Climate change and flood risk management

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Colombia

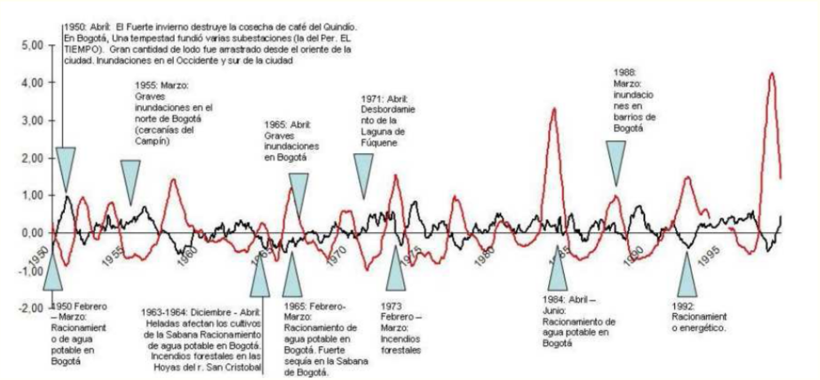
The climate of Columbia is in part controlled by the El niño/La Niña phenomena.

Wikipedia definition

El Niño/La Niña-Southern Oscillation, or ENSO, is a quasiperiodic climate pattern that occurs across the tropical Pacific Ocean roughly every five years. It is characterized by variations in the temperature of the surface of the tropical eastern Pacific Ocean – warming or cooling known as El Niño and La Niña respectively – and air surface pressure in the tropical western Pacific–the Southern Oscillation. The two variations are coupled: the warm oceanic phase, El Niño, accompanies high air surface pressure in the western Pacific, while the cold phase, La Niña, accompanies low air surface pressure in the western Pacific. Mechanisms that cause the oscillation remain under study.

Wikipedia definition

El Niño is defined by prolonged differences in Pacific Ocean surface temperatures when compared with the average value. The accepted definition is a warming or cooling of at least 0.5 C (0.9 F) averaged over the east-central tropical Pacific Ocean. Typically, this anomaly happens at irregular intervals of 2–7 years and lasts nine months to two years. The average period length is 5 years. When this warming or cooling occurs for only seven to nine months, it is classified as El Niño/La Niña "conditions"; when it occurs for more than that period, it is classified as El Niño/La Niña "episodes".


5,00
4,00
3,00
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1950
1955
1960
1970
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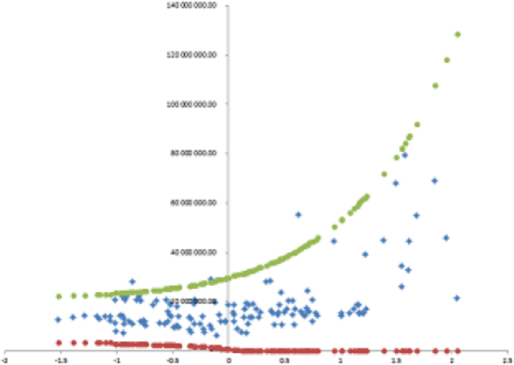
1980
1990
1995
1950: Abril: El Fuerte invierno destruye la cosecha de café del Quindío. En Bogotá, Una tempestad fundió varias subestaciones (la del Per. EL TIEMPO). Gran cantidad de lodo fue arrastrado desde el oriente de la ciudad. Inundaciones en el Occidente y sur de la ciudad
1955: Marzo: Graves inundaciones en el norte de Bogotá (cercanías del Campín)
1965: Abril: Graves inundaciones en Bogotá
1971: Abril: Desbordamiento de la Laguna de Fúquene
1988: Marzo: inundaciones en barrios de Bogotá
1950 Febrero – Marzo: Racionamiento de agua potable en Bogotá
1963-1964: Diciembre - Abril: Heladas afectan los cultivos de la Sabana Racionamiento de agua potable en Bogotá. Incendios forestales en las Hoyas del r. San Cristobal
1965: Febrero-Marzo: Racionamiento de agua potable en Bogotá. Fuerte sequía en la Sabana de Bogotá.
1973 Febrero – Marzo: Incendios forestales
1984: Abril – Junio: Racionamiento de agua potable en Bogotá
1992: Racionamiento energético.

Example of (naive) use of climate indicators

ENSO-Index (6 months before) - Monthly claims



Different types of flood : rain accumulation, direct, undirect and other

Too much rain, the soil can not absorb all the water (modification of the soil, impermeabilisation...)

Different types of flood : rain accumulation, direct, undirect and other

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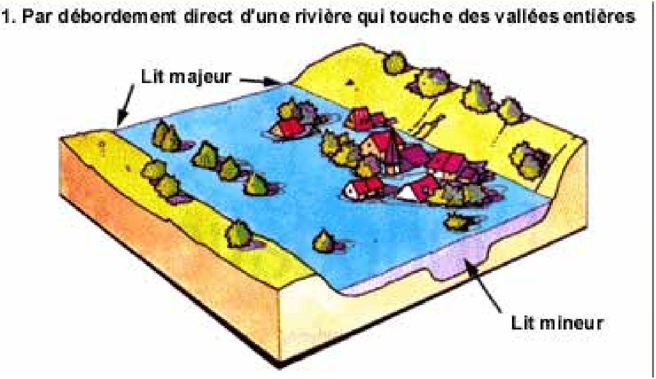
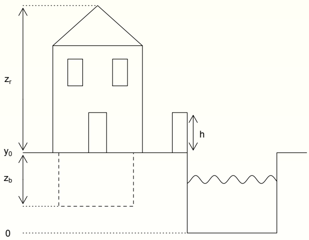


Different types of flood : rain accumulation, direct, undirect and other

- Coastal : severe sea storm, tsunami, tropical cyclone..
- Catastrophic : unexpected event (dam breakage..), other hazards (earthquake, volcanic eruption like Armero tragedy...)

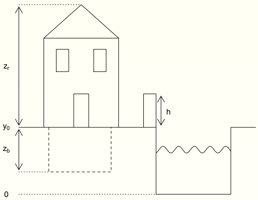
Notation

Let us consider a portfolio of m insurance contracts observed on some time period i in a specific area exposed to the risk of flood.



- B_{ij}, $i = 1, \ldots, n$, $j = 1, \ldots, m$, denotes the proportion of damage to the building j due to the flood on the period i;
- c_j is the insured value of the building;
- $X_{i,j}$ denotes the total cost on the period i for the risk j

The (simple) model



$$X_{i,j} = \begin{cases} c_j B_{i,j} & \text{if } Y_i > y_0 + h \\ 0 & \text{otherwise} \end{cases}$$

- $Y_1, \ldots, Y_n$ are i.i.d. r.v.'s representing the maximum level of the closest river for the ith period;
- y_0 is the height from the bottom of the river to the soil of the buildings;
- h may represent, for example, the height of the dyke or correspond to the "break-even" point over which the water will cause damage in the surrounding buildings.

The (simple) model (ctd)

We assume that

$$B_{i,j} \sim B(\alpha, \beta),$$

$B_{i,j} \perp Y_i$ and $B_{i,j} \perp B_{k,l}$, $j \neq l$. Denote by $p = \mathbb{P}(Y_i > y_0 + h)$.

$\Rightarrow$ $\mathbb{E}(X_{i,j}) = c_j p \mathbb{E}(B_{i,j})$

$\Rightarrow$ $\mathbb{V}(X_{i,j}) = c_j^2 \left(p\mathbb{V}(B_{i,j}) + p(1-p)\mathbb{E}(B_{i,j})^2\right)$

$\Rightarrow$ VaR, TVaR, cdf...

$\Rightarrow$ Need to estimate p correctly!

Yes, but how?

Why don't we use a parametric approach

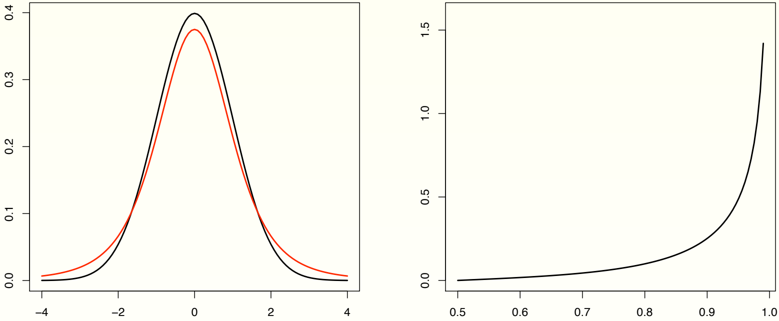
How does it work?

- Let suppose a parametric model *a priori* for the survival function: $\overline{F} \in \{\overline{F}_\theta, \theta \in \Theta\}$.

- We estimate θ by $\widehat{\theta}_n$.

Problem : A good fit in the center of the sample doesn't garanty a good fit in the tail

Illustration



Left: Normal distribution and Student distribution with 4 degrees of freedom.

A droite: Absolute difference between the $1-p$ quantile of Normal distribution and Student distribution with 4 degrees of freedom .

Context

- $X_1, ..., X_n$ i.i.d. F with mean μ and variance σ^2
- Mean behavior (CLT)

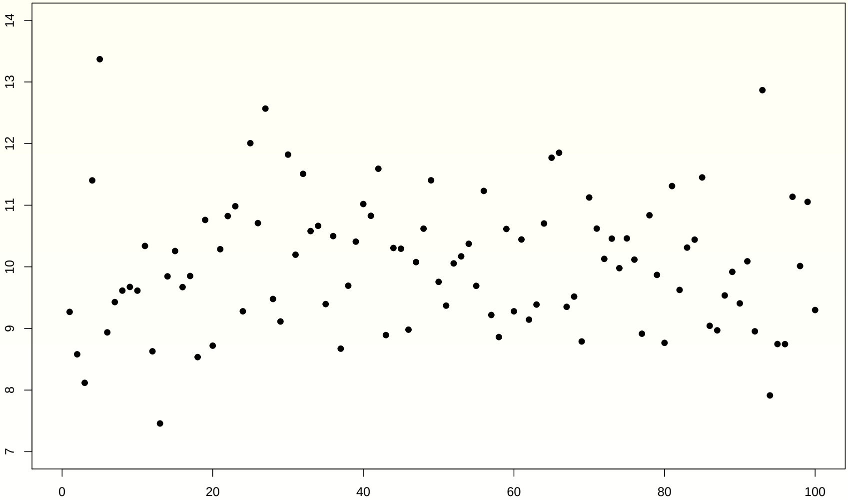
$$\sqrt{n}\frac{\overline{X} - \mu}{\sigma^2} \to \mathcal{N}(0, 1)$$

- Extreme behavior (EVT) (μ is not necessarily finite)

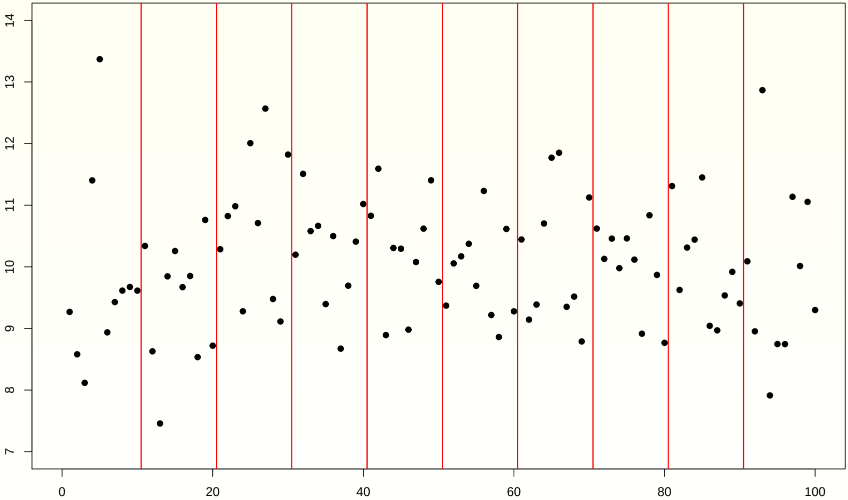
$$X_{1,n}, ..., X_{n,n}$$

$$\mathbb{P}\left(\frac{X_{n,n} - a_n}{b_n} \leq x\right) \to H_\gamma\left(\frac{x - \mu}{\sigma}\right)$$

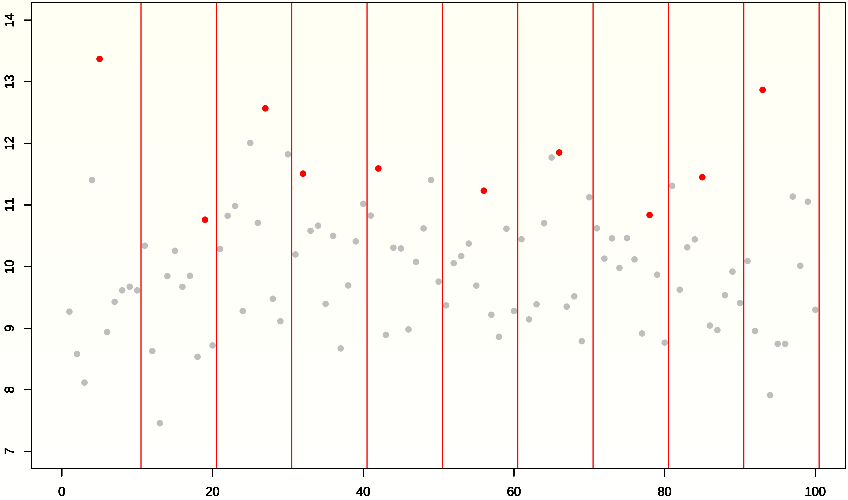
Bloc maxima : example



Bloc maxima : example



Bloc maxima : example



A too simple model?

Assume that the period length is one year, which corresponds to take

$$Y_i = \max_{k=1,\ldots,365} \{Z_{k,i}\},$$

where $Z_{i,j}$ for a fixed value of i are iid rv's representing the daily maximum height of the river for example.
Y_i is assumed to be GEV distributed. One just needs to estimate parameters of the GEV (by ML or PWM methods) to be able to obtain an estimation of p.

Problems with this model:

- not realistic: $B_{i,j} \perp Y_i$??
- we need claims to estimate quantities of interest...

The model with dependence

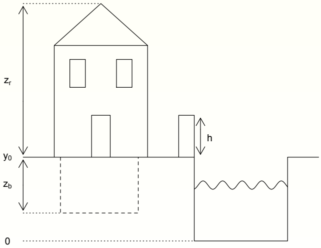
We assume now that

$$B_{i,j} \sim \begin{cases} B(p_{i,j}, 1 - p_{i,j}), & \text{if } Y_i > y_0 + h, \\ \delta_1, & \text{if } Y_i > y_0 + z_{r,j}, \end{cases}$$

where δ_a is the Dirac mass in a,

$$p_{i,j} = \frac{Y_i - y_0 + z_{b,j}}{z_{r,j} + z_{b,j}},$$

$z_{r,j}$ is the height of the j-th building and $z_{b,j}$ is the deepness of the basement.



- **Remark** $z_{r,j}$ should be seen as the level above y_0 that will lead to the total destruction of the building: if the building is well constructed, $z_{r,j}$ is simply the height of the building; if it is built in paper, $z_{r,j} = 1cm$.

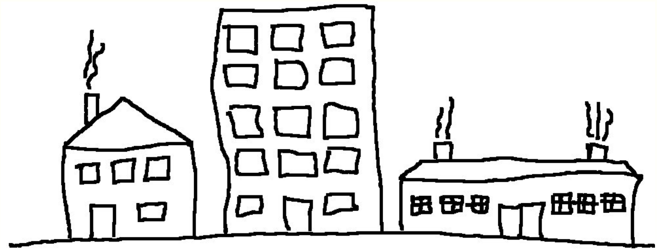
- As in the simpler model, we can get $\mathbb{E}(S_i)$, $\mathbb{V}(S_i)$, cdf, VaR, TVaR..., where

$$S_i = \sum_{j=1}^{m} X_{i,j}$$

corresponds to the aggregate amount of damage due to the flood on time period i.

An example

- $Y_i = \max_{k=1,\dots,365} Z_k$ where $Z_k \sim \mathcal{N}(2,1)$, $y_0 = 5$.
- Portfolio with 3 risks: $z_{r,1} = 6$, $z_{r,2} = 15$, $z_{r,3} = 4$; $c_1 = 1$, $c_2 = 15$, $c_3 = 4$.
- Evolution of $\mathbb{E}(S_i)$ as a function of h.
- We have 100 years of records.



Evolution of $E(S_i)$ as a function of h

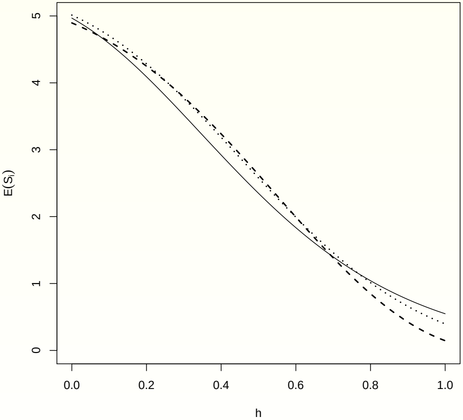


Figure: Evolution of $\mathbb{E}(S_i)$ as a function of h: true value (solid line) and estimations obtained by the GPWM (dashed line) and ML (dotted line) methods.

Ruin probability

- We are interested in the behavior of the surplus process. In the present paper, we define this surplus as a safety account set up for a specific portfolio dedicated to the ruin.
- An initial amount u of capital is allocated to the specific portfolio and an annual amount π of premium will be allocated to the portfolio.

$$\pi = (1 + \eta)\mathbb{E}(X)$$

Ruin probability

- Let $\underline{U} = \{U_k,\ k \in \mathbb{N}\}$ be the surplus process of the insurance portfolio where U_k corresponds to the surplus level at time k. For $k = 0$, $U_0 = u$ and

$$U_k = U_{k-1} + \pi - X_k = u - \sum_{j=1}^{k} (X_j - \pi)$$

- We denote by the r.v. τ the time of ruin where :

$$\tau = \begin{cases} \inf_{k=2,3,\dots} \{k,\ U_k < 0\}, & \text{if } U_k < 0 \text{ at least one time,} \\ \infty & \text{if } U_k \text{ never goes below } 0 \end{cases}$$

Ruin probability

- The finite time ruin probability is defined by

$$\psi(u,n) = \mathbb{P}(\tau \leq n \| U_0 = u)$$

while the infinite time ruin probability is

$$\psi(u) = \mathbb{P}(\tau \leq \infty \| U_0 = u)$$

- Alternative ruin probability : we want to compute the probability that the level of the safety account is high enough to pay the total property damage at the occurrence of the next flood.

Ruin probability

For a sequence of independent r.v. $\{Y_j, j \in \mathbb{N}\}$, we have

$$\psi(u) = \sum_{k=1}^{\infty} f_T(k)\mathbb{P}(X_k > u + k\pi \| Y_k > y_0 + h)$$

where

$$f_T(k) = \begin{cases} \overline{F}_{Y_1}(y_0 + h) & k = 1 \\ \overline{F}_{Y_k}(y_0 + h) \prod_{j=1}^{k-1} F_{Y_j}(y_0 + h) & k = 2, 3, .. \end{cases}$$

$\Rightarrow$ can be easily adapted to climate change (with non stationary sequence of Y_i) or with interest rate, inflation...

Conclusions

- Climatologist and climate indicators can be useful!
- The dyke should be seen as prevention : how much can I spend in prevention?
- It is important to get an accurate estimate of flooding risk! Cost of natural events may be huge for insurance companies...
- The model we propose is simple but...
- Possible to include climate change by the Y variable...

Conclusions

Gracias por su atención