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RAINFALL TREND AND DROUGHT EVOLUTION IN SOUTHERN ITALY

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RAINFALL TREND AND DROUGHT EVOLUTION IN SOUTHERN ITALY

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Study area and data

Rainfall trends

Drought analyses

Conclusion

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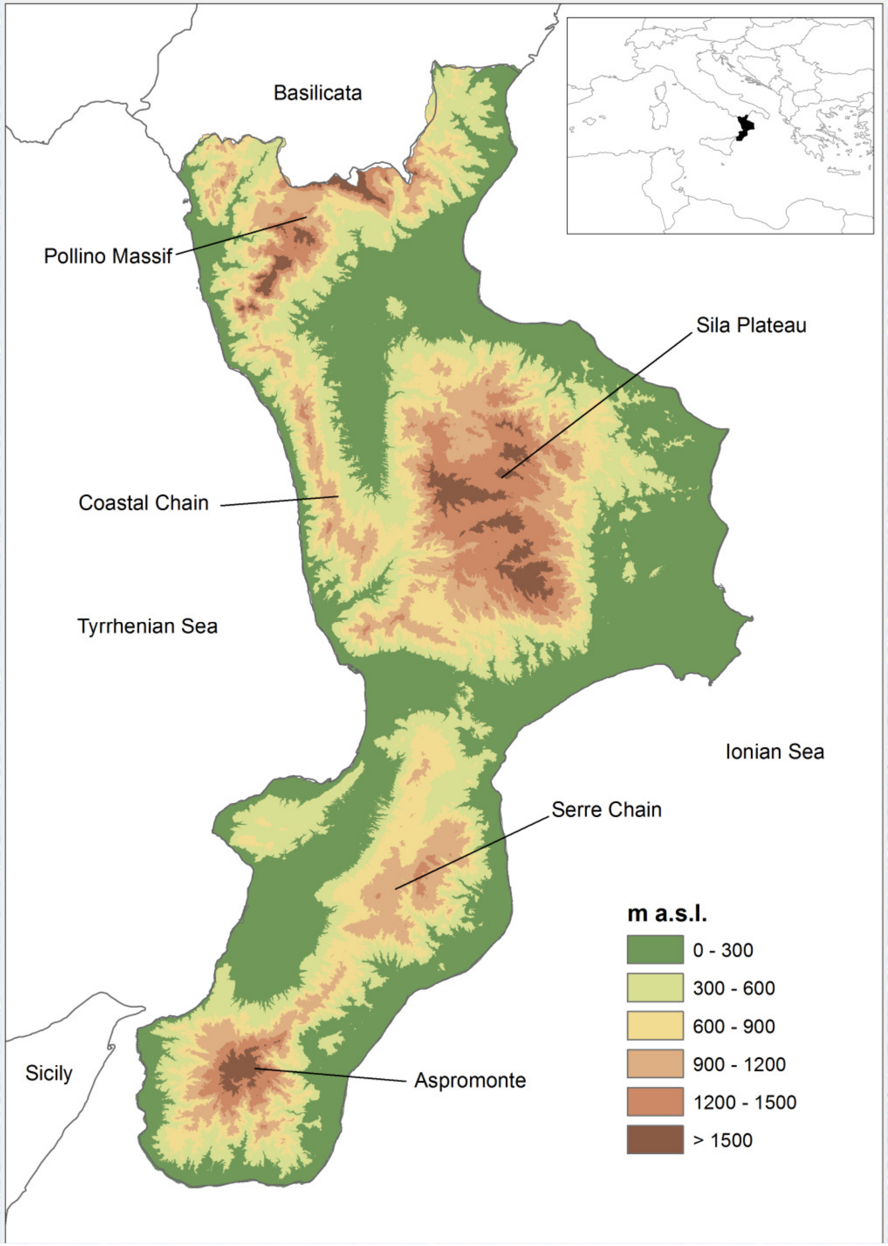


For its geographic position and for its mountainous nature, Calabria is a region with a high spatial variability of the climatic features and of the hydrological phenomena such as flood and drought.

The rainy events are mainly in autumn and winter (from October to March). The typical Mediterranean climate is present in the coastal zones with mild winters and hot summers (with few precipitation events). The Ionian side, which is affected by air masses coming from Africa, has high temperatures with short and heavy precipitation. On the contrary, the Tyrrhenian side is influenced by western air masses and presents milder temperatures and orographic precipitation.

In the inland zones there are colder winters (with snow) and fresher summers (with some precipitations).

Data quality test

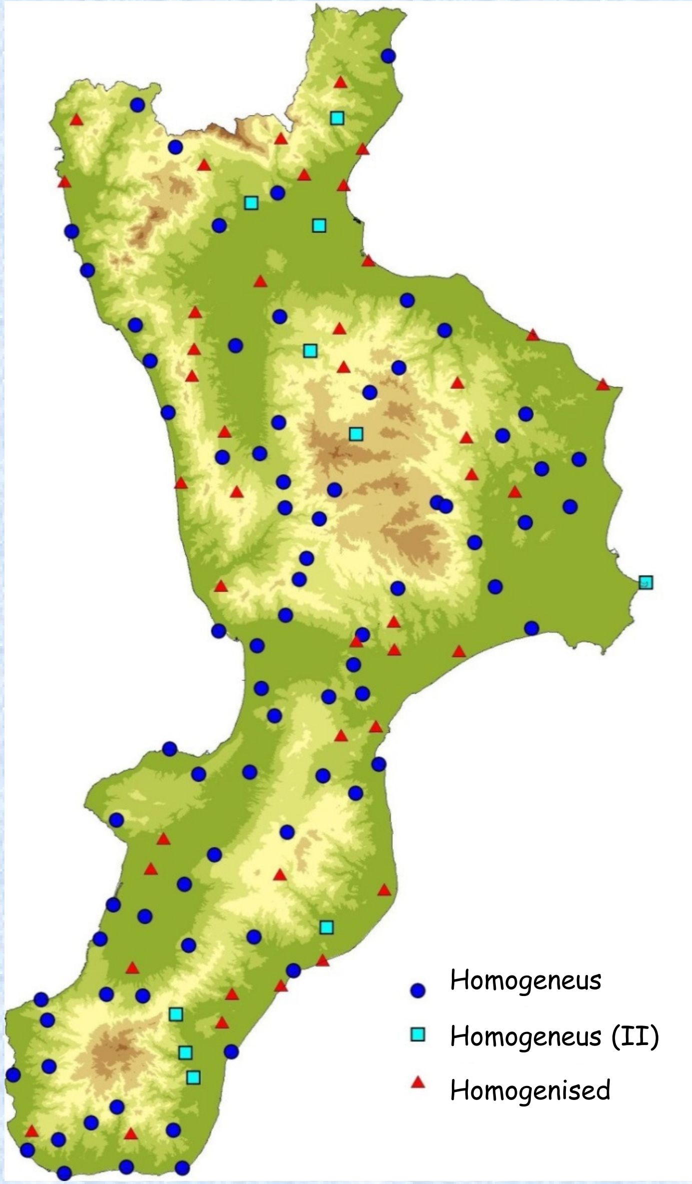
At the beginning, 197 daily rainfall series (period: 1916-2006;>50 years)

Craddock test to remove the inhomogeneities

At last, 129 homogeneous data series:

- 77 homogeneous series;
- 42 homogenised series;
- 10 homogeneous series (2nd level)

A method (Simolo *et al.*, 2010) for filling-in missing values

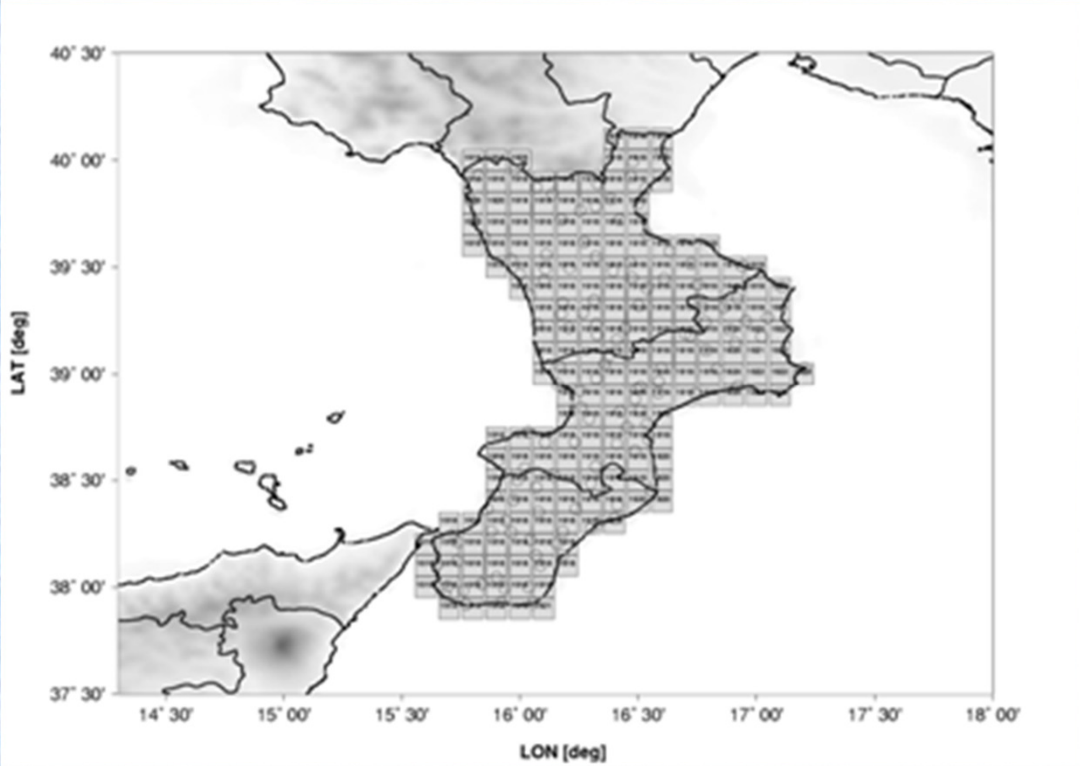


The dataset was analysed for trend, and significance assessed with the Mann–Kendall non-parametric test.

The rates of the trends were calculated by least square linear fitting.

The **trend results** were obtained through both at-site evaluations and interpolations onto a regular grid *(resolution equal to the mean interstation distance of the selected 129 rain gauges, about 8 km)*.

Before interpolating the station data on the grid cells, each series was converted into multiplicative **anomalies** normalising each monthly value by its average estimated over the **1961–1990 reference period**



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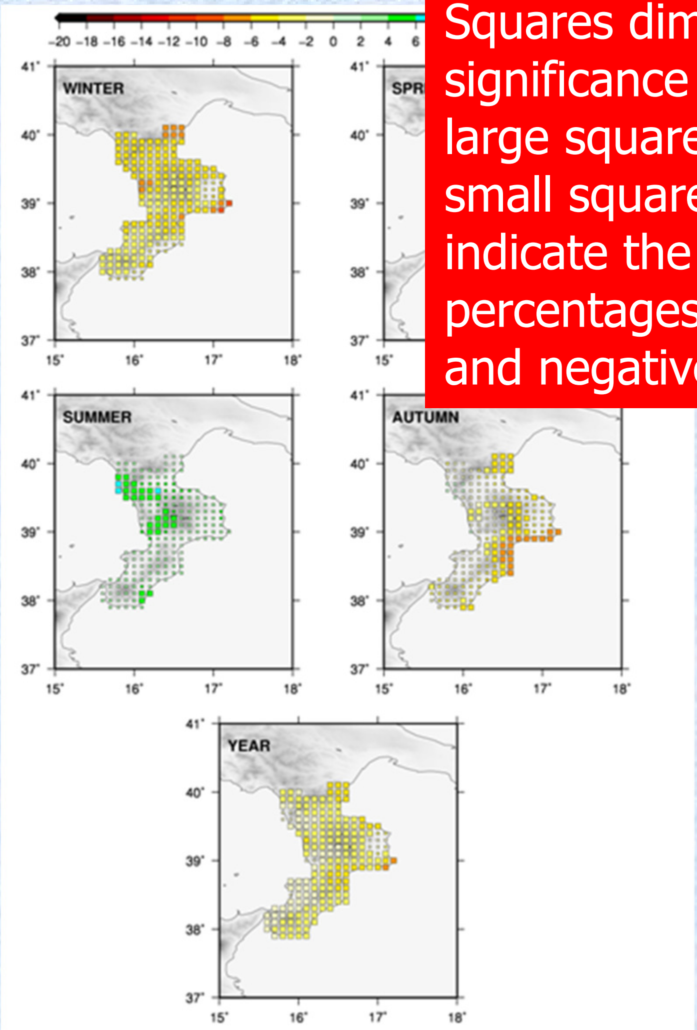
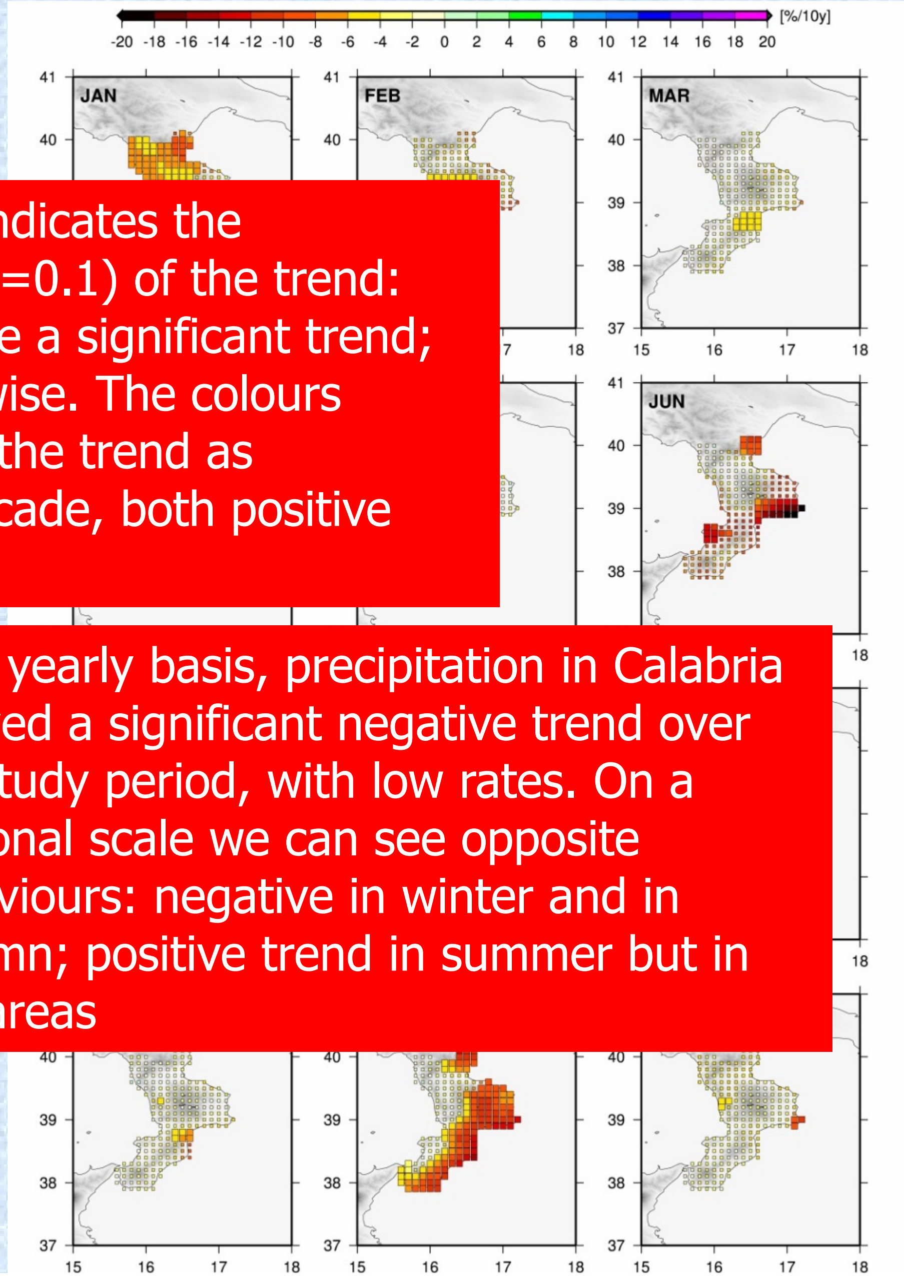
Results



Squares dimension indicates the significance level (SL=0.1) of the trend: large squares indicate a significant trend; small squares otherwise. The colours indicate the rates of the trend as percentages on a decade, both positive and negative



On a yearly basis, precipitation in Calabria showed a significant negative trend over the study period, with low rates. On a seasonal scale we can see opposite behaviours: negative in winter and in autumn; positive trend in summer but in few areas

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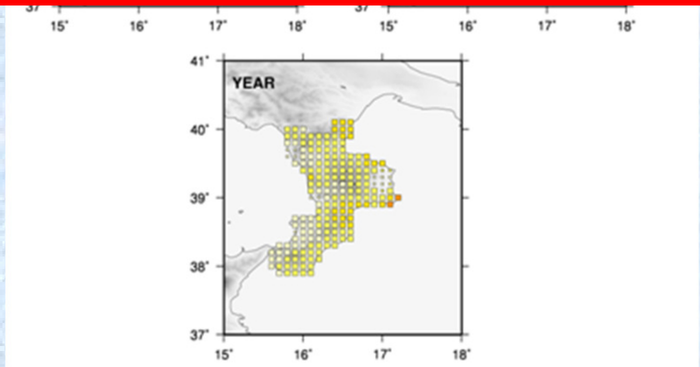
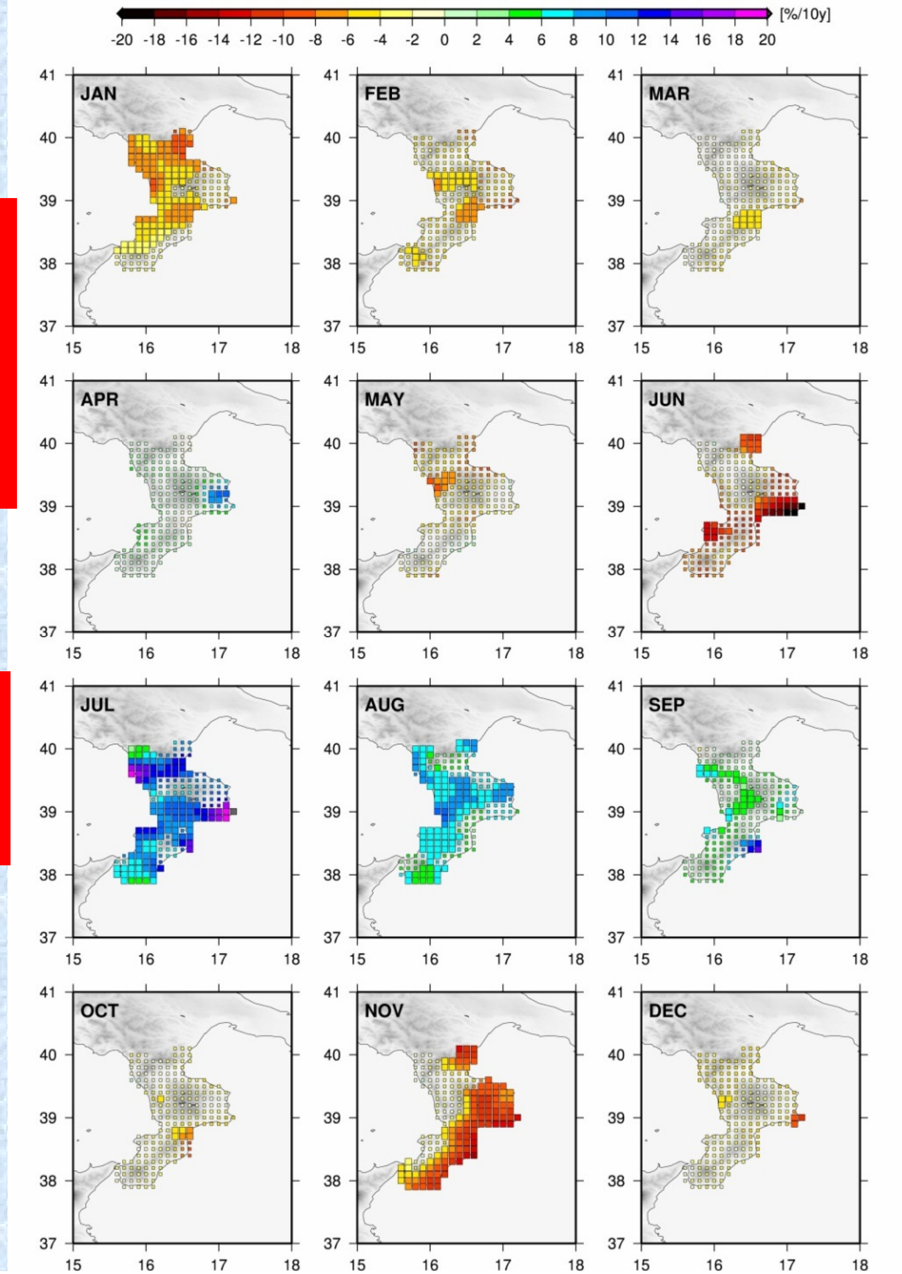
Results

A general negative trend, albeit not significant for the whole region, was detected, in particular for the autumn-winter months, with the largest trend rates in November (till to −10%/decade)

Summer months show a positive trend over the whole region (especially in July, with a rate till to +12%/decade)





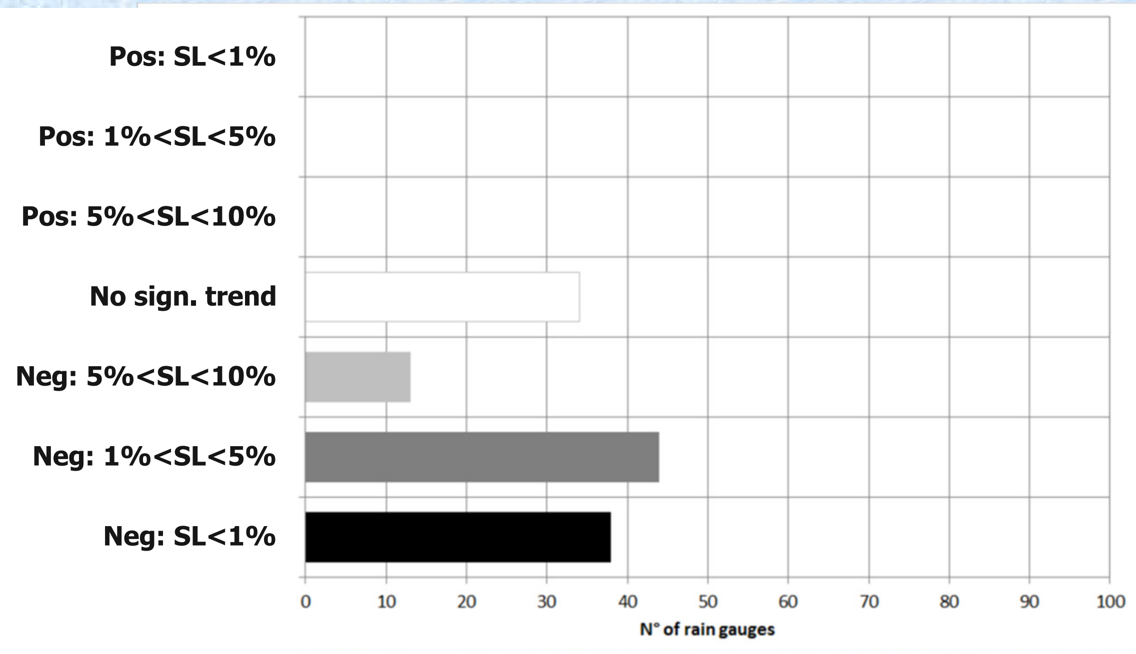
Results on seasonality of precipitation (PCI)

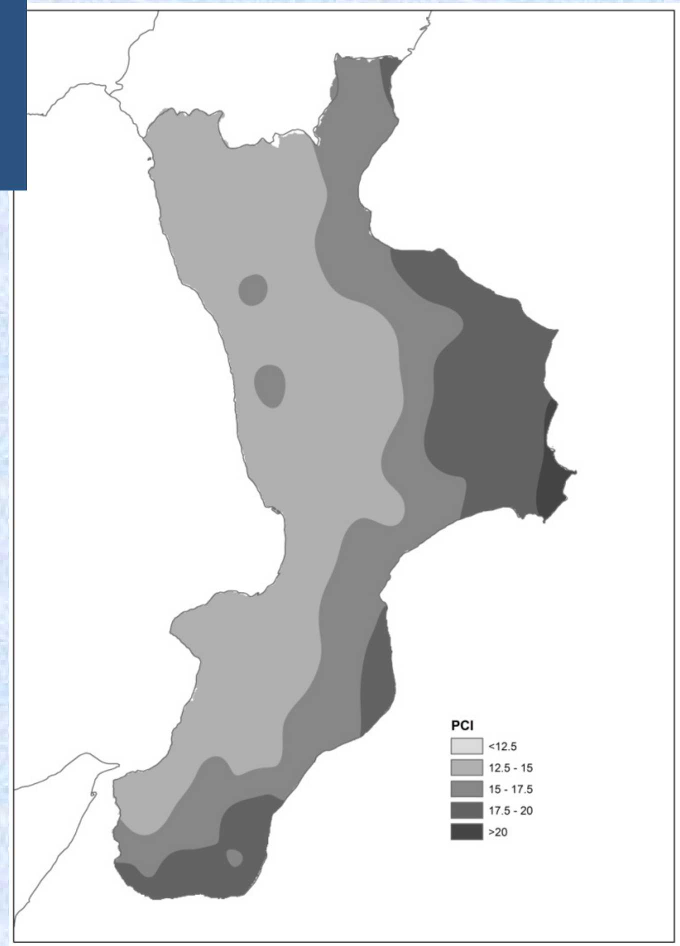
$$PCI = 100 \cdot \frac{\sum_{i=1}^{12} p_i^2}{\left(\sum_{i=1}^{12} p_i\right)^2}$$

< 10: uniform distribution

= 11-20: sesonality distribution

>20: high monthly variability





TREND ANALYSIS OF SHORT RAINFALL ANNUAL MAXIMA

Duration of hourly rainfalls	**1 h**	**3 h**	**6 h**	**12 h**	**24 h**
negative trend	10	11	12	11	15
No trend	49	48	47	48	44
% trend	*16.9*	*18.6*	*20.3*	*18.6*	*25.4*

The MK non-parametric test for trend detection has been applied to the 59 time series of annual rainfall maxima (till 2000; observation period >30 yrs). Results show a significant negative trend for about 20% of the time series and no positive trend at all.

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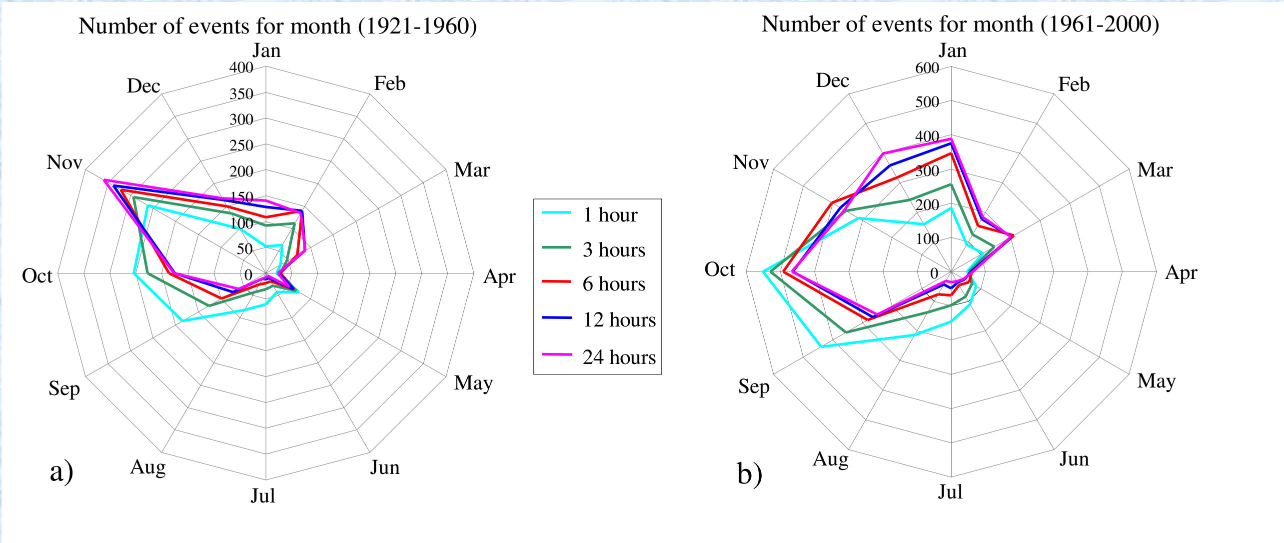


TREND ANALYSIS OF SHORT RAINFALL ANNUAL MAXIMA

A statistical analysis of the occurrence distribution of all the annual maximum values of short duration rainfalls (1, 3, 6, 12 and 24 hours) for the whole set of rain gauges has been performed, in order to point out possible temporal variation of the number of monthly occurrences during different decades. Results show that in the period 1921-1960 the maximum events were mainly located in November and with a lower frequency in October (figure a), while occurrence analysis in the period 1961-2000 shows an increased variability within months, with the most part of events located in October and a larger spread from September to January (figure b). In other terms, extreme rainfall events in the last decades of 20th century show a tendency to anticipate in early autumn, though with greater variability of dates spreading from late summer to early winter.

DROUGHT EVENTS

- Monthly scale: → Drought Indexes
- Daily scale: sequences of no rainy days («dry spell»)

DROUGHT EVENTS

- Monthly scale: → Drought Indexes
- **Daily scale: sequences of no rainy days («dry spell»)**

Main characteristics of the SPI

The SPI was designed to quantify the precipitation deficit for multiple time scales

These time scales reflect the impact of drought on the availability of the different water resources

Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, streamflow, and reservoir storage reflect the longer-term precipitation anomalies

For these reasons, McKee et al. (1993) originally calculated the SPI for 3-, 6-,12-, 24-, and 48-month time scales.

SPI	Classification
2.00 >	Extremely wet
1.50 to 1.99	Very wet
1.00 to 1.49	Moderately wet
0 to 0.99	Mildly wet
0 to -0.99	Mild drought
-1 to -1.49	Moderate drought
-1.50 to -1.99	Severe drought
-2.00 <	Extreme drought

Advantages:

minimal data requirements (only monthly precipitation data) simple and quick

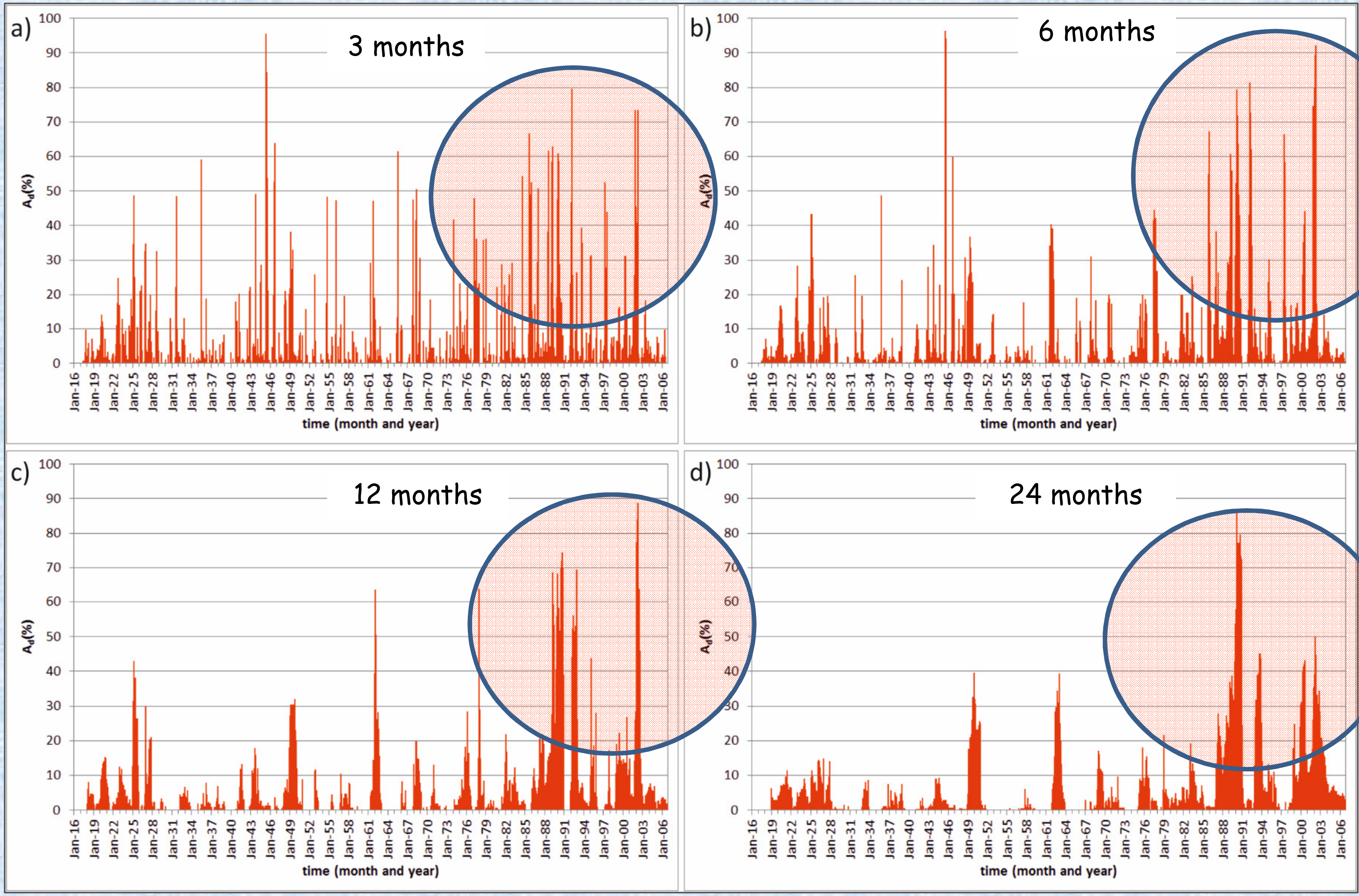
can be calculated for varying time scales

can provide early warning of drought

can answer such questions as; when, how long, and how severe a drought is.

can help assess drought severity

Areas (Ad) - as % of the regional territory – vs. time in severe/extreme dry (SPI<-1.5) conditions



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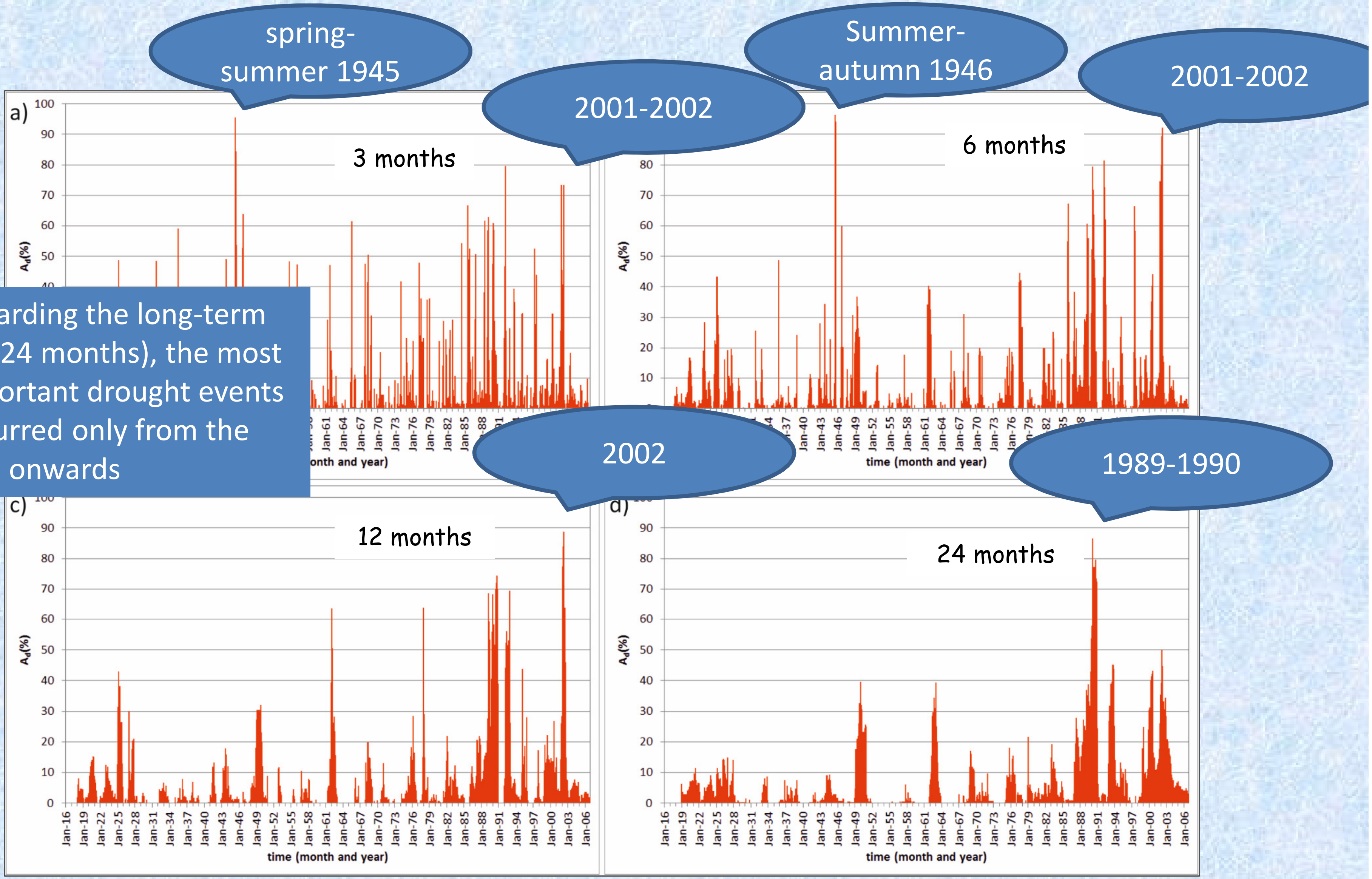
Regarding the long-term (12-24 months), the most important drought events occurred only from the '80s onwards



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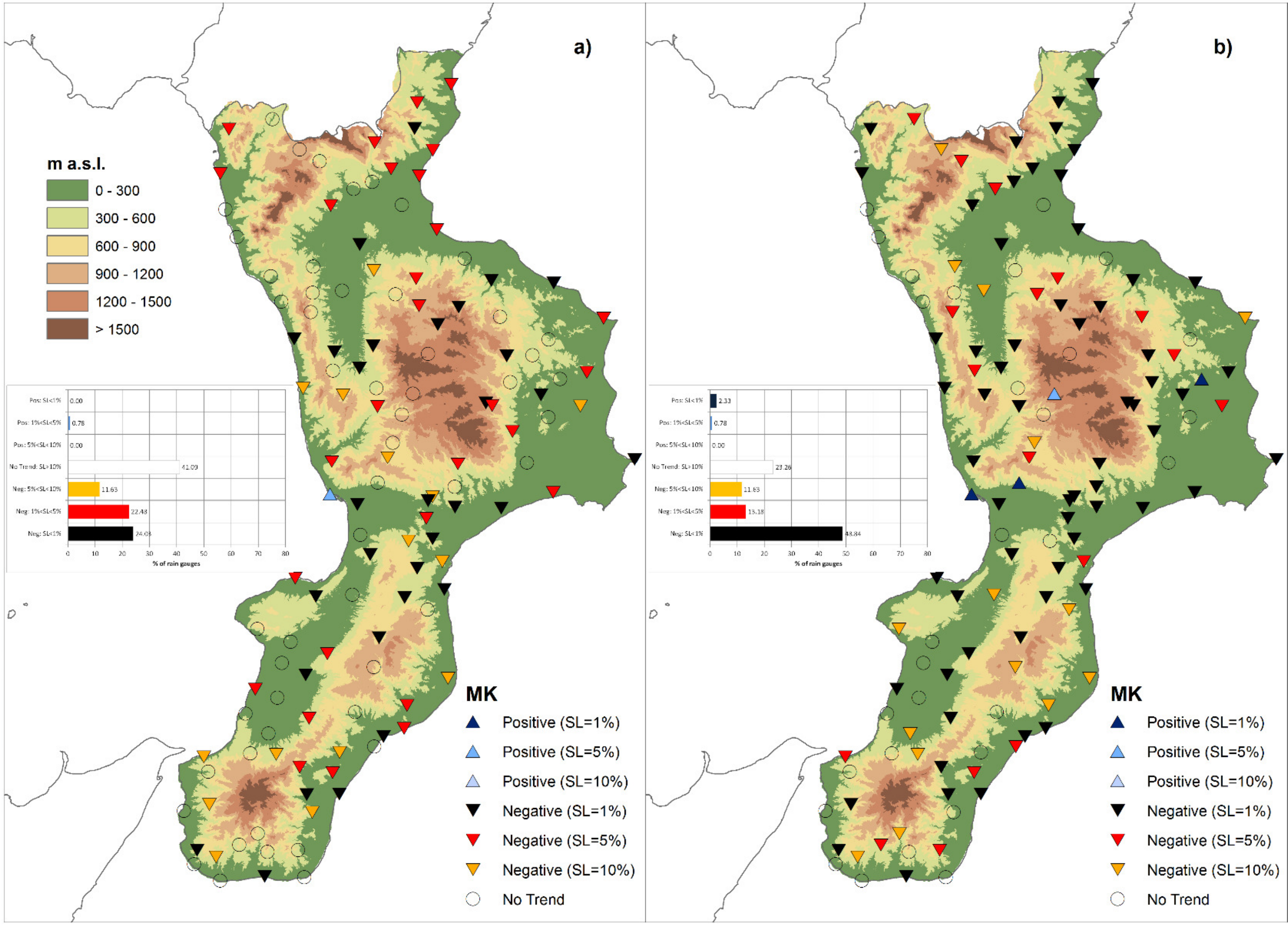

SPI trend

The MK test was applied with the aim to evaluate the long time evolution using the 12-SPI (a) and 24-SPI (b) values relative to December of each year. Three different SLs were considered 0,10 - 0,05 - 0,01

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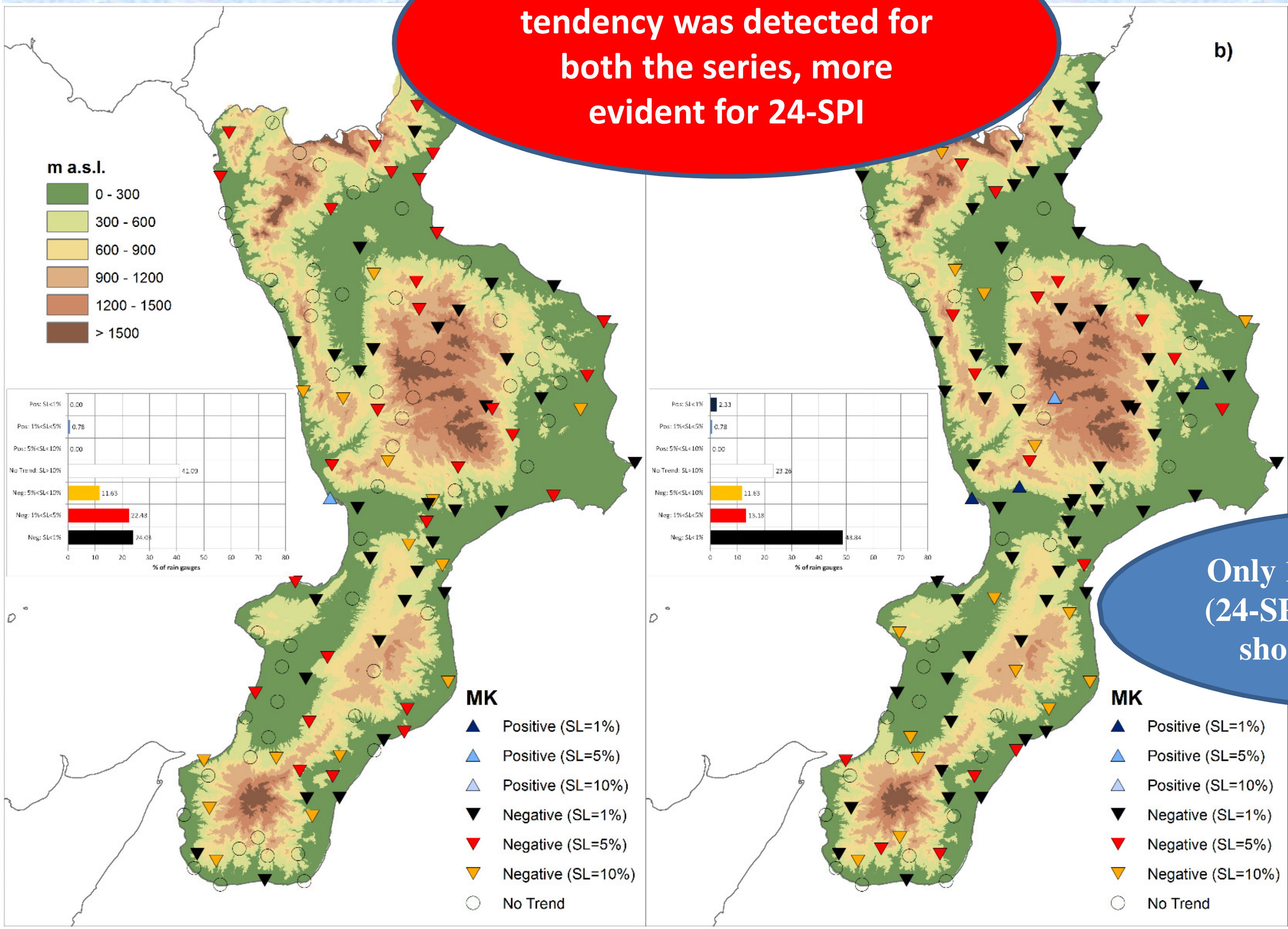
SPI trend

A general negative tendency was detected for both the series, more evident for 24-SPI



Only 1% (12-SPI) and 3% (24-SPI) of the rain gauges show a positive trend

DROUGHT EVENTS

- Monthly scale: drought indexes

- Daily scale: sequences of no rainy days («dry spell»)

Dry spell (DS)

A dry spell is defined as the number of consecutive days with a daily precipitation amount below a certain threshold:

- 0,1 mm/day: minimum value of daily rainfall registered by a rain gauge;
- 1,0 mm/day: for the evapotranspiration processes
- 5,0 mm/day: for superficial flow;
- 10,0 mm/day: for saturation processes of the superficial soil layers

Dry spell

To evaluate:

- The day number of dry spells (NDS);
- Their maximum lengths (MLDS);
- Their mean length (MDS).

On yearly, seasonal, 6-months scale

Limits:

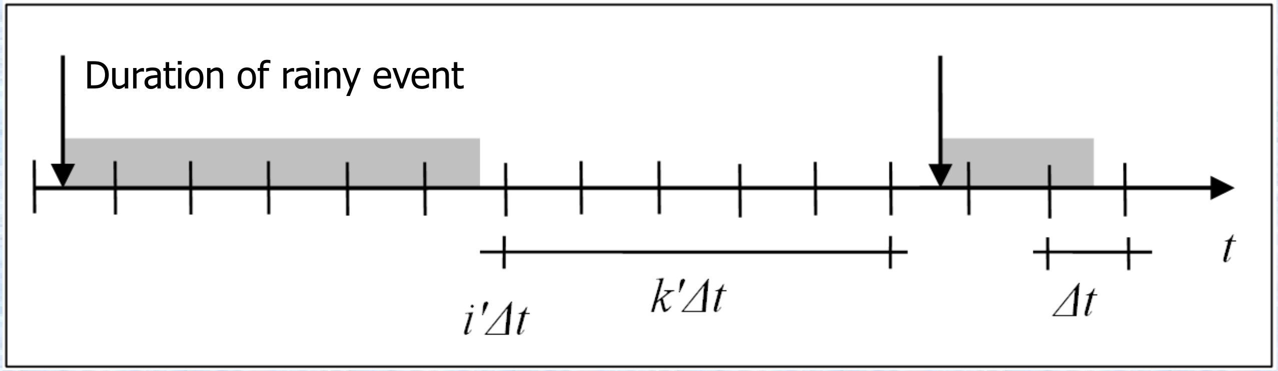
- A severe control on quality and low presence of missing data;
- the probabilistic structure of dry periods, especially with a long duration, cannot be properly investigated, due to the limited number of events in the historical series.

The proposed stochastic model for DSs

We assumed that the temporal occurrence of rainy events can be described through a non-homogeneous Poisson process, characterized by a time-dependent intensity λ

The temporal variation of the intensity parameter λ(t) can be statistically developed through a truncated Fourier series, normally expressed as a function of period D (average length of the year)

$$\lambda(t) = \frac{1}{2}a_0 + \sum_{j=1}^{n_h}\left[a_j \cos\left(\frac{2\pi j}{D}t\right) + b_j \sin\left(\frac{2\pi j}{D}t\right)\right]$$



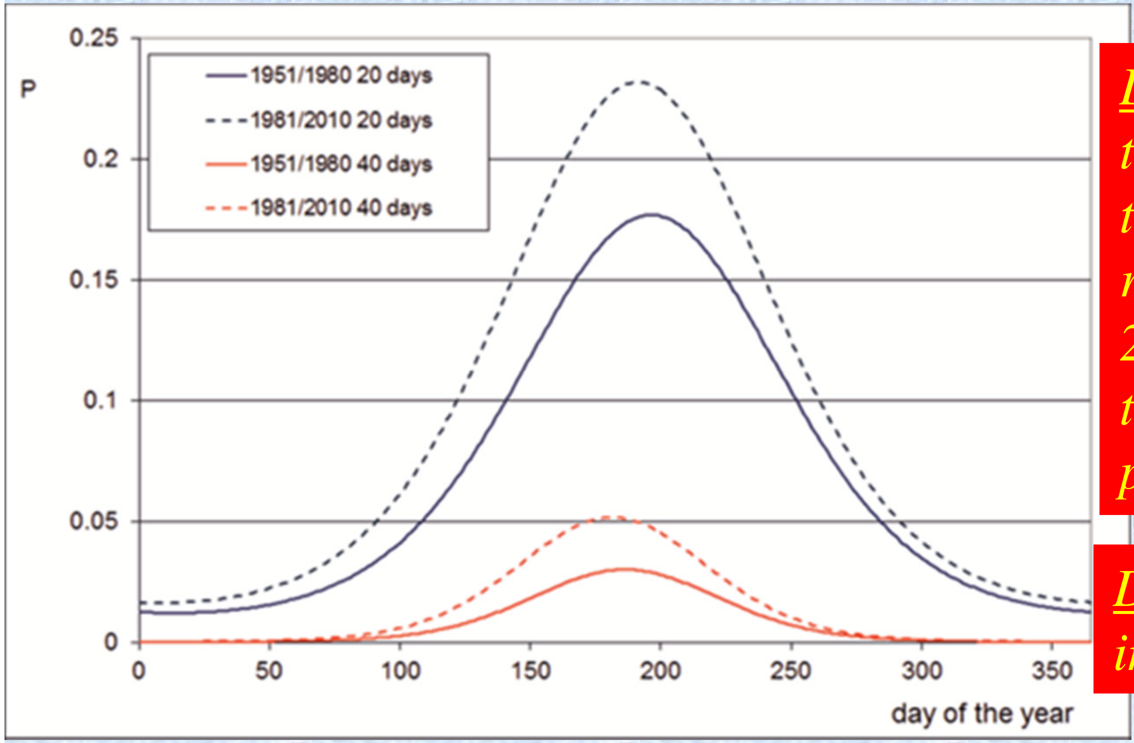
Referring to the above figure, PDF estimating the probability that in a generic instant i'Δt a sequence of consecutive intervals of length Δt (equal to 1 day), without any arrival of rainfall events, followed by at least one rainy day, can start, is:

$$p_{K'|K'\geq k'_*}(k') = \left[1-\exp\left(-\Delta\Lambda_{i'+k',i'+k'+1}\right)\right]\exp\left[-\Delta\Lambda_{i'+k'_*,i'+k'}\right]$$

Then, it is possible to estimate the CDF, the mean and the variance

For the procedures for estimating the parameters and the number of harmonics, see: *Sirangelo B., Caloiero T., Coscarelli R., Ferrari E. (2015) - A stochastic model for the analysis of the temporal change of dry spells - Stoch. Environ. Res. Risk. Assess. Vol. 29*

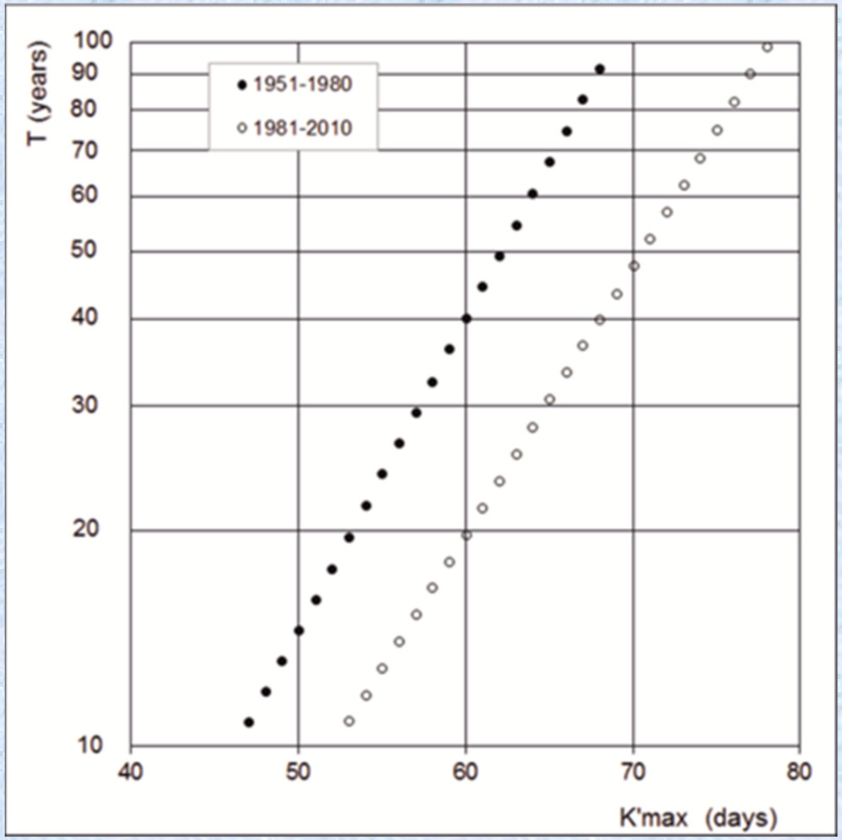
By means of the stochastic model, several thousands of series were generated (Monte Carlo procedure) starting from the daily data of two sub-periods (1951-80 and 1981-2010) relative to some rain gauges of Calabria (Southern Italy). For each day of the year, the occurrence probability to have dry spell with lengths equal or greater than 20 days and 40 days was estimated *(in fig., the results relative to the Cosenza rain gauge).*



Dry spell lengths ≥ 20 days:
the probability values evaluated by the synthetic data generated from the real data of the sub-period 1981-2010 increase up to about 33% than those relative to the previous sub-period

Dry spell lenghts ≥ 40 days:
increases up to about 70%

The return periods (T) to have dry spells with high length values (K'_{max}) were estimated from the yearly maximum values of the synthetic data, separately generated for the two sub-periods *(in figure and table, the results relative to the Cosenza rain gauge)*



K'_{max}	$T_{1951-1980}$	$T_{1981-2010}$
53	20	11
54	22	12
55	24	13
56	27	14
57	29	15
58	33	17
59	36	18
60	40	20
61	45	22
62	49	24
63	55	26
64	61	28
65	67	31
66	75	34
67	83	37
68	92	40

- 46%

- 50%

- 56%

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By coupling the precipitation concentration analysis with the trend detection, it has been possible to assess that the shift towards a more uniform climate regime during the year is determined by a generalized reduction in precipitation during the winter months and an increase in the summer ones.

Despite the general decrease in precipitation amount, these studies did not show the paradoxical increase in extreme rainfall as evidenced by other Authors in different study areas.

Relatively to drought phenomena, the increase of their frequency was detected both on monthly and daily scale.

The decrease of the return period of long dry-spells could have serious implications on water resources management and agricultural/environmental planning.

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