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Extreme rainstorms: testing regional envelope curves against stochastically generated events

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by

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Foreword 1

Context:

Estimation of rainfall extremes for design purposes

Timescales: (conventionally referred to as durations)
From sub-hourly to daily

Tools:

A. Single site rainfall simulator fitted to the available observations for the generation of long rainfall series

B. Statistical upper bound on observed rainfall maxima (envelope curve)

Origin of the Study 2

Rogger et al., GRA [2009]: "Reconciling statistical and deterministic flood estimation methods - A case study in Tyrol"

Design values for flood control measures in alpine catchments:

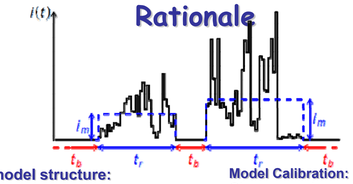
Statistical approaches: flood frequency statistics		Deterministic approaches: design storm method (event based)
+ return period of events	Differences	+ characteristics of catchments
- data samples not representative for all possible flood events	? Continuous Rainfall-Runoff simulation	assumptions very strong (max. runoff coefficients, high design storm values)

Courtesy of: Magdalena Rogger

Outlook [from Rogger et al., GRA, 2009]:

- generation of long-time precipitation series with a stochastic rainfall model
- simulations with continuous rainfall-runoff model over > 10.000 years

Stochastic Rainfall Model: Rationale 3



Rainfall model structure:

- storm duration t_r and interstorm period t_b independently distributed and seasonally varying;
- mean storm intensity i statistically dependent on storm duration t_r (this dependence is itself seasonally varying);
- within-storm rainfall intensity variations are constructed by disaggregating from the mean storm intensity, using bounded random cascades.

Model Calibration:
Given an observed time series, storm events are separated (minimum dry period criterion), evaluating the characteristics of each storm (duration, average intensity, etc.) and fitting the distribution functions to the samples

Robinson & Sivapalan [WRR, 1997]; Menabde & Sivapalan [WRR, 2000]; Sivapalan et al. [WRR, 2005]

Stochastic Rainfall Model: Rationale 4

Once calibrated, the model can be used to generate long (>10000 years) series of synthetic rainfall

Science Question A:
How credible simulated extreme rainfall events are?

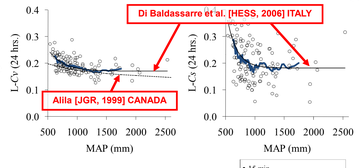
Probabilistic Envelope Curves for Extreme Rainfall Events 5

[Northern Italy - Castellarin et al., HYDROL, 2009]

Variation of statistics of rainfall annual maxima with MAP (northern Central Italy)

Variation and skewness:

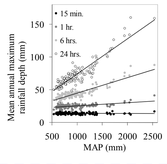
Di Baldassarre et al. [HESS, 2006] modelled the link between L-statistics and MAP through a series of Horton-type relations



Mean:

Strong dependence on MAP for long duration (frontal storms)
Weak dependence on MAP for short duration (convective storms)

This behaviour holds for various regions of the world [see e.g., Hershfield, ASCE, 1962; Bell, ASCE 1969]



Probabilistic Envelope Curves for Extreme Rainfall Events 6

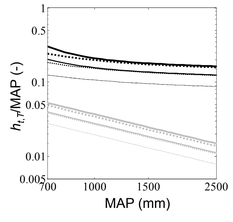
[Northern Italy - Castellarin et al., HYDROL, 2009]

Representation of rainfall quantiles standardized by MAP ($h_{t,T}$/MAP)

Storm timescale, *t*:
1 hour (grey)
24 hours (**black**)

Recurrence intervals *T*:
10, 100, 1000 years

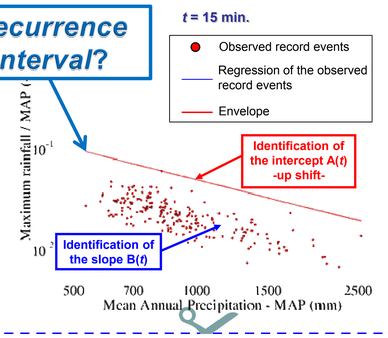
Frequency distributions:
EV1 (dashed line ----)
GEV (solid line ——)



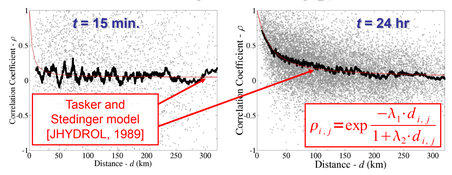
Log-linear expression (reasonable option) for representing the regional upper bound of the observed maximum point rainfall

$$\ln\left(\frac{h_{t,MAX}}{MAP}\right) = A(t) + B(t)\cdot\ln(MAP)$$

Empirical Envelope Curve (Northern Central Italy) 7



Exceedance probability of an Envelope Curve, p_{EC} 8



The algorithm for estimating p_{EC} [Castellarin, WRR, 2007] requires:

- the modelling of the cross-correlation structure – model proposed by Tasker and Stedinger [JHYDROL, 1989];

⇒ **Number of effective observations**

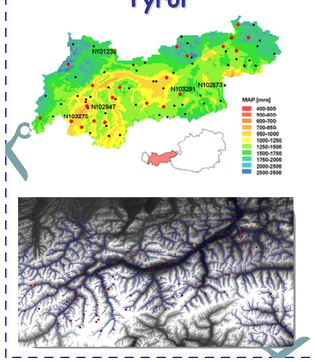
- the selection of a suitable plotting-position (pp): Hazen pp provides limited bias for GEV distribution for a wide range of shape parameters

Exceedance probability of an Envelope Curve, p_{EC} 9

Italian case study: the accuracy of rainfall quantiles retrieved from the envelope curves was assessed through a comparison with a regional depth-duration-frequency equation

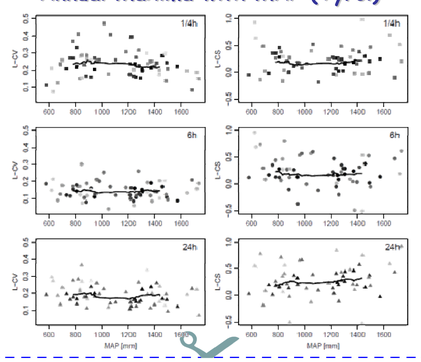
Science Question B:
How general and realistic is the probabilistic interpretation of envelope curves?

Study Area (AMS) Tyrol 10



No. of gauges		77
Altitude (m a.s.l.)	493	(min)
	1297	(mean)
	2850	(max)
MAP (mm)	523	(min)
	1076	(mean)
	1732	(max)
Series length (years)	1	(min)
	10	(mean)
	31	(max)
Station-years of data:	751	

Variation of Statistics of Rainfall Annual Maxima with MAP (Tyrol) 11

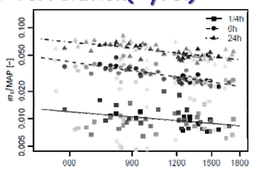


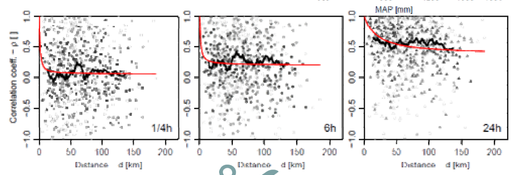
Mean Annual Maximum Rainfall Depth and Intersite Correlation(Tyrol) 12

Mean:

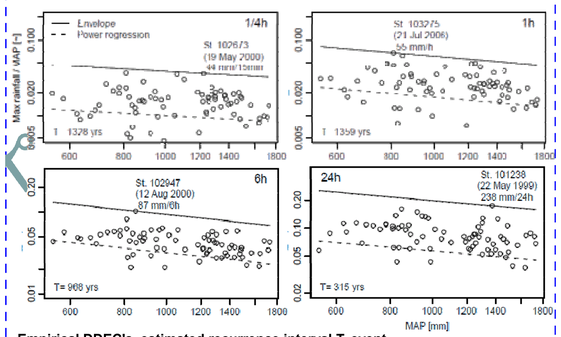
Strong dependence on MAP for long duration (frontal storms)

Weak dependence on MAP for short duration (convective storms)



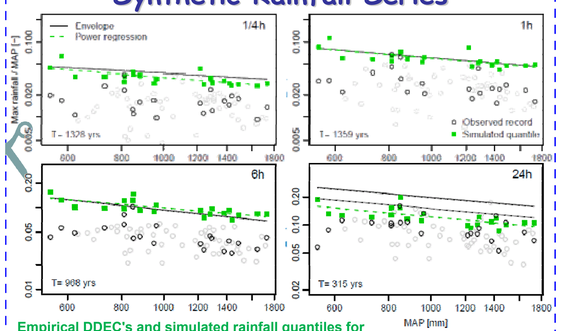


Empirical Envelopes 13



Empirical DDEC's, estimated recurrence interval T, event setting the envelope and corresponding site

Empirical Envelopes vs. Synthetic Rainfall Series 14



Empirical DDEC's and simulated rainfall quantiles for the return period given by the DDEC (50 000 years of rainfall)

Summary

Science Questions:

SQA: How credible simulated extreme rainfall events are?

SQB: How general and realistic is the probabilistic interpretation of envelope curves?

Main results:

- Good agreement (especially for intermediate timescales 1-6 hours)
- Utilization of different sources of information (storm and inter-storm characteristics, observed records and cross-correlation among series)

Possible utilizations:

☑ **Envelope Curve → Rainfall Model:**
- validation of simulated rainfall quantiles for high recurrence intervals
- critical revision of calibrated parameters for discordant sites

☑ **Rainfall Model → Envelope Curve:**
- suitability of assumptions of the probabilistic interpretation (climatic homogeneity, descriptiveness of MAP)