Drought in California: Status and Outlooks

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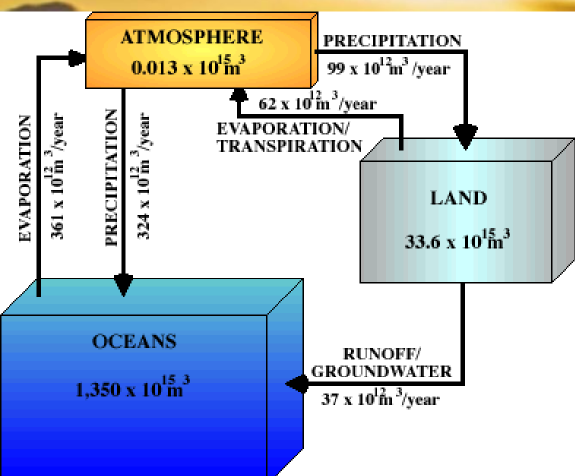
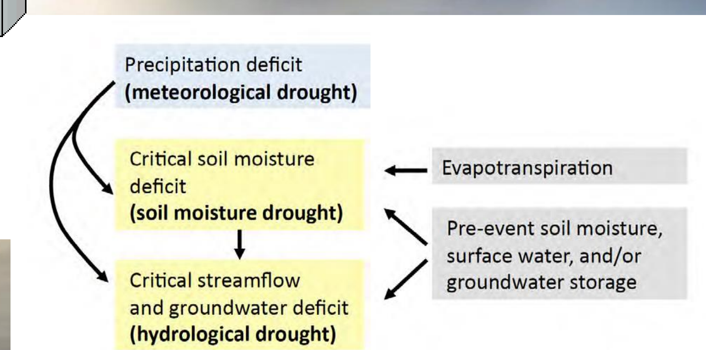
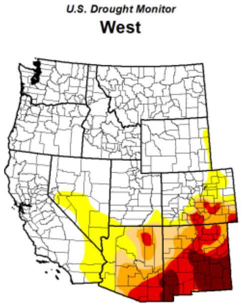
NOAA

(Contributors: Scripps/CNAP, DWR, NWS, PSD, WRCC, NDMC)

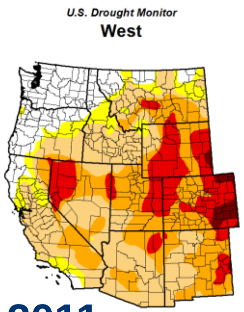






2010

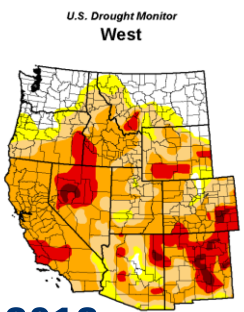
How did we get here? Status and antecedent conditions



2011

Why has it been dry/drier than normal? Is this drought like others?

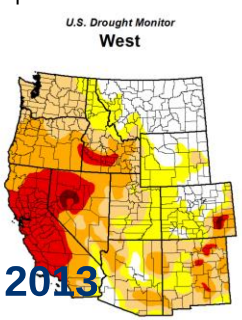
What are the impacts and where did they occur?



2012

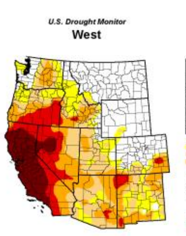
What information is being provided and by whom?

How bad might it get and how long will it last?

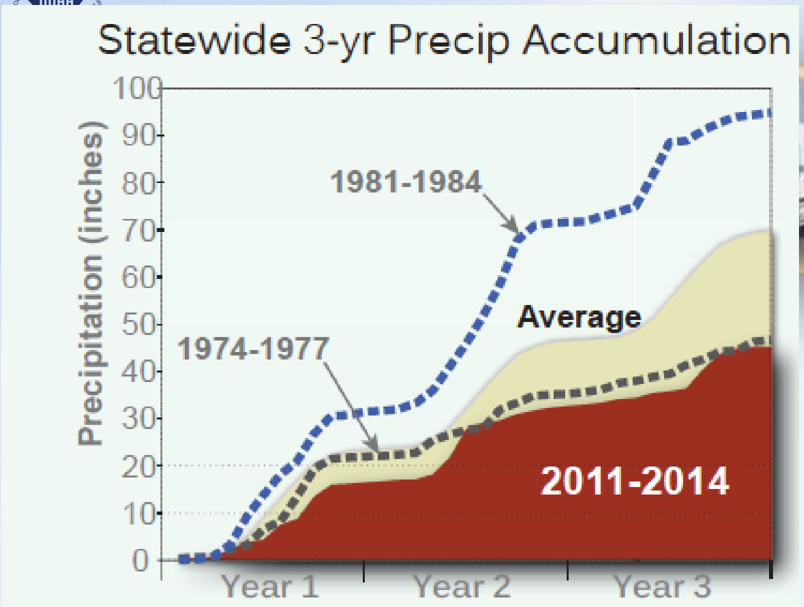


2013

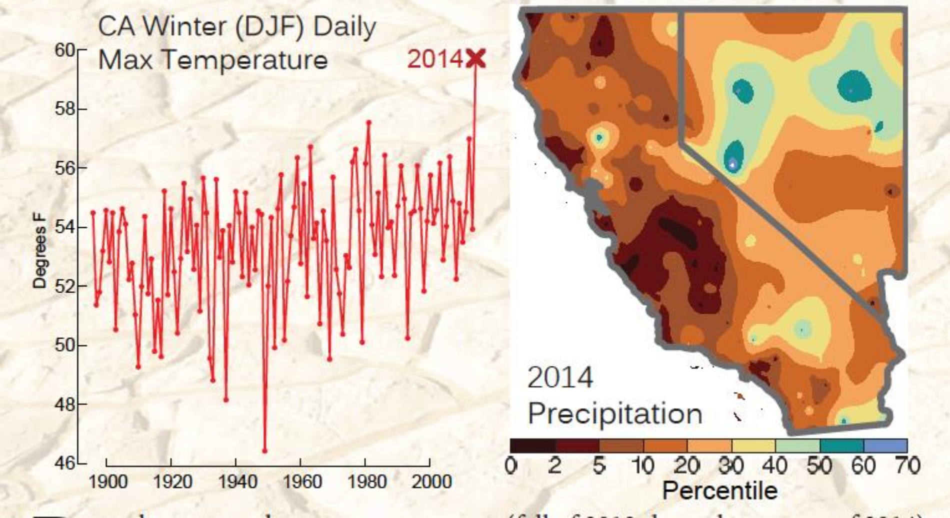
How are we planning for this year and for longer-term risks and opportunities?

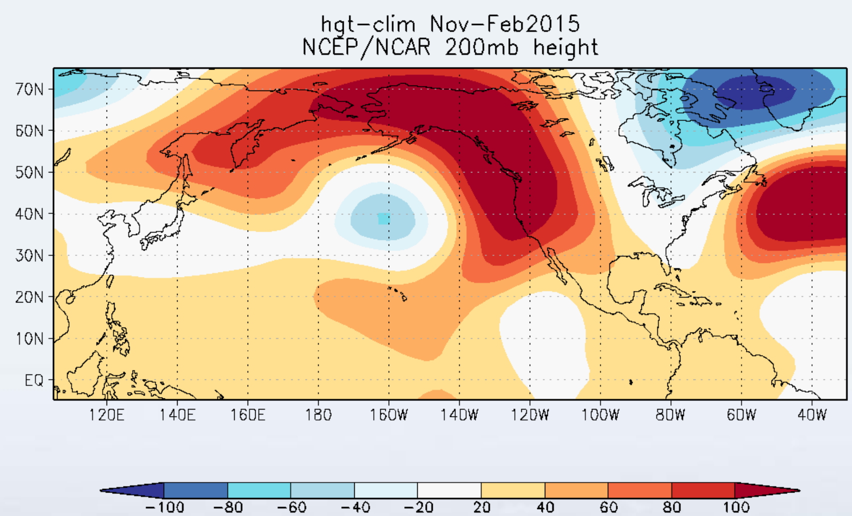


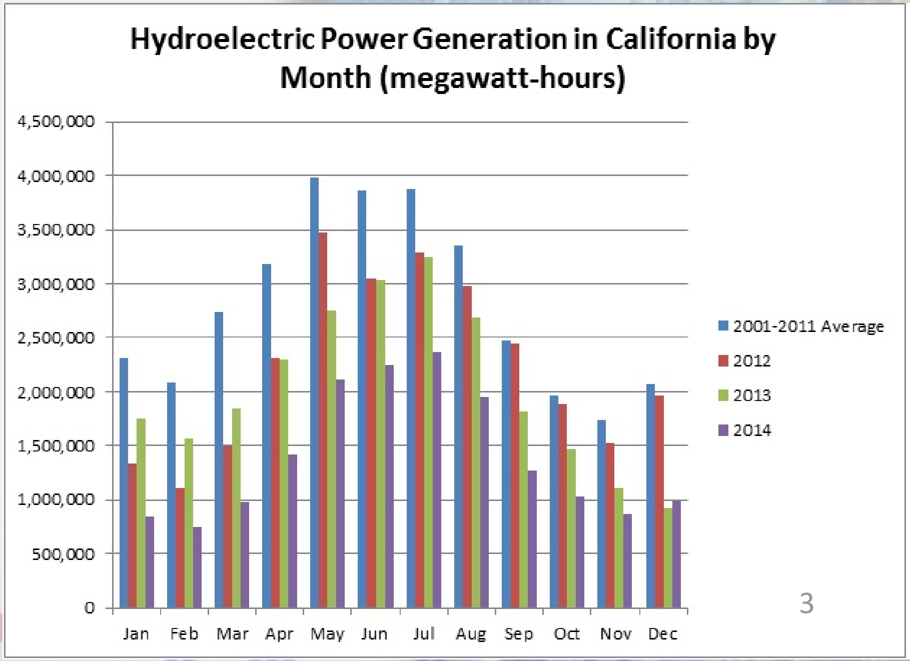
2014



The California Drought of 2014: Record Hot, Record Dry

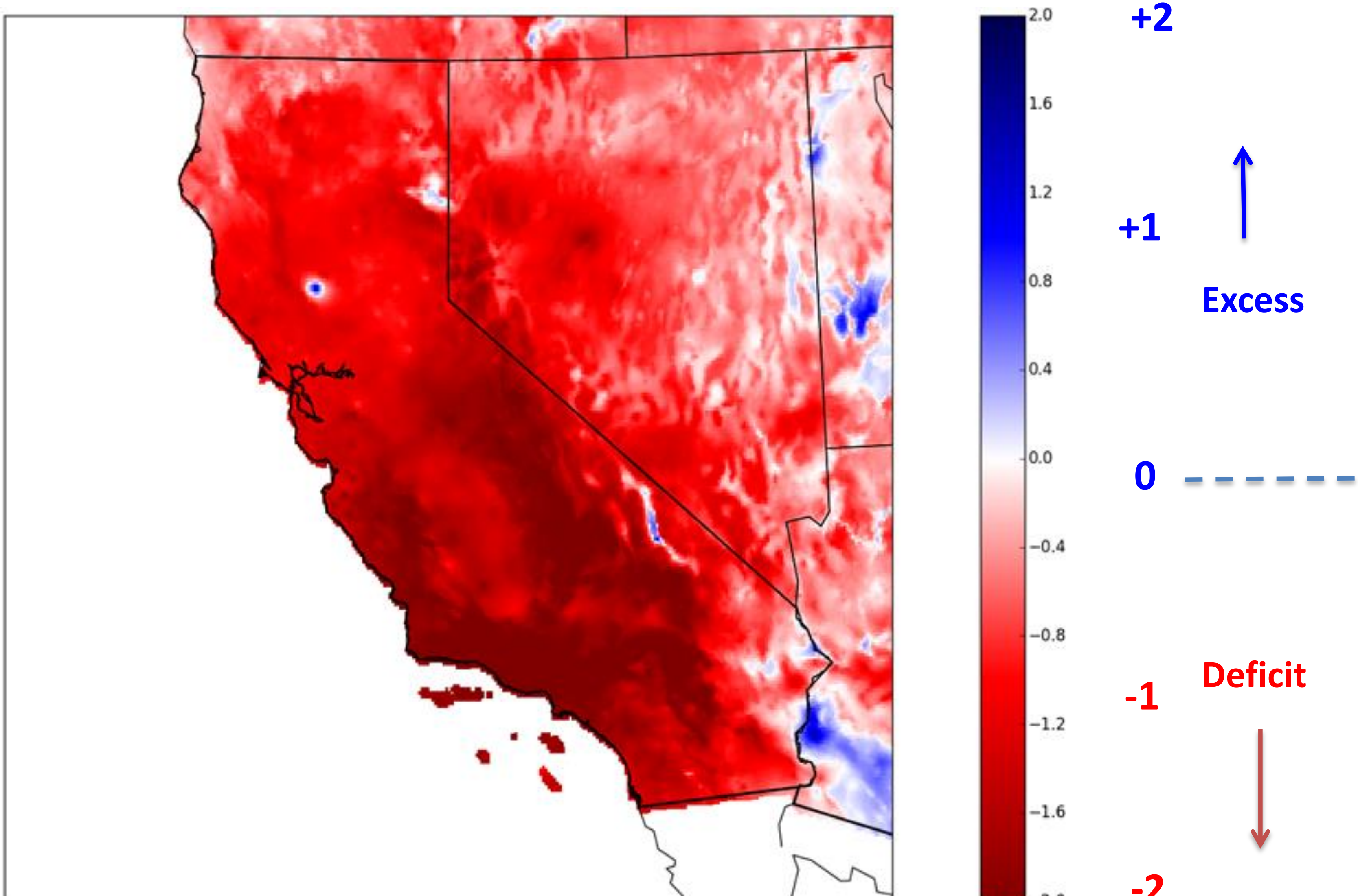




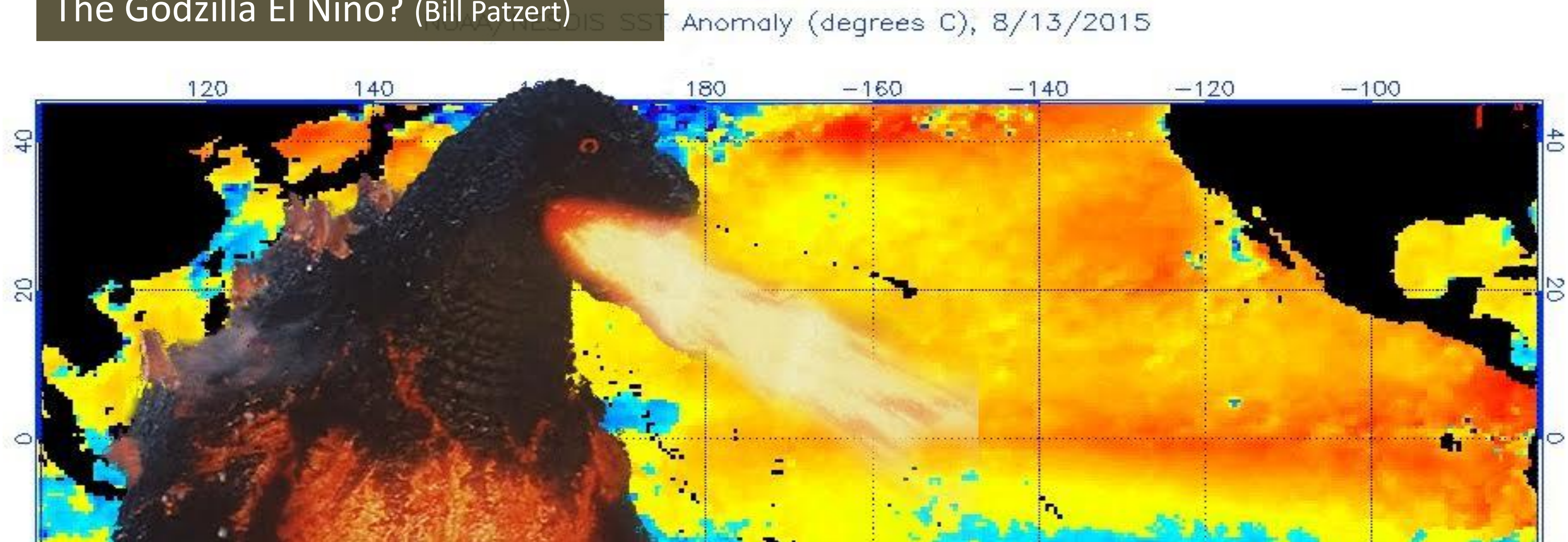


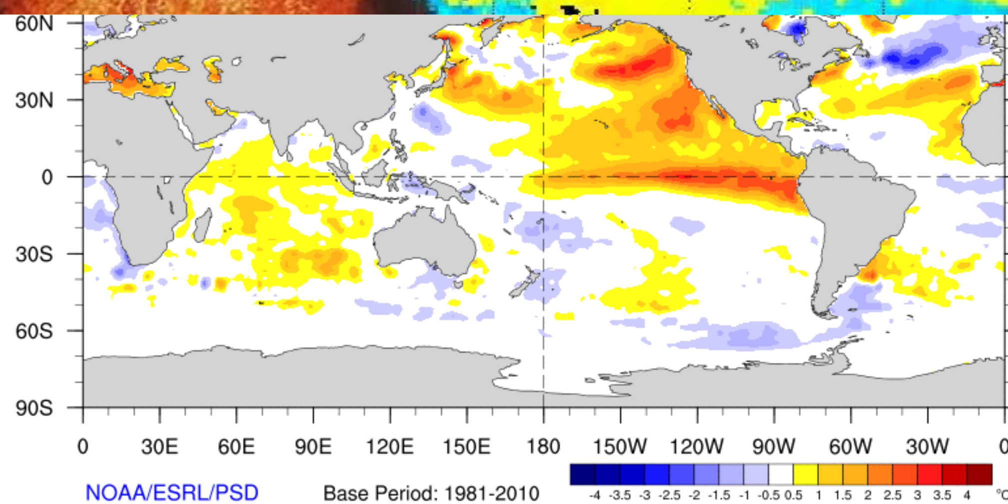
- Could “the” drought have been anticipated?

The Missing Years:
Precipitation Deficits Over Four Winters 2011-12/14-15 Expressed in Units of Average Annual Precipitation. Based on PRISM. Courtesy Paul Iniguez, NWS

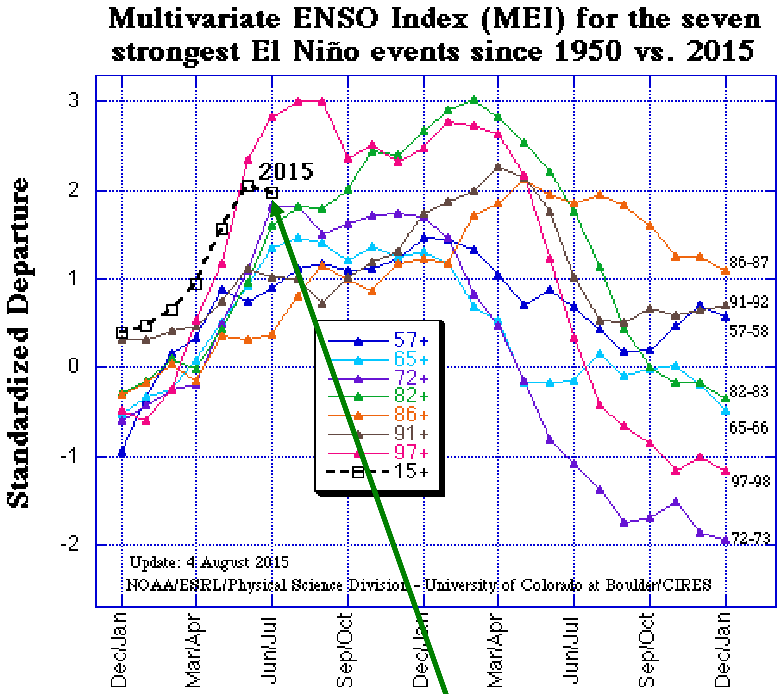


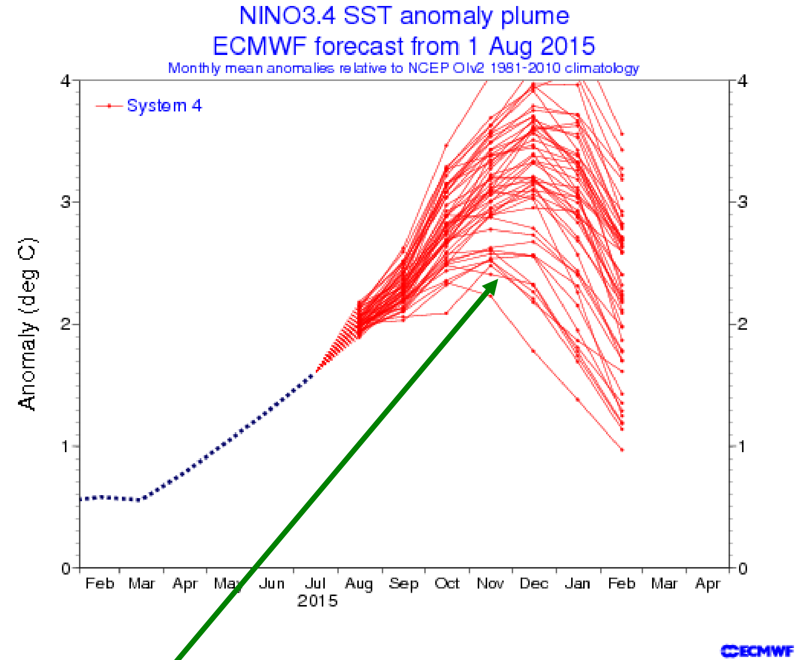
The Godzilla El Niño? (Bill Patzert)





How is the 2015 El Niño doing, and where could it end up?





The 2015 El Niño has been in the top 10th percentile of the Multivariate ENSO Index (MEI) for four months in a row, currently (left) ranked 2nd behind 1997

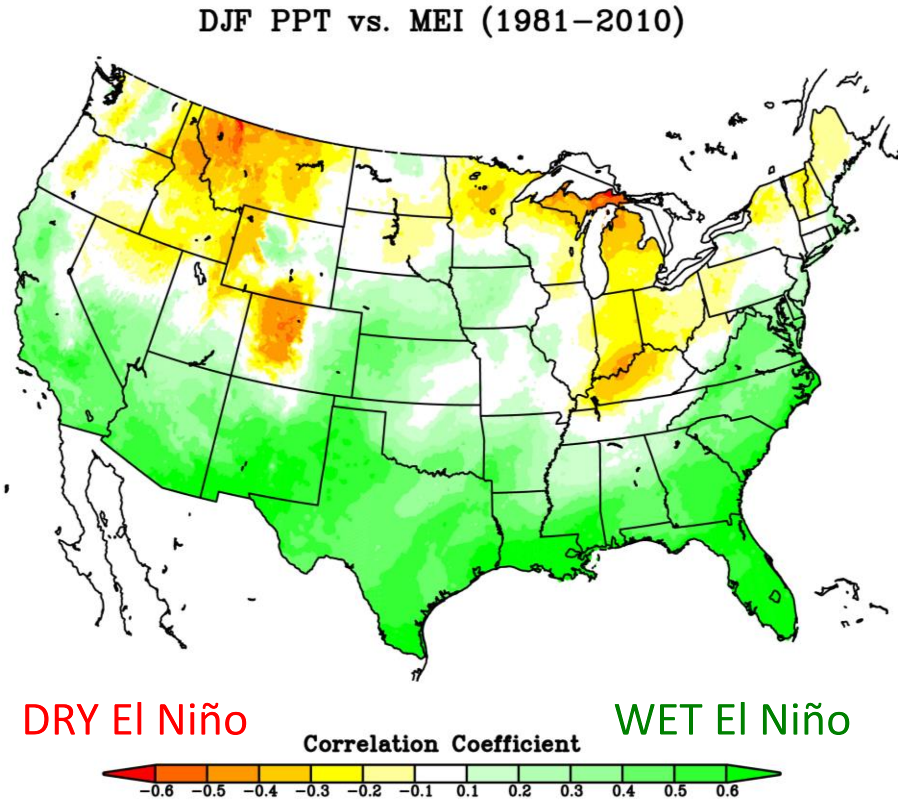
The latest 'anomaly plume' of the European forecast model has a 'majority opinion' that this will end up a 'Super El Niño' (near +3°C) by late fall

Latest observations support a cautionary approach, the event is currently in 'maintenance mode' and will need a fresh push this fall to grow further. ***Short of that it would keep its 'strong' status (upper 10%) without challenging 1997-98 or 1982-83.***

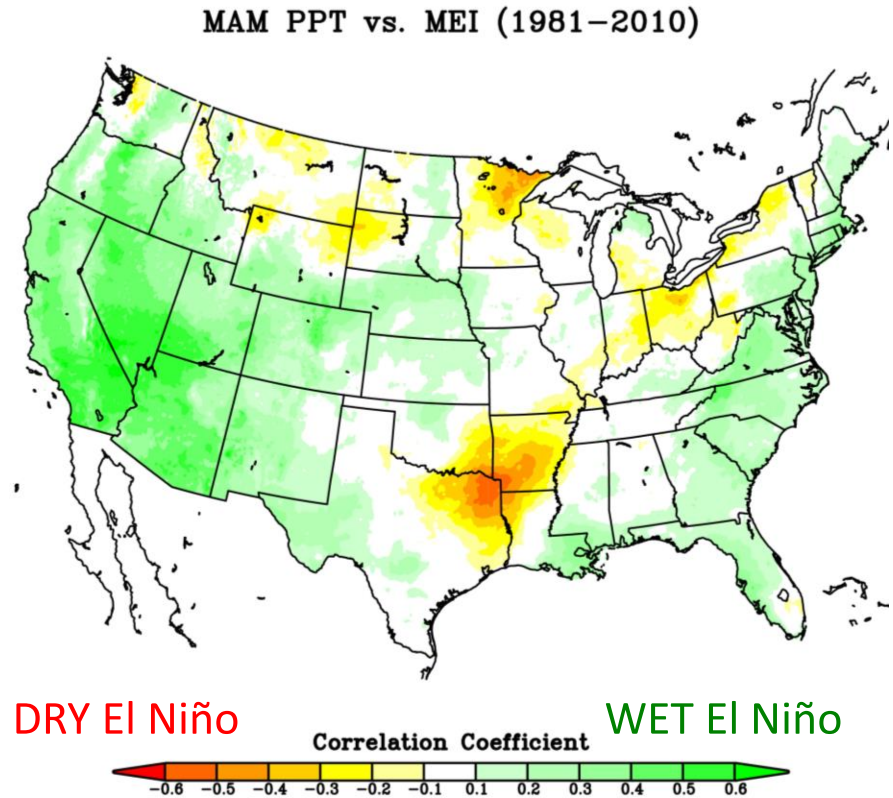
Wolter, NOAA/NIDIS, PSD)

Typical El Niño **precipitation impacts across CA**

December-January-February



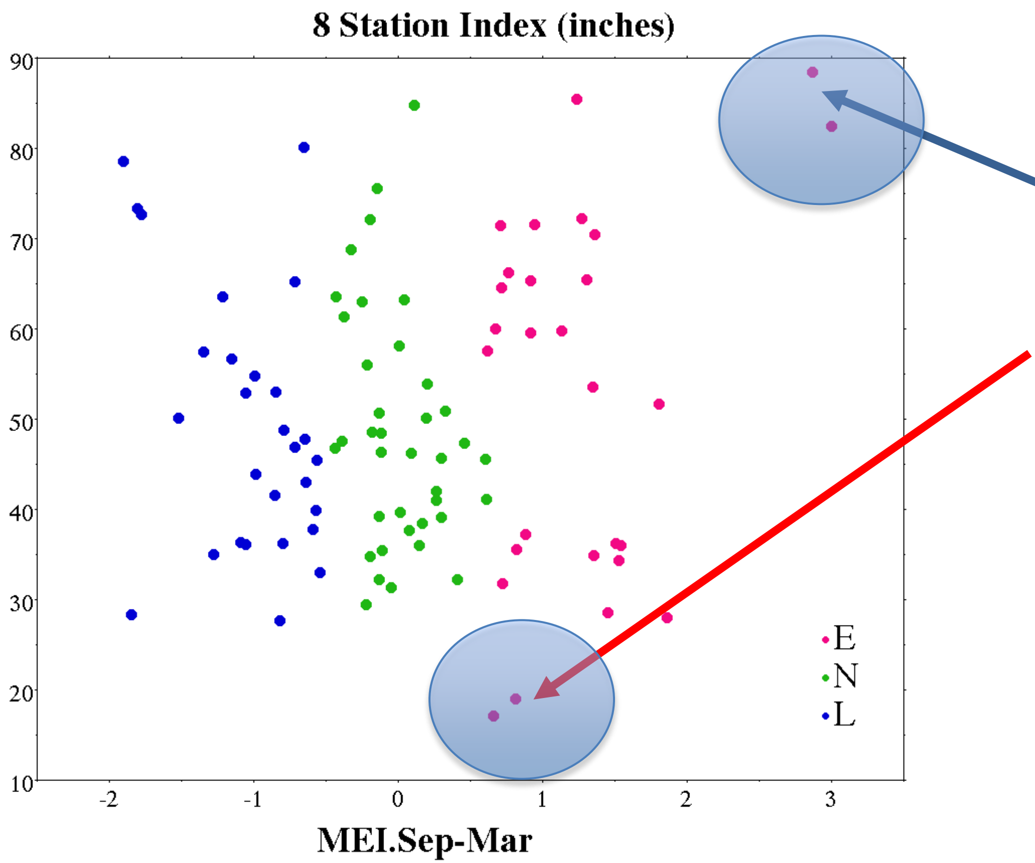
March-April-May



During winter, most of ‘wet El Niño’ signal is at lower elevations and more to the south, while northern Sierra Nevada remains ‘on the fence’ (left). This season is most important since it contributes about 50% of the Water Year moisture.

Spring precipitation is more likely to be on the wet side with an El Niño than winter (right). So, there is the opportunity for a late-season catch-up even if the winter ends ‘dry-ish’.

Cautionary plot on 8 Station Index



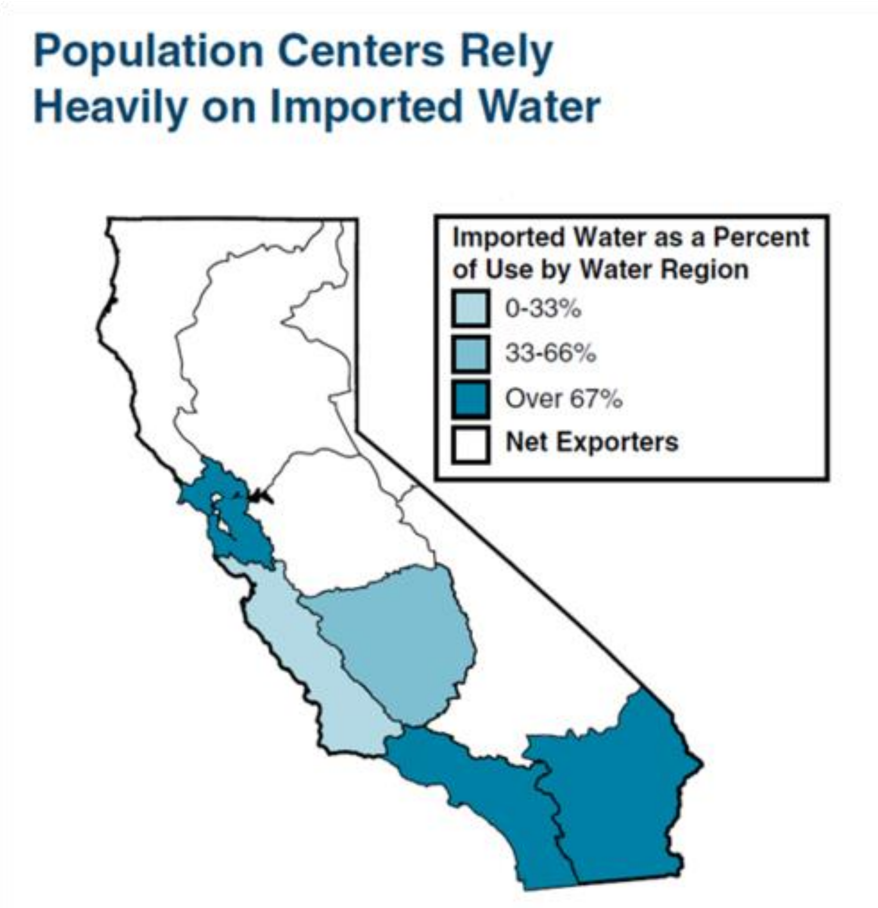
The full 95 year record of the 8SI shows little sensitivity to ENSO.

El Niño events encompass two of the wettest ('83, '98) and the two driest ('24, '77) Water Years.

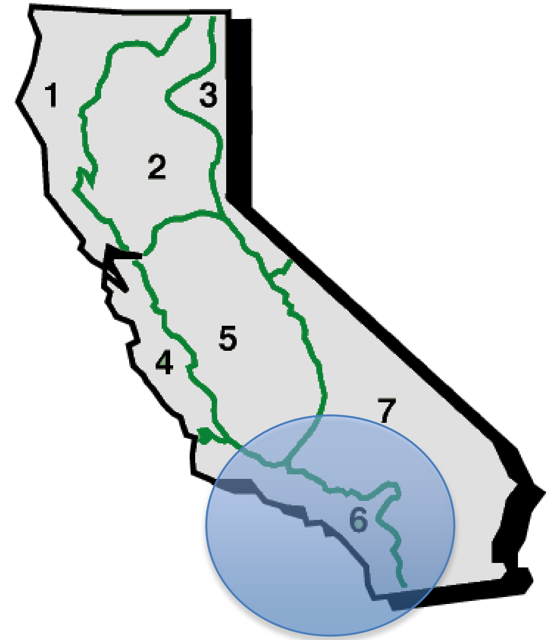
The fact that the two strongest El Niño events ended up wet may not be accidental – numerous modeling experiments confirm that really strong El Niño events have more predictable WET outcomes in northern CA than weaker ones.

These results were confirmed for Sacramento / San Joaquin runoff and 5 Station Index data.

http://www.esrl.noaa.gov/psd/enso/mei.ext/



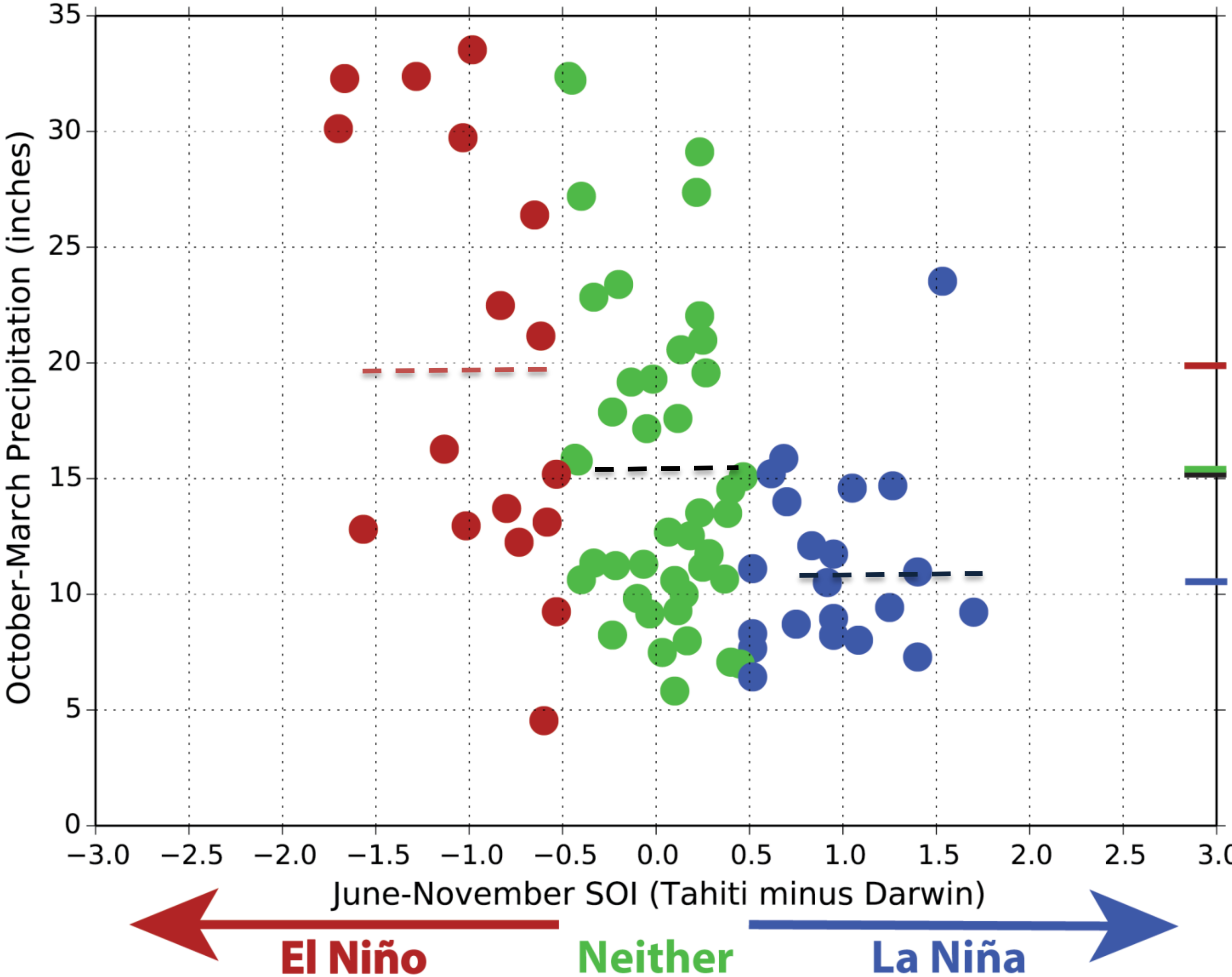
California Legislative
Analyst's Office 2013



California Climate
Divisions

CA Division 6 October-March Precipitation

(versus Southern Oscillation Index for prior June-November)



Years 1933/1934-2013/2014

r^2 = 0.22

Correlation = -0.47

Mean = 19.89 in

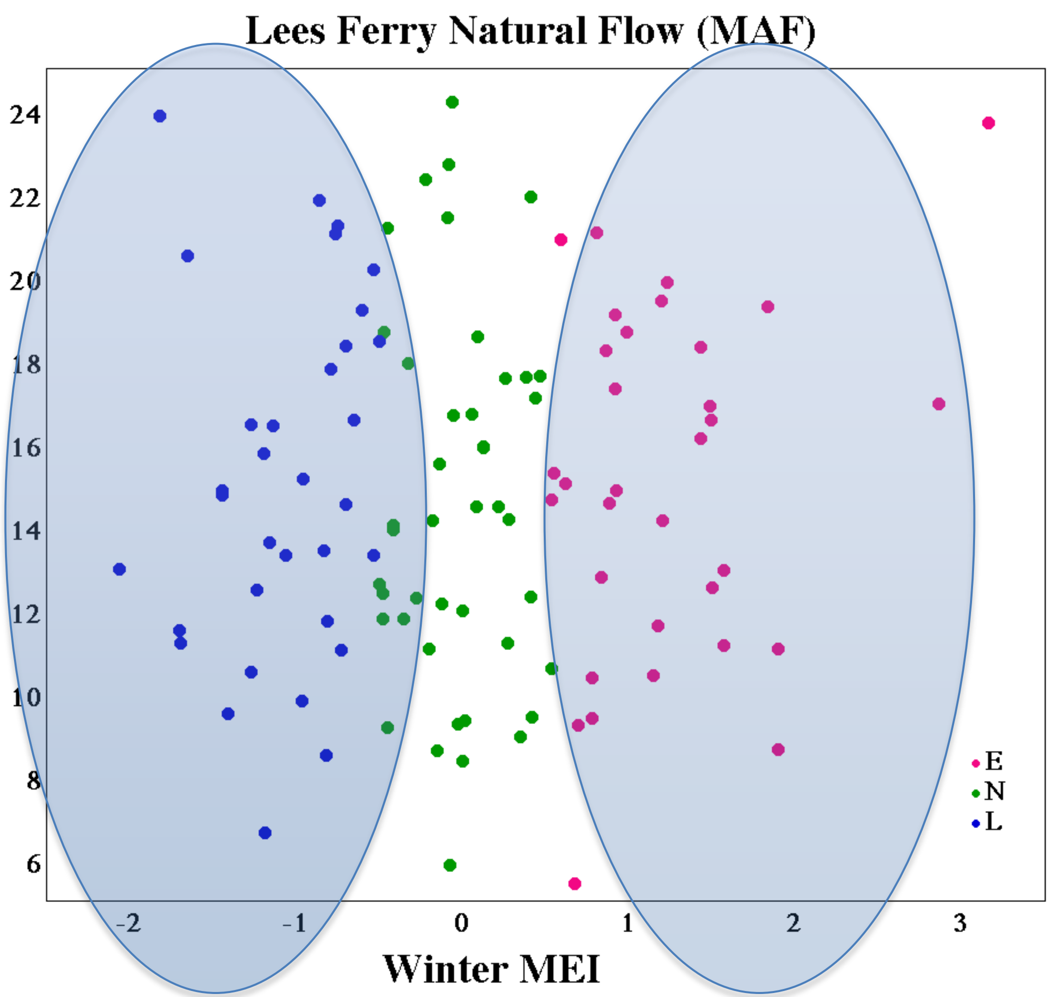
Mean = 15.45 in

Mean all = 15.30 in

Mean = 11.27 in

Western Regional Climate Center

Impacts on Colorado River runoff

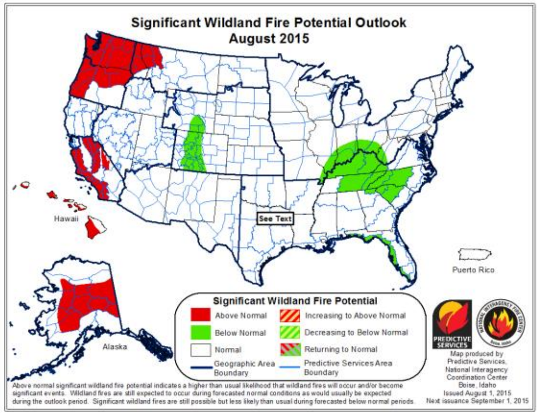


The full observed record at Lees Ferry from 1906 to 2014 shows only slightly more sensitivity to ENSO (El Niño slightly wetter than other phases).

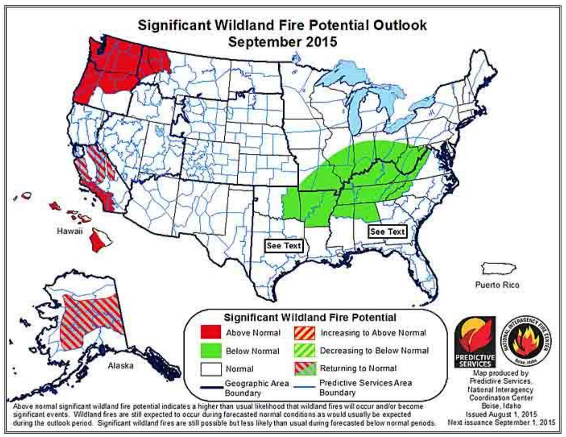
The two strongest El Niño event of the century yielded better-than-average runoff, while the next ranked two were ‘underperformers’.

All we can hope for is that 2015-16 ends up a ‘Super El Niño’!

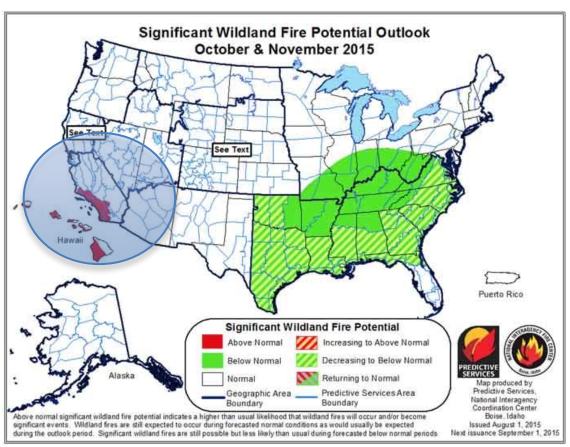
Wildfire Outlooks



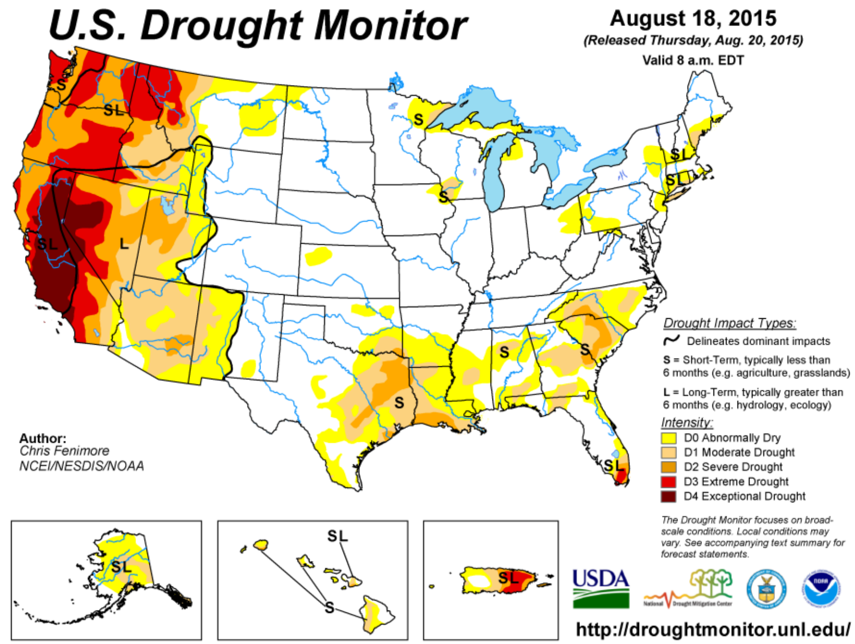
August 2015

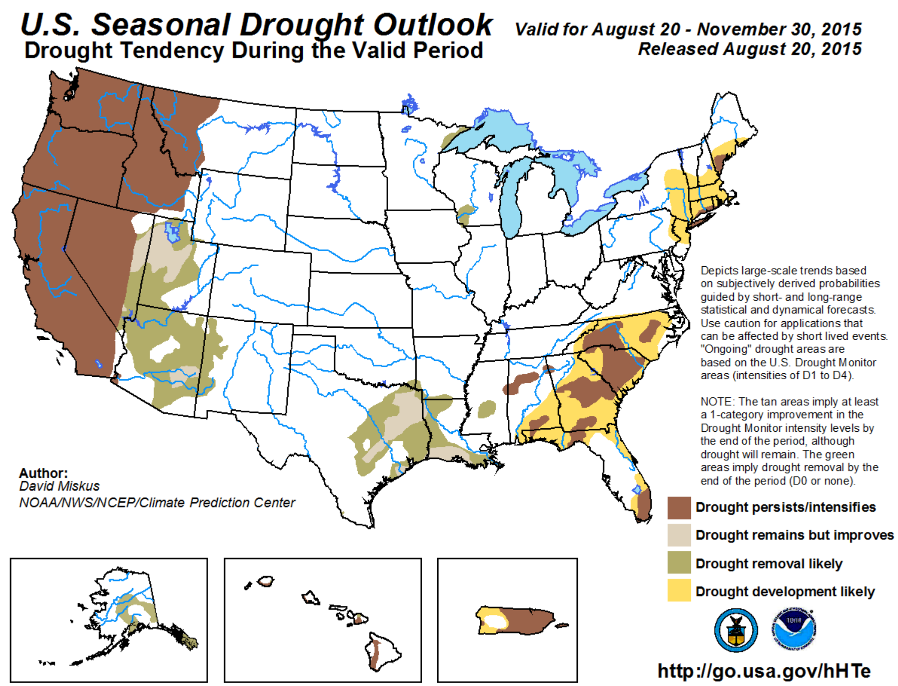


September 2015

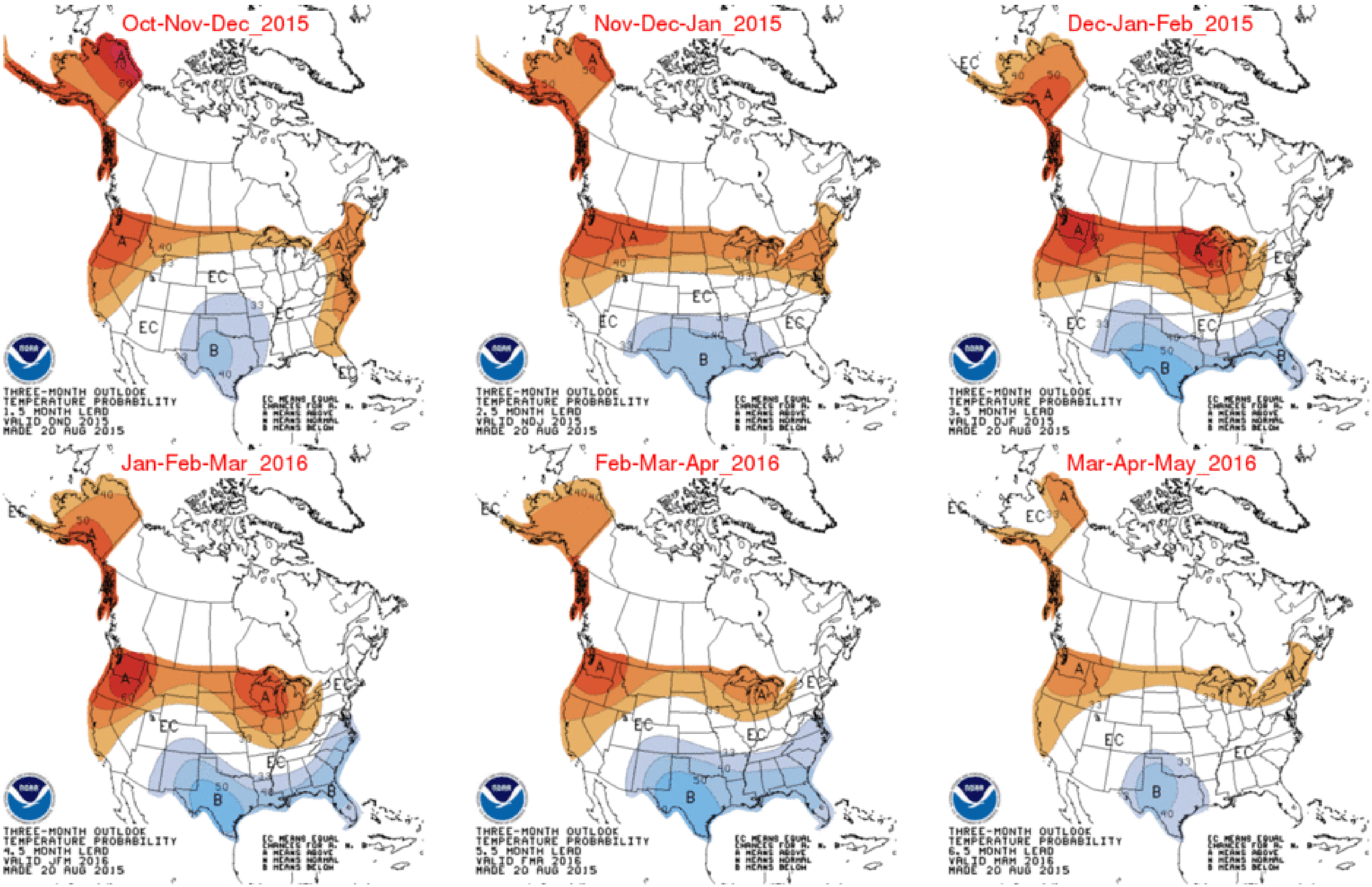


October & November 2015



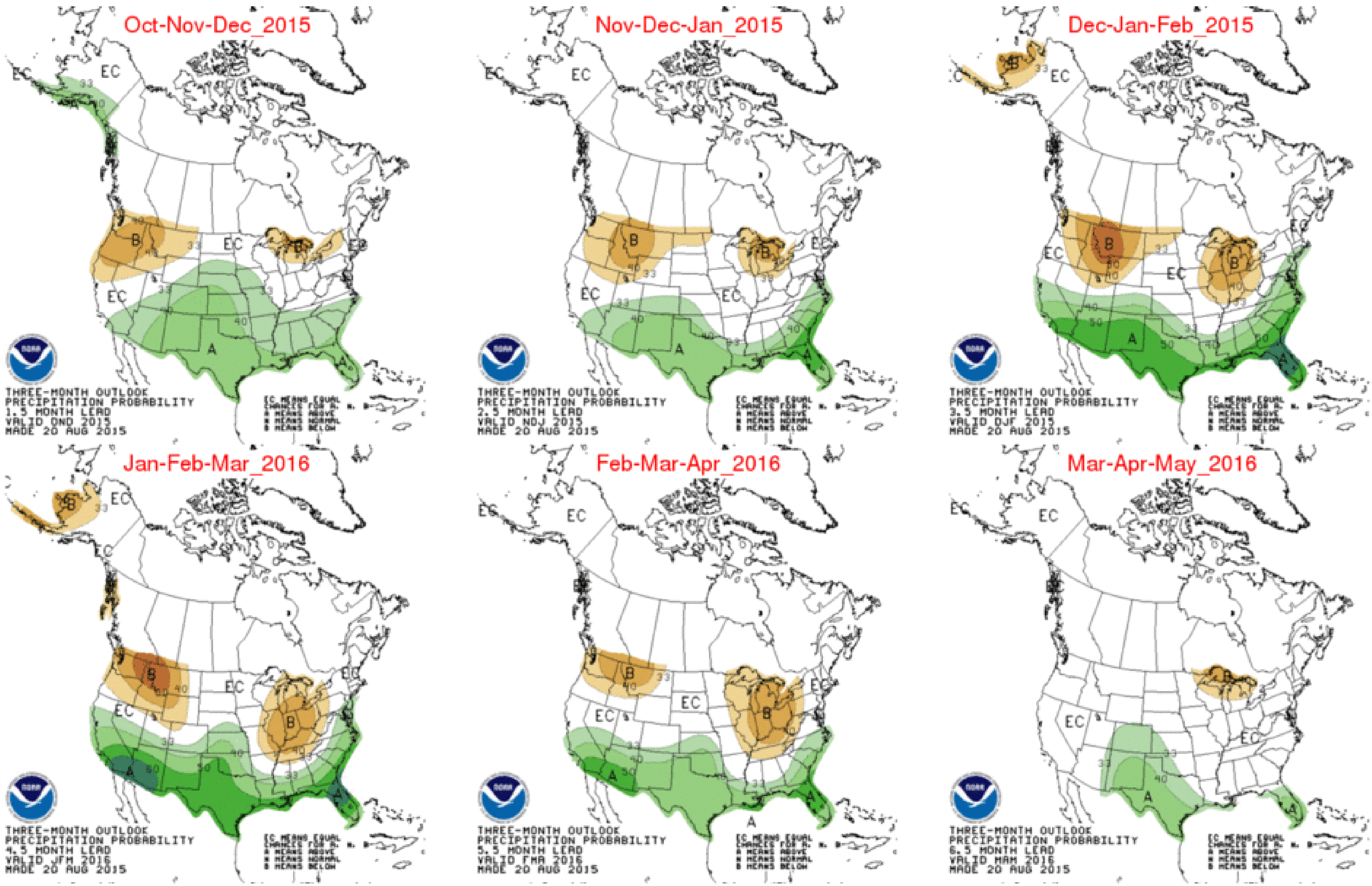


U.S. Temperature Forecasts



Source: NOAA/CPC

U.S. Precipitation Forecasts

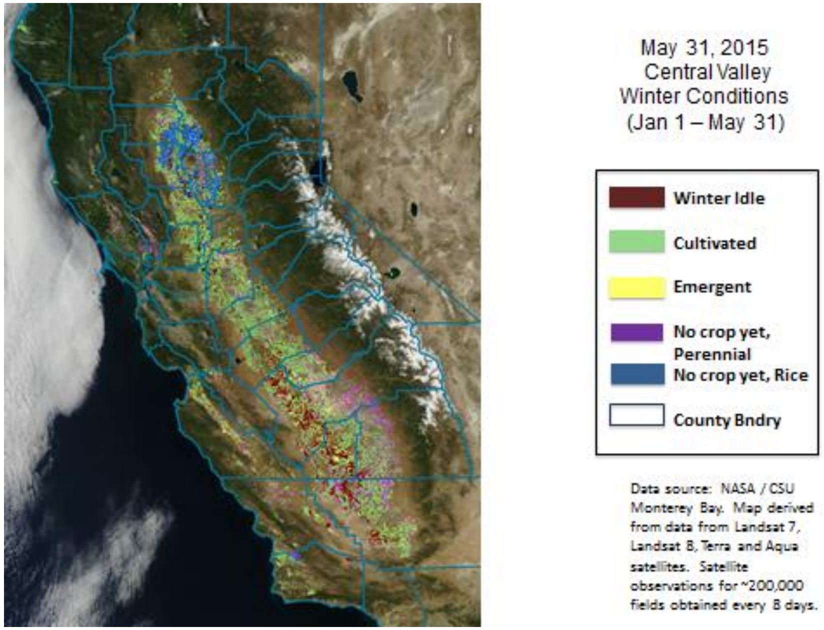


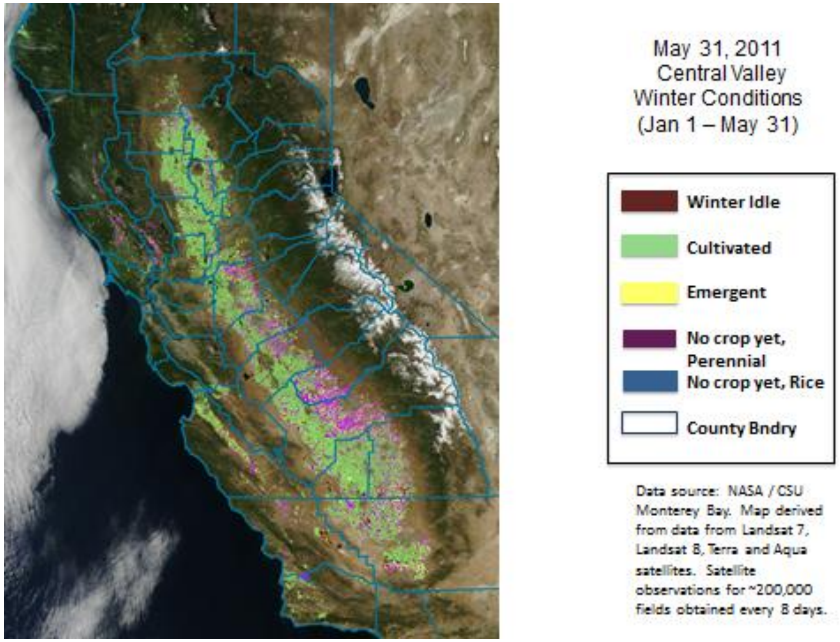
Source: NOAA/CPC


Apathy
DROUGHT
Concern
MORE
DROUGHT
Panic
RAIN
"Hydro-Illogical"
Cycle

2015 Winter Idling Summary

- Approximately 1.28 million acres have been idle all winter (since January 1, 2015). This is an increase of 1.08 million acres relative to May, 2011.
- Winter idle acreage is comparable to idle acreage observed in May, 2014 (1.49 million acres).
- Majority of idle acreage is concentrated along west side of the San Joaquin Valley and Tulare Basin.
- Delays in planting of rice in Sacramento Valley, as in 2013/2014.
- Large increase in winter idle acreage in Delta region relative to May 2011.





NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM

SOUTHERN CALIFORNIA

DROUGHT EARLY WARNING SYSTEM

Carex praegracilis in the Water Conservation Garden at Cuyamaca College, El Cajon, California

SOUTHERN CALIFORNIA STAKEHOLDERS MEETING
SCRIPPS INSTITUTION OF OCEANOGRAPHY, LA JOLLA; JULY 7, 2015

New tools, next steps for California drought

Attendees

California State Parks, San Diego
City of San Diego
CNRFC, NOAA
Department of Water Resources
Desert Research Institute
Diane Feinstein Office
Hunter Industries
Julian Community Services District
San Diego Climate Science Alliance
Metropolitan Water District
Nettleton Strategies
NIDIS Program Office
NWS San Diego, NOAA
Office of Assembly Speaker Toni G. Atkins
Padre Dam MWD
Pala Band of Mission Indians
San Diego Foundation
San Diego Gas and Electric
Santa Margarita Water District
Scott Peters Office
Scripps Institution of Oceanography
System Operation Services, Inc
U.C. Irvine
U.S. Geological Survey

Meeting goals:

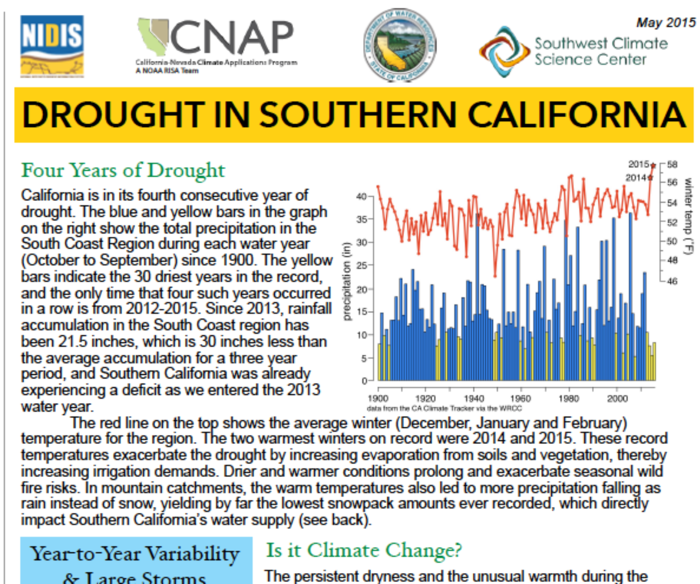
- ✦ Understand the impacts of droughts in the region and what different sectors are doing to mitigate impacts
- ✦ Present and receive feedback on new drought tools that we have developed
- ✦ Determine the best steps forward for Southern California NIDIS community

Summary of proceedings:

California Reservoir Storage, Percent of Normal, 1977 and 2010-16

The meeting began with an introduction by Alicia Marrs about NIDIS and the program goals. This was followed by a presentation by Kelly Redmond on the evolution of the current drought, the likely causes through the different years, the current El Niño conditions and what this might mean for the next water year (in short, very little). Jeanine Jones of California Department of Water Resources, Alan Hayes of the California-Nevada River Forecast Center and Alex Tardy of the National Weather Service each spoke briefly about what their respective agencies are doing about the drought.

After the presentations, there was discussion about the impacts of drought and what the different sectors were doing about it. Water agencies said they were putting a lot of effort into educating the public about the drought and their water use. They reported holding seminars, knocking on doors (one agency knocked on over 2,000 doors), reaching out to home



May 2015

CNAP California-Nevada Climate Applications Program A NOAA RISA Team

Southwest Climate Science Center

DROUGHT IN SOUTHERN CALIFORNIA

Four Years of Drought

California is in its fourth consecutive year of drought. The blue and yellow bars in the graph on the right show the total precipitation in the South Coast Region during each water year (October to September) since 1900. The yellow bars indicate the 30 driest years in the record, and the only time that four such years occurred in a row is from 2012-2015. Since 2013, rainfall accumulation in the South Coast region has been 21.5 inches, which is 30 inches less than the average accumulation for a three year period, and Southern California was already experiencing a deficit as we entered the 2013 water year.

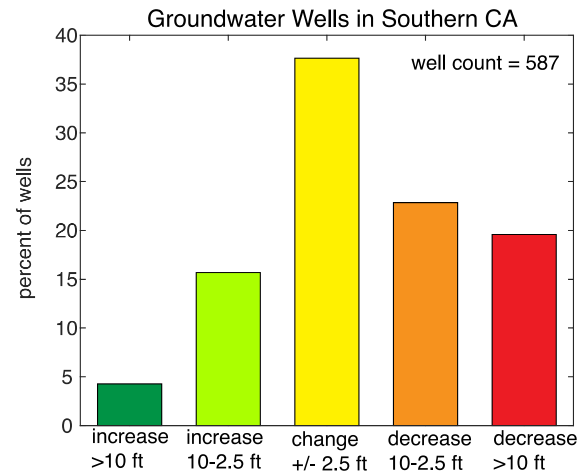
data from the CA Climate Tracker via the WRCC

The red line on the top shows the average winter (December, January and February) temperature for the region. The two warmest winters on record were 2014 and 2015. These record temperatures exacerbate the drought by increasing evaporation from soils and vegetation, thereby increasing irrigation demands. Drier and warmer conditions prolong and exacerbate seasonal wild fire risks. In mountain catchments, the warm temperatures also led to more precipitation falling as rain instead of snow, yielding by far the lowest snowpack amounts ever recorded, which directly impact Southern California's water supply (see back).

Year-to-Year Variability & Large Storms

Is it Climate Change?

The persistent dryness and the unusual warmth during the



Presentations

A PDF for all the presentations can be found on this link:
http://cnap.ucsd.edu/nidis_socal_20150707.html

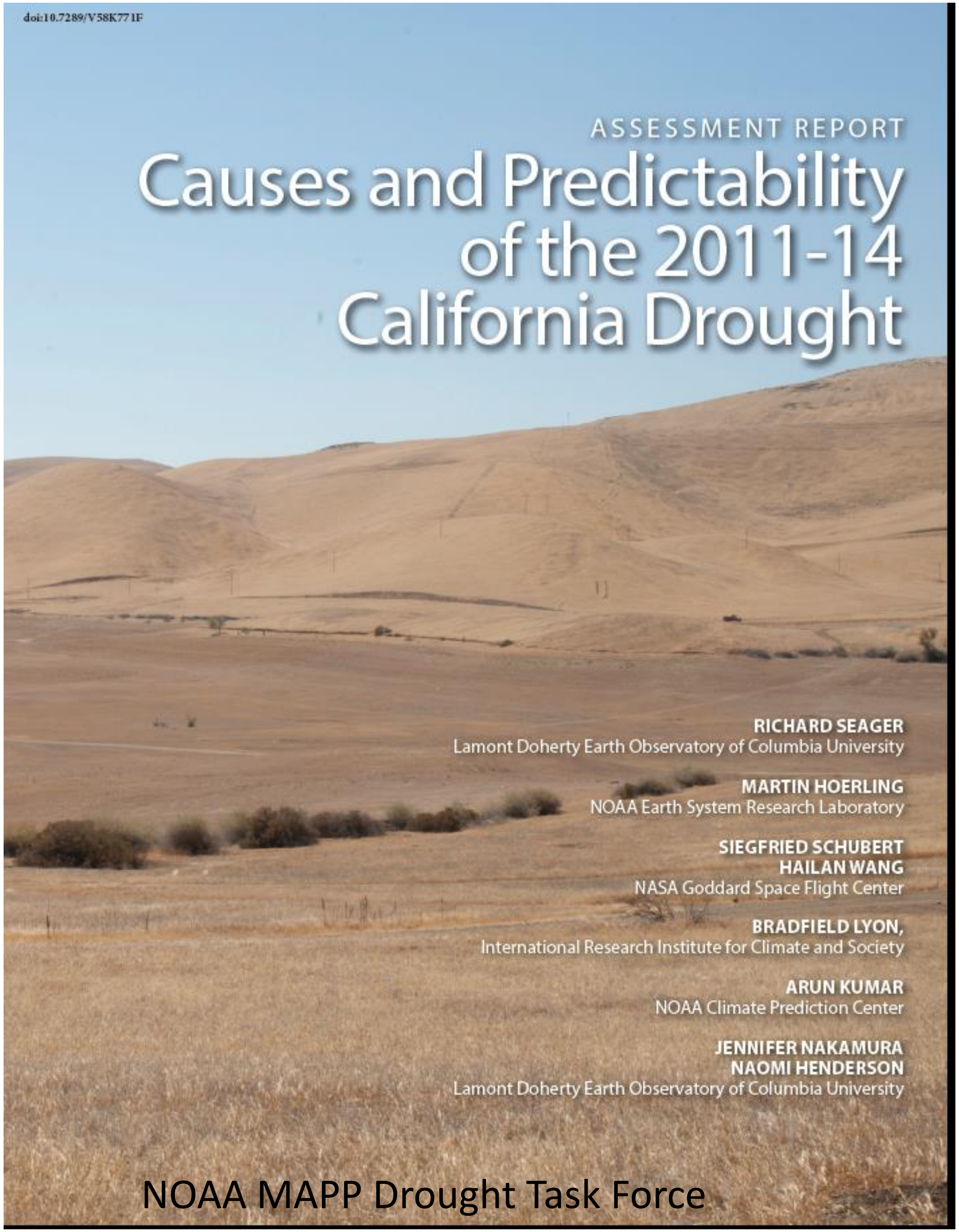
Precipitation probability tool http://wrcc.dri.edu/col/

Link to Climate Division Precipitation Percentiles
http://woodland.ucsd.edu/?page_id=2956

UCLA Drought Monitoring website (includes soil moisture)
http://www.hydro.ucla.edu/monitor_ca/index.html

National Weather Service: example of El Nino education and updates
https://www.youtube.com/watch?v=6QJO39B9XYg

Example of monthly or bimonthly drought and climate updates
https://www.youtube.com/watch?v=enrwRSo-0Hs



NOAA MAPP Drought Task Force

The First Three Winters of Drought

2014-2015 (Update in the Works)

Each winter played out differently

Background and thus causes somewhat different each winter

2014-15 cause also likely not identical to previous three winters

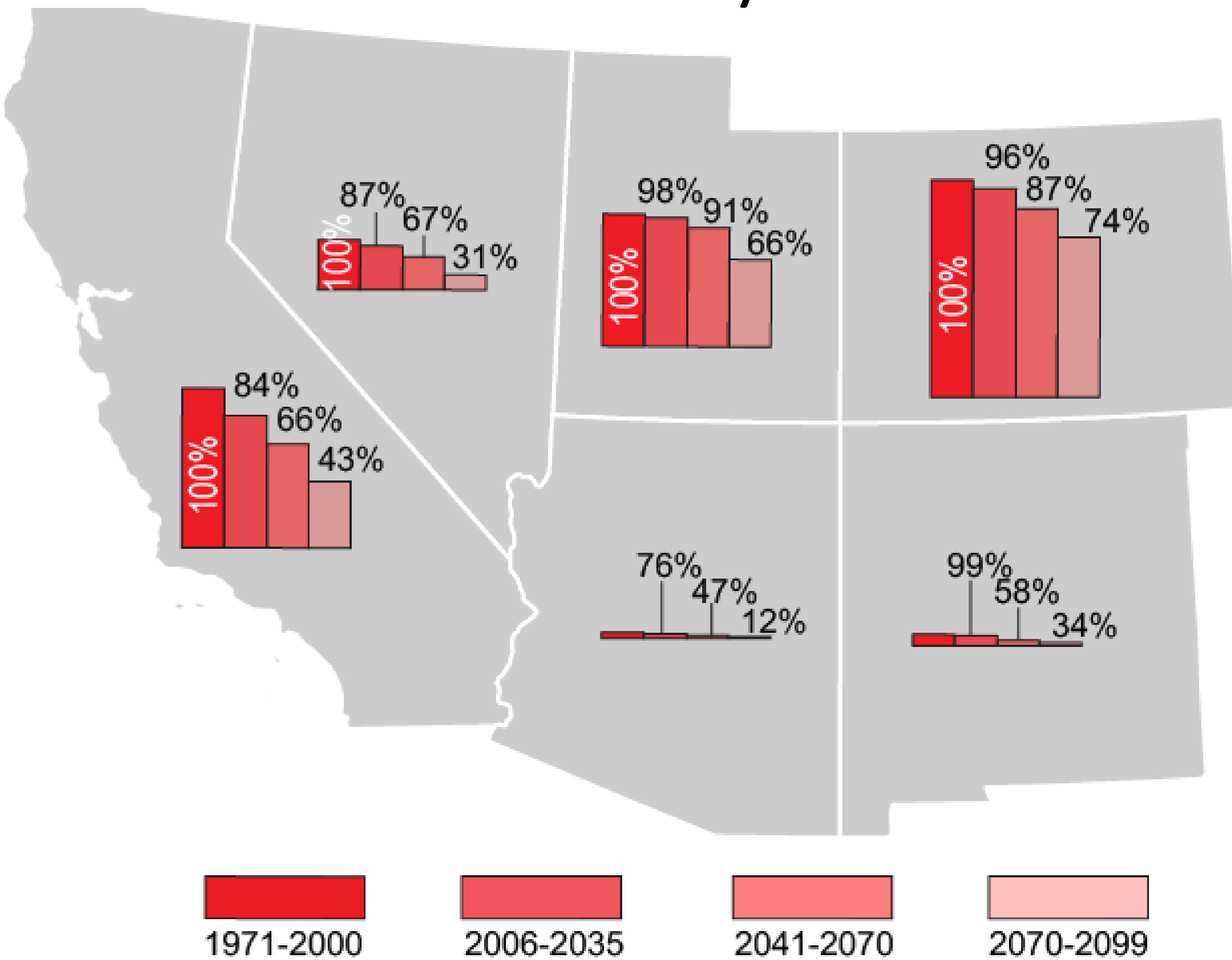
Explanations reach to western Pacific and eastern Indian Oceans

Not much sign of climate change as a contributor

But, possible harbinger of future droughts:

Not just <u>dry</u>, but extremely <u>warm</u>

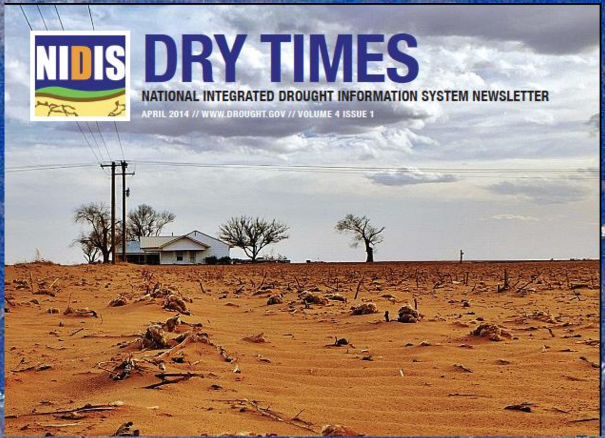
Projected Snow Water Equivalent in the 21st Century

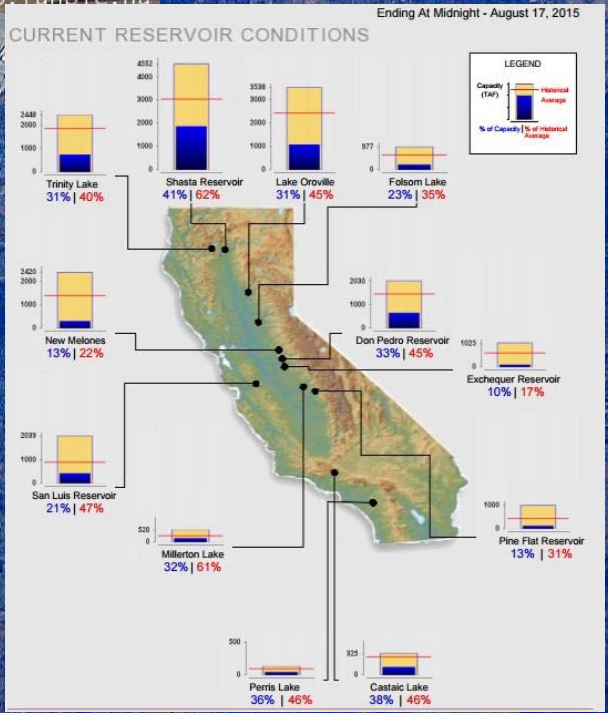


(NCA, 2014; Scripps)

Thank you

Drought.gov





Lake Mead. Kelly Redmond 2015

Extras

California Water Action Plan

NOAA AND THE CALIFORNIA WATER ACTION PLAN

Partnering for resilience

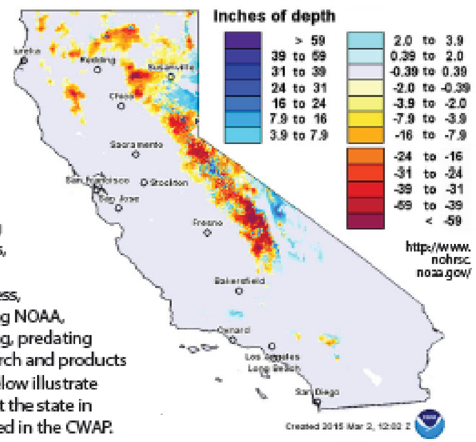
Seasonal drought outlook
Drought tendency through May 31, 2015

http://www.cpc.ncep.noaa.gov/

In response to the ongoing California drought, Gov. Edmund G. Brown Jr. released the California Water Action Plan (CWAP) in 2014, directing the California Natural Resources Agency, the California Environmental Protection Agency, and the California Department of Food and Agriculture to identify key actions for the next one to five years, to (1) address urgent needs and (2) provide the foundation for the sustainable management of California's water resources.

NOAA and its partners have been providing California with research, analyses, publications, forecasts, communications and stakeholder engagements to support drought preparedness, mitigation and recovery. Collaborations among NOAA, NIDIS and California partners are long-standing, predating the present drought, focused on linking research and products to management. The NOAA activities listed below illustrate the agency's ongoing commitment to support the state in addressing specific issues and actions identified in the CWAP.

Snow depth: departure from normal
Map compares normal depth of snow pack to current levels as of March 2, 2015



http://www.nohrsc.noaa.gov/

CALIFORNIA natural resources AGENCY

cdfa CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY (CAL/EPA)

UNCERTAIN WATER SUPPLIES

NOAA actions:

■ **Analysis of the effects of climate change and climate variability** on water supplies and resources.

■ **Development and distribution of public briefing documents** about the most up-to-date science regarding influences of droughts, atmospheric rivers, and El Niño on water supply variability and reliability.

■ **Construction of future climate scenarios** to assess potential impacts and trajectories.

RESOURCES AND LINKS

California Climate Data Archive:

Great Basin Weather and Climate Dashboard

Will El Niño Make a Difference?

Our Changing Climate 2012: Vulnerability and Adaptation to the Increasing Risks from Climate Change in California

California Climate Extremes Workshop Report 2011

Southwest Climate Assessment Summary for Decision Makers, 2012

Statistical Downscaling Using Localized Constructed Analogs (LOCA)

WATER SCARCITY/DROUGHT

NOAA actions:

■ **Documentation of the surprisingly strong role of major storms and floods** in ending previous droughts in California, and the role of the occurrence or absence of any major atmospheric river storms in cycles of plenty and drought.

■ **Within-season monthly monitoring of fallowed land** extent in the Central Valley using Landsat imagery. Knowledge of the amount and spatial distribution of fallowing helps agricultural communities and government make informed decisions to reduce the impacts of water shortage and have helped the state locate county food banks.

RESOURCES AND LINKS

Atmospheric rivers as drought busters on the US west coast

Drought and the California Delta—A matter of extremes: San Francisco Estuary and Watershed Science

Flooding on California's Russian River—Role of atmospheric rivers

National Geographic issue on the 2014 California Drought

POOR WATER QUALITY

NOAA actions:

■ **Evaluation of the historic roles of major storms on salinity** in the Delta, and how those impacts have changed with modern water management procedures.

■ **High-resolution mapping of saltwater inundation** from sea level rise.

■ **Quantification of water lost** during the drought through GPS sensors, in coordination with Scripps Institution of Oceanography.

RESOURCES AND LINKS

Climate change projections of sea-level extremes along the California coast

Contemporaneous Subsidence and Levee Overtopping Potential, Sacramento-San Joaquin Delta

Ongoing drought-induced uplift in the western United States

(In press): Promoting atmospheric-river and snowmelt-fueled biogeomorphic processes by restoring river-floodplain connectivity in California's Central Valley

California, for the past and for a future subject to urbanization and climate change

A method for physically-based model analysis of conjunctive use in response to potential climate changes

DECLINING NATIVE FISH SPECIES AND LOSS OF WILDLIFE

NOAA actions:

■ **Characterizing the historic role of major atmospheric-river storms** in initiating ecologically beneficial inundations (Yolo Bypass of the Sacramento River, floodplains along the unregulated Cosumnes Riv., as proxies for floodplain habitats in the Central Valley).

■ **Development of indicators** to protect fish populations in the Russian River through work with stakeholders to study hydrologic extremes.

FLOODS

NOAA actions:

■ **Research on atmospheric rivers** to understand and better predict major flood events in California, and help communities to reduce their vulnerability.

■ **Examination of stakeholder perspectives** on vulnerabilities and preparedness for an extreme storm event in the greater Lake Tahoe, Reno, and Carson City region.

■ **Characterization of the historic role of atmospheric-river storms** in causing levee breaks in the Central Valley and Delta, where levees are still the primary defense against salinity intrusions.

RESOURCES AND LINKS

Flooding on California's Russian River—Role of atmospheric rivers

Atmospheric rivers, floods, and the water resources of California

http://www.ncdc.noaa.gov/

LOOKING AHEAD: MANAGING AND PREPARING FOR DRY PERIODS

NOAA actions:

■ **Develop and provide drought early warning information** to decision makers throughout California, including leading drought preparedness activities, involving more than 100 water agencies, organizations, industries, tribes, and other stakeholders. Partners include the California Rural Water Association, California Department of Water Resources, and California-Nevada Applications Program (CNAP).

■ **Address drought issues and water demands in urban areas** of Southern California, where water supplies are primarily imported and water demands are heavily residential. NOAA works with stakeholders to develop indicators for drought assessment and forecasting of direct relevance to stakeholders, and to assess drought conditions.

■ **Characterize and understand historic droughts** using stakeholder-informed indicators. For example, NOAA developed a percentile-based indicator system for assessing present drought in the context of the frequency and severity of historic events. Among the findings: the severity of drought conditions developing in early 2014, based on a 12-month precipitation anomaly, would be expected to occur less than once every

RESOURCES AND LINKS

Improving Drought Prediction; April/May 2013

Drought Impacts Reporting, August 2013

Small Water Systems Workshops, California Rural Water Association, California Water Commission 2013; list of events

California Drought Outlook Forum: What's Ahead and What We Can Do; February, 2014

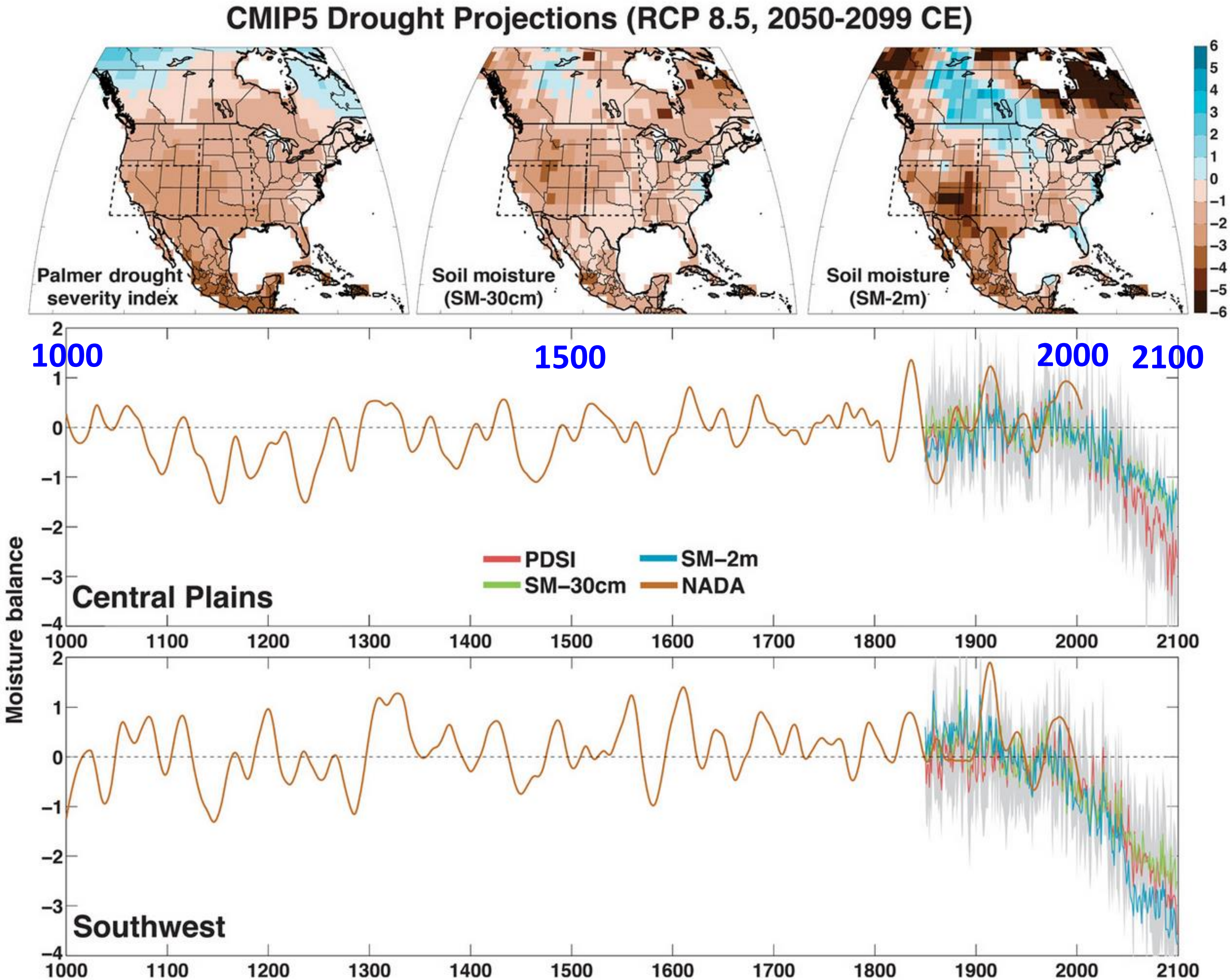
Making Decisions in Dry Times: Science and Strategies for Dealing with Drought; May, 2014

Causes and Predictability of the 2011-14 California Drought, December 2014

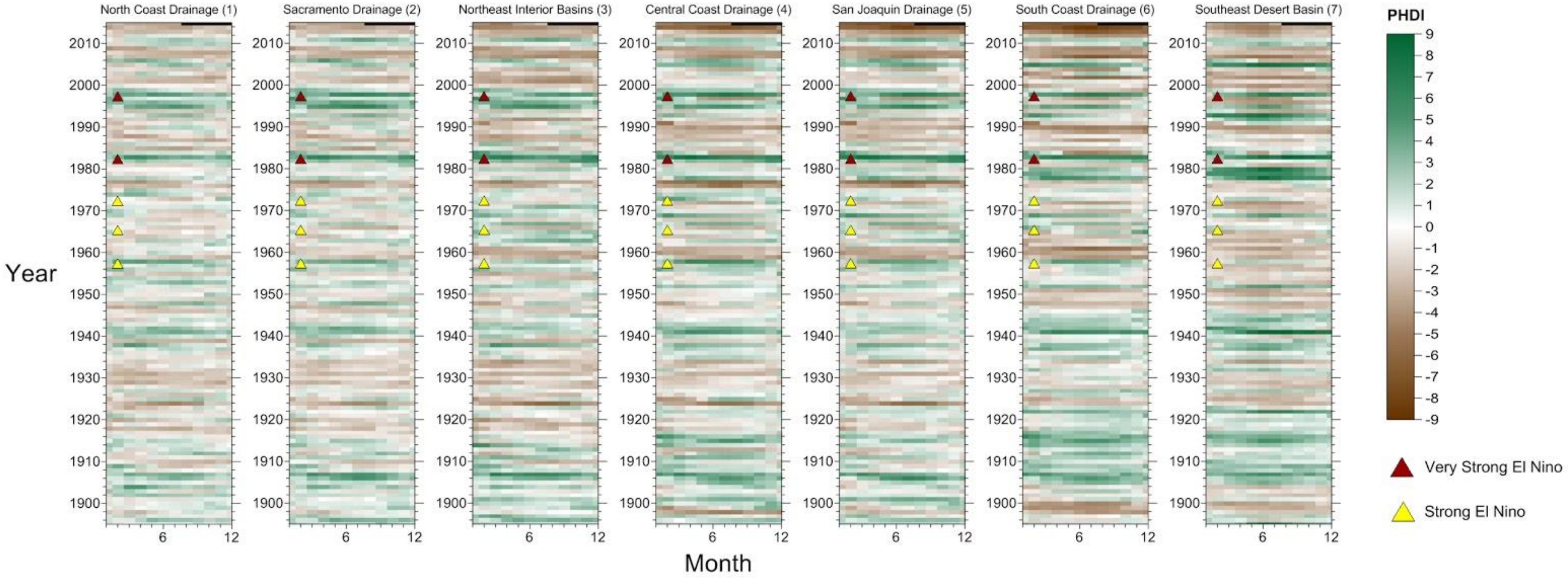
and water forecasting to help managers selectively retain or release water in a manner that reflects current and forecast conditions.

■ **Develop an integrated water resources monitor and outlook** to represent the current and seasonally forecast state of water resources including precipitation, snow, runoff into reservoirs, soil moisture, and other variables important to water management (proposal under consideration).

■ **Refinement to existing drought amelioration tools** to make them more

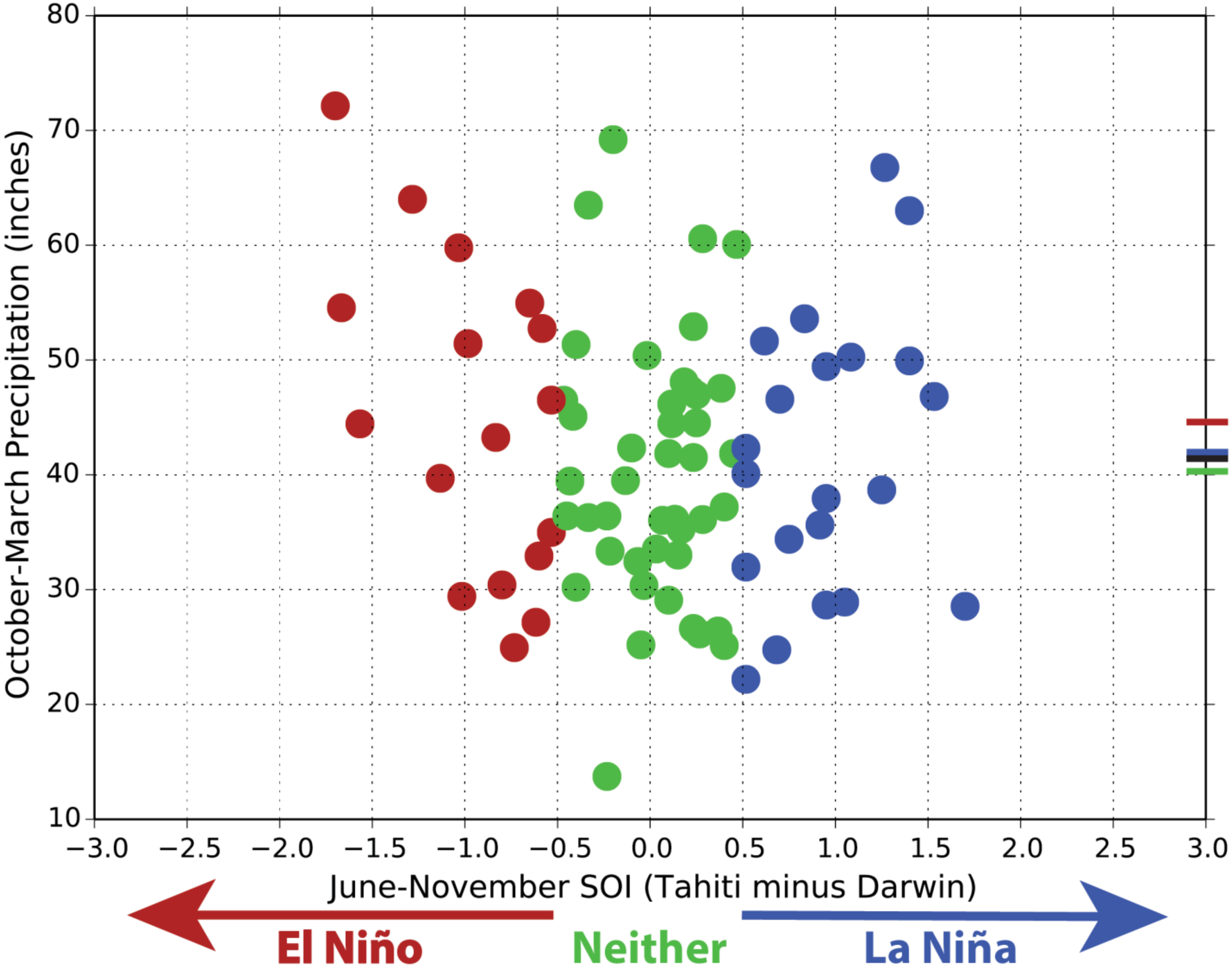


Benjamin Cook, Toby Ault, Jason Smerdon, 2015. Unprecedented 21st century drought risk in the American Southwest and Central Plains. Science Advances, 12 Feb 2015. 10.1126/sciadv.1400082



North Coast Drainage (1)
Sacramento Drainage (2)
Northeast Interior Basins (3)
Central Coast Drainage (4)
San Joaquin Drainage (5)
South Coast Drainage (6)
Southeast Desert Basin (7)
Year
Month
PHDI
Very Strong El Nino
Strong El Nino

CA Division 1 October-March Precipitation
(versus Southern Oscillation Index for prior June-November)

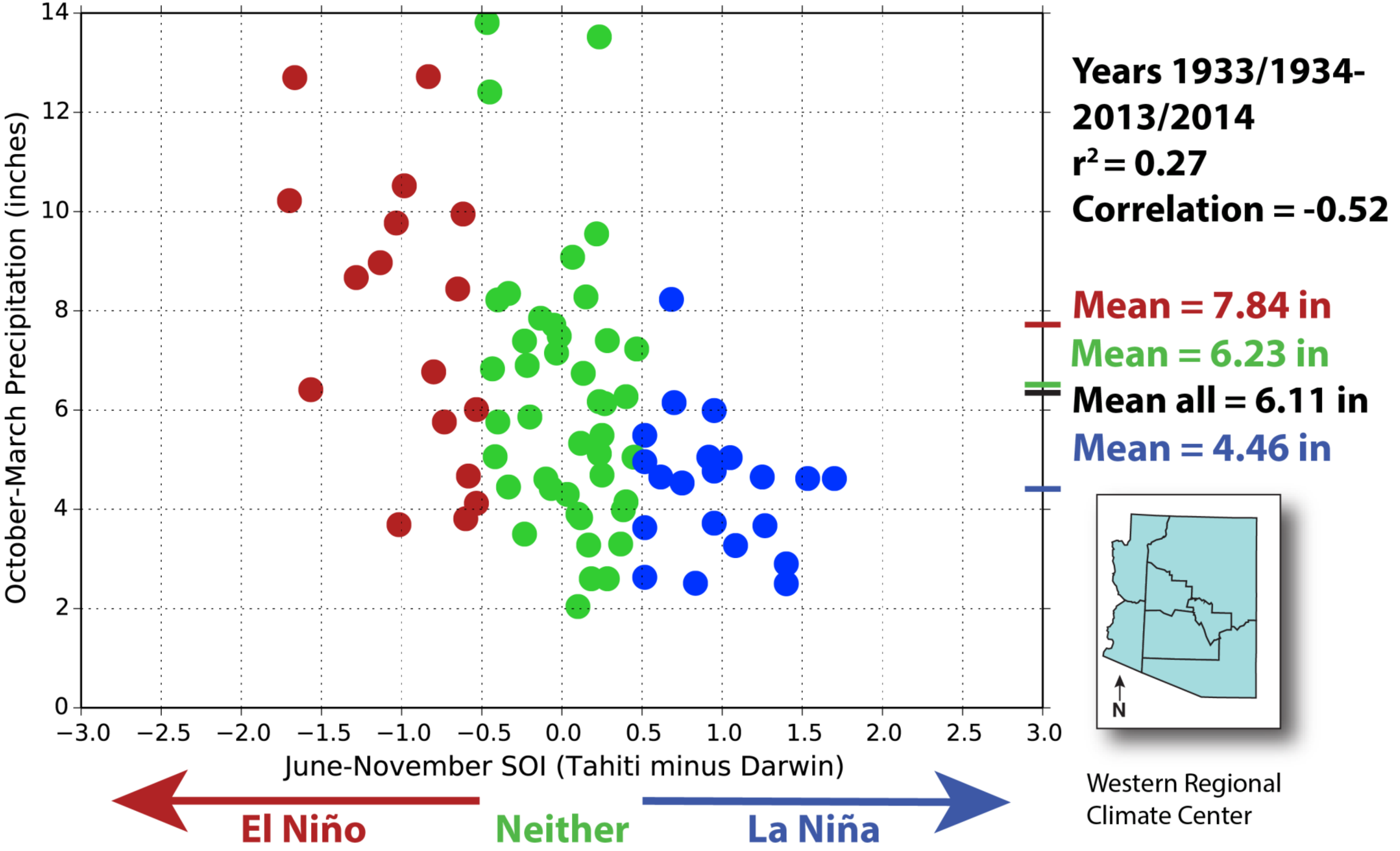


Years 1933/1934-2013/2014
r^2 = 0.01
Correlation = -0.11

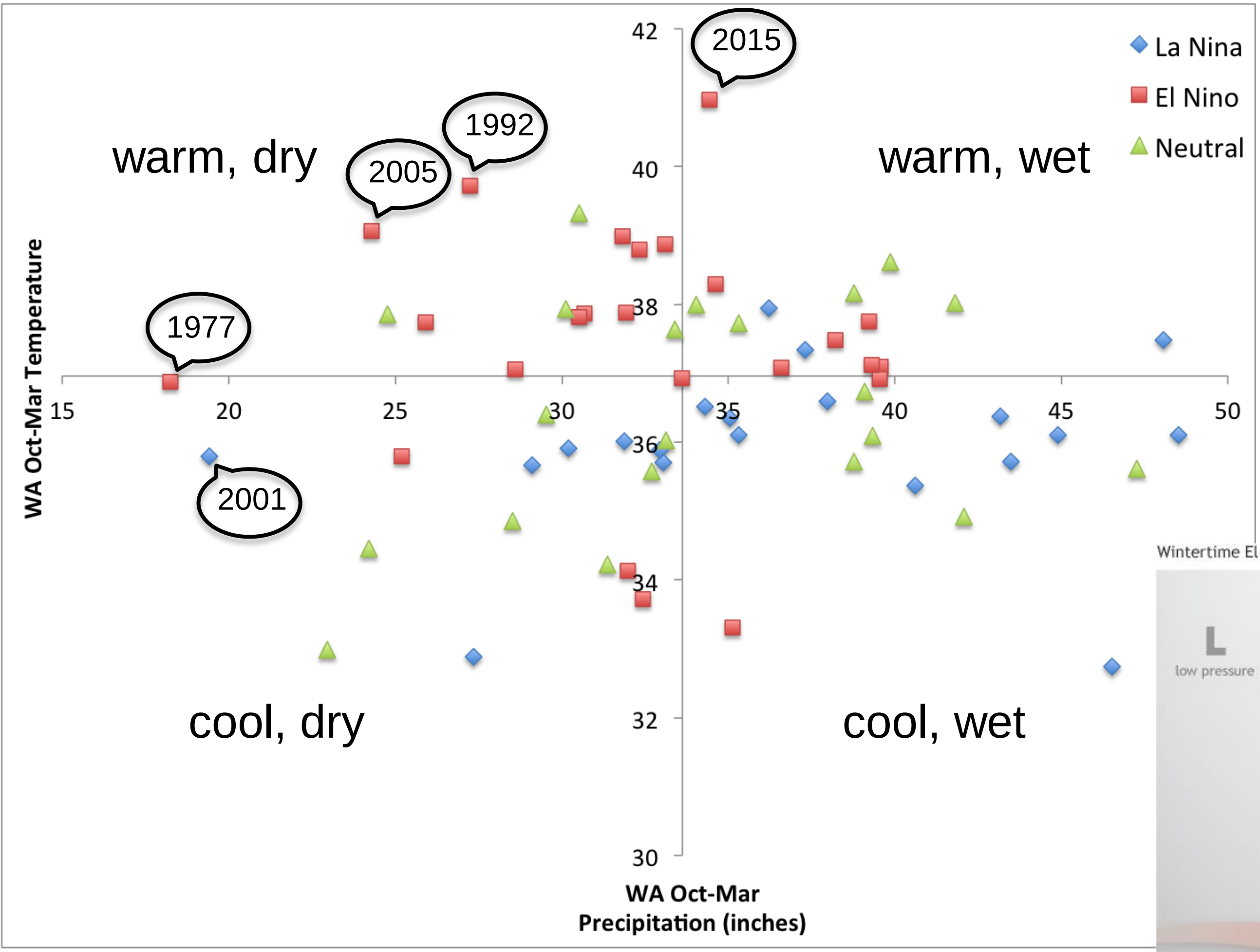
Mean = 44.9 in
Mean = 41.53 in
Mean all = 41.51 in
Mean = 40.15 in

Western Regional Climate Center

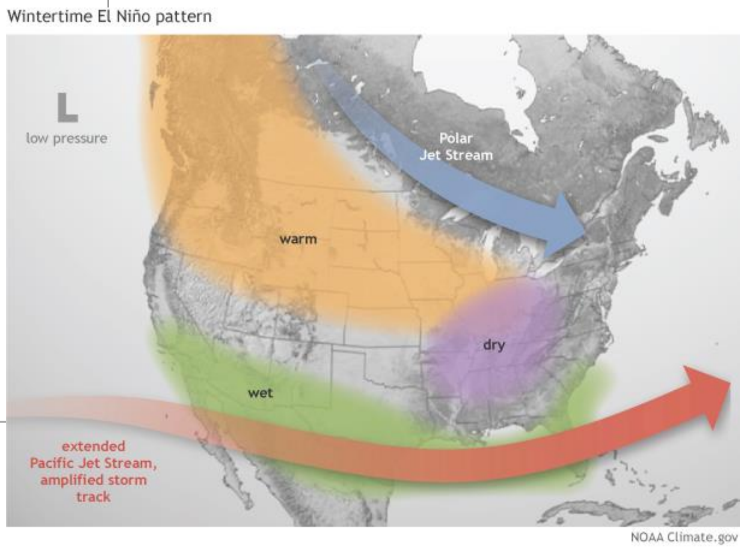
Arizona Statewide October-March Precipitation
(versus Southern Oscillation Index for prior June-November)



El Nino/La Nino and Drought in Washington



- Tendency for warmer/drier during El Niño and cooler/wetter during La Niña
- Relationship only works sometimes and doesn't take into account the different types of El Niño events.

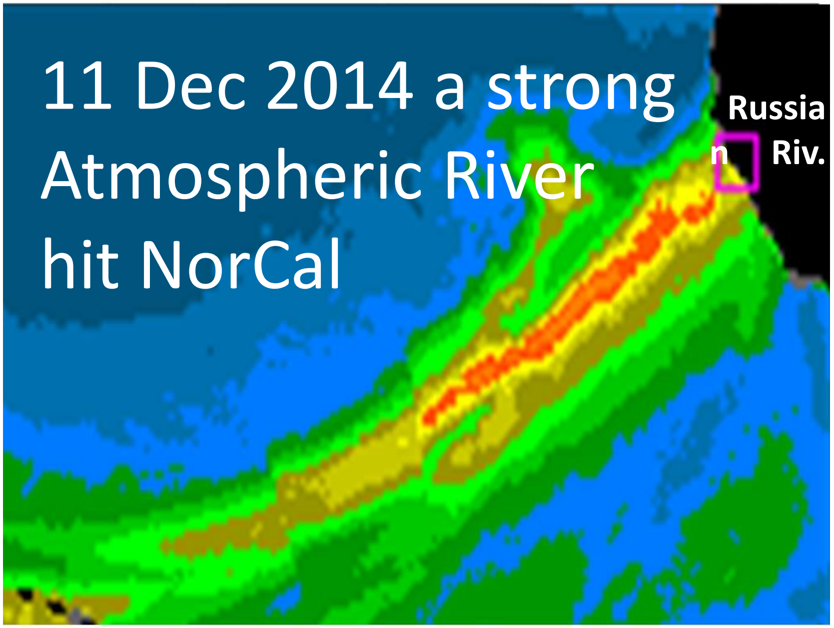


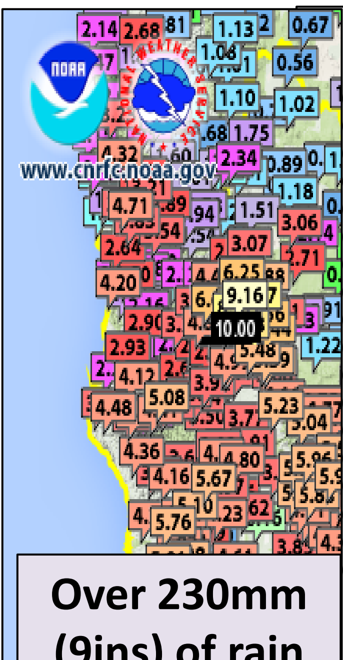
http://www.climate.gov/news-features/blogs/enso/june-el-ni%C3%B1o-update-damn-torpedoes-full-speed-ahead
Other content courtesy: Nick Bond (University of Washington)

Storm of 10-12 December 2014 Floods Can Happen During Drought

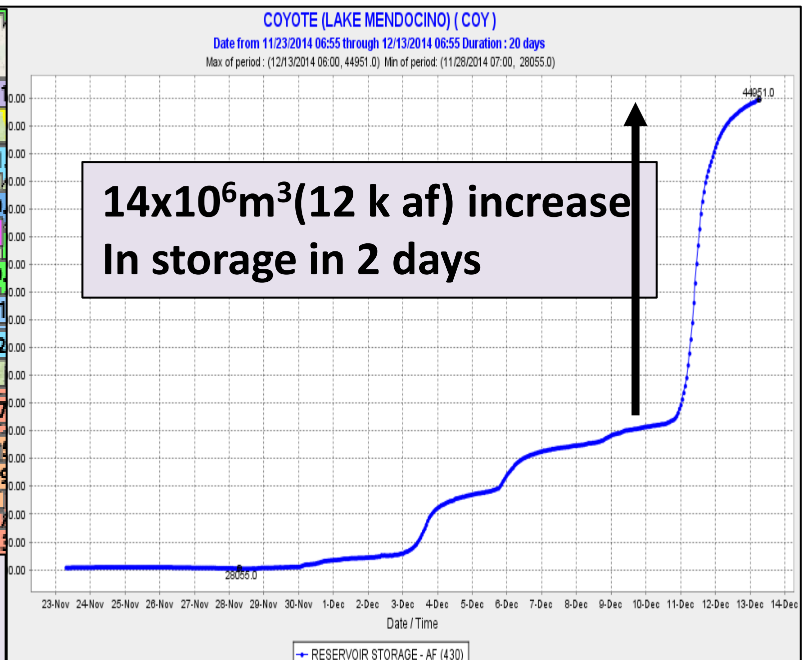
40-70% of the drought breaks in the west coast since 1950 are due to ARs

11 Dec 2014 a strong Atmospheric River hit NorCal

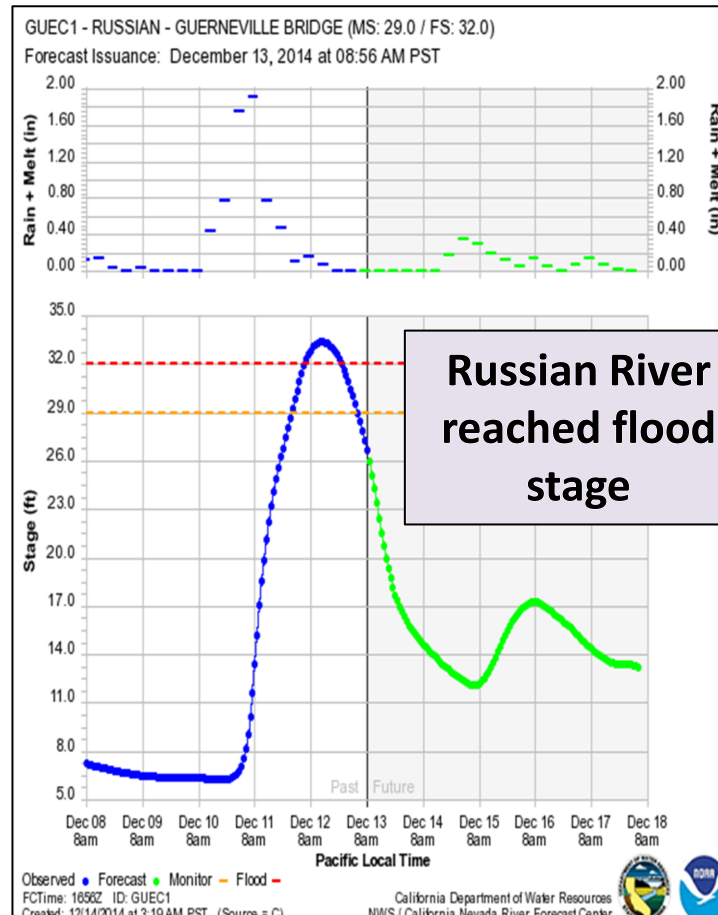




Over 230mm (9ins) of rain in 24 h



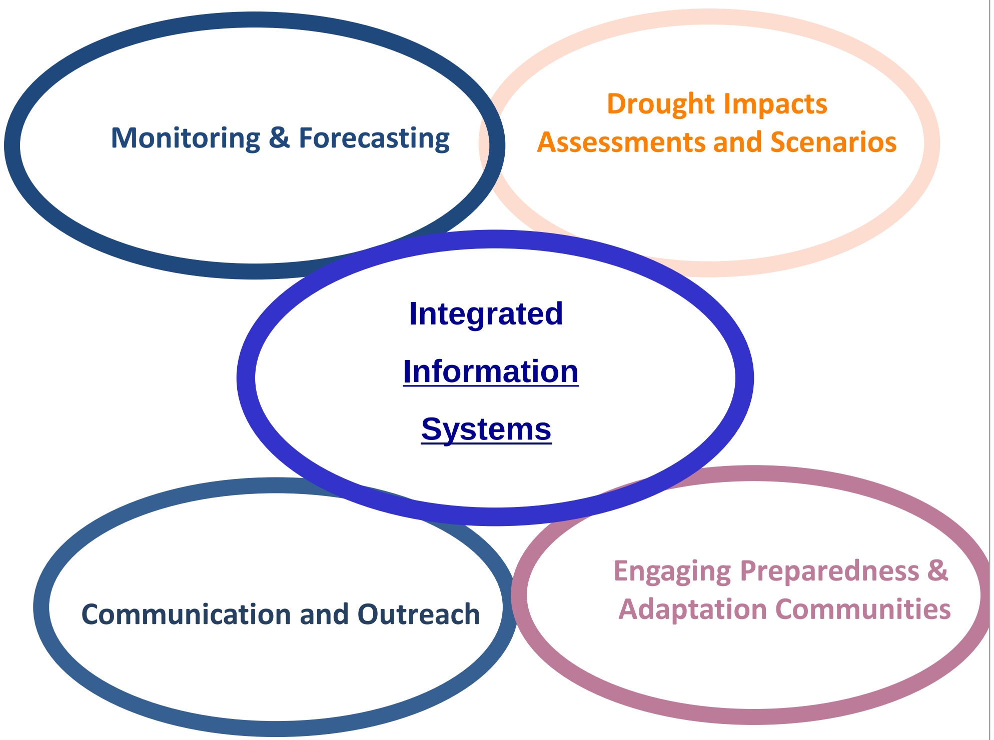
$14x10^6 m^3$(12 k af) increase In storage in 2 days

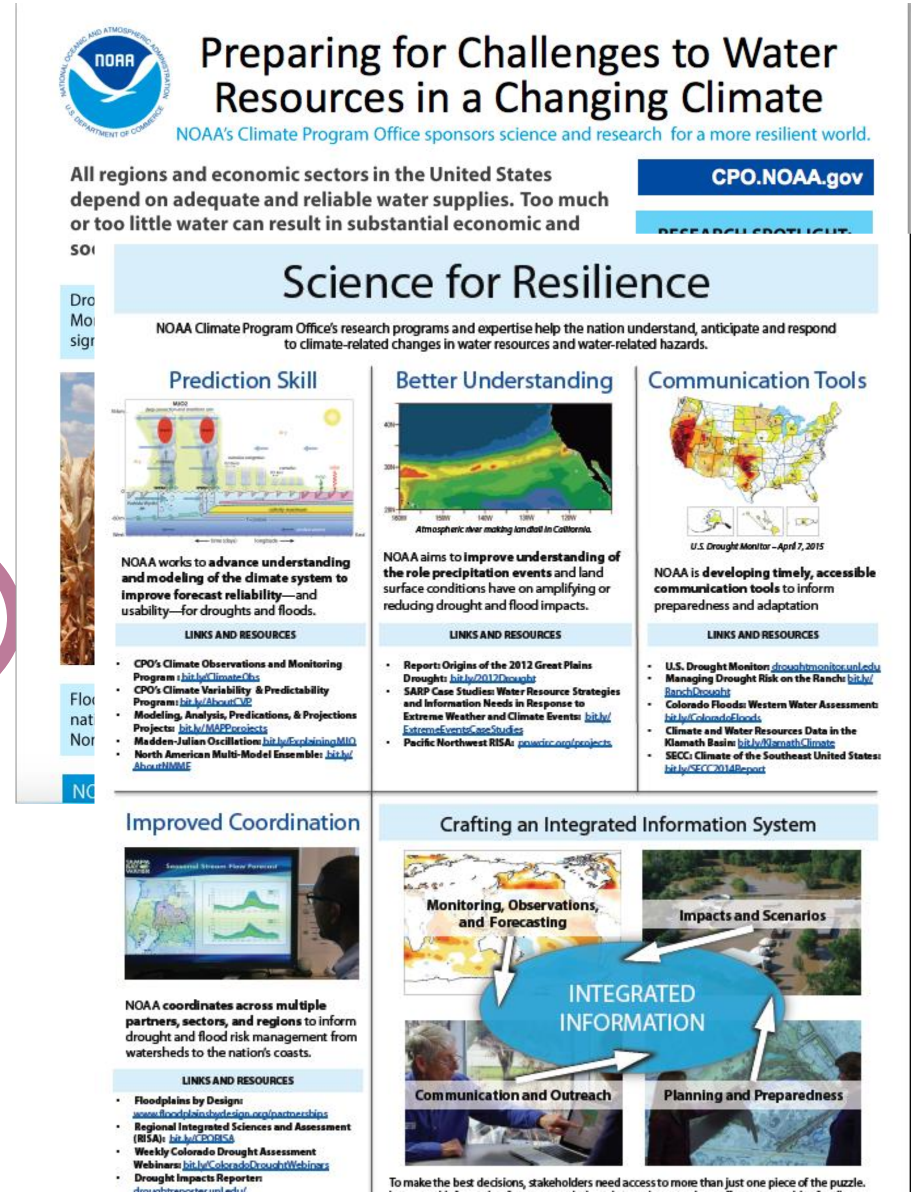


Russian River reached flood stage

F.M. Ralph

Integrated Information Systems under Changing Weather and Climate Extremes





Preparing for Challenges to Water Resources in a Changing Climate

NOAA's Climate Program Office sponsors science and research for a more resilient world.

CPO.NOAA.gov

All regions and economic sectors in the United States depend on adequate and reliable water supplies. Too much or too little water can result in substantial economic and

Science for Resilience

NOAA Climate Program Office's research programs and expertise help the nation understand, anticipate and respond to climate-related changes in water resources and water-related hazards.

Prediction Skill

NOAA works to **advance understanding and modeling of the climate system to improve forecast reliability**—and usability—for droughts and floods.

LINKS AND RESOURCES

- **CPO's Climate Observations and Monitoring Program :** bit.ly/ClimateObs
- **CPO's Climate Variability & Predictability Program:** bit.ly/AboutCVP
- **Modeling, Analysis, Predications, & Projections Projects:** bit.ly/MAPPprojects
- **Madden-Julian Oscillation:** bit.ly/ExplainingMJO
- **North American Multi-Model Ensemble:** bit.ly/AboutNMME

Better Understanding

Atmospheric river making landfall in California.

NOAA aims to **improve understanding of the role precipitation events** and land surface conditions have on amplifying or reducing drought and flood impacts.

LINKS AND RESOURCES

- **Report: Origins of the 2012 Great Plains Drought:** bit.ly/2012Drought
- **SARP Case Studies: Water Resource Strategies and Information Needs in Response to Extreme Weather and Climate Events:** bit.ly/ExtremeEventsCaseStudies
- **Pacific Northwest RISA:** pnwcirc.org/projects

Communication Tools

U.S. Drought Monitor – April 7, 2015

NOAA is **developing timely, accessible communication tools** to inform preparedness and adaptation

LINKS AND RESOURCES

- **U.S. Drought Monitor:** droughtmonitor.unl.edu
- **Managing Drought Risk on the Ranch:** bit.ly/RanchDrought
- **Colorado Floods: Western Water Assessment:** bit.ly/ColoradoFloods
- **Climate and Water Resources Data in the Klamath Basin:** bit.ly/KlamathClimate
- **SECC: Climate of the Southeast United States:** bit.ly/SECC2014Report

Improved Coordination

NOAA **coordinates across multiple partners, sectors, and regions** to inform drought and flood risk management from watersheds to the nation's coasts.

LINKS AND RESOURCES

- **Floodplains by Design:** www.floodplainsbydesign.org/partnerships
- **Regional Integrated Sciences and Assessment (RISA):** bit.ly/CPORISA
- **Weekly Colorado Drought Assessment Webinars:** bit.ly/ColoradoDroughtWebinars
- **Drought Impacts Reporter:** droughtreporter.unl.edu/

Crafting an Integrated Information System

Monitoring, Observations, and Forecasting

Impacts and Scenarios

INTEGRATED INFORMATION

Communication and Outreach

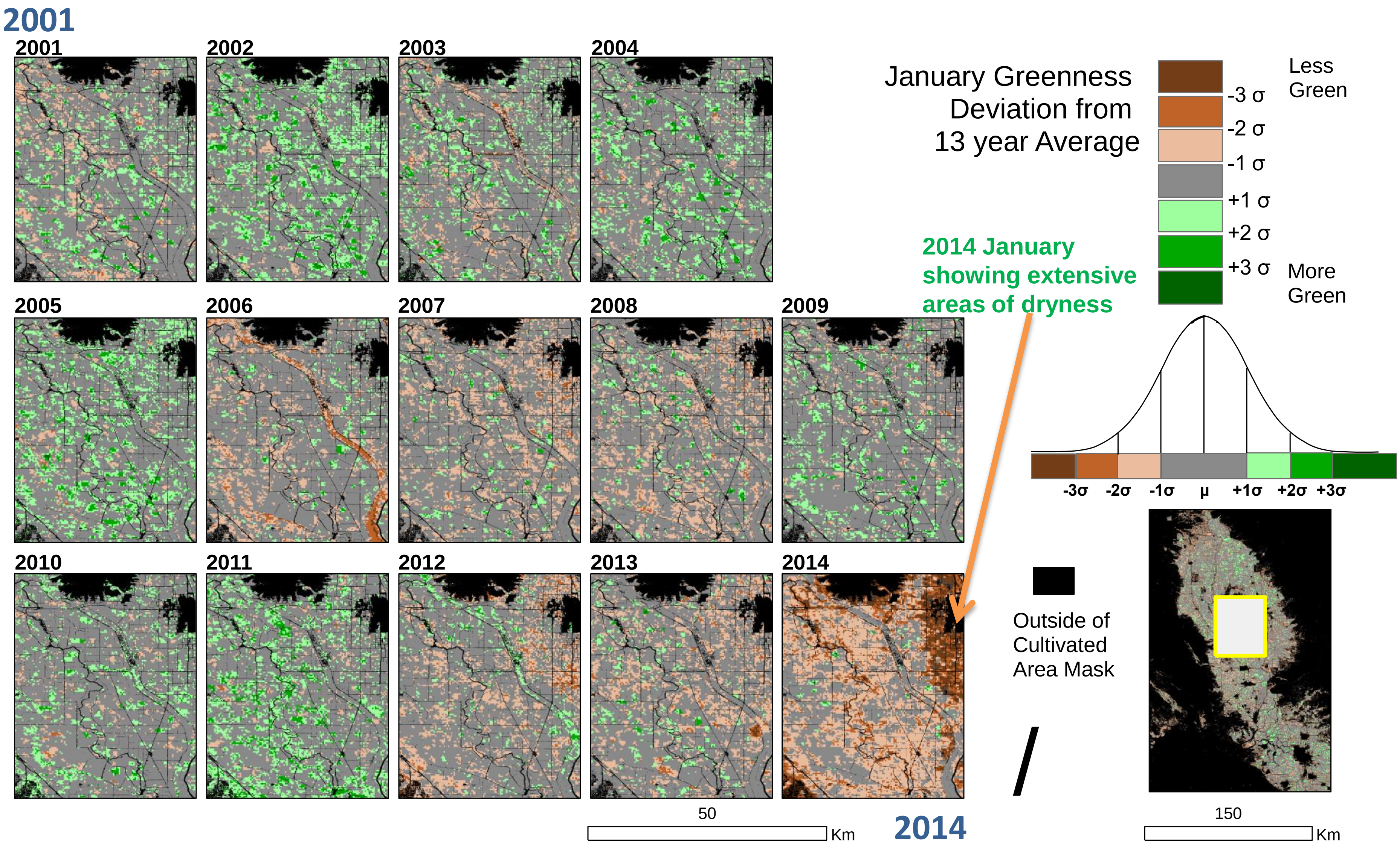
Planning and Preparedness

To make the best decisions, stakeholders need access to more than just one piece of the puzzle.

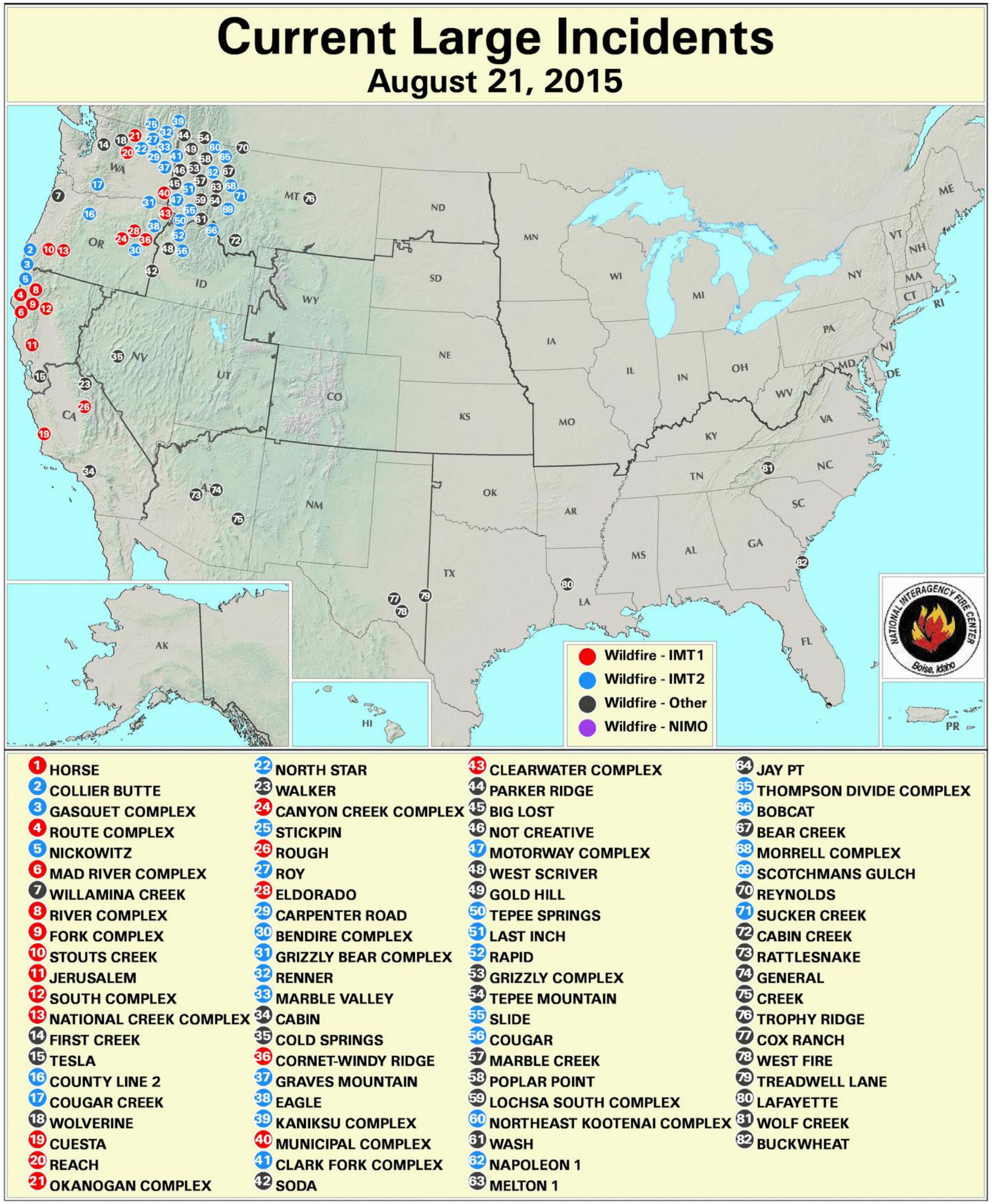
Thank you!

Cropland Greenness in January

A 35% (400,000 acre) increase in fallowing was observed in 2014 relative to 2011, a year of normal water availability-state resources for county food banks

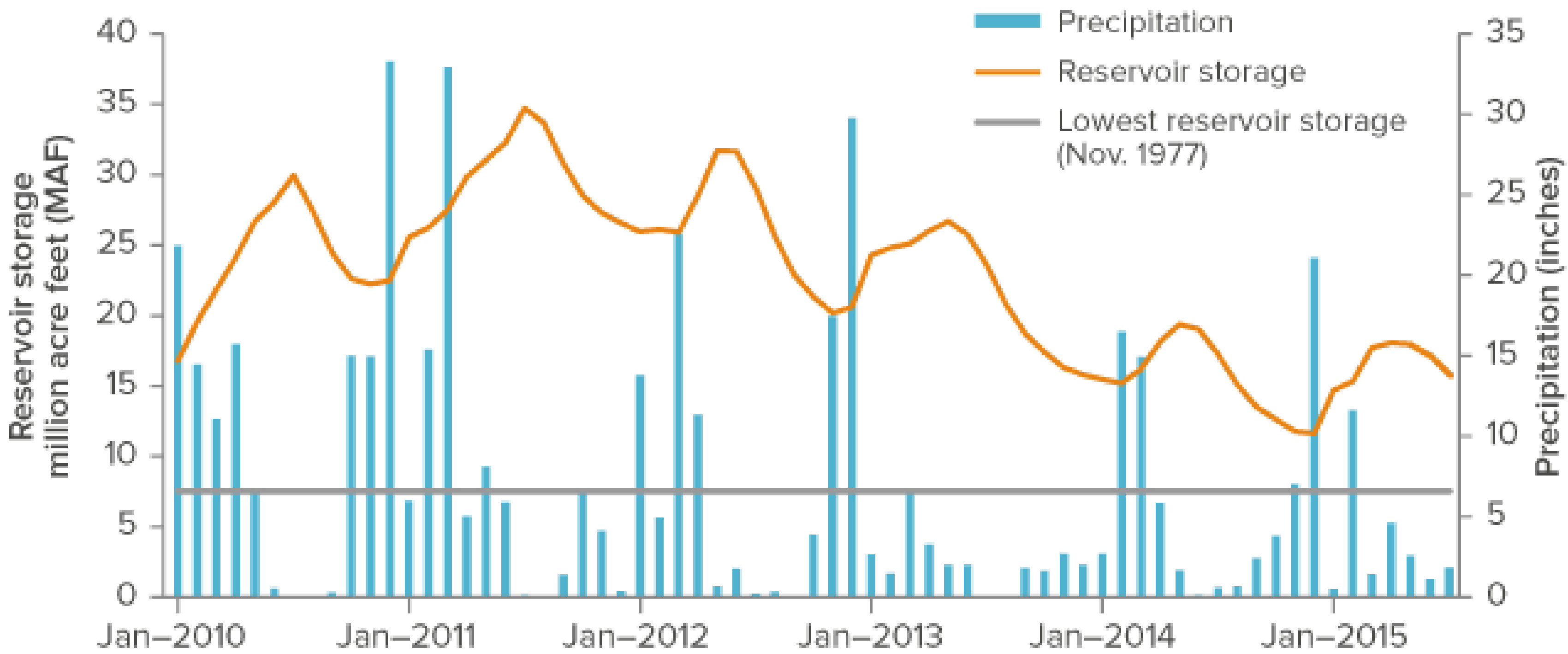


NIDIS, NASA, USDA, USGS, NOAA and the California Department of Water Resources,

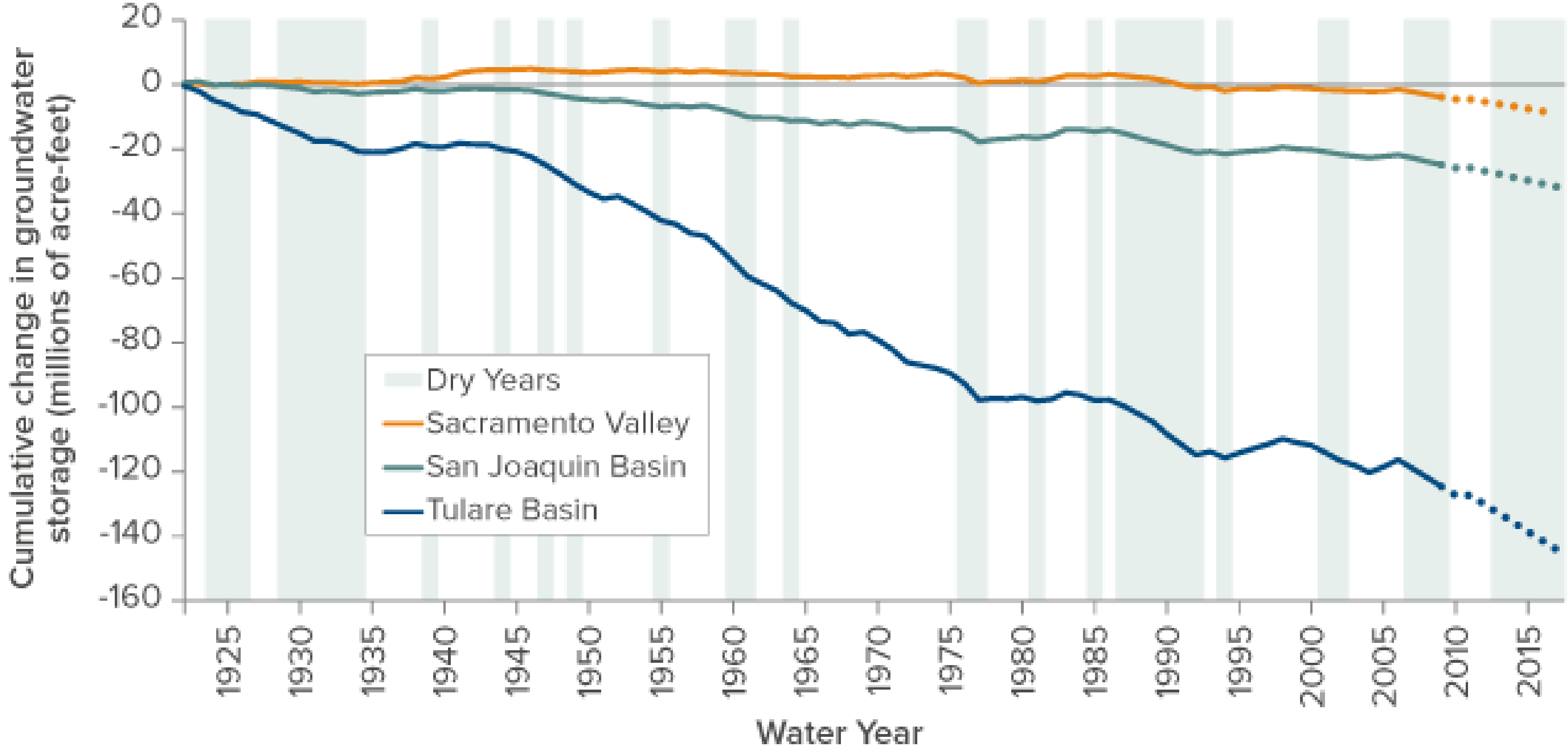


Hillside flames on Thursday near Twisp, Wash., where a 1,600-acre blaze has claimed the lives of three firefighters. Dozens of wildfires are burning across the drought-stricken Western U.S. Photo: Erika Schultz/Associated Press

Firefighters prepare to battle wildfire near Chelan, Washington, August 16, 2015. US Forest Service / Reuters



Precipitation
Reservoir storage
Lowest reservoir storage
(Nov. 1977)
Reservoir storage
million acre feet (MAF)
Precipitation (inches)
40
35
30
25
20
15
10
5
0
Jan–2010
Jan–2011
Jan–2012
Jan–2013
Jan–2014
Jan–2015



Cumulative change in groundwater storage (millions of acre-feet)
20
0
-20
-40
-60
-80
-100
-120
-140
-160
Dry Years
Sacramento Valley
San Joaquin Basin
Tulare Basin
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Water Year

Building Drought Resilience

The ongoing drought has served as a stress test for California’s water management systems, and continuing drought will test them further. Managers and businesses are employing an array of tools and strategies. Many of these have helped California reduce drought impacts. Others will need refinement and further investment.

Current drought actions fall into three general categories: those that are working well and may need minor improvements; those that are still works in progress, requiring support and refinement; and those that require substantial policy reforms or investments.

WHAT’S WORKING

Diversified water portfolios: Historic investments in diversifying water supply sources and managing demand have yielded great benefits. Further investments could be aided by streamlined permitting, as with recent CEQA exemptions for recycled wastewater standards.

Regional infrastructure: Coordinated infrastructure development among multiple agencies has built regional diversity in water supplies and reduced vulnerability.

Coordinated emergency response: Unprecedented coordination among state, federal, and local agencies has improved emergency response and reduced the economic costs of the drought.

WORKS IN PROGRESS

Mandatory conservation: Although highly successful at reducing urban use, statewide conservation mandates can have unintended economic and social consequences if they are not implemented with some flexibility. They can reduce local financial capacity and appetite for new supply investments, and they can cost jobs if they are not considerate of business water use. They can also convey an overly negative impression about urban water conditions in the state—potentially dampening future business investments.

Water pricing: Many urban utilities have encouraged conservation with tiered water pricing, but they now face significant uncertainty about the legality of these rates. Low-income households are vulnerable if utilities make up for lost water revenues with higher fixed monthly fees. Legal reforms to Proposition 218 may be needed to support both efficient and equitable pricing.67

Rural community supplies: Some domestic and small community water supplies will always be vulnerable during droughts, and emergency response has improved. But the mechanisms to report dry wells should be strengthened and response times shortened for getting water to affected residents. Continued progress is also needed to provide long-term safe water solutions to rural communities.

Groundwater management: Groundwater is a vital drought reserve, and extra pumping has reduced the economic costs of the drought. The new Sustainable Groundwater Management Act will boost the long-term drought resilience of California's farming sector and reduce negative impacts of unsustainable pumping. State and federal support for key technology and tools—such as groundwater models and well metering—can enable locals to move faster in implementing the law.68 Addressing acute short-term impacts of pumping, such as infrastructure harm from sinking lands, may require charging new pumping fees or limiting new wells in some areas

Water trading: Water trading has helped reduce the economic costs of the drought so far, and it will be vital if the drought continues. But the market is not sufficiently transparent or flexible. Processes for approving trades are complex and often opaque. Little information is publicly available about trading rules, volumes, or prices.69
Waterbird management: The risks to waterbird populations can be reduced by coordinating the management of water on refuge wetlands and flooded farm fields. State and federal investment in creative approaches, such as programs that pay farmers to flood fields, can yield great benefits with limited water and funds.

DIFFICULT WORK AHEAD

Improving the curtailment process: In principle, California's seniority-based water-rights system is designed to handle droughts. But making it work well will require better information on water availability and use, clearer state authority, and more effective enforcement.

Modernizing water information: To facilitate all facets of water management—including trading, curtailments, and environmental flows—the state will need to make major investments in the collection, analysis, and reporting of water information.70 This includes updating models to consider the extreme temperature and flow conditions of modern droughts.

Managing wildfires: The stopgap measure of suppressing fires during drought may work in the short-term, but a long-term strategy of improved forestry and fire management—with strong federal participation—is needed.

Managing surface water trade-offs: The state and federal governments have not gone through the difficult exercise of defining and prioritizing objectives among competing uses of scarce supplies, especially when managing reservoirs. The difficulties of managing Shasta Reservoir to protect wild salmon highlight the need to do better forecasting and build in a margin of safety for environmental flows.

Avoiding extinctions of native fish: Continued drought will likely lead to multiple extinctions of native fish species in the wild, and California lacks a plan to address this. More cautious strategies to save reservoir water for environmental flows may help, and purchasing water to boost flows could reduce conflicts. It may also be prudent to make immediate investments in conservation hatcheries.

Building environmental resilience: Beyond stopgap measures, California also needs to invest in improving the capacity of our native biodiversity to weather droughts and a changing climate. This requires a plan and the funding to put it into action.71

	Reduced runoff (between 25–40% of average) due to low rainfall and snowpack. Fall reservoir storage at 50% of historic average. Impacts vary regionally depending on precipitation patterns.
	Supply reduced for farms (8.5–9.0 million acre-feet/year) and cities (2.0–2.5 million acre-feet/year) compared to normal years. Central Valley Project and State Water Project allocations remain at 2015 levels. Surface water shortages require extensive curtailment of water rights, including many senior pre-1914 and riparian rights. Hydropower generation remains at half of recent average, increasing energy costs ($500 million/year or ~2%).
	Central Valley continues heavy reliance on groundwater. Excess pumping of 6 million acre-feet/year (with $650+ million additional energy cost for pumping). Increase in dry wells; acceleration of widespread land subsidence and damage to infrastructure.
	Low flows and high air temperatures cause widespread decline in water quality in rivers and streams. Low reservoirs make managing Delta salinity increasingly difficult.
bs	
an areas have reasonably secure supplies, but require continued conservation efforts upply investments. Isolated communities with a single water source face shortages and e supplies. Some water- and snow-sensitive industries that rely heavily on water (e.g., ace financial hardships, but not enough to dampen statewide economic growth.	
ll of 2.5–3.0 million acre-feet/year results in roughly 550,000 acres fallowed annually; conomic losses of more than $2.8 billion, loss of more than 10,000 full-time, part-time, m jobs, and more than 21,000 jobs economy-wide.	
es	
er of rural water districts and homes that rely on shallow wells need emergency assis- o dry. Fallowing of farmland exacerbates poor air quality in some parts of the Central ses economic hardship in farmworker communities.	
	Record-low flows and high temperatures continue to degrade habitat for native fishes. As many as 18 native fishes face likelihood of near-term extinction, including delta smelt, most salmon runs, and several species of trout. Economic losses for commercial and recreational fisheries.
	Dramatic declines in fall and winter habitat for waterbirds of the Pacific Flyway from reduced water for wetlands and flooded farmland. Bird populations reduced by limited food supplies and disease from overcrowding.
	Extreme wildfire hazard due to high temperatures, dry conditions, and increased tree mortality in California's forests. Severe wildfires (comparable to the 2013 Rim Fire) occur, impacting local communities, watersheds, wildlife, infrastructure, and air quality. Risks of permanent loss of conifer forest ecosystems in burned areas.