Understanding Risk Forum 2016

DISASTER RISK FINANCING AND INSURANCE PROGRAM (DRFIP)

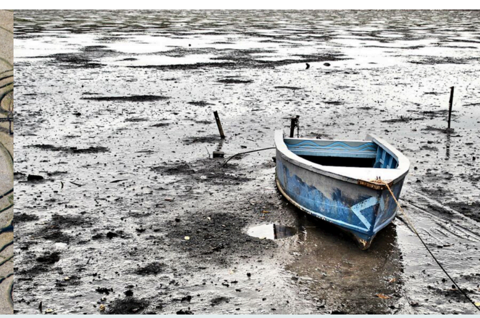
May
16
2016

Training on concepts and terminology for analytics related to disaster risk finance and insurance

Block 2: Risk Metrics & Monte Carlo Simulation. A country case study.

José Ángel Villalobos, Darío Bacchini and Barry Maher



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Block 2: Cat modelling and Financial Risk Metrics Agenda

10:45 – 12:00

- Why to quantify, before occurrence, natural disaster financial losses?
- Early Natural Catastrophe Risk analysis applied to Insurance
- Loss distributions and simulation

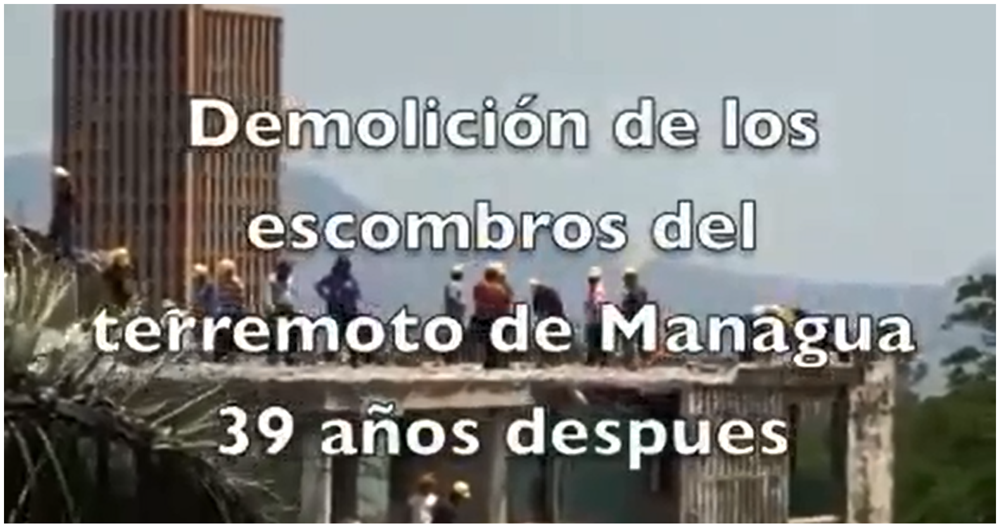
13:00 – 13:45

- Risk Metrics, then and now
- Using Risk metrics

December 23rd, 1972: Nicaragua, Managua EQ

- 6.9 Richter Scale, just 5 Km. beneath the center of capital city
- +10,000 casualties / population 400K
- Massive destruction
- Wave of emigrants

April, 2011: demolition of remaining 1972 wreckage
April, 2014: a new EQ triggers further demolition efforts



Source: La Prensa, April 20th, 2011

Reconstruction?
After 44 years… Not yet

Nicaragua inicia demolición de edificios afectados en Managua

Las estructuras de más de 40 años están siendo derribadas con maquinarias pesadas.

Varios edificios quedaron en ruinas tras el terremoto que destruyó el viejo centro de Managua. (AP)

Source: El Universal, April 11th, 2014

How to quantify natural disaster financial impact?

- Simply: we don't know when an event will occurs!
- But probabilities help us to understand and quantify uncertainty…
- Then considering purpose of measurement!

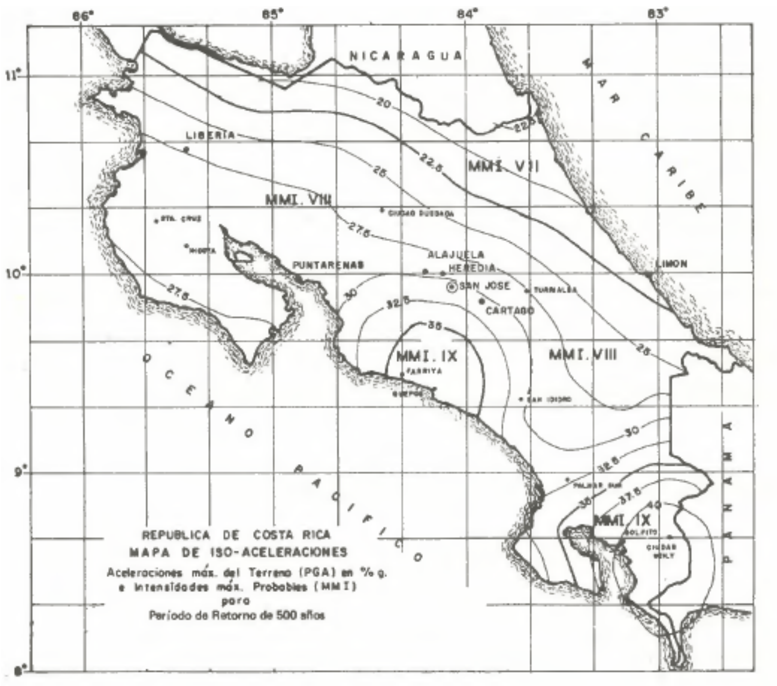
- **Work in progress!!!**

1978: Pioneer Seismology Study Applied to Insurance

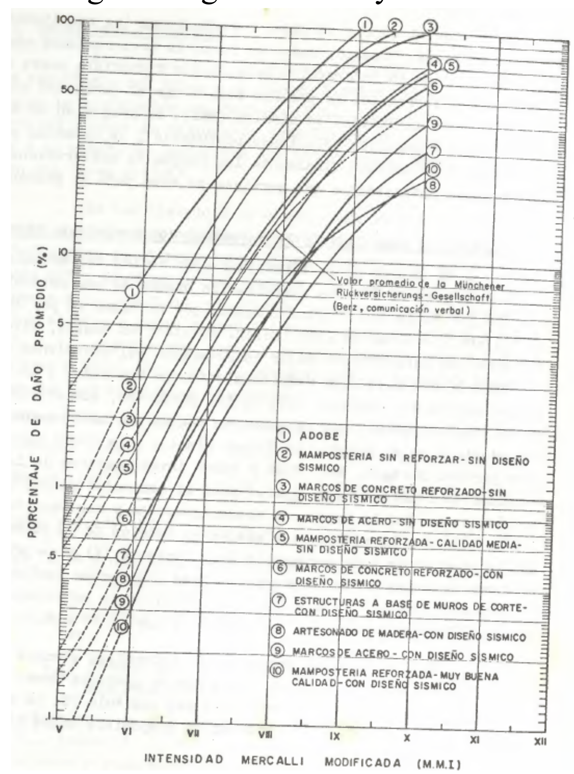
- Seismic-genetic zones identified ~ Poisson model for EQ frequency
- Attenuation, micro-zonation
- Local structural typology identified
- Detailed exposure database from monopoly state owned insurance company
- Loss functions (% of damage in function of Mercalli)
- Losses calculated in a deterministic way…
- Maximum Possible Loss v. Maximum Probable Loss

Basis of current methodology and risk metrics…

Iso acceleration curves



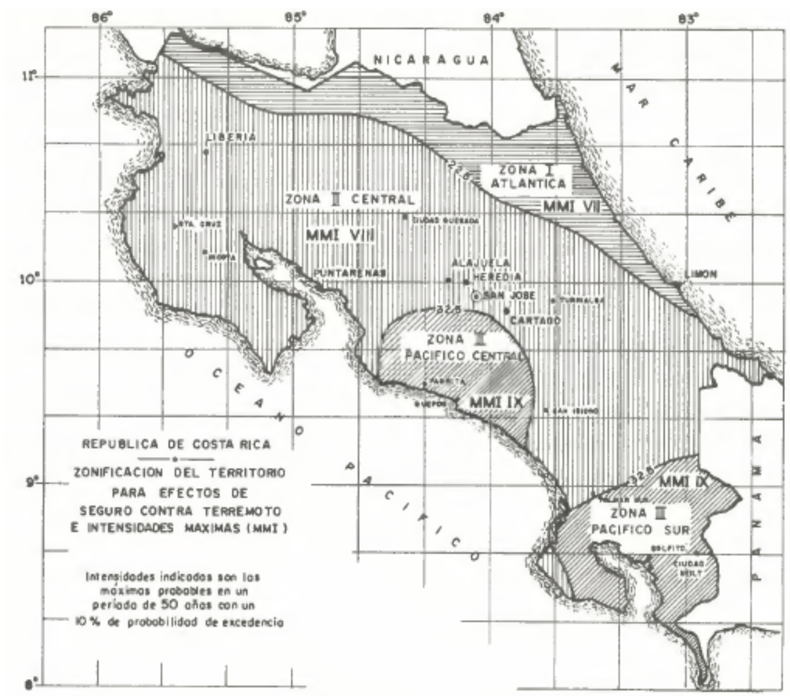
Average damage v. Intensity Mercalli scale



Source: Estudio de Seguro Contra Terremoto, Instituto Nacional de Seguros, F. Sauter and H. Shah, 1978

Average Annual Loss

Country Zonation



RELACION DE INTENSIDADES MMI VRS. ACELERACION
(RANGOS DE VARIACION)

INTENSIDAD MMI	ACELERACION (PGA) (en % de g)
V	< 5
VI	5 - 10
VII	10 - 20
VIII	20 - 35
IX	35 - 50
X	> 50

$$P.A. = \sum_{i\,=\,MM\ I}^{i\,=\,MM\ XII} P\,(MMI = i) \times RD \qquad (\text{Ec. } 8.2.)$$

donde :

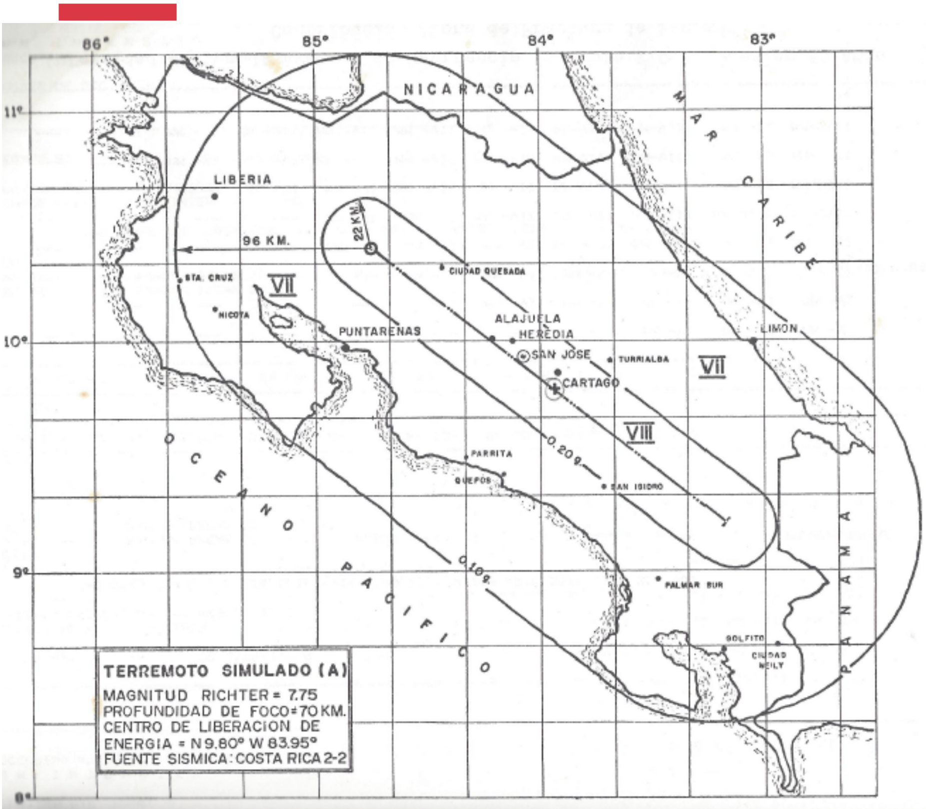
P.A.: pérdida anual esperada

P: (MMI = i) : probabilidad de ocurrencia por año de una intensidad sísmica MMI = i en determinada zona, obtenida de las Tablas 8.1., 8.12. y 8.23.

R.D. : Razón de daño promedio para determinado tipo de construcción, obtenida de la Fig. 6.22.

Source: Estudio de Seguro Contra Terremoto, Instituto Nacional de Seguros, F. Sauter and H. Shah, 1978

Probable Maximum Loss (PML)

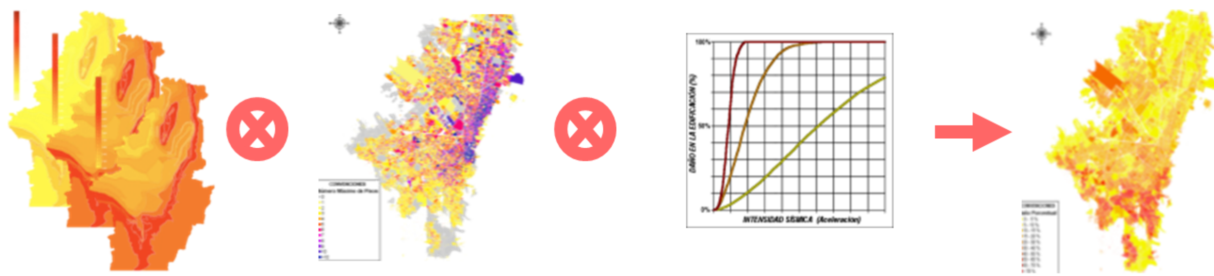


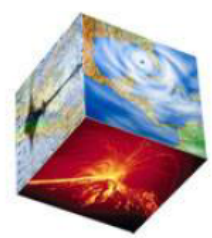
- Objective: to quantify the maximum loss amount caused by ONE event
- The probability of occurrence /return period directly associated to such event, otherwise deterministic
- Two events were chosen as the ones which may generate highest losses, and the one with the maximum loss is the PML with a recurrence period of 1/x years…

Source: Estudio de Seguro Contra Terremoto, Instituto Nacional de Seguros, F. Sauter and H. Shah, 1978

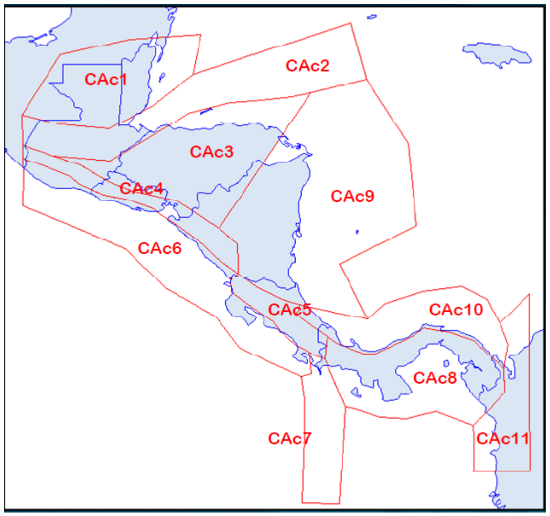
Comprehensive Approach for Probabilistic Risk Assessment - CAPRA

Hazard Exposure Vulnerability Results



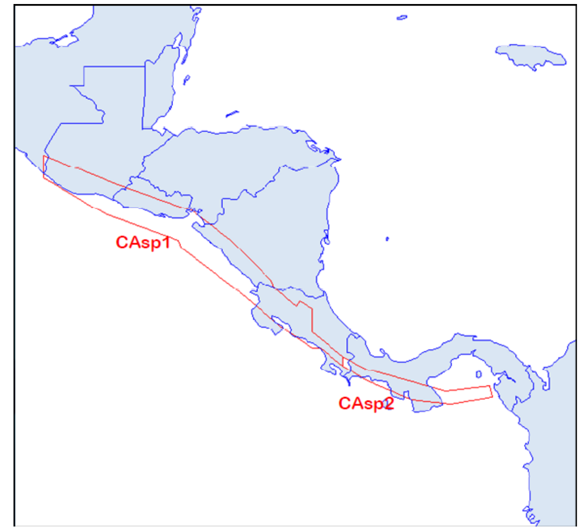


Hazard:
RESIS II: Definition of regional seismic sources



Crustal sources

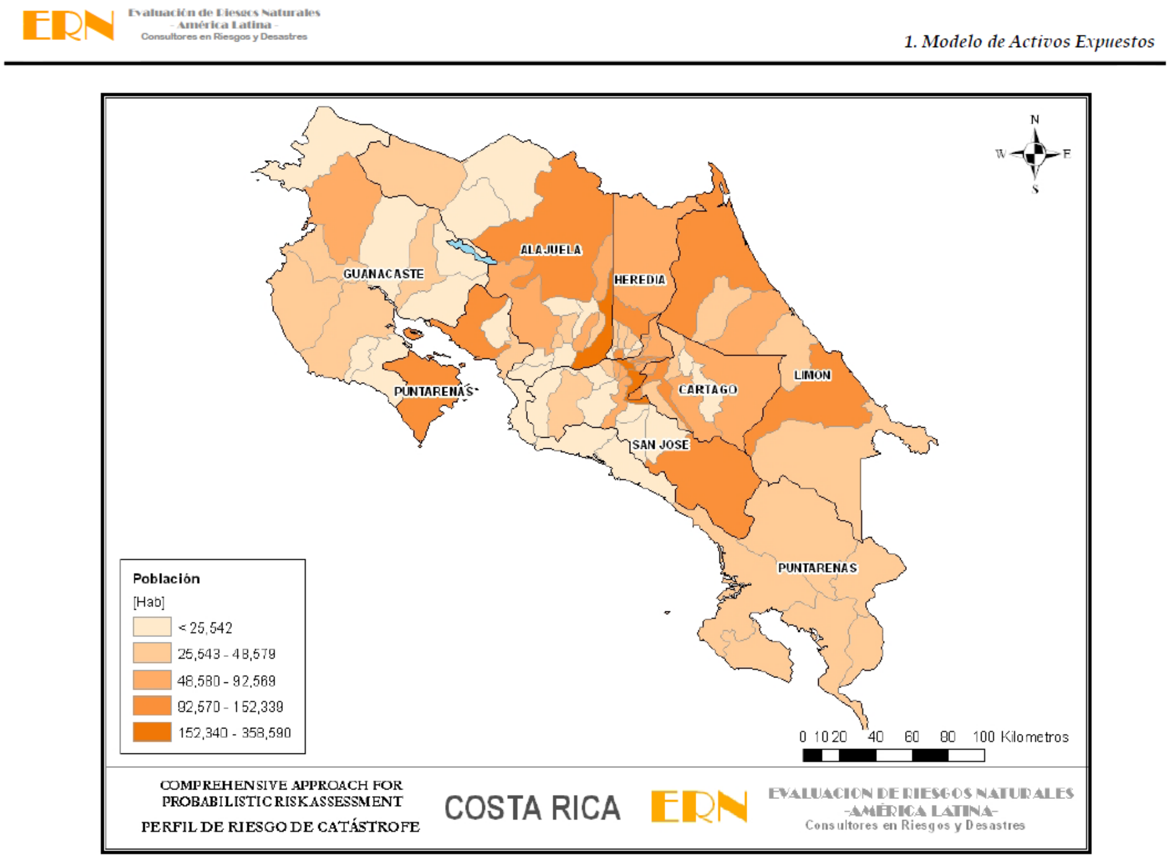
Interphase subduction sources



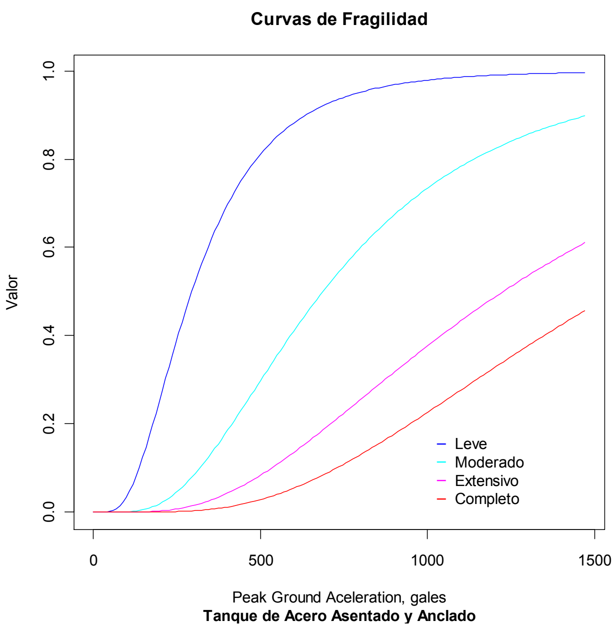
Deep Subduction sources

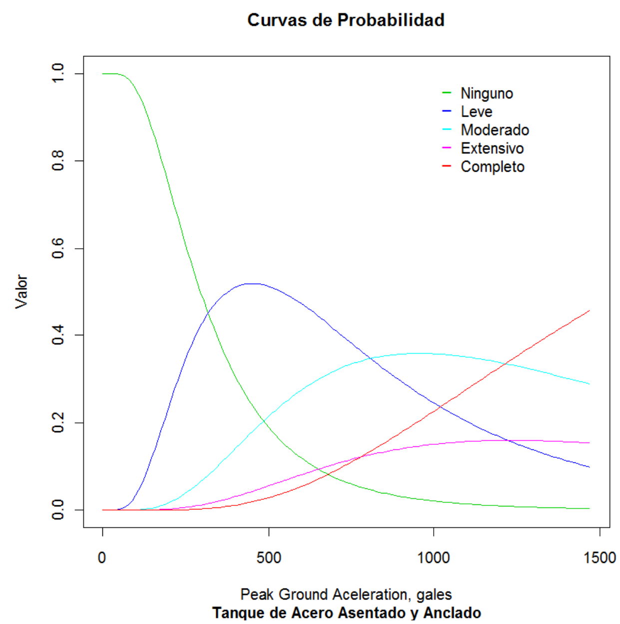
Amenaza Sísmica en América Central, Editorial Entinema, 2009

Exposure:
Inventory of Exposure ERN-CAPRA-T2-4



Vulnerability (TAP for Water & Sanitation)





$$P[x \geq ED_i] = f_i(s, \theta_i)$$

$ED_i = 0$; $ED_{MAX}(i) = 1$

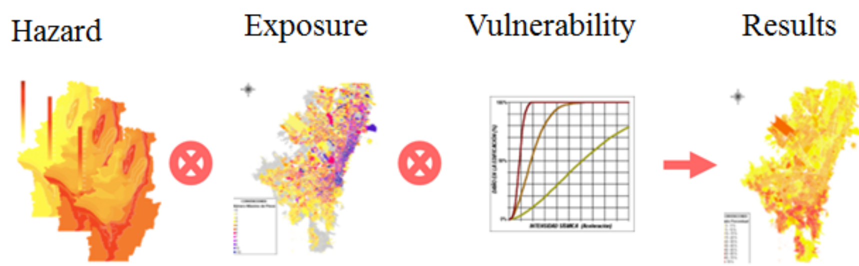
ED_i = Estado de daño i hasta n

θ_i : vector de parámetros (HAZUS)

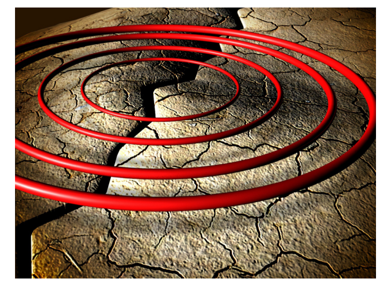
$$EDM|S = \sum_{i=1}^{n} P[ED=i|s]$$

Estado de Daño Medio se deriva de matriz de Probabilidad de daño

Compound distributions for EQ hazard



- Frequency:
  - Number of earthquakes in a given scenario
  - Total number of earthquakes in a year
  - Number of earthquakes by magnitude



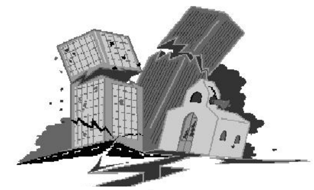
- Severity:
  - Conditional loss (given occurrence of an earthquake)

Cat. loss distributions: Why are we simulating?

- If we know the exact loss distribution, then WE DO NOT NEED TO SIMULATE!

- In general, we should rely on simulations when dealing with COMPOUND LOSS DISTRIBUTIONS
    - Frequency
    - Severity

Simulation Scheme for Seismic Hazard



Poisson Distributions (λ_k): $N_{k,y}$
Number of seism associated to scenario "k"
(k=1 to m) in year "y" (y=1 to n_{Sim}).

Beta Distributions (α_k , β_k and θ_k): $X_{k,i,y}$
Loss associated to "i-th" event (i=1 to $N_{k,y}$)
in scenario "k" (k=1 to m) in year "y" (y=1 to n_{Sim}).

How many quakes per scenario?

Loss amount from each earthquake in the scenario?

Loss amount per scenario (from all earthquakes)?

Aggregate annual loss (from all scenarios)?

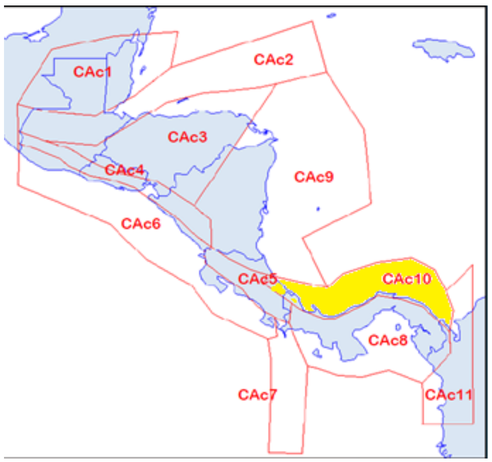
Simulation of Compound Distribution

A simple example

$$N_1 = 1 \qquad X_{1,1} = 12 \qquad S_1 = 12$$

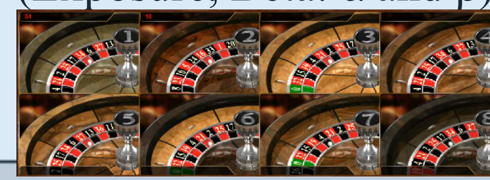
$$N_2 = 3 \qquad X_{2,1} = 6; X_{2,2} = 6; X_{2,3} = 35 \qquad S_2 = 47$$

Simulation of Losses for Costa Rica
Inputs from CAPRA



Frequency (Poisson: λ)

Conditional Loss Distribution (Exposure, Beta: α and β)

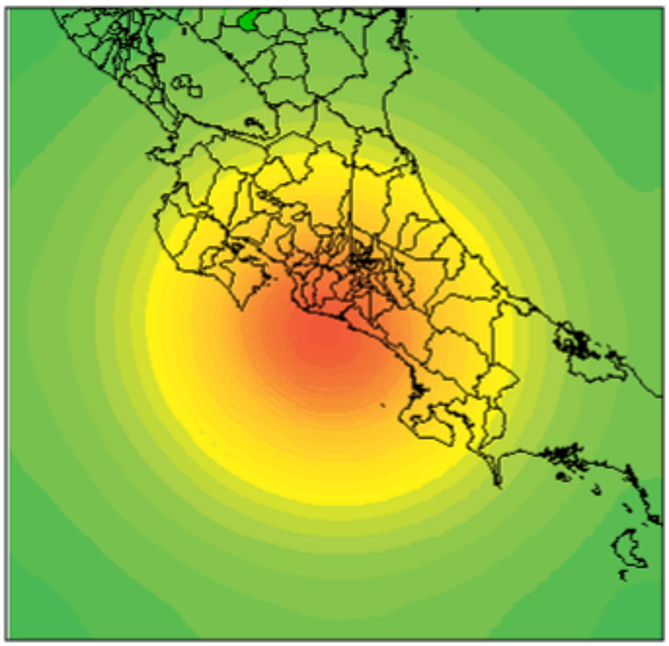


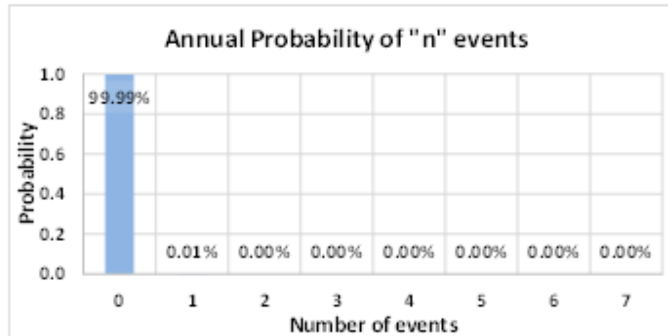
CAPRA Output							
Scenario	Magnitude	Frequency: E[N(i)] = λ	Mean Cond. Loss: E[X(i)]	Var. Cond. Loss: V[X(i)]	Beta Distr. Parameter: α	Beta Distr. Parameter: β	Exposure
CAc10_SF1_M=5.380.00323018	5.38	0.00323	73.04	14,719	0.36119	381	77,199
CAc10_SF1_M=6.130.000706832	6.13	0.00071	280.76	212,869	0.36531	100	77,199
CAc10_SF1_M=6.880.00015467	6.88	0.00015	946.82	2,223,170	0.38603	31	77,199
CAc10_SF1_M=7.630.000033845	7.63	0.00003	2,406.10	12,027,100	0.43519	14	77,199
CAc10_SF100_M=5.380.0102077	5.38	0.01021	0.12	0	1.12374	115,672	12,052
CAc10_SF100_M=6.130.00223367	6.13	0.00223	0.47	0	0.46635	11,951	12,052

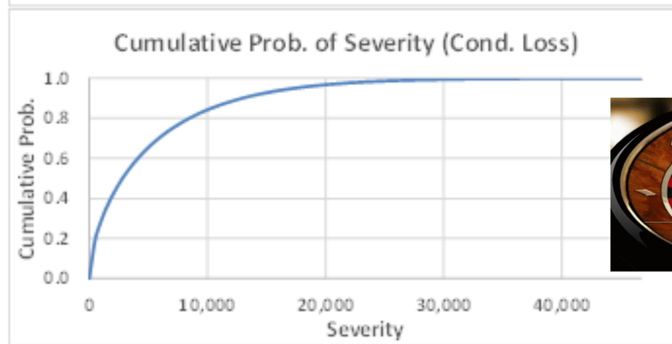
Simulation of Losses in Costa Rica

Worst scenario - but fully probabilistic!

Scenario	Magnitude	Frequency: E[N(i)] = λ	Mean Cond. Loss: E[X(i)]	Var. Cond. Loss: V[X(i)]	Beta Distr. Parameter: α	Beta Distr. Parameter: β	Exposure
CAsp1_SF45_M=7.280.000121413	7.28	0.00012	4,963.16	34,706,600	0.59983	9	77,199







Simulation of Losses for Costa Rica
All the scenarios: 1 Year – Summary

Number of EQ (Sum of N(i)):	20
Max # of EQs in same scenario:	1
Max Magnitude:	7.28
Aggregate Annual Loss:	2,148.60
Maximum Annual Loss:	1,018.24

We are interested in:
- **Aggregate Annual Loss, and/or**
- **Maximum Annual Loss**

Simulation of Losses for Costa Rica

All the scenarios: 1 Year – Detail of scenarios

We can also analyze losses per scenario:

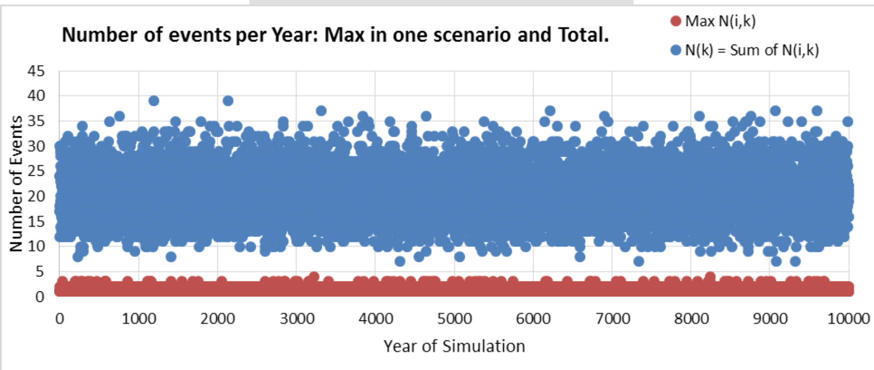
CAPRA Output								Simulation of Number of events, Loss of each event in a scenario and Total Losses per Scenario				
Scenario	Magnitude	Frequency: E[N(i)] = λ	Mean Cond. Loss: E[X(i)]	Var. Cond. Loss: V[X(i)]	Beta Distr. Parameter: α	Beta Distr. Parameter: β	Exposure	N(i): # EQs at Scenario	Event #1 Loss: X1(i)	Event #2 Loss: X2(i)	Event #3 Loss: X3(i)	Total Loss: S(i)
CAc5_SF21_M=5.290.0245043	5.29	0.02450	257.44	182,954	0.35772	107	77,199	1	1,018.24			1,018.24
CAc5_SF31_M=5.290.0354488	5.29	0.03545	15.76	661	0.37537	1,839	77,199	1	33.07			33.07
CAc5_SF32_M=5.290.0354488	5.29	0.03545	22.03	1,291	0.37563	1,316	77,199	1	203.36			203.36
CAc6_SF15_M=5.360.105274	5.36	0.10527	5.01	58	0.42847	6,607	77,199	1	7.23			7.23
CAc6_SF22_M=5.360.0712995	5.36	0.07130	4.50	47	0.42939	7,359	77,199	1	14.90			14.90
CAc6_SF24_M=6.090.00958394	6.09	0.00958	237.39	154,746	0.35997	117	77,199	1	835.66			835.66
CAc6_SF30_M=5.360.0407844	5.36	0.04078	3.21	23	0.45380	10,912	77,199	1	0.19			0.19
CAc6_SF40_M=5.360.0407844	5.36	0.04078	48.17	6,515	0.35527	569	77,199	1	25.44			25.44
CAc6_SF62_M=6.090.0120937	6.09	0.01209	0.75	1	0.44573	7,873	13,161	1	0.07			0.07
CAc6_SF71_M=5.360.0420516	5.36	0.04205	0.55	0	1.06793	126,566	65,147	1	0.41			0.41
CAc6_SF8_M=6.090.0153763	6.09	0.01538	9.93	248	0.39741	3,083	77,031	1	0.55			0.55
CAc6_SF90_M=5.360.0306239	5.36	0.03062	0.11	0	1.23470	152,853	13,839	1	0.06			0.06
CAsi1_SF52_M=6.200.00298406	6.20	0.00298	0.01	0	3.29451	894,028	2,307	1	0.01			0.01
CAsi1_SF8_M=5.400.0191554	5.40	0.01916	0.45	1	0.30217	48,476	71,787	1	0.00			0.00
CAsi2_SF70_M=5.310.00861511	5.31	0.00862	54.79	18,172	0.16436	231	77,199	1	9.25			9.25
CAsp1_SF135_M=5.980.00190963	5.98	0.00191	0.23	0	0.52753	25,573	10,977	1	0.10			0.10
CAsp1_SF203_M=5.980.00442187	5.98	0.00442	0.63	1	0.48441	15,299	19,899	1	0.05			0.05
CAsp1_SF209_M=7.280.000192986	7.28	0.00019	4.90	62	0.38217	157	2,017	1	0.00			0.00
CAsp1_SF38_M=5.980.00278192	5.98	0.00278	585.65	1,441,880	0.22848	30	77,199	1	0.00			0.00
CAsp1_SF81_M=5.330.0119787	5.33	0.01198	16.16	1,473	0.17700	845	77,199	1	0.00			0.00

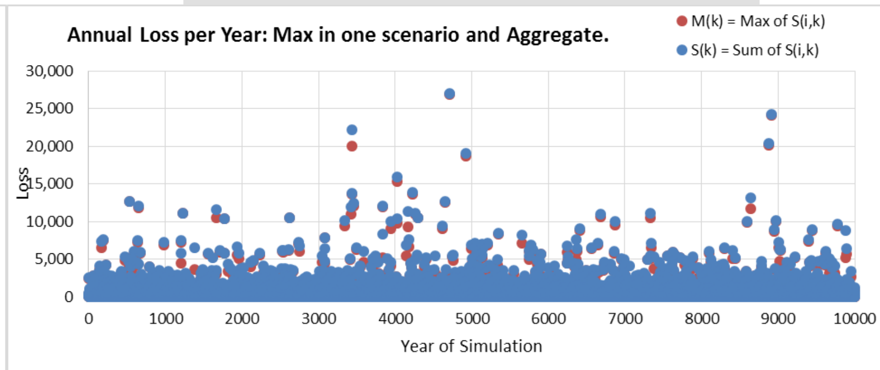
Simulation of Losses for Costa Rica

All scenarios: 10,000 Years

How many earthquakes per

Aggregate annual loss (from all scenarios)?





Are 10,000 years enough?

AAL = 556
Std. Dev. = 1,151

Risk Metrics

For Finance and Insurance

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Risk Metrics: Purpose and properties

Some purposes:

- Understanding the risk
- Setting and evaluation of sovereign cat risk strategies
- Development and increase of cat insurance penetration
- Supervision of (re)insurance
- Pricing of risk transfer instruments
- Cost evaluation of financing instruments

Coherent Risk Metrics

Axioms (being A a rd, highest annual loss of a portfolio)

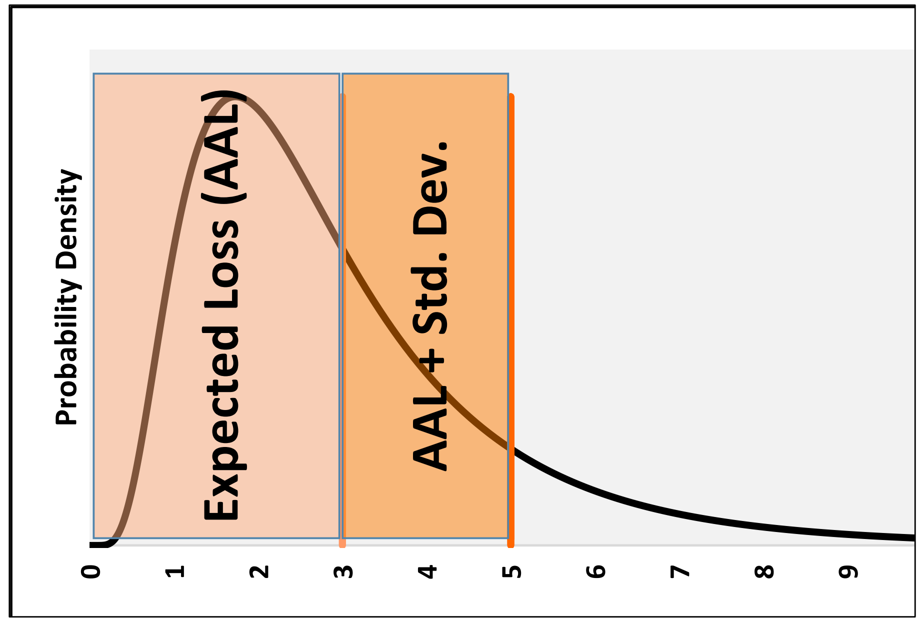
1. Translation Invariance Metric[A+c] = Metric[A] +c
2. Positive homogeneity Metric[k*A] = k*Metric[A
3. Monotonicity (if A>B then Metric[A] ≥ Metric[B]
4. Sub-additivity Metric[A+B] ≤ metric[A] + metric[B] (diversification benefit)

1 & 2 rules out non-linear algebraic function of event loss. 3) eliminates SD. 4) rules out LaR

Artzner tt al. (1999), cited by G. Woo, BAJ 8, Part V, 2002

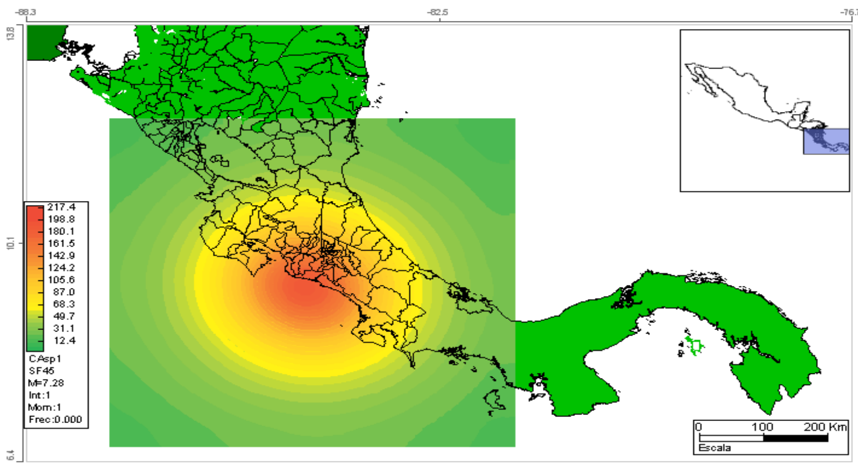
Risk Metrics
AAL and Standard Deviation

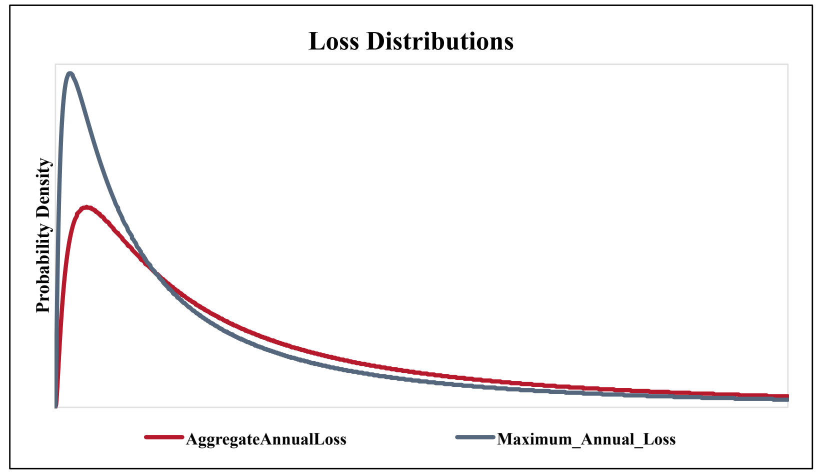
- Average Annual Loss (AAL)
- Standard Deviation
- Law of Large Numbers
- Commercial premium
- Sound market technical pricing (AAL) while competing on loadings



Metrics for extreme events (looking at the tail)

Deterministic v. full probabilistic approach:





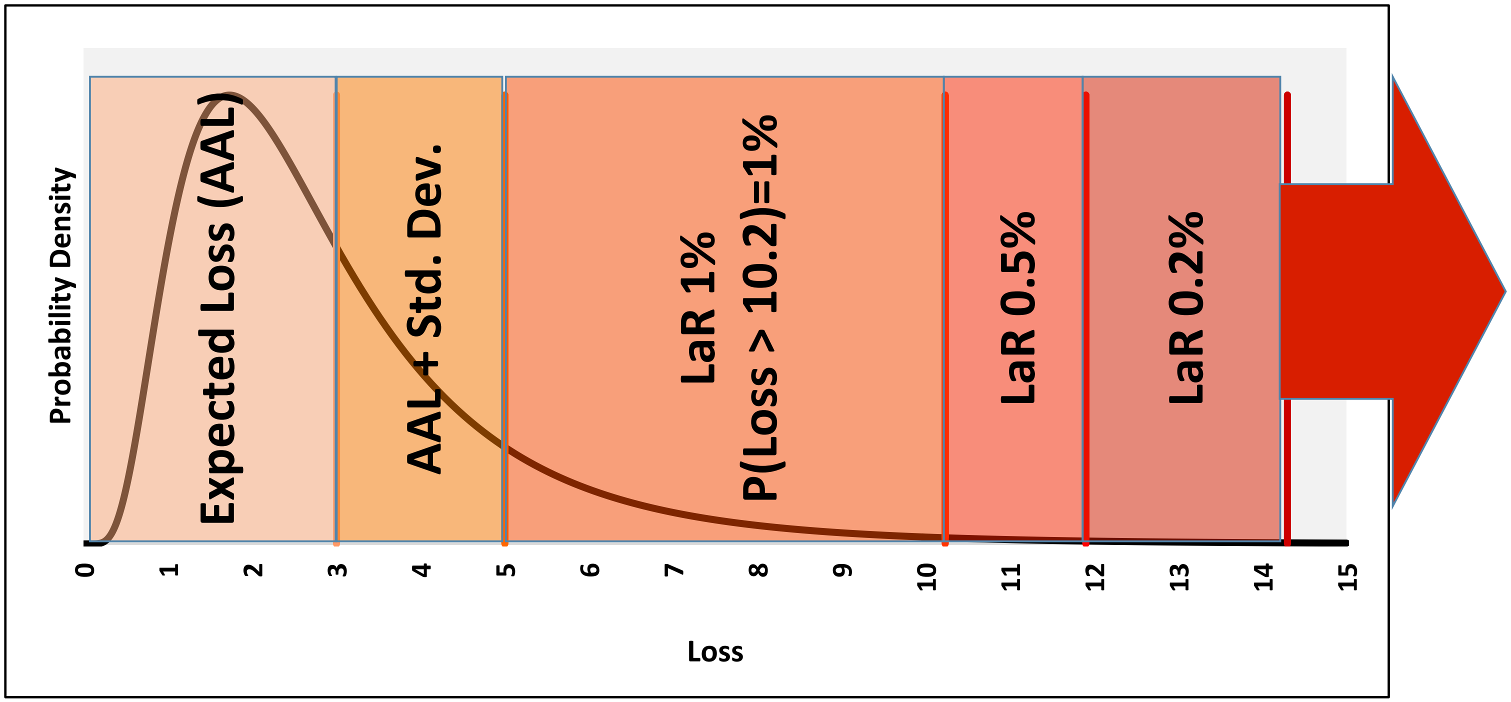
- No longer looking at the worst event, rather looking at a specific loss distribution
- Return period related to physical events occurrence, e.g. earthquakes
- Now annual exceedance probabilities related to financial loss distribution…

Metrics for extreme events (looking at the tail)

- Loss at Risk (LaR):
  P[Loss > LaR] = Annual Exceedance Probability
  - Minimum amount to be exceed with a given annual probability
  - It is a percentile of the loss distribution
  - It must be reported with its associated annual exceedance probability

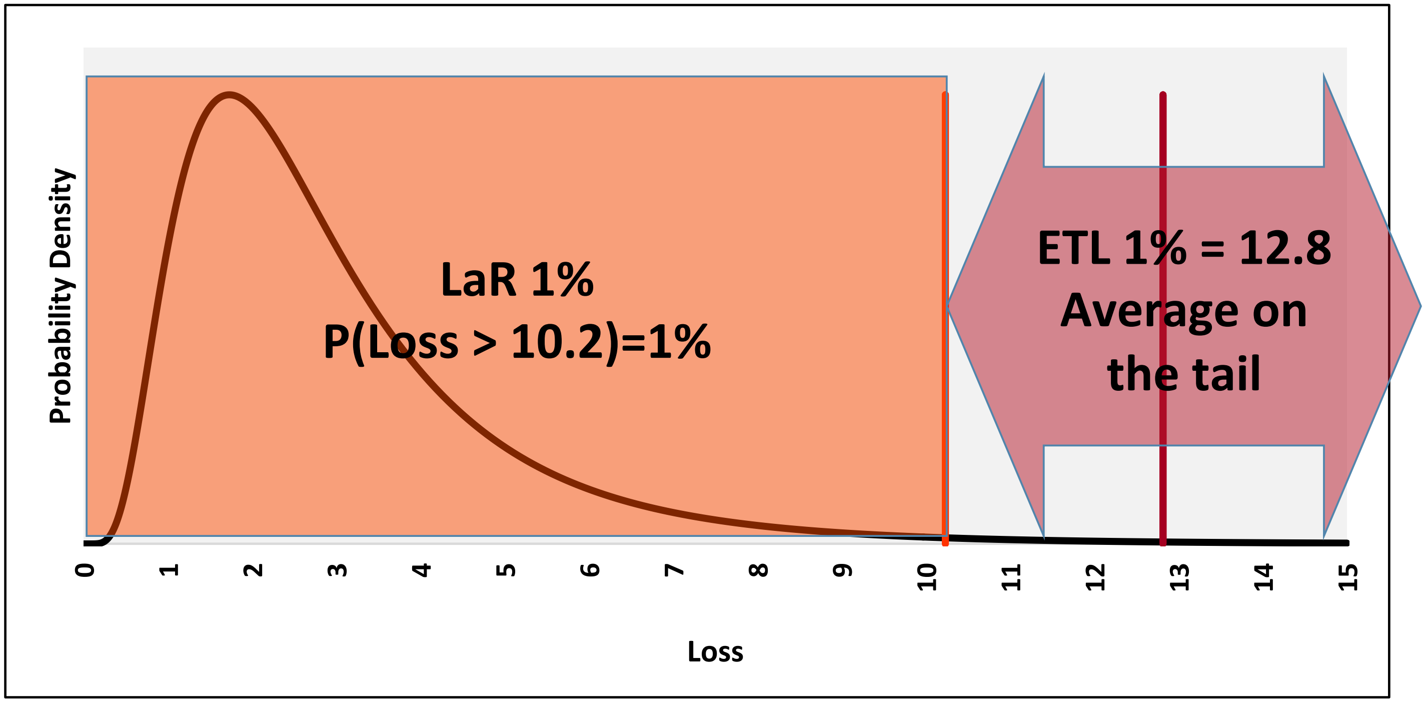
- Expected Tail Loss (ETL):
  ETL = E[Loss | Loss > LaR]
  - Conditional expected value over the loss distribution
  - It must be reported with its associated exceedance probability (related to the LaR cutoff)

Risk Metrics of a Loss Distribution



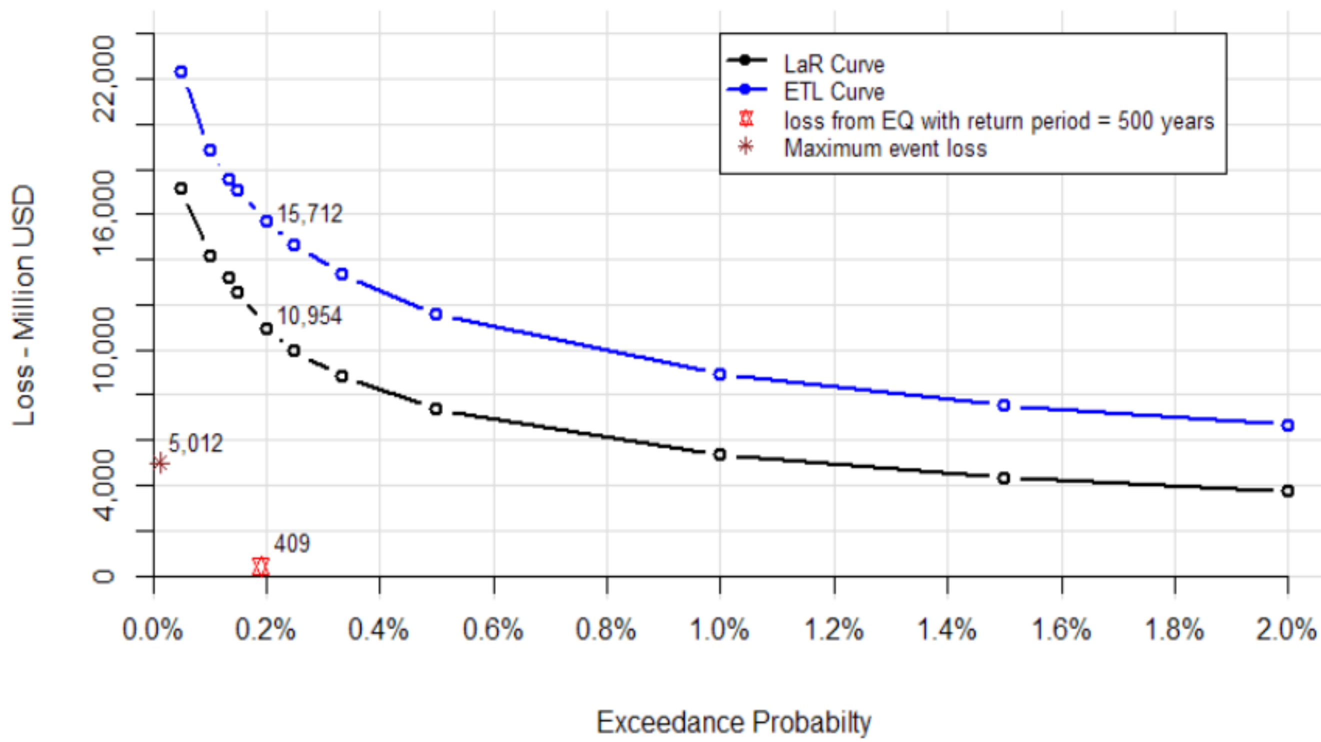
The right border of each bin indicates the cumulative value from zero.

LaR and ETL in a Loss Distribution



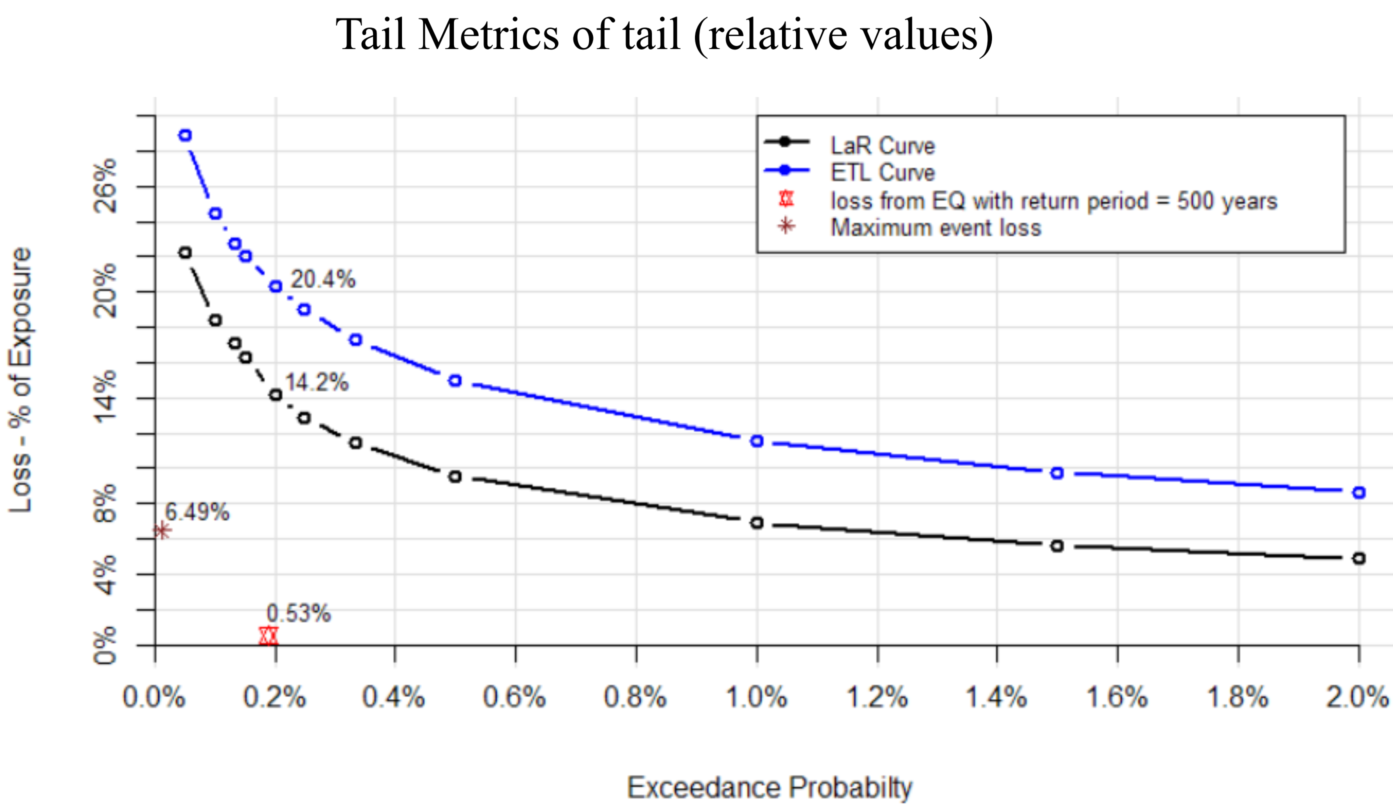
Costa Rica: comparing Risk Metrics

Tail Metrics of tail (absolute values)



- CAPRA
- 100,000 years of simulation

Costa Rica: comparing Risk Metrics



- CAPRA
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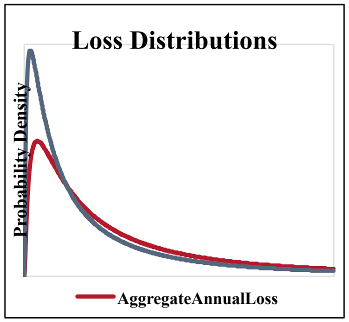
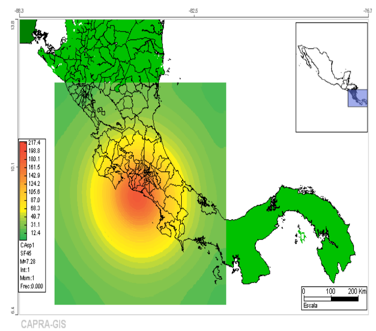
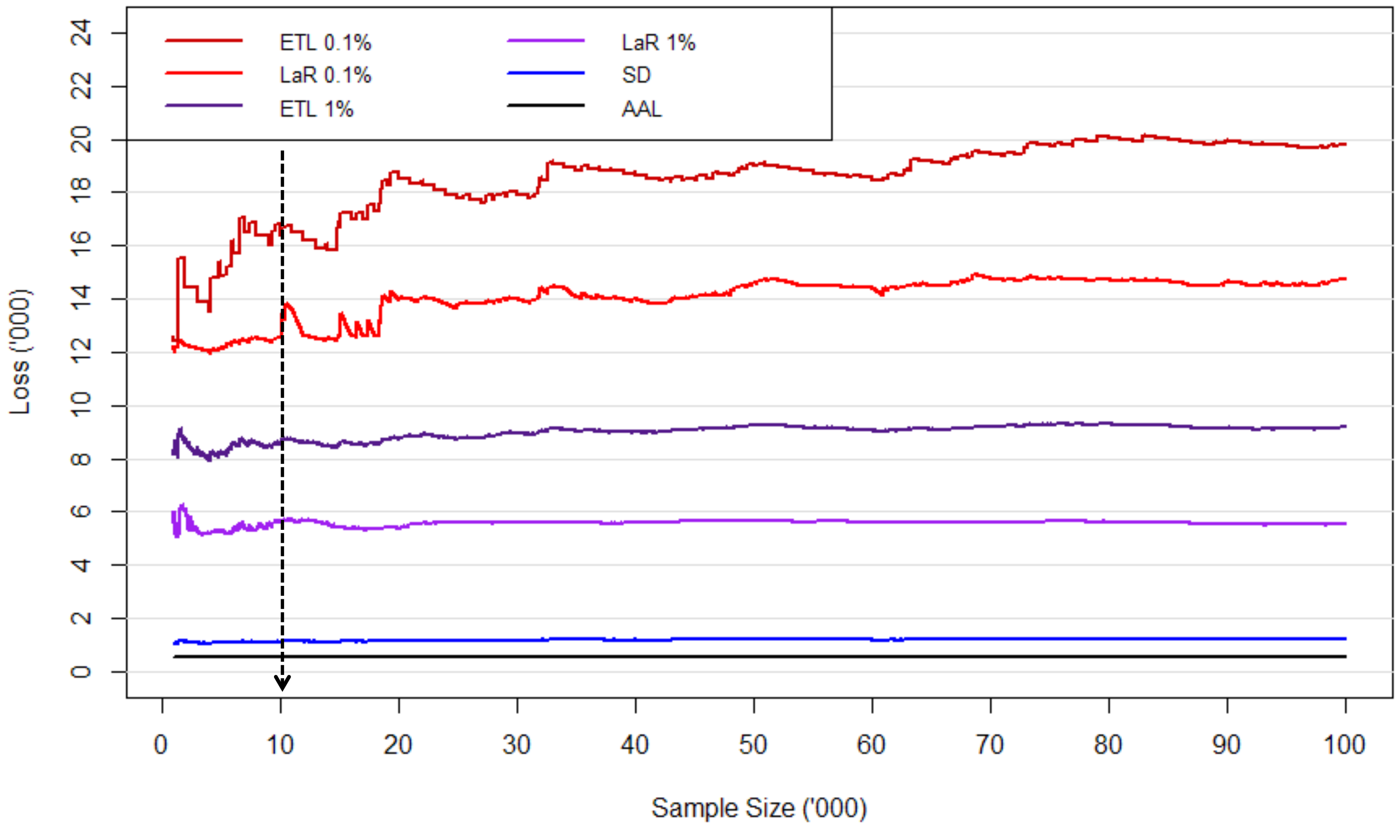




How reliable are the simulation-based Risk Metric estimates?



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DISASTER RISK FINANCING AND INSURANCE PROGRAM (DRFIP)

Using Risk Metrics

For Risk Financing and Insurance

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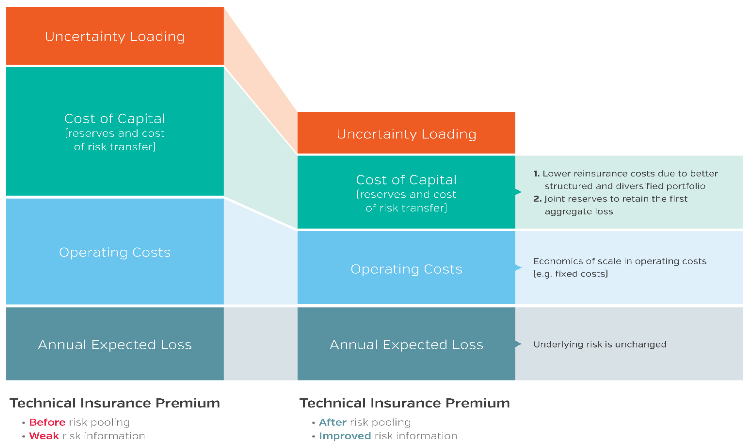
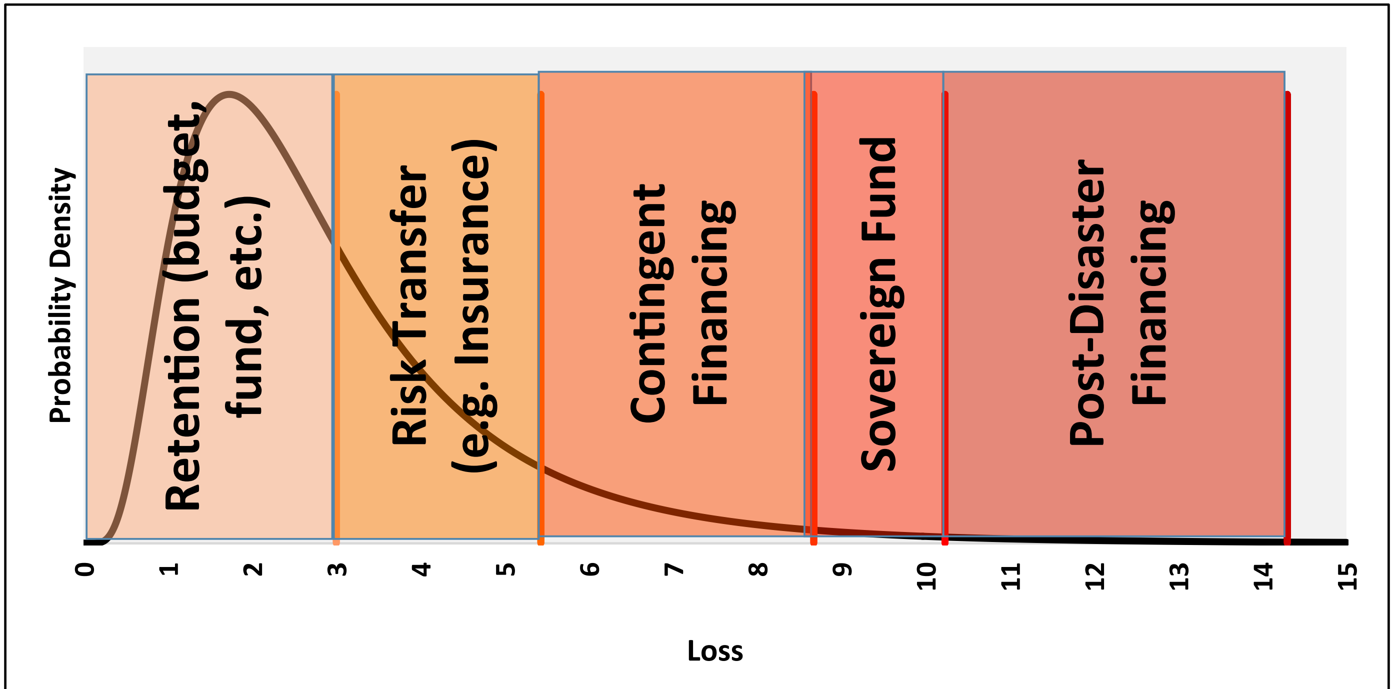
Pricing of risk transfer product/ evaluation of retention financing funds

- Ratemaking
  - P = AAL + α * Std Dev. (usual practice)
  - Other methods (PML-based, etc.)
- Expenses, Target profit, etc.

Conceptual impacts of risk information and pooling on insurance pricing



Layering of Losses (hypothetical example)
Sovereign DRFI strategy/ CXL protection



Obs.: each bin indicates **losses between left and right border**.

Capital Requirement/Catastrophe Reserving

- Ruin theory
- Conservative principle for valuating liabilities
- ETL vs. LaR vs. PML (coherent measure axioms)
- Probabilistic approach: make sense to use aggregate zone sums insured?
- Costa Rica using a return period of 500 years while Perú uses 1,000…
- What about the size of sampling? Standard of 10,000 years of simulation is enough?