

CW3E Event Summary: 22 Dec 2021 – 1 Jan 2022

Atmospheric River and Upper-Level Systems Bring Heavy Rain and Snow to the Western US

- An atmospheric river (AR) made landfall over California on 22 Dec and gradually strengthened as it spread across the interior southwestern US
- AR 2/AR 3 conditions (based on the Ralph et al. 2019 AR Scale) were observed over coastal Central and Southern California
- Significant inland penetration of this AR produced AR 3 conditions over southern Arizona and heavy snow in the Upper Colorado River Basin
- After the AR dissipated, a series of upper-level shortwaves brought additional rain and heavy snow to much of the western US
- Low freezing levels allowed for accumulating snowfall in the lower elevations of Washington, Oregon, and Northern California

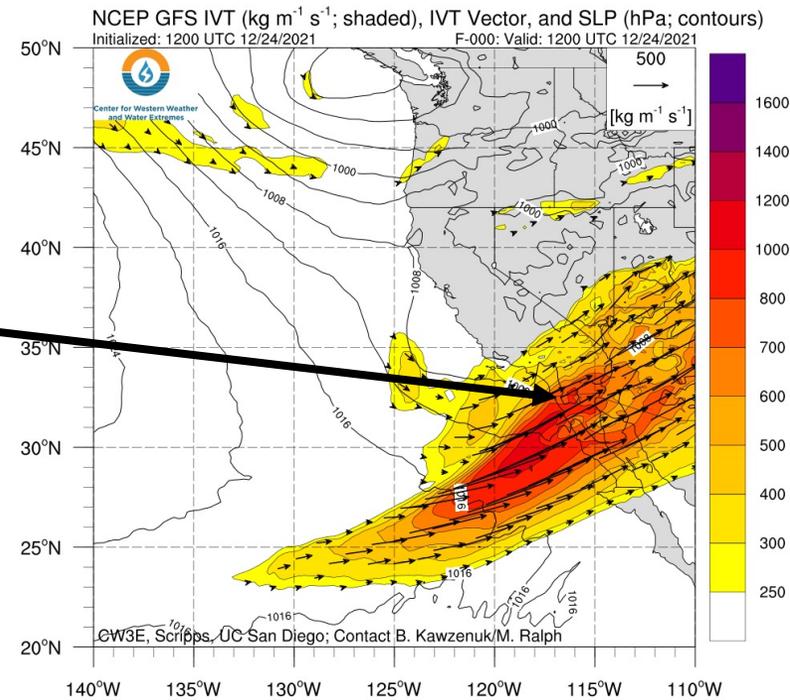
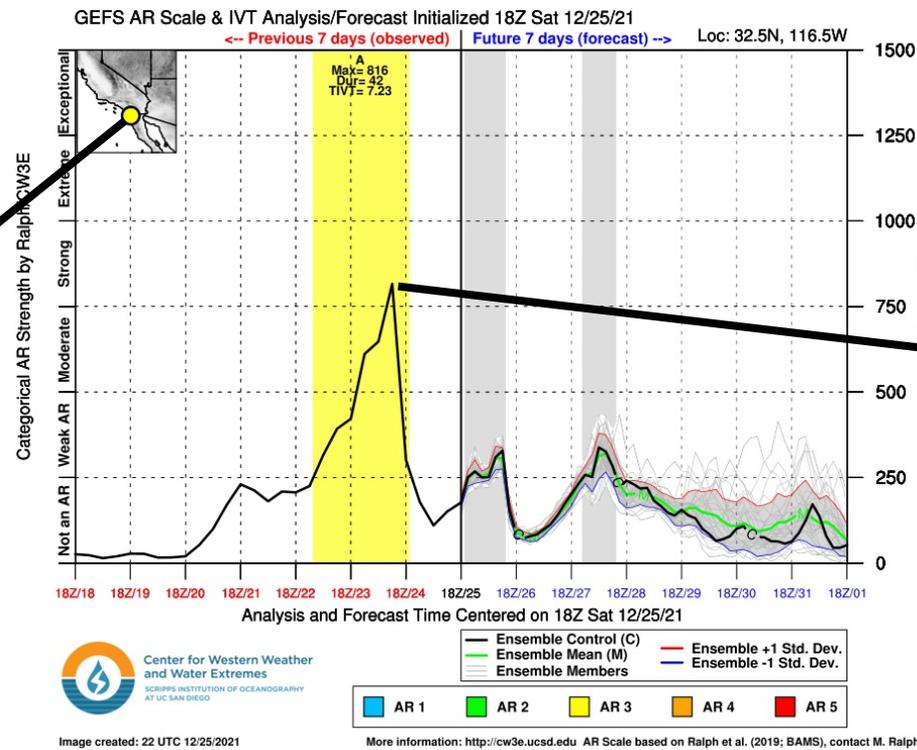
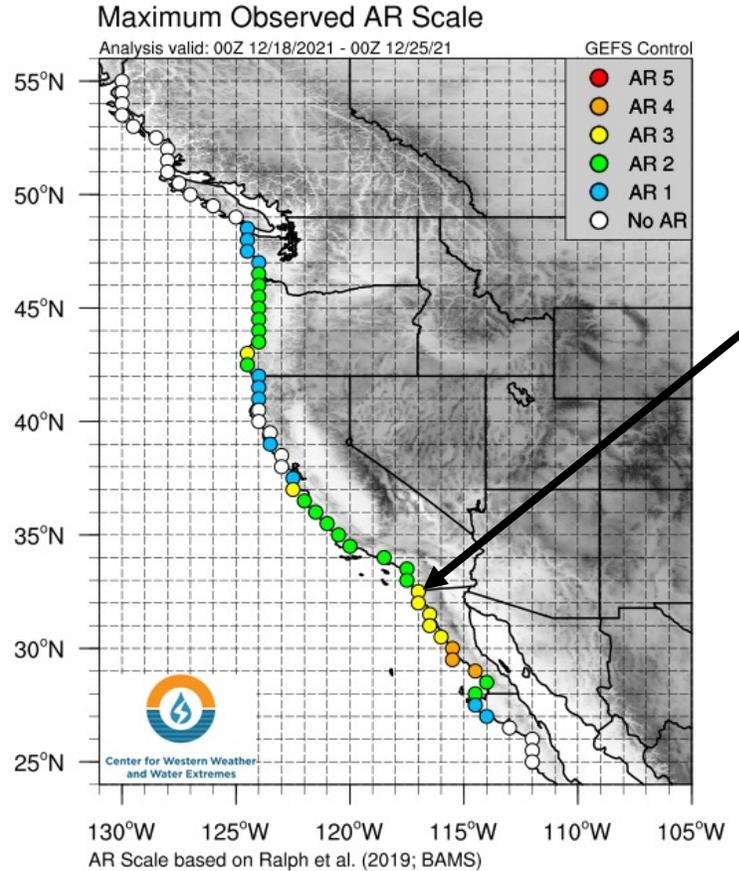
CW3E Event Summary: 22 Dec 2021 – 1 Jan 2022

Atmospheric River and Upper-Level Systems Bring Heavy Rain and Snow to the Western US

- Portions of the Sierra Nevada, the Southern California Transverse Ranges, and the Sawatch Range in Colorado received more than 10 inches of total precipitation
- Several feet of snow fell across the Cascades, the Sierra Nevada, and the Intermountain West, with the heaviest snowfall (> 10 feet) near Lake Tahoe and in western Colorado
- These storms produced dramatic increases in snowpack in the Sierra Nevada and Upper Colorado River Basin
- As of 1 Jan, statewide snowpack in California was 154% of normal, and statewide water-year-to-date precipitation had already exceed the statewide total precipitation during WY 2021
- Heavy snow in the Sierra Nevada caused major travel disruptions and numerous power outages

CW3E Event Summary: 22 Dec 2021 – 1 Jan 2022

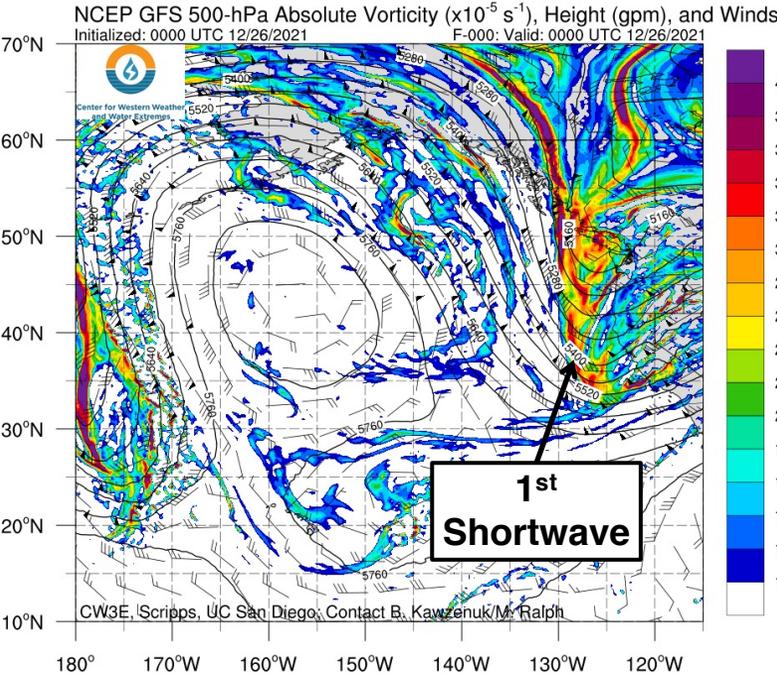
For California DWR's AR Program



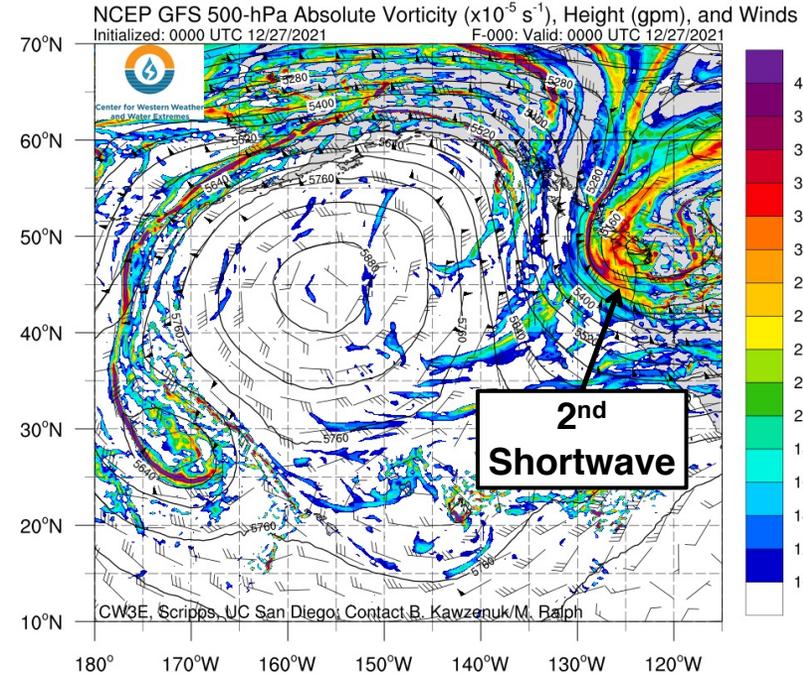
- The active stretch of precipitation over the western US was kicked off by an atmospheric river that brought AR 1 or stronger conditions to a majority of the US West Coast from 22 Dec to 24 Dec
- The AR ranked as an AR 3 in South-Bay California, southern San Diego County, and southern Arizona, intensifying to an AR 4 over the Baja Peninsula
- The inland penetration of the AR produced heavy snow in the Upper Colorado River Basin

500-hPa Shortwave Analysis

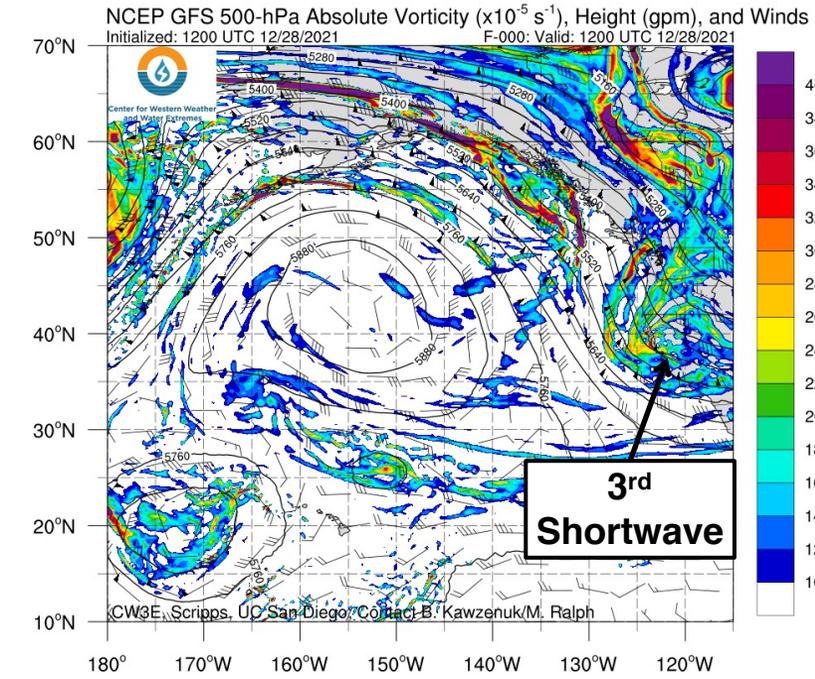
(A) Valid: 4 PM PT 25 Dec



(B) Valid: 4 PM PT 26 Dec

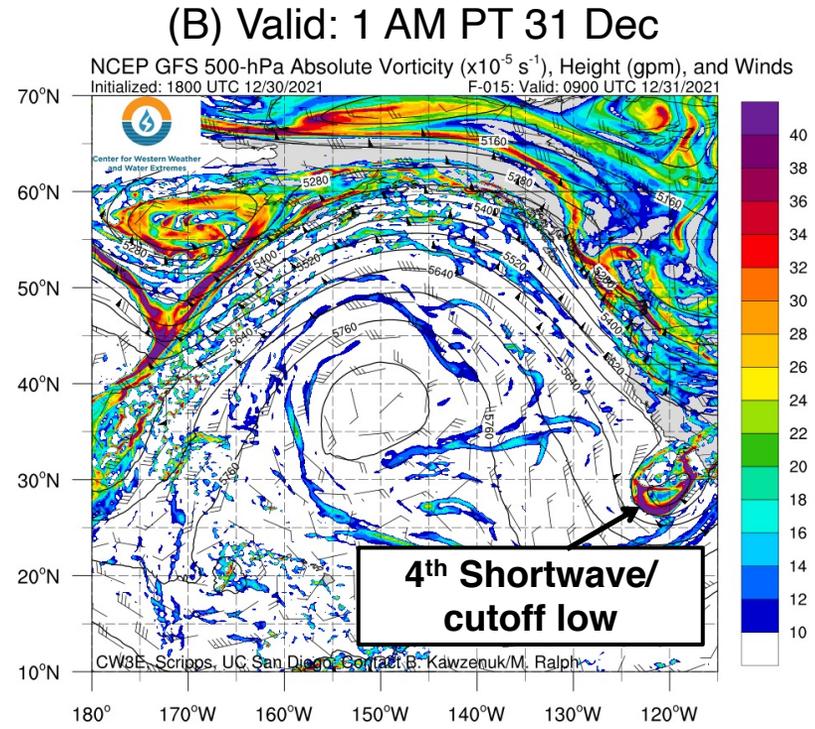
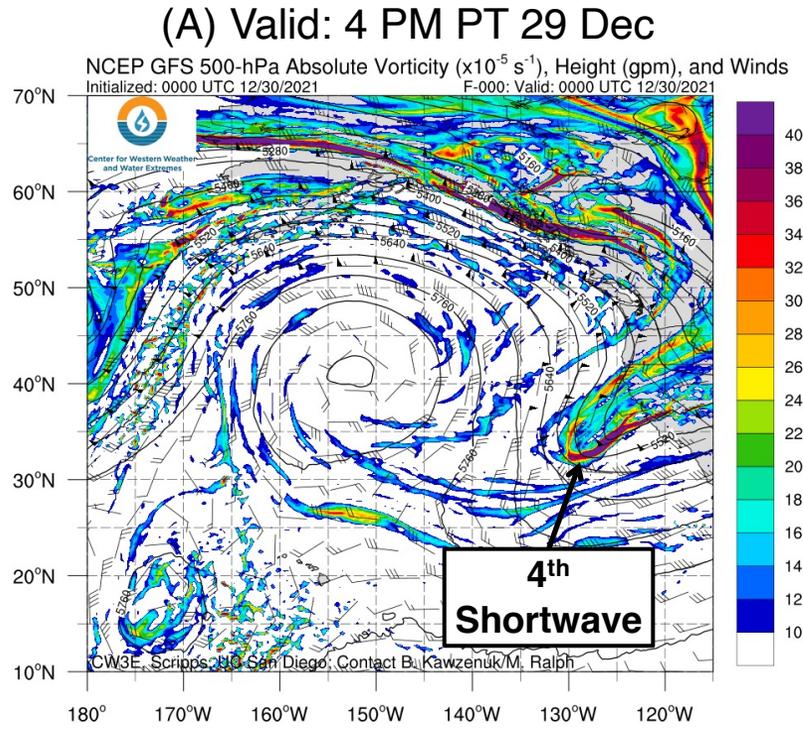


(C) Valid: 4 AM PT 28 Dec



- A nearly stationary ridge over the Central Pacific Ocean allowed for multiple shortwave troughs to affect the US West Coast between 25 Dec and 31 Dec
- The first 3 shortwaves (Figures A, B, and C, respectively) were not associated with ARs, but brought heavy precipitation and large amounts of snow to the Pacific Coast Ranges, the Cascades, the Sierra Nevada, and the Intermountain West

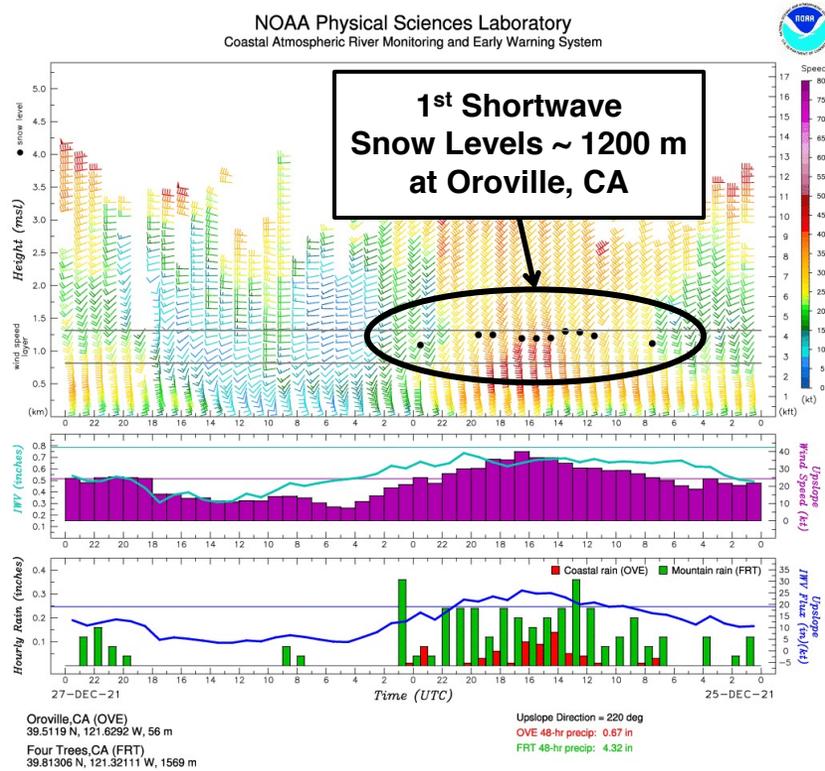
500-hPa Shortwave Analysis



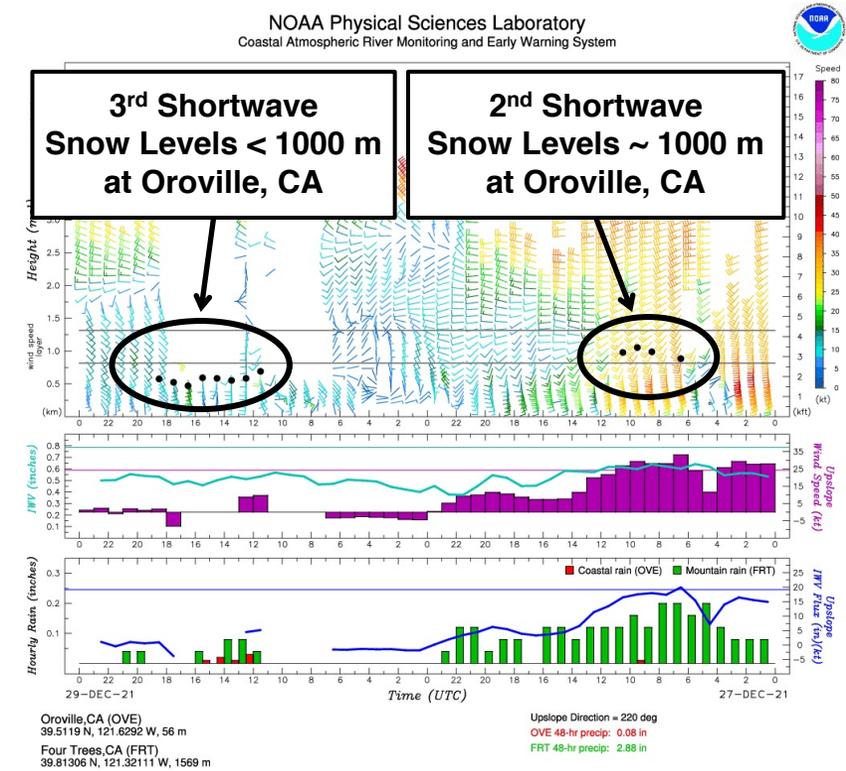
- A fourth and final shortwave moved south along the length of the US West Coast during 29–31 Dec
- This shortwave/cutoff low brought heavy precipitation to the Los Angeles area and heavy mountain snow to the Southern California Transverse Ranges
- As this shortwave/cutoff system moved onshore into Southern California on 31 Dec, the system began to tap into subtropical moisture, forming an AR over the Baja Peninsula
- This series of shortwave troughs brought much-needed drought relief to large portions of California and the Colorado River Basin

Snow Level Analysis

(A) Valid: 4 PM PT 24 Dec – 4 PM PT 26 Dec



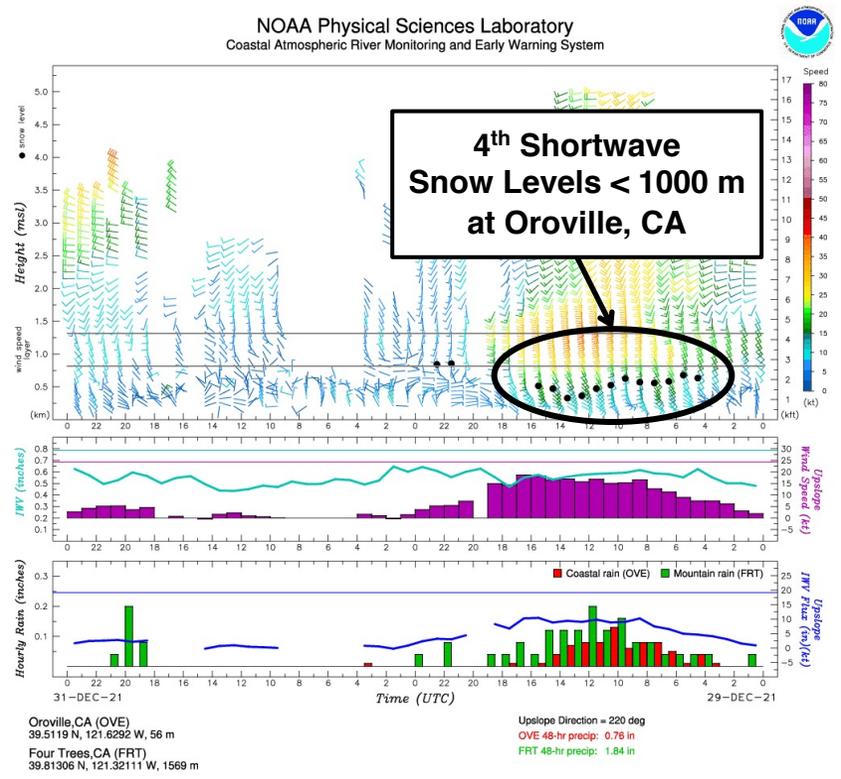
(B) Valid: 4 PM PT 26 Dec – 4 PM PT 28 Dec



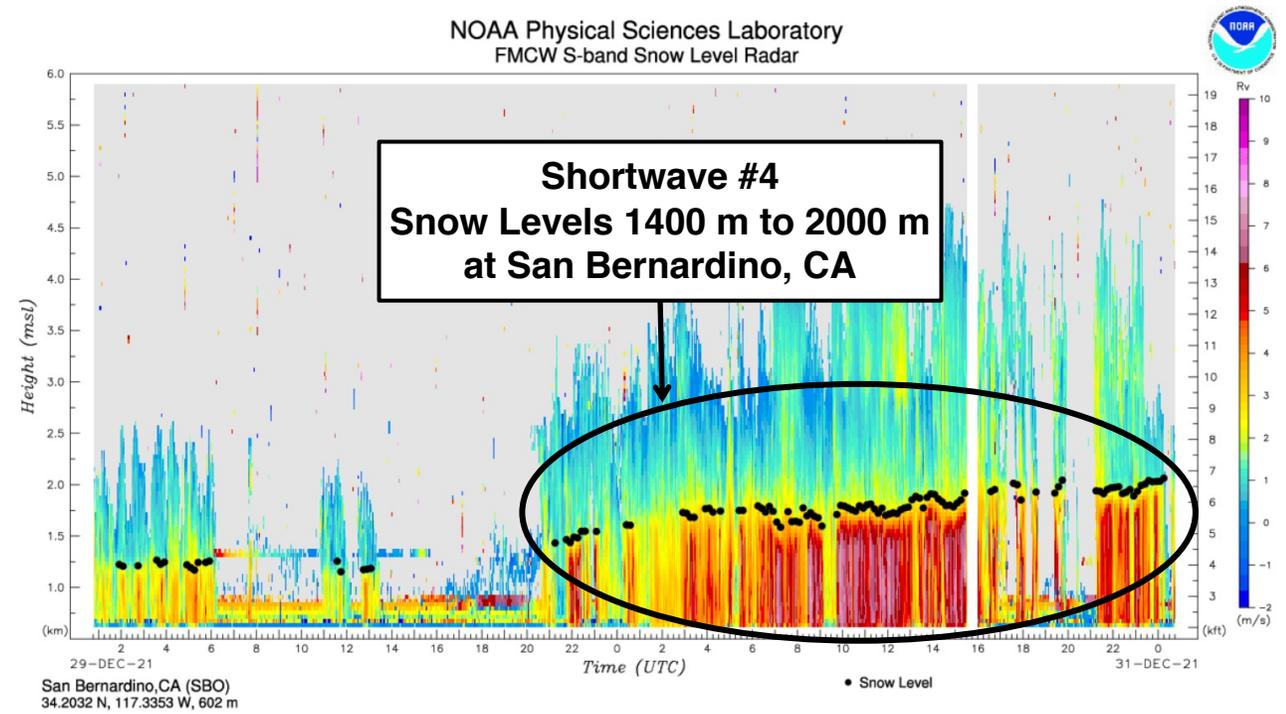
- Snow levels at Oroville remained below 1300 m for each shortwave trough
- The combination of heavy snow and high winds caused major highway closures due to whiteout conditions
- Winds also toppled trees and caused power outages for thousands of people
- Snow levels dropped below 1000 m during the third shortwave, allowing for snow to accumulate at lower elevations

Snow Level Analysis

(A) Valid: 4 PM PT 28 Dec – 4 PM PT 30 Dec

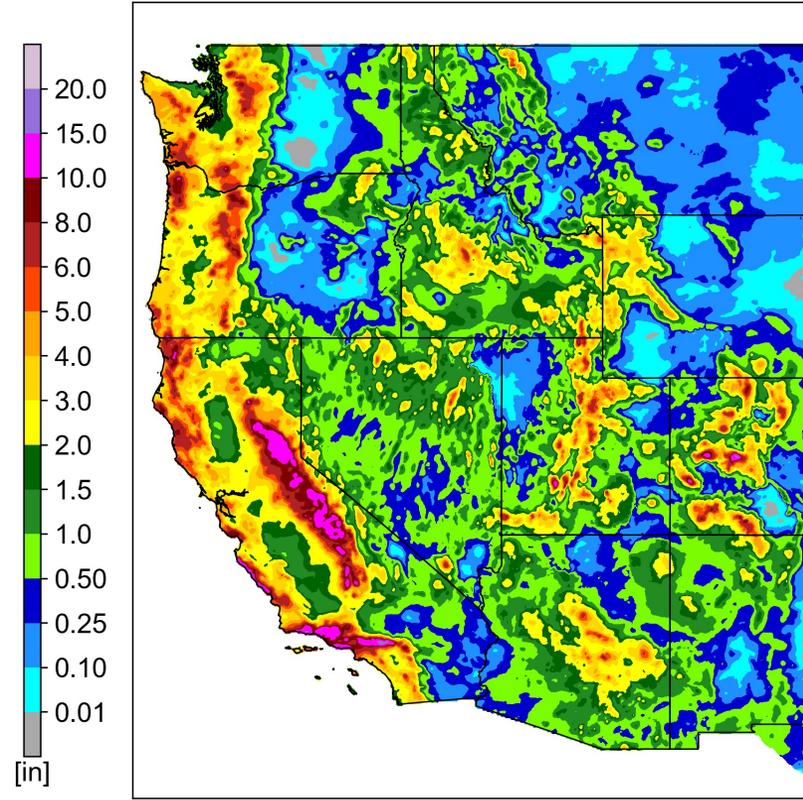


(B) Valid: 4 PM PT 28 Dec – 4 PM PT 30 Dec

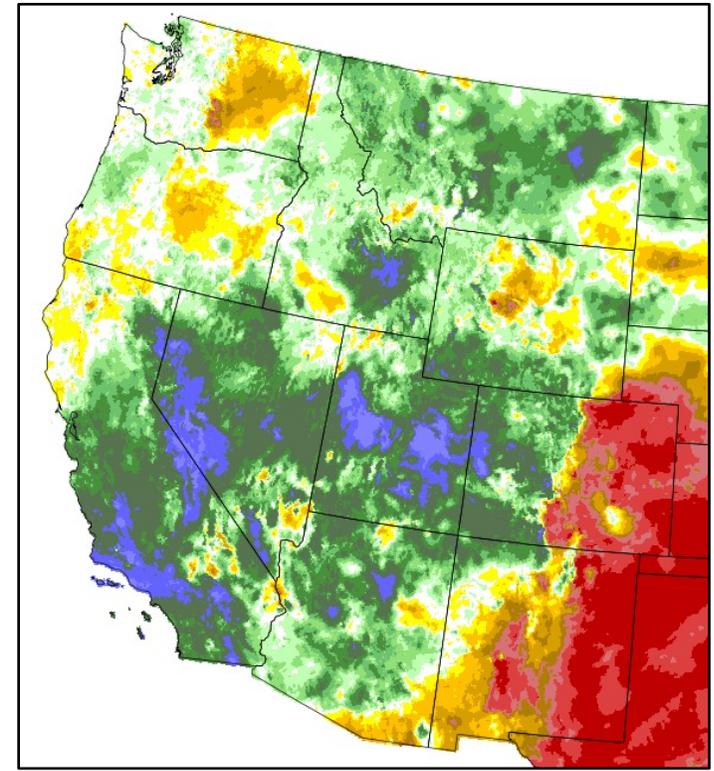


- Snow levels at Oroville during the fourth shortwave remained below 1000 m (Figure A)
- Snow levels at San Bernardino during the same shortwave started around 1400 m but rose throughout the event to near 2000 m (Figure B)

NCEP Stage IV 10-day QPE
Valid: 4 AM PT 22 Dec – 1 Jan



Total Precipitation Anomaly: Dec 2021
Period ending 31 Dec 2021
Base period: 1991-2020
(Map created 03 Jan 2022)



% of Average Precipitation

0	50 - 70	150 - 170
1 - 10	70 - 90	170 - 200
11 - 20	90 - 110	200 - 300
20 - 30	110 - 130	300 - 400
30 - 50	130 - 150	> 400

Source: PRISM Climate Group, Oregon State University

2022 Water Year Stats
As of January 1, 2022

Percent of Last WY's Total

- < 50%
- 50-100%
- 100-150%
- 150-200%
- > 200%

Gridded Data Source: PRISM Climate Group, Oregon State University
The WY begins on October 1 and ends on September 30

In fact, total volume of water that has fallen statewide this WY has already exceeded last WY...

WY 2022 Statewide Volume	33.9 TRILLION GALLONS
WY 2021 Statewide Volume	33.6 TRILLION GALLONS

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
Sacramento, California

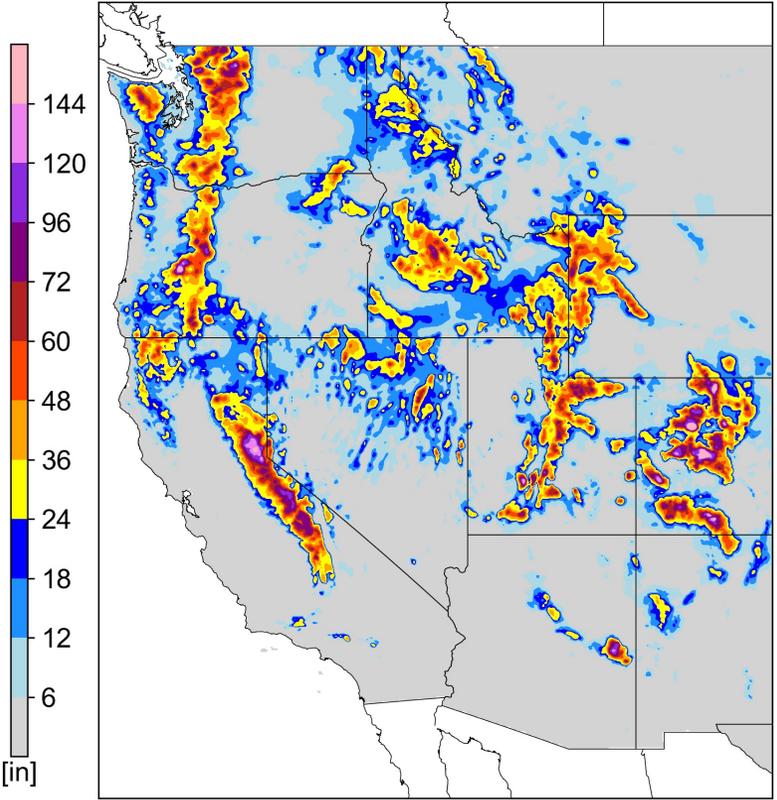
Source: NWS Sacramento

- These storms brought widespread moderate-to-heavy precipitation to much of the western US
- More than 10 inches of total precipitation fell in the Sierra Nevada, the Southern California Transverse Ranges, and the Sawatch Range in Colorado
- Total December 2021 precipitation was significantly above normal across much of the southwestern US, with large portions of California, Nevada, and Utah receiving more than 300% of the normal December precipitation
- As of 1 Jan, statewide water-year-to-date precipitation in California has already exceeded the total statewide precipitation during WY 2021
- Some parts of California have received more than twice as much precipitation in the first 3 months of WY 2022 as in all of WY 2021

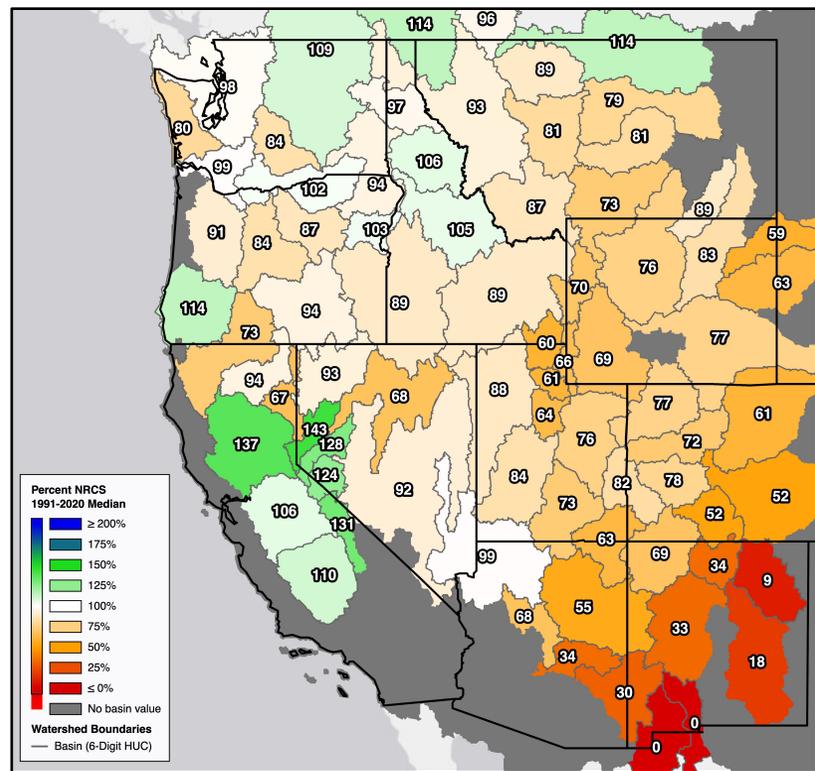
CW3E Event Summary: 22 Dec 2021 – 1 Jan 2022

For California DWR's AR Program

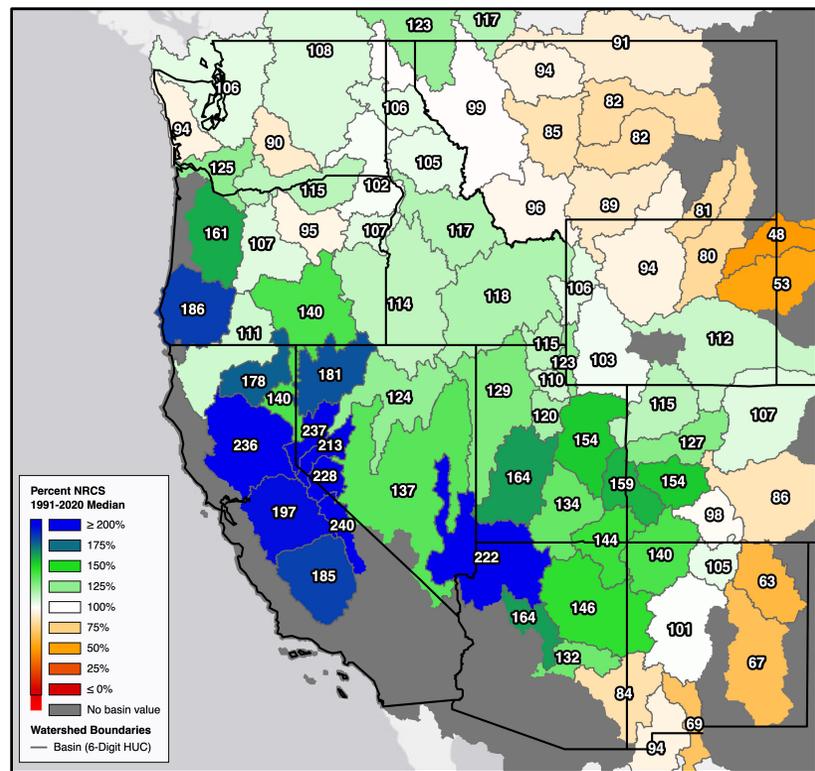
NOHRSC 10-day Interpolated Snowfall
Valid: 4 AM PT 22 Dec – 1 Jan



SWE Percent of 1991–2020 Median
Valid: 22 Dec (First of Day)



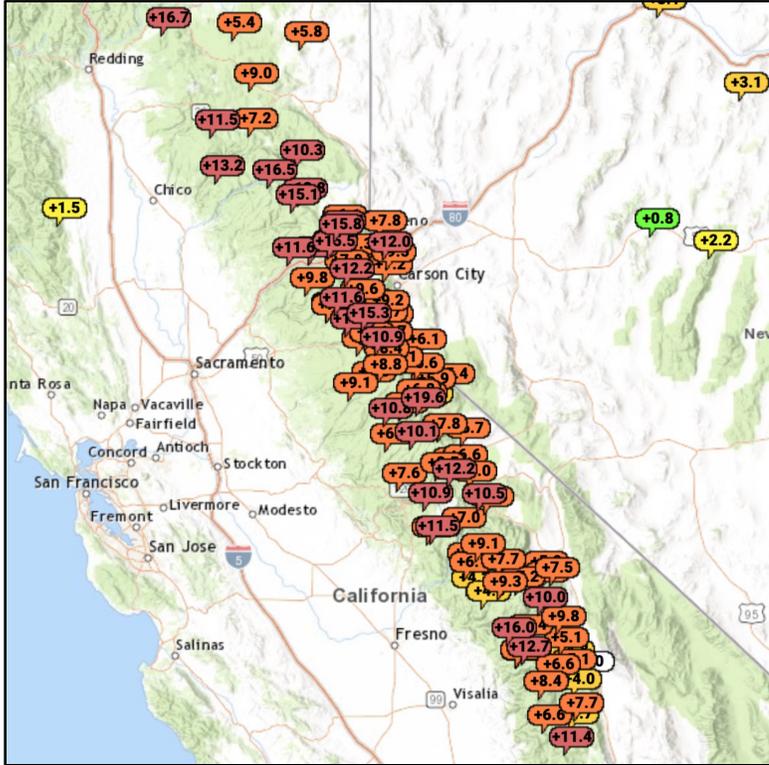
SWE Percent of 1991–2020 Median
Valid: 1 Jan (First of Day)



Source: USDA/NRCS National Water and Climate Center

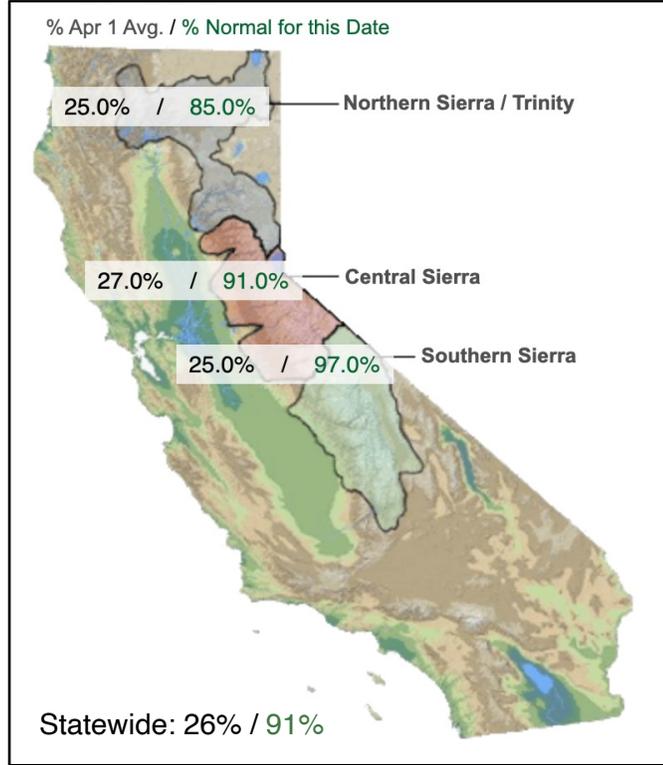
- These storms produced more than 4 feet of snow in portions of the Cascades, the Sierra Nevada, and the Intermountain West
- The highest snowfall accumulations (> 10 feet) occurred near Lake Tahoe and in western Colorado
- The UC Berkeley Central Sierra Snow Lab set a new record for total December snowfall (214 inches)
- Low freezing levels allowed for accumulating snowfall in the lower elevations of Washington, Oregon, and Northern California
- Snowpack in the Upper Colorado River Basin increased from 60–80% of the 1991–2020 median to 100–160% of the 1991–2020 median
- As of 1 Jan, most areas west of the Continental Divide were reporting near-normal to significantly above-normal snowpack conditions

14-day SWE Change: Valid 21 Dec – 4 Jan



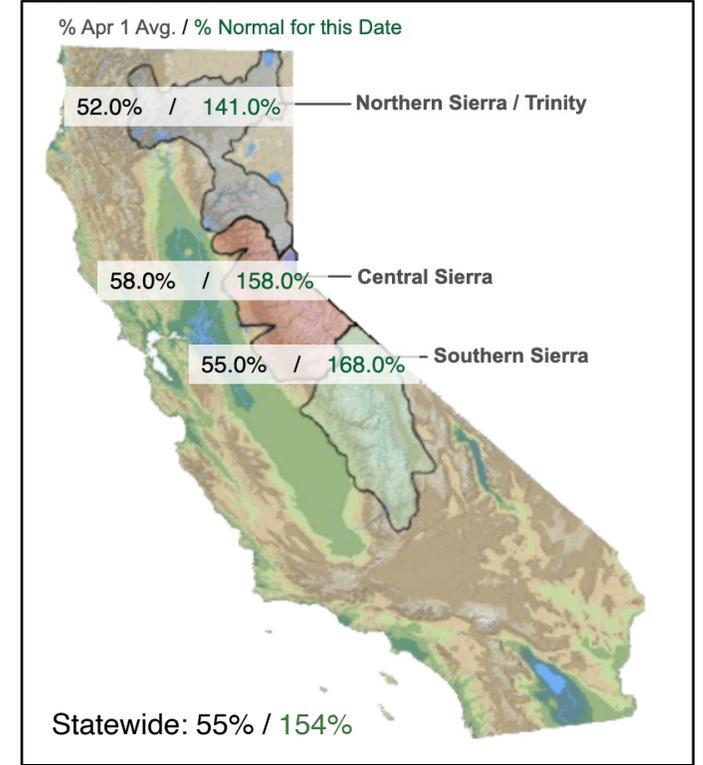
Source: NOAA/NWS CNRFC

California Snowpack: 22 Dec



Source: California Department of Water Resources

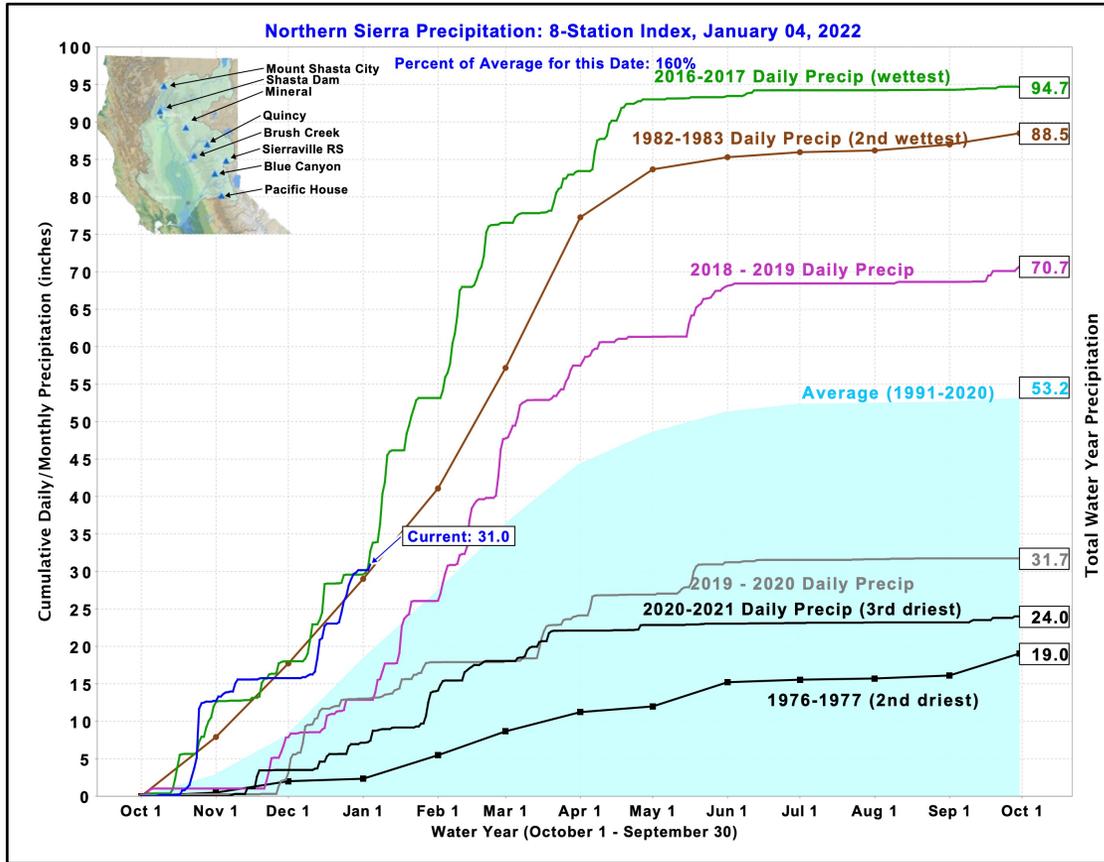
California Snowpack: 1 Jan



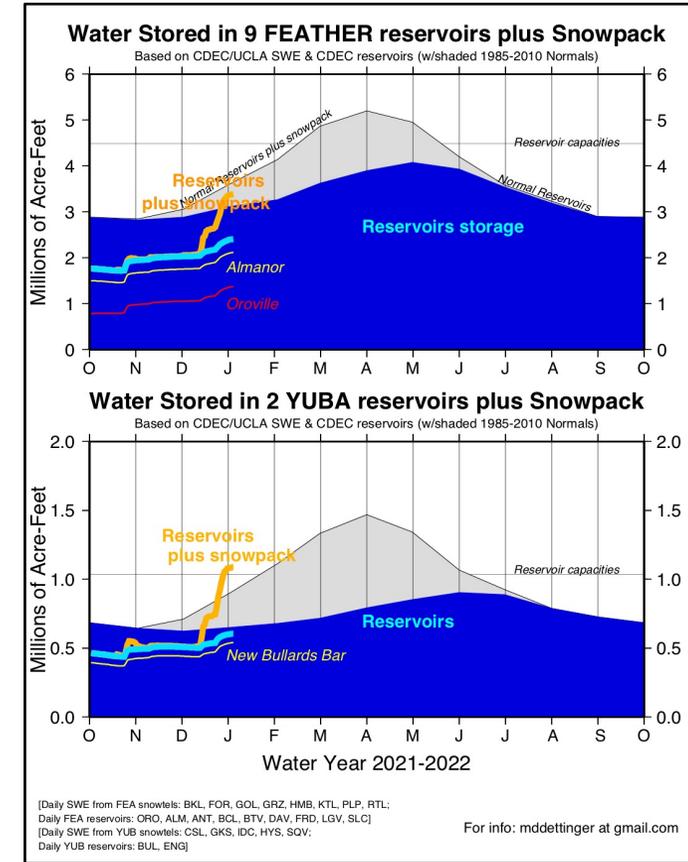
- The AR and the subsequent storms produced a dramatic increase in snowpack throughout California
- Many snow monitoring stations in the Sierra Nevada have recorded SWE increases > 10 inches over the past two weeks
- Between 22 Dec and 1 Jan, statewide snowpack increased from 91% of average to 154% of average
- As of 1 Jan, statewide snowpack was already 55% of the 1 April average (peak SWE typically occurs around 1 April)
- Snowpack is currently running significantly above normal in all three regions of the Sierra Nevada

CW3E Event Summary: 22 Dec 2021 – 1 Jan 2022

For California DWR's AR Program

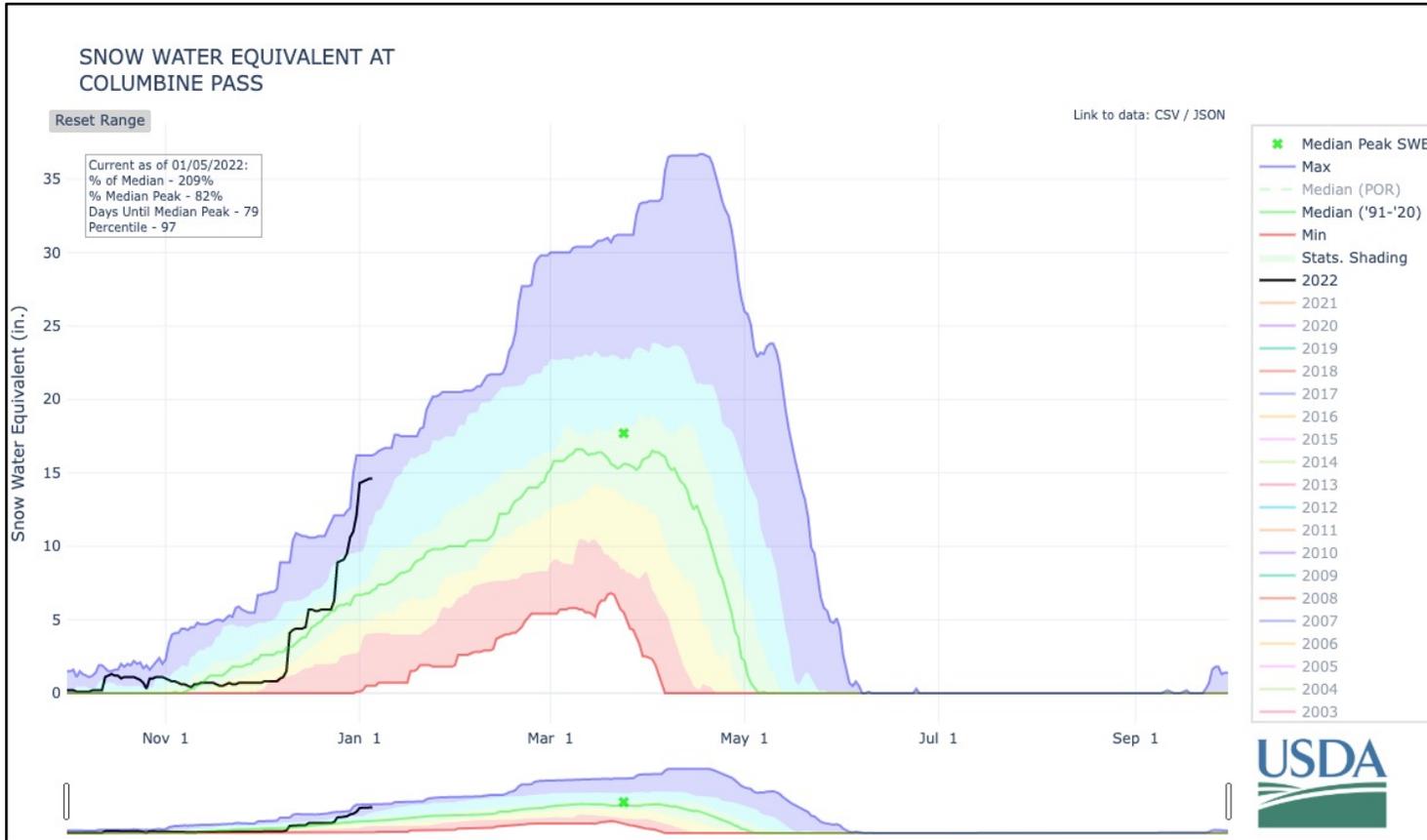


Source: California Department of Water Resources

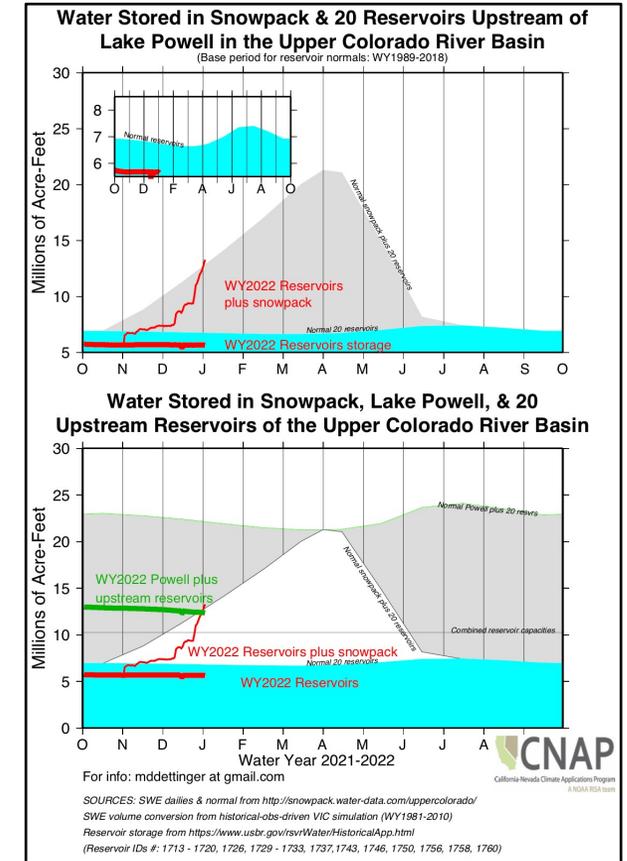


Source: California-Nevada Applications Program

- As of 4 Jan, the Northern Sierra region has already received about 58% of its average total water year precipitation
- Water-year-to-date precipitation is currently 60% above the long-term average and keeping pace with WY 2017
- Current reservoir levels in the Feather watershed are still below normal, but total estimated water storage is only slightly below normal when accounting for snowpack
- Reservoir levels are near normal in the Yuba watershed, but total estimated water storage is now above normal

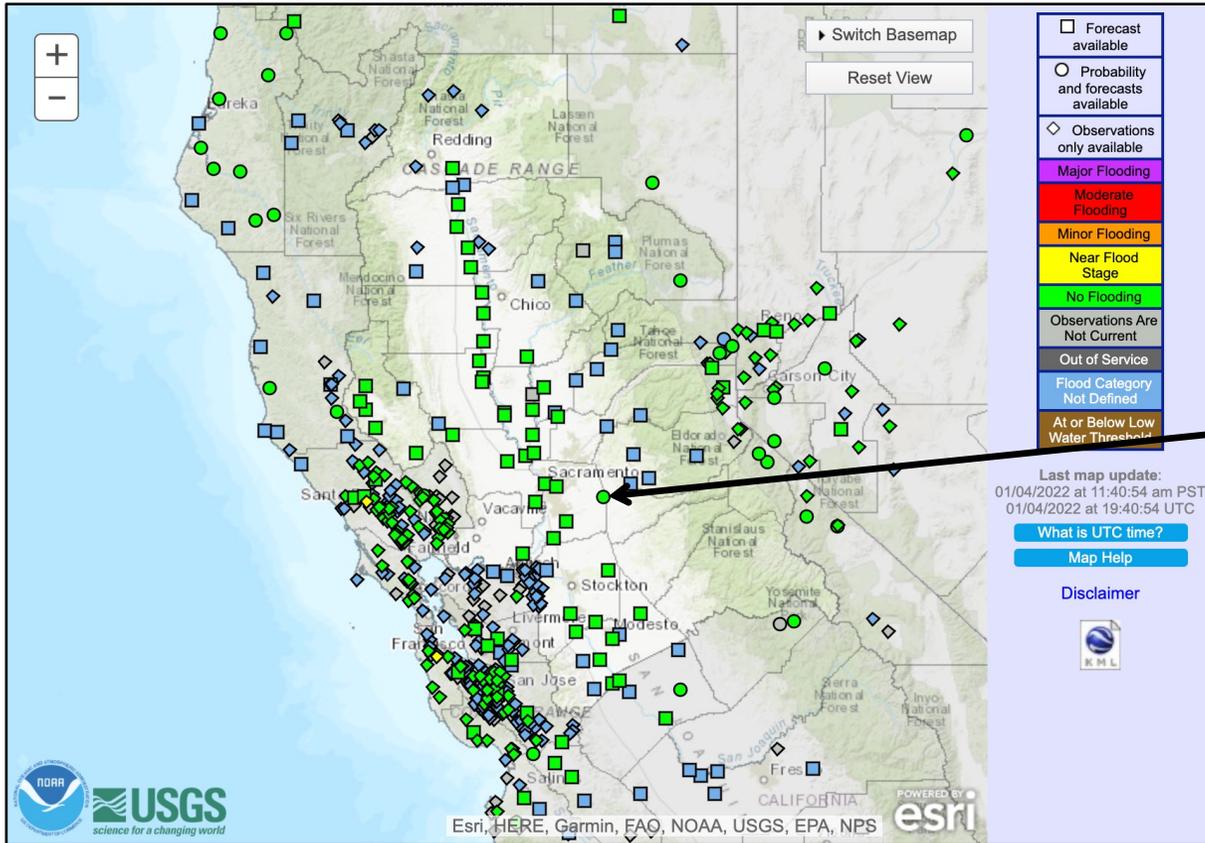


Source: USDA NRCS National Water and Climate Center



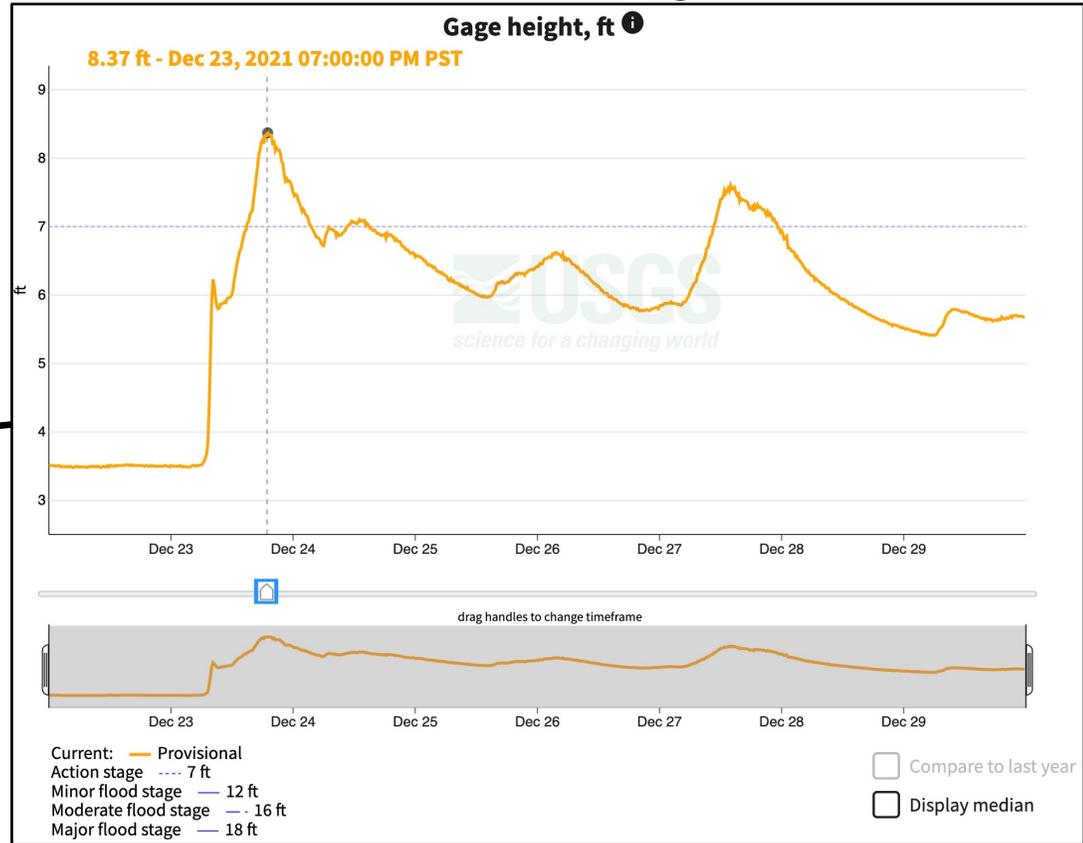
Source: California–Nevada Applications Program

- As of 5 Jan, the Columbine Pass SNOTEL station was reporting 209% of the 1991–2010 median year-to-date SWE and 82% of the median annual peak SWE
- More than half of the existing snowpack at this location accumulated during the last week of December
- Reservoir levels in the Upper Colorado River Basin are still running below normal, but total estimated water storage is near normal when accounting for snowpack



Source: NOAA/NWS Advanced Hydrologic Prediction Service

Cosumnes River at Michigan Bar, CA

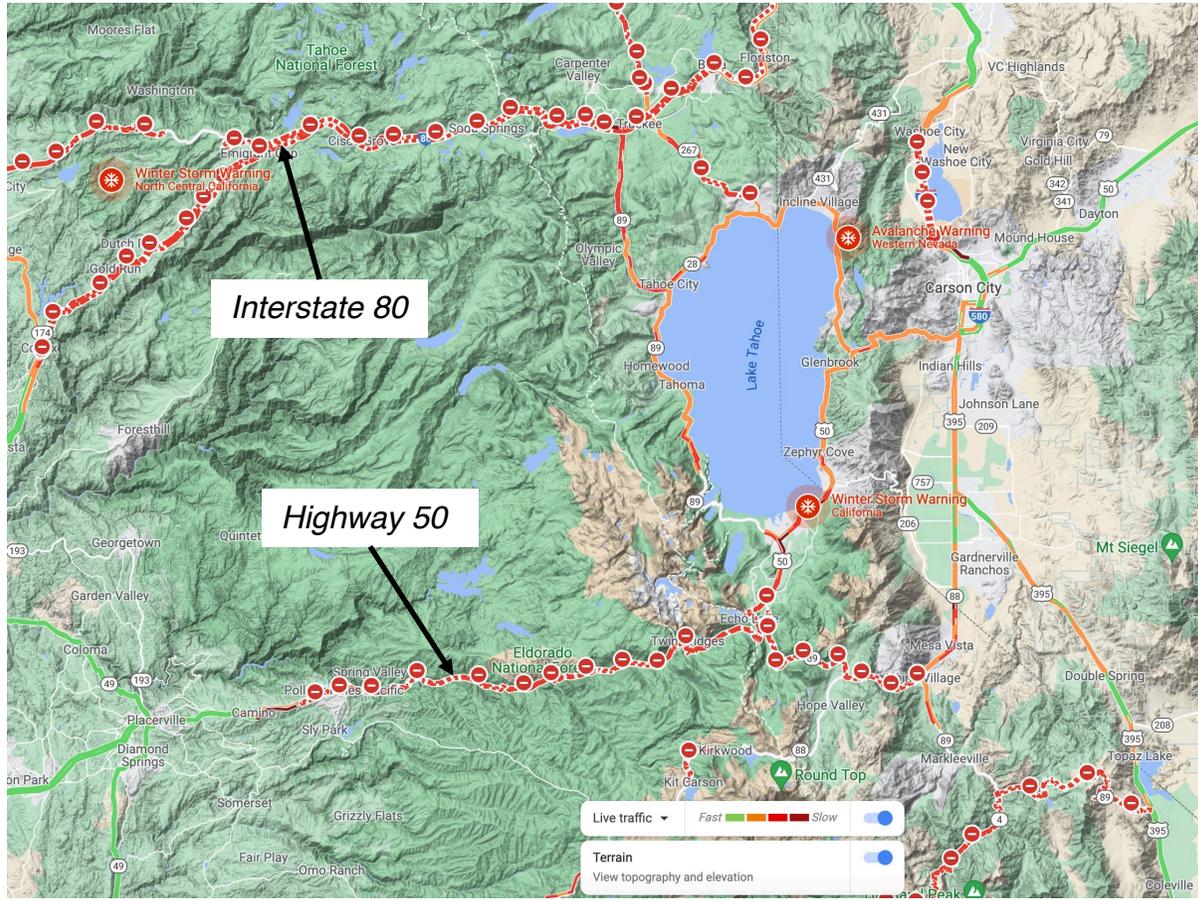


Source: USGS

- Although these storms did not cause widespread flooding, some rivers did exceed action/monitor stage
- The Cosumnes River at Michigan Bar rose above action stage (7.0 ft) on 23 Dec and again on 27 Dec
- Despite the heavy precipitation in Sierra Nevada, runoff was limited because a significant portion of the precipitation fell in the form of snow, especially after the AR

CW3E Event Summary: 22 Dec 2021 – 1 Jan 2022

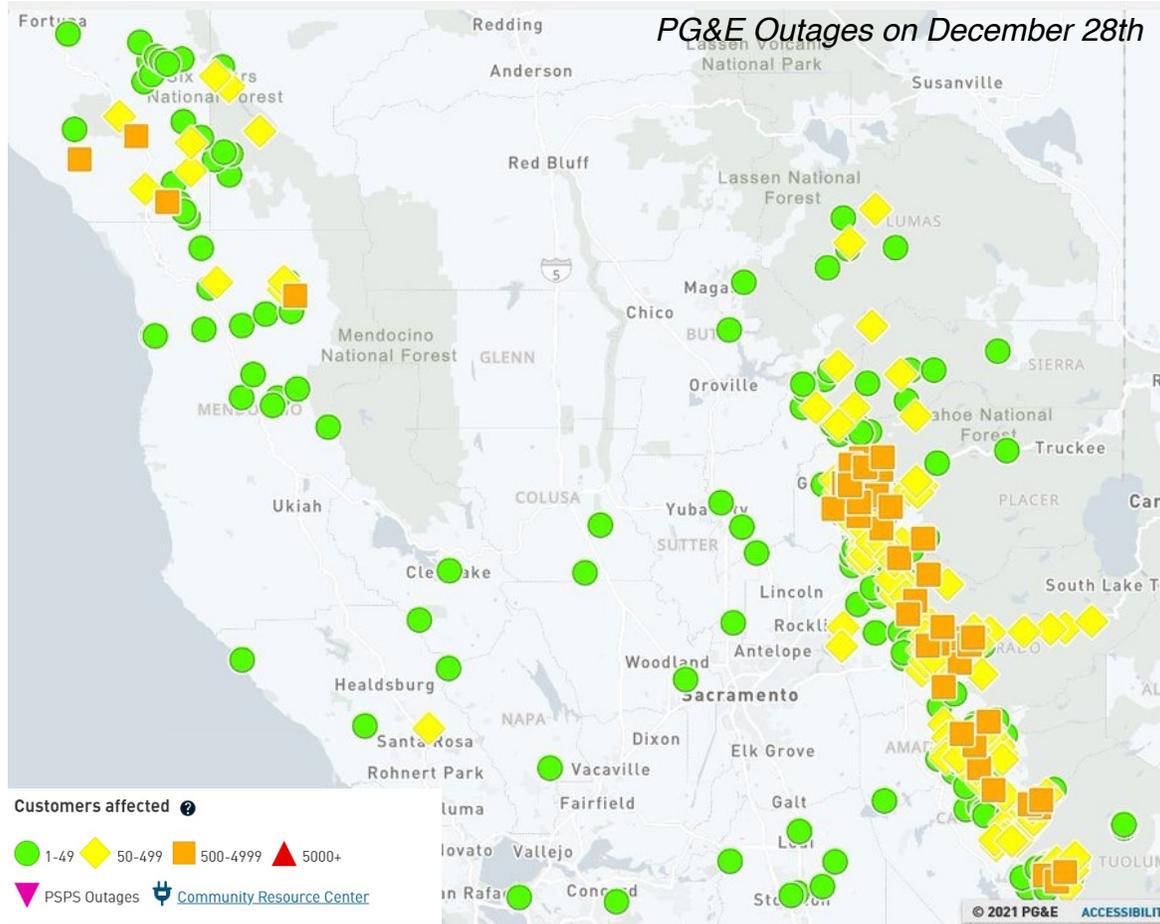
For California DWR's AR Program



- The heavy snow over the Sierra Nevada closed major mountain passes for several days around the Lake Tahoe region, such as Interstate 80 and Highway 50, two popular travel routes during the Holidays
- The closure of the major thoroughfares stranded motorists while cutting off major commerce across the region, resulting in the loss of millions of dollars
- 2019 estimates indicate that trucking carries ~\$4.7 million in goods over Donner Summit every hour, suggesting a 3-day closure would cost ~\$300 million

CW3E Event Summary: 22 Dec 2021 – 1 Jan 2022

For California DWR's AR Program



Pacific Gas & Electric reported 1,214 instances of equipment damage done by the heavy snow. This includes:

- 307 utility poles
- 580 locations where the conductor or line needs repair
- 171 crossarms
- 70 transformers



- The heavy and wet snow that fell on the 26–27 Dec knocked down trees and power lines across a large swath of the Sierra Nevada
- Estimates suggest that more than 50,000 customers lost power in the Sierra Division alone
- As of 10 AM 4 Jan, PG&E reported that 21,000 customers in the Sierra Division were still without power (~8 days since the storm)