The 2009-2010 El Nino: Hydrologic relief to U.S. regions

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Evaluating the hydrologic conditions for these past El Niño events reveals that during these times, surface water supply conditions improved in many parts of the United States, including the Southeast, Midwest, and Southwest. At the same time, the Pacific Northwest and other specific regions of the United States experienced below-average water supply conditions. This is consistent with the long-established linkages between oceanic-atmospheric phenomena, El Niño, and streamflow [e.g., Kahya and Dracup, 1993; Tootle et al., 2005].

Predicting El Niño responses is challenging. For example, in the upper Colorado River basin, mixed signals in streamflow and snowpack can be seen for past El Niño events. It is projected that Lake Powell and Lake Mead storage could increase between 9% and 48% in the next months if inflows are similar to those observed during three of the past similar El Niño events (1972–1973, 1982–1983, and 1986–1987) and could decrease by 21% if flows are similar to 2002–2003.

Accurately predicting the behavior involves statistical calculations, and once correlations are found, changes to hydrologic characteristics in different regions of the United States can be forecasted. Using the Colorado River basin as an example, forecasted patterns and their implications can be evaluated.


To determine historic El Niño events similar to the forecasted 2009–2010 El Niño, two statistical tests were performed. A similar El Niño event was defined when the monthly historic Niño 3.4 conditions and forecasted 2009–2010 Niño 3.4 conditions had a coefficient of determination ($R^2$) exceeding 90% and the $t$ test of the difference of the means did not exceed 90%. By using these tests, four historic El Niño events (1972–1973, 1982–1983, 1986–1987, and 2002–2003) were found to be similar to the forecasted 2009–2010 El Niño event.

Hydrologic Responses

Figure 2 presents the hydrologic response to the four historic El Niño events that look...
similar to the current El Niño. Through using six continental U.S. unimpaired streamflow stations (water years 1951–2002), and 323 western U.S. snowpack stations (1 April snow water equivalent (the measure of the amount of water contained in snowpack) for the years 1961–2004 [see Tootle et al., 2005; Hunter et al., 2006]), scientists found that the Southeast, Midwest, and Southwest regions of the United States had increased yearly streamflow and the Pacific Northwest had decreased yearly streamflow (Figure 2a) during El Niño years. Decreased snowpack was also observed in Idaho, western Montana, northwestern Wyoming, and central Colorado during El Niño events (Figure 2b). The streamflow and snowpack were mixed in the Colorado and Utah portions of the upper Colorado River basin.

Case Study: Reservoirs in the Colorado River Basin

To evaluate what the 2009–2010 El Niño might mean on regional scales, it is helpful to examine one example. For Colorado River basin water supply, simulations were performed using the Bureau of Reclamation’s long-term planning model Colorado River Simulation System (CRSS), which incorporates the major reservoirs and produces monthly projections of Lake Powell and Lake Mead elevations. CRSS was run for 2 years starting in January 2010 by updating the reservoir initial conditions to reflect the Bureau of Reclamation’s most recent forecast for reservoir levels at the end of 2009, along with monthly natural streamflow (the gauged streamflow that had been corrected for the upstream effects of humans) from eight historic El Niño events.

Currently, the combined storage of Lake Powell and Lake Mead is approximately 60% of full, a result of the prolonged drought of the past 10 years. Figure 3a summarizes natural flows at Lees Ferry, Ariz., that represent the contributions from the upper Colorado River basin. Average flows during the 1972–1973, 1982–1983, 1986–1987, and 2002–2003 El Niño events were 106%, 135%, 129%, and 56%, respectively, of the average. Using CRSS with these flows indicates that the combined storage at Lake Powell and Lake Mead at the end of 2011 could increase between 4.0 cubic kilometers (9%, equivalent to 3.2 million acre-feet) under 1972–1973 conditions and 16.2 cubic kilometers (48%, equivalent to 13.1 million acre-feet) under 1982–1983 conditions (Figure 3b). If 2002–2003 conditions are used in CRSS, the combined storage could decrease by 10.3 cubic kilometers (21%, equivalent to 3.2 million acre-feet).

These water elevation changes are not due solely to inflow hydrology. Lake Powell and Lake Mead are operated according to prescribed operational guidelines that include the coordinated operation of the reservoirs [Bureau of Reclamation, 2007]. The presence of these guidelines, along with the differences in streamflow response above and below Lake Powell, are partial explanations as to why Lake Mead has a larger increase in water elevation.

What Will This El Niño Be Like?

El Niño is one of the more pronounced climate drivers for the United States. As the current El Niño event progresses, water managers are encouraged to consider these projected changes in water supply and impacts to reservoir operations. It appears that regions will experience some drought relief; however, one El Niño event similar to those historically observed will not be enough to fully replenish large reservoirs such as Lake Powell and Lake Mead.

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References


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Fig. 3. (a) Eight projections of combined storage levels in Lake Mead and Lake Powell for January 2010 to December 2011 based on historic 24-month natural flows at Lees Ferry, Ariz., during El Niño years. Natural flows represent the flows from the upper Colorado River basin. (b) The projected monthly (January 2010 to December 2011) changes in reservoir storages as represented by Lake Mead and Lake Powell using the four most similar years. The total combined storage (in cubic kilometers, where 1 cubic kilometer is about 0.8 million acre-feet) of the reservoirs is shown for all El Niño years, with the four bold curves representing the most similar years. The 24-month average changes in reservoir elevations (in meters) for the four most similar years are shown as bars.