International Symposium
Qualification of dynamic analyses of dams and their equipments
and of probabilistic assessment seismic hazard in Europe
31th August – 2nd September 2016 – Saint-Malo

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Session : Session 1 Qualification of probabilistic seismic hazard assessment

Probabilistic seismic hazard assessment


Saint-Malo © Yannick LE GAL

SUMMARY

1.What is « seismic hazard » ?

The components of the hazard
Probabilistic Method
Epistemic uncertainties
The Uniform hazard spectrum (UHS)

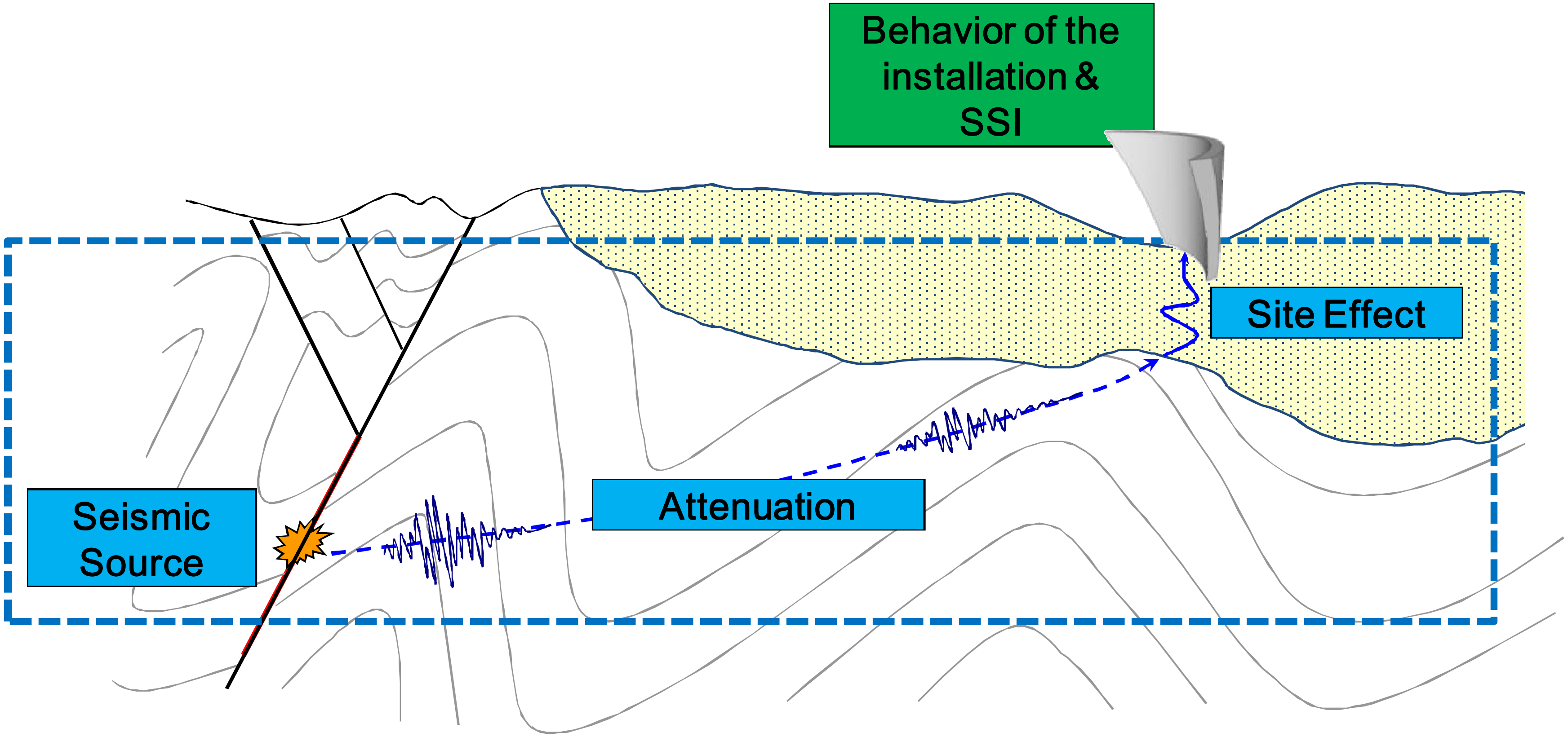
2.Research & developpment for seismic hazard assessement.

Conditionnal Spectra : rigorous use of the Uniform hazard spectrum
Qualification of PSHA : Bayesian inference

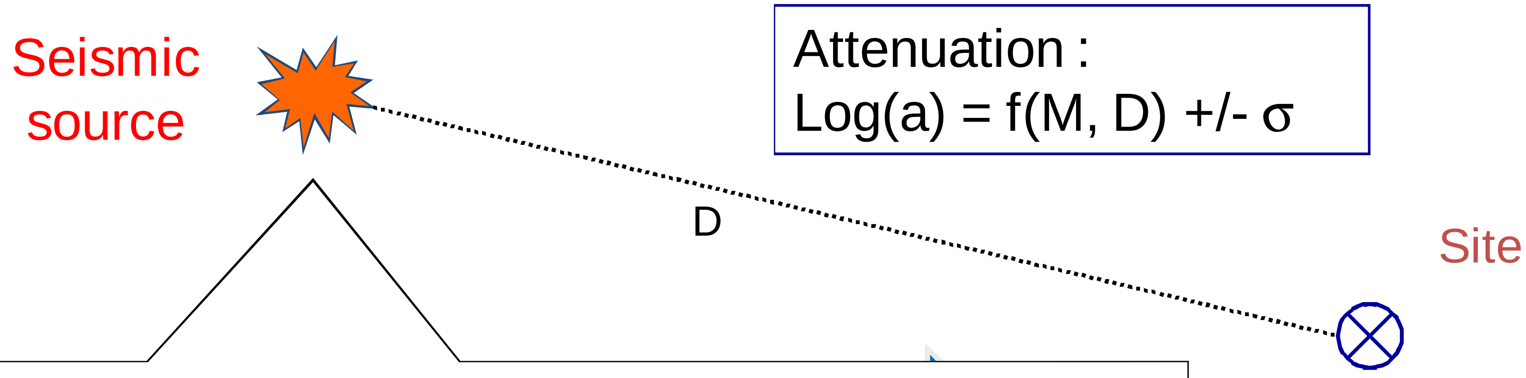
What is « seismic hazard » ?

- **Tell me what will happen**
- **Tell me what can happen**
- **Tell me what's already happened and is likely to occur again**
- **Tell me what the regulation tells me to do**

the components of the hazard

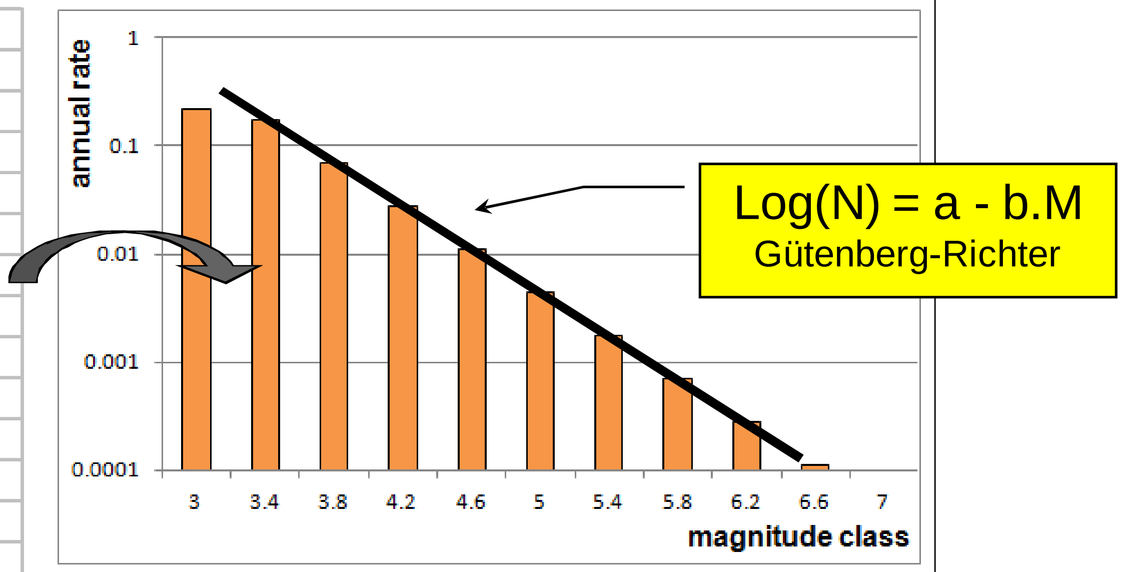


Probabilistic Method



date	M
19-juil-63	2.1
04-févr-61	6.4
25-août-68	5.2
09-nov-73	5.4
06-déc-63	4.8
10-juil-67	6.1
26-août-67	4.2
03-janv-68	4.0
26-nov-59	6.8
12-mai-76	5.1
10-avr-75	4.1
12-mars-82	2.6
…	…

Earthquake catalog



Occurrence Model

Probabilistic Method

- **What is the annual probability that the acceleration on the site exceeds the value of:** ➡ $A = 0.1\ g$

Probabilistic Method

M	M+dM	N(M,M+dM)	Acc	P(a>A)	N(a>A)
5.4	5.8	0.0008	0.082	0.3827	0.0003

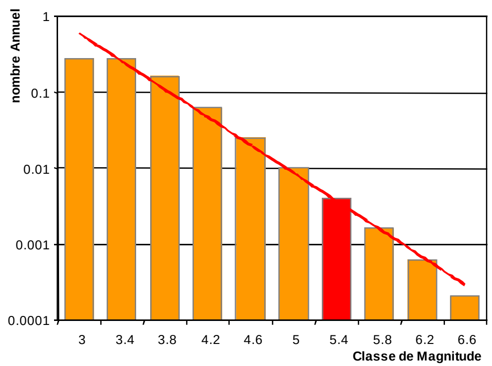
Magnitude range

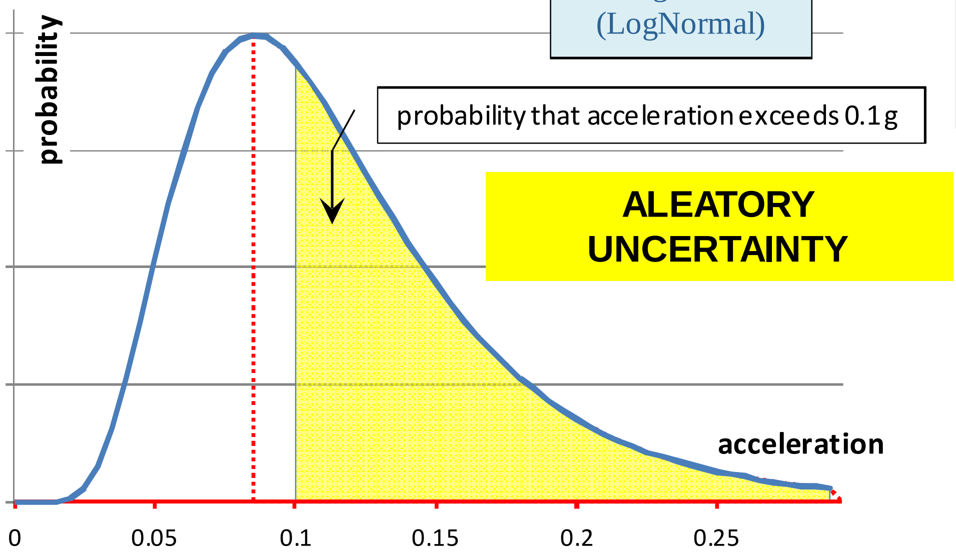
Number of earthquakes in the class
Log(N) = a – b.M

Median Acceleration
Acc = f(M,R)

Probability that the acceleration A is exceeded on the site by an earthquake in the range of magnitude (LogNormal)

Average annual number of earthquakes inducing an acceleration exceeding A, for the magnitude class





Probabilistic Method

What is the annual probability that the acceleration on the site exceeds the value of:

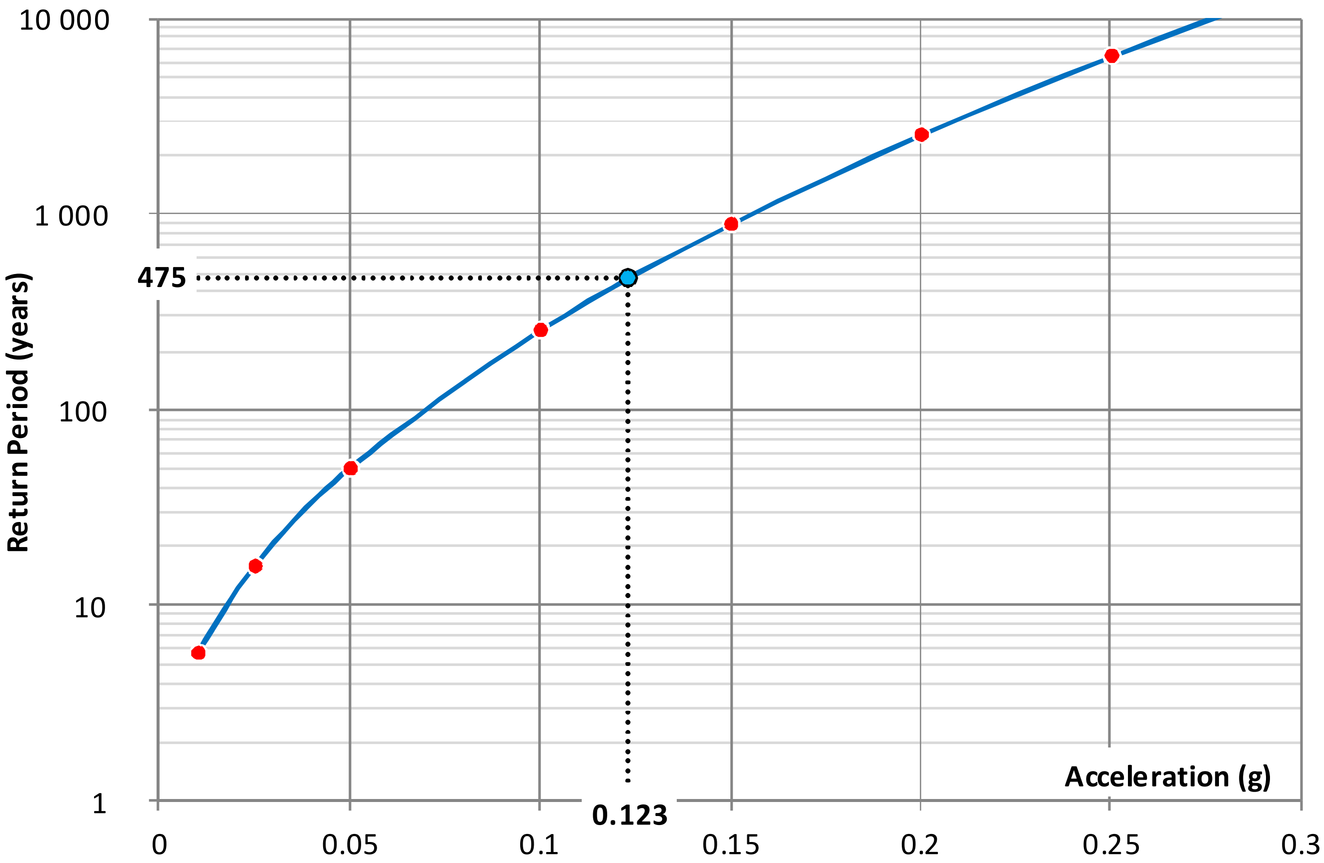
M	M+dM	N(M,M+dM)	Acc	P(a>A)	N(a>A)
3.0	3.4	0.1903	0.015	0.0021	0.0004
3.4	3.8	0.0758	0.019	0.0075	0.0006
3.8	4.2	0.0302	0.026	0.0225	0.0007
4.2	4.6	0.0120	0.035	0.0572	0.0007
4.6	5.0	0.0048	0.046	0.1247	0.0006
5.0	5.4	0.0019	0.061	0.2342	0.0004
5.4	**5.8**	**0.0008**	**0.082**	**0.3827**	**0.0003**
5.8	6.2	0.0003	0.109	0.5511	0.0002
6.2	6.6	0.0001	0.145	0.7106	0.0001
6.6	7.0	0.00005	0.194	0.8369	0.00004

N = 0.004

Return Period :

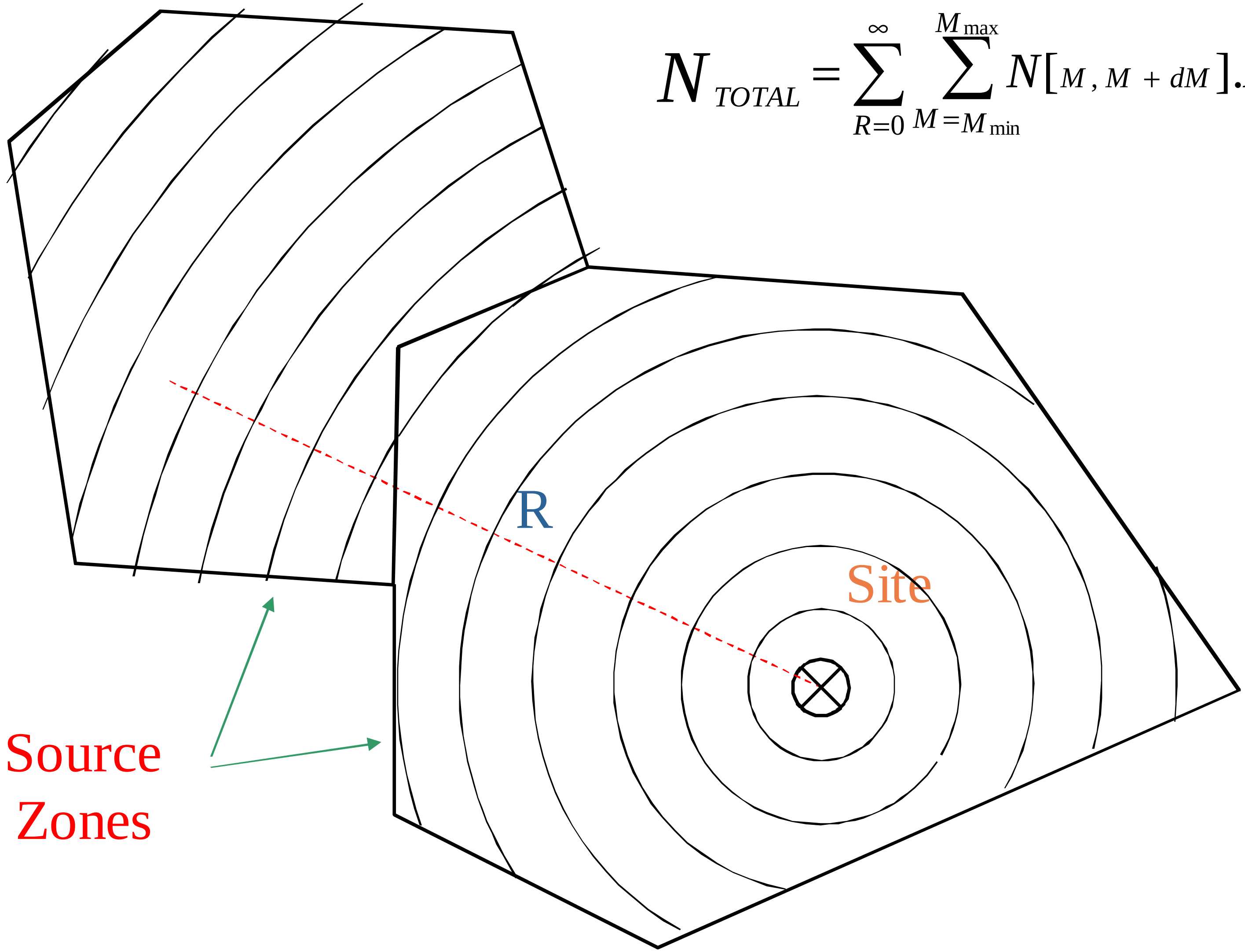
T = 1/N = 250 years

Probabilistic Method



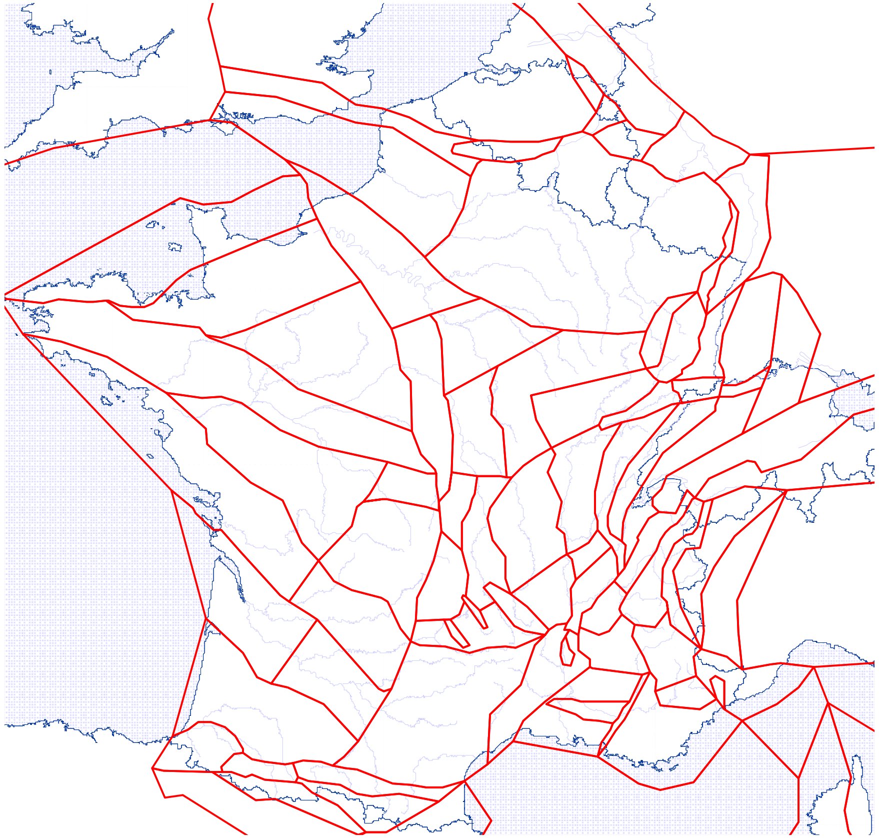
Probabilistic Method

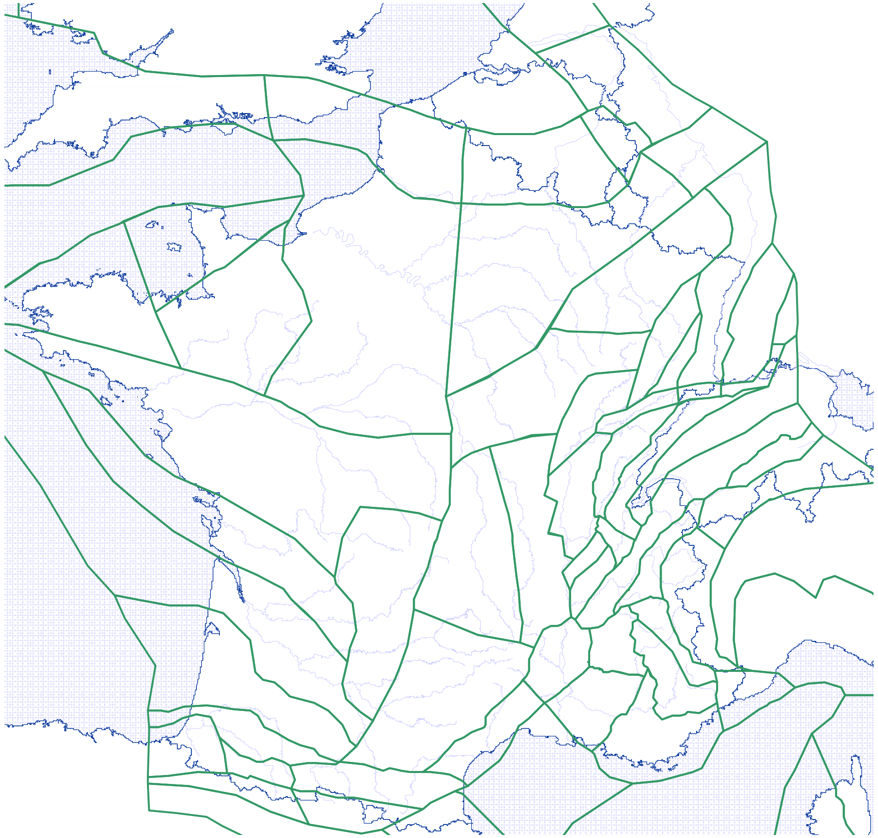
$$N_{TOTAL} = \sum_{R=0}^{\infty} \sum_{M=M_{min}}^{M_{max}} N[M, M+dM].P(a < A)$$



Probabilistic Method

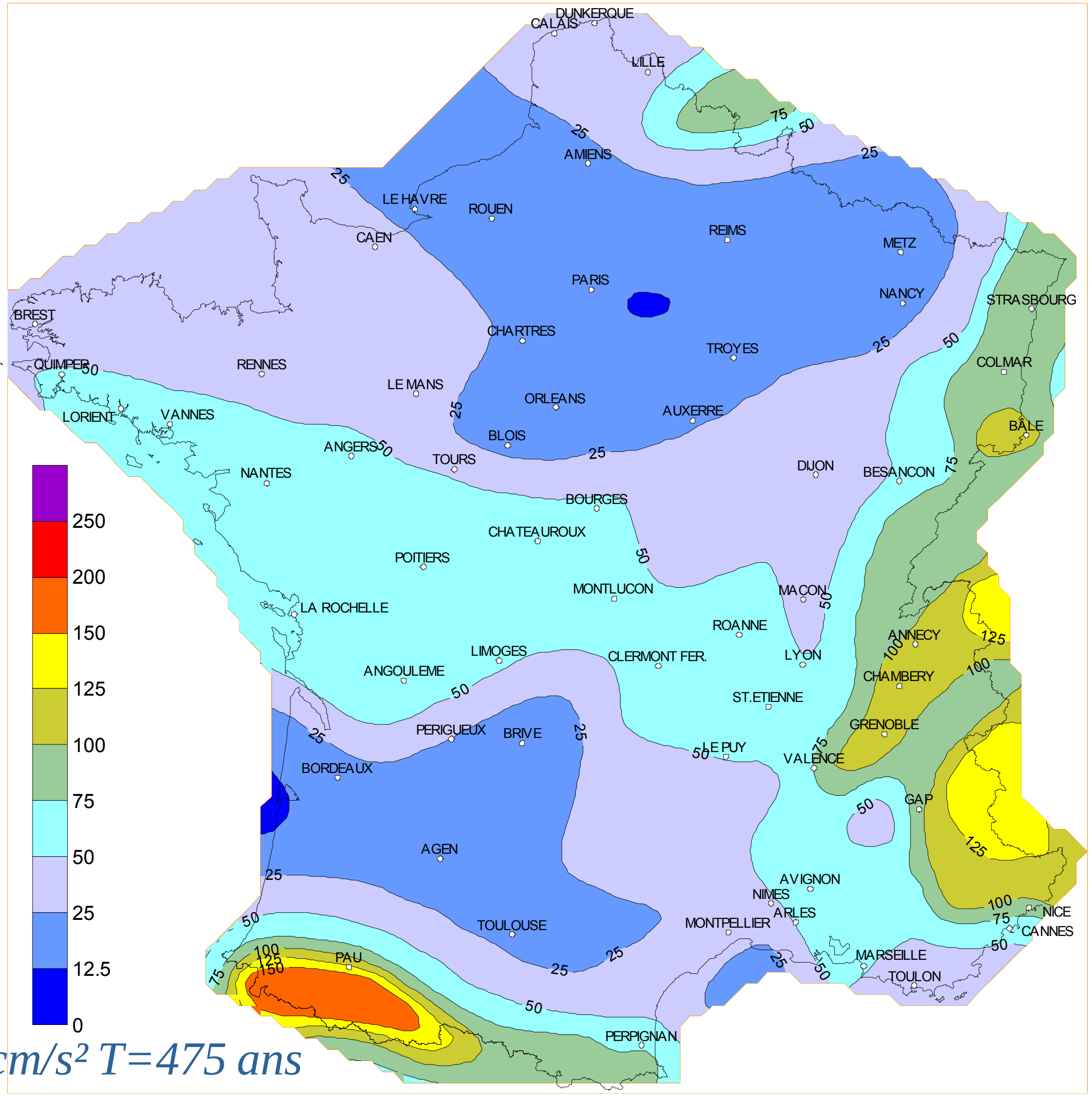
Sismotectonic Zonations





Probabilistic Method

Hazard Map



Acceleration cm/s² T=475 ans

Probabilistic Method

P = Annual probability of exceeding a given value

Probability of exceeding the given value

A LEAST ONCE IN « D » YEARS

$1 - (1- P)^{D} = RISK$

$\Rightarrow \quad P = 1 - (1 - R)^{1/D}$

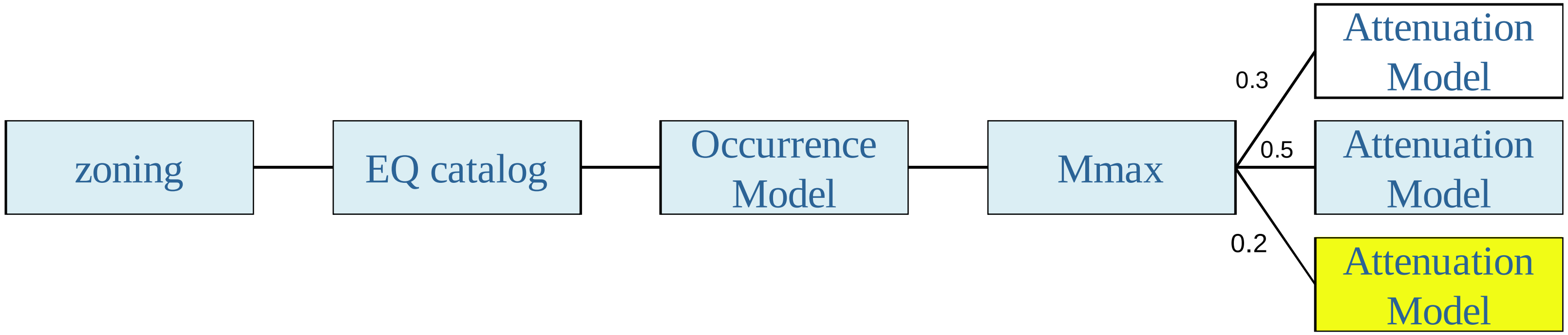
Poisson process: $P = 1 - e^{-N} = 1 - e^{-1/T}$

$T = -D/Ln(1-R)$

		Life Time (D)		
		10	**50**	**100**
Risk (R)	**0.1 %**	9 995	49 975	99 950
	1 %	995	4 975	9 950
	10 %	95	475	949
	63 %	10	50	100

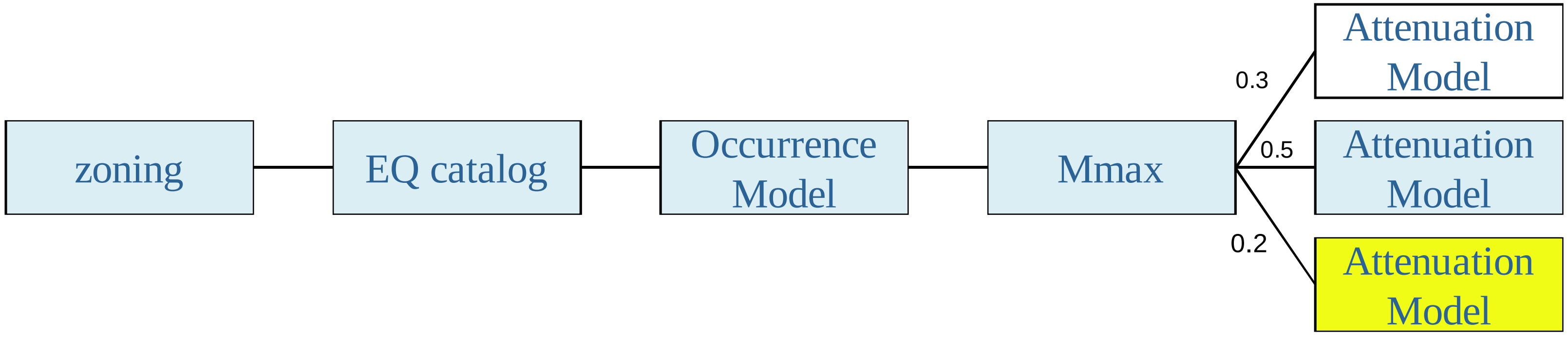
Probabilistic Method: epistemic uncertainties

Logic Tree



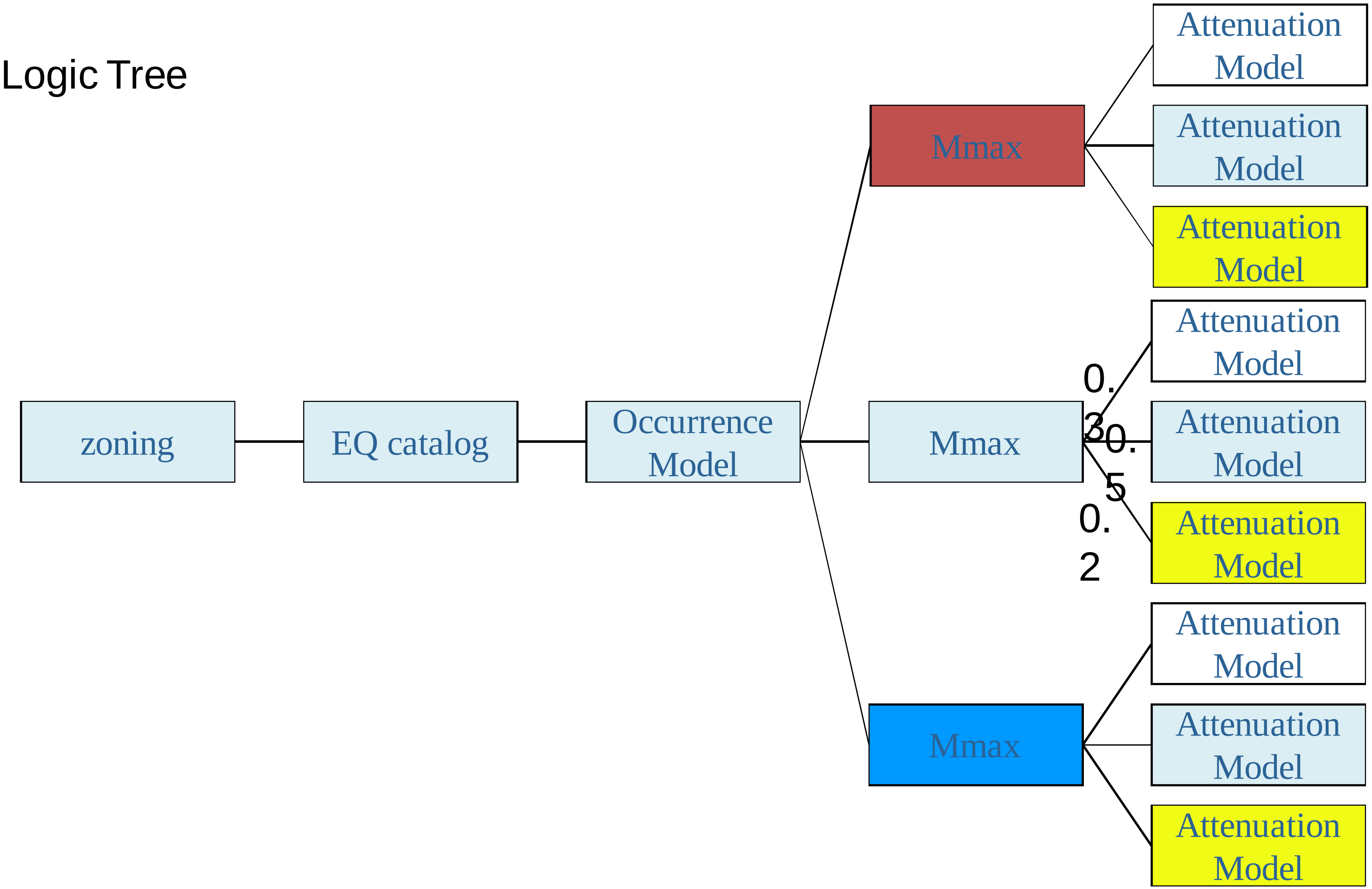
Probabilistic Method: epistemic uncertainties

Logic Tree



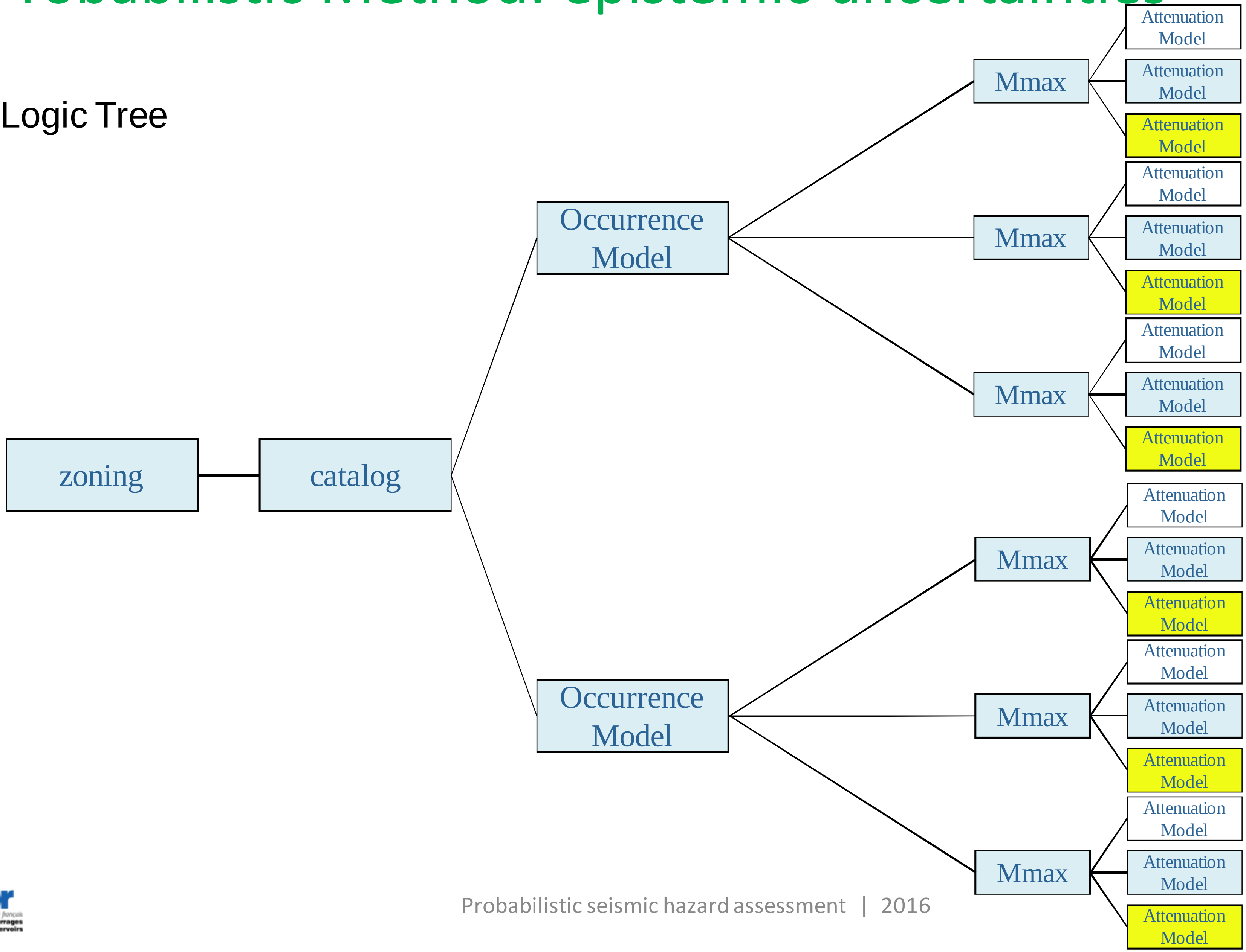
Probabilistic Method: epistemic uncertainties

Logic Tree

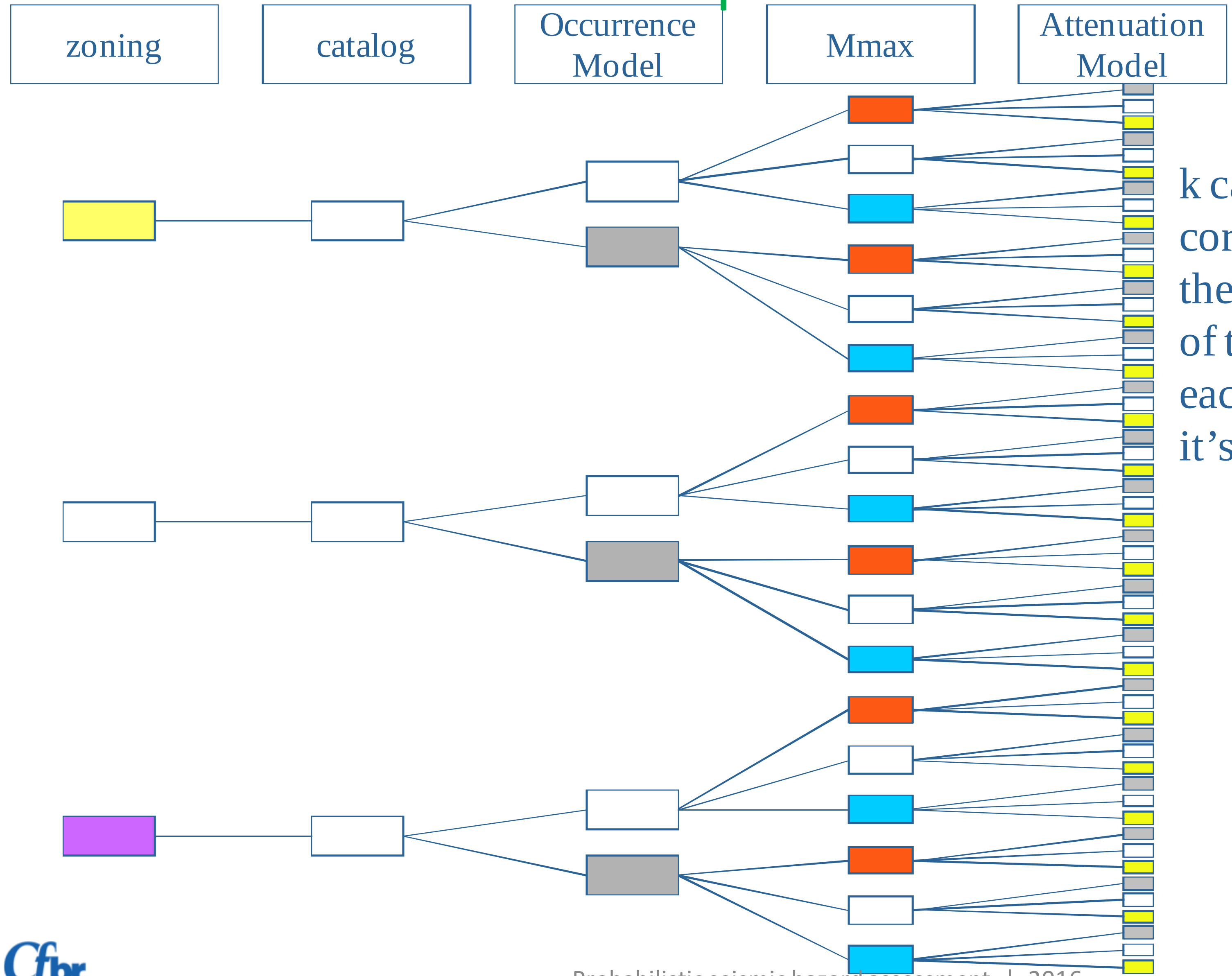


Probabilistic Method: epistemic uncertainties

Logic Tree

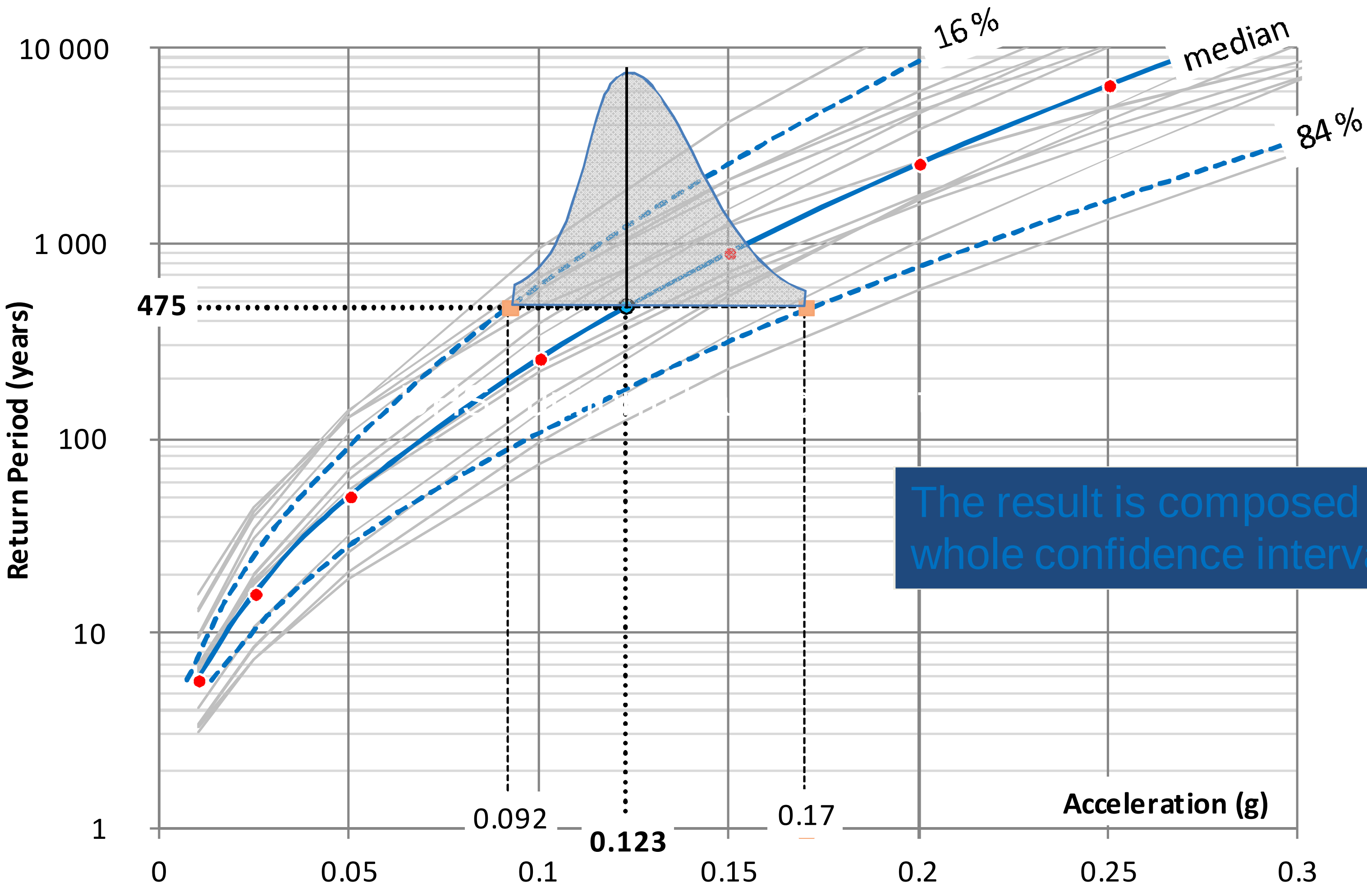


Probabilistic Method: epistemic uncertainties



k calculations corresponding to the k branches of the logic tree, each result with it's weight.

Probabilistic Method: epistemic uncertainties

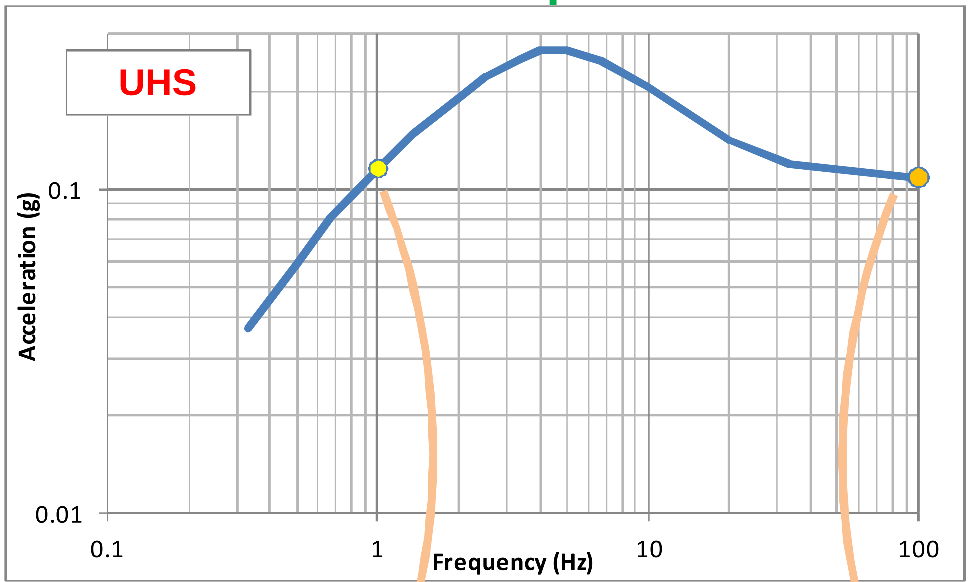


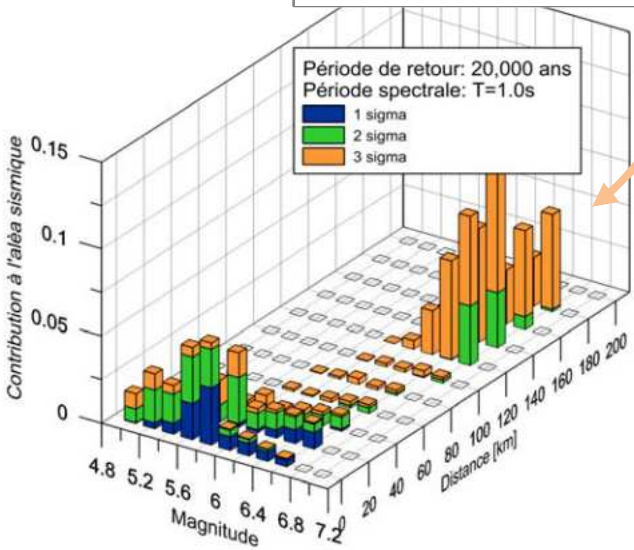
The result is composed of the whole confidence interval

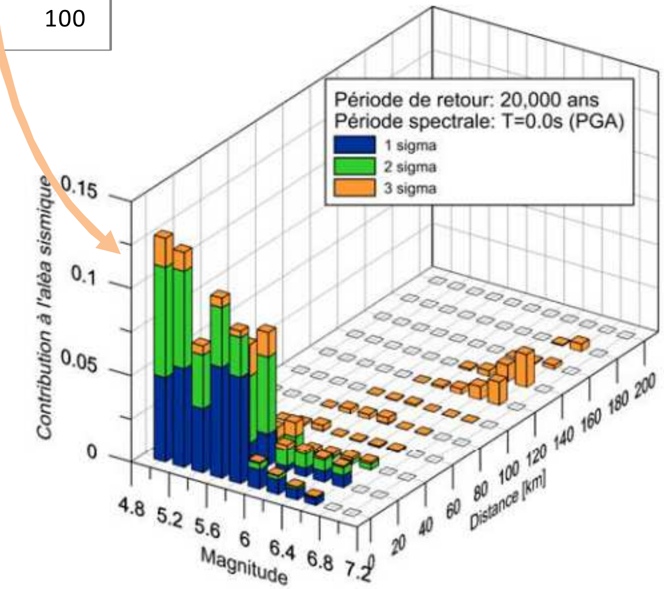
UHS : uniform hazard spectrum

- **The probabilistic calculation is done for each spectral frequency independently**
- **Each point of the UHS has the same probability of exceedance**
- **An UHS doesn’t correspond the spectrum of a real earthquake : the different parts of the UHS is generated by different types of earthquakes.**

UHS : uniform hazard spectrum







De-aggregation of the hazard

PSHA : some difficulties

- **The availability of data, validated, with known uncertainties.**
- **The meaning of s in the GMPEs ?**
- **How to take into account expert judgment / how to weight branches in the logic trees ?**
- **How to incorporate site effect into the probabilistic scheme ?**
- **How to set the Maximum magnitude ? Is the Gütenberg-Richter model still valid for rare events ?**

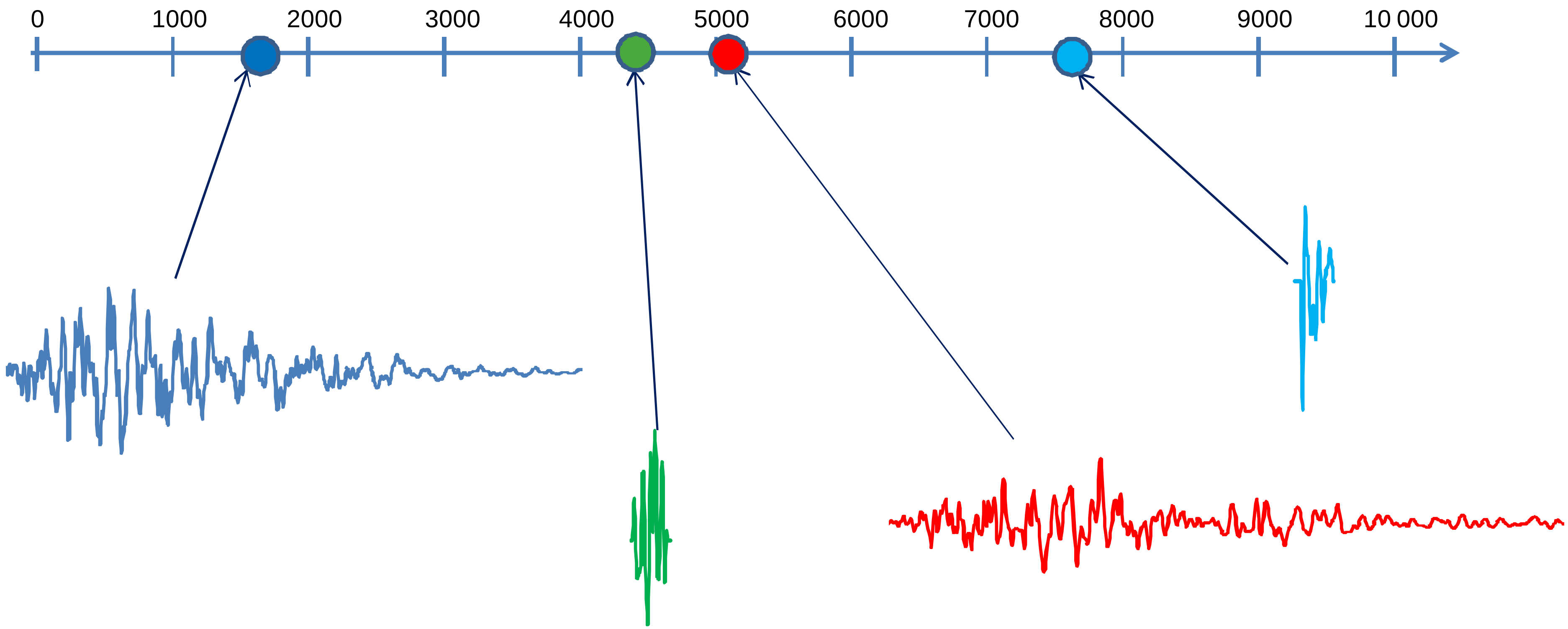
Conclusion of part 1

- **The (probabilistic) seismic hazard can not be a single value**
- **Several choices have to be done :**
- **Return period**
- **Level on confidence**
- **Avoid confusion between :**
- **The probability for an earthquake of a given magnitude to occur in the region,**
- **The probability for a given level of ground motion to occur on the site.**

Conditional Spectra : rigorous use of the UHS

- **What is the return period of a UHS?**

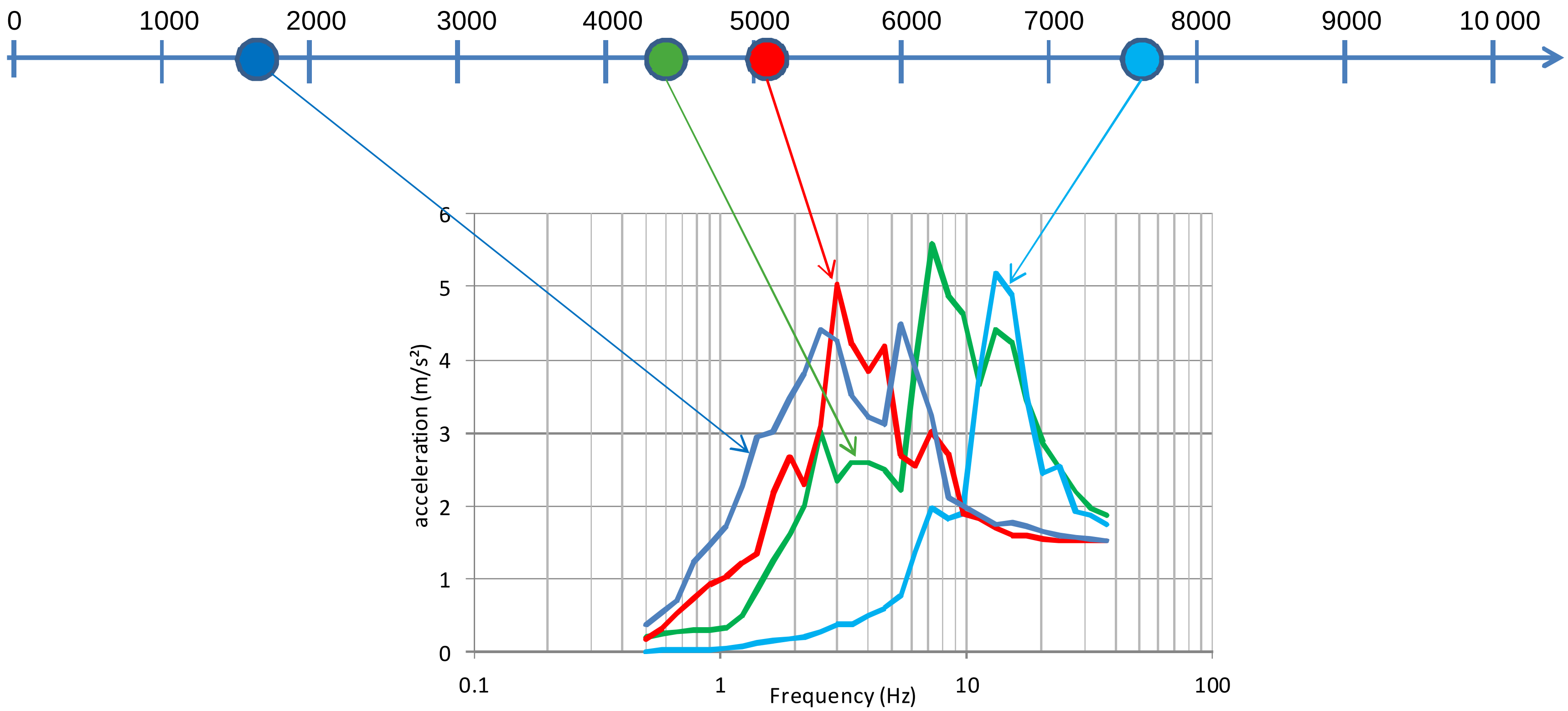
  A UHS is obtained by the observation of seismic activity during a given return period (here 10 000 years)



Conditional Spectra : rigorous use of the UHS

- **What is the return period of a UHS?**

  For a 10 000y hazard study, the UHS is the max of the recorded spectra during 10 000 year of observation

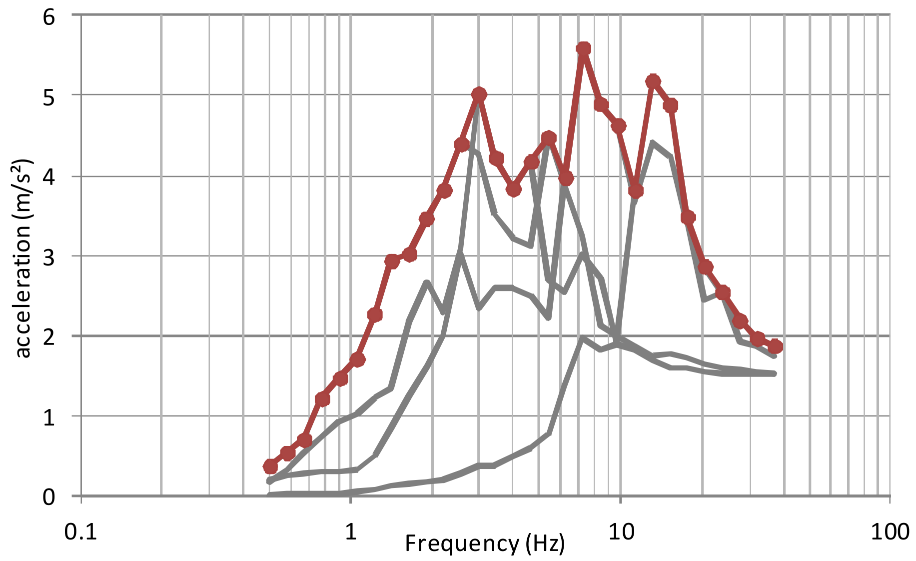


Conditional Spectra : rigorous use of the UHS

- **What is the return period of a UHS?**

  A UHS is not a single even

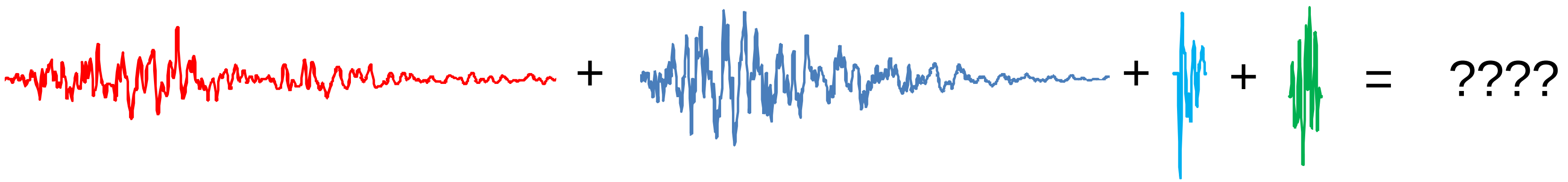
  Using the UHS as one single even leads to a much higher return period!



Conditional Spectra : rigorous use of the UHS

- **What is the return period of a UHS?**

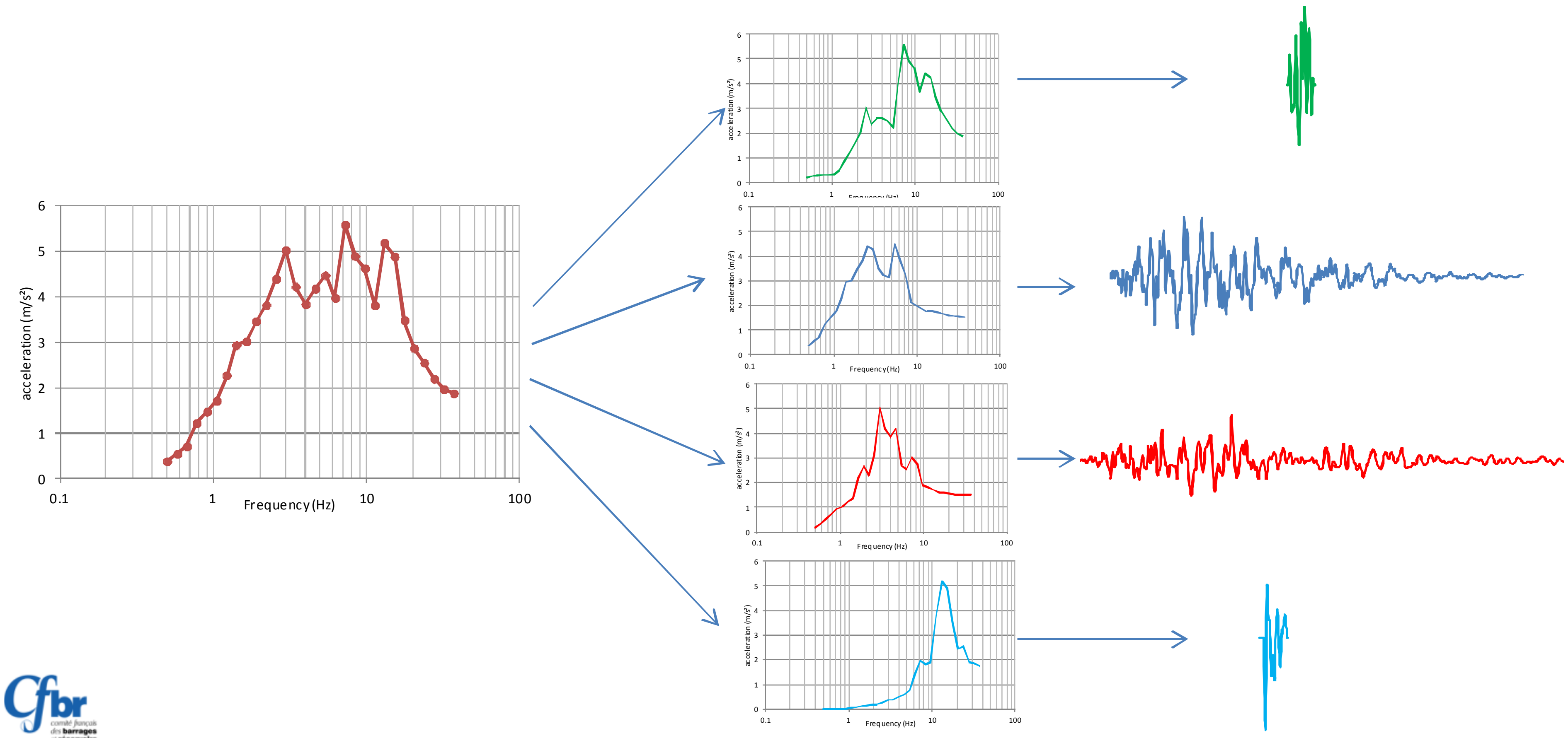
  Using the UHS as one single even leads to unphysical accelerometric time motion



Conditional Spectra : rigorous use of the UHS

- **Concept of the conditional spectra method**

  To transform the UHS in several physical scenarii



Conditional Spectra : rigorous use of the UHS

- **The method of the Conditional Spectra**
  - Go back to more physic input motion than the broad band spectra provided by modern codes
  - By dividing the spectrum in several scenarii, lead to a higher number of computations
  - Extensively published
    - "Conditional Spectra" Lin & Baker - Encyclopedia of Earthquake Engineering
    - Baker, 2011. "Conditional Mean Spectrum: Tool for ground motion selection." Journal of Structural Engineering,
    - Already used for industrial studies
    - Diablo canyon nuclear power plant

- **Partial conclusion:**

  never use the hazard from a probabilistic seismic assessment without coming back to realistic

Qualification of PSHA : Bayesian inference

- **Context & Motivations**

  - In the specific case of moderate and low seismicity areas, the lack of strong motion data lead to select an attenuation model built on data coming from high seismicity regions.

  - Surprisingly, in that context of lack of data, the local seismic recording are not frequently used to calibrate the attenuation model.

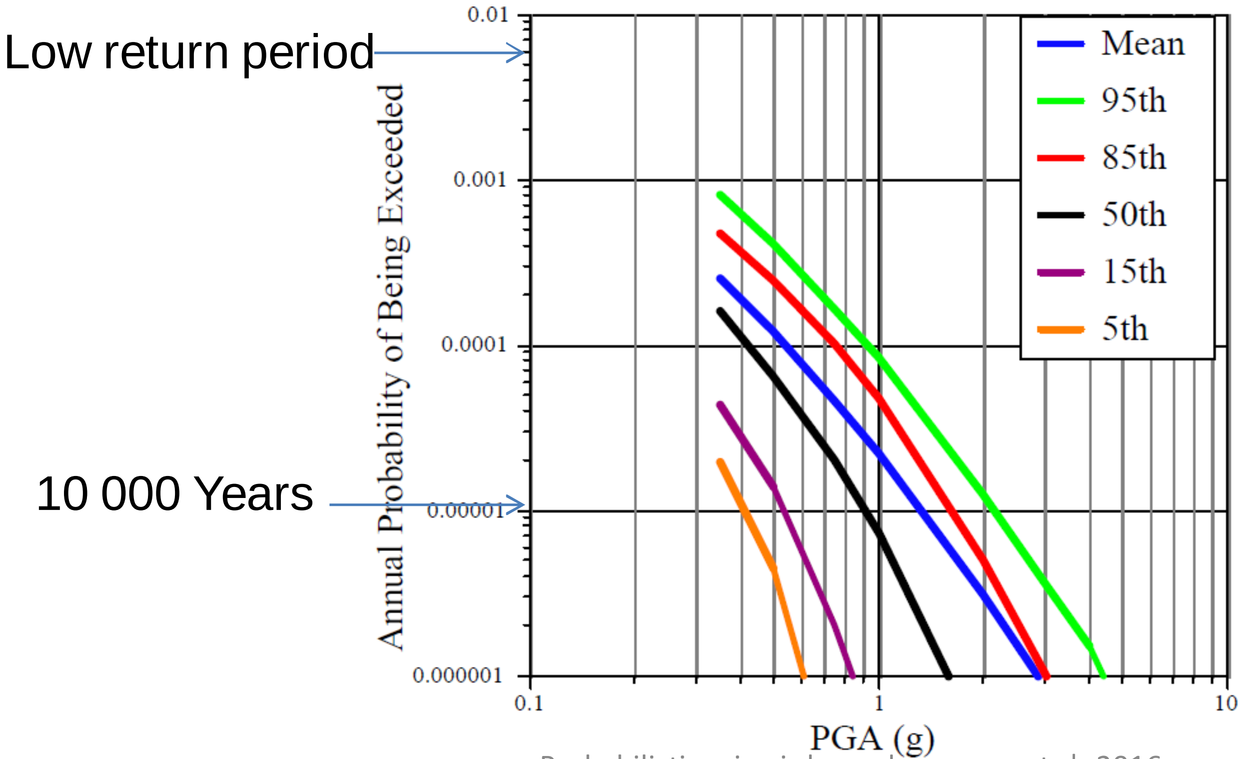
  - The updating technique hereinafter try to answer this issue by a systematic method

Qualification of PSHA : Bayesian inference

- **Example of uncertainty (Yucca Mountain)**

  First observation: the uncertainties are extreme, at high **& LOW** return period

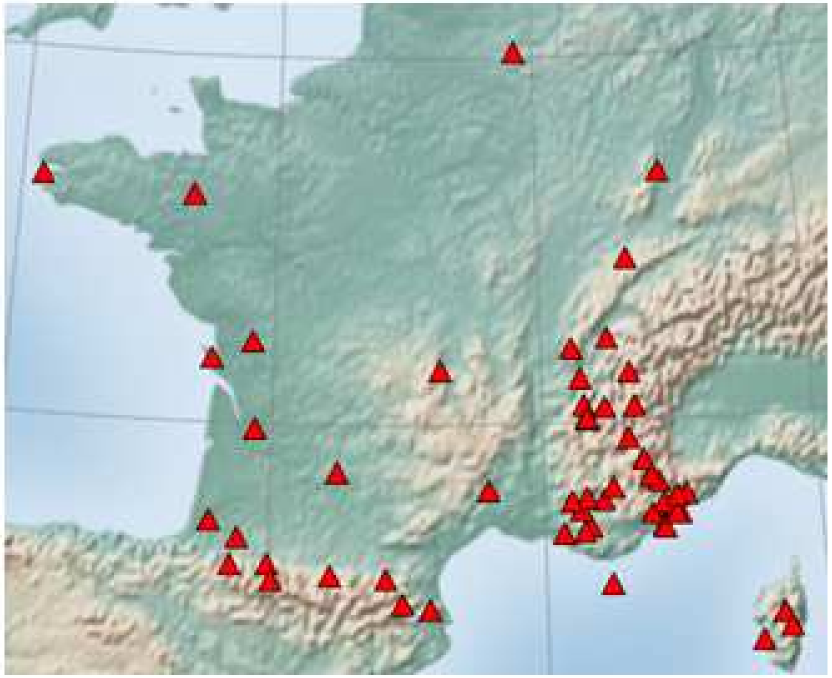
  Usually, at low return period, the uncertainties à limited by the fact that this type of events are frequent and consequently well known → it highlights the fact that local data are not used to fit the hazard assessment



Qualification of PSHA : Bayesian inference

<u>However there is local data, not used in PSHA</u>

- **Exemple 1: the French broadband and accelerometric permanent network**
  - more than 100 stations,



“PSHA Updating Technique with a Bayesian Framework: Innovations”
N. HUMBERT et Al 2015

Qualification of PSHA : Bayesian inference

However there is local data, not used in PSHA

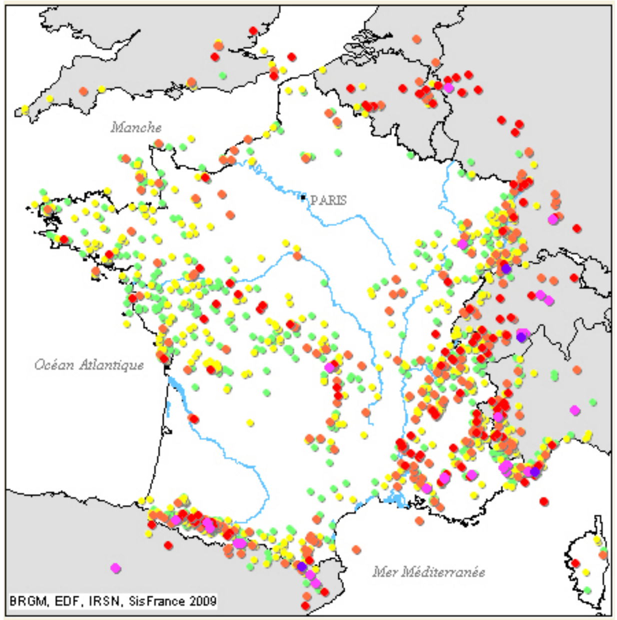
- **Exemple 2: CEA velocimetric network**
- since 1950 - 40 velocimetric stations

Qualification of PSHA : Bayesian inference

However there is local data, not used in PSHA

- **Exemple 3: Historical feedback:**
  - Sisfrance: 1300 → 2007
  - 6000 earthquakes

http://www.sisfrance.net/



Epicentres de séismes et intensités épicentrales (1300-2007)

- Degré 4 à 4.5 (secousse modérée)
- Degré 5 à 5.5 (secousse forte)
- Degré 6 à 6.5 (dommages légers)
- Degré 7 à 7.5 (dommages prononcés)
- Degré 8 à 8.5 (destructions importantes)
- Degré 9 à 9.5 (destructions massives)

UPDATING OF A PSHA BASED ON BAYESIAN INFERENCE WITH HISTORICAL MACROSEISMC INTENSITIES

E. Viallet(1), N. Humbert(2), P. Mottier(3)

Qualification of PSHA : Bayesian inference

However there is local data, not used in PSHA

- **Exemple 4: Geological unstable structures:**

Qualification of PSHA : Bayesian inference

Methods of updating are described in 20 publications presented in PAVIE

- Nicolas Kuehn - Non-Ergodic Seismic Hazard: Using Bayesian Updating for Site-Specific and Path-Specific Effects for Ground-Motion Models
- Roger Musson- Statistical tests of PSHA models.
- Pierre Labbé, - A method for testing PSHA outputs against historical seismicity at the scale of a territory; example of France
- Jacopo Selva- Probabilistic Seismic Hazard Assessment: Combining Cornell-Like Approaches and Data at Sites through Bayesian Inference.
- …..

Recommendation of OECD (PAVIE 2015)

Recommendation 2.1 ***– A state-of-the-art PSHA should include a testing (or scoring) phase against any available local observation (including any kind of observation and any period of observation) and should include testing not only against its median results but also against its whole distribution (percentiles).***


THANK YOU FOR
YOUR ATTENTION