Predictive performance of flood frequency analysis approaches: a national comparison based on an extensive French dataset

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Introduction: Flood Frequency Analysis (FFA)

Importance of FFA in engineering

Central in risk assessment and management:

- Design of civil engineering structures
- Inundation maps

An abundance of approaches

- Local estimation of a distribution
- Regional implementations
- Continuous simulation approaches

Objectives

Compare the predictive performance of FFA implementations

- Presentation of the comparison framework
- Application to an extensive dataset of French stations

A data-based comparison framework [1]

Spirit of the game

General principles

Focus is on **predictive** (as opposed to descriptive) performance => split-sample evaluation

Would you rather build a dam that will withstand upcoming floods, or one that would have withstood past floods?

Should be applicable to any FFA family (local, regional, mixed local-regional, continuous simulation)

Complements (but not replaces!):

Monte-Carlo evaluations

The truth is known, but how realistic is the Monte-Carlo setup?

Statistical testing

Tests not available for many implementations

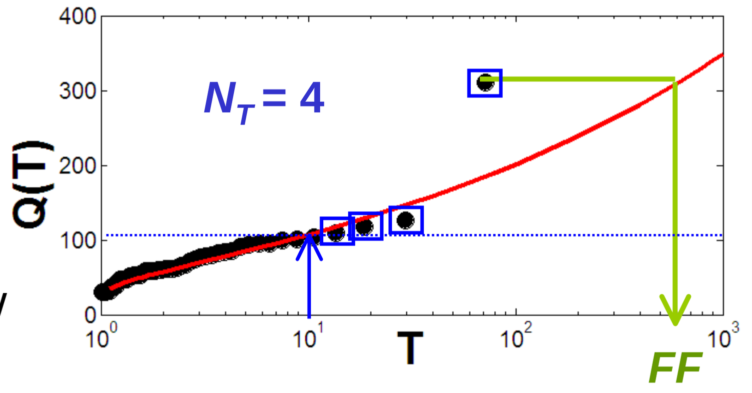
⚠ *General-purpose tests exist, but they assume known parameters!*

Rules of the game

Compute on validation data:

N_T : number of exceedances of the estimated T-year flood

FF : non-exceedance probability of the largest observation



For a reliable implementation:

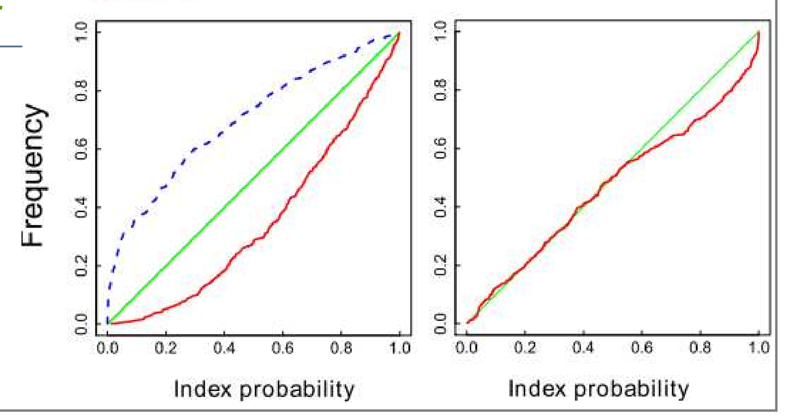
$N_T \sim Bin(n,1/T)$, $pr(FF \leq z)=z^n$

Repeat on many sites…

… and evaluate adequacy with the theoretical distribution

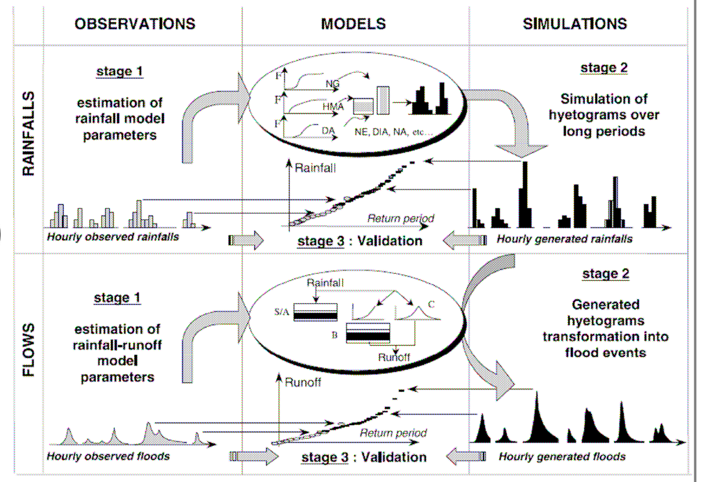
Note: due to its discrete nature, a "randomization" trick is required for N_T

Tendency to over / under estimation — Predictive failures



Application: FFA implementations in France

Competing teams

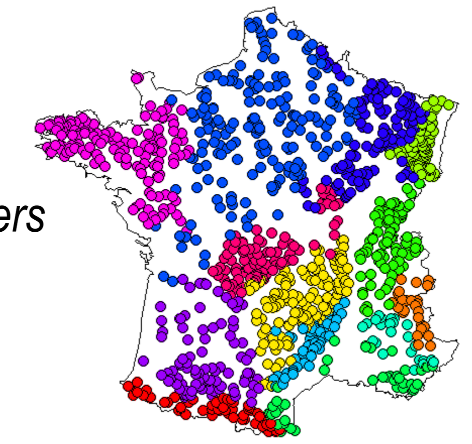


The local league: using at-site data only

1. Gumbel distribution (LOC_GUM)
2. GEV distribution (LOC_GEV)
3. A continuous simulation approach: SHYPRE [2]

The regional league: estimation at ungauged sites

Hydro-eco-regions



1. Gumbel distribution (REG_GUM)
2. GEV distribution (REG_GEV)
3. SHYREG, regionalized version of SHYPRE

1-2: Region-specific regressions between parameters and covariates (Catchment size, 10-year rainfall, mean elevation, drainage density) [3]*. Constant shape parameter for GEV*

The local-regional league: at-site estimation using regional information

1. Gumbel distribution (L+R_GUM)
2. GEV distribution (L+R _GEV)

Bayesian approach, prior = regional, likelihood = local [4]

Data

1076 stations, 20 years +

Catchment size: 10-2000 km²

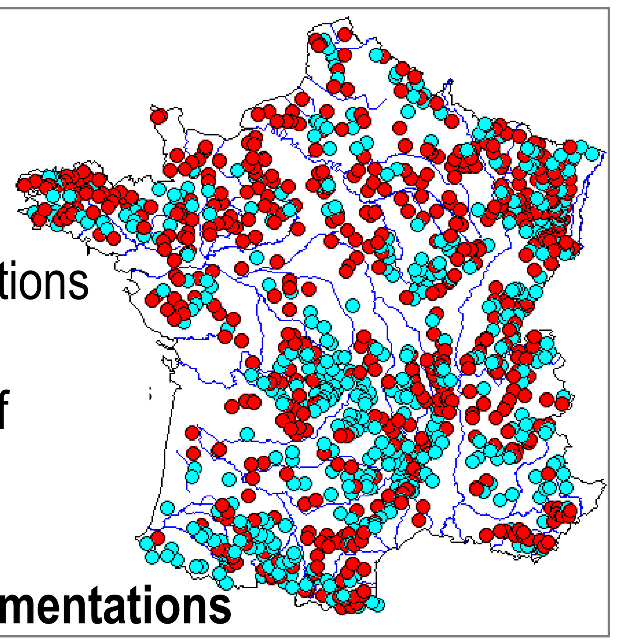
Calibration-validation decomposition

Red: calibration of regional implementations

Blue (>40 years):

- 20 years (random) = calibration of local implementations
- All remaining years = validation

Validation data identical for all implementations



Results: comparison of FFA implementations in France

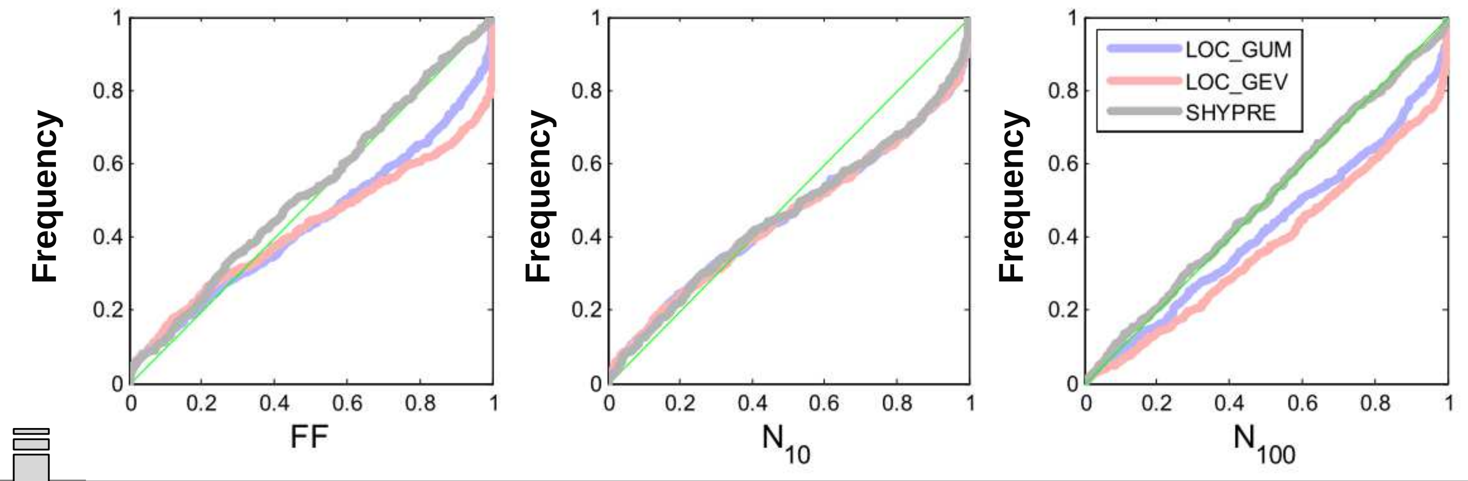
The local league

SHYPRE is the most reliable

Especially for high quantiles, cf. indices FF and N_{100}

Poor performance of locally-estimated GUM/GEV

Especially GEV: for 20% of stations, what is considered as "impossible" actually occurs in validation!



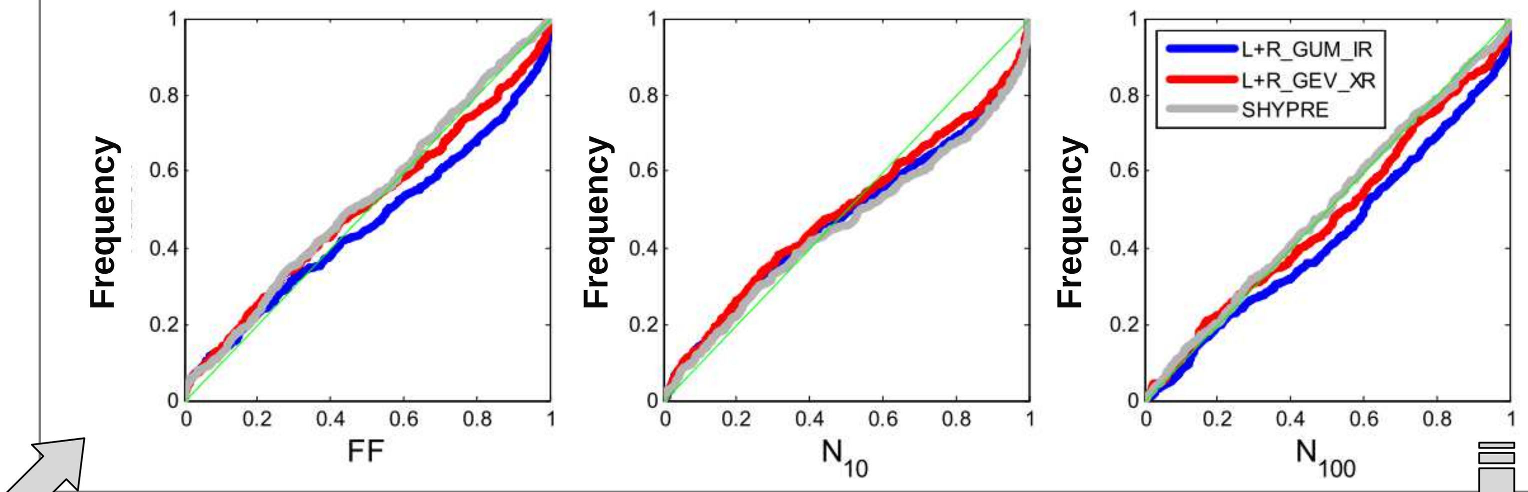
The local-regional league

All implementations fairly reliable

SHYPRE ~ L+R_GEV

L+R_GUM less reliable

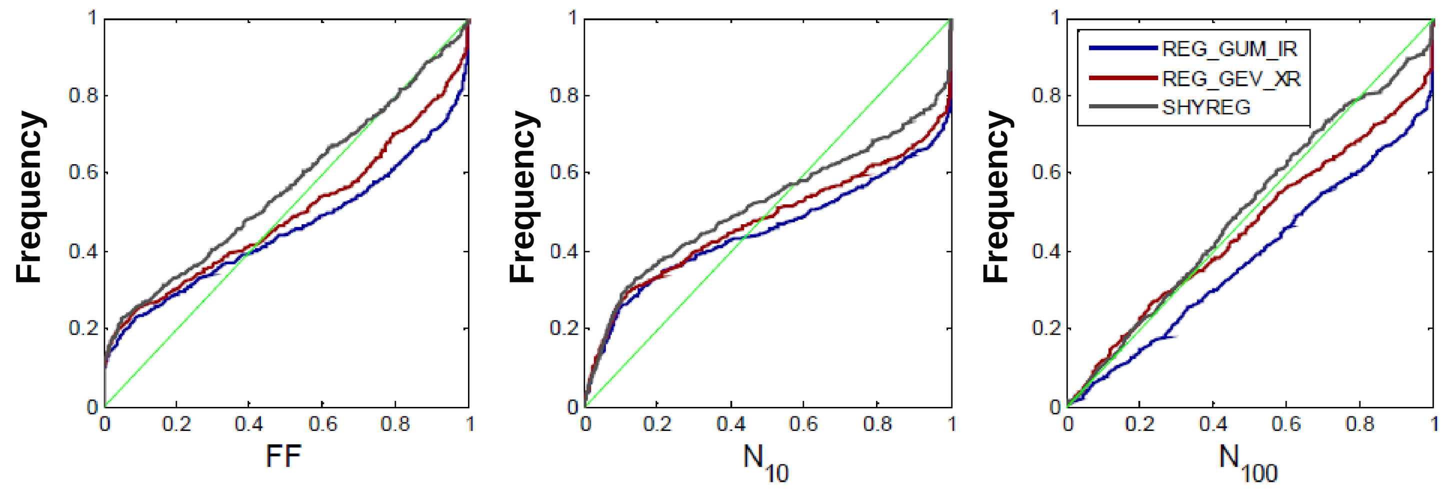
In particular, note the clear improvement for the GEV distribution, compared with both purely local and purely regional estimations



The regional league

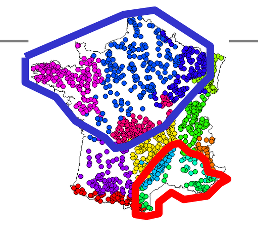
Reliability is poor for all implementations

SHYREG most reliable, REG_GUM least reliable



Results by climatic area

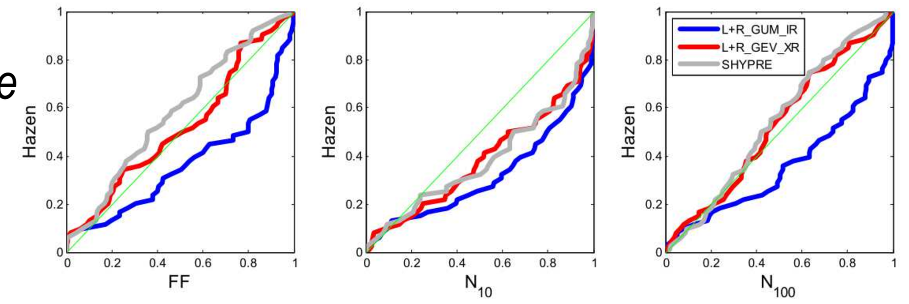
Marked regional differences



Mediterranean:

- *GUM clearly inappropriate*
- *SHYPRE ~ L+R_GEV*
- *Slight over-estimation for SHYPRE?*

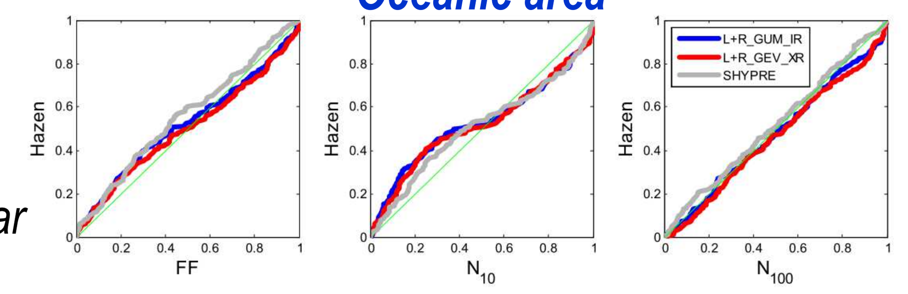
Mediterranean area



Oceanic:

- *No evidence that GUM is inappropriate*
- *All implementations similar*

Oceanic area



Conclusions

Main conclusions

- Two winners: SHYPRE and L+R_GEV
- The reliability of regional implementations is in general quite poor
- Purely local estimation of a GEV distribution is dangerous

Using more information…

- In general, purely local implementations are not sufficiently reliable
- Benefit of additional information: rainfall (SHYPRE) or regional (L+R_GEV)
- Perspective: combine more diverse sources of information

[1] Renard, B., et al. **2013**. Data-based comparison of frequency analysis methods: A general framework, Water Resources Research, 49

[2] Arnaud, P., and J. Lavabre. **2002.** Coupled rainfall model and discharge model for flood frequency estimation, Water Resources Research, 38(6).

[3] Cipriani, T., T. Toilliez, and E. Sauquet. **2012.** Estimating 10 year return period peak flows and flood durations at ungauged locations in France, La houille blanche

[4] Ribatet, M., et al. **2006.** A regional Bayesian POT model for flood frequency analysis, Stoch. Environ. Res. Risk Assess., 21(4)

Acknowledgments. This work was funded by the French Research Agency (ANR) through the project EXTRAFLO (https://extraflo.cemagref.fr/)