UNIVERSITÀ DEGLI STUDI FIRENZE

Technische Universität Braunschweig

TOP-KRIGING METHOD FOR REGIONALIZATION OF FLOOD QUANTILES IN UNGAUGED RIVER BASINS

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OVERVIEW

Albegna river flood, November 2012

Cecina river flood, October 2013

Elsa river flood, October 2014

Recent floods in Tuscany have led to record high material damage.
it is of primary importance to provide an accurate design flood estimate corresponding to a given risk level.

Main Aim

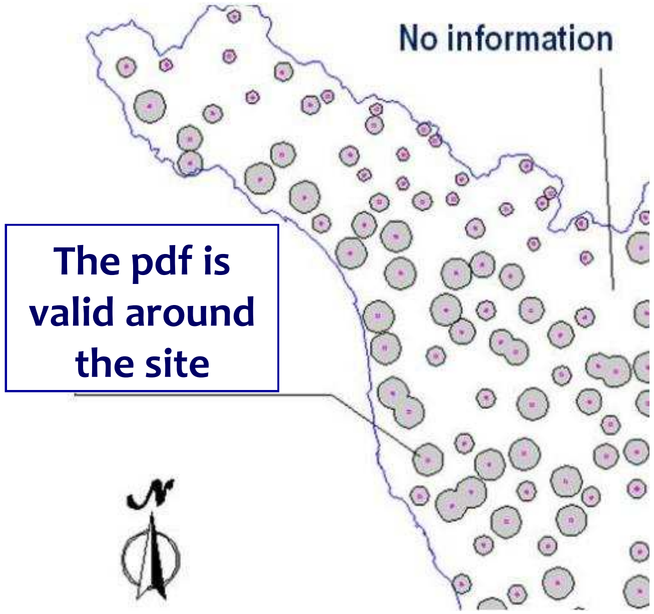
Knowledge of the desired stream flow index in ungauged river basins.

Methods

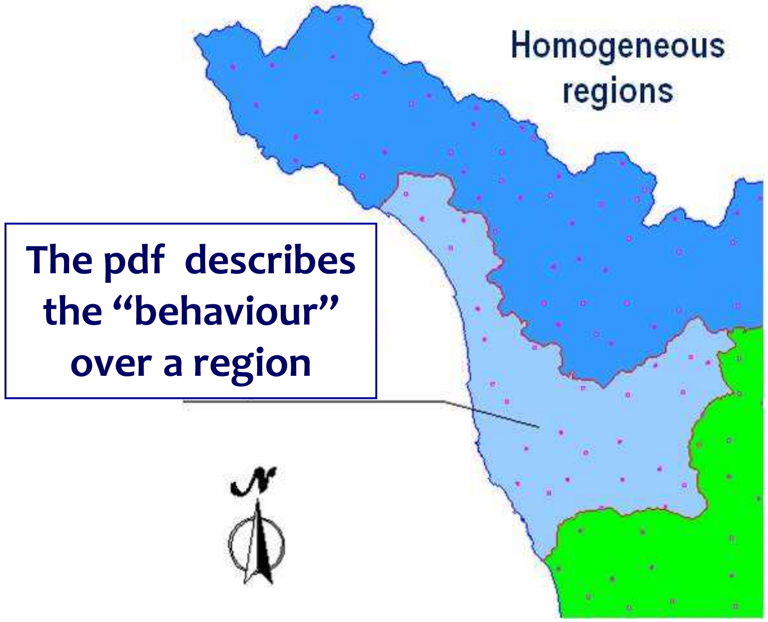
Regionalization by Geostatistics Spatial Interpolation techniques
Topological Kriging
(Skøien et al., HESS, 2006)

OVERVIEW

Local Frequency Analysis



Regional Frequency Analysis

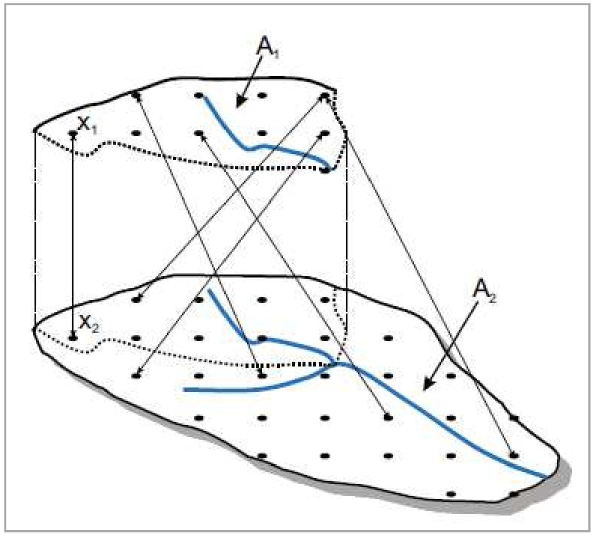


GEOSTATISTICS SPATIAL INTERPOLATION TECHNIQUES

FOR REGIONALIZATION OF HYDROMETRIC INFORMATION

Topological Kriging (TOP-Kriging)

takes into account the structure of hydrographic network, the catchment area, the stronger spatial correlation between nested catchments.



In Euclidian kriging methods (Ordinary Kriging)

$$\hat{z}(\boldsymbol{x}_0) = \sum_{i=1}^{n} \lambda_i z(\boldsymbol{x}_i)$$

$\hat{z}(\boldsymbol{x}_0)$: unknown value of the variable of interest at position $\boldsymbol{x}_0$ (i.e. the target position)

λ_i: interpolation weight of the measurement at position $\boldsymbol{x}_i$

n: the number of neighbouring measurements.

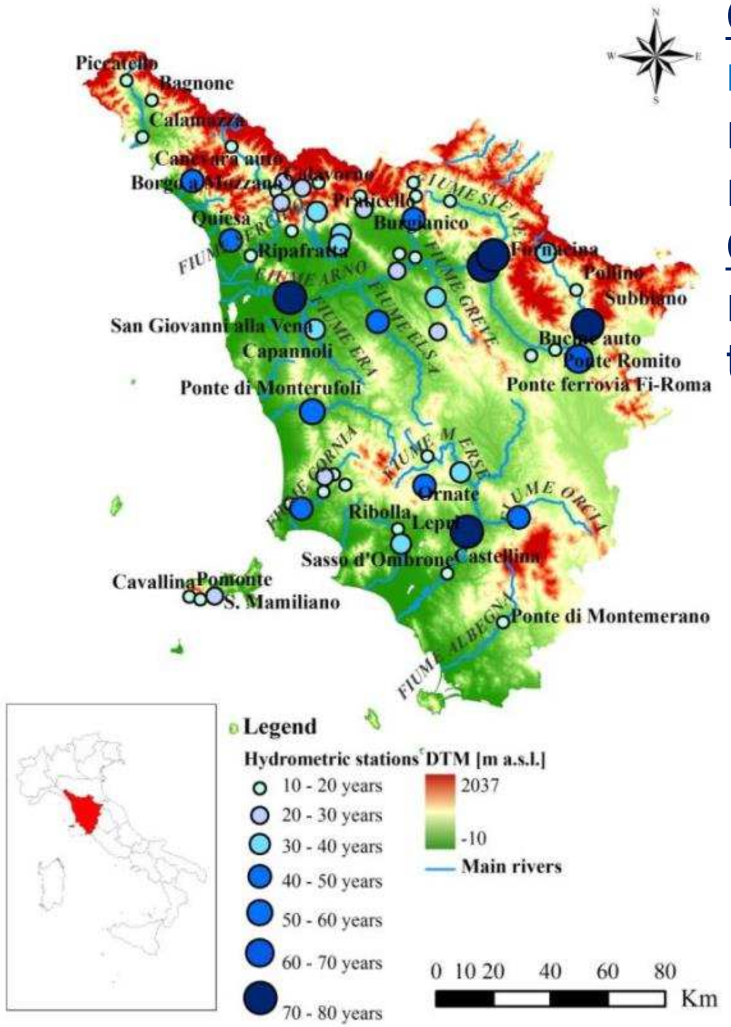
In **Top-kriging**, the measurements are **not point values** but are defined **over a catchment area A**. A point variable $z(x)$ can be averaged over an area A as:

$$\bar{z}(A) = \frac{1}{A}\int_A w(\boldsymbol{x}) z(\boldsymbol{x}) d\boldsymbol{x}$$

$\bar{z}$: spatially averaged variable

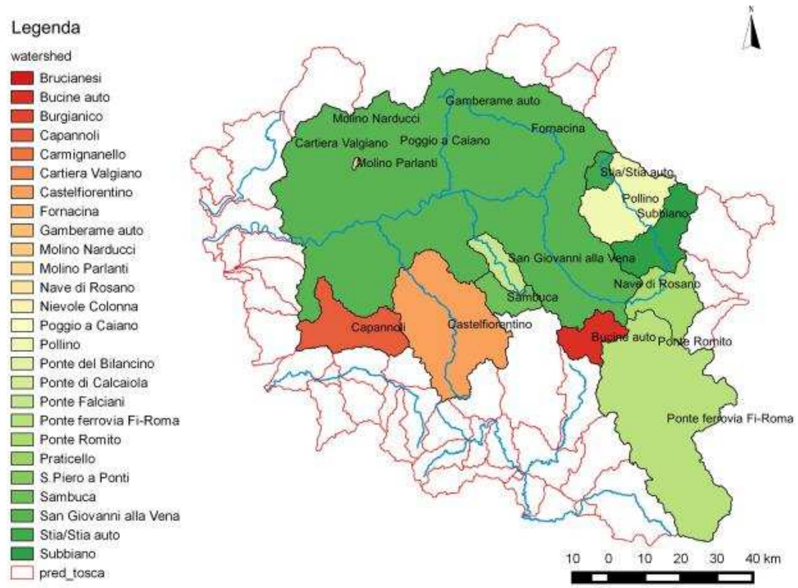
$w(\boldsymbol{x})$: weighting function

STUDY AREA & DATASETS



<u>Original phase</u>: Time series of **annual maxima of peaks discharges** in the Tuscany region, in the period 1923-2011. Dataset of 57 runoff gauges with more than 10 years.

<u>Current phase</u>: The Top-kriging interpolation method is applied to **26 stream gauges** in the Arno river basin, central Tuscany.

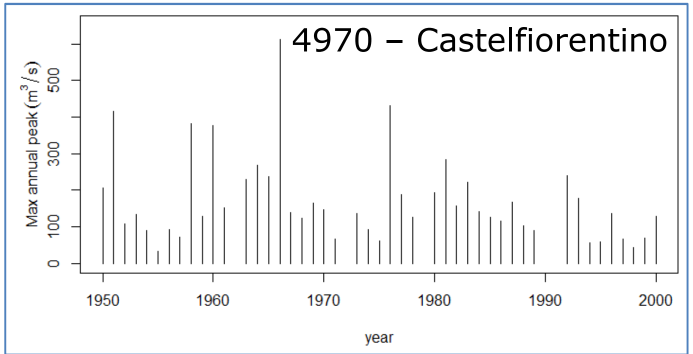


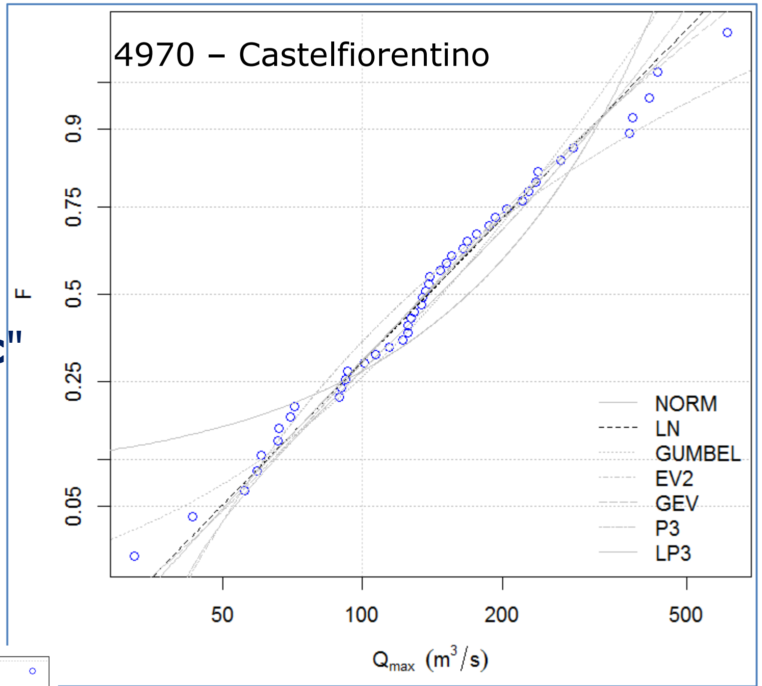
STUDY AREA & DATASETS

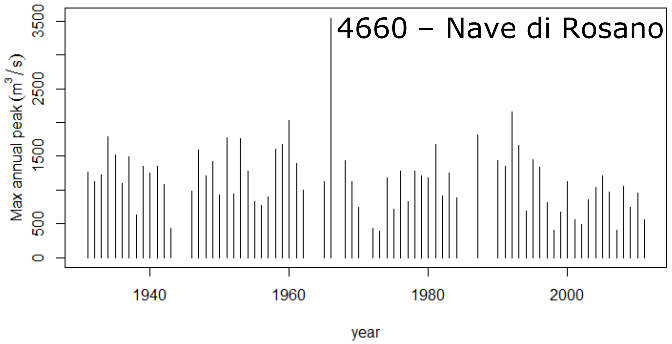
An at-site flood frequency analysis is carried out at each station. Appropriate statistical distributions are fitted to data. (**nsRFA - Fadist R-packages**)

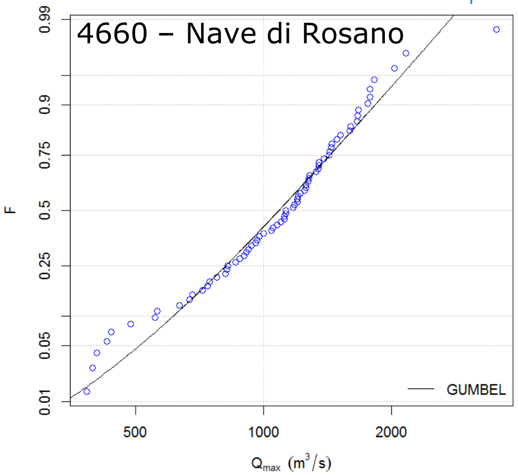
Model-selection criteria:

Akaike Information Criterion "**AIC**" & corrected "**AICc**"
Bayesian IC "**BIC**", Anderson-Darling C "**ADC**"







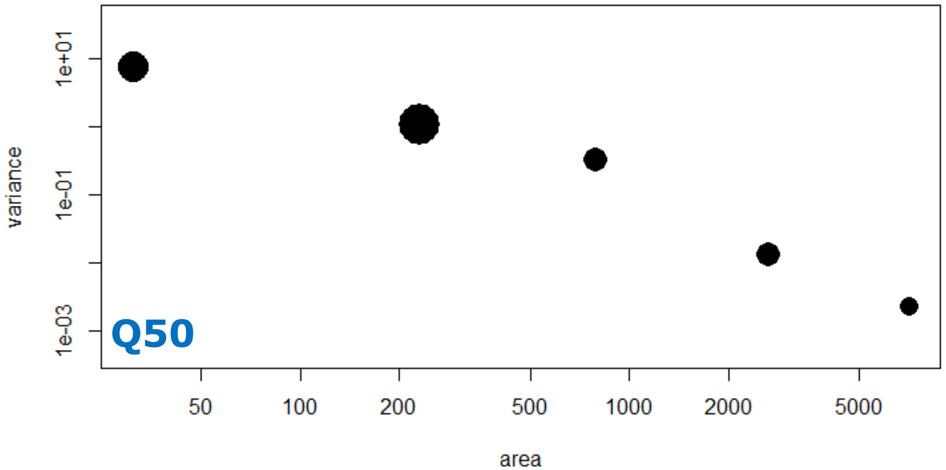


Flood quantile	Minimum [m³/s]	Median [m³/s]	Maximum [m³/s]
10 yr	2.1	245.2	1941.4
50 yr	3.1	373.5	2611.3
100 yr	3.5	395.8	2879.7
200 yr	3.9	434.1	3140.2
500 yr	4.5	537.0	3475.3

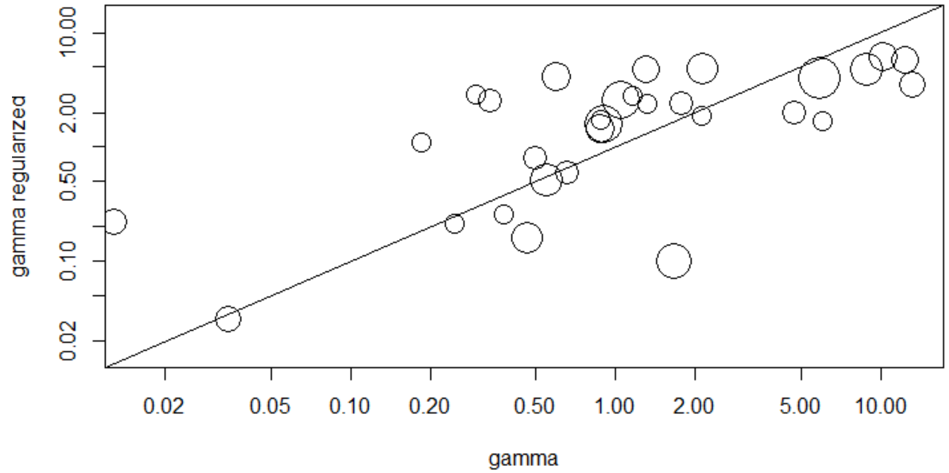
TK RESULTS

Inputs of **TK method** are the flood quantiles corresponding to the 10, 50, 100, 200, 500 year return periods standardized by the basin area, in order to account for the scale effect (specific runoff $m^3/s/km^2$). (**rtop R-package**).

Relationship between variance of observations and area size



Comparison of observed and regularized semivariogram values

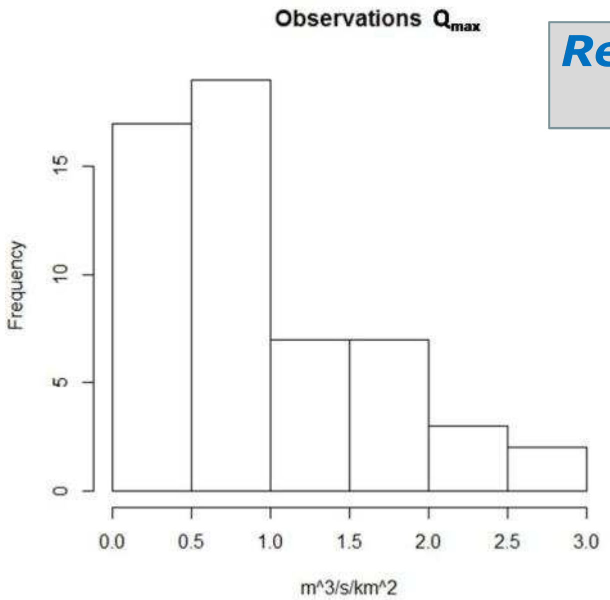



```
params = list(model = "Exp",
gDist = TRUE, rresol = 50,
hresol= 5, nmax=5,amul=2, dmul=2,
cloud = FALSE)
```

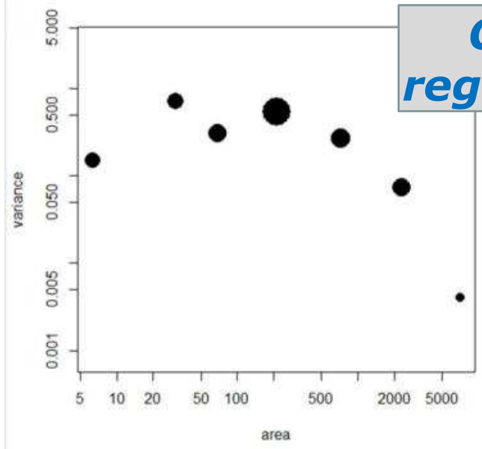
The **sample variogram** is estimated as a **binned variogram**. *Given a set of specific parameter, a variogram model is fitted to the estimated binned variogram through an automatic procedure.*

TK RESULTS

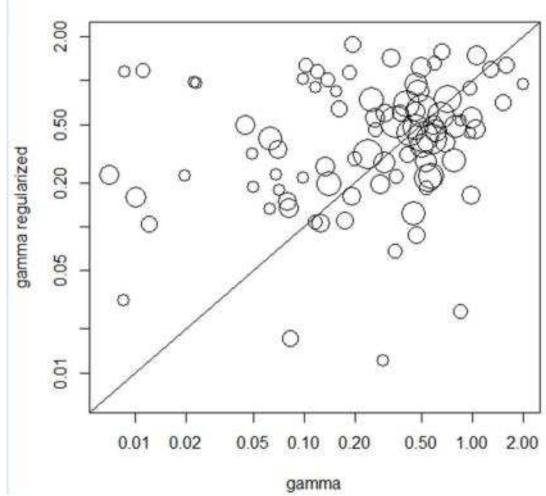
Inputs of **TK method** are in the original phase the peak discharges standardized by the basin area, in order to account for the scale effect (specific runoff $m^3/s/km^2$). (**rtop R-package**).



Relationship between variance of observations and area size



Comparison of observed and regularized semivariogram values




```
params = list(model = "Exp", gDist = TRUE, rresol =
75, hresol= 10, nmax=5,amul=2, dmul=3, cloud = FALSE)
```

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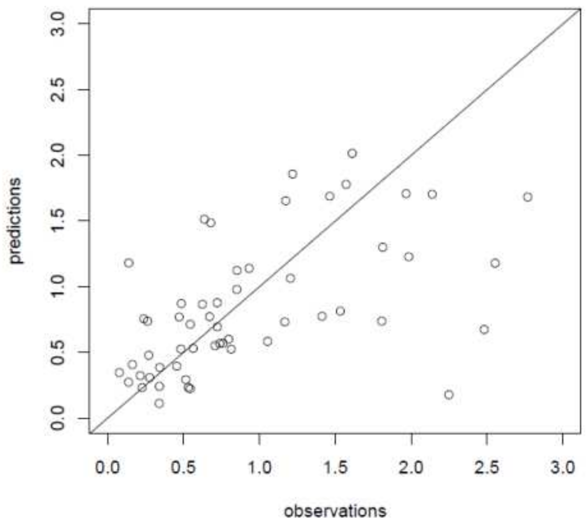
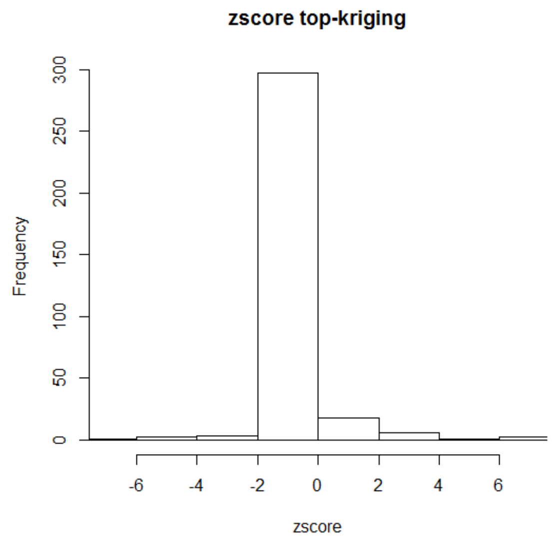
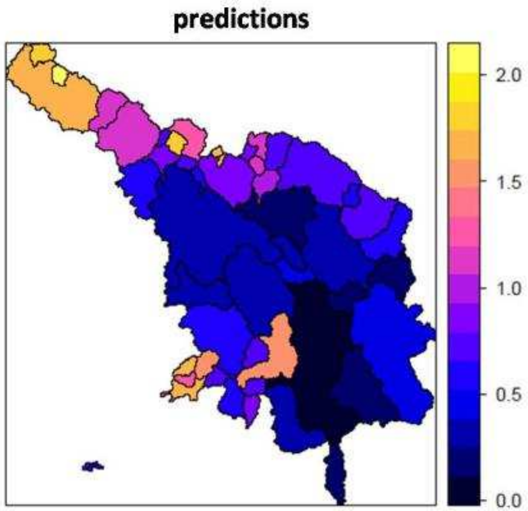
TK RESULTS



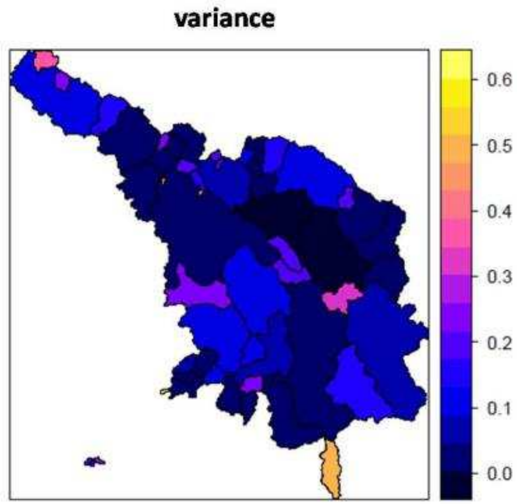
Correlation 0.55
RMSE 0.59

zscore= residual/kriging error

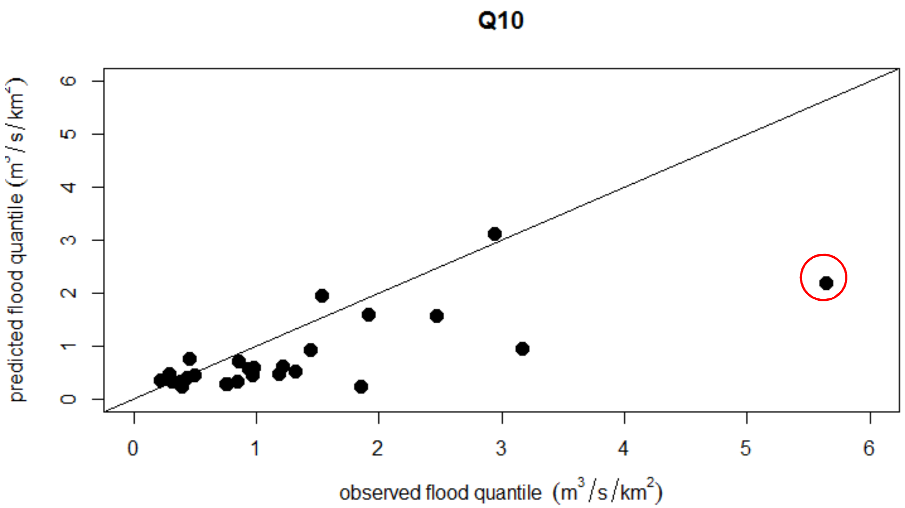


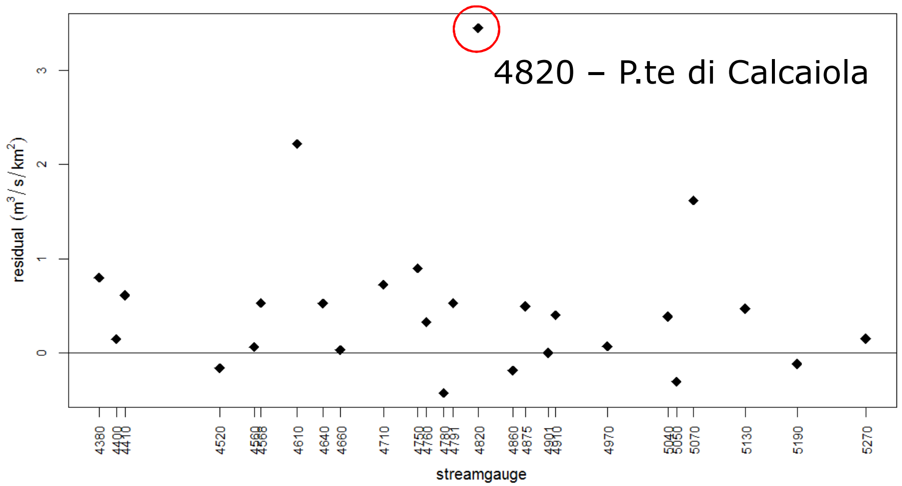


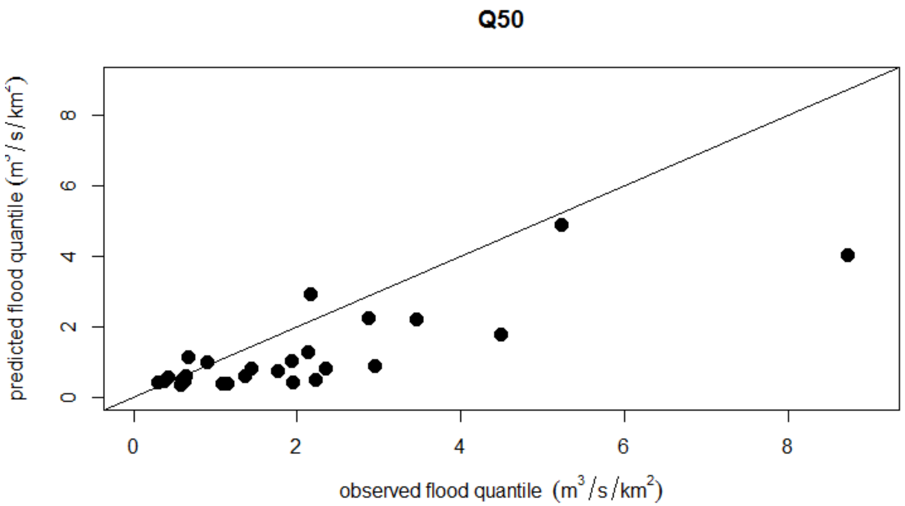
Predictions ($m^3/s/km^2$) and predicted variance ($(m^3/s/km^2)^2$) from estimation of peak discharges

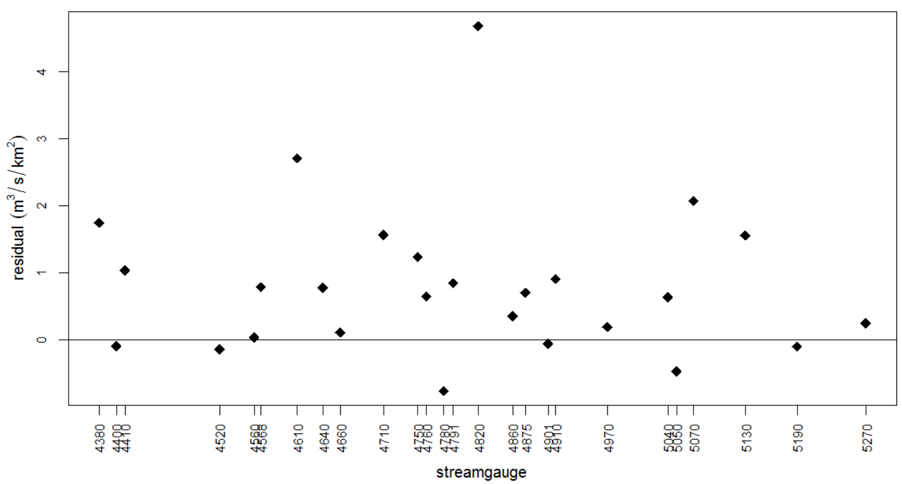


TK RESULTS


Q10
predicted flood quantile $(m^3/s/km^2)$
observed flood quantile $(m^3/s/km^2)$
0
1
2
3
4
5
6

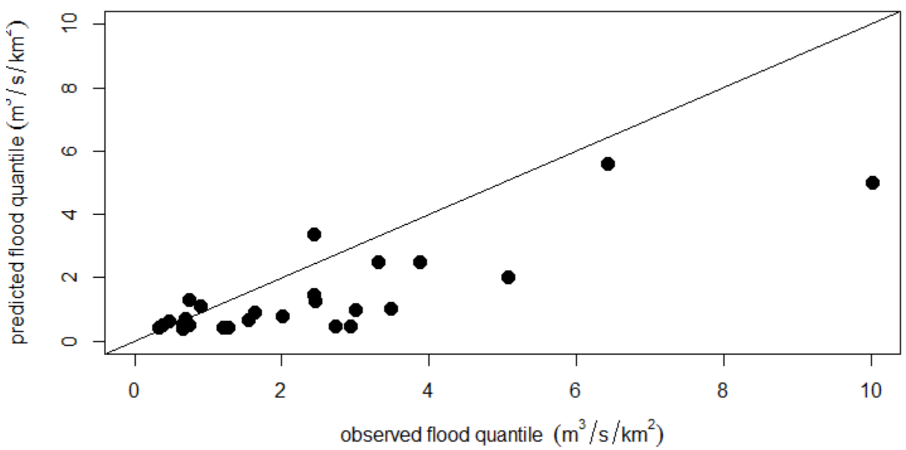

4820 – P.te di Calcaiola
residual $(m^3/s/km^2)$
streamgauge

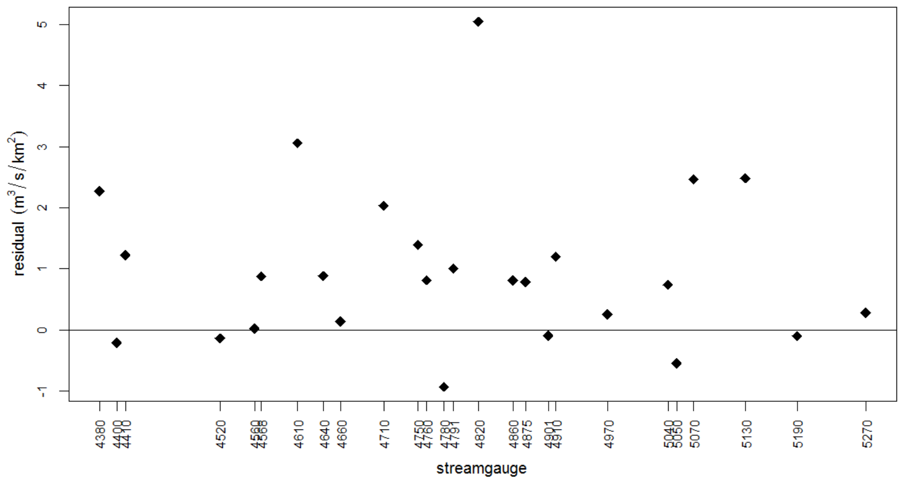

Q50
predicted flood quantile $(m^3/s/km^2)$
observed flood quantile $(m^3/s/km^2)$
0
2
4
6
8


residual $(m^3/s/km^2)$
streamgauge

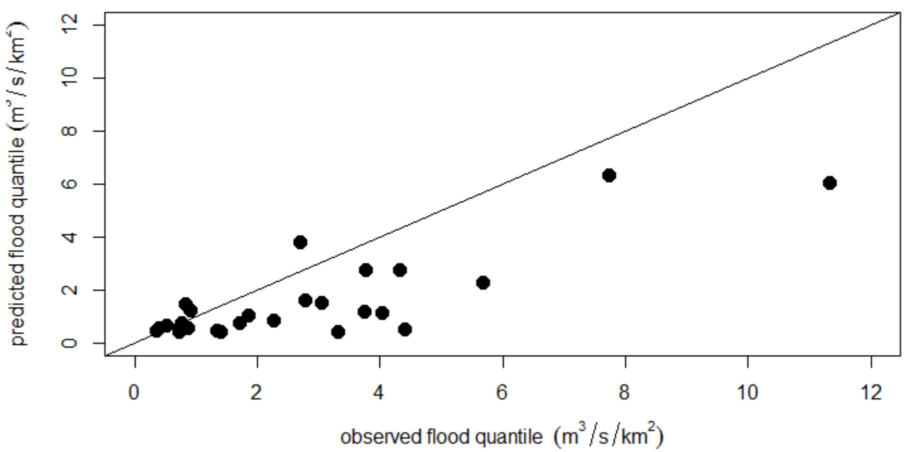
TK RESULTS

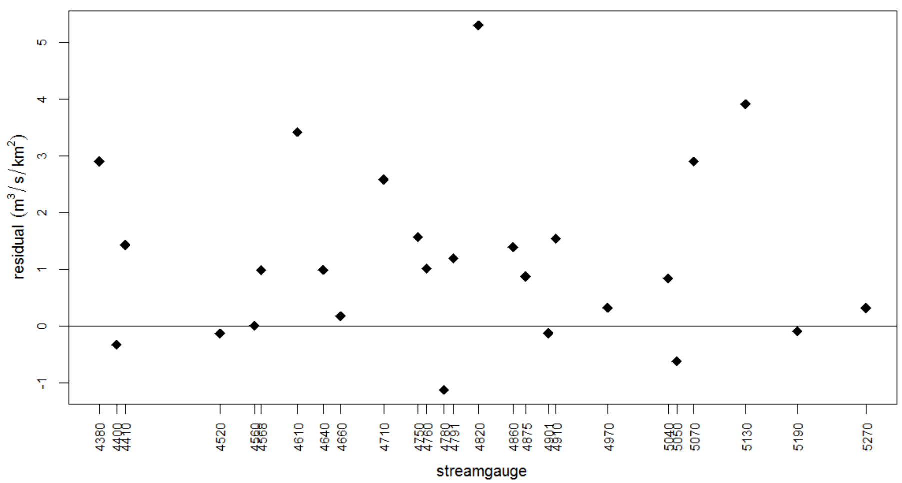
Q100



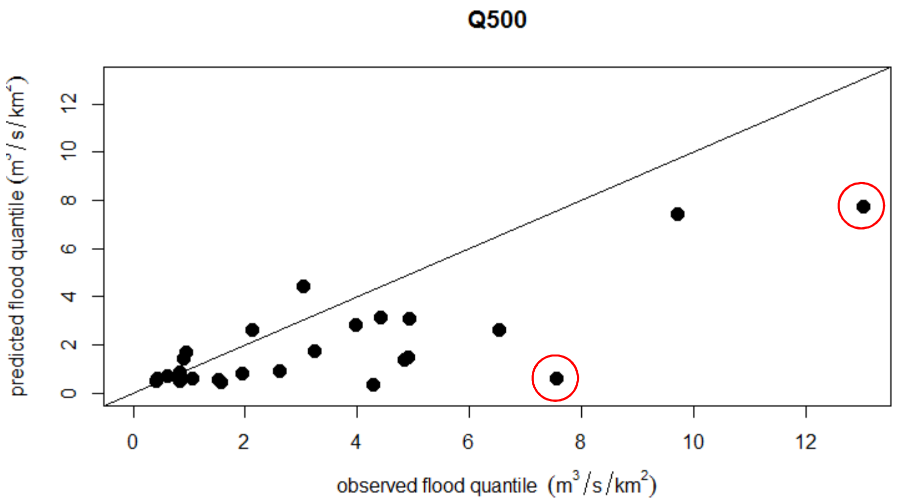


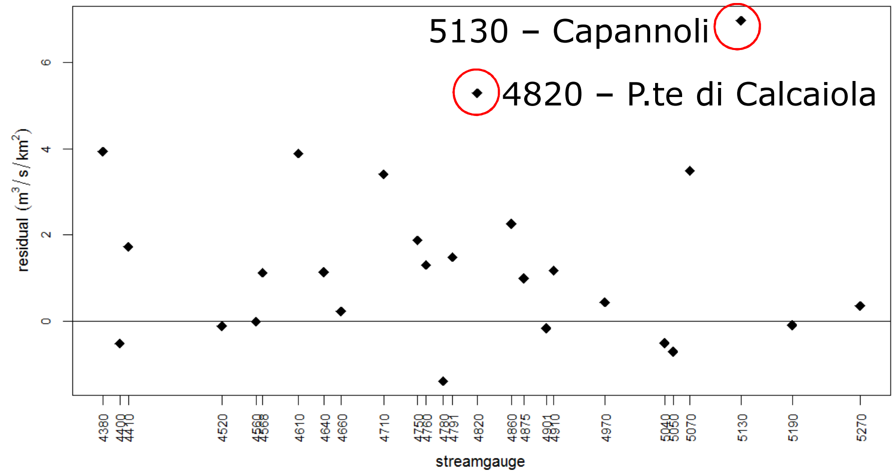
Q200





TK RESULTS - GOODNESS-OF-FIT MEASURES

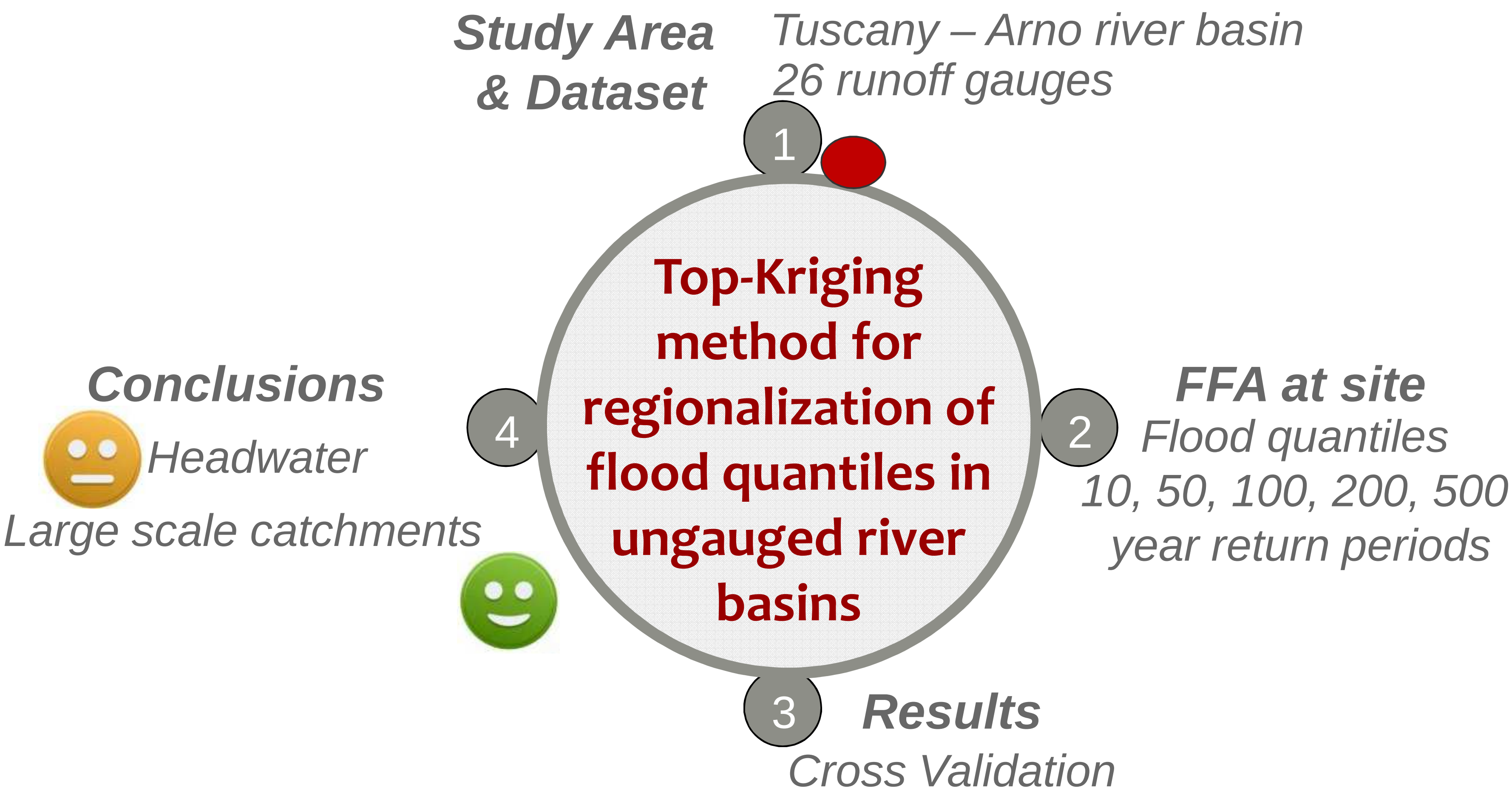




Performance indexes (cross validation mode)

	Q10/A [m³/s/km²]	Q50/A [m³/s/km²]	Q100/A [m³/s/km²]	Q200/A [m³/s/km²]	Q500/A [m³/s/km²]
ME	-0.51	-0.81	-0.99	-1.2	-1.44
MAE	0.6	0.94	1.15	1.39	1.71
RMSE	0.96	1.37	1.61	1.91	2.44
NRMSE (%)	**80.6**	**73.6**	**73.9**	**75.4**	**78.3**
PBIAS (%)	-39.4	-40.3	-41.9	-43.6	-43.1
NSE	0.32	0.44	0.43	0.41	0.36
rNSE	0.71	0.71	0.69	0.67	0.66
d	0.74	0.79	0.8	0.8	0.79
r	0.73	0.82	0.83	0.82	0.78

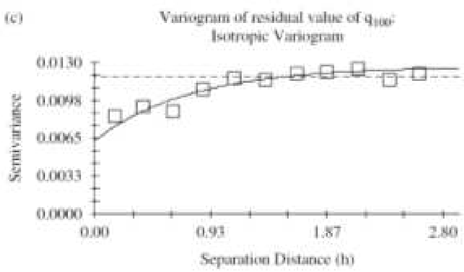
OUTLOOKS

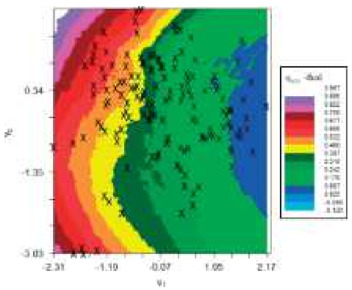

Study Area & Dataset
Tuscany – Arno river basin
26 runoff gauges
1
Top-Kriging method for regionalization of flood quantiles in ungauged river basins
2
FFA at site
Flood quantiles
10, 50, 100, 200, 500 year return periods
3
Results
Cross Validation
4
Conclusions
Headwater
Large scale catchments

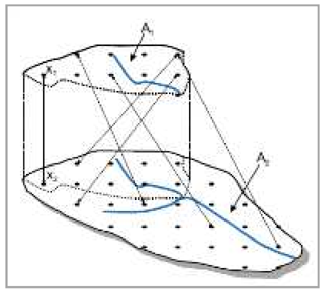
OUTLOOKS

In order to increase Top-kriging performance

- Use of a **"regular" river network**. Up to now the river channel network of Tuscany Region is composed by multiple channels and un-continuous digitalization.
- Perform a **parameter calibration**, trying to increase the number of nearest observations to be used for kriging prediction.
- Search a **criteria** to deal with upstream catchments in the analysis. Some pairs of catchments exhibit quite large semivariances also for small distances, this can particularly be the case for combinations of small and large catchments characterized by a different regime. The heterogeneity represented by the upstream gauge could be detected.







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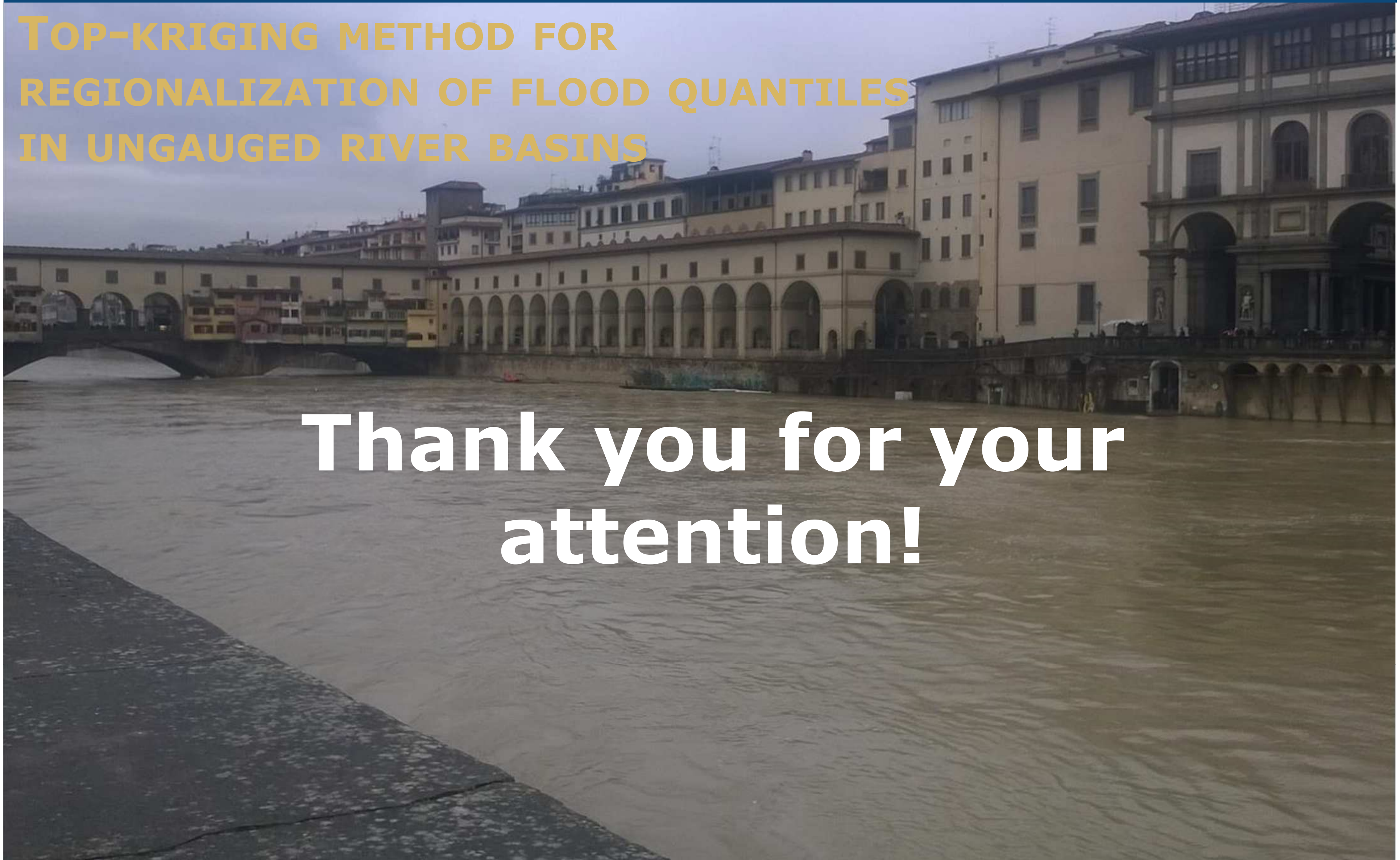

Thank you for your attention!