Trends in hydrologic time series and the climate change. Some of the Portuguese experience

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1. Background
2. Models applied
3. Results
4. Final remarks

…. background

- ✓ Nowadays it is often mentioned that the Earth is already suffering the **climate change** effects: it is no longer a matter of future climate scenarios but instead of **frequent abnormal climate occurrences.**

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- But … if changes are already happening then they should be **embedded** in some of the **hydrologic time series**, with emphasis to those series more closely related to the weather, as the **rainfall series**.

- **In the previous scope some studies were carried out aiming at identifying trends in long Portuguese hydrologic time series and at relating such trends with the climate change issue.**

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- But … if changes are already happening than they should be **embedded** in some of the **hydrologic time series**, with emphasis to those series more closely related to the weather, as the **rainfall series**.

- carried out aiming at **identifying trends in long Portuguese hydrologic time series** and at **relating such trends with the climate change issue**.

- **In this communication some of the models applied as well as some of the results thus achieved are briefly mentioned.**

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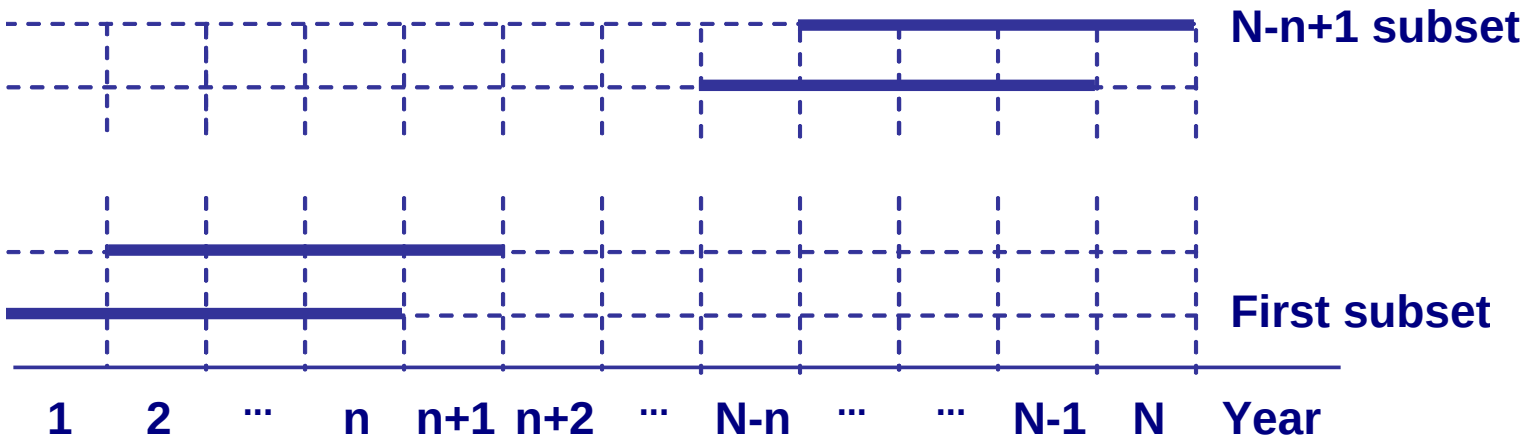
- ✓ … essentially … aimed to detect trends significant from a statistical point of view ⟺ models of statistical nature.
- ✓ The most frequent one … **moving average technique**.
- ✓ **For an annual series with length N, the moving average with length n is formed by the averages over the N-n+1 subsets of n consecutive years each into which the original series is split (with N> n).**



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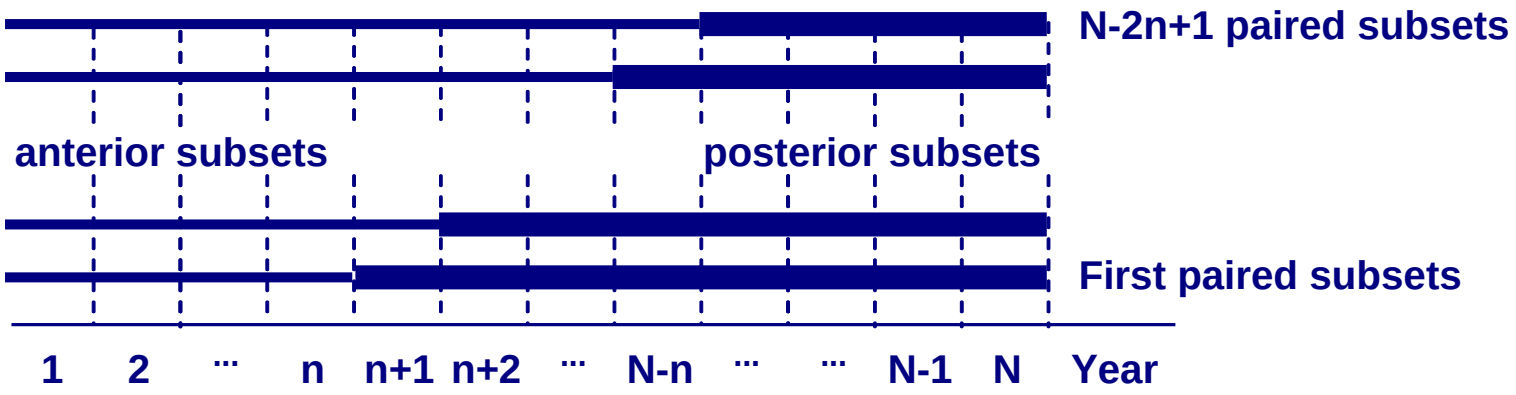
- **Each time series with length N was split into two series, one built upon the first n elements – anterior subset – and the other built upon the last N - n elements – posterior subset.**



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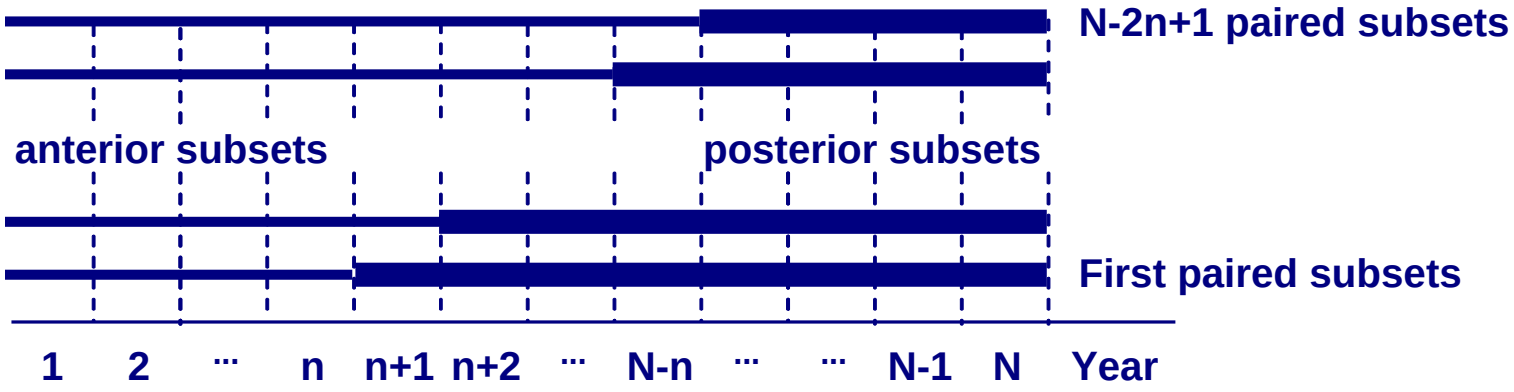

- The **averages** of each two of such subsets were **compared in statistical terms**, by applying the **Student parametric test** and the **Mann-Whitney nonparametric test**.

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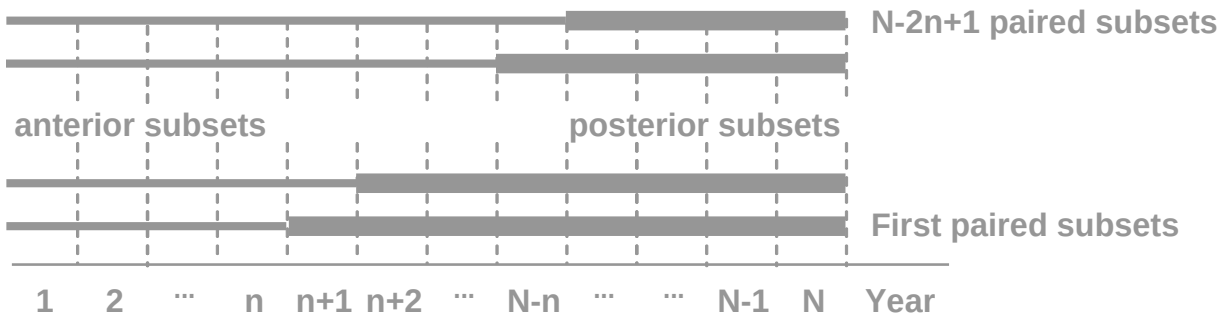
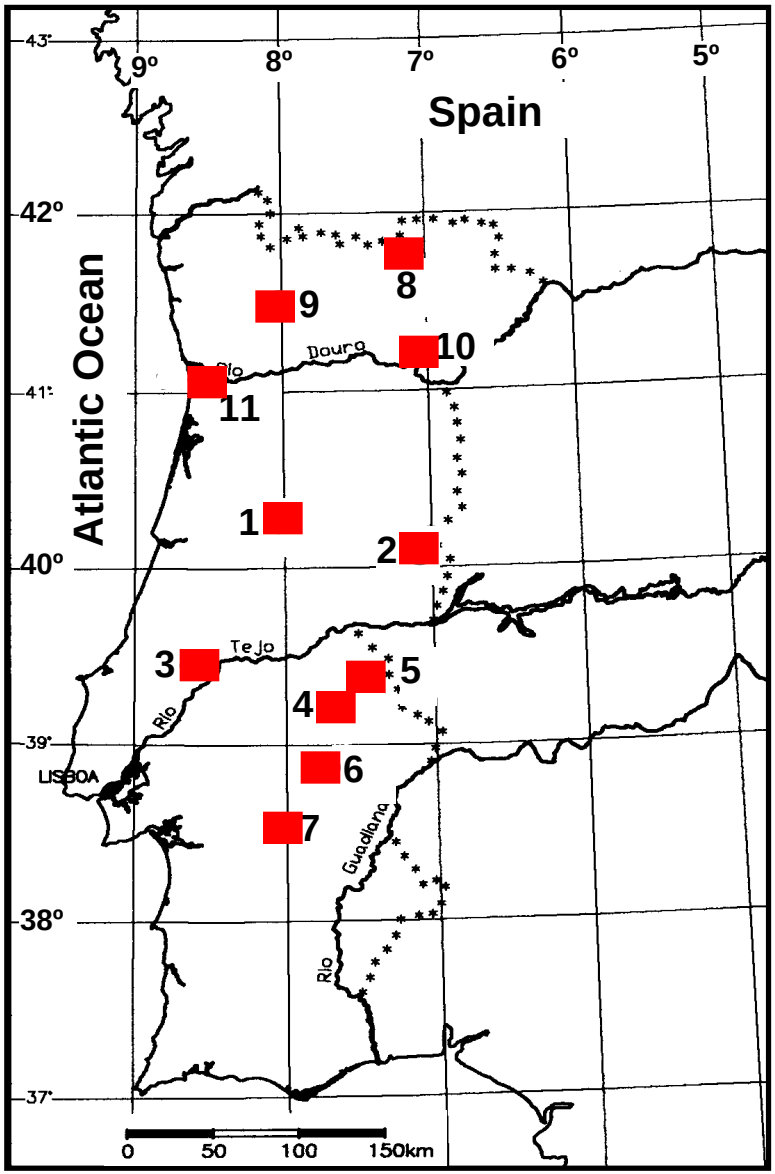


- The **averages** of each two of such subsets were **compared in statistical terms**, by applying the **Student parametric test** and the **Mann-Whitney nonparametric test**.

- **A trend** occurs whenever the **two averages** under comparison are **persistently different** (… in statistical terms).

… results



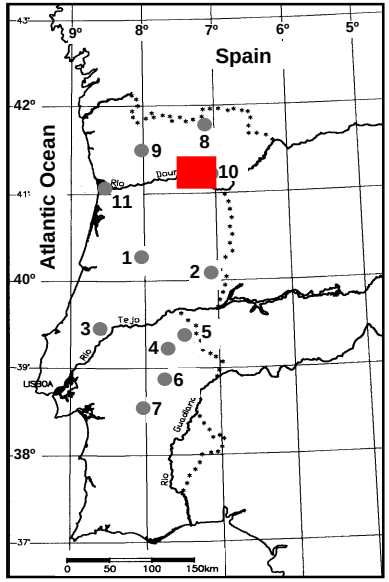
First set of results (2001)

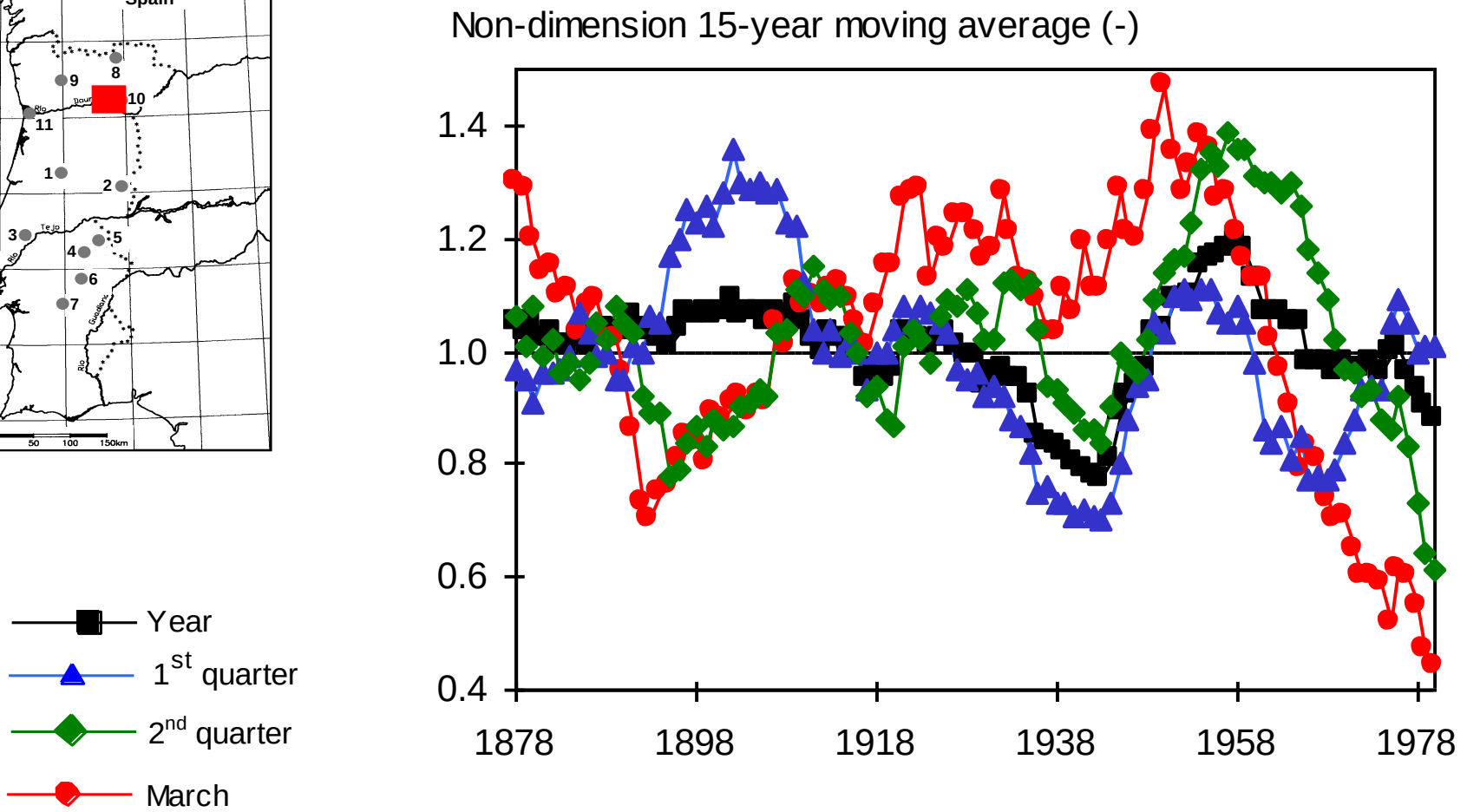
Trend detection in rainfall series in 11 Portuguese rain gages

Annual and monthly series and series in the first and in the second quarters of the hydrologic year (in Portugal, from October 1st to September 30th)

… first set of results

10 – Torre de Moncorvo (1878/79 - 1994/95)





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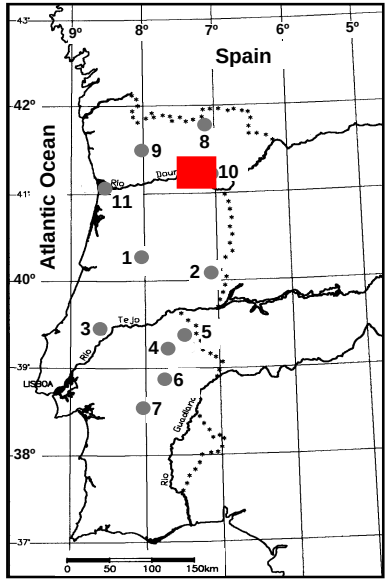

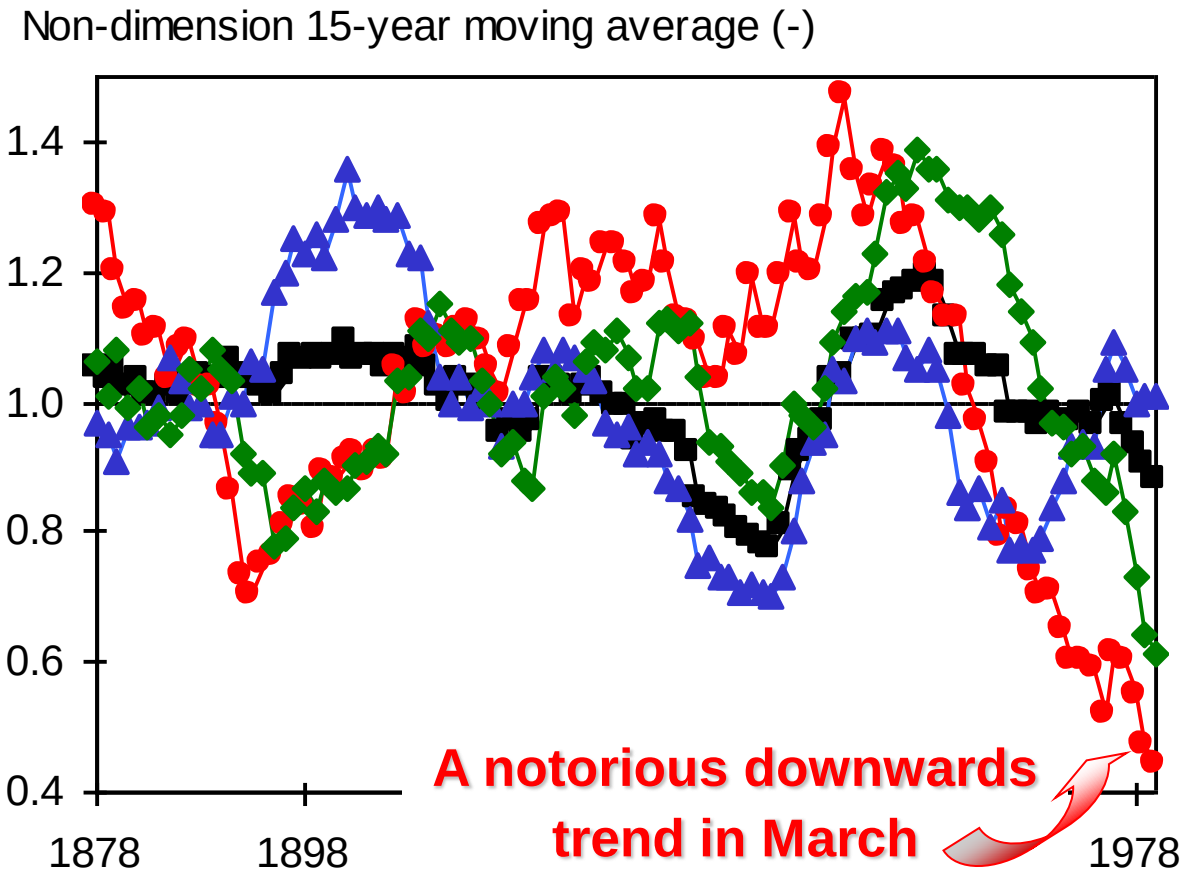

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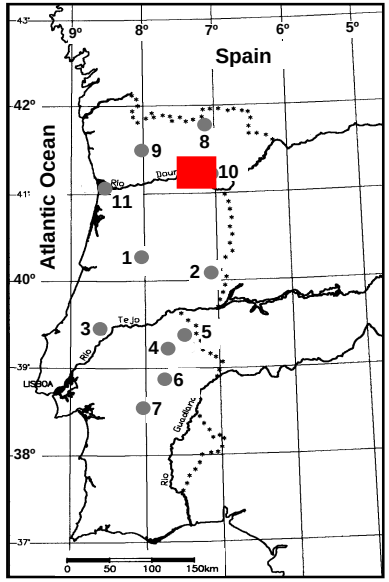
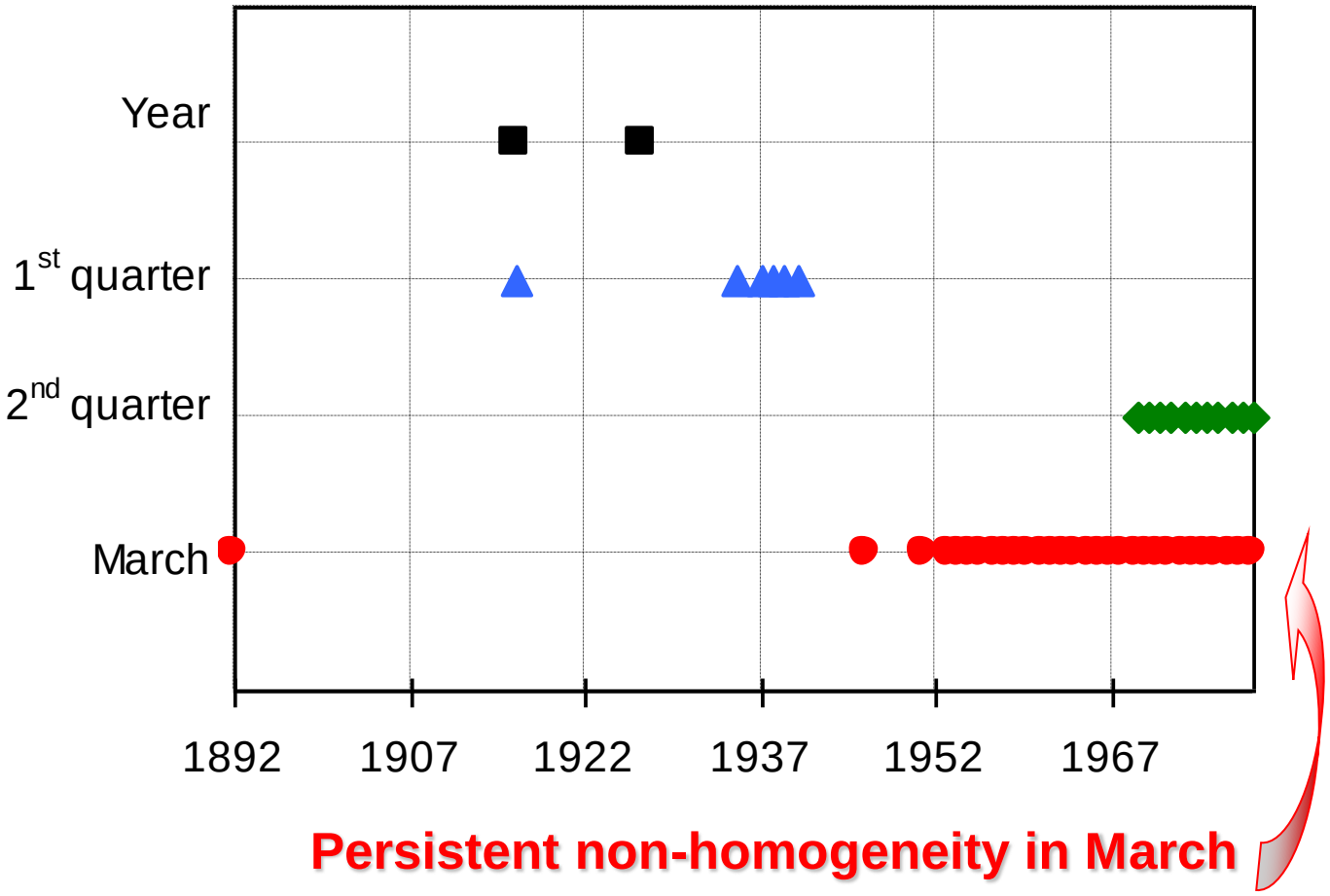
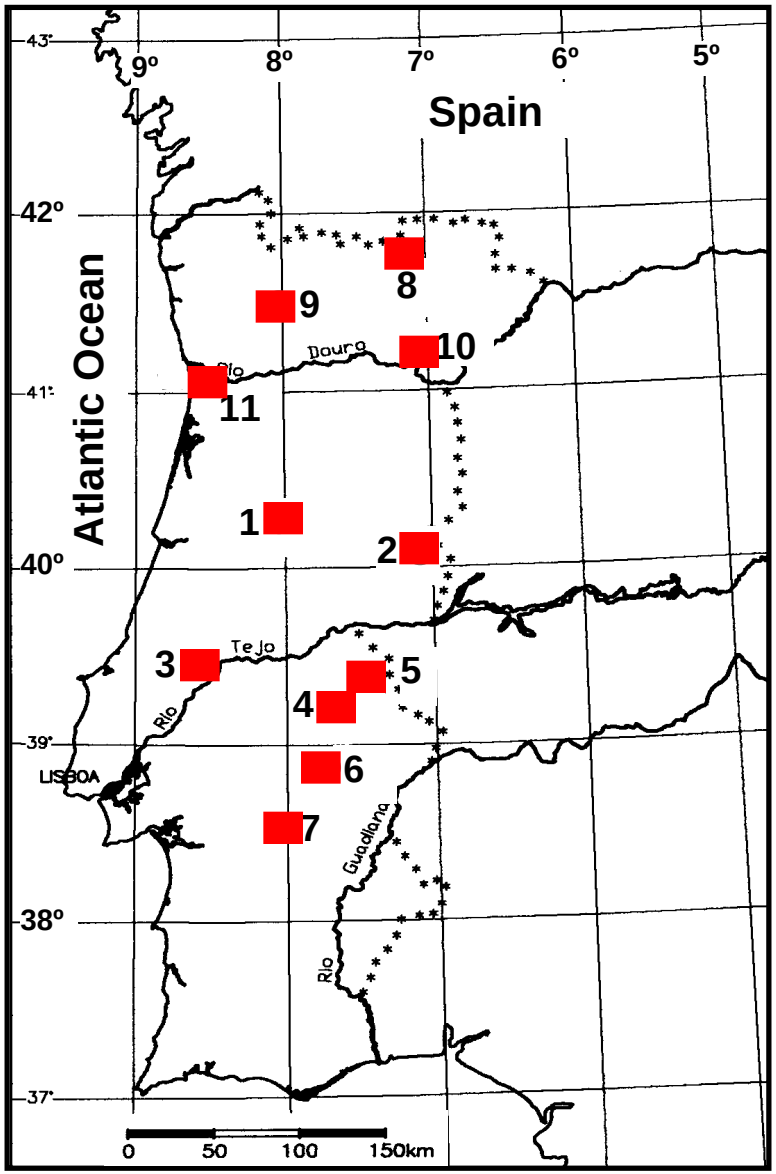




Year
1st quarter
2nd quarter
March

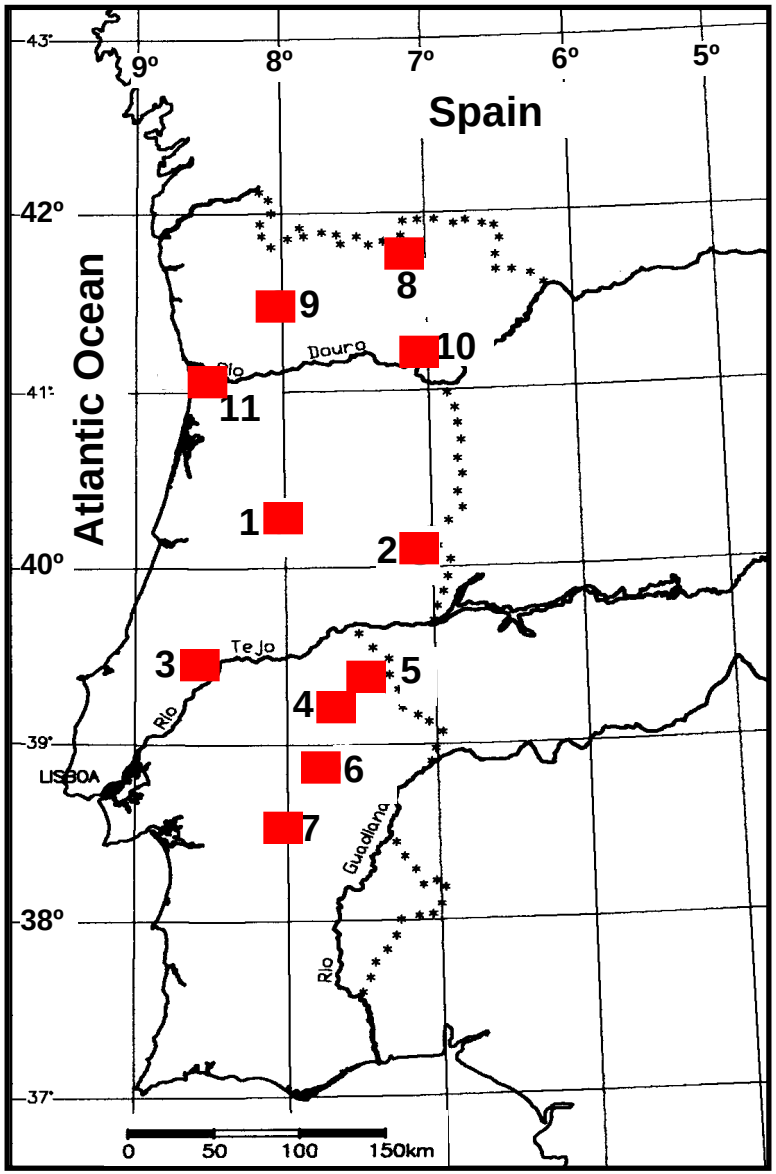
Persistent non-homogeneity in March denoting a trend (… downwards)

… first set of results



- ✓ **The 11 rain gages exhibit a notorious decrease of the rainfall in March.**

… first set of results



- ✓ The 11 rain gages exhibit a notorious decrease of the rainfall in March.
- ✓ In annual terms, the last periods of 15 years were often slightly drier then the total recording periods.

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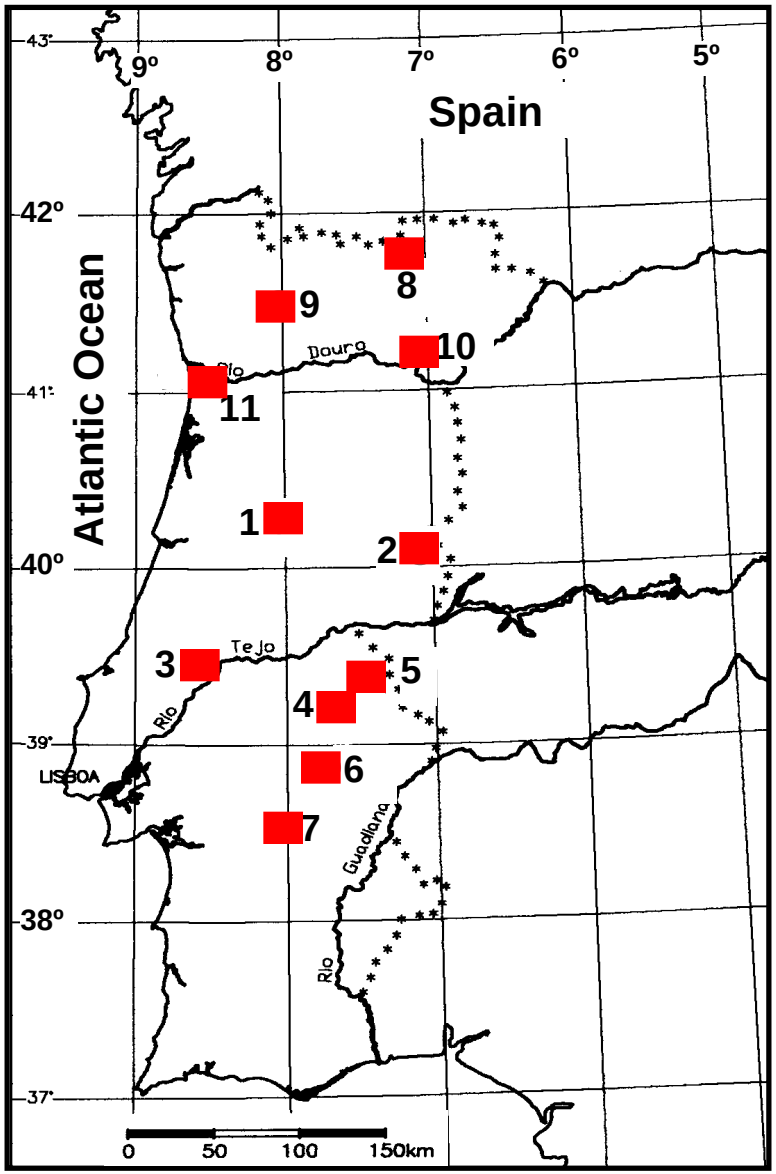
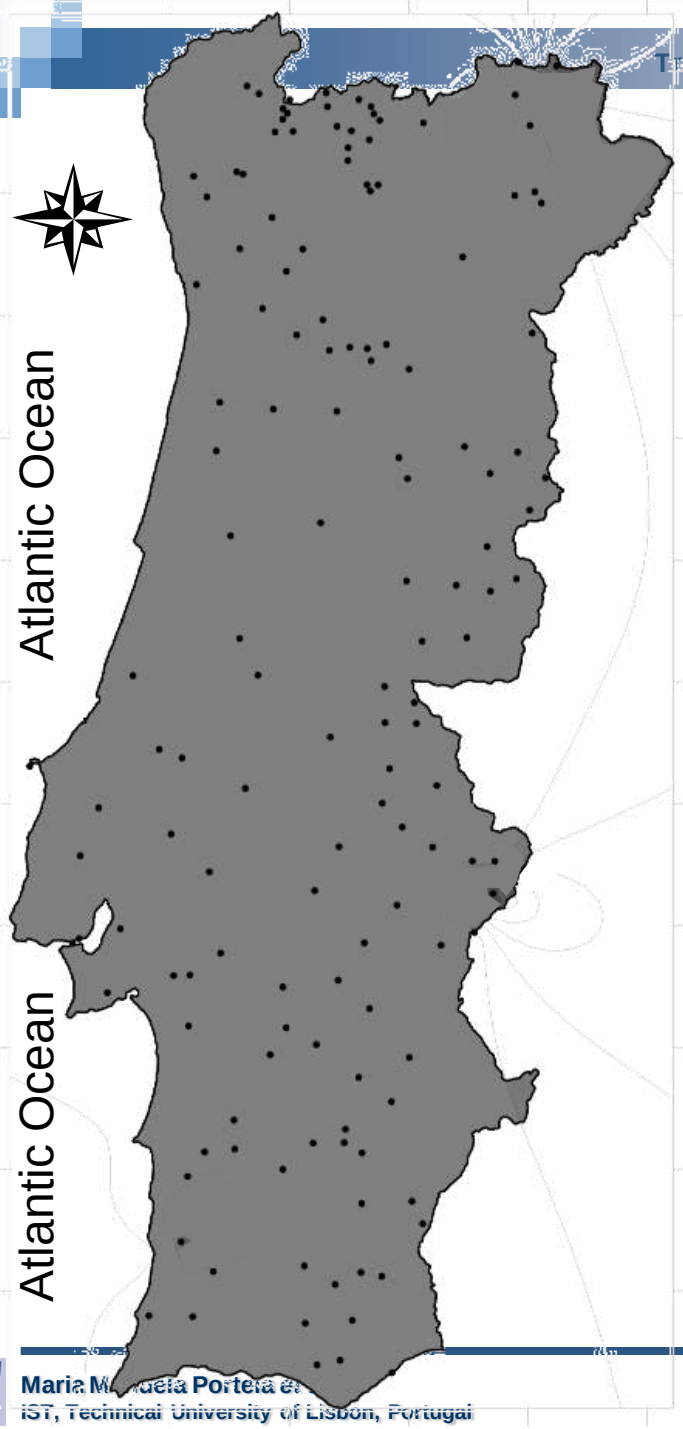


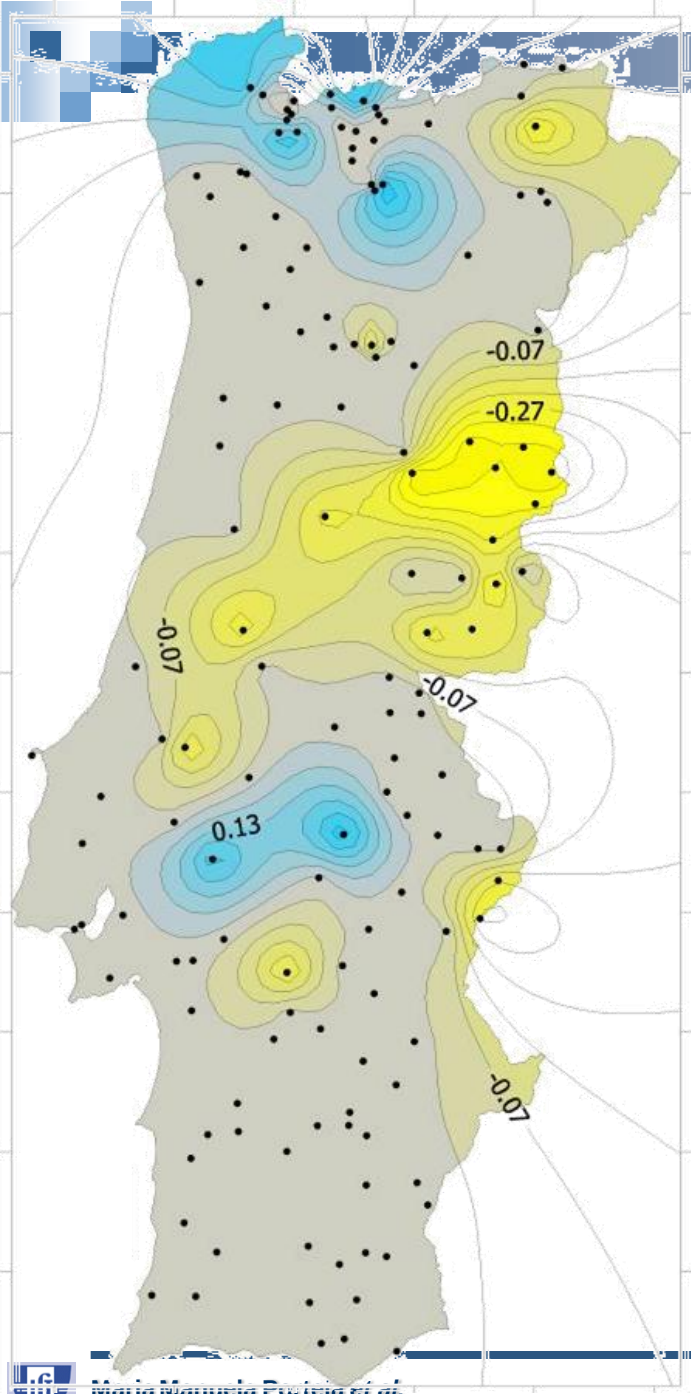
- ✓ The 11 rain gages exhibit a notorious decrease of the rainfall in March.
- ✓ In annual terms, the last periods of 15 years were often slightly drier then the total recording periods.
- ✓ **However, the slight decrease of the annual rainfall is within the natural variability of the series and, from a statistical point of view, it can not be considered a trend.**



… results

Extensive trend detection in annual and monthly rainfall series (2008)

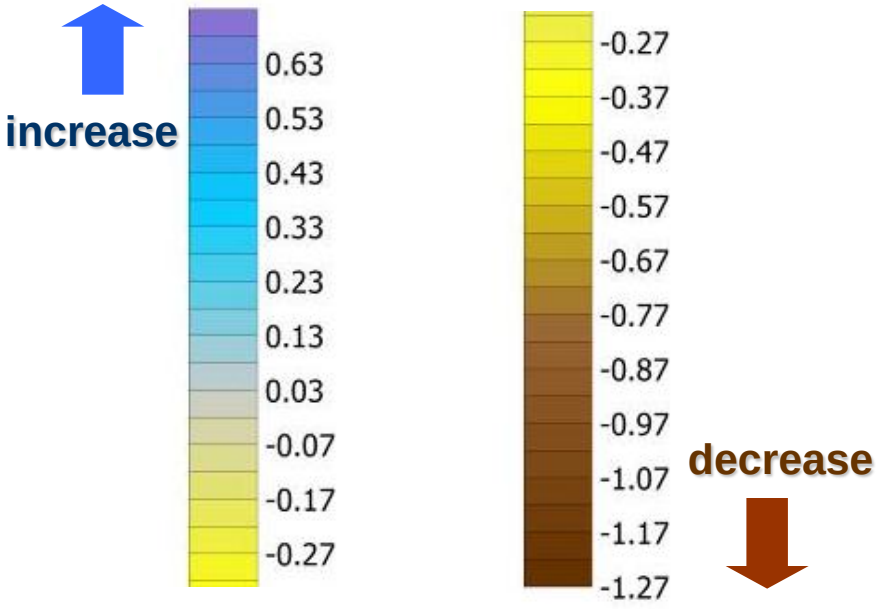
Mann-Kendall test combined with the Sen slope estimator applied to 94 years of monthly and annual rainfall (from October 1910 to September 2004) in 144 Portuguese rain gages

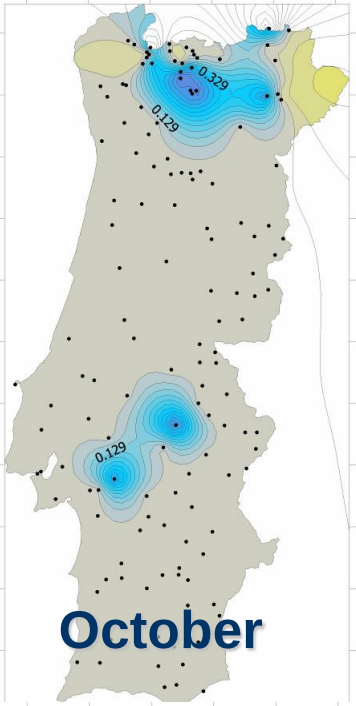


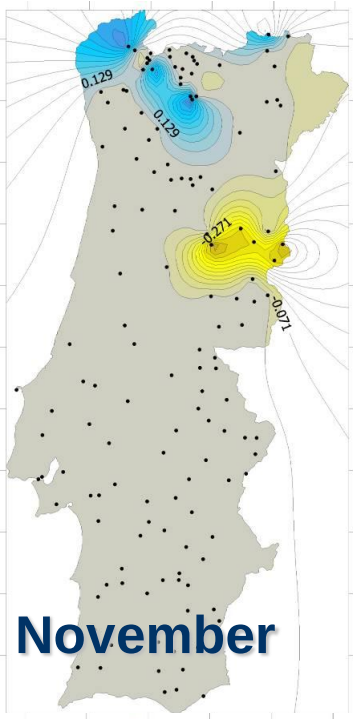
… in the next figures and for each time interval (month or year) ….

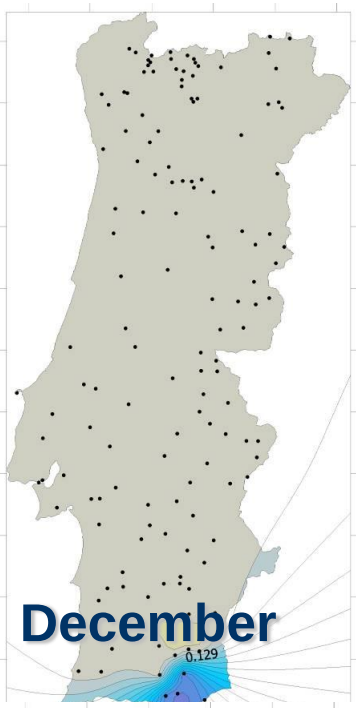
statistically significant yearly variation of the rainfall expressed in percentage of the respective mean rainfall

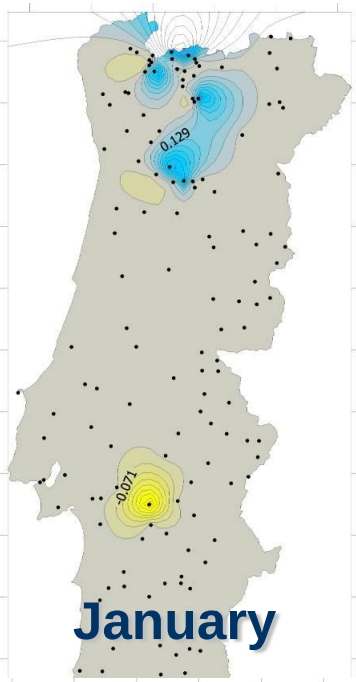
(% per year)

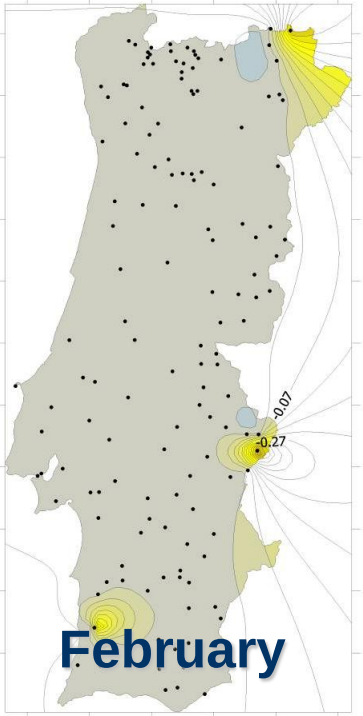


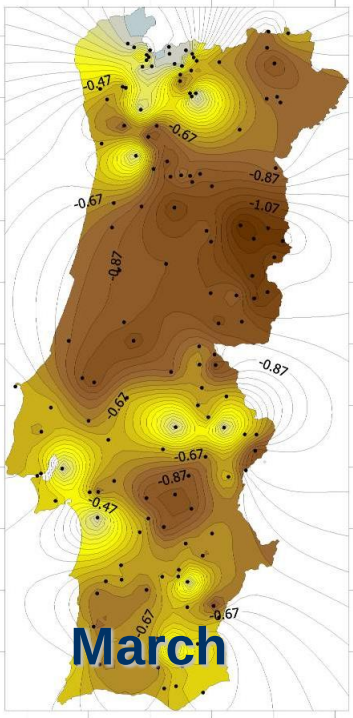

0.329
0.129
0.129
October

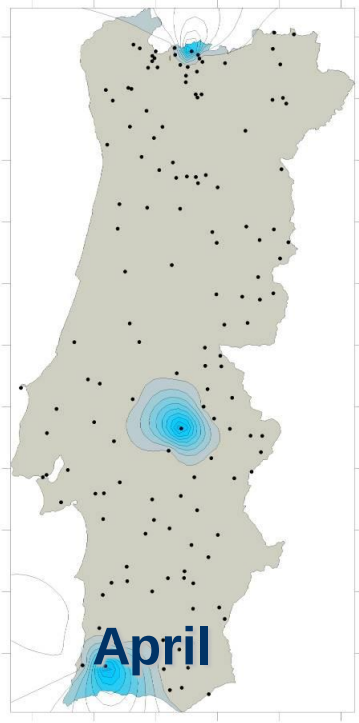

0.129
0.129
-0.271
-0.071
November


0.129
December

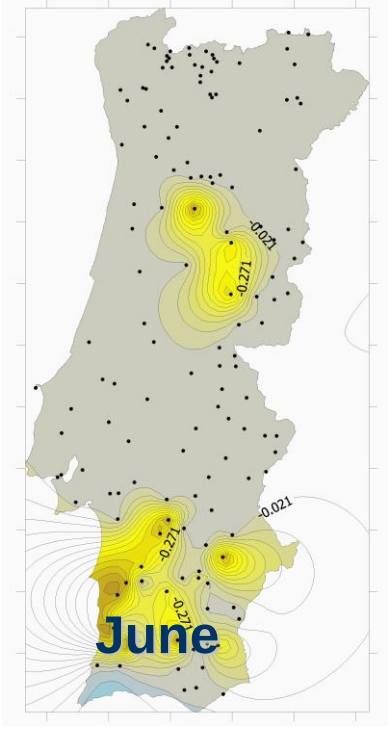

0.129
-0.071
January

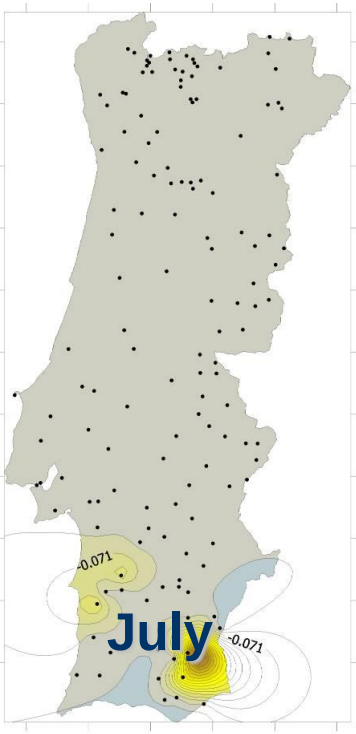

-0.07
-0.27
February

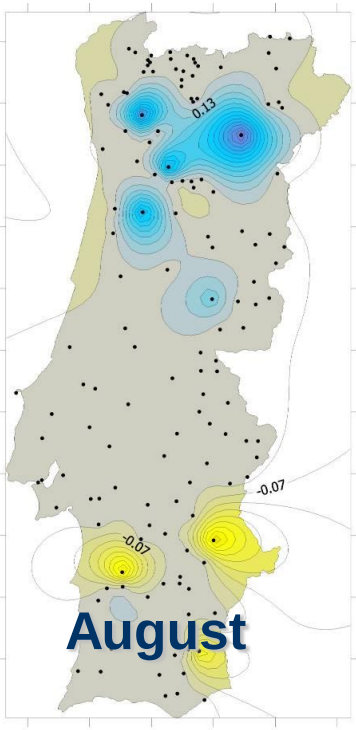

-0.47
-0.67
-0.87
-0.67
-1.07
-0.87
-0.87
-0.67
-0.67
-0.87
-0.47
-0.67
-0.67
March

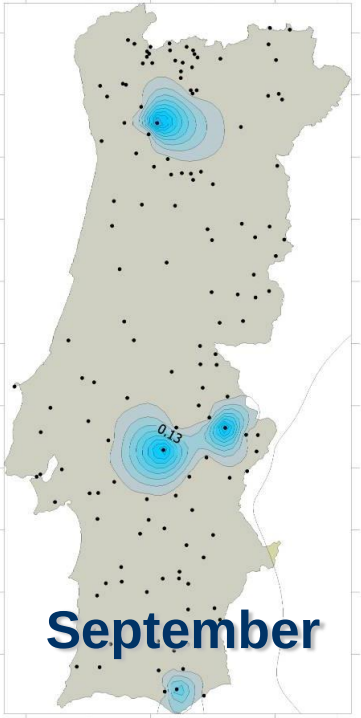

April

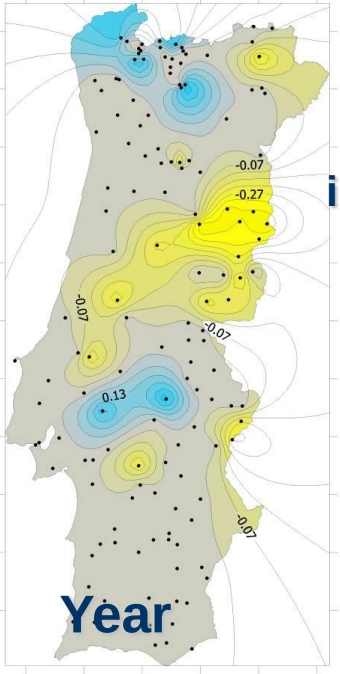

-0.07
May

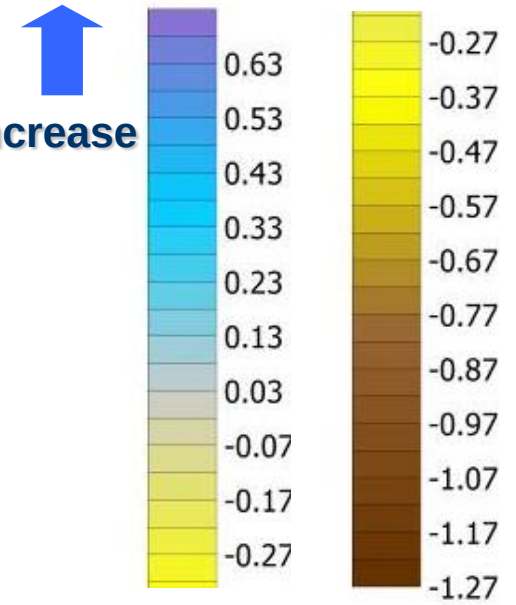








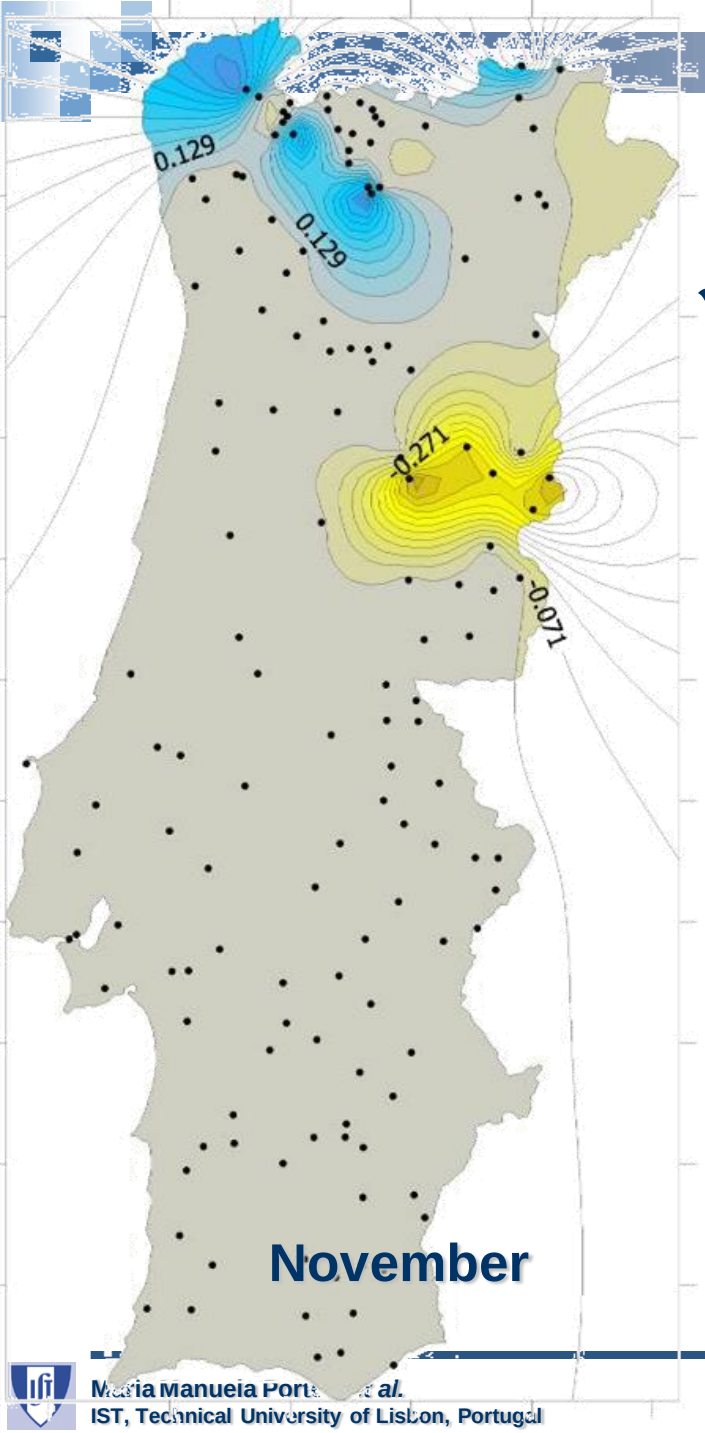




… for each time interval ….

yearly variation of the rainfall expressed in percentage of the respective mean rainfall

(% per year)



… 144 annual and monthly rainfall series

- ✓ **Most of the rainfall changes are spatially quite circumscript and almost neglectable.**

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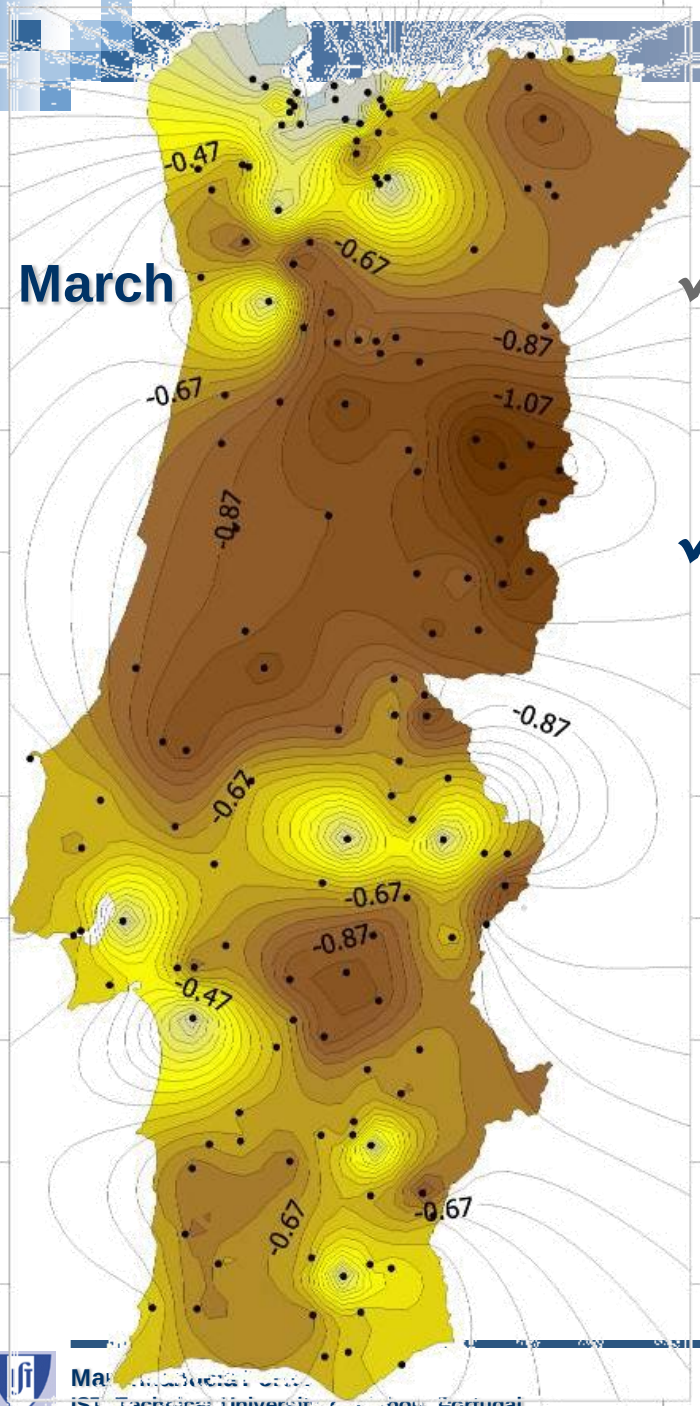

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- ✓ **Only the rainfall in March exhibits a very pronounced and widespread downward trend.**

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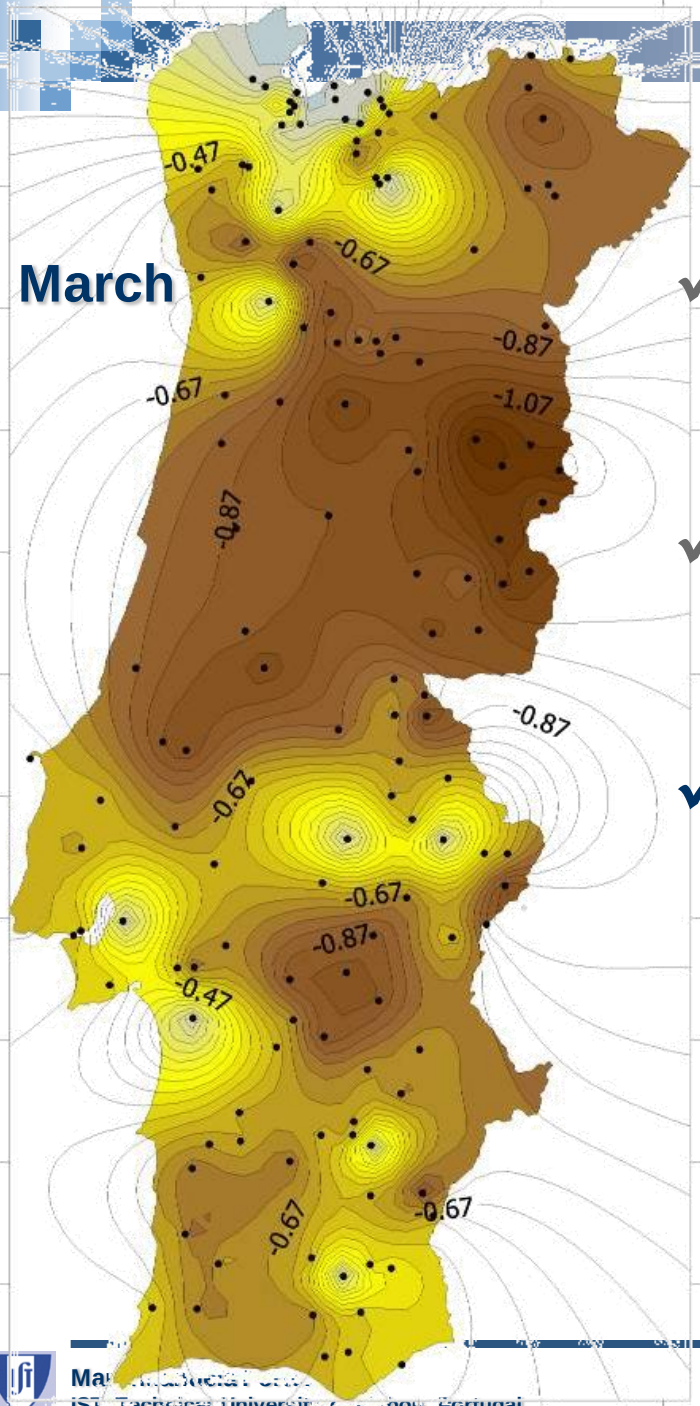
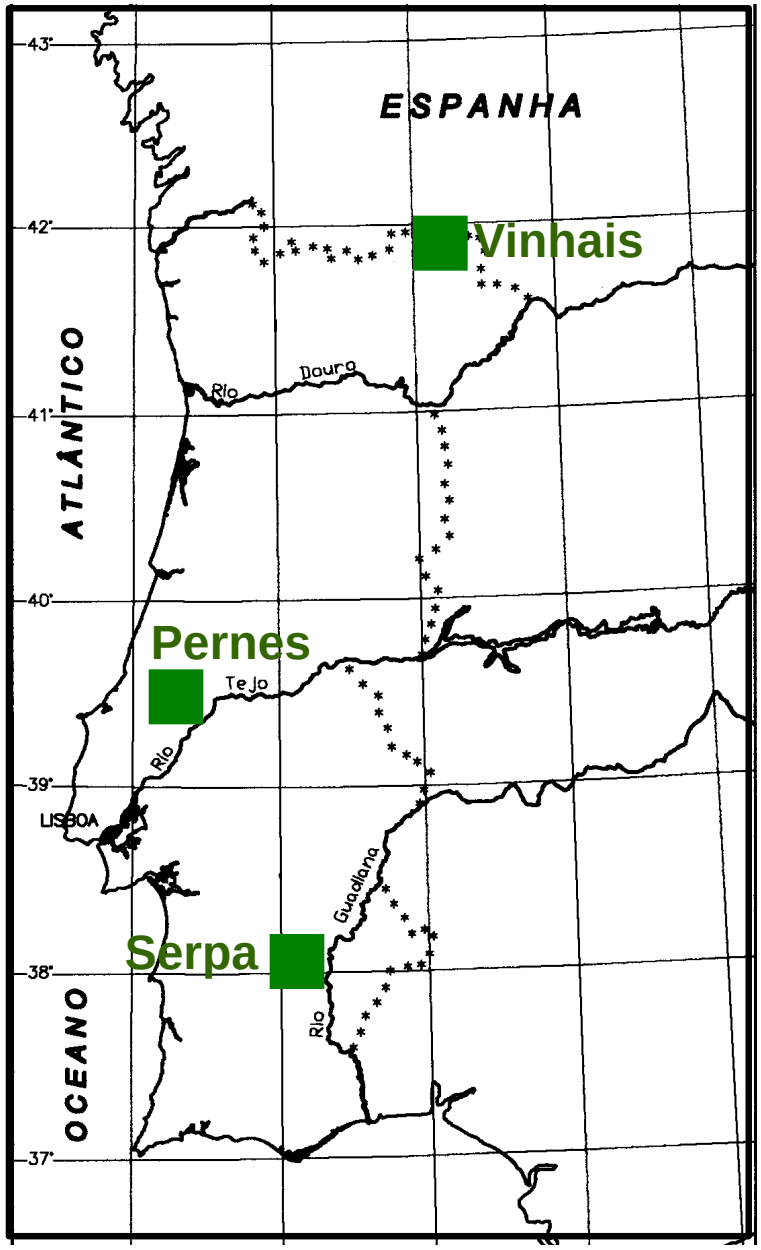


- ✓ Most of the rainfall changes are **spatially quite circumscript** and almost **neglectable**.
- ✓ Only the **rainfall in March** exhibits a very **pronounced** and **widespread downward trend**.
- ✓ **However, except for a small region in the North of Portugal, the rainfall in March is always smaller than 150 mm which means that a maximum annual decrease according to the Sen estimator of about 1.3% will represent a decrease of the annual amount of rainfall in March of only 2 mm.**



… results

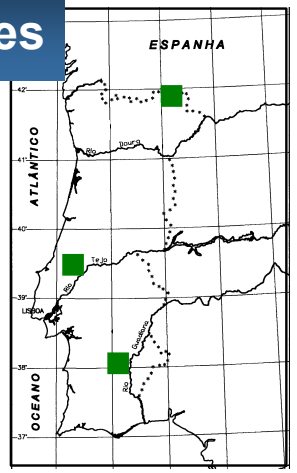
Analysis of the extreme rainfall (2008)

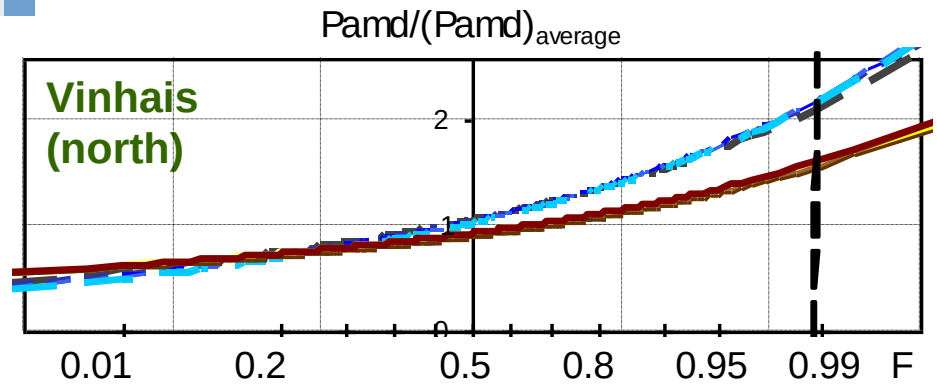
… based on application of the **Gumbel law** to **24** samples of **annual maximum daily rainfall**

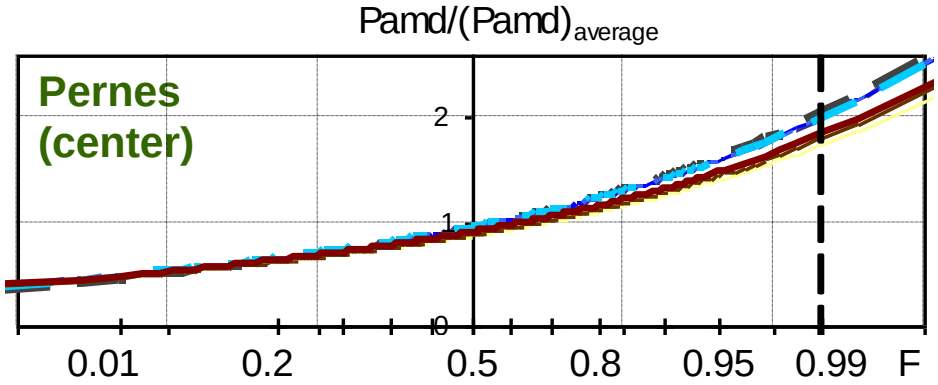
(… built upon one value per year, the maximum amount of rainfall in 24 h)

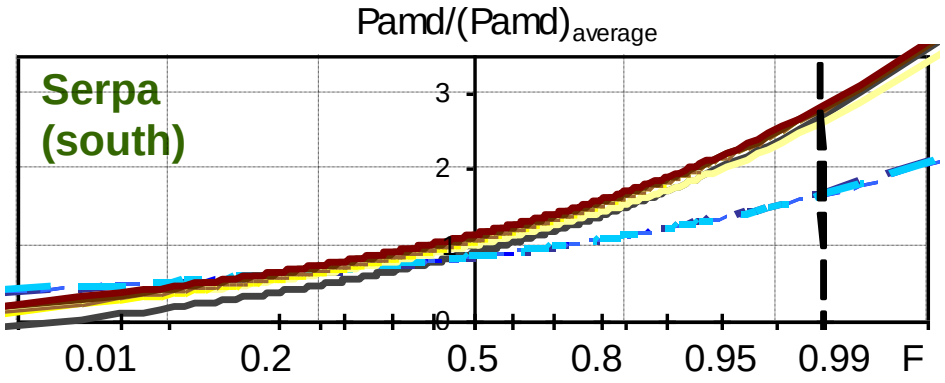
… results exemplified by 3 rain gages …

… extreme rainfall series



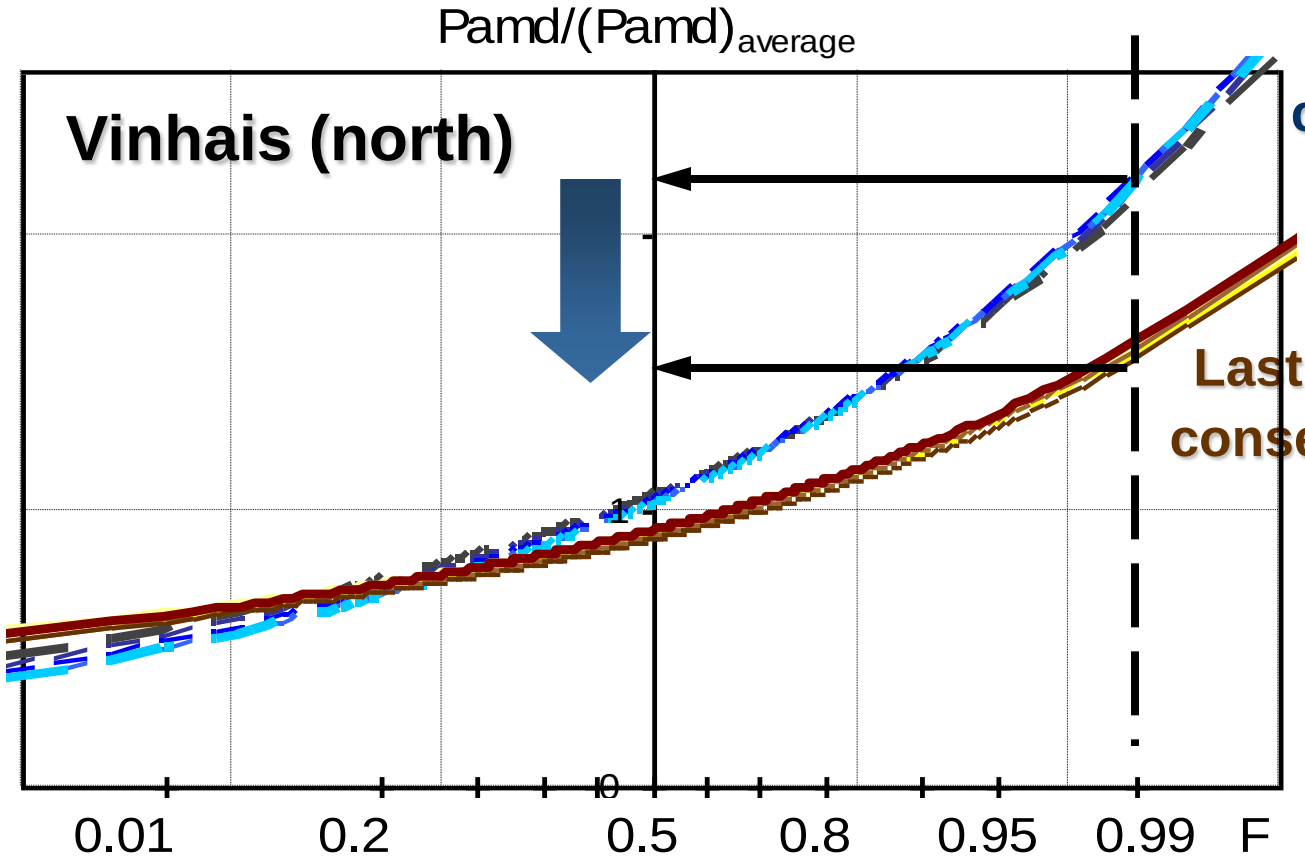






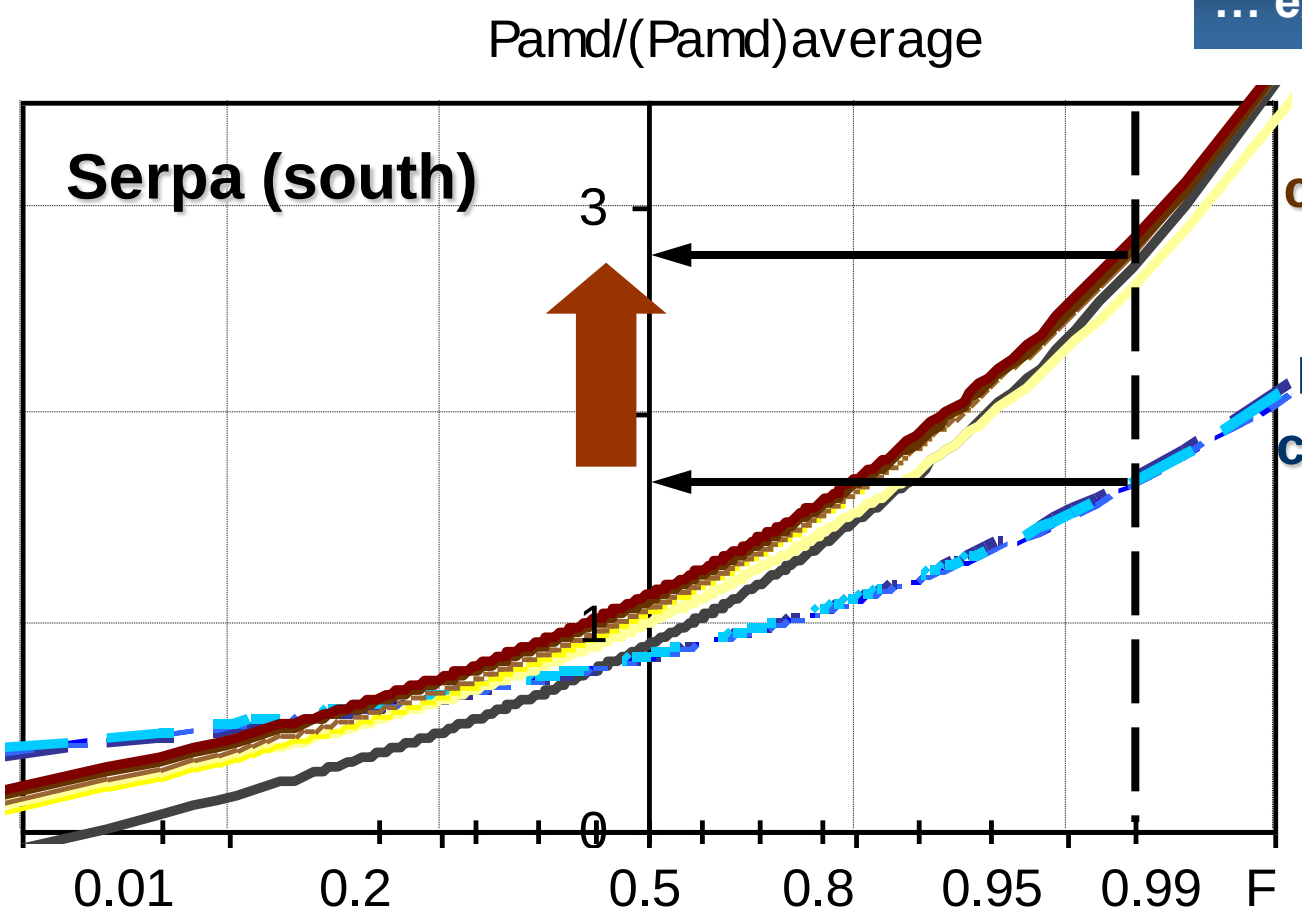
Gumbel probability distribution function based on the **first 5 sets of 25 consecutive years** – dark blue to light blue curves – and on the **last 5 sets of 25 consecutive years** – yellow to brown curves.

… extreme rainfall series



For the return periods more often adopted as design criteria, generally higher than 100 years (F=0.99), the more recent samples result in lower intensive rainfall estimates

… extreme rainfall series

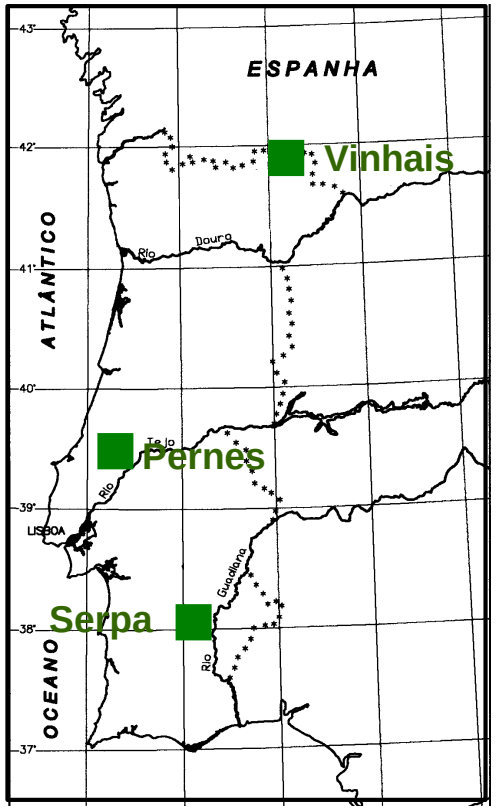


Last 5 sets of 25 consecutive years

First 5 sets of 25 consecutive years

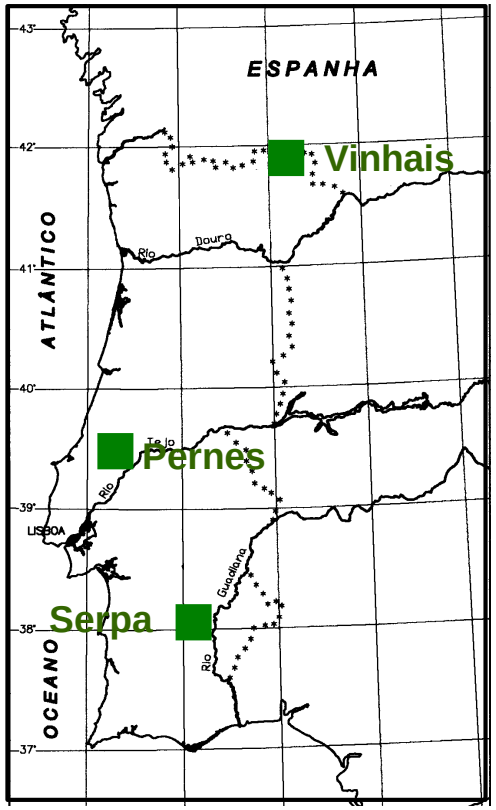
For the return periods more often adopted as design criteria, generally higher than 100 years (F=0.99), the <u>more recent samples result in higher intensive rainfall estimates</u>

… extreme rainfall series



✓ … for **Vinhais** gage **(north)** the estimates based on the latest records are not as high as those supported by the oldest records. The opposite situation occurs in **Serpa** gage **(south)** while in **Pernes** gage **(center)** both estimates are very close.

… extreme rainfall series



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- So, **different sampling periods** need to be analyzed in order to ensure **conservative design criteria**.

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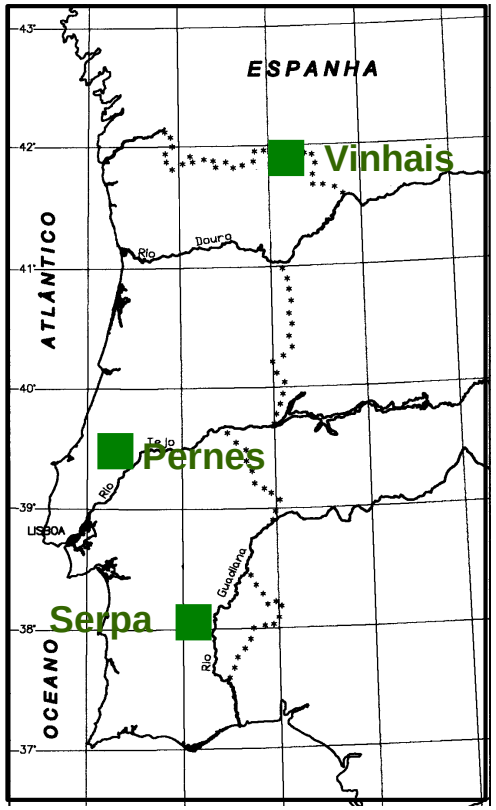

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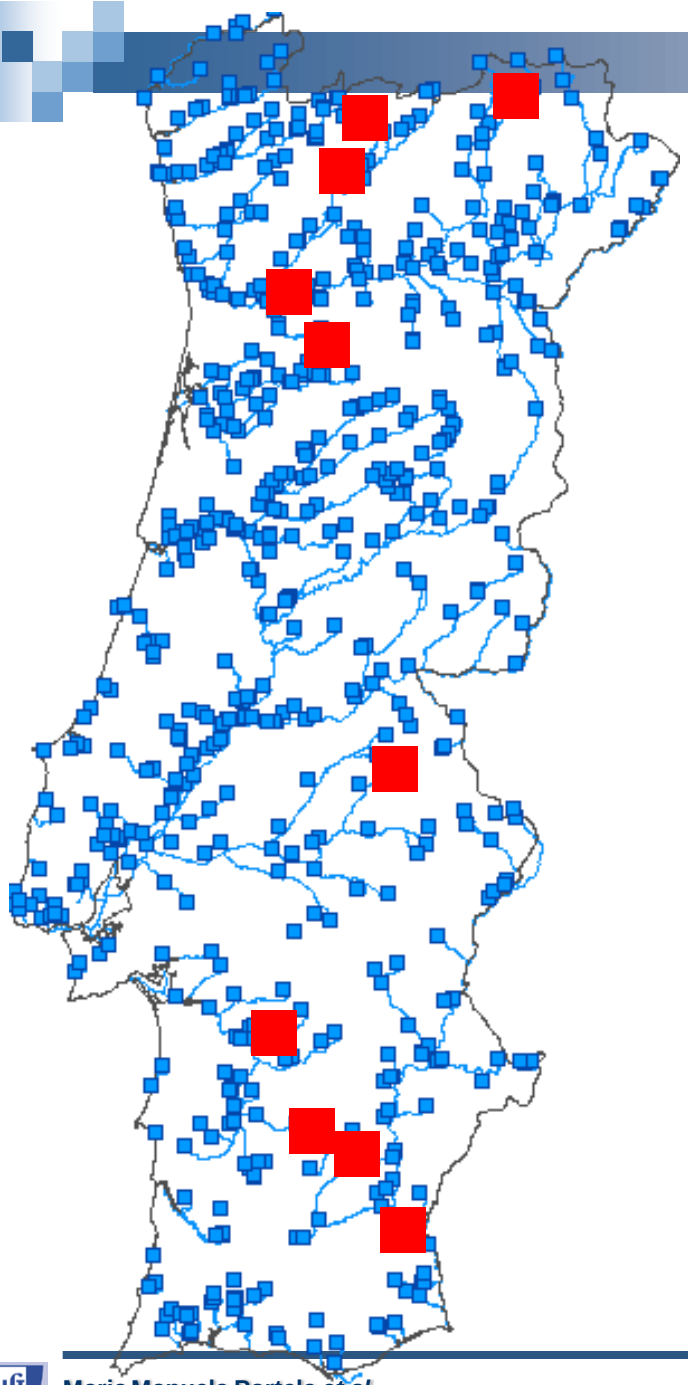
- So, **different sampling periods** need to be analyzed in order to ensure **conservative design criteria**.

- **The behaviour of the extreme rainfall series may refuse (like in Vinhais or even in Pernes) or confirm (like in Serpa) the upward trend that is generally pointed out as denoting the climate change effect.**

… results



Reliability of the water supplies for irrigation based on 10 hypothetical existing reservoirs (2008)

… reliability of the water supplies

- Due to the **temporal irregularity** that characterizes the **Portuguese hydrologic regime**, most of the water supplies are ensured by **artificial reservoirs**, a significant part of them having been built more than 50 years ago.

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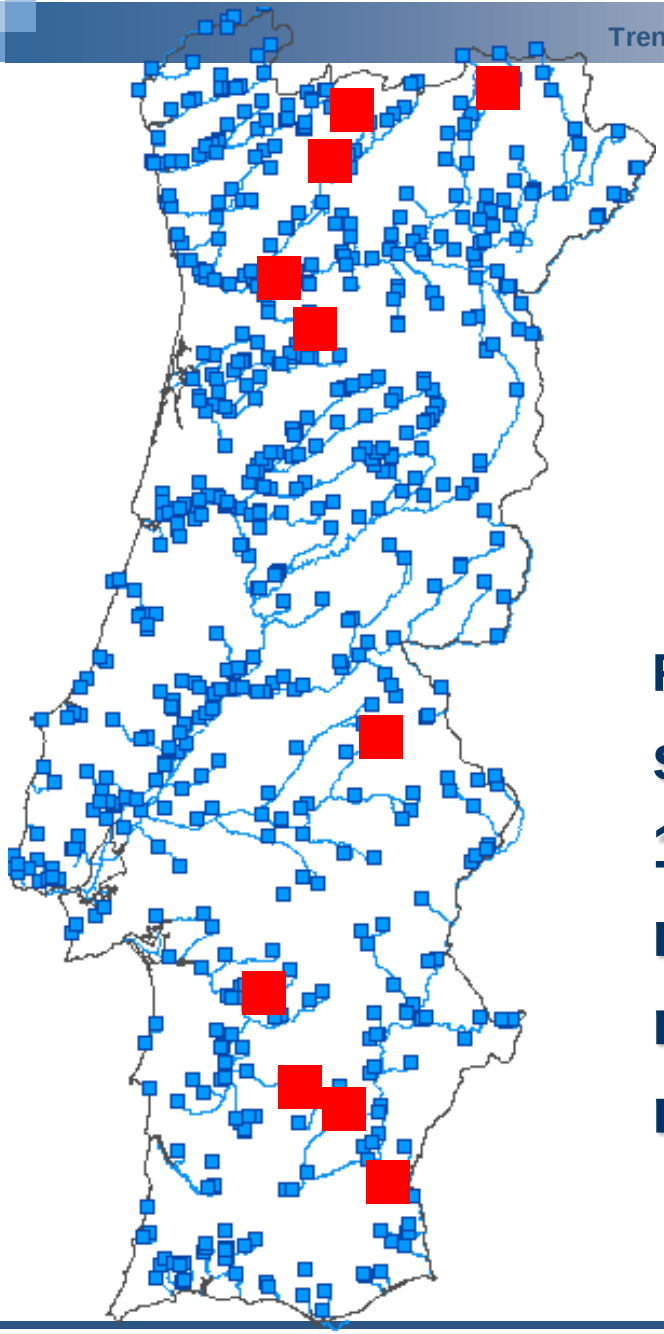
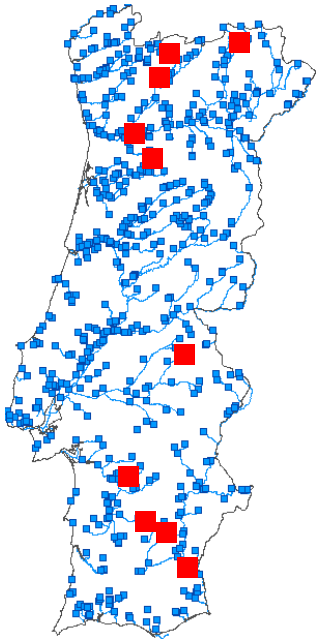
- (… a question arises …) If the **climate is changing** are those old reservoirs still able to **ensure the water supplies** (in terms of **quantity** and **guaranty/reliability**)?
- **This aspect is especially relevant for irrigation reservoirs as both the crop demand and the natural water availability may be influenced by the effects expected from the climate change.**



… reliability of the water supplies

Results achieved by **computational simulation techniques** applied **to 10 hypothetical irrigation reservoirs,** based on **94 years of monthly inflows and of crop requirements.**

… reliability of the water supplies



	CASE STYDY	TREND IN THE MEAN ANNUAL FLOW	TREND IN THE STORAGE CAPACITY					
			WATER DEMAND (% of mean annual inflow)					
			30	50	70	30	50	70
			GUARANTY					
			80%			90%		
North	Vinhais-Qta da Ranca	+	-	-	-	+	-	-
North	Castro Daire	-	+	+	+	+	+	+
North	Cabriz	-	-	-	-	+	-	-
North	Vale Giestoso	+	-	-	-	-	-	-
North	Cunhas	-	+	+	+	+	+	+
Centre	Couto de Andreiros	-	+	+	+	+	+	+
South	Torrão do Alentejo	-	+	+	+	+	+	+
South	Albernoa	+	+	+	+	+	+	+
South	Monte da Ponte	+	+	+	+	+	+	+
South	Vascão	+	-	-	+	-	-	+

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	Monte da Ponte	+						
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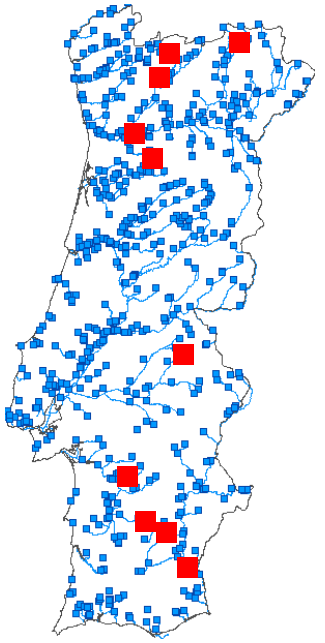

Blue arrows: **more water availability** and/or **less water storage needed** to fulfill the same demand, **contradicting** the effects expected from the **climate change.**

… results

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North	Cabriz		- ↘	- ↘	- ↘		- ↘	- ↘
North	Vale Giestoso	+ ↗	- ↘	- ↘	- ↘	- ↘	- ↘	- ↘
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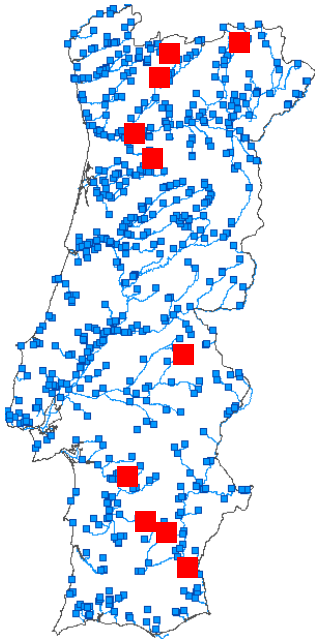

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Maria Manuela Portela *et al.*
IST, Technical University of Lisbon, Portugal

… results

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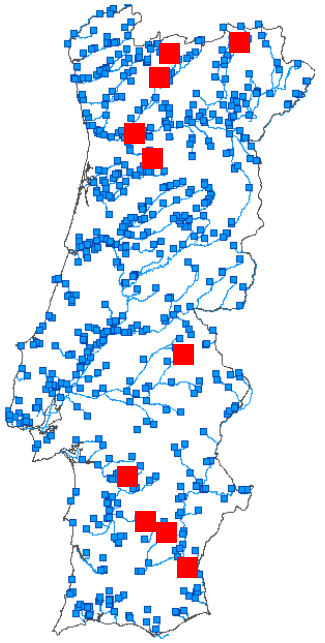
	Monte da Ponte		+	+	+	+	+	+
	Vascão				+			+



Red arrows: **less water availability** and/or **more water storage needed** to fulfill the same demand, **confirming** the effects expected from the **climate change.**

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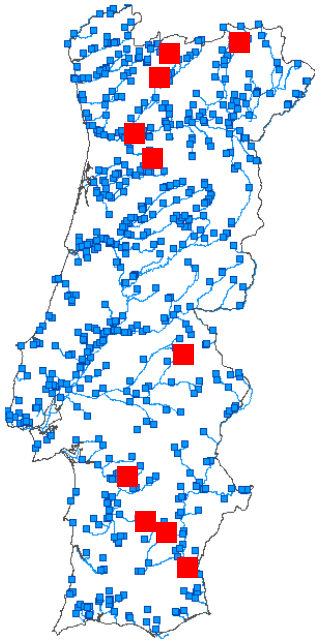

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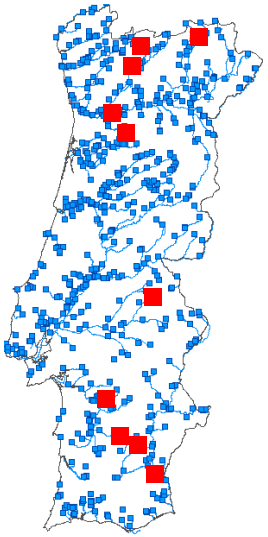

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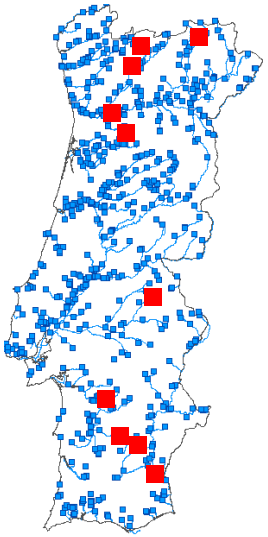
… results

- ✓ **Most of the case studies denote loss of reliability as more storage capacity would presently be required to ensure the same water demand with a given guaranty. In some of the case studies this even happens when increases of the water inflows occurred.**



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South	Albernoa	+ ↗	+ ↗	+ ↗	+ ↗	+ ↗	+ ↗	+ ↗
South	Monte da Ponte	+ ↗	+ ↗	+ ↗	+ ↗	+ ↗	+ ↗	+ ↗
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… results

- ✓ Most of the case studies denote **loss of reliability** as **more storage capacity** would presently be required to ensure the same water demand with a given guaranty. In some of the case studies this even happens when increases of the water inflows occurred.
- ✓ **However, it should be pointed out that all the increases/decreases under consideration were very small and often almost negligible.**

… final remarks

- ✓ In general terms the studies developed until now showed that some of the **hydrologic series are much more resilient** than the human perception and that it is difficult, for the time being, to clearly identify signs of the **climate changes** in such historical series.

… final remarks

- ✓ In general terms the studies developed until now showed that some of the **hydrologic series are much more resilient** than the human perception and that it is difficult, for the time being, to clearly identify signs of the **climate changes** in such series.

- ✓ **This also suggests that further studies and scientific judgments are required as, somehow, there is a gap between what is already considered as resulting from the climate change and the effective behaviour denoted by some of the hydrologic time series.**

… final remarks

- ✓ But does this mean that the **stationarity assumption** of most of the hydrologic models is no longer valid? **Will the future be statistically different from the past and if so, how can we introduce this dissimilarity in the hydrologic models and in the design criteria?**

… final remarks

- ✓ But does this mean that the **stationarity assumption** of most of the hydrologic models is no longer valid? **Will the future be statistically different from the past and if so how can we introduce this dissimilarity in the hydrologic models and in the design criteria**?

- ✓ **Though for the time being this is still an unsolved question it undoubtedly points towards the need to account for hydrologic uncertainty, for instance, by means of risk analysis tools based on scenarios.**

Trends in hydrologic time series and the climate change. Some of the Portuguese experience

Maria Manuela Portela

João F. Santos; António de Carvalho Quintela; Cristiana Vaz

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