Climate Ready North Bay

Serving natural resource agencies in Marin, Sonoma, Napa and Mendocino Counties

Regional Work Product Samples

January 2016

prepared by TBC3.org members

Lorrie Flint (USGS), Sam Veloz (Point Blue) and Lisa Micheli (Pepperwood's Dwight Center for Conservation Science)

Table of Contents

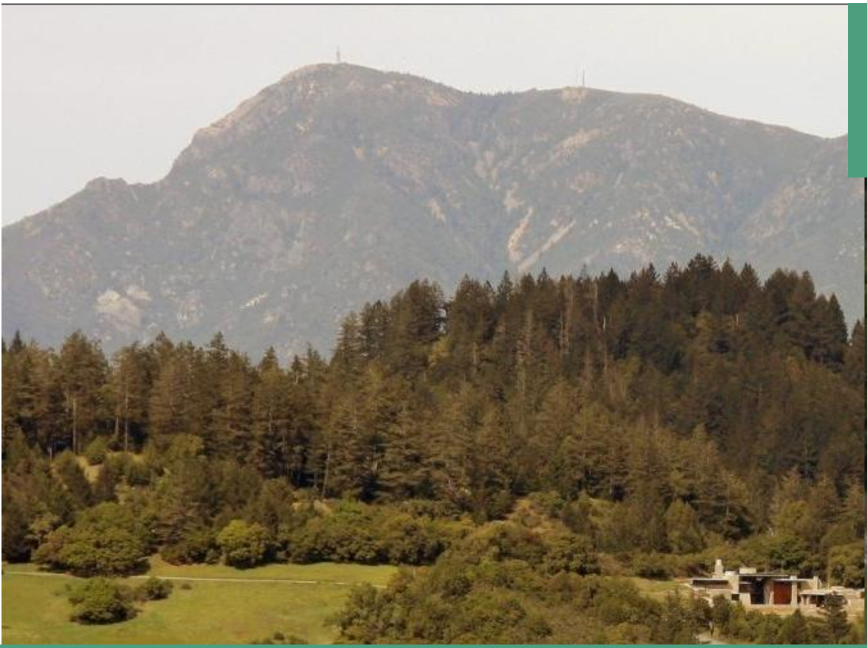
RCPA
regional climate protection authority

Point Blue Conservation Science

USGS
science for a changing world

Pepperwood PRESERVE
Inspiring conservation through science

Mission: advance conservation science across our region and beyond



The new Dwight Center for Conservation Science

3200-acre reserve in Mayacamas, partnered with CA Academy of Sciences

Pepperwood
PRESERVE
Inspiring conservation through science

TBC3

Terrestrial Biodiversity Climate Change Collaborative

Pepperwood Preserve
Inspiring conservation through science

Berkeley
University of California

An nationally-recognized climate science initiative

USGS
science for a changing world

CA.GOV

The California Energy Commission

Gordon and Betty Moore Foundation

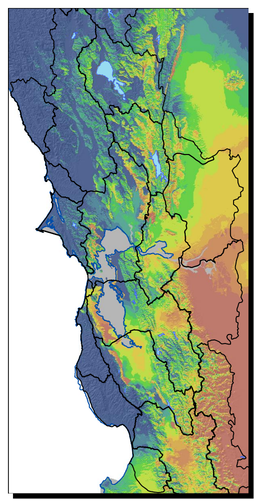
Bay Area | Open Space Council

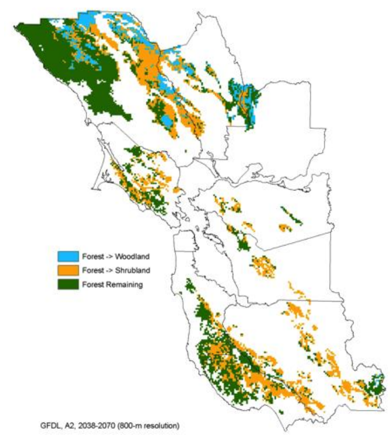
Creekside Center for Earth Observation

Point Blue Conservation Science

TBC3 has built a climate adaptation knowledge base for application to regional conservation

Climate + Topography → Watershed Hydrology + Topo-climate → Vegetation Cover + Fire Risks → Species Distributions

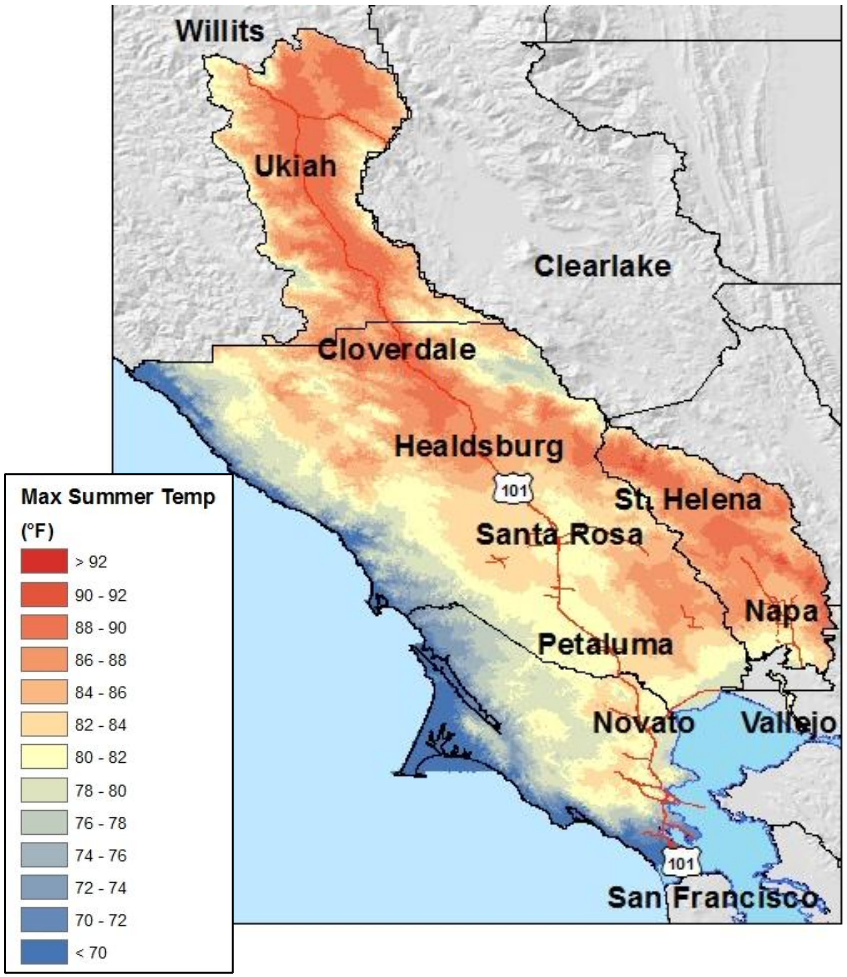




generating an ensemble of projections for use in scenario planning

Pepperwood PRESERVE

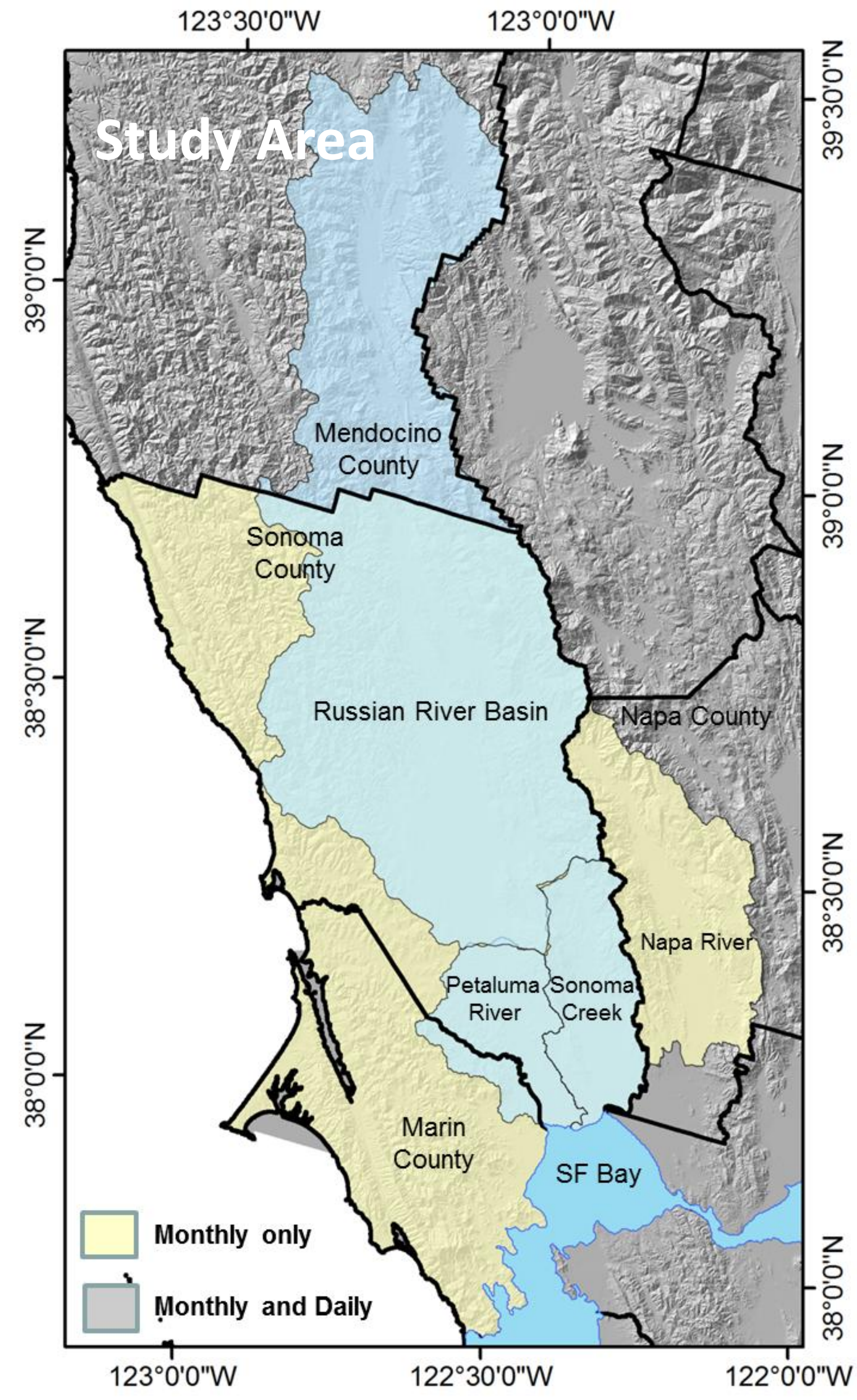
Climate Ready North Bay: translating a landscape-level climate-hydrology database into inputs for long-term planning



Source: Climate Ready North Bay 2015

- Warmer temperatures
- Greater hydrologic variability
- Greater evapotranspiration
- Increased water demand
- Variable runoff and recharge
- Shifts in natural vegetation types
- Increased wildfire risk
- (Not sea level rise!)

Pepperwood
PRESERVE
Inspiring conservation through science



project overview

North Bay Climate Ready

Serving natural resource agencies in Marin, Sonoma, Napa and Mendocino Counties

Funding: a *Climate Ready* Coastal Conservancy grant to Sonoma's Regional Climate Protection Authority plus match funds from partners

Pepperwood lead on vulnerability assessment with TBC3 members from USGS, and Point Blue Conservation Science

Pepperwood PRESERVE
Inspiring conservation through science

North Bay Climate Ready
User Groups and Partners

User Group 1: Sonoma County Water Agency with Mendocino County Water Conservation and Flood District

Domain: Sonoma County plus Russian River Basin of Mendocino County

User Group 2: Sonoma County Agricultural Protection and Open Space District and Sonoma County Regional Parks

Domain: Sonoma County

User Group 3: Napa County, Departments of Planning and Public Works plus the Watershed Protection District

Domain: Napa Valley

User Group 4: Marin Municipal Water District (MMWD)

Domain: Marin County

User Group 5: Regional Climate Protection Authority (RCPA) Municipal Users Group: all nine cities of Sonoma County-public works and planning officers

Domain: Sonoma County and sub-watersheds

Climate Ready Process

Part 1

Engage managers at the outset: define key management questions for each jurisdiction, and then refine questions through process.

First meeting: based on their concerns, managers selected one set of climate “futures” based on concerns-focus on “worst case” with one “middle of road” and one “mitigated” for entire North Bay region.

Climate Ready Process

Part 2

Managers survey: how does climate variability, including current drought, impact your operations today? What are your concerns for the future?

Agency-specific meetings to introduce our Basin Characterization Model, data menu and sample products, refine data queries based on management questions.

Climate Ready Process

Part 3

Products Generated for Each User Group

Technical Memorandum: describes project overview, stakeholder engagement process, summarizes technical analyses, provides some visualization samples but refers to PowerPoint deck for relevant illustrations, includes appendices on data product details and supporting data filenames.

PowerPoint Deck: provides presentation materials on project overview, methods, data tables and visualizations.

Data Products: ESRI Basin Characterization Model geodatabase, excel data files for extracted time series data.

Scenario Selection

Pepperwood
PRESERVE
Inspiring conservation through science

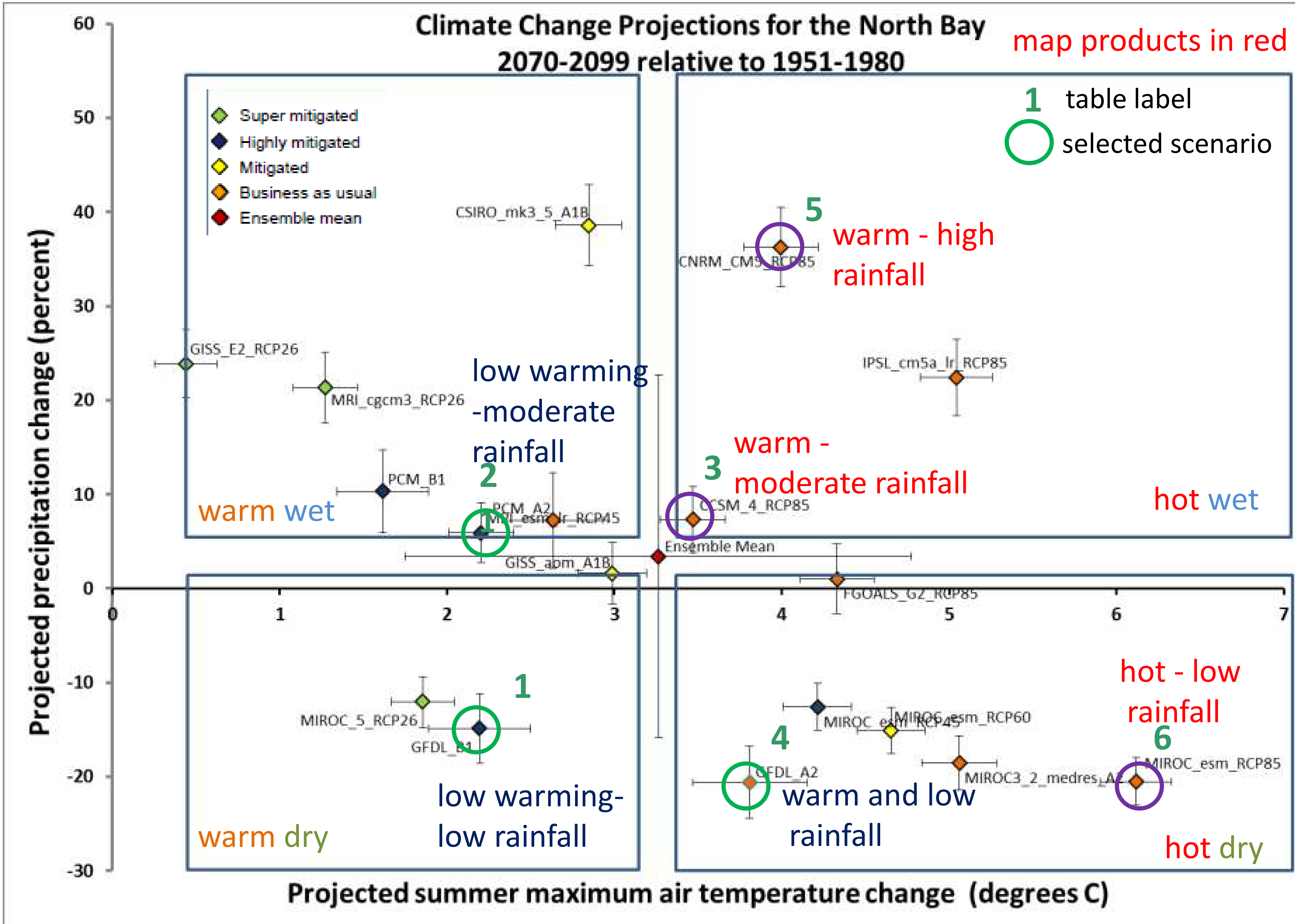
Selected Futures for North Bay Regional Vulnerability Assessment (in yellow)

Graph Label	Model	Emissions Scenario	Assessment Report Vintage	Time Period	Summer Tmax °C	Summer Tmax Increase	Winter Tmin °C	Winter Tmin Increase °C	Annual Precipitation (mm)	% Change Precipitation	% Change Water Deficit
	historic (hst)	N/A	N/A	1951-1980	27.9		3.9		1087		
	current	N/A	N/A	1981-2010	27.9		4.3	0.4	1095	1%	1%
	Assumption: Business as Usual										
6	miroc-esm	rcp85	AR5	2070-2099	34.0	6.1	8.4	4.6	865	-20%	24%
	miroc3_2_mr	A2	AR4	2070-2099	33.0	5.1	7.1	3.2	887	-18%	20%
	ipsl-cm5a-lr	rcp85	AR5	2070-2099	33.0	5.0	9.6	5.7	1325	22%	16%
	fgoals-g2	rcp85	AR5	2070-2099	32.3	4.3	7.1	3.2	1099	1%	22%
5	cnrm-cm5	rcp85	AR5	2070-2099	31.9	4.0	7.7	3.9	1477	36%	12%
4	GFDL	A2	AR4	2070-2099	31.7	3.8	7.7	3.9	861	-21%	21%
3	ccsm4	rcp85	AR5	2070-2099	31.4	3.5	7.1	3.2	1163	7%	12%
2	PCM	A2	AR4	2070-2099	30.6	2.6	6.3	2.4	1159	7%	11%
				Business as Usual Average	**32.2**	**4.3**	**7.6**	**3.7**	**1104**	**2%**	**17%**
	Assumption: Mitigated										
	miroc-esm	rcp60	AR5	2070-2099	32.6	4.7	7.1	3.2	922	-15%	14%
	giss_aom	A1B	AR4	2070-2099	30.9	3.0	6.4	2.5	1104	2%	11%
	csiro_mk3_5	A1B	AR4	2070-2099	30.8	2.8	6.5	2.6	1506	38%	4%
				Mitigated Average	**31.4**	**3.5**	**6.6**	**2.8**	**1177**	**8%**	**10%**
	Assumption: Highly Mitigated										
	mpi-esm-lr	rcp45	AR5	2070-2099	30.1	2.2	5.8	1.9	1148	6%	5%
	miroc-esm	rcp45	AR5	2070-2099	30.1	2.2	6.9	3.0	949	-13%	14%
1	GFDL	B1	AR4	2070-2099	30.1	2.2	6.1	2.2	923	-15%	10%
	PCM	B1	AR4	2070-2099	29.5	1.6	5.5	1.7	1197	10%	5%
				Highly Mitigated Average	**30.0**	**2.1**	**6.1**	**2.2**	**1055**	**-3%**	**8%**
	Assumption: Super Mitigated										
	miroc5	rcp26	AR5	2070-2099	29.8	1.9	5.2	1.3	953	-12%	9%
	mri-cgcm3	rcp26	AR5	2070-2099	29.2	1.3	4.8	0.9	1315	21%	2%
	giss-e2-r	rcp26	AR5	2070-2099	28.4	0.4	4.6	0.7	1344	24%	-4%
				Super Mitigated Average	**29.1**	**1.2**	**4.8**	**1.0**	**1204**	**11%**	**2%**
				ALL Scenarios Average	**31.1**	**3.2**	**6.7**	**2.8**	**1122**	**3%**	**11%**

TBC3 downscaled 18 global climate models selected to represent the full range of IPCC projections. 6 were selected by a consensus of all the managers engaged in Climate Ready. Model numbers correlate to the previous chart.

scenario selection

North Bay Climate Ready: Selected Futures for Regional Vulnerability Assessment



Climate Ready North Bay

6 Selected Futures for North Bay Region
Mid-Century Values

	Model	Emissions Scenario	IPCC Assessment	Short-hand name	Time Period	Summer Tmax °F	Summer Tmax Increase °F	Winter Tmin °F	Winter Tmin Increase °F	Annual Precipitation (in)	% Change Precipitation	% Change Water Deficit
Observed	historical baseline	N/A	N/A		1951-1980	82.2		39.0		42.8		
	current	N/A	N/A		1981-2010	82.2		39.7	0.7	43.1	1%	1%
Projections												
1	GFDL	B1	AR4	low warming-low rainfall	2040-2069	85.2	2.9	42.7	3.7	42.6	-1%	6%
2	PCM	A2	AR4	low warming-mod rainfal	2040-2069	85.0	2.7	41.1	2.1	43.8	2%	7%
3	CCSM-4	rcp85	AR5	warm-mod rainfall	2040-2069	86.0	3.7	42.0	3.0	42.2	-1%	8%
4	GFDL	A2	AR4	warm-low rainfall	2040-2069	86.3	4.0	43.2	4.2	39.8	-7%	12%
5	CNRM-CM5	rcp85	AR5	warm-high rainfall	2040-2069	86.5	4.2	43.0	4.0	53.8	26%	6%
6	MIROC-ESM	rcp85	AR5	hot-low rainfall	2040-2069	89.2	6.9	41.4	2.4	35.0	-18%	14%
Average						**86.3**	**4.1**	**42.2**	**3.2**	**42.9**	**0%**	**9%**

Climate Ready North Bay

6 Selected Futures for North Bay Region

End of Century Values

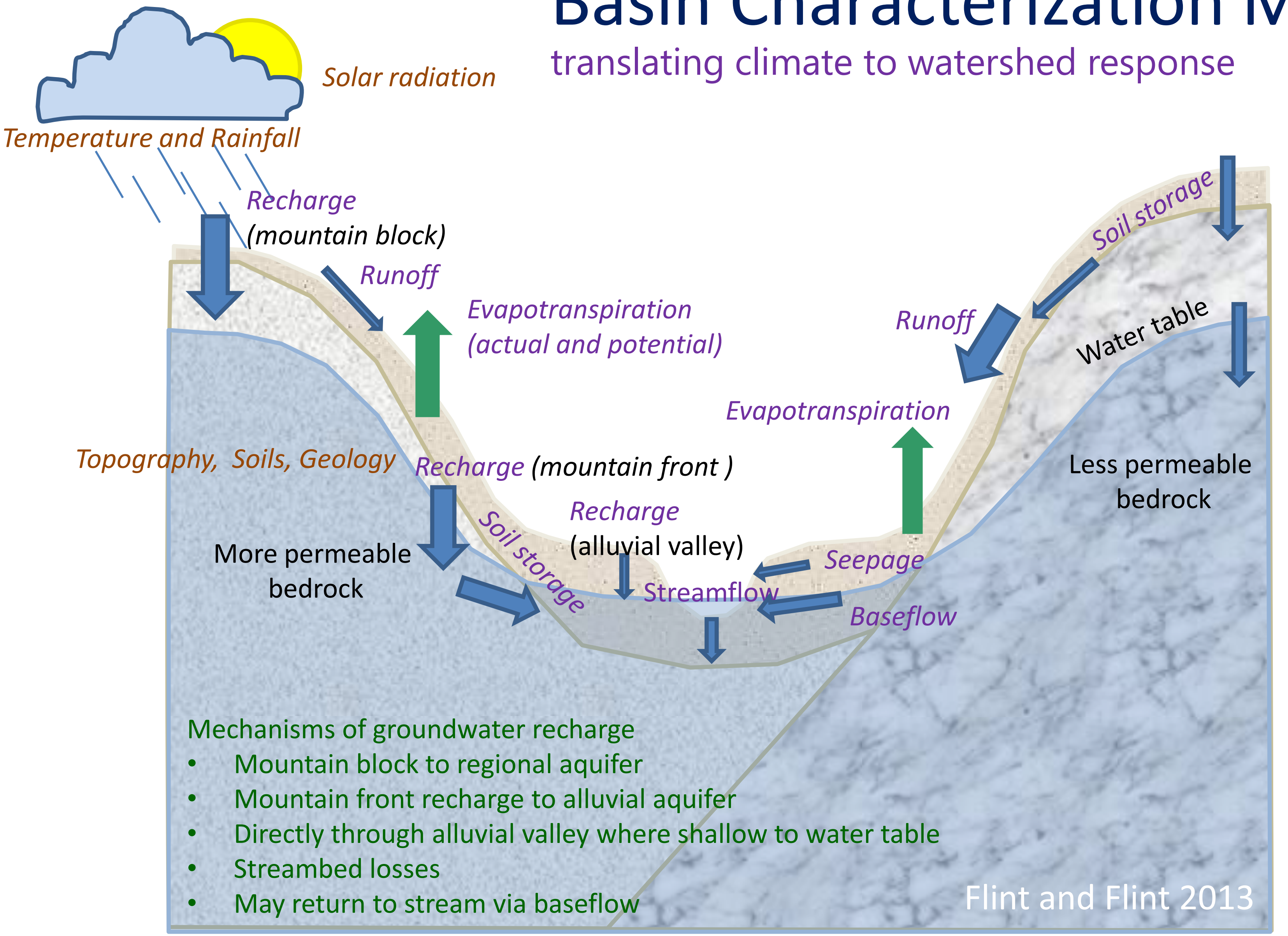
	Model	Emissions Scenario	IPCC Assessment	Short-hand name	Time Period	Summer Tmax °F	Summer Tmax Increase °F	Winter Tmin °F	Winter Tmin Increase °F	Annual Precipitation (in)	% Change Precipitation	% Change Water Deficit
Observed	historical baseline	N/A	N/A		1951-1980	82.2		3.9		42.8		
	current	N/A	N/A		1981-2010	82.2		4.3	0.4	43.1	1%	1%
Projections												
1	GFDL	B1	AR4	low warming-low rainfall	2070-2099	86.2	4.0	6.1	2.2	36.3	-15%	10%
2	PCM	A2	AR4	low warming-mod rainfal	2070-2099	87.0	4.7	6.3	2.4	45.6	7%	11%
3	CCSM-4	rcp85	AR5	warm-mod rainfall	2070-2099	88.5	6.2	7.1	3.2	45.8	7%	12%
4	GFDL	A2	AR4	warm-low rainfall	2070-2099	89.1	6.9	7.7	3.9	33.9	-21%	21%
5	CNRM-CM5	rcp85	AR5	warm-high rainfall	2070-2099	89.5	7.2	7.7	3.9	58.1	36%	12%
6	MIROC-ESM	rcp85	AR5	hot-low rainfall	2070-2099	93.3	11.0	8.4	4.6	34.0	-20%	24%
Average						88.9	**6.7**	**7.2**	**3.3**	**42**	**0.0**	**15%**

Basin Characterization Model

Pepperwood
PRESERVE
Inspiring conservation through science

Basin Characterization Model

translating climate to watershed response



Size of arrows reflect relative magnitude of water flow

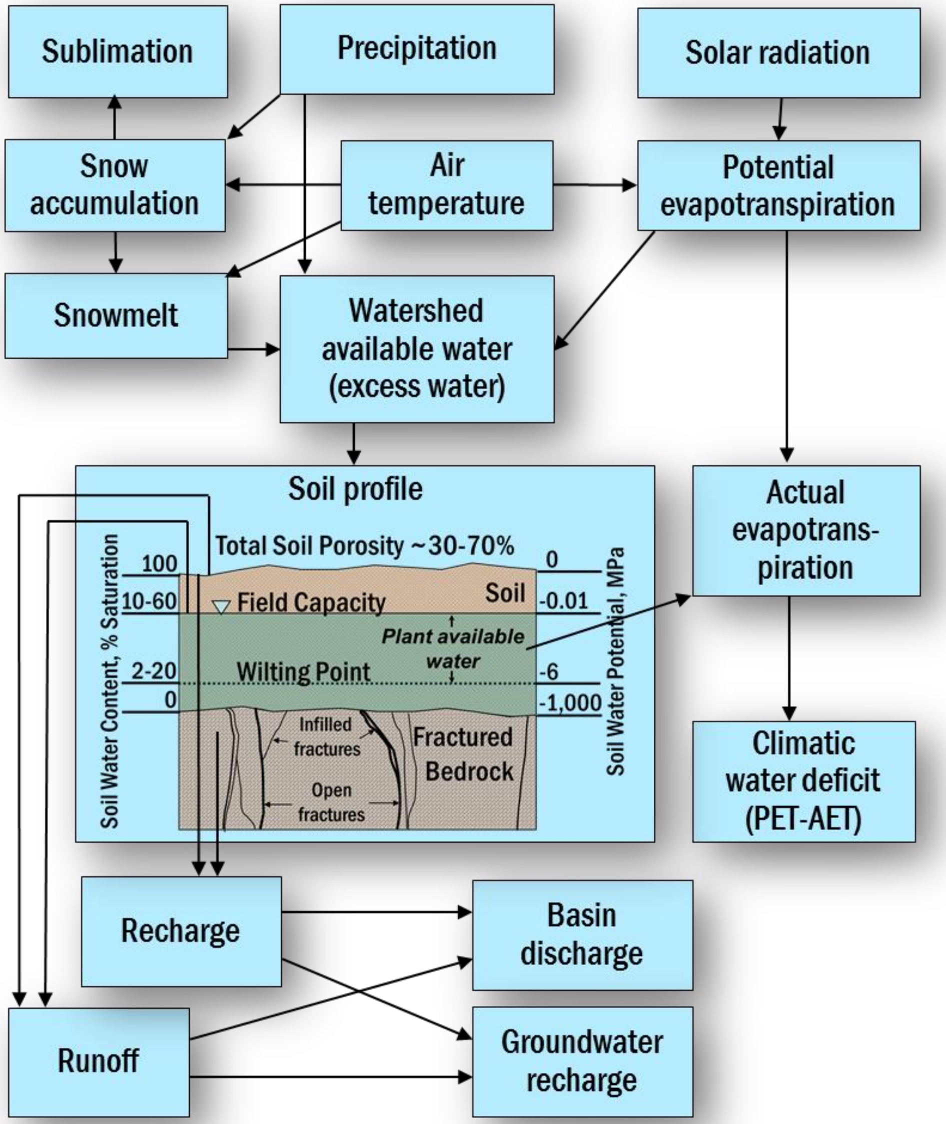
USGS science for a changing world

Brown text is BCM input, Purple text is BCM output

Pepperwood PRESERVE

USGS California Basin Characterization Model:

translating climate to watershed response



Flint et al. 2013

BCM methods

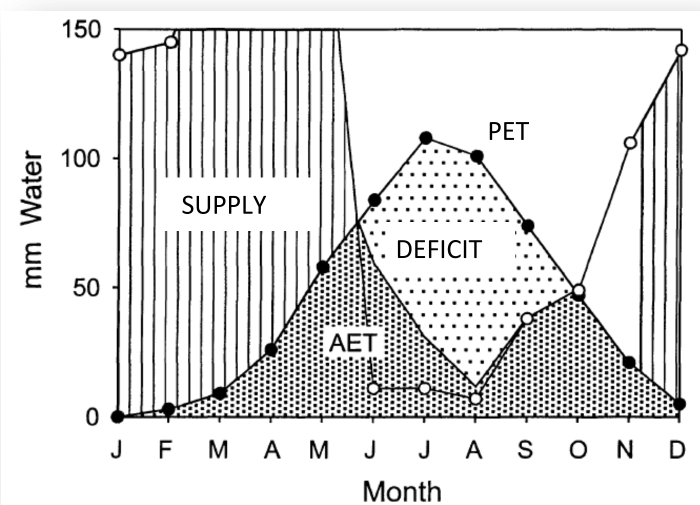
BCM output

Climatic Water Deficit

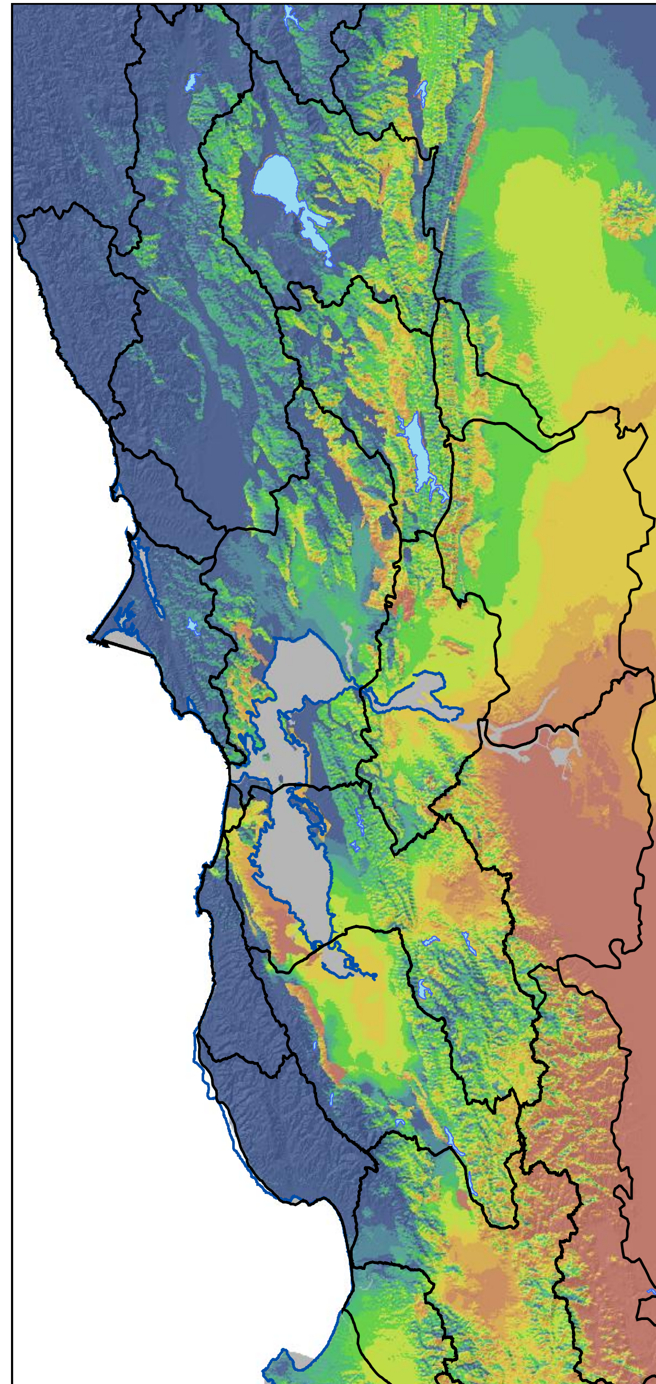
annual evaporative demand that exceeds available water= drought stress

Potential – Actual Evapotranspiration

- Integrates climate, energy loading, drainage, and available soil moisture
- Increases with all future climate scenarios
- Surrogate for irrigation demand
- Correlates with vegetation and fire risk



BCM methods



2001

mm/yr

Data menu

Primary (BCM outputs):

climate and hydology-temperature, rainfall, runoff, groundwater recharge, evapo-transpiration, soil moisture, climatic water deficit

Secondary:

Fire frequency (either percent likelihood of burn or return interval)

Potential native vegetation transitions

Time scales-historical (1910-2010) and projected (2010-2100)

30-y averages

Annual data

Monthly/Seasonal data

Spatial scales

Regional summaries-whole North Bay study area

County Summaries

Sub-regions-watershed, landscape unit, service area

Large parcels

Pepperwood PRESERVE

Inspiring conservation through science

Regional Products

- Cover entire North Bay Climate Ready Study Area (Russian River basin, Sonoma County, Marin County, Napa Valley)
- Derived from CA Basin Characterization Model (USGS)
- Put local results in regional context and facilitate regional planning

Pepperwood
PRESERVE
Inspiring conservation through science

Basin Characterization Model: North Bay Region
Trends in 30-year average values, historic-2099

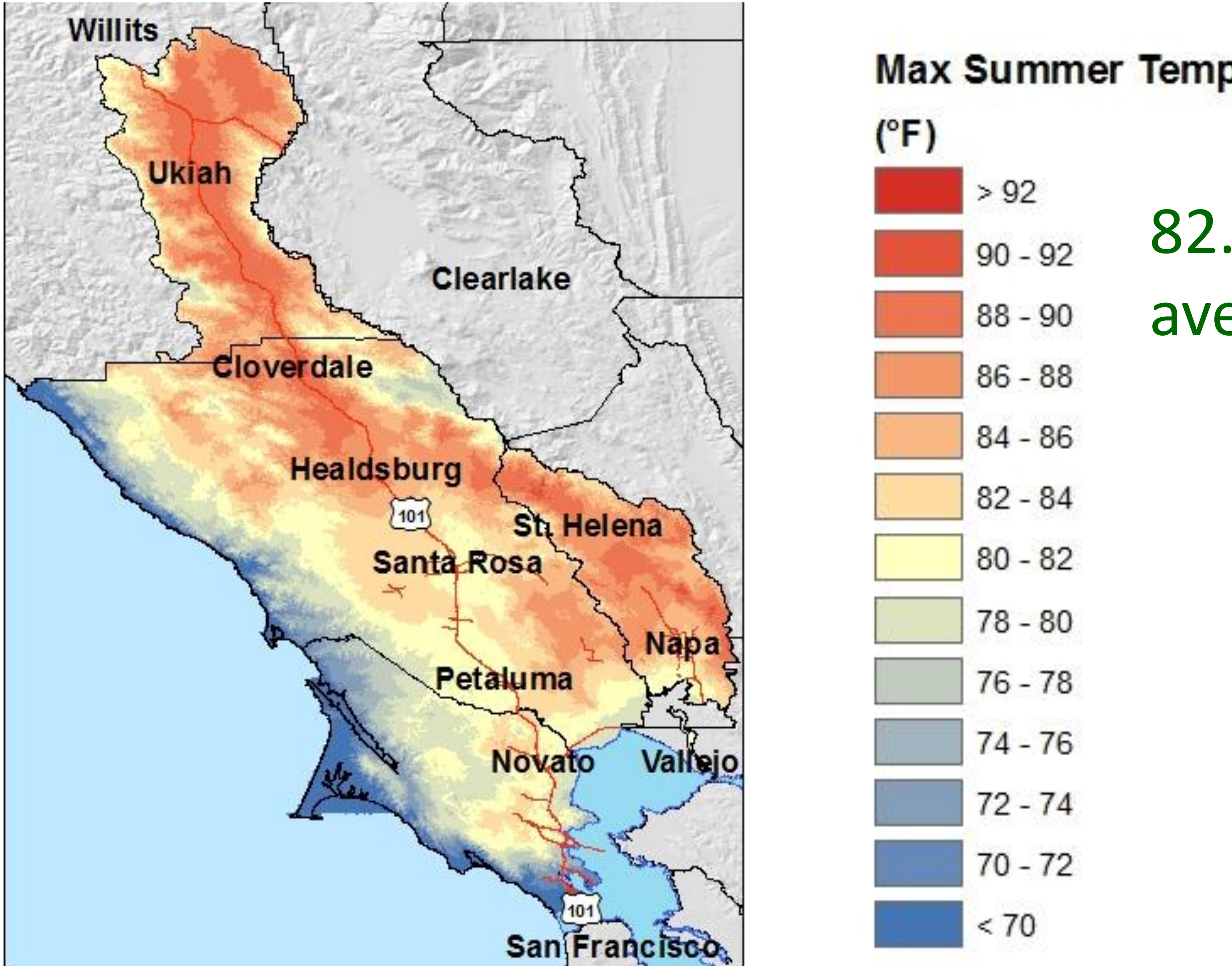
		Historical	Current	Moderate Warming, High Rainfall		Moderate Warming, Moderate Rainfall		Hot, Low Rainfall	
Variable	Units	1951-1980	1981-2010	2040-2069	2070-2099	2040-2069	2070-2099	2040-2069	2070-2099
Ppt	in	42.6	43.0	53.6	57.9	42.1	45.6	34.8	33.9
Tmn	Deg F	38.8	39.7	43.0	45.9	41.9	44.8	44.1	47.3
Tmx	Deg F	82.2	82.2	86.4	89.4	86.0	88.5	89.2	93.4
CWD	in	28.0	28.4	29.8	31.3	30.3	31.4	32.0	34.6
Rch	in	11.0	10.2	12.8	13.2	10.7	10.8	8.2	8.5
Run	in	14.0	14.2	22.8	26.9	14.0	17.3	9.7	9.3
Regional Statistics				Percent Change from Current or Change in Temperature					
			Current	Moderate Warming, High Rainfall		Moderate Warming, Moderate Rainfall		Hot, Low Rainfall	
Variable	Units		1981-2010	2040-2069	2070-2099	2040-2069	2070-2099	2040-2069	2070-2099
Ppt	in		43.0	25%	35%	-2%	6%	-19%	-21%
Tmn	Deg F		39.7	3.2	6.1	2.2	5.0	4.3	7.6
Tmx	Deg F		82.2	4.1	7.2	3.8	6.3	7.0	11.2
CWD	in		28.4	5%	10%	7%	11%	12%	22%
Rch	in		10.2	25%	29%	4%	6%	-20%	-17%
Run	in		14.2	61%	90%	-1%	22%	-32%	-34%

VARIABLES: Ppt=precipitation, Tmn=minimum winter temperature (monthly), Tmx=maximum summer temperature (monthly), CWD=climatic water deficit, Rch=recharge, Run=runoff

USGS, Point Blue, Pepperwood 2015

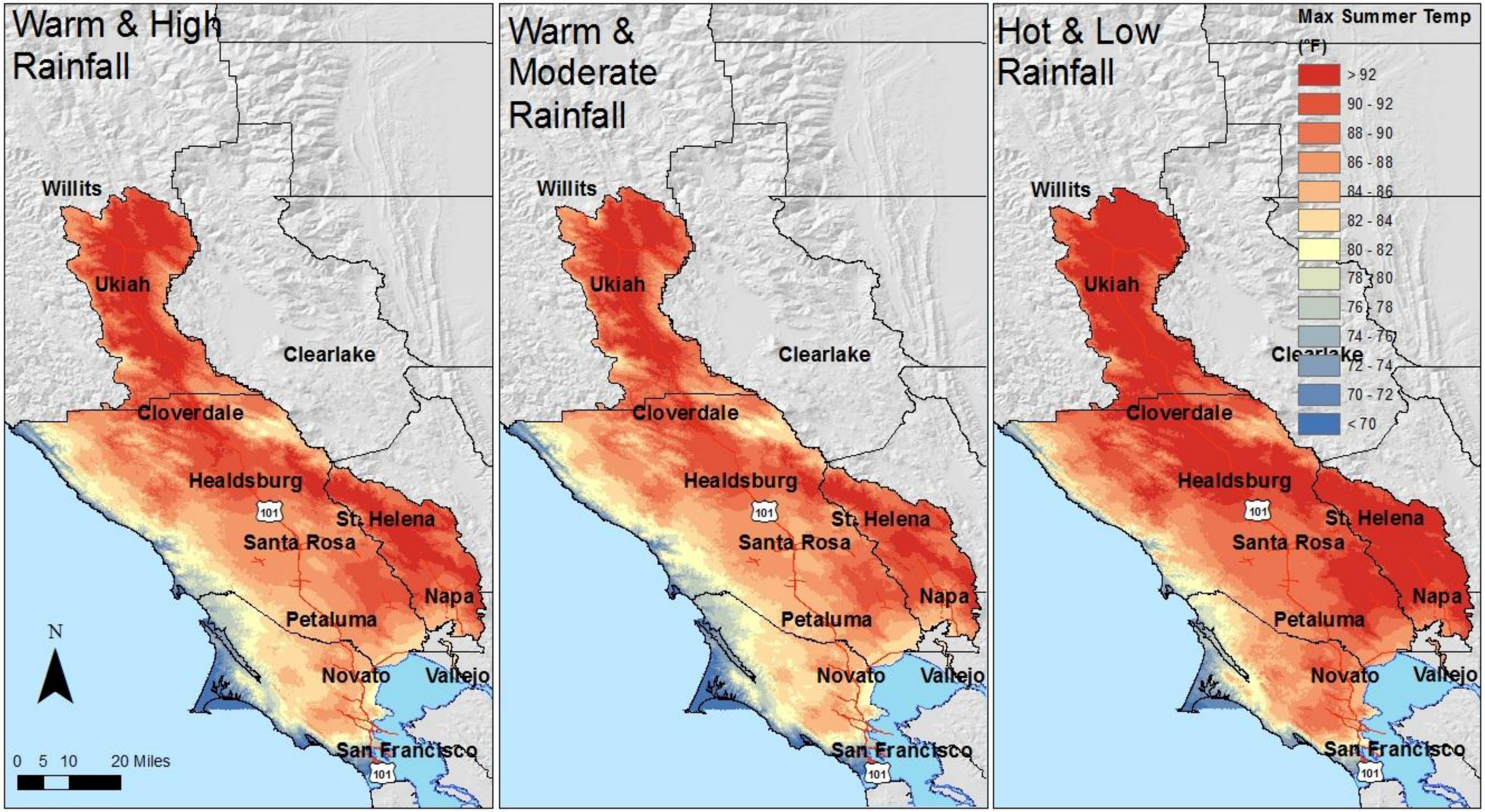
Maximum summer temperature (monthly avg) (degF)

30-year average, current-1981-2010



82.2 deg F average

Projected Maximum Summer Air Temperature, 2040-2069



86.4 average

86.0 average

89.2 average

Change relative to 1981-2010 average (82.2 deg F)

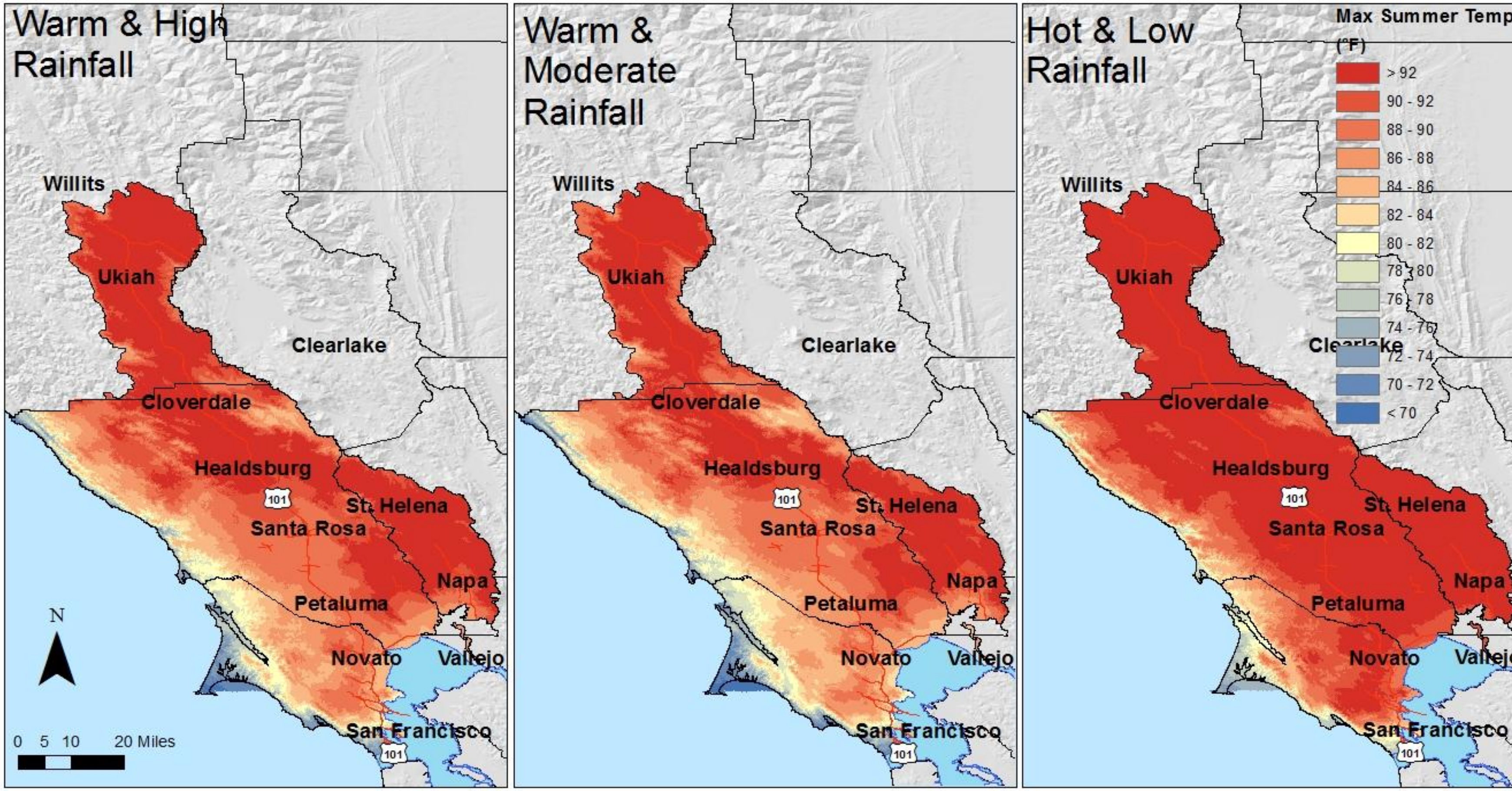
+4.2 deg F

+3.8 deg F

+7.0 deg F

"business as usual" mid-century temperatures

Projected Maximum Summer Air Temperature, 2070-2099



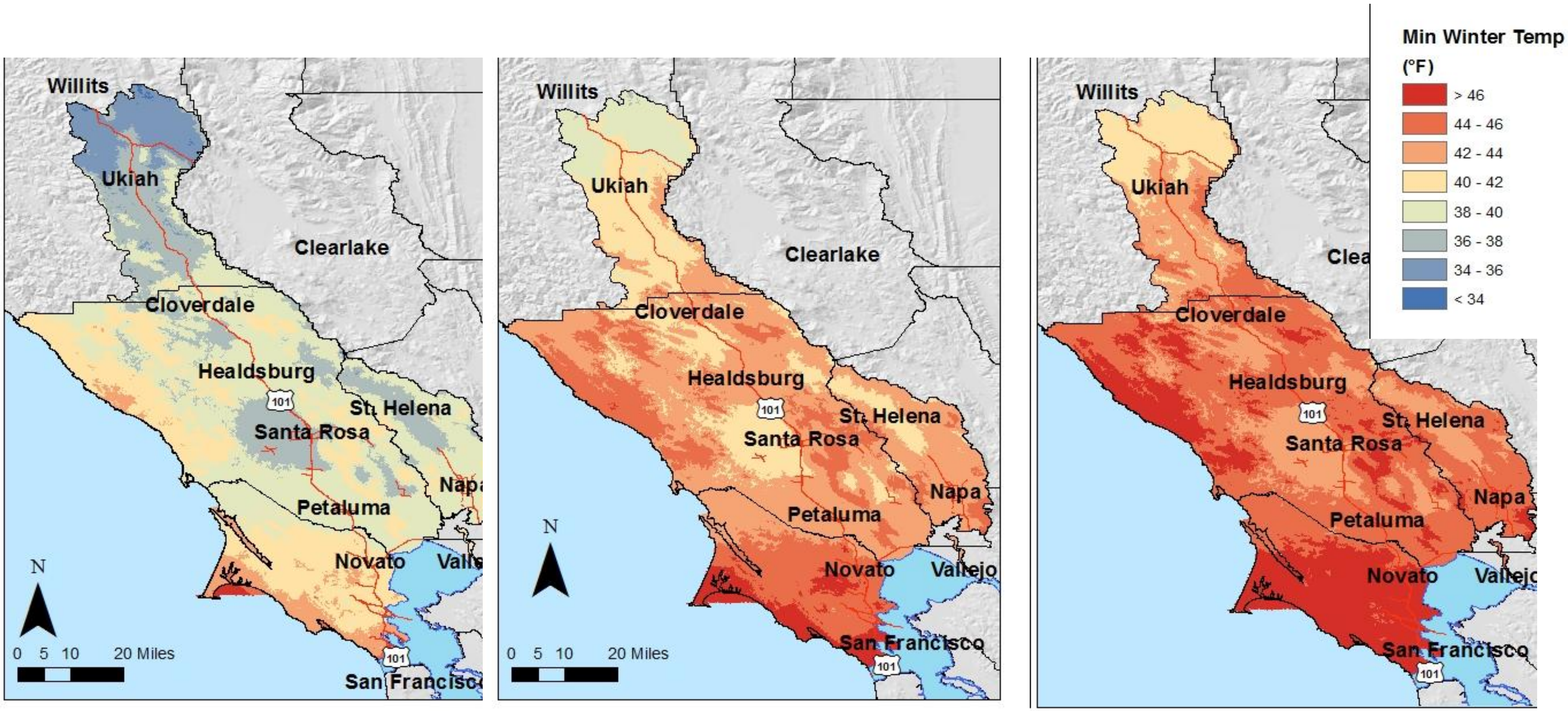
89.4 average | 88.5 average | 93.4 average

Change relative to 1981-2010 average (82.2 deg F)

+7.2 deg F | +6.3 deg F | +11.2 deg F

“business as usual” end of century temperatures- 30 y average

Minimum winter temperature (monthly) (degF)
30-year average, current-moderate warming (projected)
(mod rainfall scenario)



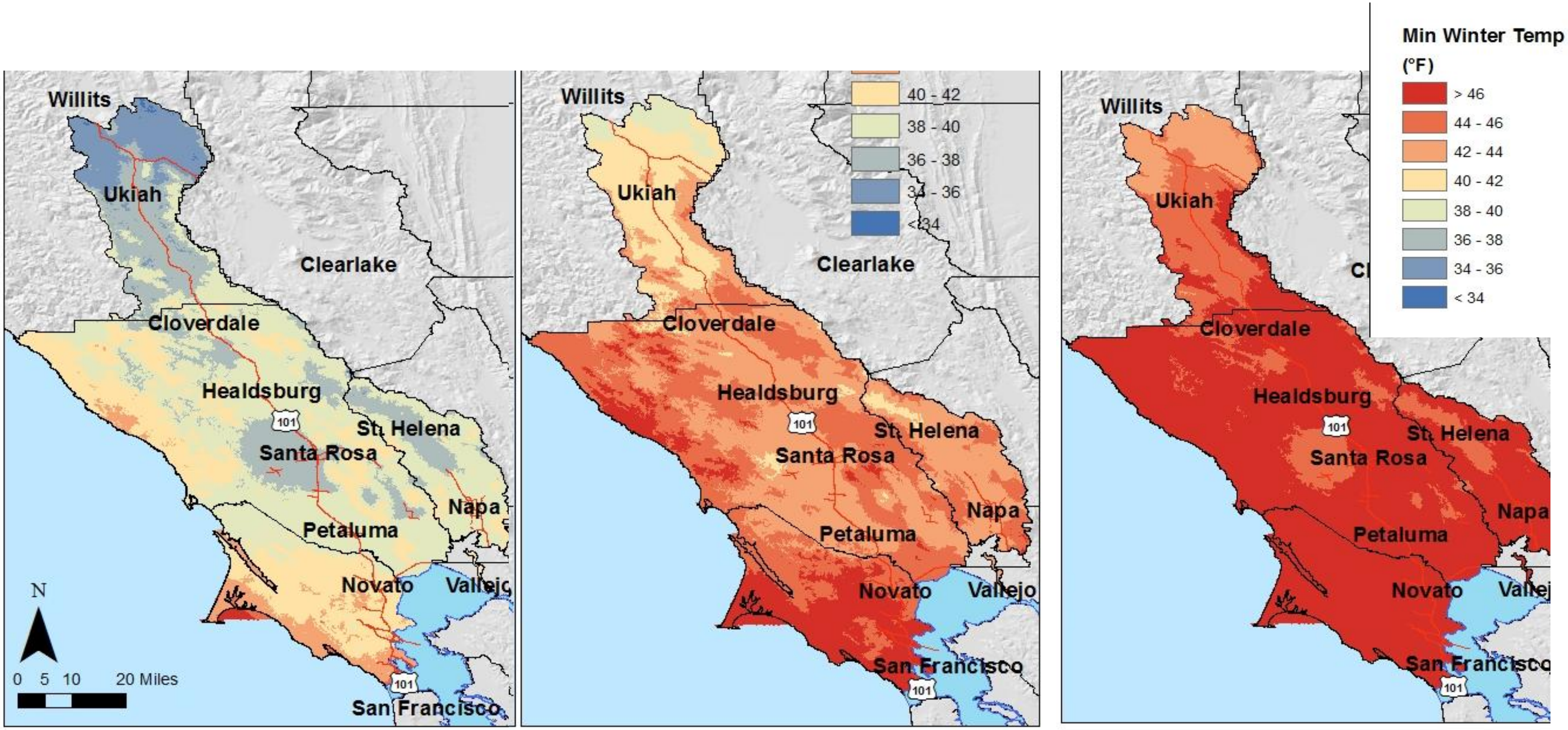
Current 1981-2010
39.7 average

Projected 2040-2069
43.0 average

Projected 2070-2099
44.8 average

5.1 deg F greater by end of century than current

Minimum winter temperature (monthly) (degF)
30-year average, current-high warming (projected)



Current 1981-2010
39.7 average

Projected 2040-2069
44.1 average

Projected 2070-2099
47.3 average

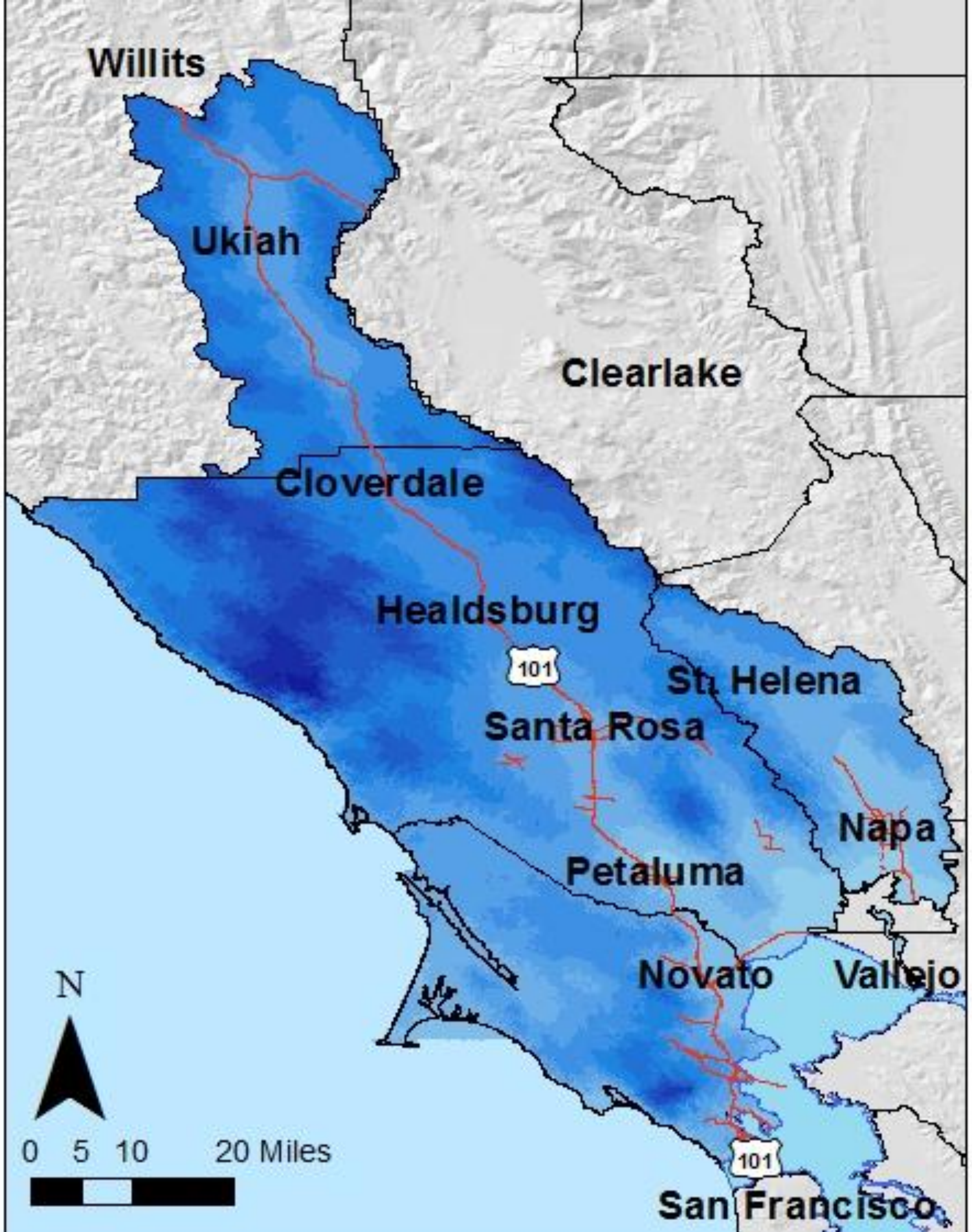
7.6 deg F greater by end of C than current, 2.5 deg F greater than moderate warming scenario

Precipitation (PPT)

30 year average

Historic 1951-1980

Regional average 43 in/y



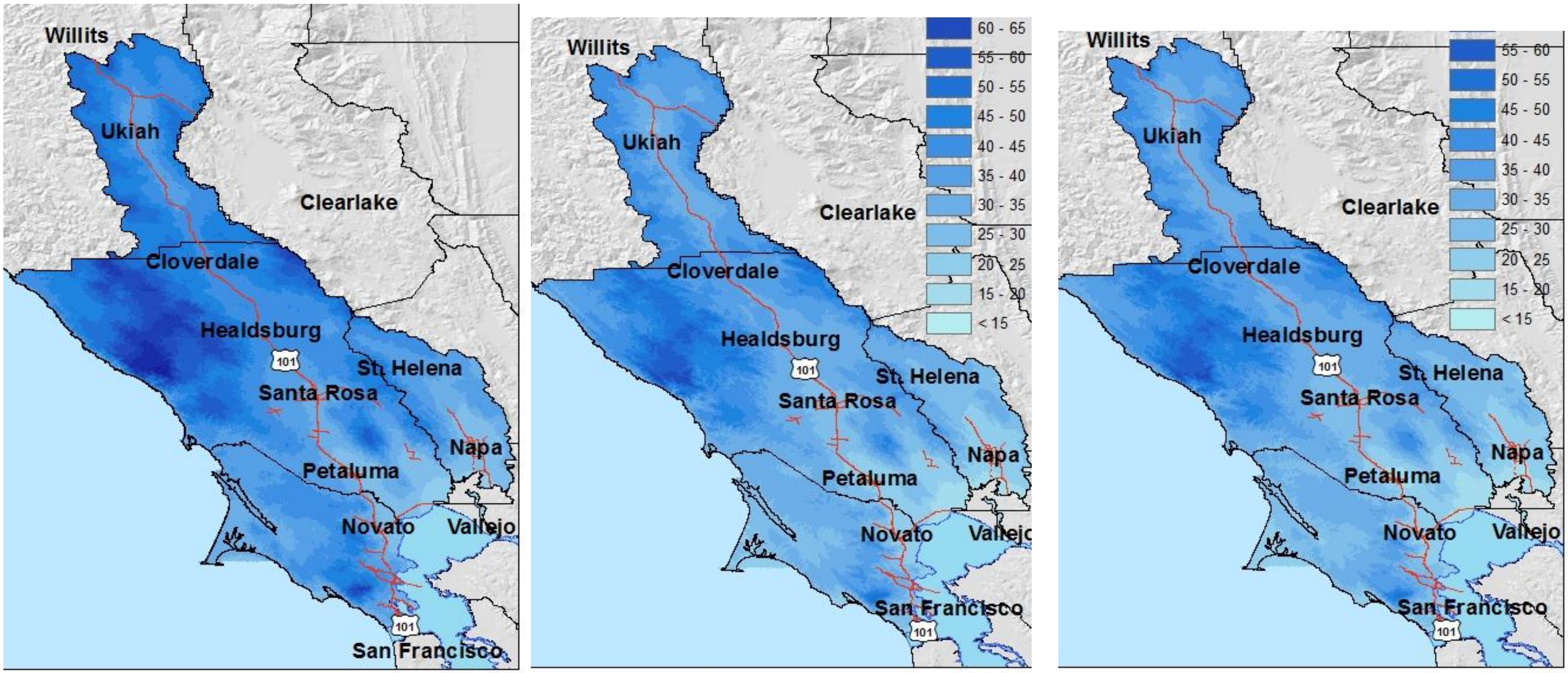
80+
75 - 80
70 - 75
65 - 70
60 - 65
55 - 60
50 - 55
45 - 50
40 - 45
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
< 15

PPT (in/yr)

Precipitation (PPT, annual in/y)

30-year average, current to projected-low rainfall

(hot scenario)



Current 1981-2010
43.0 average

Projected 2040-2069
35.0 average

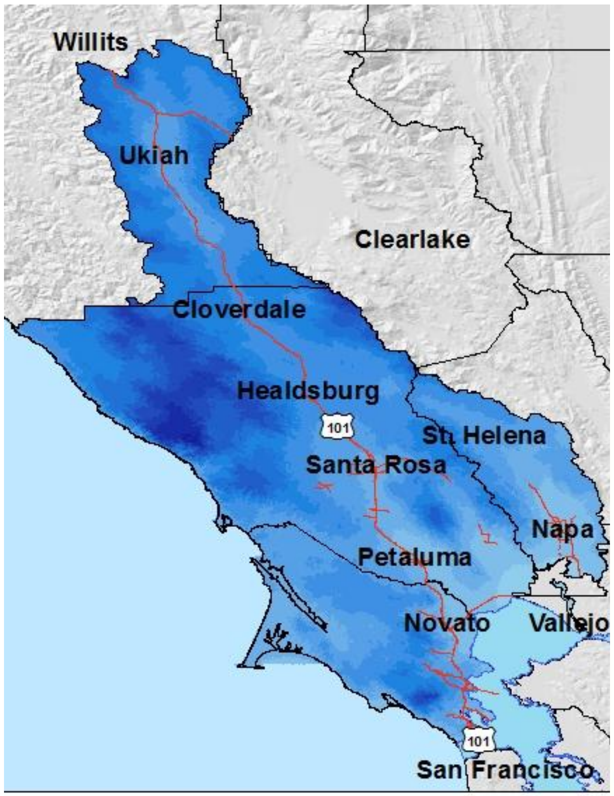
Projected 2070-2099
34.0 average

projecting 19-21% less rainfall than 1981-2010

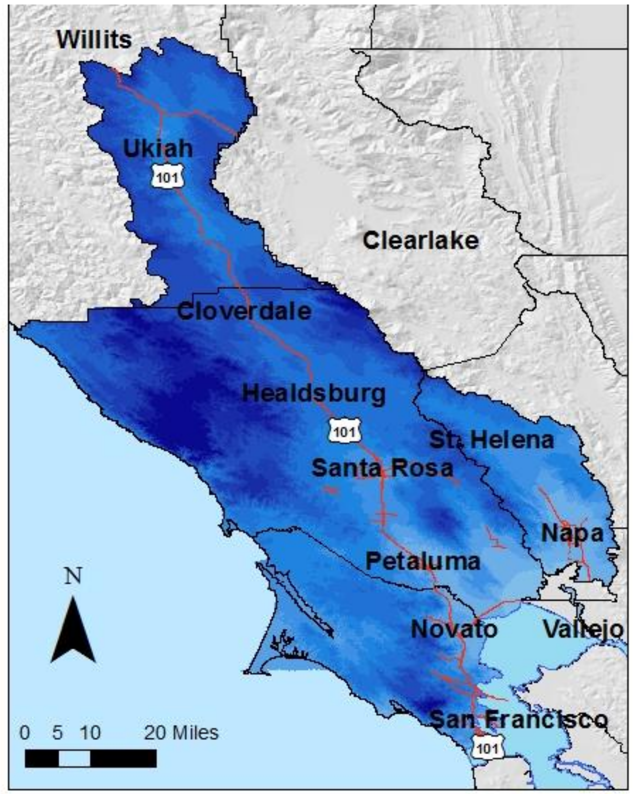
Precipitation (PPT, annual in/y)

30-year average, current to projected-high rainfall

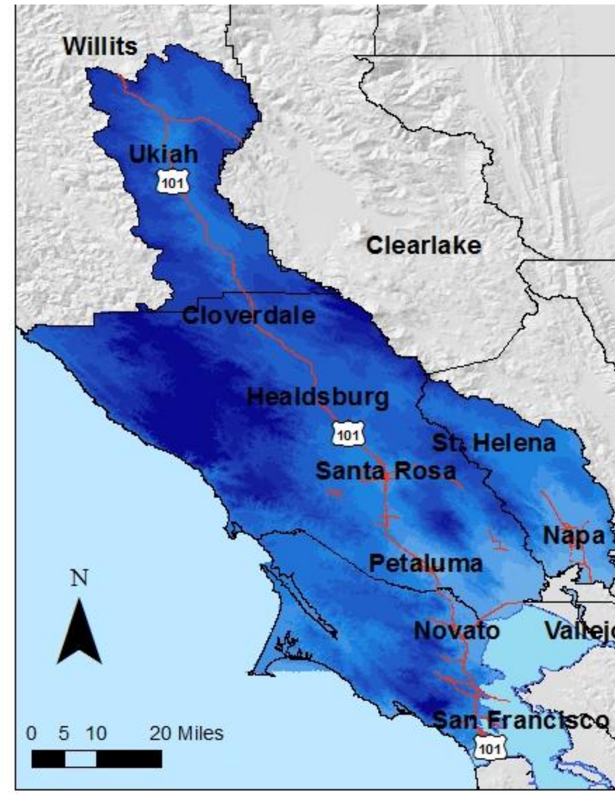
(warm scenario)



Current 1981-2010
43.0 average



Projected 2040-2069
54.0 average

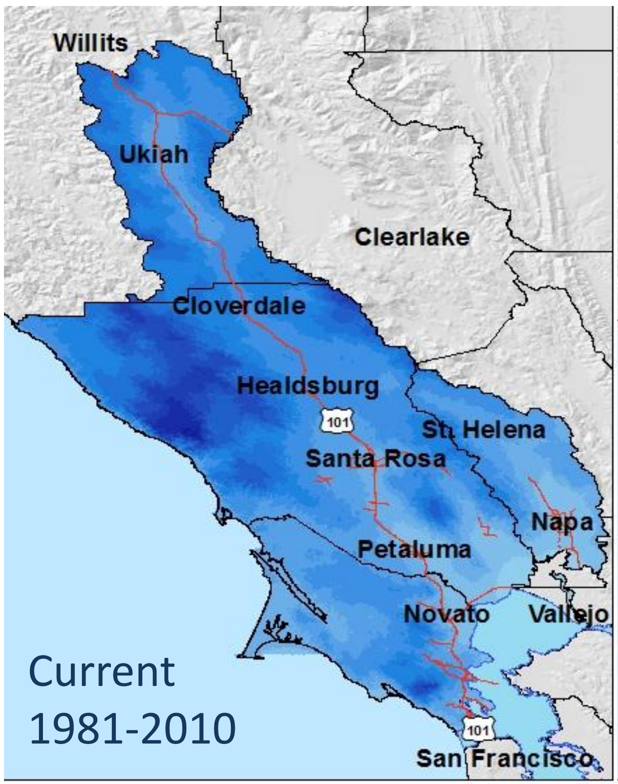


Projected 2070-2099
58.0 average

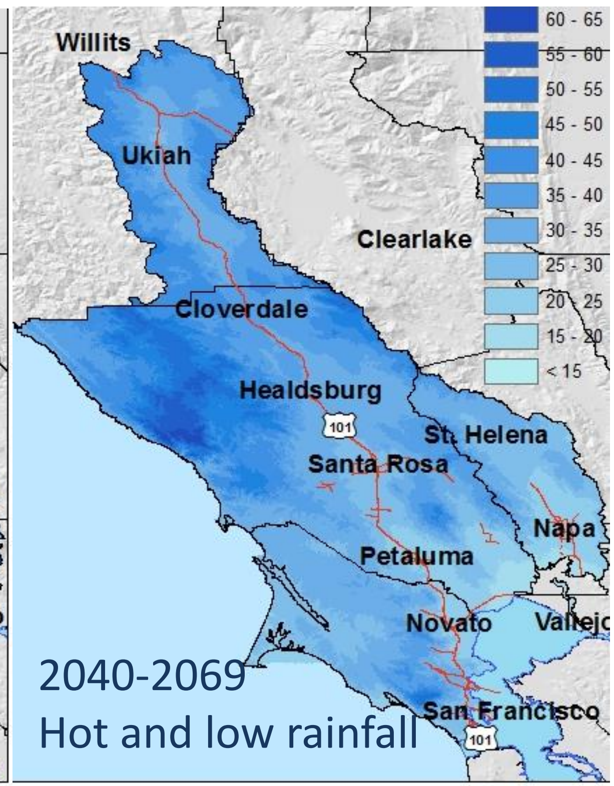
projecting 25-35% greater rainfall than current

Precipitation (PPT, annual in/y)

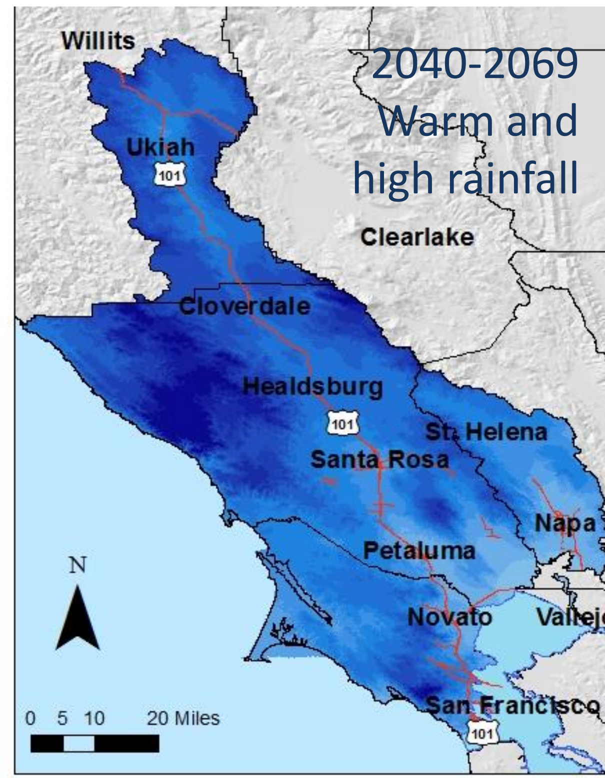
30-y averages, current (1981-2010), projected (2040-2069), hot and low rainfall and warm and high rainfall versus scenarios



43.0 in/y average



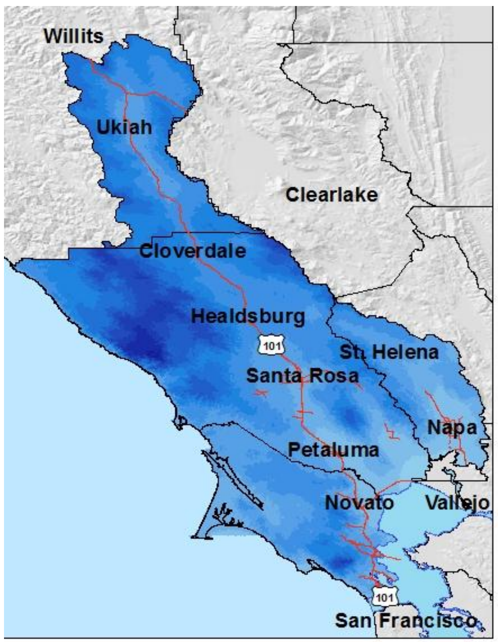
35.0 in/y average



54.0 in/y average

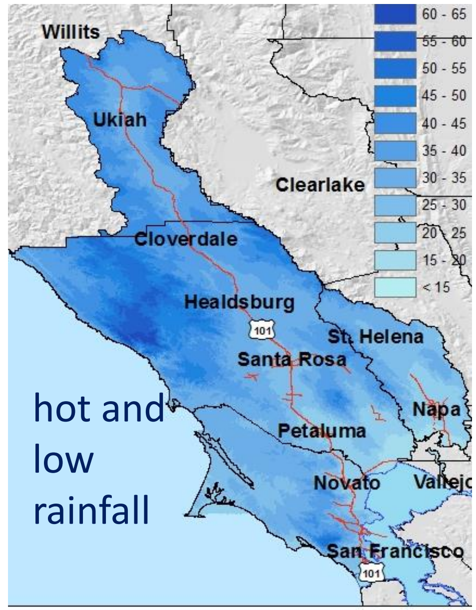
Precipitation (PPT, annual in/y)-large uncertainty!

30-y average, current to projected mid C



Current 1981-2010
43.0 average

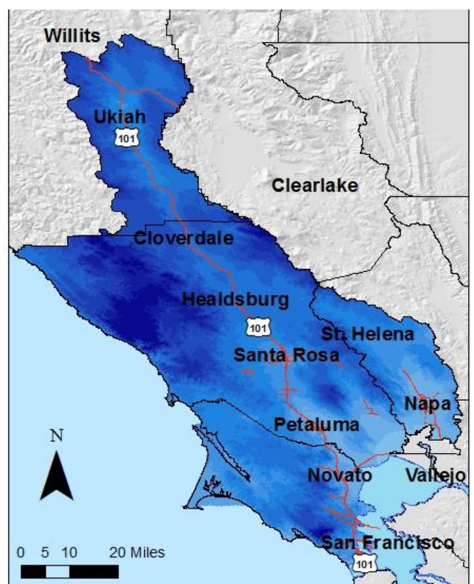
?



hot and
low
rainfall

Projected 2040-2069
35.0 average

projecting 19-21% less rainfall than 1981-2010!



Projected 2040-2069
54.0 average

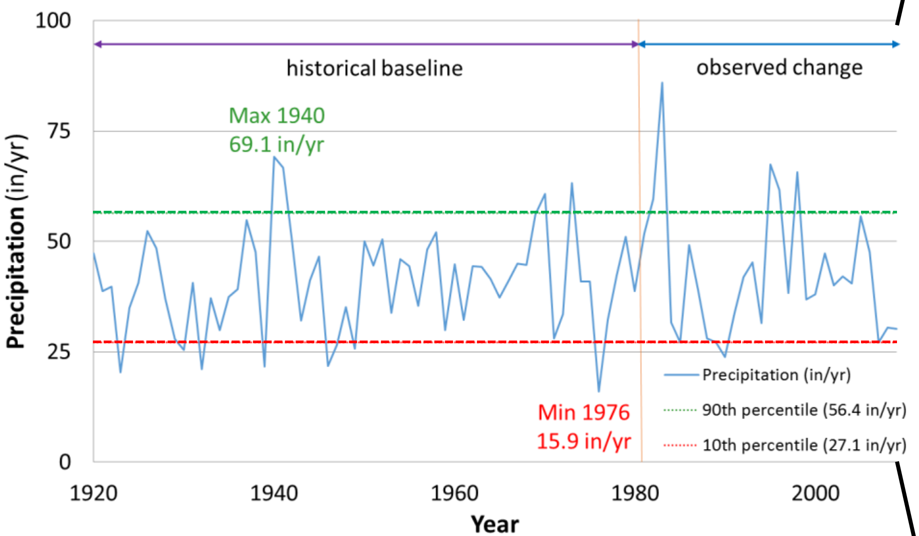
projecting 25-35% greater rainfall than 1981-2010!

North Bay Climate Ready

Regional Annual Rainfall: Historical and Projected

(comparison of 90-year periods)

North Bay Annual Rainfall Record (1920-2009)



Extremes (1920-2009)

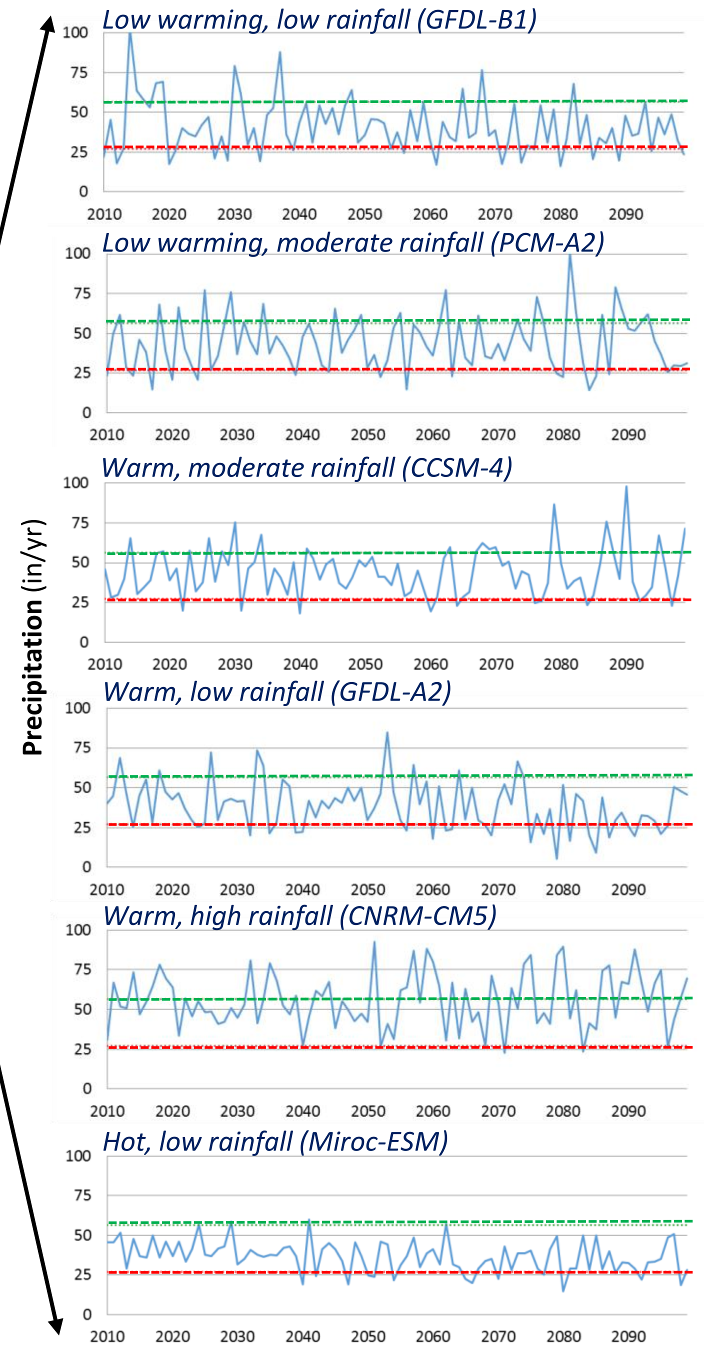
2 events >=1940

9 events >90th % (56.4in/y)*

1 events <=1976

9 events <10th % (27.1 in/y)*

North Bay Annual Rainfall Projections (2010-2099)



Scenario 1
5 events >=1940
13 events >90th %
0 events <=1976
18 events <10th %

Scenario 2
6 events >=1940
23 events >90th %
3 events <=1976
17 events <10th %

Scenario 3
5 events >=1940
19 events >90th %
0 events <=1976
10 events <10th %

Scenario 4
3 events >=1940
10 events >90th %
3 events <=1976
23 events <10th %

Scenario 5
19 events >=1940
41 events >90th %
0 events <=1976
6 events <10th %

Scenario 6
0 events >=1940
4 events >90th %
1 events <=1976
14 events <10th %

* 10th and 90th percentile benchmarks based on 1920-2009 record

Climate Ready North Bay

Annual Rainfall Extremes per Decade

Frequency of extreme annual events per decade

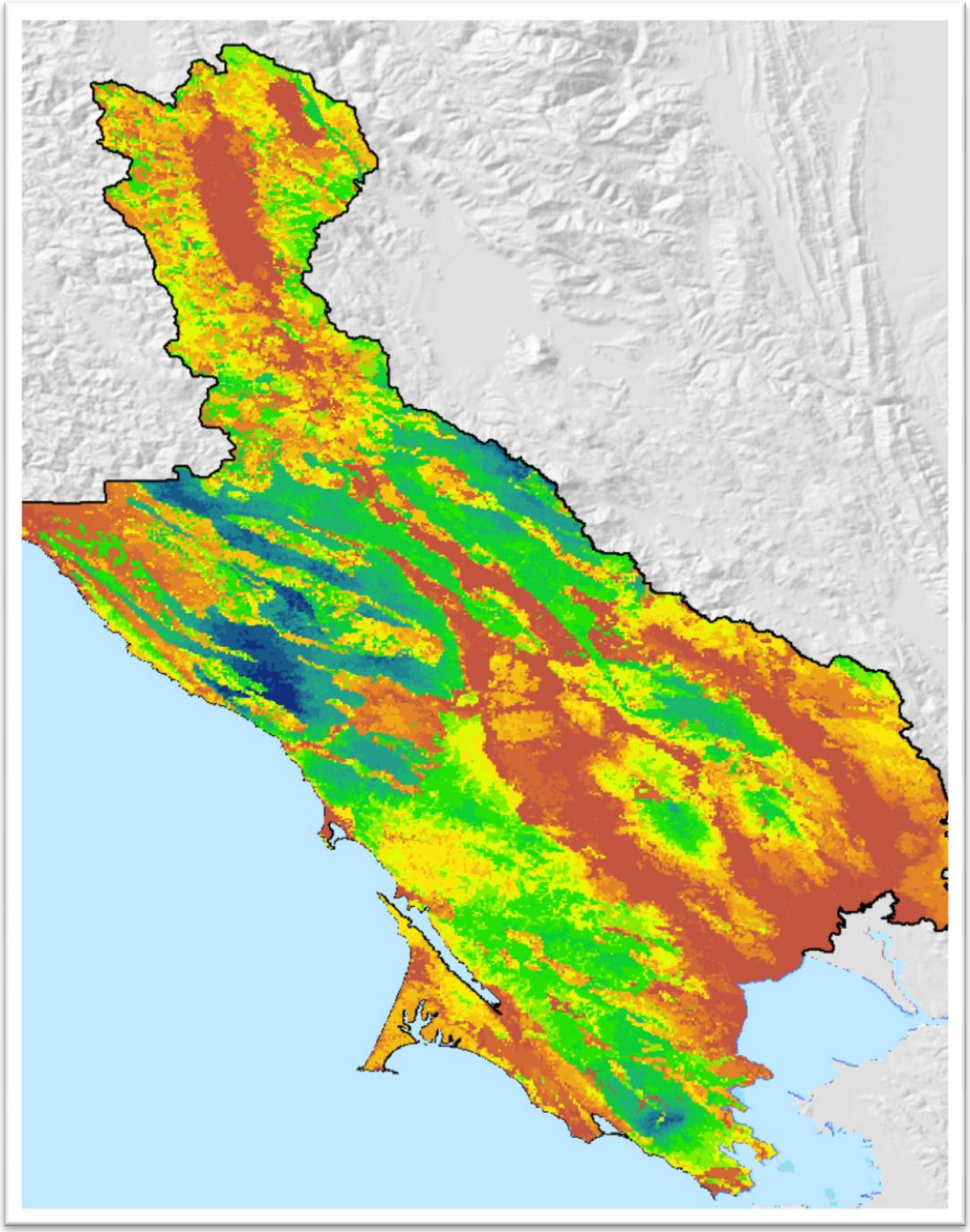
Scenario #	Model	Time Period	Name	Annual Peaks (floods) >=1940 (69.1 in/yr)	Annual Peaks (floods) >90th % (56.4 in/yr)	Annual Lows (droughts) <10th % (27.1 in/yr)	Annual Lows (droughts) <=1976 (15.9 in/yr)
	Historic & Observed Change	1920-2009		0.22	1.00	1.00	0.11
1	GFDL_B1	2010-2099	Low warming, Low rainfall	0.56	1.44	2.00	0.00
2	PCM_A2	2010-2099	Low warming, Mod rainfall	0.67	2.56	1.89	0.33
3	CCSM4_rcp85	2010-2099	Warm, Mod rainfall	0.56	2.11	1.11	0.00
4	GFDL_A2	2010-2099	Warm, Low rainfall	0.33	1.11	2.56	0.33
5	CNRM_rcp85	2010-2099	Warm, High rainfall	2.11	4.56	0.67	0.00
6	MIROC_rcp85	2010-2099	Hot, Low rainfall	0.00	0.44	1.56	0.11

Percent increase or decrease (projected relative to 1920-2009): Frequency extreme annual events per decade

Scenario #	Model	Time Period	Name	Annual Peaks (floods) >=1940 (69.1 in/yr)	Annual Peaks (floods) >90th % (56.4 in/yr)	Annual Lows (droughts) <10th % (27.1 in/yr)	Annual Lows (droughts) <=1976 (15.9 in/yr)
	Historic & Observed Change	1920-2009					
1	GFDL_B1	2010-2099	Low warming, Low rainfall	150%	44%	100%	-100%
2	PCM_A2	2010-2099	Low warming, Mod rainfall	200%	156%	89%	200%
3	CCSM4_rcp85	2010-2099	Warm, Mod rainfall	150%	111%	11%	-100%
4	GFDL_A2	2010-2099	Warm, Low rainfall	50%	11%	156%	200%
5	CNRM_rcp85	2010-2099	Warm, High rainfall	850%	356%	-33%	-100%
6	MIROC_rcp85	2010-2099	Hot, Low rainfall	-100%	-56%	56%	0%
			Average	***217%***	***104%***	***63%***	***17%***

* 10^{th} and 90^{th} percentile benchmarks based on 1920-2009 record

North Bay Region Runoff



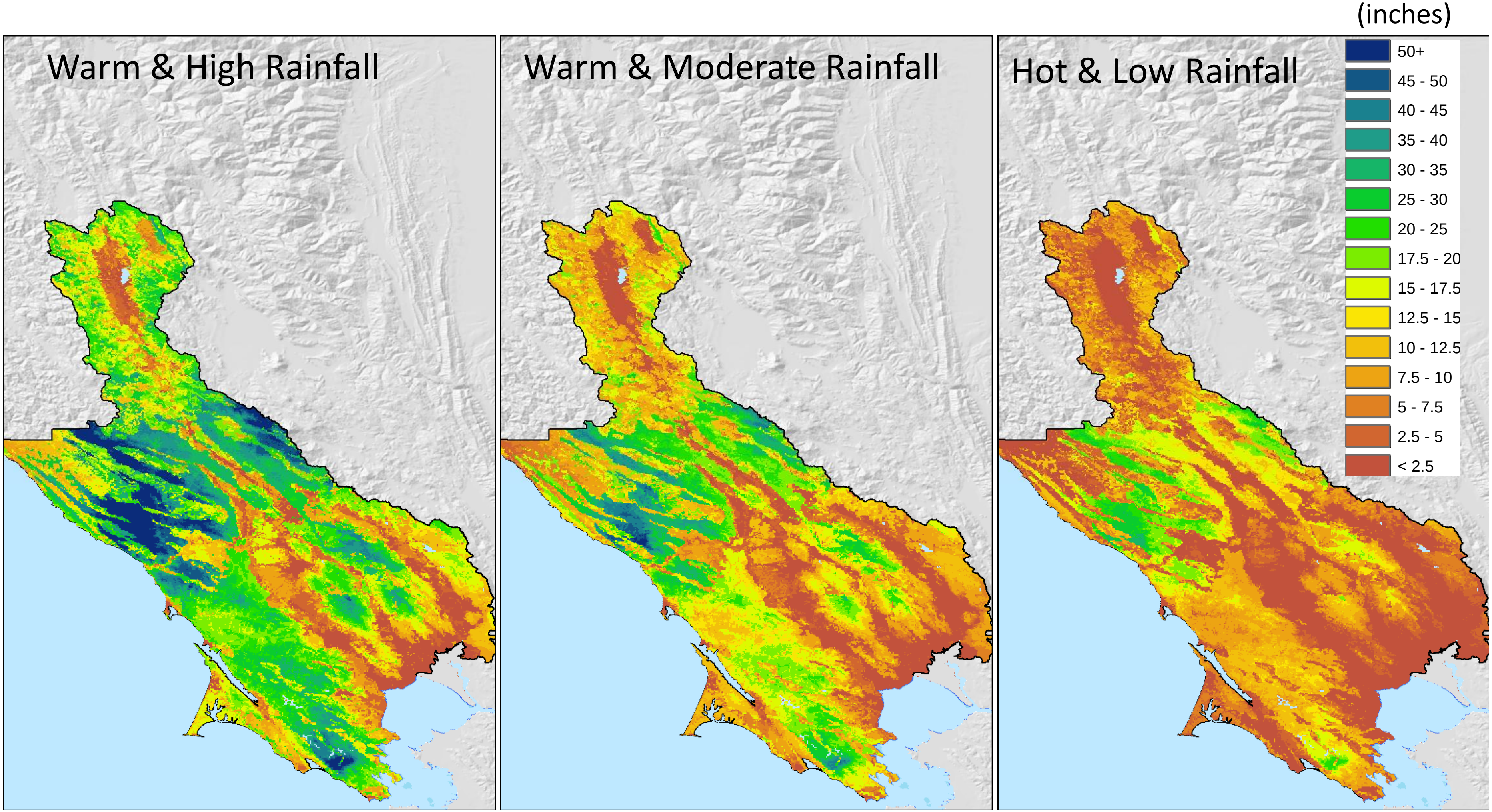
(inches/year)

- 50+
- 45 - 50
- 40 - 45
- 35 - 40
- 30 - 35
- 25 - 30
- 20 - 25
- 17.5 - 20
- 15 - 17.5
- 12.5 - 15
- 10 - 12.5
- 7.5 - 10
- 5 - 7.5
- 2.5 - 5
- < 2.5
- **Groundwater basins**

1981-2010

14.2 in/y average (per unit area)

Projected Runoff 2070-2099



26.9 in/y average

17.3 in/y average

9.3 in/y average

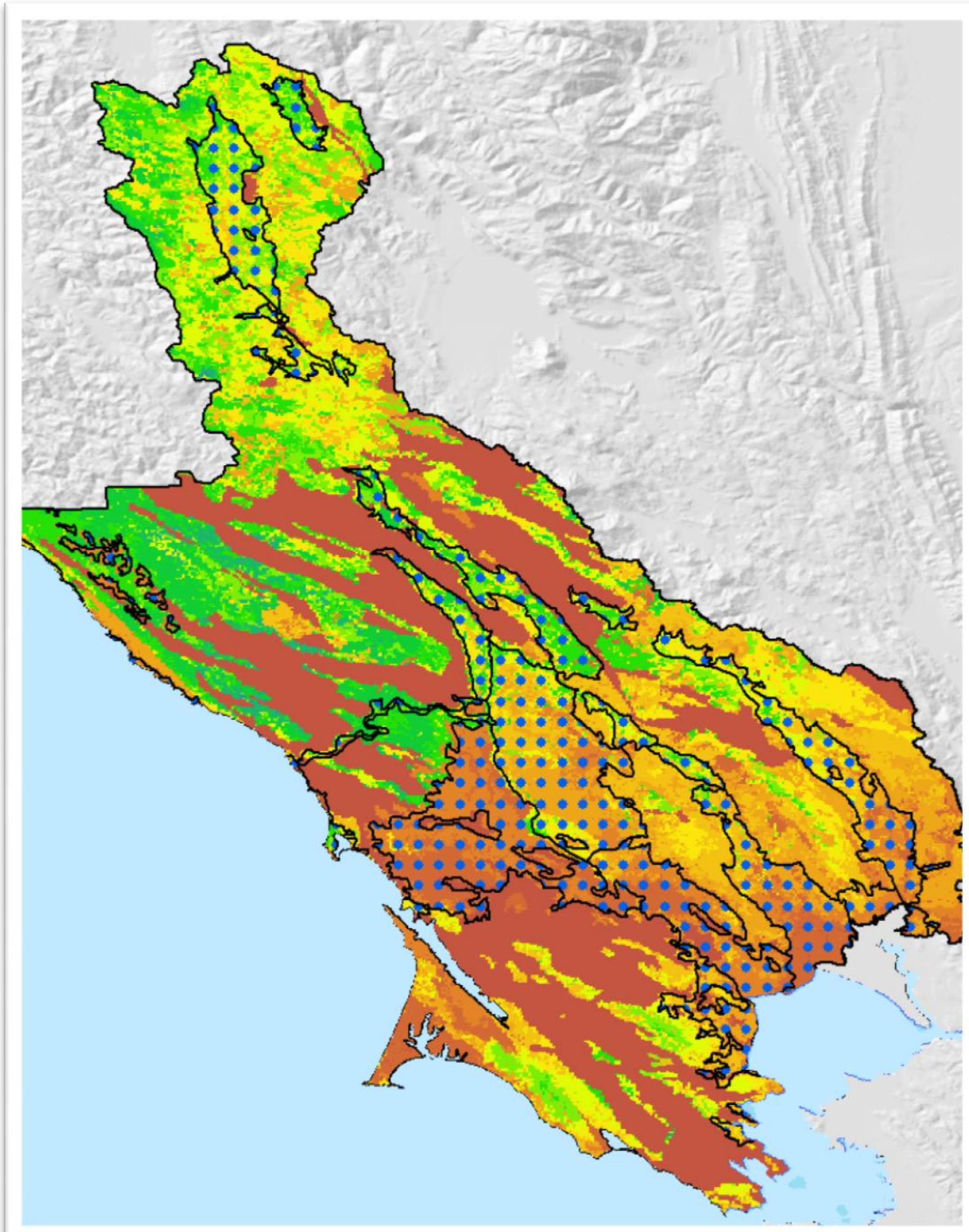
Change in runoff relative to 1981-2010 average (14.2 in/y)

+90%

+22%

-34%

North Bay Region Groundwater Recharge



1981-2010

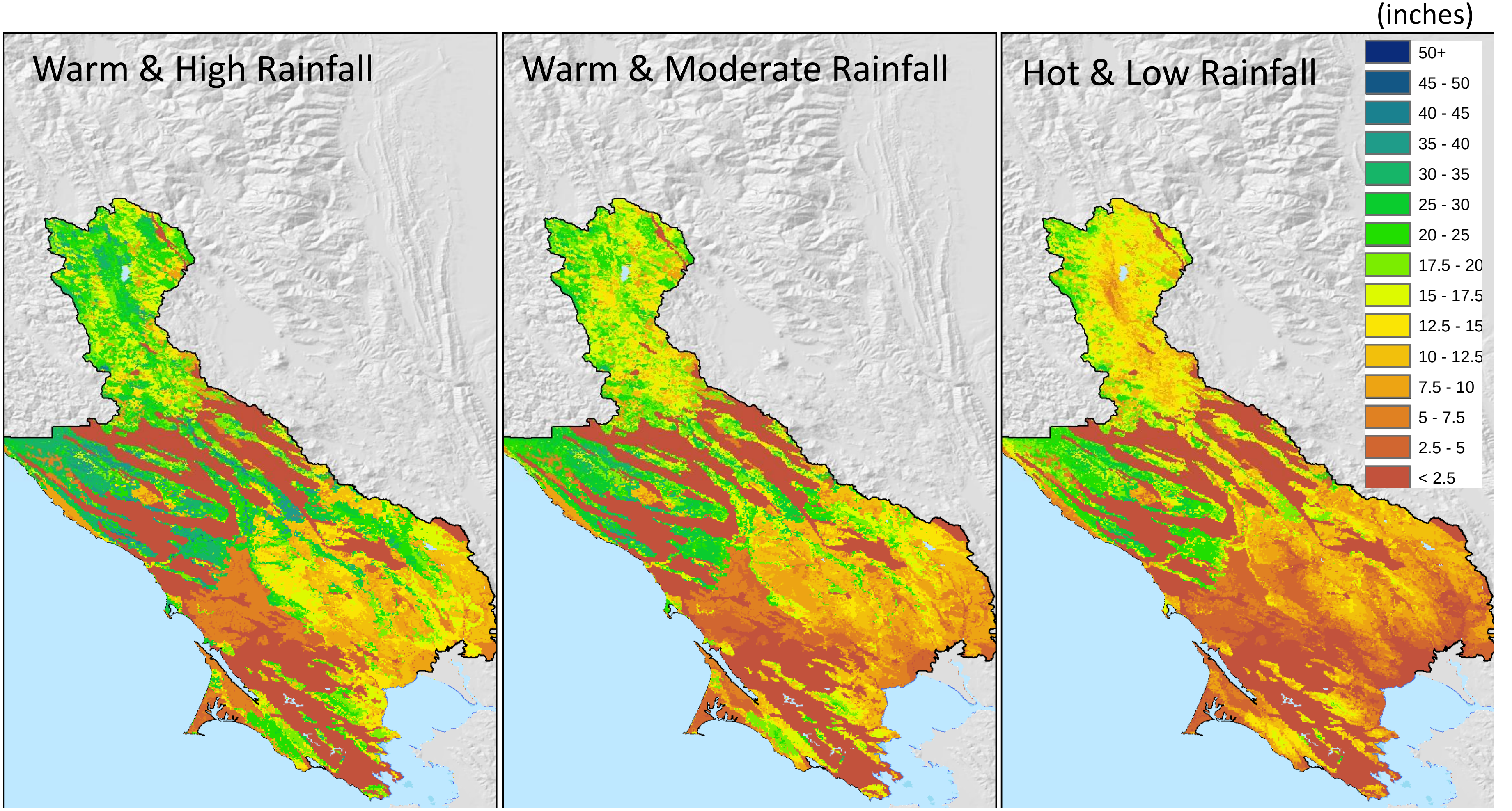
10.2 in/y average (per unit area)

(inches/year)

- 50+
- 45 - 50
- 40 - 45
- 35 - 40
- 30 - 35
- 25 - 30
- 20 - 25
- 17.5 - 20
- 15 - 17.5
- 12.5 - 15
- 10 - 12.5
- 7.5 - 10
- 5 - 7.5
- 2.5 - 5
- < 2.5

Groundwater basins

Projected Recharge 2070-2099



13.2 in/y average | 10.8 in/y average | 8.5 in/y average

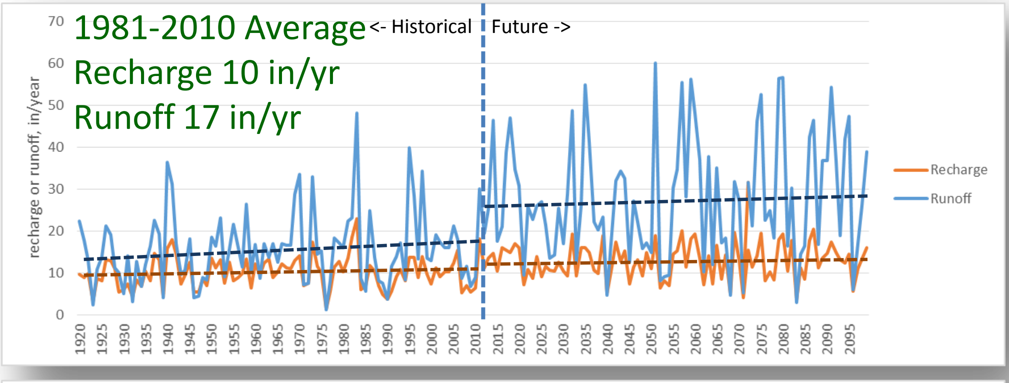
Change in groundwater recharge relative to 1981-2010 average (10.2 in/y)

+29% | +6% | -17%

A Comparison of Annual Recharge and Runoff

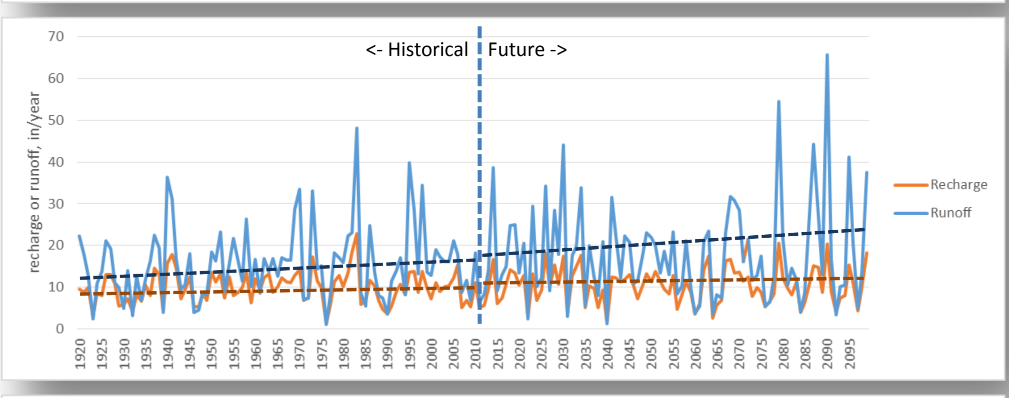
Sonoma County, Measured 1920-2009, Modeled 2010-2099

Scenario 5
Warm &
High Rainfall



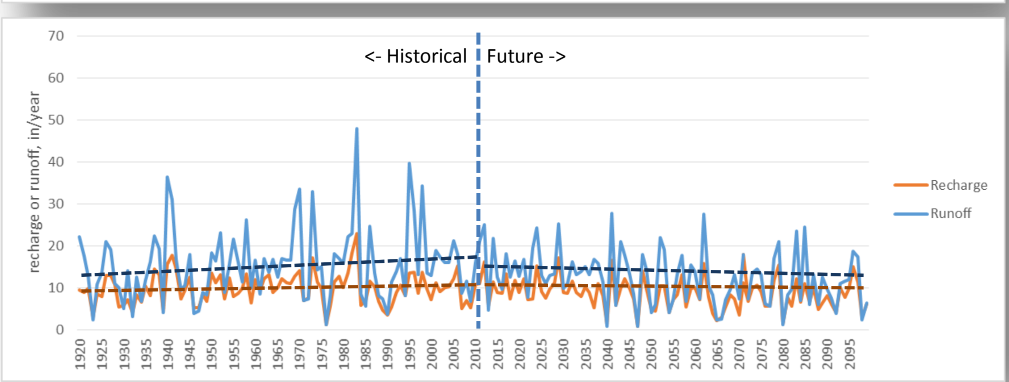
End century averages
Recharge 13 in/yr
Runoff 30 in/yr

Scenario 3
Warm &
Moderate
Rainfall



End century averages
Recharge 10.5 in/yr
Runoff 20 in/yr

Scenario 6
Hot &
Low Rainfall



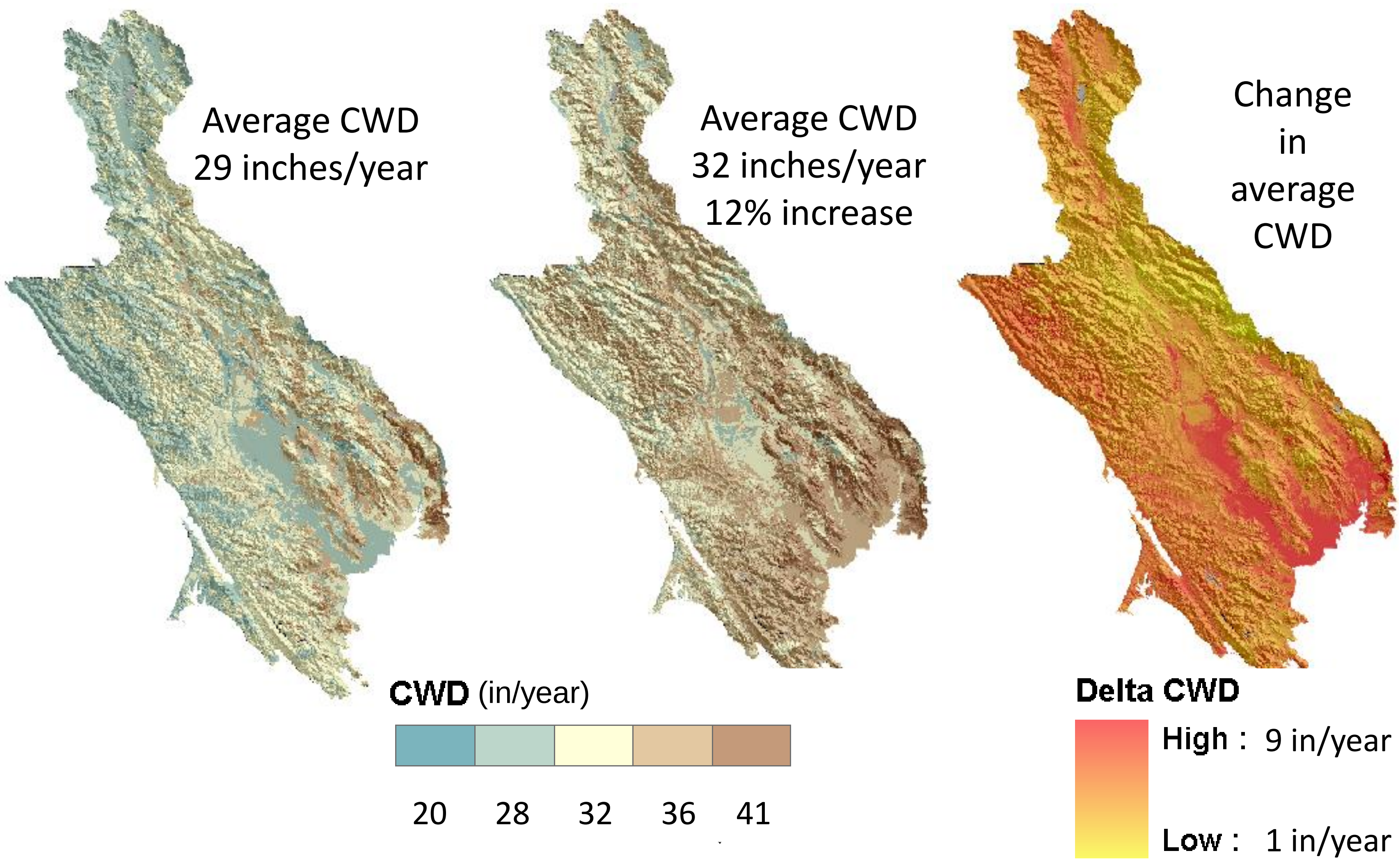
End century averages
Recharge 8 in/yr
Runoff 11 in/yr

Recharge is less variable than runoff across all futures

North Bay Region Climatic Water Deficit

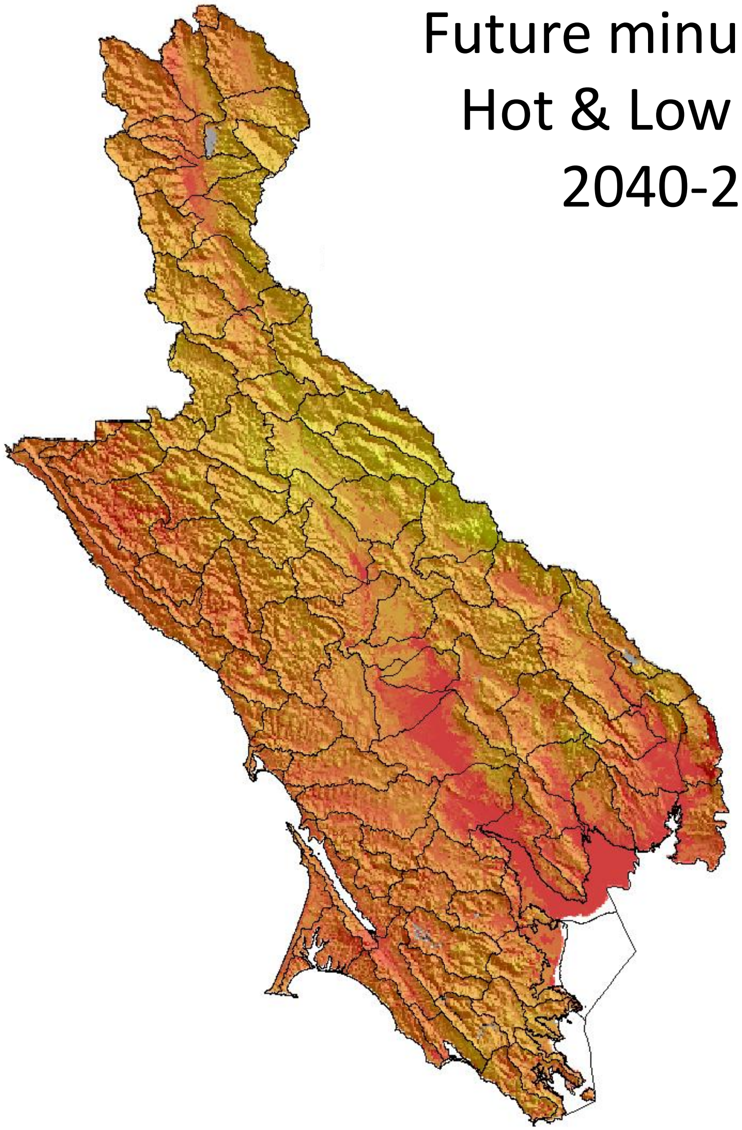
Hot & Low Rainfall

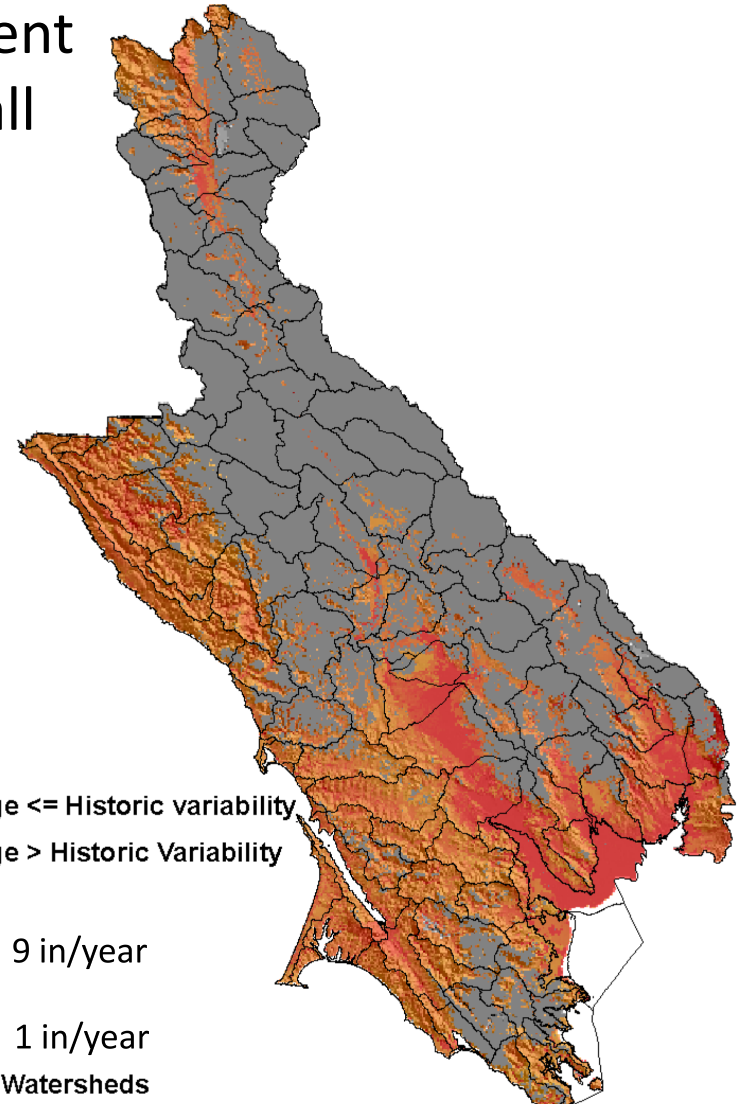
1981-2010 | 2040-2069 | 2040-2069



Change in Climatic Water Deficit

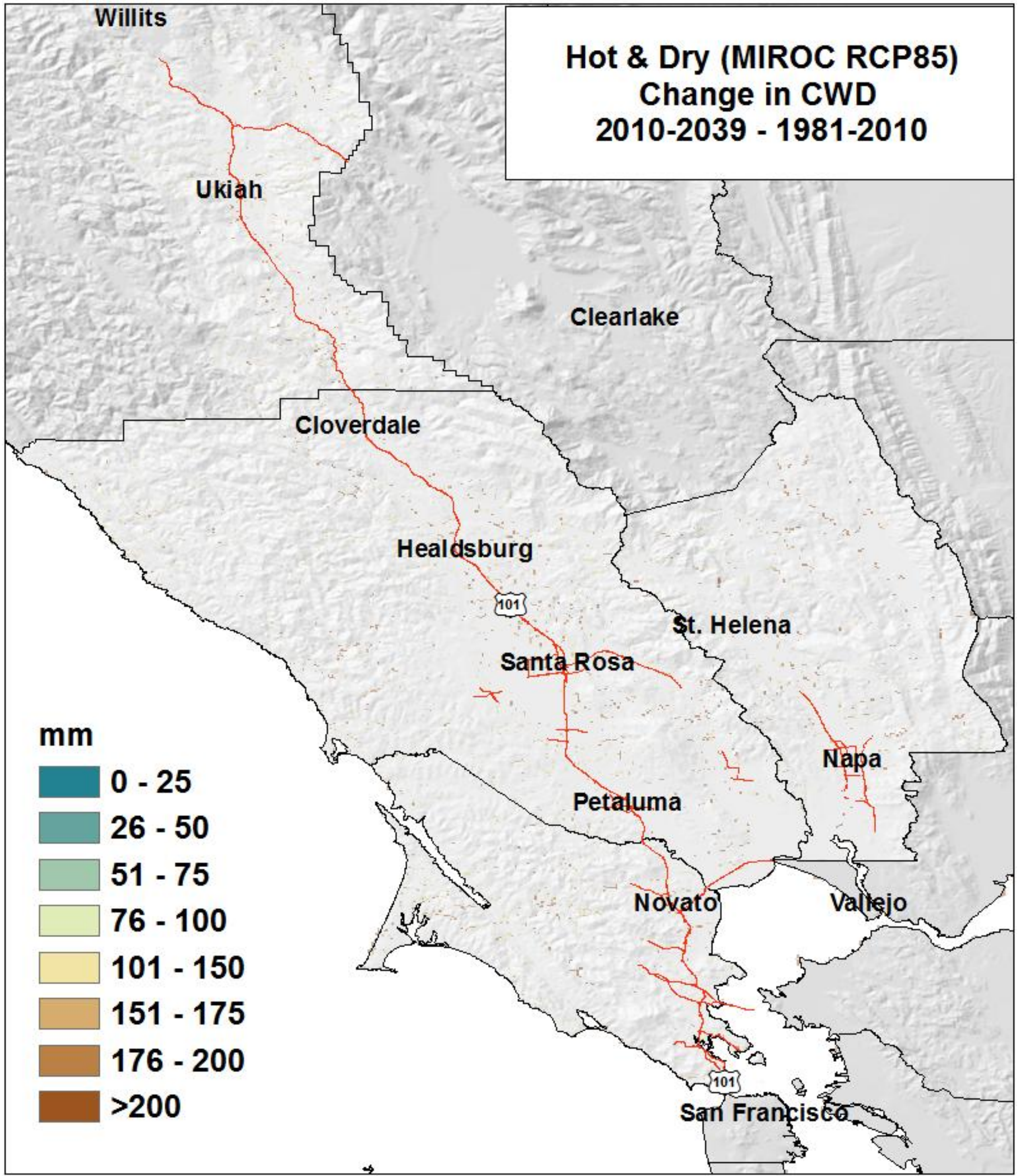
Future minus Current
Hot & Low Rainfall
2040-2069





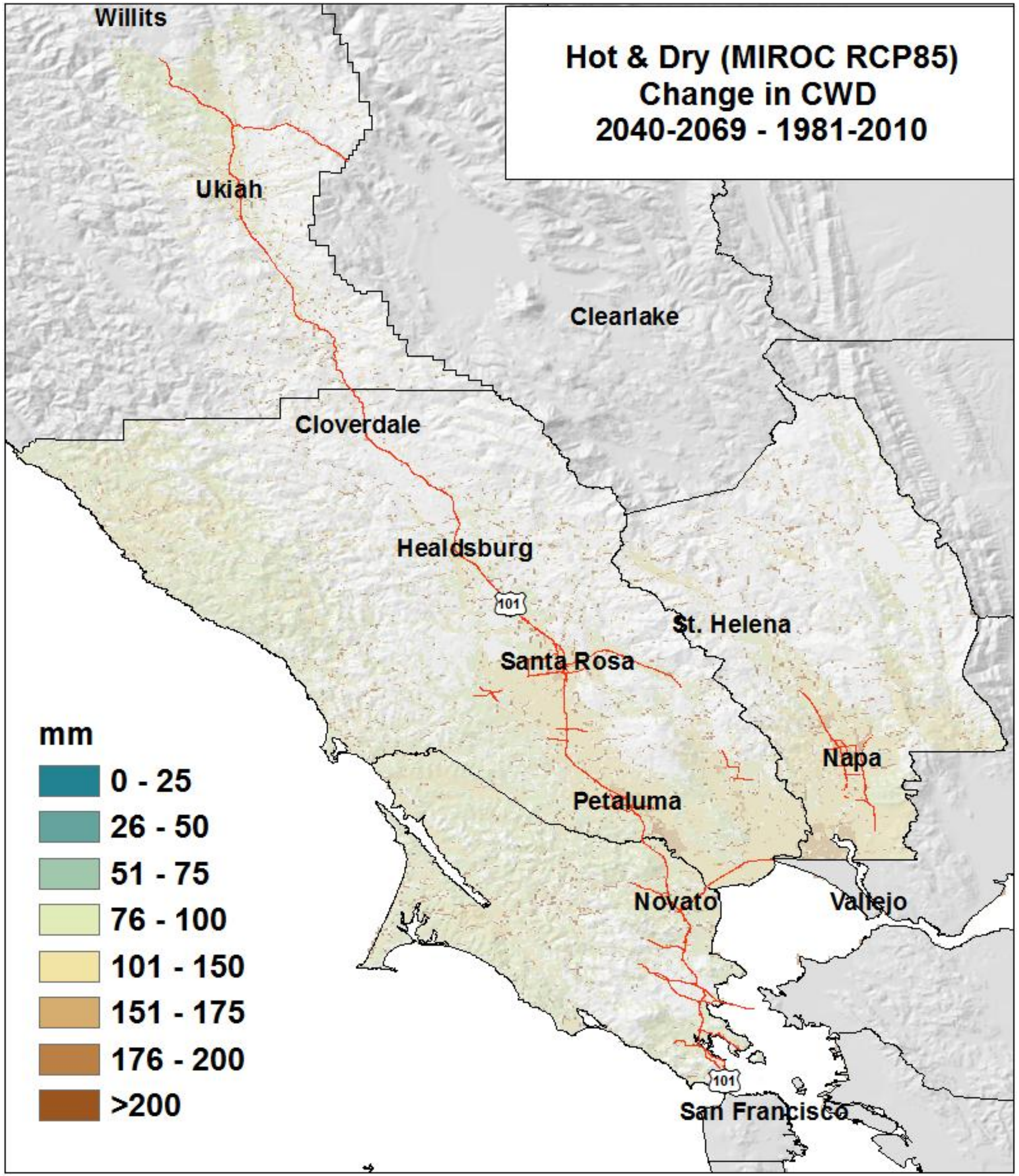
Gray indicates areas that have a projected change less than the historical variability

Change in Climatic Water Deficit



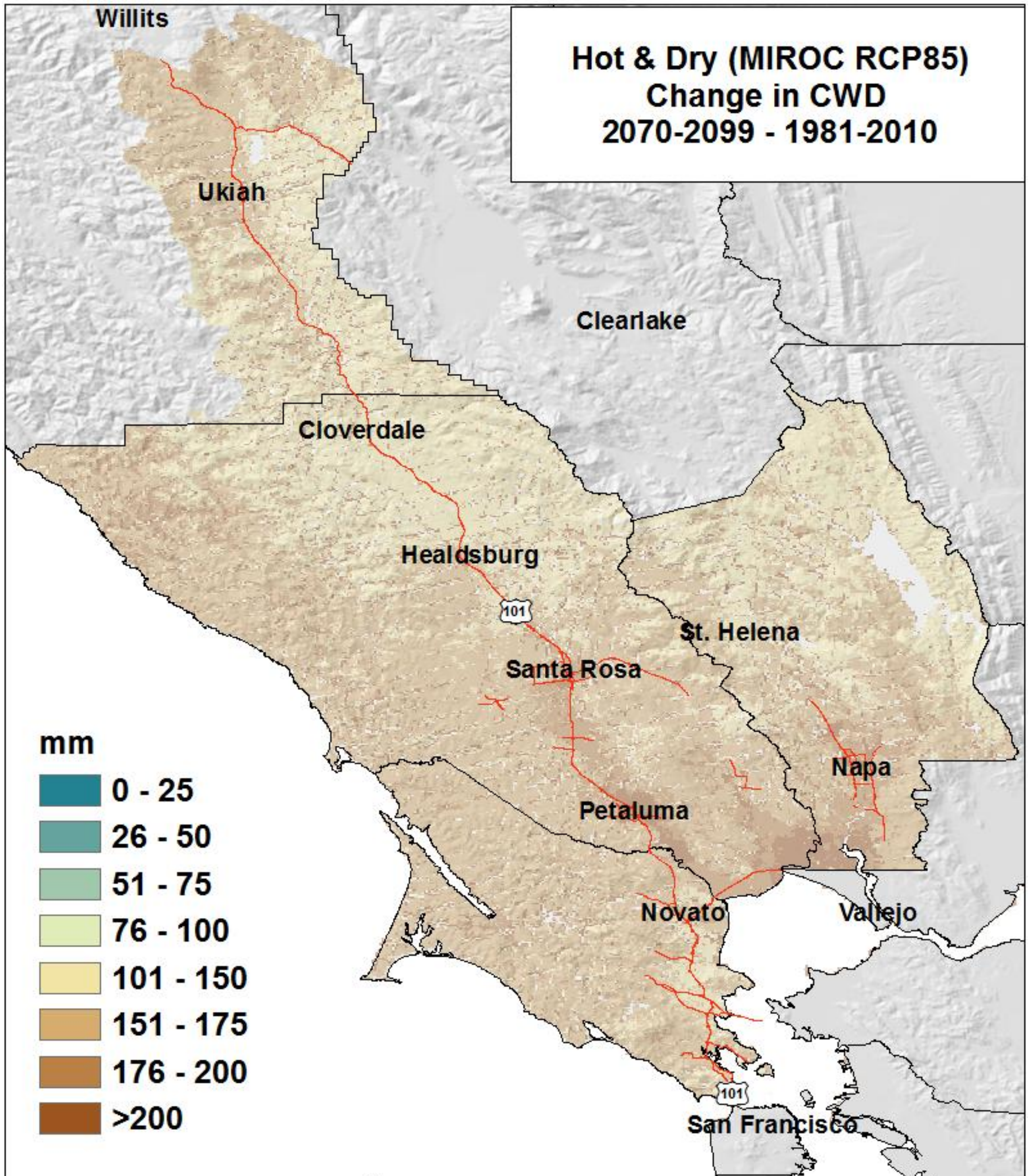
Gray indicates areas that have a projected change less than the historical variability

Change in Climatic Water Deficit



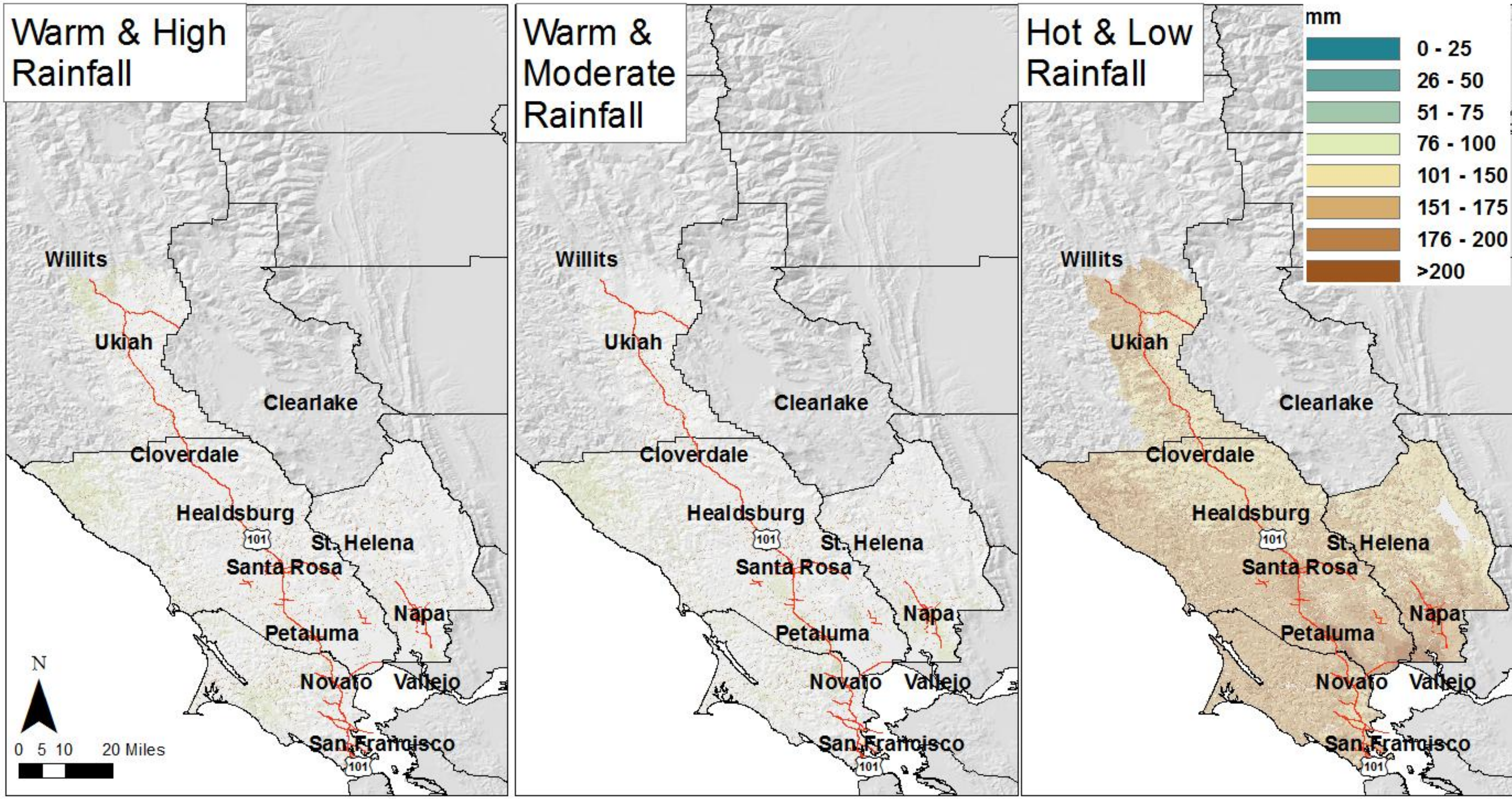
Gray indicates areas that have a projected change less than the historical variability

Change in Climatic Water Deficit



Gray indicates areas that have a projected change less than the historical variability

Change in Climatic Water Deficit, 2070-2099



Basin Characterization Model: North Bay Region
Trends in 30-year average values, historical-2099

		Historical	Current	Moderate Warming, High Rainfall		Moderate Warming, Moderate Rainfall		Hot, Low Rainfall	
Variable	Units	1951-1980	1981-2010	2040-2069	2070-2099	2040-2069	2070-2099	2040-2069	2070-2099
Ppt	in	42.6	43.0	53.6	57.9	42.1	45.6	34.8	33.9
Tmn	Deg F	38.8	39.7	43.0	45.9	41.9	44.8	44.1	47.3
Tmx	Deg F	82.2	82.2	86.4	89.4	86.0	88.5	89.2	93.4
CWD	in	28.0	28.4	29.8	31.3	30.3	31.4	32.0	34.6
Rch	in	11.0	10.2	12.8	13.2	10.7	10.8	8.2	8.5
Run	in	14.0	14.2	22.8	26.9	14.0	17.3	9.7	9.3

				Percent Change from Current or Change in Temperature					
			Current	Moderate Warming, High Rainfall		Moderate Warming, Moderate Rainfall		Hot, Low Rainfall	
Variable	Units		1981-2010	2040-2069	2070-2099	2040-2069	2070-2099	2040-2069	2070-2099
Ppt	in		43.0	25%	35%	-2%	6%	-19%	-21%
Tmn	Deg F		39.7	3.2	6.1	2.2	5.0	4.3	7.6
Tmx	Deg F		82.2	4.1	7.2	3.8	6.3	7.0	11.2
CWD	in		28.4	5%	10%	7%	11%	12%	22%
Rch	in		10.2	25%	29%	4%	6%	-20%	-17%
Run	in		14.2	61%	90%	-1%	22%	-32%	-34%

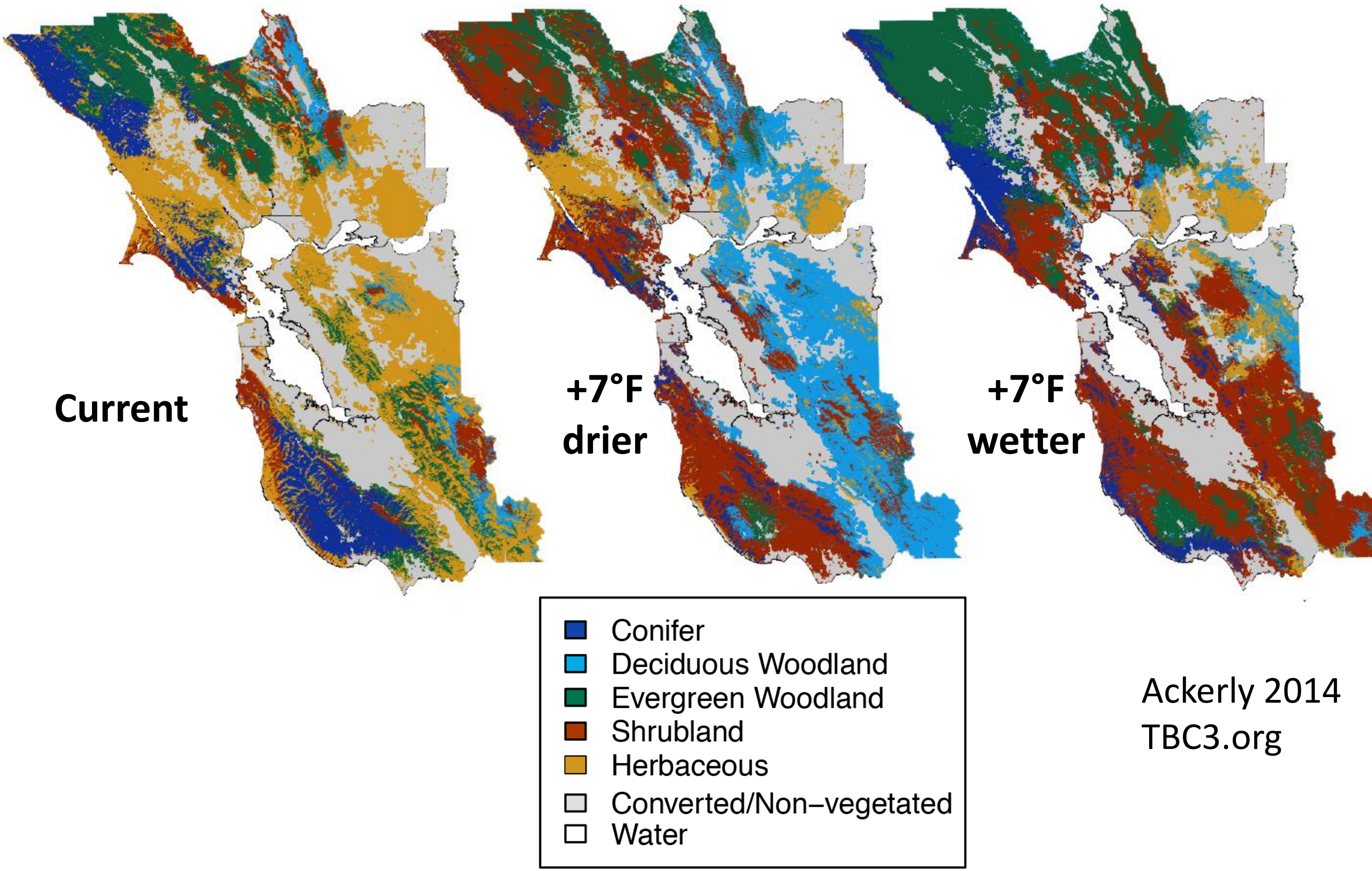
VARIABLES: Ppt=precipitation, Tmn=minimum winter temperature (monthly), Tmx=maximum summer temperature (monthly), CWD=climatic water deficit, Rch=recharge, Run=runoff

USGS, Point Blue, Pepperwood 2015

Potential native vegetation responses to changing climate

Pepperwood
PRESERVE
Inspiring conservation through science

what might the Bay Area vegetation of the future look like?

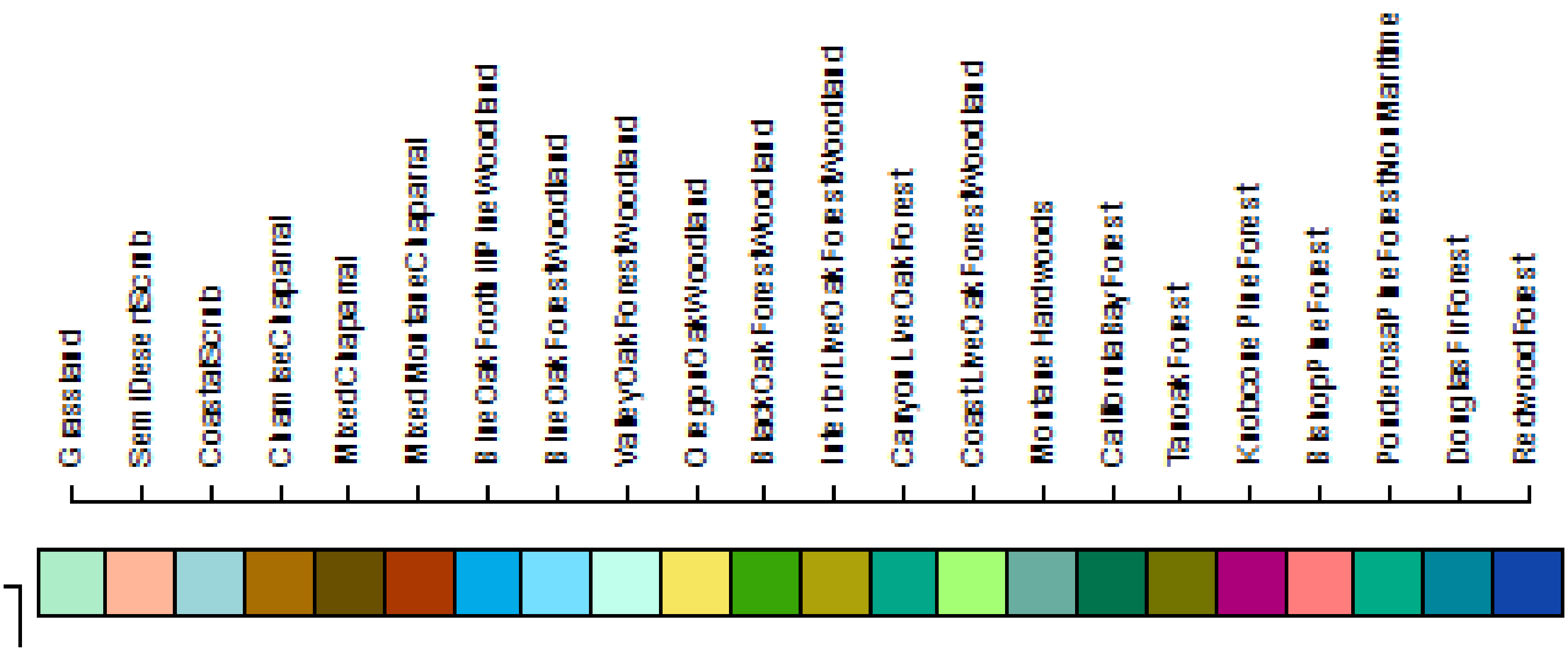


Ackerly 2014
TBC3.org

Equilibrium vegetation response to climate change in

The North Bay Climate ready Region

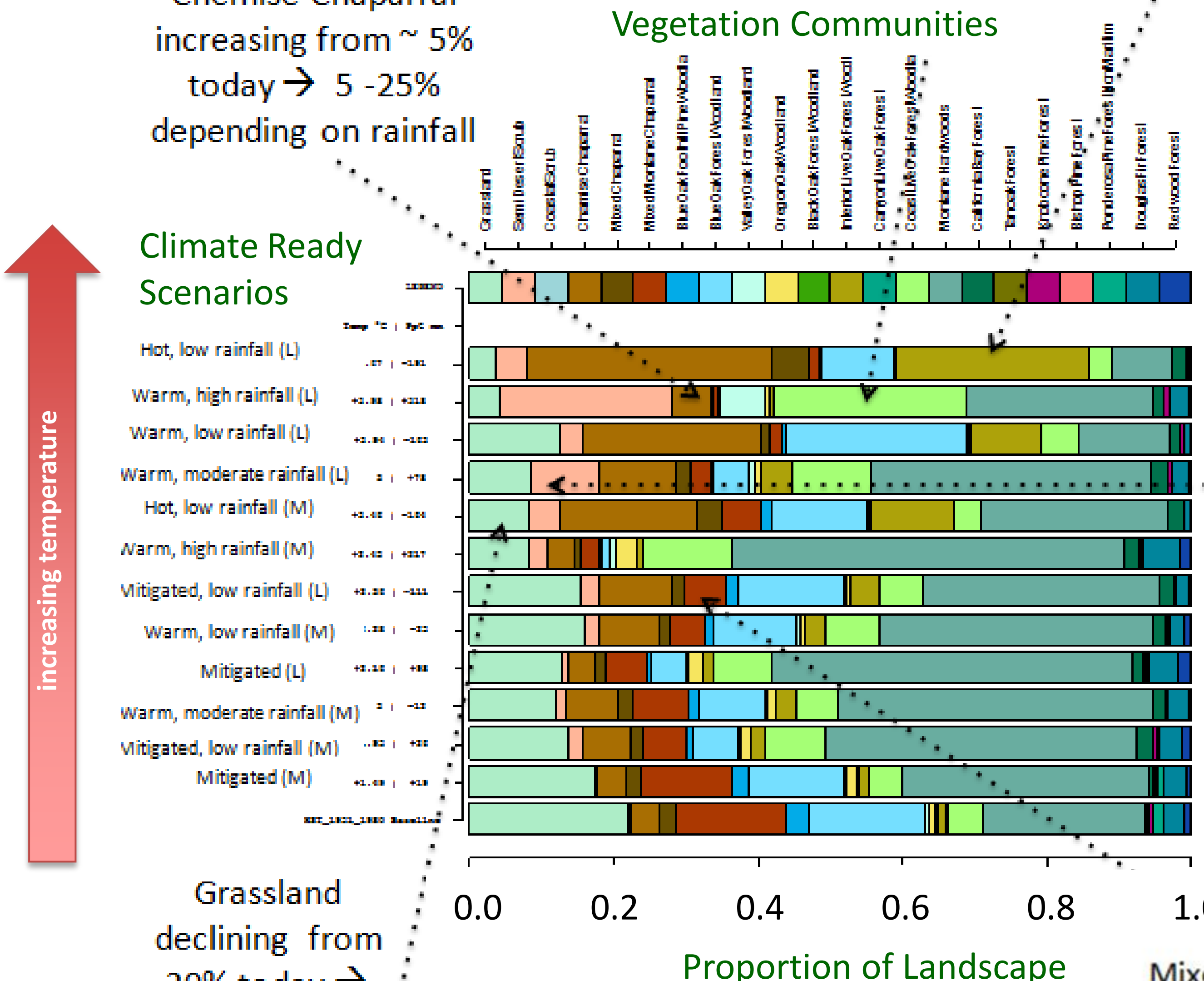
Projected proportional landscape cover of 22 vegetation types under both historical conditions and six future scenarios, organized from top to bottom by increasing temperature. This is an equilibrium model so this assumes vegetation has had time to adjust to climate conditions. In reality , vegetation turnover will take time. Fires and other disturbance can accelerate shifts. How land is managed will also affect rate of change. For example, grasslands may be maintained by active grazing, burning or mowing. Data from D.D. Ackerly 2015.



Napa County Vegetation Report Summary

Coast Live Oak and Interior Live Oak increasing from ~ 5% today → 5 - 25% late century, depending on rainfall

Conditions for Chemise Chaparral increasing from ~ 5% today → 5 -25% depending on rainfall

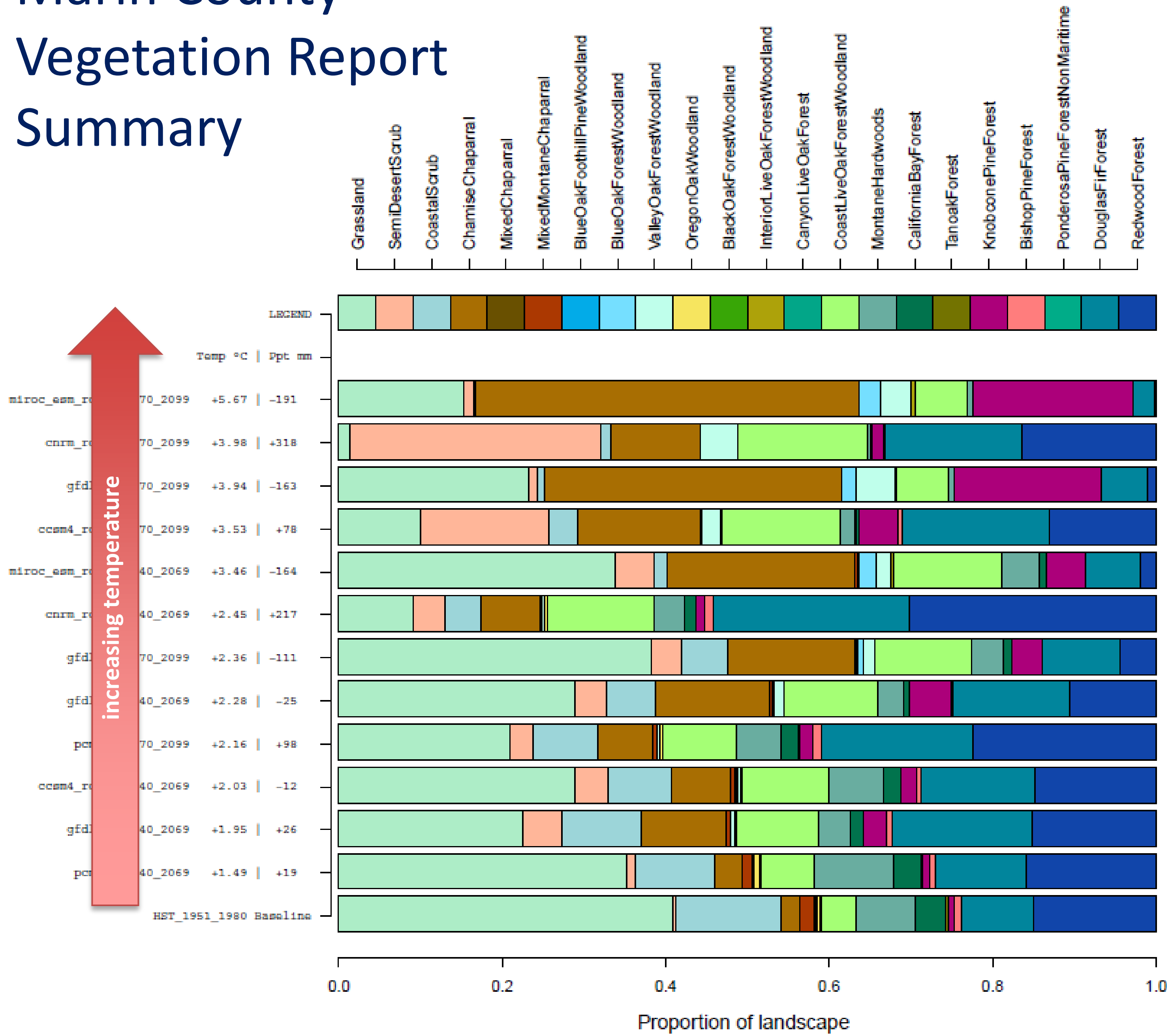


Semi-desert Scrub emerges and becomes common

Grassland declining from 20% today → < 10% in late century

Mixed Montane Chaparral declining from ~10% → < 5% by mid century

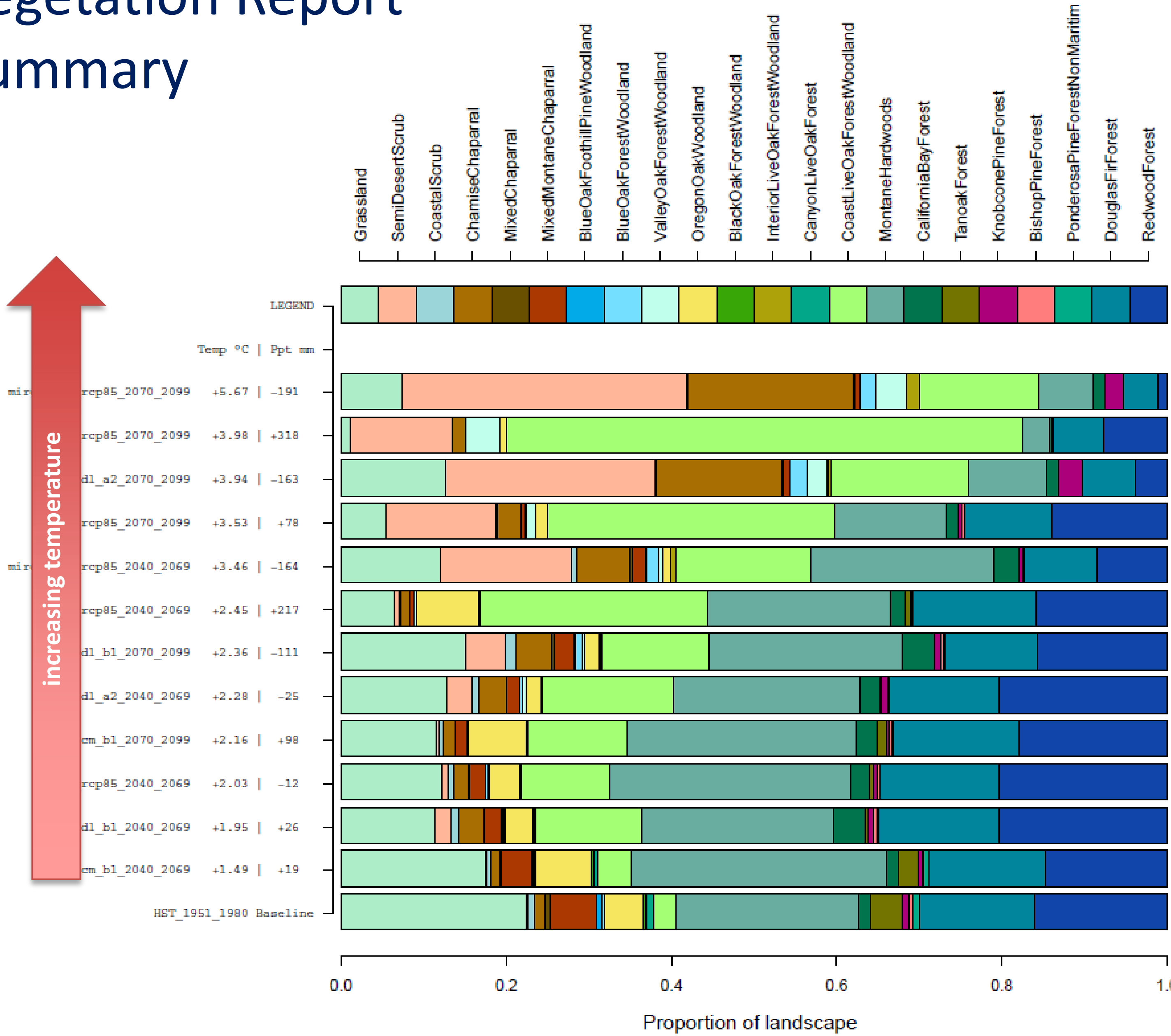
Marin County Vegetation Report Summary



Reduced suitability for redwood, doug-fir, montane hardwoods, and grasslands

Increased suitability for coast live oak, semi-desert scrub, chamise chaparral, and knobcone pine

Sonoma County Vegetation Report Summary

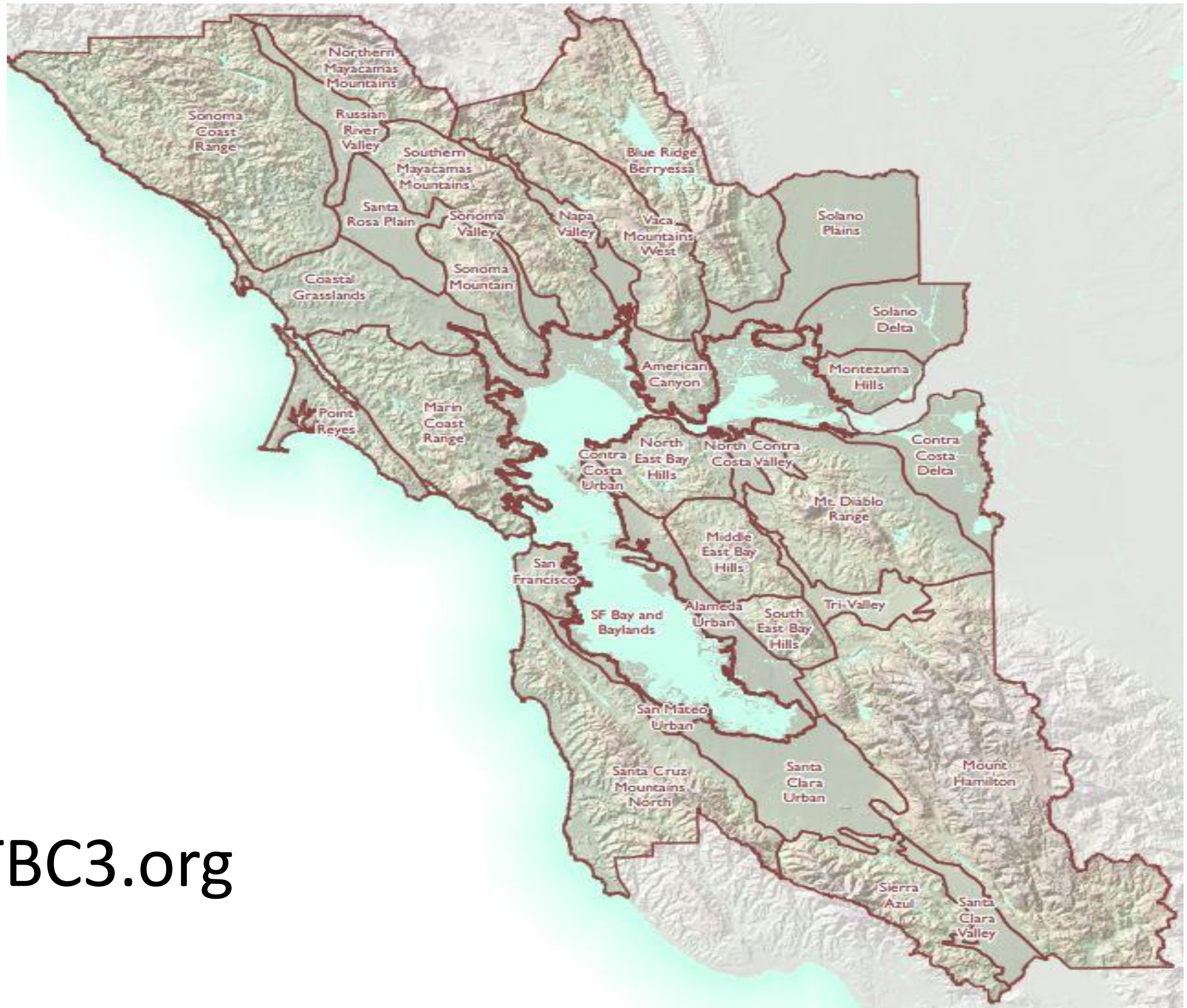


Reduced suitability for redwood, doug-fir, and montane hardwoods,

Increased suitability for coast live oak, semi-desert scrub, chamise chaparral

Climate Ready Vegetation Reports

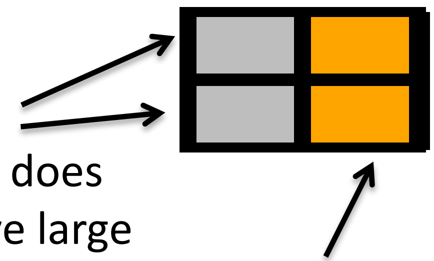
Also available for Landscape Units defined by Bay Area Upland Habitat Goals Project (2011)



TBC3.org

Another way to look vegetation data:
Four-square diagrams

***Example:** Redwood Forest is sensitive to temperature in Sonoma's Coast Range*



Rainfall does not have large affect

Significant declines emerge at hotter temperatures.

Color-coding the square quadrants shows the direction of change in percent cover in suitable climate for veg type (current to 2050)

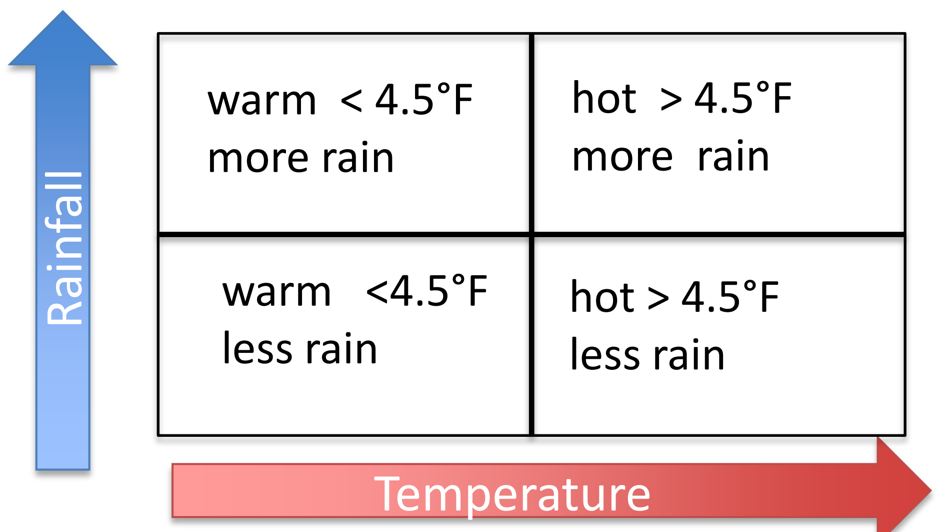
Red: Dramatic Decline (<25% of current)

Orange: Moderate Decline (25-75% of current)

Gray: Relative Stability (75-125% of current)

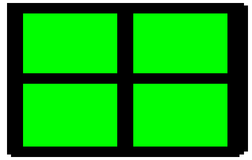
Green: Increase (>125% of current)

Each quadrant in the square higher or lower temperature and rainfall



Sonoma Coast Range Species Level Examples

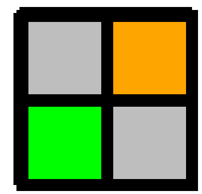
Example: Coast Live Oak



does well in all future scenarios regardless of warming magnitude and rainfall

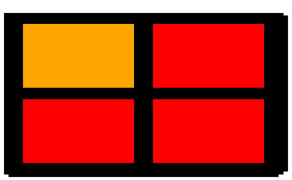
Example: California Bay is sensitive to rainfall in the Coast Ranges

does well in moderate scenario, but declines in hot and low rainfall



Identify potential "winners and losers" by landscape unit

Example: Tan Oak is sensitive to rainfall and temperature



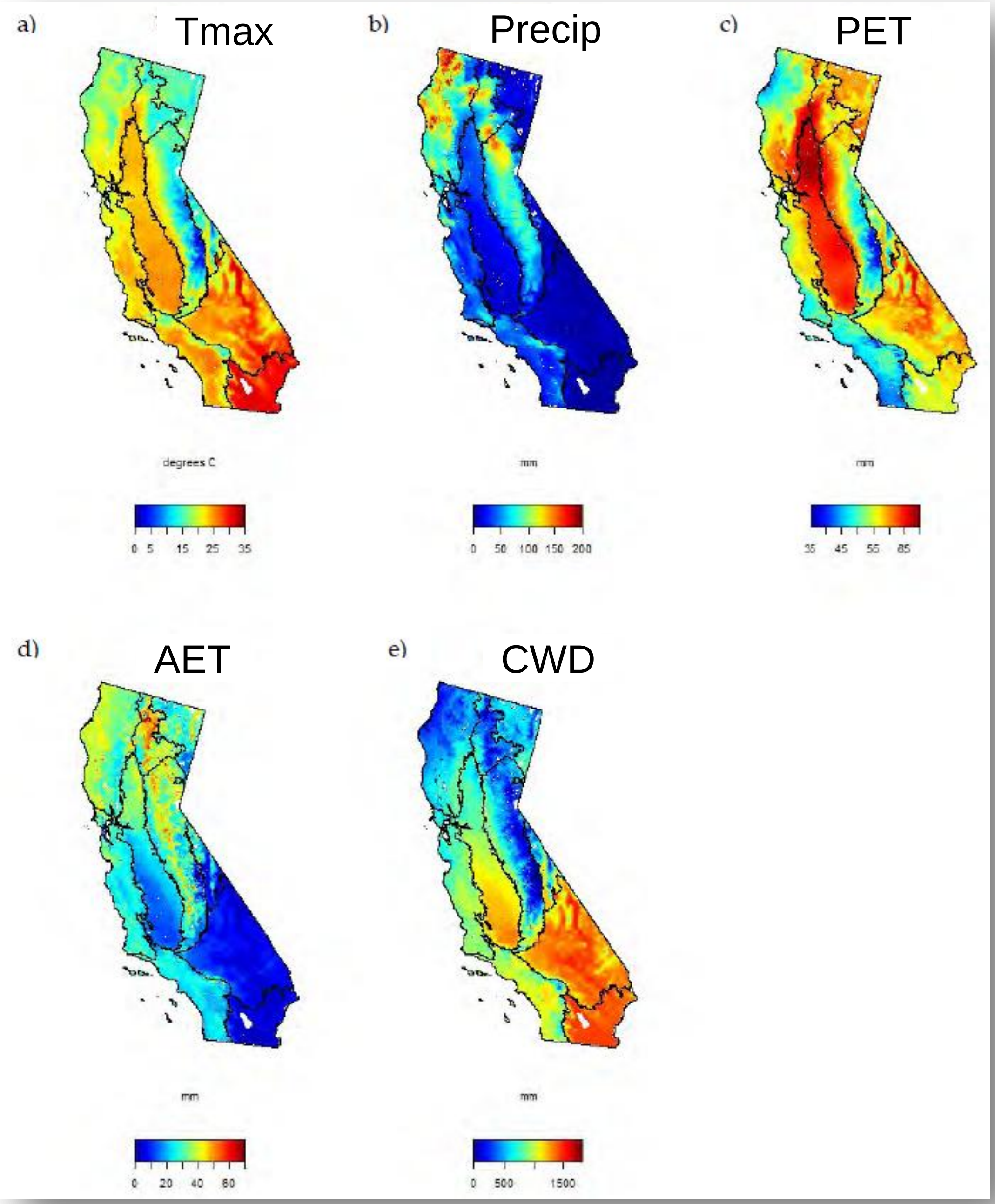
shows declines in all scenarios

Modeled fire risks
Climate Ready North Bay Region

Pepperwood
PRESERVE
Inspiring conservation through science

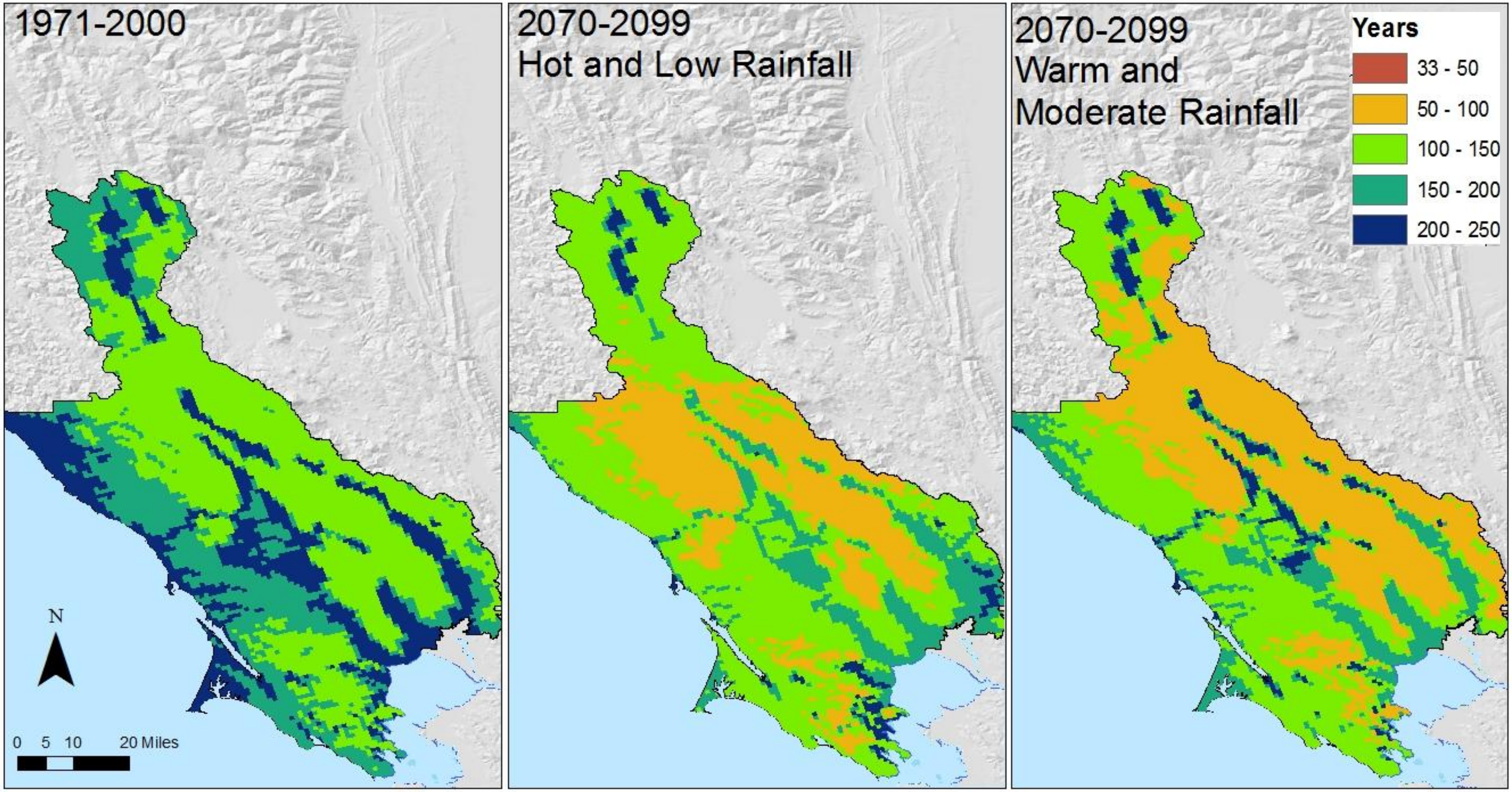
Statewide Fire Risk Model: BCM data inputs

Spatial patterns of statewide input climate variables 1971–2000



Krawchuk and Moritz 2012 PIER report

Change in Projected Fire Return Interval



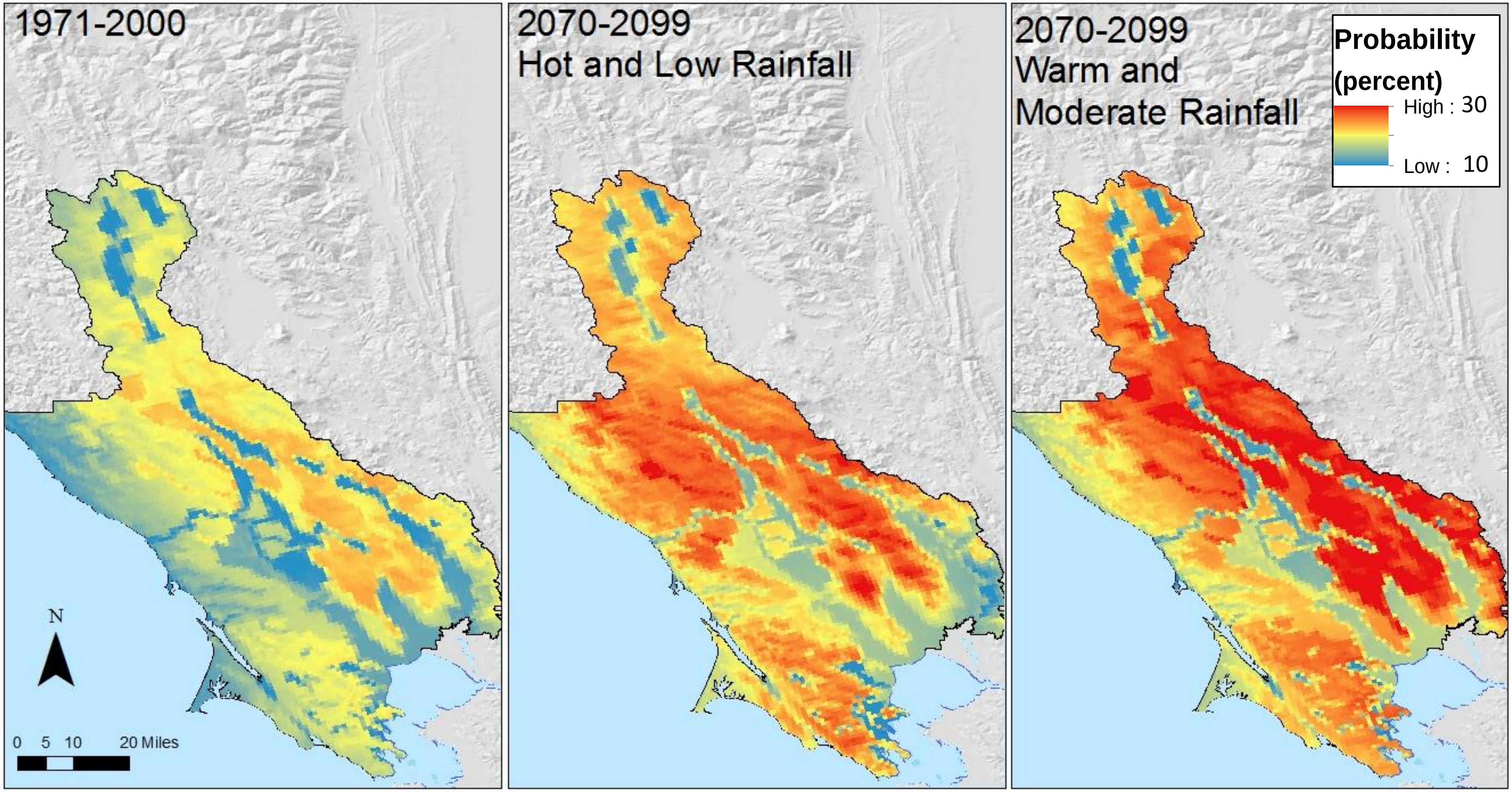
172 yr average historic return interval

117 yr average projected return interval

120 yr average projected return interval

Average regional fire return intervals reduced by approximately 30%

Change in Projected Fire Probability



Historic average probability of 17%

Projected: 23% average

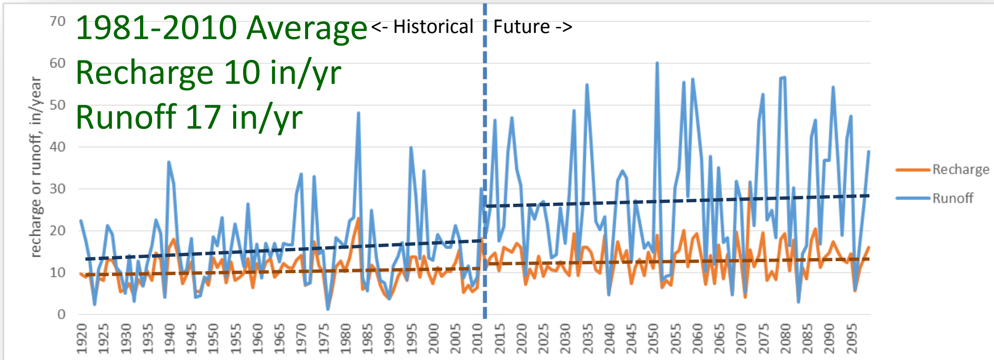
Projected: 23% average

Probability of burning one or more times within 30 years increases by an average of 35%, extremes are worse in increased rainfall locations due to additional fuels

Sample user-defined management questions (in green) and responsive products

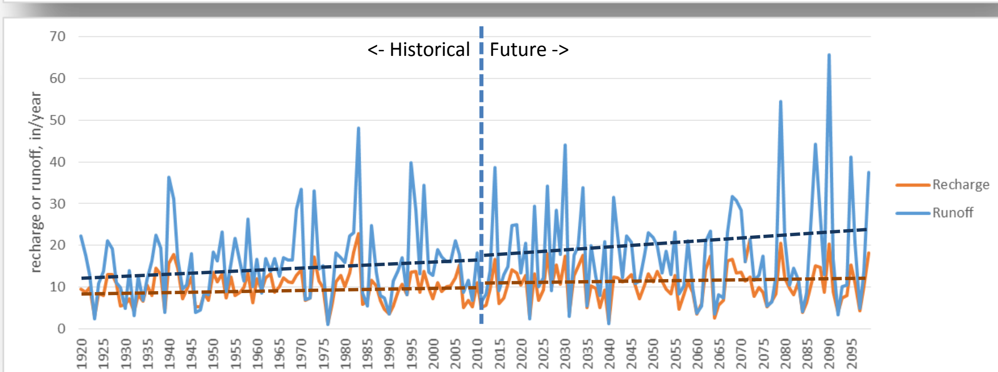
How will climate change impact the annual variability of available water supply?

Scenario 5
Warm &
High Rainfall



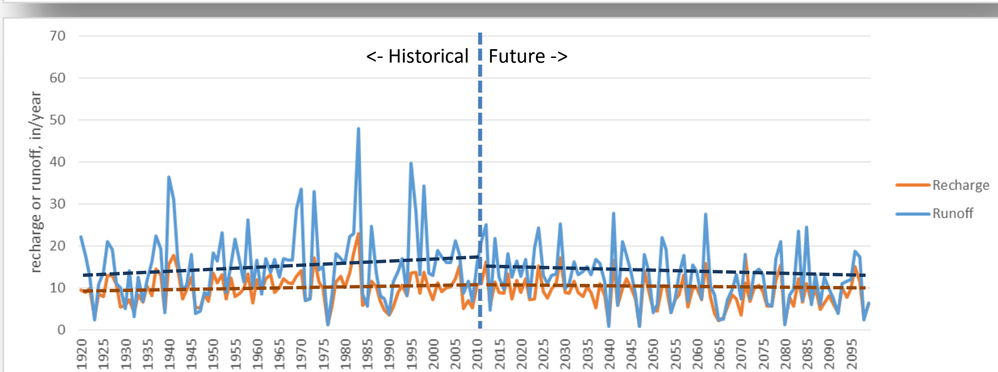
End century averages
Recharge 13 in/yr
Runoff 30 in/yr

Scenario 3
Warm &
Moderate
Rainfall



End century averages
Recharge 10.5 in/yr
Runoff 20 in/yr

Scenario 6
Hot &
Low Rainfall

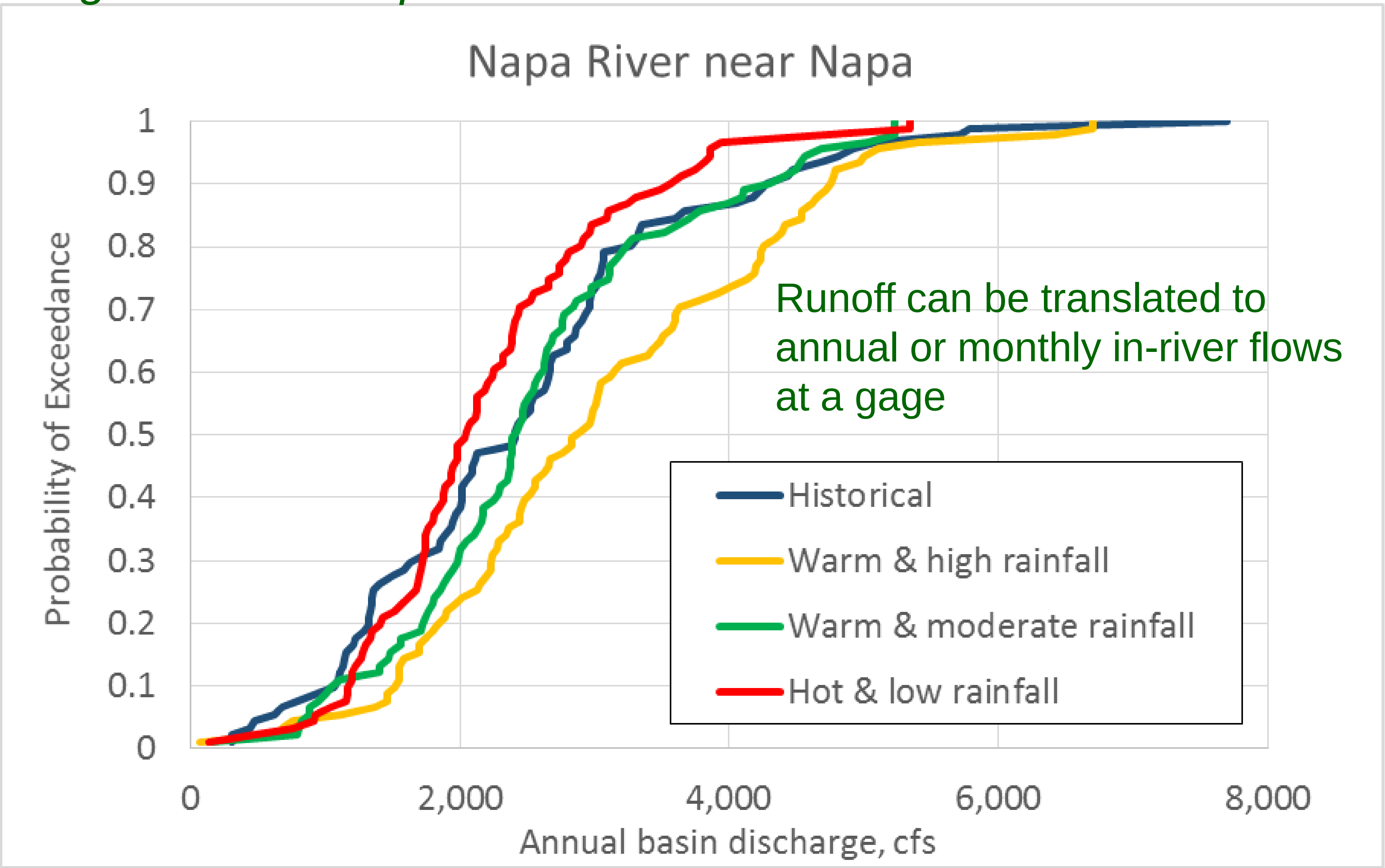


End century averages
Recharge 8 in/yr
Runoff 11 in/yr

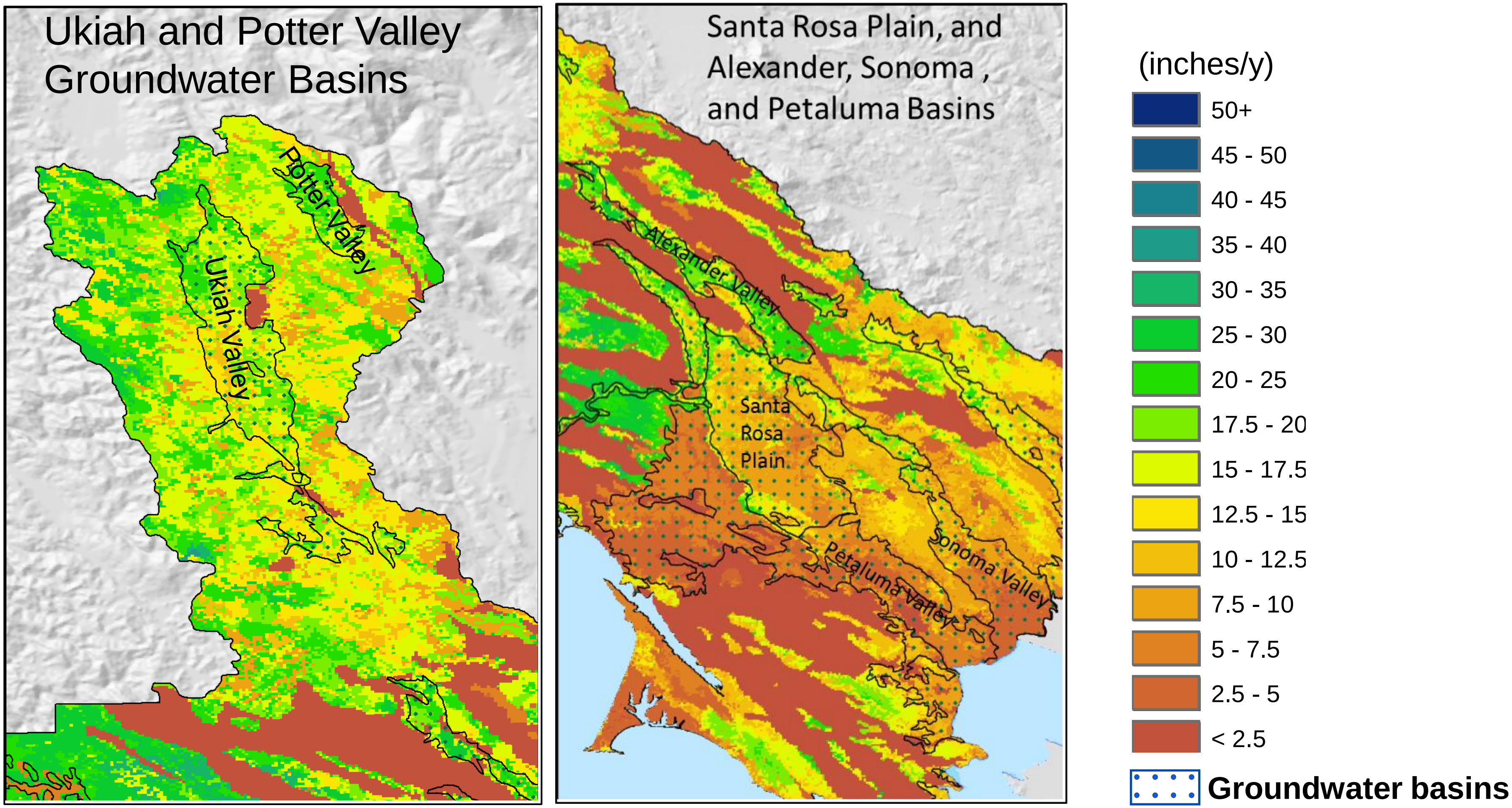
Sonoma County Annual Recharge
and Runoff, 1920-2099

Recharge is less variable than runoff across all futures

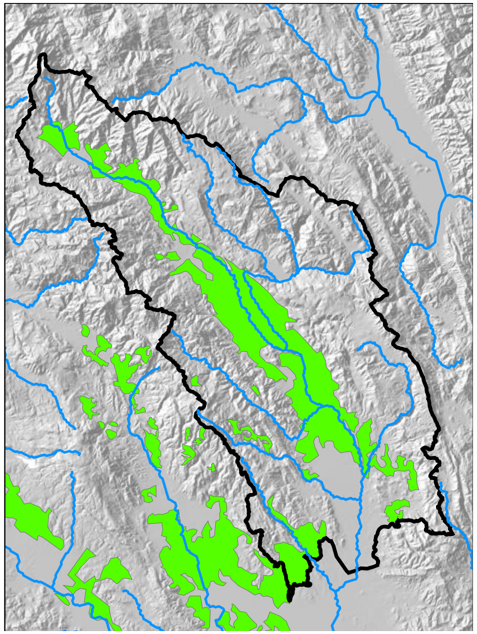
What are the potential impacts of climate change on the flow regime of the Napa River?



Russian River Valley Recharge, 30-y avgs, 1981-2010

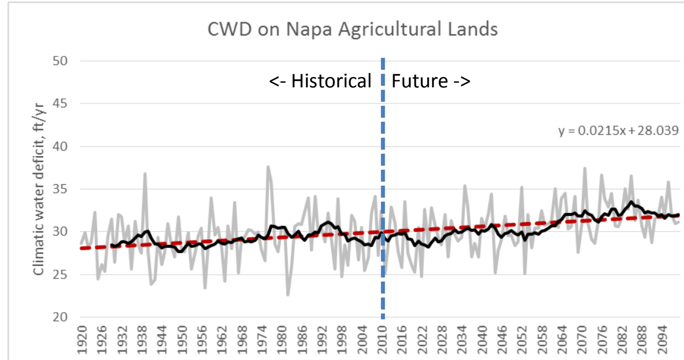


What is the spatial variability in potential groundwater recharge and where are high value recharge zones located?



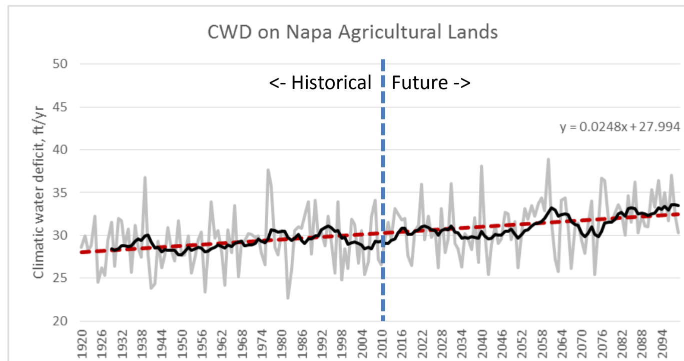
How will the agricultural lands of the Napa Valley be potentially impacted by climate change in terms of irrigation demand?

Scenario 5
Warm &
High Rainfall



last 30 years 9 % greater deficit

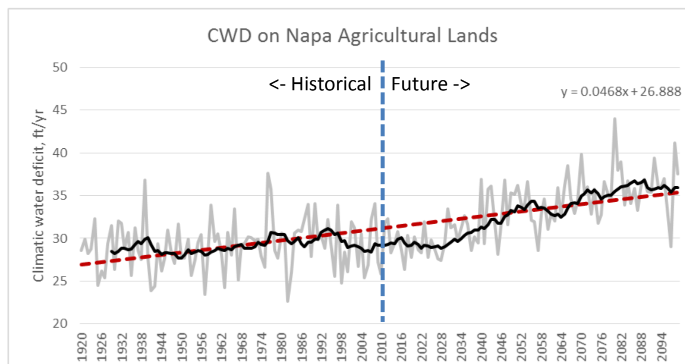
Scenario 3
Warm &
Moderate
Rainfall



last 30 years 10 % greater deficit

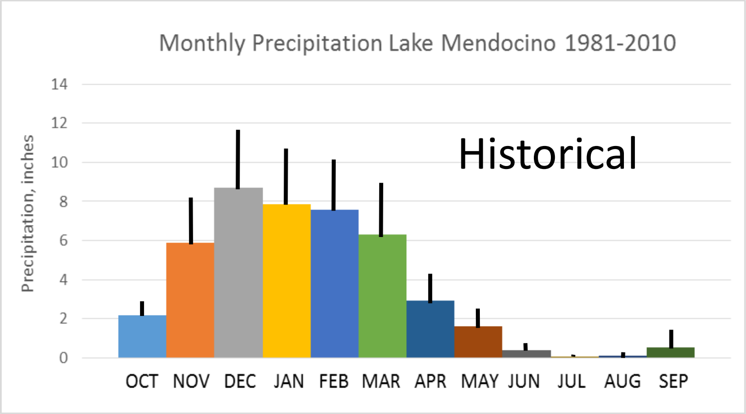
Water deficits increase in even high rainfall scenarios

Scenario 6
Hot &
Low Rainfall

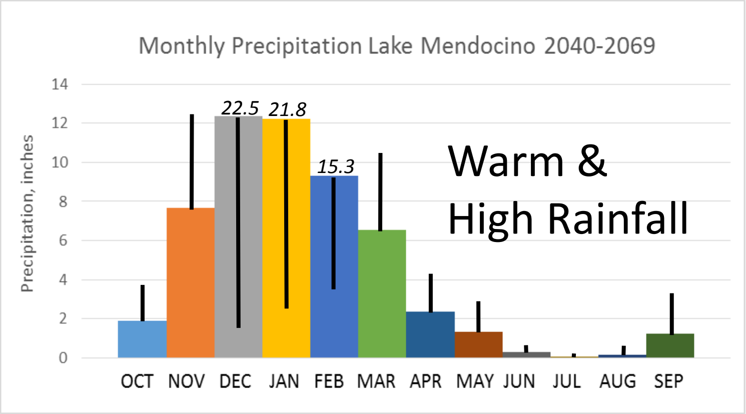


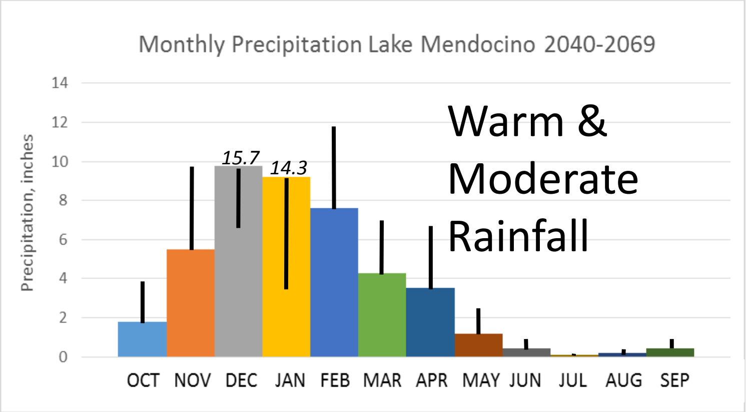
last 30 years 20 % greater deficit

How will climate change impact the seasonality of annual rainfall our reservoir basin?

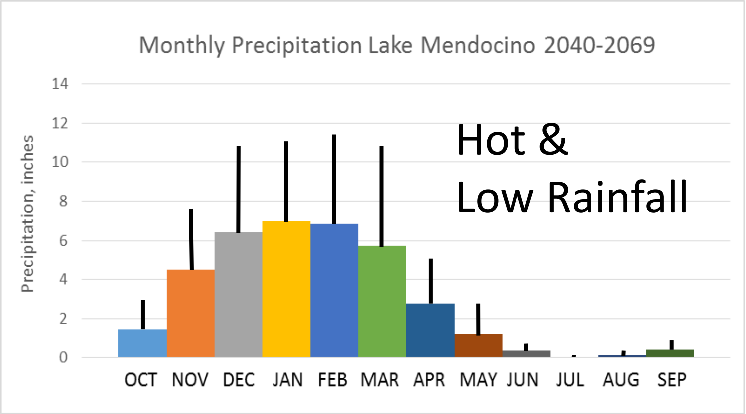


Length of bar is ½ standard deviation of monthly precipitation



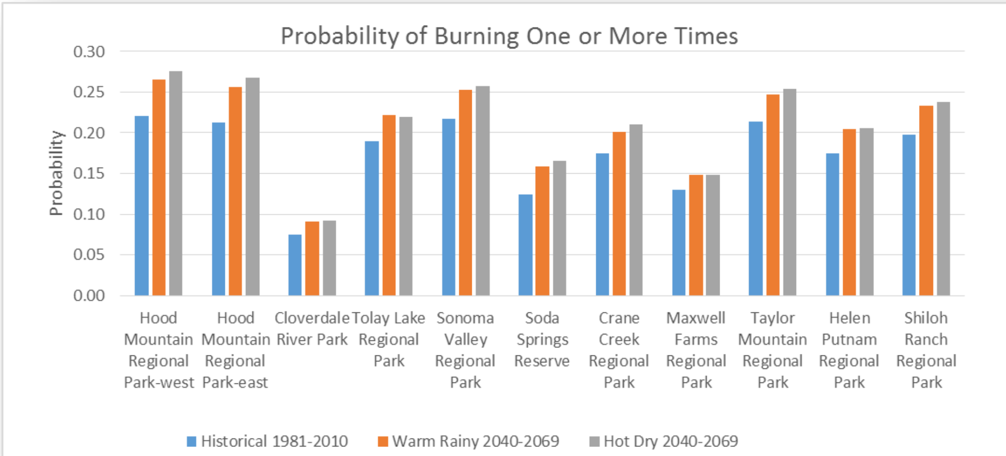


- Seasonality of average rainfall doesn't change much for Lake Mendocino watershed by mid-century
- Wet scenario: additional rainfall concentrated in mid-winter
- Dry scenario: reductions in Nov-Dec
- Increases in monthly variability for all scenarios, notably wetter ones

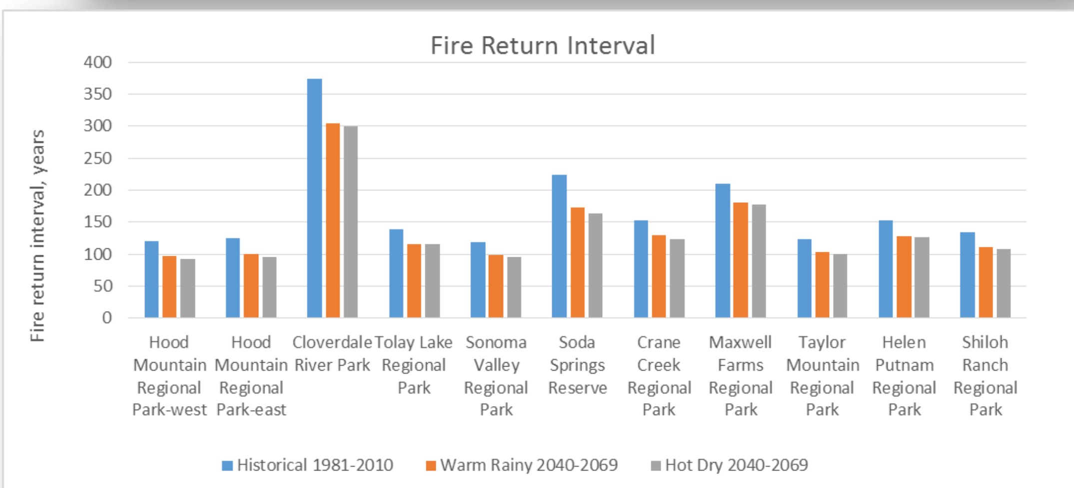


Rainfall Seasonality: Lake Mendocino Basin

How might climate change impact the risk of fire on our Sonoma County regional parks?



Average probability of a burn within 30 years goes up 18% by mid-century

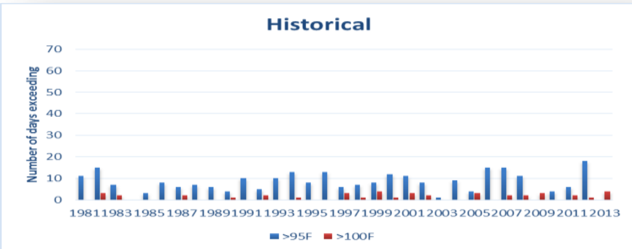


Average fire return interval goes down 18% by mid-century

See Table in "CRNB Sonoma Parks and Open Space FireRisk.xls" spreadsheet

Daily product samples

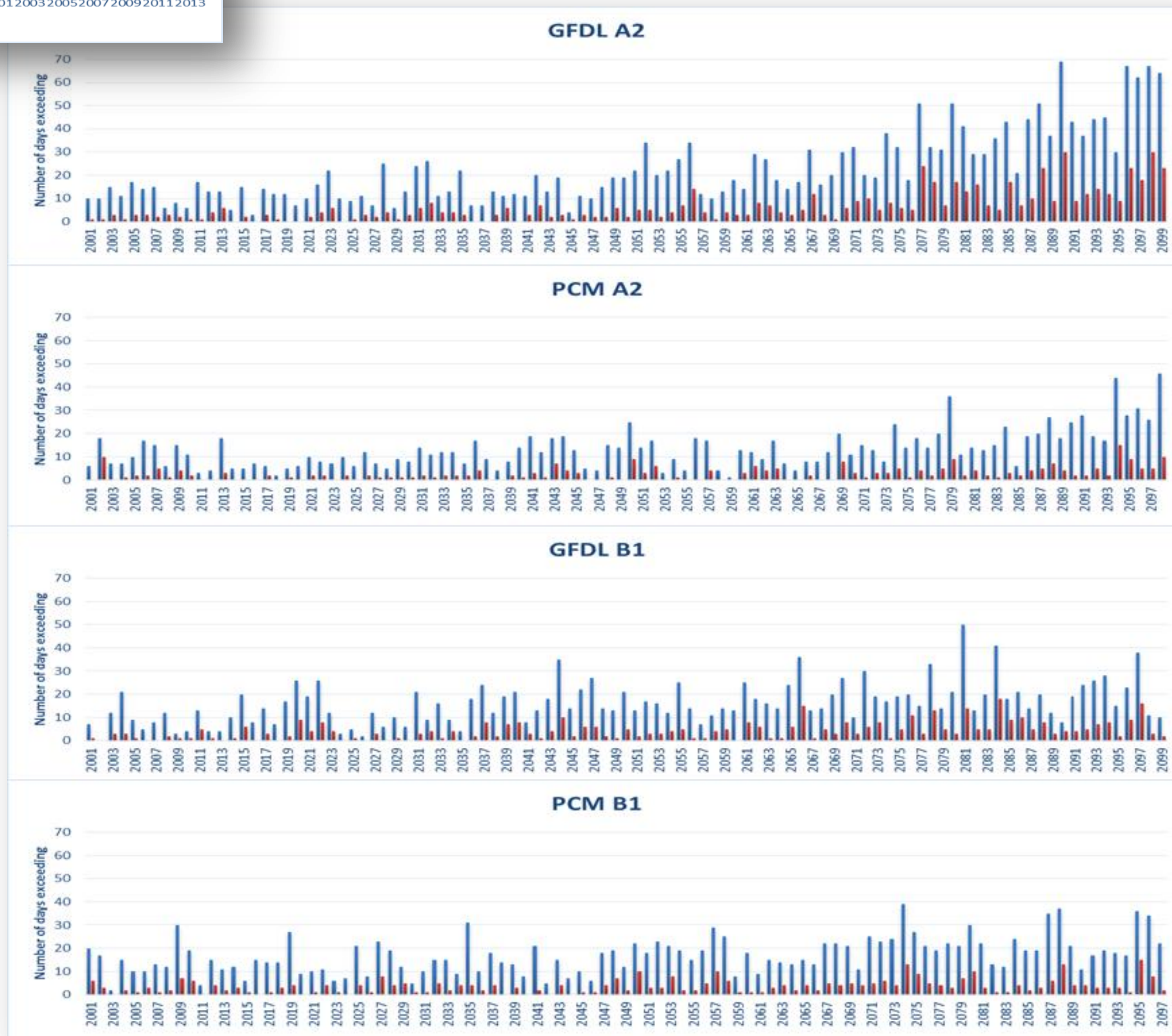
How might climate change impact the magnitude and frequency of heat waves impacting the health of vulnerable populations?



>95F

>100F

Extreme Heat Days for Santa Rosa Plain



3-day high flows for Upper River and Lower Russian River (modeled)

3-day flows exceedances of 99.9% threshold (per decade)

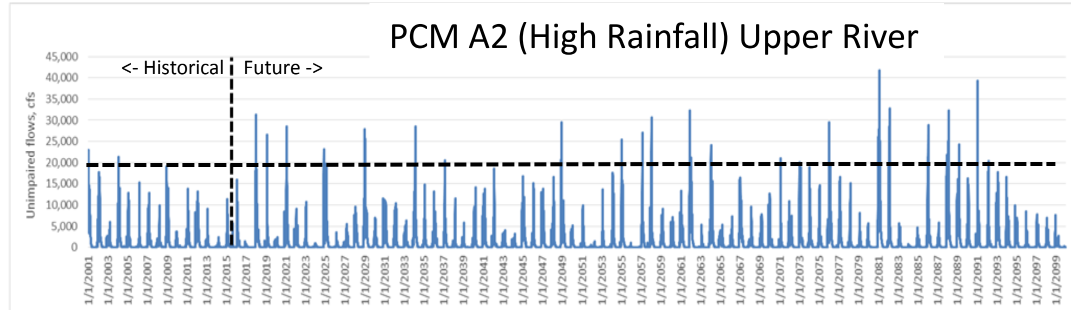
19,298 cfs threshold for upper river
38,902 cfs threshold for lower river

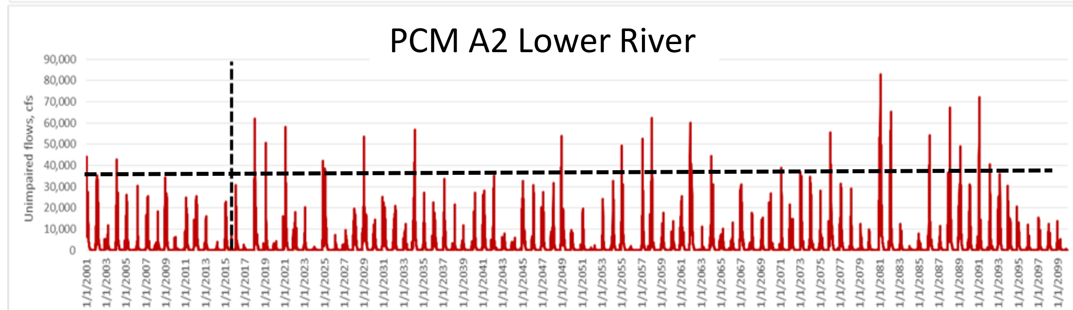
2001-2015 vs 2016-2099
(exceedances per decade)

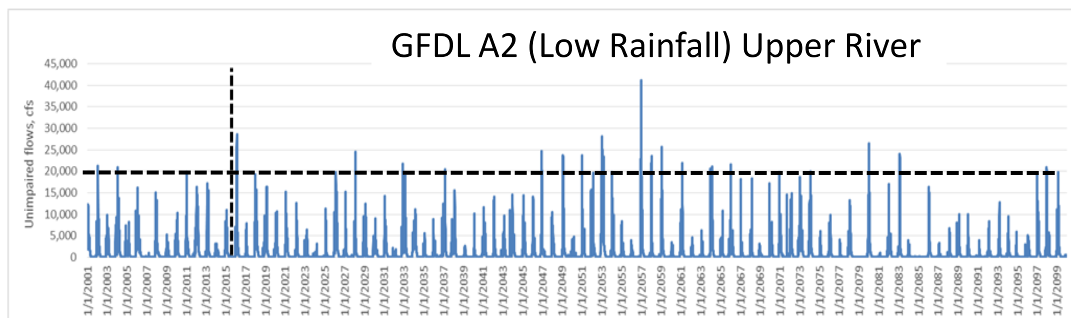
	Upper River: Healdsburg		Lower River: Guerneville	
	Current (2001-15)	Future (2016-99)	Current (2001-15)	Future (2016-99)
Business-as-usual				
PCM A2	1.3	3.9	1.3	3.6
GFDL A2	2.0	3.6	0.7	3.3
Mitigated				
PCM B1	4.0	4.8	3.3	4.6
GFDL B1	2.0	3.7	1.3	3.6

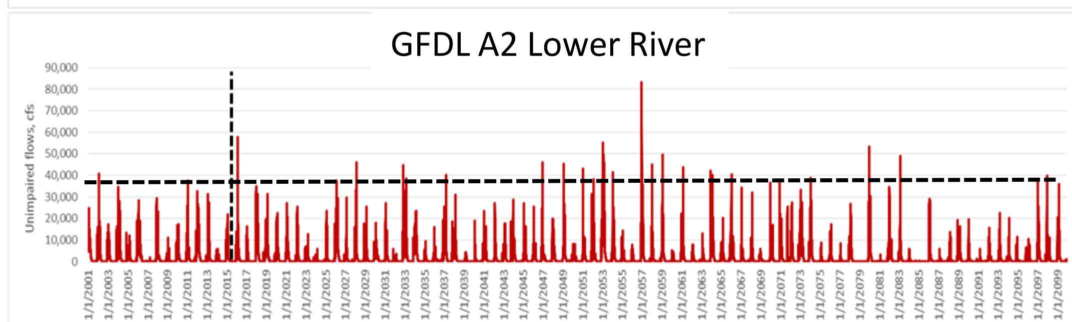
The frequency of 3-day "very high flow" events are up to 4 x more likely to occur than they do currently.

PCM wet model
GFDL dry model









Take home messages and lessons learned

What kind of long-term plans can use this landscape-level data?

In general:

human health energy demand watershed plans
surface water supply fire and hazard mitigation
sustainable groundwater management agricultural
sustainability ecological restoration

Napa: Groundwater Management

Marin: 40-y Urban Water Management Plan

Sonoma: Climate Action 2020, Basin Advisory Panels and SGMA Compliance
Water Agency Adaptation Planning-including reservoirs ops, drought preparedness, demand projections, SCAPOSD Acquisitions, Regional Parks Management Plans, RCD Watershed Plans

What do the models agree on?

Take home messages for managers

Rising temperatures across the region will generate unprecedented warm conditions for both summer and winter seasons.

Rainfall is likely to be more variable in the future.

The North Bay region is becoming more arid (subject to drier autumn soil conditions) due to rising temperatures.

Runoff may be increasingly flashy, with rates of groundwater recharge relatively less variable over time.

Protecting available recharge areas will be critical to water supply sustainability.

Water demand for agriculture may increase on the order of 10%.

Fire frequencies are projected to increase on the order of 20%, requiring additional readiness planning and more aggressive fuels management.

Vegetation may be in transition, meriting additional monitoring and consideration of a more drought-tolerant planting palette.

Lessons learned about "co-production"

Take home messages for vulnerability assessments

Time and patience are required for a meaningful in-depth iterative exchange-minimum 12 months, 12 meetings.

Key players-scientists with appetite for applied work, managers with scientific curiosity, information broker with experience in both realms. NGOs can play critical role of "flexible glue" to facilitate collaboration.

Mutual learning is possible! Engaged managers gained the most by "playing" with the data, scientists revealed cool trends when conducting management based queries.

Distillation of key take home messages a goal for managers.

Managers see products as valuable for outreach and education of their constituencies: additional resources needed to do this well.

Integration of long-term climate products into existing planning processes (instead of stand-alone adaptation plans) may be most effective local approach

Regional science linked to local implementation a potent combination-facilitates cross-jurisdictional coordination, but retains local autonomy

California Climate Commons
North Bay Climate Ready Exchange

climate.calcommons.org
hosting “Climate Smart Exchange” page for users