Changing Flood Risks in the Central Valley

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California Water Environmental Modeling Forum

Folsom, California

April 11, 2016

WT0210151051SAC

Perspectives on Flood Management in a Changing Climate

Outline

- Historical Perspectives on CV Floods
- Causal Mechanisms of Historical Floods
- Grappling with a Changing Climate
- Climate Change and Future CV Flood Risks
- Adapting our Flood Planning and Flood Management

Historical Perspectives on Central Valley Floods

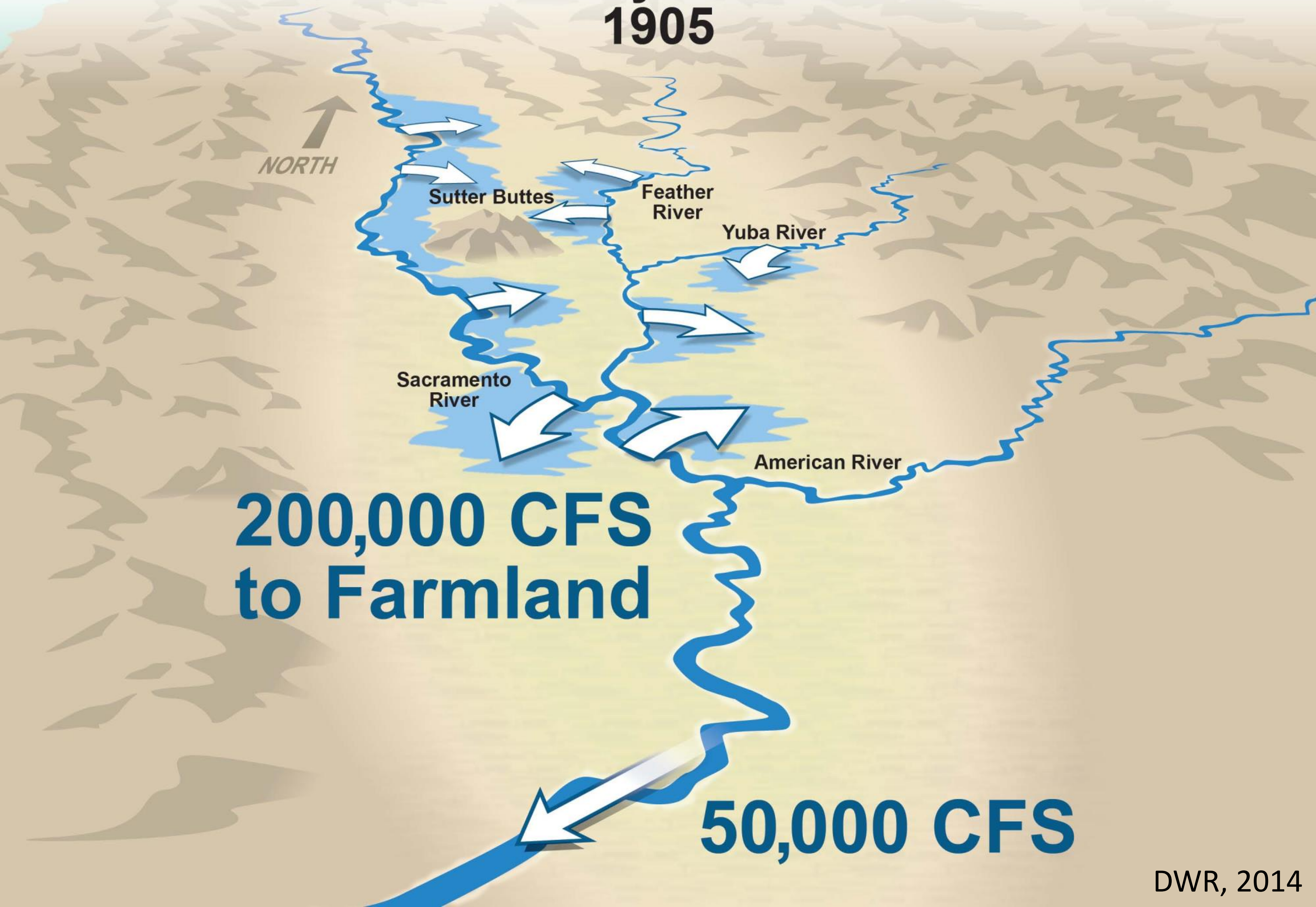
Sacramento Valley 1850

DWR, 2014

Size of Floods 1870 to 1900

DWR, 2014

State Dabney Commission 1905



DWR, 2014

Jackson Plan 1910

DWR, 2014

1997 Storm

DWR, 2014

Flood Management Timeline

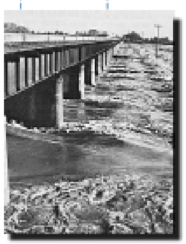
1850 1855 1860 1865 1870 1875 1880 1885 1890 1895 1900 1905 1910 1915 1920 1925 1930

- Gold Discovered (1848)
- Hydraulic Mining underway (1856)
- Hydraulic Mining underway (1856)
- **Major Flood (1862)**
- **Major Flood (1867)**
- **Major Flood (1881)**
- Sawyer Decision rendered (1884)
- **Major Flood (1890)**
- California Debris Commission established (1893)
- Congress authorizes Yuba River debris control works (1896)
- Congress reauthorizes Yuba River debris control works (1902)
- **Major Flood (1904)**
- **Major Flood (1907)**
- **Major Flood (1909)**
- Congress authorizes the Jackson Report (1910)
- **Major Flood (1911)**
- The State Reclamation Board is established (1911)
- Reclamation Board given control of "pre-project" levees on Central Valley Streams (1913)
- Debris Commission begins dredging Sacramento River (1913)
- Sacramento River Flood Control Project authorized by Flood Control Act of 1917
- Sacramento Weir completed on the Sacramento River (1918)
- Fremont Weir completed on the Sacramento River (1924)
- **Major Flood (1928)**

Gold Mining

Hydraulic Mining

Flooding in Downtown Sacramento



Sacramento Weir

Back to Text

Legend:
- All Basins
- Sacramento River Basin
- San Joaquin River Basin
- Tulare Lake Basin

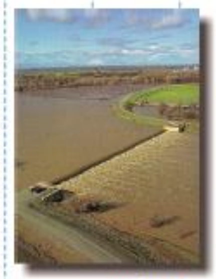
POST FLOOD ASSESSMENT FOR
1983, 1986, 1995, and 1997

FIGURE 2-1
CENTRAL VALLEY
FLOOD MANAGEMENT TIMELINE
1850 – 1930

Flood Management Timeline

1930 1935 1935 1940 1945 1950

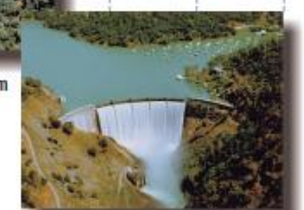
- △ Moulton Weir completed on the Sacramento River (1932)
- △ Tisdale Weir completed on the Sacramento River (1932)
- △ Colusa Weir completed on the Sacramento River (1933)
- ● Central Valley Project authorized (1933)
- △ Sacramento River dredging completed from Cache slough to mouth (1934)



Moulton Weir

- △ Congress authorizes Narrows Dam for mining debris (1935)
- △ Congress authorizes North Fork Dam for mining debris (1935)
- △ Yuba River debris control works completed (1935)
- △ North Fork Dam completed on North Fork American River (1939)

North Fork Dam



Narrows Dam

- △ Narrows Dam completed on the Yuba River (1941)
- △ Flood Control Act of 1944 assigns duty of flood control and navigation to the U.S. Army Corps of Engineers
- ● Sacramento River and Major & Minor Tributaries Project authorized by Flood Control Act of 1944

- △ Shasta Dam completed during war for interim operation (1945)
- △ Shasta Dam completed for full operation on the Sacramento River (1949)
- ◇ Friant Dam completed on the San Joaquin River (1949)

Friant Dam

● All Basins
△ Sacramento River Basin
◇ San Joaquin River Basin
□ Tulare Lake Basin

POST FLOOD ASSESSMENT FOR
1983, 1986, 1995, and 1997

FIGURE 2-1
CENTRAL VALLEY
FLOOD MANAGEMENT TIMELINE
1930 – 1950

Flood Management Timeline

1950 1955 1960 1965

- Isabella Dam completed on the Kern River (1953)
- Pine Flat Dam completed on the Kings River (1954)
- Congress authorizes construction of levee on north bank of the American River (1954)
- Legislature authorizes levees, bypasses on the San Joaquin River above Merced River (1955)
- **Major Flood (1955)**
- Folsom Dam completed on the American River (1956)
- Construction initiated on Lower San Joaquin River and Tributaries Project (1956)
- Levee on north bank American River completed (1958)
- State Water Project authorized (1960)
- Congress authorizes Sacramento River Bank Protection Project (1960)
- Sacramento River Flood Control Project substantially completed (1961)
- Success Dam completed on the Tule river (1961)
- Terminus Dam completed on the Kaweah River (1961)
- Black Butte Dam completed on Stony Creek (1963)
- Camanche Dam completed on the Mokelumne River (1963)
- New Hogan Dam completed on the Calaveras River (1964)
- **Major Flood (1964)**

Pine Flat Dam

Folsom Dam

Success Dam

New Hogan Dam

Black Butte Dam

Legend:
- All Basins
- Sacramento River Basin
- San Joaquin River Basin
- Tulare Lake Basin

POST FLOOD ASSESSMENT FOR 1983, 1986, 1995, and 1997

FIGURE 2-1
CENTRAL VALLEY
FLOOD MANAGEMENT TIMELINE
1950 – 1965

Flood Management Timeline

1965 1970 1975 1980 1985 1990 1995 2000

- Portions of Sacramento River and Major & Minor Tributaries Project completed (1965)
- **Major Flood (1967)**
- New Exchequer Dam completed on the Merced River (1967)
- Oroville Dam completed on the Feather River (1968)
- Lower San Joaquin River and Tributaries Project levees constructed (1968)
- **Major Flood (1969)**
- New Bullards Bar Dam completed on the Yuba River (1970)
- Don Pedro Dam completed on the Tuolumne River (1970)
- **Major Flood (1970)**
- Lower San Joaquin River and Tributaries Project completed (1972)
- **Major Flood (1974)**
- Hidden Dam completed on the Fresno River (1975)
- Buchanan Dam completed on the Chowchilla River (1975)
- Indian Valley Dam completed on Cache Creek (1976)
- New Melones Dam completed on the Stanislaus River (1978)
- **Major Flood (1983)**
- **Major Flood (1986)**
- Cache Creek Basin Project completed (1993)
- Redbank and Fancher Creeks Project (1993)
- **Major Flood (1995)**
- Sacramento River Bank Protection Project completed (1996)
- **Major Flood (1997)**
- **Major Flood (1998)**

New Exchequer Dam

Don Pedro Dam

New Melones Dam

Levee Break - Flood of '97

- All Basins
- Sacramento River Basin
- San Joaquin River Basin
- Tulare Lake Basin

POST FLOOD ASSESSMENT FOR 1983, 1986, 1995, and 1997

FIGURE 2-1
CENTRAL VALLEY
FLOOD MANAGEMENT TIMELINE
1965 – Present

Major Causes of Historical Central Valley Floods

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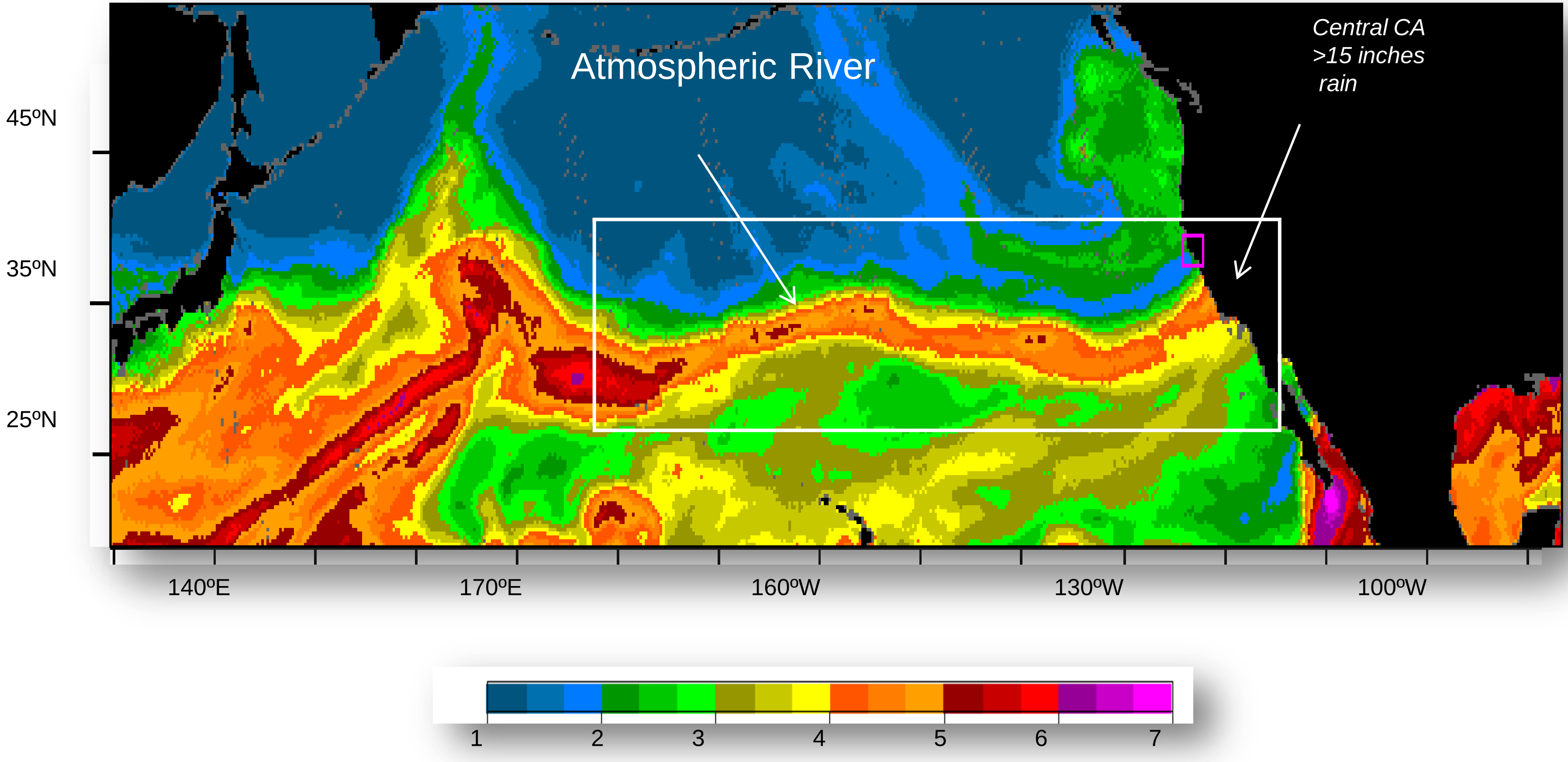
Many Floods are Linked to Atmospheric River Events



Source: California DWR/NOAA 2013

Atmospheric Conditions for 1986 and 1997 Floods

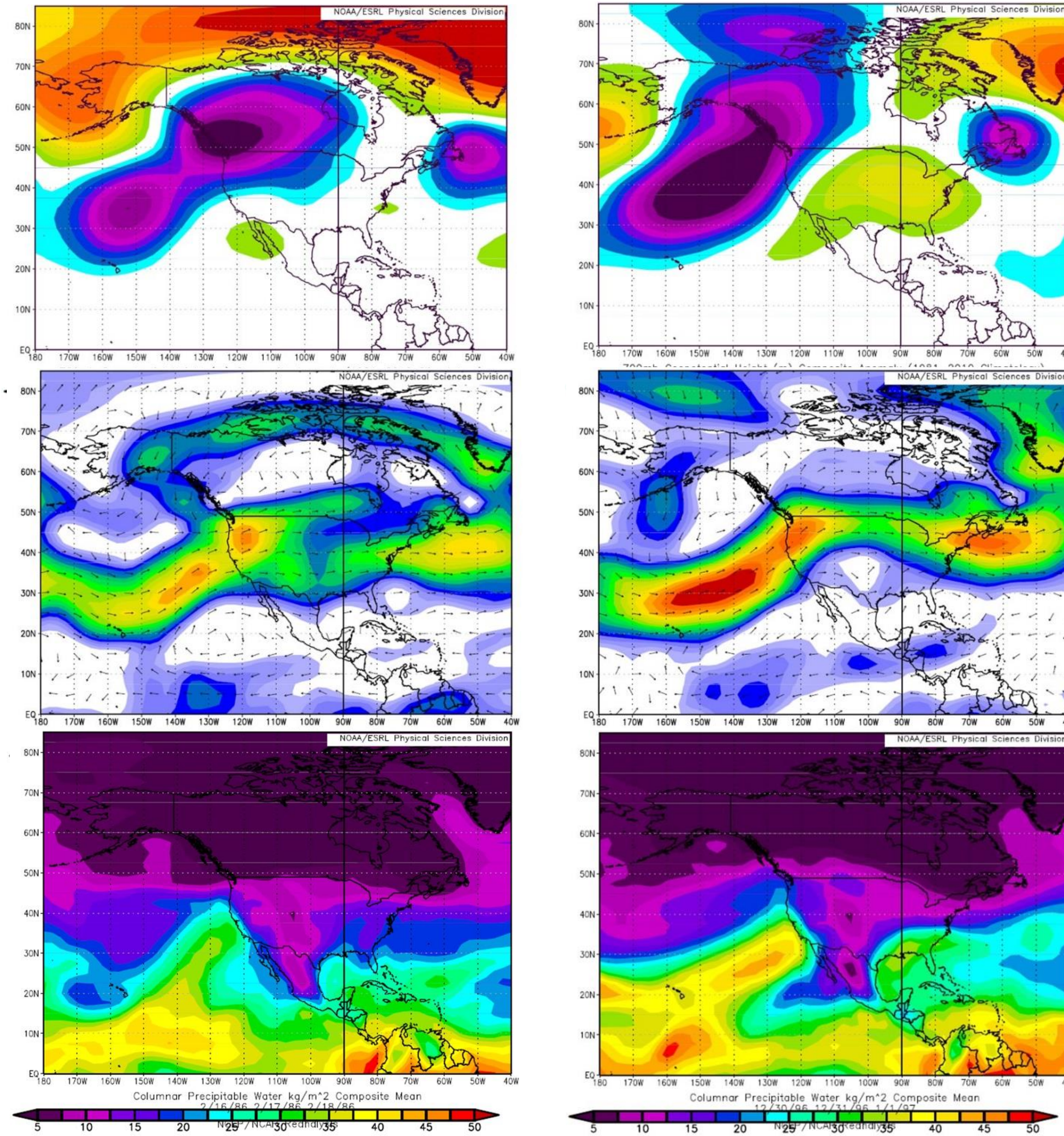
February 16-18, 1986

Dec 30, 1996 – Jan 1, 1997

GPH

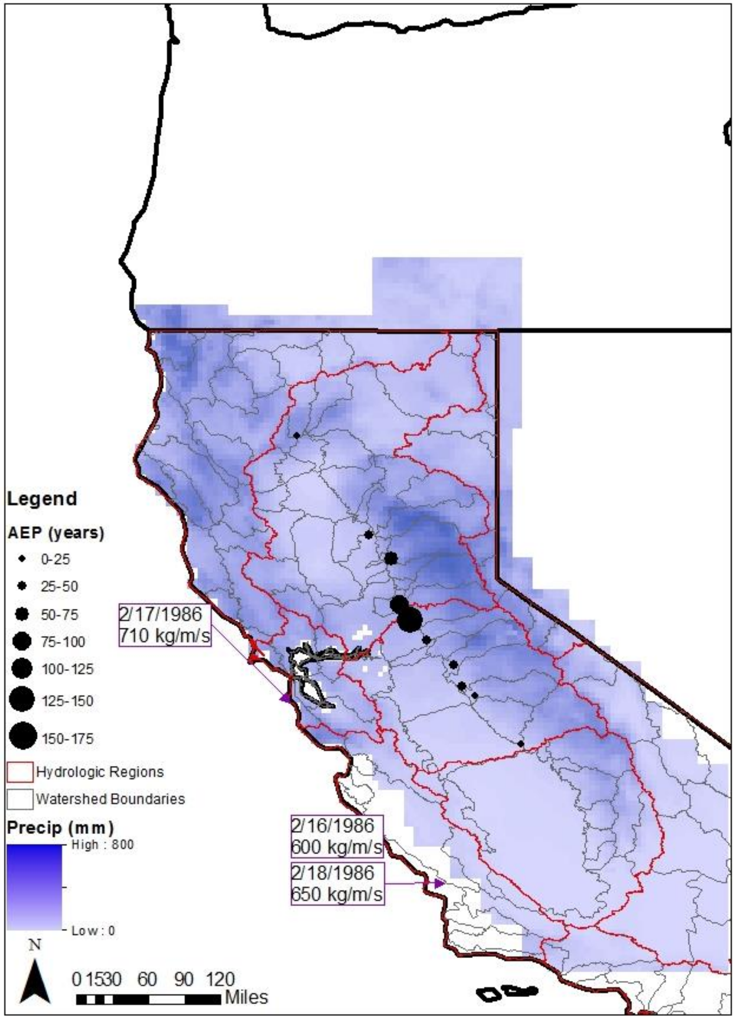
Winds

Precipitable Water

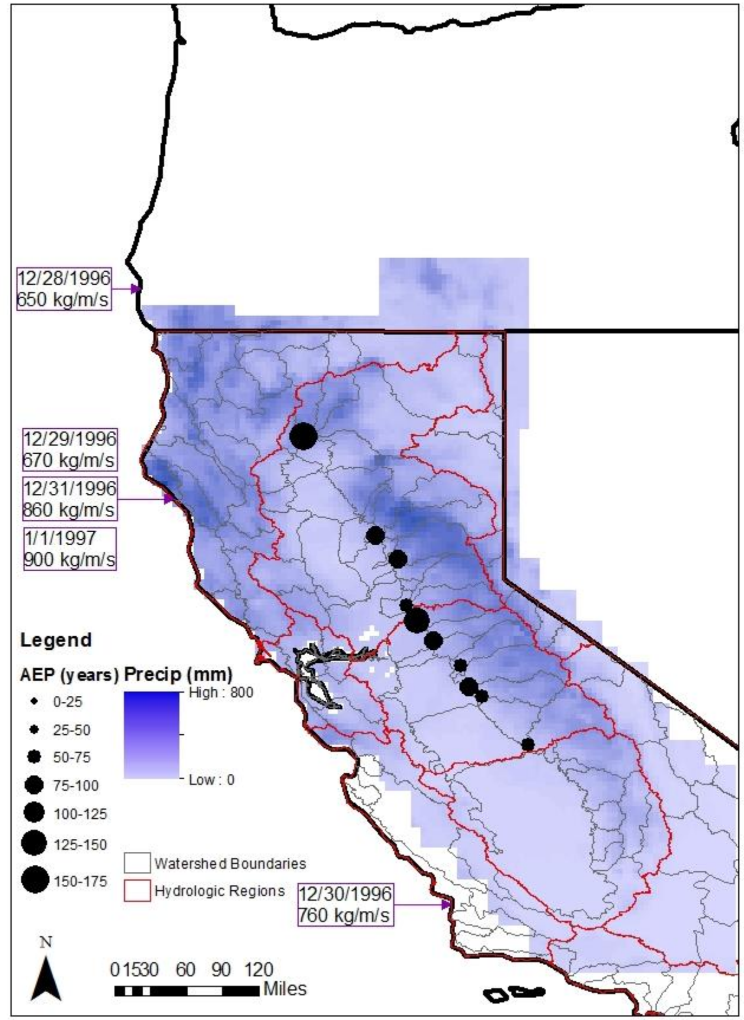


Atmospheric River Landfalls

February 16-18, 1986



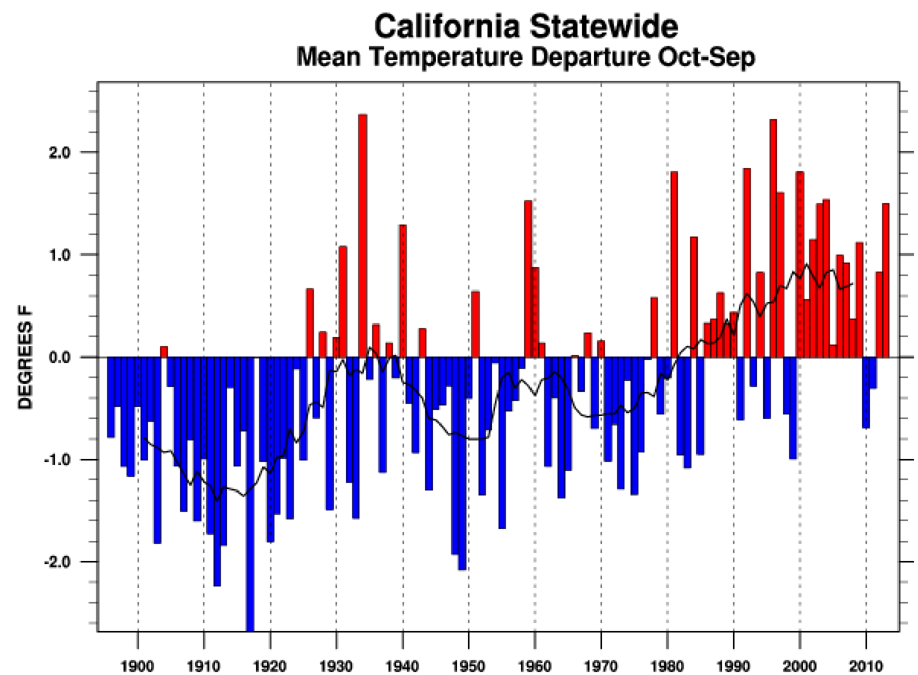
Dec 30, 1996 – Jan 1, 1997



Climate Change and Future Risks

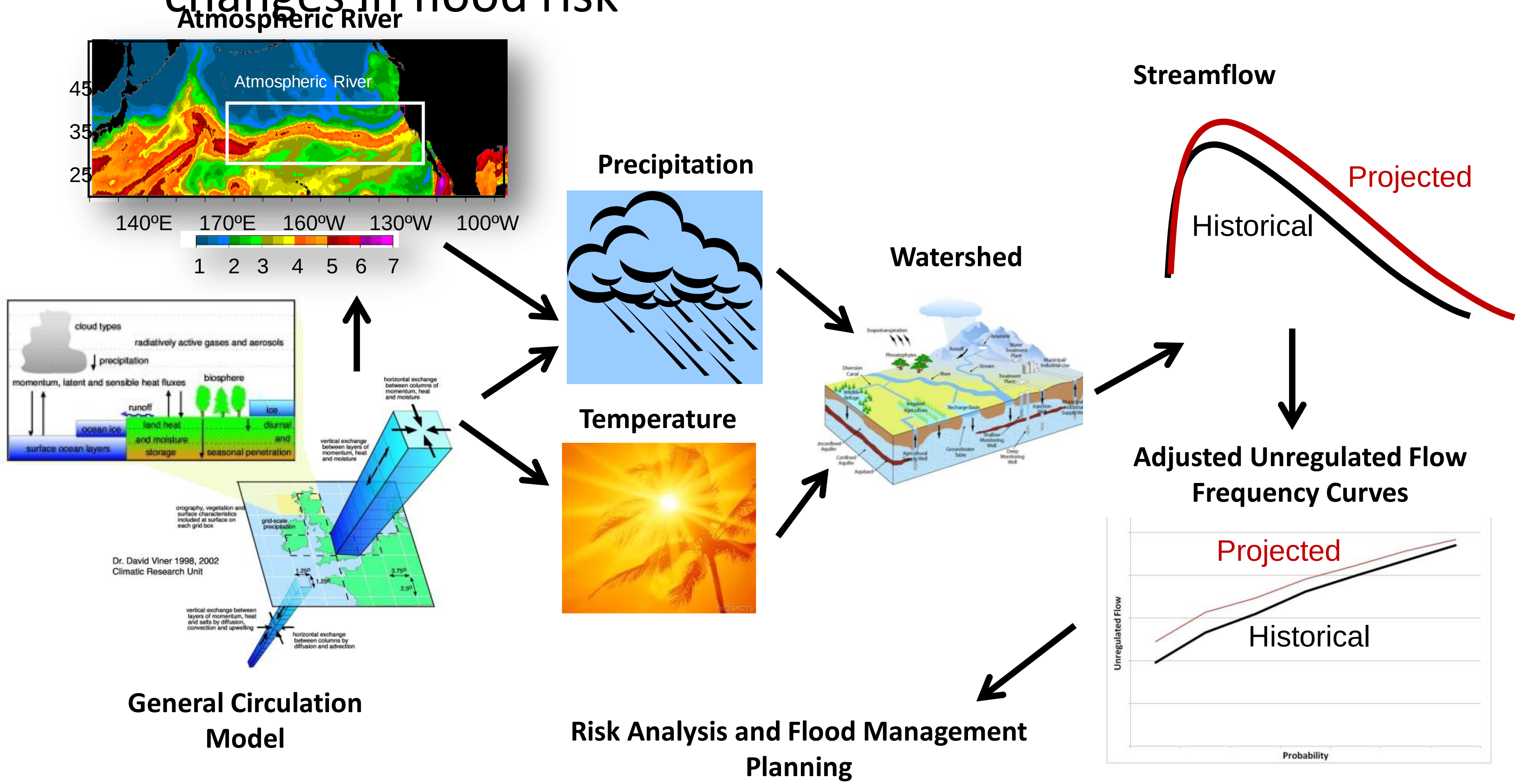
Importance of Incorporating Climate Change

- Current flood management and flood risk analyses depend on historical estimates and statistics of flood hydrology
- Flood management infrastructure and policy decisions will likely be tested against climate variability and change not experienced in the past 100 years
- Our systems need to be resilient to accommodate a range of hydroclimatic futures



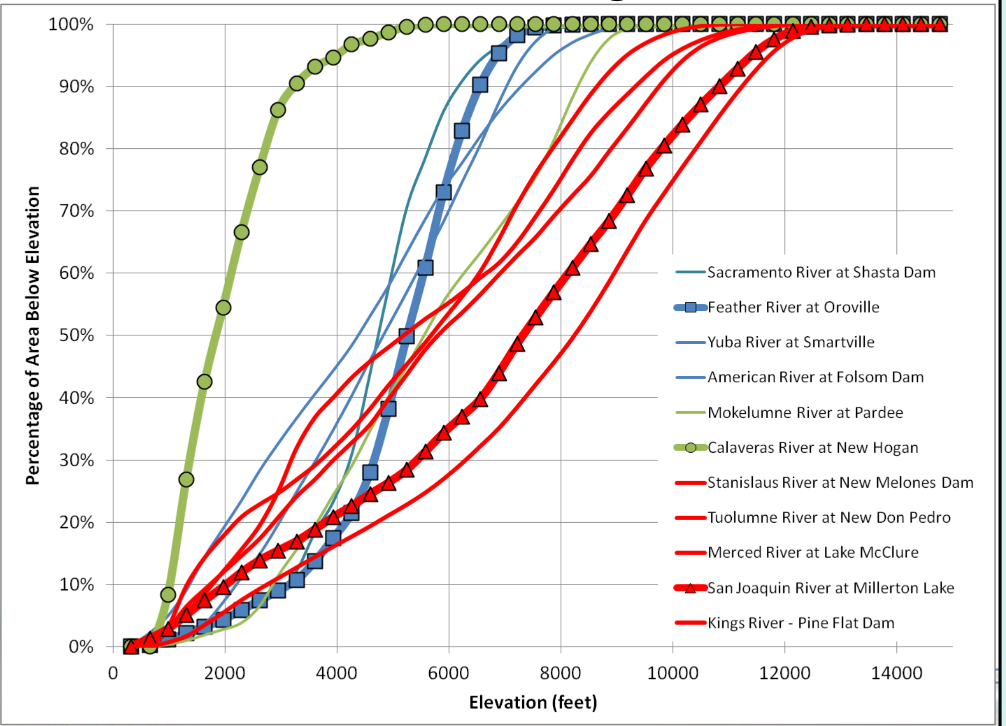
CVFPP Climate Change Approach

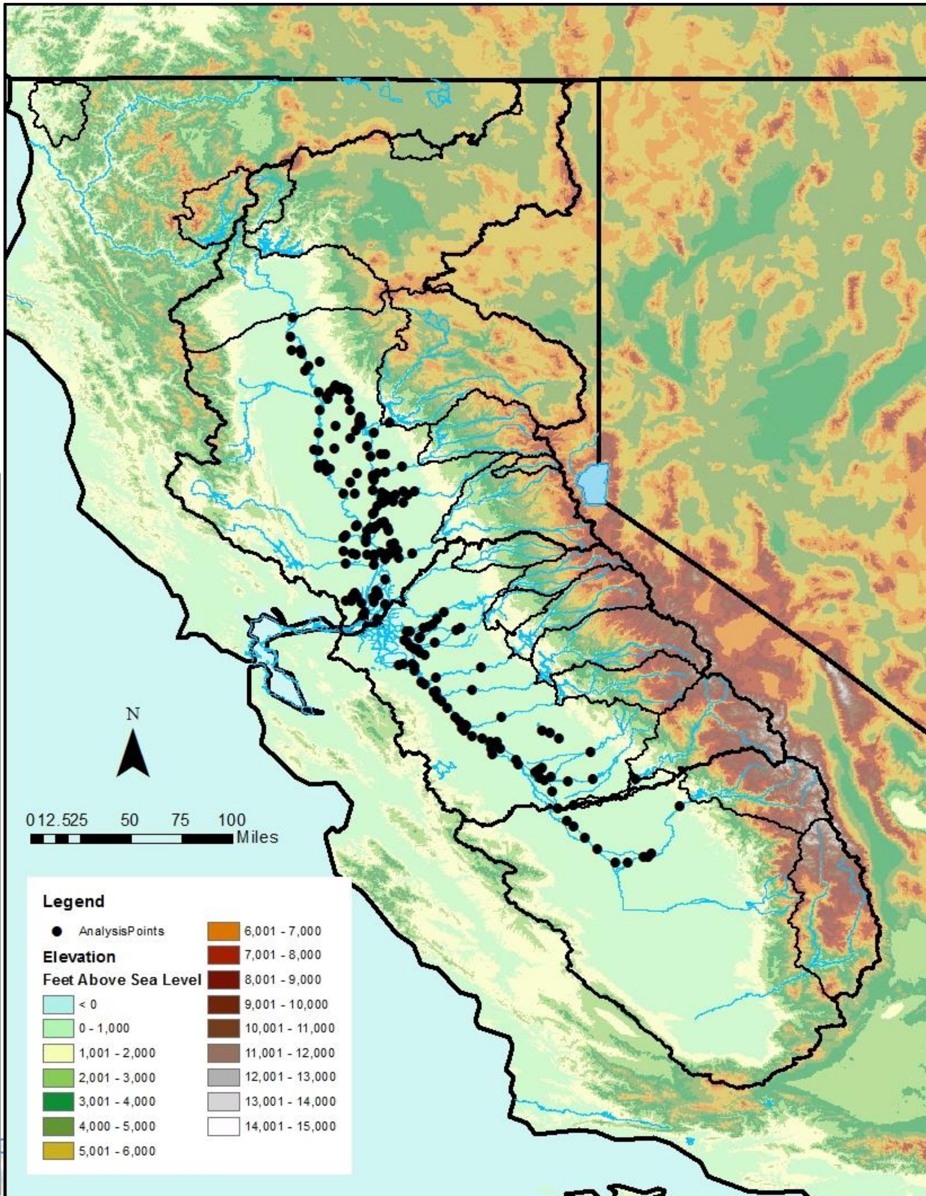
- Linking atmospheric processes, precipitation and temperature fields, and watershed conditions to inform changes in flood risk



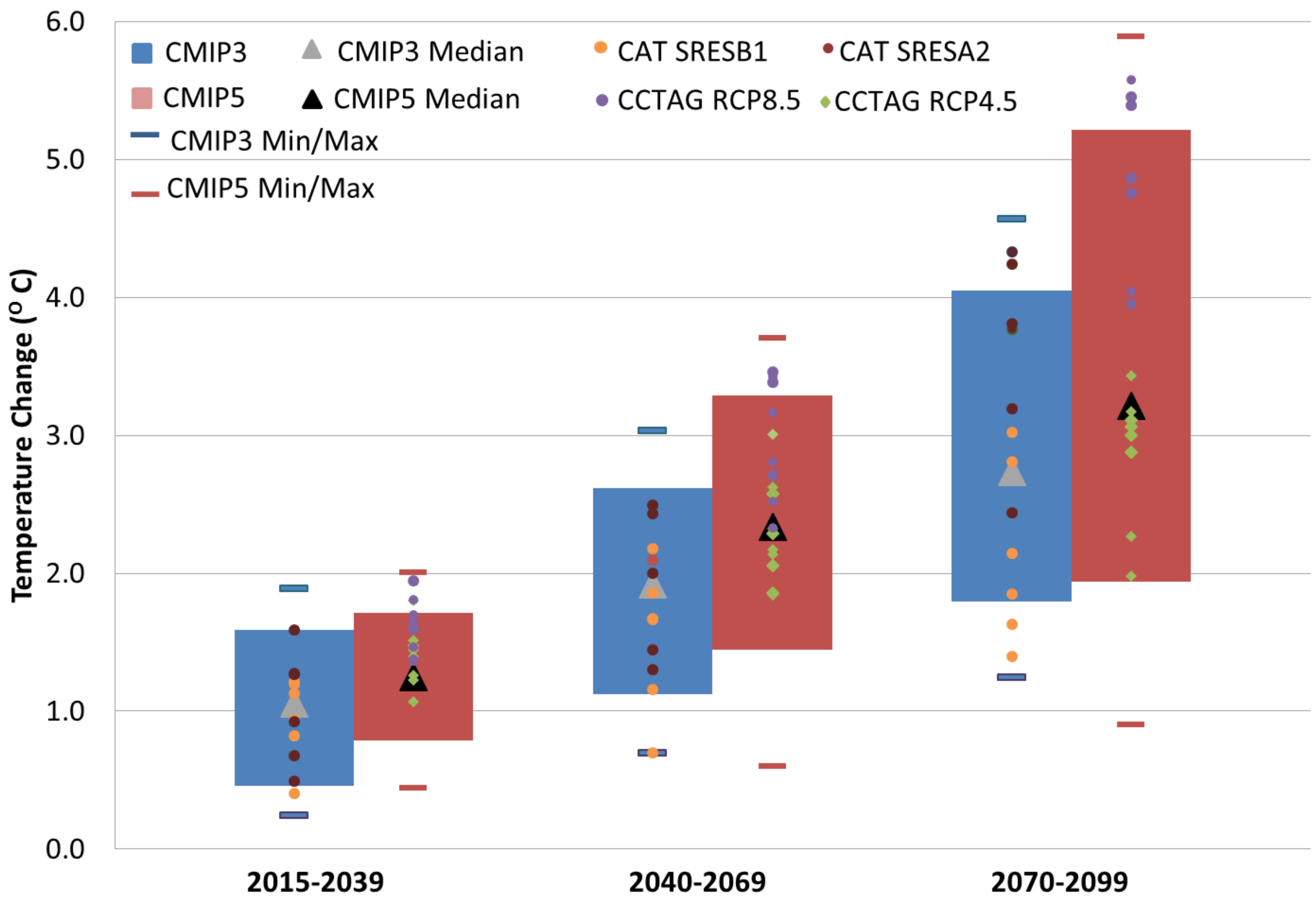
Elevation is a Major Driver of Watershed Climate Sensitivity

- Watershed characteristics influence what has been observed
- And the sensitivity of response to climate change (primarily warming)
- Sacramento watersheds have most of the contributing area < 7,000 ft
- San Joaquin watersheds have nearly half of the contributing area > 7,000 ft

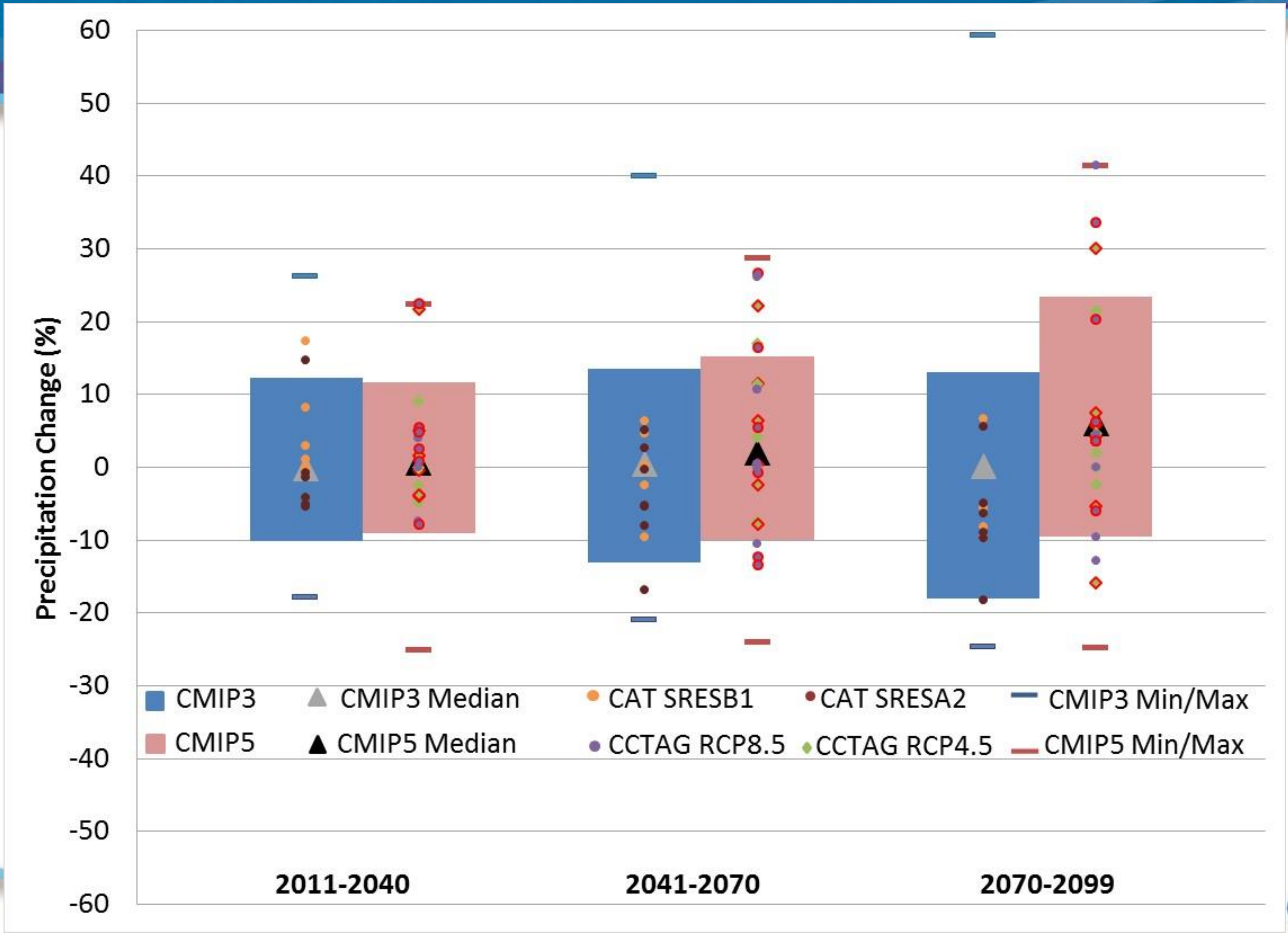




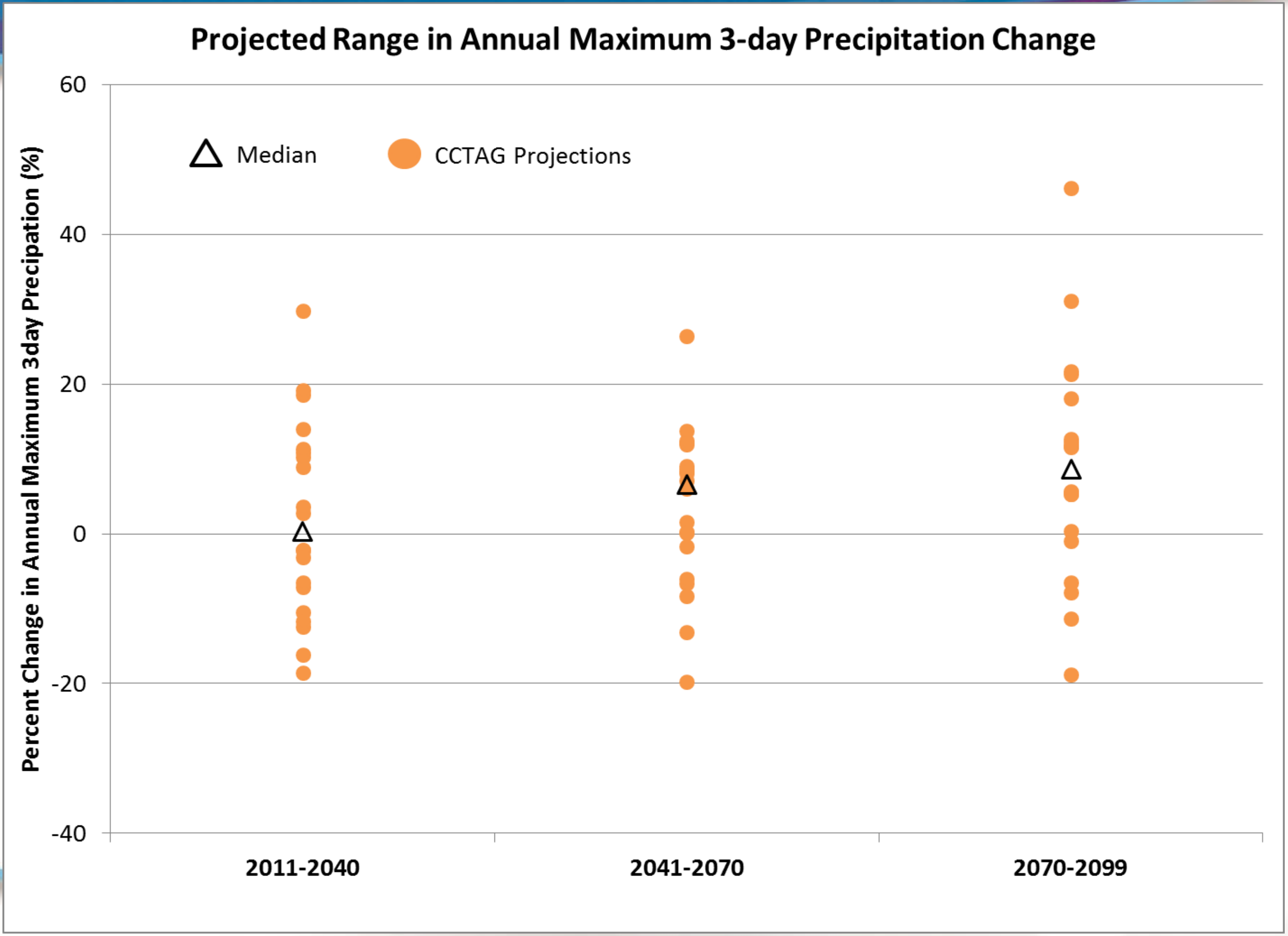
Projected Changes in Annual Temperature



Projected Changes in Annual Precipiation



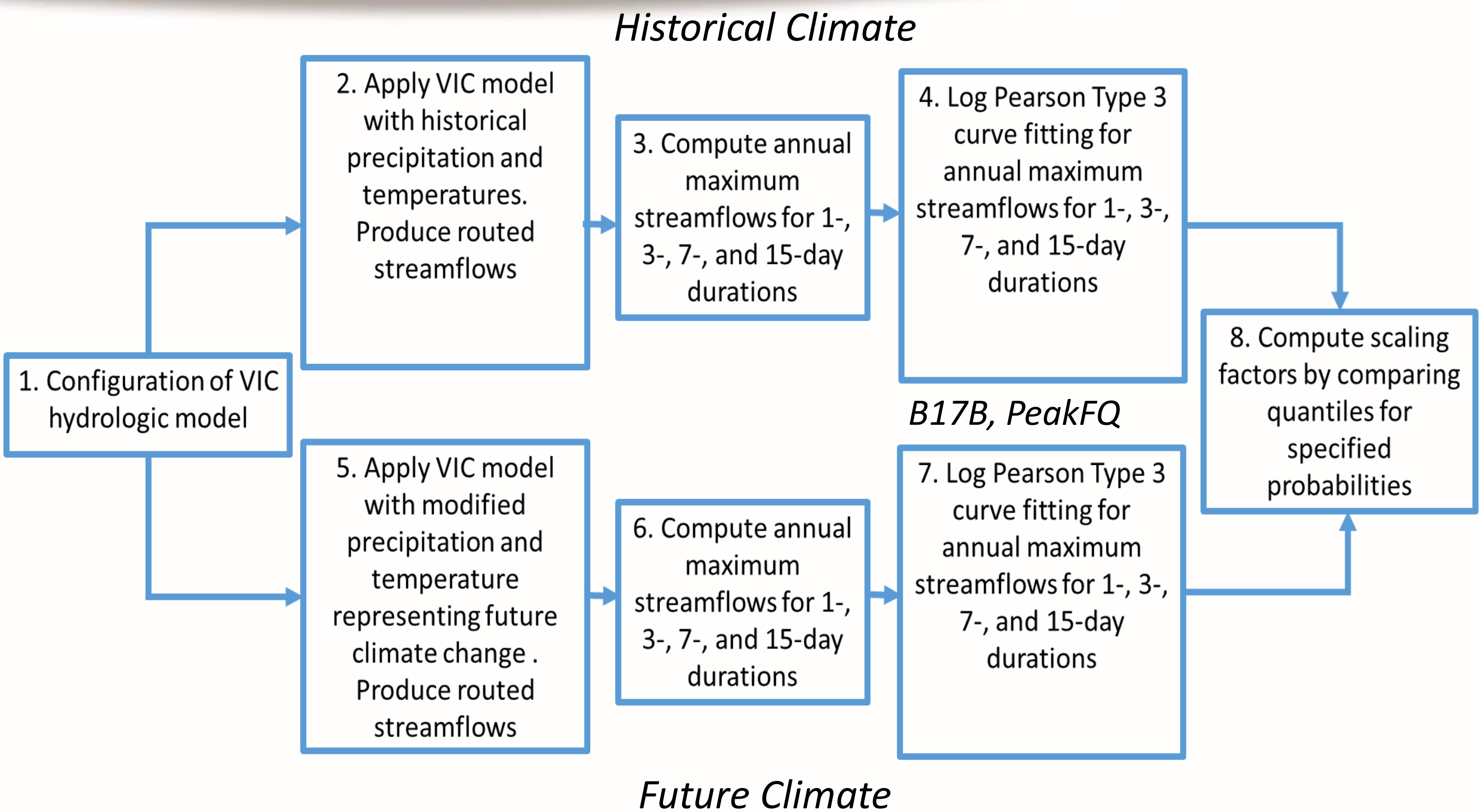
Projected Changes in Precipitation Extremes



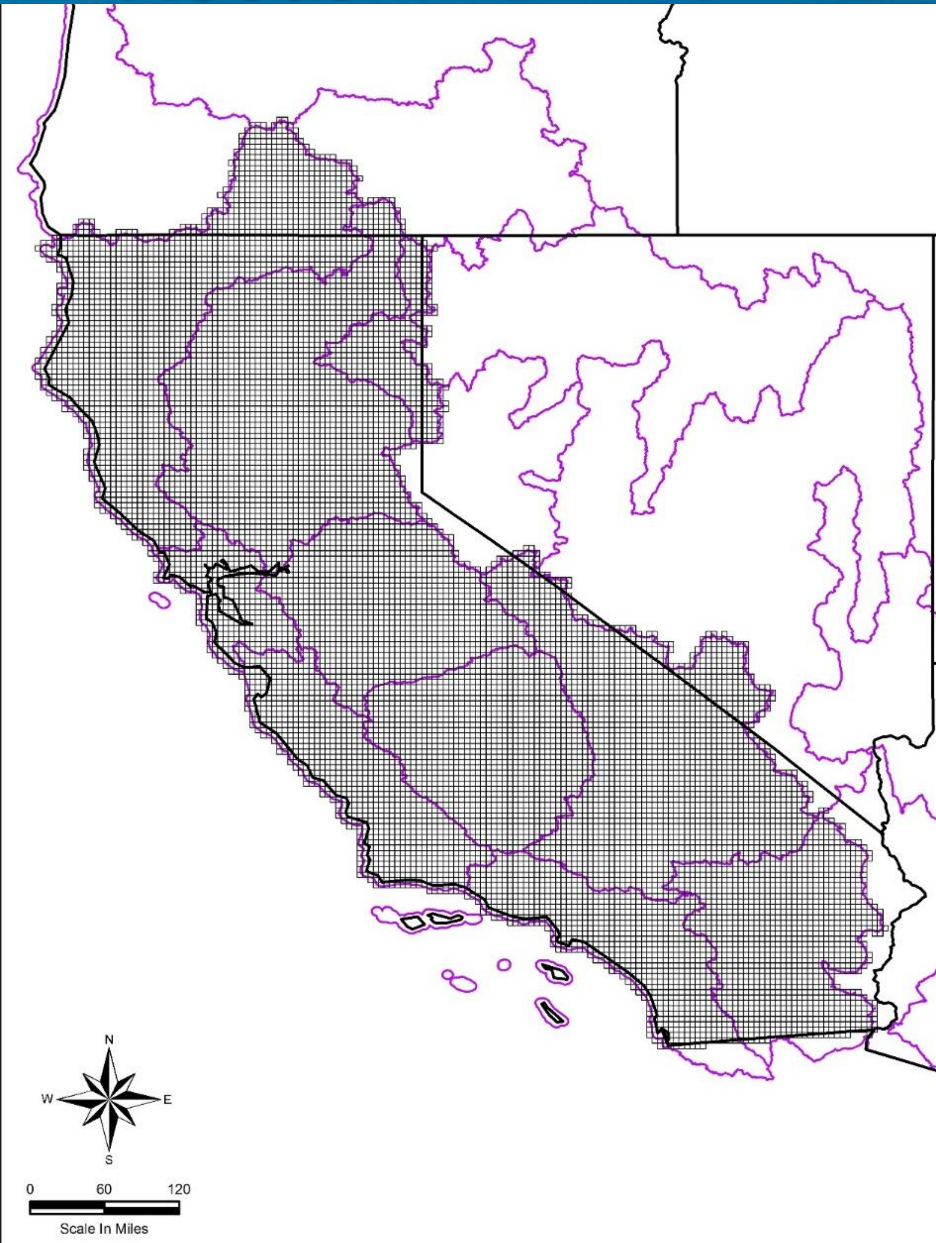
Climate Scenarios

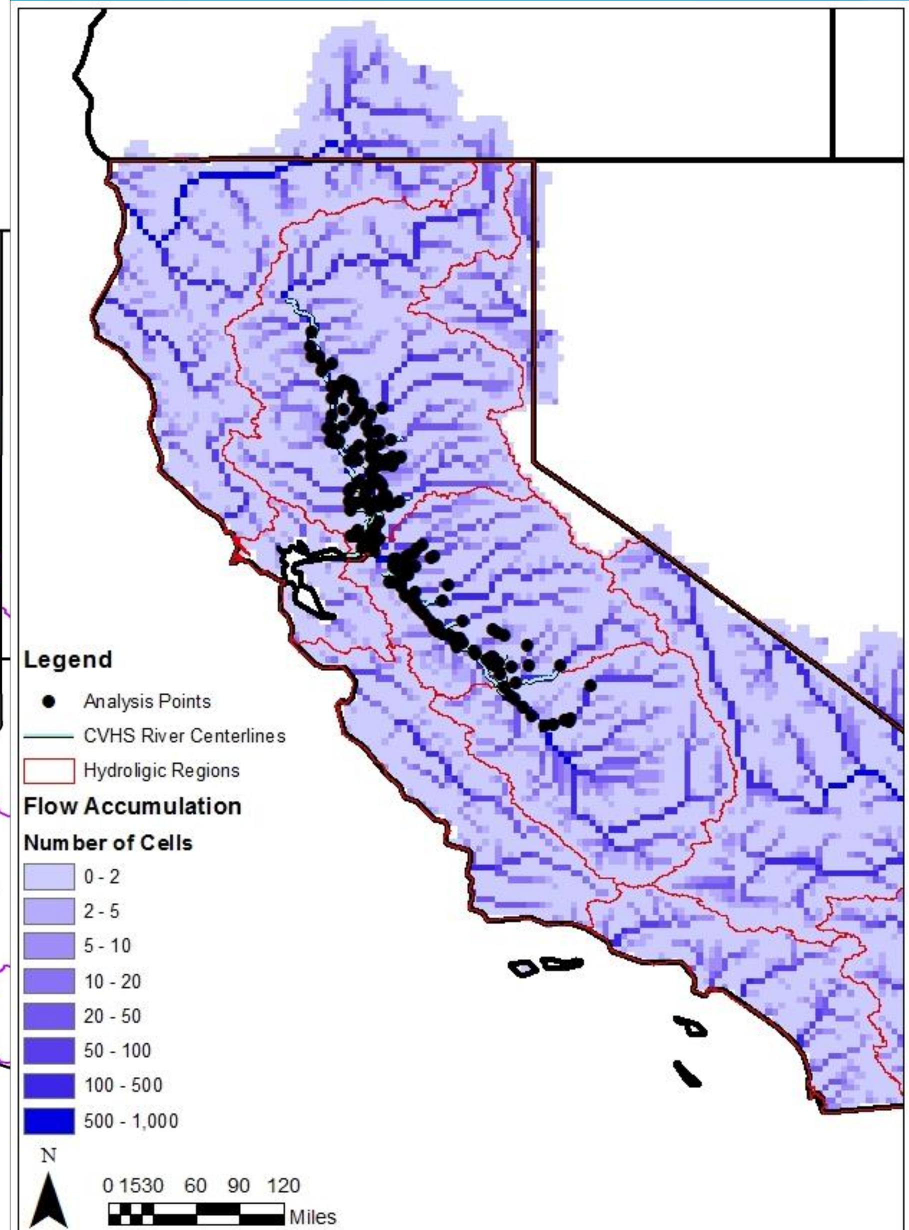
- Warming-only scenarios
  - *+1 C, +2 C, and +3 C*
  - *Approximating warming at early-, mid-, and late-century*
- CMIP5 ensemble median scenarios
  - *Changes in temperature and precipitation derived from nearly 200 individual GCM projections (GCMs x RCPs x # of runs)*
  - *Single scenario reflecting the "median" change derived from these projections*
  - *Bias-corrected and statistically downscaled (BCSD) method*
  - *Applied as change to historical climate*
- CMIP5 LOCA scenarios
  - *10 GCMs identified by the CCTAG as capturing dynamics important to California*
  - *2 representative concentration pathways (RCPs)*
  - *20 projections utilized as direct future climate*

Approach for Computing Flow Frequency Changes

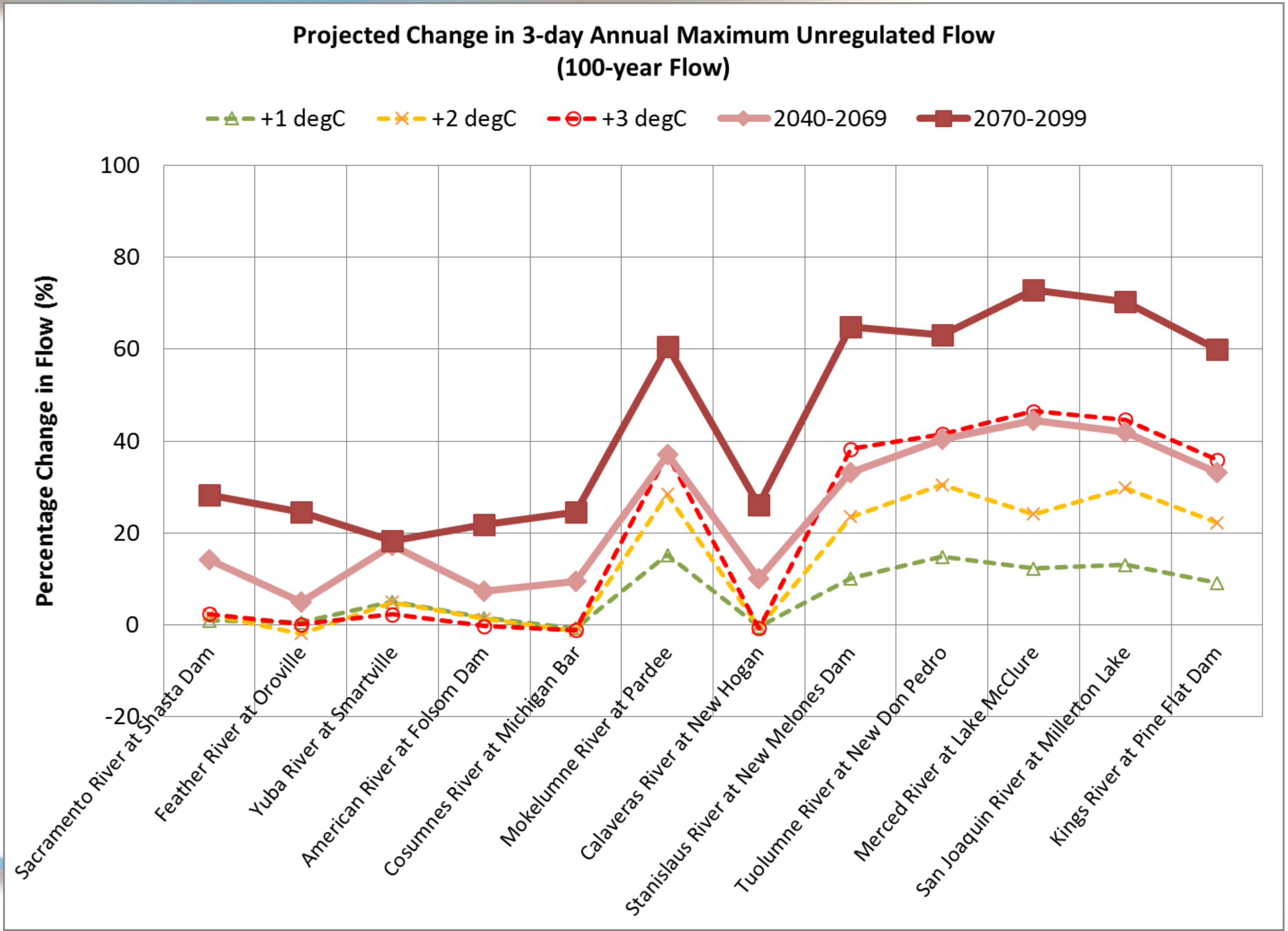


VIC Model Refined and Recalibrated for CV Floods

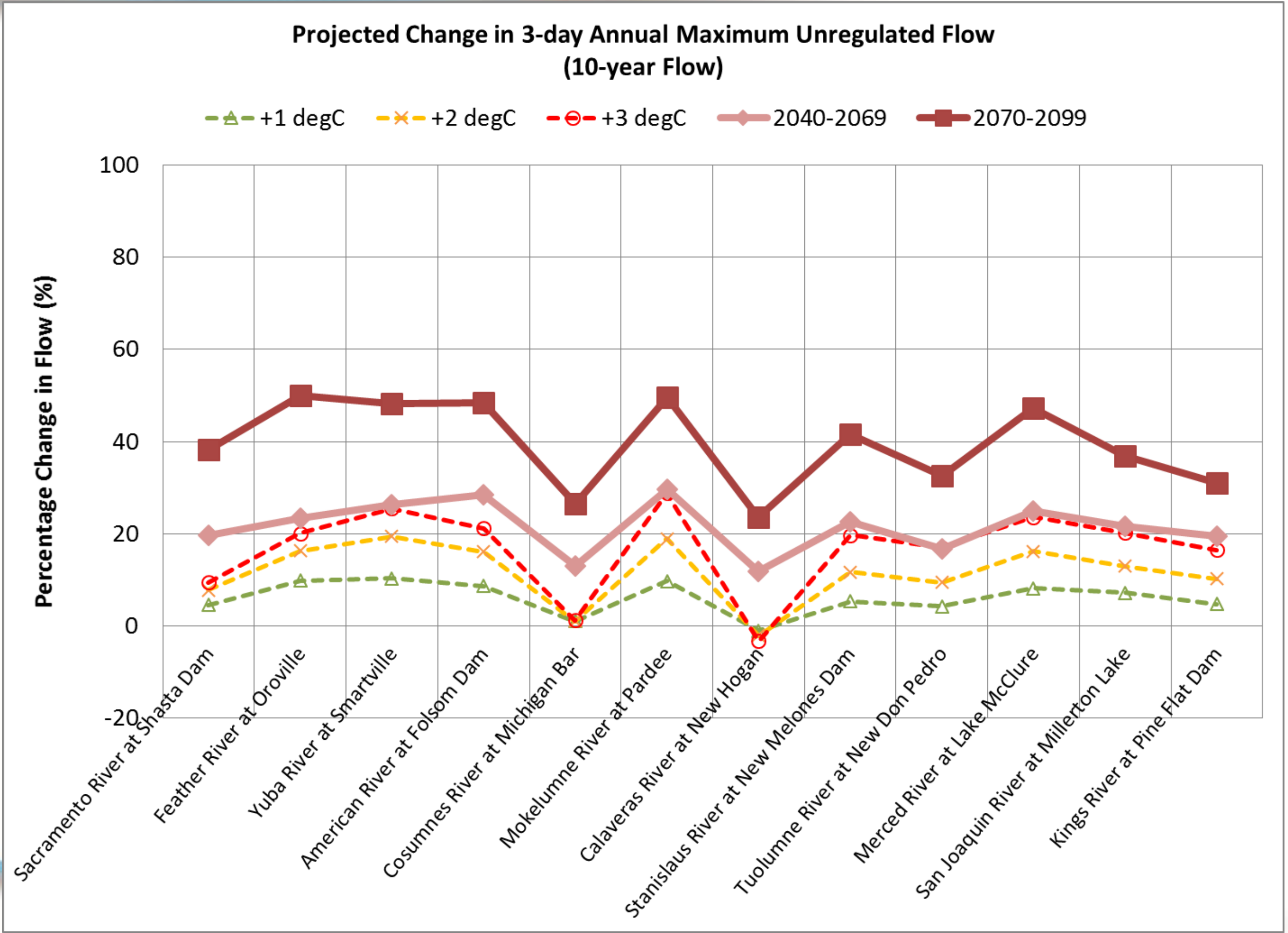




Preliminary Phase IIB Climate Sensitivity: 100-Year 3-Day Flood



Preliminary Phase IIB Climate Sensitivity: 10-Year, 3-Day Flood



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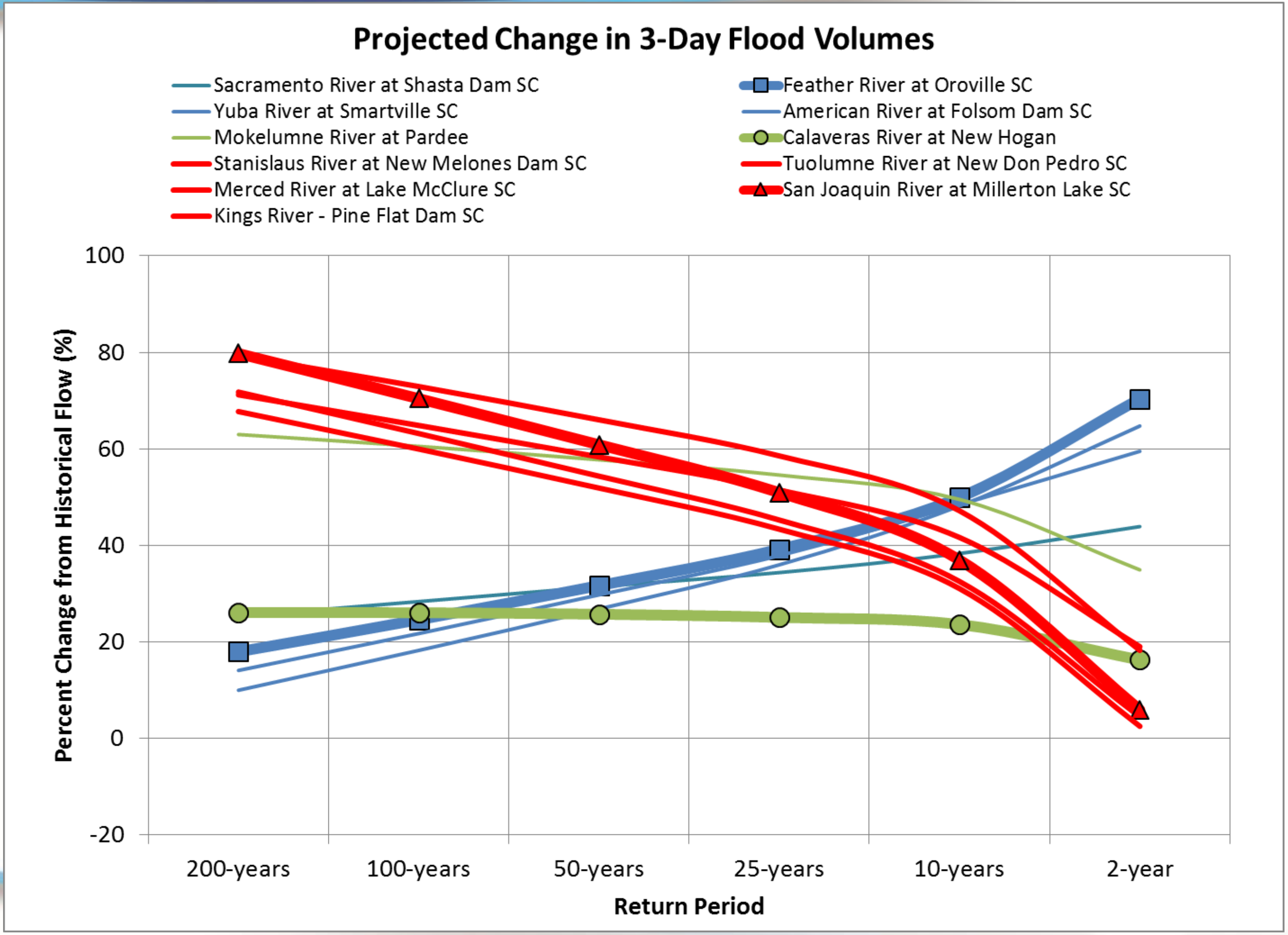
3-Day Flood Frequency Phase IIB



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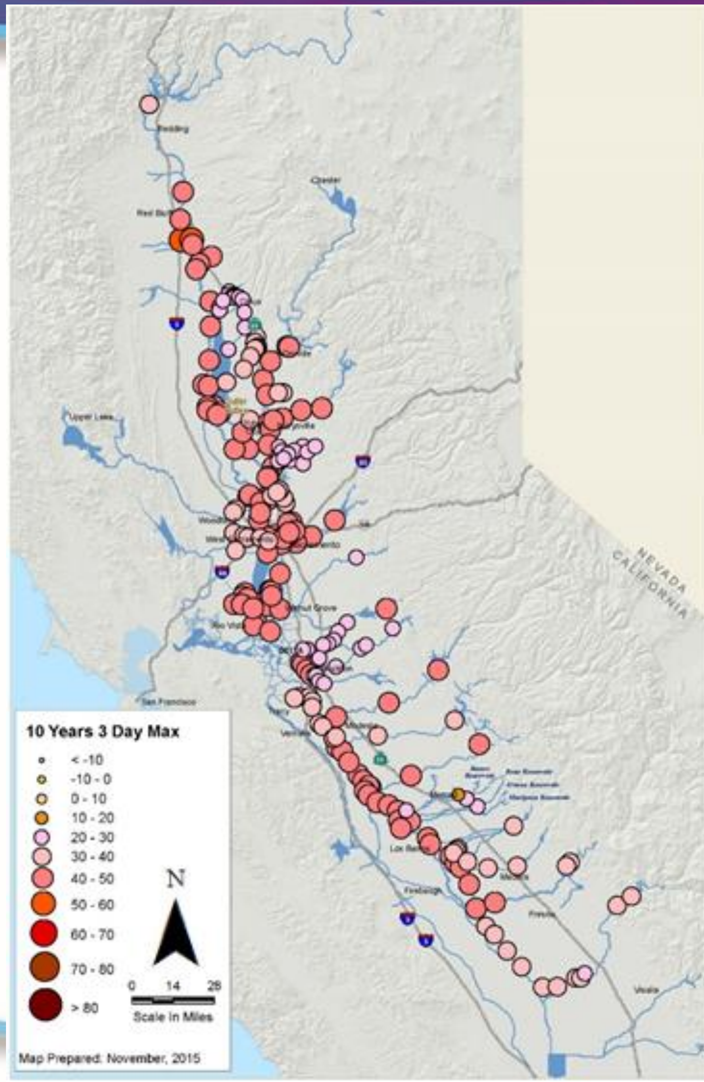
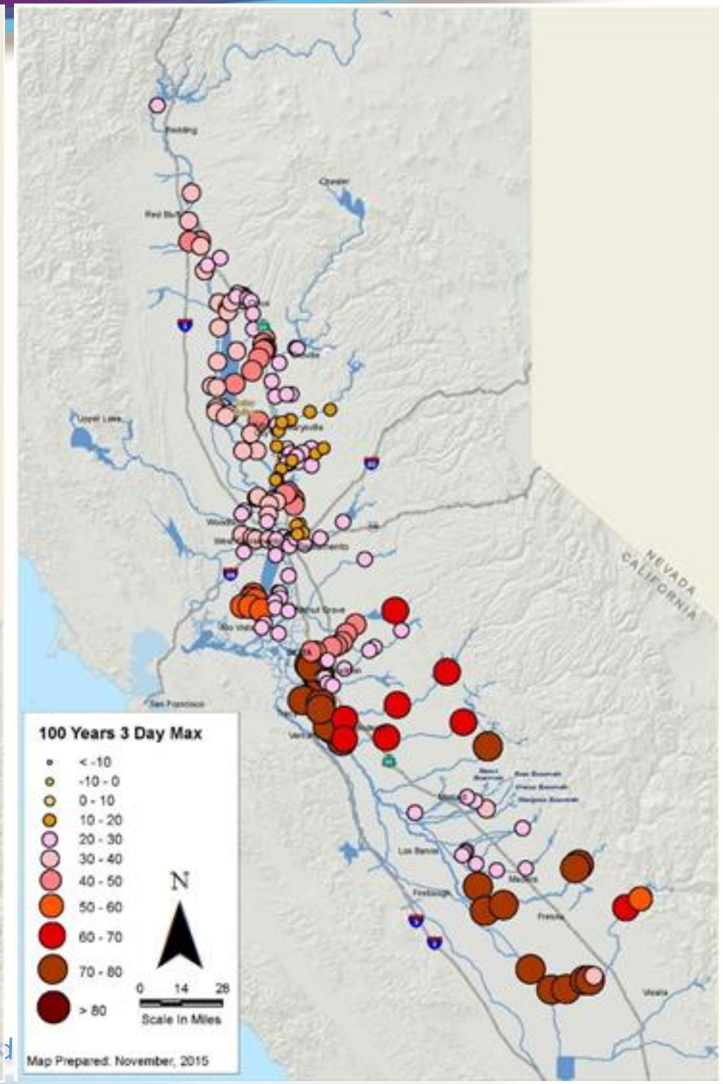
Spatial Distribution of Unregulated Flow Changes (10-yr and 100-yr)





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Projected Changes in Flood Characteristics

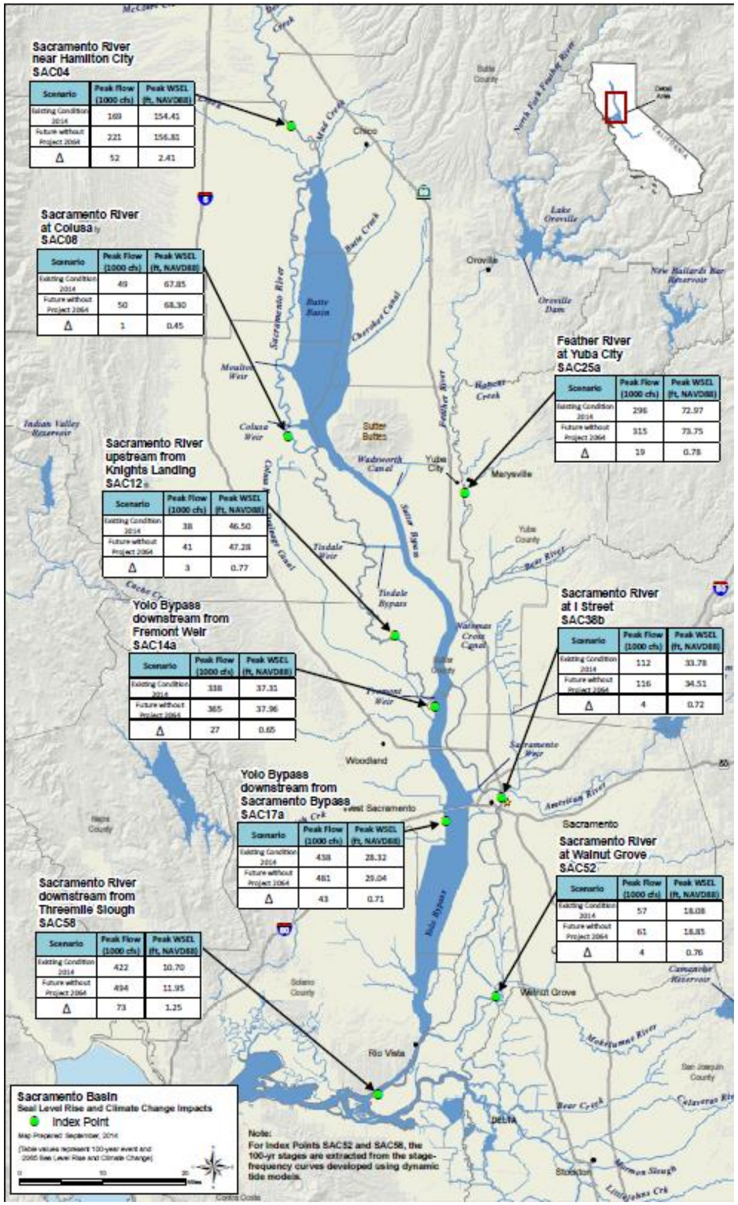
	2070-2099							
	All Annual Events				Annual Events > 66th percentile			
	Change in Date of Peak Flow (days)	Change in Annual 1-day average max flow (%)	Change in Annual 3-days average max flow (%)	Change in Flood Duration (days)	Change in Date of Peak Flow (days)	Change in Annual 1-day average max flow (%)	Change in Annual 3-days average max flow (%)	Change in Flood Duration (days)
Sacramento River at Shasta Dam	11	30	32	-28	13	18	20	-14
Feather River at Oroville	1	51	54	-33	10	19	23	-5
Yuba River at Smartville	-7	51	51	-23	3	23	25	1
American River at Folsom Dam	-3	51	51	-25	9	21	24	0
Cosumnes River at Michigan Bar	4	29	29	-9	14	6	7	0
Mokelumne River at Pardee	-25	52	45	-29	-5	24	22	-11
Calaveras River at New Hogan	5	26	26	-4	9	-2	-1	3
Stanislaus River at New Melones Dam	-39	44	37	-26	-29	33	29	-11
Tuolumne River at New Don Pedro	-36	25	17	-15	-30	23	16	-5
Merced River at Lake McClure	-34	32	25	-20	-10	10	7	-6
San Joaquin River at Millerton Lake	-41	15	8	-14	-40	18	11	-8

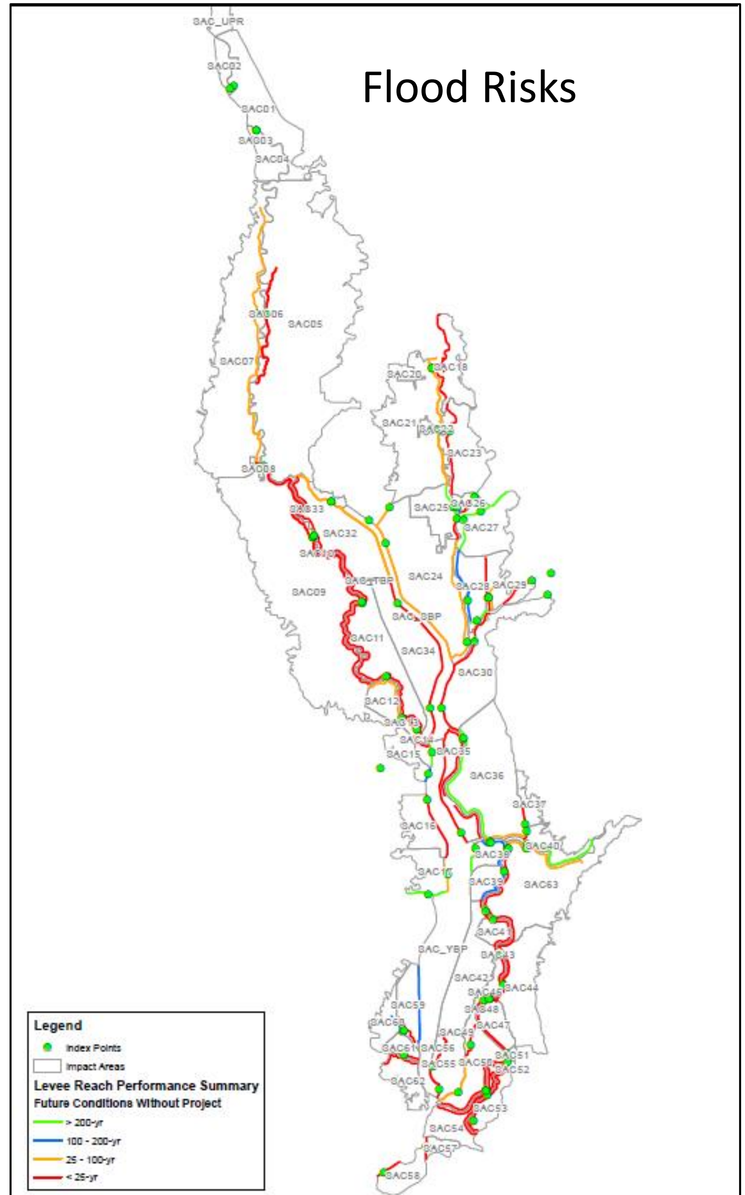
Preliminary Findings for Changes in Flood Characteristics

- ***Peak flows are projected to occur significantly earlier in the year (on the order of 2-4 weeks by late century) in the San Joaquin watersheds***. This result is likely due to the reduction in precipitation falling as snow, and a greater portion of the watershed contributing to direct runoff. Peak flows may occur later in the year in the Sacramento watersheds, but the trend is weaker except at late century.
- ***Maximum annual 1-day and 3-day flows are projected to increase for all watersheds*** evaluated. This observation suggests that the increases in flood flows may be robust for durations up to 5-7 days.
- ***Storm durations are projected to decrease in all major watersheds***. The signal of shorter duration, but more intense floods, is strongest in the San Joaquin, but is also observed for most Sacramento watersheds.

Translating Hydrologic Changes to Changes in Flood Risk

Regulated Hydrology and Hydraulics (Peak Flow and Stage)

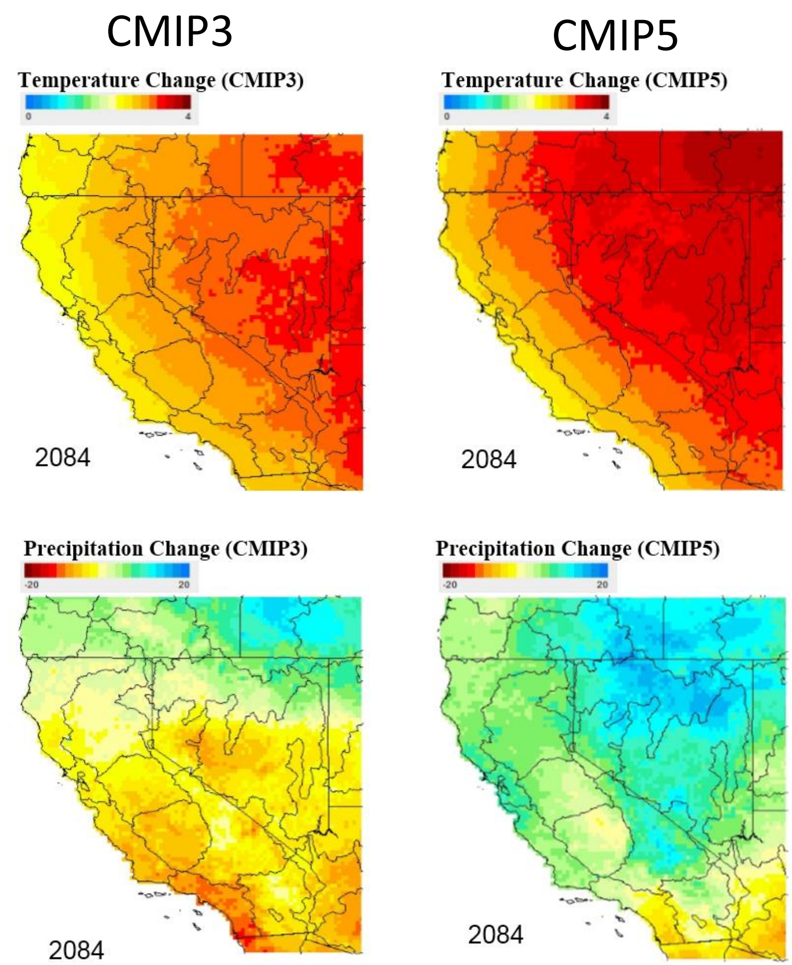




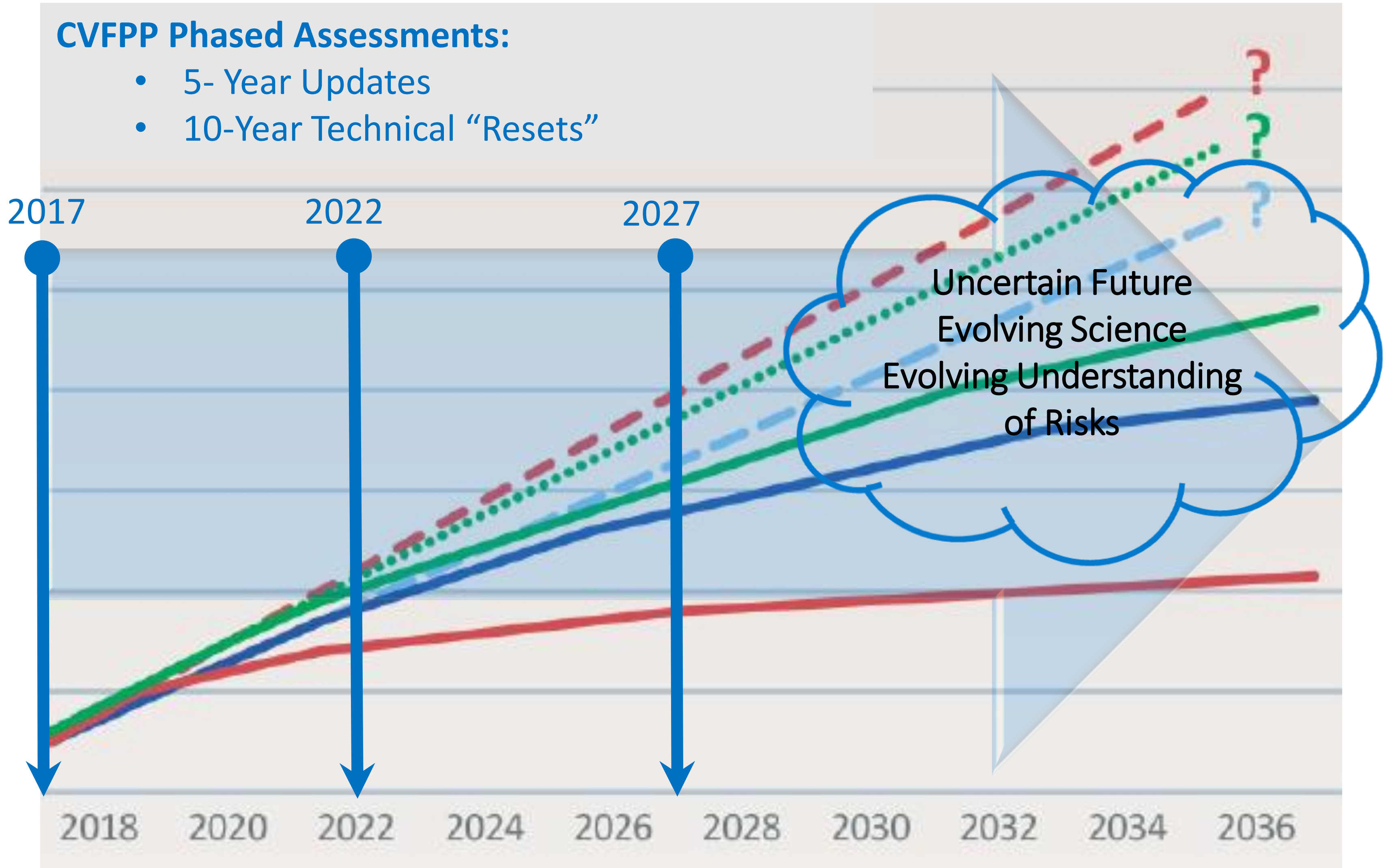
Adapting Flood Planning Frameworks for Climate Change

Climate Change Science is also Evolving

- Expand understanding of historic climate conditions related to flood risk
- Improve climate change analysis for the most recent future climate projections (CMIP5)
  - *Ensembles*
  - *Individual projections (CCTAG scenarios)*
  - *Downscaling (BCSD and LOCA)*
- Improve understanding and modeling of hydrologic model at higher spatial resolutions
- Coordinate, review, and integrate existing and on-going DWR-supported climate science research
  - *Atmospheric River Study (SIO)*
  - *Watershed Sensitivity Study (UCD)*
  - *Central Valley Sensitivity Study (USACE)*



Uncertain Futures Require Phased Assessments of Hydrologic Variability



Thank you

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