RECLAMATION
Managing Water in the West

U.S. Department of the Interior
Bureau of Reclamation

Importance of Temporal and Spatial Scale on Basin-Scale Groundwater Recharge Estimates in Historical and Projected Climate Change Conditions

Effect of Spatial and Temporal Scale on Simulated Groundwater Recharge in the Upper Colorado River Basin

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Comparison of simulated recharge results using the coarsest spatial and temporal climate data with results from the finest scale data indicated similar small differences over ten-year moving annual averages, over water years, and during high recharge months. However, differences in simulated groundwater recharge magnitude, which may be important for groundwater-flow simulations, were substantial during some seasonal comparisons

Mission Issue

Coarser spatial and longer temporal scale climate data may be sufficient for simulating changes in groundwater recharge, particularly for understanding trends in recharge over water year or longer time scales.

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Problem

Investigation of impacts from projected climate change on groundwater systems often involve the use of hydrologic model simulations with climate data from one or more general circulation models (GCM). Climate output from GCMs is typically provided at coarse spatial resolutions of ~100–200km on a cell side, which are then downscaled to ~12km (1/8th degree) daily datasets. For groundwater recharge simulations, finer spatial-scale models permit incorporation of more realistic variations in geologic, land use, and topographic information. Likewise, recharge in many areas of the southwestern United States occurs on a daily (or sub-daily) time scale. Considerable time and effort is therefore expended in downscaling GCM output to smaller spatial and temporal scales for use in hydrologic models. While smaller scales allow more realistic hydrologic processes to be simulated, it is unknown whether meaningfully different groundwater recharge simulations, either in magnitude or trend, result from using smaller versus larger scale climate data.

Solution

This paper presents results from an investigation of simulated groundwater recharge in the upper Colorado River basin (UCRB) using historical climate data at the ~12km (1/8th degree), ~4km (1/24th degree), and ~800m (1/120th degree) scales on both daily and monthly time steps. These scale choices correspond to available contemporary climate data from archives such as the Downscaled Climate and Hydrology Projections and PRISM that are routinely used in a range of water resources planning studies. Simulated basin-scale groundwater recharge results for the different spatial and temporal scale data were compared on seasonal, annual, and moving ten-year average bases. Results of the magnitude of simulated groundwater recharge were compared as well as deviations from the period-of-record mean, which may be of more interest to water managers to whom changes from 'normal' are important.

UCRB groundwater recharge was simulated with the distributed-parameter soil-water balance (SWB) model for this study. Groundwater recharge is estimated by the SWB model by calculating water-balance parameters at daily time steps. SWB uses a modified Thornthwaite-Mather soil-water-balance accounting approach and groundwater recharge is estimated within each cell of the model domain. SWB estimates sources and sinks of water within each model cell from climate data and landscape characteristics, and then computes groundwater recharge as the difference between the change in soil moisture and these water sources and sinks. Daily climate data for the 1981–2014 time period at a 1/24th degree (~4km) spatial scale covering the UCRB study area were obtained from the PRISM Climate Group at Oregon State University. The daily ~4km PRISM climate data were aggregated to 1/8th degree (~12km) spatial scale and disaggregated to 1/120th (~800m) spatial scale climate data. Disaggregation from coarse to finer scale data (~4km to ~800m) was performed using the bilinear interpolation method. Fine grid to a coarse grid (~4km to ~12km) aggregation was performed using local area averaging to interpolate from a high- resolution rectilinear grid to a low-resolution rectilinear grid. Daily precipitation and temperature data at the three spatial scales also were aggregated into monthly stress periods for SWB simulations. Daily precipitation data were summed over each month and then the daily average for a month assigned to each day in that month. Daily minimum and maximum temperatures were each averaged over each month with the daily average for a month then assigned to each day in that month. In this way, the SWB model, which runs on a daily time step, could be used to simulate groundwater recharge as if only monthly climate data were available.

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More Information

https://www.usbr.gov/research/projects/detail.cfm?id=9037

https://www.usbr.gov/research/projects/researcher.cfm?id=1962

Application and Results

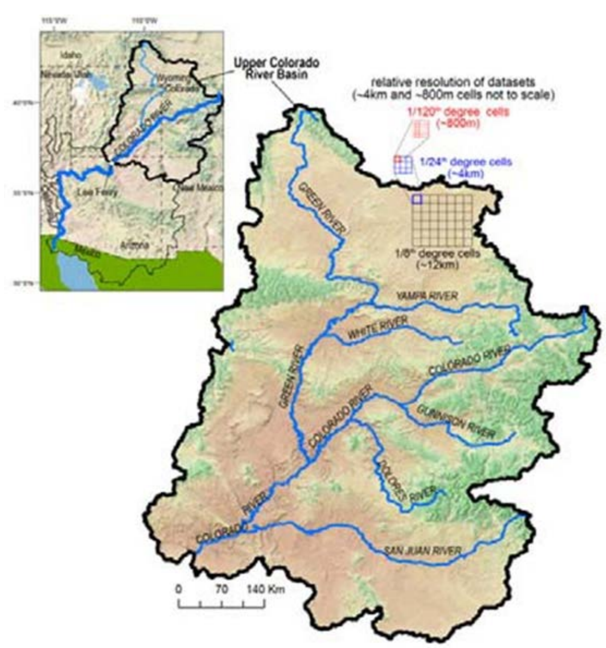
Groundwater recharge in the UCRB was simulated over the water-year 1982-2014 time period using ~12km, ~4km, and ~800m climate data at both daily and monthly time steps. For both daily and monthly temporal scale simulations, similar recharge magnitude and trend (deviation from period-of-record mean) were seen across all spatial scales for ten-year annual average and water-year comparisons. Seasonal comparisons of results revealed similarities in magnitude and trend of recharge during the spring season of March, April, and May when ~70% of UCRB recharge occurs.

Substantial differences were seen in simulated recharge magnitudes in other seasons between different spatial scales, with median differences of as much as 36% from ~4km results. Comparison of simulated recharge results using the coarsest spatial and temporal climate data, ~12km monthly scale, with results from the finest scale data, ~800m daily data, indicated similar small differences in results from the different scales over ten-year moving annual averages, over water years, and during the high recharge months of March, April, and May.

While differences in simulated groundwater recharge magnitude, which may be important for groundwater-flow simulations, across spatial and temporal scale simulations are substantial during some seasonal comparisons, trends in recharge are almost identical across scales, leading to similar conclusions about change from "normal." Especially considering the uncertainty inherent in projected climate data, coarser spatial and longer temporal scale climate data may be sufficient for simulating changes in groundwater recharge, particularly for understanding trends in recharge over water year or longer time scales.

Future Plans

An additional question regarding the impact of projected climate change on groundwater recharge is, how might future changes in land use coupled with projected climate change affect groundwater recharge? Increases in certain land use types and decreases in others will change both the magnitude and distribution of simulated groundwater recharge. Are these changes important relative to the large variance in simulated groundwater recharge from projected climate data alone?



Location of the upper Colorado River basin study area within the southwestern United States.