Comparative risk assessments for Guadeloupe: earthquakes and storm surge

Arnaud Réveillère, Daniel Monfort, Sophie Lecacheux, Ludovic Grisanti, Héloïse Muller, Didier Bertil, Jérémy Rohmer, Olivier Sedan, John Douglas, Audrey Baills, et al.

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Comparative risk assessments for Guadeloupe: earthquakes and storm surge

Réveillère, Monfort, Lecacheux, Grisanti, Müller, Bertil, Rohmer, Sedan, Douglas, Baills, Modaressi

Presentation outline

- Assets estimation & seismic loss estimation methodology
- Validation based Les Saintes 2004 M6.3 earthquake
- Probabilistic seismic losses
- Probabilistic storm surge hazard methodology

ISC earthquakes locations: 1960 to present

1985 – 2005 cumulative cyclone tracks (NHC / JTWC)
Probabilistic risk assessment & comparison

> Risk is characterized by:

- its likelihood → Return period
- its measurement → Direct economic losses

> Incomplete but quantitative measure of the disaster

<table>
<thead>
<tr>
<th>Form of damage</th>
<th>Direct</th>
<th>Indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Physical damage to assets:</td>
<td>Loss of industrial production</td>
</tr>
<tr>
<td></td>
<td>buildings</td>
<td>Traffic disruption</td>
</tr>
<tr>
<td></td>
<td>contents</td>
<td>emergency costs</td>
</tr>
<tr>
<td>Tangible</td>
<td>infrastructure</td>
<td></td>
</tr>
<tr>
<td>Intangible</td>
<td>Loss of life</td>
<td>Inconvenience of post-flood recovery</td>
</tr>
<tr>
<td></td>
<td>health effects</td>
<td>Increased vulnerability of survivors</td>
</tr>
</tbody>
</table>

- Loss of life
- health effects
- Loss of ecological goods
- Inconvenience of post-flood recovery
- Increased vulnerability of survivors

Adapted from Uhlemann et al., 2011
Assets estimation – construction cost / m²

> **based on the construction value** rather than on the market value of the building

similarly to Kleist & al., 2006; FEMA, 2003; Dutta et al., 2003

> **Local and recent data** are used, if possible

<table>
<thead>
<tr>
<th>Construction type</th>
<th>Construction cost (€ per net floor area)</th>
<th>Source (incl. year and location)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual housing</td>
<td>1127</td>
<td>EPTB 2010 for Overseas Territories</td>
</tr>
<tr>
<td>Collective housing</td>
<td>1000</td>
<td>Based on the average social housing price in Guadeloupe</td>
</tr>
<tr>
<td>Shelter</td>
<td>600</td>
<td>Assumption</td>
</tr>
<tr>
<td>Industrial / large business</td>
<td>1390</td>
<td>Based on market price</td>
</tr>
</tbody>
</table>
# Assets estimation – average surface

## Living Surface per occupancy type

<table>
<thead>
<tr>
<th>Occupancy type</th>
<th>Average living space per dwelling</th>
<th>Source (incl. year and location)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional housing</td>
<td>71 m²</td>
<td>INSEE, 2006, for Guadeloupe</td>
</tr>
<tr>
<td>Recent private housing</td>
<td>101 m²</td>
<td>INSEE, 2006, for Guadeloupe</td>
</tr>
<tr>
<td>Villa</td>
<td>150 m²</td>
<td>Assumption</td>
</tr>
<tr>
<td>Collective housing</td>
<td>65 m²</td>
<td>INSEE, 2009 for France &amp; DGAFP, for France</td>
</tr>
<tr>
<td>Makeshift shelters</td>
<td>50 m²</td>
<td>Assumption</td>
</tr>
<tr>
<td>Industrial buildings</td>
<td>300 m²</td>
<td>CCI, for Guadeloupe</td>
</tr>
</tbody>
</table>
Assets estimation – overall methodology

- Living Surface per occupency type
- Ratio of living space on net floor area
- Occupancy type per SDRS type
- Building value per construction type, per net floor area
- Net floor area per SDRS type
- Structure replacement value per SDRS type
- Content replacement value per SDRS type
- Content estimation relatively to the occupation type

« SDRS type »: building vulnerability typology defined by the « Regional Scenario for Seismic Risk » study & surveys. Cf. Bertil et al., 2009
Assets estimation - results

> Per vulnerability type

<table>
<thead>
<tr>
<th>SDRS type</th>
<th>Building stock in Guadeloupe</th>
<th>Replacement value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Description</td>
<td>Nb of dwellings</td>
</tr>
<tr>
<td>HABFOR</td>
<td>makeshift shelter</td>
<td>6 424</td>
</tr>
<tr>
<td>MCPIER</td>
<td>stone houses</td>
<td>609</td>
</tr>
<tr>
<td>CASTRA</td>
<td>traditionnal houses (wood)</td>
<td>15 710</td>
</tr>
<tr>
<td></td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

> Total assets

<table>
<thead>
<tr>
<th>Economic sector</th>
<th>Guadeloupe exposed assets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (G €)</td>
</tr>
<tr>
<td>Private housing</td>
<td>36.5</td>
</tr>
<tr>
<td>Industry</td>
<td>1.1</td>
</tr>
<tr>
<td>Commerce &amp; service</td>
<td>5.7</td>
</tr>
<tr>
<td>Schools &amp; hospitals</td>
<td>4.4</td>
</tr>
<tr>
<td>Others (roads, energy &amp; water supply, etc.)</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>47.6</td>
</tr>
</tbody>
</table>
Loss estimation per Damage State

**Loss ratio per DS**
EMS 98 DS - % loss relation for:
- Structural repairs
- Content replacement

### Structural repairs

<table>
<thead>
<tr>
<th>EMS-98 DS</th>
<th>Structure damage ratio</th>
<th>Central damage factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>1</td>
<td>0-1%</td>
<td>0.5%</td>
</tr>
<tr>
<td>2</td>
<td>1-20%</td>
<td>10%</td>
</tr>
<tr>
<td>3</td>
<td>20-60%</td>
<td>40%</td>
</tr>
<tr>
<td>4</td>
<td>60-100%</td>
<td>80%</td>
</tr>
<tr>
<td>5</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

From Tyagunov et al. (2006) for German buildings typology

### Content replacement

<table>
<thead>
<tr>
<th>EMS-98 DS</th>
<th>Replacement ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>1</td>
<td>1 %</td>
</tr>
<tr>
<td>2</td>
<td>2 %</td>
</tr>
<tr>
<td>3</td>
<td>12 %</td>
</tr>
<tr>
<td>4</td>
<td>25 %</td>
</tr>
<tr>
<td>5</td>
<td>50 %</td>
</tr>
</tbody>
</table>

Adapted from FEMA (2003) for US buildings typology
Validation using les Saintes (2004) EQ

Les Saintes M6.3 EQ hazard sc.

SDRS Seismic vulnerability

Damage State of exposed buildings

Loss ratio per DS EMS 98 DS - % loss relation for:
- Structural repairs
- Content replacement

Assets value
Economic estimation of:
- Structural repair
- Content replacement

Les Saintes losses estimation

Damage & loss model

> Post-seismic damage observations
> Post-disaster cost estimations

Available data
Validation using les Saintes (2004) EQ

> Observations

• Damage: a few D4/D5 buildings, mostly light damages (cracks), concentrated in Les Saintes islands and the South of Basse Terre

• Direct economic losses:
  – CCR (French public reinsurance institution) : estimated 60 M€
  – 43 % of households in Guadeloupe have a home insurance

→ Estimated cost: 140 M€

> Loss modeling

• Damage localization and number coherent but slightly higher than the post-seismic observations

• Losses: 148 - 513 M€, central damage factor: 325 M€

→ Overestimated cost. Hypotheses: no reimbursement of light damage (no declaration, insurance excess), signification of the CCR number, %loss - DS relation …
Probabilistic seismic risk: losses (DS)

- **Probabilistic hazard assessment**
- **SDRS** Seismic vulnerability

**Damage State** of the exposed elements for a range of return time periods

> Loss calculations are based on a probabilistic seismic hazard map. This approach leads to slightly conservative results (Bommer and Crowley, 2006)

Damage map obtained using Armagedom loss estimation software (Sedan, 2003)
Probabilistic seismic risk: losses (€)

- **Probabilistic hazard assessment**
- **SDRS** Seismic vulnerability

**Damage State** of the exposed elements for a range of return time periods

**Loss ratio per DS**
EMS 98 DS - % loss relation for:
- Structural repairs
- Content replacement

**Assets value**
Economic estimation of:
- Structural repair
- Content replacement

**Probabilistic direct losses** for a range a return time periods

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**Preliminary results**

![Graph showing annual probability of exceedance vs. direct economic losses (million euro)]
The marine submersion of the coastal areas results from the conjugated effects of:

- the tide
- the atmospheric surge (due to wind and low atmospheric pressure)
- the waves set-up (local elevation of the mean sea level due to wave breaking)

The maximum level reached by the water is the run-up
Probabilistic storm surge hazard: methodology

Selection of 291 cyclones between 1910 and 2009

Data treatment
Parametric wind field (Holland’s model)

Données

Selection of impacting cyclones (for waves and storm surge)

Parametric cyclonic wind and pressure fields

Offshore wave modelling (WAM3)
Nearshore wave modelling (SWAN)
Set-up calculation with empirical formula (Stockdon et al, 2006)

Modelling

Atmospheric surge modelling (MARS 2DH)

Time series of total water level

Statistical analysis with the POT method

Mapping of areas under specific return period levels

Cf. details in Lecacheux et al., 2012
Storm surge hazard: events modelling

- **WW3 (NOAA) (6')**
- **WW3 (2')**
- **SWAN (Univ. Delft) (100m)**

**Waves** (example: Dean 2007)

- **MARS (Ifremer)**
- **MARS**
- **MARS**

**Atmospheric surge** (example: Hugo 1989)
Probabilistic storm surge hazard: waves results

> Peaks Over Threshold sampling of the simulations for different locations around Guadeloupe

> Maximum likelihood fit with a Generalized Pareto Distribution

from Lecacheux et al., 2012
Further steps

> Direct hazard comparison
  • Validation of the economic losses (Les Saintes)
  • Finalization of the probabilistic storm surge hazard
  • Mapping inundated areas and estimating storm surge losses

> Identification, quantification and propagation of uncertainties in the seismic loss calculation

→ Restriction to the area of Pointe à Pitre
> Thank you!

> Acknowledgment

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> Ulehmann, 2011Single type risk analysis procedures in the framework of synoptical risk comparisons, Chap. 2. MATRIX D2.1