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HS29 - Objective and process-based catchment classification as a tool for predictions in ungauged basins

Hydroclimatological description of extreme events in Sicilian region finalised to describe regional hydrological patterns and to predict flood regime in ungauged catchments.

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Outlines

Aim of this paper is to analyse interactions between climate, soil moisture and catchment characteristics to describe regional flood regime in Sicily, Italy.

- Problem overview
- Methodology
  - → method based on directional statistics
  - → method based on relative frequencies
  - → climatic and hydrological features of the catchments
- Case study: Sicily
- Conclusions

Problem Overview

Flood frequency estimation at ungauged sites is one of the most significant issues in hydrology, especially in Mediterranean areas where absence of in-situ measures is a common situation.

In this context hydro-meteorological and hydrological indices should be capable of describing patterns of extremes events under various climatic and physiographic conditions.

The main advantage of this approach is that we use date data, which practically are free-error and more robust than event magnitude data.

Methodology

To describe the timing and regularity of hydro-meteorological events

Method based on directional statistics

Method based on relative frequencies

Method based on directional statistics

The date of occurrence of flood or extreme rainfall occurrences *i* can be interpreted as a vector with a unit magnitude and direction given by:

where $(Date)_i$ is the Julian day of event i, so January 1 is Day 1 and December 31 is Day 365 .

$$\theta_i = (Date)_i \left(\frac{2\pi}{365} \right)$$

Considering *n* events, the *x*- and *y*-coordinates of the mean date of occurrence can be determined by:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} \cos(\theta_i) \qquad \bar{y} = \frac{1}{n} \sum_{i=1}^{n} \sin(\theta_i)$$

using polar coordinates, the mean date of occurrence can be determined by:

$$\bar{r} = \sqrt{\bar{x}^2 + \bar{y}^2} \qquad \bar{\theta} = \arctan\left(\frac{\bar{y}}{\bar{x}} \right)$$

The mean direction represents a measure of the mean timing for the sample of n dates and can be converted back to a day of the year by:

$$MD = \bar{\theta} \frac{365}{2\pi}$$

Method based on directional statistics

mean day of rainfall → **MDR**

mean day of flood → **MDF**

A dimensionless measure of the spread of the data that gives information about the regularity of the phenomenon can be defined as:

$$V = 1 - \bar{r} \qquad \text{with} \qquad 0 \le V \le 1$$

V close to 0 → Strong seasonality in the date of occurrence: all events in the sample are tightly clustered about a mean direction.

V close to 1 → Great dispersion in the date of occurrence of flood or rain events throughout the year.

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Method based on relative frequencies

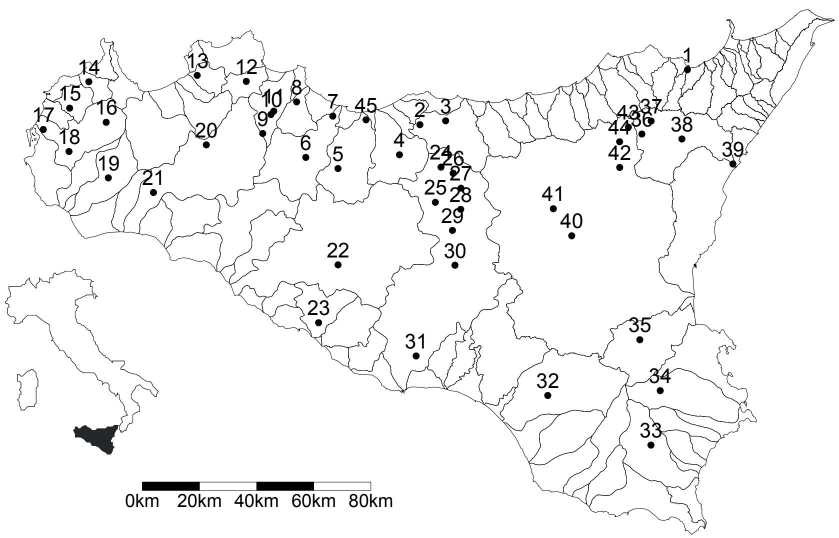
The monthly relative frequencies of flood or rain occurrence (probabilities of flood occurrence in a given month) are calculated for every month.

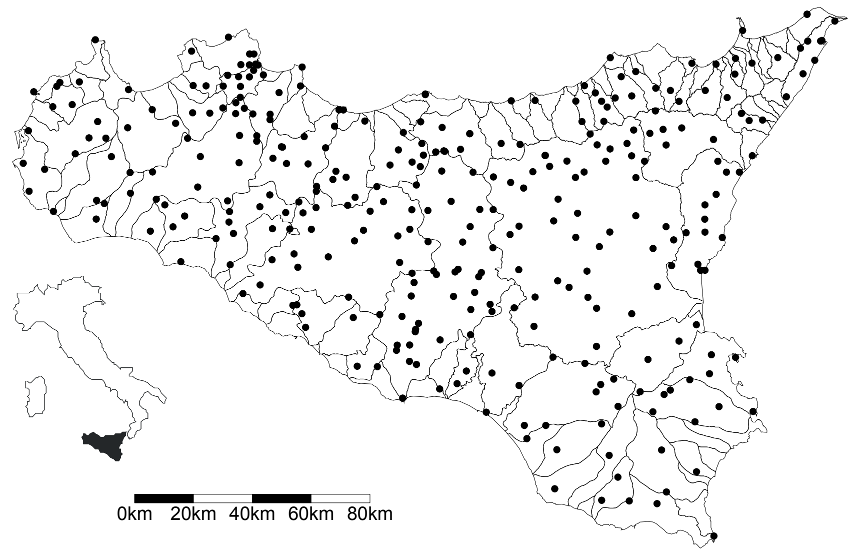
For each station, you count the number n_i of Julian days $(Date)_i$ that fall in each month i, e. g. between 1 and 31 for January, 32 and 59 for February, etc.

Then you can obtain the relative frequency F_i for month i by: $F_i = \frac{n_i}{\sum_{i=1}^{12} n_i}$

An adjustment must be applied in such a way that all months have the same length: the observed frequencies for 31-day months are multiplied by 30/31 and the frequency for February by 30/28.

Case Study: Sicily





45 Flow gauge

↓

MDF

Annual peak flow discharge

Annual maximum daily discharge

327 Rain gauge

↓

MDR

Annual maximum daily rainfall

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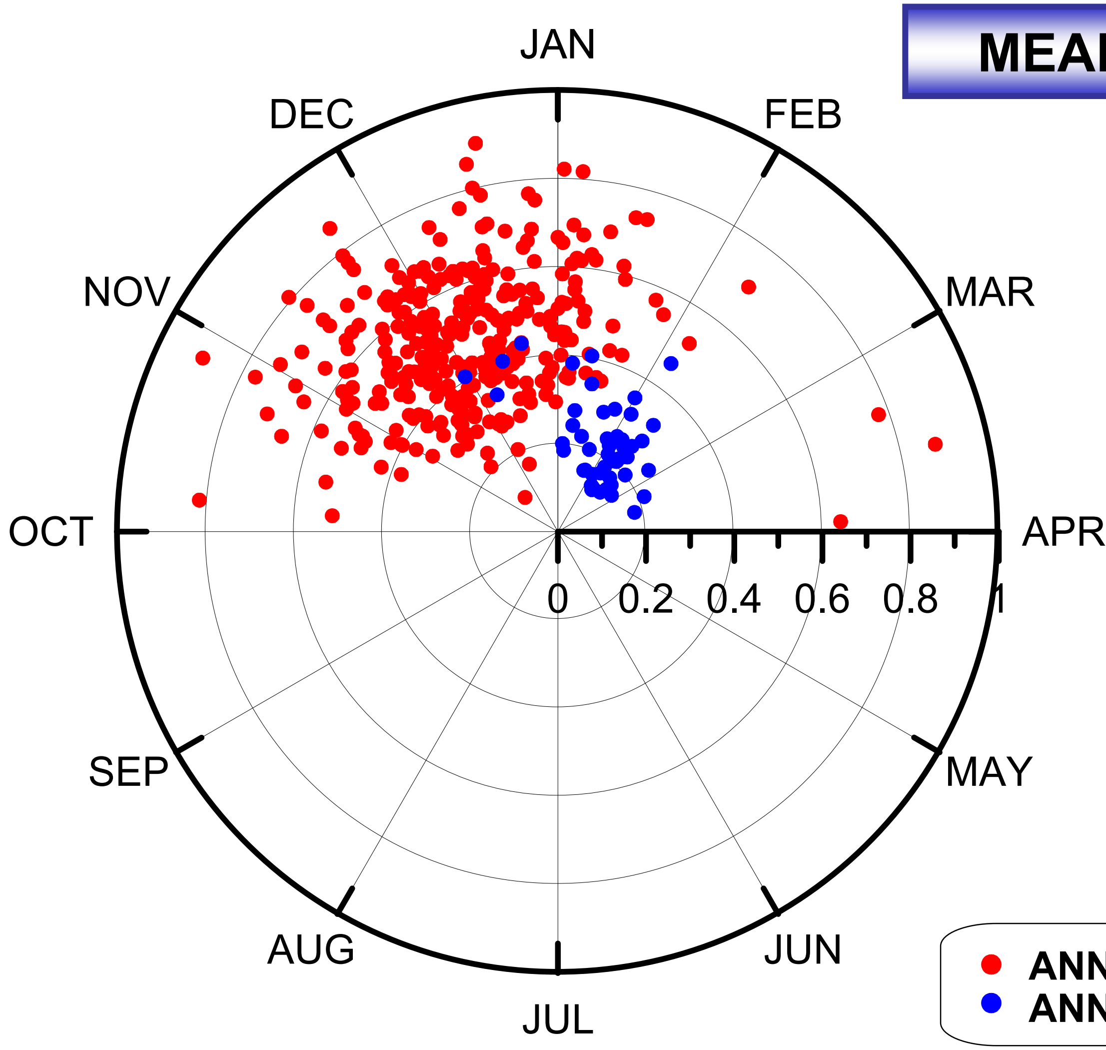
Case Study: Sicily

MEAN DAY OF OCCURRENCE



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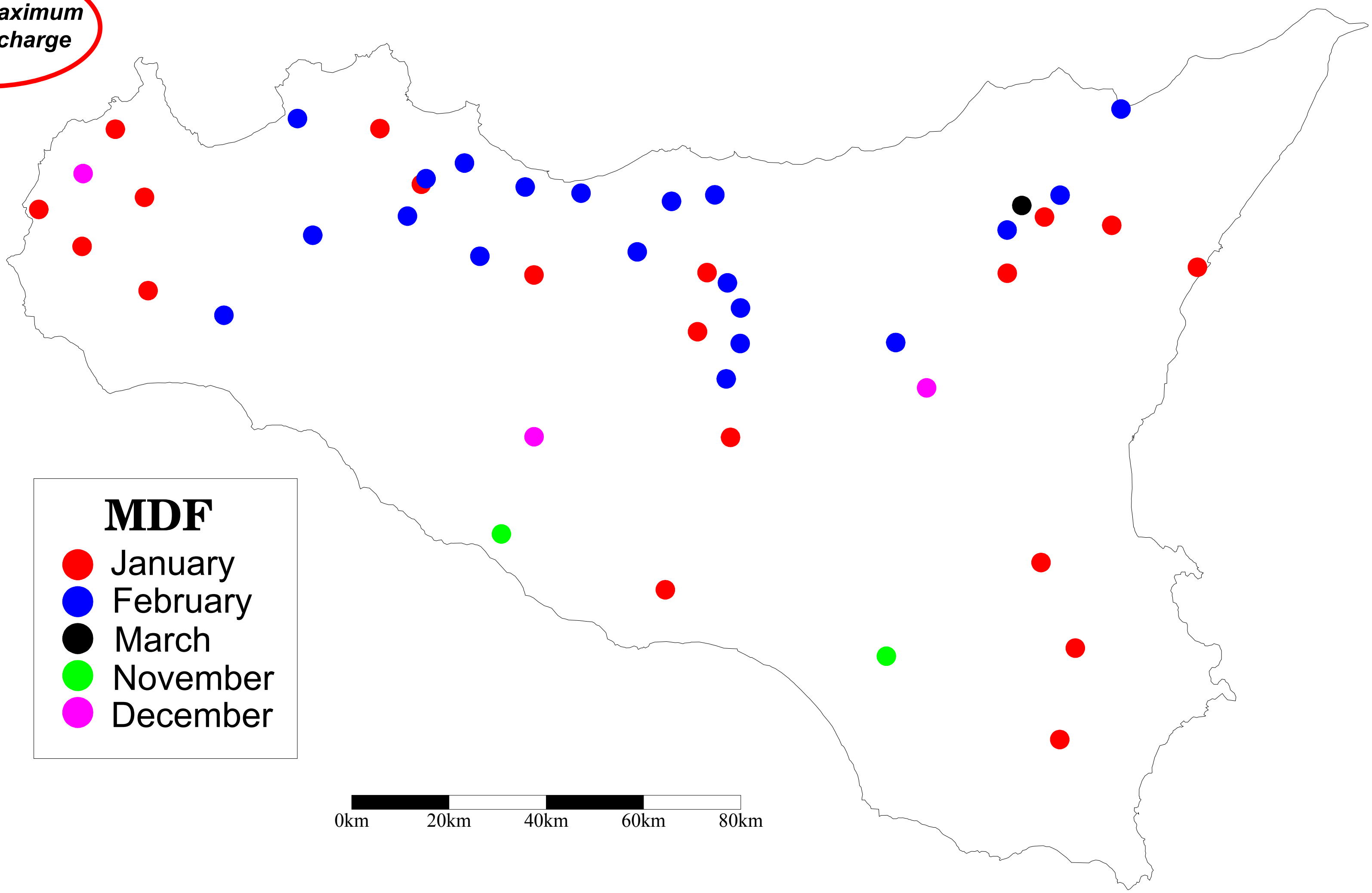
Case Study: Sicily

Annual maximum daily discharge



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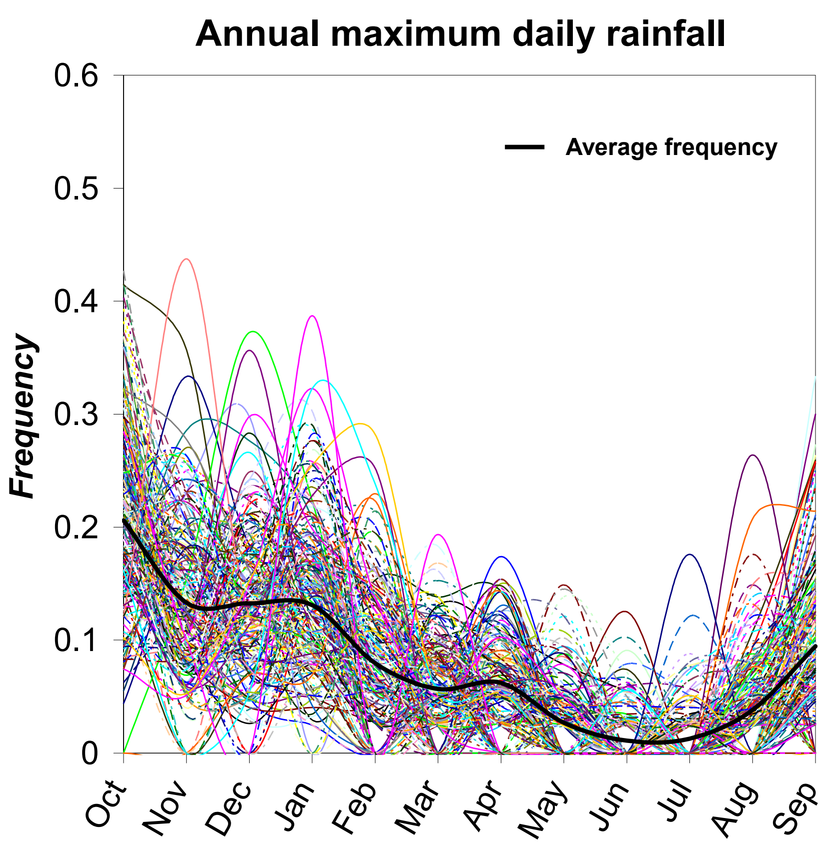
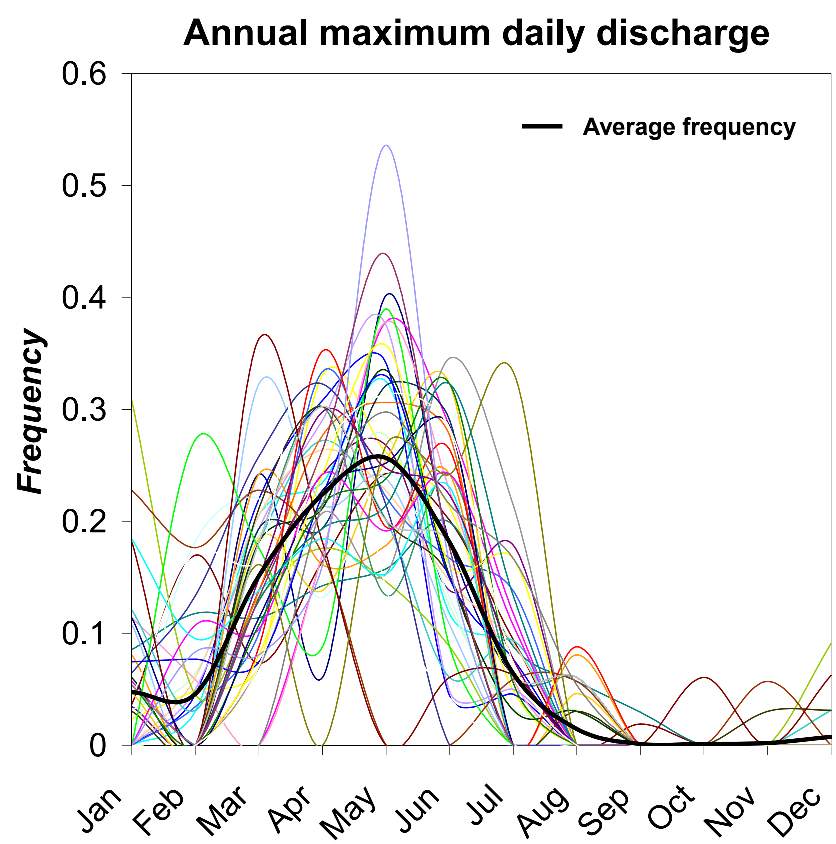
Case Study: Sicily





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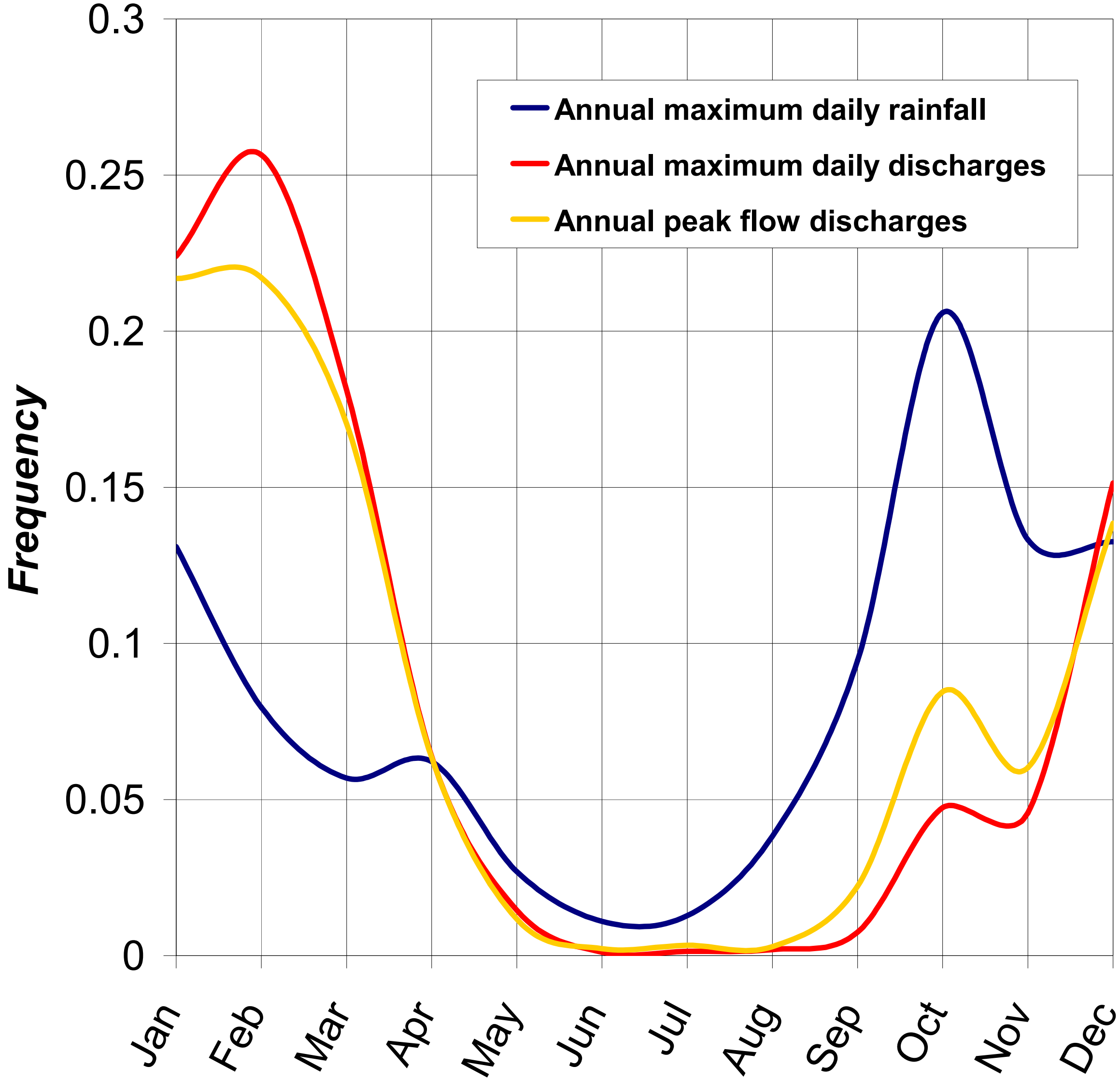

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Methodology

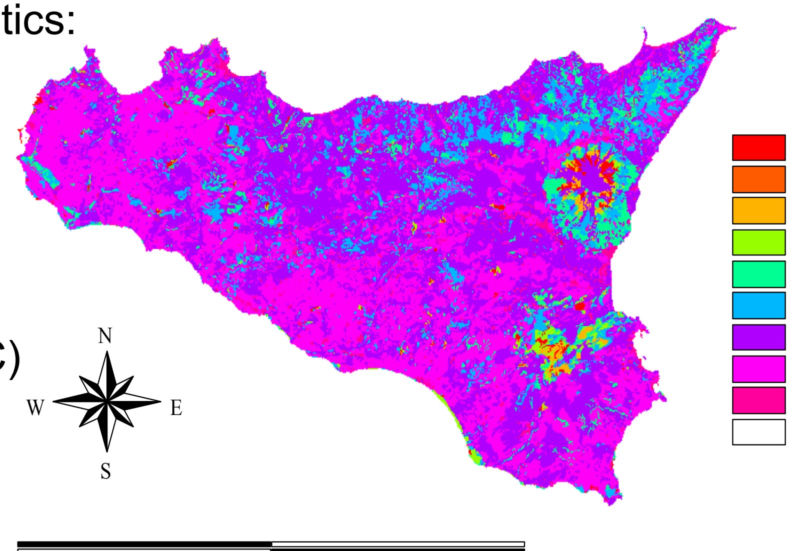
Climatic and hydrological features of the catchments

S potential maximum retention

$$S = 254\left(\frac{100}{CN} - 1\right)$$

CN Curve Number is non-dimensional, varying from 0 to 100, and it is derived from the tables presented in the *National Engineering Handbook* (Section 4) (NEH-4) for various catchment characteristics:

- ✓ Soil type
- ✓ Land use
- ✓ Hydrologic condition
- ✓ Antecedent moisture condition (AMC)



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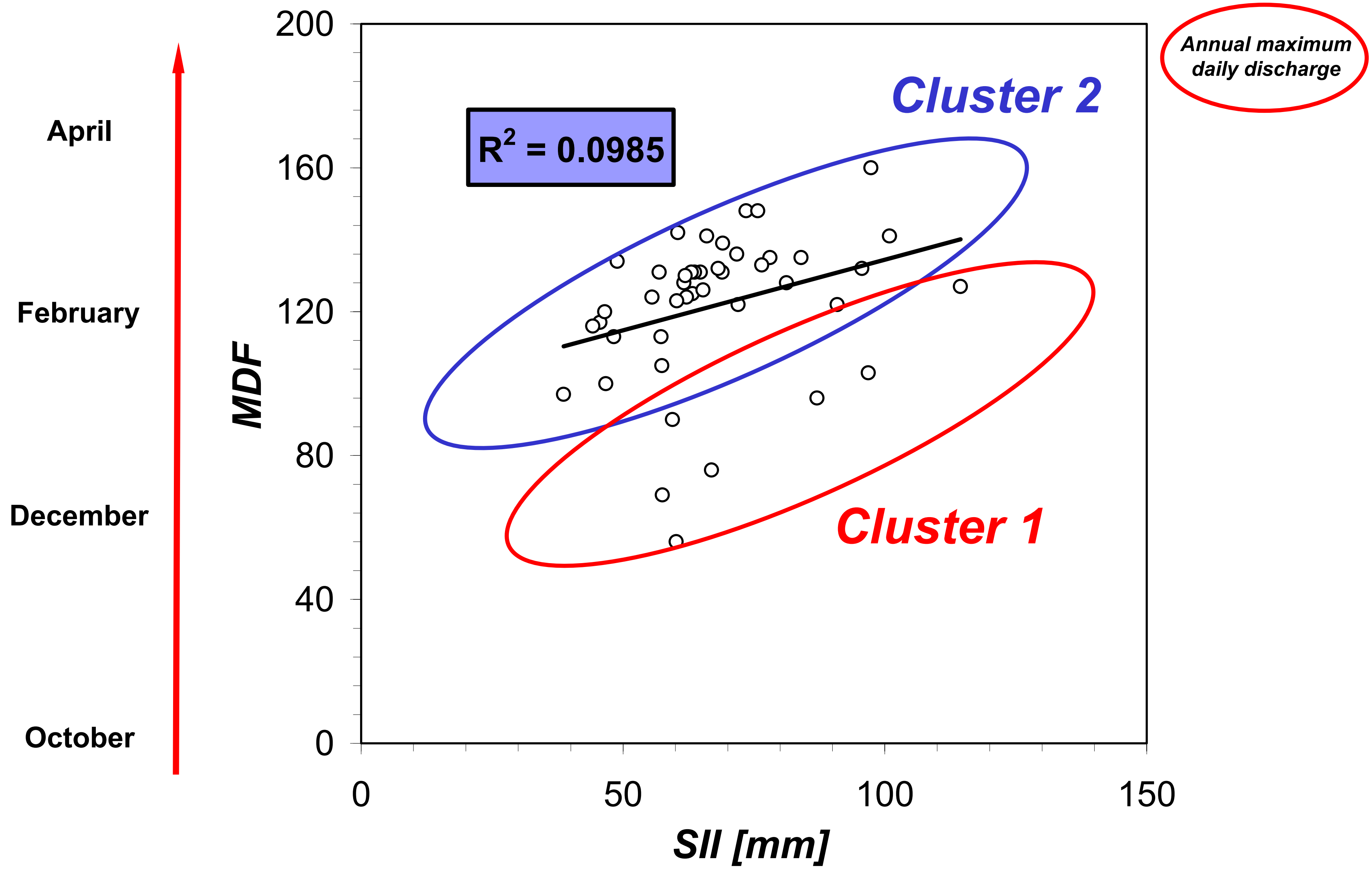
Case Study: Sicily



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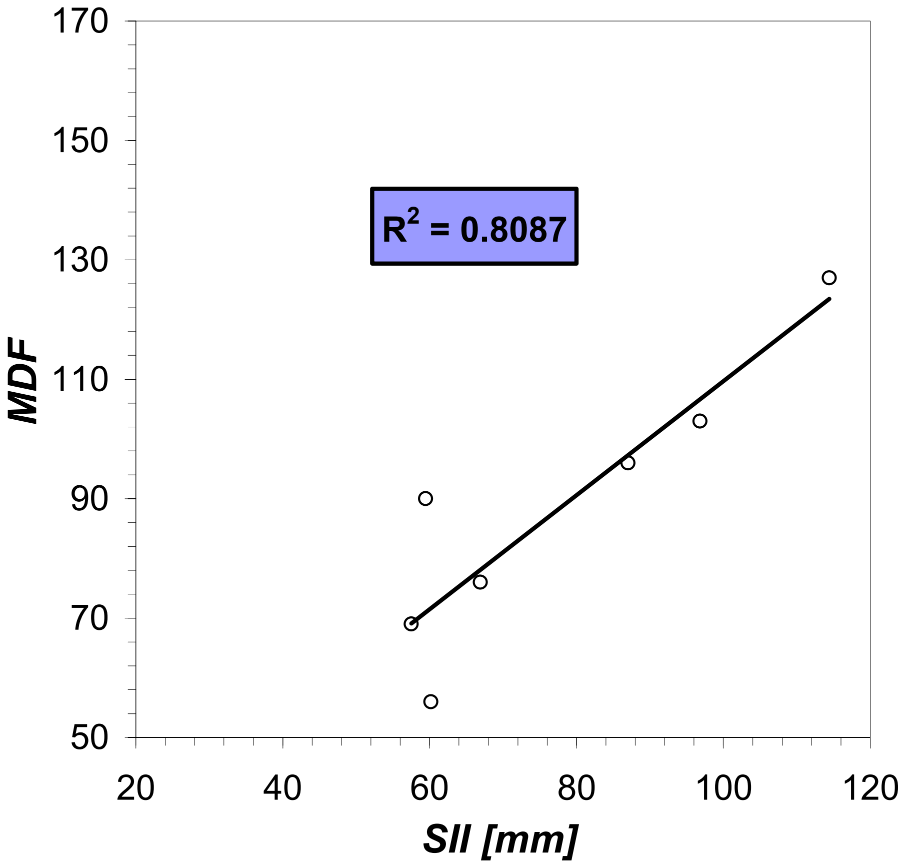
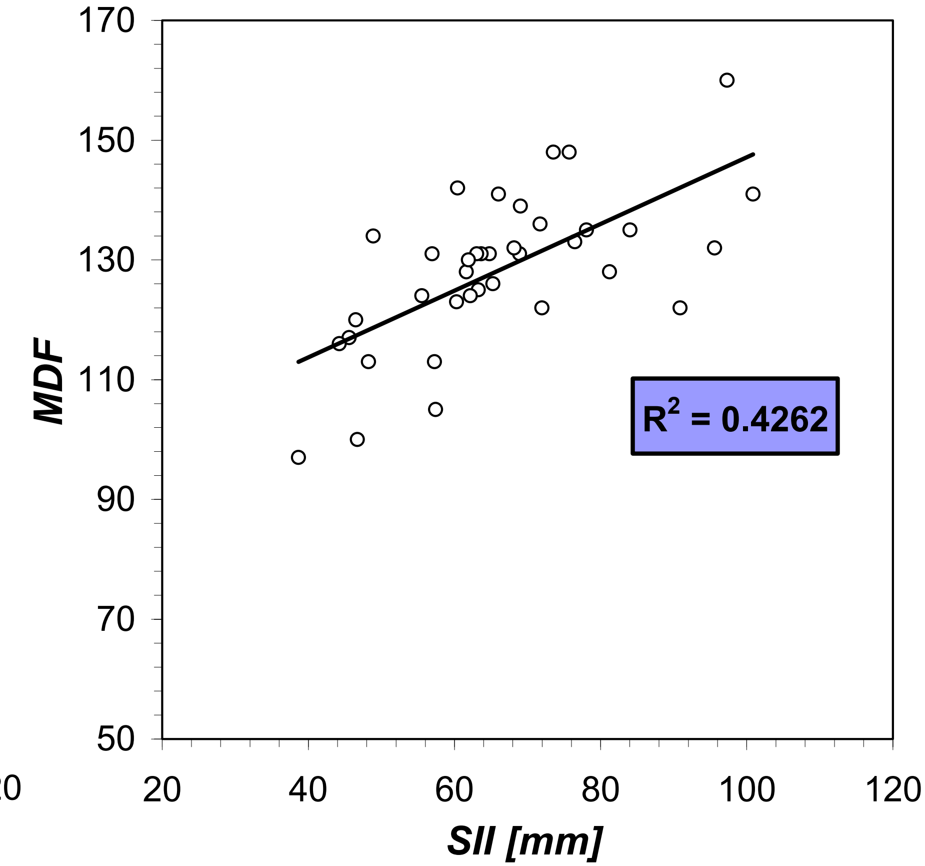
Case Study: Sicily

Cluster 1



Cluster 2



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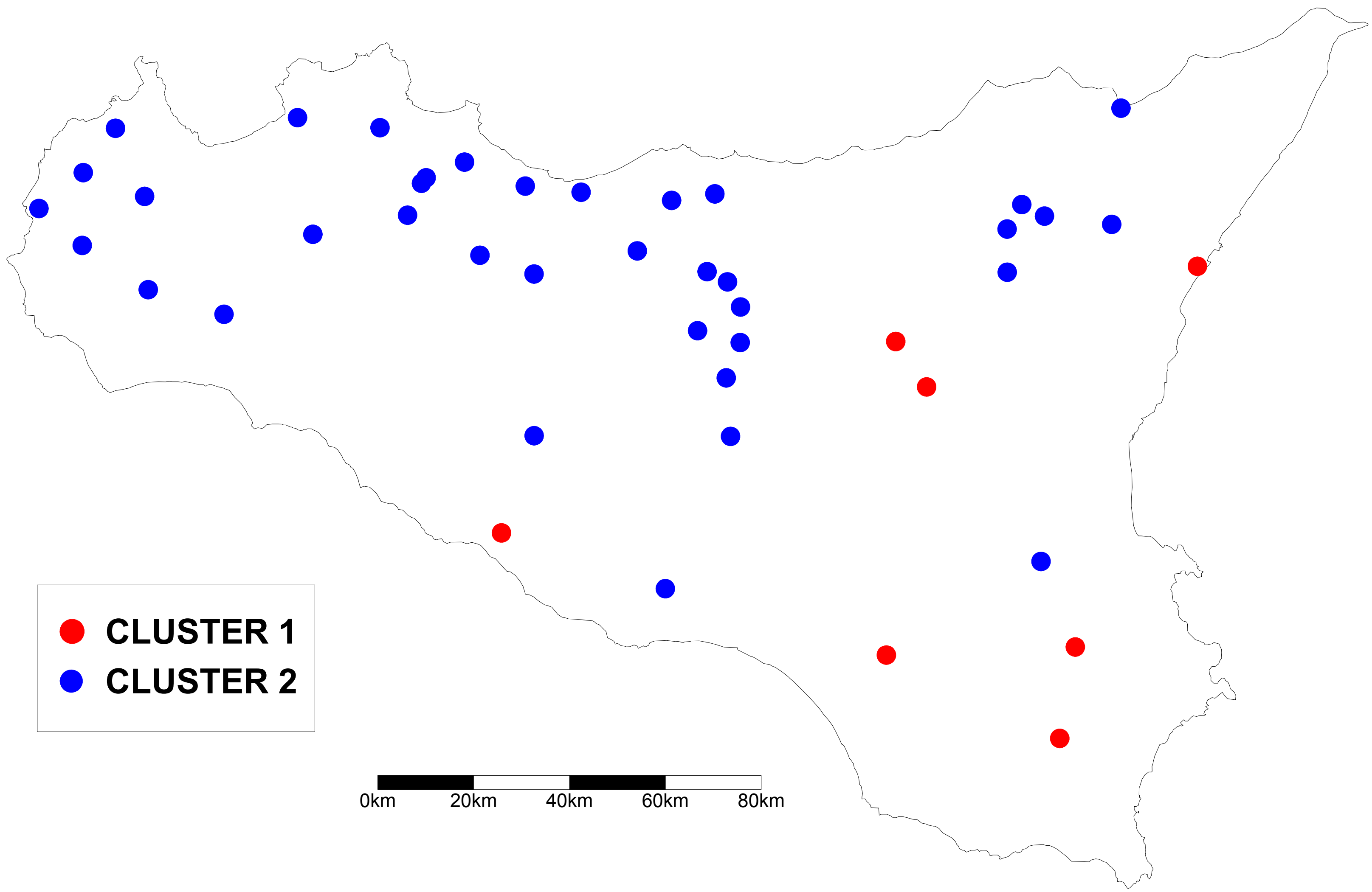

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Climatic and hydrological features of the catchments

S mean potential maximum retention

$$\underline{S} = S_I \cdot w_1 + S_{II} \cdot w_2 + S_{III} \cdot w_3$$

AMC calculation

Definition of three AMC classes (I, II and III) depending on the total 5-days antecedent the start of the storm API_5

AMC has been treated as a random variable with a discrete probability distribution

→

Only 3 classes of soil moisture condition have been considered, in accordance with the classical SCS–CN method (AMC, API5):

- dry soil (AMC I)
- moderately soil (AMC II)
- wet soil (AMC III)

→

$$\begin{cases} P(AMC = I) = w_1 \geq 0 \\ P(AMC = II) = w_2 \geq 0 \\ P(AMC = III) = w_3 \geq 0 \\ w_1 + w_2 + w_3 = 1 \end{cases}$$

S calculation

S_I, S_{II}, S_{III} represent S corresponding to AMC I, to AMC II, to AMC III respectively.

→

$$S_{(AMC)} = 254\left(\frac{100}{CN_{(AMC)}} - 1\right)$$

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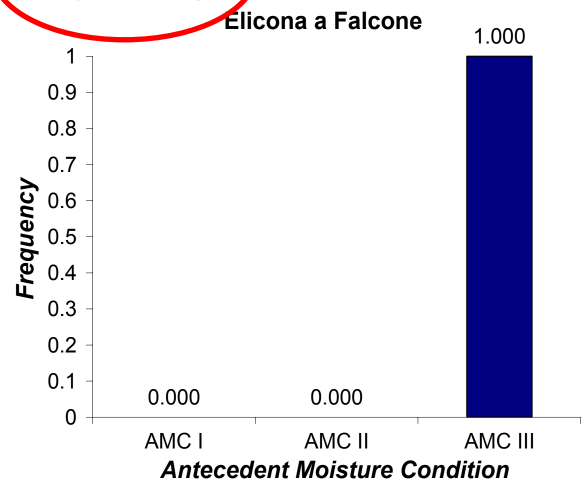
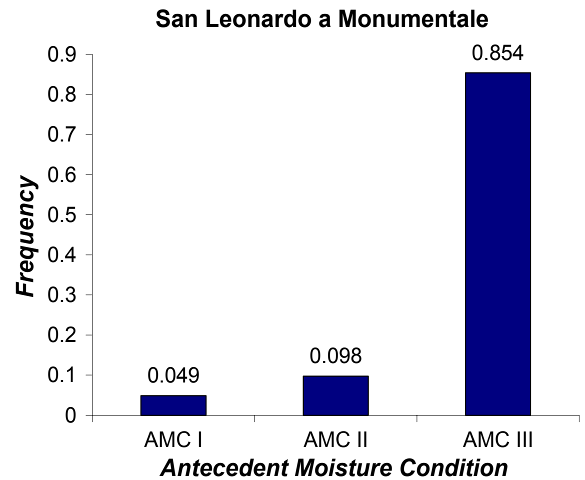
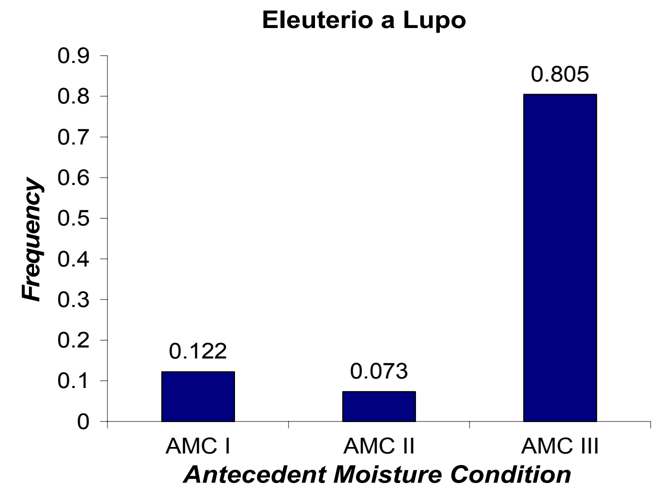
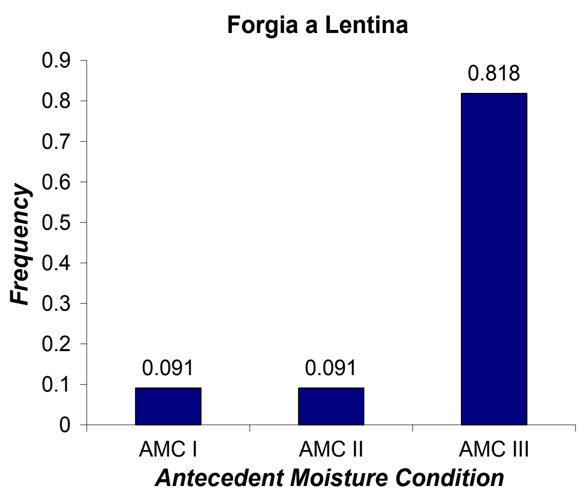
Case Study: Sicily

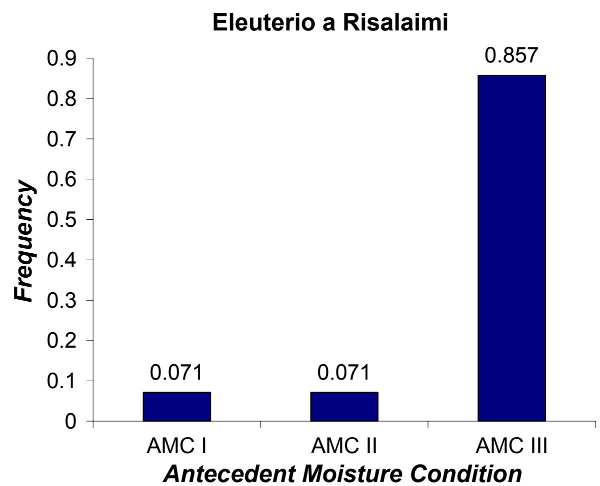
Annual maximum daily discharge

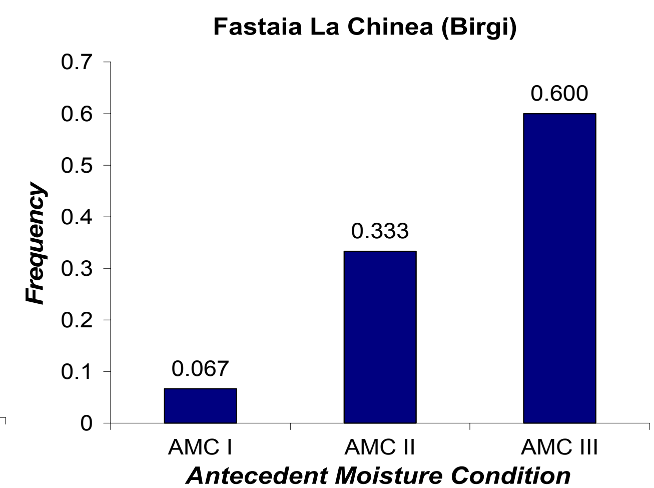












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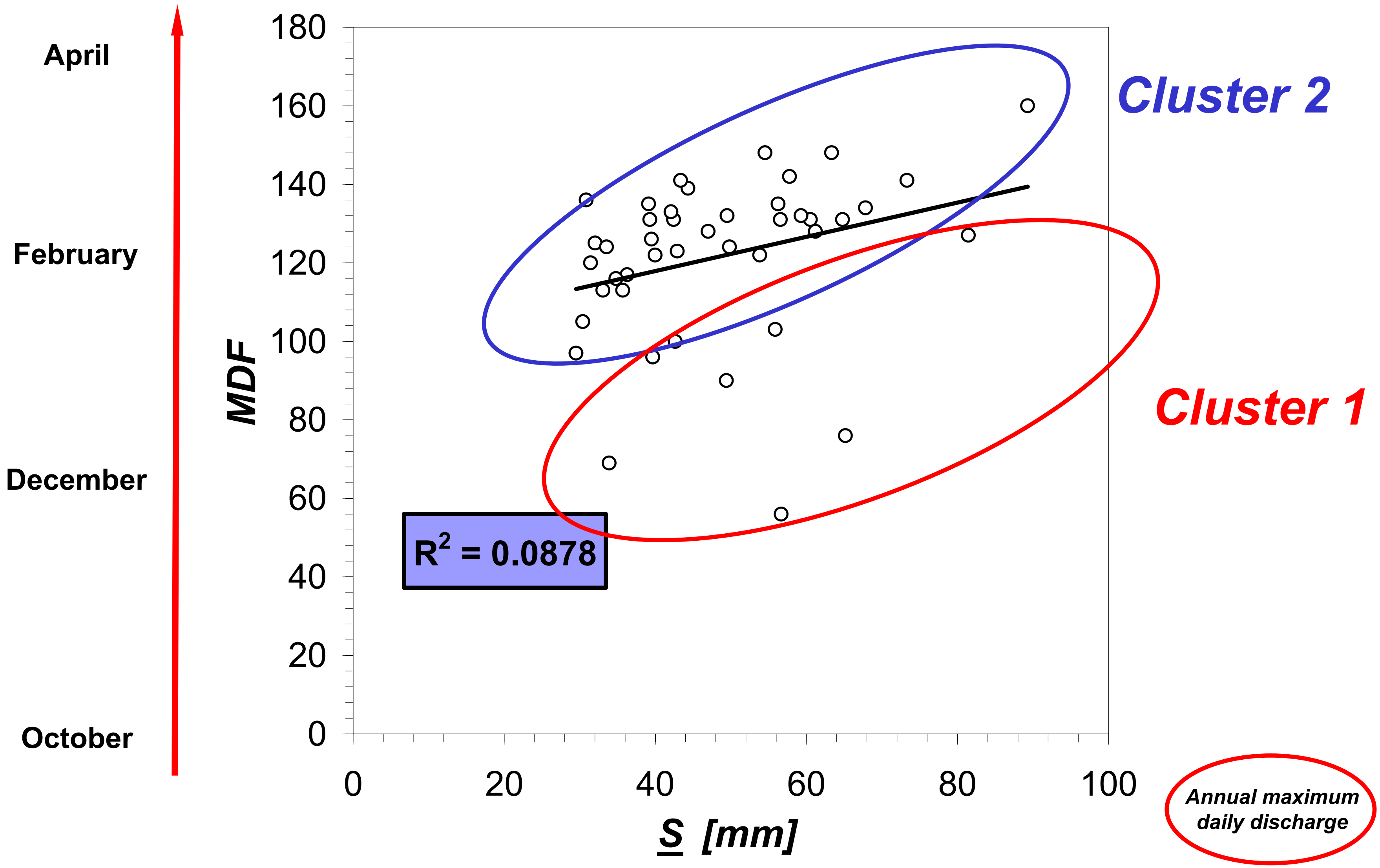

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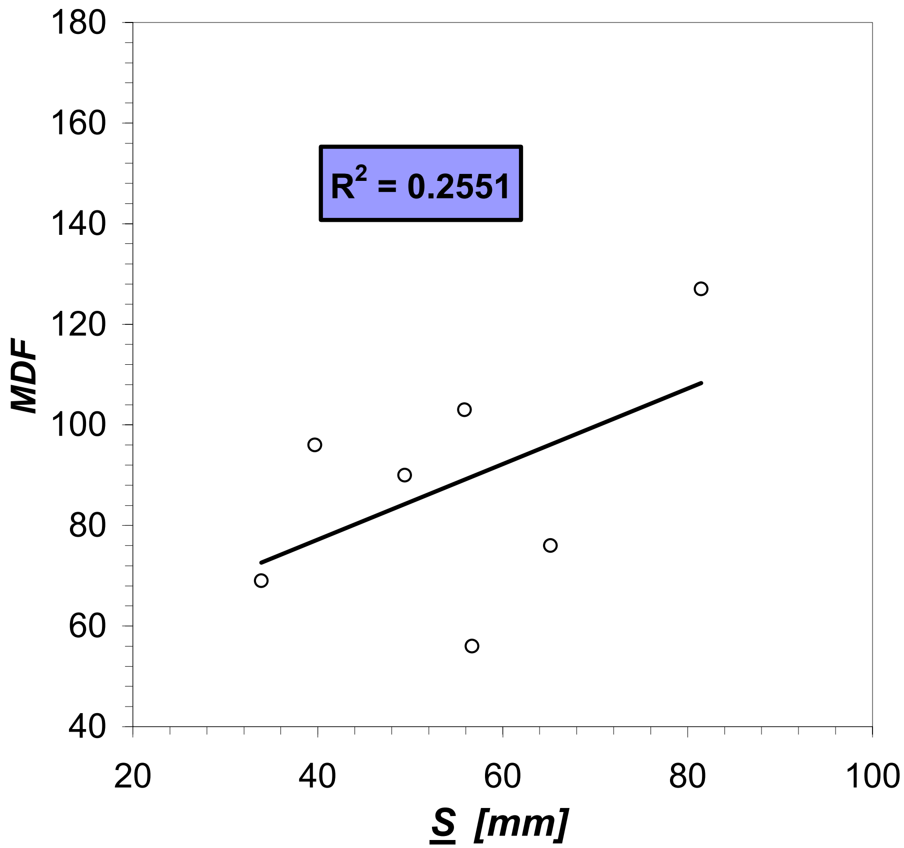
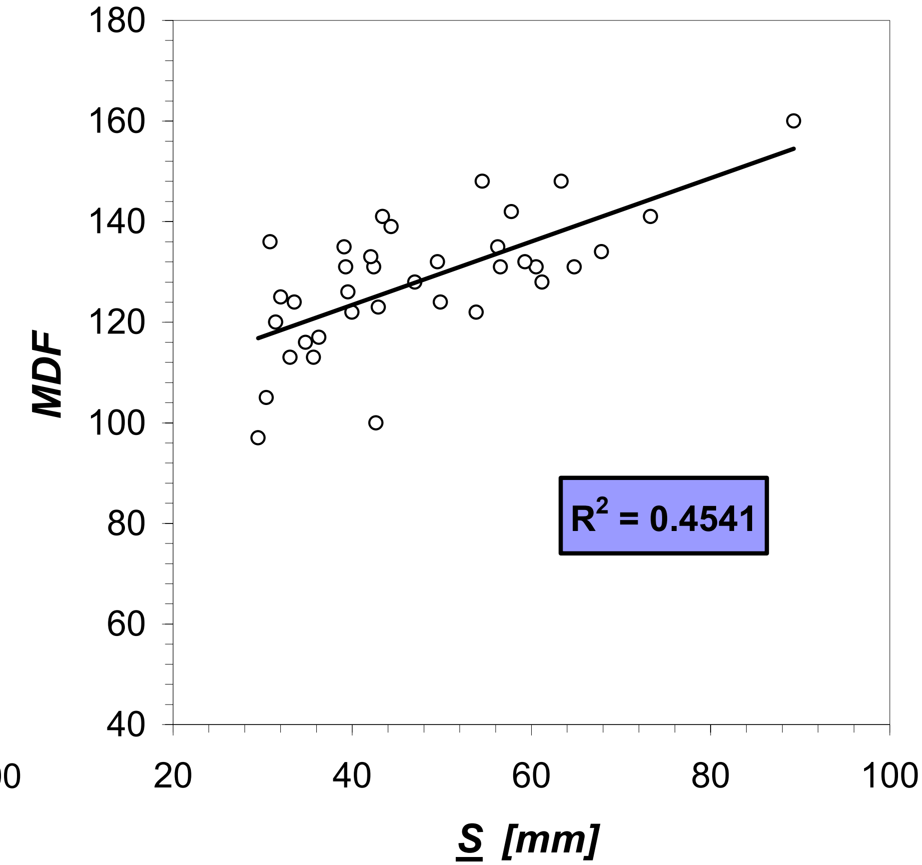
Case Study: Sicily

Cluster 1



Cluster 2



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Conclusions

- **In this study we analyzed interactions between climate, soil moisture and catchment characteristics to describe the flood regime in Sicily, Italy.**
- **In this context hydro-meteorological and hydrological indices capable of describing patterns of extremes events under different conditions has been preferred. The main advantage of this approach is that we use timing data, which practically are free-error and more robust than event magnitude data.**
- **We have shown that extreme rainfall event occur by average in Fall season, while maximum flood event occur mainly in late winter (88%).**
- **The timing of occurrence is correlated with the hydrological characteristics of catchment as the maximum potential retention and the antecedent moisture conditions**
- **A clear difference in flood regime was detected (cluster#1 e cluster#2)**

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