CNAP

California-Nevada Climate Applications Program

— A NOAA RISA —

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.

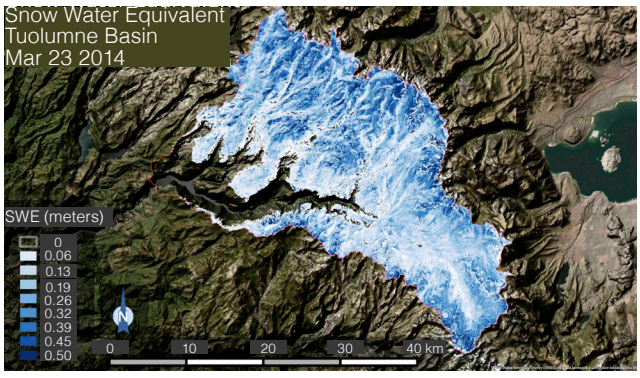

Figure 3: SWE has traditionally been measured by manual snow samples and by fixed pillows. Recently these surface measurements have been supplemented by airborne lidar. Mapped here over the Tuolumne Basin. Image courtesy of NASA Airborne Snow Observatory.

WATER STORED IN CALIFORNIA RESERVOIRS AND SNOWPACK

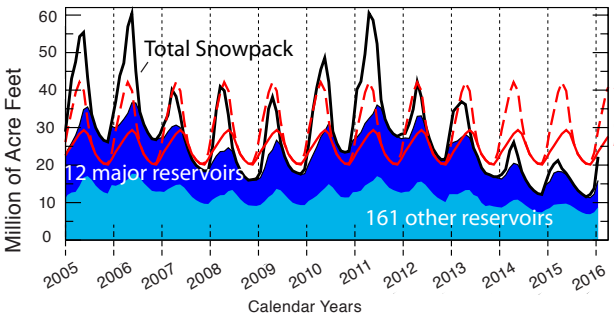

Figure 1: The total water stored in the 12 major reservoirs defined by CA Department of Water Resources, and the other 161 reservoirs, and in the monthly snowpack. The solid red line is the average reservoir storage from 2000-2015 and the dashed red line is the average snowpack plus reservoir storage.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

CALIFORNIA APRIL 1ST SWE AND WINTER TEMPERATURES

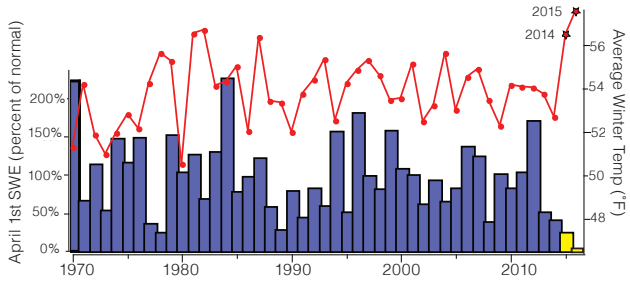

Figure 2: April 1st percent of normal SWE (blue bars and 2014 -2015 yellow bars) and winter (DJF) temperatures (red line) for California. Data courtesy of the CA DWR and WRCC.

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.

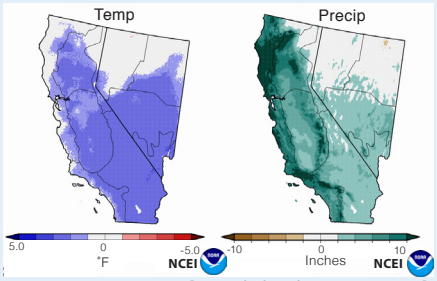

Figure 4: Temperature and precipitation Oct-Mar departure from average during strong El Nño events (1957/58, 1965/66, 1972/73,1982/83,1991/92,1997/98). Courtesy of NOAA

CONTACTS: David Pierce – dpierce@ucsd.edu
Julie Kalansky– jkalansky@ucsd.edu

Southwest Climate Science Center

NIDIS

Western Regional Climate Center

Snowpack and Climate Change

Historical observations, combined with climate models, indicate that climate change is already affecting spring snow accumulation in the western U.S. Historical snow measurements reveal that April 1st SWE values have declined in the northern Sierra, though less so in the southern Sierra. The difference is because the high elevation of the southern Sierra makes the region less susceptible to changes in temperature thus far. Observations across the West indicate that the proportion of precipitation as snow has declined also. Figure 5 shows the fraction of snow that falls between -2 and 0˚C; snow that falls in this temperature range is more likely to fall as rain as the climate warms. Besides water supply implications, snow instead of rain is an important deterrent for flooding, and has obvious impacts on recreation. Snowfall, snow accumulation, snowmelt and other aspects of snowpack are predicted to change at different rates in the future depending on their sensitivity to temperature as compared to precipitation. The table below shows the projected year when different variables related to snowpack are predicted to change beyond natural climate variability in different regions in the West.

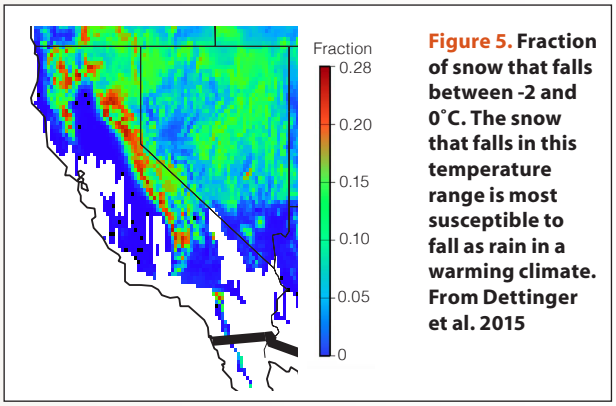

Figure 5. Fraction of snow that falls between -2 and 0˚C. The snow that falls in this temperature range is most susceptible to fall as rain in a warming climate. From Dettinger et al. 2015

PROJECTED YEAR WHEN SNOW VARIABLE CHANGES BEYOND NATURAL CLIMATE VARIABILITY

	RCP 8.5 (Business as usual emission scenario)			RCP 4.5 (Emission reduction)		
	Sierra Nevada	Great Basin	Wasatch CO River Basin	Sierra Nevada	Great Basin	Wasatch CO River Basin
SWE	2055	2045	2055	2070	2075	2075
Precip Falling as Snow	2060	2055	2080	2090	2070	2100
Last day of snow season	2035	2030	2025	2045	2030	2035

For more information see Pierce and Cayan, 2013

In mountain regions across the West as climate continues to warm over the 21st century, more precipitation will fall as rain rather than snow and the more snow will melt prior to April 1st. Projections of climate change in the Sierra Nevada find rain accounting for 50.6% (145 mm) more of precipitation and 62.3% (63mm) more of snow melt prior to April 1st than in historical norms (figure 6).

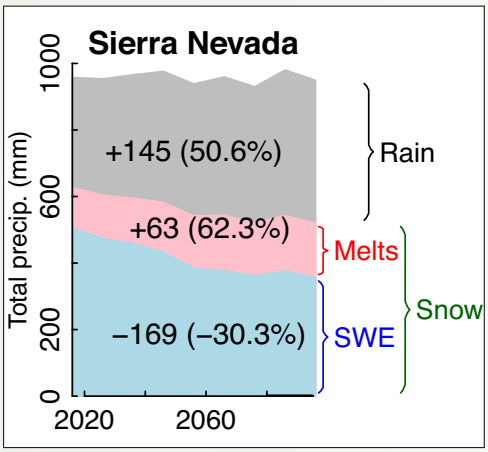

Figure 6. Projected changes in snow variables in the Sierra Nevada throughout the 21st century relative to historical norms. From Pierce and Cayan, 2013

- **CNAP**, the California Nevada 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***.
- **NIDIS**, National Integrated Drought Information System, works with the federal, state, tribal and local partners to improve drought early warning, preparedness, and response to impacts, ***drought.gov***.
- **WRCC,** the Western Regional Climate Center, develops products, provides services, and improves capabilities that enhance the delivery of climate information to the public in collaboration with NOAA partners, ***www.wrcc.dri.edu***.
- **SWCSC**, the Southwest Climate Science Center, sponsored by the US Depart. of the Interior, provides scientific information, tools, and techniques to anticipate, monitor, and adapt to climate change, ***www.doi.gov/csc/southwest***.

Dettinger, M. D., et al., 2015, *Ecological Applications*, 25 (8), 2069-2093.
Dettinger, M.D. and M. Anderson, 2015, *San Francisco Estuary and Watershed Science*, 13(2).
Pierce, D. W. and D. R. Cayan, *J. of Climate*, 26,4184-4167.