Climatic change impacts on water resources: the role of downscaling methodology

Subtitle: A tale of two semi-arid watersheds

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Bottom Line:

- Dynamically downscaled precipitation projections produced a wider range of variability than statistically downscaled projections in two water resources assessments of semi-arid basins.
- The dynamically downscaled precipitation projections also produced a greater range of uncertainty, which was expressed in the contradictory wetting and drying futures under different GCMs.
- Projected small changes in the precipitation regime were magnified substantially as runoff and streamflow were converted to stored surface or ground water.

Better, Faster, Cheaper
Using dynamically downscaled climate projections in the design of adaptation strategies will result in more robust solutions and increase the resilience of water resources in an uncertain future.

Problem:

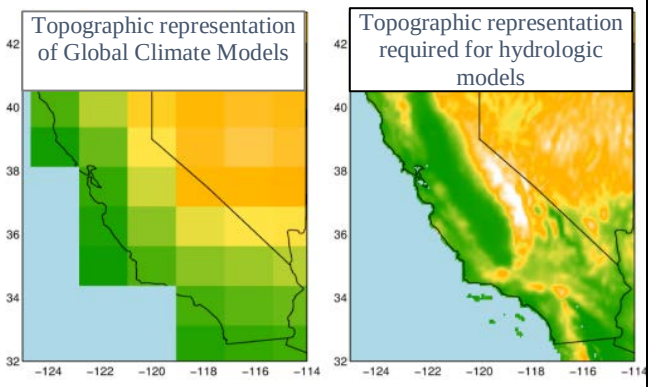
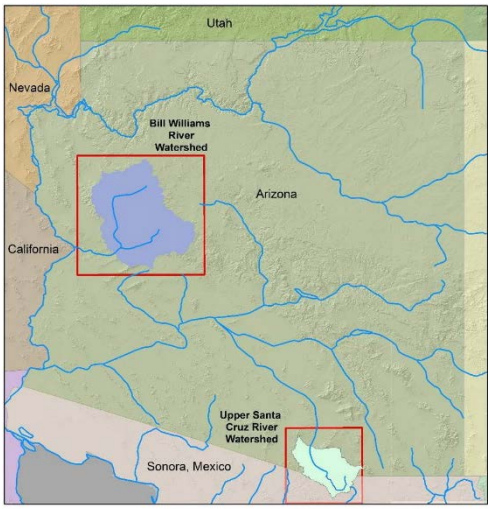


Figure courtesy of D. Pierce, Scripps Institution of Oceanography

Downscaling is the process of translating coarse Global Climate Model (GCM) projections to the spatial resolution needed for hydrologic modeling. There are two fundamental approaches: statistical downscaling (SD), based on historical observations, and dynamical downscaling (DD), a physics-based method, which uses a Regional Climate Model (RCM). Since DD projections are more difficult and expensive to produce, Reclamation studies typically use only SD projections. However, this practice may not properly characterize the actual variability and uncertainty inherent in estimates of future water resources.

Solution:

We compared the results produced by using SD and DD precipitation projections from three CMIP5 RCP8.5 GCM's (HadGEM2-ES, MPI-ESM-LR and GFDL-ESM2) in water resources assessments for two basins of interest to Reclamation: the Upper Santa Cruz River (USCR) basin and the Bill Williams River (BWR) basin. Both feature event-driven hydrology, highly variable precipitation patterns and a strong monsoon signal.



Map of Study Areas

We used SD projections from the Localized Constructed Analogs (LOCA) data set (Pierce et al., 2014) and DD projections using as RCM the Weather Research and Forecasting (WRF) Model from the University of Arizona Hydrology and Atmospheric Sciences Department. In each assessment, we employed a hydrologic modeling framework consisting of a stochastic weather generator and sequential rainfall-runoff, streamflow routing and water storage models.

The USCR Basin is a binational watershed where intermittent flows recharge a set of groundwater reservoirs that provide water to the city of Nogales, AZ. For each combination of GCM projection and downscaling method, we calculated the cumulative volume of Nogales' unmet demand over 40 years under a specified pumping regime.

Flow on the BWR watershed is controlled by Alamo Dam. The dam

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Quote:
"The use of dynamically downscaled hydrology projections provides water managers with a better understanding of the range of possible hydrologic futures. This information can be helpful with planning processes to ensure future water resource assessments have a wide range of possible scenarios."
-Noe Santos, Civil Engineer, Reclamation Lower Colorado Region, Boulder Canyon Operations Office

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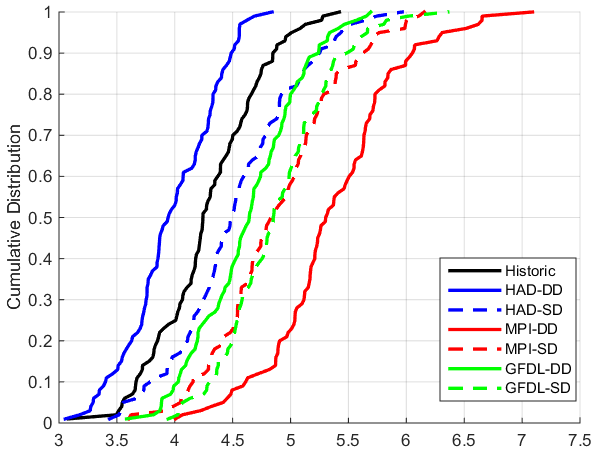
regulates high flow events into Lake Havasu, where water is diverted for delivery to central and southern Arizona. For each combination of GCM projection and downscaling method, we estimated the cumulative time that water levels at Alamo Lake are projected to drop below the recreation threshold.

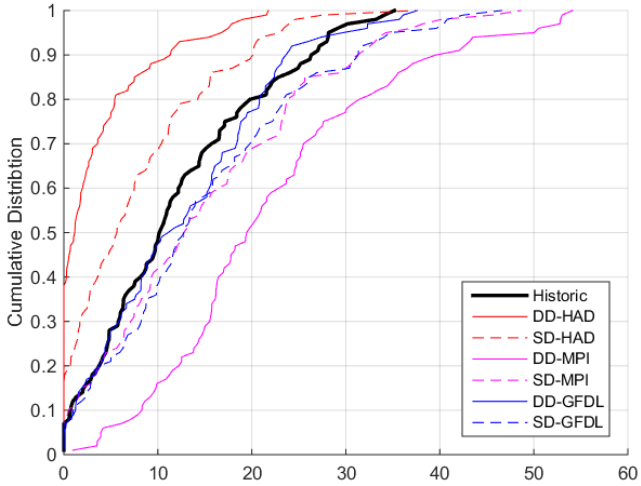
Application and Results:

In both cases, the changes resulting from DD projections were substantially larger than those from SD, for both wetter and drier futures.



Cumulative probability distribution of the volume to be supplied from another source to meet Nogales' future demand under a given pumping regime (1000 ac-ft per 40 years)

Additionally, in both basins, the projected wetting or drying was magnified as precipitation was converted to streamflow and accumulated in groundwater basins (USCR Basin) or above-ground storage (BWR Basin). These examples show that a small change in local precipitation can be magnified by the processes of runoff, streamflow and storage.



Cumulative probability distribution of the duration (percent of hours) that Alamo Lake is projected to drop below the recreation threshold level of 1070 feet over 30 years.

Future Plans:

We plan on further investigating the impact of DD projections on assessments of future water resources availability. A next step is to identify other cases in which the inclusion of DD projections could improve the design of adaptation strategies. To this end, a similar technique is being used in the Lower Santa Cruz River Basin Study for the Tucson, Arizona area.