OBSERVING AND FORECASTING SNOW LEVELS

CHALLENGE

"Snow level" is the threshold elevation above which precipitation falls as snow and below which precipitation falls as rain. Determining whether a storm will produce snowpack or generate runoff is critical for understanding flood risk within a watershed.

ACCOMPLISHMENTS

Snow-level observations. One valuable observation system is the 915-MHz Doppler radar, which monitors snow levels in real time. NOAA's HydroMeteorological Testbed (HMT) program at the Earth Systems Research Lab and University of Colorado developed a new snow level radar that is significantly less expensive than previous designs. Fifteen stations have been installed in California, mostly at the foot of major Sierra Nevada reservoirs (Figure 1). The data from these radars are currently being used for freezing-level forecast verification (see Figure 2). The radar data also allow for analysis to understand how synoptic and mesoscale features prior to and during storms affect snow levels. Forecast skill assessments have shown serious errors remain at even 1-3 days lead time, with the largest errors often associated with landfalling atmospheric river (AR) events where the predicted snow level is much lower than is observed. Recent investigations have shown that between 2008-2017, snow levels during AR events increased on average 230 feet per year and ARs are the mechanism that most often yields low-snow fraction storms.[1]

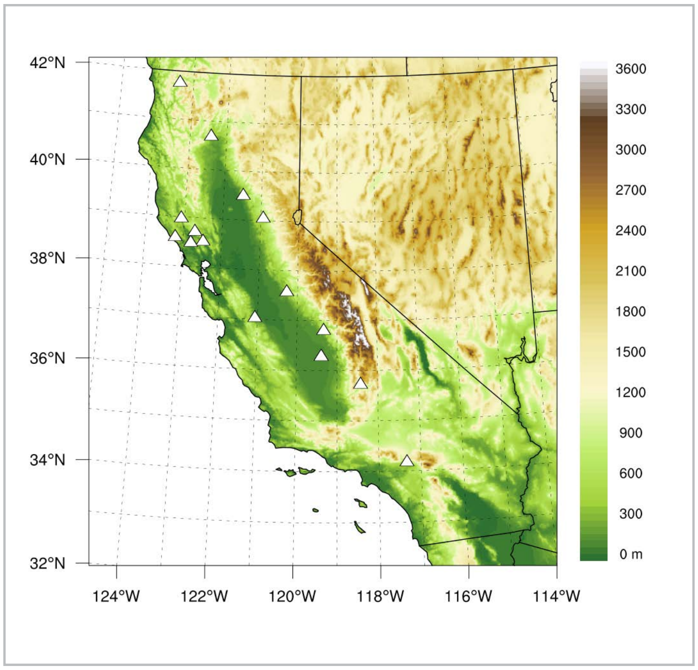

Figure 1. White triangles indicate locations of snow level radars in California

Continued research in how to improve the freezing level forecasts--using the snow level radars as verification, understanding atmospheric dynamics as it relates to snow level changes--are critical for flood preparedness and water supply planning.

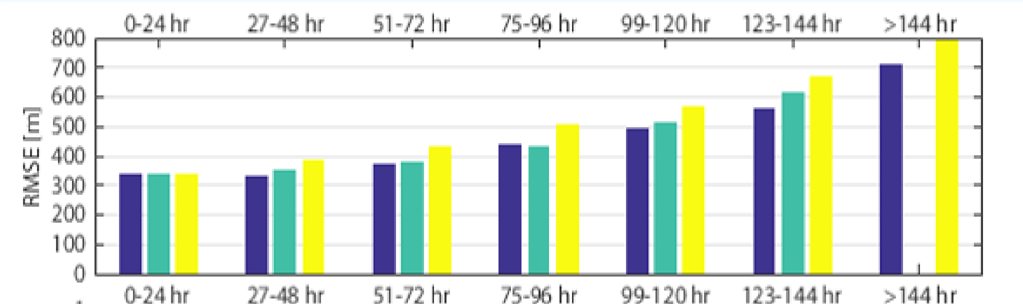

Figure 2: Root mean square error (RMSE) of rain-snow level forecasts verified at profiling radars across CA in water year 2017 sorted by lead forecast time indicated by the 3 models. Figure courtesy of B. Henn, CW3E.

Legend

West-WRF CNRFC GEFS-RV2

Snow observations. Continuous stream gauge, temperature, precipitation, and snowpack monitoring provide the historical and climate context of extreme events. Over the last 15 years, meteorological stations that include humidity, air pressure, soil moisture, solar radiation and wind (direction and speed) have provided additional data. In 2014 NASA, with support from CA DWR, created the Airborne Snow Observatory, which uses lidar to provide spatial estimates of snow water equivalent over crucial watersheds in CA.

High elevation floods. Winter floods generated in high elevations are caused by warm storms with high precipitation totals and saturated soils.[2] ARs are associated with the most extreme precipitation events in the Northern Sierra Nevada and are typically warm storms (see Figure 3). An example of this is the AR sequence that contributed to the Oroville emergency in February 2017. The ARs caused prolonged high snow levels (above 2500m) for much of a 5-day AR sequence, resulting in the Feather River watershed receiving more than 97 percent of total precipitation as rain. This event had large historical snowmelt, further contributing to inflows to Lake Oroville by ~ 10 percent (Figure 4).

Spring flooding results from large snowmelt events triggered by a rapid temperature increase. Such events have occurred 8 times between 1916-2002 that were associated with >22˚F (12˚C) increases in temperature over 5 days. These rapid warming/rapid melt events are typically associated with cooler than average March temperatures.[3] Recent research has suggested that forecasting clouds and incoming solar radiation can improve hydrological forecasts of spring melt events.

NEXT STEPS

Research needed to improve snow level forecasts include:

- Better tools to monitor snow level including automated methods to quantify snow-level forecast errors.
- Research to understand the physics of what controls the downward bending of the snow level during AR events over mountains.
- Improvement in West-WRF model forecasts of snow level.
- Continued and expanded monitoring to understand how variability and climate change affect flood risk.
- Enhanced GPS met stations and snow level radars that can be deployed in high elevations to provide information about the meteorological and hydrological characteristics of large events in locations where floods are generated.

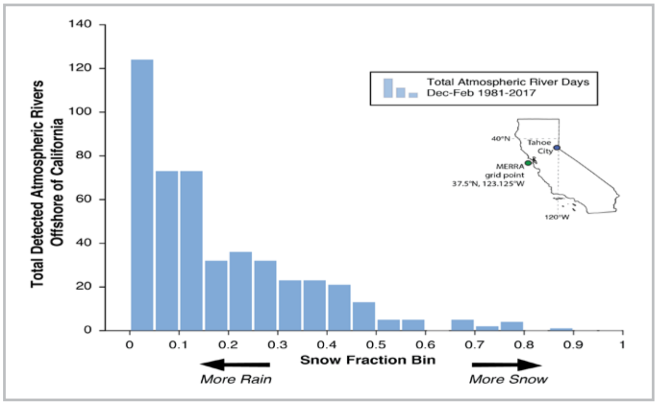

Figure 3. The fraction of precipitation that fell as snow versus rain in Tahoe City during ARs. ARs are typically warm storms with high snow levels causing more rain than snow. From Hatchett et al., 2017.

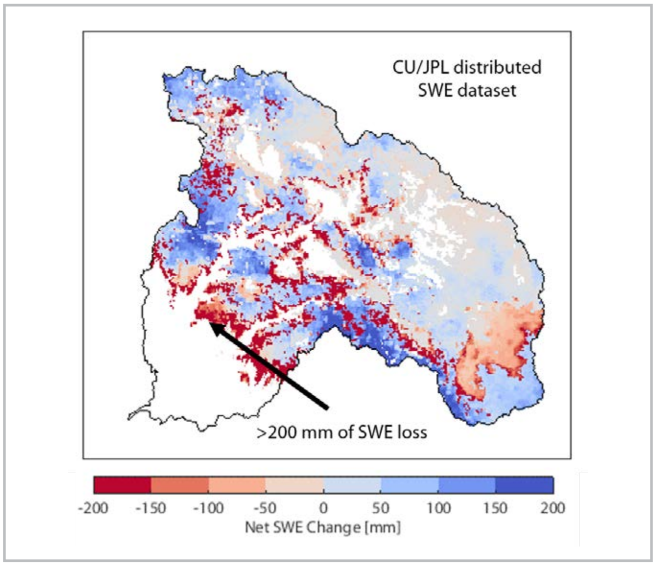

Figure 4. Feather River watershed change in snow-water equivalent (SWE) from the CU/JPL distributed snow dataset from February 6-10, 2017. Analysis and figure provided by Brian Henn, CW3E.

Leveraging CA DWR Funding

The new observations and analyses described here would not have happened without DWR's support. DWR has leveraged its support with investments from NOAA, Scripps Institution of Oceanography and USGS. The research using data from these observations has been leveraged by other funding agencies including NOAA and NASA.

References

[1] Hatchett et al., 2017, Water.
[2] Dettinger et al., 2009, CEC-500-2009-050-D.
[3] Lundquist et al., 2004, Journal of Hydrometeorology.

Center for Western Weather and Water Extremes

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