Heavy precipitation from landfalling atmospheric rivers during 18–21 January 2012 helps alleviate dry spell in Oregon and California

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Event Overview

Understanding the processes governing extreme precipitation along the west coast of the U.S. and its important role in the regional water cycle is a primary focus of the Hydrometeorlogy Testbed (HMT). As documented by past work in HMT, extreme precipitation events along the west coast can often produce flooding (Ralph et al. 2006; Neiman et al. 2011), leading to property and infrastructure damage and loss of life. Additionally, such extreme precipitation events can be greatly beneficial, serving to replenish water supplies and alleviate drought conditions in agricultural regions and population centers along the west coast of the U.S.

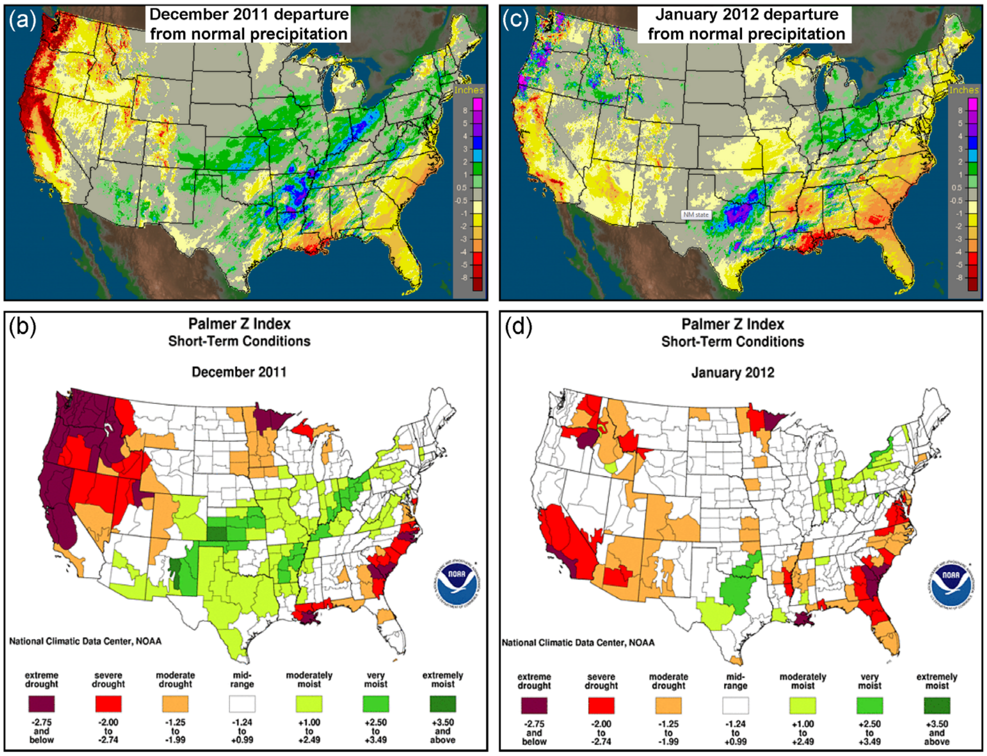


Figure 1: (a) Observed departure from normal precipitation for December 2011 (Image courtesy NOAA/NWS). (b) The Palmer Z index, which is a measure of the departure of monthly moisture conditions from normal, for December 2011 (Image courtesy NOAA/NCDC). (c) Same as (a), except for January 2012. (d) Same as (b), except for January 2012.

The late fall and early winter of 2011–2012 were characterized by anomalously dry conditions (Fig. 1a) and extreme short-term drought (Fig. 1b) along the U.S. West Coast. These dry conditions were allayed in January 2012 (Figs. 1c,d) by a period of extratropical cyclone activity over the eastern North Pacific during 18–21 January that featured prominent atmospheric rivers (AR; Figs. 2a,b) and heavy precipitation over the mountainous terrain of the Pacific Northwest and California. The highest precipitation totals were observed in southwestern Oregon and northwestern California, with local 3-day accumulations exceeding 600 mm (24 inches). These precipitation totals fall into extreme rainfall category (R-Cat) 4 defined by Ralph and Dettinger (2012; Fig. 3).

The widespread heavy precipitation alleviated drought conditions (Fig. 1d), abruptly increased stream flow at river gauge sites throughout Oregon and northern California, and produced flooding in west-central Oregon where antecedent soil moisture was relatively high. Hydrographs for the Marys River near Philomath, Oregon (Fig. 4a) and the Smith River near Crescent City, California (Fig. 4b) provide representative depictions of the river responses to the heavy precipitation. Both hydrographs show abrupt increases in gauge height of 15–20 feet during the period of precipitation; however, only the Marys River exceeded flood stage.

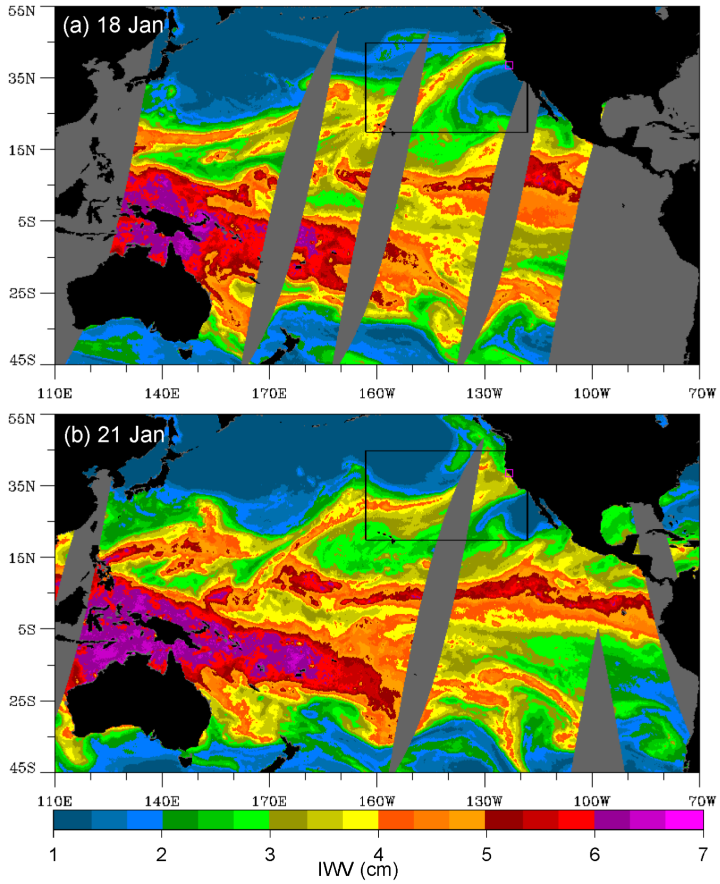


Figure 2: Special Sensor Microwave Imager/Sounder polar orbiting satellite composites of vertically integrated water vapor (shaded in cm according to the color bar) for (a) 18 January and (b) 21 January 2012.

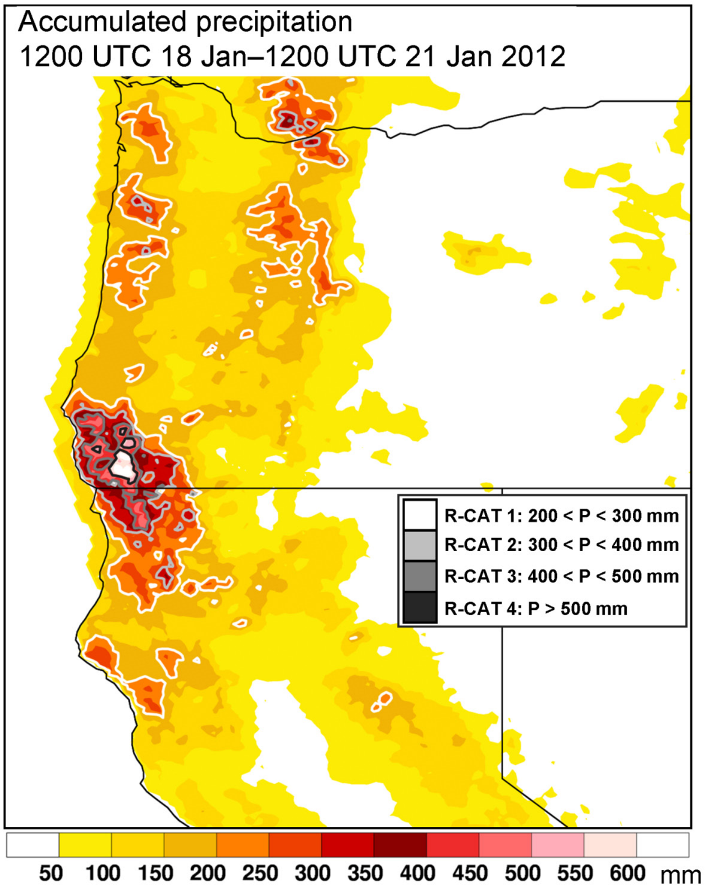


Figure 3: Accumulated precipitation for 1200 UTC 18–1200 UTC 21 January 2012 from the 4-km NCEP Stage-IV quantitative precipitation estimate product. Precipitation thresholds corresponding to the four R-Cats are contoured according to the legend.

Large-scale Atmospheric Conditions

Late fall and early winter of 2011–2012 were characterized by a persistent upper-level ridge along the U.S. West Coast. This upper-level ridge was maintained in conjunction with above-normal extratropical cyclone activity over the central North Pacific in the exit region of a strong storm track/jet stream. The structure of the storm track/jet stream and persistent upper-level ridge along the U.S. West Coast is consistent with a positive Pacific-North America (PNA) index (Fig. 5) during a predominantly La Nina winter (not shown).

A dramatic large-scale flow reconfiguration occurred on 12–18 January 2012 in association with the development of a high-latitude blocking anticyclone over the Bering Sea and a trough over the eastern North Pacific. The large-scale flow reconfiguration is manifest as a decrease in the Arctic Oscillation (AO) and a transition to a negative PNA index (Fig. 5). The large-scale flow reconfiguration was also associated with an eastward extension of the Pacific storm track/jet stream equatorward of the blocking anticyclone, the eastward progression of two extratropical cyclones, and the poleward transport of subtropical moisture along two ARs toward the U.S. West Coast (Figs. 6a,b).

The first extratropical cyclone was associated with a well-defined AR during 18–19 January that extended from near Hawai'i to the Oregon and northern California coastlines (i.e., a classic "Pineapple Express" scenario; Figs. 2a and 6a). The second extratropical cyclone was associated with a well-defined AR during 19–21 January that approached the U.S. West Coast from the southwest (Figs. 2b and 6b). The second AR merged with its predecessor during 20–21 January and made landfall over western Oregon and northern California. The two successive ARs facilitated a long duration of strong vertically integrated water vapor transport (IVT) directed toward western Oregon and northern California between 1200 UTC 18 January and 1200 UTC 21 January (Fig. 7). As similarly shown by Moore et al. (2012), the highest precipitation totals for 18–21 January were located at the terminus of a focused corridor of time-integrated IVT.

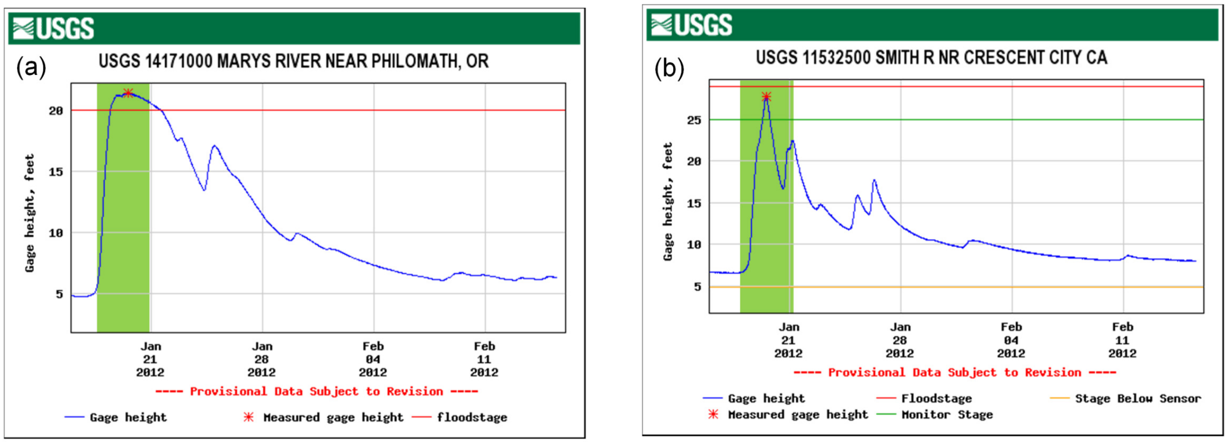


Figure 4: Hydrographs showing observed gauge height at (a) the Marys River near Philomath, Oregon, and (b) the Smith River near Crescent City, California. The green shaded regions denote the period of heavy precipitation and AR conditions.

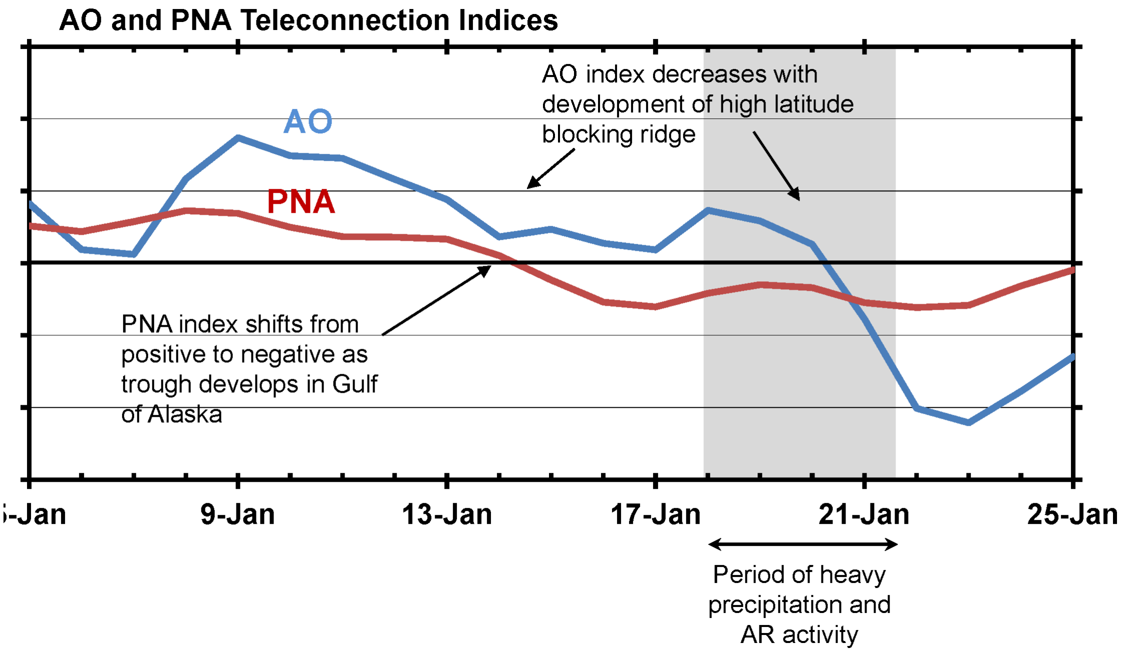


Figure 5: Time series of the AO (blue) and PNA (PNA; red) teleconnection indices. The gray shaded region denotes the period of heavy precipitation and AR conditions. Teleconnection index data were obtained from the NOAA Climate Prediction Center.

Quantitative Precipitation and River Flow Forecasts

In the days leading up to this extreme precipitation event, numerical model guidance alerted forecasters at local National Weather Service (NWS) offices and the Hydrometeorological Prediction Center (HPC) to the potential for a long-duration AR event along the U.S. West Coast. As active participants in HMT, NWS and HPC forecasters recognized the potential impact of a long-duration AR event over the mountainous terrain of Oregon and California. Quantitative precipitation forecast (QPF) guidance from deterministic and ensemble prediction systems helped forecasters to anticipate the location and magnitude of extreme precipitation in southwestern Oregon and north-western California.

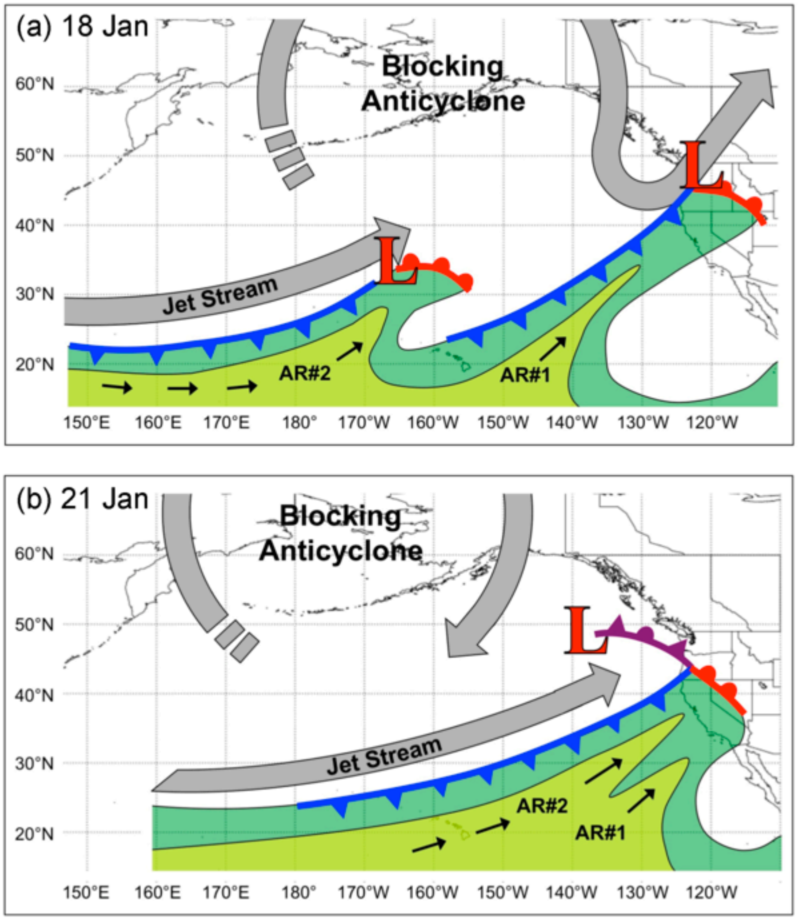


Figure 6: Schematic illustrations of the synoptic-scale conditions on (a) 18 and (b) 21 January 2012 showing the configuration of the jet stream (gray-shaded arrows), the surface low (labeled “L”) and frontal positions, and the IWV distribution associated with the two ARs (green shading).

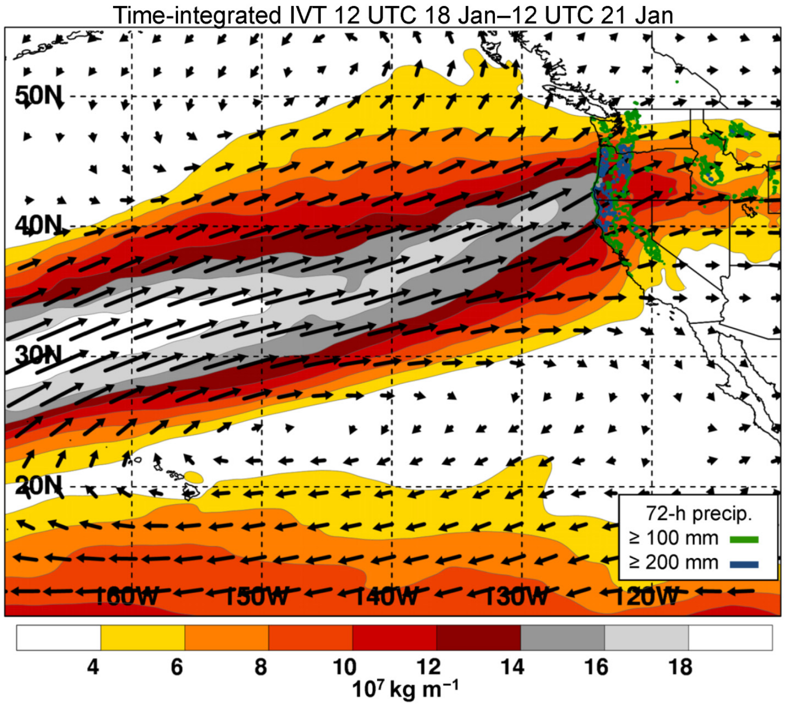


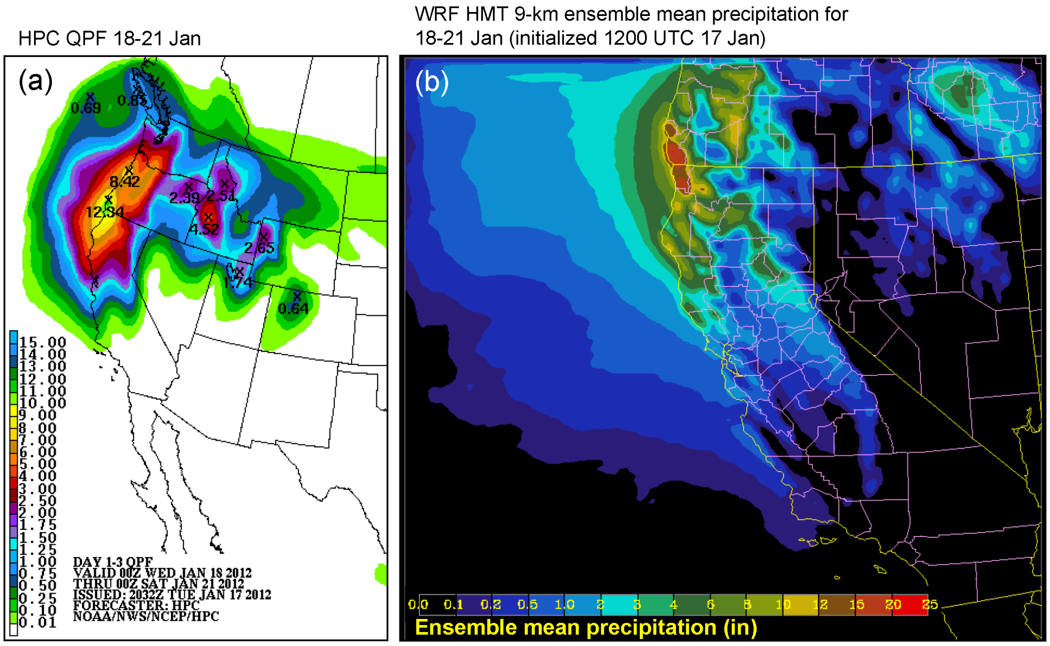
Figure 7: IVT integrated with respect to time from 1200 UTC 18 January to 1200 UTC 21 January 2012 (shaded in 10^7 kg m^{-1} according to the color bar with vectors overlaid). The 100-mm and 200-mm precipitation thresholds for the 72-h period from the NCEP Stage-IV product are contoured in green and blue, respectively.

For individual 6-h time periods during 18–21 January at lead times of 72 to 24 hours, operational model guidance from the National Centers for Environmental Prediction (NCEP) and the European Center for Medium Range Weather Forecasting (ECMWF) as well as forecaster-generated QPFs issued by HPC and local NWS offices accurately predicted the location and distribution of heavy precipitation at low thresholds [i.e., ≤25 mm (6 h) −1] and captured some of the maximum observed precipitation totals, which typically exceeded 50 mm (6 h)−1. However, the spatial coverage for large precipitation thresholds [i.e., ≥50 mm (6 h)−1] in the forecasts was typically ~25% of what was observed (not shown). Similarly, the forecaster-generated 3-day QPF product from HPC for 0000 UTC 18–0000 UTC 21 January 2012 (Fig. 8a) successfully identified the location and distribution of precipitation but did not capture the locally large precipitation totals (i.e., ≥300 mm; Fig. 3) in southwestern Oregon and northwestern California. In contrast to the HPC QPF product, high-resolution guidance from the HMT Weather Research and Forecasting (WRF) 9-km ensemble prediction system initialized at 1200 UTC 17 January showed mean 3-day precipitation totals of ~380–500 mm (15–20 inches) for 0000 UTC 18–0000 UTC 21 January in southwestern Oregon and northwestern California (Fig. 8b), much closer to observed totals there (Fig. 3).

The California-Nevada River Forecast Center (CNRFC) and the Northwest River Forecast Center (NWRFC) issued successful river flow forecasts as a result of the forecaster-generated and numerical-model derived QPF guidance. These river flow forecasts accurately captured both the magnitude and the timing of peak flows, as exemplified by a comparison of the forecast hydrograph issued at 2154 UTC 17 January by the CNRFC and the observed hydrograph for 17–21 January for the Smith River near Crescent City, California (Fig. 9).

Seasonal water resources impacts in the Northern Sierra

As of 7 March 2012 the northern Sierra Nevada had received 18.3 inches of precipitation, which is 50% of normal for this point in the water year (Fig. 10). This is measured by the "Northern Sierra 8-Station Index" that has record going back to 1922. Of the 18.3 inches, roughly 7 inches fell during the stormy few day period from 19-23 January 2012 associated with storms summarized here. This represents 37% of the precipitation for the entire wayer year to date, which is consistent with findings from Dettinger et al. (2011) that a few AR events in a water year in this region on average account for 40-50% of the total precipitation for that year. However, in this case, being a very dry year, it has only taken this one stormy period and its two ARs to do so.


HPC QPF 18-21 Jan

WRF HMT 9-km ensemble mean precipitation for 18-21 Jan (initialized 1200 UTC 17 Jan)

Figure 8: (a) The day 1–3 HPC QPF product (shaded in inches according to the color bar) issued at 2032 UTC 17 January for 0000 UTC 18–0000 UTC 21 January 2012. (b) Ensemble mean accumulated precipitation (shaded in inches according to the color bar) for 0000 UTC 18–0000 UTC 21 January 2012 from the 9-km HMT-W WRF ensemble initialized at 1200 UTC 17 January.

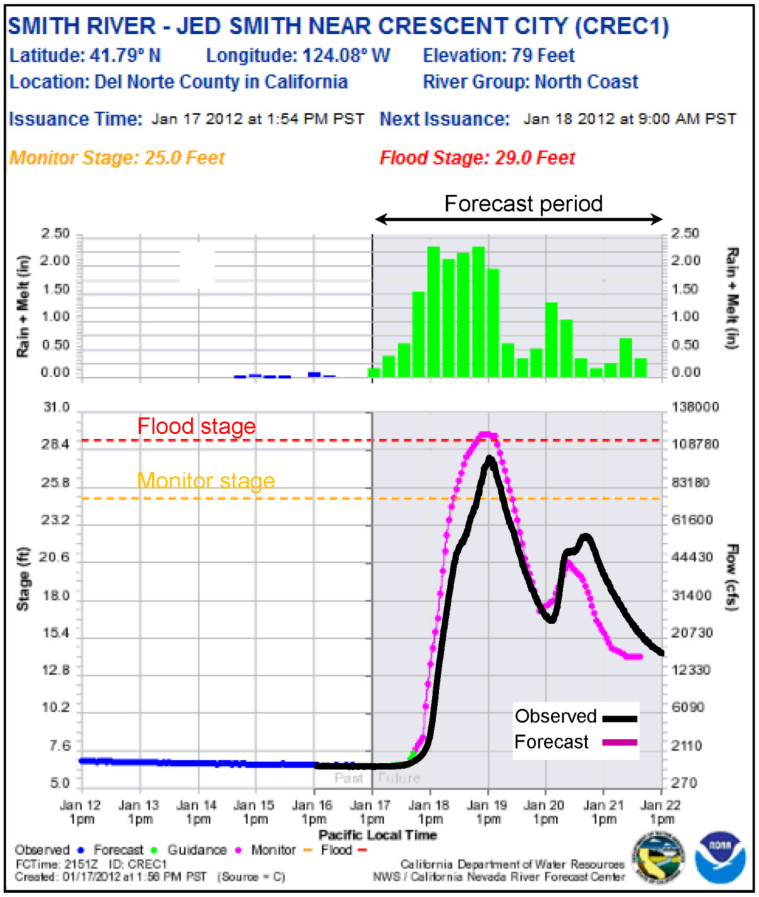
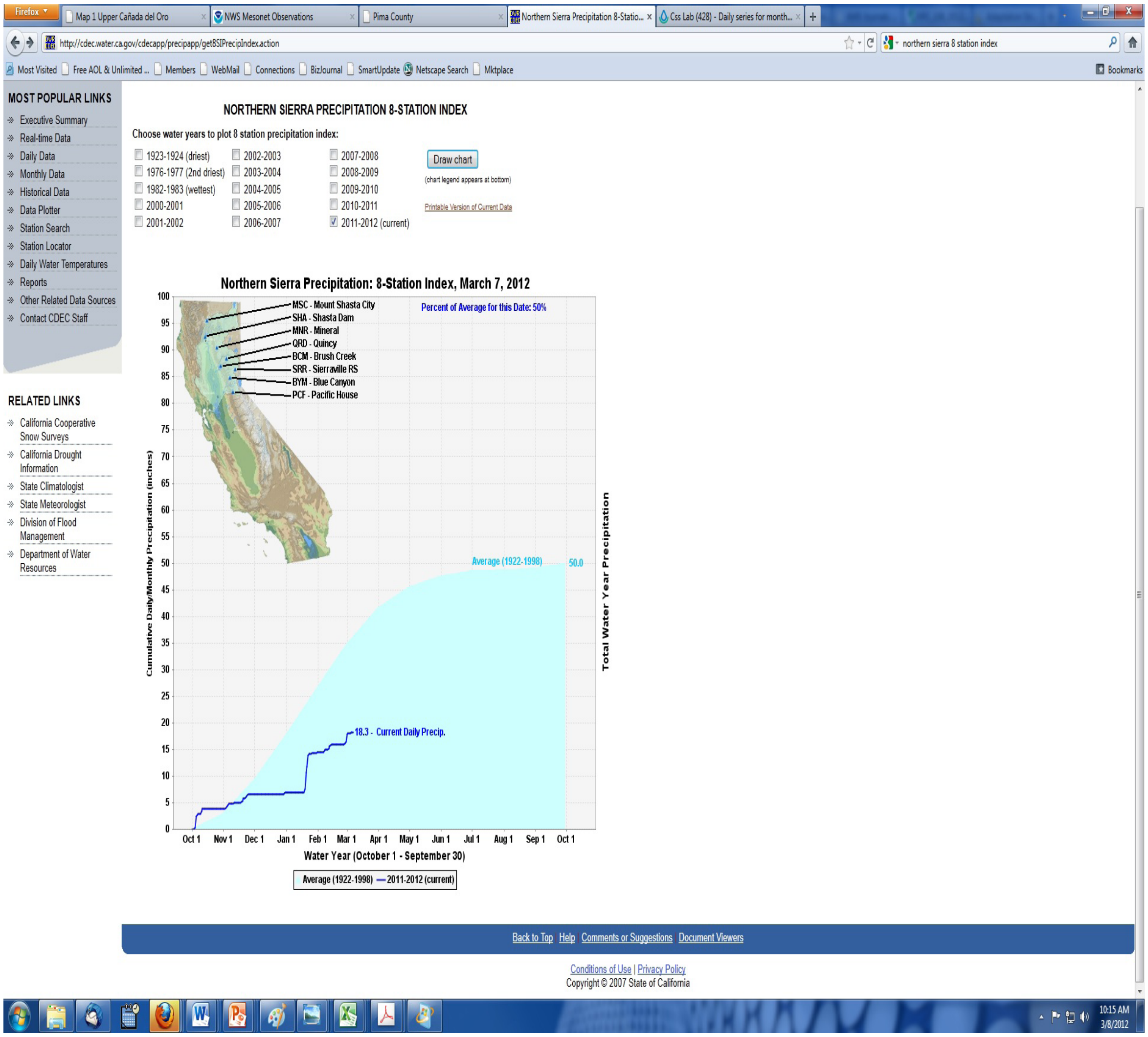


Figure 9: The forecast hydrograph for 17–21 January 2012 (pink curve; left ordinate shows gauge height in ft; right ordinate shows flow in cfs) for the Smith River near Crescent City, California, issued by the CNRFC at 2154 UTC 17 January. The observed hydrograph for 16–22 January is overlaid in black. The green bars in the top graph show the forecast precipitation-melt combination (inches).



NORTHERN SIERRA PRECIPITATION 8-STATION INDEX

Choose water years to plot 8 station precipitation index:

☐ 1923-1924 (driest)
☐ 1976-1977 (2nd driest)
☐ 1982-1983 (wettest)
☐ 2000-2001
☐ 2001-2002
☐ 2002-2003
☐ 2003-2004
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☐ 2005-2006
☐ 2006-2007
☐ 2007-2008
☐ 2008-2009
☐ 2009-2010
☐ 2010-2011
☑ 2011-2012 (current)

Figure 10. Northern Sierra 8-station Index representing mean rainfall in Water Year 2012 (i.e., 1 October 2011 to 30 September 2012) through 7 March 2012, based on the 8 stations in the map at upper left. The 18.3 inches measured thus far in Water Year 12 is 50% of normal through 7 March.

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