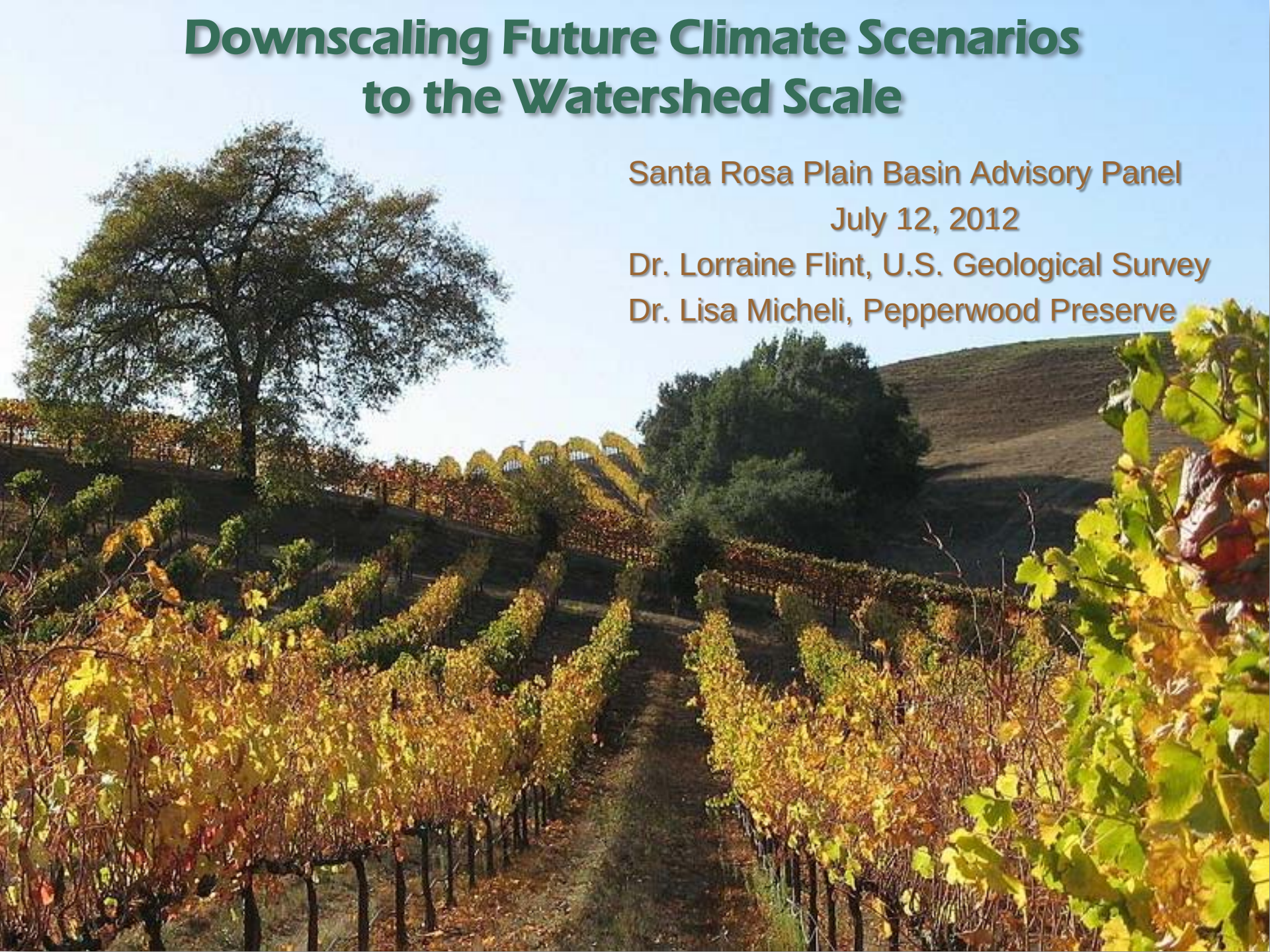
Downscaling Future Climate Scenarios to the Watershed Scale



Santa Rosa Plain Basin Advisory Panel

July 12, 2012

Dr. Lorraine Flint, U.S. Geological Survey

Dr. Lisa Micheli, Pepperwood Preserve

Outline

- Discussion of climate change, Global Climate Models, and issues of scale
- Translating climate change to hydrologic response
  - Water availability
  - Irrigation demand
  - Recharge
- Future projections in Sonoma County
- North Bay Climate Adaptation Initiative (NBCAI): local applications of science to resource management

Study: Arctic sea ice melting faster than expected

Associated Press

Buzz Up | Send | Share | Print

By RANDOLPH E. SCHMID, AP Science Writer – Fri Apr 3, 1:03 am ET

AP – In this July 11, 2008 photo, a giant glacier is seen making its way to the waters of Croaker Bay on Devon ...

WASHINGTON – Arctic sea ice is melting so fast most of it could be gone in 30 years. A new analysis of changing conditions in the region, using complex computer models of weather and climate, says conditions that had been forecast by the end of the century could occ

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"Du
Arctic surface air temperatures were greater than 5 degrees Celsius (9 degrees Fahrenheit) above" what would be expected, the new study reports.

e had been expected by the year 2070.

e Joint Institute for the Study of Atmosphere and Ocean and James E.
d Atmospheric Administration's Pacific Marine Environmental Laboratory,
rnal Geophysical Research Letters.

CO_2 emissions

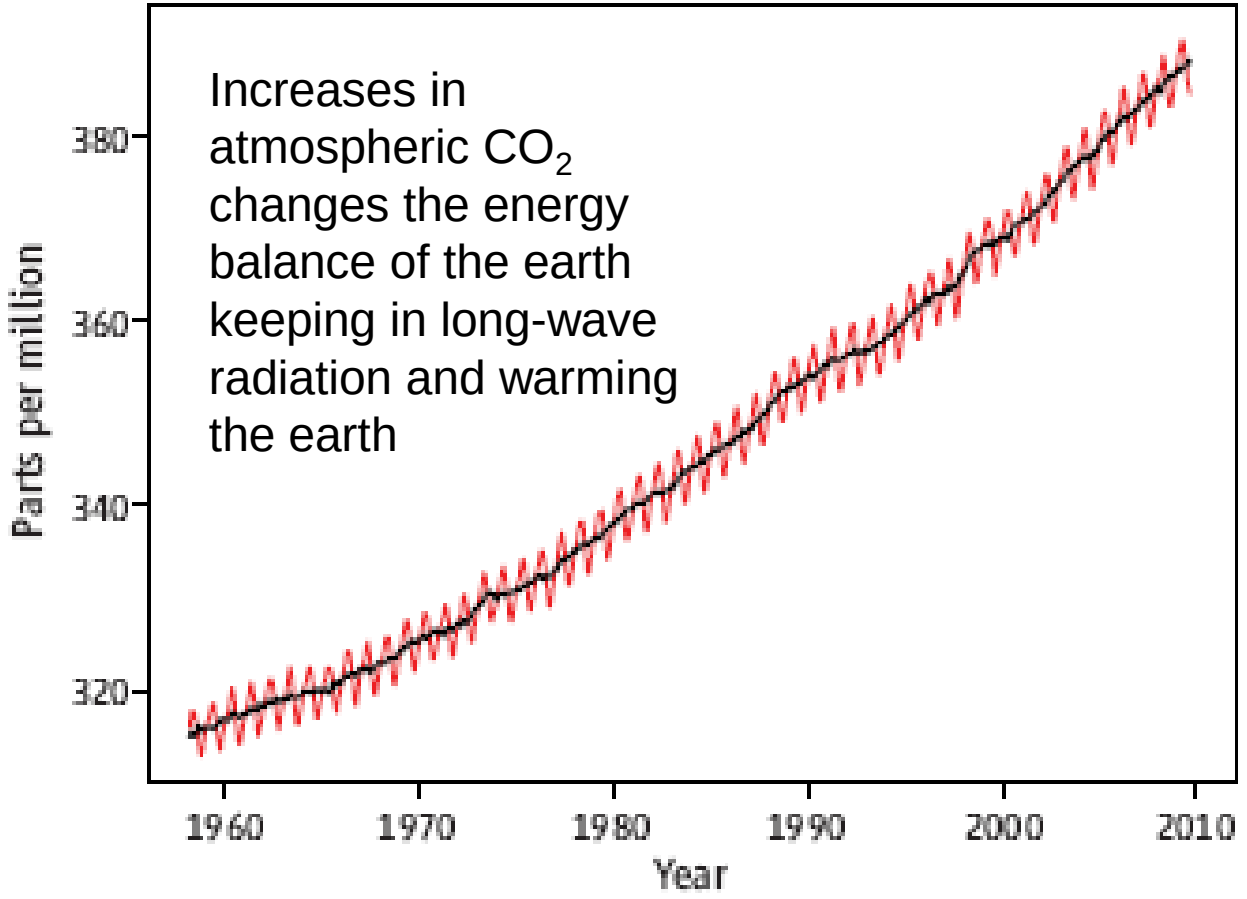
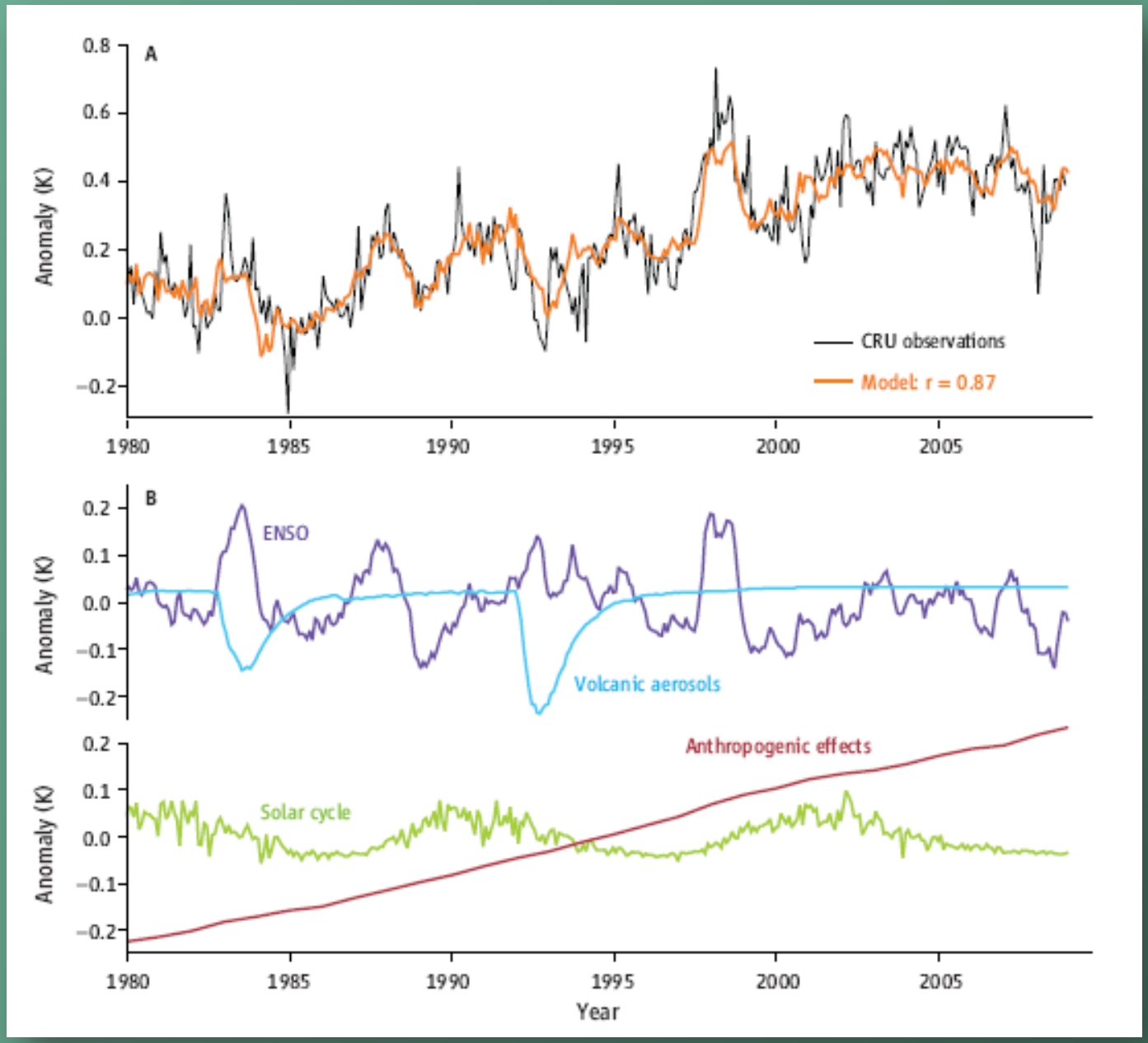


Fig. 1. Keeling curve for atmospheric CO_2. Monthly mean atmospheric CO_2 at Mauna Loa Observatory, Hawaii.

McCarthy (Science, 2009)

Climate change is a result of global increases in temperature

Influences on increased temperature by volcanos, ENSO, solar cycle, and humans



McCarthy (Science, 2009)

Science
AAAS

Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America
Richard Seager, *et al.*
Science **316**, 1181 (2007);
DOI: 10.1126/science.1139601

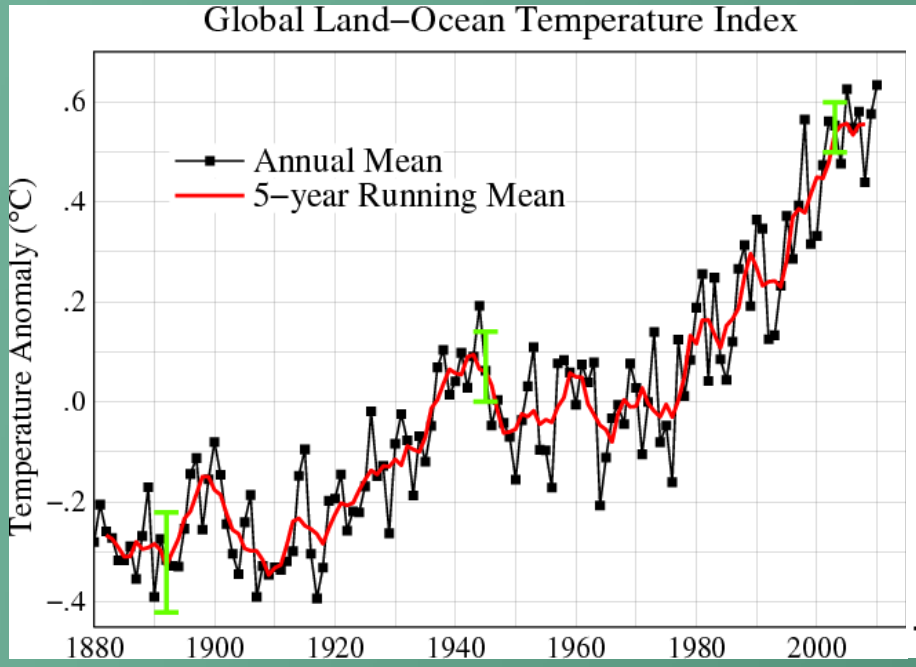
Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America

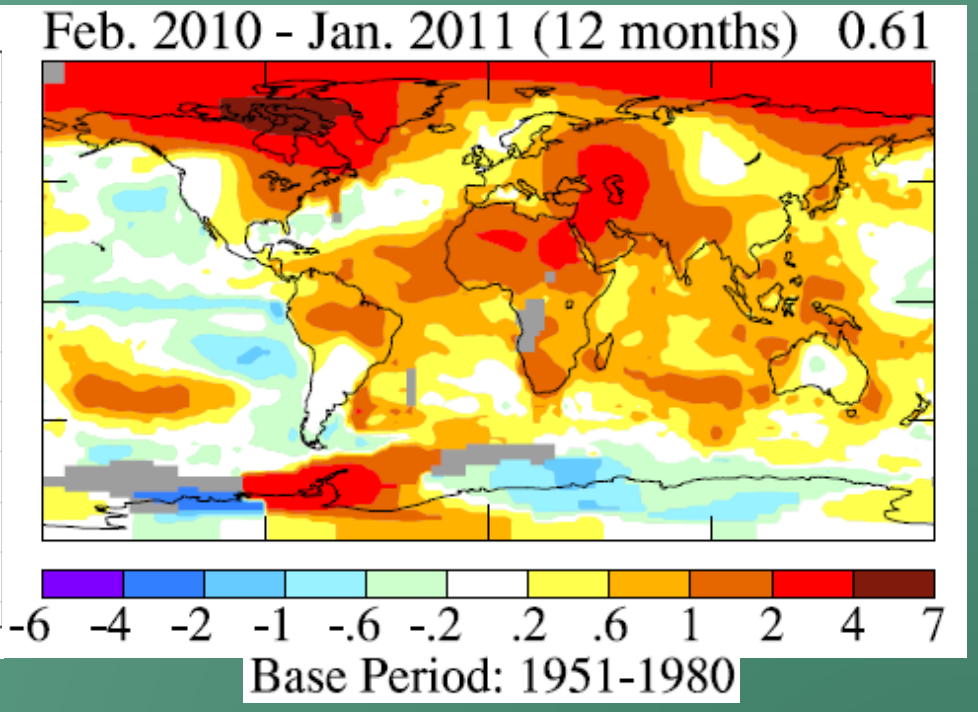
Richard Seager,[1*] Mingfang Ting,[1] Isaac Held,[2,3] Yochanan Kushnir,[1] Jian Lu,[4] Gabriel Vecchi,[2] Huei-Ping Huang,[1] Nili Harnik,[5] Ants Leetmaa,[2] Ngar-Cheung Lau,[2,3] Cuihua Li,[1] Jennifer Velez,[1] Naomi Naik[1]

How anthropogenic climate change will affect hydroclimate in the arid regions of southwestern North America has implications for the allocation of water resources and the course of regional development. Here we show that there is a broad consensus among climate models that this region will dry in the 21st century and that the transition to a more arid climate should already be under way. If these models are correct, the levels of aridity of the recent multiyear drought or the Dust Bowl and the 1950s droughts will become the new climatology of the American Southwest within a time frame of years to decades.

Current Heat Index
Air Sports Net Weather
10 20 30 40 50 C
50 60 70 80 90 100 110 120 130 F
Created: Thu

Global warming and the spatial variability of a changing climate





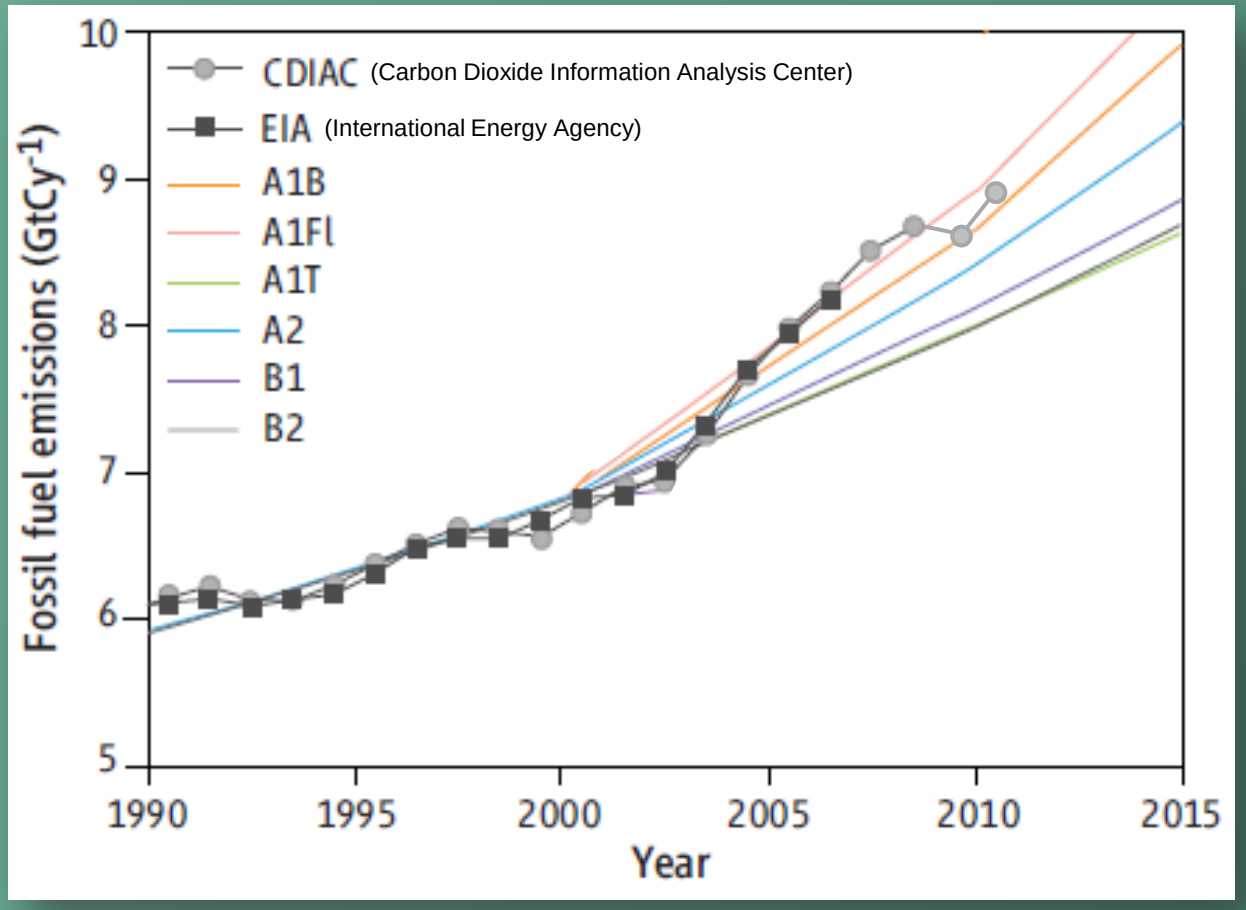
From Jim Hansen, NASA

GFDL-A2 scenario
Change in Runoff

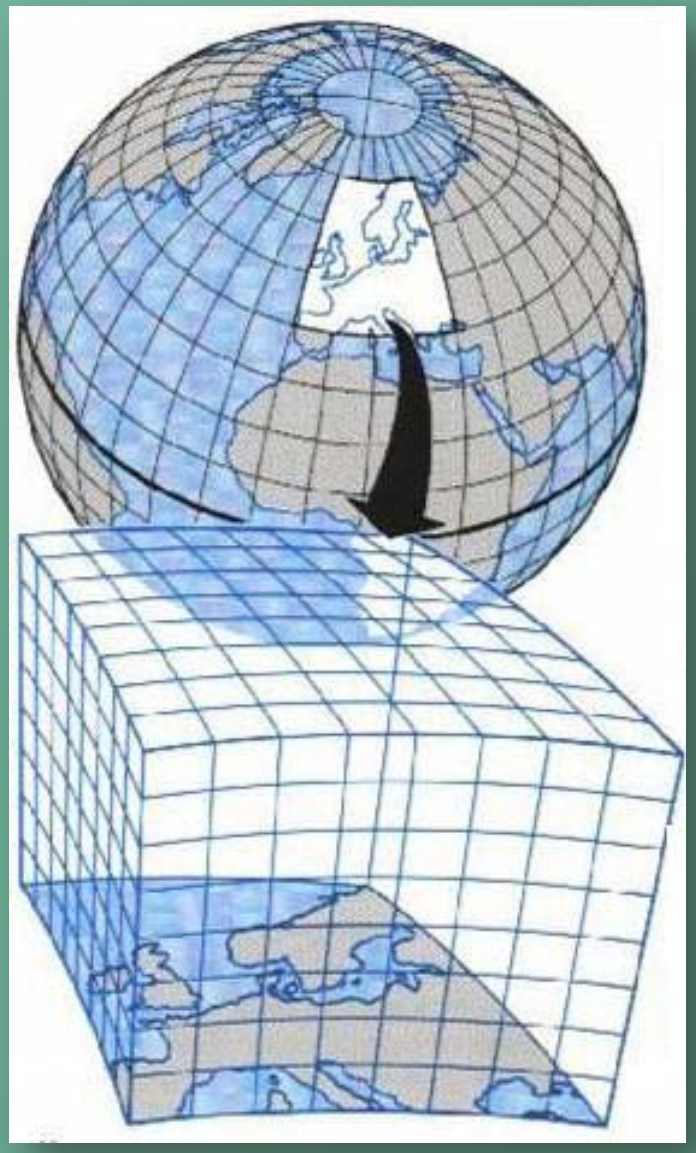
How do we get there from here?

Climate Change Scenarios

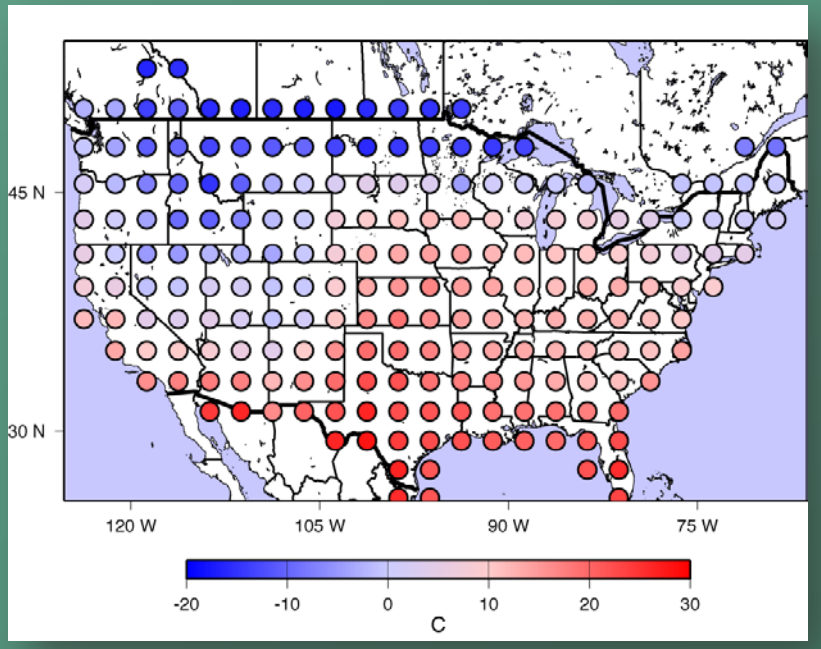
IPCC Special Report on Emission Scenarios (SRES) has developed scenarios corresponding to potential future global and regional economic and land use strategies



The downscaling problem



Global Climate Model
(actually, general circulation model)

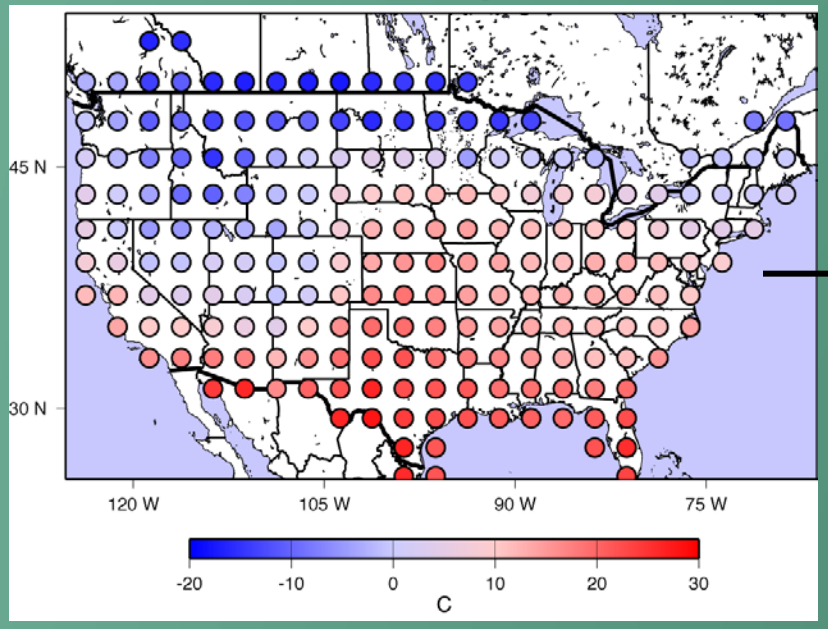


Original GCM values

Global Climate Models (GCMs) →Climate Change Scenarios

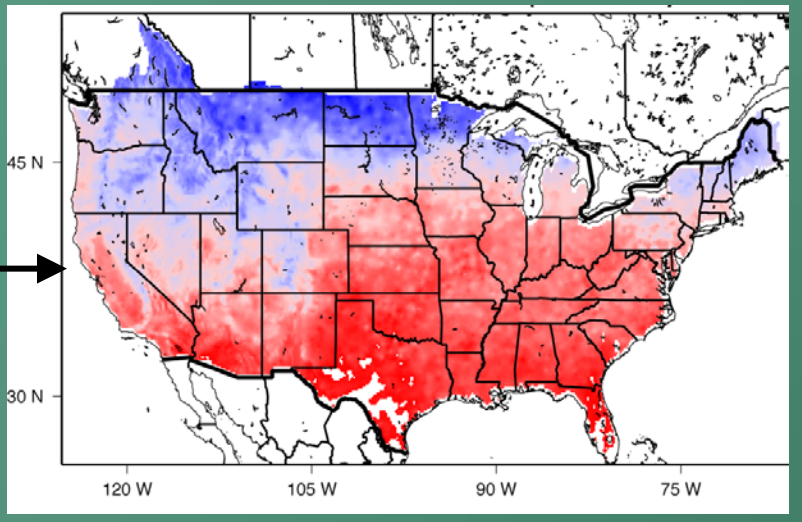
- Climate model data (precipitation, air temperature) are available from the IPCC at 2.5 degree resolution, ~275-km
- Model scenarios downscaled to 12-km
- Spatially downscaled to 270-m for hydrologic model applications gradient-inverse distance squared interpolation

GCM output



275 km grid cells

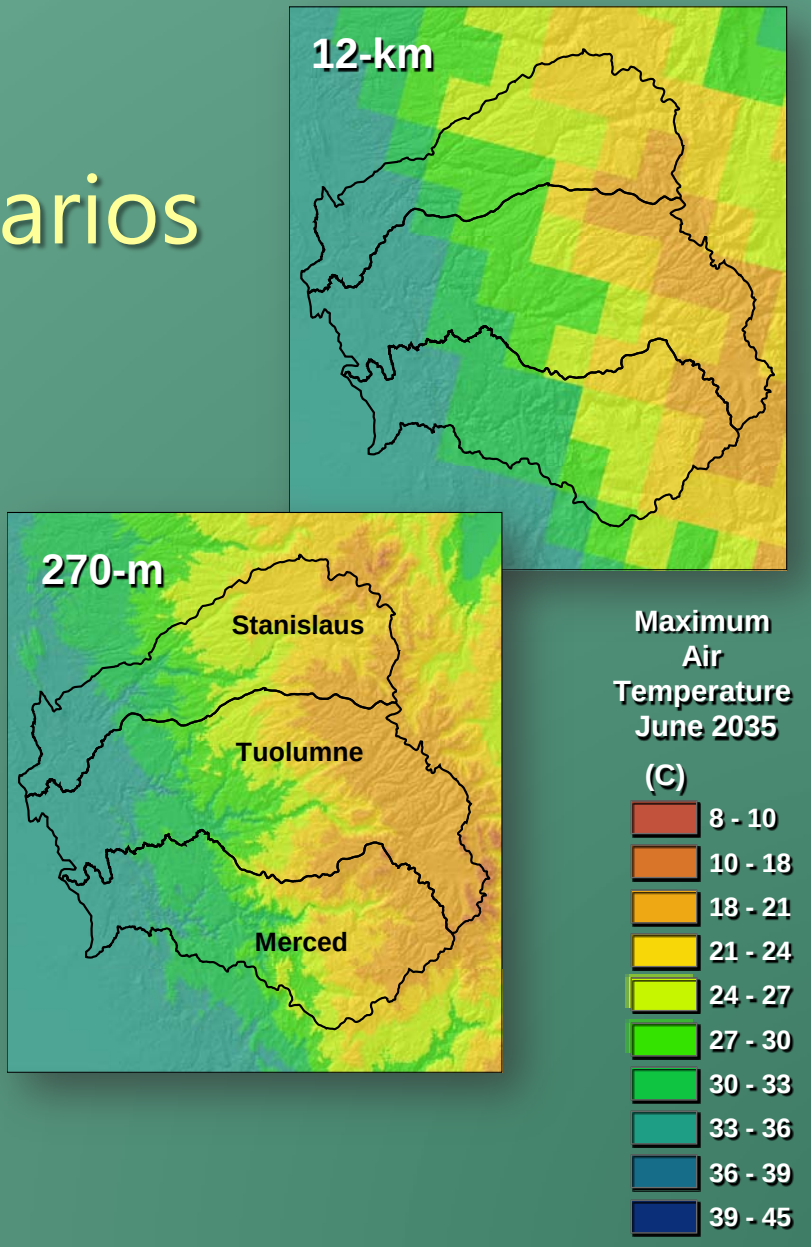
Downscaled



12-km grid cells

Downscaling Climate Change Scenarios

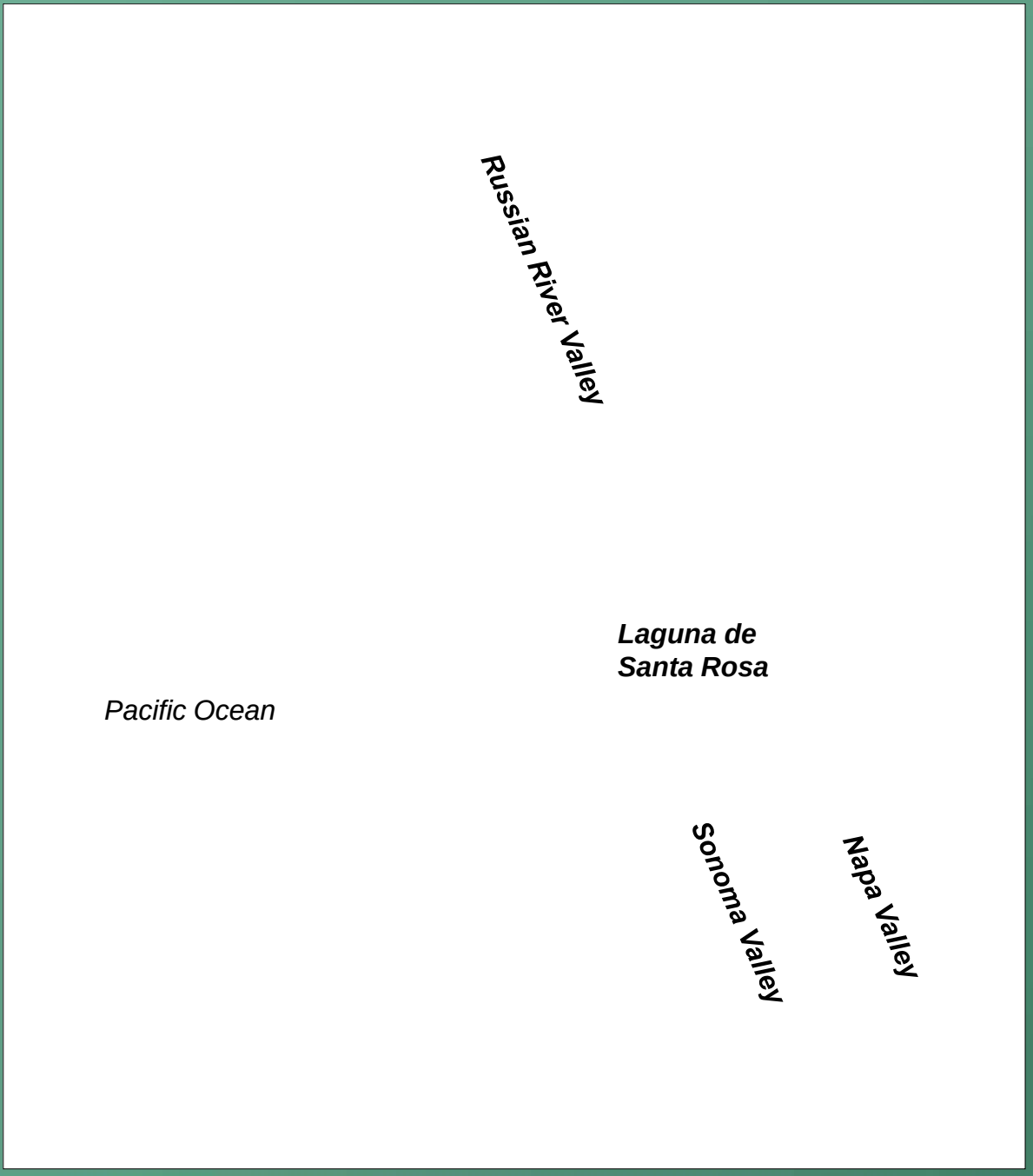
Data are spatially downscaled to 270-m using a gradient-inverse-distance-squared (GIDS) method for hydrologic model application



Fine-scale Application

- Provides information at the spatial scales at which processes occur
  - Vegetation distribution in local environments
  - Energy balance on north and south facing slopes
  - Basin-scale water availability

Sonoma County



Current Climate in Sonoma County (1971-2007)

Precipitation

(mm/yr)

- < 800
- 800 - 900
- 900 – 1,000
- 1,000 – 1,100
- 1,100 - 1,200
- 1,200 - 1,300
- 1,300 - 1,400
- > 1,400

Maximum Air Temperature

(deg C)

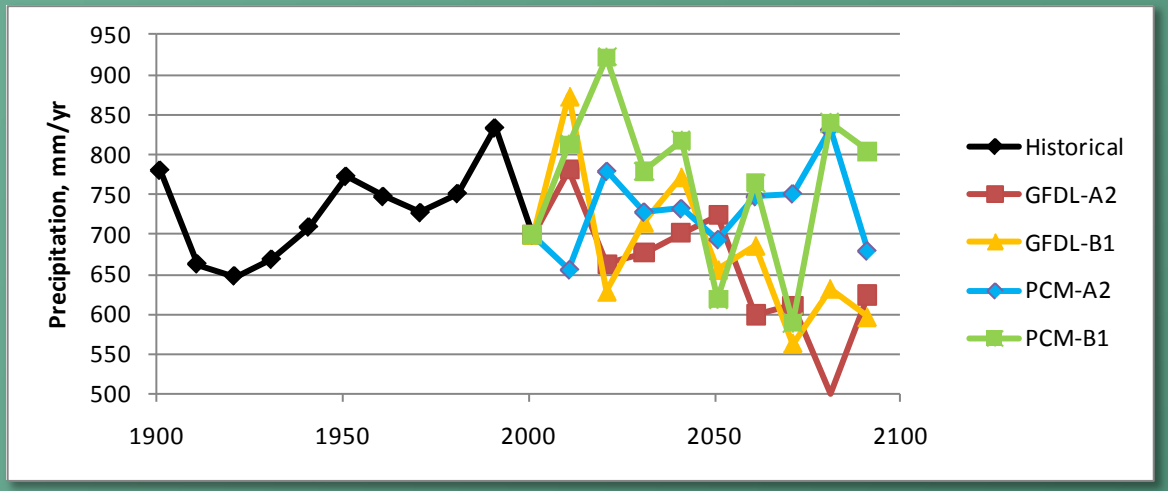
- < 18
- 18 - 19
- 19 - 20
- 20 - 21
- 21 - 22
- 22- 23
- 23 - 24
- 24 - 25

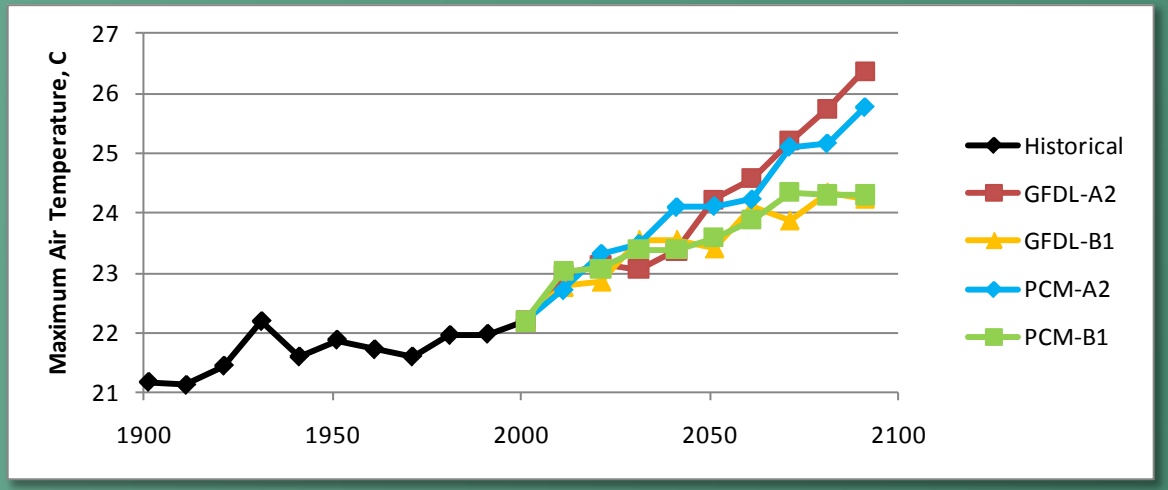
Minimum Air Temperature

(deg C)

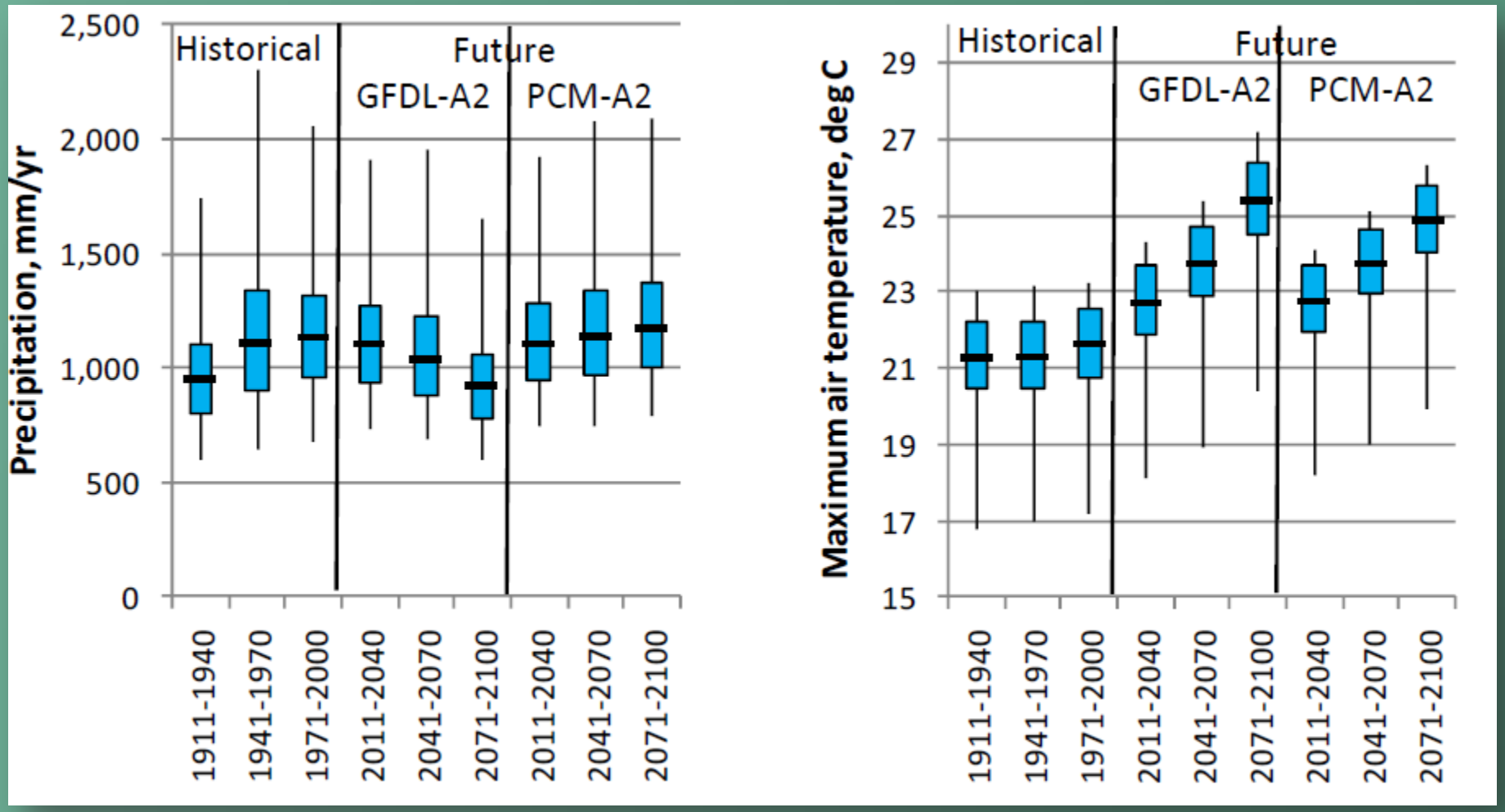
- 2 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 11
- 11 - 12
- 12 - 13

Climate for Sonoma County: current and future conditions – 4 scenarios



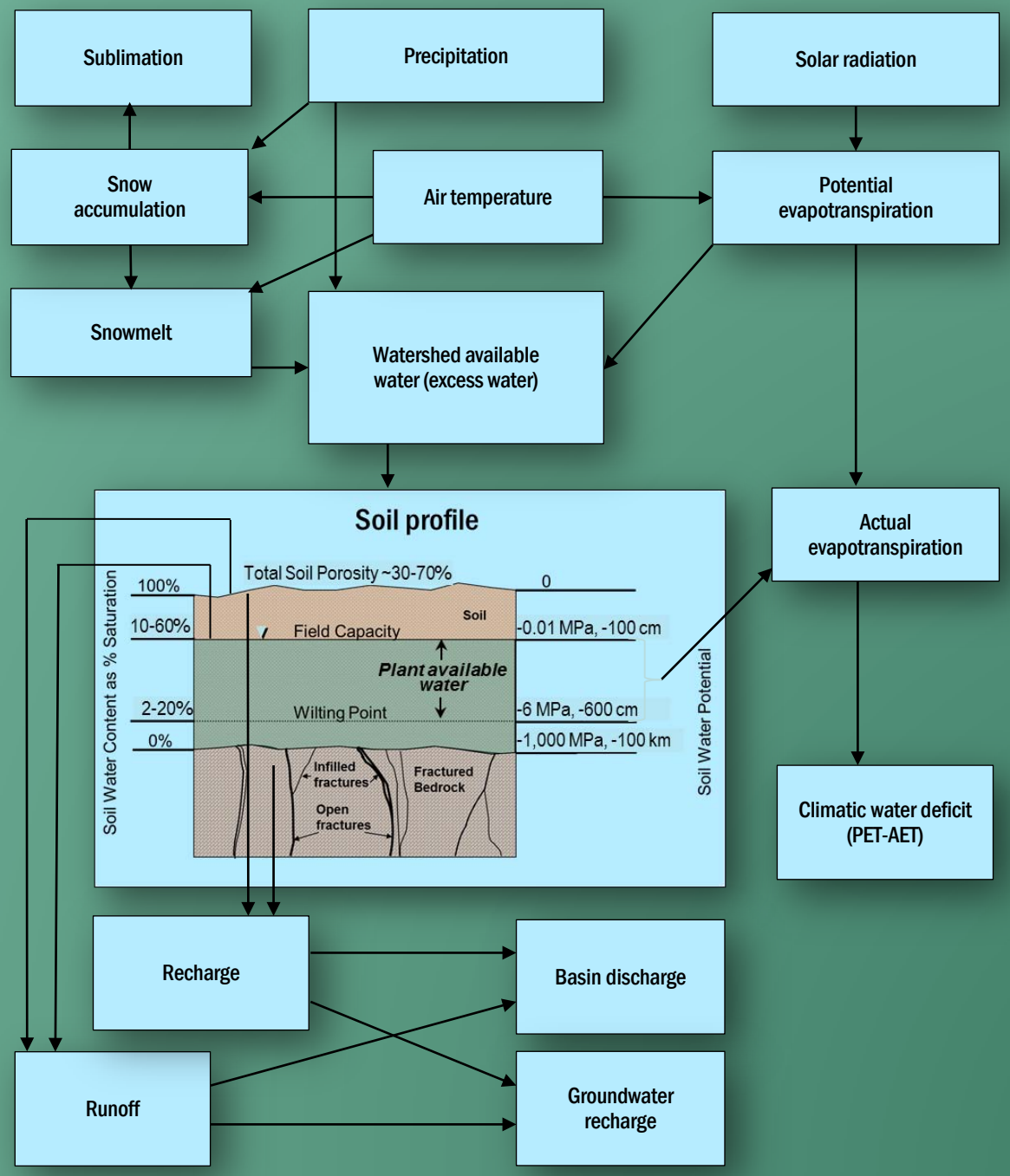


Climate for Sonoma County:
Changes for 30-yr periods for 2 models



Translating climate change to hydrologic response

- Requires downscaling from global scales to regional
- Requires an approach to simulate hydrology from available information
  - Basin Characterization Model (BCM)
    - grid-based data
    - uses climate data and calculates
      - potential evapotranspiration
      - recharge and runoff
      - actual ET
      - climatic water deficit
      - snow accumulation and snow melt


Sublimation
Precipitation
Solar radiation
Snow accumulation
Air temperature
Potential evapotranspiration
Snowmelt
Watershed available water (excess water)
Soil profile
Total Soil Porosity ~30-70%
100%
10-60%
2-20%
0%
Soil Water Content as % Saturation
0
Soil
Field Capacity
-0.01 MPa, -100 cm
Plant available water
Wilting Point
-6 MPa, -600 cm
-1,000 MPa, -100 km
Infilled fractures
Open fractures
Fractured Bedrock
Soil Water Potential
Actual evapotranspiration
Climatic water deficit (PET-AET)
Recharge
Basin discharge
Runoff
Groundwater recharge

Model Development

Geology

Geology

- Alluvium - channels
- Alluvium - landslides
- Alluvium - valley fill
- Conglomerate
- Gabbro
- Granite
- Granite - mixed
- Igneous - dikes and plugs
- Metamorphics - gneiss/schist
- Metamorphics - serpentinite
- Metasediments
- Metavolcanics
- Sandstone
- Sandstone - Santa Margarita
- Sandstone - claystone
- Sandstone - claystone melange
- Sandstone - shale
- Sandstone - shale eocene
- Sandstone - shale lower
- Sandstone - shale upper
- Sandstone - siltstone
- Volcanics - lava flows quaternary
- Volcanics - lava flows tertiary
- Volcanics - pyroclastics
- Volcanics - rhyolites
- Water

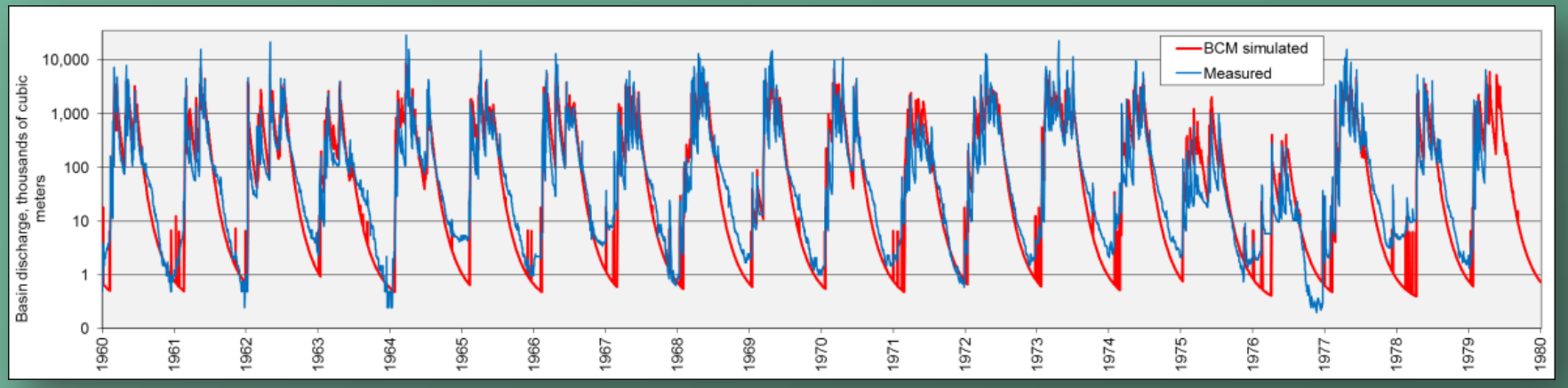
Model Development

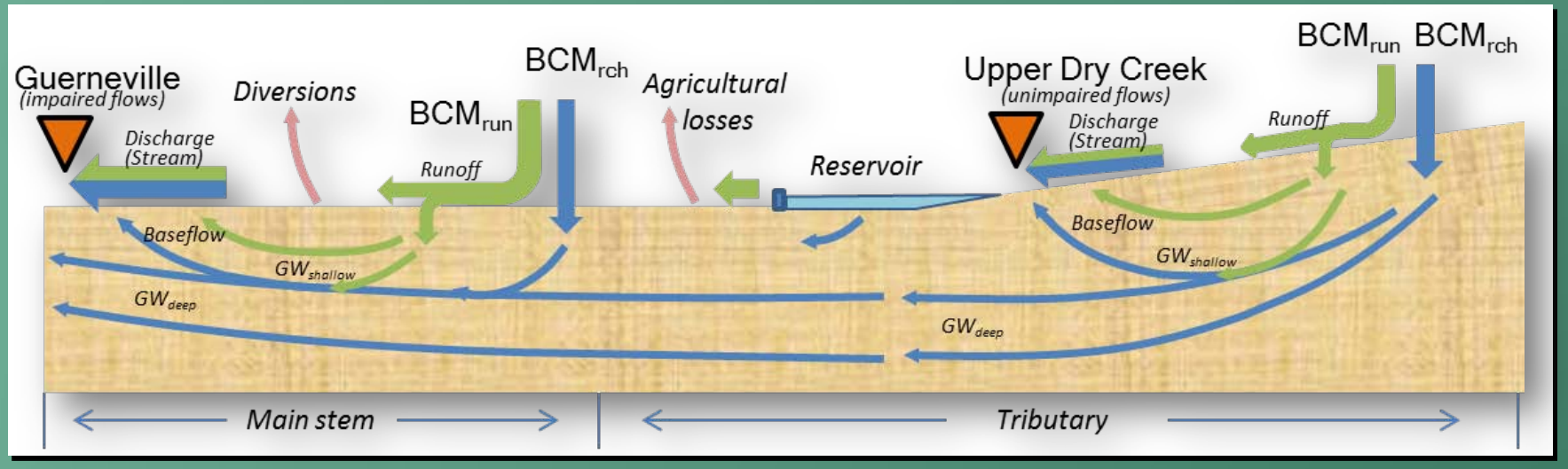
Soils

Soil thickness (meters)

- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 6

Calibration Using Discharge Measurements





Runoff

Recharge

Runoff
r recharge
.971-2000

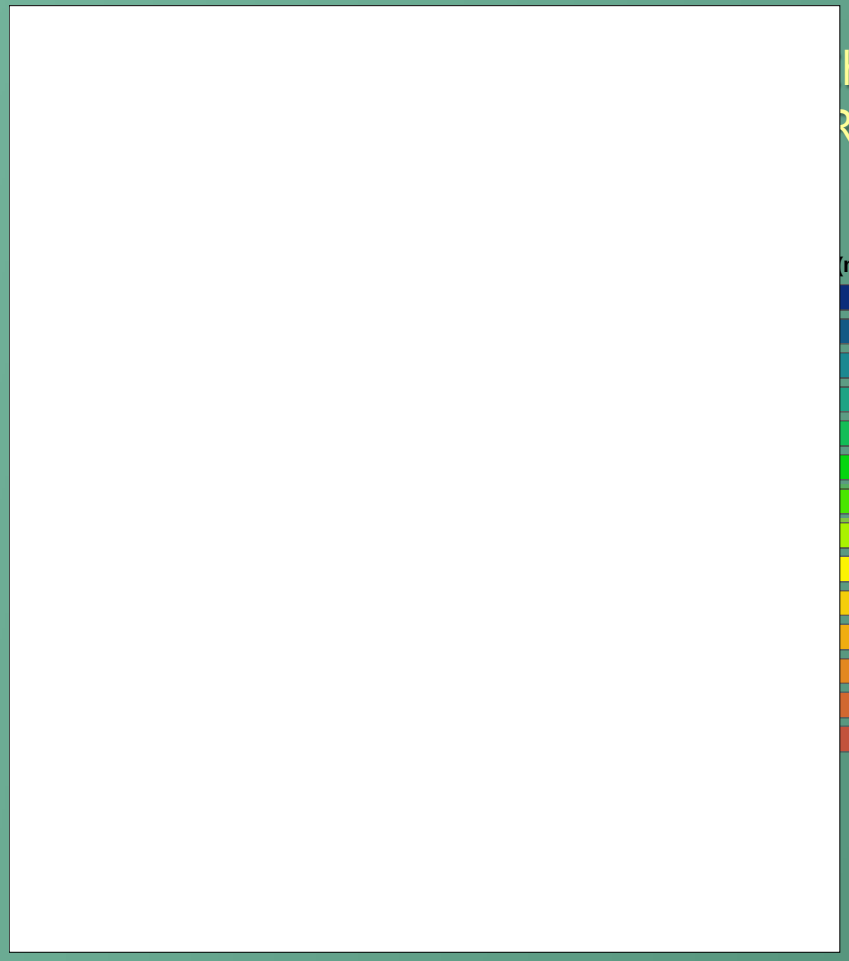
(mm/yr)

- 0 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- 400 - 500
- 500 - 750
- 750 - 1,000
- 1,000 - 1,800

Change from (1981-2010) to (2071-2100)

PCM-A2

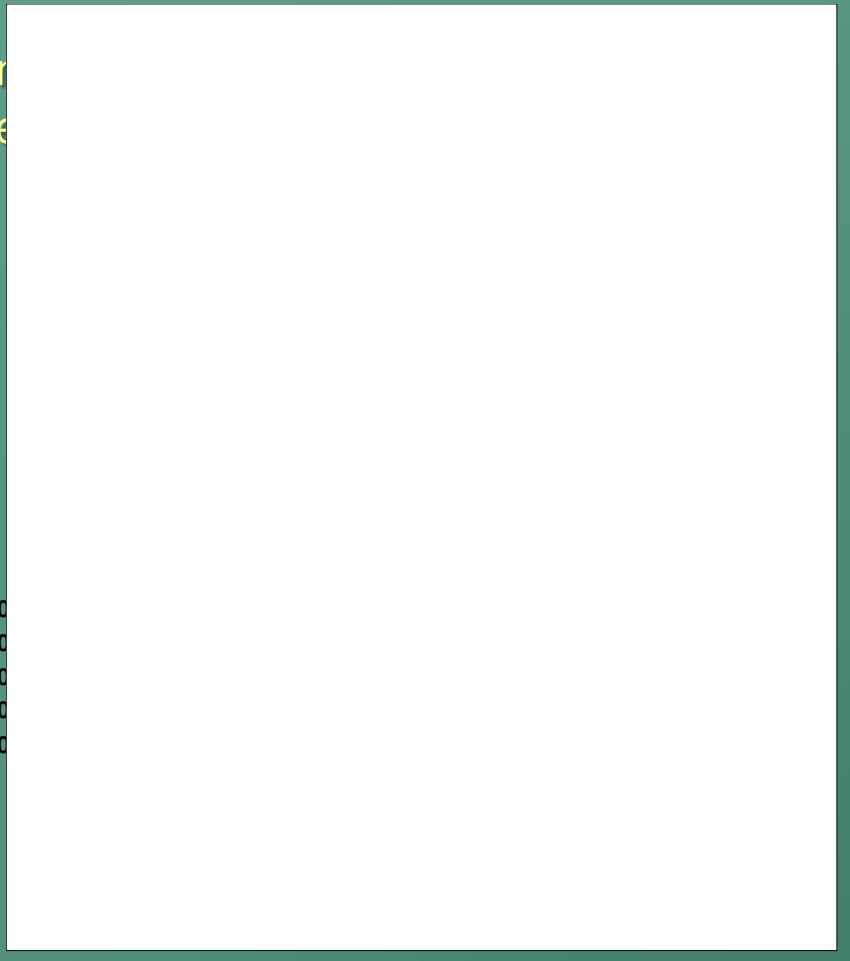
GFDL-A2



hange in
Recharge

(mm/year)

- 400 - 300
- 300 - 250
- 250 - 200
- 200 - 150
- 150 - 100
- 100 - 50
- 50 - 0
- 0 - -50
- -50 - -100
- -100 - -150
- -150 - -200
- -200 - -250
- -250 - -300
- -300 - -350



Change from (1981-2010) to (2071-2100)

PCM-A2

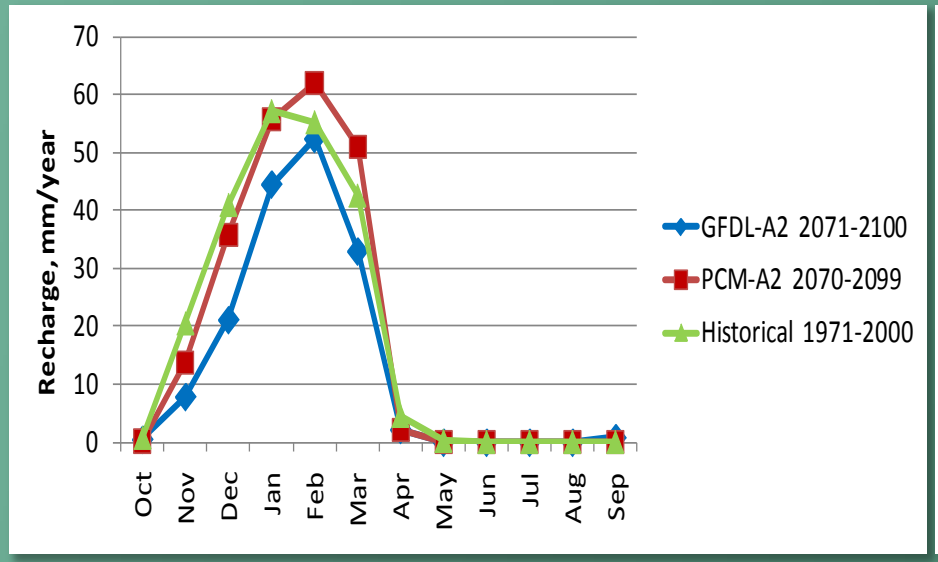
GFDL-A2

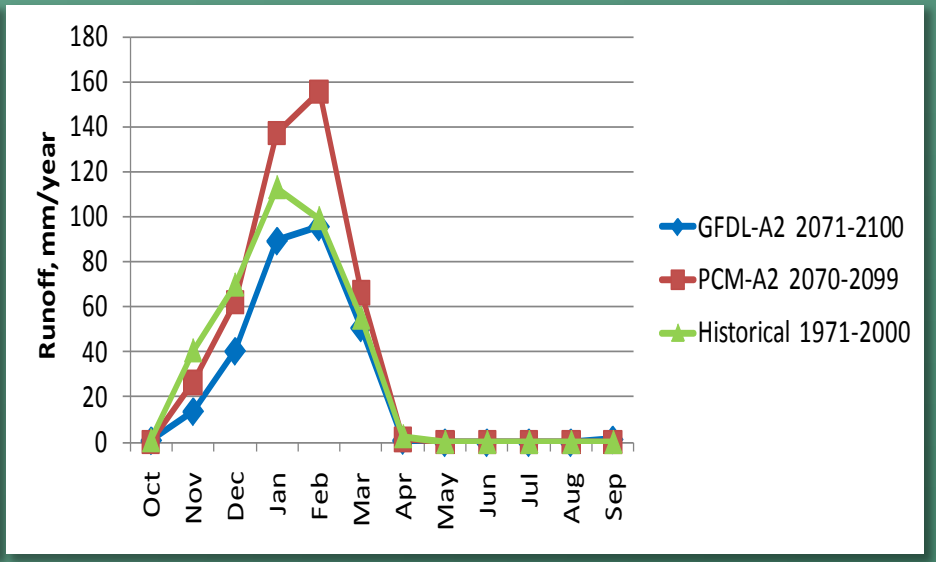
Change in Runoff

mm/year)

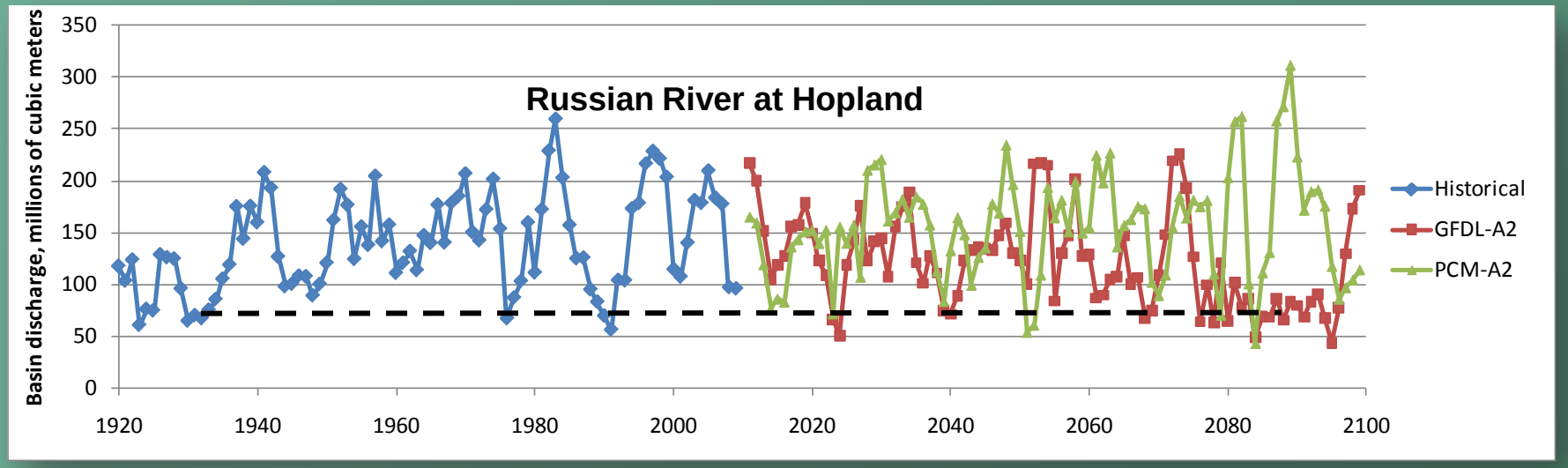
- 400 - 300
- 300 - 250
- 250 - 200
- 200 - 150
- 150 - 100
- 100 - 50
- 50 - 0
- 0 - -50
- -50 - -100
- -100 - -150
- -150 - -200
- -200 - -250
- -250 - -300
- -300 - -350

Seasonal Shifts in Recharge and Runoff





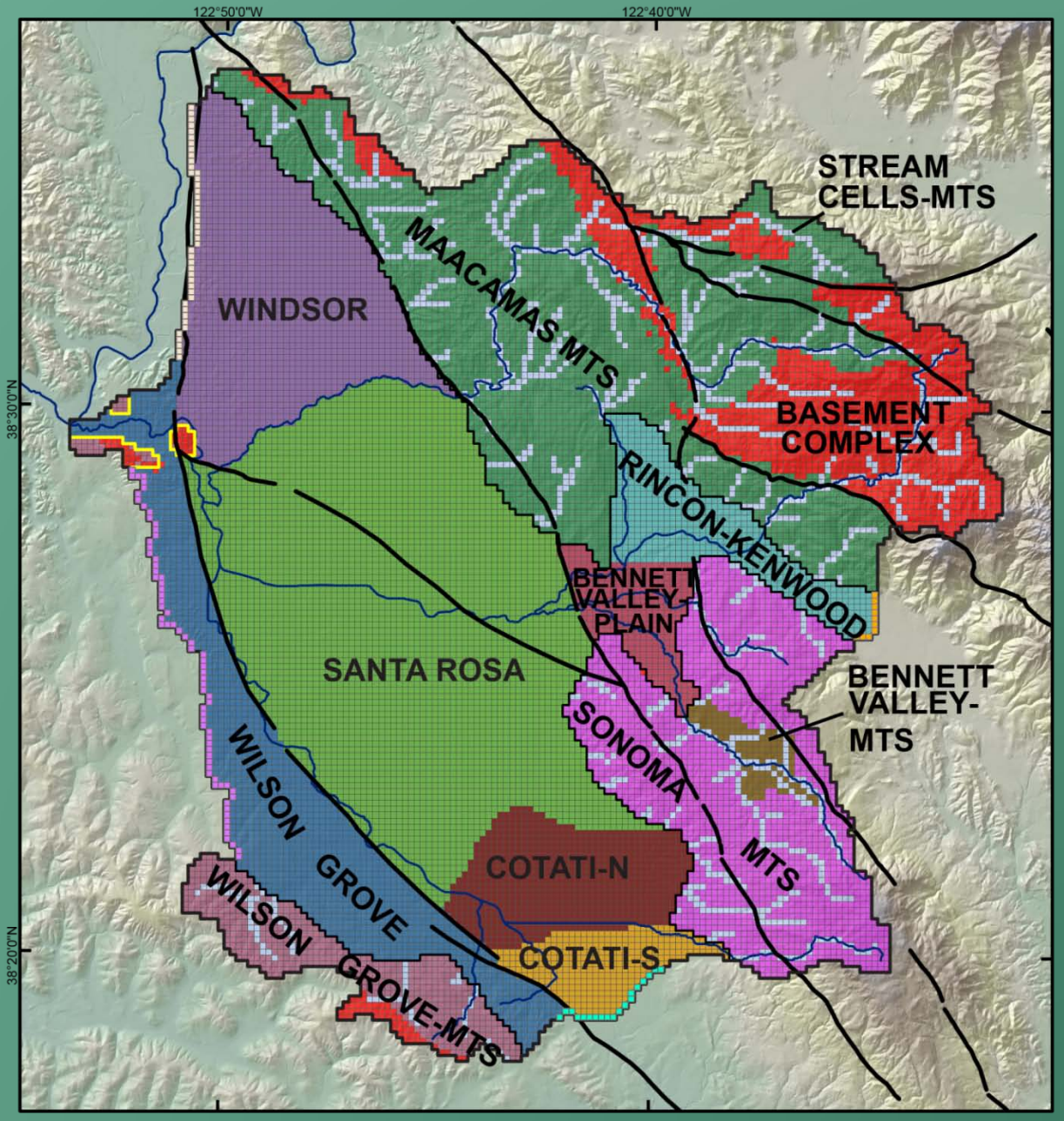
Consideration of Future Drought Conditions



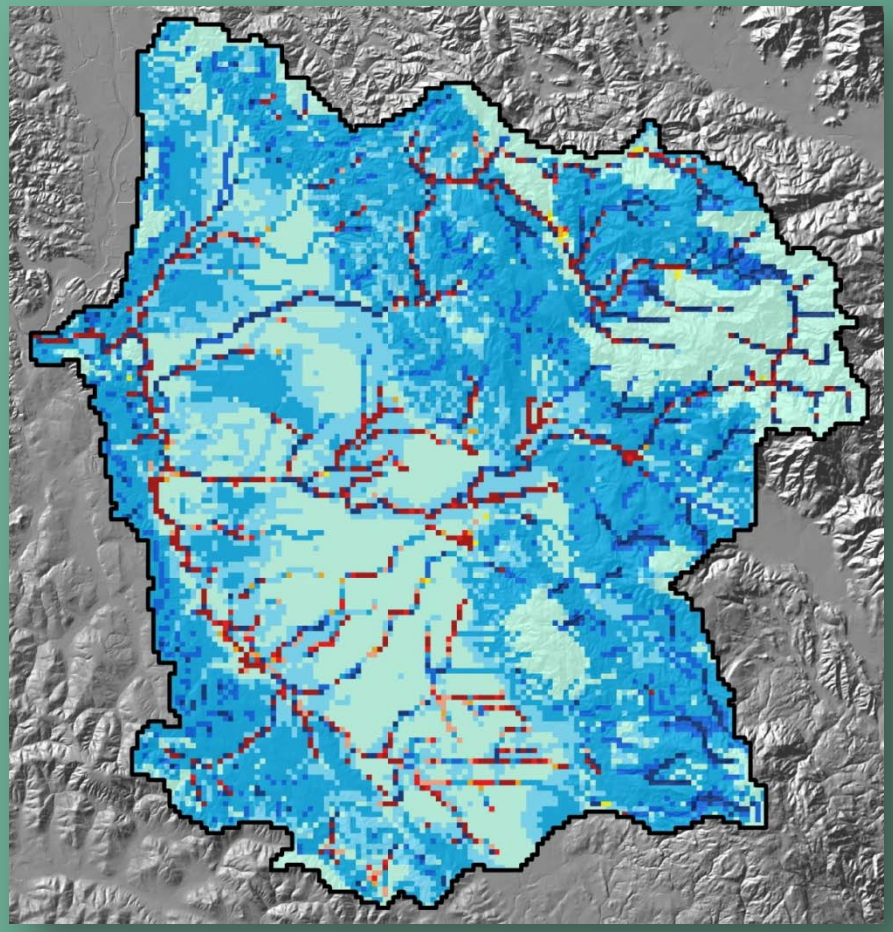
GSFLOW: surface water/groundwater model of Santa Rosa Plain

GENERAL-HEAD BOUNDARIES

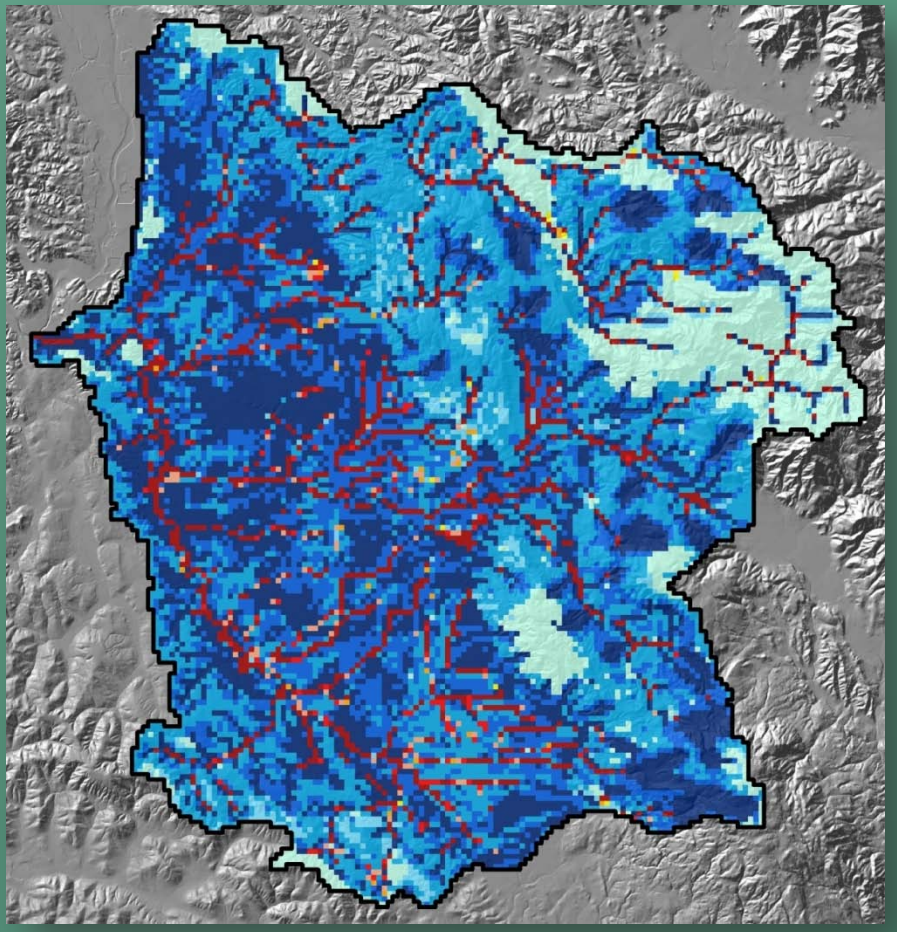
- COTATI
- WILSON GROVE
- RUSSIAN RIVER
- KENWOOD



Dry year (1977)



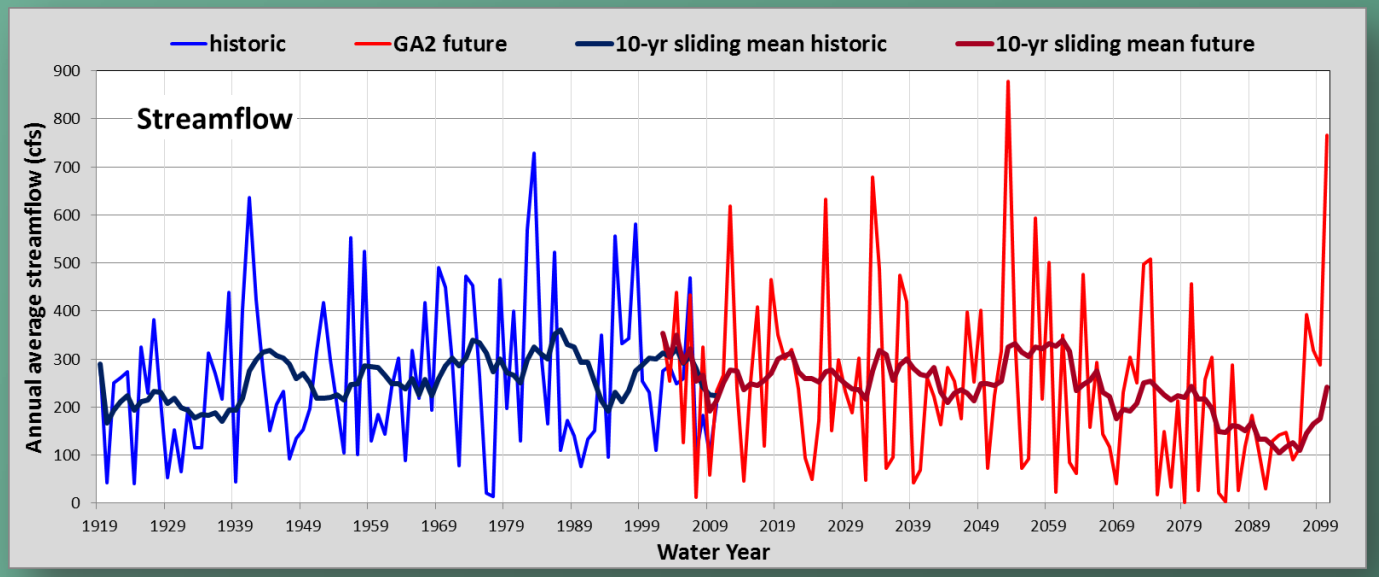
Wet year (1983)

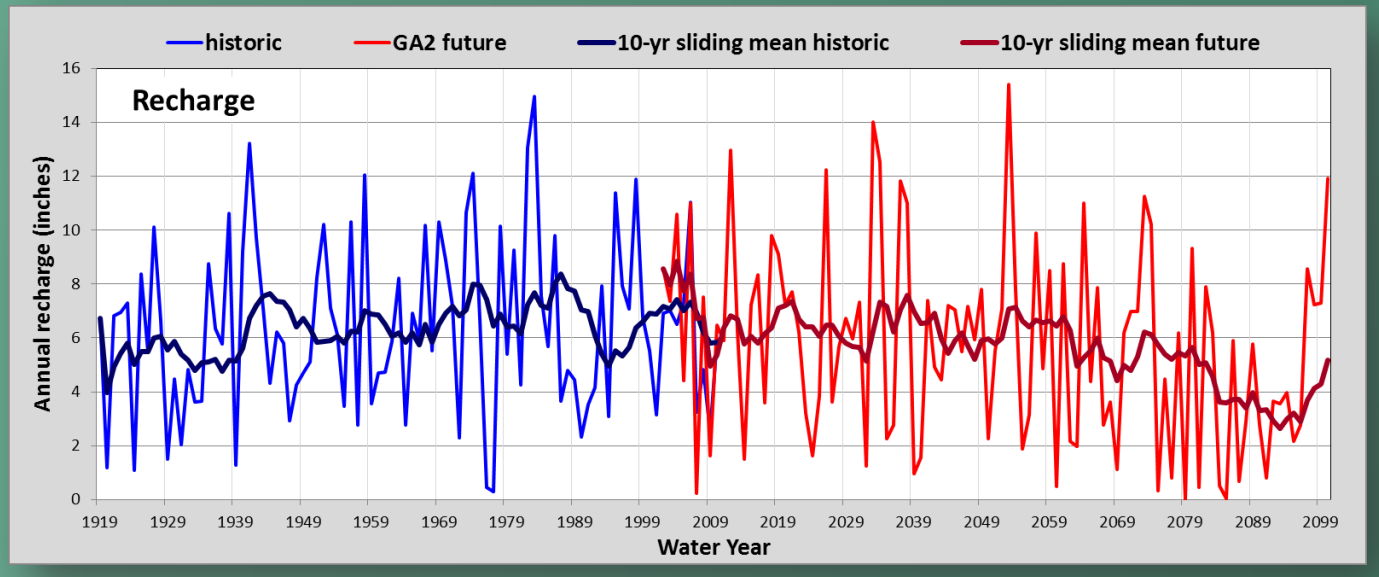


Net recharge (inches per year)

< -10	-5 - -1	-0.01 - 0	0.1 - 1	5 - 10
-9 - -5	-1 - -0.1	0 - 0.1	1 - 5	> 10

PRMS Rainfall-Runoff daily model: GFDL A2 scenario



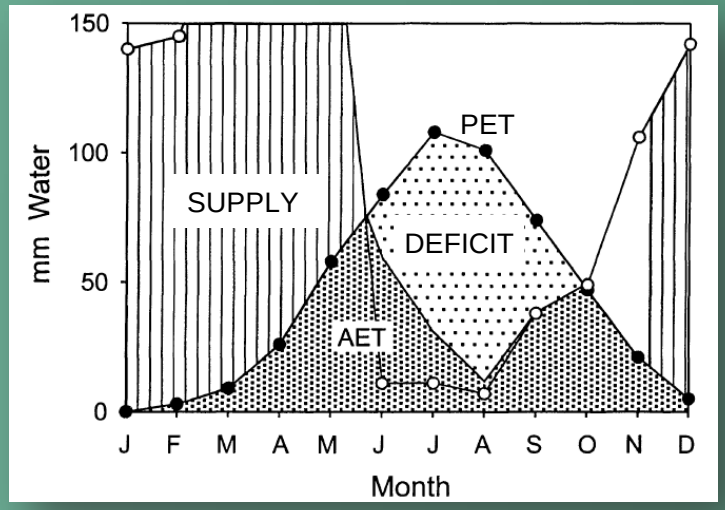


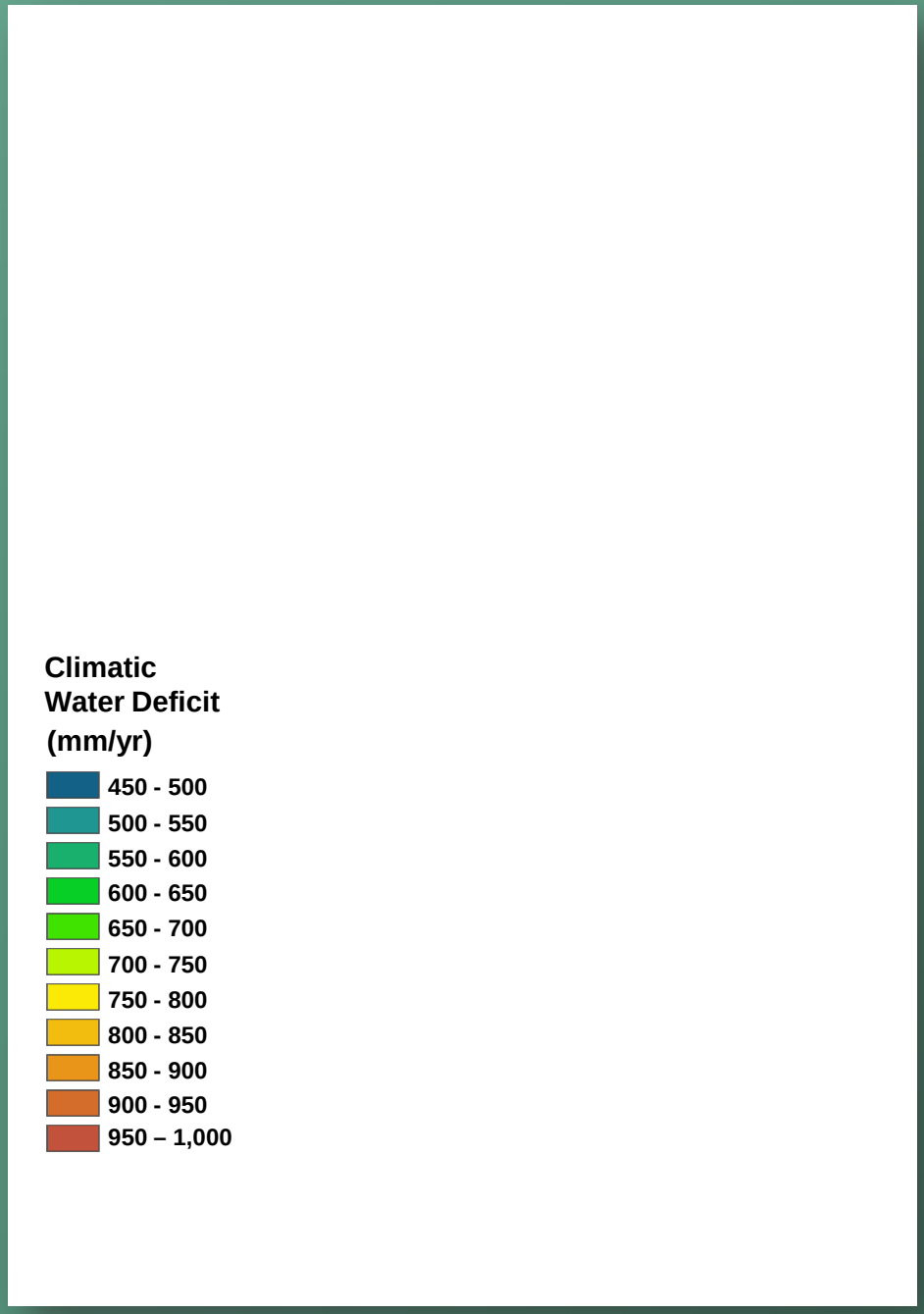
Climatic Water Deficit

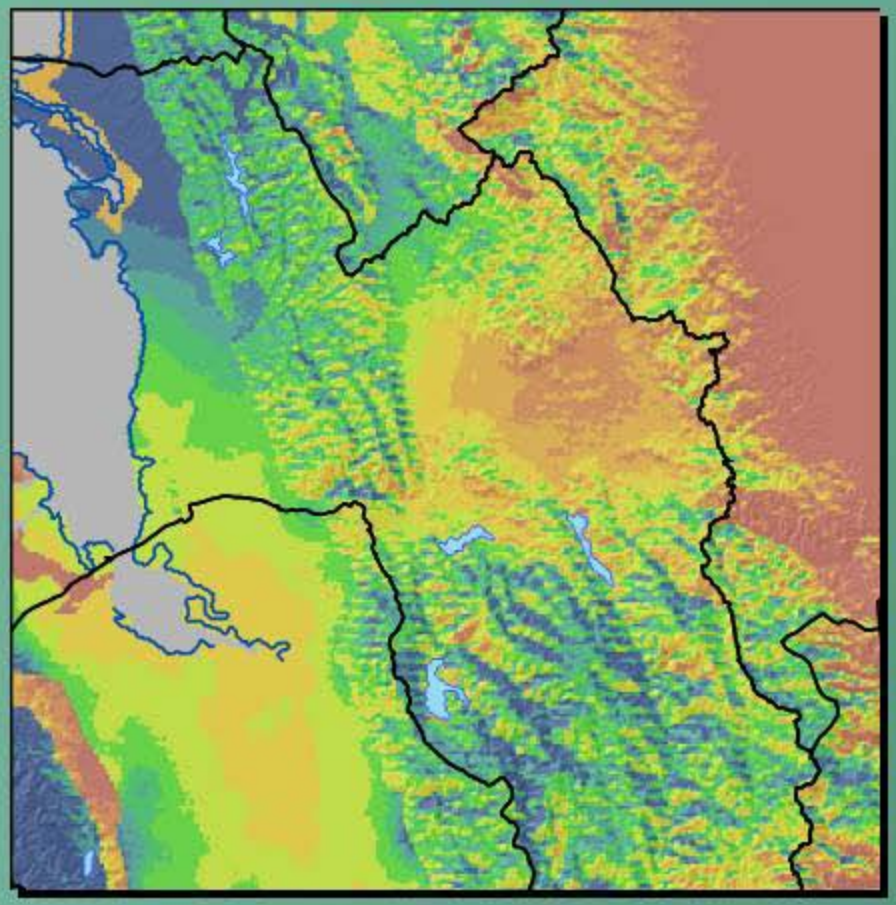
Annual evaporative demand that exceeds available water

Potential – Actual Evapotranspiration

- Integrates climate, energy loading, drainage, and available soil moisture storage
- Vegetation independent (indicator)
- Address irrigation demand
- Generally increases with all future climate scenarios



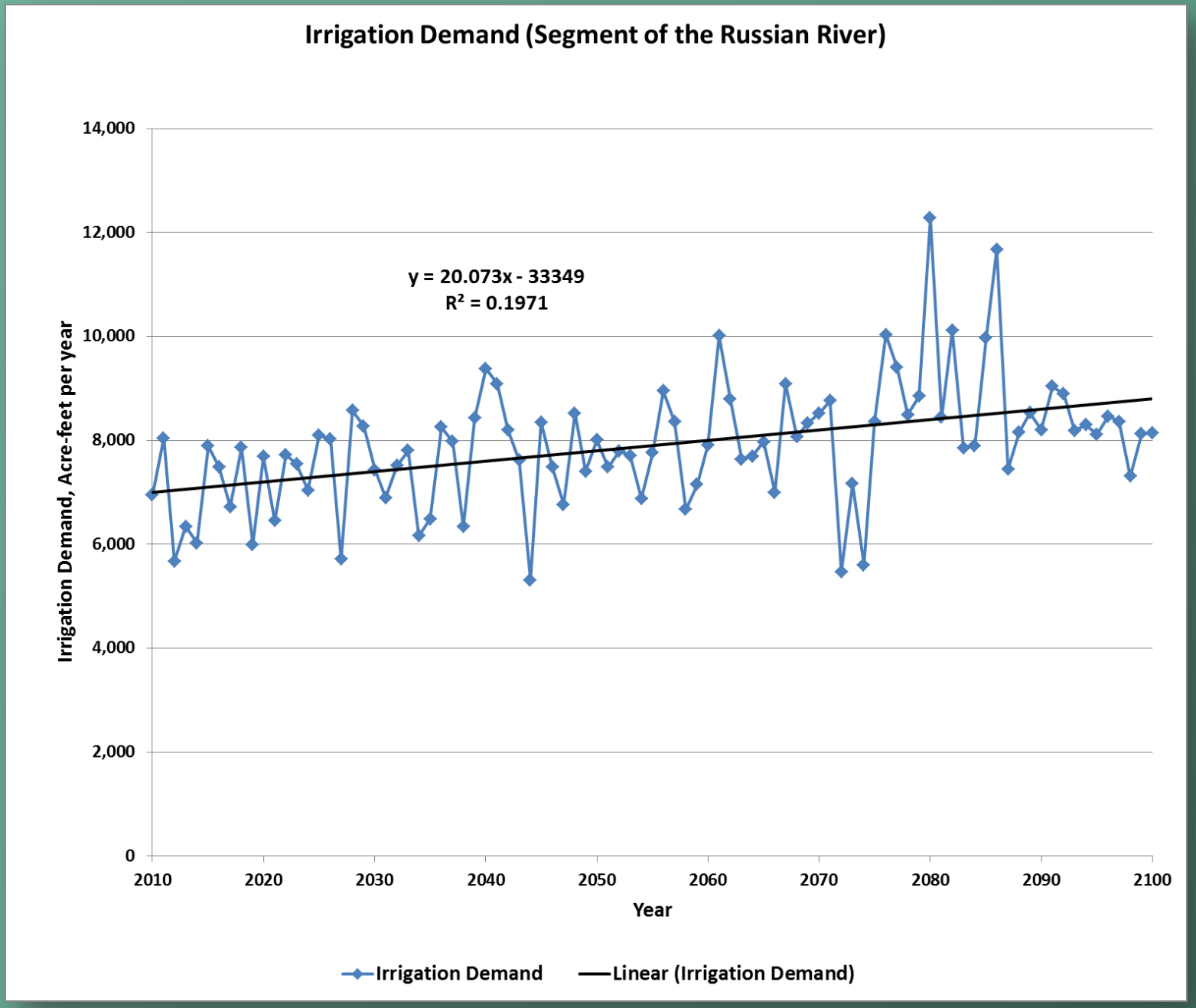




Climatic Water Deficit in South Bay

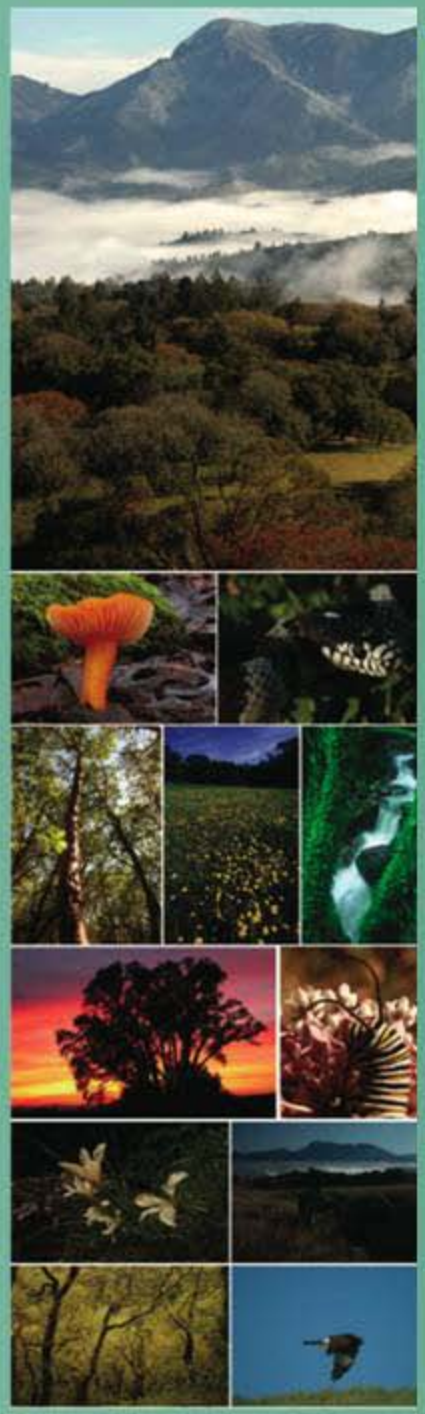
Google Earth Image of South Bay

water deficit correlates to vegetation cover


Irrigation Demand (Segment of the Russian River)
y = 20.073x - 33349
R² = 0.1971
Irrigation Demand, Acre-feet per year
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
Irrigation Demand
Linear (Irrigation Demand)

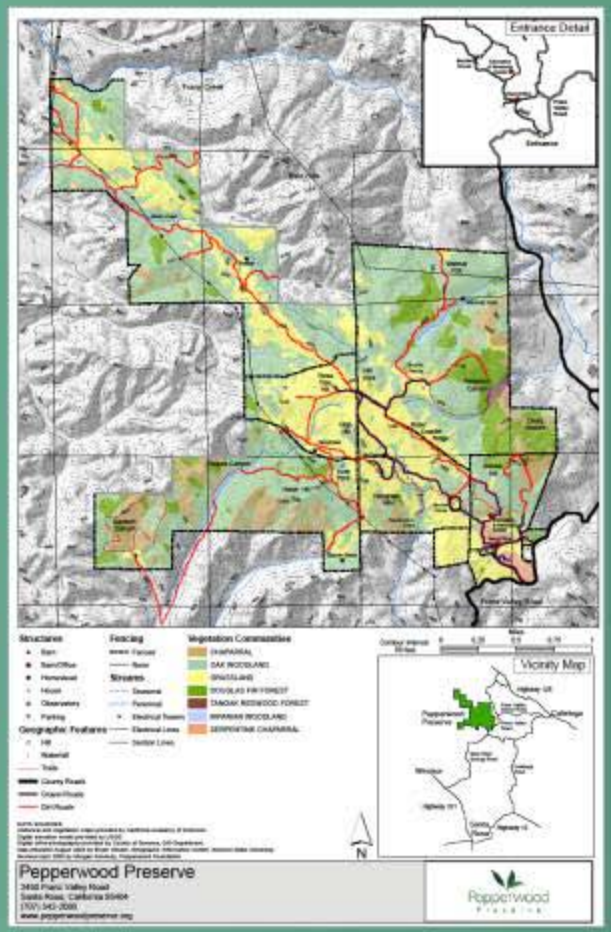
Take home message

- Climate is changing
  - It's about warming and variability
- Spatial scale matters
  - Modeling approaches can address processes at multiple scales for resource managers
- Sonoma County impacts
  - Increase in extreme events
  - Increased demand for irrigation
  - Shorter wet season, longer dry season
- Recharge resilience depends on
  - Ability to store groundwater during wet periods
  - Enhancement of recharge
  - Awareness of areas that produce recharge and store recharge



MISSION

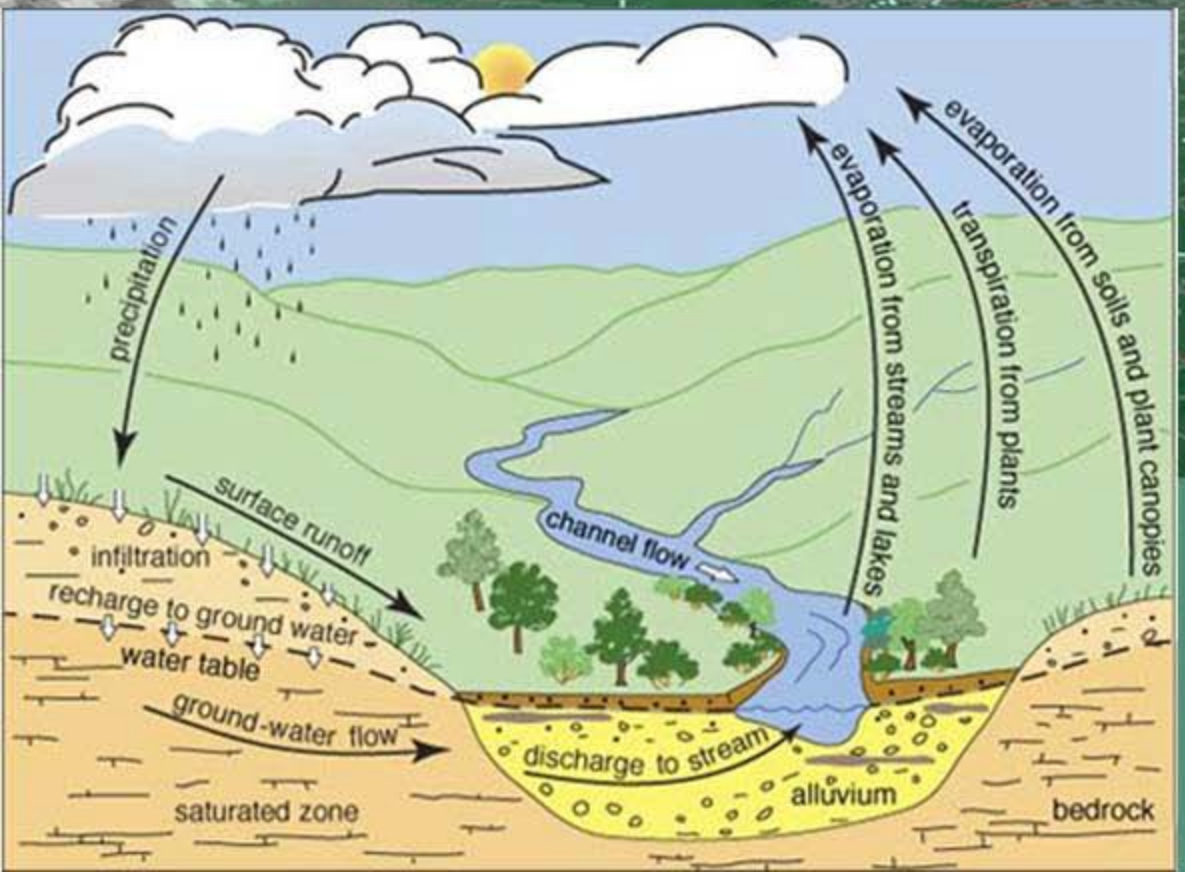
to advance science-based conservation throughout our region and beyond



Pepperwood
PRESERVE
Inspiring conservation through science

Basin Characterization Model

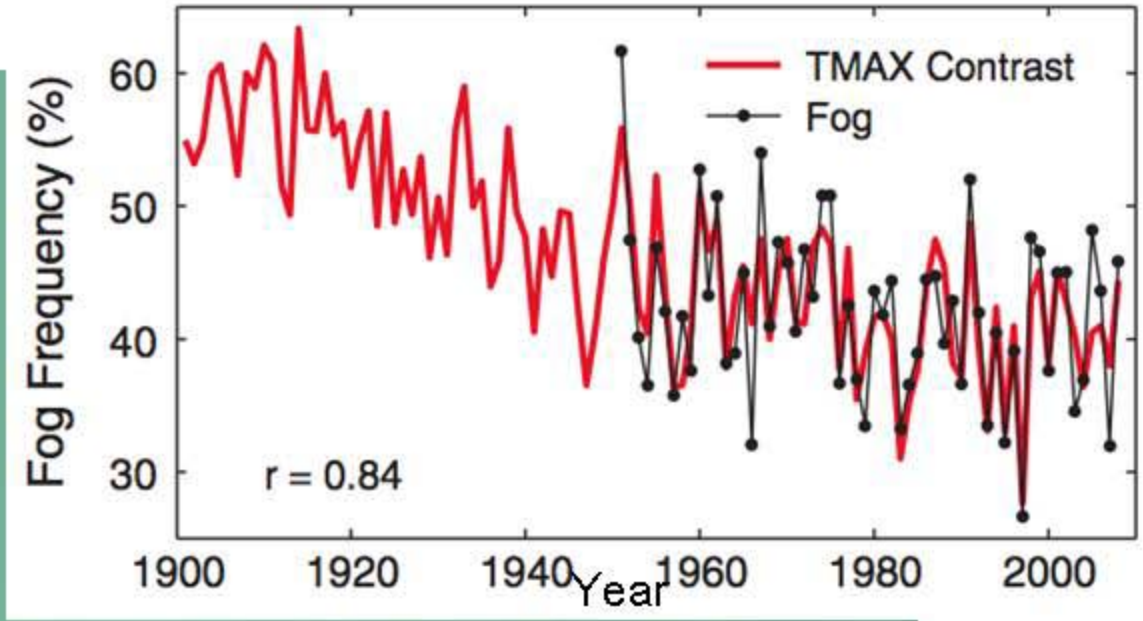
To get at important issue of available water for people and ecosystems!



Solves the physical water and energy balance based on topography, soils, rainfall, and temp for every 270m pixel in domain—to estimate flows, recharge and soil moisture

The Million$ Mystery Variable for the Bay Area: Fog frequency

Measured 2000-2010
Modis satellite imagery



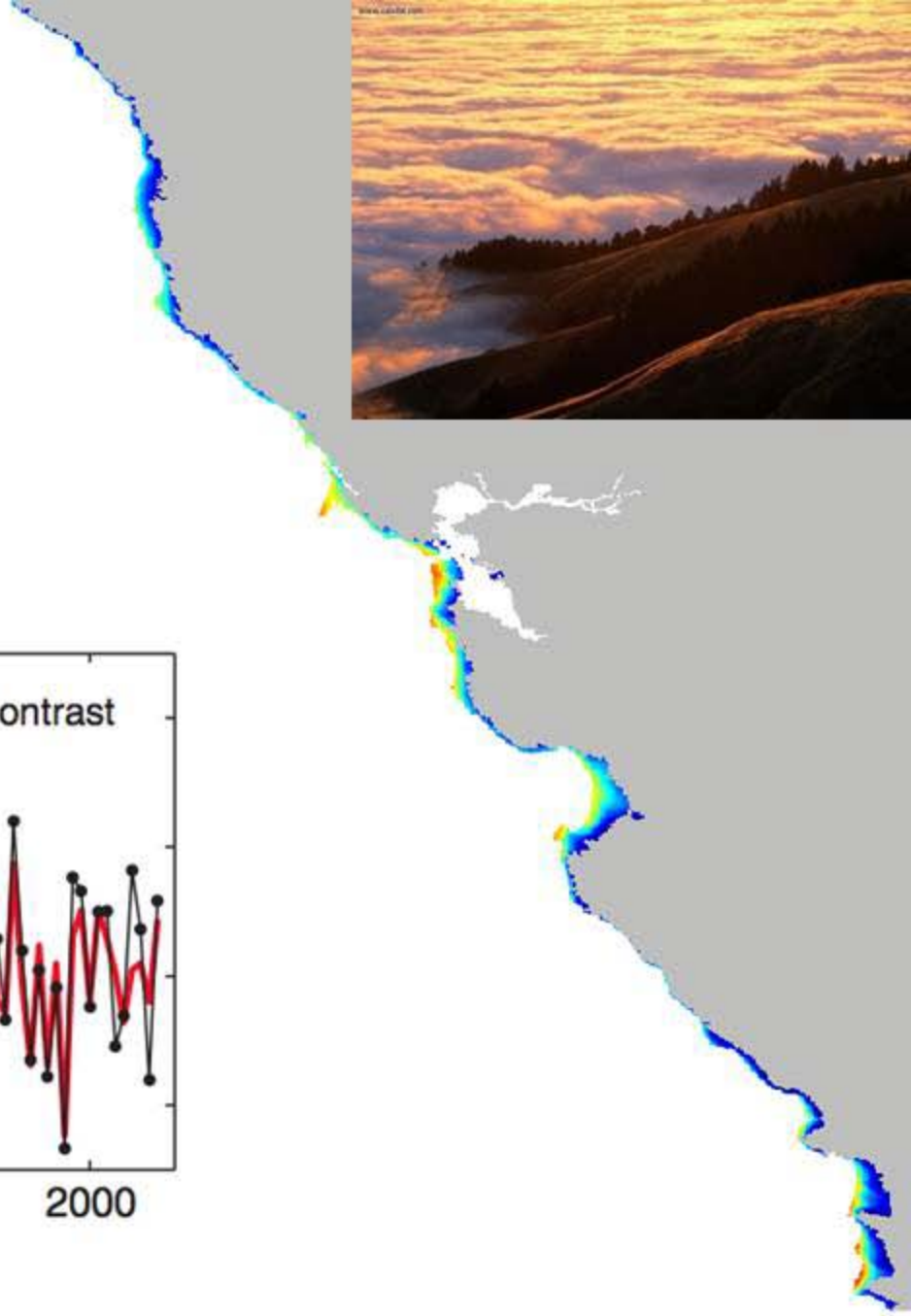


figure: Johnstone and Dawson 2010 PNAS

map: Loarie and Johnstone unpubl.

The North Bay Climate Adaptation Initiative (NBCAI)

a coalition of natural resource managers, policy makers and scientists committed to working together to create positive solutions to the challenge of climate adaptation

Coordinating Committee

David Bannister
Sierra Cantor
BC Capps
Caitlin Cornwall
Richard Dale
Deanne DiPietro
Robert Judd
Lisa Micheli
Genevieve Taylor

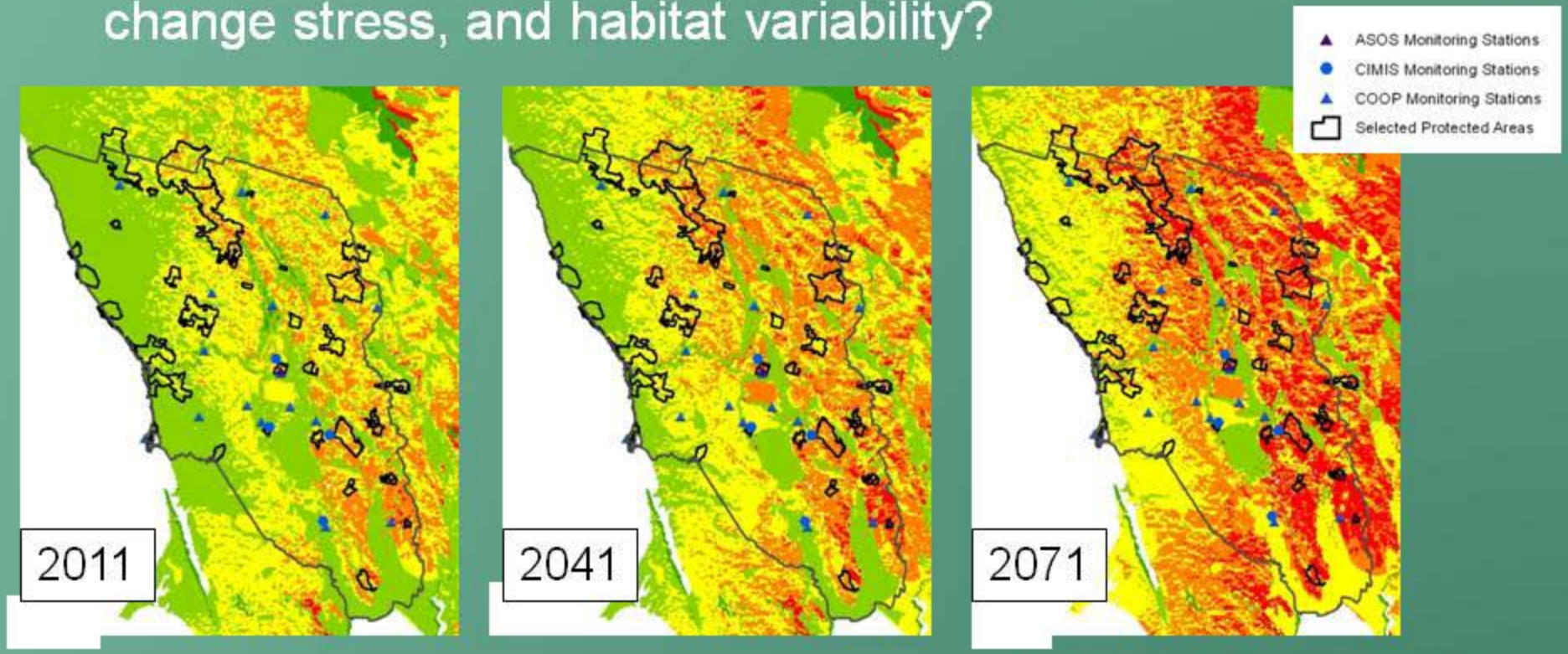
Pepperwood
PRESERVE
Inspiring conservation through science

NBCAI monitoring

- coupling climate-ecosystem measurements
- advancing real-time monitoring in So Co
- sharing data via CA-LCC Climate Commons
- creating a network of practitioners
- disseminating lessons learned

cost-effective means of measuring climate in concert with biotic "vital signs"

Question: Where should we locate monitoring stations for a representative range of iso-climates, climate change stress, and habitat variability?



Climatic Water Deficit change over time

Process:

- Examine the range of Sonoma County's current and future iso-climates and habitat variability
- Select representative preserves for potential monitoring network sites
- Assess were we need to add climate monitoring stations for integrated bio-physical monitoring

North Bay Climate Adaptation Initiative Objectives

- Decrease uncertainty to acceptable levels by estimating potential changes to climate, hydrology, and ecosystems based on the best science available at the watershed (local) scale.
- Provide managers in the North Bay with information, methods, and guidance needed to address challenges of climate change on natural systems.
- Support a Sonoma County effort for climate adaptation to implement preventative measures that reduce the impact of climate change on resources of concern
- Inform Sonoma County planning and policy processes to integrate climate adaptation strategies in local decision-making

Thank you!

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