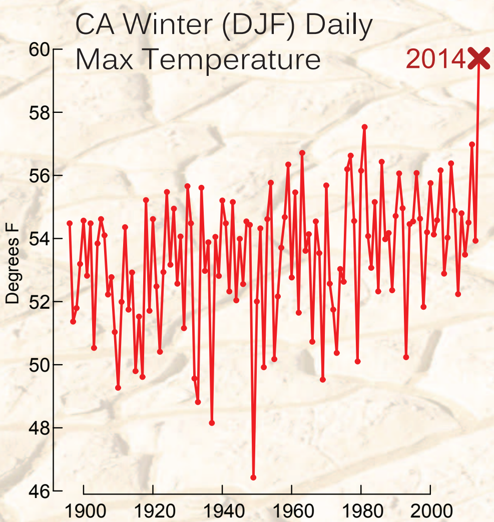
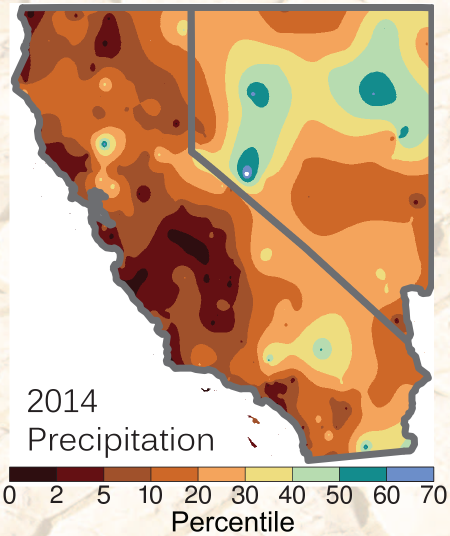
CNAP
California-Nevada Climate Applications Program

A NOAA Regional Integrated Sciences and Assessments (RISA) program

The California Drought of 2014: Record Hot, Record Dry

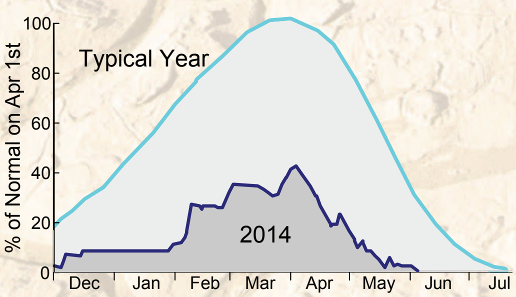




Drought occurs when water supplies cannot meet demands, and can happen for a variety of reasons. A primary cause of the current California drought has been lack of precipitation, not only in the current year, but in years prior. At some meteorological stations, such as in the middle to lower Central Valley, this has been the driest period in the observed record. Parts of Nevada have fared better, seeing normal levels. But a signature of the 2014 drought is that nearly all of California has been affected, with low precipitation from the L.A. Basin through the North Coast.

California relies on Sierra Nevada precipitation for much of its water supply. In the mountains, water year 2014 (fall of 2013 through summer of 2014) was almost as dry as the record-setting year 1977. Moreover, the state has had below-average precipitation every year since 2007, except for 2011. Having the record dry year of 2014 after years of dry conditions is hard on the state's water supplies, farmers, and other users.

Central Sierra Snow Water Content



Data from Mike Anderson, CA Dept. Water Resources

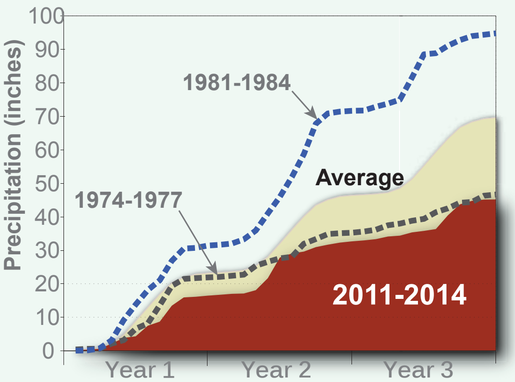
California gets the majority of its precipitation during the winter. In the mountains this typically falls as snow and is stored in the Sierra Nevada snowpack, an important natural reservoir in the state's water supply system. 2014 had even less mountain snowpack than would have been anticipated by the exceptionally low precipitation (figure below left), because the winter of 2013/14 was also unusually warm. Daily maximum temperatures were 2°F warmer than any previous winter on record. As a result, more precipitation fell as rain instead of snow, and the snow that did accumulate melted earlier. In many years such early season runoff is lost to the oceans. However in 2014 the early runoff was captured in the state's reservoirs, which were drawn down by the string of previous dry years.

Lake Oroville, Jan, 2014
California Dept. of Water Resources

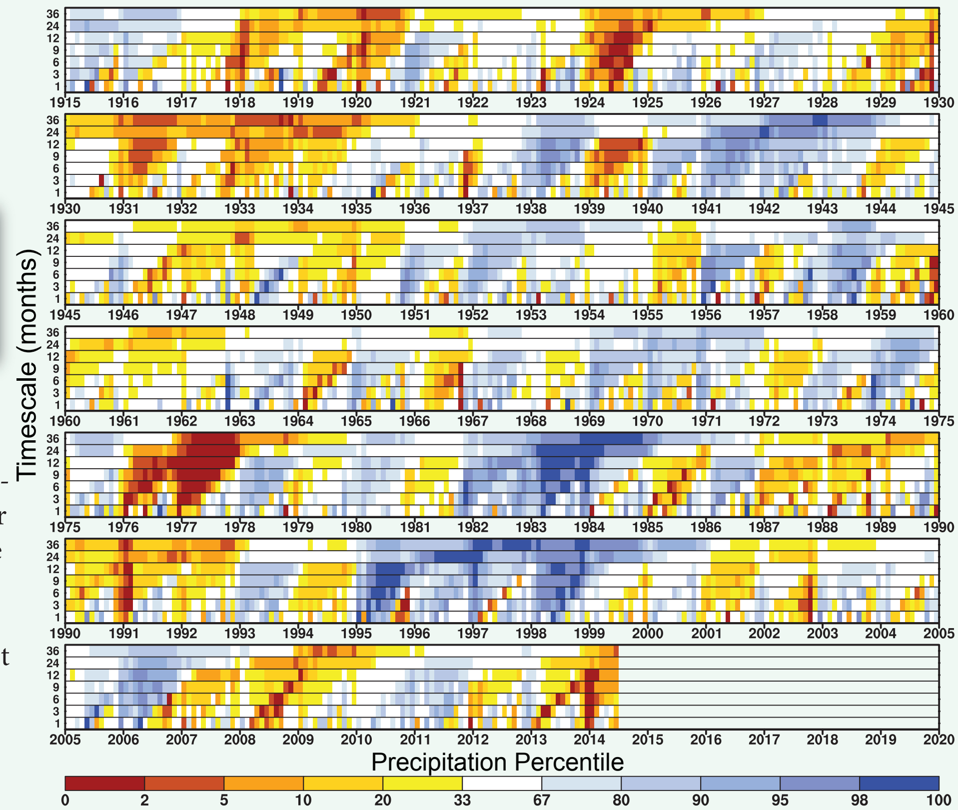
CNAP Observations No. 2, August 2014:
California Drought of 2014 special issue

Comparison to Previous Droughts

Statewide 3-yr Precip Accumulation



Sacramento River Basin

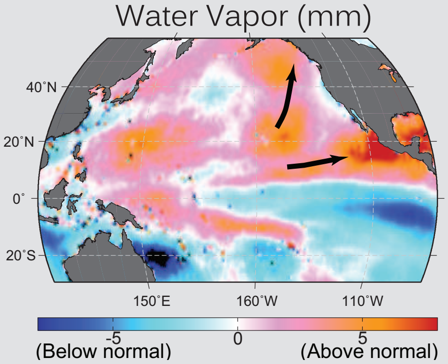


The year 1977 is often used as a model of extreme dryness in California. The figure above shows the accumulated precipitation in water years, which start in October and end the following September. Statewide accumulation in water years 1974-77 (grey dashed line) was 45 inches statewide, compared to an average of 70 inches. The wettest period on record is the 3-yr period from 1981-84, which included a strong El Niño (discussed further on pg. 3 of this newsletter), and had an accumulation of nearly 95 inches. The 3-water year period of 2011-14 (brown)has less accumulated precipitation than the period 1974-77, and so sets a new record for low 3-yr statewide precipitation accumulation totals in the historical record. It is worth noting, though, that tree rings show California has experienced century-long “megadroughts” in the past. What might trigger a new megadrought in the future is a subject of research.

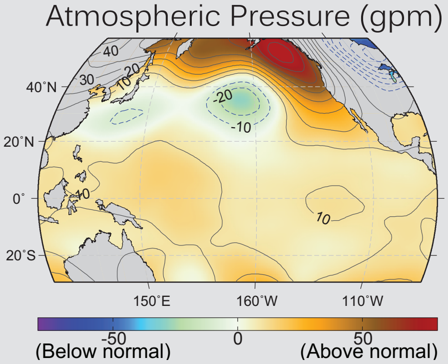
The figure to the upper right shows a more detailed view of wet and dry periods in the Sacramento River Basin. Colors show when the basin received unusually large (blue) or small (red) amounts of precipitation over the past century. Because droughts happen on different timescales—a dry month versus a dry year—the figure shows the severity of the drought measured over periods from 1 month to 3 years. The year 1977 stands out as being extremely dry on all timescales. There were also strong droughts in the 1920’s and 1930’s. The current drought is notably dry, but in the Sacramento River Basin the 1977 drought was stronger, and the 2011-14 period was not as dry as was seen statewide.

Why did the Drought Happen?

Water Vapor (mm)



Atmospheric Pressure (gpm)



There are many reasons for any drought. However the immediate cause of California’s 2014 drought can be traced to the altered route of atmospheric water vapor, which is necessary for strong winter precipitation in the state. Ordinarily, water evaporates from the ocean in the warm Tropical Pacific Ocean and winds carry that water vapor to the U.S. west coast. However in 2014 the water vapor transport split into two branches (left figure) and ended up going either north or south of California (arrows).

Why did the water vapor diverge from its usual route across the Pacific? One reason was the presence of a “ridge” of high atmospheric pressures off the northwest coast of North America (brown in right figure; at 500 hPa). This ridge steered water vapor away from California. Preliminary work suggests that such ridges could be amplified by global warming, but there is no consensus on that finding yet.

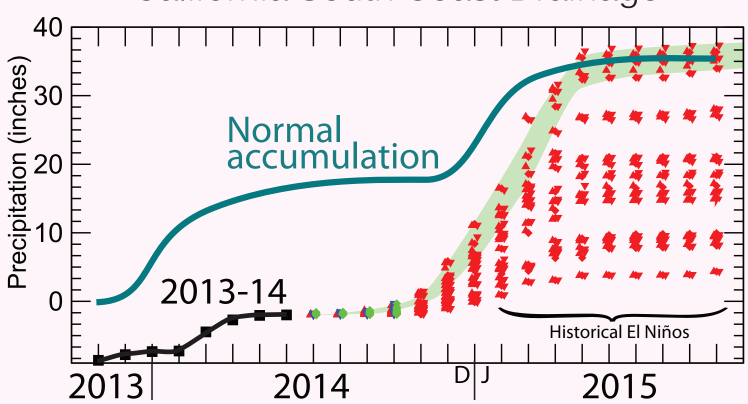
Would an El Niño Erase the Drought?

In the spring of 2014 there were indications an El Niño might form next winter. El Niño typically brings wetter than normal conditions to much of the southern half of California and the interior Southwestern U.S. As the summer of 2014 progressed it looked likely that any El Niño that formed would be relatively mild. Still, it is worth considering how an El Niño might affect the drought.

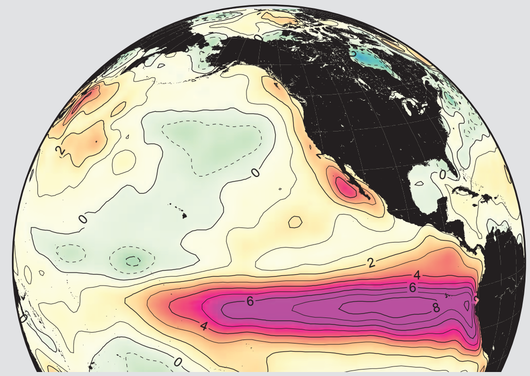
The figure below shows the normal accumulated precipitation in the southern coastal part of California (green line), along with the actual accumulated precipitation until the summer of 2014 (black boxes). There is a severe deficit, which manifests in low reservoir levels and dry soil, with attendant hardships on farmers and other users.

The red dots on the figure show the wide range of accumulated precipitation the state has experienced during historical El Niños. The heavy precipitation needed to erase the current drought has historically only been seen during particularly strong El Niños (within the green area), but even then it is not guaranteed; some strong events have near-normal precipitation. Precipitation in the northern parts of the state are less affected by El Niño than the South Coast drainage. Overall, records suggest that if an El Niño develops, only a strong event is likely to have a chance of erasing the current drought.

California South Coast Drainage

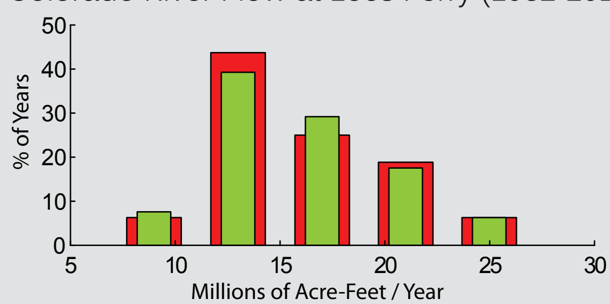


Sea Surface Temperatures During El Niño



An El Niño is when sea surface temperatures are warmer than normal in the Central to Eastern Tropical Pacific (red areas). This shifts atmospheric circulations so that strong winter storms are more likely to hit Southern California.

Colorado River Flow at Lees Ferry (1932-2010)

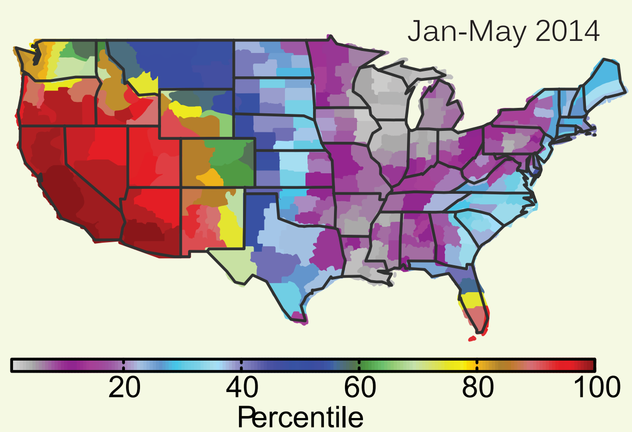


Red bars show a histogram of Colorado River flows during normal years; green bars show El Niño years. Although El Niños are associated with somewhat greater Colorado River flow than normal, the effect is modest.

Temperature's Role in the Drought

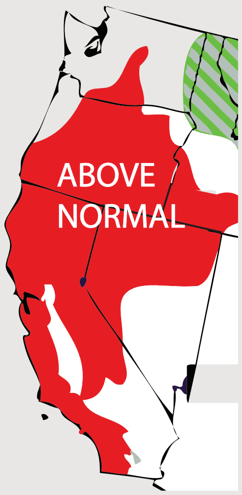
Temperature is related to drought because drier soil heats more in the sun (since there is less water to evaporate), hotter temperatures encourage evaporation from soil and plants, more winter precipitation falls as rain, and what snow does fall melts earlier in the year and runs off rather than sustaining crops and water supplies.

The first part of 2014 experienced record high temperatures in central California and greatly above normal temperatures throughout the region. Freezing levels were higher than normal in the mountains, resulting in less snowpack, and the one big storm that hit was warm, dropping proportionately more rain and less snow. So the California drought of 2014 was driven primarily by low precipitation, but warm conditions helped reduce snowpack and water availability.



Wildfire and the Drought

Droughts can increase wildfires, which destroy buildings, affect electrical transmission lines and water infrastructure, disturb river ecosystems through ash and runoff from burned out patches, and regionally degrade air quality. Fire danger in 2013 and 2014 reached record levels as the drought produced dry, highly flammable fuel loads. The 2013 Rim Fire near Yosemite National Park was the third largest area burned in state history, and produced significant smoke impacts on the populated areas of western Nevada.

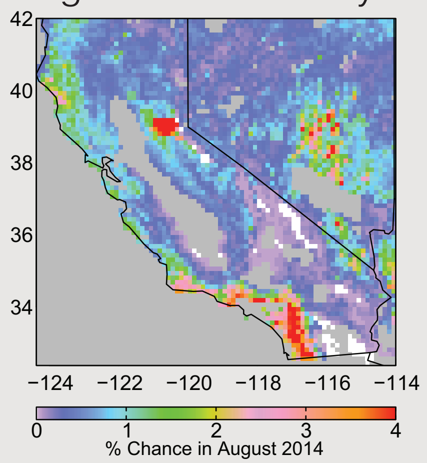


Significant Wildfire Potential

Aug-Sep 2014

Map data from Predictive Services, National Interagency Coordination Center, Boise, ID

Ignition Probability

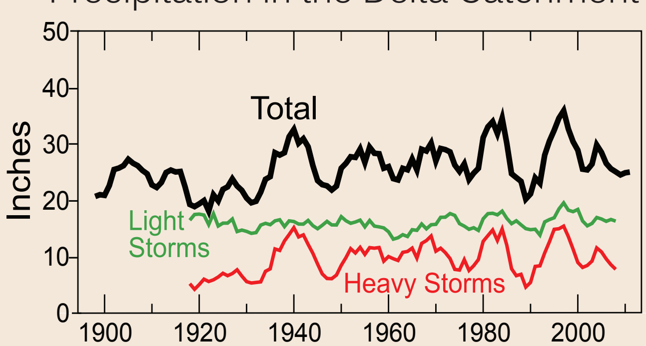


Wildfire is complicated, with both the probability of ignition (from lightning, humans, etc.) and the availability of dry fuel playing a role. The figure above shows that the western U.S. drought has produced a wide region of above normal wildfire potential, while the figure to the left shows predicted likelihood of ignition in August 2014. It is ignition together with high fire potential (abundant energy release from dry fuel) that yields large wildfires.

The Key Role of Heavy Storms

A unique aspect of California's climate is that much of the total annual precipitation is delivered in a few large storms. This is illustrated for the Sacramento-San Joaquin River Delta catchment in the figure below right. Total annual precipitation, filtered by a 5-year running average (black line), shows substantial fluctuations. However the total accumulation from light precipitation events (green) is nearly constant. Here, light storms are defined as those generating daily precipitation below the 95th percentile value. By contrast, the precipitation from heavy storms (≥ 95th percentile; red line) shows large variability that is highly correlated to the variations in the total annual precipitation. In terms of fluctuations in its total water supply, California lives or dies by just a few very heavy storms per year, which poses a difficult forecasting challenge.

Precipitation in the Delta Catchment



CNAP & Associates

The California Nevada Applications Program (CNAP) is a NOAA Regional Integrated Sciences and Assessments (RISA) program, led by climate researchers at the Scripps Institution of Oceanography at UC San Diego, the Desert Research Institute, UC Merced, and the U.S. Geological Survey. CNAP develops and provides climate information and forecasts for decision-makers in the California/Nevada region. We collaborate with a range of stakeholders from a variety of agencies, industries, and organizations.

National Integrated Drought Information System (NIDIS)

NIDIS works with a variety of Federal, state, tribal, and local partners to improve drought early warning, impacts assessments, and preparedness.

Southwest Climate Science Center (SW CSC)

CNAP has close collaboration with the SW CSC, established by the U.S. Department of Interior to provide scientific information, tools, and techniques that managers and other parties interested in land, water, wildlife, and cultural resources can use to anticipate, monitor, and adapt to climate change.

CW3E

The Center for Western Weather and Water Extremes (CW3E) at the Scripps Institution of Oceanography provides 21st century water cycle science, technology, and outreach to support effective policies on extreme weather and water events in Western North America.

USDA Forest Service

CNAP works with the USDA Forest Service, who have helped support research to develop a seasonal wildfire forecast, which has become an annual, ongoing product.

California State Climatologist

State Climatologist Dr. Michael Anderson collects, interprets, and disseminates climate information and products to the public as well as federal, state, and local agencies, and works with researchers and the community on climate extremes and change.

Contact CNAP

http://cnap.ucsd.edu
Anne Steinemann
Program Manager, CNAP
e-mail: asteinemann@ucsd.edu
Dan Cayan
Co-Director, CNAP
e-mail: dcayan@ucsd.edu