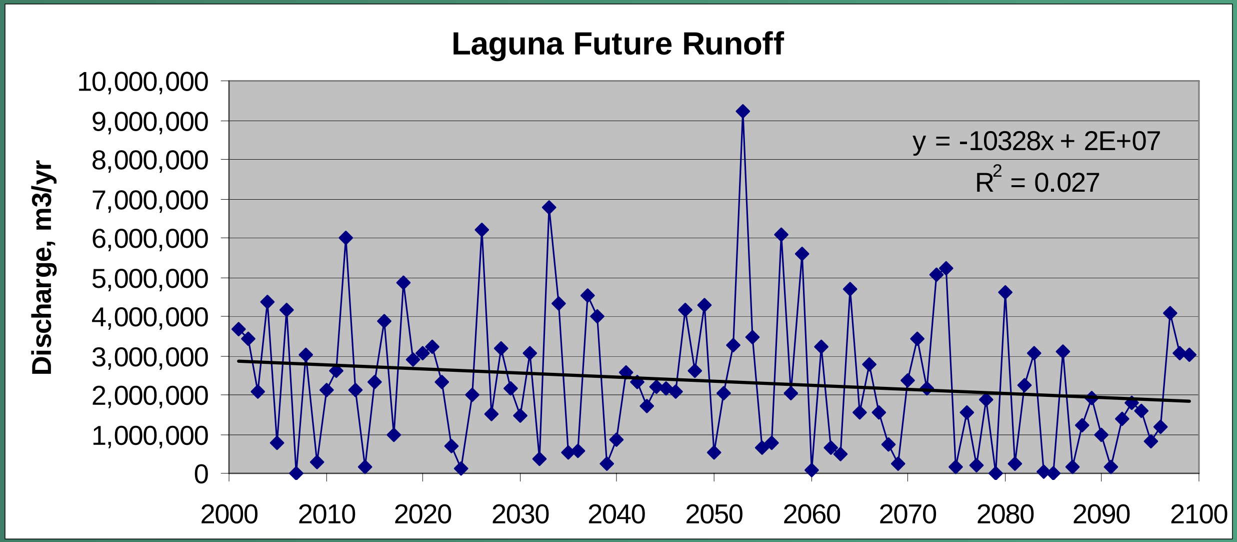


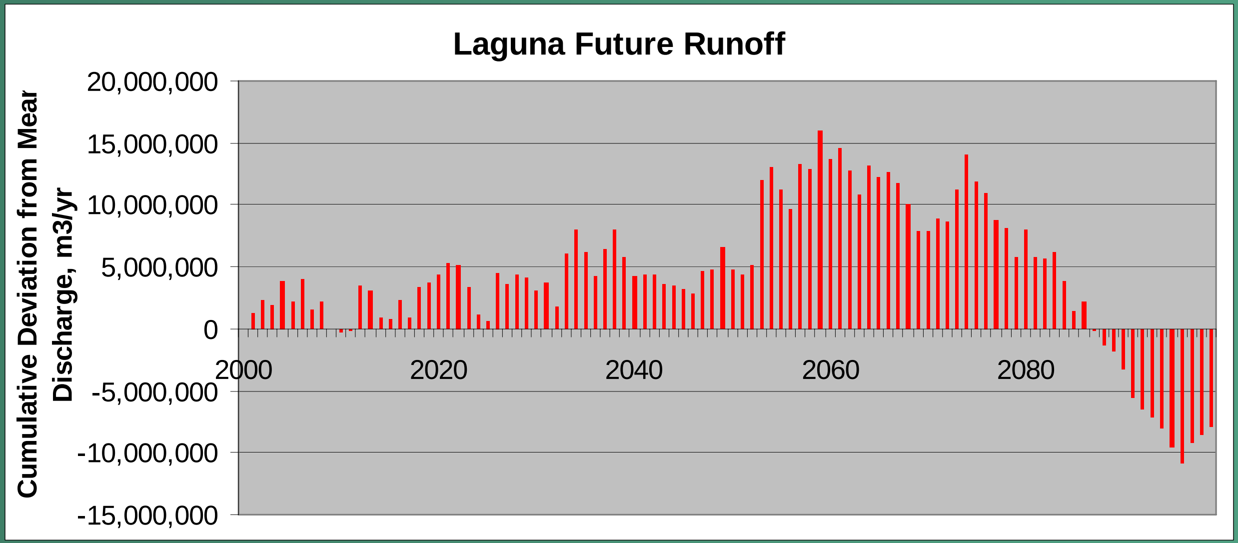


Future Climate (GFDL-A2)

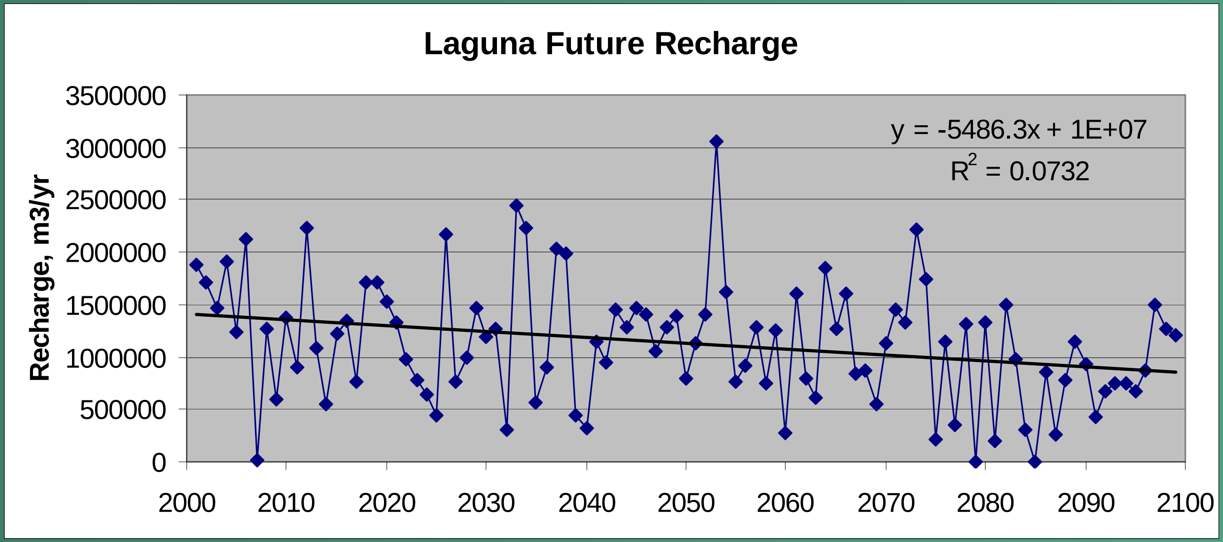


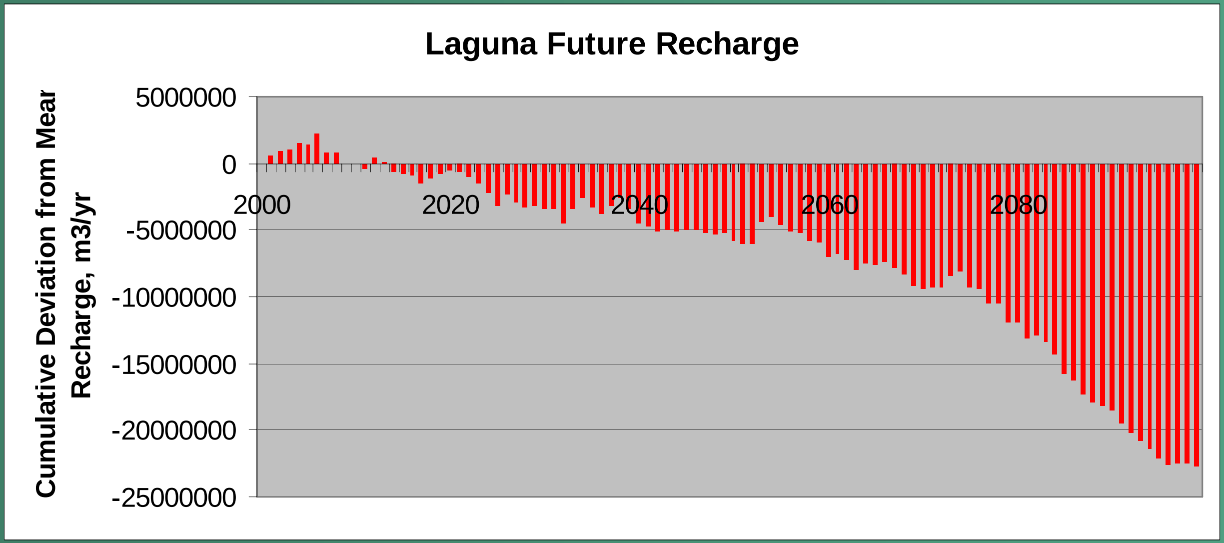
Laguna de Santa Rosa Basin
123°0'0"W
122°55'0"W
122°50'0"W
122°45'0"W
122°40'0"W
122°35'0"W
122°30'0"W
122°25'0"W
38°40'0"N
38°35'0"N
38°30'0"N
38°25'0"N
38°20'0"N
38°15'0"N





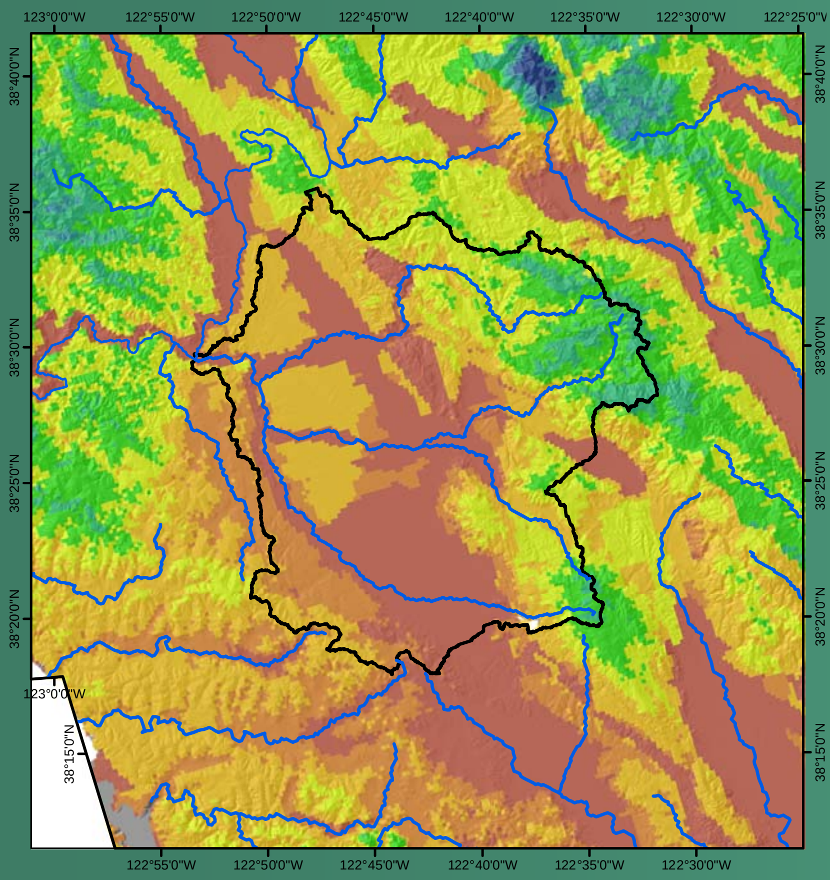
Future Climate (GFDL-A2)



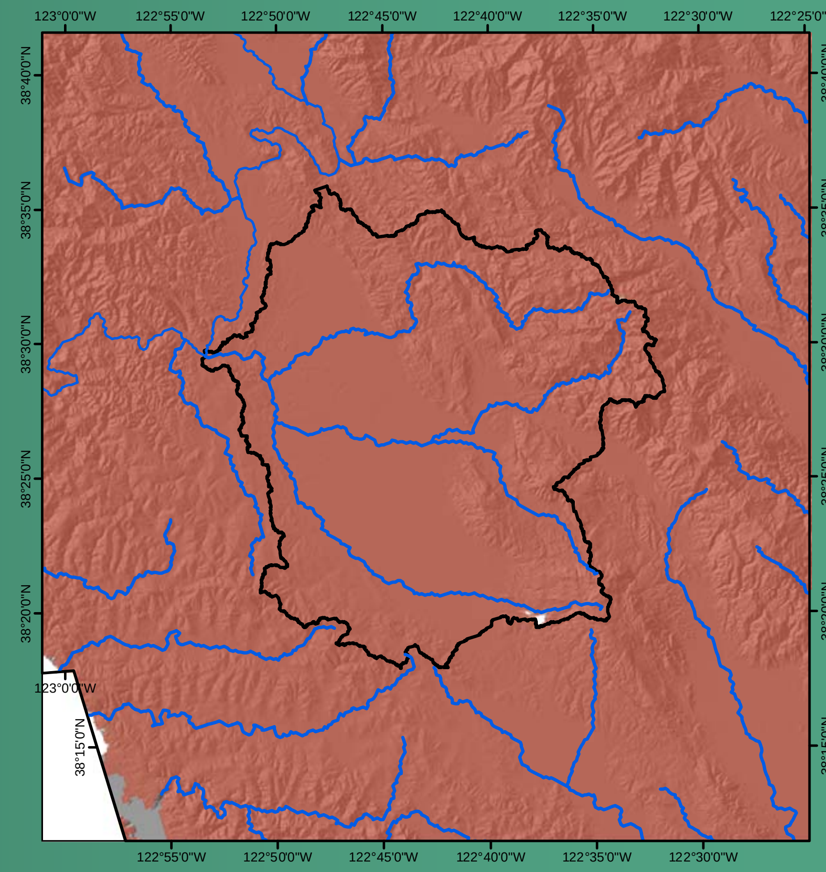


Future Climate (GFDL-A2)

2070



2079



Runoff (mm/yr)

- 0 - 100
- 100 - 200
- 200 - 400
- 400 - 600
- 600 - 800
- 800 - 1,000
- 1,000 - 1,250
- 1,250 - 1,500

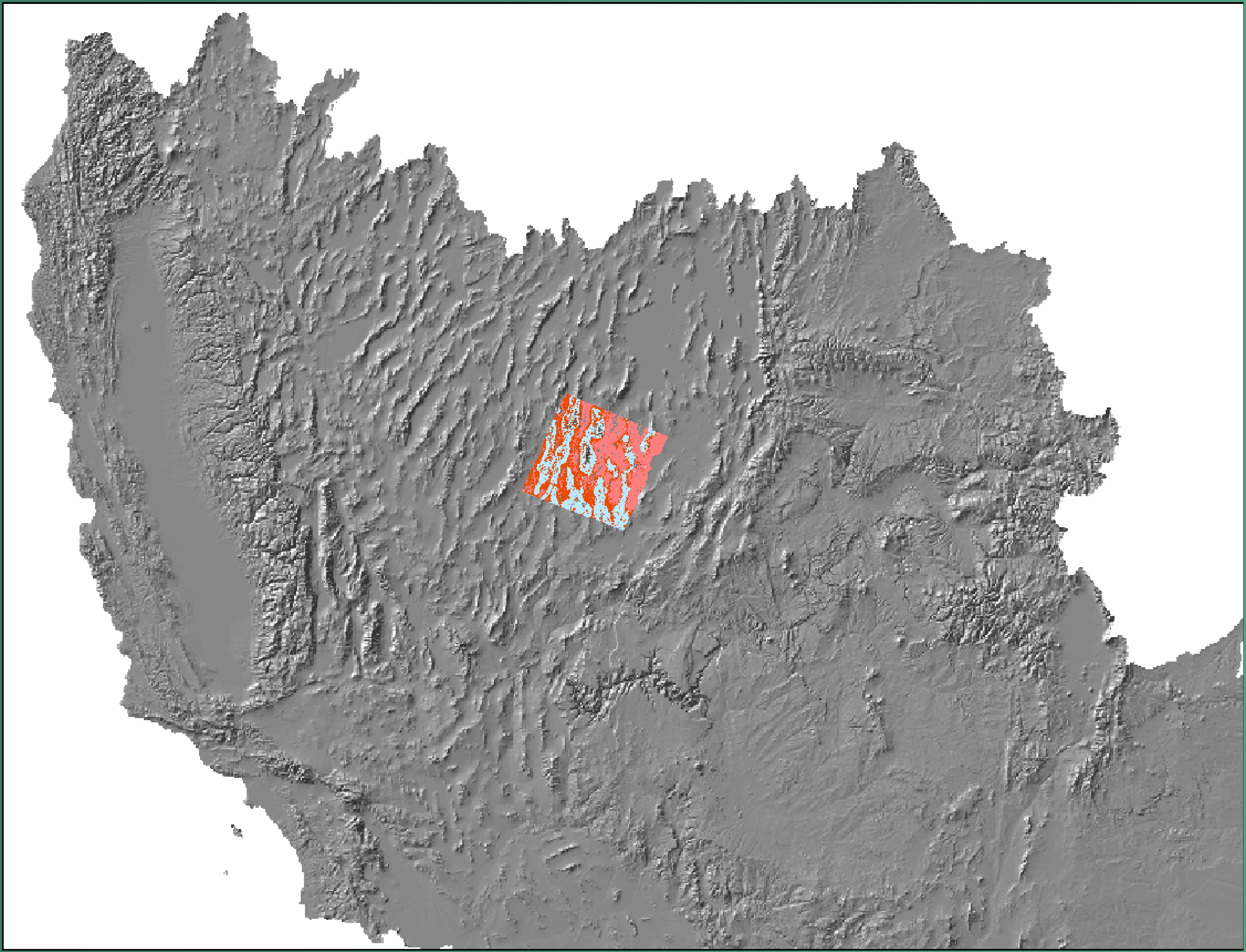
Applications of Climate Change Assessments to Ecology

- Distributed hydrology used to establish stressors or drivers for species transitions
- Climatic water deficit used to evaluate “moisture envelopes” for species and conditions driving species and landscape change

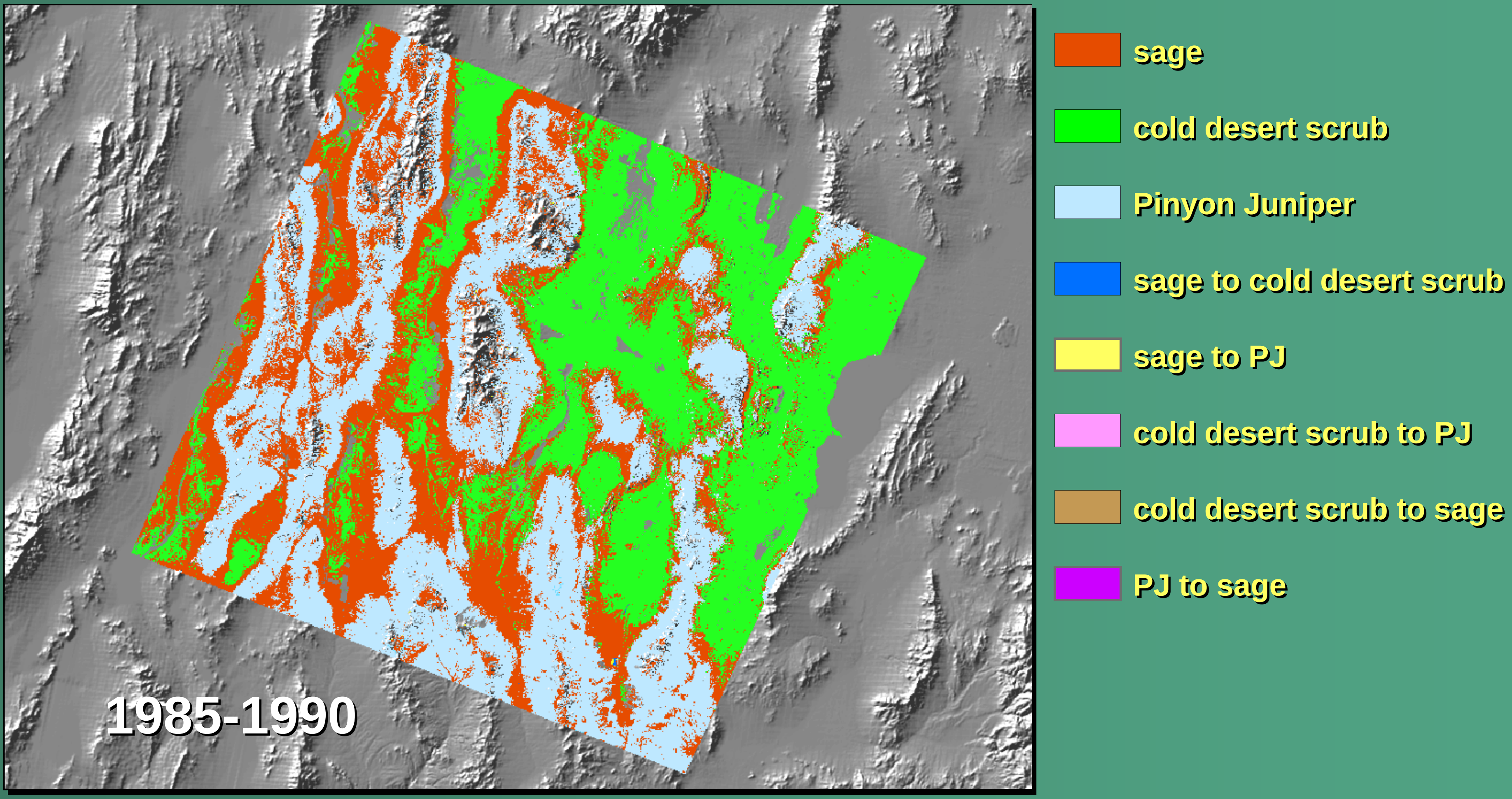
Calculation of Climatic Water Deficit: the water a plant would use if it was available

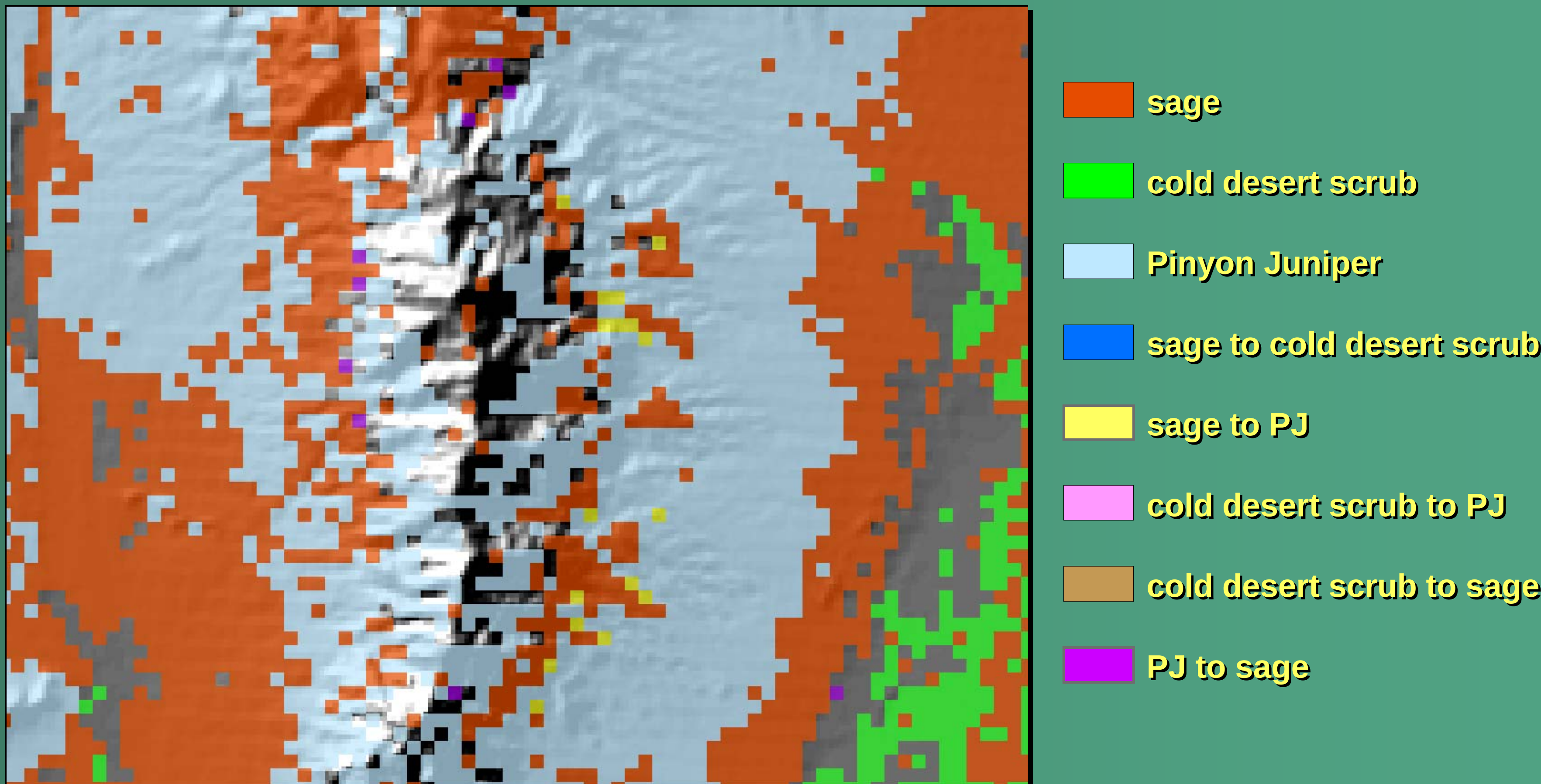
CWD = monthly potential evapotranspiration – actual evapotranspiration

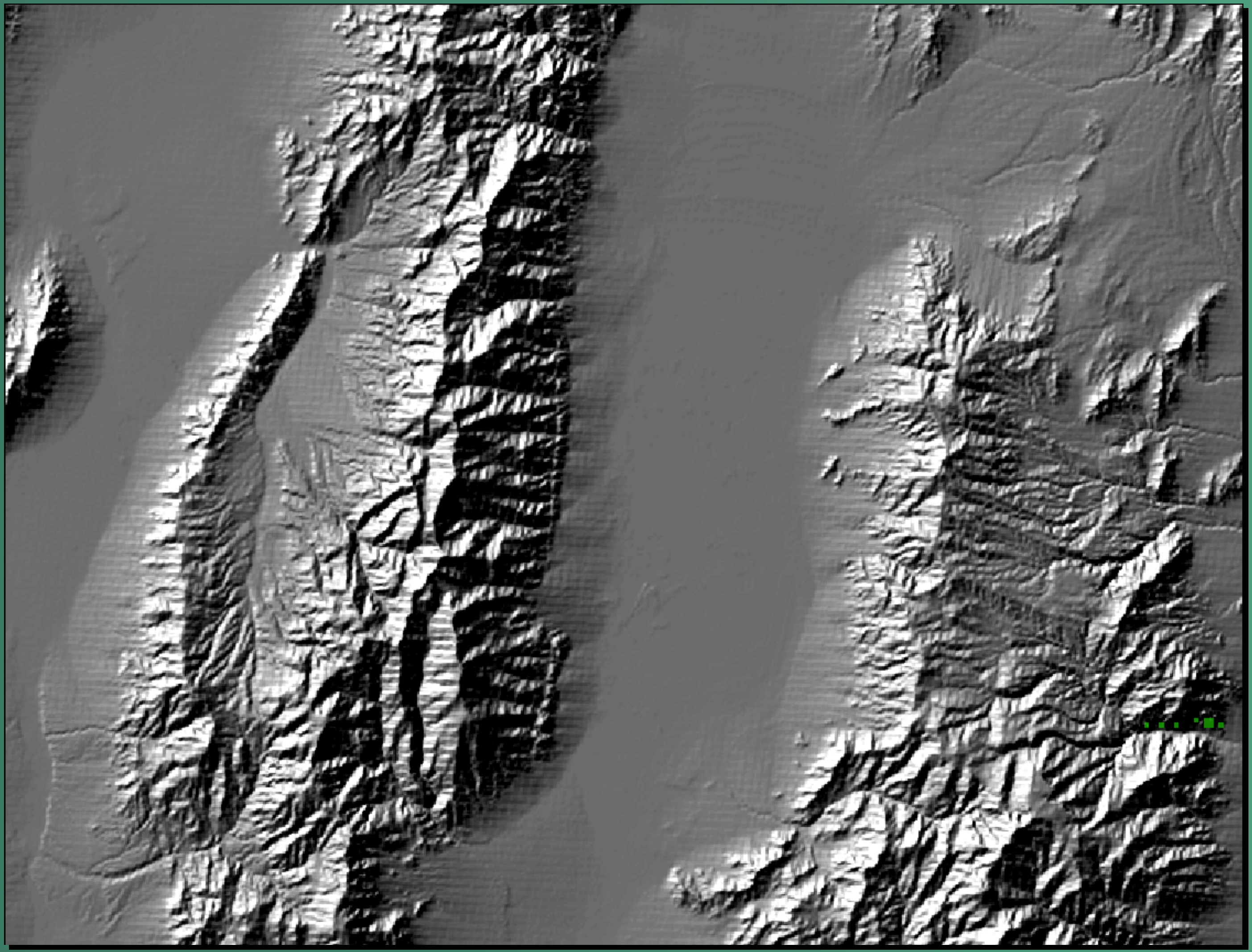
AET = precipitation + last month snowpack + last month soil water storage – soil water storage



Land cover change determined from remotely sensed images for 5-yr intervals 1975-2007




sage
cold desert scrub
Pinyon Juniper
sage to cold desert scrub
sage to PJ
cold desert scrub to PJ
cold desert scrub to sage
PJ to sage

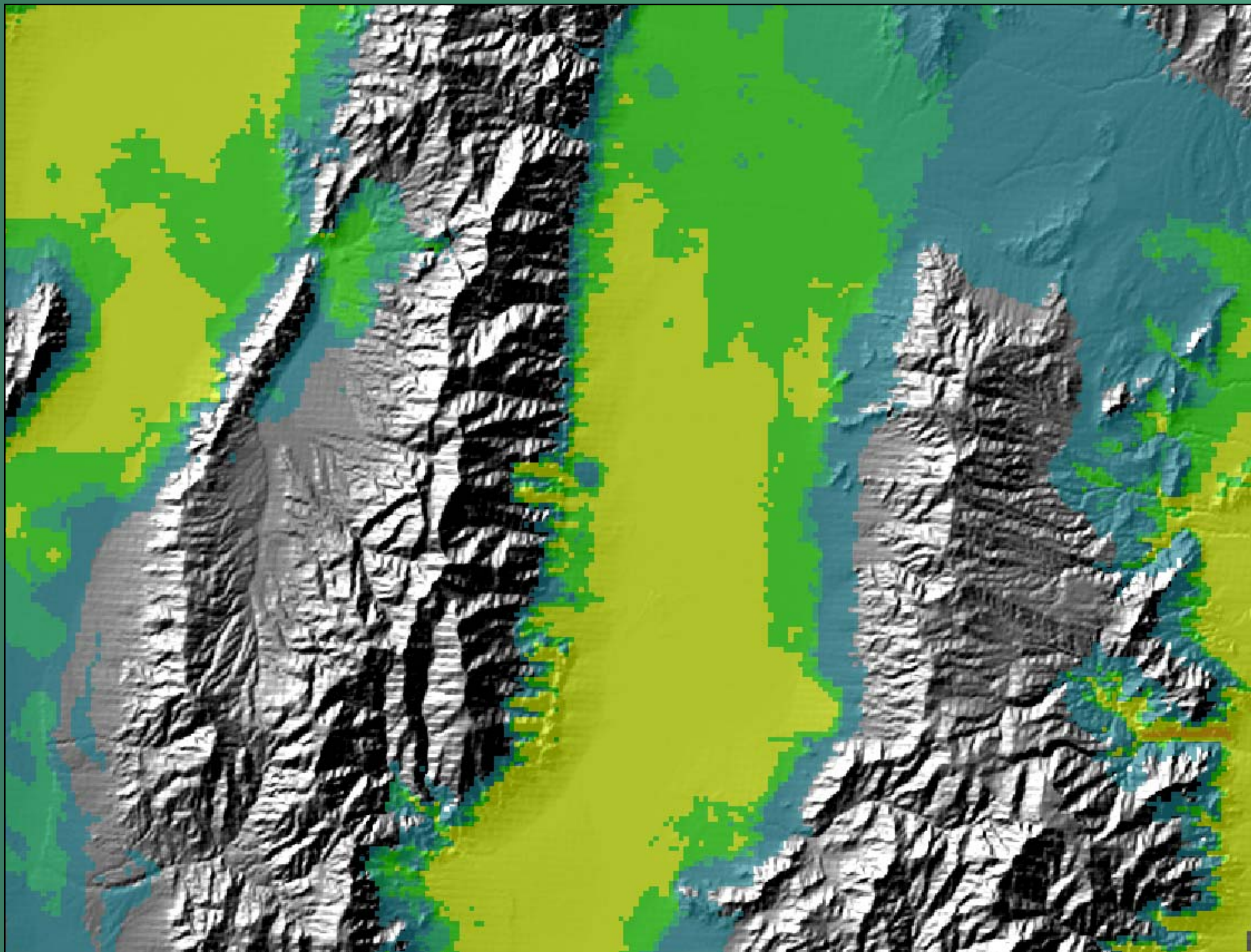


Climatic Water Deficit

Feb 2001

<mm>

- 0 - 0.1
- 0.1 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 200

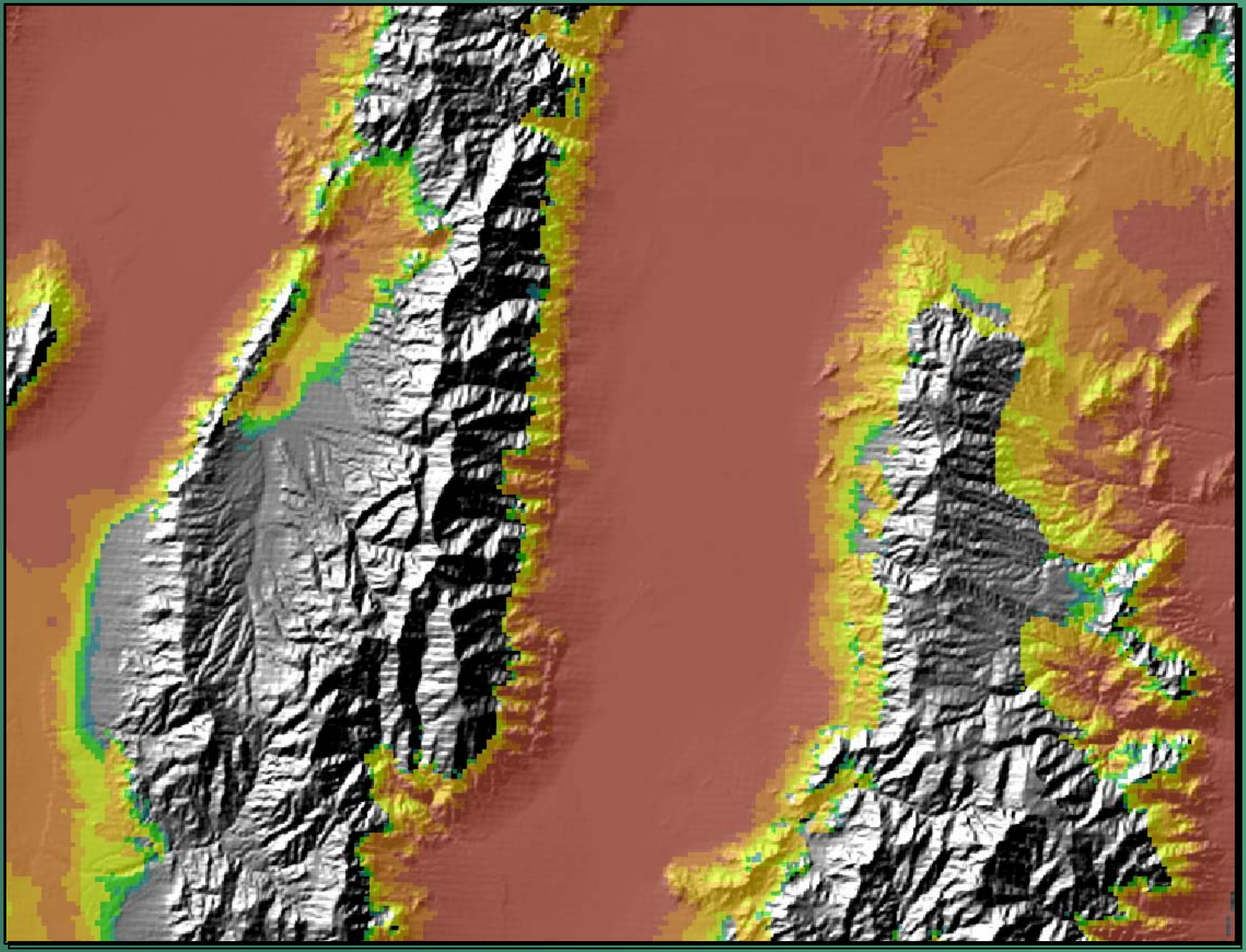


Climatic Water Deficit

April 2001

<mm>

- 0 - 0.1
- 0.1 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 200

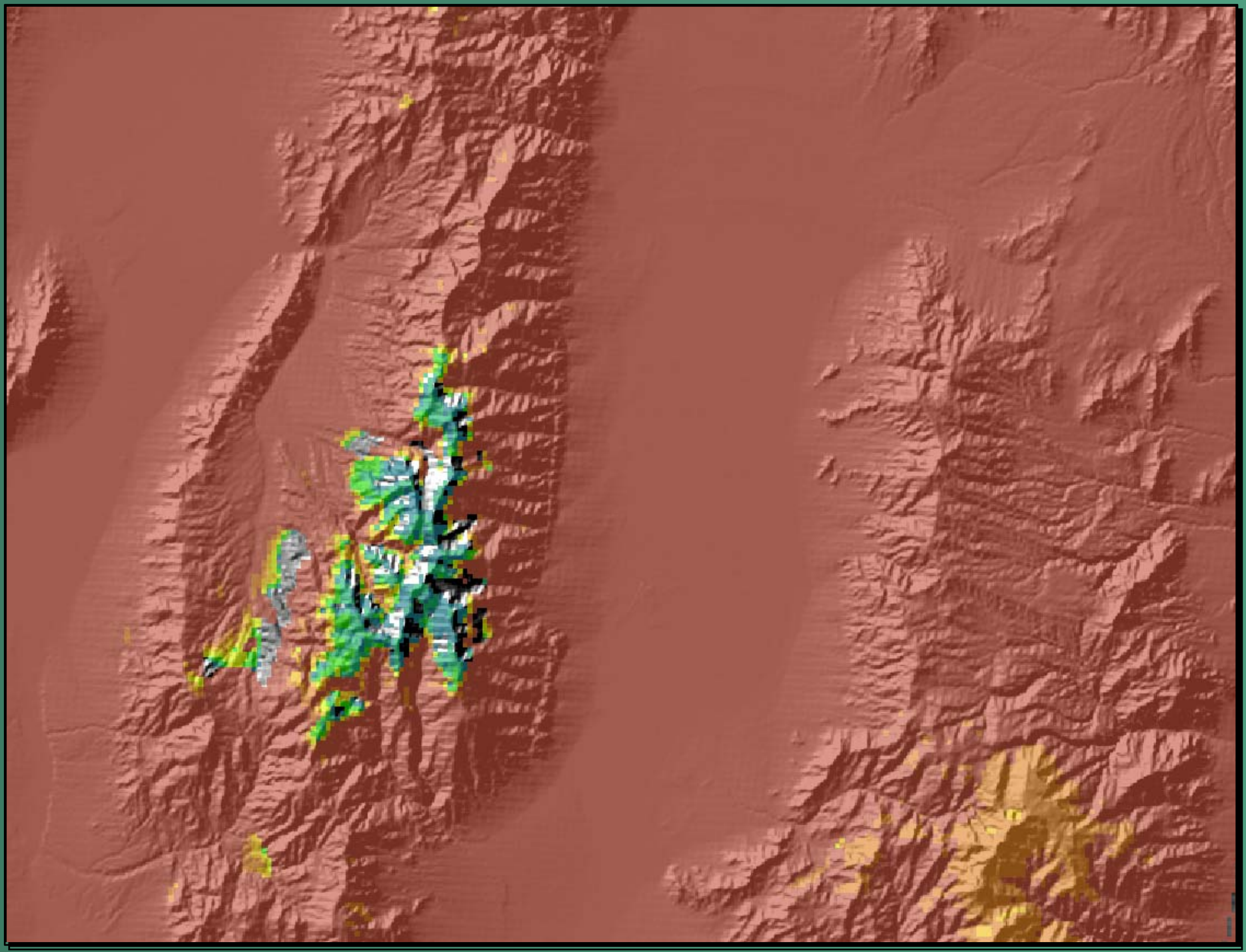


Climatic Water Deficit

May 2001

<mm>

- 0 - 0.1
- 0.1 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 200



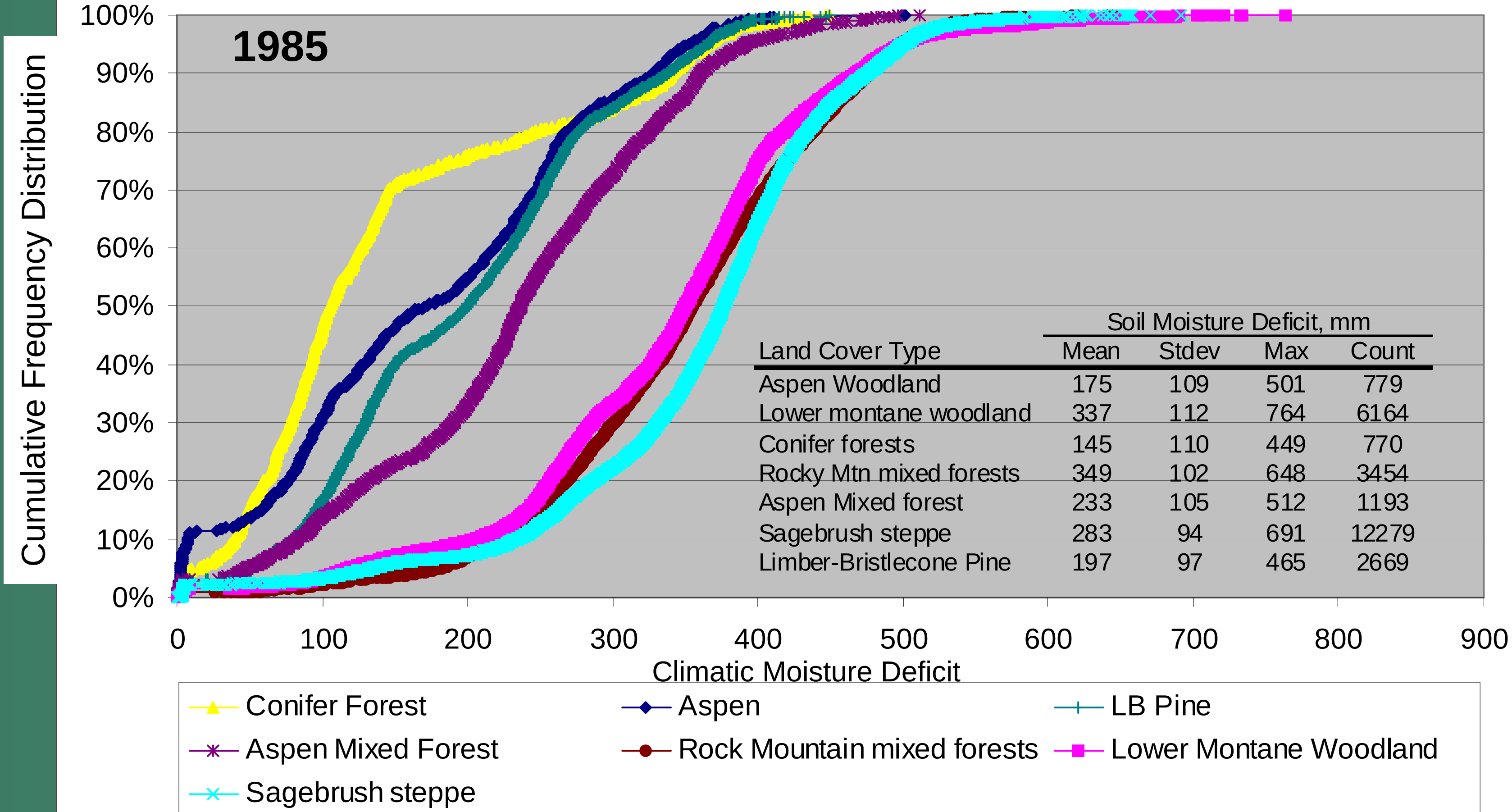
Climatic Water Deficit

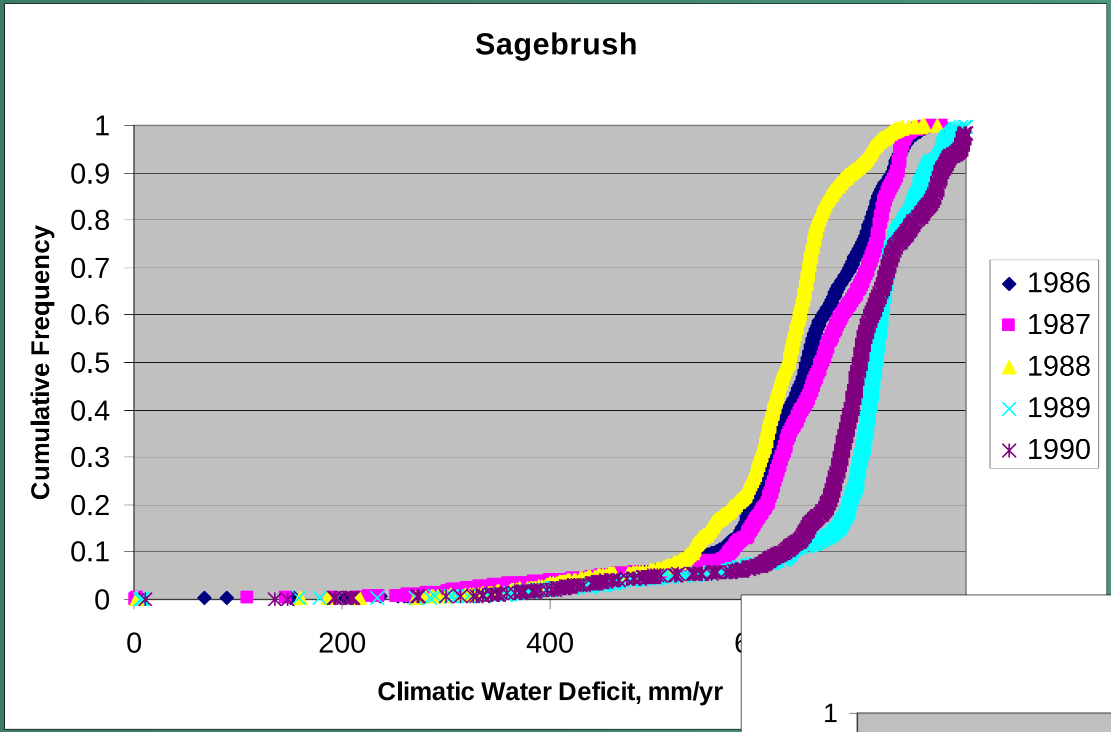
July 2001

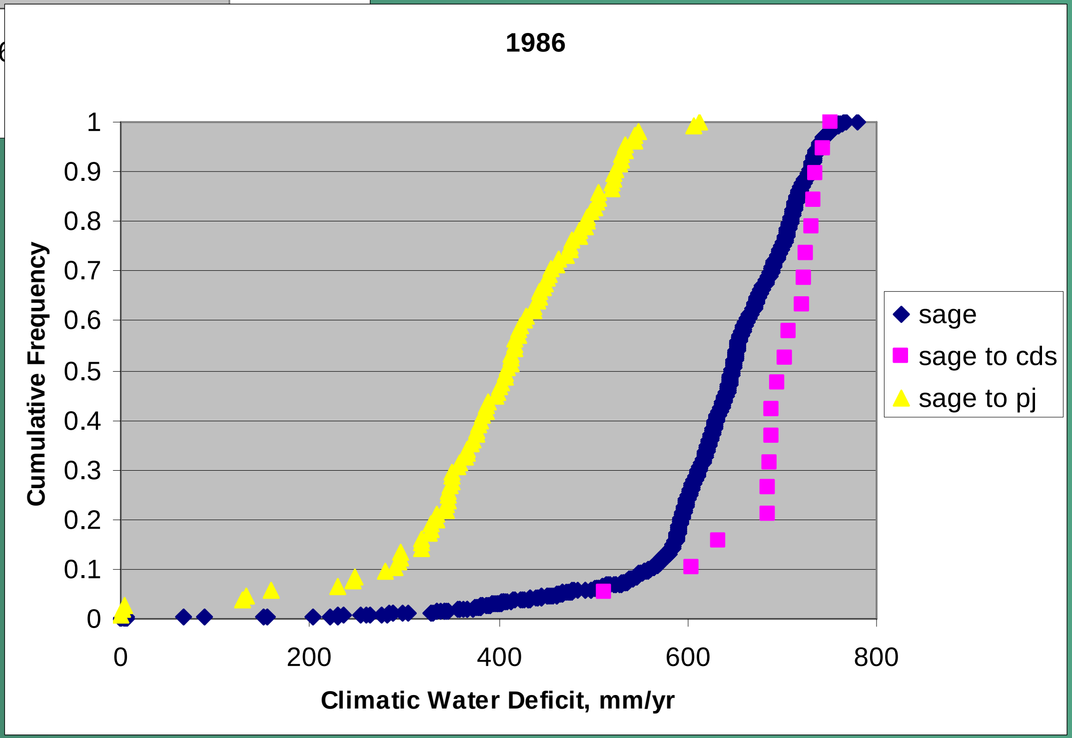
<mm>

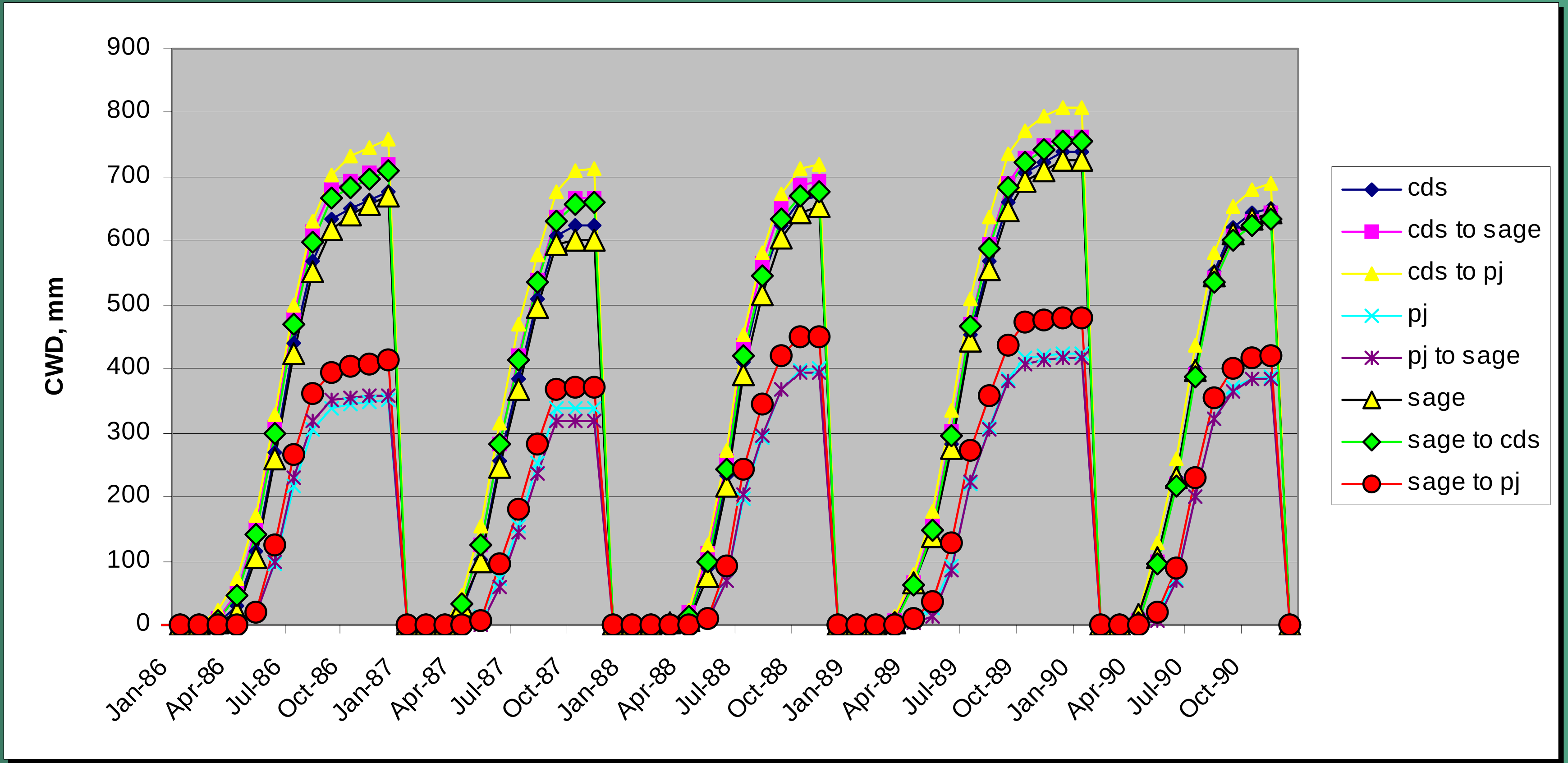
- 0 - 0.1
- 0.1 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 200

Land cover moisture envelopes

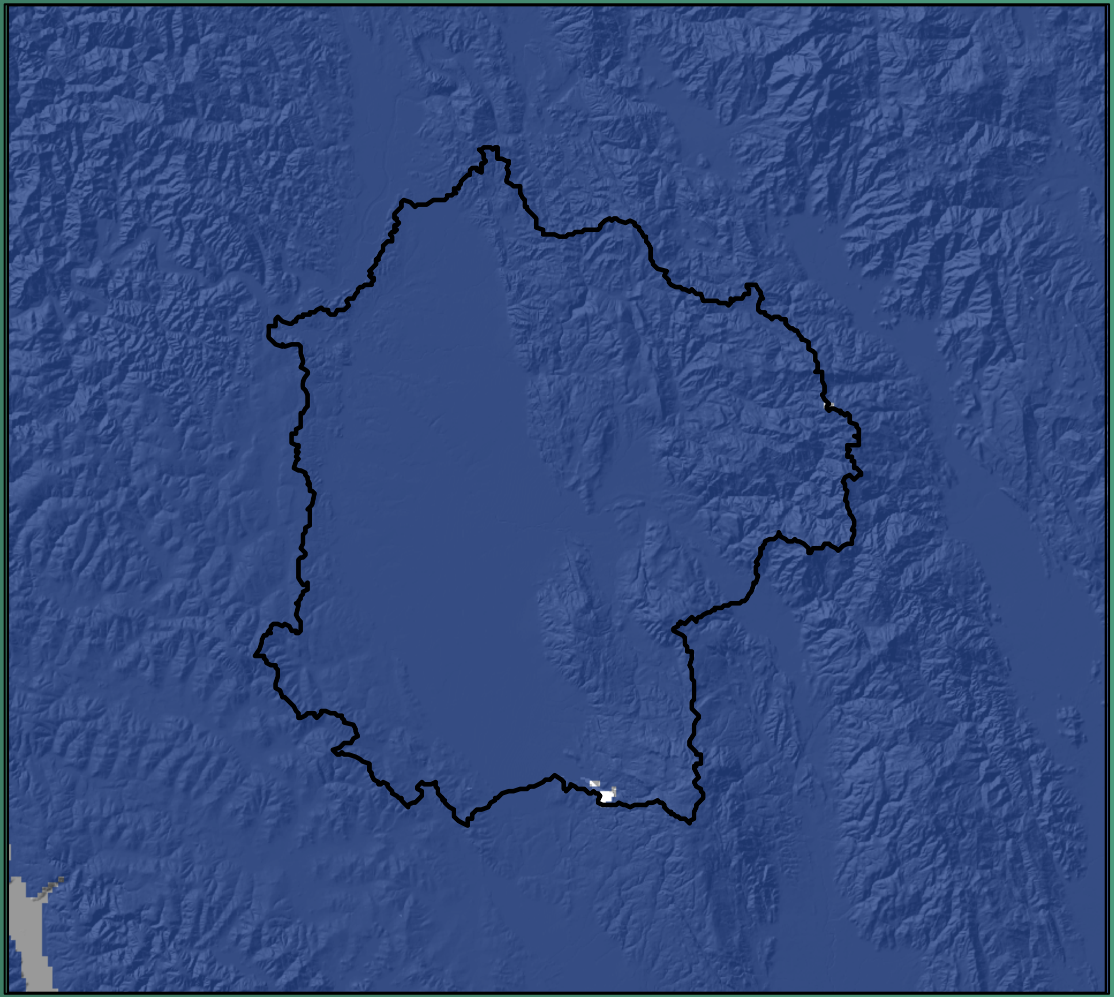



Sagebrush
Cumulative Frequency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
Climatic Water Deficit, mm/yr
1986
1987
1988
1989
1990


1986
Cumulative Frequency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
Climatic Water Deficit, mm/yr
sage
sage to cds
sage to pj



CWD, mm
900
800
700
600
500
400
300
200
100
0
Jan-86
Apr-86
Jul-86
Oct-86
Jan-87
Apr-87
Jul-87
Oct-87
Jan-88
Apr-88
Jul-88
Oct-88
Jan-89
Apr-89
Jul-89
Oct-89
Jan-90
Apr-90
Jul-90
Oct-90
cds
cds to sage
cds to pj
pj
pj to sage
sage
sage to cds
sage to pj

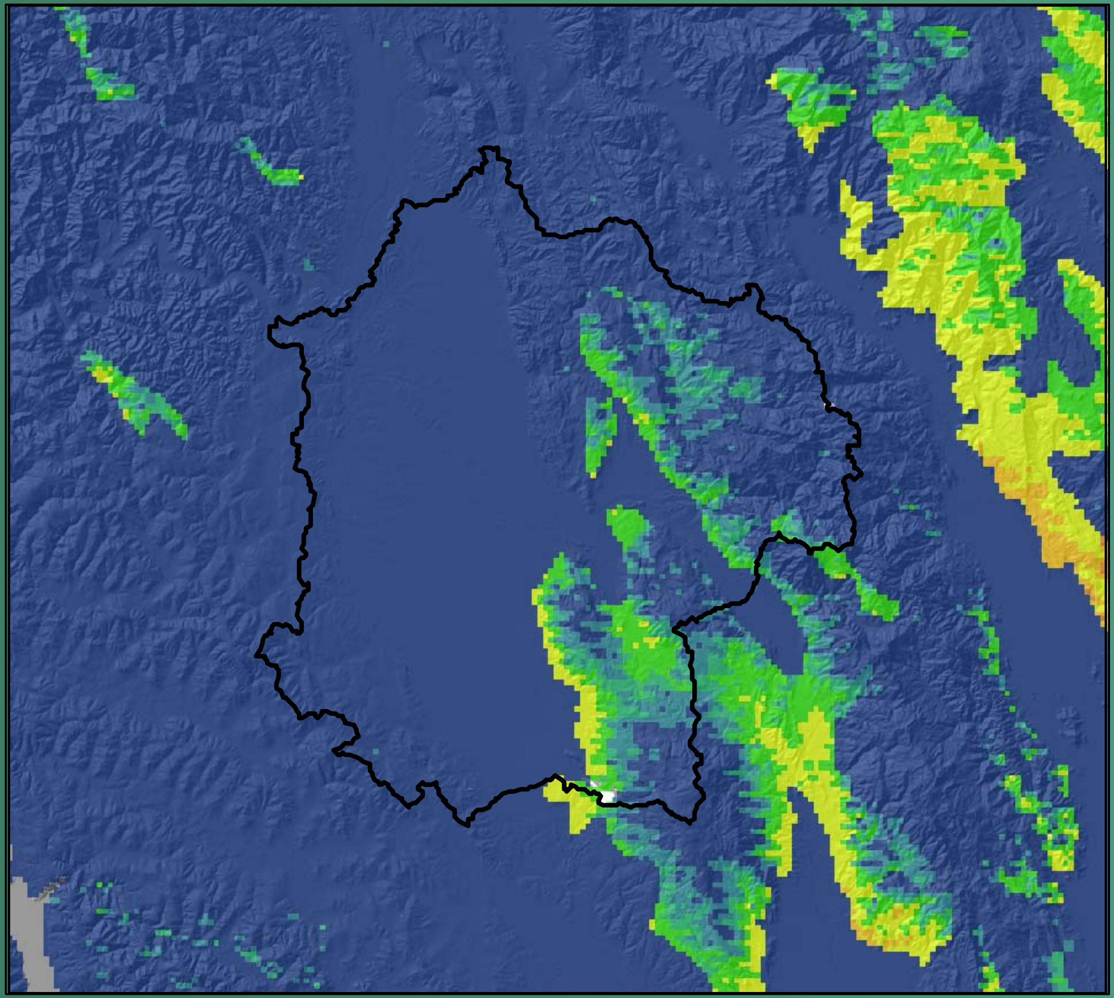


Climatic Water Deficit

May 2001

<mm>

- 0 - 0.1
- 0.1 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 200

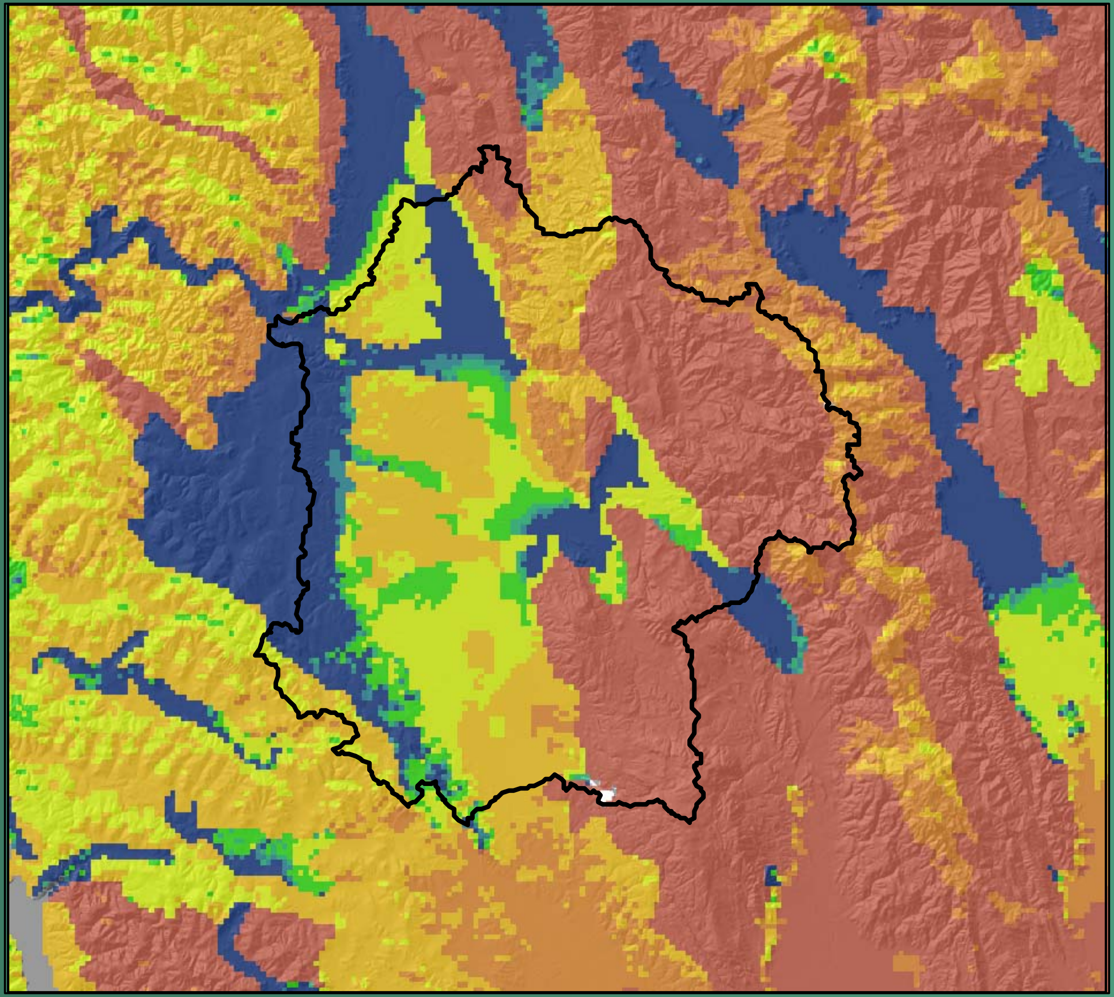


Climatic Water Deficit

May 2001

<mm>

- 0 - 0.1
- 0.1 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 200

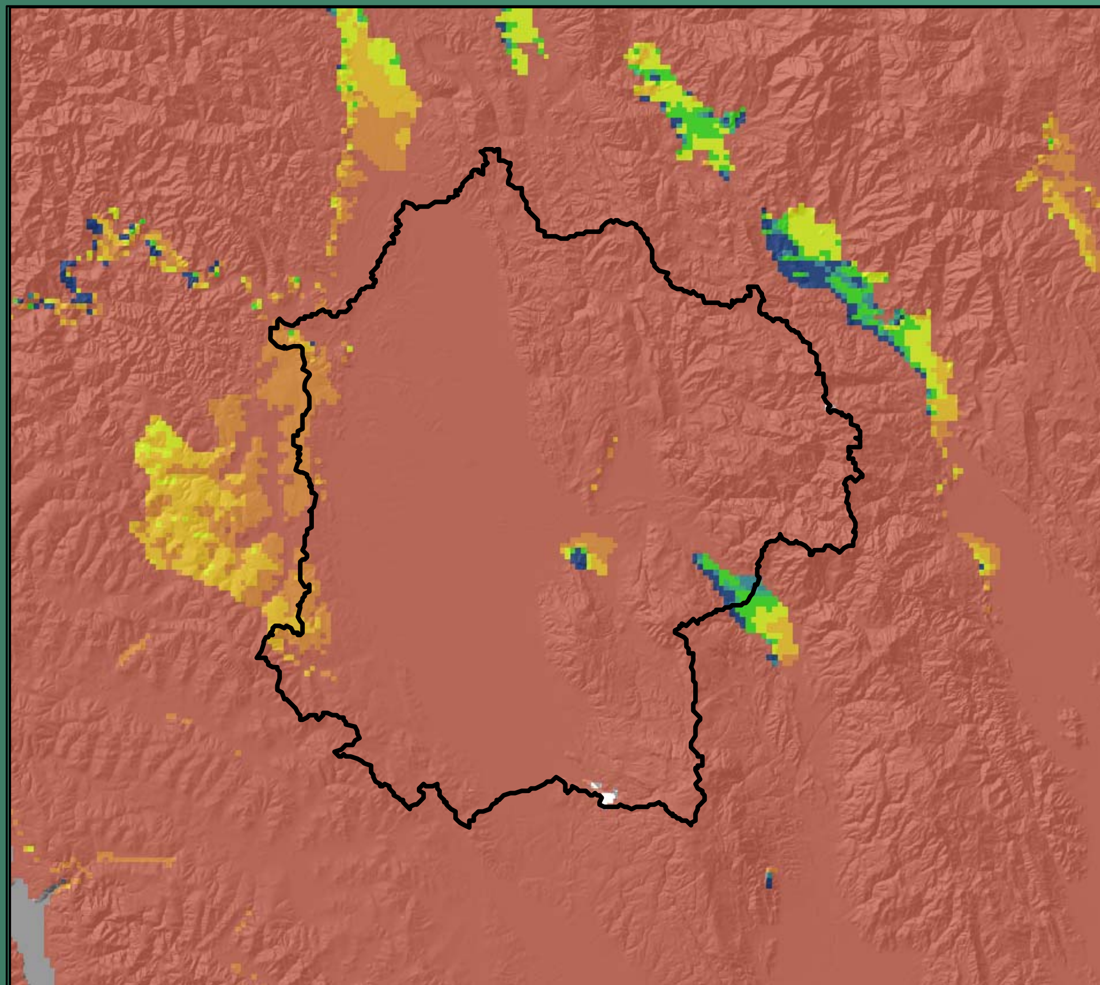


Climatic Water Deficit

May 2001

<mm>

- 0 - 0.1
- 0.1 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 200

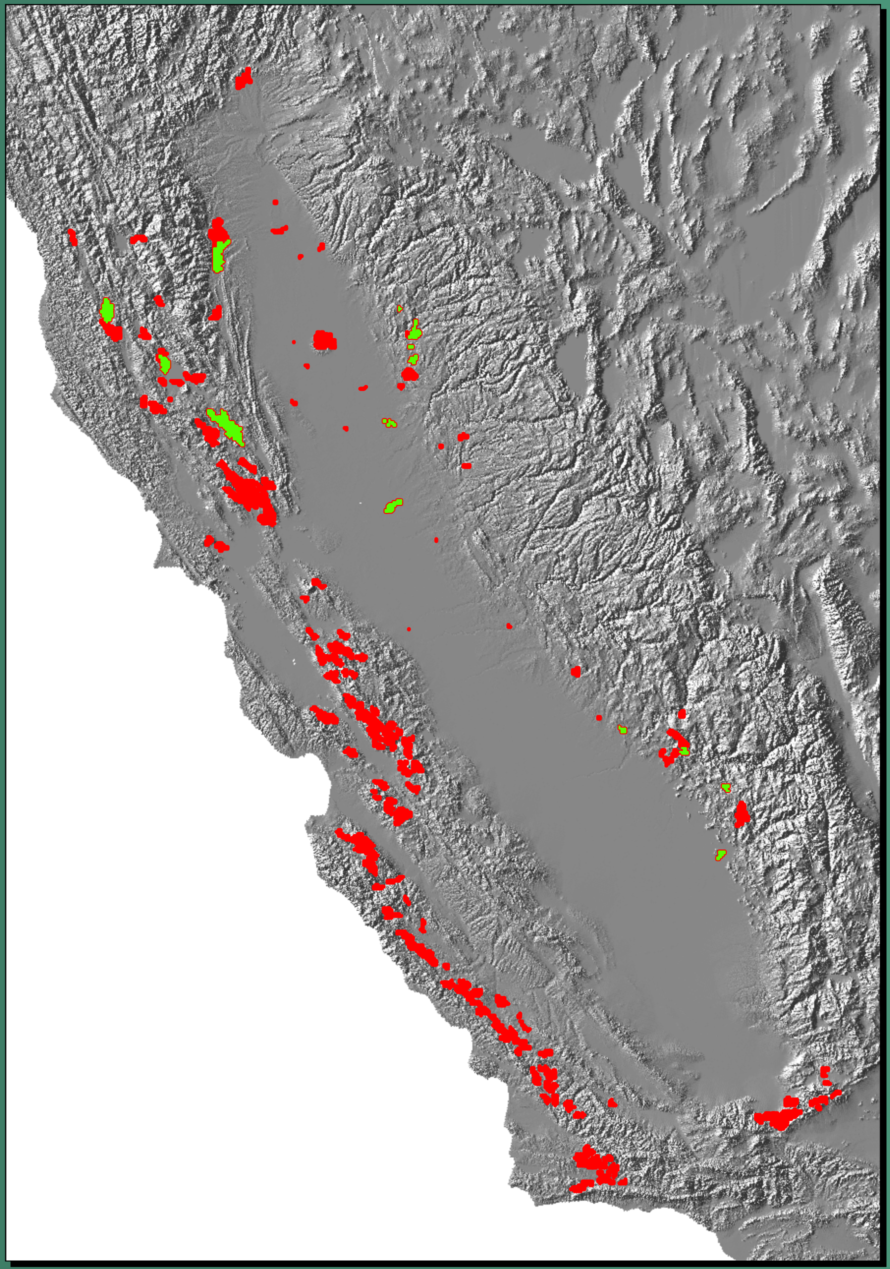


Climatic Water Deficit

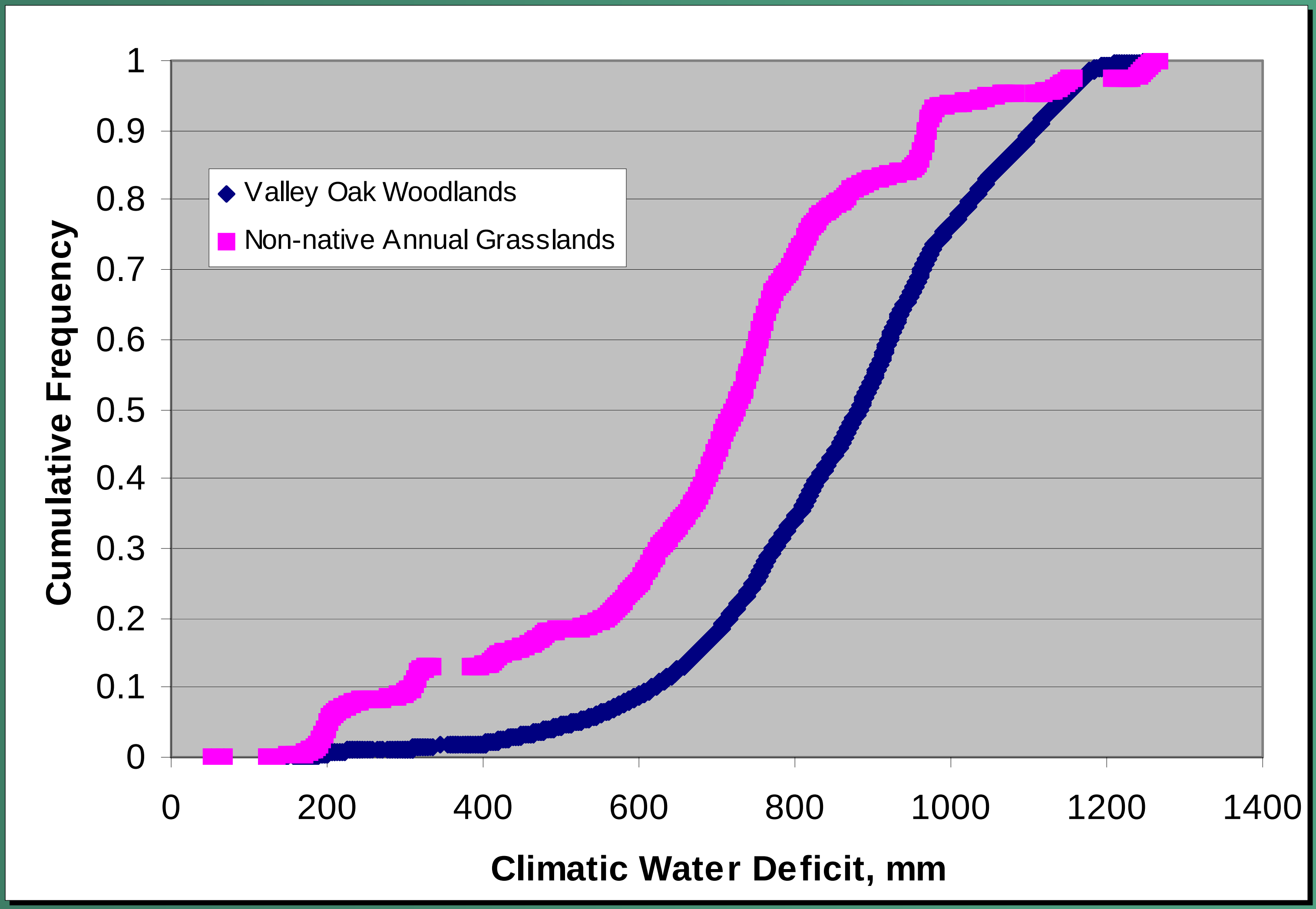
May 2001

<mm>

- 0 - 0.1
- 0.1 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 200



Non-native_annual_grasslands
Valley Oak Woodland



Valley Oak Woodlands
Non-native Annual Grasslands
Cumulative Frequency
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
200
400
600
800
1000
1200
1400
Climatic Water Deficit, mm

Implications of Climate Change for the Laguna

- Air temperatures are expected to rise and precipitation is expected to decline in the Laguna region
- Runoff and recharge are expected to diminish over the next century
- Droughts, floods, and timing of climatic conditions are likely to dominate the future environmental conditions
- Environmental stressors are sufficiently distinguishable for current species distributions to enable their use for future projections

Potential Applications of Regional Modeling Climate Change Analyses

- Region-wide monthly distributions of
  - natural streamflow and timing
  - snowmelt and timing
  - air temperature
  - potential evapotranspiration
  - soil moisture
- Changes in monthly flows along with soil type, conditions, and slope, could provide indications of vulnerability to sediment transport
- Timing of temperature and moisture conditions can be applied to potential changes in plant distributions, forest health, and vulnerability to wildfire
- Daily flows at selected pour points
  - provide estimates of peak flows for flooding and sediment transport
  - incorporate all components of the water balance and soil moisture to estimate seasonal streamflows for reservoir management