4th International Workshop on Hydrological Extremes

From prediction to prevention of hydrological risk in Mediterranean countries

15 - 17 September Cosenza

Hydrological Model Efficiency for Flood Forecasting and Simulation

Giovanna Grossi, Matteo Balistrocchi

University of Brescia - DICATA

Department of Civil Engineering Architecture Land and Environment

Introduction

Detailed distributed modelling represents a very powerful framework in hydrology.

Anyway, in order to deal with real time flood forecasting, less detailed modelling involving lower computational burden and decreasing the calibration uncertainty are hoped for.

In this perspective the possibility to delineate recurrent spatial patterns associate with severe flood events was analysed.

The Taro river watershed located in the Apennine area in Northern Italy was selected as a case study. During the last decade the basin has been monitored by means of a dense hydro-meteorological network.

A detailed database was available to characterize the key hydrological properties of the catchment

The analysis of the precipitation field was performed by using classical geostatistical techniques starting from point rainfall observations recorded throughout the catchment area.

Study catchment 1/3

Morphological characteristics: terrain analysis

Watershed area: 1920 km^2

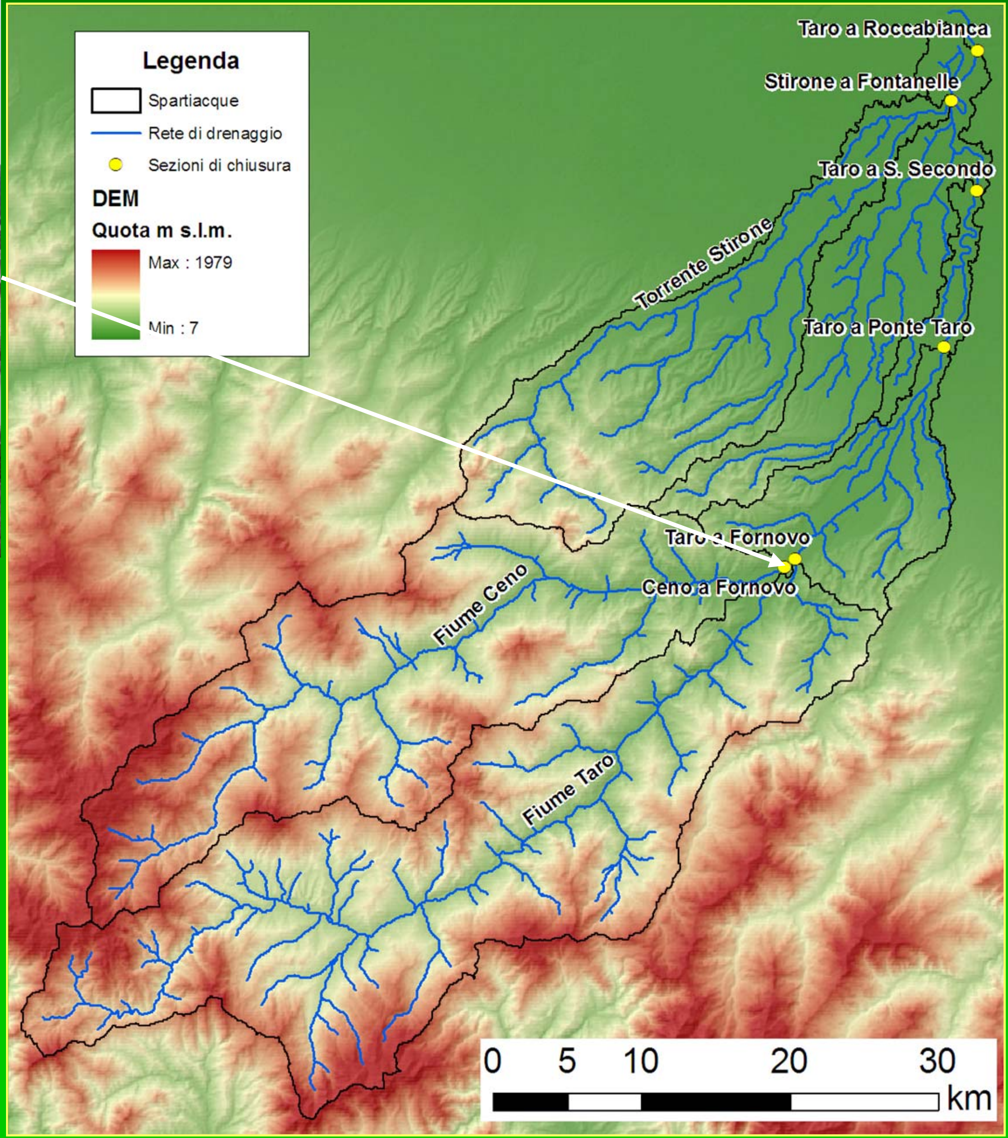
Main river length: 120 km

Source: Mount Penna (1786 m s.l.m.)

Tributaries:

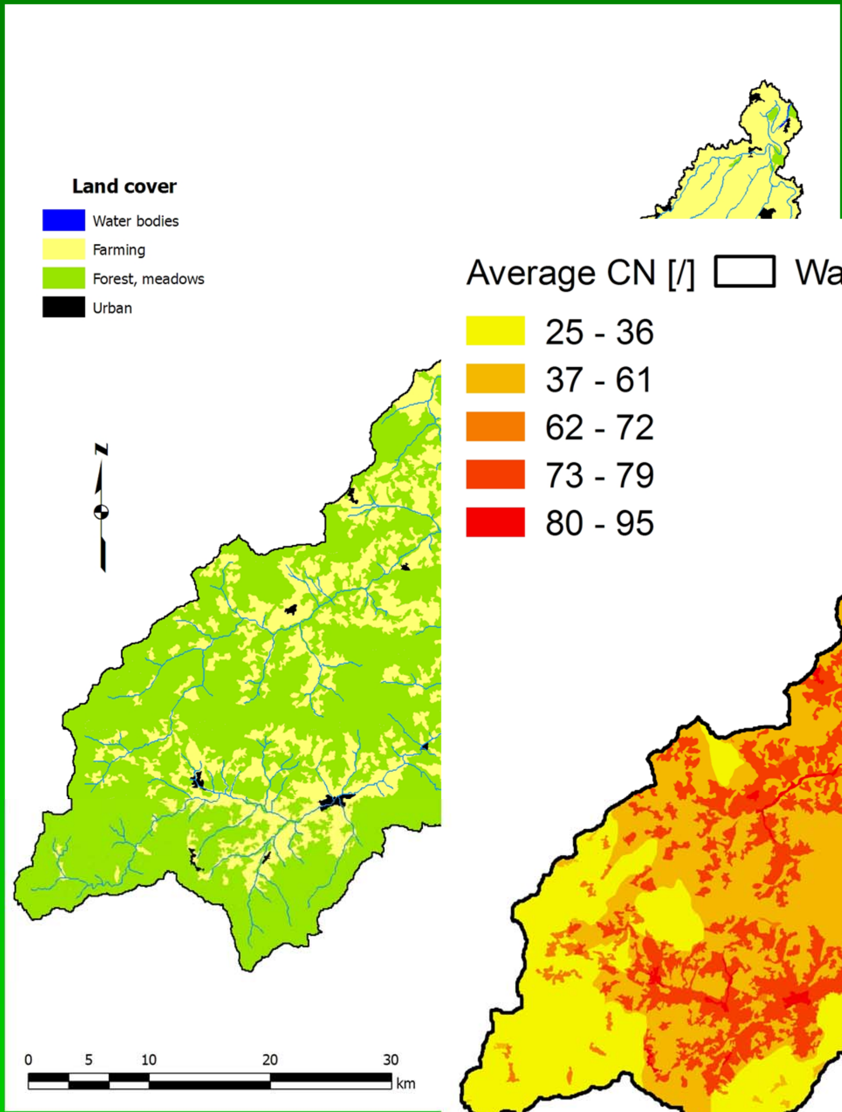
Ceno River: 538 km^2 at Fornovo di Taro

Stirone stream: 311 km^2 at Fontanelle

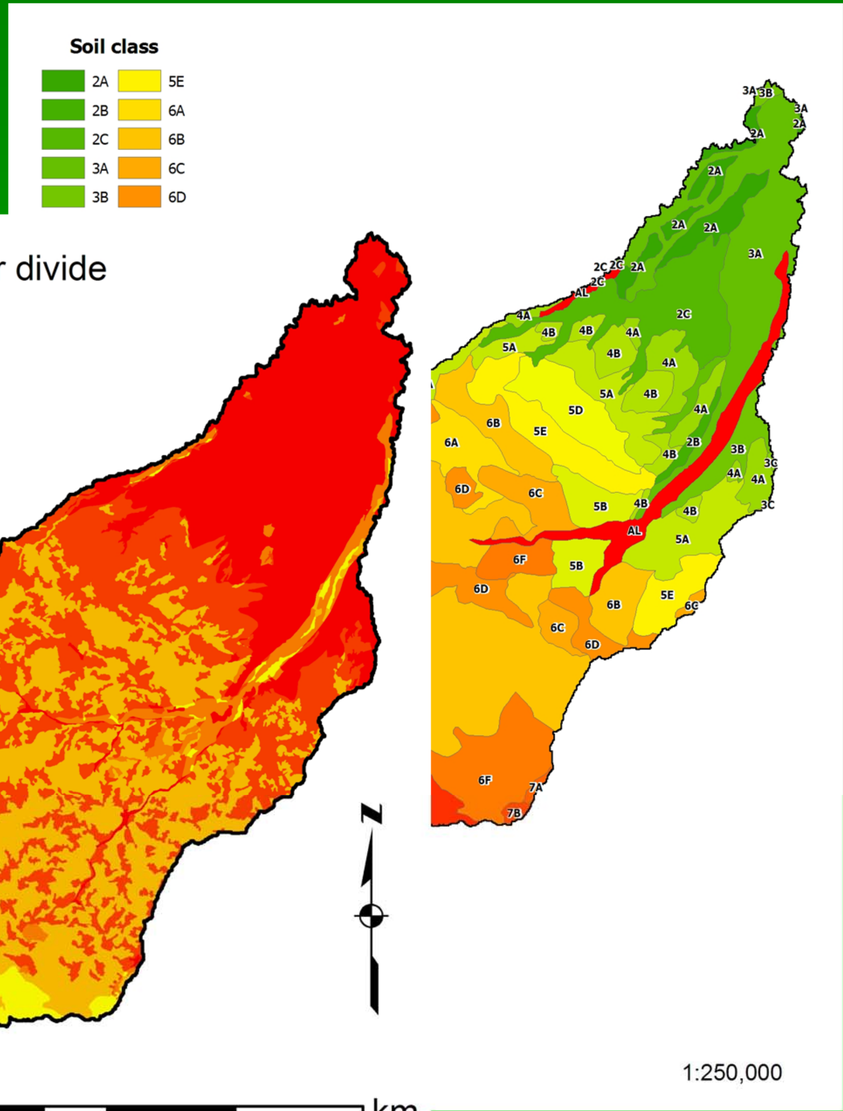


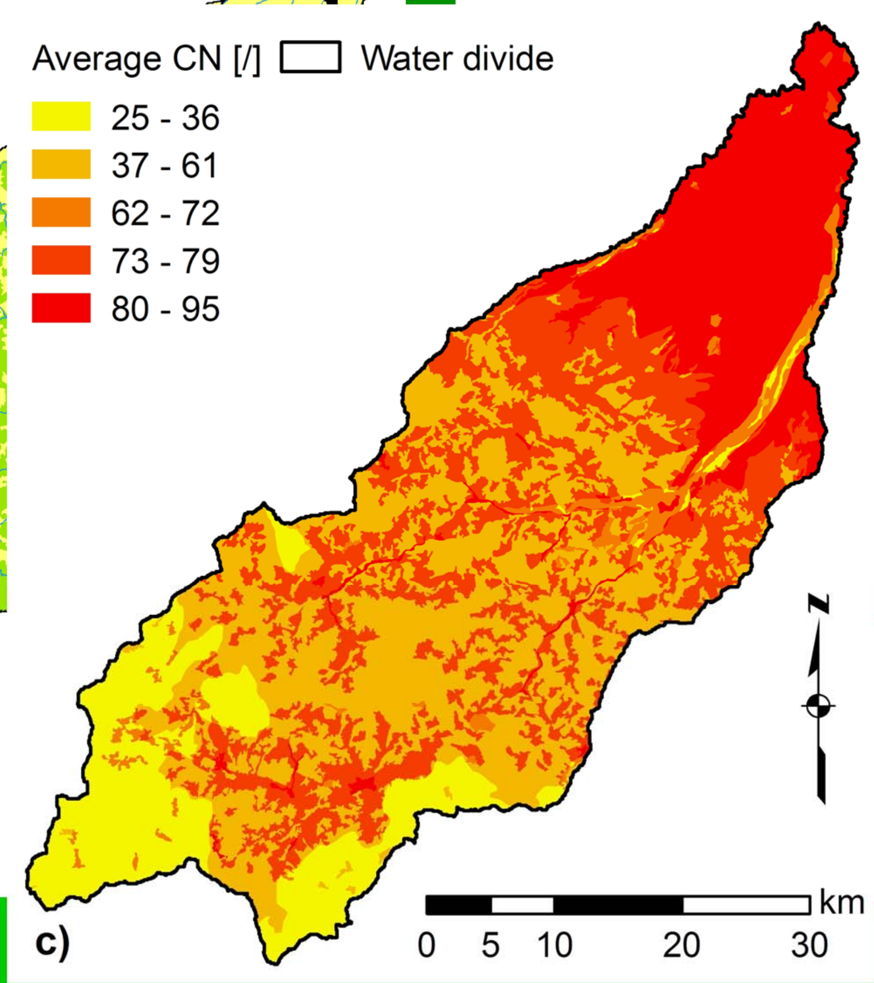
Study catchment 2 / 3

Land cover



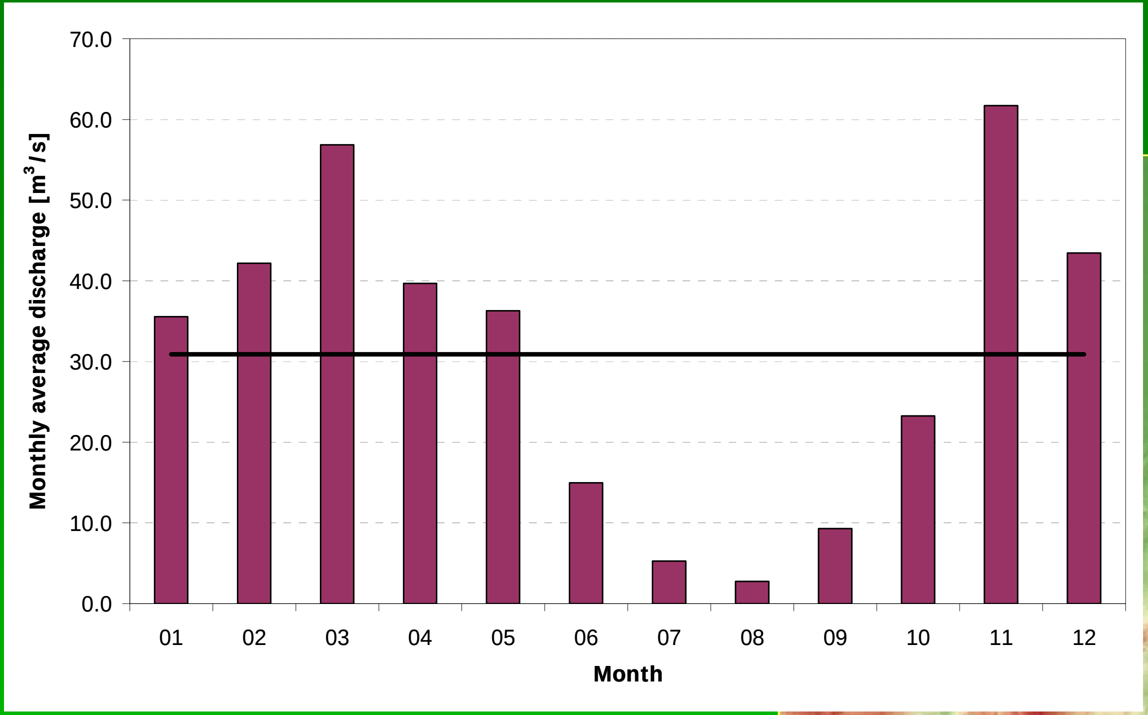
Soil types





Study catchment 3 / 3

Hydrometric regime



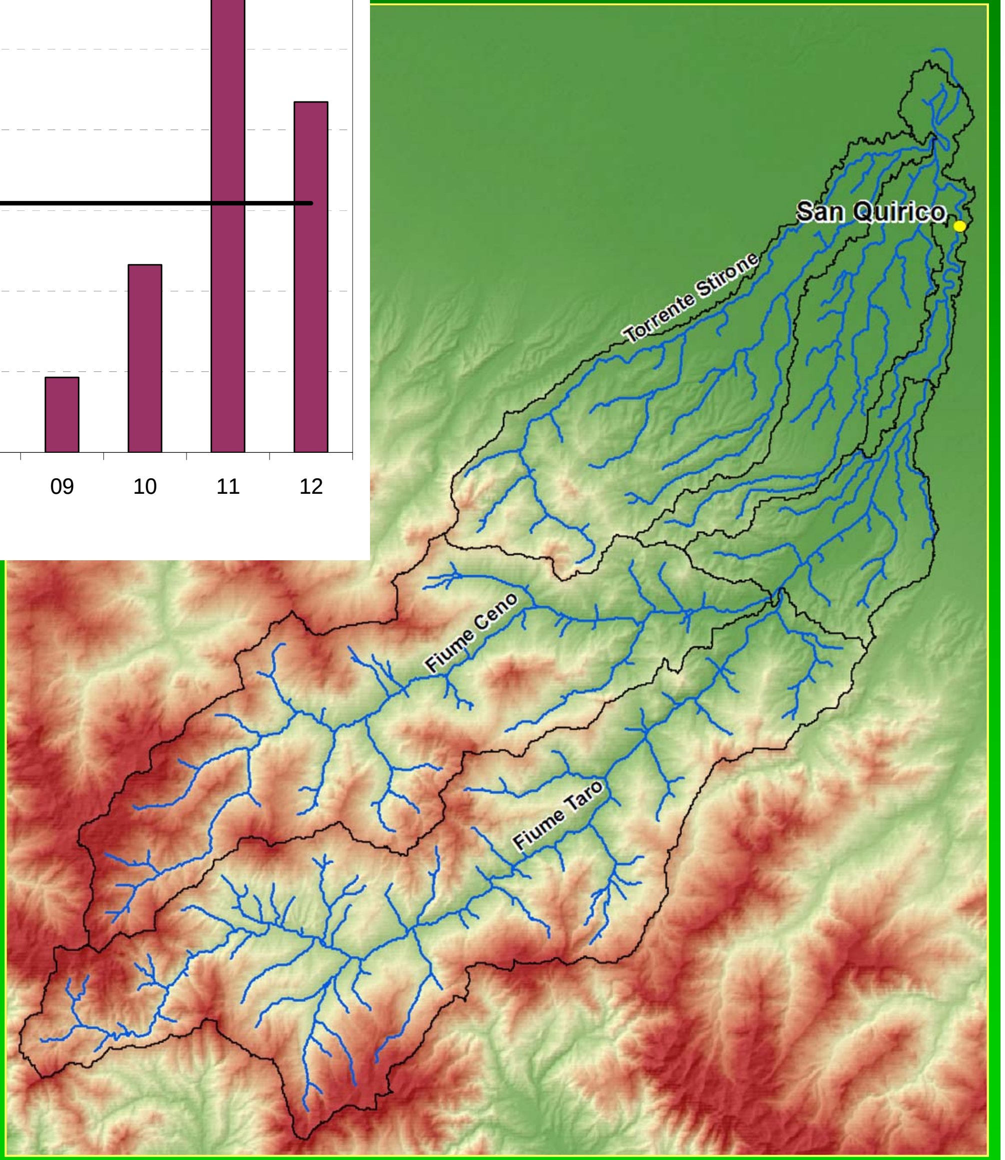
Taro’s outlet at San Quirico

Yearbooks 1923-1943

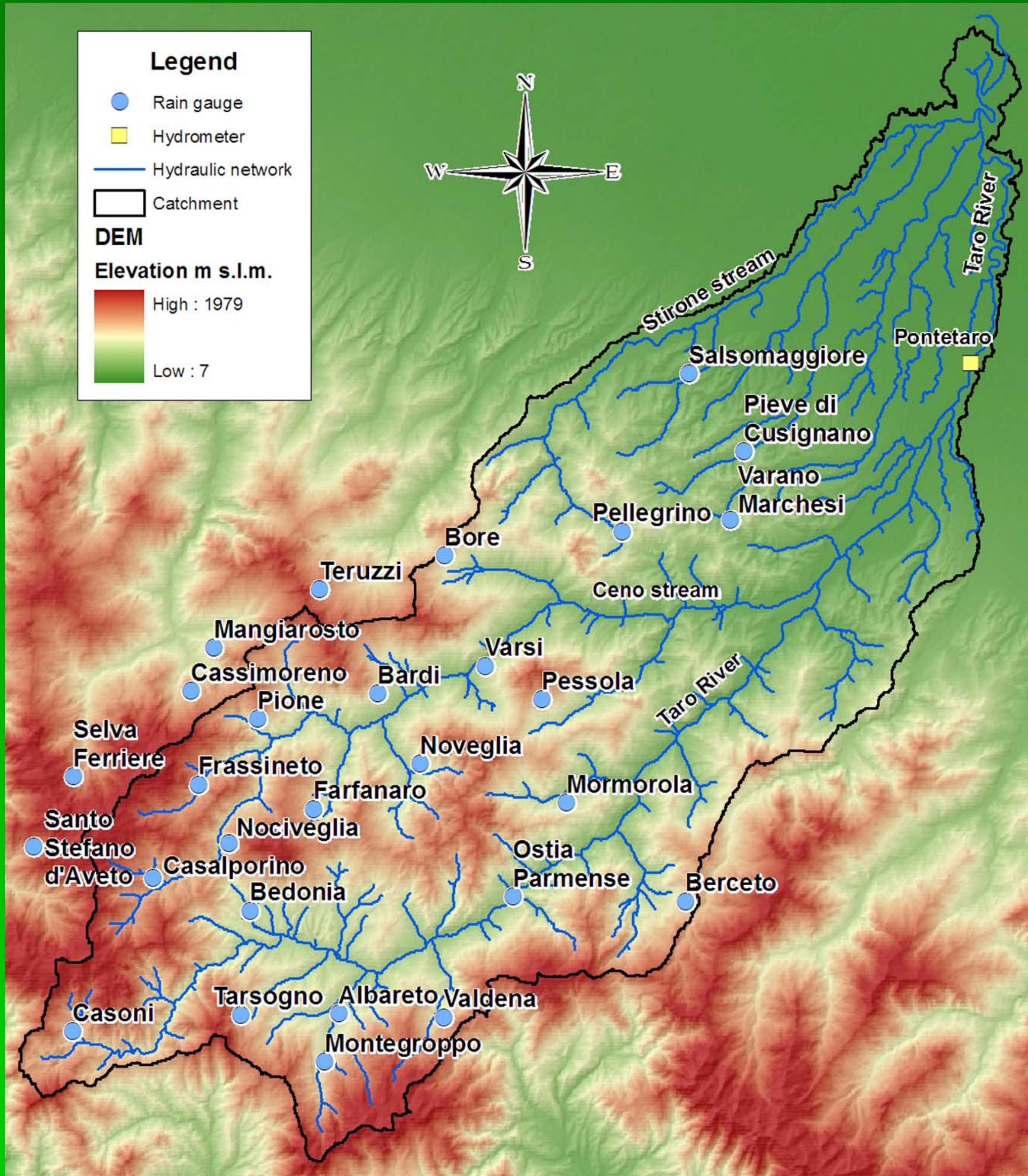
Catchment area: 1476 km^2

Annual average discharge: 31 m^3/s

Runoff coefficient: 0,50



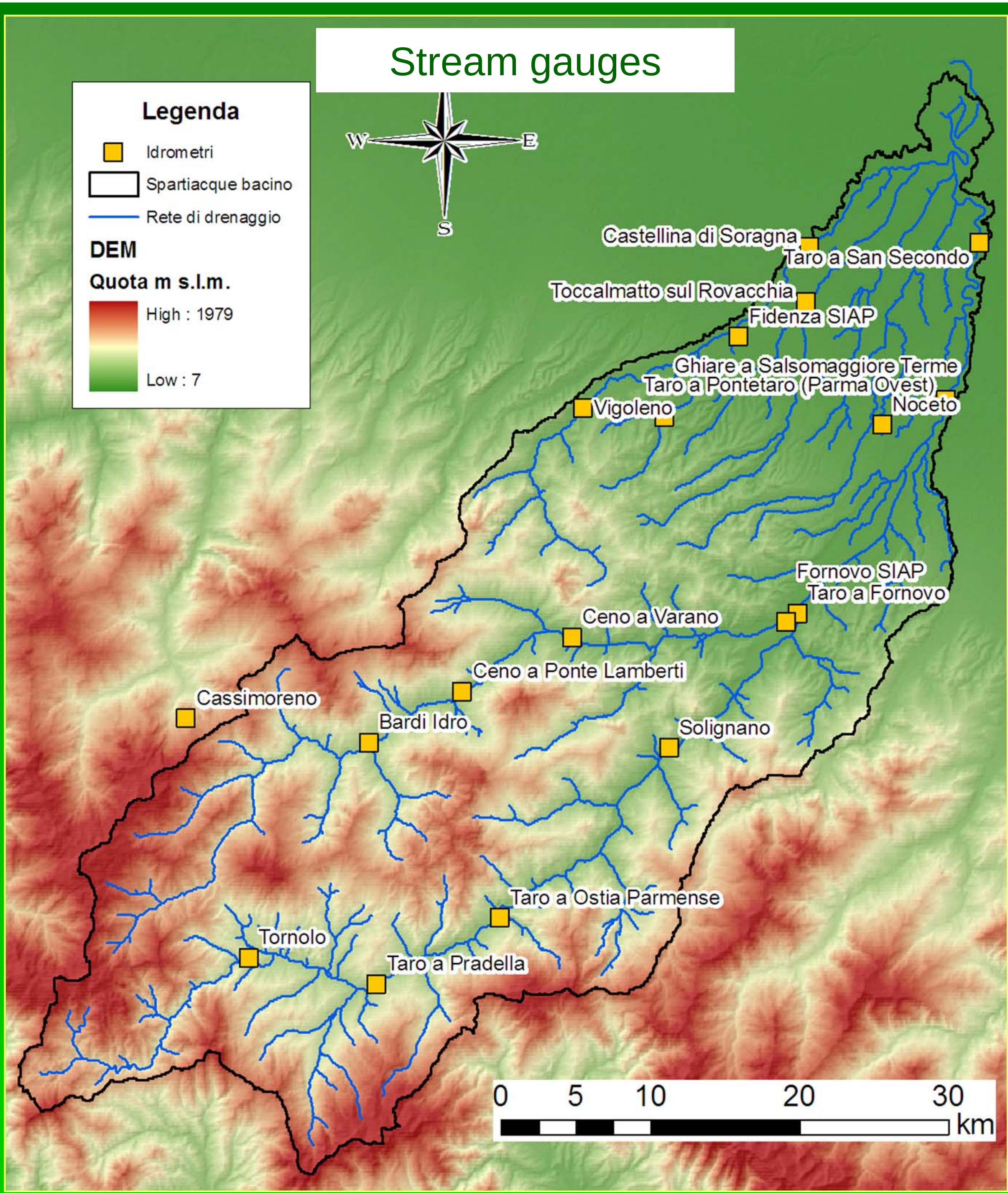
Monitoring network 1/2

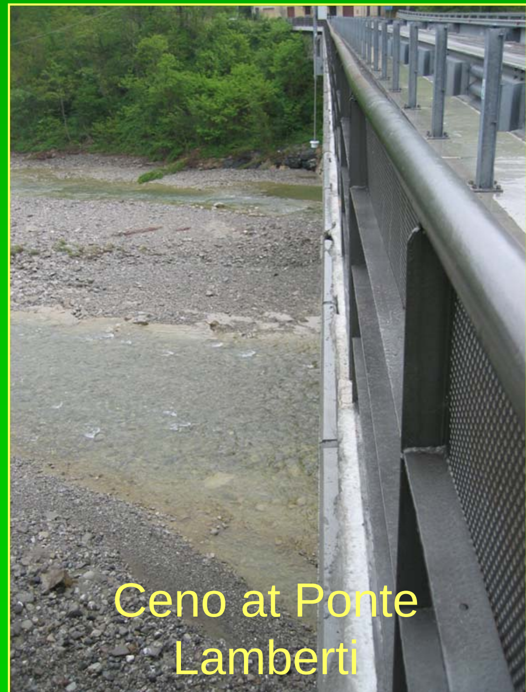



Ostia Parmense


Nociveglia

Monitoring network 2/2





Analysis method

Stochastic process depending on space

$$h_d(s) = \int_t^{t+d} i(s,\tau)\,d\tau$$

Rainfall depth for a given duration d (*Rodriguez-Iturbe e Mejia, 1974; Chua e Bras, 1982; Bacchi e Borga, 1993*)

$$h_{Ad} = \frac{1}{A}\int_A h_d(s)\,dA$$

Average spatial rainfall depth for a given duration

$$k_d(s) = \frac{h_d(s)}{h_{Ad}}$$

Non dimensional variable: comparison among various storms

$$k_{Ad} = \frac{1}{A}\int_A k_d(s)\,dA = 1$$

Simple Kriging spatial interpolation

$$\Gamma(s_1, s_2) = 1/2\, E\left[\left((k_d(s_1) - k_d(s_2)\right)^2\right] = \Gamma(h)$$

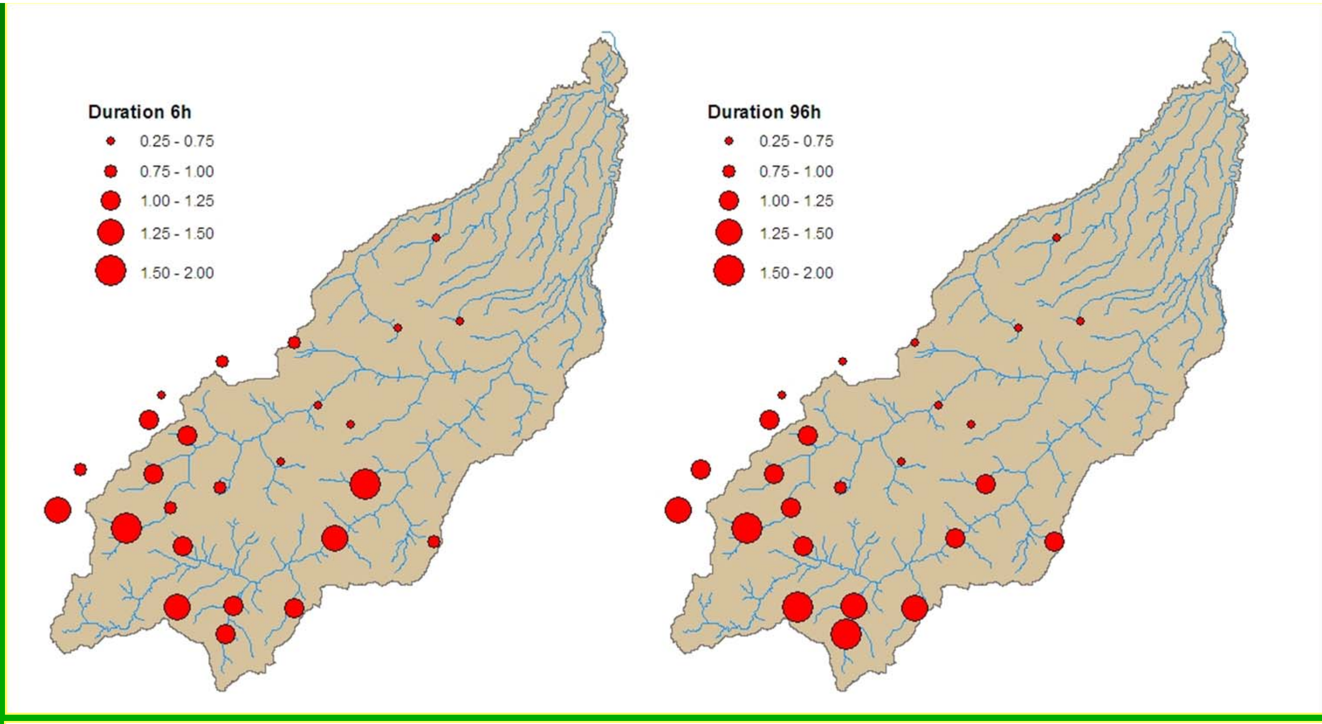
Isotropic process

Severe flood events occurred in the period 2003-2007

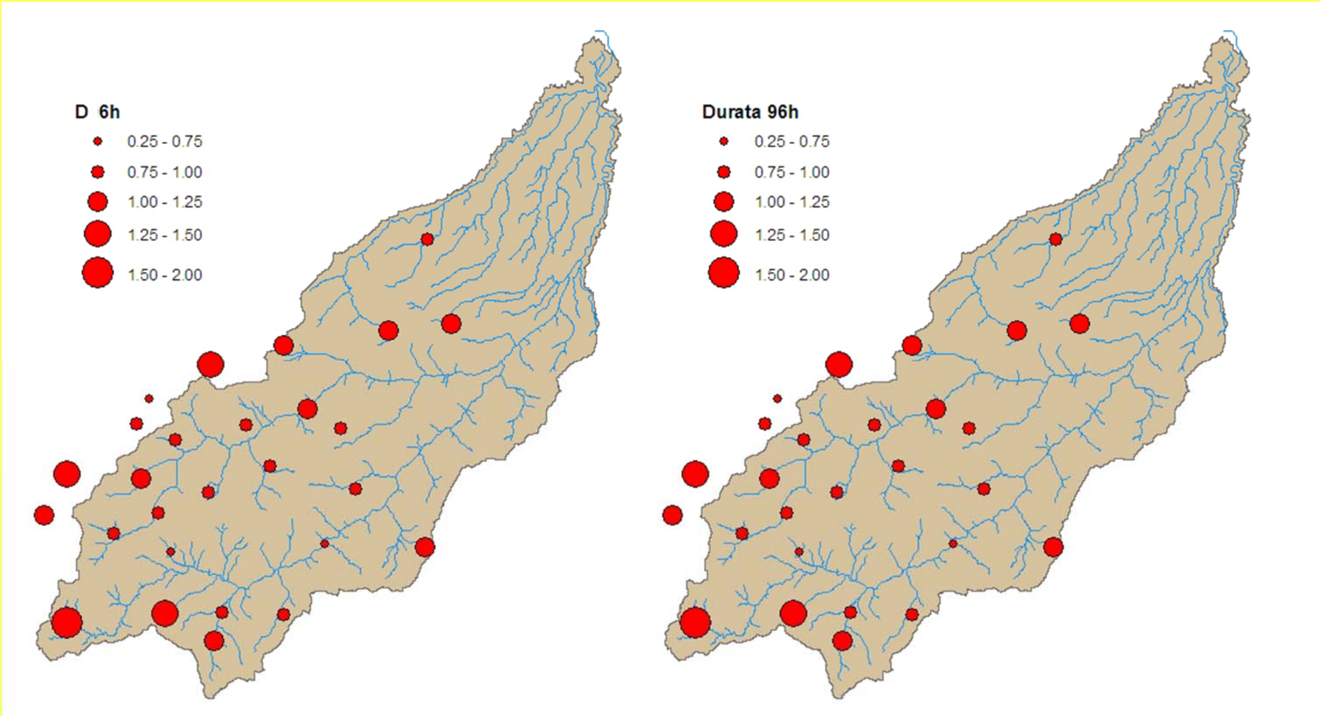
Event	Period	Rainfall depth [mm]	Storm duration [h]	Peak discharge [m³/s]
I	20÷22/1/2003	45,4	39,5	1.276,1
II	26/10÷2/11/2003	153,9	155,0	2.011,9
III	22÷28/11/2003	101,3	151,0	1.040,2
IV	3÷9/5/2004	95,5	137,0	845,0
V	30/11÷6/12/2005	149,0	187,0	2.688,5
VI	21÷25/11/2007	193,6	95,5	2.696,2

Observed events 2/2

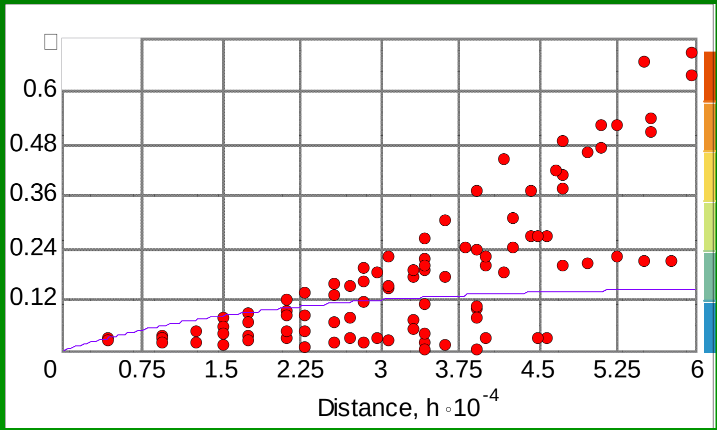
Event II



Event IV



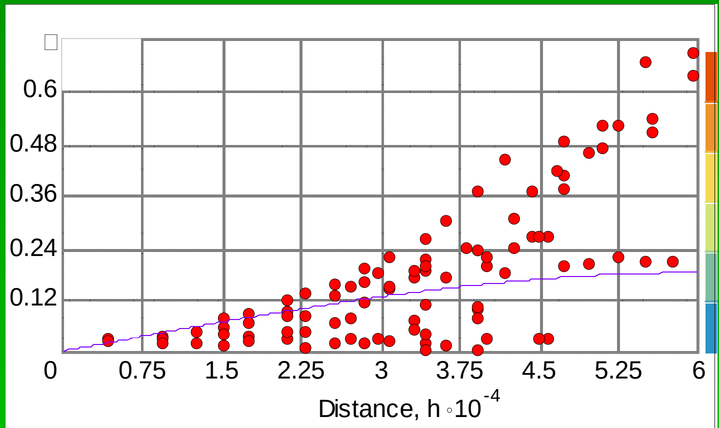
Application 1/2



Exponential model

$$\Gamma(h) = A\,\delta(h) + w\left[1 - \exp\left(-\frac{h}{a}\right)\right]$$

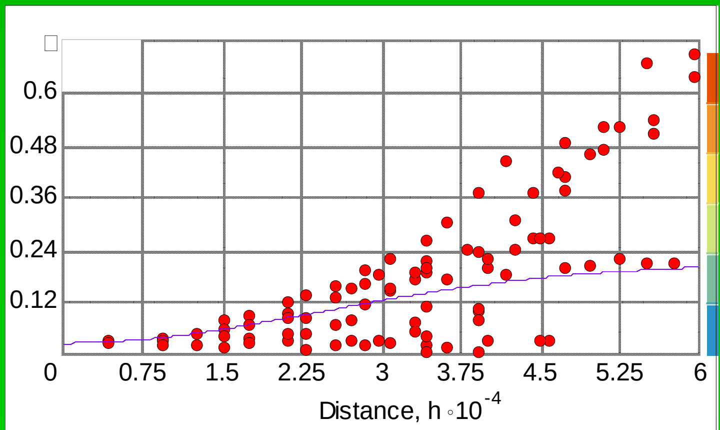
A=0; w: 0,15; a= 60 km



Spherical model

$$\Gamma(h) = \begin{cases} A\,\delta(h) + \dfrac{w}{2}\left[3\dfrac{h}{a} - \left(\dfrac{h}{a}\right)^3\right] & h < a \\ A + w & h \geq a \end{cases}$$

A=0; w: 0,18; a= 60 km

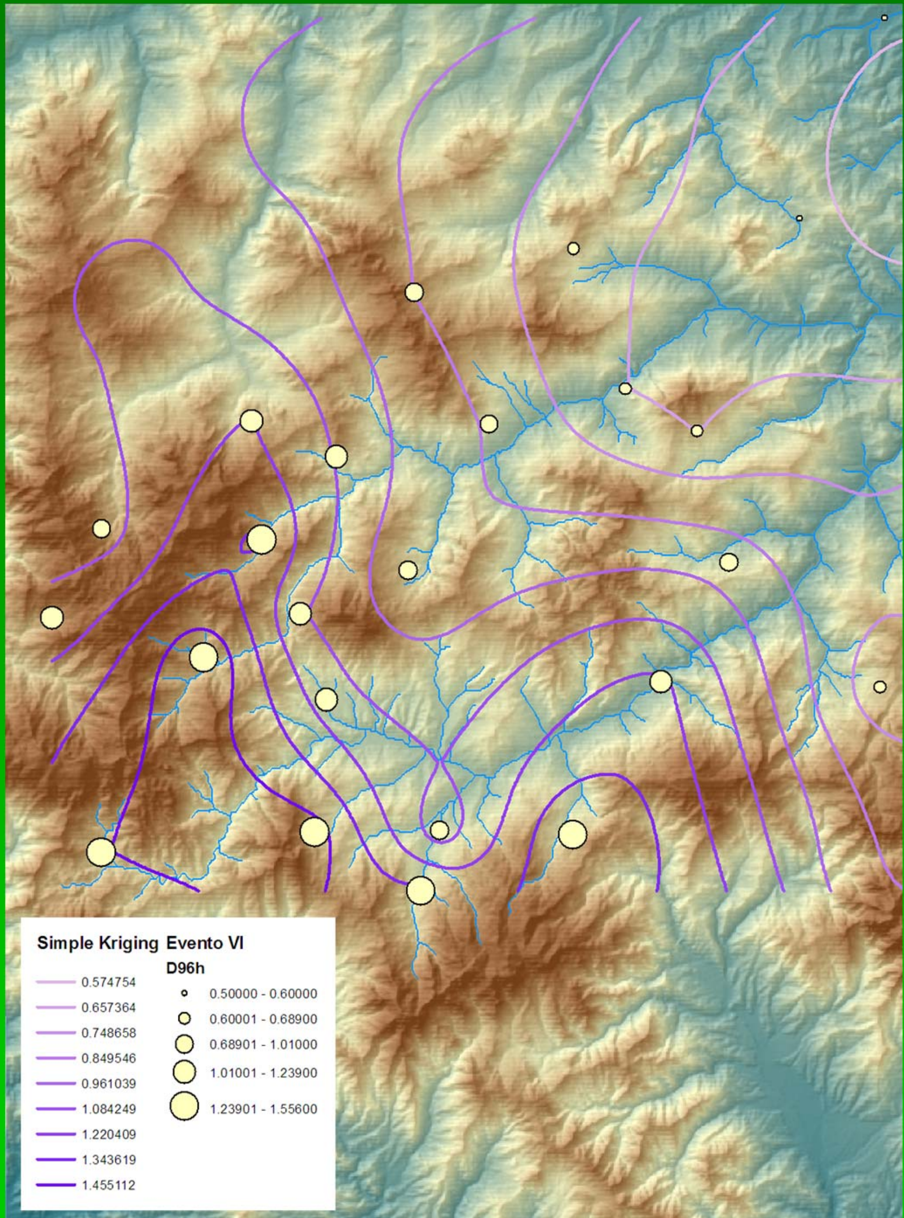


Gaussian model

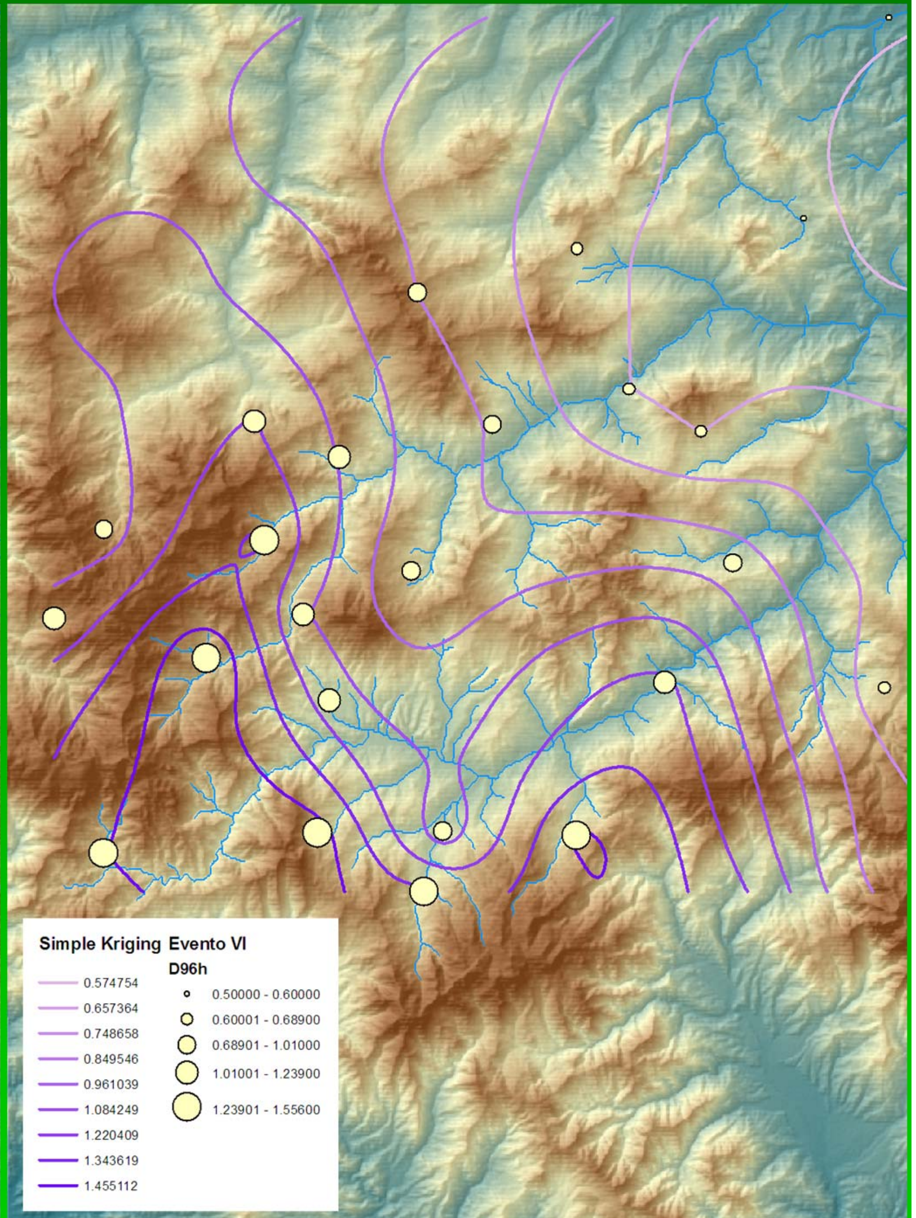
$$\Gamma(h) = A\,\delta(h) + w\left\{1 - \exp\left(-\left(\frac{h}{a}\right)^2\right)\right\}$$

A=0,02; w: 0,18; a= 60 km

Application 2/2

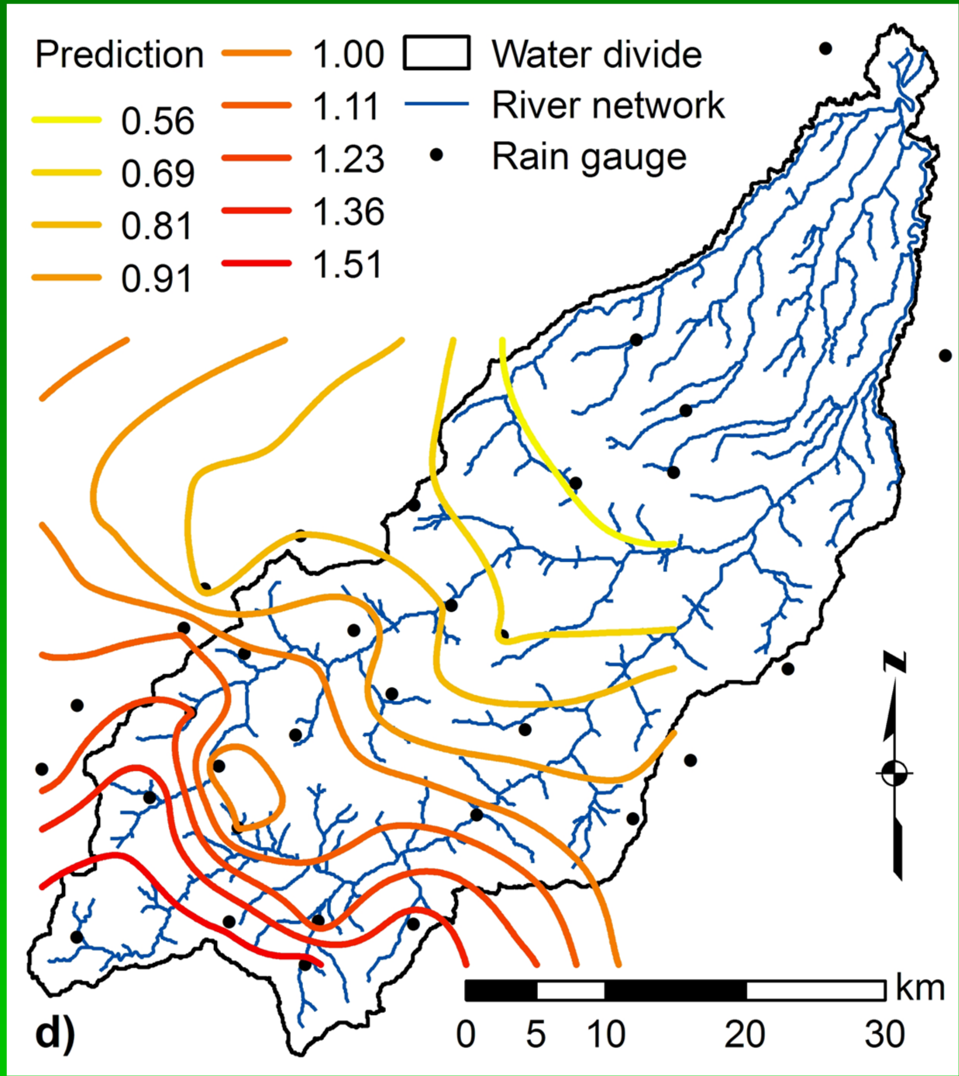


Exponential model



Spherical model

Model validation



Event	ME	RMSSE	Event	ME	RMSSE
I	-0,007876	1,0080	V	-0,006573	0,8567
II	-0,004376	0,7308	VI	-0,000085	0,8222
III	-0,006019	0,8964	Average	-0,005823	0,8167

Conclusions

- The results suggest the possibility to identify a typical spatial distribution of the rainfall fields which yields flood events particularly severe for the examined natural watershed
- The increasing trend of the total precipitation with the elevation, for a given storm duration, cannot be simply described by deterministic tools
- Aspect seems to be a relevant property in such a spatial distribution.
- The detected spatial pattern of the rainfall can be exploited to:
    - derive a spatial distribution of the precipitation field starting from an estimate of the average depth,
    - allowing the definition of scenarios having different frequency of occurrence
- Additional work is needed to:
    - quantify the improvement achievable by using complete distributed modelling in spite of less detailed ones
    - identifying a representative rain gauge station