1. CCR activities

Introduction

- CCR (Caisse Centrale de Réassurance) is a reinsurance company 100% owned by the French State.

- CCR has market reinsurance activities but its first aim is to provide unlimited state-guaranteed coverage for branches specific to the French market such as natural disasters or terrorism.
1. CCR activities

Compensation scheme for natural disasters

- All compensations under the Law of 1982 have to satisfy two conditions:
  - A natural disaster must be recognized by an interministerial commission.
  - The property affected must be covered by a “property damage” insurance policy.

- Perils covered by the scheme are not explicitly named. Therefore the following list is not exhaustive:
  - Flood (heavy rain flood, river overflow, ground-water flood, seasurge)
  - Earthquake
  - Ground movement (including subsidence due to drought)
  - Avalanche
  - Cyclonic winds in French overseas departments and territories.
1. CCR activities

Damages due to natural disasters

- Flood is the most expensive hazard since the beginning of the Nat Cat scheme: 55% over the 1990-2010 period.

- 2010 was the most expensive year for flood with two main events: Xynthia seasurge and floods in South East of France.

- 2003 drought is the most expensive event since scheme creation: more than 1 billion €.

- There is a risk for important non-yet occurred events:
  - Flood in Paris (more than 10 billion euros).
  - Earthquake in south east of France (several billion euros)
1. CCR activities

Modeling at CCR

- For about ten years, CCR has developed natural disaster models to analyze the exposition of French territories.

- To achieve this work, CCR:
  - collects data on hazards, insured portfolios and damages;
  - develops its own models for the main perils: floods and drought;
  - uses and adapts editor models for other perils with potentially extremes losses: earthquake and hurricanes.

- These tools allow CCR to:
  - estimate the cost of a major event a few days (or few weeks for drought) after its occurrence: this approach is called “deterministic”;
  - measure the exposition for the insurance market, for CCR and for the French State: this approach is called “probabilistic”.

Modeling Stochastic Event Set to Measure the Financial Exposure to Natural Disasters in France
1. CCR activities

General description of the flood model

Input Data
- Rain, ETP (Météo France)
- DTM (IGN, 50 m)
- BD Carthage (MEDDTL)
- Land use (Corine Land Cover)
- Cedant exposure portfolio

HAZARD MODEL
- Rainfall
- River flood
- Pluvial flood

EXPOSURE MODEL
- Insured risks
  - Adress
  - Risk types
  - Insured values

VULNERABILITY MODEL
- Insured values
- Destruction ratio in case of claim
- Claim probability
- Nat Cat recognition probability

COST
- Per risk
- Per zipcode
- Per event

Modeling Stochastic Event Set to Measure the Financial Exposure to Natural Disasters in France
1. CCR activities

Example of flood deterministic model

Center-East of France (November 2008)

Risk database is not exhaustive and must be extrapolated to the insurance market.

Legend
- Blue: Simulated river overflow
- Orange: Simulated surface water flood zone
- Star: Risks geocoded at address level
1. CCR activities

Probabilistic approach

- Why a probabilistic approach?
  - Pricing.
  - Knowledge of hazards.
  - Financial exposure: CCR and French State.
  - Insurance provision.

- Description of probabilistic approach:

```
Historical dataset → Event generator → Event Set
| Event 1 | Event 2 | Event 3 | ... | Event N |
```

→ Hazard and Damage model → Cost 1 → Cost 2 → Cost 3 → Cost N
2. Weather event generator

Generating precipitations with Copula theory

- A precipitation event is NxM precipitation data where:
  - N is the number of dates
  - M is the number of locations

<table>
<thead>
<tr>
<th>Locations</th>
<th>Dates</th>
<th>Precipitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>p1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>p2</td>
</tr>
<tr>
<td>...</td>
<td>1</td>
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<td>...</td>
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<tr>
<td>M</td>
<td>2</td>
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</tr>
<tr>
<td>1</td>
<td>N</td>
<td></td>
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<tr>
<td>2</td>
<td>N</td>
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<tr>
<td>...</td>
<td>N</td>
<td>...</td>
</tr>
<tr>
<td>M</td>
<td>N</td>
<td>pNM</td>
</tr>
</tbody>
</table>

Individuals are not locations or dates. They are combination of both.
2. Weather event generator

Generating precipitations with Copula theory

- A Copula is a cumulative distribution function on the unit cube with uniform marginals.

- Copula theory allows us to model separately:
  - The individual behavior by fitting probability distribution for each component of the random vector.
  - The dependency between marginal variables with the correlation matrix (because we use Gaussian Copulas).

- We use a historical dataset to compute the correlation matrix and to fit the probability distribution.
2. Weather event generator

Steps to generate a NM random vector of precipitations

● 1 – Study marginals and dependence:
  - Fit a probability distribution for each of the NM variables.
  - Calculate the correlation matrix (NM x NM).

● 2 – Randomly draw a vector $U = (u_1, \ldots, u_{NM})$ from a Gaussian copula with the correlation matrix as parameter.

● 3 – Inverse every component of $U$ with the cumulative distribution function associated to each random variable.
2. Weather event generator

An example with two weather stations

- X : { Brest weather station, first week of June}
- Y : { Nantes weather station, first week of June}
- Here we have : N = 1 ; M = 2 and 50 observed data.

Scatter plot of X and Y
Linear correlation : 0.75

Histogram and GEV distribution fitted to for X and Y
2. Weather event generator

An example with two weather stations

Illustrations of a 2-dimension Gaussian copula (correlation = 0.75)
2. Weather event generator

An example with two weather stations

- We use the inverse transform method for each component of the 1000 realizations to obtain precipitation values.

- Drawbacks of this method:
  - Using a Gaussian copula is an important assumption which is difficult to validate.
  - The highest values are uncorrelated with a Gaussian copula.
  - NxM can be quickly very high and our historical dataset can be too small.
2. Weather event generator

What do we call drought?

- In the French compensation scheme for natural disasters, the subsidence due to shrink-swell clay is called «drought».

- This phenomenon damages houses.

- It is a consequence of two factors:
  - Clay presence in the soil;
  - Soil wetness.

- The first factor is constant. So we will modelize only the second one.
2. Weather event generator

Soil Wetness Index Generation

- **Variable to generate:**
  Soil Wetness Index (SWI).

- **Locations of observations:**
  8 981 cells from a 8 x 8 km grid (SAFRAN grid).

- **Dates of observations:**
  10 days periods (3 observations per month).

*The SWI is a parameter of the SAFRAN-ISBA-MODCOU suite from Météo France used by an interministerial commission to evaluate a drought event.*
2. Weather event generator

Soil Wetness Index Generation

- The soil wetness index seems to be a periodic phenomenon. Example: 6 years of SWI for a grid cell located in Roscoff.

- Correlation is high for 2 nearby cells.
- Autocorrelation is significant for each cell.
- There are enough observations and enough cells to compute the SWI variogram.
- First the SWI is generated on a selection of cells (for example 1 out of 5) and then it is interpolated on the others.
2. Weather event generator

SWI generation – Algorithm (1/2)

1 – Decomposition of marginal process:

- Estimate and remove the linear trend and the seasonality.
- Fit autoregressive model to remove the autocorrelation and fit a probability distribution to the residual process.

The residual process has no more autocorrelation for $t>0$ but it is correlated to the residual process of other cells.
2. Weather event generator

SWI generation – Algorithm (2/2)

● 2 – Variographic analysis
  ◆ Estimate the empirical variogram of the SWI
  ◆ Fit an exponential variogram model to this empirical variogram.

● 3 – Compute the correlation matrix $M$ of the residual process

● 4 – Generate SWI on the selected cells.
  ◆ Generate the residual process on all cells with the copula method
  ◆ Use time series parameters to rebuild marginals one by one.

● 5 – Interpolate the generated SWI on the other cells (kriging).
3. Damage and exposure

Flood modeling

● Building a probabilistic model requires the creation of a stochastic event set of non-occurred but realistic events. Two solutions have been chosen for flood:
  ❖ Distribution of fictive river flow:
    ✓ SCHAPI river flow database (Banque Hydro)
    ✓ Statistical approach

  ❖ Distribution of fictive rainfall events:
    ✓ Météo France SAFRAN rainfall database: 52 years of hourly precipitation on a 8 x 8 km grid for the entire metropolitan territory.
    ✓ Collaboration between CCR and IRSTEA (Etienne Leblois – IRSTEA Lyon) for the development of a rainfall generator.
3. Damage and exposure

Flood modeling: Fictive rainfall events

- A million years of 72 hour rainfalls was simulated for France.
- Example: 1 random fictive year / 1,000,000

Annual rainfall

<table>
<thead>
<tr>
<th>mm x m²</th>
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<tbody>
<tr>
<td>300 - 5000</td>
</tr>
<tr>
<td>5000 - 15000</td>
</tr>
<tr>
<td>15000 - 20000</td>
</tr>
<tr>
<td>20000 - 25000</td>
</tr>
<tr>
<td>25000 - 45000</td>
</tr>
</tbody>
</table>

Insurance losses

<table>
<thead>
<tr>
<th>Millions €</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 5</td>
</tr>
<tr>
<td>5 - 20</td>
</tr>
<tr>
<td>20 - 40</td>
</tr>
<tr>
<td>40 - 70</td>
</tr>
<tr>
<td>70 - 130</td>
</tr>
</tbody>
</table>
3. Damage and exposure

Flood modeling: damage validation

Event in Var in June 2010:
- 396 mm observed in 72h
- Event cost: ~505 M€

3 fictive events: 310 to 562 M€ for the same amount of precipitations.

Event in Finistère in December 2000:
- 94 mm observed in 72h
- Event cost: 67 M€

5 fictive events: 44 to 60 M€ for the same amount of precipitations.
3. Damage and exposure

Flood modeling: France exposure to river overflow

Probabilistic map for river flood risk

Official flood zone map

Hazard Return Period
- 1 – 5 years
- 16 – 42 years
- 43 – 83 years
- 84 – 125 years
- 125 – 250 years

Atlas des zones inondables (MEDDTL)
- Flood zones
- Department boundaries

Sources:
- MEDDTL
- Flood carto, CHER
Probabilistic map for river flood risk

On a 50 x 50 m grid

Courbe intensité / fréquence

Fréquence annuelle

Hauteur d’eau (cm)

Communes

Période de retour

> 500 ans
> 200 ans
> 100 ans
> 50 ans
> 20 ans

Modeling Stochastic Event Set to Measure the Financial Exposure to Natural Disasters in France
3. Damage and exposure

Flood modeling: river overflow VS rainfall generation

- CCR flood model simulates the two main kinds of hazard: river and pluvial floods. There are both taken into account for damage modeling.

- Work is in progress for seasurge modeling.
3. Damage and exposure

Flood modeling : Hazard mapping validation

Modeling Stochastic Event Set to Measure the Financial Exposure to Natural Disasters in France
3. Damage and exposure

Flood modeling: limits of probabilistic approach

- The stochastic event set is not representative enough to show an exhaustive vision of flood in France.
- The historical depth of the river flow and rainfall data is limited: the use of historical data could correct this limit.
- CCR is still expecting a complete database of flood defenses.
- Seasurge exposition is not yet taken into account in the event set.
- Some data could be more accurate (DTM for example).
- There are uncertainties about:
  - fits (probability distributions, copulas);
  - correlation of extrem events.
3. Damage and exposure

- Annual losses estimation for the insurance market requires to create an Aggregate Exceedance Probability Curve.
- This curve gives us the probability (or the return period) to exceed an annual loss.

*Distribution of probable annual losses for river and pluvial floods.*
3. Damage and exposure

This model contributes:

- To analyze the financial exposition to natural disasters in France, for the State, CCR and its clients.
- To estimate the 200-year annual lost exposure for Solvency 2 requirements.
- To cost/benefit analysis and preliminary studies for preventive actions.
Thank you for your attention

CCR™ 100% Reinsurer