How changes in extreme precipitation impacts hydraulic structure design storms


Colorado, USA Flood, September 2015


Ombrone River flood (Tuscany, Italy) August 2015

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Abstract

With a global concern about climate nonstationary and predictions of more extreme weather events, considering new rainfall distribution patterns is necessary using the most current and complete data available at any location. In this study, extreme rainfall frequency is analyzed using daily precipitation data in Kansas located in the central United States and Tuscany in the central Italy. From Kansas, 39 stations with data from 1920-2009 are selected, while for from Tuscany Region, 472 stations with daily time series of at least 15 years in the period 1916-2017 are used in the analysis. Initial analysis showed an increase in extreme precipitation events in Kansas with extreme event values tending to increase in magnitude from the northwest to southeast part of the state. Comparing results of the first period (1920-1949) to the last of three study periods (1980–2009) showed that approximately 90% of the state had an increase in short-term rainfall event magnitudes. Long-term event magnitudes were predicted to be higher in 66% of the state. Tuscany analysis is being conducted. Generally, results show a shift in rainfall distribution patterns in Kansas and Tuscany spatially and temporally. This shift changes the design criteria for hydraulic infrastructures, both in runoff control and storage structures.

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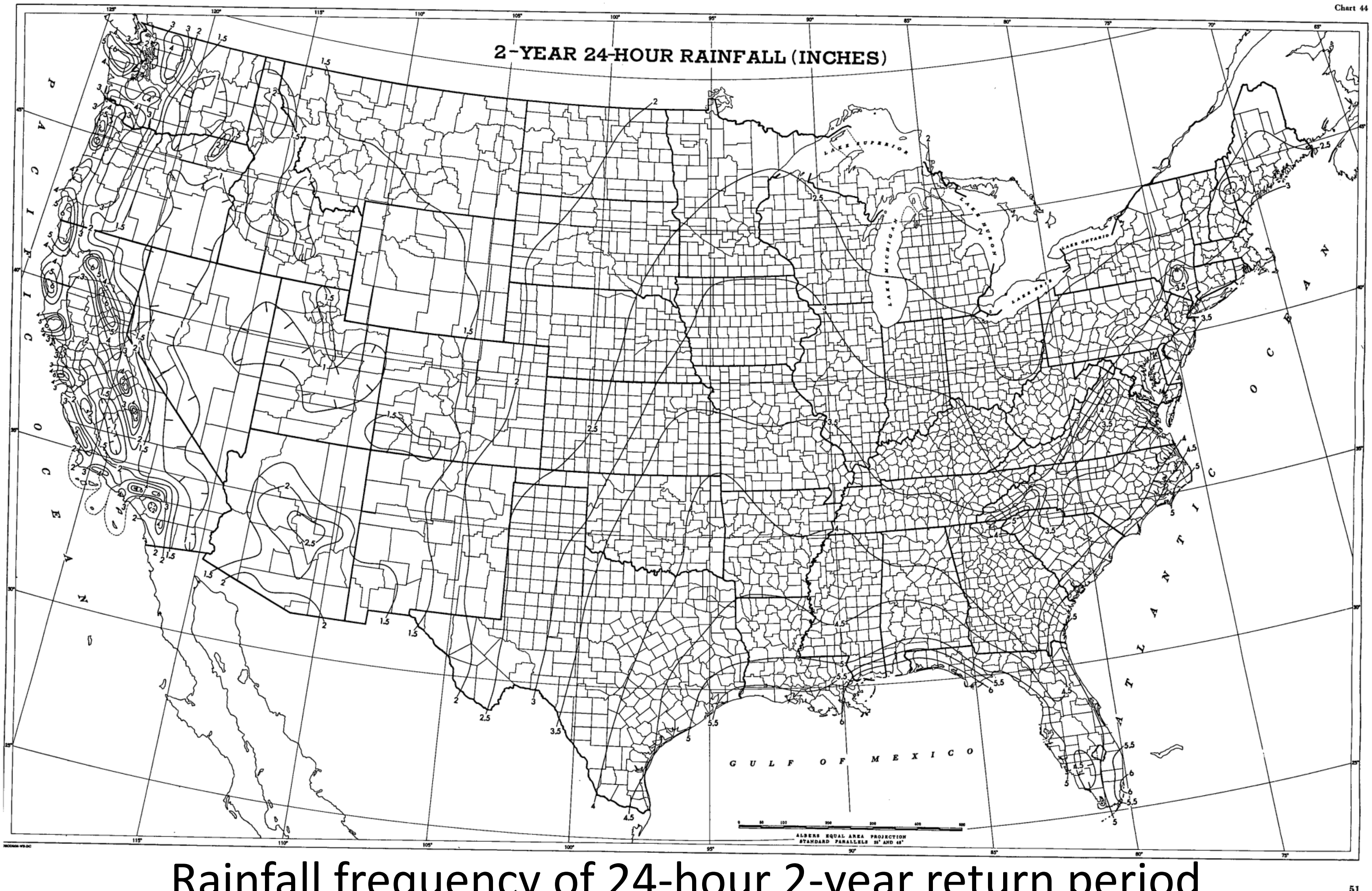
Presentation layout

Two case studies and methods:

1. **Kansas, USA**
   – Weibull method

2. **Tuscany, Italy**
   – Regional frequency analysis of annual maxima based on the index variable method

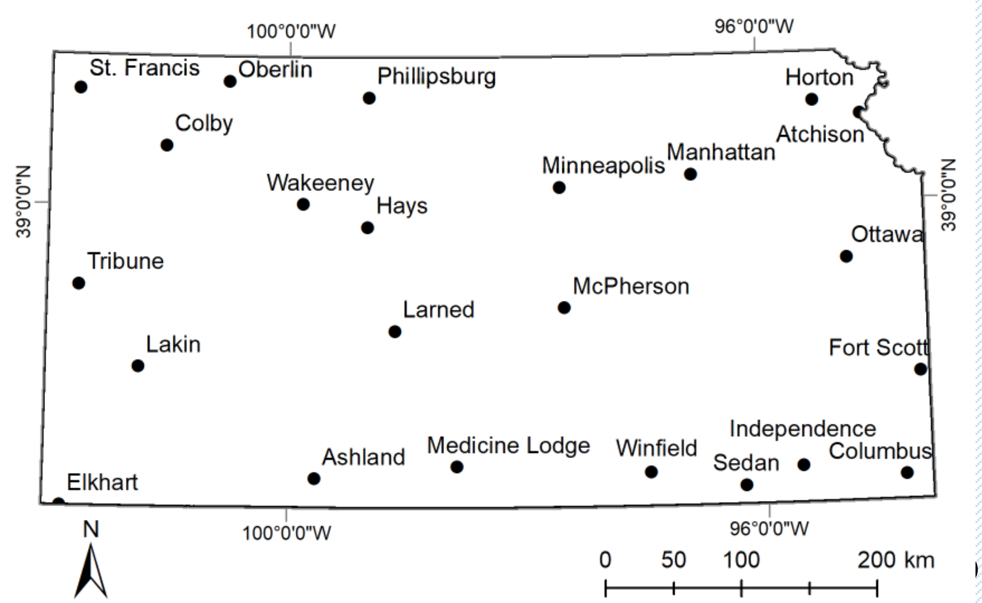
Design Storms, USA



Rainfall frequency of 24-hour 2-year return period based on Hershfield (1961)

Materials

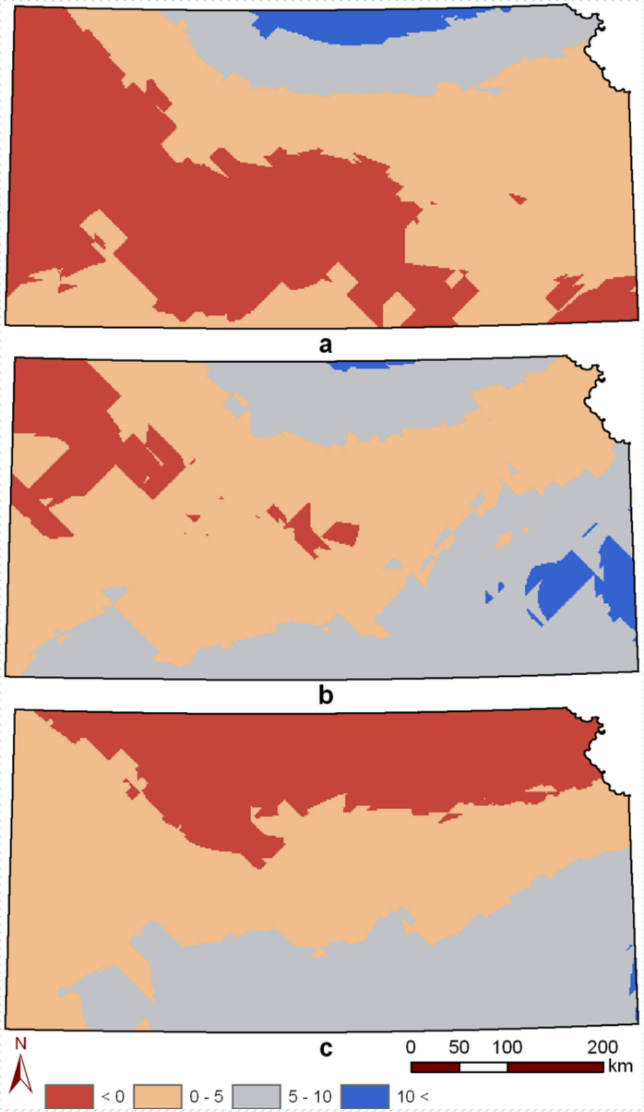
- Data source
  - Daily rainfall data from High Plains Regional Climate Center (HPRCC).
    - 24 stations across Kansas, USA
    - 15 stations from Oklahoma, Missouri, Nebraska, and Colorado



Methods

- Analysis method
  - Annual series method using Weibull Probability Distribution Function
  - Three consecutive periods which cover 90 years; 1) 1920-1949, 2) 1950-1979, and 3) 1980-2009

Precipitation shifts- 2-yr return period



Periods	Increase in area
2 vs. 1	64%
3 vs. 1	90%
3 vs. 2	68%

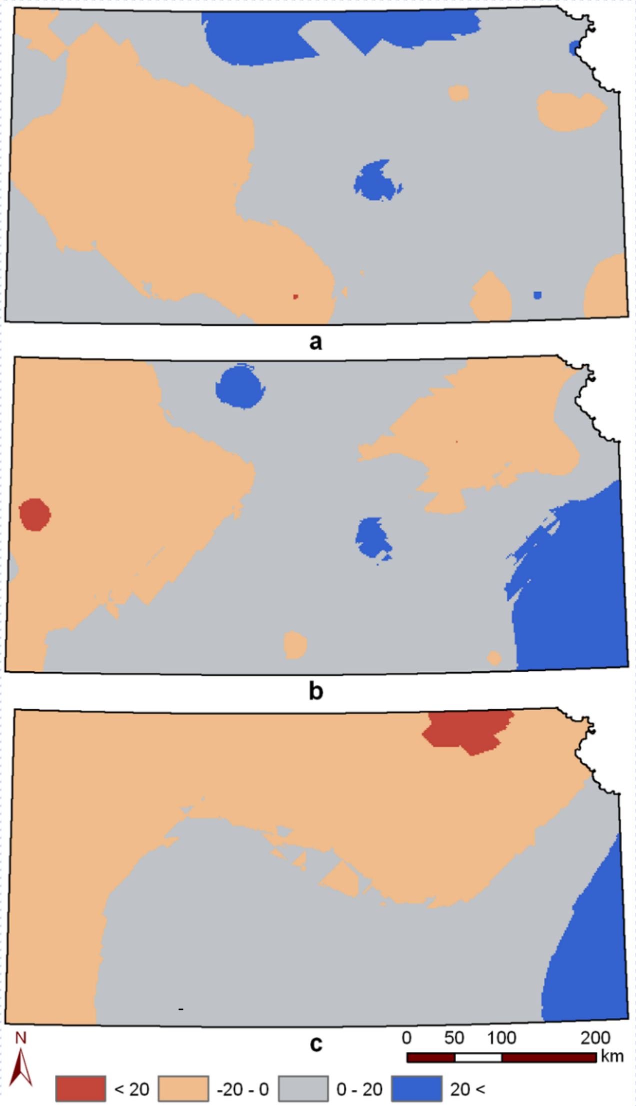
1: 1920-1949

2: 1950-1979

3: 1980-2009

Precipitation difference for 2 year return period of a)1950-1979 vs. 1920-1949, b)1980-2009 vs. 1920-1949 duration, and c) 1980-2009 vs. 1950-1979.

Precipitation shifts-100-yr return period



Periods	Increase in area
2 vs. 1	69%
3 vs. 1	66%
3 vs. 2	42%

1: 1920-1949

2: 1950-1979

3: 1980-2009

Precipitation difference for 100 year return period of a)1950-1979 vs. 1920-1949, b)1980-2009 vs. 1920-1949 duration, and c) 1980-2009 vs. 1950-1979.

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Design storms- 2-yr return period

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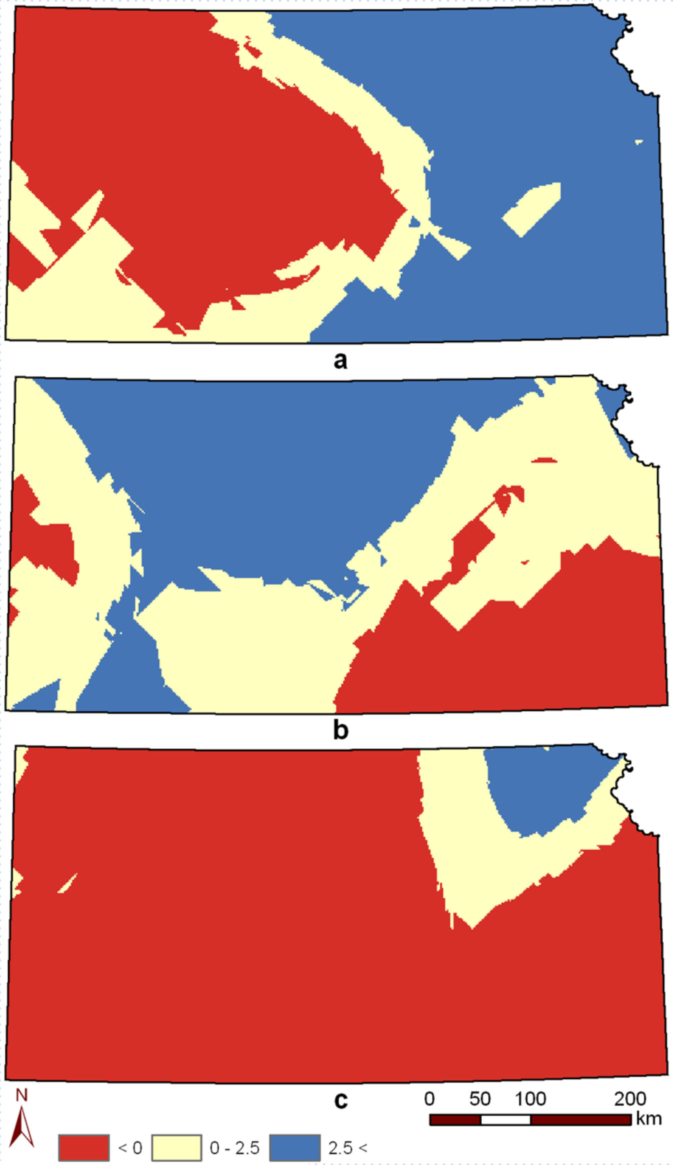

Periods	Increase in area
1 vs. TP40	33%
2 vs. TP40	43%
3 vs. TP40	84%

1: 1920-1949
2: 1950-1979
3: 1980-2009

Precipitation distribution shift (mm) of Hershfield [1961] vs. the period of a)1920–1949, b)1950–1979, and c)1980–2009 for 2-year return period

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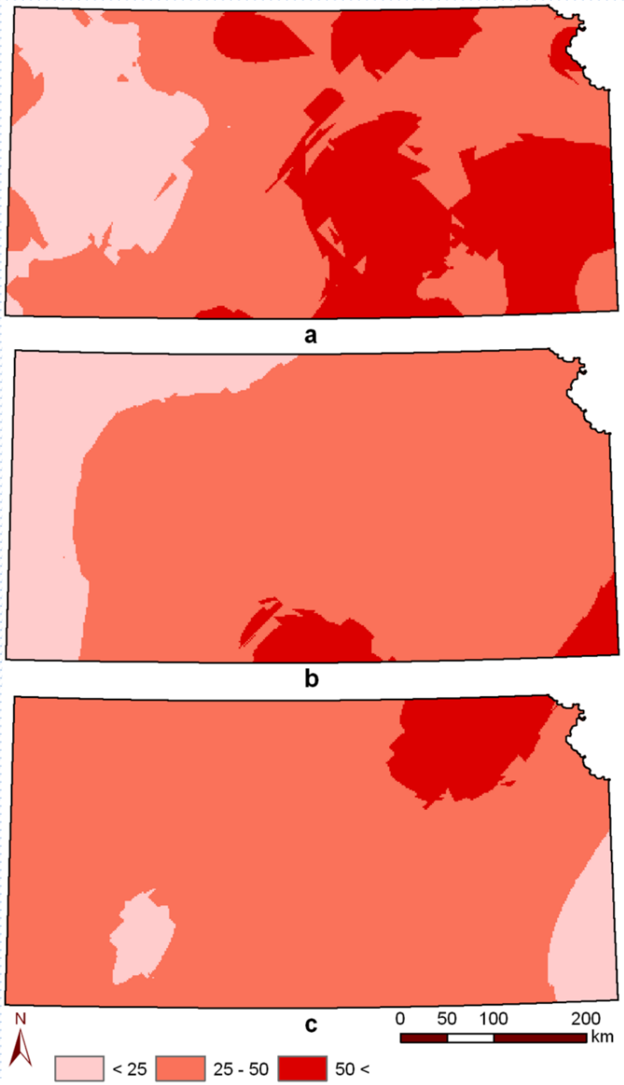
Design storms- 100-yr return period



- The entire state of Kansas was over-predicted for all three periods.
- The majority of the state was over-predicted by 25–50 mm during the first (53%), second (69%), and third (84%) period.
- Some areas in east Kansas was overpredicted by more than 50 mm.

Precipitation distribution shift (mm) of Hershfield [1961] vs. the period of a)1920–1949, b)1950–1979, and c)1980–2009 for 100-year return period.

REGIONAL FREQUENCY ANALYSIS OF RAINFALL EXTREME IN TUSCANY (I): *METHODOLOGY*

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METHODOLOGY

1. Regions Subdivision

1\.

Preliminary hypothesis of subdivision

Spatial distribution of sample coefficient of Skewness G (*Lsk*) [I level] and of variation *Cv* (*Lcv*) [II level].

2. Growth Factor

2\.

TCEV probability distribution function of the standardized variable $X' = X/\mu$

$$F_{X'}(x') = \exp\left[-\Lambda_1 \exp(-\eta x') - \Lambda^* \Lambda_1^{1/\theta^*} \exp\left(-\eta x'/\theta^*\right)\right]$$

Three levels hierarchical approach of parameters estimation

3. Index Rainfall

3\.

∀ homogenous region and ∀ rainfall duration **multivariate model**

$$\mu = a_0 + a_1 \cdot \ln(MAP) + a_2 \cdot z + a_3 \cdot \left[\sin\left(\frac{Asp}{2} - \frac{\pi}{2}\right) + \pi\right] \cdot |Asp| + a_4 \cdot hm$$

as function of climatic and geomorphological characteristics (Caporali et al., Environmetrics 2008)

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REGIONAL FREQUENCY ANALYSIS OF RAINFALL EXTREME IN TUSCANY (I): *RESULTS*

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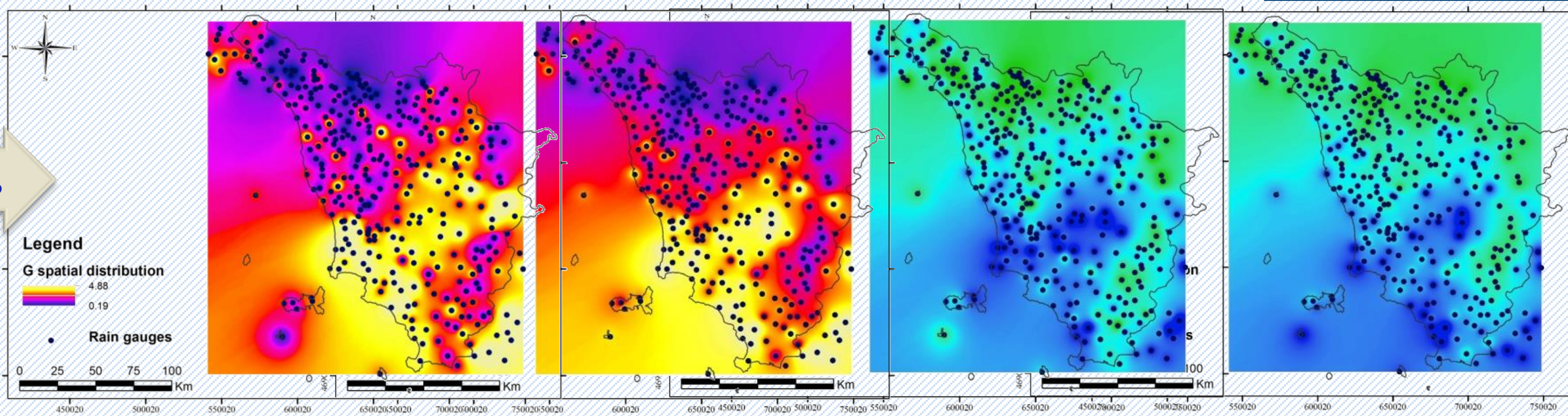
RESULTS

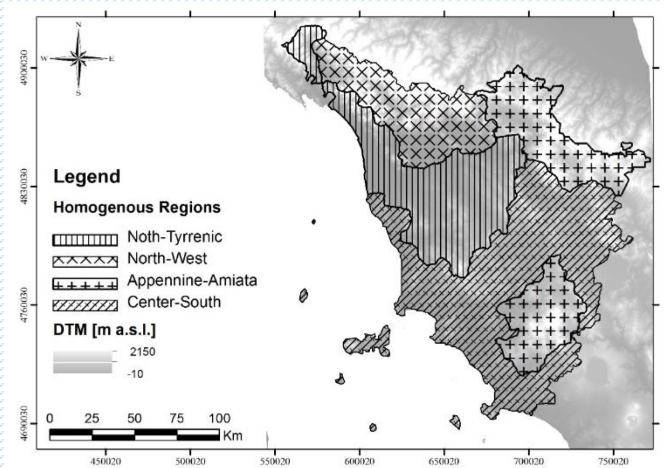
1.



2.

Regions	θ^*	Λ^*	Λ_1	η	$K_{d,Tr}$
North-Tyrrhenian	2.634	0.438	31.195	4.937	0.2558 + 0.533·Ln Tr
North-West	2.129	0.129	19.232	3.769	− 0.3705 + 0.565·Ln Tr
Apennine-Amiata	2.456	0.127	33.292	4.350	− 0.3605 + 0.565·Ln Tr
Center-South	3.381	0.206	28.325	4.516	− 0.4421 + 0.749·Ln Tr

Parameters of the TCEV distribution and simplified expression of the growth factor *Kd,Tr* for daily rainfall data.



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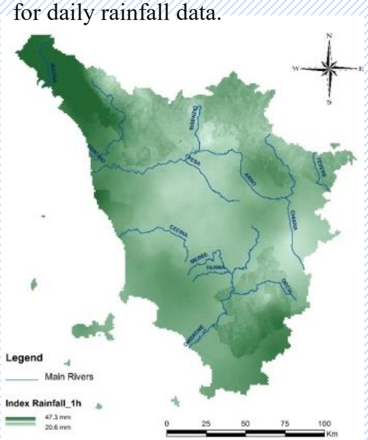

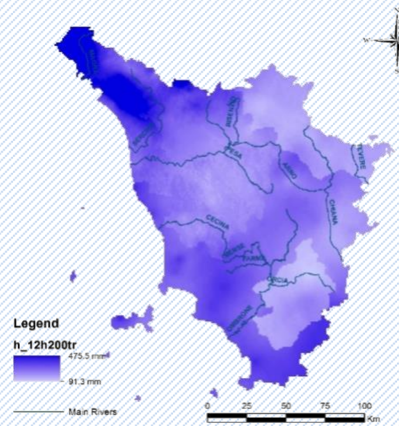

rainfall maxima records in the period 1916-2012 of duration *d*: 1 hour, 3, 6, 12, 24 hours, and return period *Tr*: 2, 5, 10, 20, 30, 50, 100, 150, 200, 500 years.

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Highlights

- **Extreme precipitation: Rethinking of design storms considering the recent changes in extreme precipitation**
- **Changes in extreme precipitation is different spatially which needs different local policy and criteria when designing hydraulic infrastructures**
- **Among the hydrological variables, design storm represents the paramount variable for the implications on flood risk assessment and territory protection measures definition.**

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Thank you!

Questions?

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https://scholar.google.com/citations?user=fXKee3AAAAAJ&hl=en

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