QueryMSC

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1 QueryMSC

QueryMSC is a python tool to query design values from Meteorological Service of Canada (MSC) database hosted @pacificclimate. This project is currently in development

2 Methods

Design values are physical and statistical derivations from samples of meteorological data that describe a given location's climatology and help inform the *National Building Code of Canada*. Canada has a large suite of historical meteorological data that are used to derive design values.

Most design values in this project are derived based on a description found in *National Building Code of Canada Volume 1 Appendix C*.

3 Gumbel Distribution

Some non-trivial statistical methods regarding the use of Gumbel extreme value distributions for rainfall amounts are described here.

The Gumbel distribution, also known as the Generalized Extreme Value distribution Type-I, models maximum and minimum values of extreme values. Some design values, such as *15 Min Rain* and *One Day Rain 1/50* both require a fitting of the Gumbel distribution to annual maximum 15 minute rainfall and daily rainfall at a given station. In simpler terms, it provides a statistically robust and accurate way of determining the likelihood of extreme weather events to occur within a given time frame based on a historical record of a given weather station.

The general form of the Cumulative Distribution Function (CDF) for the right-skewed Gumbel distribution is given by:

$$F(X) = e^{-e^{-(X-\mu)/\beta}}$$

Where X is a random variable with a Gumbel distribution of N elements, μ and β are the first two moments of the Gumbel distribution. The value of μ and β, in practice, are estimated by moments derived from X which will be the topic of this section.

The CDF of a distribution gives the probability of an event occurring between two values spanned by the distribution. For the purposes of Extreme Value Analysis (EVA) in climatology, extreme weather events are characterized by their *return period* (usually in years), and the probability that an event would occur once within the return period.

Let t_r be the return period in years, and then let f_r be the return frequency, and be defined as $f_r = \frac{1}{tr}$ with units of years^{-1}. It follows that the probability of an annual event occurring within t_r years is simply f_r.

We can then express the probability, $P(X)$, of having an event occur within t_r using the CDF of the Gumbel distribution, $F(X)$.

$$P(0 \leq X \leq x_v) = F(x_v) - F(0) = f_r$$

where x_v is the magnitude of the extreme weather that occurs with probability f_r. Note that $F(0)$ is the least extreme case of a given weather event.

To estimate μ and β, *L-moments* are used following the methods published by Hosking [1990]. The main motivators for using *L-moments*, as opposed to more conventional estimators, such as the *Method of Moments* found in Newark et al. [1989], is that *L-moments* are robust and resistant despite the nature of highly variable data, and very large outliers. Although *L-moments* are not completely resistant, they are more so than *mean* or *standard deviation*.

L-moments must be estimated from samples drawn from an unknown distribution, and in practice, this is done using U-statistics introduced by Hoeffding [1948].

For a Gumbel distribution, only the first two *L-moments* need to be calculated. Let N be the sample size, and X_i be the ordered sample.

$$l_1 = n^{-1} \sum_{i}^{N} X_i$$

$$l_2 = \frac{1}{2} \binom{N}{2}^{-1} \sum_{i>j}\sum (X_{i:N} - X_{j:N})$$

Then if $\hat{\xi}$ and $\hat{\alpha}$ estimate μ and β respectively, then $\hat{\xi}$ and $\hat{\alpha}$ can be expressed by

$$\hat{\xi} = l_1 - \gamma\hat{\alpha}$$

where γ is the Euler–Mascheroni constant and,

$$\hat{\alpha} = \frac{l_2}{\log 2}$$

Substituting $\hat{\xi}$ and $\hat{\alpha}$ into

$$P(0 \leq X \leq x_v)$$

gives us

$$f_r = e^{-e^{-(x_v - \hat{\xi})/\hat{\alpha}}} - e^{-e^{\hat{\xi}/\hat{\alpha}}}$$

Solving for x_v, the magnitude of the extreme weather event with probability f_r gives

$$x_v = \hat{\xi} - \hat{\alpha} \log\left(-\log\left(f_r + e^{-e^{\hat{\xi}/\hat{\alpha}}}\right)\right)$$

For a given station, each parameter in the above equation can be calculated from it's distribution of annual maximum values.

Note that the requirement $N \geq 10$ is used in order to calculate the estimators better.

References

Wassily Hoeffding. A class of statistics with asymptotically normal distribution. *Ann. Math. Statist.*, 19(3):293–325, 09 1948. doi: 10.1214/aoms/1177730196. URL https://doi.org/10.1214/aoms/1177730196.

J. R. M. Hosking. L-moments: Analysis and estimation of distributions using linear combinations of order statistics. *Journal of the Royal Statistical Society. Series B (Methodological)*, 52(1):105–124, 1990. ISSN 00359246. URL http://www.jstor.org/stable/2345653.

M. J. Newark, L. E. Welsh, R. J. Morris, and W. V. Dnes. Revised ground snow loads for the 1990 national building code of canada. *Canadian Journal of Civil Engineering*, 16(3):267–278, 1989. doi: 10.1139/l89-052. URL https://doi.org/10.1139/l89-052.