Supporting Information

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SI Text

Details on ECHO-g model. Goosse et al. (1) and Osborn et al. (2) have suggested that earlier ECHO-g simulations may have overestimated warming during the medieval period. To provide a more conservative estimate, the simulation results presented here were initiated from the cold conditions of the year AD 1700. In general, the results of this initiation produce estimates of medieval warming which are more consistent with other simulations (3). A time-series of annual temperature variations for the Intermountain West for the period AD 1000–1990 was constructed by averaging the annual surface temperature output from the 10 ECHO-g simulation grid points extending from 40–34ºN and from 104–124ºW and used for this study.

Details on drought variables and temperature. Both drought variables—summer Palmer Drought Severity Index (PDSI) and water year streamflow—strongly reflect cool season moisture. The largest contribution to water year streamflow in the Colorado River basin is winter snowpack, and the PDSI is a lagged measure of drought that reflects moisture conditions in the previous seasons (4). In addition, annual ring widths of Southwestern moisture-sensitive trees most strongly reflect variations in cool season climate (5). Instrumental data suggest that major droughts tend to persist across seasons (6), although in the Southwest, the degree to which warm-season and cool-season precipitation are out of phase is still being investigated (7, 8). Both PDSI and water year streamflow integrate temperature in their measures or calculation, but in both cases, moisture is the dominant variable reflected in the reconstruction. The temperature component in the reconstructions has not been isolated in either case, but understanding the degree to which temperatures were elevated during drought would be useful in considering analogues for future drought.

Additional details on PDSI and temperature reconstructions. Southwest Drought Area Index (DAI) is based on a set of gridded ($0.5° \times 0.5°$) reconstructions of summer Palmer Drought Severity Index (PDSI) (9, 10). The Southwest DAI is computed as the percentage of gridpoints each year experiencing mild-to-severe drought ($PDSI \leq -1.0$) in the region west of 97.5ºW between 27.5ºN and 40ºN. The Colorado Plateau temperature reconstruction was generated with tree-ring data from sites where trees are limited by average annual maximum temperatures (11). The series length (average of 384 yr) and conservative detrending used to compile the chronologies in the reconstruction help preserve the low-frequency information, but it is likely that centennial-scale variability is not well-represented.

Details of drought impacts on water resources. With regard to water resources in Colorado headwaters regions, drought conditions began in the fall of 1999 and peaked in 2002, with some of the lowest snowpacks and runoffs recorded in the Colorado River and other basins (12). In the upper Colorado River basin, 7 of the last 10 annual flows are below the long-term median, a frequency matched only twice before—during the 1930s and 1950s droughts (13). The story is similar for the headwaters of Rio Grande, where annual inflows into Elephant Butte Reservoir, the largest reservoir on the Rio Grande north of the US/Mexico border, have been below average for ten of the last 13 yr (14). In northern Mexico, drought conditions in the cool and warm seasons have persisted with limited relief since 1994 (15), but as in other regions have been particularly severe during the cool season since 1999 (16). In southern California, high precipitation in 2005 broke a drought that began in 1999, but since 2007 drought conditions have been widespread and severe (17). The impacts of the recent drought years have been most pronounced on cool-season precipitation deficits, which are critical for surface-water systems that require snowmelt runoff to fill reservoirs. Warm-season precipitation has also been affected, but in areas where the summer monsoon is a major contributor to annual moisture and a critical factor in water demand, precipitation has been more variable, with record wet conditions in 2006 over many locations, and extremely dry conditions in 2003 (18).

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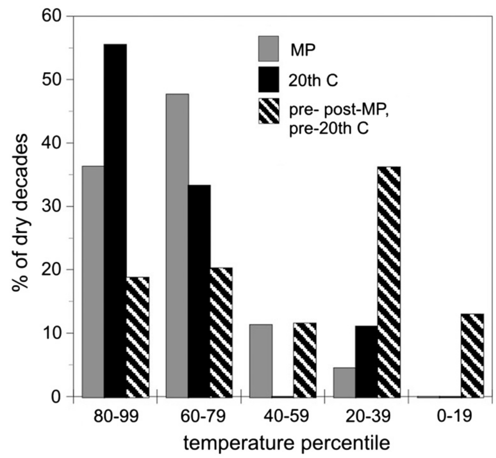

Fig. S1. Correspondence between extremely dry decades (10th percentile) in the Colorado River basin and five categories of Colorado Plateau temperature for three time periods, the medieval period (900–1300), the 20th century (1906–1996), and the combined pre- and post-medieval period years, prior to 1906 (771–899 and 1301–1905). An analysis of 10-year averages of temperature and streamflow for the three sets of years shows that periods of extreme drought (the driest 10 percent of the 10-year averages) correspond with Colorado Plateau temperatures that were in the warmest 60th percentile or warmer most often in the medieval period and the 20th century (84% and 89% of the periods, respectively). Cool droughts were more common during the pre and post medieval periods, before the 20th century (only 20% of the driest decades correspond to temperatures in the 60th percentile or warmer; 25% correspond to temperatures in the 40th percentile or cooler).

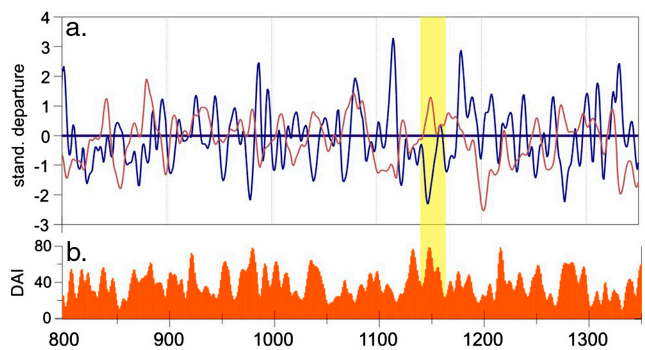

Fig. S2. (*A*) Reconstructions of Colorado (Lees Ferry) River flow, *Blue* (19) and maximum annual temperature for the Colorado Plateau region, *Brown* (11), AD 800–1350, as standardized departures based on the years AD 762–1996. (*B*) Southwest drought area index (DAI) (10). All series have been smoothed with a 10-year spline. *Shading* indicates the sustained period of warm, dry conditions centered on 1150.

Table S1. Comparison of mid-1100th century, 1950s, and 21st century droughts with 20th–21st century mean values for drought-related measures

Variable	20th/21st century	1999–2008	1951–1960	1146–1155
Drought Index (DAI) (10)	32.6% (1900–2006)	48.4% (to 2006)	59.8%	65.5%
Colorado River flow (20)	18.3 BCM (1906–2007)	14.65 BCM	16.35 BCM	14.2 BCM
Colorado Plateau	15.72°C (1909–2008)	17.54 °C	17.38 °C	15.65 °C
mean maximum temperature* (11)	16.17 °C (1961–1990)			

*20th and 21st century data for Fort Valley, AZ, Western Regional Climate Center, http://www.wrcc.dri.edu/. 12th century data.

20 Meko DM, et al. (2007) Medieval drought in the upper Colorado River basin. *Geophys Res Lett* 34m L10705, doi: 10.1029/2007GL029988.