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Qualitative and quantitative uncertainty in regional rainfall frequency analysis

Key words: qualitative uncertainty, uncertainty analysis, NUSAP method, regional rainfall frequency analysis, Pedigree matrix, diagnostic diagram

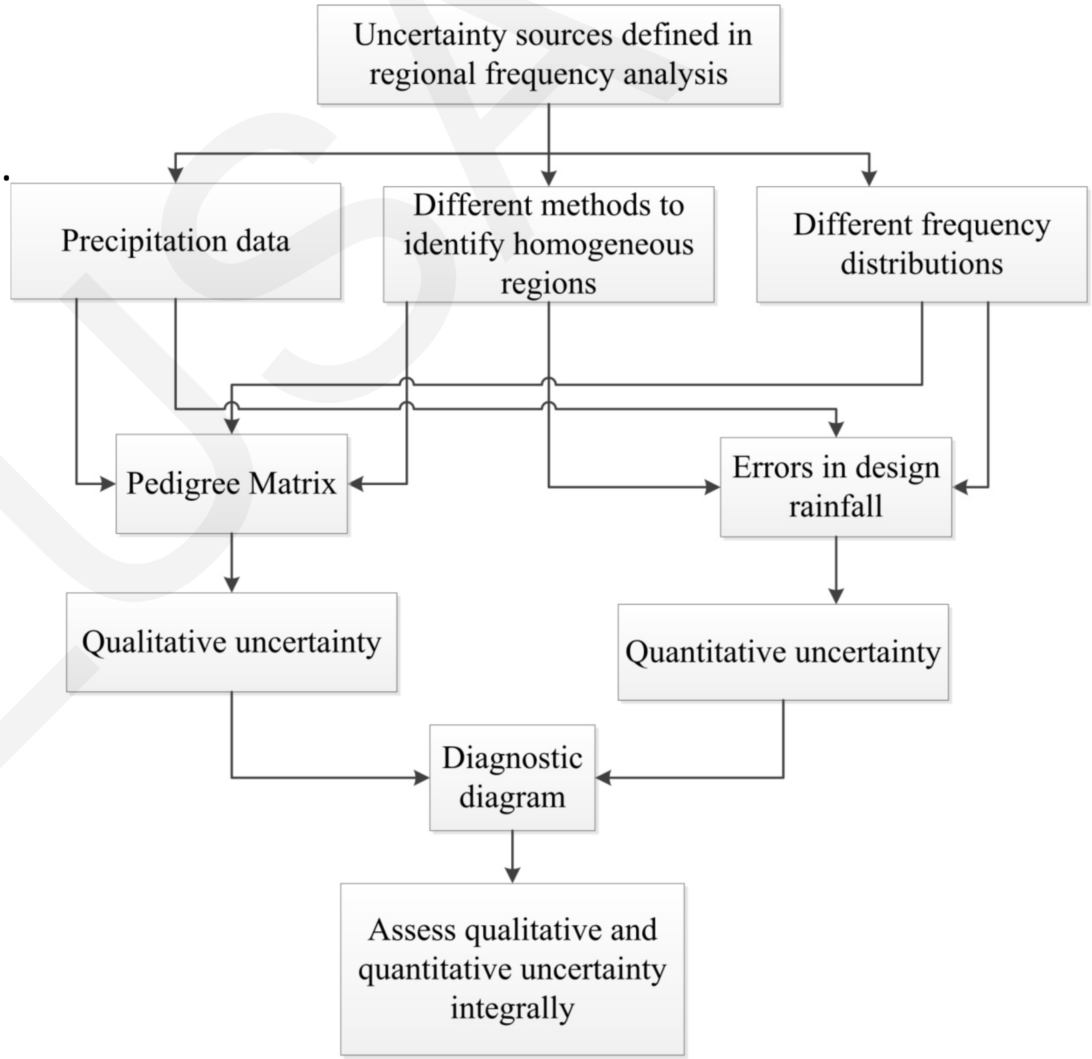
Methodology

1. Uncertainty sources in regional frequency analysis are firstly identified.

2. Pedigree Matrix, particularly designed for regional frequency analysis, is used to quantify the qualitative uncertainties

3. The impact of measurement errors in precipitations (quantitative uncertainty) is analyzed by using Latin Hypercube simulation.

4. Qualitative and quantitative uncertainties are then assessed integrally by diagnostic diagram.



Results

Table 1 Uncertainty sources of regional rainfall frequency analysis (RFA)

RFA process	Uncertainty from hypothesis	Uncertainty from method	Uncertainty from data
Precipitation data	Strictly controlled process of measurement; calibrated measuring instruments	Differences in measurement errors from different measurement methods	Insufficient precipitation stations and precipitation data series; unavoidable factors, e.g. climate change
Identification of homogeneous regions	Independent precipitation stations; unrelated precipitation series	Prediction errors from different methods to define homogeneous regions; different methods to test homogeneity of the grouped regions.	Measurement error from precipitation data; different methods to select precipitation data series
Choice of a frequency distribution	Robust models; samples excellently fitted to the selected distributions	Different frequency distributions, such as GEV, PE3 and GLO	Measurement errors from precipitation data; different methods to select precipitation data series
Parameter estimation	Precipitation data series fit to the distribution defined by the parameters	Different parameter estimation methods, such as L-moment and maximum likelihood method	Measurement errors from precipitation data; different methods to select precipitation data series
Index-variable method	Design rainfall calculated with the annual maximum precipitation series	Methods to calculate regional design rainfall other than index flood method	Uncertainty from selecting annual maximum precipitation; methods to deal with outliers
Error propagation	Completely randomly sampling	Different sampling methods, e.g. MCMC and LHS	Errors of precipitation (the propagation of quantity errors); uncertainty in defining values of Pedigree Matrix (the propagation of quality errors)

Table 2 Pedigree Matrix for regional frequency analysis

Score	Statistical quality	Empirical quality	Methodological quality
4	Excellent fit to a well-known statistical model (GEV, GLO, PE3 and so on)	Uniformly and reasonably distributed precipitation stations; strictly controlled measurement and calculation; enough direct measurements (N≥50)	RFA methods (e.g. methods to delineate homogeneous regions and methods to calculate design rainfall) in well-established discipline
3	Good fit to a reliable statistical model by most fitting tests, but not all	Well distributed precipitation stations; uncontrolled measurement and calculation; small sample direct measurements (N＜50)	Reliable and common method within established discipline or best available in immature discipline
2	Fitting tests not significant, model not clearly related to data, or model inferred from similar data	Sparsely and unreasonably distributed precipitation stations; uncontrolled measurement and calculation; indirect measurements	Acceptable methods but limited consensus on reliability
1	Distributions are chosen subjectively without using test fitting experiments	Educated guesses indirect approx; rule of thumb estimates	Preliminary methods with unknown reliability
0	Unknown models	Crude speculation	No discernible rigor

Table 3 Integrated uncertainty assessment

Number	Unit	Spread	Pedigree score	Strength
Precipitation data	mm	13.05%	（3.8，3.5，3.6）	0.91
GEV(Down Sub-region)	mm	7.02%	（3.5，3，3.5）	0.83
GLO (Down Sub-region)	mm	8.26%	（3，3，3.5）	0.79
P3 (South Sub-region)	mm	4.25%	（3.8，3，3.5）	0.86
LN3 (South Sub-region)	mm	15.49%	（3，3，3.5）	0.79
GEV (North Sub-region)	mm	3.21%	（3.8，3，3.5）	0.86
LN3 (North Sub-region)	mm	6.36%	（3.6，3，3.5）	0.84
Geographic grouping method	mm	19.05%	（3.8，3，2.8）	0.8
Cluster analysis	mm	21.23%	（3.8，3，3.0）	0.82

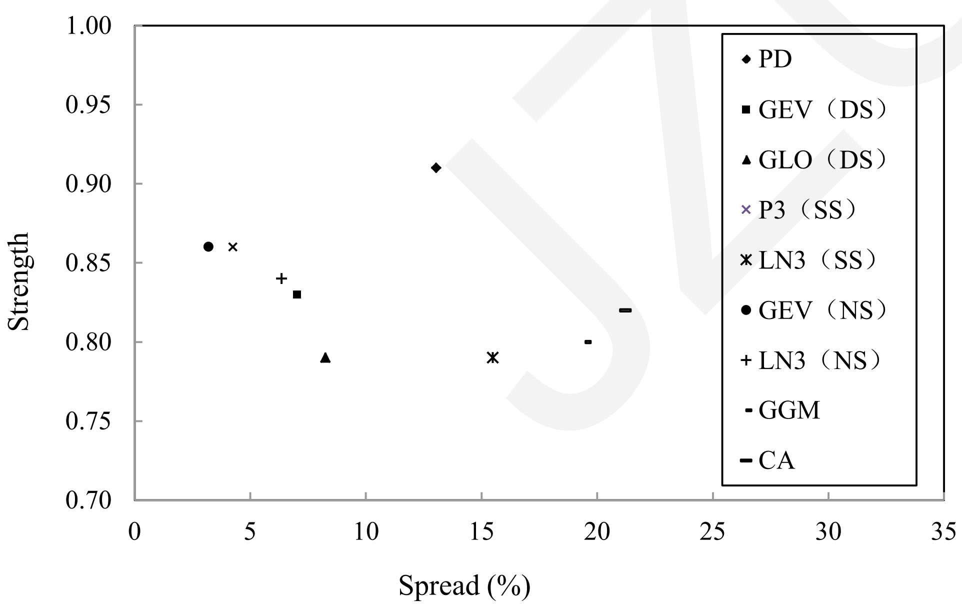


Fig. 1 Integrated diagnostic diagram of uncertainty (PD indicates Precipitation Data; DS, SS, and NS indicates Downstream, South, North Sub-regions respectively; GGM indicates Geographic Grouping Method; CA indicates Cluster Analysis.

Conclusions and discussion

Conclusions:

1. The proposed NUSAP method was proved to be effective in evaluating both the qualitative and quantitative uncertainty of regional frequency analysis.

2. The diagnostic diagram is a helpful tool for decision-makers to have an overview of the quality and quantity of data source, methods or models employed within the regional frequency analysis.

Discussion

1. Although the pedigree matrix is used to code qualitative expert judgments for minimizing the arbitrariness and subjectivity in measuring strength, much more efforts should be done (e. g. formal questionnaires).

2. Limited data, methods and models were used in this case study for illustration of the NUSAP method, which resulted in an underestimation of uncertainty in regional frequency analysis.