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The 2009-2010 El Niño: Hydrologic Relief to U.S. Regions

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Current forecasts by the U.S. National Oceanic and Atmospheric Administration (NOAA) are that the Pacific Ocean will experience El Niño conditions in late 2009 and into 2010. These forecasts are similar to past El Niño events in 1972–1973, 1982–1983, 1986–1987, and 2002–2003.

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.

By G. A. Tootle, T. C. Piechota, O. Aziz, W. P. Miller, V. Lakshmi, J. A. Dracup, and C. Jerla

Current and Past El Niño Years

Data for the current forecast and past El Niño years were obtained from the NOAA Climate Prediction Center (http://www.cpc.ncep.noaa.gov/). A region of the Pacific Ocean called the Niño 3.4 (5°N–5°S, 120°–170°W) sea surface temperature (SST) region was used as the indicator of El Niño conditions because it is heavily studied and used by NOAA in its forecasts (Figure 1).

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

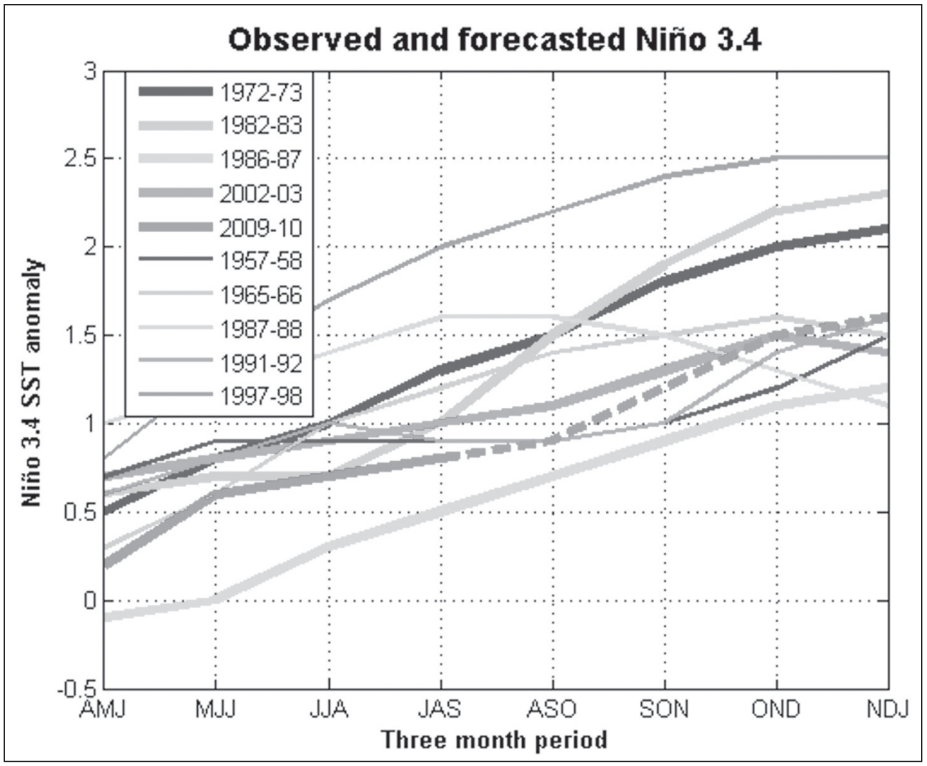

Fig. 1. Historic and forecasted El Niño events, based on Niño 3.4 sea surface temperature (SST) anomalies, during the period 1950–2010. The x-axis shows three month periods (e.g. AMJ is April-May-June). Bold curves represent the four similar El Niño events and the projected 2009–2010 event (observed data are continuous curves, and the forecasted scenario is a dashed curve). Original color image appears at the back of this volume.

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.

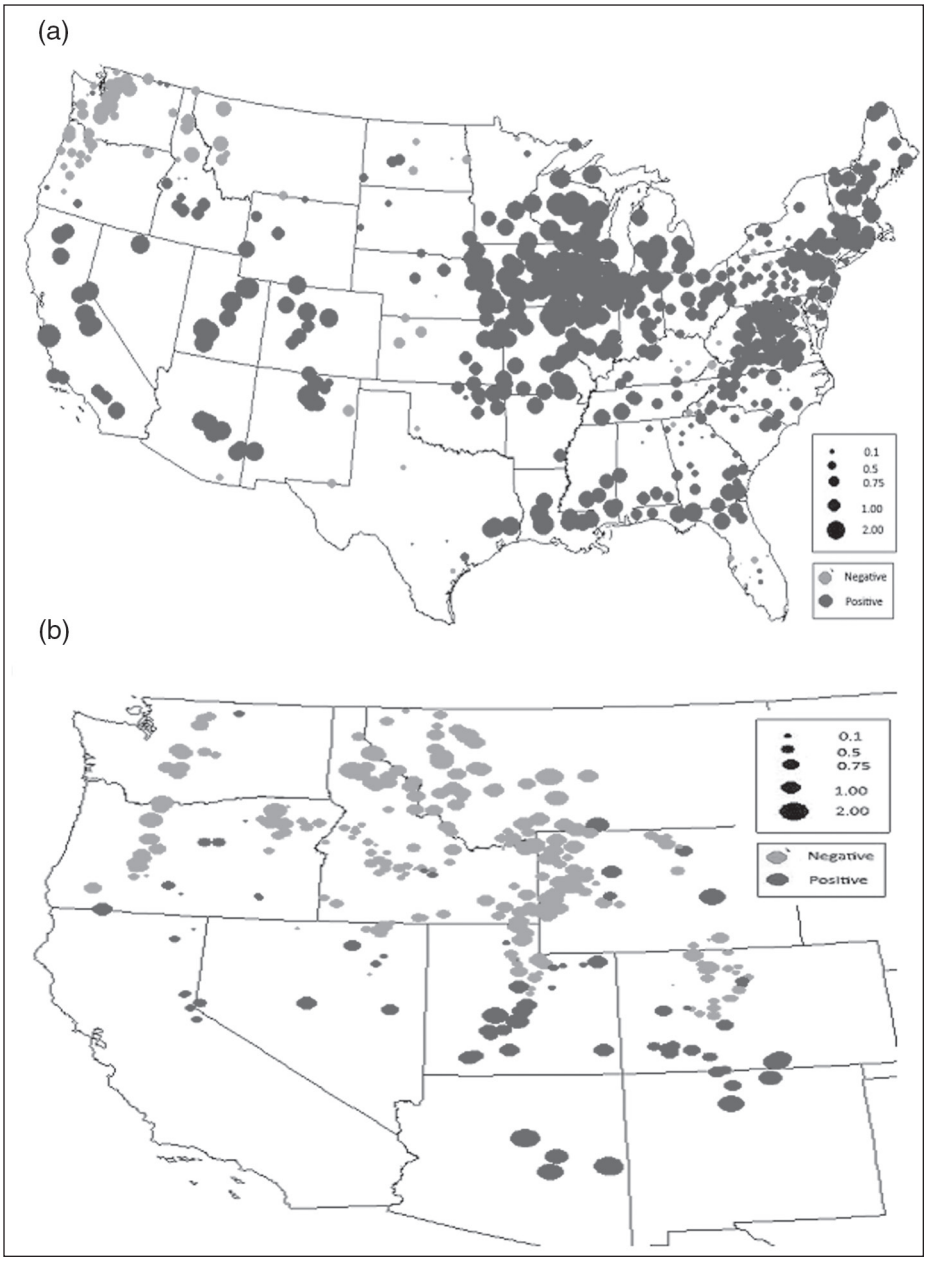

Fig. 2. (a) Continental United States unimpaired water year (October–September) streamflow and (b) western United States 1 April snow water equivalent. For each station, yearly standardized anomalies were determined, and the averages for the four similar El Niño years are displayed. Blue dots represent increased streamflow or snowpack and red dots represent decreased streamflow or snowpack; both are scaled based on the magnitude of the anomaly. Original color image appears at the back of this volume.

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.

Acknowledgments

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References

Bureau of Reclamation (2007), Record of decision: Colorado River interim guidelines for lower basin shortages and the coordinated operations for Lake Powell and Lake Mead, 59 pp., U.S. Dep. of the Inter., Washington, D. C.

Hunter, T., G. Tootle, and T. Piechota (2006), Oceanic-atmospheric variability and western U.S. snowfall, *Geophys. Res. Lett., 33,* L13706, doi:10.1029/2006GL026600.

Kahya, E., and J. A. Dracup (1993), U.S. streamflow patterns in relation to the El Niño/Southern Oscillation, *Water Resour. Res., 29*(8), 2491–2503, doi:10.1029/93WR00744.

Tootle, G. A., T. C. Piechota, and A. Singh (2005), Coupled oceanic-atmospheric variability and U.S. streamflow, *Water Resour. Res., 41,* W12408, doi:10.1029/2005WR004381.

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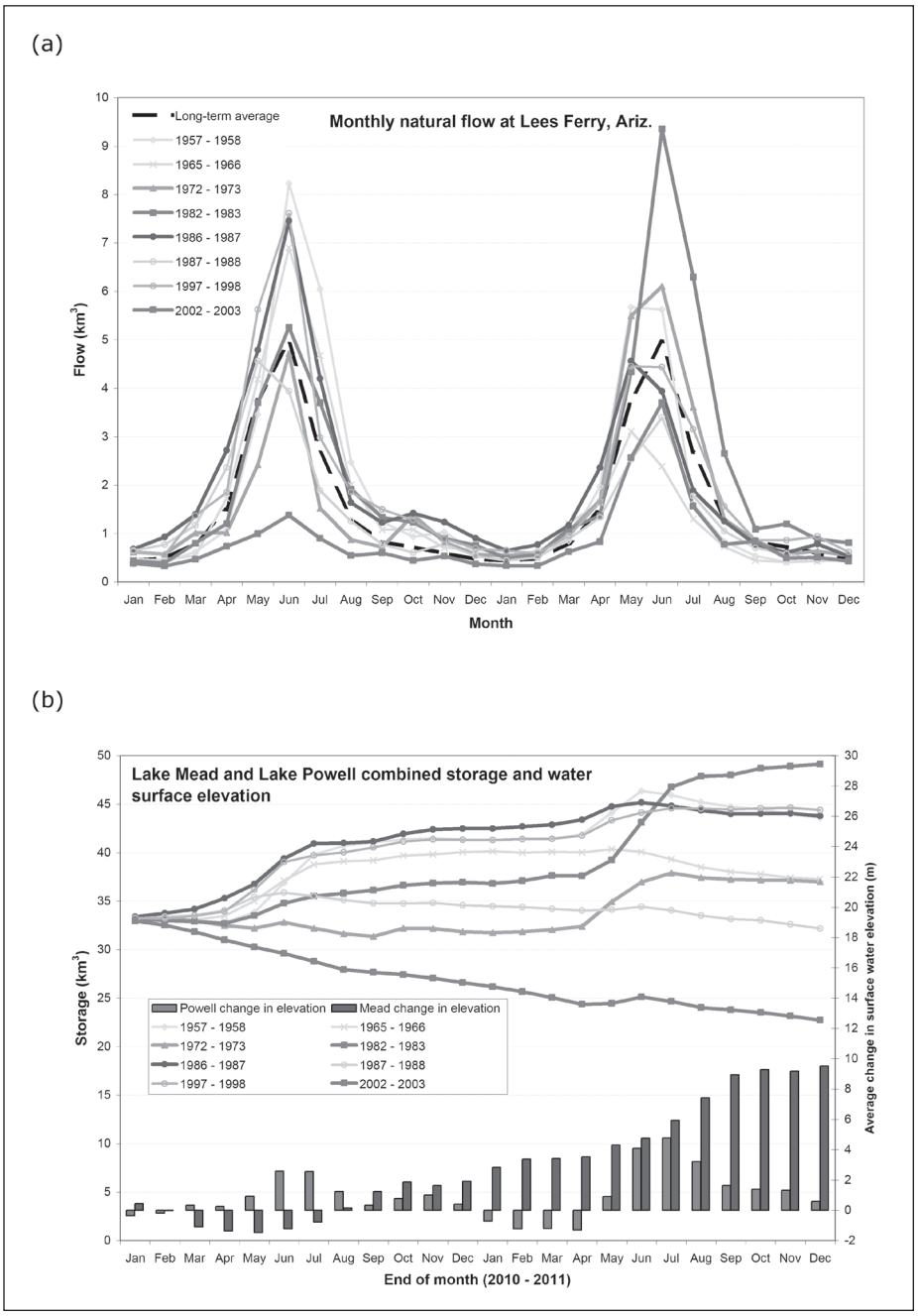
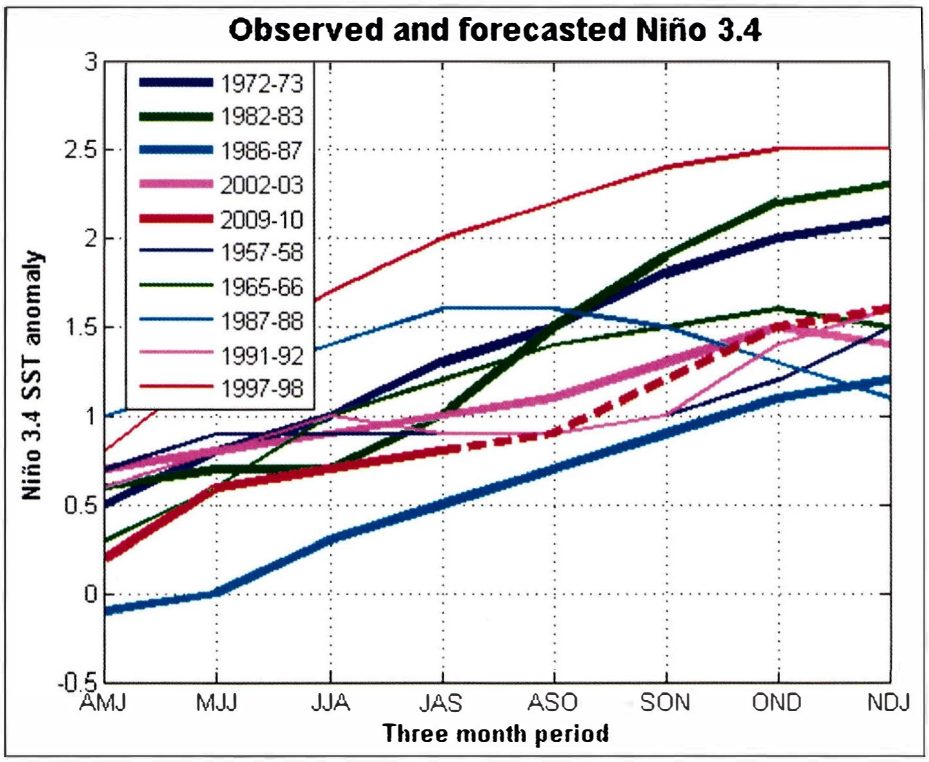


Fig. 3. (a) Eight projections of combined storage levels in Lake Mead and Lake Powell for January 2010 to December 2011 based on historic 24-month natural flows at Lees Ferry, Ariz., during El Niño years. Natural flows represent the flows from the upper Colorado River basin. (b) The projected monthly (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. Original color image appears at the back of this volume.



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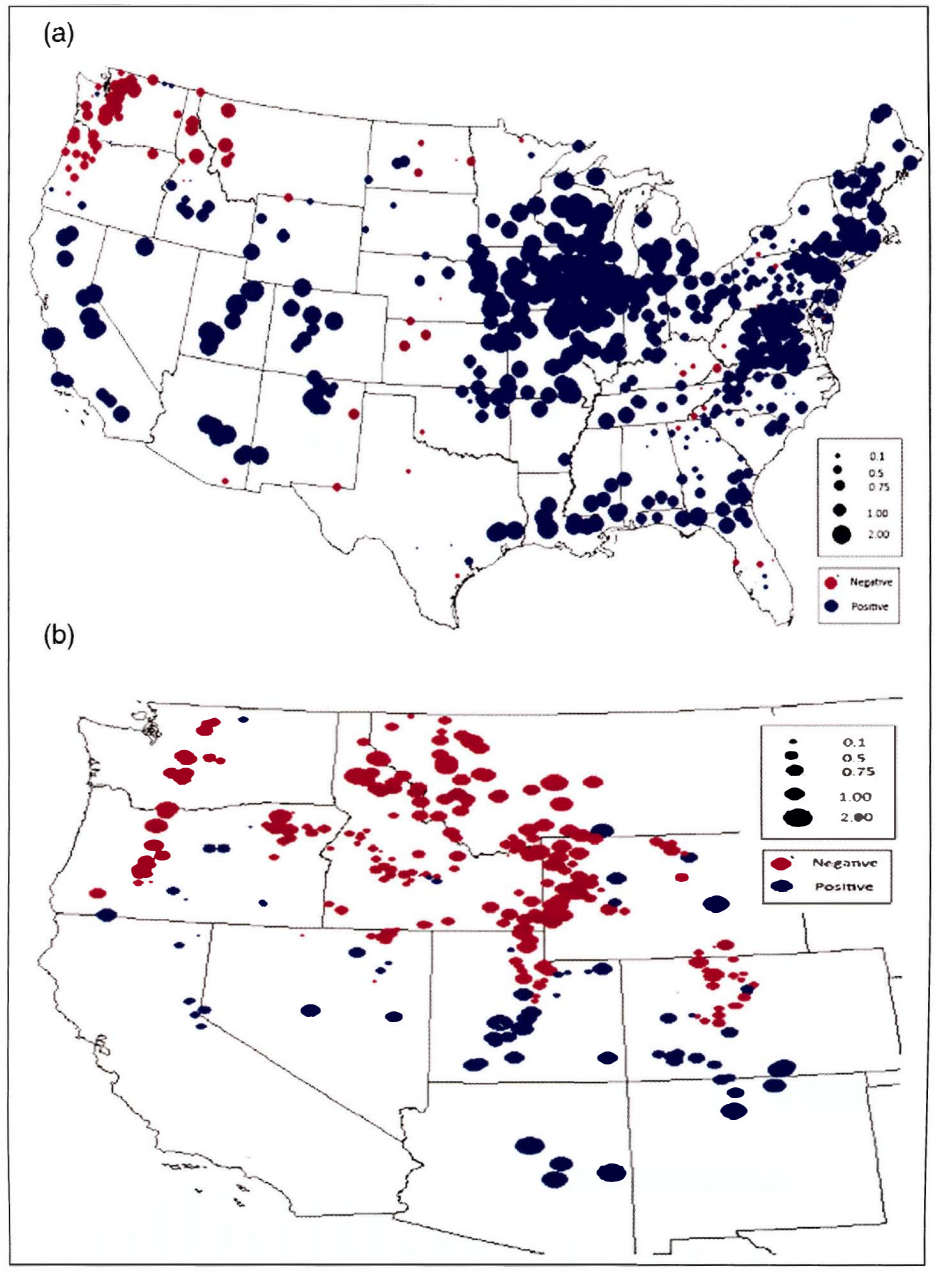

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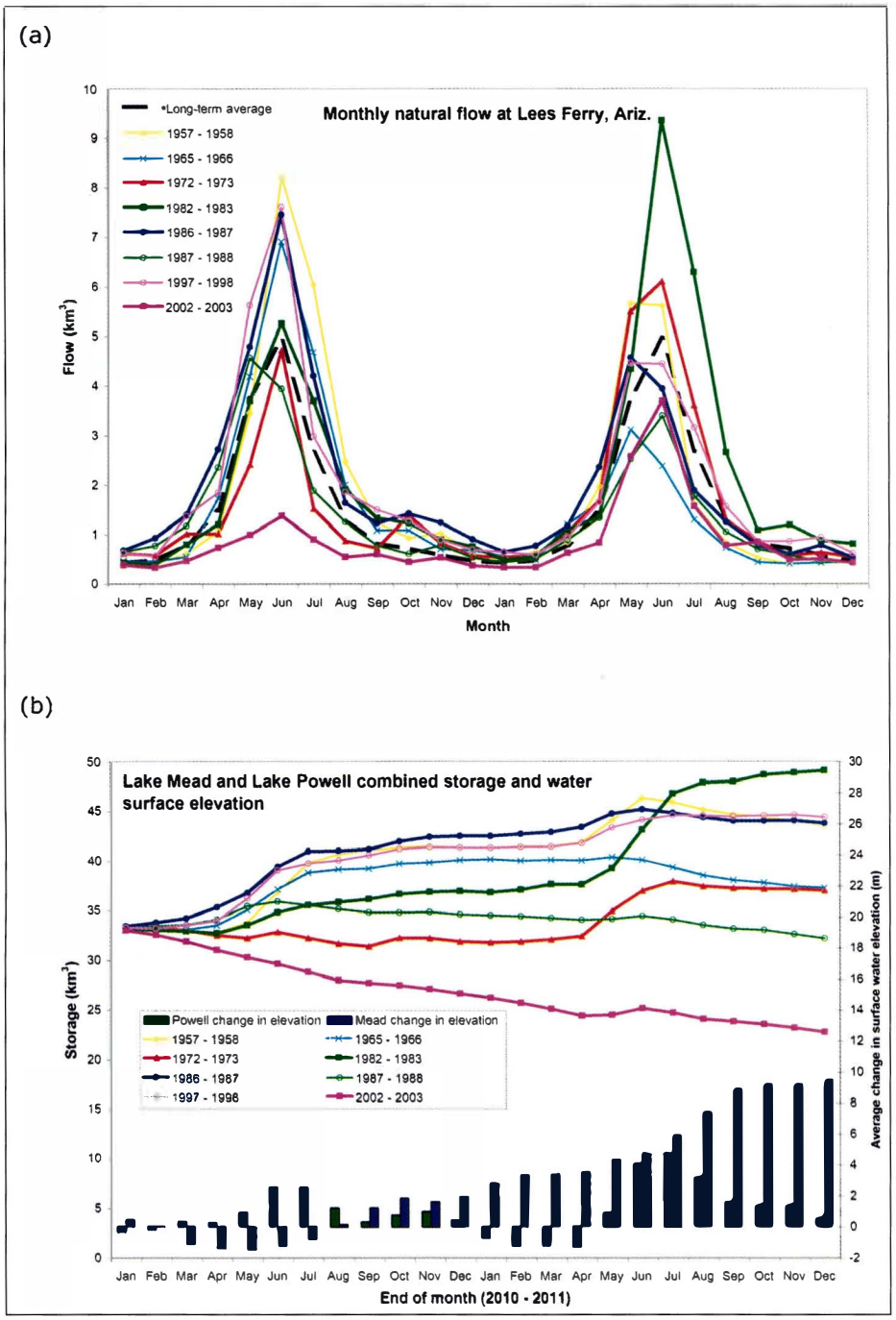

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