A rapid transition from dry to wet occurred when a family of nine ARs hit the California coast over three weeks starting on December 27, 2022. These storms were driven by the alignment of the jet stream over the North Pacific and featured the longest period of continuous AR days since 1950. They caused enormous impacts statewide.

Impacts

- **Record flooding:** At eight locations
- **Average precipitation:** >11 inches, about half of the state’s annual average in 3 weeks
- **Maximum precipitation:** Several high-elevation sites approached 50 inches
- **Snowpack:** Increased from 43% to 124% of April 1 peak snowpack
- **Reservoir refill:** Most large reservoirs >50% full
- **Severe drought:** Cut from 81% to 33%
- **NWS storm reports:** >2,000; 75% associated with flooding or heavy rain
- **Rescues:** Early forecasts helped position equipment to save lives

### California DWR–CW3E Research and Operations Partnership: Highlights of a Family of Nine Atmospheric Rivers

California has the most variable precipitation of any state, driven by the presence or absence of atmospheric rivers (ARs). ARs provide 50% of California’s water supply but also cause 90% of its floods. Projections show ARs becoming more extreme and contributing a larger share of California’s annual precipitation, with long periods of dry conditions punctuated by stronger and wetter ARs.

Drought Before and After ARs

**December 27**
- **Intensity:** D1 Moderate Drought
- **Data from NWS Stage IV**
  - Normal reservoirs
  - Normal reservoirs plus snowpack

**January 31**
- **Intensity:** D2 Severe Drought
- **Data from NWS Stage IV**
  - Reservoir plus snowpack
  - Reservoir capacities

**Water Storage: Reservoir + Snowpack**

**Northern California**
- Normal reservoirs
- Normal reservoirs plus snowpack
- Reservoir capacities

**Central Sierra**
- Reservoir plus snowpack
- Reservoirs

**Southern Sierra**
- Reservoir plus snowpack
- Normal reservoirs

**Total Precipitation from Nine ARs**

- Total precipitation from the AR family topped 40 inches. Some areas received more than 100% of normal water year precipitation.

**An AR family occurs when a series of ARs strike in quick succession. This map shows the location and maximum strength of the nine ARs according to the AR scale, as they made landfall in California.**

Drought severity according to the U.S. Drought Monitor.

1. Fish et al., J. Hydrometeor., 2019.
2. Ralph et al., BAMS, 2019.
Are These ARs Forecasted? Yes!

December 8
CW3E's sub-seasonal forecast tools indicate a shift from dry to wet conditions.

December 20
Models agree on December 27 AR.

December 28
Series of ARs evident over the next 16 days.

January 6
CW3E subseasonal forecast tools indicate shift to drier conditions in 2 weeks.

January 19
Dry conditions trigger shift to flood recovery.

Investments in the AR Program Make a Difference

- The AR Reconnaissance program has improved AR lead time forecasts by 1-2 days.
- The January 14 AR forecast was spot on, with over 90% probability of an AR 3 and the AR duration within 12 hours.
- Forecast Informed Reservoir Operations (FIRO) at Lake Mendocino allowed higher post-storm storage to enhance water supply reliability as a hedge against the possibility of a dry year.
- CW3E's experimental weather forecasting model, West-WRF, enhanced prediction of extreme precipitation using innovative modeling and machine learning methods. DWR is testing West-WRF forecast data for use in operations.
- AR Reconnaissance improved predictors of AR strength, by up to 50%. Getting these factors right leads to better forecasts.

“CW3E’s tools provide great insight into meteorological conditions for reservoir management, particularly during large AR events. This was especially true during the recent family of ARs. The ongoing development and integration of CW3E decision support products aid in situational awareness and improve forecast skill. These advances directly support Yuba Water by being better able to manage for both droughts and floods.”

– John James
Yuba Water Agency

What’s Next?

- Each AR has distinct characteristics that determine the landfall location, timing, and strength, which impact the associated precipitation. CW3E’s West-WRF model will continue to improve forecasting by integrating enhanced scientific understanding and applying novel technological advancements, including supercomputing and machine learning.
- Analyzing the transition from dry to wet at the onset of this AR family will improve subseasonal (2-4 week) forecasts.
- The AR Reconnaissance season will begin earlier and needs to ensure coverage during extreme ARs, such as this AR family that occurred over the holiday season.
- CW3E and DWR are exploring integration of AR forecast tools into emergency operations to better support water management and flood hazard mitigation.
- 73 California reservoirs are being screened for FIRO suitability to improve resilience to drought and floods. Improving forecast skill will enable greater adoption of FIRO.

AR Program Partners

For more information visit https://cw3e.ucsd.edu/