

# INTERMOUNTAIN WEST CLIMATE SUMMARY



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## The Spring Runoff Roundup: Another Look at ENSO, Dust-On-Snow, Beetles, and Lake Mead

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There were no great expectations for the winter of 2010-11 in the Intermountain West. A merely average snowpack and runoff would have seemed fortunate, given the generally dry conditions of the previous decade, and the strong La Niña conditions tilting the region slightly towards dryness. But a very wet October turned out to be a harbinger for the rest of the winter, and the snow—aside from a dry January—kept falling in all of the high mountains of the region except for southern Colorado. In April, the average initiation dates for the spring melt came and went, as the snowpacks continued to accumulate.

By May 1, snowpack levels in many basins were in uncharted territory, higher than any recorded during the SNOTEL era, since the late 1970s. The Tower site near Steamboat Springs, which on average receives more snow than any other SNOTEL site in the Colorado River basin, reached a record 202" of snow on the ground at the end of April, containing a record-tying 71" of water equivalent (Figure 1). Incredibly, as of May 23, the SWE at Tower has increased to 79". In Utah, all three river basins in the Wasatch region (Bear, Weber, and Provo) had record snowpacks for May 1, all at over 200% of average for the date. On May 23, the Snowbird, Utah SNOTEL was recording 75" of SWE, which is about 180% of the average *peak* SWE for that site, which usually occurs in late April.

With this prodigious late-season accumulation, and a large fraction of it still on the ground, most of the Intermountain West is facing a runoff season ranging from "big" to "biblical". It thus seemed appropriate to revisit four of the IWCS feature articles from the past year whose topics bear on snowpack and runoff.



*Figure 1. The snow stake and nearly-buried instrumentation at the Tower SNOTEL site near Steamboat Springs, CO, on April 28, 2011. The "17" and "18" on the snow stake mark the height above the ground in feet, indicating a snow depth of 202 inches. (Photo: Mike Gillespie, NRCS Colorado Snow Survey)*

### What happened with La Niña?

The [October 2010 Feature](#) presented an outlook for the 2011 water year based on the moderate to strong La Niña conditions that existed in the fall (Figure 2a). The article noted the tendency for La Niña events of similar strength to be associated with drier-than-average conditions across most of the Intermountain West, in all seasons except for mid-winter in the Colorado high country. However, that dry tendency is statistically significant only over southern Utah and eastern Colorado. Also noted was the very robust large-scale La Niña footprint of a drier Southwest (AZ, NM) and wetter Pacific Northwest.

So was the outcome of the winter of 2010-11 surprising given the La Niña (Figure 2b)? Yes and no. The typical large-scale pattern associated with La Niña did occur:



Arizona and New Mexico ended up very dry, and the Pacific Northwest was wet. Eastern Colorado, especially the southeast, was also quite dry, as westerly flow all winter long kept the plains under downslope (dry) conditions. In western Colorado, there was also the typical north-south gradient (not reflected in Figure 2b) with wetter conditions to the north and drier to the south. Two aspects of this winter did depart from the typical La Niña script. The first was the unusual persistence of a strong Pacific jet over the region, funneling frequent, fast-moving storms into Wyoming, northern Colorado, and northern Utah. This setup often occurs during a La Niña mid-winter, but in 2010-2011 it was stronger than usual and then continued well into spring. The recent weakening of the La Niña may have facilitated this very active spring jet, as La Niña events tend to be associated with

dry conditions in the spring.

The other unusual aspect of this winter was an atmospheric river event (*aka* “pineapple express”) from December 18-23, in which a narrow tongue of tropical Pacific moisture streamed into the southwest corner of our region, bringing up to 19” of precipitation to southwestern Utah, 12” to the Wasatch Mountains, and significantly boosting the snowpack in southwest and central Colorado as well. Atmospheric river events are not uncommon in the coastal ranges and Sierra Nevada of California during the winter, but it’s rare to have one penetrate this far inland—perhaps once or twice per decade—and such occurrences don’t appear to be related to ENSO.

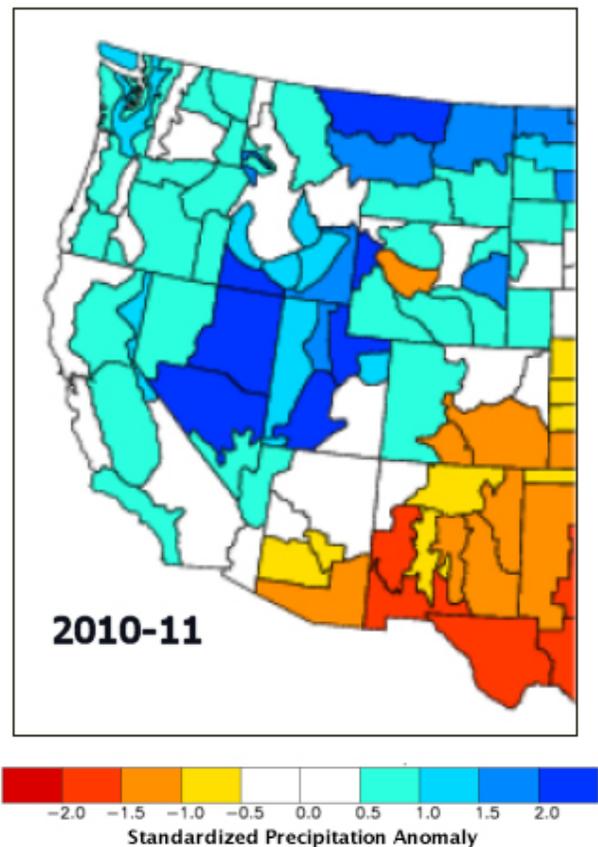
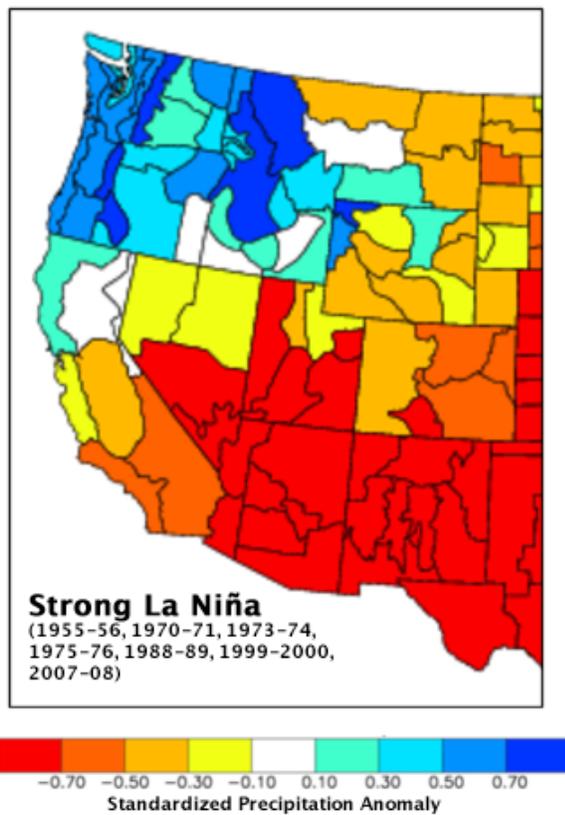


Figure 2 (A). Standardized precipitation anomalies for October-April, averaged for the 7 “strong” La Niña events since 1950, comparable to the strength of the La Niña as of October 2010. Note the marked tendency (orange and red) towards dry conditions across much of Utah and Colorado. (This figure was presented as Figure 4 in the October 2010 Feature.)

(B). Standardized precipitation anomalies from October 2010-April 2011. Note the gradient from wet north to dry south is consistent with the climatology of previous La Niña events, although with wetter-than-typical conditions over much of Utah and Colorado. See text for explanation. (The scale is different than in Figure 2a as it represents a single year, vs. an average of 7 years in Figure 2a.)



## What about the dust?

The [January 2011 Feature](#) presented the latest research linking dust deposition on the region's snowpacks with basin-scale hydrologic impacts: earlier meltout, earlier peak flows, and reduced annual streamflows. The article noted that the total dust loading observed in the snowpack of San Juan Mountains of Colorado was much greater in both 2009 and 2010 than in the preceding four years (2005-08), though it was not clear whether this increase foretold a longer-term trend.

So what's the status of the dust this winter? As of May 23, a total of 8 dust-on-snow events had been recorded at the Senator Beck Basin study area in the San Juans, which currently matches the average number of events seen in the previous six years (range: 4-12 events). The total dust loading from these 8 events appears to be less than what occurred in 2009 and 2010, and more akin to 2006 – but still a heavy dust year. This may reflect the greater annual grass cover observed in the Colorado Plateau dust-source region this winter, which would have tended to reduce dust entrainment.

At sites in northwest Colorado, where continuing snow accumulation has deeply buried the dust layers from March and April events, the impact of the dust is emerging more slowly this month into June. One result from the hydrologic modeling study reported in the January 2011 Feature is that the greatest impact on total runoff, in terms of acre-feet “lost” to dust, is expected in the high-snow years since the melt season is extended and the dust can act over a longer period. The resulting impact is that the wetter “recovery” years, where the effects of drought on soil and reservoir storage are alleviated, are not as effective as they could be.

Thus, a wet and prolonged winter does not mean that the dust won't eventually impact the region's snowpacks and runoff. In fact, the record snowpacks in the region pose a substantial flooding risk that is heightened by dust. The high sun angles in late spring lead to faster snowmelt, and in a year such as this, with large snow amounts that will persist into June, extremely fast snowmelt rates are to be expected with any sunny weather. The current dust load will combine with the intense late spring sun to enhance snowmelt, increasing the potential for damaging streamflow levels. Any additional dust storms will magnify the snowmelt impacts.

## Beetles and runoff

The [May 2010 Feature](#) presented a synthesis of a WWA science symposium held in April 2010 on the effects of the mountain pine beetle (MPB) infestation on water resources. Three studies presented at the symposium found that there was no discernable change in total runoff in beetle-impacted basins, contrary to expectation of increased runoff (and earlier timing) derived from a few studies of past infestations, and many studies of clearcutting in forests.

A second WWA beetle-water symposium was held on April 25, 2011, with the theme, “What have we learned?” in the past year. The presentations and discussions reinforced the complexity of the many hydrologic and energy-balance processes affected by the beetle infestation, and the difficulty of generalizing about the net effect on runoff. Some of the findings presented on changes to specific processes included:

- In southern Wyoming, spruce beetle mortality in an Englemann spruce forest led to reduced stand-level evapotranspiration (ET) and higher soil moisture, consistent with findings in lodgepole pine forests
- Snowmelt in red-phase (dead trees with red needles) lodgepole pine stands in Rocky Mountain National Park occurred one week sooner than in paired living stands, and snow accumulation in grey-phase (standing dead, no needles) lodgepole pine stands was 15% higher than in paired living stands
- As a lodgepole forest canopy was opened up with beetle-kill in southern Wyoming, soil moisture doubled, and 25% more solar radiation reached the forest floor, allowing much more thermal energy to be stored in the soils. At the same time, dead trees dried out, so less energy was stored within the biomass.

The changes observed to energy and hydrologic processes would on balance seem to point to greater runoff, but significant changes in runoff attributable to beetle mortality still haven't been observed. Two other presentations suggested one explanation for this, documenting (1) increased growth in remaining canopy trees and the understory vegetation, and (2) relatively rapid recolonization by new trees after infestation. This new forest growth may be quickly taking up much of the water-balance “slack” created by the death of canopy trees.

Also, the interannual variability in precipitation and runoff in our region creates a very “noisy” background from which to tease out a trend due to the beetles. There is also high variability on sub-annual time scales that makes



attribution difficult. A case in point is what happened in June 2010, when unexpectedly high peak flows occurred in some of the basins most affected by the infestation, such as Colorado’s Blue River. This led many observers to assume that the beetle mortality was causing higher peak flows. But last June’s event can also be explained by the particular weather setup: unusually heavy snowfall and cool conditions in May, especially at low to middle elevations, created a snowpack anomaly that was not fully captured by the SNOTEL network and peak flow forecast models, and then an abrupt warm spell in early June caused very rapid runoff. That said, the beetle mortality can’t be completely discounted as a contributing factor.

Several ongoing and new studies in our region are combining small-scale observations of process change in beetle-affected forests with broad-scale modeling and remotely sensed data to better represent and predict basin-scale changes in runoff and other hydrologic variables. One of these, led by WWA researchers Jeff Deems, Noah Molotch, Carol Wessman, Joe Barsugli, and Klaus Wolter, will work towards jointly assessing the effects of the beetles and dust-on-snow and identifying metrics that capture these effects and might be incorporated into flow forecast models.

**The risk to Lake Mead from climate change – postponed, but not cancelled**

The [March 2010 Feature](#) summarized and examined four recent studies which investigated the risk posed to Colorado River water supplies and storage by climate change. One of the metrics used by two of the studies was the risk of drying of Lake Mead under a scenario of 20% average reduction in flows by 2050; this was calculated as a 50% risk of drying by 2021 in one study, but a subsequent study found a much lower but still non-trivial (~20%) risk of drying by 2021. Last fall, as the level of Lake Mead dropped close to the 1075-foot level that would trigger the first round of Lower Basin delivery shortages, these risks seemed much closer

at hand. But the unregulated inflows into Lake Powell from the Upper Basin as of May 1 are forecasted to be the highest since 1996, at 15.3 MAF for the water year. Accordingly, Reclamation’s latest (mid-May) projection is for a 12.46 MAF release to Lake Mead this year, 4.2 MAF greater than the typical release, and the highest release since 1998. As a result, the surface elevation of Lake Mead is expected to rise 32 feet by fall 2011, to over 1115’.

While this year’s above-average runoff and the resulting “equalization release” to Lake Mead are surely welcome news for water interests in the Lower Basin, they don’t alter the overall picture of a river system operating very close to the balance between supply and demand, vulnerable to even modest long-term declines in system yield. Even the unusually high inflows projected for Lake Mead this water year would bring it back only to the level of fall 2006, when it was well into the downward trajectory that started in 2000.

A similar perspective is shown by looking at Upper Basin yield, as measured by water-year natural flow at Lees Ferry. The 2011 water year natural flow was projected to be around 19 MAF as of mid-May, or 4 MAF above the 100-year mean of 15.0 MAF. But the cumulative deficit, relative to that mean, that was racked up during the mostly dry years from 2000 to 2010 is on the order of 33 MAF. We would thus need another seven years in a row as wet as this year’s projected flow to balance the system deficit accumulated during the first decade of the

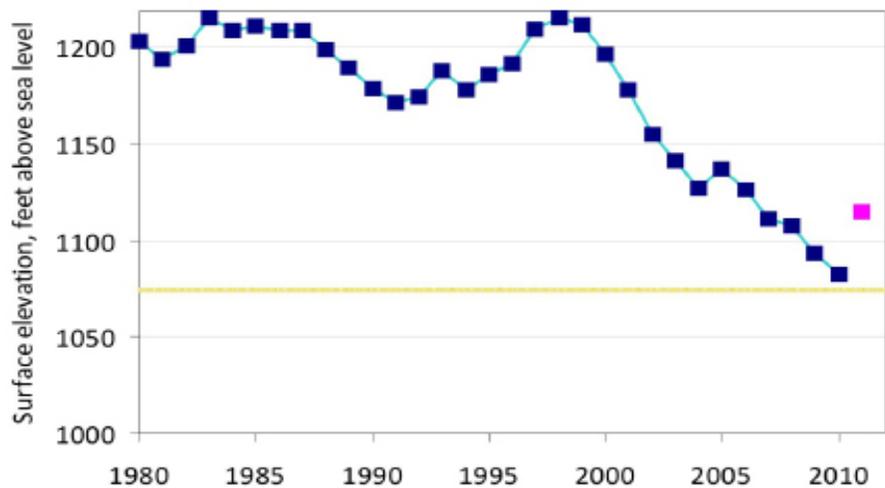


Figure 3. Observed surface elevation of Lake Mead in October for the years 1980-2011 (blue squares), and projected elevation for October 2012 (purple square). The top of the graph indicates the full pool elevation of Mead (1219’). The yellow line indicates the level (1075’) that triggers delivery shortages to the Lower Basin states. (Data from US Bureau of Reclamation)



21st century.

This year's record (in some locations) snowpack and high forecasted flows might be taken as evidence that the long-term projections of reduced runoff for the Upper Colorado basin are flawed. But those projected lower flows are driven mainly by the expected increase in sublimation and evapotranspiration due to warming basin-wide temperatures. Global climate models have mixed outlooks for precipitation trends for our region, but all indicate that the high interannual and decadal variability in precipitation experienced in the last century will continue. So we can enjoy a wet year when it comes, and know that they will come again, but the long-term projections still suggest a decline in *average* annual flow in the Colorado River basin.

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