The Expression of Drought in a Complex Environment

(Or, Climate Differences by State)

Laura M. Edwards(1,2) and Kelly T. Redmond (1)

(1) Western Regional Climate Center
(2) Climate, Ecosystems and Fire Applications

Desert Research Institute
Reno, Nevada, USA

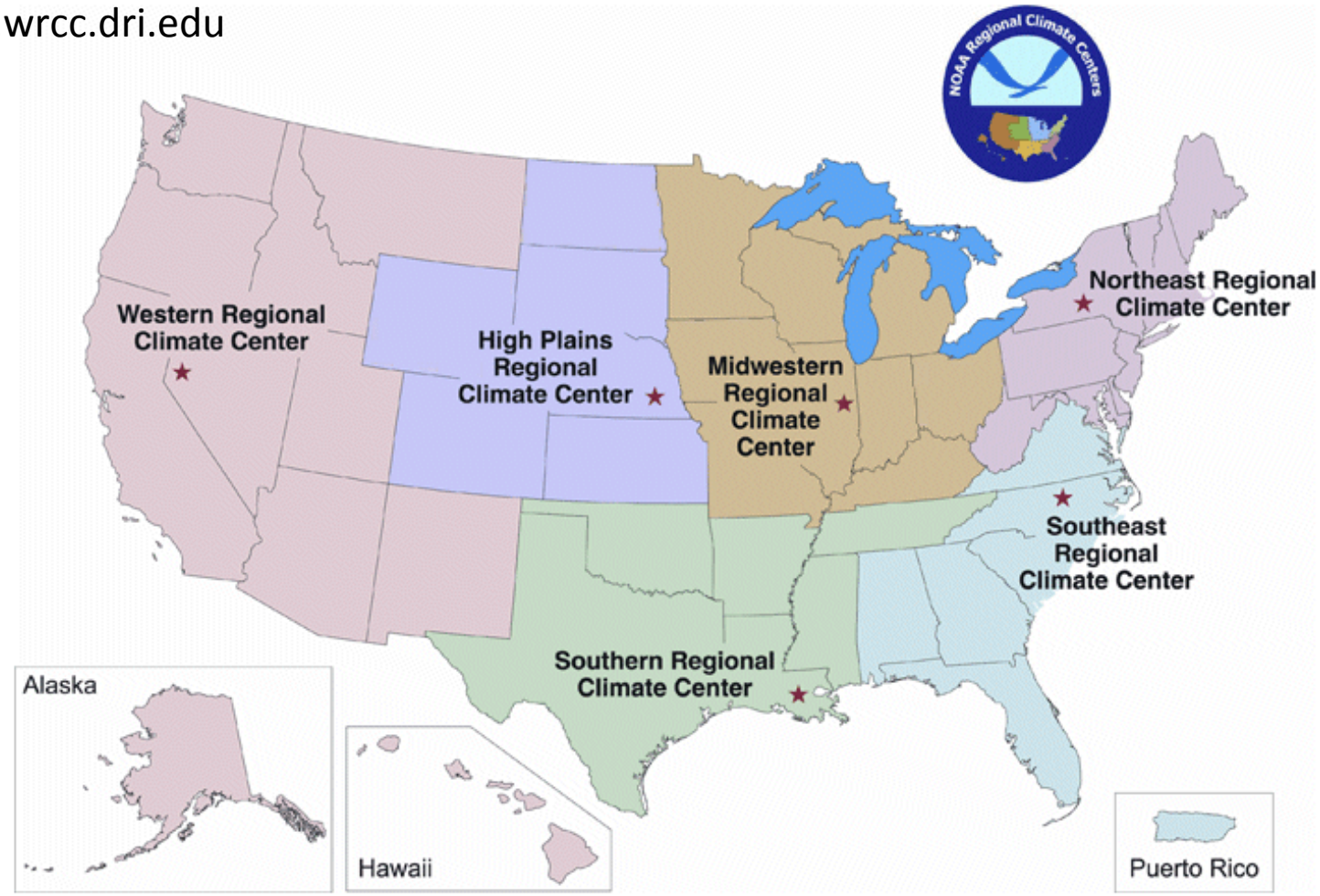
North American Drought Monitor Workshop
Ottawa, Ontario
October 15, 2008

Outline

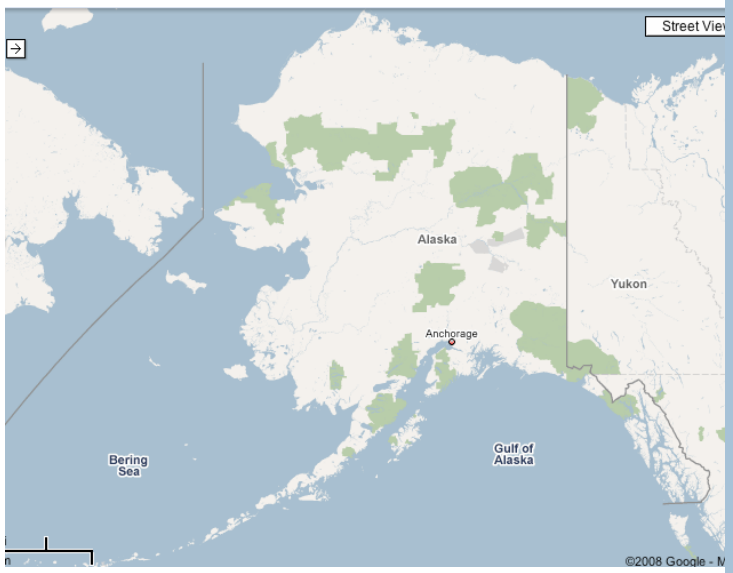
- WRCC domain: geography, topography, climates
- Climate observations
- Existing drought monitoring
- Challenges
- Case study: current drought in California

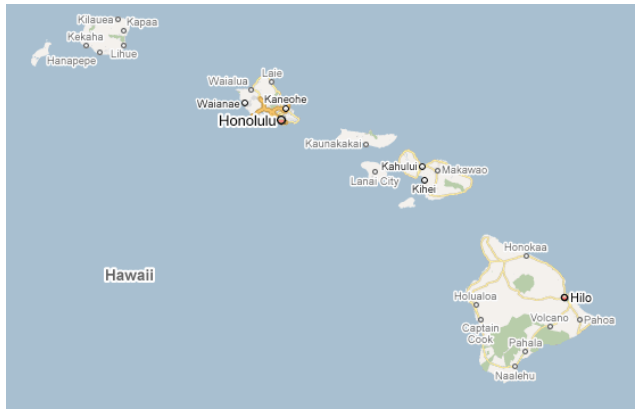
WRCC domain

www.wrcc.dri.edu



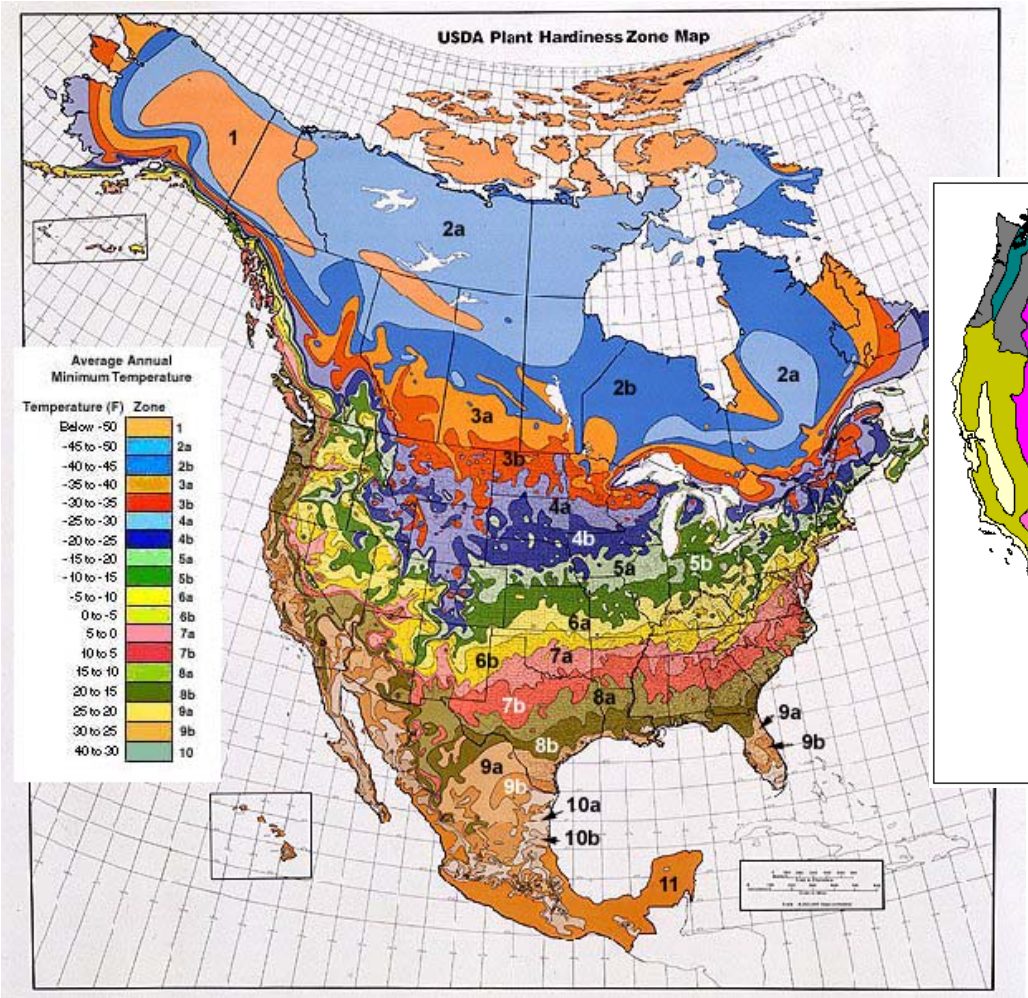
WRCC domain

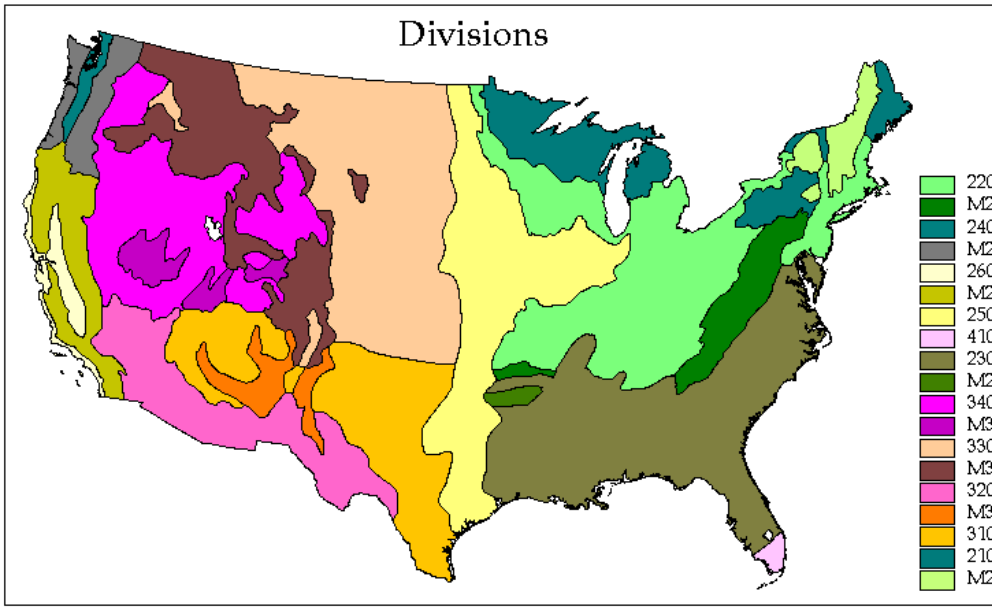

Street View
Alaska
Yukon
Anchorage
Bering Sea
Gulf of Alaska
©2008 Google - M


Kilauea
Kapaa
Kekaha
Lihue
Hanapepe
Waialua
Laie
Waianae
Kaneohe
Honolulu
Kaunakakai
Kahului
Makawao
Lanai City
Kihei
Hawaii
Honokaa
Holualoa
Hilo
Volcano
Pahoa
Captain Cook
Pahala
Naalehu

Lethbridge
Vancouver
Seattle
Washington
Missoula
Montana
Billings
Portland
Eugene
Oregon
Idaho
Wyoming
Nevada
Utah
Denver
Colorado
Santa Rosa
Sacramento
San Francisco
San Jose
California
Arizona
Phoenix
New Mexico
Los Angeles
San Diego
Ensenada
El Paso

WRCC domain

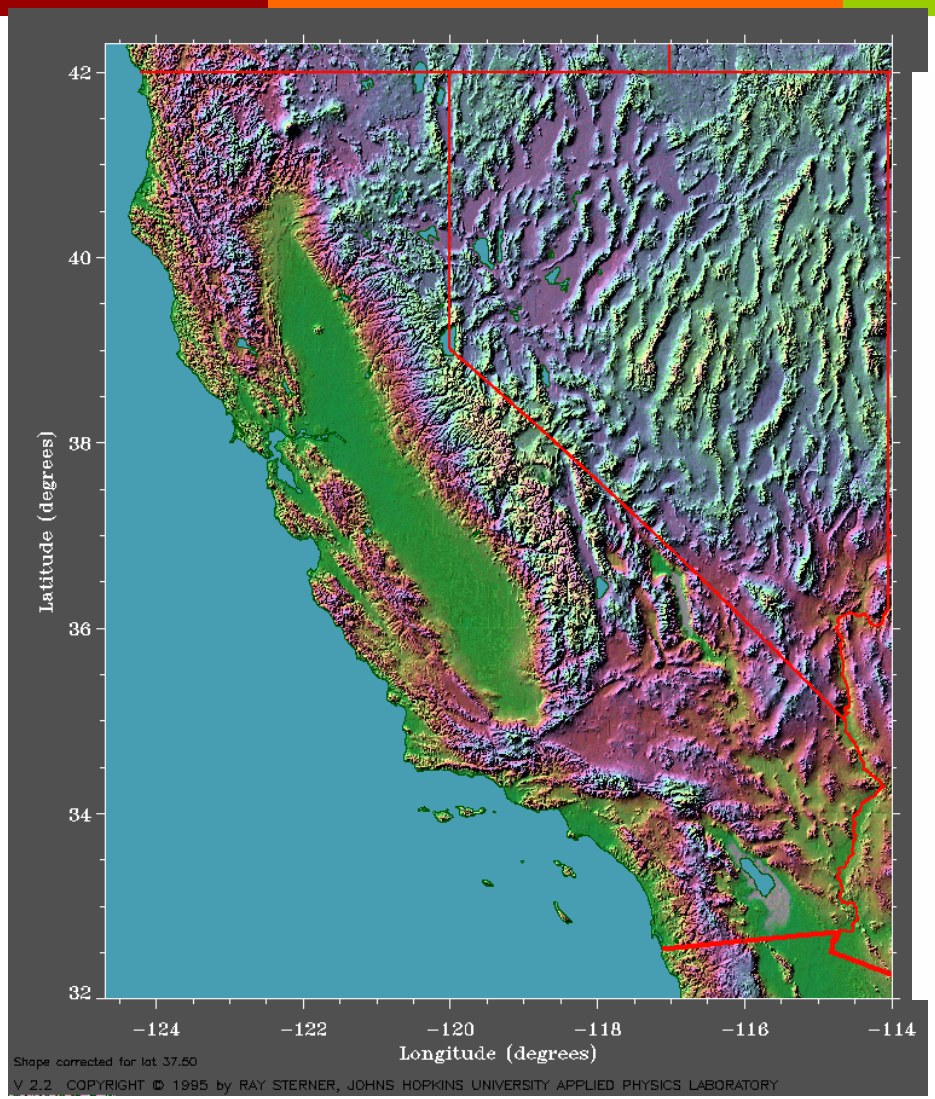

USDA Plant Hardiness Zone Map
Average Annual Minimum Temperature
Temperature (F) Zone
Below -50 1
-45 to -50 2a
-40 to -45 2b
-35 to -40 3a
-30 to -35 3b
-25 to -30 4a
-20 to -25 4b
-15 to -20 5a
-10 to -15 5b
-5 to -10 6a
0 to -5 6b
5 to 0 7a
10 to 5 7b
15 to 10 8a
20 to 15 8b
25 to 20 9a
30 to 25 9b
40 to 30 10
1
2a
2b
2a
3a
3b
4a
4b
5a
5b
6a
6b
7a
7b
8a
8b
9a
9b
9a
9b
10a
10b
11

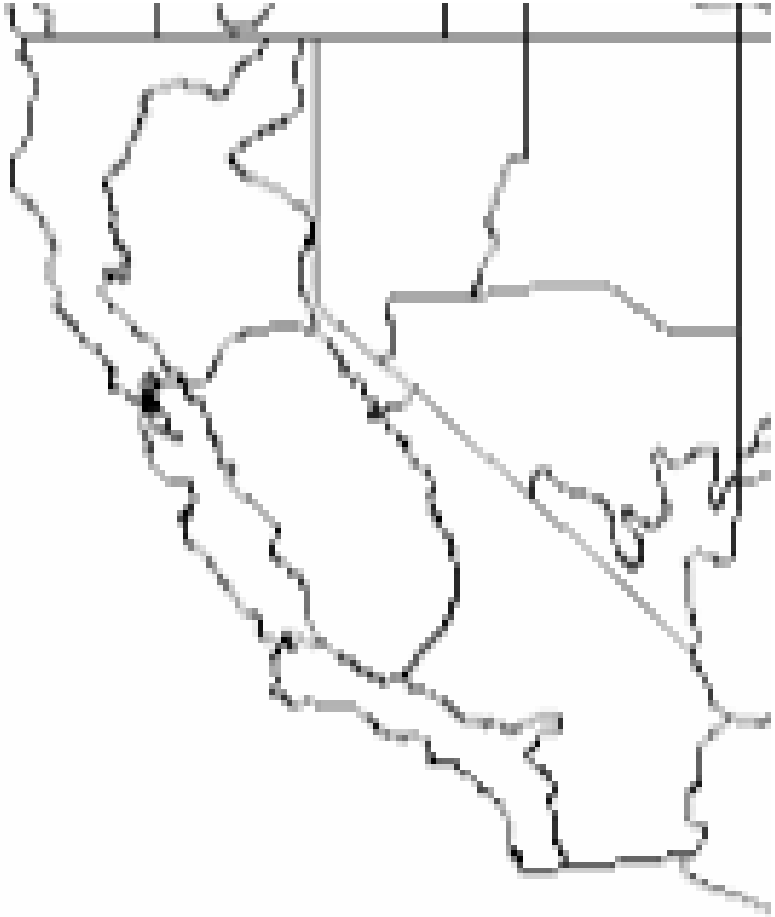

Divisions

Observations

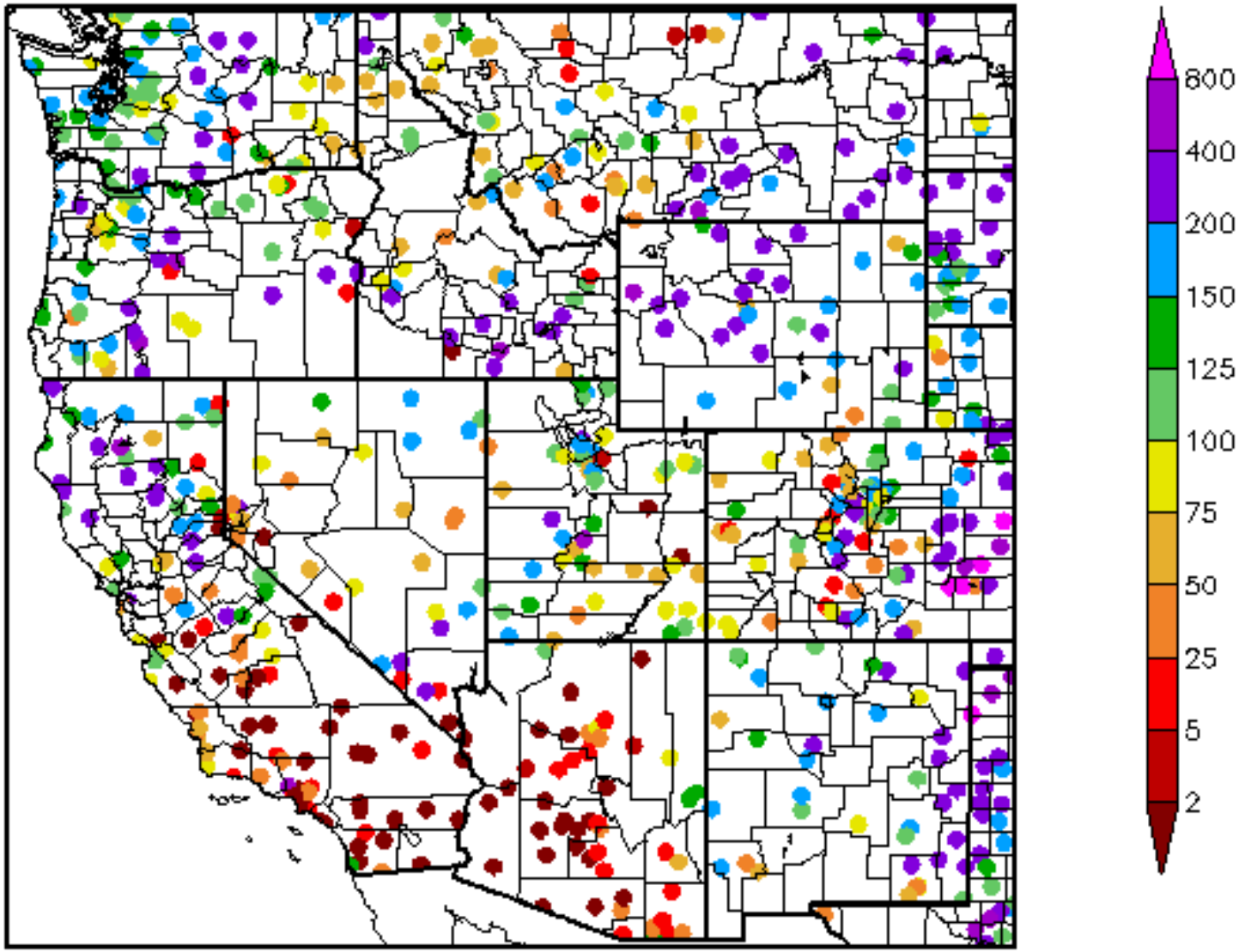
- Diversity requires dense observation network
- NWS Cooperative network generally biased towards lower elevation and urban areas
- NCDC Climate Divisions generally based on watersheds in the western U.S.—not necessarily based on climate
- Automated stations are helping greatly in our understanding climate of remote areas
- PRISM has helped to fill in gaps, and define climatology in under-observed areas, but monthly data only

Observations: Climate Divisions





Percent of Normal Precipitation (%)
10/1/2008 – 10/14/2008



Generated 10/15/2008 at HPRCC using provisional data.

NOAA Regional Climate Centers

Monitoring the Water Budget

- Working definition of **drought** = imbalance between water supply and demand, with an impact
- Precipitation percentile and percent of normal
- Standardized Precipitation Index
- Streamflow
- Agriculture reports*
- Water supply deliveries
- Reservoir storage
- Snowpack
- Vegetation greenness, VegDRI

Demand:

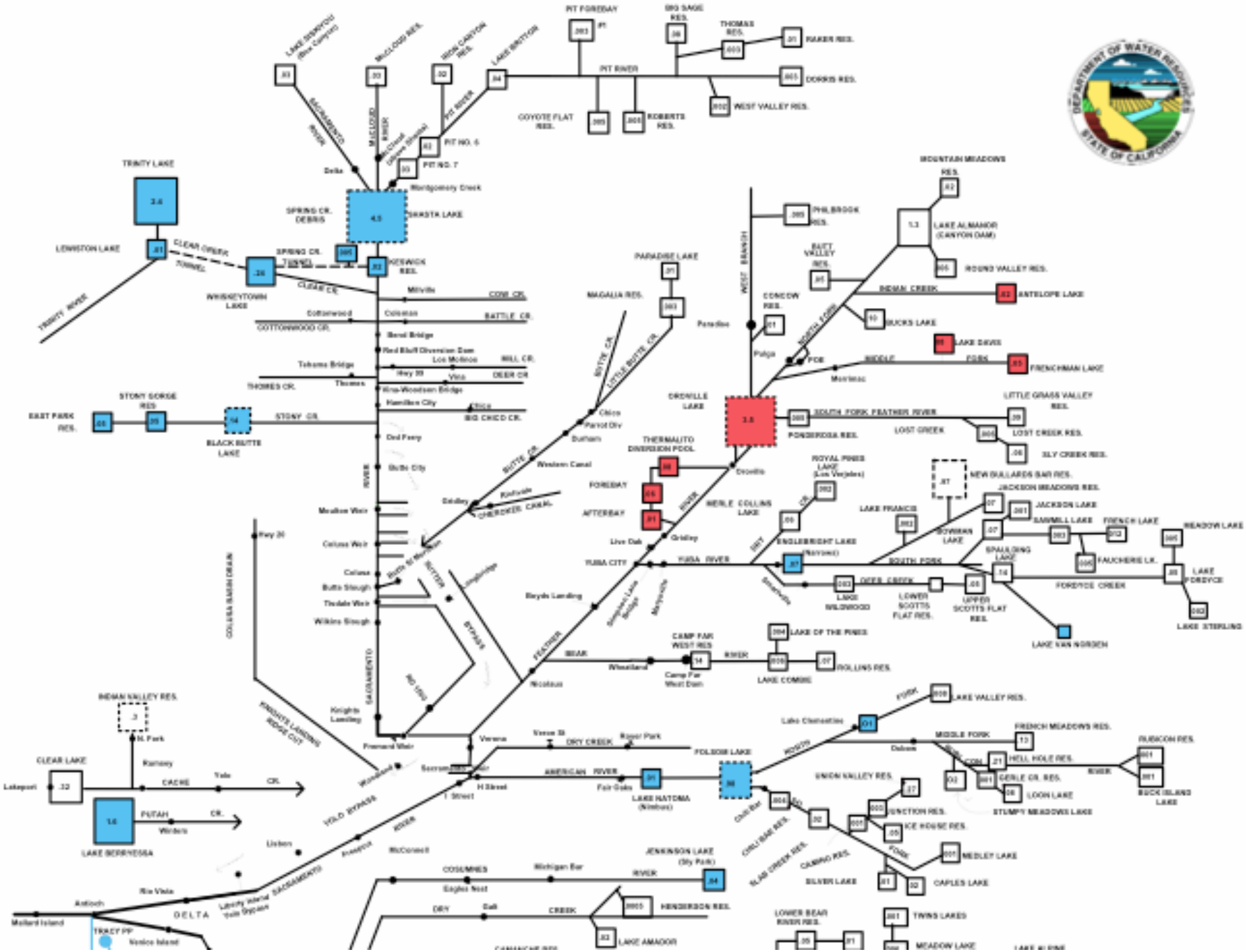
Evapotranspiration

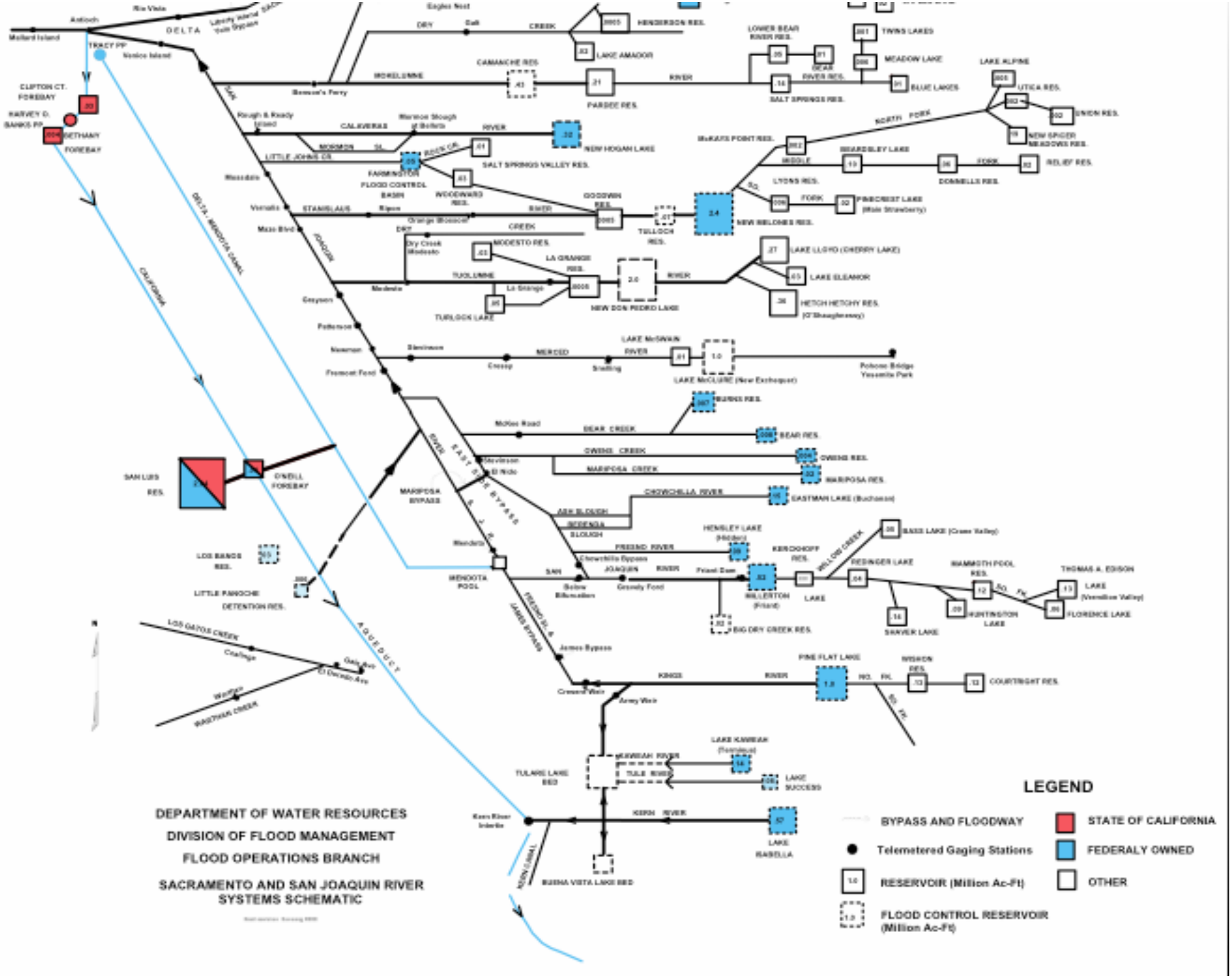
Population

Soils

Challenges

- Delayed response/hydrologic lags: Low snowpack winter results in reduced water deliveries in summer, when demand is higher.
- Mediterranean climate in southern zones: wet winters and dry summers. Drought indicators may be different for each season.
- Multiple competing demands: reservoir storage is a result of many factors (e.g., natural inflow, irrigation delivery, flood protection, fish and environmental concerns)
- Artificial vs. natural systems


DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA
PIT FOREBAY
BIG SAGE RES.
THOMAS RES.
BAKER RES.
DOWNS RES.
WEST VALLEY RES.
PIT RIVER
COYOTE FLAT RES.
ROBERTS RES.
LAKE SHASTA (Box Canyon)
McCLOUD RES.
IRON CANYON RES.
LAKE BRITTON
PIT NO. 6
PIT NO. 7
Montgomery Creek
SHASTA LAKE
SPRING CR. DEBRIS
KESWICK RES.
TRINITY LAKE
LEWISTON LAKE
CLEAR CREEK TUNNEL
SPRING CR. TUNNEL
WHISKEYTOWN LAKE
TRINITY RIVER
Millville
COW CR.
Cottonwood
Coleman
BATTLE CR.
COTTONWOOD CR.
Bend Bridge
Red Bluff Diversion Dam
Tehama Bridge
Los Molinos
MILL CR.
DEER CR.
THOMES CR.
Thomes
Hamilton City
BIG CHICO CR.
STONY GORGE RES.
EAST PARK RES.
STONY CR.
BLACK BUTTE LAKE
Ord Ferry
Butte City
Meridian Weir
Colusa Weir
Colusa
Butte Slough
Tisdale Weir
Wilkins Slough
COLUSA BASIN DRAIN
Hwy 20
Hwy 99
Knights Landing
KNIGHTS LANDING RIDGE CUT
Freeman Weir
INDIAN VALLEY RES.
H. Park
Ramney
CLEAR LAKE
Lakeport
CACHE CR.
Yolo
PUTAH CR.
Winters
LAKE BERRYESSA
Linden
Rio Vista
Antioch
Mallard Island
DELTA
TRACY PP
Venice Island
Labrity Island Tide Gauge
SACRAMENTO RIVER
YOLO BYPASS
Knights Landing
Verona
Verona St
DRY CREEK
Rioer Park
FOLSOM LAKE
AMERICAN RIVER
Fair Oaks
LAKE NATOMA (Nimbus)
H Street
I Street
McConnell
COSUMNES
Michigan Bar
Eagle Nest
JENKINSON LAKE (Sly Park)
DRY
Salt
CREEK
HENDERSON RES.
LAKE AMADOR
PARADISE LAKE
MAGALIA RES.
BUTTE CR.
LITTLE BUTTE CR.
Chico
Parrot Ply
Durham
Western Canal
Knitsville
Gridley
CHEROKEE CANAL
BUTTE BYPASS
Meridian
Live Oak
Grider
AFTERBAY
FOREBAY
THERMALITO DIVERSION POOL
THERMALITO AFTERBAY
Bryds Landing
Sutter Bypass
Feather River
BEAR
Wheatland
Nicolaus
Camp Far West Dam
CAMP FAR WEST RES
LAKE COMBIE
ROLLINS RES.
LAKE OF THE PINES
WEST BRANCH
PHILBROOK RES.
BUTT VALLEY RES.
CONCOW RES.
Paradise
Pulga
NORTH FORK
FOR
MIDDLE FORK
Merlino
MOUNTAIN MEADOWS RES.
LAKE ALMANOR (CANYON DAM)
ROUND VALLEY RES.
INDIAN CREEK
ANTELOPE LAKE
BUCKS LAKE
LAKE DAVIS
FRENCHMAN LAKE
ORONILLE LAKE
Oroville
SOUTH FORK FEATHER RIVER
FOREBAY
LITTLE GRASS VALLEY RES.
LOST CREEK
LOST CREEK RES.
SLY CREEK RES.
ROYAL PINES LAKE (Los Verjeles)
NEW BULLARDS BAR RES.
JACKSON MEADOWS RES.
JACKSON LAKE
SAWMILL LAKE
FRENCH LAKE
MEADOW LAKE
MERLE COLLINS LAKE
LAKE FRANCIS
BOWMAN LAKE
SPAULDING LAKE
FAUCHERIE LK.
LAKE ENGLEBRIGHT (Bayview)
YUBA CITY
YUBA RIVER
SOUTH FORK
DEER CREEK
LAKE WILDWOOD
LOWER SCOTTS FLAT RES.
UPPER SCOTTS FLAT RES.
FORBYCE CREEK
LAKE FORBYCE
LAKE STERLING
LAKE VAN NORDEN
Lake Clementine
LAKE VALLEY RES.
FRENCH MEADOWS RES.
MIDDLE FORK
Dutch
HELL HOLE RES.
GERLE CR. RES.
LOON LAKE
STUMPY MEADOWS LAKE
RUBICON RES.
BUCK ISLAND LAKE
UNION VALLEY RES.
IONETON RES.
ICE HOUSE RES.
MEDLEY LAKE
CAPLES LAKE
SILVER LAKE
CAMINO RES.
SLAB CREEK RES.
CHILI BAR RES.
Chili Bar
LOWER BEAR RIVER RES.
TWINS LAKES
MEADOW LAKE


DEPARTMENT OF WATER RESOURCES
DIVISION OF FLOOD MANAGEMENT
FLOOD OPERATIONS BRANCH
SACRAMENTO AND SAN JOAQUIN RIVER
SYSTEMS SCHEMATIC
LEGEND
BYPASS AND FLOODWAY
Telemetered Gaging Stations
RESERVOIR (Million Ac-Ft)
FLOOD CONTROL RESERVOIR (Million Ac-Ft)
STATE OF CALIFORNIA
FEDERALY OWNED
OTHER
DELTA
TRACY PP
CLIFTON CT. FOREBAY
HARVEY O. BANKS PP
BETHANY FOREBAY
DELTA - MENDOTA CANAL
CALIFORNIA
AQUEDUCT
SAN LUIS RES.
O'NEILL FOREBAY
LOS BANOS RES.
LITTLE PANOCHE DETENTION RES.
LOS GATOS CREEK
WAGHORN CREEK
MENDOTA POOL
MARIPOSA BYPASS
EAST SIDE BYPASS
FRESNO SL. & JAMES BYPASS
SAN JOAQUIN RIVER
MERCED RIVER
TUOLUMNE RIVER
STANISLAUS RIVER
MOKELUMNE RIVER
CALAVERAS RIVER
CHOWCHILLA RIVER
FRESNO RIVER
KINGS RIVER
KAWEAH RIVER
TULE RIVER
KERN RIVER
KERN CANAL
TULARE LAKE BED
BUENA VISTA LAKE BED
LAKE KAWEAH
LAKE SUCCESS
LAKE ISABELLA
PINE FLAT LAKE
COURTRIGHT RES.
WISHON RES.
KERCKHOFF RES.
HENSLEY LAKE (Millerton)
MILLERTON (Friant)
BIG DRY CREEK RES.
REDINGER LAKE
SHAVER LAKE
MAMMOTH POOL RES.
HUNTINGTON LAKE
THOMAS A. EDISON LAKE (Vermilion Valley)
FLORENCE LAKE
BASS LAKE (Crane Valley)
WILLOW CREEK
EASTMAN LAKE (Buchanan)
MARIPOSA RES.
OWENS RES.
BEAR RES.
BURNS RES.
LAKE McSWAIN
LAKE McCLURE (New Exchequer)
Pohono Bridge Yosemite Park
TURLOCK LAKE
NEW DON PEDRO LAKE
LA GRANGE RES.
MODESTO RES.
TULLOCH RES.
GOODWIN RES.
NEW MELONES RES.
LAKE LLOYD (CHERRY LAKE)
LAKE ELEANOR
HETCH HETCHY RES. (O'Shaughnessy)
PINECREST LAKE (Male Strawberry)
RELIEF RES.
DONNELLS RES.
BEARDSLEY LAKE
LYONS RES.
McKAYS POINT RES.
NEW SPIGER MEADOWS RES.
UNION RES.
UTICA RES.
LAKE ALPINE
BLUE LAKES
MEADOW LAKE
TWINS LAKES
SALT SPRINGS RES.
BEAR RIVER RES.
LOWER BEAR RIVER RES.
PARDEE RES.
LAKE AMADOR
HENDERSON RES.
CAMANCHE RES.
NEW HOGAN LAKE
SALT SPRINGS VALLEY RES.
FARMINGTON FLOOD CONTROL BASIN
WOODWARD RES.
Bensons Ferry
Eagles Nest
Antioch
Rio Vista
Mallard Island
Venice Island
Rough & Ready Island
Vernalis
Modesto
Newman
Fremont Ford
Patterson
Grayson
Dry Creek Modesto
Orange Blossom
Ripon
Stevinson
Crossup
Snelling
Mendota
La Grange
Stevinson
El Nido
Chowchilla Bypass
Friant Dam
Gravelly Ford
Below Bifurcation
Crescent Weir
Army Weir
James Bypass
Kern River Intertie
Waterfowl Housing MWD

Challenges (2)

- Political definitions of drought in different states
- PDSI, and other indicators that work well for the eastern states, may not work as well in the western states
- Multi-year droughts are common (e.g., recent Arizona drought), are a physical feature of the climate
- Transboundary diversions: Colorado, California, Nevada in the works
- Scale: Lake Lanier (Atlanta) ~1000 mi^2, Colorado River Basin ~238,000 mi^2

U.S. Drought Monitor

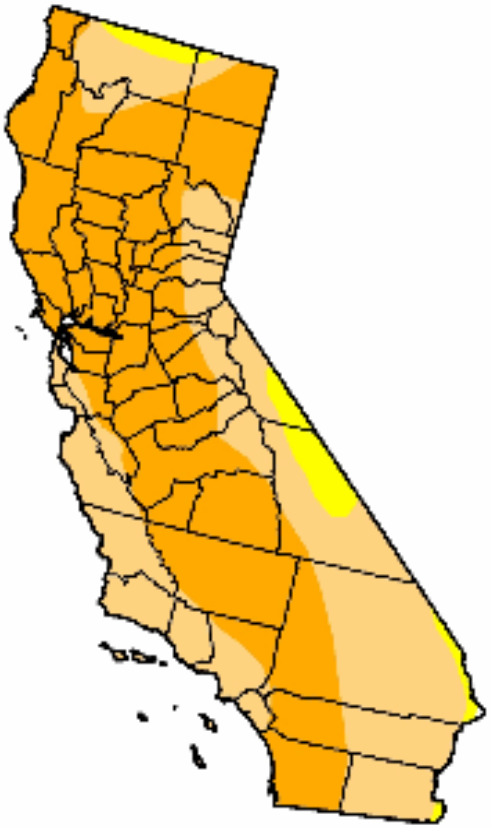
California

October 7, 2008

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.0	100.0	95.9	55.0	0.0	0.0
Last Week (09/30/2008 map)	0.0	100.0	95.9	55.2	2.1	0.0
3 Months Ago (07/15/2008 map)	0.1	99.9	89.2	18.1	0.0	0.0
Start of Calendar Year (01/01/2008 map)	8.9	91.1	84.7	58.0	14.6	0.0
Start of Water Year (10/07/2008 map)	0.0	100.0	95.9	55.0	0.0	0.0
One Year Ago (10/09/2007 map)	0.1	99.9	92.6	64.6	33.8	0.0



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements

http://drought.unl.edu/dm

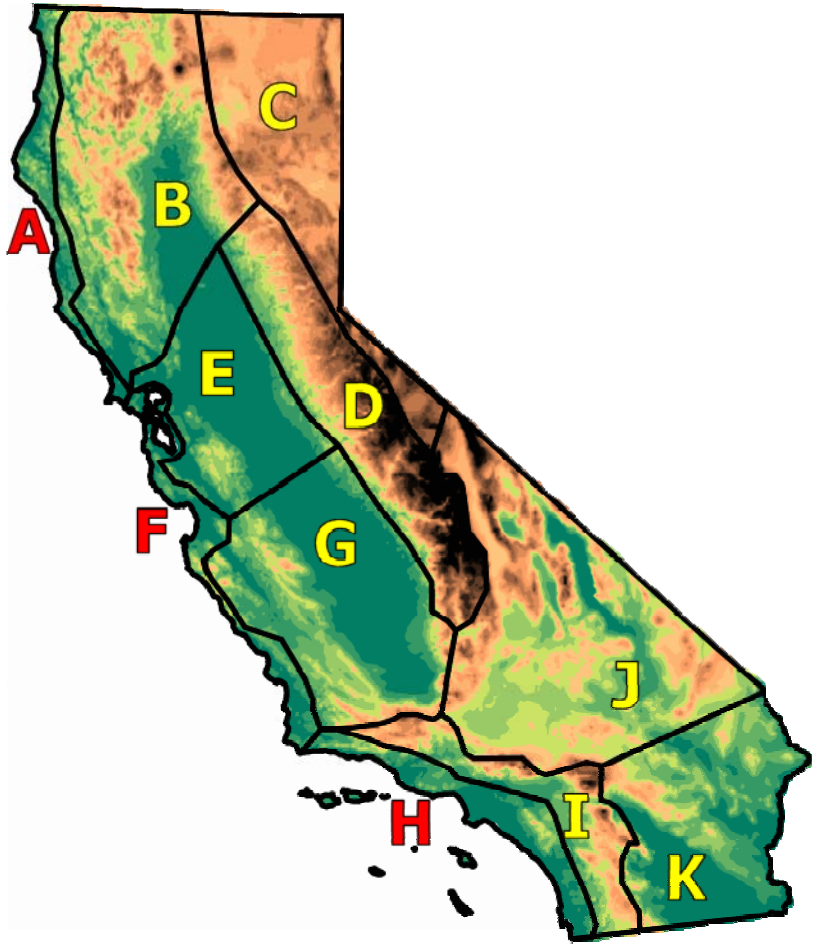
Released Thursday, October 9, 2008

Author: Laura Edwards, WRCC

Case Study: California

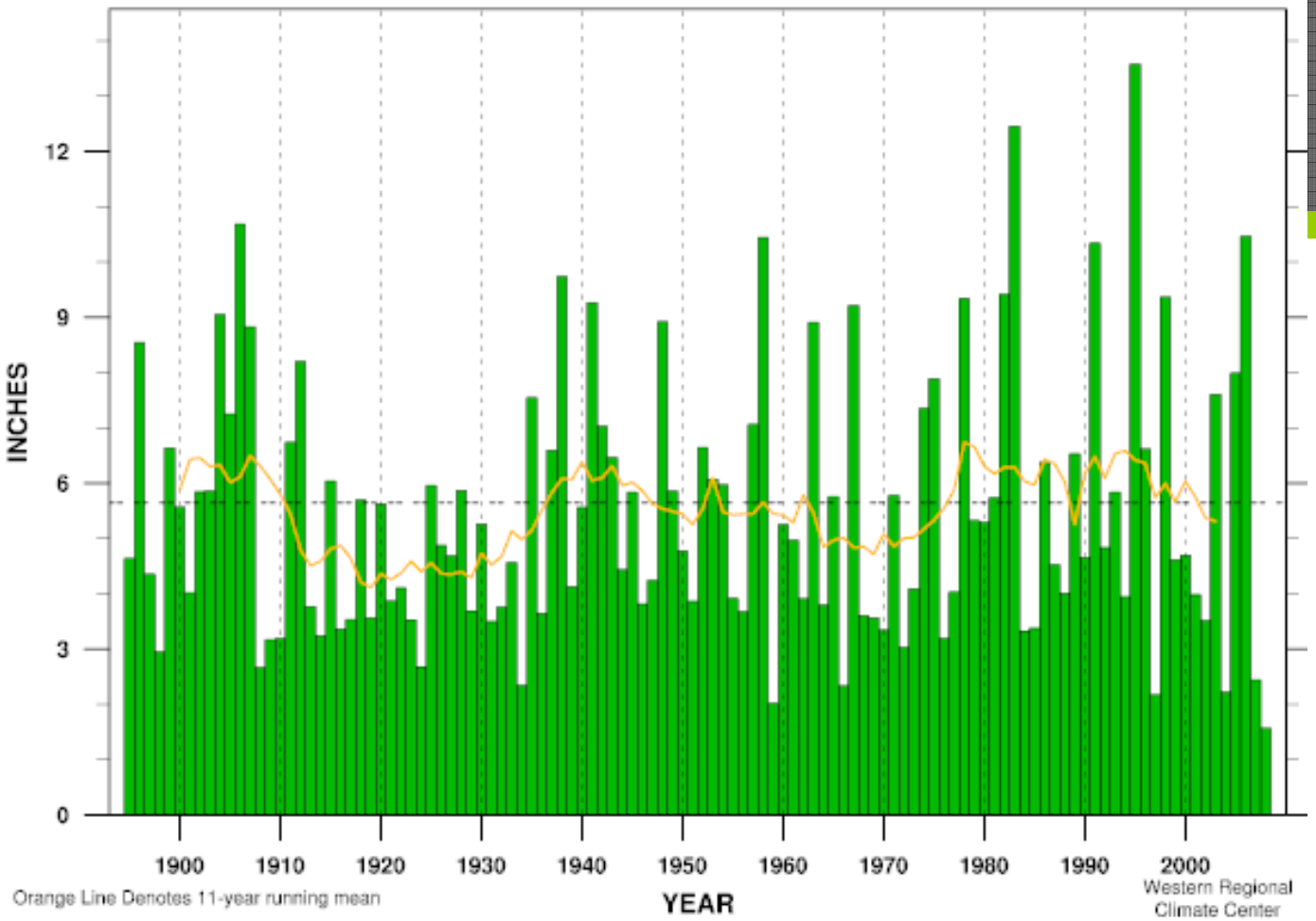
- 2 consecutive dry water years (~70% of average precipitation in key water supply area)
- Record dry spring (March, April, May) in 2008
- Governor Schwarzenegger drought declaration in early June 2008
- Low reservoir carryover…. Plus fish and environmental concerns necessitate water releases
- Irrigated agriculture has full deliveries, but natural lands left baking in the sun
- Scale & sector differences: agriculture = $50B, pasture & rangeland losses = $72+M in 28 counties (7/29/08)

Case Study: California



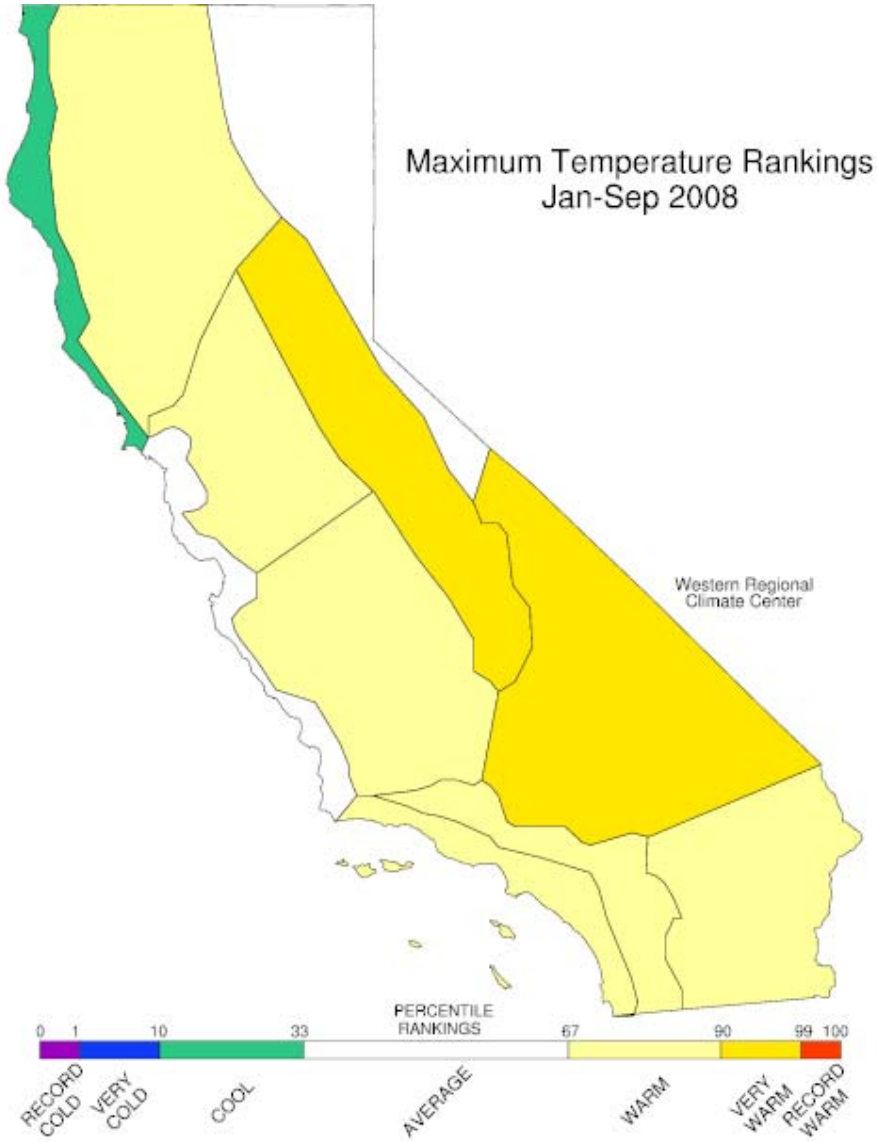
California Statewide
Precipitation Mar-May

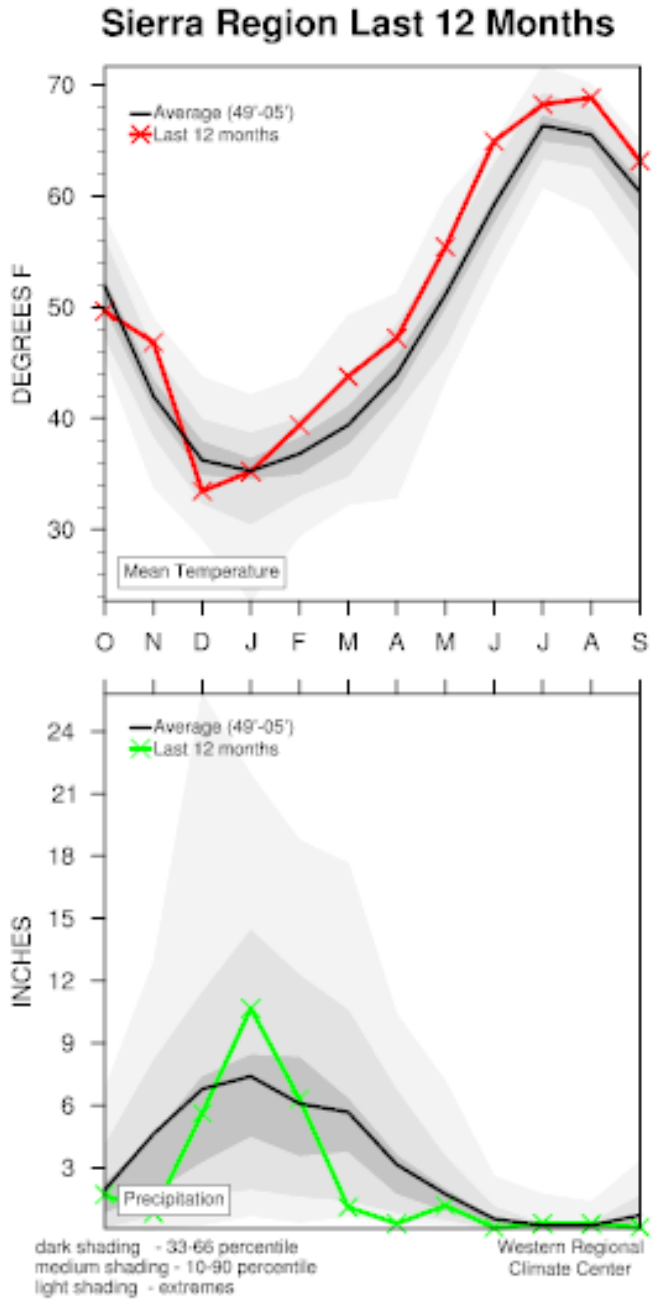
http://www.wrcc.dri.edu/monitor/cal-mon/



Linear Trend 1895-present	+ 0.43 ± 1.35 in.	(+ 7 ± 23%) per 100 yr			
Linear Trend 1949-present	+ 0.76 ± 3.99 in.	(+ 13 ± 70%) per 100 yr			
Linear Trend 1975-present	- 4.06 ± 10.74 in.	(- 71 ± 190%) per 100 yr			
Wettest Year	13.58 in. (240%)	in 1995		MEAN	5.65 in.
Driest Year	1.56 in. (27%)	in 2008		STDEV	2.56 in.
Mar-May 2008	1.56 in. (27%)			RANK	1 of 114

Abatzoglou et al 2008 (submitted)


Maximum Temperature Rankings
Jan-Sep 2008
Western Regional
Climate Center
PERCENTILE
RANKINGS
0
1
10
33
67
90
99
100
RECORD
COLD
VERY
COLD
COOL
AVERAGE
WARM
VERY
WARM
RECORD
WARM


Sierra Region Last 12 Months
DEGREES F
70
60
50
40
30
Average (49'-05')
Last 12 months
Mean Temperature
O
N
D
J
F
M
A
M
J
J
A
S
INCHES
24
21
18
15
12
9
6
3
Average (49'-05')
Last 12 months
Precipitation
dark shading - 33-66 percentile
medium shading - 10-90 percentile
light shading - extremes
Western Regional
Climate Center

Concluding Thoughts

- Many improvements needed:
  - how to depict multiple simultaneous situations
  - Monitoring and data access over the border
  - Quantified information on status and trends of all components of the water balance (supply & demand)
  - How to depict drought in a changing climate, or “chronic drought”
  - Effects of changing definitions of what constitutes “normal” climate

WRCC Future Directions

- WestWide Drought Tracker: Drill-down to local climate information, tie in to NDMC Drought Decision Support System
- NIDIS portal contributions: content and design
- Seek out international border region climate information
- Climate regions for other states??

Thanks!

laura.edwards@dri.edu

775-674-7163

www.wrcc.dri.edu