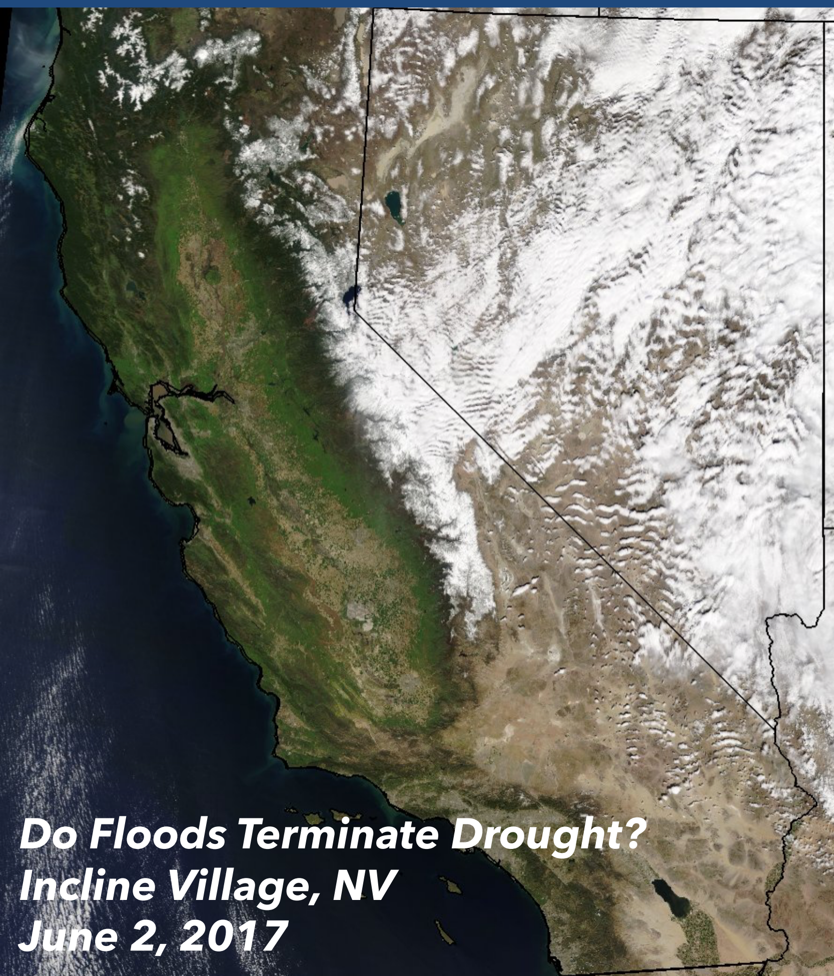
THE CALIFORNIA-NEVADA DROUGHT EARLY WARNING SYSTEM

MAKING DROUGHT SCIENCE AVAILABLE, UNDERSTANDABLE, AND USEABLE FOR DECISION MAKING



Amanda M. Sheffield

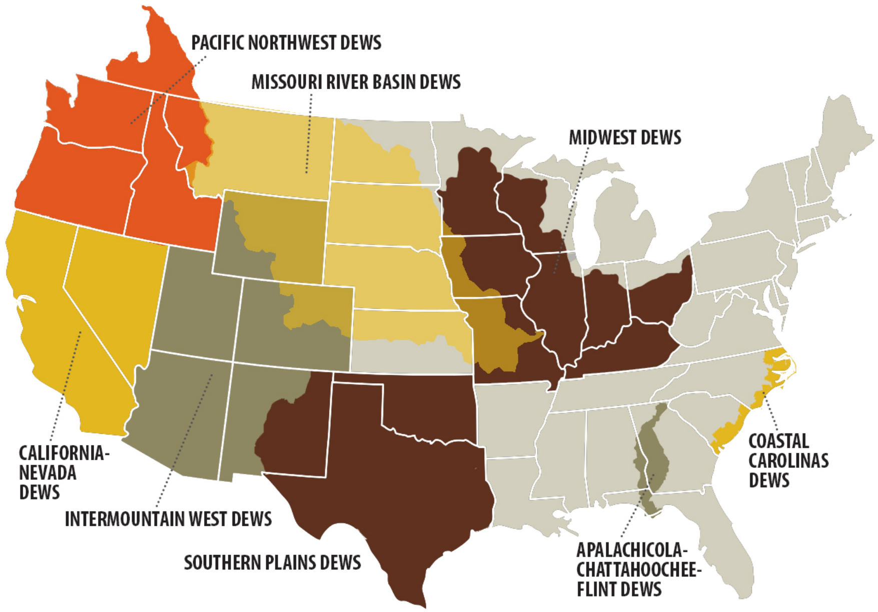
National Integrated Drought Information System (NIDIS)
California-Nevada Applications Program (CNAP)
Scripps Institution of Oceanography, UCSD
La Jolla, CA

CNAP
California-Nevada Climate Applications Program

SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego

WHAT IS THE NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM (NIDIS)?

- A NOAA program with an interagency mandate.
- Provide a better understanding of how and why droughts affect society, the economy and the environment.
- Improve accessibility, dissemination and use of early warning information for drought risk management.
- Build off of a network of **Regional Drought Early Warning Systems (DEWS)** to create a National Drought Early Warning System.



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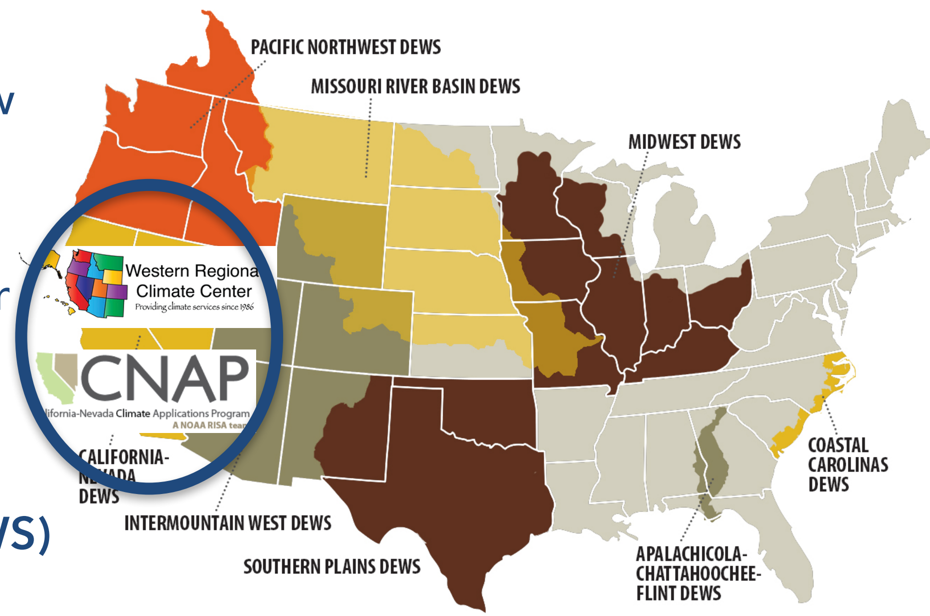
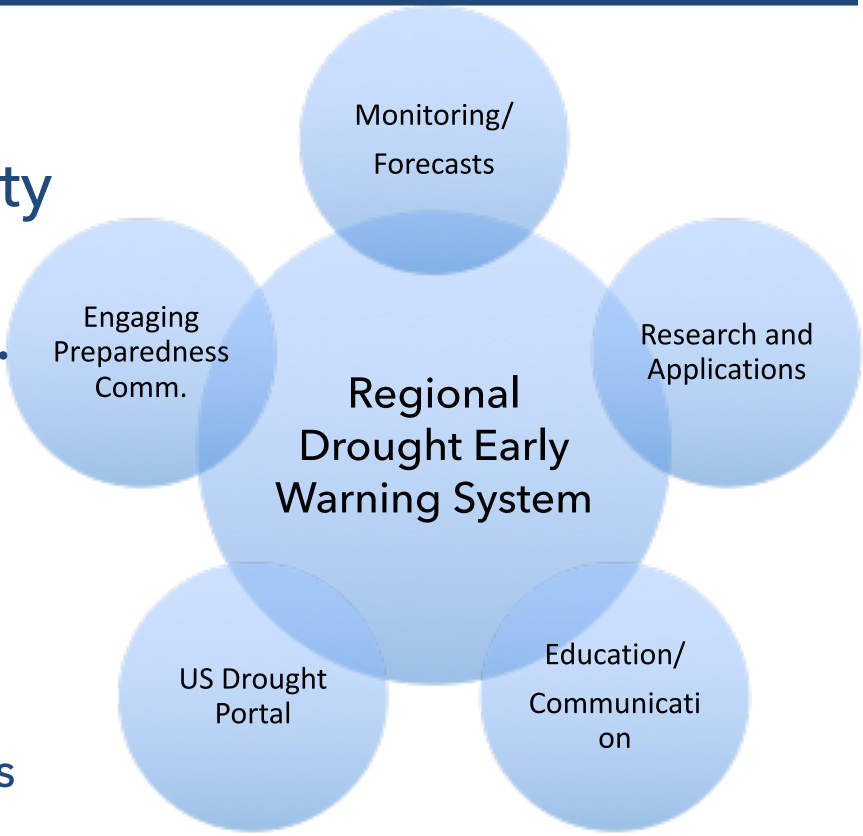


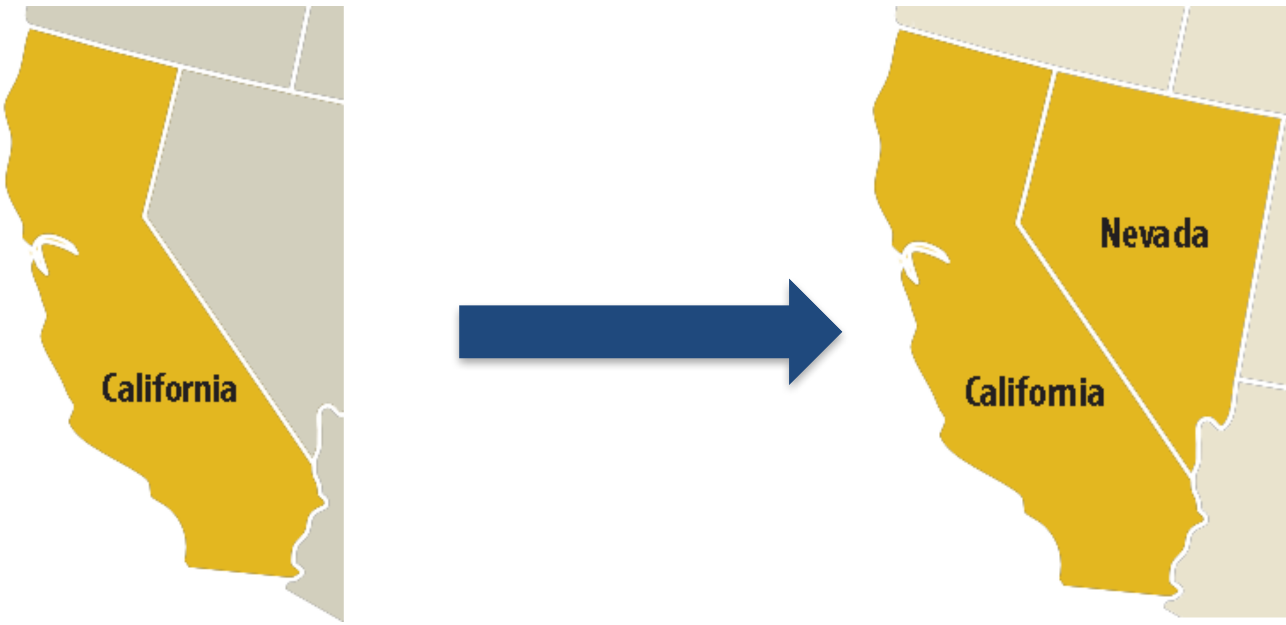
REGIONAL DROUGHT EARLY WARNING SYSTEMS (DEWS)

Working with communities and existing networks to build capacity for better decision making for drought planning and mitigation.

- Drought assessments
- Climate outlook forums
- Education and outreach webinars
- Engaging the preparedness community
- Builds capacity to utilize existing products



New opportunities with the newly expanded California-Nevada DEWS



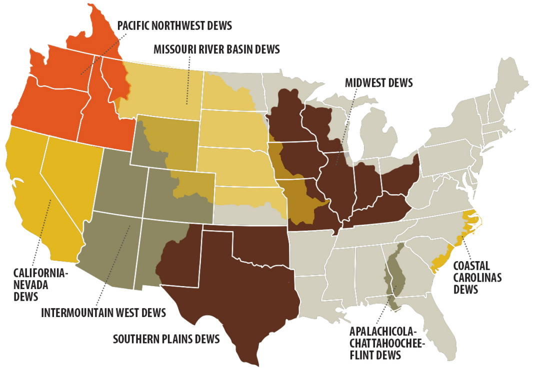
NOAA · NIDIS · CNAP California-Nevada Climate Applications Program · Western Regional Climate Center Providing climate services since 1986 · DRI Desert Research Institute

Development of the CA-NV DEWS Strategic Plan

- Roadmap for moving forward with the CA-NV DEWS
- Identify existing and new drought-related activities throughout the region
- Living document w/ 2-yr time frame
- Focus is on activities in the region

Benefits of a DEWS Strategic Plan

- Fostering a regional network
- Collaboration and coordination
- Reference to help generate policy and governmental support
- Resource to assist with leveraging funds
- Foster sharing of activities and info within and across other DEWS



THE CALIFORNIA-NEVADA DROUGHT EARLY WARNING SYSTEM

- Strategic plan provides a **roadmap** for moving forward the CA-NV DEWS

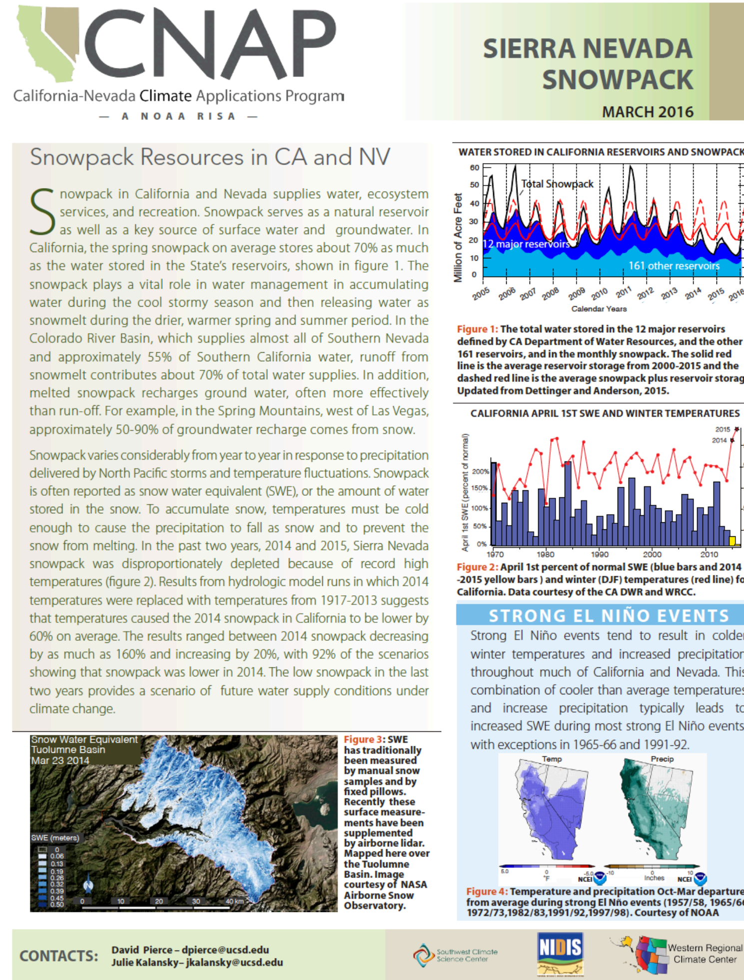
- Current priority areas include:
    - *Optimize the collaborative DEWS network*
    - *Development of Drought Monitoring Metrics & Research*
    - *Develop Forecast & Decision Support Tools for Resource Managers*
    - *Improve Drought Early Warning Communication & Outreach*

- First Annual CA-NV DEWS Coordination Workshop
  June 21-22 @ DRI, Reno NV

NOAA NIDIS CNAP California-Nevada Climate Applications Program Western Regional Climate Center Providing climate services since 1986 DRI Desert Research Institute

CALIFORNIA NEVADA APPLICATIONS PROGRAM (CNAP)

- NOAA RISA centered on California & Nevada
- Expand and build the nation's capacity to prepare for and adapt to climate variability and change
  - Advance understanding of context and risk
  - Support knowledge to action networks
  - Innovative services, products, and tools
  - Advance science policy
  - Partnership and trust building
- Currently Re-competing for next 5 years support



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SIERRA NEVADA SNOWPACK
MARCH 2016

Snowpack Resources in CA and NV

Snowpack in California and Nevada supplies water, ecosystem services, and recreation. Snowpack serves as a natural reservoir as well as a key source of surface water and groundwater. In California, the spring snowpack on average stores about 70% as much as the water stored in the State's reservoirs, shown in figure 1. The snowpack plays a vital role in water management in accumulating water during the cool stormy season and then releasing water as snowmelt during the drier, warmer spring and summer period. In the Colorado River Basin, which supplies almost all of Southern Nevada and approximately 55% of Southern California water, runoff from snowmelt contributes about 70% of total water supplies. In addition, melted snowpack recharges ground water, often more effectively than run-off. For example, in the Spring Mountains, west of Las Vegas, approximately 50-90% of groundwater recharge comes from snow.

Snowpack varies considerably from year to year in response to precipitation delivered by North Pacific storms and temperature fluctuations. Snowpack is often reported as snow water equivalent (SWE), or the amount of water stored in the snow. To accumulate snow, temperatures must be cold enough to cause the precipitation to fall as snow and to prevent the snow from melting. In the past two years, 2014 and 2015, Sierra Nevada snowpack was disproportionately depleted because of record high temperatures (figure 2). Results from hydrologic model runs in which 2014 temperatures were replaced with temperatures from 1917-2013 suggests that temperatures caused the 2014 snowpack in California to be lower by 60% on average. The results ranged between 2014 snowpack decreasing by as much as 160% and increasing by 20%, with 92% of the scenarios showing that snowpack was lower in 2014. The low snowpack in the last two years provides a scenario of future water supply conditions under climate change.

Figure 3: SWE has traditionally been measured by manual snow samples and by fixed pillows. Recently these surface measurements have been supplemented by airborne lidar. Mapped here over the Tuolumne Basin. Image courtesy of NASA Airborne Snow Observatory.

WATER STORED IN CALIFORNIA RESERVOIRS AND SNOWPACK

Figure 1: The total water stored in the 12 major reservoirs defined by CA Department of Water Resources, and the other 161 reservoirs, and in the monthly snowpack. The solid red line is the average reservoir storage from 2000-2015 and the dashed red line is the average snowpack plus reservoir storage. Updated from Dettinger and Anderson, 2015.

CALIFORNIA APRIL 1ST SWE AND WINTER TEMPERATURES

Figure 2: April 1st percent of normal SWE (blue bars and 2014 -2015 yellow bars) and winter (DJF) temperatures (red line) for California. Data courtesy of the CA DWR and WRCC.

STRONG EL NIÑO EVENTS

Strong El Niño events tend to result in colder winter temperatures and increased precipitation throughout much of California and Nevada. This combination of cooler than average temperatures and increase precipitation typically leads to increased SWE during most strong El Niño events, with exceptions in 1965-66 and 1991-92.

Figure 4: Temperature and precipitation Oct-Mar departure from average during strong El Nño events (1957/58, 1965/66, 1972/73,1982/83,1991/92,1997/98). Courtesy of NOAA

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Southwest Climate Science Center | NIDIS | Western Regional Climate Center

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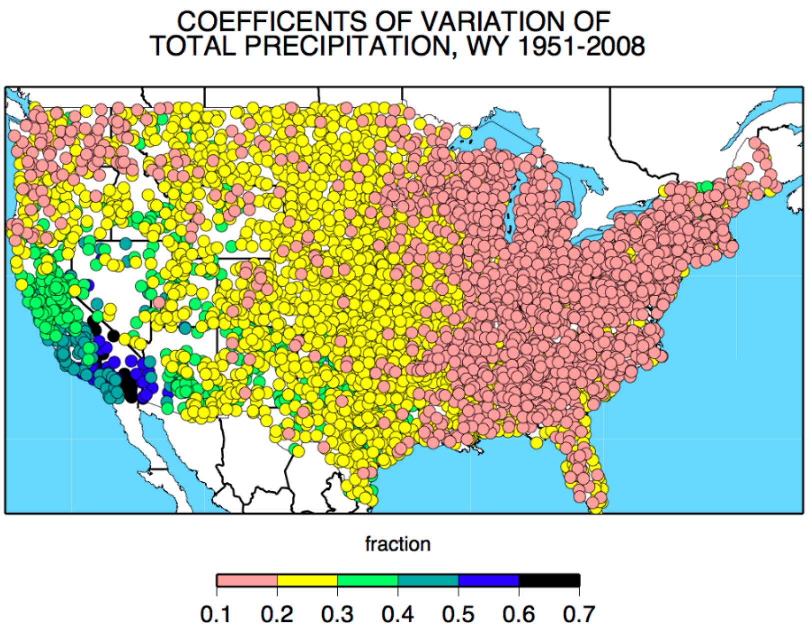
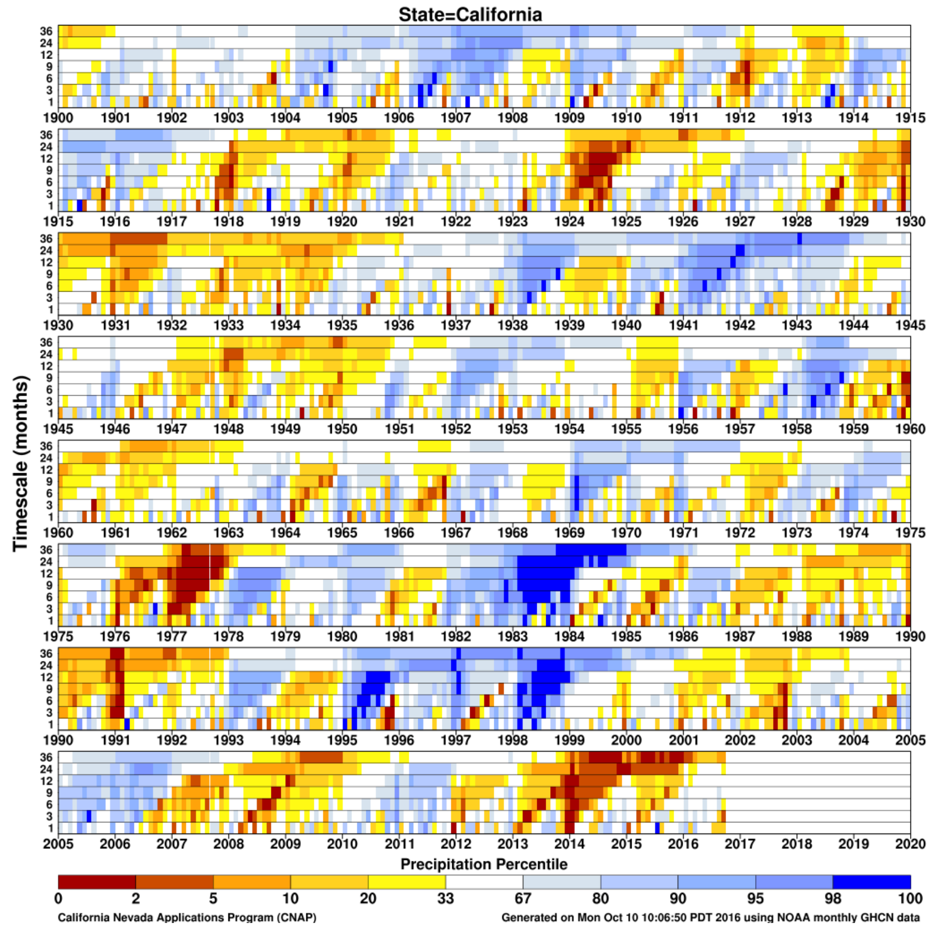
@CnapRisa

www.cnap.ucsd.edu

TAILORING TO CALIFORNIA-NEVADA CLIMATE VARIABILITY

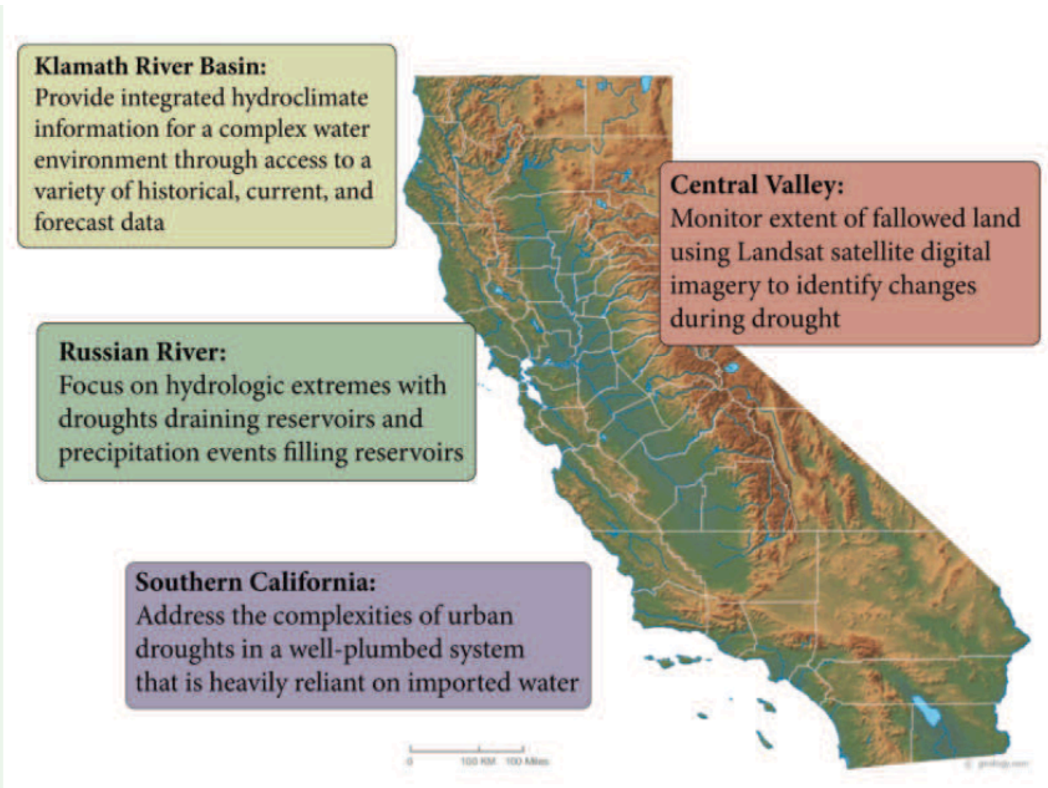




*Dettinger, M.D., et al 2011: Atmospheric Rivers, Floods and the Water Resources of California. Water, **3**, 445-478. doi:10.3390/w3020445*

https://scripps.ucsd.edu/programs/cnap/observations/
Steinemann, A., et al 2015: Developing and Evaluating Drought Indicators for Decision-Making. J. Hydrometeor, 16, 1793-1803.doi:10.1175/JHM-D-14-0234.1

PILOTING A CALIFORNIA DEWS

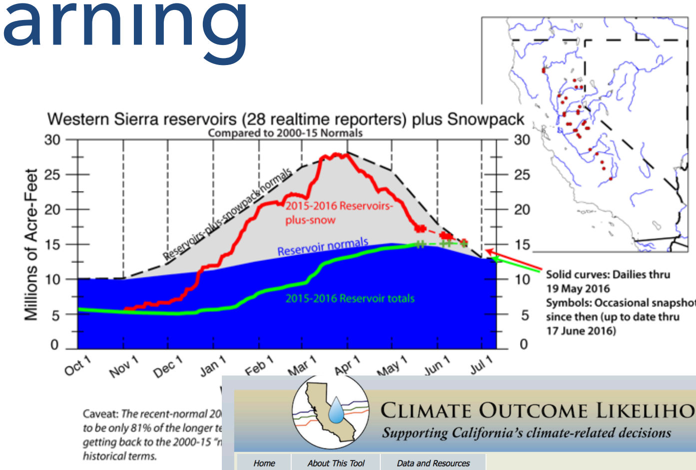


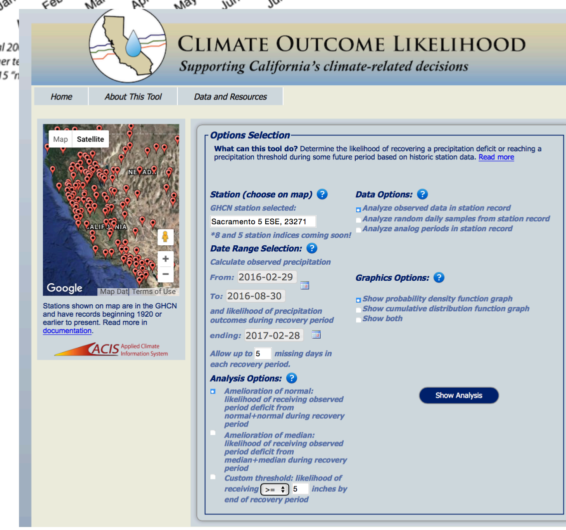
- Developed in 2010-2012 with stakeholder and decision maker meetings throughout the state to identify several 'pilot' projects
- 2014
  - California Drought Forum
  - Ranching and California Drought Meeting
- 2015
  - Southern California NIDIS Community Meeting

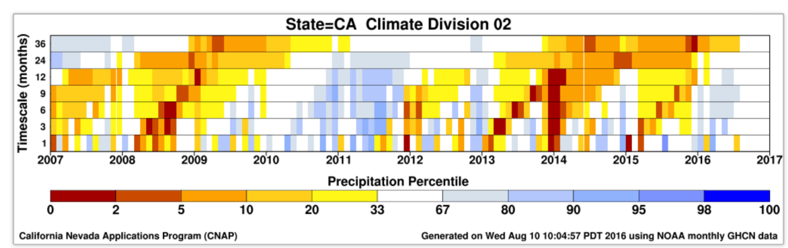
California-Nevada Climate Applications Program
A NOAA RISA team

Continued Development of Drought Early Warning

- Climate Outcome Likelihood Tool
- Evaluating and understanding **seasonal forecast skill** using the National Multi-Model Ensemble (NMME)
- Development of a historical catalogue of **atmospheric rivers**
- Investigation of the impacts of drought & climate impacts on **wildfire**
- Evaluation of **water supplies** in California, including water stored in state's snowpack, reservoirs, and to the extent possible, groundwater storage
- Evaluation of historical atmospheric circulation patterns related to major precipitation events (or lack thereof) to aid forecasts of **drought busting**
- Drought scenario planning with local agency planners and water utilities using **downscaled climate model projections** focused on California
- Near real time **groundwater** pumping in the Central Valley with USGS

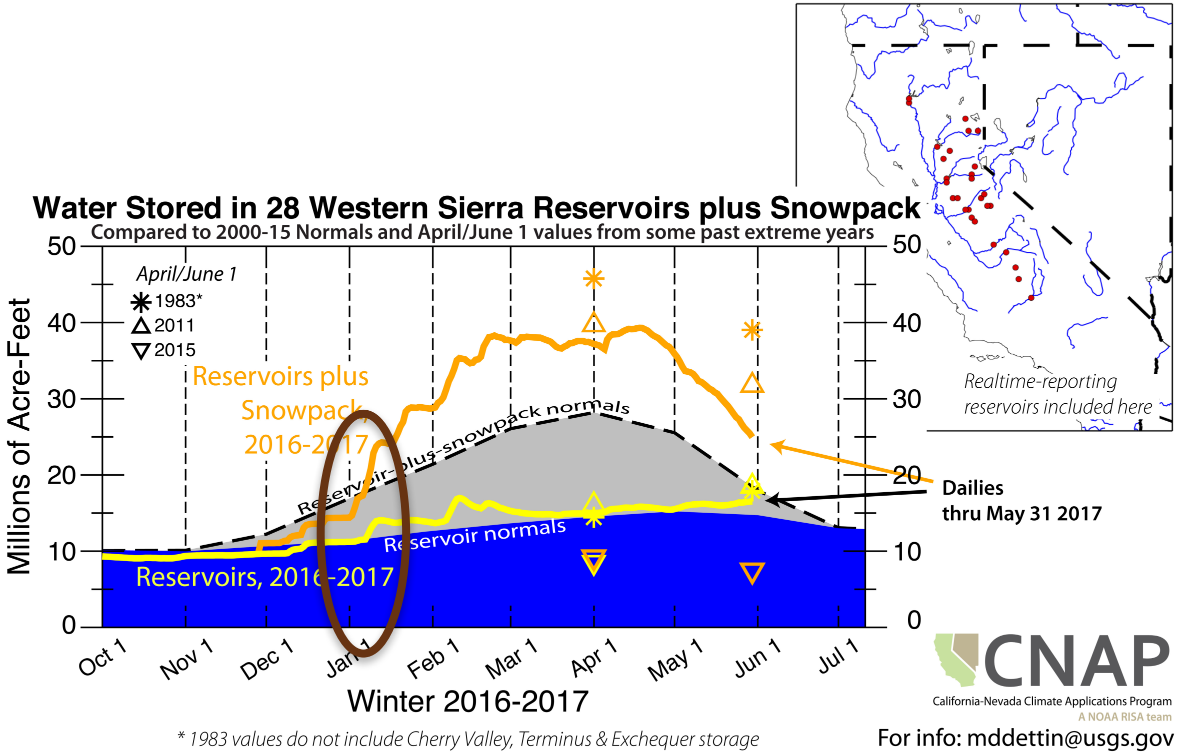






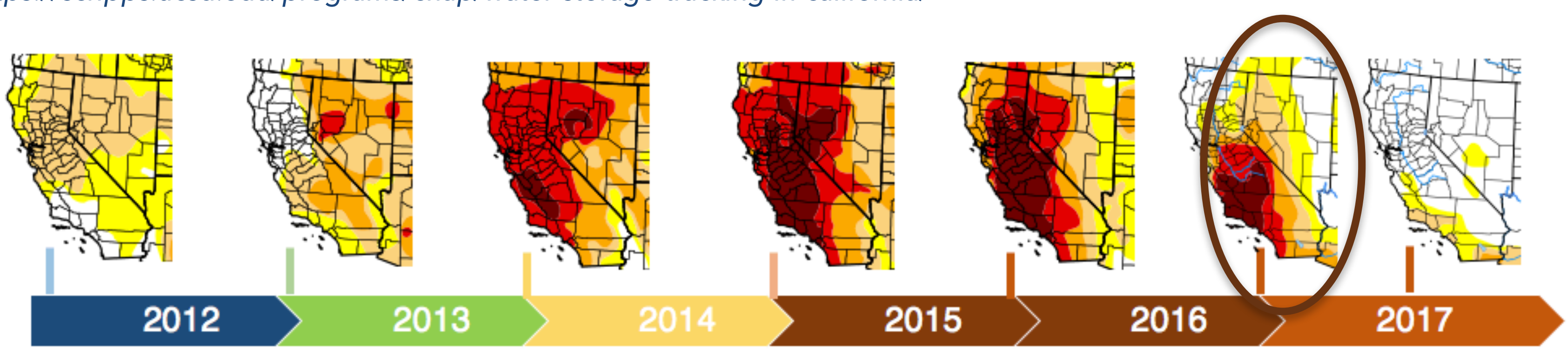
NOAA NIDIS CNAP California-Nevada Climate Applications Program A NOAA RISA team

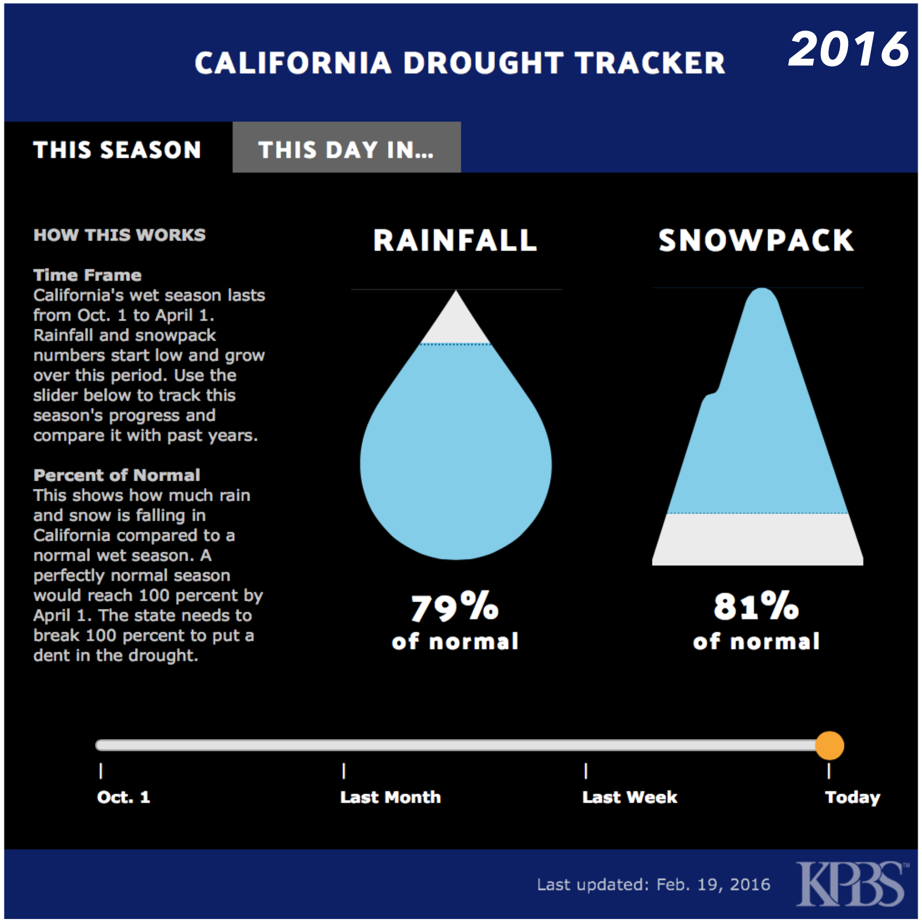
PRECIPITATION TRACKING

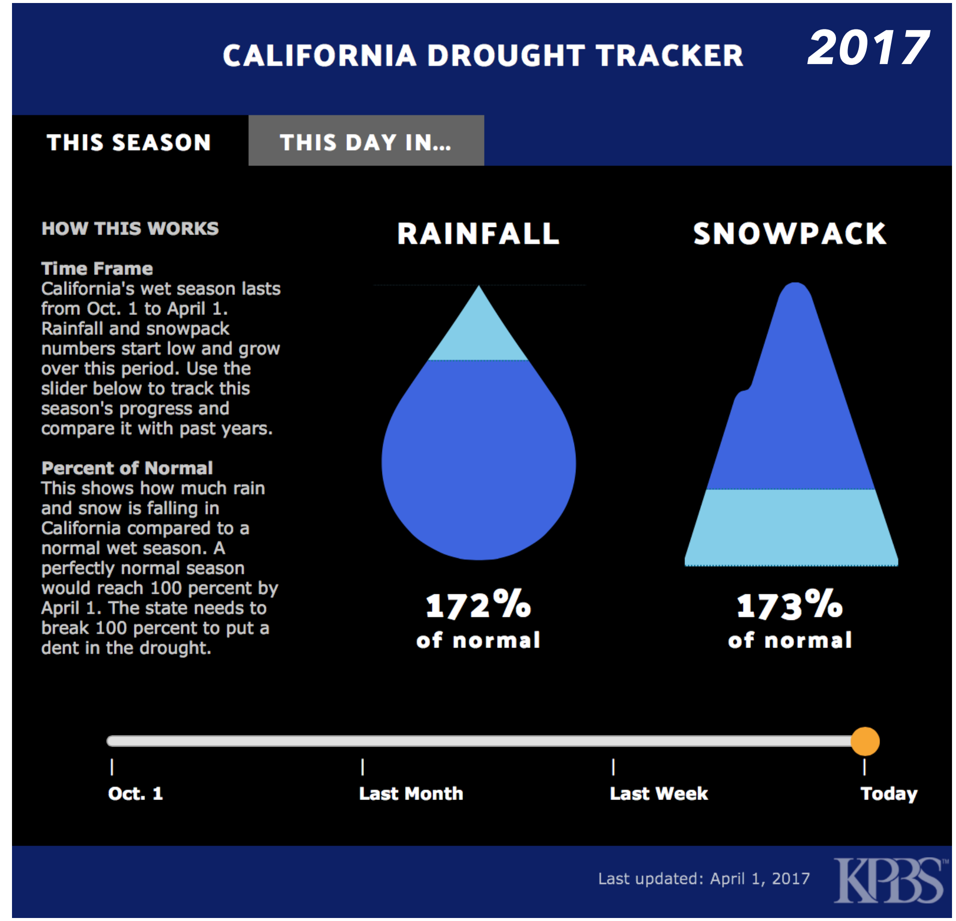


Recent Challenge: Communicating the characterization and evolution of drought (i.e. flooding during drought)

https://scripps.ucsd.edu/programs/cnap/water-storage-tracking-in-california/





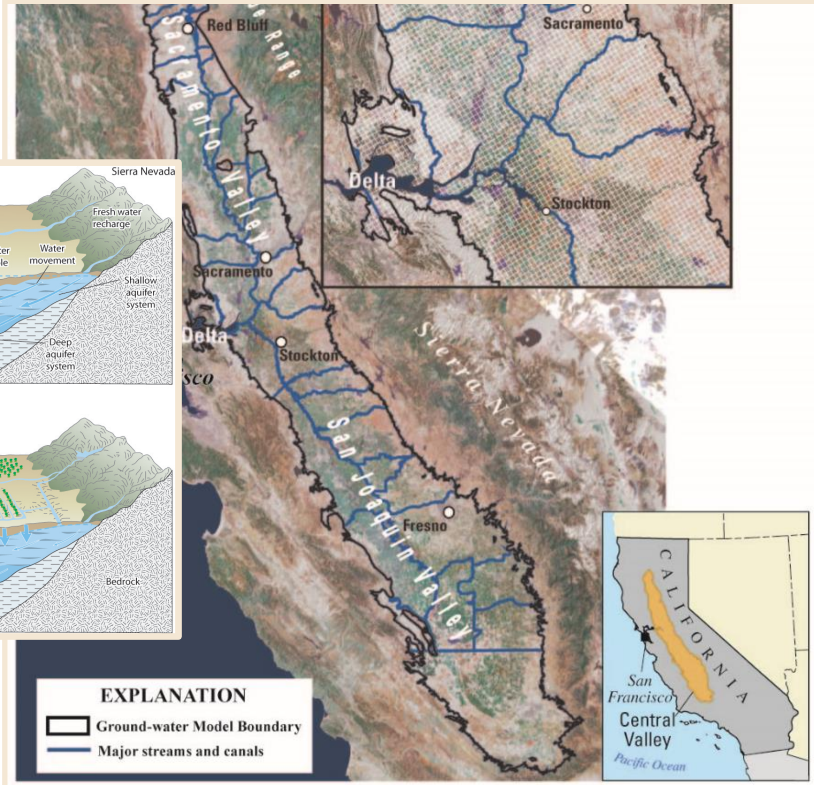


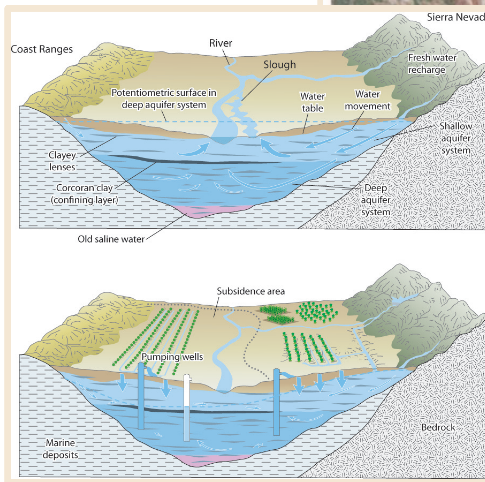
DATA SOURCES: Rainfall data comes from a weighted average of 96 weather stations throughout the state. Snowpack data represents the average of three different multi-station measures of the northern, central and southern Sierra snowpack. Scripps Institution of Oceanography researchers, through the California Nevada Applications Program RISA and the Center for Western Weather and Water Extremes, helped compile the data.

CENTRAL VALLEY HYDROLOGY

- CVHM accounts for integrated water supply and demand for entire Central Valley surface and groundwater system
- Provides a tool for drought assessment and projection
- Current delays in data integration, water use reporting etc. create time lag in the flow of information
- Work is underway to reduce this lag and provide real time estimates of groundwater pumping

Central Valley Hydrologic Model





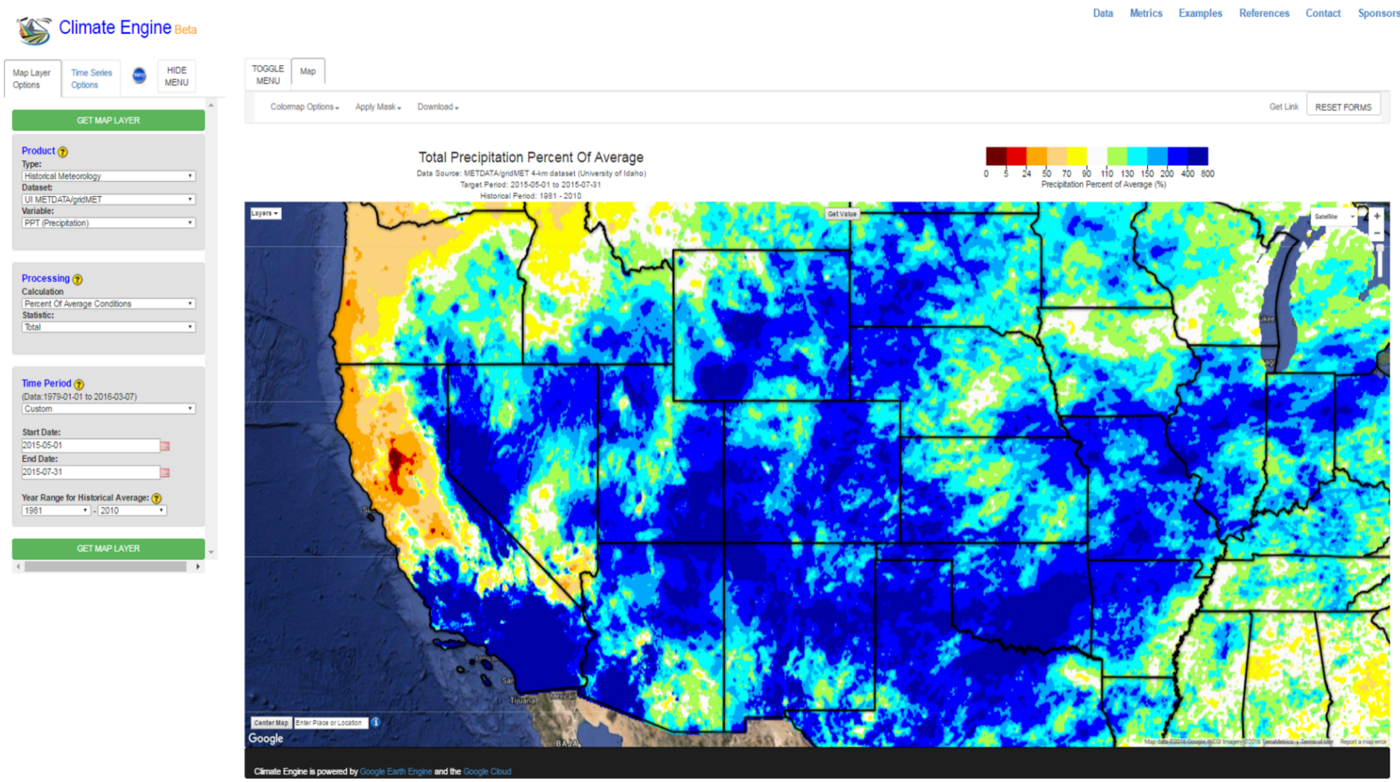
California-Nevada Climate Applications Program
A NOAA RISA team

Climate Engine

WEB APP **EXAMPLES** DATA TEAM PUBS NEWS TESTIMONIALS CONTACT

2015 West Coast Drought and West - Central U.S. Wet Summer

METDATA percent of average precipitation, illustrating anomalously low May - July precipitation in California, and high precipitation over the intermountain and central U.S.



Google Earth Engine

LDCM LANDSAT Data Continuity Mission NASA • USGS

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF LAND MANAGEMENT

FEWS NET FAMINE EARLY WARNING SYSTEMS NETWORK

USGS science for a changing world

CIRC A NOAA RISA TEAM

Western Regional Climate Center Providing climate services since 1986

REACCH Regional Approaches to Climate Change

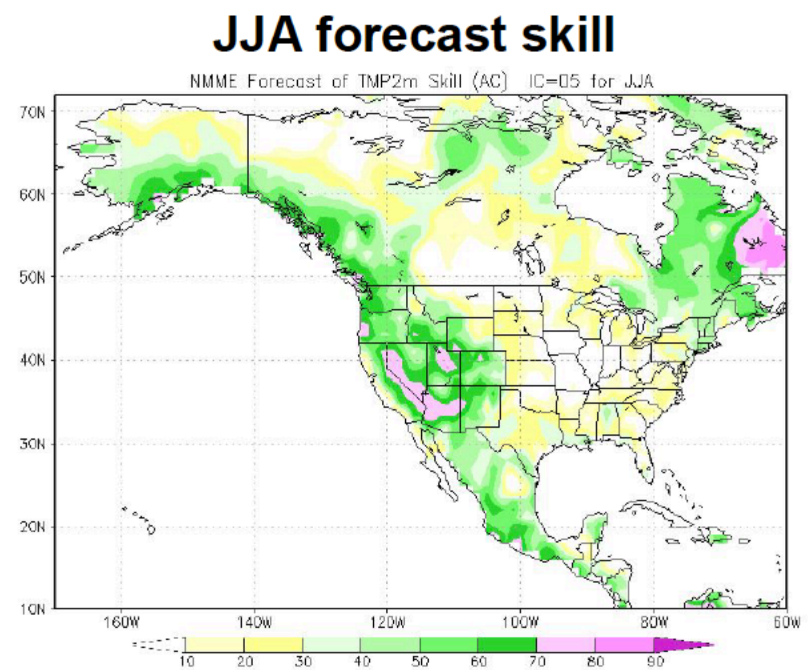
ADAMSHUB for innovation

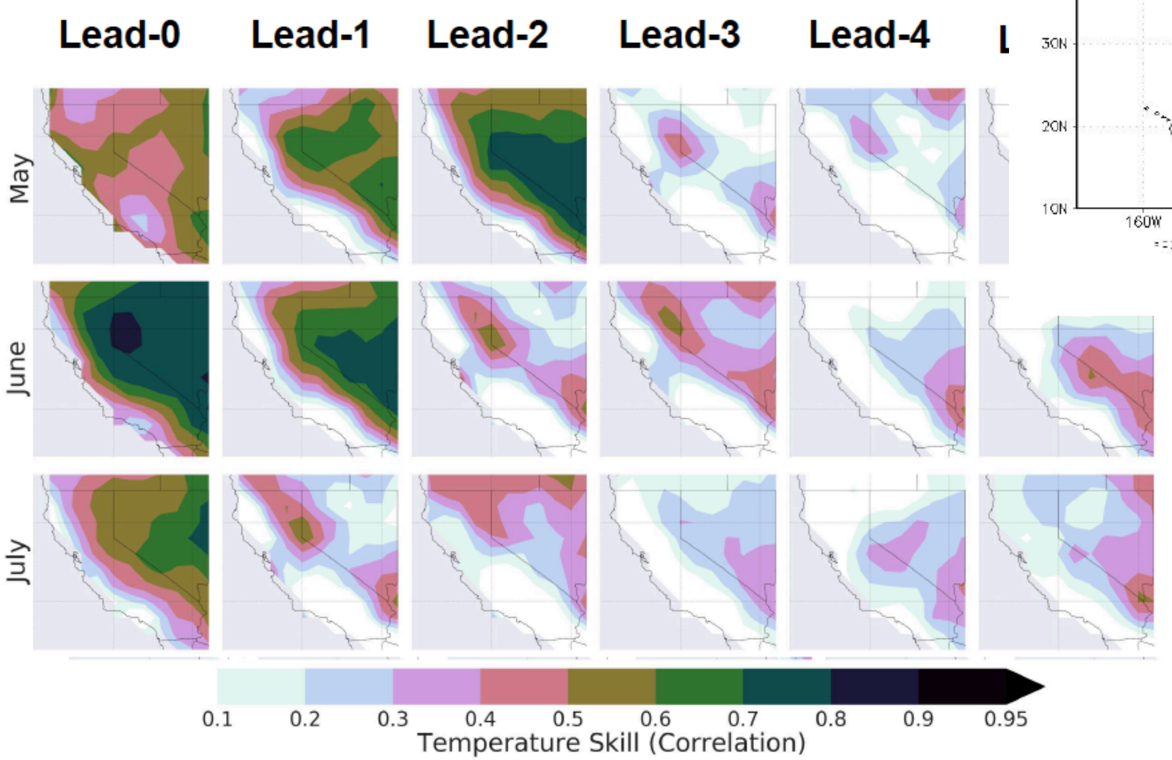
Southwest Climate Science Center

NOAA

NIDIS

NORTH AMERICAN MULTIMODEL ENSEMBLE (NMME)





Work by Shrad Shukla (UCSB/CNAP)

TAILORING COMMUNICATION STRATEGIES

CNAP

California-Nevada Climate Applications Program

— A NOAA RISA —

SUB-SEASONAL TO SEASONAL FORECASTING

JANUARY 2017

What is Seasonal to Sub-Seasonal (S2S) Forecasting?

Everyday decisions are made based on weather forecasts for various time ranges within 14 days (short-term), but **sub-seasonal to seasonal (S2S) forecasts** (long-term weather forecasts for 2 weeks to 12 months from now) are greatly needed by decision makers in water resources, energy and agriculture. According to the National Academy of Science in 2016, S2S forecasts will become more widely used in the future.

The "skill," or accuracy, of S2S forecasts varies with season, region, and whether it is a temperature or rain/snow forecast. They are also dependent on how far in advance one is forecasting (figure 1). Each type of forecast (short-term, sub-seasonal, and seasonal) makes the best use of knowledge of how the atmosphere works and what weather we see occurring right now. S2S forecasts are different than short-term weather forecasts because they are limited by all these components plus the chaotic nature of some crucial global weather and climate processes. Given these uncertainties, S2S forecasts are given in terms of probabilities rather than as forecasts for specific weather events.

S2S forecasts are made from computer models based on our current and observed knowledge of the atmosphere, ocean and land, and from statistics of historical observations.

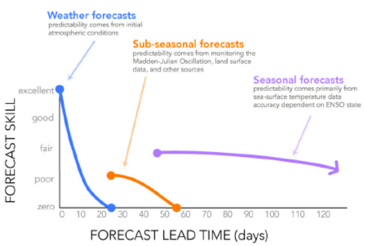


Figure 1. Different type of forecast skill by type of forecast (weather, sub-seasonal, seasonal) which depends on how far out (or lead time) the forecast is for.
Source: http://iri.columbia.edu/news/qa-subseasonal-prediction-project/

Mid-November Precipitation Forecast Skill for All December to Februarys from 1995-2016

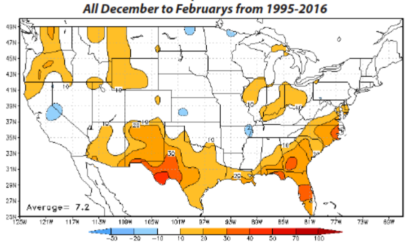


Figure 2. Heidke skill scores show low skill (whites and blues) for December-Februarys from 1995 to 2016, more so in precipitation (shown) forecasts than temperature.
Source:http://www.cpc.ncep.noaa.gov/products/verification/summary/index.

FORECAST PERFORMANCE

Forecast **skill** is a gauge of the performance of a forecast relative to a given standard. Often, the standard used is the long-term (30-year) average - called the climatology - of temperature or precipitation. Thus, skill scores measure the improvement of the forecast over the climatology. NOAA's Climate Prediction Center (CPC) uses the Heidke skill score (figure 2), comparing how often the forecast category correctly match the observed category, over and above the number of correct "hits" expected by chance alone. A score of 0 means that the forecast was not better than what would be expected by chance. A score of 100 depicts a perfect forecast and a score of -50 depicts a perfectly wrong forecast. For example, California and Nevada are shown (figure 2) to have low forecast skill in precipitation as do many other regions of the United States.

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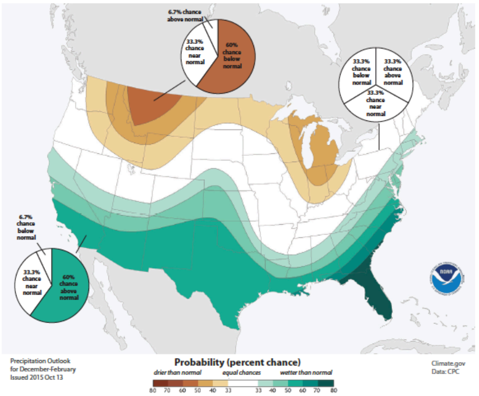


Figure 3. National precipitation outlook for December 2015 to February 2016, issued on October 15, 2015. Colors indicate the most favored odds of above- or below-average temperatures or precipitation. White indicates equal chances for any outcome—above-, below-, or near-normal temperature—not a prediction of "normal" conditions. Map by NOAA Climate.gov (https://www.climate.gov/news-features/videos/2015-16-winter-outlook), based on data from the Climate Prediction Center.

NOAA Climate Prediction Center (CPC) Suite of Official Forecasts can be found at http://www.cpc.ncep.noaa.gov/products/predictions/

Understanding NOAA Climate Prediction Center S2S Forecasts

S2S forecasts are made by several federal programs and universities, each encompassing different methods and skill. A widely used set of S2S forecasts are NOAA's Climate Prediction Center (CPC) color shaded maps of extended range outlooks (for example, 6-10 or 8-14 days to 1 month) and longer lead time outlooks for 3-month time scales. The shift from the extended range outlooks to 3-month outlooks reflects the different kinds of forecast skill shown in figure 1. Although the color shading indicates the probability of above- or below-average temperature or precipitation, the forecasts do not indicate how much above or below average (i.e. how extreme) a forecast period might be.

How are these forecast likelihoods displayed on CPC maps determined? NOAA's seasonal forecasts start with the assumption that for any summer or winter, there are three possible climate outcomes: temperature or precipitation that is **above normal (upper third of the 1981-2010 record), near normal (middle third), or below normal (lower third)**. Without looking at the current forecast, at a given location each category has equal chances of occurring, and together they must add up to 100%. Thus the default probability for each outcome is 33.3%.

Determining how the odds shift to favor above or below normal conditions is controlled by the confidence of the model forecasted conditions. For example in the forecast for December 2015 to February 2016 made in (or issued in) October 2015 (figure 3), a wetter-than-normal Southwest US was anticipated, with drier conditions in the Northwest US. Largely because the forecast models predicted a wetter than normal season in Southern California, the CPC forecasters set the odds at 60% chance of wetter than normal conditions. The remaining 40% then was split between the two other outcomes, near normal and below normal precipitation. Forecasters divided the remaining fraction (40%) by holding the chances for near-normal conditions at the default 33.3% (equal chances) leaving 6.7% as the probability of the least favored category, for this example being below normal precipitation. The region was then color shaded to match the more favored category, here being wetter than normal precipitation. CPC does the same types of maps for temperature using this same approach.

When the odds of above or below normal are very high (70% or more) such that the remaining fraction is smaller than 33.3%, forecasters set a minimum 3.3% chance for the opposite outcome, and assign the larger portion of the remainder to the near-normal outcome. This prevents the least-favored category from being assigned an impossible negative value.

- **CNAP**, the California Nevada Climate Applications Program, is a NOAA RISA team conducting applied climate research that is inspired by and useful to decision makers in the region. ***cnap.ucsd.edu***
- The **National Weather Service** is tasked with providing weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy. ***weather.gov***
- **NIDIS,** National Integrated Drought Information System, work with federal, state, tribal and local partners to improve drought early warning, preparedness, and response to impacts. ***drought.gov***
- **CW3E**, Center for Western Weather and Water Extremes, provides science to support effective policy on extreme weather and water events. ***cw3e.ucsd.edu***

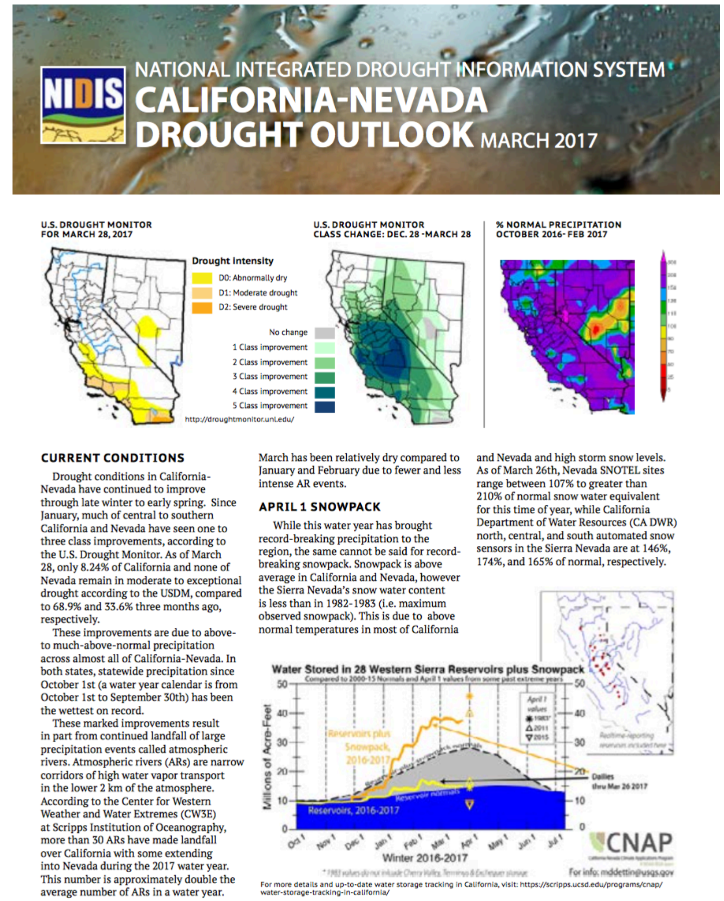
- Thank you to **California Department of Water Resources** for suggestions and revisions to this document.

2016-2017 CA-NV DEWS ACTIVITIES

- **Drought & Climate Outlook Webinars**
  - Slides, webinar recording, and 2 page summary on drought.gov
  - Next Webinar: July 24th at 11 am PT

- **Drought & Climate Outlooks**
  - Southern California (San Diego, CA; Riverside, CA)
  - North Central Coast (Seaside, CA)
  - Central Valley (Fresno, CA)

- **First Annual CA-NV DEWS Coordination Workshop – June 21-22 @ DRI, Reno NV**



NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM
CALIFORNIA-NEVADA DROUGHT OUTLOOK MARCH 2017

CURRENT CONDITIONS

Drought conditions in California-Nevada have continued to improve through late winter to early spring. Since January, much of central to southern California and Nevada have seen one to three class improvements, according to the U.S. Drought Monitor. As of March 28, only 8.24% of California and none of Nevada remain in moderate to exceptional drought according to the USDM, compared to 68.9% and 33.6% three months ago, respectively.

These improvements are due to above- to much-above-normal precipitation across almost all of California-Nevada. In both states, statewide precipitation since October 1st (a water year calendar is from October 1st to September 30th) has been the wettest on record.

These marked improvements result in part from continued landfall of large precipitation events called atmospheric rivers. Atmospheric rivers (ARs) are narrow corridors of high water vapor transport in the lower 2 km of the atmosphere. According to the Center for Western Weather and Water Extremes (CW3E) at Scripps Institution of Oceanography, more than 30 ARs have made landfall over California with some extending into Nevada during the 2017 water year. This number is approximately double the average number of ARs in a water year.

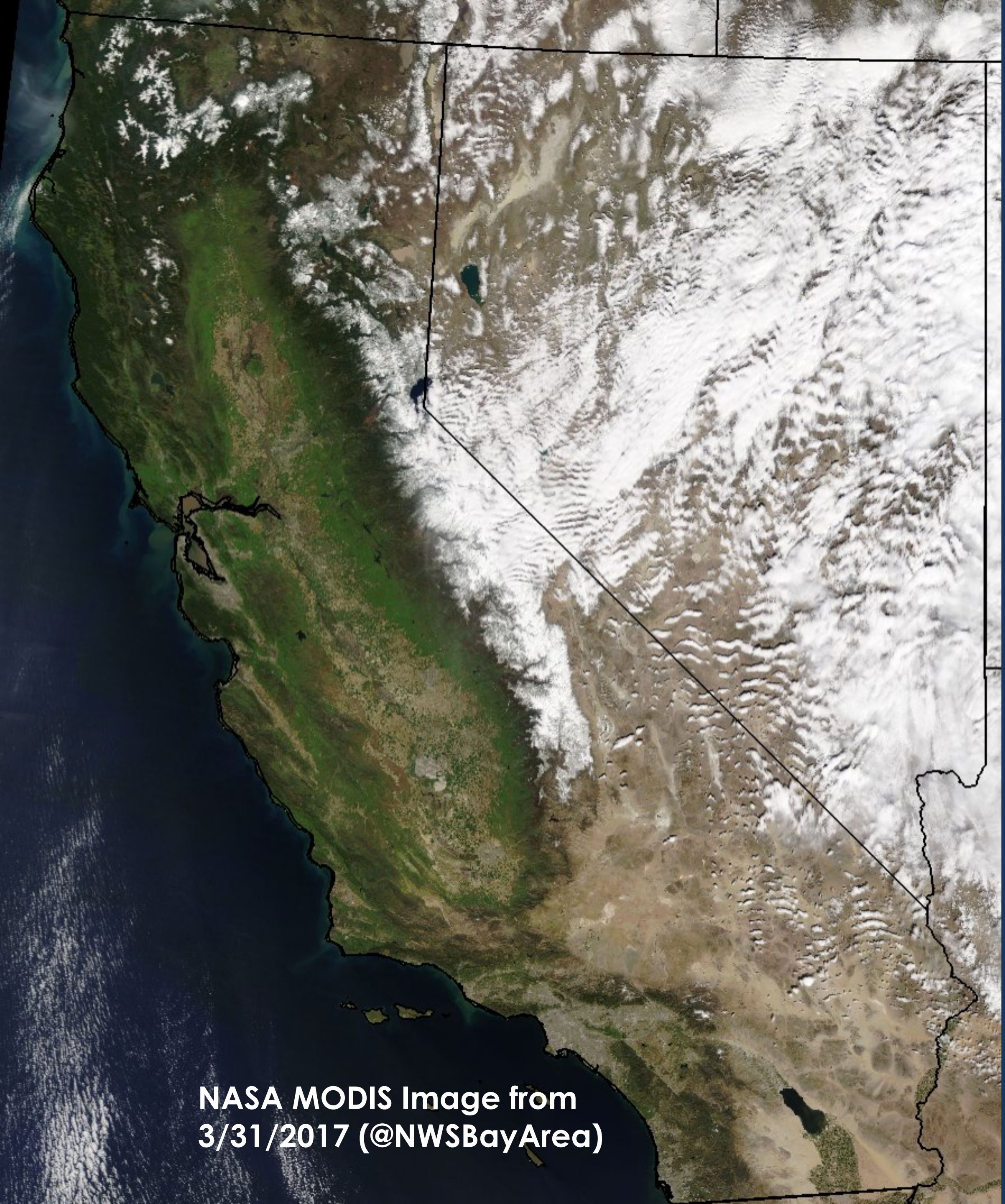
March has been relatively dry compared to January and February due to fewer and less intense AR events.

APRIL 1 SNOWPACK

While this water year has brought record-breaking precipitation to the region, the same cannot be said for record-breaking snowpack. Snowpack is above average in California and Nevada, however the Sierra Nevada's snow water content is less than in 1982-1983 (i.e. maximum observed snowpack). This is due to above normal temperatures in most of California and Nevada and high storm snow levels. As of March 26th, Nevada SNOTEL sites range between 107% to greater than 210% of normal snow water equivalent for this time of year, while California Department of Water Resources (CA DWR) north, central, and south automated snow sensors in the Sierra Nevada are at 146%, 174%, and 165% of normal, respectively.

For more details and up-to-date water storage tracking in California, visit: https://scripps.ucsd.edu/programs/cnap/water-storage-tracking-in-california/

https://drought.gov/drought/dews/california-nevada



NASA MODIS Image from
3/31/2017 (@NWSBayArea)

Thank you!

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drought.gov

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A NOAA RISA team

NIDIS
NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

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