REGIONE PUGLIA

REGIONE PUGLIA REPUBBLICA ITALIANA

COMMISSARIO di GOVERNO
PRESIDENTE DELLA REGIONE
delegato per la mitigazione del rischio idrogeologico nella Regione Puglia

asset — AGENZIA REGIONALE STRATEGICA PER LO SVILUPPO ECOSOSTENIBILE DEL TERRITORIO

Con la co-organizzazione:

OIBA — ORDINE DEGLI INGEGNERI della Provincia di Bari

ORDINE DEGLI ARCHITETTI, PIANIFICATORI, PAESAGGISTI E CONSERVATORI DELLA PROVINCIA DI BARI

ORDINE DEI GEOLOGI DELLA PUGLIA

Politecnico di Bari

STRATEGIE RESILIENTI DI CONTRASTO AL DISSESTO IDROGEOLOGICO

2^ Edizione

Scenarios and perspectives in the evaluation of hydraulic risk

V. Iacobellis

Venerdì 24 gennaio 2020 | Politecnico - Aula Magna *Attilio Alto* - Via Orabona 4, BARI

What is Flood Frequency Analysis (FFA)?	**A technique used for predicting flow values corresponding to specific return periods or probabilities along a river**
How is it performed?	**The estimation of a design flood for a given site is implemented fitting a probability distribution to a record of peak flows. This allows to achieve parameters and quantiles estimates.**
What probabilistic distributions are used?	**Tipically, the use of two- or three-parameter distributions is exploited. Gumbel, Log-normal, Generalized Extreme Value and Log-Pearson type III are the most diffused distributions**

Extreme Value Theory

Case Study

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are the most diffused distributions

Extreme Value Theory

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What pro
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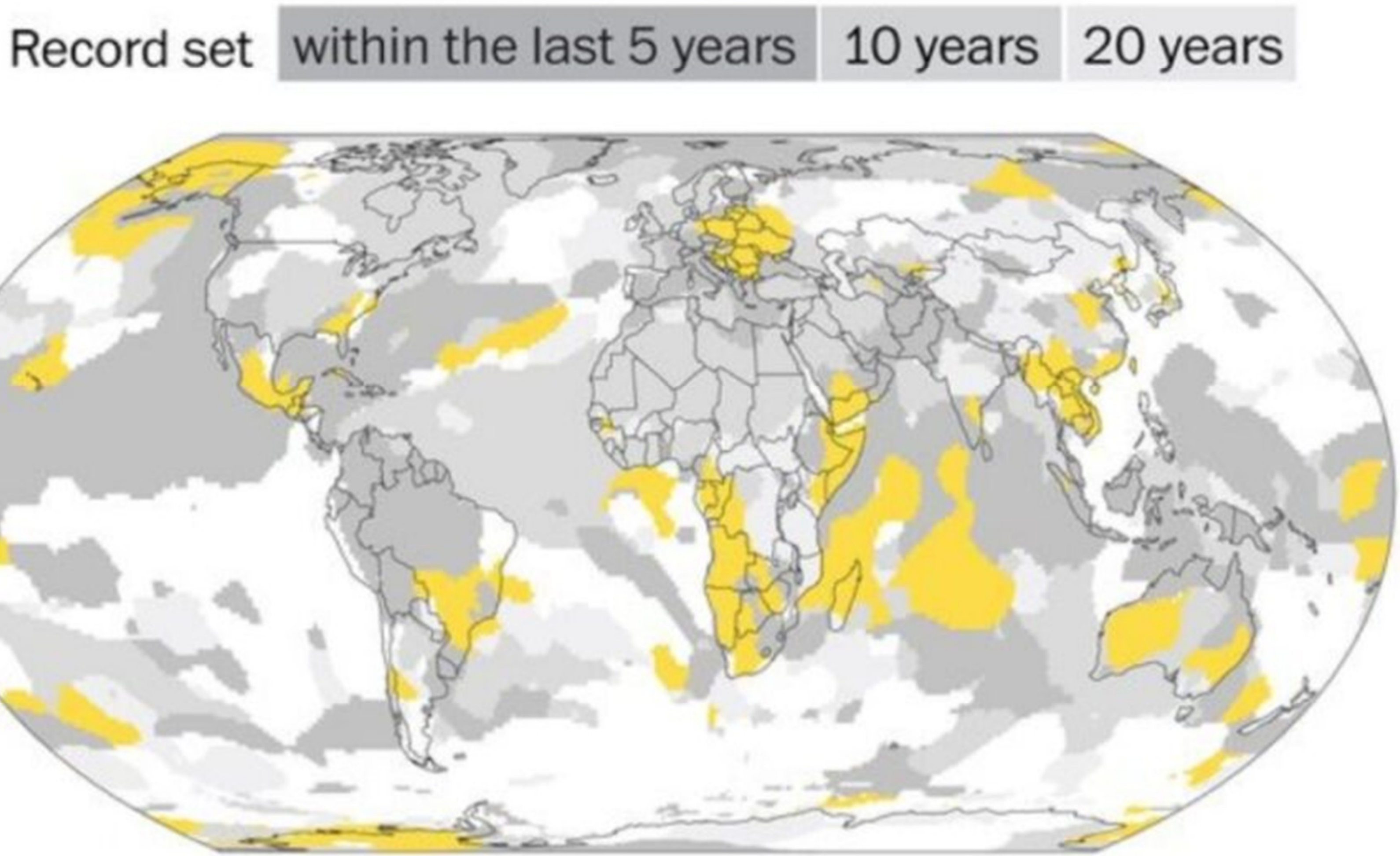
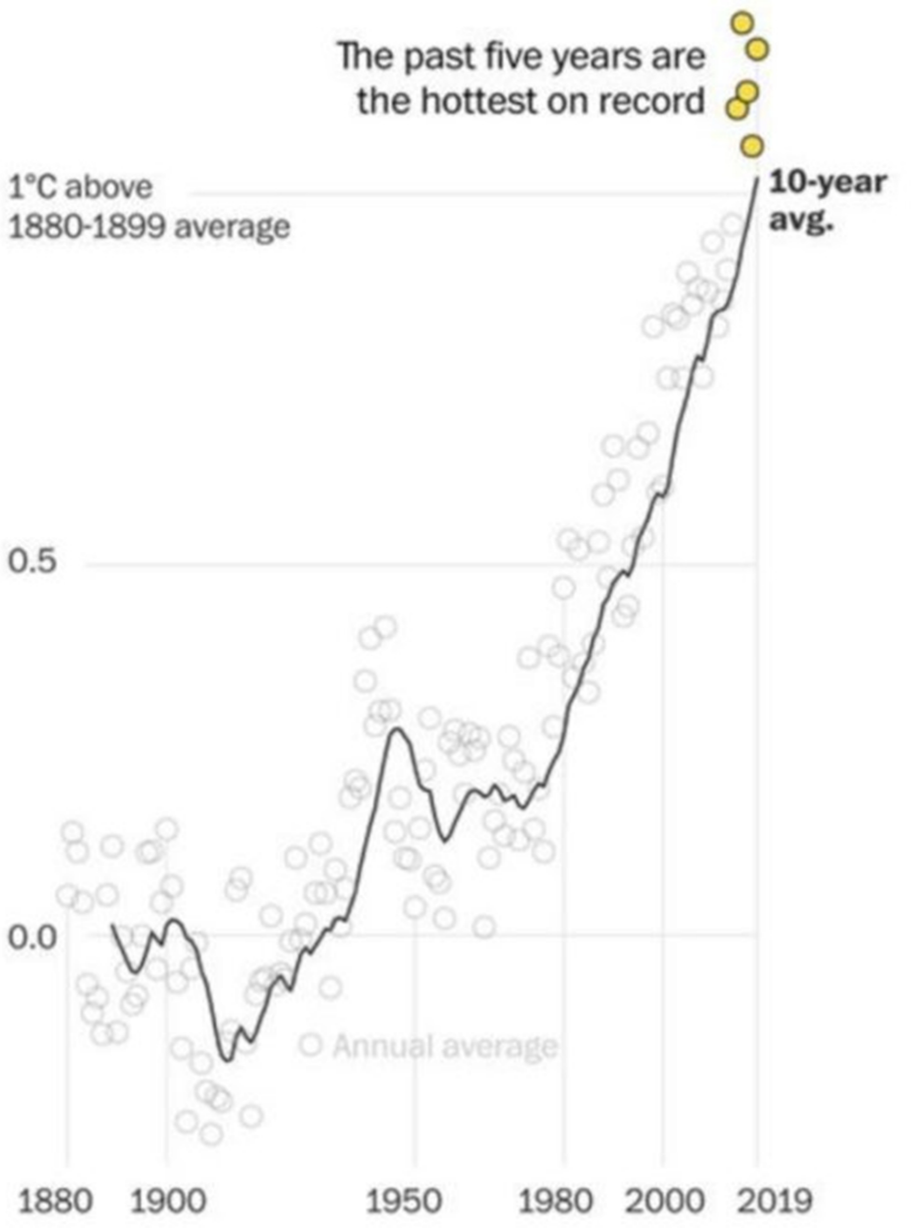
are the most diffused distributions

A global perspective:

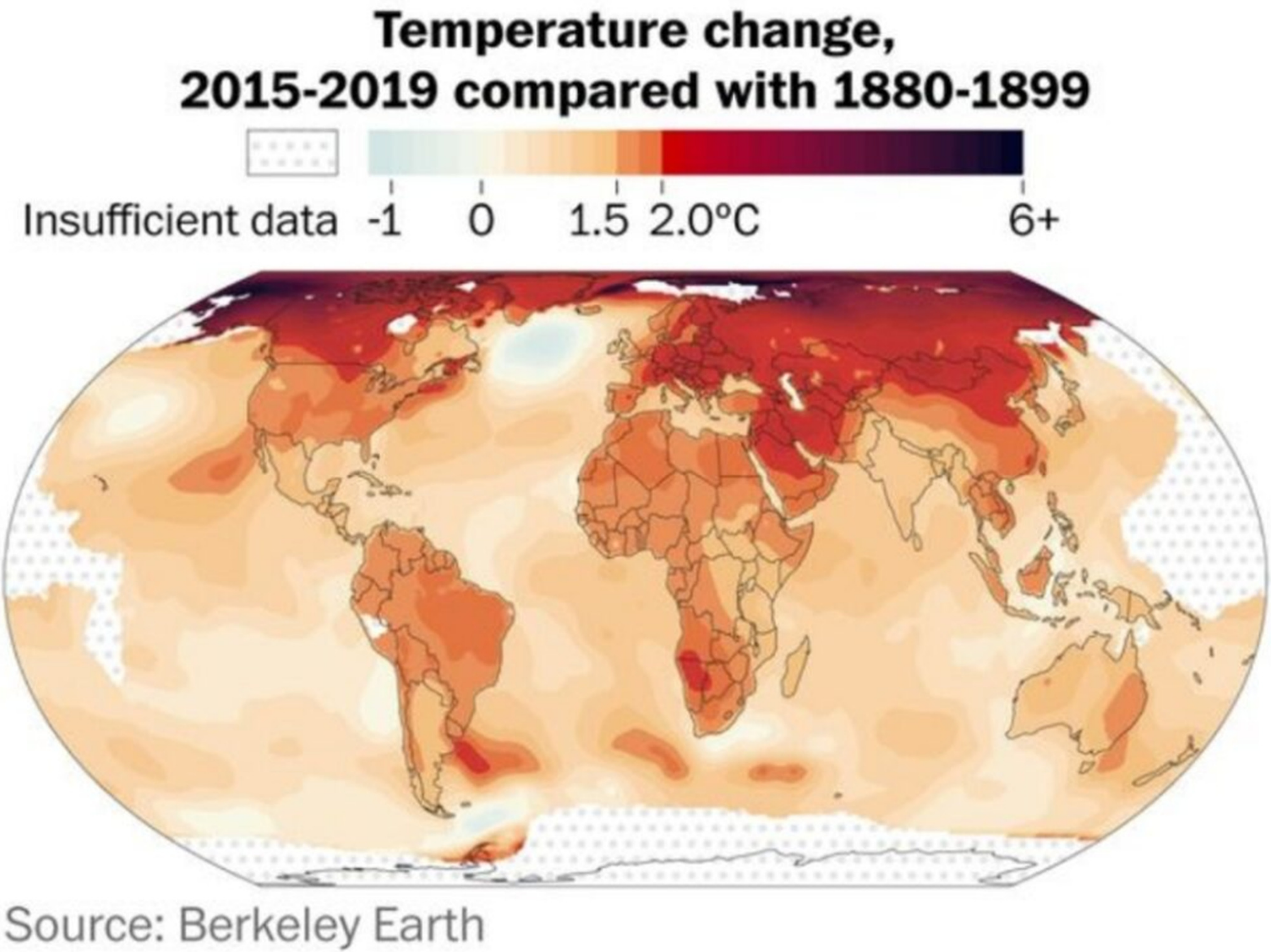
For 10% of the planet, 2019 was the hottest year on record



Source: Berkeley Earth



Source: NASA's Goddard's Global Surface Temperature Analysis (GISTEMP)


Temperature change,
2015-2019 compared with 1880-1899
Insufficient data
-1
0
1.5
2.0°C
6+
Source: Berkeley Earth

Another global perspective:

PROPHETS OF DOOM

Trump compared climate-change activists to “radical socialists” at Davos

By Isabella Steger in Davos, Switzerland • 1 hour ago

In the meantime…

«Our house is on fire»

Greta Thunberg, World Economic Forum, Jan 2019

Image by Anthony Hearsey

made from data from NASA's FIRMS between 05/12/19 – 05/01/20.

These are all the areas which have been affected by bushfires.

Inicio › Mundo › En Angola hay más incendios que en el Amazonas

Noticias Mundo

EN ANGOLA HAY MÁS INCENDIOS QUE EN EL AMAZONAS

Se han registrado 6 mil 902 incendios en Angola y 3 mil 395 en el Congo, en las últimas 48 horas

Por **Contrapeso Ciudadano** - 24/08/2019

WORLD

Destructive Hail And A Massive Dust Storm Descend On Fire-Ravaged Australia

January 20, 2020 · 4:10 PM ET

BILL CHAPPELL

Golf-ball-sized hail carpets a street in Canberra on Monday, in a new twist on Australia's summer of extreme weather. The Australian Capital Territory's emergency service said it received a record number of calls for help — more than 1,900.

Ying Tan/via Reuters

CLIMATE IN CRISIS

Heavy rain brings flash floods to parts of eastern Australia as bushfires rage on

Major highways were closed in Queensland as the state was hit with some of the heaviest rain the country has seen for months.

A staff member carries koalas after flooding caused by heavy rainfall at the Australian Reptile Park in Somersby, New South Wales.

Australia Reptile Park / via Reuters

Jan. 18, 2020, 3:11 PM CET / Updated Jan. 18, 2020, 11:13 PM CET

Qld Fire & Emergency
@QldFES

❌IF IT'S FLOODED, FORGET IT❌

The @BOM_Qld has reported flash flooding in some parts of the state this morning due to heavy rainfall overnight.

Fast-moving water can be extremely unpredictable and have devastating consequences.

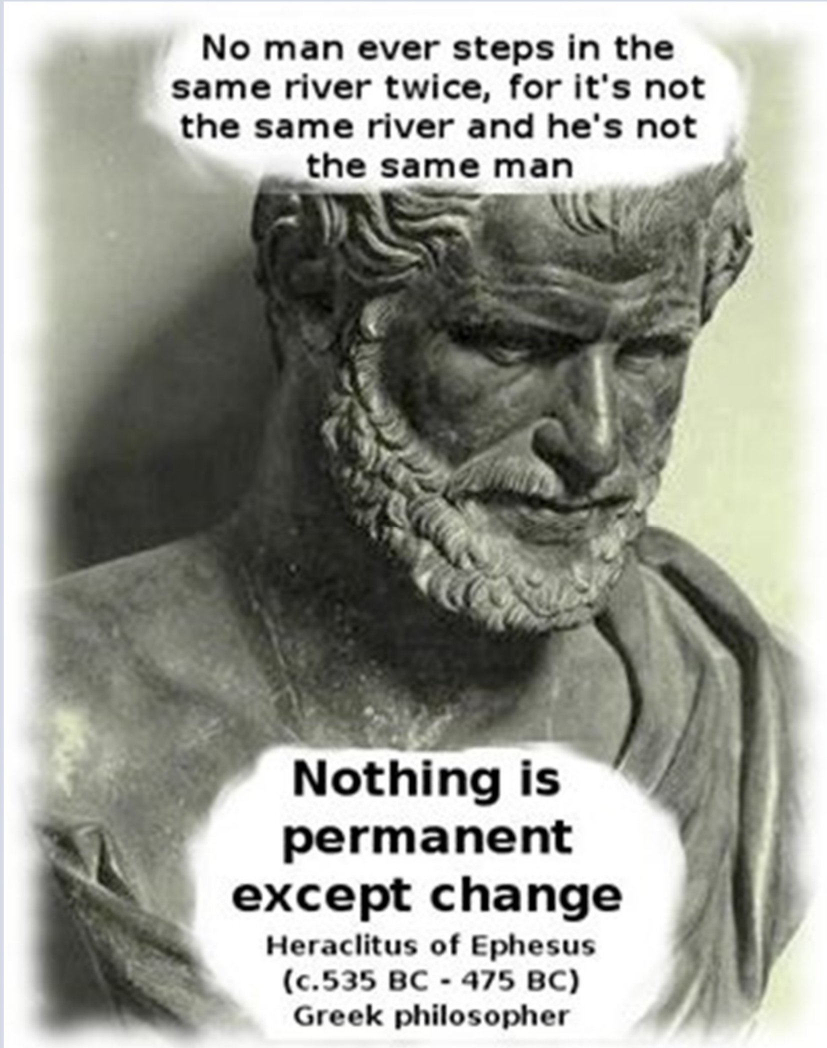
♡ 137 10:44 PM - Jan 17, 2020

The hydrological Science perspective:

Panta Rhei

IAHS AISH

Everything Flows



CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

P. C. D. Milly,[1*] Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

"Stationarity is dead because substantial anthropogenic change of Earth's climate is altering the means and extremes of precipitation, evapotranspiration, and rates of discharge of rivers […]. Warming augments atmospheric humidity and water transport. This increases precipitation, and possibly flood risk, where prevailing atmospheric water-vapor fluxes converge."

AGU PUBLICATIONS

Water Resources Research

COMMENTARY
10.1002/2014WR016092

Modeling and mitigating natural hazards: Stationarity is immortal!

Alberto Montanari[1] and Demetris Koutsoyiannis[2]

“change does not imply nonstationarity
and stationarity does not imply at all unchanging process state

nonstationarity necessarily needs to be described by a deterministic change of process statistics”

Taylor & Francis
Taylor & Francis Group

Hydrological Sciences Journal

ISSN: 0262-6667 (Print) 2150-3435 (Online) Journal homepage: http://www.tandfonline.com/loi/thsj20

Negligent killing of scientific concepts: the stationarity case

Demetris Koutsoyiannis & Alberto Montanari

"ergodicity can always be assumed when there is stationarity, while this assumption is fully justified by the theory if the system dynamics is deterministic.

Conversely, if nonstationarity is assumed, then ergodicity cannot hold, which forbids inference from data."

Hydrological Sciences Journal – Journal des Sciences Hydrologiques, 60 (7–8) 2015

An operational proposal:

Revisiting the Concepts of Return Period and Risk for Nonstationary Hydrologic Extreme Events

Jose D. Salas, M.ASCE[1]; and Jayantha Obeysekera, M.ASCE[2]

The concepts of return period and risk are reformulated by extending the geometric distribution to allow for changing exceeding probabilities over time

JOURNAL OF HYDROLOGIC ENGINEERING © ASCE / MARCH 2014

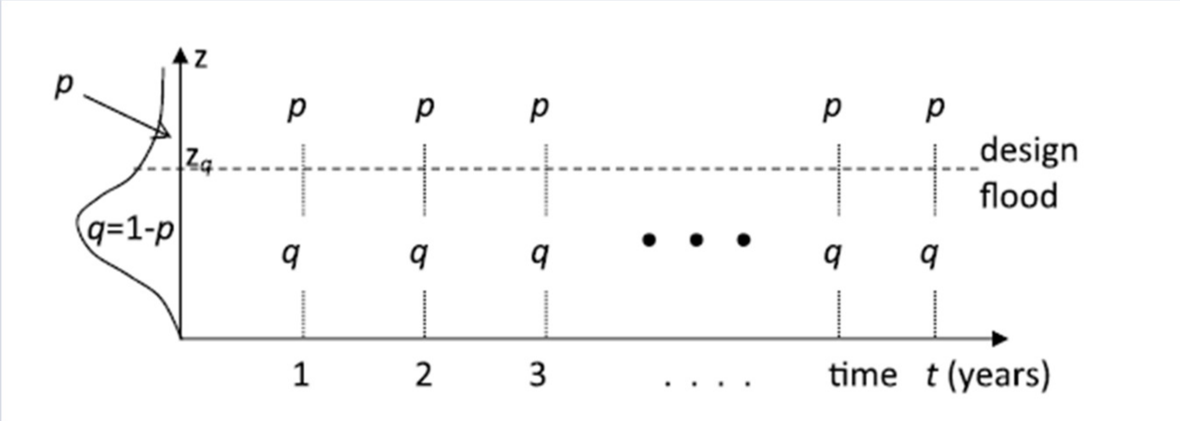
Return Period in nonstationary conditions

RETURN PERIOD

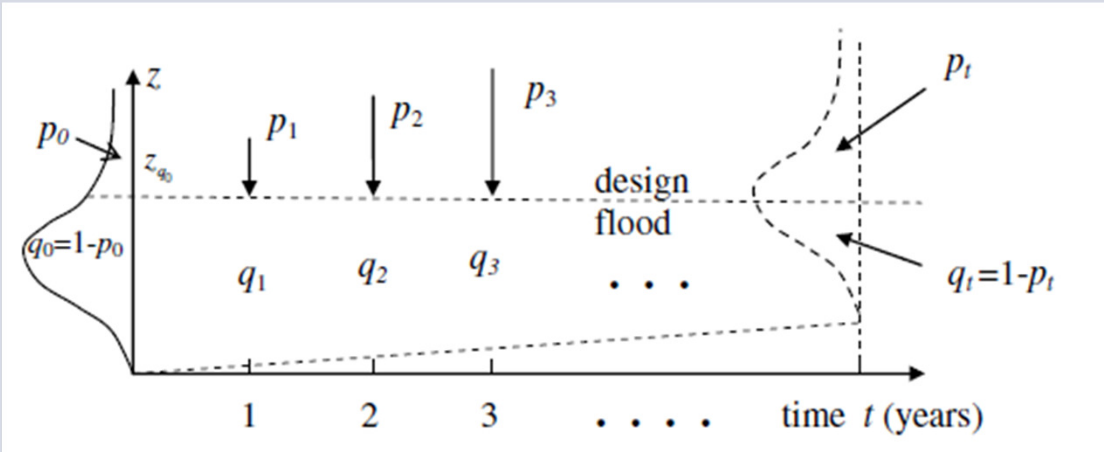
Expected Waiting Time
(EWT)
(Olsen et al., 1988)

Expected Number of Events
(ENE)
(Parey et al., 2007,2010)

Stationary stochastic process



Nonstationary stochastic process



Nonstationary GEV

Generalized Extreme Value distribution (GEV) has the following CDF (Jenkinson, 1955):

$$F(x, \boldsymbol{\theta}_{ST}) = exp\left\{-\left[1 + \varepsilon\left(\frac{x - \zeta}{\sigma}\right)\right]^{-\frac{1}{\varepsilon}}\right\}$$

where x are *iid* random variables, $\boldsymbol{\theta}_{ST} = [\zeta, \sigma, \varepsilon]$ and $\sigma > 0$.
Non-stationarity can be introduced modelling parameters as function of times or other covariates (Coles, 2001):

$$F(x, \boldsymbol{\theta}_{NS}) = exp\left\{-\left[1 + \varepsilon\left(\frac{x - \zeta_t}{\sigma}\right)\right]^{-\frac{1}{\varepsilon}}\right\}$$

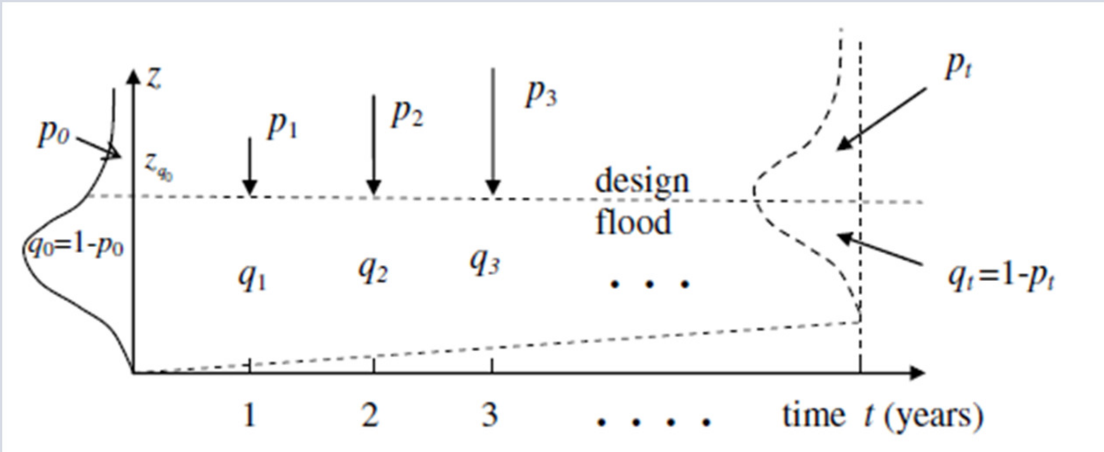
Now, x are *i/nid* random variables, $\boldsymbol{\theta}_{NS} = [\zeta_t, \sigma_t, \varepsilon_t]$ and $\sigma > 0$.
Non-stationarity has been introduced into GEV in a very simple way:

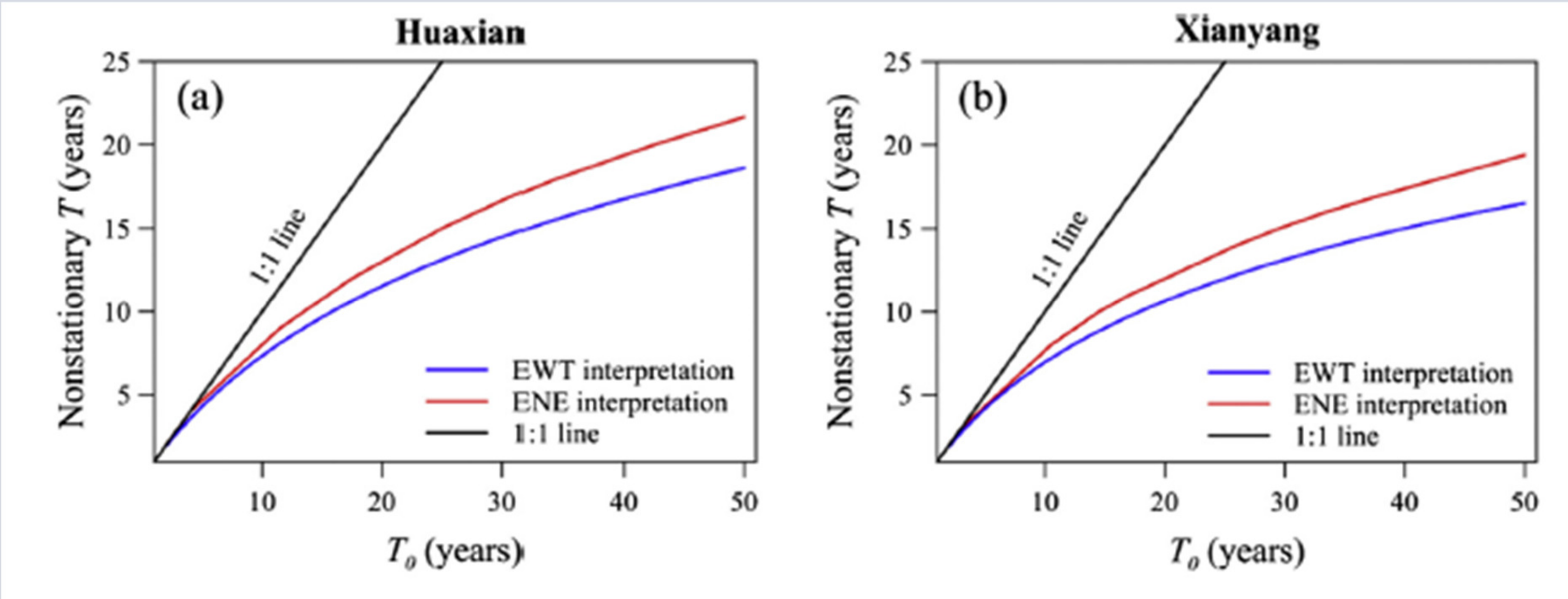
$$\zeta_t = \zeta_0 + \zeta_1 t$$

Expected Waiting Time interpretation (EWT)

"Expected waiting time until an exceedance occurs" (Olsen et al., 1988)

$$T = \sum_{x=1}^{\infty} x p_x \prod_{t=1}^{x-1} (1 - p_t)$$

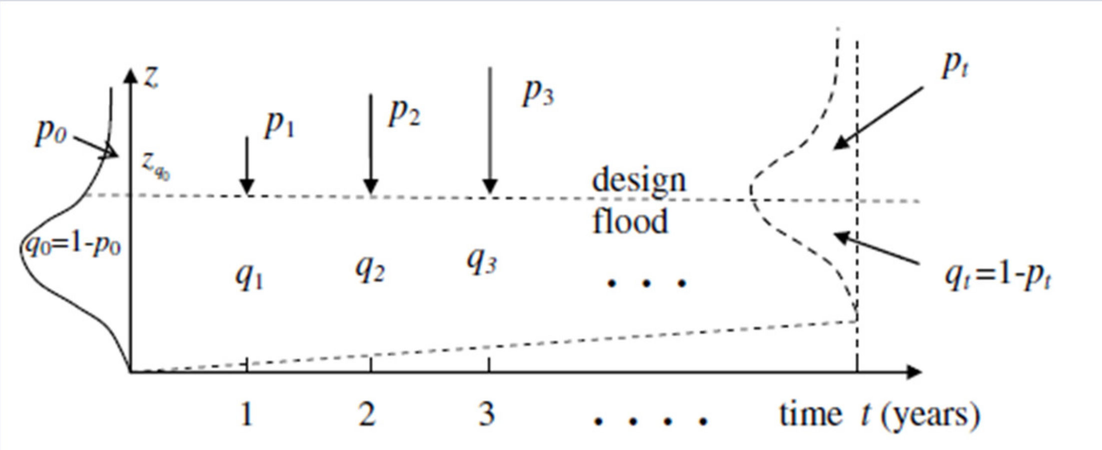



Huaxian
(a)
Nonstationary T (years)
1:1 line
EWT interpretation
ENE interpretation
1:1 line
T_0 (years)
Xianyang
(b)
Nonstationary T (years)
1:1 line
EWT interpretation
ENE interpretation
1:1 line
T_0 (years)

Du et al. (2015)

Question:

- **How to detect and model non-stationarity of flood probability ?**



Journal of Hydrology 552 (2017) 28–43

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

ELSEVIER

Research papers

A global-scale investigation of trends in annual maximum streamflow

Hong X. Do *, Seth Westra, Michael Leonard

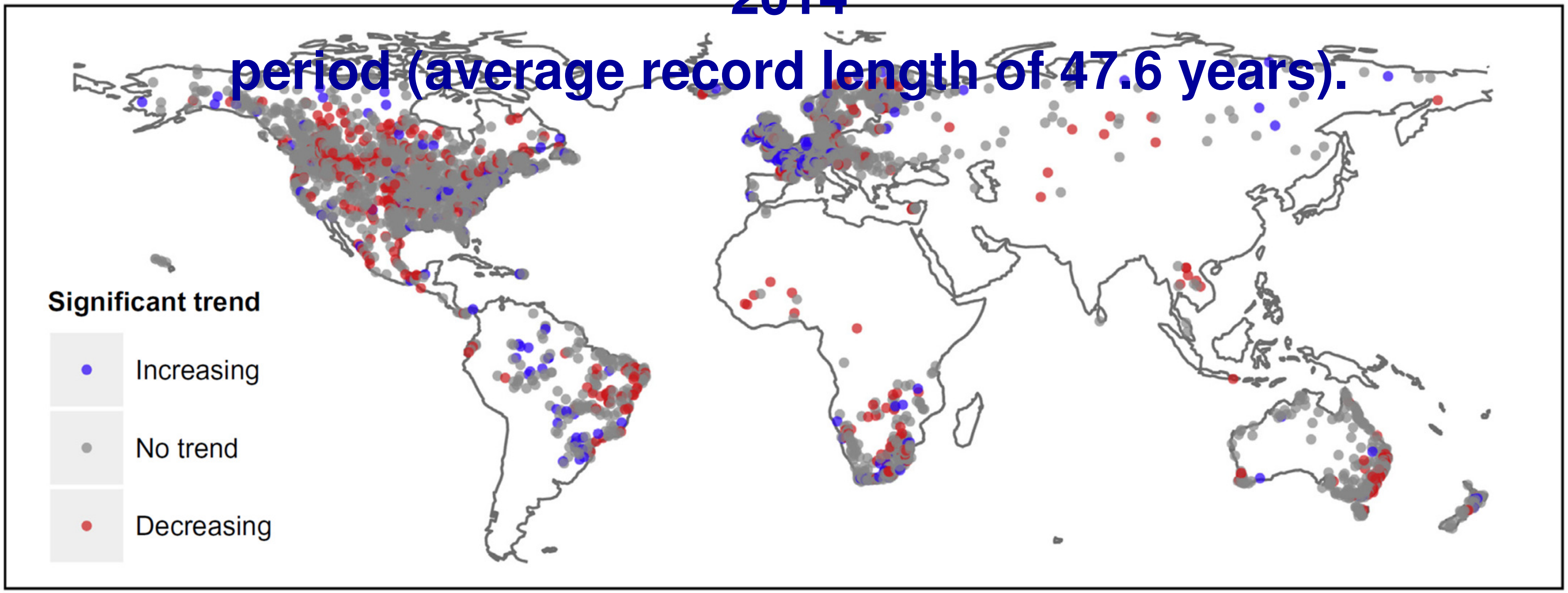
School of Civil, Environmental and Mining Engineering, University of Adelaide, Adelaide, South Australia 5005, Australia

This study investigates the presence of trends in annual maximum daily streamflow data from the Global Runoff Data Centre database.

The records were divided into three reference datasets representing different compromises between spatial coverage and minimum record length, followed by further filtering based on continent, Köppen-Weiger climate classification, presence of dams, forest cover changes and catchment size.

Trends were evaluated using the <u>Mann-Kendall nonparametric trend test at the 10%</u> significance level, combined with a field significance test.

Dataset A2 (3478 stations) comprises stations with at least 30 years annual maximum streamflow over the 1955–2014 period (average record length of 47.6 years).



"… over the main reference period (dataset A1; 1966–2005), there were 7.1% of stations with statistically significant increasing trends, and 11.9% of stations with statistically significant decreasing trends. The percentage of stations exhibiting statistically significant increasing trends is consistent with the null hypothesis of no change on average across the global dataset, whereas the percentage of stations showing significant decreasing trends is

"Despite potential concerns about data quality, one interesting pattern to emerge was that detected changes in annual maximum streamflow are inconsistent with the evidence of trends in precipitation. At the global scale, annual maximum precipitation intensities were found to have increased (Min et al., 2011) and a largescale increasing pattern in extreme precipitation was detected (Lehmann et al., 2015), with North America experiencing more increasing trends than decreasing trends in annual maximum precipitation (Westra et al., 2013). "

"… the changes in the flood hazard as assessed in this study do not explain observed increases in flood losses (Kundzewicz et al., 2013; Mills, 2005) or in the number of reported events (Munich Re, 2015; Swiss Re, 2015)."

"Further research is needed to quantify the contribution of catchment condition to the rainfall-runoff relationship at global and regional scales, including investigation of changes in other dimensions of flooding, such as their duration, volume, and intensity."

Hydrol. Earth Syst. Sci., 24, 1–16, 2020
https://doi.org/10.5194/hess-24-1-2020

Hydrology and Earth System Sciences
Open Access

Numerical investigation on the power of parametric and nonparametric tests for trend detection in annual maximum series

Vincenzo Totaro, Andrea Gioia, and Vito Iacobellis

Dipartimento di Ingegneria Civile, Ambientale, del Territorio, Edile e di Chimica (DICATECh),
Politecnico di Bari, Bari, 70125, Italy

- ✓ **Parametric Vs nonparametric tests**
- ✓ **Test Power and of experiment design**
- ✓ **Trend and other parameters evaluation**

NHST (Null Hypothesis Significance Testing)

MK: Mann-Kendall

Nonparametric test with assigned null hypothesis

LR: Likelihood Ratio

Parametric test with assigned null hypothesis

AIC_R : Akaike Information Criterion

Parametric test with not assigned null hypothesis

MANN-KENDALL TEST

This is a rank-based test for evaluating the significance of a trend. Given a sample with length *n*, $\underline{x} = [x_1, \dots, x_n]$, this test is based on the evaluation of the following statistic:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i)$$

being *sgn* the sign function. For $n \geq 8$, Mann (1945) reported how S is approximatively normally distributed.
So, for performing the test, has to be evaluated the standardized test statistic:

$$Z = \begin{cases} \frac{S-1}{\sqrt{V(S)}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{V(S)}} & S < 0 \end{cases}$$

characterized by having mead zero and unitary variance. Starting from this statistic, it's possible to evaluate p-values and comparing with the assigned significance level.
This test is used for relieving monotonic trends (not necessarily linear).

LIKELIHOOD RATIO TEST

Be θ_{ST} a nested model of θ_{NS} and $\ell(\hat{\theta}_{(\cdot)})$ their maximized likelihood, then can be

$$D = 2\left[\ell(\hat{\theta}_{NS}) - \ell(\hat{\theta}_{ST})\right]$$

This difference has a χ^2 distribution as sample size n gets large

AKAIKE INFORMATION CRITERION (AIC)

This criterion, proposed by Akaike (1973), is suitable for the selection between different models. Based on an extension of the likelihood measure, it allows to realize a quick evaluation in choosing the best fit model to observed data. In his more traditional definition, AIC of a k parameters $\theta = \theta(\theta_1, \theta_2, \dots, \theta_k)$ model can be expressed in this way:

$$AIC = -2\ell(\hat{\theta}) + 2k$$

where $\ell(\hat{\theta})$ is the maximum of the log-likelihood function of analysed model. The best fit function is that with the lower value of AIC.
In the following, because our necessity to use in a dynamic way stationary and nonstationary models, we will use this quantity

$$AIC_R = \frac{AIC_{ns}}{AIC_{st}}$$

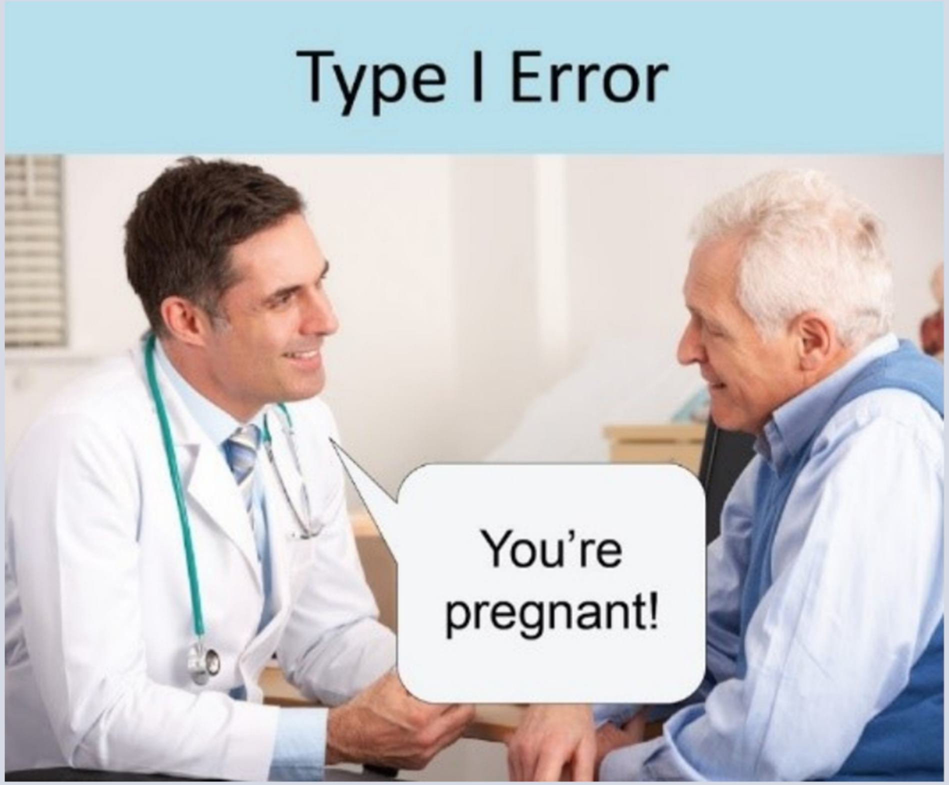
A little reminder…

Type I error: reject the true null hypothesis

Type II error: accept the false null hypothesis

Power: ability to reject the false null hypothesis

Type I error: reject the true null hypothesis



Null hypothesis: the patient is not pregnant

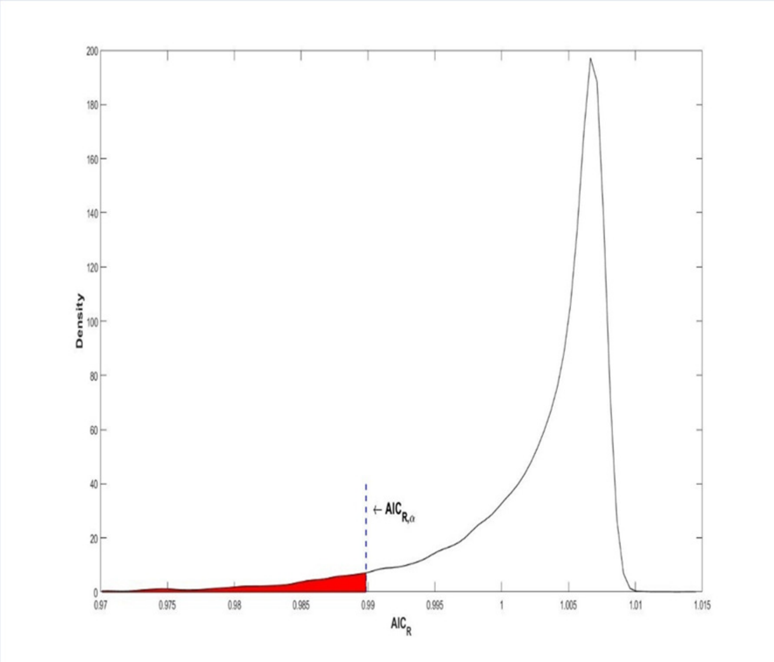
Type II error: accept the false null hypothesis

Null hypothesis: the patient is not pregnant

Power

Null hypothesis: the patient is not pregnant

HOW TO EVALUATE AIC_R?



1. **N = 10000 samples are generated from a stationary GEV parent distribution, with known parameters;**
2. **for each of these samples the AIC_R is evaluated, thus providing its empirical distribution (see figure);**
3. **exploiting the empirical distribution of AIC_R the threshold associated with a significance level of a = 0.05 is numerically evaluated: this value, $AIC_{R,a}$, represents the threshold for rejecting the null hypothesis of non-stationarity (which in these generations is true) in 5% of the synthetic samples;**

EVALUATION OF TESTS POWER

The comparative evaluation of these different measures was carried out for some values of the GEV shape ε (-0.4, 0, 0.4), and scale σ (10, 15, 20) parameters, in order to evaluate also the Gumbel distribution. For each combination of these parameters, we considered different sample sizes (30, 50 and 70).

2000 Monte Carlo time series from a non-stationary GEV have been generated, with ζ_1 comprised in the range [-1, +1] with a step of 0.1. According to Yue et al. (2002), power of the test has been evaluated as:

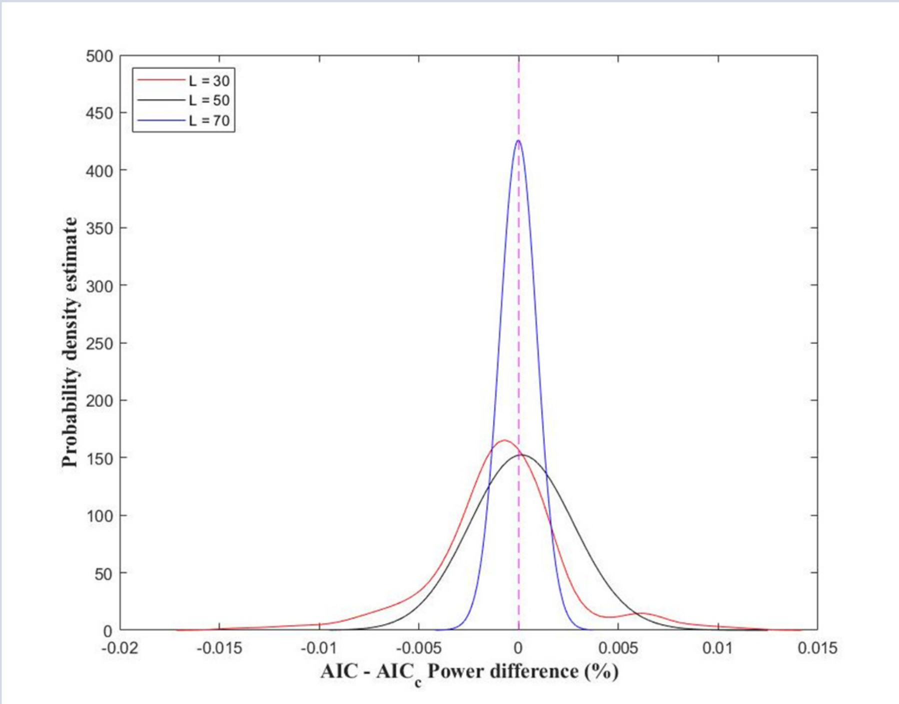
$$power = \frac{N_{rej}}{N}$$

where N_{rej} are the times when the null hypothesis has been rejected and N the number of simulations.

EVALUATION OF AIC_R WITH AIC OR AIC_C

Sugiura (1978)

$$n/k < 40$$



Results

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✓ **It is not true that nonparametric tests are independent from the parent distribution.**

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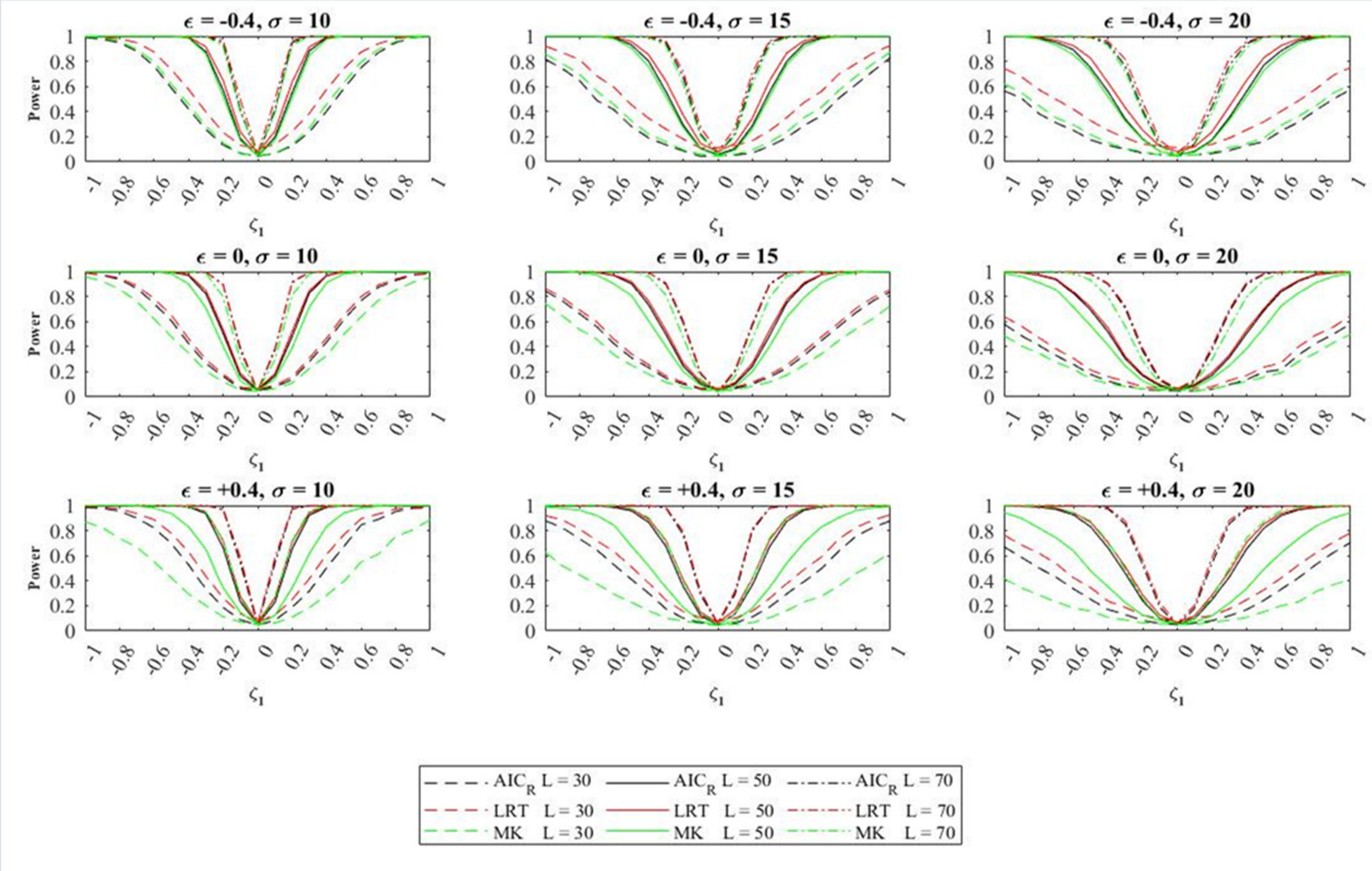
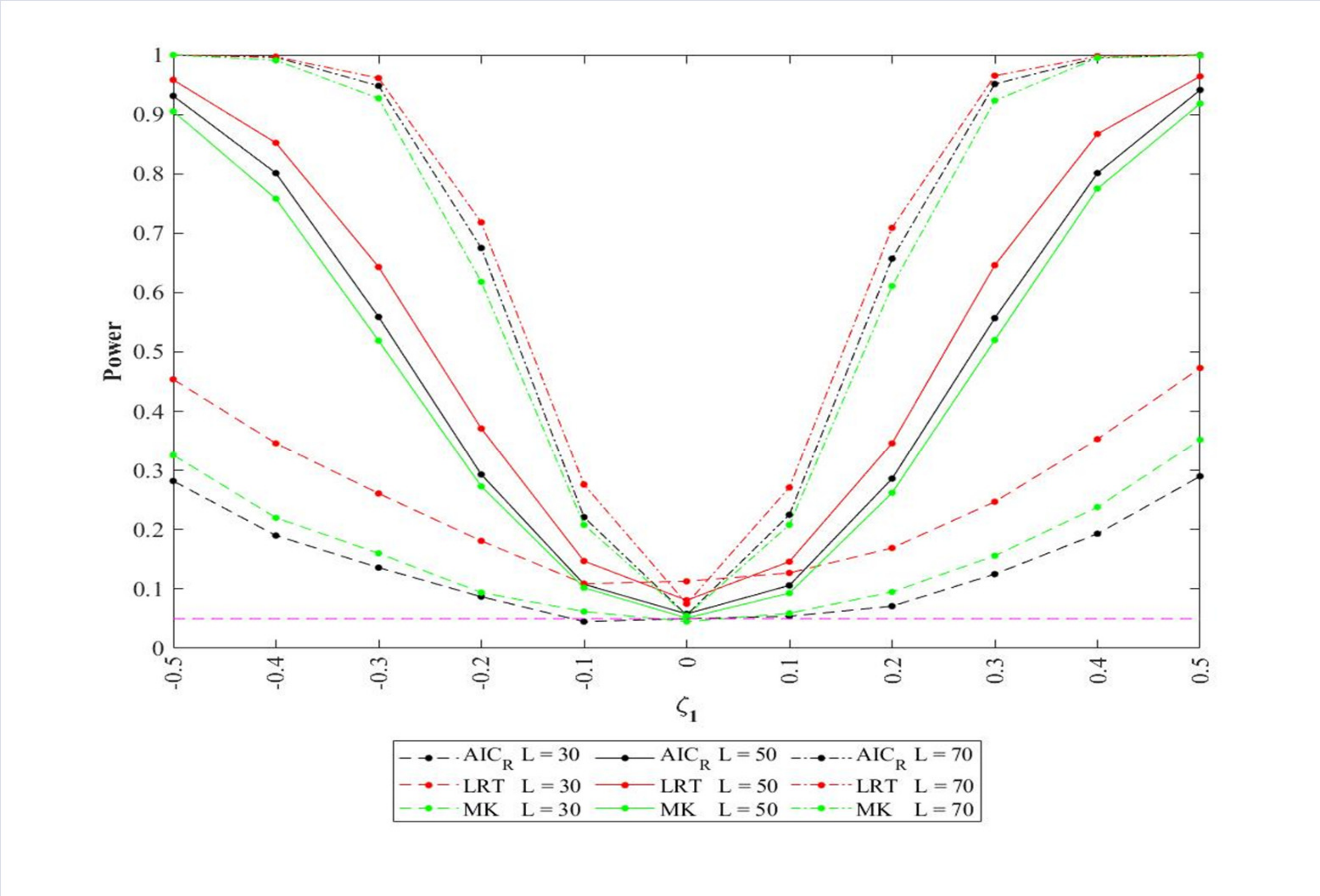
What about Power ?

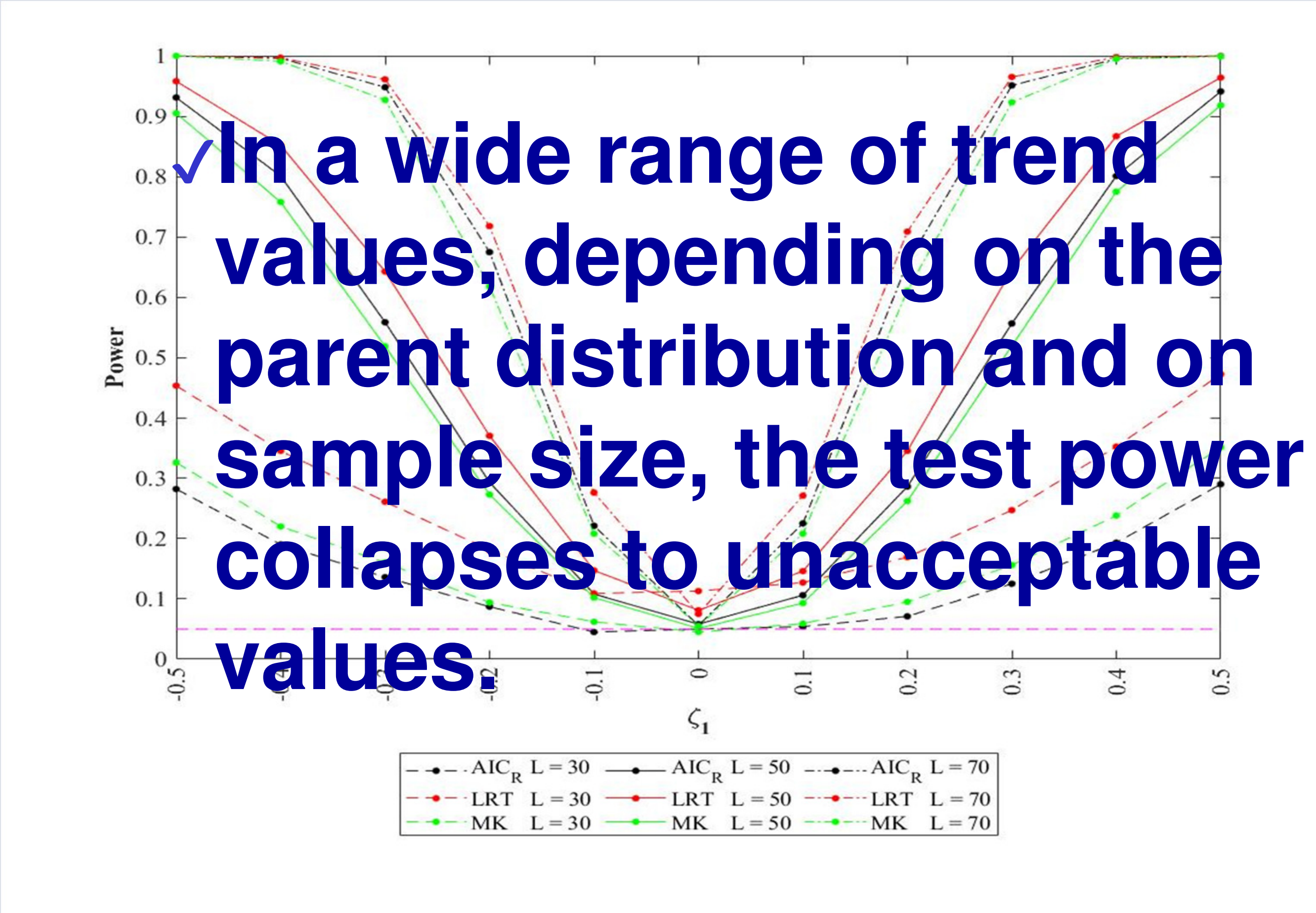
DEPENDENCE OF POWER ON PARENT DISTRIBUTION PARAMETERS AND SAMPLE SIZE



DEPENDENCE OF POWER ON PARENT DISTRIBUTION PARAMETERS AND SAMPLE SIZE



DEPENDENCE OF POWER ON PARENT DISTRIBUTION PARAMETERS AND SAMPLE SIZE



- ✓ In a wide range of trend values, depending on the parent distribution and on sample size, the test power collapses to unacceptable values.

Journal of Orthopaedic Research
8:304–309 Raven Press, Ltd., New York

Invited Opinion

Statistical Significance and Statistical Power in Hypothesis Testing

Richard L. Lieber

Division of Orthopaedics and Rehabilitation, Veterans Administration Medical Center and University of California, San Diego, CA, U.S.A.

"The interpretation of the *meaning* of the p value is therefore paramount in selecting its value and in guarding against <u>cookbook application</u> of statistical methods"

Psychological Bulletin [PsycARTICLES]; July 1992; 112, 1; PsycARTICLES
pg. 155

QUANTITATIVE METHODS IN PSYCHOLOGY

A Power Primer

Jacob Cohen
New York University

"It is not at all clear why researchers continue to ignore power analysis. The passive acceptance of this state of affairs by editors and reviewers is even more of a mistery."

American Psychologist, 1994

The Earth Is Round ($p < .05$)

Jacob Cohen

"I argue herein that Null Hypothesis Significance Testing has not only failed to support the advance of psychology as a science but also <u>has seriously impeded it</u>."

"Almost a quarter of a century ago, a couple of sociologists, Morrison and Henkel (1970), edited a book entitled *The significance Test Controversy.* […] Without exception, <u>all contributors damned NHST</u>"

Nat. Hazards Earth Syst. Sci., 13, 1773–1778, 2013
www.nat-hazards-earth-syst-sci.net/13/1773/2013/
doi:10.5194/nhess-13-1773-2013

Natural Hazards and Earth System Sciences
Open Access

Brief Communication: Likelihood of societal preparedness for global change: trend detection

R. M. Vogel[1], A. Rosner[2], and P. H. Kirshen[3]

[1]Department of Civil and Environmental Engineering, Tufts University, Medford, MA 02155, USA
[2]US Geological Survey, Conte Anadromous Fish Research Laboratory, One Migratory Way, P.O. Box 796, Turners Falls, MA 01376-0796, USA
[3]Environmental Research Group, Civil Engineering Department & Institute for the Study of Earth, Oceans and Space, University of New Hampshire, Durham, NH, USA

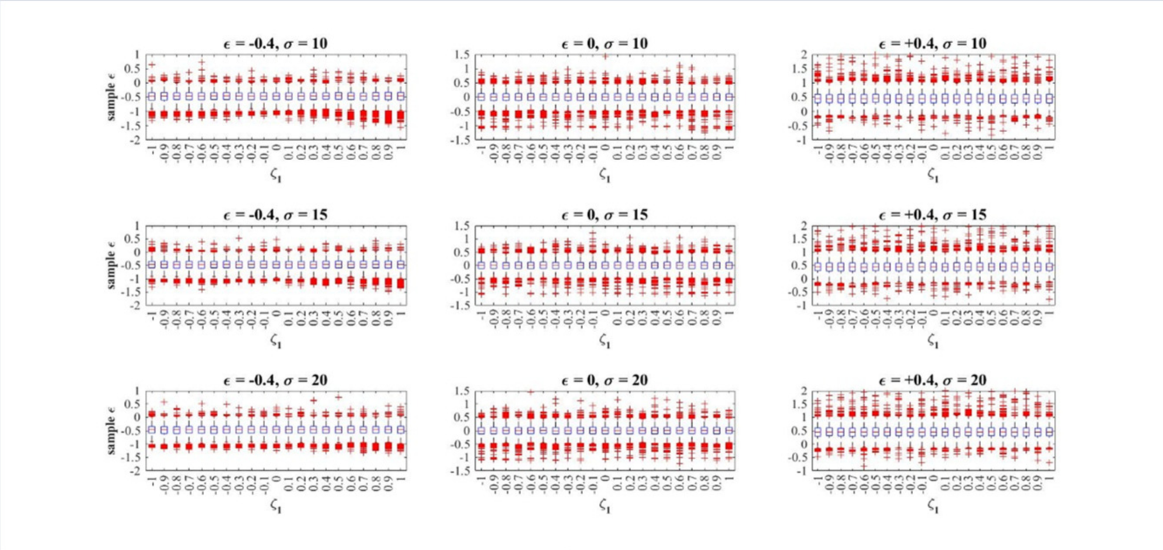
The physical implication of a Type I or overpreparedness error in adaptation decisions for flood management is wasted money on unneeded infrastructure.

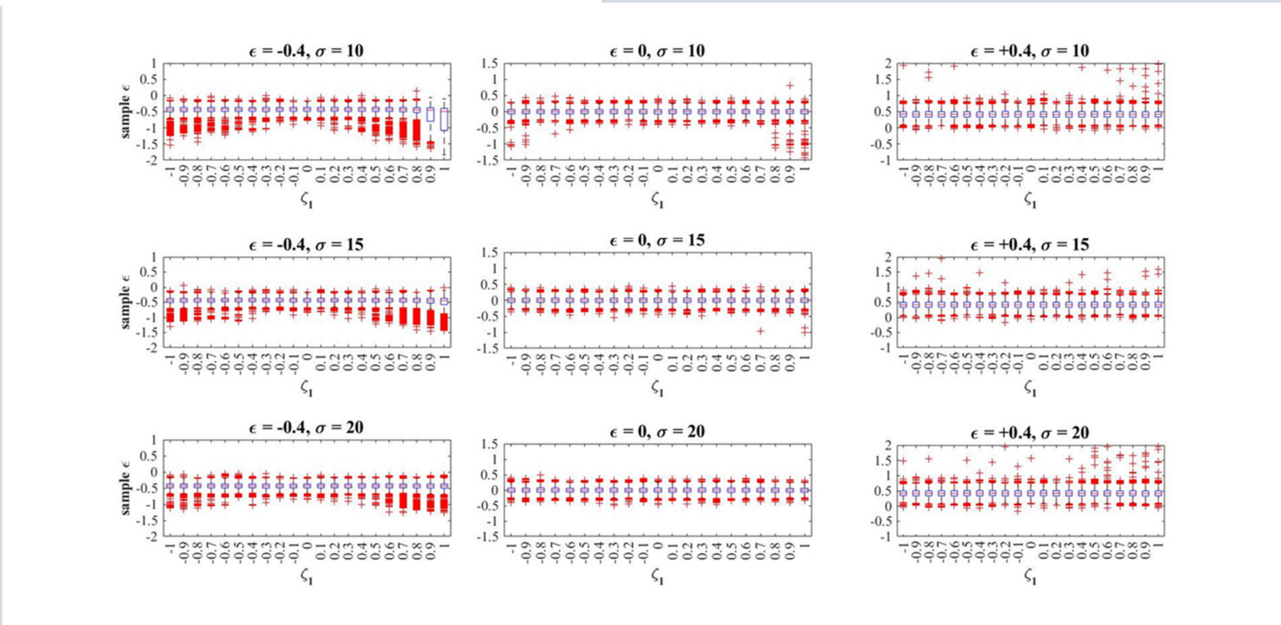
The physical repercussions of a Type II or under-preparedness error are major flood damages due to inadequate protection.

A type II error (i.e., low power) in the context of an infrastructure decision implies under-preparedness,

which is often an error much more costly to society than the type I error (overpreparedness).

SAMPLE VARIABILITY OF PARENT DISTRIBUTION PARAMETERS





MORE MOTIVATIONS AND RESEARCH QUESTIONS

Case
Study

How to develop the use of four-parameter distributions?

How to select the parent distribution ? TCEV and GEV or others and why ?

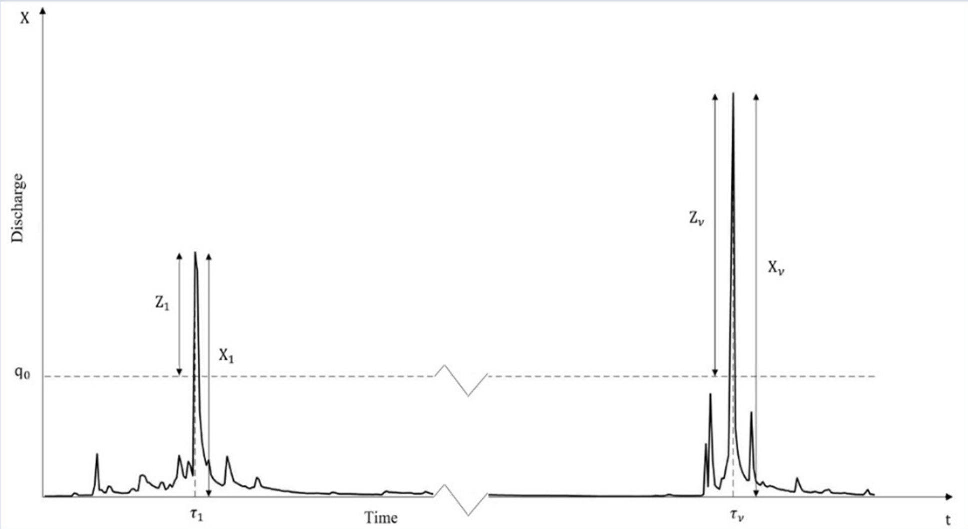
Which distributions are able to interprete floods phenomenology?

What is the uncertainty connected with these distributions?

At-site or Regional Flood Frequency Analysis?

Frequentist or Bayesian approach to Inference?

Theoretical distributions of floods



$$Z_i = X_i - q_0 \qquad i = 1,2,\ldots,\nu$$

Distribution of the number of exceedances

- ✓ Poissonian
- ✓ Binomial
- ✓ Negative Binomial

Distribution of the largest peak

- ✓ Exponential
- ✓ Generalised Pareto
- ✓ Weibull
- ✓ Gamma

TWO COMPONENT EXTREME VALUE (TCEV) DISTRIBUTION (Rossi et al., 1984)

Under the hypothesis that floods (or storms) can be generated by two different phenomenological mechanisms, is then possible to assume that:

$$F(x) = e^{\left(-\Lambda_1 e^{-\frac{x}{\theta_1}} - \Lambda_2 e^{-\frac{x}{\theta_2}}\right)}$$

$$x \geq 0 \text{ and } \Lambda_1 > \Lambda_2 \geq 0 \text{ and } \theta_2 > \theta_1 > 0.$$

TCEV distribution is originated by a mixture of processes, characterized by a Poisson distributed number of occurrences and an exponentially distributed threshold magnitude.

$$\theta_* = \frac{\theta_2}{\theta_1} \qquad \Lambda_* = \frac{\Lambda_2}{\Lambda_1^{1/\theta_*}}$$

AT-SITE ESTIMATION OF TCEV DISTRIBUTION: REVIEW

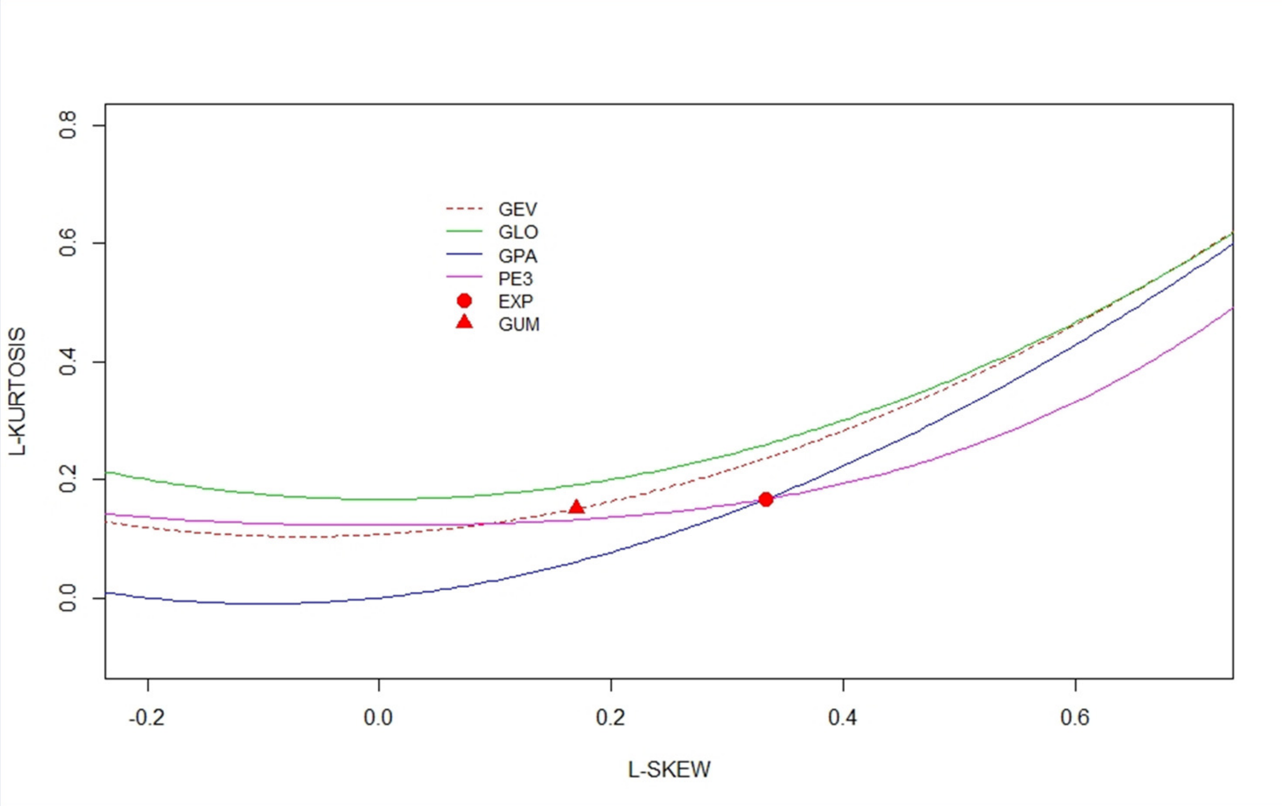
- ✓ **Rossi et al. (1984): Introduction of TCEV in Flood Frequency Analysis, with a short focus on the at-site parameters estimation**
- ✓ **Beran et al. (1986): definition of TCEV moments and PWMs**
- ✓ **Cunnane (1987): instability of at-site parameters estimation solutions**
- ✓ **Fiorentino et al. (1987): Maximum Entropy approach for parameters estimation**
- ✓ **Arnell and Beran (1988): L-Moments estimation**
- ✓ **Connell and Pearson (2001): least square estimation of parameters for annual maximum series in New Zealand**

TCEV has been employed in Regional Frequency Analysis of rainfalls and floods (e.g. Italy and Spain)

"…when the four parameters of the TCEV distribution are estimated from a single AFS, the uncertainty is great, particularly as regards the parameters of the outlying component. The uncertainty becomes extremely high for AFS's without outliers…"

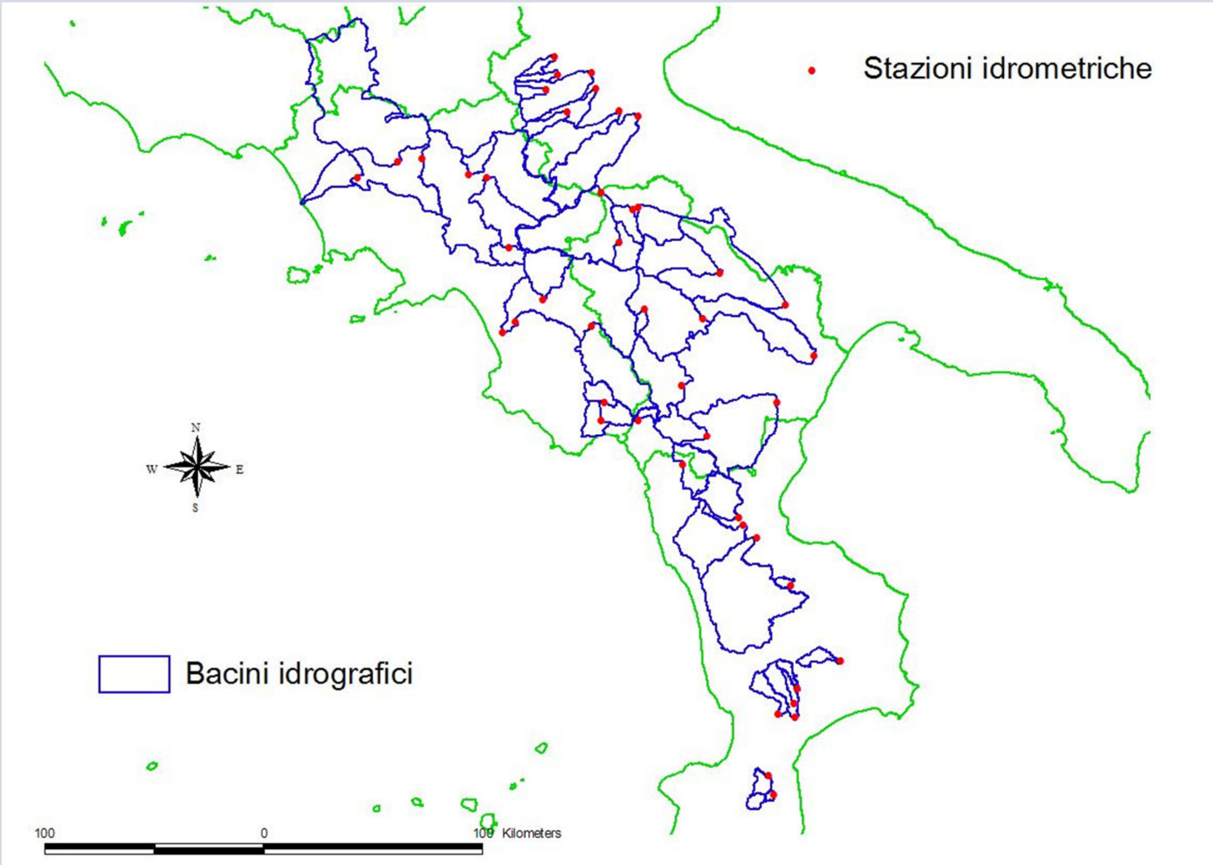
Rossi et al. (1984)

L-moments Ratio Diagram

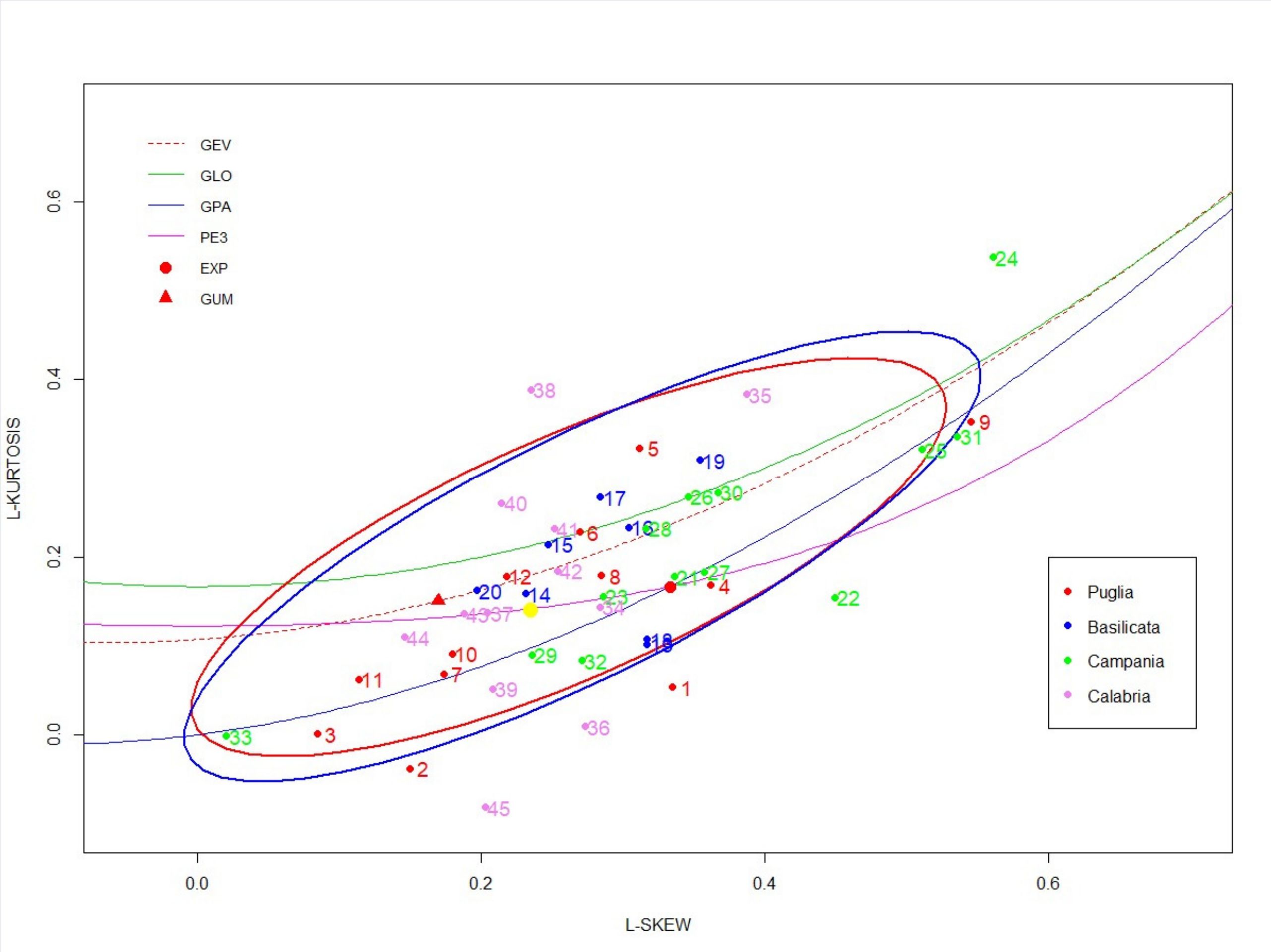


After Hosking and Wallis (1997)

Basins in Southern Italy



Basins in Southern Italy



We need more Power…

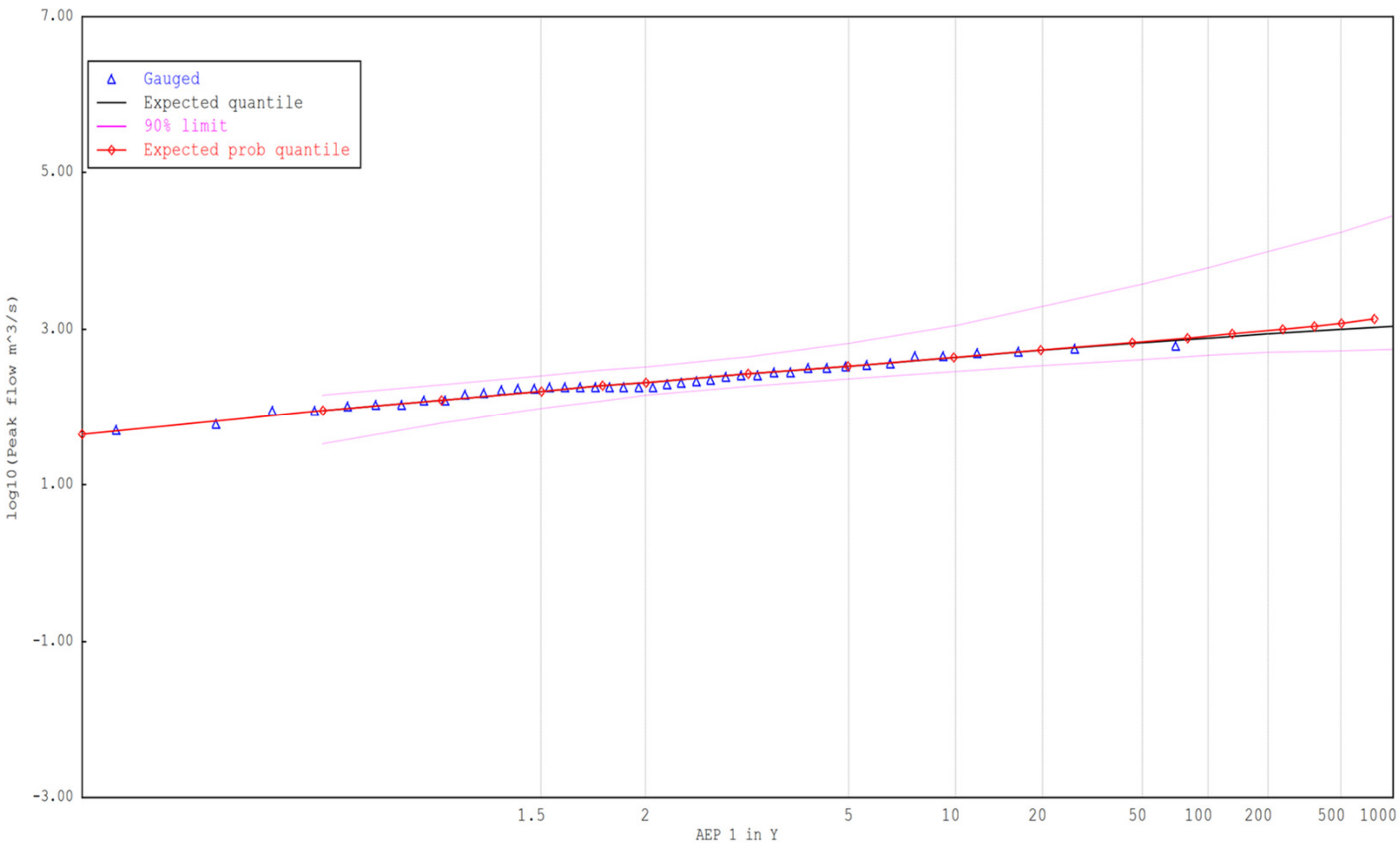
BAYES' THEOREM (1763)

$$p(\theta|x) = \frac{\ell(x|\theta)\, p(\theta)}{\int_{\Theta} \ell(x|\theta)\, p(\theta)\, d\theta} \propto \ell(x|\theta)\, p(\theta)$$

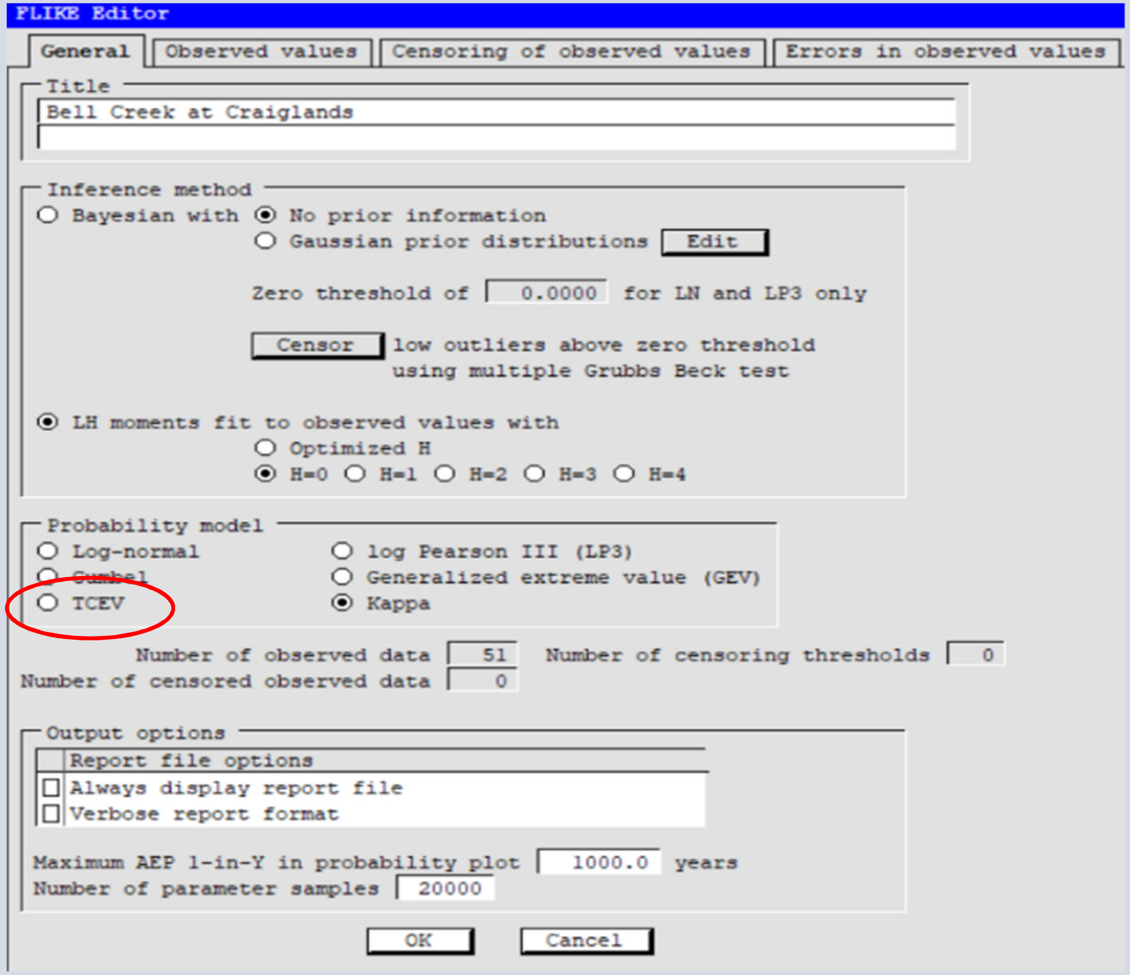
BAYESIAN INFERENCE

George Kuczera

Cumulative Distribution Function with uncertainty

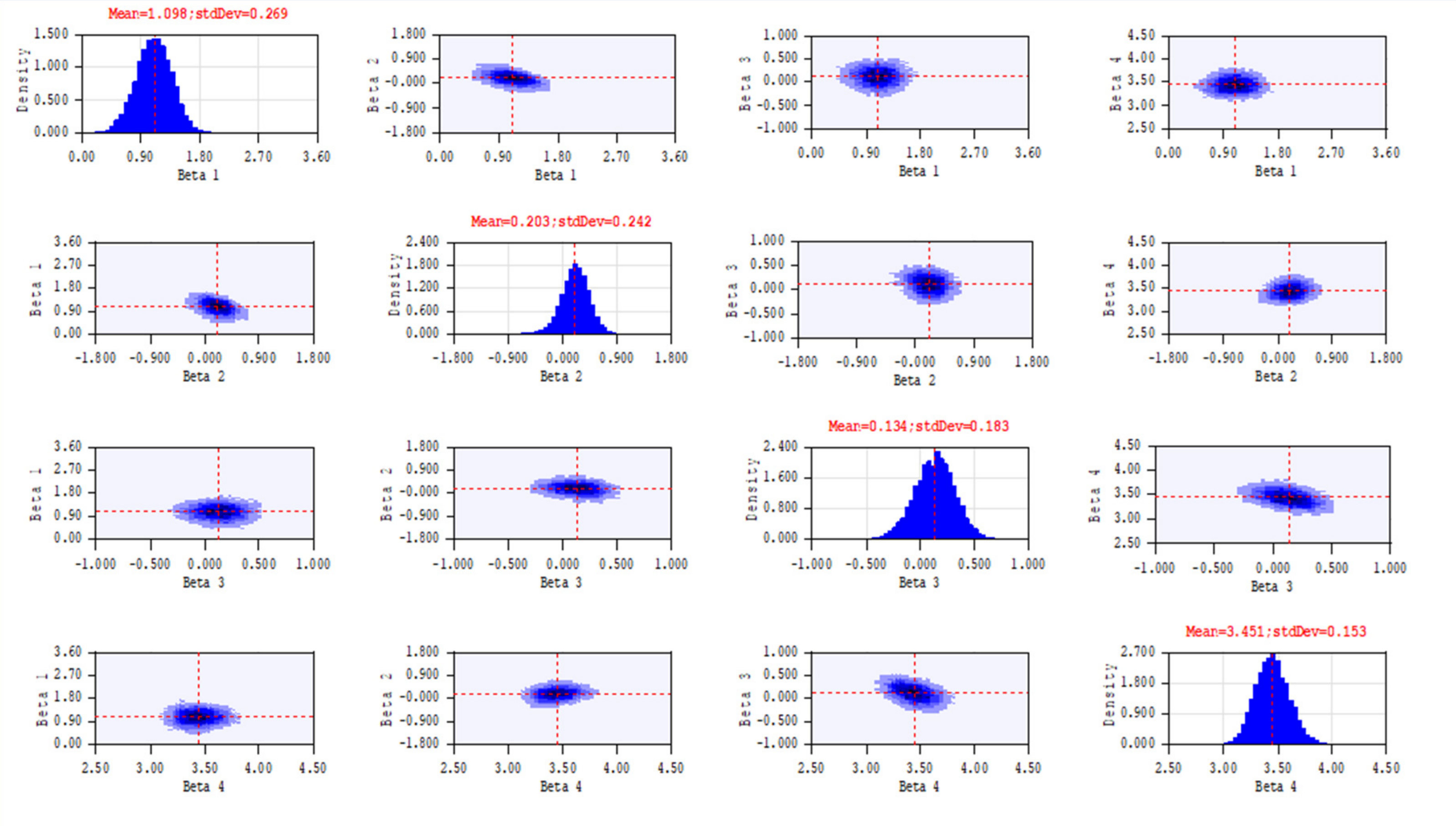


Work in progress

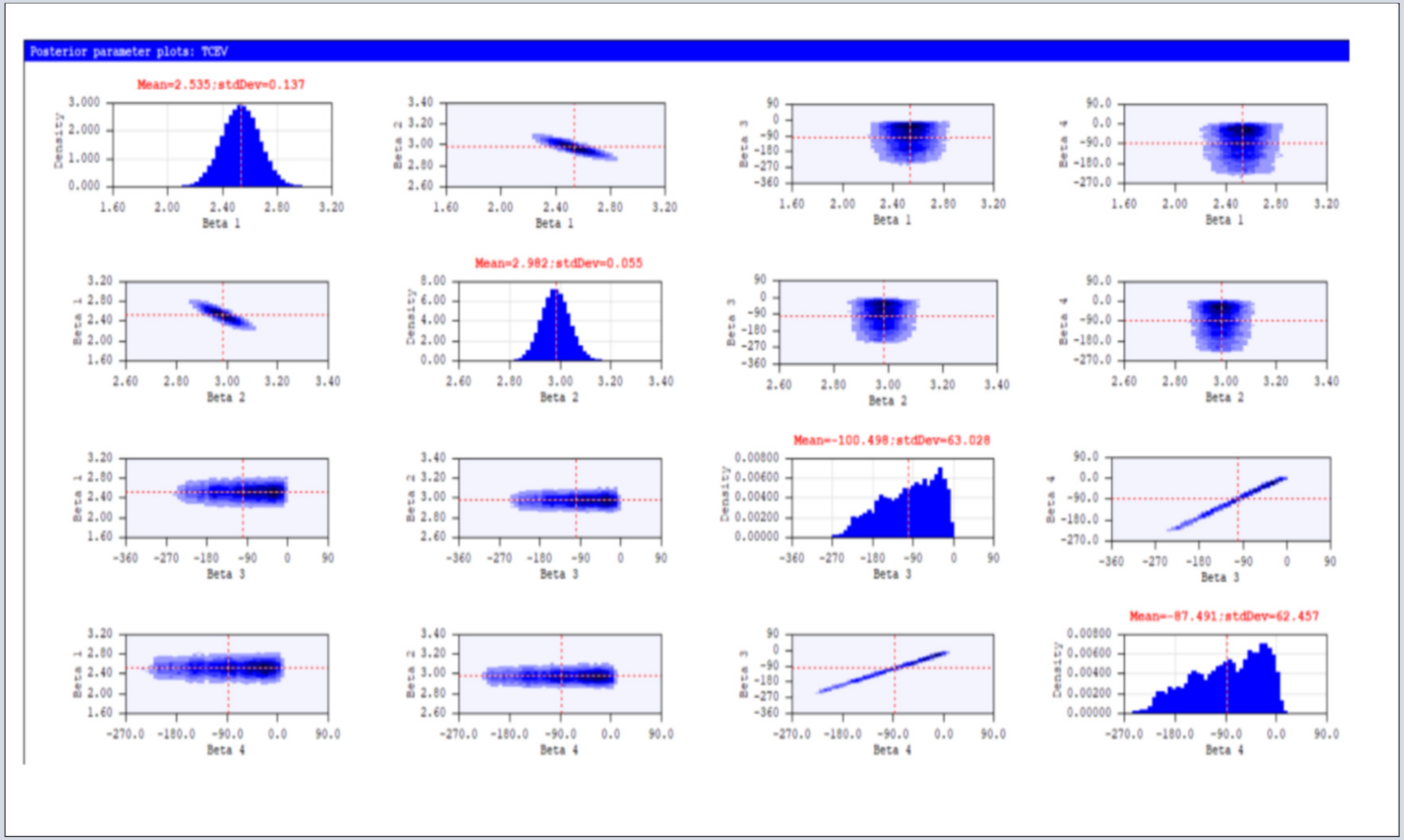


Metropolis-Hastings algorithm (1970)

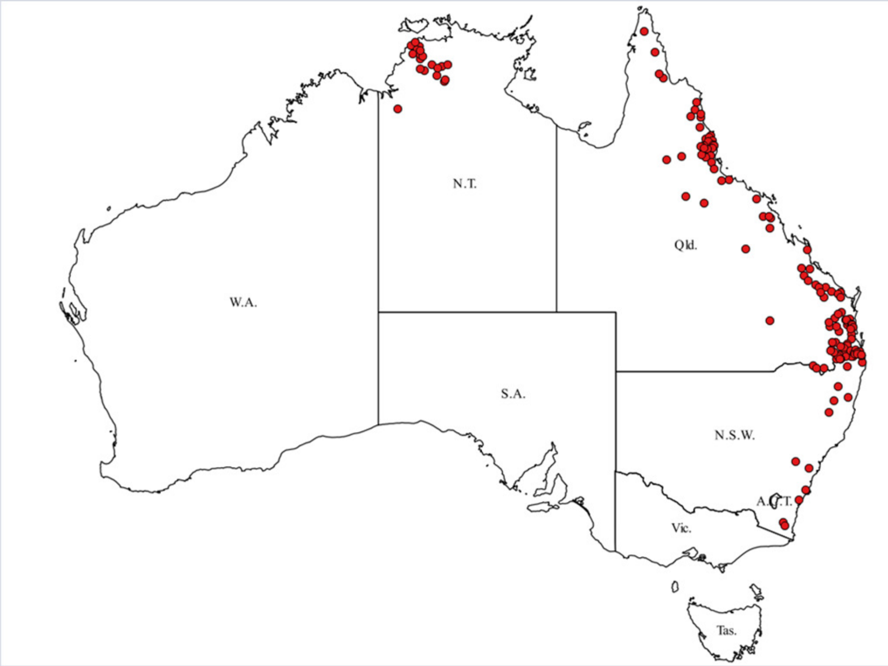
Posterior parameters plot of TCEV (from a TCEV distributed sample)



Posterior parameters plot of TCEV (from a Gumbel distributed sample)



AUSTRALIA



Project 5 (P5) Dataset

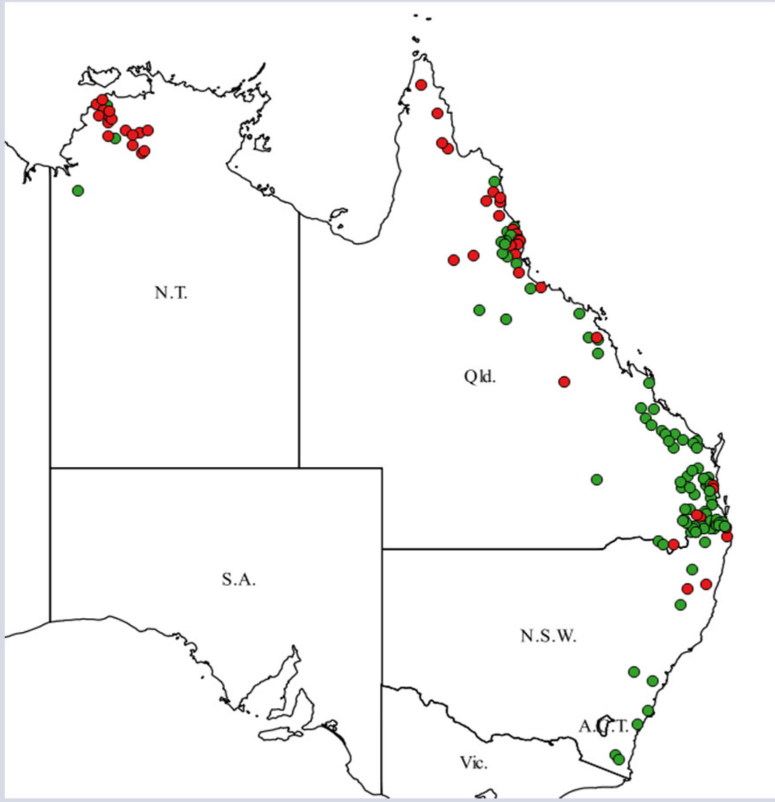
Annual maximum flood series (with more than 40 records) were investigated for:

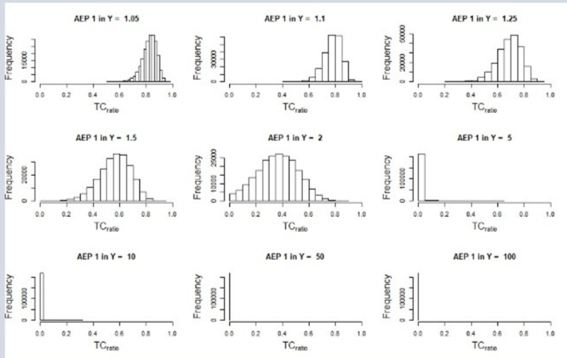
NEW SOUTH WALES
QUEENSLAND
NORTHERN TERRITORY

These regions are characterized by a wide gamma of climate conditions, which ranges from tropical (in Northern Territory) to alpine (in New South Wales).

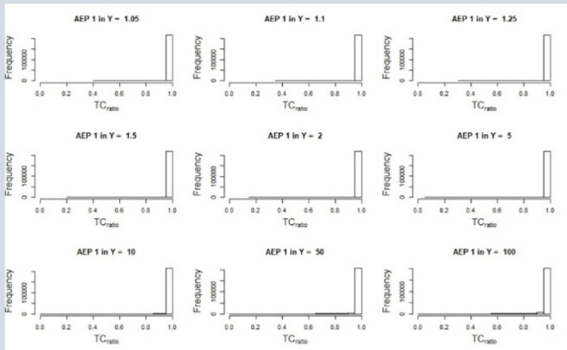
Several studies (e.g. Franks and Kuczera, 2002; Micevski et al., 2006) documented a multidecadal variability for eastern Australian flood data, with an alternance of dry and wet epochs. This led scientists to questioning the assumption that flood peaks are independent and identically distributed.

TC$_{ratio}$ TEST: RESULTS



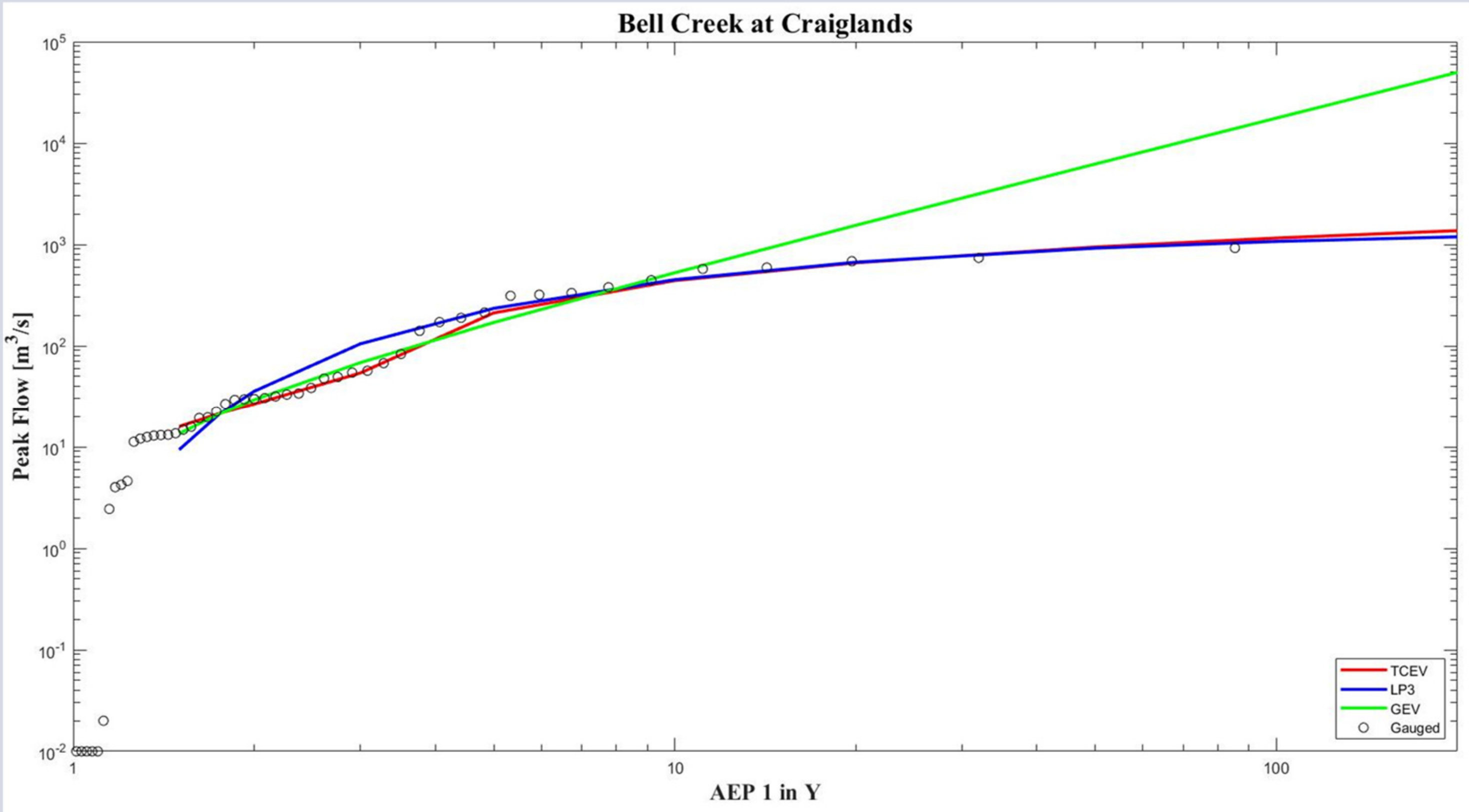


Bell Creek

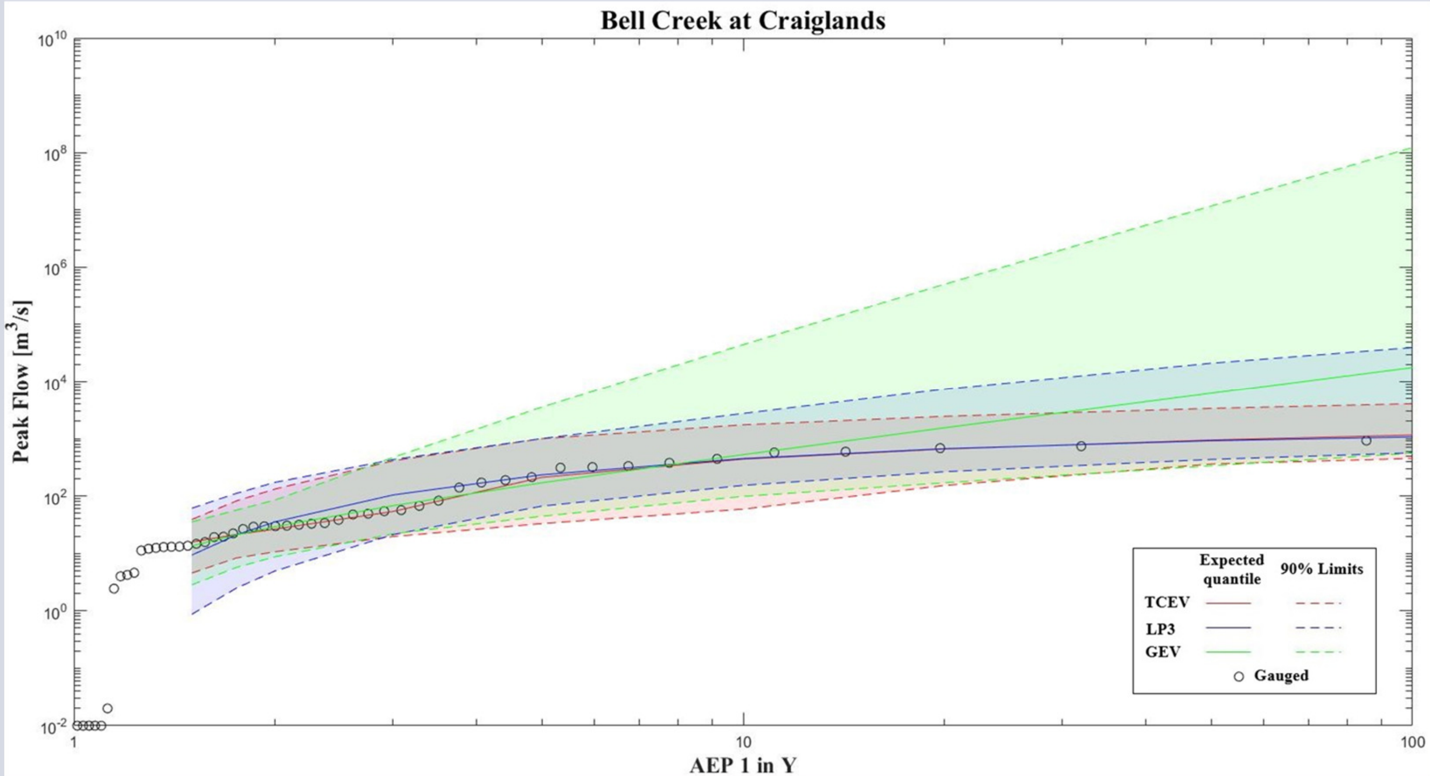


South Alligator River - El Sherana

VISUAL INSPECTION - Quantiles



VISUAL INSPECTION – Confidence Intervals



Conclusions

A rigorous approach to long medium term flood prediction requires:

Power analysis as a mandatory task in NHST use;

A public debate about acceptable power value (0.95 ?);

Advantages of Parametric approaches to be ackowledged;

Statistical efficiency and uncertainty on trend evaluation to be checked;

Advances in knowledge and tecniques may exploit:

Enhanced Physical understanding of underlying phenomena at the basin scale;

Use of Distributions with physically based parameters;

Regional methods applied to detect nonstationarity;

Final remark:

Monitoring and recording discharge will always be crucial tasks.

Acknowledgements
Alberto Ferruccio Piccinni
Umberto Fratino
Andrea Gioia
Gabriella Balacco
Vincenzo Totaro

Thank you

In memory of my father…
Vincenzo Iacobellis (1921-2019)