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ANALYSIS OF WEATHER GENERATORS: EXTREME EVENTS

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Abstract— **Stochastic weather generators (WGs) are often used to simulate synthetic weather time series based on observed statistical properties in a particular location. Most studies evaluate WG skill based on average properties. Our objective is to assess how the WGs performs in simulating extremes, especially high precipitation amounts. We analyzed 13 different WGs using two parallel approaches: extreme event indices associated with large precipitation events; and recurrence intervals based on the Generalized Extreme Value (GEV) distribution.**

I. MOTIVATION

Stochastic weather generators (WGs) are statistical models calibrated to resemble observed weather time series [1], [2], [3]. Like global climate models (GCMs), WGs are able to produce multiple-year climate change scenarios at a daily time scale to assess the impact of future climate change but are much less computationally demanding [4]. Precipitation, one of the most important variables generated by WGs, is usually generated using a 2-part model, one for generating precipitation occurrence and the other for generating precipitation amount. Stochastic weather generators can be based on either random sampling from parametric distributions or resampling from observations. The parametric strategy involves a formal stochastic model based on probability distributions, while the resampling approach imposes fewer constraints concerning the form of the distribution [5].

In evaluating WGs, the majority of studies have focused on moments, including mean, variance, skewness and kurtosis [6], [7], and [8]. We evaluate WG simulations of extremes, especially high precipitation amounts.

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II. METHOD

We used daily precipitation time series of Ashokan Reservoir, one of the six major reservoirs comprising New York City's (NYC) water supply, located in the Catskill Mountains, part of the eastern plateau climate region of New York State. Data was obtained from the National Climatic Data Center, NOAA. 60 years (1950-2009) of observed daily precipitation are used to calibrate WGs. The lengths of the simulated precipitation series are 600 years.

WGs evaluated here simulate precipitation using a two-step procedure. Typically, Markov chain (MC) models are used to generate sequences of daily precipitation occurrence, while random sampling from parametric, semi-parametric or nonparametric distributions is employed to generate daily precipitation amounts. We evaluated 13 WGs in this study. 12 parametric WGs include all combinations of three different orders of MC models (1st, 2nd and 3rd) and four different parametric probability distributions (exponential, gamma, skewed normal and mixed exponential), In addition we evaluate one semi parametric WG based on k-nearest neighbor bootstrapping.

Two methods are employed to evaluate the ability of WGs to simulate precipitation extremes. First, extreme event indices (Table 1) related to high precipitation amounts were estimated [9] and secondly, daily precipitation values associated with recurrence intervals of 50, 75, and 100 years were calculated based on Generalized Extreme Value (GEV) distributions that are calibrated to the annual block maxima of precipitation data for each WG and historical time series. [10].

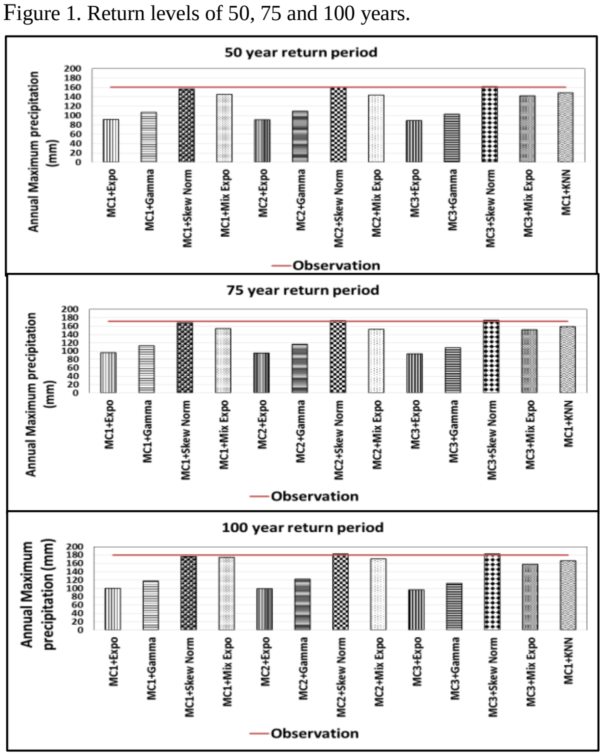
III. EVALUATION

Our evaluation of WG performance is based on the absolute errors of “extreme indices” for each WGs with respect to observation. Three-parameter (skewed normal and mixed exponential distribution) and semi-parametric (k-nearest neighbor bootstrapping) WGs are more consistent with observations for all indices. First order MC models perform as well as second or third order MC models. Evaluations of recurrence intervals (Figure1) suggest similar results.

Table I. Description of "extreme event indices".

ID	Indicator Name	Definition
CWD	Consecutive wet days	Maximum number of consecutive days with precipitation >=1mm.
R10	Number of heavy precipitation days	Annual count of days when precipitation >=10mm.
R20	Number of very heavy precipitation days	Maximum number of consecutive days with precipitation >=20mm.
RX1 day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation.
RX5 day	Max 5-day precipitation amount	Monthly maximum 5-day precipitation.
R95p	Very wet days	Annual total PRCP when precipitation >95th percentile.
R99p	Extremely wet days	Annual total PRCP when precipitation >99th percentile.

Figure 1. Return levels of 50, 75 and 100 years.



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REFERENCES

[1] Wilks, D. and Wilby, R. (1999). The weather generation game: a review of stochastic weather models. *Progress in Physical Geography*, 23(3):329–357.

[2] Ailliot P., Allard D., Monbet V., Naveau P. (2014). Stochastic weather generators: an overview of weather type model. *Journal de la Société Française de Statistique*, 156(1):101-113.

[3] Chen, J. and Brissette, F. P. (2014). Comparison of five stochastic weather generators in simulating daily precipitation and temperature for the Loess Plateau of China. *Int. J. Climatol*., 34: 3089–3105.

[4] Semenov M.A. and Barrow. E.M. (1997). Use of a stochastic weather generator in the development of climate change scenarios *Climatic Change*, 35:397-414.

[5] Furrer, E.M., and Katz R.W., (2008). Improving the simulation of extreme precipitation events by stochastic weather generators. *Water Resources Research*, W12439, doi:10.1029/2008WR007316.

[6] Chen J, Brissette FP (2014). Stochastic generation of daily precipitation amounts: review and evaluation of different models. *Clim Res* 59:189-206.

[7] Semenov MA, Brooks R, Barrow EM, Richardson CW (1998). Comparison of the WGEN and LARS-WG stochastic weather generators for diverse climates. *Clim Res.*, 10:95–107.

[8] Qian BD, Gameda S, Hayhoe H, Jong RD, Bootsma A. (2004). Comparison of LARS-WG and AAFC-WG stochastic weather generators for diverse Canadian climates. *Clim Res.*, 26: 175–191.

[9] Frich P, Alexander LV, Della-Marta P, Gleason B, Haylock M,Klein Tank AMG, Peterson T (2002). Observed coherent changes in climatic extremes during the second half of the twentieth century. *Clim Res* 19:193–212.

[10] Coles (2001). An introduction to statistical modeling of extreme values. Springer Verlag, New York, NY.