Politecnico di Torino
Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture

DATA POOR VS. DATA RICH CASES FOR FLOOD HAZARD

EXPLOITING LOCAL AND REGIONAL DATA

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UNESCO United Nations Educational, Scientific and Cultural Organization
World Water Assessment Programme
WA RRE DOC
Università per Stranieri di Perugia

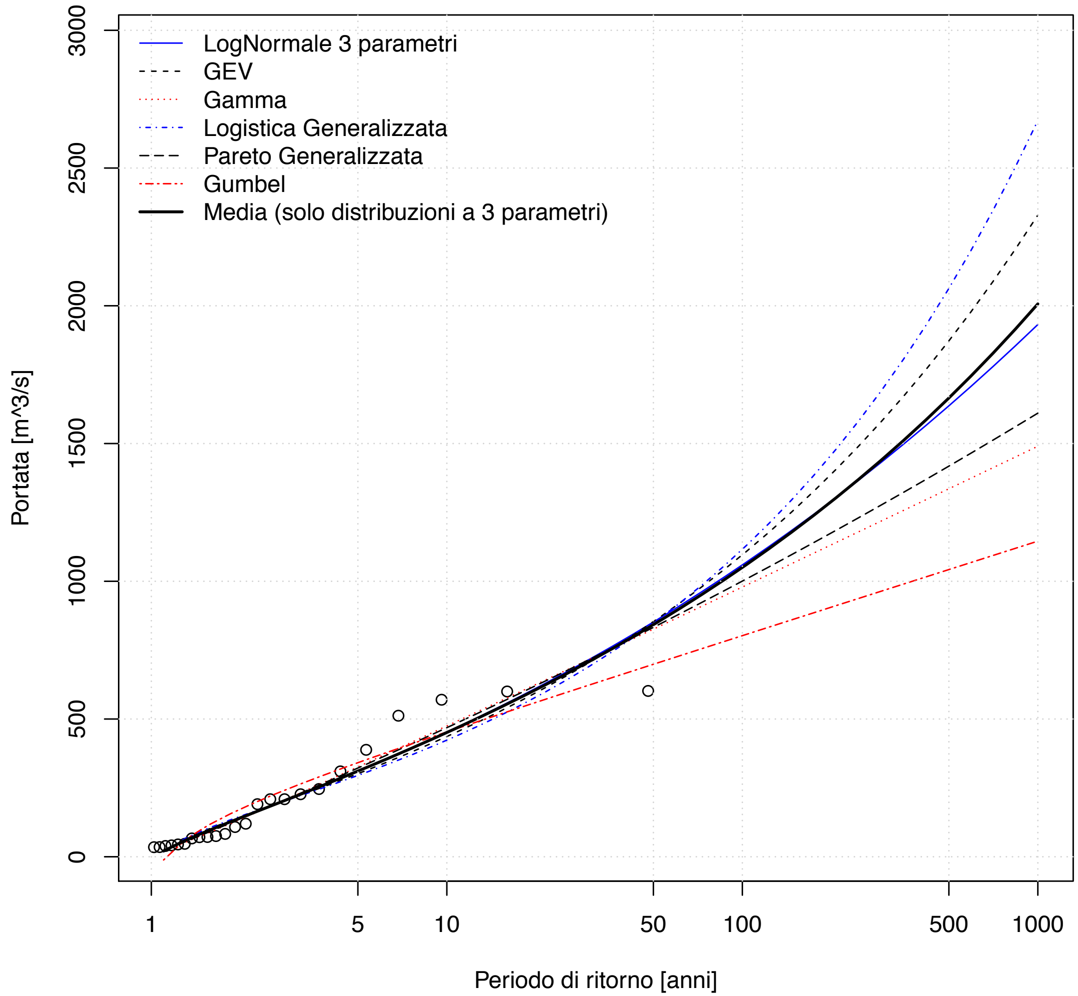
International Winter School on Hydrology

A classic problem in hydrology

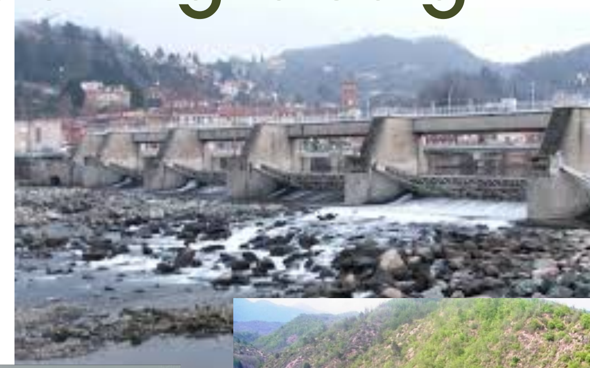
flood

frequency

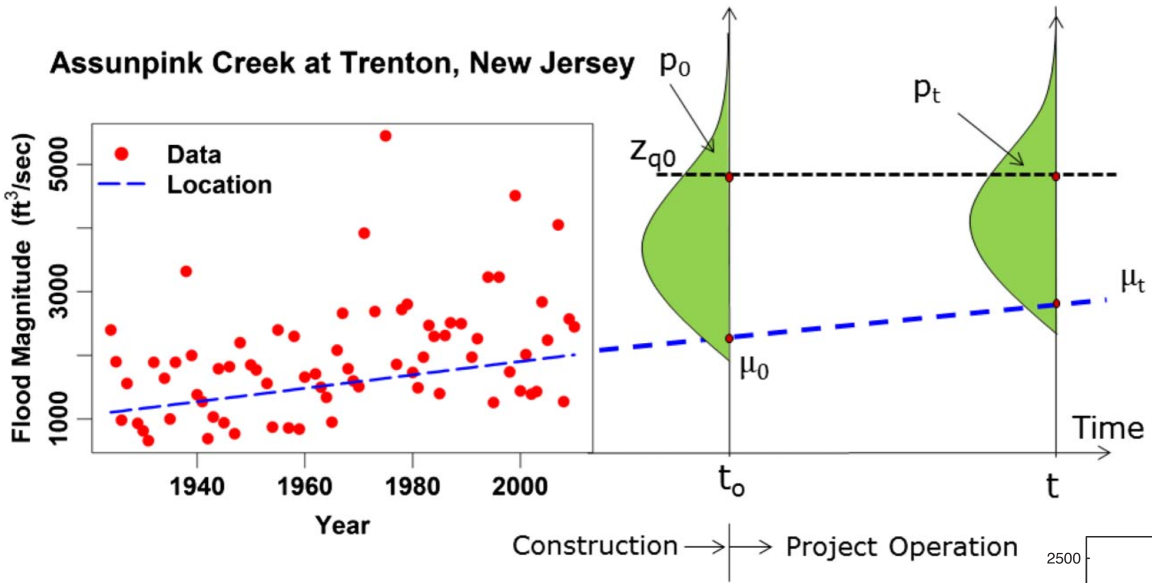
distribution



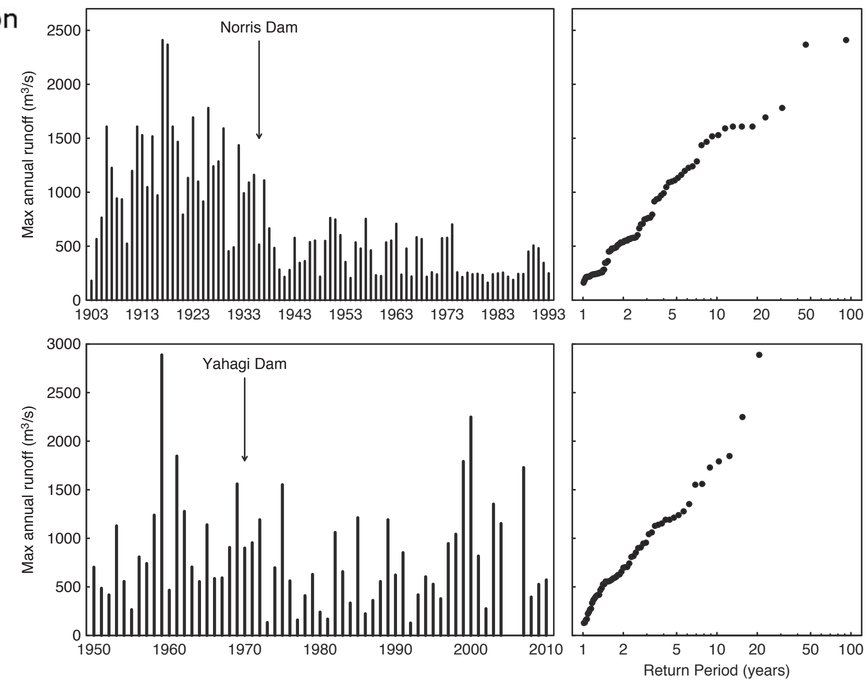
Flood flow for engineering design…



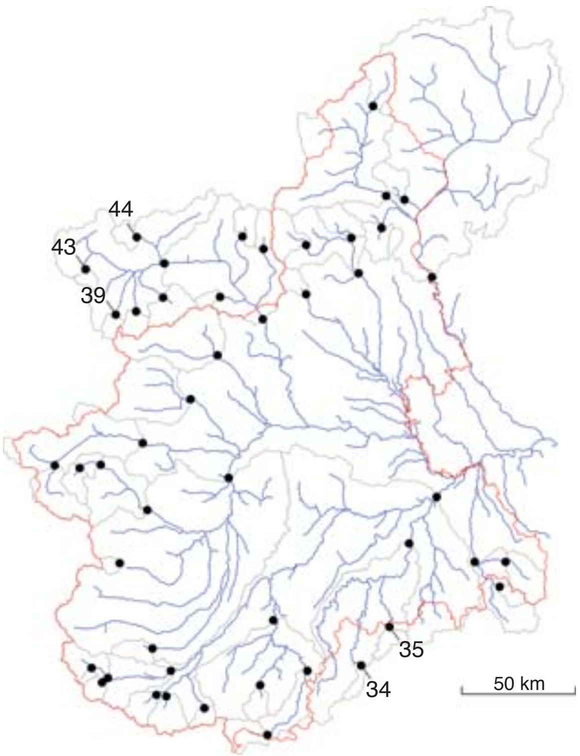
… and to understand changing systems

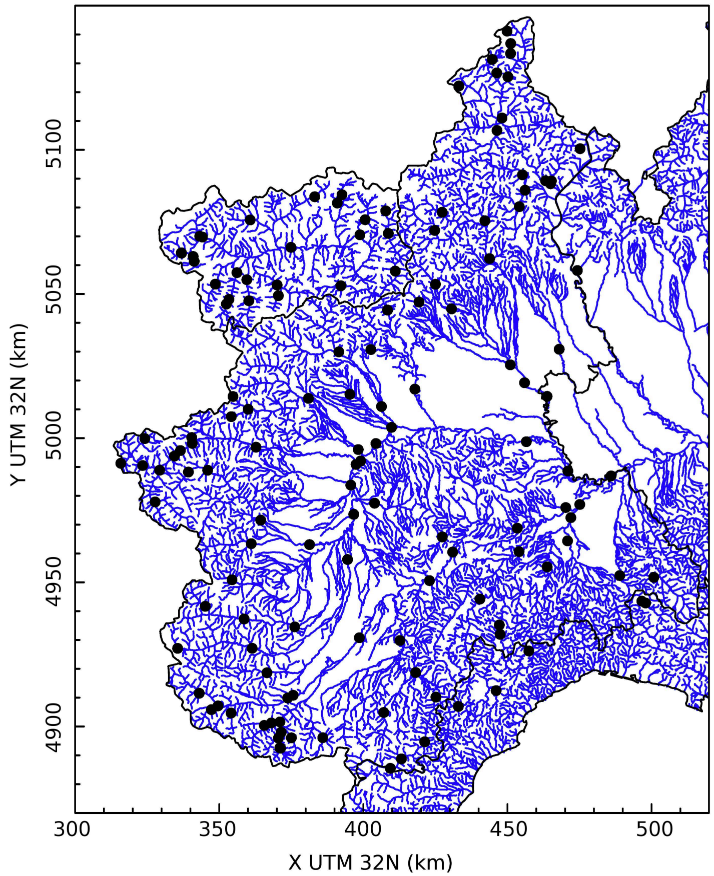


Quantifying the drivers and effects of changes (climate, land, river training, …)



Observations in the place of interest?

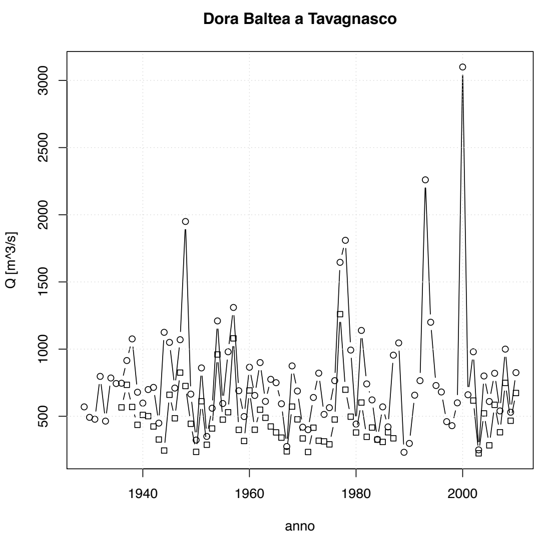


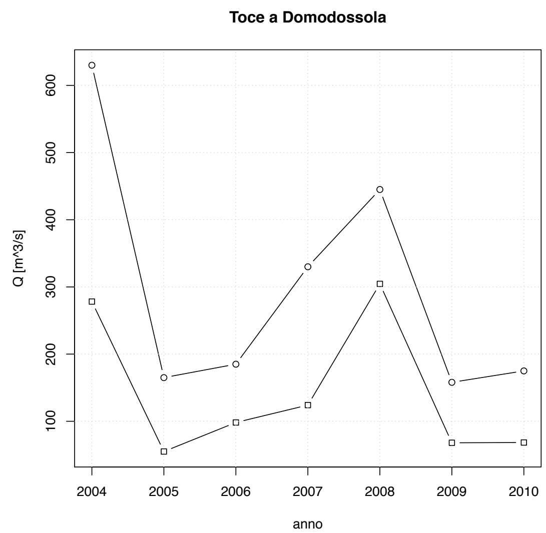


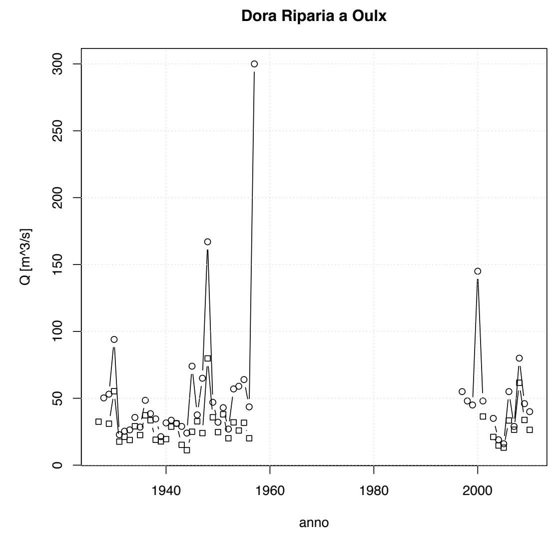
Other possible issues

- Correlation of data
- Nestedness of catchments
- Non stationarity

Observations in the period of interest?



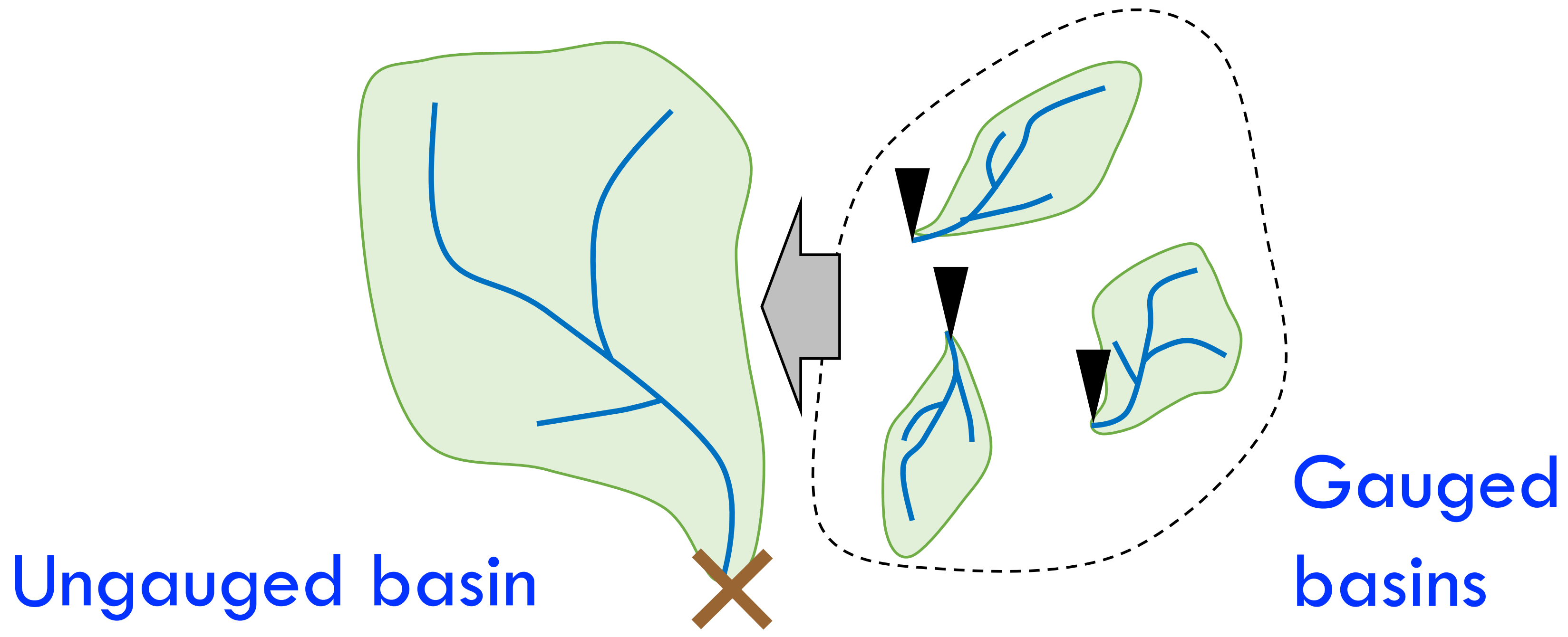




Try to extend the record with:

- Non systematic data
- Proxy measures
- New sources of information

What if no observations available?



Try to transfer information

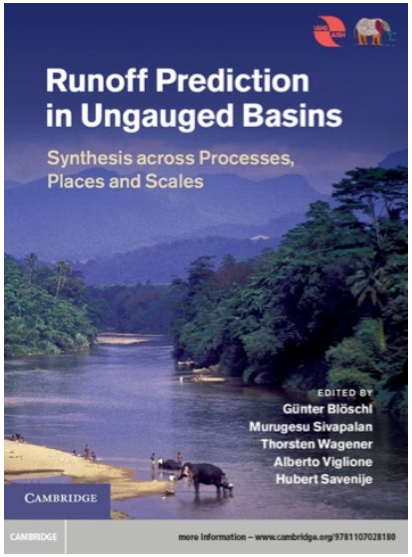
How? Regional models

Substitute time for space

time series

other "similar" catchments

- *regression methods*, where specific runoff signatures are transferred based on their relationship with catchment and climatic attributes via some analytical expression;
- *index methods*, which assume that a known, quantitative runoff, catchment or climatic signature is constant within a defined homogeneous region, except for a locally varying scaling index;
- *geostatistical and proximity methods*, which exploit spatial smoothness of the runoff signature. Here 'spatial' may refer to either geographic space or a parameter space defined by catchment attributes;
- *runoff estimation from short-records*, which exploits the relationship between moments of short runoff records and runoff in neighbouring catchments.



How? Regional models

There are many different flavors, many different implementations

Possible comparative approaches:

- Different models to the same **dataset**
- Same model across different **datasets**

Nat. Hazards Earth Syst. Sci., 14, 295–308, 2014
www.nat-hazards-earth-syst-sci.net/14/295/2014/
doi:10.5194/nhess-14-295-2014

Natural Hazards and Earth System Sciences
Open Access

A data-based comparison of flood frequency analysis methods used in France

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Received: 31 July 2013 – Published in Nat. Hazards Earth Syst. Sci. Discuss.: 6 September 2013
Revised: 8 January 2014 – Accepted: 10 January 2014 – Published: 20 February 2014

Abstract. Flood frequency analysis (FFA) aims at estimating quantiles with large return periods for an extreme discharge variable. Many FFA implementations are used in operational practice in France. These implementations range from the estimation of a pre-specified distribution to continuous simulation approaches using a rainfall simulator coupled with a rainfall–runoff model. This diversity of approaches raises questions regarding t… calls for a nation-wid… mances.
This paper presents… the main FFA implem… rately, eight impleme… to the local, regional … implementations evaluated in this study displayed a quite poor reliability, suggesting that prediction in completely ungauged catchments remains a challenge.

WATER RESOURCES RESEARCH, VOL. 49, 825–843, doi:10.1002/wrcr.20087, 2013

Data-based comparison of frequency analysis methods: A general framework

B. Renard,[1] K. Kochanek,[1,2] M. Lang,[1] F. Garavaglia,[3] E. Paquet,[3] L. Neppel,[4] K. Najib,[4] J. Carreau,[4] P. Arnaud,[5] Y. Aubert,[5] F. Borchi,[6] J.-M. Soubeyroux,[6] S. Jourdain,[6] J.-M. Veysseire,[6] E. Sauquet,[1] T. Cipriani,[1] and A. Auffray[7]

Received 7 November 2011; revised 1 November 2012; accepted 1 January 2013; published 6 February 2013.

[1] An abundance of methods have been developed over the years to perform the frequency analysis (FA) of extreme environmental variables. Although numerous comparisons between these methods have been implemented, no general comparison framework has been agreed upon so far. The objective of this paper is to build the foundation of a data-based comparison framework, which aims at complementing more standard comparison schemes based on Monte Carlo simulations or statistical testing. This framework is based on the following general principles: (i) emphasis is put on the predictive ability of competing FA implementations, rather than their sole descriptive ability measured by some goodness-of-fit criterion; (ii) predictive ability is quantified by means of reliability indices, describing the consistency between validation data (not used

Hydrol. Earth Syst. Sci., 17, 2637–2652, 2013
www.hydrol-earth-syst-sci.net/17/2637/2013/
doi:10.5194/hess-17-2637-2013

Hydrology and Earth System Sciences
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Comparative assessment of predictions in ungauged basins – Part 2: Flood and low flow studies

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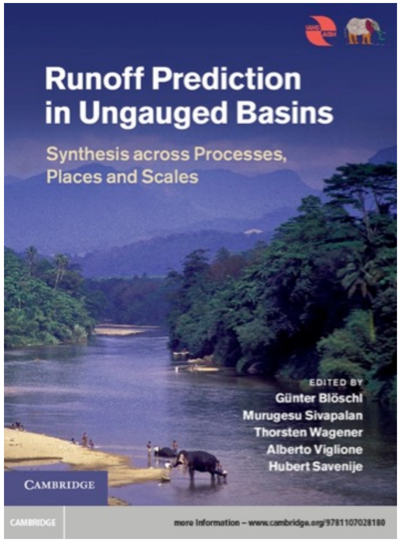
Received: 21 December 2012 – Published in Hydrol. Earth Syst. Sci. Discuss.: 14 January 2013
Revised: 28 May 2013 – Accepted: 2 June 2013 – Published: 9 July 2013

Abstract. The objective of this paper is to assess the performance of methods that predict low flows and flood runoff in ungauged catchments. The aim is to learn from the similarities and differences between catchments in different places, and to interpret the differences in performance in terms of the underlying climate-landscape controls. The assessment is performed at two levels. The Level 1 assessment is a meta-analysis of 14 low flow prediction studies reported in the lit-

1 Introduction

Estimating flood and low flow discharges in ungauged basins are among the most fundamental challenges in catchment hydrology. There is a long track record in statistical hydrology of developing methods to estimate, in an optimal way, these discharges from runoff observations in neighbouring catch-



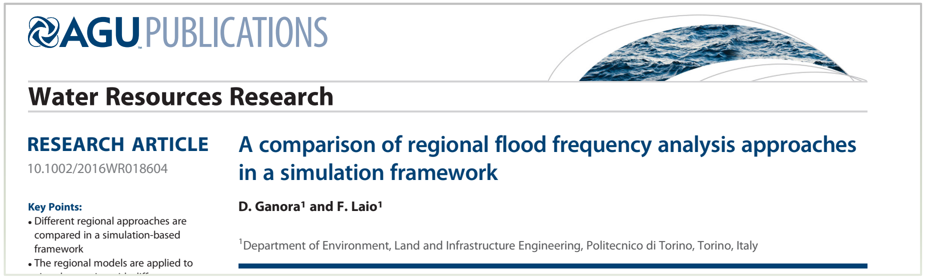
A numerical experiment

Use of (perfectly) known conditions

Simulate different realistic conditions (scenarios)

Original questions: can we identify the "best" strategy for regionalization?

Compare the behavior of different approaches to **true data**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RESEARCH ARTICLE

10.1002/2016WR018604

Key Points:
- Different regional approaches are compared in a simulation-based framework
- The regional models are applied to

A comparison of regional flood frequency analysis approaches in a simulation framework

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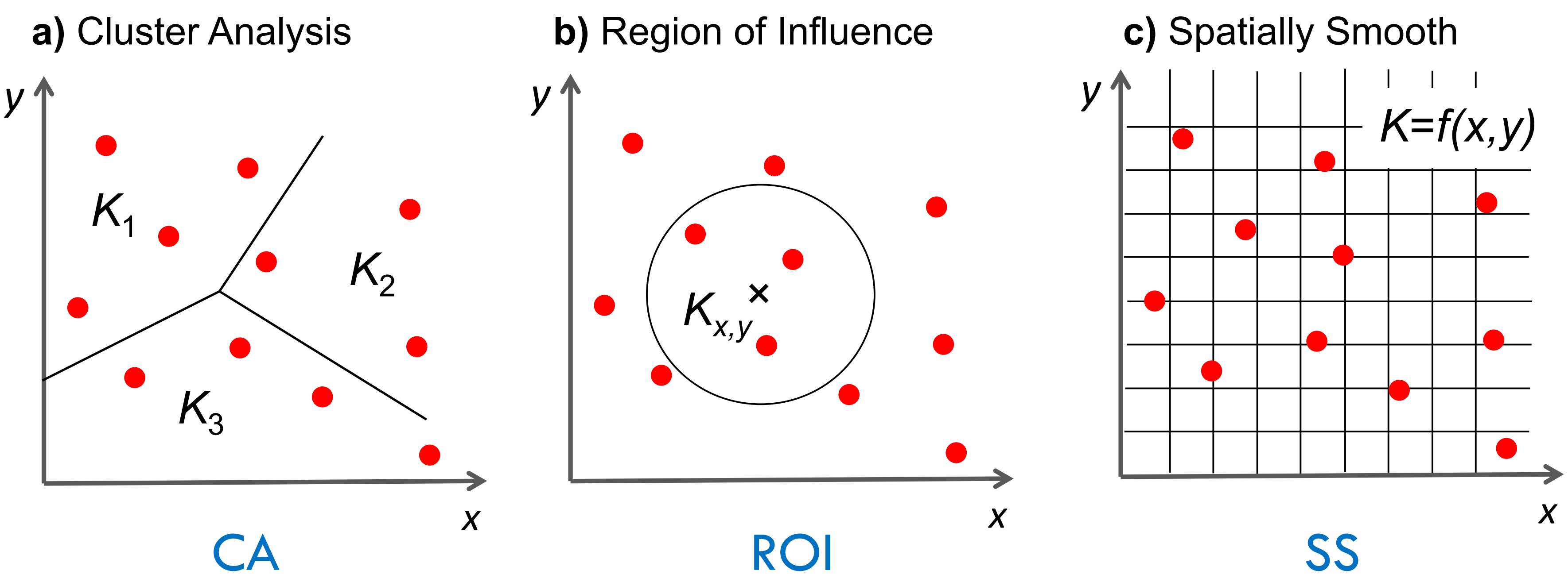
Regional approaches comparison



Plus 2 reference models:

- 1R = just averaging the results over the whole set
- SFA = at-site frequency analysis

Model implementations need to be reproducible and unsupervised

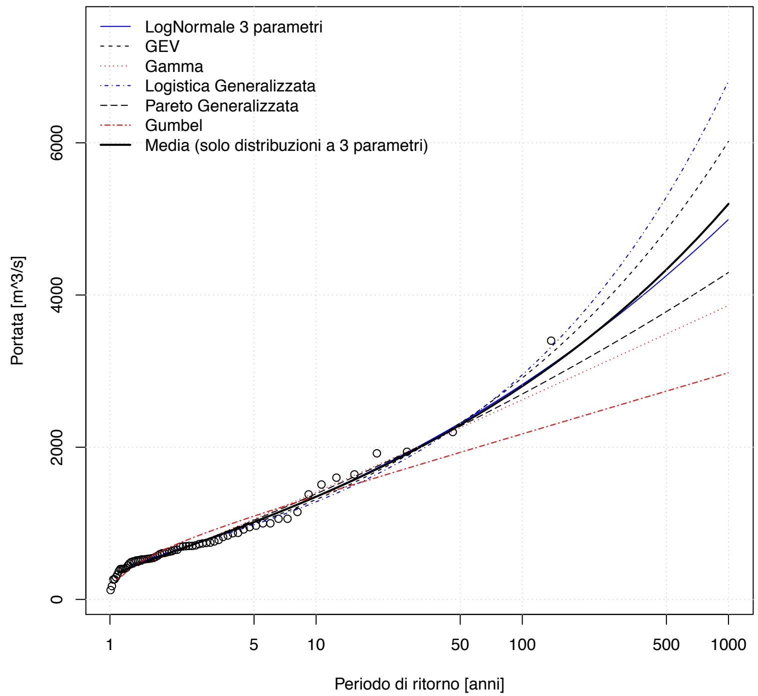
Flood frequency analysis

Choose the fitting distribution

$$Q_T = \theta_1 + \frac{\theta_2}{\theta_3}\left\{1 - \left[-\ln\left(1 - \frac{1}{T}\right)\right]^{\theta_3}\right\}$$

$\theta_1, \theta_2, \theta_3$

L1(mean), L-CV, L-skew, L-kur



From local data (at-site)

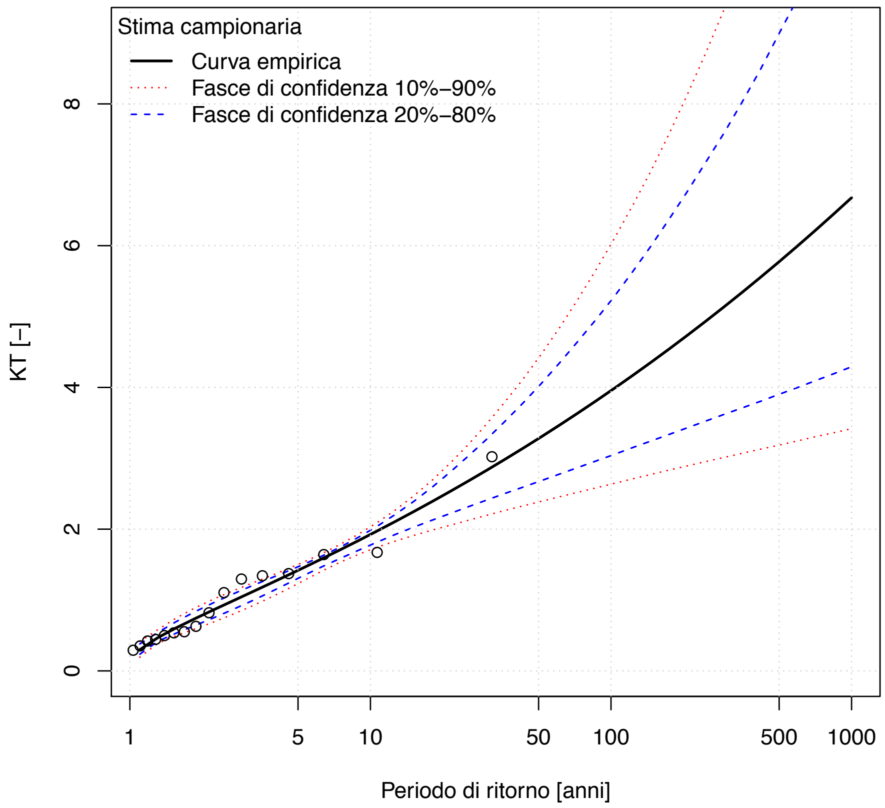
From CA

From ROI

From SS

From 1R (reference)

Here we consider the growth curve



$$K_T = \frac{Q_T}{\bar{Q}}$$

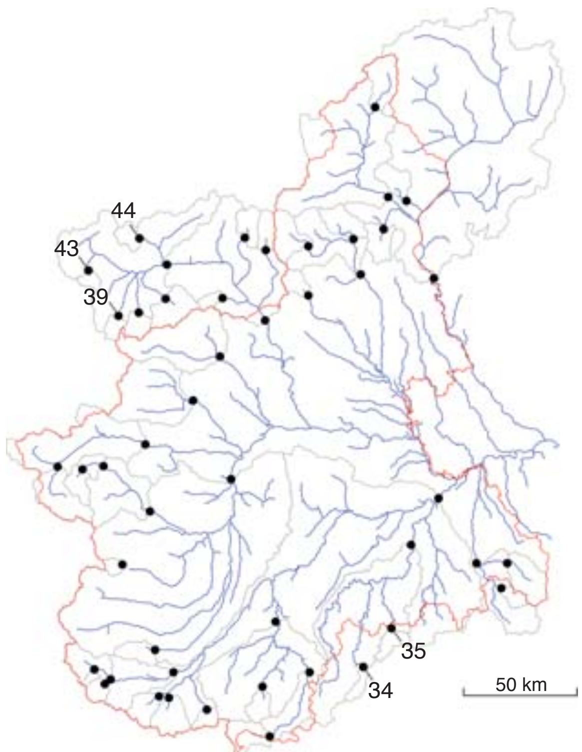
$$Q_T = \theta_1 + \frac{\theta_2}{\theta_3}\left\{1 - \left[-\ln\left(1 - \frac{1}{T}\right)\right]^{\theta_3}\right\}$$

$$\bar{Q} = \theta_1 + \theta_2[1 - \Gamma(1+\theta_3)]/\theta_3$$

e.g., GEV distribution

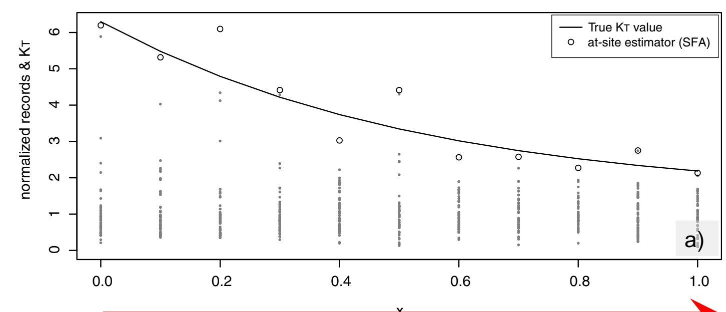
From the single site to the region

Real landscape



- Highly complex
- We have only 1 realization

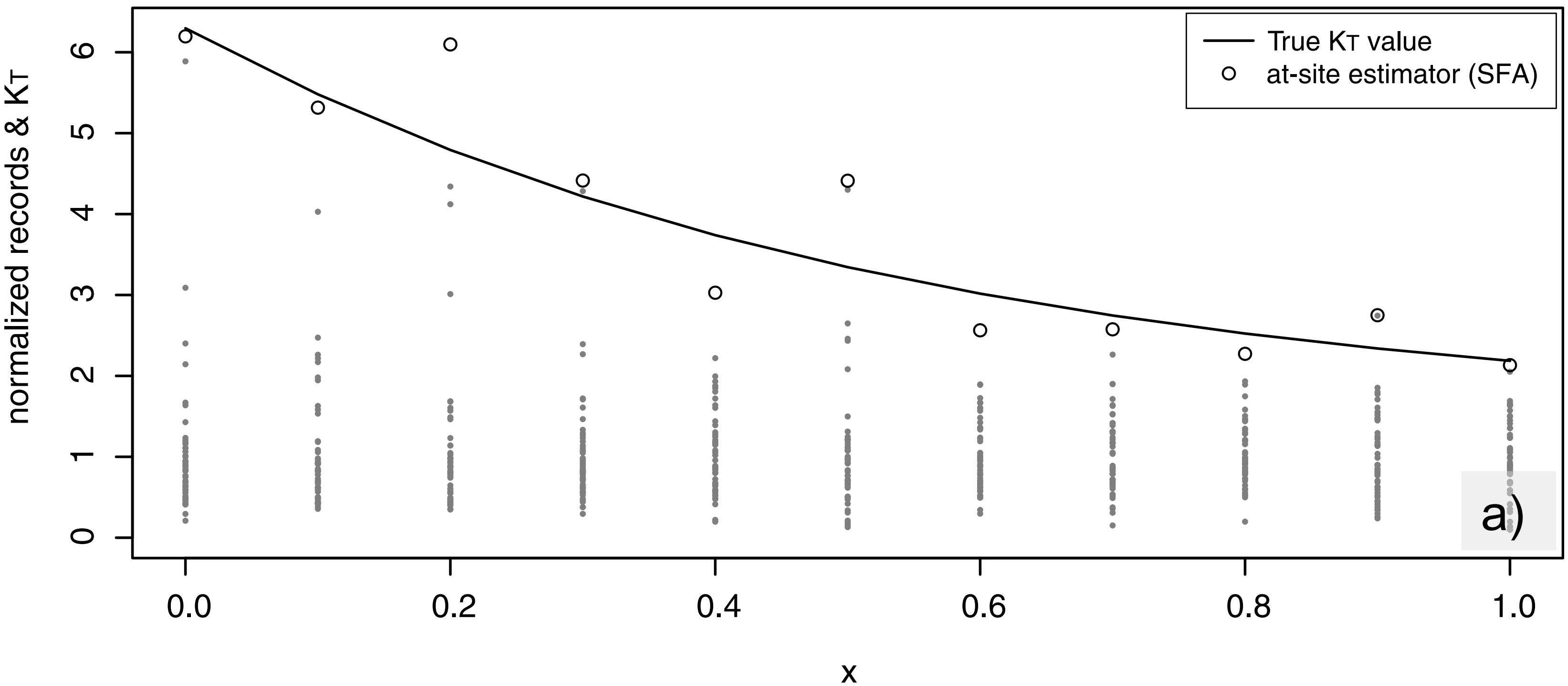
Virtual landscape



x is the generic driving variable (area, rainfall, geographical location,…)

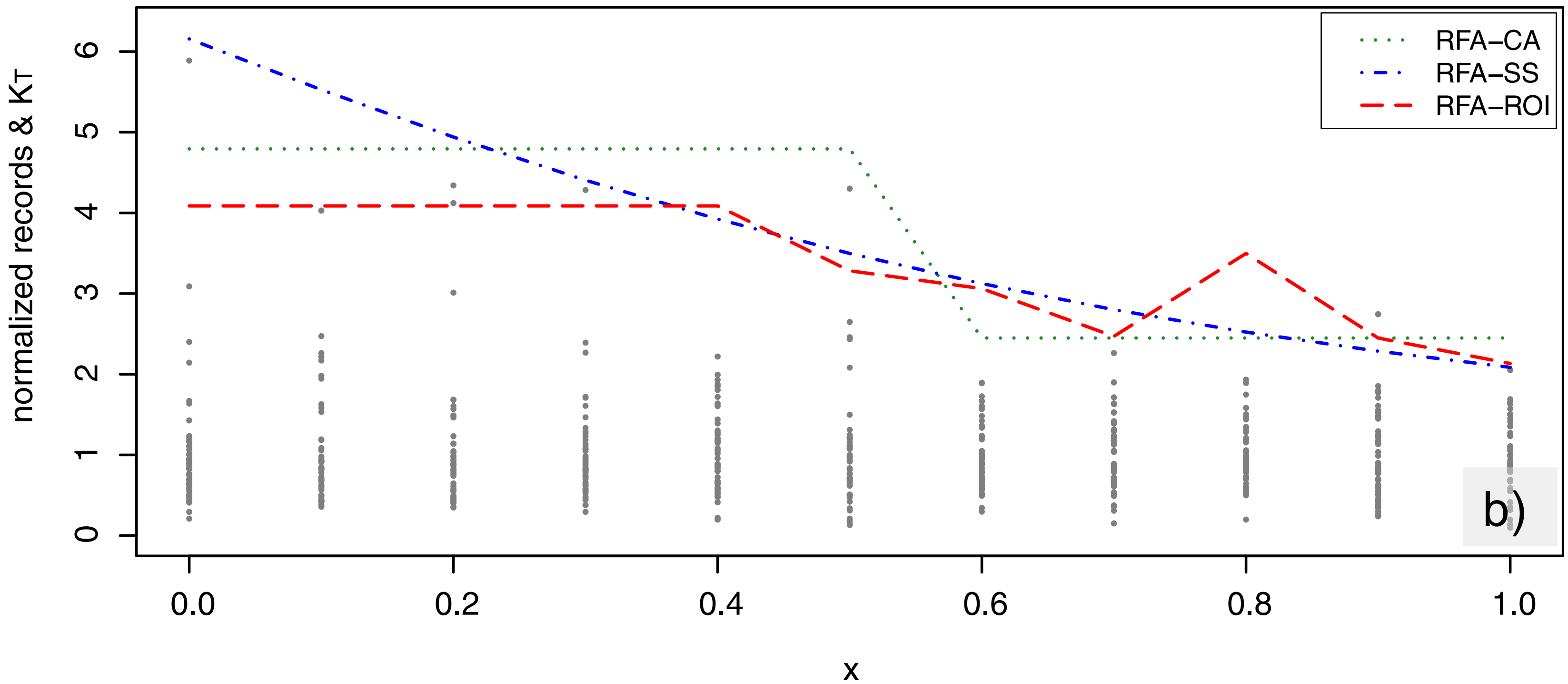
- Complexity defined by the hydrologist
- We simulate many realizations

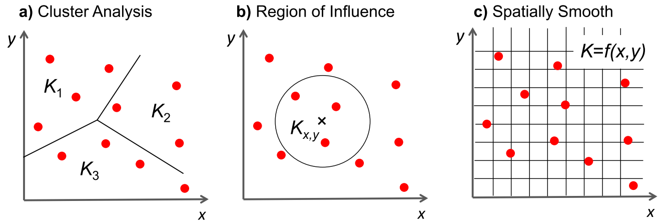
Example of a single realization (of the whole landscape)



GEV distribution divided by the sample average (with $\theta_1 = 1,\ \theta_2 = 0.5,\ \theta_3 = -0.4 + 0.6 \cdot x$).

Example of application of the regional models to the single realization (of the whole landscape)





Example of a single realization (of the whole landscape)

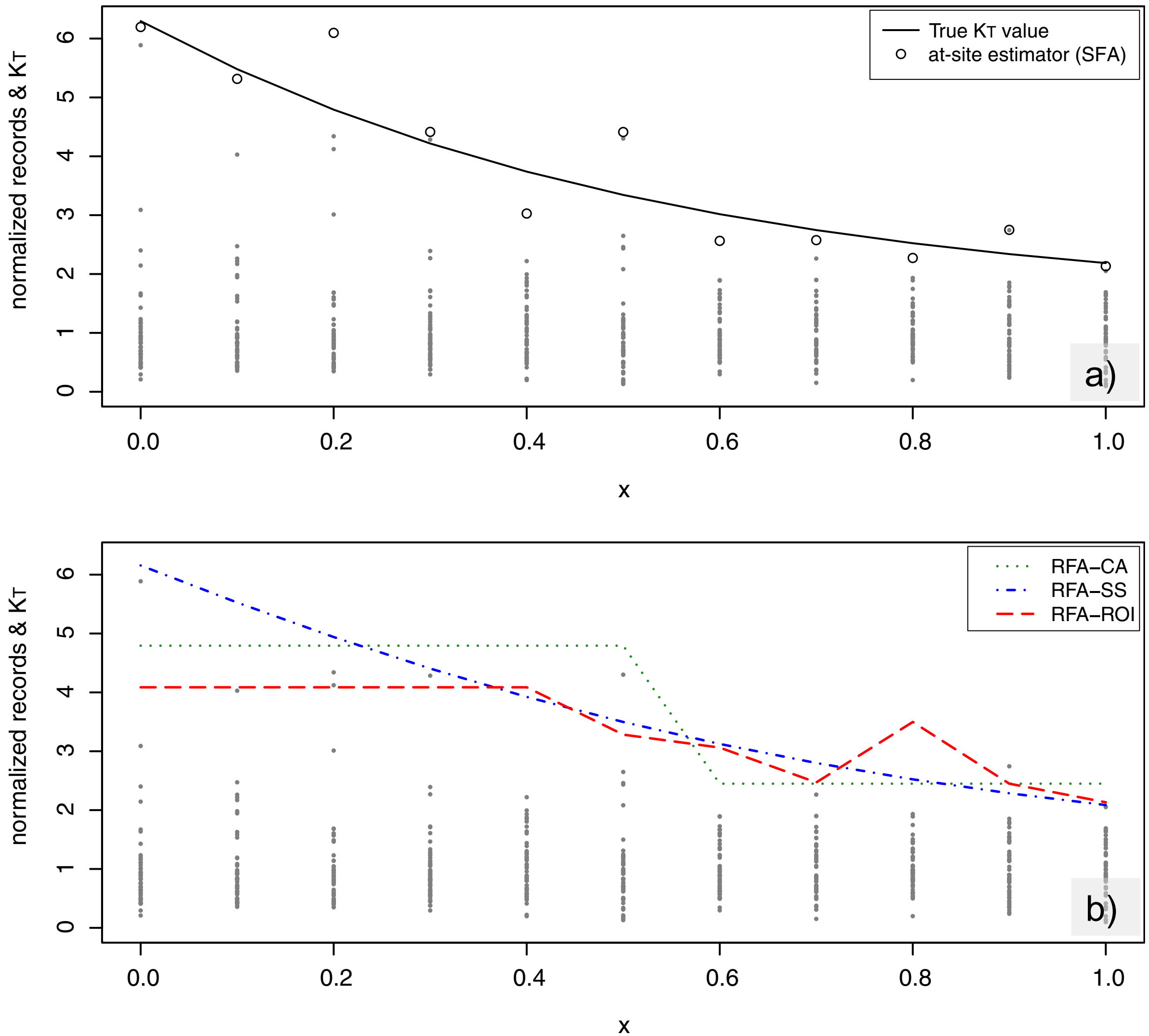


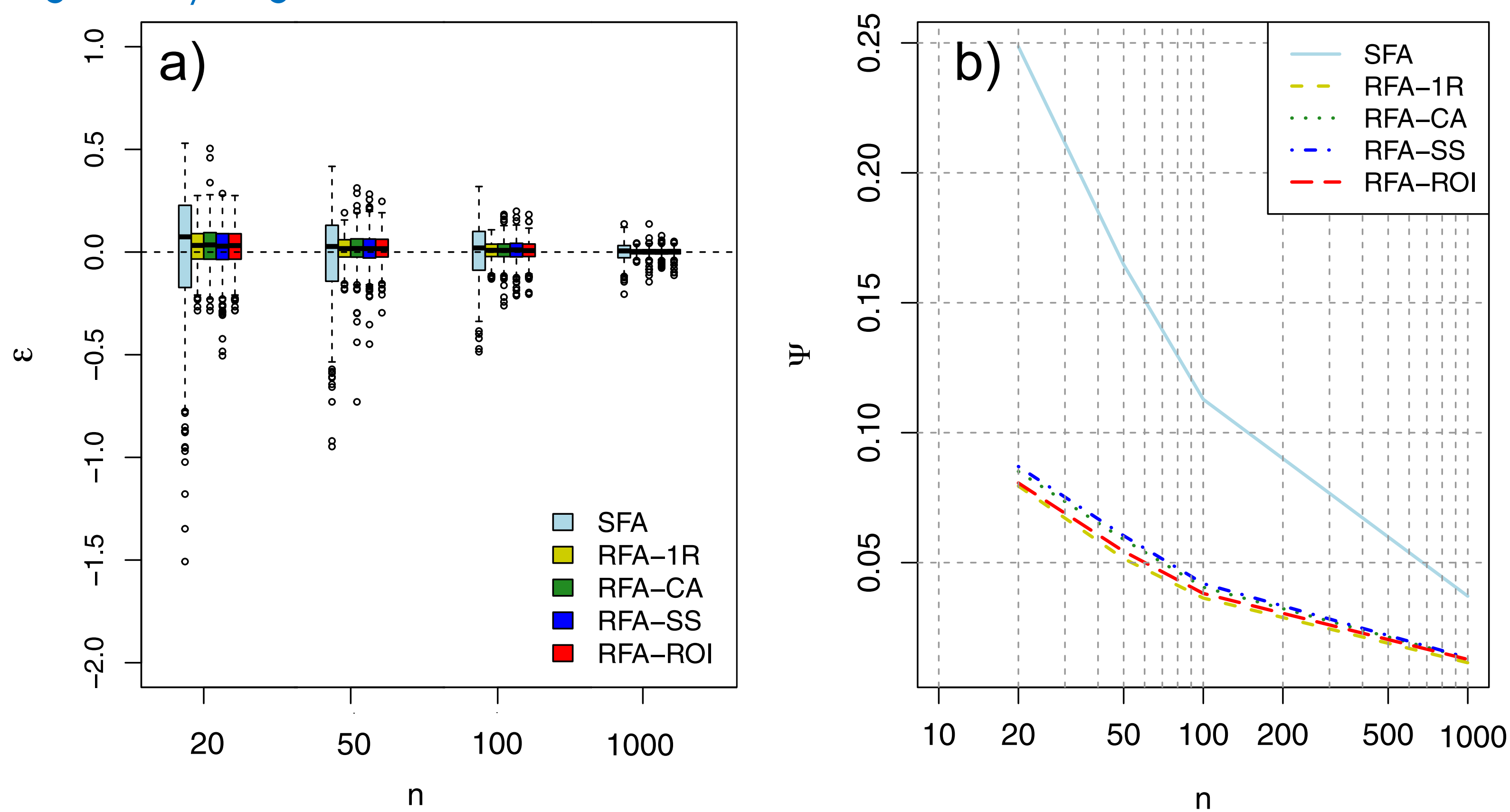
Figure 1. Example of simulation with 11 virtual gauging stations. Grey dots are the simulated data (i.e., the normalized annual maximum values) drawn from the GEV distribution divided by the sample average (with $\theta_1=1$, $\theta_2=0.5$, $\theta_3=-0.4+0.6 \cdot x$). (a) The true value and the at-site estimator of K_T; (b) the regional estimators. A return period $T=200$ years is considered.

Scenario 0: true homogeneity

Relative error

single-site/single-simulation

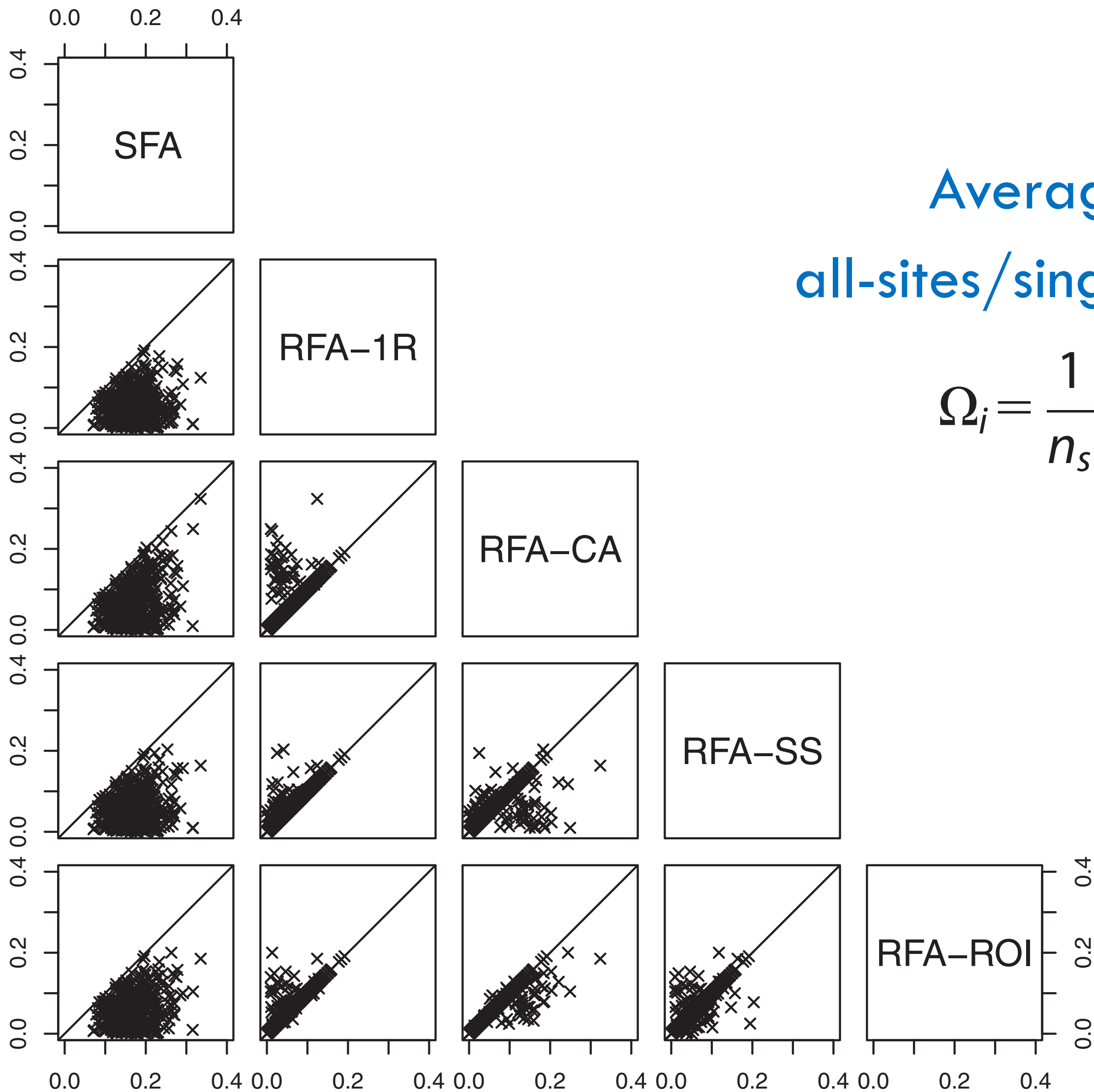
$$\varepsilon_{s,i} = \frac{K_{T;s} - \widehat{K}_{T;s,i}}{K_{T;s}}$$



Average error

single-site/all-simulations

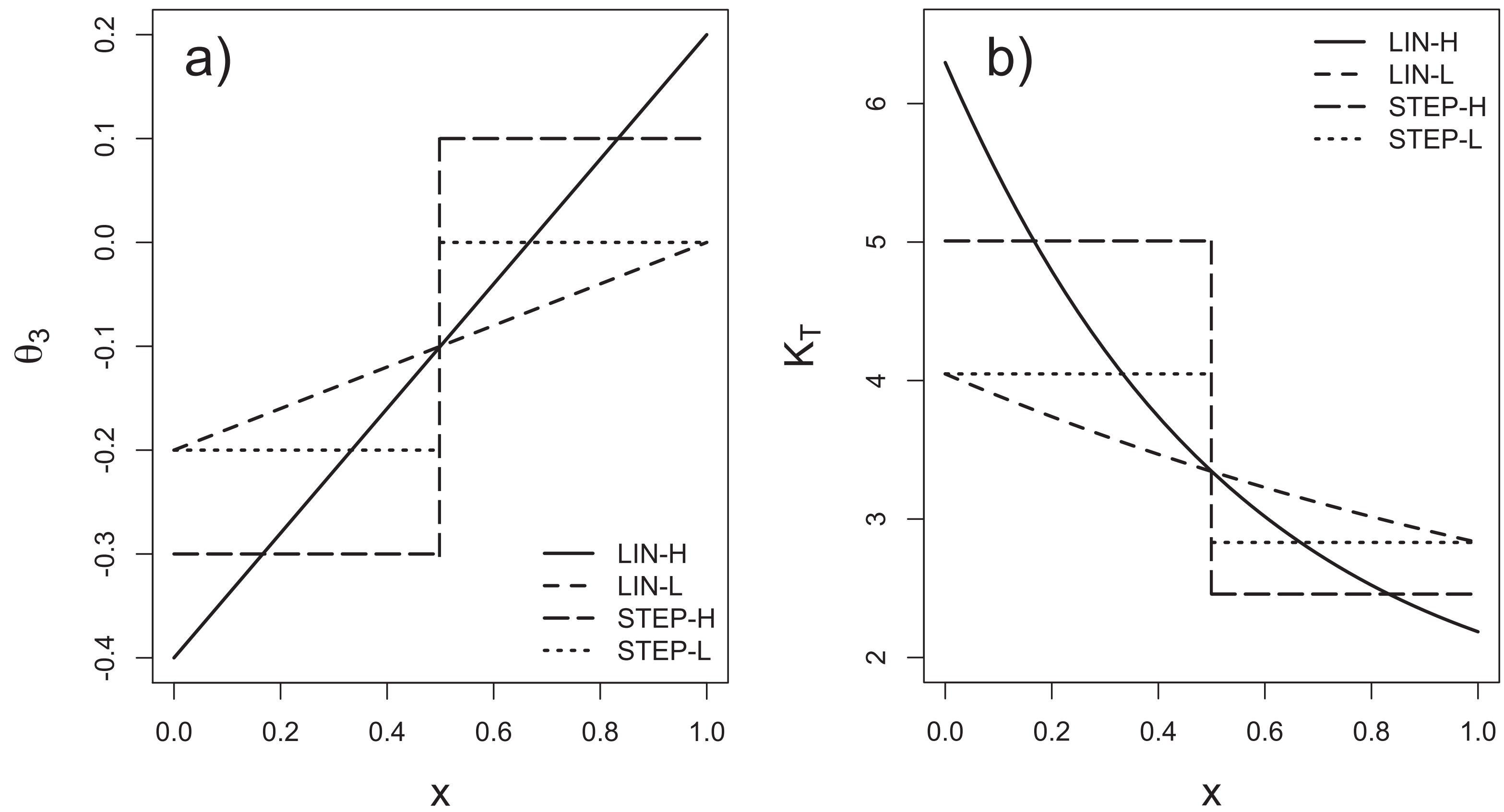
$$\Psi_s = \frac{1}{N}\sum_{i=1}^{N} |\varepsilon_{s,i}|$$



Average error all-sites/single-simulation

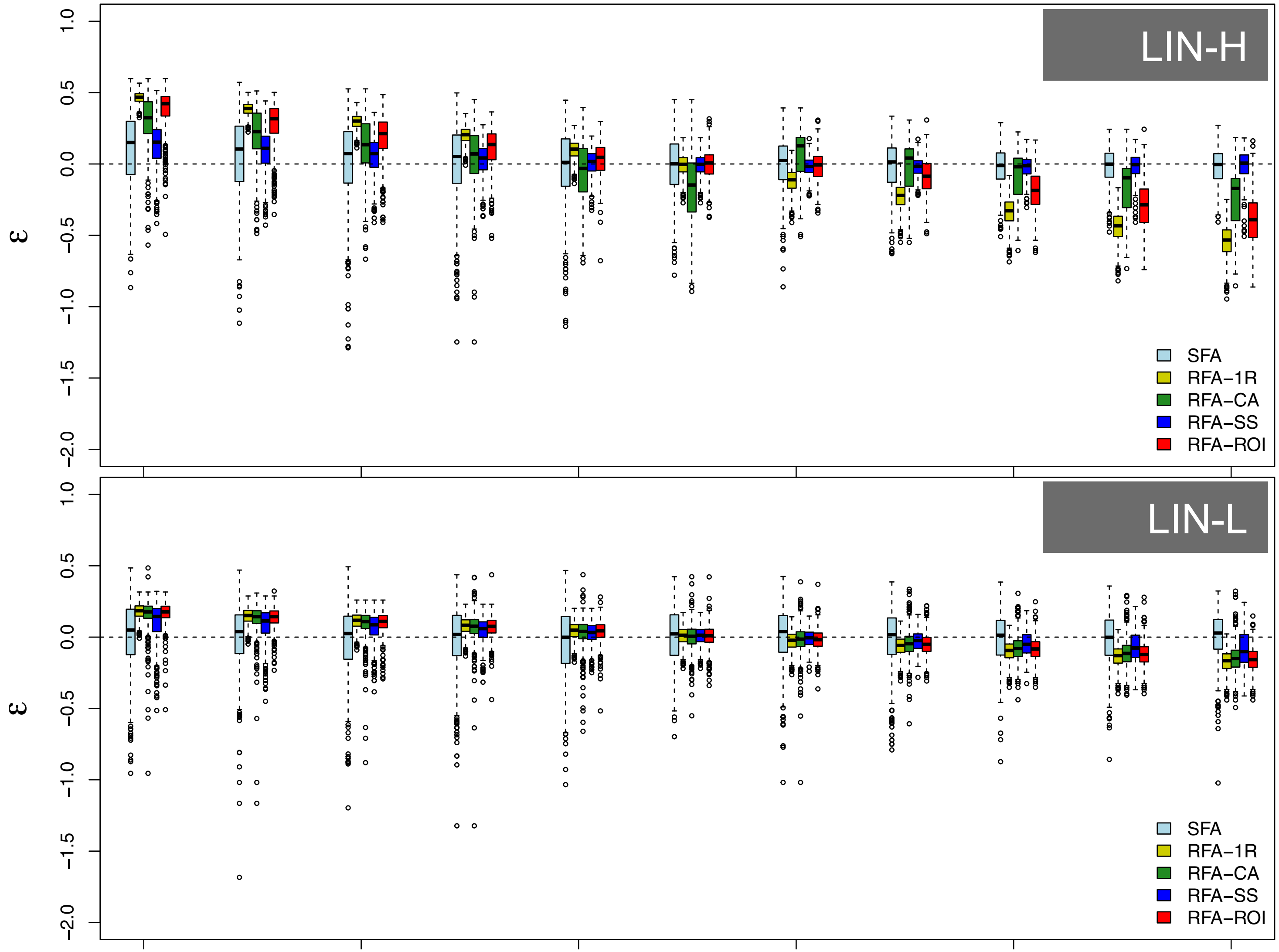
$$\Omega_i = \frac{1}{n_s}\sum_{s=1}^{n_s}\left|\varepsilon_{s,i}\right|$$

Scenarios with heterogeneity



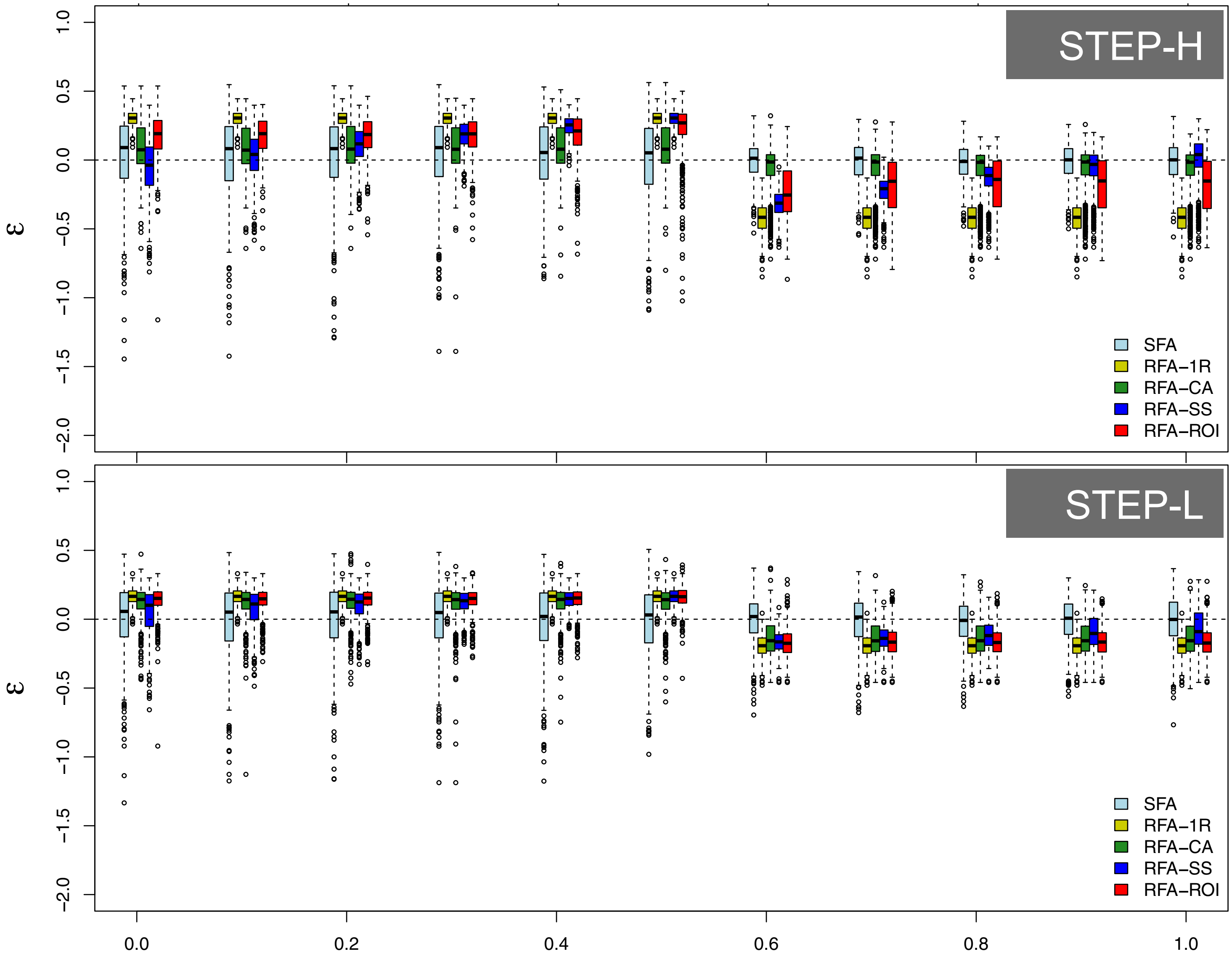
Shape parameter	$\theta_3 = -0.4 + 0.6 \cdot x$	LIN-H scenario
	$\theta_3 = -0.2 + 0.2 \cdot x$	LIN-L scenario
	$\theta_3^L = -0.3$; $\theta_3^R = 0.1$	STEP-H scenario[a]
	$\theta_3^L = -0.2$; $\theta_3^R = 0$	STEP-L scenario[a]

[a] θ^L is valid for $0 \leq x \leq 0.5$ and θ^R for $0.5 < x \leq 1$.



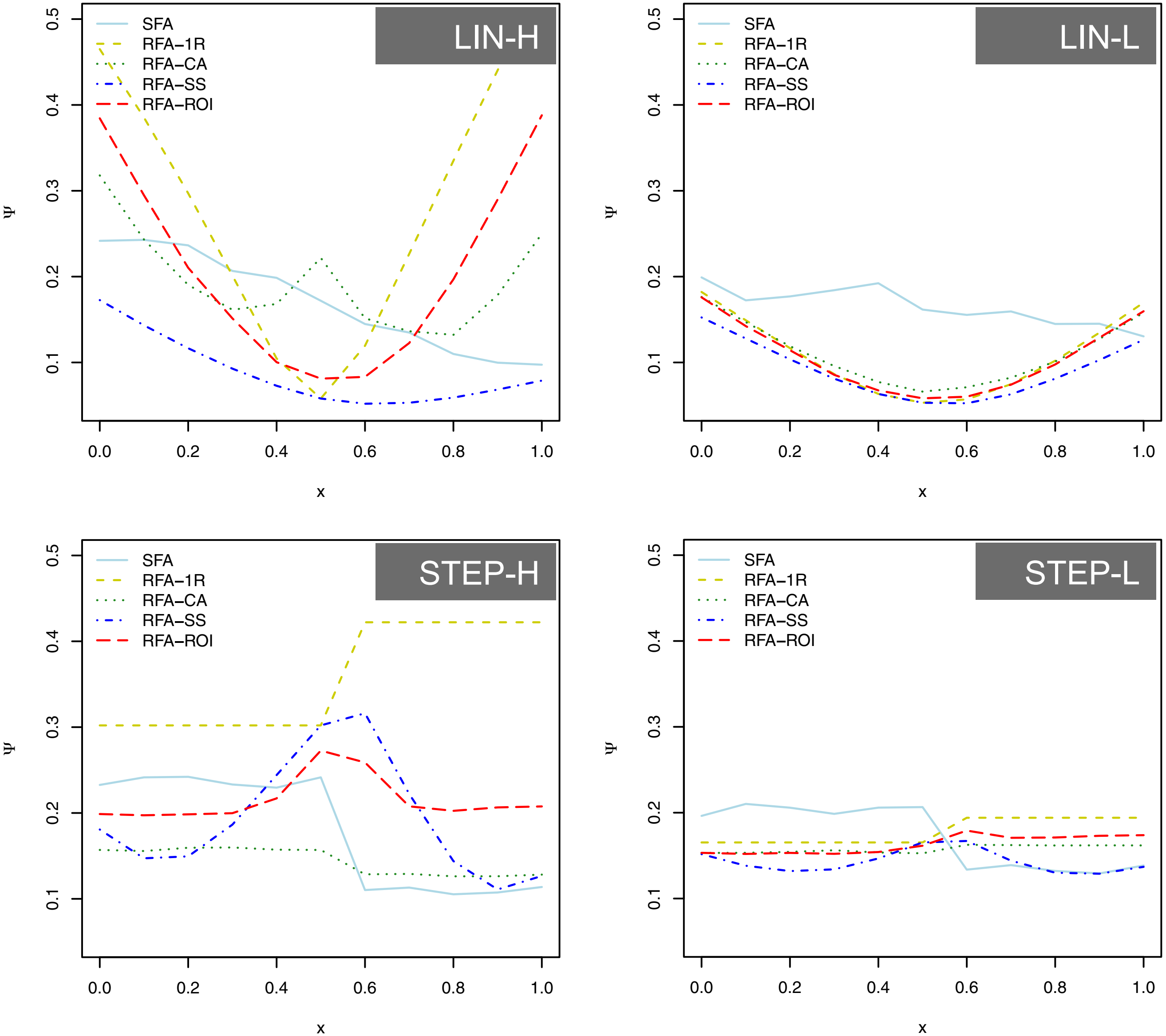
Relative error

single-site/single-simulation



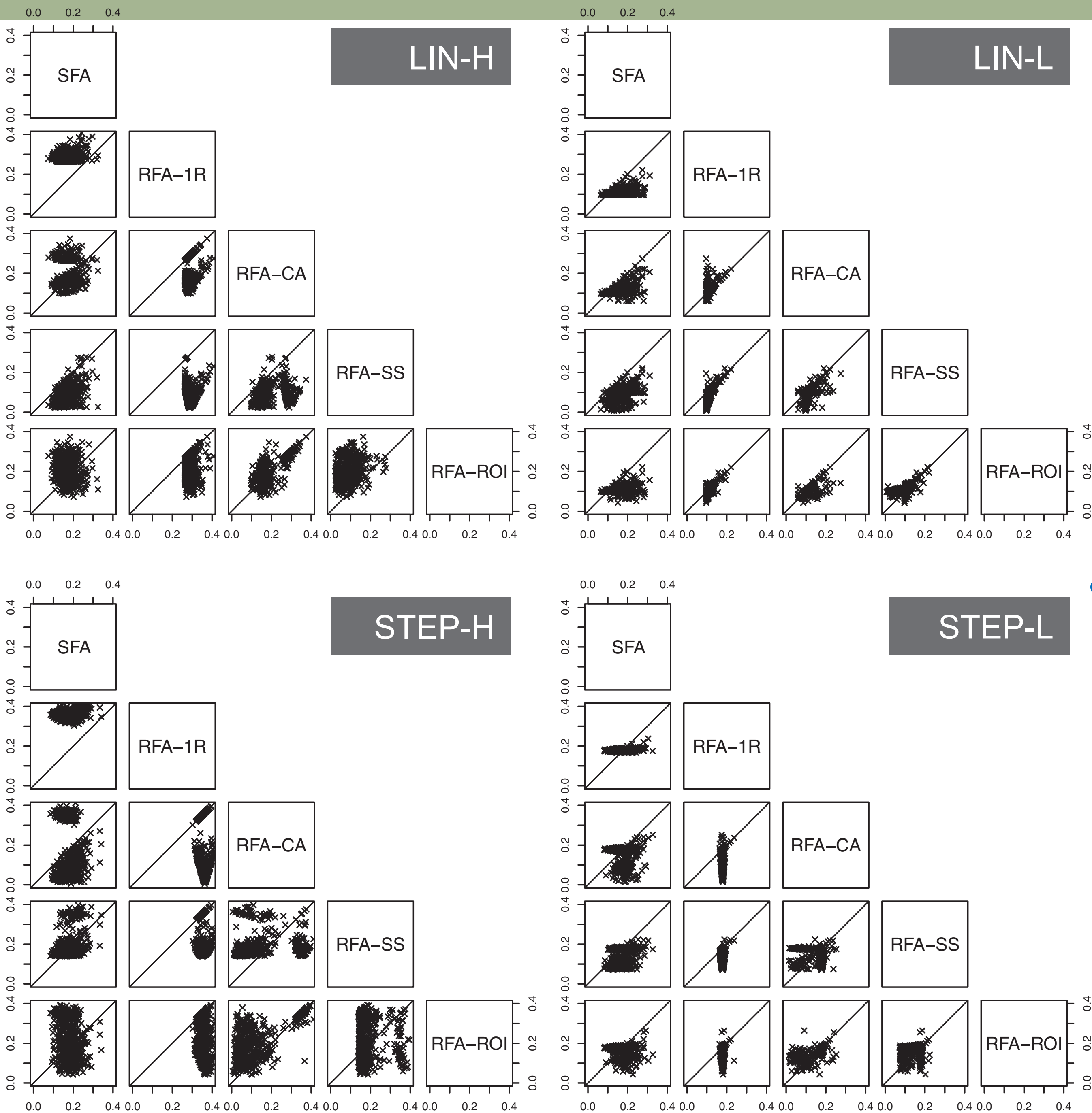
Relative error

single-site/single-simulation



$$\Psi_s = \frac{1}{N}\sum_{i=1}^{N} |\varepsilon_{s,i}|$$

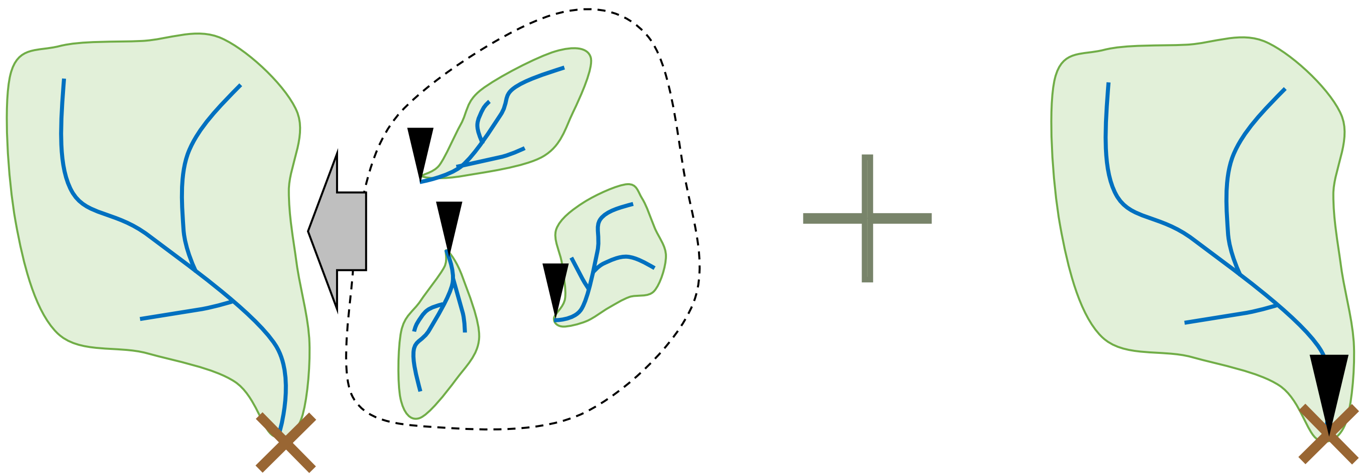
Average error single-site/ all-simulations



$$\Omega_i = \frac{1}{n_s} \sum_{s=1}^{n_s} |\varepsilon_{s,i}|$$

Average error all-sites/single-simulation

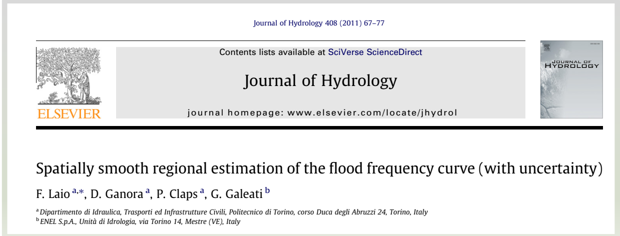
Regional + at-site



"Poorly" gauged basins = short time series

e.g., recently installed streamflow gauges or "unconventional" measurements

Useful approach to update regional models without recalibration


Journal of Hydrology 408 (2011) 67–77

Contents lists available at SciVerse ScienceDirect

Journal of Hydrology

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

Spatially smooth regional estimation of the flood frequency curve (with uncertainty)

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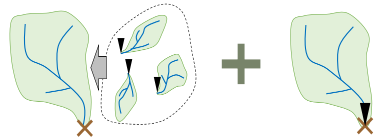
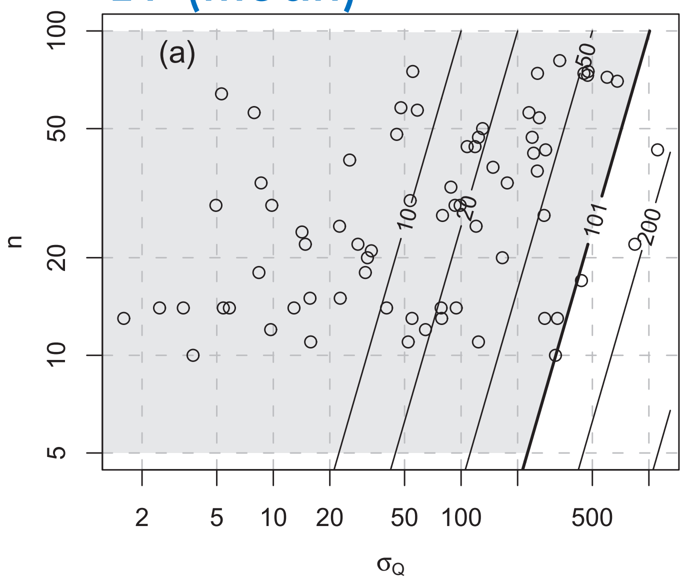
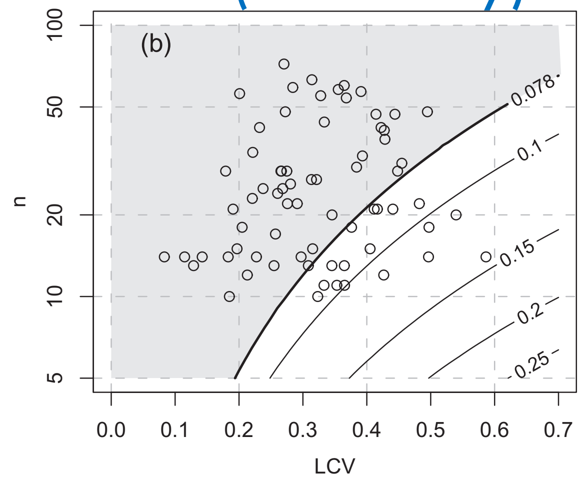


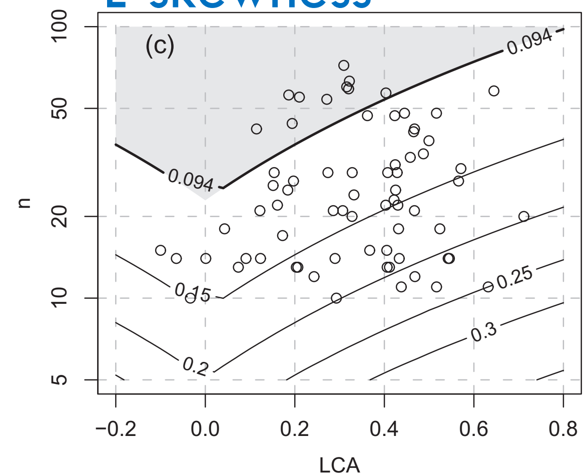
L1 (mean)

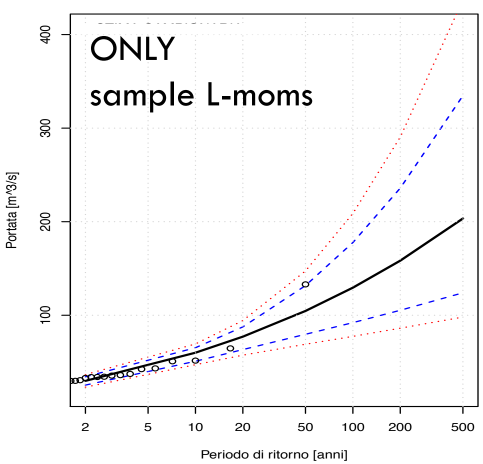


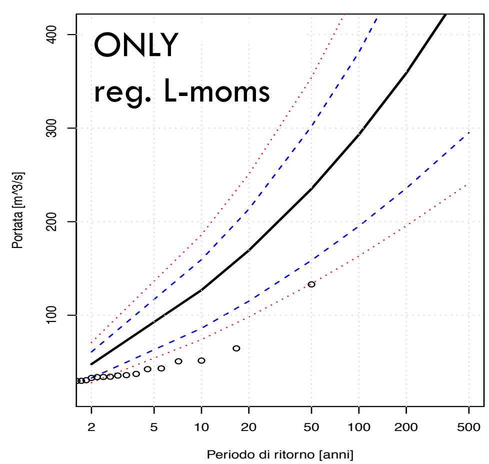
L-CV (variability)

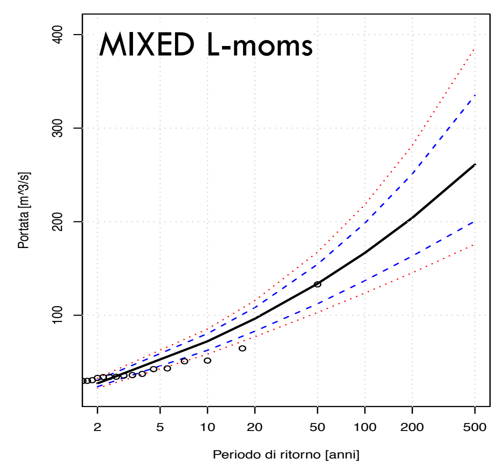


L-skewness





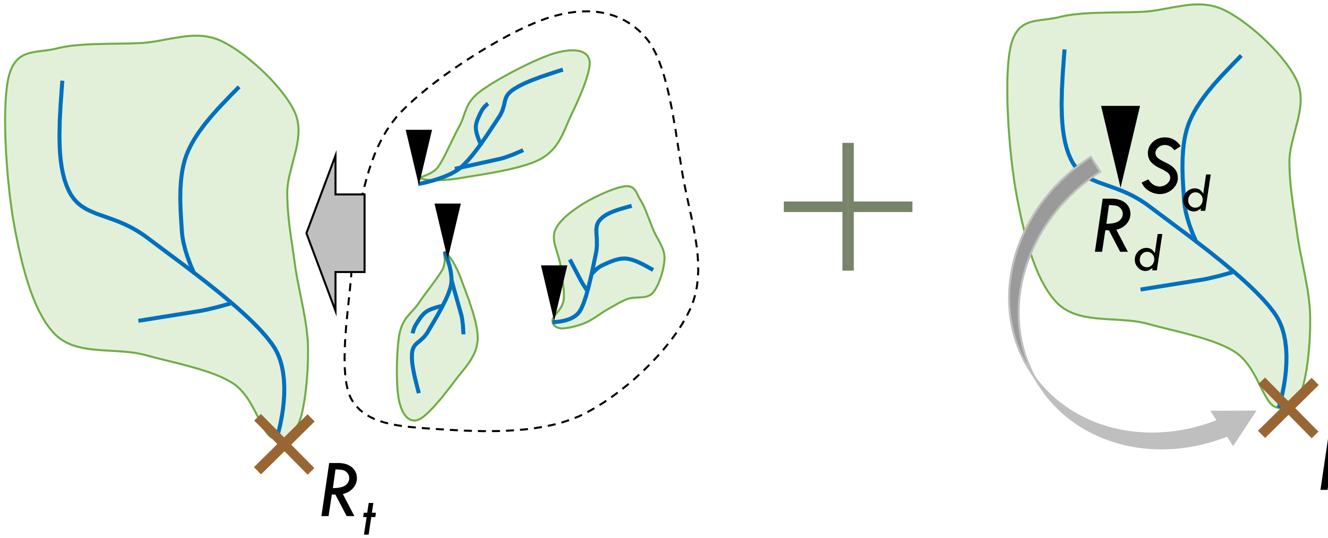




Regional + proximity

t = target site

d = donor site

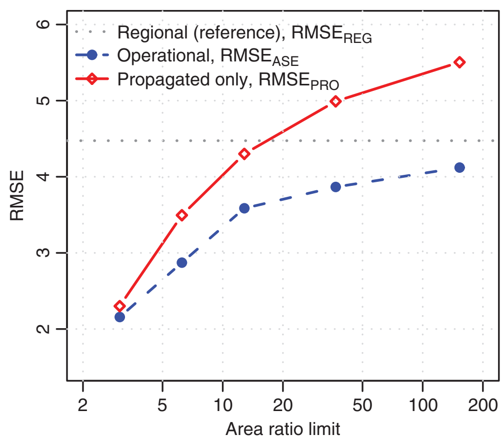


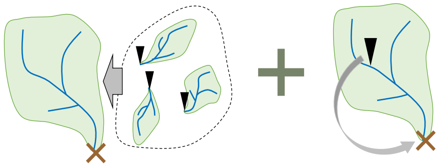
$$P_t = R_t \left(\frac{S_d}{R_d} \right)^{\alpha_{\mathrm{KJ}}}$$

S = at-site (sample estimate)

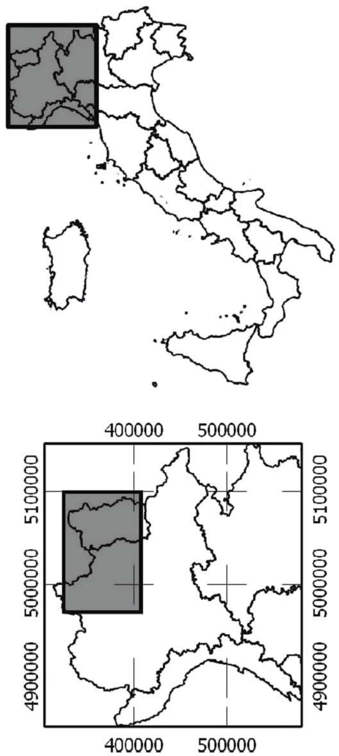
R = Regional estimate

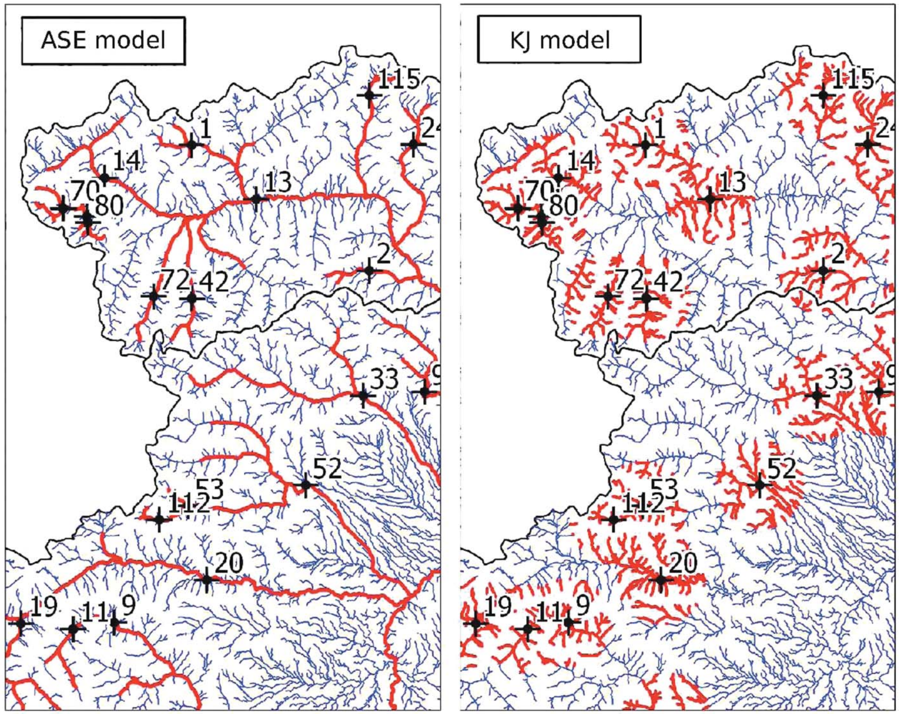
P = "propagated" estimate





Note: proximity correction performed only if it reduces uncertainty





Journal of Hydrology 387 (2010) 1–9

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

Predicting the index flood in ungauged UK catchments: On the link between data-transfer and spatial model error structure

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Hydrological Sciences Journal – Journal des Sciences Hydrologiques, i*First*, 2012 1

An approach to propagate streamflow statistics along the river network

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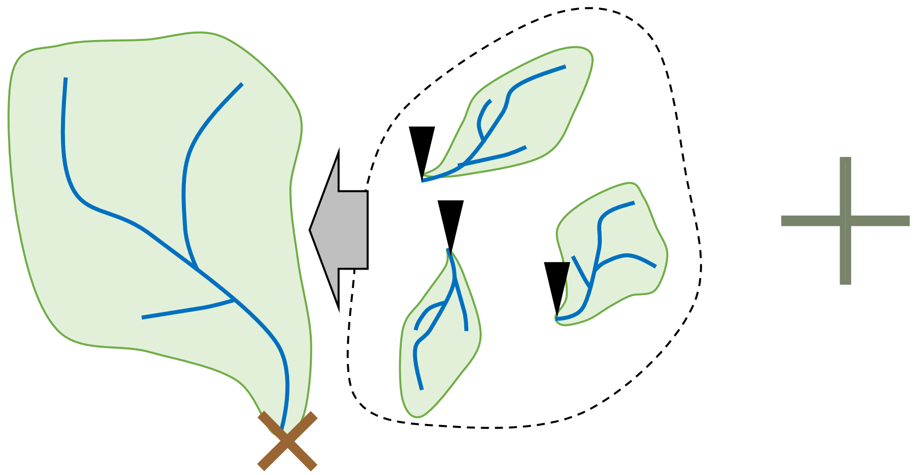
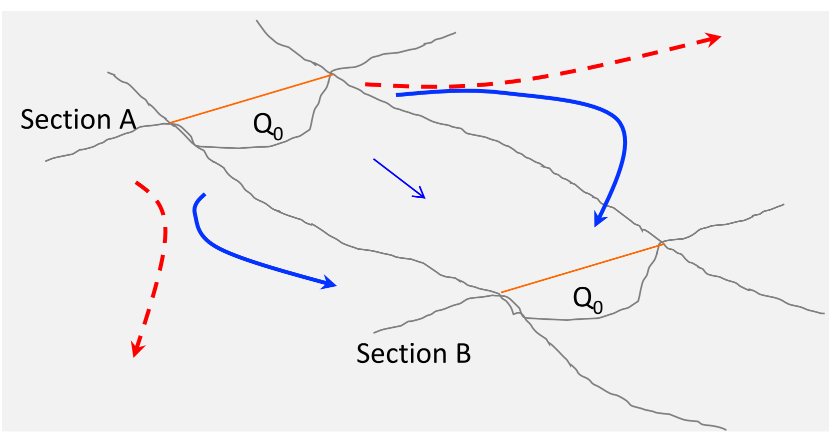
Received 3 August 2011; accepted 18 April 2012; open for discussion until 1 July 2013

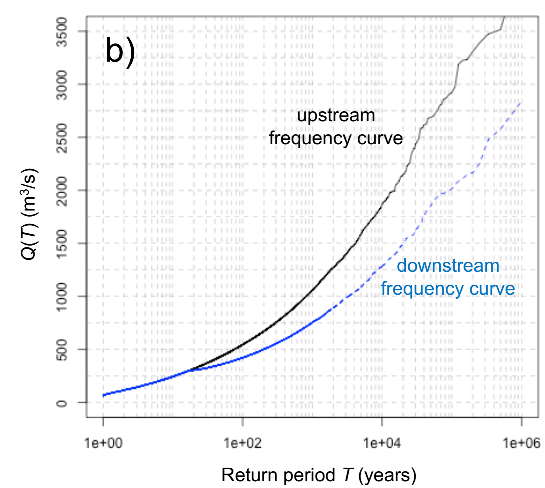
Editor D. Koutsoyiannis; **Associate editor** S. Grimaldi

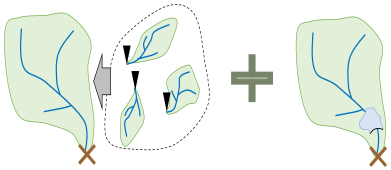
Citation Ganora, D., Laio, F., and Claps, P., 2013. An approach to propagate streamflow statistics along the river network. *Hydrological Sciences Journal*, 58 (1), 1–13.

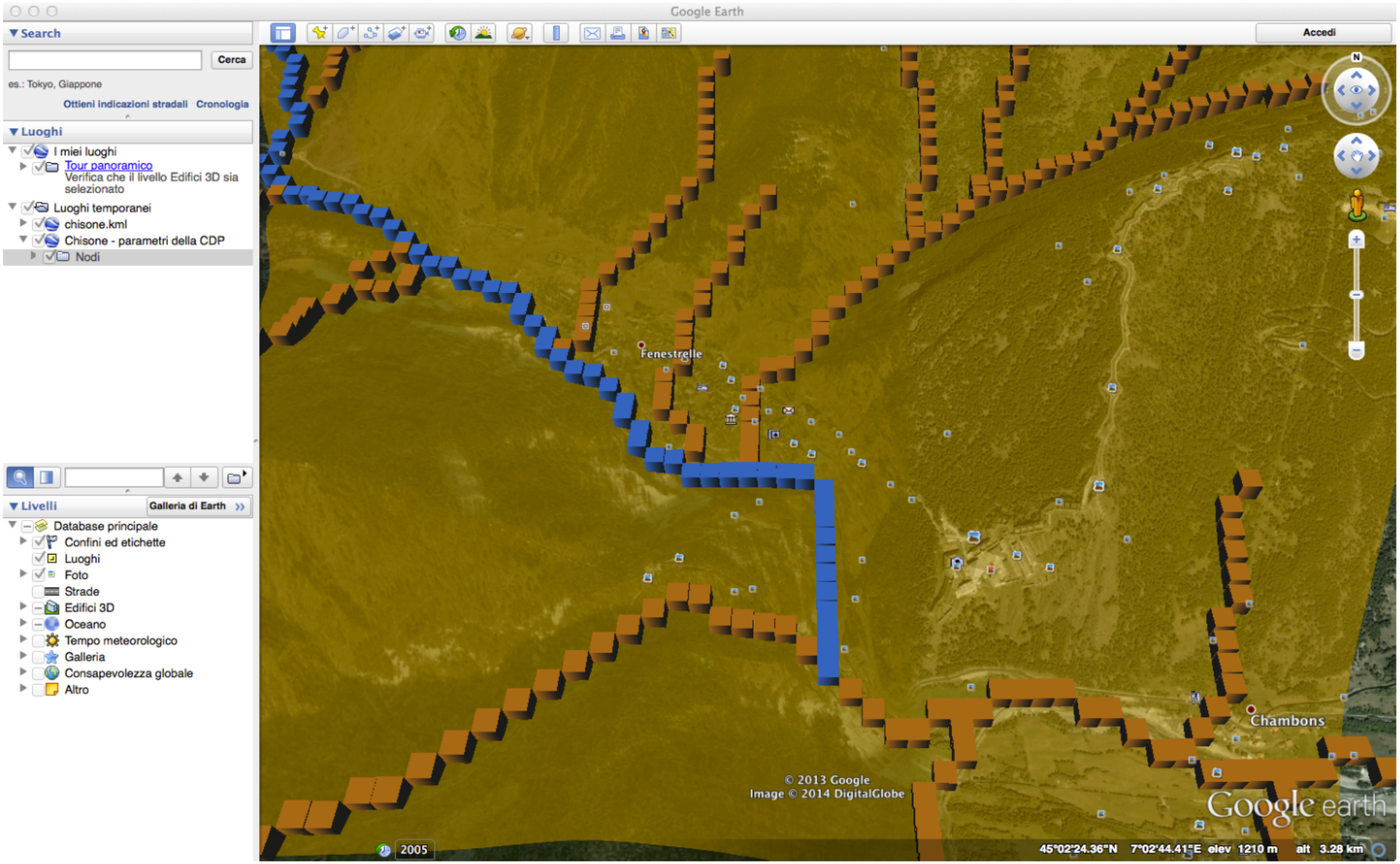
Regional + local physical processes







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