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R-tools for estimating exceedance probabilities of Envelope Curves for hydrological extremes

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Motivation

Flood quantiles, i.e. discharges and corresponding estimated recurrence intervals, are needed for hydrological research and applications.

Envelope curves graphically represent the upper bound of extreme floods in a region. The traditional empirical approach was enhanced by Castellarin et al. (2005) by introducing the method of Probabilistic Regional Envelope Curves (PREC).

Under the assumption of homogeneous region (index-flood hypothesis), PRECs assign a recurrence interval T to the regional envelope curve. A flood quantile can then be calculated for group of sites as a function of the catchment area. The estimation of T considers intersite correlation and is based on the effective sample years of data.

Actual utilization of PRECs is still somewhat limited:

(1) the application may seem cumbersome

(2) lack of an open source PREC-code.

A collection of R-tools is presented herein.

Input data

Two synthetic discharge datasets H02 and H06

- Variations in their degree of homogeneity
- Cross-correlation among discharge series of 0.2 and 0.6

Two types of input data with a matrix structure are required as shown in Tab. 1 and 2

Tab. 1: Example for region_reg_syn.txt

Site_id	Region	Area [km²]	X	Y
35	1	5179.7	174745.2	196985.6
36	1	2514.7	152761.8	267354.8
...				

Regional_statistic.R

- Estimation of statistical values for the region, e.g. unit maximum flood

Tab. 2: Example for ams_reg_syn_06.txt

	35	36	
1932	68.6	NaN	...
1933	67.6	34.5	
...	...	...	...

Homogeneity testing

- Heterogeneity measure by Hosking and Wallis
- H_1-test = Variability of sample L-CV with expected values from Monte-Carlo simulations

Hw_region.r

- Construction of two vectors with AMS values and with related sites-id.
- HW.tests from R-package nsRFA (Viglione, 2012) (Tab. 4)

Tab. 3: HW-test for region H02 and H06

Region	H02	H06
H_1	1.11	-0.24
H_2	0.31	-1.49
H_3	1.02	-1.89

Regional cross-correlation function

Coordinates.r

- Distances between centroids of all pairs of catchments

Correl.r

- Correlation between discharge time series of all pairs of catchments

Crosscorr_vectors.r

- Vectors with distances, cross-correlation and number of overlapping years for all sites

ts_model.r

- Cross-correlation ρ as a function of the distance *d* (Tasker and Stedinger, 1989) with parameters λ_1 *and* λ_2
- Applied for PRECs in Castellarin (2007) and extended in Guse et al. (2009)
- $\rho = exp\left(\frac{\lambda_1 * di_j}{1+\lambda_2 * di_j}\right)$
- Optimisation of λ_1 *and* λ_2

Crossdist.r

- Construction of cross-correlation plot (Fig. 1)

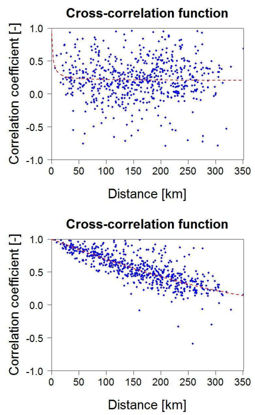

Fig. 1 (crosscorr.jpg): Example of cross-correlation function for region H02 (above) and H06 (below) optimised to pairs of correlation coefficient and distances: sample cross-correlation coefficients (blue dots); optimised Tasker and Stedinger model (red dashed line)

Probabilistic envelope curves

Regional envelope curves bounds all maximum unit discharges (floods of record)

REC_parameters.R

- Slope = regression line of mean of AMS
- Intercept = upshift of regression line up to largest unit flood of record (maximum unit discharge)

QREC_estimates.R

- Estimation of upper bound discharge for all sites

REC_plot.r

- Construction of regional envelope curve (Fig.2)

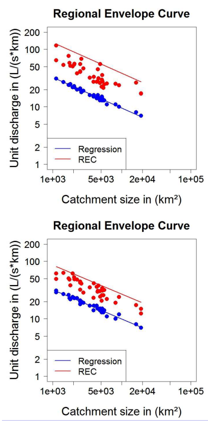

Fig. 2 (REC.jpg): REC for regions H02 (above) and H06 (below)

Effective sample years of data

Effective_sites.r

- Empirical relationship by Castellarin (2007)
- $n_{eff} = n_1 + \sum_{s=1}^{Y_{sub}} n_{eff,s} = n_1 + \sum_{s=1}^{Y_{sub}} \frac{L_s * l_s}{1+\overline{[\rho^{\beta}]}_{L_s} * (L_s+1)}$
- with $\beta := 1.4 * \frac{(L_s * l_s)^{0.176}}{\overline{[(1-\rho)^{0.376}]}_{L_s}}$
- Years n_1 with one observation are effective
- Remaining years are subdivided into subsets Y_{sub} with same number of sites L_s with length l_s
- Estimation of effective sample years of data $n_{eff,s}$ for all subsets s
- Summing up of n_1 and $n_{eff,s}$ for all Y_{sub} to n_{eff}

Recurrence interval T:

- Estimation of T for the largest unit flood of record
- Twice as high as n_{eff} (Hazen formula) (Castellarin, 2007): $T = 2 * n_{eff}$

R-list-structure

R-list: PREC

- PREC$input_data: Input data
- PREC$intermed: intermediate results
- PREC$result: final results

Output

PREC_results.txt

- The results of each region are saved in one file (Tab. 4)

Tab. 4: PREC output for region H02 and H06

Region	H02	H06
Number of sites	36	36
Total observations	2065	2065
Single observations	3	3
Different subsets	45	45
Number of effective sites	1763.39	460.29
Recurrence interval	3526.79	920.58
Intercept	3.11	3.02
Slope	-0.53	0.51

Outlook

- Check of the R-tools with other data sets
- Preparation of the rPREC Package

References and acknowledgements

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