RECLAMATION
Managing Water in the West

U.S. Department of the Interior
Bureau of Reclamation

Detecting, Interpreting, and Modeling Hydrologic Extremes to Support Flexible Water Management and Planning

Water management tools for better understanding current and future opportunities and threats from precipitation extremes

Research Bulletin
Science and Technology Program

S&T Project 1782

Precipitation and flow extremes are critical parameters in Reclamation's water resources planning, due to both the management threats and opportunities for water supply that they provide. Incorporating weather type information into statistical models of extreme precipitation enables estimates of the frequency and magnitude of extreme precipitation and streamflow events, now and in the future.

Mission Issue

In this project, we have demonstrated a technique for identifying drivers of warm season precipitation anomalies in New Mexico and modeling their extreme characteristics. Further development of these tools will allow water managers to identify both threats from extreme precipitation events and water supply opportunities, allowing for better management of a portion of the water supply that they previously could only respond to.

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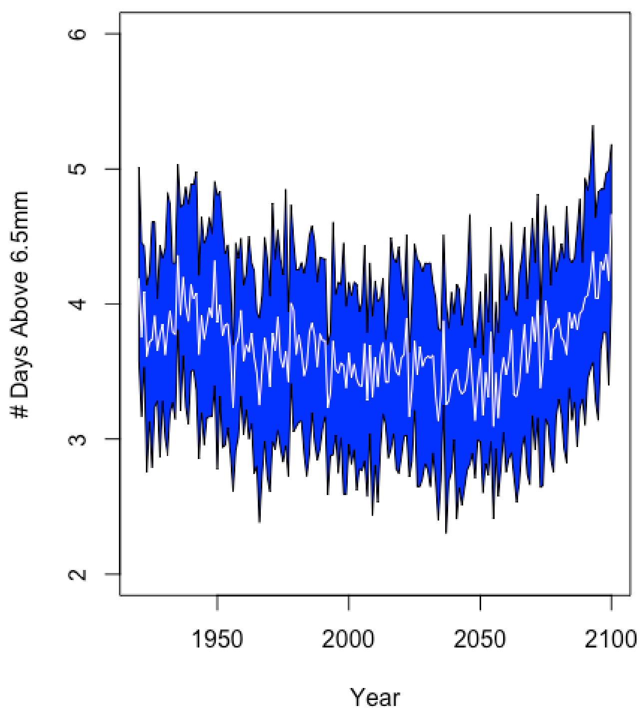
Problem

In the Western US, warm season precipitation has historically provided a secondary water source to snowmelt runoff. However, increasing temperatures and decreasing snowpack suggest that it may gain importance for water resources management. Increasing greenhouse gases are causing an intensification of the hydrologic cycle, which is generally expected to increase heavy precipitation, and potentially local runoff. In addition to posing flooding threats, increasing extreme precipitation events may present opportunities to mitigate the impacts of decreasing snowmelt runoff volumes on water supply. As such, there is a need for Reclamation to better characterize precipitation extremes, which can help inform its water management and planning now and in the future.

Solution

This research identified and incorporated dominant weather patterns associated with precipitation anomalies into a statistical model that characterizes precipitation extremes in the context of water management. A clustering algorithm identified distinct atmospheric circulation patterns, or weather types (WTs), associated with precipitation, including extremes. A statistical model based on Extreme Value Theory (EVT) was then used to describe the frequency and magnitude of extreme precipitation events, how they vary with WTs, and how they are likely to change over time. This kind of information can help water managers characterize changing risk profiles; for instance, the shifting likelihood of an extreme precipitation event based upon current or predicted meteorological conditions.



Projected changes in the number of days in which precipitation in the New Mexico Rio Grande Basin exceeds 6.5mm during the monsoon season (July-September). The statistical extremes model was driven with weather-type count projections from the Community Earth System Model Large Ensemble. The blue envelope is the ensemble 25th-75th percentile and the white line is the ensemble average.

"The strength of the summer monsoon has long been the big unknown in New Mexico's annual and long-term water supply forecasting. It is exciting that this project has been able to shed some light on monsoon drivers and changes. This will surely improve water management here."

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More Information

https://www.usbr.gov/research/projects/detail.cfm?id=1782

Application and Results

The solution was applied in New Mexico (NM), with a focus on the Rio Grande and Pecos River basins, where there may be opportunities to exploit changes in warm season extreme rainfall for water supply. To identify the WTs, three large-scale variables (precipitable water, sea level pressure, and low-level wind speed) were examined over the state of NM. The clustering algorithm identified four hydrologically important WTs that occur during NM's warm season (June through October) based on historical data. WT1 and WT2 are associated with dry conditions, and WT3 and WT4 are associated with wet conditions. WT4 represents the North American Monsoon and contributes more than 50% to the warm season precipitation, including the majority of the heaviest precipitation events (~60%). WT3 contributes about a third of the warm season precipitation, and has less intense precipitation than WT4.

The frequency and magnitude of precipitation extremes was modeled using the statistical approach based on EVT. Incorporating the wet WTs as covariates revealed several sensitivities: increasing the number of WT4 days increased the frequency of extremes, but the spread of the extremes distribution was inversely related to the number of WT3 days. Thus, more WT3 days corresponded to lower magnitude extremes. When the EVT model was driven with WT count information from a large-ensemble climate projection dataset, the frequency of a precipitation extreme decreased along with the number of WT4 days until about 2050 (-5%); this was followed by an increase in the frequency of extremes until the end of the century, as WT4 days increased by 15%. No change was seen, however, in the magnitude of extremes, as the number of WT3 days stayed constant in the projection.

Future Plans

From these encouraging results, two new research questions arise: First, can WTs be used to forecast monsoon precipitation on seasonal to decadal timescales? To this end, the skill of the WT patterns in forecast products could be assessed using existing seasonal forecast ensembles, such as the North American Multi-Model Ensemble. Second, what is the potential value of monsoon forecasts to water managers?

One approach is to develop a systematic framework to test a range of probabilistic forecast scenarios for a water system, with the goal of assessing the sensitivity of the watershed hydrology and management to monsoon predictability. These research questions are complementary to ongoing Science & Technology (S&T) projects that are focused on improving snowmelt-runoff forecasts. Future plans include explicitly linking monsoon-based forecasts with spring-runoff forecasts being developed in another Reclamation-funded S&T project, "Improving the resiliency of southwestern US water supply forecasting in the face of climate trends and variability" (S&T Project 8117), being conducted by Reclamation Principal Investigator Llewellyn and NCAR colleagues.