RECLAMATION *Managing Water in the West*

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The Knowledge Stream

Research Update

Will extreme rainfall change in Colorado's future?

Using high-resolution models to understand extreme summer precipitation events and assess possible future changes in Colorado

Bottom Line

Combining improved understanding of what past extreme precipitation events look like in space and time with projected future climate conditions can help inform decisions about dam safety, flood hydrology, and future monitoring needs.

Better, Faster, Cheaper

Out-dated historical records can be updated using a high-resolution model to represent how heavy precipitation is distributed in space and time, while also providing the potential to incorporate climate change in long-term planning applications.

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Collaborators

Reclamation:

- **FHCG, Technical Service Center**
- **Dam Safety Office**

Cooperative Institute for Research in Environmental Sciences (CIRES)

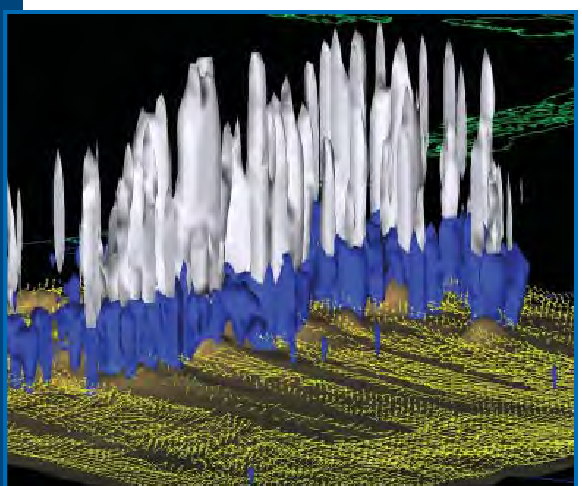
Problem

The Flood Hydrology and Consequences Group (FHCG) in Reclamation's Technical Service Center, as well as Reclamation's Dam Safety Office (DSO), are tasked with evaluating flood risk and the potential for heavy rainfalls for site-specific studies and projects. Estimating heavy precipitation potential in the Western United States is a particularly great challenge for Reclamation. Legacy methods and information resources support decisionmaking, but modern datasets and modeling technology provide an opportunity to improve these current tools. For example, knowledge of floods and short-term extreme precipitation events is limited by sparsely distributed observations of when and where storms occurred. One approach to estimating precipitation in areas of sparse station data is to smooth available data using interpolation, which often underestimates intensity in mountainous regions. A lack of such key data leads to greater reliance on approximations and outdated estimation methods that may not provide realistic information about the potential for heavy rainfall and flooding.

One possible way to improve extreme event estimation is through a dynamical weather model, but these can be computationally expensive to run. They also require a carefully designed setup in order to adequately support analysis and evaluation of extreme precipitation possibilities. Integrating a numerical weather model into FHCG's extreme precipitation assessment procedures has been discussed, but not adequately explored until this point.

Solution

Reclamation's Science and Technology Program, DSO, and FHCG teamed up with the Cooperative Institute for Research in Environmental Sciences (CIRES), a joint institute of the National Oceanic and Atmospheric Administration and the University of Colorado at Boulder to help understand the processes of summer extreme precipitation events in the Colorado Front Range region from both a historical and future climate perspective.



Example of high-resolution model output from a heavy precipitation event: surface winds (yellow arrows), three-dimensional rain isosurface (blue), and three-dimensional hail isosurface (white).

The approach featured application of a community weather and climate prediction tool, the Weather Research and Forecasting (WRF) model (www.wrf-model.org/index.php). Although many climate models are typically applied at a spatial resolution that is too low to adequately represent heavy precipitation events, in tcoloradolhis study WRF was applied at a relatively fine resolution to permit event-scale simulation, focusing on historical events of interest to Reclamation.

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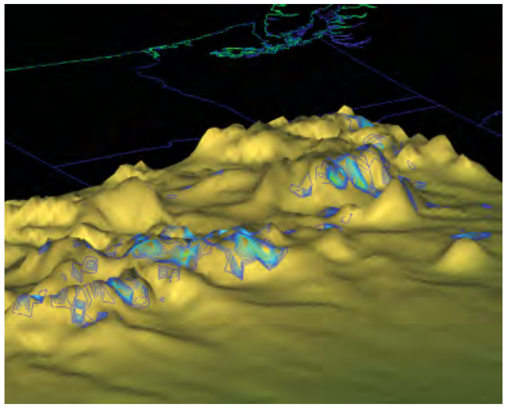
The high-resolution simulations offer improved insight into the fine-scale detail of heavy precipitation events, a more realistic understanding of their intensity, and which physical processes are realistically represented in coarser-scale climate models.

Using the model results, precipitation intensities were evaluated and intercompared, with an indepth focus on some specific Reclamation study sites (i.e., Green Mountain Dam). Assessments of possible climate change impacts on storms across Colorado were also evaluated, both from a regional-scale climate perspective as well as a higher-resolution, weather-event perspective.

Application and Results

The study identified several key findings regarding extreme summer precipitation events in Colorado, specific to the advantages of using a numerical modeling framework:

- Improved understanding of the impact of regional atmospheric conditions on individual storm events.
- Insight into the potential phase change of precipitation in future climates (e.g., snow versus rain or rain versus hail).
- Demonstration of WRF's ability to generate improved spatial and temporal patterns of extreme precipitation events for application in hydrologic models.



Example of high-resolution model output of surface runoff (colored contours) from a heavy precipitation event over the model topography (in Colorado).

In addition, regional climate model results suggest decreased mean warm-season rainfall with less agreement with respect to the potential for extreme precipitation events. The higher-resolution modeling effort suggests that chances of extreme events becoming more or less frequent are about equal overall in Colorado, but that local, heavy precipitation magnitudes will increase or remain large. One study finding also suggests that small hail (which is now common in high elevations in our current climate) may decrease in warmer future climates and instead fall as rain.

Relevant Publications

Alexander, M., J.D. Scott, K.M. Mahoney, and J. Barsugli. 2013. *Greenhouse Gas Induced Changes in Summer Precipitation Over Colorado in NARCCAP Regional Climate Models.* Journal of Climate, DOI:dx.doi.org/10.1175/JCLI-D-13-00088.1.

Mahoney, K.M., M.A. Alexander, J.D. Scott, and J. Barsugli. 2013. *High-Resolution Downscaled Simulations of Warm-Season Extreme Precipitation Events in the Colorado Front Range Under Past and Future Climates.* Journal of Climate, DOI:dx.doi.org/10.1175/JCLI-D-12-00744.1.

Mahoney, K.M., M.A. Alexander, G. Thompson, J.J. Barsugli, and J.D. Scott. 2012. *Changes in Hail and Flood Risk in High-Resolution Simulations Over the Colorado Mountains.* Nature Climate Change, DOI:10.1038/nclimate1344.

Sankovich, V., J. Caldwell, and K. Mahoney. 2012. *Green Mountain Dam Climate Change*. Dam Safety Office Technology Development Program, Report DSO-12-03.

Green Mountain Dam, Colorado (one of the key sites studied in phase 1 of this research).

"High-resolution models provide a novel approach to evaluating the character of historical and future extreme precipitation events, offering improved representation of the timing, magnitude, and spatial distribution of precipitation events for input to hydrologic models for dam safety studies."

Jason Caldwell
Meteorologist, FHCG in Reclamation's Technical Service Center

Future Plans

Future plans for this work will focus on increasing the number of high-resolution simulations to better represent the extreme precipitation potential for a given region. This will be explored through "ensembles" of model simulations. The ensembles will use a variety of atmospheric conditions, including projected future climate conditions, along with different model configurations to provide a range of potential future spatial and temporal patterns of precipitation for dam safety applications. Considerable effort will be directed toward incorporating the high-resolution gridded precipitation products into both current FHCG hydrology products and models, as well as exploring the use of new hydrological models. The main goal will be to understand which of these experimental approaches and resultant data sets offer promise to near-term improvements to current FHCG procedures.

More Information

www.usbr.gov/research/projects/detail.cfm?id=6917

www.usbr.gov/research/climate/abstracts/pace.html