The changing risk of extreme event impacts on Vermont transportation infrastructure

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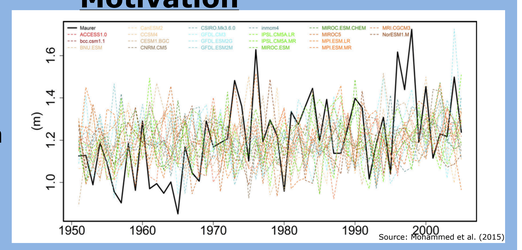
I. Introduction

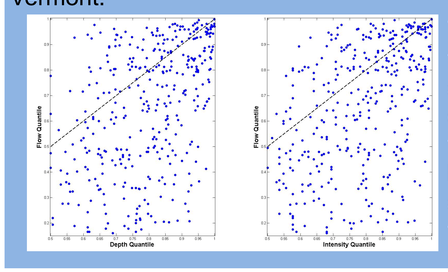
Purpose

The goal of this project was to quantify the impact of changes in extreme precipitation on flood magnitude in characteristic rivers in Vermont, in order to better understand the Vermont Agency of Transportation's hydraulic design requirements under a changing (nonstationary) climate. Extreme precipitation has been increasing significantly in recent decades in Vermont. Observed rainfall and streamflow nonstationarity calls into question the use of traditional hydraulic design methods for sizing culverts and bridges. Traditional methods are based on stationary climate assumptions, such as those using given return periods (e.g. 100-year flood).

Motivation

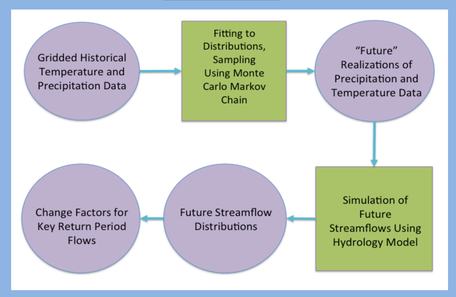
Downscaled global climate models do not reproduce observed trends in mean and variance of precipitation in Vermont.

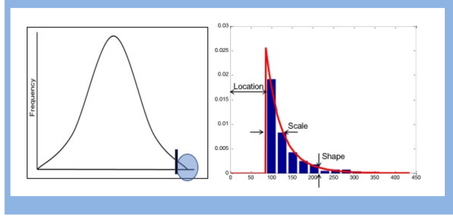




This figure shows stream flow quantile plotted against precipitation quantile, showing that they do not match well, hence hydrology models are needed for translation.

Process



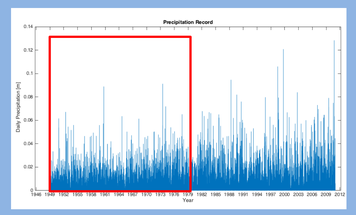


The extreme value distribution is used in a Monte Carlo Markov Chain model to generate precipitation realizations for use in a hydrology model.

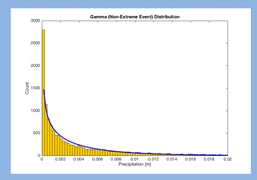
II. Weather Generator

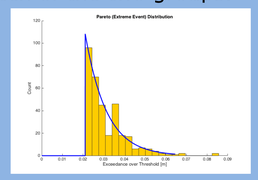
Part 1: Precipitation

A 30-year window is applied to the precipitation record, starting from the beginning of the record.

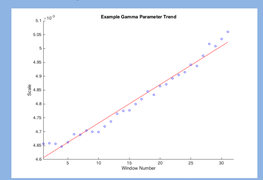


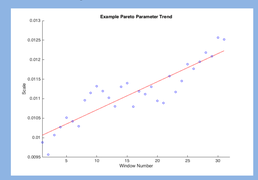
Precipitation within this window is broken up by a 95th percentile threshold. Distributions are fitted to each of the two groups.





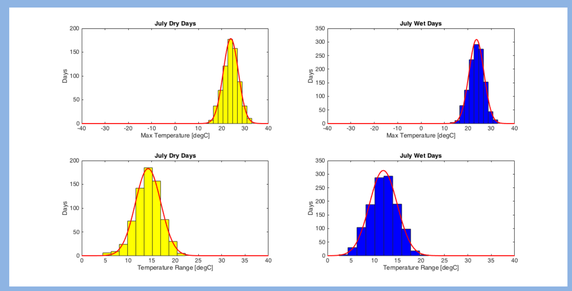
This window is advanced by one year at a time, and the process is repeated to capture trends in the distribution parameters.





Part 2: Temperature

Daily maximum and minimum temperature are broken into subsets by month. These subsets are further broken into wet and dry days. Normal distributions are fitted to each of these subsets.



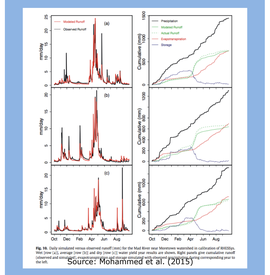
Part 3: Monte Carlo Markov Chain

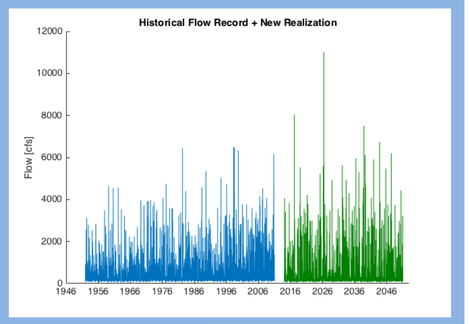
Markov Parameters (P01 and P11) are calculated for each of the 30 year windows described above. Capturing trends in these values allows for generation of future precipitation. Based upon whether a day has precipitation or not, an appropriate temperature distribution is sampled to generate minimum and maximum daily temperatures.

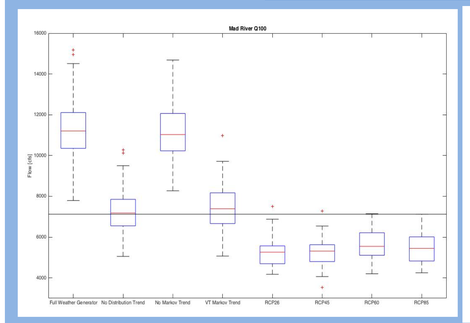
III. Results

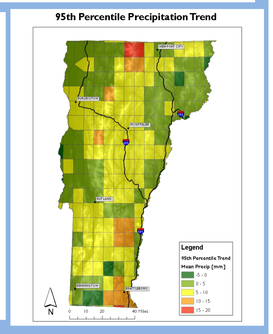
RHESSys hydrological model

The stochastic weather generator creates weather realizations, which are passed through a physics-based hydrology model, the Regional Hydro-Ecologic Simulation System (RHESSys), in order to simulate the impact of trends in precipitation on streamflow.









Example output. Results for year 2050 Q100 in the Mad River at Moretown, comparing a number of different approaches. The results show estimates of the 100-year flood magnitude using, from left to right, 1) the full weather generator MCMC model, 2) MCMC model without changing distributions and without changing Markov parameters, 3) The MCMC model with changing distributions but without Markov Chain parameter trend, 4) MCMC model without changing distributions, with Markov Chain parameter trend, 5) all CMIP5 climate model output for Representative Concentration Pathway (RCP) 2.6, 6) GCM model output using RCP 4.5, 7) GCM model output using RCP 6.0, and 8) GCM output using RCP 8.5. The horizontal black line is the Q100 as estimated using the stationary assumptions in the standard method of Log-Pearson III distribution fit using annual maxima.

Conclusions

	Q25	Q50	Q100
Mad River	1.6	1.6	1.6
Missisquoi R.	1.5	1.4	1.4

- Change factors that can be applied to design flows for the year 2050 are summarized in the above table. Approximately 50% higher design flows can be expected in the year 2050.

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