Insurance and reinsurance markets and climate risks

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Insurance and Adaptation to Climate Change

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Agenda of the talk

- Some stylized facts, and figures,
- What means "*climate risks*": catastrophes and new risks,
- Insurance and insurability: what is insurance ?
- Insurance against natural catastrophes: insuring large and nonindependent risks,
- Transferring large risks: reinsurance and ART (captives, finite, cat bonds, cat options),
- Climate change and insurance in a changing environment: modeling natural hazard, modeling economic losses, modeling insurance losses.

Some stylized facts

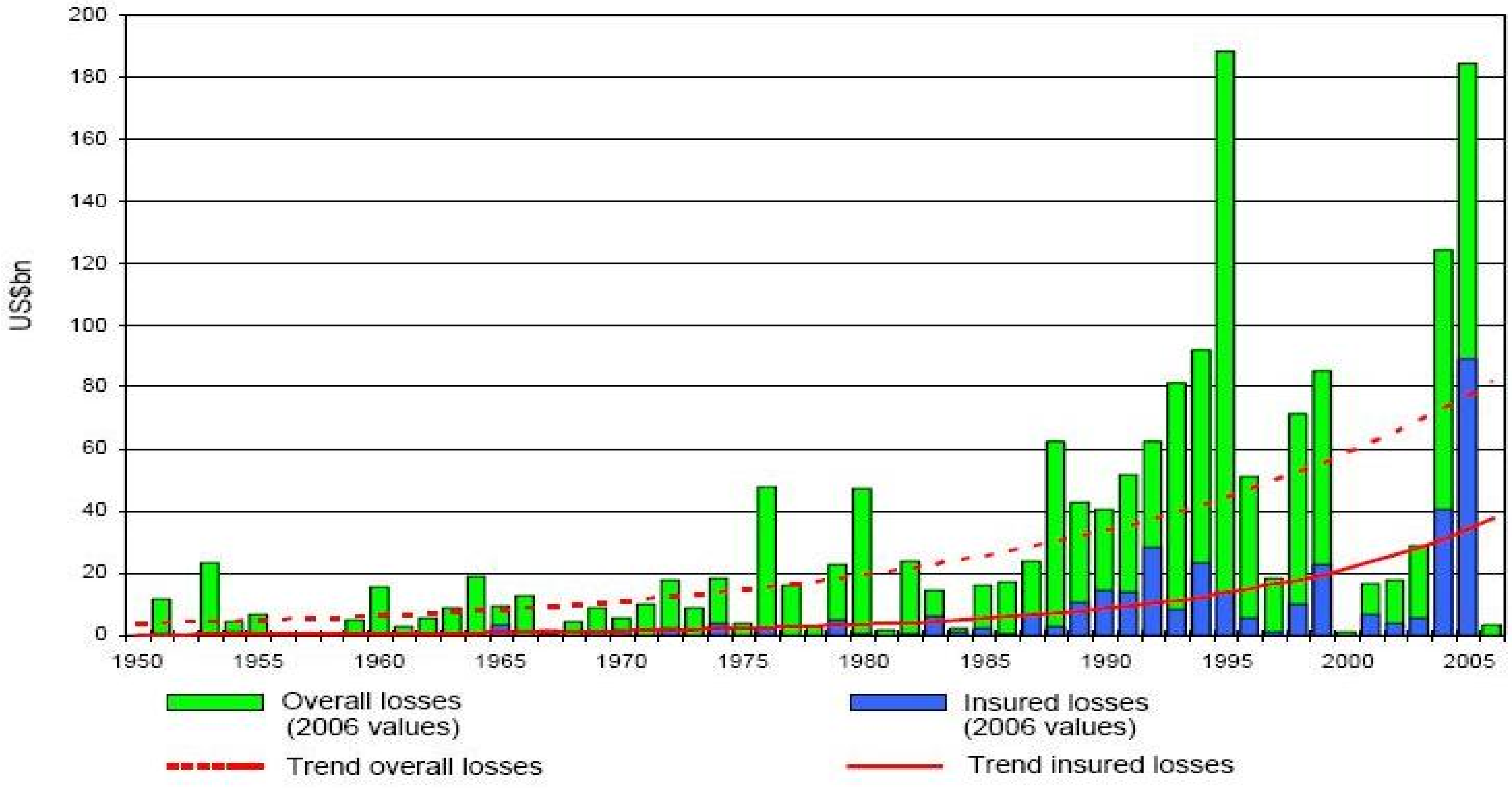


Figure 1: Major natural catastrophes (from Munich Re (2006).)

Some stylized facts

Date	Loss event	Region	Overall losses	Insured losses	Fatalities
25.8.2005	Hurricane Katrina	USA	125,000	61,000	1,322
23.8.1992	Hurricane Andrew	USA	26,500	17,000	62
17.1.1994	Earthquake Northridge	USA	44,000	15,300	61
21.9.2004	Hurricane Ivan	USA, Caribbean	23,000	13,000	125
19.10.2005	Hurricane Wilma	Mexico, USA	20,000	12,400	42
20.9.2005	Hurricane Rita	USA	16,000	12,000	10
11.8.2004	Hurricane Charley	USA, Caribbean	18,000	8,000	36
26.9.1991	Typhoon Mireille	Japan	10,000	7,000	62
9.9.2004	Hurricane Frances	USA, Caribbean	12,000	6,000	39
26.12.1999	Winter storm Lothar	Europe	11,500	5,900	110

Table 1: The 10 most expensive catastrophes, 1950-2005 (from Munich Re (2006).

What means "*climate risks*"

Climate risks are risks induced by climate change:

- impact on natural catastrophes: frequency and severity, some possible solvency problems,
- impact on health: "*new*" risks because of "*new*" diseases,
- impact on agriculture: economic implications of climate change,
- ...

"*climatic risk in numerous branches of industry is more important than the risk of interest rates or foreign exchange risk*" (AXA 2004, quoted in Ceres (2004)).

Climate change and sanitary impact

Figure 2: Disease outbreaks during the 1997-98 El Nio.

abnormally *wet* areas, abnormally *dry* areas, dengue fever, malaria, Rodent-borne: hantavirus pulmonary syndrome and water-borne (cholera).

Climate change and sanitary impact

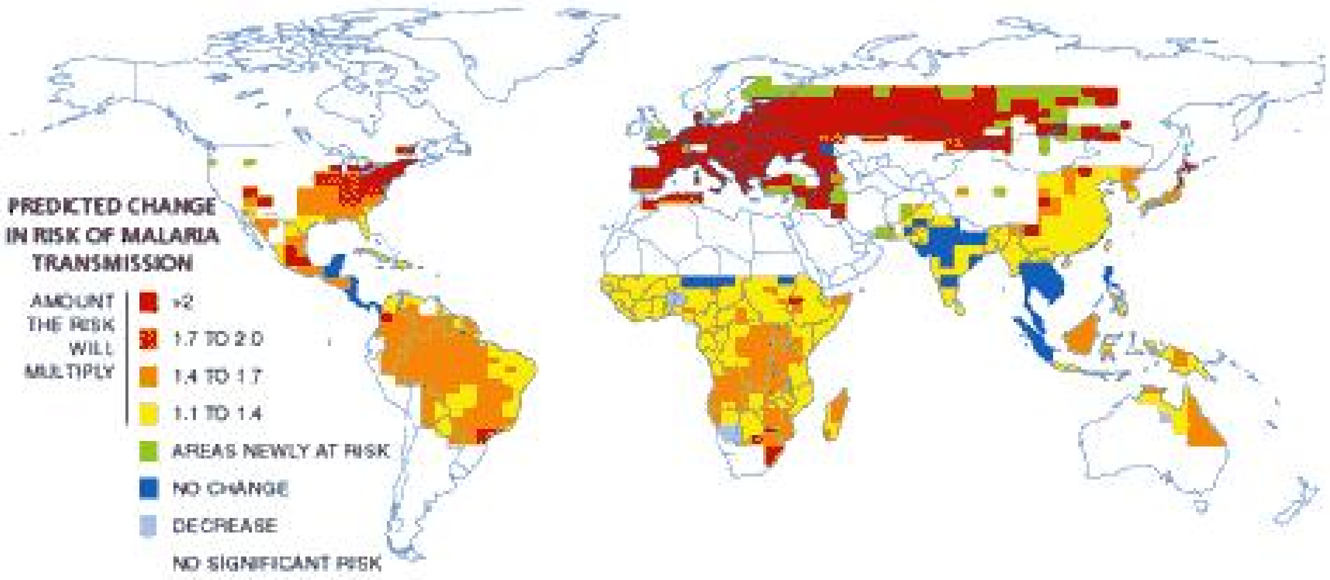


Figure 3: Risk of malaria transmission (from Epstein (2000)).

Agricultural Insurance: climate and ecosystems

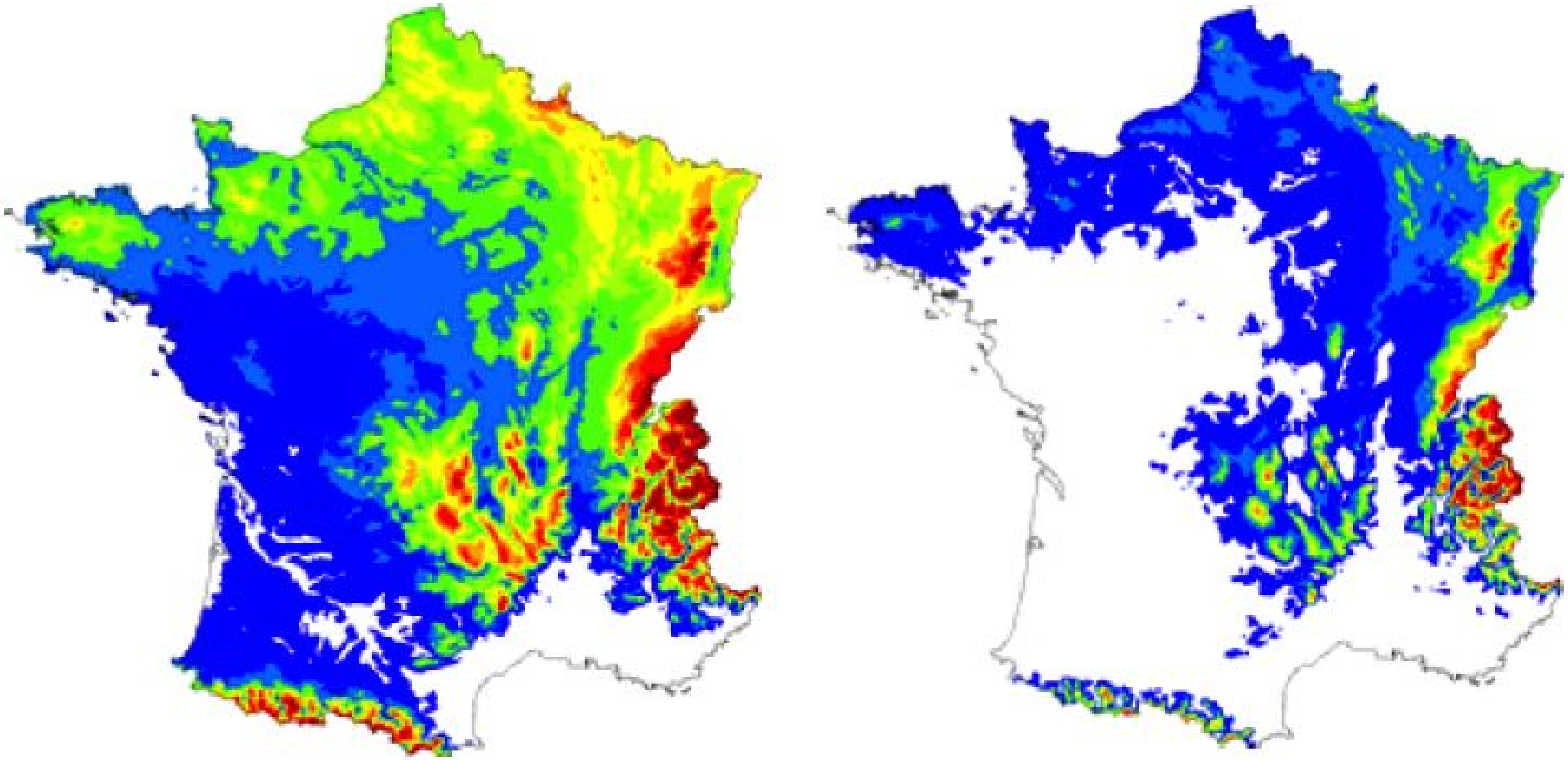


Figure 4: Impact of climate change: repartition of some vegetal species.

Primary insurance

Insurance is "*the contribution of the many to the misfortunes of the few*".

Some risk adverse agents (*insured*) are willing to pay even more than the actual value of the (predictable) risk to transfer its consequences to another agent (*insurer*).

Notion(s) of insurability: when can we sell/buy insurance ?

1. judicially, an insurance contract can be valid only if claim occurrence satisfy some randomness property,
2. the "*game rule*" (using the expression from Berliner (1982), i.e. legal framework) should remain stable in time.

Those two notions yield the concept of "*legal*" insurability,

3. the possible maximum loss should not be huge, with respect to the insurer's solvency,
4. the average cost should be identifiable and quantifiable,
5. risks could be pooled so that the law of large numbers can be used (independent and identically distributed, i.e. the portfolio should be homogeneous).

These three notions define the concept of "*actuarial*" insurability.

Notion(s) of insurability: when can we sell/buy insurance ?

6. there should be no moral hazard, and no adverse selection,
7. there must exist an insurance market, in the sense that offer and demand should meet, and a price (equilibrium price) should arise.

Those two last points define the concept of "*economic*" insurability, also called "*market imperfections*" by Rochet (1998).

Are natural catastrophes insurable ?

1. [...] claim occurrence satisfy some randomness property

In France (law n°82-600 13^{th} of July 1982), Article 1

"*sont considérés comme les effets des catastrophes naturelles au sens de la présente loi, les dommages matériels directs ayant eu pour cause déterminante l'*intensité anormale d'un agent naturel*, lorsque les mesures habituelles à prendre pour prévenir ces dommages n'ont pu empêcher leur survenance ou n'ont pu être prises*".

What means "abnormal intensity of natural hazard" ?

Is it abnormal to have recurrent floods in some areas easily flooded (in a former river channel) ?

3. [...] the possible maximum loss should not be huge

4. [...] average cost [...] identifiable and quantifiable,

Problem when modeling large claims (industrial fire, business interruption, *natural catastrophes*,...): extreme value theory framework.

The Pareto distribution appears naturally when modeling observations over a given threshold,

$$F(x)=\mathbb{P}(X\leq x)=1-\left(\frac{x}{x_0}\right)^b,\text{ where } x_0=\exp(-a/b)$$

Remark: if $-b\geq 1$, then $\mathbb{E}_{\mathbb{P}}(X)=\infty$, the pure premium is infinite.

Then equivalently $\log(1-F(x))\sim a+b\log x$, i.e. for all $i=1,...,n$,

$$\log(1-\widehat{F}_n(X_i))\sim a+b\log X_i.$$

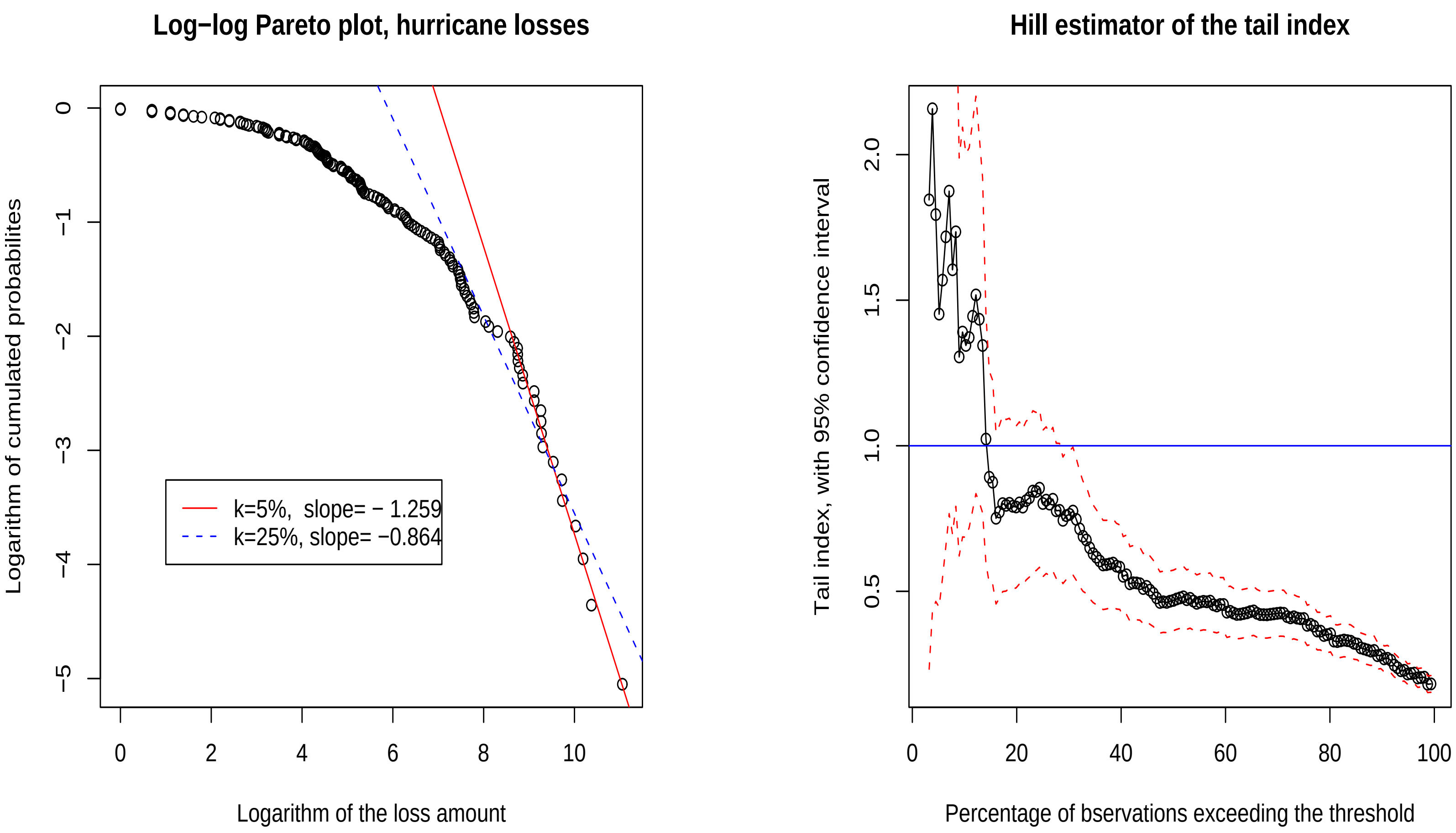


Figure 5: Pareto modeling of hurricanes losses (Pielke & Landsea (1998)).

5. [...] the law of large numbers can be used

Within an homogeneous portfolios (X_i identically distributed), sufficiently large ($n \rightarrow \infty$), $\dfrac{X_1 + \ldots + X_n}{n} \rightarrow \mathbb{E}(X)$. If the variance is finite, we can also derive a confidence interval (solvency requirement), if the X_i's are independent,

$$\sum_{i=1}^{n} X_i \in \left[n\mathbb{E}(X) \pm \underbrace{2\sqrt{n}\text{Var}(X)}_{\text{risk based capital need}} \right] \text{ with probability 99\%.}$$

Nonindependence implies more volatility and therefore more capital requirement.

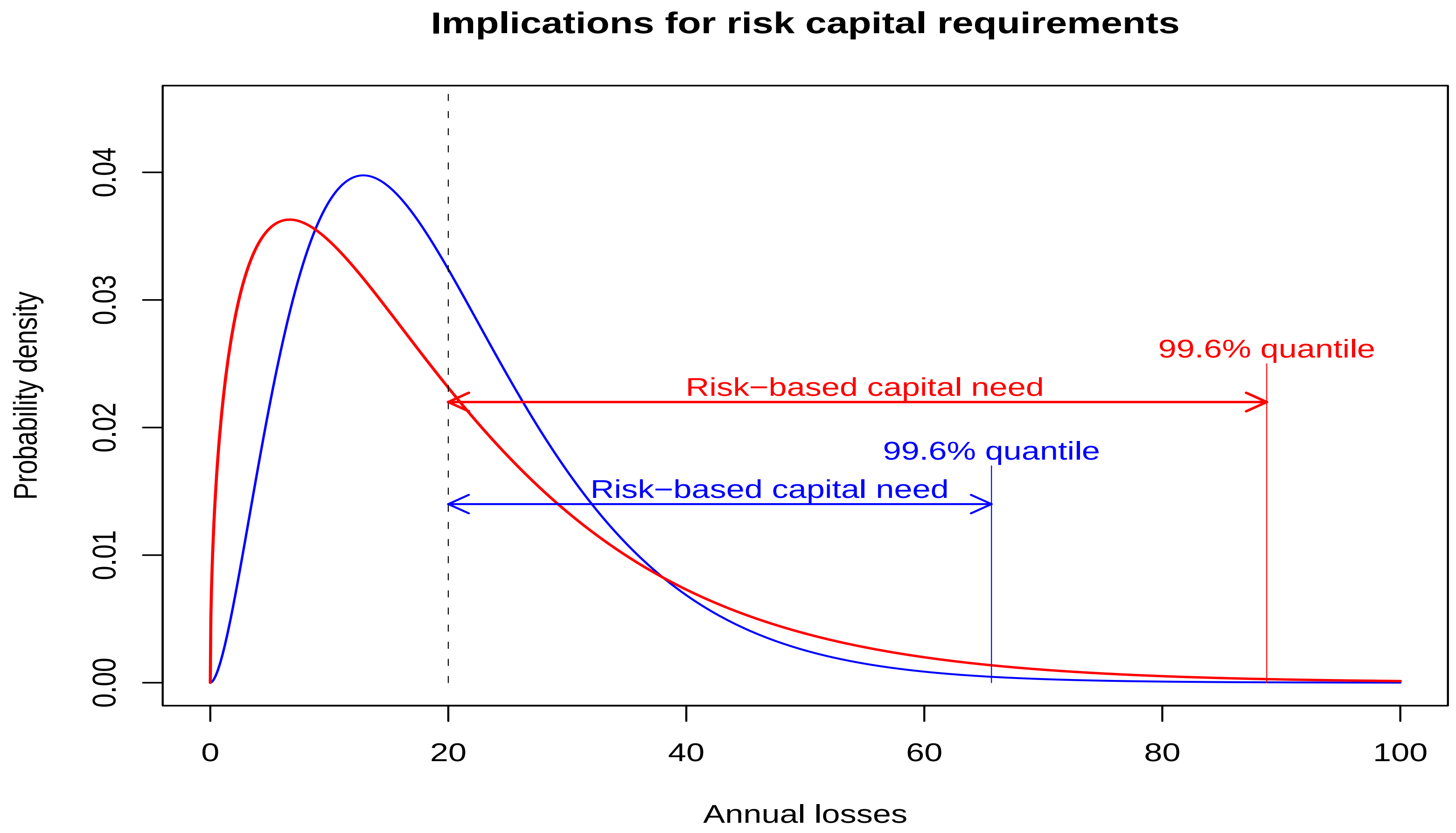


Figure 6: Independent versus non-independent claims, and capital requirements.

6. [...] no moral hazard and no adverse selection

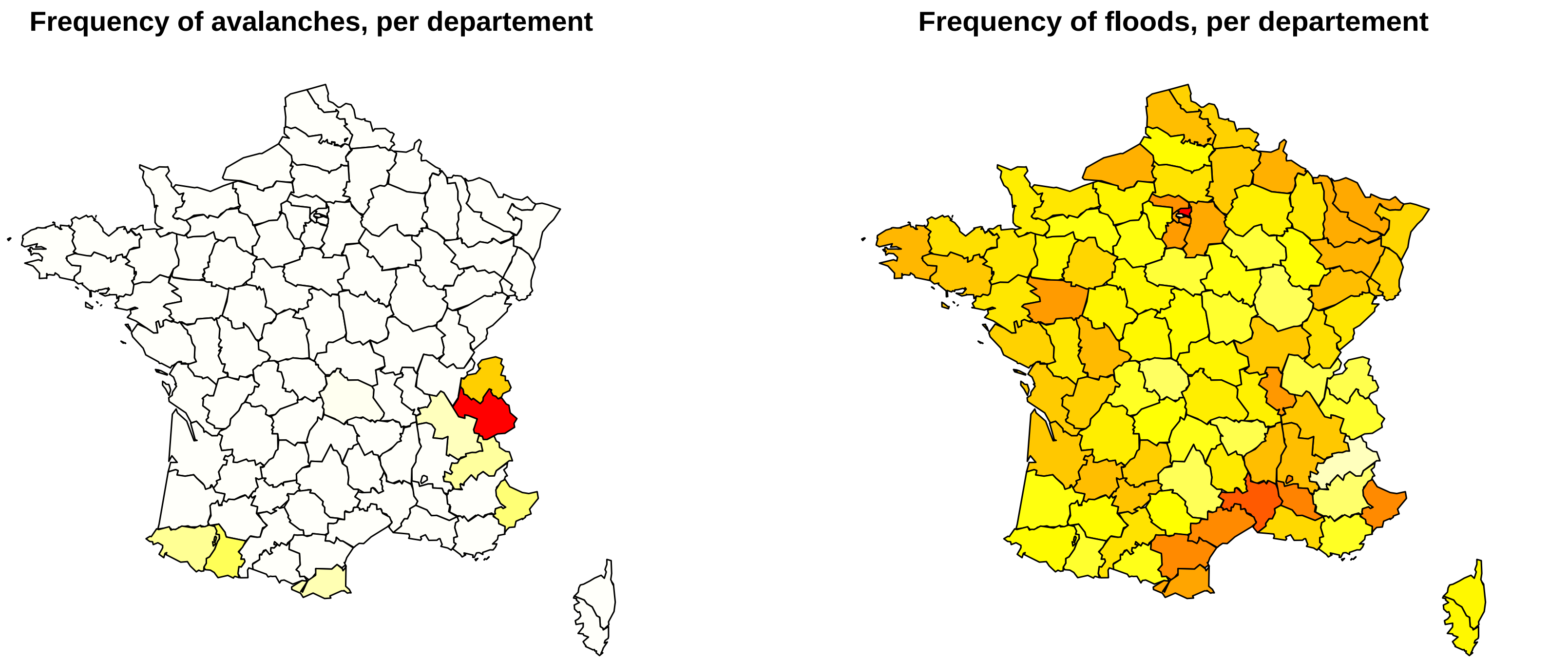


Figure 7: The frequency of "*arrêté Cat Nat*" (avalanches and flood).

7. [...] there must exist an insurance market

Natural catastrophe risk is a low probability risks, hardly predictable.

Consider the following example, from Kunreuther & Pauly (2004):

"*my dwelling is insured for $ 250,000. My additional premium for earthquake insurance is $ 768 (per year). My earthquake deductible is $ 43,750... The more I look to this, the more it seems that my chances of having a covered loss are about zero. I'm paying $ 768 for this ?*" (Business Insurance, 2001).

- annual probability of an earthquake in Seattle $1/250 = 0.4\%$,
- actuarial implied probability $768/(250,000 - 43,750) \sim 0.37\%$

It is a *fair* price

Reinsurance: excess of loss treaties

In reinsurance excess of loss (stop loss) treaties, the reinsurer undertakes the upper layer of the risk, after a certain attachment point.

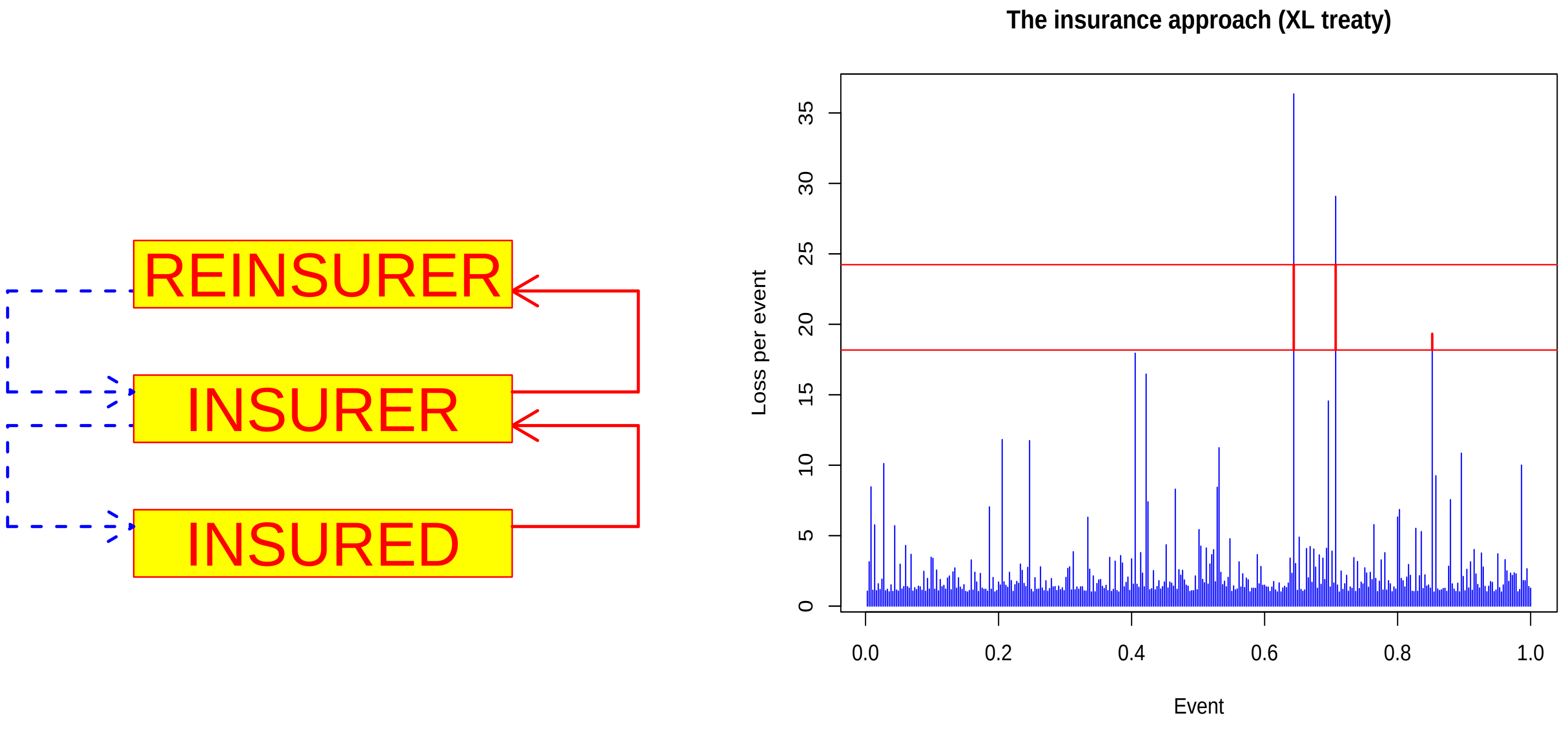


Figure 8: The XL reinsurance treaty mechanism.

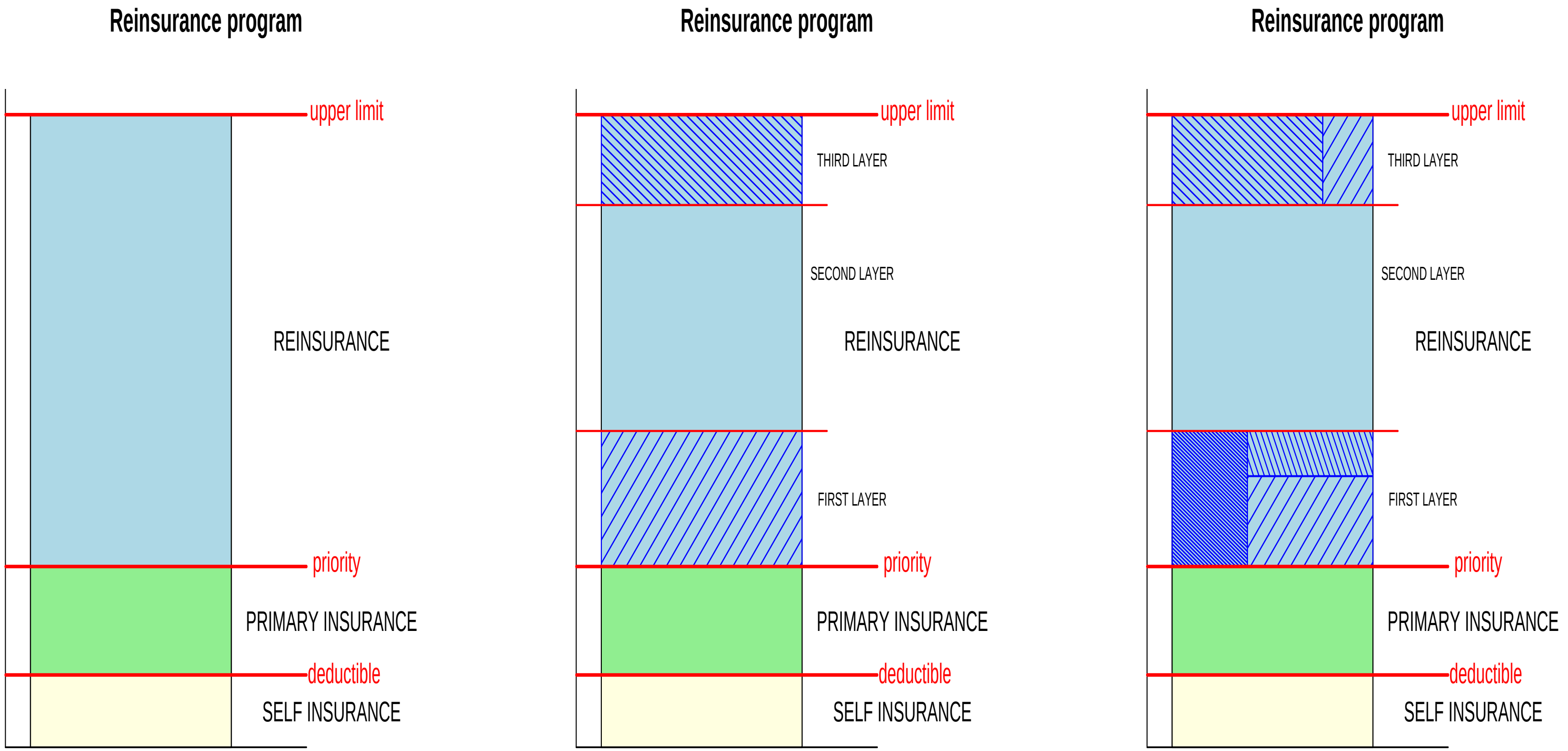
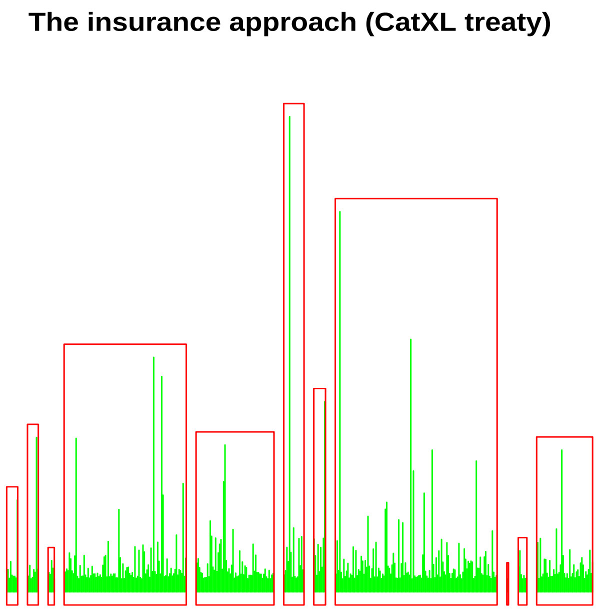


Figure 9: Evolution of reinsurance programs.

Reinsurance: *cat* excess of loss treaties

The main difficulty is to define precisely the event or a single natural event.



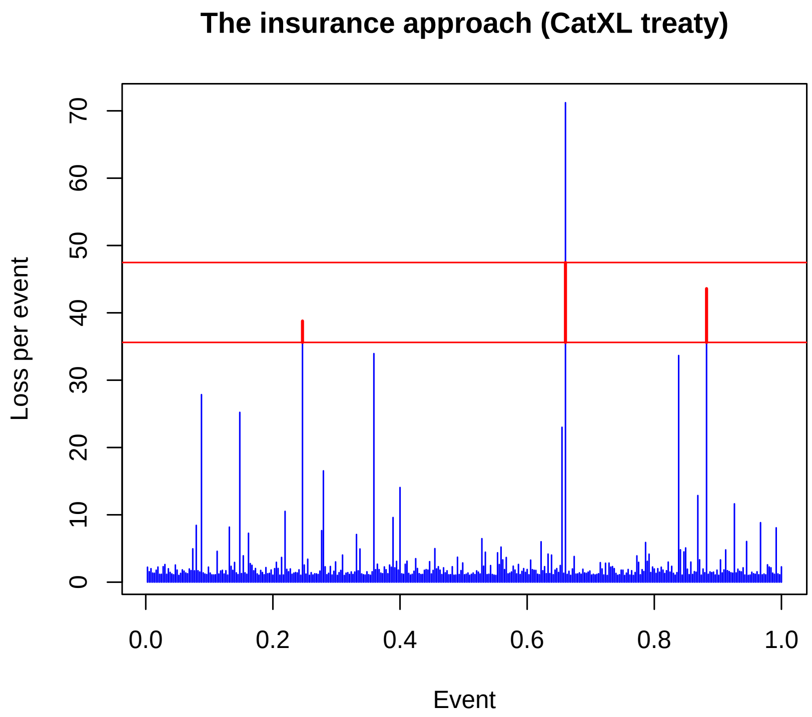


Figure 10: The Cat XL reinsurance treaty mechanism.

Captives

Purpose: provide insurance coverage for their owners (cf self-insurance).
Enhances the capability to purchase excess insurance and provides a direct access to the reinsurance marketplace.

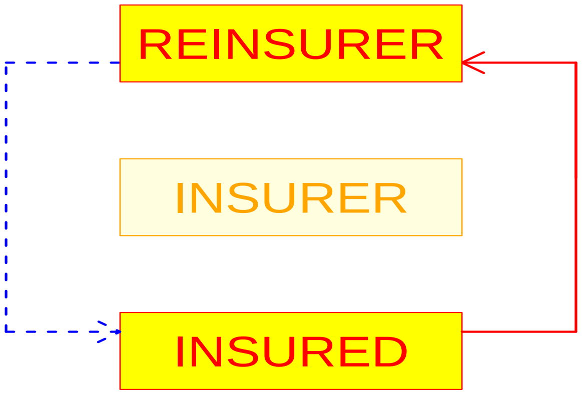


Figure 11: The captive mechanism.

Insurance derivatives (cat bonds)

Cat bonds are interesting since they help to increase capacity in the market, but are expensive to set up.

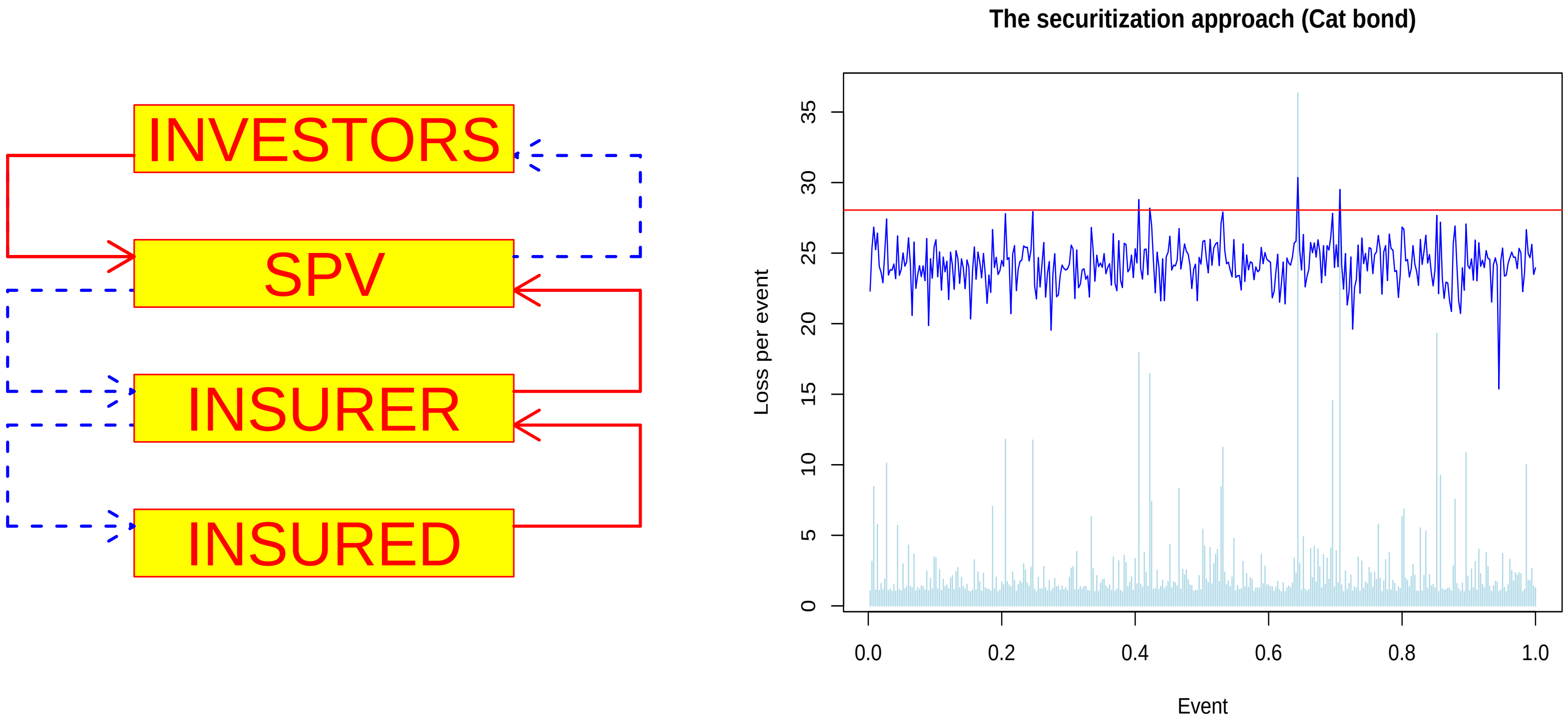


Figure 12: The securitization mechanism, parametric triggered cat bond.

The trigger is either based on a environmental index (Richter index, precipitation levels, windspeeds, temperatures...) or a claim based index.

Insurance derivatives (cat options)

Those indices can also be used for options.

Exchange-traded catastrophe options are standardized contracts bought and sold through an organized market.

"*Unlike traditional options, catastrophe options give the purchaser the right to obtain a cash payment if a specified index of catastrophe losses reaches a specified level - the strike price*".

Example *CBOT's PCS Catastrophe Insurance Options*

Those options are hardly priced (arbitrage pricing cannot be used).

For index based products (risky bonds or options), there is an additional risk of noncorrelation between the physical and the loss triggers (rarely a perfect hedge).

“the government as the ultimate risk manager”

Especially in France, where there is an unlimited government guarantee for catastrophes provided through the Caisse Centrale de Réassurance (national program covering floods, subsidence, earthquakes and avalanches).

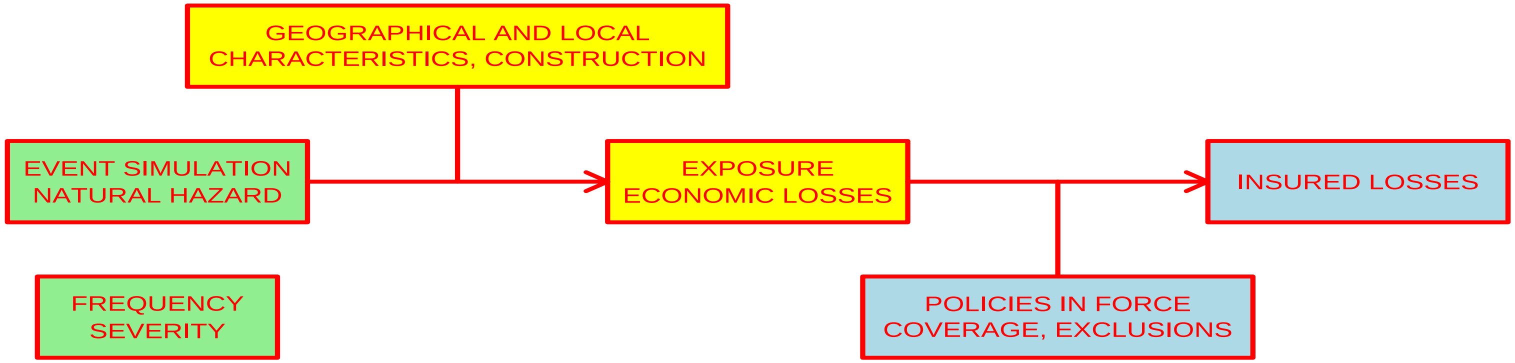
Also the case in other countries in Europe (Spain, Norway, Switzerland) and in the U.S. (for flood risks).

Remark: *some risk financing instruments can also be considered (catastrophe tax, government debt instruments, international loans), but it is not insurance anymore.*

Insuring in a changing environment ?

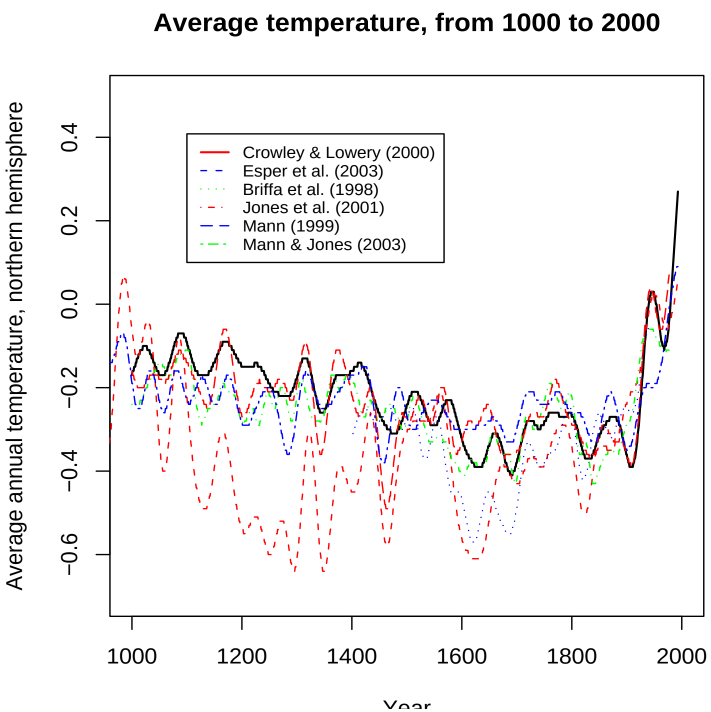
Need for accurate loss models based on environmental series.

Classical statistical problem of forecasting.



Insuring in a changing environment ?

How fast is climate changing ? perhaps quicker than previously anticipated.



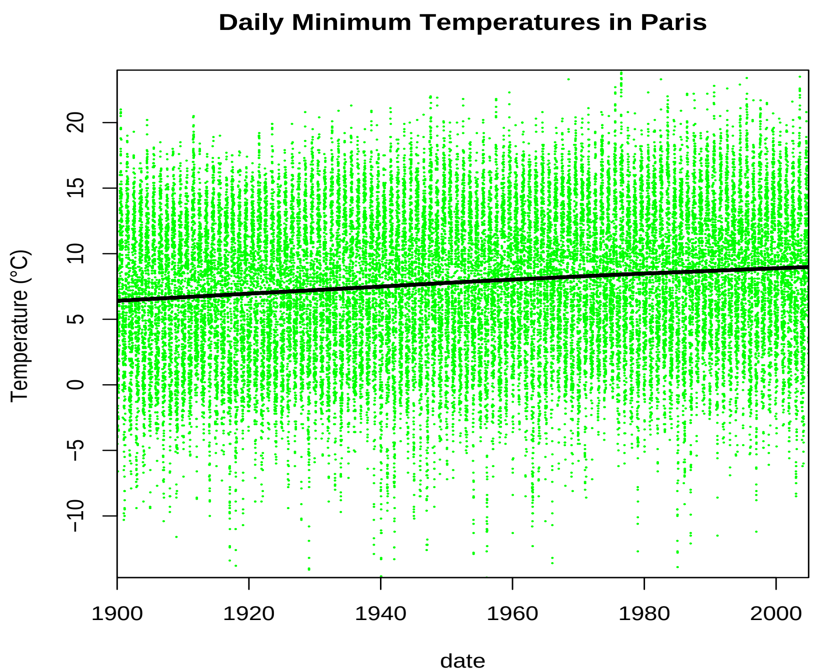


Figure 13: Global warming and climate change: modeling temperature

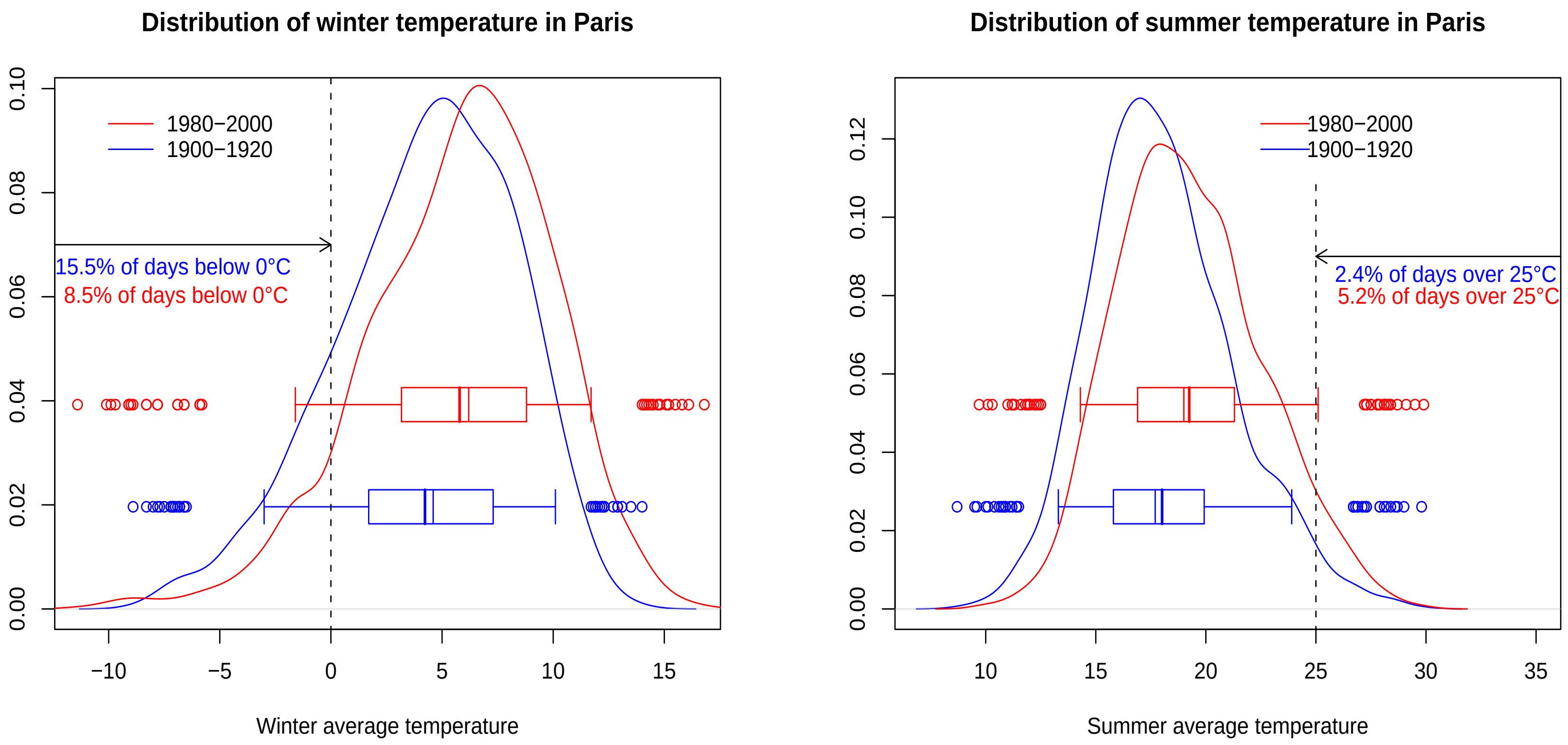


Figure 14: Summer and winter temperature in Paris, 1900-1920 versus 1980-2000.

Climate change and storms

Increase of wind related losses from hurricanes in the U.S., typhoons in Japan and storms in Europe.

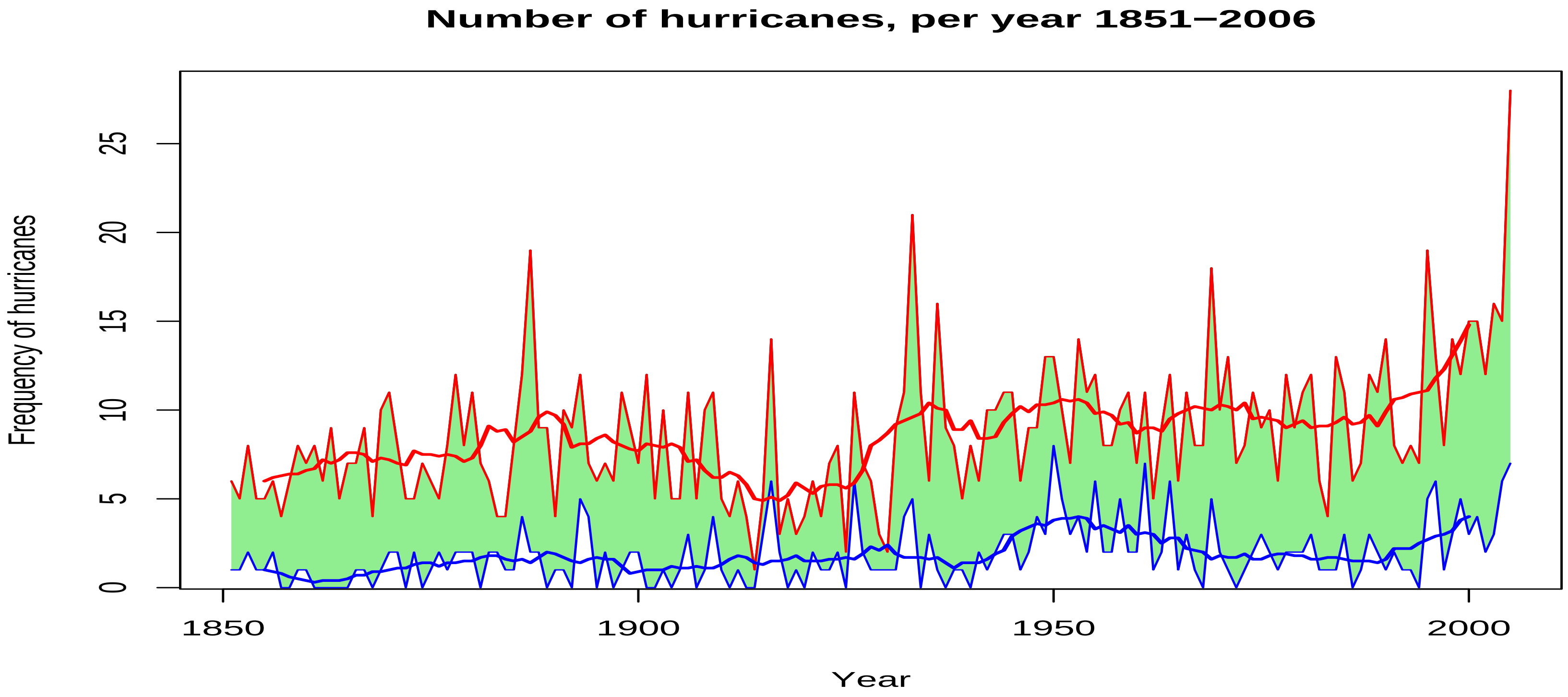


Figure 15: Number of hurricanes and major hurricanes per year.

Climate change and storms

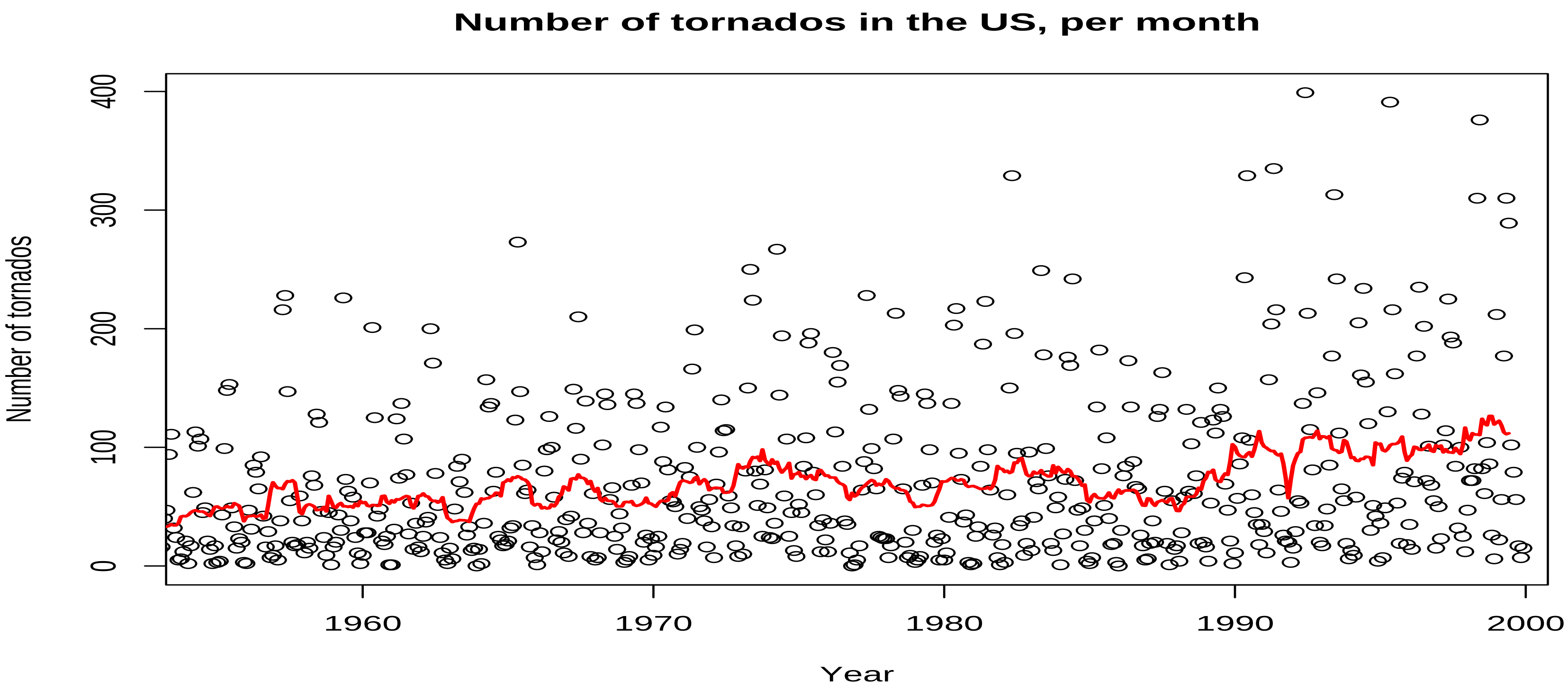


Figure 16: Number of tornadoes (from `http://www.spc.noaa.gov/archive/`).

From natural events to economic losses

The increase in population and infrastructure densities in urban centers and vulnerable regions multiply the size of maximum potential losses.

One has to look for all possible effects of climate change (negative and positive).

From Mills, Roth & Lecomte (2005), ▲ means *increased losses*, and ▼ *reduced losses*,

examples of projected impact	peril hazard	property industrial	property auto marine	liability business interrup.	health	life
Higher maximum temperatures, more hot days						
hospitalizations, death, serious illness	heatwave				▲	▲
soil subsidence	subsidence	▲		▲		
decreased ice in maritime lanes	float ice		▼			
increase roadway accident (reaction time)	accidents		▲			
increased electric cooling demand	power outage			▲		
Higher minimum temperatures, less cold days						
decrease cold related mortality	coldwave				▼	▼
extend activity of some pests	infestation	▲		▲	▲	▲
avalanche risk	avalanche	▲		▲		
permasfrost melt	subsidence	▲		▲		
Increased summer drying						
damage to building foundations	subsidence	▲				
decrease water resource quantity	drought			▲	▲	
increase risk of wildfire	wildfire	▲	▲	▲	▲	▲

From natural events to economic losses: hurricanes

"*the Saffir-Simpson Scale is designed to measure the potential damage of a hurricane to man-made structures* [...] *if the speed of the hurricane is above 156 mph (category 5), then the damage to a building will be serious no matter how well it's engineered.*"

category	sustained winds	central pressure	storm surge	*relative potential destruction*	examples
category 1	118 to 153 km/h	>980	1.2 to 1.5 m	1	Stan (2005)
category 2	154 to 177 km/h	965-679	1.8 to 2.4 m	10	Juan (2003)
category 3	178 to 210 km/h	945-964	2.7 to 3.7 m	50	Ivan (2004)
	some structural damage to small residences and utility buildings,				Jeanne (2004)
	with a minor amount of curtainwall failures				Beta (2005)
category 4	210 to 249 km/h	920-944	4.0 to 5.5 m	100	Floyd (1999)
	extensive curtainwall failures with some complete roof structure failure				Charley (2004)
	on small residences, terrain may be flooded well inland				Dennis (2005)
category 5	More than 249 km/h	<920	over 5.5 m	250	Emily (2005)
	complete roof failure on many residences and industrial buildings				Katrina (2005)
	flooding causes major damage to lower floors, near the shoreline				Rita (2005)
	massive evacuation of residential areas may be required				Wilma (2005)

Table 2: The Saffir-Simpson hurricane scale.

From natural events to economic losses: earthquakes

Richter's scale quantifies the size of an earthquake the epicenter.

Medvedev-Sponheuer-Karnik or Mercalli are related to earthquake occurrences,

degree	description
The Mercalli scale	
category 7 (very strong)	difficult to stand, furniture broken, damage negligible in building of good design
category 8 (destructive)	damage slight in specially designed structures
category 9 (ruinous)	general panic and damage considerable in specially designed structures
category 10 (disastrous)	some well built structures destroyed
category 11 (very disastrous)	few masonry structures remain standing, bridges destroyed
category 12 (catastrophic)	total damage, almost everything is destroyed
The Medvedev-Sponheuer-Karnik scale	
category 7 (very strong)	most people are frightened and try to run outdoors
category 8 (damaging)	many people find it difficult to stand, even outdoors, furniture overturned
category 9 (destructive)	general panic, people thrown to the ground, substandard structures collapse
category 10 (devastating)	masonry buildings destroyed, infrastructure crippled. Massive landslides
category 11 (catastrophic)	most buildings and structures collapse
category 12 (very catastrophic)	all surface and underground structures completely destroyed

Table 3: The Mercalli and Medvedev-Sponheuer-Karniks scales.

From economic to insured losses

The exposure for an insurance company is difficult to model.

The CRESTA was set up by the insurance industry in 1977, and CRESTA zones have been defined, related to insurance exposure.

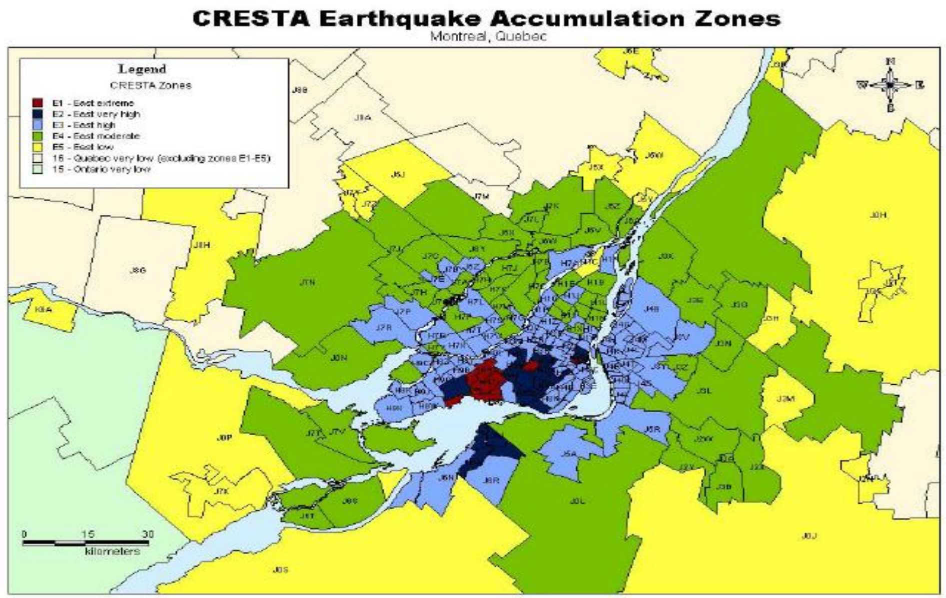


Figure 17: The use of CRESTA zones to model exposure, in Montreal.

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