# Impact of Climate Change on Extreme Rainfall in France Through Trend Detections in Average Climatic Characteristics

P. Cantet, P. Arnaud

# Impact of Climate Change on Extreme Rainfall in France Through Trend Detections in Average Climatic Characteristics

Philippe Cantet & Patrick Arnaud

Cemagref, 3275 route de Cezanne CS 40061, 13182 Aix-en-Provence, Cedex 5, FRANCE
email: philippe.cantet@cemagref.fr

## 1 Introduction

The great interest in climate change during the past twenty years has led to a quasi unanimous conclusion for scientists : the Earth's climate is changing. In order to prevent hydrological risks, it is important to know if this global change will lead to an increase in extreme events. Indeed, in the hydrological context, the statistical evaluation of return periods is key to establishing the dimensions of hydraulic works.
An original approach is applied to estimate the impact of climate change on extreme events, based on the use of an **hourly rainfall stochastic generator** [1]. Climate evolution is detected from the values of generator parameters.
We tested **the significance of a linear trend of the generator parameters**. We proposed a method which evaluates trends on a **regional scale**. The generator parameters can be estimated over the **period 1960-2003** under the climate change hypothesis. This new estimation permitted us to appreciate rainfall distribution changes due to climate change. Under the hypothesis that the trends remain constant, we can also evaluate possible changes in the future.

## 2 The Hourly Rainfall Generator

The hourly rainfall generator estimates rainfall quantiles for different durations and any return periods, leading to very good results [3] in regions with varied rainfall ranges, such as metropolitan France, Reunion in the Indian Ocean, and Martinique in the Caribbean [1]. The **three parameters** of the rainfall generator were based on observed rainfall events selected on daily criteria, i.e. a succession of daily rainfall depths of more than 4 mm, including one daily rainfall depth of at least 20 mm :

- $NE$ (event occurence) is the **average number of events per year**,
- $\mu PJmax$ (event intensity) is the **average of the maximum rainfall in one day of each event**,
- $\mu DTOT$ (event duration) is the **average of a event duration**.

Moreover we selected two seasons: summer from June to November, and winter from December to May. Therefore, from these $3 \times 2$ daily parameters, we can obtain rainfall quantiles for different durations and any return periods.

## 3 Database

Available data, provided free by Meteo-France, is the Daily Series of Reference (http://medias.cnrs.fr/imfrex/web/). **139 rain gauges** were chosen to study climate change over the **period 1960-2003**. A hierarchical clustering was applied to construct some homogeneous climatic zones in relation to the rainfall generator parameters.

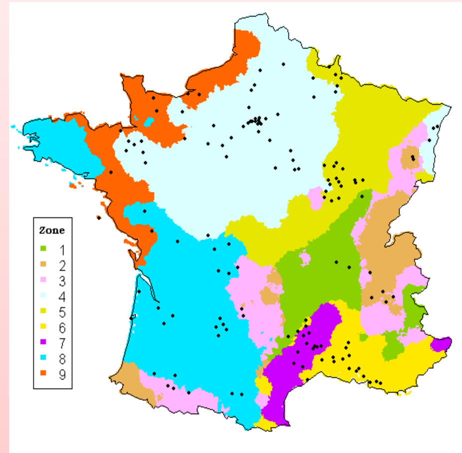

**Figure 1: 9 homogeneous climatic zones and location of the 139 rain gauges.**

## 4 Observed trends of the rainfall generator parameters

A trend test, based on the *Maximum Likelihood Ratio Test* [2], was performed to test the stationarity of the parameters versus a linear trend both in a local scale and in regional ones. We fixed the significance level $\alpha = 0.1$.

<table>
<tr><th>Zone</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th></tr>
<tr><td>$NE_H$:number of events</td><td>~</td><td>~</td><td>+20%</td><td>+45%</td><td>+36%</td><td>~</td><td>−30%</td><td>+18%</td><td>+31%</td></tr>
<tr><td>between December and May</td><td colspan="3">+17%</td><td colspan="2">+42%</td><td colspan="2">−20%</td><td colspan="2">+20%</td></tr>
<tr><td>$NE_E$: number of events</td><td>~</td><td>~</td><td>~</td><td>+12%</td><td>~</td><td>~</td><td>~</td><td>+12%</td><td>~</td></tr>
<tr><td>between June and November</td><td colspan="3">~</td><td colspan="2">+11%</td><td colspan="2">~</td><td colspan="2">~</td></tr>
<tr><td>$\mu PJmax_H$: average of event intensity</td><td>+15%</td><td>~</td><td>+6%</td><td>~</td><td>~</td><td>~</td><td>~</td><td>~</td><td>~</td></tr>
<tr><td>between December and May</td><td colspan="3">+11%</td><td colspan="2">~</td><td colspan="2">~</td><td colspan="2">~</td></tr>
<tr><td>$\mu PJmax_E$: average of event intensity</td><td>~</td><td>~</td><td>~</td><td>~</td><td>~</td><td>~</td><td>~</td><td>~</td><td>~</td></tr>
<tr><td>between June and November</td><td colspan="3">~</td><td colspan="2">~</td><td colspan="2">~</td><td colspan="2">~</td></tr>
</table>

**Table 1: Results from trend test in regional scales**

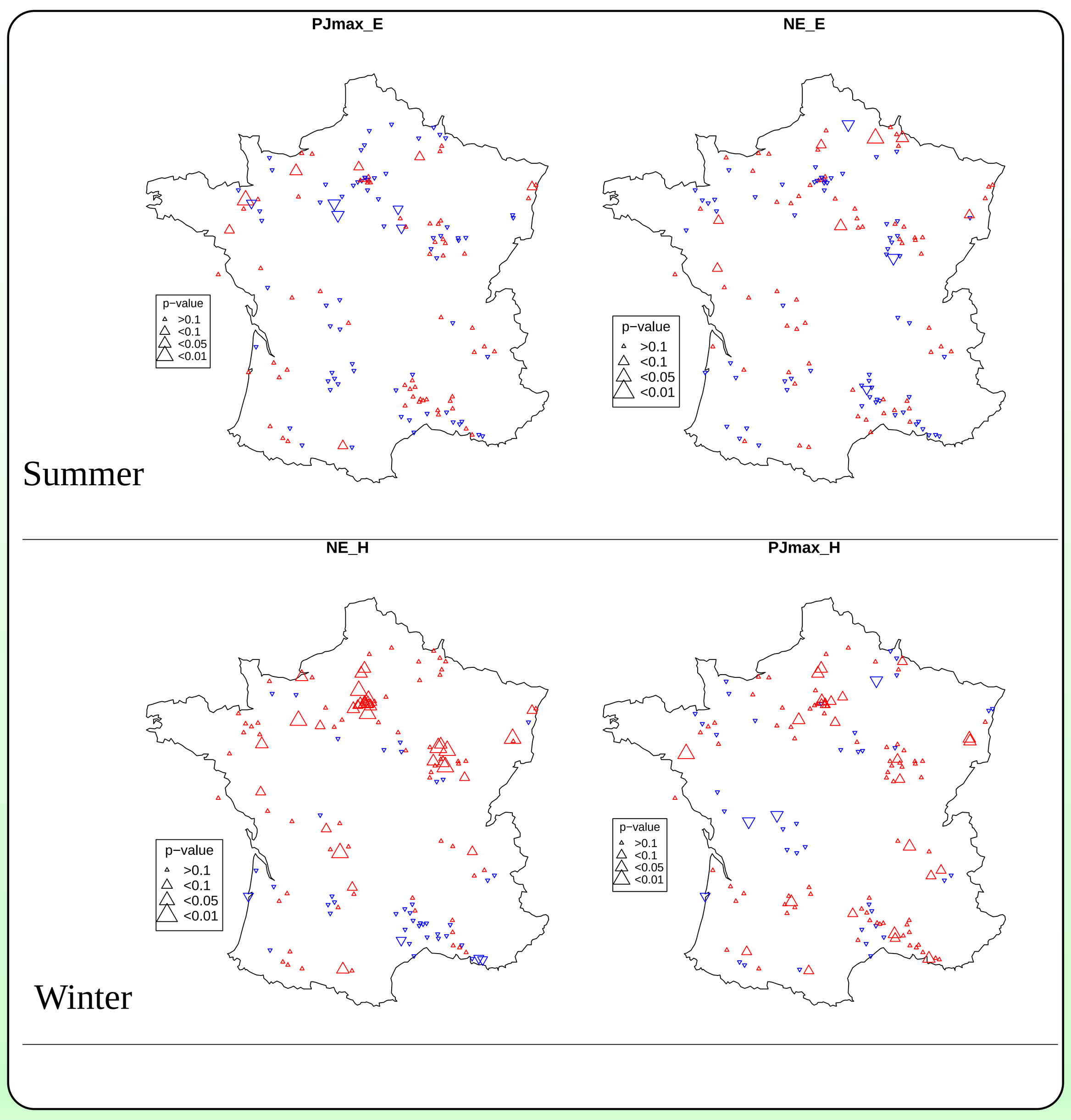


**Figure 2: Results from trend test in a local scale**

## 5 Effects on rainfall distribution

### 5.1 Effects on quantile estimation

Let $Param_0$ be the set of rainfall parameters estimated under the stationary hypothesis.
Let $Param_A$ be the set of rainfall generator parameters under the non-stationary hypothesis, estimated in year $A$.
Let $T$ be a return period.
Let $PM24$ be the volume of maximum rainfall in 24 hours.
Let $q_T^0$ be $PM24$ associated with the return period $T$ coming from generator results with the parameterization $Param_0$.
Let $q_T^A$ be $PM24$ associated with the return period $T$ coming from generator results with the parameterization $Param_A$.

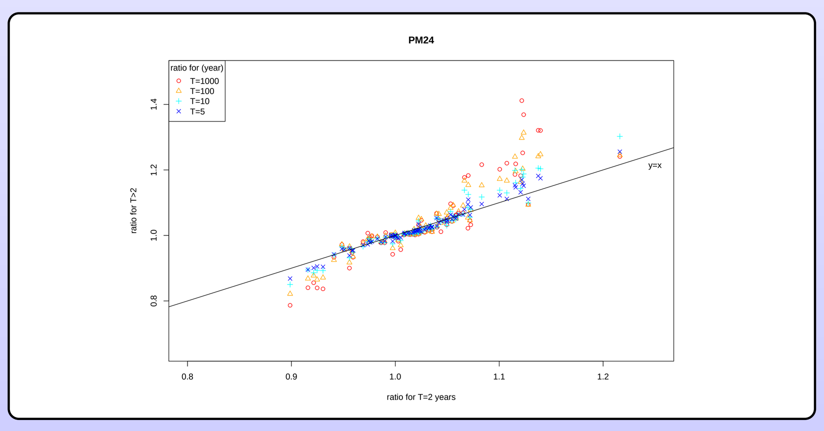


**Figure 3:** $R_T = \frac{q_T^{2003}}{q_T^0}$ **with** $T = 5, 10, 100, 1000$ **years according to** $R_2$

### 5.2 Effects on estimation of return periods

Within the context of the non-stationary framework, a return period $T$ is interpreted as "the $T$-quantiles calculated classically in a certain year $A$ is the value having a probability $1/T$ of being exceeded during the considered year $A$".
We use $x_0$ as the quantiles of reference which is the $T_0$-quantiles of the rainfall distribution resulting from the parameterization $Param_0$. Then we calculated $T_{2003}$ in such a way that the $T_{2003}$-quantile be $x_0$ of the rainfall distribution resulting from the parameterization $Param_{2003}$.

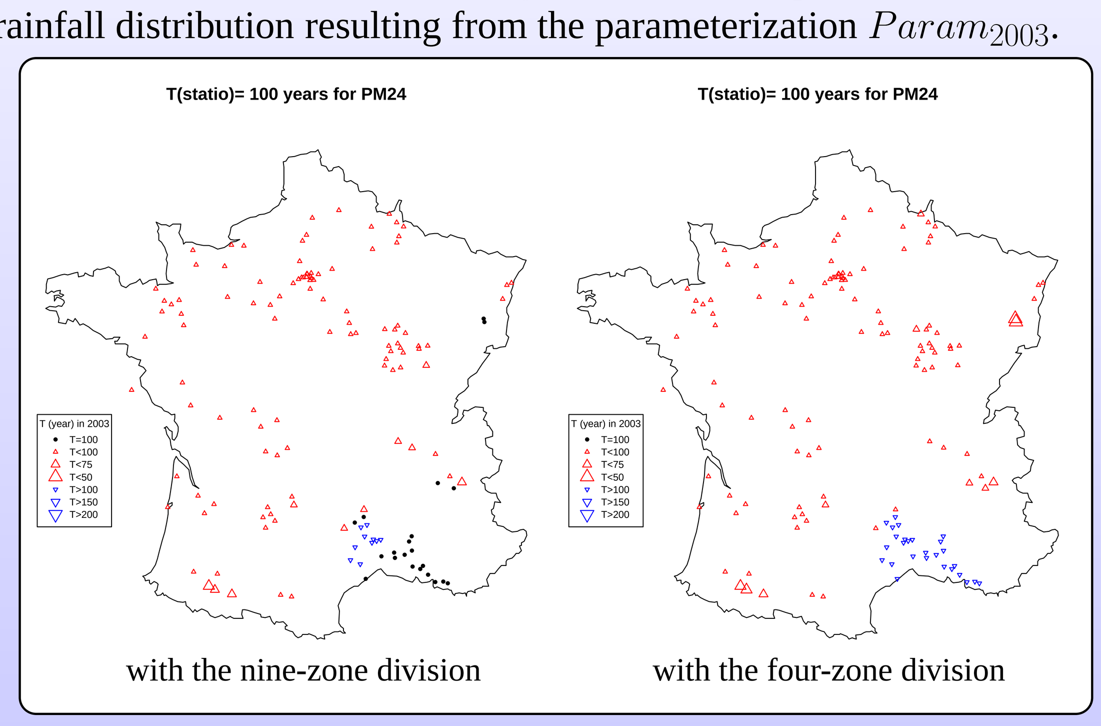


**Figure 4: Estimation of** $T_{2003}$ **in such a way** $q_{T_{2003}}^{2003} = q_{T_0}^0$ **with** $T_0 = 100$ **years.**

### 5.3 Effects in the future (in 2025)

In order to illustrate possible changes in long range forecasts, we estimated $Param_{2025}^{Regio}$ with the following hypothesis : the observed trends between 1960 and 2003 are extrapolated until 2025.

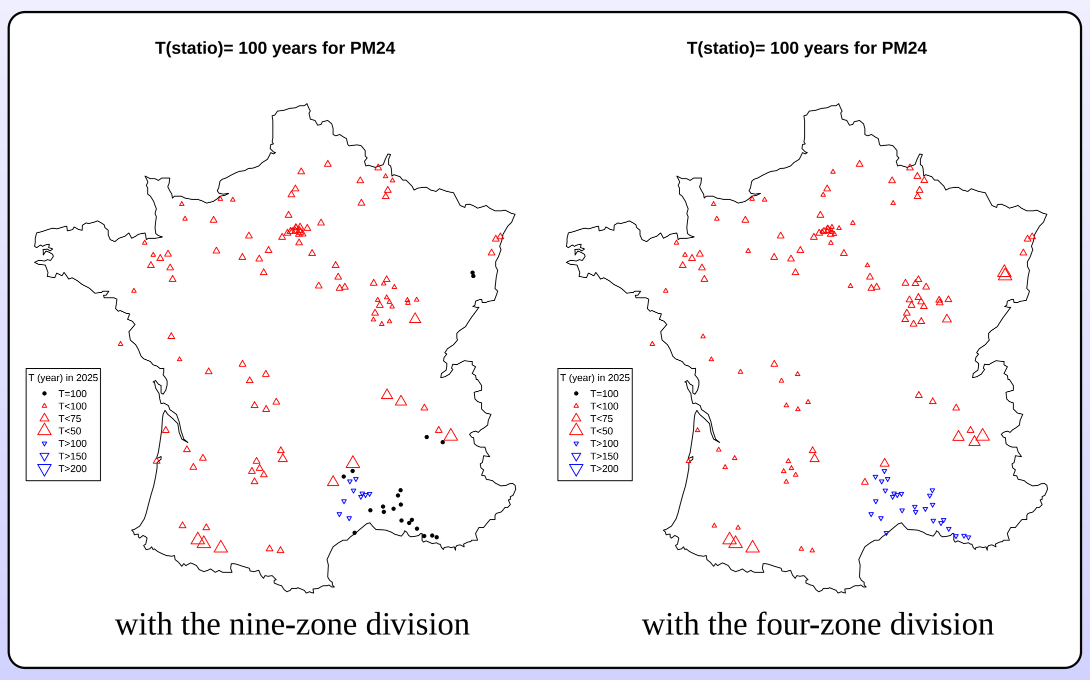


**Figure 5: Estimation of** $T_{2025}$ **in such a way** $q_{T_{2025}}^{2025} = q_{T_0}^0$ **with** $T_0 = 100$ **years.**

## 6 Conclusion

The key point of this method is that we tried to evaluate the impact of climate change on extreme rainfall in France through trend detections in average climatic characteristics, and not in extreme values. The **observed changes occur mainly in winter**, from December to May, with an increase of rainfall event occurence in France except in the Mediterannean region. These changes, which take into account climate change, did not lead to marked changes in the estimation of rainfall quantiles in 2003. However, if these trends continue, there will be a sizeable increase in extreme events in the mountain ranges of France in the next few decades.

## References

[1] P. Arnaud, J. Fine, and J. Lavabre. An hourly rainfall generation model adapted to all types of climate. *Accepted in Atmos. Res.*, 2007.

[2] P. Cantet, P. Arnaud, and J. Bacro. Impacts of Climate Change on Extreme Rainfall in France Using a Rainfall Stochastic Generator - Local Approach Compared to Regional Approach. *Submitted to the Journal of Climatic Change.*

[3] L. Neppel, P. Arnaud, and J. Lavabre. Connaissance regionale des pluies extremes. Comparaison de deux approches appliquees en milieu mediteraneens. *C. R. Geosci.*, 339:820–830, 2007.