U.S. Department of the Interior
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Stochastic Storm Transposition

Applications to Precipitation and Flood Frequency Analyses

Research Bulletin
S&T Project 1735

Rainfall-runoff models used to develop flood frequency estimates typically require complex meteorological inputs, including historical storm templates (e.g., historical precipitation and air temperature data) and a precipitation-frequency curve. These inputs can be challenging to develop in regions of sparse or low-quality data.

Mission Issue

This research addresses needs within the Technical Service Center and two priority areas in Brekke et al., (2011) by combining advanced stochastic storm transposition methods with a gridded rainfall-runoff model to produce probabilistic flood estimates.

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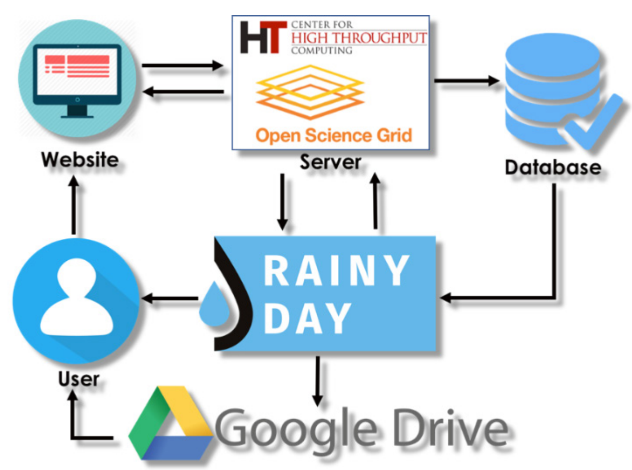
Problem

Members of Water Resources Engineering and Management Group in the Technical Service Center develop probabilistic estimates of flood hazards using observational, statistical, and numerical methods to support risk informed decision making. Numerically-based methods of generating the flood hazards typically involve rainfall-runoff models, which require detailed precipitation inputs in the form of storm templates (spatial and temporal precipitation and air temperature information) and a site-specific precipitation frequency-intensity relationship. The information is used to force the rainfall-runoff model tens to hundreds of thousands of times to produce probabilistic flood frequency estimates. However, most analyses limit their analyses (for various reasons) to between two and 20 unique storm templates and assume that such a small pool of historical events is sufficient to encompass the wide range of extreme storms that are possible at very low annual exceedance probabilities. Furthermore, uncertainties in the precipitation-frequency curve can drive uncertainty in flood-frequency estimates at large annual exceedance probabilities (Reclamation 2020).

Solution

Reclamation partnered with Professor Daniel Wright from The University of Wisconsin-Madison to develop advanced stochastic methods to assist in creating rainfall-runoff model inputs. The project focused on expansion of capabilities within RainyDay, an open-source stochastic storm transposition (SST) framework for generating large numbers of realistic rainfall scenarios. Stochastic Storm Transposition (SST) "lengthens" the rainfall record by probabilistic temporal resampling and spatial transposition of storm events drawn from a "catalog" of historical storms to effectively recreate the climatology of extreme rainfall frequency and intensity. Output from RainyDay includes a storm catalog and a precipitation-frequency relationship.



"The advanced stochastic storm transposition technology available within RainyDay has applications beyond dam safety, and we look forward to exploring those applications further."

Amanda Stone, P.E.
Hydrologic Engineer
TSC - Water Resources Engineering & Management

More Information

https://www.usbr.gov/research/projects/detail.cfm?id=1735

Application and Results

The research team combined output from RainyDay with a gridded, processed-based rainfall-runoff model, WRF-Hydro, to develop flood frequency estimates in the Big Thompson watershed above Olympus Dam, in Colorado. There are two clear advantages to coupling SST with a process-based FFA framework: First, the spatio-temporal structures of observed precipitation events are preserved, and second, the coupling enables the stochastic use of a hydrologic model that produces equally likely model output (i.e., streamflow peaks and volumes).

The modeling framework started with the calibration and validation of the WRF-Hydro model between 1979 and 2018. The physical states from this long-term simulation were saved and later used as initial conditions in the stochastic simulations. A storm catalog was developed for the basin using a gridded precipitation dataset and SST technologies within RainyDay. Finally, 10 sets of 1,000 annual maximum streamflow events (for a total of 10,000) were simulated by sampling the RainyDay storm catalog and initial conditions from the long-term WRF-Hydro simulation. The 10 sets of annual maximum flow events can be used to estimate median and uncertainty estimates at return periods less than 1,000 years or to estimate a single frequency curve (without uncertainty) out to the 10,000-year return period.

Simulated peak discharge estimates are shown in the figure below, along with observations from a USGS gage and a Log-Pearson Type III (LP-III) distribution fit to those observations. These results suggest that the process-based framework implemented can be used to estimate flood peaks at return periods up to and in some cases beyond the 1,000-year return period.