

Review HESS-egusphere-2025-3073

Climatology and trends of observed daily and hourly extreme precipitation in the French Alps

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Recommendation: acceptable after major revision.

Major Comments

The authors have carefully considered my previous comment, and have written a thorough response. Nevertheless, I disagree with the implicit assumption that the seasonal or yearly maxima should follow a GEV, and I believe the analysis they present, which discusses biases with respect to the empirical quantiles, will by construction yield better results for the seasonal and yearly GEV than for alternative estimates, since these are optimized to follow the observations. In my view, the choice of the Newton-Raphson (NR) algorithm to derive the seasonal and yearly return levels is based on theoretical considerations, just as the authors decide to use a GEV because it is theoretically the best to represent the distribution of a series of maxima, despite its occasional inability to represent observations in a convincing manner (station C2814, March, Fig. 4 of the authors' response). This being said, the authors raise practical issues that should be taken into account. I recommend keeping the seasonal return levels estimated from the seasonal maxima as they have done, but deriving the yearly return levels numerically from the seasonal maxima for reasons that I will explain below.

Theoretical Considerations

The authors point out that

$$\begin{aligned} P(\max_i(X_{1,i}, X_{2,i}, X_{3,i}) \leq x) &= P(\max_i(X_{1,i}), \max_i(X_{2,i}), \max_i(X_{3,i}) \leq x) \\ &= P(\max_i(X_{1,i}) \leq x)P(\max_i(X_{2,i}) \leq x)P(\max_i(X_{3,i}) \leq x) \end{aligned}$$

if X_1, X_2, X_3 are independent. They add that this is true, even if X_1, X_2, X_3 have different distributions. Where I disagree, however, is in the implicit assumption the authors make that $\max_i(X_{1,i}, X_{2,i}, X_{3,i})$ itself follows a GEV even if X_1, X_2, X_3 each follow a different GEV distribution.

Let us assume that $Z_1 \sim \text{GEV}(\mu = 10, \sigma = 1, \xi = -0.1)$, and $Z_2 \sim \text{GEV}(\mu = 10, \sigma = 1, \xi = 0.2)$.

Then, sampling 40000 times from each distribution, and taking the maxima thereof, we see in Figure 1 that $Z_3 = \max(Z_1, Z_2)$ differs from the GEV estimated from $\max(Z_1, Z_2)$.

theoretical return level curves for each sample

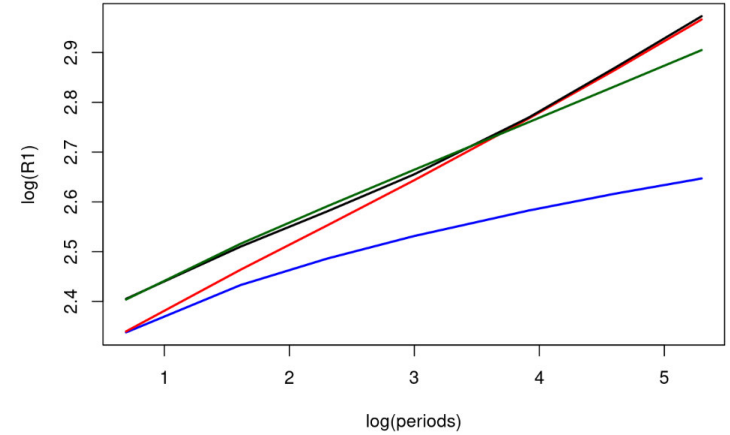


Figure 1: theoretical return level curves. Blue: Z_1 , red: Z_2 ; black: $Z_3 = \max(Z_1, Z_2)$; green: GEV estimated from Z_3 . Sample size: 40000.

We can now put ourselves in the situation of an observer who samples n values $X_1 = \{X_{1,1}, \dots, X_{1,n}\}$ from Z_1 in month 1, and n values $X_2 = \{X_{2,1}, \dots, X_{2,n}\}$ from Z_2 in month 2, then uses the observations $X_3 = \max(X_1, X_2)$ to estimate the distribution of maxima over both months. We simulate this situation $N = 1000$ times.

Possible estimators of the quantiles of X_3 are the empirical quantiles of X_3 , the quantiles of the GEV estimated from X_3 , which we will call $GEVX_3$, and the quantiles derived numerically from X_3 with a Newton-Raphson algorithm using the GEV estimates for X_1 and X_2 , which we will call NRX_1X_2 .

The question is: which estimator should the observer use to estimate the return levels of Z_3 .

The return level plots for a large sample ($n = 300$) and for a more realistic one ($n = 40$) are shown in Figure 2. We can see that NRX_1X_2 (in purple) yields the closest quantiles to those of the true distribution Z_3 (in black), and that $GEVX_3$ (in green) tends to underestimate the true quantiles at large return periods. For return periods below 20 years, NRX_1X_2 and $GEVX_3$ are rather close, especially if the sample of observations only covers $n = 40$ years. The bias with respect to Z_3 is examined in Figure 3 for a return period of 20 years, as used in the authors' manuscript. Again, for small observation samples, and for low return periods, the $GEVX_3$ and NRX_1X_2 perform similarly. Also, the spread in the return level estimates over the $N = 1000$ size sample means that indeed, an observer will run into cases in which the error in the estimation of the shape parameter of X_2 (in our particular case) propagates strongly into the estimation of X_3 via the Newton-Raphson algorithm (see Figure 4, left). Of course, there will also be individual cases in which NRX_1X_2 will be a better estimate than $GEVX_3$ (see Figure 4, right).

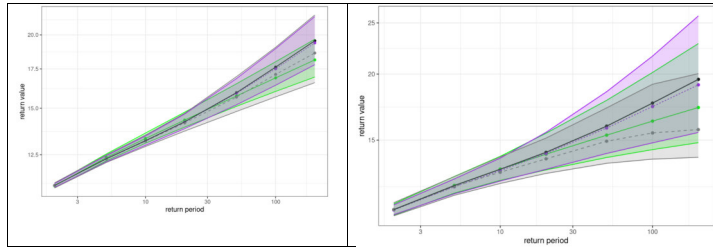


Figure 2: return level plot of the truth (Z_3 , black) and its three estimators for $n = 300$ years (left panel) and $n = 40$ years (right panel). The uncertainties are obtained by drawing observation samples $N = 1000$ times. Grey: empirical distribution X_3 ; green: GEV estimated from X_3 ; purple: quantiles derived by NR from the GEV distributions estimated from X_1 and X_2 .

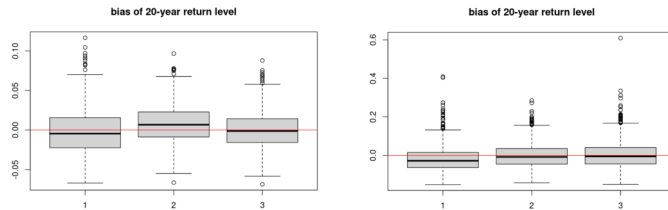


Figure 3: bias (estimator - truth)/truth of the 20-year return level for $n = 300$ years (left panel) and $n = 40$ years (right panel), each drawn $N = 1000$ times. Within each panel, the boxplots represent the empirical estimator (left), the GEV of $X_3 = \max(X_1, X_2)$ (middle), and the NR derivation of $\max(X_1, X_2)$ from the GEV distributions estimated from X_1 and X_2 (right).

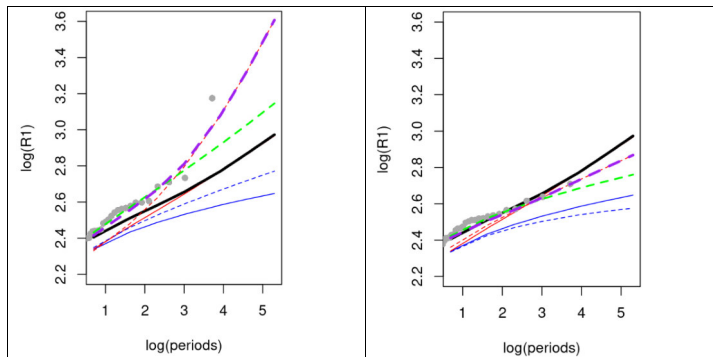


Figure 4: return level plots in two individual cases with observations (grey dots) over $n = 40$ years. Color coding as in Fig. 1 with dashed lines for estimates from the observed samples. Left: case of strong error propagation caused by a poor estimation of X_2 . Right: case in which both NRX_1X_2 and $GEVX_3$ underestimate the true distribution, but NRX_1X_2 is closer.

Obviously, the results presented here depend on the initial choice of GEV parameters for Z_1 and Z_2 . How close or how far the $GEVZ_3$ is to the truth varies if these parameters are changed. For instance, if the location parameters are far apart for the same choice of the scale and shape parameters, the results are entirely dominated by the distribution with a heavy tail (Z_2), and $GEVZ_3$ and Z_3 are essentially the same. If the location parameters are close or the scale parameters far apart, differences in $GEVZ_3$ and Z_3 appear already at relatively low return periods.

Seasonal non-stationarity

In Figs. 4 and 7, the authors present the stationary 20-year return levels month by month, in an effort to illustrate the gradual effects of the seasonal cycle. This suggests that there is a difference in the GEV distributions from month to month. And yet, by assuming that the seasonal maxima follow a GEV, they implicitly assume a common distribution over the season. This contradiction should be smoothed by addressing it in the text.

There is no way to know whether the differences in distribution are simply the result of a poor estimation of the GEV due to an unfortunate sample of observations, or whether they are the consequence of a physical difference in processes. Here, I believe the authors have, in their analysis of weather types, independent information to corroborate their implicit claim that the months of a season are samples issued from the same distribution. If we believe that weather types imply different processes for precipitation, Figs. 4, 6, and 7 of the manuscript may perhaps be used as an indicator for similar processes over subsequent months, albeit not always in the orderly 3-month sequence the authors could wish for. I recommend the authors use this, if possible, to cement their choice of the seasonal division and the estimation of the seasonal return levels with a GEV. By the same token, we cannot expect the maxima in the different seasons to follow the same GEV, and therefore, the yearly return levels should be derived numerically from the seasonal GEVs. This carries consequences for the estimation of the trends in yearly return levels, which must be based on return levels that are, they too, derived numerically, year by year, from the seasonal GEVs.

A further argument for estimating the seasonal maxima with a GEV is that the seasonal maxima themselves are determined from a larger set of values, which should lead to more reliable estimates of the seasonal return levels. Also, the numerical derivation of the seasonal return levels with NR from the monthly GEVs is very sensitive to the monthly GEV estimates, as can be seen in Figure 4 above. As discussed by the authors, this results in error propagation that the authors, with good reason, wish to avoid.

Recommendations

In summary, I recommend the following:

- Estimate seasonal return levels assuming that the seasonal maxima follow a GEV (as already done in the manuscript).
- Estimate yearly return levels from seasonal GEV distributions, both in the (long-term) stationary analysis, and year by year in the (long-term) non-stationary analysis as a basis for the estimation of trends.
- Add a paragraph in the Method description.
- Discuss briefly the ability of weather types to indicate differences in processes, and eventually justify the grouping of the months into seasons.