Introduction to catastrophe modelling

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CONTACT

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- **Experiences:**
  - IENM 2007 – 2011
  - PhD – LSCE/CEA – Paris, Saclay
  - Cat Modeler – AXA – 2016-2020
    - Development of CAT models for a better understanding of windstorms risks in Europe and hurricane risks in Mexico de modèles CAT pour une meilleure connaissance du risque tempête en Europe, ouragan au Mexique.
  - Since 2020 – Quantititative weather analyst in energy trading

CONTENTS

Basics on Insurance and Reinsurance

INSURANCE AND REINSURANCE

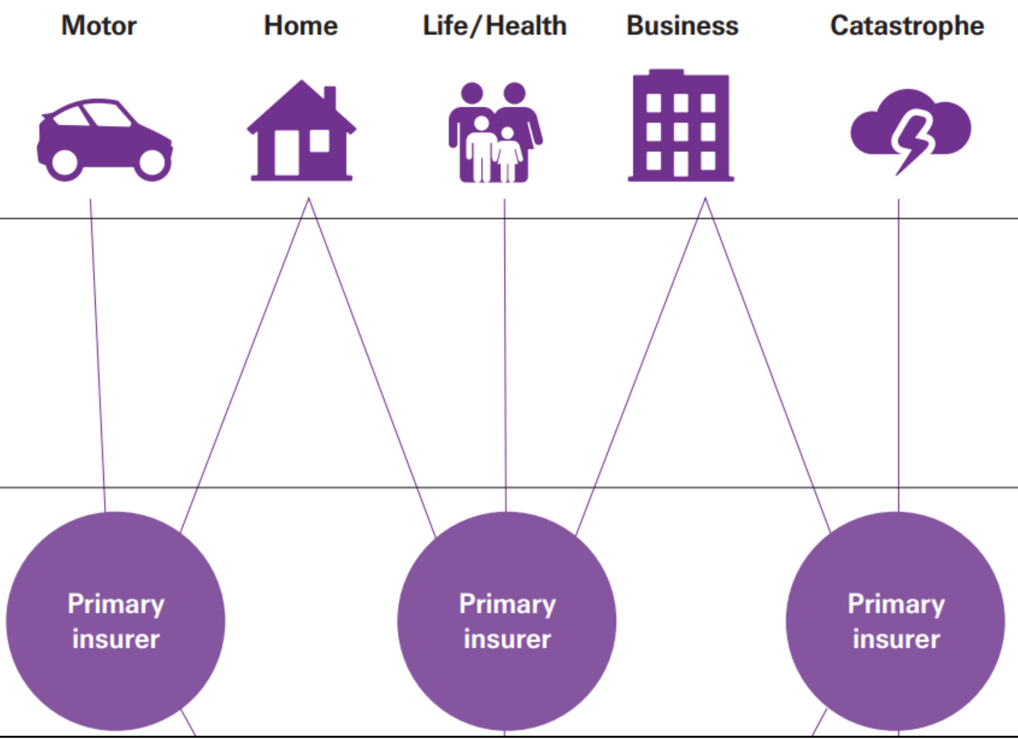
Insurance

- The basic concept of insurance is that one party, the **insurer**, will guarantee **payment** for an uncertain future event. Meanwhile, another party, the **insured** or the policyholder, pays a smaller **premium** to the insurer in exchange for that protection on that uncertain future occurrence.
- **Life insurance** companies focus on legacy planning and replacing human capital value, **health insurers** cover medical costs, and **property**, casualty, or accident insurance is aimed at replacing the value of homes, cars, or valuables.

- How do we handle risk ?
  - ***Avoidance****: Choosing not to participate in an activity because of the risk involved, e.g. not getting a driver's license;*
  - ***Retention****: Saving money in case of future losses, e.g. putting $1000 in a savings account in case of a car accident;*
  - ***Transfer****: Passing the risk on to an insurance company, e.g. paying a monthly fee for an insurance policy and expecting the insurance company to protect your assets.*

RISK TRANSFER IN INSURANCE

Insured risks
Individuals and corporates are looking to insure against specific risks relating to:



- Each party transfers a portion of the risk by paying a premium
- In return the primary insurer safeguards individuals and corporates

Primary insurance
Insurance companies

INSURANCE – MANAGEMENT OF RISKS

- Several types of risks
  - Natural (flooding, drought, windstorms, etc.)
  - Health (epidemic, disease, etc.)
  - Social (criminality, war, etc.)
  - Economical (unemployment, financial crisis)
  - Political (riots, etc.)
  - Environmental (pollution, nuclear accident, etc.)
- Potential consequences of these risks
  - Financial losses
  - Property damages
  - Temporary or permanent disability
  - Death

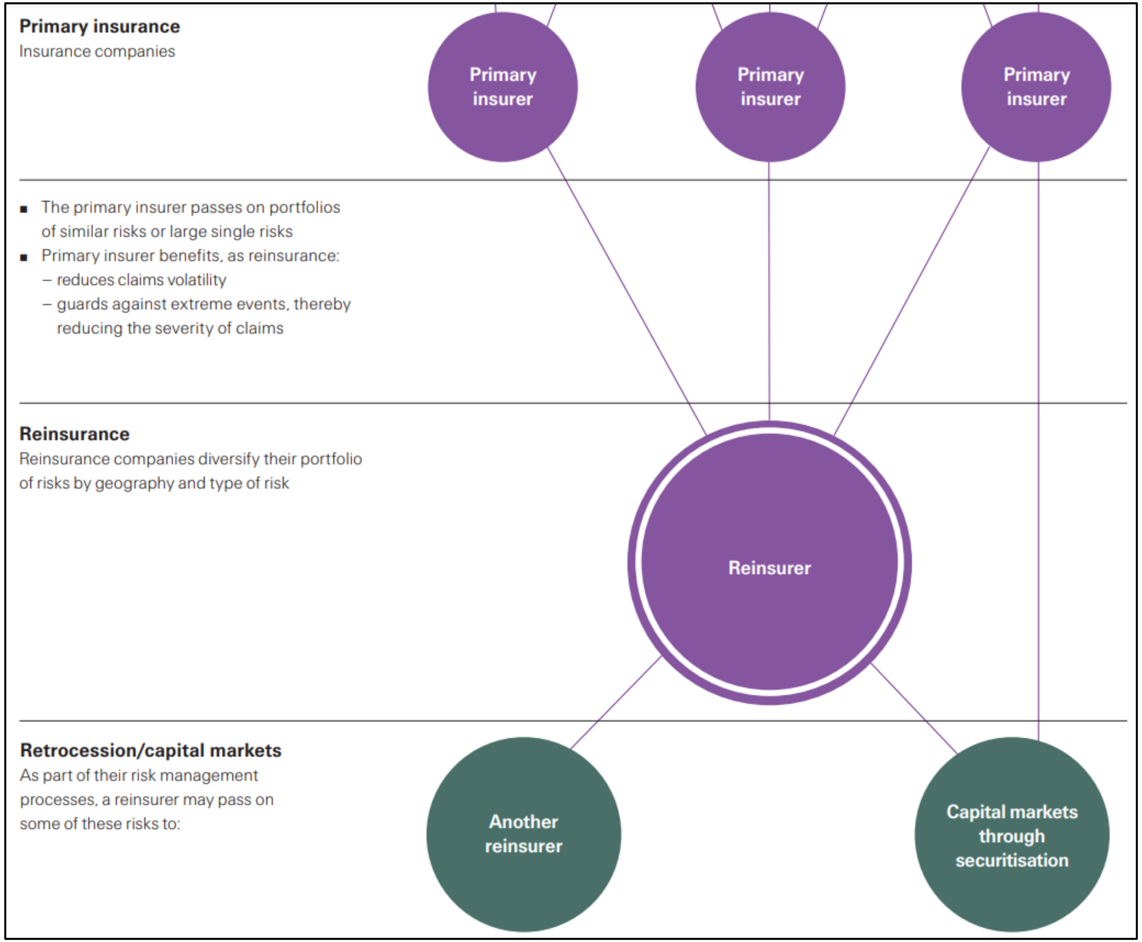
BASICS ON REINSURANCE

Reinsurance

- Described as "insurance of insurance companies" by the Reinsurance Association of America
- The main idea is that no insurance company has too much exposure to a particularly large event or disaster.
- For example, consider a massive hurricane that makes landfall in Florida and causes billions of dollars in damage. If one company sold all the homeowners insurance, the chance of it being able to cover the losses would be unlikely. Instead, the retail insurance company spreads parts of the coverage to other insurance companies (reinsurance), thereby spreading the cost of risk among many insurance companies.

- 2 main categories of reinsurance contracts: treaty or facultatives.
- Facultatives refer to single risks. They require detailed contracts and individual, facultative solutions.
  - *Example: a complex factory or a large hotel with swimming pools, night clubs, ..*
- Treaties refer to portfolio of risks. Insurers and reinsurers are obliged to cede and accept the risks on a predetermined basis
  - *Proportional reinsurance means the insurer and reinsurer share premiums and losses by a defined ratio.*
  - *Non-proportional reinsurance covers losses that exceed the insurers' deductible up to an agreed cover limit.*

RISK TRANSFER IN REINSURANCE



ASSURANCE ET REASSURANCE

Example of several insurance and reinsurance companies

- Insurance companies
  - → **Allianz** : 92 millions of clients ; 130.6€ billions of turnover
  - → **AXA** : 107 millions of clients
  - → **Groupama** : leader in agricultural insurance and local collectivities
  - → **Generali** : 1st Italian insurer
  - → **COVEA**

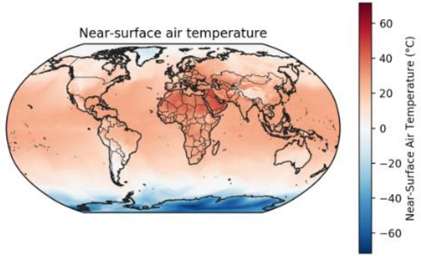
- Reinsurance companies
  - → **Munich Re**
  - → **Swiss Re**
  - → **SCOR** : French reinsurance
  - → **CCR** : caisse centrale de réassurance hold at 100% by the French state

WEATHER & INSURANCE

Weather and climate data are fundamental for insurance

Satellite data

Reanalysis (ERA-5, MERRA, NCEP,…)



(1) Manage risks related to natural catastrophes

(2) Pricing of insurance premiums

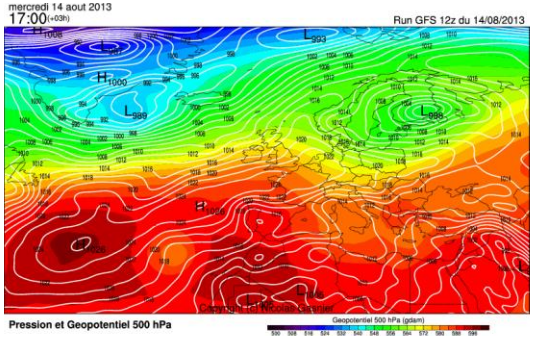
(3) Monitoring weather events in real time for assessing insurance losses

(4) Fraud detection

(5) Parametric Insurance

(6) Risk consulting

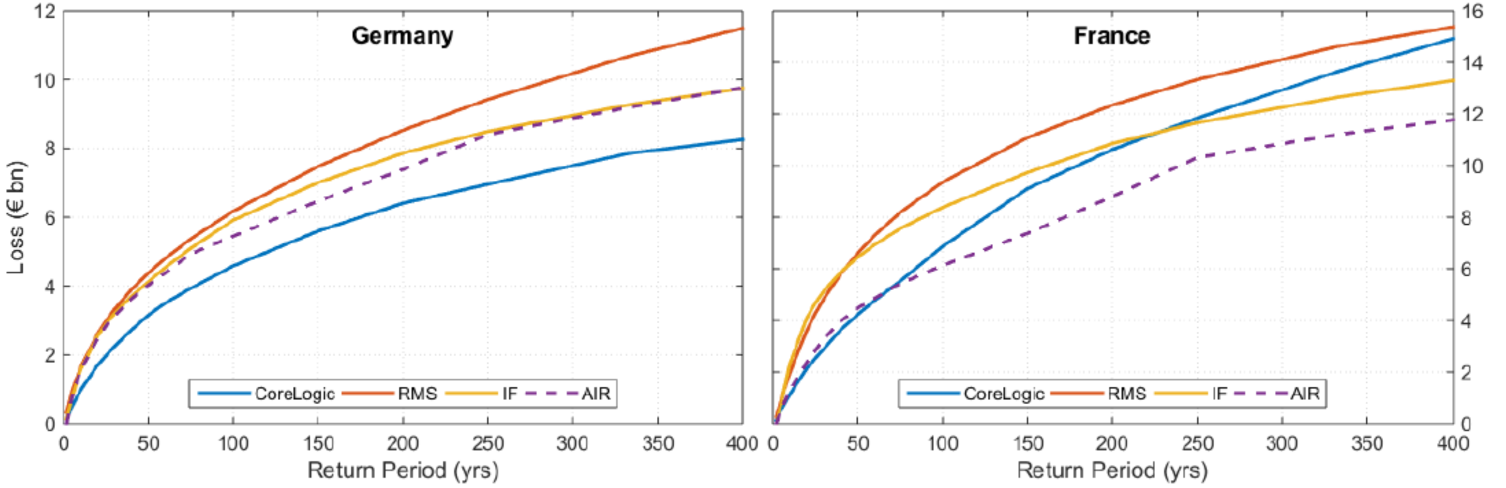
Outputs from weather models



In-situ weather data

(1) MANAGE RISKS RELATED TO NATURAL CATASTROPHES

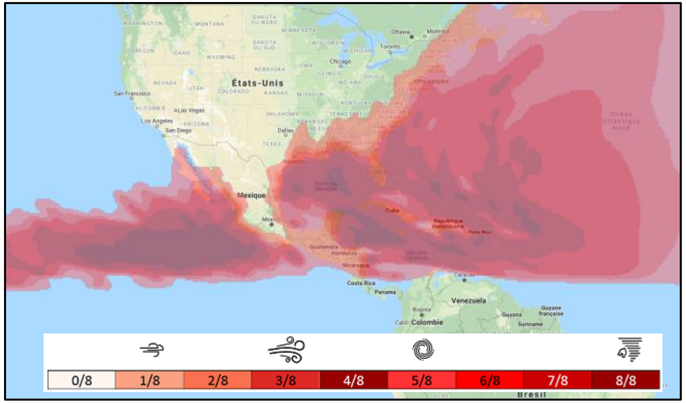
- Solvency II : each insurance company must be able to show it knows how to quantify and manage its own risk
  - → This law defines the Solvency capital requirement (SCR) for facing any major events like natural disasters
  - → The level of the SCR ensures that the likelihood of an insurer being ruined during the year is no more than 1 in 200 → an insurance company needs to face an event with a return period of 200 years
- Needs for the pricing of reinsurance treaties
- Development of CAT models or « historical » approach



(2) PRICING INSURANCE PREMIUMS

- Insurers try to define the insurance premium knowing all characteristics of a specific site
- They build statistical models based on several variables: localisation, building height, structure type, roof type, etc.
- The statistical model is constrained by historical claims

Map of the hurricane risk in the American continent



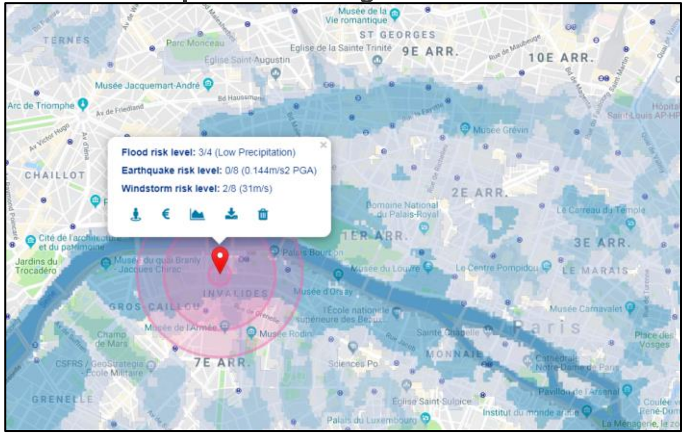
Analysis of claims circumstances

word	freq
toitur	35744
tuil	10650
vent	7878
clotur	6820
arbr	6175
dommag	5896
antenn	4888
chemine	4759
portail	4222
endommag	3970
violent	3771
endommage	3515
toit	2935
infiltr	2770

Coefficients of the Pricing Model

Occupancy	Row House	1
	General Residential	1,06
	Semi Detached House	1,36
	Apt Condo Flat	1,80
	Detached House	1,99
	Bungalow	2,23
WIND MAP	Minor	1
	Low	1,79
	Medium	2,84
	High	3,27
% Content	> 50 %	1
	< 50 %	4,63
Year Built	> 1980	1
	1950-1980	1,30
	1900-1950	1,59
	< 1900	2,08

Map of the flooding risk in Paris



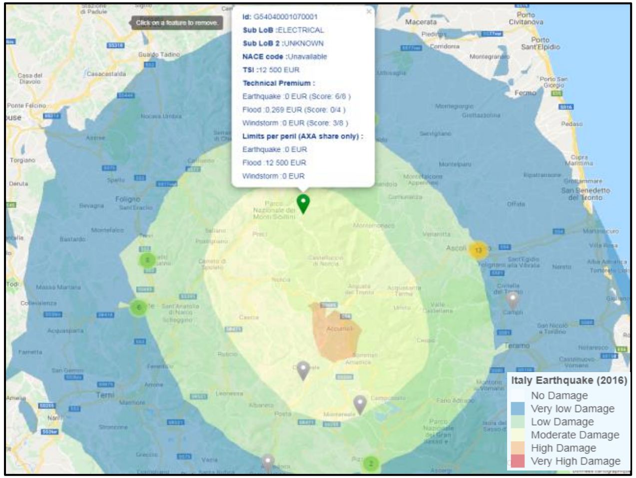
(3) MONITORING ATMOSPERIC EVENTS IN REAL TIME

- Provide accurate and detailed warnings to clients
  - → Prevention can reduce losses
  - → Increase customer satisfaction

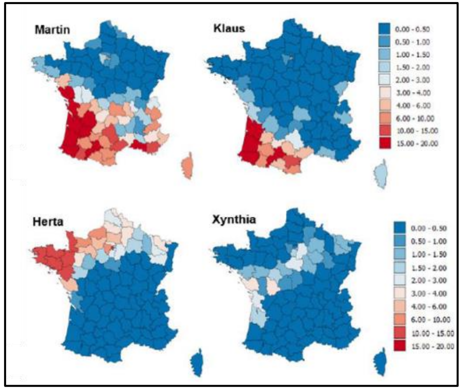
- Estimation of insurance losses related to the event
  - → Using outputs from meteorological models
  - → Effective communication showing a good management of the event and a good knowledge of the portfolio risk

- An effective claim management process
  - → Send the best experts to evaluate claims in impacted areas
  - → Be proactive for the clients who have suffered damages
  - → Using satellite data for the detection of claims

Insured sites in the footprint of a earthquake in Italy (2016)

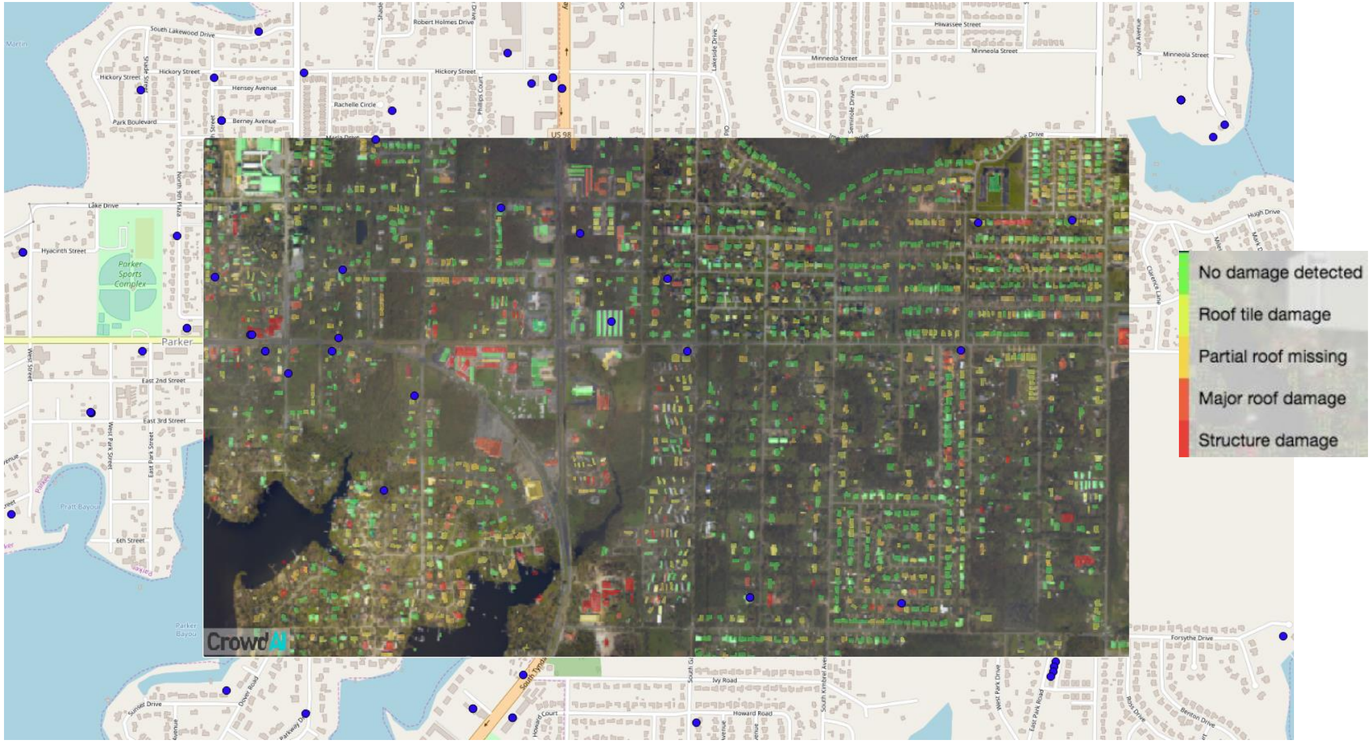


Estimation of losses for 4 storms in France



(3) MONITORING ATMOSPERIC EVENTS IN REAL TIME

- Satellite images may be very valuable for the estimation of losses during a natural catastrophe



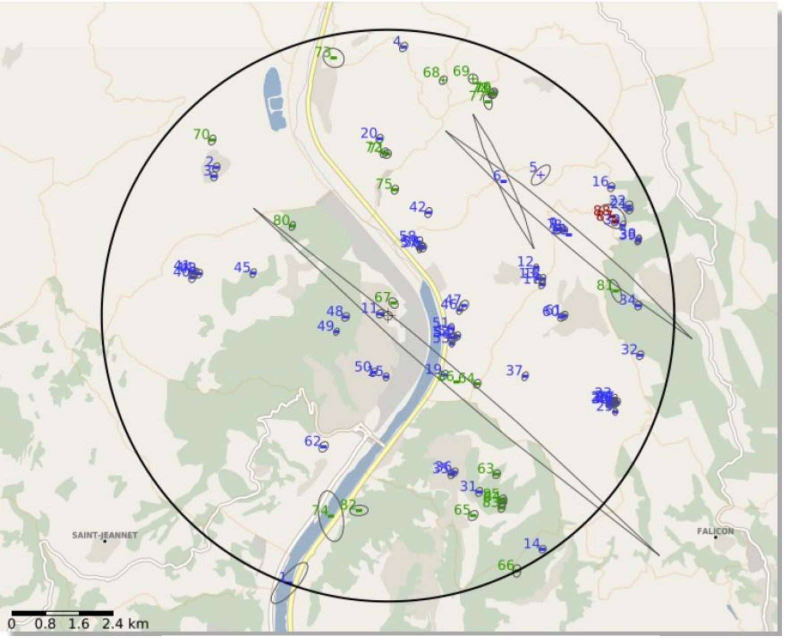
(4) FRAUD DETECTION

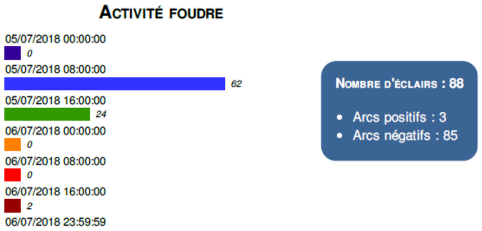
- Meteorological data can be useful to detect some insurance frauds

  → Electric damages
  - *The customer reports an electrical damage related to a thunder storm*
  - *Using lightning strikes in the area for checking the truth of the report*

  → Wind damages aux habitations liés au vent
  - *Using meteroloigcal stations in the area to check the wind speed*

Lightning strikes within a radius of 4km of the insured site





(5) PARAMETRIC INSURANCE

- New types of insurance are emerging and may be very different from traditional insuranc
  - → It is the case of parametric insurance

- Description of parametric insurance process
  - → Payments of claims are **automatically** done when a specific threshold (defined in a contract) is exceeded. This **threshold** is based on **independant** parameters (ocean temperature, wind speed at a specific station, etc.)

- Advantages
  - → Flexible and quick for the payment….
  - → …but it is necesary to use independant data

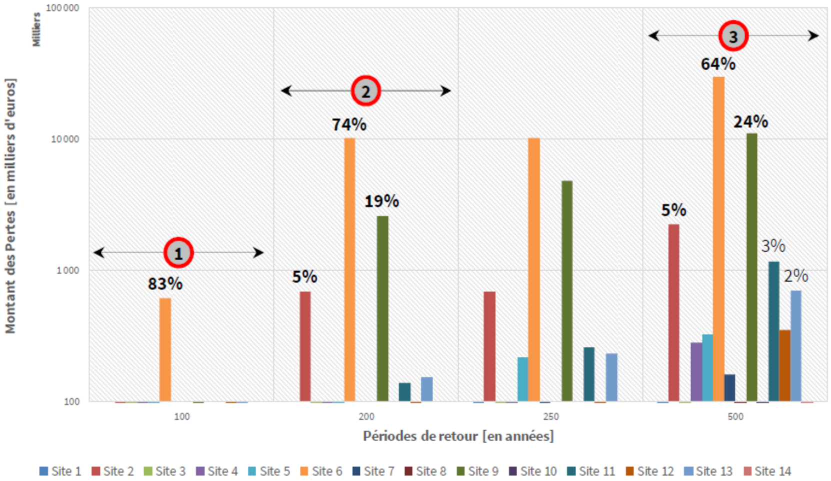
(6) RISK CONSULTING

- Insurance companies are also able to estimate potential insured losses for large industrial companies
  - → Quantification of potential losses
  - → Prevention measures
  - → Tools for structuring insurance contracts for these large industrial companies

- Percentage of
  - → (1) : site 6 contributes to 83% of maximal loss for a 100 year return period event
  - → (2) : sites 2, 6 and 9 contribute to 97% of maximal loss for a 200 year return period event
  - → (3) : sites 2, 6 and 9 contribute to 93% of maximal loss for a 500 year return period event

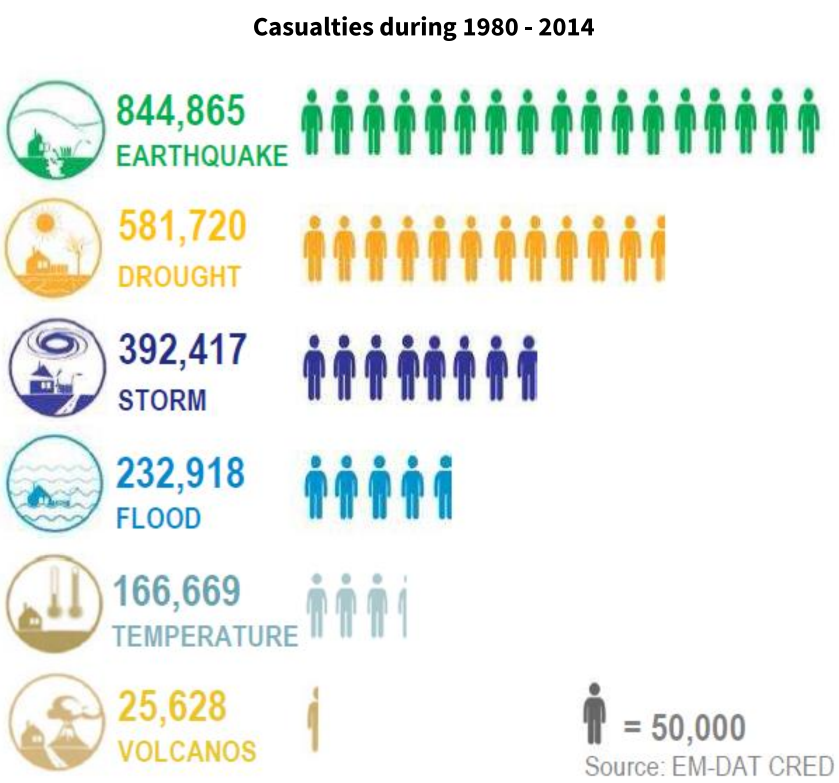
Répartition des sites et valeurs associées d'un industriel français présent dans le monde entier

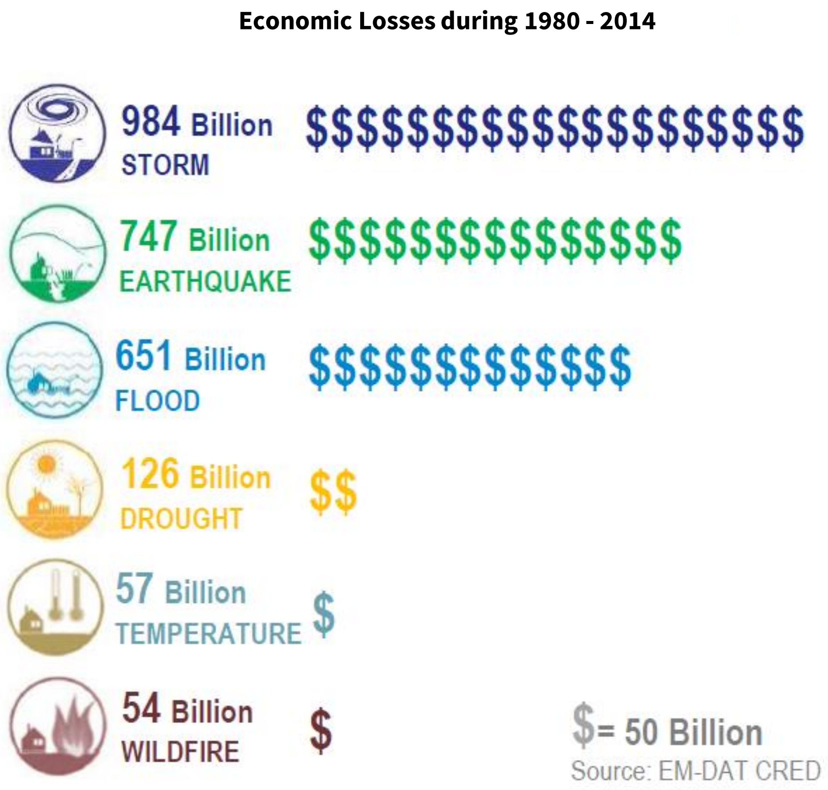
Distribution des pertes par site en fonction de différentes périodes de retour



NATCAT MODELLING

Impacts of natural catastophes in the world



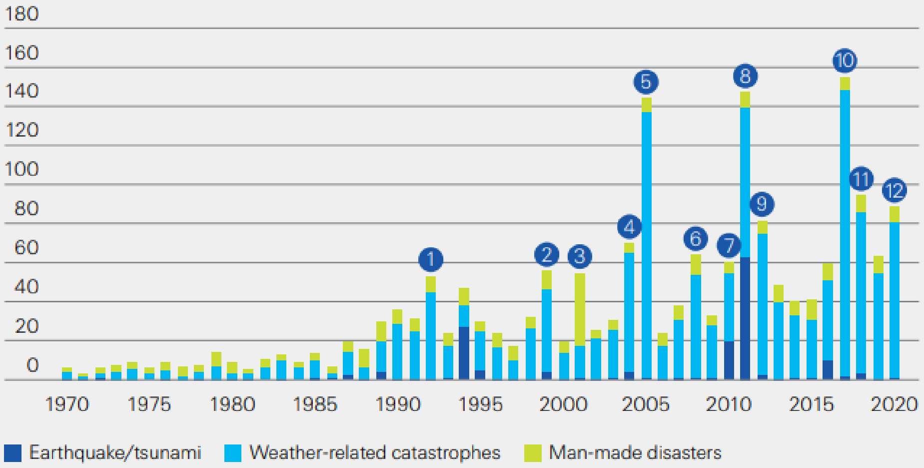


NatCat events in the world

- 3 record years for NatCat events: 2005, 2011 et 2017!
- In Europe, winter windstorm cause (in average) more than 2 billions of insured losses each year (Schwierz et al., 2010)
  - → Windstorms Daria (25/01/90), Kyrill (18/01/07) and Lothar (26/12/99) caused 5.1, 5.8 et 6.2 M$ of insured losses (Munich Re, 2015).

Figure 15
Insured catastrophe losses, 1970–2020, in USD billion at 2020 prices

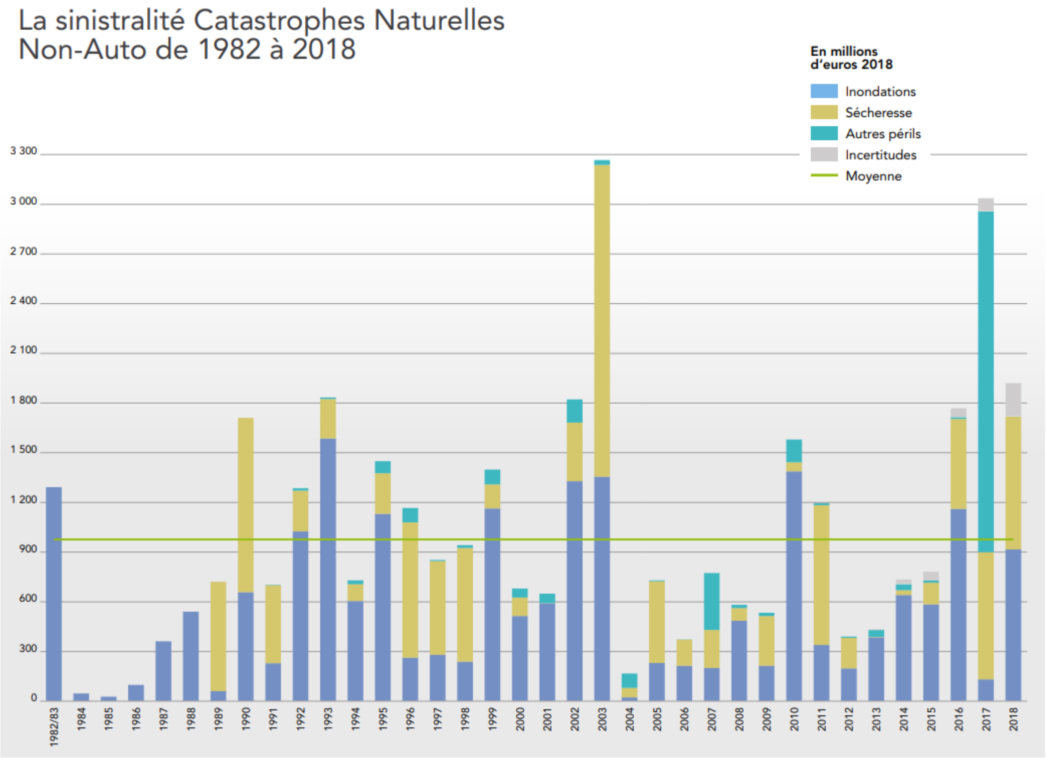
1. 1992: Hurricane Andrew
2. 1999: Winter Storm Lothar
3. 2001: 9/11 attacks
4. 2004: Hurricanes Ivan, Charley, Frances
5. 2005: Hurricanes Katrina, Rita, Wilma
6. 2008: Hurricanes Ike, Gustav
7. 2010: Chile, New Zealand earthquakes
8. 2011: Japan. NZ earthquakes, Thailand flood
9. 2012: Hurricane Sandy
10. 2017: Hurricanes Harvey, Irma, Maria
11. 2018: Camp Fire, Typhoon Jebi
12. 2020: Hurricane Laura, wildfires



Source: Swiss Re Institute

NatCat events in France

- Floodings contribute to 57% of NatCat losses since 1982
- Drought contribute to 34% of NatCat losses since 1982
- Averaged yearly loss is 977 M€ since 1982



Attention :

Les tempêtes hivernales, la grêle et le poids de la neige ne sont pas incluses dans le régime CatNat

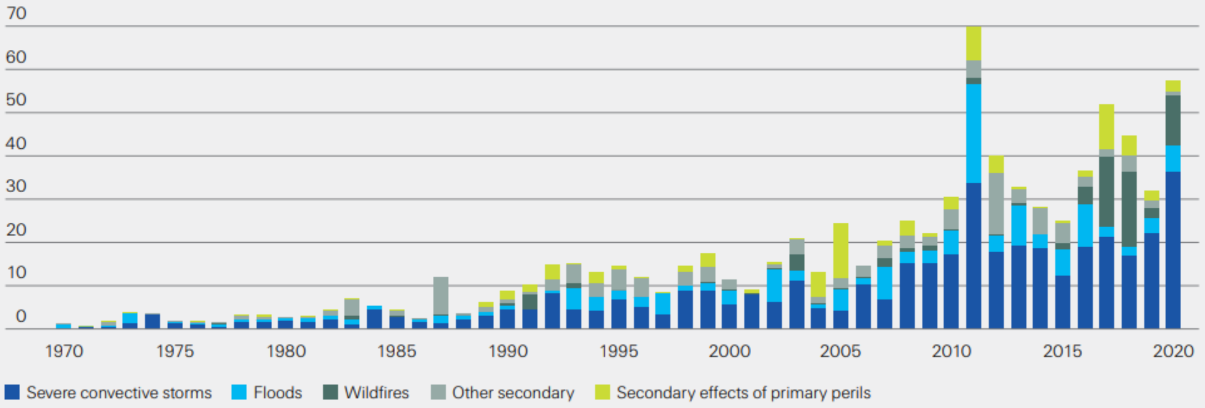
NatCat events in the world

Primary perils/Secondary perils

- **Primary perils** : peak risk with a high loss potential which is well known. Examples : tropical cyclones, earthquakes, winter windstorms.
- **Secondary perils** : perils which are not always modelled and are not monitored much by the insurance industry. Examples : flash floods, landslides, hail storms, drought, wildfires, etc.
- **Secondary effects of a primary peril**. Examples : storm surge, tsunamis, intense rainfall during a hurricane

In 2018, 62% of all NatCat damages were due to a secondary peril.

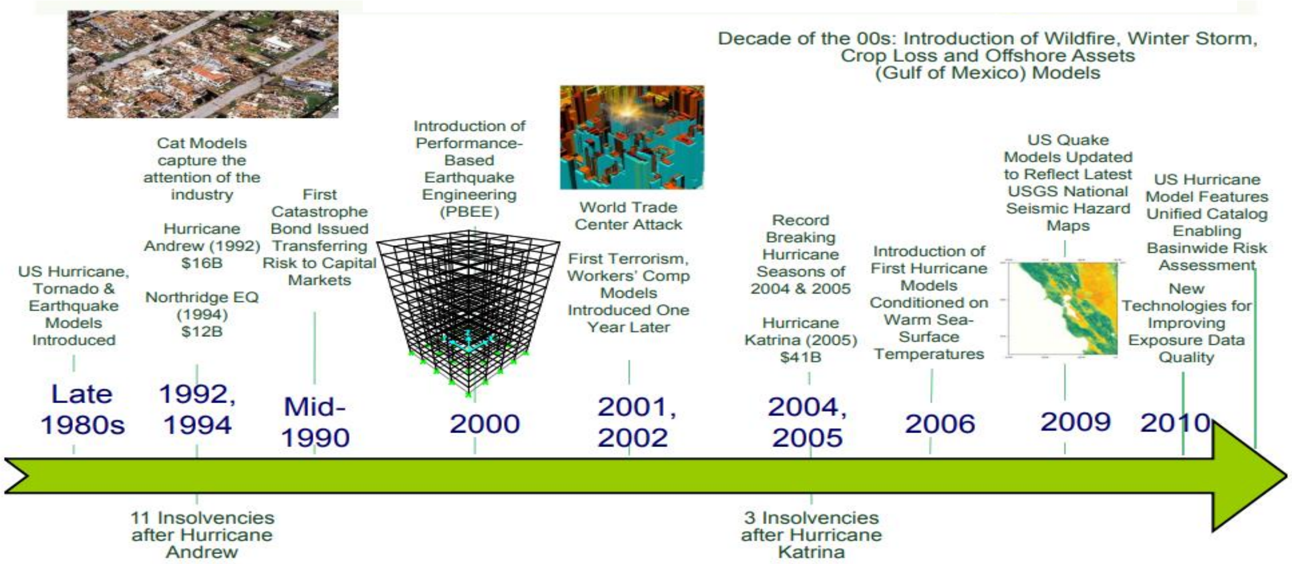
Figure 2
Global insured losses from secondary perils by peril types since 1970, in USD billion at 2020 prices



Source: Swiss Re Institute

NATCAT MODELLING - HISTORY

- Several catastrophes showed the needs to better know the risk related to natural events for the insurance community
- In 1992, south-eastern USA has been largely impacted by hurricane *Andrew* (20 billions of damages for insurers). It is the start of NatCat modelling for the insurance industry.



NATCAT MODELLING ?

- Natcat events are not predictable. But, it is possible to quantify the number and intensity of these events with probabilities.

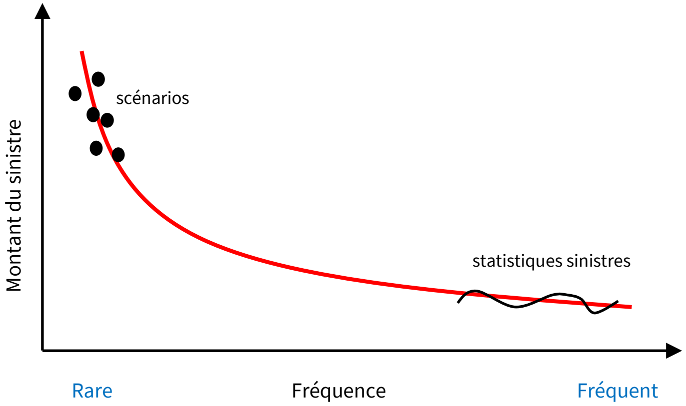
- A CAT model quantifies the risk of a portfolio regarding natural catastrophes
- CAT models can answer these questions:
  - Where are future catnat events most likely to occur ?
  - What is the expected intensity for such events?
  - What is the range of insurance losses?
- CAT models are not designed for forecasting Natcat events

- 4 main parameters to consider in NatCat modelling
  - → Hazard – where? which frequencies and what intensities for all events ?
  - → Vulnerability – what is the damage suffered by the insured objects depending on the intensity of the event?
  - → Exposure – where are insured sites located? What are their characteristics ?
  - → Financial conditions – which proportion of the damage is insured ?

DIFFERENCE BETWEEN ACTUARIAL METHOD AND NATCAT MODELS

- How can we have a knowledge of the risk ?
  - → We can use historical claims data for building statistical models
  - → We call it, the actuarial approach.
  - → This approach is well adapted for fire damages and thefts: history is a good indicator for modelling future.

  - → However, it is not the case for extreme events like the NatCat events.
  - → CAT models based on physical model is the best solution for modelling NatCat events.



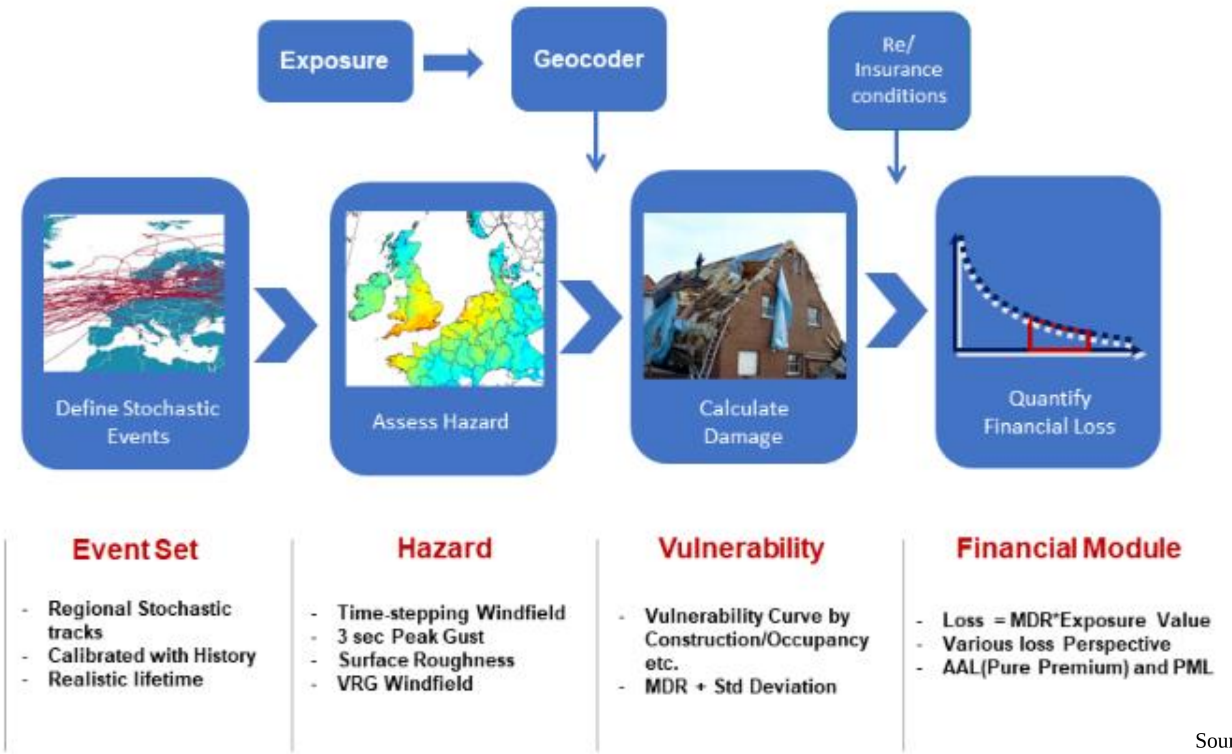
STRUCTURE OF A CAT MODEL

- All CAT models have the same structure
- 3 modules: « Hazard », « Vulnerability » and « Financial »
- The exposure (the analysed portfolio) is an input of the model
- The portfolio contains the list of insured assets with all characteristics (localisation, type of building, structure type, financial conditions, etc.)

	1 – Hazard Module	2 – Vulnerability Module	3 – Financial Module
Inputs	Peril + Geographical area	Events + Portfolio characteristics	Distribution of events + Financial conditions
Key steps	Génération des événements	Cross vulnerability curves with portfolio data	Apply financial conditions
Outputs	Events with intensities and frequencies	- Events crossed with portfolio - Destruction rate for each site	Net Losses

STRUCTURE OF CAT MODELS

- The different modules (hazard, vulnerability and financial) are shown below.



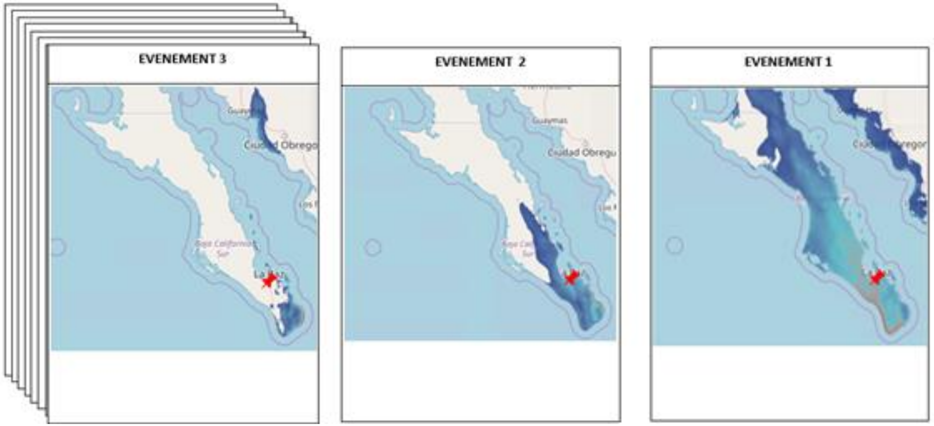
Source : https://oasislmf.github.io/modelling_methodology/what_is_a_catastrophe_model.html

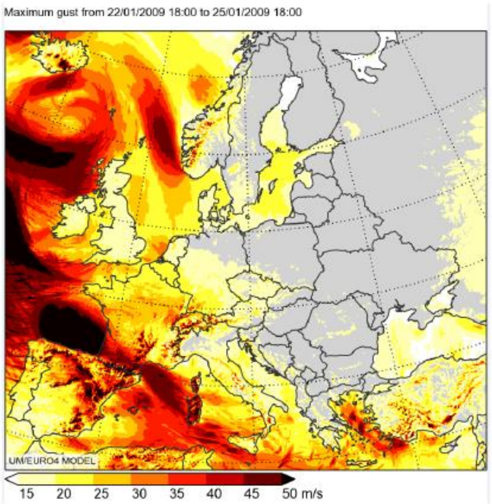
HOW IS A CAT MODEL BUILT ?

- **Hazard module**
  - → Combination between dynamical models (climate models, hydraulic models, etc.) and statistical models
  - → Calibration with historical data
- **Vulnerability module**
  - → Statistical approach constrained by historical claims data
  - → Engineering approach (vibrating table, wind tunnels)
- Softwares, languages used for the development of CAT models
  - → Modules developments : R, Python, C++, Fortran
  - → SQL server
  - → Reporting : Excel

The Hazard Module

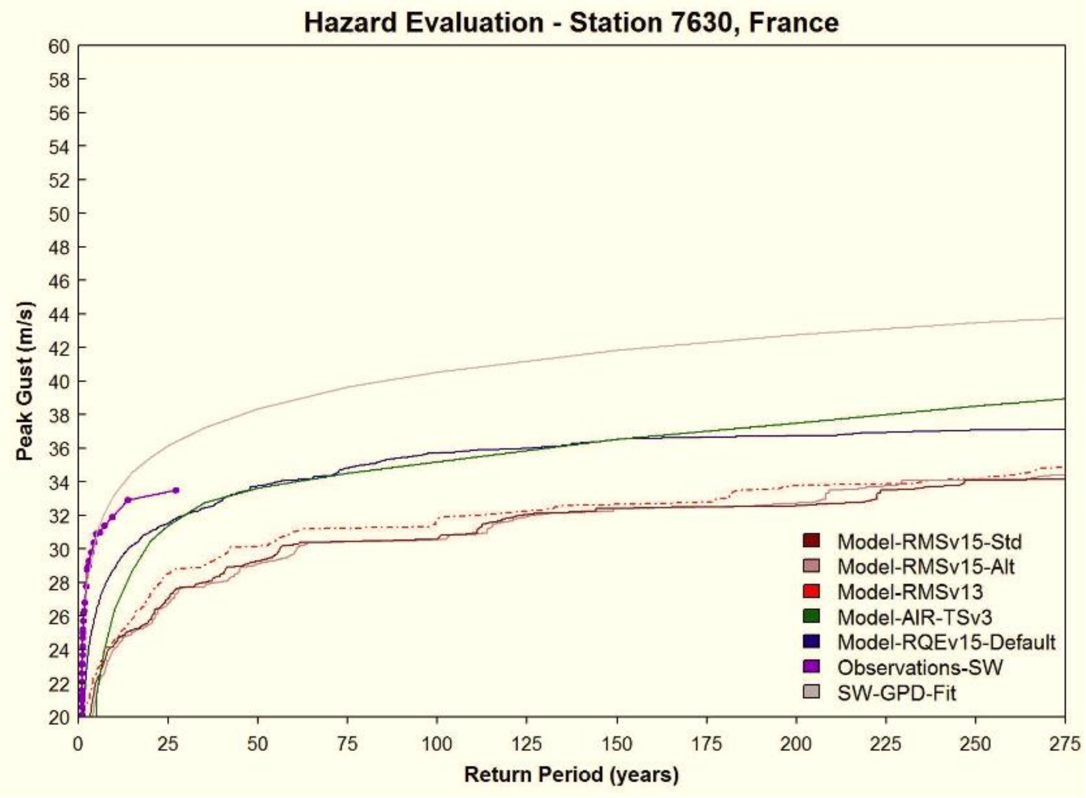
- The goal of this module is to create a catalogue of potential events with their characteristics (intensity, location, tracks, etc.) generated according to probability distributions.
- Each event is represented by a *footprint* which shows values of physical variable during the period of the event (max winds for a storm, max PGA for earthquakes, max water level for flooding, etc.)
- The determination of **frequency** and **severity** of the peril for a specific geographical area is based on historical data and physical models (geophysical, hydrology, geology, climate)





The Hazard Module – Example : Windstorm in Europe

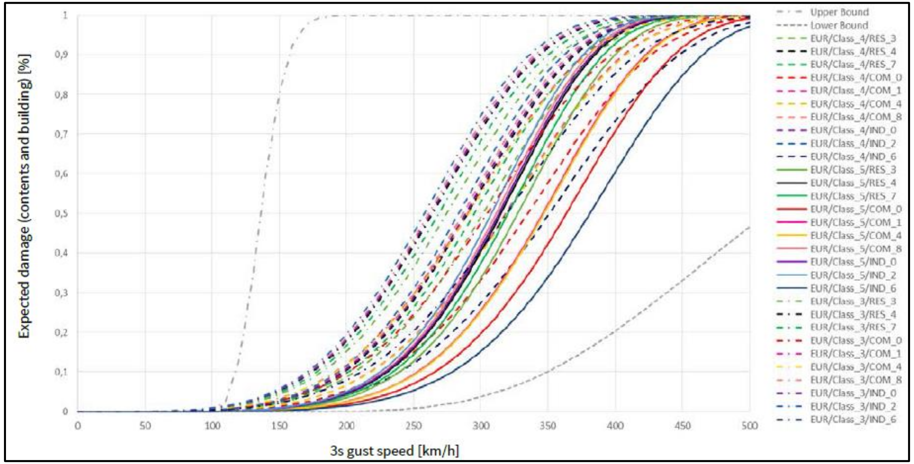
- Example of the evaluation of a hazard module by comparing outputs of the hazard module with observations and using extreme value theory



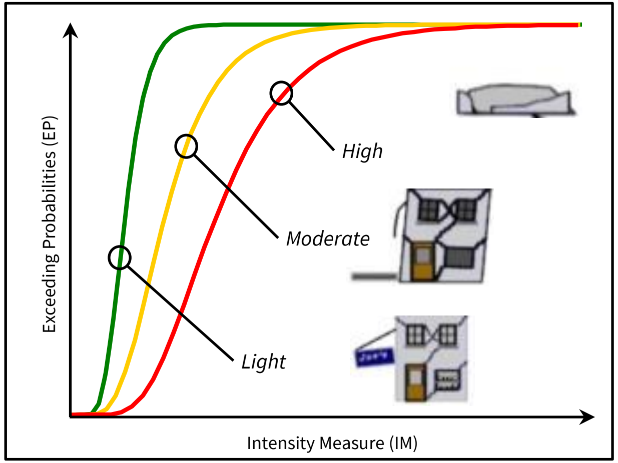
The Vulnerability Model

- **The vulnerability module estimates the damage level due to a NatCat event knowing the characeristics of the insured site (type of structure, content, height of the building, type of business, etc.)**
- The vulnerability module contains a large set of curves matching the different characteristics of the portfolio.
- These curves estimate « damage ratio » in function of the hazard intensity
- The damage ratio is defined as the ratio between the loss amount and the total value of the site. It is usually expressed in %.

Vulnerability curves



Fragility curves



The Vulnerability Module

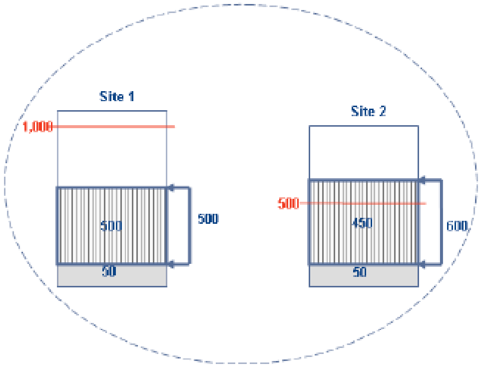
- 3 different approaches for developing vulnerability curves:
  - **Engineering method**: mechanical simulation (wind tunnel, vibrating table,..)
    - ✓ *can simulate impacts for all intensity values*
    - ✓ *biais in comparison with claims data*
  - **Statistical method** : based on claims data and optimisation of analytical curves
    - ✓ *well in agreement with observed data*
    - ✓ *No or few data for extreme intensity values*
    - ✓ *Need a large number of data to use this method (example: windstorm in Europe)*
  - **Hybrid method**: combination between engineering and statisical methods to take advantages of both methods

The Financial Module

- **The financial module takes in consideration all financial conditions (limits, deductibles, facultatives, etc.) for estimating insured losses.**
- Usually, we do not compute one single loss value but a loss distribution considering uncertainties in the whole process.

Example n°1 : Deductibles and limits.

	Site 1	Site 2
Exposure	1,100	900
Deductibles	50	50
Limits	500	600
Loss	1,000	500
Net loss of deductibles and limits (at site level)	500	450



Example n°2 : Non proportional treaties

Two key concepts in the non proportionnal treaties: XS_POINT and LAYER_AMOUNT

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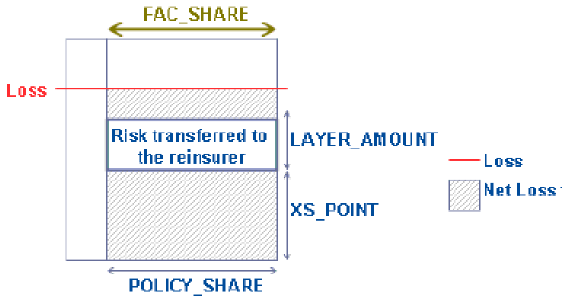
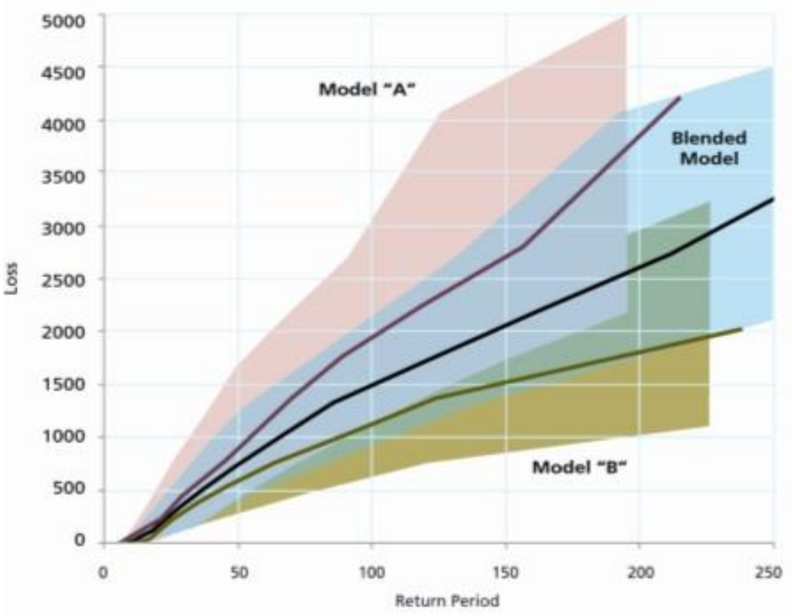
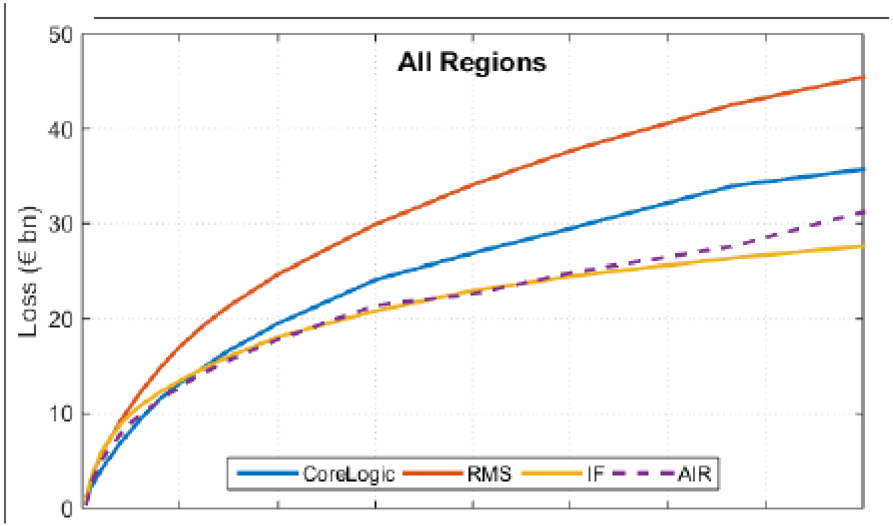


Outputs from CAT models – OEP/AEP Curves

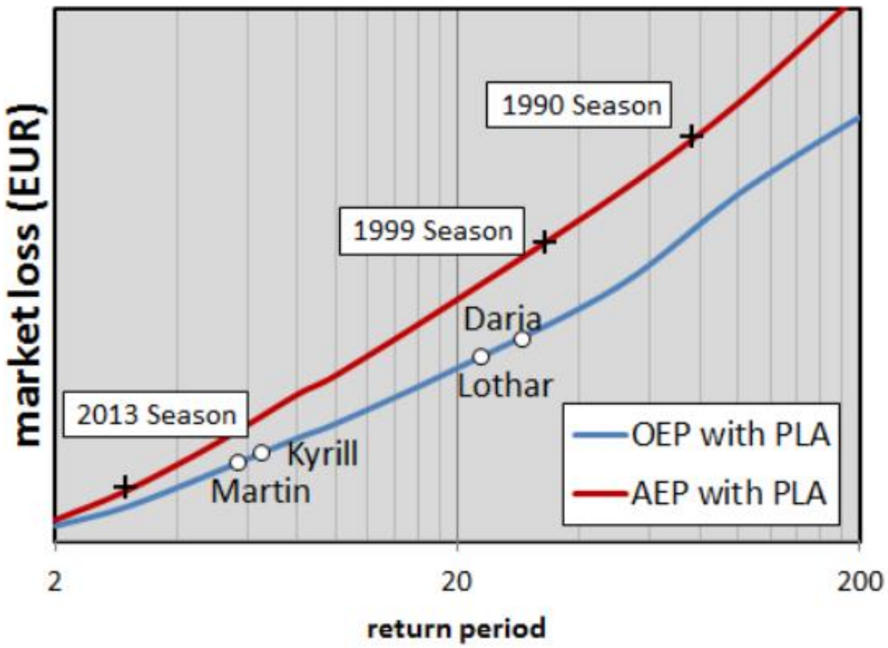
- OEP : Occurrence Exceedance Probability : a measure of the probability to exceed (at least once a year) a specific loss amount.
- The reglementation says that insurers need to be able to face an event with a return period of 200 years. It means they need a capital equals at least to the value of OEP at 200 years.





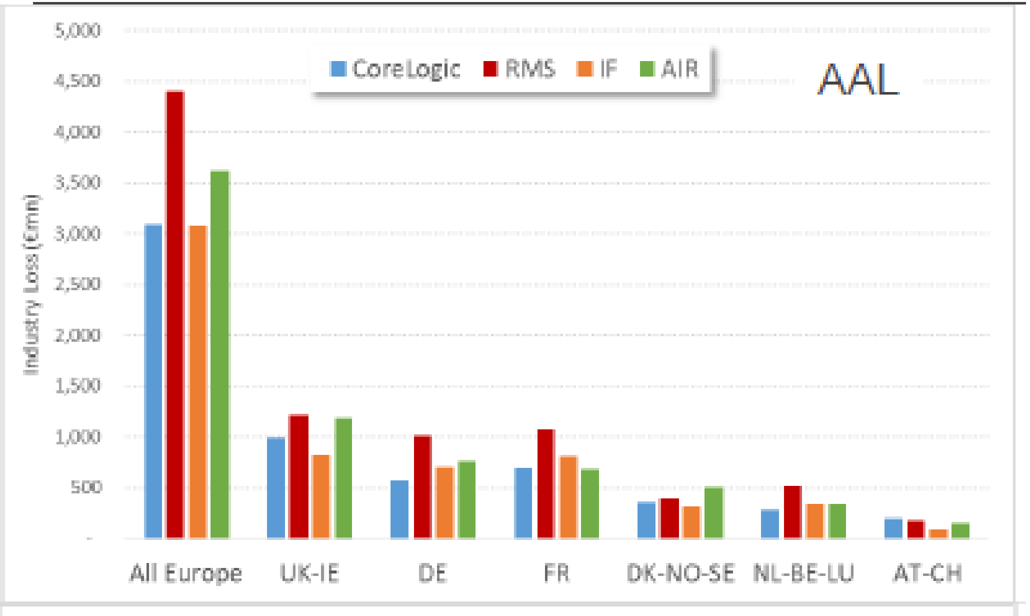
Outputs from CAT models – OEP/AEP Curves

- AEP : Aggregate Exceedance Probability : a measure of the probability to exceed (at least once a year) a specific loss amount by aggregating all event losses.



Outputs from CAT models – Average Annual Loss (AAL)

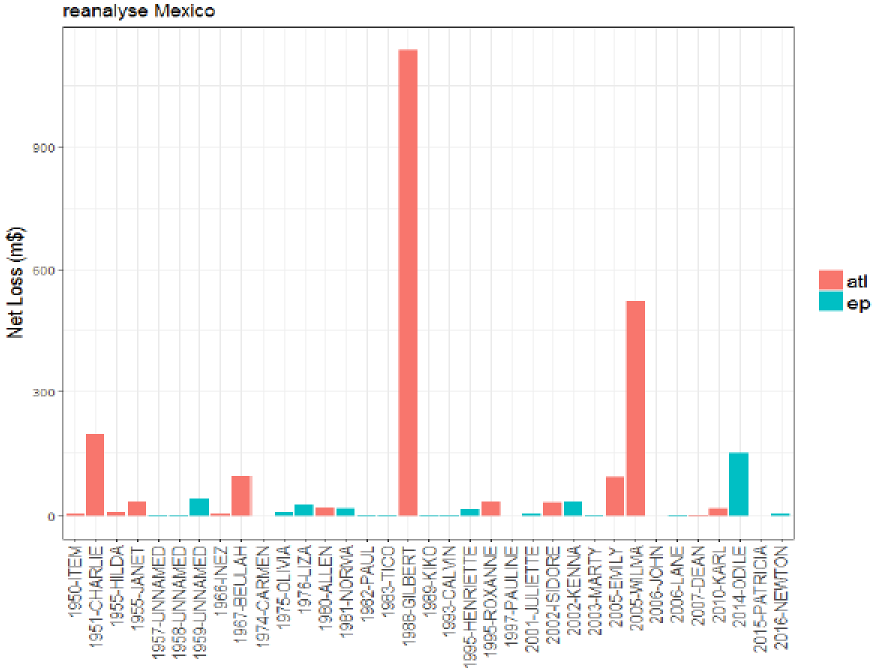
- AAL : Average Annual Loss : estimation of the annual premium needed for covering all losses for a specific peril.



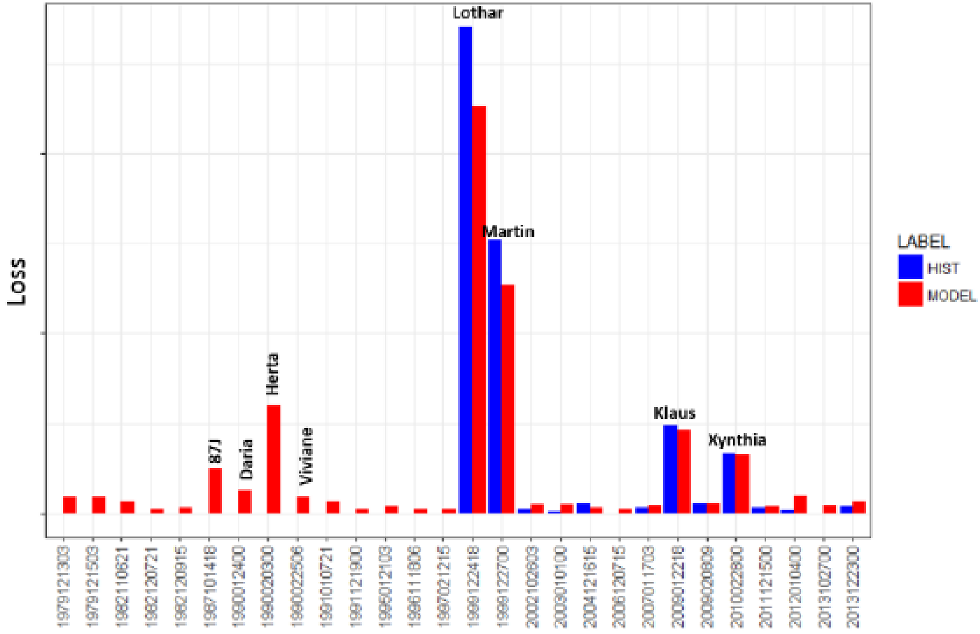
Outputs from CAT models – Historical

- Un modèle CAT permet également de simuler les pertes liées à des événements historiques.

Pertes assurantielles liées aux ouragans au Mexique depuis 1950



Pertes assurantielles liées aux tempêtes hivernales en France depuis 1980

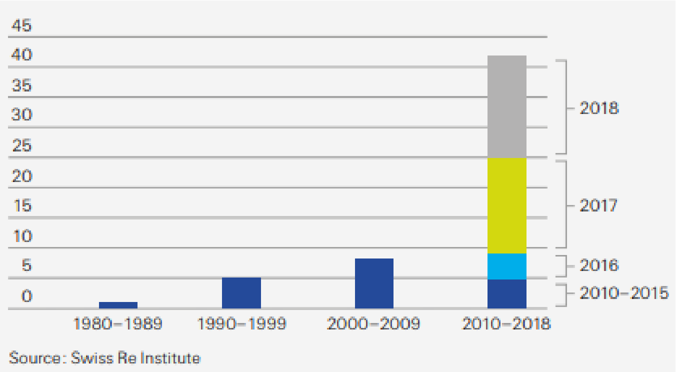


UNE RECRUDESCENCE DES CATASTROPHES NATURELLES ?

- Y'a-t-il plus de catastrophes naturelles liées au réchauffement climatique ?

- Les projections climatiques montrent une augmentation des précipitations associées aux ouragans
  - → Cela pourrait expliquer les précipitations exceptionnelles de Harvey en 2017 et Florence en 2018
- L'augmentation du niveau de la mer peut entrainer un risque plus élevé pour les zones côtières
  - → Onde de tempête liée à l'ouragan Sandy en 2012
- L'augmentation des températures est fortement corrélée à l'augmentation du risque de sécheresses et de feux de forêts.
  - → La saison des feux de forêt 2018 a été la plus meurtrière et la plus destructrice de tous les temps en Californie

Dommages assurés dus aux feux de forêts dans le monde depuis 1980 (en M$)



AN INCREASE OF NATCAT EVENTS ?

- Plusieurs autres facteurs augmentent le coût des dommages assurés lié aux catastrophes naturelles :
  - → Accroissement de la densité démographique
  - → Augmentation de la population dans les zones à risques
  - → Matériaux modernes plus fragiles
  - → Urbanisation : réduction des surfaces où l'eau peut s'infiltrer, ce qui aggrave l'impact des fortes précipitations

- CCR a collaboré avec Météo-France pour analyser l'impact du changement climatique
- Analyse de l'impact des scénarios RCP4.5 et RCP8.5
- RCP8.5 :
  - → Augmentation de l'aléa : +35%
- RCP4.5 :
  - → Augmentation des valeurs assurées +80%
  - → Augmentation de l'aléa : +20%

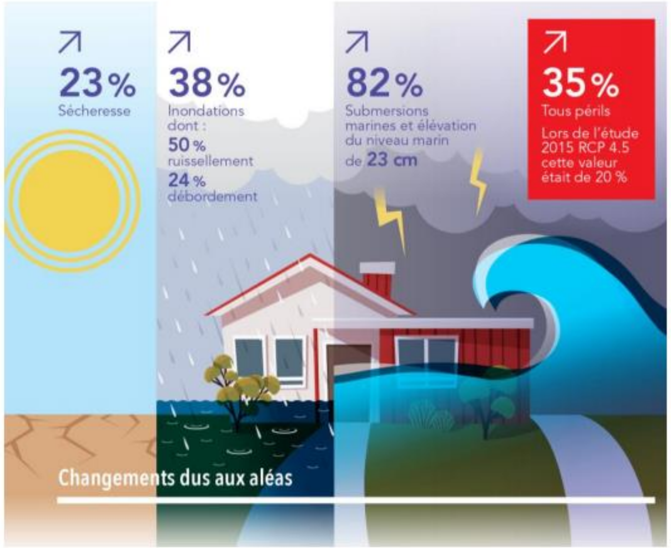


Figure 11 : Evolution en 2050 des pertes annuelles moyennes par périls liées aux évolutions du climat sur les valeurs assurées actuelles